the guard ring end heater. This should result in even better system performance. In addition, the upper temperature limit may be extended by selecting materials of higher heat resistance for the construction of the guard ring and sample heater.

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Planetary Trajectory Handbooks for Mission Analysis

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A COMPREHENSIVE set of trajectory handbooks (Parts 6–9) has been added to the NASA *Planetary Flight Handbook*.[1] They are specifically designed to be of use in mission or system studies and therefore include parameters such as planetary lighting conditions, Saturn ring passage conditions, and communication distances in addition to the relevant trajectory parameters. They cover opportunities from the mid-1970s to the mid-1980s for Mercury and the outer planets and to the end of the century for Mars (see Table 1) and they include general discussions of the missions, contour charts, and related information.

The titles of the new parts are: Part 6, *Mars Stopover Missions Using Venus Swingbys*†; Part 7, *Direct Trajectories to Jupiter, Saturn, Uranus, and Neptune*‡; Part 8, *Jupiter Swingby Missions to Saturn, Uranus, Neptune, and Pluto*,‡ and Part 9 (to be published), *Direct and Venus Swingby Trajectories to Mercury*.‡ Supplements containing the tabular data for Parts 6, 7, and 8 are bound separately from the descriptive sections and are available from the Technical Information Division, NASA Ames Research Center, Moffett Field, Calif. The descriptive sections are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. Both the descriptive section and the tabular data for Part 9 are bound in one volume which is also available from the Superintendent of Documents.

To facilitate the use of the trajectory data by computers, magnetic tapes, which contain the tabular data used in the handbooks, have been prepared. Descriptions of these tapes and instructions for obtaining them are given in the descriptive section of each part.

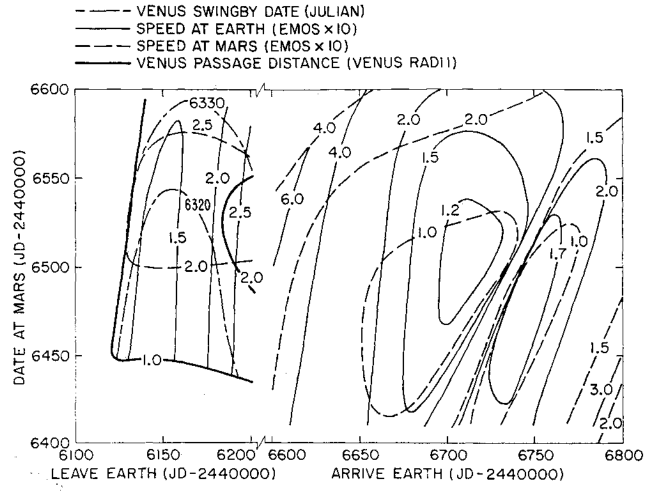

Fig. 1 Mars stopover mission using Venus swingby (1986).

Part 6

This Handbook contains data for Mars round trip missions with 0, 30, and 60 day stopovers, for which the trajectory data are contained in Supplements A, B, and C, respectively. These stopover times were selected because they encompass the region of reasonable stay times for the swingby mode and illustrate the effect of stopover time on mission parameters. Only unpowered Venus swingby missions are included in Part 6, since oneway direct trajectories to and from Mars (and also Venus) are summarized in the previously published parts 1–3.[1] The trajectory data are presented chronologically and are organized by holding stopover time, total mission duration, and Mars arrival date constant while varying Earth departure date. Next, the Mars arrival date is varied, followed by the mission duration.

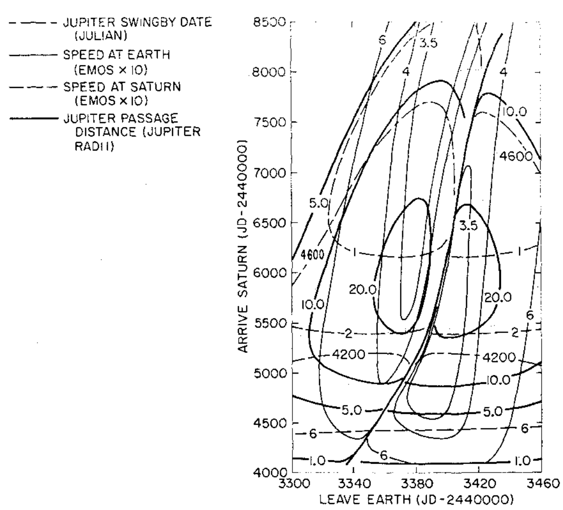

Fig. 2 Saturn mission using Jupiter swingby (1977).

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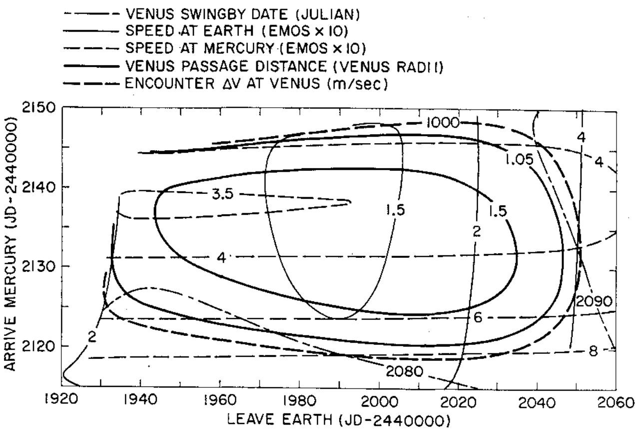

Fig. 3 Mercury mission using Venus swingby (1973).

