Renewing U.S. science policy : private sector views hearing before the Subcommittee on Science of the Committee on Science, Space, and Technology, U.S. House of Representatives, One Hundred Second Congress, second session, September 24, 1992.

RENEWING U.S. SCIENCE POLICY: PRIVATE SECTOR VIEWS

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED SECOND CONGRESS

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*Ranking Republican Member.

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RENEWING U.S. SCIENCE POLICY: PRIVATE SECTOR VIEWS

THURSDAY, SEPTEMBER 24, 1992

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:06 a.m. in room 2318, Rayburn House Office Building, Hon. Rick C. Boucher [chairman of the subcommittee] presiding.

Mr. BOUCHER. This morning the Subcommittee on Science begins an inquiry into the future of the Federal science and technology policy. This is the first in a series of hearings on this timely and important subject that will continue during the course of the coming year. This inquiry is the result of recent signs of stress in the research system, and dramatic changes in the world in the past several years that have profound implications for the future of Federal science and technology policy.

New opportunities and new challenges are created by the end of the Cold War and the rise of multilateral economic competition to U.S. companies from abroad, challenging the historic dominance of U.S. companies in the international market, and also the emergence of global environmental problems, among other factors. The fundamental tenets of Federal science and technology policy have not changed since the promulgation of Vannevar Bush's report, "Science - The Endless Frontier" in the 1940s, but we have now reached an historical breakpoint which calls into question the 45-year- old consensus with respect to U.S. Science policy that was formed in the wake of the publication of that report.

Changes are also occurring today within the research system itself, which the subcommittee is aware of and is— and is certainly considering. There is a dramatic growth in the size of the university-based research force, and while Federal research budgets that fund their work are growing, the public support for research is being out-paced by the growing size of the research force itself, with the result that there is no longer a reasonable assurance that a worthwhile research project, once proposed, will receive funding. And that fact has led to an historic high in frustration levels among researchers on university campuses nationwide.

We've also witnessed changing public attitudes toward the research community, as a result of a few incidents of misconduct in science that were widely publicized, the cold fusion debacle, and unmet societal needs that are occurring, despite significant ad-

vances in science and technology. Signs of stress and change are also evident in Government-funded laboratories, especially the Department of Energy's weapons labs, as a result of the anticipated restructuring of defense- related R&D in the wake of international changes which have occurred.

Worrisome signs are also evident in industry where, following a decade of growth, industrial investment in research and development is declining. The United States now trails Germany and Japan in non-defense research and development spending, stated as a percentage of gross domestic product. Taken together, these changes suggest the need for a broad-based inquiry into the adequacy of today's Federal science and technology policy and the directions that that policy should take for the years ahead.

The Subcommittee on Science has accepted the responsibility of carrying out this broad-based examination. During the course of our inquiry, we will seek to develop comprehensive recommendations for a re-direction of the Federal research and development mission.

Today we begin the inquiry by obtaining the views of the private sector, a very significant performer and user of the results of federally funded research. We will ask our witnesses is they're getting what they need from the Federal investment in research. We'll also ask to what extent the Federal role in funding research should be more closely tied to the creation of wealth, through the development of commercially viable technology.

We're also interested in industry's desire and ability to participate in defining national research goals, and in helping us assess the progress that we make toward achieving those goals, once they are defined. Our goal is to ensure that the U.S. research enterprise addresses the central challenges confronting the Nation in the years ahead, improving our economic competitiveness, raising our standard of living, improving public health, and improving environmental quality, among other factors.

The Science Subcommittee is not alone in its examination of federally funded research and development. Recommendations will be sought by our group from a number of other groups that are engaged in studying issues related to the future of U.S. science policy, such as the President's Council of Advisors on Science and Technology, which is currently examining the health of research universities, the Carnegie Commission on Science, Technology and Government, which will release next week a major report on the future of Federal science policy, and the recently established National Science Board Commission on the Future and Direction of the National Science Foundation.

We also intend to seek advise from other sectors of society that have concerns for the health of the research system, and we will watch with interest similar investigations concerning the funding and management of R&D activities by other industrialized nations, such as Australia, Canada, France, Germany, Great Britain, and Japan.

This morning we have two very distinguished panels of witnesses, and the subcommittee extends a warm welcome to each of you. We know that you're busy, and we appreciate very much your taking time to share your thoughts and suggestions with us on this

important subject. Before turning to your testimony, I would like to recognize other Members of the subcommittee for their opening statements, and we'll begin with the ranking Republican Member of the subcommittee, the gentleman from California, Mr. Packard.

[The prepared statements of Mr. Boucher and Mr. Packard follow:]

OPENING STATEMENT
OF THE
HONORABLE RICK BOUCHER (D-VA)
CHAIRMAN, SUBCOMMITTEE ON SCIENCE
ON
RENEWING U.S. SCIENCE POLICY:
VIEWS FROM USERS OF FEDERALLY FUNDED RESEARCH

10:00 a.m. - 2318 RHOB
September 24, 1992

This morning the Subcommittee on Science begins an inquiry into the future of federal science and technology policy. This is the first in a series of hearings that will continue throughout next year.

This inquiry is the result of recent signs of stress in the research system and dramatic changes in the world in the past several years that have profound implications for the future of federal science and technology policy. New opportunities and new challenges are created by the end of the Cold War, the rise of multi-lateral economic competition from abroad, and the emergence of global environmental problems, among other factors.

The fundamental tenets of federal science and technology policy have not changed since the promulgation of Vannevar Bush's report,

Science-The Endless Frontier in the 1940s. But, we have reached a historical break point, which calls into question the forty-five year old consensus on U.S. science policy.

Changes are also occurring within the research system. There has been a dramatic growth in the size of the university based research force. And while federal research budgets that fund their work are growing, public support for research is not keeping pace. No longer is there an assurance that a grant proposal for a scientifically meritorious project will receive funding, resulting in a rising level of frustration among academic researchers. We have also witnessed changing public attitudes toward the research community as a result of a few incidents of misconduct in science, the cold-fusion debacle, and unmet societal needs that are occurring despite significant advances in science and technology.

Signs of stress and change are also evident in government-funded laboratories, especially the DOE weapons labs, as a result of the anticipated restructuring of defense related R&D. Worrisome signs are also evident in industry where, following a decade of growth, industrial

investment in R&D is declining. This decline is reportedly due to both financial pressures and emphasis on short-term results at the expense of long-term research. The U.S. now trails Japan and West Germany in non-defense research and development spending as a percentage of gross domestic product.

Taken together, these changes suggest the need for a broad based inquiry into the adequacy of today's federal science and technology policy and the directions that policy should take as we approach the 21st Century. The Subcommittee on Science, has accepted the responsibility for carrying out this broad-based examination. During the course of our inquiry, we will seek to develop comprehensive recommendations for a redirection of the federal R&D mission.

Today we begin our inquiry by obtaining the views of the private sector, a significant performer and user of the results of federally funded research. We will ask our witnesses if they are getting what they need from the federal research investment. We will ask to what extent we should more closely tie the funding of research to the creation of wealth

through new product development. We are also interested in industry's desire and ability to participate in defining national research goals and in assessing progress toward the defined goals.

Our goal is to ensure that the U.S. research enterprise addresses the central challenges confronting the nation in the years ahead. These include: improving our economic competitiveness, raising our standard of living, improving public health, and improving environmental quality.

The Science Subcommittee is not alone in its examination of the federally funded R&D system. Recommendations will be sought from a number of other groups that are engaged in studying issues related to the future of U.S. science policy, such as the President's Council of Advisors on Science and Technology, which is examining the health of research universities; the Carnegie Commission on Science, Technology, and Government which will release next week a major report on the future of federal science policy; and the recently established National Science Board Commission on the future mission and direction of the National Science Foundation. We will seek advice from all sectors of society that

have a concern for the health of the research system. We will also watch with interest similar investigations concerning the funding and management of R&D activities by other industrialized nations such as Australia, Canada, France, Germany, Great Britain, and Japan.

We have two very distinguished panels of witnesses this morning, and the Subcommittee extends its warm welcome to each of them. We are gratified at your willingness to take time from your very busy schedules to meet with us.

Before turning to you for your testimony, I would like to recognize the ranking Republican member of the Subcommittee, the gentleman from California, Mr. Packard.

STATEMENT OF
THE HONORABLE RON PACKARD
SCIENCE SUBCOMMITTEE HEARING
THE FUTURE OF U.S. SCIENCE POLICY
10:00 A.M., 2318 RHOB
SEPTEMBER 24, 1992

I commend Chairman Boucher for calling this hearing, the first in a series of hearings on the future of U.S. science policy.

There is a reexamination of science policy that is being conducted throughout the Federal government. Both NIH and NSF are analyzing their respective futures as we move into the next decade and beyond. They are developing strategic plans to cope with what will be required of their respective agencies in the post-Cold War era.

It is essential that for the first Science Subcommittee hearing in this series we hear from members of the private sector that make up a significant portion of the "users" of the results of Federally funded research. This will give us valuable insight into both the health and future direction of the existing Federal research system.

There have been indications of stress from the research community that not all meritorious research is being funded. This is no doubt a sign of the times: a growing number of researchers who are applying for grants and an increasingly constrained Federal budget. I don't think that anybody expects the Federal government to fund all the research needs of this nation.

The stress that is visible in our research system may be a good thing in that it forces us to reexamine the direction of the U.S. research enterprise. An enterprise that was conceived of and developed after World War II. It may be that the research system is fine and that the stress is healthy. But we will never know unless we begin the process of evaluating our science policy.

One area that I will be particularly interested in hearing about from the witnesses is what they perceive will be the impact of defense downsizing on the total Federal research and development efforts. It is an area that concerns me greatly and I will welcome the perspective of corporate America.

Chairman Boucher, I join you in welcoming our very distinguished witnesses and commend you again for calling this hearing.

Mr. PACKARD. Thank you very much, Mr. Chairman. I appreciate your calling this hearing, and I apologize for being a moment late. We're having a mark-up in my other committee, and I may be in and out because of that, but it does not diminish my interest in this very important issue.

There is a reexamination of science policy that's being conducted throughout the Federal Government, and it's long overdue, frankly. Both the NIH and the NSF are analyzing their respective futures as we move into the next decade and beyond. They are developing strategic plans to cope with what we will—what will be required of their respective agencies in the post-Cold War era.

It is essential that for the first Science Subcommittee hearing in this series, we hear from members of the private sector. Our corporate leaders will be our witnesses today, and we're very grateful for them and their willingness to come and give us of their advice and their genius, and we trust that their testimony will help us as we develop national policy. This will give us a valuable insight into both the health and future direction of the existing Federal research system.

There have been indications of stress from the research community that not all meritorious research is being funded. This is, no doubt, a sign of the times: a growing number of researchers who are applying for grants and are increasingly constrained—and are—let me restate that— a growing number of researchers who are applying for grants and an increasingly restrained Federal budget. I don't think that anybody expects the Federal Government to fund all research needs of this Nation.

The stress that is visible in our research system may be a good thing in that it forces us to re-examine the direction of the U.S. research enterprise and to do a better job of prioritizing an enterprise that was conceived of and developed after World War II. It may be that the research system is fine and that the stress is healthy, but we will never know until we begin the process of evaluating our science policy.

One area that I will be particularly interested in this hearing is from the—is what they perceive will be the impact of defense downsizing on the total Federal research and development effort. It is an area that concerns me greatly, and I'm sure it concerns others on the committee, and I will welcome the perspective of corporate America. Surely, as we downsize our defense budget, we must be cautious that we don't, at the same time, inadvertently downsize our commitment to research and development.

So, Mr. Chairman, I join with you in welcoming our distinguished witnesses and commend you again for calling the hearing and look forward to the testimony of our witnesses. Thank you very, very much.

Mr. BOUCHER. Thank you very much, Mr. Packard.

The gentleman from Oregon, Mr. Kopetski.

Mr. KOPETSKI. Thank you, Mr. Chairman. I want to commend you for opening these hearings.

I know that this is jump-starting the debate and discussion and—for the—that will come this next session of—of the Congress, and I know that this is one of the more important issues that—that is facing the United States in terms of regaining our competitiveness

as a world economy, that we must, with our limited dollars, stretch the research programs that we have in partnership with the private sector as far as we can and revitalize, I believe, this whole area.

So I look forward to the testimony and thoughts that will come from today's hearings.

Mr. BOUCHER. Thank you, Mr. Kopetski.

We welcome now, our first panel of witnesses: Dr. Theodore Cooper, Chairman and Chief Executive Officer of the Upjohn Company; Mr. Bruce Ferguson, Executive Vice President and Chief Operating Officer of Orbital Sciences Corporation; and Dr. Edward Penhoet, Vice Chairman and CEO of Chiron Corporation, from Emeryville, California.

We will make your prepared statements a part of the record and would welcome your oral summaries of those statements. And, Dr. Cooper, let's begin with you this morning.

STATEMENT OF DR. THEODORE COOPER, CHAIRMAN AND CHIEF EXECUTIVE OFFICER, UPJOHN COMPANY, KALAMAZOO, MICHIGAN, AND FAIRFAX, VIRGINIA

Dr. COOPER. Thank you, Mr. Chairman. I welcome the opportunity to discuss this important topic.

I come not only with a background from the pharmaceutical industry, but in the past I've worn a few different hats: as a Director of one of the National Institutes of Health, the National Heart and Lung Institute; as Assistant Secretary for Health; and as a dean of a medical college in the past. So I bring a view that reflects all those experiences.

My particular interest will focus on biomedical research; however, I would underscore what Mr. Packard has said, that when we look at peace dividends, we need to emphasize the importance of investing in research across the entire spectrum, and while I'll talk about biomedical research, I do recognize the importance for other parts of the national infrastructure: communications, transportation, information processing, environmental remediation, food technology, and many other societal needs.

Now the Federal Government's role in biomedical research is crucial, particularly as it relates to several of the agencies that are funded and which also are involved, in some extent, in regulating research, not only NIH, but the National Science Foundation, the Centers for Disease Control, the Food and Drug Administration, the Department of Agriculture, the Department of Energy, and Department of Defense. And this Federal presence in biomedical research is closely tied to the activities of physicians and biomedical scientists in industry and academia at the present time. In fact, when one looks at the fabric and talks about policy, you have to talk about the triad, you have to talk about the interaction as well between government, industry, and academia.

Now, it's been suggested that the research enterprise needs more direction and—and evaluation processes to make the best investment of research dollars. I agree that strategic planning is always a useful tool in trying to determine how one allocates resources for the future. It's been tried in many forms and is going on now, as

you point out, at NIH and NSF, and, clearly, it's an obligation of the Government to ensure that larger policy considerations are tied to good performance, discouragement of fraud, and elimination of unproductive programs. However, it's often difficult to know that a research program is unproductive until it's been done, and we must be mindful that if you can always predict the outcome, then it's not really—always research.

So strategic planning means what we should be doing and what we should not be doing. I think as you look at the need for expanded resources, what you're talking about is, largely, how the tactical concerns need to be addressed. We have to build accountability into that, and in my opinion, this can be done without creating a third party overseer. I think the current system can address this issue, if all parties will respond to your challenge.

While the committee has pointed out in its report that the private sector has retrenched in its resources allocated to research, I would report that the pharmaceutical industry has not retrenched. This is one industry whose future depends on—the research-intensive industry depends on research for its future, and there has been a huge reinvestment in research, and at the moment, the U.S. research-based industry has reached the point where it invests more in R&D than the entire budget of NIH, for example. And this research will— investment will continue because the unmet medical needs are huge and the scientific opportunities are splendid.

The industry enjoys a positive balance of trade and is a clear leader in fostering therapeutic advances in the medicine around the world, and Fortune magazine, in March, has cited pharmaceuticals as the most competitive U.S. industry in global markets, and I think that's a reflection of the commitment over a long period of time to research. Research can focus by policy on certain selected areas, but I would point out that whether it was initially antibiotics, or the war on cancer, or steroid activities, or certain central nervous system products, that that investment multiplied itself as the findings in basic research in biology can be applied to many different areas beside the principal area of focus, so that even a policy focus is an important tool for nurturing the system.

I would hope that you would also consider in your policy review the importance of not just resources, but regulatory policy. In our business it spills over also in the general health policy. We're concerned about scientific literacy, education policies, because it's vital to our industry to have the infrastructure by investing in young people, in training. We're concerned about taxation issues as it effects science policy. We have urged, in the past, the R&D tax credits be preserved and made permanent for research investment, and there are other provisions of law that I touch on in my statement that I think—patent policy and trade policy, which are vital and cannot be excluded from the discussion.

Now, I would just suggest, then, that there is consideration given to expansion of the research investment. I would urge that basic research get the highest priority. Let the NIH, for example, do what it does best. Development—product development can come out of it, has come out of it. The investment in research at NIH has been an invaluable asset to the American pharmaceutical industry, the worldwide pharmaceutical industry.

I think Congress should continue the consensus-building as a policy for focusing research on unmet needs, but not neglecting the fundamental-based. I already mentioned the issues of research and training.

Fifth, I think Congress should take an aggressive policy to properly fund the regulatory agencies so that they do not become held up because of lack of resources in bringing products to market. We hope that the—they would help clarify some confusion that exists between agencies. For example, the Nuclear Regulatory Commission tells us to lock the doors of all the laboratories with radio isotopes, and the Occupational Safety and Health Administration tells us we can't have locks on the doors. That sort of thing is—ought to be addressed.

We should make permanent the research credit, as I mentioned. The Technology Transfer Act should be strengthened and broadened. We should not let discussions of big science versus little science—it's not an either/or—impede the process. The Human Genome Project is going to have enormous benefit throughout the system, so I would hope that it doesn't focus on that kind of competitive issue.

My final point relates to the reform of the health care system itself. I think we are only investing in, as a Nation, a small percentage of that total health care dollar in—and while I'm all in favor of eliminating waste and price gouging and all the other things that we evil folks are often accused of, the real issue here is new knowledge will reduce costs— the investment in research will reduce costs, while improving the health of the people. And, I'd be delighted to answer any questions.

[The prepared statement of Dr. Cooper follows:]

STATEMENT BY THEODORE COOPER, M.D., PH.D.
CHAIRMAN AND CHIEF EXECUTIVE OFFICER
THE UPJOHN COMPANY

BEFORE THE U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON SCIENCE
SEPTEMBER 24, 1992

Mr. Chairman, I welcome the opportunity to submit this statement to the Subcommittee. The subject at hand is of vital importance, not only to the company and industry I represent, but also to the health of people all over the world and to the economic health of the United States.

We are in a unique position to take advantage of the Cold War's end to solidify research and development in the United States. My particular interest is biomedical research, and I will focus on that subject. But my general comment to the Subcommittee is that by the late 1980s, R&D as a percent of GNP was roughly equal in Japan, West Germany and the U.S. However, when you looked at rates of growth in R&D, Japan and West Germany were growing much faster. In addition, when you factored out defense R&D, we were spending far less on R&D than our major economic competitors were.

In essence, the so-called "peace dividend" is a significant percentage of GNP that can now be devoted to health and in infrastructure improvements such as communications and transportation, as well as information processing, environmental remediation, food technology and the other pressing needs of the world.

I'd like to focus in particular on the health dimension of this dividend, particularly as it relates to the pharmaceutical industry and the American biomedical research community.

The federal government's role in biomedical research is crucial, particularly as it relates to the activities and funding of such agencies as the National Institutes of Health, Centers for Disease Control, National Science Foundation, Food and Drug Administration, Department of Agriculture and Department of Energy. This federal presence is closely tied to the activities of biomedical physicians and scientists in industry and academia. In fact, one cannot look at any single part of the industry-academia-government triad as a discrete entity. They are intertwined and highly dependent on one another.

It has been suggested that this research enterprise, with particular emphasis on the NIH, needs more direction and evaluation processes in order to

make the best investment of research dollars. I agree that strategic planning is always a useful tool in trying to determine how one allocates resources for the future. There have been many such attempts in the field of biomedical research, and these have had the virtue of focusing attention on what were perceived as the most important areas of research. And these planning systems also help us tie scientific needs and merit with larger social agenda items such as recruiting more women and minorities into research careers.

Clearly, it is an obligation of government to ensure that larger policy considerations are tied to investment of research dollars, and it is also clear that government should do all it can to discourage fraud and the perpetuation of unproductive programs. In the present time, as I will examine later in this statement, our problem is not how to rid ourselves of what's not working, but rather how to cover the enormous possibilities of what is working.

In the sense that strategic planning means "what should we be doing and what should we not be doing," I think it makes a contribution to the ongoing efficiency of the research enterprise. But if the problem is more one of rapid expansion in order to keep up with a rapidly expanding technological base, then your strategy has already been set for you, and you now have tactical concerns, not strategic ones. The trick is to build accountability into the tactics as they are applied across the industry-government-academia continuum. This can be done, in my opinion, without creating a third-party overseer.

The pharmaceutical industry has been engaged in just such an expansion for nearly a decade now by modernizing facilities and training people in the new technologies. Modernization and training are what government-sponsored research needs as well.

As to the relationship between industrial research and government science policies, what the pharmaceutical industry does best is take basic knowledge as it evolves and turn it into novel medical products. The basic science pool is what we draw from in looking at new ways to treat disease and injury. This pool also provides us with a source of talent to staff our own laboratories and support

organizations.

The U.S. research-based pharmaceutical industry has reached a point where it invests more in R&D than the entire budget of the NIH. It also enjoys a positive balance of trade and is the clear leader in fostering therapeutic advances in medicine. The March 9, 1992, issue of *Fortune* magazine cited pharmaceuticals as the most competitive U.S. industry in global markets.

We could not have reached this point of eminence without government-sponsored research and government purchasing programs. A huge impetus to the growth of the industry, for instance, was the antibiotics development and production program set up by the government during World War II.

