POLITECNICO DI MILANO

# PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

## PNRR 117 Research Field: AUTONOMOUS NAVIGATION AND CONTROL IN CLOSE-PROXIMITY OPERATION WITH UNCOOPERATIVE TARGETS

| Monthly net income of PhDscholarship (max 36 months) |
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| **€ 1400.0**<br>In case of a change of the welfare rates during the three-year period, the amount could be modified. |

| Context of the research activity | |
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| **Motivation and objectives of the research in this field** | Motivated by great scientific interest and the unique potential of technological exploitation, the exploration of minor bodies is escalating. Analogously, it is imperative to pursue technological progress toward in-orbit servicing, to make near-Earth space sustainable in the long term. Both minor body exploration and in-orbit servicing require implementing close-proximity operations with uncooperative targets: either a celestial body or an artificial object. Although safe and reliable, ground-based operations are inadequate to sustain a massive minor-body exploration and in-orbit servicing activities, due to cost and limited availability of ground stations. Also, a ground-in-the-loop approach introduces inevitably time delays, which in turn translates into flying inherently safe trajectories. This poses strong limitations to the envelope of activities that can be performed, thus dampening the vast potential of space science and technology tasks that could be performed when flying in close proximity. The objective of the PhD project is to enable autonomous operations about uncooperative targets by overcoming current limitations. The project's ambition is to prove that operations about either a minor body or an uncooperative artificial object (e.g., a defunct satellite or a rocket stage) can be performed in autonomy by a spacecraft, overcoming the current limitation given by the human-in-the-loop approach. |
| **Methods and techniques that will be** | The project methodology is structured on three main |

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| **developed and used to carry out the research** | The project methodology is structured on three main blocks: Navigation, Guidance and control, and Integrated simulation. Navigation aims to determine the spacecraft's state (e.g., position and orientation) by processing sensors' measurements. Current navigation implies tracking the satellite from the ground, which involves considerable time delays. This, in turn, yields to high safety margins in operations to avoid collisions with the target body. Autonomous navigation methods would instantaneously provide sensor information to on-board filters, thus increasing the satellite reactivity, so enabling enhanced returns, at the cost of riskier operations. Navigating in autonomy around an uncooperative target is a complex research topic since the navigation methods need to be robust to uncertainty in the target knowledge. Trajectory guidance and control aim to compute the nominal trajectory by solving an optimization problem and estimate the correction manoeuvres needed to compensate for deviations from the nominal path. Under current practice, these tasks require significant human-in-the-loop involvement. In close-proximity operations guidance and control are to be performed recursively, which is not compatible with ground-based instructions. To advance toward autonomous guidance and control, a robust algorithm has to be developed, while fulfilling both engineering and scientific requirements. The integrated GNC is simulated at the software lever first, where synthetic images, a LIDAR surrogate model, and a numerical thruster model are used. The software simulation serves the purpose to test the algorithms at low-level and it is propaedeutic for the smooth execution of the hardware simulation. The latter consists of simulating the close-proximity operations by using a piece of hardware equipment made by robotic arms and a suite of sensors. |
| **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 modelling, |

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| | numerical analysis, computer programming (Matlab, Python, C++, or similar), and image 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. These educational objectives will be also acquired through a six-month secondment at Thales-Alenia Space Italy, a European-leading satellite manufactures. In addition, the PhD student is supposed to spend six months at the European Space Agency (TBC). 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. |
| **Job opportunities** | The current research prepares the PhD candidate for both academic and industrial careers. Knowledge of model-based system engineering, modelling 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<br>0 Associated Professors<br>3 Assistant Professors<br>18 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)** | |
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| **Housing - Foreign Students** | -- |
| **Housing - Out-of-town residents (more than 80Km out of Milano)** | -- |

| **Scholarship Increase for a period abroad** |
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| **Amount monthly** | 700.0 € |
| **By number of months** | 6 |

| **National Operational Program for Research and Innovation** | |
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| **Company where the candidate will attend the stage (name and brief description)** | Thales Alenia Space - Italia |
| **By number of months at the company** | 6 |
| **Institution or company where the candidate will spend the period abroad (name and brief description)** | ESA (NL) |
| **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.
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.