TRIPLE PORTRAITURE

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TURBINE BLADE AND DISC ASSEMBLY FOR A JET ENGINE (*See page 57*)

PRINCIPAL CONTENTS

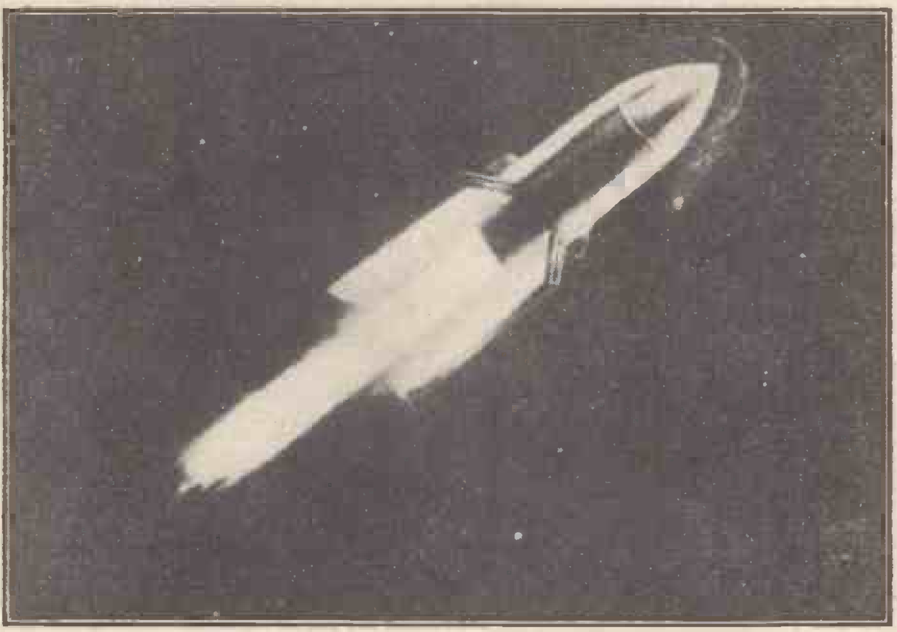
Rocket Propulsion

First Steps Into Space

By K. W. GATLAND

(*Concluded from page* 18, *October issue*)

ANY worthwhile discussion of the problem of freeing a rocket from the earth's gravitational field would occupy far more space than is available for this concluding article. Hence, it is proposed to place before the reader a summary of the types of rockets that may be expected to lead from V-2 research and, finally, to deal briefly with a possible means of harnessing nuclear energy for space-rocket propulsion.



A spaceship as conceived by Professor Oberth for the Fritz Lang film, "Frau im Mond."

The Embryonic Spaceship

Whatever may be the feeling about the rocket as a means of mass destruction, it must be conceded that Germany's V-2 was an engineering achievement of high merit, and its importance as the first positive evolutive link in the chain that produces the spaceship cannot be too greatly stressed.

Research with rockets now proceeding under Army supervision at White Sands, New Mexico, is daily adding fresh data. Hardly a week goes by but that a V-2 hurtles into the blue with recording instruments for some specialised investigation, perhaps to sample the atmosphere more than 100 miles from the surface or to test the nature and extent of radiation.

First Piloted Rockets

From work such as this, the guided missile may be expected to slowly improve in size and performance until it becomes practicable for a *pilot* to rise into the outermost reaches of the atmosphere and eventually to navigate his craft for short journeys into space. This is a stage that will almost certainly be reached in the course of military research if a proper international authority has not emerged within, say, five to ten years.

These first manned rockets will enable the physiological problems related to acceleration pressures and diminished gravitation to be studied in detail. They will make possible investigations of the pilot's ability to control his craft under the most adverse of these conditions, and improvements in the means already devised to counter expected ill-effects can be made accordingly.

The space-rocket may therefore be expected to evolve to a well defined plan and not, as one so often hears expressed, in a single "do or die" attempt to navigate moonwards. The moon expedition is not likely to be the awe-shattering event that some writers might have us suppose, for manned rocket flight will certainly have become commonplace before any attempt is made to land on our satellite.

