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END-OF-LIFE DISPOSAL FROM HIGHLY ECCENTRIC ORBITS

Abstract

International space debris mitigation standards request a permanent clearance of the LEO and GEO protected zones. Furthermore, the risk on-ground, following a potential atmospheric re-entry shall be constrained by clear safety limits. Corresponding disposal options are well established for missions in GEO and LEO and consist of near circular graveyard orbits or atmospheric decay.

Science missions, however, sometimes operate on highly-eccentric orbits (HEO) to achieve mission goals, such as astronomical observations and measurements of the Earth's environment. HEOs describe a group of orbits with perigees in or close to the LEO region and eccentricities above those of GTOs (approx. 0.73). The dominant perturbation forces on these orbits are typically caused by the gravity of Sun and Moon.

ESA's Cluster-II mission investigates the physical connection between the Sun and Earth. Flying in a tetrahedral formation, four spacecraft collect the most detailed data yet on small-scale changes in near-

Earth space and the interaction between the charged particles of the solar wind and Earth's atmosphere. The remaining delta-v constraints do not allow for a controlled de-orbit (i.e. direct re-entry boost). Instead, without dedicated disposal action, the combination of the perturbing accelerations will force the re-entry of all four spacecraft. The first re-entry will occur in 2024, followed by two re-entries in 2026 and the last one in 2038.

ESA's Integral mission is dedicated to the fine spectroscopy and fine imaging of celestial gamma ray sources in various energy range bands. The spacecraft, with 3.3ton dry mass will not re-enter naturally within 200 years, however it will repeatedly drift into the LEO region and cross the GEO protected region. Similarly to Cluster-II, delta-v constraints do not permit a controlled re-entry.

This paper highlights ESA's investigations on orbit manoeuvres to change the long-term evolution and to finally influence on-orbit lifetime and re-entry epoch for the Cluster-II and Integral missions. The approaches taken yield at a manoeuvre years before the end of the mission to target a natural re-entry driven by third body perturbations several years after the end of mission. Furthermore, this paper analyses options to minimise the risk with the available means on board. For this, among others, the possibility of predicting and influencing the re-entry zone is studied. The influence of the attitude state at re-entry epoch and the effect of atmosphere passages at perigee with velocities is analysed. Finally, a detailed break-up analysis quantifies the on-ground casualty expectation.