POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 41st cycle

THEMATIC Research Field: ROTORCRAFT PILOT-VEHICLE INTERACTIONS IN SIMULATED FLIGHT

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	Adverse pilot-vehicle interactions in rotorcraft operations encompass a broad spectrum of phenomena including Pilot-Induced Oscillations, Rotorcraft Pilot Couplings, excessive workload during demanding maneuvers, and degraded performance under vibration exposure. These interactions significantly impact flight safety and pilot performance, particularly during critical phases such as hover, low-speed maneuvering, and operations with innovative control systems. The fast changing scenario of vertical flight, with emerging advanced air mobility solutions poses further challenges to this aspects, with the possible emergence of previously unforeseen scenarios. Despite technological advances, current certification procedures lack comprehensive methodologies for assessing pilot-vehicle interaction quality, and pilot training inadequately addresses recognition and mitigation strategies. The DAER department's FRAME-Sim laboratories, and specifically the RPC Testbed, provide the foundation for systematic investigation. This research aims to develop: (1) high-fidelity aeroelastic rotorcraft numerical models for real-time pilot-in-the-loop simulations, (2) an experimental biosignal monitoring system for objective workload and stress assessment, to be integrated with the RPC Testbed current equipment, (3) training scenarios for adverse interaction recognition and recovery. The integration of numerical simulation and physiological monitoring will enable to gain insight into pilot-vehicle interaction dynamics and evaluate mitigation

	strategies acting on pilot training and active control inceptors.
Methods and techniques that will be developed and used to carry out the research	The research methodology integrates advanced numerical modeling, experimental biosignal monitoring, real-time simulation, and pilot-in-the-loop testing. Rotorcraft models will be developed in MATLAB/Simulink and using MBDyn's multibody formulation, incorporating flexible dynamics, rotor-fuselage coupling, flight control systems, and pilot biomechanical models. A biosignal measurement system will be implemented and integrated in the RPC Testbed experimental systems, selecting among available technologies (EMG for muscle activation, ECG for heart rate variability, respiration monitoring, galvanic skin response) with criteria based on simulated flight specific criteria. Signal processing algorithms will extract physiological markers correlating with workload, fatigue, and interaction quality. Implementation in FRAME Sim requires optimization for real-time performance while maintaining model fidelity, leveraging open source tools (e.g. MARSH, Godot). Systematic studies will investigate critical combinations of vehicle characteristics, control system parameters, vibration levels, and task demands affecting pilot-vehicle interaction quality. Mitigation strategies will be explored through pilot-in-the-loop experiments combining subjective assessments, objective performance metrics, and physiological measurements to provide comprehensive interaction quality assessment.
Educational objectives	This Ph.D. program aims to develop a researcher with interdisciplinary expertise spanning rotorcraft aeromechanics, flight dynamics, real-time simulation, biosignal processing, and human factors engineering. The candidate will acquire theoretical knowledge of aeroelastic phenomena, pilot biomechanics, adverse aircraft-pilot coupling mechanisms, and physiological responses to flight stressors, while developing practical skills in software development, numerical methods, experimental instrumentation, and data analysis. Specific learning outcomes include: mastery of multibody dynamics formulations and MBDyn implementation, proficiency in real-time simulation architecture and open-source tool

	integration, expertise in rotorcraft modeling and validation, competence in biosignal acquisition and processing, and understanding of human-centered design principles. Strong competencies in scientific communication will be developed through publications in peer-reviewed journals, presentations at international conferences, and collaboration with industry partners.
Job opportunities	Upon completion, the graduate will be positioned for leadership roles in aerospace research institutions, rotorcraft manufacturers, simulation technology companies, or regulatory agencies, equipped to advance both fundamental understanding and practical solutions for optimizing pilot-vehicle interactions and enhancing rotorcraft operational safety in evolving technological landscapes including urban air mobility and advanced automation systems.
Composition of the research group	2 Full Professors 0 Associated Professors 1 Assistant Professors 10 PhD Students
Name of the research directors	Prof. Andrea Zanoni

Contacts
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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.