Project 1

Already, a design for a manned rocket based on the German V-2, slightly larger but using the same engine, has been placed before the Government of this country. It is the work of two technicians of the British Interplanetary Society, Mr. R. A. Smith and Mr. H. E. Ross, who have evolved their conception on the basis of existing manufacturing techniques, and are quite satisfied that such a rocket could to-day propel its occupant to a height of 200 miles.

Not only is the scheme important in being the first workable design for a man-carrying rocket, but its construction would make possible *now* those physiological experiments which must be tackled before space-flight can become reality.

A cut-away drawing of the project appears in Fig. 97. The most obvious point about it is that there are no tail fins, the reason being that the jet vanes are adequate to maintain a vertical path, and, since the rocket would be far from the correcting influence of airstream vanes at the time of power cut-out, their fitment would incur nothing but unnecessary weight and drag.

It was a different case with the V-2 when it was important that the missile fell back to earth in a stable condition, though it was never really apparent why the Germans bothered to fit airstream vanes. As we have seen, the initial moments after take-off could not possibly have given sufficient speed for the external vanes to have any value and, again, they would have little influence in the low air density through which the V-2 moved in the last stages of power.

On the other hand, the graphite vanes in the jet-stream were masters of the situation throughout the entire thrust period; they were continually in action to deflect the jet against any movement of the rocket's axis from vertical.

The control arrangement specified for the manned rocket is rather different to the above. A tower is necessary for take-off and the manipulation of vanes in the jet-stream would impart *spin to the missile* and not the corrective influence of gyrovanes. This would immediately transform the craft into a "giant gyroscope" whose stability acts along the major axis as in the case of a bullet or shell. The reason for this will be apparent later.

Thrust will commence at 60,000 lb., giving an initial rate of acceleration of 9.8 feet per second. The consumption of propellant and the corresponding decrease in weight would naturally increase this figure as the rocket climbs higher and, after it has travelled for 110 seconds at constant thrust, the *effective* acceleration would be 2g.

Adding the natural gravity datum, the pilot would be exposed to an apparent acceleration of 3g. This is regarded as the safe limit for a man to be fully active to his controls and, when it is reached, the thrust would be progressively reduced so as to keep the value constant in conjunction with a g-meter. It might be mentioned also that should the pilot at any time lose consciousness control would be taken over entirely by an auto-pilot working on micro-wave pulses from the ground. Moreover, he would be brought automatically into a safe landing.

The pilot occupies the space in the rocket's nose and, within his pressurised cabin, has no external vision during the first two minutes of flight.

It will be seen from the drawing that the cabin is a loose fitting inside the nosing and that the external skin local to it is split into separate panels; the design is such that after a predetermined distance has been travelled, *a compressed-air device will catapult it away from the body of the rocket.*

Before the Cabin Separates

It is reasoned that separation should occur just after the climax of the thrust period when the speed has risen to about 4,700 m.p.h. From the moment power cuts out, the controlling vanes will be incapable of producing reaction in the rocket nozzle so that the torque offered by the turbine (which is positioned to rotate about the rocket's major axis) would be relied upon to build up spin. The turbine unit would, of course, continue to be fed by the steam generator despite the fact that the propellant pumps which it normally drives are no longer required to operate.

The rate of revolution would thus steadily increase until it reaches a predetermined figure at which the centrifugal force acting on a datum line passing through the pilot's body produces 32.2ft./sec. radial acceleration. At this point, the steam supply to the turbine would be cut and the rate of spin would decline slightly owing to bearing resistance in the turbine. When the spin is at maximum, the nose fairing sections will part and be thrown off due to the inertia forces acting upon them so that at any moment, subsequent to their removal, the pilot may operate the control which drives the cabin away from the rocket.

This control would also initiate the operation of a time mechanism for the ejection of the hull parachutes.

The cabin would be constructed almost entirely in light alloy, the walls embodying two ports with self-sealing conical gaskets for view and access; they would be glazed and provided with shutters as protection from the fierce and unrelenting glare of the sun.

It is suggested that the pilot's personal equipment should be a g-suit, a standard high-flying suit, parachute and oxygen apparatus. A specially designed cradle-seat is provided in the scheme on which all instruments and control boxes are grouped so that it is possible for him to change his attitude in the cabin and still have all controls ready to hand. This is important in view of the experiments to be performed and one of the new devices embodied is a "stroboperiscope," which renders a stationary external vision when the cabin is rotating.

