POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

PARTENARIATO PNRR Research Field: EFFICIENT COLLISION AVOIDANCE MANOEUVRE ALGORITHMS FOR IN-ORBIT AUTONOMOUS IMPLEMENTATION AND APPLICATION TO SPACE TRAFFIC MANAGEMENT

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	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 of the operations for their implementation at a large scale in the global space traffic management. Autonomy can be achieved if the manoeuvre is fully defined on-board both in terms of manoeuvre magnitude and direction but also in terms of decision making. The aim of this PhD is to develop efficient algorithms for collision avoidance manoeuvres both for low-thrust and impulsive applications focusing on the efficiency for in-orbit implementation. The effect of uncertainties will be included in the manoeuvre design and the operational constraints in terms of attitude and time constraints included in the optimisation problem. Moreover, artificial intelligence techniques will be used for defining whether or not to perform the manoeuvre considering uncertainties in orbit predictions and the accepted level of collision probability at the close approach. The tools and techniques developed during this PhD will be applied to the development of the Space

	Traffic Management infrastructure of the Italian Space Agency and a proof of concept of a synthetic manoeuvre will be also tested through the mission analysis and experiment design of the e.Cube mission (https://www.compass.polimi.it/research/ecube-mission/). Borsa coperta da fondi ASI-IHS - Telespazio-ASI (CUP F83C22002460005)
Methods and techniques that will be developed and used to carry out the research	Semi-analytical techniques and perturbation theory will be used for the long- and medium-term analysis of orbit, whereas for the short-term analysis, the osculating elements will be considered. Depending on the orbital region, the relevant orbit perturbation will be considered such as drag and solar radiation pressure. The effect of the avoidance manoeuvre will be modelled for different propulsion technologies: chemical impulsive and low-thrust propulsions, but also non-conventional spacecraft will be modelled such as solar and drag sails. Based on past work at Politecnico di Milano, the deflection on the nominal orbit produced by the acting manoeuvre can be modelled as a change in the orbital elements. The mean effect and the osculating term are separated, as they act on different time scales. The relative motion equations are here applied to compute the relative displacement between the nominal and the deviated orbit, so that the resulting change in position and velocity can be projected in the b-plane of the close encounter. In this framework convex optimisation techniques used in formation flying and the formulation in relative orbital elements will also be investigated and its application on collision avoidance explored. Uncertainties in the orbit determination and the dynamic model will also be included, techniques such as Gaussian mixture models and the continuity equation will be investigated. The constraints in terms of attitude of the spacecraft, or time constraints will be included, where possible, as bounds in the b-plane. An optimisation problem will be solved for minimising the resulting collision probability at the close approach or to achieve a set accepted level of the accepted collision probability. The devised approaches will be leveraged to create efficient algorithms for the fast computation of the

	manoeuvre to be implemented in the Italian Space Traffic Management infrastructure, but also targeting their future implementation on-board. To this aim the use of artificial intelligence will be leveraged to decide whether to perform the manoeuvre and its used will be tested on real conjunction data messages. Finally, within this PhD there will be the occasion of designing an on-board experiment for collision avoidance manoeuvre for the e.Cube mission that will perform a series of on-board experiments for avoidance of synthetic debris in LEO. The successful candidate will be involved in the e.Cube mission analysis and experiment design.
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 optimisation and design of in-orbit collision avoidance manoeuvres. Through this PhD project the candidate will develop skills in mathematical development, simulations, programming (Matlab, Phyton), high performance computing through CPU and GPUs. Being this PhD funded through a research and industrial 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, on-orbit operations, space traffic management, space situational awareness, space policies and mission design.
Composition of the research group	0 Full Professors 1 Associated Professors 2 Assistant Professors 6 PhD Students
Name of the research directors	Prof. Camilla Colombo and Juan Luis Gonzalo

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano - via La Masa 34, 20156 Milano - Italy - tel. +390223998323 - fax +390223998334 - email: camilla.colombo@polimi.it - web site: www.compass.polimi.it; www.aero.polimi.it

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

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.