Computational and experimental research on aeroelasticity and flutter control at ITA
ITA Today
Identity: public institute under the Brazilian Defense Ministry

Mission: provide research and engineering education in support to the interests of the Brazilian defense and aerospace industry and related institutions.

Vision: a reference school in the engineering of complex socio-technical solutions

Values: academic excellence, meritocracy, professor authority, self discipline, citizenship and social responsibility
Fundamental Course (2 years)
Mathematics – Physics – Chemistry - Humanities

Aeronautical Engineering
- Aerodynamics
- Structures
- Propulsion
- Flight Mechanics
- Design

Aerospace Engineering
- Navigation and Guidance
- Propulsion and Aerodynamics
- Electronics for Space Applications

Civil Engineering
- Structures and Buildings
- Geotechnics
- Water Resources and Environmental Sanitation
- Air Transportation

Computer Engineering
- Software and Information Systems
- Computing Systems
- Computing Methodologies
- Computation Theory

Electronics Engineering
- Applied Electronics
- Microwave Circuity
- Systems Control
- Telecom munications

Mechanical Engineering
- Energy
- Design
- Management and Decision Support
- Turbomachinany
- Mechatronics

Course duration: 5-year - Bachelor's of Engineering
600 students (120 per year)
- Strong selection
- Almost 80 applicants/place
- Full time scholarship
- Full time dedication
- Strict academic requirements
- Spread all over the world

ITA is one of the best engineering schools in Brazil
• **Master, PhD Programs:**
  - Aeronautical and Mechanical Engineering
  - Aeronautical Infrastructure
  - Electronics and Computer Engineering
  - Physics
  - Space Science and Technology

• **Professional Master Degree**
  - Aeronautical Engineering

• **Specialization courses**
  - System Analysis, Aviation Safety, Electronic Defense, Aeronautical Defense Systems
MAIN IMPACTS IN THE NATIONAL SCENARIO

- Aeronautic Industry (EMBRAER)
- Aeronautical Infrastructure
- Air Defense Systems
- Air Transportation & Traffic Control
- Aeronautical Certification
- Automotive (Ethanol Program)
- Space Researches (AEB, INPE)
- Space Industry & Infrastructure
- Telecommunications
- Others spillovers (oil, government, etc.)
ITA & the Future
ITA & THE FUTURE

- Mandate from upper level Brazilian government to duplicate the number of undergraduate students
- More than 500 students would be able to enter ITA each year. The duplication will not jeopardize excellence
- Expansion will require student accommodation, new laboratories, reviewing classroom facilities, adopting teaching aid techniques and planning new courses.
- ITA will require:
  - 200 new faculty positions in the years to come.
  - Visiting professors and post doc recruiting
- **DUPLICATION: OPPORTUNITY TO TRANSFORM ITA** - Major challenges considering expanding with growth:
  - Increased cooperation with industry, research and education institutions;
  - Internationalization and globalization without losing identity;
  - New requirement profiles in engineering education;
  - Alignment with strategic areas: aerospace, defense and main technological challenges in Brazil.
Aerospace Division

Departments

- Aerodynamics
- Design
- Flight Mechanics
- Propulsion
- Structures

Laboratories

- Center of Small Aircraft Development
- Laboratory of Aeronautical Engineering
- Laboratory of Combustion, Propulsion and Energy
- Laboratory of Aerospace Structures

Aerospace Systems

embryo department
Aeroelasticity @ ITA

- Aeroelasticity research devoted to education
- The beginning – Prof Theodorsen (1950’s)
  - undergraduate course
- The middle ages – Prof Bismarck (1970’s)
  - graduate courses

