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2012 research highlights

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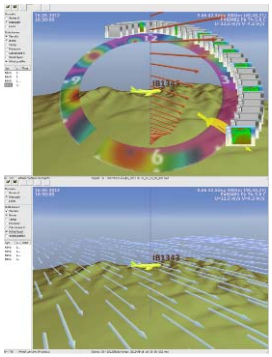
Meteorological Models for Air Traffic Automation

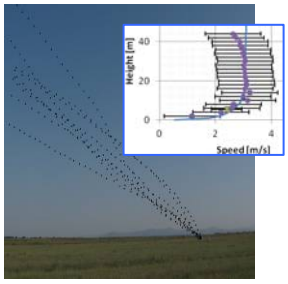
High precision dedicated meteorological models



Customised 4D weather forecast models to deliver digital meteorological data with sufficient resolution and accuracy for autonomous air traffic management. This is normally based on multi-weather-model multi-analysis ensemble prediction systems with real time assimilation of external data. Currently, the research focuses on:

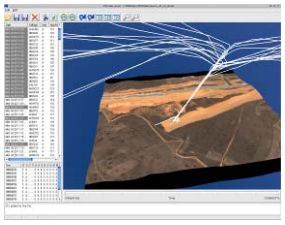
- Coupling of mesoscale models with detailed CFD (see below)
- Management and propagation of uncertainties throughout the process
- Forecast delivery and configuration control over the network

Lighter-than-air bubble tracking for real time wind profile measurements



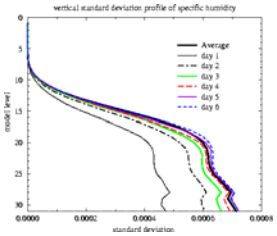
This low cost non-intrusive method allows the assessment of the real wind conditions in the airfield both visually and computationally by tracking helium filled bubbles along their ascending path. The system can remotely track bubble clusters up to 300 m height, reaching very good accuracy after filtering the readouts from several cameras. This is an interesting solution for researchers in air traffic management or unmanned vehicle operations for the last phase of the mission, were incidents concentrate.

Estimation of wind fields from observed aircraft trajectories



Some of the phases of an aircraft mission are easily predictable. When aircraft trajectory is known, differences between expected and real path can be due to meteorological conditions. Dedicated filters can be used to deduce the wind field from large dataset of real trajectories. The method is completed with meteorological models to obtain better initial estimations and with real time measurements to improve accuracy.

Coupling of Meteorological and CFD models



The coupling of mesoscale and CFD model capabilities allows to obtain a more accurate and powerful tool for wind knowledge and forecasting. CFD is able to model the details of flow around specific geographic and man-made features; mesoscale models incorporate information about the outer scale geophysical variability (evolving boundary conditions and assimilation of external data).
A model based on boundary conditions provided by a mesoscale model and fine-scale topographic features modelled in CFD is currently under development.

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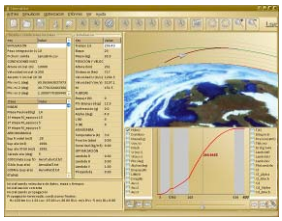
Optimisation processes

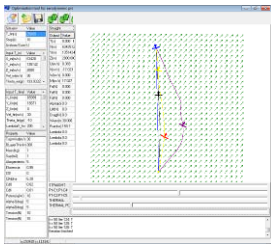
Optimisation of aerospace trajectories



The ascent optimal trajectory for small launchers can be calculated for injection at maximum orbital height with autonomous rapid corrections in real time. The angle of thrust vector -the single control- can be solved together with some system design parameters by applying an indirect optimization method iterated over the parameter space. Feasibility, accuracy and convergence of the method are part of the research, as well as necessary throughput.

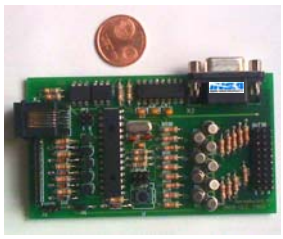
On-design and off-design performance is also investigated to help present and future designs of aero-ejected launchers.

Optimisation of airplane trajectories



Given the dependency of aircraft performance from the meteorological conditions, a research lines exploits the benefits of having a better knowledge of atmospheric conditions in real time. Thus, analytical methods (in contrast to other extended approximate solutions) are used to find best trajectories for several figures of merit, including weather forecast modifications and the occurrence of path constraints.

