PhD Program in Aerospace Engineering

INTEGRATED PROJECT IN AEROSPACE VEHICLES AND SYSTEMS

1. Summary of the motivation for the Project

Aerospace Engineering is a synthesis of advanced technologies: aerodynamics, propulsion, structures, materials, control, avionics, telecommunications and computation are the sectorial technologies to be integrated by flight dynamics in the design of an aerospace vehicle, that could be an airplane, an helicopter, a satellite or a rocket (a satellite launcher, for example). Economic efficiency and low environmental impact demands mean that the design of an aerospace vehicle cannot ignore all of the sectorial technologies, that imply a broad band interdisciplinary PhD program; there is a very strong focus on the integration of all the sectorial technologies, in order to meet the specifications in terms of performance, efficiency, economy, production, operations, maintenance, emissions and safety. This PhD Program covers not only most of the sectorial technologies that are part of today's airplanes, but also the vehicle integration aspects that go beyond a mere collection of advanced technologies.

The aeronautical sector involves a series of important activities in Portugal: (i) passenger transportation (TAP-Air Portugal, etc…); (ii) airport operation; (iii) air traffic management of the largest geographical zone of Europe, Lisbon FIR (Flight Identification Region), that extends all the way to Azores; (iv) military aeronautics, search and rescue and medical emergency, …; (v) the use of meteorological and earth observation communications satellites; (vi) industry, in several scales from EMBRAER to PMEs.

2. Examples of subjects for PhD thesis

This set of interdisciplinary areas is approached through examples of PhD thesis' subjects, grouped in 5 thematic areas, namely: (i) flight dynamics, addressing the general design of aerospace vehicles of various types; (ii) environment and safety, that deals with air traffic management, including noise and emissions; (iii) technologies for efficient design including aerodynamics, propulsion, structures and materials; (iv) on-board systems with specific functions such as control, telecommunications, energy and actuation, and computation; (v) control and management as transversal areas.

For each of the subjects the name of only one or two possible supervisors is mentioned. For most of the subjects there are multiple alternative supervisors, namely among the more senior members of the team. This proposal emphasizes the team members in intermediate phases of their careers not only to allow for new PhDs but also to give supervising experience guided by more experienced colleagues. This is an opportunity of (i) excellent students achieving a PhD and (ii) supervising PhDs to researchers, both profiting from the oversight of more senior colleagues.

The choice of subjects takes into account: (i) the operational and industrial needs in Portugal; (ii) the insertion of people and companies in the framework of the European union; (iii) the research priorities recognized in the Horizon 2020 Program of the EU; (iv) the competencies and strong points of Portugal; (v) the opportunities for Portugal to expand its areas of activity.

I – Vehicle design

1 – New airplane configurations such as flying wing: overall design and *design trade-offs*: L.M.B.C. Campos.

2 – The uncertainty in several parameters needs to be quantified in optimal multidisciplinary analysis and design in order to fulfill robustness and reliability criteria: A. C. Marta;

3 – An important class of aeronautical vehicles is the helicopter which has marked specificities: rotor dynamics and aerodynamics: F.S.R.P. Cunha;

4 – Vertical and short distance take-off and landing (V/Stol) is also possible without resorting to rotors using jet deflection: F.M.S.P. Neves;

5 – A class of vehicles with growing importance is unmanned aircraft, that is, without a pilot on board: J.R.C. Azinheira;

6 – Orbits and stabilization of satellites are also problems of flight dynamics, but with specific characteristics: V.A. Sarychev.

II – Environment and Flight Operations

7 – Noise is one of the aspects that constrain airplanes and helicopters operations the most: rotor and propeller noise, F.J.P. Lau;

8 – An important noise source, dominant in situations such as take-off, is the engine: engine noise, intake and jet noise: J.M.G. Oliveira;

9 – In some situations as the landing approach with the engines in idle, aerodynamic noise is predominant: P.G.T.A. Serrão;

10 – Minimization of pollutant emissions by reduction of aerodynamic drag and fuel consumption by the engines: J.M. M. Sousa;

11 – The previous aspects are related to air traffic management, where there is a further need to consider airplane separation as a safety measure to avoid collision and trailing vortex effects: J.M.G. Marques;

12 – Operational constraints are one of the aspects that affect the criteria and the decisions related to air transportation: J.M.R. Silva.

III – Efficient Design Technologies

13 – Aerodynamics applies to the whole airplane shape and in particular to the wings: P.V. Gamboa;

14 – Aerodynamics affects installation of propulsive systems: J.M.M. Barata;

15 – Propulsive systems in aeronautics include jet engines, rockets and alternative systems: F.M.R.P. Brujo;

16 –Multidisciplinary Design Optimization for UAVs with civilian applications: A. Suleman;

17 – These technologies allow the shape adaptation of aerodynamic surfaces such as wings: J.M.A. Silva;

18 – The integration of structural and aerodynamical aspects constitutes aeroelasticity: A. Gomes.