PROF DR MAHER NASR
BISMARCK-NASR
1940 - 2008

Theodorsen’s Problem
Faculty

- People teaching and advising aeroelasticity related research topics:
  - Maurício Pazini Brandão (Aeroelasticity) undergraduate level aeroelasticity teaching
  - Airton Nabarrete (Structural Dynamics, EMA)
  - Luiz Carlos Sandoval Goes (Aeroservoelasticity)
  - Pedro Paglione (Flight dynamics and control, aeroservoelasticity) graduate level dynamics and control of flexible aircraft
  - Maurício Vicente Donadon (composite material aeroelasticity modeling an analysis)
  - Paulo Afonso Oliveira Soviero (Unsteady Aerodynamics) - graduate level unsteady aerodynamics and high speed aerodynamics teaching,
  - Roberto Gil Annes da Silva (Aeroelasticity, Unsteady Aerodynamics) graduate level aeroelasticity and unsteady aerodynamics teaching
  - Flávio José Silvestre (Flight dynamic and control, aeroservoelasticity)
  - Flávio Cardoso Ribeiro (Flight dynamic and control, aeroservoelasticity)
Aeroelasticity related course

• Undergraduate course:
  – EST-56 – Structural Dynamics and Aeroelasticity.

• Graduate courses:
  – AA-220 Unsteady Aerodynamics;
  – AB-267 Dynamics and Control of Flexible Aircraft;
  – AE-249 Aeroelasticity I.
  – AE-250 Aeroelasticity II.
• **Strategic Research goal:** Aerial systems flight dynamic analysis and simulation assuming full nonlinear aero-servo-structural coupling:
  - Nonlinear flow regimes, as the inclusion of Mach number effects for transonic unsteady flows; reduce costs of CFD use to industry-acceptable levels.
  - Nonlinear structures: large displacements, composite material based, nonlinear FEM;
  - Optimized aero-structure design and construction based on aeroelastic tailoring
Graduate Level Research

- Flight dynamics and control of flexible aircraft – some examples...
  - Prof. Flávio José Silvestre – Flight dynamics including flexible aircraft effects - mean axes approach, linearized SD model, quasi steady aerodynamics (2007),
  - Prof. Flávio Cardoso Ribeiro - Flight dynamics including flexible aircraft effects – strain based SD model, stripwise based finite state unsteady aerodynamics (2011),
  - Antonio Bernardo Guimarães Neto - Flight dynamics of flexible aircraft including full nonlinear inertial coupling due to elastic displacements (2013).
Graduate Level Research

• Reduced order aeroelastic model development for aeroelastic stability analysis and response under transonic flow.
  
  – João H. de Azevedo: Efficient state space aeroelastic modeling in transonic flow, based on multiple-input multiple-output (MIMO) concepts in order to simultaneously excite the aerodynamic responses in all the natural modes, and reduce the costs of one aeroelastic root-locus to a single unsteady CFD calculation. (2013), based on previous developed by Alexandre Noll Marques: A unified discrete-time approach to the state space representation of aeroelastic systems. (2007) Hugo Stefânio de Almeida: Extension of the previous work in order to include viscous turbulent flow effects on the aeroelastic stability analysis. (2010)
Graduate Level Research

• Wind turbines aeroelastic modeling and analysis
  – Research goals: Development of aeroelastic numerical tools for optimum wind turbine blade design under steady and unsteady flows taking into account geometrical nonlinearities.
  • Claudio Tavares: Unsteady aerodynamic analysis of wind turbines,
  • Santiago Lugones: Aeroelasticity of wind turbine blades taking into account geometrical nonlinearities, and
  • Willmari Dayana Suarez Hernandez: Scaling rules applied to wind turbines for wind tunnel testing
• National Science and Technology Institute “Smart Structures in Engineering” has objective at the constitution of a research network devoted to the study of advanced structural systems incorporating the concepts of smart materials and structures.
• Smart Structures in Engineering Institute (INCT-EIE) has, as its leading Institution, the School of Mechanical Engineering of the Federal University of Uberlândia and associated laboratories from the following institutions: University of São Paulo (USP) at São Carlos; Federal University of Rio de Janeiro (UFRJ/COPPE); University of Brasilia (UNB); São Paulo State University at Ilha Solteira (UNESP); Federal University of Campina Grande; and Technological Institute of Aeronautics (ITA).
The Institute **INCT-EIE** has the collaboration of the following international institutions:

- Center for Intelligent Material Systems and Structures – CIMSS
- Virginia Polytechnique and State University, USA;
- Department of Mechanical and Aerospace Engineering, Carleton University, Canadá;
- Dynamics Research Group, Institute of Sound and Vibration Research, Southampton, UK;
- Laboratoire d'Ingénierie des Systèmes Mécaniques et des Matériaux, Institut Supérieur de Mécanique de Paris, France;
- Texas Institute for Intelligent Materials and Structures, Texas A&M University System College Station, USA;
- Department of Mechanical Engineering, Dalhousie University, Canada;
- Centre for Applied Dynamics Research, School of Engineering, University of Aberdeen, UK;
- **Active Aeroelasticity and Structures Research Laboratory, University of Michigan, USA.**
• ITA participation:
  – KleberCastão -Line 1: Dynamics and Control of a nonlinear aeroelastic structure under the effect of magnetorheological fluids (2013)
  – Vinicius Picirillo* - Line 2: Dynamics and Control of a nonlinear aeroelastic structure modeled with Shape Memory Alloys; (2012)
  – Carlos Eduardo de Souza** Line 3: Structural dynamics of large displacements composite material structures - mean axes approach, linearized SD model, object oriented unsteady vortex lattice (2012)

* , ** - already graduated
Research and Development
INCT-EIE - some examples

• Theoretical developments:
  – Typical section aeroelastic control based on Magnetorheological (MR) dampers;
  – Typical section aeroelastic control based on Shape memory alloys (SMA) actuation systems;
  – Blade Sailing aeroelastic response control using smart materials (MR and SMA)
  – Highly flexible composite structures under large displacements
Typical section aeroelastic control based MR dampers

- **Nonlinear aeroelastic model**
- **Wind tunnel testing**

\[ F_B(\dot{x}) = f_d(i) \text{sgn}(\dot{x}) + c_0(i)\dot{x}, \]
Typical section aeroelastic control based on SMA actuation systems

- Induced temperature
- Phases **Martensite** → **Austenite**
- Significant thermal, mechanical and electrical changes between $M_e A$.
- Large stress and strain recovery.
- Hysteretic behavior

**High Temperature**  **Low Temperature**

![Diagram showing the transformation between martensite and austenite phases](image)
Typical section aeroelastic control based on SMA actuation systems

- Control system actuation system based on SMA components;
Blade Sailing aeroelastic response control using smart materials (MR and SMA)

- Aeroelastic Modeling Assumptions
  - Torsion and lead-lag degrees-of-freedom neglected: small Coriolis forces/built-in twist
  - Linear aerodynamics: stall and reverse-flow effects neglected
  - Inflow effects neglected: small rotor thrust
  - Uniform blade mass/flapwise stiffness/airfoil
  - Time-dependent rotor rotational speed
Blade Sailing aeroelastic response control using smart materials (MR and SMA)

- **Flapping Planar Blade Element**

- **Flow Velocity Components for the WOD Conditions**

- **Blade Element Theory**

Moments due to the inertial forces, ship airwake, centrifugal forces, droop/flap stops, gravity and smart materials

\[ M_i - M_{as} + M_c + M_s + M_g + M_{SM} = 0 \]
Blade Sailing aeroelastic response control using smart materials (MR and SMA)