Industry separated itself somewhat from government-sponsored research in academia during the 1950s and 1960s. It continued to need a basic research pool, but the distinctions between applied and basic research became quite clear as industry concentrated on applying the fruits that grew from the nation's massive investment in the NIH during those decades.

Progress in those years was marked by long technological cycles that produced incremental and fairly predictable advances. For instance, once breakthroughs in antibiotics were achieved, a number of new generations appeared over time. The next technological wave was initiated by the ability to synthetically produce corticosteroids. Again, slow, predictable progress was made in refining these agents.

Another wave of this era produced the nonsteroidal anti-inflammatory drugs. The active ingredient of one variety of these drugs, ibuprofen, is now widely available as an over-the-counter product.

The late 1970s marked the end of modifying the benzodiazepine class of central-nervous-system compounds that replaced the sedative-oriented compounds of earlier years.

But during the mid-1970s, as what we now call biotechnology emerged, things began to change. The technological cycles began to shorten. New knowledge was gained in huge chunks, not in incremental steps. All of biomedical

science began to move rapidly from the symptoms of disease to the root causes of disease.

The lines between basic and applied research began to blur. No single research entity, let alone a single pharmaceutical company, could possibly keep up with the revolution going on in biology all by itself.

Government-sponsored research has been a crucial component in this new learning curve of biomedical research. We've gone from simple gene cloning to gene expression to recombinant DNA production of human proteins to cell-receptor cloning to computer modeling of proteins and their biological properties to identifying and sequencing gene fragments to amplifying or blocking biological activity at a subcellular level.

What this means to me and most of us in the pharmaceutical industry is that the nation's approach to R&D from the strictly scientific point of view has been an admirable one. It made us the world leaders and should not be abandoned or greatly overhauled.

In other words, science is the engine that drives the health industries, and the U.S. science that focuses on biomedical questions is still the best engine in the world. If the vehicle as a whole is not going straight or going fast enough, perhaps the steering mechanism should be fixed or perhaps the engine needs a tuneup. But certainly the vehicle does not need a whole new engine.

Those of us in the industries that are research-intensive share the Congress' concern about the ability of the United States to remain competitive. And for that reason, we are more concerned about larger issues such as:

- regulatory policy, both here and in the world's major nations;
- trends in health policy as they affect the financial condition of health industries;
- scientific literacy and education policies all the way down to the elementary-school level;
- taxation issues, including R&D tax credits and Section 936 of the Internal Revenue Service code;

• patent policy, particularly as it affects the products and processes of the biotechnology industry; and

• trade issues such as European harmonization and the North American Free Trade Agreement.

I have spoken and written many times in the past on the subject of national science policy, and I would like to reiterate them here, as well as add a few things.

First, I would support a doubling of the NIH budget over the next five years, in the same manner that President Bush has advocated a doubling of the NSF budget.

Second, I would resist all urges to push the NIH further down the development stream. The pharmaceutical industry is uniquely positioned to carry out the arduous task of bringing new discoveries through the development process to market. The recent controversy over the NIH decision to seek patents on gene fragments is just a harbinger of what this valuable agency would encounter if it were to take on a more commercial orientation.

Third, I would urge the Congressional leadership to continue consensus-building efforts such as today's hearings while at the same time minimizing political pressure on the scientific and medical programs of the NIH and the NSF. The temptation to micromanage science is strong, especially when some of our problems are so severe. The problem with micromanagement, however, is that it fails to account for the unaccountable, to predict the unpredictable. The real beauty of American science has been that work done in one area tends to grow and have significant consequences in other areas. For instance, all of the current research in AIDS will help us not only fight that disease but greatly enhance our understanding of other retroviral diseases and the relationship of the immune system to cancer. We must let unmet medical needs be the ultimate determinant for resource allocation among biomedical disciplines.

A fourth and related point is that until we improve our education system in general and our science education programs specifically, we will not have a nation that is capable of fully understanding technology, particularly that technology

directed toward health and wellness. And from the point of view of industry as a provider of jobs, unless the quality of our science education improves dramatically, we will not have enough people to carry on the work. A recent SRI International Report said that more progress will be made in bioscience over the next 20 years than was made in the past 100 years. In those 20 years, much more will be expected of relatively fewer people.

Fifth, Congress can play a leadership role in revitalizing the Food and Drug Administration, which is a crucial threshold in the discovery-to-marketing continuum. In particular, the industry is interested in speeding up the review of innovative pharmaceuticals because nearly half of the cost of developing these new therapies is opportunity cost, which takes on greater importance the closer one gets to a marketed drug. (The opportunity costs for a pharmaceutical that is dropped from development in preclinical trials are far less than those for one with a clear safety and efficacy profile that has spent two or three years awaiting final FDA action.)

The FDA also needs legislative-branch support in streamlining its regulatory review processes related to submissions for relatively minor matters such as changes in tablet coatings, so that the agency can concentrate more on the review of new pharmaceutical products.

Congress should also work with the leaders of other nations to encourage the transportability of safety and efficacy data related to the development of new pharmaceuticals and to make country-to-country regulatory requirements more harmonious. The North American Free Trade Agreement is a potential important step in this regard, as is the continuing harmonization process in the European Community.

Other regulations should be coordinated at the federal level and made more consistent and predictable. Our own experience at Upjohn shows many examples of what Einstein termed a perfection of ends and a confusion of means. For instance, the Nuclear Regulatory Commission tells us to lock the doors on laboratories using radio isotopes, yet the Occupational Safety and Health

Administration tells us we can't have locks on the doors. And when those isotopes are used in laboratory animals, several conflicting regulations are involved in the proper disposal of the animals.

Sixth, the research and development tax credit should be made permanent at 25 percent and should be expanded beyond incremental expenditures. Also, the moratorium on Section 861 rules on foreign income allocated to R&D expense should be made permanent. These two steps would make strategic planning easier and more productive because they would allow companies to better determine the long-range impact of their research programs on the corporate resources dedicated to other areas, such as capital improvements and employee benefits.

Seventh, the goals and fundamental concepts of the Technology Transfer Act of 1986 should be expanded. For instance, the federal government should further facilitate the development of technology transfer companies within universities and academic medical centers. A good example is BCM Technologies, Inc., at the Baylor College of Medicine in Houston. Not only do operations such as these enhance the financial return to the parent institution, they also minimize concerns about conflict of interest and undue corporate guidance of ongoing research programs.

The Human Genome Project will also be a fountain of technology transfer opportunities, many of which will be unexpected. This is an example of a federal research program providing core funding for the process of innovation in the biomedical sciences, with individual companies and academic investigators providing critical mass in the traditional aggregate sense. You should, therefore, resist arguments that the Human Genome Project is "big science" and therefore inherently at odds with our traditional approaches to funding biomedical research.

Technology-transfer issues related to the Human Genome Project await adequate resolution of pending patent issues. These are highly complex issues, but I would point out that Dr. Healy, director of the NIH, said in a recent speech,

"NIH is only interested in patenting if it will facilitate product development -- facilitate the movement of basic discoveries out of the laboratories into the commercial sector to develop new technologies and benefit the public." I obviously concur with the sentiments expressed in that statement.

My final point relates to reform of our health care system. Much has been made in recent days about the prices of prescription pharmaceuticals and the profitability of the pharmaceutical industry. Simply stated, if the U.S. pharmaceutical industry were far less profitable, it would not exist in its present form. We would not be able to generate the capital mass to wait 10 or 12 years for a multi-million dollar investment to provide returns. We would not be able to return 14 percent of sales to R&D. We would not be able to invest millions of dollars in the very information-exchange and education programs that are of interest to the Subcommittee.

Prescription pharmaceuticals continue to fall as a percent of the total health care bill, but because they often comprise the greatest out-of-pocket expenditure for individuals, they are seen as a primary cause for rising health care costs. They are not. In fact, they hold the greatest promise for slowing down the rate of growth in our health care bill over the next 10 or 20 years while greatly improving treatment of disease and injury at the same time.

The key to quality health care that is accessible to everyone at a reasonable cost is efficiency. Efficiency inside the health industries themselves, efficiency in the regulatory channels, efficiency in technology transfer, efficiency in maintaining the quality of basic research, efficiency in the legislative process that shapes our health care system.

Achieving this kind of broad-scale efficiency requires cooperation and consensus. The more of both, the more innovation we'll have. The more innovation we have, the more competitive we will be as an economic entity, and the healthier we'll be as a nation.

Mr. BOUCHER. Thank you very much, Dr. Cooper. We'll withhold our questions until we've heard from the other two witnesses.

Mr. Ferguson?

STATEMENT OF BRUCE W. FERGUSON, EXECUTIVE VICE PRESIDENT AND CHIEF OPERATING OFFICER, ORBITAL SCIENCES CORPORATION

Mr. FERGUSON. Thank you, Mr. Chairman.

I will begin by noting that the committee requested input on whether industry was sufficiently consulted in the formulation of national research and development policy. Mr. Chairman, as a Virginia company, Orbital Sciences Corporation can attest to the undoubted geographical advantages of a Virginia location from this standpoint, and I highly recommend that great commonwealth as a location for other high- technology companies.

I congratulate the committee for its focus on the strategic benefits of research and development in the context of national goals. Such a long-term, big-picture perspective is, today, desperately needed, given that pressing economic problems tend to provide a short-term focus to most of our national debate.

My co-founders and I established Orbital Sciences 10 years ago, with the explicit intention of commercializing government-funded research and development in the space industry. Today we have more than 1,100 employees and had revenues last year of $135 million. Based on that experience, I would make the following nine recommendations to the committee with respect to its proposed reformulation of Federal science and technology policy.

First, I would observe that Federal research and development spending represents an investment in activities that will benefit Americans in the future. These benefits are offset, however, by liens against the future created by budget deficits. Given the radical changes in the world environment, the Government should undertake a broad-based review of the total amount and of the mix of all Government spending. I believe the results of this study will indicate that spending is both too high and too heavily weighted towards activities with current, rather than future, benefits.

Second, Federal research and development funding priorities, outside of traditional, academic, and not-for- profit areas, should shift increasingly from defense and other programs of lower long-term benefits to areas such as transportation, communications, information processing, materials, agriculture, and health. Government investment, as Dr. Cooper indicated, should be focused on basic technology and process research.

Third, space represents one of the American ideals, that of the frontier, and should continue to receive Government funding at or above current levels. Because they also constitute a key frontier, the oceans should receive increased study and attention, perhaps under the direction of a new agency comparable to NASA in its size and goals that would consolidate some of the current ocean activities of the Navy and NOAA. As is the case with space activities, exploration and development of ocean resources represents a proving ground that could drive many technology areas of immediate usefulness to America's industrial base.

Fifth, while many of the national laboratories might be assigned new missions that are focused on areas of industrial concern, such reassignments should be studied carefully, given potential difficulties.

Sixth, current mechanisms for allocating funds to and evaluating the results of basic research are strong and should not be changed significantly.

Seventh, Government agencies should be required to provide weight to innovation in the proposals they receive. The Federal Government can play an enormously important role as first customer, or anchor tenant, for new products and services. It has played this role with respect to many of our own programs, notably the Transfer Orbit Stage that is scheduled to launch the Mars Observer spacecraft tomorrow from a Titan rocket. Every time the Federal Government buys a product or service, it has the opportunity to promote innovation.

Next, the Government should continue the process of speeding regulatory approval, license, or certification of new products and services in all areas where such review is required.

And finally, the Government should encourage the accounting profession to allow capitalization of some part of industry research and development expenditures. Currently, such expenditures are written off in the year they are expended, which effectively assumes that there is no future benefit. I believe that's contrary to the facts. The incentive provided thereby would be particularly strong for companies with growing research and development budgets.

The United States has closed one momentous chapter in its history and is about to begin a new one. The decisions made over the next few years by our citizens, and by the men and women who represent them in Government, will determine how successful the United States is in the new world order it has done so much to shape.

I wish this committee well in making the difficult choices it faces for all of us. Thank you, Mr. Chairman.

[The prepared statement of Mr. Ferguson follows:]

Testimony of
Bruce W. Ferguson
Executive Vice President and Chief Operating Officer
Orbital Sciences Corporation
before
The Committee on Science, Space, and Technology
Subcommittee on Science
United States House of Representatives
24 September 1992

Mr. Chairman and Distinguished Members of the Committee:

I appreciate the opportunity to assist the Committee in its reassessment of Federal science and technology policy. In my testimony, I reach three summary conclusions: That Federal research and development activities have been extremely important to the conception and growth of Orbital Sciences Corporation ("Orbital"); that the current mechanisms for distributing funds to, and evaluating the results of, non-defense basic research activities are strong and should not be significantly altered; and that Federal research and development funding priorities should shift significantly from defense activities to technologies and processes that will over the long term directly benefit non-defense industries.

I. Background on Orbital Sciences Corporation and Its Programs. Ten years ago, David Thompson, Scott Webster and I formed Orbital to commercialize space technology. Since that time, Orbital has generated over $500 million in cumulative sales and created over 10,000 person-years of direct and subcontract high-technology employment. Taking a "smaller, faster, cheaper" approach to our programs, we have led the development of four families of suborbital launch vehicles, two space launch vehicles, an orbit transfer vehicle, two spacecraft buses, and a number of satellite tracking systems and related space support products. We have conducted nearly 30 challenging space missions, advancing science, commerce and defense in the United States. We have helped to stimulate the "microspace revolution" by pioneering new distributed global communications and remote sensing satellite services.

Orbital has also created significant value for its investors. We have consistently been among the fastest-growing United States firms, with revenues last year of $135 million and more than 1,100 employees in four states today. In 1991, the company was awarded the National Medal of Technology for its development of the Pegasus® air-launched space booster.

Orbital Sciences Corporation has invested more than $100 million in its space programs. The Government--the National Aeronautics and Space Administration ("NASA") and the Defense Advanced Research Projects Agency in particular--has also invested significant amounts in our programs, either in research and development

expenditures, or in purchases of the first missions of new vehicles.

From their inception, most of our company-funded development programs have had the dual market goal of serving both commercial and Government customers. Because the United States Government accounts for approximately 90% of all domestic space purchases, very few space-based activities can claim complete independence from Government research and development activity. Furthermore, through its enormous purchasing power the Government has played a key role in the "reduction to practice" of new space technologies.

Orbital is also actively engaged in undertaking the development and construction of a new global communications system based on low-Earth orbit satellites that would, for the first time, provide a low-cost capability for people to exchange alphanumeric messages anywhere on Earth. The area of low-Earth orbit mobile satellite communications should be of particular importance to the Committee. Several proposals are now being considered by the Federal Communications Commission, ranging from Orbital's global data collection and messaging system to ambitious worldwide voice communications networks such as those proposed by Motorola, TRW, and QUALCOMM. The United States has a significant lead in this breakthrough communications technology, and is fully capable, assuming continued quick regulatory action, of establishing a prominent business lead in a worldwide market that is likely to grow to hundreds of millions of dollars by the end of the decade.

The antecedents of this breakthrough are illuminating. Small satellite technologies were pioneered by the military and to a lesser extent by NASA. Many of the communications techniques proposed, such as spread spectrum ("CDMA"), were also developed under Government sponsorship. The launch vehicles required to put these satellites in orbit have in all cases been developed either directly by the Government (as in the case of Delta, Atlas and Titan), or by a private company with important reliance on prior Government-funded research (as in the case of Pegasus). This pattern is also found in the introduction of geosynchronous communications satellites in the 1960's, which followed enormous Government investment in launch vehicle technology and spacecraft engineering. The conclusion I reach from this brief history is that Federal research and development investments in space have created technology bases that directly benefit the United States communications and commercial space industries.

II. Reasons for Federal Support of Research and Development.

I think that an intriguing way to understand the importance of research and development is to consider the fact that approximately ninety-nine percent of our human genome is shared with chimpanzees. Obviously, we do not conclude from this fact that chimpanzees are "99% human" or, conversely, that humans are "99% chimpanzee." Most

of what it is to be human today therefore lies not in our genes, but in the knowledge of ourselves and our environment that has been so painfully accumulated over many thousands of years. The pace of biological evolution has been surpassed by an accelerating cultural evolution, to use Bronowski's phrase, that derives almost entirely from the many layers of knowledge provided through observation and experiment. In other words, we may today define humanity as consisting in large part of accumulated research and development.

Research and development is therefore extremely important. Why should it be supported by the Federal Government, however, rather than by individuals and businesses? I believe the strongest argument is that the benefits of research and development to an industry or to the country as a whole often are greater than the particular benefits that may be captured by any given individual or firm. That is to say, the benefits to the country are well worth the investment, particularly over the long term, while the cost/benefit tradeoff may not be as advantageous to a smaller decision maker.

This is true in part, I believe, because the benefits of research and development--particularly of basic research--are sometimes hard to predict, and may not lie in the particular business area of the sponsoring company. Scientific research and development may be regarded as the assembly of an infinite jigsaw puzzle. Areas of the puzzle that are worked on independently may suddenly and surprisingly be joined. Scientific merit is defined as putting together large pieces of the puzzle, or putting together pieces in non-obvious ways that suggest faster assembly of other pieces. The most meritorious work is sometimes the least predictable.

The Federal Government should focus its research and development spending on those areas for which the benefits are diffuse and likely to be realized over many years, rather than areas for which benefits are concentrated on particular products or firms over a few years. These areas are not well covered by corporate investment, yet are vital to the long-term economic strength of the country.

III. <u>Furthering National Goals through Research and Development Policy</u>.

The restructuring that is taking place worldwide in response to the dramatic political and economic changes of the last decade must also take place in the United States. Not only research and development programs, but all of the programs instituted by Government over the past sixty years, should be reviewed, and as necessary revised, in light of the changed political and economic environment and the changed national goals that must follow therefrom. Accordingly, I strongly support the Committee's determination to begin its study with the question of how to further national goals through Federal funding of research and

development.

A difficult but necessary step in answering this question is listing the national goals we seek to achieve. From this standpoint, with the disintegration of the Soviet Union the United States lost a defining adversary. What are we, now that being the antithesis of communism is no longer as important? We no longer must argue the economic merits of capitalism, or the political merits of democracy, because capitalism and democracy have become a worldwide standard. Our country does not have a religious mission, nor should it have. It would be presumptuous for any single country to seek to speak for the welfare of the human species. The Government should facilitate individual pursuit of a high standard of living, but bread alone will not satisfy the human spirit. With respect to the goals we establish, we must ensure that "self interest rightly understood" does not become mere self interest. What, then, if any, is the distinctive ideal that the United States stands for today, now that we have reached the "end of history"?

I believe that the remaining ideal most closely associated with the United States is the concept of the frontier. The frontiers of the future will be the space above us, the oceans around us, and the knowledge that defines us. We should seek to establish the United States as the place to go for the adventurous, who wish to explore space and the oceans--and for the curious, who wish to delve deeper into the unknown than is possible anywhere else. By challenging the space frontier, the ocean frontier, and the "knowledge frontier," I believe that the United States will be true to one of its key ideals, while at the same time encouraging the development of technologies and skills required for industrial excellence and a high standard of living.

IV. Funding Priorities.

If America is to remain the home of the pioneer, the land of the pathbreaker, how should Federal research and development spending be allocated?

I suggest that the first place to start would be in setting a reasonable total Government budget. It is practically useless to debate how to carve up the pie while the dining room and the rest of the house are burning down around us--any decisions that may be reached are likely to be reexamined once the embers have cooled. The United States has an enormous budget deficit that represents a collective choice to spend much more than we earn. This choice alone imposes a burden on future generations, a burden that greatly outweighs the benefits to future generations of current research and development spending.

In addition, Government spending today is heavily weighted to areas that have very low return over a ten to twenty year period compared

to the return from research and development. In fact, it would be interesting to prepare an empirical chart based on the conceptual sketch provided in Figure 1, that would show the return--in the form of jobs, taxes, etc.--on each dollar of Government spending in various key budget areas, such as research and development, education, social security, health, and defense. Similar charts are used by business in strategic planning, and could perhaps be adopted for use by the Government.

I believe that such a chart will show two things. First, it will show that certain categories of expenditures, such as research and development, offer high long-term returns to the country. Such expenditures strengthen the country tremendously, underscoring my assumption that the Government should normally be investing in areas where benefits are diffuse, long-term, and substantially exceed the investment, rather than in areas where benefits are short term and accrue to particular individuals or companies who might, therefore, reasonably be requested to make the required investments. The second lesson I expect such a chart to illustrate is that high-return investments receive a decreasing share of the national budget. Such a result would imply that a top-level Government strategic plan is desperately needed.

Assuming that the appropriate total budget size has been established with a view towards the long-term strength of the country, and that relative spending priorities have been set for programs offering short-term versus long-term benefits, then the question arises of how to allocate research and development spending. I will address first the two physical frontiers I listed earlier, space and the oceans, and then turn to the "knowledge frontier."

Freeman Dyson, in a brief analysis of the space program,[1/] formulated a proposition that I call the "inverse benefits rule" of spending--that the most expensive space projects produce the least scientific return per dollar (e.g., the Apollo program), while the least expensive programs (e.g., x-ray astronomy sounding rockets) produce the most scientific value per dollar. Freeman Dyson, of course, is an iconoclast. Apart from the question of scientific returns, the total societal benefits of Apollo could well have been higher per dollar invested than the benefits of sounding rocket research. Space spending will represent an area of difficult spending choices in the future, because while defense spending will clearly decline in the current world political environment, civil space spending, while expensive, offers benefits that are at the same time extraordinary and hard to measure. As part of the frontier, space is part of what America should stand for--and invest in.

