WGC 7

WYLDE GREEN COLLEGE.

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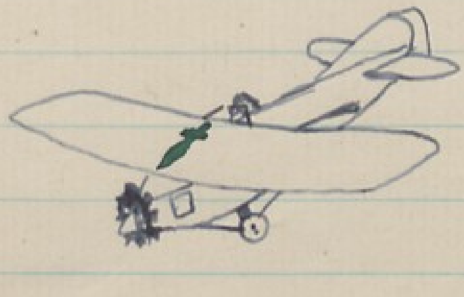
Plan

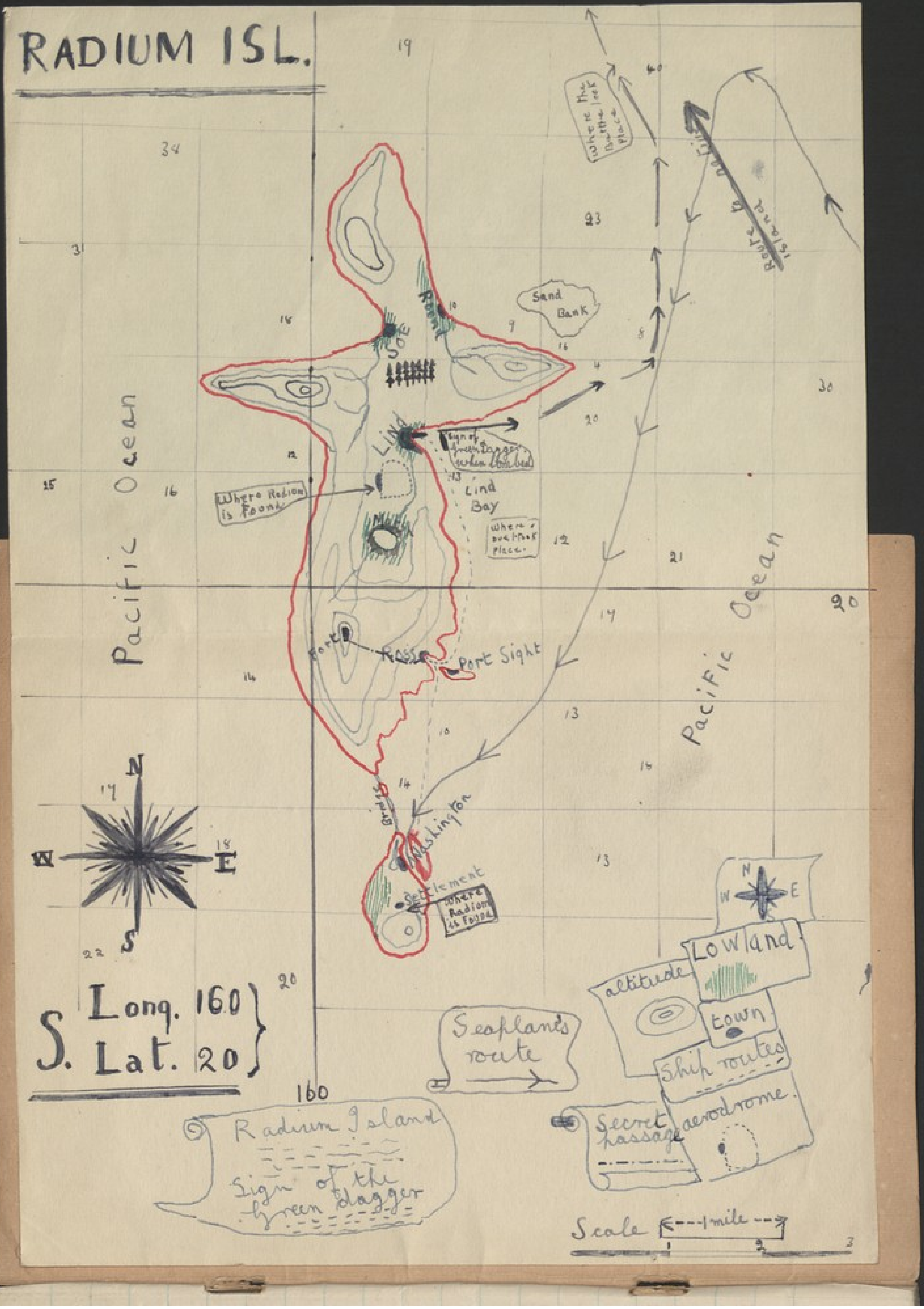
1928 (or before).

RADIUM ISLAND

By

Maurice H. F. Wilkins.




RADIUM ISL.
Pacific Ocean
Pacific Ocean
Sand Bank
Lind
Lind Bay
Where Radium is Found
Where Radium is Found
Settlement
Port Sight
N
S
W
E
S. Long. 160
Lat. 20
160
Seaplane's route
Radium Island
Sign of the green dagger
Low land
altitude
town
Ship routes
aerodrome
Secret passage
Scale 1 mile
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Contents

Chapter I

Capture - Discovery - and Escape

It was a dark night and the two men sitting in the corner of the pit shivered. They shivered because it was cold and also because they thought of the fearful fate to which they were doomed.

The two men were Hugh O'Brien and Ronald Crisp; they were found on this South Sea Island by natives, not cannibles, when looking for radium which they had heard was to be found there.

They were both middle aged men, O'Brien strong and resolute and Crisp not physically strong, but with great brains.

The pit which they were in was about six feet deep and was in the floor of a hut, the door of which was guarded by a brawny islander armed with spear and cudgel.

Crisp was sitting looking blankly at the wall, when all of a sudden he sprang up and grabbed O'Brien by the shoulder and made him look at a shinyng vein of carnotite which yields radium situated in the opposite wall!

They cut out the vein with a sharp stone and put it in their pockets. After talking for a while they retired and went to sleep.

The next day ~~in~~ was the "Feast of Drink" on which all the natives got drunk.

In the middle of the feast a drunken warrior came and changed places with the sentinel so he also might have his share of the "Drink."

The drunkard stood at the door for a few minutes and then fell to the ground in a swoon. As soon as the prisoners saw this they climbed ~~the~~ out of the pit stealthily and took the arms of the swooner and glided silently out of the village, saflly, as all the inhabitants were at the Feast.

Chapter II.

The Escpedition

Jack Furgisson was reading

hastily a pile of papers when the door of the room was opened and in walked a haggard looking man.

Jack was a well built young man of twenty-seven. He was muscular and was just six feet tall. His eyes were a grey-blue ~~c~~ colour and his skin was tanned by many a tropical summer sun.

The man who entered was none other than O'Brien.

Jack gave a shout of of ejaculation and bounded forth to meet the hand of the other.

"Where's Irish," he asked

"Paradise or Hades, more likely the latter," returned the other.

Then O'Brien explained how after escaping ~~t~~ they were picked up by a passing windjammer. On which Crisp caught fever and died but luckily he did not get it himself.

After much talk and a few months consideration, Jack bought a swift steam yacht and collected together his faithful crew of blacks.

They set out to the island under the guidence of O'Brien.

Without mishap one misty morning the lookout sighted an island in the position located by O'Brien.

It was decided to disembark at a still bay and soon had a small settlement called "Lind" founded.

Jack with a small party surveyed the island and made a map. It was found there was a small amount of carnotite found near a lake in the centre of the island. But it was in ~~the~~ great abundance on a small island south of the large one.

There were only a few natives on the island as it was found out later on it was ~~found out later that it was~~ sacred and the few natives were the peaceful priest and his family.

Other towns* founded on ~~the~~ Radium Island were Soe, Round, Ross, Washington, Port Sight foot, Settlement and a small place for ~~s~~ animal rearing by the side of the lake and by a level plain.

O'Brien found he must

* "towns" means camps or settlements.

have made a mistake about the location of the island, for this was not the one he was on before. But as there was much wealth on this island he did not trouble.

Chapter III.

The Fight

After the crew of another ship took partnership and settled on the island, a neighbouring pirate and ruler over the islanders wished to take possession of the island. He knew he would have to fight, so he got a lot of canoes and his own windjammer all manned with blacks and sailed for the island.

Lind the chief settlement was not fortified.

The pirate, "bronky Bones," asi he was called had sailed for Radium island and was going to Lind

O'Brien when he saw the swelling "Jolly Roger" on the mast was taken completely by suprise.

But before "The Sign of the Green Dagger," the name of the ship had time to fire and land her men, O'Brien had a 4·5 inch quick firing gun at work on the yelling savages who had landed.

The sagaves advanced slowly, yelling and screaming war and death cries, and hurling spears, darts, stones and bones including skulls at the tempory fortifications.

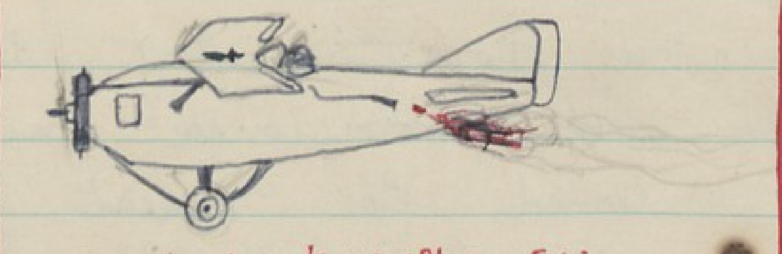
Jack had got the steam yacht out of harbour and with her two machine guns was hailing bullets into the mass of screaming blacks.

O'Brien was forced to retreat before the blacks warriors. He retreated to the fort, the well fortified and provisioned encampment where lived the priest.

Jack took the steam yacht and warned all the camps round the island.

The blacks and "Bonky Bones" followed O'Brien to the fort, and then there began a

great fight.
O'Brien and the chief amount of islanders would have been forced to surrender as the pirate, it was found by a few explosive bullets dropping into fort, had bought a little monoplane from an adventurer, who has had bad luck with it.



The adventurer's, monoplane of his own ma[illegible].

The aeroplane was out of order and very old and broken when he got it. But he reconstructed it and got it to work. He flew it up once after studying the controls; but the petrol ran out and he landed in the sea.

After being rescued he mended it and took it to pieces, and never used it again, till a passing merchant sold him some petrol.

Chapter IV

Escape

The fort was well protected and the makers, some learned race, had made a secret underground passage to a port, now called Ross, to stop the people, if besieged, from starving.

The native fort was in

runs before Jack had rebuilt it. He found the passage by chance, as the end was open. It was in good condition and had not fallen in.

O'Brein was thinking of escaping to Boss and being picked up by Jack in the steam yacht.

One dark night O'Brien departed, into the yawning cavern followed by most of the others. O'Brien went ahead holding a torch to light the way and also carrying an elephant gun.

All of a sudden there appeared a blaring light in front and a patting of feet was heard.

O'Brein looked round the bend and saw two enemy natives approaching, carrying a large shell.

He quickly fired a bullet straight at the exposed cap of the shell which explodfed bringing down earth on top of the natives.

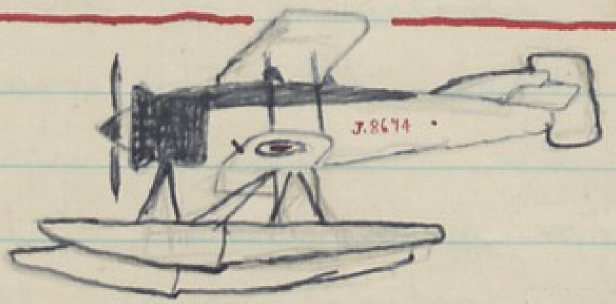
No one who was escaping was injured as the shell exploded round the other side of the corner.

The fugitives ran over the heap of earth, under which lay the two dead enemys, and got to Ross where they were taken on board by Jack.

After sailing round the island and picking up stray campers, the heavily laden yacht steamed South till it came to the small island where the radium was found at Washington. Jack was sitting on a veranda looking very thoughtful, when all of a sudden he stood erect and listened intently. then he dashed into the hut and brought out a small telescope and looked along the horizon.

After looking for a few seconds he ran down to the yacht and sent a message sizzling through the ether as follows:- .... Help ..... Turn round ... Lat. 20. Long 160 South .: Small island . South Big ... Signals .... Help!

It was a Gloster Goring naval seaplane, Jack had signalled to for help!



GLOSTER "GORING" SEAPLANE

Chapter V.

The Victory

The wireless operator mechanic, shouted the said message through the telephone to the pilot. Who felt a thrill of adventure as he pressed on the rudder ~~p~~ lever, and pulled the joy-stick slightly and the "Going" turned round banking much. The engine thundered round the bend and expoded towards Radium island!

He saw the smoke signals and landed on a smooth stretch of water in front of Washington, where every one was encamped.

O'Brien's natives had

seen ~~no~~ aeroplanes before and were not frightened or panic-stricken.

Jack went out in a canoe to the airmen who greeted him cordially and asked him if the seaplane might be ~~toed~~ towed to shelter.

Jack and O'Brien, with the airmen, pilot Wolsey and Hutton at lunch had a great talk of the "Old Country"

As the airmen munched dried meat they told them that they had bought the seaplane and were now touring the Southern Pacific

After lunch pilot Wolsey showed all the white men how to work the aeroplane; the name of which was "Umphum". It was newly filled with petrol and had an auxil-ary ten gallon tank. It had, like the Gloster Gamecock, a top speed of 150 miles per hour.

The airmen pitched a tent for the night, and slept well.

Next morning the seaplane went to observe what had happened at the fort. The mechanic saw that the natives had plundered the fort and were just awaken-ing in the tents of their fallen foes.

The seaplane carried one large bomb. They wanted to make it useful; so they turned round and circled over the "Sign of the Green Dagger" which was in Lind harbour. All of a sudden the ~~a~~ machine nose-dived and swooped down over the boat dropping the bomb amidships, and then went up with a roar.

Another roar was heard behind the seaplane and ~~the~~ Hutton turned round and saw the monoplane following and spurting out a stream of bullets.

Wolsey was a man of quick action so he throttled right back and the nose of the machine rose. He gained both height and distance for the seaplane was a faster machine than the monoplane.

The enemy pilot kept firing so Wolsey looped and swooped down on top of the other firing as he went.

The maxim gun of the enemy hailed bullets into the top plane of the attacker and Hutton observed a large rent in the fabric.

