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Current and future developments of on-board autonomy in GNC systems at ESA



Speaker: Massimo Casasco, ESA

Short Bio: Massimo Casasco works at the European Space Research and Technology Centre (ESTEC) of the European Space Agency, where he is the Head of the GNC Systems Architecture Section in the Electrical Engineering Department.

Massimo has been working at the European Space Agency for 15 years, where he has previously worked as Guidance Navigation and Control System Engineer supporting the BepiColombo mission to Mercury as well as other interplanetary and exploration missions (Mars Sample Return, EnVision, HERA, to name a few). He has also managed several R&D studies and technology developments in the domain of GNC.

Previous to his work at ESA, Massimo has covered various positions in both the space and aviation industry: he was AOCS design engineer and analyst on a number of space missions, including ESA missions Herschel, GAIA, and GALILEO. He also worked as Flight control engineer at the development of the fly-by-wire Flight Control System of advanced military aircraft.

Abstract: This presentation reviews current and future developments in spacecraft on-board autonomy at the European Space Agency, focusing on the technologies and mission scenarios driving the need for increasingly autonomous space systems. Autonomy can be defined as the capability of a spacecraft to achieve mission objectives while operating independently of external control. Such capabilities become essential when communication delays, limited bandwidth, or rapidly changing environmental conditions prevent timely intervention from ground control. Historically, spacecraft autonomy has been implemented through time-tagged command sequences, fault detection, isolation and recovery (FDIR), and basic navigation and control functions. However, upcoming missions require significantly more advanced autonomous capabilities that move analysis, planning, and decision-making functions on board the spacecraft.

Several mission domains motivate this evolution, including planetary entry, descent and landing, small-body exploration, opportunistic science observations, rendezvous and proximity operations, multi-spacecraft coordination, aerobraking, collision avoidance in low Earth orbit, and controlled de-orbit. These scenarios require

spacecraft to operate safely and efficiently in uncertain and dynamic environments. Key enabling technologies include autonomous navigation, terrain-relative and vision-based navigation, real-time guidance, hazard detection and avoidance, autonomous mission planning and re-planning, and on-board science event detection.

Autonomous spacecraft architectures are often structured in multiple layers, combining supervisory decision functions, intermediate optimisation and planning modules, and low-level guidance and control systems responsible for stabilisation and trajectory tracking. Advanced techniques such as convex optimisation, model predictive control, and artificial intelligence approaches—including reinforcement learning and data-driven algorithms—are being investigated to enable real-time mission optimisation and adaptive decision-making.

These developments illustrate the growing role of autonomy in enabling complex, robust, and efficient space missions, particularly in environments where pre-planned operations alone are insufficient to guarantee mission success.