With respect to the oceans, it has been said that we know more about some of our planetary neighbors than we do about certain parts of our own ocean floor. Ocean exploration, particularly

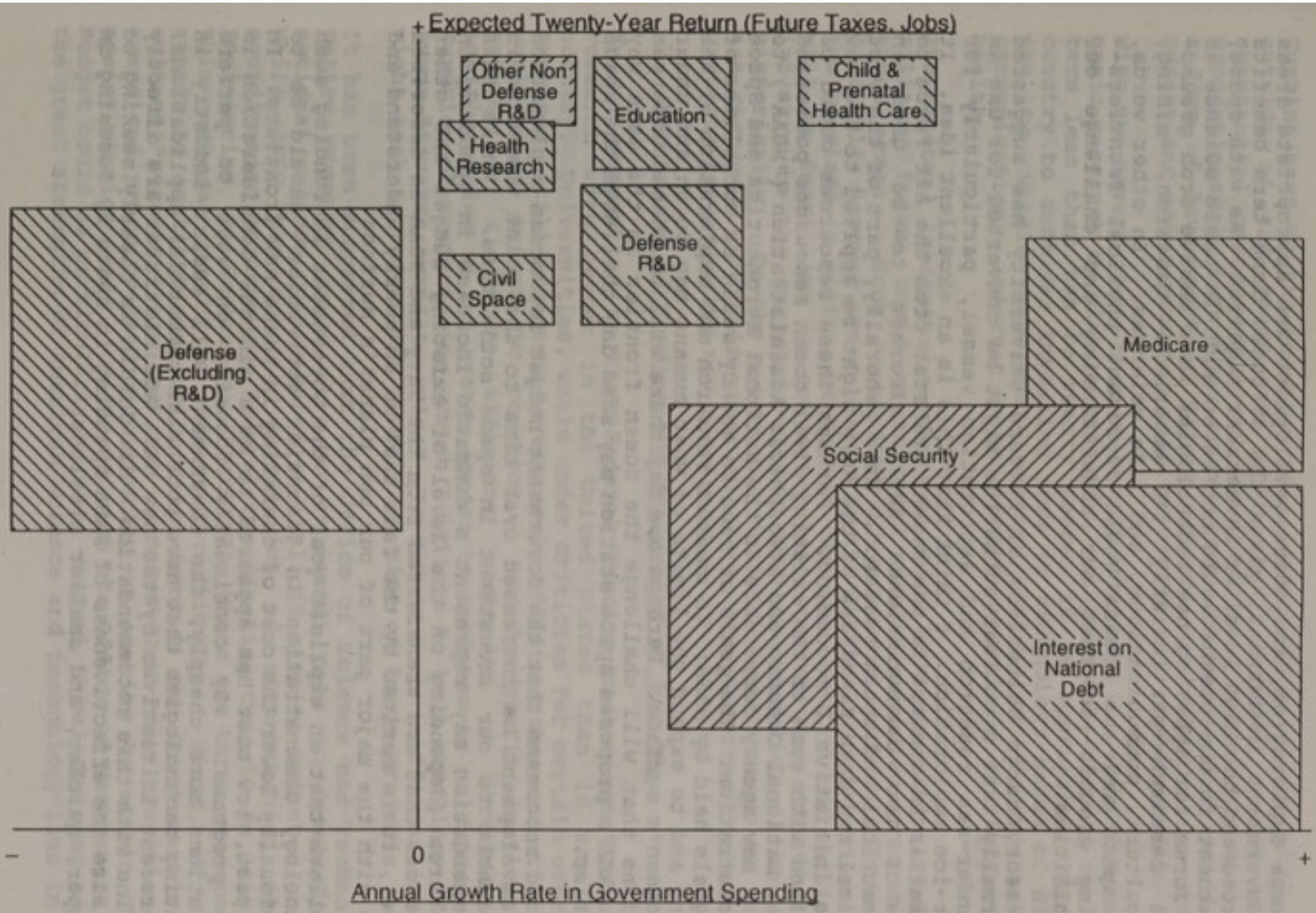

Figure 1. Form of "Return on Investment" Analysis for Government Resource Allocation Decisions

undersea exploration, and ocean development are appropriate areas for Government investment, given the diffuse, long-term benefits expected and the high level of investment required. As with space, investment in the oceans would not be so much in basic science as in a forum for applying new technologies that derive from ground-based research--particularly in materials research, mining, agriculture, communications, and life sciences. In other words, both space and the oceans would represent physical frontiers--proving grounds--to test our understanding and challenge our capabilities.

Professor George Whitesides of Harvard University has suggested informally that a nuclear submarine might be converted for use as an under-sea research and exploration vessel, particularly for under-ice exploration. I think that this is an excellent idea. It is similar in concept to the recent transfer from the Air Force to NASA of two decommissioned SR-71 aircraft to be used in aeronautical and space research. More generally, part of the vast physical and data resources of the Navy might be applied to the new ocean initiative I recommend. Perhaps these resources could be combined with some of the existing civil ocean resources possessed by the National Oceanic and Atmospheric Administration ("NOAA") to form a new agency comparable to the National Aeronautics and Space Administration. The goals of such an agency would be correlates of the goals held by NASA: to conduct research and exploration of the ocean, and to expand the limits of what humans may do on and under the ocean's surface. Perhaps one day there will be manned undersea stations that will challenge the ocean frontier in the same way that NASA's proposed space station may some day challenge the space frontier.

I would recommend that the Government budget for ocean exploration and development be increased over time to the point where it is comparable to our investment in space activities. While this recommendation may represent a dramatic increase in spending in this area (depending on the level of existing budget and other resources that are transferred from the Navy and NOAA as described above), it is merited by the fact that we so poorly understand and cope with the major part of our own planet's surface.

I believe that an explicit goal of the Government in funding such technology demonstration in "frontier activities" should be to continually lower the cost of operating in these new frontiers. In the past, low cost has appeared to be a minimal consideration in such programs. By continually focusing on ways to perform operations more cheaply, the Government will assist industry in creating technologies that have potential commercial applications. The recent initiatives by the new NASA Administrator are directly in line with this recommendation. Mr. Goldin is clearly seeking to maximize the effectiveness of NASA spending in space by focusing on cheaper, quicker, and smaller missions.

Turning next to the question of research and development spending outside of the space and ocean areas, I will assume that a substantial restructuring of the Government budget has allocated proportionately more funds to research and development spending as a form of investment in future returns, by reducing the defense budget and other programs with primarily near-term benefit.

With the caveat above that we should not judge the effectiveness of basic research by mission criteria, or, indeed by results over any term less than ten to twenty years, it is appropriate for the country to consider investing more in technology bases of direct use to vital commercial sectors, such as transportation, communications, information processing, materials, agriculture and health.

The national laboratories, many of which have traditionally had a military focus, could be assigned mission-oriented programs in these areas. Such "retrofit" of personnel and facilities is difficult, however, as evidenced by the difficulties experienced by the Russians in similar attempts. Not the least of the challenges will be instilling in converted laboratories the attitude that industry is the customer--rather than the supplier it has been historically. To the extent the national laboratories no longer are required for their prior missions, the Government should be cautious in assigning new missions.

V. Mechanisms of Funding and Evaluation of Results.

My own perception is that Federal funding mechanisms for basic research work better in the United States than in any other country. Universities, while under criticism for certain overhead expenses, still represent an extremely efficient means of attaining world-class scientific research. Not-for-profit institutions provide a similarly efficient mechanism. Stresses and inefficiencies in the system appear to increase as an exponential function of project size, which I believe to be a corollary of the Dyson "inverse benefits rule." To reduce such inefficiencies, we might seek to reduce the number and size of large projects.

It has been suggested that the Office of Science and Technology Policy ("OSTP") could play an increased role in developing a national science policy based on explicit mission-oriented goals. While OSTP has done a superb job of strengthening agency coordination through the Federal Coordinating Council on Science, Engineering, and Technology ("FCCSET"), there are three reasons why this proposal should be addressed cautiously. First, it would appear to institutionalize conflict between the Government's new science "strategy" arm and the agencies that have traditionally exercised priority-setting authority in seeking to attain their agency mission goals. Conflicts with the Office of Management and Budget could be particularly severe. Second, I believe that one of the great strengths of American science and technology lies in its

very decentralization and autonomy. There are dangers inherent in overly centralizing planning and control, not the least of which is the difficulty of following developments in many fields concurrently. In the private sector, the current trend is quite the reverse of centralized planning. Ideas of "empowerment", while requiring definition and strict delimitation, are yet on the right track, I believe, towards providing increased authority to broader strata of decision makers, allowing them to tailor responses to their particular environments.

The third difficulty that must be addressed by such a proposal rests in attempting to evaluate basic research spending against mission-oriented goals. The heart of this problem is that achievement of many such goals rarely depends solely, or even primarily, on progress in research and development. We all know that human health in the United States could be vastly improved by adherence to a simple model of eating a proper diet, obtaining enough exercise and sleep, and avoiding carcinogens, intoxicants and hallucinogenic drugs. Harm to the environment could be reduced by increasing the user cost, through duties, taxes or otherwise, of pollutants that result from burning fuels, spraying pesticides, etc. Controlling the spread of contagious diseases, such as AIDS, could be effected through changes in our behavior. National competitiveness--making better quality, lower cost products--could be increased if our consumers spent less and saved more. The point I wish to make is not that these missions are invalid--I happen to subscribe to them all. I believe it unwise, however, to rely on "technological fixes" in these areas. Advances in technology may provide us with more choices, but the choices themselves will always be ones that we face as individuals. We should not ask technology to do for us what we are unwilling to do for ourselves.

I would also note that Japan, whose comprehensive plan for economic performance is perhaps the most successful in the world, has had mixed success in mission-oriented research directed by the government. Its VLSI microelectronics initiative was successful; its civil aviation and advanced computer projects were not.

I would not wish the Committee to construe from these remarks that I am opposed to mission-oriented research and development. There have been numerous examples of success in mission-oriented research and development. The mission of sending a man to the Moon and returning him safely to Earth was achieved brilliantly by NASA. The mission of increasing our knowledge of human illness has been performed superbly by the National Institutes of Health ("NIH"). I support the concept of a "National Institute of the Environment," loosely modelled on the NIH (but probably without intramural campuses), that would spearhead research thrusts in ecosystems, atmospheric sciences, plant biology, and species diversity, among many others. Increased Government-funded applied research in communications, information processing and storage, transportation, materials, and agriculture could directly and substantially benefit

our industrial base.

These examples demonstrate that the Government can and should create mission-oriented goals for agencies and programs. Once broad goals have been assigned, however, agencies should be given substantial authority for implementation and time to show results. In addition, the Government should aim for consistency in its goals. The high future standard of living we seek to achieve through research and development is unlikely to be realized if we continue to accept enormous Government budget deficits.

The Committee requested input on whether the private sector was sufficiently consulted on the formulation of Federal research and development policy. My impression is that such consultations have taken place frequently, and become ever more important.

VI. Recommendations.

I would make the following recommendations to the Committee with respect to its proposed reformulation of Federal science and technology policy:

1. Federal research and development spending represents an investment in activities that will benefit Americans in the future. The benefits of such investment are offset by "liens" against the future created by budget deficits. Given the radical changes in the world environment, the Government should undertake a broad-based review of the total amount, and the mix, of all Government spending. I believe that the results of this study will indicate that spending is both too high, and too heavily weighted towards activities with current, rather than future, benefits.

2. Federal research and development funding priorities outside of traditional academic and not-for-profit areas should shift increasingly from defense and other programs of low long-term benefits to areas such as transportation, communications, information processing, materials, agriculture, and health. I believe that other nations with relatively high percentages of government military research and development, such as the United Kingdom and France, will soon pursue similar reallocations. Government investment should be focused on basic technology and process research.

3. Space represents one of the American ideals--that of the frontier--and should continue to receive Government funding at or above current levels. Space activities often represent application of cutting edge knowledge in transportation, communications, and materials.

4. Because they also constitute a key frontier, the oceans should receive increased study and attention from the United States,

perhaps under the direction of a new agency comparable to NASA in its size and goals. As is the case with space activities, exploration and development of ocean resources could drive many technology areas of immediate usefulness to America's industrial base.

5. While many of the national laboratories might be assigned new missions that are focused on the areas of industrial concern listed above, such reassignments should be studied carefully given the potential difficulties.

6. Current mechanisms for allocating funds to, and evaluating the results of, non-defense basic research are strong and should not be changed significantly.

7. Federal procurement regulations are quite complicated. At the risk of complicating them further, Government agencies should be required to provide weight to innovation in the proposals they receive, in addition to the normal scoring criteria of reliability, schedule, and cost. The Federal Government can play an enormously important role as "first customer" or "anchor tenant" for new products and services. It has played this role with respect to many of Orbital's programs. Were the General Services Administration, for example, to institute an aggressive program of encouraging innovation among its suppliers, I would expect that some very interesting ideas in, for example, office equipment, supplies, and furniture would emerge with worldwide markets. Every time the Federal Government buys a product or service, it has the opportunity to promote innovation.

   I would note that the charter of the Federal Communications Commission requires the Commission to reward innovation as well as efficiency in use of a scarce resource (spectrum), which I believe in part explains why the United States still leads the world in the rapid introduction of new communications technologies.

8. The Government should continue the process of speeding regulatory approval, license, or certification of new products and services in all areas where such review is required. The Federal Communications Commission, for example, has recently implemented a new process of negotiated rulemaking that promises to significantly speed its rulemaking and licensing procedures. Similar examples should be developed and encouraged in pharmaceuticals, biotechnology products, nuclear power, aviation, etc.

9. One of the reasons that industry is reluctant to increase research and development spending is because such spending is expensed in the period it is incurred, and therefore reduces current earnings. This accounting treatment effectively

assumes that none of the benefits of research and development spending extend beyond the current accounting period. I believe that this position, issued in 1974 under Statement of Financial Accounting Standards No. 2, departed from prior accounting treatment to the accompaniment of sharp disagreements within the accounting profession that continue today. The Government should consider encouraging the accounting profession to allow capitalization of some part of research and development expenditures based on studies that show the statistical likelihood of benefits flowing from such investment. Allowing companies to amortize, say, 70% of research and development expenses over a ten-year period would, for financial reporting purposes, provide an additional incentive to companies to invest in research and development. This incentive would be particularly strong for companies with growing research and development budgets, and would be consistent with tax benefits such research-oriented companies already receive through the research and development tax credit.

The United States has closed one momentous chapter in its history, and is about to begin a new one. The decisions made over the next few years by our citizens, and by the men and women who represent them in Government, will determine how successful the United States is in the new world order it has done so much to shape. I wish this Committee well in making the difficult choices it faces for all of us.

1/ Freeman Dyson, Infinite in All Directions, (Perennial Library, New York, 1989), pp. 158-179.

2/ John A. Alic et al., Beyond Spinoff: Military and Commercial Technologies in a Changing World, (Harvard Business School Press, 1992), p. 394.

3/ Report of the National Science Board, Committee on Industrial Support for Research and Development, "The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues," (National Science Foundation, August 1992), Figure 11, p. 21.

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Mr. BOUCHER. Thank you, Mr. Ferguson.
Dr. Penhoet?

STATEMENT OF DR. EDWARD E. PENHOET, VICE CHAIRMAN AND CEO, CHIRON CORPORATION, EMMERYVILLE, CALIFORNIA

Dr. PENHOET. Thank you, and thank you for the opportunity to share my views with this committee.

I'm participating in this meeting as a member of the biotechnology industry. My perspectives on the matters to be discussed have been derived from 11 years' experience as Chief Executive Officer of Chiron Corporation, one of the Nation's largest biotechnology firms, and from 20 years' experience as a faculty member at the University of California at Berkeley.

The first full decade of—for the biotechnology experience has been extraordinarily productive in this country. At least 10 significant products have entered the health care markets around the world as a result of the biotechnology industry, and these have already had a major impact on public health and on the economy of the country. The biotechnology industry of the U.S. now employs more than 70,000 people directly, spends more than $3 billion a year on research, and has created revenues of in excess of $6 billion a year. A substantial fraction of which, I might add, is export products going to other countries around the world.

By virtually any criterion, the U.S. is the undisputed leader in the biotechnology field. Recognizing this success, and in attempting to define policies for research and development in the future, it seems useful for us to try to analyze the factors that have been so important in the success the biotechnology industry has enjoyed to date. So as a participant really from the beginning of the industry, I'd like to share with you my views of what I think the most significant factors have been in the success we've had to date in the biotech industry.

I think, first of all, the Government has played an extraordinarily important role in fulfilling its responsibilities in education, in training, and perhaps most importantly, in basic research. Simply to emphasize the point made by Dr. Cooper, the role that the Government has played in education and training was primarily played in the 1950s and 1960s, because the people who are now active in biotechnology were educated in that period. And I think whatever we do in the science enterprise in this country, we must return to some of the basics, particularly, pay a lot of attention to science education in K through 12, which I know is not a direct responsibility of this committee, but it's an extremely important issue facing us going forward.

The second point is that the Government has funded basic research. The foundations of the biotechnology field were developed by microbiologists studying, of all things, sex among the microbes. This is a field of study that might have been subject to ridicule by former Senator William Proxmire. The basic science funded by the NIH and NSF has been guided by broad funding commitments to areas among the different agencies of the NIH, for example, but the implementation of these programs has been investigator-initiated and has been subject to rigorous peer review, and I do think

that review of science generally, and particularly review by peer groups not directly involved in the activities, is an important element in the overall progress of biomedical science in the country. Fourth, significant funding was made available to the scientific enterprise of the country by the venture capital community to turn the basic research findings of the academic and research communities of the country into a significant business in the private sector. This is an important point, because I think that that same opportunity to generate new businesses from fundamental technology may not always be available to every industry in the country. Biotechnology has a special place because it's captured the imagination of the public and of the private sector.

And then, finally, and perhaps most importantly, directly, that technology transfer has been carried out in an unprecedented scale between federally funded institutions and commercial organizations. As I've formulated my response to the questions that were posed by the subcommittee for our hearing today, I've tried to keep these factors in mind and determine how the biotechnology experience can be generalized. The following statements in response to the questions that you posed reflect this process.

First of all, significant changes should be made in the way that Federal Government sponsors research. The balance should be dramatically shifted from military defense-related research and development to research and developments which benefit mankind and, therefore, create economic value.

Second of all, emphasis should be placed on support of programs, not on the support of agencies, and I think this is a very important point. In general, there's a big tendency just to look at existing agencies and try to find how to split up the R&D pie among these agencies, and I think oversight such as yours should be focused on programmatic issues.

Third, strategic planning and the analysis of the flow of technology from the laboratory to the marketplace should be conducted in a comprehensive fashion. This will identify weak links in the system, many of which will be developmental in nature. As a Nation, we probably cannot expect that the venture capital—that venture capital will always be available to fund important new technical areas, particularly those which are not as captivating to the imagination of the public as biotechnology has been.

Another point is that complex and scientifically indefensible regulatory processes must be replaced with rational policies to facilitate commercial development of science-based product, and again, I simply echo the point made by Dr. Cooper that irrational regulatory policies, particularly ones that ignore fundamental science, have a depressing factor on the entire science-based industry of the country.

Finally, I do believe that the decision-making process about priorities, et cetera, should involve broad participation. Obviously, the fact that we're here today is a sign that you're committed to getting input from various segments, and we appreciate that.

And the final two points are that the NIH and NSF should continue their focus on basic research. If the Government identifies areas, particularly developmental areas, that require additional investment and should be targeted for a finite period of time, we be-

lieve that these more practical applications of the technology should be carried out by agencies other than the NIH and NSF, perhaps new agencies formed specifically to carry out a given task.

And then, finally, the most important experience of biotechnology has been the technology transfer, and we believe that technology transfer itself should be an explicit goal of literally every science-based program in the country so that the economic benefits that can be derived will be derived.

I look forward to the opportunity to discuss these issues further with you. Thank you.

[The prepared statement of Dr. Penhoet follows:]

Written statement for:

Review of Current U.S. Science Policy

Subcommittee on Science

Committee on Science, Space, and Technology

U.S. House of Representatives

September 24, 1992

by

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I. Background of the Witness and the Industry He Represents.

I am participating in this meeting as a representative of the biotechnology industry. My perspectives on the matters to be discussed have been derived from eleven years experience as the Chief Executive Officer of Chiron Corporation, one of the nation's largest, independent biotechnology firms and as a research scientist and faculty member at the University of California at Berkeley, (prior to 1981 on a full-time basis and since that time on a part-time basis). I have benefitted directly from a number of federal research and development programs: my graduate research was sponsored by the National Institutes of Health as was my

postdoctoral training. My career as an academic scientist was built largely through support of my laboratory at the University of California from the extramural grants program of the National Institutes of Health and from the National Science Foundation. As a participant in both the academic basic research enterprise and in the commercialization of products through my involvement in the industrial sector, I have had an unusual opportunity to view, first hand, the entire spectrum of biological science-related activities in this country from the most basic research in an academic laboratory to the practical commercialization and sales of products into worldwide markets.

The first full decade of the national enterprise in biotechnology has been an extraordinarily productive one. At least ten significant products have entered the healthcare markets around the world and these have already had a major impact on both public health and on the economy. (Figure 1) The biotechnology industry of the U.S. now employs more than 70,000 individuals, spends more than $3.2 billion a year on research and development, and has created revenues, including collaborative research agreements, of about $6 billion a year. Of the 6 billion dollars in sales, 750 million dollars of products are exported from the U.S. to foreign countries.

