POLITECNICO DI MILANO

# PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 38th cycle

## PARTENARIATO PNRR Research Field: PNRR MOST-AIR MOBILITY: METHODOLOGIES FOR CRASH ANALYSIS OF NEXT GENERATION OF AIRCRAFT

| Monthly net income of PhDscholarship (max 36 months) |
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| **€ 1400.0**<br>In case of a change of the welfare rates during the three-year period, the amount could be modified. |

| Context of the research activity | |
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| **Motivation and objectives of the research in this field** | The transition toward more environmentally sustainable aviation opens new challenges for the passive safety of the next generation of aircraft.<br>In particular, electric propulsion fosters the development of eVTOL aircraft, with new structural architectures and mission profiles. New safety issues arise from the characteristics of new energy storage systems, which are inherently prone to fire hazards and toxic gas emissions in case of mechanical abuse. The mitigation of the impact forces, decelerations, and deformation experienced by energy storage systems will require adequate structural protections and extremely efficient energy-absorbing concepts, based on the most advanced cellular and hybrid materials and meta-materials<br>Moreover, the weight penalties involved in electric propulsion amplify the need of reducing structural weight to make possible the design of vehicles with acceptable flight ranges. Such aspect, together with the development of innovative aircraft types, like tilt rotorcraft and the aforementioned eVTOL, will boost the research for innovative structural architectures, where the usage of composite materials and hybrid multi-material structural elements will become mandatory to increase payloads and ranges.<br>Numerical analyses are likely to represent a key factor to increase safety and to reduce significantly the time to market for the next generation of aircraft. Although crash analyses are nowadays customarily adopted in aircraft |

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| | design, significant improvements are required to address the challenges such as the ones hereby exemplified:<br>• the need of exploring new multi-material structural architectures with unknown responses in impact and crash conditions;<br>• the application and the reliable calibration of complex material models for composites, polymeric, and hybrid structural elements;<br>• the need of predicting precisely the deceleration and the deformation levels experienced by the most critical elements of energy storage systems;<br>Within this context, this Ph.D. program, activated within the research activities of the MOST centre funded by PNRR, is aimed at developing numerical models for the impact response of representative structural and functional elements and at integrating them in a modular approach for the crashworthiness of the whole vehicle, making use of advanced mathematical techniques, such as regression and non-parametric regression for model identification and exploration of new solutions (CUP D43C22001180001 D.D. 1033 del 17/06/2022). |
| **Methods and techniques that will be developed and used to carry out the research** | In the first phase of the activity, a structural element and a functional component representative of modern and future aircraft will be selected. The structural element will represent a composite or a hybrid composite-metallic structure with a primary role in the impact response of the vehicle. The functional component will be selected considering an electric battery module.<br>The current cooperation of DAER with aircraft industries will make available information to define realistic configurations for the two elements considered in the study and will provide support for the fabrication of representative items, which will be tested at DAER facilities. Simplified FE models of the elements will be developed to design the items and the dynamic tests that will be accomplished.<br>In particular, for the functional item, the test will be required to obtain data on the integrity of the module case and on the loads, decelerations, and deformation experienced by the cells. Tests and analyses will be aimed at correlating loads and deformation with the |

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| | ignition hazards, considering literature data and/or tests on real cells.<br>In the second phase of the activity, the simplified models of the structural and functional item will be evolved into high-fidelity models, which will be calibrated considering the test results. The structural models will take advantage of non-linear constitutive laws developed for composite materials at DAER, while the model of the functional component will require the adoption and characterization of the materials included in the module structure. The need for high-quality correlation at the global (impact forces, structural integrity) and local (deformation levels and failure modes, loads and decelerations on critical details) will require the identification of many model parameters, which will be pursued with parametric and non-parametric regression models and optimization techniques, exploiting the potential of the tools that are currently made available from machine learning techniques.<br>The final phase of the activity will include the integration of high-fidelity models in a multi-body platform that will represent the structural architecture of the aircraft. The platform will be developed in cooperation with aircraft industries and will make use of already developed modelling techniques for the fast evaluation of crash responses. The integration will make possible the evaluation of the performance of the structural and functional elements in a realistic virtual environment, which will account for the interactions with the surrounding structure. |
| **Educational objectives** | The numerical simulation of crash and impact events will represent the common core of the activities performed in the research program. Accordingly, the candidate will acquire both a theoretical and a deep practical knowledge of explicit FE techniques, being able to deal with structural models developed at different scales, with different types of elements, material constitutive laws, and interactions. The consideration of multi-material structural and functional elements, the testing, and the analyses tasks will provide an understanding of the most important non-linear material responses, including plasticity, visco- |

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| | elasticity, and damage, and of the relevancy of such phenomena on the structural integrity and impact performance of modern lightweight structures.<br>The specific activities on functional elements for electric energy storage will give the opportunity for the acquisition of significant knowledge at the engineering and integration level regarding innovative technologies, which are particularly appealing in all the fields of transportation.<br>The ability to implement regression techniques for model identification, by using built-in tools in commercial or open-source software packages, will complete the educational objectives included in the program. |
| **Job opportunities** | The competencies acquired by the researcher will be highly valuable for the structural design of future vehicles for air and urban mobility, where the crash response represents a driver for the definition of the general structural architecture, material selection, and detailed design.<br>The knowledge of architecture, testing, and analysis methods for electric energy storage systems represents nowadays a very important resource for successful job applications in the automotive field and is becoming particularly interesting also in the aircraft industry, both at the level of vehicle manufacturers and at one of the original equipment manufacturers.<br>The activity will provide significant competencies in the field of crash numerical analyses, which open opportunities in all the industries involved in vehicle production (automotive and aerospace, but also in railways and marine sectors) and in engineering consulting firms that provide support for vehicle development and certifications.<br>The characterization and the simulation of material responses, the use of advanced mathematical tools for model parameter identification, and the design and accomplishment of tests are additional general skills that will be acquired, which will be of general interest in all the fields of structural analyses and design, with particular interests for advanced applications like the ones in motorsport and aerospace industry. |

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| **Composition of the research group** | 0 Full Professors<br>2 Associated Professors<br>1 Assistant Professors<br>2 PhD Students |
| **Name of the research directors** | Prof. Alessandro Airoldi |

| **Contacts** |
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| **Additional support - Financial aid per PhD student per year (gross amount)** | |
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| **Housing - Foreign Students** | -- |
| **Housing - Out-of-town residents (more than 80Km out of Milano)** | -- |

| **Scholarship Increase for a period abroad** | |
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| **Amount monthly** | 2100.0 € |
| **By number of months** | 6 |

| **Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information** |
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| The Ph.D. candidate will receive a desk and a personal computer. Apart from the compulsory ones, the Ph.D. candidate will have the opportunity to follow additional courses, receive economic support to attend summer schools, and participate in conferences. There will be the possibility of paid teaching assistantship. |