The seaplane flattened out and rose again only to see the monoplane dashing down on top firing at intervals. Zoom! Rrrr — rrrr — rrrr!

The petrol pipe of the seaplane got dented by a bullet and Wolsey was obliged to turn off petrol and glide for a few seconds and thenturn on the tap for the auxilary tank.

This gave time for the monoplane to rise again and now was dashing down on top of the seaplane firing as it came.

But one of the ~~e~~ aile~~b~~rons suddenly went limp and a long piece of control wire broke and curled round the rudder, as a whip curls round a bar.

As the wire broke a strut supporting the wing broke and the wing ~~fe~~ ~~glided~~ broke with a sickening crash and glided to the sea.

The mangled remains dropped into the sea like a

stone.
The people from the fort saw it come down and saw the seaplane land near and taxi up to the smoking wreckage.
Many of the natives went to O'Brien's side the rest following suit, as they must be on the side which had conquered the "Great Flying God."
Wolsey and Hutton saw that there was no use trying to find the remains of the enemy pilot; so they returned to Washington to get repaired.

Chapter VI

The Chase

The deceased pilot of the aeroplane was a white man of windjammer's crew; not the villainous captain.

"Cronky Bones" and the majority of the white crew were on shore when the boat was split in two by the bomb.

"Haul out a canoe, yer lazy bones!" the captain cried; the few remaining natives hauled down a canoe, a large swift one, and it splashed into the water.

The brawny natives

jumped into the rowing seats while the four white men sat in the rear, their fingers twitching on the triggers of their rifles.

One of the men gave a command and the oars hit the water, spray glistened in the sunlight for a few seconds, and the canoe sped out to sea.

"I think th' best thing is to get to our isle, and fort her up," said the captain.

"Its dashed risky, but we cant do much more, an' they would take us to some place where we'd 'ave to stay," ~~reply~~ replied another.

So, continued the conversation, some not liking the plan, others knowing nothing else could be done.

Wolsey and Hutton found that nothing serious had happened to the seaplane, except the dent in the petrol tank pipe.

This was easily remedied as another piece of piping could be put in.

As soon as the sea~~pl~~
1 plane was ready it flew out, accompanied by the steam yacht, to see what "Cronky Bones" was about.

From the aeroplane Hutton saw the remains of the windjammer sunk into the sand at the bottom of the harbour at Lind.

"No sign of life," said Hutton, "S'pose they'r hiding."

"I think — I see something on the horizon, like a canoe," replied Wolsey through the telephone.

"They might be escaping, I'll give chase," thought Wolsey.

He accelerated and was soon circling over the canoe

"They'r there all right!" exclaimed the two airmen.

Wolsey kept a medium height as he did not want to be hit by a rifle bullet.

"Let's go and tell Furgisson."

Jack soon heard the message and gave the order to "Step on the gas" and to continue straight on.

"They'r in sight!" shouted Jack as he loaded his rifle. "Tell 'em not to go so fast," he said to a native, "Get out of sight till I tell yer."

"You keep down," said a voice from the canoe. "Or I'll pot at yer."

A report from behind the canvas of the yacht and one paddler fell dead was the only answer.

"Alright," said a white

man in the canoe, and he shot a bullet through a port-hole. Another bullet followed and a cry was heard.

Suddenly a shower of ~~butte~~ machine gun bullets crashed into the canoe. Three white men and a paddler fell dead including "Cronky Bones."

But before the remaining white man was dead he shot all the bullets out of his gun and his comrades'.

One black was killed one wounded and Jack was hit in the leg.

The canoe began to sink, so a boat was sent out and the natives rescued.

Chapter VII

Finis.

Three days later the airmen bade farewell to the miners. For their service they were presented with a tiny phial of radium, which had been mined and extracted, by a maishine of Jack's which he had brought with him, from a large vein of ~~cartonite~~ carnotite

A fortnight after they departed, it was found that all the layer of carnotite was finished. Jack drilled down much farther but he only found a very thin layer which was not worth mining.

Jack thought the best plan was to return to England and tell some mining company about the find.

The natives, the crew of a boat which had come there, and most of the others were to stay there; till the steam yatcht returned.

The boat started out with the same crew, including O'Bren and Jack. The voyage was begun at the beginning of day.

As Jack stood looking at the island in the twilight suddenly before his eyes he saw the island south of the big one leap into the air, smoke and flames all round it.

"I'm mad!" exlaimed

Jack as he saw a huge wave of water coming towards them and heard a terrific teriffic roar, flashes all round him, swirling water, then everything was black!

Radium island nor the steam yacht were never heard of again as the whole island was at the top of a volcano!

THE END.

Savages
Cronky Bones

at age 12
left WGC ~~before 12~~
i.e. 1928
KES Jan 1929

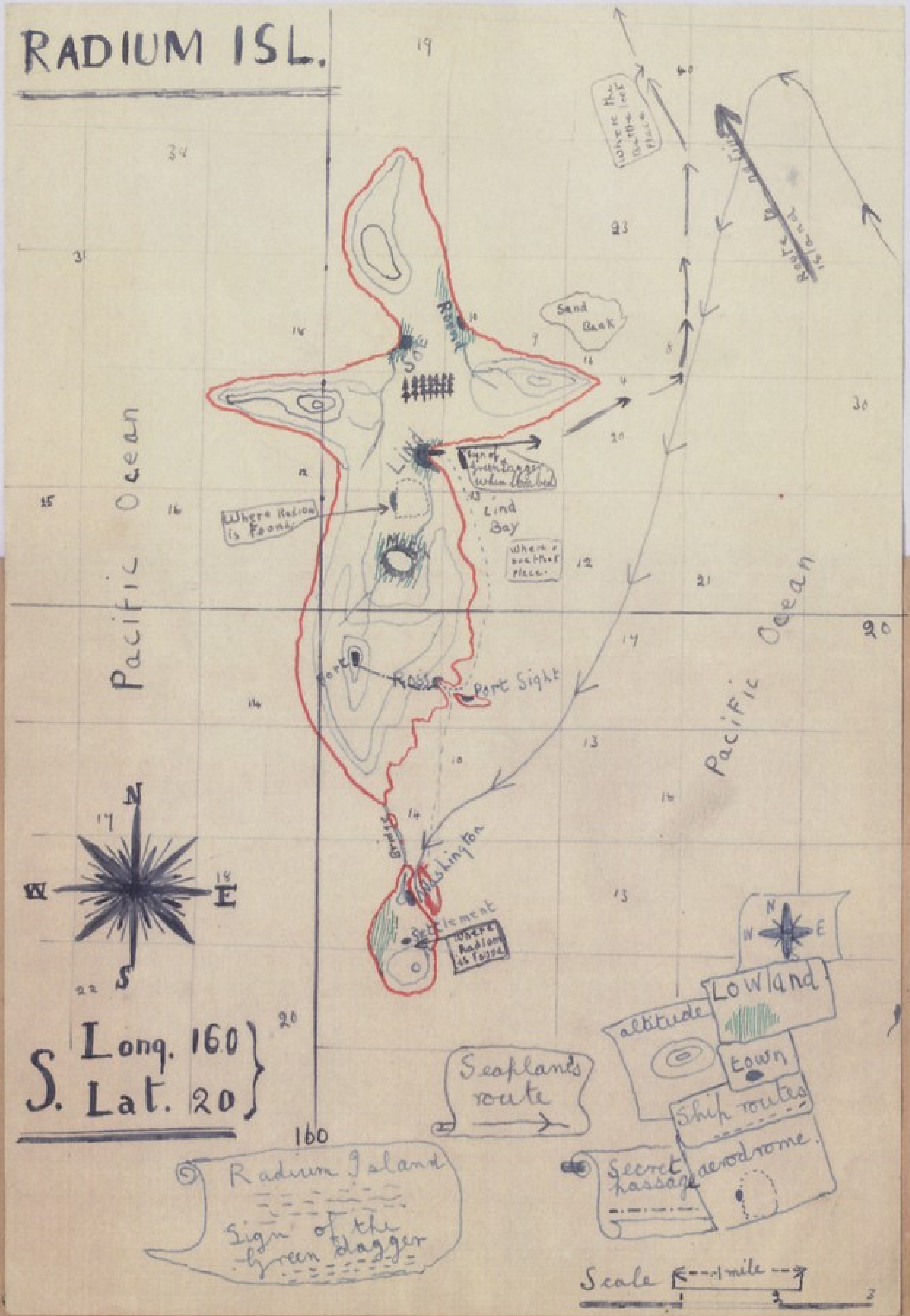
Towing Pacific with 1 large bomb

Technical details of aeroplanes
air battle
+ guns
+ shells

Good people & bad all die.

like N Z . memories

2 carnotite
5 Swift steam yatch.
8 4.5" quick firing gun at work
9 2 machine guns
12 Secret passage + elephant gun
10 old monoplane
13 fired at cap of shell
14 telescope Gloster Goring / Seaplane None
17 150 m p h. Gamecock
one big bomb
21 detailed air battle!
23 twitching fingers on trigger.
26 Sea battle
30 volcano explodes, all dead.



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~~How Fairies live & change~~. Fairiology. how fairies come & how they go -

It is not at all easy for grown ups ~~people~~ to find out about fairies in fact some ~~grown people know so little~~ ~~about fairies that they even~~ grownups even say fairies ~~and do not~~ then exist at all which shows how very very ~~ig~~ little these grown ups know about these things & how stupid ~~& ignor~~ shows children once more how stupid & silly grown ups can be ~~about~~ sometimes however, now & again we are lucky ~~to~~ to find out something new about fairies. Often these discoveries are made quite as a surprise when we least expect them sometimes they are little discoveries & other times they may tell us a lot. But we are always very ~~then~~ grateful for all our discoveries about fairies however small these discoveries are. We know so little about the fairy life & the fairy world we are grateful for all bits of news.

Growing down instead of Growing up

There is one ~~kind~~ of fairy which does not grow bigger but instead grows smaller. When people grow bigger they stop growing when they reach a certain size that is when they are grown ups if they grew bigger it would cause a lot of trouble because they wouldn't fit in houses & their feet would stick out of the bed. In the same way some of these fairies become grown down & stops growing down when they reach a certain size. The size they stop at is about the size of an egg thô not so fat. These fairies are often rather thin & slender when grown down. If these fairies grew down smaller they would be in danger of being mistaken for flies wasps

& beetles & might be eaten by rats. They are often chased by cats but defend themselves by pulling ~~the~~ cats whiskers or ~~his~~ tickling its ears. These fairies begin life very large indeed & spread out all over the place like a cloud or fog. They may be several miles long & often cause fogs in London. The cloud in the sky which looks like a cauliflower is ~~seen~~ often an un grown down fairy. floating in sky & enjoying the sun. Sometimes we can see one of these fairies being born a small cloud in the sky gradually grows bigger & bigger ~~quite a lot of~~ some of the newly born cloud babies fade away & disappear all of them do not live to become real grown down fairies.
Children grow up slowly into grown ups but cloud babies change suddenly during the night into grown down fairies so we are hardly ever able to watch ~~this~~ the cloud baby changing into the fairy but sometimes at night shooting stars or lightning may be seen & this is often a sign that a fairy is growing down & by the morning the fairly is finished growing down & has hid itself away somewhere.

Another kind of fairy never stops

growing down & gradually becomes smaller
& smaller. ~~until~~ when very small they
may be often seen through a magnifying
glass. In fact a magnifying glass, like
a crystal ball is most useful for finding
out about ~~the~~ fairies & exploring the
fairy world. These magnifying glass
fairies are frequently found in large
numbers under old stones (when one turns
them over under dead leaves & old pieces
of bark on trees of course there same
places are full of small insects woodlice
- beetles & creeping crawlies the fairies like the
to be company of these tiny insects which are
rather silly & helpless like teddy bears
& need someone to look after them.

Now these tiny fairies do not stop growing
down but go on & on getting smaller
& smaller until the whole air may be
filled with them & yet we cannot see
them. This is something grown ups dont
often realise that the whole air may be
full of fairies ~~we can hear~~ buzzing
around our heads (& we can even breath
them & yet they see nothing; children
of course can often hear the fairies
singing & talking & if they get in their
ear you can sometimes hear fairies

<u>thinking</u> that is where so many funny ideas come from daydreams & castles in the air. If you sit very still in a quiet place & listen very hard & keeps very still you will often hear the buzzing & murmuring of fairies talking to each other & maybe talking to you

Growing down instead of Growing up. All Children always get bigger & bigger the older they get they grow taller & their feet grow bigger until they have got quite big enough & then they stop & are grown ups & aren't children any more. It is just as well children don't ~~on~~ go on growing & growing because if they didn't stop growing there would be ~~so~~ a great deal of trouble with people ~~people~~ too big to fit in houses feet sticking out of the end of the bed & giants all over the place walking on the smaller people like beetles on a footpath. So that explains why we have children & why we have grown ups. When children stop growing they are grown ups and all grown ups are about the same size except dwarfs & giants but there aren't many of those about except at circuses.

Some kinds of ~~the fairies~~ One kind of fairy instead of growing bigger as it grows up grows smaller instead & so we say it grows down instead of growing up & when they have grown down to a nice useful size they stop growing smaller & they are then grown down fairies like grown up humans.

Very Early MSS
1928-1934-

28. 1

~~After Two~~ The period 1650-80 had been one of great astronomical activity, the telescope was ~~sees~~ made use of intensely and the Gravitation theory was ~~developed~~ formulated. After this period there was a comparative lull in practical astronomy ~~to~~ for fifty years while Newton's theory was developed by the French & German mathematicians. Halley sailed with the East India Company to St. Helena and made a catalogue of the stars in the Southern Hemisphere. He linked up European astronomy by ~~t~~ visits to Hevelius at Danzig and to Paris. He also commanded an expedition in a warship in the Atlantic "to improve the knowledge of the Longitude and variations of the Compasse." He made excursions into new realms of stellar astronomy undealt with by Copernican theory; he discussed the arrangement of stars in space, their motions & variability, and the appearance of nebulae. In 1720 Halley was appointed Astronomer Royal and as lunar tables were not yet accurate enough for ~~longitude~~ navigational purposes Charles II charged him with the task of making still better tables. This task took all Halley's time and made an end of ~~to~~ his more original work. Bradley was the next Astronomer Royal and carried on the tradition of positional ~~astronomy. He~~

observations which so dominated 18th century astronomy. He worked on lunar tables and Jupiter's Satellites. He also spent much effort trying to measure the distances of the stars It was important if a reasonable picture of the ~~universe~~ universe was to be formed that the stars should be at a measurable and not an infinite distance. Hooke, Molyneux & others had tried earlier to measure the distances. Bradley decided that the distances were too great to be measured with the instruments of limited accuracy which he possessed. This work lead however to the important discoveries of the aberration of light and also the nutation of the earth's axis.

