HOUSE OF COMMONS SESSION 1993–94

SCIENCE AND TECHNOLOGY COMMITTEE

First Report

THE ROUTES THROUGH WHICH THE SCIENCE BASE IS TRANSLATED INTO INNOVATIVE AND COMPETITIVE TECHNOLOGY

Volume III

Appendices to the Minutes of Evidence

Ordered by The House of Commons *to be printed*
13 April 1994

LONDON: HMSO

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The Science and Technology Committee is appointed under Standing Order No 130 to examine the expenditure, administration and policy of the Office of Science and Technology and associated public bodies.

The Committee consists of 11 Members. It has a quorum of three. Unless the House otherwise orders, all Members nominated to the Committee continue to be members of it for the remainder of the Parliament.

The Committee has power:

(a) to send for persons, papers and records, to sit notwithstanding any adjournment of the House, to adjourn from place to place, and to report from time to time;

(b) to appoint specialist advisers either to supply information which is not readily available or to elucidate matters of complexity within the Committee's order of reference;

(c) to communicate to any other such committee and to the Committee of Public Accounts its evidence and any other documents relating to matters of common interest; and

(d) to meet concurrently with any other such committee for the purposes of deliberating, taking evidence, or considering draft reports.

The following were nominated Members of the Committee on 13 July 1992:

Mr Spencer Batiste
Dr Jeremy Bray
Mr Malcolm Bruce
Mrs Anne Campbell
Cheryl Gillan
Mr William Powell
Sir Giles Shaw
Sir Trevor Skeet
Dr Gavin Strang
Sir Gerard Vaughan
Dr Alan W Williams

Sir Giles Shaw was elected Chairman on 15 July 1992.

On 9 November 1992 Mr Malcolm Bruce was discharged and Mr Andrew Miller added to the Committee

On 16 November 1992 Dr Gavin Strang was discharged and Dr Lynne Jones added to the Committee.

The cost of preparing for publication the Shorthand Minutes of Evidence published with this Report was £9,232.37.
The cost of printing and publishing this Volume is estimated by HMSO at £18,800.

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UNPRINTED MEMORANDA

Additional memoranda have been received by the following and have been reported to the House, but to save printing costs they have not been printed and copies have been placed in the House of Commons Library where they may be inspected by Members. Other copies are in the Record Office, House of Lords, and are available to the public for inspection. Requests for inspection should be addressed to the Record Office, House of Lords, London, SW1. (Tel 071-219 3074). Hours of inspection are from 9.30 am to 5.30 pm on Mondays to Fridays.

1. The Royal Aeronautical Society
2. Grand Metropolitan
3. Anne Heaton, Jupiter Consortium
4. Nestlé
5. Landis Lund (a Division of Litton UK Ltd)
6. Bundy International
7. NCR Ltd
8. Lederle Laboratories Ltd
9. Letters from Walker Wingsail shareholders
10. CVCP
11. Consumers Association
12. W Vinten Ltd
13. Letters from Bronwyn Hall, Gavin Cameron and Paul Geroski
14. St John's Innovation Centre
15. Japan Development Bank (Hand out during visit)
16. Chemical Industries Association
17. IBM

Memorandum submitted by London Business School (8 July 1993)

This paper has been drafted by Peter Swann with valuable contributions from Steven Abbott, Tim Ambler, Beverley Aston, Paul Compton, David Currie, Romano Dyerson, Paul Geroski, Michael Hay, John Hunt, Paul Marsh, Nigel Nicholson, Martha Prevezer, Kiyonori Sakakibara, Stephen Schaefer, Ian Small, David Stout, Paul Temple, Sadet Toker, Chris Voss, Paul Willman. It does not however represent a London Business School view, and those named above would not necessarily agree with all the views presented here.

SUMMARY

This submission collects some of the observations made by London Business School Faculty in response to the seven questions posed by the Committee. The main points from our submission are as follows.

1. *What is the relationship between the science base and innovation?*

Neither the linear model of science and technology push, nor a simple model of demand pull are in themselves adequate to explain the ways in which science and technology are used to promote economic competitiveness. We argue that it is necessary to recognise that science must push *and* demand must pull if the science base is to promote competitive success.

2. *Are the mechanisms for technology transfer and interaction between the science base and industry effective?*

There are two stages to technology transfer: one from the science base to the *science-friendly* part of the organisation; the other from the science-friendly part of the rest of the organisation. Much attention is focused on the first stage, but it may be that the second stage is equally or more important. The widespread use of scientists and engineers in organisations, not just in R&D, may be essential to ensuring technology transfer *within* the organisation.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

There is evidence that firms with scientists and engineers in senior management positions perform better than others, and that foreign-owned companies based in Britain have a more highly qualified board and workforce than British-owned companies. There is also a clear link between the skills generated by a firm and its governance structure.

4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

It is useful to distinguish three aspects of competitiveness, concerning the quality and quantity of inputs, the competitiveness of outputs, and the efficiency of the process which produces outputs from inputs. Input measures, such as R&D or patents, suggest that British industry is becoming less competitive. Output measures suggest that the non-price competitiveness of British products has traditionally been lower than imports from several countries (notably Germany), but that the trend may in some areas be improving.

5. *Is short-termism really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

There is little evidence that stock markets are short-termist in the sense that they discount future profits more heavily than is justified by the cost of capital. It is argued that short-termism is more likely to be internal to the company, though it could be a result of the fear of hostile takeover. There is also some evidence suggesting that firms may underestimate the future benefits from innovation relative to the current costs of innovation.

6. *Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success?*

There is much research that documents the important contribution of innovative activity towards superior trade performance.

7. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company, and which hinder this process?*

It is argued that the antiquated structures of many British companies are not conducive to innovative activity. Too frequently the strategy towards innovation is to "buy in" technology and "bolt it on", without implementing the necessary organisational change to make the strategy work. Having the right *architecture* is critical to a company's ability to succeed in innovation. Moreover there is a tendency to believe that success in innovation can be ensured by attending to one or two key factors, when in fact it is essential to promote best practice across the board.

A. Introduction

This submission summarises the views of some of the faculty at London Business School who have particular expertise in the areas addressed by the Committee. It does not however represent a *School view*, nor indeed is it a single unified view, but rather a collection of observations made in response to the seven questions posed by the Committee.

Since many of the questions identified by the Committee concern the competitiveness of British industry, it is important from the start to be clear about whether in a particular context we mean *British-owned* industry or industry *located in* Britain. While it is eminently reasonable to treat foreign-owned industry located in Britain as a part of British industry, it can be argued that many of the problems of inferior competitiveness apply especially to *British-owned* industry. For that reason, and unless otherwise indicated, we shall take British industry to mean *British-owned* industry in what follows.

London Business School has a strong interest in these issues for several reasons. The School's interest in understanding the sources of economic, industrial and corporate success leads it to undertake a wide range of research on innovation, technology and international competitiveness. The School's role in training top managers, present and future, also leads it to place appreciable emphasis on the management of innovation, R&D management, technology strategy, and new product development. These topics are taught on our MBA Programme, Sloan Programme and International Executive Masters Programme. The School is also conscious that it trains a significant number of scientists and engineers in management, and in so doing helps to enhance awareness in industry of the importance of the science base for corporate success.

B. The seven questions

1. *What is the Relationship between the science base and innovation?*

1.1 *The Linear Model*

The heart of any answer to this question will depend on where the respondents stands *vis a vis* the (so called) *linear model* of science, technology and the market. The linear model argues that the principal direction of causation here runs from science to technology to economic competitiveness, so that the development of markets for new technologies is essentially a process of *science and technology push*.[1] Opponents to the linear model would argue that a casual chain in the opposite direction is at least as important,[2] and in some cases would argue that innovation (and the required new technologies) are driven by a process of *demand pull*.

Those who accept the linear model would consider that the priority must be to *get the science right.* Any attempt to set a commercial agenda for basic science must constrain scientific development, and will ultimately weaken technological competitiveness. At the other end of the spectrum, some of those who reject the linear model would argue that as demand pull is central to technological development, and indeed technology can in turn shape the development of basic science (the obvious example being the computer), then commercial concerns do already influence the development of some basic science. From that perspective, setting a commercial agenda for parts of basic science may be attractive or unpalatable, depending on your priorities, but it does not necessarily constrain the development of science in an adverse way.

There is a strong argument in favour of taking a middle position on the technology push—demand pull spectrum. It is implausible to expect that technology push can create a new market unless demand is responsive. Equally, unsatisfied demand on its own will not bring forward new technologies unless the technological and scientific base is in place and capable of responding to such demand.[3] From this middle perspective, it makes sense to leave some (possibly quite large) portion of the most basic scientific activiy unconstrained by commercial priorities, but to accept a more strategic steer for work at the more applied end of the spectrum. This leaves open the much more difficult question of where an appropriate dividing line should lie between curiosity-led science and commercially-led science.

1.2 *Should the science base be science driven or commercially driven?*

The debate in the 1980s over what type of biotechnology research should receive support illustrates the tension between the science-driven and the commercially-driven (or "strategic") approaches.[4] Some argued for a science-driven approach while others preferred a strategic approach. Of course, the language used to describe these differences is often laden: "good science" sounds better than "curiosity-led" science, and "strategic science" sounds better than "commercially-driven".

The promotion of strategic science stems on the one hand from doubts about the objectivity of the criteria used in curiosity-led science, but on the other from a growing recognition of the contribution of science-based technology to competitiveness. The case for curiosity-led science are: first, that the range of scientific exploration is curtailed once commercial criteria are introduced, because commercial criteria, connected to known markets, have shorter time horizons and narrower focus than curiosity-led criteria; second, some consider much of the strategic science second-rate by the criteria of "good science"; and last, that those would set strategic research agenda on commercial criteria are too far-removed from the science base themselves to understand the scope and possibilities of research.

Biotechnology poses particular difficulties in this context, because the boundaries and the applicability of the science are hard to define. Moreover, the distinctions between what constitutes basic and applied research are blurred: specific applications throw up new discoveries in basic mechanisms and basic research turns out to have commercial applications. Another factor is that biotechnology brings together or draws on various underlying disciplines: biochemistry, molecular biology, biochemical engineering, and medicine, which straddle the competencies of the different research councils.

1.3 *Scientific and technological knowledge: tacit or (readily) transferable?*

A second critical influence on the relationship between the science base and innovation is the degree to which scientific and technological knowledge is *tacit*, meaning that it is difficult to write down in text-books and manuals and the like, and hence is difficult or costly to transfer.[5] When knowledge is tacit, transfer depends in large measure on personal contact, and hence it is often argued that diffusion of the most recent technological knowledge happens within tight-knit geographical clusters. It is generally recognised that the *tacitness* of scientific and technological knowledge tends to decline as it gets older. Recent discoveries, or new technological developments may be highly *tacit*, while older knowledge becomes codified in textbooks, manuals, and so on, which reduces the cost of transfer, especially over large distances.

This tacitness is part of the rationale for science parks. It also reinforces the need to promote technology networks, conferences, and the like.

2. *Are the mechanisms for technology transfer and interaction between the Science Base and industry effective? How could they be improved?*

What are the channels for technology transfer? What are the blockages?

The sponsorship of research in universities by firms is itself a part of the technology transfer process. The flow of university graduates into high-tech startup firms is another mechanism, and the flow of scientists and engineers between universities and industry is a third. Finally, we could add promotion and publicity for university research output.

There are two sorts of obstacle in the path of technology transfer. The first represents a bottleneck in transferring ideas out of the University science base. The second represents a blockage in transferring from the *science friendly* part of a using organisation to other parts of the organisation.[6] An organisation's capacity to overcome either bottleneck depends on its *absorptive capacity:* some of an organisation's R&D activity should be directed towards learning to learn from the public science base, and not to in-house invention.

It may accordingly be much more important that there are sufficient scientists and engineers in the non-research parts of organisations, and not simply involved in R&D. Many German companies, notably Siemens, have engineers or scientists in all parts of the organisation, not just on the research side. In British and American industry, on the other hand, much more emphasis is placed on managers having generic management skills (portable from one sector to another). One of the comments on question 3 has more to say on this.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

3.1 *Scientists and engineers and company performance*

A recent study in the ESRC/DTI research initiative sheds useful light on this issue. Bosworth and Wilson[7] surveyed 700 companies in the UK about the educational background of the MD, members of the board, and the workforce, and also about their technological activities and their performance. Their research found that the background of the MD, and the structure of the board (including the level of qualifications and discipline) have an important effect on the growth, technological prowess, and overall performance of the company. They find that scientists and engineers can make a valuable contribution throughout the workforce, not just in research and development. They also find that foreign-owned companies based in Britain have a more highly qualified board and workforce than British-owned firms. This reinforces a view that a more proactive policy towards the employment of scientists and engineers could generate significant benefits, both at a company and a national level.

3.2 *Skills and corporate governance*

Research at London Business School's Centre for Business Strategy (CBS) has examined the importance of skills and governance structure for economic performance. Their case studies emphasise that there is a strong relationship between the skills generated by the firm and its governance structure. Competitive success depends upon the effective management of organisational competencies, appropriation by the firm of benefits flowing from these assets, and having a suitable governance structure in place.

Integrated organisational competencies or "know-how"[8] are important for effective technological innovation. This is particularly true in high technology companies, because innovation rests upon the input of several functional groups: technologists, clerks and marketing for example.[9] In short, high technology firms require effective teamworking. Know-how incorporates bundles of both organisational and technological knowledge, tacit and coded, which grows over time with experience. The CBS cases suggest that sudden breakthroughs in the accommodation of technological competencies are rare. In other words, *history matters* in the generation of skills. The ability of the firm to absorb and act upon knowledge depends in part upon previous experience and staff continuity.[10] The most successful cases amongst the CBS case studies exhibited low levels (less than 5 per cent) of staff turnover. Practical steps to achieve this include on the job promotion and share options. More subtly, technology can be deployed strategically to "lock in" staff.

3.3 *Sectoral differences in innovative performance, and skills*

There are important sectoral differences in access to trained scientists and engineers as well as skilled labour more generally. Decentralised and fragmented industries—especially in the engineering sector—face particular problems stemming from the absence of internal labour markets. At the same time, recourse to the external labour market may be hampered by a lack of certification of relevant skills. These difficulties may make the science base relatively remote, and impede the process of diffusion. One key piece of evidence that this may be a crucial factor in competitiveness is the poor international trading performance of low-concentration industries *relative* to manufacturing generally—a trend which is evident from trends in the UK's external account dating back to at least the 1970s.

As recognised by Henry Ergas[11], the problems of decentralised industries in the absorption and diffusion of technological change are not limited to the accumulation of human capital; there are also difficulties in keeping firms in contact with the latest technological developments and in promoting product quality and compatibility. A strong case can be made for the specific provision of public goods to assist in the diffusion of technological change. This amounts to what Ergas calls a "diffusion orientated" technology policy, aspects of which include an emphasis on vocational education, co-operative research and development, and the promotion of industrial standards. It is notable that the formidable German strength in industrial standards is heavily concentrated in mechanical engineering, where UK performance has been weak.

4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

We would rephrase the first question slightly: "Is innovation by British industry *sufficient to keep Britain* internationally competitive?" In the view of many commentators, the answer would be, no, except for a few high-performing sectors. Logically, however, we need to tackle the second question before we can answer the first.

4.1 *Measuring competitiveness: potential, process or performance*

An important distinction can be drawn between three aspects of competitiveness: competitiveness of present marketed *products* and services, the competitiveness of the *process* by which a firm turns scarce inputs into marketed outputs, and competitive *potential* defined by the skills (or more broadly, competencies) of the firm.[12]

Different approaches are required to measure these different aspects of competitiveness. Measurement of *product* competitiveness might ideally be based on the profitability of individual product lines, but while such data may be known to the company, they are rarely in the public domain. More commonly, economic measures of product competitiveness are derived from prices and direct or indirect measures of product quality (relative to the competition). Some authors have also based product competitiveness measures on innovation counts, patent statistics, and even R & D expenditure. In our view, however, R & D and probably patent statistics would be better as a measure of competitive *potential*.

Productivity measurement is an attempt to summarise the competitiveness of the *process*, even if in the view of many non-economists productivity measures do not capture the subtlety of the process. Measures of competitive *potential*, on the other hand, refer to the quality of inputs (for example workforce skills—see Question 3), and as noted before, measures of competitiveness based on R&D comparisons would in our view fit more naturally here.

It is common to distinguish between *product* innovations and *process* innovations, and it is recognised that they can have rather different effects on the competitive standing of the company. The framework identified here illustrates how their effects on competitiveness could be measured.

4.2 *R&D comparisons*

A commonly used indicator or measure of the inventiveness of a firm is the proportion of sales it spends on R&D or the amount of R&D it spends per employee. International comparisons of either of these indicators show that UK firms lag behind their international competitors. Figures from Company Reporting show that with a couple of notable exceptions in the Health Care and Food sectors, UK firms spend less on R&D than their international competitors.

4.3 *Patent counts*

The committee will be aware of the large amount of work done at the Science Policy Research Unit on the technological performance of the UK in terms of patenting activity.[13] Broadly speaking, this documents the declining UK share of all patenting undertaken in the United States, and this is generally accepted as a reasonable measure of a country's success in patenting activity.

4.4 *Surveys of buyers about the competitiveness of British products*

One of the most striking pieces of evidence about the competitiveness of British products has come from surveys of buyers.[14] What the surveys tend to suggest is that amongst those buying imported products, non-price factors (such as quality) tend on balance to be more important than price, while amongst those buying British products, the balance lies the other way. This suggests that in those markets, British products are bought for their price rather than their quality.

It should be noted however that these surveys are for the most part based in the industrial machinery industries, where trade performance has been poor in many areas. We should therefore be wary about drawing any general conclusions from this that the UK is tending to *import dear and export cheap.*

4.5 *Econometric approaches to measuring non-price competitiveness*

One indirect econometric piece of evidence about UK non-price competitiveness can be obtained from a comparison of the elasticity of UK imports with respect to UK income against the elasticity of UK exports with respect to world income.[15] The UK propensity to import was traditionally high, and the elasticity of UK exports with respect to world trade was traditionally low (below one). One interpretation of this is that the high elasticity of demand for UK imports implies that imports are of relatively high quality, while the low elasticity of demand for UK exports implies that they are of relatively low quality. Yet, as Landesmann and Snell have pointed out,[16] the elasticity of UK exports with respect to world income has risen over the 1980s, suggesting that this balance may have been restored.

4.6 *Indirect measures of quality competitiveness*

One approach to measuring non-price competitiveness at a detailed sectoral level is the use of export and import unit values, pioneered at NEDO in the 1970s.[17] This looks directly at the question, *does the UK import dear and export cheap?,* by comparing the average price of exports in a sector with the average price of imports. It was found that export unit values were frequently lower than import unit values in the UK, and in addition, the ratio of export unit values to import unit values was typically lower in the UK than in France and (especially) Germany. While there are some difficulties in attributing all of the unit value differential to quality differentials, this was nevertheless suggestive that British exports were of lower quality than British imports.

A more recent study by Oulton[18] of the period 1978-87, however, found that although there were wide variations across different sectors, there was no systematic tendency across the board for the unit values of UK imports to exceed those of UK exports. In short, there are some sectors in which the unit values of British exports are well below those of UK imports, but these are offset by other sectors where the reverse is true. As with the income elasticity evidence, this could suggest that the balance has been restored.

4.7 *Direct measurement of quality competitiveness*

While economic analysis and measurement of quality has a long history, relatively few attempts have been made to compare the competitiveness of products of different nationalities. Some work has been done on this for a dozen British consumer durable markets.[19] What this found was essentially in line with the Oulton study noted above: there was no systematic tendency for British products to be of lower or higher quality than imported products. In some markets, British products were much less competitive by virtue of quality than imported products. But there was no general tendency in this direction, as in some other markets, British goods were more competitive in terms of quality.

4.8 *Performance of high-tech industries*

One way of assessing the innovativeness of UK industry is to look at the competitiveness of those industries where innovation is believed to be especially important—loosely termed as "high-tech" and which may be defined in terms of the intensity of the R&D effort. On one definition,[20] the high-tech sector encompasses some of the chemical industry (including pharmaceuticals), electronics electrical equipment, aerospace, precision instruments and medical equipment. In terms of trading performance, this group compared favourably with manufacturing in general in 1975, but the intervening years have seen this relative advantage steadily eroded, especially if aerospace (heavily dependent upon defence procurement), is excluded. It must be remembered that any industry is comprised of a variety of activities with very different degrees of innovativeness. Some high-tech sectors encompass a number of very low-tech activities. It may well be that British industry is more or less innovative than this measure alone suggests.

5. Is short-termism really a problem for innovative British industry? If so, why is this, and how might it be remedied?

5.1 *Short-termism on trial*

Paul Marsh's extensive research on and reviews of short-termism[21] have been very influential, and will be known to members of the Committee. Here we briefly summarise the main arguments.

Do stock-markets undervalue the long term? More precisely, do share prices put too much weight on short-term profits and dividends and insufficient weight on future profits? Or again, do stock-markets discount the future more heavily than is justified by the cost of capital? It is difficult to test this directly, but the large number of studies of market efficiency is broadly consistent with the view that the market is efficient, and is concerned with and (on average) correctly discounts the long-term and the short-term implications of relevant news items and key events.

In consequence, if short-termism is seen as a problem (and many still think it is), those *directly* responsible must be managers and not shareholders or financiers. One reason for internal short-termism is that managers may shun long-term investments that depress short-term accounting profits. The strongest evidence of internal short-termism is anecdotal, however, it could be argued that managers are acting under duress from the financial system.

It is recognised that investment analysts, fund managers, and institutional investors often appear to be short-termist, but in practice are not. Marsh concludes that the main source of duress arises from contested takeover bids. The fear of an unwanted takeover bid could encourage managers to maximise short-term profits and dividends in the hope that this will boost their share price and so keep the predator at bay. A review of the evidence, however, concludes that this does not necessarily happen.

If as his study suggests, short-termism is not a result of stock-market inefficiency or adverse effects from duress, then what are the causes? Three contributory factors are suggested: managerial short-termism, resulting from the way management reward systems are designed, cross-country differences in the cost of capital, and supply side factors, relating to the education and skills of the workforce.

5.2 *Short-termism from double discounting*

Popular debates on "short-termism" tend to focus on discount rates, and whether the practices of pension fund managers and other City investors lead strategic decision makers in firms to discount the future too heavily. There is, however, a second source of concern about short-termism: that strategic decision makers may understate future benefits relative to current costs (in effect, double discounting). This might arise from a deliberate decision to double discount, it might arise from over cautious predictions about demand and revenues, and it might simply reflect a failure of imagination. New innovations are, by their very nature, path breaking, and it is not at all evident what they may lead to over the medium and long run.

Recent research undertaken by Paul Geroski at London Business School[22] has generated some evidence to suggest that it is easy to understate the effects of innovation on company performance. Using fairly standard econometric techniques, the team attempted to measure the effects that the production of a major innovation had on the short and long run profitability of a sample of 721 large, quoted UK firms. They found two effects: first, that the production of each additional innovation had a noticeable but fairly modest effect on profitability over the four to six years after the innovation was first produced; and, second, that firms who produced an innovation any time during the late 1960s and early 1970s survived the recession of the early 1980s much more easily than non-innovative firms did. What is more, the size of this second, indirect effect of innovation on profitability was several times larger than the size of the direct effect.

These results suggest that innovations have two effects on the company which produces them. First, there is a *direct* effect which arises because the production of a new innovation alters a firms market position relative to rivals (say by lowering its cost, or affecting its demand). However, there is a second, *indirect* effect that arises because the act of doing R&D and producing an innovation appears to transform a firms internal capabilities, making it more alert, flexible and adaptable. It is this second effect which seems to account for the superior performance of innovators during a recession.

The moral, then, is that if firms take account of only the first effect when deciding whether or not to undertake innovative activity, then they are likely to severely understate the total benefits of innovative activity. Regardless of what discount rate they use, they will almost certainly appear to be acting "short sightedly" and not doing enough innovation.

5.3 *Is the stock market too efficient?*

Problems created by the relationship between the City and industry need not stem from a lack of foresight or any informational deficiencies; indeed, it may be that the institutions of the City are rather *too efficient* from the point of view of the economy as a whole, as Odagiri for one has pointed out.[23] In Japan companies have been able to pursue growth, as opposed to profit, oriented strategies. Constraining companies to maximise the present value of their assets is the legitimate function of the stock exchange; but if there are substantial spillovers to investment activity, as some modern thinking suggests, then society as whole would benefit from investment in excess of that which profit maximisation permits. Spillovers arise because accumulation processes involve learning, and the benefits of this learning cannot be fully appropriated by private companies.

6. *Some sectors of UK Industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?*

6.1 *Innovation and trade performance*

It is worth noting at the start that several econometric studies of trade performance have studied the effects of non-price factors (including innovativeness) on trade performance.[24] These studies find that non-price factors can be as important, or probably more so than at influencing trade performance. If, as many would agree, Britain's most internationally competitive sector is the pharmaceutical industry, then there seems to be widespread agreement that it enjoys this position by virtue of its ability to bring new products to market, by exploiting its research and new technologies.

6.2 *The relative performance of UK and foreign-owned enterprises*

The UK has been host for a huge share of inward investment into Europe; in 1990, this had reached about one-fifth of the total for the OECD as a whole, and about two-fifths of that for the European Community. By 1989, the cumulative effect of this investment has been such that by 1989, foreign owned enterprises accounted for nearly 15 per cent of employment in UK manufacturing and 21 per cent of value added, giving a clear productivity advantage. Not all of this can be accounted for by a clustering of foreign ownership in high productivity sectors: Davies and Lyons estimate[25] that if domestically owned firms were able to match foreign owned firms, industry by industry, then the level of productivity in UK manufacturing would rise by 26 per cent.

6.3 *Who benefits from innovation: users or producers?*

The question of which sectors are more successful in international markets and the attempt to attribute at least part of their success to their own innovative activity neglects the very rich network of relationships which exist between innovation producers and their suppliers on the one hand, and their users on the other hand. Successful innovation is a coupling process which marries technological knowledge to manufacturing expertise and consumer needs. It is rarely the case that all of these skills are present in one single sector, and it is usually misleading to attribute innovative success to the actions of agents in one sector alone.

Recent research by Paul Geroski at London Business School[26] reinforces this point. Using a relatively unique data set on major innovations produced in the UK over the post-war period (developed by the Science Policy Research Unit at the University of Sussex), it measured the effects of each innovation on the productivity growth of the sector which produced that innovation and on the sector in which it was first used. The results showed clearly that it was innovation-using sectors rather than innovation-producing sectors which benefitted most from new innovations. Further, the study traced back the innovations used by firms to increase their productivity to the source sector which produced them in the first place, and tried to ascertain which source sectors produced the most valuable innovations. The results were also surprisingly clear: the Engineering sector as a whole (and Electronic and Instrument Engineering in particular) were the source of those innovations which had far and away the biggest effect on users' productivity growth.

Thus, the search for successful sectors (whether they be identified as successful by their international competitiveness, or by some other criteria) must not neglect to trace the sources of success through the *entire network* of relationships which bring forth new innovations. Although it is easy to conclude from this particular study that Engineering is a strategically important sector for the UK (a conclusion which its author would not desist from), the fact remains that the international success of innovation users in the UK springs from a partnership between innovation producers in Engineering (and elsewhere) and their various users scattered throughout the economy.

7. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company, and which hinder this process?*

If "structures and institutions" are interpreted very broadly, then some of the points made in response to questions 2, 3, 5, 6 are also relevant to this question.

7.1 *Corporate design and capacity to innovate*

One of the central issues for organisational behaviour research is the question of how organisational design can constrain or liberate organisational behaviour. British organisations often have antiquated structures that are not conducive to innovative activity, and are geared to competitive and technological stability rather than rapidly changing technologies and markets.[27]

This is seen as a peculiarly British problem for the following reasons. First, many organisations have an excessive reliance on their main production system, and are very poor at the implementation of intelligent systems (such as competitor analysis and human resources management). Second, the British educational system as a whole encourages organisations to think in traditional employment categories, and its priorities are out of line with those needed for a rapidly changing technological, economic and organisational environment. The structure of labour relations may also play a part in this, but it has to been seen as simply a component of a frozen structure.

Third, British industry has been slow to learn that much organisational change follows on from technical innovation itself. Too frequently, the strategy towards innovation is one of buying in technologies as a package and "bolting on" to the existing organisation. This strategy seldom works, and leads to excessive reliance on experts, and inadequate investment in flexible manufacturing and re-skilling. Fourth, despite their considerable talents, many managers appear to suffer from *technophobia*, and tend to leave technology to the experts. This excessive managerialism is out of step with a modern innovative economy. As noted before, the managerial workforce (again, despite their many talents) are often poorly educated, poor at the management of people and co-operation.

Finally, while innovative activity on a local scale is actually fairly common, many large organisations are slow to diffuse that activity throughout the organisation. This could be described as a problem of strategic consistency or coherence.

7.2 *The process of innovation management*

Research at London Business School's Centre for Operations Management has found that innovation requires a firm to have in place good processes for: development of innovative product and service concepts; development of the product from concept to launch and marketing; innovation of processes; acquisition of technology (including, but not confined to, R&D); and leadership that sets strategic direction and enables an innovative culture to flourish. Moreover, there must be strong interaction between each component. LBS research suggests that few firms have *all* these in place, and few firms have good practice in all these areas.

For example, one case study of the UK's position in one area of innovation management—simultaneous engineering—found that although best practice was generally known, it was rarely followed in the UK, and there were many questions and problems about its implementation. One of the most important areas for UK management, therefore, is the mixed record of UK firms in searching for best practice and implementing it. Another parallel study of manufacturing firms by London Business School's Centre for Operations Management found that the problem is particularly serious, and indeed self-reinforcing, at the poorer end of the spectrum, with poor firms eight times less likely to benchmark their practices against the world's best than good UK companies.

This research implies that policy must consider how UK companies can be helped, supported and indeed led to adopt best practice in *all* areas. This emphasis on *all* parts of the innovation management process contrasts sharply with *single solution* views. These encompass, at one end of the spectrum, the view which focuses on R&D and patenting as overall measures of UK innovative performance, and at the other end, views that "if only the UK could exploit its innate capability for coming up with innovative products", all would be well. The emphasis on best practice in all areas implies that neither of these single solutions is sufficient in itself.

7.3 *British strengths and weaknesses and the characteristics of innovative organisations*

Some observers see the British as very individualistic people, liking to work creatively, but poor in groups (at least compared to the Dutch, German and Japanese). The major problem we face then is how to transfer individualistic creations (at which we are strong) through group processes (at which we are weak) into marketable products. It seems fair to say that British industrial strengths correlate quite closely with these observations. Britain is strong in television, film, radio, literature, science, consulting, merchant banking, financial services and medicine, and in the highest quality manufacturing, where individual efforts are recognised (e.g., Rolls Royce and Oxford Instruments).

Our more successful innovative companies have some or all of the following characteristics: they are generally (though obviously not invariably) small to medium sized, with no more than perhaps 500 in one location; there is a strong culture of innovation in the workforce; creativity is publicly recognised and rewarded; group processes such as project teams are used for lateral communication (i.e., between different functions), but not as the everyday unit of work; where large numbers are involved, the creative work is segmented to ensure autonomy; central control functions concentrate on issues of finance and project review, and are less preoccupied with human resource issues (especially salaries); and dual authority structures are common, so that personnel strong on creativity but weak on managing are protected from their management weaknesses. The case studies carried out by the LBS Technology project (see next section) found strong evidence of the importance of many of these factors.

7.4 *Governance structure and innovation*

The research at London Business School's Centre for Business Strategy (CBS), noted in response to question 3, also examined the relationship between governance structure and success at innovation. Teamworking was seen as essential in their case study firms, and the ability of firms to promote teamworking is influenced by the reward structure of the firm. How staff are rewarded affects the flow of information within the firm. The CBS case studies suggest that teamworking and hence innovation will not be encouraged if individual performance and reward are strongly or directly related (such as in a classical spot contract), because staff may then have an incentive not to share their knowledge, and that is bad for the overall performance of the firm. Furthermore, high technology firms can in such conditions become vulnerable to the strategic actions of specialised staff. Effective protection against this threat of misappropriation depends upon organising development such that no individual ever possess sufficient knowledge about the technology.

Formalisation of that process requires a network of explicit and implicit contracts, or what John Kay[28] has called "architecture". External appropriation is guarded against by the complexity of the contract network together with the opaque nature of most internal contracts. Internal appropriation is secured by encouraging individuals to identify with the organisation's long term performance. "Relational" teams of this type are characterised by high trust relationships in which co-operative behaviour essentially replaces individual self interest.[29] Loyalty is stimulated by giving key individuals a stake in the company's long term future, through a carefully defined bonus scheme for example or promotion policy. When both the individual and the organisation's long term interests are aligned, then the risk of strategic behaviour by individuals is reduced and information flows facilitated (Quantel and Solid State Logic are strong examples of this). Co-operative behaviour arises from mutual self interest, but individuals have to be convinced that the long term future of the organisation will be secure. Failure breeds instability within the team as individuals weigh up short term gains against the uncertainty of future rewards.

Establishing the contract structure, generating know-how, and ensuring appropriateness is the overall responsibility of the governance structure. CBS case studies suggest that high-technology companies require technically competent senior managers as a check against problems of moral hazard and strategic behaviour by employees. Flat hierarchies help to ensure that the knowledge base of the organisation, and the competencies of senior management remain complementary.

7.5 *Sophisticated buyers*

Those parts of British industry which until recently have been monopolised by a public corporation have arguably been disposed to commission equipment of an eccentric specification that could not be sold easily anywhere else in the world. Some would argue that this applies to gas, electricity, water, coal, power stations, the NHS, broadcasting, defence, the telephones, transmission lines, the railways, the airways and airports —all potential buyers of advanced technology. The UK's overall appetite for sophisticated technology has been maintained primarily by the MoD.

The manufacturers of high technology need to develop standard products if they are to survive, and to do this the technology really needs to be exposed to markets and consumers that use it as a source of competitive advantage. That is why a number of the UK's most successful high-technology firms have found the US a far better and more challenging market than the UK.

7.6 *Regulation, standards and innovation*

Do standards impede or encourage innovation? Opinions seem to be deeply divided about this, and we suggest that this is because of the failure to understand a fundamental difference between two types of standard, and the different economic principles surrounding them. The quality standard typically sets minimum quality criteria which any product must meet. It is often alleged that these are set higher than some producers would wish, and in effect the standard acts as a barrier to entry. In that sense the quality standard can act as a barrier to innovation.

The compatibility or interface standard, on the other hand, defines the norms that network products (such as computers and other electrical and electronic equipment) have to observe to be useable with other network products. It is clear that when a compatibility standard emerges, then a vigorous process of innovation can take place where a large number of firms produce network products that can be used in conjunction with other products that observe the industry standard. Without an industry standard, this innovative process never shows the same vigour. In that sense the compatibility standard encourages innovation.

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Memorandum submitted by the Management School, Imperial College (13 July 1993)

RESPONSE OF PROFESSOR DAVID NORBURN, DIRECTOR, THE MANAGEMENT SCHOOL, IMPERIAL COLLEGE

1. Links between the science base and industrial innovation

The subject of the inquiry assumes a linear model of innovation: science (invention)—technology (development)—products (commercialisation). Research suggests that his model is specific, rather than general. For example, many successful innovations originate from technological developments and new market opportunities rather than scientific research. Nevertheless, basic science has become more important in certain sectors, for example, new materials research in the aerospace and electronics sectors, and biotechnology in the pharmaceutical and food industries. This suggests that no single mechanism for technology transfer will be appropriate in all cases.

2. Mechanisms for technology transfer

There is a clear need to identify, capture and exploit the scientific and technological competencies of our universities and government agencies. Existing structures such as industrial liaison offices and the proposed Faraday Centres have been a limited success in the UK. We are currently attempting to develop alternative mechanisms, and plan a trial with the engineering schools of Imperial College.

3. Technological and managerial skills

Anecdotal evidence suggests that there are few problems with the quality of our scientists and engineers, although there are concerns regarding the quantity. Much of the blame for the relatively poor performance of UK industry has been put down to poor managerial skills. This argument is based on the linear model of innovation and assumes that the problem is simply one of exploitation. We believe that it is not sufficient to produce excellent scientists, engineers and managers. Modern business requires managers who understand technology, and scientists and engineers who understand broader business issues.

This philosophy has been enshrined in our mission statement since the Management School was formed in 1987:

> "The School operates at the interfaces of management, technology and innovation. It strives to achieve balanced excellence in both teaching and research rigour. It focuses upon the improvement of corporate performance in the management of innovation, of new technological processes, and of entrepreneurship. It is international in emphasis, particularly in the European context."

We are unique in offering a series of management specialisations which represent a third of the full-time and part-time MBA programmes. Two of these, the management of innovation and management of new ventures, are particularly relevant. The first seeks to provide the knowledge and skills to understand and manage innovation at the strategic and operational levels, and focuses on technological, market and organisational change. The second provides a framework for people involved in venturing within a large organisation, public or private, or in venture capital and the formation of new firms.

4. International competitiveness

Economists have traditionally measured competitiveness in terms of inputs and outputs. Examples of input measures include expenditure on capital equipment and research and development. Examples of output measures include patents, citations, market share and value-added. However, this "black box" approach does little to explain the process of innovation. We are currently developing measures of efficiency and effectiveness of the innovation process within firms, and plan to publish a regular *Imperial Innovation Index*.

The aim is to increase awareness of the importance of innovation, and to provide regular benchmarks against which companies can measure their performance. The School will build on its experience with the CBI Innovation Trends Survey and close links with PIMS (Profit Impact of Market Strategy) Associates.

5. Short-termism and innovation

The apparent problem of "short-termism" appears to be due largely to the perception of industry and poor communication between industry and investors. There is a widespread belief that poor short-term financial performance will depress share price and therefore increase the threat of takeover. However, it is interesting to note that two of the sectors in which the UK is internationally competitive, namely pharmaceuticals and aerospace, require substantial long-term finance in order to develop new products. There is a clear need to improve communication between industry and investors, and we support the work of the DTI Innovation Unit in this area.

6. Sectoral innovation strategies

The UK is internationally competitive in the chemical, pharmaceutical, food and defence-related industries, but is uncompetitive in most segments of the mechanical, electrical and electronics industries. The relatively poor performance of the capital goods sectors is a particular concern. However, it is too simplistic to correlate expenditure on research and development with commercial success, as it is difficult to unravel cause and effect. Do successful firms spend more on R&D, or are firms which spend more on R&D more successful? We believe that there is much more to learn from the best UK firms than their level of R&D expenditure.

We support the DTI Innovation Unit's idea of local innovation clubs to share experience. For this reason we are forming a *consortium of innovative companies*. Companies representing international "best-practice" will be invited to join to become corporate members. Members will be required to provide researchers from The Management School access to relevant data which will be pooled and analysed to provide benchmarks for the imperial innovation index.

7. INSTITUTIONS AND STRUCTURES TO PROMOTE INNOVATION

It is useful to distinguish between government, academic and business institutions:

Government should gather intelligence, improve co-ordination of government and industrial research, and in special cases make up for market failure. We fully support the work of the DTI Innovation Unit, and will continue to work closely with them. We also support the Foresight initiative proposed in the recent White Paper, and believe that it will improve intelligence and co-ordination. However, there is still scope for greater co-ordination of the work of the DTI and Education Departments.

University teaching and research must address the management of innovation. We support the concept of a modular masters degree for the management of technology, shortly to be launched the JUPITER consortium. However, we believe that there is need to cover these issues within the mainstream MBA route. Our MBA programmes reflect this philosophy. We welcome the White Paper proposal for the ESRC to fund the development of new modules on innovation. We also support the proposal for a new research programme to examine the management of innovation in the UK. This will be evaluated by the ESRC in September, and if approved, we plan to participate in the programme through our *Research Centre for Technology & Innovation Management (TIM)*.

Industry will benefit from the proposed developments in university teaching and research in the long term. In the short term, the proposed innovation clubs and consortia will provide a valuable forum to share experience.

Memorandum submitted by Dr A W Pearson and Professor T A J Cockerill of the Manchester Business School (15 July 1993)

1. INTRODUCTION AND SUMMARY

1.1 This note sets out our considered views on the education and training in the UK of scientists with respect to management skills and of managers with regard to the appreciation of technology and the process of innovation.

1.2 The content of the note is as follows:

Section 2 indicates that there is an important need for management education and training for scientists and engineers, and for awareness education and training for managers in the development and application of technology. This need is not being fully met at present.

Section 3 stresses that technological invention and innovation are bringing about changes in the organisation of enterprise and, in so doing, are requiring adaptation and development on the part of managers.

Section 4 outlines the recent and current contribution of Manchester University (including Manchester Business School) and the University of Manchester Institute of Science and Technology (UMIST) to research and teaching with regard to the management of technology and innovation.

Section 5 discusses the design and contribution of management development programmes in science and technology.

Section 6 indicates the scope for future developments, and

Section 7 is a brief conclusion.

2. EDUCATION FOR TECHNOLOGY AND MANAGEMENT

2.1 The Committee's inquiry focuses on a range of important issues which include the mangement of innovation, the management of technology-based organisations and international competitiveness. These are each major topics in their own right. They are also interdependent.

2.2 Management skills, together with the availability and the quality of appropriately educated scientists and engineers, must be considered alongside the vision, strategy and leadership of companies and industries which depend upon developments in science and technology to remain competitive worldwide. These include the commercial and service sectors, which make extensive use of high technology products and processes developed by others as well as the more traditionally considered industrial sectors which spend heavily on research and development (R&D).

2.3 Users, across a wide range of industries, have an appreciation of the potential offered by new technology and the factors which affect its introduction and diffusion. Changes in markets, societal expectations, political and environmental pressures have a considerable influence on the rate and direction of investment in all countries and hence on the demand for scientists and engineers in different sectors and countries. Recent examples include privatisation, changes in defence expenditures and in health care provision.

2.4 The old distinction between low and high technology sectors of the economy, based as it frequently was on the level of expenditure on R&D or the number of qualified scientists and engineers, is no longer relevant. It is well known that German, Japanese and other East Asian companies typically have a higher proportion of scientists and engineers among their senior management than do their UK counterparts in all industries. Arguably this is one of the factors that has led the former to seek competitive advantage through product and process innovation to a greater extent than ourselves.

2.5 Given that the utilisation of innovation has long been recognised as a *sine qua non* of dynamic value adding companies capable of delivering major benefits to national economies, then steps need to be taken to encourage the absorption of scientists and engineers into senior managerial positions and for non-technically trained senior managers to understand more of the value of technology to their organisations. While part of the problem may be associaed with how UK companies are governed, some progress could be made by ensuring that the development of a substantial stream of "managerially literate" scientists and engineers is encouraged by the educational establishment. There is increasing evidence that good scientists can be, and are, good managers and that the combination is of real value, in fact a necessity, in many industries.

3. Technology and Organisation

3.1 The scope, and necessity, for new organisations to be created in order to exploit emerging technologies and to respond to new challenges and opportunities is well recognised. The increasing internationalisation and globalisation of business with all its implications is acknowledged, including for example the need to manage dispersed manufacturing facilities, and to develop new forms of collaboration which often sit uncomfortably within an increasingly competitive environment. The emergence of loosely formed, as well as strong networks and of so called "virtual" organisations is now being increasingly discussed in the literature and in practice. The implications of these developments are wide ranging, impacting upon all areas of management from finance to human resource development and have implications for education.

3.2 The need for continuing education for scientists and non-scientists is emphasised with a number of changes being necessary, at Director and senior management levels as well as for middle management and in postgraduate and undergraduate courses. Changes in the perceptions of people in all functional areas of companies are necessary and this need is reinforced by the trends, already widespread, in companies, towards empowerment, flatter organisational structures, changing job expectations and career structures. Lateral instead of hierarchical communications, reinforced by the increasing availability of new communication technology, and greater emphasis on multi-disciplinary and mutli-cultural working all have implications for management development.

3.3 New concepts are frequently being introduced into the management vocabulary via consultancy services, the diffusion of good practice, benchmarking, and especially the international transfer of ideas —just in time, total quality management, lean manufacturing, continuous improvement or "kaizen", quality function deployment (QFD), concurrent engineering and world class manufacturing are examples of management philosophies which are made possible, or are supported, by new technologies such as computer-aided design and computer-aided manufacturing (CADCAM), flexible manufacturing systems (FMS), computer integrated manufacturing (CIM) and virtual communication architecture. The implications of these changes must be absorbed and exploited by managers alongside developments in science and technology in their own business area. Today's manager, in order to keep informed of science and technology relevant to an organisation's needs, must scan an ever widening "innovation space".

4. Technology and Management Teaching and Research in Manchester

4.1 Research and teaching in various aspects of innovation and technology management has been carried out for a considerable period of time with Manchester University and UMIST being prominent in the field for over 40 years (e.g., Carter and Williams (1954) "The Characteristics of Technically Progressive Firms"; Langrish, Evans, Gibbons and Jevons (1972) "Wealth from Knowledge") and the formation of the R&D Research Unit at the Manchester Business School in the 1960s, of Liberal Studies in Science at about the same time and Policy Research in Engineering, Science and Technology (PREST) at a slightly later date within the University of Manchester. The Centre for Research on the Management of Technology (CROMTEC) at UMIST is also very active in the field of Technology Management.

4.2 Under the same heading we can, and should, embrace a variety of activities including for example: creativity, R&D and production management, entrepreneurship, project management, technology strategy and organisational development with particular reference to implementation and the management of change.

5. MANAGEMENT DEVELOPMENT PROGRAMMES

5.1 It is generally accepted that the field of technology (and innovation) management is now emerging as an important research and teaching area. Its nature means it must be treated from an integrated standpoint with contributions being made from all the major disciplinary areas such as economics, finance and accounting, marketing and organisational behaviour. The history of science and an analysis of the processes of creative problem solving, and innovation also make an important contribution to an understanding of technological progress and how this might be more effectively managed for individual, organisational and national good.

5.2 But innovation management is not just an academic subject, and the improvement of practice cannot be fully accomplished within the classroom. Scientists, engineers and managers need to be able to seek out and identify potential opportunities, to match these to market needs, to gather resources including people and finance, to manage complexity and uncertainty, to act as "product champions" and to manage change within often unresponsive organisations. They need to be leaders with vision as well as managers with the ability to build teams, and to motivate people to achieve agreed goals. In this sense management development for innovation capability cannot be isolated from management development *per se.*

5.3 Most business activities are becoming increasingly complex and dynamic. For some, innovation is no longer a discontinuity but a norm. Managers must formulate and implement strategies which progress technology and business simultaneously, or perhaps better they must be seen as part and parcel of the same activity. This will inevitably mean forging improved relationships with shareholders, financial institutions, employees, customers, associates, suppliers, environmental representatives and others. Business ethics is an increasingly important issue. Such relationships must be maintained in order to increase business efficiency and viability as well as to help innovation. They are in themselves innovative activities.

5.4 Thus it is useful to think of management development requirements not only in terms of the needs of managers as individuals but also as members of teams, working within and across company groups in many different forms of collaboration. Such collaborations, involving as they often do, the rapid formation of project groups and their equally rapid break up on completion of their task require that managers understand more of how to work under such rapidly changing conditions. It is generally accepted that the ability to do this effectively can be developed through practice. Experience can be a good teacher but for it to become a significant part of the management development process it requires an ability by people to observe, to reflect, to analyse and to derive lessons which they can apply to subsequent and possibly different situations. It is not therefore always an effective way of learning and for many people it is a slow and painful process.

5.5 The challenge to education establishments is therefore to assist people to accelerate this learning process. Since business environments and technology are both dynamic and there is a wide range of situations in which managers may need to innovate it is desirable and necessary that interactive and experimental methods are used as extensively as possible. This enables teaching to be related to the individual's own area of expertise and responsibility and help facilitate subsequent action.

5.6 In this respect Manchester Business School has been a pioneer in the field of management education. The basic aim from the outset has been to develop managers who combine high intellectual standards with practical aptitudes and ethical principles. These aims stem from our belief, put into practice over three decades, that management education should be directed towards developing managers who can combine academic rigour with practical relevance in a changing world.

5.7 Our educational designs are developed around three basic objectives.

(a) Learning knowledge and skills and the context within which they may be mobilised.
(b) Learning through engagement and reflection.
(c) Learning through managing and developing the individual in a managerial role.

5.8 MBS is committed to the improvement of managerial practice through the development of knowledge and teaching to enable managers to set themselves to achieve the highest possible standards in a national, regional and global context. These aims and values are applied to all of our programmes including postexperience and postgraduate. In the future they will provide us with the basis for collaborating with the Manchester School of Management at UMIST and the Accounting and Finance department within Manchester University in providing new joint activities at both undergraduate and postgraduate level through the new Federal School of Business and Management. At the undergraduate level there is real value in developing a substantial stream of "managerially literate" scientists and engineers.

5.9 The evidence that our approach to management development does work is very clearly available through an examination of both our student body and of the content of our programmes. At the postgraduate level about 50 per cent of our recruitment over the last five years to our full-time MBA has been from people with a science, engineering, or mathematics background. They have been able to work alongside people with other disciplinary backgrounds and with work experience, averaging 4½ years, across many functions. In particular they have worked in a variety of mixed discipline and experienced teams on substantial projects for outside organisations. Many of these projects contain a significant technical component involving strategic analysis at both local and international level. For some of these projects they are joined by team members drawn from about 40 leading business schools across the world. The experience of setting up teams, building relationships within the team and with clients, agreeing objectives and progressing such major assignments through to the decision making stage is now recognised by other major schools worldwide as the direction in which they need to go to develop managers more effectively.

5.10 The part-time MBA adopts the same approach as do our executive programmes, the difference here often being that projects are chosen from within the companies sponsoring the candidates. In this situation real added value comes from the impact this has on the individual and on colleagues from the host organisation. We were pioneers in this approach, which under the heading "joint development activities" has been used at MBS for over 25 years for single client programmes, e.g., Kodak Limited and British Nuclear Fuels; for consortium programmes, e.g., "Managing in a Changing Environment" for ICI; and for more specific courses, such as "Operations Management for the Process Industries". In many of these courses participants have the opportunity to study problems similar to their own but in other organisations. The outcome is of benefit to all participants and to the companies involved. In addition, we offer shorter courses more specifically directed to particular constituencies, e.g., a one-week course on Creative Leadership for R&D managers.

6. Scope for Future Development

6.1 As stated earlier, the emphasis in all of these programmes is on the development of managers who must operate in an increasingly turbulent environment and generally internationally—they must not only recognise the need to change, but believe in its importance and translate this to action within their organisations. In the early days of management education we and others believed that it was very valuable to have longer open programmes for senior managers, usually of about three months' duration. These allowed them the time to take stock and reorientate their thinking and their management style. Unfortunately there are few institutions worldwide that still have activities of this nature for open-nomination, as distinct from consortia or single company, programmes.

6.2 There are exceptions at the Master's level, and clearly the MBA is one of these as is the MSc in Technology Management at UMIST. However, there is a significant gap in the market at middle and senior management level. The Sloan School at MIT has offered for a number of years a one-year programme on the Management of Technology, to which UK companies have nominated. Given the large science, engineering and management capabilities available in Manchester, such a programme could be developed here and would have real benefits.

6.3 More recently in Switzerland ETH at Zurich and IMD at Lausanne have joined together and will launch shortly a new programme focusing on Leadership in Technology for top management. This is being designed as a 10-week programme in three modules with the first of these focusing on general management, the second on technology management, and the third on issues of implementation. This is a potentially exciting development supported by public and private sector funds, and is one which could be placed within the Manchester portfolio of programmes and for which our project method of teaching would be most appropriate.

7. Conclusions

7.1 The conclusions therefore are that, taken in its widest context, the training of managers in technical appreciation and the management of innovation is being done but not as widely as is required. There is scope for further development of existing programmes but there are also opportunities for new initiatives. It is important that these are considered now otherwise the UK will not be able to translate the Science Base into innovative and competitive technology, which will have serious consequences on our position in the world in future years.

(a) Dr Pearson is Dean of the Faculty of Technology and Director of the R&D Research Unit.
(b) Professor Cockerill is Professor of Business Economics and Head of Manchester Business School.

Additional Memorandum submitted by Professor T A J Cockerill, Professor A W Pearson, Manchester Business School, University of Manchester, Professor R H Hollier, Manchester School of Management, UMIST, Professor P C Stubbs, Department of Economics, University of Manchester

1. Background

Professors Cockerill and Pearson submitted a memorandum on the above subject on 15 July 1993. In that memorandum, Section 4 dealt briefly with technology and management teaching and research in Manchester. Sections 5.6 to 5.10 covered the general aims and objectives of MBS and its postgraduate programmes, while Section 5.8 mentioned collaboration with other parts of the University of Manchester and UMIST through the new Manchester Federal School of Business and Management. Sections 6.2 and 6.3 identified more closely a significant gap in the market linking management and technological education and pointed to developments in Europe and the United States along these lines.

Section 4 gave some details of the history in innovation and technology management in Manchester going back 40 years. It mentioned the R&D Research Unit in MBS, Liberal Studies in Science and PREST in the University, and CROMTEC in UMIST (see later). Much of this work was in research with some input to course teaching, although short courses and latterly full postgraduate taught courses have evolved. In UMIST there has been a long tradition of linking studies in science and engineering with management at undergraduate and postgraduate levels.

2. MANCHESTER FEDERAL SCHOOL OF BUSINESS AND MANAGEMENT

The Manchester Federal School of Business and Management is being established to create within Manchester an outstanding international school across the full range of business and management education and research. It will include the following:

Manchester Business School in the University of Manchester (MBS)
Manchester School of Management in UMIST (MSM)
Department of Accounting and Finance in the University of Manchester (A&F)
Programme of Policy Research in Engineering, Science and Technology in the University of Manchester (PREST)

The partners will collaborate in management teaching and research, whilst retaining their individual identities. In due course, membership may be extended to other individuals, units, departments and institutions within the University of Manchester and UMIST.

The Federal School brings together over 200 academic and research staff and its formation is an important element in fostering closer working relationships. It provides a framework within which the partners can collaborate in teaching, research and other activities to their mutual benefit. It also gives a strong base on which to develop joint courses with science and engineering departments throughout the University of Manchester and UMIST at undergraduate, postgraduate and continuing education levels.

The Federal School will provide a basis for the identification and exploitation of opportunities which require a scale, range and depth of specialist resources not at present available to any of the partners alone. Furthermore by working together the partners will be able to focus their energies on achieving and sustaining even greater international prominence.

3. TEACHING AND RESEARCH PROGRAMMES

3.1 *Undergraduate*

At undergraduate level the Federal School will assist in and be directly involved in the development material for degree courses which do not include a management component. It is expected that new degree combinations will be developed such that a student could take the widest possible range of choice attracting the best students. Already the following science and engineering undergraduate courses receive management anb business input from partners in the Federal School:

Computer Science and Accounting.
Management and Chemical Sciences.
Mathematics and Management Sciences.
Management and Marketing of Textiles.
Engineering Manufacture and Management.

New courses being approved include:

Physics with Business and Management.
Computer Science with Business and Management.
Materials Science with Business and Management.
Mathematics with Business and Management.

3.2 *Taught Postgraduate*

The Federal School has a wide range of postgraduate taught courses which will continue to be developed. It is expected that the increased flexibility provided under the new structure will enhance the quality and the efficiency with which they are delivered. Currently partners in the Federal School provide the following specialist MSc programmes which meet the needs of scientists and engineers:

Technology Management.
Technical Change and Industrial Strategy.
Operations Management.
International Business.
Marketing.

A new initiative will be the introduction of an MSc in Business Information Systems. The full-time MBA, with its international and project work content, is of worldwide standing. The Federal School will provide the necessary resources to enable a series of part-time Master's degrees, comparable to the courses listed above, to allow managers in industry and commerce easier access to high quality education. Local technology-based firms will be encouraged to participate in the design and development of such programmes to ensure that the timing and content are relevant to their needs.

At Master's degree level, UMIST and the University have considerable experience in running Teaching Company Schemes. They are now collaborating in two Integrated Graduate Development Schemes, one in Manufacturing Systems Engineering (with Manchester Metropolitan University) and the other in Pharmaceutical Engineering, both with major management inputs. There is also likely to be some contribution to the nationally organised JUPITER programme on Technology Management in the near future.

3.3 *Research*

MSM, A&F and PREST were each rated five in the recent research assessment exercise and together with MBS's acknowledged skill in the action-centred research field, provides the basis for the Federal School to become the leading international multi-disciplinary, research-based business and management school.

In particular, the Federal School will allow three units which have a high reputation in teaching and research in the fields of management of research, technology and technical change to work together more closely. These units are:

- Centre for Organisation, Management and Technical Change in UMIST (CROMTEC).
- Programme of Policy Research in Engineering, Science and Technology in the University of Manchester (PREST).
- Research and Development Research Unit in MBS.

The combined staff of these units involved in teaching and research is about 50 and makes it one of the strongest in Europe. Industrial contacts are already extensive and these will be further developed through new initiatives aimed at transferring technology and knowledge of the state-of-the-art in technology management to practice.

For some years UMIST has run a successful Total Technology Programme funded by the SERC which aims to provide doctoral education for graduates working closely with industrial companies. More recently, UMIST was successful in a national competition to mount one of the first Doctorate of Engineering programmes as a direct result of the Parnaby Report to the SERC. It was also successful in creating one of the first Postgraduate Training Partnerships in conjunction with E A Technology Ltd. These three programmes between them now have 115 doctoral candidates working in companies on projects of crucial importance to their sponsors and all receive some instruction in management topics.

3.4 *Executive Education*

MBS, recently graded "excellent" in the HEFCE Quality in Education Assessment, is a leading provider in executive education in all areas of business and management in both the private and public sectors. The combined resources of the Federal School will enable additional effort on developing programmes such as:

- Technology management.
- Short seminars designed to inform industry of research progress.
- Executive programmes on technology and manufacturing management specifically designed for companies.

The Federal School will be able to offer world-class programmes, drawing on all the available resources, with collaboration not competition between the partner institutions being seen by clients as being a major strength at Manchester.

4. The Wider Context of Greater Manchester

In the wider context of Greater Manchester, the four Higher Education Institutions (University of Manchester, UMIST, University of Salford and Manchester Metropolitan University) and the North West region of the Open University are collaborating with Trafford Park Development Corporation to create the Trafford Park Manufacturing Institute. This Institute will act as a focal point for delivering postgraduate and continuing education and training for companies in the North West. With regard to continuing education, the Institute is intending to offer a programme of courses, some of which will be given by companies as well as the HEI providers, on a variety of topics of interest to industrial companies in the area.

A future possibility is the establishment of a Faraday Centre in the North West involving not only the four HEIs, but also a number of industrial research organisations which are keen to see the Faraday principles, endorsed by the recent White Paper, put into practice. This involves close links with the Innovation Unit of the DTI, NIMTECH and the North West Regional Association who are producing strategies for economic development in the North West.

5. CONCLUSION

This memorandum has given some further details about the education provided in Manchester which links management with technology generators. There is scope for further development of existing programmes, but also opportunities for new initiatives. These are important for the regeneration of the North West and for innovative and competitive technology in the UK.

Professor Cockerill is Professor of Business Economics and Head of Manchester Business School.
*Professor Pearson is Professor of R&D Management and Dean of Manchester Business School.
*Professor Hollier is Professor of Operations Management in the Manchester School of Management, UMIST.
*Professor Stubbs is Professor of Economics in the Faculty of Economic and Social Studies in the University of Manchester.

Members of the Development Management Team for the Manchester Federal School of Business and Management.

Memorandum submitted by the Warwick Business School (15 November 1993)

In general we would argue that various elements of research including that undertaken by Professor Paul Stoneman (here at Warwick) and Professor Derek Bosworth (now at UMIST, previously at Warwick), tends to show that companies where managers have some technical qualifications do better.

Warwick Business School is committed to developing and offering various forms of management courses to respond to this important requirement. However we would emphasise certain problems in terms of funding and demand.

Warwick offers a successful undergraduate degree in Engineering and Business Studies. We also teach an undergraduate course within this degree on Management of Technology (which could be more specifically seen as innovation) which has an annual participation of around 25 students per annum. Finally we offer a very successful course, mainly for scientists, under the general title of Business Studies III.

At the postgraduate level, our MBA already has an optional course on the Management of Product Innovation. We are currently planning to introduce a more broadly defined Management of Innovation option on the MBA but at the moment there is some evidence that many students find this a relatively unattractive area partly because of concerns about career prospects.

We have also had a postgraduate modular programme designed to address more directly some of these issues in our MSc in Business Management Systems. However we have had substantial problems over the last five years in generating a viable level of demand despite considerable support from specific industrial sponsors.

Warwick, of course, has a considerable interest in research in this area. In particular we have established a Technology Innovation Research Unit and the Centre for Strategy and Change has developed a major substantial Management of Change programme with major technological elements. Finally, and additionally, a number of individuals have their own related research interests such as Harry Scarbrough and Martin Corbett.

Further memorandum submitted by Professor Paul Stoneman, Director of the Warwick Business School (1 February 1994)

I have been asked by Professor Robin Wensley to respond to your letter to him of 11 January asking for further details re our submission of 15 November on education and the management of technology.

You raise two specific queries.

1. THE LINKS BETWEEN THE MANAGEMENT COURSES AND DEPARTMENTS SUCH AS ENGINEERING

As we stated in the original memo some of our courses are offered (in some cases exclusively) to students in Engineering. However I think the issue you really want to address is relationships between staff in the different departments.

There are links but of an informal nature centred on interpersonal contact. We do not have staff from Engineering teaching management courses (or vice versa). However, there are examples of joint research between Business School staff and Engineering staff. Also some of our ex-MBA students are staff in the Advanced Technology Centre which is part of the Engineering Department.

2. RELUCTANCE TO TAKE MANAGEMENT OF INNOVATION COURSES

Our original comments were based upon hearsay from other Business Schools that offer a course under this title. Further consultation with the lecturer who offers our MBA course on the Management of Product Innovation suggests that, for this course at least, the problem has not been too severe. However, she does observe that there have been cases in the past where there has been reluctance to take the course, and this often has been due to either a fear of "technology" or a belief that technological innovation is about getting dirty hands rather than performing the "clean roles" worthy of senior managers. One should note, however, that product innovation might be considered to be at the clean end of the innovation spectrum. Courses on process innovation, which our proposed new course would encompass, may be less appealing.

In our previous memo we also stated that we offer a postgraduate degree in Business Management Systems which would be considered as encompassing innovation management. We have had to make the difficult decision to close down this programme, for, despite extensive publicity and marketing, we were unable to generate sufficient registrations to the degree to cover costs. One may draw differing conclusions from this.

Professor Paul Stoneman
cc. Professor Robin Wensley

Memorandum submitted by Nomura International (4 June 1993)

NOMURA'S BANKING OPERATIONS IN GREAT BRITAIN

Banking activities of the Nomura Group in the UK are carried out through its subsidiary, Nomura Bank International plc (NBI). This company, which is wholly owned by The Nomura Securities Co Ltd, Tokyo, was established in November 1986 and is subject to supervision by the Bank of England. A copy of its most recent published Annual Report is attached.

Nomura Bank International plc engages in wholesale banking transactions with corporate clients and financial market counterparties. At a balance sheet size of £2 billion, it is still a small player in this market and its market share is immaterial. NBI's general lending policy is to develop a medium term portfolio of direct loans to corporate institutions, most of which are located in the UK. The typical loan which it makes is granted for a three- to five-year period, although in certain cases it has extended loans for up to seven years. Its lending may support new investment of corporate clients, but more typically forms part of their general funding requirements.

Risks assessment in NBI is carried out by a Credit Analysis department which has some 10 dedicated analysts, who have expertise in various industries. Their analyses are predicated both on published accounts of potential clients and visits to their management. An assessment of the quality of management is an important factor in their judgment. After they assess the customer and/or project to be funded, their recommendation is submitted to NBI's Credit Committee for review and approval.

Regarding companies in innovative industries, NBI does not have a specific policy in this regard. It concentrates on the top 200 companies in the UK, based on market capitalisation. Many of these have high degrees of innovation, for example aerospace, electronics and pharmaceuticals. NBI has no proprietary mechanisms for assessing the risks of high technology companies, but relies heavily upon the capabilities of Nomura Research Institute and on other industry or company reports available to the public. NBI does not lend specifically to high technology or start-up ventures; rather its involvement here is through larger companies which may be emphasising innovation in particular product lines. While a firm's innovative potential is obviously important and attractive to a lending bank, NBI is mostly dealing with well established companies, which succeed because of their good innovative abilities.

Being a young and small bank, NBI has no particular role to play in assisting companies in difficulties. In the recent recession, some borrowers turned out to have problems and to need restructuring of their facilities. NBI played a role in such cases, either as a member of the group of lending banks or, in a few bilateral cases, by itself.

While there are business opportunities for Nomura to operate in banking in the UK, it could not use any particular home market expertise since the headquarters company has never dealt in banking services.

The most important policy which differentiates banking in the UK from banking in Japan, of course, is the extent of industrial and bank cross-shareholdings in the latter country. Much closer and longer term relationships develop in Japan as a result, which many observers would see as a positive element in the Japanese economy and a major boost to industrial development. The same could be argued for Germany, which represents the other most successful economy in the world in the last two or three decades.

Memorandum submitted by Venture Capital Report Ltd (28 May 1993)

LETTER TO THE CLERK OF THE COMMITTEE

Thank you for your letter of 25 May, and I am pleased to enclose some information about Venture Capital Report for your committee.

I enclose:

- A copy of my CV.[1]
- A sample copy of VCR.[1]
- Examples of projects which were funded through VCR in 1992.[1]
- Sample comments from those who have featured in VCR and an explanation of how VCR charges.[1]

Under a separate cover I am also sending a copy of the sixth edition of the VCR Guide to venture capital in Europe.[1]

I apologise for this great volume of paper, but I hope there is some purpose in it. You will see from my CV that I am an engineer by training and that I have always had an interest in science and technology. The only papers I read regularly are *New Scientist* and *Scientific American,* and even today, I manage to spend a significant amount of time in my workshop where I have two lathes and a mill, etc. Having worked for Hanson for a year after leaving university, I experienced at first hand the difficulties of raising small sums of risk capital to start a business. I needed £27,000 to start an American Hamburger Restaurant (the original plan was to build a chain of five in five years and then to sell them in order to have enough capital to start a business in science) and was offered £1,000 by my bank and turned down by the only two venture capital companies of the day (3i and SBCF). I eventually managed to raise the capital from four business angels who were among the 10 people who answered a small ad in the *FT.* I was very lucky to succeed and had all but given up and actually arranged another job before the last of the capital was raised. The business was successful and five years later, there were three restaurants in the chain and 50 people employed.

I then diverted from my original plan of starting a business in science in favour of starting Venture Capital Report, which was founded in 1978. The objective of VCR was to give entrepreneurs seeking capital to start a business what I had needed myself in 1972, namely a forum in which they could present their ideas in considerable detail to several hundred genuine investors, who would indicate that they were genuine by paying an annual subscription, currently £300 pa. By contrast, only 10 people had answered my small ad in the *FT,* and even some of these had been time-wasters.

Venture Capital Report has now been published every month since December 1978 and has become the clearing house for entrepreneurs seeking smaller sums of capital which are beneath the level of interest of the venture capital companies, which usually will not look at deals requiring below £250,000 to £500,000.

Among the projects featured in VCR are many technology projects in which I am myself particularly interested.

By 1983, in other words, after VCR had been going for five years, it became very clear to me that the projects which found it most difficult to attract capital, even through VCR, were those seeking very small sums—£250,000—to build prototypes of novel engineering or science ideas. The sums were much too small for the institutions and the projects were too risky for individuals so nobody did them—or so it seemed to me. Therefore, in 1983, in order to do something practical about his in so far as I could, I founded Seed Capital and raised a small fund of £200,000 to make this type of investment myself. I am now managing the fourth fund (Seed Investments III) and have invested over £1 million in sums of less than £50,000 in over 30 businesses, all within one hour's drive of Henley on Thames (I get involved in their management) and almost all to build prototypes of innovative technology and, if the prototype worked, to found a company. I have had many failures, but overall, the business has been financially successful and I have been able to attract new funds. One of my major problems, however, has been getting the next £250,000 of investment if the original seed begins to grow. This has often taken over one year to raise, a delay which has been very damaging to the businesses concerned. The theory was that my backers, currently Apax, would provide these follow-on funds, but in practice they have become very large and this has mot happened. This has neant that I have had to look to others and although I have usually succeeded in the end, the delays have been very damaging. On one occasion I failed, and the company went into receivership as a result. In my own view this company had world-beating technology and this loss was a great shame. I will finish investing my current fund at the end of this year, and I am now endeavouring to raise a larger fund of £3 million. I will continue to invest with the same strategy—£250,000 to found businesses with innovative technology within one hour's drive of Henley on Thames, but I will then be able to provide the next £250,000 in those which show promise myself, so that there will be no delay.

In my own view (doubtless biased) VCR provides a very useful service to entrepreneurs. The problem is that it has only 400 subscribers. When I founded it I hoped that if I could keep it going for a few years, then most companies with profits of over £250,000 would subscribe (there are over 17,000 of these), but this has not happened.

[1]Not printed.

The detailed statistics about how many projects featured in VCR have been funded and by whom are contained on pages 75-76 of the VCR Guide to venture capital in the UK and Europe. This Guide also contains a section on the current business angel initiatives in the UK pages 643-657, including details of the five TEC schemes. I enclose a copy of page 645 which summarises my view of what is needed in this field.

I hope all this is of some help and I send it now so that you may ask for clarification if anything is not clear, or if you want more details.

Memorandum submitted by Schroder Ventures (22 June 1993)

INTRODUCTION

Schroder Ventures is in the venture capital (VC) industry. The term venture capital is defined as high risk equity investment in unquoted companies.

Schroder Ventures (SV) is an advisor to offshore funds. Financial institutions, e.g., pension funds, insurance companies and private individuals provide the capital for investment by the funds. SV does not lend money, the funds that SV advise make investments in unquoted companies for a percentage of the ownership.

Venture capital competes for investors' money against other asset classes such as gilts and quoted shares. The disadvantages of venture capital are that it is high risk and investment liquidity is lower. Thus, it is only by producing a track record of better returns than competing asset classes, that the venture capital industry, and namely SV, can continue to attract monies from investors.

Investments that the funds make need to achieve a capital gain so that an adequate return is given back to the investor. The funds' objective is to make a capital gain, not to create jobs, fund technology or promote the regions. The funds do not necessarily need income in the form of dividends and interest, but an exit must be achieved within 10 year on investment. The latter restriction is prerequisite of investment, because all SV funds have 10 years lives. The average life of an investment is around five years.

The investors do not want the funds to invest in high risk deals, their only interest is their return on investment with SV funds.

MECHANISMS FOR DEAL ASSESSMENT

The venture capital pre-investment process identifies the strengths and weaknesses of a deal. The process includes researching products, markets, future growth and the management. For high-technology companies innovative potential is crucial and the company must also have a demonstrable competitive advantage. A strong balanced management team is a further pre-requisite.

Investments in innovation and technology undergo the same process of assessment, with greater emphasis being placed on evaluating the technology and product development. Questions to be asked are:

How far along is the company in product development?
What are the risks in bringing the technology to a commercially viable stage?
What are the market opportunities for a new product?
Is the technology already being developed in the US and do we have a competitive edge?

SV carries out initial evaluations on high-tech deals. Our in-house strengths are in the fields of pharmacology, clinical diagnostics, medical electronics, biotechnology and information technology (IT). For further due diligence work external consultants would be brought in to evaluate specific technologies and carry out research into potential markets.

SV INVESTMENT POLICY

SV has no specific investment policy for innovative industries, it looks at deals in all sectors of industry and at all stages of investment.

Deals which SV review and that incorporate innovation and technology are typically in the life sciences and IT sectors. The stage of investment is usually one of seed capital, start-up or early stage ("start-ups").

Our past experience has shown that start-up and development capital deals in general do not provide adequate returns to the funds we advise. Evaluating a start-up is much more difficult than evaluating a management buy-out/buy-in. A start-up business doesn't exist and therefore research into potential markets, customers, competitors, and the future is more demanding and time, money and people consuming—SV's resources. The nature of start-up investments is that they require a high level of due diligence work prior to investment and monitoring post investment. In an MBO/MBI situation the deal is more clearly defined and as a result less demanding of SV's resources.

Start-up investments offer a higher probability of failure and in the UK the winners do not compensate for the losers. The rewards experienced from start-ups do not justify the amount of time and effort they consume. This has meant a change of emphasis to doing MBO/MBI deals and turnaround investments. The returns from these types of deals are more predictable and will persuade investors to participate in future fund raisings, keeping SV in business.

However, SV will do start-up deals when there are exceptional circumstances. In such cases there will usually be an experienced management team, product potential and significant differentiation which gives a competitive advantage and attractive markets.

For SV the majority of high-tech start-up deals fall in the life sciences sector. The number of investments in this sector will increase in number as we are in the process of raising a specific life sciences fund. There is no discrimination on stage of investments when reviewing life science deals, but the emphasis is on start-up deals with follow-on investment opportunities.

There are certain aspects of life sciences that offer a higher probability of success than in other high-technology investments. Successes can come from filing patents which international drug companies wish to buy in, the technology of drug patents being easier to transfer than for other high-tech developed products. Another advantage of the life sciences is the large and international market potential for newly developed drugs.

DIFFERENCES BETWEEN UK AND ELSEWHERE

The number of high-tech start-up investment opportunities in the UK is much smaller than in the US, Japanese and German markets. In those markets, because there are more opportunities to invest, there is a greater probability of achieving a high capital gain on a star investment which will compensate for the losers. There appears to be no defined policy in the UK in terms of commercialisation of innovative technology, be it within the Science Research Councils, Universities, Industry or the Government. The educational institutes do not always incorporate commercialism into the technology they develop and as such are not business orientated in their goals. If this is the case there is no reason why a venture capitalist or large company would want to finance such technology. Alternatively, universities can be too greedy in the funding they ask for and can put off potential investors. They may demand cash up front, when accepting royalty payments would be more appealing to the investor.

Mechanisms for transfer of technology to commerciality are fundamental and should encourage the entrepreneur. However, the transfer cannot be achieved without finance and the product development funding gap, which transforms ideas into products, is difficult to bridge. High-tech start-ups consume large amounts of funding, typically US$40-50 million, through several tiers and types of fund raising. In the UK science is funded by the state, innovative technologies are produced, but once patents are filed it is left to the private sector to take over funding. This next step takes technology to the product stage. It is unlikely to be financed by a large company and will fall to the unwilling venture capitalist to support. Venture capital finance is used to start a business and to facilitate future product development, but in the UK subsequent funding is hard to secure and the venture capitalist may be trapped in an unattractive illiquid investment. There is a lack of secondary finance in the UK and small companies, if unable to attract further venture capital or debt have no other financing options, such as an active small companies market.

In the past the government has funded research and development, but cash has often ended up with the larger companies who were unwilling to use their own money. Faced with a situation of limited R&D in the UK and industry falling behind other countries, the government continued giving handouts. The government does not even have a supportive procurement policy.

The government also expected the banks to fund small companies. However, they have responsibilities to their shareholders and a requirement to perform and thus cannot be relied upon to take on low margin labour intensive work which offers a high risk of failure. The economies of small deal investments do not add up for them. The more recent UK philosophy of holding back public money and relying on private finance is also clearly not working and large UK companies are usually unwilling to fill the gap. It would be ideal if larger companies were to take on an investors role, so that they could work with the developers of technology to achieve successful end results. If the larger companies remain unwilling to provide direct finance they could provide certain resources to help start-up businesses get going, e.g., distribution networks or administration services.

SV is not aware of any policy in the VC industry for investment in innovation and technology. In the UK there are very few firms that will invest in start-ups. In the UK life sciences sector there are only a handful of venture capitalists who are willing to fill the funding gap and enable product development, in the US there are hundreds.

For venture capitalists and start-up companies a principal advantage of the US system is the existence of NASDAQ which allows start-up companies to raise further financing and gives the venture capitalist the benefit of liquidity and a possible exit at a comparatively early stage. Early liquidity is a major attraction for investors. There is no European equivalent.

The UK badly needs an effective market for the public trading of shares in small companies.

Ideally, Europe needs an equivalent to NASDAQ. Recent moves by the Stock Exchange—including the decision to defer a decision on the closure of the USM—are encouraging, although the establishment of a European NASDAQ is still many years away.

COMPARISONS BETWEEN THE US AND UK

The comparisons between the markets of the US and UK are easier to make as both have established venture capital industries. A fundamental difference between the two markets is the attitudes to and nature of start-up opportunities. Those who work in the venture capital industry in the US are often ex-professional managers and ex-industrialists themselves who have a more enlightened perspective to the young accountants who often evaulate deals in the UK.

In the US high-tech start-ups are often run by professional managers, who are often engineers and may also have an MBA. Doing a start-up in the US and running your own business has a high level of status, which others appreciate. The entrepreneur is very much driven by the high risk-high return belief as well and if the start-up fails it is not seen as condemnation of the management.

In the UK high-tech start-ups are unlikely to be run by professional managers, who are engineers and have an MBA. The level of status which concerns professional managers in the UK comes from the security of an established large company and the trappings that go with it, e.g., big office, company car, etc. There is a lower status attached to working for yourself and gives rise to the limited mobility of professional managers. If the start-up venture fails then it is immediately blamed upon the management and is a stigma against them ever doing another deal. As it is there are few role models of people who have run successful high-tech start-ups in the UK and this is no incentive to potential entrepreneurs.

The challenge of making a high-tech start-up succeed in the UK is far greater than it is in the US. The UK market for a start-up's product is much smaller and the only way to survive is to begin exporting as soon as possible to expand the customer base. At the same time it is imperative to continue sales and marketing and product development, all of which demand a high level of managerial competence and skill. These items are not as readily available as in the US and trying to attract the people with these abilities is a problem in the UK.

CONCLUSIONS

Even though venture capital by definition is high risk investment, the industry is still risk averse to the financing of innovation and technology at the seed capital stage. This is a direct result of the amount of a VC company's resources that need to be allocated to such investments and the necessity to give a return to our investors (our customers, the pension funds and insurance companies), which is better than that of other asset classes and keeps SV in business.

While it can be said the UK has a venture capital industry, it does not really. In the UK it is becoming harder for start-up companies to get venture capital, without which banking will be almost impossible to secure.

Opportunities are being—and will continue to be—lost because the key mechanisms for technology transfer are not yet in place here. Government handouts are not the answer and without new incentives for private investors to provide funding, e.g., the venture capitalists or large companies, science based projects will never develop into technologies with commercial applications and eventually products. If this is the case, ideas will be lost to other countries such as the US.

Memorandum submitted by D Hodson, Chief Executive of LIFFE (25 June 1993)

I am pleased to respond to your request for comment regarding the questions raised in your letter of 11 May 1993.

The question of whether or not LIFFE is an industry within the terms of your study is not one that I will try to answer. However, in so far as I believe that I can comment on the issues raised either from a personal or industry perspective. I will try to do so.

LIFFE'S USE OF TECHNOLOGY

There are two main areas in which LIFFE is a user of "science and technology". Firstly, we have a product base of financial instruments which have evolved over time and are based on a financial "science". Thus, for example, the success of options has been predicated on the research of Black and Scholes and their definition of options pricing theory. Secondly, in common with many city institutions, we are major users of Information Technology and in this area we are very much a leading edge user often responsible for driving development by the suppliers.

In both of the areas in which LIFFE interact with science and technology, it is essentially as users with an intermediary acting to provide the link between the basic research and our use of it. In the case of financial science the intermediary would typically be a LIFFE member. In the case of our use of technology, it would be a supplier company. Thus the comments that we can make on the issues you have raised are largely those of an educated observer who sees the strengths and weaknesses of the current situation from an independent position.

A LIFFE PERSPECTIVE ON INDUSTRIAL INNOVATION

Our perception on the quality of science carried out in the UK and on the capability of British companies to use this science and innovate is probably fairly standard; the science is of the highest quality new and innovative products, particularly relating to small-scale applications.

However, the key issue that I believe should be addressed relates to the *ability of companies to bring product to market at a price and on a scale that is appropriate to the needs of the potential user.* Typically, British companies fail to capitalise on developments that need significant funding or have a long time scale. This failure becomes critical as the costs and time scales of most developments continue to escalate in the technological world that now exists. I must emphasise that this is a personal view, since this a topic on which LIFFE would not have a corporate position.

I believe that there are three main reasons for this problem. The first relates to the structure of the typical UK company, the second to the Government's attitude to the funding of infrastructure development and to the awarding of contracts for such development as does occur, and the third to a natural conservatism on the part of most purchasers.

The large UK companies are typically considerably smaller than their European, US, or Japanese counterparts. This makes it harder for them to invest in high cost, long term, speculative development; and means that some of the key technological developments now require a level of investment that is impossible for one company. Against this, UK companies have shown a marked reluctance to engage in co-operative ventures.

The UK Government has, over its time office, promoted a policy of minimal Government intervention and private sector funding which has had many benefits for the UK economy. However, it may be that there are areas where the private sector (particularly when considering the constraints on performance identified above) may not be able to deliver all of the developments that the country needs to grow and prosper. It should be the role of Government to identify areas of critical infrastructure development that will not be undertaken without its intervention and orchestrate these. Government projects can bridge the gap between innovative ideas and user demand by creating the infrastructure necessary for the demand to be realised. It can also ensure that, without compromising real competition, it is established that a UK solution should always be a preferred solution in any tendering situation.

The third area identified above relates to the conservatism in UK companies relating to procurement. "You don't get fired for buying IBM" has been a maxim in the computer industry for some time. This attitude makes it difficult for smaller innovative companies to break into the market.

LIFFE'S REQUIREMENTS FOR A WAY FORWARD

I will conclude by making some general points about the ways in which LIFFE, would like to see developments taking place to allow us, the user, to make better use of the technological innovation that is taking place in the UK, and raise one specific issue where we believe that Government intervention is essential if the UK is not to be left behind in the next technological revolution.

Government can stimulate innovation in a number of ways: the US Government has done it (whether by design or not) through its investment in NASA and the "Star Wars" project. The French Government has done it through its investment in technological infrastructure. Having decided to invest, the Government, as a procurer, can also direct that investment to companies that will benefit the UK and its development.

Government can also influence company structure using its tax and regulatory powers. Changes in this area could significantly influence a company's ability to invest in innovation.

One specific area of concern that we would like, on a capacity basis, to raise relates to communications. UK scientists have effectively solved the problems of wide area high bandwidth communications. This is the enabling technology for the "Information Revolution" which we believe will be just as significant as the industrial revolution in the history of this country. Other countries are already installing optical fibre communication links with the intention of connecting everybody to a single network. The only work going on in the UK is the installation of cable TV using outdated inflexible technology. If other countries implement this technology significantly before the UK, many UK companies and institutions (including LIFFE) will cease to exist, or become marginalised within a very short period of time. This is precisely the sort of infrastructure development that the Government should initiate and in doing so it would promote the link between science and technology in a very powerful way.

I hope that the above is of some use.

Memorandum submitted by the National Westminster Bank Plc (24 June 1993)

Q. *What is the relationship between the Science Base and industrial innovation?*

A. The "science base" is a broad term, comprising academic research, large private industrial research and publicly funded research. Industrial innovation is the exploitation of science by industry for commercial purposes, whether this be incremental changes or major advances in technological development, and is usually undertaken by the private sector.

Relationships between these functions exist at many levels. All sizes of business may be involved, from large multinationals through medium sized businesses operating in niche markets, to small specialist companies. They may be engaged in different stages of the innovation process: ideas/concepts, basic research, product development, prototyping, near-marketing activities or post launch development.

The relationship can cover just one, many, or all the different areas of support required; identification of commercial potential, management skills and expertise, technical assistance and funding are just some of the links that need to be forged.

It is clear that the situation is highly complex and offers considerable scope for enormous potential to be wasted or left untapped. Moreover, the diversity in the nature of these relationships can create difficulties when attempting to establish a coherent approach for exploiting the science base effectively.

Private relationships should not be forgotten however, with ICL, Esso, ICI, Pilkington, Simon Engineering and many other industrial companies developing close ties with HEIs to the benefit of both the institutions and the companies funding the research. The vast majority covers product development rather than basic research.

This perspective on the innovation scene illustrates a fundamental gap in the innovation curve. It is often perceived by UK industry that the only really relevant stage of the R&D process is the near-market stage. Industry is reluctant to take on undeveloped products or processes earlier than this. On the other hand, academics are frequently unable to develop their ideas sufficiently to get them to a stage ready for industry to exploit. It is this "innovation gap" that needs bridging.

Q. *Are the mechanisms for technology transfer and interaction between the science base and industry effective? How could they be improved?*

A. Technology transfer, as an activity to create competitiveness through the introduction of new products and processes, is in our experience not widely understood. Until now activities have not been effective in terms of numbers or size of "deals" done. Anecdotal evidence from discussions with other leading TT operatives suggests that a mere one to two per cent of income in UK universities is derived from Technology Transfer.

Whilst large corporations can "look after themselves" in terms of technology transfer and product development and small companies generally do not get involved in large-scale projects, the medium-sized niche market specialists are in short supply in the UK however. It is these companies who benefit from transferring in intellectual property in other countries, which helps them achieve greater degrees of competitiveness.

Mechanisms for technology transfer do exist. Science Parks aim to instill commercial practice into small academically-based business, whilst providing links with R&D expertise. Regional Technology Centres aim to help industry identify, introduce and exploit science based products and processes with varying degrees of success. Technology Transfer Centres, most of them located on university campuses, have perhaps been more successful, possibly because they have a more direct link with HEIs. The relatively new EC-Business Innovation Centres, which concentrate on manufacturing, are also trying in some measure to encourage manufacturing industries to bring in new ideas, processes and techhiques to achieve competitiveness.

Moving further along the exploitation curve, Industrial Liaison Officers, or bodies such as ISIS Innovation at Oxford and UMIST Ventures in Manchester, actively identify and help commercialise the most promising results of academic research.

Programmes such as LINK or the Teaching Company Scheme get academics and industrialists together and help to generate the mutual understanding of each other's problems. They fail however, to provide the infrastructure needed to give long-term and stable foundations to the transfer of technology, knowledge and management know-how.

We see the problem as being twofold. Firstly HEI's, the idea generators in the TT equation, are at best a loose liaison of highly individual academics and certainly not a closely knit or strategically directed organisation with a clearly defined goal. Academics frequently undervalue their developments and fail to realise their full potential. The crucial step is to get technologies out of the laboratory and into the commercial environment. Unfortunately, the basic science and technology that comes out of HEI labs is frequently insufficiently developed to make it commercially interesting to industrial customers.

On the other side of the equation, industry cannot take on technologies unless they have developed to the near-market stage at least. The primary reason for this is obvious: timescales in industry are not only shorter than for academia, but becoming shorter all the time as product life cycles dwindle and the pace of innovation increases. It is vital that this gap is narrowed so that science and technology can be taken from the potentially exploitable to the commercially viable. This requires a combination of skills and knowledge: technical, scientific, commercial and industrial.

There currently exists no obvious candidate in the UK to fill this gap by linking together academics and industry so that both can feed off each other and collectively develop successful technologies. LINK and the Teaching Company Scheme only go so far, though some of our customers have benefited from both.

Q. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

A. Much has been written and discussed about the relative uncompetitiveness of the UK workforce in terms of education and skills. NEDO pulls together a range of studies in this area and concludes that, whilst at graduate level UK companies compare favourably with our main competitors, at the intermediate and vocational levels we are at a considerable disadvantage. Only 20 per cent of the UK workforce leave with vocational qualifications, whereas 56 per cent of Germans and 33 per cent of France's workforce have approved qualifications.

Learning a new technology is not easy. Having a better trained and more educated workforce facilitates the introduction of new technology, encourages workers to learn new techniques and processes, stimulates interest in the learning process itself and generates self-reliance.

From our experiences of working with hundreds of small- and medium-sized technology businesses, we do find that the technological skills and enterprise of the owner/managers themselves and their key personnel is frequently very high indeed. Our customers' problems do not generally stem from technological incompetence.

Under our New Technologies Appraisal Service (NTAS), NatWest reviews several businesses each year, both start-up and existing, from the point of view of technology, management expertise, and market viability. Approximately three-quarters of all companies assessed in this way show major failings in the areas of management and/or marketing. Operating in sectors where the management of innovation and understanding of the market place are crucial to success, it is clear that even those companies with high potential are at serious risk of floundering through lack of often quite basic commercial skills.

Q. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

A. It is frequently said that the British are "good at invention, but not at innovation". Our expertise and track record at developing science, new ideas and inventing new technologies can easily be demonstrated. Just one British university college, Magdalen College, Oxford, has more Nobel prize winners than the whole of Japan.

Our share in the world's research activity however, appears to be declining rapidly in comparison with our competitors. The recently published R&D Scoreboard (Company Reporting Ltd) shows that of the top 100 world companies, the UK's highest ranked concern was ICI, placed 47th.

In the top 100, we have seven representatives compared with US's 40, Japan's 21. Fortunately we rate more evenly against our European competitors, France and Germany. Despite the fact that R&D spend in the UK is this year up by 6 per cent however, all the leading UK companies fell behind their international competitors.

It is also significant that R&D spending in the UK was dominated by just four drug companies, accounting for nearly one-third of the total. This concentration of investment appears to be mirrored nowhere else in the developed world.

Looking at the question in broader terms, the World Competitiveness Scoreboard (IMD/World Economic Forum) reports on R&D intensity as a percentage of GDP. This places the UK 13th overall out of 22 OECD countries, and takes into account a range of factors including participation in trade innovation finance, science and technology base, management, infrastructure and skills.

The level of patent activity in a country is an indication of its technological strength. Currently the UK has no company in the world's top 25 patenting concerns and our level of patenting activity, whether in total or on a per capita basis, is far below that of Japan, US and some European countries. In 1990 for instance, the UK Patent Office received 20,059 applications by UK-based companies and individuals. This figure is by-and-large unchanged from the 1980 figure of 19,612.

By comparison Japan received 333,373 applications in 1990, more than twice as many as ten years previously. The comparative figures for US, France and Germany were 91,410 (up from 62,098), 12,378 (up from 11,000) and 30,838, up from 28,683 (Patent World).

The CBI/NatWest Innovation Trends survey looks more closely at the results of the innovation process and is therefore perhaps a better measure than the foregoing. The survey confirms the upward trends in current and future R&D spend detailed in the R&D Scoreboard.

It also reports significant improvement in profits (64 per cent of respondents), sales and market share (82 per cent), and new market gains (78 per cent) from investment in innovation over the last three years.

The Survey also reports joint venture activity as remaining steady, with a major decline in UK joint ventures, and slight rises in overseas ventures and in academic/industry ventures. Links with academics are seen as an important element in innovation.

Innovation is about more than intellectual property, technical know-how or R&D spend. Innovation is one of the keys (though not the only one) to achieving international competitiveness. By itself innovation is hard to measure, since the innovative process itself is an amalgam of many different functions—technical, commercial and financial—and the resultant improvement in competitiveness cannot always be traced back to its true origins.

The usual means employed to gauge the level of innovative activity is either to measure pre-innovative activity (R&D spend, patents), or post-innovative results (GDP, manufacturing output, trade figures). None are entirely accurate indicators, although together they can give an overall view.

Perhaps the question should not be "how to measure innovation" but rather "what are we measuring and why?" The answer to why—from the Bank's perspective, and surely from the country's as well—is to help us identify high quality businesses and technologies with good chances of achieving success. On a broader front, the Technology Foresight Initiative outlined in the White Paper should go some way to identifying in general terms the technologies of the future.

Q. *Is short-termism really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

A. Short-termism may be indicated by the R&D Scorecard in which UK companies are reported as spending twice as much on dividends as on R&D. By contrast the top 200 international companies spend more than twice as much on R&D as on dividends.

In funding, we work within NatWest to move the emphasis away from reliance on short-term overdraft finance and currently 49 per cent of finance to small and medium business is provided on a medium term basis (either fixed or variable rate loans).

Additionally, we are encouraging alternative methods of equity funding to try and guide our small technology businesses to more appropriate sources. The role of "Business Angels" for instance, is one we are currently investigating, with a view to building a "Business Angels" database. By using this funding and other sources of finance to develop a total funding package, which potentially offers a combination of longer-term investment and management expertise input, we hope to assist in generating new equity, and to some extent bridge the skills gaps amongst innovative business.

Business planning

The only mechanism for planning within some companies is often the three year balance sheet/profit and loss account. Whilst pharmaceutical companies have to plan in terms of eight, 10 or even 12 years (the nature of their R&D process makes this inevitable), smaller businesses have no such driver. Consequently they tend to follow the line of least resistance, by putting together projections which they believe will satisfy their banker, their accountants and their investors and fail to recognise the need to keep R&D alive.

Our New Technologies Appraisal Service (NTAS) reports reveal that businesses frequently forget to provide resources for R&D once they have successfully developed products or processes. Since continuous innovation is the life blood of a technology or science based business, this has serious implications for the long-term viability for the company.

Q. *Some sectors of the UK industry are more successful in international markets than others. What contribution does innovation make to their success. What changes in corporate strategy might improve the less successful ones?*

A. The contribution made by innovation to industrial competitiveness is generally agreed upon and is the cornerstone of major DTI initiatives.

Its effect can be demonstrated by considering sector trade balances. In 1992 the UK had positive trade balances in only three sectors: chemicals, aerospace and mechanical engineering (Source: CBI National Manufacturing Council). By far the most successful in international terms is the chemical sector (including pharmaceuticals) in which the UK shows greatest innovation activity in terms of R&D spend. The results of the CBI/NatWest Innovation Trends also indicate that the sectors with highest innovation spend as a percentage of sales are chemicals and mechanical engineering (aerospace not being classed separately).

Within many small businesses, the role of the owner/manager/innovator is the domain of one or at best two like-minded individuals. Such a team is likely to have weaknesses, not necessarily technical but in the fields of finance, management and marketing. These failings ultimately hold back progress of the company in its formative years and can weaken its prospects for future and sustainable growth. We work closely with our businesses to help them recognise their management skills gaps and to address them effectively.

Q. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder its process?*

A. Evidence from our customers endeavouring to bring innovative products to market and from our Technology Managers trying to give the relevant guidance, is that there are too many institutions operating independently of each other and frequently providing competing services. The technology transfer infrastructure is fragmented and leads to confusion for the innovators.

There is no clear route from "lab to lathe" and the result is a failure on the innovator's part to utilise the best resources and help, thus wasting valuable time in which competitors can narrow the window of opportunity.

With limited resources available, a science and technology policy that marshals resources to avoid waste or duplication would be valuable. It is true that technology transfer should not be undertaken in isolation. Management, marketing, financial and other skills are crucial to exploit the technology successfully.

APPENDIX 1

Q. *Can you give an indication of market share of business lending held by your organisation.*

A. NatWest currently lends £10½ billion to small/medium businesses and holds a market share of technology-based businesses of 31 per cent.

Q. *What is your general lending policy?*

A. NatWest has funds available for viable propositions. NatWest/SBRT Quarterly Survey of Small Businesses in Britain (May '93) shows that Access to Finance ranks only equal 4th (5 per cent of respondents) amongst the main problems facing small business. Lack of sales ranks 1st (43 per cent). In addition, the 1993 CBI/NatWest Innovation Trends Survey illustrated that both manufacturing and non-manufacturing companies saw the cost of finance as a declining constraint to innovation.

The Bank's policy reflects the need for the UK to develop a "World Class" industrial base. It recognises the importance of manufacture and innovation by identifying them as "lower risk" issues in the evaluation of funding applications.

We are actively working with industry in the identification of appropriate funding requirements through initiatives such as Regional Support Teams who seek to structure funding requests into proposals acceptable to the Bank.

Q. *What is your lending policy to companies in innovative industries? Have you any specific mechanisms for assessing the risk of high-technology ventures?*

A. The Bank's general lending policy also applies to innovative industries, although our approach to financing such businesses is different. NatWest has trained more than 120 technology managers who understand the dynamics of these businesses and who are therefore in a position to provide suitable support and finance. Specialist finance packages and products have been developed to meet the needs of these companies. These include a Technology Performance Financing Scheme (which relates performance of product/company with repayment of a loan), Venture Capital and Business Angels. All feature in our funding methodology to this sector, as does SFLGS where we have historically been the lead provider of finance under this scheme.

To assess the risk of high-technology ventures, NatWest has in place a New Technologies Appraisal Service (NTAS), whereby independent experts assess the technology, markets, product life cycles and competitive positioning for commercial viability.

Whilst a full appraisal under NTAS does provide a detailed investigation of the business and its products, there is a need for the banker to have some basic information as to the technology's viability and marketability. This is provided by way of regular newsletters, advising of developing areas of technology and a "Hot-line" support service giving individuals advice and information on technical/marketing aspects.

The range of initiatives in this section have been developed following the establishment in 1989 of a central Technology Unit within NatWest. This reflects the objective of building our understanding—and support—for Technology orientated business and represents a depth of commitment which we believe to be unmatched in other Clearing Banks.

Q. *To what extent does a firm's innovative potential influence your lending decisions?*

A. The innovative potential of a company is one of the key factors considered by the Bank in making its lending decisions.

Although appraisal systems were orginially designed to identify the potential of a proposition, these now tend to be based more on the dynamics of the business. They include both financial and non financial aspects, and take into account the following:

— Management
— Market
— Product
— Producation

In assessing the viability of the market/product strategy, there is no doubt that innovation is one of the key components to success.

The Bank's internal training emphasises the need to consider all busuness issues and the role of the non-financial aspects are particularly examined during the following courses for Managers:

— Mid Corporate Business
— Premium Small Businesses
— Support for Technology Businesses

Q. *To what extent, in your opinion, does policy in the UK differ from that in other countries?*

A. Some differences appear to exist between funding policies in the UK and certain other European countries such as Germany, where companies may have access to National and Regional Government assistance, e.g., Kreditanstalt fur Wiederaufbau (KfW).

Within the UK, the stock market/capital markets have been highly developed and there are benefits in continuing to encourage the flow of equity via USM/BES mechanisms or other steps giving fiscal advantages to those investing equity in smaller enterprises, particularly where these have a technology/manufacturing orientation.

Memorandum submitted by Barclays Bank PLC (23 June 1993)

Further to your letter of 30 April to our Chairman Andrew Buxton, I am now writing to respond to your particular questions about the Barclays policy towards financing innovative ventures. However, given my close personal involvement in some of the border issues which your Committee is investigating, perhaps I might start by offering some responses to your first questions:

Relationship between the Science Base and Industrial Innovation

Much industrial innovation in the UK is market opportunity related and there is a long history of this style of innovation which makes companies uncertain in their approach to technological innovation. Increasingly, however, it seems likely that technological innovation will lead to the more important and sustainable opportunities, and hence an active Science Base is important as the prime source of such innovation.

There is not necessarily a close relationship between an active Science Base and technological innovation, and I would agree with the thrust of the Committee's enquiries that the relationship should be closer.

Technological Transfer Mechanisms

Very large company links with the Science Base are adequate and occasionally good, but appear usually serendipitous and "ad hominem" rather than part of a concerted approach to pervade a strategic area of technology. The pressures on large company research laboratories may lead to closer ties. Placing research contracts within higher education research institutes and licensing arrangements are the usual form of interaction.

Medium and small company links are in general poor-to non existent. Most companies in these ranges do not have the overhead capacity to absorb research ideas or the managerial experience to introduce complex technological process or product innovations. Licensing is rarely adopted by these companies. Participation in collaborative trade related research associations seems the most common method of assimilation that is adopted by the more advanced companies.

One sector of companies that is quite successful at interaction with the Science Base and which itself plays an important intermediary role between small, medium and large companies and the Science Base, is the technical consultancy sector. Many of these companies have in fact "spun out" of the Science Base to commercialise technological innovations that their founding teams pioneered. In this capacity they sell technical solutions on a more easily digestible basis to industrial companies which enables the latter effectively to buy "turnkey research" rather than involve themselves with the scientific community. Within Europe, Britain's small technological company sector is regarded as the most highly developed.

Relaxation of administrative attitudes in universities and other research institutions and the relaxation of the BTG's right of first refusal have helped to foster the development of these technical companies. The official position of the Committee of Vice Chancellors and Principals however creates some confusion which might helpfully be eliminated.

COMPETENT PERSONNEL

The lack of personnel is primarily in the management of technological innovation rather than a lack of scientific or technical staff. This lack is serious, deriving from the low levels of technological innovation in industry generally. There are some sectors where the absence of large British companies active in international industrial developments has meant that there are substantial internal barriers to entry: commercial electronics, as opposed to defence related electronics, is an example.

INTERNATIONALLY COMPETITIVE INNOVATION

Our market innovation skills would, on a subjective judgment, rank fairly well internationally. For the reasons cited above, we do less well on technological innovation.

Measurement of our performance within the EEC is already being monitored under the Sprint programme. Within the UK, I would expect SPRU at Sussex University and hopefully the new Centre for Busines Research at Cambridge University will be capable of providing satisfactory measures. Material is already held by the Department of Trade and Industry on our overall industrial competitiveness.

SHORT TERMISM

The abrupt volatility of our economic performance, born out of structural imbalances in the economy, and the resulting high cost of capital appear to be the two main causes underlying short-term attitudes. These exist both amongst management and suppliers of capital. This creates a difficult climate for technological innovation.

More gradual and stable economic policies and measures to address the structural imbalances might form part of the remedy.

INTERNATIONALLY SUCCESSFUL STRATEGIES

Many of our surviving industrial companies are becoming active and successful in international trade in manufactures. This appears to be because they have forced themselves to seek out overseas markets to compensate for poor domestic trade. Initially, their strategy has been based on competitive pricing and the adaptation of domestic products for export markets. Although this appears to remain the mainstay of their approach, niche differentiation and customer intensive development have followed with the more successful. Overtly technologically driven strategies are rare; distribution only strategies have not usually been successful.

SUPPORTIVE STRUCTURES

Companies in the UK appear to distrust "soft" support for innovations. Longer term direct involvement of staff through such schemes as the teaching company are problably the best method in the direct transfer mode. "Fear of missing out" is a strong spur to involvement in trade research association activities.

Low cost but quasi commercial, arms length modes, offered by private or near private sector entities, such as technological consultancies or the enterprise consultancy schemes supported by the DTI, appear to have been the most successful methods of transfer.

Turning to questions upon financing innovative ventures:

MARKET SHARE

Barclays and National Westminster Bank hold the leading share of banks in financing sectors with high rates of technological innovation. For Barclays' share please see the attached schedule. In certain areas, such as Cambridge, our share is higher than the national figures.

GENERAL LENDING POLICY

Our general lending policy is to support our customers in the development of their business where we find good management and sound business plans.

FINANCING SUPPORT FOR INNOVATION

We have a well developed policy for supporting innovative companies, particularly the small technological sector. Copies of the brochures that we have prepared to support the management of these companies are enclosed.

We rely upon existing financing structures, supported by particular insights into the developmental patterns of companies in these sectors. Our support is primarily provided through our large business centres, a number of which now have long-standing experience of handling such accounts. Over 150 managers have received special training in handling these companies, and our experience of providing such support has been relatively good.

Our technical assessment resources are good. We employ a technical consultant with access to resources in the commercial sector and in Government to enable us to appraise the market and technical aspects of propositions. In the five years during which I personally ran the Bank's technology financing team, I cannot recall a proposition for which we were unable adequately to appraise the market and technical aspects.

INNOVATIVE POTENTIAL

In our experience the primary factors determining our support are the depth of the management and their ability to relate this to the types of marketing opportunities they pursue. Technical risk can usually be managed provided the structure of the sale is suitable.

In the long term, it is the lack of a well developed demand for technological products—for the reasons cited in my earlier answers—that limits the ambitions of most of the companies that we have supported.

UK POLICY

At an overall level, UK policy has been notably less successful than other countries at avoiding substantial swings in activity and the cost of capital. Given the growing capital intensity of manufacturing and technological innovation in particular, this creates substantial difficulties not experienced elsewhere.

At a specifically technology policy level, UK Government support in the form of grants, soft loans and other direct financial schemes to support technology is substantially lower than our European neighbours, e.g., Holland and Germany. Given the bias of British companies towards a more commercial approach, this is understandable; but the UK policy has not correspondingly sought to use interest rate or tax based instruments to encourage technological innovation in industry.

Perhaps most notably, given its more commercial orientation, UK policy has paid little or no attention to Government purchasing power as a means of developing technological innovation in industry. This was the main instrument of US policy operating in a similar economic environment to our own.

Science and Technology Lending

	Sterling				Currency	
	Barclays Group £m	of which	Domestic Bank £m	Barclays Group share of Major Banks per cent	Barclays Group £m	Barclays Group share of Major Banks per cent
Electrical and Electronic Engineering	583		483	30.3	190	30.6
Chemical Industry	316		248	26.7	130	31.6
Oil and Natural Gas	385		12	41.6	163	30.3
Other Energy	225		31	47.1	2	20.0
Overall Business Sector	33,353		22,073	23.7	4,880	31.0

As at March 1993.

Memorandum submitted by the Bank of England (8 July 1993)

As the Bank's Director for Finance and Industry, I have been asked to respond to your request for a submission by the Bank of England to the Science and Technology Select Committee. I attach the Bank's submission which has been prepared by the Industrial Finance Division, and which draws on the Bank's broad-based involvements at the interface between the corporate and financial communities.

The submission concentrates on issues surrounding the financing of investment in innovation. We have not endeavoured to be prescriptive, but rather to offer our thoughts on the items which we feel the Committee will want to address in relation to this issue. I hope the Select Committee finds this a useful contribution.

1. THE BANK'S LOCUS IN THE FINANCING OF INDUSTRY AND SPECIFICALLY TECHNOLOGICAL INNOVATION.

1.1 One of the core purposes of the Bank of England is the promotion of the efficiency and effectiveness of the UK financial services sector. A significant part of this responsibility relates to the provision of finance for industry—the flow of funds between the providers and users of finance.

1.2 To this end, the Bank monitors the sources of funding available to industrial and commercial companies, and extends its interest to the various issues surrounding the provision of finance to industry. These are wide ranging, and include such matters as improvements in corporate reporting and broader forms of communication between industry and finance. The provision of finance for investment in technological innovation, one of the issues being considered by the Committee, is likewise an important part of the Bank's wider interest in these matters, particularly that concerning smaller and medium-sized enterprises.

1.3 Accompanying this interest is a broader recognition that technological innovation is a vital component for sustainable economic growth which cannot be detached from the Bank's central purpose concerning the management of UK monetary policy and the maintenance of price stability.

2. Investment in innovation in the UK

2.1 The improvements in UK industrial performance over the last decade cannot be denied. At the same time, a part of these improvements has been the result of the considerable re-organisation and restructing that took place following the recession of the early 1980s. To the extent that this process cannot be repeated, enhanced competitiveness and continued growth in productivity, profitability and, crucially, capacity will have to rely on other factors in the 1990s and beyond.

2.2 There is now an emerging consensus that increasing the innovation effort of UK firms is an important component in this process, alongside many other aspects of corporate strategy. The available evidence shows that Britain's investment record in R&D, while showing signs of improvement, has been less impressive over recent years than other indicators when compared with our main industrial competitors. Recent results based on company accounts from the DTI Innovation Unit's 1993 UK R&D Scoreboard show that larger UK companies devoted around 1.6 per cent of aggregate sales revenue to R&D in 1992 compared with an average for the world's 200 largest companies of 4.6 per cent, and only 19.7 per cent of profits compared to 94.3 per cent worldwide.

2.3 R&D as recorded in company accounts and official statistics will not account for the total R&D effort undertaken by UK companies, particularly amongst smaller companies where the R&D function is likely to be less well defined or focused on near-market development, an issue highlighted in a recent report for the Economic and Social Research Council (The role of scientists and engineers in the process of technological change). Furthermore, R&D itself is only a small part of the total innovation process for a great many firms. However, the general weight of evidence does suggest that UK firms are being outspent by their foreign counterparts, and while expenditure is in no way a measure of commercial success, this "gap" has rightly been a cause for some concern.

2.4 The DTI's R&D Scoreboard also illustrates the significant sectoral dimension to the UK R&D gap, a point established by an earlier study undertaken by Sciteb for the CBI in 1991 (R&D Short Termism? Enhancing the R&D peformance of the UK Team). The shortfall appears to be almost entirely located amongst Britain's physics-based industries such as engineering and electronics, whilst the R&D effort of our chemical-based industries compares much more favourably with the rest of the world, in particular pharmaceuticals.

2.5 This sectoral dimension also reflects important distinctions in the way R&D is undertaken in different firms and, particularly, how R&D relates to existing business activities. In turn, this will affect the manner in which businesses can finance their development programmes. While pharmaceutical companies are more typically engaged in what could be described as detached R&D on a number of fronts in the hope of developing a best-selling compound, engineering companies will tend to be more "D" orientated, and the R&D effort will often need to be integrated with the existing technological and productive effort.

2.6 These are important observations which need to be borne in mind when considering the factors which may constrain investment in innovation in the UK, including the impact of the financial system. It is important at the outset to recognise that the bulk of a company's external financing requirements will be related to the later development stages of the innovation process.

3. The financial sector and innovation: some common themes—the stock market, R&D and short termism

3.1 The debate over the reasons for the UK's poor record of investment in innovation invariably touches on the influence of the stock market. Certainly, the way the financial community interacts with companies and views longer-term investment is an important consideration in the effort to promote innovation.

3.2 The issue of short termism is a well established part of this debate. Overall, whilst it is necessary to recognise the legitimacy of the concerns about short termism, such as the role of pension funds and their trustees, the debate has proved somewhat sterile and has not delivered any satisfactory conclusions. In this respect, it is more appropriate to concentrate on the tangible ways in which the City/industry relationship can be enhanced, which are considered in Section 4. However, a few points serve to emphasise that the issues surrounding this relationship are both complicated and wide ranging.

3.3 The first point to note is that short termism is not just an issue concerning the interface between industry and finance. It also concerns the time horizons within companies themselves, in terms of both management incentive structures and the financial criteria used to determine investment priorities which can involve conflicts between the financial and production interests. Crucially, short termism is also relevant to the macroeconomic environment. The impact of macroeconomic instability which is characterised by interest and exchange rate volatility and large cyclical swings in the level of demand, cannot, historically, be excluded from a discussion about long-term investment strategies.

3.4 In relation to the stock market, any impact on R&D funding of actual or perceived short-termism is likely to be indirect and not easily identified. The bulk of R&D funding will tend to be financed from retained earnings rather than external sources. The long-term nature of R&D programmes and the lack of a known future income stream may discourage firms from seeking external borrowings which result in interest charges before profits and dividends. Alternatively, firms may prefer to conserve debt finance or new equity issues for other financial demands such as acquisition or expansion where returns are more tangible and obvious to the investor.

3.5 The behaviour of the stock market is more likely then to influence R&D expenditure via such considerations as the need to increase or maintain dividends and earnings per share growth to deter takeover bids, thereby reducing the internal funds available for investment purposes. Certainly, the evidence suggests hostile takeovers are more prevalent in the UK than elsewhere in Europe and the proportion of company income paid out as dividends is higher in the UK than many other countries. This does not, however, necessarily imply that the former causes the latter. Furthermore, it is less clear that these factors place a constraint on R&D expenditure in a systematic manner. Attempts to correlate price-earnings ratios with R&D expenditure have not proved conclusive.

3.6 R&D and innovation strategies will form part of the overall company assessment and valuation. It is far from clear how R&D and broader innovation programmes can be isolated from other factors such as current performance and the quality of management, which underpins any corporate strategy. Institutions assessing current and future earnings are primarily looking for a convincing rationale from senior management on a range of matters relevant to corporate performance and strategy, including R&D expenditure. The reaction of investors to rising R&D often centres on the quality of the management team "selling" the strategy to the investment community, and the manner in which R&D is presented as a commercial rather than an exclusively technological programme. R&D which is isolated or detached from other parts of corporate strategy should rightly be questioned by the market. Companies that simply make vague references to their R&D programme ("investing in leading-edge technology" cannot expect this to be reflected in a commercial assessment of the company, or to justify a reduction in dividends over the short term.

3.7 The difference in the R&D expenditure across sectors referred to above is relevant to this discussion. Chemical and pharmaceutical firms are often cited as evidence that high R&D expenditure is not detrimental to share price. However, it is important to recognise the differing relationship between profitability and R&D in sectors such as pharmaceuticals and engineering and, crucially, the difference between an established level of R&D expenditure and how the market responds to an increase. R&D is central to income generation in the pharmaceutical industry via patented drugs. R&D as a high percentage of sales revenue is an accepted feature and there is usually a long track record over which to assess management claims about current spending. However, the market response to an engineering company seeking to justify an increase in expenditure might justifiably be somewhat different. All these points serve to emphasise the need for a careful consideration of the impact of the stock market on the behaviour of companies.

Bank finance and innovation

3.8 While larger companies have access to the capital markets, banks are by far the most important source of external finance for the vast majority of smaller and medium-sized companies (SMEs). Furthermore, while larger companies borrow from the banking sector for a spread of purposes, banks have tended to limit themselves to funding smaller companies' working capital requirements. The general perception appears to be that it is very difficult to obtain financial backing for innovation projects from banks, either in the form of start-up or development capital (particularly where borrowing needs to be secured).

3.9 There is, of course, no inherent reason why banks should fund innovation projects as opposed to any other form of lending. In this respect, a discussion about finance for innovation should not become abstracted from the principles of the free market and the need for the banking system like any other business sector to generate from its activities a commercial return by ensuring it achieves a balance between risk and reward. However, the extent to which UK banks adopt a "liquidation" security-based approach to lending rather than a "going-concern" approach may disadvantage borrowing requests for innovation programmes, particularly by SMEs (although the fall in asset values over recent years and the lack of new security following recession may now be encouraging banks to look more closely at the underlying business case for lending).

3.10 However, finance specifically for investments geared to technological innovations is still not a typical part of bank lending. In turn, the nature of the funds SMEs typically borrow from the banking sector are quite inappropriate for the purposes of investment in technological innovation. The bulk of bank lending to industry, particularly to SMEs, is in the form of short-term lending, principally overdraft finance.

3.11 Historically, overdrafts arose to meet short-term requirements for working capital, but too often they are now used for quite long-term investments. In the late 1980s, long-term borrowing represented only 20-30 per cent of all borrowing by smaller companies (less than 200 employees). Comparable figures for large firms are in the region of 60-75 per cent. Bank overdrafts and short-term loans have been twice as significant for smaller firms than their large counterparts. This apparent preference for and reliance on short-term funding clearly has implications for the finance for innovation projects given the longer term nature and relatively higher risk of technology-based investments.

3.12 A related issue is the limited extent to which the banking sector provides equity. Banks have, traditionally, been averse to putting equity into firms, particularly smaller firms, seeing them as too risky and incapable of providing an exit route. But equally, entrepreneurs seem unwilling to relinquish equity. However, while the great majority of smaller firms may not want an equity investment, technologically-based rapid growth firms may need it as a more appropriate form of financing development projects that may last many years. Firms, as well as banks, need to address the issue of the appropriate forms of finance for the proposals they are putting forward. Section 4 considers the funding problems facing technologically-based SMEs and some of the possible ways they may be overcome.

3.13 If external finance, both from banks and capital markets, is to be more widely available for investment in technological innovation, appropriate forms of finance need to be considered and the nature of the relationship between the providers and users of finance needs to be reassessed to accommodate the particular characteristics of technology-related investment.

4. COMMERCIALISING AND FINANCING TECHNOLOGY-BASED INNOVATIONS

Near market development

4.1 The need for firms continually to improve products, processes and services cannot be overstated, particularly in a world of shortening product life cycles and increasing product proliferation. Part of the innovation effort will involve incremental improvements to existing products and processes, as well as more far sighted strategic investments. For many firms of course, product and process development—the "D" —is the primary occupation; the technological development of the business in "near-market" situations. Indeed, the link between innovation and the market is an important one. It cannot be assumed that a high level of technological input will lead to competitive success. Crucially, given shortening product life cycles and the competitive pressures in the marketplace, the effective timing of the launch of new products is vital to commercial success. The speed and effectiveness in which new developments are introduced to the market are likely to be a major determinant of profitability.

4.2 The importance of the later stages of the innovation process, including marketing, may place a greater financial burden on a company than the earlier stages of the process. The provision of external finance for innovation programmes will be primarily concerned with near-market development. Given the nature and relatively high risk of investments in technological innovations, it is necessary to consider under what conditions money can be rationally invested and to determine what forms of finance are appropriate to ensure that commercially viable technologies are developed.

Communications and understanding between the City and industry

4.3 A vital part of the answer concerns communication and the provision of effective information to the providers of finance. In relation to the quoted company sector, the DTI, CBI and Institutional Shareholders Committee have all made useful contributions to the issue of promoting more effective presentation and consideration of innovation strategies by both companies and the investment community. For instance, the Innovation Advisory Board's Innovation Plans Handbook offers guidance to companies on how to draw up innovation plans and to the financial community on how to judge such plans. More recently, the DTI have sponsored a series of sector dialogues to bring together leading industrialists and analysts, to improve the level of trust, understanding, communication and performance in these sectors. A report covering the engineering sector has recently been published which included recommendations concerning the disclosure and assessment of long-term investment strategies. The work of the Accounting Standards Board is also of relevance in that more focus is being brought to bear on the transparency of information contained in company reports and on achieving a better understanding of company strategy and market position.

4.5 The Bank of England very much supports these kind of initiatives, believing that this is the most appropriate way of facilitating a cultural shift within the market, by addressing the practical mechanics of the relationship between industry and finance. It needs to be stressed that the staple diet for the relationship between industry and finance is information.

Financial awareness amongst SMEs

4.6 The issue of information flows between the users and providers of finance is equally relevant to smaller and medium-sized enterprises, particularly technology-based businesses. Such firms need to provide a credible rationale for funding which is sensitive to the nature of the technology (the development/commercialisation of new products/processes versus improvements to existing products/processes) and the markets it will serve (entry in new markets versus expansion in existing markets), along with the financial implications of the investment. In this respect, raising finance for technological innovations also requires commercial and financial awareness. While the demands on business people to be informed across a range of matters are enormous, financial awareness cannot be overlooked in the process of technological innovation. The Bank will be endorsing a forthcoming brochure to be published by the DTI's Innovation Unit, which is aimed at technologically-based businesses seeking finance. The brochure will provide advice on the requirements of the business plan and the sources of finance to be considered.

Forms of finance for technology-based SMEs

4.7 The appropriate form of finance very much depends on the particular nature of the firm's requirements in terms of the purpose and timescale of borrowing. This may involve a package of borrowing in a variety of forms including bank finance and external equity capital. The issue of excessive reliance on overdraft finance has already been considered in Section 3. Overdraft finance involves an inherent instability if it is used as core finance and is inappropriate given the nature of technology-based businesses.

4.8 Other lending products undoubtedly need to be considered more thoroughly, particularly term loans. There are signs now that banks themselves are beginning to encourage smaller firms to move away from overdraft finance. Businesses are most at risk in their early years and this can be mitigated by firms having more certainty about their debt servicing vis-a-vis their capital spending, leaving overdraft finance to iron out inevitable or unforeseen movements in working capital requirements.

4.9 In the past, term loans have usually been restricted to fixed asset purchase, but this appears to be becoming less strict and the development of more sophisticated term lending, e.g., capital payable at the end of the loan and rolled over if the firm is successful, may be particularly suited to technology-based firms, providing a degree of permanency needed by high growth firms in particular.

Equity

4.10 Rapid growth firms may need equity if their balance sheets are not to become unstable. There would appear to be a need to improve the supply of equity to faster growing firms. Such firms, particularly in new technology, often need financing in discrete chunks as growth tends to be associated with step changes in the firms organisation, markets and/or products. Some banks have begun to provide equity packages. However, this remains relatively small scale. Equity capital is more likely to be provided by the venture capital industry or by private investors.

4.11 The Bolton Report in 1971 suggested that an equity gap existed for amounts of less than £250,000 (about £1 million in current prices). The subsequent rapid expansion of the UK venture capital industry filled some of that gap. However, most reports suggest a gap still remains for amounts of less than £100,000 (some put it at £250,000). This suggests that the gap is primarily in seed, start-up and early stage finance but could include all sorts of funding packages for smaller firms.

