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Abstract.
In the frame of the new space economy, the sustainable exploration of the solar system is shifting from exclusively large, complex and expensive spacecraft to the inclusion of miniaturized satellites. These small platforms are an affordable element to complement traditional missions for space exploration or to implement stand-alone science investigations. Thanks to their reduced mass, volume, cost and development time, and specialized capabilities, small satellites are capable of achieving complex and high-risk missions. Particularly, missions toward asteroids have become crucial to study the history of the solar system and for planetary defence. Likewise, lunar missions are becoming a priority for the space agencies, with a large number of both robotics and crewed landings expected in the following years. These provide high scientific value and open opportunities for testing novel technologies.
The Light Italian CubeSat for Imaging of Asteroid (LICIACube) is a groundbreaking CubeSat mission designed, developed, and operated by Argotec under an Italian Space Agency contract. LICIACube witnessed and recorded the effects of the impact of the Double Asteroid Redirection Test (DART) spacecraft with the Dimorphos asteroid (part of the Dydimos binary asteroid system), delivering high-resolution pictures essential for the understanding of the effects of the collision and the feasibility of this approach for Planetary Defence. The scientific objectives were accomplished by using a 6U (30x20x10 cm) spacecraft implementing an optical payload composed of two cameras and an autonomous, image-based tracking and navigation algorithm. During the challenging flyby of the asteroid, the satellite autonomously tracked and pictured the impact scene at around 7km/s with respect to the target, taking more than 600 pictures and validating Argotec's deep space technologies and autonomous optical navigation algorithms. In fact, LICIACube is derived from the ArgoMoon 6U spacecraft onboard NASA's Artemis I, that will allow further testing of the miniaturized platform in the severe environment of a super-heavy launcher while performing complex autonomous proximity operations in deep space around the SLS Interim Cryogenic Propulsion Stage (ICPS) and the Moon.
Among these challenges, the deep space radiation and thermal environment had a huge impact on the design of the spacecraft. Hence, Commercial Off-The-Shelf (COTS) equipment, which are usually implemented for Low Earth Orbit CubeSats, do not comply with the performance and reliability requirements of deep space missions. For these reasons, Argotec followed an "all in-house" approach that address the full end-to-end development, from design to manufacturing and testing. In this context, essential components such as the On-Board

Computer and the Power Conditioning and Distribution Unit were developed following ECSS and NASA standards to guarantee appropriate radiation hardness and reliability. Advanced Failure Detection Isolation and Recovery (FDIR) techniques were developed and run into the Onboard Software to guarantee the mission success. Similarly, a dedicated Mission Control Centre and its relative software were developed and tested to complete the End-to-End interface with the spacecraft through the Deep Space Network and ESTRACK.

Future scientific and commercial missions will benefit from Argotec's heritage in the development of deep space avionics and image processing and visual navigation capabilities based also on Artificial Intelligence. Among these innovative CubeSat missions, the LUnar Meteoroid Impact Observer (LUMIO), in development alongside Polytechnic of Milan and ESA, will characterize the meteoroid environment around the Moon using a telescope housed by a 12U platform in a halo orbit around the Earth-Moon L2. Furthermore, HEliospheric pioNeer for sOlar and interplanetary threats defeNce (HENON) will use a similar spacecraft in a Distant Retrograde Orbit beyond the Earth-Sun L1 to monitor the space weather and to provide early warning of geomagnetic storms. Likewise, Argotec's ANDROMEDA project will offer a turn-key and cost-effective solution for Lunar communication and navigation through a data relay constellation of microsatellites around the Moon. The general outcome is a wide development experience and legacy of reliable miniaturized space equipment, which will represent a milestone and a rule for the fate of space exploration dependent on small satellite platforms.