The rapid development of the biotechnology field has occurred as the result of an unprecedented level of technology transfer between federally funded basic research organizations, small entrepreneurial biotechnology firms, and large, well-established healthcare companies. Virtually every one of the major products so

Figure 1

Major Biotechnology Health Care Products

Approved for Use in the U.S. - 1991

Human Insulin

Human Growth Hormone

Alpha Interferon

OKT-3 Antibody

Hepatitis B Vaccine

Tissue Plasminogen Activator

Erythropoietin

Hepatitis C Diagnostics

Granulocyte Colony Stimulating Factor

G-M Colony Stimulating Factor

far commercialized has resulted from a direct and specific cooperation between a federally funded institution and a biotechnology firm. Figure 2 presents a summary of a number of these collaborations. The development of recombinant human insulin provides a fairly typical example. The first cloning of an insulin cDNA occurred at U.C. San Francisco (a Federally funded institution), the first chemical synthesis of genes encoding the A and B chains of insulin took place at the City of Hope (another Federally funded institution), the first high level of expression of the A and B chains in bacteria was accomplished by Genentech (a biotechnology firm), the production of high levels of a proinsulin analogue in yeast was achieved by Chiron (another biotechnology firm), and eventually insulin was produced, purified, and marketed by Eli Lilly (a well established healthcare company) using the City of Hope/Genentech technology and by Novo-Nordisk (another well established healthcare company) using the Chiron technology. The direct contributions of the various entities described to the successful commercialization of human insulin are readily discerned and reasonably well understood. These specific contributions, however, represent only a very small proportion of the total technology developed and shared among a number of institutions which was ultimately utilized in the human insulin project. A minimal list of generally applicable technologies utilized in the project overall would include use of restriction enzymes, DNA sequencing, ligation of DNAs, construction of suitable plasmids, transformation of host strains (E. coli and yeast), growth of cells in fermenters, protein purification, protein folding, formulation,

Figure 2

Biotechnology Collaborations

Human Insulin
University of California, San Francisco
City of Hope Hospital
Genentech/Eli Lilly
Chiron/Novo Nordisk

Human Growth Hormone
University of California, San Francisco
Genentech
Eli Lilly

Alpha Interferon
Biogen/Schering-Plough
Genentech/Hoffman-La Roche

Tissue Plasminogen Activator
University of Leuven, Belgium
Genentech

Hepatitis B Vaccine
University of California, San Francisco
University of Washington
Chiron/Merck Sharp & Dohme
Biogen/SmithKlineBeecham

Hepatitis C Test
Centers for Disease Control
Chiron/Johnson & Johnson
Abbott Laboratories

Erythropoietin
University of Chicago
Amgen/Johnson & Johnson

Granulocyte Colony Stimulating Factor
Sloan Kettering
Amgen

and so on. Almost all of these general technologies were developed at Federally funded institutions, primarily universities.

By virtually any criterion, biotechnology has been a major success. In attempting to define policies for research in the future, it seems that we should try to carefully analyze the factors that have been important in this success. The following stand out in my mind:

1. The government has acted to fulfill its responsibilities in education, in training, and perhaps most importantly, in the support of research. The U.S. today is the undisputed leader in the world in terms of both the quality and the magnitude of the biomedical science research enterprise.

2. The government has funded <u>basic</u> research. The biotechnology enterprise as we know it today owes its very existence to a number of discoveries that were made in the '50s and '60s by investigators who were exploring fundamental mechanisms of biology not specifically connected to any particular practical problem. In fact, the key technologies which led to the biotechnology field were developed by microbiologists studying sex among the microbes, a field of study that might have been subject of ridicule by former Senator William Proxmire. These studies of the exchange of genetic information between different strains of bacteria led directly to the discovery of restriction enzymes and plasmids, which are cornerstones of the field of molecular biology and applied biotechnology.

3. The basic science funded by the NIH and NSF has been investigator-initiated and subjected to rigcrous peer review. This system has provided independent, high-quality thinking of a large group of talented individuals, resulting in a collective definition of the field by its participants Competition for funds has fostered a keen interest in the maintenance of quality and productivity in investigators' laboratories.

4. Significant funding was made available by private sources (venture capital) to turn the basic research findings of the federally funded institutions into useful products in the private sector. This partnership between the scientific community and the financial community was a key element in the success of the field. The financial community became interested because it perceived a substantial opportunity to create value and because the scientific developments of the field were widely reported in the press, generating a high degree of interest in the public at large. We probably cannot count on this level of involvement for the development of most other technologies in the future.

5. Technology transfer was carried out at an unprecedented scale, in both formal and informal modes. The formal transfer of technology results in a sharing of the monetary rewards of specific inventions by inventors in federally funded institutions. It is important that this mode be expanded because reward for contribution is a fundamental aspect of fairness and incentive and because a lack of fairness (real or

perceived) will ultimately lead to a reluctance to share technology which will impede scientific progress. A great deal of progress has been made in this area. The NIH has implemented Cooperative Research and Development Agreements, most large Federally funded institutions have substantially increased their licensing and patent activities, and the number of cooperative programs between research and commercial institutions have grown.

Cooperations which anticipate the development of technology with commercial utility usually involve cross-institution scientific collaborations and frequently involve financial support for some or all of the programs by the commercial partners. The collaborations themselves facilitate personal interactions between scientists in the institutions involved (thereby enhancing technology transfer) and have the added advantage to the participating basic science organization that the sharing of the monetary rewards which result from a successful program may not be totally dependent on the issuance of patents.

II. Responses to Questions Posed by the Subcommittee

- **Given the end of the Cold War and the challenge to U.S. economic dominance from companies in other countries, are changes required in the Federal research establishment? If so, what changes should be made?**

One of the most important changes in the business environment during the last decade has been the trend toward globalization. Most significant companies today can function in many different environments, and many of them do so. These companies will obtain and utilize resources where they are economically most attractive. It has been estimated that as many as 400-500 million additional semi-skilled workers will be available as human resources to corporations of the world over the next decade. Given the global nature of today's business enterprise this relatively unskilled labor is likely to be utilized at the lowest possible price with only minor consideration of geographical location. With that reality we must assume that the continued economic viability of U.S. business in the future will be increasingly dependant on value created through sophistication and innovation. Therefore, the careful evaluation and then effective utilization of our resources to maximize both the creation and the commercialization of technology should be a matter of increasing national priority. Future national security will rest increasingly on economic, not military, power. We should substantially alter our research investments to shift the balance between military and non-military

R&D to more effectively protect our economic security. As much military R&D activity as possible should be declassified and related to broad issues of utility to society.

- **Should Federal R&D funds be allocated in a way which makes a larger contribution to enhancing U.S. economic competitiveness? What changes should be made?**

A number of changes could be made in the allocation of federal R&D funds to enhance U.S. economic competitiveness. Broad national technological goals should be established and the role of individual components of the national research enterprise in contributing to these goals should be re-evaluated. An increasing amount of Federal funds can be utilized directly to support specific programs or indirectly by the use of tax-related incentives for R&D in private enterprise. More emphasis should be placed on supporting programmatic goals rather than perpetuating existing agencies and their associated bureaucracies. The money for research programs should go to the enterprises, be they government or otherwise, which are most likely to solve the problems identified. A recent example of this which occurred in the State of California might be illustrative. Several years ago the State decided that it should invest in research in the field of AIDS and in particular in the development of strategies for providing vaccines against AIDS. The initial program as envisioned by the State would have provided research funds for public research institutions. However when the program was announced a number of

organizations including my own made the argument to the State that if it was truly interested in solving the AIDS problem, the funding process should be open to all qualified applicants regardless of their public or private nature, to make funds available to those who would be most likely to use the funds to effectively solve the problem. The State understood the issues at hand and opened up the competitive grant process to all qualified organizations. Ultimately monies to further research in AIDS were awarded to both public and private institutions. This pragmatic approach to solving research problems, that is, spending the dollars in the most efficient way, rather than using research monies to perpetuate existing research-oriented agencies of one sort or another, should be a model for future federal funding. In this regard I think that the government must continue to question the ongoing role of the large, purely federal research organizations such as the national laboratories. There is a tendency for these large organizations to be insulated from rigorous evaluation and measurement of productivity. As a result there is a widely held view that the national labs in general are not as productive as other research organizations in the country. In our view every research program in the country should have a clear mission and should be forced to confront the issue of the value of its contributions over a long period.

To make the research enterprise of the U.S. as competitive as possible on a worldwide basis we must evaluate the overall flow of products from the basic research laboratory to the marketplace and determine where major restrictions exist today in that flow.

Having made the analysis we must act to remove barriers to the commercialization of science-driven projects. There are several areas where such barriers exist today. Probably the most important advance from our point of view would be the removal of irrational and unreasonable barriers to entry of products into the marketplace which result from the imposition of complex and scientifically indefensible regulatory processes. For example, a major barrier to progress in Europe is the imposition of local regulations which are different in each of the major European countries. There is a major effort underway in Europe to unify the processes to facilitate the flow of products to the marketplace. In the U.S. we do not have such geographical restrictions. However, the multitude of government regulatory agencies now involved in regulating processes from industries like biotechnology is daunting. Frequently the regulatory processes themselves seem to have more to do with inter- or intra-agency turf battles than with the development by the government of rational, sensible standards for the regulatory environment. I think it is important to understand the overall impact of nonscientific and ambiguous regulatory procedures on the science enterprise. The ramifications are significant and extend all the way back to the basic research laboratory. First, there may be a perception that a given line of research is likely to be unfruitful because commercialization of products emerging from that research are so encumbered by regulatory processes that they're not worth pursuing. If so, then basic research will not be initiated in the first place. Second, there may be a perception that scientific contributions are not

appreciated and that regulations in the field are not based on good science. If so, there is a depressing effect on the overall scientific establishment. Third, there may be a perception that there are numerous examples where technology languishes in this country because the wherewithal to develop the science is not available. We see a special category of projects where basic research has defined a problem, but not sufficiently that any given commercial organization is willing to carry the technology to the point where it is useful for commercial projects. A recent example of this might be found in the development of ceramics. These substances have potential in many different industries, but no single industry has large enough specific interests to make it worthwhile for development as an entire field. In this circumstance the government certainly should contemplate the formation of special project-oriented agencies, task forces, etc. to further develop this as a field which would then have utility across the range of industries.

- **Does your company have an adequate opportunity to contribute to allocation decisions for federal research funds and to contribute to the establishment of relevant research o programmatic goals. What mechanisms would you suggest to improve your company's participation?**

Due to our close ties with the academic and federal research establishment we (Chiron) have reasonable opportunities to contribute to the federal research decision-making process. I

suspect, however, that most of our colleagues in other technically related businesses do not have the same kind of access. To improve access, it would be very useful to increase the direct involvement of industry personnel in the decision-making process. This could be accomplished by expanded use of advisory panels and by much broader use of exchanges of people between industry and the federal research establishment.

- **As a consumer of the results of Federally funded R&D (including new knowledge, trained people, and new products and processes), what do you consider to be the most important function of federal science and technology policy? Is this function being adequately fulfilled? How can it be better fulfilled?**

A basic and most important role of government is to ensure that the primary functions of science -- education, advanced training, and basic research -- are well-executed. We currently have major national problems in each of these areas. Science training of students in K-12, and even to some degree at the college level, has been described by many as "disastrous". Although addressing this problem is not the focus of today's discussion, I believe it is obvious that a strong educational foundation is absolutely critical to ensuring a successful R&D program for the nation. Hopefully, this issue will be addressed in the most serious and thoughtful fashion by those directly responsible. A continuing emphasis on and most likely even an

expansion of basic research in academic institutions should be a central theme of federal R&D policy going forward. Research in these institutions is generally productive relative to other research environments. It is relatively inexpensive compared to research in other settings and provides the added benefit of contributing to the education and training process while adding to our knowledge base. I think it is very important that we keep the NIH and NSF focussed on basic research. These agencies have been very effective in creating new knowledge and should stay focussed on what they do well.

In addition to supporting basic research, the government should consider investing in specific, targeted, development programs outside the NIH and NSF structures. This would necessitate the formation of new project-oriented agencies, focused by subject and limited in time so that they do not become self perpetuating and overly bureaucratic.

- **How can the Federal Government improve its use of strategic planning in developing its science and technology policy agenda? To what extent should the Federal Government use evaluation techniques to make decisions regarding the initiation, termination or refocusing of R&D? What improvements are warranted?**

We encourage the federal government to increase and improve its use of strategic planning in developing science and technology policy agenda. The government should continuously evaluate and

measure the effectiveness of its investments in the R&D area and should insist on a clear mission and a clear reason to exist over any extended period of time. In implementing a more strategic approach to federal R&D planning, we favor an orientation which focuses on problem solving rather than perpetuation of agencies and their attendant bureaucracies. The emphasis on problem solving however should not be interpreted as a call for tremendously constrained and totally mission-oriented research. The goals of research programs can be quite broadly defined particularly in the basic research areas. But even within a broad definition it is possible to measure progress, it is possible to establish goals for programs, it is possible to hold people who are in charge of these programs accountable for the progress which is being made.

The anticipation of increased emphasis on strategic planning inevitably brings up the question of who will do such strategic planning. Here I think the government has a unique opportunity to access a broad spectrum of interested parties.

In the process of strategic planning itself and evaluation and measurements of the results of the plans being implemented I cannot overemphasize the need for review of the programs by independant groups of qualified individuals. Our own interactions with large organizations worldwide, be they governmental organizations, private commercial enterprises or otherwise have led us to the conclusion that lack of objective review is the most pervasive and significant factor in limiting the productivity of research organizations and perpetuating mediocrity.

The Federal Government currently supports research at academic institutions, national laboratories, and industrial laboratories. Does the current mix of funding among these participants represent the appropriate balance? If the balance is not appropriate, what different balance would you suggest?

I believe that this may be the wrong question. As I have indicated above, I believe that the government should fund projects, not agencies. Having decided to pursue a project, the implementation decisions should be focused on the organizations which are most likely to succeed in reaching the goals of the project. Perhaps new, more sharply focused agencies could play a significant role in the future.

Thank you very much for inviting me to share my views on this vitally important subject with you today.

Mr. BOUCHER. Thank you, Dr. Penhoet.

And the subcommittee thanks all of the witnesses for their very thoughtful commentary this morning on the range of questions that—about which we had asked for comment.

Let me ask for a response from each of you as to what you think the most important function of Federal science policy should be. It has been suggested that the creation of wealth through the development of technology is an important goal, that the creation of new knowledge itself is an important goal, that the production of well-trained scientific and engineering personnel is an important goal. There may be other goals on your list that you think are worthy of mention.

Give me some sense, if you would, about which of those goals are of greatest value to you in terms of the current output of our federally funded R&D system. What are you getting out of it in order of priority, and what other kinds of goals that perhaps I haven't mentioned would you like to suggest to us that should be worthy objectives of the Federal investment in research?

Who wants to go first? Mr. Ferguson?

Mr. FERGUSON. Thank you, Mr. Chairman. I think I would repeat, in answer to your question, the point that I made, and I believe the other analysts made earlier, which is that from our standpoint, basic research is an area that is likely to receive too little funding from private industry because the benefits often are diffuse and hard to predict. Accordingly, that's an area that would normally receive less funding than it would merit, given the long-term benefits, and is an area that the Government should focus on funding. Thank you.

Mr. BOUCHER. Well, let me sort of follow that up by saying, within the general idea of funding basic research, though, what is it that we get from that industry that is the most valuable? Is it new product development? Is it the fact that the people who are performing the basic research gained training, and doing that, that makes them better employees for industry later? Is it just the general creation of new knowledge, whether that's applied directly to new product development or the—or to other goals? Which of those objectives do you find most valuable?

Mr. FERGUSON. I would say that it's very hard to rank them. In the past, we have taken advantage of new technologies, new knowledge, in the form of rocket casings. We use all-graphite casing that would not have been in existence but for Government spending. The people we have assembling our spacecraft and rockets, in many cases, are scientists who are funded by Government R&D spending through the Defense Department and through NASA, and as a result, I think it should be looked at as a continuum or from a holistic standpoint. The funding that goes into that area has benefits that appear in many forms.

Mr. BOUCHER. Okay. Dr. Cooper?

Dr. COOPER. Fifty years ago, the most important contribution was preparing the people, getting our universities ready and preparing people. At the current state, it—the most valuable yield is the new knowledge from the basic research, and the people second, but there—there have been times when the most important contribu-

tions were otherwise. So, I think you have to put it in a time frame.

Mr. BOUCHER. Okay. Dr. Penhoet?

Dr. PENHOET. Well, I'd certainly agree with what's been said by my colleagues here on the panel. I think that— that, you know, most importantly is that Government take responsibility for those areas that industry cannot really take responsibility for, and they relate to education and basic research. It's—there's a great temptation to focus on the short-term issues and, of course, to try to maximize the impact of the given program in a short period of time. That's always useful, but I think there's no question that the — what's most valuable to us are the basic research findings and the educational enterprise. From my own experience today, I would have to say, from a long-term issue, K through 12 science education in this country is probably number one on my list, although it's the most remote from our current localized activities.

Mr. BOUCHER. Okay. Mr. Ferguson?

Mr. FERGUSON. I was going to add that another area which often is under-funded by industry because of the risk is the reduction to practice—or serving as first customer for new technologies, particularly when these are expensive products or represent high risk because of their use in another system. It's difficult for industry to step up and be the anchor-tenant or first customer. That's another role the Government could play a little bit farther up stream in the R&D process.

Mr. BOUCHER. Okay.

Dr. COOPER. But, one other—

Mr. BOUCHER. Dr. Cooper?

Dr. COOPER. One of the more important contributions has, despite the vicissitudes of the appropriation process, has been the stability of the commitment, and that has been enormously valuable, and ways to ensure stable, realistic support for the basic research enterprise is a very high priority.

Mr. BOUCHER. The reason that I asked this question is because there have been suggestions from some quarters that we ought to develop a clear strategic plan for the Federal funding of research, whether that be on an agency-by-agency basis or a programmatic basis, as Dr. Penhoet suggests, or whether there be some centralized mechanism, perhaps in the Office of Science and Technology Policy, with appropriate consultation from the Congress, with regard to developing a strategic plan.

And, I guess my question is really this: Is that a good idea? Is that something that we ought to be pursuing, and if so, should we make one of the fundamental tenets of that plan the close link between the investment we make in research and new product development?

I want you to comment on that—what I think I'm hearing from you is that we certainly should not make that an exclusive goal, or even perhaps the principal objective, because we're also getting great value out of the well-trained scientific and engineering personnel and out of other kinds of new knowledge creation applied to other goals. So talk, if you would, a little bit about that general question and the extent to which we ought to be encouraging strategic planning, and if we are to encourage strategic planning,

should we be more closely linking our investment and research to new product development?

Who wants to go first? Mr. Ferguson?

Mr. FERGUSON. I'll take a stab at it. I think that strategic planning is a good thing for any organization or group. One of the major questions is, at what level of detail should the planning take place? I think it's imperative that the Government set some broad priorities for its research. For example, should we be focusing on defense R&D today, or should we be focusing on other areas, such as communications, transportation, and so forth? I believe at that level planning is imperative.

I would also take some issue with an earlier comment by one of the panelists. I feel it's important to give missions to agencies within those broad assignments. A transportation agency, for example, should possibly be looking at transportation technologies. These would include programs, but the programs shift on a much more shorter time scale than the overall objective of developing technology in the transportation area. So at that level, do some strategic planning.

With respect to your question of how that planning might be done, I would like to say that I believe Dr. Bromley has done a wonderful job in working with the Office of Science and Technology Policy to coordinate many of the science initiatives through the Government, through FCCSET.

That coordination, however, is a different thing from actually setting out imperatives. Each of the agencies, which has its own—each of which has its own goal to implement, should have some authority within that mission of setting the priorities to meet that goal, and I am afraid that if OSTP were set up to perform a strategic implementation role, that there would be very strong conflicts with the agencies particularly, perhaps OMB, and it would create a difficult situation to win in.

Second, I think one of the strengths of American research and development is its plurality. We have historically operated very well in a individualistic manner, particularly in the research area. I'd hate to see us give that up, because I think it's produced—it's in large part responsible for the world-class science establishment we have today.

And finally, the idea of centralizing planning at too great a level of detail does suffer from the—the problem or the wonder of basic research, which is that it's hard to predict precisely where you're going to end up. The research on a flower—South American flower may suddenly turn out to have health benefits—biology, ecology shifting over to health, and that type of benefit is very hard to plan for at a central level. I'd be afraid that we'd cut off some of these wonderful benefits—the diffusion of benefits that we have at present. Thank you.

Mr. BOUCHER. Dr. Cooper?

Dr. COOPER. Well, I would agree that if there were to be centralized planning, it should be geared largely to very broad topics that are essentially clarification of the statement of the national commitment to science and technology, and I think that would be helpful to focus all agencies of the Government to the priority of the—of the future.

I worry about over-centralizing detailed science programs, so I would go with Mr. Ferguson here on his analysis of what that is. So I do not think you should tie it tightly to required product—emergent—and I don't think you're going to know what is soon enough.

Mr. BOUCHER. Okay. A comment, if you would, Dr. Cooper, on the appropriateness of what I think we all would acknowledge is a new role on the part of OSTP in generic technology fields, for example, the biotechnology initiative, the critical materials initiative, the recently enacted initiative in high-performance computing and creation of the National Research and Education network, with the promise that more such cross-cuts will come in the future.

This is a centralized role for OSTP. It is an effort to link together the efforts of various agencies directed toward a common goal in areas where the policy-makers perceive that there is a national need. Talk about that in terms of a centralized effort, how's it working, does it serve your industry, and is this a valuable model that we ought to pursue somewhat more aggressively in the future by encouraging OSTP to take an even more centralized role in other critical areas.

Dr. COOPER. Well, I think, as this has been mentioned, Dr. Bromley has stepped up to trying to discuss interagency activities, and it's been particularly helpful, I think, in biotechnology. Dr. Penhoet might want to comment in detail about this, but I can recall when the new issues became clear that OSTP would step up to the challenge of trying to make sure of—that the various agencies that have a stake and responsibilities in their—we're talking with each other— we're not—we're avoiding unnecessary duplication, in particular, and we're trying to process regulations that were consistent and not confusing.

So there's been an enormous benefit from some of that interaction, and it is inevitable that it happen, because it must be addressed in order to avoid confusion. I think— again, I wouldn't know how to convert that into centralized strategic planning, however.

Mr. BOUCHER. Dr. Penhoet, does the OSTP FCCSET cross- cutting process meet the suggestion that you've made that we ought to focus more on programmatic rather than agency budgets?

