POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 40th cycle

THEMATIC Research Field: GUIDANCE NAVIGATION AND CONTROL FOR A TECHNOLOGY DEMONSTRATION IN LOW EARTH ORBIT

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	Rendezvous activities in low Earth orbit (LEO) are currently widely addressed to mature technologies required for On-Orbit-Services and Active Debris Removal missions. Particular attention is dedicated to Cubesat-based architectures, as a means to develop know-how and collect flight data in a cost-effective fashion. Precursor activities have been carried out in the past e.g., the AVANTI (Autonomous Vision Approach Navigation and Target Identification) experiment [1] or more recently e.g., ELSA-D (End-of-Life Services by Astroscale) [2]. These have shown that the robustness of the whole relative guidance navigation and control (GNC) subsystem is to be improved to comply with the autonomy level required by cost-effective operations, as demanded by recursive OOS/ADR services. The LEO region is generally exploited considering accessibility and safety aspects. Nonetheless, this comes at the cost of a considerable impact of differential aerodynamic drag into the dynamics as well as demanding scenarios in terms of illumination conditions and visibility and promptness of intervention from the ground. The objective of this research is to advance the robustness of the GNC system to enable long-term reliable autonomous in-orbit operations. At the same time, algorithms shall be efficient, in terms of delta-v expenditure and computational burden, to comply with Cubesat design limitations and in terms of accuracy achievable by the relative navigation. This latter impacts the minimum inter-satellite distance that can be

	safely reached and maintained and therefore is a measure of the success of the technology return of the demonstration itself. [1] Gaias, G., and Ardaens, J.-S., Flight Demonstration of Autonomous Noncooperative Rendezvous in Low Earth Orbit, Journal of Guidance, Control, and Dynamics, Vol. 41, No. 6, 2018, pp. 1337–1354. https://doi.org/10.2514/1.G003239.[2] Forshaw, J., Linehan, R., Wokes, S., Brettle, H., OBrien, K., Ainley, S., Auburn, J., and Lindsay, M., Towards commercial ADR services: The Elsa-M mission, Proceedings of the International Astronautical Congress, IAC, 2021.
Methods and techniques that will be developed and used to carry out the research	The position will be fully funded by Infinite Orbits s.a.s. (IO), a company designing and performing in-orbit services of satellite inspection and life extension for geostationary satellites. The foreseen research activities are part of the preparation of the GNC system of a rendezvous technology demonstration between two Cubesat platforms, currently under design by the Company, in LEO. Specifically, the focus is to develop the relative GNC algorithms required during the far- to near-range parts of the approach and subsequent target inspection, processing angles-only (AO) observations and a measurement of inter-satellite distance within the last 300 meters. For G&C, the following activities are foreseen: (1) design and computation of fuel optimal, passively safe, trajectories taking into account finite burning time and proper location of the thrusters of the propulsion system. (2) Manoeuvres will also be optimized to improve the observability property of the bearing-only relative navigation problem. (3) Development of the closed-loop controller, taking into account modelling, navigation, and control errors. (4) Trajectory planning in contingent cases, for collision avoidance. (5) In their final form algorithms will be implemented with coding techniques to ensure embeddability. For this part of the research, the main goal is to reduce the delta-v cost (specifically important for Cubesats) and to exploit synergies between the manoeuvring profile and the robustness of the weakly-observable navigation solution. Semi-analytical, linear-programming and numerical

	approaches will be investigated.For navigation (NAV), the following activities are foreseen: (1) the most convenient estimation of the differential aerodynamic drag in AO relative navigation. (2) at close range, sensor fusion with additional observations from a LIDAR. (3) investigation of the most convenient filtering scheme (e.g., adaptive unscented Kalman filter) to cope with weak observability and the need to estimate differential aerodynamic drag. (4) assessment of the filter robustness in case of mis-detection of outliers by the image processing unit. (5) In their final form algorithms will be implemented with coding techniques to ensure embeddability. Verification of (5) G&C and NAV through Processor-In-the-Loop simulations is foreseen at IO premises using an available testbed. For NAV the main goal is to enhance the robustness with respect to changes in the differential aerodynamic drag during operations.
Educational objectives	The Candidate will learn and advance semi-analytical techniques in the relative orbital elements framework, to leverage the astrodynamics perspective of the GNC problem in consideration. He/she will apply them both to the relative trajectory design and the relative navigation filter development. The Candidate will develop a core part of the relative GNC of a real mission and familiarize with code techniques for onboard applications.
Job opportunities	The Candidate will become an expert in the development of relative GNC algorithms for spaceborne implementation. In addition to the job opportunities within the funding Company, this profile is requested by the several industries currently active in OOS and ADR activities.
Composition of the research group	0 Full Professors 1 Associated Professors 2 Assistant Professors 12 PhD Students
Name of the research directors	Prof. Gabriella Gaias

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano - via La Masa 34, 20156 Milano - Italy - tel. +390223998323 - fax +390223998334 - email: gabriella.gaias@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	750.0 €
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.