POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

THEMATIC Research Field: ENHANCED SPACE SITUATIONAL AWARENESS AND FRAGMENTATION MONITORING IN THE CISLUNAR ENVIRONMENT

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	Cislunar Space Situational Awareness (SSA) and Space Traffic Management (STM) has become a critical area due to the growing activity in the space between the Earth and the Moon. With an increasing number of satellites operating in this area, it is essential to have accurate and up-to-date information about their trajectories. In particular, the characterization of the space objects fragmentation plays a pivotal role in Cislunar SSA capabilities: it allows to predict the fragments cloud evolution and, so, to mitigate further space debris proliferation. Joining an already well-established group working on these topics, the objective of this research is to enhance SSA capabilities concerning fragmentation analysis in the cislunar region. In particular, a methodology will be investigated to estimate the minimum time elapsed from the space object break-up which allows to detect the fragments separately. This procedure will be closely related to a correct modelling of the three body dynamics and to observational strategies and algorithms. The latter include methods for both Initial Orbit Determination (IOD) and Refined Orbit Determination (ROD). Moreover, the identified observational strategies will play a fundamental role in two key aspects: the construction of a comprehensive catalog of cislunar bodies, while ensuring its continuous upkeep and maintenance, improving our understanding and management of cislunar objects. The ultimate goal is to use the derived knowledge of a fragmentation event to

	subsequently derive characteristic quantities (such as Probability of Collision and Miss Distance) useful for the formulation of Collision Avoidance Maneuvers (CAMs), which would be tailored to exploit the three body dynamics peculiarities.
Methods and techniques that will be developed and used to carry out the research	Given the nature of the cislunar dynamic environment, the candidate will develop and implement a powerful observation strategy based on several aspects. First, achieving comprehensive coverage requires a strategic deployment of Earth ground-based sensors, taking into account the visibility constraints imposed by Earth's rotation and atmospheric conditions. Meanwhile, the positioning of space-based sensors in specific orbits optimizes observation effectiveness, taking into account relative geometries with respect to targets. Finally, the selection of sensors among radar and optical systems must be examined according to their ability to detect debris of varying sizes and characteristics. An optimized observation strategy is of paramount importance for obtaining data to perform IOD and ROD, both necessary to track and monitor the fragments cloud. In particular, the former procedure allows to first derive the fragment orbital state and to catalog it, while the second to update the orbital information. In this context, it is crucial to consider the challenges of the cislunar environment. For example, the limited observational data contribute to increasing uncertainties over longer data time gaps. In addition, the increased sensitivity of cislunar orbits to initial conditions and pronounced perturbations increases the importance of accurate observations, as small errors can lead to large discrepancies in the predicted orbits. Thus, traditional IOD and ROD algorithms, along with uncertainty propagation techniques, may need to be adapted or refined to address these unique challenges. In addition, the implemented algorithms will be used to compute useful quantities related to possible conjunction events, using models tailored to the novel dynamics. Subsequently, these data will be used to plan CAMs, first based on well-known techniques already used in the Earth region, and then exploiting the peculiarities of the cislunar environment, such as the stable and unstable manifolds. These

	methods will finally be applied to construct a comprehensive catalog that will serve as an inventory of objects, each of which will be paired with a unique identifier and relevant data, such as its state and associated uncertainty. Furthermore, these data will be continuously updated using the strategies developed.
Educational objectives	This research involves the knowledge of the current state of SSA services and their 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 train a highly qualified researcher that 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 about 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. The research will develop in parallel to the establishment of: 1. the European Space Surveillance and Tracking Support Framework 2. ESA’s Space Safety/Space Traffic Management programme 3. Any national initiatives aiming at establishing/improving a national SSA/STM capability All programmes support the development of a network of European and national infrastructures to ensure the long-term availability of space surveillance services, including any existing/future SSA services. To this purpose, both programmes are fostering industrial and academic excellence in the field,

	which will need the long-term support of experienced professionals.
Composition of the research group	0 Full Professors 2 Associated Professors 2 Assistant Professors 8 PhD Students
Name of the research directors	Prof. Pierluigi Di Lizia

Contacts
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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.