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THE EXPLORATION OF SPACE

REVISED EDITION

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Chapter Five

THE ROAD TO THE PLANETS

Are thy wings plumed indeed for such far flights?
WALT WHITMAN, "Passage to India"

IN the last chapter, we touched on the subject of interplanetary orbits—as opposed to "mere" circumnavigations of the Moon—and the somewhat surprising statement was made that, under favorable conditions, the planets could be reached with little more trouble than the Moon itself. Before we go on to discuss the building of true, man-carrying spaceships, we must look into this matter more closely.

When we are contemplating a voyage from the Earth to the Moon, these bodies are—astronomically speaking—so close together that everything else in space may be ignored. The picture is different when we consider a journey from Earth to any of the planets, for now we must take into account the presence of the Sun.

The reason is quite simple. It is the Sun's enormous gravitational field that holds all the planets, near and far, circling in their orbits, as described in Chapter 2. We can visualize the Sun's influence as producing a "gravitational pit" like the Earth's; but immensely deeper—on the scale we used before, not 4,000 but 12,000,000 miles deep! Like a group of motorcyclists racing round one above the other on the sides of a giant Wall of Death, the planets circle at their various distances. To move from an outer planet to an inner one means first of all losing speed slightly to drop down towards the Sun, then slowing down a little more as one goes past its orbit to match one's velocity with the inner planet. In exactly the same way, going to an outer planet means first *increasing* speed to climb upwards, then adding on a little more speed when passing the outer planet in order to keep up with it and avoid falling back again. These maneuvers, and the

velocities required for them, in the case of Mars and Venus are shown in Figure 10. The changes in speed provide the energy needed to move up and down the "slope" of the Sun's gravitational field.

It is extremely fortunate for astronautics that, at the distances of the planets from the Sun, the "slope" of this field is relatively gentle, and so little energy is needed to move along it. In most cases, in fact, much more energy is required in the escape from a planet's own gravitational field—something which has to be done in the first thousand miles or so of the voyage—than in the journey from orbit to orbit, which may cover a distance ten thousand times as great.

Once again it should be emphasized that, to travel from one planet to another, rocket power need only be used for a few minutes at the beginning and end of the journey. If the initial velocity has been correctly given, the far longer period of "free coasting" will follow automatically.

In this sense, there is an analogy between a spaceship and an artillery shell. Once the shell has been launched in the right direction, no more work need be done, even though it may still have a great distance to travel. It is much the same with the spaceship—with the important difference that whereas the shell acquires its velocity in a few feet under an enormous acceleration, the spaceship has thousands of miles in which to build up speed at a rate which human passengers could withstand. Still, this distance is as negligible compared with the total journey as the length of the gunbarrel is compared with the trajectory of the shell, so when we are considering interplanetary journeys we can forget about the initial period of acceleration and imagine that the spaceship starts with the required velocity.

The orbits shown in Figure 10 are, however, by no means the only paths that would take us from Earth to Mars and Venus: they are merely the most economical ones. Faster and more direct routes are conceivable, but they would require very much greater expense of energy. With unlimited power, it would be possible to travel from one planet to another in virtually a straight line, but this will remain a dream until long after astronautics has become a fully established science. The reason why the routes shown in Figure 10 are the easiest is not hard to see: the rocket has to "take off" and "land," if one can extend these phrases to cover such a case, in the directions in which the planets are already moving. The shorter paths would cut across the planetary orbits at an angle, and so it would require much larger velocity changes to match speeds.

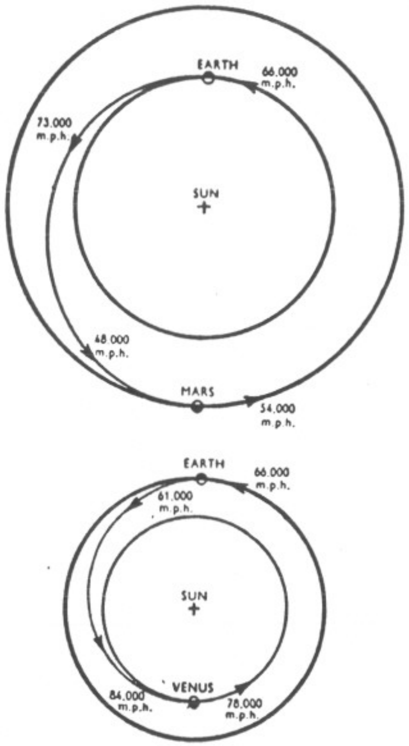

Figure 10. The Easiest Routes to Mars and Venus

One important—indeed, fundamental—point about these orbits is that one could not take off for Mars or Venus at any time one pleased. The moment of departure would have to be calculated so that, when the spaceship reached the planet's orbit, the planet was there too! In the case of the Venus journey, which would last 145 days, Venus would have made almost three-quarters of a revolution round the Sun while the ship was traveling to meet her. If the appointment was not correctly made, or the ship had run out of fuel and so was unable to match speeds, it would go past Venus and would swing back to the Earth's orbit, completing the ellipse and returning to its original point 290 days after departure. Unfortunately for the occupants, if they had survived, the Earth would

now be a long way away, so they would have no chance of being rescued. In fact, the spaceship would have to make *five* complete circuits round the Sun, taking four years in the process, before it came near Earth again!

Missing an appointment may or may not be a serious matter in everyday life, but in interplanetary travel it would, almost inevitably, be fatal.

We can now sum up the requirements for any interplanetary voyage, as follows:

(1) The ship must build up sufficient speed to escape from the Earth, and when it has done this must still have enough velocity left to put it into the required "voyage orbit." This means that it must start with a speed greater than that needed merely to escape—though in most cases only slightly greater.

(2) When it approaches the planet of destination, it must use rocket power again to match the speed of the planet, *and* to lower itself safely into the planet's gravitational field.

It will be seen that this is rather more than we had to do when we wanted to send a guided missile to survey another planet. This time we have the additional complication of the landing. And we have not yet discussed the return journey!

It is this latter factor that makes the problem of interplanetary flight so exceedingly difficult. Although there are people who, for the sake of adventure or scientific knowledge, would undoubtedly undertake one-way trips (particularly if there was a chance of survival when they had landed), one can hardly make serious plans on this basis. Spaceships will have to carry enough fuel for the round trip, which involves the same problems, and exactly the same velocity changes, as the outward journey.

It can be said at once that there is no possibility of fulfilling these requirements, for even the easiest of interplanetary return journeys, by the use of chemically fueled step-rockets alone. The starting weights would be enormous—millions of tons, in fact. Does this mean that, even if we can send television cameras to the