DAWN OF THE SPACE AGE

By

HARRY HARPER

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DAWN OF THE SPACE AGE

FOREWORD

by

KENNETH W. GATLAND

Co-Founder, Combined British Astronautical Societies

It is a particular pleasure for me to write a few lines as introduction to this book, since it is the first popular writing to embrace, in any way fully, the new and intriguing possibilities of the rocket and its peace-time implications.

As many of his readers will be aware, Harry Harper is the pioneer journalist of aviation—he became Britain's first air reporter and was Air Correspondent of the *Daily Mail* for more than twenty years. With these qualifications, he has brought the language of flying to the general reader in simplified, readily-assimilated terms.

It is only natural, therefore, that having witnessed and recorded the entire evolution of heavier-than-air flight, Mr. Harper should portray, in that same distinctive style, the ultimate trend of Man's endeavour—the conquest of space.

The science of space-flight, or *astronautics*, is a study to which technicians in each of the principal nations are devoting themselves. Indeed, there have been rocket development groups operative in both the United States and Great Britain for many years. There was, too, a very progressive rocket society in Germany, and in fact, this body was the pioneer of all rocket groups, being founded in 1927. The arrival of the Nazi regime, however, brought free German experimentation to an abrupt close by the posting of a revised explosive law, which had the effect of prohibiting any kind of unauthorised chemical research. Thereafter, rocket development became the particular interest of the Government laboratories, with results which we have witnessed in the Vergeltungswaffe long-range weapons.

Of the rocket societies that still remain, there are four groups of significance in America, and a coalite group in Britain, and this latter body, which I have the privilege of representing here (and which is now merged in the one British Interplanetary Society), has approved this book as the first authoritative, yet wholly non-technical presentation of the astronautical science.

During this second World War, we have witnessed the development of many scientific ideals as weapons, each borne out of conflict and fostered by the unlimited finance and labour that conflict demands. A great deal of this war-time research will certainly be made available for the pursuits of peace, and in its adaptation and further development, we are likely to find much benefit.

Without doubt, the war has brought us a rocket development equivalent to many years of peace-time evolution, for in the V-2 projectile we have the embryonic *space-vessel*. Its inception as a weapon aimed at the destruction of defenceless beings is, indeed, a poor way for an instrument so rich in its potentialities for progress to be introduced to the world, but we must not allow this to blind us to the vast possibilities of its scientific development.

Let us trace briefly the way in which these benefits can be brought about, basing our conclusions on the original performance of the V-2. The rocket's chief attribute for these purposes lies in its ability to project recording instruments to great heights—into the so far unexplored regions of the atmosphere.

Prior to the advent of the V-rocket, the greatest height achieved by any man-made contrivance was 23 miles, and this altitude, reached by a small, unmanned sounding balloon, is not likely to be much bettered by any device dependent for flight on air. For this reason, the rocket is likely to supersede the sounding balloon for most scientific purposes.

As a weapon, the V-rocket carried an explosive load; in the original form, a war-head of something slightly less than one ton, which, in the course of flight, was conveyed to an altitude in the region of 60 or 70 miles. It is obvious that, if the rocket were used essentially for altitude sounding and this weight of explosive replaced by mere *pounds* of delicate recording apparatus, the reduction in carrying load would add considerably to its performance.

It will be appreciated that the V-rocket achieves *height* solely in order to gain *distance*, so that, if the adapted rocket were fired *vertically*, with the sole aim of reaching altitude, it would prove highly effective. It has, in fact, been calculated that in this form, the rocket would achieve an upward range of about 150 miles.

Assuming the development of a rocket having the same relative performance as the V-2, but of slightly increased size, we can proceed a stage farther. A rocket of the required characteristics would entail no new manufacturing processes or more "powerful" fuel.

For this experiment, a further rocket would be needed, one considerably smaller, of about two tons weight. The large "carrier" rocket would have a flat nose, and to this would be attached the small rocket, making in effect one projectile having two independent parts, each part bearing fuel and motor.

In the launching, the larger rocket would be fired first, carrying the small component at great speed beyond the atmosphere and out into frictionless space. It is in vacuum that the rocket operates at its highest efficiency. Then at the "carrier" projectile's greatest velocity, the smaller rocket would be fired and released by an automatic device. Already travelling with the speed of its parent rocket, the two-ton component would accelerate away and, with its inherent power, overcome the earth's gravitational influence, escaping into outer space, never to return. Projected thus far, it could be so directed to crash on the Moon, if such a demonstration were desired.

The "carrier" rocket, having served its purpose, would then drop back to earth under the influence of gravity, and in order to minimise risk to life and property, it would be necessary to employ a parachute, or similar alighting gear.

It is of further interest to point out that if the two-ton rocket, having released from the "carrier" projectile, were designed to reach what is known as the *orbital velocity*, in horizontal flight outside the atmosphere, it would circle the earth for all time, just as the earth circles the sun. Indeed, this is a far simpler proposition than the actual *escape* from earth, and for many scientific purposes, it would be a great deal more beneficial.

Although the V-rocket's power plant is a far cry from the rocket units which the societies produced prior to the war, it should be remembered that the cost of such large-scale research as has gone into the development of the Nazi weapon is rated in millions, as against merely a few pounds raised by group subscriptions in the days of "private enterprise".

The development of the V-rocket along the lines suggested cannot take place without adequate financial backing; the knowledge and the technical ability are at hand, but the enormous sums so easily blown to nothingness in war are not so willingly staked on peace-time researches, with their attendant benefits to the world at large.

Correctly developed, the rocket would be capable of virtually doubling our present knowledge of the state and nature of the atmosphere, making possible forecasts of conditions that will exist much later, at lower levels. This would have the effect of raising meteorology to the status of an *exact science*.

The advantages to be gained from the dissipation of accurate, long-range, "weather data" are obvious in that weather has everyday influence upon our lives. To the farmer and his crops, precise knowledge of future atmospheric conditions can mean the difference between complete ruination, or a bumper yield. Transport would find greater safety and reliability; and there are scores of other advantages that come readily to mind. There is, in addition, much advantage to be gained from the investigation of electronic phenomena, principally the *cosmic ray*—but this subject is hardly within the province of this popular treatment.

With the development of the atomic bomb, we have the implication of vast energies available for propulsion, not only adequate for all terrestrial purposes, but also capable of fuelling the most enterprising "interplanetary space-vessel".

In principle, the reaction engine is the simplest means of converting the atomic energies into motive power, and it is logical to assume, therefore, that once the disruption of the Uranium 235 isotope—one of the elements that can be used—can be moderated sufficiently, the space-vessel will be evolved almost as a matter of course.

The research now being pursued toward harnessing the atom, however, is not likely to find quick solution. It has been estimated that the refinement will involve between ten and fifty years of industrious work—though perhaps nearer ten than fifty; and the cost is expected to run to a similar amount as that already expended on the atomic bomb.

There are likely to be a number of further problems associated in this development, namely, heat, pressure, and the emission of harmful radiation—all produced in great intensity. These may be such as to delay the application of atomic power for a further period of several years, or even to render its adaptation impracticable for many purposes.

One conclusion, however, is certain. It is that the research into controlling atomic energy will be pressed with all speed. Its importance is such to rival all other requirements of finance and labour, desperate though these may be.

It is not merely a matter of improving commercial and specific power services. Great though its implications may be for these purposes, the refinement of atomic power is itself a matter of international importance, such as to hold every possibility for commanding future world security.

The foregoing is some slight illustration of what can be accomplished by the adaptation of mechanisms that have been proved and are either available, or technically possible to-day. For all this, the discussions may appear somewhat visionary to the reader, gaining in these pages his first experience of the subject. The ultimate aim of interplanetary communication is admittedly not an ideal likely to find accomplishment within the space of a few years, or indeed, decades, for astronautics as it stands to-day is very much an infant science, in many ways analogous in development to aviation in the pioneering days of Henson and Stringfellow. At the present time, the primary aim is to hasten this ultimate evolution by the development of the rocket to more immediate benefits, such as the altitude sounding rocket, and the terrestrial rocket for transport purposes.

Once the atomic rocket engine is developed, however, not only will the possibility of ultra-rapid, long-range, transportation of passengers and light freight become reality, but by the same token, so also will the *military* atomic rocket.

In this further development, we have the example of an instrument that would be an unparalleled force in the hands of an aggressor. It requires no great power of imagination to conceive what the scale of destruction would have been if the V-2 rocket had contained an atomic war-head.

This does not, of course, mean that through the results of peace-time research, further perversion of the rocket will result. It is to the United Nations that the world must look to keep the rocket and all foremost weapons of modern war in such a high state of development that no nation, or group of nations, will ever again dare to challenge the peaceful way of life.

It is the aim of the rocket societies to direct the rocket's vast powers to the benefit of mankind, and in the gaining of this ideal, we on this planet will have travelled the road to the greatest of all achievements.

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PART ONE

THE STORY OF THE ROCKET, AND THE COMING OF ATOMIC POWER

I

INTRODUCTORY

Even in these days of thrill and drama, with fact so often outstripping fiction, man's greatest adventure still lies before him. It is an adventure on which scientific progress, and the development of atomic energy, is now throwing fresh light almost every day.

Already we have conquered land, sea, and the lower zones of the air, and have begun to penetrate the stratosphere.

But we have still to conquer outer space. It is this that will be our greatest adventure.

The world still awaits the departure of a space-vessel, driven probably by atomic power, on a 240,000 miles' flight to the Moon which, if successful, should be followed in due course by voyages to Mars and Venus, and by the dawn of an age of interplanetary travel.

No longer just a dream, this!

Far from it.

It is now a definite, well-defined problem to which scientists, chemists, metallurgists, wireless experts, and other technicians are devoting themselves seriously.

In Britain we have our Interplanetary Society which is well representative of science in its various aspects, and of specialised engineering in its different forms. In America they have societies and organisations which are devoting themselves to the study of rocket flight for meteorological and scientific research as well as for interplanetary communication. In Russia, where much fundamental rocket research has been carried out, there are clever people who are studying keenly the possibilities now opening up in the use of rockets for upper-air soundings and for preliminary explorations into outer space.

The same applies to France and other countries. This quest is too big to be the concern of any one group of individuals, or of any given country. Its interest is universal, world-wide. It fires the imaginations of people everywhere.

The aims of our Interplanetary Society, which has local groups in different parts of the country as well as headquarters in London, are to promote the development of interplanetary communication and travel, and to do this by a study of the sciences of thermodynamics, mechanics, chemistry, astronomy, electronics, physics, and by the organisation of research and experimental work.

It is sought to obtain further knowledge of conditions existing in the upper atmosphere and beyond. It is intended to develop manned and instrument-carrying rockets capable of being projected in and beyond the earth's atmosphere. It is proposed to develop reaction propulsion systems capable of application to rocket apparatus of various types. In addition to such studies as these, the Society will make a survey of the problems of the control and navigation of machines moving in outer space. It will investigate conditions on the surfaces of the planetary bodies of the Solar system, the design of equipment and instruments for interplanetary travel, the physiological and mechanical problems associated with space-flight, and the technique for the computation of interplanetary trajectories.

As with the aeroplane, so with the rocket. At first you have crude machines little more than suggestions of the perfected apparatus which human ingenuity devises stage by stage. The tiny one-man plane of the Wright brothers has evolved into our jet-planes and great multi-motored flying transports. So it will be with the rocket, which will evolve from a projectile-like apparatus, such as the V-2, into a machine which will become a passenger-carrying space-vessel of highly advanced design—a specialised machine embodying all that the science and engineering of the future can furnish in the shape of featherweight metallic alloys, of plastic materials, of perfected atomic power-plants, and of ingenious instruments and other devices evolved for space navigation.

The great spaceships of the future should be slim, gleaming, beautiful machines in their external appearance, while within they should be marvels of compact, ingenious, highly-developed mechanism, with quarters for their passengers and crew which should make space-travel not only meteor-like in its sheer swiftness, but providing also every comfort and luxury for those who, when this dawning space age has become an accomplished fact, will be setting out on their interplanetary journeys just as to-day we voyage here and there in winged machines about the surface of the earth.

Man's ambition to conquer space, and by so doing throw fresh light, if he can, on some of the riddles of the universe, is a natural sequel to his amazing achievements in so many different fields—to the development of the motor-car, of the flying machine, and of wireless and television; to say nothing of all the other rapid progress in so many of the realms of science and of chemistry.

We have had an age of steam-power, an age of electricity and of the petrol engine, and an age of the air, and now with the coming of atomic power the world should, in due course, find itself in the space age. And this should be the greatest age of all.

One might say of science that it practically refuses, now, to admit the existence of the word "impossible". The progress of science, of chemistry, and of engineering in many specialised directions, is now so swift, so never-ceasing, that what seemed almost incredible yesterday has become nearly commonplace to-day; while what we are wondering at to-day will be a matter of routine to-morrow.

For the exploration of space the ideal machine is the rocket. Already we have been given an inkling of its potentialities in war, and in our now-dawning era of peace it will be up to us to show not only what it can do in the conquest of space, but also in a further immense acceleration of urgent long-distance terrestrial transport.

An aeroplane has crossed the Atlantic in a few minutes over five hours.

A passenger-carrying rocket of the future should do it in an hour, and a rocket carrying mails only in less. Which makes one think again those words Shakespeare put into the mouth of Puck in *A Midsummer Night's Dream.*

"I'll put a girdle round the earth
In forty minutes".

Fantastic—a flash of the imagination—those words have seemed till now. But in the era of space-flying rockets, driven by some form of atomic power, will they still seem far-fetched?

I hardly think so.

II

THE RELEASE OF ATOMIC POWER

So immense and far-reaching are the possibilities opened up by the advent of atomic power that some of them are, even now, only just beginning to be realised.

One of the greatest of the triumphs on the horizon of science, but one about which, so far, comparatively little has been heard, concerns the possible application of atomic energy to rocket machines intended to penetrate beyond the earth's atmosphere and voyage out across space.

What the release of atomic energy means, in regard to space flight is—to put it briefly—mainly this: when it can be controlled and applied to the propulsion of a man-carrying spaceship it should give us, within practicable limits as regards weight and size, that enormously concentrated form of energy which must be available if a machine is to be driven up until it overcomes the retarding pull of the earth's gravity—and is free, let us say, to pass out beyond the gravitational influence of this globe into that of the moon, and after that to approach and descend on the lunar surface.

It is this problem of developing an enormous power output in a machine which, if it is to be launched without difficulty on a flight to the moon, and then re-launched by its crew, on the lunar surface, for a return to earth, must not be unduly heavy, or of too great a size, which has up till now been one of the chief headaches for those who have been studying seriously the navigation of outer space.

It is not as though, on landing on the moon, the lunar explorers would find fuel there with which to replenish their spaceship for a return to earth. The moon is bleak, barren, airless, and devoid of life; which means that when a space-vessel sets off from this earth it will have to carry with it sufficient fuel, whatever form this may take, for an out-and-return flight of 240,000 miles each way.

Without going into technicalities, which it is my intention to avoid, it may be said that after a considerable research, and prior to the now almost incalculable potentialities of atomic power, two methods had suggested themselves for propelling any man-carrying rocket or spaceship over long distances. One was to use such a liquid fuel as employed in the German V-2 rocket. The other was to rely on a fuel of some suitable type in a solid or plastic form.

In the V-2 liquid oxygen and alcohol are fed into a combustion-chamber in the interior of the machine. Here they are ignited, expanded and ejected in an immensely powerful stream through the nozzle in the rear of the rocket; and it is the reaction to this constant rearward gaseous stream which thrusts the rocket forward at tremendous speed.

Here you have the keynote of rocket propulsion—the reaction to the rearward discharge of the products of the combustion chamber, whatever they may be, and the greater the speed at which heated gases can be expanded and ejected the faster will be the rocket's forward speed.

One needs to bear in mind the difference between one of our jet-driven planes and a purely rocket type of apparatus. Jet propulsion needs a constant intake of air and can operate only within the earth's atmosphere. Rocket propulsion works through the feeding into a combustion chamber of liquid or solid fuel, and does not require any air intake, since it carries its own oxygen which is injected with the fuel. Hence a rocket propulsion unit will operate efficiently even in the airless conditions of outer space.

What a big problem fuel has been in space-flight calculations prior to the coming of atomic power, may be judged from the fact that in the quite provisional plans for a 1,000-ton rocket vessel to carry three men to the moon and back, as worked on just before the war by our British Interplanetary Society, it was found that some ninety per cent of the total loaded weight, when starting an out-and-return lunar flight, would be represented by fuel, only ten per cent being left for the crew and all their necessary equipment.

Now, however, the prospect of harnessing atomic energy to the making of a space voyage puts a new and infinitely more favourable aspect on the whole problem. This may be appreciated when it is mentioned that the use of atomic energy may give us a controlled, concentrated power at least a million times more potent than anything visualised hitherto.

Many technical problems, including those of heat, pressure, and harmful radiations, will have to be solved before any atomic plant can be made available for spaceship propulsion. The whole question looks like involving a long and costly research. But already technicians are discussing, in a preliminary way, methods by which this new and mighty power may be employed in rocket propulsion. In one scheme under investigation, it is suggested that there should be fed into a suitable combustion-chamber, one after another, minute quantities of that isotope or constituent of uranium which is our present source of atomic power. In this chamber each of the charges would be made to yield its vast pent-up energy, and this would be discharged instantaneously from the rear of the rocket in the shape of atomic particles travelling with an enormous velocity. These would drive the rocket at speeds far greater than has been thought possible hitherto.

The practicability of such schemes will have to be the subject of prolonged and intensive research. Some experts think a considerable time must elapse before an atomic-actuated engine becomes a practical proposition. Others are more hopeful. Much depends on the funds available for what will be a costly business. Already, however, there is promise of the development of a first experimental type of atomic engine. In this an atomic generator uses the radio-active element U-235 with an admixture of graphite and an insertion into the uranium and graphite of a rod of cadmium metal, the aim being to moderate the amount of atomic energy released. The uranium and graphite "pile" is contained in a large concrete building. Through the pile run pipes containing water. As the uranium is subjected to bombardment by slow neutrons, very great amounts of heat are generated—of the order of thousands of kilowatts. This heat turns the water in the cooling pipes to steam, and this can be used to drive steam turbines, or other suitable power-plants.

What the whole thing boils down to is this: that the titanic power which has so far been released in a single catastrophic discharge must, if it is to be available for peaceful purposes, be harnessed and controlled and made to do useful instead of destructive work.

What those best entitled to speak now tell you about the conquest of space is this: that what was once a dream was, with the development of the V-2, converted from a dream into a possibility, and that now with the dawn of atomic power that dream has grown into something even more possible—into something, in fact, one can now regard as within the realm of the probable. It is believed that with the harnessing of atomic power, and after further research—and how long that period will be nobody can tell—science should be able to achieve what will be its greatest triumph; that of the conquest of outer space; a conquest implying an ability, eventually, of effecting interplanetary voyages, and of making discoveries, away in outer space, which should solve once and for all the problem as to whether or not there is intelligent life on other worlds.

III

ASTRONOMY AND INTERPLANETARY COMMUNICATION

When I made up my mind I would become a student of astronautics, as well as of aeronautics, I found that an equally fascinating subject was beginning to engage more and more of my attention—that subject being astronomy.

This was only natural.

The ultimate aim of astronautics being, as it is, to reach out across space to other planets, it becomes obvious that anyone taking a serious interest in astronautics must also feel he wants to make himself acquainted with all that our astronomers can tell us about those two planets which it seems most likely we may be able to reach in our voyagings across space—that is to say Mars and Venus.

It is the orbit of the latter which brings it closer to us than any other of the planets. At its nearest approach Venus is only approximately 26,000,000 miles away—a comparatively short distance when one happens to be thinking in terms of the general vastness of astronomical measurements.

The planet Mars, when its orbit brings it nearest to us, is about 35,000,000 miles away.

After one's mind has been staggered by contemplating the sheer immensity of outer space, with the distances between us and other planets reckoned in figures so "astronomical" that they cease almost to have any meaning for the human mind, Venus and Mars begin to appear almost like next-door neighbours. As for that faithful satellite of ours, the moon, the 240,000 odd miles which will need to be traversed before we reach it, strike one as being nothing more than a "hop". Certainly one begins to realise the importance our astronauts now attach to the making of a first experimental voyage from earth across to moon. That pioneer space-flight, reckoned to be completed in about 48 hours, or possibly in considerably less than that with an atomic driven space-ship, will be a first test and try-out of all the preliminary researches which are to be carried out by pilotless sounding rockets and by many other means, including the systematic test work necessary with rocket power-plants of various types.

One can take it as being fortunate, from the point of view of astronautical research, that we should have such a body as the moon, situated near enough to make a rocket voyage to it a matter of hours, rather than of the much longer periods necessary to reach more distant objectives away out across space.

IV

A WORD FOR THE SCEPTICS

ONE finds that not all people have similar views as to the desirability, or otherwise, of astronautical research.

When I was explaining some aspects of the Interplanetary Society's quest to a group of people who did not share our space-flight enthusiasm, I was interrupted by one of them who said with considerable irritation:

"Oh, yes, it sounds feasible enough as you put it, but why on earth you fellows want to bother about getting to the moon at all for beats me! What good is it going to do if you do get there? Tell me that."

I mention this because it reveals a state of mind which we who devote ourselves to astronautics still encounter here and there, and sometimes among those one would hardly expect to be guilty, still, of antiquated, painfully short-sighted points of view.

They represent the sort of attitude which, had our ancestors persisted in it, would have doomed us to remain more or less in the early cave-man era.

They are the negation of progress.

In order to ensure safety, and "letting things be as they are", they imply a condition of virtual stagnation: whereas most of the progress the world has made has been the work of those who have been willing to acquire knowledge at the cost of personal risk to themselves.

Why should explorers have risked their lives in seeking to reach the North or South Poles?

Why should men have struggled heroically to scale hitherto unconquered mountains?

Why should air pioneers have taken the risks they did in making their blazing-the-trail flights above oceans?

Why should astronomers dedicate their lives to a patient studying of the stars?

Why should Marconi have embarked on that long and arduous quest to give the world all the wonders of wireless?

The answer in each of these cases is the same. It is to be found in that innate, quenchless spirit of adventure and discovery which, centuries ago, sent our old sea-rovers out across the oceans of the world.

It is the spirit which wants to find out things, which seeks always to add to our knowledge, and to give us a fuller appreciation of the world in which we live.

It is that indomitable spirit, refusing to be daunted or turned aside, which has lifted us out of our primitive ignorance and set us at the threshold of a world which promises an infinitely richer and more varied life.

If our inventors and explorers had listened to those who asked them why they wanted to do this or that, or what good it would be even after they had done it, we should have been denied many of those things which now add to the comfort of our lives, and which make those lives more pleasant and more worth living.

The more we know about our own world, the more we can get to know about the great universe which lies around us, the more interesting and profitable should be the brief spell which each one of us spends here on this globe.

We of the human race, in working out our destiny, cannot afford to stand still. We must either go forward or backward. Primitive man fashioned from a tree-trunk his first crude wheel, and began the great era of land transport. From a tree-trunk also, he managed to hollow out a clumsy vessel in which to move about on the surface of the water. That was the beginning of our conquest of seas and oceans as well as of lakes and rivers.

Man looked up, too, and in doing so envied the birds, and that in its turn, after centuries of effort, led to our conquest of the air. So it all goes on as we move forward through time to that goal which lies somewhere before us, but any sight of which is still denied us. We cannot see what lies on the other side of the hill, but that does not prevent us from trudging hopefully onward and upward. Our air conquest has led us to soar higher and higher into the stratosphere, and on some day that still lies ahead, two or three men, the first of our space explorers, will enter the control-chamber of a giant atomic-powered rocket, and will set off on the greatest of all adventures—a flight across those quarter-of-a-million miles separating our earth from the moon.

It is no use, even if we wanted to do so, trying to put back the hands of the clock of human progress.

That progress marches on!

It is inexorable.

We know in our inmost hearts that we must go forward, that it is not for us human beings to linger idly by the road-side.

There were days, away back in the past, when a sea voyage was reckoned so perilous that passengers assembled at special prayers before embarking. Now our great liners carry their passengers across oceans with all the luxury and security of an hotel on dry land. Not so many years ago, when we in the aeronautical world predicted air crossings of oceans between dawn and dusk, we were looked upon by many people as being not quite right in our heads. But already the Atlantic and Pacific are spanned by air as a matter of routine, and an aeroplane has crossed the North Atlantic not in a voyage lasting a day, as we foretold, but actually in less than five hours. And still we are merely in the infancy of science—merely turning the first pages of the great book of progress.

Just as our ships have conquered the sea, and our wheeled vehicles the land, and just as our flying machines have given us the conquest of the air, so in due course science will give us a form of rocket vessel in which to set forth upon interplanetary voyages.

V

THE ROCKET—ITS STORY FROM EARLIEST TIMES

Apart from some power or force to nullify the influence of gravity, the most suitable machine for interplanetary travel is the rocket, and the ideal power for the rocket is to be found in atomic energy.

In space-flight it is the absence of air which has to be reckoned with. And it is this lack of air which renders impossible for interplanetary travel, as already mentioned briefly, the jet-propulsion principle which has been developed with such success for atmospheric navigation. This jet-propulsion method needs an intake of air through orifices in the front of a machine. Where no air exists it would cease to operate. The rocket principle not only does not rely on air, but will actually be most efficient under the vacuum conditions of outer space, seeing that the presence of atmosphere has a dampening effect on its exhaust, the speed of which has a material bearing on efficiency. The same general principle of reaction is common to both rocket and jet system, tractive motion in each case being obtained by the reaction of the exhaust on the producing plant in accordance with Newton's Third Law of Motion. But whereas the jet system is necessarily limited in its action to the bounds of our atmosphere, the rocket principle is capable of penetrating beyond the atmosphere into space itself; hence its special suitability as the propelling force for any vessel in which it is proposed to voyage out from this earth on journeys to the Moon, Mars, or Venus.

At this point I feel I should like to acknowledge how greatly my researches into rocket propulsion, and space-flight generally, have been aided by Mr. K. W. Gatland, co-founder of the Combined British Astronautical Societies, and Mr. Lionel Gilbert, Director of Research of the British Interplanetary Society, also by the admirable technical notes and data in Bulletins and Journals of the Societies, and in addition by reading books such as Mr. Cleator's *Rockets Through Space*, and Willy Ley's *Rockets*.

In some of his researches into the history of the reaction principle, Mr. Gatland has gone back as far as the beginning of the Christian era to trace the fact that the Alexandrian philosopher, Hero, built an apparatus in the form of a hollow sphere which had two right-angle tubes fitted into it on opposite sides. This sphere was mounted centrally, and revolved on two supports, one of the latter being hollow, with steam entering it from a boiler placed just below it over a fire. This steam, after entering the sphere, made its escape through the two tubes and, in so doing, set up a reaction force which caused the sphere to rotate.

In tracing the earliest known use of any form of combustible material, one comes first to the way in which saltpetre was employed by primitive eastern tribes, probably for the curing of meat; and it seems likely that the possibilities of saltpetre as a combustible substance arose accidentally, perhaps through some being dropped on a fire while cooking, producing a flame which led to its being used subsequently in fire-making, no doubt in conjunction with wood. This, in its turn, may have led to a mixture of saltpetre and partially-burned wood and, later, of charcoal.

It seems doubtful whether sulphur or brimstone was subsequently blended into the mixture, but it appears that some such combination was being used in the East long before the Christian era, and that in Greece at about the same time there was a composition of brimstone pitch, resins, fats and possibly crude saltpetre which was known as "naphtha".

Substances like these came first to be used in war as crude incendiary weapons. They were made up into clay balls, or packed into hollow bamboo tubes, and then set alight and thrown at the enemy.

In this way, no doubt, and as a result of the explosion of the burning mixture in the clay balls or tubes, some first quite primitive form of grenade was evolved. Probably, too, a first idea of how these incendiary substances could be used for propelling purposes came by packing them into long bamboo tubes which, when ignited, would be found not only to burn but to propel themselves by the reactive force of the burning mixture; and this led to the use of what were called "fire arrows".