Control of unmanned air vehicles



Modern designs for robust control of unmanned air vehicles include commercial components and in-house developments to embed real-time algorithms, data fusion tasks and management of redundancies, reducing the workload of the onboard processors. The software includes nested loops with growing frequencies, a selection of filters for the sensor data and a variety of control algorithms.

Flight dynamics simulation

Development of flight dynamic models to be run under simulated environmental conditions and with manual or pre-programmed inputs from the user. The software is prepared:

- as a tool for engineers to test different flight configurations
- as a tool for engineers to test different control strategies
- as a tool for operators for training purposes

The aerodynamics, structural and propulsion performance of the vehicle are modelled or tested and included in the simulation.

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Alternative unmanned air vehicles

Modular airplane for educational purposes

Since unmanned vehicles do not need a conventional fuselage, many flight configurations are possible. Besides, active control even allows more combinations.

The airplane designed and developed in the laboratory can be mounted in the flight field in a vast number of shapes and configurations. Just by attaching a variety of modules to each other and with the help of configuration software to assess the aerodynamic feasibility and other centring and stability considerations, different airplanes can be immediately obtained and flied. This is especially useful for heterogeneous missions or educational purposes.

Hybrid helicopter-airplane unmanned vehicle

HADA is a hybrid vehicle that takes off as a helicopter and flies as an airplane. The UAV retract the rotor blades and spread the wings when the velocity is high enough. The engineering around the mission specification is critical, given the impact on the aircraft design and final performance. The strategy to run the transition between both modes of operation, as well as the propulsion requirements to carry it out, is part of the current research.

Unmanned blimp

With their ability to hover for days and to hold more payloads than many drones, aerostats and airships become good choices for surveillance in multiple scenarios.

Looking for these advantages, low-cost unmanned aerostatic platforms have been developed focused on fire monitoring and security applications. Two blimps have been studied, designed, built and operated. They are currently available with payload capacities from 10 to 100 kg and a helium volume of 300 and 660 m^3 respectively. The onboard autopilot allows a high degree of autonomy.

Development tasks were completed and they are available for researchers and other operational users to validate payloads, improve performances and serve commercial applications.

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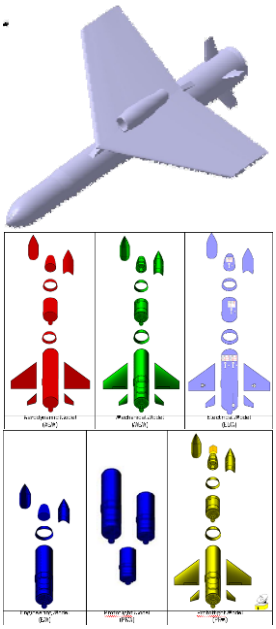
Emerging aerospace technologies

Mission analysis and design

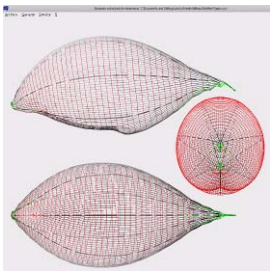
Market research for nanosatellite applications, including databases for existing missions, payloads, subsystems, launchers and other characteristics useful for the analysis of new initiatives.
Design and analysis of several missions for remote sensing and other technology validation.

Aero-ejected launcher



Feasibility studies on small aero-ejected launchers and their subsystems, led by Spanish Aerospace Research Institute (INTA). A huge effort has been carried out to setup a design of a small launcher with national technology, using military carriers. The current research activity focuses on aerodynamics and the three solid-fuel motors. Other areas like electronics and mechanisms are in progress by other partners, as well as market analysis and programmatic issues like certification plans.
The expected performance is 14 kg payload satellite in a 400-km height circular orbit at cost-per-kilogram not larger than existing launching opportunities. The initiative looks for dedicated launchings for future operational missions, in contrast to the current piggy-back options used by most of the nanosatellites dedicated to technology demonstration.
The system is developed under a rigid design-to-cost paradigm, requiring the development of dedicated tools for requirement management and interface control, already available.

Inflatable flying structures



Structural analysis of inflatable structures and their behaviour when acting as buoyancy or lifting shapes. The model can reconstruct the final geometry from initial flat patches, inflation pressure and external airflow.
Currently tested on blimps and other hybrid vehicles under stationary conditions. Applications also on ground flexible structures such hangars or small flexible containers.

