POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 38th cycle

PNRR_352 Research Field: MODEL-BASED DESIGN AND SIMULATION OF SATELLITES DIGITAL TWINS - II

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, 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, assets of such immense value are exposed to threats. The increasing influence of space systems makes them a primary target for cybercriminals. Services like telecoms, observation, and navigation are provided to government and defense organizations. End-user applications combining space data and ground assets rely on networks and clouds. The shift to the ground-stations-as-a-service approach increases the exposure of space systems to attack. Spacecraft development environments are also a potential target, as well as all ground-to-space links. All in all, new technologies and tools must be devised to protect

	the space sector. The objective of this interdisciplinary Ph.D. project is to develop a digital framework that can be used as the underlying physical environment in space cyber security exercises. The aim is to develop digital twins using novel modeling concepts and methodologies to reproduce the high-fidelity behavior of both space and ground segments. The digital twins will be developed to be compatible with state-of-the-art cyber ranges. They will then be used to model, develop and counter new types of cyber threats specifically devised for space, enabling a completely new research line.
Methods and techniques that will be developed and used to carry out the research	The proposed project has the ambition to 1) embrace digital twin concepts inspired by engineered resilient systems and 2) accelerate the adoption of model-based systems engineering (MBSE) within the space engineering community. The idea is to leverage new digital techniques to allow cyber security assessments, like those performed within cyber ranges, to deploy novel cyber threat intelligence and cyber threat analyses. The multidisciplinary MBSE approach proposed relies on the abstraction of the inherently multi-physics systems typical of the space domain, and is organized in four layers: 1) Modeling of the multidisciplinary systems from first principles, 2) Implementation of the mathematical/physical models into resilient and efficient numerical frameworks, so allowing system simulations at the fringe of their design space, 3) definition of real-life interfaces between the digital twins of the space/ground segments and a cyber range, and 4) developments of methods and tools for cyber threat intelligence and cyber threat analysis purposely developed for ground-based and space-segment assets. The proposed Ph.D. project combines renowned expertise in space systems modeling and simulation, and cybersecurity threat modeling (with a specific emphasis on the peculiarity of cyber-physical systems). 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 Ph.D. is to develop skills in space system modelling and simulation as well as in space system cyber security. 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 cyber security. 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 Ph.D. project. These educational objectives will be also acquired through a six-month secondment at an engineering firm. In addition, the Ph.D. 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 Ph.D. career development plan, to be developed within the first semester after the kick-off of the activity. In addition, by working in a diverse and vibrant academic and industrial context, the candidate will have the opportunity to learn on the job several transferable skills, including communication skills, team working, leadership, and ethical aspects associated with the use of innovative technologies. In support of this, the Ph.D. School of Politecnico di Milano provides a complete and rather diverse offer of courses. Each candidate must include in their syllabus at least 10 ECTS in transferable skills, to complement at least other 5 ECTS in technical disciplines associated with Aerospace Engineering, for a total of at least 20 ECTS.
Job opportunities	The current research prepares the Ph.D. candidate for both academic and industrial careers. Knowledge of model-based system engineering, modeling, and simulation of space systems, as well as space system cyber security 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)	BV Tech
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 Ph.D. 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 Ph.D. classes on both soft and hard skills. Moreover, there could be the possibility of carrying out activities as teaching assistants. The Ph.D. candidate will receive a desk and a personal computer. Apart from the compulsory ones, the Ph.D. candidate will have the

opportunity to follow additional courses, receive economic support, attend summer schools, and participate in conferences. There will be the possibility of paid teaching assistantship.