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Proposed mission to Mars and his Trojan Asteroid Family – An Update Report

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Abstract

In the context of ESA's call for medium class missions, we have been investigating missions to Mars. As part of proposal development, we studied the option to visit a Mars Trojan on the way to the planet. We set up a three-impulse model to determine physically possible flyby scenarios and optimum trajectories in terms of mission time and costs. We propose several mission scenarios in the time frame 2020-2050 involving trajectories which require transit times of up to 5 years and an additional delta-v of 0.1-1km/s compared to a typical Mars-only mission.

1.Introduction

DePhine – the Deimos and Phobos Interior Explorer – has been proposed as an M-class mission in the context of ESA's Cosmic Vision program [1], with a projected launch in 2030. The mission will explore the origin and the evolution of the Martian satellites. In addition to the nominal mission plan, flyby scenarios with Martian Trojans on the way to Mars were analyzed. We present results from our initial search for physically possible trajectories within given constraints of time and costs.

2.Mars Trojans

The Martian Trojans are small, with diameters between hundreds of meters to a few kilometers. While the origins of these objects are uncertain, they were likely deposited at their present locations during the early Solar system evolution [5] and some of them may represent rubble piles, originating from large impacts on Mars [4]. Eight of currently nine known Trojans are located near the Lagrangian point L5 (trailing by approx. 60° behind Mars). Seven of these, including the asteroid Eureka, have recently been identified as members of a family (the "Eureka family") of olivine-rich asteroids [2], which probably formed in a break-up or fission event [3]. A mission to the Trojans would shed further light on the properties of the population, their relation to Mars and other asteroids and is therefore of high scientific interest. Eureka family members have significant inclinations, >10° relative to the ecliptic and, specifically, to the orbital plane of Mars. For a mission to the Trojans launched from Earth, this implies either high flyby velocities (> 5 km/s) for a spacecraft approaching or high delta-v demands for a rendezvous mission.

Table 1: Main osculating elements of the five largest Martian Trojans [6]

Asteroid	Semi-major axis [AU]	Eccentricity []	Inclination [deg]
5261 Eureka	1.5236	0.065	20.28
101429	1.5241	0.101	31.297
121514	1.5244	0.039	16.749
311999	1.5237	0.054	18.622
385250	1.5237	0.035	24.402

3.Transfer Scenarios

We consider flyby missions in the time frame 2020 – 2050 including transfers that involve more than one revolution about the sun. With the Earth and Mars ephemerides relatively fixed in space and time, the Trojan candidate has to be "at the right place at the right time" to minimize costly spacecraft course adjustments. Hence, we designed a transfer to Mars, during which the Trojan would intersect the course of the spacecraft [7]. We introduced a three-impulse model. The first impulse is used to depart from Earth, the second impulse is used for a course correction at the time of the Trojan flyby and the third for orbit insertion at Mars.

While flybys in theory are possible for any target, time and costs permitting, we cut-off and present

models having delta-v < 1 km/s and transit time of < 5 years. We report on several scenarios, each including a flyby at one of two different Trojans. For our scenarios, overall additional delta-v demand is between 100 m/s and 1 km/s compared to a "regular" mission to Mars with a direct Hohmann-transfer.

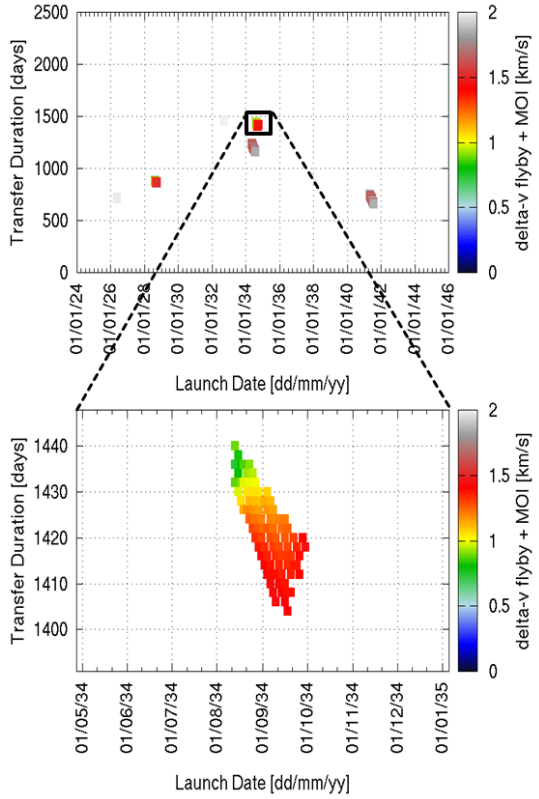

Figure 1: Example of possible Mars transfers with flybys at Martian Trojan 311999 (top). The color coding shows the overall delta-v demand for maneuver 2 and 3 (impulse after Trojan flyby and Mars orbit insertion)

4. Conclusion and Outlook

We evaluate the possibility to combine a mission to Mars with a flyby at Martian Trojans of the Eureka family. We show that it is possible to carry out flybys at Trojans with only a low demand for additional delta-v and propellant. On the other hand the low delta-v transfer requires a longer transfer time of up to 5 years. Such a scenario will increase project time line, complexity and overall costs of a mission to Mars.

While our crude model, involving 3-impulses at given time, suggests that a mission is possible in principle, the proposed trajectories can certainly be optimized. In our next steps we want to include a new model, which allows for more than 3 impulses, with the optimal time and magnitude of the impulses to be solved for. We expect to reduce the demand for delta-v.

We realize that a standalone mission to a Mars Trojan is currently probably far from practical in spite of an excellent science case. However, a combined mission to Mars and one of its Trojans may be conceivable, and science may be obtained at reasonable added costs.

References

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