Solution of the Longitude Problem

The Longitude problem was becoming still more pressing. In 1714 there was appointed a Board of Longitude in England which offered prizes of £20,000 for a method of obtaining longitude at sea to an accuracy of 30' and smaller prizes for accuracy of 40' and 1° (at the equator 1° of longitude is equivalent to 70 miles). Apart from this prize the Board (as with the Spanish Prize of 1598) gave money to encourage research and in 100 years it spent £100,000 in that way. In 1716 France offered a prize of 100,000 livres.

P.T.O

Finding the longitude became the task of hundreds, was the butt of satirists, and was popularily regarded as impossible. ~~While the~~ However, while the astronomers were reaching the solution of the problem by improved gravitational theory and observations a quite different solution was being prepared by the instrument makers. In the 17th century the scientists Hooke, Huyghens, and others had tried unsuccessfully to make pendulum and balance wheels clocks keep accurate time at sea. What was required was a clock which would be unaffected by the motion of the ship and changes of temperature and humidity. The men who could make such a clock were the skilled craftsmen earning their living by clockmaking and who combined their skill with some scientific knowledge. John Harrison was this kind of man. He made in 1728 a clock embodying new methods of temperature ~~regulation~~ compensation and ~~he~~ immediately ~~got~~ approached the Board of Longitude. He made one clock after another each ~~one~~ better than the one before. At first the Board could not test the clocks at sea ~~at first~~ because the Navy would not ~~run~~ take the risk of allowing such an important naval secret to be captured by the Spanish who were at war with England. But Later in 1761 after a voyage to Jamaica Harrison qualified for the £20,000 prize offered by the Board. Then there began an immense struggle between Harrison and the Board who withheld the award of the prize for eleven years. The behaviour of the Board is probably connected with the fact that the astronomers were at the same time perfecting their lunar distances method. For instance Maskelyne, Astronomer Royal published the British Mariners guide in 1763. If they were not dishonest the astronomers connected with the Board were certainly biassed. Tremendous animosity grew between Maskelyne and the chronometer makers. But the chronometer makers won. Improved chronometers were developed and were soon standardised. In 1825 chronometers were issued generally to the Navy. Longitude was no longer a problem, and one of the strongest links between navigation and astronomy was broken.

At the same time - - - -

The English Instrument Makers

Clock and watch making was only one of the many aspects of the 18th century instrument making industry. The roots of the industry also lay in making navigational instruments, surveying instruments, spectacles, naval & astronomical telescopes & all kinds of special observatory instruments. This industry supplied the needs of a merchant sea-going capitalism in much the same way as the 19th century heavy engineering

P.T.O

supplied the needs of a manufacturing capitalism. ~~The~~
The solution of ~~all~~ the technological & engineering problems ~~solved~~ by the instruments makers paved the way for heavy engineering.
The instrument maker scientist Hadley invented the sextant (1731) which was of great importance for navigation. Graham made the large instruments for the Greenwich Oby including special instrument for stellar distance & he also improved clocks. Bird followed Graham in supplying ~~the~~ Greenwich. Dollond improved terrestrial & naval telescopes & made the heliometer used later for stellar distances. Ramsden invented a new ~~ts~~ eyepiece for telescopes & divided scales by new methods.

The instrument-making industry affected astronomy by developing the reflecting telescope and the achromatic refracting telescope. There were ~~also~~ many minor but important improvements in telescopes. For instance telescope tubes in the 17th century had been made out of cardboard (Galileo made one of lead) ~~but~~ the only suitable material supplied by contemporary technology. Now telescopes were made with brass tubes. Dollond's achromatic telescope ~~replaced~~ made astronomical measurements more accurate but ~~but had~~ could only be made in small sizes. The reflector was made in a practical form by Hadley. Later Short combined an extensive business of making reflectors with considerable astronomical observation'. He was in this way a forerunner of Herschel. The narrow commercial interest & secrecy which was so prevalent in the instrument making industry & which held up its progress is illustrated by Short's destroyal of his telescope making tools before his death so that noone might discover his methods, ~~afterwards~~.

Herschel's Astronomy

The close link between astronomy and practical problems had been a great stimulus to astronomical advance in the 17th century but in the 18th century this link constrained astronomy to routine paths and prevented it developing itself in new directions. The best astronomical talent was employed professionally on positional astronomy connected with longitude and mapping. For instance Maskelyne worked on the Mariners Guide 1773 & the Nautical Almanac which began in 1767 and Cassini at Paris made a ~~geo~~ map of France from surveys made in 1750-1793. Non professional astronomers on the whole restricted themselves to the kind of work done by the professionals. Descriptive observation of double stars nebulae etc were not in fashion. Thus astronomy dealt only with the

P.T.O

solar system and had not extended beyond Copernican theory into the stellar universe. The theoretical astronomers were completing every detail of Newtonian theory and Laplace in his Mechanique Celeste provided a complete picture of every known mechanical motion in the universe ~~ors~~ which meant then the solar system. It was to extend knowledge beyond this restricted and rather bankerupt astronomy that Herschel began his work on stellar astronomy. He wanted to find out as much as possible about the arrangement of the stars in space, the distances between them, and the nature of the stars and nebulae. The rise of astronomy with Herschel was in some ways unexpected but was also natural enough in view of the rapidly changing ideas at the dawn of the Industrial Revolution and in view of the bankrupt nature of astronomy

Herschel saw clearly that the ~~extent~~ success of his researches depended on the size and perfection of his telescopes: He chose reflecting telescopes and he spent as much effort improving these telescopes as he did in making astronomical observations. Herschel's contemporaries were not interested in exploiting the powers of the telescope to the extent that Herschel intended. ~~But~~ Herschel realised the importance of the results which could be obtained from the use of big telescopes ~~used to~~ and high magnification.

This is probably the most important reason why Herschel made such bigger and more perfect telescopes than his contemporaries because although his skill was unusual his methods ~~were~~ of making the ~~[illegible]~~ most important part, ~~mirror~~ the concave mirror, were not ~~much in advance~~ very different from those in general use. For instance Mudge the brother of the Mudge the chronometer maker had sound ideas of mirror making but ~~[illegible]~~ says that he never considered ~~size~~ mirrors more than 4 inches in diameter whereas Herschel made mirrors ten times that size. It was in size & accuracy & not in form that Herschel improved telescopes.

In 17 Herschel ~~was~~ aged ~~who~~ was earning his living as a well known musician at Bath and began to study astronomy in his

35 A

✻ "Then it was to my sorrow I saw almost every room turned into a workshop. A cabinet maker making a tube and stands of all descriptions in a handsome furnished drawing room. Alex putting up a huge turning machine in a bedroom for turning patterns, grinding glasses and turning eyepieces etc..."

importance of the results which could be obtained from the use of big telescopes ~~used to~~ and high magnification.

This is probably the most important reason why Herschel made such bigger and more perfect telescopes than his contemporaries because although his skill was unusual his methods ~~were~~ of making the ~~constant~~ most important part, ~~mirror~~ the concave mirror, ~~were~~ not ~~much in advance~~ very different from those in general use. For instance Mudge the brother of ~~the~~ Mudge the chronometer maker had sound ideas of mirror making but ~~he~~ says that he never considered ~~sizes~~ mirrors more than 4 inches in diameter whereas Herschel made mirrors ten times that size. It was in size & accuracy & not in form that Herschel improved telescopes.

In 17 Herschel ~~was~~ aged ~~who~~ was earning his living as a well known musician at Bath and began to study astronomy in his spare moments. In 17 he began ~~to~~ to make his own telescopes and his sister ~~I~~ writes thus of Herschel's tremendously ~~eng~~ energetic efforts. ~~I~~ ※ After many rule of thumb trials Herschel had in a 7 foot long telescope easily the best in the world. With this telescope he began a complete & systematic survey of every object in the

P.T.O

sky ; only the planets moon & sun had been systematically studied before. The perfectly ~~mirror~~ true surface of his telescope mirror enabled him to use high magnifications which showed the stars as small well defined diffraction discs 'as round as a button'. During his survey ~~he~~ Herschel discovered the new planet Uranus by noting that its disc was larger than the ~~small~~ discs of the stars. The telescopes at Greenwich & other observatories were incapable of showing the disc of Uranus and the planet could only be distinguished by the professional astronomers by its motion relative to the stars.

The Uranus discovery was not considered important ~~by Herschel~~ from Herschel's point of view. But the mathematical astronomers bored by the bankrupt astronomy praised him for providing them with a new planetary orbit to compute. The discovery made Herschel famous and enabled him to give up his music & be employed full time on astronomy by George III a monarch who used ~~various~~ means to increase his power & who was the last autocratic patron of science in England. This period (of the French revolution) marks the end of the developement of culture by the aristocracy (although p.37. ※ ×

The last example of Royal Patronage of Astronomy occurred well into the 19th century & was on a particularly grand scale. It was natural that this mediaeval resistance ~~should~~ occurred in Russia which was one of the most economically backward countries in Europe. The Tsars were not content with one observatory but made two — Dorpat & the famous Pulkowa.

and for this work he made very large telescopes the biggest ~~being 40ft long~~ (for which George III paid) ~~was~~ being 40ft in length with a 4 ft diameter tube. The larger the telescope the brighter was the image of ~~the~~ a faint nebula & more of it could be seen. The great 'light grasp' of Herschels telescopes was also used by him for seeing very far into ~~stellar~~ space so that the ~~to~~ extent of the stellar universe in any direction could be judged. Another important part of Herschels work was his demonstration that double stars ~~fr rotate~~ move round each other, & for this ~~fg~~ work the excellent defining power of his telescopes was a great help ~~jus~~ as it had been ~~was~~ in the case of the Uranus discovery. P.T.O

~~The revolutionary character of Herschel's work~~

these were notable exceptions in 19th century astronomy) and the handing over of the cultural heritage to the middle class. Herschel who was a middle class man sold his telescopes to dozens of princes, princesses, counts & kings none of whom ~~a~~ made a single useful astronomical observation. ~~with those telescopes~~ ·X·

Herschel's ~~survey~~ astronomical survey lead him to make a detailed study of the form of nebulae and for this work he made very large telescopes the biggest ~~being 40ft long~~ (for which George III paid) ~~was~~ being 40ft in length with a 4 ft diameter tube. The larger the telescope the brighter was the image of ~~the~~ a faint nebula & more of it could be seen. The great 'light grasp' of Herschel's telescopes was also used by him for seeing very far into ~~stellar~~ space so that the ~~to~~ extent of the stellar universe in any direction could be judged.

Another important part of Herschel's work was his demonstration that double stars ~~for rotate~~ move round each other, & for this ~~fo~~ work the excellent defining power of his telescopes was a great help ~~just~~ as it ~~was~~ had been in the case of the Uranus discovery. P.T.O

~~The revolutionary character of Herschel's work~~

Limitation of Astronomy by Technology

Herschels work was so revolutionary in nature ~~and~~ that it caused him to break from the line of continuous development in both astronomy and telescope making. In astronomy he was an amateur who never joined with the professional astronomers but in an individualistic age dominated astronomy & commanded patronage. In telescope making Herschel
7. was also an amateur and did not follow or develope the tradition of the instrument makers. Although he very successfully overcame his own difficulties in telescope making he did not advance this subject in the way that he advanced astronomy. The rather poor mounting of Herschel's telescopes illustrates this and also shows an interesting conditioning of astronomy by the contemporary technology

In the 17th century the method of mounting a long telescope was most elementary & was to let one end rest near the ground & to lift the other end in the air by a rope hanging from a wooden pole. In the 18th century instrument makers had evolved for positional astronomy excellent metal mountings for small telescopes These mountings or simplifications of them were to be applied later to all big telescopes but at Herschel's time the refined methods of the instrument makers could not be extended to deal with the exceptionally large telescopes which Herschel used. A highly evolved technique failed when exceptional quantitative demands were made of it. Consequently Herschel reverted to the crude 17th century mounting made of wood. Herschel's skill must have been extraordinary to make ~~the~~ observations with high magnifications when his telescopes were often so badly mounted. In his ~~b~~ biggest telescope (the 40 ft) ten times bigger than those of other makers the crudity of the mounting made the telescope practically useless. In this way Herschel's observations were curtailed.

The Industrial Revolution 1780 – 1860 & Amateur Astronomers

Many factors had been slowly accumulating
In England during the 18th century & this accumulation brought
about the Industrial Revolution ~~in England~~. Money had
accumulated through trade with colonies, rationalised
agriculture had ~~driven~~ a working population into the
towns & technology had advanced. These factors
enabled large scale industries such as spinning &
weaving to be built up in ~~to~~ the towns. Shortage
of fuel caused coal to be mined in increasing
quantities and improved methods of making iron
was evolved by smelting iron ore with coal.
The power ~~supply~~ for the new industries ~~was~~
was supplied by the water wheel. At first ~~But~~ the
The steam engine was improved by the use of Steam engine was only used for pumping mines. ~~but~~ ~~& improved machines tools for~~
bigger iron castings and heavy machine tools ~~boring cylinder~~.
were evolved ~~the boring mill~~ for special purposes such as for boring ~~the cylinders~~. ~~The~~
Steam power engine was soon able to replace water
wheels. The need for transport of coal heavy & manufactured good ~~at first~~
produced canals ~~but later (1820)~~ & ~~the~~ railways
~~began~~. ~~These came into being.~~ As well as Most of the new industries manufacturing
During the industrial revolution consumers goods such as textiles pottery etc ~~are~~ the heavy
engineering industry was created for manufacturing ~~making~~ the means
but there was also created of production such as steam ~~engines & heavy transport~~
steam engines locomotives etc ~~iron bridges & rails~~
It then became ~~was now~~ possible to ~~m~~ make ~~mad machine~~ larger iron castings
& forgings & machine metals ~~of iron~~ with versatile machine tools like the lathe
and planer cast large ~~iron structures~~ such ~~to well steel bars~~.
Iron began to replace wood in all heavy structures

2

~~For instance bridges & r~~
~~Bridges began to be made in cast iron~~
such as cranes & ~~lifting tackle~~ levers & wheels & later ships. Bridges also began to be made in iron. The Accuracy of workmanship increased the ~~old~~ traditional blacksmiths ~~forg~~ iron was ~~replaced~~ superseded by accurate machine made parts for steam engines.