4.12 The majority of venture capital funds now specialise in development capital and, in particular, funds for MBOs/MBIs. According to industry statistics, the proportion of such investments rose from 28 per cent of funds invested in 1984 to 64 per cent in 1992. In that year, start-up and other early stage investments accounted for only 7 per cent of funds invested, and the average size of each investment increased from under £400,000 in 1984 to £783,000 in 1992. The concentration on larger scale venture capital funding reflects the perceived relative attractiveness of MBO/MBI type investments during the 1980s.

4.13 Factors affecting the relative attractiveness of larger deals and which may work against smaller scale technological investments in particular include:

- The costs of evaluation and monitoring (it costs as much to invest and monitor £50,000 as it does £5 million). In part this reflects smaller firms frequent ignorance of what data investors need.
- Risks associated with established businesses, with a track record, known management competencies and frequently operating in mature industrial sectors are lower than start-ups or firms based on new technologies in untested markets with uncertain future investment needs.
- The ability to exit quicker from MBO/MBIs (4-5 years is typical).
- Few venture capital teams have the capability to assess specialised technologies. Investments in consumer related industries and financial and other services accounted for 52 per cent of funds invested in 1991, compared with 12 per cent for the computer, electronics and medical/biotechnology sectors.

4.14 There are a number of factors which could depress the supply of venture capital, particularly for smaller or new technology firms. Firstly, returns to investors in specialised funds have not matched expectations and the depth and length of the recession are trying even successful investments which need further funding. Difficulties in raising new funds could lead to a sharp reduction in the pool in the mid-1990's, just when many of the 1980s funds end their life. Secondly, there has been a move to liquidity and quality. The relative under-performance of smaller quoted companies in the last year is a symptom of this. Attractive opportunities in gilts and good quality corporate paper could reduce the supply of risk capital.

Informal equity sources

4.15 An untapped source of funding for technology-based firms is likely to be in the form of informal venture capital, provided outside formal funds, usually by individuals (known as "business angels"). There are no reliable estimates of the size of the informal venture capital pool but commentators often point to the US, where estimates of informal venture capital vary from two to five times the amount in formal funds.

4.16 Business angels probably have three key advantages over formal funds. First, the costs of evaluation and monitoring are less; or they appear so because they are less explicit. The investor may be able to do a good deal of the investigation himself, particularly if the target is in an industry where he has previous experience. Second, where the investor is an entrepreneur himself, his knowledge, experience and skills may be more acceptable to the target than those of a group of venture capitalists. Third, individual investors are more likely to look for smaller investments, perhaps in the £25,000 to £250,000 range, in which they can become personally involved to some extent.

4.17 The government recognised this point in the last budget by granting rollover relief from CGT. Individuals realising investments in businesses could reinvest in qualifying small firms free of CGT. The BVCA has long argued that, in such cases, CGT discriminated against reinvestment in growing businesses, denying them both a source of new equity and of new managerial expertise. The Business Expansion Scheme had been criticised on this last point. Investors were not allowed to take any position with the firm they invested in and this tended to increase the investigation and due diligence costs. Furthermore, only 30 per cent of total investments are in schemes below £25,000; and a declining proportion is invested in sectors noticeable for technology and innovation. It remains to be seen if rollover relief generates any significant increase in informal venture capital; and, by its nature, it will be hard to monitor such a development.

4.18 It may be possible to seek to improve communication networks which link potential investors and the firms seeking them. There are a small number of "marriage bureaus" around the country performing this function. The largest is probably LINC, operated by the London Enterprise Agency. However, there does not seem to be any really comprehensive service. If the supply of informal venture capital is to grow, there must be an efficient mechanism for displaying potential investments, so that the resources can be allocated efficiently.

4.19 Any attempt to address a perceived equity gap must also address the question of how the investment is to be realised. Exit routes usually take the form of trade sale or flotation. But the five to seven year time-horizon sought by many venture capitalists can be unattractive to some entrepreneurs, because of the need to establish a track record (of profits or, at least, in sales) for a prior period so as to maximise value at sale or flotation. Both routes involve the replacement of venture capital by industrial or institutional finance. Despite the relative attractiveness of trade sales, venture capitalists also prefer to have flotation as a viable option. The question of the flotation of smaller companies is currently being considered by the London Stock Exchange's Working Group on Small Companies.

5. CLOSING STATEMENT

5.1 The Bank's submission to the Select Committee reflects its main focus of interest in relation to the debate on innovation and technology in the UK. In addressing some common themes surrounding the financing of innovation investment, we have sought to move away from casual references and inferences about financial institutions in respect of this issue, and attempt to address the very really problems underlying the need to increase the volume of commercially viable technological investment in the UK and ensure that this is appropriately and successfully financed.

5.2 Three broad points perhaps deserve emphasis:

- The importance of effective information flows between industry and finance, to facilitate an improved market culture in relation to investment in technological innovation; and a need for technologists to be financially aware when seeking investment finance.
- The need for financial packages to be custom-built to reflect the needs of technology-based firms, alongside a need for SMEs to move away from their excessive reliance on overdraft finance.
- The potential role of informal sources of venture capital.

Memorandum submitted by Deutsche Bank AG London (7 July 1993)

Following The Science and Technology Committee's invitation to provide written information on a number of questions relating to the above issue, we are pleased to respond as follows:

1. MARKET SHARE OF BUSINESS LENDING HELD BY DEUTSCHE BANK GROUP

On a worldwide basis, Deutsche Bank Group ranks No. 10 in terms of total assets as at 31 December 1992. We are the largest German Bank and the market leader in the domestic (German) corporate lending sector but with a market share of only 7 per cent. This figure reflects the structure of the German banking system, with a relatively strong presence of local and regional Co-operative and Savings Banks which mirrors a traditionally high portion of small to medium-sized companies in Germany. In the UK, we are one of the major international market participants although our market share in the corporate lending sector (large "wholesale borrowers") is small as a result of the intense concentration of many international banks and London's leading role as the financial Euro-Centre. We are also a substantial market player in the treasury area including foreign exchange and other derivatives and provide investment banking services.

2. General lending policy

In Germany and in a large number of European and other countries, we provide an extensive range of credit facilities to a wide group of borrowers which reflects our concept of operating as a universal bank. In Germany, our corporate customer base on the lending side comprises most of the large German corporates but also a significant number (about 150,000) of small to medium-sized companies which are, as a result of the German corporate structure as outlined above, of great importance to the economy with a very substantial contribution towards the German Gross Domestic Product.

Long-term financing of capital expenditure with payback periods longer than three years is a strong feature of our business. In fact, as at 31 December 1992 ca. 55 per cent of Deutsche Bank Group's outstandings (including mortgage bank subsidiaries) were provided for periods of four years and more. The risks are widely spread and conservative lending criteria are applied.

In the UK, our customer target group comprises essentially large corporates with a good track record and a stable financial position, but also smaller companies with a German parental background.

3. Risk assessment

We apply standard lending criteria which include management, standing and financial strength including cash flow potential of a borrower, track record, product quality and scope, market position and future prospects. The assessment of the management is a key element in our decision, with a proven successful experience in overcoming difficulties featuring high. We also assess the relevant industry. Apart from the assessment of individual credit risks we manage our credit protfolio globally in the relevant markets focussing on a wide spread of risks over industries, products, etc., thereby providing a frame for individual credit decisions.

4. Lending policy to innovative companies/assessment of high-technology ventures

We believe that a responsible lending approach is to advise innovative companies to finance their operations with an adequate equity portion as a risk cushion for imponderables. Bank facilities should stand up on common credit criteria, possibly reflecting an above-average risk from an innovation. Dependence on one or a few innovative products combined with an under-capitalised balance sheet are generally in the high risk area and business failures in Germany in this category have tended to be high.

In Germany, Deutsche Bank Group provides advisory services through consulting subsidiaries by analysing the market potential of innovative products and how to manage, market and distribute innovative products. Our subsidiary, Deutsche Beteiligungsgesellschaft mbH (a development capital provider) takes minority equity stakes on a selective basis. There are also public financial support schemes for under-capitalised new companies, a number of them using EC funds. Compared to the United States, however, venture capital resources in Germany are very tight.

With regard to assessing the risk of high-technology ventures, we tend to use a broad information base.

We do not widely apply specific mechanisms but do rely on external expertise on occasions. However, through out wide customer base and the information gathered from our close ties with coporates in Germany combined with Deutsche Bank's tight reporting and approval procedures, product and industry knowledge accumulates within the Bank at various levels. We do not finance such companies in the UK as they fall outside our target market.

5. Influence of a company's innovative potential on lending decisions

With a well-established Company of a solid credit standing, product innovation strength is deemed to be a strong point in credit assessment. The combination of an untested new product being marketed and a new under-capitalised company is often not bankable but within our range of services as a universal bank, we may be able to provide advisory assistance.

6. Assistance provided to companies in difficulties

Deutsche Bank's perceived role is that of a responsible relationship bank, in Germany often in a core housebank position on a long-term basis. Financial assistance and comprehensive advice is given to companies in difficulties. Also, in debt restructuring situations we liaise with other lenders and major creditors to ensure a sensible solution. We undertake every effort to assist a company to stay in business, as long as there is a genuine likelihood of its long-term viability. In this context, early and comprehensive information from the customer and a trusting, co-operative attitude is vital for a successful solution. In addition, management consultant services are available from Deutsche Bank Group subsidiaries, if required.

In the UK, we pursue a similar policy and follow the "London Rules". In debt restructuring situations we work closely with other banks although our profile—as compared to Germany—is usually much lower given the nature of our exposure and our position in this market.

7. Potential business opportunity for a bank operating in the UK as Deutsche Bank does in its home market

We believe that an understanding of credit standards should not differ between markets. Local national considerations are always very important and mean that the chance for safe credit innovations from abroad is likely to be small.

8. Extent of difference between policy in the UK and that in other countries

We do not see major differences in credit policy. The UK's capital markets are certainly deeper than in Germany. If there is an area where policy is different, it may be in the close working relationships between borrowers and lenders in Germany.

We hope that the above response is of assistance to the Committee and would be pleased to provide further information if desired. The questions raised are far reaching and of a very comprehensive nature so that we would ask the Committee to view our summarised comments in this context.

Memorandum submitted by Newmarket Venture Capital plc (13 July 1993)

I understand that you are producing a study of "The routes through which the Science Base is translated into innovative and competitive technology", and I should like to make a few comments on this subject which is of considerable relevance to Newmarket Venture Capital.

Newmarket was established as a publicly quoted investment trust company in 1981 with the specific brief of investing in early stage technology based ventures in the US and the UK. Since 1981, Newmarket has invested in 35 early stage companies in the UK and provided them with £35 million of predominantly equity capital. It is the current intention of the company to appoint a liquidator in mid 1994 in order to return the company's assets to its shareholders. The decision to seek liquidation was taken in 1990 following a number of years of decline in the Newmarket fund valuation which had been impacted by the poor performance of most of the investments made in the UK. The reasons for the disappointing results in the UK are many and inter-related, but were strongly influenced by the following factors, which I believe may be relevant to the study that you are undertaking:

1. Management

Many investments were made in companies formed to commercialise technology derived from university research. Ventures of this type are often formed by academic entrepreneurs with minimal commercial experience.

2. Syndication

Due to the small number of venture funds specialising in technology based investments if often proved difficult to find suitable syndicate partners. Where investments were made alone it was, then necessary for Newmarket to provide the follow-on financing needed. The portfolio then became exposed to the failure of a few large holdings.

3. Cost of management

Early stage technology based investment is time consuming and requires fund managers with both operating and financial experience. An investment in an early stage company may initially be very small, yet it is at the formative stage of such ventures that the greatest involvement of the venture capitalist is needed. The usual management fee of 2 per cent of assets under management is not sufficient to pay for the cost of managing early stage technology investments and investing institutions are only rarely prepared to pay a higher rate of fee to support an appropriate level of management time.

4. UK and export markets

Early stage technology based investment can only be justified in the UK if the products involved have the potential for international sales, as the home market is usually too small to generate the required level of growth. In the US companies can grow to a substantial size before they need to consider international expansion, with the additional risk which that involves.

5. Exit

Stockmarket investment exit mechanisms in the UK are not as well developed as they are in the US where NASDAQ is the primary market for emerging technology companies to raise public finance. A comparable market is needed in the UK and the moves made by the London Stock Exchange recently to allow loss making biotechnology companies to achieve a quotation are an important step in the right direction but further initiatives are needed.

6. Fund structure

Seven- or 10-year Limited Partnerships suffer from having a relatively short window of time (the first 2 to 3 years of their life) in which they can invest in early stage long-term technology ventures. Quoted investment trusts can invest in longer-term ventures but suffer from the discount problem. There is no fund structure which is really suitable for early stage technology based investment.

7. Institutions

The institutions that subscribe to venture capital funds generally employ staff with accounting and other financial experience. Thus the individuals responsible often have no experience of operating businesses and have a limited understanding of the potential of early stage ventures in the technology sector.

Newmarket was one of the earliest entrants into the field of venture capital in the UK and has learnt many costly lessons. We are absolutely convinced that venture capital is one of the most effective ways of bringing innovative ideas out of the Science Base and into the market place, as has been demonstrated in the US. Regrettably it is not achieving this effect in the UK and while venture capital investment in technology is on the decline here the situation is unlikely to improve. I hope that these comments prove useful and would be pleased to expand further on the points raised should you wish.

Memorandum submitted by the London Stock Exchange (8 November 1993)

The London Stock Exchange plays several roles: it is the major securities exchange in Europe and the world's leading market for cross-border trading of international equities. But it is also the UK's national capital market meeting the needs of all types of UK companies; the Exchange's international standing does not reduce the importance of the service provided to UK companies of every size.

The Exchange is concerned to ensure that the capital markets play their full part in financing business and industry, particularly during the current period of recovery and seeks to remain flexible, innovative and highly responsive to the needs of our markets and users by introducing new markets, amending our listing rules and adapting our trading systems.

The central role of the Exchange is to provide a means of transforming savings into long-term investment capital for industry and commerce of all sizes and in all sectors. Over 7,000 securities are traded on the Exchange, covering domestic and international equities, bonds, gilts, warrants and other fixed interest stocks. The primary capital-raising market plays an important part in meeting the financing needs of UK industry. In 1992 the capitalisation of London's market in UK stocks increased by 16.4 per cent to £624 billion, maintaining the Exchange's position as the third largest stock exchange after New York and Tokyo. Rights issues during the first nine months of this year have raised £9,595 million—more than double the amount achieved during 1992 and only £500 million short of the record 12 months total of 1991. There are currently 2,128 UK companies quoted on the Exchange (as at 30 September 1993), of which 1,865 are listed and 263 quoted on the Unlisted Securities Market. During September, Shield Diagnostics Group, a biotechnology company, became the sixth scientific research based company and the 100th company to come to the market this year.

Going public offers companies a path to further growth when other avenues such as bank finance have run their course, or access to other sources of funds may be restricted. It provides a means of broadening ownership of a company and the ability to access London's substantial pool of long-term risk capital. Equity capital can provide long-term financial stability while reducing reliance on debt finance. It is especially important in an economy such as the UK's which relies on expensive over-draft finance.

The Exchange, under the supervision of the Treasury, acts as Competent Authority for Listing under the European Directives. It admits securities to listing and monitors and enforces listed companies' continuing obligations. The Exchange's aim in carrying out this regulatory responsibility is to facilitate capital raising by companies, while ensuring that investors have adequate information to make their investment decisions with confidence. There is an inevitable cost in going public and it is important that the regulatory regime balances proper investor protection. All capital markets have to strike that balance.

The Unlisted Securities Market

In the 1980's the Exchange introduced the Unlisted Securities Market and for a short while the Third Market, to complement the Official List and to contribute to economic growth by making our capital raising markets as widely available as possible.

The USM, launched in November 1980, was originally designed to provide an easier and less costly route to the market for small or new companies. At that time, no company could be admitted to the Official List until it had a five year trading record and the USM by permitting a three year record produced a much easier route for younger companies. The USM proved a popular and successful market for new issues throughout the 1980's. As the economy gathered momentum the number of companies increased rapidly from 86 in 1982 to a peak of 448 in 1989 and the USM had a strong identity as a market for entrepreneurs and small growth companies. From 1989 the trend began to reverse as the number of companies joining the USM began to fall away.

The principal reason for the decline in the USM was the significant convergence in entry requirements applied to the Official List. In 1990 the trading record requirement for entry to the List was reduced from five years to three, to bring it into line with European Directives. The implementation of EC Directives means that the Official List now caters for companies with a market capitalisation of £700,000 or more and a three year track record which are prepared to release 25 per cent of their shares into public hands. The remaining regulatory distinction between the markets is that the USM companies need only release 10 per cent of their shares into public hands—a characteristic which leads to very few shares in public hands and which reduces the liquidity and attractiveness of the market. Since the entry criteria of the Official List are essentially the same as those applicable to the USM, most companies see no reason to join the USM for a short period, preferring instead to apply for a full listing in the first place. Moreover, the cost advantage of the USM, substantial in the early days, has also disappeared.

After extensive consultation with USM companies and their advisers, the Exchange announced on 1 April 1993 that the USM would close at the end of 1996 and no new entrants would be admitted after the end of 1994. The Terms of Reference and membership of a working party were also announced to look into the merits of a new second market for companies. The Smaller Companies Working Party, under the chairmanship of a Director of the Exchange, is considering proposals for a distinct market catering exclusively for growth companies, possibly with lower admission thresholds leading to a corresponding reduction in entry and ongoing costs. If such a market became the inheritor of the tax breaks previously available to the BES, then it would be a highly attractive vehicle for new companies. The precise format and composition of the market remain under discussion. The Working Group is hoping to report on its proposals by the end of this year.

The decision to close the USM should not therefore be seen as a decision to close the capital market to the small company. The USM for many years, brought access to public capital to those young, growing companies that could not have qualified for listing, at a time when entry requirements to the List were more onerous than they are today.

A MARKET FOR SMALLER COMPANIES—SCIENTIFIC RESEARCH BASED COMPANIES

As this subject is likely to be of particular interest to the Science and Technology Select Committee, we are reporting on this in full. When the Exchange was consulting on the closure of the USM, several respondents indicated that scientific research companies had problems in raising equity. The Exchange took the view that it would be wrong for these companies to be denied access to UK capital markets and to be obliged to look to overseas markets. As a result an entirely new chapter has been incorporated into The Listing Rules, which will take effect on 1 December 1993, to enable certain scientific research based companies without an adequate trading record to raise finance by listing their securities, providing certain criteria are met. These rules have been drawn up in the light of comments from the industry who identified the type and size of company which was having difficulty in financing its growth.

The new chapter is intended primarily for emerging pharmaceutical and diagnostic companies but could accommodate other types of research companies. The new rules were devloped in recognition of the fact that the pharmaceutical, diagnostic and other scientific research based companies form an emerging and potentially very important sector of British industry which requires large amounts of finance. Although the lead time to the production of revenue from their major intended activities may be very long, the Exchange accepts that this does not necessarily mean that the companies are without substance. The Exchange is aware that the experience of quoting such entities in the US has been satisfactory.

The company must have been conducting its activity for three years and must produce financial information for those three years. Additional conditions for listing include: the company must have already demonstrated its ability to attract funds from sophisticated investors (usually those who sponsor start-ups of this nature); have a value of £20 million; intend to raise at least £10 million at the time of listing; demonstrate that the company has at least a three-year record of operations in laboratory research and development and have as its primary reason for listing the raising of finance to bring identified products to exploitation. As these companies will have already been scrutinised by venture capitalists and their investors, in the earlier stages of their development, this will increase the confidence of those investing in these companies.

In addition, as with all applicants for listing, the companies must demonstrate continuity of management; management and promoters will be prevented from selling their shares for two years following listing. Additional matters to be disclosed in the listing particulars include both the company's business plans and its products. There is a requirement for an independent report to assess the products, the business issues and the risks. Special requirements apply to different types of companies: pharmaceutical companies must have two drugs in trials regulated by appropriate government departments. Non-pharmaceutical companies must be able to offer other equivalent validations.

METHODS OF FLOTATION

The Exchange has also demonstrated its concern to reduce the costs of flotation for all our companies by increasing the flexibility with which their securities can be brought to the market. Under the new rules the monetary thresholds which determine the method for bringing shares to listing have been increased. Shares with a value of not more than £25 million (previously £15 million) may in future be placed entirely with clients of the sponsor involved. Equity shares with a value of more than £50 million (previously £30 million) must be marketed by an offer for sale or subscription. Between these limits shares may be marketed partly by a placing and partly by an offer for sale or intermediaries offer. This variety helps reduce the cost of flotation for the smaller company whose shares are illiquid; often because individual investors are locked into holdings by Capital Gains Tax liabilities.

TAX REFORMS

Not every constraint on the smooth operation of which affects the capital market its removable by the Exchange. The Exchange has made proposals to the Chancellor of the Exchequer for reforming Capital Gains Tax which it sees as an obstacle to the efficient raising of capital. The private investor who previously might have invested in a small, possibly local, company, accepting that the level of risk was high, now finds that the high level of Capital Gains Tax removes much of the incentive for making that investment. If Capital Gains Tax allowed roll-over relief when the proceeds from the sale of one equity were invested immediately in another, individual investors might be more willing to make this sort of risk investment. Such a reform would especially benefit smaller companies whose shares are illiquid; often because individual investors are locked into holdings by Capital Gains Tax liabilities.

TRADING SYSTEMS

The Exchange seeks to maximise liquidity and to ensure the most efficient price formation mechanism. As a result of a growing unwillingness of some market makers to make markets in less liquid stocks the Exchange has introduced changes to the trading system for less liquid stocks. There were essentially two main sources of discontent: the general economic conditions had led to a declining investor enthusiasm for small companies with a resulting reduction in the new issue business and turnover. In addition market makers no longer saw profit in market making in less liquid stocks. In November 1992, the Exchange introduced the Stock Exchange Alternative Trading System, SEATS, which allows for the publication of a firm two-way quote by a single market maker alongside the display of orders, thus ensuring a two-way price in each share.

Since its introduction SEATS has met three of its aims: enhancing liquidity, offering immediacy in small size and providing a valuation price. There has been a resurgence of interest in smaller company stocks during 1993 which happens to coincide, though it is almost certainly unconnected with the introduction of SEATS.

CONCLUSION

The London Stock Exchange is the UK's principal bridge between industry and investors. It provides and regulates the central market place in which wealth producers can raise the capital they need and investors can deal with confidence. Operating on behalf of the market, the Exchange takes fully into account the public interest and the interests of companies, both large and small, institutional and private investors and other market users. In today's rapidly changing environment we recognise that it is essential to be flexible and willing to respond to the needs of our market, by providing the right kind of regulation and market support services.

Memorandum submitted by ERA Technology (13 July 1993)

I am responding to your letter of 5 May 1993 about The House of Commons Science and Technology Committee's inquiry into "The routes through which the Science Base is translated into innovative and competitive technology".

I was for many years involved with the Royal Navy's research and development programmes and on retirement from the Navy took up a number of industrial appointments. The Marine Technology Directorate Limited was largely concerned with the encouragement and promotion of research in the field of Marine Technology to provide a sound technological base for the evolving marine technology industry. I was the founding Chairman and served in this capacity for six years, retiring last year.

I became a non-executive director of ERA Technology Ltd in 1985 and Chairman in 1990. My answers to the questions you raise largely stem from my role in ERA. However, I am also a non-executive director of two engineering-based plcs.

How important is continuing technical innovation in securing the future of your business?

For a contract research organisation like ERA it is probably the single most important factor. We win business because we are seen as being at the forefront of the technology in the areas in which we operate. If we did not innovate ourselves and keep up-to-date with the innovations of others, we would not survive as a research business. Fortunately for us, our customers believe that innovation is essential to their future company wealth, otherwise we would have no business.

How critical is technical innovation in setting the medium- and long-term strategy or mission for your firm?

In ERA, we maintain a medium-term research strategy (which we revise regularly) wherein we forcast the way technology will develop. We use this to decide those areas reaching maturity and unlikely to provide us with opportunities for new business; existing areas which are worth further investment; and new areas for investment as a basis for future expansion. We use this research strategy paper as a major input to our medium-term business plans.

Does the UK's provision of education and training help (or hinder) innovation, compared with that of competitor countries overseas? Have you encountered problems in obtaining personnel with adequate scientific and technical skills. If so, in what areas were these?

The best UK scientists and engineers are as good as any in the world in my own experience. The quality of the teaching at most UK universities is first-rate and the graduates have a good foundation for an engineering career and post-graduate work. The mathematical grounding is perhaps not so securely founded as in some other countries (France, Germany). The principal shortfall I have encountered is the supply and quality of technicians and incorporated engineers. A shortfall which is not so serious for an organisation like ERA which needs first-rate professional engineers and scientists and which, as long as it is seen to be in the forefront of technology and providing well-found laboratories and challenging assignments, can usually attract an acceptable share of those available.

Because we have an international reputation we attract a substantial number of non-UK nationals. We currently have professionals from 13 countries in the company. There is, however, a serious problem in that it is virtually impossible to employ the very able graduates trained in the UK universities who come from outside the EEC. Obtaining work permits is an extreme problem and yet our competiting nations, such as France, Germany and the USA, take a far more lenient view. We lose these people to competitors despite our investment in their training.

Does the UK financial system help innovation, again compared with overseas competitors?

It is our perception that the equivalent organisations within the other CEC countries get more government financial support (particularly when bidding for CEC and European Space Agency contracts) than is available here. For example, in France equivalent organisations get an annual grant from Goverment at the rate of 10 per cent of turnover. On the other hand, we receive help and encouragement from the DTI and financial support for projects for UK industry. We also win contracts from MoD and other Government Departments.

ERA Technology, as a company limited by guarantee, has avoided borrowing money to finance the business and our policy is to finance our own growth. Over the last five years our turnover has expanded by 65 per cent, that is on average at the rate of 10.5 per cent annum (£11.5 million in 1988 to £17.2 million in 1992) and our long-term strategy is to continue to expand at this rate without recourse to the money markets. We have therefore insulated ourselves against the vagaries of the financial markets. We intend to continue in that fashion! We do not have hard evidence to claim that we are hindered in our innovating by the UK's financial system.

Do the UK's Science Base (i.e., universities and research institutes) and the mechanisms for encouraging interaction between it and industry help innovation, and are things done better overseas? What contacts does your company have with Science Base organisations? How do you think these compare with those of your competitors, particularly overseas competitors?

I suppose that we might be viewed as part of the science base, although I prefer to see us as a bridge between that base and industry. We have extensive links with unviersities (e.g., the Universities of Edinburgh, Kent, Kingston, Imperial College, Queen Mary & Westfield College and University College, London, Loughborough, Surrey and York) and are involved in a number of research partnerhsips with them. Our basic philosophy is that we engage in research because someone is willing to pay for the result; we do not engage in curiosity-driven work. We do fund research of our own to secure our own future, but the choice is largely dictated by our medium-term research strategy. I believe that the recent popularity of the Fraunhofer Institutes and the concept of the Faraday Centres failed to realise the capability and potential of the best of the UK's own equivalents—the Contract Research and Technology Organisations. We have increased our own overseas business from £1.7 million to £4.8 million over the last five years, indeed the majority of our growth in turnover is derived from overseas business with over 40 countries. This indicates to me that in situations where competition exists we compare favourably with overseas competitors. It may be worth adding that although our turnover from UK customers has remained constant in real terms, the nature of our UK business, and the customers from which it is derived, have both changed considerably.

Memorandum submitted by Campden Food and Drink Research Association (29 October 1993)

BACKGROUND

The Campden Food and Drink Research Association is a company limited by guarantee (i.e., non-profit-sharing), employs approximately 210 staff in the disciplines of Agriculture, Chemistry and Biochemistry, Food Hygiene, Food Process Engineering, Information Services, Mathematics and Computing Sciences, Microbiology, Product and Packaging Technology, Quality Management Services, Sensory Science and Training. Approximately 650 member companies subscribe to the Association and collectively represent most sectors of the food chain (see Appendix 1).

The Research Association has expanded considerably in the last 10 years. The current turnover of £6.7 million is approximately 5.0 that of 1983 and more than double that of five years ago.

Campden's mission is to provide an independent research and development expertise and have the ability to advise, train and serve our members worldwide in the food, drink, catering and associated industries so as to ensure product safety, improved product quality and processing efficiency and stimulate product, package and process innovation.

The Research Association carries out a programme of strategic and applied research which is funded by a combination of funds from the food and drink industry, the UK Government and the European Commission. The research programme is conducted under nine main areas:

— Hygiene and Prevention of Contamination.
— Analytical Methods.
— Chemical, Physical and Sensory Properties.
— Process Engineering, Monitoring and Control.
— Quality Systems.
— Product Acceptability and Market Studies.
— Chilled and Frozen Foods.
— Heat Processed Foods.
— Other Preservation Systems.

This programme is discussed and agreed at a series of industrial Technical Panels and Working Parties and the industrial Research Committee (see Appendix 2) advises on the priorities with a view to ensuring maximum benefit from funds available from industry, UK Government and the European Commission. Government representatives from Ministry of Agriculture, Fisheries and Food and Department of Health are represented on these groups.

In addition to the strategic and applied research conducted within Campden, the Research Association has established close working relationships with Universities and Research Council Institutes in the UK to provide a link into the science base. This is summarised in Appendix 3. In addition the Research Association is actively seeking to identify technologies in other industrial sectors appropriate for application, with or without modification, in the food and drink industry. Contacts have also been established with the overseas science and technology base, particularly in Europe, through the European Commission funded research programmes (FLAIR, AAIR, BRITE-EURAM), but also in USA and Japan.

The RA's knowledge base obtained via its own strategic and applied research and by personal contact with academia and Research and Technology Organisations in the UK, Europe and elsewhere is supplemented through accessing the scientific literature (scientific journals, trade journals, patents and computerised data bases).

TECHNOLOGY TRANSFER

The knowledge and skill base resulting from the strategic and applied research within Campden and links with other organisations (see Appendix 3) enables the Research Association to advise and serve companies in the food and drink industry. The knowledge and skills are transferred to industry through two main sources:

(1) Interaction between and movement of people.
(2) Distribution of published information.

The major emphasis being via people interaction and movement. This is achieved through the following routes:

Technical Panels

Technical Panels and Working Parties (see Appendix 2) which comprises approximately 500 individuals from our member companies meet three times a year either at the Research Association or at the site of a member company.

At such meetings, the Research Association staff report on results of current research and their application to industry, review possible future research with industry, report on relevant developments in basic science and on technologies in other industrial sectors. Industrial members also raise areas of generic interest to their own specific panel for discussion. A review of developing legislation relevant to the food and drink industry is also given. Companies representing different stages of the food chain are represented at most of the Panel meetings (see Appendix 2).

Visits

Many visits by Research Association staff to companies and visits by industrial staff to the Research Association take place. In 1992 the RA received over 8,000 visitors and made approximately 1,400 visits to industry and research organisations.

Factory and laboratory audits

Research Association staff do audits in factories and laboratories and advise industrial companies on good manufacturing and laboratory practice with a view to ensuring industry best practice. This provides opportunities for staff to transfer science and technology to industry.

Training courses, workshops, symposia

The Research Association runs approximately 80 scheduled short courses per annum in addition to numerous customer designed courses run at the RA or the company's own premises. The programme of scheduled courses for January to June 1994 is shown in Appendix 4.

In 1992 over 1,000 industrialists participated in Campden's training courses.

Published information

Campden produces the following technical publications and actively promotes them in the food and drink industry.

1. Campden Technical Publications.
2. Industry best-practice/good manufacturing guides.
3. Specialist bulletins, e.g., new technologies, food law.
4. Articles in Trade Journals.

A selected list is given in Appendix 5.

INTERACTION WITH ACADEMIA AND THE SCIENCE BASE

1. Interaction with Universities

Research

At present we have 19 collaborative projects with Universities in the UK as shown below.

Funding scheme	Subject area	University
MAFF	Biocontrol techniques	University of Manchester
	Dielectric spectroscopy	King's College, London
LINK	Process modelling and simulation	University of the South Bank
	Food rheology	University of Cambridge
	Nuclear magnetic resource	University of Cambridge
	Cereal processing	University of Nottingham
	Food enzymes	University of Bristol
BRITE-EURAM	Vision systems	University of Strathclyde
Case Studentships	Biofilms	University of Warwick
	Microbial detection	University of Nottingham
	Microbial growth	University of Cardiff
	Microbial attachment	University of Manchester
	DNA probes	University of Coleraine
	Tea polyphenolics	University of Surrey
	Glycoalkaloids	University of Exeter
	Food acceptability	University of Birmingham
	Mathematical modelling	University of Birmingham
Campden Studentships	Salmonella detection	University of Birmingham
	Hygiene monitoring	University of Birmingham

Towards the end of 1992 and during 1993 the Research Association has established a close working relationship with the University of Birmingham with a view of combining the basic science and engineering skills, especially molecular biology, physics, mathematics and statistics and chemical engineering, of the University with the applied research and development skills of Campden. This is an initiative to develop the principles behind the Faraday proposals as outlined in the White Paper "Realising our Potential", namely:

- Two way flow of industrial technology and skilled people between the science and engineering base and industry.
- Partnerships between industrially-orientated research organisations and the science and engineering base.
- Core research underpinning product and process development.
- Industrially relevant post-graduate training.

Examples of collaborative projects already identified are:

- Use of Positron Emission Tomography (three dimensional imaging technique) to investigate composition of food during processes such as mixing, blending and extrusion with a view to improving design of equipment and the efficiency of processes. (This is transfer of technical development in the medical field to food).
- Mathematical modelling of oxygen diffusion in packaged food.
- Novel approaches to hygiene monitoring based on multi-enzyme systems.
- Identification of *Salmonella* in foods and ability to trace source of origin.

The Director-General of Campden has been appointed Honorary Professor in the School of Biological Sciences of the University of Birmingham and three senior staff are Research Fellows. The University and Campden are actively seeking further collaborative projects and initiatives which will assist the food and drink industry through the application of science and technology.

Industrial Training for Undergraduates

Campden has for the last 10 years employed undergraduate students for six or 12 months (occasionally three months) as part of their undergraduate course at University. The number of such undergraduates has increased over this period and there are usually between 10 to 15 employed at any given time. At present we have students from University of Surrey, De Montfort University, University of Plymouth, Sheffield Hallam University, Queen's University of Belfast, University of Huddersfield and Coventry University being trained in chemistry and biochemistry, microbiology, food process engineering, mathematics and computing sciences and product and packaging technology.

Not only does this provide training for the student in an industrially orientated organisation, but assists in catalysing links with Universities which lead to further collaborative research and subsequently technology transfer applications in the food and drink industry.

Registration of Campden Staff for Higher Degrees

Currently four permanent members of staff are registered for higher degrees, three Ph.D's and one M.Phil with the following Universities, Warwick, Birmingham, Swansea and Nottingham.

Teaching Company Scheme

The Research Association is currently exploring the possibility of having a Teaching Company Associate from Birmingham University.

2. INTERACTION WITH INSTITUTE OF FOOD RESEARCH (AFRC)

Campden currently has five collaborative research projects with the Institute of Food Research (IFR) all of which involve Campden assisting with transfer of knowledge and skills to industry from the science base. The project areas are predictive microbiology, cereal processing, immunochemistry as a diagnostics tool, application of Nuclear Magnetic Spectroscopy to food structure and natural defence mechanisms against pathogens.

During the last few months Campden has strengthened its interaction with the Institute in relation to technology transfer.

The Research Association will actively seek to utilise knowledge and skills in IFR in transferring technology to the food and drink industry.

Special emphasis will be given to:

- Molecular microbiology in food preservation and safety.
- Characterisation and measurement of foods for process control.
- Biological and biochemical identity of foods and contaminants.

FACTORS WHICH HELP AND HINDER TECHNOLOGY TRANSFER AT CAMPDEN

The major benefit which Campden has in relation to technology transfer is its close working relationship with the food and drink industry and particularly its membership base which represents the whole food chain from raw material production through to the retail and catering outlets.

The frequent interaction between Campden staff and industrialists via the Technical Panels, Working Parties, personal visits, training courses, workshops and symposia, contract research projects, scientific and technical service activities and factory and laboratory audits enable the Research Association to be made aware of the scientific and technical problems and opportunities in the agri-food sector (see Appendix 3).

In addition to this the scientific, technical and engineering staff at Campden interact with and understand the science base. This enables them to act at the interface and provide an "interpreter" role between the science base and industry (see Appendix 3). This is especially relevant and important to the small and medium enterprise sector (SME's).

However, despite the privileged position which the Research Association has in the above respects there are still significant hindrances to the food and drink industry taking full advantage of its knowledge and skill base. In view of the economic importance of the agri-food sector, being the largest manufacturing sector in the UK with considerable potential for job and wealth creation, serious consideration needs to be given to alleviating these hindrances in order for the UK food sector to take full advantage of scientific and technical developments. This is especially true for the SME's.

The hindrances which need to be addressed can be summarised as follows:

1. Government help schemes must be designed to meet the commercial needs of companies in terms of transferring information/technology from wherever appropriate to that need. The schemes must not be bureaucratic with many time delays. Company's timescales for decisions are relatively short. Long delays in setting up research and transfer projects (e.g., LINK) often result in company's budgets being lost and thus companies drop our of consortia whilst waiting for revision and approval of projects. We believe very strongly that insufficient importance has been attached to the unique position of the sectoral Research Associations in collaborative research funding schemes.

2. Technology transfer invariably requires some adaption which may require innovation, development and even some research to enable effective transfer. Funding schemes must be flexible to allow for this in sufficient proportion to meet the industry need.

3. Special problems associated with SME's
   - (a) SME's in the food and drink industry generally have little technical in-house resource and often are not aware of the benefits of technology transfer. They perceive it as a cost not a benefit.
   - (b) The definition of an SME needs to be re-examined in relation to eligibility for Government support schemes. In the food sector companies with only 100 to 150 people are likely to have a turnover of more than £30 million and therefore would not be defined as an SME
   - (c) As small companies become established, many are taken over with probably more than 30 per cent financial holding by the parent company. Such companies again would not be defined as an SME. However most such companies are run autonomously including the need to fund their own technical support and innovation. The importance and emphasis on short-term profit often results in minimal technical support to meet legislative and safety requirements. This highlights the lack of appreciation that technology can increase short-term profits.
   - (d) There is an urgent need to produce a list of the names of SME's and for a promotion campaign to make them more aware of the benefits of technology. Access to the registration list held by local authorities for food companies would be of considerable help.

At present it is not financially viable for us to invest more than a little speculative time with SME's due to the lack of financial return. There is therefore need for a Government support scheme to promote technology in SME's. This would need to be accountable with defined measurable objectives. The sectoral Research Associations in the UK have the ideal knowledge and skill base to interact and assist SME's. Campden would be prepared to act as a focal point for food and drink SME's.

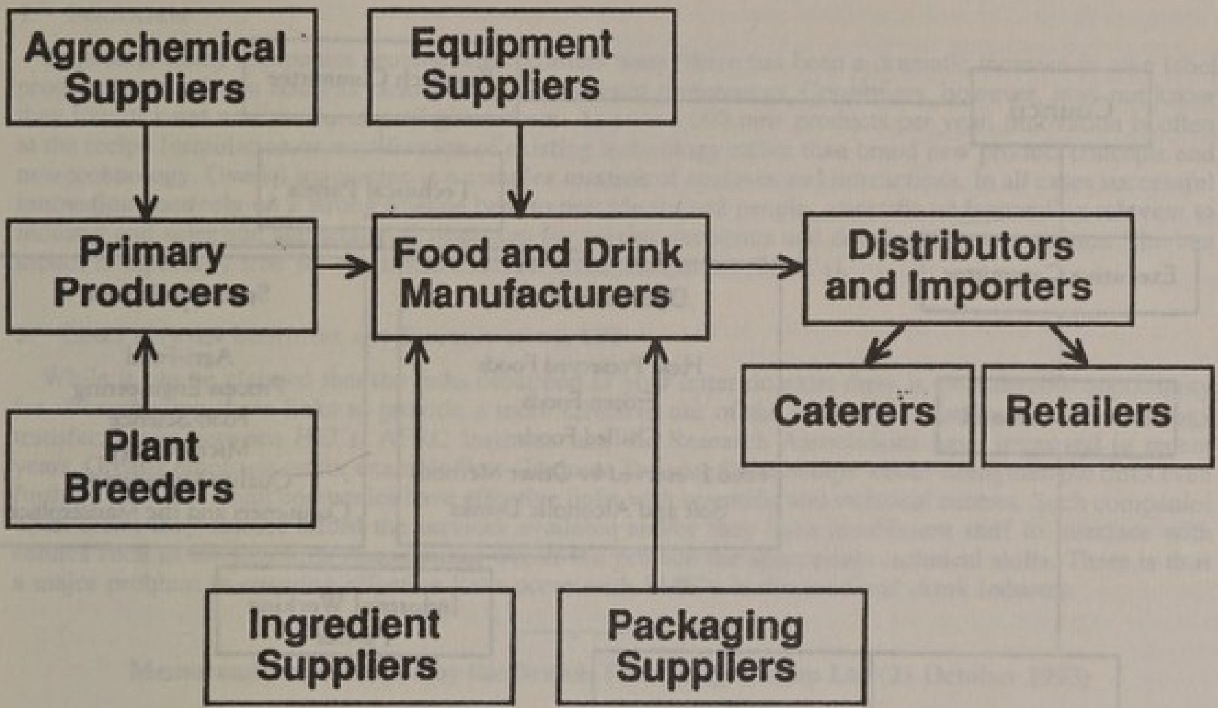
Promotional and awareness activities could include good manufacturing practice (industry best-practice) workshops and technology audits for individual companies.

The DTI enterprise grant system appears to work well for those small number of companies which access it. However we understand that grants available to individual companies have been cut by 50 per cent.

   - (e) There is a need to establish a culture in SME's which means they contact technical advisers as an integral part of business life in, for example the same way as they contact legal and financial advisers.

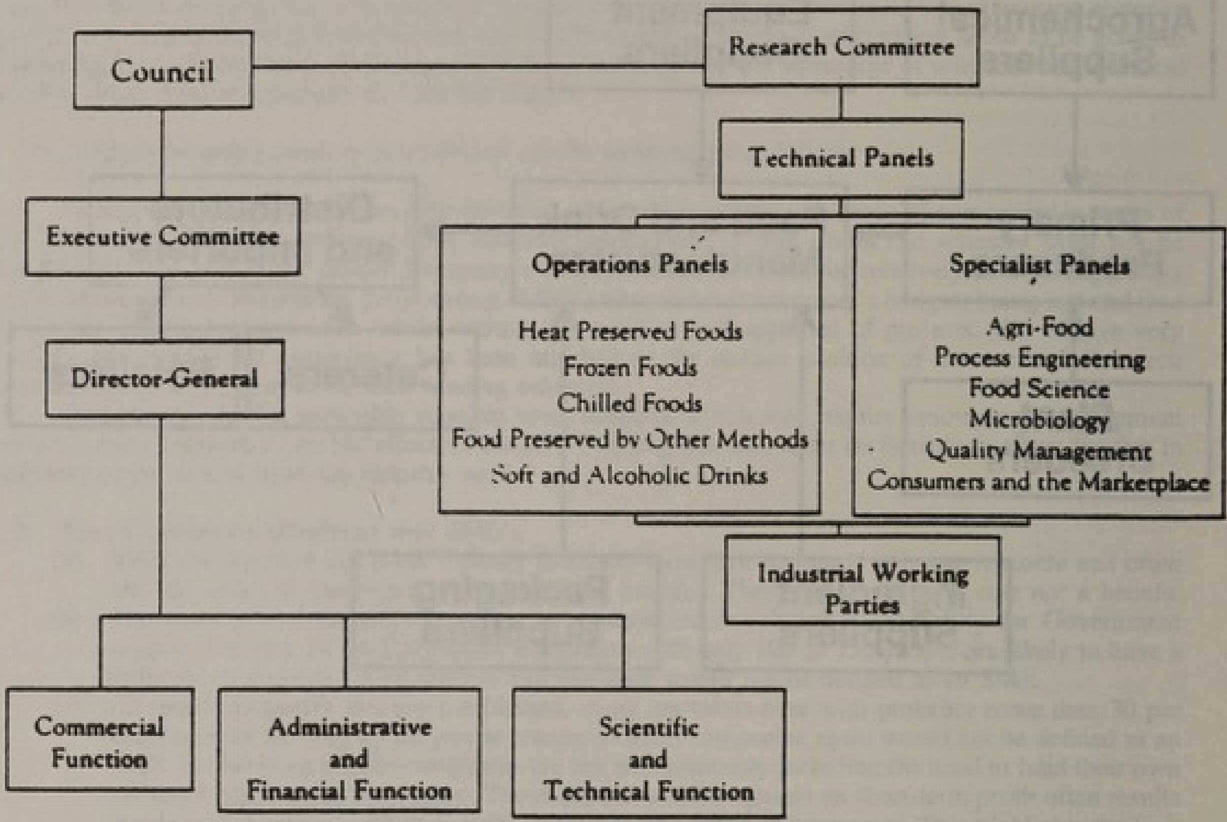
APPENDIX 1

OUR CUSTOMERS



APPENDIX 2

Panels within RA Structure



Further Memorandum submitted by the Campden Food and Drink Research Association (20 December 1993)

With regard to the summary of the response from the food and drink industry my comments are as follows:

1. Innovation

In general many companies provide what retailers want (there has been a dramatic increase in own label products) and rely on retailers' knowledge of consumer preferences. Consumers, however, may not know they like or want new products until given them. At over 4,000 new products per year, innovation is often at the recipe formulation or modification of existing technology rather than brand new product concepts and new technology. Overall innovation is a complex mixture of analyses and interactions. In all cases successful innovation does rely on a strong science base to provide trained people, scientific understanding relevant to industry and scientific and technical resources for solving problems and developing opportunities. The last aspect is especially true for small and medium sized companies (SME's).

2. Links between Institutes and Industry in the UK

While it can be claimed that the links described in your letter do exist there is considerable opportunity for strengthening these links to provide a more effective use of the science base and catalyse technology transfer. Links between HEI's, AFRC Institutes and the Research Associations have improved in recent years. Greater emphasis on for example Post-Graduate Training Partnerships would strengthen the links even further. Very few small companies have effective links with scientific and technical centres. Such companies often claim they cannot afford the services available and/or they have insufficient staff to interface with centres such as the Research Associations which can provide the appropriate technical skills. There is thus a major problem in ensuring effective links occur with SME's in the food and drink industry.

Memorandum submitted by the British Technology Group Ltd (21 October 1993)

The role of the British Technology Group

Our business is technology transfer. But technology transfer is a very broad term, and we are only one part of the technology transfer process. We commercialise technology and, more narrowly defined, we manage intellectual property (IPR). We identify technology, mainly but not exclusively in UK universities, and develop, patent and license it to companies worldwide. We then share the proceeds with the technology source. We are the largest and most successful such organisation or company worldwide, public or private sector. We are really the only such international company in this business.

Contrary to much public opinion, the UK has been more successful in patenting and licensing academic technology than almost any other country, including the USA. For example, in the two years 1989 and 1990, according to US Government data and estimates by MIT, total licence income from US university and Government civil research laboratories amounted to about $120 million. In the same years, revenues from UK academic inventions were over $102 million, of which BTG's share was over $95 million and that of Strathclyde, the largest single university licensor, was over $5 million. In the same period, US civil R&D expenditure in those sectors was about $50 billion, and the UK's about $10 billion. By that measure, therefore, we in the UK generate five times more licence revenues per $ of spend in universities than in the US. We believe the comparison is similar in most European countries and in Japan.

BTG was originally created in 1948 to protect and commercialise technology resulting from academic and public research in the UK and to create value from it. Over the period 1966-92, BTG generated £413 million in royalties, of which £270 million or 65 per cent was returned to Government or to the research base directly. We believe this is a very good record.

Privatisation

Privatisation of BTG took place in March 1992 after the passage of the BTG Act 1991. Thanks to strong support from both Houses, the Act created the right structure for the privatisation of BTG and we now have a set of long-term shareholders—including pension funds, venture capital, insurance companies—blue chip financial institutions, the Nuffield Foundation, universities and ANVAR. We also achieved substantial employee participation, 26 per cent of the voting stock being held by an Employee Share Option Scheme. Although we were privatised into a hostile economic environment, we have had a good first year in the private sector. We bettered our cash flow projections by £2 million, turned around our operating profit by £3 million, and signed 50 per cent more licences than in any of the previous four years. So far, 18 months on, we appear to be broadly on track.

Last year, our first in the private sector, we generated £26 million, of which £7.3 million was shared directly with universities (an increase of almost 50 per cent over the previous year) and other investments in, or on behalf of, our sources amounted to a further £7.3 million. Thus, a total of £14.6 million was returned to our sources. We have made substantial progress in a number of areas: magnetic resonance imaging; Torotrak, a continuously variable transmission system; and a wide range of pharmaceuticals. Today we remain the dominant group working with UK universities, filing 35-40 per cent of university patents. Our reputation is high, and particularly strong outside the UK. Over the past few years, while maintaining the UK as our core business we have begun to work with overseas universities. We also now work with companies in the UK and elsewhere to commercialise their technologies more effectively and last year 40 per cent of technologies offered to BTG arose from this sector. By coincidence 40 per cent is also the proportion of our total technologies offered to us from overseas. Last year in the US we had 400 inventions offered from 80 universities and 50 companies. Today, overall we have 1,500 technologies and 500 licences with companies worldwide.

Examples of universities we work with outside the UK are Amsterdam, Neuchatel, Princeton, Arkansas, Alabama and California. Companies whose technologies we are handling include ICI, Grumman, Eli Lilly, Du Pont Merck, American Cyanamid, Johnson & Johnson and many others. The Johnson & Johnson portfolio has now earned significant royalities for them and, therefore, BTG.

In terms of operations, we are London based, wih a subsidiary in the US, a joint venture in India, and an office in Japan. In addition to licensing early stage technology, we now also license fully developed products, undertake IPR "sale and leaseback" for SMEs, provide consulting advice and audits on IPR, and technology assessment and technology search for specific needs. We are therefore a significant source of new technology for UK companies.

Post privatisation

You have asked particularly about whether the BTG has withdrawn from particular activities. Post-privatisation, we have decided to withdraw from the venture capital activity, mainly in the area of company start-ups, where we believe BTG played at best a peripheral role. We do not believe that we met any particular market need more effectively than the mainstream venture capital industry, and have therefore decided to concentrate our resources on the core business of IPR management. We have also shifted the balance of our activity slightly in the direction of greater concentration on active pursuit of licences for technology which has already been entrusted to us by universities, as compared to seeking yet more new technology. We are, of course, continuing to seek, and develop, new technologies for the long term, but we do wish to see a small change in the balance of our activies. We believe that this shift in emphasis is understood by our university customers, who will of course benefit with us from successful licensing.

Memorandum submitted by Prelude Technology (12 August 1993)

By way of introduction: Prelude Technology Investments is an investment management company specialising in early stage technology based businesses. The company was founded in 1985 and is located on the Cambridge Science Park.

We invest the funds of financial institutions (pension funds and insurance companies) and corporations who have allocated funds for investment in this sector. To date £14 million has been committed.

We seek opportunities to create new businesses, generally based proprietary technology, and originally produced as a result of academic or commercial research. We aim to create businesses which can achieve substantial growth in international markets and long-term prosperity.

It is essentially our job to identify such investment opportunities and then act as both the catalyst and source of funding needed to create a successful commercial entity. We participate in the transfer of the technology and the engineers and scientists involved with it, the development of strategic and operating plans, the recruitment of appropriately experienced senior management, non-executive directors and chairmen, the introduction to sources of specialist advice and our network of other contacts.

As the provider of risk capital for the creation of businesses, we invest essentially in equity. Prelude is not a lender, as assumed in your letter. Our returns are obtained, by way of a capital gain, either by selling our interest in the business to another corporation or by obtaining a listing when the company has established itself in the marketplace.

The enclosed brochure[1] elaborates on some of these points.

Turning to the specific questions you ask about our business (tracking those on the second page of your letter):

— We cannot quote market share, but I can make the observation that there are very few institutions in the UK active in the provision of equity finance for the creation of technology based businesses and Prelude Technology Investments is one of these.

[1]Not printed.

— As I said we do not lend; we make investments in businesses which we consider have the potential to create an attractive return to our investors. I should emphasise that this is risk capital. We accept risk but there has to be the prospect of a commensurate return.
— Our managers have a combination of scientific and commercial background and experience, which, together with additional reference to specialists, is relied upon to assess the risk of high technology ventures, in which we specialise.
— A successful young company has to be dynamic, responsive and innovative, and so the best way to answer your question is that these are essential qualities of the type of investment opportunity we are looking for.
— I do not feel competent to discuss UK policy, however you might define this. However I can make some general observations, from our perspective, on the UK environment for the creation and development of internationally competitive technology based businesses.

A source of technology

— We encounter a good flow of internationally competitive technologies capable of commercial exploitation.

Management resources

— Thatcher's enterprise culture did much to encourage individuals prepared to take the risk of committing themselves to new and revitalised businesses. However, it is still hard to find managers with the appropriate combination of business competence and proven experience in the arena of the international (technology) marketplace.

Sources of finance

— The development of such projects need large amounts of cash; which is difficult to find. Our experience is that we have to syndicate investment abroad because of the lack of like minded risk capital providers in the UK. We also find that the typical corporate partner willing to invest the multi-million pounds needed for development, manufacture, marketing and distribution will generally be either North American or Japanese rather than European. Added to this there is not the government support for venture capital investment we see in Holland and Germany, for example.

Memorandum submitted by TWI (The Welding Institute) (14 July 1993)

Background

TWI's credentials for giving evidence to the Committee can be summarised as follows:

TWI is the largest RTO (440 staff) in the western world concerned with joining and materials. Its *stated* mission for the last 25 years has been the translation of science and technology into innovative industrial practice, coupled with the development of professional standards through training and accreditation. Its membership (customer base) comes from an industrial membership covering over 2,500 companies in 26 countries (50 per cent in the UK). These include many of the largest manufacturing and user companies in the world—Nippon Steel, General Motors, L'Air Liquide, BP and hundreds of SMEs employing less than 50 people. It is also a professional engineering institution with a regional network of 22 branches throughout the UK for its 4,500 Professional Members.

TWI has formal links with 16 Universities in the UK and three overseas. Postgraduate qualifications have been achieved by a large number of TWI staff since its founding in 1946.

TWI received 11,000 industrial visitors in 1992 concerned with all aspects of innovation. Formal technology transfer mechanisms (training workshop seminars, industry groups, etc., etc.) involved a similar number of people.

TWI probably has more direct contact with user and manufacturing industry, both in the UK and worldwide concerned with the challenge of innovation, than any other UK organisation.

General comments

1. Unless there is a firm commitment to innovation at Board level, the efforts of individuals further down the hierarchy will not have significant effect.

2. The most powerful stimulus for change is the revelation that an identical organisation has benefited commercially from taking certain actions.

3. The four possible states of a company's attitude to innovation might be described as Ignorance, Awareness, Continuous Improvement, Best Practice, 90 per cent of the UK's manufacturing companies fall into the first category.

Innovation for most companies does not involve the incorporation of new material from the science base. It consists of adopting or adapting proven technology from its own or another manufacturing sector.

4. Shortage of time is the greatest enemy of Directors of small companies. There is insufficient critical mass to consider strategic issues thorougly. Messages to them must be crisp, compelling and *repeated endlessly.*

5. Interaction between industry and those organisations seeking to encourage innovation is more likely to be successful if the person concerned is regarded as a real expert. In other words, its the best advice available.

6. Various bodies are calling for the creation of intermediate institutes to facility technology transfer and innovation. We already have some—they are called RTOs. Some are very effective, and some less so. One or two are truly world-class. It is interesting to see the Fraunhofer Institute held up as a model to which the UK should aspire. Our close contract with several Fraunhofer Institutes reveals their envy of the broad and deep industrial base of the successful UK RTOs and their ability to attract *real* industrial funding. Some RTOs do all the things they do and more besides.

TWI was asked to help set up the Edison Welding Institute by the State of Ohio in 1985 as our mirror image. Of the many Edison centres it is the flagship and the Edison programme as a whole is the most highly regarded in the USA concerned with innovation and technology transfer.

The Australian Welding Research Association was founded in our image in 1968. We are currently assisting Institut de Soudure in Paris to develop an industrial membership base using the UK model. The same exercise has just started in Eastern Europe.

There is no single remedy to improve the UK's position but the current and potential role of several of the RTOs concerned with cross sectoral technology should be examined more closely.

Innovation and technology transfer requires an investment which provides the facility and training ground for people targeted to the correct issues. TWI is such a facility and has operated to date with less than 20 per cent support from the DTI. This compares very favourably with more than 70 per cent support for the Fraunhofer Institutes from the German Government.

7. For most organisations innovation cannot be implemented without the whole raft of supporting data. In our field laser welding could not be introduced without independent data on mechanical properties, quality assessment methods, etc. Many of these activities relatively unexciting and will not enthuse a PhD. Work of this sort is undertaken within many of the RTOs in addition to the innovative activities. It was also undertaken in the central laboratories of large corporations. These are being restructured, so where is it expected to take place in the future?

Brief answers to the specific questions of the Committee are attached.

QUESTION 1

The science base is usually separated from industrial innovation by a phase in which technology arising from the science base is adapted for exploitation. This technology development "bridge" is crucial to establishing confidence in the industrial customer sufficient to cause an investment to take place.

The gulf between the science base and industry is narrowing slowly but mechanisms are needed which build more technology development bridges.

QUESTION 2

Effectiveness of the interaction can only be measured by results. Each component of the science base should be required to list those projects undertaken five years ago that have caused innovation to occur, and for this to be updated annually. Without such measurements, answers are only guesswork or opinion.

More bridges and interaction between the science base and industry could be brought about by greater use of intermediate organisations like TWI, with a long track record of developing exploitable technologies suitable for industry, at low cost to the taxpayer.

QUESTION 3

As a generality, we see little difference in the attitude to the need for change amongst large companies in the UK when compared with overseas. However large UK companies are slower to take decisions, which are often negative.

TWI is not in a position to advance reasons for this, other than to observe that the relationship between large customers and large suppliers has changed over the last five years.

For example, the CEGB recognised that, in order to have the opportunity to buy UK manufactured products, it was necessary to have a degree of continuity of orders to maintain the manufacturing base. Today, the shareholders of Powergen cannot be expected to be concerned about Babcock Power's ability to supply boilers—they can be bought from overseas.

Thus, it is not altogether surprising that heavy manufacturing in particular takes a more cautious view of innovation and its associated investment costs when faced with customers who no longer see the commercial need for partnerships to support long-term business.

We do not see British Industry's ability to innovate as being significantly hindered by a lack of technological skills in the area where technology is created somewhere in the ground between the boardroom and the shop floor.

However, in the UK fewer technologists seem to move on to senior positions. Thus, the management process that fosters innovation is hindered by a lack in technological awareness at senior level.

Put simply, technologists need more business skills, and managers need more technological skills.

QUESTION 4

Competitiveness can be measured in a variety of ways. We can observe the following characteristics in any market leader.

(1) Clarity of vision and mission.
(2) Speed to market for new products and services.
(3) Continuous improvement people culture.
(4) Capacity to monitor client satisfaction and desire to activate change on micro and macro sales.
(5) Capacity to defeat "not invented here" syndrome.
(6) Profitability.

Innovative and competitive technology is mainly concerned with (2), and affected directly or indirectly by the other factors. With "aware" UK companies we see just as much technology sloshing around as in comparable overseas companies. We see as many examples of bad practice (in technology) in overseas companies as in UK companies. But many of the overseas companies are more successful. One can only conclude that technology is not the only issue.

QUESTION 5

Innovation requires investment and investment requires funding. If the financial culture is short term then this must hinder innovation.

In our experience a different relationship exists between industry and the banking sector in the two most quoted innovative countries, Japan and Germany, than in the UK. We have never heard one of our many of hundreds of overseas clients complain about their bank. We hear it often in the UK.

Effective strategic planning necessitates a strong partnership between the financial institutions and industry which is less apparent in the UK.

The remedy for this lies in changing attitudes to manufacturing such that it is regarded by all as an *absolute* requirement for long-term prosperity. This has been debated so often that there are probably no new ideas to put forward.

QUESTION 6

We do not believe that technical innovation plays an exclusive role in determining success or otherwise in international markets. Lack of it would clearly be disastrous but more important than innovation in its own right is identification of customer needs and the associated commercial arrangements. There have been countless occasions on which the British product has been technically excellent, the price in itself satisfactory, but the order has gone to a competitor because other aspects of the package (e.g., finance) are less than optimum. One has only to look at the effect that 0 per cent finance has on car sales.

The keys to success are often simplistically quoted as product, price and promotion. When all three are right for the market success is usually assured. There are too many examples of investment in new products without investment in routes to the market. It follows that corporate strategy must address the way in which the company develops a methodology to solve these issues.

QUESTION 7

If the UK Science Base continues to produce good science then it is necessary to look at the other elements of the innovation cycle. The decimation of corporate R&D centres, associated with changes in company strategy or privatisation have removed huge chunks of activity concerned with technical innovation. The

CEGB through its PERSC scheme used to provide up to £50 million per annum to support technology creation within its major suppliers. Its own laboratories have almost vanished. The detrimental effect to the supply chain is significant. In this climate the role of intermediate organisations sitting between HEIs and industry becomes even more important.

There is no cohesion between the many agencies and initiatives concerned with innovation. The cultural gap between the science base and the majority of industry is still immense.

Most companies do not have the resources to take new science and then turn it to profit, they need to lift proven technology from somewhere else.

Memorandum submitted by AEA Technology (7 July 1993)

Q1 *What is the relationship between the Science Base and industrial innovation?*

The Science Base is in general the source of longer term, fundamental, innovations. However, industrial innovation does not derive solely from this base; it also includes the application of established know-how to existing products.

There is therefore a requirement for technology transfer organisations (such as AEA and IRO's) which can act in a bridging role between the Science Base and industry. Such organisations maintain close relationships with universities, but survive only through their ability to earn money from industry. Specific roles include:

(a) "Missions": large-scale, cross-discipline programmes which require a wide range of skills and technologies, exemplified in the past by AEA's work for the nuclear power programme.

(b) Taking technology to SME's as well as larger industrial concerns (AEA undertakes contract and consultancy work for several hundred SME's).

(c) Training. About 2,000 science and engineering post-graduates have carried out their PhD and Masters work with AEA support and supervision; many of these then went into industry. AEA also provides industrially-funded training; for example, the National Centre for Tribology has trained more than 12,000 people from industry. Collaborative projects are also a way of bringing together the Science Base and industrial requirements.

Q2 *Are the mechanisms for technology transfer and interaction between the science base and industry effective?*

Effectiveness varies: most mechanisms work well with large companies such as ICI, but not with SME's due to their lack of knowledge and their perception of the large technical and commercial risks which are involved.

AEA's experience has established that the following mechanisms can be successful in providing an interface to SMEs: awareness activities, training programmes, establishment of best practice, movement of people, services and consultancy, joint ventures, and industrial Clubs.

Q2a *How could they be improved?*

By ensuring technology transfer increasingly takes place within a real business environment having clearly identified objectives relating to added commercial value.

Through increased Government sponsorship of communication/awareness activities for SME's, and building on the success of existing schemes such as LINK and the Teaching Company scheme.

By the reduction of risk: underpinning by Government and the investment sector, through industrial Clubs, and the use of technology transfer organisations.

By ensuring that a range of approaches is adopted so that maximum impact can be achieved.

By encouraging more post-doctoral work that involves active partnership with and periods working in industry, and through more vigorous promotion of moves in both directions between staff in industry and academia.

Q3 *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

In general, there is perception of a growing shortage of skilled people who are able to drive and manage the effective introduction and exploitation of innovation. In this context the difficulties experienced by HEI's in attracting the highest calibre students into applied science and engineering degree courses is worrying.

AEA experience is that science and engineering graduates benefit from early formal training in areas such as management, business, finance and communications which complements academic (including Business School) experience.

Q5 *Is "short-termism" really a problem for innovative British industry?*

Some high technology areas are successful through innovation, but the overall position for British industry is patchy. Large sections of the heavy industry sector are currently "under siege; in order to survive they are being forced to concentrate on achieving short-term financial objectives. As a consequence, long-term investment is being stifled.

If the Foresight plans proposed in the White Paper "Realising our Potential" do give a clearer picture of technological trends, they could offer a more effective framework and encouragement for complementary long-term industrial investment. AEA experience of targeting key technology areas (e.g., environment, safety) has been successful, leading frequently to cross-sector technology transfer.

There is a reluctance for take-up in SMEs because the timescale to which they work is short compared with the perceived rates of development programmes, and their financial exposure and liquidity are considerable. Their desire to innovate and to undertake longer-term investments is inhibited by these short-term considerations: the immediate commercial risk is reduced, but only at the expense of introducing the problem of smaller potential for long-term growth and for competitive advantage.

Q5a *If so, why is this, and how might it be remedied?*

By addressing the general need for greater stability and certainly about future health of many parts of the processing and manufacturing industry sectors.

By using mechanisms which reduce and/or share the risks of longer-term ventures: the application of existing know-how through IRO's and the sharing of funding through collaborative ventures.

Through improved awareness of what is on offer and accessible, using effective networking; the DTI "one stop shops" are a step forward but they need to be backed up by the range and depth of technical support and advice available at AEA the IROs.

Continuing to give incentives to technology transfer organisations and industry by providing a business-like environment of open competition to technical services and consultancy.

Q7 *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder this process?*

The DTI and CBI through networking and other awareness activities, and by benchmarking international good practice.

Technology transfer organisations (such as AEA and IRO's) which can provide a flow of industrial scientists, offer technical services and consultancy to industry, run Clubs, provide databases, license technologies, etc.

The Science Base through schemes such as LINK, the Teaching Company scheme and CASE awards.

Memorandum submitted by Association of Independent Research and Technology Organisations (AIRTO) (13 July 1993)

AIRTO is grateful for the opportunity to respond to the above enquiry. The AIRTO response is based on an independent study carried out by Professor Roy Rothwell and Dr Mark Dodgson of the Science Policy Unit of the University of Sussex entitled "The contribution which research and technology organisations make to innovation and competitiveness in UK industry".

In particular we commend to you the executive summary, paragraph 3 of which states that innovation is a complex process and argues the need for intermediate institutions to link the various elements of the national system of innovation.

With reference to the seven questions raised by the Committee, we would like to comment as follows:

1. WHAT IS THE RELATIONSHIP BETWEEN THE SCIENCE BASE AND INDUSTRIAL INNOVATION?

Most large high technology companies have good linkages with academia. The process of technology transfer appears to be working well. There may be many reasons for this success, one undoubtedly is the flow of personnel between academia and such companies, and also the research departments of high tech companies speak the same language and understand academia. The strong linkage does not exist between academia and the more basic manufacturing industries and particularly the small and medium size enterprises in this industrial category. Personnel employed in SMEs in basic manufacturing industry often do not speak the same language as academics nor understand the workings of academia, and hence in order to couple academia with these industrial companies an intermediary has to be employed.

2. ARE THE MECHANISMS FOR TECHNOLOGY TRANSFER AND INTERACTION BETWEEN THE SCIENCE BASE AND INDUSTRY EFFECTIVE? HOW COULD THEY BE IMPROVED?

Following from the response to the first question, the problem identified was communication and technology flow between academia and basic manufacturing industry. Due to cultural differences, intermediate institutions are necessary for successful technology transfer. The SPRU report develops this theme and indicates in section 4 the RTOs' unique range of services and how these services are used to improve the competitiveness in UK manufacturing industry. Appendix 1 of the SPRU report defines RTOs. The mechanism for technology transfer between academia and basic manufacturing industry could be improved by a recognition of the importance of intermediate organisations. The OST White Paper stresses the importance of realising our potential but does not consider appropriate delivery mechanisms. The 36 RTOs which are members of AIRTO have a total turnover in excess of £300 million per annum, of which 80 per cent comes from industry. They are an extremely powerful tool for accelerating the innovation process in industry and improving national competitiveness.

3. Is INDUSTRIAL INNOVATION HINDERED BY A LACK OF COMPETENT PERSONNEL, BOTH TECHNOLOGICALLY AND IN MANAGEMENT SKILLS?

The Faraday principle, which is supported by the OST White Paper, is one mechanism for training PhD students with good academic supervision in a commercialy orientated environment. People with such training will be increasingly important in bridging the gap between academia and industry. AIRTO supports the Faraday principle, the six, Government sponsored, Postgraduate Training Partnerships are all located within the laboratories of AIRTO members and one AIRTO member, Smith System Engineering Limited, has founded the Smith Institute based on Faraday principles.

4. Is INNOVATION BY BRITISH INDUSTRY INTERNATIONALLY COMPETITIVE? HOW SHOULD THIS COMPETITIVENESS BE MEASURED?

To the extent that much of British industry in general is not internationally competitive, the weakness of the innovation system must be a contributory factor. The argument was put forward at the Foundation for Science and Technology meeting held on 21 June 1993 that lack of international competitiveness is not due to a poor science base nor even poor applied science, but to a weakness of short-term financial and marketing attitudes. The wide definition of innovation is not restricted to technology input but to financial and marketing management as well and hence where British industry is not internationally competitive it is because the British innovation system is not internationally competitive.

5. Is SHORT-TERMISM REALLY A PROBLEM FOR INNOVATIVE BRITISH INDUSTRY, IF SO WHY IS THIS AND HOW MIGHT IT BE REMEDIED?

Short-termism must be a factor contributing to the problem for innovation in British industry. The timescale for innovation is greater than the timescale for judging financial performance of a company or the individual performance of its chief executive. With such short-term pressure to produce company results, it is understandable, although regrettable, that innovation and the long-term development of British industry is neglected. With reference to the remedy, the UK financial system must be geared to making industry competitive in the long-term and not motivated by short-term manoeuvres.

6. SOME SECTORS OF UK INDUSTRY ARE MORE SUCCESSFUL IN INTERNATIONAL MARKETS THAN OTHERS

The successful innovation process requires good management of technology flow, financial stability and market penetration. In the case of successful sectors of UK industry, such as pharmaceuticals, as stated in answer to the first question, there is good linkage between academia and industrial research, hence enabling the latest ideas from academia to be turned into pharmaceutical products. In the case of the third requirement of market penetration, the fact that drugs receive patent protection and intellectual property rights are better safeguarded in the pharmaceutical than in some other industries, does enable drug companies to obtain market penetration with suitable safeguards. Financial stability is not so clear, although patent protection does in fact provide the company with a stable long-term market for its goods.

7. WHAT STRUCTURES AND INSTITUTIONS WITHIN THE UK ARE PARTICULARLY HELPFUL IN ENCOURAGING THE PROCESS OF INNOVATION WITHIN A COMPANY, AND WHICH HINDER THIS PROCESS?

As highlighted in the SPRU report, intermediate institutions such as RTOs are a powerful tool for bringing about innovation in basic manufacturing industry. It is not possible in all sectors of industry to push the boundary of academia and industry to such an extent that they meet forming a successful linkage through which innovation can be piped. The cultural differences between academia and basic manufacturing are such that intermediate organisations are needed to bridge the cultural and understanding gap. Intermediate institutions act as agents understanding the needs and capabilities of both academia and industry, and with this knowledge act as a catalyst and conduit for enhancing the innovative process across a very large sector of UK industry.

Memorandum submitted by The Machine Tool Technologies Association (21 June 1993)

We read with interest the press notice announcing the inquiry into innovative and competitive technology to be carried out by the House of Commons Science and Technology Committee. This interest was heightened by your choice of our industry as one which you would look at specifically and by the fact that some of our Members have been sent the detailed questionnaire.

That questionnaire is of course for individual companies to respond to and we would not wish to intervene in that process. However, in reading the press notice there were some points which arose—hence this letter which we hope you will receive as written evidence.

One of the key questions for the Committee would appear to be to crystallise a definition of innovation since without it you cannot hope to measure either the amount or effect. You have already spoken to the Science Policy Research Unit (SPRU) who will no doubt have given you some thoughts on measuring innovation by counting patent applications and I am sure that others will have suggested using Research and Development R&D expenditure data. While these are both valid and internationally comparable ways of measuring innovation, they can be misleading as a result of the way in which innovation is carried out in different industries.

For example, we think it likely that the machine tool companies who you speak to will have below average levels of R&D expenditure compared to other industries. There are a number of factors behind this, including the maturity of technology in the industry. More important however, is that most companies selling advanced machine tools are essentially in the business of providing solutions to their customers manufacturing problems rather than just selling a standard product range. This will mean that there is often a considerable amount of customer specific engineering which can then be drawn upon for the future. As a result, this sort of expenditure will rarely be classified in company accounts under R&D. We should add that this applies equally to the machine tool industries of most countries and is not unique to the UK.

Success in international markets is driven by a large number of factors of which innovation is only one. Clearly, if a product does not have an edge over that of the competitors then it will not sell overseas (or indeed in the home market). At the other end of the scale however, a company could have the most innovative product of service to sell but be priced out of a market by inappropriate exchange rates which makes the domestic or third party competitor's inferior product too good to ignore. The success or otherwise of an individual company is the product of the effect of a huge number of parameters some of which will be determined by external factors such as exchange rates or the effectiveness of the domestic competition in the market place. Simply making British companies more innovative as your question suggests is not necessarily going to help make them more competitive, although there are clearly situations where this would be true.

"Short-termism" is a product of the financial system in the UK, since we have a higher proportion of public companies than either Japan or Germany. That companies in these countries are supported on a longer-term basis by their domestic banking and financial sectors is a result of both the systems within which they operate and the cultures of those countries. This means that it is simply not possible to copy their systems in the UK and we have to find our own solutions to the problem of companies placing short-term profits ahead of long-term investment.

There is a lack of effective communication between the industrial and financial sectors (although this is only part of the problem). Far too often companies are exposed by short-term problems, within the institutions, to difficulties which are not of their own making. The availability of low cost finance to fund the holding of stock is crucial at times of severe recession such as we have seen in the UK and around the world. It is as much short-termism of this type as the desire for constant increases in dividend payments which needs to be considered in this part of your inquiry.

While we have not addressed all of the questions contained within your press notice, indeed we are not really qualified to answer some of them, we hope that these views will help to guide the thoughts of the Committee as they consider the evidence put before them. In particular, we would offer our services if you have any further questions about our industry as a whole as a result of the questionnaire which you sent to the companies.

Further memorandum submitted by The Machine Tool Technologies Association (10 December 1993)

Thank you for your letter of 19 November requesting some further information on specific questions raised by the Committee. I believe that you have received replies directly from some of our Member companies to whom you wrote, including Dr Colin Gaskell of The 600 Group Plc who has been kind enough to send us a copy of his reply.

On the question regarding the importance of the science base to performance, we would agree with the comments made by Dr Gaskill. It may also be true that the machine tool industry, in particular, is a relatively "mature" technology, with most development coming through work on specific projects for individual customers, rather than through basic research. It has always been rather misleading to use statistics in R&D in the machine tool industry since the majority would not necessarily be regarded even as development spending because of its relationship to a specific order.

We are not aware of the extent of the use of "benchmarking" techniques among our Member companies, but we suspect that it is generally low. There are some companies who use such techniques in some part of their business (e.g., new product development) but we do not think that they are widespread. There are, of course, a number of ideas which could be regarded as "benchmarking" such as monitoring of market share and in this area the machine tool industry would probably be around the average of British manufacturing industry in its use of these methods.

We are not sufficiently close to the financing of companies to be able to comment extensively on your third set of questions but the following points come to mind.

We did not see the actual questions used but it occurs to us that there is a subtle difference between a company being "satisfied with their finance" and being "satisfied with the procedures for financing". They are not necessarily incompatible since the former could mean that they are happy that the current level of financing of the company is satisfactory for the present circumstances, while the latter meant that they were unhappy about the terms of financing or were having problems finding additional funding for new requirements. It would be necessary to look again at the questions which were asked to understand these differences clearly.

Despite this, we can clearly see that the comments made by Dr Gaskell about the short term nature of the UK capital markets are important. We would make the comparison with Germany where manufacturing companies have access to funds provided by the KFW at fixed rates over relatively long periods and the financial institutions are generally more closely related to their manufacturing industry. It would take an extremely long time to change the nature of the UK capital markets—perhaps the influence of the Single European Market will have an effect—but there is still measures which could be taken to ease this situation. Some form of Government guarantee for long term loans might help to encourage the commercial institutions to lend on the basis if they are not prepared to do it otherwise.

I hope that these comments are of some help to you. Please do not hesitate to contact us if we can provide any more information for the Committee's inquiry.

Memorandum submitted by Andrew Sentance, Director of Economic Affairs, the CBI (16 July 1993)

IS SHORT-TERMISM A PROBLEM FOR BRITISH INDUSTRY?

1. "Short-termism" is a widely discussed phenomenon but, like the proverbial elephant, it appears much easier for companies to recognise it when they see it than to define it precisely and accurately.

2. The phrase is normally used to describe pressure from investors on company managers to produce a return on their investment within an "unrealistically" short time period. This, it is argued, causes managers to defer investments which would only pay in the longer term, e.g., innovation expenditures. Many commentators cite share price volatility, rapid turnover of stocks and shares or the quarterly, and in some cases monthly, performance targets set for market agents as evidence of a short-termism problem. However, short-term activities *within* financial markets can only have a significant effect upon the wider economy if industrial managers translate them into actions which harm the long-term prospects of their firm. It is in this sense that "short-termism", if it exists on any scale, is a damaging and dangerous phenomenon.

3. The essence of the "short-termism" hypothesis, therefore, is that British companies' relatively poor performance in capital investment, innovation and training is attributable in large part to pressure from investors in the financial markets who are seeking short-term returns.

Evidence of short-termism

4. The first piece of evidence that is cited in support of this view is a record of under-investment by British industry. As Table 1 shows, fixed capital investment as a share of GDP has been lower than our major competitor countries except the United States, though the gap has narrowed in recent years.

TABLE 1

Gross fixed capital formation (excluding residential construction) as per cent of GDP

	UK	Germany	Japan	US	OECD
1960-67	14.3	17.9	26.1	13.4	15.9
1968-73	15.2	17.2	27.5	13.8	16.7
1974-79	15.2	14.8	24.4	14.0	16.5
1980-90	14.0	14.7	23.7	13.2	15.8

Source: OECD Historical Statistics.

5. There also appears to have been under-investment in innovation, though this is harder to measure. The Frascati definition of scientific and technological innovation, now used by the OECD, identifies seven stages in the innovation process: research and development (R&D), new project marketing, patent work, financial, design engineering, industrial engineering (tooling) and manufacturing start-up. Of these, only expenditure on R&D is well quantified on an international scale.

6. As table 2 shows, the UK's performance on R&D expenditure shows the UK business sector investing around 1.5 per cent of GDP. This puts the UK in the middle of the league of the major seven industrialised economies but below, the US, Germany and Japan.

TABLE 2

Business enterprise R&D as percentage of GDP

	1981-85	1986-90
United States	1.9	2.0
Germany	1.8	2.1
Japan	1.6	2.0
United Kingdom	1.4	1.5
France	1.2	1.4
Canada	0.7	0.8
Italy	0.5	0.7

Source: OECD

7. The second piece of evidence that might be cited in support of the "short-termism" hypothesis is the perception among a significant minority of UK companies that financial institutions do not take a sufficiently long-term view of their prospects. As part of the CBI's City/Industry Task Force in 1987, a survey was conducted of UK listed companies, predominantly in manufacturing industry.[7] Thirty-five per cent of respondents replied "no" to the question:

"Are you satisfied that financial institutions take a long-term and strategic evaluation of your company?"

The missing link

8. Establishing a connection between these two findings is crucial to the short-termism hypothesis. However, it is very hard to show that short-term financial market influences are seriously inhibiting long-term investment in the UK. Moreover, there is a range of other plausible explanations for the under-investment recorded in Tables 1 and 2.

9. First, there is considerable variation in the innovation and investment performance of the major economies which cannot be simply accounted for by the attitudes of investors and the structure of financial markets. The share of national income devoted to capital investment in the UK in the 1980s was only slightly lower than West Germany and both the UK and Germany invest a lower share of GDP than the OECD average. Yet Germany is frequently cited as an example where companies can take a longer-term view because of the different nature of its financial system.

10. Similarly, the distribution of research and development spending shown in Table 2 does not appear to reflect different financial market structures. The US—which has similar financial market arrangements to the UK—invests roughly the same proportion of GDP as Germany and Japan.

11. Second, the direct linkage between stock market pressures and long term investment suggested by the short-termism hypothesis is not supported by survey evidence. Table 3 shows the responses from the CBI City/Industry Task Force survey to the question:

"Please indicate the significance of certain constraints in preventing you from taking strategic investment decisions in the long-term interest of your company, such as higher spending on fixed investment, research and development, training or marketing".

12. The three channels through which stock markets might encourage companies to take a short term view (weakness in share price, fear of takeover and pressure from financial institutions/analysis) are ranked among the least significant constraints on long-term investment by the respondents.

TABLE 3

Constraints on long-term investment
Per cent respondents mentioning

	Of major significance	Significant	Not significant
Cost of capital and/or fears of an inadequate rate of return	24	53	23
A lack of confidence in market prospects	9	39	52
Weakness in your share price or rating	7	34	59
Pressure from financial institutions/analysts	4	19	77
Shortage of capital	5	10	85
Fear of takeover	0	12	88

Source: Investing for Britain's Future, CBI City/Industry Task Force Report, 1987

13. The most important of these financial market constraints was share price weakness which was cited by a substantial minority (41 per cent) of the respondents as a significant constraint. This is not a cause for

concern if share prices are correctly valued as share price movements should then contain useful signals for management about future prospects. Share price movements will only be a channel for short-termism if the stock market is conveying an inaccurate view of the company's prospects, based on the information available.

14. In fact, there is a large body of research which indicates that the stock market operates efficiently in this respect. There is little, if any, evidence to suggest that share prices fail to reflect publicly available relevant information, which would be the case if firms with good long-term prospects were persistently undervalued. Indeed, if there is any controversy about the valuation of equities arising out of empirical academic studies on financial markets, it reflects a slight concern that the shares of companies with good growth prospects may have been over-valued rather than the other way round.[2] Indeed, various US studies have indicated that share prices typically react favourably to announcements of decisions on capital expenditure, and research and development.

Alternative explanations

15. None of this should be taken to imply that UK companies always take a sufficiently long-term view. The evidence from the investment record is that they quite possibly do not and the UK would probably be towards the top of the market league table if they did. Table 3 indicates the pressure that companies feel under to meet the cost of capital or make a required rate of return. Some, possibly many, worthwhile investments may not satisfy the high "hurdle" rates for investment that some UK companies appear to set.

16. But the short-term horizons of investors are only one possible explanation for this. There are many competing hypotheses, arguably more convincing, to explain why UK companies under-invest and may feel under pressure to earn a higher rate of return than some overseas competitors.

17. Firstly, investment in the UK may have been unattractive due to poor profitability, productivity and industrial relation difficulties. There have been genuine improvements in these areas over the 1980s, but these problems were undoubtedly an important influence in the 1960s and 1970s.

18. Second, the volatility of the domestic economy inevitably causes companies to take a short-term view. Between 1972 and 1992, the UK experienced six years of declining GDP, the largest number of recession years of any of the G7 economies. The United States has experienced four years of falling GDP but West Germany saw only two, Japan one and France none.[3] Alongside the rate of return, uncertainty about demand is normally the most important constraint on manufacturing investment cited by the CBI Industrial Trends Survey.

19. Third, relatively high UK inflation has encouraged companies to take a short-term view by adding to uncertainty about future prospects and creating interest rate volatility. A study by McCauley and Zimmer, published by the Federal Reserve Bank of New York, suggested that inflation was very significant in causing the *real* cost of capital to be higher in the UK and the US than in West Germany and Japan.[4]

20. Fourth, there may be factors internal to companies which encourage management to put too much weight on short-term profits at the expense of long-term investment. Executive mobility, associated with bonuses linked to short-term profits, may have reinforced this tendency. Decision-making structures within large companies can mean that investment decisions are remote from operating divisions, leading to worthwhile investment opportunities being missed.

Conclusion

21. The argument of this memorandum is that it is difficult to find strong support for the "short-termism" hypothesis (as stated in paragraph 3 above). Though UK industry has undoubtedly under-invested in the past and managers may feel under pressure to earn high returns, there are many other possible explanations apart from short-sighted investors. It is true that we observe short-term fluctuations in share prices and rapid turnover of stocks and shares. But it is difficult to find a link which implies that companies have taken a short-term view as a direct result of these developments.

22. A major problem of perceptions nevertheless remains. The CBI City/Industry Task Force survey found that only 20 per cent of companies were satisfied that the present links with institutional shareholders wre satisfactory. This is in itself worrying as flows of information between investors and companies are crucial to the efficient allocation of available finance. It also has implications for corporate governance.

23. Though there is reason to believe that the situation has improved since the Task Force reported in 1987, bridging this "communications gap" remains an important challenge for both companies and the investors. It is essential that Government legislation on "insider dealing" should not interrupt normal communication between companies and their shareholders, which has been a concern of CBI members about the current Criminal Justice Bill. The CBI, whose membership embraces both financial institutions and industrial and commercial companies, also seeks to play a direct role in improving communications by acting as as forum for discussion of issues of common concern to the "City" and "industry".

REFERENCES

[1] *"Investing for Britain's Future"*, report of the CBI City/Industry Task Force, 1987.
[2] See, for example, Simon Keane, *"Stock exchange efficiency: theory, evidence, implications"*, 1985.
[3] For further details see *"Rebalancing the British economy"* by Andrew Sentance, Business Economist, Winter 1992.
[4] R McCauley and S Zimmer, *"Explaining international differences in the cost of capital"*, Federal Reserve Bank of New York Quarterly Review, Summer 1989.

Memorandum submitted by CBI (28 July 1993)

The CBI welcomes the opportunity to submit views to the Select Committee's inquiry, and the comments which follow are founded on the experience of:

— Drawing up, during 1992, an updated Policy Statement on Technology and Innovation (which also formed the CBI's contribution to the consultation process in preparation for the Government's White Paper on Science, Engineering and Technology).
— Undertaking, during 1992, a major investigation jointly with the DTI's Innovation Unit, to investigate the innovation practices of UK-based companies.
— Four annual CBI/NatWest Innovation Trends Surveys (1989-92).
— A major workshop, in July 1993, to initiate business involvement in the process of implementing the proposals in the White Paper on Science, Engineering and Technology published at the end of May 1993.

A summary of the main findings of the innovation project was included in the CBI's evidence to the Trade and Industry Committee's inquiry into the Competitiveness of UK Manufacturing Industry, and we note that this will have been passed to the Science and Technology Committee. Particular points from this study will be developed in this submission where they are apposite to the questions raised by the Committee. We also note that Dr Andrew Sentance, the CBI's Economic Director, has provided, in a personal capacity, a paper in respect of issues relating to "short-termism".[1]

In formulating this primary response on behalf of the CBI, the Committee's questions have been grouped for convenience according to the pattern in Appendix 1 and the following text is referenced accordingly.

Overall the CBI believes that industry cannot effectively exploit technological developments from wherever they might be sourced (either from within the UK or internationally) unless companies have an attitude and management structure which promotes an innovative and progressive culture (6, 7). This was a very clear message coming through from the CBI/DTI study which showed that only one in 10 of the companies surveyed could be said to be truly innovative when compared with the best international competitors. However three in 10 demonstrated a number of important facets of the innovation process, while five in 10 showed elements of good performance. This offers encouragement to the companies involved that they can improve by putting more effort into the areas where they are weak. Innovation is all about management creating the right environment to nurture and recognise it, and this theme is developed later in this memorandum.

MEASURING INTERNATIONAL COMPETITIVENESS

An often-quoted benchmark of competitiveness is the World Competitiveness Scoreboard drawn up by IMD Lausanne and the World Economic Forum where the 1993 ranking puts the UK at number 16 overall when compared with 22 OECD countries. A summary of some individual key factors is given in Appendix 2, including aspects of specific interest to the Select Committee's inquiry.

The difficulty of obtaining a more detailed and quantitative breakdown of innovation performance is well known, and the CBI's Innovation Trends Survey (supported by the Technology Unit of the National Westminster Bank) has been designed to provide at least a series of more qualitative indicators. The current Survey covers 16 individual measures contributing to the innovation process, although it does not ask respondents to provide absolute figures, rather enquiring whether they have increased, or intend to increase expenditure on particular aspects, or maintain or reduce effort. It does however ask companies to provide an indication of the percentage of their turnover which may be attributed to the total of these individual measures. It also asks them to identify profits from innovation investment, market share gains, and the opening-up of new markets, during the last three years. It looks additionally at trends in product and process development times and life cycles, and it attempts to rank the importance of quality, cost, delivery and after-sales service, to companies' competitive performance.

The survey covers both manufacturing and non-manufacturing, and within these it provides a breakdown in terms of company size, region of operation, and, currently, 23 sectors, thus providing a broad in-UK benchmarking capability. Some selected indicators pertinent to the Committee's interests are provided in Appendix 3.

[1] See page 58.

This data demonstrates very clearly the high level of attention accorded to customer expectations, and also the dominant importance of quality and price over other factors, with quality being particularly critical in manufacturing.

What the survey does not do is to attempt to benchmark international competitiveness, but the CBI is collaborating with the European Commission in developing a Europe-wide comparative survey of innovation indicators which should provide a pointer in this direction. It is anticipated that this will eventually lead to one survey which, as well as satisfying the Commission's requirements, will also accommodate CBI's wish to look forward as well as retrospectively, and, importantly, will be "industry-friendly" while attempting to draw out more quantative indicators.

While the CBI's experience shows the considerable difficulty in devising a comprehensive "Innovation Scoreboard" which would rank companies individually in a way rather analagous to the DTI's "R&D Scoreboard", we are sharing this experience with the DTI's Innovation Unit which is embarking on research to identify what further options in this direction might be possible.

STRATEGIES TO ENABLE INDUSTRY TO INNOVATE MORE EFFECTIVELY (6, 7)

(a) *In-Company* (6)

The CBI/DTI study identified a large number of ingredients perceived to relate to successful innovation practice, and these are summarised in Appendix 4. It should be stressed that we do not advocate that every company has to apply every one of these in equal measure, but rather develop their own mix according to the type of business in which they are involved. But any innovation strategy, we believe, should contain the following key elements:

— Definition of a clear policy about where to invest with decisions being taken on the basis of sustainable strengths.
— A resource allocation for innovation, based on a sound analysis of the balance of risks, returns and timing, to drive a portfolio of products/services that will lead to sustained commercial success.
— Creation of competence in the ability and experience to manage the innovation process, and particularly technology, to achieve the desired results.
— Implementation of policies of total quality management and continuous improvement.

Implementation of such a strategy can best be achieved by learning from peers, and the CBI would encourage companies to take advantage of the many best practice programmes which are now available —the CBI and the DTI, for example, have significant awareness programmes to set companies on the route.

(b) *Infrastructure* (7)

Strategic Planning

The CBI's Policy Statement on Technology and Innovation identified a need for much more focused strategic thinking at a national level on how the UK's technology resources can be harnessed to better effect. The role of Government is critical in this respect, both as overall champion of the cause, and also through the practical provision of a supportive infrastructure in which innovation, and therefore wealth creation, can flourish. The White Paper on Science, Engineering and Technology is a welcome and very important opportunity to cementing the partnership between industry and Government to ensure that the optimum conditions are generated. The new Council for Science and Technology, for example, has the potential to provide the strategic direction for the setting of national priorities; and the technology foresight process, if it works properly, should produce a better match between publicly-funded strategic research and the needs of industry and other users of research outputs. The success of this process, and the effectiveness of the Forward Look (the other key plank of the White Paper policy proposals) will depend on industry providing the essential market input, and the CBI will be working closely with the OST, DTI and other relevant bodies to ensure that this happens.

Exploitation of the Science and Engineering Research Base (1, 2)

Relations between industry and the science and engineering research base are fundamental to the partnership process and are one of the key ingredients for innovation success identified in the CBI/DTI innovation best practice project. The question, rightly posed by the Select Committee, is how companies, assuming their internal exploitation processes are improved, can take full advantage of this key source of underpinning knowledge and manpower? In the light of the CBI's internal consultations leading up to the White Paper, and the outcome of our White Paper workshop, we can point to a number of areas:

— Industry must be a leading player in the technology foresight programme (see above) which will also guide the apportionment of Government funds to the science and engineering base—we note that this is not a quick fix and results will not start coming through for a number of years.
— Industry must identify and capitalise upon best practice; in particular best practice guidelines for the interaction of small-and medium-sized enterprises (SMEs) with higher education institutions (HEIs) would be helpful, as would a similar code for industrial liaison officers in HEIs to guide their general interactions with industry. The CBI is already collaborating with the DTI and the HEI industrial liaison officers to explore this latter possibility.

- The general expertise which exists in HEIs is still not being fully accessed by companies of all sizes who should be far more proactive in seeking out opportunities, not least at a local level.
- Industry needs to look closely at the people it appoints as its representatives on the Research Councils—they must behave like industrialists and not as quasi-academics (but see below).

Government, on its part, should assist this process by:

- Making Research Council procedures more industry-friendly and less bureaucratic.
- Encouraging the HEIs to introduce regulations which would stimulate them to look for ways to interact with smaller companies—one way to do this, for example, would be to make it a condition that when a staff member wishes to allocate so many hours a year to consultancy, a certain percentage of this would have to be with small companies. Another way would be to say that additional time to the existing allocation would be allowed by the university for consultation with SMEs.
- Encouraging the HEIs to reward interaction with industry in their promotion procedures.

The People Issue (3)

It is often-repeated, but a truism for all that, that the effective exploitation of technology is dependent on people, and industry looks to the Government-funded education system to provide the fundamentals upon which a well-trained workforce can be developed which is capable of taking advantage of the opportunities offered. There is still a strong cultural antipathy to science and technology in the UK which runs right through society. The basic education system is where attitudes are formed, and despite the introduction of the national curriculum and a stronger technology element, there are still deficiencies to be remedied, not least fragmentation of good practice, and over complexity of, and difficulty in interfacing with, the many strands of activity.

Harnessing the enthusiasm of the teaching profession is a key way of promoting the value of science, engineering and technology, and the CBI is encouraging industry to provide suitable teaching material to support the development of the curriculum. Also, the Understanding British Industry (UBI) network, which operates under the auspices of the CBI, is very active in providing relevant teacher placements.

At a junior level the CBI supports the teaching of problem definition, brainstorming and problem solving skills aimed at learning how to handle ambiguity, a training that could subsequently be built upon.

At a more senior level, we believe that, as well as having a broader based A-level training for technologists, there could well be considerable merit in spreading modern apprenticeship best practice, and strengthening the sandwich course route to training. At postgraduate level CBI members have been very supportive of such mechanisms as CASE (Co-operative Awards in Science and Engineering), IGDS (Integrated Graduate Development Scheme) and the Teaching Company Scheme. There is also considerable interest in the new Parnaby Doctorate programme.

We acknowledge that there is still scope for industry to provide more training and placement opportunities, and it has been suggested that a high-profile directory of such opportunities would be helpful—the CBI will be considering whether such a network can be built up under its auspices.

Education and training must be considered in tandem to prepare for a lifetime of continuous learning and ensuring that application skills to solve real problems and to innovate are acquired simultaneously. The Select Committee may wish to refer to the CBI's Education and Training Directorate if they wish to explore these wider issues in more depth.

The Wider Technology Transfer Issues (7)

Technology transfer might better be termed technology marketing—the need has first to be identified and this is not always easy, particularly for SMEs. Government, through the DTI, can assist through setting up advice networks; and technology consultancy allied to the new one-stop shops could be a valuable route forward. Larger companies are often more than willing to transfer knowledge to other companies and sectors (and not least SMEs) provided there is something in this for them, for example Government support to underwrite such activities so that the company's investment in its own core activities is not jeopardised.

We would also point to the role of the independent research and technology organisations (IRTOs) as important bridging institutions in translating the results of R&D, both that commissioned by industry and that coming out of the science and engineering base (national and international) into industrial practice. In fact, in some traditional sectors where the industrial R&D effort is small, the IRTOs are the major R&D performers. There is a role for Government in providing them with support for developing those enabling technologies which span sectors and are beyond the province of a particular company. IRTOs are also successful "club" organisers to bring together companies to exchange knowledge and generate precompetitive technologies.

A further mechanism, worthy or wider replication, is that devised by one of the "privatised" Directorates of the Science and Engineering Research Council which is developing the industry/academic interface beyond simple pre-competitive research with a proposal for "nursery" units to take ideas much nearer the market.

While the CBI has generally welcomed the recent refocusing of the DTI's support more towards the needs of SMEs, the withdrawal of support for larger company/company collaboration via the advanced technology projects has been criticised by some companies, as being detrimental to the maintenance of that informed knowledge base which encourages the better targeting of a company's own efforts. It could also discourage the speculative approaches which companies might be prepared to risk if they have additional pump-priming backing. Such backing is rarely available from other funding sources, both inside and outside the company, particularly in the financial climate in which the UK operates.

In this latter respect the CBI has also identified a clear need to bridge the development gap which new companies experience between start-up and the stage where conventional investment channels will take the risk on board. The CBI awaits with considerable interest the outcome of the current ACOST Working Parties looking into the financial climate for promoting technological development.

This leads us to comment specifically on company relations with the investment community, although for a more detailed treatment of short-termism *per se*, the Committee is referred to Dr Andrew Sentance's paper.

Relations with the Investment Community (5, 7)

The CBI/DTI study acknowledged that investors can be crucial in providing support for the innovation process. The best practice companies tended not to complain about short-termism but rather fully acknowledged their responsibility to encourage confidence and a long-term approach, and the leading companies conducted a regular dialogue with their investors. (The DTI Innovation Advisory Board's Innovation Plans Handbook, with which the CBI is associated, provides good practice guidelines for achieving a closer relationship, and a number of the best practice companies had used this to their advantage.)

It should be stressed, however, that while the pattern of ownership, and indeed there were both publicly-quoted and private companies amongst the top examples, the company management itself has to be fully committed to the innovation process to be an effective salesman to investors.

Reinforced by this experience, the CBI feels that the investment community on its part should recognise that it is in their interest to:

— Encourage companies to explain their technology and investment strategy.
— Identify and publicise their examples of communication best practice between investors and companies.
— Accept that the returns from innovation will have a variable payback and risk/reward, and should be judged accordingly.

THE WAY FORWARD

The threads of interaction among the issues being examined by the Select Committee are numerous and complicated. Real understanding of the practical realities of the exploitation of science and technology comes from seeing it on the ground. We appreciate that the Select Committee has been talking to a number of companies direct, but we would be pleased to arrange contacts with others who are good at the exploitation process. The dissemination of such best practice, coupled with a supportive framework which will encourage that practice, can, the CBI believes, only strengthen the wealth creation process in the UK.

The CBI will be concentrating its forward technology-related activities, therefore, on working to achieve the successful implementation of the White Paper's proposals in support of wealth creation (as indicated previously) and in promoting the experience of best practice.

July 1993

APPENDIX 1

ALLOCATION OF QUESTIONS POSED BY THE SELECT COMMITTEE

1. *What is the relationship between the Science Base and industrial innovation?*
Linked with:

— The effectiveness of the current mechanisms for encouraging interaction between the Science Base and industry.

2. *Are the mechanisms for technology transfer and interaction between the Science Base and industry effective? How could they be improved?*
Linked with:

— The effectiveness of the current mechanisms for encouraging interaction between the Science Base and industry.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

Linked with:

— The extent to which the standards of education and training in the UK may hinder innovation, and measures that might improve this.

4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

Linked with:

— Product design and innovation.
— Quality of process technology.
— Quality and reliability of output.
— Price and cost competitiveness.
— Relationships with suppliers and customer satisfaction.

5. *Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

Linked with:

— The extent to which UK industry is hindered by the financial system in comparison with foreign competitors.

6. *Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?*

Linked with:

— Strategies which might enable industry to innovate more effectively.

7. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder this process?*

Linked with:

— Strategies which might enable industry to innovate more effectively.

APPENDIX 2

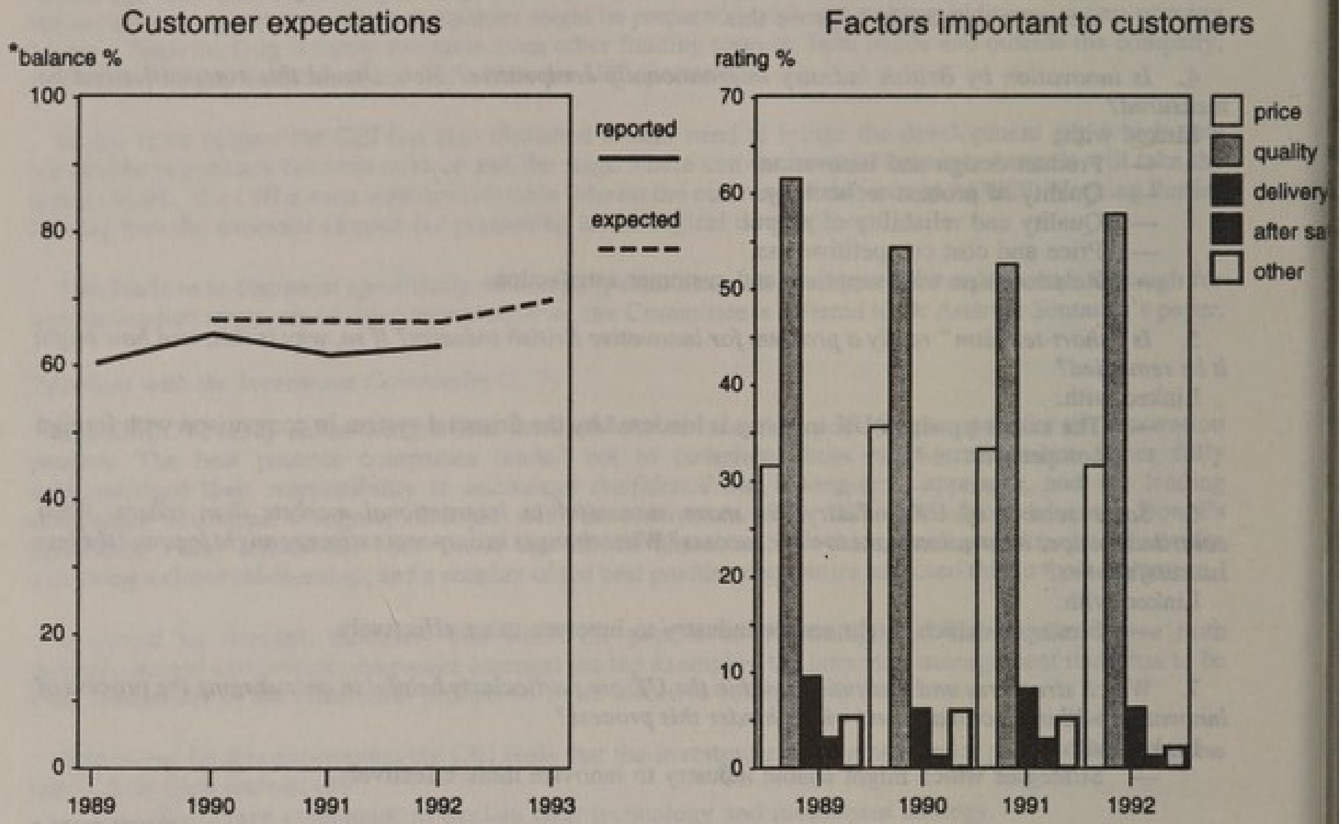
WORLD COMPETITIVENESS SCOREBOARD—UK COMPETITIVENESS BALANCE SHEET

Rank	Factor
10	*Internationalisation*—Country's participation in international trends investment flows.
8	*Finance*—Performance of capital markets and quality of financial services.
13	*Science and Technology*—Scientific and technological capability, success of basic and applied research.
16	*Management*—Extent to which enterprises are managed in an innovative, profitable and responsible manner.
13	*Infrastructure*—Adequacy of resources and systems to serve the basic needs of business.
18	*People, Education and Skills*—Availability and qualifications of human resources.

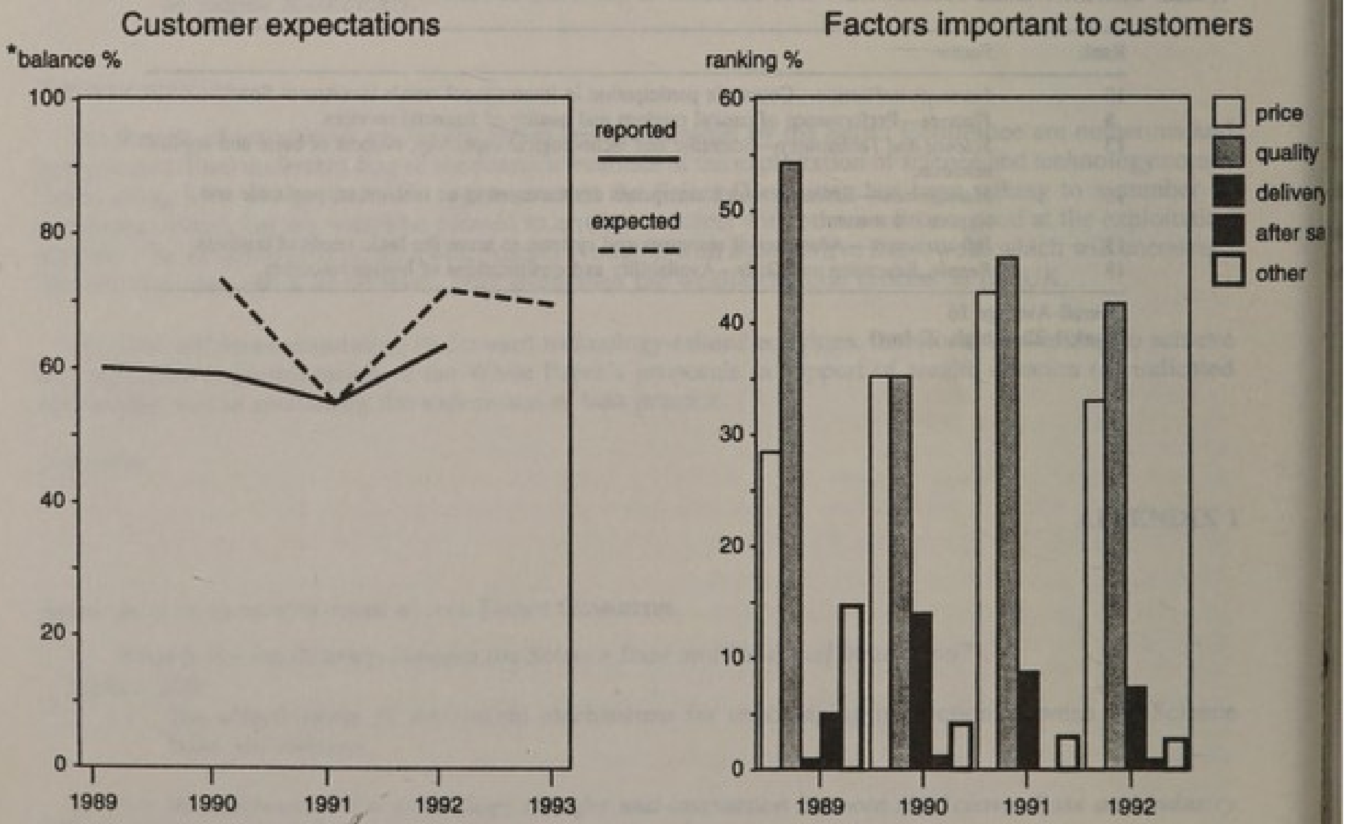
Overall Average 16
(Rank 1-22, 1-high, 22-low)

APPENDIX 3

Manufacturing: incentives to innovation



Non-manufacturing: incentives to innovation



* % balance is defined as the difference between companies reporting an increase and those reporting a decrease in the trend

APPENDIX 4

KEY INGREDIENTS FOR SUCCESS

Company Culture
- Strong commitment to innovation
- Vision
- Leadership
- Market driven
- Customer focus
- Global perspective
- Openness
- Flat hierarchies

Internal Processes
- Multi-functional teaming
- Communication levels and frequency
- Project champions
- Organisational adaptability and flexibility
- Continuous improvement
- Total quality management
- Performance measurement
- Training
- Technology

External Influences
- Other industry-joint collaborative partnerships
  - —customers
  - —suppliers
  - —spin-out
- Academia
  - —research
  - —training
  - —consultancy
- Investors
  - —shareholders (individual and institutional)
  - —analysts
- Government
  - —regulations
  - —standards
  - —support schemes
- Community
  - —environment
  - —involvement

Memorandum submitted by the Construction Industry Council (16 June 1993)

1.0 INTRODUCTION

1.1 The Construction Industry Council (CIC) welcomes the opportunity to participate in the Science and Technology Committee inquiry into innovative and competitive technology. We are particularly encouraged by the breadth and depth of the assessment being undertaken. However, we are concerned to note that companies within the construction industry were not selected to receive a questionnaire concerning this inquiry.

1.2 The CIC represents, amongst others, some 320,000 construction professionals. CIC was established to help support a single voice for the construction industry. Its Research and Development Committee is a principal Standing Committee of the Council and one of CIC's major activity centres. Annex A sets out the membership of CIC and the Corporate Plan of CIC is also attached.

1.3 One of the aims of the CIC is to improve the science and technology base of the UK construction industry and it has already undertaken several relevant studies. These include a study of building research and postgraduate education and an assessment of the potential for interdisciplinary education for all construction professionals, both of which are enclosed. The Council is currently preparing guidance for construction professionals on the successful procurement, monitoring and implementation of innovation, research, development and design (RD&D) and will publish this information in the near future.

2.0 The characteristics of the construction industry

2.1 Construction is the largest single industrial sector in the UK economy. In the twelve months up to the end of the second quarter 1992, construction output amounted to £41.7 billion, approximately 10 per cent of the UK GDP. Overseas turnover by UK construction firms in this period amounted to more than £20 billion. The supply of energy, water and sewerage services to the building stock costs a further £20 billion. Construction innovation and research, therefore, has the potential to improve the performance of 15 per cent of the GDP.

2.2 The industry is, however, highly fragmented. In 1992, some 1.8 million people were employed in a wide range of professions, trades and functions in more than 200,000 firms. More than half are sole traders while a further 70,000 employ either two or three people. This means not only that few firms have any resources to undertake or commission RD&D but also that there is a significant problem of technology transfer and innovation.

2.3 The contractual structure of the industry which generally separates design, management, assembly, maintenance and operation, inhibits research investment since, with the exception of material producers, firms are restricted in their ability to gain commercial advantage from research. This position is exacerbated by the progressive use of Compulsory Competitive Tendering, where price is invariably the principal consideration and benefits deriving from a firms expertise in construction are ruled out of consideration. Most benefits from construction research accrue to users, not suppliers.

3.0 CIC RESPONSE

Innovation and Competitive Technology

3.1 Innovation, research and development in the construction industry may occur through many routes, notwithstanding the problems identified above, including:

A. Innovations in basic science, e.g., in so-called "intelligent materials", but this is not always in a form which industrial practitioners can immediately utilise.

B. Innovations and developments in other industries which can be usefully transferred to construction (and vice versa—particularly in view of the construction industry's experience with the project environment) e.g., Information Technology, remote sensing and personal communications.

C. Funded RD&D programmes in manufacturing, consulting or contracting organisations—via RD&D groups, research centres, etc.

D. Funded RD&D programmes in or on behalf of research organisations—HEI (Higher Education Institution[s]), Building Research Establishment (BRE), research centres, etc.

E. RD&D programmes in HEI, supported by the funding councils and the research councils.

F. Research studies for postgraduate qualifications in building subjects and cognitive disciplines, from taught diplomas and MSc through MPhil, PhD and higher doctorates.

G. Project-based or practice-based RD&D which is advanced work carried out by leading organisations as part of their contract responsibilities.

3.2 These routes are vital in addressing the complex and dynamic issues affecting construction such as improvements in productivity, Total Quality Management, Facilities Management and Information Technology.

Mechanisms for technology transfer and interaction between the science base, industry and competent personnel

3.3 An important condition of improved building research and innovation—and better application of results—rests with the qualified people working in the industry. There is an urgent need for more to be familiar with research approaches and techniques to understand the potential contribution of research and innovation and to develop a large cohort of people from the industry able to undertake research. This may be in collaboration with others from outside the industry.

3.4 The Higher Education Funding Councils (HEFC) have so far failed to create the opportunity to develop academic strengths that are currently weak and poorly served in important and substantial industries, and particularly in construction. While in general CIC agrees with building on success, construction is an example of a generally weak academic sector that needs strengthening.

3.5 The industry increasingly needs people who combine a proper theoretical training with practical experience. Familiarisation with innovation and technological developments through the industry will not only relate to the creation of more HEI courses, meeting the needs of industry, but also to Continuing Professional Development (CPD) and other form of continuing education such as post-graduate study.

3.6 CIC welcomes the proposal to introduce technology foresight programmes and for government's use of funds and its efforts in science and technology to be set out in the annual "Forward Look".

3.7 CIC's Research and Development Committee advocates a levy for research which would recognise firms' current research funding and act as an incentive to invest more. A working paper about this is available and CIC is now discussing the issues with others within the construction industry to seek a consensus view.

Short-termism

3.8 The UK construction industry, along with most other UK industries, suffers from an overwhelming need to respond to short-term financial criteria such as profitability—driven to the point where publicly quoted companies may find it dangerous to commit significant resource to longer-term goals such as RD&D

or education and training beyond immediate needs. For the construction industry, where these investments (not "costs") are beginning to become critical conditions for future developments, this mentality is particularly unfortunate.

International markets

3.9 Overseas comparisons are not invariably helpful, but they do provide instructive views—especially in terms of attitudes, including "short-termism". For example, the largest Japanese contractors each support a major research centre. This encourages a holistic approach to design and production, to research and applications while also demonstrating their technical expertise and current awareness. By contrast, in this country, contractors' RD&D appears to rely to a greater extent upon outside contracts. A further comparison with the former Federal Republic of Germany shows that much of the research in construction has depended upon public funds, mostly concentrated in HEI, which in turn has fed more coherently into teaching. This appears to have contributed significantly to the industrial attitude towards RD&D in the country.

The role of Government and industry

3.10 Government must play an essential facilitating role to aid the industry in developing innovative and competitive technology. Government can do as a major client of the industry, as an overseeing authority for the HEI, as a contributor to the regulatory framework, as a major funder of RD&D, and as an employer of skilled people in the construction industry.

3.11 Positive government measures are necessary conditions for a general improvement in the innovative and RD&D capability of the industry as it transforms from a bespoke and craft-based activity to a technologically-based industry, with ever closer links to a science-conscious manufacturing base. This is particularly the case with SMEs and CIC welcomes the introduction of the innovation support programmes.

3.12 There is a strong case for using public sector procurement methods to encourage forward-thinking attitudes in the industry—good practice, the pursuit of quality, the avoidance of simple reliance on lowest bids, to stimulate innovation and RD&D. Such conditions may similarly be created through contribution to the deliberation of EC Directives and legislation on the industry, including explicit recognition of the importance of construction within the programmes of the Fourth Framework.

3.13 The role of the DoE, and the DTI, in providing matched funding for certain research studies is welcomed through such schemes as LINK, CASE and Teaching Company Scheme (TCS). However, although the construction industry has made the most of available opportunities, further efforts should be made to extend collaboration and research clubs, especially within organisations without an established research orientation. Construction has long needed its equivalent to ADAS, which has successfully raised the technological competence of a fragmented agricultural industry.

3.14 It is also essential that the valuable work of the Building Research Establishment, funded by Government in the national interest, should continue. Now a "Next Steps" Agency, BRE will be considered for privatisation under the proposals in the White Paper "Realising our Potential". We think this step should be approached with great caution.

3.15 The government should explore and consider its appraisal of priorities with the industry about further methods of research to be developed, especially where they might involve "near market R&D", construction representation and the links with HEI.

4.0 Summary

4.1 The construction industry is directly or indirectly concerned with 15 per cent of GDP. Because of the structure of the industry, and the fact that users are the main beneficiaries of research and innovative developments, there are strong natural barriers to industrial investment in RD&D.

4.2 However, as outlined above, there are many factors which may be addressed to improve the competitive profile of the UK and the innovative capability of large dispersed industries such as construction. We believe the appropriate policies are as follows:

(i) Technical and management skills within the construction industry to translate innovation into successful technology, disseminated effectively and capitalised upon.

(ii) Tackling short-termism, particularly with regard to financing construction, to encourage longer-term investment.

(iii) Government departments and other organisations, such as the Commission of the European Communities, to give greater support for construction RD&D.

(iv) Encouraging the HEFCs to develop academic strengths that are currently weak and poorly served in important and substantial industries such as construction.

4.3 The Construction Industry Council would be pleased to discuss these points further with the Science and Technology Committee.

CIC MEMBERSHIP AT 1 JULY 1993

CHARTERED COLLEGE

CIOB	Chartered Institute of Building
CIBSE	Chartered Institution of Building Services Engineers
ICE	Institution of Civil Engineers
IStructE	Institution of Structural Engineers
RIBA	Royal Institute of British Architects
RICS	Royal Institution of Chartered Surveyors
RTPI	Royal Town Planning Institute

NON-CHARTERED COLLEGE

ASI	Architects and Surveyors Institute
ABE	Association of Building Engineers
BIET	Board of Incorporated Engineers and Technicians (ICE)
BIAT	British Institute of Architectural Technicians
IBC	Institute of Building Control
ICWGB	Institute of Clerks of Works of Great Britain
ICM	Institute of Construction Management
ICES	Institution of Civil Engineering Surveyors
IHIE	Institute of Highway Incorporated Engineers
IMBM	Institute of Maintenance and Building Management
IoP	Institute of Plumbing
LI	Landscape Institute
SST	Society of Surveying Technicians

BUSINESS COLLEGE

ACA	Association of Consultant Architects
ACE	Association of Consulting Engineers
BFRC	British Flat Roofing Council
CQSA	Consultant Quantity Surveyors Association
GF	Ground Forum

ASSOCIATE MEMBERSHIP

AHS	Association of Heads of Surveying
BACH	British Association of Construction Heads
CITB (NI)	Construction Industry Training Board (Northern Ireland)
FoB	Faculty of Building
ICT	Institute of Concrete Technology
SCHOSA	Standing Conference of Heads of Schools of Architecture

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Memorandum submitted by the Society of British Aerospace Companies (SBAC) (16 July 1993)

INTRODUCTION

The Society, the trade association for the aerospace sector, represents the interests of 200 companies responsible for £11 billion worth of manufacturing turnover annually. Member companies cover the full spectrum of aerospace companies, including the large UK prime constructors, the diverse equipment sector, and the product support and materials sectors.

BACKGROUND ON THE STRENGTHS OF THE UK AEROSPACE SECTOR

The UK benefits from full systems capability, encompassing advanced material design and fabrication in engines and airframes, sophisticated electronics, a multifaceted equipment sector, and a broad range of product support services. Only three other countries can claim this level of aerospace capability. The industry possesses an advanced product range developed as a consequence of long-standing company commitment to technological innovation and investment, and enhanced by the cross-fertilisation of technologies between military and civil aerospace projects.

The UK's competitive success in overseas aerospace markets is based upon the utilisation of such technologies and advanced manufacturing techniques within a framework that relies upon an expansive infrastructure, a highly-skilled, trained and productive workforce, and widespread competence in project management, overseas marketing, and the operation of international collaborative programmes.

As a consequence of high performance in these areas, UK aerospace companies export some 70 per cent of their turnover and have won over 11 per cent of the total world aerospace market.

However, a viable UK aerospace industry operating at this level is dependent upon companies continuing to work at the leading edge of technological innovation to meet customer demands for improvements in mission performance and affordability in the military field and greater safety, economy of operations and environmental compatibility in the civil sector. These customer requirements can be met only by the employment of increasingly sophisticated and complex technology derived from a substantial base of research and development. Failure to innovate would inevitably result in reduced market share and, eventually loss of industrial capability.

Is innovation by UK industry internationally competitive?

A commonly accepted definition of innovation is the commercial application of knowledge or techniques in new ways for new ends in anticipation of developing customer requirements. Within this definition, the aerospace sector can be said to have been a leading innovator over the last 30 years or more. However, if one measure of innovation is the range of profitable products or processes fielded by industry, then it must be recognised that as a result of restructuring within the aerospace sector and reduced military spending on forward projects, the UK industry is progressively manufacturing a reduced range and depth of products.