For illustrative purposes, the contour chart for the 1986 Mars-Venus opposition from Part 6 is shown in Fig. 1. The chart is in two parts: the left side shows the characteristics of the outbound (Venus swingby) leg and the right side illustrates the direct, return trajectory. The chart graphically illustrates the variation in velocities at Earth and Mars, and in Venus passage distance and date. Parameters relevant to Venus passage appear only on the left side of the chart, since this is an outbound swingby. Note that the region of feasible solutions is contrained by the 1.0 Venus passage distance contour.

Part 7 and Part 8

Direct trajectories to Jupiter, Saturn, Uranus, and Neptune are given in Part 7. Part 8 contains Jupiter swingby missions to Saturn, Uranus, Neptune, or Pluto and also the Outer Planet Grand Tour (a mission which passes Jupiter, Saturn, Uranus, and Neptune). All trajectories with Earth departure velocities less than 0.65 emos and reasonable trip times were included in the tabulation.

An example of a contour chart from Part 8 is shown in Fig. 2, namely, a Saturn mission using Jupiter swingby with launch date in 1977. The relevant speeds and Jupiter passage parameters are shown as contours of constant values. Note that Saturn arrivals before about J.D. 244 4100 are not possible because of the Jupiter passage distance constraint. The dark, nearly vertical line up the center of the chart separates the type one transfers (transfer angles <180°) on the Earth-Jupiter leg from the type two transfers (>180°).

Part 9

Part 9 contains direct and Venus swingby trajectories to Mercury for the time period 1973 to 1985. A 13-year period was selected to encompass one Earth-Mercury synodic cycle. Characteristics of the direct missions are essentially repeated every 13 years so that trajectories outside this time period can be estimated. There are 3 and occasionally 4 direct launch opportunities to Mercury every year. Only the trajectories associated with the minimum Earth departure velocity launch opportunity of each year are listed in detail in the Handbook. For each of the other launch opportunities, the characteristics of a single trajectory with minimum Earth departure velocity are given.

Launch opportunities for Venus swingby missions to Mercury occur every 19 months. Detailed trajectory information for each launch opportunity from 1973 to 1985 (except 1977 which has extremely high Earth departure velocities) is available. Figure 3 is an example contour chart for the 1973 launch opportunity. It shows the speeds at Earth and Mercury and the parameters relevant to Venus passage: the date, and either periapsis distance, R_p, or Venus encounter ΔV if R_p is less than 1.05 radii. The encounter ΔV is that ΔV required to perturb the post-encounter trajectory so that the minimum passage distance at Venus can be maintained at 1.05 radii. The trajectories which require an impulsive maneuver at Venus are included in the tabular data if $\Delta V \leq$ 1000 m/sec. An additional constraint, imposed on all Mercury handbook data, requires that the Earth departure excess speed be less than 0.60 emos.

Table 1 SP-35 summary

PART	SUPPLEMENT	DESTINATION PLANET	TRAJECTORY MODE	YEARS
6	A,B,C	♂	♀ SWINGBY	1975-1999
7	A	♃	DIRECT	1981-1986[a]
	A	♄	DIRECT	1976-1986
	B	♅	DIRECT	1976-1986
	B	♆	DIRECT	1976 1986
8	A	♄	♃ SWINGBY	1976-1980
	A	♅	♃ SWINGBY	1978-1982
	A	♆	♃ SWINGBY	1978-1982
	A	♇	♃ SWINGBY	1976-1980
	A	♆	GRAND TOUR	1976-1980
9	-	☿	DIRECT	1973-1985
	-	☿	♀ SWINGBY	1973-1985

a) DATA FOR 1970-1980 ARE CONTAINED IN PART 5 OF THIS HANDBOOK SERIES.

It is hoped that Parts 6–9 will be a useful addition to the trajectory handbook series. As new missions become of interest, for example, the modified Grand Tours (Earth, Jupiter, Saturn, Pluto or Earth, Jupiter, Uranus, Neptune), the preparation of new handbooks will be considered.

Reference

[1] *Space Flight Handbooks, Vol. 3—Planetary Flight Handbook*, Pts. 1–3, 1963, George C. Marshall Space Flight Center, NASA SP-35.

Selection of Astronaut Cooling Systems for Extravehicular Space Missions

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Because of man's inherently low efficiency, the metabolic oxidation of food hydrocarbons results in the production of large amounts of thermal energy with very little useful work output. If this excess energy is not removed or transferred to the external environment, it will accrue within the relatively large thermal mass of the crewman's body. Skin temperatures are then elevated by the body's liquid transport system which transfers this heat from the interior. The phenomenon is signified by increasing mean body temperatures and reduced effectiveness of the human machine. If body heat storage is not controlled, physiological tolerance limits will be exceeded.[3] The reduced effectiveness is brought about by three major factors: 1) eye irritation, visor fogging, and general discomfort due to massive sweating without evaporation; 2) exhaustion and collapse due to excessive body heat storage; 3) dehydration from prolonged sweating.

Accumulated data on extravehicular activity (EVA), have demonstrated the inadequacy of astronaut gas cooling systems for sustained periods of high work rate. Liquid cooling

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