~~formed an important new & rising class.~~

The industrial capitalist who owned the factories in the towns ~~was~~ arose mainly from the middle class & was not the same class as the ~~aristo upper~~ & began to compete for political power with the upper class landowners & bankers who had ruled England in the 18th century. ~~The whig Party which represented the interests of the manufacturing capitalist~~ ~~For~~ 50 years After 1830 the manufacturing capitalist was in power. The industrial capitalists effectively formed the ruling class. The interests of the new ruling class produced a break in the traditional religious & science.

Science was ~~an~~ a necessity for the development of the new industries. Chemistry had to be studied ~~to improve~~ so that ~~chemical industries could be~~ the processes of the chemical industry could be improved & understood. Physics had to be studied so that the principles of working ~~the~~ steam engines could be understood & more efficient engines designed. It was ~~an~~ the industrialists themselves who became the leaders of science ~~of~~ at the beginning of the 19th century. Men like Rumford, Watt, Priestley & Joule ~~Rumford~~ etc. ~~inspire~~ & was rated as amateurs ~~outside~~ ~~the established scien~~. The Royal Society had degenerated & ceased to ~~form~~ be the vital link between practice & theory that it had been formed in the 17th century. The Universities were dead.

The industrial capitalists who owned the factories in towns formed an important new & rising class. The industrialists came mainly from the middle class & began to compete for political power with the upper class landowners & bankers who had ruled England in the 18th century. By 1830 & for 50 years after the manufacturing capitalists through the Whig party effectively formed the ruling class in England. The interests of this new ruling class produced a break in the tradition of religion & science.

Science was a necessity for the developement of the new industries, chemistry had to be studied so that the processes of the chemical industry could be ~~improved &~~ understood & improved. Physics had to be studied so that the principles of working of steam engines could be understood & more efficient engines designed. It was the industrialists themselves who became the leaders of science at the beginning of the 19th century. Men like Rumford, Watt, Priestley, Joule etc worked in a semi organised way as amateurs. The Royal Society had degenerated & ceased to be the vital link between practice & theory that it had ~~been~~ ~~formed~~ been in ~~in~~ the 17th century. The ~~the~~ ~~older~~ universities were dead.

The new developements in 19th century astronomy had no direct economic ~~root~~ link with the Industrial Revolution. The exploring kind of astronomy begun by Herschel was in many ways an intellectual luxury which, although it was ~~very much~~ conditioned by changes in technology, concentration of wealth & the developement of other sciences, it was not developed with the prospect of obtaining economically useful ideas.

3 9

The other side of astronomy ~~had direct economic~~ of positional routine positional observation had direct economic roots & was continued ~~in~~ by professional astronomers like the Astronomer Royal. The general growth of sciences associated with ~~during~~ the Industrial Revolution reflected itself in an increased interest in astronomical discovery. Engineers & industrialists who ~~had~~ were wealthy ~~enough to have~~ & had leisure enough often became amateur astronomers ~~Most~~ The important new advances in astronomy ~~came~~ were made by these amateurs..

William Herschel had been the first great amateur astronomer & his son John, another amateur, followed him & developed his work further. Baily who founded the Royal Astronomical Society in 18__ was a London stock broker ~~who~~ who & was drawn to astronomy through the acquaintance of the chemist Priestley. The man who followed Herschel by combining astronomy with making reflecting telescopes was Lassel, a brewer from Liverpool. One of the biggest of Lassel's telescopes was made with the aid of Nasmyth the engineer who invented the steam hammer. The Earl of Rosse was one of the ~~ar~~ notable exceptions to the rule that the aristocracy had ceased to advance science. He built at Birr Castle on his estate in Ireland an immense 72" telescope costing £12,000 finished in 1845. The telescope was however very unwieldy but because of its size provided some

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important new information about nebulae. ~~It showed that many nebulae were composed of stars~~ The Spiral form of some nebulae was discovered & many nebulae were shown to be composed of stars. The Earl of Rosse was president of the Royal Society for five years.

~~Dato~~ Developements in the study of the sun were begun by Carrington who was a brewer. DelaRue who applied photography to the telescope had time to do so because of his as a paper manufacturer in England. ~~It is clear that the new advances in astronomy in 1830–1870 were made by amateurs who in the main belonged to the wealthy industrialist class. This class was also the most active in developing the economics of industrial England & was the politically dominant class.~~ Other ~~ex~~ examples of leading astronomers were Roberts & Common who both developed ~~photogr~~ the modern methods of photography with reflecting telescopes. Roberts was an important contractor & Common a director of the British Aluminium Company. Stellar spectroscopy was founded by Huggins who had wealth enough not to be interested in business. Lockyer followed Huggins in the same field but had to earn his living as a Government official. The engineer Newall who laid the Atlantic cable had the biggest refractor in England made for him.

~~In the late 19th & the 20th century physical sciences ceased to be developed by individual amateurs but became organised in ~~Inst~~ Universities & other Institutions. Astronomers began to acquire elaborate techniques & thorough training in mathematics & physics. These were reasons ~~why amateur~~ astronomers no longer lead new~~

The Industrial Revolution had ~~to~~ by its improved technology an important influence on astronomy. Most of the new industries manufactured consumers goods such as textiles pottery etc but there was also created a heavy engineering industry for manufacturing the means of production such as steam engines, locomotives etc. It became possible to make larger iron castings & forgings & ~~vasta~~ versatile machine tools like the lathe & planer were created for shaping accurately large pieces of iron. Iron began to replace wood in all heavy structures such as cranes levers & wheels & later ships. Bridges also began to be made in iron. Accuracy of workmanship increased and traditional blacksmith's iron was superseded by accurate machine made parts ~~for~~ as used in steam engines. It was no longer necessary for astronomers to mount big telescopes as Herschel had — with in the manner of sailing ships with wooden poles & rope, it was ~~now~~ possible for a big telescope to be supported by an iron casting & to turn on accurate & steady large metal bearings. A powerful telescope could ~~turn~~ now be turned by clockwork ~~& could~~ to follow the motion of the stars, all modern astronomical techniques ~~are~~ depends on this. The older instrument making industry combined with the heavy engineering industry to make the most rigid & accurate telescopes. Thus The famous telescope making firm of Grubb represented the synthesis of the instrument makers & engineer. But even in the middle of the 19th century technology failed ~~for~~ in the face of exceptional demands. The Earl of Rosse's great telescope bigger than Herschel's largest was ~~had to be~~ mounted in the Herschel fashion & consequently ~~had~~ its usefulness was so impaired. Only now in the 20th century can the very biggest telescope be mounted scientifically.

Technology & Astronomy

10

A modern example can be found in the much used highly evolved triode valve which failed ~~entirely~~ at first to amplify very exceptionally small electric currents, but with further evolution of the triode ~~now can ie do amplify the currents~~. this is achieved.

In the 19th century progress ~~also~~ in astronomy was, as ~~always~~ it always has been, dependent on improvements in instruments. As well as the improvement of telescope mountings ~~the~~ the size of refracting telescopes of the achromatic type invented by Dollond became ~~so~~ much larger. Herschel had made reflecting telescopes because it was not possible then to obtain sufficiently large pieces of clear glass for making the lenses of large refracting telescopes. ~~In Germany~~ Almost all ~~the~~ instrumental improvements in the 18th century had come from England but in the early 19th century ~~the~~ very important improvements were made in Germany. In 1804 an artillery officer formed the Optical & Mechanical Institute at Munich. The institute soon became an important centre ~~& attracted~~ directed by Fraunhofer a brilliant technician & physicist. A Swiss spectacle maker who had learnt to make perfect discs of glass 6" in diameter was attracted to the Institute. Soon Fraunhofer was making much larger glass discs & in 1840 a telescope with a 15" diam. lens was supplied to the Tsar's Observatory at Pulkowa. Other advances also emanated from Germany. Bessel, who had ~~been~~ been trained in arithmetic in a mercantile office, evolved a new method of combining ~~observations~~ astronomical observations so that errors were a minimum & he also devised an improved method of dividing circles for astronomical ~~in~~ measuring instruments. The combination of Bessel & Fraunhofers' improvements ~~made it~~ in practical astronomy made it possible to measure the positions of stars so accurately that in 18 the long sought victory of measuring the distances of the stars was achieved.

<u>Wilkins M.H.F.</u> <u>U S. VI</u>.

Gone are the irregular disturbances of human history, the biological & erratic improbabilities of the the human , the entangling conventions & fictions of mans intelligence . The research worker is up against the ultimate. It has often been said that no one can appreciate the joys of original Science until ~~the~~ engaged in ~~it~~ actual research themselves. Then the man is surrounded by Nature stark & ideal, & seeing things in their actual light & true proportions, his own insignificance becomes an elementary truism. Real Science is for the chosen few, the general scientific education produces its failures; So that the man may be unaffected, he may be as other men are; he may see no further than his own menial handwork, ~~the~~ ugly practical laboratory & ~~the~~ strange apparatus; the interpretation of his work may be left to a greater mind.

The whole of Scientific theory is based upon practical experiment; here-in lies the difference between Science & the other intellectual pursuits. The need for the scientific worker ~~him~~ to perform practical ~~scientific~~ significance with his own hands, appears to some to lower his intellectual developement, & others even consider it essential to the welfare of his mind to stuff the poor Scientist in his spare time with literature & the other humanities. Many educated persons do not seem to understand how Science proper can exist at the same time in the mind, as a real appreciation of Music & the Arts; one is assumed to be antagonistic towards the other. Convention, with regard to what is meant by the Intellectual, is the cause of this relative narrowmindedness. Unscientific people ~~cannot~~ are not in a position to understand Science.

(can we?) The taint of the nineteenth century still pervades Science, but as we can afford to disregard Victorian Art, so may we overlook the weaknesses of Victorian Science. The time has come when the New Science must be truly regarded as an Art & Philosophy; & a scientist who sells his brain to Science must be placed in no worse category than a classicist who absorbs himself in Classics.

We must not regard the test tube as ~~a sign of~~ the melting pot of materialism ~~inherent moral stagnation~~, nor look upon the telescope as but lacquered brass & turning. Let us forget the fact that we are human beings in human bodies speaking this our language, but let us regard ourselves merely as eternal minds, living a Life, in a Universe. And ~~synthesizing~~ arraying ourselves in Absolute proportions, then we truly see ~~we cannot forget~~ Science as the idealistic & true Art & Philosophy.

Williams M.H.F. 2– VS. VI.

Partial Circumspection of the Scientific

Science may be approached — if nothing more than approached — from a variety of standpoints, & may be attacked by any means, for its method is universal & envelopes the whole of human conception.

Treating Science as a useful assistance to material endeavours, the conclusions reached are of orthodox & obvious nature.

Science is a tool to be used for the developement of civilisation & the benefit of humanity. A section of the human beings ~~to~~ inhabitating this planet live under a system known as the Western Civilisation. The fundamental ideas of this arrangement consist of ~~a~~ the will to a comfortable physical existance, commercial expansion & exploitation of natural recourses, & the mechanisation & systematisation of social & personal existance & inhabitation. Science, & the practice of its method, enables all these endeavours to succeed to the desired state. This ~~to~~ application is the result of necessity; the Science always exists beforehand, its application is a secondary scientific consideration, just as the poster & publicity is a sidelight of Art, & a consequence of our human propensities. The details of a comfortable physical existance are of domestic & mundane character, for we ungratefully wallow in a sea of applied Scientific principles & we are are never without them from one end of the day to the other. Science allows the greatest developement of aesthetic ideals, in so far as we make use of them in physiological & general processes.

?

Commercial expansion & exploitation of natural ~~recources~~ & human recources is a purely competitive matter; its success depends upon the superior application of mathematical system & general Scientific proportions.

Lastly, mechanisation & organisation is the most obvious developement of Western civilisation; its importance has rapidly been increasing for the past century. This phase of.

Williams M.H.7. USc VI.

Science has occupied too large a part of the attention of the ~~pla~~ public, to the extent of ignoring Science in many other equally important ~~phases~~. aspects. In the eyes of the true Scientist, the mechanisation of Western life is only an interesting biway of Science proper: if the educated world of today would realise these proportions, a better understanding of the aims of Science could be formed, so that failure in direct usefulness would not be represented ~~by~~ as a failure in the Purpose.

Science is a tool to be used for the developement of civilisation & the benefit of humanity. When the scientist hands over his methods for the still greater control of physical circumstance to the people, to use as they think fit, he should not forget the possible responsibility of his position; for he deals with an unstable unknown, an all-important entity, the preservation of which may depend upon the workings of his mind. The new Power is misused by the people, just as they can misuse everything else. The future of life lies at the will of the plebean lusts. Science, as brought to play in the systematic disruption of the order, is but another indication of the grossness of some human conception

The effect of the Mechanical Age & its derivatives upon the Scientist ~~ox~~ becomes only an additional incentive to his pure research.

Science may be served up to the public in the 'popular' view, so as to arouse in the ignoramus a sense of inconcieved wonder & amazement.

Science is the most direct method of analysing the material Universe; it is a precise explanation & exposition of the Physical State. ~~Science~~ Even when not an explanation, Science is Knowledge & is always a striving toward the Truth. The investigator is sounding the depths of Nature, he pits his ~~mind~~ intelligence against the mysteries of the elements. He has the whole universe before him, he holds it in his puny brain, & while equating its cycles & dimensions & analising its causes & effects, he is in direct contact with the Absolute Truth of the Great Mathematician

Some Roots of Astronomy.

