IN the first part of this article, in our issue of May 4th, the author discussed general aspects of his subject and reviewed certain rocket-propelled ground-to-air missiles; Part II (May 18th) went on to discuss air-to-air missiles and rocket-driven interceptors. The third instalment (June 29th) reviewed the development programme carried out by the Germans with the A-4 ("V.2") rocket and its projected derivatives. In Parts IV and V Mr. Gatland dealt with the use of rockets as instrument carriers for high-altitude research. The final instalment herewith discusses the interplanetary project and, more particularly orbital technique.

WITHIN the last decade, mainly as the result of pioneer development in Germany, the rocket has been lifted from the realm of speculation into the world of practical engineering. The Americans, swift to recognize its value as an instrument of scientific research as well as a powerful weapon, are developing the rocket for all manner of important uses and in their hands the science of space-flight, or astronautics, is being shaped. *

The prospect of interplanetary flight, if only in terms of the pilotless missile, has been improved considerably by the RAND Project sponsoring the Earth Satellite Vehicle programme, and the Sunday press has missed no opportunity for projecting its favourite adjectives into the customary mixture of half-truth and fantasy in dealing with the subject. It is often the case that newspaper articles give the impression that the flight to the moon—the initial objective, since it is our closest neighbour in space—will be something of an awe-shattering, "do-or-die," enterprise; but in fact the venture will be the climax of a long series of carefully planned experiments. These can be said to have already begun with our attempts to send instrument-carrying rockets into the upper atmosphere.

The experience accumulated with rockets making further exploratory journeys away from the earth will later enable us to design and build the first man-carrying rockets. Such vehicles, however, will be nothing like the glamourised "space-ships" of fiction but, in the first place, will be used simply to test human reactions to rocket flight close to the Earth, and they will probably be equipped with wings which enable them to glide back through the atmosphere and land in much the same way as conventional high-speed aircraft. And, certainly, not until a high standard of reliability is achieved in all the various techniques of space-flight, will anything so spectacular as a moon-voyage be attempted by a human crew.

It is, in fact, likely that the approach to the Earth's satellite will be made in six distinct stages, approximately in the following sequence: (a) a pilotless missile to orbit the Earth; (b) a pilotless missile to strike the Moon's surface; (c) a pilotless missile to orbit the Moon; (d) a man-carrying rocket to orbit the Earth and descend to the surface; (e) a man-carrying rocket to orbit the Moon and return; and (f) the actual Earth-Moon-Earth flight with a lunar landing. The first of these stages may be reached within ten years—the last may be fifty or even one hundred years away.

It was undoubtedly Oberth who laid the theoretical basis for the space-ship in his classical work, "Die Rakete zu den Planetenraumen," published in 1923, whilst credit for the first engineering analysis is due to the pre-war Technical Committee of the British Interplanetary Society.† A study of the literature to recent date will show that the initial objectives of interplanetary flight have always been considered in terms of direct point-to-point missions, such as one finds in the film, "Destination Moon." The "Cellular Rocket" (Fig. 29), as the B.I.S. conception was called, focused attention upon the major design problems that would have to be faced, suggesting many solutions (notably in the design of the cabin and instrumentation) which are still considered valuable; and if our modern propulsion techniques do not support the optimism expressed in 1938 for the solid-propellant motor, the research at least corrected the widespread belief that space-ships must be magnificent streamlined creations with fins and rows of portholes. Although now purely of historic interest, the "cellular" propulsion unit comprised approximately 2,000 solid-propellant motors, each quite self-contained, arranged in a kind of honeycomb. The cabin was situated in the nose and the clusters of rocket units were built up layer by layer beneath it, so that the spent cartridges in the first layer dropped off and the next layer fired, and so on, until the vehicle reached escape velocity. Similarly, more layers of rockets were assumed to be used in braking against the Moon's gravitational pull and for the return flight.

In the previous article, it was shown that by employing step construction, guided missiles could be built to achieve escape velocity with propellants already available. That this can only apply to step rockets designed for small payloads, however, is evident from fundamental chemical considerations, which suggest that exhaust velocities of 4 to 4.5 km/sec, will set the practical limit for rockets employing bi-propellants. It is a sobering thought that even when such theoretically promising propellants as oxygen-hydrogen, fluorine-hydrazine, and fluorine-hydrogen, have undergone full development, they will still not be adequate for any two way interplanetary flight if launching is made direct from Earth.

Interest in recent years has, therefore, centred in methods for overcoming these limitations, by refinements in motor design and structural technique, and attempts to improve the theory of space-flight to effect useful economies. Investigation has also been made

---