POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 38th cycle

PNRR_352 Research Field: MODEL-BASED AUTONOMOUS GUIDANCE, NAVIGATION, AND CONTROL OF DEEP-SPACE CUBESATS

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	Funded by PNRR M4C2 (dalla ricerca all¿impresa) Contributes to M1C2 (digitalizzazione, innovazione e competitività nel sistema produttivo) The New Space era is here to stay. Space exploitation is key for the sustainability of humankind on planet Earth. Satellites are crucial to monitor carbon emissions, oceans and forests, adverse weather, volcanic and tectonic activities. Constellations of artificial satellites yield positioning information all over the world, and soon internet access even in the middle of oceans. Space economy is booming. The near-Earth space, once a prerogative of few national agencies, is now accessible to a wider community. Private companies develop nano-to-large satellites regularly. Constellations made of thousands of satellites are the standard. Sub-orbital flights and space tourism are a fact. Yet, the current proliferation of space assets will soon become unsustainable from ground-based tracking facilities. Most of the deep-space spacecraft navigation techniques rely on radiometric tracking and ground-based orbit determination through the European Space Tracking Station (ESTRACK) and the Deep Space Network (DSN). Radiometric measurements yield accurate orbit determination, but the drawback relies on the interaction with the ground station, which is unavoidable. This in turn dictates the costs of operations to navigate spacecraft. All in all, new methodologies for determining and controlling the orbit of spacecraft must be

	devised to reduce the exploitation of ground-based tracking facilities. The objective of this PhD project is to advance the state of the art in guidance, navigation, and control of deep-space CubeSats with a model-based approach for autonomous systems. The aim is to develop technologies for space environment perception, onboard data processing, autonomous navigation, and orbit control in view of typical requirements of lunar and deep-space CubeSats. The technologies will be tested on an in-orbit space laboratory in low-Earth orbit for autonomous navigation and control of miniaturized platforms. This is to verify the requirements and validate the performances of the devised autonomous guidance, navigation, and control system for exploitation in next-generation deep-space CubeSat applications.
Methods and techniques that will be developed and used to carry out the research	The proposed project has the ambition to 1) enable autonomous guidance, navigation, and control of space platforms and 2) accelerate the adoption of model-based systems engineering (MBSE) within the space engineering community. The idea is to develop novel autonomous guidance, navigation, and control techniques for miniaturized platforms with a model-based approach to enable autonomous space exploration. The proposed MBSE approach is exploited from the initial definition and design of the concept to the final verification and validation of the performances through an iterative approach as a feed-back of the analysis on the design. The MBSE approach involves multiple disciplines that the candidate will master during the PhD programme. Disciplines in space environment simulation, environment perception, onboard data processing, onboard guidance determination, optimal control determination, and hardware-in-the-loop simulations will be key building blocks for the autonomous guidance, navigation, and control system design of deep-space CubeSats. The PhD programme is organized in different phases: 1) Review of GNC methods for space missions, on-ground GNC simulations, and miniaturized components; 2) Definition of autonomous GNC simulation scenario in view of typical requirements of low-Earth orbit and deep-space

	CubeSat missions; 3) Design of autonomous GNC systems for low-Earth orbit, lunar, and deep-space CubeSats through MBSE; 4) Implementation of autonomous GNC architecture into a mathematical/numerical simulation environment; 5) Simulation and performance analysis of autonomous GNC system in numerical environment and iterative feedback on GNC design; 6) Implementation of autonomous GNC architecture into hardware-in-the-loop (HIL) simulation environment; 7) Performance analysis of autonomous GNC architecture in HIL simulations. The proposed PhD project combines renown expertise in the field of space guidance, navigation, and control simulation and miniaturized space systems integration and test. These two branches are both at the edge of research in their fields, and they are merged here to forge a novel research line.
Educational objectives	The objective of this PhD is to develop skills in space system modelling and simulation as well as in autonomous guidance, navigation, and control. The candidate will gain relevant expertise in near-Earth and deep-space missions. Through this project, the candidates will develop skills in mathematical modeling, numerical analysis, computer programming (Matlab, Python, C++, or similar), and image processing. Moreover, the candidate will develop skills on both computer and processor/hardware-in-the-loop simulations. Soft skills in disseminating the research, writing reports, performing outreach, and preparing industrial progress meetings will be also achieved through the PhD project. These educational objectives will be also acquired through a six-month secondment at a CubeSat company. In addition, the PhD student is supposed to spend 6 months in a foreign university/research center/company. The timeframe and location of the secondment at the CubeSat company as well as the period abroad will be defined during the PhD career development plan, to be developed within the first semester after the kick-off of the activity.

Job opportunities	The current research prepares the PhD candidate to both academic and industrial careers. Knowledge of model-based system engineering, modeling and simulation of space systems, as well as autonomous guidance, navigation, and control are fundamental skills for careers in space-related companies and universities.
Composition of the research group	1 Full Professors 0 Associated Professors 1 Assistant Professors 10 PhD Students
Name of the research directors	Prof. Francesco Topputo

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

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Tyvak International
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	The PhD student is supposed to spend 6 months in a foreign university/research center/company. The timeframe and location of the secondment as well as the period abroad will be defined during the PhD career development plan, to be developed within the first semester after the kick-off of the activity.
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The candidate will be hosted in the DART Lab (Deep-space Astrodynamics Research & Technology Laboratory) at the Department of Aerospace Science and Technology, Politecnico di Milano. During the PhD program, the candidate will have access to the facilities of the DART Lab

to carry out experimental activities. The candidate will also have the opportunity to attend some PhD classes on both soft and hard skills. Moreover, there could be the possibility to carry out activities as teaching assistant. The PhD candidate will receive a desk, a personal computer. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses, to receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship.