# Trajectory Navigation and Guidance Operation toward Earth Swing-by of Asteroid Sample Return Mission "Hayabusa2"

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This paper describes the first one-year inorbit operation of Hayabusa2. Hayabusa2 is a Japanese interplanetary probe launched in December 3, 2014 to visit a NEA (Near Earth Asteroid) 1999 JU3. It is a round-trip mission, planned to reach 1999 JU3 in the middle of 2018, and will perform an asteroid proximity operation for 1.5 years. Three touch downs for sampling and one 2m class-crater generation by a kinetic impact are planned during the asteroid proximity operation. The sample is to be brought back to the Earth by the re-entry capsule in 2020. The mission enabler for this round-trip mission is a high-specific ion engine system, capable of producing >2km/s delta-V with very small amount of xenon propellant.

The outward trajectory to 1999 JU3 incorporates an Earth swing-by after one-year interplanetary cruise in vicinity of the Earth. This trajectory sequence is called EDVEGA (Electric Delta-V Earth Gravity Assist). The objective of the EDVEGA phase is to smoothly connect with the asteroid transfer orbit via the Earth swing-by while (i) enlarging the operational margin of the ion engine, (ii) isolating the launch constraints and asteroid accessibility constraints, (iii) providing back-up windows (though Hayabusa2 was launched in the nominal launch window).

After the successful insertion to an interplanetary orbit by the launch vehicle in December 3, 2014, several ion engine commissioning operations have been successfully conducted, which is followed by two long-term ion engine maneuvers to direct the spacecraft onto the Earth swing-by corridor.

The ion engine continuous-thrust trajectory is generated by a trajectory design software developed by the authors based on optimization theories. The software effectively incorporates spacecraft-specific constraints so as to derive feasible trajectories taking into account power, thermal, communication and attitude constraints of the spacecraft at once. The last two months before the swing-by, on the other hand, is planned to be guided using chemical reaction control system (RCS).

This paper describes how the guidance / navigation operation is conducted in the EDVEGA phase of Hayabusa2 and shows how the fuel-optimum trajectory correction maneuvers are made toward the Earth swing-by by combining the ion engine and the RCS delta-Vs.

**Fig.1: Artist's image of Hayabusa-2 Spacecraft**

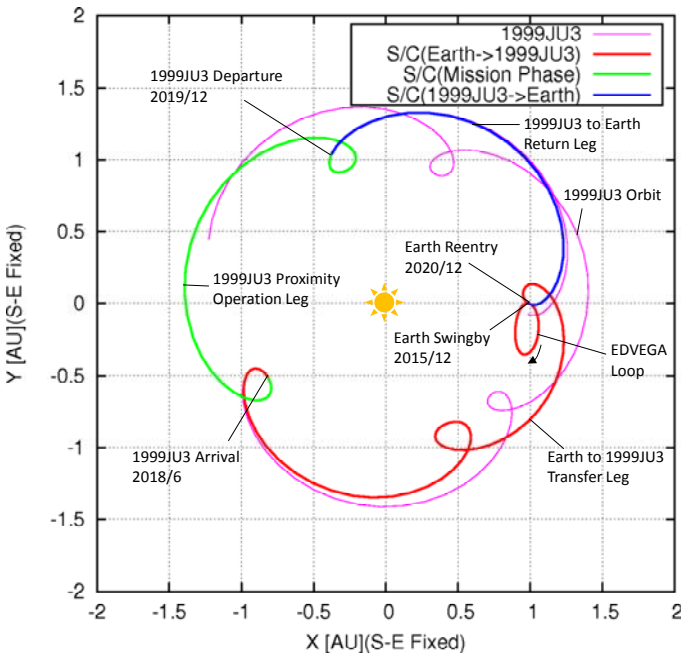


**Fig. 2: 1999 JU3 round-trip trajectory design for Hayabusa 2 (Sun-Earth line-fixed rotational coordinates).**