- **MagnetoRheological Damper (MRD)**
- The viscosity of a magnetorheological fluid (MRF) can be controlled by the application of a magnetic field
- The stress-strain relation of the Bingham viscoplastic model is often used to describe the behavior of a MRF
- In this model, the plastic viscosity is defined as the slope of the measured shear stress versus shear strain rate data
- Thus, for positive values of the shear rate, $\dot{\gamma}$, the total stress is given by:
  \[\zeta = \zeta_{(field)} + \xi \dot{\gamma}\]
- $\zeta_{(field)}$ is the yield stress induced by the magnetic field and $\xi$ is the fluid viscosity
- A great number of authors have adopted this mathematical model of MRD, which consists of two elements: an element modeled as the Coulomb friction placed in parallel with a linear viscous damping element
Blade Sailing aeroelastic response control using smart materials (MR and SMA)

- **Simulation Results – MRD Effects**
  - The simulation results show the effect of the nonlinear MRD on the blade flapping response, for the same gust conditions that are used in the SMA simulations.
  - The applied current to the damper is $i = 0.25$ A. With this value of current, a significant MRD effect on the blade-sailing phenomenon can be observed.
  - It is obtained a reduction of approximately 30% in the flapping vibrations for the considered MRD element.
  - Therefore, it is possible to avoid tunnel strikes by using these smart-material devices.

MRD response: $K_f = 0.1$ and $\omega_f = 5$ rad/s, $i = 0.25$ A
Highly flexible composite structures under large displacements

• Collaborative work UMich/A²SRL – Prof. Carlos Cesnik

• Motivation:
  – Increased use of UAS - Unmanned Aerial Systems -which are now having its use extended to the civilian services.
  – Micro Air Vehicles - MAVs.
  – Highly flexible lifting surfaces.
  – Evolution in construction techniques and in materials allowed the weight reduction of airframes, better power-to-weight ratio: laminated composites.
  – Flat plate wings (wings without moving parts).

• Goals:
  – Obtain a nonlinear aeroelastic frame dedicated to analysis of composite at plates subject to large displacements and rotations.
  – Couple the UM/NLAMS corotational shell finite element frame to an UVLM aerodynamic formulation.
  – Characterize Limit Cycle Oscillation (LCO) through time response simulation.
  – Investigate the influence of lamination parameters in the LCO response behavior.
Highly flexible composite structures under large displacements

**Time response**

Direct integration methods:
- Newmark
- Generalized-$\alpha$

**Moving frame**

Coordinate systems are used to describe the large rotations in the moving system.
Highly flexible composite structures under large displacements

- Implemented code UVLM only
- Domain discretization: wing and wake
- Wake shedding scheme: limitation on the wake panel chord. Time step defined as: $c_P/(v_{\text{inf}} n_x)$.
- Wake rollup
Complementary Research

• Further applications under development aiming the the aeroelastic control through:
  – piezoelectric actuation for morphing wings
  – passive aeroelastic control for improving aeroelastic stability and response

• Flight dynamics of highly flexible vehicles
  – Mainly built based of composite materials
  – Simplified structural anatomy \(\rightarrow\) nonlinear dynamic behavior large displacements
Flight Dynamics of Very Flexible Vehicles


• A computational tool was developed and used to analyze how flexibility affects the airplane flight dynamics.

• A nonlinear beam model was applied for structural dynamics representation considering large displacement effects.

• For aerodynamics calculations, the strip theory was used including three aerodynamic modeling approaches, a quasi-steady, quasi-steady with apparent mass effects and full unsteady aerodynamics representation.
Aeroelastic Tailoring

• “Aeroelastic tailoring using Fiber orientation and topology Optimization”
  Daniel Milbrath De Leon, Carlos Eduardo de Souza, Jun Sérgio Ono Fonseca, Roberto Gil Annes da Silva (IAE/UFRGS)
• Aeroelastic tailoring – passive aeroelastic control
• Aeroelastic Optimization Method by Finite Difference (AOMFD) →
• Difficult to tailor the fibers – further investigation on composite material manufacturing.
Research and Development

- **Experimental developments**: Main focus wind tunnel testing of aeroelastic systems.
  - High aspect ratio flexible wing wind tunnel flutter testing;
  - Moderate aspect ratio flexible wing wind tunnel flutter testing;
    - Isotropic material, ballasted wing
    - Anisotropic material wing fiberglass-epoxy composite wing
Research Facilities