Artificial Gravity

Once the engine has ceased thrusting, the pilot will no longer be pressed down into his seat and he will become subject to a very changed condition of gravity. Travelling in a high trajectory and freed from appreciable air-drag he may be regarded as moving in uniform obedience to the combined forces of momentum and gravitation and, if the spinning of his cabin were completely annulled, the pilot would experience a condition of "weightlessness"; nothing in the cabin would displace relative to anything else.

The nearest approach to "zero gravity" so far experienced is in the parachutist's "delayed drop." He jumps from a height at which the air density is small and incurs this same condition of reduced weight when, for a short time, his body is accelerating freely. However, as soon as air-drag builds up to a significant figure, "free-fall" no longer obtains, and as terminal velocity is approached, the sensation of weight slowly returns to normal. The critical period is short-lived, and in no way can it be taken to infer that the problem of changing gravitation on the human system is non-existant.

What would be the result of prolonged periods of zero-gravity or even of a reduced gravity is simply not known; biologists on the whole are doubtful whether man could long remain conscious where gravity does not exist, and, indeed, many are ready to predict a paralysis of the nervous system with even fatal results. That digestive disorders would be caused is fairly certain.

If the biologists are right, then it seems likely that the solution is largely mechanical, though a combination of the mechanical and the biological may ultimately provide the ideal space-piloting conditions. It is the former solution—that which results in an "artificial gravity" stimulated by centrifugal force—that Messrs. Smith and Ross have set out to provide in their manned rocket, and this explains more readily why it is necessary to impart the axial spin.

It is obvious that during those periods when the pilot in his cabin was either ascending or descending through air of very low density he would be able to conduct experiments with varying degrees and periods of "weightlessness." Small peroxide-permanganate motors firing tangentially from the cabin at right angles to the major axis would provide the means of rotational control. One pair would thrust in the direction of spin to increase the rate of revolution while the other, at another time, fired in the opposite direction to reduce the spin or even to stop it altogether.

The time available for test would be about seven minutes, after which the parachute, stowed above the cabin, would release and bear the pilot gently to earth.

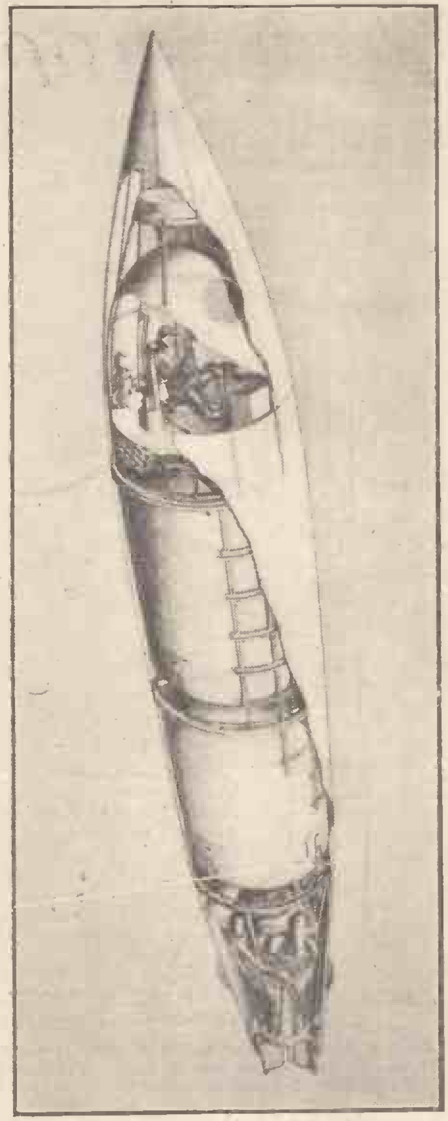


Fig. 97.—Two technicians of the British Interplanetary Society combined to produce this design for a piloted research rocket. Its operation is explained in the article.

