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# A study on a low-cost deep space exploration mission utilizing a small kick stage

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This study aims to realize low-cost deep space exploration missions utilizing dual launch system equipped with a small kick stage, and flexible orbit design method using a concept of interplanetary parking orbit.

In this study, it is assumed that 800 kg dual launch system consisting of 500 kg deep space explorer and 300 kg small kick stage is launched together with a primary payload into geo-stationary orbit, GTO, whereupon the small kick stage is initiated at perigee to inject the deep space explorer i.e. Mars explorer into an orbit whose orbital energy, C3, is almost zero. Then the on-board ion engine system, IES, accelerates the explorer through the electric delta-V Earth gravity assist, EDVEGA, scheme to increase the Earth relative velocity at the Earth re-encounter point, which enables the explorer to inject into Mars transfer orbit after the Earth gravity assist. The Japanese H-2A 206 has ability to launch a 6 ton payload into GTO, accordingly, the 800 kg dual launch system assumed in this study can be launched together with about 5 ton of primary payload.

Throughout the simulations conducted in this study, it is revealed that the assumed dual launch system can send the 500 kg deep space explorer equivalent to HAYABUSA-2 to Mars. The dual launch system suggested in this study has possibility to decrease the cost and increase the opportunity of deep space exploration missions. However, the launch window, which is critical for deep space missions, is severely constrained in this launch configuration because the launch epoch is determined by the requirement of the primary payload. To solve this problem, this study suggest a concept of interplanetary parking orbit to increase the flexibility of deep space orbit design and to widen the launch window.

Keywords: small kick stage, dual launch system, low-cost deep space exploration, electric propulsion, interplanetary parking orbit