Trajectory Design for Jovian Trojan Asteroid Exploration via Solar Power Sail

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Abstract:

JAXA has been preparing for a Trojan asteroid sample return mission via solar power sail. Jovian Trojan asteroids are as one of a few remaining final frontiers within our Solar System, which may hold fundamental clues of the Solar System formation and revolution. However, bringing back the sample from Jovian Trojans are much more difficult than NEOs simply because large amount of fuel is required to reach them. Moreover efficient power supply is difficult around 5 AU. Solar power sail is a way to realize such a challenging exploration.

A typical solar sail is a concept of a fuel free spacecraft with a large membrane that acquires propulsive force by the reflection of sunlight. It is considered to be one of the most essential propulsion systems for future deep space exploration. Its precursor was successfully realized by IKAROS, the world's first deep space solar sail spacecraft, in 2010. However, because the force of the photon is very small, it is difficult to obtain sufficient propulsive force. A huge area membrane is required for the deep space explorations, but it is impossible to manufacture and deploy after launch by the existing technology. JAXA therefore has proposed the concept of "Solar Power Sail" by expanding the concept of a solar sail. A solar power sail combines a solar sail with electric power generation capability and high efficient ion engines. Thin flexible solar cells attached on the sail membrane generate the electric power and high efficient ion engines are driven by the large eclectic power supply. The solar power sail is not fuel free, but it can realize flexible and efficient orbital control capability, even at outer planetary regions of the solar system, without relying on nuclear technology.

JAXA are now performing the conceptual study of the spacecraft. We anticipate its launch in the early 2020's and the return in the late 2050s. The weight of the spacecraft is around 1300 kg including the lander weighting about 100 kg. It is the spin type spacecraft like IKAROS and the ultra-high Isp ion engines are attached on the dayside/shadowside surface of the spacecraft. The area of the sail membrane is assumed to be 3000 m2.

Our paper shows the outline of the spacecraft and it also provides the trajectory design method and results for the Jupiter Trojan asteroid sample return mission. Jovian swing-by is used in the mission to reduce the required delta-V. The current scenario for the exploration consists of six phases: 1) an EDVEGA phase to increase the departure velocity relative to the Earth, 2) a transfer phase from the Earth to Jupiter, 3) a rendezvous phase from Jupiter to the asteroid, 4) a proximity operation phase, 5) a return phase from the asteroid to Jupiter and 6) a transfer phase from Jupiter to the Earth. 1), 3) and 5) are the powered flight phases. Preliminary ballistic analysis picked up several asteroids easy to reach and the low thrust trajectory design is performed. Because the spacecraft is spin-type, the direction of the thrust force is restricted. As a result the trajectory becomes characteristic one. Especially, the direction of the thrust vector of the ion engine (dayside/shadowside) greatly influences the trajectory design. In this paper, some results of the trajectory design are shown.

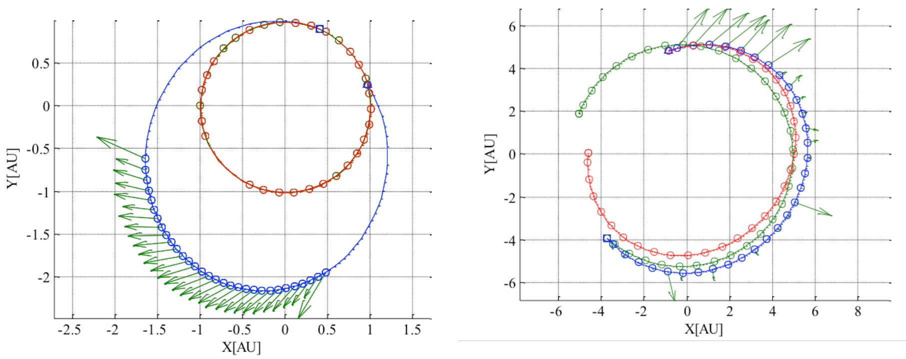

Fig. 1. Examples of the trajectories to an asteroid