New Trajectory Options for Ballistic Mercury Orbiter Mission

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ABSTRACT

This paper reports on recent advances made in obtaining low ΔV trajectories to conduct Mercury Orbiter missions. Almost all Mercury mission designs to date are based on the methodology and the data given in Reference 1. The design of MESSENGER (a recent winner of NASA Discovery 6 Program) mission followed the similar path. Hoping to enhance the performance potential of the mission, re-evaluation of its trajectory optimization was made on behalf of the MESSENGER program.

This study lead to several new ways of conducting **Multiple Venus Gravity Assists** which gave lower ΔV and/or ways to utilize more naturally the attendant Earth-Venus phasing. Further more, two new **Multiple Mercury Gravity Assists** types derived from the concept contained in Refernce 2 were incoporated to add further ΔV reductions in mission ΔV's, if needed. As an example, Table-1 compares performance profiles of eight different modes of multiple venus gravity assists but without Mercury gravity assists. Associated mission ΔV's and the flight times are provided. As was the case in Reference 1, which addressed only the option 1, this Table assumes E-V-M phasing to be perfect for each trajectory type. Only this way, one can make the comparisons among them meaningful. An example trajectory plot corresponding to Option 7 is provided in Figure 1.

All useful $V^N M^K$ trajectory types and the phasing requirements for each of these options will be detailed in the paper.

References:

1) "Ballistic Mercury Orbiter Mission via Venus and Mercury Gravity Assists", C.L. Yen, AAS/AIAA Astrodynamics Specialist Conference, Vail, Colorado, August 12-15,1985.
2) "Chemical and Solar Electric Propulsion Options for a Mercury Cornerstone Mission", Y.Langevin, 50th International Astronautical Cogress, Amsterdam, The Netherlands, October 4-8, 1999.

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Table-1: Performance Summary for $V^N M$ Trajectories

Option	V-V Transfer Type	FT (yr)	C3 $(km/s)^2$	DSM/MOI* (km/s)	ΔVPL** (km/s)	ΔV_T ** (km/s)
	Two VGA's with Perfect Synch.					
1	Venus: 1 yr SC: 1 Rev	1.31	18.90	0.30/3.48	3.48	7.53
2	Venus: 2 yr SC: 3 Rev	1.91	19.54	0.47/3.12	3.59	7.67
3	Venus: 3 yr SC: 4 Rev	2.50	13.75	0./3.16	3.16	6.99
	Two VGA's with Non-perfect Synch.					
4	Venus: 1.8 yr SC: 2.8 Rev	1.59	18.64	0.23/3.12	3.35	7.39
5	Venus: 2.1 yr SC: 3.1 Rev	1.96	21.07	0.57/3.15	3.72	7.86
6	Venus: 2.8 yr SC: 2.8 Rev	2.19	13.76	0./3.15	3.15	6.99
	3 VGAs					
7	Venus: 1.3 yr SC: 1.3 Rev Venus: 2 yr SC: 3 Rev	2.73	13.34	0./3.15	3.15	6.97
8	Venus: 1. 5 yr SC: 1.5 Rev Venus: 1 yr SC: 1 Rev	2.00	18.71	0.08/3.15	3.23	7.28

* DSM/MOI –Deep Space Maneuver/Mercury Insertion ΔV to 12-hr Orbit
**ΔVPL – Total post launch ΔV
***ΔV_T – Total ΔV including launch ΔV from a 200 km LEO

Figure-1. Example Trajectory Using Option 7 (E-VVV-M)