It has been established that a reference to such incendiary weapons was made in a Chinese document dating as far back as A.D. 1220, the arrows being used in battle against the Mongols.

It was the famous English monk, Roger Bacon, who in 1242 first detailed a composition for preparing true gunpowder, the ingredients being saltpetre, charcoal, and sulphur.

Rockets embodying various preparations of gunpowder were being used in experiments by a German engineer, Von Eichsteadt, in 1405, and a little later an Italian, Joanes de Fontane, was said to have been working on similar experiments. It was he who was credited with having designed some sort of wheeled vehicle propelled by rocket impulses.

VI

FIRST USE OF ROCKETS IN LAND AND SEA WARFARE

MOVING on through rocket history, one finds that in 1429 they were being used against the English in the defence of Orleans, while in 1561 a technical treatise published in France dealt with the construction of several types of "war firework", and described among other things a way of making rocket cases of leather rather than of paper or bamboo.

Among the next phases in the development of the rocket were its use against cavalry in the field and also for sky illumination, and by 1630 a rocket had been evolved embodying a form of grenade, the idea being apparently that it should operate in a way similar to a light shrapnel shell.

Rockets were used fairly extensively during the Thirty Years' War. A Polish treatise, published in 1650, refers to military rockets weighing as much as 100 lb. There are records, too, of experiments with gunpowder rockets in Germany in 1688, one type weighing 120 lb. and carrying a charge of about 16 lb.

One item of interest to astronauts is that as far back as 1710 the Frenchman, Cyrano de Bergerac, was suggesting the use of a rocket that could be "fired at the moon".

In the battle of Paniput in India, in 1761, it is on record that the Rohillas made such an extensive use of rockets that they were firing a couple of thousand at a time. The noise of these volleys not only terrified the horses of the enemy, the Mahrattas, but the rockets themselves were apparently so effective that they checked a charge the Mahrattas were just about to make.

Towards the end of the eighteenth century rockets were being used frequently against British cavalry in the India campaigns. These projectiles were iron-cased and were thrown by hand. They proved so troublesome that British military experts, on returning to England from India, advocated some form of rocket artillery in the British army.

This led to experiments at the Royal Laboratory, Woolwich. It was here that Colonel Congreve, a well-known artillery expert of his day, designed rocket projectiles which were used in subsequent military operations. It was a form of rocket evolved by Congreve which helped in the fall of Boulogne in 1806. Rockets were also produced which could be used in naval operations, being fired in salvoes from special projector-boats. Such marine rockets were filled with a form of liquid incendiary which, when the rockets struck their target, became ignited and caused a fire. These rockets had pointed metal noses which became imbedded in the wooden ships against which they were launched.

In the siege of Copenhagen, in 1807, rockets were fired which could carry an incendiary or explosive charge for a distance of about two miles. An improved rocket designed by Congreve had a case of sheet-iron, being gunpowder-filled and weighing when complete about 24 lb. This projectile was launched from an iron tube.

Another milestone came in 1810 when a paper published in London by W. Moore, *On the Motion of Rockets*, made a first technical investigation of the motion and trajectories of these projectiles. Soon after this came the formation of a Rocket Brigade in the British army. This was in 1812 and the Rocket Brigade was in action at the siege of Leipzig in 1813, and also in the battle of Waterloo.

Up to this time the rockets used had developed no great amount of thermal efficiency and, being more or less unstable in flight, could not be fired with much accuracy.

It was a French engineer, Frezier, who suggested the use of rockets with stabilising fins, and Congreve incorporated fins successfully in some of his projectiles.

A further advance came from America, where rockets were produced which would rotate while in flight. At about the same time, in England, Congreve evolved a method whereby a rocket case could be filled with a series of propelling charges, these being ignited one after another, so enabling a rocket to fly considerably farther.

A still greater efficiency was obtained by the Russians in their use of rockets against the Turks. They employed a launching mechanism capable of firing several explosive projectiles against the enemy at one loading.

VII

DEVELOPMENT OF THE LIFE-SAVING ROCKET

So far, and apart from being used for illumination, signalling, and display purposes, the rocket had seen its chief use as a weapon of war.

Now, in its further development, it came to be put to constructive rather than destructive uses, being developed as a means of saving life rather than of taking it.

It was in 1826 that rocket life-saving stations were established at certain points on the British coasts which were specially dangerous to shipping, the rockets used at these stations replacing a mortar apparatus which had been in use previously.

The rocket system proved considerably more efficient and also more portable, and it had the additional advantage that at night the path followed by the life-line, after it had been discharged, could be traced by the flame emitted by the rocket exhaust.

By 1870 these rescue rockets, carrying life-lines to ships wrecked near our shores, had come into general use, and have since been the means of saving thousands of lives. It is interesting to note that one of the 6 lb. rockets, as employed in 1870, could carry a half-inch circumference hemp line a distance of roughly 1,000 feet.

A scheme for a reaction-driven projectile employing steam as its propellant was being worked on in 1841 by S. Golightly, while at about the same time improvements were being made in stabilising the flight of rockets. In one case the launching tube was rotated in order to

Photos by courtesy Schermuly Pistol Rocket Apparatus, Ltd.

An important role of the rocket is to carry life-lines to ships in distress. The top photograph shows a line being fired from a Schermuly rocket pistol apparatus to a trawler in distress. The lower picture shows the last man from this vessel—its Captain—being hauled ashore by breeches-buoy.

impart an initial rotary movement to the rocket as it left the tube. In another the rocket exhaust was made to impinge on small vanes so as to produce a rotary movement. In yet another method rotation was obtained by the action of the air pressure on a spirally-shaped rocket head.

By about this period cannons with rifled barrels had come into use, and as a result less attention was paid to rocket projectiles.

Research now became directed to the rocket for life-saving purposes, and one of the improvements was to increase the range of these life-saving projectiles by employing more than one propelling charge in each rocket case. Attention was also paid to rocket propulsion for dirigible balloons, a scheme in this connection being worked out, but not developed, by the American engineer, Betty. At the same time further improvements were being made in the rotation of rockets while in flight.

In 1866 Jules Verne published his famous book, *From the Earth to the Moon*, and though this was a work of fiction, it had the effect, none the less, of directing considerable attention to the technical problems of interplanetary flying. Though Jules Verne was said to have employed an engineer to work out the details of many of the inventions he outlined in his romances, it is curious that, in the case of the imaginary moon flight, instead of employing rocket propulsion for his space-vessel, which would have been a feasible proposition, he relied on the impracticable method of a giant form of "space-gun" for projecting his machine out beyond the gravitational influence of the earth—forgetting, apparently, that the initial acceleration of such a projectile, when fired from the gun, would have killed its occupants instantly; whereas in the case of a rocket its velocity after the moment of release can be increased gradually, thus keeping the acceleration within limits the human body can stand.

A remarkable real-life romance of the rocket dates from the year 1881. In that year a Russian named

Kibaldchitch was imprisoned for being concerned with others in the assassination of the Czar Alexander II. While Kibaldchitch was in prison, awaiting the trial which led to a death sentence, he managed to work out what was the first plan in any detail for a flying machine to be driven by the reaction of a rocket power-plant. But this design, a really striking achievement at its time, lay forgotten for many years after its author's death. It was not until 1918 that it was discovered among some of the dead man's manuscripts and drawings, and though in the intervening years technical progress had rendered out of date the ideas Kibaldchitch had been working on, his scheme was none the less a striking forecast of the progress that lay ahead.

VIII

A MILESTONE IN ROCKET HISTORY

If we want to study the beginnings of modern research in rocket propulsion, we need to take the work of the Russian scientist, Konstantin E. Ziolkowsky. It was he who, in 1903, prepared for publication in a Russian scientific journal a paper in which he dealt technically, and at length, with the possible use of large rockets for interplanetary communication. In this paper, among other things, Ziolkowsky discussed the functioning principles of rocket reaction, and also stressed, as a fundamental advantage of the rocket for space-flight, that it could operate efficiently in a vacuum.

A famous pioneer in aeronautics as well as in astronautics was the French engineer, Robert Esnault-Pelterie, whom it was my privilege to meet, and have several talks with, at the world's first aviation meeting at Rheims in 1909. For a year or so before that Esnault-Pelterie had been engaged upon a mathematical investigation of space-flight. His researches extended over a number of years, and I shall have an opportunity of referring to them later. But it was as far back as 1912 that he submitted some of his chief conclusions to the Société Française de Physique.

In 1912 another outstanding figure became associated actively with astronautical research. This was the American engineer, the late Dr. Robert Goddard, who had been engaged upon theoretical investigations for several years previously.

Dr. Goddard carried out in 1912 an experiment to prove that rocket propulsion could operate successfully in the vacuum of outer space.

This test was conducted by pumping out a large glass case until it was completely air-tight, and then firing inside it a rocket charge, the impulse obtained being measured. This showed that in the vacuum within the case the impulse recorded was greater than had been the case with a similar experiment conducted outside under ordinary atmospheric conditions.

In this way it was proved that with rocket propulsion the atmosphere, instead of being the medium which causes propulsion, has actually a damping or retarding effect. By lowering the velocity of the exhaust it tends to reduce efficiency.

IX

ROCKETRY IN WORLD-WAR NO. I

WITH the coming of World War No. 1, rockets for signalling and illumination soon began to play their part, the latter type being designed to eject a parachute flare when at the top of its trajectory. A special message-carrying rocket was also evolved for maintaining communication with advanced bodies of troops.

Another use for rockets in the 1914–18 conflict was in destroying hostile airships and observation balloons. These rockets, used from aeroplanes, consisted of a tubular case with a gunpowder propellant, there being barbs on the head of the rocket which caused the missile to adhere to the fabric of the balloon or airship attacked, the exhaust from the rocket then igniting the hydrogen within.

A biplane of a Henri Farman type was the first aeroplane fitted with rocket projectiles as an offensive armament. This aircraft carried ten rockets fired electrically from tubes on the interplane struts. Some scout-planes of the Nieuport type were also fitted to carry rockets.

By 1917 a special single-seater rocket-firing aircraft of the pusher type had been developed by Messrs Vickers for attacking Zeppelin airships, but this machine did not come into operation owing to the fact that by this time a suitable form of incendiary ammunition had been produced which could be used against airships in machine-guns.

In 1915 plans to increase the flight efficiency of shells, and particularly of rocket-shells, were being worked on by Chilowsky, and a method he advocated, to reduce "drag" or head-resistance at high speed, was the projection of a flame just in front of the nose of the projectile so as to raise the temperature of the air locally in this frontal area, the effect obtained by this heating of the air being to reduce its density.

In 1917 the French engineer Melot was evolving what came to be known as a "thrust-augmenter", to increase the efficiency of a rocket when operating under atmospheric conditions. By this method air was sucked in at the sides of the operating unit to augment the flow of the exhaust. Further tests of such thrust-augmenter systems, made since then, have suggested that as they are further developed they may provide a means for rocket propulsion to operate with equal efficiency in atmosphere and vacuum.

X

WORK OF GODDARD, OBERTH, AND ESNAULT-PELTERIE

In America Dr. Goddard had been continuing his researches and experiments into rocket propulsion. Some of these he outlined in a report in 1919 to the Smithsonian Institution.

One aspect of Dr. Goddard's work led him to concentrate upon evolving a form of rocket which could be sent up for scientific sounding purposes to heights impossible by balloon or aeroplane. Another field explored by Dr. Goddard was in the use for rocket propulsion of liquid fuels, capable of being throttled to the combustion chamber under direct control, and in this way maintaining a constant chamber volume. In this connection he considered the use of petrol burnt in a medium of oxygen, the latter in a concentrated liquid form.

Somewhat similar researches as to liquid fuels had been carried out by the Roumanian scientist, Dr. Hermann Oberth, who suggested a combination of liquid oxygen and hydrogen. Dr. Oberth's researches, in Germany, were directed mainly to the problems of rocket flight through space, and in 1923 he dealt with the subject in a technical treatise on interplanetary communication by rocket which was subsequently published in book form, and attracted considerable attention.

So, too, did a lecture delivered before the French Astronomical Society, in 1927, by the pioneer I have already mentioned, Esnault-Pelterie. In this he outlined how, by the use of high-altitude sounding rockets, the way might be paved for the development of space-vessels for interplanetary travel. Later this lecture appeared in book form, and was subsequently expanded by the author in another volume which gave the results of his mathematical researches into rocket performances and trajectories.

Apart from Esnault-Pelterie's lecture, the year 1927 was memorable for the fact that the world's first organised rocket research group, the Society for Space Navigation, was formed at Breslau, in Germany, numbering among its members such pioneers as Dr. Oberth, Dr. Hohmann, and Willy Ley.

In its first experiments this pioneer society devoted itself chiefly to adapting rocket propulsion to road vehicles. Here there were many technical difficulties to be faced. But though such tests did not result in any marked progress, they served the purpose of directing public attention to rocket propulsion, and in this way had their propaganda value.

XI

EXPERIMENTAL ROCKET-CARS, GLIDERS, AND MAIL CARRIERS

THE German rocket society was fortunate in obtaining the support and active assistance of the motor-car magnate, Fritz von Opel who, apart from his personal interest in the experiments, no doubt saw in them a useful means of keeping before the eyes of the public his Opel cars. It was through his assistance that the Society was able to produce and test, early in 1928, their first rocket-propelled car, which had been designed for them by Max Valier.

A preliminary trial of this vehicle took place on the Ruessilsheim racing track. The machine was a single-seater of the light-car type, and was driven by 24 gun-powder charges. Each of these weighed 26 lb., and were located behind the driver's seat, the firing being arranged in sequence, either electrically or by clockwork timing. After the first test von Opel himself drove this rocket-car at a public demonstration. On this occasion, from a standing start, it attained a speed of 60 miles an hour in 5 seconds, and reached a maximum of 131 miles an hour.

This public demonstration attracted a great deal of attention, and von Opel himself was so impressed by the performance of this first rocket-car that he ordered the construction of several more, these being put under test during the summer of 1928. One vehicle was equipped to run on rails, and from a standstill, and in 5 seconds, attained a speed of 62.5 miles an hour.

On a later type of rocket-car, to prevent the wheels leaving the ground when accelerating, short stub wings were fitted. These "retaining-planes", placed just behind the front wheels, were set at a negative angle of incidence, and as the car gathered speed the air pressure on them restricted any lifting tendency.

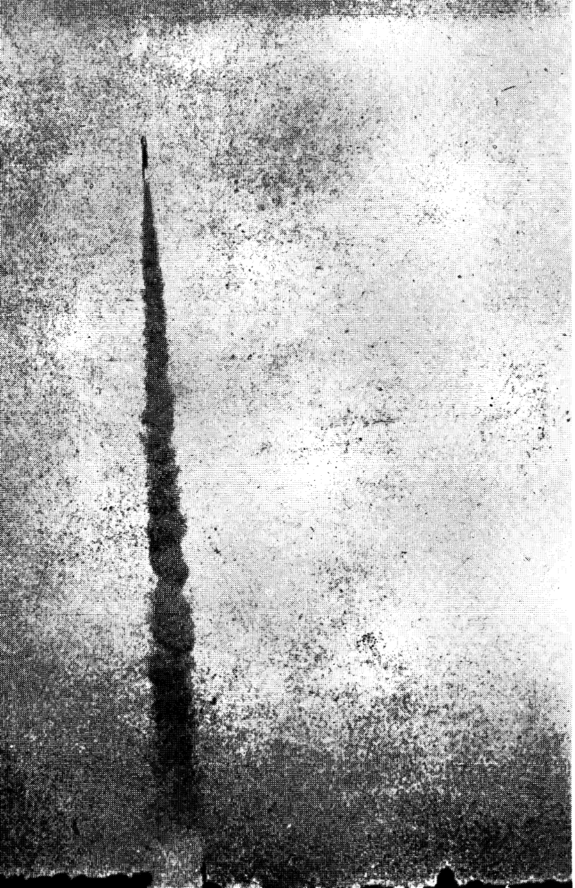
From rocket-car to rocket-aircraft was a natural stage, and in that same year of 1928 a first flight was made by a man-carrying plane actuated by rocket propulsion.

The machine was of the tail-first glider type, and was driven by two powder charges, the pilot being Friedrich Stahmer. The first rocket-aircraft flight was made from a point up in the Rhon Mountains, and the machine flew for a little less than a mile. Subsequently tests were made with another machine driven by a battery of four propelling tubes.

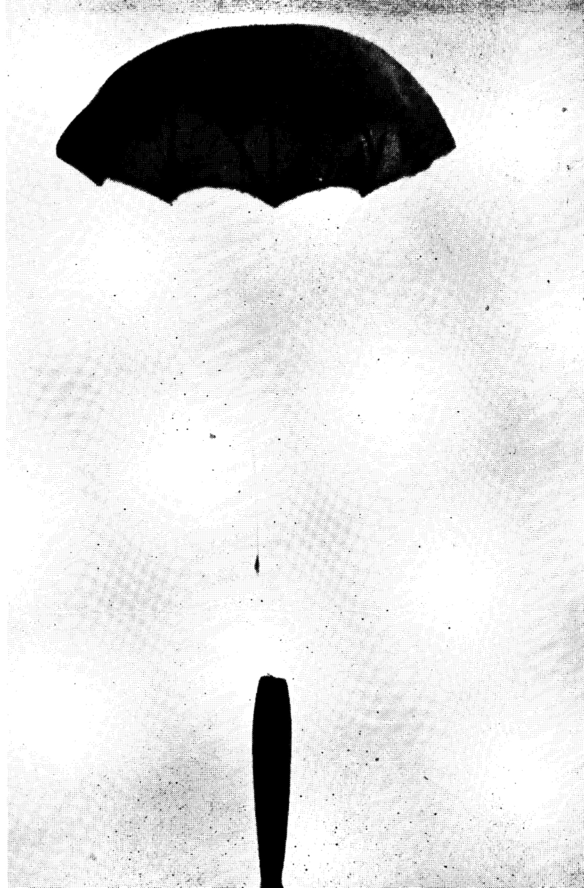
It was also in 1928 that the Austrian engineer, Schmiedl, was carrying out some pioneer experiments with a view to carrying regular mail-matter by rocket dispatch.

He built several experimental rockets, which were tested in free flight with recording instruments in a compartment in the nose of each rocket. As a result of this experimental work, which was highly encouraging, Schmiedl was able, in 1931, to establish a first officially-recognised rocket-mail service. His mail-carrying rockets were projected for a distance of approximately two miles over mountainous country between the Austrian towns of Schockel and Radegund. Schmiedl's projectiles made this two miles' flight with remarkable accuracy, and his pioneer rocket-mail came to be looked upon as so reliable that the postal authorities entrusted it with registered letters as well as ordinary correspondence. The rockets operating this first postal service carried their mails in a special nose compartment, and when the rocket had reached the top of its trajectory, and had ceased firing, a parachute was then ejected from the nose to carry the mails to earth.

Meanwhile Max Valier, previously mentioned, had been evolving a new rocket-car of wooden construction, using gunpowder as its propellant. At a first test this vehicle did 112 miles an hour, and in further trials the speed was increased to over 130 miles an hour. But while the car was moving at speed in one of these trials, and with Valier at the wheel, it overturned and was wrecked. Its driver, however, escaped serious injury, and the mishap did not deter him from further experiments, which now took the form of designing and building a rocket-driven sleigh. When tested on an ice-covered lake this sleigh reached a maximum of 235 miles an hour. After this Valier turned from car and sleigh propulsion to the design of an aircraft in which he hoped to be first to make a crossing of the English Channel in rocket-driven flight. But for one reason or another this plan failed to materialise. At a later date, when Valier was making a fuel-tank test with a new type of rocket-car, prior to a series of proposed trials with this vehicle, there was a sudden explosion which wrecked the car and killed Valier instantly. So, at the early age of thirty-five, died an astronautical pioneer. One of the tributes paid to him was by David Lasser, founder of the American Interplanetary Society, who dedicated a book which he



On the left a rocket carrying postal matter is ascending. The photograph on the right shows the method by which a mail rocket, its flight completed, can be brought down over its objective by a parachute ejected, automatically, from a container in its nose.



wrote "To Max Valier, first to give his life for the conquest of space."

Fritz von Opel, continuing his rocket studies, had by now fitted a man-carrying glider with twenty gunpowder charges.

This aircraft, with von Opel at the controls, flew for about a mile-and-a-half at a height of fifty feet, and attained a speed of eighty-five miles an hour. The machine made a bad landing, and was much damaged, but von Opel escaped with minor injuries.

XII

TESTS IN ROCKET CONTROL

ALL such experiments as those described, made with both surface vehicles and flying craft, had not only proved interesting in themselves, but had served to focus public attention upon the growing possibilities of rocket propulsion. But from a technical point of view what they had done, more than anything else, was to reveal the impossibility of obtaining a sufficient amount of control over any rocket vehicle that was driven by powder fuel, seeing that once a charge had started firing, its reactive thrust could not be increased or diminished at will.

It was this need for controllability while in operation which turned the attention of research-workers to the use of liquid fuels which could be made capable of control throughout the firing period.

To Professor Goddard, in America, went the credit for carrying rocket research yet another stage farther by concentrating upon the employment of liquid fuels.

After considerable preliminary work, he designed and built a rocket nine feet in length which employed liquid oxygen with petrol as its propellant. This rocket was also equipped with lightweight meteorological recording instruments. A steel tower was erected on the outskirts of Worcester, Mass., for the launching of the rocket, and it was duly fired in July, 1929. After rising about 900 feet the rocket exploded. Even so, and though the success of the experiment was limited, it was none the less considered so promising that Dr. Goddard received a substantial donation from the late Daniel Guggenheim in order that he might carry out further test-work with liquid rocket propellants.

It was after receiving this Guggenheim grant that Professor Goddard established a laboratory in a remote part of New Mexico, and continued his experiments with rocket motors and feeding systems. Some rockets which he constructed, and which were tested in free flight, attained a speed of over 400 miles an hour. Then the Professor turned his attention to the building of a large rocket which it was intended should be sent up to obtain meteorological data. During an early trial this rocket rose 7,500 feet and reached a speed of over 700 miles an hour. In this rocket the Professor employed a special gyro-stabilising device. This mechanism came into play, automatically, directly the rocket axis deviated from the vertical, small moveable vanes acting on the projectile's exhaust and forcing it back on its true flight path.

While this phase of research was in hand in America, Professor Oberth in Germany had continued to devote himself to some of the wider aspects of interplanetary travel, and 1929 saw the publication of a new and much-expanded edition of a volume which he had issued previously.

Yet another milestone of 1929 was the institution of the R.E.P.-Hirsh award of 10,000 francs for encouraging the development of space-flight, this annual award being for presentation to the author of the most original piece of technical literature on astronautics, or to any scientist or research-worker who had carried out the most valuable experimental work.

The prime mover in establishing this award, the famous French space-flight pioneer, Esnault-Pelterie, was associated in its creation with the well-known and wealthy banker, Andre Hirsh. A committee of French scientists had been appointed to decide who should be the recipient of this pioneer space-flight award, and in its first year they decided that it should go to the well-known Roumanian authority, Professor Oberth, in recognition of his researches and writings on interplanetary communication.

It was at about the time this award came to him that Professor Oberth was interesting himself in an experimental rocket-car driven not by powder fuel, as hitherto, but by a propellant employing liquid oxygen with denatured methylated spirit. The motor into which these propellants were pressure fed had been designed by Dr. Paul Heylandt, and although it weighed only just about seven pounds, tests showed it to be capable of developing approximately fifty horse-power. But when on test at the Tempelhof aerodrome, Berlin, although the car accelerated well, it did not reach the speeds of previous powder-fuel vehicles. Even so, the building of this experimental liquid-fuel rocket-car was considered well worth while, as it taught those who had produced it many technical lessons.

XIII

RUSSIAN RESEARCH

SPACE-FLIGHT developments in Germany, France, and America had been followed closely by technicians in Russia. Their interest culminated in 1929 in the formation of two research groups to study rocket propulsion and the possibilities of interplanetary communication. One was established in Moscow, on the initiative of

Ing. Petrovitch, and the other in Leningrad by Professor Rynin and Dr. Perlmann.

It was Professor Rynin who, after the formation of the Leningrad group, wrote an extensive space-flight review under the title of *Interplanetary Traffic*. This played a very useful part in promoting Russian interest in astronautics and its problems. An outstanding figure in Russian astronautical research was, of course, the famous engineer Ziolkowsky, who, as previously mentioned, was first to outline, comprehensively, how rocket propulsion could be applied to the conquest of space.

Ziolkowsky was now devoting himself not only to rocket propulsion for interplanetary travel, but also for greatly accelerating terrestrial transport by its adaptation to specially designed aircraft.

Research-workers on rocket propellants, while finding much promise in experiments with liquid fuels, were at the same time not neglecting the solid-fuel question. Tests already made with rocket cars and aircraft had shown, as I have indicated, how extremely limited was the control that could be exercised over any solid-fuel system of propulsion, and had emphasised that once any individual charge had been fired it became virtually impossible to regulate in any way its subsequent reactive force.

In their endeavours to cope with this problem, Opel and Valier had, in some of their experiments, managed to obtain a certain measure of control by the employment of a power-plant incorporating a number of separate powder charges, these being fired in sequence by the pilot of the plane or the driver of the car. But, though serving its purpose to a certain extent, this method still left much to be desired. There was also the drawback of the limited operation period of any such firing system. In the solid-fuel battery unit employed in Opel's rocket-plane of 1929 each single 10 lb. powder charge was, for example, operable for only twenty-five seconds.

Solid propellants are, generally speaking, carried inside their containing or combustion chamber, this taking the form of a tube closed at one end and with a narrow orifice at the other, the fuel burning rapidly on ignition without actually exploding, and the gases developed exerting pressure inside the chamber before their ejection through the orifice or nozzle. But in one German design, developed rather on the lines of the liquid propellant system, a pressure-feed device pumped powder-fuel into a combustion chamber from an outside containing tank. When, however, this method was actually put under test, it was found that there were too many premature explosions while the fuel was being forced into the combustion chamber.

XIV

PROJECT FOR PILOTLESS MOON FLIGHT

THE problem of controlling solid-fuel propellants was studied closely by Dr. Goddard in America, and it was he who, as a result of his researches, evolved the reloading "cartridge-injector" system. In the operation of this device the combustion unit was made to recoil under thrust, and by this recoil a series of nitro-cellulose powder charges were fed automatically to the unit, the re-loading process being achieved in much the same way as with a quick-firing gun. Considerable research was devoted to improving this cartridge-injector system, and to enabling a greater number of cartridges to be fired. It was a propelling unit of this type which, it was proposed, should be fitted into a rocket weighing from eight to ten tons, which should be fired experimentally through outer space in an attempt to reach the moon.

This rocket, carrying no human occupant, was to have been so directed that it would arrive on that portion of the moon which was in shadow; and that on its impact with the lunar surface it should ignite a flash-powder charge which could be seen by those watching through telescopes from the earth.

Though this project did not materialise, all the plans for it were worked out in detail, and it was proved that such an unmanned space-flight was theoretically practicable.

XV

FURTHER AMERICAN EXPERIMENTS

VALUABLE researches in the United States were carried out under the aegis of the American Interplanetary Society, the President of which was Mr. G. E. Pendray. He paid a special visit to Germany, prior to the taking over of rocket work in that country by the Nazi authorities, and watched tests by the German Society at their station outside Berlin.

On his return across the Atlantic, Mr. Pendray and his fellow enthusiasts carried out experiments with rockets which incorporated many new features in their design and construction. One of these rockets took eighteen months to pass through its design and construction stages and, after being tested on the Society's proving-stand, was fired out over the sea from an experimental station on Staten Island, New York. But after reaching a height of about 250 feet it exploded. This was found to be due to the bursting of the liquid oxygen tank, even though the precaution had been taken of fitting a special relief-valve.

A good many other experimental rockets were produced by the American Society, each with some new technical feature as to fuel, motors, the number, position, and length of exhaust nozzles, and so forth.

The firing of one of these test rockets from the Staten Island station was described in *Astronautics*, the journal of the American Society.

This rocket leapt up from its launching-rack as soon as its valves had been opened. It ascended almost vertically about 300 feet. Then it headed out over the sea, attaining a speed of more than 600 miles an hour. But soon it began to "hunt", or wobble in its course, eventually striking the sea with an immense splash.

The erratic movement of the rocket was found to have been due to a defect in one of its exhaust nozzles, this having upset the stability of the projectile.

Much of the American Society's work was, after this, devoted to motor design and testing. One of the points that emerged was that the varying length of exhaust nozzles did not appear to have much effect on the thrust developed by any particular combustion chamber. Another fact established was that increased efficiency could be obtained by forcing fuel into the combustion-chamber under higher pressure.

XVI

THE TILING WINGED ROCKETS

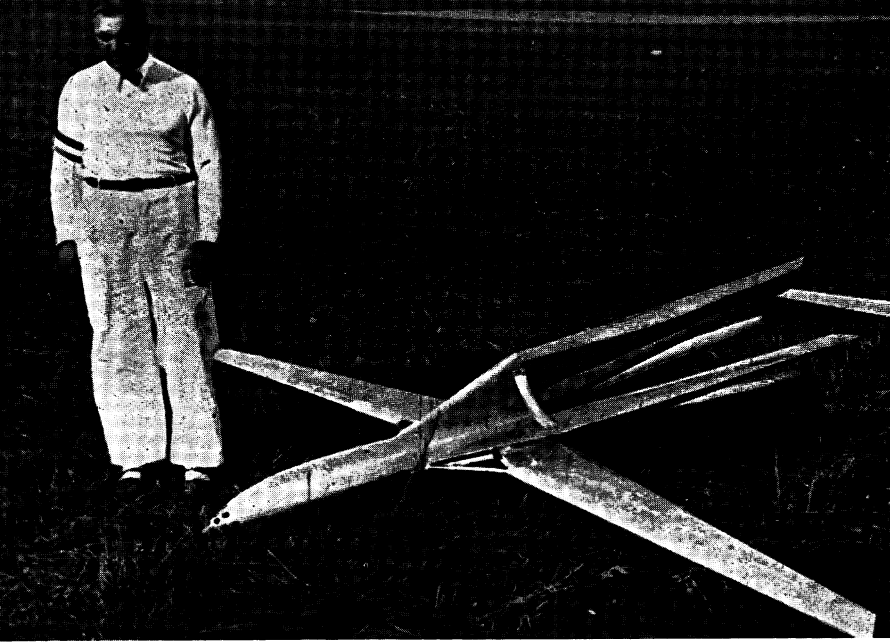
It will be remembered that powder-fuel had been the propellant of those postal rockets which, as already mentioned, had been employed by the engineer Schmiedl; and another experimenter who made use of this solid form of propellant was the well-known pioneer, Ing. Reinhold Tiling. Some of the rockets Tiling constructed showed themselves able to rise to a height of over a mile, and to reach speeds of more than 700 miles an hour.

One unusual feature of some of the rockets Tiling evolved was that he discarded in them the use of a parachute device for bringing down to earth any load in the shape of recording instruments or mails that the projectiles might be carrying. Instead, he fitted his rockets with a retractable rotor-blade device, operated by a clockwork timing apparatus. This rotor-blade, as soon as it came into operation, span round in the air in the same way as the freely revolving vanes of an autogiro, and brought the rocket back to earth at a sufficiently slow rate.

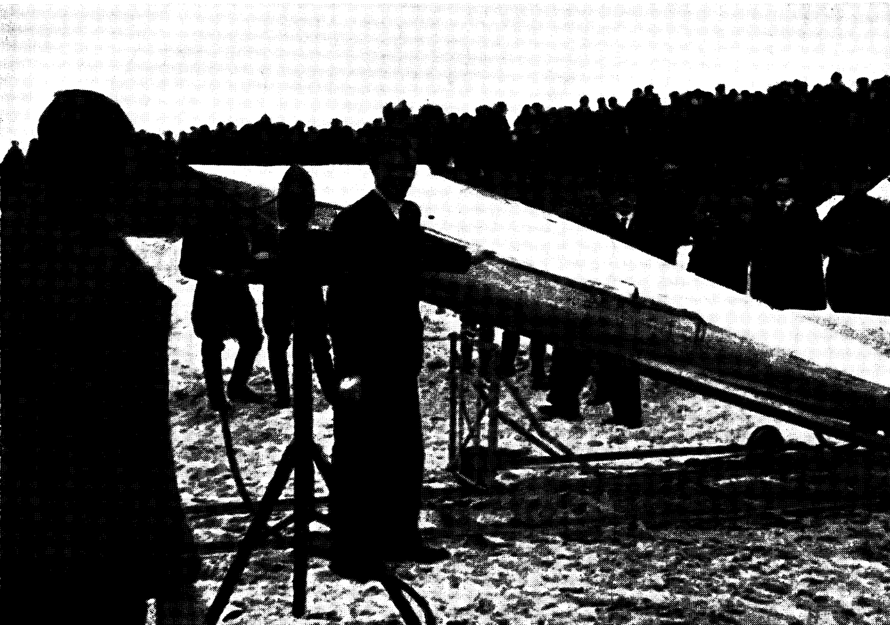
In another direction, also, Tiling carried out exceptionally interesting tests. This was in fitting certain of his rockets with wings. Mr. Cleator, in his *Rockets Through Space* book, was able to give a photograph of some of the winged Tiling rockets. Very striking-looking they were, with slender bodies and narrow, widespread wings. One type was four feet six inches long, and with a wing-span of nearly seven feet. Many of these winged projectiles gave encouraging results.

A number of the Tiling rockets were used to carry loads of mail-matter, and in one demonstration postal flight a rocket of his design and construction carried some 200 letters a distance of just on 6,000 feet.

It was while he was carrying out further experiments with powder-fuel that Tiling met his death. He and three assistants were at work in the small building in which he conducted his experiments when a charge of powder exploded. The building was wrecked by the force of this explosion, and all its four occupants sustained fatal injuries.



The top photograph shows an interesting type of winged rocket evolved by the inventor Tiling. The lower picture (supplied by courtesy F. J. Field, Ltd.) was taken during a demonstration of a "controllable aerial torpedo" designed in 1931 by Gerhard Zucker.



XVII

MAIL ROCKET EXPERIMENTS IN GREAT BRITAIN

Among those who advocated rockets for mail-carrying was another well-known German experimenter, Herr Gerhard Zucker, who carried out tests over the Hartz Mountains.

Zucker, in pre-war days, visited England and, in connection with an air-post exhibition in London, arranged for some demonstrations of mail-carrying by rocket.

One of his tests was made near Rottingdean, in Sussex, the powder rocket employed carrying more than 1,000 letters. The projectile was launched from an inclined rack and flew more than 3,000 feet.

After a second successful launching the letters carried, bearing a special "rocket" postmark, were taken into Brighton by mail-van and sent through the ordinary post to their recipients.

Another of Zucker's experiments was in the Outer Hebrides, with a view to providing a mail-rocket link between the islands of Scarp and Harris. Here again the powder rocket was loaded with approximately 1,000 letters. But this experiment proved a failure, the rocket exploding and its contents being destroyed.

In another test Zucker planned to fire a postal rocket across from the Isle of Wight to the mainland. But in this case it appeared that, through official permission having been withheld, Zucker was warned that his rocket must not reach the mainland but must, in order to avoid risk to life or property, be made to alight in the sea. To fulfil this requirement, he reduced the powder charge in his rocket. After rising successfully the projectile came down in Pennington Marshes, the mail being retrieved and sent on by ordinary post.

After this Zucker returned to Germany, and nothing much more seems to have been heard of him until after the outbreak of World War No. 2, when a report which was not confirmed made it appear that he had been detected by the Gestapo in attempting to convey information as to German rocket progress to some foreign power, and had been sentenced to death and shot.

XVIII

EVOLUTION OF THE STEP-ROCKET PRINCIPLE

PROFESSOR OBERTH, continuing his researches, had come to the conclusion that voyages across space would become possible only by a development of machines propelled by independent rocket units, each containing its own fuel and motors. This proposed solution became known as the "step-rocket" principle, the Professor basing his calculations on the employment, as fuels, of liquid oxygen and liquid hydrogen.

Professor Oberth's investigations led to plans for a giant space-flight vessel driven by four separate power-units arranged one behind the other, and each capable of being detached to save weight as soon as its contents had been exhausted.

At the front of this vessel there was to be a first propulsive "step" comprising sixty tons of fuel and ten tons of structure, with ten tons allowed for crew and equipment. Attached just behind this first step was a second one including 400 tons of fuel and eighty tons of structure. Then behind the second step came a third comprising 3,840 tons of fuel and 640 tons of structure. But this did not solve the problem completely. The three "steps" mentioned provided fuel only for an outward journey across space, say to the moon.

There was still the return journey to the earth to be considered. So a fourth stage, on a similar basis to the others, had to be provided.

As Professor Oberth worked out, provisionally, the sequence operation of his battery of propelling units, the third "step" came into play first, and it was reckoned it would contain a charge sufficient to enable the space-vessel to reach a velocity of two and a half miles a second. Immediately this "step" had exhausted its contents, and had become inoperative, the empty structure—now representing so much dead weight—would be detached from the vessel, it being planned either to provide means for destroying it by explosives, or to return it to earth by parachute, the latter expedient being adopted to avoid any risk to life or property through the jettisoned structure crashing heavily.

Once the third "step" had used up its contents, Professor Oberth's plan provided that the second should come into play, its impulses increasing the speed of the vessel by another two and a half miles a second. As soon as this "step" had exhausted itself the process of jettisoning would be repeated, and the third step would now begin firing, its propelling force increasing the velocity of the space-ship to seven miles a second—a speed sufficient to carry it out beyond the earth's gravitational influence.

This plan, although worked out in detail, was not more than a tentative approach to the many technical problems involved in obtaining a space-vessel with a fuel system sufficiently powerful and yet sufficiently light to gain for the machine a speed high enough to ensure its gravitational release from the earth and, at the same time, to provide a reserve for a return journey to earth after an outward interplanetary voyage.

When the scheme for the vessel the Professor had envisaged had been worked out to include every item, it was found that when ready to leave the earth, carrying fuel for an out and return flight across space, its total weight would reach a figure of rather more than 40,000 tons. Such an initial mass-weight figure could not, it was recognised, be regarded as a really practicable solution of the problem, or that further designs must imply a vessel of such large proportions. But what was seen to be practicable, and in fact essential, if space-flight was to pass from theory into practice, was the jettisoning of unwanted weight as the vessel made its way out from the earth against gravitational influence.

This made it evident that the "step" principle, in which a vessel would become progressively lighter, with a resulting economy in fuel, would be one of the keys to success in space navigation.

It became equally clear that, apart from any discovery of some fuel or fuels capable of greater propulsive power, the evolving of a practicable space-vessel would depend upon a number of technical considerations, prominent among them being the development of motors of a high thermo-mechanical efficiency, and the attainment of the utmost efficiency in fuel-weight ratios.

The experiments of Professor Oberth and others had created so much interest in Germany that a well-known authoress in that country, Thea von Harbon, seized upon space-flight as her theme for a popular novel which she entitled *The Girl in the Moon*. This book met with such success that the German Ufa Film organisation decided to base a full-length picture on it, and in order that this project should be as realistic as possible they invoked the technical assistance of Professor Oberth. For the purposes of the film Professor Oberth supervised the construction of a large and imposing-looking replica of his projected lunar rocket, and this projectile, put together with technical accuracy according to the Professor's plans, played a prominent part in the filming of the story.

This space-flight film, when publicly shown, proved extremely popular. In fact the interest in the whole subject grew so keen that the Ufa film group made up their minds that it would be good policy on their part

Photo by courtesy F. J. Field, Ltd.

Launching a mail-carrying rocket during pre-war experiments carried out in England in connection with an international air-post exhibition.

to act as sponsors in the production, to Professor Oberth's designs, of a large liquid-fuel rocket for a scientific high-altitude sounding flight. Construction work was begun and a great deal of preliminary matter was written in the German newspapers; but for various reasons this big rocket was not completed, and the much-discussed flight up into space, which had been anticipated so eagerly, never materialised.

XIX

LIQUID FUEL PROGRESS

It was now that the experts of the German Interplanetary Society—which had been founded by Max Valier and Ing. Johanes Winkler—decided that the time had come for a series of researches and experiments into the whole problem of liquid fuel propulsion, their idea being to evolve a more efficient combustion chamber and to determine the most satisfactory way of feeding liquid propellants to such a chamber.

In the early stages of this programme a number of quite small rocket units were produced and were put under test, the idea being to obtain in this way data for the construction of larger projectiles of improved types. Some of these first small rockets were not built with the idea of firing them in free flight. This was not considered necessary, as it had been agreed that more technical information could be gained at first by ground tests with the rockets mounted on a special "proving-stand".

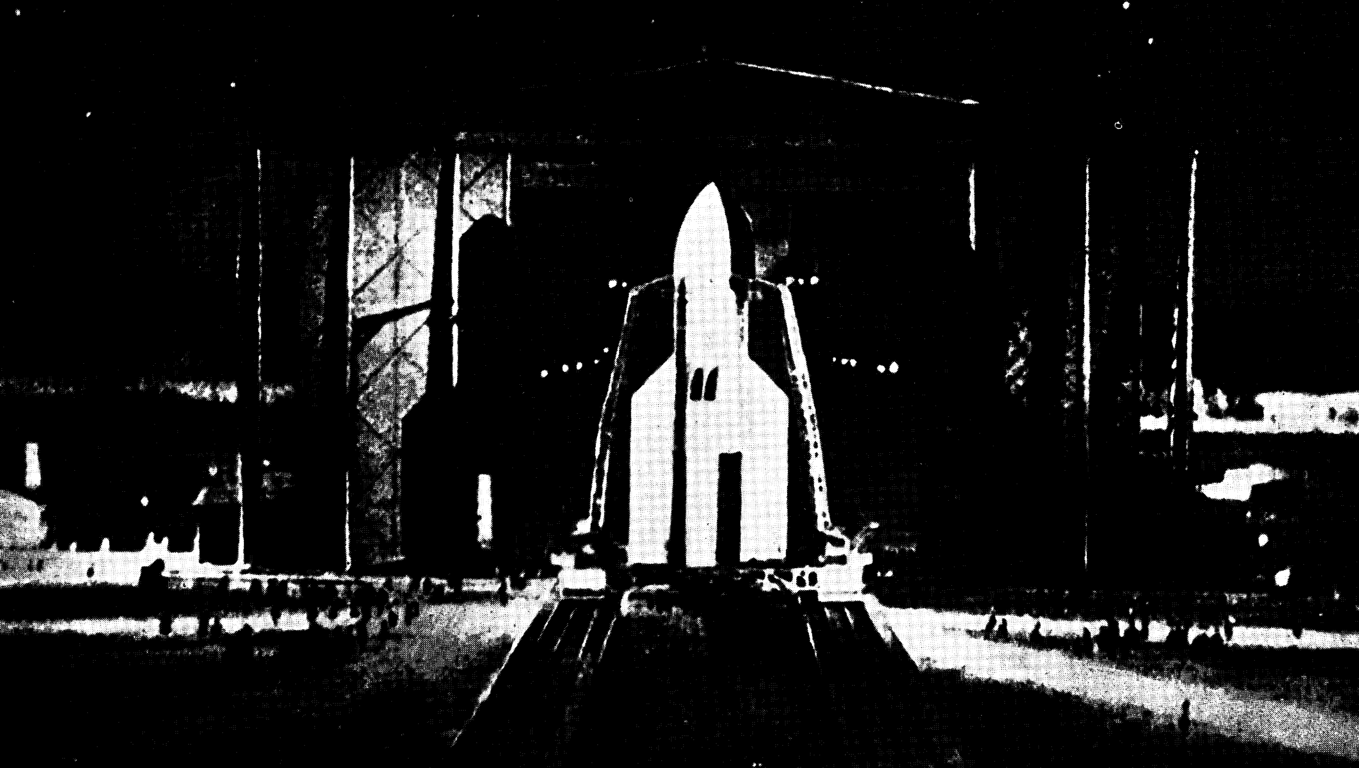
When a rocket was mounted on one of these stands, it was possible to record accurately the thrust reaction developed, and also the velocity attained by the exhaust; thrust being registered directly by a spring device, and velocity calculated from the thrust and the amount of fuel consumed.

This proving-stand method also served a further purpose. It could, when required, be employed as a launching platform for firing any rocket which, after completing successfully its ground tests, might be thought worth trying out still further in an experimental flight.

In the first liquid-fuel rocket of this German research programme, one of the features was the adoption of a gas pressure system for feeding the propellant to the combustion chamber. The rocket had its tankage space in the shape of a streamlined nose shell, and in this was the liquid oxygen. It also contained a conical combustion chamber with its nozzle projecting centrally from the base of the tank; while placed just off-centre to this nozzle was a tube containing fuel petrol, there being a small pressure-feed charger at the end of this tube. Valves in the feed-lines, linking tanks with combustion chamber, were fitted so that the rate of fuel delivered could be under control.

One of the technical researches was to ascertain the best materials from which to construct these experimental rockets. It had been found that a good many metals showed a tendency to become brittle when in contact with liquid oxygen, and this raised tank construction problems. Attention had to be paid to the choice of the material employed in the combustion-chamber. Here something was needed which would resist great heat, and which would not burst when subjected to extremely high pressures. After a careful investigation, it was decided that in the first rocket to be put under test duralumin should be used in tank construction, with a special heavy copper alloy for the combustion chamber.

The first rocket the Society's engineers subjected to tests on the proving-stand gave results which were thought satisfactory. But one fact revealed was that in order to obtain a better exhaust flow, improvements would have to be made in the shape of the combustion chamber. A further examination of this question showed



In the days between World War No. 1 and No. 2, the famous astronautical scientist, Professor Oberth, worked out a design for a giant lunar rocket which played a prominent part in the film, "Girl in the Moon". Here is a scene from that film at the moment when the spaceship is about to leave the earth on its lunar voyage.

that the chamber, as first designed, lacked adequate space at the top for the gases to mix sufficiently before their passage out through the nozzle.

It was while further tests were being made with this first rocket that it exploded, and when an examination was made of the remains it was found that the accident had been due to the development of too great a pressure in the oxygen tank, causing this to burst.

XX

THE FIRST GERMAN "RAKETENFLUGPLATZ"

WHILE the phase of rocket research I have just described was in progress, officials of the German Society had been on the look-out for some site, at a safe distance from human habitations, where a permanent rocket testing-station might be established. Such a ground was found, eventually, at a point near Reinickendorf, one of the suburbs of Berlin. Here the engineers of the Society established their "Raketenflugplatz", or rocket flying-field, buildings being erected in which experimental rockets could be constructed.

Further experiments were now put in hand with rockets of improved types. These embodied, among other things, methods for relieving excess pressure in the oxygen tank, and for increasing combustion-chamber efficiency. It was to augment the strength of the latter that a lining of steel was provided on a copper alloy base. But for a time trouble was still experienced in the tendency of oxygen tanks to explode. Then a model was evolved which operated more successfully on the proving-stand, and this led to the building of larger rockets for free-flight testing. In the first of these the combustion chamber was housed in a water-cooled jacket. When this rocket was tested it proved unstable in flight. A later model was more successful, and rose more than 15,000 feet. Even better results were obtained with another, which reached an altitude of approximately 33,000 feet, being brought back safely to earth by parachute.

While such firing trials were in progress, another technical section of the Society was busy with laboratory tests to determine the best metals for the construction of further motor-units for rocket propulsion, and in this test-work a considerable use was made of aluminium.

Later on, for various reasons, largely financial, the first German astronautical society was disbanded, its work being continued by another space-flight organisation headed by Dr. Willy Ley. Financial difficulties began to bar the way to further experiments, while another problem which arose was the growth of National Socialism in Germany. This, before long, led to complications as between the astronautical research-workers and the military authorities. In fact Willy Ley and some of his immediate associates took such an unfavourable view of the situation, and of the way things were developing from their point of view, that they decided to leave Germany—while still able to do so—and to migrate to the United States.

Here Ley was able to continue his researches without official interference. Among his experimental work he took part with F. W. Kessler in the design of small rocket aircraft intended for the carriage of mails. The propulsion units for these machines, incorporating a special pre-mixing system, used liquid oxygen with a denatured alcohol as fuel.

The rocket aircraft, of which two were built, had a wing-span of 14 feet 6 inches and were 11 feet long, there being a special nose compartment for mails, with the propelling unit and exhaust nozzle at the rear of the fuselage. Launching was from an inclined track. In the first trials one of the machines, after climbing steeply, stalled and fell. In the case of the second, it was found that the wings lacked sufficient strength. After it had flown a few seconds one wing broke. But in each case the propelling unit, designed by Mr. Nathan Carver, of the American Rocket Society, functioned admirably.

Another of Ley's activities was to produce in the United States a book entitled *Rockets—The Future of Travel Beyond the Stratosphere*.

It appears from Ley's book that the first schemes for a rocket-propelled space-vessel were put forward, simultaneously, by Ziolkowsky in Russia, and by the German expert Garswindt in Germany. One point emphasised by Ley is that apart from Ziolkowsky becoming, as he did, a national hero in Russia prior to his death in 1936, the Russians have published more books and technical articles on astronautics than any other nation—which may have an important bearing on the future development of this science.

XXI

BIRTH OF THE V-2 PROJECTILE

THOUGH Ley and certain fellow-workers felt no desire to play into the hands of the Nazis, and got out while the going was still good, this seemed hardly the case with Oberth, Von Opel, and others who had been associated with the early stages of rocket research in Germany. At least they remained on the scene, and it is evident that the fruits of their work came to be at the disposal of the Nazi régime, although how far Professor Oberth actually co-operated with Hitler and the others is at present uncertain. At any rate, on the coming of the Nazis into power, there was an end of private, individual research into rocket problems, and the whole subject was placed under the control of a special Government department, further research becoming a "hush-hush" and closely-guarded affair.

Professor Oberth has been described as probably the world's greatest living expert on astronautics. With a mystical and eccentric personality, this Roumanian scientist is reputed to be strongly pacifist in his outlook, which made him not at all in sympathy with Nazi policy and methods.

It seems clear that his devotion to astronautics has not been with a view to any sinister application of the science, but almost entirely from its aspects as a means of interplanetary travel. From all that can be learned, it would appear that the Gestapo were instructed to seize all data available as to rocket progress in Germany, and no doubt the fruits of the Professor's researches were laid hands on in this way, whether that met with his wishes or not. Actually it looks more likely that the Nazis found a willing collaborator in another expert who had been associated with Oberth and others in pre-war rocket researches in Germany. This was Rudolf Nebel, an engineer who was also understood to be an ardent supporter of the Nazi party. Actually, Germany's V-2 rocket weapon, as used for attacks on the civil population of southern England and the London area, is understood to have been developed mainly by the German technician Werner von Braun. It carried a war-head of explosives weighing about a ton. But this same rocket, with its war-head removed, and meteorological and scientific apparatus substituted, could play an important part in those high-altitude investigations which are necessary in further space research.

Scientifically, the production of such a rocket as the V-2 represents an achievement which should have a marked influence on astronautical progress in our post-war era, seeing that it should enable data to be obtained from those zones, high above the earth, which have so far been uncharted and unexplored. But while German science has this rocket to its credit, and it is a triumph of outstanding significance, the point should be made that we in Britain—to say nothing of America or Russia—have chemists and astronautical experts whose specialised knowledge should have enabled them, could they have relied on the powerful backing and incentives accorded their opposite numbers in Germany, to evolve a projectile as efficient as, and perhaps in some respects even more efficient than, the one enemy technicians put into the hands of their Nazi masters.

As a purely war weapon the V-2 was not designed for the attainment of any extreme altitude. All it had to do was to fly high enough—between 60 and 70 miles—to carry its load of explosives from launching sites either in Holland or Germany to a target area in and around London. But estimating that the total loaded weight of the projectile is about 12 tons, and that its propelling force is liquid oxygen with alcohol as fuel, it becomes possible for our experts to calculate that, if sent up vertically for the attainment of a maximum altitude, it could attain a height of about 150 miles. Even in its war guise it has already penetrated higher above the earth than any previous apparatus, seeing that the greatest height attained previously by any kind of air machine was the 23 miles of a pilotless meteorological balloon.

The peace-time use of a rocket having the present performance of the German V-2 would increase to an immense extent our knowledge of conditions at great altitudes. One of the advantages to be derived from such a greater knowledge, and it would be an advantage to everybody in one way or another, would be the higher accuracy possible in forecasting weather.

Another important field opened up by the use of such high-altitude rockets would be in the further investigation of ionospherics, including the subject I have already mentioned of cosmic radiation, and of its possible influence on human beings who venture out into zones beyond the earth's atmosphere.

XXII

OTHER USES OF THE ROCKET IN WORLD WAR NO. 2

THOUGH my business here, I am glad to think, is with peace-time astronautics, it is at the same time interesting —and apart from such a weapon as the V-2—to note in passing some of the other uses that were found for rockets during the course of World War No. 2.

There was what is known as the "snare-rocket". This anti-aircraft device was carried aboard ships of the merchant marine. It was a large powder rocket, and when it had reached the peak of its trajectory it ejected a parachute and a long flexible steel cable.

Then there was the anti-aircraft rocket known as the "Z" gun, which was in use in British home defence against hostile aircraft. These rockets, used with a barrage effect, had a range of about four miles, and could be exploded on contact or by a time-fuse.

Next one might mention the use of the rocket as an aircraft launcher. Here one gathers that planes carried on the decks of some merchant ships were launched into the air by rocket power as well as by compressed air.

Another scope for rocket propulsion lies in assisting take-off and as a means of "boosting" power. Rockets are employed for assisting the take-off of heavily-laden aircraft; also for accelerating into the air machines which, owing to special circumstances, are required to make a minimum take-off run. Rockets have also been employed to obtain sudden bursts of additional speed while machines are manœuvring in combat.

An increasing war use was made of rocket projectiles fired from aircraft. Such rockets, fitted with an explosive head, have been fitted to British fighter-bomber aircraft such as the Typhoon, Hurricane, Beaufighter, and Swordfish. Eight projectiles are usually carried, four beneath each wing, and they are fired along rails from the under-surface of the wing. The chief advantage of a rocket projectile is that it gives greater penetration owing to its higher speed, while liability to error in sighting is also lessened. An ordinary bomb falls with a curved trajectory, but the rocket projectile, owing to its own inherent power, takes up a straighter flight path. The rocket-firing aircraft is dived on the target, the objective being sighted through an ordinary aircraft gun-sight.

In sea war rocket projectiles are fired from special "projector" vessels.

It is interesting to note that Russia was the first nation in World War No. 2 to make use of rockets fired from aircraft, their targets being principally tanks and armoured vehicles. Among other Russian rocket weapons is a gun, the projectiles of which are fitted with contact and time-fuses and explosive heads. Some of these rocket projectiles are launched thirty at a time from multiple projectors. Others are shot off from launching troughs. One such weapon can be fired from a mobile truck.

One should not omit to mention that famous American "bazooka", or anti-tank rocket gun. Launched from a metal tube, this projectile which is about two feet long and has a streamlined explosive head, is said to be able to cut through two or three inches of armour-plate or as much as three feet of concrete.

As for the rocket activities of our enemy, apart from their sinister V-2, one should not forget the production of their Messerschmitt 163 rocket-propelled fighter; while German fighters were also fitted to carry explosive rocket shells for firing against Allied bomber formations. The advantage of these is that they can be launched outside the range of the bombers' guns; but they do not seem to have been particularly accurate.

The M. 163 rocket-driven fighter was a remarkable machine—a portent of a new era. Its single rocket propulsion unit gave it a phenomenal performance particularly in climbing, while it was reported to be capable of a maximum horizontal speed of between 500 and 600 miles an hour. It was used primarily as a home defence interception fighter. Its rocket unit was said to give it an endurance of not more than about 4½ minutes, though it could prolong this aerial time-limit somewhat by shutting off its rocket power and gliding for short spells. The machine suggested the "flying-wing" principle; or it might be called a man-carrying rocket with wings.

The Germans were also using a type of remotely-controlled rocket bomb. These winged rocket-driven bombs, using liquid propellant, were directed chiefly against shipping. They were guided by wireless after being launched from a parent-plane, and could be radio-controlled for a distance of several miles.

XXIII

OUR BRITISH ASTRONAUTICAL PIONEERS

THOUGH, to-day, the world is growing so much more enlightened, there are still forces of repression, and of reaction, with which even modern pioneers have to contend; as instance the experience—described so admirably by Mr. Eric Burgess—of the Manchester Interplanetary Society not so long before the outbreak of World War No. 2.

Having established a technical research committee, the Society—of which Mr. Burgess was President at the time—wanted to carry out some practical experiments in rocket construction and propulsion. To facilitate these, and to ensure at the same time that they should involve no element of risk for the public, an experimental station was established far out on a wild and lonely stretch of moorland. Here trenches were dug and a launching site prepared. Then just as what looked like being an interesting programme of tests was about to begin, the blow fell. The police suddenly descended on four of the leading members of the Society, and served summonses on them. From these it appeared that, quite without any of them being aware of it, these members had in their construction of experimental rockets been guilty of several alleged contraventions of the Explosives Act of 1875.

The case, when it came on for hearing at the Manchester City Police Court, attracted a considerable amount of interest. In opening for the prosecution, the fact was mentioned that these summonses had been taken out against members of what was known as the Interplanetary Society.

"Inter—what?" questioned the Magistrate, with an expression of surprise.

He registered even greater astonishment when it was explained to him that the avowed objects of this Society were to send projectiles up to great heights and ultimately, if possible, to reach the moon, Mars, and Venus.

After an amazed silence in Court, the legal pundits found themselves involved in a complicated argument which seemed concerned, chiefly, with the meaning, according to the strict letter of the law, of the words "making" and "manufacturing".

For the defence the contention was that from the viewpoint of the provisions of the Explosives Act, under which the summonses had been taken out, there was a decided difference between "making" and "manufacturing". This Act, it was held, had been passed to prevent the manufacture of large quantities of explosives for commercial purposes, but actually did not apply to the making of any small quantities for purely experimental purposes, such as had been the case with the members of the Interplanetary Society in their construction of rockets for scientific test purposes. With this interpretation the Bench, however, did not seem willing to agree, and after further more abstruse legal arguments, the case was adjourned.

At a subsequent hearing the problems that came under discussion grew even more difficult to follow, ranging from Newton's Third Law of Motion to jet-reaction, and from thermal efficiency to such questions as delayed combustion and instantaneous explosions.

For the defence a further contention was now brought forward. This was that the rockets designed and constructed by members of the Interplanetary Society were not really rockets at all, at any rate within the meaning of the Explosives Act, seeing that they were employed purely for experimental purposes, and were not intended to produce any sort of pyrotechnical effect.

At this dictionaries were called for, and from them it was ascertained that a rocket was "a firework made out of a case filled with saltpetre, sulphur, and charcoal, fastened to a stick and projected through the air". This definition, the defence was quick to point out, could not apply to the Society's experimental projectiles. For one thing they had no "stick" and, for another, they were constructed specifically for scientific purposes and not for anything in the nature of a "firework" display. In fact, as it was no intention with them to produce a pyrotechnic effect of any sort or kind, it was argued that they could not be classed as fireworks at all.

The case dragged on after this without appearing likely to reach any definite conclusion, and in the end, having apparently become weary of the whole affair, the Magistrate suggested that the best thing to be done was for the prosecution to withdraw their summonses on an undertaking from the members of the Society that they would not in future use in the propulsive charges of their rockets certain chemicals which, according to the Act, it was apparently illegal to employ in any such experiments as the Society was conducting.

On this basis the matter dropped, but it still seems uncertain, according to the strict letter of the law, whether or not an interplanetary rocket is to be regarded as a "firework".

I have dwelt on this case not only because it caused more than a little interest at the time, and is in many ways amusing, but because it shows what a thorny path has had to be trodden by so many of our inventors and research-workers in this country.

For our British laws, as such, one cannot have anything but respect for their integrity and impartiality. Yet in certain of their aspects, where they are applied unyieldingly, without any adequate recognition of such special circumstances as may often arise, one is bound to feel some sympathy for the attitude of those exasperated individuals who have not hesitated to declare that "the law is an ass".

Certainly there is one thing that needs to be said, and said emphatically. In our great post-war era, when the world is developing its scientific resources in all possible directions, no old-fashioned rules or enactments must be allowed to check the experiments and researches of our scientists, chemists, and other technical workers. They do not want to be hampered in quests which may bring fresh and vital knowledge in many different fields.

Encouragement, not restriction, is what our scientific explorers require. All our searches for fresh knowledge, all probings into avenues hitherto unexplored, must be given the whole-hearted support not only of officialdom but of the community at large.

At the present time, according to our existing laws, the use of liquid oxygen for any kind of rocket experiment is prohibited entirely. In fact the whole range of propellents that can be used for any kind of private research in this country come under the heading of certain "approved compositions" of the solid or powder form.

Nor does this end the restrictive influence of the law as it still applies to British rocket research. Even if any experimenter is scrupulous in confining himself to one or other of the "approved compositions", he is still up against some of the provisions of the now obsolete Explosives Act of 1875. These make it obligatory upon him to obtain the sanction of the local police for any firing-range he may wish to employ. Not only this, but the design of whatever rocket he may want to test must be approved by the Secretary of State through his advisers; while the actual filling of rockets must be carried out only in approved premises which have been licensed under the out-of-date Explosives Act.

In America, by way of contrast to all this restrictive bureaucracy, rocket research has received the full encouragement of the authorities and has not been hampered in any way by the dead hand of repressive legislation; while as for Germany there is no need to stress the technical strides with rocket weapons that country was making during the war.

Even though conditions in this country were generally discouraging, there were enthusiasts who refused to have their ardour quenched.

One of these was Mr. P. E. Cleator, whose admirable *Rockets Through Space* book I have already had occasion to mention. In spite of all the difficulties confronting research-workers, Mr. Cleator was the moving spirit in the formation of the pre-war British Interplanetary Society, with whose valuable researches into space-flight problems I shall be dealing in ensuing sections.

It was on October 13th, 1933, that this Society held its first official meeting, Mr. Cleator being appointed President, with C. H. L. Askham vice-president, and L. J. Johnson, secretary.

Though officialdom proved so unresponsive to space-flight ideas, this was certainly not the case with the British Press. The newspapers gave considerable prominence to the early work of the Society, and this had an effect which was immediately beneficial, seeing that it directed public attention to the growing significance of space-flight problems, and emphasized that in this scientific field, as in others, it would not do for us to lag behind.

In the years following its establishment in 1933, and up to the outbreak of World War No. 2 in 1939, the British Interplanetary Society was carrying out scientific investigations which embraced every major aspect of space-flight research, including the design of sounding rockets to obtain data from high altitudes, the preliminary design of a full-scale space-vessel suitable for a flight from earth to moon, and the evolution of rocket craft for commercial purposes in the transport of urgent loads, and more particularly of mails.

After the coming of the war it was impossible, at any rate unofficially, to do more than theoretical research work into rocket propulsion.

Part Two

OBJECTIVES OF SPACE-FLIGHT—THE MOON, MARS, AND VENUS

I

WEEK-ENDS ON THE MOON?

It is amusing to read some of the comments that are made on space-flying and its problems and possibilities, particularly since the advent of atomic power.

Giving full rein to his imagination, one writer has been picturing the day when big man-carrying rockets may be taking parties of tourists for week-end trips to the moon.

Another scribe, writing in America, has urged the immediate organisation of an United States rocket expedition to the moon, so that the Stars and Stripes could be planted on the lunar surface, and the moon annexed as yet another possession of the United States, complete with any mineral or other resources that might be found upon it. This might raise the question, "Who really owns the moon?" And it might prove a question which would be yet another headache for our United Nations organisation. As the moon shines its silvery light on all nations, everywhere, I feel myself that when it is reached it should be looked upon as an international possession, not to be claimed by any one country. What one would feel as being most satisfactory would be, when the time comes, for a first expedition to the moon to be organised on an international basis, with representatives of different great countries forming members of the space-vessel's crew.

All this is certainly looking ahead. But at the same time it is not wise, in these days of super-rapid progress, to ridicule any such ideas, far-fetched though they may appear at the moment when they are put forward.

If one did so, one might be guilty of the same error as was made by those members of Parliament who, years ago, laughed scornfully when a first proposal for the establishment of an aerial transport enterprise was brought before them; or of those sceptics who made much fun of an old-time picture depicting a sort of "aerial train", with one big flying machine towing a number of smaller ones behind it.

That same Parliament, which laughed at the idea of flying machines ever being used commercially, now spends quite a lot of time in serious discussions of how Britain can maintain its aerial position in a world given over largely to civil aviation.

As for that once ridiculed notion of a flying train, we have seen already how a powerful aeroplane playing the part of a flying tug can tow heavily-laden gliders behind it through the air, while in post-war transport the flying train, in the shape of an engined-plane towing a string of mail or goods-carrying gliders, promises to be used extensively, and profitably too, on long-distance air routes.

With examples like this to act as warnings, it behoves one to be chary even about laughing at the idea of excursions to the moon, far-fetched though it might appear to a good many of us from our view-point here and now. Sceptics have been made to look silly so often that scepticism is now too much of a boomerang to be indulged in light-heartedly.

Personally, I am not too sure about the popularity of week-ends on the moon, even if the necessary transport could be provided. After a first natural curiosity has been satisfied, there will be little enough attraction about the lunar surface, seeing that the moon is very definitely bleak and inhospitable, with nothing to offer visitors but a strange, grim kind of desolation.

Still, even though it is unlikely ever to become anything of a pleasure resort, the moon has always provided a fascinating study for astronomers, astronauts, and others. Its origin and history should, as a matter of fact, be of interest to all of us, seeing that away back in the very dim and distant past, something like 4,000 million years ago, when our solar system was in process of taking shape, the theory is that while our earth was still in a more or less molten condition the action of the sun separated a portion of matter from the earth's surface, and that this detached portion formed itself in due course into our satellite the moon; while looking very, very far into the future, peering in fact some 50,000 million years ahead, it is reckoned by that time that the effect of the earth's tides on the moon will be to draw our satellite back nearer to us until eventually it breaks up into a number of smaller moons, which will then in their turn begin to revolve around the globe.

But it is only experienced astronomers who can really appreciate the significance of the vast passages of time, and of the enormous distances, which have to be reckoned with when studying the immensity of outer space. To ordinary folk they tend to become just a headache. When, for example, you are told that the Milky Way system is roughly 180,000 million million miles away from the sun, you feel an inclination to give it all up, and to turn with relief to the mere quarter of a million miles which separate us from the moon.

II

LUNAR PROBLEMS THAT ASTRONAUTS MAY SOLVE

BEING so near to us—at any rate in astronomical distances—our telescopes can tell us a good deal about the moon. They show, clearly enough, its rugged surface, its greyish-brown rocks, its volcanic mountains rising from plains of lava and ash.

But, though telescopic observations of the moon can reveal a good deal, they still leave unanswered questions which we are not likely to solve until there are actual landings on the moon by rocket-borne astronauts.

There is the intriguing question of all those craters, large and small, with which the lunar surface is so liberally pock-marked. Some of the largest are more than 100 miles in diameter. But there are a good many not more than a few miles wide. Whereas volcanic action can, no doubt, account for some of these craters, the theory has been advanced that quite a number may have been due to the moon having being struck at various times in its history, and more particularly at an early phase, by some of those meteors, large and small, which rush here and there through space at enormous speeds.

It is calculated that in the early stages of our solar system there were very large numbers of such meteors dashing about through space, and that both our earth, and the moon, were being struck pretty frequently by them.

Traces of such a "bombardment" are to be found in different parts of our globe, and more notably than anywhere else in that great crater located out in Arizona, which goes 600 feet deep, and measures more than a mile in diameter.

Then there is the question of those many crevasses, or fissures, which can be seen extending for hundreds of miles across the lunar surface. They have the appearance of being deep cracks which, it has been assumed, might have been caused by contractions of the interior of the moon.

Another of the lunar problems concerns those very odd-looking streaks, of a lightish colour, which stretch out from some of the craters on the moon, and can be observed passing for long distances across lunar mountains and valleys. Exactly what these are nobody knows, though it has been conjectured that they may be stains on the lunar surface which might have been brought about by the long-continued action of some powerful vapour. Certainly there will be plenty of scientific, geological, and meteorological observations to be made, and other vital data collected, by the first party of adventurers from the earth who succeed in alighting on one of the lunar plains. In

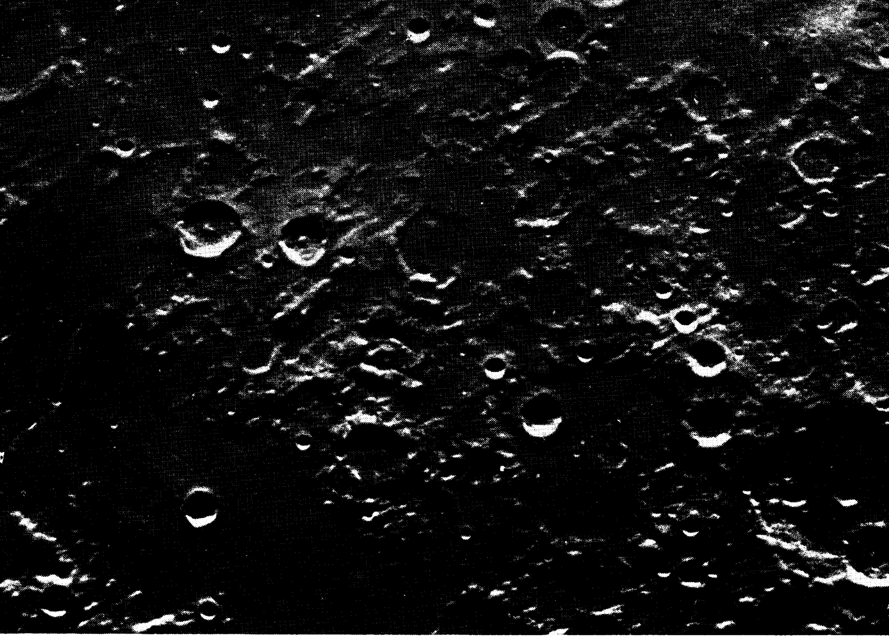
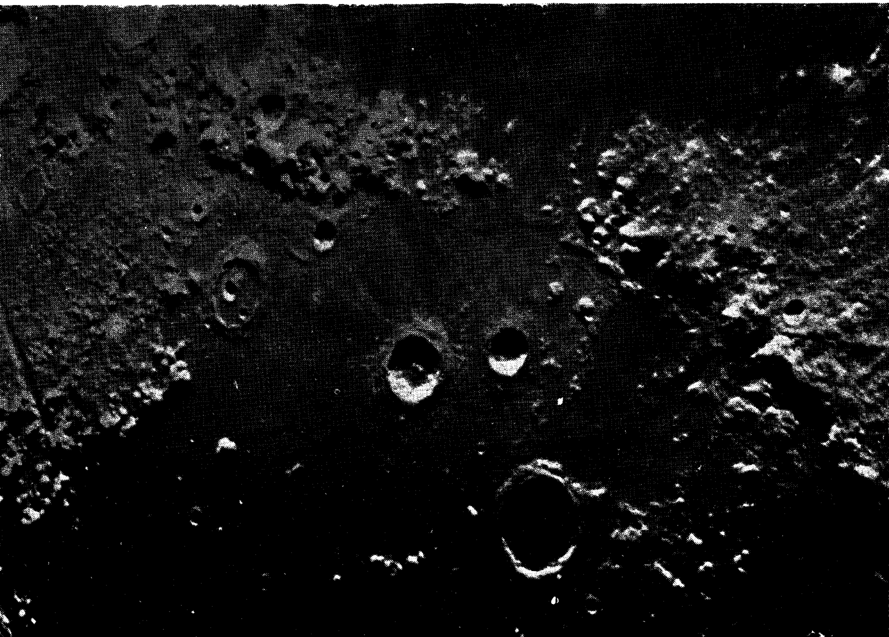


Photo copyrights Ellison Hawks.

Photographs of some of the mountains, plains, valleys, and craters on the Moon. The first space voyagers to alight there will seek as smooth a landing-point as they can find, probably on one of the lunar plains, or in one of the valleys.



their favour, incidentally, will be the fact that they will not have to worry, as we often do here when there is much to be done, about the shortness of any given working day, seeing that the lunar day is equal to fourteen of ours. They will benefit, too, by the lower pull of gravity on the moon, as compared with the earth, which will render it easier for them to move about without fatigue, and also make it easier to lift any object they may wish to carry with them.

There is one thing the first lunar visitors must be prepared for. They must not expect to be greeted on their arrival, either in a friendly spirit or otherwise, by any living creatures. Though writers of romances, and producers of films, have taken the liberty of imagining there are living, intelligent beings on the moon, such fantasies have no basis in fact, it being as certain as certain can be that the moon is an utterly dead world, with no vestige of life to be found on it anywhere.

Whatever atmosphere the moon may have had originally, it has now lost. Not only is it an airless world, but it is also a waterless world, with nothing in the shape of vegetation.

A strange, empty, still world!

As it has no atmosphere it has no winds or air movements, while it is also a silent world, seeing that as sound is carried by air, and with the moon having no air, there are no sounds to be heard on it.

Utter stillness broods over its bare mountains, and its plains and valleys.

When one remembers, also, that the climate of the moon leaves very much to be desired, being subject to tremendous extremes of heat and cold—extremes far greater than any we experience on this earth—it becomes clear that nobody is likely to want to visit the moon unless he has some very definite reason for so doing.

There will be those who have reason to visit the moon. Very definitely so. And their objects, too, will be perfectly clear and precise.

First there will be all the data—scientific, geological, and meteorological—that a voyage to the moon and back should provide; data which may throw fresh and valuable light on many a hitherto unsolved problem.

Secondly, there is the point as to the vitally important information which astronautical experts should obtain from a pioneer lunar voyage—practical, first-hand information as to the propulsion, control, and navigation of a space-flying vessel, and as to the bodily effects of a voyage across space on those first to embark on such an adventure.

III

THE MOON AS AN INTERPLANETARY "AERODROME"

I have mentioned some of the main inducements for the making of a space-flight from earth to moon.

There is yet another and an even more important one—at any rate from the view-point of our astronautical experts. It is not their attitude to look upon a voyage to the moon just as an end in itself. They regard it as a preliminary step towards a fuller amd more complete conquest of outer space.

As Mr. P. E. Cleator wrote in that admirable book on the dawn of interplanetary travel, which he entitled *Rockets Through Space*, the moon may be the body which will give us the key to unlock the door that leads to the planets.

Here it should be explained that what Mr. Cleator and other astronauts have in mind is to take advantage of the fact that the force of gravity on the moon is so much lower than that existing on the earth—one sixth as much, to be exact.

It is this fact which assumes importance as soon as one examines the technical problems of any projected voyages from the earth to either Venus or Mars. For one of the biggest problems, if such voyages are started from the surface of the earth, is the tremendous amount of concentrated power that will have to be generated by any space-vessel before it can release itself from the gravity-pull exercised by the earth. And it is here that the lower gravitational influence of the moon comes in.

It has been calculated that whereas any space-vessel starting on an interplanetary voyage from the earth's surface would have to attain a velocity of seven miles a second to release itself from the earth's gravity, if that same vessel could make its ascent from the moon's surface it would only need an escape velocity of approximately one-and-a-half miles a second.

As this question of obtaining a sufficient initial gravitational release velocity is of paramount importance in space-flight, and more especially when long interplanetary voyages, such as those to Venus and Mars, are being envisaged, the value of the moon as a starting-point for any of these voyages becomes apparent.

But is this idea of using the moon as a space-flight refuelling station really practicable? May not it be just another of those "inventor's dreams"?

Experts who have made it their business to study this particular question say very emphatically that it is not. They say that, given an ability to reach the moon in space-vessels such as are now in design, it should be a perfectly feasible proposition to establish some sort of permanent station on the moon's surface, and to staff it with men to keep it in operation.

But how could this be done?

Well, it has of course to be assumed first of all that pioneer space-flights to the moon and back have actually been accomplished, and the necessary working knowledge gained as to questions of propulsion, navigation, control, and other matters.

Once this preliminary stage had been completed, larger types of space-ships would then be constructed, capable of carrying across in sections, from the earth to moon, the parts necessary for the erection, on some suitable site on the lunar surface, of a large pressurised or air-tight building, which would be equipped internally with all such essentials as temperature control and a constant supply of breathable air, together, of course, with an adequate provision of other necessities such as food and water. It has been advocated also that, in order better to adapt such a lunar "outpost" to the severe and rapid temperature changes taking place on the moon, it should be established mainly underground; a step which would have the additional advantage of protecting it from being damaged by any of the meteors which may still, at times, be bombarding the lunar surface.

In such a big underground workshop and refuelling station, complete with comfortable living and sleeping quarters, the staff of any Interplanetary Travel Company or Corporation could work just as they would in a similar building here on the earth's surface.

When they wanted to emerge from their building, and move about on the lunar surface, they would have space-suits completely covering their wearers and resembling somewhat a diver's dress. These special space-suits would be light and convenient, and would provide their wearers with an air supply sufficient for several hours' breathing, and they would also have means for protecting those using them against extremes of temperature.

Once they have established and equipped their outpost on the moon, complete with stores of fuel and other necessary material, the space-flight organisation preparing for voyages to Venus and Mars can do either one of two things: it can construct, here on the surface of the earth, a very large space-vessel suitable for long interplanetary voyages, and fly this machine out to the moon, refuelling it there for its further flight across space to Venus or Mars; or it can complete all the parts of such a machine here, and then send them out by space-ship to be assembled in the workshops on the moon. Expert opinion seems to favour the latter course.

There is another advantage which should not be overlooked in the establishment of any out-station on the moon. Owing to the observational clarity obtained from the absence of any obscuring belt of atmosphere, the lunar surface would be very much more suitable for astronomical studies of other planets than would be the case with any observatory here on earth.

Another point would be that to have skilled observers out on the moon would enable our experts here on earth to make a much more exact science of meteorology, and of long-range weather forecasting.

In the fascinating vistas now unfolding before those who study space-flight, there is a further scheme which suggests itself as to the employment of planetary satellites as refuelling stations.

Although the planet which approaches nearest to us, Venus, has no satellite, Mars has been provided with a couple.

One of these Martian satellites has been called Phobos, and the other Deimos. Both are very small. But they would not be too small for the purpose astronautical experts already have in mind for them. This is that they should serve the same purpose, in space-flying between the earth and Mars, as has been planned for our own satellite, the moon. The idea would be to establish on these Martian satellites, Phobos and Deimos, space-flight refuelling stations and depots of the same type as the one installed on the moon, such Martian stations being of course used to facilitate flights from Mars to this earth, in the same way as the moon station would fuel space-vessels starting from the earth en route to Mars.

Here it is a matter of interest to note how the need for intermediate refuelling crops up in space-flying just as it does in long-distance flying in those air zones lying immediately above the earth's surface.

In order to save long-range ocean aircraft from having to carry very heavy loads of fuel in non-stop flights, such fuel loads militating against pay-load capacity, it is proposed to establish, at suitable points out in the Atlantic, huge floating stages which have been described as "artificial islands".

These stages, anchored to the ocean bed, and constructed to ride out even the heaviest Atlantic gales, will have large unobstructed decks raised high above the surface of the water, on which ocean-flying craft can alight to refuel; and it is proposed, also, that they should have suitable accommodation for aerial passengers and crews.

It is this same idea, on an even more imagination-stirring scale, which we now see emerging in plans for spanning those vast distances which separate us from the nearest of the planets.

IV

CREATING "ARTIFICIAL ISLANDS" OUT IN SPACE

A use of existing planetary satellites, as refuelling stations, does not exhaust the possibilities which space-flight experts are now reviewing. A well-known foreign astronautical authority, Ing. Guido von Pirquet, has suggested in space-flying the equivalent of the "artificial islands" referred to previously as projected for the refuelling of ocean-going aircraft.

Ing. Pirquet has worked out plans for an artificial island, or rather an "artificial moon", which he proposes should be stationed out in space, hundreds of miles above the earth's surface, and which would act as a permanent fuelling-point for space-craft setting out on interplanetary voyages.

Here it is interesting to note that Mr. Cleator, President of the pre-war British Interplanetary Society, had an opportunity prior to the war of meeting Ing. Pirquet and discussing with him the project for this outward space-station; and in his book, *Rockets Through Space*, Mr. Cleator gave some details of the scheme.

The space-station would, Mr. Cleator explains, take the form of a huge air-tight metallic globe, containing living quarters for its crew, and with big tanks for the storage of fuel.

How would such a station be placed in position out in space?

One idea, apparently, was to construct it on the earth and then to project or "shoot" it up by some means to the location required.

Another was to tow it out into position. But neither of these, Mr. Cleator says, was found to be really practical. The best solution of the problem is to build the station in sections on the earth, take these sections up to the required height by space-ship, and then to begin assembling them away up there in space.

This might seem a very tall order to anyone not conversant with space-flight and its amazing possibilities.

Actually, as Mr. Cleator explains, any object raised high up into space above the earth, as would be the case with this small artificial moon, would then take up an orbital path round the globe in the same way as does the real moon; and once it had begun to revolve round our globe it would not deviate from its circuit any more than does the moon.

What this would mean is that, after a space-ship carrying the parts of the proposed station had reached, and halted at, its pre-determined point out in space it would then, for the time being, become an artificial "satellite" of the earth, and the orbital velocity it attained would not only render it weightless in an ordinary sense, precluding any tendency for it to fall back to earth, but any object unloaded from it would become weightless also, remaining suspended there in space.

Similarly, since any occupant of the space-vessel who, clad in a suitable space-suit, emerged from his vessel through an airlock, would share the orbital velocity of the machine he had just left, he would hover, suspended in space, there in the neighbourhood of his craft. In this connection it has been suggested that the space-workers' suits should be fitted with some form of miniature rocket motor, thus enabling them to propel themselves easily in whatever direction they wanted to move.

The way in which any artificial refuelling station, once placed in position in outer space, would then be held suspended there after it had taken up an orbital path round the globe, can be illustrated by a simple analogy. Take a strand of elastic and, to one end of it, attach a small ball. Then take the free end of the elastic and twirl the ball round and round with such a circular motion that it assumes a constant "orbit" round one's hand, or radius centre-point. In this analogy the ball represents the refuelling-station out in space, and one's hand the earth. If the orbital speed of the ball was decreased beyond a certain limit, the tension in the elastic would cause the ball to fly back to the hand; and, still applying the analogy to the refuelling station, the same would take place as a result of any decrease in its orbital velocity. It would, that is to say, crash back to earth.

When one first examines this "space-island" scheme it certainly puts something of a strain on one's imagination to picture those craftsmen of the future, working there high in outer space on the assembly of their "artificial moon", and handling fittings and pieces of apparatus which, like themselves, defy our familiar law of gravity by just "staying put" in space till they are removed and placed in position. But when one's imagination does seem to jib at some of these promised wonders, it is well to remind oneself, once again, that progress and research in science are still only in their earliest infancy, and that as time goes on, unfolding to us one marvel after another, we may see things actually accomplished which are more wonderful even than the erecting of a fuelling-station out in space.

British and American experts, who have studied such a space-station scheme as I have been describing, point out that the establishment of such stations out in space might be made to serve an extremely practical purpose by equipping them with special wireless installations, and using them as relay stations to facilitate wireless broadcasts and transmissions from one part of this earth to another, their position out in space giving them certain advantages, from a technical point of view, which would be unobtainable with any station working down on earth level. They could also be made to add, in many important respects, to our knowledge of astronomy, physics, and meteorology.

When I think of things like these I am reminded of something an airway friend of mine told me.

In the early, pioneering days of our Empire air-lines he took a portable wireless set one afternoon to a native village near one of the remote landing-grounds which had been hewn from out of the heart of an African jungle.

Here, putting down the set in the centre of the village, he switched it on and let the amazed natives hear the chimes of Big Ben. When he told them that this big clock which they were listening to was actually striking thousands of miles away in far-distant London, and that the sound was coming invisibly through the air to be picked up and reproduced in this box on the ground, they were too dumbfounded to say a word, and stood there shaking their heads.

They could make nothing of it at all.

It was just "white man's magic" to them—a piece of witchcraft that was absolutely beyond them.

Well, this magic of wireless has ceased to be a mystery to we more enlightened folk. We know how it works. It has become part of our lives. But we, in our turn, are prone to shake our heads in mystification, and perhaps even in disbelief, when some far-seeing research-worker, peering ahead into the future, tells us of things which we, or those who follow us, are likely to see accomplished in the march of science. And when one comes to think of it, and in the particular case of this refuelling station out in space which I have been discussing, we are decidedly better off than were those natives who stood round that portable wireless set in the jungle. The idea, in itself, is not so incomprehensible to us as was hearing the chimes of Big Ben to them. Ing. Pirquet's scheme can, in fact, be shown by mathematics to be a feasible proposition. All that is needed is a sufficient period of research and experiment to transform the plan from the laboratory and drawing-board to the goal of full-scale construction. The inventor has worked out his design so completely that he can estimate the actual cost of erecting out in space a first interplanetary refuelling station. This would come to a figure of approximately £2,000,000.

V

PROFESSOR OBERTH'S "SOLAR MIRROR" SCHEME

ANOTHER notable contributor to plans for the "anchoring" of structures out in space, at great heights above the earth, is Professor Oberth, whose name and work—like those of Dr. Goddard and M. Esnault-Peterie—needs no introduction to students of astronautics.

Professor Oberth's idea is first of all to establish a station or workshop out in space, and then to assemble round it in sections, fixed on a vast spider-like web structure, an enormous solar mirror, the object of which would be to intercept, and reflect back to earth for all sorts of beneficial and useful purposes, those of the sun's rays which, at present, stream past the earth and are lost in space.

The many facets of this tremendous space-mirror would not be of glass, but of a specially thin lightweight metallic reflecting substance. They would be movable, by a control-mechanism located in the central station, or heart of the "web", so that the sun-rays they collected could be directed, as required, upon any part of the earth's surface.

Herr Oberth's conception includes the provision of a large number of these vast mirrors, circling the earth out in space, their collective action being such that night could be turned into day in great centres of population lying in the path of the rays they reflected, thus rendering any form of artificial illumination unnecessary; while there would be many other uses to which such collected and focused sunlight, always so to say "on tap", could be put with profit to all concerned.

Fantastic such notions may seem to many. It is not surprising that such should be the case. But so at one time, do not let us forget, did many another idea which has since brought almost incalculable benefits to mankind; and future generations may well have cause to revere the names of those astronautical workers in whose brains have been born the plans for first conquering, and then utilising, the vast potentialities of space.

I recall that it was Mr. Cleator in his book *Rockets Through Space* who ventured a prophetic pen-picture of what may be happening as far ahead as the year 200 A.I.T.—that is to say in the year 200 "After Interplanetary Travel". There may then, as he envisages things, be three prosperous worlds in the shape of a trinity of the void—a Solar Federation. Busy space-ports will be acting as the nerve-centres of interplanetary travel, and there will be a regular chain of communication between the Earth, Mars, and Venus, operated by a Lunar Corporation which, apart from having its out-station on the moon, will also operate depots and refuelling-points on the Martian satellites, Phobos and Deimos.

Huge space-ships trailing flame astern of them, and with a thunderous roar from their propelling tubes, will rush up from the earth and travel across fifty million miles or more of outer space.

In this future year of 200 A.I.T., at any rate as Mr. Cleator foresees it, our interplanetary experts may be on the point of executing plans for developing still further their space-flight activities, and may be organising expeditions to reach the planets Mercury and Jupiter. But, adds Mr. Cleator, there may even in such days of super-progress be those who will be apt to take up a cautious, disapproving attitude towards anything which seems to them risky and overbold. It is such critics, Mr. Cleator thinks, who may be predicting disaster for any Mercurian expedition on the ground that the luckless explorers will perish from heat through Mercury's proximity to the sun; while as for reaching Jupiter, they will be anticipating an equally ill-fated end to any attempt owing to the immense gravity-pull exercised by this giant among planets. But I do not think that such people of little faith of the future, should they exist, will have any more deterring effect on the adventurers of those days than do our critics and sceptics on our explorers of the present era. The spirit of adventure will never die.

VI

NEW GIANT ASTRONOMICAL TELESCOPE

APART from the moon—first objective of space-flight journeys—the two planets which chiefly interest the student of astronautics are Venus and Mars; and this because these are the two planets which it will be the aim to reach as soon as successful voyages have been accomplished between earth and moon.

We members of the British Interplanetary Society are keenly interested in every established fact, and in every reasonable conjecture, which can be drawn upon as to the conditions existing on Venus and Mars. And the astronautical student certainly has much to thank our astronomers for.

Astronomy is not one of the spectacular subjects. It is only rarely that some discovery is made by astronomers which arouses the interest of the world at large. At other times, and from year to year, and decade to decade, it is usually a case of patient unremitting observation with telescope and spectroscope, and of one methodical research-worker devoting his entire life to a study of some single planet or special astronomical phenonemon—the fruit of his life's toil being then handed on for the information and guidance of those who follow him in the engrossing, never-ending quest.

It is in this way, by a sort of mosaic of research by skilled observers in all parts of the world, extending over an extremely long period of time, that we have learned all we know to-day about the planets and other bodies which lie out there at vast distances across the void.

More than once I have heard those who have just begun to study astronomy express the opinion that, having regard to all the research which has been put into this fascinating subject, the results in our actual knowledge of the Universe are apt to prove disappointing. With this I do not agree; and I am sure my view will be held by others. I myself am always impressed not by the little astronomers can tell me but by the extent and scope of the knowledge they have to impart.

It does not do to expect too much. The astronomer does the best he can, having regard to the instruments at his disposal. He cannot tell us more than his telescopes show him, or his spectroscopic studies reveal. He has nothing like a complete answer to the riddle of the universe. Nor does he pretend to have any such answer. His general attitude is one of caution; of understatement rather than of overstatement. He sees certain things and he draws careful conclusions from them. These he checks and verifies in every way in which it is possible to do so. And he will make no statement or claim that he is not in a position to justify by long and patient researches.

In a good many cases his work can be shown to produce fruitful results. In others, through no fault of his own, these results are less enlightening. But science is not standing still in astronomy, any more than in other branches of research. Better instruments, newer methods, are aiding the astronomer as he probes into space.

Just before the outbreak of war we in England were hearing something of that new giant astronomical telescope which is being constructed in America, and one of the members of the Astronomical Section of our Society, Mr. Kunesch, has furnished us with some further information about this wonderful new instrument—the most ambitious of its kind ever designed or built.

Work on the great telescope, and on its many intricate accessories, had to be abandoned temporarily when war broke out, but apparently it should not take long, now, to complete the instrument and get it into operation.

It would not suit my purpose, here, to involve myself in any of the purely technical details of this most complex piece of apparatus. But one may summarise its immense potentialities by saying that it is hoped it will enable those operating it to penetrate more than three times farther into outer space than has been possible with any previous instrument. This will open up for further investigation an unexplored area of space more than thirty times the volume of that which has hitherto been sounded.

In the view of astronomers, the most important use of this new telescope, and all its magnificent equipment, will be in the more intensive investigation it will allow of objects which are already known, but which have been studied inadequately, so far, owing to optical limitations. An idea of the size of this monster telescope can be gained from the fact that its huge concave reflecting mirror is nearly 17 feet in diameter, and many tons in weight.

One of the most interesting things about the new instrument, at any rate from the view-point of those of us who study space-flight and its problems, is the fresh light it should throw on some of the mysteries of the two planets with which we are most concerned, Venus and Mars.

VII

VENUS, OUR EARTH'S "TWIN-SISTER"

THOUGH it comes so near to us, the planet Venus provides the astronomer with one of his most tantalising and elusive subjects for research.

It is the planet about which we should know most, and yet about which, in a good many respects, we seem to know least.

There are many things which make Venus of particular interest to we earth-folk. This planet is so bright in the sky, when it nears us, that it can be seen in daylight with the naked eye. For another thing, it arouses our curiosity, and our speculation, owing to the fact that in its size Venus more nearly resembles the earth than does any other planet. It has been called "the twin-sister of the earth". Actually, it is just a trifle smaller than the earth, its diameter being 7,700 miles as compared with the earth's 7,927 miles.

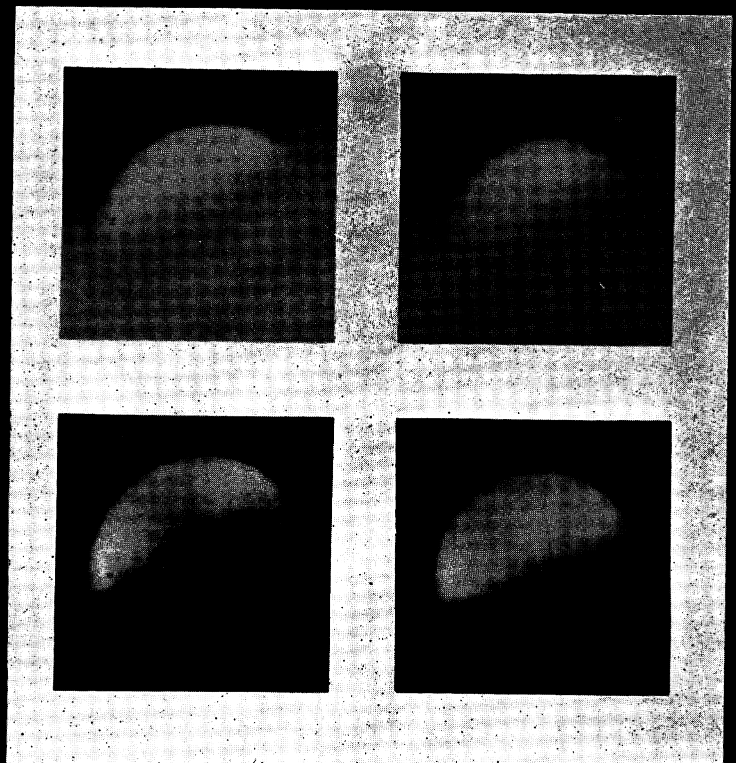
One of the most significant things about Venus, as astronomers will tell you, is that of all the planets it is the one on which we have the greatest chance of finding conditions approximating to those existing here on this earth. Yet, though at times Venus is only about 26,000,000 miles away from us—a comparatively short distance according to astronomical reckonings—our actual knowledge of this fascinating planet is disappointingly meagre, with all sorts of vital questions still unsolved.

No blame attaches to our astronomers for this.

They have been, and are, studying Venus with close attention. The trouble is that Venus is so coy and shy that she will show us practically nothing of herself. The planet is veiled perpetually in layers of cloud; and just what may exist, or may be taking place, under that baffling cover of cloud and hazy atmosphere we can only surmise; while spectroscopic studies as to the planet's atmosphere are also difficult. The fact is that Venus simply will not yield up any of its chief secrets, though it is true that a certain amount of data, amplified by some quite justifiable deductions, now stand to the credit of astronomical research.

When conditions happen to be specially favourable for observation, certain rather faint markings and shadings can be detected on the planet, and when photographs are taken in violet or ultra-violet light these vague, shadowy markings become a little more clearly defined. Even so, they do not tell the astronomer much. They are not distinct enough for any particular deductions to be drawn from them. Some are merely like dark, dusky spots. Others, it is thought, may be mainly cloud formations of varying shapes and densities. It is impossible to say. But one thing which observations of Venus suggest is that the planet has a fairly extensive atmosphere, one probably comparable in its extent with that of the earth, and that in this Venusian atmosphere the gas which is exhaled by oxygen-breathing life on this globe, carbon dioxide, can be traced and identified. Yet another conclusion drawn from a study of Venus is that, owing to its nearness to the sun, it must have a very much higher surface temperature than we have.

Summarising all such knowledge as we have been able to glean of Venus, it is an intriguing, thought-compelling picture that presents itself; one sufficient to stimulate the interest of all astronautical enthusiasts, and to make them long for the day when space-voyagers may be able to reach this baffling planet, and solve some of the mysteries which at present enshroud it.



The planet Venus, which will be a space-flight objective, is so shrouded by cloud that little can ever be seen of it. Here, in the top picture, is all that is revealed by a photograph taken through an infra-red light screen. The lower photograph was taken through an ultra-violet screen.

Should such space-flyers ever get there they will not have to worry, as we do, about the brief period of a day, with its few hours of light, being too short for all we have to do. It has been reckoned that a Venusian day lasts for a period equal to four or five of our weeks.

Primarily, what astronomical research suggests is this: that Venus, in the stage of development it has now reached, is probably to be compared with the stage reached on this earth some thousand million years ago. All such calculations have to be largely approximate, depending on the accuracy with which geological experts can estimate the passage of such vast periods of time in the history of planetary development.

The mind-picture one builds up of Venus is of a young world in the process of formation—a world lying under the heat of a sun which bathes the planet in a dull, stifling, all-pervading glow.

Beneath the heavy, steamy atmosphere of this tropical climate there are likely to be huge, jungle-like swamps and humid seas. Probably, also, there are big, semi-fluid areas which will later on become seas. Other zones, in the process of becoming solid, may be shaken by earthquake disturbances and volcanic eruptions. What one can picture is a world in the making—a primeval, embryo world! Amid all this heat and moisture, all this vast hot-house of a dawning world, one can imagine there may be the first faint stirrings of some form of life.

It is this possibility which intrigues those who study Venus, and who fit together, and draw their deductions from, all the data their observations can furnish. But the life that may be beginning to evolve there—if such should be the case—may be a form of life very different from that which has been in process of development on this planet.

VIII

PROBLEM OF LIFE ON OTHER WORLDS

It is here one reaches a point which is the keynote of any study one may make as to the possibility of life on other planets.

It is this.

When we are considering conditions as they may appear to exist on these other planets, and estimating the chances of there being life on them, we must not make the mistake of thinking in terms of what we know to be the state of affairs here on our own earth, or to visualise "Venusians" or "Martians" in terms of living creatures whose biological structure is in any way similar to that of Earth Men.

It would be almost impossible for life on any other planet to evolve, stage by stage, just as ours has done on this globe, or that living creatures on those other worlds, if they exist, would function biologically as we do. I remember it was Professor Low, in an introduction to the book by Mr. Cleator I have already mentioned, who wrote in this connection: "It is a pitiful example of conceit to suppose that life must necessarily be in human form, or to assume that the circle of nature runs through every crystalline structure to the two-legged animal we consider the highest form of agglomerate matter. Martians and Venusians may not have mouths, ears, eyes, or noses like ours. They may see, hear, and assimilate their nourishment in some quite different way. There may be creatures who see by what we call heat, or who move in thought-form alone."

I always recollect with what avidity, at an extremely impressionable age, I read Mr. H. G. Wells's *War of the Worlds*, and what struck me more than anything else was the ingenious way in which he approached, in that piece of expert fiction, the problem of the biological development of living creatures which, after evolving on Mars to a point greatly in advance of anything so far reached on this globe, decided on a voyage across space from that planet to our earth.

The imaginary picture Mr. Wells built up of those Martians was of creatures which had gone through such a process of evolution that they had arrived at a stage at which, physically, they had become little more than brains, their limbs having ceased to be of any particular use to them, seeing that they had made pieces of specially designed machinery do practically everything for them except think.

So when Mr. Wells shows us one of these creatures from Mars climbing laboriously out of the projectile in which it has just landed on our earth, we see an uncanny, globular-like apparition which, before it can become physically active, has to hoist itself into an elaborate machine which converts its mental impulses into suitable action, and in which it can move swiftly from point to point.

This appeared to me then, and still appears to me now, as a dexterous piece of literary craftsmanship. It avoids the error of representing one of these creatures from another world as being in the least like man, and, at the same time, it gives a logical suggestion of how, in a planet like Mars, which may be assumed to have advanced, biologically, very considerably farther than the earth, evolution may have produced a highly-intelligent form of life which is fundamentally different from ours.

Once we can place ourselves in the mental position of ceasing to think of life on other worlds as being anything like life on this planet, we shall have gone a long way towards attuning ourselves to such suppositions as seem reasonable concerning planetary development.

Take the question of the extremes of heat and cold which observations suggest must exist on some of the other planets. These extremes, very considerably more arduous than anything life on this planet has to endure, have too often been taken to preclude the possibility of any form of life on the planets where they exist. But it is here that we need to pause and think afresh, bearing in mind the fact that science can already tell us of certain forms of life which survive in extraordinarily low temperatures, and that there are also certain germs which it has been ascertained can continue to exist in temperatures not far removed from boiling-point.

If such is the case here on this earth it is foolish to assume that life would be impossible on some other planet where conditions involve temperature and other variations far more extreme than those on our globe. What we must be prepared to accept is that forms of life completely different from ours may, and quite probably do, exist out in space under conditions which would be fatal to us.

The possibilities of life on other planets are infinite. We are millions of light years away from certain stars on which there may be beings millions of years in advance of us. We can do little more than conjecture and, while doing so, it is essential that we should keep open minds.

When one is dealing with problems as vast as these, when one is face to face with the enigma of the universe, it is helpful if one tries, as far as one can, to build up some sort of a pattern in one's mind—something in the shape of a plan which is better than just a hopeless groping. It is here, personally, that I have found some mental satisfaction in the theory which, broadly speaking, regards the universe as what one might call a form of mighty experimental station. What this great experiment is, assuming there is such an experiment in progress, it is of course beyond our puny intelligences to fathom. Even if we could be told something about it, our brains might probably not have the capacity to grasp it. Man needs to develop some new sense before he can appreciate the mysteries of the universe. Yet the assumption I have mentioned is one which, when you think it over, seems to throw at least some helpful gleams into the otherwise heavy darkness of ignorance and doubt.

It is possible to imagine the planets of our solar system, and of other systems more distant, being set off on their long journeys through time with conditions developing on their surfaces which gradually produce widely-differing forms of life, and one can also picture these forms of life, in their turn, evolving in all sorts of different ways.

Just as in some research-station here on earth, though on a vastly greater scale, one can imagine each planet as a plot, or piece of ground, on which some great experiment in evolution is actually in progress—an experiment which is being watched and noted by higher intelligences, the nature of which we can only guess at dimly.

Might not this be the answer to our riddle?

Who can say?

But an answer there must be. Some key must unlock these mysteries. Perhaps we may never find it. Perhaps we are not intended to find it. But this should not prevent us from persevering in our search, and it is in this great quest that the possibility of interplanetary travel plays so vital a part.

IX

THE FAMOUS "RED PLANET", MARS

Of all the planets that have been studied by our astronomers, both by telescope and spectroscope, none has attracted more attention than Mars.

That this should be so is not surprising, seeing that for some sixty years or more controversy has been raging round this famous "red planet"—so named owing to its reddish and orange-coloured expanses which are believed to be vast areas of desert-land.

One need hardly remind readers as to what all this argument has been about. Almost everybody, at one time or another, has found himself or herself speculating as to the existence of some sort of intelligent life on Mars, and as to those famous markings on the planet which may perhaps be artificially-created "canals", or which may on the other hand be merely natural features.

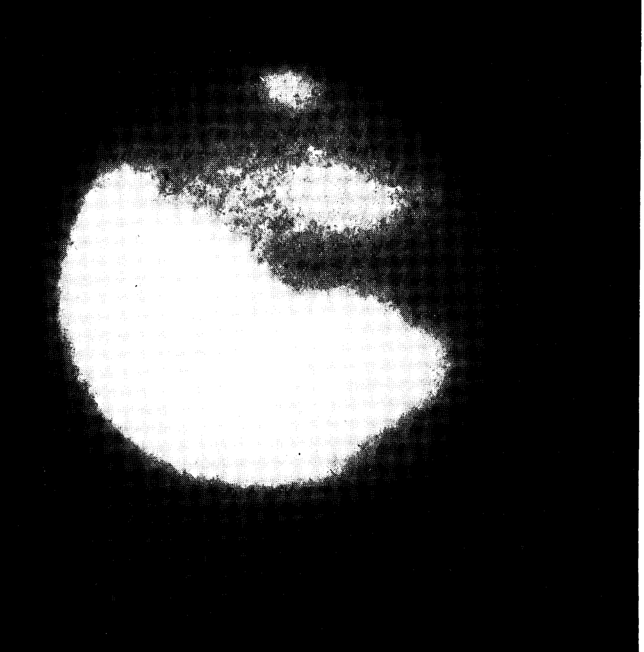
To those of us of the Interplanetary Society this much-debated "red planet" has a particular interest, because although Venus approaches some nine million miles nearer to us than Mars, it seems fairly probable that, for various good reasons, when in due course the time arrives for such an adventure, Mars may be the destination of our first interplanetary voyage.

More than one famous astronomer has devoted many patient years—practically in fact a lifetime—to a study of Mars and its intriguing problems; such authorities, among others, as Schiaparelli, Antoniadi, Lowell, and Barnard.

That experts should not be found to agree as to some of the objects and features on Mars, as seen through telescopes located in different parts of the world, is due largely to the fact that what they see on the planet, in the shape of detail, is practically at the limit of telescopic vision, and that whatever feature on the planet is being studied particularly can only be seen for short periods under favourable conditions. Only for a few months, every year or so, are observational conditions really satisfactory; and then the best atmospheric conditions for studying small details may only occur momentarily.

Even then much depends on the observer. Years of experience are required before the human eye can be trained to a fine perception of telescopic detail.

In photographing Mars, a difficulty is that much of



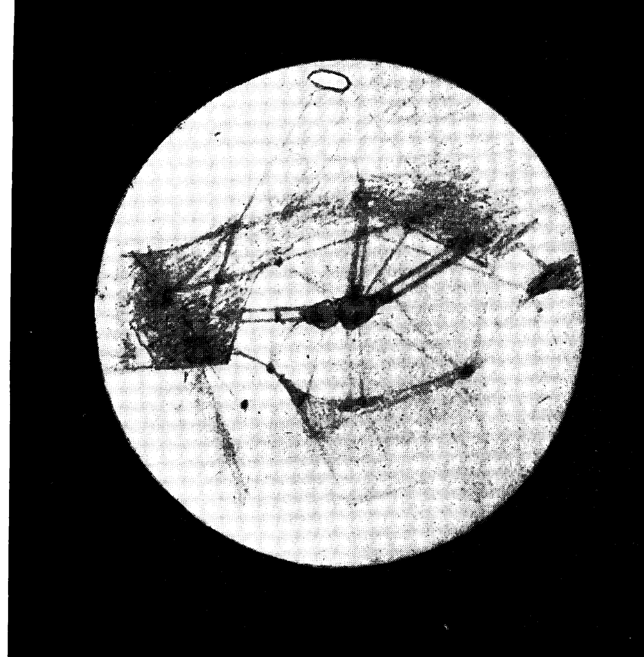


Photo copyright Ellison Hawkes.

On the left is an enlarged photograph of the planet Mars, one of the chief objectives in space navigation. The whitish lower areas are reckoned to be big expanses of desert. The darker parts are taken to be areas of vegetation, with one of the polar caps showing at the top of the photograph. On the right is a view of Mars from observations at the Lowell Observatory, and showing the much-debated "canals", as seen by Professor Lowell. The dark markings are areas of vegetation. The numerous straight lines are the mysterious "canals".

the detail it is being sought to study is so faint and elusive that it is lost in the grain coarseness of fast plates; while if time exposures are resorted to, there are slight tremors of the atmosphere to be reckoned with which may blur just those details about which there is most speculation. Here a recent and improved method, to which I shall refer later, is to expose a number of separate plates and then merge some of these into a photographic mosaic. This tends to eliminate the adverse effects due to the grain on the plates and, when reinforced by drawings made from visual telescopic observations, gives the most satisfactory results obtained so far in these studies of Mars. One should add that data even more valuable is expected to result from the use in America of the big new super-power telescope to which I have already referred.

When one is trying to reach any sort of conclusion as to the Martian controversy, one needs to bear in mind all the difficulties, and chances of error, confronting those studying an object which appears very small in even the most powerful existing telescope, and of which it is so difficult to obtain satisfactory photographs; while one must also remember that the drawings made by those recording what they see, when details are extremely minute and viewed only occasionally for a short time, may vary considerably owing to the personal factors involved.

X

START OF THE GREAT MARTIAN CONTROVERSY

LOGICALLY-MINDED investigators like Schiaparelli, the Italian astronomer, have always taken a wise course in the Martian controversy. What they have done is to record as faithfully as possible all they have seen, and never to draw from these observations any conclusions not strictly in accordance with the observed facts.

It was Schiaparelli who started this controversy on its way.

He studied attentively those dusky markings on Mars which could be seen standing out against the reddish background, these markings being taken to be seas or swampy areas and the reddish background dry land, probably in the form of vast areas of desert.

Schiaparelli studied the planet more closely and continuously than had been the case before, and having a good telescope, and equally good conditions for observation, he made discoveries which were of outstanding importance.

One of the things he observed was that there were certain curious dusky streaks crossing the supposed land areas or continents of Mars, and that these streaks, which appeared a strangely regular pattern, seemed to connect with one or another of the Martian "seas", or areas believed to be mainly water.

Schiaparelli studied these streaks very closely and with an ever-growing interest, and it was he who, in his own language, gave them the name of "canali", or channels. And it was in this way that the word "canal" first came to be used in connection with them. This word "canal" suggests to any ordinary person the existence of engineering or constructional processes which must be the work of intelligent beings of some kind or another. But Schiaparelli himself never went so far as to put any such definite construction on what he had seen.

Continuing his studies of Mars for many years, Schiaparelli paid constant attention to these puzzling "canali". Some, he noted, showed up quite clearly. Others it was no easy matter to see at all. Some, he reckoned, might be from a hundred to perhaps two hundred miles across. Others looked as though they were not more than twenty miles or so wide. What struck this patient observer more than anything else was the way in which these channels stretched across Mars for long distances in perfectly regular lines, their straight courses not resembling in the least the winding of great rivers such as we have on our earth.

These channels, Schiaparelli further noted, usually intersected each other at certain small dark, clearly-seen spots. These spots Schiaparelli took to be areas of water in the shape of lakes, Another fact this astronomer recorded was that each of the main channels opened at its end either into a sea or lake. None of them appeared to end anywhere in the middle of one of the Martian continents.

Though his studies of Mars were so profound, and extended over such a long period of time, Schiaparelli's conclusions about all he had seen were always cautious and non-committal. Obviously, he said, these "canali" which he had studied so closely must be immense furrows or fissures in the surface of Mars. It seemed equally obvious that their purpose must be to carry water. But beyond that he was not prepared to go, preserving always the perfectly open mind of the trained observer.

"The singular aspect of these canali, and their being drawn with absolute precision, as though by rule or compass, has"—he wrote—"led some to see in them the work of intelligent beings, inhabitants of Mars. I am very careful not to combat this supposition, which includes in it nothing impossible."

He himself was prepared to deduce from his observations that the channels might be of a purely geological formation, and that it need not be taken that they were the work of intelligent beings.

Schiaparelli's work on Mars included, of course, studies of the famous white caps to be seen in the polar regions of the planet, and which he noted showed regular seasonal changes in their size.

During the Martian northern summer the north polar cap could be seen to shrink, while the south cap increased; and then with the further seasonal changes the northern cap grew again while the south cap tended to decrease in size.

What all this suggested was that there were seasonal processes at work on Mars similar to those taking place in the polar regions on our own earth.

XI

SUMMARY OF THE WORK OF SCHIAPARELLI AND OTHERS

YEAR after year Schiaparelli and other astronomers added to their knowledge of Mars.

Gradually, piece by piece, a picture was built up of a world on which conditions are such as to render reasonably possible the existence of some sort of life; but a planet which, at the same time, is long past its prime in the sense that in its evolution it represents what may be the position of our earth many, many millions of years hence; a world, that is to say, which is in the process of becoming colder and colder, and losing more and more of its atmosphere and moisture—what might be called a slowly dying world.

But spectroscopic studies show that Mars still has an atmosphere, even though it may be thin, and in this atmosphere there is still evidence of some water-vapour and also of a certain amount of oxygen. The existence of this belt of atmosphere is confirmed by the presence of clouds over the planet. These reveal themselves not only in the telescope but also in photographs. Some which form over Mars appear white to the eye. These white clouds are, however, not seen so often as those of a distinctly yellowish tint which, sometimes, can be observed to cover quite a large part of the planet.

A probable explanation of the colour of these yellow clouds is that they are dust-clouds forming above the many desert areas of Mars.

As for the Martian climate, astronomers can tell you something about this. In the words of our Astronomer-Royal:

"The climate of Mars may be said to resemble that of a clear day on a very high mountain."

The climate of the planet is a climate of extremes—a climate very definitely more rigorous than ours.

In the tropical areas of Mars, in the middle of the day, it is reckoned that the temperature may reach fifty degrees Fahrenheit or perhaps a little more; while at the poles, in the Martian summer, it must rise above freezing-point. During the afternoon on Mars, however, as the sun sinks lower, the temperature begins to fall very quickly, and by night-time is very cold indeed—very much colder than any of the winter-night temperatures we have to endure.

It will be seen, from the various facts and inferences I have mentioned, that the methodical research-work on the problems of Mars has certainly not been wasted, and that we really know, or can deduce, quite a lot about this intriguing planet.

One might look upon Mars as a somewhat smaller edition of our own earth. The Martian day is only some thirty-seven minutes longer than ours, while the inclination of the planet's axis is also approximately the same as that of the earth; which means that the Martian seasons resemble ours. But of course there are fundamental questions about Mars which still remain unanswered, and will probably continue to be unanswered until, on some day in the future, a first party of space-voyagers from this earth can make their landing on the planet.

XII

PROFESSOR LOWELL'S CONCLUSIONS

ONE of the most famous of all students of "the red planet" was Professor Percival Lowell at his observatory at Flagstaff in Arizona—an observatory admirably-placed at a high altitude in a dry region, with atmospheric conditions favourable for systematic planetary studies.

Professor Lowell devoted himself particularly, over a considerable period of time, to trying to elucidate the problem of the much-discussed channels or canals on Mars. Aided by skilled assistants, and studying Mars closely whenever the planet was well-placed for observation, Professor Lowell found that dark areas previously taken as being seas actually revealed quite a lot of detail, being crossed here and there, as were the reddish zones which had so far been taken to be continents, by a network of channels or canals.

Not only this, but certain changes in form and colour, which Professor Lowell was able to detect in these dark areas made him to believe that such changes were mainly of a seasonal character. This led to the further inference that the dark areas could not be seas, but that they were more probably zones of vegetation, as contrasted with the reddish, desert regions, where evidently no vegetation existed.

Gradually, year by year, Professor Lowell built up from his observations of Mars an interpretation of the seasonal changes on the planet. In this interpretation the channels or canals played an important part. Here it is necessary to remember that a familiar feature to those studying Mars is the way in which the planet's Polar caps shrink and almost vanish in summer and reappear in winter. It was soon after the melting of these icecaps that Professor Lowell observed that there was a distinct darkening of the canals in the regions nearest the poles.

This darkening could be seen spreading slowly down the planet, while following this darkening of the canals there appeared gradually a number of darker green-coloured markings on those dusky parts of the planet which have already been mentioned.

The process involved first in the melting of the polar caps, then in the darkening of the canals, followed by the turning to a darker, greenish colour of lower portions of the planet, Professor Lowell accounted for by the existence on Mars of a vast system of irrigation which, seeking to compensate for the growing lack of moisture on the planet, was making every possible use of such water as became available through the seasonal melting of the ice. And as the water from the poles was carried down and distributed by the canals, so the irrigation process on the planet was accompanied by a visible growth in vegetation in the areas served by the canals.

One point stressed by Professor Lowell, after concentrating his attention upon the canals, was the way in which many of them, meeting at the dusky spots noted already by Schiaparelli, then passed on from one to another of these spots—which came to be known as "oases"—in straight unswerving lines. The regularity in the pattern of the canals, as the Professor saw and drew them on his maps of the planet, and the way in which they linked-up systematically at these oases, made it impossible—in his opinion—for them to be natural features of the Martian landscape.

"The observer," wrote Professor Lowell, "apparently stands confronted with the workings of an intelligence akin to, and therefore appealing to, his own. What he is gazing at typifies not the outcome of natural forces of an elemental kind, but the artificial product of a mind directed to a purposed and definite end."

Summing up the results of all his Martian observations, Professor Lowell did not hesitate to state that, in his considered view, the canals on Mars were artificial channels constructed presumably by intelligent beings, and that their obvious purpose was to convey melting water from the poles across the planet from point to point, thus making it possible for vegetation to spring up and grow along the courses of the canals—the various "oases" which had been noted being fertile zones where, it was to be assumed, the inhabitants of Mars lived.

In his famous book, *Mars as the Abode of Life*, Professor Lowell wrote:

"To our eventual descendants life on Mars will no longer be something to scan and interpret. It will have lapsed beyond the hope of study or recall. Thus to us it takes on an added glamour from the fact that it has not long to last. For the process that brought it to its present pass must go on to the bitter end, until the last spark of Martian life goes out. The drying-up of the planet is certain to proceed until its surface can support no life at all. Slowly but surely time will snuff it out. When the last ember is thus extinguished, the planet will roll a dead world through space, its evolutionary career forever ended."

Professor Lowell's long and brilliant work, and his published conclusions that the Martian channels and their arrangement—indicating irrigation on a scale greater than anything ever attempted by man—gave proof not only of the workings of an intelligence, but of a very high order of intelligence, naturally aroused keen and world-wide interest.

People, everywhere, grew fascinated at the idea that an authority so eminent should have satisfied himself, after expert research, that he had found evidence not only of life, but of intelligent life, on another of the bodies in our solar system.

It opened up a new vista.

It gave men food for thought such as they had never had before.

XIII

OPPONENTS OF THE LOWELL THEORY

THOUGH the Professor's Martian investigations aroused such universal interest, they failed to receive universal agreement—not, at any rate, among some of his fellow-experts in the astronomical world.

None of these other astronomers sought in any way to belittle what the Professor has done.

The fundamental importance of his work on Mars was fully recognised, and acknowledged.

The trouble lay in the fact that other astronomers who had been observing Mars on all suitable occasions with just as much attention as had Professor Lowell, confessed themselves unable to see things as he said he had seen them.

More particularly there was disagreement as to the interpretation of what was actually visible, under favourable conditions, of that supposed canal system of Mars.

This was the main stumbling-block. An observer as experienced as Dr. Barnard, operating with the big telescope at Mount Wilson—one of the most powerful in America—found that he could not agree with Professor Lowell as to there being any appearance of planned, systematic arrangement in the Martian channels. Certainly he could see the larger of these channels, but to him they did not form anything resembling a clearly laid-out or geometrical pattern.

All Dr. Barnard could make of them, at those times when the planet yielded the best opportunities for observation, were that they were markings of a broad, diffused character, irregular in their outline. Dr. Barnard could not read into his study of Mars anything like what Professor Lowell had read into his.

This divergence of view arose from the different appearance presented by the surface of the planet as seen by different people, relying on their visual observations from different points—observations which could not, as already explained, be reinforced by any conclusive form of photographic proof.

Whereas the maps drawn by Professor Lowell, from what he saw of the planet's surface, showed this intricate system of canals, those prepared by Dr. Barnard with equal care from the way in which details unfolded themselves to his eye showed no such regular patterns at all. To him that geometrical network simply did not exist.

Both these highly-trained observers were perfectly honest in putting down what they saw. The whole trouble was that owing to the image of Mars appearing so small in even the largest telescopes, and with the clarity of any detail on its surface depending on conditions which might be favourable on perhaps only a few nights of the year, it was almost impossible to get any complete unanimity among those who were studying the planet.

Some experts were in more or less general agreement with the Lowell theories. Others, including the well-known astronomer Antoniadi—who had studied Mars for years with the big telescope at Meudon—felt obliged to join Dr. Barnard in saying they failed to see any systematic or intelligent arrangement in those channel-like markings on the Martian surface.

A British astronomer, Dr. Waterford, who made a careful study of Mars, emphasized what a long time is needed before the eye can become trained to a fine appreciation of telescopic detail when studying the planets. As regards Mars, this expert was inclined at first to see as lines what, subsequently, began to resolve themselves into nothing more than disconnected streaks, and sometimes these streaks tended to blend into a still more hazy background.

A suggestion about the much-debated canals, made by Dr. W. H. Pickering, is that they may be cracks due to some form of volcanic action on Mars.

XIV

THE UNSOLVED RIDDLE

An interesting contribution to the Martian canal controversy was written in *Spacewards*, the journal of the Manchester Astronautical Association and of the Astronautical Development Society, by the research secretary of the former, Mr. Sidney Harris.

"It is generally admitted," he wrote, "that the larger canals have an objective existence, but the others are held to be optical illusions. Be that as it may, the writer's opinion is that they are probably belts of vegetation occupying the course of former waterways which may, or again may not, have had an artificial origin.

"Is there any rational life on Mars?" asks Mr. Harris, and goes on:

"There are certain things on Mars which might be interpreted as the mark of intelligent beings, but these objects are at the very limit of our telescopic vision and we may well have to wait for the astronautical conquest of this planet before the problem is finally solved."

So there you have it, for and against. I do not think I could conclude this section better than by quoting again from Mr. Harris. He is picturing the first party of astronauts from this earth emerging from their space-vessel on their arrival on Mars.

"Their first impression on stepping out onto Martian soil—or, rather, sand—would run something like this," writes Mr. Harris.

"There is an air of intense solitude and dreariness about the place. Sand, and still more sand, stretching away to the horizon—which, incidentally, is much nearer than on earth—is the immediate prospect.

"The scene is not, however, entirely featureless. Shallow depressions, and long, low ridges, introduce a limited contrast. The sky, devoid of clouds, is purplish-black, and forms the setting for a much-shrunken sun. Clouds would indeed be a rarity, while any sort of atmospheric precipitation—apart from the polar caps—would be confined to a fine drizzle, or perhaps merely a ground mist over a relatively small area."

And what else will our astronauts find on Mars? Will they find life still there in some form or another, or will they find only signs of a life, and of a civilisation, which has already vanished from the dying planet, leaving nothing perhaps but the remains of a vast irrigation system to tell the grim story of its final struggle against extinction?

Who can tell?

Part Three

DESIGN AND CONSTRUCTION OF VESSELS FOR THE NAVIGATION OF SPACE

I

SOME OF THE INITIAL QUESTIONS

Of all the work the experts of our British Interplanetary Society were able to carry out, in their pre-war investigations, the most outstanding was their examination of the technical problems in the design of a space-vessel of a sufficient size and power to carry a crew of three men on a flight to the moon and back.

It is with this scheme I shall now deal, in a non-technical way, drawing upon data to be found in the Journals and Bulletins of the Society, and in the reports of committees which were concerned with specific enquiries of one kind and another.

There is one thing that should be understood. There can, as yet, be nothing hard-and-fast, nothing finished or conclusive, about the design of any space-vessel. A vast amount of further research will be necessary, and a long experimental programme embarked upon, before final decisions can be reached on many technical problems.

What the experts of the pre-war Interplanetary Society managed to prepare, and what our post-war Society will be developing in the light of the latest knowledge, is a provisional design for a lunar space-ship which is more detailed, and more generally comprehensive, than any previous effort along these lines.

The pre-war work of the British Interplanetary Society was, in its essentials, a preliminary technical exercise in space-ship design, based on all information available at that time; but since then, of course, we have had the evolution of the V-2 rocket and, more recently, the epoch-marking advent of atomic power.

Apart from their work in space-ship design, the experts of the pre-war Interplanetary Society examined the question of special instruments by means of which the speed, altitude, and surroundings of the space-vessel could be observed while it was in flight, and they made demonstration models of certain of these instruments.

They also examined the problems which would have to be faced in ascending, navigating, and landing in a space-vessel; while yet another research was concerned with the stay of the members of the expedition on the surface of the moon, and with their safe return to earth on the completion of their voyage of exploration.

A description of all this work was written in a Journal of the British Interplanetary Society just before the outbreak of World War No. 2, by Mr. H. E. Ross, and this and other data concerning such technical matters as liquid and solid fuels I have before me as I write. As Mr. Ross points out:

"In designing a space-ship the designer has a completely different problem to that involved in the design of any other means of transport. A motor-car, a railway train, an aeroplane, or a ship, consists basically of a vessel and a fuel tank—in which latter being placed the fuel required for a journey or journeys. The shortest space voyage, however, is the journey to the moon, and with the most optimistic estimates of fuel energy and motor efficiency the quantity of fuel required will still be such that the fuel tank would require to be much larger than the rest of the ship."

One might point out that the above was written prior to the advent of atomic power, which should in due course put a far more favourable aspect on the fuel and power problems arising in space navigation.

The main object of the Society's preliminary research was to get out a quite provisional design for a vessel which, while providing for the fuel load necessary for an out-and-return lunar voyage, and affording accommodation for its crew and their instruments and equipment, could still at the moment of take-off, when fully-loaded, be kept within figures for size and weight which would render the vessel a practical proposition from the view-points of cost and construction.

The technicians of the Society devoted a great deal of time and attention to the question of what kind of fuel, or combination of fuels, should be employed for the propulsion of a lunar space-ship, remembering that to drive a great man-carrying rocket up till it is clear of the earth's atmosphere, and out in the vacuum of space, will need an immense output of controlled and concentrated power. It is here that you have one of the key researches; and it is here, too, that after further research work, atomic power should furnish the solution to the problem.

II

THE FUEL INVESTIGATIONS

PRELIMINARY test-work was carried out by Interplanetary Society technicians with more than eighty suggested fuels and combinations of fuels, both liquid and solid, and the majority were, after careful investigation, eliminated as being unsuitable for one reason or another.

At the same time the committee which devoted a couple of years to this research came to the conclusion that fuels could undoubtedly be obtained, after further research, which would provide ample energy for a lunar voyage, provided that methods could be developed for controlling combustion, and for ensuring a reasonably efficient energy utilisation.

The committee's pre-war investigations included not only a comprehensive review of liquid fuels, but also of a number of possible solid or paste fuels with an oxygen-bearing content.

Liquid-fuel motors in their existing forms have, it was recognised, still a number of difficulties to overcome.

These are largely of a constructional nature, but also in such matters as cooling and fuel-feed; while in favour of solid-fuel systems are their general simplicity and cheapness of design. In considering possible compositions to be used in solid fuel propulsion units, the committee pointed out that there are a number of metals and metalloids which produce extremely high energy values, but which still await fuller technical investigation.

With many possible combinations there is still the problem of producing them in a sufficiently stable, safe, and controllable form. What it all amounts to is that years may have to be spent on further experimental work in this particular field, and also, of course, in that of the utilisation of atomic energy. In the meantime, and in their provisional design for a lunar space-vessel, the pre-war committee favoured a fuel system employing some plastic compound with an oxygen-bearing content, the actual composition of this fuel to be decided later, after an opportunity had been found for further experimental work. Since these investigations were carried out, the development and use of the V-2 rocket with its liquid fuel system, has focused a great deal of technical attention on this method of rocket propulsion. And here—at any rate so far as I am concerned in this non-technical dissertation—one feels one must leave this highly complex subject of rocket fuels, with all the still unsolved problems of their composition, methods of employment and control, and ultimate energy values.

Anyone who wants to pursue in detail this aspect of the research should join our Interplanetary Society, and in this way gain access to the reports of the committees which are keeping abreast of fuel-research progress in this and other countries.

There is one thing that those in the best position to judge do not hesitate to tell you, even at this preliminary stage of development. It is that further progress in rocket propulsion—and particularly in atomic rocket propulsion—will without doubt solve one by one the problems arising in propelling a man-carrying vessel across space, and that what is theoretically feasible already will, as these further researches bear their fruit, be converted into accomplished fact.

III

A FIRST GLANCE AT THE MOON-ROCKET PLAN

BEFORE me I have details and diagrams of the preliminary lunar space-ship evolved by the experts of the pre-war British Interplanetary Society after their probings into all the essential factors as they then presented themselves.

The design of this pioneer machine for navigating space shows a long tubular structure with a curved or domed head. One thing that strikes you is that no particular attempt seems to have been made to streamline the vessel. When you ask why this is so you are told that the form of the ship has been dictated largely by other considerations; while as compared with the terrific power needed to lift the vessel out of the earth's gravitational field the total air resistance is so negligible that it does not matter greatly.

The essential design feature of the vessel is that it embodies the cellular step principle of construction, there being six of these steps, one behind the other, extending from the nose of the vessel rearwards. Each of these steps is built up on an ingenious honeycomb formation, comprising a large number of separate rockets, or tube units.

Each of these rockets is filled with its own combustible charge, and each is so arranged that it can be fired independently of the others.

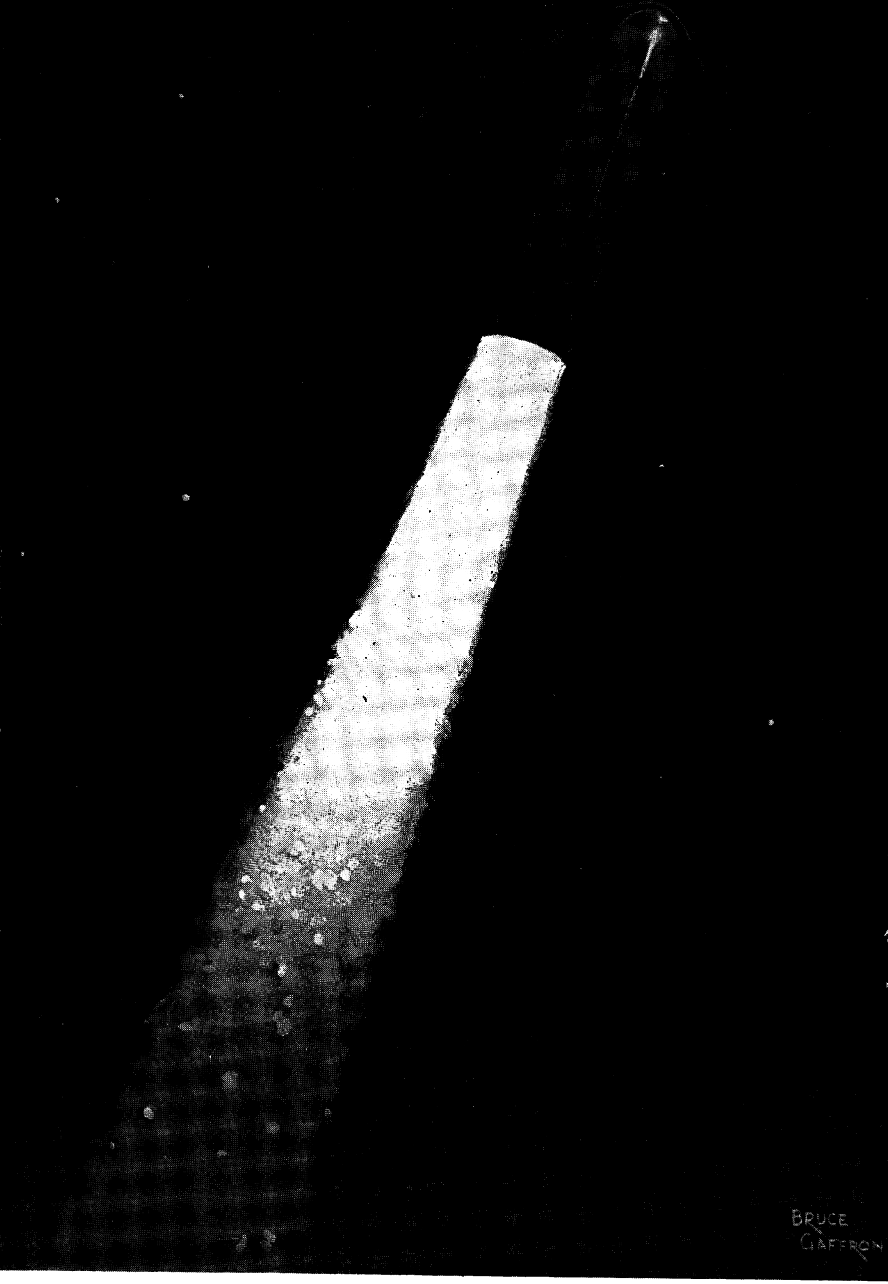
At the same time each propulsive unit forms part of batteries which will be fired in sequence, according to the impulses of an automatic "pilot".

Encasing each of the steps, or tube unit honeycombs, is a light covering sheath which serves to keep the tubes in place until they are ready to be discharged. Altogether, in these six steps or propelling rocket batteries, there are several thousand separate units, each in its individual tube. And here one comes to the essence of this cellular or honeycomb form of design. In order to reduce weight progressively, as the space-ship rushes up to obtain its gravitational release from the earth, each tube after it has fired its contents, and done its work, ceases to be carried by the space-ship just as so much dead weight.

Instantly each tube has ended its firing, it is so arranged that it is jettisoned automatically, falling away from the space-vessel and so ensuring that no useless or idle weight is being carried.

It is this method of jettisoning dead weight, and doing it progressively from the start of a space flight, which has meant a tremendous increase of efficiency over earlier space-ship designs, and which has reduced the total fuel-load figure, for an out-and-return flight to the moon, to something which, instead of being almost prohibitive as hitherto, is now within practical limits.

As shown in this design the Society evolved, it is possible to plan a lunar space-vessel which, having an overall size about that say of a large barge, will have a total loaded weight, at the time of discharge from the earth, of approximately 1,000 tons. And it may be noted further that, in order to provide power sufficient for an out-and-return lunar flight, roughly 90 per cent of this loaded weight is represented by fuel, the remaining useful load being allocated to the crew and their equipment. Figures far better than this should be obtained with any form of atomic power-plant.



This picture shows the giant 1,000-ton rocket (described in these pages) just about to leave the Earth's atmosphere on its voyage to the Moon, with its huge fiery trail behind it, and with a "compression wave" showing on either side of its nose which is due to its tremendous speed.

IV

VALUE OF THE CELLULAR STEP PRINCIPLE

AMONG the advantages of employing a large number of separate power-units, each capable of being fired individually, is that the rate of ascent of the space-vessel, in the period immediately after leaving the ground, can be so controlled that there will be no fear of the crew suffering from any such physical ill-effects as might result from a too rapid acceleration. This is a point to which I shall be returning later.

Five of the six steps, or cellular formations of power-cells, will be allocated to propelling the space-ship from earth to moon, the remaining step containing power sufficient for the return flight of the astronauts from moon to earth. That only one step should be necessary for the flight back from the moon is accounted for by the fact that, owing to the small gravitational influence of the moon, as compared with that of the earth, very considerably less power will have to be expended in securing the space-ship's release from the moon.

Not only will each rocket-tube drop away from the machine after it has expended its contents, but the sheathing or outer case of each step will also be jettisoned automatically when all the tubes contained in it have been fired.

This will mean that the space-ship will not only be very considerably lighter, but also very appreciably smaller in size, by the time it reaches the moon on its outward flight. This will be an advantage not only when the vessel is being manoeuvred for its descent on the lunar surface, but also when the time comes for the crew to launch their machine prior to its return flight to the earth —a process which will, of course, be facilitated by the lower gravitational pull of the moon.

V

MATERIALS TO BE USED IN CONSTRUCTION

CAREFUL consideration was paid, in the preliminary design of a lunar space-ship, to the question of the materials to be employed in construction, this whole matter being dealt with comprehensively by Dr. Arthur Janser, Ph.D., Dipl. Ing., A.M.I.M.E., F.Inst.P., in the journal of the Interplanetary Society.

Dr. Janser explained that in addition to a theoretical and technical study of the problems involved, a number of practical experiments had been carried out.

In summarising some of the results attained, he said it had been agreed that, in preference to any kind of light-weight metal alloys for constructional parts of the space-ship, it would be better to rely chiefly on synthetic plastics.

An outstanding advantage of such plastics is that while they can now be given a mechanical strength equal to that of metals, and in addition have valuable thermic and electrical insulating powers, they also possess extremely light specific gravities as compared with metals.

Such synthetic plastics as would be employed in the space-ship would, generally speaking, prove too expensive for use, say, in the construction of aircraft, but their choice for such a very special piece of work as the space-ship would be fully justified by the results obtained. It is proposed that the space-ship should have a protective outer hull of a glass-like fused aluminium-oxide, which is produced by a special thermite process in a furnace.

The vessel's inner hull, containing the compartment for the crew, will be made of several layers of a strong linen fabric, stretched over a light frame, and bonded together with a compound of chlorinated rubber and a resin made from chlorinated substituted diphenyl.

For the interior equipment and instruments of the space-vessel the constructional material will be balsa wood, treated with a hard lac-resin.

This, Dr. Janser has explained, can now be made extremely light and, at the same time, with a quite sufficient strength.

For the vessel's optical instruments and mirrors it is proposed to use a poly-methyl-methacrylate resin. This can now be produced with a transparency and refraction co-efficient similar to glass. It has the additional advantage of being unbreakable. The use of this substance for the portholes in the control-cabin is also being considered.

For electrical purposes throughout the vessel, the resinous material known as eu-poly-styrene was favoured. This is clear as glass and possesses all the qualities needed in dielectric and mechanical strength. The flexible tubing employed in the craft will not be of rubber but of poly-vinyl-chloride, which is flexible and non-elastic.

Liquids in the space ship, and more particularly the hydrogen-peroxide it is proposed should be taken for water and oxygen supplies, will be carried in strengthened plastic containers made of ethyl-cellulose, with a protective coating of a vinyl-acetylene resin inside.

Special attention, Dr. Janser explained, had been devoted to the design and construction of the adjustable reclining chairs on which the crew of three, in the control-chamber of their vessel, will have to spend most of their time while on their space-flight from earth to moon. What it is proposed to use in this connection is a closely interwoven fabric of phosphor-bronze and horse-hair, impregnated in a rubber solution and vulcanised. This material has a degree of resilience and elastic recovery which would make it specially suitable for supporting the bodies of the crew against acceleration pressures and for absorbing thrust.

Details such as the clothing to be worn by the three space-voyagers has been a matter of careful study. Their clothing, it is proposed, should be woven specially from a yarn with a high silk content. It is also intended that they should wear a tight-fitting interlock-weave garment of elastic threads for the purpose of controlling blood pressure in view of the considerable changes of gravity to which they will be subjected.

One research has been concerned with the constructional features of the space-ship's rocket or firing tubes, experiments having been carried out with certain inorganic bonding materials of great mechanical strength and heat resistance. It is intended that the firing tubes should be made by bonding asbestos cloth in a mould with these materials, and then cementing the shaped bodies into metal tubes. By adopting this method, it is reckoned that a considerable saving of weight will be effected.