Two reliable indicators of innovation might be said to be the number of profitable "Market Leader" enterprises in an industry and, in the longer term, the total (public and private) investment in R&D, expressed as a percentage of turnover. On both counts, UK industry is beginning to fall behind foreign competitors.

While in industry in general there is no lack of invention, the ability to translate inventive ideas into product innovation is increasingly difficult due to the combination of Government policy, which has concentrated funding into the research rather than the application phase, and the lack of affordable private finance which has inhibited companies' own efforts in this area.

The extent to which UK industry is hindered by the financial system in comparison with foreign competitors

The UK aerospace industry is hindered in two ways by the financial philosophies operating within both Government and Financial Institutions.

At Governmental level

HMG has progressively reduced public funding, particularly of the technology demonstration and development phases of the innovation process, in the belief that industry should self-fund these activities. The recent White Paper on Science, Engineering and Technology would appear to suggest that a broader recognition of all stages of the innovation process may be forthcoming, but the fact remains that the Government's total R&D spend will remain considerably smaller as a percentage of GDP than some important competitor countries. It is also a matter of great concern that unlike virtually all other European countries, HMG does not make separate provision for funding collaborative programmes. In the UK, this funding is provided at the expense of national programmes.

In the past, Government has frequently failed to consult industry on the reshaping of the scale and scope of some collaborative programmes. Consequently, the prospects of such programmes fully complementing national programmes have been reduced. While the White Paper does promote improvements in the area of consultation with industry, the recent decision to redirect some funding away from large enterprises towards smaller companies appears to have been taken without broad consultation and without industry having the opportunity to talk through the consequences of the action for particular sectors.

The most successful industrial countries tend to have national technology strategies in one form or another. These range from publicly-funded industrial/technology polices to looser "Technology Support" strategies.

Aerospace Industrialists firmly believe that UK industry needs such a strategic framework within which it can plan and fund its innovation and against which Government spending priorities in this area can be judged. To this end, industrialists have proposed to DTI Ministers that a National Strategic Technology Acquisition Plan (NSTAP) be developed to establish a framework in which investment for future innovation can be managed. The aerospace sector does not have any great difficulty in identifying the types of technology and processes that will take the UK industry forward as a leading marketeer of advanced products. What is now needed is a joint commitment with HMG to create the framework in which this process can be achieved.

In Financial Institutions

The decline in government support for innovative activities has placed a greater burden on companies to make up the shortfall in investment. Furthermore, the very nature of innovation in aerospace—involving the identification of markets, followed by investment in research, technology demonstration, development, and production capability over extended timescales—implies funding of an order of magnitude above that which applies to many manufacturing industries. For high technology industries with long product gestation periods access to sources of affordable venture capital, in the absence of public funding, is essential.

Yet, in the UK, there has been a lack of affordable long-term venture capital. The prevailing business culture has been one in which investors have looked for short-term, high interest returns on capital.

Moreover, profit levels have generally been lower in the global aerospace sector than in other manufacturing industries, and profitability in the UK has not been helped in recent years by the need for companies to carry heavy restructuring costs while continuing to meet the financial market's dividend expectations.

In contrast, competitor countries have benefited from a longer-term investment culture, possible arising from a pattern of more stable currencies, a history of low inflation, and, most importantly, a national acceptance of the importance of the manufacturing base.

Mechanisms for encouraging effective interaction between the science base and industry

Aerospace industrialists welcome the moves outlined in the White Paper to develop more effective mechanisms to promote interaction between the science base and manufacturing industry. They believe that these moves would be enhanced by the development of a National Strategic Technology Acquisition Plan for the sector, jointly formulated by government, research agencies and industry.

As part and parcel of such a Plan, renewed efforts should be made at all levels to ensure that the whole process of innovation, from research through demonstration and development to production, is adequately recognised in national funding priorities.

In the recent past, the range of consultative bodies advising funding Ministries has led to confusion, duplication, or the absence of a core direction. The advice Ministers have received has frequently emphasised academic interest in pure science at the expense of innovation. The recent bringing together of previously diverse sources of advice is a positive sign, but clear channels for industrial input must be established.

In particular links between industry and academia are important and need to be strengthened further. It is therefore of some concern that while the "Faraday Principles" have been accepted no formal programme to action the principles has been planned.

Much firmer direction must be given to government department in the role they should play in supporting UK industry. At an early point, Government must resolve the dichotomy whereby the Ministry of Defence with relatively large research and development funds, repudiates any responsibility for UK industrial innovation, whereas the reverse applies in the case of the Department of Trade and Industry, which seeks to promote aerospace innovation with almost insignificant resources.

In essence, the existing structures will be unable to deliver sustained innovation unless priority is given to targeting strategic areas that will enable companies to bring a wide range of new products to the marketplace in a timely and cost-effective manner Government must set the trend, because profit and production levels within the aerospace industry are insufficient to meet the current expectations of the financial institutions when sustained investments of a high order of magnitude are required. Partnership between Government and industry would establish a climate in which the longer-term aspirations of the UK aerospace companies would be more readily acknowledged, and add further momentum to the innovative efforts of UK manufacturing industry.

The importance of education and training within the innovation process

Successful aerospace innovation arises when skilled individuals, working across disciplines, combine to analyse future market needs and develop leading edge products at affordable cost to both the manufacturing company and the end customer. It is the application of scientific, engineering, management and marketing skills throughout the process that ensure projects succeed.

Much has been written about the need to improve education and training standards in the UK to ensure that there is a flow of qualified individuals into our innovative industries. Within the aerospace sector, technology advances and changing job structures are creating a workforce in which a larger and larger proportion of occupations require professional or technical qualifications. The international profile of the industry also leads companies to require recognised qualifications and skills who can effectively contribute to multinational projects. It is vital that adequate investment is made in the UK educational system if the pool of suitably qualified individuals is to be expanded and companies' future requirements met. In particular, progress must continue to be made in developing a credible technology syllabus with the national curriculum.

At Higher Education level efforts must be made to ensure that disciplines relating to processes, manufacturing, standardisation, quality, and multi-skilled team-working receive greater intellectual attention.

The need for a more qualified workforce also implies greater efforts to provide training within industry. UK government funding channelled through Training and Enterprise Councils is primarily directed at those not in full-time employment. This contrasts within the long-standing national policies in many other European countries. A strong case can be made for increased government support for developing the skills of those in employment.

Conclusions

UK aerospace companies operate in a global market which is witnessing, and will continue to witness, intense international competition. Our indigenous market is insufficient to provide the economies of scale or the marketing opportunities that would allow a broad-based and innovative product range to develop.

Therefore, overseas sales are vital. If the UK aerospace industry is to continue to excel and maintain its excellent share of world markets, added momentum must be given to the innovative process. This implies a greater focus on all aspects of technology development and in particular upon the urgent need for a national aerospace funding strategy to be agreed as a framework in which the industrial/academic/government partnership can operate.

The UK's economic and social aspirations can only be funded at the current level if our world-class manufacturing businesses are able to bring the right products to the international market in a timely and cost-effective fashion. By placing the full weight of industry, government and the science community behind the innovation process, we will take an important step towards improving the nation's capacity for wealth generation.

Memorandum submitted by the Chemical Industries Association (20 July 1993)

The Chemical Industries Association is the major trade body representing the UK chemical industry, with a membership which is drawn from all sectors of the industry including some of the UK's most successful and innovative companies.

The chemical industry is the UK manufacturing sector's number one export earner with a net export surplus of over £3 billion in 1992. The success of the industry has been, and remains, strongly dependent upon scientific and technological innovation through effective research and developments, to remain competitive and satisfy the needs of its customers. Because of this the chemical industry invests more of its own money in research and development than any other manufacturing sector, approximately £2 billion, over 6 per cent of total sales revenue in 1992.

Apart from its own industrial activities, the chemical industry is heavily involved in a wide range of collaborative projects with public sector research institutions, successfully translating academic research into commercial products and processes.

We are therefore grateful for the opportunity of submitting evidence to this enquiry, and we hope that the demonstrable success of the chemical industry in translating research into innovative and competitive products and processes will lend particular weight to the comments which we make here.

The Committee has posed a number of questions which cover a very wide range of topics. We have not addressed all of these but have instead concentrated on those areas in which we have particular interest. We should also refer here to other relevant enquiries and reports on the general topics of the science base and innovation, including, of course, the recent White Paper on Science, Engineering and Technology, but also the 1991 House of Lords report on "Innovation in Manufacturing Industry", The Royal Society's "Enquiry into the Science Base", and the DTI report from the Secretary of State on "Innovation: Competition and Culture". These, and other similar enquiries, have led this Association to comment at length on this important subject, most recently through the House of Lords enquiry on "Priorities for the Science Base". We hope that the resulting large body of information which has subsequently become available to government will be examined in the context of this enquiry.

1. WHAT IS THE RELATIONSHIP BETWEEN THE SCIENCE BASE AND INDUSTRIAL INNOVATION?

In its evidence to the recent House of Lords enquiry into "Priorities for the Science Base" this Association addressed the central question; "What is public expenditure on the science base for?". Our answer, coupled with our definition of what the science base is and how it relates to the innovation process (*see Chart I*), is relevant here.

Although science and technology have an intrinsic cultural value, they are the driving forces for innovation and wealth creation. As the economies of developed countries become more dependent upon technology-based industry, the UK must regard its traditional strength in research as a source of competitive advantage for its manufacturing sector. A strong science base will become an increasingly important factor in attracting inward investment by international companies operating in a wide range of manufacturing activities.

The science base is vital in providing a source of leading-edge research expertise, particularly in areas of science and technology which underpin industrial activity; it is essential for the provision of well trained graduates and postgraduates for industry and the academic sector; and, through effective collaborative research and technology transfer, it provides the platform for the process of industrial innovation.

2. IS INNOVATION BY BRITISH INDUSTRY INTERNATIONALLY COMPETITIVE? HOW SHOULD THIS COMPETITIVENESS BE MEASURED?

There is no agreed measure for an industry's capacity to innovate, other than its economic success. We believe that it would be counter-productive to establish such a measure, since increasing it or optimising it, whatever it may be, is not necessarily the same as increasing or optimising innovation itself. There is danger of creating a misleading goal for companies to attain. Companies should be encouraged, however, to continually assess the technical maturity of their products and processes, and their ability to achieve any significant advances in relevant areas. This is the essence of what might be termed a company's "capacity to innovate".

The chemical industry has always recognised that to remain competitive it must be innovative. This is not simply a trite observation, it is a demonstrable fact of business life which is becoming even more important as developing countries increase their production of low-value-added bulk products. Maintaining an adequate science base in the UK is therefore of crucial significance to our industry. This is one of the few sources of competitive advantage available to us over developing countries, and it is an advantage which UK industry generally must exploit effectively if it wishes to continue to compete successfully with them, and with other developed countries, in the future.

3. Is "SHORT-TERMISM" REALLY A PROBLEM FOR INNOVATIVE BRITISH INDUSTRY? IF SO, WHY IS THIS, AND HOW MIGHT IT BE REMEDIED?

In harsh economic conditions every business must inevitably increase its focus on the short term. To some extent this has the positive effect of sharpening company operations generally, but there is little doubt that short-termism, both in City institutions and within companies, is a threat to the innovation process and hence the future competitiveness of technology-based industries. This serves to highlight the importance of maintaining a sound science base (a platform for innovation), and the importance of government's role in supporting initiatives which seek to encourage effective technology transfer, both within industry, between customer and supplier, and between companies and the academic sector.

We do not believe that it is the role of government to undertake research initiatives that should be carried out by individual companies in their efforts to remain competitive. However, government does have a vital role in ensuring that innovative companies are encouraged to operate and invest in the UK, and are not hindered by ill-conceived legislation or regulatory measures. We would highlight three important areas that government can influence which are central to industrial innovation:

— An adequately resourced education system which provides a continuing supply of well prepared recruits for industry, and well qualified teachers, particularly in science and engineering.
— A high quality science base which provides a platform on which to develop technology-based industry.
— A strong and equitable system for intellectual property rights that gives innovators a level of protection comparable with that available in other regions.

4. SOME SECTORS OF UK INDUSTRY ARE MORE SUCCESSFUL IN INTERNATIONAL MARKETS THAN OTHERS. WHAT CONTRIBUTION DOES INNOVATION MAKE TO THEIR SUCCESS? WHAT CHANGES IN CORPORATE STRATEGY MIGHT IMPROVE THE LESS SUCCESSFUL ONES?

As we have stated in our introductory remarks, the chemical industry is the UK manufacturing sector's number one export earner, with a net export surplus in 1992 of over £3 billion. While no industrial sector, and no individual company, can afford to be complacent about its international performance, the chemical industry can claim a considerable degree of success in effectively exploiting international markets: the industry is international in nature.

This success has been achieved through effective research targeting in relation to international market opportunities, strong collaborative links with the academic sector (academic research is itself international in nature), sound management, and of course a sustained financial investment (nearly £2 billion in 1992) to support these activities.

Innovation, the successful commercial exploitation of inventions, primarily depends upon two essential factors:

— Co-operation and understanding between those involved in generating the inventions and those concerned with their commercial exploitation, and
— A favourable climate, economic, legal, political and social, in which to innovate.

Government, industry and the academic sector each has a vital role to play in fostering innovation, and each has a responsibility for ensuring that the above factors are optimised.

5. WHICH STRUCTURES AND INSTITUTIONS WITHIN THE UK ARE PARTICULARLY HELPFUL IN ENCOURAGING THE PROCESS OF INNOVATION WITHIN A COMPANY AND WHICH HINDER THIS PROCESS?

In its submission to the Office of Science and Technology as part of the consultation process for the White Paper on Science and Technology, this Association stressed the need for greater cohesion between the various funding agencies and government departments, under a clear and co-ordinated strategy. We have therefore welcomed the establishment of the OST as a central body directing overall policy, and we are encouraged that the White Paper contains a strong emphasis on the importance of wealth creation (through innovation), and partnership between government, industry and academia.

The proposal to replace the existing advisory structures of ACOST and ABRC, (with the Council for Science and Technology and the Expert Group advising the Director General of the Research Councils, respectively), is also welcome: we hope that there will be strong industrial representation on these new bodies, and that their advice will be delivered openly, and acted upon. The formulation and implementation of government policy will depend upon the success of the "Technology Foresight" and "Forward Look" initiatives, which will in turn depend upon close liaison between, and within, government, industry and the academic sector; i.e., partnership as mentioned above.

We stress that whereas we welcome the move to focus government support, through the Technology Foresight programme, on science and technology which underpins the creation of wealth, care must be taken to ensure that this support is directed towards wide, generic areas which are relevant to large sectors of industrial activity. Allowance needs to be made for a degree of diversity to ensure that "curiosity" research is not stifled and cross-disciplinary research is not discouraged.

Regarding particular government programmes designed to increase technology transfer and research collaboration, we are pleased that the White Paper has not put forward a number of new initiatives but rather, as we had hoped, concentrated on developing the existing programmes. We support the move to centralise the LINK scheme within the OST which should result in easier access to the scheme for our member companies, many of whom are key participants in LINK. We hope that the Technology Foresight and Forward Look initiatives will work in synergy with such schemes and serve to increase their impact for industry.

The Committee has also sought our views on four general topics, two of which we would like to address briefly:

The extent to which the standards of education and training in the UK may hinder innovation, and measures that might help to improve this.

Although the White Paper has addressed the issue of provisions for postgraduate training in science and technology, we were disappointed with the lack of emphasis which was given to the importance of teaching and teachers, at all levels, in delivering many of the objectives set out in the document, not least the central goal of achieving a higher level of public understanding and acceptance of science and technology within the UK.

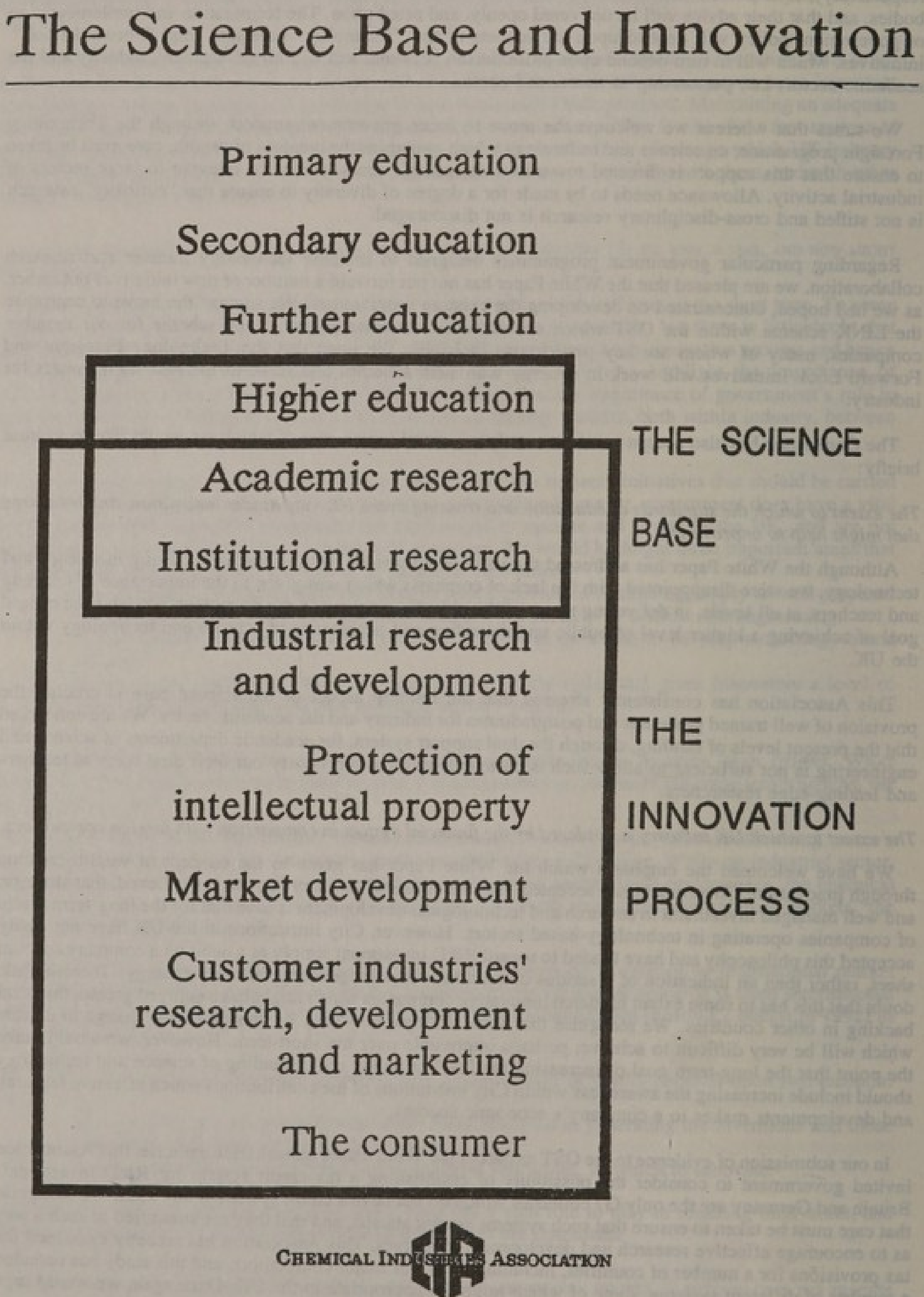
This Association has consistently stressed that the training aspect of the science base is crucial: the provision of well trained graduates and postgraduates for industry and the academic sector. We are concerned that the present levels of funding, through the dual support system, for academic departments of science and engineering is not sufficient to allow such departments to effectively carry out their dual roles as teachers and leading-edge researchers.

The extent to which UK industry is hindered by the financial system in comparison with foreign competitors.

We have welcomed the emphasis which the White Paper has given to the concept of wealth creation through innovation. Government has accepted, and the chemical industry has always believed, that strategic and well managed investment in research and technological development is essential for the long-term future of companies operating in technology-based sectors. However, City institutions in the UK have not easily accepted this philosophy and have tended to regard R&D investment simply as a debit on a company account sheet, rather than an indication of a serious commitment to a longer-term business strategy. There is little doubt that this has to some extent hindered innovative companies which might have enjoyed greater financial backing in other countries. We recognise that such attitudes may only be changed by a change in culture which will be very difficult to achieve; perhaps impossible over the short-term. However, we would make the point that the long-term goal of increasing the level of public understanding of science and technology should include increasing the awareness within City institutions of the contributions which effective research and developments makes to a company's economic success.

In our submission of evidence to the OST as part of the White Paper consultation exercise, this Association invited government to consider the possibility of establishing a tax credit system for R&D investment: Britain and Germany are the only G7 countries which do not have a credit system of any kind. We recognise that care must be taken to ensure that such systems are not abused, and that they are structured in such a way as to encourage effective research and development initiatives. This Association has recently examined the tax provisions for a number of countries, including all of our major competitors, and this study has revealed a number of different systems, some of which might be appropriate in the UK. Once again we would urge government to fully consider the possibilities which exist in this area.

CHART 1


The Science Base and Innovation
Primary education
Secondary education
Further education
Higher education
Academic research
Institutional research
Industrial research and development
Protection of intellectual property
Market development
Customer industries' research, development and marketing
The consumer
THE SCIENCE BASE
THE INNOVATION PROCESS
CHEMICAL INDUSTRIES ASSOCIATION

Further Memorandum submitted by the Chemical Industries Association (10 December 1993)

Thank you for your letter of 19 November requesting further information on specific questions arising from the above enquiry.

Concerning variations in the importance of the science base to innovative performance between sectors we can only refer to our original evidence to the enquiry (sections 1 and 4), which addresses this issue from a chemical industry perspective.

To answer your second question, concerning the extent to which companies use benchmarking techniques, we would reiterate the comments which we made on this subject in our evidence to the consultation exercise for the White Paper on Science, Engineering and Technology: "There is no agreed measure for an industry's capacity to innovate, other than its economic success. We believe it would be counter-productive to devote resources to establish such a measure, since increasing or optimising it, whatever it may be, is not necessarily the same as increasing or optimising innovation itself. In other words there is a danger of creating a misleading goal for companies to attain. Companies should be encouraged, however, to continually assess the technical maturity of their products and processes, and their ability to achieve any significant advances in relevant areas. This is the essence of what might be termed a companies 'capacity to innovate'."

We cannot make detailed comments concerning the use, and nature, of benchmarking techniques: our member companies will use benchmarking when and where it is appropriate for them.

Finally, your third question outlines an anomaly: while most companies are satisfied with their finance, they are also concerned at the short term attitude of the financial institutions. In our original submission to the enquiry we outlined our views on the extent to which UK industry is hindered by the financial system compared to foreign competitors. We have little to add to our comments, except to say that finance for investment in R&D and other projects in the chemical industry is usually generated within companies, and not acquired from external sources.

Memorandum submitted by Food and Drink Federation (6 August 1993)

A. INTRODUCTION

The Food and Drink Federation (FDF) represents the UK's largest manufacturing industry, which currently employs over 500,000 people and includes 18 of the 100 largest companies. It has a high potential for added value, contributing in 1990 some £11 billion to the GDP over 8.4 per cent of the total. Food processing is fundamental to the health and prosperity of the nation. For its own technological development and competitiveness the food and drink industry depends on the publicly-funded science base over a wide range of disciplines. FDF therefore warmly welcomes the recent White Paper "Realising our Potential" which addresses many of the key needs of the industry.

FDF particularly welcomes the recognition in the White Paper of the need to focus on selected areas of research where scientific capability can be matched with opportunity for wealth creation. The food and drink industry is a major customer for the results of publicly funded research and presents significant opportunities for enhancing international competitiveness through product innovation, process efficiency and quality improvement.

To compete nationally and internationally some companies have become highly sophisticated technologically, using leading edge technology based on engineering, information technology, the biosciences and materials science. At the same time there are numerous smaller companies, not so technologically developed but making a significant contribution to the food supply, for which further government support for technology transfer would be beneficial.

To encourage and promote the future development of the industry, the Government has a key role to play in providing: the science base on which the industry depends; appropriate science education; a legislative environment that both encourages consumer confidence and facilitates innovation; and a fiscal environment that stimultes investment in R&D and innovation. These will enable strategic priorities to progress.

B. COMMENT ON SPECIFIC QUESTIONS

1. *What is the relationship between the Science Base and industrial innovation?*

The science base on which the food industry draws includes the biological and engineering departments of the universities, AFRC Institutes (funded through the OST) and the industry's Research Associations (RAs). Larger companies draw on the sophisticated research of the universities and AFRC and, on the whole, lead innovation. Technology transfer to medium and smaller companies tends to be from their suppliers, the RAs and the larger companies.

The UK food and drink industry devotes a substantial proportion of the added value it generates to research and technological innovation. Total UK research expenditure by food sector companies is large and growing. It was estimated by FDF in 1991 to be approximately £200 million per annum, of which about 5 per cent is spent with public sector institutions and around 5 per cent collaboratively in the RAs.

A qualitative review of UK research spending changes by 20, predominantly larger companies within the FDF membership, showed R&D to have increased in real terms over the five year period 1987 to 1991, particularly in the area of food safety. Moreover, 90 per cent of companies reported funding some research in universities and institutes. Notably 70 per cent of the sample reported taking part in Link projects and 25 per cent in European Community funded projects.

Whilst in comparative cost terms, the amount of food-related research in the public sector is small, it is critically important in providing the basic knowledge to underpin the industry's own programmes, and in providing trained people and expertise on which both the public and private sector can draw. FDF has been concerned, therefore, that the reduction and restructuring of the science base relative to the industry, which occurred in the 1980s, should not weaken that base and disadvantage the UK food and drink industry and consumers.

We believe that it is critically important that the Science Budget allocation to strategic research is augmented to sustain and extend the knowledge and science which underpins the development of the food chain and ultimately its economic viability.

The food and drink industry values the centres of excellence within the current Agricultural and Food Research Council, notably the Institute of Food Research (IFR), which has successfully developed into a leading international research centre with a reputation for scientific excellence and independence in basic sciences related to food and food safety. The scrutiny of government research laboratories foreseen in the White Paper should aim to strengthen the mission, quality and independence of the IFR so that it will have the resources to maintain the broad science base necessary to underpin the industry. FDF believes that interaction between the biological and engineering science bases should be actively promoted.

2. *Are the mechanisms for technology transfer and interaction between the science base and industry effective? How could they be improved?*

(a) *Technology transfer and interaction*

Ideally the process of technological innovation should be considered as a seamless continuum from:

(i) Basic scientific enquiry, to
(ii) Strategic research, to
(iii) Applied science and engineering research, to
(iv) Development and
(v) Application in new products and processes.

Technology transfer should be the responsibility of all elements in the research and development chain. FDF does not see a need for any new institution in the food sector to effect or assist this process but Government initiatives would be valuable. Government departments should not be afraid to support competitive technological innovation. Since scientific knowledge diffuses quickly, measures should be taken to help UK science benefit the UK economy first.

The food and drink industry is well served by the Research Associations which are already heavily engaged in technology transfer and information provision. The diverse scale and nature of food and drink processing makes the availability of the RA resources particularly necessary. In enhancing technology transfer, the industry would wish to see the effective model provided by these structures built upon. FDF believes that MAFF has an important role in supporting initiatives to extend technology transfer to small and medium sized enterprises and that the RAs provide an appropriate basis for such initiatives. The development of the RA service, together with strategic links to other research centres, would be in the spirit of the Faraday Principles endorsed in the White Paper.

FDF believes that one of the greatest contributions to technological progress is probably to be gained by bringing the majority of companies up to "best practice" standards and that diffusion of technology between companies is the most effective way to achieve this. Measures to encourage it should be given a high priority, Secondments between the research base and industry can also make a valuable contribution to this process.

FDF recognises that the technology transfer needs of companies vary greatly according to their size, market and internal technological capabilities and supports, therefore, the availability of a range of measures to improve technology transfer to industry. We believe that a useful package to assist technology transfer should include:

— Schemes to provide for non-member access to information bases held at RAs and to expand those bases as necessary.
— Schemes to assist the diffusion of new technologies by companies, including demonstration projects.
— A scheme to assist with the costs of staff interchange and on-site training.

Industry can only exploit if it knows what is being done, and is in a position to take up ideas and technology competitively. This means that publicly funded research should be evolved with the industry and results communicated early to interested UK parties. This should be encouraged and, indeed, where relevant, made a condition of research grants. FDF is concerned that public sector institutions seeking to derive commercial benefit from research do not erect barriers to technology transfer to the private sector.

Collaborative programmes, such as those under the Link umbrella are helpful, though greater flexibility and user friendliness are needed.

In recent years it is very noticeable that more universities are looking for more industrial contacts. A continued government stimulus to universities to look for industrial funding will help in this. This process should not be pressed, however, to the point at which academic scientists are unable sufficiently to pursue new science for science's sake. The UK needs to continue to afford some pursuit of science without regard to its market applicability.

(b) *Influencing the relevance of publicly funded research to commercial needs*

If a criterion of success for government funding is the application of results by industry, then industry, like any other customer, should be influencing the areas of priority and monitoring progress. The mechanisms for industrial advice to government should, therefore, be maintained and improved. For industry to invest the manpower needed it must see that it has real influence. FDF sees a key role for industry, with government, in setting priorities and guiding the research in the public sector.

Food processing is the major customer of agriculture, more than 70 per cent of agricultural produce being processed, and makes almost double the contribution to GDP which arises from agriculture. Current government funding of agri-food research is, nevertheless, heavily weighted towards agricultural production rather than manufacturing or consumer interests, reflecting out-dated priorities; many areas which affect manufacturing competitiveness or consumer interests are poorly supported or ignored. FDF would re-iterate its long-held view that there is need to redress this imbalance and would hope that this will be achieved by better representation of the voice of the customer in the new priority setting arrangements.

The management of agriculture and food research through the current Priorities Board reflects the expenditure pattern and, with all but one of the Board's Advisory Sectoral Groups (ASGs) being concerned with primary production and dominated by producer representation, the system appears to be established to maintain the *status quo*. FDF believes that the stance of the Food ASG has effected some change in the right direction, but this needs to be sustained and augmented significantly and manufacturer representation strengthened in all the ASGs if the current Priorities Board structure remains beyond the Board's 1994 review date.

Regarding the consultative arrangements set out in the White Paper, FDF will be able to provide strong food and drink industry input to all the envisaged levels of strategy development and implementation and would wish to be involved in establishing the appropriate mechanism for these contributions which should include commercial as well as scientific/technical representation.

The food and drink industry should also be represented on the advisory boards of the Research Councils in whose work has a significant interest and on which it will draw. The breadth of this interest is illustrated by the industry's direct concern with, amongst other things, the properties, processing and health implications of food and biological materials; nutrition; materials handling and manufacturing technology; distribution and information technology; consumer perception and awareness and marketing.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

The future availability of adequately trained scientists and engineers is a matter of importance to the food and drink industry. During recent discussion of this topic, the following observations were made by members of FDF:

(i) Not enough of the graduates in management positions in British industry have a background in science and perhaps more particularly in engineering subjects, and there is a general shortage of good engineers.

(ii) Too often discussions on training in technology concentrate on the supply of graduates. Good practical technicians with training in all aspects of science and engineering (for example electronics and mechanical skills) are in short supply.

(iii) A higher priority should be given to the training of nutritionists at undergraduate level. The multi-disciplinary nature of nutrition has contributed to its receiving poor recognition and status but the breadth of knowledge acquired by well trained nutritionists is essential to its application whether in government policy, consumer education or food product research.

(iv) If the UK trade deficits with, for example, Germany and Japan disappeared, our total trade deficit would be reduced substantially. Good technical products can best be sold by technically competent people, but can be sold most effectively in the language of the prospective buyer. German, and even more so Japanese, are not sufficiently taught in British schools and recent developments in universities to combine engineering subjects at undergraduate level with a language are welcome.

(v) Within the industry itself, the need for continuous technical training is substantial due to the diverse nature of the industry and the high standards to which it operates.

FDF supports the proposal in the White Paper to devote more resources to the MSc as the first post-graduate qualification and will encourage the availability of courses suitable for entrants to the food and drink industry from a range of scientific and technical disciplines.

4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

The UK is strong internationally in the added value sector of the food chain. The food manufacturing industry and the retail sector are well organised, with several large strong, often multinational, companies. This sector of the industry is innovative as measured by successful new products and innovative in processing necessary for global competition. Its cost base is competitive with any in Europe. For example, the average flour mill capacity in the UK is several times greater than that in Germany or France. In the UK the nation's flour is provided by some 80 mills; in Germany the figure is closer to 800. One UK company provides more than 25 per cent of the nation's bread from 20 bakeries; in France there are more than 30,000 bakeries. The five largest national retailers are responsible for the distribution of over 60 per cent of food to the consumer, a far higher proportion than elsewhere in Europe. Product innovation, measured as product introductions, particularly in the higher added value sectors, has increased during the 1980s and 90s. In 1992 the rate of product launch was twice that in 1987 (Campden Food and Drink Research Association data). The structure of the UK food industry makes it possible to exploit innovation nationally and internationally and FDF believes that it is at least as successful as its main competitors at translating invention to innovation.

FDF does not propose a single measure of innovative capacity. Ultimately a key indication of a firm's innovation performance is its survival and growth, particularly given the rapid pace of technical change in recent decades and the driving force of consumer demand which the industry constantly strives to meet. We have referred above to an increasing rate of product introduction in the food industry over the last five years.

5. *Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

There has been a trend to focus on competitiveness and reduce longer term research in companies' own establishments. This enhances the need for industry to engage with and draw on the public sector.

The public sector must take responsibility for basic science and strategic research, guided by industry, inter alia, in the selection of strategic research priorities. Applied science and engineering is the area of overlap in which most work must be in collaboration with, and led by, industry. Thus we see a key role of industry, with government, in setting priorities and guiding the research in the public sector.

Development and application are principally the responsibility of industry. Where they depend on strategic and applied research from the public sector, it is critical that the transfer of research to technology be smooth and effective; the "near market" tests relatively recently introduced by civil servants at the behest of Ministers have, in FDF's view, inserted an arbitrary hiatus into the system. The market should determine the point of transfer to industry responsibility: if research becomes competitive, it will be sought and bought by commercial interests. Technology transfer then depends on the choice of the right strategic research priorities and communication with and involvement of the potential exploiting interests. Early commercial input to determining priorities for basic and strategic research will maximise subsequent market exploitation.

6. *Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?*

See the response to question 4.

7. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder this process?*

As already stated in response to question 1, the food and drink industry values the centres of excellence within the current Agricultural and Food Research Council, notably the IFR, which has successfully developed into a leading international research centre with a reputation for scientific excellence and independence in basic sciences related to food and food safety. Also, the food and drink industry is well served by the RAs, which are already heavily engaged in technology transfer and information provision, the diverse scale and nature of food and drink processing making the availability of the RA resources particularly necessary.

The UK Link schemes have been adopted widely by the larger food companies. In general, they are well thought of by the participants except for the bureaucracy in the establishment of these necessarily "precompetitive" projects. In particular, whilst there must be some planning for success, the intellectual property rights agreements between the partners, which are insisted upon by MAFF/DTI, are often regarded as wasting management time for no benefit to the project or its participants. Nonetheless, the scheme appears to be effective in bringing awareness of the applicability of scientific developments to participants, although it is too early to quantify the economic benefits.

The industry is keen to see the Link concept continue and develop. Changes in management resulting from the transfer of overall responsibility to the OST should be accomplished without damaging the momentum of the current MAFF and DTI-led food Link programmes.

Whilst there are examples of successful UK industry participation in European collaborative research projects, the level of such participation in general compares poorly with that in the Link schemes. There are several areas in which other European countries have advanced skills from which the UK might benefit including, for example, process equipment and packaging technology. More effective UK use of Community funds might be made if promotional and managerial effort similar to that supporting Link schemes was made for the European programmes. FDF believes that the responsible Government department should consider ways of generating more UK company participation in Community programmes.

Except for some technology development companies, there is little participation of small or medium companies in Link or European projects. Whilst progress in smaller companies may often be made by picking up technology elsewhere, it is likely that smaller companies would find the costs of taking part in projects beyond their means, except as a minor partner. Mechanisms for supporting smaller projects for smaller companies, which have commensurately less bureaucracy, should be sought.

The legislative framework is a key influence on innovation in the food sector. The Government can, through the precedents it sets nationally, and through its negotiations in Brussels, influence that framework on a European and international scale. Whilst consumer protection must remain paramount in food legislation, some recent developments, such as the proposals for implementation of the Biotechnology Directives and the Food Advisory Committee's proposals on labelling of foods produced using genetic modification, go beyond the needs of consumer protection by establishing requirements additional to those necessary to food safety. Such approaches will reduce the UK's competitiveness by impeding innovation in this country.

Innovation can be seriously impeded by unnecessary bureaucracy, procrastination or indecision on the part of regulatory bodies, and unjustified demands for information on the part of expert advisory bodies. It is not unusual for product innovations to be delayed for many years and investments to be held unproductive, thus losing their competitive lead. This situation has been aggravated by the delays in establishing legislation for product and process approval and the mechanisms for its implementation at the European level.

The OST could have a key role in tackling these problems. Government departments, in reviewing petitions, should work to statutory short time targets. Expert advisory committees should be required to give reasoned justification of requests for additional information (which may take years to generate). Patent life extension should be considered for cases of prolonged regulatory review delays. A culture of collaboration to facilitate safe innovation needs to be adopted by the Government and its advisers.

C. ADDITIONAL COMMENT ON SOME ISSUES IDENTIFIED AS BEING OF PARTICULAR INTEREST TO THE COMMITTEE

8. *The effectiveness of the current mechanisms for encouraging interaction between the science base and industry*

See response to question 2 above.

9. *Strategies which might enable industry to innovate more effectively*

See response (a) to question 2 above, regarding technology transfer.

Industrial spend on R&D is an expense which only healthy, profitable businesses can support. Government can create an economic climate in which business flourishes, can provide tax incentives to sustain R&D investment through the bottom of economic cycles, and can ensure that regulatory processes are not relatively disadvantageous to innovation in British industry.

Given a finite availability of public funds there is a need to focus resources on selected areas of research where scientific capability can be matched with opportunity for wealth creation. The food and drink industry is a major customer for the results of publicly-funded research and presents significant opportunities for enhancing international competitiveness through product innovation, process efficiency and quality improvement.

The current spend on S&T is too heavily science oriented, and within that is too heavily weighted towards curiosity driven, basic research rather than strategic research. The view that engineering and information technology are somehow of less intrinsic merit than elementary particle physics, astronomy or molecular biology is not in the national interest. Within the sectors of direct interest to the food and drink industry, FDF is concerned at the orientation of agricultural research to producer rather than consumer priorities.

FDF believes a more strategic approach to the funding of basic science, driven in some large part by the need for national benefit, is necessary and welcomes the customer oriented approach of the recent White Paper.

10. *The extent to which the standards of education and training in the UK may hinder innovation, and measures that might improve this*

Whilst demanding increasing quality and diversity, consumers are conservative with respect to acceptance of overtly new technology. Hence food manufacturers are cautious in the use of technology perceived by the consumer to be new. Insofar as the acceptance of technology is closely linked to understanding, the Government has a clear role in providing sound scientific education to all at school level, and in providing information and education to consumers in general so that informed choice can be exercised.

FDF welcomes the Government's commitment in the White Paper to encouraging the public understanding of science, technology and engineering. Such understanding is vitally necessary to public confidence in an increasingly sophisticated, technologically-based food supply: the current lack of confidence is inhibiting implementation of new technologies.

The key issues are not only adequate training but also a culture of scientific and technical awareness. An improvement of the basic appreciation of science and technology by consumers and the work force alike will enhance public perception of the status of scientists and engineers in the community.

11. *The extent to which UK industry is hindered by the financial system in comparision with foreign competitors*

FDF understands that there are difficulties facing UK research organisations which are currently only eligible for 50 per cent funding from European programmes such as FLAIR and AAIR. Where EC Research Programmes clearly accommodate UK needs and research organisations have succeeded in attracting EC funds, FDF believes that the Government should provide supplementary funding. It is understood that this is available in some other Member States. The Research Associations are particularly disadvantaged in this respect.

More effective UK use of Community funds might be made if promotional and managerial effort similar to that supporting Link schemes was made for the European programmes. Whilst there are examples of successful UK industry participation in European collaborative research projects, the level of such participation in general compares poorly with that in the Link schemes. FDF believes that the responsible government departments should consider ways of generating more UK company participation in Community programmes.

12. *The Committee would also be interested to know how you would rate the following factors in determining the competitive positions of UK firms in your industry:*

- Product design and innovation.
- Quality of process technology.
- Quality and reliability of output.
- Price and cost competitiveness.
- Relationships with suppliers and customer satisfaction.

These are certainly all key elements in innovation and competitiveness. They are, however, strongly interrelated in our industry, their relative importance varying by sector and with individual circumstances. We do not believe, therefore, that they can meaningfully be ranked, in general practice, in order of importance.

Further Memorandum submitted by the Food and Drink Federation (22 December 1993)

Thank you for your letter of 25 November seeking further input to the Science and Technology Committee. We have the following comments.

FIRST INSET PARAGRAPH

FDF is broadly in agreement with this conclusion. Although product innovation is consumer-driven, the range of opportunities is technology-driven and innovation is an iteration between technological opportunity and consumer demands.

SECOND INSET PARAGRAPH

FDF agrees strongly with this conclusion for the three basic reasons given.

THIRD INSET PARAGRAPH

Agreed. The legislative proscription of specific processes, e.g., irradiation, or of technologies, e.g., genetic modification, on other than scientifically-based safety grounds not only hinders innovation but encourages unfounded public fear of new technology.

FOURTH INSET PARAGRAPH

Many sound links are in place but FDF would wish to see stronger links between agricultural/horticultural research and food research. There is need of greater emphasis pre-farmgate on research into the required quality of crops for processing. Current Government funding of agri-food research is heavily weighted towards agricultural production rather than manufacturing or consumer interests, reflecting out-dated priorities; many areas which would affect manufacturing competitiveness or consumer interests are poorly supported or ignored. We hope that this imbalance will be redressed by better representation of the voice of the customer in the new priority setting arrangements envisaged in the Science Engineering and Technology White Paper.

PENULTIMATE PARAGRAPH

FDF welcomes the effort which, following the White Paper, is now being put into Foresight Assessment. FDF particularly welcomes the recognition of the need to focus resources on selected areas of research where scientific capability can be matched with opportunity for wealth creation. The food and drink industry is a major customer for the results of publicly-funded research and presents significant opportunities for enhancing international competitiveness through product innovation, process efficiency and quality improvement. FDF has put forward to the Office and Science and Technology a model whereby it might provide a co-ordinated interface between the food and drink industry and the OST in pursuit of the Foresight Process.

LAST PARAGRAPH

FDF believes that steps should be taken to ensure that the UK benefits more fully from EC R&D Programmes. In the context of co-operation and collaboration in Europe, the results of the current Technology Foresight studies should provide the basis for a more effective UK contribution to determining priorities and initiating research programmes. FDF would draw attention, however, to the difficulties facing UK research organisations which are currently only eligible for 50 per cent funding from European programmes such as FLAIR. Where EC research programmes clearly accommodate UK needs and research organisations have succeeded in attracting EC funds, FDF believes that the Government should provide supplementary funding. It is understood that this is available in some other Member States. The Research Associations are particularly disadvantaged in this respect.

We hope that these supplementary comments are of further assistance to the Science and Technology Committee in concluding its deliberations.

Memorandum submitted by Science and Engineering Research Council (11 February 1993)

SERC has conducted three reviews in the past year which are relevant to the Select Committee's investigation; all three reviews were actions from the Council's Third Corporate Plan. Copies of these Council reviews are attached; they are:

"SERC's Interactions with Industry"
— A review conducted by Council's Industrial Affairs Panel.

"A Review of Support for Engineering"
— A review by a special panel chaired by Mr R Malpas, CBE.

"Review of Information Science and Engineering"
— A review by a special panel chaired by Sir John Fairclough.

Also attached[1] is a report of two years ago from the Council's Science Board, reviewing their interactions with industry.

The following notes (presented in question and answer form) attempt to define the SERC's role in encouraging innovation and technology transfer.

1. WHY DO GOVERNMENTS FUND THE SCIENCE BASE?

The reasons are to contribute to:

(a) *Industrial/commercial competitiveness*—National wealth-creating potential depends increasingly on capabilities in high technology.
(b) *National security*—Surveillance, advanced weapon systems, secure communications require sophisticated technologies.
(c) *Food, resource and energy self sufficiency*—Covering the efficient utilisation and effective stewardship of the land, oceans and atmosphere.
(d) *Health and public well-being*—There is wide public support for investment in research relating to public health, improved public utilities and social services, forensic science and law and order.
(e) *Culture and national status*—Research motivated by curiosity is one of the more noble endeavours of humankind, and the UK remains a world leader in many areas of fundamental scientific research (such as astronomy).

Clearly there is overlap between these five broad headings (for example, transport and communications comes under (a) to (d)); nevertheless it can be helpful to characterise research under these principal objectives. Objective (a) is *wealth creating;* all other objectives are *wealth consuming* (although they may contribute to the infrastructure for the wealth creation process—or contribute to wealth creation through spin-offs.) Hence although (a) is enormously important, care must be taken not to neglect (b) to (e) when discussing technology transfer and innovation.

2. WHAT IS INNOVATION?

Innovation is sometimes defined as *"the profitable commercialisation of invention"*. While this definition is well matched to objective (a) in paragraph 1, it overlooks the fact that the innovation process is also important for objectives (b) to (e). A broader definition is *"the effective utilisation of know-how"*. (The Prince of Wales Working Group on Innovation adopted the definition *"profitable change";* however objectives (b) to (e) may involve no profit element, yet require an innovative approach. Conversely, "profitable change" often requires little or no innovation—for example, profitable change in telecommunications in the 1950s involved little more than changing the colour of BPO phones and introducing helical cords.) The DTI view of innovation is that it usually requires technological advance, together with the added dimensions of market awareness and business skills—a common banner is "Science alone is not enough".

3. WHAT IS TECHNOLOGY TRANSFER?

In the UK the expression *Technology Transfer* includes *awareness of technology*—those who know telling those who do not". It also involves the *adoption of technology* to improve profitability. Finally it embraces the *merging of technologies,* so that the resultant technical capabilities are richer in potential than the sum of the component parts.

The Japanese recognise these differing requirements, and adopt different expressions to stress the difference:

Technology Fission — Awareness; "those who know telling those who do not".

Technology Fusion — The merging of technologies, to produce emergent capabilities of rich variety (e.g., mechatronics, bioelectronics).

Technology Transfer — The focused adoption of technology for problem solving, and to improve industrial/commercial profitability.

Perhaps in the UK we should also start using these different expressions to avoid confusion in describing the technology transfer process? Governments should fund *technology fission,* and catalyse *technology fusion;* but what is government's role (if any) in *transferring technology* to improve industrial/commercial profitability? Is this not the responsibility of industry itself, with the government's role limited to awareness and the promotion of best practice, and (where necessary) regulation?

4. WHAT IS THE NATURE OF THE TECHNOLOGY TRANSFER PROCESS?

It is necessary to first define the various categories of research:

Basic/fundamental research — Motivated primarily by curiosity, with initially no particular application in mind.

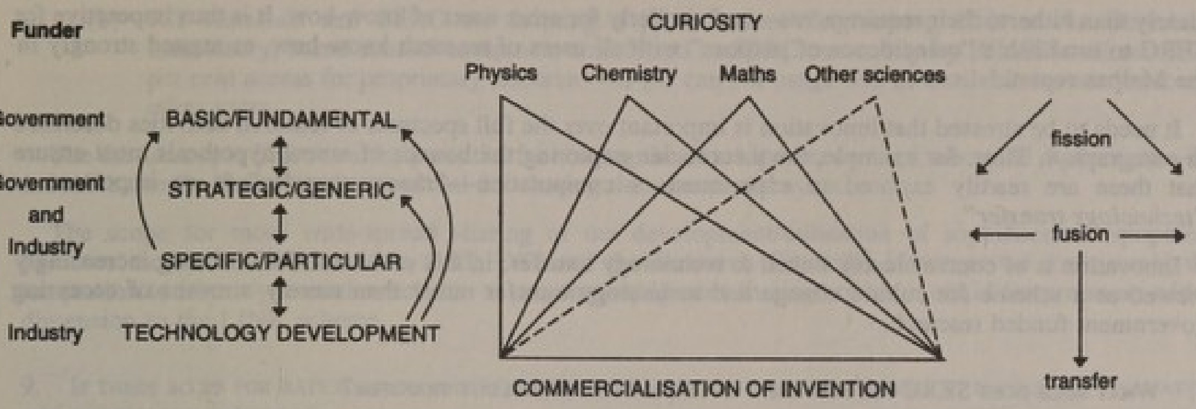
Strategic/generic research — Recognised as potentially applicable on a 5 to 10 year horizon.

Specific/particular (applied) research — Directed to problem solving for particular applications (likely to involve demonstrators).

Technology development — Leading to system/process/product prototyping.

In reality there is a continuous spectrum of activity from basic research to application; nevertheless the above definitions are useful reference points. (The above definitions differ somewhat from the commonly-used Frascatti definitions; which are now deemed by many to be inadequate.) Basic research is rightly the realm of academic researchers; the intellectual challenge of basic research is closely allied to the teaching of the core scientific disciplines.

The relationship bewteen the various categories of research can be depicted diagrammatically, as follows:



On this diagram, *technology fusion* represents horizontal integration; *technology transfer* represents vertical integration; *technology fission* is the spreading out of knowledge.

The interactions between the various categories of research need to be emphasised. There is strong feed-back at each stage of the process. The *scientific method* is a cyclical process (hypothesis leading to controlled experiment—interpretation of the results of experiment leading to refined hypothesis—and so forth); emphasising the feedback inherent in the whole research system.

There has been a rather sterile debate recently about the non-linearity of the *technology transfer process.* It is *wrong* to envisage technology transfer as a type of relay race, with the first leg run by the academic scientist who then passes on the "baton" of know-how to the applied scientist—who in turn passes it to the engineer, who passes it to industry for the final run to the tape. *Technology transfer must be a "team sport"*, involving the active and continuing interaction between scientists, engineers and technologists in academe, industry and elsewhere.

Government should be the principal patron of basic/fundamental research, and industry must fund technological development; the other categories of research are likely to be funded collaboratively.

5. What is the difference between science, engineering and technology?

Science is concerned with understanding the nature of the material world (both natural and human-made). *Science* involves the acquisition of knowledge—*Engineering* involves the application of knowledge. (Since in applying knowledge engineers will identify the need for new knowledge, it is not surprising that engineers encourage scientists to address particular problems; almost 50 per cent of the grant funding of SERC's Engineering Board is spent in science departments.) The application of knowledge leads to *technology*—the devices, systems, processes and products which contribute to the lifestyles of people (hopefully in a helpful way). Of course the results of technology feed-back to increase the capabilities of science and engineering research. Thus for example *logic* is the acquisition of knowledge—*systems engineering* is the application of knowledge—the resulting technology is the *computer*, which increases the research capability in the underlying basic research.

Engineers need to organise knowledge in a way in which it can be easily handled, and produce tools and techniques for its efficient/effective utilisation. Thus, engineers need to undertake research in such areas as systems, modelling and design.

The differences between science and engineering are too often emphasised, to no constructive purpose. Both science and engineering cover the same continuum of research categories described in paragraph 4, covering all headings in paragraph 1. Science and engineering are strongly interdependent—although success in science does not ensure success in engineering unless positive action is taken to encourage strong coupling. The British research culture has traditionally placed greater emphasis on the acquisition of knowledge than its application—that is on science rather than engineering. The culture *must* change, so that equal emphasis is given to science *and* engineering.

6. What role does SERC see for itself in promoting Innovation?

SERC works to its preferred definition of *Innovation,* as "the effective utilisation of know-how". Through its research grants schemes SERC sponsors the generation of know-how; and through its studentship schemes SERC ensures the passing on of research methods for the generation of know-how.

The effective utilisation of know-how means that the users of scientific knowledge (see paragraph 1) should be actively involved in defining requirements. Thus in meeting the requirements of industry (user (a) in paragraph 1), industrialists must be involved in setting the agenda for innovation, and articulating more clearly than hitherto their requirements—and similarly for other users of know-how. It is thus imperative for SERC to establish a "coincidence of purpose" with all users of research know-how, as argued strongly in the Malpas report.

It needs to be stressed that innovation is important over the full spectrum of research activities described in paragraph 4. Thus, for example, the theoretician exploring the bounds of a new hypothesis must ensure that these are readily exposed to experiment or computation—*"theory transfer"* is as important as *"technology transfer"*.

Innovation is of course closely linked to technology transfer; in this context, LINK is being increasingly viewed as a scheme for culture change and technology transfer rather than merely a means of accessing government funded research.

7. WHAT ROLE DOES SERC SEE FOR ITSELF IN PROMOTING TECHNOLOGY TRANSFER?

Paragraph 3 emphasised that in the UK the term *technology transfer* includes awareness and fusion of technologies as well as focused application. Here we will embrace all three activities within the description *"exchange of ideas and know-how"*—or simply, *knowledge exchange. This definition emphasises the continuous interchange of ideas we should be encouraging in a strengthened partnership between academia and industry, rather than a one-off passing of know-how sometimes envisaged.* (It is worth noting that LINK emphasises the two-way flow of ideas and benefits between industrial and academic research groups.) SERC stresses the importance of exploiting the results of the research it sponsors, and has given increased attention to promoting best practice in the identification and exploitation of intellectual property. Questions of the ownership of intellectual property are best agreed between academic and industrial partners.

Using this broad definition then, SERC supports technology transfer in three principal ways. These are the support of:

- *Collaborative research:* Catalysing partnerships, via LINK and other mechanisms, between the users of research results (e.g., industry) and the providers of research (e.g., academia).
- *Relevant postgraduate training:* Identifying the needs of the employers of postgraduates (e.g., industry) through schemes such as IGDS, Teaching Company, CASE, the Engineering Doctorate and Industrial Studentships.
- *People transfer:* The best way to exchange ideas and know-how is to exchange people—"technology transfer on the hoof".

Although SERC has effective mechanisms in place to pursue the first two of these objectives, increased attention needs to be given to the third. The SERC/Royal Society Industrial Fellowship scheme encourages secondments between academe and industry (both ways); however this has not generated a high-level of demand. The Teaching Company Scheme is seen by many as principally a "people transfer" scheme—although, as its name suggests, it originated in SERC as a mechanism for providing industrially-relevant training.

The improved flow of young researchers from the "hot house" of academia to industry *must* be given increased attention. The size of the contract research population in academia doubled from 9,000 to 18,000 during the 1980s. Only a small fraction of this number will have the opportunity of staying in academia long-term. There must be a high-kudos route provided for young researchers to move out of academia and into industry/commerce and the service sector.

DTI has a key role in promoting technology transfer, and the respective roles of SERC and DTI need to be understood. Inevitably there is overlap, and therefore it is entirely understandable that so many of SERC's activities in the general area of strategic research and industrially relevant training are in collaboration with DTI.

As already emphasised, industry needs to articulate its requirements, both for strategic know-how and trained people, rather more clearly than hitherto; the shift in academic culture during the 1980s has demonstrated the willingness of HEIs to respond to ideas/advice from industry.

8. DOES THE DEVELOPMENT/UTILISATION OF SOPHISTICATED EQUIPMENT FEATURE IN THE TECHNOLOGY TRANSFER PROCESS?

Academic and industrial research is becoming increasingly dominated by sophisticated (and expensive) equipment. There is potential for strategic partnerships to be formed around the shared development and utilisation (and shared costs) of advanced equipment.

Two recent examples can be given:

(a) ICI Pharmaceuticals, Oxford Instruments and Oxford University (with SERC/DTI funding under LINK) are sharing in the development of the next-generation 750 MHz NMR spectrometer. This partnership has something to offer to all participants—Oxford Instruments get assistance with the development of the high-field superconducting magnet technology, ICI pharmaceuticals will get early access to 750 MHz technology ahead of their industrial competitors, and the academic partners get the first 750 MHz machine in the world to pursue their research in protein structure.

(b) ICI Materials and SERC are forming a joint Surface Engineering Unit at the Daresbury Laboratory, based around equipment transferred to SERC ownership by ICI. ICI will retain 35 per cent access for proprietary research—65 per cen t of usage will be available for academic and other users.

The first example illustrates the potential for sharing the development costs of advanced equipment—the second example illustrates the potential for sharing the operational costs.

The scope for more wide-spread sharing of the development/utilisation of sophisticated equipment deserves increased attention from OST, DTI and the Research Councils. However we must avoid the temptation to invent yet another scheme to promote equipment sharing; rather it could feature as an added dimension to the LINK scheme.

9. IS THERE SCOPE FOR RATIONALISING THE PRESENT PLETHORA OF GOVERNMENT SCHEMES TO ENCOURAGE INNOVATION AND TECHNOLOGY TRANSFER?

Urgent attention needs to be given to reducing the current selection of schemes with overlapping objectives. Governments/Departments/Research Councils have shown themselves as being extremely adept at inventing new schemes—but less creative in closing down schemes of doubtful continuing value.

As indicated in paragraph 7 SERC sees its support for innovation and technology transfer being via its support of *collaborative research, relevant post-graduate training,* and *people/knowledge transfer.* If these are the three principal objectives, is there need for more than three schemes? All *collaborative research* (including the shared development and utilisation of advanced instrumentation, as discussed in paragraph 8) could come under the umbrella of LINK. (SERC is discussing with DTI the question of introducing increased flexibility into LINK.) *Industrially relevant training* could be concentrated under the new Engineering Doctorate—or via the existing CASE scheme. SERC is studying the options for rationalising the methods of support for post-graduate training at the masters and doctorate level. As already noted, increased attention needs to be given to *people transfer*—one option being discussed with DTI is to offer a fourth year in industry to Postdoctoral Research Assistants on LINK projects (that is, three years will be completed in academia —with an optional fourth year of support in the collaborating company).

10. ARE OPEN MARKET PRINCIPLES APPLICABLE TO THE SCIENCE BASE?

Objective (e) in Paragraph 1 (the pursuit of basic research for reasons of culture and national kudos) has no obvious "customer"—patronage by Government is a matter of tradition and the recognition that the cultural base to science represents a foundation for strategic and applied research. However objectives (a) to (d) do have customers, paying (mainly through the taxation system) for the products of the Science Base; namely knowledge and highly-trained people. Thus for example industry is the "customer" for objective (a); academic and other researchers are the "suppliers"; the Research Councils can be thought of as "customer's agents" making sure that the "products" required by the "customers" are obtained. On this model, there seems to be no reason why objectives (a) to (d) should not be exposed to full Open Market principles, with Research Councils fulfilling "customer requirements" through any suitable channel—academia, Research Council institutes and establishments, Government Research Laboratories, Industrial Research Organisations, and so forth.

Further memorandum submitted by the Science and Engineering Research Council (15 July 1993)

Thank you for your letter of 4 May requesting further input from SERC to inform the Select Committee's study into innovation and competitive technology. I sent to you earlier a detailed input and several relevant reports from SERC. I would place special emphasis on two of these, which are particularly relevant to the Committee's task:

"SERC's Interactions with Industry"
— A review conducted by Council's Industrial Affairs Panel
"A Review of Support for Engineering"
— A review by a special panel chaired by Mr R Malpas

Please let me know if you require further copies of these reviews. I also enclose 12 copies of a recently released "SERC Beginner's Guide" to Innovation and Technology Transfer. This is intended as introductory advice to applicants for SERC grants; it reflects SERC's general position on the technology transfer process.

Let us now address the specific further questions you raised in your letter.

What organisational arrangements are in place to ensure developments are disseminated to industries, and to enable industry to make contact with researchers whose expertise may be of interest to them? How much responsibility is delegated to institutions?

It is SERC'S policy that any results obtained in the course of research it supports in academic institutions should be exploited. Responsibility for exploitation is usually vested with the academic institutions; either directly or through BTG. As part of the case for support in all grant applications, arrangements for exploitation are requested. Details on exploitation plans are also sought in Final Reports on all completed grants.

The degree to which exploitation opportunities are pursued, or SERC takes an active role in the dissemination of information in industry, varies. For what are known as "responsive mode grants", SERC plays only a peripheral role in the dissemination and transfer of the results; responsibility lies with the academic institution. For our Directed Programmes (in Manufacturing, IT and Biotechnology), and in major co-ordinated activities such as LINK, we play a more active role—brokering partnerships, circulating reports on research results, and promoting take-up.

A recent innovation is the circulation to industry (via a bulletin sponsored by Norsk-Hydra) of grants judged to be of "alpha quality", but which SERC has been unable to fund because of the large number of high-quality requests for support. We know that these bulletins have already led to several new academic-industrial partnerships.

It is extremely difficult to quantify the level of office investment in these arrangements. If I assume that 10 per cent of the in-house effort in our Directorates and LINK relates to technology transfer, and add to this the role of our Finance Division and Industrial Affairs Unit in overseeing the exploitation process, this would be equivalent to about 12 people—annual cost ca £350k. There would be a similar level of investment from our Laboratories. We do *not* include in our grants funding for identification *or* protection of intellectual property—although many academic institutions have argued that we should.

Do you have a policy on IPR? What arrangements have you for ensuring that developments receive IPR protection, when appropriate?

SERC itself makes no claim to the intellectual property rights arising from research grants. While we actively encourage exploitation, responsibility for identification and protection of intellectual property resides with the academic institutions. Royalty returns accrue to the academic institutions. We expect suitable arrangements to be made to secure a suitable return to the institution and the investigator. SERC would not expect to be included in negotiations on IPR, which need to be direct between the academic institutions and companies. On collaborative schemes such as LINK we seek assurance that IPR agreements have been reached between collaborating partners. We are encouraging best practice on IPR issues through training courses for academics. At our own Laboratories, we give particular attention to IPR issues, and work through BTG. Details are given below.

What is the total income you receive from industry each year?

Details on Patents

Year	(a) Income received from UK Industry £ million	(b) Income received from UK Industry as Percentage of total research expenditure %	(c) Revenue received from BTG sharing agreement (relates to six agreements) £000
1986-87	1.0	0.3	10
1987-88	1.7	0.4	11
1988-89	1.6	0.4	2
1989-90	1.7	0.4	10
1990-91	2.1	0.5	28
1991-92	2.9	0.6	31
1992-93	1.8	0.3	1

The following points should be noted:

(i) Total research expenditure represents gross domestic and international expenditure less administration costs.

(ii) There were no revenue sharing agreements with BTG prior to 1985.

Any income derived from exploitation of a SERC invention assigned prior to 1985 was retained in full by BTG.

We have not been able to gather in the time available the following data which is sought by the Select Committee:

(i) Industrial funding figures for 1983-84, 1984-85 and 1985-86.

(ii) Overseas industrial funding figures (SERC accounting classifications do not distinguish industry from any other receipt from overseas).

(iii) Figures for *full* income received through royalties and patents.

(iv) Figures for the number of developments patented in each year.

The Committee may be interested to note that we have just received (in FY 93/94) £471k, inclusive of VAT, under a revenue sharing agreement with Oxford Instruments.

How much interaction with industry takes place at the specific instigation of a company, how much is initiated by researchers? What form do these relationships take?

The form of relationships between academia and industry takes three general forms:

— Collaborative research.
— Industrially relevant training.
— People transfer.

Details of the various schemes SERC uses to encourage such collaborations are given on pages 7 to 9 of the "Beginner's Guide"; and levels of spend on each scheme are given in the report "SERC's Interactions with Industry".

Estimating how much interaction is instigated by companies, and how much by academics, would be virtually impossible. I hope you will allow instead a few general observations.

(a) Major companies, such as ICI and Glaxo, have academic liaison officers. Our experience is that the best of these are extremely effective in seeking out the best academic groups—nationwide. Smaller companies often develop very strong local partnerships, with the Company in the lead; a good example is the partnership between Oxford Instruments and several departments at Oxford University.

(b) Most academic institutions now have Industrial Liaison Officers. The best of these are extremely successful in brokering partnerships between academia and industry—although not always with *UK* industry. Our experience is that the success of ILOs varies enormously. SERC has been particularly impressed by the activities at Strathclyde, Edinburgh, Warwick, ICSTM—with recent improvements at UCL and Oxford. But many academic institutions have been slow to change their culture.

(c) For collaborative research schemes, such as LINK, partnerships are as likely to be initiated by industry as by academe. Industrially relevant training schemes, such as CASE, tend to be initiated by academe (although we are considering introducing a mechanism of awarding CASE quotas to companies which are large users of the scheme). People transfer between academe and industry does *not* work well. It is a stated objective of the White Paper. We await with interest proposals from Government as to how they intend to encourage greater flows of people between adaceme and industry.

Please let me know if you require further information.

Memorandum submitted by the Agricultural and Food Research Council (16 July 1993)

HOW ARE ACADEMIC DEMANDS BALANCED EFFECTIVELY WITH INDUSTRIAL DEMANDS WITHIN A RESEARCH INSTITUTION?

Research programmes at AFRC institutes are based on three main components:

(i) Fundamental science and engineering, which is the pursuit of knowledge and understanding.
(ii) Strategic/generic science and engineering, i.e., long-term research targeted to general areas which may be expected to lead eventually to commercial exploitation but where no specific product is identified.
(iii) Specific research usually consisting of short-term programmes (three to five years) directed to immediate policy or industrial requirements and to problem solving.

Industrial funding for contract research mainly falls into category (iii) above, whereas technology interactions, although mainly deriving from (iii) are increasingly arising from (ii), and even (i). It is essential to achieve a balance of these components. Research institutes are not homogenous; they relate to different sectors of industry and their balance between fundamental and strategic research varies. Therefore common targets for interaction with industry are inappropriate. Accordingly, each institute prepares annually, as part of an overall three year forward plan and in consultation with AFRC Central Office, individually tailored targets for industrial funding and technology interaction.

WHAT ORGANISATIONAL ARRANGEMENTS, IF ANY, ARE IN PLACE TO ENSURE THAT DEVELOPMENTS ARE DISSEMINATED TO INDUSTRIES WHO MAY WISH TO USE THEM, AND TO ENABLE INDUSTRY TO MAKE CONTACT WITH RESEARCHERS WHOSE EXPERTISE MAY BE OF INTEREST TO THEM? HOW MUCH RESPONSIBILITY FOR THIS IS DELEGATED TO THE INSTITUTION IN WHICH RESEARCH IS CARRIED OUT? COULD YOU GIVE AN ESTIMATE OF THE INVESTMENT IN THESE ARRANGEMENTS?

In 1986 the Council set up a Central Commercial Office with the remit of formulating, implementing and monitoring commercial and technology interaction policies, and of establishing procedures and guidelines for commercial activities. Commercial Officers have been appointed at each institute; these officers and their units have delegated responsibility for increasing external funding and for technology interactions at their institutes.

Commercial Officers seek to ensure that IP is protected and to transfer technology to customers by means of patent and licensing agents, technology interaction agencies (e.g., BTG) and direct contact with relevant industrial and venture capital companies (e.g., Agricultural Genetics Company Limited and Pharmaceutical Proteins Limited). But AFRC also has many technology transfer routes for IP which need not or cannot be protected. One of the most important is the transfer to practice of "know-how" emerging from improved understanding of basic processes in plants, animals, micro-organisms, soils, etc. The principal product of these studies is information. This diffuses through various formal and informal channels to audiences which range from those who are just generally interested to very specific end users. The practical options arising from this incremental know-how undoubtedly has benefitted and continues to benefit the agriculture and food industries. Institute Associations are a good example, where members are entitled to attend open days and seminars and receive information packages. Other technology interactions involve:

- Preferred papers in scientific journals.
- AFRC and institute annual and periodic reports.
- Articles in popular press and journals.
- Exhibits at the "Royal" and other shows.
- Presentations at scientific conferences and seminars.
- Agricultural and horticultural levy bodies.
- Agricultural consultants (e.g., ADAS).

It is very difficult to cost the investment in these arrangements, particularly as many of them are not designed solely for the purpose of disseminating information to industry. However, a very rough estimate, based on the number of commercial staff involved, is £0.5 million.

Dissemination of information, and technology interaction with industry is being encouraged by incentive schemes. Current Council policy is that income from exploitation is retained by institutes up to a threshold of 10 per cent of their individual annual cash limits. Also, Council is considering a range of mechanisms to encourage and reward invention and exploitation.

DO YOU HAVE A POLICY ON IPR? WHAT ARRANGEMENTS HAVE YOU FOR ENSURING THAT DEVELOPMENTS RECEIVE IPR PROTECTION, WHEN APPROPRIATE?

Since the removal of BTG's monopoly rights to IP in 1986, the Research Councils have been responsible for managing IP arising from their own research programmes. Since then AFRC has developed its own approaches to managing IP. The primary aims are to transfer technology by the most appropriate and efficient route and to maximise exploitation income. Responsibilities vary according to the funding sources (e.g., Science Budget, MAFF or industry) and where the research is undertaken (e.g., AFRC institute or HEI).

AFRC Science Budget Funded Work—Higher Education Institution Programmes

The Research Councils adopt a common approach to the transfer of IP and responsibility for exploitation to universities and other higher education institutions. Universities retain the IP and any income from exploitation arising from standard AFRC research grants. The effectiveness of HEI arrangements has been monitored by an Inter-Research Council Exploitation Scrutiny Group. In the case of major co-ordinated programmes involving AFRC institutes and HEIs, e.g., Transgenic Animals and BSE, the institution employing the inventor retains the IP and is responsible for its exploitation. Revenue received by institutes is retained by them but revenue received by HEIs is shared with AFRC.

AFRC Science Budget Funded Work—Institute Programmes

IP arising from Science Budget funded programmes, together with responsibility for its exploitation, has been passed to institutes. A flexible approach to exploitation is adopted, guided by the principle that industry and commerce are generally better-placed than the scientific community to make commercial judgments. IP may be assigned, or licensed, on an exclusive or non-exclusive basis direct to industry; or it may be assigned technology transfer to agencies such as BTG to exploit on AFRC's behalf.

MAFF Funded Work

Under the current Memorandum of Understanding with MAFF, all IP arising from MAFF commissioned work at AFRC institutes is assigned to the Ministry. The responsibility for identifying potential IP rests primarily with institutes' Commercial Officers and with the scientific staff employed on MAFF commissions. Appropriate exploitation routes are then decided jointly by MAFF, AFRC and the Institute. MAFF is, however, responsible for implementation. Net exploitation revenue is shared.

Industrially Funded Research

AFRC institutes' contract income covers a wide spectrum of activities; varying from major agreements to minor contacts and consultancies. Here too a flexible, case by case, approach to exploitation is adopted. Most contracts are on at least a full economic cost basis and, under such conditions, IP is usually requested by, and assigned to, the customer. However, revenue sharing arrangements are normally negotiated to reflect the ARFC's contribution of underpinning research and background knowledge.

WHAT IS THE TOTAL INCOME YOU RECEIVE FROM INDUSTRY EACH YEAR (GIVE FIGURES FOR THE LAST DECADE)? PLEASE SHOW INCOME FROM ROYALTIES SEPARATELY AND INDICATE WHAT PORTION OF THIS COMES THROUGH BTG. WHAT PROPORTION COMES FROM UK BASED COMPANIES AND WHAT COMES FROM OVERSEAS? WHAT PROPORTION OF YOUR TOTAL RESEARCH EXPENDITURE DOES THIS REPRESENT?

External funding of research at AFRC institutes covers R&D contracts, grants, sponsored research and consultancies from all sources other than the Science Budget and MAFF commissions, e.g., other Government Departments, EC, Trusts and Foundations, etc. Total income from industry each year normally represents about 50 per cent of income from external sources. The following table shows (i) total external funding, (ii) total income from industry and (iii) industrial income as a percentage of research expenditure at ARFC institutes over the last decade.

	(i) External income £ million	(ii) Income from industry £ million	(iii) (ii) Proportional to research expenditure Per cent
1983-84	4	2	3
1984-85	5	3	4
1985-86	6	3	8
1986-87	10	6	8
1987-88	13	7	8
1988-89	15	8	9
1989-90	16	8	10
1990-91	16	8	10
1991-92	20	10	12
1992-93	24	11	14

The proportion of income from industry which is derived from levy bodies is normally in the region of 20 per cent. Calculating the proportion of industrial income from non-UK sources is more difficult as it is not always possible to establish the nationality of companies. However, our estimate is that about 20 per cent of industrial income is derived from non-UK sources. In addition, of course, AFRC receives income from EC framework programmes which is currently at the level of £4 million per annum.

BTG retained the income from AFRC discoveries up until 1986 and since then it retains all income arising from pre-1986 discoveries. AFRC now receives exploitation income from post-1986 discoveries. This has been incresing steadily and there is a real expectation of substantial income in the relatively near future.

	Exploitation Income £000
1986-87	100
1987-88	200
1988-89	400
1989-90	500
1990-91	500
1991-92	600
1992-93 (estimate)	800

The proportion of those royalties received through BTG are minimal. It is interesting, however, to note that directly attributable income to other bodies (primarily BTG) in 1991-92 in respect of pre-1986 discoveries by AFRC institutes amounted to over £10 million. Similar figures are expected in respect of 1992-93.

PLEASE GIVEN ANY INCOME FROM PATENTS THAT YOU HAVE RECEIVED EACH YEAR SINCE 1983. HOW MANY DEVELOPMENTS WERE PATENTED IN EACH OF THESE YEARS?

Prior to 1986 AFRC did not have the responsibility to patent any of its discoveries nor receive any income generated by them. Since 1986 the details are as follows:

	Patent Income £000	Number of Patents
1986-87	100	3
1987-88	150	6
1988-89	180	14
1989-90	200	10
1990-91	200	23
1991-92	250	18
1992-93	300	42

The reason for the difference in figures for patent income (above) and exploitation income (response to previous question) is mainly due to sales of (unpatented) vaccines and kits by the Council's Institute for Animal Health.

How much interaction with industry takes place at the specific instigation of a company, how much is initiated by researchers and how much arises from ongoing relationships with industry? What form do these relationships take (e.g., commissioned research, Teaching Company Scheme, LINK, CASE studentships)?

Interaction with industry often takes place on an informal basis, e.g., at conferences, seminars, institute open days, with researchers seeking funding opportunities and companies looking for ideas of value. It is difficult to evaluate how much of this interaction is generated by industry and how much by the Council's staff but AFRC is proactive in the early stages.

AFRC attaches great importance to maintaining ongoing relationships with industry. A recent survey showed that "repeat business" at institutes with individual contractors averaged at about 60 per cent. This is a good indicator of customer satisfaction.

Relationships with industry are mainly direct, fully-funded commissioned research by industry, but there is an increasing emphasis on collaborative schemes such as:

- LINK: AFRC is a co-sponsor of 10 of the 32 programmes approved to date and has committed £5.3 million to this scheme.
- CWIS: The AFRC Collaboration with Industry Scheme which follows LINK's principal rules, but operates on a less formal basis and a smaller (project) scale. AFRC has committed £3.4 million to this scheme.
- Co-operative Students.
- Co-operative Research Grants.

These activities are likely to increase in the light of the emphasis on wealth creation in the recent OST White Paper and of the concomitant formation of the Biotechnology and Biological Sciences Research Council.

What are your policies towards time spent on technology transfer activities? How effectively are they implemented?

A pre-requisite to technology transfer is identifying IP. This is the most difficult step. AFRC Commercial Officers, normally ex-scientists, are responsible for identifying IP at their sites and for co-ordinating its protection and exploitation. This involves regular liaison with technology transfer agencies, such as the BTG and the AGC Limited, the MAFF Intellectual Property Liaison Unit and, of course with institute scientists.

However, Commercial Officers are not experts in the whole range of disciplines performed at their institutes and must rely to a large extent on the scientists bringing forward their potential IP. But scientific and business cultures do not always mix. Some scientists resent the intrusive and (apparently) restrictive aspects of potential commercial development and are unco-operative. This attitude has in general changed considerably within AFRC over the last five years, mainly due to a process of education coupled with a developing awareness of financial realities. There is still room for improvement.

The need, therefore, to further increase commitment to technology transfer has been recognised. All staff must realise that it is in the interests of Council, the institutes and themselves to identify IP as it arises and to exploit it. Training and education is being arranged to inculcate a commitment to commercial exploitation, in particular so that institute scientists:

- Will be prepared to identify IP.
- Will be capable of identifying IP.
- Will know what to do if IP emerges in their project.
- Will understand that it need not deal publication of scientific papers to any great extent.
- Will recognise that exploitation of their IP will enhance their career prospects.

AFRC is in the process of appointing consultants to assess our procedures for identification of exploiting intellectual property and technology transfer mechanisms.

Memorandum submitted by the Natural Environment Research Council (20 July 1993)

Summary

The NERC evidence is structured in response to the Committee's request for views on the broad topics of science/industry interactions, on improving science/industry interactions, and on balancing academic and industrial demands. Specific inputs then follow on NERC's technology transfer activities, in response to the six questions raised by the Committee.

NERC's Mission is to promote and support high quality environmental science. It has always been concerned to see the successful application of this science and has developed a range of mechanisms to enable greater contact and dissemination of information between the environmental science base and its users both in government and the business community.

The type and character of interaction with industry will depend on the form of business relationship sought. NERC sees the most fruitful area for further development of science base/industry interactions as likely to be through the delivery of understanding to the private sector, working through the development of long-term partnerships and early involvement of industrial partners in research foresight and programme design.

Success will depend on changes in attitudes and improved communication on the part of both science base and industrial partners. In particular, industry will need to perceive research as a necessary long-term investment and have the professional capability to receive the messages it is being given. The science base will need to be prepared to open up planning to industrial involvement, to communicate with industry in a language it can understand, and to ensure that its reward systems recognise innovation and application in equal terms.

Science base funding is already supporting considerable efforts to improve science/industry links. Government funding for innovation should be available to support some of these science base activities, at least in part.

1. SCIENCE AND INDUSTRY INTERACTIONS

Industry and the Environmental Sciences

1.1 Results from environmental science are applicable to a wide spectrum of industry and commerce. For example, manufacturing industry (where environmental concerns relate to the supply of raw materials, environmental impact of processes and end products, handling of waste, etc.), production industry (e.g., food and forests), resource exploitation industry (e.g., water, mining, oil, gas and other mineral extraction), utilities (e.g., transport, electricity supply) and service industries (e.g., insurance, tourism, amenities). Interaction may be direct or more indirect (e.g., in helping Government set sensible environmental standards and regulation and helping industry foresee and comply with future regulation).

1.2 *Direct environmental science contributions* to industry include:

(i) *Exploitation and management of natural resources:* earth sciences research and geological survey contribute to the competitiveness of the energy and mineral extraction industries, providing vital background to the development of resource exploration and exploitation strategies. Sustainable and cost effective management of water supply and quality, of land for production of food and other crops, of sea and freshwater fisheries, and of the marine, terrestrial and freshwater environment for amenity value and leisure pursuits are all dependent on a sound basis of environmental understanding.

(ii) *Reducing the cost of commercial operations and/or avoiding costly failures:* forecasting of the physical and chemical marine environment has direct benefit in terms of navigation and ship routeing, and in the design and operation of offshore and coastal structures. Geological information, the characterisation and forecasting of extremes events and impacts of weather and climate and the identification of natural hazards, all form essential inputs to the siting of developments on land and the design of buildings and structures. For example, thorough geological site survey and environmental appraisal is needed by civil engineers and the construction industry if costing failures, such as the collapse of the earthfill dam at Carsington, are to be avoided.

(iii) *Development of potentially commercial products and technologies:* environmental research has led to the development of products such as biological pesticides, clonal tree material, vaccines, diagnostic kits and cultures. Technological developments such as the design and production of sophisticated sensors for environmental research purposes have found wider application for operational environmental survey and analysis. NERC has received two Queen's Awards for Technological Achievement: in 1986 for the GLORIA system of underwater surveying using high powered sound beams and in 1990, jointly with VG Elemental, for the development of an ultra-powerful inductively coupled mass spectrometer (ICP-MS) capable of detecting elements at minute concentrations. Mathematical models, software packages and information handling systems developed in the course of environmental research are also now finding commercial application.

(iv) *Environmental risk assessment:* in a tightening regulatory regime, environmental risk assessment is a requirement for many industrial activities. There is also growing interest in the legal and insurance professions in provision of environmental information to underpin their services. Competitive insurance services will, for example, depend on good risk assessments based on the results of environmental research and survey. A digitally based Geo-Hazard Susceptibility Package (GHASP), created by the British Geological Survey to hold information on ground movement investment and subsidence risk is already eliciting interest.

1.3 *Indirect contributions* are made to industrial competitiveness and wealth creation through the role of environmental research and survey informing the process of environmental legislation and regulation. The routes for these inputs:

(i) To government, advising on the scientific basis for regulation and the best environmental options.
(ii) To industry to help them operate effectively within existing regulations.
(iii) To industry to inform their strategic thinking and decision making.

1.4 Compliance with environmental legislation and regulation has the potential to put up business costs. Sound advice is needed to avoid unnecessary over-regulation. Equally, compliance with existing legislation requires industry to have a knowledge of the environmental impact of its processes and products and to take steps to minimise these impacts. Sound scientific advice can provide this knowledge and enable options to be considered. It should prevent costly mistakes being made, for example in solving one environmental problem only to create another.

1.5 Forward looking companies are now including environmental concerns as an integral part of their corporate strategy, and planning strategically to minimise the environmental impact of their production and processes. The concern of industry is not simply to improve its public image or to improve competitiveness in a future legislative environment, but also to be in a position to respond to the lending policies of financial institutions that increasingly take account of environmental performance. Inputs from environmental science to this strategic decision making need to go hand in hand with technological inputs if the best environmental, and cost, options are to be determined.

NERC Interactions with Industry

1.6 The range of NERC interactions with industry and commerce include:

(i) Contracts from industry involving full cost recovery.
(ii) Consortium arrangements often involving a modest amount of seed funding from the science budget.
(iii) The purchase of NERC products (data, maps, software, etc.) by industry.
(iv) Provision of advisory services by the NERC data centres (a particularly important interaction with small and medium sized enterprises—SMEs).
(v) Collaborative research and training partnerships such as LINK, the Extractive Industry Partnership Scheme, NERC targeted studentships and the NERC scheme of Co-operative Awards in the Sciences of the Environment (CASE).
(vi) Networks and user groups aimed at bringing together common interests and complementary skills.
(vii) One to one arrangements with industry such as that between the NERC Institute of Hydrology and Hydraulics Research Ltd to promote complementary expertise in overseas markets.
(viii) Professional contacts at meetings and conferences.
(ix) Industrial inputs into the NERC decision making process through membership of NERC Council and science committees.

NERC also interacts with Government departments who may be acting as proxy customers for industry, particularly in the area of strategic research where the application across a number of sectors can be seen but the customer in an individual industry is not yet ready to fully take it on board.

1.7 A high proportion (some 47 per cent) of the MSc students supported by NERC obtain jobs with industry at the end of their training. Greater industrial involvement in collaborative funding of MSc courses is being encouraged. Schemes are also in place for some industrial involvement in the training of NERC research (PhD) students. The NERC CASE scheme has, for example, been running successfully for a number of years; many of these awards are co-operative with industry and require time to be spent in the industrial workplace. More recently NERC has introduced a new mechanism whereby a small number of tripartite studentships have been awarded to consortia involving industry, a university and a NERC institute; these require at least 40 per cent of the student's time to be spent in the industrial workplace. One result of such initiatives should be to provide young scientists with a more balanced understanding of both industry and the science base.

1.8 Further information on NERC interactions with industry is provided in later sections in response to the Committee's specific questions on the more mechanical aspects of technology transfer.

2. Improving Science/Industry Interactions

2.1 The science base can interact with industry (and other users) in two main ways:

(i) Through delivery of a solution to a market problem.
(ii) Through delivery of understanding to private (and public sector) partners, and working with them to develop the understanding for a product or service which they can then deliver to the marketplace.

2.2 Both routes have their place and, as indicated in para 1.6, NERC already interacts through both routes. However, we believe that further development of science base/industry interactions is likely to be more successful through the delivery of understanding and private sector "partnership" routes. We are currently looking at possible new initiatives in this area.

2.3 Effective development and operation of partnerships requires a sense of shared value and ownership. This will mean involvement of industry at an early stage of research foresight and programme design, and long-term partnerships to develop and exploit effectively the close understanding required for successful technology transfer.

2.4 In some respects this approach parallels that which, historically, operated between NERC and Government departments in the development of long-term strategic science programmes. The more recent move of some departments to focus on their short-term applied needs has reduced the effectiveness of this relationship in terms of meeting longer-term departmental needs.

2.5 Development of effective partnerships with industry will require changes in attitudes and improved communication on the part both of the science base and industrial partners. A number of requirements can be identified including:

(i) For industry to perceive research as a necessary long-term investment and to develop a strategic approach to the identification of their future requirements. This would enable effective industry input into the research foresight activities of Research Councils and the Government's technology foresight activity.

(ii) For the science base to be prepared to open up their planning to industrial involvement and to an open exchange of early ideas (i.e., free from an over zealous application of an IPR protection policy—see also para 4.11).

(iii) For industry to develop the capacity to receive and understand the messages it is getting from the science base. The recent White Paper has proposed the development of new modules on innovation, new product development and management of science and technology within the Master of Business Administration (MBA) and other Business School training. NERC would support this recommendation and, with its experience of using young qualified MBAs and MBA students in its own marketing and communication activities (see para 4.3), would be well placed to contribute to the development of such modules.

(iv) For more training within the science base on, for example, business awareness and planning, market research and negotiation. These are all areas which NERC has already been addressing in-house.

(v) For both industry and the science base to promote the idea of secondments of staff and to see such secondments as a part of the normal pattern of career development both in industry and in the science base. NERC has supported secondments of its own staff, mainly to Government departments, and has recruited staff from industry. Secondments to and from industry are, however, more difficult, partly through lack of knowledge of the opportunities that might be available and the mutual benefits that might be captured. Salary differentials may also be a problem.

(vi) For the science base to communicate its ideas and expertise in a language that industry can understand, and to target such communications appropriately. This presupposes an understanding of different markets and their needs, which comes back to more training within the science base in business awareness, and more contact with industry to learn of their needs. Professional expertise will need to be developed in-house or bought in from outside.

(vii) For academic societies to be encouraged to seek more members from industry and for industrial groups such as the Institute of Directors, British Consultants' Bureau, and the Confederation of British Industry to invite direct participation of academic managers in their affairs.

2.6 Interactions with the larger companies will normally be easier to pursue than with the Small and Medium Sized Enterprises (SMEs). Many SMEs, apart from consultancies and the high technology companies, will have little or no history of research association. The use of networks and bridging organisations, on a local or regional basis, will probably be the only route by which to explore partnership with such companies.

2.7 It should not be seen as a responsibility for the science base alone to help Government achieve its wider objectives of instilling a research culture in industries that do not possess it. The Department of Trade and Industry and other departments acting as proxy for industry should be willing to provide support for science base activities in this area. There is already a high investment of research staff time in seeking to develop interactions with industry but the cultural inertia in many of the potential recipient organisations is such that returns are unlikely to be immediate. The responsibility for trying to overcome this inertia should be a shared one.

2.8 At the end of the day, however, no amount of effort made by the science base and Government will have any effect if there is a lack of receptiveness at the industry end. The lack of scientifically trained people in the senior echelons of British industry is notable compared with other countries. This is an area that needs to be addressed in training and recruitment policies.

3. Balancing Academic and Industrial Demands

3.1 The recent White Paper has provided each Research Council with a revised mission statement which places particular emphasis on "meeting the needs of the users of its research and training outputs, thereby enhancing the UK's industrial competitiveness and quality of life".

3.2 NERC has always been concerned to see the successful application of its research and has made considerable efforts over a number of years to promote links between environmental science and its application, to users in the business community as well as in government. The fact that NERC's commissioned research income has remained reasonably buoyant throughout a period of economic recession is an indication of the success of these efforts.

3.3 However, NERC is also concerned to ensure that the health of the basic underpinning science is sustained. Maintaining a balance of activities that continues to nurture scientific innovation as well as deliver utility requires skilful management both of financial and human resources. Performance measures, reward systems and career prospects need to reflect the equal importance of discovery and application, rather than, as in the past, tending to favour the former. There are already some encouraging signs of the necessary culture change in the science community to allow this to happen.

3.4 Within NERC and its institutes the balance between Science Budget and commissioned activities is monitored closely. Too much dependence on commissioned research, and in particular short-term contract research, within institutes could lead to erosion of the important base of longer-term strategic research and survey that needs to be maintained as a national base from which utility is developed. A single correct balance is hard to define. In 1991-92 in NERC, the proportion of an institute's overall budget derived from commissioned research income ranged from 19 per cent to 75 per cent depending on the institute and its research and survey programme.

4. PROCESSES FOR TECHNOLOGY TRANSFER

Question 1: *What organisational arrangements, if any, are in place to ensure that developments are dissseminated to industries who may wish to use them, and to enable industry to make contact with researchers whose expertise may be of use to them? How much responsibility for this is delegated to the institution with which the research carried out? Could you give an estimates of the investment in these arrangements?*

4.1 A corporate objective of NERC (1993 Corporate Plan) is "to make NERC expertise and facilities, and the results of NERC-supported research available to Government and industry and to promote technology transfer". Specific targets associated with this objective are to:

(i) Review and selectively target national and international markets.
(ii) Participate in collaborative schemes with industry.
(iii) Review and develop marketing systems and aids.
(iv) Raise marketing and business awareness inside NERC.

4.2 Marketing of NERC expertise is a key activity that is spread right across NERC. There is a well developed marketing network involving a corporate activity within the Communications and Commercial Affairs Group (CCA) in Headquarters, and Heads of Marketing in each Science Directorate, with marketing liaison staff located at each site. A NERC Commercial Planning Group has been established to improve planning and co-ordination of cross-NERC marketing and technology transfer activities and linkages between science planning and marketing. A series of internal marketing and business awareness seminars and training courses have been developed to strengthen expertise and to widen knowledge of these issues within NERC.

4.3 Directorate and institute staff are responsible for promoting expertise in their own areas to industrial and other users. The CCA Group in headquarters provides the focus for cross Council marketing activities and also provides advice and services on market research and business planning to the Directorate and institute groups. Young qualified Master's in Business Administration (MBAs), MBA students, and business sandwich course students carry out such studies for these groups. At the same time institute staff are being trained to carry out some of these tasks themselves in the longer term. The use of qualified MBAs and business students in this way is well suited to the needs of NERC. Their exposure to the science culture during their time with NERC will also, help in a small way to input scientific understanding into the wider business community when they move on.

4.4 It is not possible to provide firm estimates of the investment in these arrangements or of the additional effort of scientific project leaders and NERC data centre managers in marketing and selling functions as part of their normal endeavours. Direct investment through those involved in the formal marketing network may be about £1 million per annum. To this would need to be added the unquantified effort of all other groups involved.

4.5 A wide range of different promotional activities are employed in disseminating knowledge of NERC's expertise and results to industrial and other users. These include:

(i) National and local seminars and industrial fora targeted at specific sectors (oil, minerals, water quality and supply, land use, coastal management, etc.).
(ii) Production of special brochures and pamphlets, including the NERC commercial brochure, and institute and special group flyers on NERC expertise and contact points. A copy of the NERC commercial brochure "Environment and Resources—Questions, Answers and Solutions" is attached.[1]

[1]Not printed.

(iii) Customer days at NERC institutes.
(iv) Newsletters.
(v) Participation in exhibitions such as Oceanology International (Brighton).
(vi) Appointment of agents in areas of special interest overseas (currently Taiwan and Asian Development Bank).

4.6 Data and information held by NERC represent a valuable national resource, much of which is of direct value to industrial and other users. In order to ensure full and appropriate access to these data, NERC has set up a number of Designated Data Centres (see Table 1) that act as a focus and repository for environmental data and information and as an interface to NERC expertise. As a part of this process, user-friendly interfaces and data directories are developed to allow easy user access to the data holdings.

Table 1: NERC Designated Data Centres

BODC	British Oceanographic Data Centre
EIC	Environmental Information Centre
NGIS	National Geosciences Information Service
NWA	National Water Archive
AEDC	Antarctic Environmental Data Centre

In the case of NGIS at the NERC British Geological Survey (BGS), some £6 million has been spent since 1989 in developing the Service and in ensuring better access to, and marketing of, the extensive data collections.

Question 2: *Do you have a policy on IPR? What arrangements have you for ensuring that developments receive IPR protection, when appropriate?*

4.7 NERC is currently reviewing its policy on intellectual property. This will update earlier guidance to staff on the procedures to be followed when applying for a patent and the potential for compensation for inventions made by staff members, and will provide further guidance on the protection and exploitation of IPR more generally.

4.8 Intellectual property (IP) generated by NERC manifests itself in many different forms. These include data, software, innovative products and innovative processes. Responsibility for identifying IP rests at the NERC institute level, or in the case of support to universities, with the university and the principal investigator.

4.9 Ownership is influenced by the conditions under which the IP was generated. Thus IP generated from research carried out by NERC institutes and units and financed totally by the Science Budget is the sole property of NERC. Although NERC's aim is to secure ownership from external contractors, the IP ownership for research either partially or fully funded by external parties varies according to the contract conditions negotiated. Ownership of IP generated through NERC funding to universities is vested with the university.

4.10 A variety of mechanisms are used within NERC for protecting IP generated as a result of research in NERC institutes and units. Copyright, patents, trademarks and confidential information are all employed successfully. NERC has independently developed and marketed its IP to secure direct financial benefits, has licensed exploitation rights to other organisations and has undertaken joint-ventures with industrial partners to develop and exploit opportunities based on NERC's IP.

4.11 In some circumstances a free exchange of ideas and knowledge may be of greater benefit to science than over zealous application of an IPR protection policy. For example, free or low cost dissemination of IP may well be an appropriate vehicle for increasing awareness of NERC's capabilities and skills amongst potential future collaborators and contractors in industrial and other user communities. A judgment needs to be made in each case whether increased image and promotion of expertise is likely to be more valuable than potential short-term rewards from commercial exploitation of the IP.

Question 3: *What is the total income you receive from industry each year? Show income from royalties separately, and indicate what portion of this comes through BTG. What proportion comes from UK based companies and what comes from overseas? What proportion of your total research expenditure does this represent?*

4.12 The income received by NERC from industry since 1988-89 is shown in Table 2. Income from such bodies as the National Rivers Authority (NRA) and the UK Atomic Energy Authority (UKAEA) are included in the amounts shown; in 1991-92 such income represented 30 per cent of the total shown.

TABLE 2

NERC Income from Industry (£ million)

	1988-89	1989-90	1990-91	1991-92	1992-93
Income from Industry	4.6	6.9	9.4	13.5	13.2
Percentage of total NERC expenditure	3.6	4.5	5.3	8.0	7.6

4.13 Government departments such as DTI, MAFF and ODA may, in some instances, be seen as proxy customers for industry. It has not been possible to include such factors in the table above.

4.14 It has also not been possible to provide separate figures for income from overseas companies. Although NERC institutes undertake work overseas, much of the income will come from contracts with UK consulting and civil engineers working overseas, from ODA as a proxy customer, from overseas governments, and from development banks.

4.15 NERC does not keep separate records of income from royalties, but the income received by NERC from such agreements is estimated to be low and currently of the order of some £20-£30k per annum. None of this income is received as a result of actions taken by BTG. Examples of current licence/royalty agreements established by NERC include:

ARK Geophysics	:	Gravity and magnetic atlas.
Simon Robertson Ltd	:	Geochemistry; petroleum prospectivity.
W&S Ocean Systems	:	Ship borne wave recorders.
Chelsea Instruments	:	Sea-Soar; bioluminescence sensor.
Environmental Measurements	:	Rain gauge; river level recorder; automatic weather stations.
Oravax	:	Blue tongue antigens; hepatitis B viral antigens.
ICL	:	Water information systems.

Question 4: *Give any income from patents that you have received each year since 1983. How many developments were patented in each of these years?*

4.16 Responsibility for applying for patents rests at the level of the individual NERC institute and the appropriateness of protection through patent application is determined on a case by case basis. At present NERC does not routinely collect information on the numbers of patents held and the income generated from them. This situation is currently being reviewed both within the ongoing review of IPR and as a result of the recognition of the need to generate performance related data that can be linked to technology transfer.

Question 5: *How much interaction with industry takes place at the specific instigation of a company, how much is initiated by researchers and how much arises from ongoing relationships with industry? What form do these relationships take (e.g., commissioned research, Teaching Company Scheme, LINK, CASE studentship)?*

4.17 It is difficult to provide sensible figures that define how interaction with industry is initiated; it will vary between industrial sectors, with the length of association, and with the extent to which the science maps on to the immediate concerns of the industry. Where a clear industrial focus exists some NERC institutes estimate that 60 per cent of their commissioned research is a result of long standing ongoing relations with industry. This figure can fall to around 30 per cent where the industrial interface is more diffuse.

4.18 The majority of NERC's relations with industry in terms of research are in the form of commissioned research contracts. Other collaborative mechanisms used for research and training including LINK, where NERC is involved in research programmes on hydrocarbon reservoirs and on the bioremediation of soil and water, CASE studentships and the small number of new tripartite studentships involving NERC institutes, industry and universities (see also para 1.6). NERC is also developing links in terms of seeking industrial sponsorship for different activities.

Question 6: *What are your policies towards time spent on technology transfer activities? How effectively are these implemented?*

4.19 NERC policy is to encourage technology transfer to all potential users of NERC research and survey. Posts and groups have been created across NERC to develop specific marketing activities (see para 4.2 on the NERC marketing network). Many NERC scientists also spend significant time on marketing and wider technology transfer activities.

4.20 In addition to the range of promotional activities already referred to in para 4.5, some of NERC's targeted research programmes, for example the Farm Forestry Special Topic and the Joint Agriculture and Environment Programme (with AFRC and ESRC), have discussion meetings specifically aimed at technology transfer of the results to user communities.

4.21 Commercial outputs and technology transfer activities are thus a recognised part of NERC scientific activity. They are now specifically included in the staff appraisal process and more generally in output and performance indicators of NERC activities.

Memorandum submitted by Medical Research Council (23 July 1993)

1. *What organisational arrangements, if any, are in place to ensure that developments are disseminated to industries who may wish to use them, and to enable industry to make contact with researchers whose expertise may be of interest to them? How much responsibility for this is delegated to the institution with which research is carried out? Could you give an estimate of the investment in these arrangements?*

The MRC established an Industrial Liaison Group (ILG) in 1982 to foster greater interaction with industry. Consequently when, in 1985, the MRC assumed responsibility for exploitation of its own inventions (i.e., those within MRC's own laboratories), Council already had some mechanisms developed for handling industrial collaboration and exploitation. Since its creation, the size and scope of the group has been steadily extended—crucially, by the recruitment of staff with industrial experience. In 1991, ILG was renamed the Technology Transfer Group (TTG), to reflect that its function had ceased to be simply a liaison role and that it strove to take the lead in relationships between the MRC and industry.

The primary areas of activity of TTG are:

(a) Exploitation of MRC Intellectual Property, including patenting, licensing, and participation in "start-up" companies.

(b) Establishment of collaborative research of scientific interest to Council in which one or more companies fund part or all of an agreed programme of work, usually within MRC laboratories.

(c) Advice to MRC scientists on other relationships they may establish with specific companies —most frequently consultancies.

(d) Advice to MRC Council, and liaison with other public and industrial bodies on policy issues in the broad field of commercial exploitation and academic/industrial collaboration.

In addition, the MRC has established the MRC Collaborative Centre at Mill Hill in North London, which began operating in 1986. The Centre was set up specifically to undertake collaborative projects with industry and to participate in technology transfer using laboratory based staff. The Centre received a capital investment from the MRC of £2.8 million over five years for building refurbishment. It has operated at a surplus, amounting cumulatively to more than £600,000. An important recent Council decision has been to incorporate the Centre as an MRC-owned technology transfer company with charitable status. Working capital for the company, amounting to the Centre's cumulative operational surplus, was at the same time endowed to the company. The Centre's management reports to an MRC appointed Board and integrates the Centre's activities with broader MRC exploitation policy.

The Centre has become an international focus for technology transfer. To date 33 contracts have been executed: 12 from British industry whilst the remainder are from German, Swiss, US and Japanese companies. Total secure income from contracts is now £11.5 million. Annual income is expected to rise from £3.3 million in 1992 to £4.5 million in 1995. The Centre currently employs 42 staff and plays host to a further 10 visiting company scientists.

A number of the Council's research institutes and units have scientific or administrative staff with experience in commercial exploitation matters who can provide day-to-day advice locally; there is, of course, substantial interaction between these individuals and TTG.

The cost of the Technology Transfer Group in staff terms is around £320K per annum.

2. *Do you have a policy on IPR? What arrangements have you for ensuring that developments receive IPR protection, when appropriate?*

MRC is the beneficial owner of all intellectural property arising from inventions in MRC research institutes and units. Our broad objective is to license Intellectural Property Rights (IPR) to a partner or partners who will exploit the knowledge to spread healthcare and economic benefits as widely as possible. To this end, IPR based upon "enabling technology" are usually licensed on a non-exclusive basis. In contrast, for specific technologies, it is usually necessary and appropriate to complete exclusive licensing arrangements in order to obtain the commitment from an industrial partner to exploit the technology. Historically, licensing arrangements have usually been completed with established companies. In recent years MRC has also licensed its IPR through participation in the creation of "start-up R&D companies' (or working with existing "start-ups") with generally encouraging results. The choice of the exploitation route requires case-by-case judgment in which the Technology Transfer Group works in partnership with the originating scientist(s).

MRC files patents in its own name when there is reason to believe that an invention is technically eligible to be patented and that the IPR conferred by the parent are likely to aid development of effective healthcare or other products and return income in excess of the cost incurred by patenting and licensing of the patent.

3.-4. *What is the total income you receive from industry each year (give figures for the past decade)? Please show income from royalites separately, and indicate what portion of this comes through BTG. What proportion comes from UK based companies and what comes from overseas? What proportion of your total research expenditure does this represent?*

Please give any income from patents that you have received each year since 1983. How many developments were patented in each of these years?

The attached table[1] sets out these details insofar as they are appropriate. The Committee should note that in the "healthcare" industries, development times usually exceed a decade and often more. As MRC has only taken responsibility for is own exploitation since 1985, products based on MRC IPR and licensed since 1985 and still in development. It is reasonable to expect significant growth in royalty income from the mid-1990s

[1]See page 63.

onward. In the interim, income has been dominated by "up-front" payments at the time of licensing, and not sustained royalty income from sales of products. Consequently, income currently fluctuates but should move to a steadier and growing level with time.

5. *How much interaction with industry takes place at the specific instigation of a company, how much is initiated by researchers and how much arises from ongoing relationships with industry? What form do these relationships take (e.g., commissioned research, Teaching Company Scheme, LINK, CASE studentship)?*

In the case of collaborative research, it is difficult to provide figures on the "instigating" parties. Initial discussions on specific cases will frequently be between senior MRC and company scientists, but the Technology Transfer Group and MRC Collaborative Centre maintain regular contact with most of the major UK pharmaceutical and biotechnology firms. Licensing is normally the result of MRC rather than company initiative. Most of the interaction of MRC's own institutes and units with industry have arisen outside any predetermined structure or scheme although there is well-established good practice and guidance relating to the terms and conduct of collaborations, consultancies, etc.

Although a minor component, the LINK Protein Engineering Programme has been helpful in the establishment of substantial innovative projects at the MRC Cambridge Centre for Protein Engineering. MRC also participates in two other LINK Programmes: Selective Drug Delivery and Targeting and Bio Medical Implants. In these cases MRC support has been in the form of grants to universities collaborating with industry.

Two other schemes are:

(a) *Co-operative Grants*
The MRC operates a scheme to support projects within universities in which a selected industrial partner also contributes its expertise and resources including some additional funding.

(b) *Collaborative awards*
Modelled on the SERC's CASE scheme, these are studentships for projects involving collaboration with a defined industrial partner. The MRC provides the major component of the funding with additional support from the industrial partner. Some of the students are based in MRC institutes and units but most are placed in University departments.

(c) *Specialised specific arrangements*
In addition to the general schemes, MRC has established both a Nutrition Forum and a Toxicology Forum to aid working with industry in these defined fields.

6. *What are your policies towards time spent on technology transfer activities? How effectively are these implemented?*

In view of the Council's mission to promote research which has as its ultimate objective the maintenance and improvement of human health, great importance is attached by the MRC to its relations with industry and staff are positively encouraged to participate in the exploitation process. Naturally, the primary role of the MRC's scientific staff is to conduct research; however, it is recognised that for technology transfer to be conducted successfully scientific staff will usually have to spend time on discussion and formulation of collaborative projects with commercial partners, advise on preparation and prosecution of patent applications, and take up consultancies with companies. The MRC facilitates this process through the staff of the Technology Transfer Group dedicated to these activities.

While the approval of MRC management is required before staff members may enter into consultancies, they are very much encouraged, and staff are allowed to retain fees in full. The scope of such consultancies is usually to advise industrial companies on:

— Their ongoing programmes.
— Areas in which new R&D programmes might be launched.
— Developments within science pertinent to the companies' R&D.

Currently around 100 MRC staff hold consultancies with industry. The MRC regards consultancies as quite distinct from collaborative work within its establishments, and also distrinct from the assistance which our inventors give to MRC in the exploitation of MRC intellectual property. The MRC operates an awards to inventors scheme which provides substantial personal rewards to inventors and a share of income to the establishments in which they work, and adds both to motivation and prestige.

B. Comments on questions raised in the press notice (no. 9 of session 1992-93)

1. *What is the relationship between the Science Base and industrial innovation?*

Industrial competitiveness is increasingly dependent on the willingness and skill of individual companies to recognise early the "breakthrough" opportunities that follow from fundamental advances made within the Science Base. Within academia and industry there needs to be mutual respect and recognition of the benefits which follow effective relationships and the highly dynamic and interactive nature of these relationships. Experience has, however, shown how readily specific relationships can flourish or flounder depending upon the basis, the terms and conditions, on which they are established. Each side needs to appreciate the other's objectives and the different constraints and environment in which each operates.

While we recognise that in the healthcare field there is an unusually long time span (a decade or more) between original invention and eventual marketed products, we believe that in practice most exploitation of Science Base research is a long-term process and both working relationships and formal agreements need to reflect this. There are bound to be disappointments—for in every country only a minority of promising research results lead to commercial success—and occasional setbacks in the development stages are very probable. The Massachusetts Institute of Technology, which is highly regarded for its exploitation achievements, believes that licensing of one of three patents filed represents a very high success rate. Financial returns usually follow some considerable time after the investment of resources into the technology transfer process. The Science Base in particular needs to recognise that successful technology transfer is often a complex and arduous process; it should not nurture unrealistic expectations and should be prepared to invest time and effort in continuing interaction with collaborators and licensees. The term "interaction" here is not used lightly. Technology transfer is not a simple linear process—a straightforward handling over from academia to industry—but involves continuing links and transmission of knowledge, awareness and mutual understanding in both directions.

2. *Are the mechanisms for technology transfer and interaction between the science base and industry effective? How could they be improved?*

In the context of the MRC techology transfer includes both arrangements for the transfer of specific technology between MRC's own laboratories and industry, and more general measures to establish a climate which fosters both motivation and opportunity for technology transfer. The aim is to develop a culture which includes thinking about the applicability/exploitation of results (consistent with a mission-oriented organisation) and exposure to industrial personnel and industry's scientific strengths both in the work-place and through the HQ office. Also of fundamental importance is the contribution the MRC makes to technology transfer through the training of technically competent staff for employment in the healthcare industry, etc.

While we consider our own mechanisms for technology transfer to be effective, they can be improved. The MRC has identified the following ways of extending its relationships with industry:

— The single most important issue remains the need further to raise awareness amongst MRC scientists of the opportunities and obligations they have to work with industry in pursuit of the MRC's objectives. This aim will be addressed by a combination of: presentations to MRC units on interaction with industry; circulation of information to all MRC scientists and administrators advising on working with industry and providing illustrations examples of good practice; and a "case study analysis" conference.

— The demand of most Patent Offices, the major exception being the USA, that patents be filed prior to any publication inevitably leads to hurried decisions on patenting, and consequently exposes inventing organisations to errors. This is a particular danger in basic research; the importance of basic research findings usually takes time to become apparent. The MRC will continue to conduct thorough examination of patenting decisions and seek to learn from accumulating knowledge; the MRC strongly supports the introducation of the 12-month "period of grace" available to inventors in the US system.

— Experience in the USA, and more recently within the MRC, has illustrated how effectively "start-up" R&D companies can advance new research findings through applied research and early development. The UK lags behind the USA in the creation of these companies. The MRC is eager to do what it can to rectify this deficit. Recent progress to create constructive relationships with Venture Capital and other sources of funding will be maintained, and extended. The MRC will work with others to persuade Government that steps should be taken to foster the climate for "start-up" R&D companies, e.g., creation of an "exit-route" for the investors. The MRC will also use its experience in partnership with others to assist in the creation of new companies, when it has cause to believe that suitable IPR exists, and that its exploitation objective will be well served through this route.

— The MRC Collaborative Centre has made major contributions to MRC/industry relationships and technology transfer. The principles of the Centre should be used to create new Centres in other places of major MRC research investment. The MRC has initiated, in collaboration with Scottish Enterprises and Lothian and Edinburgh Enterprises Ltd, an analysis of the potential for creating a new Centre in the Edinburgh area. The MRC also intends to start a similar process to establish the issues around the extension of the present Collaborative Centre into additional laboratory space in the Cambridge area.

While we have highlighted above the (in our view generally successful) mechanisms which MRC has established, and the ways to improve these mechanisms, we do not suggest that there are necessarily applicable throughout the Science Base. Indeed we are sceptical of any search for universal panaceas, and believe the widely differing disciplines and institutions within the science base require differing systems and approaches. When there is scope for general measures to improve technology transfer, we consider the Anderson report on Intellectual Property in the Public Sector generally provides good analysis of problems, and we would support most of its recommendations.

The above focuses on technology transfer to industry. Clearly the MRC also has a strong interest in the take-up of its findings in a clinical context. In addition to the dissemination of results of MRC research through professional journals, the MRC is now producing annually a list of MRC research results relevant to the NHS, forging effective links with NHS Information Systems and collaborating with NHS Regions to set up "implementation" studies to evaluate the most effective approach to adopting the results of the MRC research.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

Within the MRC our technology transfer operations are run by a mix of recruits from industry and venture capital, together with former research scientists and generalist administrators. We have sought to create a balanced team with broad experience. This is possible because:

(i) The MRC's mission delimits the area of science to be covered to something manageable.
(ii) The MRC supports a sufficiently extensive programme of work to support a team of critical mass.
(iii) The MRC recognised from the outset that significant financial returns would be delayed and has been prepared to underwrite the early costs of an active technology transfer process.

In contrast, many Universities are required to work in a broad range of science and technology, often without significant scale in any area. Consequently, it is difficult, or even impossible, to create a body of expertise for technology transfer in the defined areas of University expertise. There is also a lack of funds to support the technology transfer activities of the universities. Successful exploitation requires heavy investment in staff and in patenting and legal costs, and most academic institutions will be unable to finance a professional technology transfer *ab initio* from royalty income alone.

We detect no lack of competent personnel within the UK industrial sector with which the MRC normally collaborates. However we doubt whether in general posts in R&D, production and management in UK manufacturing enjoy the same status, within the country at large, that would be the case with overseas competitors. An image of being second rate, socially inferior occupations (however misconceived) will have an effect on recruitment and impact within a company.

4.7 *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?

Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?

Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder this process?

With regard to the more general questions of industrial innovation, the MRC cannot comment on broad economic issues. The MRC's interactions with UK industry are predominantly with the biotechnology and pharmaceutical sectors, neither of which are typical of British industry overall. The UK pharmaceutical industry has been remarkably successful over the past decade, and it is this sector which is most obviously prepared to invest heavily in long-term R&D (whether in-house or in academic collaboration). Moreover, all biotech companies, almost by definition, regard innovation as their lifeblood; they all think in terms of technological development and markets on a world-wide basis and all look to the long term. We question whether the UK financial markets are properly geared to the needs of the biotech industry; we have in mind in particular restrictions on early public flotation of a start-up company in advance of profitability and specific products, so deferring risk investment in the early phases. There seems little doubt that this impediment is encouraging UK biotech companies to establish a US base, or merger with US firms.

TABLE

Income from grants, industry, BTG and royalty, and patents filed

Financial year	Income from industry £	Total MRC income (Grant-in-Aid) £	BTG[1] income £	Royalty[2] income £	Patents filed
1982-83	586,913	112,992,755		35,326	13
1983-84	646,000	119,770,602	142,638	56,810	21
1984-85	927,866	123,726,839	(1982-86)	66,615	24
1985-86	725,554	128,996,000		55,482	30
1986-87	2,400,000	137,603,000	61,846	143,154	28
1987-88	4,400,000	148,965,000	227,024	118,300	15
1988-89	5,000,000	163,012,000	71,081	507,651	25
1989-90	3,000,000	190,816,000	99,134	840,905	25
1990-91	4,500,000	203,422,000	41,680	540,710	27
1991-92	5,300,000	227,519,000	89,079	541,607	22

[1] This represents income received by the MRC (for allocation to inventors) from the exploitation of MRC-generated inventions by BTG and not the revenue earned by BTG itself from such inventions.

[2] Prior to the removal of BTG's monopoly in 1985, the only other source of royalty income for the MRC consisted of Celltech Ltd who, by agreement with BTG, had first option on inventions in specific fields. Other than this, the MRC had little involvement in licensing before 1986, and most royalty income to date represents royalties on research reagents, instrumentation and software which can be marketed relatively quickly. Development of therapeutic products from patented MRC inventions necessarily takes longer and substantial royalties from such products are not expected for several years. High income in the years 1988-90 represents licence fees for one particular case rather than any overall trend. It should also be noted that MRC's role in the creation of new companies has led to shareholdings rather than payment of "upfront" licensing fees. These shareholdings have potential for very significant exploitation income to MRC in the medium to long term.

Memorandum submitted by the Economic and Social Research Council (19 August 1993)

TECHNOLOGY TRANSFER AND THE ESRC

In line with the White Paper's new mission statement for the Research Councils, the ESRC has a strong commitment to fostering collaboration between social science researchers and industry, complementing efforts by higher education institutions and individual or groups of researchers, and of supporting research which is policy relevant and addresses the needs of practitioners. The Council also sees dissemination of research findings in forms which are accessible to those outside academia as an important element in this endeavour.

1. *Organisational Arrangements for Dissemination of research findings to industry*

The effective communication of research findings to a wide constituency is an important mechanism for raising general awareness of issues of innovation and technological change. By drawing the attention of potential users and policy makers to significant research results, interest is raised and potential collaboration and co-operation could be facilitated. However the form in which research is presented in academic fora is often inappropriate to the needs of industry. In addition, academic publications sometimes favour papers which address an academic research agenda, rather than that of user communities.

In addition, opportunities for discussion between academics and practitioners helps to establish a climate of trust and enables users to contribute to research in progress and possible future research agendas. The ESRC funds a number of seminars, workshops and conferences, as well as groups such as the Commission on Management Research some of whose members come from industry. Such activities bring together researchers and users in this way. The Council also encourages academic institutions to produce user-relevant and accessible material on ESRC-funded research. Attention is paid to proposals for dissemination when assessing applications and when completed projects are evaluated.

The ESRC, through its information Division, produces publications based on many areas of funded research which are aimed at a non academic audience. In addition, press releases accompany the more significant areas of research, and the Council has a good record of attracting media interest in the work of researchers it funds. General requests for further information from business compares favourably with other categories, being the second largest grouping. An enquiry analysis for the period 1 April 1993 to 30 June 1993 gave the following results:

Category	Number of Requests	Per cent
Higher Education	532	43
Media	90	8
Government	136	12
BUSINESS	165	14
General Public	123	11
Voluntary Organisations	27	3
Book Co/Libraries	42	4
International	46	5

The number of requests for information from business is higher as a percentage of total requests for specific initiatives relating to industry. An example of this is the information pack on the Small Businesses Research Programme which was launched in 1989. The major findings and policy implications of each project are outlined in accessible form. Since the pack was produced, of the 656 requests, 142 have been from business (21.6 per cent, the largest category).

The Information Division commits a significant proportion of the Council's Central Communications Budget of £400k to the dissemination of research which addresses user needs. The Division takes a pro-active approach and has established target mailing databases of individuals in business and industry, in addition to established contacts with umbrella organisations such as the CBI. Additionally, the Division sends press releases on new research initiatives and significant research findings to specialist journals which have a readership in particular industrial sectors.

A major initiative on innovation, the Innovation Agenda, was launched by the ESRC in 1993; a publicity campaign designed to address recent ESRC-supported research to the needs of policy makers in both business and government. Central to this has been a series of high level seminars bringing together senior industrialists, MPs, government policy makers, and professional associations. The exercise has attracted considerable attention amongst these audiences and has received widespread media coverage. Updates are regularly published on significant research issues and findings, which are widely disseminated. The largest number of enquiries on innovation in response to the Innovation Agenda have been from business (28.2 per cent).

The published seminar papers are:

"Government Policy and Innovation"
Professor Paul Stoneman
Warwick University Business School

"Why British Research Matters (to Britain)"
Professor Keith Pavitt
Science Policy Research Unit, University of Sussex

"Innovation, Technology and Competitive Strategy"
Professor John Kay
London Business School.

"The Innovative Organisation: Organisational Change and Competitive Advantage"
Professor Richard Scase
University of Kent, Canterbury

Innovation and the Social Sciences
Professor Howard Newby
Chairman, ESRC

Three innovation updates have been produced. These are:

(1) Urban and Regional Innovation Policy.
(2) Regenerating British Industry—An Agenda for Management.
(3) The Role of Scientists and Engineers in Technological Change.

2. *ESRC Income from Industry*

The Council's income from industry averaged 0.45 per cent over the past ten years. This is accounted for by the fact that the ESRC does not have its own research institutions.

ESRC Centres are autonomous higher education institutes in receipt of Council funds for specific programmes of research. Monies which the Centres receive as a result of contract research and consultancies for industry do not, therefore, pass through the Council's books.

A detailed breakdown of income from UK-based and Overseas-based industry from 1983-84 to 1992-93 is given in Annex 1.

3. *Instigating Interaction between Academic Research and Industry*

The ESRC sees its role as that of a catalyst for dialogue, co-operation and collaboration, rather than directing the nature of relationships between social science and industry or creating formal institutional structures. This is based on a belief in the desirability of a flexible approach reflecting the differing needs and priorities of different sectors and firms within industry, and researchers and institutions within academe, and the maintenance of a degree of autonomy for both sides.

The Council encourages dialogue through seminars, workshops and conferences, and a number of Research Centres and Programmes which the Council contributes funds to, are working in close partnership with industry. The ESRC has business representatives on its various Boards, and also engages in dissemination to business and government through its Information Division and Business Links Office, and publicises research findings with important practice and policy implications. Researchers funded by the Council are encouraged to consider presenting their research findings in forms which are appropriate to users and policy-makers, as well as to an academic audience.

The difficulties of achieving good quality relationships between researchers and industry should not be underestimated, and require mutual cultural acceptance, communicative partnerships, open exchange of ideas, research which is both of academic excellence and relevance and direction, and effective delivery of results. Building trust is extremely important, and some academics remain concerned that their intellectual agenda may not be valued by business. Similarly, some in the business community remain sceptical of the practical relevance of university-based research.

Collaboration in the natural sciences has been better documented than that between social science and industry. Largely, however, the success factors are similar, but there are two important exceptions. Firstly, social scientists may need access to all levels of an organisation, and financial independence may be essential to gain the trust and co-operation of employees. Autonomy also helps both researchers and management reduce understandable concerns about confidentiality and potential business disruption. Secondly, there is a lack of a clearly defined peer group within business which can easily relate to the social scientist. This lack of an obvious network of partners, and the need for sensitivity on the part of researchers calls for a carefully thought out approach.

The ESRC is actively looking at ways of forging links between social scientists and industry, not only with regard to the results of research, but also in actually contributing to developing proposals for new programmes of research and to the agenda for future research. The Council's network of business contacts is growing, and there are plans to expand this through, for example, further subject focused seminars in areas of business interest.