Dr. PENHOET. Well, it was in that sense that I made the comment, and—and I certainly believe that, but—though, ultimately, once these programmatic decisions were made, they all would be implemented by agencies, and so I'm not sure I'm really in conflict with Mr. Ferguson in that regard, but it is in the context of broad priority setting and a concern on our part that agencies tend to have lifetimes of their own and to some degree become self-serving entities with respect to carving up the science dollar, and so I think it's very good to have some oversights—other groups, obviously, would not want to see a tremendously centralized, absolutely powerful agency controlling all the science in the country, but it's in this sense, a broad priority setting in facilitating interdisciplinary work between the various agencies in attempting to bring to the—to the enterprise as a whole an understanding, really, of the flow of science, if you will, from the—from the various components.

And in that regard, we do think there is a role for funding of specific developmental projects. For example, you — you—you brought up the point of material science, which has been, to some degree—it's not a—it's not a topic that captures the imagination of the average American, but it's a very important technology going forward economically.

So, you know, from time to time, we see a role for specific funding of developmental projects, making the assumption, however, that the basic research will be in place to do that. Another way of stating that people want everything. But—the—you know, I think the—the important element is, if you had to choose, basic research is key for the Government, but having a level of basic research in place, that funding specific targeted areas, particularly where we're in a very competitive battle with other nations, et cetera, is not inappropriate, in our view.

Mr. BOUCHER. I take it that, from your comments, you generally endorse what OSTP is doing and the Presidential cross-cut process. I see heads nodding. And you would encourage that process to continue as other areas of important generic technology are identified. Mr. Ferguson?

Mr. FERGUSON. Yes, Mr. Chairman, I would draw an analogy of the process, as I understand it, to that of peer review. As I understand it, OSTP goes to each to the agencies and finds out what's important in the area of R&D, and then consolidates that opinion across a broad range to present to decision-makers, such as yourselves. So it's a bottoms-up evaluation of what technologies are important.

Mr. BOUCHER. Okay. I have some other questions, but I'll withhold those temporarily.

The gentleman from California?

Mr. PACKARD. Thank you very much, Mr. Chairman.

In the 1986 Tax Reform Act, a good deal of tax incentives for research and development were removed. What effect has that had upon—we've now had six, seven years to evaluate— or five or six years to evaluate the effect of that change in policy. What effect has it had on our research and development community, and should it be changed, and are there other incentives or other policy changes that would be helpful to incentivize better and more research and development? Let me just get a cross-section on that.

Dr. Cooper?

Dr. COOPER. As I mentioned in my remarks, I do believe it's—removing of those incentives has had a negative effect, and it does affect the investment, and although our investment increases, it increases less as a result of that. So I would urge the—the Congress to rethink and make permanent an investment tax credit.

I think the procurement issue that Mr. Ferguson raised also has some tax implications. We also have benefitted greatly from the tax proposal Section 936 in Puerto Rico and the Caribbean initiative that has been very successful not only helping the economy down there, but in stimulating our own activities. So I would support that activity.

Mr. PACKARD. Mr. Ferguson, do you feel the same?

Mr. FERGUSON. I would concur with Dr. Cooper that the research and experimentation tax credit should be continued and if, possi-

ble, made permanent. I would also just bring forward the following anecdote.

Our company was established through what was called the research and development limited partnership back in 1983, which provided particular tax benefits to individual investors. These individuals, who numbered almost 1,000, invested $50 million in the new rocket technology that we were pioneering. That form of investment, I believe, today is extinct. The benefits that the investors relied on to help produce risk are no longer present. In addition, the difference between the capital gains tax rate and the individual tax rate, which helped to spark those partnerships, is no longer present. I'm not sure I'd call for that difference to re-emerge, but it is, I think, true that today individual investments in R&D are much lower, and part of the reason for that is the changing tax treatment.

Mr. PACKARD. Dr. Penhoet?

Dr. PENHOET. The biotechnology industry was similarly affected by that change. In fact, a substantial fraction of the funding in the first five years of the 1980s was provided by R&D limited partnerships of exactly the kind that Mr. Ferguson mentioned. So that has been a significant factor.

Second of all, I do believe that individual companies will make better decisions for themselves about research than — than involving outside agencies, and, therefore, that—if the Government wants to stimulate private R&D, the way to do it is through the tax credit mechanism rather than direct subsidies. We've had an unusual opportunity in Chiron to interact with health care companies around the world, and particularly in Europe, in many companies, direct subsidies are available to—from governments to companies for given projects.

It's virtually a uniform characteristic of those programs that the projects which are funded are projects that the companies themselves wouldn't invest their money in, and so I think that that form, as I've seen it, has been a very inefficient use of—of monies. It's the lowest priority that gets funded by the government under those circumstances. So indirect mechanisms like tax credits would be far preferable to direct subsidies.

Dr. COOPER. Mr. Packard, the—the suggestion made before about allowing the capitalization of certain kinds of investment and research would also be enormously helpful policy.

Mr. PACKARD. Dr. Cooper, the FDA has been accused of being slow in the processing and the delays either create inequities in the approval processes of drugs or certainly increase the costs and make it more difficult for companies to recapture their investment, and also shortens the time frame in which they can recapture their investment. Is that being changed? Do you see a change in that area with new leadership at the FDA, and are you—do you sense that there is an inequity or a bias toward certain companies, certain drugs, certain research, that is either due to the regulations or due to the implementation of the regulations?

Dr. COOPER. Well, I—I do agree that the—the speed of the process is a very important determinant in being able to recapture the investment and be successful at the market, so delays at the FDA are important. There is a place for a policy decision at the congres-

sional or Federal level for giving attention to a speedier review for life threatening illnesses and very special problems, and that has been done recently and is an important step forward. That does put sometimes some of us who aren't—happen to be working on that at a little disadvantage, but I think we have to look at that in the national interest.

I do not believe that there is any other calculated desire to play one against the other. I do believe that the new initiatives started by the current commissioner and his staff have the right intention, if they can be implemented with adequate resources. The recent discussions of other ways to get resources in it through user fees ought to be considered, but I think for those of us who know the agency and have visited their infrastructure on their information management, their computer basis, on—it needs a real shot in the arm as well as the commitment to getting them the work force they believe they need. So, I think there's a lot that can be accomplished there, if there is implementation of the new concepts.

Mr. PACKARD. Thank you very much.

Mr. Ferguson, you mention in your testimony that Orbital is involved in the development and construction of a global communications system, based on a low-orbit—low-earth orbit system or satellites. What impediments are there that hamper your progress or your process as you move forward, and is the United States retaining a leadership in this area?

Mr. FERGUSON. The major impediments to the new systems that are being proposed are two: one is technical, and that devolves into a financial question; the second is regulatory. From a technical standpoint, while many past investments in R&D by the Government, particularly military, have indicated that constellations of small satellites in low-earth orbit should be able to work, to provide global communications, essentially creating a worldwide village, there are still challenges in creating a commercial system, one that is easily understandable and affordable by commercial customers.

As far as the regulatory challenges, I will say that I believe the process of obtaining worldwide authority to operate has proceeded much more quickly than the introduction of any other comparable new communications technology. There was a worldwide approval of the new spectrum required for these systems at the 1992 World Administrative Radio Conference in Torremolinos, and the FCC is proceeding very quickly, using some new procedural techniques, to do the rule- making and the licensing in this country.

So, I think both of the challenges are there but are both being addressed, and the net result is that, as I mentioned in my written testimony, the United States, I believe, has a clear lead today, and it should translate into a very large business by the end of the decade.

Mr. PACKARD. Thank you, Dr. Penhoet. And I'll—this will be my final question. We have a call for a vote, and we'd like to finish, I think, this panel before we leave.

You indicated in your testimony that there should be a major shift from defense to civilian R&D, and I think we all agree that's going to happen, because there is a downsizing of our defense budgeting, and I think you—certainly one of my concerns is the possibil-

ity of losing significant dollars to R&D, because so much goes through the defense budget. About 60 percent of all R&D is done through the defense budget. At least Government-sponsored.

What do you think are the best ways to make this transition without losing our commitment toward R&D?

Dr. PENHOET. Well, I think that it's very difficult to make an abrupt transition, and there's a general concern about the overall effectiveness of some of the national laboratories, for example, who are engaged in defense research, and et cetera. I do believe that over time, that this has to be a phased development where the research and development activities are phased over time.

I think that all of our research enterprise is highly interdependent today. For example, in the pharmaceutical industry, we're increasingly dependent on innovation in the computer industry as a major tool, and so I think that opportunity exists for an examination, really, of all the tools available there. Declassification of a lot of that research would help, because those of us in peripheral industries would have a better understanding and access to that R&D.

I think that, certainly, many of the current activities could take on a commercially relevant overlay, if you will, to their current mission, which would be useful. So, I think we'd advocate a transition which was a phased one, in which the existing skill base was utilized more and more to apply to problems of economic value, rather than military value.

Mr. BOUCHER. Thank you, Mr. Packard.

The House of Representatives has issued a call for Members. That means we have to respond, and so I do have some other questions, which I will take up with the members of this panel in more informal discussions at a future time. We will continue to consult with you, and we'll look forward to your continuing advice as we pursue this inquiry. And again, we thank you very much for coming over this morning. You have stimulated some thought here, and we hope that you'll continue to do that as our inquiry goes forward. Thank you very much.

The subcommittee will stand in recess for about 10 minutes while we answer this call of the House, and then we'll proceed with the second panel.

[Recess.]

Mr. BOUCHER. The subcommittee will come to order.

We welcome now our second panel of witnesses this morning and would ask that they take a seat at the witness table: Dr. Arden Bement, the Vice President for Science and Technology of TRW, and also a member of the National Science Board; Dr. Robert Frosch, Vice President for Research and the Environment for the General Motors Technical Center; Dr. David Nagel, Senior Vice President, Advanced Technology, for Apple Computer Company; and Dr. Alan G. Chynoweth, Vice President for Applied Research at Bellcore, from Morristown, New Jersey.

Without objection, your prepared statements will be made part of the record, and we would welcome your oral summaries, and Dr. Bement, we'll be glad to begin with you.

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STATEMENT OF ARDEN L. BEMENT, JR., VICE PRESIDENT FOR SCIENCE AND TECHNOLOGY, TRW, INC., CLEVELAND, OHIO

Dr. BEMENT. I appreciate appearing before you today— in fact, I'm delighted—and being able to address needed changes in the Federal research establishment. I wish to focus my remarks on the relationships between science and technology, and the role of Federal R&D investments in global industrial competitiveness.

Since World War II, the Bush report, "Science - The Endless Frontier," has guided U.S. science policy. This extraordinary report outlined three principal goals for federally sponsored research: to support national security, to improve national health, and to advance national well-being and prosperity.

At the time President Truman received the Bush report, the U.S. found itself in a world leadership position in nearly every field of research, by circumstance of history. It was also a time when the period from conception to application of basic research could be measured in decades. Consequently, distinctions between basic and applied research were relatively unambiguous.

During the decade of the 1950s, national well-being often meant pushing out the frontiers of science and exploration, and expanding the human body of knowledge. Times have changed in the following ways: the lead time from scientific discovery to practical embodiment has contracted to the degree that many scientists today are able to engage in the commercialization of their discoveries and financially benefit from them; universities are much more involved in the management and brokering of the intellectual properties resulting from federally funded research; policy-makers now interpret national well-being in terms of a robust economy and job creation; competitiveness is now being gauged more on the basis of global markets than domestic markets; technological leveling among the fully-developed nations has taken away the comparative technological advantages that U.S. corporations enjoyed during the decades of the 1950s, 1960s, and 1970s; and today a science policy that aims at making the U.S. preeminent in every field of science is no longer realistic. This is especially so considering the substantial growth in total world investment in scientific research.

I believe a science and technology policy for the Nation that is more in tune with these new realities would have the following features, among others: first, it would endorse OSTP's emphasis on Federal investment and generic pre- competitive technologies, and its use of the FCCSET process to improve interagency planning and coordination in cross-cut R&D programs. Second, it would recognize that the distinction between basic and applied research is less meaningful today than in the past in delineating the Federal role in scientific and engineering research investment. There's much more of a continuum at play. It would encourage utilitarian-oriented but fundamental research at U.S. universities, and it would provide to industry the legal and financial incentives to increase its investments in long-term research and to further leverage these investments against focused Federal investments in civilian research at universities and Federal laboratories.

Consistent with the findings and recommendations of the National Science Board Committee on industrial support for R&D, I be-

lieve the Federal Government must increase support for civilian research that can make a larger contribution to enhancing U.S. economic competitiveness. But to do this at a time of serious budget constraints and the critical need to reduce national debt requires other policy actions.

First, a strategic review of Federal mission-oriented laboratories should determine if the missions supported are still relevant and address the most critical national needs. Part of this review should determine if the performing research organizations are closest to and best linked to the users of the research results. In many cases, the users themselves should be the performers to optimize cost-effectiveness and lead time.

Mission-oriented Federal laboratories should employ adequate assessments initially to justify new R&D investments in view of expanding opportunities to acquire needed technologies or to share investments with scientific and engineering research themes in other countries. Strategic planning for the purpose of developing a national science and technology agenda should focus on identifying those scientific and engineering capabilities needed to meet current and future national needs.

I believe in the area of basic research these policies should focus more on input to the innovation process rather than output, whereas in mission-oriented research focus on output is also important. Linkages between performers and users of mission-oriented research should exist before program initiation to assure the development and understanding of requirements and the planning of the transition from research to application. Linkages established after program completion for the purpose of technology transfer are usually ineffective and costly of both time and money.

OSTP needs mechanisms and resources to get the voice of the user in the formulation of cross-cutting R&D initiatives in ways that circumvent the cumbersome procedures of the Federal Advisory Committee Act. In other words, joint working groups are needed in order to get input and understanding from industry at the very onset of program development, especially in the cross-cutting areas.

The Federal Government should employ evaluation techniques to measure the quality, productivity, and outputs of the research it sponsors. Definitions of metrics before program initiation and consistency in their application throughout programs are important considerations.

Finally, the hardest questions to cope with in setting science and technology policies are: How much is enough, and what is the optimal balance among performers? We're already in the era of where wealth generation is being leveraged by ideas and new scientific concepts; therefore, one can expect the benefits will generally increase with increasing investments in science and technology. However, I don't believe that the Federal Government should invest solely to relieve stress in the national R&D system.

Stress can be healthy in bringing about change in the system that otherwise adjusts slowly over long time constants. As in industry and other systems that must compete for survival, the research community must learn to constantly rationalize their needs and priorities against available resources. In this respect, balance among performing communities must also adjust constantly to

achieve greater overall scientific excellence and productivity. There should be no sacred cows.

From my experience, scientists who are close to the user community and have a healthy concern for their needs are more productive than those who work in isolation and in a relatively sterile, stress-free environment. However, as always, there are exceptions.

In closing, I thank the subcommittee for the opportunity to express these views, and would be happy to address any of your questions.

[The prepared statement of Dr. Bement follows:]

Statement of Dr. Arden L. Bement, Jr.
before the
Subcommittee on Science,
Committee on Science, Space, and Technology
U.S. House of Representatives

September 24, 1992

Mr. Chairman and Members of the Subcommittee:

I appreciate appearing before you today and addressing needed changes in the Federal research establishment. I am speaking from my perspective as Vice President of Science and Technology of TRW Inc., as a former researcher, teacher, and manager in industry, government, and academia during a forty year career, and as a current member of the National Science Board. My opinions also draw upon former government service as Deputy Under Secretary of Defense for Research and Advanced Technology and as the Director of the Office of Materials Science at the Defense Advanced Research Projects Agency. I also wish to stress that my comments and opinions are my own. Also, I wish to focus my remarks on the relationships between science and technology and the role of Federal R&D investments on global industrial competitiveness.

A New Era for Science Policy

Since World War II, the Bush Report, "*Science the Endless Frontier,*" has guided U.S. science policy. This extraordinary report outlined three principal goals for federally sponsored research: to support national security, to improve national health, and to advance national well being and prosperity. With the rapid onset of the "cold war" and growing opportunities in medical research, the first two goals became predominant and remained so over the ensuing four decades. At the time President Truman received the Bush Report, The U.S. found itself in a world leadership position in most fields of science. It was also a time when the period from conception to application could be decades. Consequently, distinctions between basic and applied research were relatively unambiguous. A significant fraction of universities and university investigators eschewed "utilitarian oriented" research. National well being often meant pushing out the frontiers of science, exploration and expanding the human body of knowledge.

Times have changed in the following ways:

(1). The lead time from scientific discovery to practical embodiment has contracted to the degree that many scientists today are able to engage in the commercialization of their discoveries and financially benefit from them.

(2). Universities are much more involved in the management and brokering of intellectual properties resulting from federally funded research.

(3). Policy makers now interpret national well being in terms of a robust economy and job creation.

(4). Competitiveness is now being gauged more on the basis of global markets than domestic markets.

(5). Technological leveling among the fully developed nations has taken away the comparative technological advantage that US. corporations enjoyed during the decades of the 50s, 60s and 70s.

(6). A science policy that aims at making the U.S. preeminent in every field of science is no longer realistic. This is especially so considering the substantial growth in total world investment in scientific research.

There are some alive today who have witnessed the major shifts in the fundamental factors that generate wealth in our manufacturing sector. The first third of the 20th Century in the U.S. was an era of wealth creation through labor intensity, the second third an era of materials and energy intensity, and the current third an era of idea intensity. It is during this later era that the Japanese have been the teachers to the world. They have demonstrated that investments in plant modernization and automation, in new technologies that have high leverage in the marketplace, and in the training and education of the work force can bring about astounding economic growth and the mastery of world markets. They have also demonstrated that investment in new technologies can have a double multiplying benefit. It not only creates new markets for manufactured products but also improves the productivity of manufacturing these products.

Most other developed nations have learned these lessons and have formed close partnerships between their public and private sectors to facilitate investments in commercially oriented technologies for economic development. In the U.S., during the past decade the states have been much more active in responding to these new realities than the federal government. However, OSTP's statement of U.S. Technology Policy, the current focus on critical emerging technologies, advanced technology investment programs in the Department of Commerce, increasing emphasis in university-industry coupling programs in the National Science Foundation, efforts by the current Administration to increase the rate of technology transfer from the federal laboratories to industry all signal a shift in the direction of federal R&D investment policy.

A science and technology policy for the nation that is more in tune with these new sealities would have the following features, among others:

(1). It would endorse OSTP's emphasis on federal investment in generic, pre-competitive technologies and its use of the FCCST process to improve interagency planning and cooperation in cross-cut R&D programs.

(2). It would recognize that the distinction between basic and applied research is less meaningful today than in the past in delineating the federal role in scientific and engineering research investment.

(3). It would encourage "utilitarian oriented" fundamental research at U.S. universities. (The current focus on critical, emerging technologies in Federal R&D investments presupposes a utilitarian outlook.)

(4). It would provide to industry the legal and financial incentives to increase investments in long-term research and to further leverage these investments against focused federal investments in civilian research.

Why is a Shift in Science and Technology Policy Needed Now?

A recent report issued by the National Science Board finds a drift and stagnation in U.S. industrial R&D. This report entitled: *"The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues"* reached four principal findings:

(1). The real rate of growth in U.S. industrial R&D spending has declined since the late 1970s and early 1980s. In addition, the Nation's position has deteriorated relative to that of its major international competitors whose investment in non defense R&D has been growing at a faster pace than U.S. non defense R&D since the mid-1980s

(2) The allocation of U.S. R&D expenditures is not optimal:

- The balance between defense and non defense expenditures is disadvantageous compared to our foreign competitors,
- Too little is spent on process-oriented R&D,
- Inadequate effort is devoted to fundamental engineering research,
- There is insufficient emphasis on emerging and pre competitive technologies, and
- The United States faces an emerging risk of losing its traditional strength in pioneering discoveries and inventions.

(3). U.S. expenditures are not as effective as they should be in producing needed results:

- The U.S. competitive position in important, technologically based industries is deteriorating,
- The U.S. time horizon has become too short, and the Nation's business decisions tend not to be based on strategic technological considerations, and
- U.S. R&D is not translated into beneficial economical and social results quickly enough.

(4). The current information base on industrial science and technology is inadequate: it has gaps, is questionable in parts, and does not provide enough detail to meet the needs of policy makers.

The report recognizes that industry is responsible for its own survival and must deal directly with those factors that determine its competitiveness. However, the report recommends that government contributes to industry's leadership in three principal ways:

(1). Creating legal and economic environments more conducive to industrial R&D investment and innovation, principally through tax credits for R&D and changes to federal regulatory processes.

(2). Investing in research designed to encourage active collaboration among the "doers" of research (often in universities) and the users of research (principally in industry) in three essential areas: replenishing the nation's base of fundamental engineering knowledge, developing new industrial processes (as contrasted with products), and filling gaps in emerging, pre competitive technologies that may prove profitable only in the long run.

(3). Improving the quality and adequacy of industrial science and technology indicators that would be useful to policy makers.

The report reaffirms the direction the NSF has been taking in recent years. That is, government can help stimulate industry's innovation by investing in long-term scientific and engineering research and by encouraging closer interactions between industry and universities. It also reaffirms the U.S. Technology Policy statement issued by OSTP and encourages its further implementation.

I believe the two questions posed by the Task Force on the Health of Research, the Committee on Science, Space, and Technology, have particular meaning; namely,

(1). For a given national goal, what research is most necessary?

(2). What mechanisms for administering, performing, and evaluating research create the optimal pathways from research to goal attainment?

I will try to address these questions and those posed by the Subcommittee in the remainder of my testimony.

