TRAJECTORY DESIGN FROM THE EARTH TO THE MOON USING THE MULTI-OBJECTIVE OPTIMIZATION FOR DESTINY MISSION

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ABSTRACT

This study investigates the trajectory design of the small scientific spacecraft, DESTINY (Demonstration and Space Technology for INterplanetary voYage), which aims to be launched by the third Japanese next-generation solid propellant rocket (Epsilon rocket) around 2017[1]. In the DESTINY mission, the spacecraft will go to the moon by the ion engine from the large ellipse earth orbit. Afterward, by using the lunar swing-by, the spacecraft will transfer to the vicinity of the libration point of the Sun- Earth L2 (See Fig. 1). This study focuses on the transfer trajectories from the Earth to the Moon.

By using the Epsilon rocket, spacecraft is supposed to put into the elliptical orbit of 250 x 24000 km at first. Subsequently the orbital energy is increased by the high specific ion engine to reach the moon. During this phase, the degradation of the solar array panel due to the damage by the radiation of the Van Allen belt should be reduced. Moreover, the apogee altitude with the low use of the ion engine should be increased. Furthermore, the spacecraft should reach the moon in less time. To solve this kind of complicated mission design problem, in this study we utilize a multi-objective optimization, considering the mission constraints such as the eclipse and the direction of the solar incidence for the thermal control. The objective functions, design parameters, and mission constrains of the multi-objective optimization problem are as follows.

< Objective function>

1) Minimization of the transit time in the Van Allen belt (VAB)
2) Minimization of the use of the ion engine
3) Maximization of the final C3 (orbit energy)

<Design parameter>

a) Launch date/time

b) Time of flight

c) Range of the use of the ion engine

<Constraint>

i) Eclipse

ii) Solar incidence to the ion engine system (SPZ angle)

iii) Solar beta angle (SPY angle)

From the result, it was found that the transit time in the Van Allen belt tends to decrease as the time of the use of Ion engine increases (Fig. 2). Moreover, the launch date/time has a strong effect on the time of flight and the transit time of spacecraft in the Van Allen belt. Moreover, we found that it would take at least about 1.1 years to reach the Moon from the initial high elliptical orbit by the constant use of the ion engine except for the time period of the constraints. In this computation, it takes approximately one week to obtain these results with Core i7. Therefore, we can say that the multi-objective optimization is significantly useful for this type of the complex mission design problem.

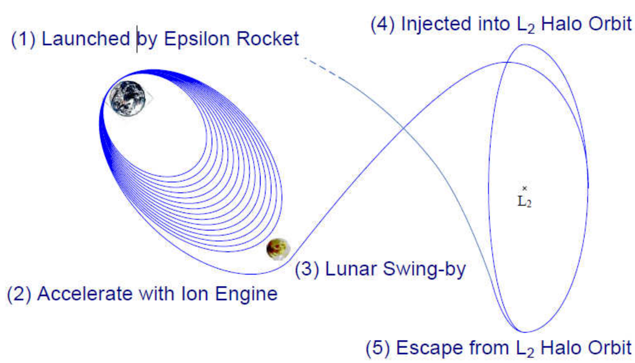

Fig. 1: Profile of DESTINY Mission

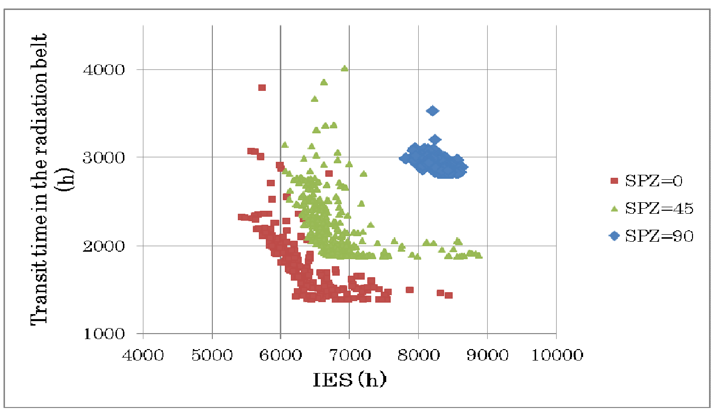

Fig. 2: Transit time in VAB vs. IES

Reference

[1] DESTINY official web page (in Japanese), URL: https://www.ep.isas.jaxa.jp/destiny