The Council's *Business Links Office* was established in 1991. In response to the *ad hoc* nature of relationships with business, the Business Links Office is responsible for developing ESRC policy on its relations with the business community, and to identify and co-ordinate opportunities for improving this relationship across a range of Council activities. Its role is not to act as a broker for all academics and businesses, but relates primarily to business organisations such as the Confederation of British Industry, British Institute of Management, Business in the Community, and the Strategic Planning Society, rather than individual companies. The ESRC has found no reluctance from the business community to engage in discussions.

The Business Links Office, and Steering Group's objectives are to raise awareness of the potential value of quality social science research; fostering more collaboration between business and social science in universities and independent research institutes; increasing the ESRC's understanding of the social science research and manpower needs of business; and promoting good practice in the conduct of research on, for and with business. In addition, the Office can play a valuable role in monitoring the business community's research agenda, and fostering understanding and sensitising researchers to the business dimension of their work.

Practical outcomes of contacts established by the Office include joint research publicity with the Institute of Management, an "innovation" network with the CBI, and practitioner input to the Commission for Management Research. The Council is also committed to encouraging closer links with business in developing proposals for new research under the programmes mode of funding.

In 1992, the Office organised a *Director's Forum*, at which business representatives were invited to discuss future research needs, together with academics and policy makers, and to explore the nature of the relationship between business and academia. Opportunities for dialogue of this kind such as seminars and workshops can be valuable opportunities to bridge the gap between the two communities.

Senior directors presented a range of ideas to the ESRC both on problems and issues requiring further social science research, and on means of improving knowledge generation and exchange. The dialogue between Social Science and Business: Forum participants recognised that social science has a key role to play in understanding the reasons for, and bridging the gap between business and academia. The latter is essential, as rapid social, technologial and economic change is forcing an increase in the knowledge and skills required to harness and understand the forces underlying business success and failure. Research Council funding is fiercely competitive, ensuring a degree of excellence in academic research which can be of tremendous value to industry. To gain from this, however there is a need for mutual cultural acceptance; communicative partnerships; open exchange of ideas; research relevance, excellence and direction; innovative methods of study; and effective delivery of results.

Business has an important role in research design and management through the exchange of experience, opportunities, data and information. Key to this is improved access to organisations and their ideas to act as "research laboratories" for social scientists. There is a need to re-appraise the context, training, motivation, outlook and expectations of both researchers and research organisations, in turn some practitioners remain sceptical of the value of basic and strategic social science (as opposed to the national and technological sciences) research. Business should be able to alert academia to new issues and concerns, and social science should in turn respond by helping to shape them into researchable topics, and contribute to the analysis of past mistakes.

Unlike other research councils, the ESRC does not have its own research institutes. The Council's research centres (funded under our Centres mode) are independent academic institutions and initiate their own contracts with industry and other users which are separate from the research for which the ESRC supplies core funding. A number of our Centres have substantial links with industry through contract research, and the Council actively encourages such relationships. An example of this is:

Centre on Science, Technology, Energy and Environment Policy (CSTEEP).
Science Policy Research Unit, University of Sussex—ESRC funding (1984-97).

CSTEEP's objectives include exploring the nature, determinants and economic impact of innovative activities in industry; analysing innovative activities in relation to international trade and production, to industrial structures, and to firm behaviour, and contributing to theory and policy formation at the level of the firm, industry and country, energy and environmental issues relate to industry.

In addition to ESRC funding, the Centre's Energy Group receives support via the SPRU "Energy Club", established in 1971 as the result of a collaborative project with BP. Ten industrial sponsors and the DTI contribute funds for research. These include British Coal, British Gas, British Nuclear Fuels, Esso, National Grid, National Power, Nuclear Electric, PowerGen and Shell. An advisory committee comprising up to three representatives from each of the sponsors meets bi-annually to review research progress and proposals. The research agenda is set by the Energy Group at SPUR in consultation with sponsors.

Club sponsors receive copies of all the main research papers before publication, and participate in seminars and conferences.

Ad-hoc bilateral contact with sponsors' senior staff is frequent, and highly valued by both parties in keeping pace with key issues in a rapidly changing field.

Key factors in the success of the interaction between CSTEEP and industry are: topicality of the research which is valued by the sponsors, long-term support without reduction of academic independence or research standards, the international standing of SPRU, and the establishment of mutual trust.

Other ESRC funded centres with collaborative research relationships and co-funding arrangements include: Industrial Relations Research Unit (IRRU—University of Warwick), Research Centre on Micro-social Change (RCM-SC—University of Essex), Human Communications Research Centre (HCRC —University of Edinburgh), and the Centre for Economic Performance (CEP—London School of Economics/IRC), and the Northern Ireland Economic Research Centre (NIERC). External sponsorship from business can be substantial in some cases, e.g., CEP received 27.8 per cent of its external funding from this source in the period October 1991—September 1992.

Whether interaction is initiated by industry or academia varies with the research institutions concerned, and there are differences in the nature of the relationships established.

In the case of HCRC, the relationship takes the form of consortia projects. Initially, research staff initiated contacts, but as the Centres representation has grown, approaches are increasingly made by R&D personnel in businesses, particularly IT and Telecommunications. Recently, the Centre was approached by Sharp Laboratories of Europe Ltd, and collaborative research has been undertaken.

In the cases of the IRRU, the collaborative relationship is rarely financial but is based on networking initiated by the researchers.

With the Institute of Educational Technology (ET—Open University) the long-standing relatively unstructured collaborative relationship with the Xerox Corporation's R&D teams in California and Cambridge arose from personal contacts. The availability of Xerox facilities to the researchers, and the input of new ideas to Xerox R&D resulted in successful research.

ANNEX 1

ESRC Income from Industry (£000)

	UK Based		Overseas		Total (UK and Overseas)		
Year	Total	Per cent Total research expenditure	Total	Per cent Total research expenditure	Total	Per cent Total research expenditure	Total research expenditure
1983-84	12	0.1	—	—	12	0.1	11,993
1984-85	14	0.1	—	—	14	0.1	11,198
1985-86	12	0.09	—	—	12	0.09	12,272
1986-87	3	0.02	2	0.03	5	0.03	12,827
1987-88	13	0.09	—	—	13	0.09	14,229
1988-89	90	0.6	—	—	90	0.6	15,502
1989-90	236	1.2	20	—	256	1.3	18,950
1990-91	181	0.8	26	0.1	207	0.9	21,697
1991-92	25	0.1	221	0.9	246	1.0	24,299
1992-93	38	0.1	18	0.05	56	0.1	30,175

Note: ESRC's Income from Royalties is negligible.

HOW TO BALANCE ACADEMIC AND INDUSTRIAL NEEDS WITHIN A RESEARCH INSTITUTION

If properly organised and managed there are considerable benefits to be gained from combining academic research with industrial research in a single institution. The fact that such collaboration often has a poor image in the academic world is due, very often, to a failure to *manage* this process in a active manner. If this does not occur then there certainly is a danger that, in an academeic version of Gresham's Law, short-term quasi-consultancy, "industrial" research will drive out long-term, basic scientific activity. There is, however, nothing inevitable about this process. Industrial-led research activity can enrich basic science, not only financially but also intellectually. Similary, industrial "customers" have much to gain from research conducted in an intellectually stimulating, high-quality research environment.

Management is, however, crucial. Much curiosity-driven research is inherently "divergent" in the sense that an initial research problem frequently ramifies into a wide range of somewhat unpredictable channels of enquiry. Much (though by no means all) industrial research is, on the other hand, "convergent"—i.e., it is more often focussed towards the achievement of a particular (often tangible) output of a certain specification to be delivered by a particular date. Any well managed research institution will attempt to strike a balance between these potentially conflicting interests. In part, at least, a simple awareness of this potential and a determination to take steps to avoid the deleterious consequences will, in themselves, ensure that the entire research enterprise is mutally enriching.

The ESRC has set out guidance for research managers in its recent document, "Forging Research Partnerships". A copy of this is appended. Here it is merely necessary to list the common problems and common benefits which the ESRC document considers in further detail.

The common problems in combining academic and industrial demands can be listed, in no particular order to precedence, as follows:

- The poor image of collaboration, which may lead to a reluctance to participate.
- Financial aspects.
- Maintaining commitment and motivation.
- Staffing constraints.
- Free-rider problem.
- Publication rights and confidentiality.

The ESRC report discusses each of these and how research managers can take steps to minimise the problems arising from them.

However, it is also important to stress the potential benefits, which may be listed as follows:

- Access to resources.
- Extension of research databases.
- Development of a research agenda.

These issues are also elaborated in the ESRC report.

There are also benefits for the business partner:

- Access to independent academic expertise and opinion.
- Potential for commercial application.
- Timeliness of research.

And there are also benefits for the host (academic) institution:
- Public relations and promotion.
- Research opportunities for students.

The factors for success which the ESRC report identifies included:
- Market awareness.
- Business skills.
- Quality and independence of research.
- Overcoming cultural differences.
- Personal relationships.
- Institutional policy.
- Fostering an entrepreneurial attitude.

The ESRC report exemplifies all these points with reference to a number of case studies drawn from a variety of research institutions covering a wide range of (social science) disciplines and research agendas. We have recently published this report, which in turn was based upon research undertaken for the ESRC by Segal, Quince, Wickstead, in order to provide a guide to the academic social science community. We would suggest that there is a need for this kind of publication for researchers in other scientific fields.

Memorandum submitted by the Advisory Board for the Research Councils (20 August 1993)

RESPONSE OF SIR DAVID PHILLIPS

The routes through which the Science Base is translated into innovative and competitive technology

A. TO WHAT EXTENT DOES THE ABRC CONSIDER THE POTENTIAL FOR INDUSTRIAL EXPLOITATION IN MAKING ALLOCATIONS FOR RESEARCH, AND WHAT ARE THE REASONS FOR THIS?

1. The ABRC has developed a set of criteria of the Research Councils and the Board to apply in setting priorities which include internal considerations of excellence, timeliness and pervasiveness, and external ones of exploitability, applicability, and significance for education and training.

2. The key criterion for selecting scientific priorities must be the quality of the proposed research and of the scientists involved. The other most significant criteria are potential exploitability and applicability. Priority setting in practice involves first and foremost the operation of peer review, which enables judgments to be made about the relative merits of research proposals. Peer review is most effective when judging between proposals for research in a relatively narrow research field. It is much harder to judge between equally good, or equally mediocre, projects in, say, geophysics and human genetics. At this level, other considerations have to be brought to bear, and the criteria outlined above are applied.

The Board's advice on scientific priorities and the allocation of resources among the funded bodies is informed by the Board's discussions of science and science policy throughout its yearly cycle of meetings, but it is based particularly on the exhaustive discussion of the Corporate Plan and Forward Look submissions of the Research Councils and other funded bodies.

The Corporate Plans and Forward Look documents submitted by funded bodies are intended: to set out their scientific and management plans for the next few years; to describe how their present expenditure allocations for these years will be spent; to indicate the extent to which such spending will enable corporate and scientific objectives to be met; and to identify how further progress towards these objectives could be achieved should additional funding become available.

The two inter-related purposes of the exercise are:

(a) To enable the ABRC to assess the overall health of the science base in relation to national needs, and the implications for that of the Government's plans for the Science Budget. This forms the basis for the Board's annual *PES advice* to the Chancellor of the Duchy of Lancaster (due in March).

(b) To enable the ABRC to consider the relative merits of the current programmes and future plans of the Research Councils and other funded bodies. This informs the Board's annual advice to the Chancellor on the *allocation* of the Science Budget.

3. With the emphasis in the White Paper on wealth creation and enhancement of the quality of life, greater account will have to be taken of the potential exploitability and applicability of the proposed research.

B. WHAT IS THE RELATIONSHIP BETWEEN THE SCIENCE BASE AND INDUSTRIAL INNOVATION?

4. Before discussing the relationship between the science base and industrial innovation, it is important to be clear about what is meant by "innovation". Innovation in its broadest sense includes both new ways of doing things and new technologies. It can be manifested in a new product design, a new production

process, a new marketing approach, new management methods, or a new way of conducting training. Much innovation involves incremental improvement in a product, process or approach, although some does stem from a significant advance, be it technological, scientific, marketing or managerial.

5. The relationship between the science base and industrial innovation is complex, and inadequately represented by the so-called "linear model" in which ideas originating from basic research lead to the identification of specific applications and hence product and process development. Science contributes to technological development, and technological development in turn influences the course of science. Technology changes our everyday lives, but it can be successfully developed only where there is a market, or where the products are socially desirable or acceptable. Expressed in this way, it is clear that the relationship between science, technology and society is not one-way or linear but inherently interactive. To exploit the science base effectively, the interactive nature of the relationship between science, technology and the economy and society must be recognised.

C. ARE THE MECHANISMS FOR TECHNOLOGY TRANSFER AND INTERACTION BETWEEN THE SCIENCE BASE AND INDUSTRY EFFECTIVE? HOW COULD THEY BE IMPROVED?

6. The phrase "technology transfer", which is an unfortunate linear-sounding phrase, encompasses the transfer not only of directly applicable knowledge, but also the transfer of the background knowledge, research skills, instruments, methods and networks of professional contacts developed by scientists in the course of their research, and can be between the science base and industry and within industry itself.

7. The Research Councils are continually working to sustain and enhance close links with industry, and encourage the mobility of researchers between academia and industry. Such interaction is an integral objective of each Council's planning and management of science and technology, and has become more important following the White Paper which announced the setting up of six new Research Councils with missions orientated towards wealth creation and the enhancement of the quality of life.

8. The following gives a flavour of the current activities of the present Research Councils.

(a) The AFRC sees the interaction with industry as a natural outcome of mission-oriented research, and encourages it through joint research programmes and by entering into joint royalty and profit-sharing agreements with industry and "technology transfer" companies. It is involved in nine of the 31 LINK programmes approved, and also operates its own Collaboration with Industry Scheme (CWIS), which is operated along LINK lines, but on a smaller individual project basis. The Council currently supports over 30 projects at universities and institutes under these collaborative schemes; in 1993-94, the income from industry is estimated to be about £12 million. A major collaboration has been set up with Bayer and Pharmaceutical Proteins Ltd to develop Alpha 1 antitrypsin production in sheep, and the Queen's Award for Technological Achievement was awarded to the Silsoe Research Institute for developing the stripper harvester. There are also three biotechnology companies, which are based on AFRC research: the Agricultural Genetics Company Ltd (plant sciences); Annual Biotechnology Cambridge Ltd (embryo research); and Pharmaceutical Proteins Ltd (transgenic animals).

(b) The ESRC is successfully disseminating the results of social science research, through increased press and professional coverage, through involvement of ESRC-supported researchers in providing policy advice, and through increasing emphasis on links with business and industry. An office and associated information programme to expand business links has been set up, which includes a "Directors Forum" to provide contact with leading industrialists. This office invited Segal Quince Wicksteed Ltd to conduct a survey of best practice in collaborations between social scientists and business, which has recently been published.

(c) The MRC exploits a wide variety of mechanisms for joint working with industry. The Collaborative Centre is self-financing and has now managed over 30 collaborative projects with industrial partners. The Council is considering whether a second Collaborative Centre-like laboratory can be established in Edinburgh. The Council also actively encourages the setting up of start-up companies based on MRC discoveries (for example: Cambridge Antibody Technology which was set up through an MRC Laboratory of Molecular Biology initiative to exploit advances in antibody engineering; and Therexsys, which will exploit intellectual property in the field of gene therapy based on work at the National Institute for Medical Research). The number of research programmes undertaken in collaboration with industry has increased from 42 to 49 in 1992-93. The MRC participates in three LINK programmes.

(d) The NERC is involved in two LINK programmes, and carries out programmes closely related to the needs of industry in areas such as forestry, water quality and resources, hydrocarbon and mineral resources, waste disposal, pollutant transport, land use planning and construction. The Council maintains comprehensive database and advisory services, available to and used by industry across a range of geological, geophysical, marine and terrestrial applications. The Council is currently involved in collaborative research and survey ventures with industry in areas such as geological mapping of the continental shelf (with oil companies), geological hazards on land (with the insurance industry), and genetic engineering systems for pest control (with chemical companies), and collaborates with industry overseas, particularly in areas such as geology and hydrogeology. Many of the NERC's Advanced Courses are industrially relevant; research studentships under the Co-operative Awards in the Science of the Environment scheme involve contracts between universities and industrial and other bodies; and a new targeted studentship scheme is providing a small number of awards to consortia of collaborative partners from industry, universities and NERC institutes.

(e) The SERC spends about £70 million per year on collaborative schemes between HEIs and industry. Within this, the Teaching Company Scheme is funded; more than 5,000 CASE students are supported; the Integrated Graduate Development Scheme, which offers modular training courses tailored to the needs of specific industrial sectors, is being expanded (from eight to 24 programmes by 1994-95); and 25 out of 31 government LINK programmes are supported. In addition, last year, the SERC launched the four-year Parnaby engineering doctorate, based on an industrial project and including intensive course work; and, together with DTI, launched a pilot scheme for postgraduates jointly based at HEIs and industrial research organisations. It is committed to strengthening interactions with the industrial base in order to gain greater knowledge of the long-term needs for industry, and for industry to become more aware of the capabilities of the country's science and engineering base. Interactions at a programme level are already extensive, but greater involvement of industry in top-level policy matters is also being sought.

D. Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?

9. A recent ESRC-funded study from the University of Warwick has examined specifically the impact of scientists and engineers on a firm's technological activities and economic performance. It found that firms that employed a higher proportion of science and engineering graduates at all levels in the company, not just in research, outperformed companies with lower proportions. The study also showed that foreign-owned companies based in the UK had more highly qualified boards and workforces than British-owned firms, and outperformed their UK counterparts in both profits and turnover. All this would seem to indicate that industrial innovation is hindered by a lack of competent personnel.

E. Is innovation by British industry internationally competitive? How should this competitiveness be measured?

10. Innovation alone is unlikely to provide a company with sustainable competitive advantage, as shown by the work of Professor John Kay, Chairman of London Economics. It is usually allied with another source of competitive advantage, e.g., strategic assets (monopolies and licences); reputation (customers are more likely to accept new ideas from a company that they trust); and architecture (internal and/or external relationships that allow the organisation to transfer information and innovations quickly and effectively and to respond rapidly).

11. Measures of competitiveness are not straightforward, but examples of what could be looked at are: technological performance of the UK in terms of patent statistics; and the proportion of the sales of UK-owned firms spent on research and development (or the amount of R&D spend per employee), compared with those in other countries, although this is perhaps more of an indicator of potential inventiveness and hence potential competitiveness.

F. Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?

12. It is often suggested that the short-term attitude of the City, with its concern with current profits, rather than long-term success, has constrained R&D investment and risk-taking innovation by British industry. However, some studies suggest that managerial short-termism is more of a problem, with future benefits of a product or process innovation likely to be underestimated. The employment of greater numbers of scientifically literate people in strategic decision-making roles within a company might help to address this problem.

G. Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?

13. One of the most successful sectors of British industry is the pharmaceutical industry which generates new products by exploiting its research and development. However, as I mentioned above, case studies of successful companies indicate that innovation alone is not usually sufficient to guarantee success. Professor Kay points out that successful innovative companies integrate new technology into their business so that it becomes an organisational asset.

14. Companies that strive to achieve success through innovation should develop strategies for enhancing their innovative capabilities, which recognise the importance of organisational cultures and the need to manage interpersonal networks and communication systems, so that ideas will flow freely across the firm. Present structures and management styles within companies can stifle rather than stimulate the creative process, and flatter hierarchies within organisations might facilitate the flow of knowledge. Media and professional service companies are cited by Dr Richard Scase (University of Kent) as providing good examples of how to achieve competitive advantage through cultivating an innovative culture, as they tend to have flexible, fluid and open channels of communication. In such companies, innovative ideas and attitudes are not isolated within a particular section or department but pervade the entire organisation.

H. WHAT STRUCTURES AND INSTITUTIONS WITHIN THE UK ARE PARTICULARLY HELPFUL IN ENCOURAGING THE PROCESS OF INNOVATION WITHIN THE COMPANY AND WHICH HINDER THIS PROCESS?

15. Some of the points made in answer to questions D, E and G address this question.

Memorandum submitted by Professor J Sizer, Chief Executive of the Scottish Higher Education Funding Council (10 June 1993)

1. INTRODUCTION

1.1 The Scottish Higher Education Funding Council is a relatively new organisation, which only became fully operational on 1 April 1993. Its main task is to fund teaching and research in Scottish higher education institutions. In doing so it seeks to promote the volume and quality of teaching and of research and to ensure adequate accountability for public funds while respecting institutions' positions as autonomous bodies. The Council cannot, at present, directly fund applied research but its aims include the encouragement of a wider funding base in higher education and helping the institutions to meet the needs of the Scottish and UK economies. It intends to review its work in these areas in the light of the Science and Technology White Paper and any subsequent guidance from the Secretary of State for Scotland.

1.2 As noted in the Council's earlier submissions it intends to work closely with other interested organisations, including Scottish Enterprise, in promoting and facilitating the transfer of science and technology know-how from higher education institutions to industry. Some progress had been made in establishing these relationships and the Council will seek to develop them further.

1.3 The Council also recognises the major role of the higher education system in providing and adequate supply of scientists and technologists for industry.

1.4 In that SHEFC provides funds for the support of the science base, but does not directly influence the details of research activity, and is still developing its external relationships, it is not well placed to comment on innovation and technology at this time.

2. THE RELATIONSHIP BETWEEN THE SCIENCE BASE AND INDUSTRIAL INNOVATION

2.1 The funding of facilities for curiosity-driven research across the full range of academic disciplines allows the exploration of idea which might not lead to commercially exploitable items in the short term. Nevertheless, the advantages in knowledge and technique and in theory and practice, can have long-term benefits in more practically based fields.

2.2 The provision of candidates trained in scientific methods, to understand the technology and organisation of industry, gives the industrial base skilled mediators who can translate and develop new and emerging concepts and techniques into profitable products.

2.3 The science base is a dedicated source of detailed, basic knowledge about the workings of the world. It provides both the concept from which industrial innovations can develop and the personnel who have the ability to develop these ideas beyond the theoretical stage. Without the science base industrial innovation would not cease but the opportunities for true innovation, for the interaction of diverse knowledge to produce new insights and new products, would be limited.

3. USE OF APPLIED RESEARCH IN ALLOCATING GRANTS

3.1 On the Council's establishment it received guidance from the Secretary of State for Scotland that it should not fund near-market research but that the ratings given to applied research work in the 1992 UFC Research Assessment Exercise (RAE) could be used to distribute a small amount of recurrent research funding. Very few Scottish Departments submitted applied work for consideration in the RAE. There may be a number of reasons for this, including the problems involved in practice in distinguishing between basic, strategic and applied research and the institutions' prior knowledge of the intention that only a small amount of recurrent research funding should be distributed by reference to ratings for applied research, so, where both ratings were given, a weighted average was used.

3.2 It intended that the issues surrounding the evaluation of applied research will form part of the forthcoming consultation on the next Research Assessment Exercise. Technology transfer may also be covered in the deliberations of the Funding Councils' Joint Working Group on Performance Indicators.

3.3 The institutions' earnings for applied research are counted as part of the volume measure with other forms of research income. Thus success in attracting support for applied work benefits an institution's basic research base. Technology transfer as such was not used in allocating grants, although the externally funded research which, as set out above, figures in the volume measure may often have the added effect of transferring technology. The level of technology transfer activity might be gauged through the institutions' strategic plans.

Memorandum submitted by professor G Davies, Chief Executive of the Higher Education Funding Council for England (12 July 1993)

I write further to my letter of 12 May, in response to your invitation to prepare a submission on behalf of the HEFCE to the Science and Technology Committee in relation to their enquiry on "The Routes through which the science base is translated into innovative and competitive technology".

First, by way of background, I attach a copy of a briefing paper which was prepared on behalf of the Council for submission to the Chancellor of the Duchy of Lancaster in advance of publication of the recent White Paper "Realising our Potential" (Cm2250).[1] This provides an explanation of the nature and purpose of research funding provided by the HEFCE, and I hope that the Committee can take it into account in considering some of the more specific issues which it will be addressing.

In addition I would also like to make the following points.

(a) We strongly endorse the importance of translating basic scientific knowledge into innovative and competitive technology, and believe that universities play a critical part in this through their co-operation with commerce, industry and charities. Measures to promote such translation should not be to the detriment of the science base itself, and we must ensure continuing support for basic and fundamental research which is largely undertaken in the UK by our universities.

(b) The Council pays careful attention to technology transfer and related issues at several points in the process which gives rise to its grant allocations. First, a major factor in our allocation of research funds is the assessment of research quality embodies in the result of successive Research Assessment Exercises, the last of which was completed by the former UFC in 1992. In reaching the assessments of research quality by subject area, full attention was paid to the importance of applied research as well as basic and strategic research. Second, there is a small but significant element in our funding formula which is allocated directly by reference to institutions' success in obtaining contract based research funding from industrial and commercial resources.

(c) I would draw attention to section H of the enclosed submission which deals directly with the issue of technology transfer.

(d) You recognise in your letter that "funding from Funding Councils is allocated to departments rather than projects"; if anything, we would go further than this and say that funding is allocated to *institutions* to undertake research, and is not earmarked to any particular department or subject area. Subject to the proper requirements of accountability, we believe it important that institutions retain a degree of flexibility to allocate the resources we provide on the basis of their own well informed judgements of needs, and I hope that this point is fully drawn out in the enclosed submission.

(e) We will continue to review our research funding methods and policies in the light of the Government's White Paper (Cm2250), and on the basis of our assessment of the needs of the sector.

Please let me know if we can be of any further help to the Committee.

Memorandum submitted by Professor J Andrews, Chief Executive of the Welsh Funding Councils (14 July 1993)

I am replying to your letter of 10 May 1993 regarding the Science and Technology Committee's inquiry into "the routes through which the Science Base is translated into innovative and competitive technology".

The Council, in its response last year on the proposed White Paper on Science and Technology, a copy of which was forwarded to the Committee, did comment on the links between higher education and industry with regard to the exploitation of the Science Base. I reproduce below the relevant extract:

> "Concerns regarding the capacity of an industry, or a firm to innovate and the related quest to improve the links between academia and industry to encourage maximum exploitation of the science base are not new. There is considerable evidence to suggest that the concerns are well placed, the example of the way in which the exploitation of the invention in Britain of liquid crystal

[1]Not printed.

technology was lost to Japan being one of several sad reminders of missed opportunities. Of course in some other areas (all too few) such as chemicals and hydrocarbons, the reverse is true. Here there is an excellent record of continuing strategic research into money-making projects leading to a significant positive trade balance. The reasons for this might bear examination. The Council does not have a direct role to play in this regard, however it feels that it can make a contribution as part of the task given to it by the Secretary of State for Wales to work with HEIs to raise the quality of research in Wales. Part of this task is seen by the Secretary of State as providing support for his economic policies. This points to an HEI contribution to the promotion of enhanced technological competence at regional level. The Centre for Exploitation of Science and Technology in its report on attitudes to innovation in Britain and Germany recommends that the regional dimension to national technology policy needs to be expanded, and this is a theme taken up by the Working Group on Innovation, chaired by Sir John Fairclough, in its recently published report, which advocates the need for a regional focus in creating a climate of innovation. Additionally there is European evidence that well-networked economies where effective interactions take place between firms, and between firms and non-market institutions, work particularly well at regional level. Council would wish to lend its support to the Working Group on Innovation's proposals and hopes that they may be explored in the White Paper. The Council itself intends to pursue the matter in response to the Secretary of State for Wales' request. It has established a working group on research under the chairmanship of Sir John Cadogan, and it is expected that as part of its work, the group will explore ways in which HEIs in Wales may effectively contribute to the enhancement of innovation within the Principality."

I am able to report that the working group on research referred to above has given preliminary consideration to the ways in which higher education institutions may provide support for the Secretary of State for Wales' economic policies. It expects to consult institutions on the subject in autumn of this year. Council is of the view however that innovation, i.e., the translation of science and technology into marketable products, must be seen as the responsibility of industry. Universities are not well placed to carry out this task although there is a role in the provision of training in the management of innovation. It is, however, necessary for industry to be fully aware of where new developments in science and technology are taking place as a prerequisite to apply the process of innovation, and it is at this level that interaction and liaison between higher education and industry must be effective.

You enquire as to whether the Council gives any weight to technology transfer or industrial applicability in allocating grants. Whilst the brief provided by the Secretary of State to the Council at its inauguration in 1992 made clear that the public funds made available to it should only be used to support basic and strategic research; it has allocated grants to institutions awarded an applied rating in the 1992 UFC Research Assessment Exercise. In addition a small proportion of the Council's overall research grant (3 per cent) has been allocated on the basis of the success of institutions in attracting contract research income. Finally, in allocating its initiative monies—for stimulating potential centres of excellence and encouraging selective development of research potential—the Council paid regard to the extent to which the proposals submitted might support economic growth and development and wealth creation.

You will appreciate that the Council, in partnership with its sister councils in England and Scotland will wish to consider how its method for funding research may take account of the White Paper—"Realising Our Potential".

Memorandum submitted by The Amalgamated Engineering and Electrical Union

Obviously, our main interest is in the industrial aspects of the problem under review by the committee and we will confine our comments to those—hopefully they may be useful as there is an overlap between research and development and innovation; and between finance for industry and short-termism.

As a union, we are obviously concerned that certain areas of British industry are not matching the industrial performance of overseas competitors and have given consideration to the most efficient means of correcting those shortcomings.

In our view, the two main failings are in investment in new high-technology machinery and equipment (for decade after decade British investment was two-thirds that of Germany and France and half that of Japan); and in training the highly-skilled workers to operate it.

Coupled with those two key problems are the questions of research and development policies (especially in respect of the diversification out of defence production); and the repeated failure of British industry to exploit the inventions and new ideas of our innovators.

No one can disagree that recent history has seen a catalogue of brilliant British inventions and ideas which British industry has failed to support or develop—yet alone put into production.

If we accept that foreign competitors have a higher level of capital investment, invest more in skills training, and utilise new inventions more effectively; then we need to find out why British management lacks the skills of those overseas—could it be that our educational structure fails to produce their kind of innovative entrepreneurs, and how does our managerial training compare with that in other countries?

An additional problem is that caused by the city's short-termism—where someone does have a brilliant idea, they often cannot go forward with it because it will only bring in a return in the long term and the institutions which normally provide financial backing insist on a short term return on their capital.

Perhaps we *are* producing people with an entrepreneurial spirit but their enterprise is being stifled by lack of financial support.

THE PROBLEMS—INDUSTRIES LOST

Some try to argue that these problems do not really exist, things are not all that bad, all that we need is a little more consumer confidence and things will come right by themselves.

Unfortunately for those who would attempt to pursue such an argument, apart from the new defence situation created by the ending of the cold war, all the problems mentioned have existed for many decades —they are not creations of the present recession.

The British motorcycle industry is a classic example—virtually all replaced by Japanese imports.

The car industry, that small portion which is British owned is up for sale to anyone who wants it. Rover is already 20 per cent owned by Honda of Japan. The list of British car companies which have gone out of business would fill a page.

How is it that so many British companies came to the conclusion that it was not possible to produce cars profitably in this country and closed down; while Japanese manufacturers such as Toyota are building new factories from the bare earth upwards and are confident that they will be selling 200,000 cars per year in a few years' time? Total Japanese UK production is planned to reach 600,000 by 1995, and 1,000,000 by 1999.

No British company would dare to build a brand new car production plant in this way. The British management seems confident of failure while the Japanese management is confident of success—both would be selling to the same market and employing British workers—so why the different attitude?

Another example—over the past few decades, British television manufacturers have gone out of business one by one saying that it is not possible to profitably manufacture television sets in the UK using British employees.

Since then, the Japanese companies have come in and are now producing all the TVs that we need in factories in the UK using British employees. More than this, Britain now has a surplus and is exporting more TVs than it imports for the first time in decades.

A clear pointer that something is seriously wrong in other industries are in the UK import penetration ratios.

These showed that 48 per cent of the textiles consumed in the UK were imported; as were 49 per cent of ships and aircraft; 51 per cent of motor vehicles and parts; 52 per cent of leather goods; 52 per cent of electrical and electronic equipment; 60 per cent of instrument engineering; 69 per cent of man-made fibres; and 95 per cent of office machinery and data processing equipment.

Those latest figures from the May 1993 edition of the Monthly Digest of Statistics relate to *mid-1989* —so one of the first things that needs to be done is to persuade the Department of Trade and Industry to recommence publication of this crucial measure of Britain's industrial performance on a regular and more up-to-date basis.

The DTI should also examine whether it would be possible to break the figures down to individual product groups instead of these blanket groupings.

It is essential to have a regularly published, accurate monitor of industrial performance, otherwise it is impossible to highlight problem areas and find the means to put matters right.

A manufacturing nation should be able to provide the bulk of its own home market—if its industries cannot compete successfully against foreign products "on its own turf", where can they compete?

TRAINING

It is obviously necessary to have highly trained managers at the cutting edge of industry for it is they who will decide what new developments and innovations can be incorporated into the production process of their company.

However, according to a report by NEDO, 55 per cent of manufacturing foremen have no qualifications and only 42 per cent have some form of intermediate vocational training—compared with *93 per cent* in Germany.

The TUC Skills 2000 Report found that only 20 per cent of managers in Britain had a degree or professional qualification. In Germany, the figure is *63 per cent*, while in the USA, it is *85 per cent*.

In respect of employee training the picture is just as bad—on average, British employers spend 0.3 per cent of turnover on training. In comparison in Germany and Japan, the figure is 2 per cent—over six times as much!

In France, employers are required by law to spend a minimum 1.2 per cent of turnover on training. In practice, employers in France have spent much more, some 3 per cent of the payroll last year, on top of government training programmes.

Another factor in their favour is that 66 per cent of 16 to 19-year-olds stay on in education in France compared to only 35 per cent in this country—nearly 80 per cent of their workforce have undergone vocational training.

In Italy the figure is the same, and in Germany, part-time vocational training at a rate of one day a week is compulsory for all 16- to 18-year-olds—nearly 70 per cent of the workforce have undergone skilled vocational training, much of this funded by the German state.

In Japan, 90 per cent of over-16s are in full-time education and training.

In the European Community only Greece sends fewer of its youngsters to college or into training than the UK.

Qualifications are another guide: in Britain every year, approximately 35,000 craftsmen and women gain their qualifications; in France the figure is 92,000 and in Germany, 120,000.

What hope can we have of regaining our international engineering reputation while we only produce 9,000 engineering graduates a year, compared to Japan's *80,000*?

We firmly believe that there is a need for framework legislation in the UK to ensure that training is undertaken or paid for by every employer requiring a skilled workforce in order for their company to prosper.

In our view, there needs to be a training grant/levy system in the UK as is used by our major foreign competitors. There should be a levy on all employers of 0.5 per cent of their payroll to be paid into a training fund—with exemption given to those companies which provide proper training for their employees.

A training levy is the only way to make sure that all employers contribute to the skills creation process —with employers that do spend sufficient on training being exempt from it.

Research & Development

As far as defence diversification is concerned, it is essential for alternative products to be found to make use of the skills and expertise of the workers in the defence industries, as demand for their traditional military output diminishes in the defence review and as a long-term result of the peace dividend.

It is no good those in power hoping this may happen—it needs to be *organised* at government level. There needs to be a dedicated "Defence Diversification Agency" whose function will be to oversee the process and ensure that vital skills are not just dissipated by neglect.

A related problem is that a great proportion of Britain's research and development funding is undertaken by the Government for the purpose of defence (46 per cent)—within the MOD there are over 24,000 staff working in R&D.

There is almost always some form of spin-off which manufacturers can use to advantage for their civilian products (although it is worth noting that the spin-off in the UK is not as great as in other countries).

If the defence reductions merely result in a reduction of that large defence-related Government input into research and development, then many brilliant organisations and some of Britain's best scientific brains will be redundant.

In the United States, the problem is greatly eased by the government involvement in the space programme —which develops a similar technology stimulus to that of military development.

For example, NASA undertakes massively expensive government funded fundamental research which is then passed on to their aerospace companies. Not just space research—NASA has been involved in the development of the "NOTAR" (no tail rotor) helicopter, which has air jets in place of the normal tail rotor which makes the craft much less vulnerable to ground fire.

NASA was also involved in the development of the tilt-rotor aircraft which has extra large propellers and tilts its wing to a vertical position to take off like a helicopter and then returns the wing to a horizontal position for forward flight like a normal aircraft—thereby eliminating the helicopter's major inefficiency. Just two examples from many projects.

Britain has no equivalent to NASA but perhaps serious consideration needs to be given to creating such a fundamental aerospace research organisation in the UK to guarantee continuing Government involvement in R&D, as the defence requirement diminishes.

Aerospace is a key industry in this respect as it is the largest scale utiliser of innovative technology.

A British NASA would act as a magnet to the scientists and highly skilled engineers and technicians displaced from the defence industries by the defence review and would become a centre of excellence for the practical application of all aerospace innovations.

To sum up these brief comments, our view of the situation is that it is not so much necessary to ask where companies are going wrong but much more important to evaluate what the government is not doing which it could do to support those companies which are on the right track and pressure others to move in the proper direction.

Britain needs an industry and technology policy which:

(1) Must contain measures to raise capital investment in high technology equipment to a higher level.
(2) It must contain a programme to increase the percentage of payroll spent on training—both for management and employees.
(3) It must find some alternative to replace the lost government defence spending on research and development.
(4) It must find means to ensure that British inventions and innovations are explored and exploited by British industry.
(5) It must seek measures to eliminate the short-termism of the providers of finance so that UK companies can undertake projects which will only pay back in the long term.

The best British companies are world class and competitive with any and they are fully exploiting the latest available technological innovations—we need to spread this excellence of the few to cover a much wider spectrum of our companies and industries—and the *government* must set up the guiding agencies which will ensure that this happens.

Memorandum submitted by the IPMS inquiry into innovative and competitive technology (16 July 1993)

1. Institution of Professionals, Managers and Specialists (IPMS) is the trade union which represents 90,000 scientific, technical and other specialist staff in the civil service, research councils and other related public organisations and an increasing number of private sector companies.

2. Of particular relevance to this inquiry is the fact that IPMS represents scientific and professional staff in both government research establishments (GREs) and Headquarters divisions and regional offices in the Department of Trade and Industry (DTI), in Ministry of Defence (MOD) and in Ministry of Agriculture, Fisheries and Food (MAFF) which are departments which play a key role in support of the various industrial sectors; in Research Council institutes, and AEA Technology which also have a role in technology transfer. IPMS also represents scientific and other technical and professional staff in the British Technology Group, the Patent Office, and in the British Library Technical Services Directorate, all of which have an important role to play in technology transfer.

3. In answering the questions we shall be taking account of and commenting on the Government's White Paper "Realising our Potential: A Strategy for Science, Engineering and Technology" and its consequences insofar as they can be discerned at this point in time.

WHAT IS THE RELATIONSHIP BETWEEN THE SCIENCE BASE AND INDUSTRIAL INNOVATION?

4. The relationship between the Science Base and industrial innovation is complex and will vary between different scientific disciplines and industrial structures. There is a very broad spectrum of research activity and there are no clear divisions within that spectrum. Many exploitable ideas arise out of undirected pure research. On the other hand, many companies, particularly those at the "cutting edge", engage in basic or strategic as well as applied research in order to fulfil their objectives. Basic, strategic and applied research are often conducted side by side in the same laboratory, whether this be in a Higher Educational Institution (HEI), research council institute or company laboratory. A number of different commercial and non-commercial objectives can be included in the same research programme. Although most "basic" and particularly "curiosity driven" research will be done in HEIs and other research institutes and most "applied" or "near market" research should be done in industry, there is a vast range of R&D work which falls into the strategic and precompetitive area and which cannot necessarily be provided by a direct relationship between the science base and industry.

5. Concentration on the two extremes at the "pure" and "applied" end of the spectrum fails to appreciate the connection between them and the strength and importance of that "intermediate" area. While we welcome

the White Paper's recognition that too rigid a distinction should not be drawn between "basic" and "near market" research we fear that the Government is still operating with far too simplistic a model of the technology transfer or innovative process and that it still fails to appreciate the vital "bridging" role which the research infrastructure between the two poles of "basic" and "applied" research can perform. By focusing its attention almost exclusively on a direct link between the science base and industrial application, the White Paper proposals may undermine the UK pure science base, which is generally acknowledged to be of high quality, thus killing the goose which is supposed to be laying the "golden egg" of wealth creation.

6. The process of moving from basic research to innovation (defined as realisation into marketable products) can involve a whole number of stages, depending on the nature of the particular innovation in question. In the extreme case the following processes could be involved:

Development of scientific ideas.
Laboratory testing.
Pilot plant operation.
Pilot production.
Plant scale-up.
Plant construction.
Plant production.

These building blocks can only be put in place when the following decisions have been made:

Acceptance of idea.
Recognition of potential scientific results.
Investment in laboratory work.
Investment in pilot plant.
Marketing.
Investment for full-scale production.

7. It is the later stages of this process which usually cause the greatest difficulty for UK industry because they involve high risk and high "up front" costs. The level of support for R&D often declines in these critical stages of the innovation process. Several factors are involved in bridging the gap at this critical point in the process, including the provision of "patient money"; recognition by industry of the potential of the research; and the capacity in terms of both equipment and intellectual resources to take it on to completion. These issues are covered under the various questions below.

ARE THE MECHANISMS FOR TECHNOLOGY TRANSFER AND INTERACTION BETWEEN THE SCIENCE BASE AND INDUSTRY EFFECTIVE? HOW COULD THEY BE IMPROVED?

8. Although technology transfer from the science base is generally weak the degree of that weakness varies between industrial sectors and according to the structure of industry. For example, medical research and the pharmaceutical industry have enjoyed a fairly close and well defined relationship, with the existence of an assured market in the form of the NHS. In the defence area, the strong relationship between clearly specified military need, research effort and manufacture did not pose major problems of technology transfer, except (and this is a large "except" particularly in these days of defence rundown and the need to diversify into civilian needs) that there was a very poor take-up of military R&D into civilian application.

9. A good example of a smooth and highly effective technology transfer lies in the agricultural area where the Agricultural Development and Advisory Service (ADAS) transmitted through free advice to farmers the latest developments in agricultural technology, many of them dervied from MAFF's own laboratories or the Agriculture & Food Research Council (AFRC). At the same time there was a close relationship between the customers, the advisers and the researchers. Also the innovations spread to all because there was no secrecy and very few barriers either motivational or financial to the transmission of ideas. This success in transmitting innovation was a major factor in producing a highly efficient agriculture sector in the UK which by 1990 delivered two-thirds of UK food needs compared to just under half in 1960. In the words of the Priorities Board for Research and Development in Agriculture in June 1990:

> "The agriculture and food industries are important parts of the UK economy, contributing around £6 billion and £10 billion respectively. The present efficiency of these industries owes much to the successful exploitation over many decades of the results of Government sponsored research and development. It is vital to UK interests that the agricultural and food industries continue to increase their competitive edge and respond to market demands, whilst meeting consumer expectations of greater assurances on food quality and safety, improved animal welfare and enhance protection of the environment."

10. *The positive lessons of such an arrangement should not be lost,* especially since many of the decisions taken to change that system, including the creation of ADAS as an Agency which gives advice on a fee paying basis; the abrupt withdrawal of "near market" public funding from agricultural research on the assumption that the market will provide for the research if the research is worthwhile, have done so much damage to research in that area and to the research continuum between agricultural research and agricultural production which previously existed. Much of the research judged "near market" and therefore no longer financed by government was not taken up by industry. In the June 1990 review the Priorities Board noted

that the food industry had shown only a small interest in funding near market R&D—"due in part to the fragmented nature of the industry. In some sectors, most notably eggs and poultry, no mechanism is in place to facilitate the funding process". It continued:

> "Even in those sectors with established mechanisms for funding R&D there is an element of risk that the R&D continuum will break down at the point where publicly funded work ends and industry's near-market R&D begins".

11. The Centre for the exploitation of Science and Technology (CEST) has identified other sectors where the industry structure is fragmented and composed largely of small and medium sized enterprises (SMEs) so that technology transfer does not operate smoothly. An illustration is the problem of getting environmentally sound new technology adopted by the metal finishing industry which is composed of hundreds of SMEs and represented by no less than six trade associations.

12. The number of companies undertaking genuinely pre-competitive research are relatively few and tend to be the larger corporations which would normally expect to fund and execute this type of research inhouse. The SMEs which do need assistance actually require more development oriented and "near market" research. They rarely have the in-house knowledge and resources to be able to form the complex relationships required for pre-competitive collaboration networks such as the DTI's LINK programme with the time consuming procedures associated with them.

13. *Permanent research establishments whether they are research council institutes, government laboratories or universities are well equipped to perform the bridging roles between basic research and application.* They have the ability to assemble the critical mass of scientific and technical personnel, expertise and physical equipment. They also have the ability within single institutes to range from the basic, through strategic or pre-competitive, to "near market" research.

14. CEST in its *"Report of the Working Group on Innovation: The Faraday Programme"* in May 1992 recognised that there was a major and continuing problem of technology transfer within the UK and that such "intermediate institutions" as those in paragraph 13 (CEST mentioned specifically AEA Technology, the Defence Research Agency, Laboratory of the Government Chemist, the National Physical Laboratory, and Research Council laboratories) had a major role to play in bridging the gap between research and application. While IPMS had some reservations about certain aspects of the "Faraday Centre" proposals, especially that if no new funding was introduced they could divert resources from existing "intermediate institutes" we welcomed the emphasis "Faraday Centres" put on the role of such intermediaries in the transfer of technology from science to industry and their proactive approach and felt that they could at the very least provide a useful mechanism for harnessing the collaborative funding available from DTI and EC sources for the benefit of SMEs.

15. *We welcome the fact that the White Paper has accepted the "Faraday principles" and that the Government has now accepted that public funds can once again be applied to "near market research", particularly "in cases where the 'market' breaks down, e.g., in generic technologies or where the market is characterised by small firms" (para 2.22).* These encouraging signs for more effective technology transfer, however, are marred and possibly rendered largely ineffective by the fact that no extra funding is provided to apply the "Faraday principles" and by the fact that many of the delivery mechanisms—the "intermediate institutions"—are threatened with closure, rationalisation, and privatisation, (see paragraphs 5.12 and 5.13 of the White Paper). An exercise which the DTI has already pre-empted with its decision to close Warren Spring Laboratory and the prospective demise of the other DTI laboratories currently under review.

16. *The DTI should play a major facilitating role in supporting innovation and its conversion into wealth creation.* We welcome the change to a more proactive approach to this task developed within the DTI and reflected in the White Paper. We welcome the emphasis on the need to change the culture of industry and the city to recognise the vital importance of innovation to competitiveness (see also para 33 below). But because of the squeeze on departmental budgets this is being carried out at the expense of other vehicles for the innovation process which are equally important. Thus funding for advanced technology projects is to be phased out. Also the new generic technologies identified by the proposed Foresight Programme will not have the funding to establish pilot projects and bring them further along the processes identified in paragraph 6 to smooth their transfer into development and application.

17. Thus, although the DTI rhetoric is more encouraging to technology transfer the infrastructure and funding to deliver it will continue to decline. DTI expenditure on R&D declined from £443.3 million in 1982-83 to £309.5 million in 1991-92 (1990-91 prices) and is destined to decline further to £177.2 million in 1994-95. The expansion of the DTI Innovation Unit from five to 30 staff while welcome will hardly be adequate to effect a culture change rapid enough and sufficient to replace the role of public funding and technical infrastructure with new private sector involvement in innovation. A further vicious twist to the downward spiral in UK's technological competitiveness is therefore likely to happen in the interim. *The resources and infrastructure must be provided so that DTI can fulfil the full range of roles required to support innovation and technology transfer.*

18. The role of military R&D also needs to be taken into account in any strategic approach to technology transfer and the identification of emerging and generic technologies. ACOST in its report "Defence R&D:

A National Resource" (1989) and the POST review paper on "Future relations between Defence and Civil Science and Technology" (1991) both recognised the role which military R&D could play in underpinning civil technology by developing generic technologies of use to both civil and military sectors and stimulating civil exploitation of defence technologies. The establishment of the Defence Research Agency should have given a new opportunity to develop wider integration and spin off to the rest of the R&D community. One of its specific objectives is to meet the requirements of other public or private sector cutsomers and to support the government's overall environmental objectives. It should be given the encouragement and resources to develop this role. At the moment, however, it is reeling under defence expenditure cuts which are undermining its capacity to fulfil either its core defence remit of the broader role envisaged by POST and ACOST. In the process a highly skilled scientific and technical workforce is being laid off with no strategy or mechanism for their effective redeployment.

19. In the late 1960s the Atomic Weapons Research Establishment at Aldermaston was placed under a statutory obligation for 25 per cent of its research to be in non-weapons areas. The work undertaken resulted in major new advances in areas such as kidney dialysis, prosthetics and microscopic surgery. Today the Defence Research Agency is virtually exclusively funded on defence related work. Levine and Stewart in their "Review of Allocation, management and use of government expenditure on science and technology" published simultaneously with the White Paper recommend that:

> "The DRA should aim and be allowed by the MOD to become very much more involved with civil markets than is presently envisaged and that, to this end, the Agency, should market its skills more widely and actively in order to realise more of its commercial potential."

Disappointingly the White Paper makes no such recommendation. *The Select Committee should do so.*

20. Communication is essential for innovation to succeed. High quality information leads to high quality innovation. There has always been a tension between the ideal of communication and the requirements of military and industrial secrecy. However, the growth of contract based research at universities, research councils and other public agencies has reduced the amount of information which flows freely. The fragmentation of the research base by the process of privatisation and contracting out will put further barriers in the way of this free flow of communication. The goal of openness of information, especially for publicly funded research must be supported. The crucial role of databases such as the British Library Science, Technology and Industry Division must be strengthened and a halt called to budget cuts in that area.

21. In the more commercially exploitable areas the role of Intellectual Property Rights (IPR) is a vital issue. The OST Report in 1992 on "Intellectual Property in the Public Sector Research Base" showed that this was a very weak link in the technology transfer mechanisms especially for smaller research organisations in the HEI sector and SMEs in the private sector who lacked the in-house expertise.

22. The report mentioned the role of the Patent Office and the British Technology Group (BTG) in encouraging knowledge of IPR processes and helping organisations to use the system. As the report also points out, however, the privatisation of BTG is likely to reduce the attention paid to the needs of HEIs and other public sector research organisations, or to the needs of SMEs, as it proceeds to concentrate on larger projects with a significant rate of return.

23. IPMS and many others warned that the privatisation of BTG would jeopardise its long-term "patient money" approach, forcing it to focus on short-term profits. Indeed, so great were the disadvantages of privatisation that even the Government's own advisers, Coopers and Lybrand, recommended that BTG should be kept in the public sector. BTG's first annual report after privatisation confirms those fears, it shows that BTG is concentrating on big projects, particularly from outside the UK.

24. *The British Technology Group*, recognised as the world's leading technology transfer organisation *should have a key role in promoting the adoption by industrial companies of technologies developed in the public sector.* However, if as now seems likely it is unable to perform this role adequately in its privatised form it should either be returned to the public sector so that it can resume its vital role in encouraging innovation and technology transfer or an alternative public agency which can do so should be created.

25. The Patent Office, too, is now threatened with privatisation. It is likely that, like the privatised BTG, it will concentrate its attention on the major profit making areas and neglect the needs of SMEs and other organisations who are weak on IPR. The major programme which it has been developing to promote knowledge and positive attitudes towards intellectual property in industry and academia is likely to suffer, as is the advisory service which the office provides, backed up by a unique patent document collection and the expertise of patent examiners, to help firms take advantage of the enormous amount of technical information in published patents. *Such services should be expanded if industry is to take full advantage of the science base and become highly innovative.*

IS INDUSTRIAL INNOVATION HINDERED BY A LACK OF COMPETENT PERSONNEL, BOTH TECHNOLOGICALLY AND IN MANAGEMENT SKILLS?

26. *Competent personnel are needed at every stage of the innovation chain and there should be as few barriers as possible to the free flow of ideas and people between the various stages and between "customers" and "contractors". "Customers" or "pull" are as important as "contractors" or "push" in producing effective technology transfer.*

27. Innovation is certainly hindered in SMEs by a lack of properly trained people who can interact with the centres of excellence noted above and apply the technology available. There are skilled people running SMEs, but they are usually concerned with production operations and do not have the time to take a long-term view to ascertain what their requirements will be in two, three or five years ahead. Significant innovation could be undertaken by SMEs if they employed a nucleus of properly trained people whose function was to take a long-term view and innovate new ideas and products—but they would have to be backed by commitment from their management and given the resources needed to apply new technology for innovation.

28. But this is not a problem restricted to SMEs. Recent research commissioned by ESRC and reported in "Nature" in June 1993 demonstrates for the first time a clear link between the number of graduate scientists and engineers in a company's senior management and the likelihood of having formal management goals and the ability to out perform the companies which lack them and to have an eye to long term growth rather than short-term profits. They are also more likely to stimulate a demand "pull" for technology.

29. This is also important in government where both as general policy makers in an increasingly technologically complex society and as "intelligent customers" for research and other scientific and technological services; *it is important to have a flow of high calibre scientists and technologists into senior positions.* At present this is not the case and current government policies on market testing and privatisation are likely to reduce the flow further.

30. One of the ways of improving the flow of relevant expertise is to facilitate the flow of people and their ideas between university and industry and "intermediate institutions" as suggested under the Faraday Centres proposal. But as we have seen above although the "principles" have been adopted in the White Paper there is no real indication of how they will be put into practice without resources.

31. There is also a danger that with the accelerated development towards a free market in R&D outlined in the White Paper the pressure to compartmentalise institutionally the roles of "customers", "contractors" and "policy makers", rather than simply recognising their separate roles, will greatly hinder the free flow of people and ideas, impoverish the quality of advice and reduce the ability to be "intelligent customers" for research. *There must be close communication between researchers on the one hand and those who need to make use of the research on the other.* In the real commercial world good "customers" take the trouble to cultivate and establish close links with "suppliers"; they don't "shop around" at "arms length" as the market theologians suggest.

Is innovation by British industry internationally competive? How should this competitiveness be measured?

31. IPMS is not fully competent to answer this in technical terms. However, one or two observations can be made. Firstly the pattern will not be uniform; some products or industrial sectors are more competitive, e.g., chemicals, pharmaceuticals, defence, racing cars, while other are not, e.g., production cars (although improving with Japanese help). Secondly the latter appear to far outweigh the former. Thirdly, the indicators which do exist, although they may not be perfect, e.g., patents and the new "R&D scoreboard" do all point in the same direction, i.e., a poor performance compared to our main competitors and generally getting worse.

Is "short-termism" really a problem to innovative British industry? If so, why is this, and how might it be remedied?

32. Short termism is a major problem in a variety of ways, covering both capital and human resources. The essence of R&D and innovation is that it is a long term process; particularly so where the outcome is highly uncertain; where the research and product require large plant; or where several stages are involved. In the development of new sources of forms of generating energy, for example, the lead times can be as much as 30 years. This requires "patient money" and long term scientific and managerial skill. Successful innovation in such areas is hampered by "short term" approaches, whether these be in terms of policy or priority switches, short term contracts for funds or staff, or private finance.

33. Short-termism in research must ultimately be bad for the science base and hence in the long term bad for innovative British industry. Short-termism will reduce career opportunities for scientists which is wasteful in terms of training and loss of skills. It will demotivate scientists and reduce the number of people entering science as a career. It will lead to loss of expertise (long-term experience) and consequently weaken the ability of research to respond to a crisis. In a time of recession such a policy is attractive because it will tend to reduce costs and encourage competition. The net result is likely to be a loss of investment in long-term research, a lack of investment in the training of scientists and a tendency for cost rather than quality to dictate funding of research.

34. An increasing source of funding for basic research in the future is likely to be EC funding. The availability of a strong science base is a necessary requirement for bidding for such funding. The requirement to provide 50 per cent funding and to co-ordinate in house research with EC research will become increasingly difficult both in timing and resources if all science research is reduced to short-term projects.

35. On the financial front it is now very generally acknowledged that there is a tendency in industry and the city to take a short-term view of profitability, to look for a quick and certain return and therefore to be

more risk averse than many of our competitors. In particular critics attribute lack of enthusiasm for investing in high technology companies to the conservatism of financial institutions such as pension funds, which assess fund managers' performance by high dividend returns. In the UK even well established companies have difficulty in bringing new products to the market place. The record for venture capitalism is very poor. Companies are much more concerned with their present performance, their financial growth, their share dividends, etc. They worry about the effect on their share price if they have to borrow funds for R&D investment.

36. Thus the high ratio of share ownership in the hands of pensions funds in the UK (see Table below) is a vital issue.

Share Ownership (per cent)

	Households	Companies	Pension Funds	Banks	State	Foreign
United Kingdom	17	12	49	15	3	4
Germany	17	36	7	9	7	24
United States	66	—	25	4	—	5
Japan	23	29	16	24	1	7

There is also anxiety about being taken over and "asset stripped" since taking over an R&D company and shedding its R&D is seen to be profitable, especially if the laboratories are in desirable "home counties" locations. Takeovers in the UK are running at a much higher level than other countries.

37. The latest results from the R&D Scoreboard highlight the impact of "short-termism" showing that the average spend on R&D by the world's top 200 companies was 4.6 per cent compared with a meagre 1.6 per cent in the UK. Furthermore, in stark contrast to many large international corporations UK companies distributed about five times as great a proportion of their profits as dividends as the global average.

38. The White Paper and latest developments in the DTI recognise the problem and suggest ways in which the culture might be changed. However, the White Paper rejects the solution of tax incentives for spending on R&D on the grounds that there is already substantial tax relief for current and capital R&D expenditure. However, it is much more likely that tax incentives which at one point looked as though they might be on the Minister for Science's agenda and have certainly been advocated by a large number of contributors to the White Paper exercise, have fallen victim to the Treasury as have so many other areas tackled in the White Paper. Although campaigns to change attitudes are important the extra incentive which financial "carrots" can import should not be overlooked.

SOME SECTORS OF THE UK INDUSTRY ARE MORE SUCCESSFUL IN INTERNATIONAL MARKETS THAN OTHERS. WHAT CONTRIBUTION DOES INNOVATION MAKE TO THEIR SUCCESS? WHAT CHANGES IN CORPORATE STRATEGY MIGHT IMPROVE THE LESS SUCCESSFUL ONES?

39. IPMS is not in a position to answer this question in detail but we would argue that innovation does play a significant part in the success of a company. In today's highly competitive conditions a company will need to innovate and be flexible or die. The degree which that will depend on technological innovation will vary but in today's sophisticated world that must also be a very major factor.

Changes required in corporate strategies include:

- Longer term view of the market than.
- Assess likely markets in four or five years time, depending on the time required to bring the product to market.
- Employ and reward properly trained staff who will innovate, and provide them with the necessary resources.

Most crucial in both devising and implementing these strategies is to have staff who are both scientifically aware and perceptive about market potential in the top decision making teams in any organisation.

WHICH STRUCTURE AND INSTITUTIONS WITHIN THE UK ARE PARTICULARLY HELPFUL IN ENCOURAGING THE PROCESS OF INNOVATION WITHIN A COMPANY AND WHICH HINDER THIS PROCESS?

40. Many of the institutions and structures which can be helpful or unhelpful have been mentioned already. The helpful include:

- "Intermediate institutions" such as AEA Technology, Warren Spring Laboratory, and research council institutes which can bridge the gap between the science base and application.
- Organisations such as DTI and its various schemes which can provide funding and advice, especially for SMEs.
- Financial institutions and public funding agencies which can provide "patient money" for long-term investment in R&D.
- Organisations such as the Patent Office, British Technology Group, and the Science, Technology and industry database in the British Library, who have a vital role in transferring information.

41. Unhelpful are:
- Financial institutions and shareholders who demand short-term profits and dividends at the expense of long-term R&D and growth.
- The Treasury who put cost cutting expediency before recognition of the need for long-term investment and who prescribe ludicrously short-term perspectives and "annuality" rules for organisations and pay little attention to the long-term nature of their activity.
- The Government zeal for "markets" and the universal extension of the "customer-contractor" principle well beyond the areas where they are appropriate, and too rigid a demarcation between customers, contractors and policy advisers which militates against the free flow of information, the provision of good quality advice, and the existence of scientifically "intelligent customers" within the government machine.

Memorandum submitted by MSF (19 July 1993)

INTRODUCTION

MSF and Science

Manufacturing Science and Finance (MSF) is a multi-industry union spanning the public and private sectors with over 500,000 members. The union was formed as a result of a succession of mergers in the trade union movement. One of our predecessor unions was the Association of Scientific Workers (AScW) which was largely responsible for placing the general importance of science onto the agenda of the national trade union movement.

The AScW was part of the merger that formed the Association of Scientific, Technical and Managerial Staffs (ASTMS) in 1968. ASTMS continued to developing policy in the area of science and worked with the Association of University Teachers (AUT) and Institute of Professional Civil Servants (IPCS) in the Alliance for Science.

ASTMS in turn merged with TASS in 1988 to form the MSF. The new union brings together scientific workers in universities and professional scientists and engineers in industry, we also have scientific membership in the National Health Service and Research Council field. Because MSF also has a large membership in the finance sector we can bridge the gap between innovation, development, investment and marketing. With an estimated 120,000 members engaged in science, R&D and transferring innovation to marketable goods and services, MSF is organised in many of the key areas of the next generation of scientific and technological advance.

1. *What is the relationship between the Science Base and industrial innovation?*

There is no iron law which states that a certain size of science base or level of science investment will guarantee an acceptable level of innovatory activity. However MSF can state with some confidence that although a country with a strong science base may not successfully innovate, one without a strong science base will definitely not innovate.

This is basically the theme of the message outlined in the recent Government Science White Paper. This is a step forward. For too long the Government has given the impression, real or false, that science did not deserve attention as a separate and important policy area.

Through the recent science and technology White Paper the Government intends to harness the intellectual resources of the science and engineering base to improve economic performance and the quality of life.

MSF accepts that there has been many positive developments in this area. The expansion of the network of University based science parks is very welcome. They help create an organic link between the Universities and industry.

Also the Research Councils have made major advances in this area. They have developed closer links with industry to promote the utilisation of their work. Developments such as the Medical Research Council's collaborative centre with industry should be encouraged.

Information about the links between the science base and innovation are detailed elsewhere. The question is whether this present arrangement generates enough innovation and whether this relationship is sufficient to turn innovation to our economic or social benefit.

MSF believes that the structures that presently between the science base and industry are too weak. Whilst the Department of Trade and Industry (DTI) and the Office of Science and Technology (OST) quite properly play a role of promoting links between centres of research and industry, and the research centres are making their own advances, MSF believes that intermediatory structures are needed to effectively carry out work in this area. We believe that new institutions, either expanding the network of Faraday Centres, or based on the German Fraunhofer Institutes, should be introduced. Our reasons for this are expanded upon in answer to the next question.

2. *Are the mechanisms for technology transfer and interaction between the science base and industry effective? How can they be improved?*

Over the past 10 years our world share of scientific publications and citations has fallen.

— Research by the Observatoire des Sciences et des Techniques (Fr) reveal that Britain's share of the world's research papers fell by 3 per cent between 1982 and 1988. The decline covered all fields except clinical medicine. And the largest decreases were in physical sciences (–16 per cent) and biological sciences (–12 per cent). The decline in comparison with countries of the EC is 5 per cent.

— Research by the Dutch Advisory Council on Science and Technology Policy have come up with similar findings. Between 1984 and 1990, the UK experienced a decline of 3.5 per cent. The largest of all scientific nations. Germany (–2.9 per cent). US (+1 per cent). Japan (+16 per cent).

— Research by the Philadelphia-based Institute for Scientific Information of citations per paper earned by G7 nations between 1981 and 1990 shows that the US improved its citation impact by 6.9 per cent, Germany 3.6 per cent, Japan 2.2 per cent, France 1 per cent, Italy =, Canada –2.8 per cent, UK –3.4 per cent.

The effect of this decline can be shown across all industrial sectors. The chart below highlights that even in the strong British areas of chemicals and pharmaceuticals there has been a decline in the number of British patents registered in the USA. This decline has also occurred in France and Germany. However France has had a comparatively slower decline. The German comparison starts from a higher base and therefore the fall is relatively lower. The Japanese record is nothing short of extraordinary and highlights that a national effort can produce concrete results.

Percentage of non-USA patents issued in the USA

Industry		UK	France	Germany	Japan	Rest of world
Chemicals	Per cent	8.34	8.77	23.82	36.73	22.34
	Change 1991/80	–2.68	0.13	–3.44	11.36	–5.38
Drugs and medicines	Per cent	13.28	9.92	17.27	29.56	29.97
	Change 1991/80	–2.35	–0.51	–5.09	5.26	2.69
Rubber and plastics	Per cent	5.04	5.72	20.14	47.56	21.54
	Change 1991/80	–5.09	–2.13	–6.21	20.99	–7.55
Fabricated metals	Per cent	7.18	7.07	20.1	31.64	34.01
	Change 1991/80	–2.92	–2.15	–3.73	11.35	–2.56
Machinery	Per cent	4.7	7.38	16.12	50.65	21.15
	Change 1991/80	–3.44	–0.96	–7.99	17.6	–5.21
Electrical	Per cent	4.7	7.38	16.12	50.65	21.15
	Change 1991/80	–3.44	–0.96	–7.99	17.6	–5.21
Communications	Per cent	5.46	6.21	8.9	63	16.43
	Change 1991/80	–4.38	–4.72	–6.1	19.82	–4.62
Transportation	Per cent	4.7	6.01	21.92	47.56	19.81
	Change 1991/80	–5.41	–2.69	–6.62	18.54	–3.82
Aircraft and parts	Per cent	8.07	7.32	19.43	52.39	12.79
	Change 1991/80	–4.7	–2.78	–3.69	12.96	–1.78
Professional and scientific instruments	Per cent	5.54	4.74	13.62	56.24	19.86
	Change 1991/80	–1.56	–1.1	–8.44	15.73	1.26

Perhaps the weakest aspect of the recent Government White Paper "Realising our potential: A Strategy for Science, Engineering and Technology" is the plan for assisting the process of technological transfer. Indeed this is barely covered. This is a strange contradiction because the whole tone of the White Paper views science as a means of wealth creation.

But the question is that without effective sectoral and regional structures how is the Government going to fund its new and welcome commitment for near market research? The Government is presently looking into transferring from the Department of Trade and Industry (DTI) to the Scottish Office responsibility for a range of schemes in Scotland for encouraging industrial innovation and technology transfer. A similar review is being proposed for Wales. The aim is to bring about transfer of responsibility wherever practicable. But what is good for these countries should also be good for the regions of England.

Also technology transfer is split between DTI and Office of Science and Technology (OST), with the DTI keeping major share of resources. This will result in confusion and possible tension between Government departments. The fact that the White Paper itself appears to MSF to be a product of such infighting does not bode well for future co-operation between these departments.

MSF would argue for regional structures to assist in technological transfer. The Government supports the principles that underlie the idea of Faraday Centres but the White Paper did not commit itself to providing additional resources to establish a new network of such centres across the country. In his statement to the House of Commons the Minister also stated that he believed that UK could not benefit from the experience of the Fraunhofer Institutes in Germany.

MSF would disagree with the Minister and the House of Lords Select Committee which investigated the Fraunhofer Institutes and opposed the establishment of similar institutes in the UK. We believe that the proven record of success of the Fraunhofer Institutes should not be so easily dismissed.

The Fraunhofer Institutes have made an international name for themselves in the field of research. There are now 45 research institutes in all. Recently the scope of research has been effectively enhanced. Some 7,600 employees work today to solve the specific research problems on behalf of industry and the public sector.

The Fraunhofer Institutes help German industry remain competitive through the transfer of knowledge from research to practical applications. Public funding provides the infrastructure necessary to carry out its work. The results of in-house research subsidised in this way can also be put to good use by customers from industry. The Fraunhofer Institutes are recognised as non-profit making organisations, with charges for contract research being limited to the actual costs incurred.

Industry remains competitive through constant innovation. Shorter product cycles and more stringent demands in terms of quality and safety make it more imperative for industry to invest in research. The research and technology capacities available in companies are not always sufficient to master sophisticated or state-of-the-art technologies. Therefore forward looking companies thus increasingly tend to acquire the necessary knowhow in co-operation with external research establishments. A research contract with the Fraunhofer Institutes is an obvious way of buying in extensive expert knowledge.

The latest report of the Fraunhofer Institutes reveals an annual growth rate in research projects over recent years in double figures. The research volume for 1992 was over one billion DM (£400 million). More than two-thirds of this amount was earned through contracts from industry and the public sector. This is a testament to the testing of research projects in the Fraunhofer Institutes and their responsiveness to new developments.

This is precisely the organic type relationship between research and industry which the Minister is seeking. They are evolving through responding to the needs of industry. But for such organisations to be effective they need seedcorn finance and underwriting from Government.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

MSF shares the concern expressed by many industry organisations such as the Association of the British Pharmaceutical Industry (APBI) that there is a decline in the number of science graduates of the calibre it needs and of the erosion of the academic infrastructure.

Total employment in industrial R&D has declined in the last decade from 195,000 staff in 1981 to 165,000 staff in 1990, or by 15 per cent. However this is less than the percentage reduction in total industrial employment over the same period.

This raises two separate but related questions. Firstly, whether the total number employed in industrially based R&D meet our economic needs. Secondly, whether the people presently being employed in scientific occupations are of the calibre required by industry. Unfortunately, there is presently scant statistical information covering this important area.

Therefore MSF welcomes the intention expressed in the recent Government White Paper of producing greater statistical information on the stock and flows of scientists and engineers, and on indicators of labour-market demand and supply. This will provide the basis for a reasoned debate on the way forward.

However some provisional survey work has already been undertaken to indicate that there presently is a skills shortage. In a survey produced by the Centre for the Exploitation of Science and Technology stated that 41 per cent of German companies said that skill shortages were a problem, compared with 88 per cent in Britain.

More interestingly, almost 90 per cent of German companies intended to address this issue by making better use of staff through retraining. Only 25 per cent of British companies planned to retrain staff as the main solution. Instead almost 75 per cent planned to solve this problem by increasing recruitment from graduates.

The Economic and Social Research Council (ESRC) has also highlighted that shortages were most acute in the intermediate skill groups. Twenty per cent of companies reported shortages in the professional and technical, and craft and skilled groups. There were greater shortages of professional science and engineering (PSE's) graduates than other types.

MSF has long argued that the markets of the future will be skills intensive and there is little future for the UK in being a low wage assembly line for the inventions of other countries. The UK needs the Government to lead a training revolution to upgrade our skills base and change the parsimonious approach to training adopted by many of this country's employers.

MSF launched its own training initiative six years ago. It is a continuing commitment. Just before the most recent budget, MSF's industrial strategy blueprint "Manufacturing Matters" called for:

— An extra £1 billion per annum for the training and enterprise councils.
— £75 million for a new training and job search scheme aimed at the long term unemployed.
— A training levy on all companies set initially at 0.5 per cent of payroll.

4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

This is a difficult concept to measure scientifically. Perhaps one of the most surprising facts is that Britain still is a major science nation. This though can be largely attributed to historical reasons and the size of our Gross Domestic Product (GDP). Britain maintains a strong scientific reputation and is one of the contributory reasons why a large number of overseas multi-nationals choose to locate in this country.

The competitiveness of British science should not be measured simply on the basis of the number of inventions per pound invested. Of course companies, universities and research organisations should constantly monitor the performance of their research programmes. But a crude accountant-type approach runs the grave risk of stifling innovation. It leads to a disproportionate emphasis on "getting the science right".

Therefore more responsive measures of competitiveness are needed, ones which are responsive to the needs of innovation, rather than hinder innovation. This could include the comparison of the innovation record of foreign-owned subsidiaries in Britain and their domestic competitors.

Innovation is a means of generating wealth and improving the lives of humankind. British companies all too often choose a low skill, low technology route in preference to a high skill, high technology one. The higher route leads to higher value added, higher incomes and increased competitiveness giving positive effects into the wider economy.

The low route results in lower value added, lower incomes, a reduced ability to fund training and R&D, leading Britain into competition with third world producers but buying from countries that took the high route.

5. *Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

The short-termism of the City is correctly recognised as a major constraint on British industry, inhibiting investment in R&D. It reflects the existing relationship between manufacturing companies and financial institutions.

The tendency is to avoid risk-taking and to be more pre-occupied with short-term returns on investment. Short termism is exemplified by a focus on growth of earnings per share as a key measure of corporate performance. This leads to an understatement of the corporate value of R&D as only immediate earnings are taken into account.

R&D spending can be capitalised and written off against future earnings, but only if future earnings can be ascertained—which excludes most innovatory activity. This is in marked contrast to Japan where there are closer relationships between manufacturing companies and banks, and where the market takes a much longer term view of the underlying technological value of companies.

In addition, in Japan and Germany there is much less risk of hostile takeovers. Companies can pursue longer term projects without the fear that a short-term dip in profits will lead to a failing share price and unwelcome predators. Competition law should be changed to place the onus on those initiating takeovers to prove that it is in the public interest.

The problem of short-termism in Britain has been exacerbated by high interest rates, with City institutions looking for returns of 40 per cent on more risky investments compared with 9 per cent in Japan. Even on standard investments, returns of 19 per cent are expected in the UK, considerably more than in competitor countries.

Life insurance and pension funds have at times helped to make the short-term a priority by such practices as quarterly performance reviews, high activity rates and equivocal attitudes to takeover bids. To change this approach would require an overhaul of the regulatory framework governing the stewardship of such funds because fund managers and trustees are almost legally bound to get the best possible return and therefore act in this manner.

6. *Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?*

While investing in R&D does not guarantee a company's ability to innovate, companies that do not support research put themselves at a severe disadvantage. There are industrial sectors where Britain can justifiably claim to be amongst world leaders. Comparisons in R&D expenditure between British companies and their foreign competitors do show some bright spots.

The 1993 UK R&D Scoreboard produced by Company Reporting Limited reported that there are 51 companies in the chemicals sector in the top 200. Their aggregate spending on R&D rose by 9.3 per cent last year. By contrast, Britain's chemicals industry increased its overall investment in R&D by 10 per cent. The picture in the health care sector is similar. There was a 16 per cent increase on research spending in this sector. Internationally the figure was 14 per cent.

The greater willingness of British companies in these sectors to invest in R&D should help them to maintain their competitive position. On the negative side of the scales, R&D spending by Britain's aerospace companies declined by 8 per cent, while the corresponding figure for the top seven international aerospace companies was an increase of 11 per cent.

British companies spend twice as much on dividends as on R&D. In contrast the top 200 international companies spent more than twice as much on R&D as on dividends. In the international rankings of companies by R&D expenditure, British companies accounted for seven of the top 100 places, which was less than Germany but the same as France. The United States dominated with 40 entrants and Japan had 21. Nearly all the leading UK companies fell behind their international competitors. BT spent an eighth as much as AT&T on R&D in absolute terms and less than half of R&D as a proportion of sales. Lucas spends far less proportionately than its competitors.

International ranking of UK companies by R&D expenditure

Company	Industry	R&D expenditure ranking: By total expenditure	Per employee	Percentage of sales	Percentage change R&D expenditure 1992-91
Rolls Royce	Aerospace	6	4	2	+6
British Aerospace	Aerospace	7	7	7	–23
ICI	Chemicals	12	45	34	+9
GEC	Electrical and electronics	17	30	14	–4
Unilever	Food	1	2	2	+8
Shell	Fuel	1	6	8	+7
BP	Fuel	4	9	5	+2
Glaxo	Health care	2	5	1	+25
SmithKline Beecham	Health care	4	8	7	+11
Wellcome	Health care	5	7	2	+11
BT	Telecommunications	5	5	5	–1

Source: 1993 R&D Scoreboard—Company Reporting.

A further cause for concern about the relative position of British companies shows up in the number that feature in the international top 200. This fell to 11, from 13 in 1992's scoreboard. The reduced representation of British companies does come at a time when more companies in some countries are declaring their R&D spending. There has been a small increase in Britain this year.

There is a strange paradox about R&D. It is crucial for industries, but can be disastrous for companies. According to the Department of Applied Economics at Cambridge, between 1973 and 1989 the six fastest growing industries were the six with the highest intensity.

Some companies have rapidly increased their spending on R&D. They have convinced the City that such spending is indispensable to its continued success. This is particularly true in the pharmaceuticals sector. But this example appears to be more the exception than the rule.

There needs to be a combined effort from Government, companies, the business community and trade unions to promote the importance of R&D. At present there is no requirement on the part of companies to report properly defined R&D expenditure in the company accounts and reports. The fact that this is the case helps to create the image amongst brokers that R&D expenditure is not important. Companies need to be less sanguine and apologetic where there is reason to report a commitment to innovation. The absence of any statutory requirement to report R&D expenditure allows many companies to hide their poor record on innovation.

Part of this problem should be laid at the door of British industrialists. The CEST survey mentioned earlier highlighted that German industrialists are also more aware of how technology generates revenue. Almost 90 per cent of German executives were able to quote the share of their company's turnover which came from new products. The survey stated that British industrialists had difficulty quoting a comparable figure, with nearly a quarter unable to respond to the question and a fifth reporting a guess of 50 per cent.

About 73 per cent of German companies believe that in-house R&D is the primary source of technology compared with about 40 per cent in the UK. The next most important source of technology for British groups are joint ventures, the source which Germans regard as the least important.

Companies also need to recognise the importance of scientists as one of the company's best assets. This means greater financial reward and status for scientific workers. The number of scientists on British boards of directors is depressingly small.

7. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder this process?*

MSF has consistently argued that Britain suffered from a weak and diffuse scientific infrastructure. What is clearly evident from the recent White Paper is that science policy will be given greater direction from Government. This was perhaps expected with the establishment in 1992 of the Office of Science and Technology (OST).

The new structures being set in place by the White Paper are an interesting development and should be given a cautious welcome. In fact many of the White Paper's proposed changes were actually advocated by MSF in its evidence to the Select Committee.

> MSF is clear that it is not at this stage seeking a new Ministry to assist company policy in relation to R&D but instead a Government initiative to co-ordinate the efforts of the science community. A collaborative project between Government, research institutions and both sides of industry to assist in meeting the best needs of the country. Our objective is not to seek to build levers of intervention but develop an organic relationship between the involved parties to assist in creating a science culture in the UK. Simply the distinction that we are seeking to make is between intervention and support.
> We advocated in our pamphlet: "*Science for Britain*" the creation of a Council of Science and Technology, under the direction of the Minister, which will advise the Government and report directly to Cabinet.
> We believe that such a body will ensure wider and informed participation in decision making. This will also replace existing bodies such as ACOST and the ABRC. The work of the ABRC could be undertaken by a committee of the Council and better review funding applications from individual research councils.
> *(Extract for MSF evidence to Science and Technology Committee on S&T in the UK).*

Traditionally science has had a weak voice in Government and the White Paper can only strengthen its position. However it is clear that the Treasury will remain the dominant voice in Cabinet. And MSF members will have bitter experience of the President of the Board of Trade claim to further the interest of UK industry. If the Department of Trade and Industry was unable to win the argument with the Treasury will the Office of Science and Technology be any more successful? The proof of this particular meal—breakfast, lunch or dinner—will be in its eating.

MSF hopes that the effect of the White Paper is to improve the UK's scientific performance. But our fear is that the intentions expressed in the White Paper will either be diluted or not fully realised. However our fear is that the measures are not strong enough to reverse the UK's relative decline. MSF therefore believes that the Government will reach the same conclusion as that eventually it will be necessary to create a proper science Ministry under a Minister will full cabinet status.

Quite properly the White Paper has also sought to devise mechanisms for the advancement of science in the UK. But the question of resources will potentially undermine any benefits from the White Paper. It should be remembered that during the 1980's the UK was the only member of the Group of Seven industrial nations to experience a decline in spending on research and development (R&D) as a proportion of Gross Domestic Product (GDP).

Total Government expenditure on R&D fell nearly £1 billion between 1986-87 and 1991-92. Of this fall, about £400 million was in support of civil R&D. Had the UK followed the average rate of increase of spending by governments in other G7 countries, the total would have risen by about £1 billion, that is nearly £2 billion above the actual 1991-92 level (Source: Save British Science).

The White Paper commits no new resources to addressing this issue. There are no benchmarks for increasing industry financed R&D and no targets for increasing Government investment in civil R&D which is one of the lowest in Europe. In fact the White Paper states that there is no case for additional tax incentives for R&D. MSF believes that there is an exceptional case for such a new incentive to be introduced.

We thank you for inviting MSF to make a submission to your inquiry and hope that you find our comments are of use in your deliberations. We would of course be willing to expand on these and provide verbal evidence.

Memorandum submitted by the University of Salford (16 June 1993)

LIAISON BETWEEN THE UNIVERSITY OF SALFORD AND INDUSTRY

The predecessors of the University, the Royal Technical Institute, founded in 1896, the Royal Technical College, and the Royal College of Advanced Technology, grew out of strong and close involvement with local industry and commerce. The University, granted its charter in 1967, has built on and developed these relationships, particularly over the last decade. This special character is reflected in the University's published aims and objectives which include technology transfer and skill transfer alongside teaching and research as primary aims of the University. That for technology transfer reads:

> "Drawing on the expertise in research of its staff and on its particular relations with industry, commerce and the public service, the University seeks to extend the dissemination of knowledge and techniques beyond the intellectual or other field in which they were first developed. The main vehicles for this transfer of technology are the University's departments, SUBSL and its subsidiary companies, and CAMPUS."

In the same document the aims for research include the following:

> "To respond to the needs of industry and commerce for innovatory products, processes and services as indicated, but not exclusively defined, by the University's industrial and commercial customers and friends (e.g., through CAMPUS and SUBSL)."

ORGANISATIONAL ARRANGEMENTS

Because the University's *ab initio* relationship with industry, *University engineering and technology departments* and their staff, many of whom have industrial backgrounds, often develop important and long-term relationships with particular industrial companies through contract research, collaborative research, and consultancy. Thus, important technological developments at Salford such as surface engineering or electracoustics often evolve in collaboration with industrial compaines which ensures that innovation is immediately utilised. In several key areas, relationships have been strengthened by *Integrated Chairs*—senior managers of leading organisations who are also full professors in the University. British Aerospace, British Gas, British Nuclear Fuels, British Rail and Unilever are among those participating in this innovatory scheme.

CAMPUS is the organisation through which industrial organisations are encouraged to improve their links with the University. Some 130 industrial, commercial and public sector organisations are members of CAMPUS and many of these receive research or technological support from the University, and the University in turn enjoys their support for many of its initiatives. The CAMPUS operation, which has annual running costs of some £150,000, is funded entirely by its members. Each CAMPUS member is assigned a member of academic staff as a liaison officer, and fully staffed CAMPUS office is an important element in ensuring that industrial enquiries for expertise are properly serviced.

Salford University Business Services Ltd (SUBSL), which has a staff of nearly 100 and an annual turnover of some £10 million, is the organisation through which the majority of the University's consultancy work is managed. SUBSL is a major mechanism for technology transfer between the University and industry. Having been operating for over 20 years, SUBSL has a large client base and its reputation for delivering solutions ensures a steady stream of enquiries from industry. A sister company *Salford University Business Enterprises Ltd* (SUBEL) is the University company which, amongst other things, maintains an interest and control in spin-off companies developed in the University. SUBEL, together with Salford City Council, also helped to create the *Salford University Business Park* of which Phases 1 and 2 are now built and operational. Both SUBSL and the University, along with industrial companies are partners in the national *Advanced Robotics Research Centre* on the Salford campus.

The University's *Development Unit* provides support to staff making research grant and contract bids, and administers the University's research grants and contracts, including those with industry. The Development Unit maintains information on intellectual property generated within the University, and is responsible for ensuring that IPR is appropriately exploited.

The University is currently considering the establishment of interdisciplinary research institutes which would in future be the focus for research activity.

The University's investment in arrangements for liaison between academia and industry can be judged by the fact that CAMPUS, the University companies, and the Development Unit employ a total of 115 staff.

EXPLOITATION OF INTELLECTUAL PROPERTY

The University seeks to ensure that the discoveries and expertise of its researchers are translated into practical use, and seeks to protect intellectual property where possible and appropriate.

When intellectual property is generated it is notified to the University's Development Unit which is responsible for ensuring that intellectual property is appropriately exploited. Exploitation normally takes place through SUBSL or the British Technology Group. The University has a written policy on IPR which has been distributed to all academic staff.

Some 10 developments have been patented over the past decade.

INTERACTION MECHANISMS

The most important conduit for working with industry in developing innovative and competitive technology is *collaborative research*, which may be fully funded by industry, either through the University or through SUBSL, or partially funded through programmes such as SERC research grants and CASE studentships, the ACME Directorate, the LINK programmes, the Teaching Company Scheme, the DTI Enterprise Initiative programmes and the European Commission industrial research and development programmes.

In terms of initiating research projects with industry the most important "drivers" are the academic research staff and their relationships and reputation with particular industrial companies. Several build long-term relationships with particular companies and these ongoing relationships are a major element in industrial funding of research at the University. New research relationships are originated by academic staff seeking industrial partners, and arise from contacts through the Development Unit, SUBSL and CAMPUS. An increasingly important mechanism of widening industrial interaction is through multi-partner research consortia funded through UK or European schemes.

POLICY TOWARDS TECHNOLOGY TRANSFER ACTIVITIES

As was noted above, technology transfer is very much part of the Salford ethos and is specifically included amongst the University's published aims and objectives. The criteria for promotion to readerships and senior lectureships consider performance under four headings, which are given equal importance or weight, the fourth of which is "innovative activities successfully undertaken in pursuit of the distinctive aims and objectives of the University" which includes technology transfer and entrepreneurial activities.

Participation in the Teaching Company Scheme has been a particularly effective way of transferring technology from the University to industry. The University has taken part in over 60 teaching company projects.

INCOME FROM INDUSTRY

The total income, as defined in the 1992 HEFCE Research Assessment exercise, to the University from industry for research and development over the past decade, including industrial contributions to collaborative research projects but excluding income to the University's companies is as follows:

	£ million
1983-84	0.5
1984-85	0.4
1985-86	0.7
1986-87	1.0
1987-88	1.2
1988-89	1.2
1989-90	1.5
1990-91	1.2
1991-92	0.9

Virtually all this industrial income is from UK based companies and many of those are companies with a 50 mile radius of the University. The research income from industry represents about 20 per cent of the total income of the University from all sources.

The income from industrial contracts to University companies for the past four years is:

	£ million
1988-89	0.5
1989-90	0.6
1990-91	0.7
1991-92	1.0

Direct University income from intellectual property commercialisation over the decade is of the order of £20,000, less than £1,000 coming through the British Technology Group.

Memorandum submitted by Professor G Musgrave, Department of Electrical Engineering and Electronics, Brunel University (21 June 1993)

Further to your letter of 26 May I would like to make some comments which I hope may be useful.

1. High technology transfer between academia and industry. In my experience a great deal of the lack of transfer is caused by the "not invented here" syndrome. Very often people in industry are so focused in spending too much time solving yesterday's problems, or trouble-shooting, that when academia comes along with new ideas they are not readily accepted. This is because the ideas are first introduced to the R&D department who believe they are better at doing the same. Or, if they accept that an idea is better than their own, they have to protect themselves from senior management accusing them of not doing their job. The best

way of doing this transfer is to move people across this divide. My experience in moving ideas from the research base into "Science Park" type companies, is that one moves some researchers into the company, add to them people with commercial nous and you have success. This is the way in which we created CIRRUS Computers which was eventually bought by GenRad Corporation in the USA.

I have to add that one of the factors which enables this to be achieved effectively is to have the right physical environment. Very often if you just move people who may be in the minority from say, academia, into the industrial environment, then they are soon absorbed and constrained by that environment. Moving groups into a new environment allows this degree of freedom and exchange.

2. It is very annoying in this country to still find the divide between science, engineering and management. It is still seen that if you are successful then you must be in the management stream. That is very much reflected in the positions of people on Boards of Directors and indeed the general remuneration. As a Director of Siemens plc I see how that company rewards may engineers doing engineering jobs but still holding a fairly senior position with appropriate remuneration.

A consortium of British Universities organised under the JUPITER Initiative with the help of the DTI and support from CBI are launching a new set of Master's Programmes named Technology of Management. In a nutshell this is to address the very questions you raise. If you like, it is trying to enhance the competence of an MSc programme with that of an MBA programme. Or, it is to provide more technical skills of the right kind to would-be managers coming from an MBA programme. The fact that this has the support of the organisations mentioned above together with some 15 universities indicates that there is recognition for skills in this area and that this programme will hopefully address it. I append an outline of the programme for your information.

3. In my opinion, innovation in British industry is not a real problem. We have lots of innovation in the UK but we are not successful in being internationally competitive. To some extent this is due to the fact that we are too high bound by innovation and don't recognise that the necessary skills to turn an idea into a product is just as important, and in fact can cost a lot more than the initial R&D activities. On top of that you then have to do the sales and marketing which are extremely expensive. The latter area is very well handled by our American colleagues. In my area of electronics, software tools in particular, one finds that the American companies dominate the scene. Not because they have better innovation, quite the reverse, it is because they have actually put more time and money into the marketing side.

4. In respect of amalgamists and "short-termism" I believe this is likely to be aimed at the Stock Exchange. Comparing by experience at board level with UK companies and that of Siemens, there is a very significant difference; namely Deutsche Bank have a very large stockholding in Siemens and are there for the long term. The British companies have a much more fickle shareholding base and as a consequence they are being judged on their short-term situation. For example, as Chairman of Synergo, a software house providing stockbrokers with appropriate tools, because of the TAURUS close-down, quite a number of our banks, etc., have been very concerned about our wellbeing. It is clearly short term until the appropriate Stock Exchange guidelines are renewed but the input on the company is devastating.

5. In respect of international markets where the UK is very successful, for example in the food processing industry, very often it is not innovation that has enabled their success. It is very solid product quality.

6. I think many of the institutions within the UK have been changing very rapidly. My own university, Brunel, is a pioneer of the sandwich course structure which is particularly successful in turning out engineers with a broader remit. This is considerably enhanced by the thin sandwich course structure where they gain experience and knowledge as they progress through their course. It is horrifying to report however that through the Funding Council and other Government directives, we are beginning to see the demise of this four year programme. This is basically because it costs too much to produce someone with a degree. The fact that it produces greater added value than with just a degreed person but with a very significant aptitude and ability to work effectively in industry which is very much reflected by Brunel often being at the top of the Financial Times Employability League, is totally sacrificed for some short-term cost savings as judged by the powers that be.

Memorandum submitted by the University of Birmingham (23 June 1993)

Thank you for your letter of 6 May 1993 inviting me to give details of the arrangements for liaison between higher education and industry which exist at the University of Birmingham. I am attaching a response which sets out information about how we organise matters here and draws attention to our policy and procedures.

I have instructed my response in accordance with your specific queries, but I have also made some general comments about the topic. I would emphasise that liaison takes place at every level in the Institution from individual contacts generated by members of staff, to School and departmental liaison. Faculty-wide initiatives and corporate-level strategy and policy.

The relationship between higher education and industry is also a dynamic one which develops very much on the basis of personal interactions and which can be disontinuous as well as continuous as people change roles or leave organisations, or areas of research and development progress both in the University and with our industrial partners. The aim of corporate policy is to set up structures which are facilitating or which provide a conducive environment for interchanges of ideas and technology within a fully commercial framework. As the White Paper—Realising our Potential—makes clear technology transfer is not a linear process. It is best modelled as a series of cycles which take projects and partnerships forward (and occasionally backwards) as the key relationships develop. This takes time and the investment of resource and commitment on the part of industry and universities.

I was struck by areas which the inquiry does not seem to highlight. I would stress the importance of professional consultancy; the provision of other services and facilities within the laboratory; continuing education and training; short courses; graduate, recruitment; student projects and placements; and attachments. These are all mechanisms which contribute significantly to interaction between industry and higher education and which foster the transfer of technology and innovation into British companies. Indeed, British businesses could profit greatly in this respect if they were to recruit much higher levels of graduates. This is especially true for small and medium sized enterprises where, if a graduate is employed at all, it will often be in the Accounts section or the Financial Director. We should encourage much greater awareness of the value to innovation in British companies which can be obtained from being more science and technology aware, from fostering strategic linkages with universities and from employing more graduates. Sectors of industry which do this are the most successful, e.g., the pharmaceutical industry. British industry must invest in ideas. Graduate recruitment is an important way to achieve this.

One example from this University of a commercially successful and innovative company which has been developed from the University's research base in BDS.

The company which is located on the University's Research Park was set up by staff in the Department of Immunology in the Medical School. It develops and sells reagents and immuno assays for medical and veterinary diagnosis employing over 100 people and has subsidiary companies in the US and Germany.

I trust you will find my comments to be of use to the Committee. Please contact me further if you wish to clarify any matters.

THE UNIVERSITY OF BIRMINGHAM

THE HOUSE OF COMMONS SCIENCE AND TECHNOLOGY COMMITTEE INQUIRY INTO INNOVATIVE AND COMPETITIVE TECHNOLOGY

Comments

1. General

It is encouraging that the Committee has sought information from universities in its inquiry into innovative and competitive technology. These comments describe policy, procedures, organisations which has been established at the University of Birmingham to foster links with industry and to make our contribution to the wealth creating capacity of British companies.

2. Organisational Arrangements

The University set up an Office of Research Support and Industrial Liaison (RSIL) in 1989 under a Director who reports to the Registrar and Secretary. This Office brought together staff and expertise previously responsible for the University's links with industry which date back to the 1970s.

The Office consists of the Director, a European Liaison Officer, an Industrial Liaison Officer and a Biotechnology consultant. More recently, a Metallurgy and Materials consultant has been added to the portfolio. The Director also has direct responsibility for the Careers Centre as the importance of co-ordinating the University's liaison with industry in research, training and graduate recruitment is a key feature of our integrated corporate strategy. Appendix A shows the investment which we make in this operation.

RSIL has many functions but in the areas with which you are interested, the Office provides a single point of contact for business and industry wishing to explore links on general or specific research topics. It also promotes the University's centres of excellence to the outside world and facilitates the process of obtaining research grants and contracts by disseminating information on opportunities to our academic community and developing projects and partnerships with external collaborators in the UK and in Europe.

The University has established a company, Birmingham Research and Development Ltd (BRDL) to deal with the dissemination and exploitation of inventions and other developments to industry. BRDL is involved with IPR protection and exploitation, new/joint venture companies, consultancy work by academic staff, and to a small extent, direct sales of instruments, reagents, etc.

The University's investment in setting up BRDL is not easily separated from its investment in its Research Park (see below), which is managed by BRDL, but approximately £100,000 was spent in the late 1980s over and above property investment. Since 1989 BRDL has been profitable and has now more than returned the University's investment through covenants.

The University's Research Park is controlled by Birmingham Research Park Ltd, a joint venture with Birmingham City Council in which the University holds 51 per cent of the equity. The University's investment in the property amounts to approximately £340,000. The Research Park has two buildings—the Apricot Computers Research Centre and the Institute of Research and Development, a multi-unit building which currently accommodates 17 companies, more than half of which originated within the University. They include BRDL, which as indicated above, provides management services, since the joint venture property company does not employ any staff.

RSIL and BRDL work closely together. Whilst RSIL is responsible for maximising the inputs to the University's research base, BRDL is concerned to maximise its outputs.

3. INTELLECTUAL PROPERTY POLICY

The University has a well-established policy on intellectual property. Details are attached in Appendix B which is an extract from the University's Regulations.

4. INDUSTRIAL INCOME

Appendix C gives an indication of our income, in direct terms, from industry. This only applies to research grant and contract income. It has only been possible to produce overseas industry figures for the years 1991-92 and 1990-91. Given the small percentage contribution, falling below 1 per cent, the income from overseas companies in earlier years is not material in the context of the University's total reserach income. It is emphasised that these figures only apply to research grants and contracts income and not to the totality of our interactions with industry as set out in my covering letter.

5. ROYALTIES AND PATENTS

Period	Total royalties £	Per cent foreign source	Per cent via BTG	Number of new filings
Up to 31 December 1987	398,000	[1]	[1]	[1]
1 January 1988 to 31 December 1988	271,000	[1]	[1]	[1]
1 January 1989 to 31 December 1989	537,000	5	63	14
1 January 1990 to 31 December 1990	570,000	4	47	15
1 January 1991 to 31 December 1991	904,000	11	49	16
1 January 1992 to 31 December 1992	998,000	16	[2]54	18

Notes:
[1] We cannot, without unreasonable effort, provide a breakdown of the early income.
[2] The BTG percentage was distorted (upwards) in 1992 by a substantial late payment of royalties due from earlier years; about 45 per cent of *current* royalties are received via BTG.

6. INITIATION OF INTERACTIONS

It is difficult to assess the balance between those interactions which are initiated by companies and those by the University and its staff. Clearly, we promote our strengths vigorously, by advertising and in marketing campaigns, seek partners for collaborative opportunities in the UK and in Europe, network at seminars, conferences, exhibitions and via individual presentations and promotions. I am attaching for your information some promotional materials (including a short video) which are designed to publicise our research. We also make use of the outcomes of public scrutiny exercises. The recent "league table" in the *Times* which gave the University of Birmingham sixth place overall in the United Kingdom is a very important indicator of our strength, ability and quality which industry can use. It is important that government departments and other public agencies should present the Higher Education sector selectively to UK industry and recognise that some institutions are better than others and that we do not offer more or less the same services to more or less the same level of excellence.

Most relationships which are fostered at the corporate level develop from known links in the University or from the initiative of specific, usually large companies, who are seeking to develop selective strategies towards universities.

Your list of mechanisms is not exhaustive. We make use of all of these (CASE, LINK, Teaching Company, contract research) but I would add consultancy; short courses; student projects and placements; continuing education and training; European collaborative research; joint ventures; once-off public-funded initiatives (sponsored by DTI, Department of Health, Employment Department, etc.); collective projects with charities and foundations which involve industry.

7. Policies towards technology transfer

The principal effort is in BRDL, which was set up for this purpose.

Support is needed from academic staff. This cannot take priority over teaching or research, but through royalty sharing agreements the academic staff have a financial incentive to find time for it in relation to patents and licensing. If staff agree to involvement in sales or new venture activities with BRDL, then other arrangements can be made for them to be financially rewarded.

8. Conclusions

Turning to the questions raised in the Press Notice, the following comments are made.

No mention is given of the fiscal incentives which could be considered by the Treasury as is common in other competitor nations. This was specifically rejected in the White Paper. "Short termism", if it is a problem, seems to be as much in the area of investment and finance as in the structures of British companies themselves. It is important to encourage the City and the financial institutions to take a longer view where innovation is concerned.

Innovation is about involvement in people and ideas of which there are no shortage in the Science Base and in many sectors of industry. As an institution, the University of Birmingham seeks to develop strategic partnerships with industry. It requires commitment and resource on a longer-term basis and a greater awareness in industry, together with the development of specific policies within individual companies, of the need to foster innovation through direct involvement with advanced science and technology in (through contact with universities) and through the recruitment of graduates.

APPENDIX A

University of Birmingham
Research Support and Industrial Liaison
Expenditure on General Funds

	Staff	Non Staff	Industrial promotions	Total
	£1,000	£1,000	£1,000	£1,000
1993-94 Budget	129	82	—	211
1992-93 Forecast	126	85	—	211
1991-92 Actual	123	79	transferred into non staff	202
1990-91	112	51	29	192
1989-90	93	54	1	148
1988-89	55	13	26	94

APPENDIX B

THE UNIVERSITY OF BIRMINGHAM

3.18 Patents and exploitation of inventions

1. (1) When a member of the staff makes an invention or discovery in the course of his or her normal duties or in such other circumstances that by law the invention or discovery belongs to the University and which he or she has reason to believe may be commercially exploitable he or she will report the same to the Managing Director, Birmingham Research and Development Limited (BRDL) for action and to the Head of School or, in the case of multi-Departmental Schools, through the Head of Department to the Head of School, for information. "Member of Staff" in this Regulation shall include all those engaged in work on behalf of the University without exception whatsoever, and "invention or discovery" shall include the production and development of computer software. Those with responsibilities for exploitation in this Regulation shall always act with all due expedition, according to the circumstances of the case.

(2) The Managing Director of BRDL will consult the Inventor and the Head of School and will recommend to the Registrar and Secretary whether and how steps shall be taken to protect and exploit the invention.

(3) If the Registrar and Secretary, advised by the Managing Director of BRDL, concludes that the University does not wish to participate in the development or exploitation of the invention the benefit thereof shall belong exclusively to the Inventor as between himself or herself and the University.

(4) Members of staff shall consult the Managing Director of BRDL as to the timing and procedure to be followed in connection with the publication of the results of researches likely to form the subject of a patent application by the University, or to lead to exploitation in which the University has an interest.

2. BRDL on behalf of the University will normally undertake financial responsibility for the preliminaries for further development and exploitation of inventions within a budget agreed between BRDL and, if appropriate, the Head of School concerned. The member of staff concerned shall, as directed by BRDL acting on behalf of the University, do any one or more of the following:

(1) Assist the University in applying for patent protection in the University's name in the UK or elsewhere.

(2) Enter into appropriate agreements for protecting the secrecy of the invention unless and until it is patented.

(3) Collaborate with BRDL, acting on behalf of the University, in the exploitation of the invention.

3. Patents and Licences will be written in the name of the University, and Licences will be subject to formal authorisation by the Registrar and Secretary of the University.

4. BRDL will make arrangements, acting on behalf of the University, to share any returns on the invention in such a way as to ensure that after BRDL has been reimbursed for the initial costs and administrations the member of staff and, if appropriate, the School concerned obtain a fair share (whether in a lump sum, by periodical payments, or both) having regard to all the circumstances, and, in particular to:

(1) Whether the invention was made in the course of his or her normal duties or of duties specially assigned to him or her.

(2) Whether the circumstances were such that an invention might reasonably be expected to result from the carrying out of his or her normal duties or duties specially assigned to him or her.

(3) Whether, because of his or her special responsibilities, he or she had a special obligation to further the interests of the University.

(4) The nature of his or her duties and the remuneration and other advantages which he or she derives or has derived from his or her position with the University.

(5) The effort and skill which he or she has devoted to making the invention.

(6) The extent to which the invention was made jointly by him or her with any other person and the effort and skill which such other person has devoted to the invention.

(7) The extent of the advice and assitance contributed by any other member of the University who is not a joint inventor of the invention.

(8) The contribution made by the University to the making, developing and working of the invention by the provision of advice, facilities and other assistance and by its managerial skill and activities.

(9) The extent of the return and other benefits derived from the invention.

5. Any rights in a discovery arising from the work of a member of staff sponsored by outside bodies, or those directly employed by outside bodies, shall be subject to this Regulation unless any special conditions relating to patents and commercial exploitation have been agreed by the University and included in the terms of the relevant contract or agreement with the outside body.

APPENDIX C

University of Birmingham
Research Grant and Contract Income over the past decade

Line Reference	Financial Year	UK Industry/ Commerce £000	Percentage of Total Income	Overseas Industry £000	Percentage of Total Income	Total Industry Income £000	Percentage of Total Income	Total Income £000
1.	1982-83	715	9.8	N/A	0.0	715	9.8	7,287
2.	1983-84	668	8.2	N/A	0.0	668	8.2	8,153
3.	1984-85	1,247	12.6	N/A	0.0	1,247	12.6	9,900
4.	1985-86	1,759	15.3	N/A	0.0	1,759	15.3	11,519
5.	1986-87	1,861	13.9	N/A	0.0	1,861	13.9	13,398
6.	1987-88	1,870	12.8	N/A	0.0	1,870	12.8	14,619
7.	1988-89	1,835	10.8	N/A	0.0	1,835	10.8	17,039
8.	1989-90	2,076	9.4	N/A	0.0	2,076	9.4	22,160
9.	1990-91	2,332	10.2	367	1.6	2,699	11.8	22,955
10.	1991-92	2,540	10.2	517	2.1	3,057	12.2	25,001

Memorandum submitted by Middlesex University (24 June 1993)

Organisational Arrangements

Middlesex University is represented by a Research Committee, membership of which comprises the heads of the separate Faculty Research Committees. From this Faculty level developments are disseminated to industry, contacts being made with individual members of University staff rather than with the Committees.

The Research Committee's terms of reference do not encompass directly the translation of the Science Base into innovative and competitive technology. However, expanding links with industry and the transfer of technology is included in the University's key objectives and responsibility for achieving this is shared by all Faculties, Schools and Research Centres.

Support for all members of staff is provided by Middlesex University Services Limited (MUSL). This commercial company:

— Acts as a central point for industry wishing to contact the University and for members of staff wishing to make contacts in industry.
— Incorporates the Industrial Liaison role.
— Provides commercial support to the University with guidance on IPR and its exploitation.
— Provides funds for development of new technology into new products and processes.

POLICY ON IPR

The University does have a policy on IPR. Arrangements for ensuring the protection of IPR operate through the University's Commercial Manager (who is also General Manager of the subsidiary company) reporting to a Deputy Vice-Chancellor.

A new policy is being prepared which will encompass copyright, patent and design rights for students and staff and will include guidance notes for the commercial area and for those undertaking and supervising research.

MUSL has acquired a Laser Disc Training Package from the Patent Office and will be making this available for all staff. It will be sited in the Faculty of Technology.

INCOME FROM INDUSTRY

Year	SERC £k	Industry £k	Per cent
1990-91	189	29	15
1991-92	185	49	26
1992-93	125	37	30

Approximately 10 per cent of industry income listed above comes from overseas companies. Currently no industry income comes as royalties.

This industry income relates to industry sponsored research—an additional £100k per annum comes into the Faculty of Technology for specifically commissioned consultancy and applied research projects.

INCOME FROM PATENTS

Since 1983 the University has been involved with the development of five patents but so far has only one signed agreement where it will receive a share of royalty income. Negotiations are also expected with two of the other patents.

INTERACTION WITH INDUSTRY

We would estimate that 15 per cent of interactions with industry take place at the specific instigation of the company, 15 per cent is instigated by the University and 70 per cent comes from ongoing relationships.

The predominant form of contact is commissioned research with some contribution also from the Teaching Company Scheme.

POLICIES ON TECHNOLOGY TRANSFER ACTIVITIES

The University has introduced policies within the last year which *inter alia* actively encourage technology transfer activities within its key objectives of developing research and increasing its contribution to industry and the community. At this stage it would be too early to judge the effectiveness of the policy.

I do hope the above is sufficient for your Committee's purpose but please let me know if you require clarification on any of the responses or any further information.

Further Memorandum submitted by Middlesex University (16 August 1993)

MIDDLESEX UNIVERSITY AND IPR

1. The University respects the rights of owners of IPR and will try to ensure its staff and students do not infringe these rights which action could lead to civil or criminal actions.

2. The University will seek to develop IPR in its own name as a means of providing external income streams into the future.

3. The University will encourage the development of IPR in the name of students and where appropriate in the name of staff.

4. The development of IPR should be built into all University activities of a creative or inventive nature rather than being an afterthought at the end of the process. Such emerging IPR should be actively monitored and supported.

5. The decisions to develop, protect, defend, abandon, license, sell or otherwise exploit will be taken by the Resources and Commercial Director on a case by case basis bearing in mind costs, benefits and risks.

6. The University will provide early and impartial advice to staff and students on the question of IPR and will also provide training in this area.

7. Ownership of IPR is defined by the following guide:

Patents	For University staff, the Contract of Employment applies giving ownership to the University for any patents arising during the period of employment.
	For Researchers and Students, subject to claims for intellectual contribution from academic staff and from funding organisations, the ownership will reside with the individual inventors.
Copyright	Contractual arrangements for copyright are included in the Staff Handbook.
Designs	The contractual arrangements for copyright should be extended to include design rights.

8. Income sharing will apply where IPR is held in joint ownership with the University or where the University invests in the development and commercialisation of any product or service arising out of the IPR. Income sharing will be calculated according to the formula:

After deducting all direct costs for development and commercialisation, the individual owner(s) of the IPR will receive 75 per cent of the first £10,000 with the University receiving 25 per cent. Thereafter, the income after costs will be split 50-50 between the University and the owner(s) without limit.

Memorandum submitted by Professor K N C Bray, Department of Engineering, Cambridge University (25 June 1993)

Thank you for your letter dated 8 June inviting me to submit evidence to the Science and Technology Committee of the House of Commons.

The questions posed by the Committee are important but also complex and I believe that different patterns will be found in different fields. It may therefore be relevant to note that I am a Mechanical Engineer and that the industrial companies with which I interact are mainly in the automotive, aircraft and energy buisnesses.

In the following paragraphs I first answer the four questions posed in your letter and then draw attention to some other matters which I regard as even more important.

In my experience the most efficient communication occurs between individuals with similar scientific backgrounds. Successful major companies in the automotive, aviation and energy fields maintain highly qualified specialist staff whose job it is to liaise with university research groups and to assist the process of technology transfer. The most efficient transfer occurs when researchers from a university and an industrial company actually work together in a sponsored research programme. Successful examples of technological innovation originating in this manner may be found in my own laboratory at Cambridge.

Many universities have set up special units to assist in industrial collaboration and technology transfer. Some also offer programmes of continuing education with the aim of bringing recent developments to the attention of industry. These activities play a useful role. Again, in my field, many small firms exist at the interface between universities and industry which provide consultancy and other specialist services to industrial companies. These small firms also assist in the process of converting university research into industrial innovation. I would like to stress that an essential stage in the process of translating the Science Base into industrial innovation takes place inside universities in the transfer of ideas and techniques from the "pure" sciences to more applied subjects. Unless the pure sciences are actively fostered and appropriately funded this process will dry up and industrial innovation will eventually suffer.

In your letter you ask whether I consider myself to be well informed about technological interaction with industry and whether good advice on such matters is available to me. My university appointment requires me actively to foster links with industry. Therefore, it is my business to be well informed; the companies with which I interact also see it as their job to keep me up to date. This happens through research contracts, consultancies, conferences and also through informal contacts.

However, the industrial companies which participate in this close and largely successful interaction with university research groups are always self-selecting. There are many other industrial concerns which do not employ any staff to liaise with university research groups, or to attend scientific conferences and do not seek any contact with academic research. If the Committee wishes to encourage the translation of the Science Base into innovative technology it should begin by recognising that hindrance to this process does not arise mainly in universities. University departments and individual staff members are usually keen to see their ideas exploited and need the associated research funds. From my perspective the bottlenecks to technology transfer are almost always within industry and commerce. Companies which do not employ appropriately qualified staff, or participate in scientific conferences, or join in collaborative research programmes are not always well informed about the most recent scientific developments and their possible applications. In other industrial concerns, where all of the necessary scientific liaison infrastructure is in place, senior management may still not follow the advice of their own specialists. These are problems which cannot be addressed by universities.

Finally, you ask whether my experience in this area could usefully be passed on to other research workers. I believe that my experience is no different from that of many others in my field and that most university research workers are in any case well informed about technological interaction with industry.

I do however strongly believe that better advice should be offered to industry. The European Community sponsors many collaborative research programmes which provide excellent examples of the ways in which academic research groups and industrial companies can co-operate in order to foster technology transfer. I participate in several such programmes together with, in one case, a group of car manufacturers including Rover and, in other case, a small consortium including British Petroleum. These joint programmes provide a mechanism by which industrial and university partners can work closely together. They ensure that academic participants are well informed about industrial needs and that their partners from industry know of the latest developments of academic research.

In my opinion the Committee should seek ways of convincing senior industrial management of the need for collaboration along these or similar lines.

Technology transfer and the relationship between the Science Base and industrial innovation are of course also taken seriously in other Western countries. I am writing this letter while working in France at an institution in the University of Rouen which is devoted to the process of technology transfer to industry. Similar institutions exist in many British universities and, as Dean of the Faculty of Engineering at Southampton University, I was actively involved in their formation. However, the foundation of the Laboratory in Rouen has been actively encouraged by agencies of both central and regional governments in a way which reflects the high priority of technology transfer in the policies of these agencies. As a consequence the Rouen Laboratory posesses a remarkable infrastructure of expensive computing and measuring equipment which is far in advance of the equipment available in corresponding institutions in the UK. Infrastructure on this scale will not become available to us through our system of research grants and contracts. As in other fields we in the UK will get what we pay for.

Memorandum submitted by the University of Hertfordshire (30 June 1993)

I am responding to your request to the Vice-Chancellor for answers to specific questions relating to our arrangements for liaison with industry.

Within the University of Hertfordshire's mission to provide a comprehensive system of higher education and advanced training which is responsive to local, regional and national requirements, is a determination to make provision for the development of research and consultancy work and an objective to increase income from these and other commercial activities by a considerable factor over the next five years.

Exploitation of research achievements are considered of vital importance and the University has set up a commercial company, UH Ventures Ltd, to enhance this activity. The company is a wholly owned subsidiary of the University and does not employ its own staff but uses the services of existing members of staff of the University. The company acts as the interface between industry and the academic community, being the first line of enquiry for industrialists with solutions to problems and marketing the various products of the University.

Research exploitation is specifically the responsibility of the Research Office headed by the Director of Research, an academic acting in a part-time capacity, and supported by two administrative/clerical staff.

The University has established a policy on the ownership and exploitation of intellectual property rights (IPR), which has been accepted by the Research Councils, and has agreed a royalty sharing arrangement with its staff. Technical audits are carried out at regular intervals to establish IPR status of new projects and project leaders are also required to bring potentially exploitable developments to the notice of the Director of Research before publication takes place. The University provides funds to cover the initial costs of patent protection and expects the intellectual property to be developed either by direct licensing to industry or in a collaborative programme such as LINK.

Research income from industry over the past 10 years has averaged at least £2 million per annum and grants won in the last year total £3.9 million, of which £2.4 million has come from industry.

We have averaged four patents per annum over the last 10 years and we have not tried to yield royalties by direct licensing to industry but have used the patents as an encouragement to industry to become involved in collaborative projects, a evidenced by the income this year. We have not used the services of BTG.

Interaction with industry takes place increasingly at their instigation. For instance a formal collaborative agreement for research and training between the University and British Aerospace has been in existence for the past six years and is about to be renewed at their request. Similarly Glaxo Ltd have funded the establishment of a Chair and laboratories to support collaborative work at the University. Four Teaching Company schemes currently running were initiated by approaches from industry and three LINK schemes were generated from industry's interest in our intellectual property. There are a number of CASE studentships particularly invovling the pharmaceutical industry.

The University encourages staff to become involved in technology transfer activities, both by collaborative research and consultancy work, and shares both royalties and consultancy fees with them. Staff are keen to be involved in these activities within the limits imposed by teaching and related duties.

I trust this response satisfies your requirements but please let me know if you require any further information.

Memorandum submitted by Professor S Roberts, Department of Chemistry, University of Exeter (30 June 1993)

Thank you for your letter of 8 June. We have considerable experience in interacting with those industrial Companies involved, in one way or another, with the pharmaceutical industry.

The major advantage that I have, as an academic, is six years experience (1980-86) as Head of Chemical Research at Glaxo. Obviously, from this experience, I am sensitive to the needs and the urgency in the industry and I can therefore dovetail our research into appropriate areas. In essence it allows me to second-guess where Glaxo and like-Companies will need help in the medium term and I can channel effort into strategic areas ahead of that time.

Moreover we have had most positive and exciting interactions with small/medium companies who act to supply intermediates to the pharmaceutical giants. We have helped Chiros (Cambridge) to commercialise three processes in the last three years. We also interact with Ultrafine Chemicals (Manchester) and International Specialty Chemicals (Southampton) in the same upbeat way.

I believe academic groups must endeavour to make serious contact with industrial partners (through LINK schemes, CASE awards, etc) in order to ascertain and foster current and future areas of mutual interest. The academic partner must endeavour, of course, to pursue science of the very highest quality and novelty, and remain flexible to take up new challenges.

I do believe there is a real opportunity for the chemical community in the British HEIs to increasingly join forces with industry to allow it to go from strength to strength. The Government needs to continue to build bridges in the fashion of the LINK programme.

Memorandum submitted by Glasgow Caledonian University (5 July 1993)

INTRODUCTION

The University is delighted to respond to the inquiry into routes through which the science base is translated into innovative and competitive technology through links with industry.

Glasgow Caledonian University is a new institution established formally on 1 April 1993. Its mission has been developed in the light of achievements, traditions and aspirations of its parent institutions, Glasgow Polytechnic and Queen's College, Glasgow. However, Glasgow Caledonian University is more than the sum of its predecessor institutions. The University has three Faculties: Science and Technology, Business and Health in which more than 10,000 full-time and part-time students study. The University's three campuses are all in Glasgow; the City Campus situated in the heart of the City Centre; Park Campus which is in the City's West End and Southbrae Campus situated futher West in Jordanhill. In seeking to achieve its mission the University aims to create a community of professional in education provision committed to achieving the highest possible standards in their activities and it endeavours to maintain a local, national, European and international focus to the mutual benefit of the students, staff, its partner institutions and industry and commerce.

The University, in responding to the routes through which the science base can be translated most effectively into innovative and effective technology, welcomes the recent publication of the White Paper on Science and Technology. The University believes that the White Paper addresses some of the significant issues which are currently facing UK science and technology and develops ways forward. In particular the University was pleased to note that there was a clear government committment to both basic and applied research and that particular emphasis was being placed on the fundamental importance of science and technology to wealth creation in UK industry. The University also believes that statements relating to the commitment of the integration of basic and applied research is of particular importance to a new university such as Glasgow Caledonian. In particular the University agrees with the statements in the White Paper regarding the need to place particular emphasis on the importance of the public understanding of science and technology.

The University is aware that much of industry in the UK is still science-based and believes that research and development has a critical place in the survival of industry in the future. It is recorded in the corporate plan that the University will play a critical role in training a generation of research students capable of developing research in the industries in which they are employed to the benefit of the competitive nature of the UK.

The University supports the need for better UK manufacturing competitiveness and believes that for a nation to perform well industrially it is important that sectors such as the science based industries, the specialist supply sector, and traditional sectors all perform well and interact and feed from one another in terms of innovations, ideas and knowledge. The University believes it is important to train a cross-section of scientists and technologists to provide an effective balance to serve these industrial sectors.

The University believes technical audits will increase effective transfer of the science base. Glasgow Caledonian University has recently commissioned a science and technology audit with a view to developing a complete profile of the assessment of opportunities for exploitation of intellectual property. The University views this as an important development in relation to improving the effectiveness of future technology transfer to industry by being aware of the expertise available for transfer to the large range of industrial companies with which it has contact.

The University is convinced that the purpose of the science base of the UK cannot be separated from the economic welfare of its high technology industry and believes that there is an increasing need for a greater proportion of the budget for the science and technology to be used for the purposes of strengthening high technology in industry so that competitiveness can be sustained and extended at international level. The University believes that the basic criteria of success should be the conversion of scientific and technological research into measurable economic effects of new products and processes operating within industry.

As a new University it will take time to become involved in the delivery of effective products from research as in many cases time scales which can take up 10 to 12 years are involved. However, the University has made a commitment to the conversion of results of research to products and believes that the process leading to success does involve high quality research results backed by appropriate investment, management, market research, prototype creation and reacting to feedback from the market. The University believes that its University Company will be able through its specialist Divisions to take forward partnerships with industry deriving from the high quality research work completed by University staff. The University will selectively direct its resources to create and maintain the largest possible scale of research groups capable of being internationally significant thus building on already well established groups such as the Centre for Bulk Solids Handling Ltd and The Software Metrics Laboratory. However, the University also sees a great importance in providing underpinning finance to catalyse and develop new research areas and therefore the University's management of research is designed to selectively take forward well established areas while at the same time providing the framework for the support of new research areas.

Balancing academic demands with industrial demands

For some time the University has considered the rather difficult question of how it should effectively balance academic demand with industrial demand. The University considers this aspect to be fundamental to the development of effective technology transfer to industry. A number of factors are regarded as providing an increasingly difficult situation to control. The demands on lecturing staff have tended to increase over past years making it increasingly difficult for staff to apportion time for technology transfer activities. The main functions within an academic institution are to provide effective teaching to undergraduate and postgraduate courses and to be involved in a range of research activities from basic to applied research. At present most academics advance their careers by research, teaching and administration. There is not a defined career path for the academic who links up extensively with industry to develop a product from research. Promotion is generally viewed on the basis of a good teaching record and a publication record.

