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Final Report:

A STUDY OF INTERPLANETARY TRANSPORTATION SYSTEMS

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FOREWORD

This volume contains a series of investigations covering five areas of current importance in the planning of manned interplanetary missions. Although these studies are closely related to one another, and oriented toward the main problem of flight trajectory selection, each of the sections is self-contained, and may be read separately from the others. While none of the subjects is considered to be closed, it is nevertheless hoped that the material presented herein may be of use in understanding the basic physical concepts involved in scheduling these flights.

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Section 5
NONSTOP TRIPS PASSING BOTH MARS AND VENUS: THE INTERPLANETARY GRAND TOURS

The investigation of nonstop round trips to Mars or Venus quite naturally leads the analyst to inquire whether any orbits might be found which pass near both planets during an uninterrupted ballistic flight. Of course, any round-trip orbit whose aphelion exceeds the maximum orbital distance of Mars, and whose perihelion falls within the minimum distance of Venus is a likely candidate for such a mission, providing that the analyst is either patient enough or young enough to await the proper relative alignment of the three planets for that trip.

A somewhat more fruitful exercise, however, might involve the systematic search for all such trips which exist during any given calendar period, and the selection of those flights which show hope for execution, keeping in mind the realistic limitations of propulsion technology. At the outset, we are confronted with a paradox: Low-energy transfers to Mars seldom dip appreciably within the Earth's orbit while, on the other hand, low-energy transfers to Venus rarely stray outside the Earth's orbit. These contradictions make it painfully apparent that the trips presently sought will not likely be found among low-energy transfer orbits. Nevertheless, the problem is worth considering not only as an interesting academic pastime, but also because the velocity requirements required in some cases may actually be attainable using presently envisioned nuclear power plants.

By adopting a preliminary model for the solar system in which all planets move in coplanar circles, the relative geometry between any two planets is rendered strictly repetitive, permitting systematic generalizations of the dynamical phenomena involved. The results from this preliminary study are expected to lie reasonably close to their true values, and may be used as first estimates in refinement procedures which later involve more realistic models for the planetary motions.

The desired orbits may be found graphically as follows: For every trip duration of reasonable length (say, 2 years or less) all ellipses which pass from Earth to Earth in the specified time may be generated, using Lambert's theorem in the manner outlined in Section 1. For the special case when the mission duration is an integral number of years, a complete family of ellipses (i.e. the nonsymmetric trips) exist for each trip time specified. All members of each such family may be found by employing the Earth-Sun-Mars angle, L, as the generating parameter, again using the technique described in Section 1.

The Earth-Mars transfer time, plus the transfer angle for each case then dictate the launch date, measured from opposition. Any three independent parameters, viz. major axis, launch date, and heliocentric flight-path angle at departure, ψ , (which has a unique correspondence with eccentricity), define the size, shape, and orientation of each Mars round trip. Similar considerations apply for Venus.

If p denotes the number of complete years in any trip, and m the number of complete orbital circuits, then for each set of flights with identical values of p and m, the angle ψ may be plotted against departure date, as in Figs. 5-1 to 5-3. By superimposing the corresponding Mars and Venus plots and aligning the conjunction and opposition marks to correspond in spacing to the calendar period of interest, points at which the two curves cross are acceptable orbits of the type sought. That is, these intersection points have associated values of major axis, eccentricity, and departure date which are identical for trips to both Mars and Venus; therefore, the orbits must be one and the same.