- ITA low speed wind tunnels: Feng Lab. Open Circuit Wind Tunnel

Blower type – aerodynamic teaching low speed aero R&D facility

New Blower Type – Aeroelastic Wind tunnel (to be delivered 2012 / INCT-EIE)
Research and Development

- High aspect ratio flexible wing wind tunnel flutter testing;
  - Isotropic material, ballasted wing (Feng Wind Tunnel)
- The design of flexible wings which flutter occurs at low speed flow
- The first wing model designed is similar to Dowell and Tang’s (2002) wing and the second was developed in order to study flutter mechanism with CG position variation

Research and Development

- Flutter onset predicted by linear theory (Nastran/DLM and ZAERO)
- Accelerometer output signal power spectral density (Sheta et al, 2002) for identification of experimental flutter onset
- LCO behavior governed by
  - Structural nonlinearities (Dowell-Hodges beam like, Dowell and Tang, 2002)
  - Nonlinear aerodynamic – separated flow effects

Research and Development

- Moderate aspect ratio flexible wing wind tunnel flutter testing;
  - Anisotropic material: wing carbon fiber-epoxy composite wing,
  - Low speed blower wind tunnel - ITA
Future applications

  - Measurements of unsteady pressure
    Aerodynamic loading – PVDF Foils for buffet pressure measurements (Luber, W. Recent Advances on Transonic Aeroelasticity – ICNPAA 2010, Brazil)
FLUTTER CONTROL OF ORTHOTROPIC SHELLS WITH EMBEDDED PIEZOELECTRIC MATERIALS

Alex Evangelista da Silva and Maurício Vicente Donadon

This work focuses on the development of a finite element formulation for orthotropic shells with attached piezoelectric actuators for flutter control.
FLUTTER CONTROL OF ORTHOTROPIC SHELLS WITH EMBEDDED PIEZOELECTRIC MATERIALS

- **Preliminary results indicate that piezoelectric materials are good smart material candidates for the aeroelastic instability control of composite laminates.**

- **The preliminary results also indicate that the piezoelectric stress stiffening significantly affects the flutter characteristics of composite shells.**

- **The correct application of such materials may lead to more efficient and safe designs.**
– **Clayton Marqui – Line 4** (2015) – Methodology for analyzing the aeroelastic response due to buffet based on time series and pattern recognition (Fuzzy). The numerical results shall be validated by wind tunnel testing (aeroelastic apparatus).

– **Douglas Bueno – Line 5** (2015) Investigation on real-time active suppression of flutter using the Takagi-Sugeno fuzzy model solved via LMI shall be used to stabilize an airfoil limit cycle oscillation airfoil with control surface freeplay

Future Research Challenges

• Nonlinear reduced order modeling for low speed separated flow unsteady aerodynamics – model development through unsteady wind tunnel testing (TR-PIV) validation (with Aeronautics and Space Institute);

• Computationally efficient use of CFD for aeroelastic analyses in the transonic regime; extension of the capability to handle LCO and other nonlinear phenomena with large displacements;

• **Design and construction of unhumanned aerial systems for in-flight validation of aeroelastic modeling and analysis**;

• **Wind tunnel testing of aeroelastic systems using smart materials for actuation / data acquisition**

• Wind mills modeling and testing for optimized aero-structural design (application of composite material based aeroelastic tailoring, aeroelastic energy harvesting).
Laboratory of New Concepts in Aeronautics
What is LNCA?