Principles for Policy Changes

As a starting point, I am a strong proponent of the OSTP statement on U.S. Technology Policy and the balance it seeks among strategy elements dealing with the **Role of the Private Sector, Government Incentives for the Private Sector, Education and Training, Federal R&D Responsibilities, Transfer of Federally Funded Technology, and Federal-State Initiatives.** While there may be ideological differences on how to implement these strategies, I believe these basic strategic elements and their policy frameworks deserve strong bipartisan support. I also believe that the FCCST process now in place for defining and implementing cross-cutting R&D programs among the Federal agencies should continue and be stronger. These programs have their origin in national inputs from the private sector and the science and engineering communities at large on critical national needs and high-leverage opportunities. What is currently lacking are the sufficient resources within OSTP to carry out the planning and goal setting processes; to establish the procedures for program assessment, measurement, redirection, and termination; and to establish linkages to industry for advice, coordination and outreach.

The end of the cold war and the growing challenges to comparative U.S. technological advantages by competing countries signal the need to both reevaluate the fundamental assumptions guiding federal science policy and reexamine the linkages between federal R&D investments and national needs. In particular, I believe that there is evidence to support the following assertions:

(1). Scientists and engineers in small interdisciplinary teams can be the most productive of new ideas in complex fields of research.

(2). The merging of scientific and technical insights to meet a need, opportunity or threat more often leads to innovation, technology development, and economic growth than the mere availability of fundamental knowledge. Fundamental knowledge is freely available around the world to the "fleet and able." It's technological knowledge (to include "know how") that must be bought, handed off, borrowed or stolen.

(3) Applied research often uncovers enigmas that eventually lead to new directions in basic research.

(4). If applied research restricts creativity and serendipitous discovery, it is often because it is poorly conceived, improperly led or conducted by unimaginative investigators, none of which needs to be the case.

(5) "Scientific excellence," as judged by peer review, should not be the sole criterion for determining which projects should receive funding. Past performance and productivity, relevancy to national needs, adequacy of capabilities, and purpose of results also warrant consideration, among others, in making funding decisions. However, the

use of peer reviews for scientific excellence should be more universal for research conducted at national laboratories. The current reviews at DoE laboratories directed by the Secretary of Energy are highly commendable.

(6). Although on average the effective educators at top universities are also those who conduct cutting-edge research, this is not invariably true. A number of top researchers are ineffective educators, and there are great educators who use their creative energies to synthesize knowledge or develop new frameworks of knowledge rather than generate new knowledge.

(7). Because of the rapid state of flux in scientific and engineering research, the "traditional" scientific disciplines may not form the most natural and appropriate framework for funding, administering, performing, and evaluating research. Some of today's disciplines (such as biochemistry, cognition science, macromolecular science, materials science and engineering, computer science and engineering, and solid state chemistry) are yesterday's "inter disciplines." Many of tomorrow's disciplines are emerging from today's inter disciplinary research teams. This is especially true in engineering research. One needs to keep an open mind on the future when it comes to making choices among and between disciplines.

Other Views in Response to Subcommittee Questions

Consistent with the findings and recommendations of the NSB Committee on Industrial Support for R&D, I believe the federal government must increase support for civilian research that can make a larger contribution to enhancing U.S. economic competitivenes... **and with a sense of urgency**. To do this at a time of serious budget constraints and the critical need to reduce national debt will require other policy actions:

(1). A strategic review of federal mission oriented laboratories should determine if the missions supported are still relevant and address the most critical national needs. Part of this review should determine if performing research organizations are closest to and best linked to the users of the research results. In many cases, users should be the performers to optimize cost effectiveness and lead time.

(2). The first step in mission oriented research should employ adequate assessments initially to justify new research investment in view of expanding opportunities to acquire needed technologies or to share investments with scientific and engineering research teams in other countries

(3). Strategic planning for the purpose of developing a national science and technology policy agenda should focus on identifying those scientific and engineering capabilities (to include both human and physical resources) needed to meet current and future national needs. Federal R&D investments should both establish and sustain these capabilities. Such an agenda should assure that American colleges and universities remain the best in the world and are capable of attracting and retaining the best research talent.

(4). Linkages between performers and users of mission oriented research should exist before program initiation to assure the development and understanding of requirements and the planning of the transition from research to application. Linkages established after program completion for the purpose of technology transfer are usually ineffective and costly of both time and money.

(5). OSTP needs mechanisms and resources to get the "voice of the user" in the formulation of cross-cutting R&D initiatives in ways that circumvent the cumbersome procedures of the FACA.

(6). The federal government should employ evaluation techniques to measure the quality, productivity and outputs of the research it sponsors. Definitions of metrics before program initiation and consistency in their application are important considerations. Most mission oriented Agencies do this very effectively and generally design into their programs "mid-term assessments" and potential "off ramps" for program redirection or termination. In the case of basic research programs, there is a need for output measures other that the number of peer-reviewed publications. However, from a policy point of view, investments in basic research are "inputs" to the innovation process and require reasonably patient expectations of returns.

TRW is one of many companies today that are looking increasingly outside the company for new technologies. However, every dollar invested in the outside acquisition of technology requires three dollars or more of additional investment to adapt the technology for use, integrate it with other technologies, modify existing designs, or prove out the technology for high-reliability or safety-critical applications. For this reason we generally find teaming relationships with federal laboratories and universities to be far more productive than investments in technology transfer or loosely coupled consortium relationships. I believe that federal resources invested in technology transfer following the conduct of research are not as effective as resources invested in teaming relationships before and during the conduct of research. Federal laboratory directors and their senior managers need the authority and budget flexibility to enter into these types of relationships. Flexible guidelines coupled with sufficient accountability standards are preferable to current multilevel, bureaucratic approval and micro management procedures.

Finally, the hardest questions to cope with in setting science and technology policies are "how much is enough" and "what is the optimal balance among performers." We are already in the era where wealth generation is being leveraged by ideas and new scientific concepts. Therefore, one can expect that benefits will generally increase with increasing investments in science and technology. However, I don't believe that the federal government should invest solely to relieve stress in the national R&D system. Stress can be healthy in bringing about change in a system that otherwise adjusts slowly over long time constants. Furthermore, we have reached a stage in our national development where we educate many more medial than outstanding researchers and where older, world class investigators are still productive and will be so for several years to come. As in industry and other systems that must compete for survival, the research community must learn to constantly rationalize needs and priorities to available resources. In this respect, balance among performing communities must adjust constantly to achieve greater overall scientific excellence and productivity. There should be no "sacred cows." From my experience, scientists who are close to the user community and have a healthy concern for their needs and enigmas are more productive than those who work in isolation and in a sterile, stress-free environment. As always, however, there are exceptions.

In closing, I thank you for the opportunity to express my views to the Subcommittee, and would be happy to address any questions you have.

Mr. BOUCHER. Thank you very much, Dr. Bement.
Dr. Frosch?

STATEMENT OF ROBERT A. FROSCH, VICE PRESIDENT, RESEARCH LABORATORIES, GENERAL MOTORS CORPORATION, WARREN, MICHIGAN

Dr. FROSCH. Mr. Chairman, Members of the subcommittee, it's with great pleasure that I appear before you today.

Last week I began the 42nd year of my professional career in research and development. I've spent my career in the generation of scientific knowledge and technology intended for application to the solution of problems of business or of society, and I have done that as a researcher or a leader of research and development in a Government-sponsored university setting; in the U.S. Government in DARPA, as Assistant Secretary of the Navy for Research and Development; as Administrator of NASA in the U.N. Environment Program; and now in industry at GM. I believe, in the course of this time, I have learned something about the processes and problems involved and would like to make several observations based on my experience.

In transmitting the task force report, Chairman Brown poses our dilemma: "either that we are not adequately using the knowledge that we already have, or that we are not sufficiently producing the knowledge that we actually need," or both. I believe our problem is dominated by inadequate attention to the use of what we know, and inadequate use of the skills and the technical competence of those who have the knowledge of science and technology.

This does not mean that we need a pause in knowledge generation—we are far from knowing what we need for further progress in attacking problems of business and of society— but only that while both aspects of the Chairman's question need work, the more serious problem lies with the use of knowledge. We tend to pay inadequate attention to replacement of old and unsatisfactory processes and systems and to the longer-range future problems that business and public policy are likely to face. We allow the requirements of the present to drive out consideration of the possible requirements of the future.

My second point is that technology does not really consist of the widgets, or even of the processes used to produce the widgets, but of the underlying knowledge and skills that are used to produce both the widget and the processes. It is the knowledge of how to do things which is the technology. For this reason, all technology is multiple use, because the underlying knowledge is multiple use.

My third point is that for the process of transfer of technology to work, it must be seen as what it is: a dialogue between people who have technological and scientific knowledge and people with problems that might be solved, or be suitably redefined and then solved, by the application of the combined knowledge and skills of both parties. It cannot be engaged in at arms length, and it takes time. Bureaucratic attempts to force arms length negotiations at this level of discourse are simply destructive of the root of the process and lead, inevitably, to failure. These observations lead to some recommendations.

First, Federal science policy should continue to focus on and increase knowledge and technology that is believed to be broadly relevant to the development of industry and to industrial processes and manufacturing, as well as to useful products.

History suggests that our ability to know in advance all that is relevant is very poor. In the days when polio was a scourge, it was easy to know that working on better iron lungs and treatments for affected muscles was relevant. Nearly no one saw or listened to the relevance of research into virology and possible immunization techniques. As in so many other examples, the urgent and obvious nearly drove out the fundamental, subtle, and long-term.

Thus, it is essential to keep working in fundamental scientific, technological, and exploratory areas that may seem irrelevant, but that the best minds—if we can agree on whose minds those are—that the best minds believe are important. This work should continue to cover the basic scientific disciplines. There should also be specific support for the fundamentals of subjects upon whose importance there is reasonable consensus in the technical community. The various strategic technology reports all seem to be in violent agreement about which these are.

For the subjects in which I am especially interested these days, I would include at the top of my own list all the technological areas underlying manufacturing, but especially computer technology, both hardware and software, and the disciplines of mathematics, science, and engineering that underlie them, all varieties of material science, including the creation, forming, shaping, and processing of materials, and the understanding of the functioning of all kinds of complex multi-structured and multi-level systems.

I also recommend that we all work hard to build upon the substantial recent progress that has already been made in facilitating the interaction between private industry and the Federal laboratories. At GM we are deeply concerned about our ability to address both market demands and regulatory requirements. Working cooperatively with appropriate partners, especially the Federal laboratories, will help GM and other U.S. companies to develop process technologies as well as products needed to compete globally.

Of the technology transfer mechanisms now available for leveraging Federal R&D resources, those that appear most useful to us are the Cooperative Research and Development Agreement, the CRADA, the consortium mechanisms, and the Advanced Technology Program. We have signed several CRADAs in 1992. Excellent examples of important consortia is the U.S. Advanced Battery Consortium, which GM was instrumental in forming and which the Department of Energy has strongly supported; the National Center for Manufacturing Sciences, which is supported by a number of industrial partners, over 100, and supported by some Federal funding as well. GM is also a partner in eight other consortia with Ford and Chrysler, all of which are exploring partnerships with national laboratories. An umbrella organization, the U.S. Counsel for Automotive Research, oversees these consortia. Under the Advanced Technology Program, the Department of Commerce's grant program, we submitted three proposals in fiscal 1991, two of which were funded.

Industry and Government are making excellent progress in these complex cooperative efforts. I believe this progress could be improved with some fine-tuning. The National Technology Initiative Sessions held around the country this past spring and summer have raised the technology transfer demands from the Federal labs beyond the resources that they have available to them for this purpose. These labs need a major increase in funding for technology transfer activities if Congress wants more of industry's needs to be addressed. This is not necessarily an increase in funding for the laboratories, but an increase in the availability of funds they have for this purpose. Those are separately limited, of course.

Secondly, we're working with the Government now to simplify and standardize the CRADA process. And finally, we need to ensure that proprietary information used or developed under these programs is inaccessible to competitors who are not part of the cooperative process in question for the particular subject.

Mr. Chairman, as I noted when I began, the U.S. does not produce too much science and technology, even too much "apparently irrelevant" science and technology; however, we have been too lax in using for industrial purposes what we are producing, and we still have far to go to ensure that we have adequate mechanisms to encourage much wider use of the knowledge and skills we do possess. Thank you very much for the opportunity to testify.

[The prepared statement of Dr. Frosch follows:]

Testimony of

Dr. Robert A. Frosch

Vice President, Research Laboratories

General Motors Corporation

Before the

Subcommittee on Science

U. S. House of Representatives Committee on

Science, Space and Technology

Thursday, September 24, 1992

Mr. Chairman, Members of the Subcommittee,

It is with great pleasure that I appear before you today. Last week I began the forty-second year of my professional career in research and development (R&D). I have spent my career in the generation of scientific knowledge and technology intended for application to the solution of problems of business or of society, and in the leadership and management of R&D intended for those purposes. I believe I have learned something about the processes and problems involved and would like to make several observations based on my experience.

In transmitting the Task force report, Chairman Brown poses our dilemma: "... either that we are not adequately using the knowledge that we already have, or that we are not sufficiently producing the knowledge that we actually need," -- or both.

I believe our problem is dominated by inadequate attention to the use of what we know, and inadequate use of the skills and the technical competence of those who have the knowledge of science and technology. This does not mean that we need a 'pause' in knowledge generation -- we are far from knowing what we need for further progress in attacking problems of business and of society -- but only that, while both aspects of the Chairman's question need work, the more serious problem lies with the use of knowledge. We tend to pay inadequate attention to replacement of old and unsatisfactory processes and systems and to the longer range future problems that business and public policy are likely to face. We allow the requirements of the present to drive out consideration of the possible requirements of the future.

My second point is that technology does not really consist of the widgets, or even of the processes used to produce the widgets, but of the underlying knowledge and skills that are used to produce the widgets and the processes. It is the knowledge of how to do things, which is the technology. For this reason, all

technology is multiple use, because underlying knowledge is multiple use.

My third point is that for the process of 'transfer of technology' to work, it must be seen as what it is: a dialogue between people who have technological and scientific knowledge and people with problems that might be solved, or suitably redefined and then solved, by the application of the combined knowledge and skills of both parties. It cannot be engaged in 'at arms length,' and it takes time. Bureaucratic attempts to force 'arms length' negotiations at this level of discourse are simply destructive of the root of the process, and lead inevitably to failure.

These observations lead to recommendations. First, Federal Science policy should continue to focus on and increase knowledge and technology that is believed to be broadly relevant to the development of industry and to industrial processes and manufacturing, as well as to useful products.

History suggests that our ability to know in advance all that is relevant is very poor. In the days when polio was a scourge, it was easy to know that working on better iron lungs and treatments for affected muscles was relevant. Nearly no one saw, or listened to, the relevance of research into virology and possible immunization techniques. As in so many other examples, the urgent and obvious nearly drove out the fundamental, subtle and long-term.

Thus it is essential to keep working in fundamental scientific, technological and exploratory areas that may seem irrelevant, but that the best minds believe are important. This work should cover the basic scientific disciplines. There should also be specific support for the fundamentals of subjects upon whose importance there is a reasonable consensus in the technical community. The

various 'strategic technology' reports all seem to be in violent agreement about which these are.

For the subjects in which I am especially interested these days, I would include at the top of my own list all the technological areas underlying manufacturing, but especially: computer technology, both hardware and software, and the disciplines of mathematics, science and engineering that underlie them, all varieties of material science, including the creation, forming, shaping and processing of materials and the understanding of the functioning of all kinds of complex and multistructured and multilevel systems.

I also recommend that we all work hard to build upon the substantial recent progress that has already been made in facilitating the interaction between private industry and the federal laboratories. At GM we are deeply concerned about our ability to address both market demands and also regulatory requirements. Working cooperatively with appropriate partners, especially the federal laboratories, will help GM and other U.S. companies to develop the process technologies, as well as the products, needed to compete globally.

Of the technology transfer mechanisms now available for leveraging federal R&D resources, those most useful to GM are: 1) the Cooperative Research and Development Agreement (CRADA); 2) the Consortium; and 3) the Advanced Technology Program. GM has signed several CRADA's in 1992, including one, between Oak Ridge National Laboratory and our Saginaw Division, and one, with Lawrence Livermore National Lab.

An excellent example of an important consortium is the U.S. Advanced Battery Consortium (USABC), which GM was instrumental in forming and which DOE has strongly supported. GM is also a partner in eight other consortia with Ford and Chrysler, all of

which are exploring partnerships with national laboratories. An umbrella organization, the U.S. Council for Automotive Research (USCAR), oversees all of these consortia.

Under the Advanced Technology Program (ATP), the Department of Commerce's grant program, GM submitted three proposals in FY1991, two of which were funded.

Industry and government are making excellent progress in these complex cooperative efforts. I believe this progress could be improved with some fine tuning. First, the National Technology Initiative (NTI) sessions held around the country this past spring and summer have raised the technology transfer demands from our federal labs far beyond their available resources. These labs need a major increase in funding for technology transfer activities if Congress wants more of industry's needs to be addressed. Secondly, we are working with the government now to simplify and standardize the CRADA process. Finally, we need to insure that the proprietary information used or developed under any of these government programs is inaccessible to competitors.

Mr. Chairman, as I noted when I began, the U. S. does not produce too much science and technology -- even too much "apparently irrelevant" science and technology. However, we have been too lax in using for industrial purposes what we are producing; and we still have far to go to insure that we have adequate mechanisms to encourage much wider use of the knowledge and skills we possess.

Thank you.

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Mr. BOUCHER. Thank you, Dr. Frosch.
Dr. Chynoweth, we'll be pleased to hear from you.

STATEMENT OF ALAN G. CHYNOWETH, VICE PRESIDENT, APPLIED RESEARCH, BELLCORE, MORRISTOWN, NEW JERSEY

Dr. CHYNOWETH. Mr. Chairman, I feel honored to have this opportunity to present my views on the operation of the Nation's research system. I am Vice President of Applied Research at Bellcore, Bell Communications Research—the R&D organization that serves the seven regional Bell operating companies, and I've been involved in telecommunications research and development for 40 years.

What I want to focus on, and is elaborated more in the written testimony that I have submitted, is on how we get the innovation chain aligned. We have research at one end of the innovation chain, and we have society's needs, national goals, and so on at the other end, and how do we get that—the research aligned with the national goals, and secondly, how do we get that innovation chain moving.

Since World War II, the federally funded research system has been heavily influenced by defense needs, and by and large, it has served the Nation well, and now it is appropriate to be examining whether this system can better serve this Nation's economic needs. Industry, in both its manufacturing and service sectors, is the primary instrument for creating economic strength. Any Federal funding of R&D aimed at improving the economy has to work through and with this free enterprise industrial system.

To mobilize this industrial system, it is essential first to identify broad societal objectives. Knowing its mission and objectives is fundamental to the success of the Defense Department in orchestrating the whole innovation chain, from the support of R&D at one end to procurement and operations at the other. Knowing its mission and clear objective was also fundamental to the success of the Apollo Program. And in the civilian sector, the former Bell system operated in much the same way to fulfill its mission of providing the country with the world's most cost-effective telephone system.

Now, these management systems do not translate smoothly or effectively into the free market system without modification. New mechanisms are needed for mobilizing the whole team, involving the universities, the national laboratories, and industry. The vital role of having a mission has to start with the various arms of the Government arriving at, through the political process, a clear vision of what kind of society we aim to be and a clear set of critical societal goals that will enable us to achieve that vision.

The vision and the goals have to be clearly and repeatedly articulated. They are the first requirement for pulling the innovation teams together. It is also what our major foreign competitors have often been so successful at doing. I believe this country has had the luxury, in resources and time, of being able to rely largely on funding technology push and relying on trickle-down, the vagaries of the marketplace, and Darwinian selection for much of its innovation.

This approach has certainly had outstanding results, and it must remain as a unique strength of the research system. But times have changed. There has to be more applications or market pull working its way back through the industrial system to the funding of R&D. A clear set of critical societal goals, together with a nested set of critical technical goals, can contribute significantly to providing this pull as a necessary first step.

I believe it is vital for the Government, in partnership with industry and academia, to be generating this set of critical technical goals, in much the same way as it has generated sets of critical enabling technologies. I also believe that, with rare exception, these goals should be societal systems in nature, rather than specific commercial products or processes. Besides defense, societal systems that draw the proper concern of Government include education and health systems, environmental and energy systems, agricultural and natural resource systems, and of course, the infrastructure systems of transport and communications.

In a sense, these systems are society's enabling technologies. Societal goals need to be translated into realistic, critical technical goals for these systems. All relevant sectors, including industry as well as academia, should participate in this goal-setting. The key role for Government, of course, is to bring all parties together and to represent society's interests.

Corresponding teams are then needed to develop realistic technical road maps and schedules and to identify the roles the various sectors and participating parties can be expected to play in an innovation chain. But I wish to emphasize that this—I'm still talking about a relatively high level of strategic planning in the spirit of the earlier discussion. It is not getting down to micromanagement.

Strategic planning along these lines helps lead to greater alignment of R&D at one end of the innovation chain, with societal goals at the other. And as brought out in the task force's excellent report on the health of research, the Executive Branch already has in place, with the OSTP and the FCCSET, a very appropriate and useful structure on which to build for addressing goal-setting and developing technical road maps. But more than alignment of the innovation chain will often be needed in order to get things moving.

Incentives may have to be provided, barriers removed, and seed funding and focused application of funds for R&D, particularly to foster linkages in the chain involving industry, both at the input end and at the output end. On this subject, I found the task force report relatively silent. Regarding industry, advantage should be taken, as much as possible, of the usual business drivers—go with the flow, so to speak. Among these drivers on which to leverage, there is no greater incentive to industry to invest its own funds in R&D than the belief that it will be able to have equitable opportunity to compete for any market that may result from its investment.

The Defense Department's procurement programs have often served this role in that sector. The extent to which this approach may be adapted, and perhaps considerably adapted, but nevertheless thought about in terms of society's civilian needs, may well be worth exploring. Other incentives for industrial companies include

tax relief for investing in R&D, perhaps offset by taxes raised on companies that do not so as not to impose any additional burdens on the general taxpayer.