One of the main problems of academics working with industry is that often a company requires confidentiality in respect of work carried out and hence it cannot be published. Generally this is a discouraging feature for most academics where a publication record is vital. The University is of the view that the academic contract involving teaching and research must be honoured and thereafter it is realistic to become involved in the technology transfer to industry via consultancy where staff obtain extra income as a result of generating external income for the University. To operate such a scheme effectively means a clear policy laid down by the University which provides the staff with an indication as to how much time they may be expected to spend in this form of activity. There is obviously a need to place careful control on the balance between time expended on the academic contract and on consultancy. There is a basic conflict between the two types of activity particularly where academic members of staff are involved in the transfer of technology associated with urgent problems in a company. This can lead to conflict when an academic is involved in the delivery of agreed aspects of technology transfer to a company for income generation while at the same time having direct commitments to teach undergraduates and supervise research. Academics cannot be involved in directing transfer of technology into a company while at the same time be present in the classroom. It is this tension that makes it difficult to develop a well defined policy for academic staff to operate with industry. Although it might be argued that longer-term research places less constraints in terms of time this has not been found to be true as contract research work again requires staff to meet specific deadlines generating conflict with teaching. In addressing this problem the University is convinced there is a need for the appointment of full-time staff who are capable of progressing and controlling technology transfer to industry and who can form the bridge between the academic and industry. By having full-time staff who can provide an industrial liaison function, a marketing function, a development function and a project control function this means that the academic can concentrate on delivering his/her science and technology expertise at appropriate intervals which can be integrated and in balance with the academic contract. It is the view of the University that this balance of academic demand with industrial demand can effectively be controlled by the use of a University company with a full-time staff capable of acting as the bridge between academia and industry. Glasgow Caledonian University Company Limited, (formerly Glasgow Polytechnic Enterprises Limited) has over the past six years been increasingly effective in terms of creating a bridge between the academics in the University and industry. By having a number of full-time staff with a range of professional disciplines as a back-up to the academic staff this means that technology transfer projects can be led by full-time staff within the company but utilising at the same time the high academic expertise in science and technology available from the academic staff. This facilitates a solution to providing effective technology transfer by resolving the tension between an academic completing the teaching/research function while at the same time providing a fast response to industry. Thus the Company can provide a smooth link to the industrial company ensuring that the projects are delivered within an industrial time scale while at the same time using effectively academics' expertise. The University has found that the company can connect with both environments by responding quickly to enquiries by industry, by influencing research topics to satisfy industry's needs and providing the commercial infrastructure to manage projects effectively thus providing and effective solution to balancing academic and industrial demand.

It needs well defined guidelines for staff to operate through the University company and Glasgow Caledonian University has evolved guidelines for operation through the company where staff by agreement with their Head of Department are able over and above their academic contract to engage in transfer of technology to industry. It is therefore the responsibility of each Head of Department to ensure that a healthy balance is maintained by academic staff involved in the delivery of the academic contract with the demands for technology transfer to industry. The University believes that in providing services from the University Company that it should do so on a commercial basis, therefore all projects are professionally costed. This is considered to be important as many of the academic staff are not qualified to make commercial costing decisions and do not have time to become involved in an area where they have least expertise.

Another aspect which cause problems in terms of academic staff becoming involved with industry is the relative weighting given in the research assessment exercise to applied research and to basic research. Generally academic staff are aware that basic research gains greater recognition in this exercise and therefore there is a need for government to give more recognition to staff who become heavily involved with applied research in industry.

IMPROVEMENT OF MECHANISMS FOR TECHNOLOGY TRANSFER AND INTERACTION BETWEEN THE SCIENCE BASE AND INDUSTRY TO IMPROVE EFFECTIVENESS

Staff are not always aware how marketable their technology is in the wider market place and highly motivated and dedicated researchers are often capable of producing high quality research results with little or no ability to analyse their commercial potential. The University believes that this is probably a more general problem within universities and believes that government should address mechanisms whereby the technology transfer can be improved. One way would be by investing in significant staff development to educate academic staff as to ways and means of converting research results to marketable products. However, it is believed that this could be best solved by the appointment of appropriately trained facilitators capable of commercially analysing research results. Significant improvement could also be achieved by government investment in collaborative schemes between industry and universities to analyse research results in terms of a potential marketability. This could take the form of local forums of appropriate personnel meeting with the University Company, the latter having drawn together at appropriate intervals the results of research in the University. Another possible method could be for industrialists in the region to form a club through the University Company thus giving access at appropriate periods to research results for analysis. Generally, small to medium enterprises are slow to see benefits and are less keen to convert research results to a marketable product as it involves large financial investments. However such a scheme would certainly improve the quality of contact between industry and academia but government would need to provide the financial underpinning particularly to medium sized companies. In the longer term a change in culture is required where academics able to produce research results are also in a position to assess the commercial potential of the results. It is University policy to encourage staff to obtain information early enough to be able to initiate strong patent protection where there is a belief of a marketable result. Within the University Company consideration has been given to the formation of a Product Division which would become the focus for assessing the marketability of ideas developed within the institution and this Division would also facilitiate the productisation of the products and processes from research. The University believes that this will provide a strong motivating factor for future growth of technology transfer in the University. The Product Division will seek licensing agreements with appropriate companies for the development of marketable products and will act as a professional facilitator between the academic and appropriate companies.

CULTURE CHANGE

The University believes that one of the basic problems affecting the transfer of science and technology to industry is a traditional lack of support for the UK's industrial culture. The University believes that over the past 50 years attitudes to science and technology in Britain have not really changed and it believes that until a significant culture shift takes place effective transfer will not be realised in the UK.

To support the needed culture change the University believes that more effective technology transfer could be established over time by strengthening the support for science and technology at government level by establishing a separate Ministry to support research, technology and innovation. The University believes that to achieve transfer of the science base to support UK competitiveness on an international basis that the education system needs further tilting and steering towards science and technology causing the skills developed to veer more sharply towards numeracy, science and engineering, and to further underpin the need for education and training to continue through adult working life. This could be best achieved by supporting interface developments between academia and industry and encouraging industry by tax allowances against expenditure on approved education thus ensuring industrial investment in effective transfer of science and technology.

SHORT TERMISM

The University believes that the government should be prepared to commit itself to a long-term policy on technology transfer independent of fluctuations in the economic climate where longer term innovation can be established as appropriate to all companies and not simply those traditionally regarded as being in the high technology field. The UK economy is largely supported by small to medium companies and it is here that innovation requires to be supported with much greater technology transfer. Therefore the University believes that a new form of partnership is need between government, industry and academia which establishes and fosters much closer collaboration across the interface at postgraduate master's and doctorate levels and continuous professional development. It believes that much greater exploitation of linkages between academia and industry could be supported and developed leading to more efficient transfer of the science and technology base. The University believes that these changes in themselves will be driven by the imperatives of international competitiveness on the one hand and by the dynamics of knowledge production on the other. If the UK is to survive by establishing international competitiveness then it believes government must ensure that firms become involved with and are committed to a continuous process of technological innovation.

RELATIONSHIPS WITH INDUSTRY

The University believes that a strong science base itself is not sufficient to guarantee international success in the science and technology industries. The University supports the extension of Teaching Company Schemes and similar schemes on the basis that they provide much greater cross linkage of research and development with other functions such as marketing, production and associated management skills. It believes that the development and training of human resources to provide a range of integrated skills combined with a good intellect to drive forward the research and development function will provide better underpinning to improve the transfer of the science base to industry. Many small to medium companies find themselves unable to make best use of highly trained specialists in advanced technology and the University believes that these companies would benefit greatly from postgraduates trained in an appropriate area of advanced technology in association with a broader based range of skills who would be capable of transferring specialised technology into creative and inventive developments in small to medium companies. The University believes the basic problem is achieving change of attitudes within industry, and believes that by training postgraduates in a more multidisciplinary based system that as these graduates progress through industry and reach senior management positions then they will be much more predisposed to the transfer of the science base into industry.

The University has been particularly pleased with technology transfer achieved through its Teaching Company Schemes in the last eight years. It has allowed the academic perspective to change whereby the transfer of the science and technology in the Teaching Company Schemes is achieved within industrial time limits of an operating company and has led to a greater understanding by academics of the transfer of commercial aspects of science and technology to the industrial base. The University sees the joint task of the industrial-academic collaboration as providing a strong support for a mutual learning process for both partners and providing a much greater and significant foundation for technology transfer mechanisms where academics can respond to fast changing technological and business factors in industry. On the basis of the success of the Teaching Company Schemes it believes in the need for development of novel integrated schemes with industry at postgraduate level. Already established within the University over the past two years is a Postgraduate Learning Contract Framework which integrates Business with Advanced Manufacturing Technology and brings companies and academics in the University together in the drive for new developments and growth within companies through transfer of advanced manufacturing technologies and relevant business attitudes to companies. The pilot scheme is organised through a joint programme between the University Company who organise and supervise the scheme and the academics who provide transfer of science and technology to the companies. This scheme has given excellent results and the University believes that this is an area for investment in the future where significant success will be achieved in transferring the science base to industry. On the basis of the success of the scheme at master's level, recently the University has embarked on the development of a framework at doctorate level where the University will work closely with a number of companies involved in research and development. The University strongly supports academic/industrial collaboration schemes such as the Integrated Graduate Development Scheme and Case Awards and believes that these interface techniques are particularly important within the UK to underpin efficient transfer of science and technology from university to industry.

It believes that basic science and research skills within industry have to be given increased importance in the future if industry is to become more competitive on an international scale. This means that a greater investment is required in producing research doctorates from integrative schemes between industry and academia. It believes that present resources are insufficient to sustain this type of development and while the University accepts that industry should be prepared to make a much greater contribution it believes that a greater resource must be made available through government.

The University Company

Glasgow Caledonian University Company operates through four main divisions: Industrial Efficiency Division, Special Projects Division, Business Division and the University Division. The Business Division is well established and includes consultancy involving a wide range of industrial companies where integrated business and advanced technology developments are transferred to companies. In delivering these projects a mixture of academic staff with specialist expertise and professional consultants within the Business Division operate together as a team.

The University Division provides a main bridging link between the academic staff and the Company. The University Division provides a vehicle through which staff can develop and have new ideas considered, explore patent rights and intellectual property agreements, can develop technology transfer courses and offer them to a range of industries. The Division facilitates the transfer of science and technology to industry by providing a vehicle through which academic staff can develop their ideas and turn them into professional products. One of the main functions of this Division is to address the need for professional updating which is required due to the very fast pace of scientific and technical change. It provides a range of high technology/science courses to allow the industrial base to update in these technologies and believes this is vitally important to drive change in UK industry. It believes that the UK has a poor track record of internal industrial retraining compared to countries such as Japan and Germany and therefore sees as one of its missions for the future to contribute to the transfer of science and technology through a number of advanced courses.

The Special Projects Division takes a number of ideas which are developed in the University Division and where there appears to be considerable potential for development with industry then further develops these as special projects. In addition the Special Projects Division has supported the development of overseas contracts in a number of European countries including the development of business centres in Poland, Russia, and Romania and the development of a company in Budapest, Hungary. Further developments within a number of European companies have progressed through this Division with a longer term aim of financial return.

The most recent development is the Industrial Efficiency Division which will provide a main vehicle for the transfer of advanced science and technology to a range of industrial companies with a view to improving efficiency.

An example of the type of development is the setting up of a specialist advanced technology company named The Scottish Maintenance Centre Ltd. The University believes that where there is particular expertise to be offered that to focus the research a specialist company may be developed. The Scottish Maintenance Centre Ltd operates collaborative grants between the Centre and industry, a typical example being the application of condition monitoring for the integration of predictive maintenance, toolwear and quality monitoring in manufacturing which is supported by a number of major manufacturing companies including Rolls Royce and Associates, Derby. The objective of the Centre is to be in a position to use the specialist expertise available in the University to take forward industrial collaborative developments involving the transfer of advanced technology associated with the maintenance function in industry and to provide professional development and postgraduate level training in advanced technolgy relating to maintenance.

Each division is co-ordinated by a full-time Chief Executive reporting to the Managing Director of the Company. The Company has a full-time staff of approximately 45 and therefore is in a position to provide the major bridge and link for the academic staff to reach industry and for industry to reach the academic staff and the science and technology developments within the University. The Company also provides a main marketing and publicity function in relation to making industry in the region aware of what is on offer in terms of science and technology from the University and regularly operates briefing seminars for senior industrialists. It brings together and facilitates the transfer of technology by matching appropriate groups of academic staff to an appropriate company or organisation. The company is completely self-financing and at the end of its operating financial year returns a profit to the University. It reports directly to the University Court.

SPECIALIST CENTRES IN DEPARTMENTS

The University also operates alternative models to the Company. Where specialist expertise is available in a Department, the University has encouraged the establishment of special units either as technology centres or as separate companies with full-time staff who are able to put the main thrust of their contract into developments with industry.

Typical of developments which have taken place in the University is the Software Metrics Laboratory which was formed in 1990 and has a major role in research and development work combining statistical modelling with software engineering. This Centre collaborates extensively with industry and is heavily involved in a number of UK and European projects.

One of the best examples of high technology transfer to industry is the operation of the Centre for Bulk Solids Handling Limited, a specialist company which was set up in the University six years ago. This has become a unique centre of excellence with an international reputation in the technology of bulk solids handling. This centre operates with full-time staff dedicated to working on technology transfer to industry either through direct collaboration between the Centre and industry or through collaborative grants. In addition, the Centre provides a specialist training at Master's level in Bulk Solids Handling Technology providing an essential technology transfer function through its postgraduate students. The Centre is located in the Department of Physical Sciences.

A recent example in the health area is the establishment of a new Clinical Research Centre which transfers research into an environment where patients benefit at Glasgow's Southern General Hospital. The Centre, equipped with specialised instrumentation and equipment investigates problems of balance, gait, mobility and cardiorespiratory performance and patient handling. This initiative derives from the transfer of successful research to practice by the Department of Physiotherapy.

The University believes that Glasgow Caledonian University Company Limited with its specialist Divisions and the creation of specialist technology centres within Departments provide ideal mechanisms whereby technology transfer can be effectively achieved between the University and industry. In each case it believes one of the fundamental points is the provision of full-time staff who can dedicate themselves to the professional development as opposed to being caught up in the conflict between the delivery of technology transfer to industry and the academic contract. Each model allows staff to participate as specialists for short periods either through the Centres or through the Divisions in the Company.

Income generation by transfer of technology to the industrial base through areas of specific expertise has a high priority within all relevant departments not only for the obvious benefits of increased income but also to maintain the name of the University at the forefront of the professional and industrial community to teaching activities. The University considers itself to have an innate responsibility to enhance the industrial potential of both the local region and Scotland. It believes that the credibility given to its academic courses will be much enhanced by being underpinned through research and the exposure of staff to industrial problems.

Prior to the establishment of the University Company in 1988 the institution operated through an Industrial Liaison Officer who facilitated contact between academic staff and industry and commerce. Prior to 1988 the level of industrial activity was less significant, the main direction of the institution being that of a teaching establishment. The industrial liaison office now forms part of the University Division.

RESEARCH ORGANISATION

The Research Committee in the University advises Senate on the overall research policy and strategy in the light of the University's mission. It also oversees arrangements for active marketing of the University with research funding agencies and is involved in ensuring the dissemination of research developments to industry. It ensures the publication of the University's research report which is publicised widely and is available to all organisations and industries in Scotland. The Research Committee is also involved in advising the senior management in the University on resource implications of University research policy and the allocation of available research funding within the institution. The University believes that the Research Committee and the University Company are in a strong position to ensure that all developments relating to research and other forms of technology transfer including specialist postgraduate courses are widely disseminated to industry in such a way as to enable industry to make direct contact with the appropriate persons in the University. The University is committed to improving on the significant progress made in research activity over the past years.

Research and consultancy activities clearly enhance the reputation of the University, provide an essential underpinning to its academic programme and considerably strengthen links between the University and its business, social, professional and industrial environments. Each Faculty operates a Faculty Research Committee.

The achievement of increased research activity is pursued by each Department in a manner most suited to its current research profile. As a relatively new University involved in developing a greater research profile, for some Departments this means a need to increase the number of active research staff and for others where there are a high number of such staff there is a need to channel resources towards increased numbers of research studentships and postdoctoral fellowships. Through the assignment of readerships and personal professorships active promotion of research groups within Departments takes place.

The University welcomed the element of new funding arrangements which makes it eligible to receive research funding from the new Funding Council. The University fully recognise the importance of the UFC research assessment exercise which was completed in 1992 and participated in this exercise for the first time. The outcome of the assessment exercise has now provided a guide to the University in relation to its future development policy in research with particular emphasis on the technology transfer of such research to the industrial base.

A central research database has been established in the University for preparation of a biennial research report and for research information purposes. The research report is widely distributed throughout industry providing information which allows companies to approach the University with a view to further development of the various research areas.

Industrial—Academic links

The University benefits greatly from established links with industry and having established a successful collaboration with a company it encourages members of staff and the University Company to retain these links in the form of ongoing relationships involving industrial-academic collabortion such as Teaching Company Schemes or other academic-industrial grants. The University Company is highly proactive in contacting industry and commerce in Scotland and the UK and many of the developments taking place in the University are led by individual academic members of staff interacting with industry. On an equal basis the University is approached by a large number of industries in the local region on a range of matters such as technology transfer relating to consultancy, the development of specific postgraduate courses, professional development courses and collaborative grant such as a Teaching Company Scheme.

A range of relationships exist involving the Teaching Company Scheme, ACME grants, Case studentships, industrial/academic collaborative grants. European grants, such as TEMPUS and ESPRIT, Overseas Development Agency, British Council Academic Links Projects with Hungary and the Czech Republic, DTI grants and Department of Employment grants.

New challenges in science and technology

The University believes that the UK economy now faces new challenges such as the environmental, pollutive, ecological, energy efficiency and physical infrastructural challenges and that this will require a high quality human resource output to meet these challenges, particularly in relation to interdisciplinary studies and skills combined with ability to research. It believes that Universities will require to invest in new Departments capable of providing training in systems skills.

The University, mindful of the need to transfer much of this new science and technology to industry has invested in the setting up of a new Department of Energy and Environmental Technology which will provide training at postgraduate level in interdisciplinary studies and skill in research. The University will shortly make an appointment to an industry sponsored Chair of Environment and Society and expects this appointment to provide a focus for the development of research programmes in the environmental systems area and to work closely with industry in the transfer of the science and technology base of such programmes to the benefit of the UK economy.

Investment in postgraduate training

The University believes that more investment in postgraduate training would lead to better transfer of science and technology to the industrial base. Given the three main locations where postgraduate training is carried out, i.e., within academia, within industry, or at the interface, the University believes that there is much gained by investment in the interface area. The University believes that British industry has a poor track record of re-training and professional development inside companies and therefore feels that development of interface postgraduate teaching to be a vital component for the translation of science and technology to industry. It accepts that it is not possible for a University to supply high technology expertise in all branches of science and technology and believes institutions should prioritise the areas where they can provide specialist transfer of science and technology to help establish efficient industrial practice. Thus the University believes that the science base can be best transferred and developed with industry through a much closer operation of postgraduate training between academia and industry using non-traditional methods such as Postgraduate Learning Contracts and doctorates in the workplace. It believes that postgraduate interface developments can become the bridge between academia and industry using postgraduates trained to take a wider, multi-disciplinary perspective but equally capable of undertaking in-depth research in industry on a jointly supervised basis and increasingly able to play a critical role to ensure that industrial production is supported by a more effective technology transfer. This implies equal partnerships between academia and industry with both being mutual beneficiaries. The University believes that if a successful postgraduate system is to be established to give more effective technology transfer then the government must work closely with industry to ensure that an equal impetus is established from industry as from academia. It believes that the problem is also one of scale with a greater number of more highly trained postgraduates being required from such a partnership. It accepts that this will involve considerable increased funding and agrees that some of this funding will require to come from industry. It will take time to establish an expanded programme and the UK economy requires to improve in the shorter term. This means that there is an urgent need for in-depth discussions between academia, industry and government with a view to increasing in the scale of postgraduate training at master's and doctorate level.

Policies on Time Spent on Technology Transfer Activities

Having previously discussed the tension between the time spent on the delivery of technology transfer activities and the delivery of the academic contract the University now gives consideration to each individual case. For example, in relation to the Scottish Maintenance Centre Ltd where a large DTI grant is operating over a two year period it has been agreed that a Reader and research staff directly involved in the project will devote their total time to the delivery of this research contract. In other cases policy decisions involve the back-up of academics by staff with specific expertise in the area under investigation. In the operation of a Department of Employment grant for Structured Industrial Practice Studies, while the research and development project is led by a Reader as part of the academic contract the development of this project is supported by the appointment of three full-time specialists to operate the project over the two year grant period.

The University policy is to encourage its academic members of staff to become involved in research and other entrepreneurial activities including postgraduate teaching which underpins the transfer of technology to industry and while the postgraduate teaching and research is part of the academic contract it encourages staff through agreement with the Heads of Department to operate as consultants through the University Company and to become involved in the development of inventions or ideas through the Company. For each development there is a discussion within the University Company and agreements drawn up between the individual, the University Company and the University to the satisfaction of each. The balance of involvement in technology transfer activities over and above the academic contract is controlled through the Head of Department who, as a strategic manager, is able to judge for the staff in the Department the respective availability to become involved in such activities. The University's policy is to encourage all staff to operate through the Company to provide appropriate support facilities including professional indemnity.

Exploitation of Research and IPR

The University is committed to the need to raise awareness about the potential for exploitation of research and ensuring exploitable results are properly managed. Staff in the University are able to consult professional full-time staff in the Company and are able to exploit results either through the University Division of the company or through a more formal collaboration with an industrial partner arranged through the Special Projects Division. Staff are encouraged to report research results to the University Division where professional staff can facilitate the potential exploitation of the results by communicating with a range of industries in the region. Where there is a high degree of possibility of exploitable results from collaboration with industry then it is University policy to encourage the establishment of an IP agreement at an early stage in the research. The University is still at an early stage in the development of an IPR policy but is aware of the increasing importance of establishing such. It is the intention of the University to establish within the University Company the management of and the development of IPR agreements. The University believes that professional full-time staff within the University Company are in a better position to exploit the results of the research by using professional business and marketing skills thus allowing academic staff to concentrate on the research itself.

The University has had a minimal involvement in the development of patents but holds the view that more research will be converted to products in the future and considers that a policy will require to be introduced on royalties giving an agreed split between the inventor, the University/the University Company and the academic Department. The University accepts that it is not possible for the Company and its professional staff to be totally proactive in terms of isolating every possible marketable idea that is generated from the research and development within the University. Therefore it puts a strong emphasis on communication where it expects that academic members of staff to be sufficiently motivated to communicate potential discoveries to the University Company with a view to exploitation.

INCOME TO THE UNIVERSITY

External research income and income generated by the University Company has been steadily climbing over the past number of years as follows:

EXTERNAL RESEARCH INCOME

1988-89
Number of grants/contracts started: 28
Total initial value of research income: £740,579.00

1989-90
Number of grants/contracts started: 60
Total external research income: £883,392.00

1990-91
Number of grants/contracts started: 75
Total initial value of external research income: £1,064,091.00

1991-92
Number of grants/contracts started: 123
Total initial value of external research income: £1,918,283.00

The proportion of the research external income associated with overseas is as follows.

1988-89: £81,500.00
1989-90: £467,080.00
1990-91: £108,600.00
1991-92: £249,100.00

In the period prior to 1988-89 research and consultancy income developed at a much slower rate as the institution changed its mission and funding body. By 1986 external income in total was £150,000.00.

At present the University has no significant income from royalties and no income from Business Growth Training. The external research income is the total income deriving from bodies such as SERC and involves all grant based activities. At present the level of developments relating to patents within the institution is such that the University at present derives no income from patents.

INCOME FROM UNIVERSITY COMPANY

Income generated and covenanted to the University by the University Company is as follows:

1988-89	
Turnover	£424,000
Operating Profit	£103,000
Covenant to University	£175,000
Number of full-time staff	5
1989-90	
Turnover	£759,000
Operating Profit	£187,000
Covenant to University	£200,000
Members of full-time staff	18
1990-91	
Turnover	£1,400,000
Operating Profit	£263,000
Covenant to University	£250,000
Members of full-time staff	34
1991-92	
Turnover	£1,764,000
Operating Profit	£91,000
Covenant to University	£155,000
Members of full-time staff	39
1992-93	
Turnover	£1,778,000
Operating Profit	£173,000
Covenant to University	£165,000
Members of full-time staff	42

Income generated from overseas European work by the Company is as follows:

1991-92	£35,000
1992-93	£60,000

INCOME FROM THE QUEEN'S COLLEGE, GLASGOW ENTERPRISE LIMITED

	Turnover £	Profit £
1989-90	270,192	28,141
1990-91	214,177	44,117
1991-92	270,121	69,664

EXAMPLES OF EXTERNAL RESEARCH INCOME FROM THE TEACHING COMPANY SCHEME

Carntyne Electronic Engineering Ltd (with Department of Engineering)

Development of a computerised system for design of wiring/cable form assemblies and JIT (Just in Time) manufacturing system.

TC grant £134,607. Company £57,689.

4 Associates, 2-4-2 pattern (1989-92).

Elite Bedding Company Ltd (with Department of Mathematics)

The development of a Total Quality Management System.

TC Grant £38,466. Company £16,485.

1 Associate, 1-1 pattern (1992-94).

Honeywell Control Systems Ltd (with Department of Mathematics)

Design, development and implementation of a software quality management system.

TC grant £29,977. Company £29,977.

1 Associate, 1-1 pattern (1992-94).

Bowater Containers Scotland Ltd (with Department of Management)

Development and implementation of a Total Quality Management System.

TC grant £27,909. Company £27,909.

1 Associate, 1-1 pattern (1992-94).

This is part of a multi-site Teaching Company Scheme with Bowater. It operates with seven universities in the UK. Glasgow Caledonian University is the partner in the Scottish Region.

RECENTLY COMPLETED TEACHING COMPANY SCHEMES

DAK Holdings Ltd (with Department of Mathematics)

The development of an integrated business system.

TC grant £35,468. Company £15,201.

1 Associate, 1-1 pattern (1990-92).

Edgcumbe Instruments Ltd (with Department of Engineering)

Design and implementation of a production related computer based recording system.

TC grant £56,000. Company £24,000.

2 Associates, 1-2-1 pattern (1988-91).

Hulley & Kirkwood (with Department of Engineering)

Development and implementation of quality assurance records system. Development of computer based design and management information systems.

TC grant £175,533. Company £43,884.

4 Associates, 2-4-2 pattern (October 1987–January 1992).

Johnston Shields & Co Ltd (with Department of Mathematics)

Development of a process planning and control system.

TC grant £33,066. Company £14,171.

1 Associate, 1-1 pattern (1989-91).

Kelvin Diesels Ltd (with Department of Engineering)

Introduction of computerised stock/production planning and control system. Development of a computerised data acquisition system for test bed monitoring. A feasibility study into the use and application of CAD.

TC grant £104,345. Company £63,709.

3 Associates, 1-3-3 pattern (March 1986–November 1989).

Scomagg Ltd (with Department of Mathematics)
High integrity software for industrial process control).
TC grant £163,535. Company £47,872.
4 Associates, 2-4-2 pattern (1987-90).

Memorandum submitted by The University of Warwick (9 July 1993)

SUMMARY

I. The University of Warwick has always been known for its close links with industry and commerce. The aim has been, and remains, to create mutually beneficial partnerships with business through all of the many different ways of achieving this.

II. Over the last 10 years the extent of these fruitful interactions has greatly increased, permeating most aspects of University life, ranging from sponsored research including LINK programmes, Teaching Company schemes, CASE students, consultancy, post-experience training and a Science Park.

III. Some key indicators of the growth in technology transfer activities:
- (i) Sponsored research by business, has risen from 3 per cent (£77k) to 23 per cent (£3.9 million) of non-HEFC research income.
- (ii) Income from short and modular courses run in collaboration with business has grown £187k to £8.14 million.
- (iii) Initially 18 companies employing 100 people on the Science Park. Now 64 companies employing 1,100 people.
- (iv) Income from royalties and licences has grown from £2.4k to £183k.

HOUSE OF COMMONS : SCIENCE AND TECHNOLOGY COMMITTEE
EVIDENCE SUBMITTED BY THE UNIVERSITY OF WARWICK

1. The University of Warwick welcomes the opportunity to give evidence to the Committee on the translation of the science base into innovative and competitive technology. Warwick has extensive experience of working closely with industry and commerce and has used most of the many different ways in which fruitful interactions between academia and business can be developed.

GENERAL OBSERVATIONS

2. The University will continue to develop these interactions since it regards them as mutually beneficial. Working with business is an integral part of the work of the University and no sharp distinction is made between this activity and advanced teaching and scholarship/research.

3. Industry and academia have different imperatives that drive them and different priorities. In order for both sides to obtain the maximum benefit from these interactions it is important to be aware of these differences and to understand them. In this way disappointment is avoided, as is the creation of expectations that cannot be fulfilled.

4. Technology transfer requires at least two willing partners. Both need to be committed to the success of the transfer and both should fully understand what is involved in the process if it is to be successful.

5. Warwick's general aim is to develop and maintain partnerships with business on as broad a basis as possible. Whilst we have many experiences of one off relationships such as single research projects, the University believes the most valuable and mutually beneficial relationships are broad based partnerships where the University and one or more companies interact in many different ways such as in research, consultancy and training including undergraduate and postgraduate teaching. The University believes this policy to be in harmony with the general philosophy outlined in the recent White Paper, Cm 2250 "Realising our Potential". To create and maintain these partnerships takes effort and time. All of the partners need to understand this and be prepared to commit the necessary amounts of effort and time to ensure the partnership is successful.

6. There are no set ways in which these partnerships come to be initiated. Sometimes they flow from a single research project into multiple interactions, and at other times and in many of the situations at Warwick they have developed from the University providing tailor-made training courses for one or more firms to meet identified needs.

7. In general the science base is some distance from the market in terms of the research outcome and its relevance to a product or process. This can be a severe problem for some industrial sectors. The pre-development gap that was identified by the Richards' report issued by SERC in the mid 1970s still exists for certain industrial sectors and very often also for Small and Medium Sized Enterprises. It exists in general where there is little or no in-house research. Sectors such as chemicals, pharmaceuticals, oil, electronics and

computing are generally one where firms can readily relate to University research results. The companies in these sectors on the whole have their own in-house R&D and can take research results from academia and turn them into product or process.

Other industrial sectors may find some difficulty in taking ideas and exploiting them in this way. They have no in-house capabilities for making these developments and in general much prefer to have research results that are very near market. Warwick has a very successful record of working closely with certain industrial sectors in the engineering field and providing research outcomes that are near market and can be fairly easily translated into product or process. This has needed a clear policy decision on the part of the University and in particular strong commitment on the part of those academics involved, to provide a research outcome that the firms can readily use. This has been achieved whilst still maintaining academic excellence and undertaking internationally relevant work.

8. There is a further aspect to academia/business interactions that needs to be mentioned since it does lead to frequent misunderstandings between academia and business and makes more difficult the development of harmonious relationships. This is the different perceptions that exist as to the meaning of contract research. A distinction can be drawn between contract research which involves business itself setting the objectives, the criteria for success of the research, and the University delivering results within an agreed timescale, and collaborative research where business shares with the University a process of scientific exploration where there is a division of resources based on a partnership in setting objectives. Most academic research is longer term in nature and should be seen as collaborative and not contract research, and this reflects the spirit of partnership between the University and the company. The pricing of the research and the ownership and exploitation of intellectual property generated are two important interlocking issues in negotiations between academia and business and contract agreements should therefore reflect the contributions of the partners, both tangible and intangible, to the research project.

9. There are also other issues that affect the development of academic/business interactions including:

— The time available to individual academics to devote to the subject bearing in mind their commitments to undergraduate and postgraduate teaching and other University duties.
— The extent to which their time for research is fully committed.
— The existence of career or financial incentives to the academic community to undertake work with industry rather than via the Research Councils.
— The presence of a Science Park.
— Difference of working attitudes for SMEs relative to large companies.

THE WARWICK SITUATION

10. Turning now to the specific situation at Warwick and addressing the questions that the Committee has drawn up, the University offers the following observations.

11. Regarding the organisation at Warwick for technology transfer, the University has had in place for some years now an Industrial Development Office (IDO). This currently comprises a Director plus three professional staff, who act as the central University focus for enquiries from business. The IDO is also responsible for the identification, protection and exploitation of intellectual property that arises from research in the University and the policy on intellectual property rights is described below. The IDO negotiates all research contracts that the University undertakes and therefore is closely involved with negotiations with firms, and has a number of other duties and responsibilities many of which are concerned with building partnerships between the University and business. One member of IDO is part-funded by the University Science Park and spends over half of his time interacting with companies. The total salary bill for the professional staff within the Industrial Development Office together with one and a half secretaries is approximately £100k per annum.

12. Table 1 appended shows the total research income to the University from all sources over the period 1982-83 to 1991-92. These data are from the Form 3 returns to the Funding Council. From the table it can be seen that the proportion of non HEFC research income to the University from UK industry and commerce has risen from 3 per cent in 1982-83 to 23 per cent (£3.88 million) in 1991-92. Table 1 also shows the growth in income from the research councils and from overseas sources. These latter sources were not sub-divided into European Commission and others until 1989-90 when 2.6 per cent of total research income was from the European Commission whilst 4.1 per cent was from other overseas sources. The current figures are 4.9 per cent and 3.1 per cent respectively. Thus over 8 per cent of the University non HEFC research income in 1991-92 was from non UK sources.

13. The University has an active policy with regard to Intellectual Property. Technology audits have been undertaken to identify intellectual property and action then been taken to protect via patenting or other appropriate means where this has been desirable. Protection by patenting is not always the most cost-effective way of protecting a discovery and the cost of obtaining and maintaining protection can be high. Whether the University files a patent itself or a company is found to act as a partner and to undertake the patenting and exploitation of the property depends upon the particular situation. A further option is for the University to invite BTG to seek protection and then exploit the particular innovation. All of these routes have been used

by the University to protect and exploit its intellectual property. Currently three patents are earning royalties. The University however has only spun-out a small number of companies to exploit its intellectual property and in general has not actively developed this approach to exploitation.

14. Table 2 indicates the income that Warwick has received from the exploitation of intellectual property. This income is a mix of up front payments and royalties and the major part of this income (£0.5 million) relates to one patent which is concerned with a structure of potential use in anti-cancer therapy. The proportion of royalty income flowing to the University through BTG is identified.

15. The initiation of interaction between the University and business can take place in any of the many different ways that the Committee has identified. The University encourages every academic to develop his own links with business and the involvement of the Industrial Development Office does not necessarily take place until a contract is required. It is not possible to give meaningful statistics as to the extent to which interaction with industry occurs at the specific instigation of the company, or has been initiated by members of the University and arises from ongoing relationships with industry. Both of these processes take place and the University is always active in extending its company involvements. For example over the last five years the University has had 14 active Teaching Company Schemes and seven LINK programmes some of which involve very many partners such as 12 in one instance and in a more recent case 21 partners.

16. An independent survey in 1989 identified 886 industrial and commercial companies with whom the University had one or more links. Thirty-two companies were in the Fortune list of the largest 500 companies, and 211 of the 886 companies (24 per cent) were local to the University.

17. The imparting of knowledge and skills through high quality education and training is also an important technology transfer activity. Warwick has actively developed its spectrum of education and training opportunities to meet more closely the needs of industry and commerce, with major developments being made by the University's Business School and also by the Manufacturing Group within the Department of Engineering (see below).

Following extensive consultations with industrial firms, it was concluded that most of their in-career training needs would be met by the provision of modular short courses designed and delivered jointly by the University and the companies. This approach has been successful and this success is reflected in the growth of short course income over the 10-year period 1982-83 to 1991-92 from £187k to £8.14 million.

18. In order to meet this demand for short course post-experience training the University has had to create high quality residential training centres. Thus over the last six years Radcliffe House and latterly Scarman House have been opened and have joined with Arden House to provide more than 500 high quality study bedrooms plus teaching accommodation on campus open for business in term and vacation.

19. One of the groups at Warwick most closely involved with industry is the Warwick Manufacturing Group (WMG). Starting in 1980, the group first developed the Integrated Graduate Development Scheme (IGDS), a modular part-time masters degree course. The course is designed and run with a consortium of companies, and seeks to integrate career development with vocational education of company employees, typically graduates with at least 2-3 years experience in the firm.

20. The scheme is probably the largest one of its type in Europe and currently there are more than 40 companies providing 400 students. Each student takes a series of one-week modules at the University each followed by six to seven weeks in the firm during which a specific assignment is carried out. Each student takes two compulsory modules plus at least 12 selected modules from a total of around 50 module options, and undertakes a major in-company project during the three year course.

21. In 1988 the WMG launched a further scheme, the Integrated Manager Development Scheme (IMDS), which is a part-time modular diploma course similar to IGDS based on half-week residential modules. No formal qualifications are needed for entry to the course. There are currently 18 companies involved in the scheme, providing some 450 students, most of whom are "middle managers" in industry.

22. Since 1980 the staff of the WMG has grown to more than 230, including industrial secondees and at present some 3,800 students per annum are involved in training provided by WMG.

23. The WMG also undertakes research and a custom built centre—the Advanced Technology Centre (ATC) was built on the campus in 1986 with the aid of the Rover Group and Rolls Royce. Research in the ATC is collaborative with at present 30 companies sponsoring about 30 projects with a total value of £6 million.

24. The University of Warwick Science Park Ltd was formed in 1984 and is a company owned by Coventry City Council (45 per cent), the University of Warwick (35 per cent), Warwickshire County Council (8.5 per cent), and the West Midland Enterprise Board (11.5 per cent). The Vice-Chancellor of the University is Chairman of the Board and University staff are Board members. The Science park Director is also on the University staff. Initially the Park began with 18 companies employing 100 people and has now grown to

64 companies employing 1,100. The Park is designed to allow Companies a wide range of accommodation with a system of flexible leases to allow easy growth. It is possible for a company to begin with a 400 square feet incubator unit, grow through 1,000 sq ft and 3,000 sq ft units, to end up in its own building. A condition of the lease is that a company should work with the University, and companies often appoint Warwick graduates to facilitate this.

25. An important reason for the University's wish to build a Science Park was to establish an additional method of technology transfer, as well as encouraging the growth of new "high tech" industry in the Coventry area. The presence of high technology companies on the campus allows technology transfer in both directions, with both the companies and the University benefiting. The University has technical links with 44 per cent of the companies on the Science Park. These links vary from the sponsorship of postgraduate students and co-operation in student projects to a major collaborative initiative with a computer aided design manufacturer.

26. The importance of Warwick's experience is that technology transfer is multi-faceted and different activities inter-relate. Industrial led research can grow out of post experience courses. Pure research can be disseminated in such courses which can lead to exploitation. Relations between research groups in the University can attract companies to the Science Park which can then lead to contracts between Science Park companies and major manufacturing companies which can lead on to the University becoming involved in post-experience training. Companies use the post-experience centres like Scarman House for their own training programmes and then develop contacts within the academic community. The essence of the process is that the University is always willing to be postive about its relationships with industry and see them as partnerships which can have mutual benefits.

TABLE 1

University of Warwick

Research grants and contracts sources of income 1982-83 to 1991-92 (Source—Form 3)

	Research councils	UK based charities	UK central Government	UK Local authorities	UK Public corps	UK Industry/ commerce	(Percentage total income)	UK Health hospital authorities	EC	(Percentage total income)	Other overseas[1]	(Percentage total income)	Other sources	Total income
1982-83	1,957,298	390,722	39,864	*	*	76,908	3.05	*	*	—	14,831	0.59	45,728	2,525,351
1983-84	2,672,624	342,706	128,828	*	*	44,707	1.38	*	*	—	11,465	0.36	28,406	3,228,736
1984-85	2,640,252	397,634	802,249	1,501	914	483,604	10.27	*	*	—	275,491	5.85	107,863	4,709,508
1985-86	3,250,639	466,725	773,988	36,661	14,115	1,025,748	16.52	*	*	—	378,889	6.10	262,348	6,209,113
1986-87	3,886,022	462,827	938,832	71,397	16,489	1,885,828	23.15	*	*	—	686,386	8.43	197,371	8,145,152
1987-88	4,828,921	390,892	1,493,232	129,801	25,665	2,025,709	20.25	*	*	—	865,923	8.65	244,809	10,004,952
1988-89	5,196,496	436,255	1,885,364	253,212	7,116	2,193,226	19.32	*	*	—	1,067,947	9.41	312,257	11,351,873
1989-90	4,902,023	670,372	1,988,654	973,037	2,649	3,405,066	24.63	99,401	365,261	2.64	572,358	4.14	847,376	13,826,197
1990-91	5,670,685	953,754	3,081,399	219,253	132,114	3,525,819	21.83	303,790	425,508	2.63	899,435	5.57	941,905	16,153,662
1991-92	5,454,271	987,708	3,295,551	224,625	15,483	3,884,037	23.06	331,737	832,693	4.94	522,325	3.10	1,291,432	16,839,862
Total						18,550,652	19.95		1,623,462		5,295,050	5.69		92,994,400

* Not identified.

[1] Probably includes EC income up to 1988-89.

UNIVERSITY OF WARWICK

TABLE 1

Patents, Royalties and Licences Incomes Received

	BTG £	Other £	Total £
1983-84	2,420	—	2,420
1984-85	3,971	18,043	21,014
1985-86	4,797	13,967	18,764
1986-87	7,410	21,393	28,803
1987-88	—	1,083	1,083
1988-89	—	—	—
1989-90	1,737	—	1,737
1990-91	1,974	150,000	151,974
1991-92	2,509	175,656	178,165
1992-93	3,226	180,000	183,226
Total	28,044	559,142	587,186
		Check	587,186

Memorandum submitted by Heriot-Watt University (12 July 1993)

1. *What organisational arrangements (e.g., research committee, Industrial Liaison Officer, Science Park) if any, are in place to ensure that developments are disseminated to industries who may wish to use them, and to enable industry to make contact with researchers whose expertise may be of interest to them? Could you give an estimate of the investment in these arrangements?*

(a) Heriot-Watt University has an Industrial Liaison Unit (UNILINK) which has been in operation since 1969, and a Research Park, the first of its kind in Europe, was established in 1971. Technology transfer is actively and successfully promoted through these offices with the key assistance of the Research Advisory Committee.

(b) In addition, the Institute of Technology Management is becoming increasingly proactive in linking University academics with companies in Scotland, and the University is responsible for several Teaching Company Schemes. Furthermore, UK and overseas industry has purchased significant numbers of modules in a Distance Learning MBA degree which is proving another successful vehicle for technology transfer in the field of Business and Financial Studies.

(c) Organisations telephoning the University seeking expertise are transferred to UNILINK with respect to Consultancy and Research, or to the Director of Continuing Professional Education with regard to Training. The inquiry is then directed to the academic considered to have the most relevant expertise so that specific requirements may be discussed directly with the enquirer.

UNILINK maintains a database of consultancy and research expertise, and also has access to the Heriot-Watt entries in the BEST (British Expertise in Science and Technology) database.

Of course, many organisations often will make direct contact with an academic department where the expertise of that department is already known.

(d) It is difficult to quantify the investment in these activities.

2. *Do you have a policy on IPR? What arrangements have you for ensuring that developments within the institution receive IPR protection, when appropriate?*

(a) Our policy on IPR is contained in a document titled "Statement of policy regarding the ownership and exploitation of Inventions, Intellectual Property and Research Results". The document, contained in our Staff Handbook, is currently being revised and updated.

(b) The above referenced statement of policy indicates that the Director of UNILINK is the University Officer concerned with advising on matters relating to patent applications and intellectual property. Members of staff are prompted to consult the Director of UNILINK at the earliest opportunity concerning these matters.

If patent protection is deemed to be desirable the University will, in the first instance, afford BTG the opportunity of processing a Patent Application.

3. *What is the total income your institution receives from industry each year (give figures for the past decade)? Please show income from royalties separately, and indicate what portion of this comes through BTG. What proportion comes from UK based companies and what comes from overseas? What proportion of your total research expenditure, including income from bodies such as the SERC, does this represent?*

(a) Details of income are provided at Annex A, but it should be noted that it has not been possible to distinguish amounts specifically for research. For example, a proportion of student fees are paid by UK and overseas companies but no analysis is available.

(b) Royalties in the past have not been very significant and have arisen from the sale of a video course entitled "Microwave and RF Component and Subsystem Manufacturing Technology" and from the sale of Shaft and Bearing design software. Actual amounts are recorded in Annex A.

No royalties have been received from BTG.

Book royalties are not included.

4. *Please give the income from patents that your institutions has received each year since 1983. How many developments were patented in each of these years?*

On the basis of the Patent Files held in UNILINK, we have received no income from the commercialisation of any patent. No income has been received from BTG. It is, however, true to say that in 1992 we received £20,000 from Medical Laser Technologies Ltd for the transfer of Patent Rights from the Medical Laser Unit. In 1993 we received £4,000 from Coherent Hull Ltd as an option to licence a patent.

The number of patent applications submitted (with successes shown in brackets) since 1983 are:

1983—2 (2)	1984—4 (3)	1985—4 (4)	1986—3 (3)	1987—2 (2)
1988—2 (1)	1989—4 (4)	1990—5 (0)	1991—4 (4)	1992—2 (1)
1993—2 (0)				

5. *How much interaction with industry takes place at the specific instigation of a company, how much is initiated by members of the University and how much arises from ongoing relationships within industry? What form do these relationships take (e.g., commissioned research, Teaching Company Scheme, LINK, CASE studentship)?*

(a) The interaction directly from industry in terms of a consultancy is high, but in terms of research is fairly low.

(b) Interaction initiated by University staff is considerable especially in the field of oil and gas. Furthermore, specialist Institutes, in a range of disciplines, are exclusivly devoted to co-operation with industry, and technology transfer.

Continuing relationships with industry generate a great deal of interaction as attested by Research Contract Income. The Times Higher Education Supplement of May 1993 featured University League Tables showing Heriot-Watt University as second top in terms of per capita Contract Research.

(c) A considerable amount of commissioned research is processed each year, and we currently have a number of Teaching Company Schemes in progress as well as Case studentships. We have from time to time been involved in the LINK Scheme.

6. *What are your policies towards time spent in technology transfer activities? How effectively are these implemented?*

(a) Technology transfer is encouraged in all departments, although as regards individual consultancy there are conditions limiting the amount of time that can be devoted to this activity.

(b) The effectiveness of technology transfer by departments is usually extremely good.

1. *What is the relationship between the Science Base and industrial innovation?*

The Science Base is closely connected with industrial innovation but only on a long-term and statistical basis.

2. *Are the mechanisms for technology transfer and interaction between the science base and industry effective? How could they be improved?*

The current mechanisms for technology transfer and interaction are not effective.

In the past research has been artificially divided into basic/strategic and applied with far too little emphasis being given to applied. The artificial distinction of disqualifying work considered to be near market has simply cut-off the activity at the point at which it is most needed. The White Paper on Science and Technology promises to improve this.

The biggest general problem is the lack of investment, both private and public, at the point of new product development. This must also be combined with investment into market research, sales and marketing. Only if all these components are present can success be expected.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

There is probably no lack of technically competent people but there is probably a shortage of management skills.

4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

No and yes. It should be measured by the percentage participation in new and growing high technology market areas, e.g., information technology, optoelectronics and biotechnology.

5. *Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

Short-termism is a really major problem. Experience shows that even simple products can easily take 10 years to reach the market. Although there have been in the past some government support for innovation by means of helping new small companies and new starts, the current rules expect such investment to be recovered within five years. This often is just impossible and leaves an investment gap which is very serious. Two remedies are possible:

Firstly, a preferential interest rate for borrowing for the first 10 years of a new start-up and for the introduction of new products in an attempt to expand existing companies.

Secondly, tax benefits for R&D and new product development.

6. *Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?*

No useful comment.

7. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder the process?*

All pretend to be helpful and all suffer considerable defects.

ANNEX A

INCOME FROM INDUSTRIAL SOURCES

(a) *Research Income*

	Total Research Income £'000	UK Industry and Commerce £'000	UK Public Corporations £'000	Overseas Industry £'000
1992	9,275	3,652	160	406
1991	9,131	3,520	111	343
1990	8,613	3,665	1	394
1989	7,885	2,407	29	396
1988	5,505	2,981	38	419
1987	4,877	1,078	285	466 may include EC
1986	4,800	967	69	507 may include EC
1985	4,201	1,506	51	379 may include EC
1984	3,442	1,134	N/A	74
1983	2,164	178	N/A	50
	59,893	21,088	744	3,434

(b) *Estimated expenditure on research from income not specifically designated for research*

(i)	UK Industry and Commerce £'000	Overseas Industry £'000
1992	3,455	610
1991	2,965	523
1990	2,494	440
1989	1,440	245
1988	1,357	240
1987	986	174
1986	1,144	202
1985	862	152
1984	725	128
1983	1,146	202
	16,575	2,925

(ii)	Capital Grants	£'000
1992	Enterprise Oil Building	270
1988	OWTC Set-up Funds	1,250
1986	Conoco Building	320

(iii) *Tuition Fees*

A proportion of student fees are paid by home and overseas companies but no analysis is available for this.

(c) *Royalties*

1990	750
1991	3,360
1992	2,930
1993	750

Memorandum submitted by University of Manchester (13 July 1993)

Thank you for the invitation to contribute to the Select Committee's inquiry into the routes through which the science base is translated into innovative and competitive technology. The inquiry is timely and I would hope that the White Paper "Realising our Potential" published in May, can assist the Select Committee in elevating the importance of science and technology in the United Kingdom. The benefits of doing so are clearly set out in the White Paper. The University of Manchester is ready to take up the challenge of the White Paper and its implications are being studied closely.

My reply to you is in three parts:

(a) Comments on the broad topics of the inquiry.
(b) Answers to the specific questions you have raised.
(c) An appendix containing the statistical data you require.

(A) BROAD TOPICS

(i) You will not be surprised if I take the opportunity to stress the overriding importance of having a strong science base. Without it the aspirations of the White Paper will not be realised. The arguments over the current state of British science and its prospects for the future have been aired frequently and there is no need for me to repeat them except to restate that science as a career, in a industry or a university environment, will only be attractive to young people if it has status and adequate rewards. I hope that the Select Committee will give this due prominence in their recommendations.

(ii) The University is particularly proud of the contribution PREST (Programme of Policy Research in Engineering Science and Technology) has made over the years to the debate on the role of science and technology. As long ago as 1972 Professor Michael Gibbons, then a member of the University, was a co-author of a publication, "Wealth from Knowledge" and since then PREST has continued the long tradition of studies of management of innovation. The current Director, Professor Luke Georghiou, would be most willing to assist the Committee in its more detailed investigations or by forwarding relevant publications.

(iii) The University welcomes many of the recommendations of the White Paper. In the context of the Select Committee's inquiry I would emphasise particularly the following:

(a) The maintenance of the dual-funding mechanism.

(b) The greater attention that will be given to MSc degrees.

(c) The concept of "technology foresight". this has been a key theme of PREST and one discussed in some detail with the DTI.

(d) The support for systematic interchanges between industry, scientists, engineers and science policy makers. I note that the DTI has launched "Senior Academics in Industry Scheme". While this may be worthwhile a reverse scheme "Senior Industrialists in Academia" would also be worthy of serious consideration.

One worry is that the pressure on universities to teach throughout the year will detract from our ability to devote as much time and effort as previously to the pursuit of research and the interaction with industry.

(iv) I am sure that the Select Committee will appreciate the growing importance of EC Research and Development programmes not only as a valuable source of research funds but also as a means by which collaborative networks can be established with other European universities and European companies. Although the research is pre-competitive in nature it generates ideas and contacts which are crucial to industrial innovation. It would be to the UK's advantage if greater prominence and publicity were given to the forthcoming Fourth Framework Programme.

(B) SPECIFIC QUESTIONS

To take your questions in turn:

(i) *Organisational Arrangements*

In 1972 the University set up a Research Consultancy Service to facilitate the interaction with industry, including the provision of advice to academic staff on matters such as intellectual property, research opportunities and collaboration with industry. During the latter part of the 1970's steps were taken to create and maintain an academic database of skills, expertise, facilities which were available to industry and commerce. This database was the fore-runner of the national database of research expertise. BEST (British Expertise in Science and Technology). Since that time an industrial liaison office has been maintained within the University largely concerned with this function and in assisting academics with links with industry. The University, unlike many other institutions, has not been persuaded that a large industrial liaison office is the optimum method of liaising with industry. The University is a very large organisation where a significant number of academics, individually or departmentally, have strong links with industry. These have been developed over a number of years and result from the ideas and/or reputation of the individuals/disciplines. The industrial liaison office plays a valuable complementary role to that of "entrepreneurially minded" academics, particularly with small and medium sized companies. The cost of the office is currently £50K. In the 1980's the University also set up a commercial company to undertake those activities relating to technology development and exploitation which are outside the University's Charter. The most significant of these activities relate to the patenting and licensing of intellectual property and the formation of subsidiary companies to develop particular ideas, products and processes. We maintain good relations with BTG and work with them on the basis of the standard arrangement devised by them to regulate the relationship with universities. Patenting and licensing is, of necessity, a "risk business" and the University has sought over recent years to provide a reasonable level of funding (currently close to £400K per annum) to help exploit its intellectual property. We have recently reviewed our arrangements on patenting and licensing and, given the significant sums involved, will continue to monitor progress in the interests of value for money.

In 1991-92 the University set up a Research Committee chaired by the Pro Vice Chancellor with specific responsibility for research. Initially, the Research Committee's terms of reference were focused more closely on academic research—its internal organisation and structure, the need to prepare for the 1992 Research

Assessment Exercise, advising on and monitoring of research initiatives and similar matters. It is envisaged that in the next academic session research exploitation will receive greater prominence in the Committee's deliberations.

Manchester Science Park Limited is a company set up under a Joint Venture Agreement in 1983. The shareholders are Manchester City Council, the University of Manchester, the University of Manchester Institute of Science and Technology, and four large commercial companies (Ciba Geigy, Ferranti, Fothergill and Harvey (Courtaulds Aerospace), Granada Television). We believe it is the only UK Science Park to have this degree of industrial support.

The Science Park has been immensely successful fulfilling its mission of encouraging the growth of high technology industries on an attractive 15 acre site where tenants can have easy access to scientific expertise and equipment on the adjacent campus. The first two buildings (56,000 square feet in total) are currently fully let to science based commercial operations. The third phase (40,000 square feet) was completed earlier this year. It is particularly gratifying that the first two tenants of the third phase building started their operations on the first phase building and are now in a position where they can expand into larger premises. This will enable smaller units to fill the space they have relinquished thereby starting the cycle of business development anew. A fourth phase is now at the advanced planning stage. Overall, the Manchester Science Park has attracted firms and employment to the area and assisted collaboration between such firms and the local academic institutions providing a good working environment in close proximity to academic resources. It is significant that 45 per cent of the occupied space is taken by companies concerned with health and a further 33 per cent by firms using or exploiting computer technology. Both the University of Manchester and UMIST are pre-eminent in these fields.

Reviewing the University's organisational arrangements, there is ample evidence to demonstrate the commitment to technology transfer and the opportunities that exist for mutual interaction between the worlds of industry and academia.

(ii) *Policy on IPR*

University Senate has considered recently a policy statement on IPR. It had been asked to do so for two reasons:

(a) It is desirable that both staff and students have a clear understanding of their rights and obligations on this matter.

(b) Ownership of IPR can be a source of tension between industry and universities. Clarification of the University's position will assist those negotiating on its behalf on research contracts, exploitation agreements and so on.

The University follows the provisions of the Patents Act 1977 and the Copyright, Designs and Patents Act 1988 in asserting its rights, as employer, to the work created by an employee in the course of his/her employment. This principle has now been extended to students so that unless a formal agreement is drawn up to the contrary, IPR will be retained by the University in works generated by staff in the course of their employment or by students during their courses of study relating to matters such as patentable and non-patentable inventions, university commissioned works and computer generated work, other computer software and firmware.

Appropriate steps are now being taken to implement and monitor these changes. Staff and students will be advised to contact the University's technology development and exploitation company should they require advice or assistance on IPR, have made an invention, created a copyright work or design during the course of their duties or studies.

It should also be noted that for the most part copyright in written material (e.g., books, articles, theses), is regarded as the property of the author and that in seeking to protect the value of IPR the University will recognise the importance to the academic of the need for unrestricted publication and dissemination of research results. This is a pertinent example of balancing "academic demands" with "industrial demands" within an academic institution.

(iii) *Interaction with Industry*

There is no central database which records every interaction with industry. In a university of Manchester's size it would be an onerous task to maintain such a database even if academics undertook to notify the appropriate persons of each interaction. The recently completed Technology Audit, part funded by DTI, does suggest that with the exception of a few entrepreneurially led research groups, we are largely reactive to industry, although there is growing evidence of initial approaches by our academics to industry. There are numerous examples of ongoing relationships with industry across a broad spectrum of disciplines. Most of the interaction with industry takes the form of commissioned research, training programmes, endowments to support particular disciplines or sub-disciplines. The level of participation in other collaborative schemes (Teaching Company Schemes, LINK, CASE) is probably below the national average. The University supports technology transfer and in its recently published paper "The University in the 1990s" its commitment is described in the following words:

> "We shall give greater prominence to research and technology transfer, creating a climate in which staff are encouraged to look to the exploitation of intellectual property and know that the University will support this centrally".

(iv) *In addressing the series of inter-related questions set out in your Press Notice I would offer the following comments;*

The relationship between the Science Base and industrial innovation is complex. The science base is not homogeneous. The experience of engineers, for example, will be very different from those in the biological sciences or in pharmacy. It is more sensible to compare the performance and experience of different disciplines and not generalise about the science base. In recent years the relationship between industry and our School of Biological Sciences has been very productive and provides a valuable lesson for others in that neither side expects the other to do something in which it is not proficient. This applies also in Pharmacy. In both cases the academic's role is to produce ideas. Industry has to develop and market those ideas. That is an efficient and effective division of resources and responsibility. The most enduring of the University's relationships with industry is that between the Department of Computer Science and Ferranti, later ICL. In 1962 the ATLAS machine, designed at the University, introduced the concept of Virtual memory. The machine became a direct Ferranti product. In the 1970s the ICL 2900 series incorporated many ideas from a research prototype built at the University but designed by a joint University/ICL team. In 1985 the Flagship project funded by the DTI/SERC Alvey initiative was a collaboration between ICL, the University of Manchester and Imperial College, London which focused on parallel computers and associated software systems. In turn this work provided a significant input to the EEC ESPRIT European Declarative System (EDS) project. The partners added to this initiative included Bull (France) and Siemens (Germany). Many of the principles embodied in the new ICL high performance parallel database machines, due for imminent release, can be traced back directly to EDS, Flagship and the contribution made by the universities. Finally, in addition to this transfer of ideas there has been a productive exchange of personnel between ICL and the University. However, when the academic discipline is working with a less wealthy and more fragmented industrial sector (e.g., in the Physical Sciences there is often a bias in favour of small and medium sized firms) it is more difficult to establish and maintain a fruitful exchange of ideas and subsequent development. It may be that the greatest benefit small and medium sized firms can derive from an interface with the academic sector is in terms of consultancy and training.

On a more general level it is all too easy to cite examples (the invention of the stored programme computer, the discovery of the structure of DNA) where the science base was the innovator with no lead from industry. Fortunately, there is now a better understanding within some sections of industry of science and its potential. This process may well be accelerated if there were more scientists from all disciplines serving as directors on Company Boards. This is the Japanese model and represents the most effective form of technology transfer—people transfer. One would hope that it would also assist in promoting the importance that should be attached to the training and re-training of workers. The Higher and Further Education sectors are ready to play their part in overcoming the shortage of skilled and trained personnel, which is a barrier to improved industrial performance. The University of Manchester, through the Manchester Business School and the fledgling Federal School of Business and Management, is well placed to carry out training in management and related skills.

Other issues such as international competitiveness and "short termism" have been discussed widely in other fora and there is nothing specific I would wish to add. The University's experience of industry has indicated that where responsibility for innovation is given to specific senior employees in industry, things progress more smoothly and with a clearer sense of direction. Elaborate chains of command or committees are often inimical to swift decision making and impair strategic clarity.

The attached appendix provides the statistical data you require. I hope that you find my reply of some benefit to the Select Committee's inquiry. I and my colleagues would be willing to provide clarification on points of detail or further assistance should you need to contact us. If any members of the Select Committee should wish to visit the University they would be most welcome.

APPENDIX

INCOME FROM INDUSTRY

The most common sources of income from industry are:

(a) Research contracts (commissioned research).

(b) Support for Professional Chairs, lectureships usually through endowments, deeds of covenant, Gift Aid.

(c) Patenting and licensing agreements.

(d) Collaborative schemes (Teaching Company Scheme, LINK, Case studentships).

(A) Commissioned research

Figures, on a consistent basis, are only available for the past seven years. They are tabulated as follows:

(Seven years only)	Total Research Income (all funding bodies) £000	Income (UK industry and commerce) £000	Income (Overseas industry and commerce) £000	Total (UK and Overseas industry and commerce) £000	Percentage of research income from UK industry and commerce	Percentage of research income from Overseas industry and commerce	As a percentage of total research income from all sources
1985-86	13,209	889	140	1,029	86.4	13.6	7.8
1986-87	14,977	963	135	1,098	87.7	12.3	7.3
1987-88	16,586	1,178	108	1,286	91.6	8.4	7.8
1988-89	19,729	1,521	170	1,691	89.9	10.1	8.6
1989-90	22,884	2,108	451	2,559	82.4	17.6	11.2
1990-91	24,741	3,282	386	3,668	89.5	10.5	14.8
1991-92	28,026	3,447	522	3,969	86.8	13.2	14.2
1985-92	140,152	13,388	1,912	15,300	87.5	12.5	10.9

(B) Endowments, deeds of covenant, gift aid

We would prefer to treat the individual donations as confidential but the following companies have supported the University in the areas listed:

Barclays	Microprocessor Applications in Industry	1980-89
Herbert Smith	Chair in Law	1988-97
British Gas plc	Chair in Urban Renewal	1989-93
Zeneca	Technicians	1989-93
Zeneca	Chair in Physiological Sciences	1989-
ICL	Chair in Computer Engineering	1989-98
Boots	Chair in Pharmacy Practice	1990-96
Halliwell Landau	Lectureship in Law	1990-99

In addition, the Chair of Occupational Health is supported by ten companies making modest individual contributions. Glaxo has provided a permanent endowment for the Chair in Neuroscience and offers a prize in Chemistry. British Telecom and BOC also offer prizes in Electrical Engineering and Business Studies.

(C) Patenting and licensing

Licensing fees/Royalty income

Year	Total	UK	Per cent	BTG	Per cent	Overseas	Per cent	Income from patents	Per cent
1982-83	92,470	77,200	83.5	15,270	16.5	—	—	—	—
1983-84	115,300	87,500	76	17,800	15	10,000	9	—	—
1984-85	155,000	137,000	88	18,000	12	—	—	12,000	8
1985-86	236,275	215,373	91	20,902	9	—	—	11,582	5
1986-87	220,975	182,080	82	28,895	13	10,000	5	63,363	29
1987-88	160,881	135,347	84	25,501	16	33	—	60,692	38
1988-89	95,195	82,570	86.8	12,401	13	224	0.2	50,358	53
1989-90	249,855	166,590	67	17,800	7	65,465	26	143,829	58
1990-91	370,755	328,761	89	16,240	4	25,754	7	151,340	41
1991-92	366,337	343,169	94	3,000	0.8	20,168	5.2	171,739	47

Per cent=percentage of the total column.

(C) PATENTING AND LICENSING

Number of developments patented

	Number of developments having patent applications filed	*Developments patented*
1982-83	4	2
1983-84	3	3
1984-85	2	5
1985-86	7	6
1986-87	15	8
1987-88	22	9
1988-89	6	6
1989-90	13	8
1990-91	19	3
1991-92	15	5
1982-92	106	55

(D) COLLABORATIVE SCHEMES

	Teaching Company Scheme	*Case*	*Link*
1985-86	0	0	1
1986-87	2	1	0
1987-88	1	0	0
1988-89	4	5	1
1989-90	1	5	2
1990-91	1	1	1
1991-92	1	0	2
1985-92	10	12	7

Memorandum submitted by Imperial College of Science, Technology and Medicine (14 July 1993)

Thank you for your letter of 30 April 1993 seeking written evidence on the universities' links with industry in connection with the above. I am pleased to respond giving Imperial College's views on the subject.

First I address your general question regarding how to balance academic needs with industrial demands in a university context. We do not see this as a particular problem at Imperial College. As the figures given later in this document illustrate there is strong interaction with industry across the whole College in almost all branches of science, engineering and medicine in which our researchers are active. Even in the most basic subjects, like high energy physics or astronomy, the sophisticated instrumentation which is developed can sometimes have industrial potential. For example, special cameras designed at the College for use in particle physics experiments are finding application in medical X-ray scanning equipment.

In any properly constructed industry/university collaboration each side recognises that it has a different, but complementary, role to play. Academia, in touch with the latest advances in science and technology, will be seeking to produce new knowledge, sometimes embodying innovative ideas, insights and inventions. Some of the latter will have commercial potential, and in such cases the necessary steps to transfer the technology to industry must be taken.

Industry, aware of its requirement to generate new products and processes, will be looking for such ideas or prototype systems, including those arising from projects which industry itself is supporting, with a view to commercialisation. If a university's industrial partners take such a line, no pronounced pressure should be felt by the university forcing it to move too close to the market-place, and thereby deflecting it from its main role in longer range research. There seems little danger of such deflection viewed from an Imperial College standpoint.

I turn my attention now to your detailed questions.

ORGANISATIONAL ARRANGEMENTS

In 1986 the College set up IMPEL (Imperial Exploitation Limited) as a joint venture with 3i plc. The objective of the company is to promote the transfer of technology with commercial potential arising from research programmes undertaken in the College. With 3i's knowledge of hi-tech start-up companies and of technology licensing, and the College's experience in research, this brought into one company all the complementary skills needed to undertake successful exploitation of inventions and other types of intellectual property. IMPEL's turnover in 1991-92 was about £500,000. Imperial College's 51 per cent majority holding represents an investment by it of £51,000 spread over the years 1986 to 1989.

ICON (I C Consultants Limited), wholly owned by Imperial College, offers a consultancy service based on the expertise of its academic staff. It also manages the use of the College's technical facilities, for example its windtunnels, when these are hired out for commercial purposes. ICON's turnover in 1991-92 was £2.3 million. It covenanted its profits of £0.16 million to the College.

Imperial College earned an income from research grants and contracts in 1991-92 of £45 million, the work being co-ordinated through the Industrial Liaison Office. This office itself has an annual budget of around £800,000. This covers a modest amount of promotional work aimed at attracting new research sponsors as well as all negotiations of grants and contracts, and the invoicing and collection of payment. At any one time the College has around 2,000 grants and contracts active. In addition it spends about £100,000 per annum in maintaining its portfolio of patents. In negotiating contracts with the many sponsors contributing to this portfolio, a prime consideration is the ownership and protection of arising intellectual property.

Imperial College is involved in two Science Parks, Silwood Park, near Ascot, and Imperial Park, situated between Newport and Cardiff. The latter is a recent joint venture with the Welsh Development Agency and Newport Borough Council. The College's interests in both Parks is managed through its property company, IMPACT Ltd, a wholly owned subsidiary of the College. Rental income from Silwood Park, net of expenses, enabled IMPACT to earn for the College around £0.5 million in 1991-92. At Imperial Park, a central feature is Imperial House, built to accommodate start-up and other small technology companies. This has just commenced producing rental income for IMPACT.

Policy on IPR

The College takes the view that it should retain ownership of intellectual property rights (IPR) wherever possible. Sometimes it is more appropriate for the collaborating company to have the ownership of arising IPR assigned to it. In such cases an arrangement bringing royalties to the College is, as a general rule, negotiated.

Guidelines are used in deciding how to negotiate on ownership of IPR. In brief the guidelines say that where the industrial partner is reimbursing the College for the fully overheaded cost of the research (normally without any "profit element" included), the company has a strong case for requesting ownership. The company would, however, be expected to pay the College royalties if successful commercialisation ensued. (Where the company does not wish to pay some royalties, it is asked to pay an initial higher price for the research, thus providing a sum in compensation for royalties foregone). In the case of some potential contracts, the College may decide that it is not prepared to assign arising IPR to the company if such IPR is mainstream to the activities of the research group in question. The justifiable fear is that, if IPR is surrendered to a particular company, this could limit the freedom of action of the research group to work with other commercial companies on projects based on the results of its earlier research. In these days where universities have to seek research sponsorship from many sources, the need for them to retain such freedom of action is a vital consideration.

Not infrequently a company may feel that the research being suggested is of too long range a nature for it to fund the work entirely by itself. When this occurs the company may still be prepared to share the full cost of the work with the university, assuming always that the university is in a financial position to do so. Such cost-sharing is commonplace at present.

In either of these two latter cases, the usual arrangement suggested by the College, and frequently (but not always) accepted by the company, is that the company will be given the right to a non-exclusive licence to exploit arising IPR commercially, and with royalty payments to the College scaled down to reflect the financial contribution to the project made by the company.

The guidelines described in the four preceding paragraphs were written in collaboration with the Universities of Cambridge, Oxford and Warwick, and University College London. They are now in use by these five, as well as by a number of other universities.

The arrangements at Imperial College for protecting IPR are as follows: IMPEL is employed as agent of the College to undertake a systematic technical audit of research results with a view to discovering items of commercial potential. Where protection by patenting or other means is appropriate, IMPEL staff (comprising at present four full-time and two part-time technology transfer executives) advise the College what is required, and then make the necessary arrangements with appropriate patent agents on behalf of the College. Thereafter IMPEL seeks suitable outlets for the technology.

Income from industry

Research grants and contracts income at Imperial College from UK industry and commerce has risen from £2.8 million in 1986-87 to £6.5 million in 1991-92. That from overseas industry, commerce and governments (excluding EC) has risen from £1.5 million to £2.9 million over the same interval. Taken together the above represent about 20 per cent of the College's total research grants and contracts income.

Income from technology licensing in 1991-92 amounted to about £0.7 million. This has been built up from less than £0.2 million pa in 1986. Less than 10 per cent of the present total came from BTG. More than 70 per cent of the total came from overseas companies. Income from patents amounted to about 20 per cent of the total, with the other 80 per cent coming from the licensing and sale of computer software. The College has about 60 active patents at the moment, and handles around 15 to 20 new patent applications each year.

INTERACTION WITH INDUSTRY

You ask how interaction with industry is instigated. Most of our academics already have strong contacts with the industrial sector to which their work relates. In many cases they really require these contacts to be able to attract financial support for their research. Some general promotional work is organised centrally by the Industrial Liaison Office. For example, a group of senior technical people from a company considered to be a prospective future supporter of research would be invited to visit the College to be given a presentation of the work of relevant Departments by a team of senior academics. Follow-up activities afterwards sometimes then result in new research contracts being placed.

Experience has shown that once a relationship is established with a company, support is likely to continue for five to 10 years or more. A lot of return business is thus involved. Within its substantial portfolio of research projects, the College is involved in all the individual schemes you mention—Teaching Company, LINK, CASE studentships, and many commissioned research projects.

TIME SPENT ON TECHNOLOGY TRANSFER

Most of the effort on technology transfer is provided by the staff of IMPEL. Academic "inventors" are inevitably involved as well, but the approach is to keep this to a minimum. IMPEL is a company which is required to pay its own way. In 1991-92, it covered all its own costs and returned a sum of around £0.34 million "profit" to the College. Furthermore it secured development contracts for the College which brought in over £0,37 million in the same year.

I trust the above goes some way towards answering your questions. I enclose for your further information a copy of each of the latest Annual Report and Accounts of both IMPEL and ICON together with an analysis of the business aspects of our research grants and contracts portfolio presented to the College's Governing Body in December 1992.[1] The latter is, I fear, rather detailed for present purposes, but it does show the degree of sophistication being reached by at least one university in the handling of its interactions with industry in competitive technology leading to innovation.

Memorandum submitted by the University of East London (15 July 1993)

I refer to your letter dated 6 May addressed to Professor Gould, and in response would like to furnish you with the following information. Your questions have been answered in order and numbered which I hope makes for ease of reference.

1. The University's arrangements operate on an ad hoc basis with no defined first point of contact, but the institution's training and consultancy company, ELCO, might fulfil that role. Many of the University's academic departments have within them properly constituted research groups and units which, as part of their aims and objectives, actively seek research partnerships with the commercial sector and to which inquiries from that sector might be directed.

2. The policy relating to intellectual property rights is written into the contract of employment of University staff. As yet there are no formal arrangements for ensuring that developments from within the institution received IPR protection. ELCO has acted as the broker, but not formally.

3. I am not sure what this questions seeks to aim at: should the following comment be unsatisfactory, please do not hesitate to contact me in order to discuss the matter further.

The institution receives in excess of £1.5 million per annum from industry, but much of this income is in the form of payment for services rendered. In addition there are formal award bearing teaching and related programmes designed by or for industry and given University recognition.

The University has undertaken a number of research projects supported by funding from the Science and Engineering Research Council and is a party to the exploitation arrangements provided by SERC. To date, however, no inventions have been exploited as a result of SERC funded programmes. Research grant income from SERC over the past five years has been:

1988-89	£98,953	(1 teaching company award)
1989-90	NIL	
1990-91	£121,546	(2 awards)
1991-92	£106,722	(2 awards one of which was a teaching company award)
1992-93	£108,571	(1 teaching company award)

4. The University has not received any income from the exploitation of patents or registered any patents during the period specified.

5. The majority of contact with industry is from the University or existing relationships rather than from industrial initiatives. For example, the institution's Environment and Industry Research Unit has in the past

[1]Not printed.

forged useful links with British Coal. The Faculty of Technology has a number of teaching company scheme developments. Another example is a link with a rose-breeding company which has entered into a partnership with one of the University's research units which is working in the field of plant biotechnology.

6. The University is still in the process of developing policies towards time spent on technical transfer activities.

I hope that the above information answers the Committee's questions, but should you have any queries or require any additional information please do not hesitate to contact me.

Memorandum submitted by the University of Westminster (14 July 1993)

I am happy to reply to your letter requesting details of the arrangements for liaison between academia and industry in the University of Westminster. Dealing with each question in turn:

1. The University of Westminster (UoW) is extremely conscious of the need to have in place an organisational structure that facilitates strong academic interaction with industry. To that end, a Research Policy has been in place since 1970 stating that the University gives preference to supporting research which applies and develops knowledge to meet contemporary needs and provides a service to industry, commerce, the professions and the community at large. A further step was taken in September 1992 with the setting up of an Industrial and Research Support Unit (IRSU) with responsibility for this Unit being placed with the member of the University's Senior Management Group who has the portfolio for research and consultancy in the institution. This Unit is responsible for research support and other associated functions, industrial liaison, consultancy and exploitation. It assists the academic staff in developing relationships with commerce and industry. Staff in the Unit are available for giving advice, helping to locate sponsors and preparing submissions to grant/contract awarding bodies, including costings. No applications for research/contract support from the University can be submitted without proper authorisation and the route for this approval is through the Unit. All activities undertaken by the IRSU have a high degree of professionalism and, in providing services, it is able to access a large network of external expertise, including patent agents. Any issues pertaining to potential intellectual property which arise are referred, in the first instance, to this Unit. The staffing of this Unit also includes part-time support from a recently retired senior civil servant who served as Branch Head within the DTI.

2. The University is committed to making the fruits of its high quality research increasingly accessible to external organisations and individuals in both the private and public sector. With regard to intellectual property, the UoW policy has been clearly set out in documentation distributed to all staff and, more recently, the contractual position has been included in all contracts of employment. This has been supplemented by acceptance by the Court of Governors of the "Guidelines for Arrangements for Exploitation" prepared by the Exploitation Scrutiny Group of the Research Councils. This sets out the principles of making financial returns to individuals in the case of relevant inventions and also creates a favourable climate for staff to consistently question whether any current (or past) work should be protected. In the course of the last year, the IRSU has created a strong link with an internationally recognised firm of patent agents. Over the last four months, three cases have gone to the agents for consideration of cover and one patent has been applied for. Copyright protection has been applied for in the US for a software development whilst, in the third case, there is a hope that marketable products dependent on know-how will emerge.

3. The total income the UoW has received each year from industry, together with the total annual research income over the last decade, is set out in Appendix I.

4. Prior to the setting up of the IRSU and the clarification of the specific contractual position being set out in new contracts of employment, the University has seen little return from exploitation of its research. There have been no patents nor income from royalties since 1983 although the answers above will show how strongly the University is supporting the new policy. Where technology has been transferred, it has been to processes and products in industry under a previous contractual agreement, the terms of which would be unlikely to be accepted today. However, recently, the University was awarded DTI financial support to carry out a Technology Audit. This Audit was carried out on behalf of the University by British Technology Group. The Report, involving research in two faculties (Environment and Engineering and Science), has recently been presented to the University and is currently under discussion by a scrutiny group composed of industrialists from the University's Court of Governors, the Rector, Financial Controller, Director for Research Liaison and two senior members of the University's research community. We anticipate that more specific targeting of commercial opportunities from the University's research will follow from this analysis.

In the past, contacts with industry were generally via individual members of the staff. The UoW is fortunate in having many senior members of staff—usually at Professorial level—who, by their personal efforts and reputation, have secured substantial research and consultancy contracts. In the very competitive field of today, it is recognised that these efforts must be buttressed by professional support in areas which are within the experience and expertise of few academics. The development plan for the IRSU envisages a gradual recruitment of more professional staff able to advise on a wide range of problems associated with achieving maximum commercial exploitation.

5. The University has a developing portfolio of external activities, including commissioned research by Government Departments, research funding by all the Research Councils, collaborative research funded under LINK, and the Commission of the European Communities, Teaching Company Scheme (currently six projects) and Research Council CASE Studentships. The University works fully across a spectrum from basic to applied research and, occasionally, includes working closely with industry and commerce on projects close to the market. This research policy has developed during the University's proud 155-year history as the Polytechnic in the heart of central London and our staff find such research involvement very satisfying and intellectually challenging. Many of our undergraduate and postgraduate courses are vocationally linked and very great use is made of visiting lecturers from the professions. This also gives great opportunity for interaction with their employers. In addition, the UoW has a very high percentage of students studying at postgraduate level (20 per cent), many of whom are part-time students in employment. This also is leading, increasingly, to further contact with industry. Furthermore, the University has been in receipt of a grant from the Training, Enterprise and Education Directorate for the Enterprise in Higher Education initiative where one of the major outcomes has been a more directed attempt to increase contacts with industry.

The University also has a policy of appointing Visiting Professors, most of whom are important industrialists or other senior figures in public or commercial life. In addition to advising on strategic plans, developments and course curricula associated with a particular School or Faculty, the Visiting Professors often bring about closer relationships with the sector in which they operate.

6. A major role of universities is to promote technology transfer. This is happening regularly against a background of imparting knowledge and skills to our students; in doing research which is incorporated into scientific papers that are subsequently published, presented at conferences, etc.; and by the day-to-day contact our staff enjoy with a wide variety of colleagues in the outside world. Above all, time is clearly spent by staff in specifically promoting an identified piece of work or invention. However, the measurement of time spent on technology transfer, defined in its broadest sense, would be extremely difficult to assess. We hope that the practice or process of technology transfer will be so pervasive in our business that it would be almost impossible to quantify because of its inextricable link to our other activities.

I hope you find the above helpful and I would be happy to be contacted, if you have any further enquiries.

APPENDIX I

Year	Total Research Income £	Of which Income Industry (UK and Overseas (OS))	£	Per cent
1982-83	630,499	UK	60,627	(9.62)
		OS	85,980	(13.64)
1983-84	1,033,662	UK	82,772	(8.01)
		OS	71,005	(6.87)
1984-85	1,162,078	UK	86,287	(7.43)
		OS	50,950	(4.38)
1985-86	1,051,232	UK	88,583	(8.43)
		OS	62,004	(5.90)
1986-87	1,412,388	UK	104,928	(7.43)
		OS	112,344	(7.95)
1987-88	1,580,669	UK	112,642	(7.13)
		OS	182,584	(11.55)
1988-89	1,406,340	UK	309,245	(21.99)
		OS	176,076	(12.52)
1989-90	1,294,983	UK	327,368	(25.28)
		OS	222,706	(17.20)
1990-91	1,357,815	UK	413,390	(30.45)
		OS	112,367	(8.28)
1991-92	1,261,496	UK	116,295	(9.22)
		OS	205,602	(16.30)
1992-93	1,375,895 to date	UK	279,114	(20.29)
		OS	267,730	(19.46)

Memorandum submitted by University of Central England (15 July 1993)

Further to my letter dated 6 May, I attach the University's response to the Select Committee on Science and Technology as requested.

The University believes that the linkage between industry and academia is fundamental both in preventing a further demise of manufacturing industry and eventually enabling the regeneration of manufacturing industry as a base of excellence in technology coupled with a core activity of product innovation.

Traditionally the United Kingdom has been poor in this area and the close partnerships that exist between industry and academia in our competitor countries provide clear examples of how they have succeeded in developing and sustaining a strong manufacturing base.

I should be grateful if you could submit the attached information to the Select Committee. If appropriate I would be pleased to provide further information in support of the claims being made. You may also be interested to note that the Dean of the Faculty of Engineering and Computer Technology, Professor David Tidmarsh, recently undertook a presentation to the Parliamentary and Scientific Committee at their request in which several of these points were identified.

RESPONSE TO REQUEST FOR INFORMATION

SELECT COMMITTEE OF SCIENCE AND TECHNOLOGY

The University of Central England in Birmingham has recognised the importance of close links between industry and academia and the need to develop meaningful partnerships between the two.

It can be argued that there are comparatively few examples within the UK of close partnerships existing and frequently careers within either industry or academia are seen as being mutually exclusive. This is at variance to many of our worldwide compettitors where long-term relationships and partnerships are encouraged and established achieving benefits to both the development of the teaching and learning within an academic environment and to the future development of industrial and commercial partners.

The University of Central England is committed to teaching excellence underpinned by collaborative arrangements with industry and commerce. The University, after considerable debate, decided not to submit under the recent Research Selectivity Exercise on the basis that technology transfer and industrial links should be the key focus and not the more traditional "blue sky" research activity commonly associated with "old" University practice.

The University has an annual turnover of technology transfer activity in excess of £4 million 80 per cent of which is directly funded by either industry or European bodies.

Whenever working with industry, industrial property rights (IPR) are fundamental and the position taken by the Faculty of Engineering and Computer Technology, the leading faculty in this area, is to transfer technology to the industry by working with and for them to exploit this technology through a series of mechanisms, viz, DTI initiatives, Teaching Company Schemes, SERC/ACME projects, CEC programmes, contract research and so forth. Consequently, early on in any potential relationship IPR is addressed and rewards for satisfactory exploitation on a global percentage (royalty) term identified between the University and industry.

Within the UK currently there are many significant projects on which industry and academia are working closely together where comparatively near market product innovation requires funding to allow the partnership to flourish.

Frequently, industry is willing to commit up to 50 per cent of the total funding for these projects and yet there is a major gap within the existing arrangements (SERC, DTI programmes and so forth) for equivalent funding to be made available. The recent White Paper "Realising our Potential" goes some way to addressing this problem. However, this University has had significant projects in the past where the lack of support by the DTI has stopped potential industry/academic collaborations with proven exploitability from going ahead and in effect some many years of project innovation have been wasted.

The confidence in the DTI to fund these types of activities where partnership for product innovation and technology transfer is regarded as low. The University is fully aware of significant initiatives such as Link, teaching company schemes which exist specifically to address this area but nevertheless the UK, it seems, is losing out to its international competitors primarily because of a lack of funding to support these genuine partnerships.

Underpinning research is always necessary and should be the basis upon which much of the technology transfer exists. However, it is vital to realise that the "blue sky" research can only be effective if it leads to exploitation. The eventful regeneration of the manufacturing base will have to be based not only on manufacturing excellence but also product innovation which has been the main reason behind the success of many progressive companies.

In response to the direct questions posed by the Select Committee, the University would make the following comments.

As far as the organisational arrangements in the University are concerned, the academic units have been encouraged to develolp their own mechanisms for interaction with outside organisations. The Faculty of Engineering & Computer Technology has a number of committees and activities supporting liaison with industry such as the External Affairs Committee which co-ordinates research and technology transfer activities, an Engineering Policy Committee composed of prominent industrialists, an Industrial Liaison Unit, an Industrial Placement Office and a major Advanced Manufacturing Centre. The latter is a collaborative arrangement between the City Council, the Faculty and a local company, Delcam International, as well as city colleges. This Centre is a company support unit acting as a focal point which provides local companies with a range of services including informing them about sources of funds for particular activities.

In addition the Faculty holds a number of seminars and two major conferences each year to ensure that various developments are disseminated to industries who may wish to take advantage of them as well as enabling them to make contact with researchers involved with these developments. The investment in establishing the Birmingham Advanced Manufacturing Centre has been in the region of £2.5 million.

The total income received from industry in the Faculty in 1991-92 was in the region of £1.6 million and in 1992-93 exceeded £2 million in cash terms whilst the value of contribution including cash donations and support in kind exceeded £4 million in 1992-93. The Faculty at the moment does not receive any royalties and in the past has not beeen involved with BTG. There has, however, been some special arrangements between some companies and the Faculty in the past where royalties were paid in "non-cash" terms. There is no income from patents. There have been numerous contract research projects, teaching company schemes and a number of SERC supported research projects, CASE studentships and so forth.

The Faculty has a Community Support Policy which primarily supports technology transfer activities. Considering the letters of support and thanks received from companies on the receiving end and income from these activities which has been substantial in the past, it could be assumed that these activities have been effectively conducted.

There is, however, a University-wide Enterprise Unit which co-ordinates a number of interface activities with outside bodies. The Unit acts as a focal centre enabling new organisations wishing to collaborate with the University to do so. The Unit operates on the basis of a "node" receiving information from the outside and disseminating this information to specific academic units for action.

Memorandum submitted by Cranfield Institute of Technology (15 July 1993)

In your letter of 6 May, you sought information from Cranfield into the routes by which the science base is translated into innovative and competitive technology. In responding, I will follow your questions.

1. Organisational Arrangements

(a) The first organisational arrangement lies in the culture and ethos of Cranfield. This is enshrined in our Mission Statement in whcih Cranfield seeks:

> "To be a leading National, European and International Institution for the advancement, dissemination and application of knowledge in Engineering, Applied Science, Manufacturing and management in the industrial, commercial, rural, defence and public sectors. Cranfield's particular mission is to transform world class science, technology and management expertise into viable practical solutions to serve the world economy."

Our experience of successful transfer of technology into industry over many years shows that to be successful requires a lot more than good technology. That is essential, but "technology push" is rarely sufficient. That is why we insist that all our academic staff are not only experts in their particular academic discipline, physics, mechanical engineering, electro-optics, etc., but are also deeply involved with a range of companies in a particular industry, offshore engineering, biotechnology, gas turbine engineering, aerospace, etc. Thus they are not only experts in the knowledge itself (technology push) but the same individuals are in intimate contact with their industry and thus acutely aware of its needs and current problems (market pull).

(b) Virtually all Cranfield's post-graduate students move from Cranfield into industry and commerce. They are a very major source of technology transfer.

(c) We do not have *an* Industrial Liaison Officer, every member of the academic staff acts as an Industrial Liaison Officer (as described in 1a) above.

(d) We are developing a Technology Park on our own land adjacent to the Cranfield Campus. On that we seek to attract the R&D centres of major companies with whom we can have a major interaction. Our first company is Nissan's European Technology Centre and they are typical of the type of company we seek to attract: global, seeking to interact with several of our departments in a major (at least £50,000 p.a.) way.

2. IPR

Our policy on IPR is to seek to retain IPR wherever possible, and to charge much higher rates (i.e., full overheads plus an element of surplus). Where this is not possible we seek to exploit the IPR through non-exclusive licences wherever possible, charging extra for exclusive licences.

However the system described above works reasonably well in fields such as Biotechnology. In fields such as Engineering we usually find it more effective to transfer IPR to a company in return for long-term support of our research activity. In this way we have built many mutually beneficial relationships with companies with whom we have collaborated on a series of consecutive programmes over many years. In this way we gain advantage from our IPR without the need to invest significant sums in legal protection of that IPR.

3. Industrial income

Since the early 1980's a remarkably stable 33 + or – 1 per cent of our income has been obtained from industry in the form of sponsored research. Our current turnover is £80 million. Again since the early 1980's we have a remarkably stable track record of generating £9 from industry for every £1 from the Research Councils such as SERC.

In addition to our industrial research income we also earn a further 20 per cent from industry in our teaching programme both from students on post-graduate courses and on our Continuing Professional Development Programme.

4. Patent income

Our direct patent income is very small, reflecting the fact that we do not have chemistry or pharmacy departments, that our Biotechnology Department is quite small (annual turnover £640,000) and that in Engineering we find it more effective to transfer technology to industry and gain income through ongoing research support than through patent income.

5. Interaction

Given our culture described in paragraph (1a) above, it is difficult to specify how much interaction takes place at our instigation and how much at industry's. Certainly we actively seek to work with new organisations, and are regularly approached by new organisations. With the many organisations we work with year after year even the staff themselves have difficulty clearly identifying who first thought of the particular project being worked on today.

As stated above we currently undertake about £25 million of commissioned research per annum. We are responsible for the management (under contract) of the Teaching Company Scheme as well as active participants in the scheme. We are involved in all the LINK projects within our areas of competence. We work closely with industry, universities and research institutes on EC-sponsored research programmes.

In short we are active participants in all schemes that link universities and industry including the DTI "Partnership PhD Programmes" and the SERC's "Parnaby Engineering Doctorate Programme".

6. Policy on Technology Transfer

Technology Transfer is in many ways Cranfield's "Raison d'etre". It lies at the heart of our Mission, both teaching and research. We not only actively do it, we have a small "Innovation and Technology Assessment" group that undertakes research into what makes for success in technology transfer. It is the work of this group plus our own experience that reinforces our belief in the vital importance of market pull and the relative ineffectivenesss of technology pull. It is this commitment together with our track record of success that we presume led the SERC and the DTI to invite us to manage the Teaching Company Scheme on their behalf. Under our management that scheme has developed and grown substantially, and whilst it is the two Departments that have provided the funds for growth, it is Mr Robson and his staff who are Cranfield employees who have created the opportunities to allow the successful deployment of those funds.

I trust that the Committee will find these comments helpful. If they wish I or my colleagues to amplify them we will be pleased to do so.

Memorandum submitted by Sir David Williams, Vice-Chancellor of the University of Cambridge (15 July 1993)

Thank you for your letter of 30 April 1993 in which you invited comments from this University on the inquiry being conducted by the Select Committee into the routes through which the science base is translated into innovative and competitive technology. You have asked both for comments on the broad topics of the inquiry and also for information on certain more specific questions, and I will begin by giving our general comments.

We see no conflict in principle between the interests of academic staff in the advancement of knowledge and the interests of industrialists in the creation of wealth. Both groups include technologists who are interested in the solution of practical problems. There is no reason why these should not come together in collaborative projects of mutual interest and benefit. There is abundant evidence of successful collaborations between industry and academia through a wide variety of projects, not only fully funded industrial research grants but also from CASE studentships where the company's financial contribution is very small to the largest consortia under the LINK scheme or the various EC programmes where a large number of companies may contribute effort, know-how and resources to a multi-million-pound venture. Clearly, at one end of the spectrum, the testing of a product or process in the industrial context may become mechanical and will lose the intellectual interest which requires the involvement of academic researchers, but we are content to allow our members of staff to judge the interest of any project in academic terms and to set their own priorities.

Possible tensions between the academic and the industrial point of view can arise, however, over questions of publication and of value for money. It is a fundamental principle in this University that any research project must be able to contribute to the advancement of knowledge through the publication of the research results in the appropriate journals, i.e., in the public domain. This is important not only for our academic standing, which is now being subjected to a more searching and quantitative analysis by Government, but also for our tax status as a research and educational institution. Therefore, it may be difficult for us, or for any university, to undertake industrially-sponsored research where the results are likely to be highly commercially sensitive because they are already near-market, so that the sponsor will not wish them to be immediately made public. In practice it is usually possible to find a way forward by setting up consultation procedures prior to publication, with an agreed period of delay to allow for patent applications to be filed, but a member of the academic staff can easily become subject to conflicting pressures, on the one hand to publish promptly for academic reasons, or to withhold publication for commercial reasons. The current UK and European patent legislation, whereby any prior disclosure can invalidate a patent application, contributes significantly to these pressures.

The question of ownership of the intellectual property arising from collaborative research projects also has certain complications. The policy followed in this University is described in greater detail in the second part of this reply. In general terms, however, it should be noted that some universities see advantages in retaining ownership of the IPR, since they can then control the steps taken to exploit it. If ownership is vested in a single sponsor, this can restrict the university's scope for undertaking future research projects with other partners, and it can also be difficult to ensure that the research is actively exploited and not merely kept as confidential know-how by the sponsor. On the other hand, universities may find it difficult to provide the financial, legal and marketing resources necessary to pursue patent applications themselves. Some commercial sponsors are unwilling to invest in research unless they have a clear guarantee of IPR ownership to justify their investment.

If a university research team is working in an area which is of interest to a number of companies, so that grants from more than one sponsor are available, it may become difficult to avoid conflicts of interest unless a consortium or joint collaboration can be set up. The LINK scheme has of course done much to foster this and a model LINK agreement might have helped to avoid some of the difficulties. However, these arrangements by their nature are difficult to negotiate and can involve an additional burden of administration in running the management committees and liaison meetings which are inevitably required.

Although the question of the level of research funding is not in itself directly relevant to the effectiveness of technology transfer, it has an important bearing on the willingness and ability of universities to carry out industrially-sponsored projects. If the project is a collaborative venture of mutual interest, there is still a reluctance on the part of many sponsors to meet the full economic cost. Some improvements have been made in our recovery of indirect costs, but there is still an element of subsidy of industrially-sponsored research from our general funds. Overheads are sought to reflect true costs, though where there is predictable economic benefit to the sponsor the charge may be abated in return for a share of the resulting wealth. Apart from the practical difficulties of ensuring that all such revenue shares are duly claimed, it is uncertain whether any particular project will have any exploitable results, and any revenue will not become available until some time after the project itself has been completed. Although the concept of a revenue share is still important, it is not generally satisfactory as a means of funding research in progress.

The points noted above realate to the difficulties for universities in dealing with industrial sponsors. However, we are frequently aware of cases where, although research results have been achieved which seem to have commercial potential, no investment in them is forthcoming from companies based in the UK. There is a lack of resources for development, and the effects of the recession in recent years have made companies even more cautious. The particular deficiency of the LINK scheme, which has already been extensively commented upon, is that it still requires a substantial investment by participating companies and it still carries a significant risk in that, if the outcome is judged by the DTI to be unsatisfactory, the grant funds may even be reclaimed by the Secretary of State. The scheme represents a level of commitment which companies may still find difficult to make in the present climate, and we believe that the same is true of investment in new developments generally.

We are aware of the fact that an effort has to be made, both by universities and companies, to identify potentially exploitable results. We have recently received a DTI grant to undertake a technology audit, which could have commercial applications, but that it is not always properly recognised and developed. There is a role to be played here by research development laboratories, provided that there is also scope for interaction with venture capital companies, of which there are already some successful examples in Cambridge.

Our comments on the specific points listed in the second part of your letter are set out in a separate Annex attached to this reply. I am sorry that it has not been possible for us to supply all the statistics you requested, but I hope we have given enough information to provide an accurate picture of the scale of our activities. As you know, a number of other recent enquiries, most notably in relation to the White Paper but also from the OST and SERC, have covered similar topics and no doubt some of this information will be available to you. We look forward to outcome of the Select Committee's investigation in due course.

ASPECTS OF TECHNOLOGY TRANSFER—REPLY FROM UNIVERSITY OF CAMBRIDGE

(a) Organisational Arrangements

The University's Industrial Liaison and Technology Transfer office has been in existence for 22 years and was originally endowed by the Wolfson Foundation. Its role is to promote contacts between the University and industry. It is an institution under the supervision of the University's General Board, and independent of any Faculty or Department. It currently consists of a Director, an Assistant Director and a secretary.

The Unit acts as a central clearing house for external enquiries, and can advise on research contracts, consultancies, and other forms of collaborative activity. It produces lists of members of staff and their research interests and department-by-department summaries of current research.

The Unit is responsible for co-ordinating the Cambridge entries in the British Expertise in Science & Technology (BEST) database, a commercial database that contains entries describing the work of some 70 per cent of all UK scientists.

The Unit has a particular responsibility for advising University employees on the commercial exploitation of inventions derived from research funded by the Research Councils, and to ensure that this is carried out to the benefit of the inventors, their Department and to the University itself. The Unit makes arrangements for protecting intellectual property, can advise on appropriate routes for its commercial development, and can obtain specialist help and resources as necessary. Assistance available includes funding for provisional patent filing, use of the University's wholly owned company Lynxvale Ltd, as an exploitation vehicle and close contact with a number of sources of venture capital including local funds such as Cambridge Research & Innovation, and the Cambridge Quantum Fund.

The Unit at present is supported by funds from some of the commercial activities, which it handles on behalf of Lynxvale Ltd; interest from its endowment fund, built up over the past two decades; and a contribution from central funds, currently £50,000 per annum.

(b) Policy on IPR

It is the policy of this University not to take title itself in the IPR of its employees nor to apply for any patent in the name of the University itself. The University would normally expect to disclaim those rights and assign them to the inventor(s), as part of a suitable arrangement for exploitation and revenue sharing either with the grant sponsor or with the University's company, Lynxvale Ltd. The University encourage members of staff to pursue the successful exploitation of their results, and created Lynxvale Ltd for this purpose. The "Cambridge Phenomenon" has been attributed to the University's policy on IPR.

Full details of the University's present policies and administrative arrangements relating to IPR are given in Part II of the Research Grants Handbook (copy enclosed) (see pages 17-21).

(c) Income from Industry

It is not easy for us to give comprehensive statistics covering every aspect of industrial support, as we receive this in so many ways: through research grants and contracts, personal consultancies, donations, endowments for buildings or posts, contributions to our general fund-raising programme, studentships (either fully or partly funded), exchange visits, loans or gifts of equipment, etc. Our expenditure on research grants and contracts over a five-year period from 1987 was as follows:

	UK Industry/ Commerce £000s	Overseas other than EC £000s
1991-92	4,375	2,619
1990-91	3,919	2,512
1989-90	3,209	1,815
1988-89	2,760	1,393
1987-88	2,372	1,077

This figure is exclusive of studentships. Our total research grant and contract expenditure for 1991-92 was £48.5 million; the total from SERC within that figure was approximately £11.5 million.

(d) Income from Patents and Royalties

The following figures include income from sales of software, biological reagents, licensing income and a small amount of consultancy work:

Year ending July	Gross income £K
1989	693
1990	607
1991	632
1992	893
1993	(estimate) 1,000

Figures for patent applications are not collated centrally, but the recent Research Selectivity Exercise showed a total of 116 patents for the period 1989-92. This includes patents filed by Lynxvale and those assigned to companies with whom we have collaboration agreements.

Total income from BTG has always been very low, of the order of £100,000 over the past eight years.

(e) Interactions with Industry

The University occasionally receives general enquiries from industrial sponsors who wish to carry out a project, and these approaches can take the form of a "competition" or invitation for tenders. However, the majority of interactions arise naturally from areas of research of mutual interest, and are fostered by attendance at conferences, exchange of published papers, etc. Exchange of personnel is also very important, and the CASE studentship scheme is particularly valued in that the students often go on to take up research posts in the company concerned, so that an ongoing link is established.

(f) Time Spent on Technology Transfer

We believe that our present policies provide a suitable framework for technology transfer to be fostered, but it is clear that much more could be achieved if more resources were available, both within the University to identify exploitable results, and within industry to invest in new developments.

Memorandum submitted by Sheffield Hallam University (15 July 1993)

1. Executive Summary

1.1 The University fully subscribes to the Faraday principles and considers that technology transfer is fundamental to its success in developing as a National Professional University, committed to delivering the education, training and development needs of the professions, industry and commerce, through active collaboration and partnership with employers.

1.2 Technology transfer needs to be set in the context of a broad range of activities and the organisational arrangements should reflect this. This includes policies and practices with respect to intellectual property and the need to develop partnerships with industry which are long term and broadly based.

1.3 Government policy should aim to reinforoce existing partnerships, particularly those which are based on the exploitation of intellectual property through interaction between people, and where there is a clear mutual benefit to the organisations involved. Examples are given.

1.4 Sandwich education is a cost-effective way of promoting links between education and industry.

1.5 The University supports the White Paper proposals concerning the revision of postgraduate education at Masters level and sees partnerships with industry, such as the Integrated Graduate Development Scheme (IGDS) and in-employment training programmes as helpful models.

1.6 Strategic and applied research is important and should be separated from discussions on so-called "near market" research. Continuing professional development in employment provides a good vehicle for technology transfer, particularly in support of small and medim-sized enterprises.

1.7 There should be more co-ordination of Government initiatives, a reduction in their number, and a move from short-term "pump-priming" funding to medium and long-term support.

2. Background

Sheffield Hallam University's development plan is guided by its vision of the National Professional University, building on the current environment where interaction with employers embedded in the mission, life and culture of the institution. This interaction is a two-way process. The University is seeking to involve employers in determining policy direction, programme development and collaborative ventures. In return, the University is actively seeking to influence and support industry, the professions and commerce to develop a healthy and vigorous enconomy, particularly in the region, but also nationally and internationally. These processes often merge, resulting in joint ventures in partnership with employers. Such partnerships need to be firmly based on the quality of provision and mutual respect if they are to be successful. The requirement to be responsive and proactive in support of employers is apparent in the business planning process, feedback mechanisms and most University activities.

3. ORGANISATIONAL ARRANGEMENTS

3.1 With the University commitment to working with industry employers and the professions so deeply embedded within the institution, a very wide range of partnership initiatives exist and are successful. Nevertheless, the University has recently conducted a technology audit with a view to building on good practice, within the institution and in other universities, and to improve the technology transfer process.

3.2 The University is of the view that schemes which are people focused, whether this be through students, staff research and consultancy, joint projects or training programmes, are the most effective way of exploiting intellectual property. This must, of course, be supported by a good information base, staff development programmes, channels for communication, support for partnership ventures and sufficient flexibility in staff time.

3.3 The technology audit has identified the need for further central co-ordination and support to provide a focus for enquiry, promotion and communication for employers who do not already have contact with the University. In consequence, the University is strengthening this aspect through the creation of an Employer Liaison Office.

3.4 The organisational arrangements within the University which support the exploitation of the science base are set in the context that:

3.4.1 Each member of the senior management executive has a role in working with employers and the professions and one Assistant Principal has specific responsibility for technology transfer and external liaison.

3.4.2 A development group, chaired by a Director of School, advises on improvements to the technology transfer process.

3.4.3 The development group and each of the 12 Schools within the University are supported by the Employer Liaison Office.

3.4.4 Each of the 12 Schools has a senior academic on the executive team with specific responsibility for employer liaison and technology transfer.

3.4.5 The Schools have developed many ways to promote employer partnerships, including advisory groups, business clubs, newsletters, joint ventures and alumni associations. Each School supports the University's major commitment to sandwich education (all the University's courses involve a work-related element and 70 per cent are sandwich based, making it the largest provider of sandwich education in Europe), through a structured approach to placement and monitoring which involves all academic staff. This also provides valuable feedback for student projects and staff research.

3.4.6 The University's Board of Governors, which includes many members from employers and the professions, has established a number of policy committees, chaired by industrialists and having national membership from industry, to advise on the development of specific areas of work such as Engineering, Information Technology, Business and Management and Food Science.

3.4.7 In addition, the Board of Governors has established an independent company, Sheffield Hallam University Enterprises Limited, to facilitate the exploitation of intellectual property.

3.4.8 The Academic Board has established a Research Policy Committee to advise on policy and strategy and the quality of provision. In addition, a Research Degrees Committee is responsible for advising on standards. Strategic and applied research, and professional activity feature strongly in their work. The Univiersity has adopted the selective approach focusing on key research areas, and has established a number of research institutes and centres to promote these areas as interdisciplinary and inter-School activities, each with a commitment to working with industry.

3.4.9 Finally, the University has an annual review procedure to consider issues concerning quality and good practice, leading to agreed action plans for improvement. The review covers research, professional practice and employer linkages.

3.5 The internal organisational arrangements described above are complemented by three other areas of activity: the promotion of a responsive University by fostering industry's demand pull; the two-way communication of information between the University and industry; and the work with intermediate funding agencies to facilitate technology transfer.

3.6 The first of these, namely, *fostering the demand pull*, is promoted by the provision of information for industry on expertise, facilities and innovations and by intelligence gathering with feedback from industrial placements, joint ventures, professional associations, etc. University staff are encouraged to work with employers and are frequently involved with employer associations, particularly within the region. Support for Science Parks, Technology Parks and non-executive board membership of companies present opportunities for fostering the demand pull. The University is involved in most significant partnership arrangements throughout the region. It must be said, however, that this aspect of the University work is particularly time consuming and difficult with respect to working with small- and medium-sized enterprise.

3.7 The two-way *communication* between industry and the University can always be improved, although we have a good record in this respect. The University will be broadening its database of staff expertise, co-ordinating employer database information, including alumni data, and supporting a major development on promotional material.

3.8 The work *intermediate funding agencies* is of major importance to the University in supporting its commitment to exploit intellectual property to the benefit of the economy. The University is consequently extending the partnership notion to include organisations active in this field, whether this is Research Councils, Government Departments, Foundations, the European Community, or other international organisations. The involvement of these agencies is generally positive, but for the University it can be a time-consuming and difficult exercise. More could be done to limit the plethora of initiatives, providing more co-ordination and reinforcement of existing good practice.

3.9 In estimating the *extent of investment* involved in this work, we have taken account of staff time in the actual delivery of research, consultancy, industrial placement visits and other initiatives. This amounts to around 25 per cent of their time which, when added to central support, results in a figure of approximately £12 million per annum.

4. IPR POLICY AND PROTECTION

4.1 Sheffield Hallam University believes that higher education has a central role to play in the economic, professional and social development of the nation. Technology transfer services between higher education and industry are considered to be of strategic economic importance. These include research, consultancy, training and continuing education, and research exploitation.

4.2 The University encourages the commercial exploitation of ideas and inventions arising from activities of staff, students, members of the general public and industry. When exploitation results in a net royalty, Sheffield Hallam University guarantees an equitable share in the benefit to the person(s) involved. Support services, guidance notes and procedures are established to promote the efficiency and effectiveness of the innovation process. These procedures require the commitment and involvement of the innovator and School management throughout the exploitation process.

4.3 The procedures, support and protection arrangements cover *identification, assessment of potential* using the Centre for Product Development (SCEPTRE), where appropriate, *division of benefits, student support*, arrangements for *other inventors* and *monitoring*. These include staff development programmes and support from Sheffield Hallam University Enterprises Limited. Detailed guidelines are available and recognised by the Science and Engineering Research Council (SERC) on behalf of all Research Councils.

5. INCOME FROM INDUSTRY OVER THE LAST 10 YEARS

5.1 The University presently has no net income from royalties on patents and, therefore, none through BTG, but this is because patents are not the usual route whereby intellectual property is exploited.

5.2 Copyrights, Design Rights, Patents and computer generated works all feature in the exploitation process, but in many instances, inventions are incremental improvements on existing products rather than new products, and whilst they may be subject to patent application, the relationship with the employer is one of their retaining parent right and the University benefiting from continuance of research funding. Examples of this are Richardson's new product range of knives, posture mirror, wire coating monitor, laser disc training programmes, domestic dehumidifier and CASE tools. There are many others, with each making a significant contribution to industrial competitiveness, but none being shown up in the inquiry data.

5.3 A breakdown of income in the form requested is not available over a 10 year period because of the changes in financial systems resulting from incorporation. The following data may assist in giving a guide to *income received from industry:*

	1990-91 £	1991-92 £
Total Income:		
Research Grants and Contracts	1,297,927	1,517,000
Other income generating activities	3,693,456	5,308,000
Totals:	4,991,383	6,825,000
Income from industry:		
Research	233,548	287,375
Consultancy	981,823	1,223,391
Totals:	1,215,371	1,510,766

5.4 It should be noted that the above figures represent cash income only. A major contribution is made from industry in terms of gifts, equipment and software donations and staff time.

6. INCOME FROM PATENTS

As indicated earlier, there is presently no income from patents, but the University considers that other indicators are more appropriate for the inquiry team. The University currently holds two patents, but those presently held by partners as a result of collaborative projects may exceed 30. In some instances, the University is unaware of the industry decision on exercising the option to take out a patent.

7. RELATIONSHIP WITH INDUSTRY

7.1 The commitment of the University to working closely with industry is given in section three. Whilst emphasis is given to support within the region, the acute difficulties faced as a result of decline in the traditional industrial base means that the University can often best serve the region through developing partnerships with industry nationally and internationally.

7.2 The University has identified as best practice those schemes which are people-focused, and where there is clear identification of mutual benefit to the industry and the University. Experience indicates that as confidence is built in the partnership, a transition occurs from short to longer-term initiatives which are of more benefit to the University.

7.3 From the good practice partnerships the University wishes to highlight the following:

7.3.1 The University is developing a Teaching Company Centre of Excellence based on its existing experience. It is looking to extend this further to small and medium-sized enterprises through a common-purpose groups, for example, supply chains, and to involve further education colleges in initiatives with their local industry through the Associate College network.

7.3.2 In-employment training programmes conducted jointly with industry for industry have proved very successful as a partnership route to facilitate technology transfer. When reinforced through programmes such as the IGDS and the new Masters level provision, proposed in the White Paper on Science and Technology, this will be a very powerful model for technology transfer.

7.3.3 A range of projects promoted by Government agencies highlight the importance of promoting schemes which have a people focus including:

- LINK Schemes
- CASE Awards
- EC, BRITE-EURAM initiatives
- Staff Exchange
- Academics on Company Boards
- Equipment Timeshare Clubs
- SME Technology Audits
- Training Needs Analysis

Such schemes should be viewed as a whole rather than be promoted as individual initiatives.

7.3.4 Contract research, consultancy and staff secondments are a valuable means of promoting lasting links with industry.

7.3.5 Sandwich education and the contact between education and industry it fosters is a valuable mechanism for promoting technology transfer.

7.3.6 Staff and student sponsorship is becoming common practice as a way of cementing longer-term relationships.

7.3.7 The University is finding that industry is now more prepared to become involved in partnerships aimed at promoting science and engineering in schools, and to the population at large. The University is pleased to be involved in such arrangements, many of which are in support of communities in deprived areas. These include:

— Education and Business Partnerships
— The Sheffield Strategic Education Forum
— Science and Technology Regional Organisation
— Community Service Volunteers initiative
— Economic Regeneration Groups

7.3.8 The University continues to support specific developments within the region. These include the Science Park, which contains University spin-off companies, the Technology Park (promoting high-tech companies), the development of cultural industries in a specific areas of the city, and the development of Sheffield and South Yorkshire as a "Technopole" in Materials and Engineering Design: the latter being in tune with concepts expressed in the Faraday principles.

8. POLICIES TOWARDS TIME SPENT ON TECHNOLOGY TRANSFER

8.1 The commitment of the University to working in partnership with employers is so deeply embedded within the institution that all of its activities are influenced by the philosophy. If the significance of the inquiry question is to ascertain if the University supports consultancy work, then the question needs to be set in a broader context.

8.2 The University believes it is effective in promoting technology transfer, but intends to augment this activity much further, arguing that it is essential to its success in developing as a National Professional University. The University subscribes fully to the Faraday principles.

Memorandum submitted by the London School of Economics (20 July 1993)

Further to your letter of 6 May to our Director, Dr John Ashworth, and his reply of 27 May, I am writing as promised with a more detailed response to your enquiry, although I am afraid that as a specialist social science institution much of the issues are not esepcially relevant to LSE's mission.

1. *What organisational arrangements (e.g., research committee, Industrial Liaison Officer, Science Park) if any, are in place to ensure that developments are disseminated to industries who may wish to use them, and to enable industry to make contact with researchers whose expertise may be of interest to them? Could you give an estimate of the investment in these arrangements?*

A variety of arrangements exists:

(a) LSE's Research Committee is responsible for overseeing and making recommendations on research policy, those issues affecting LSE's industry-sourced research (estimated cost of regular annual meetings £10,000 staff time and associated costs) a cross-indexed guide to LSE research expertise, *LSE Experts* (copy enclosed), is mailed to some 20,000 targeted potential research clients including those from industry (1992-93 costs including printing, mailing, staff time and DTP £40,000); LSE has for some years successfully exhibited at a variety of conferences including those of the CBI and the major political parties and as a result has enhanced existing and developed new links with industry (1992-93 costs including exhibitor fees, staff time, publicity, etc., £20,000).

2. *Do you have a policy on IPR? What arrangements have you for ensuring that developments within the institution receive IPR protection, when appropriate?*

LSE's policy is that IPR should reside with the School unless good reasons obtain to the contrary. Specific instances requiring IPR protection are guided by legal advice co-ordinated by Enterprise LSE, LSE's wholly owned company, and the Research and Consultancy Office as appropriate.

3. *What is the total income your institution receives from industry each year (give figures for the past decade)? Please show income from royalties separately, and indicate what portion of this comes through BTG. What proportion comes from based companies and what comes from overseas? What proportion of your total research expenditure, including income from bodies such as the SERC, does this represent?*

Total Industry and Commerce

Year	£k	£k	Per cent of total
1981-82	874	18	2·1
1982-83	863	119	13·8
1983-84	963	139	14·4
1984-85	1,366	213	15·6
1985-86	1,408	230	16·3
1986-87	1,990	316	15·9
1987-88	2,248	489	21·8
1988-89	2,359	611	25·9
1989-90	2,790	513	18·4
1990-91	4,381	710	16·2
1991-92	5,037	514	10·2

4. *Please give the income from patents that your institution has received each year since 1983. How many developments are patented in each of these years?*

Nil: None.

5. *How much interaction with industry takes place at the specific instigation of a company, how much is initiated by members of the University and how much arises from ongoing relationships within industry? What form do these relationships take (e.g., commissioned research, Teaching Company Scheme, LINK, CASE studentship)?*

It is difficult to disaggregate the income generated from industry into these specific categories: our estimate, based on analysis of the statistics outlined in response to question 3 above, suggests the following:

(a)	Instigated by the company	75 per cent
(b)	Initiated by LSE staff	10 per cent
(c)	Arising from ongoing relationships	15 per cent

The majority of these relationships involve research/consultancy activities, although industry does and has sponsored academic posts and benefits in kind, e.g., computer equipment, often as part of a commissioned research project.

6. *What are your policies towards time spent on technology transfer activities? How effectively are these implemented?*

Given its specialist social science niche, technology transfer does not play a major role in the LSE's research activity. Implementation of any such activity would be co-ordinated by the Research and Consultancy Office, with the support and guidance of Enterprise LSE.

Memorandum submitted by the University of Sunderland (20 July 1993)

INQUIRY INTO INNOVATIVE AND COMPETITIVE TECHNOLOGY

I am responding to your letter of 6 May 1993, addressed to the Vice Chancellor, requesting information regarding the inquiry being conducted by the Select Committee on Science and Technology.

1. The University of Sunderland mission contains a commitment to support industry locally, regionally and beyond. We do not restrict our activities to the narrow view that technology transfer is the only way in which our "science base" can be translated into innovative and competitive technology. Rather, we take a broader view that this is but one element. More important is the development of the capabilities of SMEs. We address the whole panoply of these interactions through an External Development Support Team, led by myself. Within this team is our Industry Centre, details of which are enclosed. The Industry Centre provides a single interface point of contact for industry and ensures a professional approach whether this be for example technology transfer, development of IT skills in local industry through our "Make IT Grow" initiative or consultancy. Whilst, of course, there may also be individual contacts with individual academic staff, our formal procedures for approval of work by staff are routed through the centre so that the University can ensure its policies, procedures and standards of good practice are met.

2. We have a policy for IPR which is deliberately kept brief and straightforward. A copy is attached. All staff are aware of the policy, and research is monitored comprehensively as part of our Research Committee procedures such that whilst it is still possible that a major IPR opportunity may be squandered, it is unlikely.

3. Details of industry funding over the last decade are attached.

4. *Interaction with Industry*

Universities today have a multitude of connections with industry, which have developed as the range of their activities has extended over recent years, involving the majority of their staff. Training courses, consultancies, testing services, funded research, sandwich placements, Enterprise in Higher Education initiatives, Teaching Company Schemes, Case Studentships, departmental and course advisory boards and representatives on governing boards give a measure of the numerous occasions when academics and industrialists meet. Thus within this complex of interrelationships it is difficult to quantify what proportion of initiatives arise at the specific instigation of industry. However, it is true to say that where industry takes the lead, rather than an HEI, it is the larger firms which are involved. The involvement of larger companies in these matters is not a problem. They are generally well aware of the objectives, are in a relatively strong bargaining position and are able to ensure through their network of contacts that they get the inputs which they require from the higher education sector. Indeed, we are in a world where the influence and economic contribution of multi-national corporations is very significant and growing. They undertake in-house training, research and development on a large scale, utilising and purchasing external contributions as required or, in the case of innovatory ideas, as they arise.

A principal difficulty, however, lies in the relatively poor participation of SMEs in partnership arrangements with universities. Yet they are the most numerous of all producers, operating in limited or niche markets, and are crucially important to the future course of UK economic prosperity. There are several reasons why relatively poor liaison exists between them and universities; they are often relatively isolated, the owner-managers uncomfortable working with academics, or even graduates, conscious of their own limited technical and managerial skills; concerned about survival, rather than expansion, in a competitive world; and tentative about innovation, given the resource commitment and the financial risks involved. Even the prospect of success carries a fear of losing control of the company, so many tend to prefer a less entrepreneurial, but manageable, existence. However, where partnerships with universities do exist they tend to prove extremely beneficial to the company. Nor is the technology transfer merely incremental; good minds and new ideas exist in industry, as well as in universities, and partnership arrangements offer mutual benefits through the exchange of ideas and the prospect of further joint developments.

Given the nature of the problem the answer lies in the initiative being taken by the universities operating as principal elements in strong local and regional networks with partners who have a common purpose in securing an enterprising and expanding economic base. Universities are normally based in urban areas and it is within these city regions that SMEs largely operate. It is thus within their immediate environment that universities can become prime movers in securing, in association with other public and private agencies, the involvement of SMEs in beneficial partnerships in the context of regional/sub-regional strategic programmes which effectively address the specific economic and social problems of their areas. One of the major objectives of such networks should be a regional/sub-regional focus on R&D, technology transfer and management training appropriate to the specific needs of the industrial complex. Within these networks the interests of particular companies and industries become readily indentifiable and partnerships with universities develop.

As an example of the above process the University of Sunderland (not an institution apart from local industry, but rather a part of it) has formed strong partnerships with TECs, development agencies, the City Council, industrial companies and other educational institutions to promote industrial and economic regeneration. In the local context the University of Sunderland, the City Council and Wearside TEC have formed an association comprising the Wear Euro Group and the Strategy for Innovation and Enterprise on Wearside (SINEW) through which their joint strength is directed toward promoting the above objectives. The University has an Innovation Centre to nurture through to company formation good ideas owned by graduates and a Business Innovation Centre is currently under construction to more generally assist the commercialisation of new ideas.

In addition to this local contribution, the University works in association with the other Universities in the region through HESIN (Higher Education Support for Industry in the North) to promote, in conjunction with the Regional Technology Centre, technology transfer to industry. One relevant recent development is a proposal for EC support to establish a regional Centre for Technology Commercialisation.

UNIVERSITY OF SUNDERLAND

POLICY STATEMENT

INTELLECTUAL PROPERTY: COPYRIGHT INVENTIONS AND PATENTS, etc.

The main functions of the University are to provide Higher Education and to carry out Research and publish the results. In so doing, intellectual property rights will be created. These can have a commercial value, which may be exploited for the benefit of the University and its staff, without in any way compromising the academic commitment to the free dissemination of ideas. The University wishes to encourage the initiative of staff in the creation of intellectual property, and the identification and exploitation of discoveries and other income generating activities. Accordingly this policy statement indicates how the proceeds of commercial exploitation will be apportioned between the University and the staff.

