POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

THEMATIC Research Field: AUTONOMOUS NAVIGATION FOR CLOSE PROXIMITY OPERATIONS IN ASTEROIDS MISSIONS

Monthly net income of PhDscholarship (max 36 months)
€ 1600.0 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	The New Space era is here to stay. Space exploitation is key for the sustainability of humankind on planet Earth. Satellites are crucial to monitoring carbon emissions, oceans and forests, adverse weather, and 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. The 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 and their delayed measurements. 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 navigation of autonomous space missions, with

	a focus on CubeSats missions. The aim is to develop technologies for space environment perception, onboard data processing, and autonomous navigation in view of typical requirements of close proximity. The technologies will be tested in numerical simulations and then in hardware-in-the-loop simulations. This is to verify the requirements and validate the performances of the devised autonomous algorithms 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 navigation of space platforms and 2) investigate innovative techniques and sensors for close proximity navigation. The idea is to develop novel autonomous navigation techniques for miniaturized platforms considering innovative sensors and algorithms to enable autonomous space exploration. Disciplines in space environment simulation, environment perception, onboard data processing, onboard orbit determination, and hardware-in-the-loop simulations will be key building blocks for the autonomous navigation of asteroid close proximity CubeSats. A particular focus will be devoted to novel methodologies and approaches that are attracting interest in the on-board spacecraft navigation community to enable onboard navigation algorithms in synergy with state-of-the-art approaches. The PhD programme is organized in different phases: 1) Review of navigation methods for space missions, on-ground navigation simulations, and measurement sensors; 2) Definition of autonomous navigation simulation scenario in view of typical requirements of close proximity CubeSat missions to small bodies; 3) Design of autonomous navigation systems for CubeSats mission in asteroid close proximity; 4) Implementation of autonomous navigation architecture into a mathematical/numerical simulation environment; 5) Simulation and performance analysis of autonomous navigation system in numerical environment and iterative feedback on developed design; 6) Implementation of autonomous navigation architecture into hardware-in-the-loop (HIL) simulation environment; 7) Performance analysis of autonomous navigation architecture in HIL simulations. The proposed PhD project combines

	renowned expertise in the field of space sensor processing, navigation filtering, and their combined integration. 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 close proximity navigation. The candidate will gain relevant expertise in asteroid space missions. Through this project, the candidates will develop skills in mathematical modelling, numerical analysis, computer programming (Matlab, Python, C++, or similar), and sensor processing. Moreover, the candidate will develop skills in 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.
Job opportunities	The current research prepares the PhD candidate for both academic and industrial careers. Knowledge of filter design, sensor processing, sensor modelling and space system simulation are fundamental skills for careers in space-related companies and universities.
Composition of the research group	1 Full Professors 1 Associated Professors 2 Assistant Professors 20 PhD Students
Name of the research directors	Prof. Francesco Topputo

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano Via La Masa 34, 20156, Milano - Italy Phone: +390223998351/7157 email: francesco.topputo@polimi.it- web site: www.aero.polimi.it or https://dart.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	800.0 €
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.