MSCA-ITN UTOPIAE: ESR scholarship at Politecnico di Milano on Uncertainty Characterisation in Multi-Fidelity Anti-Ice System and Design

ESR10 of Uncertainty Treatment and OPtimisation In Aerospace Engineering (UTOPIAE), A Marie Skłodowska-Curie Action European Training Network

UTOPIAE is a training and research network funded by the European Commission through the H2020 funding stream.

The main objectives of this research programme are to train, by research and by example, 15 Early Stage Researchers in the field of UQ and Optimisation and to become leading independent researchers and entrepreneurs that will increase the innovation capacity of the EU, and to equip them with the skills needed for successful careers in academia and industry, to develop, through the ESR individual projects, fundamental mathematical methods and algorithms to bridge the gap between Uncertainty Quantification and Optimisation and between Probability Theory and Imprecise Probability Theory for Uncertainty Quantification, and to efficiently solve high-dimensional, expensive and complex engineering problems.

Start date: September-November 2017, applications close April, 15th, 2017.

Supervisors: Prof. Alberto Guardone, Prof. Giuseppe Quaranta

Research field: Aircraft aerodynamics; Modelling and simulation; CFD; Ice accretion; Anti-ice systems, Uncertainty Quantification.

Objective: to develop and analyse diverse models of variable complexity to determine the aerodynamic flow-field, the droplet trajectories and the ice accretion over an aircraft equipped with an anti-ice system; To characterise both aleatory and epistemic uncertainties in the above multi-fidelity models; To produce the optimised design of a robust anti-ice system for fixed- and rotary-wing aircraft.

Secondments: the ESR will be temporarily based in the following institutions

- Leonardo Aircraft Division, Turin, Italy, for 3-6 months, to work on multi-fidelity models of anti-ice systems and best practice for in-flight ice prediction and anti-ice system design.
- INRIA Paris, France, for 3 months, to implement Bayesian-based techniques for handling uncertainty in model and experimental measurements.

Research outline: Protection from atmospheric hazards is one of the most demanding challenges in the design of a new aircraft. During its lifespan, an aircraft experiences a wide variety of environmental conditions, which often change abruptly during normal operation. For example, only a short period elapses from passenger boarding to the far-below-freezing conditions at cruising altitude. Manufacturers guarantee safety against all the possible atmospheric hazards a flying machine may encounter---unexpected wind gusts, rain, snow and ice, among others. Exposure to clouds composed by super-cooled droplets or to precipitations such as freezing rain or drizzle possibly leads to the accumulation of ice on critical components of the aircraft. Super-cooled droplets hold in an unstable equilibrium state which is perturbed by the impact against the aircraft surface.
Drop impact triggers water freezing and it possibly results in the formation of an ice layer which modifies the shape of the airfoil sections. Thus, aerodynamic performances are significantly compromised: maximum lift drops, stall angle reduces and parasite drag increases. Ice accretion over engine nacelle alters the airflow in the inlet manifold, whereas the ice accumulating on rotating devices possibly results in ice shedding and aerodynamic and structural load unbalancing. Moreover, localized ice structures accumulating on external sensors may cause misleading information to be conveyed to the pilot and ice accreting on the inner of mechanisms operating control surfaces may lead to

mechanical lock of the control surfaces themselves. Thus, aircraft stability and controllability, and hence passengers' safety, are severely compromised.
The interest towards ice accretion is not only limited to the aerospace industry, but it is also relevant in nautical and civil applications. A considerable research effort is being devoted to the design and operation of power generation and distribution plants located in alpine environments. Ice build-up reduces the efficiency of wind turbine blades, thus affecting energy production. Moreover, power cables and antennas can be slender structures which can get damaged by the overload introduced by the accreted ice or due to the activation of destructive aeroelastic modes.
The development of effective ice protection systems allowing to improve safety standards and, at the same time, to reduce operational costs and environmental impact, stems from a deep knowledge of the icing phenomenon and from an accurate prediction of the related performance degradation. Reliable investigation tools may help researchers and engineers understanding ice accretion. Moreover, quantifying the uncertainty of the operating conditions and of ice accretion models will enable the robust design of ice protection systems delivering the optimal effect in diverse operating conditions.
The research will exploit the library PoliMIce (Politecnico di Milano Ice accretion software) that provides a general interface allowing different aerodynamic and ice accretion software to communicate. The built-in ice accretion engine moves from the well-known Myers approach and it includes state-of-the-art ice formation models. The ice accretion engine implements a fully three-dimensional representation of the two-phase flow over the solid body, accounting for both rime and glaze ice formation. The software is described in *G. Gori, M. Zocca, M. Garabelli, A. Guardone, G. Quaranta, PoliMIce: A simulation framework for three-dimensional ice accretion, Applied Mathematics and Computation, **267**:96-107, http://dx.doi.org/10.1016/j.amc.2015.05.081*, current implemented models based on the exact solution of the Stefan problem are reported in *G. Gori, M. Zocca, G. Parma, A. Guardone. "A model for in-flight ice accretion based on the exact solution of the unsteady Stefan problem", 7th AIAA Atmospheric and Space Environments Conference, AIAA AVIATION Forum, (AIAA 2015-3019), http://dx.doi.org/10.2514/6.2015-3019*
Research activities will be carried out in close collaboration with the industry. A 3/6-month secondment will be carried out at Leonardo Aircraft Division in Turin, where best practices for design of anti-ice systems and practical applications. A thoroughly review of past and current experimental campaign will be carried out to identify the diverse source of uncertainties in the problem, including drop distribution and flight conditions, surface properties and test conditions, see M. Zocca, G. Gori, A. Guardone, *"Blockage and Three-Dimensional Effects in Wind-Tunnel Testing of Ice Accretion over Wings"*, Journal of Aircraft (in press), http://dx.doi.org/10.2514/1.C033750
The 3-month secondment period at INRIA Paris will be dedicated to the application of state-of-the-art techniques for uncertainty quantification to the prediction of ice accretion and for anti-ice system robust design. To cope with the competing requirements of moderate computational efforts desired during early design phases and the interest in solution accuracy, a coupled multi-fidelity approach will be developed, linking hybrid 2D/3D CFD-icing approach to simplified models for surface properties and anti-ice systems.

Requirements: Degree in aerospace or mechanical engineering, experience with CFD, ability to program in C/C++/Fortran, solid background in fluid mechanics and thermodynamics.

Type of contract: The successful ESR applicant will be offered a three year full-time funded contract by Politecnico di Milano. Duration: 36 months, Gross salary: 39,820.00 € per year. Work location: mainly Milano, Italy, and also Paris, France (3 months), and Turin, Italy (3-6 months).

Additional Eligibility criteria: English language (IELTS overall score 6.5; no sub-test less than 6.0), the applicant must not hold a PhD at the time of the start of the contract and have less than four years of experience in research. All researchers recruited in an ITN must be Early-Stage Researchers (ESRs) and undertake transnational mobility. Mobility Rule: at the time of recruitment by the host organisation, researchers must not have resided or carried out their main activity (work, studies, etc.) in the country of their host organisation for more than 12 months in the 3 years immediately prior to the reference date. Additional information can be found at the website utopiae.eu.

Application Procedure: Instructions for applicants can be found in the UTOPIAE website (utopiae.eu), which directs all interested applicants to submit: a CV, a cover letter and two letters of reference. Each applicant can apply for a maximum of 2 posts within the network, and must indicate their order of preference. All applications should be sent to apply@utopiae.eu.