



PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 40th cycle

**PNRR 630 Research Field: VIBRATION CONTROL IN SATELLITE ANTENNAS THROUGH
PASSIVE AND ACTIVE METAMATERIALS**

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**

Metamaterials are periodic structures composed of repeating unitary elements that form a lattice configuration. This unique arrangement provides the structure with reduced mass and inherent filtering capabilities for elastic waves and vibrations within specific frequency ranges, known as bandgaps. Consequently, metamaterials offer a promising solution for addressing vibration challenges in satellite antennas, especially during launch phases when antennas are stowed. This stowed configuration necessitates decoupling the antenna's resonances from those of the satellite, typically achieved through mechanisms such as Hold-down and Release Mechanisms (HRM). In missions like Mars Ice Mapper, HRMs, particularly Primary HRMs (PHRM), are crucial for maintaining structural integrity. Introducing metamaterials at the interfaces between these HRMs and the satellite panel, as well as at the bracket of the deployment mechanism, could potentially mitigate the vibrations transmitted to the antenna during launch. These efforts aim to enhance the antenna's structural stability, reduce mass margins, and lower vibration levels. Even after deployment, micro-vibrations originating from satellite attitude control mechanisms, such as thrusters, present additional challenges. To maintain stable antenna performance, especially for missions involving optical instruments, minimizing micro-vibrations is paramount. Innovative brackets capable of attenuating such vibrations, through passive or active control, would



	<p>significantly benefit missions with optical instruments dependent on adjustable antennas. During this PhD project, the candidate will develop passive and active metamaterial solutions to suppress vibrations within specific frequency ranges, while adhering to mass constraints and addressing the challenges posed by the space mission. In addition to vibration mitigation, the research will consider buckling and snap-through phenomena, tensegrity, and deployable mechanisms to control motion, deformation, and energy dissipation in these structures.</p>
<p>Methods and techniques that will be developed and used to carry out the research</p>	<p>The candidate will develop advanced optimization methods tailored for metamaterial design. This will include adapting techniques such as topology optimization and PDE-constrained optimization to meet the specific requirements of space missions and to accommodate desired multiphysics interactions, control schemes, and nonlinear dynamics. In addition, theoretical and numerical methods will be developed to investigate the role of tensegrity and deployability in metamaterials, where large motions and deformations are integrated with vibration control challenges. Particular emphasis will be placed on how these mechanisms can control motion, deformation, and energy dissipation, thereby enhancing the adaptability and robustness of the metamaterials. The process will involve numerical modeling and optimization, followed by prototyping and experimental testing of the metamaterials in a laboratory environment. These tests will replicate the dynamic excitations experienced under real-world conditions, ensuring the practical viability and effectiveness of the developed metamaterials.</p>
<p>Educational objectives</p>	<p>The PhD candidate is expected to develop a solid competence in structural dynamics, metamaterials and space engineering. The candidate is also expected to acquire (at least) the rudiments of multi-physics modeling and strong coding skills in Matlab/Python/C++.</p>
<p>Job opportunities</p>	<p>Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary compared to Master of Science holders in</p>



	<p>the same field.</p> <p>List of Universities, Companies, Agencies and/or National or International Institutions that are cooperating in the research include: Thales Alenia Space, Georgia Tech, University of Colorado Boulder, Imperial College, ETH Zurich.</p>
Composition of the research group	<p>1 Full Professors 0 Associated Professors 2 Assistant Professors 1 PhD Students</p>
Name of the research directors	<p>Proff. Francesco Braghin, Emanuele Riva</p>

Contacts
<p>Email: francesco.braghin@polimi.it; emanuele.riva@polimi.it</p> <p>For questions regarding scholarship/support please contact phd-dmec@polimi.it</p>

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

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Thales Alenia Space Italia (Rome)
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Georgia Institute of Technology (USA)
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
<p>Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 6.114,50. Our candidates are strongly encouraged to spend a research period abroad, joining high-level research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 750 euro/month- net amount). Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for</p>



activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.