POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

THEMATIC Research Field: ONBOARD SPACE SITUATIONAL AWARENESS ALGORITHMS FOR SATELLITE SELF-PRESERVATION

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 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	Nowadays satellites are exposed to many risks during their operational lifespan, not only owed to the ever-increasing number of uncontrolled and untracked debris in orbit but also because of interferences, jamming, spoofing, blinding of on-board sensors or active neutralization, (i.e., via close approach spacecraft capable of physically interfering with the essential function of an operational satellite). The deployment of large constellations including hundreds of satellites may also provide hiding opportunities for malignant spacecraft. In this context, guaranteeing the security of satellites is of paramount importance. Conventional methods for achieving satellite security involve refining ground procedures to promptly identify high-risk situations, thereby reducing response times and minimizing human intervention. However, the predominant reliance on ground-based radar and optical sensors in isolation poses challenges, particularly in detecting and tracking small objects with diminishing relative separations. Even when a threat is identified, inherent delays arise due to ground-based data processing and decision-making, necessitating command communication within visibility windows. This research project seeks to address these challenges by proposing solutions for satellite self-protection. Key objectives include developing strategies for threat detection through sensor acquisitions and designing decision-making frameworks to support evasive maneuver planning. Emphasizing autonomy, the project

	aims to manage the complexity of Space Situational Awareness (SSA) data and respond promptly to dynamic situations, aligning with tactical timelines.
Methods and techniques that will be developed and used to carry out the research	The central objective of this research project is to develop a comprehensive solution addressing the challenge of equipping satellites with sensors and capabilities for effective self-protection against both accidental and intentional collisions. To initiate this research, a thorough tradeoff study will be conducted to identify the requirements for the sensing payload to be integrated into a Low Earth Orbit (LEO) spacecraft. Exploring various payload types, including optical and radar, will be a key focus to determine the most suitable solution. The student will conduct sensitivity analyses on key performance parameters, emphasizing the advantages of having an onboard sensor. Once a suitable sensor suite is identified, the student will leverage acquired measurements to extract high-level information, potentially employing Artificial Intelligence for tasks like object detection from images. Subsequently, the candidate will implement analytic or semi-analytic methods to correlate measurements with a limited catalogue of objects, executed onboard to maximize satellite autonomy. Different approaches, such as Unscented Kalman Filter (UKF), Extended Kalman Filter (EKF), or batch methods, will be explored for rapid updates of orbital parameters. The updated orbital information will be crucial for assessing whether a detected object poses a threat to the target satellite, utilizing fast analytical and semi-analytical uncertainty propagation methods. The analytic propagation of uncertainty is paramount to rapidly computing the probability of collision with analytical short-term encounter models such as Pelayo-Ayuso, Serra, or Chan. Upon identifying potential conjunctions, the candidate will investigate the application of sequential machine learning methods to screen events with a higher risk of worsening in subsequent encounters. Temporal sequences of high-level data will be analyzed using recurrent neural networks. Finally, for cases where the collision probability surpasses a given threshold, a fast analytic method will be implemented to suggest a collision

	avoidance maneuver. This method will be designed to operate analytically, ensuring efficient execution with the limited resources available onboard.
Educational objectives	This research involves the knowledge of the current state of SSA capabilities, thus leading to the training of a professional figure able to effectively interact in such an international context. The practical implementation of the earlier mentioned analysis must pass through a literature review of the current state of the art of these strategies and methods, thus leading to an improvement in the scientific knowledge of the candidate. This will contribute to training a highly qualified researcher who will be able to tackle current space-related issues in order to contribute to the enhancement of the space sector. The candidate will gain a profound knowledge of the concepts related to the fields of astrodynamics, estimation techniques, numerical methods, mathematical modelling and computer programming. Soft skills in writing reports, searching bibliographic resources, preparing progress meetings and presenting work advancements will also be achieved.
Job opportunities	Activities aiming at guaranteeing a sustainable use of space are nowadays the focus of several companies, national agencies, and universities. Deep theoretical and practical knowledge of the topics investigated in this research will ensure a high appeal for the candidate in the space community. Moreover, the activity is strictly linked with the development of dual-use technology and will involve the interaction with: 1. the Italian Ministry of Defence 2. European Defence Agency The candidate will have the possibility of working on an international project involving several companies and agencies from Italy, Germany, and the Netherlands.
Composition of the research group	0 Full Professors 2 Associated Professors 2 Assistant Professors 10 PhD Students
Name of the research directors	Prof. Pierluigi Di Lizia

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano - via La Masa 34, 20156 Milano - Italy - tel. +390223998323 - fax +390223998334 - email: pierluigi.dilizia@polimi.it - web site: www.aero.polimi.it

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	700.0 €
By number of months	6

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