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GRAVEYARD ORBIT SELECTION FOR SPACECRAFT IN HIGHLY ECCENTRIC ORBITS – AN ANALYSIS FOR THE THOR MISSION

Abstract

Safe disposal of spacecraft is now ubiquitous amongst almost every space mission. Major space agencies have now detailed clear guidelines for disposal and missions to be launched by these agencies must be designed to be compliant. Most notably, the standard ISO 24113 has found widespread adoption. For example, ESA has made this standard applicable to all its future missions by the adoption notice ECSS-U-AS-10C.

While every disposal solution is unique and tailored for the constraints of every spacecraft, the overall strategy for most missions is well understood and defined – LEO missions will generally opt for a re-entry (controlled or uncontrolled), whilst GEO missions will select a graveyard orbit insertion. Even most Lagrange and deep space probes have well identified solutions.

An interesting exception exists for missions in HEO – highly eccentric orbits, for which the ISO 24113 defines no clear constraints. As such, many different solutions can be compliant and include controlled re-entries, disposal to interplanetary space, or Earth-bound graveyard orbits. This paper outlines the design of the disposal strategy for THOR – previous candidate for ESA's fourth medium-class mission of the Cosmic Vision 2015-2025 programme (final selection: Ariel), which would have operated in a HEO about Earth.

The paper will detail the trade-off for a disposal strategy and the design of a graveyard orbit, with the aim of maintaining stability for at least 100 years as required by the ISO standard. In this specific environment, orbital effects are dominated by lunar perturbations, and it is thus important to exploit the Moon's influence by selecting appropriate synodic resonances. Stability in such orbits has been already explored for the IBEX [1] and TESS [2] spacecrafts.

The novelty of this paper is to demonstrate that stability can be achieved for more than 100 years, which can serve as a safe disposal solution for future missions in HEO with minimal Delta-v and system impact. This demonstration uses an extensive Monte Carlo campaign with high fidelity propagators to show that stability is well maintained irrespective of initial starting conditions, navigation errors, and maneuver uncertainties.

[1] Dichmann, Donald J., Ryan Lebois, and John P. Carrico. "Dynamics of orbits near 3: 1 resonance in the Earth-Moon system." The Journal of the Astronautical Sciences 60.1 (2013): 51-86.

[2] Dichmann, Donald J., et al. "Trajectory design for the transiting exoplanet survey satellite." NASA Technical Reports Server (2014).