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AUTONOMOUS GNC SYSTEM TO ENHANCE SCIENCE OF ASTEROID MISSIONS

Abstract

Asteroids and comets offer great scientific opportunities. Robotic exploration missions to small bodies, sample-return or in-situ characterization, require advanced on-board technologies. One enabling technology is the Guidance, Navigation Control (GNC) system. The requirements on the GNC for missions to small bodies are very demanding. Cost is a main driver for the design and development. Tight orbital and landing specifications are required. Furthermore, robustness is fundamental because of the high level of uncertainty of most environment parameters.

An autonomous GNC system for proximity operations, including descent and landing, has been developed by a consortium led by GMV under ESA contract. The objectives of the autonomous GNC are to enable flexible, robust proximity operations for different small-body missions and to minimize the development and operation costs. The GNC system is based on advanced algorithms fitting into existing flight processors, and low-cost, off-the-shelf actuators and navigation sensors (wide-angle camera, radar altimeters, star-tracker) with high Technology Readiness Level.

The proximity operations start at the end of approach phase at a safe distance (e.g. 100 asteroid average radii). In this far station keeping, a novel strategy to maintain safe distances without any altimeter has been developed (if operational range of the radar altimeter is lower than 5 km). The GNC allows autonomous injection and maintenance on Self-Stabilised Terminator Orbits, which are interesting for global characterization and radio-science. Descent and Landing must be fully autonomous below a certain altitude (typically 500 m).

The navigation filter hybridizes camera and altimeters measurements (whenever available) in order to achieve the required landing specifications including proper alignment wrt surface. The image processing

provides different type of observables for absolute navigation, when known features are available, and for relative navigation otherwise (at low altitude). The guidance and control modes are designed to maintain safe operations while minimizing maneuvers.

Testing of the GNC modes in a high-fidelity functional engineering simulator with realistics image generation has validated the system to TRL-4 (extensive Monte Carlo analyses). The validation and verification considered ESA's MarcoPolo sample-return mission with different asteroids (Itokawa-like, cratered, heavy-bouldered). In nominal conditions (no degraded sensors or actuators), the landing requirements are achieved, accuracy better than 3.5 m (3σ) and cm/s level touch-down. In robustness tests (degraded equipment or large dispersion of environment parameters), the most critical parameters have been identified. Even in the worst cases, graceful degradation of landing performances is achieved.