Some General Particulars

Calculation has shown that the cabin could ascend to over 225 miles, but, as 180 to 190 miles is considered the limit from which a safe return could be effected using parachute braking, the apex of the flight would be timed to occur around the 180 miles mark. This, of course, is not to infer that safe descents from higher altitudes is impossible to rockets equipped with *retarding motors* and parachutes.

The rocket would have an all-up weight at take-off of 20.9 tons, of which 17.2 tons is contributed by propellant—alcohol and liquid oxygen—and 1.292 tons by cabin and pilot. Thrust is timed to last for 148 seconds, followed by a period of ascent under momentum of 228 seconds, so that peak trajectory is reached after 6 minutes 16 seconds.

At his greatest altitude, the pilot would in clear weather be able to see for 1,300 miles in every direction, and if the ascent were made over London he could observe Iceland, Norway, Sweden, Finland, Estonia, Latvia, Poland, the Carpathian Mountains, Rumania, Greece, Sicily, the Mediterranean seaboard of Africa, Gibraltar, Spain and Portugal. The area within his vision would be in the region of 5,300,000 square miles.

The Way Ahead

Such rockets as this will pave the way for still more ambitious flights into space itself, and eventually we shall arrive at the stage where gravity is defeated by missiles which reach "escape velocity."

The powers that rockets must achieve to obtain this condition may be explained as follows. The earth exerts a pull of 6.95 miles per second and any body released into its gravitational field at a sufficient distance from the surface will fall into the atmosphere at that speed, no more, no less. It is true that meteorites often enter the atmosphere at a higher velocity, but that is because they already possess a high velocity at the time of being influenced by the earth, and some run headlong into the planet as it speeds on its orbit at 18.5 miles per second.

Hence, it seems that for a rocket to fully escape the earth, the minimum speed it must attain is in the region of seven miles per second—and yet this is not necessarily so. A space-rocket with *unlimited* propellant could travel to the moon at a steady 30 m.p.h.

However, to bring the problem down to a practical level, it is essential that the necessary energy for the journey should be imparted as quickly as possible, not so rapidly as to destroy the crew nor so slowly that energy is needlessly wasted in raising a great bulk of propellant. The slower a rocket travels, the longer it remains near the earth's surface and the more propellant it will need to push upwards against gravity.

This is the essence of the problem. A compromise has to be found in which the rocket may attain "release velocity" as quickly as possible with a rate of acceleration that does no harm to its occupants. This means that working to the "safe" acceleration of 2g., the rocket must travel a distance of something just less than 1,500 miles before the engines can be cut out, when it will coast out of the earth's field without any other expenditure of power.

So long as the missile achieves the release velocity of seven miles per second, it matters nothing how close it is to the earth when power ends; theoretically, it could attain the figure when a few feet from the surface and still escape.

For a manned space-rocket to achieve gravitational release, it may be necessary to wait for a form of atomic propulsion, though, if necessary, there is little doubt that one employing a chemical propellant could be made equal to the task. It would, however, be excessively massive and composed of several "steps," having in effect a series of large boosters which jettison one after the other as each becomes spent.

It is even likely that the earliest *atomic* space-rockets will be large and multi-stepped.

Popular Science

Whenever world affairs fail to produce a headline, it is frequently the case that fantasy replaces fact in the feature pages of our papers. Currently it is sought to embellish the magic words "atomic energy" with irritating flights of fancy into the "Utopia of to-morrow," and all too often are we told that our most ambitious journeys, by ship, aircraft or even rocket, will require no more fuel than is inherent in a "tumbler of water."

Statements such as this should not be taken too seriously. The employment of the actual recoiling nuclei in a propelling jet (which the above implies) is really quite fantastic, since the production of so high a velocity stream would involve the dissipation of energy so vast that complete and immediate vaporisation of the vehicle could be the only result.

A marked rise in combustion temperature is the inevitable outcome of improving the jet velocity in any rocket system, and, as its effects have been held down by liquid cooling in chemical rockets, so in a reverse manner is it proposed to transfer the energy of nuclear reaction to a "working fluid," preferably of a low molecular weight such as hydrogen or helium. In this way, the heat energy of the fissible element would be absorbed by the "fluid" which flashes into a jet of rapidly expanding gas and out through a propulsive nozzle.