This policy statement covers commercial exploitation of intellectual property rights by the University: such exploitation will normally be undertaken through its subsidiary company. This statement supplements the University's policy on External Work and Consultancy which is set out in the Code of Practice approved by the Board of Governors in June 1991. This latter code outlines the procedures for obtaining approval to the carrying out of external work and consultancy.

Legal position

The ownership of intellectual property rights gives the owner a monopoly over the exploitation of such rights. The extent of the monopoly, and the length of time it may be exercised, varies.

The general legal position on the ownership of Intellectual Property is that ownership of any such property that has come into existence in the course of employment is vested in the Employer—unless there is an express agreement to the contrary.

Where work, such as research, is to be carried out for a sponsor, the draft contract may often provide that all intellectual property rights in the results will be owned by the sponsor. However, the University's policy is that, wherever possible, ownership should remain wholly or partly with the University. Staff must take account of this when discussing proposals with sponsors, and should take advice from Legal Services before concluding any negotiations. The University's policy on research contracts and research costing gives full details of the requirements. (This policy will be promulgated in late 1992/early 1993).

THE SCHEDULE

1. Inventions/Patents

Any royalties that arise from a patented invention (after the deduction of all expenses and fees directly incurred by the University) will be apportioned between the inventor(s) and the University in accordance with the sliding scale set out below:

	£	Inventor(s) Per cent	University Per cent
First	5,000	100	—
Next	45,000	75	25
Next	100,000	60	40
Next	200,000	50	50
Thereafter		25	75

Inventors will share any income on an equal basis unless there is a specific agreement to the contrary. A student who is a co-inventor of a patentable invention will be required to accept the conditions applicable to staff.

2. Copyright

Income from the commercial exploitation of copyright material (e.g., from the distribution or sale of courses and course materials) will not engender royalty payments to the author except in rare instances. An example of the latter would be where the copyright in material which the University wishes to incorporate in a course is clearly vested in a member of staff. A payment for its incorporation and use would then be negotiated.

Proceeds of Commercial Exploitation

Where Intellectual Property Rights have been commercially exploited by the Unviersity the proceeds will normally be dealt with in accordance with the guidelines set out in the Schedule to this Policy Statement. The guidelines will be subject to periodic review.

Note

This Policy Statement is not intended to be either comprehensive or exhaustive. Members of staff can always discuss any specific case in point with their Director of School (or Head of Service). In cases of dispute a final ruling will be made by the Vice-Chancellor.

Intellectual property means

Copyright, Design Right, Registered Designs, Trade and Service Marks, and Patents.

The first two rights arise automatically; the rest have to be registered in order to be protected (protection applies from the date of appliation for registration)—and fees paid to maintain that registration.

University's position

The University wil, of course, comply with the statutory provisions as contained in Copyright, Designs and Patents Act 1988, The Trade Marks Acts 1938 and 1984, and The Patents Act 1977 (and any subsequent amendments or re-enactments thereof).

The 1988 Act makes it clear that copyright (including the copyright subsisting in computer programs devised by the employee), and the new design right in industrial designs, belong to the employer. It also gives the author certain moral rights—rights to be identified as author, to object to derogatory treatment or modification, etc.

The Patents Act gives the inventor-employee (notwithstanding the general rule of ownership being vested in the employer) a right to compensation if the employer receives outstanding benefit from the commercial exploitation of the Patent.

Whilst apart from this provision, there is no statutory obligation on an employer to compensate an employee for the use made of intellectual property generated by the employee, the University wishes to encourage exploitation of intellectual property and so provides incentives at its discretion.

Specific provision is included in the academic contract on how the legal rights and duties between employer and employee relating to intellectual property should be applied. Although this contract applies to academic staff only, these provisions will also be applied by the University to intellectual property arising from the work of non-academic staff.

In summary, the academic contract provides:

(1) All inventions and applications or know-how developed or determined in the course of employment are the property of the University, and inventors/originators are required to disclose them to, and assist the University (at the University's expense) in taking all necessary steps to protect them. This includes a duty to ensure that patent applications are filed before the invention becomes publicly known and the right to file is lost. If the University decides not to exploit an invention or application the inventor/originator may be entitled in certain circumstances to do so.

(2) The Copyright in all records, documents, papers and other articles made or acquired in the course of employment belongs to the University. This includes the copyright in material produced for courses, and in the outcomes of research. However, copyright in any published "scholarly work" (this includes books, published articles and published papers), and in any material produced for own personal use and reference (including as an aid to teaching) belongs to the author.

Externally Funded Research

1983-84	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	10	4	14			
Teaching Co Schemes	13	0	13			
CASE Studentships	0	0	0			
	23	4	27	316	343	7.87

1984-85	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	15	1	16			
Teaching Co Schemes	23	0	23			
CASE Studentships	3	0	3			
	41	1	42	483	525	8.00

1985-86	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	36	23	59			
Teaching Co Schemes	31	0	31			
CASE Studentships	5	0	5			
	72	23	95	674	769	12.35

1986-87	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	60	2	62			
Teaching Co Schemes	38	0	38			
CASE Studentships	11	0	11			
	109	2	111	1,079	1,190	9.33

1987-88	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	34	3	37			
Teaching Co Schemes	37	0	37			
CASE Studentships	22	0	22			
	93	3	96	747	843	11.39

1988-89	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	82	0	82			
Teaching Co Schemes	38	0	38			
CASE Studentships	20	0	20			
	140	0	140	469	609	22.99

1989-90	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	35	0	35			
Teaching Co Schemes	75	0	75			
CASE Studentships	26	0	26			
	136	0	136	635	771	17.64

1990-91	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	37	0	37			
Teaching Co Schemes	86	0	86			
CASE Studentships	27	0	27			
	150	0	150	470	620	24.19

1991-92	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	27	0	27			
Teaching Co Schemes	49	0	49			
CASE Studentships	35	0	35			
	111	0	111	350	461	24.08

1992-93	Receipts from Industry UK £000's	Overseas £000's	Total £000's	Other External Funding £000's	Total External Funding £000's	Receipts from Industry as percentage of Total Funding
Commissioned Research	101	0	101			
Teaching Co Schemes	43	0	43			
CASE Studentships	32	0	32			
	176	0	176	669	845	20.83

Memorandum submitted by the University of Edinburgh (28 July 1993)

PART 1 BROAD COMMENTARY

1.1 In addition to undertaking their normal duties, including the prime functions of teaching and research, academics in the Universities of the United Kingdom (whether "old" or "new") are currently having to find time for extra or new duties. Examples of these are the additional teaching sessions which may be required because of increased student numbers, the extra administration involved in supplying data for internal or external assessment exercises, the production of higher numbers of publications in some instances and the requirement to set time aside to improve teaching skills.

1.2 As part of their research activities, many academics are also involved in collaboration with industrial or commercial companies or are actively seeking such collaboration. The additional pressure on time created by the new duties is clearly limiting time available to seek and carry out research or development for industry or commerce. By how much this is so, depends on the particular schedules of individual staff. These can vary from a commitment to research of over 80 per cent total time to individuals with responsibilities in all the areas outlined above, together with internal and external administrative responsibilities. Collaborative work with industry and commerce is seen by this University as an essential part of its role as one of the United Kingdom's premier research Universities and it is not, therefore, because it has low priority that time for it is being limited.

1.3 To say that additional pressures are limiting time for collaborative work with industry pre-supposes that such work is available to universities. Current evidence suggests that industry is not increasing its budgets for R&D, nor is the volume of work being "out-sourced" by industry expanding.

1.4 There is also undoubtedly a conflict between academics seeking R&D funding from industry and pursuing other academic goals and routes to obtain research funding:

(i) Academics are having to spend more time to obtain industrial support for R&D, particularly where this involves research with longer term, rather than short term goals. As the industrial base shrinks, fewer companies are budgeting for strategic (longer term) research, particularly in the Engineering, Chemical, Agricultural and Healthcare sectors. The additional time spent pursuing industrial finance includes that spent in presenting and selling proposals to industrial companies, which often need to be strongly persuaded that the project work is valuable and should be "out-sourced". This is also the case for consultanices, where ideas are the prime product. In addition, concern is growing that, where companies have disbanded their own R&D sections, the expertise to assess ideas or research proposals put to the company may be lacking to a greater or lesser degree.

(ii) Academic staff find industrial projects, which tend to be strongly milestone driven, very time consuming in terms of the administration relative to the bench work required. Industry needs constant and frequent reassurance that the project is on course, on budget and on time. The administrative element in industrial projects therefore compares very unfavourably with research work for government and the Research Council.

(iii) Irrespective of the size and duration of the project, industrial funders may wish the results to remain confidential. This precludes or makes it difficult for academics to publish results from such studies, which, in turn may make it difficult for them to claim credit adequately, either for academic assessment or promotion reviews. This is a considerable disincentive to becoming involved. This situation is, however, slowly improving as the value of collaborative work with industry is more widely recognised.

(iv) UK industry in particular appears to resent paying the full economic price for R&D and as a result there are constantly quibbles over the overhead level charged by universities. In contrast, Japanese companies and US corporations find the UK an inexpensive and high quality research environment and are prepared to pay for quality work with a longer time horizon than their UK equivalents.

1.5 At Edinburgh these problems are recognised and we seek to ameliorate the problems in i-iv above as follows:

(i) The University has set up UnivEd Technologies which has the objective of marketing the University's resource base to industry, Government and the EC.

(ii) UnivEd's role extends beyond R&D to Consultancy, Training and the development of the Technopole, Edinburgh's Science Park. Through effective marketing industry is kept informed that Edinburgh has resources available for R&D, Training and Consultancy.

(iii) Clearly it is important to identify what resources are available to market, and at Edinburgh UnivEd has conducted Technology Audits, partly funded by DTI, in Medicine, Science and Engineering and Veterinary Studies to pinpoint these resources. Part of the Audit has included the needs of industry and how these relate to the resources identified.

(iv) The policy of Edinburgh in respect of industry is to encourage UK and International industry to approach the University to discuss not only specific project work (which tends to be short term and very resource specific) but more importantly to design and implement partnership relationship with companies whereby shared objectives can be researched over a longer term time horizon.

Examples are Syntex Clinical Research Centre and the Fujisawa Institute for Neurosciences. These longer term partnerships, whereby both sides recognise each other's organisational needs, are the linchpin of future industrial relationships at Edinburgh.

(v) Equally importantly UnivEd operates *in each* of the major Faculties, with local offices which are close to the location of the R&D work. This means that communication between the Researchers and the Technology Transfer staff is improved and UnivEd is thus more likeley to identify a marketable idea as it arises and be alerted to market opportunities as perceived by academics. This is being improved experimentally within the Science & Engineering Faculty by the addition of four "Stringers" who will concentrate on Departmental groups within Science & Engineering, attempting to "burrow into" the Departments and thereby identify Technology "hot spots" as they arise. These Stringers will have industrial backgrounds (as have all UnivEd staff) and be able to identify potential market sectors and companies who can be approached as potential clients, thereby relieving Academics of this task. The role of the Stringers is, first, to identify resources within Departments available for contract work with industry and second, to market these resources effectively. Their criteria for success will be the expansion of business with industry and Government.

(vi) The key back-up to all of these features is the ability to negotiate strong and effective contracts, which is assisted by having a full-time commercial lawyer on the UnivEd staff, backed by a patenting expert. Hence contracts which are concluded are both legally water-tight for both parties *and*, as far as possible, take account of the Industrialist's need to patent whilst respecting academic publishing conventions.

1.6 It is therefore possible to encourage academic staff to proffer services to industry and to ameliorate problems which can arise when industrial projects are being carried out by academic staff. Far more difficult, however, is the problem of trying to motivate industry to become involved with universities and to proceed on the basis of a partnership arrangement to the benefit of both parties.

INDUSTRIAL COLLABORATION ESTABLISHED THROUGH LINK, TEACHING COMPANY AND OTHER RELATED SCHEMES

1.7 Within the general context set out above, LINK, Teaching Company and the scheme operated by SERC's specialist, industrially oriented Directorates (1.8) provide welcome methods for additional collaborative work with industry. A significant percentage of this would clearly not occur, if it were not for the Government support available through the schemes. This is most often true where the industrial partner is a small or medium enterprise (SME).

1.8 Academic researchers are made aware, both by UnivEd and by the University's newly created Research Support Section, which deals largely with Research Council Funding, of opportunities in this category as they become available, either within new or existing schemes. UnivEd's knowledge of local industry can also assist in identifying industrial partners for specific projects. It is notable, however, that again the current financial status of companies has led to some applications being aborted at a late stage in the development progress because of insufficient industrial resources. (In 1992-93, Edinburgh initiated four Teaching Company Awards and only two new LINK projects.) This notwithstanding, a very high proportion of those which are submitted are successful, because of the helpful iterative/advisory process operated by the Departments, scheme consultants and the Research Council secretariats. This process, most commonly involving an outline proposal which is considered for relevance prior to submission of a full application, and allowing advice to be given during the development of the proposal, is also operated by the specialist, industrially-oriented Directorates of SERC, such as ACME (Application of Computers to Manufacturing Engineering), Biotechnology and Marine Technology. In all cases it is strongly welcomed by the University's research staff, because of its more targeted use of the effort required in the production of a research proposal.

INDUSTRIAL COLLABORATION THROUGH CASE AND WHOLLY INDUSTRIALLY FUNDED STUDENTSHIPS

1.9 The University has studentships funded under SERC's CASE (Collaborative Studentships in Science and Engineering) Scheme, similar schems run by other Research Councils and studentships wholly funded by industry.

CASE Studentships and Similar Schemes

1.10 The University strongly welcomes SERC's CASE scheme and the similar schemes run by other Research Councils, in the belief that they are a very valuable mechanism for reinforcing desirable linkages between the University and industry. The skills learnt by the student during the time spent on the premises of the co-operating industrial body are likely to be of significant benefit both to an eventual employer and to the student. In addition, the ability to prepare an adequate workplan for some piece of research or development, to timetable it effectively and to monitor its timely completion are skills which are of significant general usefulness in academic, administrative and commercial applications, as much as in industry. For these reasons and also to foster further the view held by the great majority of the industrial and commercial firms involved that University graduates are useful employees, the University would very much welcome an extension of these schemes. (For 1993-94, the University will have 17 SERC CASE awards).

Wholly Industrially Funded Studentships

1.11 The University also has a variable number of PhD, MSc and other studentships each year funded by industry, either wholly or to a very large part. In 1992-93, the total was 116, making this a significant contribution to total income from industry. Where the awards are PhD studentships, they are frequently part of a major collaborative project. All these awards are welcomed for the same reasons set out for the CASE scheme above (1.10), but may, in many instances, give closer or more extended contacts with industrial partner(s) than the CASE awards.

PART 2 MECHANICAL ASPECTS OF TECHNOLOGY TRANSFER

2.1 The responses in this section are directly related to the order in which the questions are raised by the Committee's request for evidence.

(a) The University's Internal Organisation

2.2 The University has a Research Committee which has the remit to determine overall research policy. The University's Director of Industrial Liaison, who is also, at present, Managing Director of UnivEd (see 1.5(i-ii)) is a member of the committee.

2.3 UnivEd's Board is chaired by the Secretary to the University and contains the Senior Vice Principal, the Director of Finance, and two independent Directors from Industry.

2.4 As mentioned earlier (1.5(v)) the structure of UnivEd is such that contracts managers are located within the major Faculties of Science & Engineering and Medicine. This enables these executives, who have industrial experience, to become part of the Faculty structure and hence closer to the academics than might otherwise be possible if they were to be seen as part of the University's administrative structure. Clearly the Contracts Managers have become experienced in dealing with the companies and government departments which form the target markets for both these Faculties. In 1993 a further five "Stringers" will be employed to provide Business Development capability for both the Science & Engineering Faculty and the Veterinary Faculty. The Stringers will be employed to cover specific groups of departments which tend to share similar markets.

2.5 In addition UnivEd employs a full-time marketing manager, provided under a grant from DTI, whose role is to assist academic colleagues to effectively market IPR and know-how, and to carry out promotional activities to create awareness of the University's ability to solve problems for Industry and Government.

2.6 This type of professional assistance is not inexpensive and UnivEd's expenditure in 1992-93 amounted to just over £504K. Through commercial activities this cost is largely defrayed and the Company is able to covenant a healthy profit on its activities (this year £380K) back to the University.

(b) Policy on IPR

2.7 The University is pro-active in implementing IPR protection via patenting or copyright, and exploitation.

2.8 The policy on IPR is that where intellectual property arises out of Research Council funded inventions UnivEd is the chosen mechanism, via the Kingman License, to exploit. Where other intellectual property arises, UnivEd arranges patenting (under the Red Star System) at no charge to the Academic(s), registering the Academic(s) as the inventor(s) who then assign to the University.

2.9 As explained earlier UnivEd's Contract Managers are responsible for trying to exploit the IPR, and revenue sharing arrangements (see attached) are in place.

2.10 Normally 10-15 patent applications are made each year, and UnivEd will attempt to license out within the 12 months initial protection period. If no licensee is forthcoming within 12 months UnivEd will either re-apply for an extension or will re-assign back to the Inventor. Given the considerable expense in prosecution of a patent (£8-£10K minimum) it would be impossible for the University to prosecute each of the 10-15 patents. UnivEd has on staff a patents expert who normally formulates the applications in collaboration with a patent agency, and a budget of £6K per annum is set aside for speculative patent applications.

2.11 Given the size and potential of an organisation such as Edinburgh (2,000 academics +) UnivEd has set up the system of local Faculty Managers and Stringers who concentrate on trawling for new marketable intellectual property within Departments. This is critical as academic staff are very often not aware that they have discovered anything which has a market value and which should be patented.

(c) R&D INCOME FROM INDUSTRY

2.12 The income statistics for R&D received have been compiled for the past five years as follows:

	Total R&D income £ million	UK industry £ million	Total Per cent	Overseas industry £ million	Total Per cent
1987-88	21.0	2.1	10.0	0.7	3.3
1988-89	25.2	2.7	10.7	0.7	2.8
1989-90	27.5	1.9	6.9	0.5	1.8
1990-91	38.6	2.8	7.3	1.3	3.4
1991-92	35.8	3.1	8.7	1.3	3.6

2.13 Income over the five year period for total R&D has increased by 70 per cent in total, whilst from UK industry the increase has been 48 per cent and for overseas industry the comparable figure is 86 per cent.

(d) INCOME FROM PATENTS

2.14 Figures for royalties are available from 1988-89 and are as follows:

Royalty Income Received by the University

	£'000
1988-89	585
1989-90	594
1990-91	594
1991-92	1,199
1992-93	3,516

2.15 This has primarily been derived from one major licensing arrangement with BIOGEN, a European based Biotechnology company, which markets a Hepatitis B vaccine developed by Edinburgh.

2.16 On average the University has made 10-15 patent applications per annum during the period 1985-92.

2.17 Arising from these patents at least five major products were exploited during 1983-92:
- Hepatitis B—see above.
- Porous Graphite Carbon—developed within the Department of Chemistry, licensed to Shandon Ltd.
- Fingerprint Algorithm—developed within the Department of Electrical Engineering, licensed to VVL Ltd.
- Poppet Valve—developed by the Department of Mechanical Engineering, licensed to Fenner Ltd.
- Tracker Device—developed by the Department of Medical Physics, licensed to Reynolds Medical Ltd.

(e) INTERACTION WITH INDUSTRY

2.18 Edinburgh is pro-active in seeking relationships with industry and has evolved an infrastructure to do so.

2.19 The initiation of relationships with industry occurs in many different ways:
- Academic publications which are noted by industry and followed up.
- Conference papers given by Academics whereby contact is established at these meetings.
- Marketing by UnivEd directly via mailings, followed by presentations.
- Appearance in the media of developments arising from University discoveries and inventions. These are normally initated by UnivEd.

2.20 Whilst the University has provided an infrastructure and a marketing budget for reaching industry there is very little comparable infrastructure by industry to contact the University.

2.21 The form of relationship with industry varies:
- Project work on a short term specific task often expressed as consultancy contract.
- Longer term commissioned work which may take the form of team building and project work related to basic research.
- Technology Transfer in the sense that the client commissions courses to train company employees in new technologies arising out of University discoveries and inventions.
- Ring-fenced partnerships where the client has specified that a specific group is tasked, often together with company employees, to undertake a mix of routine development work and research. Often these relationships are expressed as "Institutes" or "Centres". This type of relationship is highly valued at Edinburgh and a short example is given below of how it works and was initiated.

(f) The Fujisawa Institute of Neurosciences

2.22 In 1989, the University was approached by Fujisawa, a major Japanese Healthcare company interested in establishing collaborative links. UnivEd represented the University and involved the relevant academics in visits from the Japanese party.

2.23 Arising from the visit the University won a short-term contract (three years) to provide specific research services on a Fujisawa product. By 1991, the Company had sufficient confidence in the University to put forward plans for an "Institute" employing 16 research staff, located within the University. The key elements of this contract were as follows:

— The members of the Research team are a mix of Fujisawa and University staff, headed by a Director who is Professor of Neurosciences at Edinburgh. A small Board of senior Company and University staff meets annually to determine policy.
— The Institute is fully funded with all costs met and significant overheads for the University. Some of the overheads (35 per cent) trickle back to the Department of Pharmacology and are available for research activities.
— The staff have University contracts which allow them to teach or to research for up to 30 per cent of their working time. Where research is carried out by its staff during their "own" time they use Fujisawa facilities, with the Company having first option on any discovery which arises on commercial terms.
— The publications that arise are quickly scrutinised by the Company and they may, providing sufficient evidence is given, oppose immediate publication. However this is automatically appealed using a "scientific committee" set up with equal members of Fujisawa/Edinburgh staff. Thus far no publications have been turned down.
— Eventually the Company may wish to re-site the Institute at the University's Science Park.

2.24 A further Centre, set up in a very similar way has been in operation for three years for Syntex Pharmaceuticals, a US Healthcare Company, this has proved so satisfactory to the client, and to the University, that a further five year extension has been re-negotiated.

2.25 Unfortunately British industry appears to prefer to relate to universities on a project by project basis, projects normally being short term, and low risk in terms of finance. The US and Japanese companies are reaping significant rewards by following the above pattern, particularly gaining access to a very significant pool of background IPR established by Edinburgh over many decades of work in particular areas.

(g) Policy on Technology Transfer

2.26 Edinburgh's policy has been in place formally since 1969 when the forerunner of UnivEd (1.5(iv-vi)), CICL, was established with a full-time Director. Over the past 23 years the process of Technology Transfer has evolved from being re-active to pro-active (1.5(i-ii)). UnivEd now provides a "one stop shop" for industry requiring R&D, Training and Consultancy, with the latter two activities being used as part of the marketing strategy to attract industrial R&D projects. UnivEd equally provides support to academics in seeking funding and in pro-actively seeking partners for University initiated projects.

2.27 Despite the increasing load on staff referred to in 1.1-2, academic staff are generally keen to become involved with industrial projects, particularly where these are geared to exploitation of University ideas in the market-place.

(h) Summary

2.29 In summary, the University's unequivocal view is to encourage and welcome staff involvement with industry and its commitment to this is expressed in the systems which it has established to provide practical support for members of its staff with relevant ideas and for industrial/commercial companies requiring assistance in research and development.

Memorandum submitted by Professor Sir Richard Southwood, Vice-Chancellor, University of Oxford (30 July 1993)

I am now in a position to reply to your letter dated 30 April, in which you request details of this University's technology transfer activities and links with industry.

If I may, I should like to begin by addressing each of the Committee's specific questions before I turn to the broader topics of the University's links with industry and of how one attempts to balance academic demands with industrial demands within the university environment. First, as background information, the Committee may wish to know that the University of Oxford succeeded in academic year 1992-93 in securing over £63 million of research funding, approximately one-third of the University's total income for that year. Of that £63 million, £12 million (19 per cent) came from industry, which is playing an increasingly crucial role in maintaining Oxford's academic excellence and research-related activity in spite of the recession. The majority of the University's research and technology transfer activity is associated with departments in clinical medicine and the sciences.

What organisational arrangements . . . are in place to ensure that developments are disseminated to industries who may wish to use them, and to enable industry to make contact with researchers whose expertise may be of interest to them?

It is the University's policy to encourage and facilitate research with industry, and to promote the successful transfer and exploitation of its intellectual property. In the organisational structuring of its research support and technology transfer activities, Oxford has taken a two-pronged approach to ensure that companies are provided with adequate introductions to the University's research resources and that industry is made aware of technological developments of potential interest. This approach combines the activities of the following:

1. Oxford University Research Services

Central to the University's continuing success in attracting research income is the Research Services Office, the focal point within the University's central administrative structure for its research support, industrial liaison and technology transfer activities. Primarily responsible for all matters associated with external funding and intellectual property, the Research Services Office oversees the progression from research proposal at the application stage, to negotiation of the relevant terms and conditions governing the research, and finally to authorisation on behalf of the University of the research agreement itself. In negotiating the terms of research sponsored or commissioned by industry, the staff of the Research Services Office endeavour to ensure not only that the full costs of the research wil be met by the sponsor, but also that any intellectual property arising from the research will be satisfactorily safeguarded and exploited.

The main activities of the Research Services Office can be listed as follows:

(a) Scrutiny, negotiation and authorisation of research, consultancy and research-related service contracts.
(b) Provision of advice on the legal and financial aspects of research and on intellectual property matters.
(c) Promotion of links with industry and other organisations with interests in funding research at the University.
(d) Introductions for representatives of industry to relevant departments asnd individual researchers.
(e) Contract administration in respect of collaborative, applied or basic research projects research clubs and government-sponsored schemes.
(f) Formulation of new policies in regard to the University's intellectual property, costing and pricing of research, and other matters connected with research funding.
(g) Negotiation and authorisation of licence agreements.
(h) Production and dissemination of publications describing the University's research activities *(Oxford works with Industry, Directory of Scientific Research).*

The Director of Research Services reports directly to the Registar and enjoys a high degree of independence.

A flexible approach to relations with industry is the hallmark of the University's collaboration with a growing number of companies supporting research at Oxford. The scale of industrially-funded research varies, as do the methods by which the University exploits this research. Current arrangements for commercialising the University's research involve a wide range of links with industry such as collaborative research, contract research, basic research, consultancy, and the provision of services to industry. The Research Services Office also works closely with Isis Innovation Limited, a subsidiary company owned by the University (see below) and established to exploit the results of research funded by the research councils and other results where there are no pre-existing rights; together, Research Services and ISIS manage the licensing and patenting of intellectual property developed by the University's scientists.

The cost to the University's central administration budget of the Research Services Office, which comprises five full-time professional members of staff and nine full-time/part-time clerical employees, is £282,000 per annum. The figure given is for staff and non-staff costs (travel and telephone) for August 1992 to July 1993.

2. Isis Innovation Limited

Isis Innovation Limited, which is a wholly owned company of the University of Oxford, was formed in 1988 to exploit results arising out of research funded by the five research councils and those funded by other bodies which are not subject to an agreement with the University whereby the rights have to be assigned to the grantor. The function of the company is to ensure that the results of research bring reward to the University and to the inventors. Commercial exploitation is achieved through licensing or, in appropriate cases, by setting up a company dedicated to developing and marketing the technology. Isis has at its disposal a small pre-seedcorn fund for paying the costs of protecting intellectual property rights and for taking work to a stage where its potential can be assessed.

By December 1992, Isis was handling in excess of 60 pieces of intellectual property and 11 licences had been completed or were near completion. The Oxford Innovation Society, which was established to promote interest in the University's potential for technology transfer continues to earn income for Isis through the subscription of its members (Membership currently stands at 37; it is hoped that this number will increase to 50 in the near future.)

Isis Innovation was originally funded by loans from the University and from two commercial sponsors: Advent Limited, venture capitalists, and Cogent Limited, the technology transfer group wholly owned by the Legal and General Assurance Society. The amount which each sponsor gave to Isis each year was an equal share of the administration costs. At the end of the agreement between the three sponsors on 30 June 1991, the loans were assigned by the venture capitalists to the University; Isis repaid the loans by issuing share capital, increasing its issued capital from 100 £1 shares to 400,000 £1 shares. The University holds all but one of these shares.

The University of Oxford has agreed to grant Isis £20,000 per annum towards its running costs. Isis covenants all its taxable profits to the University, which for the year ended 31 March 1993 amounted to £15,000. The expected outcome of the year to 31 March 1994 is more optimistic as the taxable losses will be expunged and the covenant from Isis will be greater than the grant. This situation will continue into the foreseeable future, and hopefully beyond.

Isis Innovation has one full-time professional member of staff, and two clerical employees (one full-time and one part-time). Expenditure on staff and non-staff costs for the period April 1992 to March 1993 was approximately £150,221.

OTHER OXFORD-BASED TECHNOLOGY TRANSFER FACILITIES

Although the University does not own or run a science park itself, having in the past declined to be drawn into supporting any individual scheme, the University has always expressed its general support of science park developments in the Oxford area, as long as such schemes have received the full approval of the relevant planning authorities. Of the many technology transfer and business park facilities available in the Oxfordshire region, the University has established mutually beneficial relationships with, *inter alia*, the Oxford Science Park (developed by Magdalen College and the Prudential Assurance Company) and the Oxford Trust's STEP Centre.

Do you have a policy on IPR? What arrangements have you for ensuring that developments within the institution receive IPR protection, when appropriate?

Following the authorisation of the University by the research councils as the competent body to arrange for the exploitation of inventions arising out of research funded by the research councils, the University took the opportunity to review the policy on all forms of intellectual property. One object of the review was to produce a set of rules that would be as simple as possible within the restraints necessarily imposed by such a complex subject. In formulating this policy, the University was keen to provide a framework to encourage exploitation of potentially valuable research results by providing financial incentives for individuals and departments. The policy takes into account computer software and includes provision for the treatment of all intellectual property arising from research funded by the HEFC or by other University resources, and work sponsored by external organisations on terms which do not prescribe the treatment of any intellectual property arising.

The University's Intellectual Property Policy is as follows:

1. TYPES OF INTELLECTUAL PROPERTY COVERED BY THE POLICY

(a) Subject to paragraph (b) and unless otherwise agreed in writing, the University claims ownership of the following forms of intellectual property created by staff in the course of their employment by the University, by students in cases where intellectual property is developed with the aid of university facilities, whether on university premises or elsewhere, and by persons engaged by the University under contracts for services who work on research projects:
    (i) Patentable and non-patentable inventions.
    (ii) University commissioned works and works generated by the University's computers.
    (iii) Other computer software and firmware and related materials if they may reasonably be considered to possess commercial potential.
    (iv) Registered and unregistered designs and topographies.

(b) It is understood that few books produce royalties of more than £5K per annum (on average) and few produce significant royalties for more than five years. Since, therefore, University authors will rarely receive in excess of an aggregate of £25K (which under para 7 of the policy statement, is the first "ceiling" on royalties paid to inventors) it has been decided not to assert any possible ownership of copyright in books, articles, lectures or other written work other than that specially commissioned by the University, or in computer-related work other than that specified above.

In asserting its ownership of the intellectual property referred to in (a)(i)-(iv) above, the University does so for the purpose of ensuring the applicability of the intellectual property policy and in order to achieve the joint exploitation of the technology with the inventors.

In the policy statement that follows the term "intellectual property" refers only to the items detailed in (a)(i)-(iv) above and to any associated know-how and information. The term "researcher" refers to a member of staff, a student or other person of the kind described in the preamble to (a) above.

2. PROCEDURES

(a) Where a researcher creates intellectual property which, in his or her opinion, is capable of commercial exploitation, he or she shall report its existence to the head of department and to the University's Director of Research Services. The next step will depend upon the source of funding, as follows:

(i) Subject to the provisions of paragraph 2a(iii) below, Isis Innovation Limited ("Isis") is responsible for the exploitation of research funded with research council grants, the conditions of which do not require the assignment of intellectual property to industrial collaborators.

(ii) Whenever the conditions of research council grants do include such a requirement, and whenever there is a similar requirement in an agreement for research sponsored by some other party, the industrial collaborator or sponsor will be given the responsibility for exploitation.

(iii) In all other cases, the University's preferred route to exploitation is through Isis, but a researcher who wishes to exploit the intellectual property by some other means may do so, provided that permission is received from the General Board. Approval will only be granted if the alternative means of exploitation result in a reasonable return to the University from royalties or equity or other means of sharing profits that may accrue. Members of the University who wish to seek approval from the General Board are asked to contact the Director of Research Services in the first instance.

(b) Whenever exploitation is entrusted to Isis, the Managing Director of that company shall be consulted at an early stage.

(c) In the event of a disagreement concerning the ownership of the intellectual property, which cannot be resolved between the researcher and the University, the matter shall be referred to an independent expert to be agreed between the researcher and the University. If the identity is not so agreed within thirty days of a request by either of them to do so, the independent expert shall be a barrister specialising in intellectual property law, who shall be nominated for the purpose by the then Chairman of the General Council of the Bar. The expert's fee shall be paid by the University, but shall constitute a first charge on any profits which may accrue, whether to the researcher or to Isis or the University, whichever party or parties is or are held by the expert to be the owner of the intellectual property.

(d) Where it is decided to seek exploitation of intellectual property to which the University lays claim, discussions between interested parties will be held to determine the appropriate action to be taken. This may include one or more of the following:

(i) The retention of confidentiality and strict avoidance of prior disclosure.
(ii) The filing of a UK patent application in the name of Isis or the University, with the researcher as named inventor.
(ii) The indentification of potential licensees.
(iv) The assignment of rights to Isis and/or to a third party.
(v) The formation of a company to exploit technology.

(e) Notwithstanding the provisions of clause 2d(i) above, Isis and the University may consult on a confidential basis with appropriate experts in the field of the intellectual property in question in order to assist with the assessment of the degree of innovation and of the commercial potential.

(f) Where it is decided to seek exploitation, the researcher shall provide reasonable assistance in the exploitation process by, for example, promptly assigning his or her rights to Isis and/or a third party specified by the University, providing information promptly upon request, attending meetings with the potential licensees, and advising on further development.

(g) Revenue received by the University as a result of the exploitation of any item or intellectual property shall be distributed as follows:

(i) A first charge shall be any professional fees and expenses, and any other costs necessarily incurred in protecting the intellectual property and negotiating the arrangements for exploitation.

(ii) Thereafter, the following arrangements shall apply:

Total aggregate receipts to the University	Researcher(s) per cent	University per cent
Up to £25,000	100	0
From £25,000 and up to £250,000	50	50
From £250,000 and up to £2,500,000	25	75

If the aggregate receipts exceed £2.5 million, the distribution shall be subject to negotiation.

Monies received by the University will be divided equally between the department concerned and the University's central funds. In cases where Isis has been responsible for exploitation, the University's receipts will be net of the proportion of the total income which it has been laid down by agreement between the University and the sponsors of Isis should be received by the company.

(h) There may be instances, where development of the intellectual property has been assisted by a contribution from colleges' resources. In such cases, appropriate *ad hoc* ajdustments to the normal distribution pattern will be made by agreement between the University and the college.
The policy does not affect any right which colleges may have in terms of intellectual property generated by their employees in the course of their contractual college duties.

(i) Where more than one researcher is involved, the distribution of their share of the income between themselves shall be a matter for them to determine; save that where there is failure to agree, the distribution of income shall be prescribed by the Vice-Chancellor, taking into account each individual's contribution.

What is the total income your institution receives from industry each year? What proportion comes from UK-based companies and what comes from overseas? What proportion of your total research expenditure, including income from bodies such as the SERC, does this represent?

The figures given in the attachment to this letter are intended to provide an indication of the University's *research* income over the past six years. The table also shows the annual level of research income which the University receives from each research council. (Detailed figures for the whole of the past decade are, unfortunately, not available). The breakdown of costs, which shows an increase in total research income of £33 million over a six year period, includes funds received from industry, both British and overseas. However, these figures do not take into account funds received from industry through other means, such as consultancy and the provision of services to industry, the organisation of training courses or the endowment of posts at the University. With regard to the latter, Oxford has been fortunate in securing funds from industry to pay for a number of professorships. Although it currently costs in excess of £1 million to endow one such post in perpetuity, certain companies see advantages in establishing an enduring link and in associating their names with Oxford. The BP Professorship in Information Engineering and the Glaxo Professorship of Cellular Pathology are only two such examples.

The University of Oxford is also fortunate to have established long-term alliances with individual companies which, although they have supported research projects at Oxford for over a decade, have in recent years directed substantial resources into the development of new facilities in which to house the research activities which they fund and which are key to the development of new ideas and products.

The Oxford University SmithKline Beecham Centre for Applied Neuropsychobiology, for example, was established through funding from the company in 1989. SKB met the costs of refurbishment of premises directly beneath the department in the Radcliffe Infirmary (then under area health authority control), thus extending the existing accommodation by some 400 square metres. The University negotiated a lease for the new premises from the Oxfordshire Healthy Authority, since when the company has paid the rent and related premises expenses, together with the cost of repairs and maintenance. In return, SKB has the right to second three research staff to collaborate with University researchers in the Centre. The Professor of Clinical Pharmacology is the Honorary Director of the Centre, and all of the research is carried out under his overall direction and is subject to his approval (a good example, perhaps, of balancing academic and industrial needs).

SHOW INCOME FROM ROYALTIES SEPARATELY AND INDICATE WHAT PORTION OF THIS THROUGH BTG

Income received from royalties for 1991-92 is as follows:

University centrally	£154,837
Isis Innovation Limited*	£107,311
Total	£262,148

*figures for Isis are for the April 1992—March 1993 financial year

Unfortunately, the University's accounting system does not allow the separate identification of royalty revenue arising from technology exploited by the BTG, and royalty figures for the preceding years are not immediately available. (The latter are stored in an accounts form on microfiche and collation of the relevant information for the past ten years would require substantial staff resources.)

GIVE THE INCOME FROM PATENTS THAT YOUR INSTITUTION HAS RECEIVED EACH YEAR SINCE 1983. HOW MANY DEVELOPMENTS WERE PATENTED IN EACH OF THESE YEARS?

The University's present system does not allow us to identify patent income separately from general royalty income. All income from patents is included in the royalty figures shown above. Similarly, we are unable to supply an accurate answer to the question as to how many developments were patented in each year over the past ten years, since a great deal of this patenting activity takes place outside the University through the companies which support the research and through their patent agents.

How much interaction with industry takes place at the specific instigation of a company, how much is initiated by members of the University and how much arises from ongoing relationships with industry? What form do these relationships take?

It would be an impossible task to try to determine exactly how much of this University's interaction with industry is "university-driven" and how much is "industry driven". A number of research projects are funded by companies as the result of a formal application process following the announcement of a particular scheme (the Esso/Royal Academy of Engineering Teaching Fellowship programme, for example). Some collaborative research proposals arise out of University employees' performance of consultancy services for industry; a large proportion of research funding is derived from companies which have supported the development of their research interests at Oxford over a number of years and which have ongoing relationships with Oxford; an indeterminable number of links are forged as the result of informal meetings between individual academics and representatives of industry who happen upon each other at conferences of mutual interest.

Relationships between the University and industry take a number of different forms. The main types of academic/industry interaction at Oxford are listed below:

1. *Recruitment of graduates*

One of the University's primary roles is to educate and prepare young people for their future working life. Industry, along with professions such as law, medicine and accountancy, is one of this University's largest employers of graduates. Past national surveys showed that industry often puts access to well qualified potential employees as the highest priority in forging links with universities.

2. *Services and consultancy*

The provision of services and consultancy to industry is, for the University and its individual employees, the most lucrative type of collaboration.

Consultancies for individual members of staff need not necessarily arise out of research-related activities for a particular company, but they are often linked to a research project and, indeed, sometimes precede or result in the development of a joint research proposal. Services usually take the form of short-term, one-off tasks with a clear objective, such as the evaluation or testing of materials, or the interpretation of data.

The University permits the provision of services and consultancy to industry, but only subject to certain safeguards: consultancy arrangements are scrutinised carefully in advance to ensure that university facilities will not be misused or intellectual property rights transferred unnecessarily.

3. *Training*

Courses conducted at the University for employees of companies are increasingly common. Such courses may be aimed to bring industrial technical staff up-to-date on the latest technologies or to train middle-to-senior grade employees in management skills. Such courses can be as short as one day but usually last for two to three days and serve to initiate useful contacts between the University and the future managers of industry.

4. *Endowment of posts*

(I have already touched upon this subject in the previous section of this letter.)

5. *Research Sponsorship and Collaboration*

Not surprisingly, the University's most rewarding links with industry arise from research collaboration. Industrial research sponsorship at Oxford usually takes one of three basic forms, as follows:

(a) *Basic Research:* Industry will sometimes agree to fund basic research because the researcher has asked for funds in support of a specific project which he or she wishes to carry out, or because a company has a long-term interest in a particular programme of research and is prepared to sponsor the work over a period of time to see where it will lead. Companies pay for such research often in the interests of maintaining a link with a particular group.

(b) *Contract research:* Industry often commissions the University to carry out research which is directed towards its own interests rather than those of the academics. Such research has a precisely defined objective, and it is not always easy to distinguish between contract research and services to industry. (The latter tends to be more short-term, one-off tasks, whereas the former almost invariably calls for the application of the research group's existing knowledge or techniques.)

(c) *Collaborative research:* funded by industry, sometimes in conjunction with grants under DTI/research council schemes or with joint awards from some Government departments, collaborative research is carried out part in the University's laboratories and part on industry's own premises.

The University participates frequently in government-funded collaborative schemes with industry: CASE studentships have proven to be extremely popular and in many cases have provided valuable introductions to the University's research resources for small to medium-sized companies which otherwise might not have funds available to enter into full research collaborations; the Teaching Company Scheme has found particular favour in the University's Department of Engineering Science; and academics from Oxford are currently participating in some 20 LINK projects, with at least four more LINK proposals likely to be approved and to begin in the next 12 months.

What are your policies towards time spent on technology transfer activities? How effectively are these implemented?

The University has no fixed policy on time spent on technology transfer activities. Members of staff may hold consultancies or other outside appointments for up to 30 days a year (subject to the University's approval of the arrangements), but there is no restriction on time spend on R&D activities, as opposed to "pure" research.

All research-related activities which involve outside bodies are processed by the Research Services Office, and I believe that the University's policies relating to technology transfer matters are very well managed.

I should like to end this response, if I may, by answering the Committee's more general enquiry—how can a university balance effectively academic demands with industrial demands?—in the form of an example:

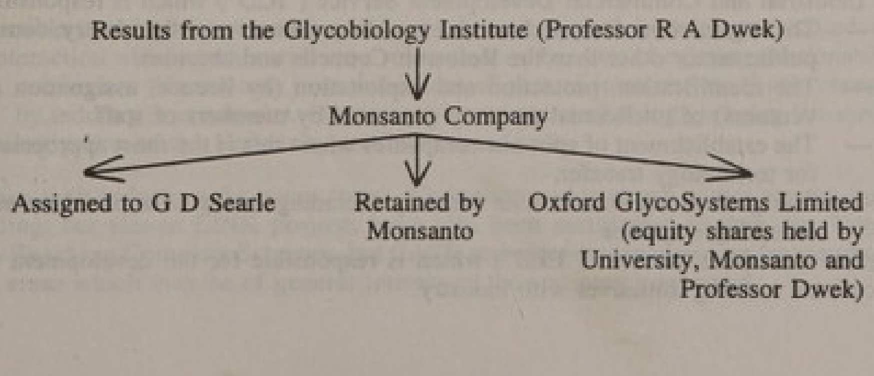
A collaborative relationship between the University and an American company, Monsanto, was formalised in 1984 through a basic research agreement to fund the work of Professor R A Dwek and his group in the field of oligosaccharides over a set term. The principles underlying this collaborative venture were not dissimilar to the terms of the Unviersity's standard research agreement at that time, whereby the University granted the company all rights to any invention arising from the research in exchange for royalty income, the rate of which would be negotiated on a case-by-case basis. (The University's present policy is to retain rights in intellectual property arising from research carried out by its employees and to grant to companies a royalty-paying licence to commercialise the results of the research.)

Since the research covered such a wide-ranging field, it was agreed that Monsanto (essentially an agrochemicals company) could assign certain relevant technology to its pharmaceutical subsidiary, G D Searle, without changing the terms of the original agreement. All intellectual property arising from the research was therefore assigned in the first instance to Monsanto, which would then assign appropriate technology to Searle. (Royalties would be paid to the University by Monsanto.)

During the first year of the research agreement, the possibility had been discussed of establishing an independent company for the purpose of exploiting the technology developed by Professor Dwek's research group which Monsanto had opted not to exploit. In 1987, however, after further injections of funds by both Monsanto and Searle, all parties agreed that the equipment designed and developed during the course of Professor Dwek's research had become a selling point in itself. Monsanto, in co-operation with the University and Professor Dwek, subsequently founded a new company, Oxford GlycoSystems Limited, with the aid of venture capital; Oxford GlycoSystems not only manufactures the equipment for research laboratories such as Professor Dwek's, but also provides related laboratory services and technical advice.

The establishment of Oxford GlycoSystems not only added a further dimension to the collaboration, but also gave the University an opportunity to make its first major investment in a commercial operation. Both Monsanto and the University hold equity in Oxford GlycoSystems, and the University recently elected to reinvest in the company in order to retain its equity shares.

In summary, arrangements for the exploitation of technology arising out of Professor Dwek's research group were as follows: all results went initially to Monsanto; if the research was pharmaceutical-related, Monsanto assigns to Searle; if the results were not pharmaceutical-related and were of no interest to Monsanto, they were passed to Oxford GlycoSystems Limited.



The success of Oxford Glycosystems is by no means limited to its commercial activity, for the company has also yielded significant discoveries in glycotechnology and related areas. Twenty-seven patents have been registered thus far, two of the more notable inventions being a drug to combat rheumatoid arthritis and an AIDS treatment.

Monsanto's total funding of basic research in Professor Dwek's laboratory reached some £10 million over seven years: a long period, for a company to retain its interests in a research programme which offers no guarantee of results or commercial success. Moreover, a further donation of £3 million for new laboratories for Professor Dwek's research group—the Glycobiology Institute—provided Searle with its own direct link to the University.

More recently, Monsanto has been forced by the effects of the recession to end its long-term commitment to research into oligosaccharides, but in doing so it provided the University with investment funding for the future: a lump sum endowment of US$10 million for the University to spend on research into glycobiology (a term coined by Professor Dwek and now cited in the *Oxford English Dictionary*).

The above example, I think, serves as an excellent illustration of the development of a symbiotic relationship between industry and academia, each party having preserved its own interests and reaped benefits from the results of the collaboration. I should hasten to say that it is merely one of a number of examples I could have selected, and indeed if the Committee would find it useful to collect further examples of successful academic/industrial collaborations at Oxford, the University would be pleased to provide more evidence. It is difficult to paint a complete picture of the University's activities in this regard in a relatively brief response, but the Committee may find it helpful to contact the Director or our Research Services Office for further details.

As science and technology become more sophisticated, and as collaborative—sometimes interdisciplinary—solutions to problems are needed, so too companies and universities must adopt imaginative policies which will establish frameworks for successful research. In the light of cuts in Government spending on research in universities, the University of Oxford has recognised that if its research infrastructure is to be sustained and improved well into the next century, it must work hard not only to preserve its present links with industry and continue to forge new relationships with companies, but also to foster innovative ideas for creative forms of research collaboration.

Research Grant and Contract Income

	1986-87 £ million	1987-88 £ million	1988-89 £ million	1989-90 £ million	1990-91 £ million	1991-92 £ million
Research Councils						
AFRC	0.25	0.23	0.28	0.59	0.88	1.1
ESRC	0.63	0.75	0.93	0.85	1.1	1.2
MRC	5.13	5.80	6.94	7.1	8.3	9.3
NERC	0.39	0.45	0.42	0.71	1.2	1.3
SERC	7.77	7.76	8.70	9.3	10.3	10.1
	14.2	15	17.3	18.5	21.7	23
Government Departments	3.7	4.1	4.8	4	4.9	6
British Industry	2.0	2.3	3.3	3	3.5	4.5
Overseas Industry	1.2	2.49	10.12	4	6	7.4
European Commission	0.4	0.3	0.4	1.39	1.6	2
Charities, Foundations and Trusts	7.5	8.1	11	14	16	18
Other	0.7	0.8	1.1	4.2	3.3	2
Total	30	33	48	49	57	63

Memorandum submitted by the University of Glasgow (5 August 1993)

1. ORGANISATIONAL ARRANGEMENTS

1.1 The University's principal interface with industry are:

(i) The Industrial and Commercial Development Service ("ICD") which is responsible for:

— The negotiation of research contracts and consultancies with industry, commerce and the public sector other than the Research Councils and charities.

— The identification, protection and exploitation (by licence, assignation or other joint ventures) of intellectual property generated by members of staff.

— The establishment of spin-out companies where this is the most appropriate mechanism for technology transfer.

— The general interaction with industry including acting as a one-door entry point for incoming enquiries.

(ii) External Education Services ("EES") which is responsible for the development of vocational educational training initiatives with industry.

1.2 The University manages the West of Scotland Science Park jointly with the University of Strathclyde and the Glasgow Development Agency.

The University has established a commercial floor in its recently opened Robertson Institute of Biotechnology. This floor is designated for use by incubator and University spin out projects in the field of biotechnology.

1.3 A number of market-specific projects involving collaboration with other agencies, (including the Glasgow Development Agency and other LECs) are currently in place or at the planning stage.

An illustration of such mechanisms is *Services to Software Limited,* a company formed by the Glasgow Development Agency in partnership with the University of Glasgow, Glasgow Caledonian University and National Engineering Laboratory, with the objective of providing software consultancy services to SMEs in the Strathclyde Region.

1.4 The University's investment in ICD, EES and in support of specific projects is in the region of £450K p.a.

2. Policy on IPR

The University Court has formally approved a Policy Statement on Intellectual Property, and a copy of this Statement is attached. The Policy Statement on IPR has been circulated to all members of academic staff. As employer, the University is the owner of all IPR developed by members of staff during the course of their employment with the University, and staff are reminded that any proposal involving commercial exploitation of such IPR requires the approval of the University Court. In practice, the power to grant such approval has been delegated to the Secretary of the University Court, who is advised in these matters by the University's Industrial and Commercial Development Service. In the event of IPR being successfully exploited, any revenues received by the University are distributed (after deduction of any patent and legal costs incurred by the University) on the following basis:

50 per cent to the inventor(s)
25 per cent to the inventors(s) department(s)
25 per cent to central University funds

Members of staff are advised that where they consider an opportunity to exploit IPR may exist, they should consult ICD at the earliest opportunity. This usually involves an initial discussion with either the Director of ICD or the Intellectual Property Manager, at which close attention is paid to such matters as the state of technical development, the protectability of the IPR, the commercial potential of the proposal, and possible routes for exploitation. In technical matters, ICD will generally rely on informal peer review, but may also use external consultants in some cases. ICD also has long standing contacts with BTG and with local development agencies who give valuable assistance in protecting and commercialising IPR.

If a proposal is considered to be commercially attractive, then patent protection will frequently require careful consideration. ICD has an annual patent budget and will normally take out a UK patent application in the first instance. However, most ideas and inventions require further development before they can be commercially exploited. Sometimes this can be supported internally, but more usually a commercial sponsor will be identified and contacted. The invention is discussed under a confidentiallity agreement and development funding is sought, ideally with the University retaining ownership of the IPR but the sponsor acquiring a first option to exploit. Commercialising a new technology requires the full co-operation of the academic concerned who will be involved in all-important decisions. Particular regard is paid to protecting academic publication rights.

3. Income statistics

A summary of the University's total royalty income and income from patents is attached, together with details of the number of developments patented each year. No figures for royalty or patent income prior to 1987-88 are available. No royalty or patent income was received from BTG. A further summary of total income from industry is also attached.

4. Relationships with industry

It is not possible to categorise research quantitatively according to how it was initiated. Our assessment is that most interaction with industry arises at a research level because of existing relationships and informal contacts, e.g., conference discussions, joint awareness of mutual interests, etc. Little research arises from "cold calling" by industry or academics. However, where a new technology is being licensed, this is almost always at the instigation of the University and/or the academic.

Relationships with industry take many forms. Commissioned research comprises the bulk of industrial research funding, but eleven LINK projects have also been established to date. the University has had relatively few Teaching Company Schemes, but CASE and other studentships are frequently used to support research into areas which may be of general interest of the company concerned.

5. The University encourages staff to undertake projects and other activities which may lead to the transfer of technology to industry. The University Court has approved a number of projects involving members of staff spending time in, or having a shareholding or a directorship in, spin-out companies.

The University Staffing Committee, on a regular basis, authorises members of staff to undertake consultancies on behalf of industrial companies. In general terms, members of staff are encouraged to undertake outside consultancies up to a limit of around 30 days per annum. However, the move towards increasingly performance-related funding of research, in which the weighting has historically been heavily biased towards publication and academic research, does cause some tensions in the system. It is to be hoped that the implementation of the White Paper proposals will result in greater recognition of, and therefore freedom to undertake, commercial research.

We believe the policies in general operate in an effective way. However, we recognise that technology transfer activities and the exploitation of research are areas that raise complex questions and may generate pressures arising from conflicts of interest and other issues. It is therefore important that the need to be flexible and imaginative is tempered by the fundamental requirement to ensure that the University's primary objectives of teaching and research are not prejudiced.

Licence Income and Patent Activity

Year Ended July	Licence Income by Type (£k)			Licence Income by Source (£k)		Developments Patented[1]
	Patent	Other	Total	UK	Overseas	
1984						5
1985	(INFORMATION NOT AVAILABLE FOR THESE YEARS)					4
1986						3
1987						3
1988	21	22	43	22	21	3
1989	37	109	146	48	98	4
1990	48	137	185	65	120	4
1991	25	133	158	51	107	4
1992	44	187	231	58	173	8

[1]Refers to individual developments. A number of patents may be filed in respect of each development.

Total Income from Industry

Year Ended July	Income from Industry £k	Per cent of Total Research Income
1984	2,482	29
1985	2,403	29
1986	3,684	34
1987	6,077	46
1988	7,107	42
1989	11,055	47
1990	13,367	47
1991	14,966	44
1992	15,687	45

Notes:
1. For the purposes of this table, "Income from Industry" has been taken as "CR Income" as included in the Form 3 return of University stastistics. This includes income from other sources such as Government Departments, Local Authorities, etc.
2. An exact calculation of the percentage of income from industry from UK based companeis has not been possible for all years reported on. The figure of the year ended July 1992 is aproximately 35 per cent.

Memorandum submitted by Aston University (11 August 1993)

In response to your letter of 6 May 1993 we offer you, somewhat belatedly, the following information:

1. ORGANISATIONAL ARRANGEMENTS

The University has non-executive agreements for the exploitation of inventions with:
British Technology Group,
3i Research Exploitation Ltd, and
Cancer Research Campaign Technology Ltd

In some cases, the University also collaborates directly with industrial or commercial organisations to facilitate the exploitation of inventions or computer software.

To further this process, on a number of occasions the University has arranged for members of BTG to address groups of staff; in November 1991, it organised an Open Day for industry/commerce to meet members of staff and discuss the potential of their research work. More locally, we have close links with the Aston Science Park which was promoted by the University in the early-1980s, and the West Midlands Technology Transfer Centre Ltd which was established as a joint venture between the West Midlands Enterprise Board and Aston University to facilitate the transfer of technology to local industry.

2. INTELLECTUAL PROPERTY RIGHTS POLICY

Two policy documents on this subject are enclosed (Appendices 1 and 2). We have a member of staff who is available as a contact point regarding IPR protection.

3. INCOME FROM INDUSTRY

See enclosed schedule (Appendix 3).

4. INCOME FROM AND NUMBER OF PATENTS

See enclosed schedule (Appendix 4). The 1992 royalty income as a proportion of our total research expenditure is 4 per cent.

5. INTERACTION WITH INDUSTRY

Whilst there is some variation among departments, we estimate from a recent survey that 40 per cent of our interaction with industry was initiated from outside, 40 per cent was the result of ongoing relationships, and 20 per cent was initiated by the University.

A breakdown of our 1992 industrial collaboration is as follows:

	United Kingdom £	Overseas £
Commissioned Research	174,452	115,113
CASE	115.799	—
Per Appendix 3	290,251	115,115
Teaching Company Schemes (Industrial Contribution)	41,072	—
LINK (DTI contribution)	24,097	—
	355,420	115,113

In addition, we offer a range of short, video-based distance learning courses through our Continuing Education Unit. These are aimed at improving industry's awareness of new developments in science and technology. Industrial placement of students also helps stimulate the interaction between the university and industry. Many of the facilities of our Library and Information Services are available to industrial users. They are exploited particularly by the companies in the Aston Science Park.

6. TECHNOLOGY TRANSFER

Staff are encouraged to spend time facilitating technology transfer (see policy document on the distribution of royalty income, Appendix 2).

APPENDIX 1

GUIDELINES ON INTELLECTUAL PROPERTY RIGHTS AND THE EXPLOITATION OF SPONSORED RESEARCH

UNIVERSITY FUNCTIONS

Before getting down to the specific points at issue, it is as well to return to first principles and remind ourselves of the primary functions of universities. They are the

Generation	(=research)
Marshalling	(=scholarship)
Transmission	(=teaching), and
Application of knowledge	(=services)

The last category may include, for example, clinical work forming part of degree programmes, consulting by academic staff, and provision of testing services by technicians.

UNIVERSITY TASKS

In relation to their several functions, universities carry out certain tasks; in particular, to provide the external world with a flow of educated men and women. They offer a first "apprenticeship" (typically at the BSc/BA level), in which students learn some useful facts, and some relevant techniques for their manipulation, within the context of a specified discipline; students also learn the more important and longer-lasting elements of communication, and of learning to learn.

A second "apprenticeship" is offered at a higher level (typically that of MPhil/PhD), on which new knowledge, or new patterns of knowledge, are generated through research and scholarship. Between these levels, stand MSc/MBA/Postexperience offerings, whose aim is to broaden and deepen knowledge, and possibly to introduce the student to research and scholarship.

It is worth noting, in passing, that a technological university does not differ from other universities on these fundamental functions and tasks, but in its choice of disciplines, all of which should have evident application in the world outside.

UNIVERSITY FREEDOMS:

The conduct of university affairs is characterised by two cherished freedoms:

Choice of Direction (in teaching, scholarship and research).

Dissemination of Ideas (through discussion and publication).

These freedoms are, of course, always limited by internal and external resource constraints (time, space, staffing, facilities, etc.), and moral considerations (human subjects, overriding national concerns, etc.). The extent to which Society is willing to support them is determined by the benefit it believes that it derives from the universities. Within the universities, such freedoms facilitate the education of their clientele, and the scholarship and research processes which are advanced within the wider "Invisible College". Recognition of university achievements, through free dissemination of ideas, maintains and strengthens their sponsorship base.

EXPLOITATION OF IDEAS:

With these generalities in mind, we may approach the question of commercial exploitation of ideas generated within universities. Three obvious options are:

Initiate and conduct the process within the university, or in a subsidiary company.

Participate in the exploitation process with an external sponsor.

Promote the exploitation process by communicating ideas to close affiliates, or through consulting.

Tension between sponsors and universities can arise because the universities receive their main support from a broad sponsorship base, whereas individual sponsors seek individual benefits. A variety of problems can be recognised:

(1) The time-scale on which external sponsors seek results may conflict with the academic pace set by research and teaching obligations for staff, in an environment where students are learners and therefore slower than experienced professionals.

(2) The directions of development of research may be constrained by the sponsor's preference for a speedy working solution, rather than the academic researcher's preference for the most general, or most elegant solution, or for the most effective contribution to development of the relevant discipline. (It is to be regretted, too, if sponsors view the university as a low-overhead job shop!)

(3) Early profits for the sponsor may depend on patents, and secrecy about objectives and results. Sponsorship may then be offered on conditions inimical to the two freedoms mentioned above: choice of direction and dissemination of ideas.

The University can gain little prestige, or sponsorship within its wider community, if it allows substantial portions of its operations to be effectively purchased and silenced by external sponsors. HEFC research selectivity exercises, for example, can hardly take them into account.

SOME SOLUTIONS

The dangers can be recognised, and generally become more acute as the time-scales on which sponsors wish to operate shorten. Strategic research is probably five to 10 years from exploitation; applied research, five or less. If the "good" money (Research Councils, etc.) is not to be driven out by the "bad" (sponsors seeking to impose powerful constraints and secrecy), then mechanisms such as Science Parks. Technology Transfer Companies, and personal consulting, should be used to respond (if at all) to short-term needs of sponsors. The basic University functions should never be forgotten: universities are not supported by Society to do the work of industry and commerce, but to supply the graduates and knowledge with which that work can be tackled.

A realistic position for universities is, first, that they should have control over decisions on whether work should be published or not. It is reasonable, however, that sponsors should have advance sight of manuscripts, and have the opportunity of commenting on them, particularly if privileged company information is involved in the project. One month would be an appropriate period for this process.

Second, universities should retain intellectual property rights. It is reasonable that the sponsor should be given the first opportunity for exploitation and, if patents are involved, a reasonable time before publication (up to one year, say) to preserve those patent rights. To avoid subsequent disputes, it is important that such issues, and the division of potential profits and costs between the universities and their sponsors, should be negotiated formally at the inception of the work.

OVERHEADS

This question must be tackled in a financially sound manner within HEFC funding conditions. If a sponsor requests decision-making power over publication, or exploitation rights over the ideas generated, then at least full overheads should be charged: academic time and effort is being taken out of the University's normal mode of operation. The payment made by the sponsor should therefore cover replacement time and effort from other academic staff, elements for space and equipment used, and an element of profit for the University.

It should also be remembered that, if a sponsor is gaining a competitive advantage through a University-based project, its competitors will be legitimately aggrieved if general University funds, to which they have contributed indirectly, are being used to subsidise the work.

That sponsors should not expect control over exploitation or publication unless they have paid at least the full costs involved is still not an entirely satisfactory position. If this arrangement is accepted within the University, rather than in a subsidiary company set up for that purpose, such sponsorship erects a highly undesirable communication barrier between the students and staff concerned and the rest of the University. Such barriers often engender heated debate in universities when research with military implications is involved. The principle is the same, however, whatever the topic, and whatever the perceived applications.

PATENTABLE INVENTIONS

Inventors are encouraged to take the initiative in the identification and exploitation of discoveries and ensure that patent applications are filed before the invention becomes publicly known when the right to file is lost.

All patentable inventions, other than those arising from sponsored work for which a separate agreement with the sponsor has been made, are the property of the University. They will usually be forwarded to British Technology Group or Research Corporation Ltd to determine whether or not a patent application should be made or the invention exploited. In the event of these organisations declining, or taking out a patent and subsequently wishing to relinquish their responsibilities and rights, the University would normally assign its rights and responsibilities in relation to the patent to the inventor, if requested to do so.

Alternatively, members of staff may propose different patent arrangements. They may if they wish, pursue exploitation themselves (subject to satisfactory arrangements for the University to receive a share in royalties). Where arrangements do not involve British Technology Group or Research Corporation Ltd it is desirable that any organisation with which an agreement for exploitation is to be made is a UK organisation and the benefit to the University should not be less than that offered by the above organisations.

Only in very exceptional circumstances will the University consider making a financial contribution to the costs associated with the patent application, and in such cases, the University would take a higher proportion of the patent revenue than under other arrangements.

In negotiations with external funding bodies, the University should attempt to obtain an agreement on patents similar to the type of arrangement that is normally reached with organisations referred to above, i.e., that gross benefits, less agreed expenses, be shared on a fair and reasonable basis between the external body and the University. This should however, be a matter for negotiation between the member of staff, the Director of Finance and the external body and should be pursued to the extent that potential sponsors are deterred. Any such negotiations should take into account the level of overheads being paid by the sponsoring body.

Any benefits that arise from a patentable invention will be apportioned between the inventor and the University in accordance with the following sliding scale which is reviewed at the beginning of each University financial year in accordance with the movement of the Retail Price Index.

	Inventor Per cent	University Per cent
On the first £3,600 of annual income	100	0
On the next £3,600 of annual income	80	20
On the next £3,600 of annual income	70	30
On the next £7,200 of annual income	60	40
On the remainder of annual income	50	50

A student who is the sole inventor of a patentable invention should be given the option of either being treated the same way as a member of staff, outlined above, or in proceeding to obtain a provisional patent in their own right. The University will not be obliged to assist either financially or otherwise a student who wishes to take the latter course of action.

A student who is a co-inventor of a patentable invention with a member of staff will be required to accept the conditions applying to members of staff, since a co-inventor may not unilaterally apply for a patent for, or exploit, an invention with which they have been involved.

Investors will share any income on an equal basis unless they agree otherwise.

APPENDIX 3

Year	Total income £	Income from industry UK £	Overseas £	Proportion from UK Per cent	Overseas per cent	As a percentage of total income UK Per cent	Overseas Per cent
1991-92	3,106,664	290,251	115,113	72	28	9	4
1990-91	3,041,660	322,085	56,209	85	15	11	2
1989-90	2,964,065	322,138	38,580	89	11	11	1
1988-89	2,920,112	312,434	24,686	93	7	11	1
1987-88	2,892,305	223,038	31,088	88	12	8	1
1986-87	2,874,062	348,364	48,892	88	12	12	2
1985-86	2,754,912	341,468	38,361	90	10	12	1
1984-85	2,617,653	331,975	37,902	90	10	13	1
1983-84	2,590,626	452,154	90,132	83	17	17	3
1982-83	2,462,533	413,815	70,808	85	15	17	3

ASTON UNIVERSITY

Income from royalties

		Total £	From BTG £	From UK companies £	From overseas companies £
1992	3i Research	19,250	—	—	19,250
	BTG	75	75	—	—
	Cancer Research Campaign Technology Ltd	112,285	—	—	112,285
		131,610	75	—	131,535
1991	3i Research	10,000	—	—	10,000
	BTG	170	170	—	—
		10,170	170	—	10,000
1990	BTG	137	137	—	—
1989		nil	—	—	—
1988	BTG	92	92	—	—
1983-87		nil	—	—	—

Number of Patents	
1992	nil
1991	2
1990	1
1989	10
1988	4
1987	5
1986	5
1985	4
1984	8
1983	13

Memorandum submitted by the Institution of Civil Engineers (28 May 1993)

This Institution has been promoting the need for greater investment in research and development, by both government and industry, for a considerable time. In this regard, we have published several reports in the past decade and I enclose the most recent: "A National Agenda for Long-term and Fundamental Research".

I enclose a copy of our submission to the Office of Science and Technology,[1] a copy of a press release concerning the recent White Paper, some copies of our research newsletter "Research Focus"[2] and I also offer the following observations for your inquiry:

[1]Published in HC (1992-93) 228-II.
[2]Not printed.

(i) PUBLIC FUNDING

As a generality, basic or fundamental research should be funded by government and near market research by industry. There is also a strong case for Government participation in long-term R&D. There is a stronger case for government assistance with R&D in the Construction Industry than in more scientific sectors of the economy due to the fragmented nature of the industry and the impracticality of patenting most construction developments. Further there is direct benefit to the whole country through such factors as housing stock improvements.

It is essential that productivity in the Construction Industry is increased as it is below that in mainland Europe, the USA and Japan. Two major causes of this are outside the control of individual companies in the Industry, namely, the adversarial structure and working practices which are encouraged by some forms of government contract, and trade demarcation. There is a strong case for government assistance both in relevant R&D and encouraging improved practice.

(ii) ORGANISATIONS OF THE UK SCIENCE BASE

The Government should encourage team research and collaboration between research associations, higher education establishments and industry. Long term commitments to the funding of centralised facilities should be avoided. It is preferable to "pump prime" areas of need and let them expand or contract in sympathy with market forces.

(iii) FUNDING OF THE UK SCIENCE BASE

Too much of the funds presently available are precommitted to long term work at interdisciplinary centres leaving inadequate amounts to fund good new research which is proposed annually. Some subjects, such as nuclear physics, have had and continue to have a disproportionate slice of the cake. Such a change of policy could lead to the demise of some existing laboratories but this may have to be accepted, they must not be subsidised just because of their long standing.

Both directed and responsive research are important and often there is a need to strengthen some areas of responsive work thus making them directed. Perhaps 70:30 is a reasonable balance but we do not really feel competent to advise on this balance.

(iv) HIGH COST RESEARCH

As the UK is no longer high in the league of industrial nations, it should be selective in its support of high cost research. There should be a continued shift of emphasis away from Space/Astronomy/Physics to Engineering R&D where direct benefits more quickly accrue to the nation. If our engineering industries continue the present decline we will not be able to support any research.

Medium size facilities are useful in achieving co-ordination of effort and are capable of liaising internationally.

(v) CAREER STRUCTURE

Research is no longer attractive to Civil engineering graduates and an ICE survey in 1989 revealed that there is likely to be a staffing crisis in British Universities in the mid-1990s. Salaries for researchers and assistants are far from sufficient.

(vi) THE EUROPEAN DIMENSION

We should make maximum use of the opportunities presented by EC research funding and in particular co-operation between member states. The UK should take the initiative wherever possible and not just trail along. To achieve this the Treasury attitude needs to be changed, EC funds should not always be viewed as an alternative to national funds but as extra funds. We do badly in our take up of the EC opportunity compared to some other member states due to lack of home financial support.

(vii) NATIONAL/MULTINATIONAL BALANCE

The criteria for determining this balance should be the benefit of UK Ltd and to the global environment, not just on the benefit to the science base.

(viii) TOTAL VOLUME OF RESEARCH ACTIVITY

The total volume to UK civil research must be enhanced if we are to compete internationally and at home with Japan, the USA and other member states of the EC. There should be some selectivity in this with support concentrated in industries which are or can be competitive. In this respect, the construction industry has done well abroad and should be supported.

A larger proportion of the military R&D budget should be transferred into the civil sector.

(ix) Dissemination

It is a matter of concern to the Institution that research results are used by the practising engineering community and you may be interested to learn that since 1990 the Institution has published a newsletter called "Research Focus", which is circulated to 80,000 practising engineers in the UK and worldwide each quarter. It is believed to be the largest circulation of a research newsletter in the world and has proven to be a highly effective mechanism for disseminating news of research to practitioners.

Memorandum submitted by David Inwood MA (Cantab) Inwood Ryan Limited (10 June 1993)

This submission broadly addresses the questions raised in press notice 9 of session 1992-93—"inquiry into innovative and competitive technology". The response is structured as a number of points that should be read as a whole—they are not intended to address the individual questions separately.

1. Our experience confirms that science and technology are important sources of competitive advantage. However, innovation is the *exploitation of invention or change*, and a host of management disciplines (including marketing) *must* be in place, and practised effectively, to permit successful commercial exploitation of technology. It is these disciplines that are the major barrier to exploitation, not the availability of technology *per se*.

2. Effective commercialisation of science and technology requires multi-disciplinary skills that cross-over traditional British education and training boundaries, as well as recognised professional disciplines. In spite of this, education seems to be producing people with increasingly more specialised and narrow knowledge. As evidence of this, graduate applications to this company over the last six years show an entrenched educational and training background of narrow expertise and limited flexibility. The professional bodies (and other institutions such as the Design Council) reinforce this by further compartmentalising the necessary skills.

3. In particular, there is insufficient understanding amongst scientists, technologists and designers about marketing issues, and amongst marketing people about technology issues. There is little understanding in *either* group about the commercial issues surrounding the development and effective exploitation of new products. Indeed there seems to be little attention paid to the fact that it is only when *products* are developed that any science or technology can be commercialised.

4. However, the management techniques needed to guide the market-focused exploitation of technology are well understood in certain quarters. In our experience these are much less well understood (or believed in) by British owned and managed small to medium sized technology based companies—normally acknowledged to the source of Britain's future wealth. This company has been consulting in these techniques for six years with noticeable market successes—however the large majority of our turnover has been with foreign owned clients. We have found it extremely hard to persuade UK companies (with a few notable exceptions) that these techniques are worth investing in. To help rectify this, we have written a book (just published by Kogan Page) that brings together the different skills in a practical guide to how the techniques can be implemented. We are told that this is the first book to do this.

5. We have come to the conclusion that the DTI's assistance to industry in this area is badly focused. Its two main thrusts at the M90s programme and the Enterprise Initiative. The former is very strong on exhortation and provides no practical help. The latter actually encourages companies to view new business development as split into different disciplines. In our experience, managers need practical training and guidance from experts, not just pious words from the DTI or other industrialists. We have attended DTI M90s events and spent time talking to delegates who confirm this view.

6. The Enterprise Initiative exists to provide expert help for companies—but this is not aimed at quickening the pace of adopting effective product development management practices. Even if this were done, help should be made contingent upon grasping all the issues in effective technology development and exploitation. E.g., funding for any technical help should only be allowed if the marketing and commercial issues have been clearly addressed.

7. We believe there is a real conflict between the right-handed approach to business (i.e., creating value, looking forward to long term market share) needed to exploit technology, and the left-handed approach more typical in British Industry (i.e., concentrating on controlling costs and generating short-term profits). Companies *and* nations need to be able to take a longer term view, and it is interesting to note that British companies main objectives are normally focused on profitability, (i.e., left handed), whereas the Japanese focus more typically on long term market share (i.e., right handed).

8. All the evidence suggest that the real, useful measures for success should be based on:
— Time to market.
— Long term market share.
— Added value (after all development costs).
— Proportion of business coming from new products.

9. It is clear that the UK needs a centre of excellence and reference point for product development management. The Design Council claims to be this, but fails because (a) it is too "design" oriented and does not cover management techniques at all well, (b) it does not have a good grasp of marketing and other management issues, and (c) there is a mismatch between how it sees itself and how industry perceives it regarding its expertise in managing product development. It also contributes to the confusion of terminology —in particular the confusion between "design" and "product development", trivialising the scope and complexity of the latter.

It is unclear how such a body should come into existence, but the future for "New Product Introduction" (NPI) clubs based on Cambridge University Department of Engineering's experience is worth exploring. So far this is limited to a small number of local SMEs who meet to share experiences, but it is hoped it will expand outward to embrace a larger number and variety of different industries. With the right support, these could evolve into centres of excellence, training resources, or even a new professional body. However, it is vital that they attract small and medium sized business, and are not limited to an exclusive club of large companies as suggested recently by the DTI.

10. We have a British Standard that claims to show how to manage product development (BS 7000, Guide to Managing Product Design), but it contains nothing of substance about the marketing issues or how to manage the process of adding value through technology. If it is worth having a standard at all, surely it should embrace all the accepted practices of cross-functional product development (especially the marketing and commercial issues) with as much detail as is given to managing the design process?

Memorandum submitted by Professor R Needham, Computer Laboratory, University of Cambridge (13 June 1993)

I have been Head of the Computer Laboratory since 1980 and have extensive experience of the interaction of research with industry starting long before that.

I believe that much of UK industry has a basically inappropriate approach to research and its exploitation. The products of the research carried out in a Department such as this are two-fold—people as well as ideas. We may produce new knowledge or proofs of concept—remember that Computer Science is an engineering subject and showing that apparently far-out ideas are actually feasible is an important aspect of our research. We do research, often in collaboration with industry, at all levels—basic, strategic, and applied. We regularly produce people with doctoral degrees who are at the forefront of research in their subjects and have shown a high degree of personal initiative and independence. If we define UK industry as being industry in UK ownership, then the UK industry is largely unresponsive to our efforts in both respects.

If it were the case that no industry cared about what we do, I would be more likely to look into our behaviour to find out what we do wrong. However, non-UK companies do pay attention to us, and these companies are not tiny or unprofitable. I cannot recall the last time a UK company got in touch with me and said "who are the really smart students you are turning out this year?", referring to prospective Ph.D. graduates. But yesterday and the day before we had an internationally well-known man here from AT&T. His mission was to persuade our Ph.D. students that they should put AT&T on the list of places they would consider for employment after graduation. He was concerned that this was not automatically the case whereas some of their competitors were, so to speak, on the circuit. His main purpose was to talk to the students as individuals—not to sell a proposition to me. Every year I am approached by other US companies who want to know who we have coming on stream that they should go after. I am simply not prepared to believe that the skill and experience our students have are irrelevant to the needs of industry.

Most of our PhD graduates want an industrial career, not an academic one. The only major industrial research laboratories in the UK I would recommend to a real high flyer in computer technology are Olivetti and Hewlett-Packard, which are not, of course, UK companies.

When it comes to exploitation of results, the situation is not much better. An extreme but nevertheless genuine case is as follows. A man came to us as a research student after working for GEC for ten years. In the course of his PhD work he took out a patent on an invention and he talked to BT and GEC about it. They were polite but uninterested although the subject matter was very relevant to their businesses. He published a paper in an international journal, sold his patent to a California startup, and is now with them as a respected engineer.

On the specific questions you put to me:

(1) The most fruitful relationship between research and application is informal relations between people and the exchange of ideas. Things may be different in science, but in engineering I am sure of my ground here.

(2) I consider myself very well-informed about technological interaction with industry. For me and for people like me it is a daily matter, not an exception. Collaborative prodects are common. We also have pretty regular interactions with small-scale industry in which the arteries have not hardened.

(3) Adequate advice is easily available. I am not an expert on intellectual property matters, but the University has people who can help.

(4) I do it regularly.

In relation to some of the questions you ask to people generally:

I have often encountered well-informed and innovative rather than junior people in industry who have dire problems with their superiors. I believe short-termism is a real problem. It is what causes industrial people to feel the need to justify each and every step. Its symptom is that you have to go too far up the hierarchy before you find someone who can say "Fine. Let's do it". I personally could, if convinced that it was the right thing to do, say to someone this afternoon, "This is fine, you can try it out for £50,000, go ahead and start tomorrow. Get Fay to give you an account code". I could not afford to do this very often, and it would take a lot of conviction to make me do it at all, but I have the authority. You would have to go quite far up in a big UK company to get to that power —as far as much more expensive people than I am.

Memorandum submitted by G J Lomer, CBE (14 June 1993)

I was very pleased you invited me to give eidence to the Committee on the above subject, although I should make it clear that the views I have expressed are my own, and that both the Institution of Electrical Engineers and the Royal Academy of Engineering will submit their own inputs. I have however copied my submission to both of them as a matter of courtesy.

I should also explain that after 15 years as the Technical Director of the Racal Electronics group of companies, I retired from that position in December 1992. Inevitably therefore the views I express are largely the result of my career in the electronics industry, and with Racal in particular. I now have no direct connection with Racal, although I am a non-executive director of Vodafone Group Plc—a company which was demerged from the Racal Group in 1991—and am Chairman of Satellite Information Services Ltd, a company in which Racal is the largest shareholder. I also enclose a copy of my CV for your information.

The form of my response accordingly does not address specifically some of the questions you pose in your letter, particularly those relating to "your firm" or "your business". Instead I have made some general comments, followed by an attempt to respond to the questions posed in the Press Release, which I have numbered as in the attachment for ease of reference.

I hope that my views are of interest; I would be glad to enlarge on any aspect you might wish to consider further.

GENERAL COMMENTS

Almost all the activities of the electrical engineering industry depend for their prosperity on a continuous flow of innovative products. This is especially true in the fields of electronics, computing and software, where product life in the market place rarely exceeds five years and often may be two to three years. In "heavy" electrical engineering, products have very much longer installed lives than in these areas, and the rate of introduction of totally new products is correspondingly slower, but even apparently tiny enhancements in performance are of immense economic value over the product life, so that the demands for innovative design are equally strong as in the "light" electrical industry.

It is important to note that "innovation" becomes translated into "wealth creation" only at the final point of the creative cycle—that is when product design and introduction to manufacture has been successfully completed to the point where the innovative features can be reliably replicated for the customer at costs which allow the price paid to be set at acceptable market levels. Only too often the very heavy costs of production engineering and product launch (often described as the "Big-D" element of R&D) are not properly considered when proposals for the exploitation of scientific advances are made.

In general terms, companies which operate in international markets need to explore the whole "Science Base" from world sources before embarking on innovative development of products or services; although there are clear advantages to UK companies if the basic work is available in the UK, this factor in no way could compensate if a better basis were available from another country. Indeed there seems to be little correlation between a particular *country's* excellence in its science base and its success in industrial exploitation—as comparisóns between Japan and the UK often have demonstrated.

One important factor which seems to be fundamental is that normally the results of basic scientific work are widely published on a worldwide basis; indeed the success of the work, and the personal career progress of individual researchers, is measured on the basis of publication. Conversely the financial success of the exploitation depends on being "one step ahead" of the competition, and on following the traditional path of "industrial secrecy" in the near-market phases of product design. So a company will inevitably be drawn to search the world's publications for innovative ideas—particularly to establish the competitive status of a UK proposal—before embarking on serious development, and UK scientists may often find their work taken up by organisations outside the UK.

Nevertheless there are clear concerns that UK industry is not willing to exploit innovative work, from whatever source, whilst other countries do. The problem appears to be fundamental and largely results from the financial environment and culture of British industry. It will not be significantly changed by giving attention to the science base, which cannot of itself produce the solution to the exploitation problem, and must not be expected to do so.

Government funding of science and technology has been the subject of many submissions in recent months, culminating in the White Paper issued on 26 May, the thrust of which is very welcome. Certainly Government support of some aspects of the science base is essential for the underpinning of innovation and industrial prosperity, but the insistence in the past of bodies like the SERC on the support only of "basic and strategic" science (i.e., excluding "applied" science) has left a serious gap in the whole process of innovation which it is urgent to fill.

As a final comment, the term "science base" is not very clearly defined and has different meanings to different groups of people. It is important, following the White Paper, that clear distinctions are made between those parts which are to be supported for the extension of human knowledge or to provide a stiumulating research environment to attract and train the best people, and those parts which offer the hope —may be in the distant future—of industrial exploitation. The confusion of objectives is further compounded by the publication of statistics by the Cabinet Office and others which aggregate under the heading of "Government R&D" expenditure orientated to such widely differing objectives as the detailed design of specific weapons and systems for the MOD (the ultimate "near-market" support) and the SERC's support of astronomy and particle physics. These statistics can then be used in a multiplicity of ways to "prove" particular points which on closer evaluation are completely invalid, and more meaningful forms of reporting are required as a matter of urgency.

REPLIES TO THE SPECIFIC QUESTIONS (as numbered)

1. Industrial innovation is critically dependent on those aspects of the "science base" which are potentially capable of exploitation, but there are many aspects of the science base which are not intended to be justified on this basis or where the probability is exceedingly low. Moreover the science base is an international, worldwide source of knowledge, and there appears to be little or no correlation between a particular *country's* excellence in science and its industrial prosperity. Companies which operate in worldwide markets will access the best science available from worldwide sources—so that countries like Japan with a very well developed culture of industrial exploitation and the financial environment to support it will exploit the science base of many countries, whilst the UK which lacks both of these factors would not become more industrially successful if the science base, or links to it, were somehow drastically strengthened.

2. "Technology transfer" is an ill-defined and variously used term. In the UK however there has been a serious gap in the total innovation process between the excellent work in the areas of basic and strategic science and industrial exploitation in terms of product design. This is in part the result of the emphasis on "pre-competitive" work and the elimination of "near-market" support by the Government for both industry and academe. It is further compounded by the relative failure of our postgraduate education and training system to produce high quality people motivated to make a real contribution in this area.

One example which illustrates the problem can be seen in Japanese industry's domination of the high-precision high-volume mechanical engineering market, typified by the video recorder. Machine tools capable of working to tolerances and output rates *both* an order of magnitude better than those available in the West were the key to world domination in this area, and were so identified at Government level as soon as the potential market for these products was identified. In the UK it would not be possible under the existing regimes and rules for project support to achieve any useful level of Government support for a project of this nature, a key to "technology transfer".

3. A weakness of British industry is the relatively small numbers of qualified scientists and engineers employed in non-specialist parts of the organisations. The result is often a lack of appreciation *in depth* across the organisation, from Boardroom to shopfloor, of the opportunities and risks associated with particular fields of work or products. Whether this can be explained as a "lack of competent personnel" is perhaps questionable, but it is unfortunate that when the educational system considers the quantified "demand" for technologically competent people it seems that only specialist posts apparently are considered. The same criterion is never applied to the humanities!

It is doubtful that the innovation process is *directly* hindered by lack of competent personnel in terms of available numbers. In time of economic boom there are often clear shortages, but when recession occurs unemployment rears its head. A much greater problem is the *quality* of the available technical people, particularly in terms of management and business appreciation skills. Certainly it would appear that if innovation is to flourish, a significant increase in numbers of those people possessing these parallel skills is required, both in large companies at senior level and also as entrepreneurs getting businesses started.

4. and 5. British industry is in general not short of *ideas* for innovative products and services, and has adequate access to the necessary science base either from the UK or overseas, as described above. By far the largest problem is the difficulty of constructing an acceptable "business plan" which can yield suitable returns on investment against the criteria used in the UK and in the financial environment prevailing. High interest rates not only make the costs of supporting capital investment and start-up losses very high, but they also set an expectation of financial returns which are impossibly high. If money placed on no-risk deposit earns high returns, no prudent investor will invest in a business plan showing somewhat better returns, but with the associated risks inevitable in an innovative project.

Even the largest companies, who need to undertake large expenditure on innovation, are extremely vulnerable if their annual (or half-year) profits are significantly weakened by unexpectedly high R&D costs or delayed revenues due to projects being late to market.

Many hi-tech companies have R&D budgets comparable (or even greater) than their pre-tax profits, and significant deviations can have a substantial effect not only on profits but also on share prices, with the inevitable threat of takeover. Management who are prepared to take a longer-term view may well find themselves replaced as victims of a takeover if they allow profitability to be depressed for the best of reasons.

Unless the financial environment in the UK can be modified so that interest rates are closer to those of our main competitors *for long sustained periods*, and some steps taken to reduce the threat of takeover when results temporarily are depressed, all other efforts to stimulate an innovative environment will fail.

6. The pharmaceutical and specialised chemical industries are highly innovative and the UK has several successful companies of international stature in these fields. Their high level of investment in R&D seems to be sustainable because they operate in an environment of great "industrial secrecy" and where patents have immense value—partly because infringement is relatively straightforward to prove. Conversely in the electronic and computing industries, patents are rarely of great value because there are normally a multiplicity of ways of designing circuits or software to achieve an end result. As a result the payoff from innovative R&D is often simply the consequence of being "first to market" and may only be sustained until a competitor can design and manufacture a competitive product. It does not appear to be useful to try and make comparisons across these fundamentally different industrial boundaries, but to focus more on international comparisons within similar industrial sectors.

7. It is not easy to identify structures and institutions which are "particularly helpful" in encouraging the process of innovation. Many universities and HEIs are structured to exploit access to their science base by industry, and some sources of finance for small companies specialise in this area.

The greatest hindrances are those associated with the inability of companies, large and small, to justify the financial investment required by the innovation process against the rewards expected and the possible risks involved. If this problem could be eased, other constraints like an inadequate supply of people of adequate quality would probably also be solved, and it does not appear that "shortage of ideas" or "unwillingness (of middle management) to accept innovation" are factors which would then be serious problems.

Memorandum submitted by Dr John Muellbauer and Mr Gavin Cameron, Nuffield College, Oxford (July 1993)

Introduction

Although productivity growth in UK manufacturing has recently been strong in comparison with other leading industrialised countries, the recent technological performance of the UK has been weak. Many reasons have been advanced for this poor performance, such as short-termism in UK financial markets, problems of union bargaining, the volatility of the UK economy, and the poor structure of the UK national innovation system. It is often difficult to disentangle the various causes and effects.

Previous research by Muellbauer ("Productivity and Competitiveness" in Oxford Review of Economic Policy, 1991, which we attach) has investigated recent UK manufacturing productivity growth. This paper updates this research using data up to the first quarter of 1993, and also looks at UK innovation performance.

Trends in UK competitiveness

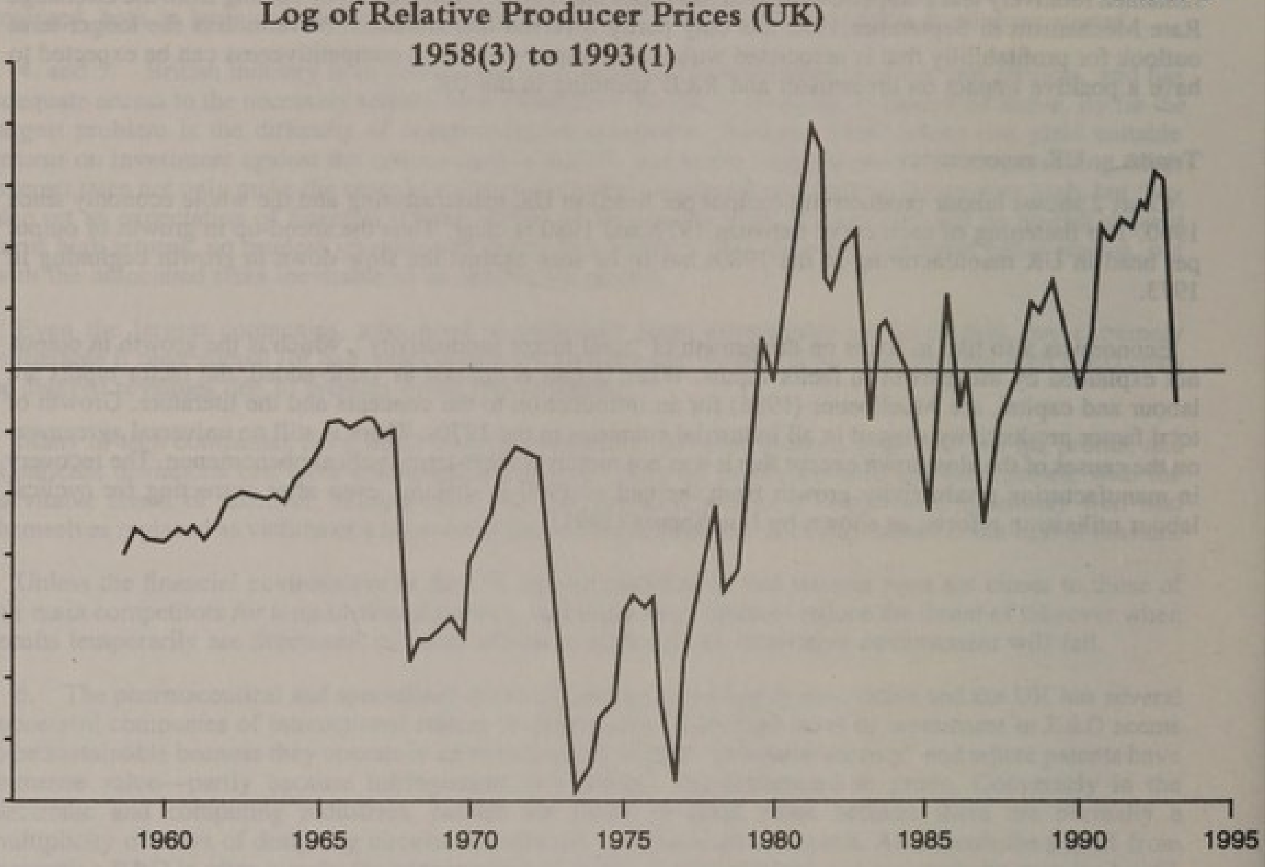
There are a number of ways of measuring the international competitiveness of UK manufacturing. Chart 1 plots UK relative producer prices, that is, the UK producer price index of manufactures divided by 1985 weighted averages of competitors' indices of output prices of manufactures, both expressed in the same currency. A downward movement implies that the UK has become more competitive. The chart shows that after the dramatic deterioration in UK manufacturing competitiveness in 1979-80, UK manufacturing has remained relatively less competitive than in the 1960s and 1970s. Even the exit of sterling from the Exchange Rate Mechanism in September 1992 has only partly reversed this situation. Nevertheless the longer-term outlook for profitabililty that is associated with recent improvements in competitiveness can be expected to have a positive impact on investment and R&D spending in the UK.

TRENDS IN UK PRODUCTIVITY

Chart 2 shows labour productivity (output per head) in UK manufacturing and the whole economy since 1960. The flattening of each curve between 1973 and 1980 is clear. Thus the speed-up in growth of output per head in UK manufacturing in the 1980s has to be seen against the slow-down in growth beginning in 1973.

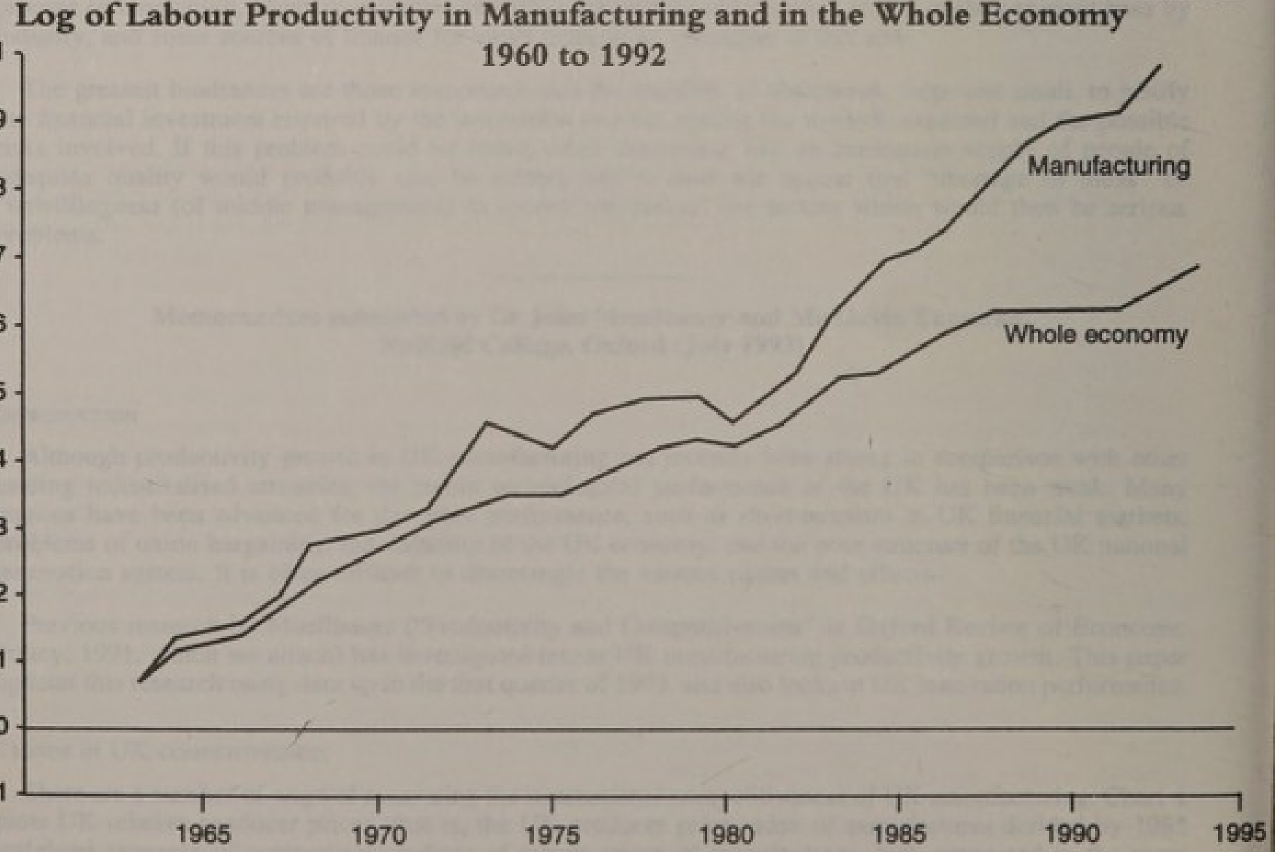
Economists also like to focus on the growth of "total factor productivity", which is the growth in output not explained by the growth in factor inputs. When output is defined as value-added, the factor inputs are labour and capital, see Muellbauer (1986) for an introduction to the concepts and the literature. Growth of total factor productivity slowed in all industrial countries in the 1970s. There is still no universal agreement on the causes of the slowdown except that it was not merely a short-term cyclical phenomenon. The recovery in manufacturing productivity growth from the end of 1980 is striking, even after correcting for cyclical labour utilisation effects, as shown by Muellbauer (1991).

Chart 1



UK producer price index of manufactures divided by 1985 weighted averages of competitors' indices of output prices of manufactures, both expressed in US dollars. A downward movement implies that the UK has become more competitive.

Chart 2



We have updated this research to the first quarter of 1993. The method consists of fitting a production function to UK manufacturing data for 1958Q3 to 1993Q1, assuming constant returns to scale. Output is real value added. Various biases in the index of output are discussed in Muellbauer (1986). Labour input is measured by the combination of number of workers, number of weeks worked per year (which falls because of longer holidays) and *effective* weekly hours of work. As explained in Muellbauer (1984, 1986), data on overtime hours and CBI capacity utilisation can be used to construct a utilisation index that corrects labour input for cyclical variations in utilisation.

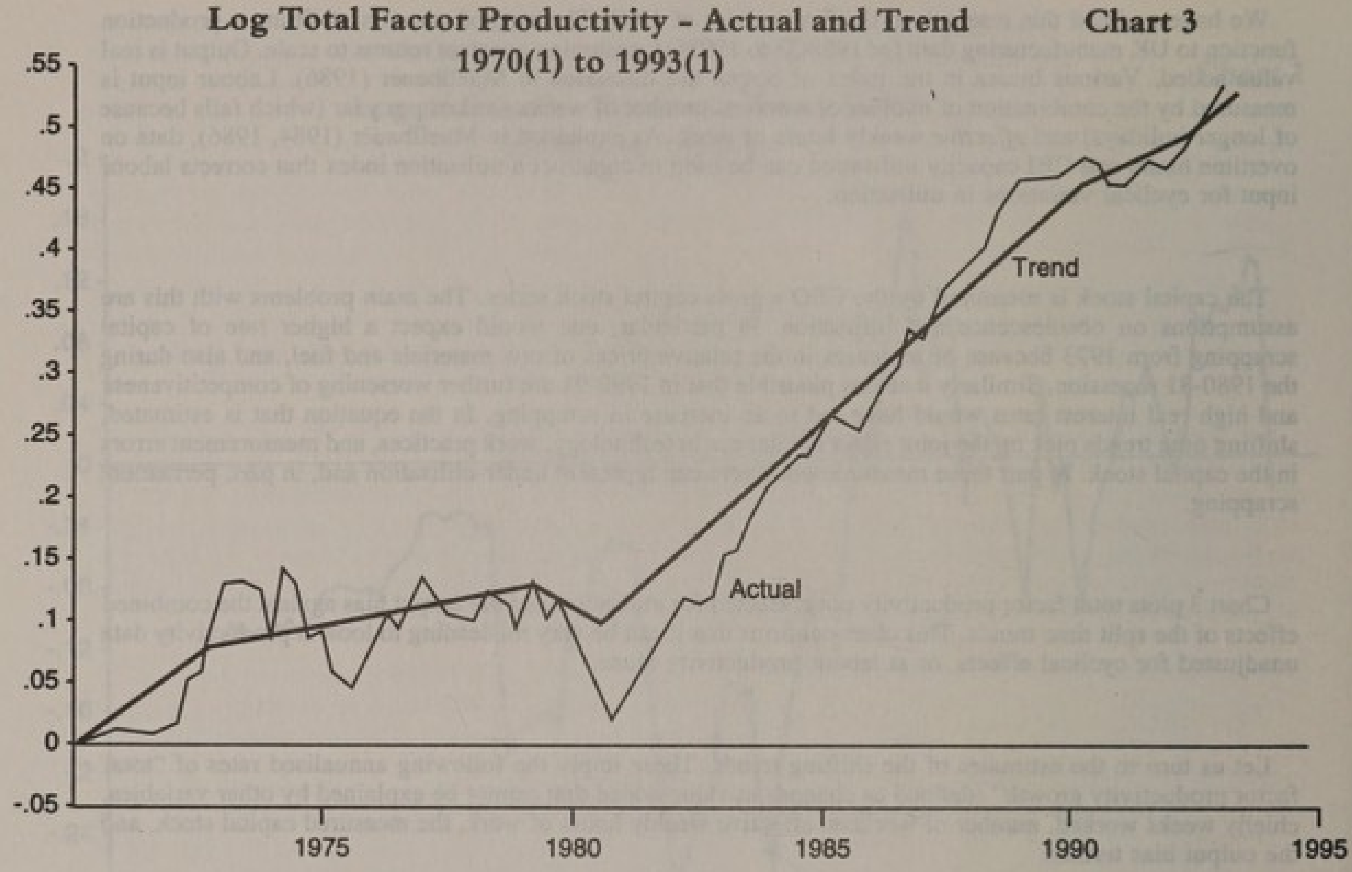
The capital stock is measured by the CSO's gross capital stock series. The main problems with this are assumptions on obsolescence and utilisation. In particular, one would expect a higher rate of capital scrapping from 1973 because of increases in the relative prices of raw materials and fuel, and also during the 1980-81 recession. Similarly it seems plausible that in 1990-91 the further worsening of competitiveness and high real interest rates would have led to an increase in scrapping. In the equation that is estimated, shifting time trends pick up the joint effect of changes in technology, work practices, and measurement errors in the capital stock. In part these measurement errors can represent under-utilisation and, in part, permanent scrapping.

Chart 3 plots total factor productivity not corrected for utilisation and the output bias against the combined effects of the split time trends. This chart confirms that it can be very misleading to look at productivity data unadjusted for cyclical effects, or at labour productivity alone.

Let us turn to the estimates of the shifting trends. These imply the following annualised rates of "total factor productivity growth" (defined as changes in value-added that cannot be explained by other variables, chiefly weeks worked, number of workers, effective weekly hours of work, the measured capital stock, and the output bias terms):

	Per cent
1958Q3 to 1972Q4	3.0
1973Q1 to 1979Q2	0.8
1979Q3 to 1980Q2	−2.4
1980Q3 to 1990Q2	3.7
1990Q3 to 1992Q2	2.0
1992Q3 to 1993Q1	3.7

There was a dramatic increase in the trend rate of growth of productivity in the 1980s. There are a number of possible explanations for this. First, capital scrapping in 1979-80 meant that from 1981 onwards, the proportionate increase in the capital stock would be substantially higher than recorded by official statistics. This would lead to an upward bias in the total factor productivity figures. Second, the 1980-81 recession led to a major shake-out of labour that had been mistakenly hoarded during the late 1970s. Amongst other possible hypotheses are the weakening of trade-union power; the withdrawal of state subsidies; the shedding of below average labour and capital; increasing subcontracting; the widespread adoption of "microchip" technologies; and simply that UK manufacturing had so much lost ground to catch-up on international best-practice.



UK PRODUCTIVITY DURING THE RECESSION

We experimented with a number of specifications in an attempt to capture the effect of the 1990-91 recession on productivity. The model that worked best, although it did not fully capture the cyclical effect, suggests that the recession temporarily reduced the trend rate of growth of total factor productivity from its 1980s rate of 3.7 per cent per year to around 2 per cent per year between 1990Q3 to 1990Q2. If we attribute all of this 3.4 per cent reduction in total factor productivity growth over two years to permanent capital scrapping, this would imply a 10 per cent loss of the capital stock, not measured in the CSO data. Over the same period, manufacturing employment fell by 11 per cent. Employment peaked in 1989Q3 and over the longer period 1989Q4 to 1992Q2, manufacturing employment fell by 13 per cent. One would expect employment to be substantially more sensitive to the recession than the capital stock so that a 10 per cent permanent loss of capital stock seems to be at the top of the credible range.

It is very early to draw conclusions about what has happened since 1992Q2, but we have assumed in chart 3 that the trend rate of growth has returned to its 1980s rate of 3.7 per cent per year. However, productivity in 1992Q4 and 1993Q1 was actually above the values fitted by our model. There are three possible explanations for this. First, it may be a statistical "blip" for which we are unable to account because it is so close to the end of the time-period. Second, it is possible that our method of accounting for cyclical utilisation does not fully capture the changes going on. Thus we may be overestimating the part of the 1990-92 slowdown in productivity growth that was permanent and similarly underestimating the cyclical element in the recovery. Third, and more improbably, it is conceivable that a 1980-81 style shake-out in manufacturing industry occurred in 1990-92 and has actually raised the trend rate of productivity growth. In any case, the fact that the downturn in productivity growth and in labour and capacity utilisation was less severe in this recession than in that of the early 1980s suggests that firms were less overmanned in 1989 than in 1979 and were more prepared to cut employment rapidly in response to a deteriorating economic environment. It appears that productivity growth has now returned to trend with a strong cyclical upswing in progress.

THE LINK BETWEEN INNOVATION AND PRODUCTIVITY

Many studies have shown that there is a strong and enduring link between innovation and productivity growth. In addition to the benefits to the innovating firms, there are wider benefits to other firms and to consumers, increases in the knowledge of research and engineering staff, as well as sharpened competition for rival firms.

The earliest studies of the relationship between output and technological change tried to account for economic growth in terms of changes in capital and labour inputs. Anything not explained by capital and labour was attributed to technological change. Solow (1957) suggested that technological change was responsible for the majority of economic growth. Later researchers made more comprehensive adjustments for input quality, which reduced the unexplained residual to about 20 per cent of output growth.

Dislike of previous approaches led researchers such as Griliches (1986) to regress estimates of total factor productivity growth against various measures of innovation input, normally R&D spending (either aggregated, or broken down into components such as basic and applied, private or government), along with other factors associated with productivity growth, such as capacity utilisation. However, researchers often found it difficult to model the long and significant lags that exist before R&D affects productivity.

In any case, most studies of this kind found a positive and significant relationship between R&D and residual productivity change. Griliches (1988) suggests that, as a rule, every 1 per cent increase in the stock of R&D capital leads to a permanent one-tenth of 1 per cent increase in output.

Is innovation by UK industry internationally competitive?

Although there can be no single, simple measure of technological performance, R&D statistics can provide valuable insights into the resources devoted to innovation by different countries and industries.

UK Business Expenditue on R&D (BERD) was 1.4 per cent of GDP in 1990. The UK spends about the same as France as a proportion of GDP, but significantly less than Japan (2 per cent of GDP), West Germany (2.1 per cent), and the USA (2 per cent). UK BERD grew more slowly than did BERD in the UK's major competitors between 1975 and 1990, as did that part of UK BERD funded by industry itself. Government funding of BERD has become less imporant during the 1980s, with the contribution of industrial funds to BERD having risen from 63 per cent to 68 per cent between 1975 and 1990, and overseas funding having more than doubled as a percentage of all BERD. The rising importance of foreign funding is due to a number of factors, such as the advanced multinational presence in the UK, increasing levels of EC funding, and increasing funding of defence R&D in the UK by foreign governments and firms.

Manufacturing is much more R&D intensive than the service sector. The UK has a smaller manufacturing sector (about 22 per cent of GDP), than some of its competitors (Germany at 31 per cent, and Japan at 29 per cent). It is therefore somewhat obvious that the UK spends less on BERD as a percentage of GDP. It would be better to look at BERD relative to the size of manufacturing industry (BERD divided by manufacturing value-added).

Although there are a number of problems with this approach, the available data suggest that UK manufacturing is slightly *less* R&D intensive (spends less on BERD relative to manufacturing value-added) than its competitors. As table 1 shows, the R&D intensity of UK manufacturing is currently around 5 per cent, compared with 6.4 per cent, in West Germany, 6.5 per cent in France, 6.6 per cent in Japan, and 7.2 per cent in the USA.

As the table also shows, the R&D intensity of UK manufacturing has increased more slowly than in other G5 countries. In 1973, the UK R&D intensity was higher than in any country except the USA, but has since been overtaken by Japan, Germany and France. Furthermore, R&D intensity in the UK has been static during the 1980s, while other countries were increasing their efforts.

The UK now spends a relatively high amount on R&D in the electronics (radio, television and communications) and pharmaceuticals industries, and a relatively low amount on R&D in aerospace and motor vehicles. UK spending in other high technology industries, such as computers, chemicals, and instruments, is only a little below the G5 average. UK R&D intensity in aerospace has more than halved since 1973, while other countries have increased their efforts. High UK spending in electronics may reflect the small relative size of the UK industry and the high fixed costs of R&D in this industry. The UK performance in pharmaceuticals appears to genuinely reflect strength in this industry.

The UK R&D intensity is lower in the medium and low technology industries than the G5 average, and less in most industries than Germany, Japan and the USA. Low UK spending in rubber and plastics and non-electrical machinery is particularly marked.

These R&D intensity data support the often argued view that the UK is still reasonably strong in high technology sectors, but that the UK is relatively weak in medium and low technology sectors. UK R&D intensity is lower than any other G5 country and its strengths are concentrated in fewer industries. The UK appears to be in a similar position to France, albeit slightly weaker overall, but is a considerable distance behind Germany, Japan and the USA. As usual, the main bright spot for the UK is the pharmaceuticals industry.

R&D statistics cannot tell the whole story about a country's innovative performance. We merely offer a brief summary of the other available data. First, the UK science base is still relatively strong, but its position, especially in engineering, has deteriorated over the recent years. Second, the UK has a technically less-educated labour force (including management) than its major competitors. Third, the performance of the UK in international patenting has also declined significantly and shows weaknesses in many areas. Last, the UK has a relatively modern stock of production machinery, but that machinery tends to lack the most efficient numerical and computer control devices.

In general, the indicators show that the leaders in international technology are the USA, Japan and West Germany. The UK and France are fairly level, but are some way behind the leaders. The UK's position has also deteriorated significantly over the last 20 years.

WHICH STRUCTURES AND INSTITUTIONS WITHIN THE UK ARE HELPFUL IN ENCOURAGING INNOVATION AND WHICH HINDER IT?

(i) *Market Failures*

As we have seen, the evidence suggests that there is a significant and enduring link between productivity and R&D. This, however, is not sufficient argument for government intervention. It is the market failure inherent in innovation that provide the rationale for government support.

There are a number of reasons that markets can fail, with the result that an inadequate volume, or an incorrect distribution, of resources is spent on R&D. R&D is a classic public good, in the sense that it is not rival (two or more firms can use the same piece of information without reducing its value), and not perfectly excludable (except to the extent that patents, trade secrets and so on are successful). R&D is also risky and highly uncertain activity, and firms are generally considered to be more risk averse than society as a whole. Overall, studies (such as Mansfield, 1981) suggest that the private return to R&D may be only a third of the social rate of return.

Since innovation and productivity are so closely linked, and because the market for innovation is likely to fail, there is a strong case for some form of government intervention. This is generally acknowledged, although debate centres on the scope of intervention that is necessary.

(ii) *The UK problem*

Successful innovation is an extremely complex process, and is dependent upon a whole range of institutions and relationships. In the UK, this network of institutions principally consists of firms themselves (with their suppliers and customers), Higher Education Institutions, Research Councils, research establishments, the Government, financial institutions, and consumers and workers themselves. Furthermore, the UK is able to import technologies from, and exchange ideas with, other countries. If information flows freely between institutions and sectors; if firms and research institutions compete effectively against one another; and if institutions recognise the importance of innovation, then the "national innovation system" may be said to be working properly.

As we have seen, there are reasons to believe that the technological performance of the UK has been weaker than that of its major competitors. This has often been attributed to failings of the UK "national innovation system", such as short-termism in UK financial markets, low levels of technical education and training, problems of union bargaining, the volatility of the UK economy, lack of competition in UK product markets, and general cultural attitudes to science and technology. It is difficult to disentangle the various causes and effects.

(ii) *Tax credits for R&D*

Improving the technological performance of the UK economy will not necessary lead to improved productivity growth unless steps are taken to solve many other supply side problems. However, it has sometimes been suggested that the introduction of a tax credit for R&D would significantly increase UK R&D spending.

In an influential review of previous studies of R&D tax credits, the Inland Revenue (1987) concluded that tax credits for R&D were not cost-effective because for every pound of tax revenue forgone, less than a pound of additional private R&D expenditure was stimulated.

Two approaches have been used to attempt to quantify the effect of R&D tax credits on R&D spending. Some researchers have used surveys to ask executives the extent to which their decisions were influenced by the tax credit, while other researchers have estimated econometric models of R&D spending.

Most of the studies were conducted in the USA after the 1981 Economic Recovery Tax Act allowed firms to claim a 25 per cent tax credit for R&D spending in excess of the average of the firm's spending in a base-period (the previous three years). The credit was originally intended to last until 1985, but was subsequently made permanent.

The most widely quoted study was conducted by Mansfield (1985), on a survey basis. His results suggested that for a 1 per cent reduction in the price of R&D, firms would increase their R&D spending by about 0.3 per cent. Whether this is cost-effective (that is, whether the additional R&D stimulated is greater than the tax revenue foregone) obviously depends upon the current level of R&D spending and the percentage reduction in the price of R&D as a result of the credit. Nonetheless, the Mansfield study, and a number of others, were able to show that R&D tax credits were not cost-effective.

In 1990, the US system for calculating a firm's spending in the base-period was changed significantly. The new base was calculated as the 1984-88 ratio of R&D to sales for each firm (with a maximum of .16, and set at .03 for start-ups) multiplied by current sales. This substantially increases the effective reduction in the price of R&D because extra spending in one year no longer increases the base in the next year (although firms may expect the base-year period to be changed eventually).

A recent study (Hall, 1992) has taken into account such recent changes in the US tax credit system and has also used a more credible econometric approach that uses firm-level data as well as data at an industry and aggregate level. Hall concludes that previous estimates of the effect of the R&D tax credit on R&D have been underestimates and that the additional spending stimulated in the short-run was about £2 billion 1982 dollars per year, while the forgone tax revenue was about $1 billion per year.

A couple of previous studies found that the US tax credit was cost-effective (such as Baily and Lawrence, 1987). However, these previous studies were fatally flawed because they ignored both the dead-weight losses that arise when firms would have increased their R&D anyway, and the reclassification of other activities as R&D that inevitably occurs when a tax credit is introduced. However, the Hall study is scrupulous in correcting for such problems. Furthermore it is likely that the new structure of the US tax credit will have greatly reduced these problems since payment of tax credits is dependent upon increases in the ratio of R&D to sales which reduces deadweight losses compared with credits linked, more crudely, to just increases in R&D spending.

The evidence, therefore, now seems to suggest that a properly designed system of tax credits for R&D could be a cost-effective way of stimulating additional R&D spending. This is because the latest studies have been more rigorous than previous work, and also because the new structure of the US tax credit is much more efficient. There is no reason that an identical system could not be implemented in the UK.

CONCLUSION

Our econometric work on UK total factor productivity up to the first quarter of 1993 suggests that by comparison with the 1980-81 recession, the cyclical downturn in productivity was less pronounced and productivity growth now appears to have returned to trend with a strong cyclical upswing taking place. However, there is circumstantial evidence to indicate that some permanent capital scrapping took place in 1990-92 in the manufacturing sector.

The structural changes in the UK economy over the last 15 years, although profound, owe little to improved technological performance, and the *level* of UK productivity remains lower than in its major competitors. With innovation becoming increasingly important in world markets, it is likely that the UK needs to improve its technological performance if it is to catch-up on international levels of productivity.

The evidence on UK technological performance is fairly clear-cut. R&D data suggest that the UK has tended to under-invest in R&D compared with its major competitors, and this problem is even more marked when defence R&D is excluded. Other data on the innovative performance of the UK support this conclusion.

There are a number of likely reasons that the UK may have under-spent on R&D, such as problems in financial markets, labour markets, and lack of competition in product markets. There are no easy solutions to these problems. However, it has been suggested that a well-designed tax credit for R&D would help to increase spending in the UK, and recent evidence from the USA is supportive.

TABLE 1

Disaggregated R&D Intensities 1973-1990

	UK			FRANCE			GERMANY			JAPAN			USA		
	1973	1981	1990	1973	1981	1990	1973	1981	1989	1973	1981	1989	1973	1981	1989
	Percentages			Percentages			Percentages			Percentages			Percentages		
Aerospace	43	33.4	19.5	45.9	26.2	43.1	67.8	33.5	48.6	19.9	13.4	20.8	39.8	32.7	40
Electronics	15.3	32.4	26.9	18.1a	23.8	30.5b	10	12	14.4	10	11.1	12.9	16.3	13.6	23.8
Pharmaceuticals	18.4	22.1	25	16.5	13.5	28.5	12	11.7	17.8	8.9	10.6	13	14.7	14	15.2
Computers	16.2	25.7	18.7	8a	8.2	7.9b	8a	7.2	11.2	7	9.5	19.8	32.1	21.8	34.6
Motor vehicles	5.6	5.2	6.3	5.9	5.6	10.9	6.4	6.4	10.3	6.3	7.6	9.7	11.4	12.2	12.4
Chemicals	5.9	6.3	7.5b	4.3	6.5	8.1	5.2	5.6	7.8	5.4	6.5	8.7	6.8	6.2	6.4
Instruments	5.8	7.2	5.4b	3.8	5.8	4.1	4.8a	5.2	5.8b	5.8	9.1	15.3	11.5	11.5	7.8
Elec mach nes	7.3	5.8	4.6	5.2a	4.5	2.3	9.5	7.3	7.9b	6.6	7.8	11.3	12.6c	10.2c	2.8
Petroleum refining	4.8	1.9	3.6	1.7	3.6	2.4	0.4	0.6	0.8	2.3	2.6	7.5	9	7.3	7.9
Non-ferrous metals	1.7	2.6	2.5	0.9	2.6	2.4	1.9	1.9	1.1	1.9	4.6	7.7	1.8	2.2	2.7
Rubber and plastics	1.1	1	0.7	3.8	4.7	5.2	1.6	2.1	2.5	2.9	3	4.1	4.8	2.9	1.6
Non-elec machinery	2.3	2.6	1.5b	1.9a	1.5	2.2	4.3	3.8	4.2b	3	3.2	3.9	2.9	2.1	1.9
Stone, clay and glass	1.5	1	0.7	1.3	1.5	1.6	0.4	1.2	1.7	1.5	2.1	4.1	1.8	1.8	2.4
Ferrous metals	1.7	1	1.5	0.7	1.1	2.6	0.9	1.7	1.2	1.6	3.1	3.9	0.9	1.7	0.8
Shipbuilding	2.9	0.8	0.5	0.4	0.7	1.9	2.9	1.3	3.5	1.1	1.1	1.9	N/A	N/A	N/A
Metal products	0.6	0.9	0.7	0.5	1.1	0.6	0.2	1.5	1.8	0.8	1.2	1.3	0.9	1.1	1.1
Textiles and footwear	1	0.3	0.2	0.5	0.4	0.5	0.3	0.5	0.6	0.6	1.3	1.4	0.3	0.2	0.3
Wood and furniture	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.5	0.7	0.2	0.5	1	0.4	0.7	0.4
Paper and printing	0.4	0.3	0.3	0.3	0.3	0.3	0.1	0.4	0.4	1	0.3	0.9	0.7	0.7	0.4
Total Manufacturing	4.3	5.2	5	3.4	4.3	6.5	3.2	4.3	6.4	3.1	4.4	6.6	6.3	6	7.2

Source: OECD STAN database, UK Census of Production, OECD Industrial Structure Statistics.

Notes:

R&D intensity is defined as Business Enterprise R&D (BERD) divided by value-added.

a Data not available for this year: data for nearest year used instead.

b 1988 data.

c Includes computers.

nes not elsewhere specified.

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Memorandum submitted by Professor Reza Ziarati, Director of the Factory of the Future Project, Birmingham Advanced Manufacturing Centre (7 July 1993)

RE: INQUIRY INTO INNOVATIVE AND COMPETITIVE TECHNOLOGY

I am referring to your Press No.tice (No 9 of Session 1992-93) in connection with the above. Please note below my comments which I hope will be of some use to your Committee.

The responses given below should be read with realisation that with support from industry, Royal Academy of Engineering and European Commission the members of the EUROTECNET team based in Birmingham have visited almost every industrial country in the last three years and have been involved in four major surveys. The results of these surveys have been complemented by the findings of Clark [1], Womack [2], New [3] and Ziarati [4]. Further information on these four references will be provided if requested. To keep the responses simple references have only been made to the innovative practices in Japan as examples to help the Committee with this enquiry.

It is also worth noting that the Business Enterprise R&D in relative terms in the UK has remained the same throughout the 1980s whereas there has been significant increases in France, Japan, Germany, Italy and many other OECD countries [5].

Q1. *What is the relationship between the Science Base and industrial innovation?*

Industrial innovation is only possible if a vigorous Science Base is in place and that there are mechanisms for exploiting results and findings of science based research world-wide. Japanese are master of the latter who had, up to recently, adopted a Technology Base philosophy (as against the UK's Science approach) to develop comparable products in competition with similar products produced in the UK with a great deal of success up to late sixties.

