POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 40th cycle

THEMATIC Research Field: PROGETTO SPACE IT UP CONTRATTO DI FINANZIAMENTO ASI N. 2024-5-E.0 CUP MASTER I53D24000060005 CUP POLIMI D43C24000350006 - TRAJECTORY DESIGN AND GUIDANCE NAVIGATION AND CONTROL SOLUTIONS FOR EARTH OBSERVATION DISTRIBUTED 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	Bando di finanziamento ASI decreto n. 687/2022 - Deliberazione n. 71/2022 – Tematica 15 Attività spaziali, di cui all’avviso MUR n. 341/2022 per Partenariati estesi. Progetto di ricerca "SPACE IT UP!" approvato con decreto ASI n. 53/2024. Contratto di finanziamento ASI n. 2024-5-E.0 (CUP Master I53D24000060005; CUP POLIMI D43C24000350006). ASI Funding Notice Decree No. 687/2022 - Resolution No. 71/2022 - Topic 15 Space Activities, referred to MUR Notice No. 341/2022 for Extended Partnerships. Research project "SPACE IT UP!" approved by ASI Decree No. 53/2024. ASI Funding Agreement No. 2024-5-E.0 (CUP Master I53D24000060005; CUP POLIMI D43C24000350006). Earth observation missions support our daily life and allow studying natural processes, and climate changes. Several missions carry Synthetic Aperture Radars (SAR) or interferometers to measure key parameters in the microwave range. However, most of these missions, are based on a monolithic satellite architecture. This approach limits the potentiality to improve data quality and spatial resolution to monitor natural events: with a monolithic approach, this can only be obtained by employing rather large antennas. The introduction of constellations and

	large antennas. The introduction of constellations and distributed systems promises a significant improvement in data quality and coverage. Few mission concepts with active SAR have been developed based on distributed systems improving scientific data quality by observing the same terrain area from different platforms; however, no distributed missions carrying passive radiometers have been designed and launched, and few studies are currently available to design such missions. Several challenges are connected to these mission concepts. First, s/c should be separated by a few tens of meters to perform passive interferometry with a swarm/formation, which triggers many difficulties in operating such space systems. Second, precise navigation and control techniques are required, even for the real-time relative guidance, navigation, and control sub-system. This PhD will further develop the group research to design guidance, navigation and control techniques to support distributed systems for remote sensing applications. focusing on analysis and design of future distributed multi-satellite systems for high-resolution interferometry. The work will generate guidance profiles for formation maintenance and reconfiguration during the mission. Moreover, the challenges of guidance, navigation and control of each spacecraft in the formation will be tackled. Algorithms for the relative guidance, navigation and control framework will be developed to simulate in a reliable, robust, and fast way the overall achievable performances of the distributed system, including operational requirements. The methodology will be applied to mission proposals involving active and passive microwave-distributed systems, in Low Earth orbit and extended to other orbital regions and space applications.
Methods and techniques that will be developed and used to carry out the research	This PhD research will contribute to WP1.3 Distributed Space System: A novel paradigm for Earth Observation of the Space It Up! Project. It will develop novel techniques and algorithms for the mission analysis and design, trajectory optimisation and control and guidance navigation and control for distributed mission for remote sensing application considering more than two-spacecraft. The mission analysis and design phase will

	bring to the development of a procedure and tools to design and select the optimal formation architecture given the mission requirements, the payload constraints and the coverage requirements in terms of resolution and frequency. Coverage analysis, orbit maintenance under the effect of perturbations and control of the nominal orbit will be tackled. The control of the spacecraft's orbit within the formation will be developed using optimal control techniques, convex optimisation and exploiting a dynamics expressed in relative orbital elements. As for the relative guidance navigation and control algorithms, this research will focus on methodologies to enhance the overall control accuracy during operations, taking into account the whole chain of tasks: from inter-satellite communication, relative navigation, and formation control in both nominal and contingent scenarios. Selected references * Scala, F., Gaias, G., Colombo, C., Martin-Neira, M.. Design of optimal low-thrust manoeuvres for remote sensing multi-satellite formation flying in low Earth orbit. Advances in Space Research, 68(11), 4359-4378, 2021 doi:10.1016/j.asr.2021.09.030 * Scala, F., Colombo, C., Duesmann, B., Martin-Neira, M.. Enabling distributed passive interferometry through natural relative trajectories. Unpublished manuscript in preparation for Aerospace Science and Technology. * Monteiro-Minan, A., Scala, F., Colombo, C.. Manoeuvre planning algorithm for satellite formations using mean relative orbital elements. Advances in Space Research,71(1), 585-603, 2022, doi:10.1016/j.asr.2022.09.043 * Erbeia, C., Scala, F., Colombo, C.. Robustness analysis and station-keeping control of an interferometer formation flying mission in low Earth orbit. Advances in Space Research, 2024.
Educational objectives	The objective of this PhD is to develop skills in the mission analysis and design, orbit propagation, guidance navigation and control and trajectory design applied to distributed missions. Through this PhD project the candidate will develop skills in mathematical development, simulations, programming (Matlab, Simulink, Phyton). Being this PhD funded through a research contract, soft

	skills in presenting the research, writing reports, developing operational code, outreach, dissemination, and preparing industrial progress meetings will be also achieved through the PhD work. The PhD candidate will be involved in further developing the groups tools for mission analysis and design, orbit propagation, trajectory design and control, relative guidance navigation and control. The PhD candidate will be also involved in the research, industrial projects, organisational and outreach activities of the group. For further information on the project visit: www.compass.polimi.it. For further information contact camilla.colombo@polimi.it and gabriella.gaias@polimi.it
Job opportunities	Job opportunities after a PhD on this topic can be in any of the space agencies, in particular the European Space Agency, the Italian Space Agency and the several European companies and research institutions involved in space economy, remote sensing mission, mission analysis and design, guidance navigation and control.
Composition of the research group	0 Full Professors 2 Associated Professors 1 Assistant Professors 12 PhD Students
Name of the research directors	Prof. Camilla Colombo

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	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.