POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 40th cycle

THEMATIC Research Field: OPTIMAL ONBOARD EVASIVE MANEUVER DESIGN FOR SATELLITE PROTECTION

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Over the past two decades, reliance on space infrastructure has grown significantly, elevating these systems to the status of critical assets. Satellites now play a vital role in providing global positioning, navigation, intelligence, and communication services, capabilities essential for both civil and military operations.These space assets face a range of threats, both accidental and deliberate, with the increasing variety and scale of these risks establishing space as a conflict domain on par with land, sea, and air. Consequently, there is a rising demand for robust military Space Situational Awareness (SSA) capabilities. Such capabilities enable states to monitor activities in space, execute precise missions, and ensure that military SSA data remains reliable and free from bias or manipulation. However, only a handful of countries have achieved a fully operational, comprehensive, and independent military SSA capability. The U.S. Department of Defense shares some space-related information with allies on a selective basis and with limited fidelity, but this approach creates dependencies and imposes constraints. At the industrial level, the European market for military SSA is fragmented, primarily national in focus, and reliant on non-European services or solutions.To fill this gap, it is necessary to develop a European infrastructure for management of military SSA data which is capable of detecting threats to critical space assets and that defines a guideline for the management and mitigation of such menaces. This PhD study aims at developing novel

	maneuver design techniques for the mitigation of kinetic threats to target satellites. These threats can come from anti satellite weapons, ballistic missiles and proximity operations. The maneuvers designed need to support decision making of the European Space Command &Control while also guaranteeing a sufficient level of autonomy to respond to time critical scenarios and in those cases where communication with the ground segment is impaired or actively disrupted.
Methods and techniques that will be developed and used to carry out the research	This PhD thesis will focus on the development of spacecraft anomaly detection and characterization techniques. After a deep study and investigation of the significant data that have to be included in the analysis, pre-processing steps will be taken to turn raw information into the optimal shape to highlight out-of-nominal behaviour and the design of the actual detection model will take place. The first phase will involve the analysis of the wide literature on anomaly detection methods, encompassing very diverse applications. Both classical statistical signal analysis methods will be investigated as well as machine learning, including both supervised (Sequential Neural Networks) and unsupervised learning techniques (Auto-encoders). Part of the survey will be devoted to thresholding, proving crucial when it comes to the classification of an anomaly. Once a general overview on the field is obtained, the specific application, and corresponding data, will be the main focus of the analysis. This will translate in a tailored pre-processing pipeline in order to optimize the features ingested by the developed models for improved detection purposes. An important aspect to consider is the noise level and uncertainty involved in the data on which anomalies are being identified. These sources of error should be retrieved from the available data and modelled as part of the nominal behaviour of the target. Moreover, a first characterization of the anomaly event type should be performed by analysing the affected parameters or by remapping them to a different set of coordinates or phenomenon (e.g., transforming shifts in orbital parameters to possible manoeuvres). Once the selected pipeline is designed, an extensive testing campaign is foreseen to consolidate the

	results. Both synthetic and real nominal data can be used to start assessing the developed methods performance, by realistically simulating anomalies as well. The following step is instead to test the same algorithms on real data.A particular focus has to be devoted to processing time as well, as one key aspect to grant is responsiveness. In the final stages of the program, the research will delve into the application of artificial intelligence (AI) to maneuverer design. A notable direction includes employing a generative-adversarial neural network (GAN) paradigm to simultaneously train complementary strategies for both the pursuer and the evader. This innovative approach is expected to yield robust and adaptive solutions for complex pursuit-evasion scenarios.
Educational objectives	The educational objectives of this PhD focus on cultivating a comprehensive understanding of space dynamics and control, particularly in the context of spacecraft maneuvering. The candidate will gain expertise in orbital mechanics and advanced control theories, with an emphasis on low-thrust propulsion systems and pursuit-evasion game strategies. A key aspect of this research activity is developing proficiency in cutting-edge optimization techniques to design energy-efficient trajectories that account for practical operational constraints and limited onboard resources. The program also emphasizes the integration of artificial intelligence into aerospace applications, training the student to apply innovative methods like generative-adversarial neural networks to maneuver design. Through this, the PhD candidate will explore the creation of adaptive and autonomous solutions for managing complex space threats. They will acquire the skills to analyze and address scenarios ranging from kinetic threats to multi-pursuer engagements, fostering a robust problem-solving approach tailored to real-world challenges. A strong focus is placed on interdisciplinary research, merging aerospace engineering, control theory, applied mathematics, and artificial intelligence. This integration enables the student to develop strategies that are both theoretically sound and practically applicable, ensuring they are well-equipped to design autonomous decision-making systems for

	spacecraft. The program also nurtures advanced research capabilities, encouraging critical thinking, experimentation, and hypothesis testing to contribute impactful knowledge to the field. Additionally, the student will be guided to consider ethical and strategic dimensions of space defense technologies, preparing him/her to address global challenges responsibly. By the end of the program, he/she will be well-prepared to assume leadership roles in academia, industry, or governmental organizations, driving innovation in space systems engineering and contributing meaningfully to advancements in space situational awareness and spacecraft autonomy.
Job opportunities	The program is supported by funding from an EDF project and is conducted within the framework of an international consortium comprising multiple firms. This setup provides the candidate with valuable opportunities to collaborate with industry partners, gaining firsthand insight into the professional landscape they will enter upon graduation. The demand for skilled trajectory designers is rapidly increasing within the industry, driven by a strong push from international agencies toward greater autonomy in space operations. By the end of this program, the candidate will have fully developed the expertise and skills necessary to meet these growing needs, positioning them for a successful and impactful career in the field.
Composition of the research group	0 Full Professors 2 Associated Professors 3 Assistant Professors 16 PhD Students
Name of the research directors	Michele Maestrini

Contacts
The PhD candidate will receive a desk, possibly through a hot-desking procedure, and a personal computer, if needed. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses and receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship.

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents	

(more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
--