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Enabling exploration and science missions thanks to in-orbit rendezvous

J. Poncy, C. Le Peuvedic, S. Clerc, P. Couzin, J.P. Prost and X. Roser
Thales Alenia Space, Cannes, France (joel.poncy@thalesaleniaspace.com / Fax: + 33 4 92 92 64 90)

Abstract

Thales Alenia Space presents in this poster the different challenges and solutions for in-orbit rendezvous, in view of mid-term and longer-term robotic and human exploration of the Solar System.

1. Introduction

Past human exploration missions like the ISS and the Apollo programs have depended upon in-orbit rendezvous.

This technology will be even more critical in the future for robotic or human exploration missions like for Sun-Earth L2 point, Deimos, or Mars.

It will also be a key element for future Sample Return missions from the large or distant bodies of our Solar System (e.g. Mars, Venus, Ceres).

2. Technology drivers

Three main drivers have been identified for the technology:

- The level of autonomy in the Rendezvous orbit: availability of GPS measurements, ground tracking of the chaser or the target, orbital period (approach can be different if relative dynamics is slow), elliptical or circular orbit, communication windows with the Earth
- The level of cooperation of the target: knowledge of the geometry, retroreflectors or not, attitude controlled or not, RF link or not, optical coefficients and lighting conditions, surface of the target (docking mechanism, specific features, dust in case of asteroid, etc…)
- The type of mission: manned or robotic, which influences the level of redundancy and the dimensions of the involved mechanisms (e.g. docking)

3. Key technologies and challenges

3.1 Relative navigation

- Current implementations for optical, laser and RF systems are mid-TRL (long-range RF, optical based navigation sensor and 3D cameras in ESA roadmap ~2008-2015)
- Image processing algorithms validation requires flight experiments or at least dynamic benches.
- Pose estimation algorithms rely on retroreflectors, or a CAD model or can be preceded by an object recognition phase in case of unknown target. Major challenges consist in finding robust algorithms able to cope with various lighting conditions and tumbling objects (asteroids).

3.2 Capture and docking mechanism

- Several concepts exist (Inflatable capture mechanism, IBDM…): they require further validation. In-orbit assembly of large vehicles for exploration would require development of new mechanisms
- Grappling to asteroids or to a tumbling object can be challenging especially if it is not possible to count on specific features such as engine bells, or if the surface is dusty.

3.3 Autonomy

- Autonomy is required for interplanetary missions due to the delay of communication with the Earth. There are several possible levels of autonomy up to the fully autonomous level able to react to all environment changes. The degree of autonomy shall be improved.
- The verification of autonomous GNC software is challenging because manual exploration of all possible cases is not feasible. A new generation of verification techniques is needed, with verification for a manned vehicle being an additional challenge.

4. Summary and conclusions

We then conclude by presenting in figure 1 a review of the rendezvous techniques, per target and per type.

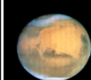
		OPTIONS PER TECHNOLOGY TYPE		
DESTINATION	MISSION	Relative navigation	Capture&docking	Autonomy
Earth's neighborhood 	Robotic Debris Removal (Earth)	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms GPS assistance available Target attitude tumbling determination and control	Variable: from mere tethering to full docking	Autonomous control but with possibility of ground support
	Manned mission in Earth Orbit	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms GPS assistance available Cooperation with target	Full docking with large elements (transfer of large masses)	Possibility of real-time manned control / possibility of man-triggered aborts
	Manned mission to an L2 station	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms Cooperation with target	Full docking with large elements (transfer of large masses)	Real-time manned control
Moon 	Manned mission to the Moon	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms Cooperation with target	Full docking with large elements (transfer of large masses)	Possibility of real-time manned control / possibility of man-triggered aborts
	Robotic Moon Sample Return	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms	Low contact (sample capture, arms, transfer of a small mass)	Autonomous control but with possibility of ground support
Distant small gravity bodies 	Robotic Sample Return from small Asteroid, Phobos, Deimos or Comet (*)	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms Target geometry in-situ analysis Target attitude tumbling determination	Anchoring	Full autonomy
	Manned mission to Small Asteroid, Phobos, Deimos or Comet (*)	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms Target geometry in-situ analysis Target attitude tumbling determination Far range autonomous relative navigation	Anchoring	Possibility of real-time manned control or aborts but fair level of automated autonomy/FDIR needed
Mars 	Robotic Mars Sample Return	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms Far range autonomous relative navigation	Low contact (sample capture, arms, transfer of a small mass)	Full autonomy
	Manned Mission to Mars	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms Cooperation with target	Full docking with large elements (transfer of large masses)	Possibility of real-time manned control or aborts but fair level of automated autonomy/FDIR needed
Distant medium gravity bodies 	Robotic Ceres Sample Return	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms Far range autonomous relative navigation	Low contact (sample capture, arms, transfer of a small mass)	Full autonomy
	Manned mission to Ceres	Optical, laser and RF systems Pose estimation algorithms Image processing algorithms	Full docking with large elements (transfer of large masses)	Possibility of real-time manned control or aborts but fair level of automated autonomy/FDIR needed

Figure 1: Review of the rendezvous techniques per target and type.