ORBIT RAISING TRAJECTORY AND SYSTEM ANALYSIS FOR THE MISSION DESTINY

Chit Hong Yam(1), **Federico Zuiani**(2), **Yasuhiro Kawakatsu**(1), **Takayuki Yamamoto**(1), **and Massimiliano Vasile**(3)

(1) *Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa, 252-5210, Japan, +81-50-336-26364, chithong.yam@jaxa.jp, Kawakatsu.Yasuhiro@jaxa.jp, yamamoto.takayuki@jaxa.jp*

(2) *University of Glasgow, James Watt South Building, Glasgow G12 8QQ, United Kingdom, f.zuiani.1@research.gla.ac.uk*

(3) *University of Strathclyde, Graham Hills Building, 50 George Street, Glasgow G1 1QE, United Kingdom, massimiliano.vasile@strath.ac.uk*

Keywords: *DESTINY, low-thrust, mission design, orbit raising, system analysis*

ABSTRACT

The JAXA mission candidate DESTINY (which stands for Demonstration and Experiment of Space Technology for INterplanetary voYage) is expected to be launched in 2017 by the Epsilon launch vehicle—JAXA's next-generation solid fuel rocket. The main objective of DESTINY is to conduct demonstration and experiment on key advanced technology for future deep space missions. For example, the ultra-lightweight solar panel, the large scale ion engine, the high energy launch by the Epsilon rocket, and the Halo orbit transfer and maintenance.

Figure 1 illustrates the DESTINY mission profile. The spacecraft will first be placed into a low elliptical orbit by JAXA's next-generation solid fuel rocket, the Epsilon launch vehicle. Then the ion engine will be used to raise the orbital altitude to reach the Moon. After that it will be injected into a transfer orbit for L2 Halo orbit of the Sun-Earth system by using lunar gravity assist.

On the orbit raising phase, one of the crucial requirements is about eclipse which happens when the spacecraft enters the shadow of the Earth. Without sunlight, the spacecraft is powered by the onboard battery during the eclipse, which is therefore important to make sure the maximum eclipse time of the whole mission does not exceed the life of the battery (1 hour). Previous work [1] demonstrated that under certain assumptions, the constraint on the eclipse duration greatly limits the launch opportunities or it leads to an increase in the transit time in the radiation belt.

In this paper, we aim to broaden the scope of the study to include more system parameters into considerations that were previously given as constants. This can help us understand the impact and sensitivity of a certain parameter to aid the team fine tuning the design of the system. For example, the orbital elements of the initial parking orbit, given by the simulation of Epsilon launch vehicle, was assumed constant in previous studies. However, we expect the inclination and argument of periapsis of the initial orbit can affect the orientation of the spiral trajectory and hence the location and duration of the eclipse. Another important factors are the parameters of the ion propulsion system such as thrust and specific impulse, which can clearly affect the characteristics and efficiency of the orbit raising phase.

Due to the complex nature of the many revolution, low-thrust transfer problem, we use an analytical averaging technique [1] to speed up the computation of propagating the long spiraling trajectory. To reduce the number of parameters in the problem, we adopt a simplified low-thrust control scheme (see Fig. 2). In one revolution, we allow only two thrust arcs, one at perigee and one at apogee, in which thrust is assumed to be at maximum along the tangential direction. An offset angle is introduced to allow for an asymmetric thrust pattern which could be useful in controlling the orientation of the line of apsides for avoidance of long eclipse (e.g. near apogee).

The problem is formulated as a global, multi-objective optimization problem, in which the following objectives are to be minimized: time of flight to reach the lunar orbit, duration of thrust, time passing through the radiation belt, and maximum eclipse time. For the optimization variables, besides the angular distances of the perigee and apogee thrust arcs, the aforementioned system parameters are also included in the search (e.g. thrust, specific impulse, orbital elements of the initial parking orbit). Our results are expected to provide insights to identify key elements in the system which are crucial to affect the whole mission of DESTINY and future planetary low-thrust missions with many revolutions.

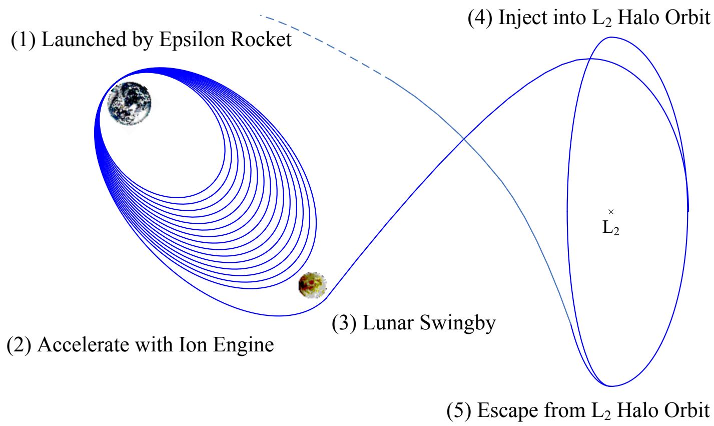

Figure 1: DESTINY mission profile.

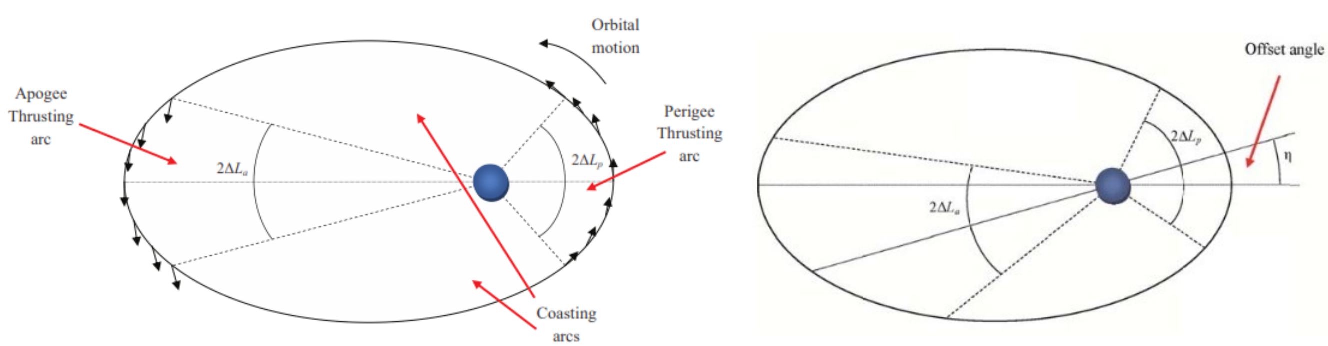

Figure 2: Simplified thrust scheme for the orbit raising phase: symmetric (left) and asymmetric thrust pattern (right).

References

[1] Zuiani, F., Kawakatsu, Y., and Vasile, M., "Multi-objective optimisation of many revolution, low-thrust orbit raising for DESTINY mission," *Proceedings of the 23rd AAS/AIAA Space Flight Mechanics Meeting*, Kauaii, Hawaii, U.S.A., 2013.