~1939 MHF Wilkins

In this article we are concerned with the new astronomy which grew up in Western Europe since Feudalism and as Capitalism developed. The Babylonian and Greek astronomy that went before had reached a fair level of theoretical complexity. But as the problems which astronomy had then to solve were of a simple nature; namely, provision of a rough calendar, approximate time, & rudimentary maps — the kind of problems connected with trade which arose in that elementary form of society — positions of objects in the sky were not measured accurately and the physical side of astronomy was not developed. But because of these practical problems astronomy was the one branch of Greek Science in which observation was on a comparable footing with theory.

It was the Greek astronomy which formed the basis of the new Western European astronomy. Greeks developed instruments for measuring the angles subtended between objects in the sky, trigonometry and mathematics for dealing with the angles observed, theories of the motion of the planets, moon and sun, tables of these motions and of the positions of the stars.

Arabian Astronomy After the decay of the Greek civilisation Western Europe was in a state of Political barbarism and was intellectually confused in a narrow theology. The task of keeping astronomy alive was left to the arabs who, as the Islam Empire was built up, kept Greek astronomy alive and refined it in many ways. This astronomy was related to the same trading problems as in Greece but considerable incentive was also derived from astrological prediction. The Toledo tables (1080) of stellar and planetary positions were the result of more accurate observations than those of the Greeks and were the climax of Arabian astronomy. The Almagest, the standard work of Greek astronomy by Ptolemy, was translated into Arabic. The Ptolemaic theory, in which the earth was fixed and the celestial bodies moved round it in paths given by the superposition of several circular motions, could not account accurately for the motions of ~~the~~ celestial objects as measured by the Arabs. But as no satisfactory alternative was brought forward, Ptolemy's theory remained entrenched.

Feudal Astronomy

Feudalism in Europe was now entering a stage where it began to outgrow itself - and trade added itself to war as a new means of aggrandisement. Astrology had developed as a counterpart to authoritarian theology ※ ~~Scholars~~ and many were ~~were now~~ employed as astrologers by wealthy patrons to assist them in wars and trade. ⊠ Arabic science now began to be acceptable in the Latin world and the 13th century was one of immense translating

※ Almost every Latin scholar was an astrologer,

~~⊠ Medicine was dominated by astrology.~~

⊠ In medicine ~~the~~ astrology was as important as physiology.

activity from Arabic to Latin ~~and As Arabic activity decreased~~
The effect of these translations was to produce a minor Renaissance in Europe at the same time as Arabic activity decreased.

2

The production of ~~..~~ improved horoscopes demanded more accurate tables than those made by the Arabs. ‡ ~~Hence~~ Thus Alphonso of Castille, situated geographically between the Arabic & Latin world, while transmitting translated Arabic material into the Latin world ~~..~~ also went to great pains to get the best Moors + Jews to draw up new tables from more accurate observations.

‡ ~~These tables of~~ Observations were made of past positions of objects and then the Ptolemaic theory gave by calculation ~~their predicted position~~ prediction of their future positions.

The increased accuracy of these Alphonsine tables (1270) may be associated with the growing technologies of the time ; armour, fortresses and cathedrals.

all

Astronomy at that time was not separate from astrology. Prediction & final causes occupied the minds of scholars, and astrological problems required astronomical ~~pr~~ observation and mathematical calculation. It was not ~~..~~ until ~~much later~~ a century or two later that astrology ceased to be part and parcel of astronomy & astronomers made predictions insincerely and only for making money. But apart from astrology (and a general reawakening of Medieval thought) there were other factors causing an ~~growth~~ increase in the number of scholars astronomers and universities. The transition

3

Date of Hansa: League [illegible] and Merchant Adventurers Sort of Trade

3

from Feudalism expressed itself in increased trade, mining and manufacture. Travel and regular trade between countries necessitated an accurate calendar. It also required maps of sea coasts. and a knowledge of the latitude and longitude of places and the distance between them. More accurate measurement of time was needed ~~and~~ to supplement the new sundials & clocks ~~[illegible]~~ ~~made~~ These problems had to be solved astronomically. New geographical treatises were written, not separately, but as one with astronomical treatisis ※ ~~Astronomy also received an indirect impetus~~

※ The most strikingly deficient aspect of Scholastic thought had been an abstract (& largely incorrect) ~~Ptolemaic astro~~ geography ~~laid down~~ defined by the authority of Ptolemy, ~~which~~ such geography must have been of very negative assistance to traders in their travels.

Astronomy, astrology, and mathematics were now to be found in centres of learning which were also generally centres of growing trade; for instance, Northern Italy trading with the Levant and North Germany with its Hanseatic League of merchants.

4

Thus a group of astronomers, Purbach, Regiomontanus, and Waltherus, are to be found at the end of the 15th century working at ~~P~~ places like Konigsberg & ~~Nuremberg~~ an important port, and Nuremberg an inland trade route centre. ~~Why~~ Pope Gregory ※ when he wanted an accurate observation of solar motion so that a new calendar could be drawn up which would make calendar seasons correspond with climatic seasons and place

※ went to Regiomontanus Date please

6

(dates in brackets)

religious festivals on a sound basis. Copernicus too was born in the Hanseatic area, studied there, and went to N. Italy to learn more in the area where the original Greek works were becoming available.

Dates — The advance of experimental methods by Roger Bacon and Leonardo, which was partly suppressed by the Church, had not yet driven astrology from its leading part in astronomy. Copernicus' teachers at Cracow & in Italy practised astrology. However, as more & more accurate observations were required, as for the Gregorian Calendar, the Ptolemaic theory was found more inaccurate & intellectually unsatisfying. This question was Copernicus' chief concern and he evolved a more accurate and simple theory which placed the Sun at the centre of the universe with the planets & earth revolving round the sun. The Copernican theory was still in terms of Greek Ideas & still placed the stars on a distant sphere. It was published in 1543, and as printing had come into general use a few years before, it was circulated widely. The Copernican theory was one of the powerful levers which displaced medieval scholastic theory. The Prutenic tables were the result of Copernicus' work.

Tycho Brahe followed Copernicus'

theory with exact observations. Tycho ~~in Denmark~~ received lavish assistance from Royal ~~Danish~~ patronage in Denmark and Bohemia and built all kinds of large divided circles and sighting arrangements which were the biggest pretelescopic astronomical instruments. The instruments were partly made of metal and were more accurate than any before. Tycho was only half a Copernican, but his pupil Kepler developed Copernican theory to a higher level by deriving from Tycho's observations ~~a~~ precise ideas of the elliptical motion of planets round the sun. Because of this improved theory the Rudolphine tables (1627, Prague) were far more accurate than any which had gone before.

The Telescope ~~and the Longitude Problem~~

all
5

The old astronomy of astrology and the calendar was now to be rapidly left behind as a series of important changes arose out of the new world created by the rising merchant class. The telescope was invented and ~~the~~ America discovered. The telescope made it possible to study in detail the physical nature of the Copernican universe and the America discovery 1492 raised navigational problems of immense difficulty and importance for astronomy to solve.

The telescope did not come into being by chance. Lenses had a restricted ~~on~~ use in the 13th century as spectacles for reading manuscripts and as magnifiers for technical processes such as jewel engraving. They were made in Venice where the crystal out of which they were made was imported together with all kinds of gemstones from the East. The unusual process of grinding and polishing lenses, ~~is~~ being almost the same as that used for polishing gems, ~~and~~ these processes were probably carried out by the same technologists. As the merchants supplied more gems, ~~the~~ wealth increased and more gems were worn. Printing was invented and spectacles needed for reading and merchants ~~making~~ keeping their accounts developed myopia. These factors caused the gem & spectacle industry to expand, and when American trade developed the centre ~~it~~ moved from Venice to the Netherlands. ~~Then~~ Here in 1608 the epochmaking but ~~epoch-making~~ inevitable discovery of the telescope was made. The chance fitting together of two spectacle lenses was all that was required.

Date 1560–1590

The ~~D~~ discovery was immediately sold to the Dutch army for use in the war with Spain. No one seems at first to have thought of connecting the telescope ~~invention~~ with astronomy until Galileo received report of the Dutch invention while in Venice (16– among the spectacle makers. He promptly made a telescope himself with lenses of Venice glass. The scientist of that day was essentially a man of the world and Galileo sold ~~his~~ the invention for . . . . . to the . . . . . . & was appointed a professor of military science. He then improved the process of lens grinding & raised the magnification of his telescope from 3 to 30. With this telescope he observed that the shape of the planets was the same as that of the earth, that Jupiter & its satellites formed a miniature Copernican system, ~~and~~ that some planets showed phases like the moon, and that the sunspots showed the sun to be rotating about its centre. Galileo thus made the first of the series of observations which showed the truth of the Copernican idea and elaborated it. Also His improvements in the telescope were the first of the series of improvements in telescope lens making which ~~were to~~ have continued for 300 years, ~~and which~~ each of which in its turn has made new astronomical discoveries possible.

(Subheading) The Longitude Problem

Galileo was quick to see that ~~the~~ Jupiter's satellites might solve the longitude problem. The problem

6

had arisen ~~thus~~ in this way. Trade in the 14th & 15th centuries was carried on either over a few great land trade routes or by coastal voyage, the compass and mariners charts of the coasts ~~were~~ being used. But when America was discovered trade voyages had to be made across the open ocean and out of sight of land for weeks. A course was set by means of the compass and the tiller of the ship, the distance travelled was found by dragging a log in the sea, allowance being made for tides & currents. ※ The ~~movements of~~ movement of the ship in latitude could be checked easily by means of the ~~~~ altitude of the sun or the pole star, but there was no simple astronomical method of ~~the~~ finding the longitude accurately. As a result Columbus estimated that the longitude of Cuba was that of India and announced that the size of the earth was much smaller than had hitherto been believed. As more & more ~~~~ long voyages were made, very serious difficulties arose. For instance one navigator thought he had rounded the Cape of Good Hope into the Pacific but found after weeks of sailing that he had sailed North again into the Atlantic. Unless he ~~~~ had seen land ~~he~~ did not know which side of America he was on. Countless navies (e.g. The Armada) were lost and cargoes were wrecked on well charted coasts; & sailors died of scurvy because they could not find land.

※ The so called Dead reckoning then gave a very rough idea of the position of the ship.

For these reasons, the ascertainment of ~~As a result, finding~~ the longitude became the leading technical problem ~~question~~ from 1500 – 1750.

All that is needed to find a longitude is to know the time and to measure the position of the stars or sun. Galileo drew up tables predicting the future motion of Jupiter's satellites so that navigators could observe them with telescopes & find the time while at sea. Galileo unsuccessfully offered his method, which was just beyond the limit of practicability, to all the big sea powers in turn, at the same time demanding enormous reward. Spain and Holland had already offered prizes for finding the longitude. ~~There were other astronomical methods more promising than Galileo's. The moon or~~ The Spanish prize of 1598 was 6,000 ducats and anyone who persuaded the Government that they were doing genuine research was paid a lump sum & told to continue. Most of the methods centred in the variability of the compass. Columbus had found on his first voyage that the compass did not point exactly north and that the difference ~~or variation~~ of direction or variation changed with longitude. Halley in 1660 drew up a chart showing the relation between variation and longitude. A Royal Commission in England decided against the method in ~~England~~ 16–

? Subtitle here "The Telescope or Improvements in the Telescope".

The telescope ~~and~~ along with the longitude problem caused a to follow [ ]

The revolutionary spirit of the age is typified by the following due to Galileo which incidentally bears close resemblance to the ideas of Marx & Engels, the revolutionaries thinkers of the 19th century:

"hear it to be attributed to natural bodies, for a great honour and perfection, that they are impassible, immutable, inalterable, etc. And on the contrary, to hear it to be esteemed a great imperfection to be alterable, generable, mutable, etc. It is my opinion that the Earth is very noble and admirable, by reason of so many and so different alterations, mutations, generations, etc., which are incessantly made therein ..... The like I say of the Moon, Jupiter, and all the other Globes of the World" a considerable growth of interest in astronomy ~~& other~~ among the gentlemen merchants of the time. Other problems connected with trade & war stimulated interest in science generally. Evelyn in 1665 writes thus " I called at Durdans, where I found Dr Wilkins, Sir Wm. Petty and Mr Hooke contriving chariots, new rigging for ships, a wheele for one to run races in, & other mechanical inventions, ---- ". [ ] But Because the Universities were out of touch with the problems & adventurous spirit of the gentlemen merchants, there came into being new organisations specifically scientific and practical. Such was the Royal Society founded 166 . ~~and~~ In the

[The creation of a new bourgoisie, the building up of merchant capitalism, swept aside the last traces of scholasticism and brought experimental philosophy to the ~~fore~~ fore.]

new para.

Philosophical Transactions of the Royal Society we can see ~~the sort~~ what sort of work was done. Improvements in making telescopes caused a tremendous outburst of descriptive astronomical observations most of which were concerned with ~~for~~ elaborating the Copernican picture and removing ~~the last~~ any final remnants of the ~~Sch~~ Aristotelian idea that the heavens were of different nature from the earth. For instance every planet was carefully scrutinised for spots on its surface ~~to see~~ which would shew if it was rotating. Saturn was seen surrounded by a ring, and then this ring was seen as consisting of two concentric parts. More satellites were discovered round Jupiter and Saturn. Satellites were seen passing across the planets' disc or casting shadows on it, Saturn cast a shadow on its rings and vice versa. The moons surface was explored. Such observations as these showed conclusively

? the physical reality of the solar system. There ~~was~~ also a large number of observations on nebulae, new stars etc, but this extra solar system astronomy had to wait until Herschel's time to be fully explored. It is significant that in the Philosophical Transactions for every 2½ papers on astronomy there was one paper on telescope

imp. making, and most of these ~~papers~~ were accounts of lens grinding methods. This (1670) was the ~~period of~~ stage of of experiments on ~~the~~ all kinds of new methods of making lenses, and almost every serious scientist ~~who were celebrated~~ spent a good proportion of his time polishing lenses. During the next few years these methods became relatively standardised, and improvements in telescopes reached a temporary saturation point. Then descriptive observation of the

"positional"? (since you use the word later without definition) appearance of astronomical objects gave way to quantitative observations ~~as before the~~ on positions & time of eclipses transits, ~~etc~~ and the paths of comets etc. In fact, except for this rather brief outburst of descriptive observat[ion] most of the astronomical work was of the same positional nature before the invention of the telescope and for 150 years after. It was not until Herschel that the ~~—~~ possibilities of descriptive telescopic observation became exploited to the full.

It is important to consider the kind of telescope in use in the latter half of the 17th century. Refracting telescopes were always used. ~~with~~ The object glass was 2"–6" in diameter, and was made from thick glass sheet such as was used for mercurised glass mirrors and windows. The lens was made large to increase the brightness of the image and to sharpen the definition; but a large lens would only give good definition if it had a very long focus so that refraction in the lens was a minimum. This was a very serious difficulty which meant that a telescope which would show Saturn's rings double had to be 100 ft or so in length. In practice the unwieldiness of such telescopes greatly reduced the amount of observation which could be made in a certain time & lack of rigidity ~~reduce~~ impaired the observation. The leading mathematicians and physicists therefore gave their attention to the problem of making short focus telescopes with large diameter lenses. (which would define well). Such a problem could not be solved without a thorough knowledge of the way in which light is refracted in various media. Only scanty observations bearing upon this were at hand, ~~because the short telescope~~

problem as there had been no need before for more detailed study. Descartes and others were of the mistaken opinion that indistinctness of the images formed by lenses was due to the incorrect shape of the lens surfaces. Futile effort was made to grind lenses with hyperbolic surfaces. But the essential characteristic of lens grinding is that almost exact spherical surfaces are necessarily produced and the slight deviations from the sphere are very difficult to control.

improve

Newton attacked the problem with more success by making a large number of new experiments on the formation of colours by refraction. With the aid of these new data he was able to point out that the poor definition of telescopes was almost entirely due to dispersion, an inherent property of refraction, and the spherical aberration of Descartes was of secondary importance. It is interesting to note that all Newton's work on colours was due to his interest in shortening telescopes and removing chromatic aberration.

? "discover" or "explore" [as it is, it is ambiguous]

Newton did not follow up the possibilities of overcoming chromatic aberration by using compound lenses. Instead he decided that refracting telescopes could not be improved and advocated reflecting telescopes in which a concave mirror instead of an object lens formed the image. The surface of the mirror should ideally be in section parabolic but Newton saw that an accurate sphere ~~of small curvature~~ would be good enough, if of small curvature. He tried his idea ~~out~~ in model form making two telescopes six inches long which were equivalent to refractors of about ten times the length. Newton made ~~the~~ his concave mirror out of an alloy of tin and copper with a trace of arsenic. He was fortunate in the choice of this alloy. It ~~which~~ was still the best Lassel could devise 200 years later, ~~during which period~~ and in the interim thousands of alloys had been tried out. Newtons metallurgical knowledge, later on, ~~lead~~ led to his ~~appoin~~ being put in charge of the Mint. Newton had very clear ideas of the conditions ~~necessary~~ during the polishing process ~~necess to~~ necessary for the production ~~lenses & mirrors~~ of spherical surface on lenses and mirrors. Pitch, he recognised, had ideal properties as a coating for the polishing tool; it gave way slowly to the average pressure on it, but would not give way to sudden irregular pressure as the mirror was rubbed on it; it was thus able to ~~a~~ retain a spherical surface. He criticised opticians for distorting their lenses by too great pressure during polishing. Newton communicated his ~~results~~ experience to the Royal Society and presented ~~it~~ that body with one of his 6" long telescopes. In some quarters, indeed, Newton became better known as a telescope maker than as a mathematical physicist.

Although Newton tried to make a bigger reflector — four feet long — the difficulty of figuring or giving an accurate surface to the concave mirror was so great that he left the matter in 167_ _ after publishing recommendations to anyone who liked to ~~pursue~~ make further attempts. Gregory had (before Newton, ~~made~~ tried) to make a reflector, but he said that 'being discouraged both because he could not get a parabolic speculum and because that which he tried was not well polished he gave over the thought of bringing such telescope into use ..." After Newton, Hooke and others made more attempts but no useful reflector was produced until 50 years ~~later~~ ~~after~~ later.

[Margin: trs/ — ? because — Is this really a quotation? If so why "be"?]

While attempts were being made to bring the reflector into use refracting telescopes were being made bigger and longer. The observatories of the time were characterised by having long tubes, sometimes more than 100 feet long pointing from windows of observatories in all directions. Huyghens in his aerial telescope removed the need for a rigid tube by having no tube at all; the object glass was mounted on the top of a pole, and the observer was on the ground with an eyepiece. Observational work with these big telescopes was, on account of their expense, limited to well-to-do individuals, and government observatories, and scientific academies. ~~This~~ But this descriptive observation was only one application of the telescope; the other, quite as important, was ~~the~~ in the realm of

[Margin: x?]

3.

quantitative, positional astronomy.

~~Public~~ Government Observatories

all

Galileo had ~~attemp~~ tried to solve the Longitude Problem by ~~an astronomical method~~ Jupiter's satellites. Another method first tried by Baffin on a voyage in 1515 was to tell the time by the position of the moon in relation to the stars. This method, ~~was~~ called "lunar distances", dominated astronomy from ~~1650–1750~~ the middle of the 17th century to the middle of the 18th century. This close association of navigational problems with astronomy assisted the centre of astronomical work to shift with the centre of trade from Germany & Northern Italy to the specifically maritime commercial area of England and France. Spain was not included probably because its naval supremacy had declined before the longitude problem became so closely linked with astronomy. Where the need was concentrated astronomy was taken up very seriously; and In rapid succession, in the middle of the 17th century Denmark, France, & England founded official ~~obs~~ State Observatories.

using the moon as the hand of a clock moving over the stars as a dial.

I don't like this construction

x

~~It would be incorre~~ The Longitude problem was only one side of ~~the~~ 17th century astronomy. There were many changes taking place in the organisation of science. The founding of the Royal Society in England and the Academy of Sciences in France ~~which~~ was the first conscious organisation of scientists by themselves as part of the community. ~~On this basis~~ This was the basis on which organised astronomy grew.

The Copenhagen Government Observatory 1656 was in the area of Copernicus and Tycho and it represented the old kind of astronomy stimulated by the general growth of interest of the new demands. Tycho had been fortunate to receive liberal patronage, for part of his life, at Uraniborg near Copenhagen from Frederick II of Denmark; but there was no very deep connection between Tycho's observation and the Danish community. Longomontanus, formerly one of Tycho's assistants was appointed in charge of the new Copenhagen observatory. In practice the Copenhagen observatory did not differ much from the extensive private observatory of the rich merchant Hevelius in Danzig except that Hevelius' observatory was not founded on a permanent basis.

The moving forces behind 17th century astronomy were more clearly seen at Paris where scientists had formed an Academy of Sciences & secured ~~under~~ Royal Patronage. The Academicians persuaded the King to put up the money for a Royal Observatory (1672) but their organisation was not strong enough to prevent the money being spent on a totally unsuitable observatory with massive walls and turrets and with no ~~&~~ convenient rooms for observing. Cassini, brought from Italy, was semi-officially in charge ~~of directing~~ of the Observatory and after him was his son, grandson, and great grandson until the Revolution. There was no proper programme of work, no official positions, and some of the most important instruments were not supplied. The Paris observatory was was one of the most striking examples of a public scientific institution ~~hamstrung~~ frustrated by official vice and stupidity. Yet the Academy was such an active organisation with excellent connections abroad and containing such a wealth of talent that much excellent work was forced through in the Paris Observatory. Cassini spent much of his time preparing tables of Jupiter Satellites with a view for Longitude purposes. Out of these observations Römer found that light did not move instantaneously and found its velocity by calculation.

A confused redundancy! Astronomy like most sciences cannot be studied most profitably by one man working in one place & only for a lifetime. Observations are of much greater value if extended uniformly over hundreds of years and it is often essential to combine observations made in different parts of the world.

There is no short way of saying what I think you mean here!

The organised observatories on a permanent basis made these kinds of observations possible and caused international connections to grow up in science. For instance the distance of Mars from the earth (+ thus the distance of the Sun) was found by combining observations made at Paris with those made at Cayenne by Richer who was sent there from Paris amongst other things to find the longitude of Cayenne by Jupiter's satellites.

~~all~~ The connection between the Longitude problem and astronomy is most obvious in the case of Greenwich Observatory. The Royal Society had been trying to start an observatory. The President of the Society, Sir Jonas Moore who was Surveyor of Ordnance intended one of his scientific circle Flamsteed to be observer. Then there was a Royal Commission to consider lunar distances for longitude and Flamsteed pointed out that new and more accurate observations of the position of the moon and the fixed stars was essential if the method was to work. ~~When~~ Charles II was told this and he "said, with some vehemence, 'He must have them (star places & moons motion) anew observed, examined, and corrected for the use of his seamen." So a Royal Observatory was founded and Flamsteed employed as Astronomer Royal at the low wage of £100 a year. As at Paris, the astronomer was left to provide his own instruments and

Flamsteed was a sufficiently keen scientist to spend £2000 of his own money on providing his own instruments. These instruments were made by Sharp the first of the line of great English instrument makers. As well as being exploited by the Government Flamsteed developed something of a persecution mania and objected to having his work organised by the Royal Society which took the view that Flamsteeds work was of public importance & should be published more rapidly than Flamsteed thought fit. In his observations of the moon Flamsteed laid the basis of accurate astronomy and was able to supply observations ~~on which~~ to Newton on which ~~he founded his~~ the Gravitation Theory. was founded.

It is interesting ~~to~~ that although the importance of the telescope for descriptive astronomical observation was fairly rapidly appreciated it was not ~~for~~ until 50 years after its invention that it began to be used for measurements ※ Hevelius who was a leading descriptive observer with the telescope refused to use it for his extensive quantitative observations after it was in general use (166) for such purposes and stubbornly held to naked eye sights. The main characteristic of the work at Paris, Copenhagen, and Greenwich was its much increased accuracy. This was possible by the use of the telescope.

9

※ (This use of the telescope ~~was~~ as a measuring instrument was quite as important as its use for descriptive observation.)

It was now possible to measure very small movements and thus verify some of the more important aspects of the Gravitation Theory.

There are two ways of using the telescope for measuring angles. The first is to make the image of the distant object focus on a fine measuring instrument or eye piece micrometer and to set the micrometer exactly on the parts of the image (say two stars) to be measured. For accuracy of setting the image and micrometer is magnified by the telescope eye piece. The other device for measuring large angles is to use a telescope with fixed crosswires at its focus as a pointer which turns on a large divided circle or quadrant.* The eye piece micrometer was invented by Huyghens in 1659 when he was very carefully studying the shape of Saturn & its rings. Later when Huyghens was at Paris, Azout & Picard developed ~~the an eye piece~~ a micrometer using a screw thread for measuring small distances. Hooke, Wren & others in England were working on the same device at the same time. But unknown to the scientists in London & Paris, Gascoine in Yorkshire had much earlier in 1640 invented and used extensively a screw eye piece micrometer. It is a striking illustration of the concentration of scientific work in a few leading centres and the persistance of Feudal insularity that Gascoine's invention was used and generally known in the North of England but was unknown to the Royal Society in London.

* The telescope thus replaces the older naked eye sight

The use of the telescope as a pointer on large quadrants was developed at the Paris and Greenwich observatories. This invention was combined with Huyghens new pendulum clock and gave a simple and accurate method of measuring the position of objects in the sky. Clocks in public places in centres of trade like Nuremberg had been developed since about 1200 but had been made to work by clever craftmanship and adjustment rather than by scientific design. Huyghens clock was much more accurate & was the first clock built on scientific principles. With the aid of this clock and the transit circle (a simple instrument in which the telescope rotates on a fixed axis) Romer (who was Astronomer Royal of Denmark) (1681) was able to measure the position of an object by one measurement of an angle and one of time. The transit circle then became the standard observatory instrument for positional measurement. It was cheap to make, easy to use, the observer required no assistants and it gave the angles required without any computing. Romer developed the use of a complete divided circle instead of a quadrant because the circle could be divided better & instrumental errors could be avoided. The demand for new precision instruments of this kind was one of the causes of the development of a new kind of industry namely that of instrument making.

all

The Gravitation Theory

The relation between the changing astronomical practice and the new theory developing must now be considered. There was rapidly accumulating an immense number of observations of solar, lunar, and planetary motions which were of no use or interest in themselves but were very useful & interesting if they were combined with a theory and prediction of future motion could be made. The better the theory the better would be the tables of predicted motion. In the past Copernicus' theory had improved the Prutenic tables and Kepler's theory made the Rudolphine tables outstanding. The Kepler theory was still the best but it was quite empirical, simplified, and not exact, ~~and~~ The leading mathematical brains were busy linking up the experimental studies and theory of practical terrestrial mechanics with astronomy in an endeavour to explain astronomical motion completely.

Ideas of attractive forces between astronomical bodies were being developed on all sides. It was Newton, the outstanding mathematical technician, who was able to express these ideas in the most precise, simplified & complete form. By collaborating with observers at Greenwich and Paris he was able to satisfy himself[16] that gravitational attraction extended beyond the earth & acted between all bodies according to a simple law. Then it was merely a question of calculation to find the motion of any astronomical body. If the law was true every detail & irregularity of motion could be predicted. One of the main tasks of theoretical and practical astronomy after Newton was the testing of the Newtonian theory by calculating and measuring all the small irregularities of motion.

The relation of the Gravitation theory with practical needs extends, as it does with most important theories, much more deeply than in the fact that the theory was based on observations made for practical ~~needs~~ reasons. The outstanding nature of the theory is not restricted to its very great logical importance & intellectual interest but lay also in its very usefulness, and in fact these characteristics should not be considered apart but as a whole. It happens that this can be seen in a similarity between the astronomical observations made before and after the Newtonian theory. It might be supposed that the observations made to test an all embracing theory would be of a different nature from the observations made before the theory. But the same problems were facing astronomy before and after the Newtonian theory and the theory was so closely interwoven with these problems that no very new directions were

~~produced~~ created in astronomical research. ~~As with the more~~ As with the more restricted theories before it the usefulness of the theory lay in its ability to produce accurate tables. This was not immediately possible because the calculations required ~~were~~ when several bodies interacted were so complicated that it was beyond the capacity of current mathematical methods. The application of the theory ~~the~~ had to wait for almost 50 years while the methods of calculus were developed by mathematicians. When the theory began to be worked out completely many of the results were of immediate practical importance. For instance the final result of Mayers' continual developement of the theory was a set of lunar tables for which he was ~~aw~~ awarded £3,000 by the Board of Longitude.

