POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 41st cycle

THEMATIC Research Field: ROBUST OPTIMAL CONTROL OF THE SPACE DEBRIS POPULATION AS A COMPLEX DYNAMICAL SYSTEM

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 privatisation of Space and Space Economy, led to the increase in the number of orbiting objects in space. As the number of launches increases, as well the number of space debris objects in space is following an exponential growth. Many sources cause the creation of new debris, such as launcher upper stages, satellite failures, inoperative satellites left in orbit at the end of life, fragments from in-orbit explosion and collisions, etc. As our life is becoming more and more interconnected thanks to satellites, and space is more easily accessible, Space can be seen as the extension of our planet biosphere. As such, the long-term sustainability of space activities will be possible in the next decades only if a change of behaviour is put in place by space faring nations. The mitigation of space debris requires the active control of its population and the definition of feedback action onto it. Models of the overall population on the other side needs powerful tools of high performance computing due to the very high dimensional problem and advanced formulation of the dynamics to integrate their evolution in a stable and efficient manner.
Methods and techniques that will be developed and used to carry out the research	This PhD research is part of the GREEN SPECIES project funded by the European Research Council. In this PhD project we will model the dynamical evolution of space debris as a complex dynamical system, considering the accurate definition of all the sources, sinks of the space debris population and the underlying dynamics of orbit

	debris population and the underlying dynamics of orbit perturbations. The density of space debris objects in the space of the orbital elements will be used as an as an adjoint variable. The continuity equation will be applied for the first time to a N-dimensional space debris environment to directly output the space debris density time history for a given orbital shell. Also a statistical one-dimensional model, will be used to simulate space environment evolution, considering factors like atmospheric drag, collisions, launches, and active debris removal. This PhD combines debris models and a control system to allocate mitigation resources for sustainability to define the optimal number of active debris removal missions, and post mission disposal for different orbital slots and mission configurations (large constellations or single satellite missions). Then we will implement robust feedback control techniques for the space debris problem. The analysis of transient and asymptotic behaviour of the complex dynamical system as such will be performed to reveal its sensitivity to sources, sinks and control parameters. First a state-dependent differential Riccati approach will be applied for feedback control, handling non-linear dynamics. The novelty lies in automatically identifying actions needed to meet space debris targets. Then robust control techniques will be devised to account for model, processes, and parameter uncertainties and to account for uncertainties in the prediction of economic and policy nature. The control output will be translated into policies and regulations to be inputted to the Inter Agency Space Debris Coordination Committee and to the European Space Agency for its discussion. Results from this ERC-funded GREEN SPECIES project provide insights into optimal strategies for minimising risks and the effort required for mitigation. [1] Rusconi M., Colombo C., "Application of a controlled evolutionary model of the orbital population to target sustainable space utilisation", European Conference on Space Debris, ESOC, Germany, 1-4 Apr. 2025.
Educational objectives	The objective of this PhD is to develop skills in the modelling of the impact of a space mission to space sustainability. Through this PhD project the candidate will

	develop skills in mathematical development, numerical simulations and analysis, optimal control, robust control, optimisation, programming (Matlab, Python, C++ or similar), parallel computing and Agile approach for software development. Soft skills in presenting the research, writing reports, outreach, dissemination, will be also achieved through the PhD project. As this PhD is funded by projects, the PhD will also achieve skills in project management and preparing industrial progress milestone meetings. For further information on the project visit: www.compass.polimi.it and contact Camilla Colombo.
Job opportunities	This position prepares to the role of Space Sustainability engineer that is an emerging career path at large constellation and space operator companies. Job opportunities after a PhD on this topic can be in any of the space agencies, in particular the European Space Agency and the several European companies involved in space traffic management, space situational awareness, space policies and mission design. The current research prepares the PhD candidate to both academic and industrial careers. Knowledge of modelling and simulation of space assets and operations are fundamental skills for careers in space-related companies and universities.
Composition of the research group	1 Full Professors 1 Associated Professors 1 Assistant Professors 15 PhD Students
Name of the research directors	Camilla Colombo

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.aero.polimi.it; www.compass.polimi.it

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents	--

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.