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Aircraft propulsion

Test bench for piston engines

A test bench is a really important facility in order to ensure the reliability and performance of small piston engines, which frequently are not developed under the aviation quality standard. A facility to test piston engines up to 100 HP is available, which virtually enables the performance verification of any suitable engine employed in unmanned aviation. The picture shows a ROTAX 911 engine under performance verification to be employed in the HADA vehicle from INTA, a convertible aircraft able to take off as a helicopter and later flight as an airplane.

The facility houses several sensors that are able to measure variables of interest, which typically include crankshaft torque and angular velocity, fuel consumption rates or temperatures and gas pressures at several locations.

Analysis, design and integration of propulsion systems in UAV's

Selecting the most adequate propulsion system is a critical task in any UAV project. Several aspects should be taken into account like engine requirements, limitations, accessories, integration issues, etc. The group has a probed experience in this field, having led the analysis, design and integration of the propulsion systems for several national UAS, including the SANCHO airship or the HADA vehicle.

Customisation of small propulsion systems

In some occasions, piston engine need relevant modifications before their installation. As an example, thrust vectorization systems can cause extreme operation conditions for the lubrication, which require a dry sump. Some other requires adaptation of auxiliary systems like alternators, gears, starters or ignition.

Currently, development of multi-fuel engines and the commanding electronics are the main activities in this field.

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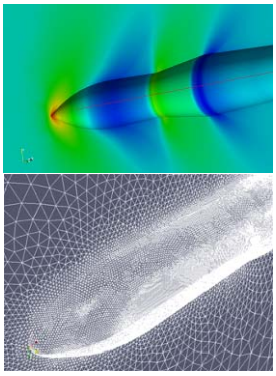
Computational Fluid Dynamics and Numerical Aerodynamics

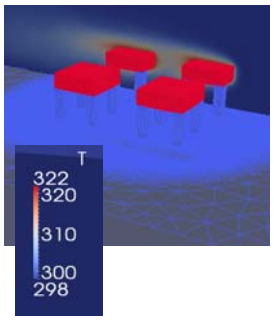
Supersonic flows in external aerodynamics



Supersonic flow simulations are of vital importance to the aerospace engineering community making the use of high performance computing strategies invaluable. Incompressible flow designs are capable of being physically tested (e.g. A tow tank for ships or wind tunnel for subsonic aircraft) at a reasonable cost, but for designs such as hypersonic and supersonic aircraft, CFD simulations may provide the best option due to the high cost and energy demands (and difficulty) of testing in supersonic and hypersonic wind tunnels.

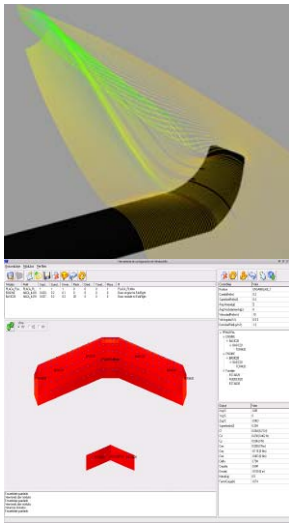
An important research work is under development trying to generate reliable simulations of supersonic flows around rocket's fairing. This capability, coupled with a shape optimization model, should be able to look for the most efficiency geometry for the flying conditions encountered by a nanosatellite launcher.

Heat transfer in forced convection



Heat transfer analysis is just one of the capabilities of the CFD codes with a broad range of applications. As a remarkable effort, some simulations have been conducted in order to predict performance features of the wind sensor of the REMS station, onboard the Curiosity rover on Mars. It is able to measure Martian wind speed and direction as a function of the heat evacuated from small heated dices.

Low speed aerodynamics



Low speed aerodynamics applies to objects moving through fluids of constant density, typically when object speed is below 0.3 Mach. It is a relatively simple flow that involves a lot of industrial design problems. Numerical modelling is a very useful tool as it helps to reduce wind tunnel tests during the design process, which implies lower development costs.

CFD solutions has been applied not only for aerodynamic design, an important effort is conducted in order to increase the CFD skills of undergraduate, as it is an excellent tool in order to enhance student knowledge of fundamental concepts.

Alternative numerical methods, like vortex lattice, have also been embedded in computer programs, helping to estimate aerodynamic characteristics of new designs.

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