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History and Status of CF09

The problem which CF09 solves numerically on the 7090 is the following:

Let P_1, P_2,...,P_n represent n planets of the Solar System. Let $P_1 - P_2 - \ldots - P_n$ represent a free-fall interplanetary trajectory having origin at P_1 at time T_1 which approaches the planet P_i ($i = 2,3,\ldots n-1$) in such a way that its gravitational influence causes it to encounter P_{i+1}. Suppose T_i denotes the time of perihelium passage to P_i ($i = 2,\ldots n$). Corresponding to the given trajectory profile $P_1 - P_2 - \ldots - P_n$ and given times T_1, T_2 is a class of trajectories each satisfying these initial conditions. The determination of these trajectories in essence ~~means~~ ~~closing~~ is the general n-body problem of classical mechanics, the solution of which is not known. It is however possible to obtain approximate solutions by making certain simplifying assumptions.

Due to the inverse square law of gravitational attraction, all bodies in the solar system move on trajectories which are very close to true conic paths. In particular where a space vehicle approaches a planet its trajectory quickly changes from an approximate elliptical trajectory with respect to the sun, to an approximate hyperbolic trajectory with respect to the planet. The region about the planet where the trajectory becomes hyperbolic is called the gravitational sphere of influence. By assuming that a free-fall interplanetary space vehicle moves only under the influence of the sun when it is outside a planetary sphere of influence and moves under the influence of a near by planet only when it is inside its sphere of influence, it is possible to determine trajectories satisfying the given conditions. That is to say with only this basic assumption it is possible to calculate how a space vehicle should approach P_i so that its gravitational influence will cause the vehicle to proceed to P_{i+1}.

During the break between the fall and spring semester of 1962 I received permission to program my solution of this problem for the 7090 by Mr. Hollandar and was given the job number MA II. The first step of constructing a planetary ephemeris and storing it in ~~case~~ core was completed at the end of Feb. 1962. By the end of March the basic program (also stored in ~~case~~ core) was completed. The month of May was devoted to determining various δ values corresponding to sufficiently small ϵ's and checking out a few machine computations with a slide rule.

There is at Cal Tech's Jet Propulsion Laboratory a very elaborate integrating program which, if given a free fall vehicle's position vector $\vec{R}(t)$ and velocity vector $\vec{V}(t)$ at any time t, can determine $\vec{R}(t')$ and $\vec{V}(t')$ for any later time $t' > t$ when all planets in addition to the sun continually influence the vehicle's motion. The initial results of MA II was checked with this program. For each trajectory checked, remarkable agreement was discovered. Never before had actual approach trajectories to P_i been accurately determined which caused the vehicle to encounter P_{i+1}. With these results and with the recommendation of Dr. Henrici, Mr. Hollander gave me stand by status with new job number CF09.

Thus began the first detailed numerical analysis of advanced free-fall interplanetary trajectories. By June of 1962 it became evident that these trajectories may be very useful in three distinct types of interplanetary missions:

(1) Unmanned exploration of planets

(2) Manned planetary reconnaissance and landing missions

(3) Interplanetary transportation systems

At this time the computing facility at the Jet Propulsion Laboratory also started computation. With the aid of both facilities the analysis was greatly speeded up. Thus within a few months it was possible to analyze in great detail the following types of trajectories;

Earth-Venus-Mercury

Earth-Venus-Mars

Earth-Venus-Earth

Earth-Mars-Earth

Earth-Venus-Mars-Earth

for the decade 1965 through 1974. The results of these computations along with possible applications are significant and have been made known to many research laboratories of the National Aeronautics and Space Administration.

Since the determination of advanced trajectories involving more than 4 planets take more time and are considered at the present time to be a little futureistic, little actual analysis in this area has been made. However, trajectories involving 8 and 9 planets have been determined at this facility which show that they may be very useful in terms of transportation systems.