• Visionary concepts in aeronautics:
  – new geometries and technologies;
  – higher energetic efficiency and lower environmental impact;
• Industry needs: Demand from the aviation future, guide R&D in the direction of this future vision (ecological demands, economic, social and political);
• In academia it is found a fertile substrate:
  – plurality of knowledge, multidisciplinary, training and contact with people
• And how? Modeling and simulation according to the identified needs to explore a particular design concept
Vision

• The development of Laboratory of New Concepts in Aeronautics aims to create an unique environment in Brazil for developing innovative philosophy in aeronautical design considering “boundary conditions” as:
  – Climate change, greenhouse gas emissions reduction
  – Rising prices of resources - impact the economy worldwide.
  – Social affairs - aging population demanding new travel conditions.

• The focus of the research lines and innovation for the Laboratory of New Concepts in Aeronautics will consider the complex aviation system from different viewpoints.

• The aircraft conceptual design now includes a different sort of unconventional inputs → economy, social and ecologic affairs are considered holistically.

• Research orientation: Based on a proposed core competency of the lab, application of modeling and simulation methodologies in aircraft design for investigating new aeronautical concepts.
Laboratory Mission

• Opportunity for redefining engineering → innovation and invention as well as environmental sustainability,

• Identification of research opportunities and needs of the productive sector,

• Investment in creation, innovation and entrepreneurship within the academic environment.

• Beneficiaries: Aerospace and Defense, as well as Undergraduate and Graduate programs at ITA and associate partners.
Strategy

• Innovative laboratory with the primary goal of being a "think thank" driven by Aeronautical needs
• Identification of the aviation scenario in the future.
• Innovation seeking initiative, for aerospace industry, teaching and academic environment.
• Different knowledge areas in a single place, economic and socio-political affairs, environmental, systems engineering, flight physics modeling and simulation, computational sciences, virtual reality
• Multidisciplinary approach - futuristic scenarios as input conditions for the modeling and simulation of an aerospace system to be designed for the future
ITA’s Tradition, Knowledge and Skills

Up to now, the Division of Aeronautical Engineering ➔ Flight Physics Oriented Research as the “core business”:

- Applied (numerical and experimental) aerodynamics
- Computational Fluid Dynamics
- Nonlinear computational structural dynamics and aeroelasticity
- Flight dynamics and control of aeroelastic vehicles
- Lightweight composite material structures
- Fracture mechanics, fatigue and stability of composite structures
- Multidisciplinary Design and Optimization - Aerospace Systems
- Unmanned Aerial Vehicles – design and systems integration.
- Numerical Aeroacoustics,
- Aircraft propulsion - engine emissions, biofuels
- Nonlinear computational structural mechanics (dynamic impact on composite materials)
Modeling and Simulation

• The way to predict whether the conceptual design reached the goal or not;

• Design oriented, open source, numerical models embedded in user friendly computational framework;

• Collaborative development with other design oriented tools;

• Drivers for investing in further refined solutions per request – academic research on high fidelity modeling and analysis
Some Research Topics

- **Aviation Ecological Aspects** (reducing emissions, alternative energy, noise)
  - Physical-chemical composition of alternative fuels and derivatives with a focus on reducing greenhouse gas emissions, cleaner and non-fossil fuels (biofuels);
  - Study the impact of aircraft the increased size in the airport infrastructure and surroundings;
  - Condensation trails (contrails) impact on cloud formation, emission of particulate and impact on clouds;
  - Study aeronautical configurations with restrictions on noise emission due to aerodynamics and propulsion.
  - Electric Propulsion, energy harvesting.
Some Research Topics contd

- **Socioeconomic and political aspects of the future** (including aviation, flight safety, continuing airworthiness and operating costs):
  - Flight Safety - accidents and intentional acts or threats;
  - long-range, time-efficient, ultra-safe flight operation;
  - Customer-oriented design; Ride quality, comfort and low cost
  - Reduction of operational costs by reducing the aircraft grounded time – structural heath monitoring, new materials
  - Unmanned Aviation - cargo and sensorcraft, (lighter-than-air);
  - Study of social impacts arising from unconventional aircraft concepts, engineering interiors - cabin.;
  - Cognitive and Intelligent systems minimization of human interference while preserving the robustness;
**Flight Physics Modeling and Simulation**

