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Missions to Mars and his Trojan Asteroid Family – A Feasibility Study

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Abstract

In the context of ESA's call for medium class missions (M5), we investigated missions to Mars. As part of proposal development, we studied the possibility to visit at least one Martian Trojan either through a flyby on the way to Mars or by going from Mars to a Trojan at the end of the mission. We find that both options are possible but require considerable mission resources. While the first option requires less fuel, it is very limited in terms of available time windows and margins. In contrast, the second option offers a more flexible mission schedule, but requires more propellant and time.

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 natural satellites. In addition, we analyzed rendezvous scenarios with Martian Trojans, which could possibly be achieved in combination with missions to Mars.

In our study we focused on two different scenarios:

- Option 1: Flyby of one Trojan as part of a transfer to Mars
- Option 2: Going from high Mars orbit (i.e. an orbit near Deimos) to one or more Trojans at the end of the mission.

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 [5] and some of them may represent rubble 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 the Earth or Mars, this implies either high flyby velocities for a spacecraft approaching or high delta-v demands for a rendezvous mission.

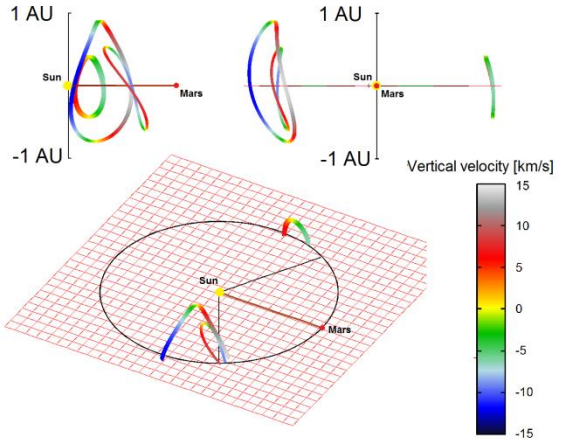

Figure 1: Orbits and color-coded vertical velocities of 3 Martian Trojans (5261 Eureka and 101429 near L5 and 121514 near L4) in a Sun-Mars co-rotating reference frame; top-left: xz-plane, top-right: yz-plane, bottom: 3D view

3.Transfer Scenarios

In our study we consider flyby missions only following two different scenarios. One is a flyby during the transfer from Earth to Mars. We studied scenarios in the time frame 2028 – 2032 including transfers that involve more than one revolution about the sun. As the Mars trajectory is 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. We report on several flyby opportunities, which require only moderate course corrections.

As a second option, we studied a transfer starting from Mars, moving along Mars' solar orbital path initially in high equatorial Mars orbit (e.g. near Deimos). Here, the spacecraft may stay at Mars to await a favorable nodal crossing for a selected Trojan and leave the Martian gravity field just in time for a flyby. We study flyby opportunities and produce associated time tables. Such a transfer requires a velocity increment of approximately 1-1.2 km/s while transfer times are approximately 600 days.

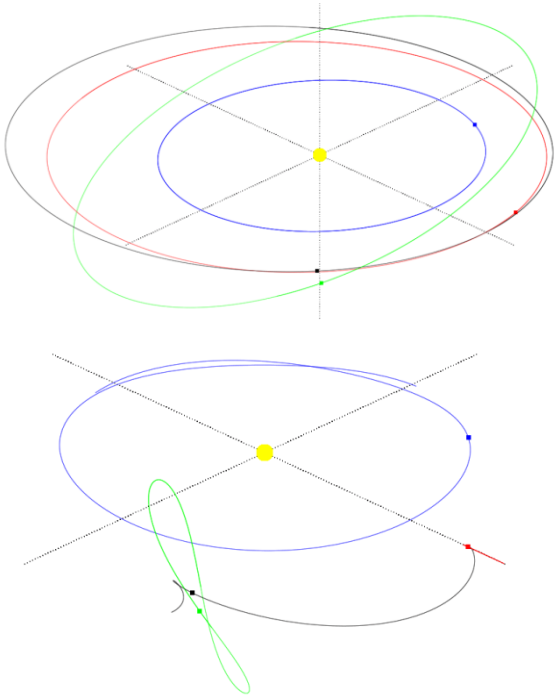

Figure 1: Example of a transfer orbit from High Mars Orbit to 5261 Eureka; shortly before arrival at Eureka (blue: Earth, red: Mars, green: 5261 Eureka, black: spacecraft; top: inertial reference frame, bottom: Sun-Mars: co-rotating reference frame)

4.Summary and Conclusions

We evaluate the possibility to combine a mission to Mars with a flyby of Martian Trojans in the Eureka family. We show that both options (flyby during transfer to Mars and launching from a High Mars Orbit to a Trojan) are technically feasible.

We show that a flyby during the transfer to Mars is possible. This option has a very narrow time window and requires a transfer orbit with ~1.5 revolutions about the sun leading to transfer durations of approximately 2.5 years. The transfer to a Trojan from an orbit close to Deimos allows departing within a wider margin in mission schedule, but requires more propellant mass, along mission duration and increased total operation costs.

Consequently, both options would increase mission resources, complexity and overall cost. Nevertheless, while a standalone mission to a Mars Trojan is currently probably far from practical, a combined mission to Mars and one of its Trojans may have a valuable scientific case, conceivable in the future.

References

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