Disposal of libration point orbits on a heliocentric graveyard orbit: the Gaia mission

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Libration Point Orbits (LPOs) in the Sun-Earth system have been selected for astronomy missions, such as Herschel, Planck, SOHO, and Gaia and future missions, such as Euclid, ATHENA, PLATO will also use this type of orbits. Indeed, LPOs have a stable geometry with respect to the Sun and the Earth, thus offering a vantage point for the observation of the Sun and the Universe together with optimal operating condition in terms of radiation environment, telecoms and thermal design. In addition, the amount of propellant to target orbits around L_1 and L_2 is low compared with alternative orbits.

Recent ESA studies have highlighted the importance of considering the end-of-life disposal since the early stages of the mission design to define a sustainable strategy for the disposal with the objective to avoid interference with the GEO and LEO protected regions and to minimise the possibility of an uncontrolled re-entry at the Earth many years after the mission end. Three possible options have been considered for end-of-life LPO disposal: Earth re-entry, lunar impact or transfer into a graveyard heliocentric orbit. The last strategy was already implemented for strategy already implemented for ISEE-3/ICE, Planck and Herschel.

This paper will analyse the options for Gaia disposal though transfer into a heliocentric graveyard orbit. The disposal manoeuvre sequence is designed in a high-fidelity dynamical model using an energetic approach written in the osculating restricted three-body problem. A first manoeuvre is given to leave the LPO, while a second manoeuvre is used to decrease the three-body problem energy of the spacecraft. The disposal design is optimised to maximise the distance from Earth for a period of 100 years and to minimise the possibility of gravitational interaction with the Earth, due to perturbation induced by other planets. Moreover, the Elliptical Restricted Three Body Problem formulation is used to show the dependence on the sensitivity of the manoeuvre to the angular position of the Earth-Moon barycentre with respect to the Sun.

The philosophy behind the study is to understand how the dynamics influences the efficiency of the disposal manoeuvre and to design a disposal strategies that is sustainable and robust to error in the manoeuvres and minimises the chance of return to Earth on the long term. Therefore, a sensitivity analysis is performed on the available Δv on-board at the end-of-life and an uncertainty analysis is performed on second Δv manoeuvre.

Keywords: Libration Point Orbit, end-of-life disposal, restricted three-body problem.