

Politecnico di Milano

PhD in Aerospace Engineering

Research Title:

Development of methodologies to enhance autonomy of guidance, navigation, and control for deep-space CubeSats

| Scholarships and Financial support | |
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| Monthly net income of PhD scholarship (max 36 months) | €. 1425,00 (In case of a change of the welfare rates during the three-year period, the amount could be slightly modified) |
| Increase in the scholarship for stays abroad | € 566,36 per month, for up to 6 months |
| Number of scholarships | 3 |
| Beginning of PhD | 1 February 2021 |
| Deadline for application | 3 December 2020 |
| Context of the research activity | |
| Motivations and objectives of the research in this field | In the last decade, miniaturization of electronics has enabled nanosatellites, or CubeSats: shoebox-sized systems that are able to carry out scientific investigations alike conventional spacecraft. CubeSats have reduced the entry-level cost in low Earth orbit by one order of magnitude, and are nowadays the standard for NASA, ESA, and JAXA, the three main space agencies. Nevertheless, the current paradigm prevents their usage for deep-space exploration. The ERC-funded project EXTREMA (Engineering Extremely Rare Events in Astrodynamics for Deep- |

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| | <p>Space Missions in Autonomy), introduces the “self-driving interplanetary CubeSats”: miniaturized probes able to drive themselves during the cruise, without requiring any contact with ground. This concept implies that nanosatellites must self-determine their position by sensing the environment (autonomous navigation), and must elaborate and implement a guidance law (autonomous guidance and control). The project also exploits ballistic capture, a delicate celestial mechanism to acquire an orbit about a planet.</p> |
| <p>Methods and techniques that will be developed and used to carry out the research</p> | <p>The research is articulated in three main pillars, and each pillar will be associated to one PhD candidate.</p> <p>Pillar 1: Autonomous navigation This pillar involves conducting research in the field of celestial triangulation, where the aim is to determine the spacecraft trajectory by acquiring and tracking the line-of-sight directions to the visible planets and minor bodies, whose motion is known via ephemeris models. Task 1: To develop an optical navigation algorithm. In this task, the optical navigation algorithm based on celestial triangulation will be developed. This includes the extraction of the target bodies from the images, the estimation of their lines of sight, and the implementation of nonlinear filters.</p> <p>Pillar 2: Autonomous guidance and control This pillar involves conducting research in the field of autonomous guidance and control. The aim is to shift the computation of the guidance and control scheme from ground, which is state of the art, to on-board the spacecraft. Task 2: To develop a deep-space closed-loop guidance algorithm. This task involves developing a two-layer closed-loop guidance algorithm based on deep reinforcement learning and convex programming. The task includes also the construction of the training sets for the first layer.</p> <p>Pillar 3: Autonomous ballistic capture This pillar involves conducting research on ballistic capture, a mechanism that allows a spacecraft to approach a planet and enter a temporary orbit about it without requiring manoeuvres in between, which is suited for limited-control platforms. Task 3: To design and execute an experiment to prove validity of autonomous ballistic capture. This task involves constructing an off-line catalogue of stable sets, developing an on-board ballistic capture algorithm, and executing a hardware-in-the-loop experiment.</p> |
| <p>Educational objectives</p> | <p>The objective of this PhD is to develop skills in the design and analysis of autonomous guidance, navigation, and control as well as in the wider deep-space astrodynamics. Through this project, the candidates will develop skills in mathematical modeling, numerical analysis, and computer programming (Matlab, Python, C++, or similar). Moreover, the candidates will develop skills on both computer and</p> |

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| | processor/hardware-in-the-loop simulations. Soft skills in presenting the research, writing reports, outreach, dissemination, and preparing industrial progress meetings will be also achieved through the PhD project. |
| Job opportunities | The job opportunities that this project opens up are in the field of spacecraft guidance, navigation, and control. The research is framed in the context of deep-space exploration, a former niche that is nowadays growing within the wider space field. |
| Composition of the research group | Number of Full Professors: 0 Number of Associated Professors: 1 Number of Assistant Professors: 1 Number of Post-Docs: 6 Number of PhD students: 1 Number of contracted researchers: 0 |
| Names of the research directors | Francesco Topputo |
| Contacts | Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano Via La Masa 34, 20156 Milano - Italy +390223998351 - email: francesco.topputo@polimi.it |
| Additional support | |
| <u>Housing:</u> financial aid per PhD student per year (gross amount) | |
| Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other informations | |
| <p>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.</p> <p>The candidates 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 candidates will have access to the facilities of the DART Lab in order to carry out experimental activities. The candidates 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. A personal computer will be provided, and funding are available for attending meetings, workshops, and international conferences.</p> | |