It was when commenting generally on all this research work that Dr. Janser wrote:

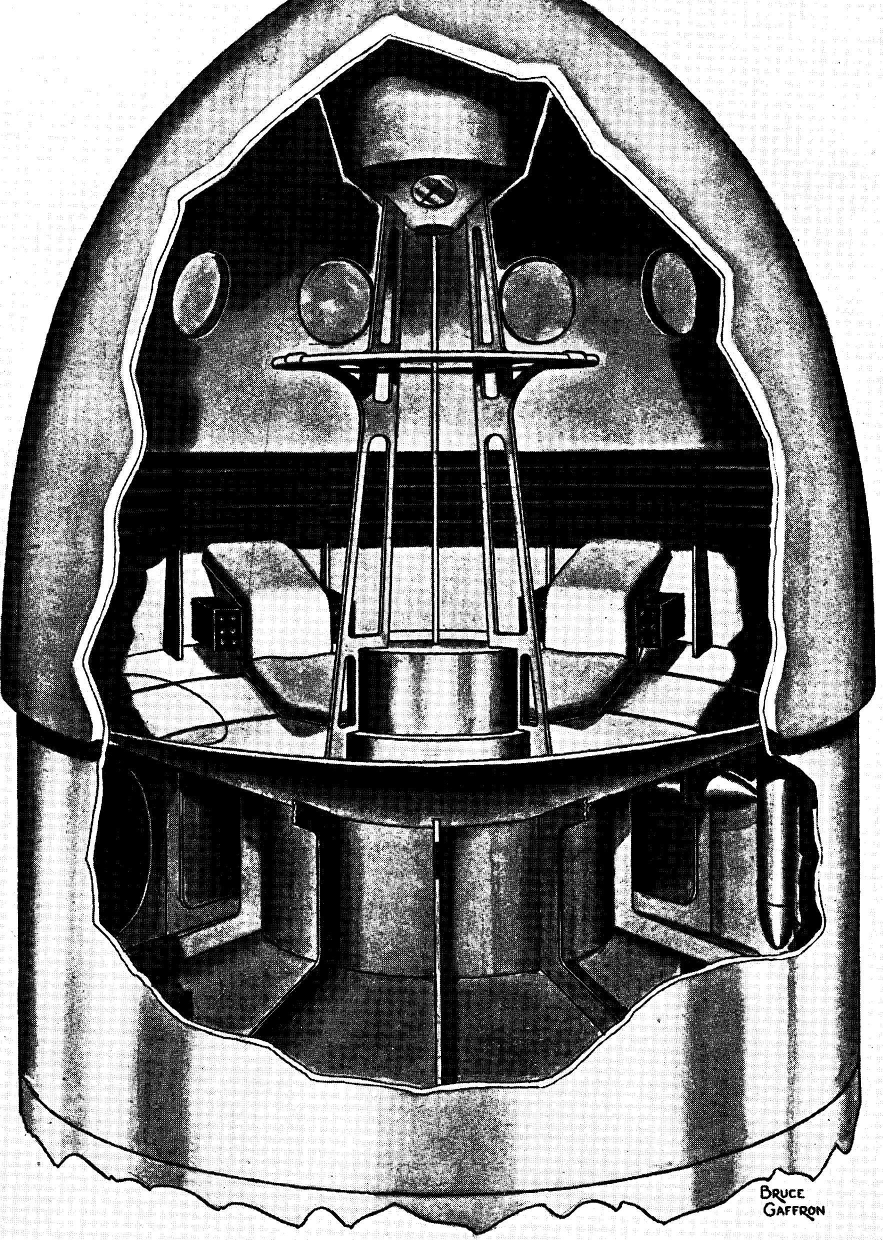
"It contributes to render the construction of a lunar ship a practical proposition, worthy of the serious consideration of scientific bodies."

VI

THE POWER TUBES AND THEIR FIRING

I have referred already to the descriptions, by Mr. Ross in the Journal of the Interplanetary Society, of the long research which preceded the working out of a first design lunar space-ship, and these I am drawing upon again for some further details of lay-out and equipment.

In my previous section I was mentioning how the firing-tube batteries of the vessel would be constructed. In dealing further with this aspect, Mr. Ross explains that, in their actual arrangement in the space-ship, these firing-tubes will be stacked in conical layers to secure greater structural stability, since apart from what might be



This is an accurate representation of what the control-chamber will look like in the nose of a big Moon-flying rocket. Its occupants will be accommodated on special reclining chairs, this prone position being best for withstanding the acceleration pressures and gravity changes encountered. On each side of their chairs they will have controls which they will be able to operate without leaving these chairs. Dials and gauges will be fitted in a position above their heads so that they can read them while still reclining in their chairs.

called the vessel proper—that is to say the top section containing the control-room of the crew—the whole strength of the ship will lie in the tubes. It will not however be necessary to fix these rigidly together. They will simply be stacked and held in position by one-way bolts and light webs.

The firing order of the tubes will be in rings, starting from outside and progressing inwards towards the centre. While the power-tubes are firing, their thrust will hold them in place. When they have expended their contents, the acceleration of the space-ship will cause them to release themselves and drop away. As previously mentioned, there will be a light sheath encircling the outermost ring of tubes. This metal sheath, and the webs, will be discarded as soon as the particular bank of tubes they enclose have finished firing.

Some medium and small firing-tubes will be reserved for use for purposes of deceleration as the space-ship approaches the moon. To facilitate any fine manoeuvring of the space-ship while on its flight across space, and also when about to alight on the moon, it is proposed that the vessel should be provided with certain auxiliary liquid-fuel motors in addition to its batteries of solid-fuel tubes.

VII

LANDING ON THE MOON

QUESTIONS arising in making a landing on the moon have been examined thoroughly.

As the space-ship approaches the lunar surface the crew will be able, by means of its special liquid fuel manoeuvring tubes, to turn their vessel round very slowly, a few degrees at a time, until it is heading for the moon stern-first.

As soon as the space-ship has been manoeuvred into this position, the crew by means of their manual controls will then begin firing a number of medium and small rocket tubes. These, seeing that the vessel is now in a stern-first position, will have a decelerating effect. In this way the crew will be able to slacken the speed of their vessel, as it nears the moon, until it is moving slowly enough to make a safe contact with the lunar surface, the final operation being facilitated by an appropriate use of the liquid-fuel manoeuvring tubes.

There will be no attempt to make any run-in, or horizontal landing, such as would be the case with an aeroplane. It is reckoned that the lunar surface, at the spot where the space-ship lands, may quite likely be of a rough or broken nature. Therefore it is thought best for the vessel to come straight down, at a suitably slow rate, and make a vertical landing in the same way as would any helicopter-type of flying machine.

Prior to the actual moment of contact, the crew will be able to extend into position a special hydraulic shock-absorbing landing device which, when not in use, will lie collapsed along the sides of the space-ship's hull and which when it has been brought into its extended position, should enable the vessel to come to rest on the moon without damage to itself or undue shock to its occupants.

This alighting device will also incorporate features enabling it to be used as a launching platform from which to start the lightened space-ship on its return flight to the earth.

It was recognised by Mr. Ross, and also by other technicians of the Society, that very careful attention will have to be paid to the question of the descent on the moon, and also to the method of alighting on the earth at the conclusion of the return flight across space.

More research work will, it is realised, have to be devoted to shock-absorber design for the moon landing, it being specially important to obtain a device which, while bringing the space-ship gently to rest in a vertical landing, will not dig into the ground or snap off, or buckle under the vessel's weight.

Further studies are being directed to this matter.

As to the method to be adopted when the time comes to land on the earth, on the completion of the return space voyage, careful consideration has been given to several proposed devices, but the one most favoured, so far, is for the top portion of the space-ship, containing the crew, to be arranged so that a very large parachute can be ejected from it as the machine nears the earth, this parachute being capable of wafting the astronauts down without risk of injury.

VIII

SOLVING SOME FURTHER PROBLEMS

AMONG the many questions to be dealt with in navigating a man-carrying rocket on a journey through space, there is that of the extreme heat generated at the front or nose of a space-vessel while it is rushing up through the earth's atmosphere on the first stage of its flight; while when it is out in space another problem arises in the fact that on the side of the vessel nearest the sun there will be very great heat to contend with, while on the other side, away from the sun, there will be extreme cold.

As regards the first problem, this it is reckoned can be dealt with by fitting the space-ship, at the front, with a form of false "nose" or reinforced ceramic carapace, capable of withstanding all the frictional heat due to the immense speed of the vessel as it leaves the earth. A method is also to be adopted whereby, as soon as the vessel is clear of the earth's retarding atmosphere, this heat-resisting carapace can be jettisoned or made to fall away from the vessel, its work having been done.

To prevent too much heat being developed on one side of the vessel during its flight across space, and too great an amount of cold on the other, the expedient may be adopted of making the craft rotate slowly as it travels on its voyage.

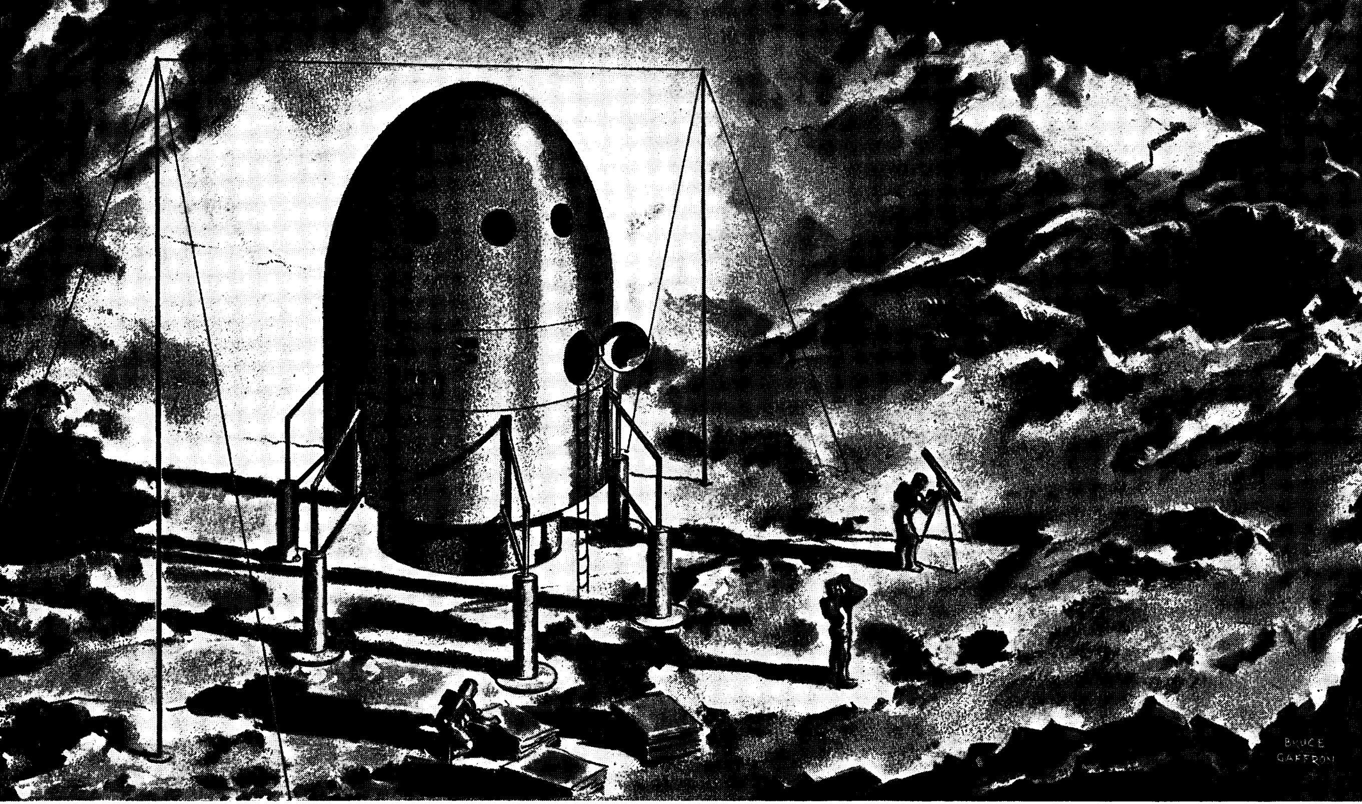
This rotation will be under the control of the crew, and will not inconvenience them in their chamber in the nose of the machine. It will not only have the advantage of coping with the heat and cold problem on the vessel's hull, but will also provide for the crew, by the effect of centrifugal force, a form of artificial, self-contained gravity, or feeling of weight within the machine—this compensating for the lack of any such influence in outer space.

Not only is the creation of this artificial gravity considered a necessary precaution—the physical effects of long periods of no-gravitation being at present unknown—but in any case it is thought likely that a haphazard rotation of the vessel might occur during flight, making navigational observations impossible.

Hence some form of controlled rotation is thought to be desirable; although the question is, at present, somewhat controversial. The crew would have power to stop the rotation of the vessel just before it reached the moon's surface, and was about to land.

In their control compartment in the nose of the rocket-ship the crew of three will recline on their specially-designed shock-absorbing chairs with their heads towards the centre of the vessel.

The reclining chairs will be constructed so as to move easily on rails round the control-cabin, enabling the crew to shift their positions, while navigating and controlling their vessel, without any need to rise from their seats. Some of the controls, such as those governing the firing of certain of the rocket batteries, will be placed conveniently to hand on the arms of the chairs. A circular



Here is a representation, in a technically-accurate form, of the scene just after a first lunar rocket has landed on the Moon. Its three occupants have emerged on to the lunar surface. One is setting up a telescope. Another is viewing the landscape. The third is busy with the canvas for a big tent which will be stretched above the rocket to protect it from the heat of the sun.

catwalk will also be provided round the chamber for the members of the crew to move about whenever they desire to do so.

IX

INSTRUMENTS FOR SPACE NAVIGATION

For observation purposes, during the space-flight, the dome of the ship's control-room will be provided with outlook ports. Some of these, at the top of the compartment, will be for looking out ahead. Others will be for obtaining a view sideways and astern.

During the initial thrusting period, while the space-vessel is ascending from the earth, the heat-resisting carapace—or nose-piece which will be discarded subsequently—will obscure any view forward, while the tail-blast from the ship's exhausts will prevent any view being obtained earthward. During this initial thrusting period navigation will be accomplished entirely by the instruments with which the crew will be provided in their control-cabin.

These will include specially-designed altimeters, speedometers, and accelerometers. Another essential instrument will be a chronometer. A gyroscope will ensure maintenance of direction.

A suspended pendulum will provide any indication of "wobble" as the ship ascends, and modified sextants and range-finders will be used to determine the ship's position. All these instruments will be placed conveniently near the members of the crew in their reclining chairs.

It will be necessary, at regular intervals during their flight, for the crew to make navigational observations. But as the space-ship will, as previously explained, be rotating slowly, the occupants of the control-cabin will see their surroundings apparently spinning about a point in the axis of rotation of their vessel; and anything like accurate observations would be impossible under such conditions.

It was to solve this problem, and to devise some means for presenting an appearance of a stationary field of vision to those within the space-ship's control cabin, that a technical committee of the British Interplanetary Society carried out a special investigation of the various possibilities presenting themselves.

One suggestion was that the scene should be scanned by an electron camera, and the picture elements projected on an internal viewing screen after having been suitably reassembled, to present the desired stationary appearance by suitable electrical circuits in the scanning control. But this scheme, upon examination, was abandoned owing to the weight that would be involved in the amplifier, and in view also of the complex nature of the circuits which would have to be provided.

After further consideration it was decided that it would be possible to devise a special system of moving mirrors which would provide the effect desired without involving any undesirable weight. This line of research was pursued and a model of the machine evolved, which is known as the "coelostat", was constructed and demonstrated successfully. Without going into technical details, it may be said that the machine embodies certain synchronised, motor-driven mirror devices, on lines somewhat like a stroboscope, and that by means of these mirrors, some moving and some motionless, it will be possible for a suitably stationary view of the heavens to be provided for navigational purposes even while the space-ship is rotating.

In the navigation of a space machine, instruments which rely on air pressure, or on the earth's magnetic field, would be inoperative in the airless void. For example, the speed indicators used on aeroplanes, relying on an intake of air, would be useless in space-flight. In order that space voyagers may check their rate of progress, a special form of accelerometer is being evolved. This instrument will rely for its operation on momentum and not on air pressure, the acceleration of the space-vessel affecting an internal mechanism of springs, weights, and magnets.

One question upon which no final decision has yet been reached, is as to the method of starting the space-ship from the earth on its outward voyage to the moon. A special mechanism will be necessary, and various suggested systems have already been discussed for establishing a suitable launching site either on land or water.

In the latter case, as there are certain astro-navigational advantages to be gained from starting a lunar flight from somewhere in the neighbourhood of the Equator, it has been suggested that a specially-designed launching stage should, after it has been built, be taken out in sections to Lake Victoria, in Africa, and that the space-vessel should begin its flight from the surface of this great equatorial lake.

Such a lake ascent would ensure calm water conditions, and there would be an additional advantage that, if a start was made from a point in the middle of equatorial Africa, the empty rocket tubes and the discarded sections of the carapace, which the space-ship would drop as it rushed upward, might be reckoned to fall without endangering human life either on some almost uninhabited land surface or somewhere out in the Atlantic Ocean.

Though such schemes are still quite tentative, certain designs have already been worked on for a floating stage of concrete with a central cavity extending down below water level which would hold the big space-rocket in a vertical firing position, and which would act as a sort of gigantic "gun" from which the projectile could be discharged.

One suggestion is that the space-ship should be made to rest in its launching "gun" in such a way that, when high-pressure steam jets in the sides of the "gun" came into operation, the vessel could be given an initial rotating movement before its actual ascent.

The big floating stage would, it is planned, have erected on it a boiler-house and workshops, and would be provided also with buoyancy chambers not only to keep it afloat but also to absorb the recoil when the space-ship leaves its "gun".

X

THE SPEED OF INTERPLANETARY FLYING

IN space-flying, speeds infinitely greater than anything so far reached by human beings are now contemplated.

By the time any space-ship, as already planned, has reached the limits of the earth's atmosphere, at a height of about 200 miles, it is reckoned that it will be moving at approximately 10,000 miles an hour. Higher, in outer space, its speed is expected to exceed 20,000 miles an hour, while greater velocities still are contemplated with a future use of atomic power.

The question it is natural should be asked is:

"Can the human body stand such speeds?"

The answer lies not in the maximum speed attained, but in the rate of acceleration by which this speed is reached.

The human body is not affected by sheer velocity. The human system has no means, other than visual observation, of determining the velocity at which it may be travelling. Everybody on this earth is continually travelling round the sun with a velocity of 18 miles a second, but none of us feels any the worse for that!

What the human body cannot stand is too violent an acceleration.

With space-ship propulsion as it is now being planned the power will be so fully controllable that, at the start say of a lunar flight, the acceleration of the machine from a stand-still will not be allowed to reach any rate that would impose dangerous strains on the human body. Actually pilots in high-speed aircraft of to-day can withstand, without adverse effects, acceleration pressures —or "g" pressures as they are called—which are in excess of those to which the occupants of a lunar space-vessel will be subjected during any period of their flight; and provided the factor of acceleration is kept within the limits it is now known the crew of a space machine will be able to stand, subsequent maximum speeds will not have any unpleasant or injurious effects at all. It should be noted that the questions of acceleration, and also those of power-control while out in space, should have a far more favourable aspect put on them with the immense reserve of power obtainable from an employment of atomic energy.

Among other problems which those studying space-flight have to bear in mind is that of the possible effect of cosmic radiation on any space-flying vessel and its occupants. Hardly any problem in science has produced more conflicting theories than that of cosmic radiation. It has been reckoned that these rays, consisting in part of highly-charged electrical particles, have an influence on the human body in various ways. Yet little, so far, is known about them, beyond the fact that it appears evident they must emanate from the very depths of outer space. But by what means they do this is, however, still uncertain. The point about cosmic radiation is that when the primary rays, or true cosmic rays, arrive from outer space, they strike the upper layers of the atmosphere and cause an avalanche of secondary rays, which are themselves absorbed in the atmosphere. This means that, on going up from sea level, the intensity of the rays rises to a maximum and then falls again, and it is considered quite possible that the intensity of the primary rays is very little greater than at sea level, although the energy is very much greater. As to the problem of what effect the rays might have on human beings who rose into zones high above the earth's atmosphere, researches already made in high-altitude balloon ascents do not suggest that this should be any seriously adverse factor; while more precise information should be obtainable from the higher penetrations into outer space now being planned with sounding rockets.

Another problem of a somewhat similar kind is that of the risk of a space machine, while on a lunar or interplanetary voyage, coming into collision with a meteorite. Many of these meteorites are constantly rushing here and there through space at a speed of thousands of miles an hour. But calculations show that owing to the sheer immensity of outer space this particular risk should be small indeed—something, in fact, like a million to one against.

As for methods of communication between those in a space-ship, and those on earth, existing radio equipment is considered to be adequate for communication between any space-ship travelling between the earth and the moon, or between this globe and any of the inner planets. Already "radar" signals have reached as far as the moon, and have produced "echoes" from that body which have been received here in earth. All that have been received from the sun, so far, have been emissions from the sunspots on that body. But what has been proved is that the Heaviside layer is no barrier in either direction to the very high frequencies used in radar, and there is no reason why a signal should not, for example, be sent as far as Mars.

The radio equipment in a space-ship would be a very short-wave installation. It is also possible that light beams, modulated by speech frequencies, would be used for communication between vessels navigating in space. This type of transmitter is considered by experts to be very simple, all that is needed being some kind of light source that can be made to vary in brilliance with speech, and a focussing system to send the beam in the right direction. The receiver is a powerful telescope with a photo-electric cell and amplifier at its focus. The Germans were using this type of "photophone" at the beginning of the war.

XI

EQUIPMENT AND SUPPLIES FOR A LUNAR VOYAGE

ONE of the questions to which the experts of the Interplanetary Society gave consideration was that of the equipment and supplies to be taken by those making a first voyage from earth to moon, the main consideration being that the total pay-load, or useful load of the space-ship, would not have to exceed more than one ton in weight.

It was found that there would have to be severe limitations in both the weight and bulk of the material carried, and that the utmost economy would have to be exercised, more particularly in the factor of weight. This assumed the employment of a very heavy load of some plastic or solid fuel. With the development of atomic-driven space-ships there should be space and weight available for comfortable and well-equipped quarters for passengers and crew.

The actual material of which the space-ship's "useful load" will consist has been divided by the experts into roughly four classes or groups, the first comprising the sort of general supplies and equipment needed for the maintenance of life during the lunar trip, and including food, air, water, heat, light, and so forth.

The space-ship's supply of air and water will be taken in the combined form of hydrogen peroxide, one molecule of which can be very readily split up into one molecule of water and half a molecule of oxygen. This arrangement has the advantage of enabling weight to be saved, seeing that only one storage tank is necessary, and it also provides a saving of space. Furthermore, one set of controls will be sufficient to regulate the supply of both air and water.

The pure hydrogen peroxide which would be employed is a syrupy viscous liquid which can be broken up into air and water either by application of heat or by catalytic action. When fine particles of practically any metal are placed in contact with the liquid, the reaction proceeds continuously at an easily-regulated rate so long as any hydrogen peroxide remains in the combined state, the metal itself not being consumed. The hydrogen peroxide would be stored in a tank of a light non-corrodible alloy, and run as required into a reaction chamber from which oxygen would issue into the atmosphere and water flow into a small storage vessel.

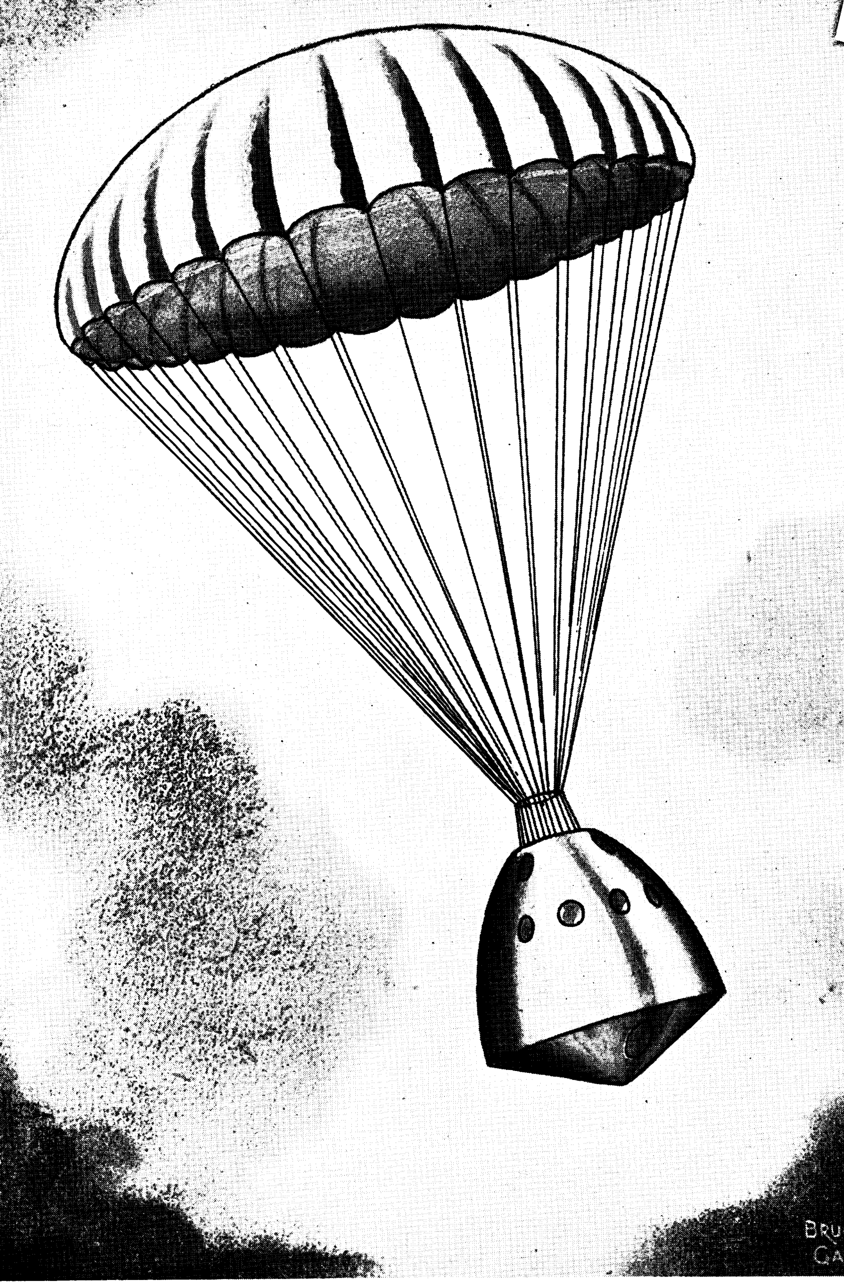
The excess carbon dioxide and water vapour accumulating in the atmosphere inside the space-ship from the breath of the three astronauts will be removed by soda-lime or other suitable chemicals.

In addition to the hydrogen-peroxide, a small amount of liquid oxygen will also be taken in the ship for use in the case of an emergency such as a breakdown in the plant splitting up the hydrogen peroxide.

The food taken by the space-flyers will be selected chiefly for its energy-yielding properties.

Water will of course be the basis of all beverages, chief among which will be cocoa, while a small quantity of coffee might be advisable as a stimulant. It is considered questionable whether any alcoholic beverage should be carried to celebrate say the landing on the moon; but in any case there will be a small emergency supply in the medicine-chest.

Culinary operations will be carried out in an electrically-heated vessel made of some lightweight alloy.



This picture shows the final stages of a lunar voyage, the astronauts having visited the Moon, and made their voyage back, their actual contact with the Earth being by means of a large parachute which will waft down the rocket's control chamber—containing its occupants and the specimens they have brought back with them—to a smooth and safe contact with the ground.

Electric lighting will operate on power from a primary battery. Light may be needed frequently during the voyage, as the control-room windows will be small. Artificial light will also be required while the explorers are on the moon.