IV- On-board Systems

19 – An important class of on-board systems deals with navigation: J. Fernandes e G. Tavares;

20 – An important interface for navigation is telecommunications: M.H. Sarmento:

21 – Data merging from multiple sources and sensors is essential to build timely complete and coherent operational scenarios: L. Sousa e P. Tomás;

22 – The functions mentioned require distributed and reconfigurable computation: H. Neto;

23 – The execution of command actions requires the use of actuators on control surfaces, landing gear, etc…: G. Marques e D. Sousa;

24 – A modern airplane can use up to 2MW of electric energy, generated by engines and distributed throughout the airplane: F.A. Silva.

V- Control and Management

25 – Control applies to the several functions in an airplane and to space missions, starting with stabilization and optimization J.M. Lemos e B. Costa;

26 – Control is performed both for local stability and for flight trajectories optimization: K. Bousson;

27 – One other example of trajectories optimization is satellite launchers and satellite space missions: P.J.S. Gil;

28 – The final proof of an aerospace vehicle and its systems is flight testing: A.A. Fonseca

29 – Aerospace technology raises a number of ethical and philosophical issues: C. Mitcham

3. Management of the PhD Program

The Director of the PhD Program is Prof. L. M. B. C. Campos.

Most PhD subjects have several possible choices of supervisor.

Each area will have one coordinator:

I – Vehicle design – J.M.M. Barata

II – Environment and Flight Operations – J.M.M. Sousa

III – Efficient Design Technologies – A. Suleman

IV – On-board Systems – L. Sousa

V – Control and Management – J.M. Lemos

The coordinators of each area together with the Program director form the Scientific Council, which is the collective body that supervises the implementation of activities.

4. Participant institutions and available means

This project is led by CCTAE (Centro de Ciências e tecnologias Aeronáuticas e Espaciais) with 40 years of experience in the area and 25 years of practice in flight tests, and more recently in an aeroacoustic wind tunnel and a flight simulator with 6 degrees of freedom.

The Centro de Aeronáutica da Universidade da Beira Interior belongs, as CCTAE, to LAETA (Laboratório Associado de Energia, Transportes e Aeronáutica). These are the only two national research centers dedicated to Aerospace Engineering and connected to the two PhD programs accredited in this area in Portugal.

Other participants are members of IDMEC, which is the largest member of LAETA and the host institution of CCTAE.

Recognizing the importance and close connection between mechanics and electrotechnics in aerospace systems INESC-ID is a fundamental partner in the project.

The collaboration of a private university (J. Marques, ULHT) has the objective of encouraging new contributions.

The list of companies with which the partners have collaboration and joint research projects include:

EADS Innovation Works
AIRBUS France
AIRBUS Germany
AIRBUS Spain / CASA
Eurocopter
BAE Systems
Dassault
Alenia
Embraer
Agusta-Westland
Rolls-Royce
Snecma
MAN Turbomotoren
Fiat Avio
Thales
Liebherr
OGMA - Indústria Aeronáutica de Portugal
NAV Portugal
Vinair
UAVision

5. Benefits of the PhD Program

The fundamental reasons why the aerospace sector is a pioneer in the use of new technologies are related to two factors: (i) new technologies are in general expensive in their initial phase of development and small scale production; (ii) their use is economically viable in applications with a large benefit as is the case of the aerospace sector. Some examples are given. An increase in 50 C at the entry to a jet engine turbine reduces fuel consumption in 3%; such a reduction in all flights of all planes has a significant impact in the cost of air transportation and pollutant emissions. As a result the development of materials with increased resistance to high temperatures and of methods for the cooling of turbine blades justifies large investments and research programs.

To place a satellite in orbit has a cost of 10000€ per kilogram for the launcher and several times more for the satellite. To reduce the empty weight of an airplane or satellite launcher has major advantages that multiply: larger cargo, smaller size and aerodynamic drag, smaller engine, lower fuel consumption, smaller fuel tanks, etc…. The reduction of 1 kg in one item allows for an overall reduction of 10 kg for the same overall performance. Therefore the use of light and strong structures is justified even if its cost is high.

Electrical energy generation systems and electronic converters are the power supplies for avionic systems and for flight control/actuation of some of the most advanced aircraft. Si based electronic converters of current aircraft have a power density of 2kW/kg. The use of SiC type high temperature semiconductors doubles that density, implying a reduction of 50% in the weight of the electrical power supply systems. The use of variable frequency generators coupled to almost unity power factor rectifiers, filters and direct current power supplies, allows a 30% further reduction in the weight of the power generation systems. The hybridization of power generation systems with electrical energy storage systems is also a promising way to reduce the aircraft weight.

As these new advanced technologies become more economical with larger scale production, their use spreads to other sectors. Aeronautics and space are pioneers in microelectronics, control, telecommunications, computation, high temperature materials, light structures, efficient engines, and sophisticated aerodynamics, integrated in a complex vehicle. The first integrated microcircuits were developed to place computers in airplanes and rockets, in a confined space and subject to strong accelerations (very different from the mainframes in the air conditioned rooms of the time). The telecommunication capacity of a satellite in orbit exceeds those of much larger earth installations.