ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

MUR DM 117/Argotec - Development of solutions that increase the autonomy and resilience of a spacecraft by means of on-board artificial intelligence

Funded By	ARGOTEC S.r.l. [P.iva/CF:09819810012] MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Politecnico di TORINO [P.iva/CF:00518460019]
Supervisor	CHIABERGE MARCELLO - marcello.chiaberge@polito.it
Contact	Alessandro Balossino
Context of the research activity	The development of solutions enhancing spacecraft autonomy and resilience through on-board artificial intelligence (AI) is a cutting-edge field. By leveraging AI algorithms and advanced technologies, spacecraft can make intelligent decisions, adapt to changing conditions, and respond to unforeseen events without relying solely on ground control. These AI-powered systems enable spacecraft to analyze vast amounts of data, optimize resource allocation, perform complex tasks, and mitigate risks in real-time. Ultimately, this technology enhances spacecraft autonomy, improves mission success rates, and enhances resilience, ushering in a new era of self-reliant and adaptable space exploration. Progetto finanziato nell'ambito del PNRR – DM 117/2023 - CUP E14D23002000004
	Abstract: This Ph.D. project aims to advance the field of space exploration by focusing on the development of solutions that increase the autonomy and resilience of spacecraft through the integration of on-board artificial intelligence (AI) systems. By leveraging AI algorithms and advanced technologies, the project aims to enable spacecraft to make intelligent decisions, adapt to changing conditions, and respond to unforeseen events without heavy reliance on ground control. Introduction:

Objectives	As space exploration endeavors expand and missions become more complex, there is a growing need to enhance the autonomy and resilience of spacecraft. Traditionally, spacecraft operations have heavily relied on ground control for decision-making, which introduces communication delays and limits real-time responsiveness. The integration of on-board AI systems offers a promising approach to overcome these limitations and enable spacecraft to operate with increased autonomy and resilience. Objectives: The primary objective of this three-year Ph.D. project is to develop innovative solutions that leverage AI techniques to enhance the autonomy and resilience of spacecraft. Key focus areas include: AI-enabled Decision-making: Designing intelligent algorithms to analyze vast amounts of data collected by spacecraft sensors, enabling real-time decision-making for various mission scenarios. Adaptive Systems: Developing AI systems that can adapt and optimize resource allocation, system configurations, and operational strategies based on changing mission requirements and environmental conditions. Anomaly Detection and Recovery: Creating AI algorithms capable of identifying and responding to anomalies or failures in spacecraft systems, thereby increasing the ability to mitigate risks and ensure mission continuity. Intelligent Task Execution: Designing AI systems that enable spacecraft to perform complex tasks autonomously, such as navigation, maneuver planning, and instrument calibration, without constant intervention from ground control. Methodology: The project will employ a combination of theoretical research, algorithm development, and experimental validation. The initial phase will involve a comprehensive review of existing literature and state-of-the-art AI techniques applicable to spacecraft autonomy and resilience. Based on this research, novel algorithms and methodologies will be developed to address the specific challenges in enhancing spacecraft autonomy and resilience. To evaluate and validate the proposed solutions, a combination of simulation-based experiments and hardware-in-the-loop testing will be conducted. These experiments will simulate real-world mission scenarios and assess the performance, robustness, and efficiency of the developed AI systems. Additionally, collaboration with industry partners and space agencies will provide opportunities for real-world testing and validation. Expected Outcomes: By the end of this project, it is anticipated that several significant outcomes will be achieved: Development of AI algorithms and methodologies specifically tailored for enhancing spacecraft autonomy and resilience. Demonstration of increased autonomy and resilience in simulated and real-world mission scenarios. Identification of potential challenges and recommendations for the integration

	of on-board AI systems into future spacecraft designs. Contribution to the advancement of the field of space exploration by promoting self-reliant and adaptable spacecraft. Conclusion: The development of solutions that enhance spacecraft autonomy and resilience through on-board artificial intelligence is a crucial step towards enabling more efficient and robust space missions. This Ph.D. project aims to contribute to this field by developing innovative AI algorithms and methodologies, validating their effectiveness through comprehensive experiments, and providing insights for the integration of AI systems into future spacecraft designs. Ultimately, the project seeks to push the boundaries of space exploration and pave the way for more autonomous and resilient spacecraft systems.

Skills and competencies for the development of the activity	Key competences for a PhD project on developing spacecraft autonomy and resilience using on-board AI: expertise in artificial intelligence (AI) and machine learning, space systems and aerospace engineering knowledge, autonomous systems understanding, data analysis and signal processing skills, algorithm development and optimization abilities, system modeling and simulation proficiency, research methodology and experiment design, effective communication and collaboration, problem-solving and critical thinking capabilities, and creativity for innovative approaches.