POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 40th cycle

PNRR 629 PA Research Field: AIRCRAFT STRUCTURAL DAMAGE FROM DRONE AIRBORNE COLLISION

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 increasing use of drones in various civil and commercial applications has raised significant safety concerns, particularly regarding potential collisions between drones and aircraft. High-risk areas like airports can be protected with preventive techniques such as geofencing; however, the risk of impact remains for aircraft operating outside these zones, such as recreational or rescue aircraft, necessitating an accurate study of passive safety for these scenarios. Bird strike regulations are not sufficient to protect against UAS (Unmanned Aircraft System) impact. Many scientists agree on the fact that UAS impacts are likely to cause more damage than bird strikes for an equivalent initial kinetic energy, due to the hard-bodied mechanical construction of some parts of the UAS, like batteries, cameras and motors, made of dense, rigid materials. Additionally, a recent experimental test conducted at the Crash Test Laboratory of Politecnico di Milano compared the damage caused by collisions between drone components and a rotor blade with the damage from a bird strike on the same rotor blade. The study, not yet published, showed that the drone impact caused significantly greater damage. Therefore, preventive actions need to be taken as a consequence of the increasing popularity of drones; these actions may consist of appropriate delethalization of drones or protection of the aircraft structures; in any case, a deep analysis of the structural damage determined by a drone impact should

	be the starting point for any countermeasure aimed at enhancing the aircraft structural crashworthiness.
Methods and techniques that will be developed and used to carry out the research	Past studies have investigated the interaction between an entire drone and aircraft structures in drone strike events. However, using entire drones implies the need to have a gas gun with an extremely large bore to fit the drone, or accelerate the aircraft component by means of a rocket sled. Both test setups are extremely challenging and costly; therefore, the initial goal of this research is to verify the level of approximation associated with the use of the main components only (battery, motors, camera) with respect to the full drone. This approach would allow the use of smaller gas guns, which are cheaper and more widespread among research centres, enabling simplified and more cost-effective tests. The gas guns available at the Crash Test Laboratory of Politecnico di Milano are suitable for this kind of test. A comparison with the full drone system may be done by numerical analysis, once the model subcomponents are properly validated against experimental tests, as follows: - Low-Level Tests: Static and dynamic tests on individual drone components (motors, camera, battery, frame) to accurately characterize their properties and develop their finite element models; this includes comparing material models used for drone components, such as SPH for modelling batteries versus the Crushable Foam and Jonson Cook models typically used in the literature; - Mid-Level Tests: Tests on sub-assemblies of various drones to evaluate interactions between different components; - High-Level Tests: Tests on complete drones to refine model behaviour under controlled impact conditions, using instrumented targets which are accurately modellable (e.g. instrumented rigid plate); - Full-Scale Tests: Validation tests under real impact conditions against key aircraft components potentially involved (windshield, fuselage, wings, and rotor blades. The numerical analysis will be based on LS-Dyna, which is currently being used for a preliminary study on drone impacts. Following the market analysis, this study will include drones of different

	masses, reflecting the main types available, such as lightweight (250 g, e.g. DJI Mavic Mini), medium (1 kg, e.g. DJI Mavic 2), and heavy (3.5 kg, e.g. DJI Inspire 2). Finally, this research will investigate potential protective materials and solutions to mitigate the damage caused by drone collisions to aircraft. This involves testing various materials, such as titanium layers and fibre metal laminates (FML) with aramid or carbon fibres.
Educational objectives	This research aims to set the basis for increasing the crashworthiness of drone strikes for future studies, contributing to the development of more resilient aircraft structures. The principal educational outcome is the refinement of experimental and numerical techniques for the study of the aggressivity of drones in aircraft crashworthiness. From the experimental point of view, the design and execution of tests with the gas guns are quite complex, because they require creativity and intuition. From the numerical point of view, the main challenge lies in the different types of materials involved in the study, which include metal, composites and gel, interacting with each other. Consequently, the PhD candidate will necessarily develop valuable skills in a variety of complex experimental and numerical applications, as well as in the technical development of solutions to mitigate structural damage.
Job opportunities	In the last 10 years, the aviation authorities FAA and EASA have expressed concern about the increasing risk of drone impacts, have started a survey and promoted research on the topic. Different research centres have started some preliminary studies. Aeroplane and rotorcraft manufacturers may soon have to cope with new regulations, extending the structural impact protection from birds to drones. A scientist with a doctorate on this subject is likely to find job opportunities either in aviation authorities, to contribute in the definition of future regulations for drone impact assessment, or in aircraft

	manufacturers, to contribute to designing crashworthy structures.
Composition of the research group	0 Full Professors 2 Associated Professors 2 Assistant Professors 1 PhD Students
Name of the research directors	Prof. Paolo Astori

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano - via La Masa 34, 20156 Milano - Italy - tel. +390223998323 - fax +390223998334 - email: paolo.astori@polimi.it - web site: 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	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)	Leonardo Helicopter Division
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	DLR Stuttgart
By number of months abroad	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.