- Integrated Flight Dyn. Aeroservoelasticity
- Aeroacoustics Noise Emission
- Lightweight Structures Special / Composite Materials
- Integrated Aircraft Propulsion System

**LNCA Framework**

**Surrogate/ROM (NL)**

**MDO**

**Conceptual Design**

**Green, Ultra Safe, Integrated Mobility, Economic/Social Affairs**

**Industry Regional Benefits (Aerospace & Defense)**

**Academic formation R&D Orientation**
Development of dynamic models of a flexible aircraft and validation through aeroelastic flight testing (Silvestre, 2012)
Assess the impact of acoustic emissions for new A/C configurations

- Field average speeds through experiments or RANS simulations.
- Jet fluctuations using - Parabolized Stability Equations - PSE)

Fluctuations $\rightarrow$ acoustic analogy (Ffowcs Williams and Hall, 1970)

- Low computational cost noise generation prediction (Cavalieri, Jordan & Gervais 2012).
- Validation - wind tunnel testing aerodynamic measurement $\rightarrow$ jets / wing interaction
A SENSITIVITY INVESTIGATION ON THE AEROELASTIC DYNAMIC STABILITY OF SLENDER SPINNING SOUNING ROCKETS

Development of design criteria for aeronautical composite material structures subjected to fatigue-induced damage

Nonlinear Aeroelasticity based on Vortex-Lattice Method and a Laminated Shell / Beam Corotational Finite Element (Souza, Silva and Cesnik 2012)
Propulsion systems emissions

Effects of Component Size and Cooling Air Flows on the Performance, Weight and Dimensions of High and Ultra-High Bypass Ratio Turbofan Engines

- Engine performance modeling
- Cooling flow modeling
- Component efficiencies modeling
- Estimates of engine weight and dimensions
- Models integration

Source: The ICAO Environmental Report – 2010
The Laboratory at ITA

- The leading division research projects management,
- Research ideas inspiration for ITA faculty / students
  - Drivers for academic research
  - Fund-raising, fostering options
- Structuring Projects – Laboratory startup
  - Industry / Government needs
Available knowledge base at ITA:

- **Division of Mechanical Engineering**: Market Intelligence, rapid prototyping, propulsive systems, robotics and mechatronics systems,
- **Division of Electronic Engineering**: dynamic simulation and control systems, integration of aeronautical systems.
- **Division of Computer Sciences**: simulation and distributed processing, software engineering, virtual reality.
- **Division of Civil Engineering**: aviation economy, environmental economics, architecture and energy efficiency of airport facilities, aircraft climatology, environmental impacts: aeronautical pollutants, economic-ecological modeling, environmental modeling.
- **Division of Fundamental Sciences**: Applied chemistry to combustion of energetic materials.
ITA associate Labs / Programs

• Laboratory of Aeronautical Engineering
  – Wind tunnel facility
• Laboratory of Aerospace Structures
  – Clean room, composite material manufacturing,
  – Static and dynamic (impact) structural testing
• Center of Small Aircraft Development
  – UAV development, small aircraft building undergraduate course (Aerospace design class)
• Laboratory of Combustion, Propulsion and Energy
  – Small size turbine

• Professional Master in Aviation Safety and Continuing Airworthiness
• Professional Master Program in Aeronautical Engineering
Further Applications in Aerospace / Defense Systems

• Space systems design – MDO for launch vehicles:
  – 14-X / VSB-30 integration for hypervelocity experiments.

• Aircraft selection: Air Force fleet replacement or modernization, simulation based RTLIP/B

• Novel Air systems: UAV, Nano Sats, MAV,…,

• Defense systems: Aircraft with new weapon configuration
  – Virtual Flight Testing, DOE;

• Simulation-based defense systems evaluation,
  – Operation Theater simulation.
Thank you!