POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 40th cycle

THEMATIC Research Field: COLLISION AVOIDANCE MANOEUVRE APPROACHES ENHANCING ORBIT NEIGHBOURHOOD AWARENESS

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 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 population of space debris has increased over the past decades including inactive satellites, rocket bodies and fragments generated from breakups in space due to collision events and explosions. Collisions with debris fragments objects can lead to the failure of operational missions and increase the operational cost due to more frequent collision avoidance manoeuvres. The automation of the procedures for collision avoidance activities can decrease the cost of operations and increase the reliability and information sharing with other operators for their implementation at a large scale in the global Space Traffic Management (STM). Traditional collision avoidance operations are only defined and decided based on the collision risk or miss distance and they do not consider the effect of not implementing the manoeuvre itself. On the contrary, in the framework on STM it is important (1) to know the effect that a missed manoeuvre will have on the neighbourhood satellites in similar orbital slot, for example if a fragmentation takes place and (2) to assess the cost in operation that would be required by other spacecraft operators. In this respect the STARLING tool could be applied to assess the impact that a fragmentation has on the external environment [1,2]. [1] Lorenzo Giudici, Juan Luis Gonzalo, Andrea Muciaccia, Camilla Colombo, Mirko Trisolini, Francesca Letizia, "Environmental impact of object breakup in medium-Earth orbit", Advances in Space Research, Vol.

	74, Issue 4, 2024, pp. 1900-1915, https://doi.org/10.1016/j.asr.2024.06.012. [2] THEMIS software https://indico.esa.int/event/511/page/823-themis-final-presentation-and-demonstration
Methods and techniques that will be developed and used to carry out the research	This PhD research will consider cases of collision risk where large covariances are measured and therefore the loss of Gaussianity does not allow using standard uncertainty propagation methods to be considered. Different formulations of the dynamics such as equinoctial coordinates will be used and compared with the Cartesian formulation, different methods for uncertainty propagation will be considered such as the STARLING approach [1, 3] and Gaussian mixture models [4]. Non nominal phases of the mission will be also considered such as launch phase and manned missions. On the other side different consequent metrics will be devised to measure the effect of not performing a collision avoidance manoeuvre. Different methods for assessing the environmental impact of a mission will be taken into account such as [5, 6, 7] and also economic indicator will be used to evaluate the cost of a missed manoeuvre for other operators [8] Moreover, ways to evaluate the orbit neighbourhood affected by a manoeuvre or a fragmentation will be evaluated using periodic conjunctions analysis both for cloud evolution and anomalous behaviour, for LEO in particular: (1) Conjunctions to be analysed via Minimum Orbit Intersection Distance (MOID) calculation (2) orbit resonances, (4) reachable orbital elements by a manoeuvre. [3] Giudici Lorenzo (2024), Space debris environment analysis with continuum mechanics, PhD thesis, Politecnico di Milano, Supervisors: Colombo C., Letizia F., https://hdl.handle.net/10589/220512 [4] Frey, S. (2020). "Evolution and hazard analysis of orbital fragmentation continua". PhD thesis, Politecnico di Milano, Supervisors: Colombo C. S. Lemmens, https://hdl.handle.net/10589/165144 [5] Colombo, Camilla, et al., "Tracking the health of the space debris environment with THEMIS", Aerospace

	Europe Conference 2023, 10TH EUCASS 9TH CEAS, Lausanne, July 2023. [6] NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook, NASA/SP-20230002470 Rev 1, February 2023. https://nodis3.gsfc.nasa.gov/OCE_docs/OCE_51.pdf [7] F. Letizia, S. Lemmens, B. Bastida Virgili, H. Krag. Application of a debris index for global evaluation of mitigation strategies. Acta Astronautica, Volume 161, 2019, Pages 348-362, ISSN 0094-5765, https://doi.org/10.1016/j.actaastro.2019.05.003 [8] Borelli, Giacomo, et al. "A comprehensive ranking framework for active debris removal missions candidates." 8th European Conference on Space Debris
Educational objectives	The objective of this PhD is to develop skills in the dynamical system theory and long-term orbit evolution, modelling of space debris and definition of space debris indicators and software development. Through this PhD project the candidate will develop skills in mathematical development, simulations, programming (Phyton and Matlab), high performance computing through CPU. 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 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
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 debris mitigation, space traffic management, space situational awareness, space policies and mission design.
Composition of the research group	1 Full Professors 1 Associated Professors 1 Assistant Professors 13 PhD Students
Name of the research directors	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	750.0 €
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.