Harry Ross delivered this paper to a meeting of the British Interplanetary Society in London on **November 13, 1948,** and it was published as "Orbital Bases" in the January 1949 issue of Journal of the British Interplanetary Society. Note in particular the first known use of the word "rendezvous" for such operations, along with a realistic appreciation of the practical problems to be faced in actually carrying it out.

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ORBITAL BASES

By H. E. Ross

(A paper read to the British Interplanetary Society in London on November 13, 1948.)

The advent of powerful military rockets is certainly a useful step forward in the progress of astronautics, but it still leaves the Moon a long way off in space—and perhaps in time. It would seem that rocket drive in one form or another will be used but no one yet knows how soon a sufficiently potent technique will emerge to provide us with the key to interplanetary travel. On the other hand, we should bear in mind that certain proposals have been advanced which, superficially at least, promise to make the requirements of a round trip to the Moon much less exacting than the commonly accepted *modus operandi* envisages. I refer in particular to the reduction in overall energy requirements which occur if, instead of postulating a journey direct to the surface of the satellite and back again, we consider splitting up the voyage into easy stages and refuelling our ships in space. As I shall presently attempt to show, a specific variant of this general conception does in fact materially improve the prospect of reaching the Moon without being forced to contemplate building and projecting one enormous vessel—although, even so, it would seem that some mild version of atomic power would still be needed for the drive. On the other hand unfortunately, several new difficulties arise with any method that involves refuelling in space, chiefly enhanced problems of precision manoeuvreability, navigation and pilotage, and these to no small degree offset the advantages of a considerable reduction in the initial launch weight. For of course it will be apppreciated that in a rendezvous between spaceships, or between a spaceship and a *spacestation*, there would be no sensible gravitational attraction to facilitate homing, as would, on the other hand, be the case in seeking a planet or moon.

Nevertheless, let us go back to the beginning and trace the present trend in rocketry, for I think it will indicate that the stepping-stone method of crossing to the Moon, which entails a precision rendezvous in space, may, in fact, creep upon us without any deliberate intention on our part to foster and evolve this technique as an approach to the Moon.

At present the larger rockets are being used for research into various phenomena and to collect data about the upper atmosphere. The densities, pressure, temperatures, humidities, constituents and winds of the air up to 100 miles and beyond are being investigated, the velocity of sound and the

In the scheme about to be described we are, unfortunately, for the present still tied to the idea of jettisoning parts of the ships in order to minimise weight —indeed, we shall be assuming that the vessels employed are compositions of Step and Cellular construction. On the other hand, as just hinted, we shall be invoking more than one ship for the purpose of completing a round trip to the moon. The basis of the particular method about to be outlined has, in fact, been propounded and treated in one form or another by Oberth, Pirquet, "Noordung" and others, but the variant about to be delineated appears to contain some advantages hitherto overlooked. In particular, whereas formerly it was considered that employing more than one ship involved a greater *overall* earth projection weight, this scheme promises to effect a major saving in the total weight launched.

Briefly, the scheme proposes splitting up the Earth-Moon-Earth round trip into stages, on the principle that it is easier for a person to transport a load of bricks a few at a time in this way than it is to attempt to carry the lot all the way in one journey. For the purpose of outlining this scheme it is necessary to make the following assumptions:—

1. That it is possible to build and launch manned cellular-step spaceships of at least 442 tons and preferably not less than 600 tons gross weight.
2. That these ships are capable of developing an exhaust velocity of at least 5 km./sec.
3. That navigation, manoeuvre and pilotage are perfected to a stage where it is possible to obtain precision rendezvousing in space.

The *modus operandi* of the scheme is as follows: three 442-ton ships, each carrying one man, would be launched simultaneously from the earth. They would be navigated and piloted to a rendezvous in a substantially circular orbit 500 miles up. Here they would be warped together and one (A) of the three would be refuelled from the other two (B and C). Ship C would be totally discarded and ship B would be fuelled with the surplus not required by A. With all three men aboard her, ship A, which now weighs about 65·2 tons gross, then departs from the 500-mile sub-orbit, heading for the moon. On approach to the moon, ship A is piloted into a circular orbit, say 500 miles above the satellite. Here fuel tanks weighing about 3·9 tons are detached and left circling in the orbit, whilst ship A descends to the moon. After touchdown on the moon, ship A will weigh about 10 tons gross. In due course ship A rises from the satellite and heads for the 500-mile orbit about Moon. Here, with the aid of radar or other search equipment, it seeks out and comes alongside the fuel tanks which were left in this orbit. This fuel is pumped into the

It will, of course, be appreciated that ability to rendezvous in space is an essential concomitant of this type of project. However, although the difficulties are indeed formidable, they do not appear insuperable. As a matter of fact, if we manage to survive present world-wide interest in guided missiles, we may, in the end, find ourselves master of a technique which even Homer seems to have envisaged when he wrote:—

> "In wondrous ships, self mov'd, instinct with mind:
> No helm secures their course, no pilot guides:
> Like man intelligent, they plough the tides."*

* Homer (*Odyssey* viii), Pope's translation.