The Japanese and some emerging industrial nations are now in the process of investing heavily in and further developing their science based research as a strategy to retain and expand their markets in the world. The strategy also embraces the creation of new markets for high technology products and other by-products of their research activities.

To this end, therefore the UK has been extremely short-sighted and ill-advised in maintaining its science base while not encouraging exploitation of its research findings or the results of research elsewhere. This behaviour or policy is analogous to playing good football and allowing the team to score own-goals.

The main armour of many progressive companies and indeed countries is the realisation of the importance of long and co-ordinated planning with the aim of maximising the use of resources through a continuous programme for improvements. It is vital for the main organs of a country as is the case in Japan, to work together and plan ahead with due concern both for the realities challenging the nation and, the importance of long-term planning.

Q2. *Are mechanisms for technology transfer and interaction between the science base and industry effective? How could they be improved?*

The existing mechanisms for transfer of technology in the UK is haphazard to say the least. The two worlds of academia and industry are as wide apart as they have been for decades. The success of a nation does not necessarily depend on these mechanisms and/or the level of interactions. In Japan apart from the industrial and commercial universities the two worlds of industry and academia are not as close as we have been led to believe.

The secret of success is meaningful collaborations between those involved with research and technological developments and those involved in turning these into saleable products at the right time, right cost, right quality to the right place and at the right time.

The current management both in industry and academia in the UK, in comparison with their Japanese counterparts, are mere apprentices suffering amongst other things from risk aversion, passing the buck syndrome, "scape-goating" and lack of vision.

There has been numerous initiatives and programmes, some of which have been extremely beneficial. Amongst these probably the Teaching Company Schemes have helped to establish meaningful interactions between the academia and the industry and commerce. The ACME Directorate of the SERC has through its near market yet generic approach, has been very successful in bringing the universities and industry together.

The DTI enterprise initiative has also been viewed by many as successful.

There has been several high level initiatives particularly in the past few years which included the work by NEDO, the House of Lords Select Committee, The CBI and the Fellowship of Engineering and creation of high-profiled innovation Unit at the DTI. However the outcome to date has been rather muted primarily due to the poor understanding of the world class manufacturing requirements by many senior industrialists.

The second problem is that there are so many initiatives and programmes not to mention the CEC R&D that have and are leading to the re-invention of the same wheel over and over again.

It is a full-time job just to keep up to date as to what's going on. Most of these initiatives are unbelievably oversubscribed leading to a waste of time for many who were not successful after a substantial amount of effort put to formulate proposals.

I have attached an appendix[1] which gives an example of a mechanism used to bring different interest groups in Birmingham together. This project which is known as "Factory of the Future" generates income and obtains funding from different sources to support its various technology transfer programmes. There are a number of these centres in the UK which are directed by the EUROTECNET project in Birmingham. The projects in the UK are linked with other innovative programmes throughout Europe. The enclosed diagram depicts the interaction of various partners and major activities. The NTTS (New Technology Training Initiative) has been a joint initiative between the Birmingham City Council and the EUROTECNET project team based in Birmingham.

From the recent Birmingham TEC and EEF (WM) surveys carried out it is clear that the local industry are very supportive of the EUROTECNET approach in creating a focal centre and networking of companies for a particular technology transfer programme.

The EUROTECNET approach has also brought the expertise in the city under an umbrella and has facilitated the participation of many individuals or organisations with a contribution to make.

Q3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skill?*

The British industry for a long time has been reliant on markets in the "friendly" countries mainly in the Middle East, Commonwealth countries and so forth as well as defence based markets.

Considering that the Commonwealth countries can no longer be classified a "good" market and the Middle East as a region is diversifying its supplier source, these together with the difficulties with political mismanagement will require more than a mere maintenance of the existing levels of activities witnessed during the last two decades. Therefore, a more concerted and determined effort is required if the UK is to be put in a position of expansion.

The level of industrial innovation has primarily been hindered by the incompetence of managers in industry and the academia, and the tendency to risk aversion. The Government has also been paralysed due to a number of factors, hence unable to redress the difficulties the country has been facing.

One good example is the story of the establishment of a company called Renishaw in Wootton-Under-Edge. The Chairman and Chief Executive of this company was an HND-qualified

[1]Not printed.

Rolls Royce employee. When he innovated the art of measuring geometries of engineering components by a new means which superseded the existing techniques used in the company at the time, the company did not take any notice of this young and able technician's proposal. Later with support from a colleague he formed his own company and using the back of his garage founded one of the most progressive and innovative companies in the UK.

Q4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

There again the level of innovation is not the problem but a lack of understanding that innovation in itself may in fact be detrimental if not managed and or exploited accordingly.

If effort is put into an activity then there must have been an objective or set of objectives and an action plan of some kind to achieve the intended outcome. Furthermore, some form of measurement depending on the activity concerned needs to be carried out leading to an evaluation and re-definition of the initial action plan and the cycle is then repeated. Most projects funded by the Government are not really evaluated in a meaningful manner. There are however clear exceptions such as the SERC/ACME and TCS and some others.

Evaluation is an analytical process which needs to be designed and developed. The main element of an evaluation should however contain a set of parameters and variables and, a means of using and measuring these, should be identified at the outset. For instance, if an innovation is identified then a process should be established to set priorities for its exploitation? Or is the improvement in the productivity, or quality is the objective? What about the growth considerations! What about the competitors, should an exercise be formulated to fend them off. Fending competitors off is an art as described in the following paragraph.

A battle for motor car supremacy raged between Honda and Diahatsu in Japan in 1965. Both companies at the time were comparable in every respect. A plan to automate their manufacturing operations was rejected by Diahatsu while although Honda could not really see the benefits in pound notes for a major step, opted for automation with massive borrowing. The gamble was taken based on "What If" analysis. What if Diahatsu decided on the same course of action which at the time Honda thought was almost a certainty. Honda were unaware at the time that Diahatsu had already decided against the investment.

Q5. *Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

This is probably the most vital question so far. Companies who do raise their voice are those who are still solvent. These companies unfortunately do whatever they can to balance their books and the moment their order books are full for a year or so they become rather indifferent to the needs of their smaller and newer clients.

They put a great deal of work in looking after their major clients. Everything from organisational to technological and human resource issues are based on short terms.

Every business plan is devised on a three-year cycle and most investments are based on a rate of return of minimum of 20 per cent and a period of return of three years. Even Senior managers generally plan their careers in a three-year cycle. The fact is that for a country to go bust takes a lot of beating but the UK having exploited its natural resources rather foolishly and having privatised its major public assets will sooner or later have to realise that current arrangements are not satisfactory and a more concerted and determined effort is necessary if further erosion of our standard of living is to be checked.

The solution is the introduction of the world class manufacturing practices into our manufacturing operations through a tripartite arrangement between the Government, the Industry and the financial institutions with support from the progressive academic institutions.

CONCLUDING REMARKS

The main reason for the failure of many Government schemes has been due to both short term and fragmentary nature of many of the funded programmes. It is important to realise that the problems of the large companies are in the main very different to the problems faced by the smaller enterprises. The OEMs require a different type of support. It should be realised that if an OEM goes under it will drag with it many smaller supplier companies.

The support provided to most companies is usually in a specific activity or improvement which even if it leads to success it may not help the company overall and in fact may have a detrimental effect on its business. Support should be only provided if it is in line with the three main pillars of a company's business viz, its technology, organisation and human resources.

The exploitation of research findings and results are the main weakness of the British industry. The process of exploitation involves many complex interactions and close examination of the situation by mediocre experts has led to a fragmentary evidence of what needs to be done.

It is prudent to identify good programmes such as Teaching Company Scheme and other good practices in industry and the academia.

There is a shortfall of expertise in institutions of higher education and a lack of understanding by many vice chancellors of the importance of collaborative research with industry and commerce.

The British management also needs to be encouraged to understand the concept of innovation management.

More emphasis needs to be placed on the importance of evaluation and monitoring of funded projects particularly the application of funds by the institutions of higher education.

Memorandum submitted by The Institution of Electrical Engineers (9 July 1993)

The Institution has considered carefully the questions raised by the Committee and our formal submission in response is appended to this letter.

The Institution has a membership of almost 130,000 electrical, electronic, computing and manufacturing engineers working in universities, industry and Government service. We therefore represent a broad spectrum of expertise and knowledge of the innovative process from basic research to final product, and have a comprehensive view of the British industrial scene.

We strongly believe that the wealth and well-being of our nation is dependent on our engineering and manufacturing base, and that the Government must give more broadly-based support to engineering and technology in UK. We are pleased that this concept has been acknowledged in the White Paper from the Office of Science and Technology "Realising Our Potential" and as an Institution we hope that we can contribute to the fulfilment of the objectives of that paper.

The views expressed in our response to the Select Committee are consistent with those made to the Chancellor of the Duchy of Lancaster, and to the House of Lords Committee on "Priorities for the Science Base". The underlying theme of our submissions is that it is necessary to support the whole breadth of the innovation process development to product development. This requires effective technology transfer and a well trained work force, with, in particular, high quality engineering managers who are not only technically competent but have the necessary commercial, financial and organisational skills.

These points are discussed in more detail in our formal submission, and the Institution would be pleased to elaborate the points further if so requested.

General comments

The Institution wishes to stress the importance to the national economy of effective industrial innovation. All the activities of the engineering industry depend for their prosperity on a continuous flow of innovative products. This is especially true in the fields of electronics, computing and software, where product life in the market place rarely exceeds five years and often may be two to three years. In "heavy" electrical engineering, products have very much longer installed lives than in these areas, and the rate of introduction of totally new products is correspondingly slower, but even apparently tiny enhancements in performance are of immense economic value over the product life, so that the demands for innovative design are equally strong as in the "light" electrical industry.

We would also stress the fact that the innovation process is a dynamic entity. For reasons we shall elaborate below the "science base" does not lead directly to innovation, nor is it the driving force in the process. If we take "science" to refer to the fundamental knowledge base which gives us the understanding of how the natural world functions, then "technology" defines the total innovation process which runs from the innovative concept, through the engineering phase of research, advanced development, manufacturing process development, to product development. Engineering is the real driver for the innovative process in response to market pull. This "demand pull" feeds back into the science base, as the technology defines areas where our knowledge is incomplete and where further research may be fruitfully carried out, and it also provides the scientist with improved tools and expertise to explore areas previously unattainable.

It is important to note that "innovation" becomes translated into "wealth creation" only at the final point of the creative cycle—that is when product design and introduction to manufacture has been successfully completed to the point where the innovative features can be reliably replicated for the customer at costs which allow the price paid to be set at acceptable market levels. The very heavy costs of production engineering and product launch (often described as the "Big-D" element of R&D) must be recognised and accepted when proposals for the exploitation of scientific advances are made.

In general terms, companies which operate in international markets explore the whole "Science Base" from world sources before embarking on innovative development of products or services; although there are clear advantages to UK companies if the basic work is available in the UK, this factor in no way could compensate if a better basis were available from another country. Indeed there seems to be little direct correlation between a particular country's excellence in its science base and its success in industrial exploitation—as comparisons between Japan and the UK often have demonstrated.

One key fact regarding basic scientific knowledge which seems to be fundamental is that the results of basic scientific work are widely published on a worldwide basis; indeed the success of the work, and the personal career progress of individual researchers, is measured on the basis of publication. Conversely the financial success of the exploitation depends on being "one step ahead" of the competition, and on following the traditional path of "industrial secrecy" in the near-market phases of product design. So a company will inevitably be drawn to search the world's publications for innovative ideas—particularly to establish the competitive status of a UK proposal—before embarking on serious development, and conversely UK scientists may often find their work taken up by organisations outside the UK.

Nevertheless there are long-standing concerns that UK industry is less effective in exploiting innovative work, from whatever source, than some other countries. The problem appears to be inherent in our approach to innovation and largely results from the financial environment and culture of British industry. It will not be significantly changed by giving attention to the science base, which cannot of itself produce the solution to the exploitation problem, and must not be expected to do so. There is a need to support the total infrastructure of the innovative and industrial process, and to develop a well-managed approach to engineering innovation as exemplified by the German Technical Institutes.

Government funding of science and technology has been the subject of many a wide-ranging discussion in recent months, culminating in the OST White Paper "Realising Our Potential" issued on 26 May, the thrust of which is very welcome. Certainly Government support of the fundamental research component of the science base is essential for the underpinning of innovation and industrial prosperity, but the insistence in the past of bodies like the SERC on the support only of "basic and strategic" science (i.e., excluding "applied" science) has left a serious gap in the whole process of innovation which urgently needs to be filled.

As a final comment, the term "science base" is not very clearly defined and has different meanings to different groups of people. Although the White Paper goes some way in this direction, it is important that clear distinctions are made between those parts which are to be supported for the extension of human knowledge or to provide a stimulating research environment to attract and train the best people, and those parts which offer the hope—may be in the distant future—of industrial exploitation. The confusion of objectives is further compounded by the publication of statistics by the Cabinet Office and others which aggregate under the heading of "Government R&D" expenditure orientated to such widely differing objectives as the detailed design of specific weapons and systems for the MOD (the ultimate "near-market" support) and the SERC's support of astronomy and particle physics. These statistics can then be used in a multiplicity of ways to "prove" particular points which on closer evaluation are completely invalid, and more meaningful forms of reporting are required as a matter of urgency.

REPLIES TO THE SPECIFIC QUESTIONS

(1) *What is the relationship between the Science Base and industrial innovation?*

Industrial innovation is critically dependent on those aspects of the "science base" which are potentially capable of exploitation, but there are many aspects of the science base which are not intended to be justified on this basis or where the probability of practical application is exceedingly low. Moreover the science base is an international, worldwide source of knowledge, and there appears to be little or no correlation between a particular country's excellence in science and its industrial prosperity. Companies which operate in worldwide markets will access the best science available from worldwide sources—so that countries like Japan with a very well developed culture of industrial exploitation and the financial environment to support it will exploit the science base of many countries. In the UK it is the innovation/engineering/manufacturing criteria and the financial investment which need to be changed. UK will not become industrially successful unless the science base, or links to it, are greatly strengthened.

The science base is, therefore, only one element of the process of industrial innovation. There is a great need for the Government to have an overview of the total process and to think in terms of technological planning which embraces all the elements. The OST White Paper proposes to develop the process of technology foresight, which is strongly endorsed by this Institution, as it requires a view of the innovative process in breadth of technologies and extended in time. The DTI has a strong role to play in developing this activity, and the Institution is keen to be involved, and to contribute from the breadth of its expertise which encompasses the whole innovative spectrum from university research to industrial R&D and manufacturing.

2. *Are the mechanisms for technology transfer and interaction between the science base and industry effective? How could they be improved?*

Technology transfer is an ill-defined and ambiguous term. In the UK there has been a serious gap in the total innovation process between the excellent work in the areas of basic and strategic science and industrial exploitation in term of product design. This is in part the result of the emphasis on "pre-competitive" work and the elimination of "near-market" support by the Government for both industry and university programmes.

One example which illustrates the problem can be seen in Japanese industry's domination of the high-precision high-volume mechanical engineering market, typfied by the video recorder. Machine tools capable of working to tolerances and output rates *both* an order of magnitude better than those available in the West were the key to world domination in this area, and were so identified at Government level as soon as the potential market for these products was indentified. In the UK it would not be possible under the existing regimes and rules for project support to achieve any useful level of Government support for a project of this nature, a key to "technology transfer".

A most significant process of technology transfer is by the movement of highly skilled and motivated people between and within universities and industry. The new engineering doctorate is a step towards the objective of training high quality industrail managers, and the scheme should be extended. One of the difficulties in achieving technology transfer is the complex structure of the Government research support organisations and of matching these mechanisms to the industrial scene. The engineering doctorate overcomes this by means of a close university-industrial interaction through the research and training activity.

(3) *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

A weakness of British industry is the relatively small numbers of qualified scientists and engineers employed in non-specialist parts of the organisations. The result is often a lack of appreciation in depth across the organisation, from boardroom to shopfloor, of the opportunities and risks associated with particular fields of work or products. Whether this can be explained as a "lack of competent personnel" is perhaps questionable, but it is unfortunate that when the educational system considers the quantified "demand" for technologically competent people it seems that only specialist posts apparently are considered. The same criterion is never applied to the humanities!

Japan produces many more engineers *pro-rata* than Britain and still complains of shortages, so if Britain does not experience an apparent shortfall in engineering skill it must be that we fail to utilise the potential of scientists and engineers.

A specific problem is the quality of the available technical people, particularly in terms of management and business appreciation skills. Certainly it would appear that if innovation is to flourish, a significant increase in numbers of those people possessing these parallel skills is required, both in large companies at senior level and also as entrepreneurs getting business started.

There must therefore be a much greater emphasis on the teaching of management of technology to post-graduates, either at second degree level, or as continuing career development for those already working in industry. Such training needs to integrate the engineering, financial and administrative management disciplines—there is a danger that business management schools neglect the former. The Institution would stress the importance of extending the implementation of new engineering doctorates, and also regrets the Government's decision not to set up Faraday Centres which would provide a most effective interface between university and industrial research programmes, and produce post-graduate engineers with the managerial and commercial skills which industry needs.

(4) *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

(5) *Is "short termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

(Items (4) *and* (5) *are closely inter-related and are considered together.)*

The yardstick by which international competitiveness of British Industry must be measured is by looking at world market share. To be successful it is necessary to be a major player in world markets and to maintain that position. Even companies as large and secure as IBM have lost market share and suffered as a result. In too many areas British industry is not world class.

British industry is in general not short of ideas for innovative products and services, and has adequate access to the necessary science base either from the UK or overseas, as described above. By far the largest problem is the difficulty of constructing an acceptable "business plan" which can yield suitable returns on investment against the criteria used in the UK and in the financial environment prevailing. High interest rates not only make the cost of supporting capital investment and start-up losses very high, but they also set an expectation of financial returns which are impossibly high. If money placed on no-risk deposit earns high returns, no prudent investor will invest in a business plan showing somewhat better returns, but with the associated risks inevitable in an innovative project.

Even the largest companies, who need to undertake large expenditure on innovation, are extremely vulnerable if their annual (or half-year) profits are significantly weakened by unexpectedly high R&D costs or delayed revenues due to projects being late to market.

Many hi-tech companies have R&D budgets comparable (or even greater) than their pre-tax profits, and significant deviations can have a substantial effect not only on profits but also on share prices, with the inevitable threat of takeover. Management who are prepared to take a longer term view may well find themselves replaced as victims of a takeover if they allow profitability to be depressed for the best of reasons.

It is therefore essential that the City should look, not only at current performance, but also at longer term prospects. A detailed analysis of management teams and structures, of business plans, of investment in technology, should yield a much sounder evaluation of future profitability.

Unless the financial environment in the UK can be modified so that interest rates are closer to those of our main competitors for long sustained periods, and some steps taken to reduce the threat of takeover when results temporarily are depressed, all other efforts to stimulate an innovative environment will fail.

However, "short-termism" is not just an attitude which affects the City's relation to industry. Many industrial managers are "short-termist" in their approach. They concentrate strictly on operational items and do not develop professional managed approaches to development and change. A major educational initiative may be necessary, coupled with specific funding support to SMEs to help them change their culture. In contrast to Britain, German engineering companies are mainly run by people with engineering doctorates who have been properly trained in the engineering development approach.

(6) *Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?*

The pharmaceutical and specialised chemical industries are highly innovative and the UK has several successful companies of international stature in these fields. Their high level of investment in R&D is sustainable because they operate in an environment of great "industrial secrecy" and where patents have immense value—partly because infringement is relatively straightforward to prove. Conversely in the electronic and computing industries, patents are rarely of great value because there are normally a multiplicity of ways of designing circuits or software to achieve an end result. As a result the payoff from innovative R&D is often simply the consequence of being "first to market" and may only be sustained until a competitor can design and manufacture a competitive product. It does not appear to be useful to try and make comparisons across these fundamentally different industrial boundaries, but to focus more on international comparisons within similar industrial sectors.

(7) *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder this process?*

It is not easy to identify structures and institutions which are "particularly helpful" in encouraging the process of innovation. Many universities and HEIs are structured to exploit access to their science base by industry, and some sources of finance for small companies specialise in this area.

The greatest hindrances are those associated with the inability of companies, large and small, to justify the financial investment required by the innovation process against the rewards expected and the possible risks involved. If this problem could be eased, other constraints like an inadequate supply of people of adequate quality would probably also be solved, and it does not appear that "shortage of ideas" or "unwillingness (of middle management) to accept innovation" are factors which would then be serious problems.

Memorandum submitted by Professor D L Georgala, CBE Director, Institute of Food Research (12 July 1993)

I am writing in response to your letter of 25 May 1993, inviting me to make a submission to the above inquiry.

Before responding to your four questions, just a note about the Institute of Food Research (IFR) of which I am Director. The Institute is the leading UK Institute for basic and strategic research on food safety and quality; diet and health; and the impact of new technologies, particularly biotechnology. It is funded by the Office of Science and Technology (OST) through the AFRC, but also takes on strategic contracts for MAFF, and for manufacturing industry, and is increasingly winning EC research projects.

With a staff, plus visiting workers and research students, of some 480, it is based on two laboratories —at Reading and at Norwich.

I was appointed Director of the Institute and Director of Food Research of AFRC in 1988, after a long career in food research an technology with Unilever plc.

In the past five years IFR's science has been totally restructured to put in place advanced research on key topics relevant to food, and very substantial investments have been made available by AFRC for this purpose.

In answering your questions I have, therefore, reflected some of the initiatives we are taking in the Institute, as well as providing some personal observations.

My answers to your four questions are as follows:

1. *What, in your view, is the most fruitful relationship between research and application? How do they interact?*

The relationship is a two-way process. Firstly, there are messages from the market place and from investment strategies of industrial companies as to what are the likely opportunities for innovation in new products or processes. At the same time there is science and technology "push" arising from new knowledge which leads to the first recognition of new options which then have to be tested. In some cases these new options will meet an already recognised market opportunity. In other cases the new science "push" options may generate new thinking about possible market opportunities.

In the food and drink industry both of these are likely to operate. Firstly, the industry is highly sensitive to its markets. On the other hand the industry depends upon a very broad science base from which innovation could arise, ranging right across from basic biology through to physics and engineering.

The food and drink industry may, however, be rather different from other industries in that scientific or technical information, or specification, usually does not in itself sell the product to the consumer. This may relate to the widespread interest in naturalness and quality and taste, and the strict requirements concerning labelling and food product claims. Scientific knowledge may have been important in developing a product's composition, or its processing, preservation and packaging, but this would not usually be mentioned in advertising or labelling, or in the ingredients list.

With this background it is clear that those responsible for research should be sensitive to the special nature of the food and drink market place, the sensitivities of consumers, and the general trends in demand, e.g., convenience, naturalness, purity and safety, healthy eating, etc. On the other hand the scientists in key basic and strategic areas must have the capability to transmit new knowledge in a form which allows non-specialist food industry professionals to recognise potential innovations.

There is no one process for this and the procedures will differ in different sectors of the food and drink industry and with different types of innovation, and between large and small companies.

In the Institute of Food Research (IFR) our output is organised to stimulate innovation. Our mission is basic and strategic research on food safety and quality, diet and health, and the potential of new technologies, particularly biotechnology. We carry out one to one confidential projects with individual companies, as well as collaborative programmes with industry funded by the Government LINK scheme. At an international level IFR is very active in EC funded research programmes which involve European industry more widely.

2. *Do you consider that you are well informed about technological interaction with industry? If not, what do you think should be done to improve things?*

The Institute of Food Research is indeed well informed about technological interaction with industry. A number of steps have been taken in recent years to improve the contact with those parts of industry where technological innovation is most likely. At a structural level we have established Visiting Fellows to the Institute, which include senior industry technologists. The Institute has an Advisory Board, which includes Chief Executives of key companies, and is currently chaired by the Chairman of Weetabix (Mr Richard George), who is also the President of the Food and Drink Federation—the main trade association for the industry. The AFRC Food Research Committee, which also offers advice, includes industrial scientists. Scientists of IFR have many additional informal contacts with industry technologists.

Programmes carried out at IFR under MAFF commissions are largely concerned with safety or wholesomeness of food, e.g.

- Understanding how food structure and composition influences growth of food poisoning bacteria.
- Molecular characterisation of botulinum toxins.
- Influence of dietary fatty acid intake on serum and membrane function in man.

MAFF commissioned programmes—where appropriate—have programme managers from industry appointed by MAFF, who maintain close contact with Institute scientists.

The Institute has been particularly active within the Government's LINK programmes to develop collaborative projects with industrial companies, and through this route we are growingly involved in interactions with industry. Current examples of LINK projects with industry include:

- The optimisation of solid food processing operations.
- Principles determining quality of processed cereal products.
- The incorporation of water into foods containing fat.
- Heat induced flávour formation in foods.
- Improving the flavour acceptability of reduced fat foods.

Under the AFRC funded Co-operation with Industry Scheme, IFR has a number of projects with food companies, including advanced research on ethanol fermentation, and on food flavours.

More widely the Institute of Food Research is becoming a major player in EC funded collaborative programmes, which brings us into contact with a wider range of European industry, and which also brings to our scientists experience of technological developments across the Community.

IFR has recently been awarded 10 projects in the second round of the EC Agro-Industry (AIR) programme, which include research on topics such as:

— Spoilage yeasts in food and beverages.
— Food composition and allergy potential.
— Enzymes for pectin manufacture.

The food industry and food scientists need to be sensitive to consumer perceptions and behaviour. In 1990 the Institute, therefore, set up a Consumer Sciences Department, which now has research projects on the nature and origin of consumer attitudes about new food technology.

The implications of biotechnology for innovation in food and drinks poses major questions for the coming years. In the past year IFR has jointly, with the National Consumer Council, hosted workshops on food biotechnology, to explore with consumer groups the perceptions of the risk/benefit balance associated with possible biotechnology innovation. These workshops serve to improve mutual understanding, and to improve the climate in which industrial innovation will have to operate.

Further initiatives taken by the Institute of Food Research, are to establish joint fellowships with the Food and Drink Federation for research on nutrition at the Institute, and we are currently exploring intellectual partnerships with individual companies and with the industrially sponsored research associations. We believe these activities are fully in line with the spirit of the Government's White Paper on Science, Engineering and Technology.

As mentioned above, LINK is an important vehicle for collaboration with industry. We would welcome any steps which make LINK more flexible and easier to operate.

3. *Is good advice on interaction with industry readily available to you? If not, what do you think should be done to improve things?*

Given the above contacts at various levels with leading industry figures, we believe that good advice is available on how to further develop interaction with industry.

4. *Do you have personal experience of interaction with industry which you think could be usefully passed on to other research workers? If so, how might this best be done.*

It so happens that I do have personal experience on this question having worked for many years in industrial research and as Head of Unilever's Colworth Laboratory, before becoming Director of the AFRC Institute of Food Research in 1988. Most of my experience, therefore, relates to the special nature of innovation and market forces and the role of science in the food and drink sector. Inevitably, I would have experience and observations that are useful to research workers elsewhere. For example, this has been made use of in AFRC by my personal appointment to the Director General's Think Tank. I imagine some of my experience would be useful more widely, perhaps in the biological/biotechnological industries, where I have experience in research policy and as a co-author of the OECD report on biotechnology, agriculture and food.

My personal experience is further utilised by my role in Government advisory committees, for example, as deputy Chairman of the Food Advisory Committee, which advises Ministers on the labelling, composition and chemical safety of food, including food additives. I am also a member of the Advisory Committee on the Microbiological Safety of Food, which advises Government on food safety issues and policies.

Other ways in which my experience has been more widely available are:

As a member of the LINK Food Process Sciences Committee.

As a member of the Advisory Committee of the Food Science Department at the University of Leeds, where I am a "visiting" Professor.

Although many of the activities mentioned above are concerned with policy and advice, they bring me into wide contact with other scientists and scientific leaders, and in many cases issues of the interaction of science with industry are pertinent.

Memorandum submitted by the University Directors of Industrial Liaison (14 July 1993)

INQUIRY INTO INNOVATIVE AND COMPETITIVE TECHNOLOGY

I am responding on behalf of the University Directors of Industrial Liaison (UDIL) to the general invitation to submit evidence to the above.

I should perhaps first explain that UDIL is a part of the informal sub-structure of the Committee of Vice-Chancellors and Principals (CVCP). UDIL's membership is drawn from every one of the "old" UK universities. UDIL's main subject interests are in research-related matters, including technology transfer. Negotiations on a merger with The Academic Industry Links Organisation (AILO), the nearest equivalent to UDIL in the "new" universities, are close to a satisfactory conclusion.

UDIL sees itself as an engine of change. The encouragement given to universities by Government over the past decade to lessen their dependence on public sources, and to increase the funding they attract from the private sector, has required a substantial change in attitude both by the academic community itself and by the sponsors of academic research from industry, commerce and Government Departments. Changing attitudes is rarely easy, and so it has proved in the case in point. Nevertheless—slowly but surely—progress has been made, and UDIL can rightly claim to have contributed significantly to this progress.

The changes required encompass attitudes toward cost recovery on commissioned research and towards ownership of intellectual property. In former times universities paid little attention to the recovery of research overheads when they worked for industrial sponsors. They were content to accept contracts at prices which usually covered marginal costs only, rarely requesting any significant contribution towards their overheads. Furthermore few universities took much interest in intellectual property management and royalty payments, particularly before 1985 when the British Technology Group's right of first refusal to exploit intellectual property from academia was still in operation.

One important activity, aimed at introducing change, which UDIL undertook several years ago was the preparation of a comprehensive guidance document for negotiating research contracts. This was subsequently endorsed and published by CVCP and circulated to all UK universities—*Sponsored University Research: Recommendations and Guidance on Contract Issues; CVCP Guidance; June 1992*. The document has undoubtedly been of great value to universities.

It does however suffer from one major disadvantage; the principles it enunciates have not been ratified by a body representative of industry. An attempt is now being made by UDIL to involve in this role the Confederation of British Industry (CBI). The stage has been reached where an informal group serviced by CBI called the Inter-Companies Academic Relations Group (ICARG) has begun meeting with representatives of UDIL. The object is to produce a revised document to be endorsed by both CBI and CVCP. The Department of Trade and Industry and the Office of Science and Technology have also been invited to become involved, so that the final document could also cover guidance on negotiating LINK and other projects which draw on public funds. Overall the omens for success are encouraging.

In spite of the concerted efforts of recent years, a great deal of misunderstanding still exists between industry and universities about appropriate terms and conditions for research commissioned by the former and undertaken by the latter. This is particularly true with regard to arising intellectual property and its exploitation. All too often such misunderstandings at best lead to extremely protracted contract negotiations. If a set of guidelines could be made available endorsed on the one hand by a body speaking authoritatively for industry, and on the other hand by a body speaking authoritatively for universities, this would go a long way towards removing the difficulties mentioned above. What is being sought is, of course, an equitable compromise between the rather orthogonal needs of industry and academia in these matters.

I thought that the Select Committee may wish to know about the above endeavour which is now being vigorously promoted by the universities collectively. The hoped-for end result is the creation of an environment where true partnerships between industry and academia can flourish, and one where universities can get an equitable and proper reward for the innovations they produce. This should be a spur to UK universities to give more attention to innovation and competitive technology to the ultimate good of the national economy.

Memorandum submitted by Professor John Scott-Wilson, OBE, FEng (14 July 1993)

1. Background

The evidence that I am presenting to the Committee is based on my experience:

(a) In British Aerospace where I worked up to the end of 1991, when I retired from my position as Technical Director of the Commercial Aircraft Company.

(b) In Nato's Advisory Group for Aerospace and Development (Agard), with which I have been associated since 1967, and of which I am now Chairman, and

(c) In Manchester University, where I have been a Visiting Professor for the last 12 months. The views that I present are mine, and not those of any organisation with whom I have been involved.

2. Science, Technology and Innovation

Wealth creation depends on United Kingdom industry being able to develop and market products which have a competitive edge in the world markets. This in turn requires Industry to have the ability to use innovative technology. However this alone is not enough, as has been so clearly shown in the first United Kingdom Innovation lecture given in 1992 by Akio Morita, the Chairman of the Board of the Sony

Corporation—"Science does not equal Technology, and Technology does not equal Innovation" (Ref [1]). Morita says "Basic scientific research provides us with information which, though previously unknown, only offers hints at the future. It is the engineer who can take these theories and basic building blocks and from them create technology. Technology comes from employing and manipulating science into concepts, processes and devices. These in turn can be used to make our life or work more efficient, convenient and powerful. So it is technology, as an outgrowth of science, which fuels the industrial engine. And it is engineers, not scientists, who make technology happen," and later "just having innovative technology is not enough to claim true innovation. I see true innovation to be made up of three key elements which I call the three creativities—creativity in technology, plus creativity in product planning, and marketing as well."

Wealth creation needs all three of these creativities to be brought to bear for the development of the necessary new products to succeed.

Science—basic research—can be given a relatively free hand, but in the United Kingdom we cannot afford to develop Technology as we please. This would spread our limited resources, both human and financial, too thinly to achieve the innovation goals that will bring wealth creation. This requires selectivity, and this in turn requires these additional elements of market and product planning to be part of the selection process. The challenge is the greater because the long-time cycle between science through technology to product, forces us to take a forward view of the world into which our products will be launched. The Science through to Innovation chain can never be about solving short-term market problems. We have to generate a strategy which is based on an assessment of the competitive marketplace of 10 to 20 years hence.

In the United Kingdom we have a good Science culture based on the intellectual strengths of our Universities, but there is poor perception of the boundary between Science and Technology. Universities are moving into Technology development in an unstructured and hence ineffective way. Our development of Technology, when planned, has a fair record but it has often lacked both the financial backing and the urgency to give us a lead position in product development. An example of a national technology programme that has succeeded is the development of computational fluid dynamics. Here a programme involving a Government defence research establishment and industry developed the basic scientific ideas from the universities into a proven design process which has led to our success as designers, and hence manufacturers, of the wings for the Airbus family of aircraft. In the past we have too often invested in technology-led products like Concorde, an outstanding technological achievement but a market failure with sales of only 14 aircraft. The market drivers were not properly assessed at the time the launch decision was made. We undertook the basic scientific work on carbon fibre for composites, but we did not develop the manufacturing processes to enable us to be the leaders in marketing the product. This was given to the Japanese. We invested heavily in the use of linear electric motors and magnetic levitation for railway trains, but the market was not there.

We tend to develop an "inventor" mentality, rather than a "product" mentality. Innovative products come from the team approach, that brings together technology, the market, and product planning, as Morita has so clearly described. Getting the right technology decisions requires more than the enthusiasm of the engineers or scientists putting forward their proposals.

3. CURRENT ATTITUDES TO MARKET FOCUSSED RESEARCH

Government. The position taken by Government is that except for Defence where Government is the product funder and purchaser, funding should only be provided for research which is generic. This is, I believe, the result of the very British concept of trying to avoid support to any specific organisation and the accusation of unfairness. This is a valid argument if we only do research which is applicable to near term projects, but quite invalid if the research is aimed at long-term product application. By applying "generic" to Science and Technology we miss the opportunity to achieve Innovation and lose out on wealth creation. By applying market focus at the early pre-competitive stage of the Science, Technology, Innovation chain the Government could help to launch wealth creation and avoid the accusation of unfair support.

Our competitors in the world markets are well aware of the need to focus on national market driven research. This has always been a hallmark of the French, who succeed in bringing together Government Science, Industry, and Academia, to the overall benefit of product innovation and market success. Their successful nuclear programme, which has led to major exports, and their TGV high speed train, are but two examples.

In the United States there is a marked change in approach. A recent report to Government on Aerospace funding (Ref [2]) removes such extreme technology-led projects as their orbital National Aerospace Plane, from the high priority list, and replaces it with civil subsonic airliners as the top priority item for funding. This is a direct response to the success of Airbus, and requires a corresponding response from the European nations in such areas as laminar flow control. If Airbus is not to be squeezed back in the civil airliner market.

In a different marketplace the Los Angeles City Council is funding a multi-disciplinary multi-organisation study with a simple task definition—reduce vehicle exhaust emissions to zero for 600,000 vehicles on the streets of Los Angeles by the end of the century. This study brings together in a single market-focused team the whole range of engineering skills, from chemical to aerospace, coming from local industry, academia and city planners.

Industry. Although most industrial organisations see the need to invest in long-term research, their ability to do so is often limited by the availability of funding and manpower to undertake the work. When the going is tough top management have survival in the short-term as their top priority and research, unless part of a multi-organisational activity suffers. Getting an Industry wide view of the long-term market in any sector, and hence the Science and Technology goals to be achieved is by no means easy, but is vital.

The Aerospace sector has succeeded in producing such an industry-wide plan (Ref [3]) for the DTI Aviation Committee, on which the major companies in the sector are represented. From my limited knowledge of the other sectors I believe that they have not tried to do this, as they have never been challenged to do so.

Academia. The approach to research in the Universities seems to be a curious mix of a traditional belief in academic freedom to go entirely their own way in deciding what research topics they will undertake, and an unquestioning acceptance of any work that will bring in funding. They have a belief that they have a better view of the future offered by Science, but I see little understanding of the Science, Technology, Innovation chain. At best their understanding of how Industry develops products through Technology is hazy.

4. Key Technologies

The Government White Paper on Science and Technology (Ref [4]) includes a commitment to undertake a major exercise in Technology Foresight as a means of gaining early notice of emerging key technologies. In my view this will only be effective, and beneficial to the nation if it follows the logical process set out below:

(1) Identify the future market needs/user problems—20 years out if need be.
(2) Establish the whole range of technologies that might be available on the timescale.
(3) Establish conceptual "product" solutions, based on these technologies, to meet the market needs in 1 above.
(4) Make a simple cost/effectiveness analysis of the alternative "product" solutions.
(5) Determine the best solutions.
(6) Hence identify the best technologies for support.

This analysis starts with the market and ends with key technologies—it is about "problems looking for solutions" not about "solutions looking for problems."

The effectiveness of this approach has been demonstrated many times in Agard studies for Nato with which I have been involved. In particular in 1977 Nato's Military Committee asked Agard to describe "with relation to the most probable technological trends/developments, the state of the art in the year 2000, and the conceivable military applications in terms of systems".

The first step taken by Agard in its "Project 2000" was to ask its technology panels to list their view of most likely technologies. This produced a very large, and quite useless book of technologies, as everyone wanted to make sure that his special interest was included. To make progress the military were then asked to define their most important operational needs—the market input.

From this statement of need three major study areas were refined. Studies on the lines described above then produced an output of best technologies that enabled a focussed programme of development to be undertaken.

In British Aerospace we undertook a similar study "Air Transport 2010" in 1989 to determine "How do we best meet the needs of the civil aircraft market in 2010, and where should we spend our research effort". This study started with the market projections for 2010, not with the project dreams of engineers. Much of the end product of this study is incorporated into the National Strategic Technology Acquisition Plan for Aeronautics referred to above.

These studies used a two-tier system. A study group of younger creative people undertook the study to terms of reference set by a senior review board. Their work was reviewed at mid-term, and again at full-term by the review board. The members of the study group were drawn from those with a wide range of relevant experience, but were there as individuals, not as the representatives of their parent organisations. They were given free rein to consider any possibilities during their group discussions, but were required to report as a group to the senior review board. The fact that valuable studies have been accomplished for NATO in this way with study groups of 20 or so people from government science, industry, academia and the military, drawn from seven or more nations, demonstrates the power of the study method. By bringing creative minds together in this way best technologies have been identified leading to innovative solutions, rather than a repetition of the long-held opinions of those in senior positions.

The White Paper states "a closer partnership, and better diffusion of ideas between the science and engineering communities, industry, the financial sector, and government are needed as part of the crucial effort to improve our national competitiveness, and quality of life". I believe that in trying to establish such a partnership the study group approach would enable creative people from the different parts of the community to come together to propose common national goals. Senior members of the community would form the review board that set up, and approved the studies. The Technology Foresight Steering Group might consider this as a possible way to achieve some of their objectives.

It is not hard to imagine a study "Road Transport 2010", or a study on "Tackling the Urban Terrorist".

5. SUMMARY

I believe that the country will not succeed in improving its wealth creation unless it recognises that it has to develop long-term market goals as the foundation of its Science and Technology strategy. This requires a change on the part of Government, abandoning its obsession for "generic research". It requires the establishment of national targets in tomorrow's world marketplace. We will then be providing Industry with the technologies that will enable it to produce the innovative products on which our future wealth depends.

A study method, originally developed and proved in Nato, is put forward as a possible way to capture the creativity of "young" minds, and also help to bring together the sectors of the community, Government, Industry, and Academia that at present have such diverse views on the way ahead.

REFERENCES

[1] Akio Morita. *"S Does not equal T, and T does not equal I"*. The First United Kingdom Innovation Lecture published by DTI. 1992.
[2] National Research Council (USA) *"Aeronautical Tehnologies for the 21st Century"*. Published by the National Academy Press. 1992.
[3] *"National Strategic Technology Acquisition Plan for Aeronautics"*. DTI Aviation Committee. October 1992.
[4] *"Realising Our Potential—a Strategy for Science, Engineering, and Technology"*. HMSO Cm 2250.

Memorandum submitted by the Science Museum (15 July 1993)

I have pleasure in enclosing a submission, on behalf of the National Museum of Science & Industry, to the House of Commons Science and Technology Committee Inquiry into Innovative and Competitive Technology. By way of background this letter contains information about the Museum.

We should be happy to furnish you with additional material on our various initiatives in, for example, the various fields of education and the public understanding of science in which we believe we play an important leadership role, if this would be helpful to the Committee.

The National Museum of Science & Industry welcomes the inquiry of the Science and Technology Committee into the routes through which the Science Base is translated into innovative and competitive technology. Identified as the key to the governance of science and technology in the recent Government White Paper *Realising our Potential,* the successful exploitation of science and technology in industry is crucial to Britain's future as a manufacturing and trading nation.

The National Museum of Science & Industry is the world's foremost museum of scientific and technological endeavour. Our principal goal is to promote public understanding of the history and the contemporary practice of science, medicine, technology and industy. With some 3 million visitors annually across our three principal sites (the National Museum of Photography, Film and Television, Bradford; the National Railway Museum, York; and the Science Museum, London) we play a leading role nationally fostering greater public awareness of and interest in scientific and industrial innovation. We serve a larger number of pre-booked school parties than any other institution in the country; and we believe that we have a particularly important role to play in the field of education.

INTRODUCTION

The National Museum of Science & Industry endorses the Office of Science and Technology's concern to secure the Science Base in this country and to harness it more effectively in the service of wealth creation and enhancement of the quality of life. We welcome the recent White Paper on science and technology, *Realising Our Potential.* This provides a lead by underlining the need "to give a clearer sense of the vital national contribution made by the ideas, inspiration and dedication of our science and engineering communities" (p. 7), by setting out a framework for the more effective exploitation of science and technology, and by underlining the importance of promoting public awareness and understanding of science and technology.

OBSTACLES TO THE EXPLOITATION OF SCIENCE

The White Paper makes a number of important new provisions for linking scientific and technological innovation with wealth creation and the improvement of the quality of life. The Forward Look, the Technology Foresight Programme and the creation of the Council for Science and Technology will all contribute to these goals.

At the same time, we believe that it is important to recognise and overcome a number of major obstacles that lie in the path of the successful nurturing of the country's scientific and technological endeavours. We should like to draw the Science and Technology Committee's attention to three obstacles in particular.

First, we believe that the extremely specialist nature of our educational system at the post-16 level continues to encourage an unhealthy and counterproductive split between the cultures of the sciences and the arts. A broader system of post-16 education that requires all students to take at least one science and one arts subject would help to break down a "two cultures" mentality that works against the proper integration of science and technology into the economic and social life of the nation.

Second, we believe that at present the Science Base suffers from a lack of adequate career opportunities for gifted young scientists. For most of the past century, Britain has been very near the top of the international scientific league table. There is some evidence to suggest that we have already slipped somewhat from this high position. Arresting and reversing this decline depends crucially upon encouraging our most able young people to continue with careers in science and technology.

At present, the career prospects for post-graduate and post-doctoral students are so bleak that some even among our most highly skilled young scientists are choosing to leave the world of science altogether. There has been a sharp increase in the proportion of scientists who are working on fixed term contracts. While there is a proper place for fixed term research contracts, it is vital that these should not undermine the planning of longer-term research programmes within the context of long-term research careers.

A third obstacle in the path of the successful harnessing of science and technology in the service of wealth creation is the comparative lack of strategic support for research and development within British industry. In certain areas (such as the chemical and the pharmaceutical industries) long-term investment in strategic research has taken place, and here competitive and commercial advantages have clearly been obtained. Elsewhere, by comparison, Britain's science-based industries have been far less successful in the international market-place.

There is a need to develop much closer links between the scientific and engineering base and those who are responsible for industrial and commercial decisons, including the financial institutions of the City of London, with a view to the more effective support of R&D all the way from initial conceptions to eventual successes in the market place.

The National Museum of Science & Industry is a national forum for discussion concerning the place of science, medicine, technology and industry in the life of the nation. We look forward to playing our part in facilitating the debate about science and technology policy in the interests of wealth creation and the enhancement of the quality of life.

Valuing Science in the National Culture

We should like to bring to the attention of the Science and Technology Committee the very great importance of fostering a national culture in which science and technology are highly valued. A national culture that values science and technology is an essential pre-requisite of continued scientific and industrial innovation; yet in the past the fostering of such a culture has not figured prominently in the development and implementation of science and technology policy.

We welcome the fact that the White Paper calls for a new campaign to spread the understanding of science and technology in schools among the public. This campaign should build not only on the work of the Committee for the Public Understanding of Science (COPUS), in which we are closely involved, but also upon our own Public Understanding of Science Initiative.

The Science Museum plays a leading role nationally in the promotion of public awareness and understanding of science and technology. With the appointment in 1989 of a new Assistant Director who was also the first Professor of the Public Understanding of Science in the country, the Science Museum launched an initiative which has come to embrace new research and teaching programmes, new exhibitions and public displays, and new educational initiatives.

We collaborate closely with Imperial College in the conduct of research on public perceptions of science and science in the media. At the same time, we have developed with the College the first post-graduate MSc course in Science Communication. This course, now in its second full year, produces graduates with the skills that are needed to bridge the yawning gap between science and the general public.

The Science Museum is also pioneering new exhibitions that complement its historical collections by providing topical displays on the latest ideas and issues in the world of science and technology. "Science Box", a fast-changing series of exhibitions devoted to contemporary science and technology sponsored by Nuclear Electric plc, provides visitors with a glimpse of the cutting edge of science and technology. A recent Science Box dealt with new evidence concerning the health effects of passive smoking; and the current exhibition in the series deals with the nascent area of nanotechnology.

The Science Museum sets very high store by its educational programmes. Currently, the Museum is investing £2.25 million in a new Education Centre which will open up the world of science and technology for students of all ages. We are continually developing new educational programmes in order to win new educational audiences. For example, we have recently launched "Science Nights", a programme in which several hundred children camp in the Museum overnight in order to participate in a wide range of scientific activities.

PUBLIC AND PRIVATE SECTORS WORKING TOGETHER

The fostering of a broader and deeper public understanding of science and technology will involve partnerships between government and both the public and the private sectors. We believe that it is crucial for government to give a clear lead to, for example, the Research Councils, by requiring them to include the promotion of public awareness and understanding within their formal remits and by providing specific incentives for public awareness programmes. At the same time, we look to government to encourage joint ventures between the public and the private sectors, with a view to transforming public awareness, public interest and public understanding in ways that will be of lasting economic, social and cultural benefit to the British people.

CONCLUSION

The White Paper calls for a national campaign to spead the understanding of science and technology in schools and amongst the public. The National Museum of Science and Industry is determined to play a full part in this campaign. We look to the Science and Technology Committee to support this campaign, which will contribute to bringing science and technology to the very centre of the nation's economic, social and cultural life.

Memorandum submitted by Cambridge Econometrics Ltd (16 July 1993)

INNOVATION, COMPETITION AND UK ECONOMIC PROSPECTS

INTRODUCTION

1. This note is concerned with the contribution of industrial innovation to UK industrial and economic performance in the 1990s. It reports on some conclusions arising from research undertaken by Cambridge Econometrics using a large-scale industrial model of the UK economy (the "Cambridge industry model") which suggest that innovation plays an important role in the long-term prospects of the UK economy and that measures to promote innovation may be highly cost-effective whilst at the same time contributing towards reducing the PSBR and the balance of payments deficit. Such measures must be instituted and financed by government simply because the social returns are likely to be far higher than the private returns.

2. Economic policy over the past 15 years has conspicuously failed to produce full employment with the PSBR and the balance of payments at sustainable levels. One reason has been that policy has been concerned primarily with the short-term outlook for macroeconomic variables such as inflation, the money supply and the PSBR rather than with prospects for long-term industrial competitiveness. Innovation policy appears to be one area where policy, at a relatively small short-term cost to the Exchequer, can yield substantial long-term benefits.

3. These are generalisations, and the result for innovation policy comes from one particular model of the UK economy, but the conclusions are so striking and important that at the very least they justify further research using other models and methods to check their validity. If the findings are confirmed then a substantial change in direction of UK innovation and competition policy is warranted.

INNOVATION AND THE TRADE DEFICIT FOR MANUFACTURING

4. In the last three years some of the political debate about the Government's handling of the economy has focused on the fact that the UK now has a very substantial trade deficit for manufacturing industry. In 1990 this deficit stood at £24 billion. The industries with the greatest individual trade deficits have been Electronics, Motor Vehicles, Manufactured Food, Textiles, Clothing and Footwear, Timber and Furniture and Paper and Board. These have been offset by large trade surpluses in the Chemicals and Aerospace industries.

5. This trading performance has been widely attributed to the failure to secure a strong domestic industry over the long term, and in particular to a failure to compete in technological innovation. Reports from the House of Lords (1991) and the CBI (1991) have focused on UK industry's commitment to innovation as a source of long-term competitive advantage, and also on the appropriate policy stance. Only the Chemicals and Aerospace industries have a consistently good record in this respect, though the reasons for this go beyond the notion of a "cluster" of strong firms as advocated by Porter (1990). In particular, government support for innovation in these two industries has been substantial and has represented a significant reduction of risk to industry. In Chemicals, this support has been indirect through the pricing mechanisms for new drugs; in Aerospace the support has been much more direct through DTI launch aid. Also, in Chemicals in particular, there has been an instrumental role played by the strength of the science base, another form of indirect support for industrial innovation.

6. Although the long-term growth of UK manufacturing is dependent on industry's relative innovation performance, the short-term performance is more influenced by the pattern of past and present inward investment. As above, the case of the Motor Vehicles industry offers one indication of where UK manufacturing is going over the next 10 years. The commitment to the use of the UK (rather than other European countries) as a manufacturing base by the American multinationals Ford and GM has increased in recent years, partly as a result of improved productivity and labour relations. Unit costs remain low by European standards, and this has attracted other manufacturers, notably Peugeot and Nissan to invest heavily. Future production by Honda and Toyota should re-establish the UK Motor Vehicles industry as one of the largest in the world. The ability to export to other European markets in particular are a critical part of the plans of the Japanese car manufacturers.

7. Other manufacturing industries are also benefiting from the UK's position as a low cost base relative to other European countries. In non-defence electronics, the bulk of UK output is now controlled by overseas-based multinational companies such as IBM, Compaq, Sony and Philips, and it is expected that exports will increase in the Single European Market. The overall impact in the short term of improved trade balances in transport equipment and other engineering will be to offset increasing deficits in other sectors, notably other manufactures (the principal components of which are increasing deficits in Textiles and Clothing and Footwear). In the long term, the strongly increasing supluses in transport equipment and other engineering should more than offset increasing deficits elsewhere.

THE ROLE OF FOREIGN TRADE

8. The key to success for manufacturing and the economy in the 1990s lies in the area of foreign trade. This is for two reasons. First the serious imbalances in the economy, evident in the huge balance of payments deficits of recent years, will require a fast rate of growth in exports relative to that in imports in order to stabilise the position, let alone to correct it. Second, the UK economy has become so closely integrated with the rest of the world that in many goods and some services the efficient scale of production is such as to supply the European if not the world market.

9. Since manufactures tend to be more tradeable than services, the export market is much more important for manufactures. In 1989 exports, at over 24 per cent of total demand, were twice as important for manufacturing than for services. In contrast, consumers' expenditure, at 19 per cent of the total, was less than half as important for manufacturing than for services.

INNOVATION AND UK TRADE

10. Previous research, both of a theoretical and empirical nature, suggests that innovatory activity is becoming an increasingly important element in international competitiveness and the trading performance of nations (see Greenhalgh *et al* (1990a) and Englander *et al*, (1988) for details). Previous econometric work for the UK by Schott (1984) and by Hughes (1986) had established important links between patenting and trade performance using cross-sectional data sets. However, relatively little work had been done using time-series data (see Erber, 1988). New empirical work has developed this research in order to improve the modelling of trade performance within the Cambridge industry model, based on work conducted as part of a project on Competitiveness, Trade Performance and Employment in the UK Economy funded by the ESRC. Further details of the project may be found in Greenhalgh (1990) and Greenhalgh *et al* (1990a and 1990b). The project aimed to establish whether there was hard evidence of a link between trade performance and innovatory activity within the UK economy. A secondary hypothesis concerned the effects of supply interruptions on competitive performance.

11. In order to test these hypotheses using time-series methods, measures of innovatory activity were assembled and entered as additional explanatory variables into the various econometric equations within the model concerned with trade performance. The amended equations were then embodied within the Cambridge model. The original econometric methodology followed the "general-to-specific" modelling approach within a cointegration framework. Subsequently this has been modified when incorporating those effects into the Cambridge model with the innovation and supply disruption variables simply being added into the existing specifications within the Cambridge model for import shares, export quantities and export prices.

12. The collection and processing of data constituted a major component of the research. Ideally, measures of UK innovatory activity relatives to those in its main competitors, were needed on a regular annual basis, at a detailed industrially disaggregated level covering most of the post-war period. The data collected fall into four categories: innovations; patents; research and development activity; and miscellaneous—including measures of supply interruption. In each case the available information had to be manned into the industrial classifications used in the Cambridge model. This required a very detailed examination and comparison of the systems of classification used in each case. In a number of instances this involved comparing classifications across countries. For some variables further processing was also necessary in order to create the final time series data required. In some cases this involved detailed interpolation of missing values.

13. Data on innovations represent the outcome of the innovatory process. The series adopted was that developed by the Science Policy Research Unit (SPRU). It represents "important" innovations as defined by

a panel of experts. Its main advantages are that it is available at an industrially disaggregated level over a long time period (1945-83). Its main limitations are: that it is not a relative measure, relating just to UK innovatory activity; that the industrial classification used was the 1968 SIC whereas the current version of the Cambridge model used the 1980 SIC (industries are classified according to user or producer of each innovation); that it does not cover the most recent period, 1984 to date. It was therefore necessary to extend the series by extrapolative methods when estimating the latest version of the equations for the Cambridge model.

14. Patenting activity represents an alternative measure of innovatory activity. It is well established that different industries have different propensities to patent. It was therefore decided not to use data on patents taken out in the UK. This decision was reinforced by problems incurred in attempting to assemble the UK data into useful time series by industry. A potentially much more valuable data set exists in the form of the series collected in the United States by the Department of Commerce, Office of Technology Assessment and Forecasts (OTAF). These data indicate the level of patenting activity by industry conducted by most major countries within the United States. Given the latter's key role in innovation and the world economy generally, these data provide a potentially very useful measure of relative innovatory activity in different countries. However, the data suffer from a number of limitations as far as the present exercise is concerned: the time series only cover the period from 1968; the industrial classification used is a US one (although the problems of mapping to UK sectors is probably only marginally more problematic than those incurred in the innovations data when comparing the 1968 and 1980 SICs); and finally, by their nature, patents tend to focus attention on manufacturing industries rather than the service sector. (Again, however, this is also a problem with innovations data).

15. The third measure considered was Research and Development Expenditures (and related employment). In contrast to the previous two indicators this is a measure of input rather than output from innovatory activity. The OECD publishes a series of data on R&D activity by industries for major economies. These, in principle, enable relative measures of UK performance to be constructed. In practice, the OECD data are based on irregular surveys conducted within each individual country. There are therefore large numbers of missing observations. A considerable amount of interpolation and adjustment was therefore necessary to convert these data into a usable form for time series analysis. They also suffer from similar problems of matching industrial classifications and time scale coverage as the other series already discussed.

16. Amongst the miscellaneous category can be included attempts to find series on employment of scientists and engineers, etc., to use as time series indicators. Although some information was collected, this proved impossible to use within a time series model framework. The most important item which should be mentioned here is the attempt to measure supply disruptions. In addition to the central hypothesis that competitive performance depends upon innovatory activity it was also intended to examine how supply disruptions might affect performance. This was proxied by two measures—the level of strike activity and working days lost. The former proved the more significant in the econometric work.

17. The final analysis was conducted for 36 industry groups covering both manufacturing and services. Moving averages of the innovation variables were taken which represent crude stock figures for knowledge capital, with high depreciation reflecting diffusion and loss of monopoly. The main focus was on equations which explain the volume of UK exports and imports at a detailed industry level (see Landesmann and Snell, 1989a and 1989b for further analysis of the export equation). A simple constant elasticity function reflects the view that consumers are concerned as much with product quality and reliable delivery as with more conventional demand side variables. Similar relationships concerned with the determination of export prices and the share of imports to the volume of domestic sales were also estimated. The empirical results suggest that non-price factors do have a part to play in explaining UK trade performance at a disaggregated level. Given the limitations and problems with the innovation data it is perhaps not surprising that the results are somewhat mixed. Nevertheless, they suggest that worsening relative trade performance in innovatory activity has a significant role in the story of relative UK decline over much of the post-war period and that, before the recent improvements, poor industrial relations also contributed to trade failure.

18. In terms of volumes there appears to be quite strong evidence of a positive effect of innovation on exports, particularly in manufacturing. For the price side of the picture both significant positive and negative effects are found. In some cases, innovation appears to have resulted in product enhancement and consequent price rises. In other cases the main effect has been to enhance productivity and lower prices.

THE ASSUMPTIONS AND THEIR EFFECTS ON THE ECONOMY

19. A stylised set of assumptions has been chosen to represent a new policy of promoting innovation as a long-term policy for the UK economy. These are described below, together with secondary associated assumptions and their main consequences. The results are conditional upon, amongst other things, the mix of assumptions. However, the importance of achieving *all* the desired changes *together* as part of an overall programme of improvement in the performance of the manufacturing sector has been stressed by Barker (1981) and Yates (1992) for example.

(1) *Increases in Innovation*

The level of innovation, as measured by a number of indicators is assumed to be increased by 10 per cent above base for the period 1993-2000. This increase is achieved in modelling terms by increasing the rates of innovation in the export and import equations by 10 per cent above base for each of the forecast years. An analysis following closely that by Greenhalgh *et al* (1990) has been made of the effects of innovation on volumes of exports and imports and unit-values of exports as classified in the Cambridge model. New equations incorporating the innovation variables have been introduced into the model, which gives the scope for running scenarios based on higher levels of innovation performance by UK industry. Two other points are worth making, following the study by Geroski (1991) on innovations and productivity by industrial sector. First, the use of the innovations is perhaps more important than their production for increases in productivity and trade; and second the beneficial effects of innovation take place over some 10 to 15 years, so it is a long-term policy.

(2) *Education and Training*

The growth of local authority spending in real terms on education is increased by 5 percentage points 1993-96 and 4 percentage points 1997-2000. Increased spending by government on education and training is seen as a crucial requirement to increase productivity, to innovate and to develop overseas markets. Local authority spending on education and related activities has been raised to 7 per cent per annum 1993 to 2000, compared to the 2 per cent per annum of the base forecast. No doubt this would have to be supplemented by spending in the private sector, although no specific assumptions have been made here. It is worth noting that spending by the company sector in the UK on training compares unfavourably with that in, for example, West Germany even allowing for the relative size of the economies.

(3) *Increased Marketing*

Private sector resources devoted to marketing in the Single European Market are assumed to be increased sufficiently to raise export growth in line with the effects achieved by the changes to the innovation variables.

20. Extra investment by industry is required to support the increases in innovation and training and to improve the quality of exports and products competing with imports. It is assumed that in the first instance, increased commitment to R&D will need to be stimulated by Government action, such as the research grants currently available under the SMART, SPUR and LINK schemes, rather than by the use of tax credits for R&D as has been the case in Australia. In the short and medium term, increased corporate spending on R&D may lower profits and hence corporation tax revenues to the government, but in the long term this is likely to be offset by higher corporate profits resulting from increased competitiveness. Therefore no attempt has been made in modelling the "innovation" scenario to alter corporate profits and corporation tax revenues.

21. These assumptions were introduced into the version of the model used to produce Cambridge Econometrics' November 1991 industrial forecast. Modified sets of similar assumptions have been used in subsequent forecasts to provide the basis of the "high growth" scenarios presented as an alternative to the main forecast. The results below describe the differences between the scenario with the strong innovation policy and associated supporting policies and the base forecast.

22. The outcome is growth of about 4 per cent per annum on average 1995-2000, compared with a base case forecast of some 2.8 per cent per annum; the high growth is comparable to the rates during the 1980s boom, but on a more economically sustainable basis. Unemployment falls to just under one million, close to full employment, compared to the 1.8 million unemployed which might otherwise be expected. The balance of payments moves into surplus by the mid 1990s. Although the manufacturing share of GDP rises to 27 per cent, the employment share continues to fall to 18 per cent due to the higher productivity. The rate of *price* inflation is slightly increased, in part due to a higher rate of *wage* inflation coming from the much lower levels of unemployment. The inflationary effects of a tighter labour market are offset by the reduction in unit costs achieved by higher productivity. The slightly higher price inflation also represents an increase in quality attributable to the innovation effects.

23. An estimate can be made of the social returns to the investment in encouraging innovation, although it should be emphasised that these are uncertain and speculative results. The spending on R&D in the UK is which allowing for inflation and accumulated over the five years 1993-97 amounts to some £4.2 billion. This sum allows for a full 100 per cent coverage of the cost of new R&D. The reduction to the PSBR in current prices over the period 1993-97 is estimated by the model to be £10.2 billion, allowing for increased government spending on education and training, increased revenues from VAT and other taxes, and reductions in social security payments as unemployment is reduced. This implies a payback factor between two and three, well above other forms of social investment. This is a dramatic and important result; at the very least it is worth checking by further research.

CONCLUDING REMARKS

24. Although the assumptions are very stylised (for example it is assumed that the extra investment and training leads to the extra exports and reductions in imports after a lag of one year) the empirical results support other studies at a micro and a macro level which suggest that there are considerable social returns to investment in innovation.

25. An important qualification on the results is that consumers' expenditure is held down by the increase in the standard rate of VAT. In other words, the extra incomes generated firstly by training measures and secondly by the additional exports and investment are assumed to be partly taxed away. Thus it is argued that increases in tax rates would be necessary to restrain consumers' expenditure to the base levels, although this also implies higher government revenues and a lower public sector borrowing requirement.

26. The relation between R&D spending and innovations is complex. There is not a one-to-one relationship of R&D spending and innovations; indeed the use of innovations is probably more important than their production. Moreover, the increases in corporate R&D required to achieve a 10 per cent increase in innovations must be set against the current context where R&D expenditure has been cut heavily in many industries during the recession. An increased commitment from industry to R&D on the scale required will almost certainly require a lead from Government in the first instance and substantial fiscal incentives.

27. A programme of incentives for innovation is likely to be much more successful if it is combined with a linked programme to improve industrial training and to stimulate export demand.

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Memorandum submitted by Sir Denis Rooke CBE, FRS, FEng (16 July 1993)

The recent White Paper "Realising our Potential" Cm 2250, marks an important step forward on the part of HMG by explicitly and clearly recognising the critical importance of wealth creation to the future prosperity of Britain and the priority that must be accorded to harnessing science and technology if the nation's wealth creating performance is to be maximised.

The White Paper sets out in logical fashion the steps which the Government can take to improve the Science and Engineering Base and the benefits to be derived therefrom. Save for some reservations on the part of those most involved in research of a fundamental nature this blueprint has been widely and warmly welcomed. It now remains to be implemented swiftly and totally and there should be no holding back on the resources needed to convert aspirations into reality.

The White Paper acknowledges that there is a perceived contrast between the nation's excellence in science and technology and relatively poor performance in industrial exploitation. It is this performance which has to be dramatically improved if the wealth creating potential of the UK is to be realised. And while Governmental policies can be designed to encourage an innovative society the essential drive towards exploitation must come from industry itself and industrial managements must take active steps to improve the innovation chain. Successful companies are not solely strong in research, nor in technological application, but have skills and expertise in market appreciation, design, modern manufacturing methods, inspection and testing, quality assurance, sales and after-care. They are mission oriented but also multi-faceted in capability. Research and development input is only one link in the exploitation chain, albeit an important one. Equally, pure innovation, i.e., the introduction of novelty, is not sufficient for economic success; the innovative product or process must already command a market at a competitive price or be such that one can be created in a relatively short timescale. It is the need to satisfy, at one and the same time, all these multiple factors that renders the link between the Science and Engineering base and successful commercial exploitation complex and requires the integration of a number of otherwise discrete skills.

It is a commonly held misconception that successful innovation entails a great leap forward, based upon original research. But examination of the progress made by Japan since the last war, reveals that, although many of her new products are innovative in a market or manufacturing sense, they were based upon integrating existing scientific knowledge in an inventive way. Thus microwave ovens, video recorders, production robots, etc., were based upon scientific knowledge gained, often in other countries, two or more decades earlier. Accordingly even small companies can make a significant contribution to the economic success of the nation by focussing their efforts on incremental improvements in existing products and processes. Furthermore the financial risks entailed in such action are more readily containable for the smaller organisation.

The report of the Fellowship of Engineering "The Management of Technology in United Kingdom Manufacturing Companies", June 1991, based upon in-depth studies of 11 companies that had come through the difficult economic conditions of the 1980's with improved performance clearly indicates the need for continuous improvement in every activity by means of technical and organisational programmes, focussed on the long term and motivated from Board level. The conclusion of that report "Any Company which neglects to invest consistently in its people and in its products and manufacturing technology will ultimately fail, or fall victim to one of its more enlightened competitors" underlines the point.

The evident limits on available resources for R&D indicate that the UK will only ever be able to undertake about 5 per cent of the total world's activity. This leads to the need for focusing effort preferentially on those generic areas where we already occupy a leading position and which are likely to lead to a range of commercial opportunities. It is noteworthy that at present the level of R&D financed by industry seems to be markedly less than that of our main competitor nations although links between Universities, Research Councils and Industry are improving steadily and there has been a recent growth in industrially relevant contract research. This growth needs to be stimulated further, not only in terms of the conduct of research activity in this country, but also with the explicit objective of gaining an understanding of the results of the 95 per cent of the activity carried out in the rest of the world and to seek out appropriate technical advances therefrom. The management of small firms, other than those with an explicit high technology mission are often inhibited by their concept of the nature of R&D. For them direct experimental work is probably of lesser importance and they should be encouraged to engage in market appraisals, either directly or by contract, so as to gain a deep knowledge of their sector of the market and identify windows of opportunity for evolutionary innovation. This is not to suggest that the importance of market appraisal lies only with small firms, it is equally valid for all, but for them it may well be the only research type activity that can be justified to the Directors.

In general, if innovative performance is to be improved, it is essential that science and engineering are seen as being part of one continuous spectrum rather than a series of discrete packages with arbitrarily designed boundaries. Increasingly most scientists need to gain some appreciation of the innovation chain and to be prepared when necessary to join a development team for a project both to ensure effective technology transfer as well as valuable feedback for further research. Equally engineers and others primarily engaged in development need to be welcoming to scientific colleagues drafted in for specific projects. In the formal education of engineers and scientists aspects of innovation and commercial exploitation need to receive attention.

One of the perceived failures of the last few decades has been in the quality of design and over the years three committees have commented upon this and suggested remedies. Their principal conclusion has been that design should permeate the initial training of all engineers and become the "cement" binding together the various aspects of engineering study. No official action having resulted from these reports the Fellowship of Engineering (now The Royal Academy of Engineering) in 1988 took the initiative to establish a co-operative movement to fund the appointment of 50 Visiting Professors in the Principles of Engineering Design at 22 Universities. These Visiting Professors are all working engineers and designers and they have had a remarkable catalytic effect from linking the teaching of theory to practical problems of design and production, and in adding realism to courses. This success suggests that steps should be taken to extend the scheme to allow for the appointment of two or preferably three such persons to every University offering engineering courses. The Royal Academy would no doubt be willing to find suitable people to undertake the task, if the necessary finance were to be made available.

The translation into commercial operations of individual scientific discoveries or specialist developments is often attempted by very small companies formed by the originators of the technology. One of the principal difficulties they face is that of very early funding, for example to build and demonstrate one or more prototypes.

The sums of money are not usually large, often only £100,000 to £200,000, but there is no track record and venture capital companies are much more ready to make loans at a somewhat later stage when sales are beginning to take off and profit forecasts can be made. Furthermore, even if a loan is available it is often only for a relatively short period, usually too short to cover the period to achieving self-financing. It does appear that the process of wealth creation, as distinct from the making of profit by financial transactions, is not well understood in the City. More needs to be done to improve that understanding and to establish sources of "patient money" and real risk finance analogous to the "angels" who fund theatrical ventures.

The export of innovative products and technology can also be difficult because the "not invented here syndrome" is still very strong in some developed countries. Where this does obtain success is only likely to be achieved if the promoter is already powerful in that technological field and financially strong enough to withstand a long campaign by reason of possessing a substantial home market. This points to the need for national champions in some areas, but it has to be observed that the current fashion for the promotion of competition at all costs in all areas is already undermining some previously successful national champions, particularly among the public utilities.

An efficient wealth creating society cannot be constructed overnight and it is certain that many initiatives will have to be pursued for a decade or more to achieve optimal success. It is of crucial importance therefore that policies introduced by the Government to assist the wealth creation process achieve wide consent and are not seen as "party political" instruments. Equally they need to be maintained in a stable fashion, not subject to tinkering or stop/go performance. Alongside scientific and industrial activity must be cultural developments designed to overcome the present bias against industry of much of the public and to improve the general understanding of science and technology of the adult population. As far as schools are concerned the National Curriculum is a most important development which should lead in time to a new level of technological literacy but in this process attention should be paid to illustrating the way in which science is put to beneficial use in industry so that future generations will be more receptive to the merits of an industrial career. This may seem at first sight to be rather remote from the objectives of the current inquiry but it has been the failure to maintain public interest in and understanding of industrial enterprise that has led to the situation we are now trying to reverse. It is vitally important that a better performance once achieved should be maintained and wealth creation needs to come to be regarded as an activity of high prestige.

16 July 1993

Memorandum submitted by Lyndon Davies Associates (19 July 1993)

I have just seen a copy of your letter of 30 April 1993 addressed to University Vice Chancellors.

For the last 12 months I have been leading a team engaged in a DTI sponsored Technology Audit at the University of Manchester covering about half of the departments which might reasonably be expected to be sources of exploitable technology.

In addition to the main Audit, an additional objective was to assess the resources and organisation of the University which are concerned with the exploitation of Technology and faciliting its transfer to (hopefully UK based) industry. As part of the process I visited a number of other universities in order to examine how they organise themselves in this respect.

It is not appropriate to go into the recommendations which I made to the University of Manchester, but there are a number of general points which I would like to draw to the Committee's attention.

To be effective the university officers responsible for Industrial Liaison, Technology exploitation, research and exploitation Contracts, Intellectual Property protection, licensing and arguably also those responsible for liaison with EC on Research Grants need to be collected together as a unit in one part of the university's organisation. The manager of the unit can with benefit have significant industrial experience and should either report to or have easy access to a senior university official and best to the Vice Chancellor or Principal. Technology exploitation is an area fraught with misunderstandings and the commitment of the highest university officials needs to be apparent if the efforts of the more junior staff are to be effective. Although the message is getting through, some academics are still reluctant to engage in exploitation of technology or facilities to the financial benefit of the Institution.

In many universities the staff resource devoted to Technology exploitation, IPR, technology marketing and licensing is very small and is I believe a limiting factor on the effective exploitation of university science (defining "science" in the broader sense). Sometimes the task is entrusted to junior staff and in a number of institutions one can find an Industrial Liaison Officer or his equivalent ploughing a lone furrow with neither adequate resources nor real management backing.

While there are examples of universities that make a great success from Technology exploitation, Salford being a clear example, some are still paying lip service to the problem and the majority are not dedicating nearly sufficient resource. One curious example of serious limitation is that quite a number of the universities that I approached filed nearly the same number of patents per annum, often around 10, with only three to five of these being finally pursued to grant. I believe that this number equates one official's workload. With universities differing in size by a considerable factor I suggest that this is irrational.

I attach for the Committee's attention an extract of my Manchester report which gives my summation of the most commonly found organisation.

Concerning IPR policy most universities that I approached had a policy but the policies differed considerably between the two extremes of the individual owning his own IPR to absolutely all IPR including that generated by research students being the property of the university.

We took a full inventory of the industrial contacts between the University of Manchester and industry in the departments. We found there to be a very large number and I am sure this would be reflected in most other institutions. However, those contacts need harnessing. I am sure that there is goodwill on both the part of industry and academia but maximising co-operation and stimulating strategic liaisons requires real work and in general in my view the universities are not devoting nearly enough resource to accomplishing this end. The request for input to the Committee's deliberations would have been more meaningful if the resources had been examined as well as the output!

10.10 PRACTICE AT OTHER UNIVERSITIES, AND THE ROLE OF THE ILO

During the course of the Audit, enquiries were made at a number of other universities, Liverpool, Bristol, Dundee, Salford, Bradford and UMIST about how their organisations deal with the industrial interface, contracts IPR, exploitation, Europe and CET. Through those contacts, information on a number of other universities was also obtained.

Although there are variations, the most common structure is a single office under a senior manager responsible for:

(a) Industrial liaison.
(b) The active marketing of the university' technology.
(c) Intellectual property protection and licensing.
(d) *All* research contract negotiation and administration involving industry.
(e) European research grants (which frequently involve industrial partners across Europe and significant contractual implications).

Often, the Director of Industrial Liaison (or similar) is also responsible for:

(f) Research grants administration.

Sometimes the Director is responsible for:

(g) Research grant claims or, failing this, is located close to the research grant administration office and retains the authority to sanction changes. This duty is more likely to be included at smaller universities.

Less common is responsibility for:

(h) University companies.
(i) Central co-ordination of CET.
(j) EC student and staff mobility grants.

COMMENT

The rationale for item (f), research grant acquisition, being included is to give the Industrial Liaison Office early sight of all university research activities with a view to their current or subsequent protection, and later exploitation and, that by so doing, one senior officer of the university is responsible for ensuring that proper regard is paid to guidelines concerning costs and overhead recovery.

The case for the inclusion of item (g), financial administration, is not regarded as appropriate for a large university.

The case for item (h), university companies, is that the Director is then responsible for all aspects of exploitation, but there has to be a serious reservation that including responsibility for the companies with inevitable short-term pressures could result in a dilution of effort devoted to longer-term matters.

Concerning CET, item (i), the argument in favour is clearly that CET contacts with industry can be used to catalyse research funding but there must be concern on the dilution of management effort devoted to exploitation of technology.

EC student and staff mobility grants, item (j), are usually seen as a Registrars or Personnel function, where considerable short-term workload is not easily compatible with the quest to maximise research grant income.

SENIORITY AND RESPONSIBILITIES OF THE DIRECTOR

It is usual for the Director of the composite organisation (often described as the Director of Industrial Liaison and Research Exploitation) to report directly to a senior officer of the University to ensure that exploitation of technology and its efficient management is visibly a high priority subject. In many instances the Director reports directly to the Vice-Chancellor or Principal and never usually at a lower level than Register of Director of Finance. Even when the reporting is not directly to the Vice-Chancellor, the Director normally has reasonable access to the Vice-Chancellor, since in such a contentious area the active commitment and support of the university's senior management is seen as most important.

Frequently, the Director has delegated powers from the university to approve all outside contracts involving research funding and exploitation of technology. Often he/she also has responsibility for the approval of all research grant applications and acceptances.

In the other universities at which discussions have taken place, the overall manager of the activity more often than not has an industrial background. This seems to help liaison with industry, insofar as the industrial companies concerned see that there is somebody negotiating for the university who understands industrial problems.

Memorandum submitted by The Royal Society (23 July 1993)

1. Introduction

1. This evidence has been endorsed by the Council of the Royal Society and was prepared on Council's behalf by a group chaired by Sir David Jack. Members of the group were Professor Alec Jeffreys, Professor Malcolm Lilley, Professor John Midwinter, Mr Peter Rainger, Professor David Rhodes and Sir John Vane.

2. Before answering the questions posed by the Science and Technology Committee, the following definitions and descriptions are given to ensure common understanding of the topics discussed and of the answers provided.

(a) The *Science Base* is taken to be all the scientific, technological and engineering research postgraduate training conducted in British Universities and Research Council institutes. The general relationships between this science base and other R&D activities in Britain and elsewhere are illustrated in the diagram in which the reality is that every box interacts with every other box. The meanings of the main activities included in it are as follows.

(b) *Exploratory research* is work primarily intended to increase knowledge and understanding of nature and natural processes. It is a primary source of starting points for further work of a similar kind and for applied research projects.

(c) *Applied research* is the creative use of existing knowledge to devise better products or processes that are clearly useful and, in industrial companies at least, have obvious commercial potential. The prototype products or processes discovered are candidates for development.

(d) Both exploratory and applied research draw upon and, in time, add through publication to the *world scientific data base*. The latter provides the starting points and technologies for most research projects.

(e) *Development* is the work needed to convert development candidates into products or processes that are approved for use, and the scientific, medical or other evidence needed to facilitate their sale or use.

The development plan for each candidate is unique and should be designed to minimise lead-times since this maximises the ultimate turnover and profit. Such plans commonly involve many technologies, details of which may be jealously guarded company "know-how". As a rule, development projects involve many more staff and are much more costly than the preceding research stages. Accordingly, development candidates should be chosen because of their novelty and probable advantages, and feasibility with the available resources.

Differences between R&D activities in different sectors of manufacturing industry

3. The relative contributions of research and development activities to the success of industrial companies vary with their technological base. For example, the absolute potential of a research-based pharmaceutical company, the archetypal biology-chemistry-based organisation, is determined by the success of its applied research activities. Its performance within that potential is determined by the efficiency of its development and marketing efforts. The minimum time from the start of an applied research project and a marketing application for a saleable product is 10 years and the actual times may be 20 years or more. New products must therefore be significantly better than established products and be protected by strong patents. They must also be expeditiously developed if they are to beat rivals to the market and have relatively long patent-protected market lives. If these conditions are met, world-wide sales and profits can be very great indeed.

4. All of this engenders a culture in which the need to invest heavily in speculative R&D is understood and business "horizons" of 10 years and more are accepted as normal. Continuous interactions with academe at all stages in the R&D process are also normal because of the need to be as sure as possible about the starting objectives and the quality of the science and technology throughout.

5. Some physics-based industries, such as aerospace, mechanical engineering and power generation, also operate on long lead-times on projects with very heavy development and marketing costs. Their strategic

importance, for economic or defence reasons, may necessitate considerable Government funding. Investment in projects of this kind is justifiable only if the intended products are reasonably expected to be superior to their competitors when they are marketed.

6. Other physics-based industries, for example in fields of microelectronics, may be concerned with products that are superseded within two years, so speed and secrecy are central to competitive strategies. The innovative focus is then not so much on revolutionary products derived from prolonged exploratory and/or applied research, as on development and production where in-house engineering capabilities are crucial.

7. A basic requirement for successful physics-based industries is access to a pool of technologies, many of which may not be in the public domain. Such expertise is not easy to create and is difficult and expensive to maintain.

8. There is, of course, a full range of intermediary positions between the extremes of high-tech and low-tech, long-term and short-term, extensive or negligible interactions with the Science Base. The internal culture of companies varies accordingly. Nevertheless, all science or engineering based companies share a basic need for gifted innovative scientists and engineers who understand the complexities and realities of their respective businesses and are strong enough to accept responsibility for R&D objectives and performance. A further, crucial, requirement is an informed top management willing and able to provide the necessary resources in a timely way.

II Specific Questions

Science Base and industrial innovation

9. A strong UK science base is crucial for industrial innovation in our country, for the following reasons:

(i) Nearly all of the starting ideas or hypotheses that lead to exploratory or applied research projects are provided by individuals who understand and can make creative use of the world scientific data base and other sources of information. Whether they remain within the science base or are employed in UK industry, a great many of them received their basic research training within the science base. Indeed, the creation of potentially innovative scientists is one of the most important reasons for public and other financing of research within our universities and Research Councils.

(ii) Work done within the science base can provide good starting points for applied research projects. That is why industrial companies are increasingly supporting exploratory research in universities and engaging in joint research projects within university departments. This, and any additional Government investment in the Science Base, are to be encouraged.

(iii) It is nevertheless vital to maintain the capacity and freedom of academe to conduct genuinely basic research. This can be threatened by excessive contract work for industrial customers. Academe has a duty to explain the need for basic science to Government and to industry.

(iv) There is positive need to encourage the best British students, particularly in science, to study for a PhD as a background for their future innovative work. Quality here is more important than quantity.

Technology transfer

10. Transfer of technology and information between the science base and industry has greatly improved in recent years. Improvement depends largely on individual initiatives by the scientists and institutions concerned.

11. CASE studentships and LINK programmes can be effective means of stimulating interactions between individual companies and universities.

Hindrances

12. Too many industrial R&D organisations set themselves too obvious objectives, which is usually a downhill path to mediocrity or worse. Every project should contain the possibility of a clearly better product or process. When necessary, company policy and management should be changed to meet this objective.

13. A company's employees are one of its key assets. The quality of their training is therefore important. Companies should be encouraged to devote more resources to the continuing education of their scientific and engineering staff. This includes training scientists and engineers to move into managerial positions.

14. Inadequate understanding by senior management of the role of innovation in achieving long-term competitiveness and profitability, and the role of science and engineering in innovation, is an evident hindrance to successful innovation strategies. Responsibility for addressing this falls both to senior management and to the research community.

International competitiveness

15. Given effective international marketing, the competitiveness of any industrial innovation is most easily assessed by the world market share and the price and profits it achieves. However, many a good invention has failed for want of good marketing.

Short-termism

16. Short-termism is a problem that resides not only in investors but also in main Boards and senior management, many of whom may hold relatively brief fixed-term appointments. Unsuccessful companies typically lack a coherent vision of their long-term objectives, a situation whose correction usually requires a change in top management.

Innovation and international success

17. Genuinely better products or processes and effective marketing are the keys to success in international markets. Internationally successful companies have the capacity not only to market their goods worldwide but also to access technology worldwide. The nation's ability to be aware of, and to exploit, the 95 per cent of world science and technology that originates outside the UK is becoming an increasingly important determinant of long-term economic prosperity.

Other issues

18. There are many sources of innovation. Those that stem from the experience of the production, marketing or long-term planning functions need to be considered alongside those that stem from R&D.

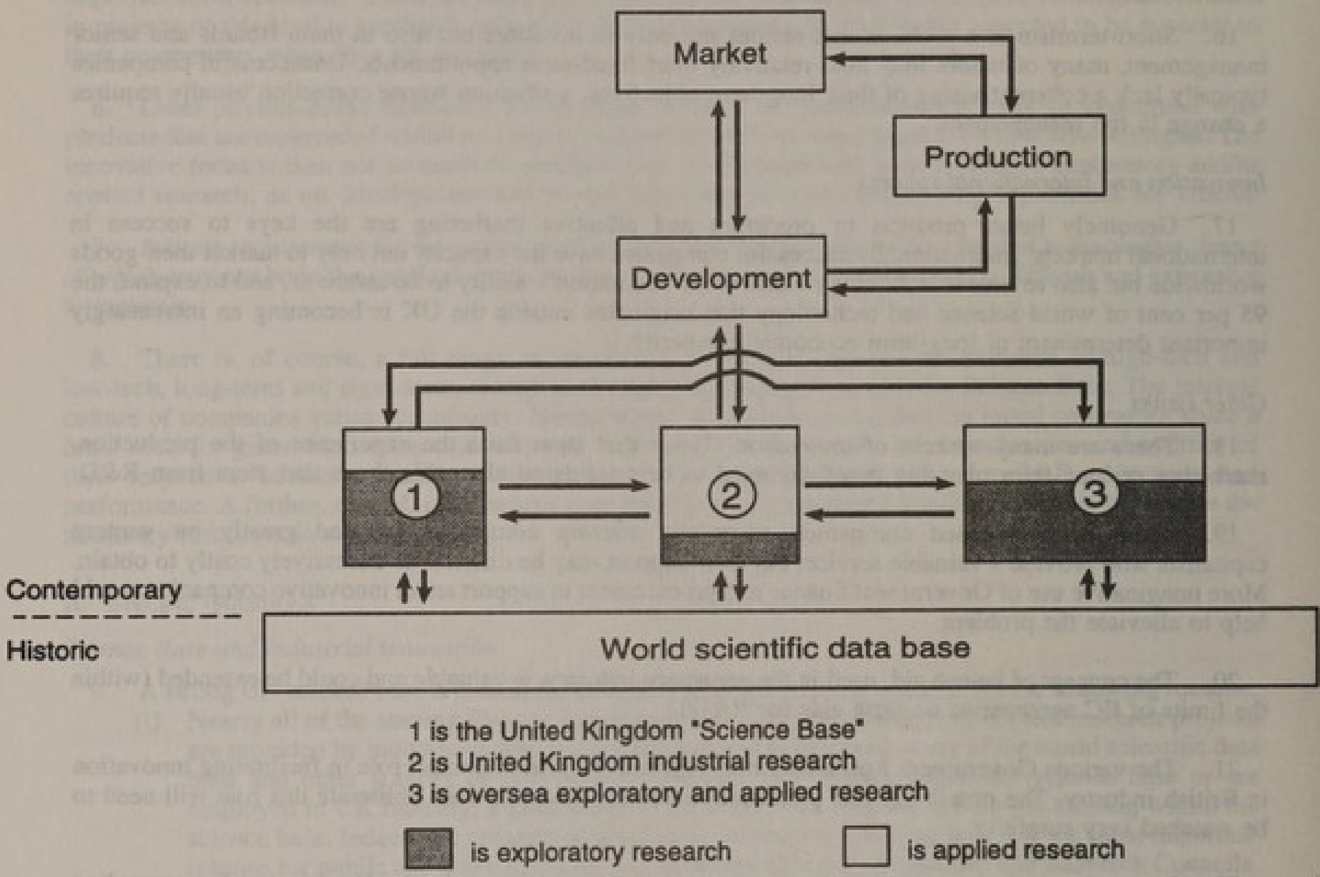
19. Small research-based companies, especially start-up companies, depend greatly on venture capitalists who provide a valuable service, but their support may be difficult or excessively costly to obtain. More imaginative use of Government finance and procurement to support small innovative companies would help to alleviate the problem.

20. The concept of launch aid, used in the aerospace industry, is valuable and could be extended (within the limits of EC agreements on state aids for R&D).

21. The various Government Research Establishments play an important role in facilitating innovation in British industry. The possibility that privatisation could weaken or even obliterate this role will need to be watched very carefully.

22. Innovation in industry would be encouraged if the provisions in the Patents Act for rewarding inventors according to the novelty and economic importance of their contributions were seriously observed.

23. The prior disclosure rules used in the UK patent system put the UK at a severe disadvantage. When applied properly they greatly impeded the normal proceses of fruitful academic discourse; when not followed strictly they destroy early on the chances of gaining protection for any discovery whose potential utility is not immediately apparent. The 12-month leeway allowed under the American system is greatly to be preferred.



Diagrammatic representation of UK and world-wide research and development activities

Memorandum submitted by Professor C Andrew, Manufacturing Engineering, University of Cambridge (23 July 1993)

Thank you for your letter dated 8 June requesting my views on aspects of technology transfer. I am pleased to respond.

The topic is so large that I shall restrict myself to your questions. Well, nearly! I cannot resist just one comment on the White Paper. I was delighted to see a recognition of the problem of defining Applied Research (S2.22). I think in the past this has presented UK Limited with a significant impediment to the effectiveness of its centrally-funded research in relation to other industrialised countries. Now correct interpretation is critical.

My response to your first question is "people transfer and interaction", in that order: the researcher into the application environment, and the applier into the research environment. The new DTI/TCS scheme is aimed at the former, but exchange must be visibly in a person's interests. It must be seen to contribute positively to career progression, not the usual university lip-service; the industrial sabbatical should be de rigeur for the academic engineer; academic departments should have spare rooms for visiting industrialists, not visiting Chinese academics; and there must be a reason why people want to do it: some do because they are like that; others must be induced—short-term money helps, but long term it must be career. Could the Government show the way by having a significant number of attachments from academe in, say, the DTI?

Exchange might not be so easy in the direction from industry to university. Rolls-Royce University Research Centres are good. Hitachi have "bought" space at the Cavendish Laboratories in Cambridge, and their staff live there. Why Hitachi?

If we can't live together for reasonable periods, how about days out together; a standing fund for academics to travel to companies? Any (checkable) attempt at technology transfer to have expenses paid? Why does an SERC grant stop when the research has finished? That is exactly the time when the academic should be out selling his wares, not (only) writing papers for other academics to read.

Is the following a possibility? No DTI R & D money to industry unless there is a clear and significant interaction—people and time—with a university research group. No SERC money to a university without a clear and significant interaction with industry, and a clear plan for technology transfer.

The Teaching Company Scheme is most effective, of course, although I thoroughly disapprove of its "centres". I thought the whole point was to involve as many staff as possible in the scheme, not isolate a few into a centre. The people who want to do it anyway will probably find the way without help. Those who wouldn't do it anyway are beyond help. It is the middle group we have to swing over.

The next two questions are related, and, I think less significant than the first, if only on the principle that "You can lead a horse to water . . .". That is not to say that we must not try, but we should seek to attain the situation in which people want the information and advice rather than having it thrust on them. I think there is already a lot of information available. Again, however, it is people who must be involved, and not paper. A focus also helps; could there be an "interaction hot line" into SERC/DTI; an "exploitation adviser" serving a group of universities—or, indeed, an office for the larger institutions? And we need all the subliminal help we can get, like trying to get over the glamour and excitement of technological innovation to the public in general. That may sound facetious, but image and peer pressure are strong forces.

There are one or two stimulating innovative technology journals around; "Eureka" comes to mind. You might have a word with the technical editor. He writes up promising-looking research and gives it a wide audience.

On the last question, yes, I think so. I have had one identifiably valuable interaction (i.e., with continuing savings many times the research cost of the whole programme, with a six-months, four-days-per-week sabbatical in the collaborating company subsequently, looking for further applications), many smaller positive ones, and my current one in which I am helping the collaborating company plan their own development programme as a result of our research. In addition, the Manufacturing Engineering Group, for which I have overall responsibility here in Cambridge, is *highly* industrially-interactive, in teaching as well as research. However, it is difficult to see a structured approach by which this could be passed on. It is the ethos of the group, and relates strongly to personalities (several) so you could argue that we have got back to my earlier point that this way of thinking and working should contribute to career progressions.

Memorandum submitted by Vauxhall Motors Limited (26 July 93)

WHAT IS THE RELATIONSHIP BETWEEN THE SCIENCE BASE AND INDUSTRIAL INNOVATION?

There is a direct relationship between a company's ability to innovate and the skills base available. Therefore there should be greater emphasis on the development of education and training in sciences as a key success factor for industrial innovation.

ARE THE MECHANISMS FOR TECHNOLOGY TRANSFER AND INTERACTION BETWEEN THE SCIENCE BASE AND INDUSTRY EFFECTIVE? HOW COULD THEY BE IMPROVED?

Effective transfer of technology is measured by a company's commercial success, or otherwise, of the implementation process. Effective transfer requires business and financial support. Whilst the current situation is adequate further venture capital needs to be made available to allow the implementation of innovation and technological inventions to become practical reality.

Industry has a poor public image at all levels of UK society—particularly among students and educational institutions. The image must be improved.

The National Manufacturing Council of the CBI is working hard to change the way manufacturing industry is perceived. Government must lend weight to this effort by ensuring the departments of Education, Employment and the Treasury do all in their power to influence local and central Government policy in this direction.

IS INDUSTRIAL INNOVATION HINDERED BY A LACK OF COMPETENT PERSONNEL BOTH TECHNOLOGICALLY AND IN MANAGEMENT SKILLS?

Industrial innovation in the UK is hindered by a significant imbalance of technologically qualified personnel with key countries, such as Japan and Germany. This must be addressed to ensure UK industry is well placed in the future in terms of both innovation and competitiveness.

IS INNOVATION BY BRITISH INDUSTRY INTERNATIONALLY COMPETITIVE? HOW SHOULD THIS COMPETITIVENESS BE MEASURED?

In certain sectors British industry is competitive with regard to innovation, but is largely restrained by a lack of venture capital and more recently by government policy in relation to interest rates, inflation, etc.

Is "SHORT-TERMISM" REALLY A PROBLEM FOR INNOVATIVE BRITISH INDUSTRY? IF SO, WHY IS THIS AND HOW MIGHT IT BE REMEDIED?

"Short-termism" is a common failing of industry in general and is reflected in UK government's short-term fiscal and financial policies. Short-term political cycles prevent governments having a long-term view with regard to policy making R&D programmes tend to be prolonged and innovation is viewed over a longer term. To reconcile the two, continued lobbying of government is required to encourage a longer term view, whilst extended research and development programmes in respect of innovation should be trimmed.

SOME SECTORS OF UK INDUSTRY ARE MORE SUCCESSFUL IN INTERNATIONAL MARKETS THAN OTHERS. WHAT CONTRIBUTION DOES INNOVATION MAKE TO THEIR SUCCESS? WHAT CHANGES IN CORPORATE STRATEGY MIGHT IMPROVE THE LESS SUCCESSFUL ONES?

When sectors of UK industry are successful in international markets it is because they have identified customer requirements and used innovation to evolve product capabilities to meet those demands. This varies by sector due to the different management attitudes and cultural issues abundant in UK industry. Changes in corporate strategy need to focus on using innovation to improve productivity, reduce the time to take a product to market and also develop competitive advantage.

WHICH STRUCTURES AND INITIATIVES WITHIN THE UK ARE PARTICULARLY HELPFUL IN ENCOURAGING THE PROCESS OF INNOVATION WITHIN A COMPANY AND WHICH HINDER THIS PROCESS?

During the last two to five years considerable flexibility and positive support for innovation from the Department of Trade and Industry has been evident. This encouragement for companies to invest in new technology through Enterprise Initiative and other similar programmes have promoted industrial innovation in companies.

Factors which discourage or hinder innovation are financial and economic, such as the implication of high inflation and fluctuating exchange and interest rates. HM Treasury needs to develop a more pro-manufacturing and venture capital stance if the process of innovation is to prosper.

Memorandum submitted by the Department of Health (28 July 1993)

Thank you for your letter of 7 July to Mr Brown about the role of the Department of Health as sponsor and customer of the pharmaceutical industry.

The Department believes that there are a number of important advantages to the UK in the current arrangements but recognises that on occasion these functions can and do pull in opposite directions. Under the current arrangements for the pharmaceutical industry, these conflicts are resolved within one department, the Department of Health, after consultation on major issues as appropriate with other departments such as the Department of Trade and Industry, the Treasury, Cabinet Office and the other health departments.

There are also issues on which the interests of sponsor and customers do coincide. In any long-term supplier-customer relationship, the customer has an interest in sustaining his supply. The Department of Health, the customer, wishes to see the pharmaceutical industry improve and develop its production methods and its place in international markets. The pharmaceutical industry also has a major research and development programme. The Department of Health, with its wider health responsibilities, supports this and is keen to see the industry extend its product range with better and safer medicines.

The Department of Health currently combines both functions of sponsorship and customer through the Pharmaceutical Price Regulation Scheme (PPRS). The objectives are:

- To secure the provision of safe and effective medicines for the NHS at reasonable prices.
- To promote a strong and profitable pharmaceutical industry in the United Kingdom capable of such sustained research and development expenditure as should lead to the future availability of new and improved medicines; and,
- To encourage the efficient and competitive development and supply of medicines to pharmaceutical markets in the UK and other countries.

The Department of Health in its recent evidence to the White Paper on science and technology "Realising our potential" stressed that the pharmaceutical industry in the United Kingdom has been and is remarkably successful in terms of a highly favourable balance of trade, in the provision of jobs in the UK, and in producing new medicines for the benefit of both NHS and overseas patients.

Under the present system, the sponsorship element is contained in the prices the NHS pays for its medicines. If sponsorship were to go to another department, such as the Department of Trade and Industry, then an interesting scenario arises. If the Department of Health were to be charged with securing medicines at the lowest possible prices, the Department of Trade and Industry would have to be present at the purchasing negotiations with the pharmaceutical companies to fulfil the Government's sponsorship role. The conflicting tensions would still be there to be settled within Government but now involving two departments.

One likely result of such a change would be an increase in the number of civil servants involved with the industry since the Department of Trade and Industry would have to increase its staff resources to sponsor the pharmaceutical industry and the Department of Health would need to liase regularly with the DTI. It would also lead to an increase in the number of contacts that the industry has with Government officials in the course of providing medicines to the NHS.

One of the major strengths of the present United Kingdom system for the pharmaceutical companies is the one stop business facility provided by having most of the essential contacts with Government under one roof, unlike any other country in the world.

Memorandum submitted by Dr I D Nussey, OBE (16 August 1993)

I am writing this in a personal capacity, having already contributed to my company's submission to this most interesting study, in order to bring your attention to an example where moving from a good academic idea to a product has cost industry dear. I apologise if the jargon is rather too dense and would be happy to explain if required.

The example comes from the field of Open Systems Inter-connection (OSI). OSI is the architecture which facilitates computers or different architectures to exchange information. The idea behind this sprang from UK University thinking and their so-called "Coloured Books" JANET implementation was the first articulation of the ideas influencing OSI. The UK academic sector also contributed a great deal to the formulation of the OSI standards on which general implementation was later to occur.

During the '80s, and in the form of the DTI, well-intentioned UK Government lent considerable weight to these proposals. It promoted the ideas in the European Community and wider, and subsequently used the weight of CCTA to make actual, and conforming OSI products prerequisite for tenders for Central Government Telecoms bids. In the earlier '80s, this was a significant commercial issue, and several major computing companies invested substantial sums of money in order to conform. At the same time, DTI launched a significant awareness programme, seeking to foster OSI goodness. During the formation of these inter-working standards, there was a very strong emphasis on the concept of a level playing field when it came to implement them. Consequently, a promising, existing open approach (known as TCP/IP) and a highly successful proprietary, implemented architecture (SNA) were rejected without regard to cost. The more elegant OSI approach was preferred.

One consequence of this was to inhibit private sector take-up of OSI. Also, and notwithstanding CCTA and OFTEL interest, the public and recently privatised sectors of Government procurement have so far largely failed to enforce the CCTA requirement. The consequence is a serious commercial setback, with industrial investors in OSI products unlikely to recover more than a small fraction of the development costs which I estimate may collectively exceed £100 million.

This experience would seem to suggest that Government should take the greatest possible care before it imposes (or appears to endorse) procurement standards without regard to their implementation cost. In addition, expressions of market interest and user opinions on the standards proposed need to be tested before quasi-regulatory advice emerges.

In this instance, failure to apply such rules has meant that translation of an apparently elegant concept from Science Base to implementation has had what appears to be an unstisfactory outcome.

The particular lesson for Government is that regulation needs to take the fullest possible account of the costs of conformance and the marginal increase of markets before it is enforced.

Memorandum submitted by J Walker, Managing Director of Walker Wingsail Systems plc (1 September 1993)

Our own experience in the funding of innovation in the UK may be of interest to the members of the Committee.

I conceived the use of aircraft type wings to propel yachts and ships in 1965 at the age of 28. I was at the time a junior aircraft designer, a pilot with around 200 hours solo, and a weekend sailor. My concept of the weather vane or self trimming wingsail worked very well straight away, offering fingertip control of a sailing vessel of any size, fitted with my invention, to a single person seated as in a plane or a car.

The market reaction from customers, even so long ago as the late 60's, was cautiously enthusiastic. Few sailors actively relish hard work on winches in driving spray, and it was clear that my alternative could command at least a niche market and perhaps much more. This market support has remained steady throughout.

The Oil Shocks of the 70's added the extra dimension of saving fuel and reducing pollution on ships, since my wingsail could easily and economically be built in very large sizes, also providing an emergency steering and propulsion system in the event of main engine failure. Ship owners were as cautiously optimistic as our yacht customers that my concept could prove valuable, and we designed, built and installed a successful eight tonne wingsail for a 6,500 tonne ship. The Oil Flood of 1986 made this potentially huge market recede into the middle distance, but we stand ready with better technology waiting for a Carbon Tax, an IMO safety injunction, or simply for the price of oil to rise. In the meantime the leisure market is just as attractive and just as ecologically sound.

Finding the capital has always been, by contrast, extraordinarily difficult. Initially, in 1967, a small group of private investors backed my ideas with not enough money, which duly ran out in 1970. I tried again in 1976 with another small group of private investors, and the modest amount of cash available had run out by Christmas 1978. No money was owed to anyone, so I was able, as ever, to get a job and bide my time. Walker Wingsail Systems plc was incorporated in June 1981 and commenced work in January 1982, backed by again a small group of private and institutional investors, who subscribed what they described as "Phase 1" funding. By 1983 that money was exhausted and the typical British crisis occurred, which the company only overcame by a hair's breadth.

Our bacon was saved through a powerful radio broadcast by Hugh Sykes on the "Today" programme, which brought in a small flood of new individual private supporters. That emergency funding gave us the time to plan a full public offer under the terms of the BES, and in due course true venture capital in appropriate quantities became available to us from large numbers of shareholders in every walk of life who chose to invest in us, rejecting the blandishments of "secure and short term" schemes such as that offered by a major clearing bank, where they could have had their tax relief and the bulk of their money back in six months.

Some 6,000 of them have so far invested about £8 million in this long term innovative high technology company, words which seem to be anathema to professional venture capitalists. In many cases they have increased their holding every year for several years, because it seems that they believe that Britain can and should be a principal supplier of high quality products to the world once more, and that innovation is one of our national skills. They, like us, are appalled at the plan to bar entry to the BES at the end of this year.

We believe that the BES should be reprieved and dedicated to innovative manufacturing, both ab initio and for new product development as existing companies expand. Short term, secure "tax avoidance" schemes should be stringently rejected. Up to £5 million in any year should be available.

Using this route we have brought a British invention to the beginning of production. We have now taken some £91,000 in deposits on the first 17 boats, worth some £4,000,000, of which 75 per cent will be for export. And we still have, quite exceptionally we believe, all the original shareholders on board.

The attitude of our typical shareholder is long term, thoughtful and imaginative and we believe that there are a very large number of such people in the country who could, given a little encouragement through the BES or something like it, and adequate information and publicity, provide very substantial support each year for innovators and innovative companies in the manufacturing, and hence wealth creating, sectors. There are other important areas of weakness to address, such as team construction, but all that can follow if the money is there.

Financial support is, in our experience, typically available from:
- Banks;
- Venture capital firms;
- Large corporations;
- The City;

either not at all, or only at too late a stage, or on completely unacceptable terms for the originators. Thus a giant resource of innovative skill, and the market advantage that confers, lies virtually untapped.

Memorandum submitted by the Oxford Centre for Industrial and Applied Mathematics (OCIAM) (29 September 1993)

1. Mathematics is playing an increasing role in industry, both in the UK and worldwide. In particular, mathematical modelling and data analysis complement computer studies and engineering simulations to bring advanced theoretical ideas to bear on complex technological problems. This approach provides enhanced insight and design information which may be cheaper and quicker to obtain than by experiment. A mathematical approach to problem solving is distinctive in being more flexible and providing theoretical analogies leading to technology transfer. High technology is usually based on a mathematical framework which is at the "cutting edge" of competitive technology.

2. The Oxford Centre for Industrial and Applied Mathematics (OCIAM), initiated in 1989, is part of the Oxford University Faculty of Mathematical Sciences. It was formed to focus the collaborative activities with industry in high level mathematics which have existed in the Faculty since 1970. The Centre has an

international reputation for mathematical modelling in applied science and has stimulated applied research activities in universities in the USA, Australia and Europe. OCIAM is a founder member of the European Consortium for Mathematics in Industry (ECMI), an organisation with European university and industrial groups as members which has received considerable support from the European Community to promote the use of mathematical modelling in European industry. The OCIAM/ECMI programme of industrial workshops and training courses for both postgraduate students and technologists already working in industry has attracted considerable interest in ten European countries. These activities stimulate collaboration between universities and industrial companies, and between university groups in different countries.

3. Despite the benefits of these collaborative activities for industry most of OCIAM's contacts have come about by chance because there appears to be no structure in Britain that encourages or co-ordinates the use of mathematics as an industrial resource. By contrast, in the US, small profit-making private companies, acting as consultants, link university departments with major industrial projects; in France many applied mathematicians have two positions, one in a university and another in a consultancy company or government laboratory; the Fraunhofer Institutes in Germany and Doppler Institutes in Austria also link universities and industry in applied science. British universities have always had strong applied mathematics departments interested in "real world" problems but this expertise has not been much used to help create wealth for the nation (although it was harnessed with great success to defend the nation in World War II).

4. The Smith Institute is a new initiative concerned with both research and postgraduate training in applications of mathematics. It is designed as a bridge between university departments and industrial companies which will stimulate industrial innovation and the recruitment of highly-trained mathematicians into industry. Four university groups from Oxford and Cambridge, co-ordinated by OCIAM, are providing postgraduate students who will spend half of their three-year PhD course at the Smith Institute. They will have both an academic and industrial supervisor and be working in areas of application of mathematics approved by the Institute Council. There will also be postdoctoral research assistants at the Institute working on more specific industrial projects using the expertise of the university groups. The operation of the Smith Institute will be very similar to that proposed for the Faraday Institutes.

5. OCIAM is concerned that applications of mathematics to industrial and environmental problems may not be recognised as an essential component of wealth-creating activities. Radical changes are taking place in higher education and research, and in applied sciences, in which mathematics must play a new role. This implies closer links between British institutions, British industry, and the European Community. These links need to be fostered and co-ordinated by Government, both nationally and through Brussels. In particular sponsorship of applied mathematical research should be the responsibility of an organisation with a broad remit that crosses disciplinary boundaries.

Memorandum submitted by the Royal Academy of Engineering (October 1993)

The Royal Academy of Engineering is the United Kingdom's independent self-governing body of professional engineers of all disciplines. The Academy's objectives are the pursuit, encouragement and maintenance of excellence in the whole field of engineering in order to promote the advancement of the science, art and practice of engineering for the benefit of the public. By recognising Britain's most distinguished engineers the Academy aims to take advantage of their wealth of engineering knowledge and experience. The interdisciplinary character of the the Academy's membership provides a unique breadth of engineering experience with which to further all forms of engineering.

In order to overcome traditional barriers, the Academy promotes a multi-disciplinary approach to demonstrate the interdependence of different areas of expertise in the effective use of modern technology and engineering. Emphasis is also placed on the importance of well-informed communication between engineers, Government, research establishments, industry, public services and academia.

This evidence represents a collation of personal views from Fellows of The Royal Academy of Engineering. It cannot reflect the views of all contributing Fellows nor those of the Academy as a whole. It may, however, be regarded as representative.

EXECUTIVE SUMMARY

1. The Royal Academy of Engineering welcomes the opportunity to submit evidence to the House of Commons, Science and Technology Committee on the subject of "The routes through which the science base is translated into innovative and competitive technology". As was stated in the Academy's submission to the House of Commons Trade and Industry Committee's inquiry into "The competitiveness of UK manufacturing industry", it is believed that "Manufacturing industry is essential to this country's future. If we do not actively seek to control our destiny through innovation in manufacturing technology the UK risks becoming dependent on the whim of others remote from this land. Our future wealth and freedom lies in retaining the ability to innovate, to develop, to manufacture, to add value and to market successfully".

2. Innovation means risk and a characteristic of a highly innovative culture is the courage to fail. The UK must develop this culture and expect a high proportion of innovative ideas to fail or be delayed.

3. There is no clear one to one relationship between the science base and industrial innovation. To innovate and create technology industry has to understand and pull on the science base whilst, at the same time, understanding the customer's needs, the technology production, delivery, management focus and follow through.

4. The existing mechanisms for technology transfer and interaction between the science base and industry are not as effective in the UK as they are in other countries, e.g., Japan. Improvement lies in continuing to learn how to achieve more effective technology transfer.

5. UK industry appears more risk averse than its international competitors and there is perceived to be an inability by engineering companies to recognise, develop and encourage the inventiveness of their staff. This poor management of technology together with the shortage of technical entrepreneurial managers is a hindrance to industrial innovation.

6. Some sectors of UK industry are internationally competitive whereas some are not. UK industry is often competitive at the innovative stage but falters at the difficult stage of forcing the initial concept through to a marketable product, not recognising the business/marketing strengths required in addition to scientific invention.

7. "Short-termism" in terms of time to a return on an investment cotinues to be a problem for innovative UK industry when seeking funds and competing with the high interest rates available elsewhere. When faced with a request for funds to invest in new technology, as opposed to the exploitation of proven technology/designs, lenders take up the low risk option of the existing technology. There is a need to overcome the cultural problem whereby short-term returns take precedence over long term growth. Meanwhile, companies must strive for international market share and not concentrate on percentage profits.

8. The nature of the most successful businesses includes an imperative to capitalise on R&D in order to survive and the need to create an appropriate corporate approach to innovation.

9. The stimulus for innovation must come from within a company but fundamental to its success is the creation of a favourable climate for long-term investment.

10. The provisions of the White Paper for a national strategic policy for Science and Technology, formulated through the Technology Foresight programme, are viewed as a promising move to create the technology focus essential for product innovation.

PREAMBLE

Prior to addressing the seven questions asked by the Select Committee, Fellows of the Royal Academy of Engineering made a number of observations/comments:

(a) There is a concern that the so-called "linear model" is being assumed; that is that the innovation starts in the science base and flows into industry. In general, most innovative ideas have not emerged initially from the science base; they have usually been conceived by someone in industry attempting to solve a problem. Once the idea has emerged and been applied crudely it then falls to academics to analyse and optimise the concept. In many cases they have succeeded in extending the applications.

(b) Industrial innovation sits between scientific and engineering research which provide the means, and the market which provides the impetus. In this sense, the "market" for innovation covers more than the commercial world—it includes a company's international market, defence, education and the needs of the researcher. In fact, anything that might supply a clearly defined and consistent need to the innovator, and some form of pay-off in either financial or personal terms if the need is met. For successful innovation, the means and the impetus must be in balance. Provision of the means alone has, in the past, led to pointless innovation (such as the Sinclair C5) which fails in the marketplace, while need alone leads to over-ambitious projects which fail technically—for example the Channel Tunnel for the first 100 years. Clearly the chances of a given project succeeding are strongly dependent on both the quality and quantity of the output from the research base; quality for obvious reasons and quantity because innovation puts unpredictable demands on technology in areas quite unrelated to the main thrust. Concorde, for example, required the late abandonment of electromechanical control of the engine intake and a "crash" development of the first flight safety critical digital system. Fortunately, digital electronics technology had just about reached an adequate state in the mid-60s.

(c) There is no limitation on timing for the innovator to make use of the science and engineering base. For example, the discovery of the laser is still prompting innovation (such as the compact disc) 40 years later. The corollary is that demanding an immediate return on investment in the science and engineering base illustrates a monumental misunderstanding of the process.

(d) There is a difficulty with the term "competitive technology" since only products, processes and services can be competitive. Most of these rely on a number of technologies and it is the ingenious combination that provides the competitiveness. In effect, it is the design that matters in providing "fitness-for-purpose", "cost-effectiveness for the specification"; "match-to-the-market"; and the "feel" of the produce or service. It is what the Japanese and the Germans recognised as "integrity" and "ability to delight" that finally matters in selling a product. In other words, innovation and competitiveness are only two factors in the equation of success.

(e) *Innovation means risk* and all concerned must recognise this. In producing the 747, Boeing took a major risk and succeeded. They have been number one in commercial aircraft ever since. One of the characteristics to be expected of a highly innovative culture is the courage to fail. At present the UK does not have this culture, nor the expectation that a high proportion of ideas may fail or be delayed. As a consequence, decisions are protracted by the fear of failure, half measures are taken when a full effort is required, careers are destroyed by unreasonable emphasis on continued success and projects are continued beyond their natural life by fear of the admission of failure that termination would bring.

RESPONSES TO QUESTIONS

1. *What is the relationship between the Science Base and industrial innovation?*

1.1 Given that industrial innovation can take many forms, there is no clear one-to-one relationship with the UK science base (a subset of the international base). This is also believed to be true even when academic research is industrially sponsored. The benefits are more often in terms of new computational methods, materials databases or instrumentation, which can then be applied in the industrial R&D from which the product innovation is most likely to be derived. If the aim is to co-ordinate the science base, industrial innovation and industrial application such that wealth is created for the UK, the present system is probably not as efficient as it should be. This situation exists because it is difficult for this research to be sufficiently inter-disciplinary, market orientated or concerted.

1.2 Industrial innovation arises from an understanding of the customer's needs together with invention, technology, production and delivery, management focus and follow through. Industry should pull on the science base but also needs to understand elements of the science base to enable it to be innovative and create technology. Most important innovation starts in industry in finding solutions to problems.

1.3 "Science Base" appears to mean different things to different people. It can be regarded as that science undertaken by the Research Councils and Universities, in which case it is mainly Government funded; or, as in many cases, it is in industry itself. The Government funded science base can provide for random pure research with no regard to market forces or industry needs; is that which provides industry with well-educated young graduates, trained in the latest scientific techniques and capable of lateral thinking, who can transfer the latest knowledge into industry and apply it there; is that predominantly basic research carried out in order to generate new knowledge; has to progress some joint projects with industry to demonstrate its scientific capabilities and to learn what industry's real problems and challenges are i.e., to develop a partnership based on mutual respect and understanding. In an international company, the science base may refer to worldwide research activities. Another view of the "Science Base" is the scientific knowledge held by the public at large, particularly the workforce. In this context, the total lack of comprehension on the part of the majority of the public of the fundamental laws of physics and the concepts of efficiency contributes to inefficiency and low productivity. There are strong sociological reasons which underpin our low productivity but these are supported by ignorance.

1.4 Wherever the Science Base is located it may provide an innovative idea that may then be exploited. It may equally well provide the means whereby a pre-existing idea may be implemented or improved. It is able to develop the detailed understanding for further exploitation and application by industry and may also provide key elements of supporting technology that make the idea practical in terms of timing and price in the real market. The science base needs to help generate new technologies with industry which can be used in innovation (e.g., bioscience for medical diagnostics) to feed into established technologies and businesses. Wealth creating innovation is primarily science based but the source of the original discovery is not crucial. the key factor is that of conversion of the opportunity presented by the discovery into a viable product. Too few of our population are open to such possibilities because scientific principles are lost on them.

1.5 In a sense, the science and engineering base is the topsoil in which innovation may grow. Whether it does or not depends on both the suitability of the seeds (ideas) and the appropriateness of the climate. "No topsoil—no growth" applies equally well to innovation as to agriculture.

2. *Are the mechanisms for technology transfer and interaction between the science base and industry effective? How can they be improved?*

2.1 The existing mechanisms for technology transfer and interaction between the science base and industry are not effective in general and are not as effective as they are in some other countries, such as Japan. The process of technology transfer is NOT a linear process since successful industrial innovation requires multiple technologies to be brought together with much interplay and interaction between customer needs and technologies. The basic mechanisms—recruitment, CASE Awards, the LINK scheme, consultancies, industrial fellowships, joint SERC/Industry sponsorship—work well in some large and, usually, multi-national companies where the industry/university interface is taken very seriously. Arrangements whereby relatively long-term funding is guaranteed through collaboration between a company and a University permitting "Centres of Excellence" to be established and to be integrated with the company's business have proved to be effective. The existing mechanisms do not work well with smaller companies although, through special efforts to establish a "niche" relationship with academe, some companies have done well. A point of concern in the current climate, with an emphasis on cost cutting in industry, is that the university interface could suffer as line managers and experts come under more and more pressure and no longer have the time to dedicate to this activity.

2.2 Improvement lies in recognising the need for technology transfer at company, university and national levels and continuing to learn how to do it more effectively. There is no one magic answer but one really effective way to achieve technology transfer is through the transfer of people. Some of the best graduates do not enter industry and remain in academe, with no experience of industry to enthuse future graduates. Graduates entering industry tend at the outset to be rather academic with little grasp of the fact that it is the application of science to products that creates wealth, not the pursuance of science for science's sake. Arrangements whereby academics could spend more time in industry, without detriment to their careers, would be beneficial in promoting innovation. (An interesting comparison can be drawn with the situation in Germany, where industry relies much more heavily on academic personnel to pursue its research. Indeed, many personnel have dual roles, holding influential positions in both academia and industry. In addition, the maintenance of Fraunhofer Institutes is seen by the government as part of their support for the industrial structure. Typically, 80 per cent of their work (including near market research) is funded by government, the remainder being industrial contracts, which are relatively cheap and which are the mechanism for technology transfer). While it is acknowledged that the majority of the UK HEI's funding should be allocated on the basis of scientific merit, rather than industrial relevance, a somewhat larger proportion than at present (about 7 per cent) could be allocated to co-funded awards. This would strengthen the industrially relevant component and yield more effective results both in stimulating creativity and ensuring real industrial commitment.

2.3 Industry must be made aware of relevant scientific developments through a change to the practice of the obscure publication of developments designed to suit the needs of academia and not industry. Since innovation thrives on constructive argument and debate the researcher must be challenged to refine and focus his thinking to overcome the real problems, and the development engineer to throw away his preconceptions of what is possible. Real teamwork is required between scientist and engineer to achieve this without destructive acrimony. Where both a University and a company have placed sufficient emphasis on the collaboration the outcome appears to have been successful; however too often the partners are working to different agendas. There is no single answer, except not to give up trying. Better publicity of successful examples would help create a climate of confidence between industry, academia and government. An improved understanding of the industrial infrastructure is necessary; there are tiers of enterprises which need to co-operate to achieve success for the UK. No support flows from tier to tier and only market forces operate between levels, unlike our main competitor countries.

2.4 Existing mechanisms could be improved by working to a co-ordinated plan or series of plans such as may emerge from the Technology Foresight Programme currently under way. Insufficient effort is allocated to worldwide scanning for ideas, technologies and processes for the allocation of scarce R&D funds. Nationally co-ordinated funding and technology scanning on the lines of MITI in Japan could greatly assist technology transfer and interaction between the science base and industry. Funded initiatives such as the DTI LINK scheme tend to be slow, and recent developments to focus attention purely on SMEs to the exclusion of large companies is likely to make a weak situation worse. There is also a danger in focusing the science base purely on technology transfer and the perceived needs of industry; the science base itself must keep developing. A balance has to be struck between what is seen as too great an emphasis on research in pure science and too little on applied science. Whilst researchers are individually competitive, and are rewarded for individual achievement and not for teamwork or integrative studies, their research efforts tend to be esoteric rather than market orientated. Government could change this scenario by placing more emphasis on development and exploitation of concepts and less on pure research and encouraging industrial sponsors for all research projects to bring market forces into the allocation of funds. Government grants or tax benefits could be used to assist Industry R&D and augment and support University based research, thus ensuring that R&D is market led.

3. *Is industrial innovation hindered by a lack of competent personnel, both technologically and in management skills?*

3.1 Cause and effect are difficult to prove in this area since personnel competence, technological or managerial, has to be combined with opportunity and resources over a sustained period to permit successful innovation. Within the UK there is perceived to be an inability by engineering companies to recognise, develop and encourage the inventiveness of their staff. UK industry appears more risk averse than international competitors, has a less courageous approach to trying ideas—preferring to theorise and analyse rather than "cut metal", thus innovation is not actively encouraged. Also, too often an idea is pursued on an *ad hoc* basis, without adequate funding and without a game plan if it should be successful. The result is a company taken by surprise by the success, not clear on the way forward in funding and market terms, agonising over what it wishes to do and then missing the boat.

