Small lander and CubeSats on ESA's Asteroid Impact Mission – a GNC perspective

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The Asteroid Impact Mission (AIM) is a small mission of opportunity currently undergoing preliminary design (Phase B1). AIM's goals are to demonstrate a number of new technologies, to carry out fundamental asteroid research and to assess the capabilities of a kinetic impactor for planetary defence (this last goal performed in collaboration with NASA-led DART as part of the AIDA mission). Launched in October 2020, AIM will reach the binary asteroid system Didymos in 2022. The main AIM spacecraft will perform high-resolution visual, thermal and radar mapping of the Didymos system, focusing in particular on the smaller asteroid (informally called Didymoon) to build detailed maps of its surface and interior structure. The AIM main spacecraft is planned to carry three smaller spacecraft – the MASCOT-2 asteroid lander, provided by DLR, as well as two CubeSats. The close proximity operations needed for deploying MASCOT-2 and the CubeSats impose significant challenges on the GNC subsystem in terms of performance and reliability.

MASCOT-2 is a small lander (13 kg, 33x30x20 cm) that will perform in-situ investigation on the surface of Didymoon. MASCOT-2 has no means of propulsion and needs to fully rely on the AIM spacecraft for being injected into a ballistic trajectory that will allow achieving successful landing on Didymoon. The foreseen release strategy consists in injecting AIM on a safe hyperbolic arc that approaches Didymoon in the proximity of the Lagrangian point L2. MASCOT-2 will exploit the unstable manifold passing through L2 to minimise the velocity at touch-down.

Five candidate CubeSat missions are under evaluation, which involve a number of different scenarios, ranging from landing on the asteroids, to orbiting them, to monitoring the asteroids from the L4 or L5 Lagrangian points.

In all cases, the GNC subsystem on the AIM spacecraft is required to support the critical proximity operations in the vicinity of the asteroids by means of autonomous operations. Uncertainties in the ephemeris of the asteroids require that relative navigation techniques are used. The baseline is to use vision-based navigation techniques, exploiting the experience obtained with the Rosetta mission (with ground in the loop) and the developments for other NEO missions (e.g. Marco Polo-R). The optional use for navigation of laser and radar altimetry information as well as of infra-red images provided by payloads on board AIM is also under investigation.

The inter-satellite link that will be established between AIM and the CubeSats could also be valuable for navigating the CubeSats.