Paper ID: 89090
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

Author: Mr. Alessandro Nitti
Politecnico di Torino, Italy

Dr. Luigi Mascolo
Politecnico di Torino, Italy
Prof. Manuela Battipede
Politecnico di Torino, Italy

MINIMUM-PROPELLANT OPTIMAL TRAJECTORIES FOR THE DE-ORBITING OF DECOMMISSIONED SATELLITES IN LUNAR POLAR GRAVEYARD REGIONS

Abstract

Recent developments in the global space exploration have put a spotlight on the Moon, attracting the attention of major space agencies and private companies. NASA's ambitious plans for sustained human presence in cislunar space, e.g. the Lunar Orbital Platform-Gateway (LOP-G) program, has raised interest in cislunar orbits, looking for some desirable properties such as relatively low transfer costs from Earth, low orbit maintenance costs, and favourable communications opportunities with both Earth and the lunar south pole. A category of libration-point orbits of particular interest are the Halo Orbit families, in which the Near Rectilinear Halo Orbits become appealing from a number of perspectives. Perfectly periodic in the Circular Restricted Three Body Problem (CR3BP) model and quasi-periodic in higher fidelity models, NRHOs comprise a subset of the halo orbit families in the Earth-Moon system, characterised by close lunar passages and nearly-stable behaviour, thus requiring low-cost maintenance.

As the cislunar region is anticipated to become increasingly populated with spacecraft, including potential debris, it is important to highlight the necessity of strategic deorbiting planning and compliance with international laws governing space debris. This study, therefore, focuses on optimizing lunar de-orbiting trajectories from NRHOs, with a particular emphasis on minimizing propellant usage. The chosen reference orbit is the LOP-G's southern L2 NRHO, with perilune and apolune radii of 3,300 km and 70,000 km and 9:2 synodic resonance with the Moon's orbit around Earth.

The main objective of the proposed research is to optimize lunar de-orbiting trajectories from the NRHO using an indirect method based on the Optimal Control Theory, which transforms the propellant minimization problem into a Multi-Point Boundary Value Problem. For this purpose, the trajectory is divided into a number of thrust and coast arcs, hence improving the numerical behaviour of the bang-bang problem. The multiple shooting method shows bang-bang control to optimize the burn and coast arc to ensure that a specific region in the lunar north region is targeted. The dynamic model considers 4-body gravitation (spacecraft subject to Earth, Moon, and Sun gravity), JPL's DE440 ephemeris for precise positional data of the bodies and solar radiation pressure. A GRGM12000A 42x42 spherical harmonics model for the Moon is also employed to enhance the fidelity of the optimized orbit.