Heating will be necessary in the control-room while the machine is on the moon, but not during the voyages across space, as the vessel will then be rotating, and will be obtaining heat from the sun.

Electric heaters in the control-cabin will be supplied from the same battery which will furnish all the other power needed. A small steam boiler will also form part of the equipment. This will supply steam at high pressure for manoeuvring jets which will be used for obtaining a more delicate control over the space-ship than would be possible with the rocket fuel.

In the second category of material under the heading of useful load will be various fittings in the control-cabin, together with a number of miscellaneous articles required at various times during the voyage. Reference has already been made to the specially-designed reclining chairs for the crew. On these the three astronauts will spend quite a lot of their time during the voyage, and these chairs will also act as beds during the stay on the moon. Owing to the ship's rotation, and changes of direction which will be brought about in starting and stopping, the arrangement of the chairs will need to be studied very carefully. They will be so upholstered that the pressure on the bodies of those occupying them will, during the initial acceleration, be reduced to a minimum. They will, as previously indicated, be mounted on rails so that they can be moved round the control-panel with a minimum of physical effort.

The main control-panel of the space-ship itself will be in the centre of the compartment. This panel will contain, among other controls, those for firing different groups of rocket tubes, and in appearance it will not be unlike an organ console.

Much ingenuity will have to be exercised in arranging the various articles needed by the crew so that they are kept securely in place during the acceleration, rotation, and manoeuvring of the space-ship, and more particularly when it comes to the landing on the moon.

Among the vessel's miscellaneous equipment will be a carefully chosen repair kit and a medicine chest. The repair kit will be for coping with any possible mishaps to instruments or apparatus, and also for general use on the moon. In the medicine chest there will be a good selection of medical supplies. The chief risk of any injury to members of the crew will probably come from bruises and concussion incurred through sudden movements of the space-ship, and from abrasions sustained by contact with sharp rocks on the moon.

A selection of reference books, almanacks, and mathematical tables, printed on light paper, as well as geometrical instruments, will be necessary for navigational purposes. Paper will be needed also for making calculations on, and for keeping the log and records of the voyage. Pencils of balsa wood will be provided for writing.

One of the amenities provided will be a lightweight pack of playing-cards to help pass the time during those periods on the voyage when the crew are not occupied with their controls or calculations.

Another article in the equipment will be a small but powerful telescope for making observations of earth and moon, and also a range-finder for use, when the space-ship is about to land on the moon, to calculate height above the lunar surface.

XII

SPACE-SUITS FOR EXPLORATION ON THE MOON

FINALLY there is the question of what the astronauts will need in the way of equipment while actually on the moon; and, as the lunar day lasts for a fortnight, this is approximately the time that the explorers are expected to stay on the moon.

First in importance will be the provision of the space-suits the crew will wear while out on the moon.

Four will be carried, one being a spare in case the suit worn by one of the explorers might be torn or damaged by contact with sharp-edged rocks.

The space-suits will be made of thin, strong rubber or leather. They will have roomy headpieces, comfortable to wear, and will be provided not only with an oxygen supply but also with heating.

It is thought there may be areas of quick sand-like dust on the moon's surface, and so large flat-bottomed shoes will be taken for wearing under such conditions.

During their explorations across the lunar surface the astronauts may need to communicate with the space-ship. This may be done by means of rockets, or by electric-light flashes. Each member of the crew will have a light but reliable watch; while other items of the outfit will be dark goggles, and a small amount of sunburn lotion in case actinic rays on the moon prove troublesome in the absence of any atmosphere.

One of the main tasks of the lunar visitors will be to carry out mineralogical investigations on those portions of the moon they are able to explore. To aid such examinations they will need small dynamite charges for removing surface and outcrop rocks, together with spades for clearing away rubble. They will also be equipped with geological hammers, and with a supply of thin glass tubes for their specimens.

Instead of carrying with them to the moon chemicals for any detailed analysis of specimens on the spot, these samples will be sealed in the tubes for a complete study after the party's return to earth; though it may prove advisable for the explorers to have with them just a small supply of a few salient reagents.

A microscope will be provided for an immediate examination of such mineralogical specimens and spores, lichens, and other forms of life which might be affected adversely when exposed to conditions on this earth. A light spring balance, in conjunction with a gravity pendulum, will be used to determine the gravitational influence of the moon at any particular spot.

Among further items of general equipment will be a light canvas tent to go over the space-ship as it rests on the moon, and so reduce the heat that will be lost by radiation owing to the fact that the vessel will be in a vacuum on all sides except for its base on the ground.

The explorers will have with them in their surveys a light cine-camera and an ordinary miniature camera, together with a supply of films and chemicals for developing photographs taken.

It was when summarising this preliminary research work that the Technical Committee of the British Interplanetary Society added the footnote:

"There is always the possibility that there may be problems to be dealt with which cannot be foreseen until the voyage is actually in progress, but we feel confident that no difficulty which it is at all possible to foresee has been overlooked."

XIII

THE YEARS OF EXPERIMENT THAT LIE AHEAD

ONE of the mistakes that will not be made in space-flight development will be to embark on the construction of any great moon-flying or interplanetary machine before sufficient preliminary data has been obtained.

In the early days of aviation, as those of us who remember those days will recall, men were often guilty of the error of constructing some big, full-scale machine before they had mastered the technical problems sufficiently to ensure anything like successful flight. Many of those machines, after costing quite a lot of money, ended ingloriously in an almost immediate crash. This was not only a bad business for the inventors and constructors, but it also had an adverse effect on public opinion.

Mistakes such as these are to be avoided in the development of astronautics. Those engaged in this quest are determined that the conquest of space shall be made in logical, carefully-planned stages. As one of the reports in the Journal of the British Interplanetary Society puts it:

"A great deal of work is yet to be done, but we feel confident that consistent and sustained research will eventually yield results which will bring the realisation of our object, the conquest of space, within our reach."

It is a very big research which lies before astronautical science. Some experts reckon that if ten or fifteen years could be devoted to preliminary test work, with some fairy godmother providing funds for personnel and apparatus, then the actual construction of a large space-vessel, based on the designs already prepared, but modified and improved in the light of these years of experiment, could be undertaken with every confidence that it would function satisfactorily. Others are not quite so optimistic, while at the present time, of course, a great deal depends on what progress can be made in the very costly business of adapting atomic energy to space-flight purposes.

There has been discussion as to whether it would be advantageous to construct an experimental space rocket—something in the nature of an enlarged projectile like the V-2—for a first pilotless voyage from earth to moon. Dr. Goddard, it may be recalled, had a pre-war plan for such an unmanned lunar test flight. In favour of this project it is argued that, if successful, the feasibility of lunar flight would be demonstrated without involving any risk of human life.

It is also pointed out that such a pilotless flight would serve as valuable preliminary propaganda, focussing attention on the potentialities of space navigation, and making it probably easier to finance schemes for manned flights to the moon and also to Mars and Venus.

Those are some of the main points in favour of this idea, and, of course, the proof that an unmanned rocket had actually reached the moon, after its discharge from the earth, would be forthcoming by the method advocated by Dr. Goddard—i.e., that the rocket would be discharged so as to alight on the dark part of the lunar surface, and that on its impact it would emit a flash which would be visible to those on this earth who were watching through their telescopes.

Among astronautical experts there are many who, while conceding the advantages already mentioned, are not greatly enamoured of this scheme for a first pilotless moon flight, unless perhaps a rocket like the V-2 could be adapted for the purpose. What they point out, among other things, is that it would cost a very large sum of money to construct an unmanned rocket capable of reaching the moon, and that even after this projectile had arrived on the lunar surface it would not mean as much as might be imagined to astronautical research, seeing that it can be demonstrated mathematically, already, that a rocket can be built capable of achieving the flight. What is really more important, they submit, and what a pilotless flight would fail to throw light on, is the physical effect of a voyage across space on those undertaking such an adventure—the much debated effect, for example, of cosmic radiation on any human body not shielded by the earth's atmosphere, and also the effect on a space-ship crew of the non-gravity conditions which would be experienced during a voyage through outer space. And there are also other problems, such as those concerning human navigation and control, which would still remain unsolved even after a pilotless projectile had sped across the 240,000 miles between earth and moon.

What experts who cannot see much value in a pilotless flight really say is this:

"If after our phase of preliminary experiment we have the chance of constructing a moon-flying rocket, let us go the whole hog and build one that will carry a crew and make an out-and-return flight, thus enabling its occupants to regain the earth with all the data that this first space-voyage should enable them to acquire."

Well, there it is, and there is more than a little to be said on both sides. Fortunately, it is a matter which can be left for further debate.

So can another question. This is as to the necessity of having two man-carrying space-vessels ready for a first lunar voyage, the idea being that should some mishap attend say the landing of the first on the moon, and should those engaged on this inaugural flight find it impossible to get away from the moon in their machine, it would be possible for them to signal to the earth for the second vessel to start out across space as a rescue ship.

Naturally, in a matter like this, the question needing chief consideration would be the extent of the funds available for any constructional programme, although even if two space-vessels were laid down at the same time, and even allowing for preliminary research work, the total sum involved would still be insignificant when compared with the astronomical figures of war expenditure.

Obviously some fairy godmother will have to wave her magic wand in this vital matter of space-flight finance. But if funds can be forthcoming, as they have been, for expeditions to the North and South Poles, and to conquer mountains, and make pioneering flights across oceans, and also for many another scientific quest, then it is not unreasonable to hope that finance will be available for the conquest of space. With the uses of atomic energy controlled internationally, it should be logical for the countries of the world to come together and finance, jointly, an international project for a first lunar flight; this to be followed, in due course, by other and farther explorations into outer space.

XIV

NEED FOR BRITISH "ROCKET-FIELD"

As emphasised in one of the issues of *Spacewards*, the official organ of the Combined Astronautical Societies, the need in such a new science as astronautics is for experiment, experiment, and still more experiment, one of the prime requirements being for further test work with motors, fuels, and their methods of combustion, and also as regards the commercial applications of rocket propulsion in accelerating terrestrial transport.

The German rocket societies, in pre-war days, were lucky enough to have for their experiments their special stretch of land known as the "Raketflugplatz", or rocket flying-field. And it is much to be hoped that there will be similar facilities for post-war rocket experiments in Great Britain.

Our technicians recommend that, as soon as the time is ripe, attempts should be made to obtain a suitable lease of a stretch of land so located that the Home Office will be willing to give permission for rocket experiments to be carried out on it.

It is thought that some quarry that had been worked out might provide a site for an experimental rocket station. Such a quarry would probably already have an explosives licence, and it should provide good cover for blast protection and for the siting of observation posts; and as it would be unsuitable for cultivation, and would have no further industrial use, the value of a worked-out quarry should be low, and it should be possible to acquire it for rocket experiments on favourable terms. Efforts would be made to obtain such a site within fairly easy reach of London.

It would be the aim to provide a suitable club-house in which experimenters could spend a few days, or stay for a week-end. In fact, this rocket-field, with its club-house and other facilities, and apart from the experimental programme carried out there, would provide a general centre for all interested in the science of astronautics—a centre where annual holiday conferences could be held which would keep the whole astronautical world in touch with the latest progress in experiment and research.

XV

HIGH-ALTITUDE SOUNDINGS

One of the most interesting aspects of the research programmes at our post-war rocket-fields will be the design, construction, and firing, of a series of pilotless rockets for high-altitude sounding.

Both the Manchester Astronautical Association, and the Astronautical Development Society, devoted considerable attention to this question of the altitude rocket—a projectile capable of probing the atmosphere to heights considerably greater than those attained, hitherto, by any form of air machine.

Here it should be emphasised that such an altitude-sounding programme, though of prime interest to astronautics, has many other scientific implications.

Take meteorology, for example. Here you have a comparatively young science which, though not spectacular in any of its work, none the less affects you and me and all of us to a very marked extent. Weather-lore, and more especially the forecasting of weather for a certain period ahead, may be of primary importance not only when the world is at war, but also when we are more happily at peace. The success of great military operations may depend largely on the accuracy of the weather-forecasting which the meteorological staff can provide. In massed air-raids the question of what the weather will be like over target areas is of critical importance. As such operations must, owing to the growing intricacy of their timing, often be planned some time ahead, weather-forecasting can either make or mar the results obtained; and it has many other applications, also, in modern war as waged on land and sea, and up in the air.

As for peace-time meteorology, it would be hard to put any sort of limit on its growing value. It is often of primary importance to the farmer to get as long a forecast as possible as to whether conditions are going to hamper or aid him. The success or failure of big outdoor sporting events depends largely on what the weather is going to be like when the great day comes. And the ordinary individual who is going away for a holiday would give a good deal to have an accurate forecast of what he will have to enjoy, or endure, so far as the weather is concerned.

The whole point about meteorology, and more especially about forecasting weather for days, weeks, or possibly for months ahead, lies in the fact that, before this can be made into anything like an exact science, it will be imperative for us to know much more than we know to-day about what is going on at very great heights above the earth.

To put matters in a nutshell, it may be said that our weather at ground level is very largely "made" for us in the upper layers of the atmosphere, at extremely high altitudes above the earth's surface. It is right up there, much higher than we have been able to penetrate so far, that there are what might be called the great "weather factories" which govern all that happens to us, meteorologically, as we move about on the ground below. If our weather men can obtain regular and frequent information as to temperature and other conditions right up there at extreme altitudes, they will be much more certain as to what is going to happen in the immediate future with our weather down here below.

Already we have our special meteorological aeroplane squadrons. The pilots of these machines, ascending at pre-arranged hours, climb to considerable heights and bring back with them much useful information. Such data, too, is reinforced by the records obtained by sending up pilotless meteorological balloons, carrying special radio equipment which signals down, automatically, to observers below, measurements as to temperature and other conditions of the upper air. Incidentally, it may be mentioned that at heights of round about 30,000 feet, the wind may sometimes be blowing at 200 miles an hour.

It is still higher reaches of the upper air which remain unexplored, and here the instrument that will help us is the specially-equipped sounding rocket, capable of penetrating into zones which have been beyond our reach hitherto.

British astronauts, in preparation for this phase of research, have worked out plans for some extremely practical sounding rockets—projectiles which, while being simplified and lightened in their constructional features, will at the same time ensure full efficiency for the work they will have to do.

In one design I have been examining, the rocket is encased in a light aluminium shell and employs as its propelling force liquid oxygen with petrol as fuel.

This projectile will be gyro-controlled. Any deviation from its correct flight path will bring into operation the gyro-control, restoring the rocket immediately to its normal line of ascent.

This rocket, equipped with fuel, scientific instruments, and parachute, will not weigh more than about fifty pounds. The parachute the rocket will carry in a nose-compartment will be made to open at any pre-determined height, and it will then bear the projectile and its recording instruments safely back to earth. And the work of small rockets of this type can be amplified, as required, by the construction of larger projectiles to carry explorations to still greater heights. In fact the whole of the earth's higher atmosphere can be explored systematically in this fashion, and data secured which should be of the utmost scientific value.

Not only this, but the knowledge gained by the operation, over a considerable period, of rockets which are pilotless and automatically controlled, will pave the way for further exploratory flights in which manned-rockets can be employed, and this phase of research, in its turn, will provide the data necessary for those greater adventures in which, by means of very large man-carrying rockets, we embark on our conquest of outer space.

XVI

POST-WAR ROCKET MAILS

AMONG the glimpses we are getting already of the future of rocket propulsion, and more especially of the future of the atomic-driven rocket, one of the most interesting is to be found in its possibilities for accelerating the post-war transport of urgent mail-matter of all kinds.

We have been told, often enough, that one of the greatest necessities in our era of reconstruction will be to speed-up commerical enterprise of all kinds, thereby quickening the building-up again of ravaged lands, and the restoration as speedily as possible of normal trading relations between the great countries of the globe.

This huge programme of rehabilitation—by far the biggest the world has ever faced—will of course make the heaviest calls on every kind of transport, whether it goes by land, sea, or air—or even, as is the case with the rocket, through the vacuum of outer space. Sea and land transport, as hitherto, will be concerned largely with those heavy types of load which, though urgent enough, will not have quite the urgency of the express cargoes with which the air will have to deal. Our postal-planes, our big passenger airliners, and also our small, swift taxyplanes—either winged machines or craft in the form of helicopters—will all play their vital parts in saving hours, days, and weeks in every kind of transport in which the time-factor is urgent.

Apart from all such machines as these, there will be a new and infinitely swifter instrument upon which our war-weary world will be able to call—and here I mean the rocket which leaps skyward at an almost incredible speed, and which after rising hundreds of miles will span oceans and continents in what one might call the twinkling of an eye.

I have referred, already, to some of those experiments with mail-carrying rockets carried out in pre-war days, and by some of which mail-matter was flown regularly between points separated by mountains making ordinary transport difficult and slow. Such early trials, though significant enough, touched merely the fringe of the vast possibilities which, in the light of all our more recent knowledge, now lie before the commercial rocket mail. Projectiles on the lines of the V-2 can be transformed in times of peace from weapons of destruction to time-saving machines of an almost incalculable value. Which illustrates, aptly enough, that time-honoured saying that out of evil cometh good.

It is amazing, when one studies the development of the world's transport, to realise how the sheer speed of communication has been increased from year to year and from decade to decade. This emerges all the more strikingly when one comes to the long-distance routes of the globe, and more particularly those which cross the great oceans. At one time it took months to span a big stretch of water like the Atlantic. Then, by degrees, the time was reduced from months to weeks. After which, as time went on, it became a question not of weeks but of days. Then the flying machine appeared on the world's stage and again the transit times were cut, this time from days to hours. And in the great era ahead, when huge atomic-driven rockets rush up from one side of the Atlantic, climb like meteors into the vacuum of outer space, and then sweep down again on the other side, all previous travel times will go by the board, and what takes an aeroplane hours will be reduced by these projectiles to a matter of minutes.

Apart from fresh developments increasing the efficiency of the rocket in its construction and propulsion, there are immense strides in wireless and radio-location which will be available in commercial rocket flight. Already our war progress in wireless, as applied to air navigation and control, should make it possible to launch a pilotless machine from one side of the Atlantic, guide it accurately in its flight across the ocean to the other side, and bring it safely to earth at the end of its flight, without a human hand being needed at its controls.

What this implies is the accurate functioning of ocean rocket mails, such services operating at a speed not of hundreds but of thousands of miles an hour, and making it possible for a business man say in London to send some urgent document over for signature in New York in the morning, and to have it back again on his desk, duly signed, well before the close of that same business day.

Long-range postal rockets will be under full control during the whole of the time they are crossing oceans or continents. After they leave the ground they will rush up under the guidance of radio-beams operated from their dispatching station. Then, after they have come to the top of their trajectories, somewhere at a vast height above mid-Atlantic, they will pass under the influence of the receiving station on the other side, and will be held in other beams as they sweep down towards their objective, their gradual slowing-up process, as they approach the ground, being governed by wireless signals actuating braking devices with which each machine will be fitted, and which may take various forms—the final descent, probably, being effected by one or other of the parachute arrangements already tested satisfactorily.

All those who make a study of astronautics attach the utmost importance to the development of rocket mails, and it is to be hoped that such a super-swift method of communication will have high priority in our schemes for a further acceleration of the transport of the world.

XVII

THE PASSENGER-CARRYING ROCKET

ONE thing has interested me considerably in discussing the evolution of rocket design and construction with the experts of our astronautical bodies.

This is the future adaptation of very large rockets for passenger transport on the world's long-distance routes.

It is here, perhaps, that one may be permitted one or two general observations.

In peace-time, when any transport machine has to show that, in addition to its other advantages, it is a sound proposition economically, capable of paying its way, it is necessary to strive for the utmost all-round efficiency in operation. But in war-time, though your machine may be costly in operation, that does not matter so much provided that it can "deliver the goods", and do so promptly. Everything becomes subservient to winning the war. It is not so much a question of what a thing will cost as what it will do.

But when you come to peace transport you cannot afford to spend money quite so liberally. You have to get down to the "brass tacks" of what a machine is going to cost in such things as fuel, maintenance, and in a good many other ways. It is for this reason that many a war-type plane is not looked upon with much favour by any civil operator who may be called upon to use it as a stop-gap before he can obtain a more commercially suitable machine. Its very powerful engine-plant, though justified for strictly military needs, often drinks up a lot more petrol than is reasonable in regular commercial use. Speed is wanted in civil transport, but it must not be speed at any price. Cost must come within the limits of normal, commercial enterprise.

In giving our world those further speed increases it will ask for in all its express forms of transport, there are now two new propulsive systems, both of which offer greater rates of travel than can be provided by the ordinary propeller-driven aeroplane, fast though that machine has become. One is the jet form of propulsion which has dawned upon the world during our recent war-years. The other is that rocket system which, though existing experimentally for many years, has still to make its mark in any form of regular transport.

Though both systems offer such big advances in actual speed, they do not attain their full efficiency under similar conditions of operation. The jet method, needing an intake of air, can operate only within the bounds of the atmospheric belt surrounding our globe. The rocket system, though operative with a certain degree of efficiency in atmospheric conditions, does not attain full efficiency until it is free of the earth's atmosphere, and in the airless conditions of upper space.

This raises a question which astronautical engineers are already considering.

What has already been discussed is some form of combined apparatus which, in one and the same machine will while moving through the atmosphere provide the advantages of the jet system, and which when in outer space will switch over to the efficiency and power of rocket propulsion. This implies some hybrid form of craft; and mechanical hybrids are not, as a rule, regarded with favour by engineers, who are apt to say that though such machines may do several different things moderately well, they do none of them particularly well. But there seem possibilities, and simplifications, in a combined jet-and-rocket prime mover which may enable designers to avoid in such units any of those complications, in regard to moving parts or weight factors, which may afflict a machine when it is built to fulfil several different tasks.

XVIII

COMBINING JET AND ROCKET PROPULSION

I have been privileged to look over some quite provisional plans for a power-unit intended not only for operation within the atmosphere but also in vacuum.

In this combined jet-rocket reaction unit, the thermal section is intended to operate to an altitude of approximately 45,000 feet, at which height the rocket component would begin to function to propel the craft still higher.

Some experts are emphatic as to the advantage to be obtained by such a combination, including as it would high efficiency with relatively low fuel consumption. By employing thermal-jet reaction within the more dense atmospheric regions, and true rocket propulsion above these zones, it is claimed that a satisfactory efficiency-economy ratio could be assured under all operating conditions.

It is pointed out that the fuel for the thermal unit would not need to be petrol, or any highly-refined spirit. Paraffin, tar oils, or any similar product would probably do just as well; while for the rocket part of the plant the fuel could be liquid or solid; or, when available, an atomic plant.

The potentialities with combined power-plants such as these are now so great that it is considered they may open the way for a post-war era of cheap, world-wide travel, conducted at speeds which will dwarf anything obtainable hitherto.

Apart from any such combined jet-rocket units as I have mentioned, one must not forget that there is what is known as the "thrust-augmenter" method for increasing the efficiency of rocket propulsion when operating in atmosphere. Here, without involving oneself in technicalities, it may be explained that mechanism is provided for sucking in air at the sides of a rocket unit, and then for using this to build up and increase the mass-flow of the efflux or exhaust.

To anyone who has studied, as I have, the evolution of the air machine from its infancy to the present day, all these new trends in design have a special and personal interest.

Years ago I was drifting above the country in balloons. After which I flew in one of the earliest of our dirigible balloons.

I saw the kite followed by the man-carrying glider, and the motorless glider by a heavier-than-air machine fitted with an engine and air-screw. I have seen our earlier biplanes, with all their resistance-creating wires, give place to the cleaner streamlined monoplane.

I have seen all the remarkable improvements that have been effected with wing-sections, air-screws, and in many other technical directions, including the retraction of undercarriages within the bodies of machines. All this pageant of progress has passed swiftly before me, and now to-day I can already see in my mind's eye some of the wonders of our future days.

XIX

OUR "MAGIC CARPET" OF THE FUTURE

WHAT I myself foresee as a "magic carpet" of the future —and it is a personal opinion which is advanced with due deference to my more technical friends—is an ingenious combination of all the best features of these two fastest of the world's machines—the jet-plane and the rocket.

I seem to see a machine more or less in the shape of a scientifically streamlined aeroplane, but minus its air-screws, starting away in an immensely swift climb sky-ward under the power of its jet unit. This machine, as I visualise it, may perhaps embody some system for gradually telescoping or retracting its sustaining surfaces until, when operating above the atmosphere, it converts itself into a wingless rocket projectile capable of devouring distance at thousands of miles an hour. And then when it begins to descend its supporting surfaces may be brought gradually into play again, not only sustaining it in a glide as it lessens speed, but also decelerating or breaking its rate of descent as it passes down through the earth's atmosphere, and thus enabling it to make a normal landing at a reasonable speed at any pre-determined point.

Quite a lot of money has been spent, at various times since aeroplanes first flew, in experiments with devices for retracting, telescoping, or varying the camber of wings while a machine is in flight. A certain measure of success has been attained, experimentally, but there are formidable technical difficulties confronting those who try to impart to the flying machine that "wing-reefing" capacity which comes so easy to nature's flying machine, the bird. Aeroplane designers have, generally speaking, sought the simpler methods of air-brakes and wing-slots.

Perhaps what I have in mind, in any future combination of rocket and aeroplane, may be accomplished by devices which have not yet taken shape on the draughtsman's board.

One thing, at any rate, is certain.

Though it will not matter to the passengers in one of these meteor-like craft of the future what the velocity of the machine is once it is in full and steady flight, it will of course be essential, no matter by what means it may be accomplished, to keep the acceleration of the machine when it is starting, and its deceleration when about to land, within a speed range which will not prove injurious, or unpleasant physically, to those occupying its silenced and pressurised saloons.

Some adaptation of the helicopter principle, embodying rotors to control acceleration and deceleration, might perhaps meet the case; or it might be effected by a fine control of the jets of the prime-mover, giving a sufficiently smooth and gradual acceleration at the start of a flight, and by means of auxiliary jets exercising a braking or retarding effect, in combination with moveable surfaces or fins, reducing speed sufficiently at the completion of a journey.

Both aeronautics and astronautics are still such young sciences that one can merely speculate as to the actual methods which will be employed to give the world the benefit of these immense speeds that should be technically possible in the future. One thing, however, does seem clear. There are now no problems that, given only time and money, cannot be overcome.

Transportation is civilisation, and the jet and the rocket will, between them, open up a great speed era, the effects of which it is almost impossible to calculate, seeing that it will revolutionise completely all our previous notions as to the meaning of those vital words "time" and "distance".

I remember well enough how my friend, Sir Alliott Verdon-Roe, was laughed at when, a good many years ago now, he dared to predict that there would be machines ultimately, which would rush above the surface of the earth at 1,000 miles an hour, making the passage over great oceans in a few hours.

Fantastic it sounded then!

But already fact has begun to outstrip prophecy.

The big German V-2 rocket annihilated distance at 3,500 miles an hour, travelling from Holland to southern England in a few minutes. And in our Atlantic rocket-planes of the future we should be able to rush up from London, flash at immense heights above the ocean, and glide down at New York, all within the space of an hour.

And with that amazing glimpse of an ever-shrinking world I do not think I could do better than finish what I have set myself to write in these pages. It has been an exacting job to represent, quite non-technically, a subject which bristles with so many technicalities—and with so many pitfalls, too. But though I am very conscious—almost painfully so—of my shortcomings in grappling with this highly complex subject, I have a feeling that the subject itself is so fascinating that it will come to my aid in holding the attention of the reader. And if I have succeeded in my object of giving ordinary readers, who do not want to be bothered by technicalities, an illuminating pen-picture of this, the most romantic of all quests, then I shall be consoled for any lapses of which I may have been guilty.

At any rate, here it is—the dawning of the great coming space age simplified as far as I find it possible to simplify it; and if it interests you, the reader, as much as it interests me, the writer, I shall feel that the time I have spent in preparing this book has been labour well rewarded.

THE END