What exactly does this mean in practice? First, the combustion chamber with its convergent-divergent nozzle would be no great departure from that of the chemical unit. Instead, however, of injecting into it a fuel and oxydiser as separate components, an "atomic" engine would embody its fuel in the form of graphite-fissile material actually *inside* the chamber. This would be conveniently sectioned up to allow the greatest possible area of the substance to be exposed to the inlet of "working fluid," which for the example we may take to be liquid hydrogen.

A steam jacket in the combustion chamber might be employed to supply superheated steam for driving the pumps, both for feeding the propellant fluid and for working a continuous liquifaction plant to prevent pressure building up in the tanks, thereby overcoming one of the greatest problems associated with liquid hydrogen. In this case the tanks might be quite light with comparatively thin walls.

Performance Estimates

Some interesting figures for a propulsion unit of this type have been given by L. R. Shepherd, B.Sc., Nuclear Physicist at the Cavendish Laboratory and Technical Director of the British Interplanetary Society. A thousand ton spaceship is conceived whose propulsion units work with an exhaust velocity of 10 km./sec., and discharge some four tons of propellant per second. He adds that the initial heating of the working fluid involves the utilisation of energy at a rate exceeding 2×10^{11} watts and that, assuming a small number of units, each element must generate some 10^{11} watts of useful energy and discharge something of the order of one ton of propellant every second.

This implies that the chain-reacting system of graphite and fissile material must be capable of withstanding a temperature of about 3,000 deg. C., in the presence of hydrogen under high pressure.

The assumption that some 100 watts per square centimetre can be transferred from the fissile material to the gaseous propellant implies that about 10^9 square centimetres of the former must be exposed. A means of obtaining such a large area, Mr. Shepherd has suggested, would be the division of the graphite-fissile substance into spherical beads 1 mm. in diameter, which means carrying 40 tons of the solid alone. For circumnavigating the moon and returning to land on the earth, it would take at least 700 tons of liquid hydrogen occupying 10,000 cubic metres of storage space.

The "Atomic" Spaceship

The magnitude of the problems to be overcome in the design of spacecraft will be apparent from the above, and, while the atomic engine may provide the main solution, there is little doubt that, initially, the chemical engine will remain important for supplementary use. It would, for example, be ideal as a first stage booster and, indeed, may prove highly necessary in the most powerful atomic spaceships owing to the radioactivity they would otherwise leave behind in the lower atmosphere.

Such a combination of power is represented in Fig. 98. The vessel here conceived is a three-step arrangement in which the first step "A" is a chemical boost rocket. This section is complete in itself and has its purpose in raising the entire craft to a height of sufficient safety for the atomic engine to take over.

As soon as "A" is empty of propellant it automatically drops off to expose the nozzles of the atomic engine in the second step "B."

From this point, the sequence is rather different to that normally followed in "step" design. The section "B" is the main propulsion step and houses the one engine group. The third step "C" is nothing more than a tank and from the time the booster jettisons, the nuclear engine will be drawing on propellant in this section, so that as soon as escape velocity is reached, it is empty and of no further use. It is therefore detached from the main body and driven away by rocket charges.

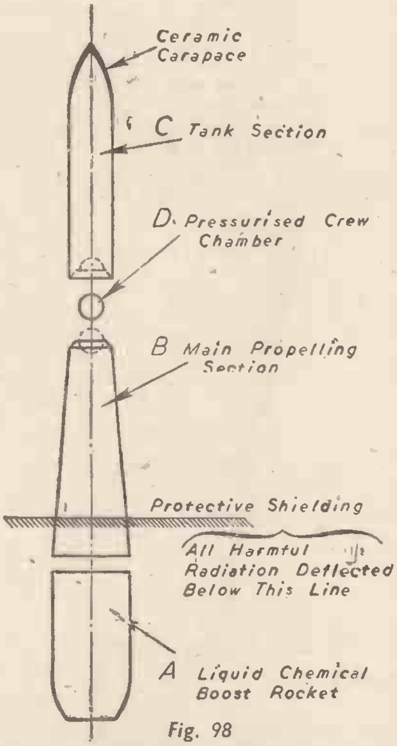


Fig. 98

A SUGGESTED SCHEME FOR AN EARTH-MOON SPACE-ROCKET

A—is a chemical booster section of which it might be necessary to employ two or more. The vessel is driven from its launching tower by thrust in the lowermost section which jettisons automatically as soon as the propellant exhausts and fires the second. This continues until each of the boost sections are cast off, when the engine of step "B" operates.

B—is the main propulsion section and derives its power from the expansion of hydrogen by a fissile substance in the combustion chamber. It draws on propellant in the tank section "C" to reach "release velocity" so that its own propellant remains intact during the outward journey.

C—has no other purpose and when empty at the climax of power, it is detached and propelled away by rocket charges.

D—is the spherical cabin which houses the crew, controls, provisions and equipment. It is normally attached at the extreme nose of section "B" but can be jettisoned and landed by parachute once the vessel has returned to the earth's atmosphere.

This leaves the main step "B" travelling alone at the velocity of gravitational release. All its propellant is intact and it will coast at slowly decreasing speed out of the earth's field. A spin would previously have been imparted to the vessel to stimulate a gravitation within the spherical cabin (which is now exposed at the nose of the section) and also to provide directional stability. The rate of revolution would not need to be more than about once every three seconds for the centrifugal force to approximate normal earth conditions of gravity and the crew would lie horizontally on extended "chairs," their heads towards the axis.

Having passed beyond the so-called "neutral zone" of the two gravities, earth and moon, the vessel would again be subject to acceleration, and if allowed to continue it would eventually crash into the surface at a velocity of about 1½ miles per second.

The headlong rush would most effectively be checked by turning the rocket completely round so that ultimately the aft end faces forwards and the engines can retard instead of propel; this could probably be accomplished by a system of jets firing from the sides, synchronised with the rotation. It has been suggested elsewhere that rocket motors firing from the nose would provide a more simple solution, but this is not too obvious. Not only would the additional space and weight mean a sacrifice in the amount of propellant carried, but the simple fact is that there is no practicable means of landing a rocket without the presence of atmosphere when it does not approach the surface stern first.

Landing

The rearward approach, therefore, greatly facilitates the landing and hydraulic legs, retracted during flight, which are provided in the rear of the section. As the surface is approached, a radar transmitter will send out waves which reflect back from the surface of the proposed landing area, giving a constant check on height and speed.

The final descent is controlled to balance out gravity a few feet from the surface. It would, of course, be necessary to nullify the vessel's rotation during this time and to employ a means of deflecting the exhaust in conjunction with gyroscopes for stability.

"Blind Approach"

The absence of any appreciable atmosphere means that from the time of cutting in the engines to retard, the full force of their exhaust will remain to blast down on to the surface so that if, as is now believed, volcanic dust is much in evidence on the moon, the vessel's arrival will be preceded by a dust-storm of some violence. Though this may have the advantage of clearing the landing area of loose matter, it would certainly obscure the surface from the crew and so make the alightment a largely automatic process. However, instruments are highly developed and in many ways more reliable than the human controller, so that where navigation is accurate and the vessel is retarded on to pre-selected ground which is reasonably flat, landing should not present too great a problem.

The return is effected simply by blasting the craft off directly from its legs. Its weight at this time would be less than one-third that which obtained at the moment of departure from earth, and the fact that the Lunar gravity is small and there is no atmospheric drag means that the flight back to the Mother Planet would be made with a much less prodigious consumption of propellant. It nevertheless remains to retard the rocket so that it may re-enter the atmosphere at a reasonably slow velocity, and again it would be necessary to turn the craft through 180 deg. for the motors to act.

The spherical cabin is detached from the hull as soon as a safe velocity has been reached and special "air-blown" parachutes are then released to bring the crew into a safe landing.

Conclusion

To the reader who is sufficiently interested in the subject to desire more information, it is suggested that he contacts the British Interplanetary Society which is now established as the National group with headquarters in London. The Secretary, Mr. L. J. Carter, has kindly offered to supply a complimentary copy of the Society *Bulletin* to anyone sending a *4d. stamp* to cover postage, and all inquiries should be addressed to him at 157, Friary Road, London, S.E.15. The author will be pleased to reimburse his Society for postage incurred by readers applying from outside the sterling area.