Another mechanism that I feel is well worth considering is to have industry perform as a prime contractor for some R&D, jointly proposed with universities and/or appropriate national laboratories, as indeed is happening already with some agencies. Subcontracting some of the work to the universities and national laboratories would serve further to strengthen the alignment of the R&D with the societal goals and, perhaps even more helpfully, close the technology transfer gap that often exists between these organizations and industry.

And one further point, while this committee is focusing on how to make federally funded R&D more effective in the civilian sector, I find it ironic that my own company, Bellcore, and its seven owners, the regional Bell operating companies, are severely handicapped by the terms of the modified final judgment which will become Federal law if the Brooks Bill is passed, as to the extent they can use the fruits of their own R&D to improve the Nation's telecommunications and information networking system and services. I think it's tragic that so many handicaps are placed in the way of benefiting from a very significant investment of the private sector in R&D.

Mr. BOUCHER. Dr. Chynoweth, we are a little bit pressed for time, because the full committee has informed us that they will start a hearing in this room at 12:30 p.m. So that we'll have a little bit of time for questions, could I ask you to summarize, perhaps in a minute, and then we'll proceed with Dr. Nagel, and then have questions.

Dr. CHYNOWETH. Certainly, Mr. Chairman. I think the important point that I want to make is the importance of pulling the whole team together in this innovation chain— the Government, industry, and academia—working these strategic goals and road maps so as to achieve the innovation. And I think you'll find many of those views further developed in the testimony I have submitted.

[The prepared statement of Dr. Chynoweth follows:]

TESTIMONY

OF

DR. ALAN G. CHYNOWETH

VICE PRESIDENT, APPLIED RESEARCH

BELLCORE

ON

REVIEWING U. S. SCIENCE POLICY

PRIVATE SECTOR VIEWS

BEFORE THE

SUBCOMMITTEE ON SCIENCE

OF THE

COMMITTEE ON SCIENCE, SPACE & TECHNOLOGY

SEPTEMBER 24, 1992

TESTIMONY FOR THE HOUSE SCIENCE SUB-COMMITTEE
Improving the Effectiveness of Federally Funded R and D
in Meeting the Needs of the Private Sector

FOCUS ON R and D PROCESS FOR ECONOMIC HEALTH

With the lessening of cold war tensions and the harshly increasing realities of global economic competition, it is all the more vital that the Federal Government address the question of how its expenditures on R and D can have maximum beneficial effect on this nation's economic strength which, in turn, largely influences the role this country will play in future in the global economy.

Industry, with its manufacturing and its service sectors, is the primary agent for achieving economic health and wealth. Ensuring that, wherever appropriate, the federal government's R and D activities feed into and support industry is a critically important element in a total strategy for industrial health and U.S. economic competitiveness. *But technology push alone is insufficient and can even be useless. There also has to be an overall applications or market pull so as to provide orientation and purpose in the industrial R and D.* This pull can be provided by perceived needs and opportunities in the marketplace and/or by broad societal needs.

IMPORTANCE OF MISSION FOR ALIGNING R and D

The needs of the Defense community have traditionally provided an applications pull or mission. This pull has helped to align the whole supply train which starts with basic or long-range research, mostly in the universities. It leads on to applied research in industry and some of the national laboratories, resulting in technologies which in sequence, spawn product development and manufacture, equipment procurement and ultimately, deployment and operation in the field. The whole innovation system, from research and technologies to product manufacture and systems operation, is orchestrated and supported by the Department of Defense. On the whole, the system has served the country well, as evidenced by the outcomes of the Cold War and the Gulf War.

Perhaps the closest analogy to this functioning innovation system in the civilian sector was the former Bell System. The management of the Bell System orchestrated the total innovation process from research to operations in the field for a large part of the nation's telecommunications infrastructure.

In many respects both the Defense Department and the former Bell System are or were self-contained mission-oriented systems able to align their research activities relatively efficiently with the needs of the end users of the technologies. While clearly, federally funded R/D is a natural element in the Defense strategy, the former Bell System funded virtually all its R/D internally and did not require federal funds.

However, the R/D funding strategies appropriate for the Defense sector and the former Bell System do not work so effectively in the competitive private sector. In particular, *under the relentless pressure of marketplace competition and contemporary management practices, industrial research that is not obviously relevant to meeting the needs of products and services in the short-term tends to be driven out unless some incentive or a degree of protection is provided.*

A significant factor causing this elimination of the 'seed corn', or attention to the future, is the phenomenon of what the economists call the 'free rider' - one who is able to gain in one way or another the fruits of a competitor's investment in research without having to make anything like a comparable expenditure. Another, and probably even greater factor, is market uncertainty causing the risk-to-benefit ratio to be unacceptably high for financial prudence.

Recognizing the difficulties that industry seems to have in supporting enough R/D, especially the medium- to longer-term research required for the future, undoubtedly suggests that this is where some of the federal government's R/D funds and capabilities could be re-deployed. This can lead the government, if it acts more or less on its own, into the trap of having to make product decisions for the commercial sector early in the innovation process, something which it is not equipped to do nearly so well as industry - though the latter can hardly claim perfection.

VISION, LEADERSHIP and PARTNERS

Instead, *what industry looks to the government for is long-term vision for society, which by definition should be bi-partisan, and steady leadership towards achieving that vision.* The high level vision for which government has greatest responsibility relates to broad societal needs which underlie the economic health of the country as a whole - such as health, education, crime, the environment, agriculture, natural resources, and communications infrastructures, both transport and telecommunications, as well as defense.

It is important to note that many of these items are *systems.* None of them are discrete products, though systems are made up of many individual products. But pushing the advance of just one or two products alone, though maybe catalytic and worthwhile in the small, will often fail to bring about the major desired advances in the large, at the systems level. Furthermore, marketplace competition generally works well at the component level, less so at the large, complex systems level.

This is where coordination is needed. *Piecemeal approaches, or laissez-faire approaches to the marketplace, will seldom lead to the efficient and expeditious advance of these complex systems.* As in any major industrial enterprise, it is necessary to pull the whole team together, to include *all* the players, to work out agreement on directions and goals for these complex systems and what part each of the participants will play in reaching the goals.

It is worth noting the way Japan has developed visions and goals and how it has implemented programs to help achieve those goals. I remember being impressed in the mid-sixties by official Japanese government documents describing in considerable detail their vision of the global Information Society of the 21st century and then identifying the various technologies that had to be developed to help Japan establish a leadership position in the Information Society. Once identified, various national projects, programs, and consortia were launched under government leadership, with industry and the banks as partners, to help move the country towards the desired goals and visions.

Returning to the present challenge, the team required for the total innovation process includes the thinkers and discoverers in academia, the doers and creators in both big and small industries and in the national laboratories, and the users and adapters in society as a whole as represented by the various arms and agencies of government and other

organizations. These are the various key institutional partners in the innovation process for new technologies, component products, systems, and services.

CRITICAL SOCIETAL GOALS AS WELL AS CRITICAL ENABLING TECHNOLOGIES

Without common agreement as to the broad, national goals, these various elements will tend to head off in various directions, thereby dissipating much of the energy and resources that might have been oriented towards achieving these goals. But once consensus has been reached on these goals and they have been clearly articulated and disseminated, the whole innovation process involving the techno-industrial complex, can more easily get aligned towards achieving these goals and start to operate more efficiently.

Government must clearly perform the central role of bringing the various parties together to arrive at agreement on realistic visions and practical goals towards achieving those visions. *The government needs to be defining critical technology-intensive societal goals in much the same spirit as it has been identifying critical technologies. In other words, the societal systems applications pull has to be agreed upon and articulated just as much as the critical technologies push.* And working with industry and academia, the government needs to be developing long-term technological route-maps aimed at achieving the systems goals, and the means for tracking progress towards these goals. Given such route maps, the technology pushes at the R/D end of the innovation process are more likely to lead to components which fit into a system which, at the other end, meets society's needs; more so than does the present approach which perhaps places too much reliance on trickle-down from technology push and "hoping for the best" that the vagaries of the marketplace and Darwinian selection will eventually lead to improvement in the overall technological fabric of the nation. But the latter approach requires the luxury of time and resources that international competition generally does not allow.

Fortunately, we see increasing signs that government is moving in the direction of increasing and ongoing dialogs with the technical communities in industry as well as in academia. In the telecommunications infrastructure arena, for example, we have Congressional Hearings such as the present one; we have bills that relate to advancing the telecommunications networks by focusing on meeting the needs of the research community for high speed data networking and anticipating that these same networks will make a significant contribution to the nation's educational systems; we have many of these activities being shepherded under the Administration's High Performance Computing and Communications Initiative; under the Federal Coordinating Council for Science, Engineering, and Technology there is increasingly close coordination between the various government agencies regarding their common needs and interests in an advanced communications infrastructure; the Department of Commerce through its National Telecommunications and Information Administration recently issued a vision of the nation's future telecommunications infrastructure; and the Federal Communications Commission is wrestling with several major, highly techno-business issues that relate to the kinds of telecommunications networks and services that will become available to the public, and the performance and reliability of these networks and services, this latter being an area in which my own company Bellcore is taking a leading role, working with the FCC. In all of these planning activities there is now increasing participation by industrial representatives, practitioners, and technical experts. If the goals are to be realistic and practicable, such

involvement by industry is vital as well as welcome; it should be encouraged broadly and not hampered by any short-sighted restrictions on the one hand or unduly influenced by any particular groups on the other.

Clearly, the political process helps define the vision of what kind of a society the country aims to be, though nowadays this cannot be done in isolation since the influences brought about by global interdependence are greater than ever. Within this vision are the various system-level objectives such as, for the field with which I am most familiar, the objective of a first class, nationwide, telecommunications and information networking infrastructure that will enable all people to share fully in the benefits of the Information Age and the operations of all businesses to perform most efficiently and competitively. More specifically this objective might require setting the goal, for example, of a reliable, broadband, user-friendly service capability, at acceptable cost, to nearly every home and business by some date in the early part of the next century.

I feel that fundamentally, *many of the necessary mechanisms for establishing critical societal goals and related critical enabling technologies are already in place in the federal government.* Particularly central and relevant in this regard appear to be the Office of Science and Technology Policy on the one hand, and the Federal Coordinating Council on Science, Engineering and Technology on the other. I believe that many of the very important functions carried out by these bodies could be strengthened and made even more effective by increased participation by experienced industrial personnel. I believe that increased, purposeful industrial participation could significantly expedite the development of realistic route-maps outlining the ways towards achieving societal goals and the roles of the various parties that need to be involved.

FUNDING and INCENTIVES FOR R and D

Reaching consensus on goals does not necessarily mean that government then has to foot the total R and D bill, or even a large part of it, for getting there. At times, some federal 'seed funding' may be appropriate, but given some confidence as to where the country is heading, and given some assurance that if they work towards meeting the goals, the systems and service providers will be able to participate in the ensuing market, then the private sector will be all the more encouraged to make the necessary investments and to support the necessary R and D. After all, *there is no greater incentive to a business than its belief that it has an equitable chance to compete for or participate in any market that results from its own efforts and that it will be able to reap a fair return on its outlays on research and development.* Conversely, to the extent that these incentives and safeguards are not present, so the reliance on federal funds for the medium-to longer-term research and development, and thereby the burden on the taxpayers, are likely to increase.

In the past, the major information age infrastructure industries, including telecommunications and computers, generally had sufficient internal resources to support their own research and development. But with the present trends in the marketplace it is quite possible that this situation will not continue. Thus, federal attention to identifying the societal pulls for complex systems (as distinct from component products) has to be accompanied by actions that will help the industrial sector, together with its sources of 'patient' capital, move towards such objectives. *In this regard, a major incentive that the Defense Department can use is federal procurement; the extent to which such a technique can*

be adapted to the commercial sector by federal and state governments may be worth serious attention.

Secondly, other factors that tend to limit industry's ability to support the necessary research and development aimed at improvements in the communications infrastructure are the legal and regulatory forces that lead to debilitating fragmentation of services and industry units into sizes less than the critical masses required to support the necessary R and D individually on the one hand, and to amass the capital required for *widespread* deployment of the technologies and services on the other. Further, undue fragmentation introduces increased costs because of the increased number of interfaces that have to be coordinated. *The opportunity to aggregate various types of communications services on to the underlying network, or network of networks structure can go a long way towards making the upgrading of the infrastructure economically viable by achieving desirable economies of scale and/or scope.*

A third mechanism to encourage industry to invest more in R and D is by providing tax incentives. Because of the well-known mismatches between the time horizons of the financial community on the one hand and of R and D on the other, investing in medium-to-longer term research is perhaps one of the few areas where government intervention in the workings of the commercial market place not only appears to be warranted, it may even be necessary. *Providing tax relief to those companies that invest in R and D versus those that do not could be operated in a zero-sum mode so that it would not impose any additional burdens on the taxpayer.*

Fourthly, it is worth noting the irony that while the federal government is funding R and D aimed in part at upgrading the communications and information networking infrastructure of this country, particularly through such projects as the National Research and Education Network, at the same time a Bill is being considered that would make permanent, among other things the restrictions of the Modified Final Judgement on the Regional Bell Operating Companies that cast a chill on the ability of these companies to do the same by transferring their own relevant technology and design ideas to manufacturers or introduce information services, fruits of R and D abilities they fund at Bellcore.

Though these Hearings are focused on how the federal funds for R and D should best be allocated and spent to achieve societal goals, so far in this testimony I have addressed mainly ways in which *massive* new dependence of industry on government for the support of R and D in the telecommunications industry could be avoided. I believe that much can be done by attention to streamlining the total innovation process and by taking advantage of the normal business forces that drive industry. In particular, I have stressed techniques for aligning the 'output' end of industry with societal goals. By implication, this works back upstream in industry, causing it to optimize how to spend its resources on internal R and D. Nevertheless, there can still be a significant gap between the research being performed in some of the universities and national laboratories on the one hand and that in industry on the other. Again, just as industry has to be aligned with society's needs, there is a need or opportunity for some of the research being carried out in universities or in the national laboratories to be aligned with industry's needs and to eliminate the technology transfer gaps between them.

COUPLING UNIVERSITIES and NATIONAL LABORATORIES WITH INDUSTRY

One of the most effective ways for the government to ensure better coupling between industrial research and federally supported research at the universities and the national laboratories is for the government to support joint proposals, programs, and other collaborative activities. Many programs and projects of this sort exist already but I believe many could be made more effective if some federal funds for the universities or national laboratories were funneled through the industrial laboratory, with the latter devoting matching resources and taking on a role and accountability akin to that of a prime contractor. This is simply applying well-established and familiar business practices to some of the applied research and exploratory development activities. While there must always be ample support for the 'let 10,000 flowers bloom' approach for basic research and the upper reaches of applied research, funneling some funds via the industrial laboratories would certainly help to align the allocation of federal funds and orient more research and technology transfer activities in the universities and national laboratories with societal goals. It is to be recognized, however, that for this approach to be most effective, there has to be mutual respect at the working level, between the scientists and engineers in the various collaborating institutions. At the research phase, technology transfer relies very heavily on the personal 'chemistry' between the participants and respect for each other's intellectual capabilities. It is difficult to achieve even in autonomous companies let alone in multi-party collaborations. A heavily bureaucratic and impersonal process, therefore, has to be avoided as much as possible when involving federal support if the programs are to have maximum chance of success.

These last remarks are also at the heart of whether research consortia are successful or not. In principle, research consortia offer the opportunity for each of the participants, and the government where federal funds are involved, to get maximum 'bang for the buck' - by sharing costs and scarce expertise. They can be particularly well suited for addressing generic technologies and systems, standards-related questions and problems, and for bringing together all the participants needed for achieving major technological objectives which none of the participants have the resources, the ability, the structure, or the opportunity to achieve on their own. For cost sharing, for standards-related, and/or for major multi-party and multi-sector projects, research consortia can be a particularly cost-effective way of applying federal funds, a practice that several of our major foreign competitors have employed for quite some time. Furthermore, because of the multiple participants, various paths to impact in the marketplace for the federal funds usually exist, thereby increasing the chances of achieving payoff.

In essence, research consortia embracing industrial affiliates have existed for many years at the university research level. What is now needed is for the principle to be extended more boldly into the applied research and exploratory development phases involving industries with some of the national laboratories as well as with the universities.

INTERNATIONAL BENCHMARKING

Finally, there is the question of benchmarking. In dealing with societal goals it is natural for the country to benchmark itself against its international competitors. When one is clearly in the lead, one gets complacent about benchmarking against would-be competitors. But this is not always the case now for this country.

Again, focusing on the country's communications infrastructure, direct international comparisons between the relative levels and rates of progress are quite easy to make and they help in estat'ishing what this country's goals and timetables have to be if it is to remain competitive. These international benchmarkings can be, and often are, carried out on an ongoing basis by federal agencies, by individual industries, and by various other organizations. They should be part of the ongoing dialogs between government, industry and academia concerned with identifying societal goals and timetables, tracking progress towards them, and recommending mid-course corrections as appropriate.

Mr. BOUCHER. Thank you, very much.
Dr. Nagel?

STATEMENT OF DAVID C. NAGEL, SENIOR VICE PRESIDENT, ADVANCED TECHNOLOGY, APPLE COMPUTER, INC., CUPERTINO, CALIFORNIA

Dr. NAGEL. Thank you, Mr. Chairman. I'm honored to appear before the subcommittee and offer our views on the important topic of Federal R&D in the private sector.

Like other members of this panel, ones before, I appear with a mixed background, having worked in NASA for 17 years prior to going to Apple, and part under Dr. Frosch's able tenure as the Administrator. Although I am appearing for Apple, I will draw heavily on research and analysis done by members of the Computer Systems Policy Project, which is an affiliation of the chief executives of the 13 leading American computer companies.

In 1991 CSPP companies had worldwide revenues in excess of $140 billion, 60 percent of which was derived from outside North America. Perhaps more than any other industry in the United States, computer systems producers on the high- technology industry of which they are a part are highly integrated in the global market system. There's quite possibly no other sector in the U.S. economy that contributes so much to, and depends so heavily upon, international markets for its domestic as well as its international success.

The rapid pace of technological advancements and the computer industry's success in domestic and global markets makes it among the most fiercely competitive of all U.S. industries. In this highly competitive environment, the speed with which any given company can bring a new product to market increasingly determines the success or failure of our multi- million dollar investments in the maintenance for loss of thousands of jobs.

Typically, companies that manufacture computer systems derive almost half their revenue from products that did not exist two years earlier. As an extreme case in point, Apple, in 1991, derived almost 85 percent of its revenues from new products introduced in that fiscal year. These incredibly short product life cycles demand that the computer industry continuously harvest new products from innovative technologies.

The computer industry, along with the semiconductor industry, invests heavily in R&D. More than 24 percent of all industrial R&D spending in the U.S. is spent currently by these companies. According to the June 29, 1992 issue of Fortune magazine, six CSPP companies currently account for over 13 percent of all the exports generated by the country's top 50 exporters. More than 90 percent of these companies' R&D activities are conducted in the United States.

CSPP companies spend over $2.25 million per year to educate and train those they employ and to reach out to future generations of employees. Since the mid-1980s, more than 60 percent of the Government's R&D spending has been devoted to defense research. Historically, the split in U.S. Government spending between defense and non-defense research has been about 50 percent.

It clearly is the time to begin shifting back to the historical balance, or perhaps even beyond. And it seems also clear that the Government and industry should work together to increase the Nation's return on the Federal R&D investment. For example, while 24 percent of private industry spending was devoted to computer-related R&D in 1991, the U.S. Government allocated only 2 percent of its R&D budget to computer-related R&D. Our major competitors globally maintained a much better balance, we believe, between public and private computer and communication industry investments.

The CSPP is developing a set of recommendations designed to help improve national economic performance. We believe the Government and industry should work together to increase the allocation of funds to commercially relevant technologies, to improve the Federal R&D budget review mechanisms and industry involvement, and improve Government incentives for U.S. R&D.

The CSPP strongly supports basic research and the acquisition of basic knowledge and understanding. In addition, we believe the Federal Government should work with industry to reallocate, over the next four years, between $5 to $10 billion per year of its total R&D budget to support the development of pre-competitive generic technologies.

The CSPP has applauded the recent high-performance computing in communications initiative as a significant and critical undertaking by the Federal Government in this direction. We have offered specific recommendations for strengthening the initiative and for increasing the focus of the program to better bring the benefits of the research and technology developed to individual Americans and to U.S. industry.

We have suggested, for example, that the HPCC be enhanced and expanded to provide a foundation for an information and communications infrastructure of the future and more quickly bring the benefits of the technology to individual Americans in areas such as health care, education, life-long learning, and manufacturing, in addition to basic science and engineering. We believe that HPCC and future programs like it can plan an important role by providing a framework of challenging national goals, goals which can catalyze focus and direct the individual efforts both of Government and industrial R&D activities.

In a 1990 article published in the McKinsey Quarterly, the commercialization practices of the most successful companies were compared and contrasted with those of poor performers. The best companies view commercialization as a highly-disciplined system, establish it as a high priority, set measurable goals for ongoing improvement, develop the necessary organizational skills to accomplish it, and encourage managers to take aggressive action, and they bring their products to market in less than half the time of the poor performers. The development of superior commercialization or technology transfer skills, then, is viewed as among the most important competitive challenge that a manager faces in the best companies.

I believe a similar set of principles could be brought to bear to improve the return on the Federal R&D investment. Although support for basic research should remain among the top priority of

Federal R&D managers, for those programs with the greatest immediate potential for commercialization, the transfer technology from Government to industry should be given a much greater emphasis and attention than is typically the case for federally funded research today. In many cases, legal barriers impede this transfer. The CSPP has recently negotiated with the Department of Energy a model cooperative research and development agreement, or CRADA, which goes a long way to removing some of these barriers, at least ones that are significant to the computer industry.