3.2 There is ample evidence that few top grade school leavers enter science and industry but industry gets what it seeks and rewards. If industry in general attracted more competent personnel, more industrial innovation would occur. Since the UK industrial culture is based more on craft and skills training than on the innovative professional engineer it does not attract innovators and thus industrial innovation on a broad front is hindered. Some prestigious high technology companies have reported no major problems in recruiting personnel with adequate technological skills, thereby implying that their demands for innovative engineers are being met. In such companies, management skills are usually acquired through training in the early stages of a career.

3.3 Industrial innovation is hindered by the poor management of technology and a shortage of technical entrepreneurial managers. The skills which are lacking are not to be found in our centres of management education. They are the interpersonal skills which our education system displaces by its excessive emphasis on academic achievement and individual performance. Modern management methodology and techniques must be taught, possibly through the inclusion of a properly structured approach to developing technological and business skills in longer undergraduate courses, in common with some of our overseas competitors. However, a contrary view, expressed by a very large company, recognised that some courses provide a blend of skills better matched to their requirements than others, but supported the belief that the UK's general scientific and engineering first-degree courses are beneficial in maintaining innovative capabilities, compared with the more prescribed, vocational courses normal in overseas countries.

4. *Is innovation by British industry internationally competitive? How should this competitiveness be measured?*

4.1 No single answer can be given to the question of the competitiveness of innovation by British industry. Some industrial sectors are competitive whereas some sectors are not. If innovation is expressed as the sustained and successful exploitation of new ideas, generally we are not good at it. British industry is generally competitive at the inital stage of the innovation process, but falters at the difficult stage of forcing the inital concept through to a marketable product, not recognising the business/marketing strengths required in addition to scientific invention. Alternatively, having understood the technology, there is a failure to use it, leaving other countries to benefit. A major problem is commitment and, in many cases, this reflects on the definition of company strategy, which would help in the selection of projects to back. Another problem is the obsession with "the big new idea", pushing incremental innovation to the back seat, which appears to contrast with the Japanese approach for example. The difficulty with "the big new idea" is the host of little, maybe not so new, ideas that are also required to make it work; in most cases exhaustion overcomes enthusiasm and the idea stalls until technology and the market catch up. At which point someone else recognises the opportunity and steps in. Aggressively seeking international market share early on is an important element for success. Since more and more markets are supplied by companies from many countries, if UK companies aim solely at the UK market, they will fail against international companies aiming at the UK and many other markets. Customers will buy the "best" wherever it comes from.

4.2 Many suggestions have been made on the measurement of competitiveness including: commercial success; the medium/long term trend in share price in the international market; the financial return on new processes, products or services over a three to ten year timescale; the time taken from R&D to market; industrial applications which create sustainable wealth; the rate of new product introduction within a single sector; in a free market, the proportion of the home market supplied by home producers of any durable product; or international market share. The number of patents filed, whilst a visible manifestation of innovation, is not a meaningful measure of competitiveness in innovation. The UK's share of OECD national patent applications fell during the 1980s but, since national ethos and company strategy are major factors in making applications, comparisons are dangerous. Nevertheless, in any analysis of competitiveness in British Industry, all of these measures have some value as a contribution to the whole.

5. *Is "short-termism" really a problem for innovative British industry? If so, why is this, and how might it be remedied?*

5.1 "Short-termism" is a problem, particularly for small to medium sized companies, but is less of a problem for large companies able to invest from income. It is a problem of the City analyst and hence the investor but it has caused many a good company to fail due to the fact that institutional investors are driven by the performance criteria set by their pension fund clients and are not able to take the longer-term view. A large and influential part of British industry is managed within conglomerate organisations where the shareholding is largely in the hands of insurance companies and pension fund managers. The horizons of the company managers are dominated by their regular presentations to the fund managers who will provide the resource for their future growth. Growth is almost exclusively by acquisition; they have a lower than average expenditure on research and development and a poor record of international capital expenditure. Unfortunately the large organically grown companies are also forced to behave like conglomerates in order to avoid being taken over. Witness to this is the recent Hanson-ICI debacle.

5.2 The long-term investment necessary to bring many ideas to the market place is not encouraged by high interest rates and the high dividend expectations of the Stock Market. It may be that the UK and European high real interest rate economies have obliged companies to pay more attention to short-term growth than in the US or Pacific Rim—certainly a long-term commitment becomes more difficult the higher the cost of borrowing. This is probably compounded by the lack of a "private investor" culture more willing to take a long view compared with the disinterested institutional fund manager. The influence of high dividend expectations is illustrated by recent statistics (1993 R&D Scoreboard) showing that internationally the average company spends a comparable sum on R&D to that declared as profit, whereas UK companies spend only a fifth of the sum declared as profit. It has been said that Government is the driver for short-termism by using high interest rates as the only instrument to manage the UK economy. Since returns to shareholders are measured against the bank rate, a lowering of the bank rate will provide the conditions for long-term growth. Using the economy between booms and depressions in order to obtain votes for re-election is also conducive to British industry.

5.3 Companies wishing to invest in new technology compete on level terms with companies wishing to invest in growth to exploit proven technology/designs. Within small companies, generally there is a need to achieve a return on venture capital in one to two years, four years at most. Few institutional investors will lend on unproven technology and there is no incentive for lenders to take the risks associated with encouraging new technology. Lenders take up those low risk projects with early payback and for projects based on new technology to become attractive, they need to offer a greater return of interest or they may not proceed. The reluctance or fear of being first must be overcome and our industrial leaders must be prepared to back a technology without first waiting to see it developed and applied in say Japan. It is not fully recognised in the UK that having the bright idea is not the difficult bit. Taking the idea through development, solving the shortages of supporting technology that may exist, creating a sustained consistent line of funding and hitting the market at the right time are all equally critical. If innovation is to succeed, it must have backing through the inevitable difficult stages.

5.4 The remedy to the problem is not an easy one but a better understanding is part of the route towards overcoming the cultural problem where short-term returns take precedence over long-term growth. This was aggravated by the myth that "market forces" rather than strategic planning would secure our future. The principle that innovation funding is part of a national overall plan could be very significant and the recent White Paper on Science, Technology and Engineering holds out hope that, at last, the thinking power of industry/academe/government and the financial institutions will be co-ordinated to develop some sound longer term plans.

5.5 Government could: take fiscal measures (for example, tax breaks for innovation) to offset the short termism created by high interest rates and an institution-dominated investment market; offer part funding of investments which have some private funds and require top-up only; and offer clearing house activities to marry up investors to project sponsors seeking funds.

5.6 Companies must strive for international market share and not concentrate on percentage profits. This means working for profitable growth and not static sales with high percentage profit. This must be achieved as soon as possible through short-term measures but with the aim of profitable organic growth of market share aimed at market leadership and dominance. "Strategic" should not mean "never profitable".

6. *Some sectors of UK industry are more successful in international markets than others. What contribution does innovation make to their success? What changes in corporate strategy might improve the less successful ones?*

6.1 The more successful sectors of UK industry are Pharmaceuticals, Aerospace, Defence, Petrochemical and Software Development. Less successful sectors include the Shipbuilding, Automotive and Manufacturing sectors. The nature of the more successful businesses includes an imperative to capitalise on R&D in order to survive and the need to create an appropriate corporate approach to innovation. A view has been expressed that the pharmaceutical and aerospace industries have been underpinned by a strong home market funded by the tax payer. The ability to make high margins has made it possible to carry large R&D costs to maintain the cycle of innovation. This cannot continue indefinitely, as evidenced by the aerospace sector following the termination of cost-plus purchasing and the reductions in defence expenditure. Also, current government policies are directed towards reducing the tax funded demand.

6.2 Innovation is an essential ingredient of success in an international market. However, it is a combination of innovative approaches to design, style, selling, distribution and not just technological innovation that provides success. Innovation begins with understanding an existing or potential customer's need together with a corporate determination to achieve a significant international market share in meeting that need profitably. Companies which try to operate only in the UK market will fail against foreign competition operating internationally.

6.3 Innovation and corporate renewal is critical for the long-term survival and success of any organisation. The successful ones generally regard their research strategy as an important component of their business strategy and operate with commercial, technical, legal and financial professionals all in the same team. They also have global business and technological networks. It may be that the unsuccessful sectors do not recognise sufficiently that their long-term survival depends on remaining competitive through innovation, producing a total package better than the competition. The only way to succeed in an international market is to strive continually to be the best in the World. Some critical sectors of UK industry, such as machine tools, appeared to rest on their laurels too long and have suffered the consequences. As the UK is a high wage/high cost economy, industry has difficulty with "lowest cost producer" strategies which are necessary for basic industries. Product differentiation based upon product innovation is the only way that UK companies can succeed in international markets such as steel and shipbuilding.

6.4 The obvious corporate strategy which might result in improvement is to seek high margin businesses and then keep on running, but this is not likely to be a recipe for success for many in a technically illiterate country. Technical innovation is absolutely crucial in maintaining a competitive position against rivals. Companies which preserved a viable level of R&D through the 1980s (e.g., pharmaceutical and chemical companies) continue to innovate successfully since the stock of such technology requires continuous replenishment. Innovation, even small incremental innovation, is vital to success. Commitment to continuous improvement at all levels of the company is vital. Other factors which have made some companies more successful than others are: a market-led strategy for product development; sufficient scientists and engineers on the Boards for the potential of R&D to be understood, and for it to have a high profile in the company; sufficient staff technically competent to adopt technology from licences or other intelligence; and the delegation of responsibility to small, self-contained multi-disciplinary units, with proper involvement of the principal suppliers in the design processes.

6.5 It is interesting to consider some of the variety of reasons for the failure of some technology-based firms. Some have not matched marketing strengths to product growth. Others have neglected the need for product replacement. Perhaps most frequently, the scale of financial resources required and the time over which they have to be deployed have been seriously underestimated.

7. *Which structures and institutions within the UK are particularly helpful in encouraging the process of innovation within a company and which hinder this process?*

7.1 Innovation can be thought of as a state of mind in which ingenious solutions are used to overcome current problems. The stimulus for innovation must come from the companies themselves but the creation of a favourable climate for long-term investment is fundamental to the whole process. It is also essential that more direct support for R&D is provided by Government, including some for "near-market" activities, if UK companies are to compete effectively with overseas rivals. Bringing an innovative product to market is a project (within a business) which is hindered by the structures and institutions built around a business model. This creates the "catch 22" situation when large companies that are not so innovative can spare the effort to overcome the bureaucracy whilst the small highly innovative unit gives up the struggle.

7.2 Many UK companies have individuals who have developed management teams and recognise the need for innovation in all aspects of their business. Unfortunately there appears to be no institution within the UK which fully recognises all the facets. Particular weaknesses appear to be in being able to recognise the potential of new ideas to be exploited in the market place. Having designed a plan to drive a venture through to success it is necessary to ensure adequate effort is expended at each stage.

7.3 There have been some serious attempts to create support structures, but generally they have been short-lived. Many features of the UK are unhelpful, starting with the culture, education, and management by accountants. The industrial associations, like the CBI, the Institute of Directors and the EEF do not have any evident role in relation to innovation. Increasingly, innovation is dependent not only on good communication within a given discipline, but across disciplines. The existing scientific and engineering institutions are not well structured to encourage this inter-disciplinary technological exchange. The problem has been recognised by most, but will take a long time to solve at the present rate of progress. The professional institutions and learned societies have played and continue to play an important role in bringing industry and academe closer together but, with so many institutions, there is much duplication of effort. In addition to some of the engineering institutions other organisations which encourage and assist innovation include: industry sponsored Research associations; Trade Associations; commercially operated Abstracts/Library services; LINK and other collaborative programmes when used properly; and DTI information on EC markets. A lack of government sponsored University/Industry collaboration hinders innovation as does an overemphasis of the trend to try to change good universities into commercial money makers, with the consequent growth in bureaucracy and legal negotiations at the expense of good research and teaching. The Quality Management Standard BS 5750 is, in some quarters, thought to be a travesty and a disaster and the classic Western bureaucratic "inspectionist" response to Total Quality Management (TQM). TQM has to be internalised by everyone in a company: it cannot be pasted on, prescribed or "inspected on".

7.4 The provisions of the White Paper for a national strategic policy for Science and Technology, formulated through the Technology Foresight programme, should be helpful in providing the technology focus which is essential in product innovation. A move towards establishing MITI type strategic steering groups for major sectors drawing together the best brains and experience from across the whole spectrum is favoured.

7.5 In the past, major international projects have been used in the UK and elsewhere to stimulate innovation. The Japanese fifth generation computer project was perhaps the definitive example, but high definition TV, the Strategic Defence Initiative and the Apollo programme create the same spin-off. All provide rapid access to sufficient funding to test the predictability and relevance of an idea and while the time for large national projects has gone, it may be appropriate to consider how to provide such funding—none of the government schemes implemented so far come anywhere near the mark in terms of response time. The DTI's retreat from direct funding of R&D, except in special cases, and its concentration on technology transfer, is unlikely to aid innovation, unless major branches of MoD-funded work are thereby released for civil exploitation.

Memorandum submitted by Toyota Motor Manufacturing (UK) Limited (4 October 1993)

I. Introduction

1. This memorandum has been prepared in response to the request made by the Science and Technology Select Committee which is currently undertaking an inquiry into the routes through which the science base is translated into innovate and competitive technology.

2. It has been prepared by Toyota Motor Manufacturing UK Limited, but Toyota's worldwide operation and the decision to invest in the UK are matters which are dealt with by the Toyota Motor Corporation who is the sole shareholder of Toyota Motor Manufacturing UK Limited.

3. Following discussions with the Secretary to the Committee, while particular reference is made to the worldwide research and development operations, the emphasis of the report is Toyota's activities in the UK in the area of education and training.

4. The opportunity is also taken to express views on the general issues raised by the Committee.

II. Background

Toyota's Worldwide Operation

5. Toyota's Motor Corporation was established 56 years ago, and its main business has been the manufacture and sale of automobiles. The major philosophies which have led Toyota for half a century are:

(a) The strong contention that manufacturing provides the basis for economic activity. Toyota has made great effort to contribute to society through the manufacture of vehicles wherever it is located.

(b) The priority is customer satisfaction achieved by putting the customer first.

(c) The belief that the physical involvement in determining what is happening, where it's happening is fundamental to all activity. This practice has been implemented by everyone from top level management to members on the shop floor.

As a result of this, Toyota's worldwide production in 1992 was 4.7 million. 3.9 million were produced in Japan and 2.2 million were sold in Japan; sales overseas were to over 150 countries. There are 35 plants in 25 countries, and the production of vehicles overseas was 767,000. The overseas operation has been greatly increased over the last 10 years. This is due to the promotion of localisation which contributes to the local economy and industry (attachment I).

Facilities in the EC

6. Toyota first came to Europe in the early 1960s when the company began importing cars to Denmark. Toyota Motor Sales opened its European Office in Copenhagen in 1963.

7. Since the 1960s, operations in Europe have grown significantly. Toyota now has the basis for a totally integrated operation which includes research and development and design facilities, manufacturing plants, marketing and sales support and distribution companies in European countries.

8. Toyota has had a long relationship with Caetano of Portugal producing commercial vehicles. Since 1989, Toyota and Volkswagen AG have jointly produced commercial vehicles at Hanover in Germany. In France, Manitou BF has carried out production of fork lifts with Toyota's technical assistance since early 1987. In 1989, the latest project, Toyota Motor Manufacturing UK Limited, was announced (appendix II).

9. Toyota Motor Europe Marketing and Engineering SA (TMME) is located in Brussels and is responsible for the following four functions in Europe:

- Developing the overall marketing for Europe.
- Sales, planning and product support.
- Dealer/Distributor support.
- Co-ordination of design and development on Toyota vehicles for the European market.

Facilities include a purpose built Design Centre and Technical Centre.

10. Toyota Motor Europe Marketing and Engineering not only markets the vehicle produced in the UK, but is also committed to the development of materials and parts procured for the vehicles. Toyota's research and development is shared by the resources of Japan, North America and Europe, but the function played by Europe will grow increasingly due to the start of vehicle manufacture in the UK.

Facilities in the UK

11. Toyota has had a presence in the UK since 1965. It was in this year that a distributor agreement was signed with Motor Imports Co. The Motor Imports Co separated off its car division as Toyota GB Limited in 1968. Toyota GB is currently owned by Inchcape and Toyota has 25 per cent equity.

12. Toyota Motor Corporation's London Office was opened in September 1985—the office is the representative office of Toyota Motor Corporation in the UK, responsible for public affairs and intelligence gathering, and sales co-ordination for the UK, Irish (in conjunction with TMME) and African markets.

13. Toyota Motor Finance UK plc was incorporated in November 1989. Its main activities are: financial information for Toyota Motor Corporation and other group companies and the recording and settlement of deals on behalf of Toyota Motor Finance (Netherlands) BV.

14. Toyota Motor Manufacturing UK Limited was established in 1989. There are two manufacturing facilities—a full production operation at Burnaston (rolled steel in one end; Carina E out the other) and an engine manufacturing plant in Deeside, North Wales.

15. Toyota Industrial Equipment UK Limited was established in 1990. The company is a wholly owned subsidiary of Toyota Motor Corporation. It is the UK import concession for forklift trucks from Japan and France.

III QUESTIONS RAISED

What resources in terms of manpower and finance are assigned to activities included under the heading of research, technology, design and development?

16. As explained in paragraph 10, Toyota's research and development is shared by the resources of Japan, North America and Europe. Without the clarity of definition of the activities referred to in the question, it is difficult to be specific as to the exact numbers of engineers, technicians and other support staffs engaged in such activities. However, there are presently around 11,900 engineers, technicians and other support staff in the TMC organisation. Together, they account for approximately 16 per cent of Toyota's total workforce. Of them, approximately 5,800 are engineers, 4,600 are technicians and the remainder operate in support functions. In terms of overseas operations, total staffing is around 500, including 400 in the US, and about 100 in Europe.

17. The budgeting process is a simple compilation of division-based budget proposals to reach a total figure which is then adjusted to reflect company-wide profit strategy for the coming year. Allocation to individual projects is, for the most part, left to the discretion of each division, with input from related divisions regarding development priorities for the year.

18. Toyota's policy with regard to the use of outside research and development expertise is threefold:

(a) Toyota encourages its suppliers to work jointly through a process the company terms "design-in" to develop new parts and components, as well as systems for future products. As Toyota relies heavily on outside suppliers (about 70 per cent out-sourced) for its products, it also encourages suppliers to take an active role in developing and proposing new technologies for possible future application.

(b) Toyota works with external research and development organisations in fields where they possess clear expertise not available internally.

(c) Toyota maintains active communication and exchange of ideas on various fields of research and development both with other automobile manufacturers and research organisations.

19. Toyota currently devotes about 5 per cent of annual net sales to research and development. This percentage has remained constant since 1989. (This represents expenditure around £2 billion per annum).

What is the background to you investing in the UK? How was the project financed?

20. Toyota made the decision to establish a car manufacturing plant in the UK in April 1989. The decision was fully supported by the British Government, but there was no state aid associated with this project. Since then, the plan has progressed to schedule and production commenced in September 1992 at the engine plant in Deeside, North Wales, and in December 1992 at the car plant at Burnaston, Derbyshire.

21. Before looking at the reasons for locating in the UK, it is prudent to examine the broader European situation. Europe is seen as significant for the following reasons:

(a) Although now in recession, the basic demand in Western Europe remains around 15 million vehicles per year. Some institutions forecast that the demand will increase by 20 or 30 per cent by the year 2000, and we share this view.

(b) The sales of Toyota vehicles in Europe has remained at a level around 430,000 per year, and its market share has been less than 3 per cent.
(c) Strong requests to increase the supply of vehicles were being made by our distributors and dealers. When we consider the increase of the total market, a reasonable increase in supply was considered to be appropriate.
(d) Toyota's long held philosophy is to manufacture products either in or near the place where the product is used.
(e) Europe is seen as the biggest single market.

22. Toyota plans to start with 100,000 vehicles per year, and will increase this figure to 200,000 vehicles per year, of this production 70 per cent is scheduled for export to mainland Europe.

23. The magnitude and importance of the project was reflected in the planning and research undertaken. Literally hundreds of items were examined. It is not possible to do justice to such an exercise in this memorandum, but the following four examples are recorded to indicate the kind of elements considered important:
(a) The UK has a reasonable sized domestic market.
(b) There is a tradition of vehicle manufacture in the UK, including a significant parts and components sector.
(c) The UK offers good access to the rest of Europe.
(d) The co-operative attitude of both National Government and Local Authorities.

(N.B. the above examples, taken in isolation, could be applied to other European countries. However, they are shown simply as representative of the many issues that had to be considered; it was the total study that led to UK selection).

24. The total investment, in terms of capital expenditure, is £840 million. Funding was a combination of three elements:
(a) Share capital (we are, as stated, a wholly owned subsidiary of Toyota Motor Corporation).
(b) Finance leasing—provided by UK institutions.
(c) Loans—provided by Toyota Motor Finance (Netherlands) BV.

Over 94 per cent of the funding was provided by the share capital and finance leasing provisions.

25. Our experience of the UK institutions was, and indeed continues to be, very satisfactory.

Have you experienced any difficulty in obtaining personnel with adequate skills? What have you done with regard to training?

26. As at the beginning of October, there are just under 1,500 people employed in the company. The recruitment of Members (employees) started one and a half years before the start of production.

27. Our recruitment process was developed to identify a particular kind of individual. We are looking for people who are keen to learn, enjoy working in a team environment and relish the challenges posed by our approach to manufacturing.

28. In general, we have not faced any major difficulty in being able to identify suitable candidates for employment. Specifically, we did find difficulty in two areas. Firstly tool and die maintenance, and secondly in our attempt to identify an engineer specialising in environmental engineering. It would appear that both categories are areas where particular attention on a national basis is required. We are already examining internally how to provide our own resource in these areas for the future.

29. With specific regard to skills, it is important that we explain our definition of skills. Traditionally, skills refer to the ability to do, or indeed to make, something to a particular standard. We seek much more. We seek to empower the individual through education and training, to enable them to apply judgment, analysis and to continuously improve all facets of the operation. An understanding of the process of production, the principles of the company, together with the standards and values are therefore essential in achieving our level of "skilling".

30. It is our view that in order for us not to experience the difficulties faced by the industry over the last decade and in order to be successful over a number of years, continually seeking to grow the investment in training of Members at all levels is essential. As evidenced above, education and training are key. We commenced training some 18 months prior to production start-up.

31. Courses were designed and developed internally with the advice and guidance from our colleagues at Toyota Motor Corporation. Training was then undertaken at local educational institutions; at our plants in Japan and North America and increasingly, as they became available, on the facilities at Burnaston and Deeside (attachment III).

32. Over 100,000 man days and £19 million was spent on training prior to start of production. However, we do not see training as now ended. Our approach is to continually train our members. It is through the successful application of the members' skills that the company will prosper and, as a result, will be able to offer the stable employment and improvement of the financial security sought by our Members.

Where do you see your business going in the near future?

33. Toyota UK plans to produce 36,000 vehicles in 1993, and 100,000 vehicles in 1994. Beyond 1994, in order to meet market demand, it is hoped that production of the initially projected figure of 200,000 vehicles per annum will occur as soon as possible. If all goes to plan and production is increased to 200,000 vehicles per annum, product variation will occur and we believe additional investment will be required. However, no firm plans for this exist at present.

34. With regard to recruitment, we have just started to recruit an additional 600 Members. The hiring programme runs between June 1993 and January 1994. By the time Toyota UK is producing 200,000 vehicles per annum, we will have employed 3,300 Members.

What general observations do you have with regard to issues being examined by the Committee?

"TECHNICAL INNOVATION"

35. An automobile is the product of the integration of many diverse technologies in areas such as materials, electronics and manufacturing processes. We recognise the need for continued technical innovation, and this is evidenced by the amount of resource and the wide parameters Toyota gives to the subject of research and development.

"EDUCATIONAL LINKS"

36. In general, we have not experienced any difficulty in finding suitable candidates for employment. However, we share the general concerns about skills in the workforce and wished to contribute to this area.

To this end, we established the Toyota Science and Technology Education Fund, in partnership with Business in the Community, to enhance the quality of science and technology education in primary and secondary schools within the framework of the National Curriculum. Similarly, we support the DTI "Engineers to Japan" scheme by providing places for British engineers at our operations in Japan.

37. We believe such initiatives are important contributions. However, they will not succeed if left in isolation. We believe that industry will need to establish a framework that supports the practical application of the skill and knowledge gained. For example, a company sending a young engineer to Japan must provide a climate in which, on his/her return, the knowledge and experience gained is shared with all levels of the organisation and acted upon. In addition, the engineer must understand his/her responsibility to share this knowledge and experience with others—this may require some time for adjustment on the part of young ambitious engineers who may consider such knowledge and experience as important in terms of job opportunity, rather than important in terms of improving the performance of the company.

38. Toyota UK has not yet established formal links with any university or research institution. Informal discussions and support in certain areas have taken place, and it is likely that our involvement will develop over time. Naturally, our prime responsibility is to establish a successful company—a company that will strive to provide long-term stable employment for its Members.

"UK FINANCIAL SYSTEM—GOVERNMENT ACTION"

39. First, we in Toyota accept our responsibility to provide the opportunity for education and training of our Members. But, there are a number of issues that could be addressed:

(a) Has the introduction of technology as a subject in schools been rushed?

Is the structure firm enough to support the teaching?

Has the training of teachers been sufficient (i.e., turning CDT teachers into technologists). Are there appropriate facilities available in schools?

(b) Should not Government consider that to ensure opportunities are available to those students who choose science and particularly technology, the framework has to be in place so that manufacturing industry can prosper.

Prosperous companies grow, and with them so do job opportunities. Young people must believe that the opportunities are there if they are to be truly motivated to become scientists and engineers. Reducing arts places at university to "force" students to follow the sciences may prove counter-productive in the longer term.

ATTACHMENT II

TOYOTA'S UK MANUFACTURING PROJECT

	Burnaston	Deeside
Type of plant	Passenger car plant	Engine plant
Location	Burnaston, Derbyshire	Deeside Industrial Park Deeside, Wales
Plant size	580 acres (2.35 million sq metres, approx)	115 acreas (0.46 million sq metres, approx)
Total investment	Approximatley £700 million (£400 million Phase 1)	Approximately £140 million (£110 million Phase 1)
Construction start	May 1990	June 1990
Production start	December 1992	September 1992
Production volume	200,000 units per year (100,000 units at Phase 1)	200,000 units per year (100,000 units at Phase 1)
Employees	3,000 (1,700 at Phase 1)	300 (200 at Phase 1)
Model to be produced	Carina E	1600 cc class engine

TOYOTA MOTOR MANUFACTURING UK MANAGEMENT

Chairman	Eiichi Kumabe
Managing Director	Yukihisa Hirano
Deputy Managing Director	Takeshi Nagaya
Deputy Managing Director	Hiroaki Watanabe
Director of Manufacturing	Alan Jones
Director of Corporate Affairs & Human Resources	Bryan Jones
Director of Purchasing	Osamu Komori

ATTACHMENT III

TYPICAL TRAINING COURSES FOR G/L, T/L

(i) *Production Group Leader*

Timing	Training Content
January to February	Introductory Course—4 days 1st week Extended Introductory Course—2.5 days 2nd week Overseas training—TMC (3w) TMM (1w) TMMC (1.5 days)
March to April	On-the-job training (OJT) combined with: Role of Leader (1 day), Standardised Work (2 days) Job Instruction (3 days), Leadership (2.5 days)
April to August	OJT — Designing line job and UK standardised work — Training Team Leaders Equipment Manufacturers training
August to December	OJT — Production trials — Line training with T/L, T/M

(ii) *Maintenance Team Leader*

Timing	Training Content
January to February	Introductory Course—4 days 1st week Extended Introductory Course—2.5 days 2nd week Overseas training—TMC (3 weeks)
March to April	Introductory Skill training—6 weeks (local vocational school)
April to December	OJT — Work with Manufacturing during installation — Learn to maintain equipment — Attend manufacturers training
	Level 1 Skill Training — PLC courses (5 days for each) — Hydraulics, Inverter, Servo Control — Machine structures (3 to 5 days for each)

Memorandum submitted by the Defence Research Agency and Ministry of Defence (22 October 1993)

The Ministry of Defence and Defence Research Agency has considered each of the questions raised in the Clerk to the Committee's letter of 7 July 1993 and offers the following responses.

HOW DOES THE MINISTRY RECONCILE THE ROLE OF SPONSOR, CONTRACTOR, AND, GIVEN THE ROLE OF DRA IN PROVIDING TEST FACILITIES AND CONSULTANCY, CUSTOMER FOR KEY SECTIONS OF UK INDUSTRY?

The MOD's role of sponsor and customer and the DRA's role of contractor to elements of British Industry do in practice go well together. The MOD wishes to encourage industry in the development of the capabilities necessary to meet the needs of the defence procurement programme—and it is continually exploring ways of improving this process. For example, it has recently published for industry's benefit the first annual list of Staff Targets and Staff Requirements so that industry can obtain a better idea of the future shape of the procurement programme and respond accordingly. The MOD also wishes to be an expert customer for defence equipment and to that end funds an extensive programme of research in the Defence Research Agency which in turn allows it to ask the difficult questions of industry and ensure that it is getting realistic solutions to its requirements. But as subsequent sections of this memorandum show, the DRA's expertise, as well as informing the procurement process in the MOD needs also to flow across to industry in order to provide the basis for development and production programmes. A direct contractual relationship between the DRA and industry provides one possible route for this transfer—but there are others which can equally usefully be fostered—and which are discussed further below. Provided the MOD's role of sponsor and the DRA's of contractor—or in many instances collaborator with industry does not get in the way of competitive procurement by the MOD, which it does not, then there is no conflict. Indeed over the next few years the amount of work competed for by the DRA will increase to 66 per cent of its turnover.

HAVE THERE BEEN ANY DEVELOPMENTS IN THIS AREA [TECHNOLOGY TRANSFER, NON-GOVERNMENT USE OF AGENCY FACILITATES, COMMERCIAL EXPLOITATION OF TECHNOLOGY] SINCE THE MEMORANDUM SUBMITTED IN 1992? IF SO, CAN YOU GIVE MORE DETAILS OF THESE POLICIES AND ACTIVITIES.

The DRA, as a producer of ideas and know-how rather than actual equipment, attaches great importance to the effective transfer of its technology into the defence industrial sector where it can then form the basis for subsequent development and production. It has, over the past year, been developing a number of ways of improving the transfer mechanism. Some are simply an extension of existing mechanisms, others are new initiatives.

Strategic Alignment

This involves building a close relationship between the DRA and industry in order to facilitate at the earliest stage in the "ideas into products" process an exchange of knowledge and an enhanced awareness of what each side is doing, and where their work is heading. By ensuring this early co-operation, it is intended to prevent the duplication of effort and waste of scarce resources and to make good gaps and deficiencies; to make the eventual take-over of ideas more effective and indeed to allow industry to identify at an early stage which ideas are likely to have wider application and are worthy of investment for development, not just for military purposes but for civil application as well; and to ensure that industry's own financial contribution will have a better chance of being rewarded. This "strategic alignment" was begun last year with a series of high level meetings and briefings between the DRA and a number of key firms. Further work is now in hand to build on the initial contacts and to identify possible areas of co-operation.

Pathfinder

This is dealt with in more detail below.

Dual Use Technology Centres

The DRA has recently put forward the idea of Dual Use Technology Centres which involve bringing in industry and academia to work alongside the DRA on projects that it needs to do in pursuit of its customers' objectives, but which, by the nature of the technology being explored, lend themself to further exploitation through both spin-in and spin-out. The DRA believes that industrial participants would gain through getting a better chance of funding for their research teams, and through access to a broader research base; MOD and DRA would gain through better value research; and the UK would gain through having a world class critical mass research capability able to generate products for civil and military markets.

The first centre which the DRA is proposing to set up is in the area of advanced structural materials. As part of the DRA's wider rationalisation programme, it is intended to collocate most of DRA's many separate materials laboratories in a new dedicated laboratory in Farnborough. If there is sufficient support for the idea of dual use centres from industry the DRA would allocate some of the laboratory's space for staff and teams from companies and academia. This would facilitate an interchange of staff between the research centre and research being carried out elsewhere in the DRA on applications, and also encourage a strong flow of staff to and from industry, thus providing technology transfer and linking the work closely with specific products. Discussions with outside parties over their participation in the Structural Materials Centre are currently under way; so far the level of interest shown has been high although the DRA is not yet in a position to seek firm commitments. If the Farnborough model proves successful, the DRA would want to explore the possibilities in areas of information systems and in electronics, optoelectronics and sensors.

The Extra Mural Research Programme

This programme, which involves the DRA placing contracts in industry and academia for elements of the defence research programme, not only ensures that the DRA and ultimately the MOD tap into the best expertise that exists outside but that industry and academia become involved in what the DRA is doing thus allowing the migration of ideas backwards and forwards between the two sides. The Extramural Research Programme in 1992-93 was worth some £200 million. For the future, it is both the MOD's and DRA's policy that an increasing proportion of the Applied Research Programme should be subjected to competition at the secondary level which could lead to an increase in Extra-Mural Research.

Non-Governmental Use of Agency Facilities

The DRA's current business with Other Government Departments, supra-national agencies and industry currently amounts for 8.3 per cent of turnover. As well as providing a welcome source of additional income for the DRA, this involvement with other players also facilitates the exchange of ideas and the spread of technological knowledge. As the Science and Technology White Paper makes clear, the DRA intends to develop non-MOD use of its facilities and indeed to seek a wider market for its scientific and technological expertise, all of which can only assist in the process of technology transfer.

Commercial Exploitation of Know How

The DRA already enjoys a steady income stream from royalties paid by industry for using its technological developments such as liquid crystals, aluminium for aircraft structures, dinitrogen pentoxide for energetic materials, remote sensing of gases, speech recognition, and industrial resins and glues. This income amounted to £5.1 million in 1992-93 but effort is being applied to increase this to somewhere in excess of £15 million by 1996 through an energetic policy of identifying in-house technologies with civil potential and going out into the market place to find those interested in developing them.

COULD YOU GIVE MORE DETAILS OF THE PATHFINDER PROGRAMME?

The first Pathfinder conference was held in November 1992 and attended by over 300 senior representatives from industry. At the conference Industry was invited to put forward proposals for research ranging from those which it wished to carry out itself but which would require funding from DRA's programme through collaborative projects where DRA and industry work together on a joint funding basis, to entirely industry funded ventures where formal coupling to a DRA programme is considered advantageous. Industry responded with enthusiasm, putting forward over 600 proposals. Of these, 40 have been accepted in full and will be incorporated either in this year's or next year's research programme and a further 70 are under consideration.

This year's Pathfinder round, beginning with the conference in November 1993, should build on the progress acheived last year and, it is hoped, lead to even more successful proposals. One major change is the decision to try and involve, in addition to the major defence and industrial concerns, Small and Medium Sized Enterprises (SME) who may have interesting technological ideas and projects that could be of benefit to the defence research programme.

DOES THIS MEAN THAT IN CHOOSING WHICH TECHNOLOGIES TO DEVELOP IN FUTURE, THE DRA WILL TAKE THE LIKELIHOOD OF SUCCESSFUL CIVIL APPLICATIONS INTO ACCOUNT?

The DRA does not believe that it is necessary to make such specific choices. Its research programme is aimed at meeting the requirements of the Ministry of Defence. But within that overriding objective, and because of the potential for dual use of many of the technologies in which the DRA is expert, there is plenty of opportunity for exploitation for civil applications. The initiatives listed above are all intended to facilitate that exploitation.

Memorandum submitted by The Oxford Trust (1 February 1994)

Thank you for the opportunity to respond to the questions posed by the Science and Technology Committee. I hope that you will find the accompanying sheet of comments helpful. In commenting I have drawn on the experience of The Oxford Trust which has worked as a charitable trust to gather and disseminate knowledge in this precise field since 1985. This has included the operation over eight years of an incubator for technology based business.

More specifically the work of Oxford Innovation Ltd, a consultancy company which is a wholly owned subsidiary of the Trust, has concentrated recently on the relationship between the science base and industry and the ways mechanisms for technology transfer can be developed. The company undertakes special studies and pilot projects. The Oxfordshire Innovation Forum convened by The Oxford Trust has also studied technology transfer and innovation as it affects the region and is co-ordinating specific actions in Oxfordshire to promote innovation. A recent two-year action research project examined technology transfer in relation to small companies in Oxfordshire and Dr Bell who undertook this work on leave of absence from ESRC has now returned to work for the council. I have drawn freely on all these sources in offering comment to the Committee's questions.

Finally I enclose further information on the Trust, Oxford Innovation and from the Forum and Research project which I trust you will find informative. If there is anything further you need to know or to have expanded please let me know.

The following are general comments on the questions posed by the Science and Technology Committee of the House of Commons relating to innovation and competitive technology. These comments are based on the experience of staff at The Oxford Trust whose work to encourage the study and application of science and technology has been running since 1985. They also draw on: the specific researches of Dr Elizabeth Bell, Oxford Trust/Leverhulme Research Fellow at the Oxford Trust 1991-1993; surveys on attitudes to innovation amongst Oxfordshire based SMEs; considerations of the Oxfordshire Innovation Forum; and the extensive work of Oxford Innovation Ltd, a subsidiary of The Oxford Trust, in conducting technology audits in British Universities.

WHAT IS THE RELATIONSHIP BETWEEN THE SCIENCE BASE AND INDUSTRIAL INNOVATION?

The science base provides the training and the infrastructure for innovation; it educates and helps train and motivate bright minds. Some find careers in industry. On rare occasions in history a new technology or a new approach is thrown up through scientific curiosity and this has an immediate and major impact on industry and society. More often new technologies may wait some time before society's need for them is recognised and realised (example: Laser technology). At other times, advances of knowledge run alongside applications in a rapid dynamic interchange with each feeding off the other in a way which influences society markedly (examples include Computing Pharmacology). The trigger for this process may come from academic research or, and it is just as likely, from industry. The interaction of biological sciences and biotechnology is today's outstanding example where advances flow as much from the interaction between industry and the science base as from either one.

ARE THE MECHANISMS FOR TECHNOLOGY TRANSFER AND INTERACTION BETWEEN THE SCIENCE BASE AND INDUSTRY EFFECTIVE? HOW COULD THEY BE IMPROVED?

With regard particularly to small companies, technology transfer from the science base is inefficient, ineffective except in rare cases. Formal mechanisms on the whole tend to prevent small company technology transfer; they are regarded suspiciously as regulating and policing and create a perception of disproportionately high cost. Informal methods on the other hand appear to have positive effect (Liz Bell The Oxford Trust/Leverhulme research project). Culture, human relations and communications are key issues for successful technology transfer. Technology transfer, I am tempted to say, wears on average size eight shoes —to indicate that it has most to do with the movement and the perceptions of people.

There is a strong perspective that people in industry have lower status than those in academic research and those in smaller companies lower still. This "class" view works against effective communication and hence effective technology transfer. Probably the most effective transfers occur when the "inventor" accepts the product champion role and moves with the idea through all its initial phases towards maturity in the market. People who do technology transfer should be rewarded. For example criteria for academic promotion should take into account matters to do with technology transfer as much as papers published. Ideally people would move freely between academic research and industry and in both directions as the need and the opportunity arose.

Cultural change is required. The divide between academic research and industrial development needs more bridges. Such schemes as Teaching Company, Case, Link are beneficial though historically biased too much towards the larger company. Academics must feel that problems derived from industry make worthy projects for, for example, new PhD students to pursue and industry must feel that it can contribute to the R&D process on equal terms with academia. The SBIR programme which operates in the USA directs a small but definite percentage of state and Federal funded research to the small company sector each year and is a powerful lever to assist this cultural change.

IS INDUSTRIAL INNOVATION HINDERED BY A LACK OF COMPETENT PERSONNEL, BOTH TECHNOLOGICALLY AND IN MANAGEMENT SKILLS?

Skills in both the management of technology and the management of people in an innovative culture are in short supply in the UK. Training in these skills should form a part of courses for scientists, engineers and technologists as well as for students choosing business-related subjects. Traditional Business Management courses rarely weight training in Innovation Management equally with say Financial, Marketing or Production Management even if it is offered as part of the course. Managers, even amongst the highly technically competent, recognise the need for new skills in developing, selecting and managing innovations.

Oxford Innovation has recently developed an Innovation Action™ tool kit to assist SMEs to assess the skills required to manage innovation.

IS INNOVATION BY BRITISH INDUSTRY INTERNATIONALLY COMPETITIVE? HOW SHOULD THIS COMPETITIVENESS BE MEASURED?

It is clear from surveys in Oxfordshire that the best of companies are internationally competitive, many export more than they supply to UK markets, some achieve figures of 80 per cent of turnover and some have significant shares of global markets. This need to export is particulary true of companies who supply an advanced technology where the USA and Japan markets tend to pre-dominate. It is a strange requirement that relatively young companies which are technology based have to learn to manage global markets very early on. Often the UK market alone is too small to buffer the new company from the global stage whilst it learns to manage its business at home. It would be extraordinarily difficult to devise a suitable measure of competitiveness which would work for all sizes and types of company but perhaps some global benchmarks in specific industrial sectors could be published to inform managers.

IS SHORT TERMISM REALLY A PROBLEM FOR INNOVATIVE BRITISH INDUSTRY? IF SO, WHY IS THIS AND HOW MIGHT IT BE REMEDIED?

There is a serious shortfall of patient capital for innovative SMEs. Institutional funds are rarely applied to the innovation process. UK Banks are not sufficiently in partnership with industry. The venture capital industry puts too much emphasis on rapid growth. It is easy to forget that many of the world's current major players in electronics, chemicals, engineering, etc., grew quite slowly over very many years, that sunrise industries are a short lived modern exception rather than the rule. Remedies might include incentives for Business Angels, for local government pensions to invest in local business, for regional schemes such as investment trusts.

SOME SECTORS UK INDUSTRY ARE MORE SUCCESSFUL IN INTERNATIONAL MARKETS THAN OTHERS. WHAT CONTRIBUTION DOES INNOVATION MAKE TO THEIR SUCCESS? WHAT CHANGES IN CORPORATE STRATEGY MIGHT IMPROVE THE LESS SUCCESSFUL ONES?

It seems to be a characteristic of the companies in Oxfordshire who are successful in export markets that they have identified specific niche opportunities to exploit. In this sense they are dependent on innovation and also focus their activities in a determined way. Many consider the export markets to be their principal goal and direct resources to it appropriately.

WHICH STRUCTURES AND INSTITUTIONS WITHIN THE UK ARE PARTICULARLY HELPFUL IN ENCOURAGING THE PROCESS OF INNOVATION WITHIN A COMPANY AND WHICH HINDER THE PROCESS?

In the past the so called science base has not been particularly encouraging of innovation. AEA Technology in Oxfordshire, for example, has had a remarkably minor influence on innovation in the local economy over the years of its existence in the county, though it has been a world class centre of technology. Similarly universities have not in the past directed their influence into the local economy to help build on local strengths in terms of the people trained or the ideas generated and fed into local companies. On the other hand Polytechnics played a more practical role in the local economy. Similarly local government, property estates, banks, etc., have tended to assume reactive and regulatory rather than supportive and strategic stances. DTI schemes ranging from Support for Innovation through to current schemes such as SMART, LINK, etc., have been helpful but tend to be underfunded and often in the past preferentially taken up by the large companies, when one might argue that those companies were well capable of funding the innovation from their own resources.

SERC and DTI through the Teaching Company Scheme and CASE have made a unique contribution to innovation. Oxford Innovation Ltd has recently completed a study for SERC to explore the role of shared instrumentation between the science base and industry as a means of encouraging relationships. It is clear that the Training and Enterprise Councils (or Business Links) could have an impact on innovation training and target the local economy. Business estates providing premises for companies could be made to see the benefit of supporting innovation as a way of growing good tenants and maintaining yields from their property investments. This could be thought of as extending some of the ideas of so called science-parks into the industrial and business property sector. Oxfordshire boasts a good example in Milton Park. Local government could be encouraged and helped to develop plans for economic growth which reflect the strengths and abilities inherent in the local economy. This might take the form of an "audit" of a local economy to inform economic planners.

Memorandum submitted by Professor J E Midwinter, OBE, FRS, F Eng, Department of Electrical Engineering, University College, London (15 June 1993)

Thank you for your letter and enquiry. Please note that I am not working in Industry so that some of the questions are not directly relevant although I do work very closely with many companies and have spent most of my career in Industry.

I feel that in many of the discussions on this subject, there appears to be an unstated assumption that if only the good "science" in our HEIs could be transferred to our Industry, all would be well. I believe this view to be flawed in a number of respects and discuss below what I believe to be nearer the truth.

1. The basic "science" in UK HEIs is a very small fraction of the world's activity but is our contribution to it. Likewise, the world's basic science is largely open to our Industry, since basic science is normally published in the open literature. Hence, on a pure probability basis, the chances of a basic discovery of great interest to one of our companies actually being made in a UK HEI is rather small, no matter how good they might be—ergo—companies need to scan the world's science base, not just the very small part in the UK. Maintaining working links with HEIs may assist them in that.

2. The outcome and timescale for truly exploratory "basic science" is, by definition, not predictable. However, very few people have the ability to excel in this type of work and despite protestations to the contrary, it appears to me that equal quality research can be done in almost any area of endeavour, so that channeling resources into directions more likely to be of National value does not reduce the opportunities for carrying out top quality study. This implies that in apportioning funding for basic science, there should be some broad overview of the areas where benefit is more likely to accrue and funding should be weighted towards those areas.

3. One might conclude that we do not need to have our own "science base" but could rely on others. In part this would be correct. The Japanese have done very well for a long time with a very weak one, little of which was in HEIs but now that they are rich, they feel they need one of their own and the Koreans seem unimpeded by the complete lack of one!

4. But this ignores the fact that there should be steady output from much of the science base related teaching into the wealth creating parts of the economy in the form of trained people. This seems frequently to be overlooked and it seems particularly tragic that, at a time when we are short of trained manpower, PhD studentships seem to be reducing in numbers in favour of funding for RA positions which tend to trap manpower in HEIs rather than releasing it.

5. Much of the work done in HEIs is not basic but strategic in that the likely range of outcomes is relatively well defined and the likely area of their potential application is also known. Such work includes most in Engineering Departments and I suspect at least 50 per cent even in good Science Departments. However, in the second rate Departments I suspect there is no really basic exploratory work and rather limited work of genuine strategic value. I note in passing that the term "strategic" implies that things are being done in line with a "strategy", i.e., an overall long term view of where one is attempting to go to which by definition must be a highly public target if it is to be effective. However, this argument needs to be applied with great caution since mindless application could lead to rolling closures, generating positive feedback through minor weakness in an area leading to closure, leading to no skills in that field leading to further collapse in related areas. I believe this is particularly a problem when the technical planning to be applied to HEIs attempts to become too detailed or fine grained.

6. I sense from discussions associated with the HEFC Research Assessment that there is a widespread feeling, at least among many Academics, that as one moves from Basic through Strategic to Applied research, there is an inherent reduction in the difficulty of the task and a consequential reduction in its value. Conversely, one senses that in Government, there is often a feeling that Applied Research generates greater benefit more readily than Strategic or Basic and should therefore be more highly valued. It seems evident that the Applied Research that makes BMWs, Canon Cameras or Harrier Jets possible is of the highest quality but in each case, the relevance of HEIs to the process is debateable. A key factor in Applied Research that

is almost totally absent in Strategic and Basic Research is the notion that the "best solution" is that solution that "fits the users needs best", taking into account production process, cost constraints, potential manufacturing volume, etc. Such constraints are exceedingly difficult for HEIs to respond to and make the measurement of Applied Research quality very difficult (see attached reprint on Research Assessment).[1]

7. New products arise, at least in the "physics based" industries such as Electronics, IT and Telecommunications, from a fusion of original product inspiration, perceived market need, ability to manufacture and/or assemble the many components required at the right price, reliability, functionality, etc., and the ability to market and sell the product worldwide. The "audit trail" from the novel component or device, concept or software package to the successful product on the shelf is a long and very complex one. It also resides predominantly in Industry and it seems doubtful that HEIs can influence it very directly at all. One should also note that, despite very long and complex audit trails, product lifetimes in many high-technology areas are extremely short (<2 years) so that trying to plan the whole process too closely and rigidly ensures failure.

8. The commonplace Compact Disk Player illustrates the problem well. It relies upon special plastics and extrusion techniques for high precision mouldings, very cheap semiconductor lasers, ultra-high precision "mechatronics" to track the information on the spinning disk, sophisticated digital error correction coding and digital signal processing as well as quality audio circuits, etc., all in a package for about £100.00. It highlights the way that physics-based industry needs a broad portfolio of key technologies under their control out of which a great variety of differing products can emerge. Advances in a single technology seldom lead to new products on their own but only when coupled with many other technologies also. HEIs tend to feed into one aspect at a time of the key-technology pool

9. These observations highlight the key role of "systems engineers" in defining and bringing forward new products drawing upon the key-technology pool that is more likely to be fed by scientists. It is notable that the UK produces very few engineers *vis-a-vis* its competitors and is notably weak at spawning successful products, even when the technology pool is relatively rich. I suspect that there is a connection. Many Physics based companies have also been traditionally weak on market assessment because of their defence backgrounds and this inhibits the formation of customer-friendly products. *I am convinced that the Committee should focus its attention on the problems facing companies at this level to find where the real blockage to successful exploitation lies.*

10. Thinking about Telecommunications and Electronics, it is quite difficult to find key breakthroughs that occurred in an HEI anywhere, not just in the UK. However, everyone that I can think of was made by a PhD trained scientist or engineer, working in an Industrial laboratory (ATT Bell, BTLabs, etc.), but deriving his initial skills from HEI research training. In addition, such work draws on long-term fundamental understanding built over many years through painstaking fundamental research often from an HEI (which it would NOT have been appropriate to "technology transfer" at the time).

11. But in addition, all such laboratories maintain very close relations with many HEIs to obtain a broader window on the world, to assist recruitment and to supplement their own skill base by specialist skills.

12. My own Department and most of those in Electrical Engineering and Physics with which I am acquainted work closely with companies in a two-way relationship with lubrication flowing in both directions. When I visit Overseas Departments, I am usually astonished at how little interaction they have by comparison. Hence I believe the relationships in the UK are, relative to other countries, very strong, sometimes to the point of being counter-productive through requiring too much interaction. This is particularly true of multi-partner collaborative programmes such as the EC ones where the drain on resources (financial and human) from many meetings and much trans-European travel can be excessive.

13. The companies we work closely with are often large, with large R&D centres of their own (e.g., BT, Siemens, Northern Telecom, GEC, etc.) which means that the gap between where they start their studies and where we tend to leave off is non-existent, indeed there is usually overlap. This enormously eases the flow of ideas back and forth, to and from the company key-technology pool to the point that it happens effortlessly. But note that it does not necessarily lead in any direct way to identifiable new products, as discussed under (8) above. The Government's desire to link HEIs with SMEs is much more difficult since they cannot normally afford to think ahead more than a very short time whilst HEIs cannot normally respond very fast (e.g., SERC Grants are for three years, PhD studies are for three years, MSc projects only occur at set times, staff must teach at set times, etc.). Moreover, SMEs are likely to be single—or few technology companies and thus are barred from participation in many major product sectors.

14. I am not competent to address the financial issues affecting UK Industry but have been greatly pursuaded by the analyses carried out by Dr Ivan Yates, FEng and presented most recently at the RSA in their series of seminars on "Mánufacturing, Wealth Creation & the Economy". One interesting observation is that the existing economic models through which policy is generated (i.e., the Treasury model) do not apparently distinguish (at all or adequately?) between capital investment in, for example, retail warehousing

[1]Not printed.

versus primary manufacturing. As a result, this has led to the astonishing and mistaken conclusions of the last decade that the UK could survive as a service economy selling Japanese products just as well as it could by selling British products, i.e., with little manufacturing. The evidence from ones own senses seems to be to the contrary (ergo-strong economies like Japan are based upon manufacturing and growing ones like Korea similarly). The law regarding take-overs also seems to be cast in terms of hamburger-stalls rather than manufacturing industry. In either case, destruction of the enterprise takes only days but rebuilding takes decades or centuries in the case of manufacturing.

15. I am of the firm opinion that a significant factor in the way many UK companies operate with regard to the role of science and engineering in their business is affected seriously by the sparcity of Board Members with Science or Engineering training. The excessive attention to financial capital and the relative lack of attention to maintaining and developing the human capital marks them out from more successful overseas competitors. Good companies instantly impress one by the quality and breadth of the training and knowledge of their employees. Such training comes from a lifetime commitment to learning, not just a better Degree of A-level! But given the comments under 13 above, with short-term fiscal measures being the dominant ones in measuring company performance, this is perhaps not surprising and must be addressed.

16. It is frequently asserted that the UK education system is seriously lacking and many weaknesses are now both widely acknowledged and being slowly corrected (e.g., National Curriculum, replacement of A-levels, NVQs, etc.) but this will take time. More seriously, there appears to be no action to plug the trade-skill training gap (in quantity or quality terms) that so vividly exists between UK and its competitors whilst continuous on-job skills improvement cannot go too fast.

17. These latter comments may seem irrelevant to science/HEI-industry relations until one considers the following. A company following a long-term strategy with confidence naturally looks for long-term inputs to supplement and broaden its own work and frequently finds them in the HEI sector. A company expecting to be taken-over tomorrow is not interested in the day after and certainly will not waste time with HEIs! Too often, British companies have found themselves in the latter position. Likewise, striving to increase Industry-HEI collaboration will only destroy the HEIs if it succeeds in forcing them to become short-term Research Job-Shops whilst at the same time, it will do nothing to help companies preoccupied with short-term survival.

Memorandum submitted by GKN plc

GKN plc is an international Group, with headquarters in the UK, that is engaged in Automotive and Engineered Products (75 per cent of sales) and Industrial Services (25 per cent). It is a world leader in automotive driveline systems (in which it has annual sales of £1 billion) with a 30 per cent share of the global market for constant velocity joints (CVJ), the key components in front-wheel drive vehicles; it is the UK's leading supplier of light armoured vehicles (notably the Warrior and Saxon); Industrial Services includes the unique and highly successful Chep pallet pool.

Total annual sales are in excess of £2.5 billion, of which some 40 per cent are from its UK operations. There are 28,400 employees worldwide.

Answers to Questions Raised by the Science and Technology Committee

1. *How important is technical innovation in securing the future of your business?*

1.1 GKN's strategy in it manufacturing operations is to be the market leader through being *product led* and *process driven*, i.e., it seeks to provide its customers with the products they need and produced to the highest quality in the most cost-effective manner. This stance can be maintained only through continuous innovation to the most demanding standards in all areas of its business.

1.2 Technical innovation is vital in three main areas:

— **Product Development**—Most of GKN's manufacturing relates to the production of components and systems for the automotive industry. Although these are not end products, they are being supplied to vehicle manufacturers amongst whom competition is becoming increasingly severe, and they are under pressure continuously to improve their product performance. Environmental aspects and end user expectations are demanding quieter, more fuel efficient vehicles—this translates into pressure for GKN to produce smaller, lighter and smoother-acting components at competitive prices.

Product innovation is essential to our competitive position. GKN has two types of competitor. Firstly, its vehicle manufacturing customers often have component production capacity in-house; if GKN does not provide a superior product, the customer can take a higher proportion of its requirements in-house and/or seek to licence improvements back to GKN. Secondly, there is more conventional "independent" competition where GKN must stay ahead in order to protect and enhance its market position.

— **Process Engineering**—The vehicle industry is highly competitive, and the pressures to reduce costs and improve quality, product performance, etc., are intense, continual and given greater impetus by the growing influence of the Japanese. Improvements in manufacturing techniques and organisation, together with the involvement of all employees, are essential. Also, the growing number of variants within model ranges leads to lower batch volumes and the need for greater manufacturing flexibility.
In-house capacity at the vehicle manufacturers also gives rise to a specific pressure; these manufacturers can be persuaded to give up some of this capacity but only if the cost performance of the supplier is below their internal cost which, on the basis of contribution costing, is likely to be lower than the normal commercial price.

— **Application Engineering and Customer Service**—GKN seeks to be *the* design authority in its field(s). Therefore, it has encouraged greater interaction with its customers, particularly at the design stage, to ensure the optimum solution for any given application. Similarly, post-delivery troubleshooting and problem analysis are integral aspects of customer service. Improvements to this process through means such as direct CAD/CAE links with customers are constantly sought.

2. *How critical is technical innovation in setting the medium and long-term strategy or mission for your firm?*

2.1 GKN's published aims and values include the following:
— Provide our customers with high quality and competitively priced products and services.
— Quality is our first priority. We must look for quality in our products and services, in our working practices and in our human relationships—with our customers, with our suppliers, with the communities in which we work and with each other. We must pursue excellence and continuous improvement in everything we do.

2.2 Given GKN's strategy for its manufacturing operations and the pressures for continuous improvement on our business, all of which are set out in the response to Question 1, these aims and values cannot be fulfilled unless technical innovation is a key component of our strategy. Our strategic planning approach is to identify and develop the key factors for future success in any given business area, rather than address "technical innovation" *per se*.

2.3 The importance of innovation is reflected in both the size and nature of GKN's R&D effort. Annual expenditure on R&D is approaching £60 million (GKN ranked 21st in the recently published UK "R&D Scoreboard"), which relates almost entirely to its manufacturing subsidiaries; these have total turnover of some £1.5 billion so R&D expenditure represents about 4 per cent of sales. This effort is focused on process development and product improvement, reflecting the philosophy of continuous improvement.

3. *Does the UK's provision of education and training help (or hinder) innovation, compared with that of competitor countries overseas? Have you encountered problems in obtaining personnel with adequate scientific and technical skills? If so, in what areas were these?*

3.1 It is not easy to separate out promotion of innovation within education and training performance. Looking at engineering, successful innovation by an individual comes from:
— A sound technical understanding with good depth and breadth within the subject. This requires proper education and training.
— An understanding of the context (market and customer needs) in which he is operating. It is essentially up to industry to train its people accordingly. GKN's Graduate Training Programme and early career development addresses these needs.

3.2 New recruits must be properly educated, have appropriate vocational training and be motivated to perform well. However, the standard of the UK education system is variable and, in terms of the requirements of industry, there are some serious deficiencies:
— Comments about the secondary education system have probably changed little in the past 40 years —the top slice output is excellent by international standards, the bulk of the remainder is not. The weaknesses are in basic literacy and numeracy and in the limited level of vocational training. Some of these weaknesses can be overcome by in-house training, some by designing jobs that accommodate the limitations.
— Accommodation of these limitations is becoming increasingly difficult as the demands of new technology raise the skill levels required for engineering jobs. For example, the Japanese transplants (Nissan, Toyota, Honda, etc.) specify post-GCSE qualifications (A level, BTEC, etc.) for production line operators, and we are seeking similar levels in new recruits to our Continental European plants. With only about 60 per cent of 16- to 19-year-olds continuing in full-time education or comparable training, as compared with around 80 per cent in France and Germany and over 90 per cent in Japan, this is difficult to do in the UK, and will become an increasingly serious disadvantage.

— Education tends to be academically-orientated. This serves the top-slice well (although even at this level more basic vocational skills would be beneficial), but does not adequately meet the needs of the varying levels of technician. Many Continental European countries grant qualifications of equivalent level to both academic subjects and key vocational skills.

— At graduate level, the standard of the best is again excellent. However, the low number of graduates, and particularly engineers, going into industry gives particular cause for concern. It is not a new problem but is not getting better. The attractiveness of industry must partly be in our own hands, but actions and career advice that recognise its value and opportunities (e.g., the recent "Industry Matters" programme) would be helpful.

— Difficulties also arise because engineering degree courses are shorter than overseas (typically three to four years as against six in most Continental European countries) and not normally as focused in terms of engineering content. The main difference is that there is only a minimal input of industrial experience and basic vocational training; GKN's Graduate Programme has first to train its UK intake to raise them to the same level.

3.3 The organisation and use of engineers is important—industry has the capability of "turning them on" and encouraging innovation, or indeed "turning them off". The good sign in industry in this respect is that the move to flatter structures, and wide use of multi-functional project teams, puts engineers closer to customers and their needs, and provides the opportunity to solve them creatively.

3.4 There is a national problem of retaining engineers in engineering roles; migration into various areas of management is too large and too early. Management roles tend to be rewarded more highly than technical roles, and even the education system is guiding engineers in this direction. It is open to question whether innovation could and should be rewarded specifically in our payment systems.

4. *Does the UK financial system help innovation, again compared with overseas competitors?*

4.1 Generally, the availability of finance (whether for innovation or any other use) is not an issue for GKN. It is a well established Group with a good reputation and strong balance sheet, so it has a high credit rating. As a result, it can and does source finance internationally.

4.2 It is, however, influenced by its shareholder base being largely UK-domiciled. Traditionally, UK investors have sought a high proportion of their income from dividends on equities, as compared with countries such as Germany where other sources such as bonds are the prime source of income and equities are held more for capital growth. This is largely because UK equities are held more by pension funds, etc., than by banks and other corporate entities, and because equities have been seen as an inflation hedge. It is particularly the case in "yield stocks" such as GKN, which are regarded as sources of high and increasing dividends rather than capital growth.

4.3 The consequence is that UK companies distribute a relatively high proportion of earnings as dividends, putting pressure on the company to earn high rates of return and reducing the internal funds available for reinvestment (in times of recession, surplus funds can be eliminated completely). The result is that UK companies are relatively risk averse and tend to seek growth primarily through acquisition. There is also pressure, particularly during a recession, to reduce discretionary costs such as R&D in order to protect the dividend; a reduced dividend can have serious consequences in terms of lower share price and possible takeover. GKN has been able to resist these pressures, and maintain spending on R&D, training, etc., through the present recession.

4.4 The extent to which this situation affects UK companies adversely is debatable. There is a counter-argument that it promotes greater efficiency, and it is certainly the case that the UK has more major corporations relatively speaking than Germany. However, it is indisputable that Germany's manufacturing performance has been superior; a contributory factor could be that its financial system has prompted greater growth in the small/medium sector and allowed a longer-term view to be taken of R&D and other "risk" investment.

4.5 Although the UK financial system does encourage "short-termism", this is less of a problem than the lack of stability in the UK economy relative to its major competitors. The uncertainty caused by excessive economic cyclicality (and, particularly, two deep recessions in little more than a decade) has a very damaging effect on long-term investment such as R&D.

5. *Does the UK's Science Base (i.e., universities and research institutes) and the mechanisms for encouraging interaction between it and industry help innovation, and are things done better overseas? What contacts does your company have with the Science Base organisations? How do these compare with your competitors, particularly overseas competitors?*

5.1 The recent "Realising our Potential" White Paper on Science and Technology focused on weaknesses in the translation of science and technology into wealth creation, as follows:

- The widely perceived contrast between our excellence in science and technology and our relative weakness in exploiting them to economic advantage.
- The absence of a clear statement of Government objectives with the consequent transmission of mixed and sometimes contradictory signals to the scientific and engineering community.
- Within limited resources, the need to manage Government investment in science and technology to better effect.
- The need for more effective mechanisms for implementing policy, including those policies relating to international collaboration.
- Problems in relation to the management of careers in science and engineering.

GKN believes that this represents a good summary of the UK position, with one major omission—perhaps the overriding lesson to be learned from the Japanese is that we do not make sufficient effort to find out what our customers really want. Development of techology serves little purpose if it has no end use.

5.2 Science, technology and engineering represent a wide spectrum from pure research at one end to applications engineering at the other and, as already identified, the bias in the UK is very much towards basic scientific exellence. GKN, in common with most engineering companies, operates very much at the other end of the spectrum and, therefore, finds that its interaction with the Science Base is not as effective as it might be.

5.3 Extensive contacts are maintained with universities, in particular, and with research institutes. These are effective in terms of graduate recruitment, interchange of ideas, flow of information, etc., but have not led to much joint development work. This is because the prime interest of the Science Base appears to be in undertaking large funded projects which can be operated under their own control so as not to infringe the concept of academic freedom; GKN's need is for smaller, more continuous developments that must be interactive with the market and competitively priced.

5.4 A definitive statement on whether things are done better overseas is difficult to make. In many ways, the UK culture can be quite innovative (e.g., the quality of software development is second to none), but some things are done more successfully elsewhere. The challenge is to learn from others, and the following are selected examples of practices that the UK could aspire to:

- **Sweden**—has a high level of *communication* between its universities, etc. and industry, built on good personal contact (because the country is smaller) and a system where, because industry has provided a higher proportion of academic funding, it has a greater say in the output.
- **Germany**—benefits from a different perspective on the importance of engineering to the nation; the *status of the engineer* is comparable with that of, say, medical research in the UK (engineering is not even recognised as a "profession" in the UK).
- **Spain**—realised the importance of manufacturing in the modernisation of the country in the post-Franco era, and *Government policy* over many years has been to promote its significance, particularly within the education system.

5.5 GKN's manufacturing activities have few UK-based competitors. Overseas competition is from the major automotive producing countries (i.e., Western Europe, USA, Japan). For the reasons already outlined, it is a reasonable generalisation that the support they receive from the Science Base is probably more effective than in the UK, although the extent of this advantage is hard to define.

6. *What measures might be taken by Government, by industry or by the Science Base to enable industry to innovate better? How could your firm do better?*

6.1 If the Government and the Science Base are to assist industry to innovate better, all the parties will need to:

- Accept that innovation is really about continous improvement related to the needs of customer and markets, and not necessarily basic scientific invention.
- Understand better the needs of industry on one hand and the abilities, motivations and constraints of Government and the Science Base on the other.
- Communicate more effectively.

6.2 The Government's prime responsibility is to provide an environment in which industry can flourish, fundamentally through economic stability and provision of appropriate education and training. It is also essential that it promotes a cultural framework that emphasises the importance of industry to the nation, and in doing so it needs to get much closer to industry in order to understand its needs better. the apparent Government bias towards services in the 1980s was not helpful, but the recently raised profile of the DTI is more encouraging and needs to be developed.

6.3 The Science Base continues to be biased towards the pure science end of the science-engineering spectrum. Priorities are driven either by individual academic advancement and/or large funding sources. Engineering product and process development is usually at a more mundane level that does not excite. Other than some aerospace companies, few engineering activities are large integrated businesses; as indicated in the response to Question 2, GKN has one of the highest R&D spends of UK-based groups, yet its largest manufacturing site employs less than 3,000 people and it is engaged in few large-scale development projects. The need is for "little and often" more than major leaps of scientific discovery.

6.4 Industry has not done a good job of making its expectations from Government and the Science Base very clear. There are numerous Engineering Institutions, Trade Associations and management organisations (CBI, EEF, IoD, etc.), all with somewhat different priorities, so a co-ordinated view rarely emerges; and, just as Government/the Science Base needs to understand industry better, so the opposite applies. Equally, industry tends to be highly risk averse which drives a "blame" culture towards problems, whereas the more innovative Japanese reward the highlighting of problems.

6.5 The mechanisms for communication do not work well. Contact is too dependent on formal structures such as steering committees, where the views expressed will be biased by the representation (e.g., how will government learn the views of, say, the automotive industry, and vice versa, if the "engineering" representative on a given committee is from the aerospace sector?). The only effective way is to promote greater every-day contact through working groups, secondments, staff interchanges, etc., but these are difficult because they cut across rigid career structure in each sector. This is, arguably, the greatest problem, but one to which there are no easy answers.

Memorandum submitted by Glaxo Holdings plc

INTRODUCTION

We welcome this enquiry by the Science and Technology Committee into the role of the Science Base in the generation of innovation and competitive technology. With the recent publication of the White Paper we believe this enquiry to be particularly timely as it seeks to address some of the fundamental issues that lie behind the exploitation of UK science technology and engineering for the well-being and health of the people of this nation and its economy.

In the comments we make in this submission we have used the term "Science Base" as meaning science and technology within the Universities and public research institutes. However we would stress that the UK science base should extend to encompass science and technology within the industrial and government science sectors. We believe that it is important that all of these sectors should see themselves as components of, and partners within, the UK science base.

The comments that follow are made in the light of our own experience as a member of an industrial sector which is critically dependent upon science and technology. It is also a sector which has a demonstrable record of both innovation and exploitation of scientific and technological knowledge. Thus the whole process of drug discovery and development is intimately dependent on advances in science and technology, whether we are considering the pathological, cellular and molecular changes involved in a disease process to identify new targets for intervention, or the development of novel methods of chemical synthesis and analysis, or the scaling up of processes for manufacture, or more efficient analysis of data from large clinical trials.

Glaxo employs over 7,000 people in its world-wide R&D facilities and in 1992-93 spent about £740 million on drug discovery and development activities. Including capital expenditure, the total investment was £1 billion. In addition we have developed many collaborative arrangements with the Science Base in universities and research institutes and strategic alliances with biotechnology-based companies in the UK, Europe, USA and elsewhere.

1. *How important is continuing technical innovation in securing the future of our business?*

The dependence of the pharmaceutical industry upon science and technology means that it is vital that there is continuing relevant technical and scientific innovation within the Science Base, within the laboratories of the industry itself and also those of other industries ancillary to our own such as, for example, those operating in the field of biotechnology and information technology. In particular, the developments that have occurred in the area of recombinant technology and genetic engineering have already had a very significant impact upon our own activities. Thus it is now possible to use the techniques of molecular biology to probe disease mechanisms and processes, enhancing our understanding of them, and so we are better able to identify targets for drug intervention than previously. This will be increasingly the case as these techniques start to allow us to probe important and common, but hitherto badly understood, diseases such as the degenerative diseases of the brain, connective tissues and joints (e.g., senile dementias, rheumatoid arthritis, autoimmune diseases, etc.). The current research activity in the human genome field is another example of the value of innovative technology that will make significant contributions to the future of the pharmaceutical industry.

It is important that innovative science is encouraged within the Science Base, but to be maximally effective this should be carried out within "mission research" contexts. This will ensure that the innovative skills of academia are employed in areas which can be of value and enhance the ability of industrial science and technology to move forward in existing and new areas of activity. It is hoped that implementation of the framework provided in the White Paper, "Realising our Potential", will make it possible to develop the relationships between the academic and industrial sectors of the science base in order to optimise the potential for innovation which exists within the public Science Base.

2. *How critical is technical innovation in setting the medium- and long-term strategy or mission of our Company?*

The research and dvelopment activities of the pharmaceutical industry are essentially long term in nature. Thus technical innovation, of the sort mentioned above, which may take place today is unlikely to yield marketable products within the next 10 to 15 years. However, for the reasons discussed above, an understanding of the underlying defects which give rise to disease states, and so allow the discovery of novel targets for drug intervention, is necessary to get us to the starting line. Thus innovation is both important and urgent for us. It is because of these considerations that we have entered into alliances with biotechnology companies, and academic groups in order to ensure new technology is translated into useful practice without delay. (See below.)

Technical innovation is also important for other aspects of our activities. Thus innovation may improve our ability to synthesise and manufacture novel chemical molecules; the development of new methods for the synthesis of chiral molecules and the application of biotransformation technology provide examples in this field. New technology, such as the advances in analytical chemistry and drug delivery, can and have, allowed us to carry out certain development activities more effectively or produce new ways of formulating or delivering medicines.

Thus we believe that continuing technical innovation across a wide area of activities is of overriding importance to the continued, and long-term development and well-being of our Company.

3. *Does the UK's provision of education and training help innovation compared with that of competitor countries?*

Being a company in a highly science-dependent industry, Glaxo is dependent upon the public sector Science Base for the provision of well trained scientific and technical staff for our own laboratories. The present system of training in science and technology places too much emphasis on getting large numbers of people through the degree system without having sufficient regard to the scientific and technical needs of the universities, industry and government science departments. Thus there is now a shortage of trained and skilled technicians in the UK. In many cases graduates who have pursued a science course are commonly employed in what were once regarded as technician posts because of this shortage. The training given during most science degree courses now lacks a sufficient amount of practical skill development. This is due to the increasing amount of scientific knowledge that it is deemed necessary to impart and also, and importantly, the high cost of providing laboratory experience.

Glaxo has long recognised the importance of scientific education and training and annually provides over 90 places within our research and development departments to allow undergraduate students to acquire experience of industrial science and technology whilst undertaking their degree courses. In an increasing number of cases we now hear complaints from PhD students, and even post-doctoral scientists, that they are in effect employed as research assistants. Thus the system that has arisen in the UK now fails to provide the technician cadre which once formed key personnel in research departments and brought with them particular innovative flair. The graduates replacing them lack the necessary skills and have to receive much of the training in post that they should have received during their scientific education.

In general Glaxo does not have difficulty in obtaining scientific staff because of our position in the industry. However other companies, particularly the smaller ones and depending upon their geographical location, do experience difficulty. The number of young people entering science training, particularly in the physical sciences is, we believe, declining. The reasons for this must be identified and remedied. The lack of any real career structure in academic science must also be seen in the context of this question as being one deterrent to entry into a scientific or technological career. Thus the UK is losing a considerable innovative potential by this failure to attract people into science and we view this as potentially serious for the long-term success of the UK's science-based industries.

The White Paper does contain proposals to remedy the deficiencies in the present degree system. The elevation in the status of the Masters Degree, so that it becomes the major qualification for the professional scientist, is a move in the right direction. We hope it will provide an opportunity to make good the shortcomings of the present first degrees by enlarging specialist scientific knowledge and developing laboratory skills. Glaxo provides PhD studentships and scholarships for about 250 PhD students at over 50 universities and similar institutions in the UK. More than half of these are fully funded by Glaxo and the rest are funded in conjunction with Research Councils. These awards provide the student with research experience in both academic and industrial environments.

4. *Does the UK financial system help innovation, again compared with overseas competitors?*

Glaxo has for many years been financially self-sufficient, and is therefore not well-placed to comment directly.

5. *Mechanisms for encouraging interaction between the Science Base and industry*

The cut-backs in Government funding for research in academia over recent years have had the effect of forcing the universities and similar institutions to turn towards alternative sources of finance, particularly industry, for their research activities. Whilst this has brought advantages to both sides, it has lead to the development of tensions between the institutions and industry which inhibit, or even prevent, collaboration between industrial and academic scientists.

One important issue is the failure on the part of some university Industrial Liaison, or Technology Transfer Departments to understand, or accept the differences between collaborative, or inquiry, research projects and "contract" research and also the needs of different industrial sectors. This becomes particularly acute when attempting to set terms relating to contributions by the industrial partner to the indirect costs ("overheads") of the project, and also ownership and exploitation of intellectual property rights (IPR). This failure does lead to support for research projects being rejected by industry. The tendency of some Industrial Liaison Departments to attempt to operate blanket rules, or develop doctrinaire policies, have created barriers between the academic and industrial sectors.

The policy of encouraging universities to seek industrial funding for their infrastructure and research activities, together with an inadequate level of central Government funding, has lead to this situation developing.

A further problem which arises out of the same financial imperatives, and which is increasingly being encountered in the biotechnology field, is the tendency for overoptimistic views of the commercial potential of their work or discoveries, by academic groups. This leads to applications for patent protection in inappropriate circumstances, and then attempts to licence out the technology. This has recently been most clearly seen in the human genome cases where attempts have been made to patent DNA sequences without knowing the functions of the genes they may represent. The effect of this trend could well be to effectively "sterilise" areas of biotechnology and make exploitation difficult as far as industry is concerned.

Whilst we see it right for universities to undertake work of a more obviously "contract research" nature, where their expertise and experience allows them to, there is the danger that, if carried too far, this trend could result in a compromising of the nature of academic science activities and the stifling of creativity. The tendency of academic departments to see themselves as providers of services for industry—i.e., as "contract houses"—must not be taken too far.

In Glaxo we regard collaborations between ourselves and the Science Base as important because of the opportunity they provide for interactions between industrial and academic scientists, and also their potential to allow for the rapid application of new technologies and exploitation of new knowledge. At present we have collaborative research projects or programmes in 37 UK academic institutions and devote approximately £5 million to these per year. In addition we also enter into major collaborations with academia, such as that made possible, by the creation 18 months ago, of the Glaxo Institute of Applied Pharmacology at Cambridge. This Institute is an integral part of Glaxo Group Research Ltd and has as its main objective the exploration of biological processes and identification of novel targets for drug discovery. However it operates outside the more rigid restraints imposed by the very focused drug discovery research within the Company's main programmes. It is set within an academic department in a leading university with staff drawn both from Glaxo's staff and also appointed by the university, using grants from Glaxo. Thus this development has allowed interaction between academic and industrial scientists, it fosters close collaborations, and provides opportunity for a beneficial mixing of two "cultures". It is we believe also a good example of how curiosity or "basic" research can be an integral and essential part of "Mission" research which the White Paper seeks to foster.

We have also recently launched a multicentre and multidisciplinary research initiative—*"Action tb"*—in the field of Tuberculosis research. This again brings together academic scientists across a range of disciplines, in the UK and South Africa, and Glaxo scientists at Greenford with a common mission. This is to understand the organism causing Tuberculosis and to discover new drugs or vaccines to meet the growing and urgent threat that this disease poses.

It has been our experience that there is considerable opportunity for valuable partnership and collaboration between industrial and academic scientists, particularly at the basic end of the research spectrum. This is to be encouraged. However if barriers are erected, either in the form of unrealistic financial demands or contractual terms, then UK industry will be encouraged to look to the Science Bases of other countries for their collaborations. For example, in our experience indirect costs levied on collaborative projects with universities in Europe or the USA are significantly lower than in the UK. At present we will contribute 42 per cent of the overall costs of the collaborative project as an overhead in the UK, whilst in Europe and many of the US universities we have agreements in which the indirect cost is usually in the region of 20 to 25 per cent.

6. *What measures may be taken by Government, industry or by the science base to enable industry to innovate better?*

The pharmaceutical industry has an excellent record of innovation and development of new medicines. It is one of the sectors of UK industry which makes a substantial positive contribution to the UK balance of trade by its exports. Whilst it is not easy to isolate any particular factor which lies behind this record, there are a number of points which can be made.

(a) There is a commitment to devote a very significant amount of money to research and development activities. Glaxo devotes approximately 15 per cent of our annual turnover to R&D and about 30 per cent of this resource is devoted to drug discovery research.

(b) In our research organisations within Glaxo we employ a large number of scientists and technologists most of whom are versatile and willing to change and adapt their interests and activities to meet new challenges. This is in marked contrast to the usual academic tradition of specialisation to a high degree. Thus our scientists can often see peripheral issues which might come to assume an importance for their research.

(c) Our research staff are given very clear objectives which are set within broad therapeutic areas and have moreover often been involved in the decision-making process which established projects and priorities. They can then pursue these and can adopt a "mission" approach to their work rather than having the acquisition of data for the next paper as a major objective. This is an encumbrance on our colleagues in academia who must publish papers in order to further their own careers or get the next grant: such an outlook necessarily encourages short-term research projects and operates against the longer term basic research needed to unravel fundamental processes and phenomena which we depend upon.

(d) Industrial research is "managed" and the research teams are accountable and yet free to follow ideas within their particualr project. This accountability is generally accepted, and regular appraisal of the performance of staff is part of our culture and is seen as a part of career development.

(e) The infrastructure of our laboratories is maintained at a high level, which we believe to be essential for the practice of high quality scientific research and development activities.

(f) There is significantly less bureaucracy within our research organisations compared with the public sector. This results in an ability to develop a new resource, change direction, follow leads or enter new fields with considerable flexibility and minimum of delay.

Government—can encourage innovation by ensuring that the Science Base can take a longer-term view of their research activities, a significant amount of which should be set within a "mission" environment. It is hoped that within the spirit of the White Paper the new Research Councils will adopt a longer-view of support for projects and individuals. The present short-term pattern of funding without any obvious policy or strategic elements is not conducive to innovation because the "peer review" system probably tends to work against the novel or unknown and favours conservatism and the status quo.

The infrastructure of the Science Base needs urgent support to enable it to meet the needs of late twentieth to early twenty-first century science and technology.

The career structures in the Science Base must be created to remove the dependence on short research contract-type support for the post-doctoral scientist. He or she must have a sufficiently secure career to enable a concentration on scientific or technological objectives.

The Science Base—scientists and technologists within the Science Base should be more willing to be open with potential industrial partners and collaborate on a partnership basis with sharing of ideas and research results. The academic scientist with an innovative and potentially exploitable idea should endeavour to develop an industrial link earlier rather than later in his or her development of the concept rather than adopting an over-secretive attitude.

Industry—As shown above the three key features of the pharmaceutical industry which contribute to successes in innovation are:

— A willingness to invest significant funds.
— The establishment of R&D organisations; and
— The management of science and scientists.

It is suggested that some other industrial sectors could learn from this.

Memorandum submitted by J B H Jackson, Chairman of Celltech Group plc (22 June 1993)

I am replying to your letter of 19 May. You wrote to me in my capacity as chairman of Celltech Group plc but my reply also reflects my experiences as chairman of Xenova Group plc and my other connections with young high technology British companies.

It is useful when considering a topic of this sort to have some basis for comparison and I think that a comparison of the rate at which biotechnology is being "commercialised" in the US on the one hand and in the UK on the other is particularly informative.

The gross domestic product of the US is, very broadly speaking, six times that of the UK. This is driven by a population some four and a half times that of the UK. One would expect these ratios to be reflected in statistics relating to business and, in particular, one would expect the rate of commercialisation of new "brain intensive" technologies in the US to be somewhere in the range of four and a half to six times that in the UK.

Over the 10 years to June 1992, some 1,230 new biotechnology companies were created in the US. On a like for like basis the UK figure was 100, at most. In the human health area, i.e., therapeutics and diagnostics, the figure for the US was about 800 and for the UK about 50. These crude figures are striking enough. They become, I believe, more striking when one looks at money and people. In the 12 months to June 1992 those young US biotechnology companies raised between them approximately $3.5 billion of new money. As at June 1992 the stock holders equity in those companies was some $13.6 billion. And as at June 1992 also those US companies were employing a total of 79,000 people. I do not have published UK comparisons and I suggest you obtain comparisons from the DTI which should have made them. However, I am confident you will find they provide ample evidence that compared with the US we are not investing sufficient money or people in the commercialisation of biotechnology. I am also confident that the position in respect of biotechnology (which is probably an extreme case) is likely to be reflected in the position of other advanced technologies. By "sufficient" I mean what is needed if we are to keep our place as a major industrial nation able to maintain, let alone improve, the standards of living of its people as the newly emerging countries gradually dominate many of the older and labour intensive industries. Some may say that all this is a matter of timing and the UK will catch up. But we cannot afford the time lag: competitive advantage in the world of new technologies is measured in time lead.

I believe that underlying this are deep rooted cultural differences between the US and the UK which influence attitudes to risk, change and the role of the individual in society. This is partly a European phenomenon of 19th Century origin but it has some distinct British "overlays" stemming from our early industrialisation and imperial past and the social "war" fuelled by the damaging class system bred by them. I think that we have yet to understand what is needed to be a modern industrial nation. In particular we fail to value sufficiently either our business base or the business aspects of our science base. Nor do we value those who take risk to obtain material reward. These failures are reflected particularly in our education system and the way in which young people are taught about business and science and their economic and social value. I think they are reflected particularly also in our attitude to private wealth creation and our tendency to disparage those who "look after" themselves and their families instead of embracing collective approaches. There is ample evidence that during the greater part of the post war period the creation of wealth, particularly at the individual, as opposed to the collective level, has not been given high priority as a desirable objective. In the US the big sin is not to try, one could be forgiven for thinking that in the UK the big sin is to succeed.

Of more immediate moment, during nearly the whole of the post war period fiscal and economic policies have been pursued which have driven private savings into housing and particularly into collective pension schemes. One very important consequence of this is that there is now virtually no retail private placement market for shares of young companies in the UK and virtually no retail market in quoted shares. Both of such markets are large and active in the US and are used extensively by young companies. Furthermore, the attitude of the London Stock Exchange to the listing of companies is "protectionist". This again is in marked contrast to the US where if a young company's sponsor is satisfied that there would be a market for that young company's shares and that young company is prepared to accept the demanding consequences of full continuing disclosure, a quotation can be obtained. Two hundred and fifty of the young US biotechnology companies are quoted. The figure for the UK is five. A very important source of capital for young companies anywhere has to be venture capital either in the hands of funds or individuals. Venture capital will never be readily available from either source unless investors can see the possibility of liquidity after a relatively short period. This is why the permissibility of early quotation can be important. There is a growing risk that young UK high technology companies will be financed increasingly from the US. A number of the UK's young biotechnology companies, for example, raised money in the US last year. The consequences of "relating" to another country's capital market can easily result in pressure to migrate to that country.

The problem does not lie, I believe, in the science base or the "rate of innovation" in the UK. There has been some interesting evidence produced recently by the Medical Research Council which suggests that in quality and quantity terms we more than hold our own in the UK. The MRC have also demonstrated, however, that about one half of the work that comes out of the laboratories they fund is commercialised in the US or by US controlled corporations. This is evidence which supports my contention that our problem lies in the rate of commercialisation of new technology, not in the rate of creation of new technology.

So far as remedial action is concerned, the cultural aspect can only be tackled with patience and determination over the long term. Much of that work will have to be done in our education system. More immediately, I believe government should consider with some urgency what steps can be taken to re-divert the savings stream so that more private individuals can contemplate investing in young companies a part (only a small part is needed) of their savings whilst exercising their right to make their own wealth and provide for their own futures. Such steps should also help to re-establish a vigorous retail market in quoted shares. None of this can happen without people taking risks. The price, particularly the political price, lies in that notion of risk. People will not like it when things go wrong—as they will. Somebody will lose money they cannot afford to lose. But to have a world in which people are protected from the consequences of their own risk taking is like having a pure world. The trouble with a pure world is that it is sterile and in it nothing happens.

Tempting though it is to believe that investing institutions and pension funds can be cajoled and coerced into making high risk investments in young companies, I believe that is a dangerous, even a dishonest, approach. Most of those bodies are, or acting on behalf of, trustees. One cannot as a nation pursue for many years fiscal policies designed to encourage people to place their private savings in the hands of trustees and then say those trustees must be encouraged to yield to pressure from seomebody else. The price that lies in the notion of risk cannot be lessened by making it indirect, collectively spread and less obvious. The whole question of "tax breaks" in relation to private capital formation needs looking at again.

Nor is direct government intervention by the provision of "enterprise" capital likely to provide an attractive solution. Whilst it is probably true that Celltech would not have been created as a hybrid (part publicly owned, part privately owned) without interventionist action by the National Enterprise Board and the MRC, that very act of creation caused a problem for Celltech. for much of its early history Celltech was uncertain whether its mission was "to commercialise British science" as a duty to its public sponsors and the tax payer or to "cherry pick" and drive single mindedly for hard commercial objectives as a duty to its private sponsors. Those two alternatives are not easily made compatible and time and energy lost in the attempt to do was a major factor in difficulties experienced by Celltech in the late '80s. A wholly publicly owned Celltech would probably have found the choice even more difficult.

Memorandum submitted by C Scroggs, Chief Executive, Fisons plc (5 July 1993)

Thank you for inviting Fisons to contribute to your enquiry into the routes through which the Science Base is translated into innovative and competitive technology. It is an issue which I believe is important not only to Fisons, but also to the future success of UK manufacturing industry generally.

Before I answer the specific issues you list, I should like to give a brief introduction to Fisons so that the Committee has a context in which to consider my responses.

Fisons' two core businesses are ethical pharmaceuticals and scientific equipment. Shown below are the 1992 trading results and a territorial breakdown of sales.

Fisons' Activities	Turnover £ million	Profit £ million
Pharmaceuticals	427	71
Scientific Equipment	676	35
Other Businesses	181	11
	1,284	117

Fisons' Group Sales to	£ million	Per cent
United Kingdom	170	13
Continental Europe	297	23
North America	660	52
Rest of World	157	12
	1,284	100

I regard Fisons as a science based company which competes in many of the world's most aggressive markets and must compete against top international companies. Fisons generates 87 per cent of sales overseas of which over £200 million represents goods that are exported from the UK. This undoubtedly forms a useful contribution to Britain's trade position.

Rapid and effective innovation is becoming an increasingly important source of competitive advantage. Although Fisons' access to the Science Base is already quite good, we are constantly striving to improve our exploitation of science and technology and our abililty to create valuable new products and services for our customers.

The questionnaire, which is attached,[1] has been completed in respect of Fisons' ethical pharmaceutical business. I have completed the more general questions raised in your covering letter to reflect the interests of the entire company.

I hope my opinions are found to be useful by the enquiry. We participate actively in our key trade associations, the CBI (National Manufacturing Council), ABPI and BEAMA, who are aware of these views.

[1]Not printed.

Q1: How important is continuing technical innovation in securing the future of your business?

1.1 The exploitation of technology is fundamental to the future success of Fisons. Pre-requisites for this include a suitable marketing infrastructure, the possession of (or access to) an effective manufacturing capability and continuing technical innovation. Technical innovation is important but the assumption that better products alone will lead to more successful companies is simplistic.

1.2 Evidence of Fisons' commitment to technical innovation can be seen from the £85 million investment made in R&D last year. This represents a ratio of R&D expenditure to sales of 6.6 per cent, up 0.4 percentage points from 1991. The recent International Business Week survey ranked Fisons among the top 20 UK investors in R&D. A further example of Fisons' increasing awareness of the importance of technical innovation was the appointment of the R&D Director for the Pharmaceutical Division to the Fisons Board of Directors in February. This is in addition to the long standing commitment to science that Fisons has demonstrated by always ensuring that the Main Board includes a Fellow of the Royal Society, currently Sir Walter Bodmer, Director General of the Imperial Cancer Research Fund.

1.3 Ethical pharmaceuticals is one of UK industry's success stories and to maintain this position requires frequent scientific discoveries and technical advances. It is well recognised that a significant part of the value of a drug company, such as Fisons Pharmaceuticals, lies in its intellectual property. This includes patented chemical entities, dosage forms and delivery devices. Branded drugs remain a valuable asset, even when patents expire, as they can sometimes command a price premium over generic competition. The R&D pipeline is also an important piece of intellectual property and, although difficult to value, certainly contributes to the high P/E ratio pharmaceutical stocks have commanded historically.

Recently, it has been suggested that pressure to control the price of healthcare may bring about further curbs on pharmaceutical reimbursement in the USA. This is, in fact, continuing a trend that has been observable in a number of countries for some years. In addition, generic drug launches can rapidly erode market share and the population is becoming ever more litigious. Thus, the pharmaceutical market environment is becoming increasingly hostile and if the industry is to remain as attractive as it has been, the invention and licencing of new drugs will need to occur both more rapidly and more frequently. Keys to this are higher investment in R&D and greater use of technology.

1.4 Fisons' laboratory supplies businesses distribute a large range of scientific products to laboratories in the EC, the USA, Australia, New Zealand and Singapore. Technical innovation by these companies is not contained within what would traditionally be considered the product (which could be test tubes, laboratory chemicals, etc.). Instead, investment in technology is focused on the delivery of high quality customer service. Our British company has recently gone a step further than this and suggests it is undergoing a fundamental transformation from a company which profits from marketing products to one that profits from developing relationships. Information technology is a valuable aid in enabling this change in mind set. Fisons' American laboratory supply company has gained competitive advantage by providing each sales representative with a lap-top computer by which he can not only show potential customers product details, but also place orders, find stock availability, check on customers' payment of invoices, etc. The database is updated every night, while the representative is asleep, using a modem connection to a central computer. This is one example of how the innovative use of technology can dramatically improve the quality of a service.

1.5 Fisons Instruments manufactures and markets analytical instruments, such as gas chromatographs and mass spectrometers, for use in markets such as pharmaceutical research or environmental testing. Important market trends are towards lower and lower detection limits, physically smaller instruments, simpler operation and increased reliability. These trends all demand technical innovation. A fundamental management issue concerns the rate of technical change. In order to keep ahead of or even up with competitors, there is a need to innovate more rapidly or make larger innovations or, preferably, both. So-called concurrent engineering is a valuable technique in this regard.

Q2: How critical is technical innovation in setting the medium- and long-term strategy or mission for your firm?

A2: Setting strategy is a complex issue. It requires a good understanding of market trends, competitor activity, potential legislative changes, the world economy, regional trading blocks, etc. Certainly one important element of creating strategy concerns the potential offered by technical innovation, and the level of resources Fisons invests in research and development demonstrates Fisons' commitment to this process. The Pharmaceutical Division and Scientific Equipment Division are both well staffed by technical experts who make a significant contribution to the creation of medium- and long-term plans. The Planning Department at Fisons' Group Headquarters is small, but scientists/engineers who understand both technology and technology exploitation issues are well represented. As I mentioned earlier, two Main Board members are well respected scientists.

Gaining competitive advantage from technical innovation is, therefore, deeply ingrained within Fisons. It is both a subconscious and a high profile input into corporate strategy, reflected explicitly in our annually updated 10 year corporate plan.

Q3: Does the UK's provision of education and training help (or hinder) innovation, compared with that of competitor countries overseas? Have you encountered problems in obtaining personnel with adequate scientific and technical skills. If so, in what areas were these?

3.1 Fisons employs approximately 1,000 graduate and post-graduate staff in technical departments in the UK. The majority of these people hold degrees in physical science, biological science or an engineering discipline. In addition, several hundred more graduates are employed in commercial and administrative functions.

3.2 During the past five years, Fisons has encountered difficulty in recruiting highly qualified molecular biologists. In a few disciplines, such as information technology, Fisons has also had to correct an apparent under-supply of graduates by offering relatively high salaries. The economic recession has certainly made it easier to fill vacant positions with the high quality people we demand. We also recruit experienced personnel who bring with them not only scientific and technical skills, but also a knowledge of the industry, management skills and experience of different cultures.

3.3 The UK has a tradition of producing first rate scientists and engineers, and I believe that our graduates can still hold their own with most competitor countries such as the US. Countries such as Singapore appear to be developing very sophisticated higher education systems that offer a first rate technical training. Germany retains a very successful range of technical and commercial "apprenticeships". There is a worry, however, that Britain rather neglects the education and training of a significant proportion of the population. It is outrageous that 40 per cent of boys and 30 per cent of girls leave school with less than one GCSE Grade C. Fewer than 18 per cent of boys and 15 per cent of girls achieve a Grade A-C at GCSE in chemistry. It is of concern to Fisons that the pool of people capable of studying chemistry or biological sciences at university may not increase rapidly enough to supply the graduates pharmaceutical companies will require as the emphasis on R&D continues. This could serve as a future block to technical innovation in the UK, offsetting the advantage of a good supply of post-graduates who are "cheap" by international standards.

Q4: Does the UK financial system help innovation, again compared with overseas competitors?

4.1 The arguments that the UK financial system is "short termist" are well rehearsed. To counter this, there are studies which demonstrate that, in general, when companies with a good track record in innovation invest in product development, stock markets react positively. Perhaps the question of whether short termism exists is less important than the belief held by many industrial managers that the City is short termist.

High flying executives often spend a relatively brief period in any one position and quite a short time within a company. I believe a study in the US showed the averages to be 3-4 years and 5-6 years respectively. There is a danger that a newly appointed manager may think he must make his mark quickly and could assume that he will not be around when long-term investments bear fruit.

Incentive systems are frequently short termist, targeting one year profit levels. Unless some aspect of investment or future returns is built into the scheme, this can lead to a lack of goal congruency between individual managers and the longer-term benefits of innovation.

4.2 The swift write down on 100 per cent of R&D capital expenditure is a helpful feature of UK taxation. In 1991, a House of Lords Select Committee report (Innovation in Manufacturing Industry) recommended a system of additional tax allowance on R&D expenditure. It is unfortunate that this initiative has not been acted upon. Within the US, there are Federal R&D tax credits and certain State tax incentives to encourage higher levels of R&D. Japan also offers a system of tax credits and grants. There are also certain tax benefits to be gained by operating in such diverse countries as Malta, Singapore, Canada, Pakistan and Belgium. Although the detail is complicated, I would be unlikely to recommend a site for an R&D establishment merely to take advantage of a favourable tax regime; the greater importance is to have a pool of well trained scientists available and contact with a benign local scientific culture.

4.3 In Britain and in certain other countries, the price level that can be charged for ethical pharmaceuticals is affected by R&D expenditure. In the UK, this is an element in the Annual Financial Return (AFR) scheme, The AFR is not without its difficulties for the industry, but it does serve to a degree in encouraging R&D and innovation.

4.4 There does appear to be anecdotal evidence that it is difficult for young companies to raise intermediate or mezzanine funding. Whilst this might not be of direct concern to Fisons (which has good access to capital markets), it could act as a brake on high tech start-up companies which appear to be an important source of technical innovation.

Q5: Does the UK's Science Base (i.e., universities and research institutes) and the mechanisms for encouraging interaction between it and industry help innovation, and are things done better overseas? What contacts does your company have with Science Base organisations? How do you think these compare with those of your competitors, particularly overseas competitors?

5.1 Despite the accelerated development of the Science Bases within other countries, Britain's universities and research institutes (such as those of the Medical Research Council) remain a valuable source both of intellectual property and of trained engineers and scientists. There are, however, few powerful independent research institutes in the UK Science Base and British research associations are not perceived to be very dynamic.

The highly respected Battelle institute was founded in the United States but now has several international locations. SRI International began as the Stanford Research Institute 45 years ago and now has more than 3,000 professionals working in 100 disciplines biased towards physical and life sciences, engineering, industry research and marketing. Although the resources of these and similar facilities are, in theory, available to all who are prepared to pay, in practice they retain a national bias and play a rather small role in assisting technology transfer in the UK.

Government methods of encouraging interaction between the Science Base and industry have often been via financial incentives. Fisons participates in both domestic and European collaborative programmes. The DTI's LINK-TAPM (Technology for Analytical and Physical Measurement) programme appears to be rather over-bureaucratic and has a slow approval process. It can take between one and two years before confirmation is given that a project will be funded and at what level that funding will be. The European Eureka programme has a simpler application procedure and a well prepared project tends to have a rather better probability of being funded than under domestic schemes. Fisons' current participation in a Eureka Euroenviron project is to kit out a mobile laboratory with analytical instrumentation for environmental applications.

5.2 A new business, Fisons Applied Sensor Technology, worked closely both with Plessey and with Cambridge University during early research phases and received financial assistance from the Laboratory of the Government Chemist under the LINK scheme.

5.3 Fisons is aware of various intermediaries such as BTG (the recently privatised British Technology Group), the Centre for Exploitation of Science and Technology (CEST) and Defence Technology Enterprises, but in general obtaining information on the capabilities and expertise of academic research establishments can be difficult. Overseas, these matters appear better organised. In Germany, for example, the 48 Fraunhofer Institutes are well respected and command a high public profile. Prior to the election, there was talk of "Faraday Centres" for the UK which would focus on technology transfer. This was to be brought about by training graduate engineers to PhD level in a commercial environment, undertaking contract R&D and acting as a gateway to academic institutions. I understand that the most recent proposals represent a significant watering down of the earlier ideas.

Q6: What measures might be taken, by Government, by industry or by the Science Base, to enable industry to innovate better? How could your firm do better?

6.1 The absolute size of the UK Science Base is small in global terms and this could limit access to new ideas. Not only should Europe become thought of as Britain's home market, but also the entire European Science Base should be made available to UK companies. When competing in world markets against those who can tap into the resources of the USA or Japan, Britain cannot afford to lose out on the leverage European collaboration offers.

6.2 There appears to be sufficient anecdotal evidence to suggest that the status of engineers and scientists is too low in Britain, both within companies and society as a whole. Engineers and scientists create a significant proportion of the UK's wealth but the public perception of these professionals is often crude—a boffin in a white coat or a man in a greasy overall. Compare this with a German chartered engineer who would share a status similar to that of a medical doctor.

6.3 Similarly, insufficient importance is given to scientific developments and newly developed products. Japanese newspapers, including the Nihon Keizai Shimbun, frequently print items about technological innovations. The Nikkei Weekly of 14 June 1993, for example, contains articles about new products including electric reels for deep sea fishing, flashing armbands for cyclists, a watch with a built-in remote control for television and VCR, a new shampoo for hair with split ends, and electric bedpans. In addition, there are brief reports on technological stories including ultra thin wire developed for large scale integrated circuits, faster low voltage bipolar CMOS, genetically engineered rice and the manufacture of insulating films of barium strontium titanate. On the other hand, British newpapers concentrate much more on the financial activities of companies—profits, dividends, takeovers, lawsuits and liquidations.

There tends to be two exceptions to this. The first is when some truly remarkable scientific development is announced. An example of this type of story is "scientists may have found how to stop cancer cells producing tumours" (*Financial Times*, 21 June 1993). The second exception occurs when a column is devoted to science and technology. This is equivalent to Radio 4's Science Now or the BBC's Tomorrow's

World; they present accurate and interesting features but in a rather compartmentalised way. Science and technological issues are important to society and need to be integrated into the mainstream of the media as in Japan.

6.4 Trade associations are also significant players in facilitating the transfer of technology from the Science Base to companies and from company to company. This they achieve by acting as a broker, presenting industry views to government, assisting in the arrangement of inward and outward missions and organising seminars. I personally devoted considerable effort to my role as President of the Federation of British Electrotechnical and Allied Manufacturers Asssocation (BEAMA) in 1991-92 because of the importance of these organisations. Fisons remains an active member of GAMBICA, the trade association of the instrument control and automation industry within the UK, which is federated within BEAMA. I represent BEAMA on the CBI National Manufacturing Council.

The Association of the British Pharmaceutical Industry (ABPI) is another trade association to which Fisons belongs. It lobbies government on behalf of pharmaceutical companies and has an active group working in research strategy. I personally contine to work with the British Pharma Group (BPG) which represents pharmaceutical companies that invest heavily in research and are significant exporters. The mandate for the BPG includes, for example, patent issues. Failure to maintain the integrity of patents would have serious repercussions on the level of innovation within the pharmaceutical industry.

6.5 In the post-war years, the production of food in Britain benefited greatly from the efforts of numerous agricultural research institutes. Indeed, UK agriculture remains among the most productive in the world, despite the contraction of these centres in the 1970s and 1980s. As the country's economic priorities shifted from agriculture to high tech industry and services, government does not appear to have demonstrated the same degree of vision or commitment to emerging technologies. The Alvey programme in information technology, for example, although significant, was short in duration and was not of the same scale as the assistance given to aid innovation in farming.

6.6 The most interesting aspect of the White Paper published in May concerns "technology foresight". This is an attempt to do for the country what some individual companies do already. It involves looking for a fit between promising areas for research and the abililty to exploit the results. Fisons does some of this, but it would be complacent to suggest that our process could not be improved. It is, however, notoriously difficult to "spot winners" and the concept of "technology forecasting" which was in fashion 20 years ago now has little more credibility than a crystal ball.

6.7 The day after the publication of the White Paper, the DTI announced it was to stop funding strategic technology within industry. The Advanced Technology Programmes, and some of the club R&D projects will be wound up. Yet the White Paper suggest that the LINK steering group will be strengthened. There does not, as yet, appear to be an integrated process for developing the conditions needed by the UK to innovate and exploit science and technology.

Memorandum submitted by Nissan Motor (GB) Limited (23 July 1993)

I enclose the questionnaire[1] which has been answered by Nissan European Technology Centre based in Cranfield. However first I would like to respond to your initial and more general questions.

How important is continuing technical innovation in securing the future of your business?

Technical development is absolutely vital in an industry as competitive as the automotive sector and one where there are exacting demands to meet ever more stringent safety, noise and emissions legislation.

However, it is important that the meaning of innovation is defined. All too often it is used to describe "blue-sky" technology where scientists devote their attention to technological breakthroughs for their own sake. Nissan believes this is wrong as re-inventing the wheel is not what British industry currently needs.

As a nation we are less successful than our competitors because we put too much effort into "blue-sky" invention and not enough emphasis on application and execution. The British culture emphasises the individual invention of completely new concepts derived from basic principles. Other cultures (Japanese and German) emphasise the refinement of existing technology by group activity focused on customer satisfaction. Thereby satisfying the "market pull" and exploiting the commercial advantage to the benefit of industry and national economy.

For example we need to apply innovation to improve steels to have higher strength with improved corrosion resistance, aluminium alloys that can be cast with less porosity and wheels that can be made lighter and stronger. In terms of total contribution to wealth creation these would have a greater effect than inventing a car road wheel made from plastic or steel substitute. Much of our key innovation occurs in improving our product technology for the customer and in developing manufacturing processes in order to raise quality and reduce unit costs.

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[1]Not printed.

How critical is technical innovation in setting the medium- and long-term strategy or mission for your firm?

Innovation, according to our definition, is an integral and continuous part of our business. Because of regular product replacement cycles and the market demands for new types of vehicles, we are continually developing improved products and using innovative approaches to provide more customer benefit for lower expenditure of resource.

Does the UK's provision of education and training help (or hinder) innovation compared with that of competitor countries overseas? Have you encountered problems in obtaining personnel with adequate scientific and technical skills. If so, in what areas were these?

At a general level we have not experienced serious problems but Nissan shares the growing concern about the falling standards of numeracy and literacy among school leavers. A high standard of basic education remains vital for industry.

Nissan's experience is that academic education for degree engineers is high but that technician training has reduced in volume as has attention to quality achievement in detail.

Recent initiatives from government appear to acknowledge this and are moving in the right direction.

The UK's education system emphasises individual inventive or research capability at the expense of team oriented practical achievements.

Does the UK financial system help innovation, again compared with overseas competitors?

What is missing is the encouragement for small- and medium-sized enterprises to invest in design and development. When we compare our UK and German component suppliers it is evident that the German firms have a long-term commitment to design and development to satisfy customers. This is reinforced at every level by the importance placed on high class engineering in German society.

We want our UK suppliers to have to take full responsibility for designing and developing their own components but for many firms this is a major cultural shock.

Any increased commitment to design and development should be reinforced by government support for engineering training in these SMEs.

Does the UK's Science Base (i.e., universities and research institutes) and the mechanisms for encouraging interaction between it and industry help innovation, and are things done better overseas? What contacts does your company have with Science Base organisations? How do you think these compare with those of your competitors, particularly overseas competitors?

We fear that any interaction is currently too directed towards "blue sky" research. The reason for this could be that most science and technology academics achieve promotion and stature through pure and individual undirected research. Many of the science and technology staff in universities have a very limited experience of industry. A few have only a passing knowledge which is usually obsolete. Technological links between technology in universities and industry could be improved by studying the German system where engineering academics have to spend set periods in industry.

What measures might be taken, by Government, by industry or by the Science Base, to enable industry to innovate better? How could your own firm do better?

Looking at the success of industry in Germany and Japan over a long period it is clear that more innovation is not needed and that detailed analysis and development of materials and products is the key to providing the customer with what he wants. (NB Conversely we already produce far more Nobel Prize winners than Japan).

Government should review all of its initiatives directed towards innovation and consider in stark commercial terms the usefulness of every programme.

Priority should be given to "real world" development which will have a broad impact and allow British industry to become more competitive and better serve its global customers. For example we must have a basic strategic infrastructure of industry. We need to be able to source basic materials and commodities steel, glass, plastic, fasteners especially those of the highest product quality. However we cannot be pre-eminent in everything so we should decide what is of strategic benefit to industry and the economy.

Memorandum submitted by The Rover Group (24 June 1993)

I would like to provide the following input to the inquiry your Committee is conducting, concerning the routes through which the Science Base is translated into innovative and competitive technology.

Q1. *How important is continuing technical innovation in securing the future of your business?*

A. It is very important for any car manufacturer to keep pace with its competitors in the technical specification of its products. Sometimes this is driven by legislation, particularly in respect of exhaust emissions, noise and safety, and sometimes by customer expectations or the desire to secure a temporary marketing advantage.

In general, however, technical innovation for the automobile industry is not about basic research, but the development of familiar technical principles and their application to specific products. This can, however, result in product features or even new products which are widely perceived as innovative in the broader sense. Examples could include the Mini, air suspension on the current Range Rover and the progressive adoption of air-bags on many of today's products. In this sense innovation is extremely important to Rover.

Although not the subject of this enquiry, the potential for innovation today extends beyond the purely technical to all the business processes in which a company is involved. In Rover's view, the ability of a company to be continuously innovative in this wider sense of the word is fundamental to commercial success.

Q2. *How critical is technical innovation in setting the medium- and long-term strategy or mission for your firm?*

A. See previous answer.

Q3. *Does the UK's provision of education and training help (or hinder) innovation, compared with that of competitor countries overseas? Have you encountered problems in obtaining personnel with adequate scientific and technical skills. If so, in what areas were these?*

A. Formal educational credentials provide only a starting point as far as technical skills (or indeed any other skill) are concerned. The value of an individual to the company comes from the training and experience they obtain subsequently which enables them to become experts in their field. Universities cannot provide this, and such individuals are difficult to replace, although we can normally recruit the graduate "raw material" when needed. While more educational awareness of how industry works would be helpful, there is no substitute, in our view, for company specific training and experience. Rover devotes considerable attention to this and currently supports a number of post graduate university courses geared to specific aspects of the company's activities; while certain modules of these courses would probably be common to other industry firms, most need to reflect Rover's particular operational methods and philosophy. In this framework, innovation (in the widest sense of the word) is a function of the development of expertise in a particular field where education provides the "key to the door" but not more. We cannot easily assess educational standards between the UK and other countries and there may well be differences. For example, in the automobile industry we note that there is a tendency for Japan and Germany to employ a far greater proportion of engineers in management positions than in the UK or USA. This reflects the greater stature of engineering as a profession in these countries. However, we do not believe these differences need be fundamental to the ability to be innovative.

Q4. *Does the UK financial system help innovation, again compared with overseas competitors?*

A. We have no direct experience of the financing of innovation, *per se*. Our perception is that any tendency to focus on short-term returns will mitigate against basic research being undertaken where the returns are uncertain and if the companies involved have not an established track record in their field. The only international comparison we can make is with Japan where there appears a greater preparedness to extend finance on the expectation of returns only in the longer term.

Q5. *Does the UK's Science Base (i.e., universities and research institutes) and the mechanisms for encouraging interaction between it and industry help innovation, and are things better overseas? What contacts does your company have with Science Base organisations? How do you think these compare with those of your competitors, particularly overseas competitors?*

A. Rover has a wide range of contacts with universities and research institutes. The principal contribution these make is in the transference of scientific knowledge to industrial applications.

Funding assistance is available through the Science and Engineering Research Council which is responsible for the review of proposals for research. So far this process has tended to favour scientific over industrially orientated projects and we welcome the proposal in the recent Government White Paper on Science and Technology that industrialists should be involved in the review process.

Rover also uses LINK projects which involve both the DTI and SERC; these have been very beneficial but rely heavily on Government financial support which is becoming more difficult to obtain. A tendency to focus on SMEs may overlook the fact that larger companies work in partnership on technological issues with their suppliers and that this can be an efficient means for the transfer of technology from larger companies to what are often smaller companies.

In Rover's view access to the UK Science Base via SERCs and LINK projects are valuable mechanisms to assist innovation in industry, but, as indicated above, each has its deficiencies at present.

In countries such as Japan and Germany the automobile industry is perceived to be a fundamental part of the national economy and appropriate encouragement is given to promote the technological advance of the industry. This includes the állocation of a greater proportion of Government funded R+D for industrial applications.

Even the USA is now making moves in this direction with its USCAR programme of collaborative R+D. Much of this work will be undertaken in conjunction with the National Laboratories.

Q6. *What measures might be taken by Government, by industry, or by the Science Base to enable industry, innovate better? How could your own firm do better?*

A. As indicated in the answers to the preceding questions, we would like to see:

- Greater awareness by universities of the environment in which industrial companies operate.
- An improvement in the perceived stature of engineering and manufacturing industry as a career.
- Government financial assistance with the post graduate training that companies need to undertake in conjuction with universities in order to translate academic qualifications into commercially applicable expertise.
- A greater orientation of SERC projects towards industrial applications, rather than the pursuit of pure scientific research.
- Continued Government support for LINK projects and a recognition of the role of large companies in the transfer of technology.
- A full recognition of the importance of the automobile industry to the UK economy and a determination to ensure the long-term global competitiveness of our industry in the UK.

In addition to the above responses, I would also refer you to the input we recently provided to the Trade and Industry Committee. This also included the topic of innovation. I hope this will be of assistance in your enquiry.

Memorandum submitted by IBM

The answers to many of the questions posed in the questionnaire are difficult to answer when considering research in a company with product range as large and diverse as IBM's. The response would depend on the area of the company and the type of research being undertaken. For example, the processes involved in software development are somewhat different from research into new hardware processes and products. Even when looking at innovation in computer hardware, the development of a new personal computer is very different from a new mainframe computer. In view of these problems we have concentrated on the questions outlined in your letter, while answering the background section of the questionnaire.

Before turning to these questions there are a few remarks we would like to make.

First, we very much welcome the recent White Paper on UK science and technology as a significant contribution to national policy. It conveys a long-sought conviction that the relationship between academia and industry really does matter, and that the thrust of public funded research should be towards medium- and long-term economic benefit.

A further point relates to the smaller enterprises and their role. Their position at an intermediate point in the supply train, yet out of the international scene, leaves them exposed. Satisfaction of their need for training, finance, access to technology and the latest methodology know-how, is inhibited by their size. This has a high cost, both in the competitiveness of products at the top of the supply chain and in realising the potential for overall economic growth.

Other topics worth considering are the relevance of universities' computer science research and the real need for vocational IT courses.

While the White Paper retains the dual funding of university research, thereby maintaining a competitive element, there is a serious question as to how much independent university computer science research is contributing to useful innovation.

Innovation brings with it the need to continually refresh the skills and abilities of the practitioners of new technologies. This involves focusing on the lifetime maintenance of professional skills. Here the professional institutions could provide considerable impetus by ensuring the maintenance of professional skills is a condition of membership. It is also vital that industry and academia get together to provide vocational training programmes, including on-site tailored courses which result in recognised qualifications. (IBM's manufacturing site in Greenock have examples of this sort of on-site course, in association with Strathclyde University.)

Turning to the questions in your letter:

(1) Continuing technical innovation is vital for the future success of our business which is dependant on the regular supply of new technology and the expertise in its effective use. We would stress the importance of innovation in a particular sense—the process of exploitable, continuous improvement in products and processes. Innovation is rarely a functional step, it is generally incremental. It is also important to recognise that while some innovation relates to core and high technology, most activity concerns lower technologies. Here, simple sustained attention to detail and the removal of redundancy at every possible point, will result in more predictable and less risky benefits.

(2) Throughout the entire business the need for technical innovation is critical. The best-of-breed benchmark for some of our product sectors is moving at 40 per cent or more a year. The cost of

providing competitive manufacturing processes for some of these products is in the £'00s of millions. Supply chain management and incremental process improvement based on innovation are important medium-term strategies. We pursue longer-term programmes as well, for example super-conductivity, these programmes have potential as part of the strategic future plan. The technical imperatives fuelling the staggering changes in technologies such as; logic, memory and communications, have an enormous effect over our product, plant, supply, manpower and financial strategies.

(3) In addition to the comments we have already made concerning the need for vocational training to continually refresh skills, there is a need for a culture which encourages, through fiscal and social incentives, young bright people to acquire engineering and technical expertise. This applies to young people who need to be well educated at all levels (not just brilliant PhDs). In particular UK figures compare very poorly for 16- to 19-year-olds against our major competitors. That said, partly due to our internal sponsored students and poor external pay norms, we have not had significant difficulties in recruiting staff with the necessary manufacturing, scientific and technical skills.

(4) Long-term funding is a prerequisite for much innovation, the availability of this funding is a particular problem for smaller enterprises. In this area the UK financial environment has probably been a hindrance compared with our main competitors. In the UK (and possibly the US) it seems that there is more incentive to divert profit into dividends, thereby maintaining the current worth of a company in the markets, rather than invest in research and development. Unstable and variable economic conditions are also major factors which drive investors to short-term thinking.

(5) The OST White Paper and the supportive comments suggest that near market linkages and market led policies are taken seriously. Britain's university science and technology research is relatively small compared with the private sector near market arrangements. In general the scale and organisation of the science base is not bad and we would not see this as something to focus on. On the contrary, it is the private sector that often fail to recognise the need to exploit the good people and ideas provided by the science base.

(6) Innovation is best encouraged by effective communication, the spread of best practice through involvement and secondment with more emphasis on continuous improvement and bench-marking. There is a need to concentrate on relevant incremental innovation as well as the more exciting long-term, high tech programmes. It is also essential to match innovation with the necessary training, providing skilled practitioners that implement and disseminate the new technologies.

There is always a requirement to improve communication, Government could establish a National Communication Strategy that covers every level of the innovation process and that involves all parties. This strategy should actively stimulate and continue to promote secondment and the transfer of skills, between industry and the science base.

Lastly there needs to be some evaluation of the role of standards, such as BS5750 and ISO9000, in respect to innovation. While these standards have significantly enhanced the awareness and adoption of quality procedures, their attention to fixed processes could have a considerable stifling effect on innovation.

Memorandum submitted by Dr C Gaskell of The 600 Group PLC (1 July 1993)

Thank you for your letter of 20 May. I regret the late reply but I have been overseas for most of the past month. Before responding, perhaps I should state my qualifications for replying to your enquiries. I studied electrical engineering at Manchester and Oxford Universities receiving a first class Hons degree for the former and a doctorate for the latter. Following this I held a number of technical and general management appointments in the engineering and electronics industries including 17 years with GEC, during which time I acted as Managing Director or supervisory Managing Director for a number of their high technology businesses. My current appointment is Chief Executive of The 600 Group which encompasses a range of engineering products from machine tools to lasers.

I believe I can save the committee a lot of time in their deliberations by giving a very simple answer to your first question. The Science Base is almost totally irrelevant to the development of the innovative products and processes necessary for the success of manufacturing industry in the UK. In my experience, obsession with the Science Base has led to British industry being encouraged to concentrate on "technology push" products rather than "market pull" products. The classic example is of course Concorde but there are many others.

What is really required in our business, and in all the others with which I have been associated, is the application of available technology to generate the new product or new process that the market requires. The essential innovative element comes in finding a novel solution to the customer's problem which most often, and most successfully, involves the application of current technology rather than innovative new technology. It is the insistence on approaching innovation from the research and technology end rather than from the market end which is the root cause of much of the failure of British industry to develop competitive new products.

To turn next to your detailed questions in order, my experience suggests that the quality of under graduate and post graduate education given to engineering students in UK universities is considerably inferior to that provided in the equivalent US organisations. One root cause is that university teachers are well aware that their promotion depends on the publication of scientific papers whereas their efficiency as teachers is virtually unmeasured. I believe that the bulk of university funding should be based on a detailed assessment of the quality of training provided. Research funding should perhaps be concentrated on a much smaller number of post graduate establishments. The recession and consequent shake out in manufacturing industry has meant that there is currently little difficulty in obtaining staff with adequate technical skills. My experience of the boom years suggests that university courses might currently have too much concentration on digital and software skills for electrical engineers rather than the traditional analogue and radio frequency area.

I have little experience of overseas financial systems but it does seem to me that the UK system, which expects short-term returns and high levels of dividend, gives greater recognition and support to those companies which expand by aggressive takeovers rather than those which do so by development and marketing of innovative new products. The relative lack of availability of venture capital for new start ups is also an inhibiting factor in the UK compared with the USA.

As I have already said, the links between the UK Science Base and the engineering industry are largely irrelevant to development of innovative new products. One of the few successful examples of university industrial interaction that I have seen was the joint Rolls Royce/SERC programme in which the two jointly funded the research programmes but Rolls Royce had sole choice of the projects. I understand that this was so successful that it was terminated. Our own companies have a small amount of contact with universities under the teaching company scheme and also as an occasional source of consultancy. My experience of overseas companies suggests that companies and Governments there do not expect the Science Base to generate innovative products for industry and therefore are not disappointed when it doesn't happen.

Having spent many years looking at competitors in the capital goods industries in overseas countries and studying those that have been the most successful innovators, I have come to the conclusion that the single most important factor for market led product innovation is access to a large stable domestic market having low interest rates to encourage industrial investment. This means that the UK Government must forswear the use of high interest rates (which destroy capital goods markets) as virtually their sole mechanism for controlling the economy.

Although our company has maintained its investment in new product developments through the recession, the continuing contraction of the UK capital goods market makes it difficult to concentrate on anything other than survival. The Government should take 3 per cent off interest rates immediately and eliminate the borrowing requirement by knocking 20 per cent off all departmental budgets. We have had to reduce our direct and indirect costs in this company by over 40 per cent over the last three years. It is painful, but it can be done by firm management.

I hope this is helpful to your Committee's deliberations. Please let me know if I can give any further assistance.

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