05/3203 Electrodynamic tether microsats at the giant planets

Type of activity: Medium Study (4 months, 25 KEUR)

Background

Missions to the outer planets are especially demanding in term of propellant mass required for capture by their planetary targets if chemical propulsion systems are employed. In addition due to the low light intensity at these large solar distances, the Radioisotope Thermal Generators (RTGs) are usually used to supply electrical power for the instruments. As a result, both *Galileo* and *Cassini* missions to Jupiter and Saturn were characterized by a small scientific payload mass fraction, a large launch mass, and concomitant heavy launcher to provide the high escape velocity. Although returning extremely valuable new data on the gas giant planets, their satellites, and orbital environments, these missions were not able to perform detailed investigations of the icy moon satellites due to the excessive manoeuvre demand for multiple rendezvous. NASA tried to address these limitations by planning the *Jupiter Icy Moons Orbiter (JIMO)* under the Project Prometheus programme, based on nuclear electric propulsion [1]. A nuclear fission reactor would supply electrical power to a cluster of ion thrusters for low-thrust but highly fuel-efficient electric propulsion. Whilst the design looked feasible for multiple moon rendezvous, the development/testing costs of the high-power nuclear reactor and the overall spacecraft were substantial and the project is currently being scaled-down and re-targeted. An RTG-based electric propulsion solution could also be possible on a much smaller scale (1000kg class rather than 20,000kg in the case in JIMO), though the costs are still high [2,3].

An alternative novel mission concept has been recently conceived based on conductive tethers providing both power and propulsion at Jupiter to allow a cost-effective tour of the Jovian system [4] including rendezvous with the moons Io and Europa [5]. The method proposed is the Lorentz force applied on an electrodynamic tether passing through a planetary magnetic field. Due to their strong, rotating magnetic fields, electrodynamic tethers are predicted to perform very well in a Jovian or Saturnian orbit. Preliminary analytical assessments indicate that one can expect the tether to perform a capture into a very elliptical orbit and then decrease the apojove progressively to the various altitudes of the Jovian moons. Raising of the perijove can also be achieved with the tether in order approach the moons at low relative velocity for detailed characterisation. However, detailed assessments need to be performed at greater depth of mission analysis in order to determine a precise prediction of mission performance, so that the concept can be reliably compared against competing solutions.

Study Objectives

The objectives of this study are to assess the performance of the concept, taking into account realistic models of the space environment and tether interactions, and the additional constraints imposed on the mission concept due to both the environment effects and thermal heating effects on the tether.

The following tasks shall be undertaken:

- Review and select suitable state-of-the-art models of Jupiter's magnetic field and plasma environments for use in the study.
- Establish constraints on the spacecraft trajectory due to plasma and thermal effects on the tether and due to the radiation environment effects on spacecraft electronics during capture and orbital transfer to the moons phases.
- Perform mission analysis in terms of predicting the spacecraft trajectory, tether rotation and power profile during orbital capture from hyperbolic approach, resulting capture orbit, orbital transfer to rendezvous with the Jovian moons, and operations in the vicinity of the moons within the identified constraints.

Deliverables

- Final report
- Final presentation at ESTEC

References

[1] Report of the NASA Science Definition Team for the Jupiter Icy Moons Orbiter (JIMO), http://ossim.hq.nasa.gov/jimo/JIMO_SDT_REPORT.pdf

[2] Fiehler and Oleson, Neptune Orbiters Utilizing Solar and Radioisotope Electric Propulsion, AIAA-2004-3978, 40th Joint Propulsion Conference, Fort Lauderdale, Florida, July 2004.

[3] Bondo, T., Walker, R., Willig, A., Rathke, A., Izzo, D., Ayre, M., Preliminary Design of an Advanced Mission to Pluto, paper ISTS 2004-k-10, 24th International Symposium on Space Technology and Science, Miyazaki, Japan, June 2004.

[4] Sanmartin and Lorenzini, in Proceedings of the 8th Spacecraft Charging Technology Conference, Huntsville, AL, USA, October 20-24, 2003.

[5] Sanmartin and Lorenzini, Exploration of Outer Planets Using Tethers for Power and Propulsion, AIAA Journal of Propulsion and Power, Vol. 21, No. 3, May-June 2005.