Finally, the best method for transferring technology lies in linking those who perform the research and develop the enabling technologies with those who convert these technologies into products. Better methods must be found to encourage the interplay of scientists and engineers in universities and the national laboratories, with engineers in companies attempting to harvest these results.

The Federal Government can and must play an increasing role in the scientific and technological health of America. If it does not develop more effective policies and programs for doing so, the U.S. will lose more ground to aggressive, increasingly competitive foreign economies. Apple and the other members of the CSPP have demonstrated both the willingness and ability to work closely with the Federal Government to implement the required changes.

Thank you.

[The prepared statement of Dr. Nagel follows:]

Hearing on Renewing U.S. Science Policy:
Private Sector Views

Committee on Science, Space, and Technology
Subcommittee on Science

U.S. House of Representatives

September 24, 1992

Statement of David C. Nagel, Ph.D.
Senior Vice President, Advanced Technology
Apple Computer, Inc.

Mr. Chairman and Members of the Subcommittee:

On behalf of Apple Computer, I am honored to appear before this Subcommittee to offer our views on the important topic of the relationship of Federal R&D activities to the private sector. Although I appear for Apple, I will draw heavily on research and analysis done by the members of the Computer Systems Policy Project (the CSPP), an affiliation of the chief executives of thirteen leading American computer companies.

In 1991, CSPP companies had worldwide revenue in excess of $140 billion, 60% of which was derived from outside North America. Perhaps more than any other industry in the United States, computer systems producers, and the high technology industry of which they are a part, are highly integrated into the global market system. There is quite possibly no other sector of the U.S. economy that contributes so much to, and depends so heavily upon, international markets for its domestic as well as its international success.

The rapid pace of technological advancements and the computer industry's success in domestic and global markets makes it among the most fiercely competitive of U.S. industries. In this highly competitive environment, the speed with which

any given company can bring a new product to the market increasingly determines the success or failure of multi-million dollar investments and the maintenance or loss of thousands of jobs. Typically, companies that manufacture computer systems derive half their revenue from products that did not exist two years earlier. As a case in point, Apple in 1991 derived almost 85% of its revenues from products introduced in that fiscal year. These incredibly short product life cycles demand that the computer industry continuously develop new products based on innovative technologies.

The synergy between investment in R&D and the success of high technology industries is widely recognized by our international competitors. Much of the competition the U.S. computer industry faces from its foreign competitors comes from the degree of support foreign governments provide their domestic industries. This support typically includes governmental commitments to setting national technology priorities and identifying technologies of strategic importance to the economic well-being of the country in addition to direct financial support.

Clearly, the primary responsibility for meeting the challenges posed by the current domestic and international environment rests with each company. In response to a highly competitive global market, American computer companies: (1) invest steadily and substantially in R&D; (2) focus on commercialization; (3) emphasize quality; (4) compete enthusiastically in the most competitive and rapidly growing foreign markets; and (5) continually train and educate their work force.

The computer industry along with the semiconductor industry invests heavily in R&D; more than 24% of all industrial R&D spending in the U.S. is spent by these companies. According to the June 29, 1992 issue of *Fortune Magazine*, six CSPP companies currently account for over 13% of all exports generated by the country's top 50 exporters. More than 90% of these companies' R&D activities

are conducted in the United States. CSPP companies spend over $2.24 bill on per year to educate and train those they employ and to reach out to future generations of employees.

While the primary burden for competing successfully rests with industry, the federal government has a clear role to play. In 1991, total U.S. R&D spending, both public and private, was $151 billion, of which $66 billion, or slightly less than one-half, was expended by the federal government. This latter sum represents more than that of all of our major competitors' governments combined. Despite this fact, there is a clear need to re-focus federal R&D spending to better reflect new global realities and to realize a better return on our investments.

Since the mid-1980's, more than 60% of the government's R&D spending has been devoted to defense research. Historically, the split in U.S. government spending between defense and non-defense research was 50%. It clearly is the time to begin shifting back to the historical balance, or perhaps even beyond. And, it seems also clear that the government and industry should work together to increase the nation's return on the federal R&D investment. For example, while 24% of private industry spending was devoted to computer-related R&D in 1991, the U.S. government allocated only 2% of its R&D budget to computer-related R&D. Our major competitors maintained a greater balance between public and private computer and communication industry investments.

The CSPP is developing a set of recommendations designed to help improve national economic performance. CSPP believes the government and industry should work together to: (1) Increase the allocation of funds to commercially relevant technologies; (2) Improve federal R&D budget review mechanisms and increase industry involvement; and (3) Improve government incentives for U.S. R&D.

The CSPP strongly supports basic research. In addition, we believe that the federal government should work with industry to reallocate, over the next four years, $5-$10 billion per year of its total R&D budget to support development of pre-competitive, generic technologies. The CSPP has applauded the recent High Performance Computing and Communications (HPCC) initiative as a significant and critical undertaking by the federal government in this direction. We have offered specific recommendations for strengthening this initiative and for increasing the focus of the program to better bring the benefits of the research and technology development to individual Americans and to the U.S. industry.

The CSPP, for example, has suggested that the HPCC be enhanced and expanded to provide the foundation for an information and communications infrastructure of the future and to bring the benefits of the HPCC technology to individual Americans in areas such as health care, education, lifelong learning, and manufacturing in addition to science and engineering. The CSPP believes that the HPCC, and future programs like it, can play an important role by providing a framework of challenging national goals, goals which can catalyze, focus, and direct the individual efforts of government and industrial R&D activities.

To examine how government and industry might work more effectively to achieve these goals and to maintain and enhance the health of American industry and our economy, it may be instructive to examine briefly successful practices for commercialization of basic and applied research and technology development.

In a 1990 article published in *The McKinsey Quarterly*, the technical journal of an international consulting company with a long history of working with the high technology industry, the commercialization practices of the most successful companies were compared and contrasted with those of poor performers. The best companies: View commercialization as a highly-disciplined system; Establish

it as a top priority; set measurable goals for ongoing improvement; Develop the necessary organizational skills; Encourage managers to take aggressive action; And bring their products to market in less than half the time of the poor performers. The development of superior commercialization skills, then, are viewed as among the most important competitive challenges managers face.

I believe that a similar set of principles could be brought to bear to improve the return on the federal R&D investment. Although support for basic research should remain among the top priorities of federal R&D managers, for those programs with the greatest immediate potential for commercialization, the transfer of technology from government to industry should be given a much greater emphasis and attention than is typically the case for federally funded research today.

In many cases, legal barriers impede this transfer. The CSPP has recently negotiated with the Department of Energy a model Cooperative Research and Development Agreement, or CRADA, which goes a long way toward removing some of these barriers.

Finally, the best method for transferring technology lies in linking those who perform the research and develop the enabling technologies with those who convert these technologies into products. Better methods must be found to encourage the interplay of scientists and engineers in universities and the national laboratories with companies attempting to harvest the results.

The federal government can - and must - play an increasing role in the scientific and technological health of America. If it does not develop more effective policies and programs for doing so effectively, the U.S. will lose more ground to aggressive and increasingly competitive foreign economies. Apple, and the other companies of the CSPP, have demonstrated both a willingness and the ability to

work closely with the federal government to implement the required changes. The result can be a more competitive and vital America.

Thank you. I would be happy to answer any questions that you may have.

Mr. BOUCHER. Thank you, very much, Dr. Nagel.

The subcommittee extends its thanks to each of the four witnesses for their testimony this morning.

Dr. Nagel, let me simply say that as the subcommittee that initiated the high-performance computing legislation and took the first steps toward enactment in the House last year, we are also very interested in oversight of that initiative, and if you have some specific recommendations for ways that we can improve that program, we would very much welcome your supplying us with that, and would look forward to receiving those suggestions.

Let me begin this series of questions with Dr. Bement, who has suggested that we develop closer ties between the performers and the users of research. What specific recommendations do you have for us on ways that we can accomplish that?

Dr. BEMENT. Congressman Boucher, I feel that in some of these cross-cut initiatives, we need to be improving the perception and credibility of these initiative within the private sector in the sense that they should be more national programs than Federal programs. There needs to be private sector leadership involved rather than just Government leadership involved in the planning, the implementation, and the execution of the programs.

In that sense, Government should bring more to the table than just money, and industry should bring more to the table than just advice and requirements. There really does need to be a partnership throughout.

I think also, in some instances, because of the reluctance of some agencies to fully embrace this cross- cutting process, because it is threatening in some established programs—where appropriate, it would be helpful to have authorization bills that back up the cross-cut—to get a partnership between OSTP and the Congress, as well as with OMB. Otherwise, the programs tend to be very fragmented, and they have to live within the circles of each of their agencies, which is sometimes very difficult.

So I think this is still a fragile mechanism, but it's off to a reasonably good start, and I think it does pave the way to the future in getting a much better partnership between the private sector and Government.

Mr. BOUCHER. Well, that's a very thoughtful suggestion, and it addresses very squarely what I think is one of the fundamental questions we raise as a subcommittee as we start this inquiry, and that is, how really—should the presidential cross-cuts—the FCCSET initiatives be established? How should they be selected? And to what extent should the private sector be called on in order to advise that process, and through what mechanism should the private sector be advising that process? And then extending that series of questions, how can the Congress become more closely involved with that process as well?

There have been five initiatives selected. They have been selected entirely by the Executive Branch. There's been some informal consultation with some Members of Congress, but there has never been a formal process established by which policy-makers in both branches participate in a collaborative way in deciding what these major targets are going to be. So far, that's been done entirely by the executive.

I hear you recommending that, at least through authorization bills, we ought to be participating perhaps on equal terms, or at least in a supportive way, with the Administration in that regard, and that's certainly food for thought, and we will take that to heart.

Dr. Frosch, would you like to comment on that inquiry?

Dr. FROSCH. I would like to address that question, in fact, with a specific. The point I made about dialogue—I think my colleagues would agree with—it is not adequate to develop a requirement—or a proposal, and to put it out for comment, and then get a kind of arms length comment, and not really ever discuss the matter. There was a period earlier in which part of the OSTP mechanism involved the incorporation into its staff of fellows who came from industrial organizations, not from specific companies, but for example, from the Industrial Research Institute, and were designated as outsiders who operated inside the staff.

That mechanism has been more or less destroyed by a legal opinion which stated that, under the conflict of interest regulations, it was impossible to do that. Now, none of us are very interested in having conflict of interest problems, but it seems to me that someone whose origin and background is clearly known and is present in the staff is not likely to be able to operate with a very concealed conflict of interest.

And I would argue that the benefits of that kind of direct contact and representation in the discussions, even though it would be appropriate to exclude such outsiders from final decision-making, might be extremely valuable, and it would be useful to find some way in which that can be done. That is a specific instance, but I think it is important to do this in a way that involves people from the various sectors talking together rather intensively as a way of formulating both what the important strategic programs will be and deciding how to interact in technology transfer.

Mr. BOUCHER. How recent was that legal opinion to which you referred?

Dr. FROSCH. Well, I—my recollection is that it's in the course of the past year, because certainly in the Board of the Industrial Research Institute, which I was on for several years, we struggled very hard to find a way to cope with what seemed to be a rather arbitrary ruling. It was not clear to us, by the way, whether that was a generally agreed ruling among legal counsel, whether there was court precedent. As far as we could tell, it was a local ruling.

Mr. BOUCHER. Well, I'm glad you pointed that out to us. Obviously, we need to structure ways that the private sector can have a major advisory role as these presidential initiatives are selected, and to the extent that we need to modify other requirements or take down barriers, we certainly need to consider doing that, and that's a helpful recommendation.

Do you have any suggestions today on ways that that structure can be made better and the lines of communication clearer so that the private sectors views and opinions, with regard to what your needs are, are taken into account? Dr. Bement?

Dr. BEMENT. Well, I have two suggestions. One is that within the FCCSET process, in the various committees that are planning—have planning oversight of these new cross-cutting initiatives, they

do have a number of working subgroups that break it down into rather specific elements. It seems to me possible that industry could marshall working groups also that parallel these subgroups within FCCSET in order to get dialogue going in the planning and the execution of the program.

Mr. BOUCHER. Is that something that potentially we should require by statute, or is that something that should operate on a less formal basis?

Dr. BEMENT. I think it's beginning to—it's beginning to emerge, so I would certainly monitor it and see how well it comes before requiring it. The other thing is that we now have established the Critical Technologies Institute at Rand to provide input to OSTP, and it occurs to me that part of their role ought to be planning and assessment to the extent that, again, they can bring together committees from industry to participate in program assessment periodically as the programs emerge. That would be also another helpful mechanism.

Mr. BOUCHER. Okay. Dr. Nagel?

Dr. NAGEL. I'd like to echo comments of Dr. Frosch. We have found, in our experience with the high-performance computing cross-cut, that the ability of the private sector to participate fully in the advisory process is—has been compromised by, presumably, the same kinds of rulings and conflict of interest laws as in other areas. It is very important—it's essential that, in planning these sorts of programs, that we be involved early and actively.

I think another point that I would make is that there are many sectors within the private sector, and, of course, each of these, I think, generally truly believes in their importance and role in the national priorities and goals. What we do need, I believe, for national policy is informed judgment on what are the appropriate priorities, and this can really only be done through policy research.

Another role I think that the Federal Government could very productively play in developing a—factor data base under which national goals could be formulated. That's something that's difficult for industries to do—certainly difficult for any given industry to do in a dispassionate or objective way.

Mr. BOUCHER. Dr. Chynoweth, would you care to comment?

Dr. CHYNOWETH. Well, I'm struck by the—I'm struck by the violent agreement, using Volpe's phrase—the violent agreement amongst all four of us of the need to have industry participate in these planning and coordinating and other discussions and debates as an equal partner, not as a second- class citizen. I think it's a tremendously important factor in getting the whole innovation team working together as a team of equals, and—

Mr. BOUCHER. What—let me ask you on that—on that point, if the telephone industry was sufficiently consulted at the time that the cross-cut on high-performance computing was constructed—obviously, communications lies at the core of that initiative—do you feed that your industry was sufficiently brought into the process of planning for that and designing the cross-cut?

Dr. CHYNOWETH. I'm not aware of the industry being brought in in the same way that the linkages were formed with or by the computer industry. But, nevertheless, it's clear that they share a common need and goal and desire to see that this country has a

first-rate communications infrastructure, and I think it's vital, going on, that the communications companies, both the local and the long distance companies— the public carriers, are really brought into the picture to help go forward together here and plan this country's first- rate infrastructure.

Mr. BOUCHER. Let me ask this question of each of the panel members. Do we start with basic agreement that the FCCSET process of selecting broad-based interagency initiatives is the right way to begin to target the needs of the private sector in terms of developing critical technologies that are usable across a number of industries— do we agree that this is a helpful process? I see Dr. Bement saying yes. Any doubters on that front, or is that pretty much a unanimous view?

Dr. CHYNOWETH. Well, I think it's a—speaking up again, I felt that we were all in very much agreement on the the emerging role of the OSTP, and the FCCSET mechanisms— the mechanisms are in place and need to be nurtured, and I'm sure they will be going forward under the watchful eye of this committee and other agencies.

Mr. BOUCHER. One additional question that I have, and then I'll yield to my colleague—I think with regard to mission agencies and the various Government-funded research and development roles that they are carrying out, the process of evaluating the results of that research is somewhat easier than it is with regard to basic research. We don't really have very good mechanisms for determining whether our investment in basic research pay off. We don't have evaluation mechanisms that are reliable today or, in fact, any that are formalized. Do you have any recommendations for us as to how we might better judge the results of our investment in basic research?

Dr. Chynoweth?

Dr. CHYNOWETH. I think we have the same sort of problem in industry. How do we evaluate the value of our own basic research, or the research that we look to elsewhere? What we seem to fall back on more and more these days is customer satisfaction. Is the user satisfied? What proportion of that research is being taken up by the user? I think it really comes down to that as one of the best measures of the value of the research—what percentage of it is being taken up by the users.

Mr. BOUCHER. Okay. Dr. Frosch?

Dr. FROSCH. I have two things that I have used to try to do such an evaluation. The defect in most attempts to evaluate basic research comes from two things: one, it attempts to do it in too much detail, to ask project by project; and two, mostly it has attempted to be prospective, which introduces a lot of speculation about what is going to happen.

If one does it on a historical basis and does it not for single projects, but for a body of basic research—body of research of any kind, then it is frequently possible to make some reasonable estimate as to the return on investment. We've been able to make a reasonable investment of the return on investment of our laboratory as a laboratory by comparing the value of successful outputs to the cost of the laboratory, and it has turned out that the leverage is extraordinarily high.

I believe one could do something like that for fairly- well structured portions of the basic research program. One would not, I think, be able to find out that a particular line of research had a particular return, but only that the body, for example, of materials research of a particular kind was or was not extremely valuable. One could not go back and thread- out particular lines very well, but I think it is possible to do something like that. It is not an easy endeavor, and it takes a considerable investment of people's time and energy to collect the data.

Mr. BOUCHER. Is this something we ought to be concerned about?

Dr. FROSCH. Oh, I think that it would be easy—it is easy to produce enough evidence of success in the actual effect upon industry and economics so that one could do something, but I would not, myself, encourage anyone to try to do a complete or precise job. It would be very expensive, and I think the results would probably not be worth the result.

Mr. BOUCHER. All right. Dr. Nagel?

Dr. NAGEL. One other comment, I think, is that something like this has to be done with a very long time constant.

Mr. BOUCHER. Yes.

Dr. NAGEL. If the same measures were applied that we apply in industry, I think inevitably we would lose a very important function of the Federal Government, and that is, patient investment and basic research—that's something that's—and the computer industry's become practically impossible to do as a practical matter.

Mr. BOUCHER. Well, it's an intriguing question and one we'll continue to ask, and your further thinking on the subject would be extremely welcome.

Mr. Packard?

Mr. PACKARD. Thank you, Mr. Chairman.

Dr. Bement, you indicated in your testimony that OSTP lacks the sufficient resources to properly set goals and to assess the programs to establish linkages with industry, et cetera. How do you respond to Mr. Ferguson's earlier testimony, and in expressing his concerns of an overcentralization of OSTP, how do you relate your testimony with that concern?

Dr. BEMENT. Well, I also would be concerned if it were done to a point where it became overcentralization of the total process of planning and executing research. What I'm not advocating is that we bypass the agencies and their ability to develop and implement their own programs; but rather a planning and coordination role, which is what I'm really talking about, and having adequate resources to carry out effective outreach to the private sector, and to carry out the various workshops around the country necessary to get the kind of input that we've been talking about.

I don't really feel that they have adequate staff or adequate resources to do that broader job. And as I would agree with my colleagues, I do believe that there should be flexibility, either under FACA, through special provisions, to allow for representatives from the private sector to play a direct role in that process.

Mr. PACKARD. I've been interested for some time in battery research, Dr. Frosch. The U.S. Advanced Battery Consortium that GM is participating in, how is that working? I'd like an update on it, if we may, relative to how the private sector and the Federal

resources have been leveraged through the Consortium, and what do you envision is the ultimate outcome of the cooperative venture, and how is it progressing?

Dr. FROSCH. Well, I think it's a pretty new venture, and I—in fact, I would say it's still struggling to get itself born and operating, and still working out some of the mechanisms and the problems. There are a number of administrative things that are still being untangled.

What we expect to have it do is to be able to pull together the knowledge and technological resources that are in the Federal Government and that are in the private—various parts of the private sector to attack the underlying problems of particular battery systems and bring some of them into real commercial use.

There are a number of proposed advanced batteries that are somewhere between laboratory curiosities and batteries that have been built and used for special purposes, but whose real manufacturing possibilities and limits are not really known, and the idea is that by pooling knowledge on these, we will be able to find out which of these have real commercial promise, and then leave it to the battery industry and the manufacturers to draw their own conclusions and do the work necessary to make them commercial products.

I will expect that it will be several years before I can give a real answer that says it's a crashing success or whatever. It's too soon to tell. That is even true of the CRADA process and the ATPs. We're getting our feet wet, we're beginning some of them, but these processes are a year or two old, and that is too short a time for us to have a real evaluation.

I'm afraid that we have to take seriously our words that you have to have a fairly long time horizon in this kind of work.

Mr. PACKARD. We'll follow it with interest, of course, because of the alternate fuels we need for alternate vehicles, et cetera, but certainly, it's of great importance, I think, to this committee.

Dr. Nagel, you stated in your testimony that the computer industry is one sector of the economy that contributes to and relies rather heavily on international marketplaces. Briefly, how will the North American Free Trade Agreement affect that process?

Dr. NAGEL. Well, we think that the NAFTA will have a beneficial effect on the computer industry by opening up the—even further the interplay, and global markets that underlie the success of the computer industry. So we believe NAFTA is a good idea in the industry, and, in fact, we would like to see relaxation of other regulations which currently impede the free interchange of parts and pieces that make up these systems across international lines.

This is a global industry now, and it's simply not possible to construct a computer system or, increasingly, even a communications system without relying on bits and pieces from all over the world.

Mr. PACKARD. I'll conclude there, Mr. Chairman, because of the time. Thank you, very much.

Mr. BOUCHER. Thank you, very much, Mr. Packard.

We've been joined by our New Mexico colleague, Mr. Schiff.

Mr. Schiff, would you care to make a comment or ask questions?

Mr. SCHIFF. I'm not going to ask questions, Mr. Chairman, because obviously I was delayed in arriving here, but I did want to

pick up all the statements of the panelists, because I'm interested in what they have to contribute, and I thank them for that, and I yield back.

Mr. BOUCHER. Thank you, Mr. Schiff.

I have a large number of additional questions which I'm going to defer and perhaps take up in less formal discussions with our distinguished panelists today as this inquiry continues.

On behalf of the subcommittee, I want to thank you very much for your enlightening comments and suggestions today and for the time you've taken to be with us, and we will continue to discuss these various matters with you as our inquiry continues.

The Subcommittee on Science stands adjourned.

[Whereupon, at 12:22 p.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

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