Physical Astronomy

During the first half of the 19th century astronomy ~~studied~~ continued along Herschelian lines it gave a description of the shapes sizes & distances of astronomical bodies. ~~& did not~~ With the Industrial Revolution a new kind of astronomy arose which ~~gave~~ described the physical & chemical constitution of the sun & stars. The continual study of the problems of power supply, heating & lighting, & chemical manufacture brought new branches of ~~chemistry & physics~~ science into being. These new sciences began to be applied in astronomy & to develope with it. Thermodynamics ~~was~~ is the fundamental study of how heat & light are created & how they can be turned into other forms of energy. The thermodynamic principles were very usefully applied to improving steam engines & they also enabled astronomers to obtain approximately correct ideas of the constitution of the sun. Herschel had made the suggestion that the sun was a ~~globe~~ cool inhabited globe surrounded by clouds which radiated heat & light to the earth. Nasmyth's suggestion was ~~even~~ more ludicrous for he supposed the sun's surface to consist of immense luminescent organisms each million miles across. Thermodynamics put an end to such inadequate ideas & enabled Helmholtz in 1853 to form a reasonable picture of the sun as a mass of extremely hot glowing gas heated by gravitational compression.

Fraunhofer, & Bunsen & Kirkoff had found the principles of spectroscopy or the analysis of emitted & absorbed light. Fraunhofer had ~~worked~~ made observations of the sun's spectrum as part of his work on improving telescopes. Bunsen & Kirkoff as chemists & physicists had been as much interested in ~~explaining~~ coloured flames as they were in ~~the in~~ explaining the sun's spectrum. Spectroscopy was soon applied to the stars & in chemical analysis. Huggins ~~work was the first in the~~ ~~fo~~ working with Miller a professor of chemistry fitted Millers chemical spectroscope on to his telescope. By comparing the spectra of the stars with the spectra of flames it was possible to find the chemical constitution of the stars. Huggins's observatory became like a ~~chem~~ labratory as it became fitted ~~up~~ with with Miller's chemical & physical apparatus. This new astronomy had in fact become a branch of ~~chem~~ physics. The spectroscope when combined with the telescope became as important an instrument of astronomical research as the telescope itself. The constitution of the sun stars, & nebulae, & planetary atmospheres was ~~be~~ found. Some nebulae gave spectra similar to stars & were thus known to be masses of indistinguishable ~~mass~~ faint stars while other nebulae gave spectra characteristic of a gas glowing under low pressure. More accurate spectroscopy ~~also~~ gave all sorts of information such as the velocities of approach or recession of stars & the expansion ~~of~~ & contraction of variable stars & the rotation of double stars too close together to be seen separately.

Photography, a technical biproduct of science, gave as much help to astronomy as did the new sciences themselves. The technique of photography became as necessary to astronomy as the telescope. Telescope observations were almost entirely made with photography instead of ~~the naked~~ ~~ey~~ with the eye, as a consequence the amount of observation was increased enormously. Powerful new methods of observation were created. Particularly important was the photography of spectra (by Huggins) star mapping by photography & the photographing of faint nebulae by Common & Roberts. ~~As~~ improved photographic materials became available new astronomical advances ~~bec~~ were made possible. The development of photographic method was not made out of theoretical interest (the nature of the processes involved has not yet ~~never~~ been fully understood) but were made ~~for~~ ~~to~~ to increase the sales of photographic manufacturers.

Astronomical Photographic technique generally meant long exposures with ~~big telescopes~~ slit scopes which had be moved ~~very accurate movement of big telescopes~~ very accurately on their mountings. It was thus necessary even more than before to use the very best engineering methods for making telescope mountings.

from Germany. Bessel, who had ~~learnt~~ been trained in arithmetic in a mercantile office, evolved a new method of combining ~~the~~ astronomical observations so that errors were made a minimum & he also devised improved methods of dividing circles. The combination of Bessel's & Fraunhofer's improvements made it possible to measure the positions of stars so accurately that in 18__ the long sought victory of measuring the distances of ~~the~~ the stars was achieved. ~~Telescopes continued to be made larger & better.~~

After Fraunhofer the secrets of optical glass manufacture spread to England & France ~~were spread,~~ but were confined to ~~to cert~~ a very small number of ~~few~~ manufacturers. ~~in England and France.~~ Refracting telescopes were needed in larger sizes for the same reasons that Herschel had made reflecting telescopes; bigger telescopes meant better definition and ~~more light~~ ability to see fainter objects. The glass manufacturers learnt to make larger discs of glass & soon telescopes of over 30" diam were made. ~~At the same~~ But as the size of telescopes increased so did their ~~price~~ cost & the ~~price~~ cost of the large lenses & the telescope mounting became enormous. For this reason the ~~help given~~ finance of telescope making by ~~the~~ the millionaires in America was a very important factor. ~~endowment~~ It was not merely ~~a question~~ necessary to have one big telescope but many large telescopes,

P.T.O

the rate of advance of astronomy being proportional to the number of telescopes. In 1861 no achromatic telescope exceeded 15" diameter, but by 1900 there were 41 over 15", 23 over 20", and 5 over 30".

Parallel with the developement of the refracting telescope was the developement of the big reflector. The improvement of the refractor depended on improvement of the material of the large lens and in a similar way ~~by~~ the reflector was improved by the use of better materials for the large concave mirror. ~~For~~ The French physicist Foucault found in 1856 that he could deposit chemically a film of silver on a glass mirror. These silver on glass mirrors reflected almost twice as much light as the older speculum metal. ~~For~~ ~~Also~~ the Again ~~Also~~ the rapid tarnishing of ~~the~~ speculum metal mirrors of Herschel, Lassel etc. had been a serious disadvantage as repolishing necessitated repeating the laborious process of ~~making~~ the accurate ~~mirror~~ surface of the mirror. But when a silver on glass mirror tarnished, the silver was easily dissolved ~~away~~ off and a new film deposited. After Herschel the ~~developement~~ refractor had, in the hands of Fraunhofer, become ~~the~~ superior to the reflector. but silver on glass mirrors gave the advantage rather to the reflector. Foucault also devised the first scientific methods of making a true ~~surface~~ parabolic surface for the concave mirror of the reflector. This was very important for now any skilful & persistent optician could be sure of making a telescope which would define as well & even better than the best of Herschel's telescopes.

The size of reflecting telescopes increased steadily through ~~two~~ diameters ~~sizes~~ of 2 foot, 3 foot, & ~~four~~ six foot ~~sizes~~ * ~~the~~ Today a 200" mirror is being made. Pyrex glass mirrors coated with ~~an~~ aluminium ~~coa~~ films are the most modern developments only made possible by the highly developed modern scientific & electric technology. The pyrex glass keeps a constant shape & the aluminium reflects ultra violet light which can be photographed & is very important for spectroscopy.

* Dr Common was a pioneer in the use of big reflectors.

~~Economics of 19th Century Astronomy~~ aspects reasons that it always has — to provide data for mapping, navigation and time. Today wireless time signals are kept accurate by astronomical observations, and the Nautical almanac is produced under the direction of the Astronomer Royal. The directly practical astronomy became in the 19th century concentrated in a small number of government observatories But professional astronomers in other observatories have also done a very great deal of routine positional astronomy because such work is basic to the newer astronomical studies.

A7.

The new developments in 19th century astronomy had no direct economic link with the Industrial Revolution. The Explaining kind of astronomy begun by Herschel was in many ways an intellectual luxury

Towards the end of the 19th century capitalism became more highly organised & rationalised. Finance & industry began to work together ~~in~~ & form big monopolies. There was a more conscious realisation of the necessary part which science played in industry. For this reason new universities & ~~more~~ technical schools were formed & Science was made part of education. Science began to be an Institution organised in state colleges, universities & industrial laboratories. Astronomy was included in this organisation. Leading astronomers now had no need to function as amateurs, they were instead directors of big ~~ast~~ observatories & professors in Universities. Another reason why amateurs astronomers ~~ceased~~ became less important was that astronomy began to need more elaborate techniques & a ~~more~~ through training in physics & mathematics.

<u>Millionaires & mountain observatories</u>

A 1 2 17

Because
~~For the very reason that astronomy became most~~ expensive

Because astronomy became most expensive and regular funds were still ~~very~~ meagre, patronage by private individuals was ~~became~~ an important factor. Money was now concentrated in the hands of capitalists & not kings ※ In America specially it became the custom for millionaires with a social conscience or a desire for publicity to finance astronomical observatories.
※ (Carnegie & Smith founded the Carnegie & Smithsonian institutions which were a help to science generally). Although astronomy began rather suddenly in America it developed rapidly being assisted greatly by the excellent climate. Atmospheric conditions at observatories on the mountains ~~near~~ along the Pacific Coast were immensely superior to those in Europe. In 1876 an excellent mountain sight for a new observatory was chosen by James Lick the millionaire of San Francisco. 700,000 dollars of Lick's money maintained the observatory & provided it with the great 36" refracting telescope then the biggest in the world.

Mr Yerkes of Chicago in 1892 offered an unlimited sum ~~of money~~ for the making of a "superlative" telescope. The result was the 40" Yerkes telescope the biggest refractor ever built. Lowell was the one american millionaire who actually made astronomical observations. He founded Lowell Observatory specially for the study of ~~the planet~~ Mars. for he believed he had evidence of the existence of intelligent beings on that planet. Millionaire Hooker wished to provide a memorial to himself & his wife & ~~he~~ considered building a stone pillar in the middle of the Pacific ocean before he was persuaded that a 100" reflector would be a better monument & would be of tremendous help to astronomy. Thus the biggest telescope in the world was built on Mount Wilson. Dozens of other big telescopes & observatories have been financed by American millionaires. While government funds have played their part in providing for astronomy the advances of modern astronomy depend for the greater part on the bequests of millionaires to the American mountain observatories. ~~in~~

47. advances in astronomy. The important astronomers were now directors of big observatories & professors in Universities. But the wealth of individuals was still an important factor. It became the custom for millionaires to finance observatories. ~~An important characteristic of astronomy in the late 19th & the 20th century was has been the finance of observatories by millionaires.~~ This custom, for ~~such it has become a custom~~, ~~resembles the patronage of astronomy by mediaeval rulers~~. The last example of Royal patronage had occurred as late as ~~been in the beginning~~ well into of the 19th century & had was on a particularly grand scale. It was This ~~mediaeval~~ persistence of medievalism & occurred naturally in Russia as one of the most economically backward countries in the world ~~Europe~~. The Tsars were not content with one observatory but made two — Dorpat & the famous Pulkowa.

Half a century later monopoly capitalism was flourishing in western Europe & America & ~~many~~ money was concentrated in the hands of capitalists & not kings. ~~such men came into being~~. ✳ Although ~~astronomy~~ it began rather suddenly astronomy developed rapidly in America & was assisted greatly by the excellent climate. Atmospheric conditions at observatories on ~~the~~ mountains near the Pacific Coast ~~far surpassed~~ were immensely superior to those in Europe. In 1876 an excellent mountain sight for a new observatory was chosen by ~~the~~ James Lick the millionaire of San Francisco. Lick's $700,000 of money maintained the observatory & provided it with the great 36" refracting telescope then the biggest in the world. ~~In 1892~~ Then

✳ ~~Carnegie's immense wealth was collected together & Smith's money formed the Smithsonian Institution~~

✳ The wealth ~~money~~ of Carnegie & Smith founded the Carnegie & Smithsonian Institutions which have given great help to astronomy & science generally.

Modern Astronomy.

Very far reaching advances in astronomy have been made in the last century as a result of new developements in physics. At the beginning of the 20th century physecists like Rutherford were in a position to explore the structure of the atom. And by the quantum theory ~~to~~ Bohr correlated the structure ~~which~~ of an atom with the light it radiated. ~~&~~ ~~Extension~~ These ideas enormously increased the usefulness of spectroscopy. ~~By the~~ The extension of quantum theory lead to definite ideas of how atomic structure & the light radiated from an atom would alter in gases at various temperatures & pressures. The kind of light radiated from sparks, ~~&~~ arcs & furnaces agreed with these theoretical predictions. These ideas were then extended to interpret the spectra of the stars & the sun & with many other ideas drawn from ~~so~~ different branches of physics & chemistry a general theory of the constitution of stars has been built. This science called ~~of~~ astrophysics begun by Huggins with his spectroscope now makes it possible to calculate the temperature, mass, size & distance of a star from data derived from its spectrum.

Modern astronomy is closely connected with the general body of science. New scientific & technical tools ~~such as are developed by astronomy~~ when made available to astronomers ~~are developed by astronomers and~~ become indispensable for new advances. Examples are the diffraction grating, the bolometer, the aluminised mirror & the photoelectric cell. ~~Then~~ Also there are direct connections between terrestrial physics & astronomy, sunspot activity & radio interference are correlated, & attempts are made to connect cosmic rays with stellar radiation, and Lockyer discovered the new element helium in the sun before it was found on the earth. ~~All the~~ On the theoretical side all the new fundamental principles in physics become part of astrophysical theories & in return astronomical observation provides data on which generalised & fundamental physical theories, such as relativity theory, can be based. Also, astronomical bodies contain matter in all sorts of conditions such as extreme pressure & temperature which cannot be produced in terrestrial laboratories and ~~in~~ astrophysical work in this way resembles the work of physicists at low temperatures, low pressures, & high voltages. Such work increases our knowledge of the fundamental properties of matter & reveals new prospects of the utilisation of natural forces. ~~A further~~ Another aspect of modern astronomy deals with the evolution ~~& changes~~ & changes of stars & nebulae. As the sun is a star information is thus obtained about the evolution of the solar system and the earth. This work overlapps with geological study of the evolution of the earth & in this way astronomy ~~links with~~ becomes part of the general study of the growth of the earth, living matter, & man.

At the same time as these new developements are taking place in astronomy the old routine positional astronomy has to remain for the old reasons, ~~that~~ ~~namely~~ for ~~of~~ providing data for mapping, navigation, & time. Today wireless time signals are kept accurate by astronomical observation, & the Nautical Almanac is produced under the direction of the Astronomer Royal. The directly practical astronomy is now concentrated in a small number of government observatories, but professional astronomers in other observatories also do a very great deal of routine positional astronomy because such work is basic to the newer astronomical studies. The considerable amount of laborious routine observation in astronomy is a characteristic not present in many other sciences. Another characteristic is that there is no economic profit to be gained from astronomical work; there are therefore no commercial research laboratories which work in secrecy or semi secrecy. Again a very great deal of astronomical work such as Star mapping has to be ~~done~~ ~~organised~~ performed on an international scale. For these reasons astronomy has become the one branch of science ~~specially in the~~ in which research is to some extent at least organised & coordinated. Thus The International Astronomical Union meets at an international congress every three years to decide what the most important problems ~~are~~ facing astronomy are, & what are the best methods of working & specially in the routine fields to coordinate work & avoid overlapp.

Revolutionary nature, steam era. unpredictable. (electricity for nothing [fanciful thinking]. end of civilisation
world government. (relation between scientific & political) reality of political Capitalism / socialism
Nature 3 forces. compactness 10^6. per human effort. scientific indirect.
The atom unit of matter. elements. compounds & molecules. strength gas solid
living matter. The inside & outside isotopes. uranium isotopes. only element
Pu made from U in slow explosion. (nature of chain reaction) critical size.
Bombs. U_{235} & Pu size. isotope separation weight only (centrifuge diffusion
e.m. jet of charged atoms) Size of plant. Pile $U_{238} \to Pu$. Peace & War intermixed
Distribution of U & Th. Solar energy. → coal & oil etc.
Peacetime application ① power stations economics 40% saving, electricity. heating.
small units. new areas rocket high temperatures. blasting. coal running out
British plan.
② Medical. radium I* hyperthyroidism P^{32} leukemia. polycythemia vera.
tracers labelling. intake & exit. drugs & hormones. Photosynthesis $CO_2+H_2O+\mu \to$ sugar
③ Physics research. energy of sun.
War 2000 tons. various actions. counter measures. surprise. mines. end of civilisation
dispersal safety in armies. Russia. preventive war out.
Political ① Saved trust ② American scientists campaign Smyth report.
~~Bar~~ no secret some control essential. inspection possible. S.
Baruch plan control of mining & large energy plants
Russian plan outlaw & destroy stockpile free use for peace.
American view giving up secrets in stages. U.S. start of materials
U.S.S.R. security in secrecy of plants. Veto. economic influence
Breakdown Suspicion. Build up British plan.

~~200,000 tons~~.

Revolutionary nature steam era. unpredictable. electricity for nothing end of civilisation
world government reality of political – capitalism – USA
socialism USSR.

Nature ~~The atom. unit of matter. the elements~~

chemical & nuclear force. compactness 10^6. per human effort. scientific indirect effects.
The atom. unit of matter. the elements. compounds & molecules strength gas & solid living matter
The inside & outside. isotopes. Uranium isotopes only element. Pu made from U in slow explosion. Bombs. U_{235} or Pu critical size isotope separation size of plant.
Pile $U_{238} \rightarrow Pu$. Peace & war intermixed. Distribution of U & Th.

Peacetime applications ① power stations economy 40% saving electr. heating houses. small units. polar areas. rockets. high temperatures, blasting. Coal running out British plan

②. ~~Biologicals~~ medical. radium I hyperthyroidism P^{32} leukemia. Polycythemia vera.

③ Tracers. labelling intake & exit drugs & hormones. Photosynthesis $CO_2 + H_2O + \mu \rightarrow$ sugar.

③ Physics research. Energy of sun.

War. 2000 tons, various actions, counter measures. surprise. mines. end of civilisation
(750 bombs on Germany.) Dispersal. safety in armies. Russia. Preventive war out

Political. no secret. some control essential. inspection possible.,

Baruch plan. – result of scientists propaganda. control of mining & large energy plants.
Russian plan. outlaw & destroy stockpile free use for peace.
U.S. short of raw materials. USSR. security in secrecy. handing over of information in stages.
Atom bomb not in isolation as part of disarmament.

Biological application

hyperthyroidism · iodine

Polycythemia vera P^{32} · excess red blood cell production

Leukemia excess nonantiinfective white cells P^{32}

Power ·

Chem Intermediate compounds

Function of drugs & hormones

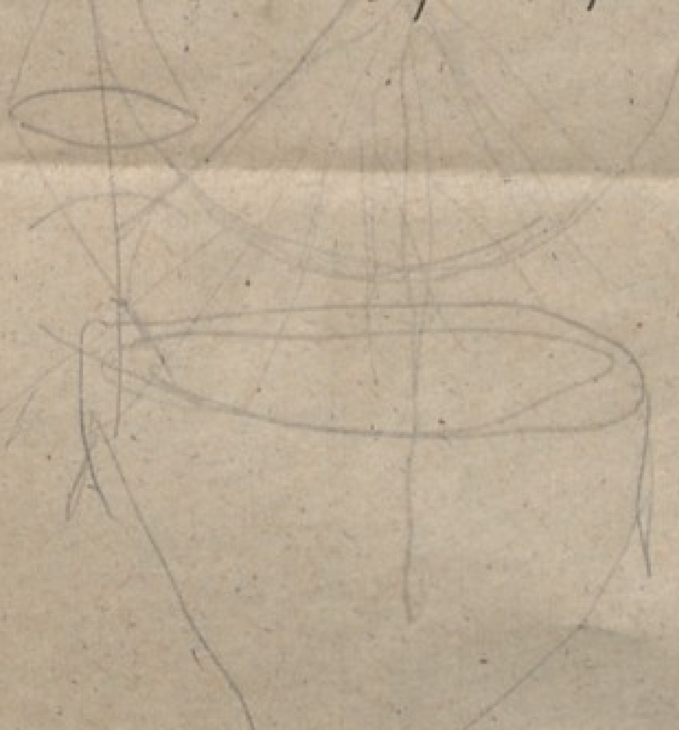
Human body changing

* · Photosynthes CO_2 H_2O + μ → sugar ·

Flow of blood ·

Patable X ray sets ·

small traces for analysis



electricity for nothing
Revolutionary nature steam era. unpredictable. end of civilisation. world government
No visionary thinking reality of capitalism US / socialism USSR
Nature The atom inside & outside chemical & nuclear. compactness. per human effort. scientific importance

atoms & molecules
isotopes
chemical & nuclear force
Radioactivity.

Uranium. 2 kinds of inside. Only element. Pu made from U. in slow explosion.
Bombs. U_{235} or Pu. critical size. Isotope separation. size of plant.
Pile $U_{238} \rightarrow Pu$. Peace & war intermixed. Pu denaturing.
Distribution of U.
Peacetime applications. power stations economy. small units. new areas.
rockets. medicine & physics. Coal running out. British plan
War 2000 tons. various actions. counter measures in general. surprise.
mines in cities. end of civilisation 750 bombs on Germany. ~~Safety~~ o
Dispersal. safety of armies. Russia. Preventive war out.

Political (1). Sacred trust.
(2) AASA. propaganda. no secret. Synth Report. May.
(3). U.N.O. commission.
(4) Baruch Plan no certainty it goes thro'
(5) Russian Plan. outlaw. destroyal of stockpile free use for peace. national control.
Position (4) + (5). Veto question. continuance of manufacture. America decides on amount of information handed over in stages. destruction of stockpile indefinite. Raw materials first stage. U.S. short of materials. Secrecy of USSR. towns.
Immediate war unlikely or control.

40% — cost of el
avail. of radioisotopes
750 bomb on Germany
British plans.
Fuel 238 + 235.
Pamphlets.
Recent dev.

half ½ Moon 75. Mrs Goldberg or Ted Arnley.
Write to Moon for form

Int control & inspection essential
political approach.

New yardsticks   prediction.

<u>Nature of N.E.</u>   3 forces ^sun's E^. compactness. per unit human effort.

scientific importance.

<u>Peacetime applications</u>   power stations, small units, new areas. climate.
slow explosion   rockets. medicine + physics.

<u>Possibility of coal</u> running out   doubled in 10 years for 50 years.

<u>War</u>   1000 bombers. decrease in size of world. saturation.

countermeasures in general. surprise. mines in cities. dispersal.

[<u>E. source + society</u>. agriculture (landowners). slave. sailing boat (mercantilists). water. coal (industrialists).

electricity. petrol.   Rapid { scientific / social → Ruling class.

<u>Present changes</u>. international science organised. Nazi Science. Roosevelt.

Too big for private enterprise → socialism. ≠ individualism. → International.

Arms race spies + secrecy

U.N.O. commission. 1 ~~interchange of basic scientific information~~

a. for extending between all nations, the exchange of basic scientific information for peaceful ends

b. for control of atomic energy to the extent necessary to ensure its use only for peaceful purposes

c. For the elimination from national armaments of atomic weapons & of all other major weapons adaptable to mass destruction.

d. For effective safeguards by way of inspection and other means to protect complying states against the hazards of violation & evasion

<u>Effect on scientists</u>   1. technical realisation

2. conditions of work. freedom necessary. scientific incentive

<u>State Dept Committee Report</u> 1. 5 year period   3 year period. Policing.

International   illegal activities { 1 mining
2 prod. U^{235} & Pu. ½ power
~~3 Research on bombs + nuclear phys~~ Secret.

national { small power ½
research. medical + nuclear.

International Research → policing.
Development equally divided
<u>Safety at all stages of sharing.</u>

Radical ideas. Difficulty of digestion. Britain today dlbosmani

Bombs: . fast explosion.

Material. ① Isotope separation - EM. etc.

② Plutonium. Non fission capture in U^{238}. slow neutrons.

$$ {}_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{92}U^{239} \rightarrow {}_{93}Np^{239} + {}_{-1}e^{0} $$

$$ Np^{239} \rightarrow {}_{94}Pu^{239} + {}_{-1}e^{0} $$

chemical separation
xenon & I high stack.

Power.. water cooling.
Remote control. . no pilot plant.

Design of bomb. → (|) ← a few pounds. Size of upright piano.

tamper
reflector. efficiency a few %.

1. blast.
2. heat
3. γ rays
4. radio: material

350 times area of blockbuster 10 sq miles.
~~350 times area~~ = 1000 blockbusters for area.
$\frac{1}{5}$ less efficient for blast but heat in greater proportion
Cost for explosive effect $\frac{1}{100}$ - $\frac{1}{1000}$ TNT.
cost of war $\frac{1}{10}$ - $\frac{1}{100}$

1. Shock wave
2. wind.

1 sq mile brick buildings
. . . . γ ray deaths
4 sq miles scorch wood. γ rays 3 weeks.

~~3~~ Saturation of defences.

Defence.
1. Specific
2. radar
3. IFF
4. homing rockets
5. Surprise
6. 70% afterwards.

underground
dispersal.

Mines in cities. Countermeasures in general. Decrease in size of world.

Balance of power gone.
Saturation in attack. limit to no. of bombs useful.

1. blast
2. heat
3. γ.
4 rad. gas

Saturation. 1% in stars.

$\frac{1}{350}$ area blockbuster for ~~a[illegible]~~ ≡ 1000.

Attack. burning. reinf. concrete. 3 weeks 12 days. — Small fraction concealed

1. Shockwave
2. winds

1 square mile brick built

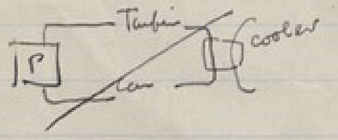
large prop. in heat.

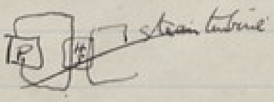
scorch wood 1 mile away

γ ray deaths

1lb U. ≡ 1400 tons Coal. 13,000 TNT

1lb matter ≡ 1.5×10^6 tons coal





·4 mech power ($\frac{1}{2}$ stationary)

·2 non industrial heating

·4 industrial ..

sunlight equiv. coal 15 days.

U known 30,000 years

U est 3 mins

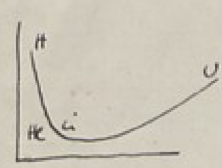
Cost of power $\frac{1}{10}$ – $\frac{1}{100}$

Cost of explosive $\frac{1}{100}$ – $\frac{1}{1000}$

$\frac{1}{5}$ less efficient blockbuster for blast. only lots heat.

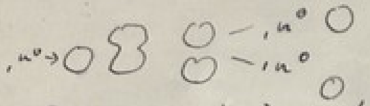
Defence
1. spec.
2. radar
3. IFF.
4. homing rockets
5. Surprise.
6. 90% afterwards

Neutron 1930. no repulsion – penetration
Artificial radioactivity 1934 — ~~more electron~~.
~~Fission~~ ~~Finish heavy~~. 



combining light $4H + H \to He + {}_0e^{+1}$ 1%
splitting heavy. 0.1%.

need for chain reaction.

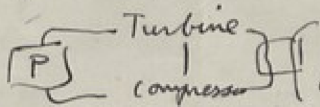
Neutron. no repulsion slow neutrons very effective
Fission  excess neutrons escape.

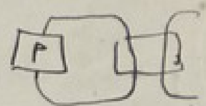
chemically. chain reaction.

Only fast for U^{238} ineffective.
fast or slow U^{235}
Critical size escape, impurities, non fission capture.

1939 Roosevelt. Bomb fast neutrons U^{235} for small mass.
Peace time slow neutrons controllable.
without isotope separation. moderator. lattice.

Piles Dec 2 1942.
Moderator C or heavy water. good loss at each bounce.
Cooling helium water liquid Bi.
Coating of U. Al.
Shielding products give γ & β rays.

Power stations. 



Cost of fuel. 1/10 cost electricity is in ~~pe~~ fuel.
~~New areas~~

Supply. sunlight equiv. coal 15 days
U estimated 30,000 year
U known 3 mins.

Possibility of coal running out if doubled in 10 years for 50 years.
Higher standard of living
g. 40% mech power ½ stationary
g. 20% non ind. heating
l. 40% industrial heating

New areas.
Min weight. locomotives.
Rockets.
Medical applications

Stellar power

Out of Calthrop

Width of slit by Michelsons method.
Estimate temperature of flame.