



SAPIENZA
UNIVERSITÀ DI ROMA

Dipartimento di Ingegneria
Meccanica e Aerospaziale

Welcome to DIMA



Paolo Gaudenzi

Director of Department of Mechanical
and Aerospace Engineering

The Department of Mechanical and Aerospace Engineering - DIMA - is part of Sapienza University of Rome.

DIMA inherits the tradition of the School of Industrial Engineering and the School of Aerospace Engineering, founded in 1913 and 1926, respectively.

We are about 100 people, including faculty members, technicians and administrative staff.

We offer 2 Bachelor Degrees and 3 Master Courses plus 2 Programs entirely taught in English, as well as three Ph.D. programs and five Professional Master Courses.

Our research activities are focused on theoretical and applied mechanics, fluid dynamics, aerospace propulsion, technological projects, mechanical and thermal measurements, machines and industrial plants management, energy and power systems, buildings, space systems and structures.

The department is located in the premises of the Faculty of Civil and Industrial Engineering of Sapienza, on the Esquiline Hill, near the Flavian Amphitheatre, also known as Colosseum, and next to the church of San Pietro in Vincoli.





- PEOPLE
- EDUCATION
- RESEARCH
- THIRD MISSION



PEOPLE



58
Faculty
Members

36
Research
Fellows

22
Staff

3000+
students

Director

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Administrative Responsible

Dott.ssa Bianca CIABATTI
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Full Professors

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Carlo Massimo CASCIOLA
Guido COLASURDO
Guido DE MATTEIS
Zaccaria DEL PRETE
Dionisio DEL VESCOVO
Fausto GAMMA
Paolo GAUDENZI
Giorgio GRAZIANI
Luciano IESS
Franco MARINOZZI
Marcello ONOFRI
Franco RISPOLI
Giovanni P. ROMANO
Raffaele RUSCITTI
Enrico SCIUBBA
Massimo TRONCI
Mauro VALORANI
Francesco VENIALI

Associate Professors

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Alberto BERSANI
Giovanni B. BROGGIATO
Francesca CAMPANA
Giuliano COPPOTELLI
Alessandro CORSINI
Francesco CRETA
Nicola DE DIVITIIS
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Annalisa FREGOLENT
Paolo GASBARRI
Diego LENTINI
Luca MARINO

Francesco MASSI
Franco MASTRODDI
Francesco NASUTI
Renato PACIORRI
Sergio PIROZZOLI
Fulvio STELLA

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Francesco COSTANTINO
Antonio CULLA
Giulio DI GRAVIO
Lorenzo FEDELE
Annamaria GISARIO
Paolo GUALTIERI
Luca LAMPANI
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Claudio SCARPONI

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Matteo BERNARDINI
Daniele BIANCHI
Fabiano BINI
Domenico BORELLO
Roberto CAPATA
Luca CEDOLA
Luca CORTESE
Alberto GIACOMELLO
Simone MELONI
Eduardo PALERMO

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Ioannis ASPROULIAS

Andrea CALABRISO
Gabriella CALDERARI
Giammarco CIALONE
Pietro Paolo CIOTTOLI
Katuscia CIPRI
Elisabetta CONTI
Fabrizio DE MARCHI
Mariano DI BARTOLOMEO
Marco EUGENI
Sara FEUDO
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Andrea MARCHEGIANI
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Emanuele RIZZUTO
Giacomo ROSSI
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Alessandro TALLINI
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Claudia TORO
Luigi VECCHIONE
Paolo VENTURINI
David VOLPONI
Alessandro ZAVOLI

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Laboratories

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Francesco RAPANOTTI
Maximo O. CAPPONI
Antonello BINNI

EDUCATION

BACHELOR AND MASTER OF SCIENCE

Bachelor and Master of Science programs last three and two years respectively. They have a fixed number of students, admitted by competitive examination. DIMA offers two Bachelor (Aerospace and Mechanical Engineering) and three Master of Science programs (Aeronautical, Space and Astronautical, and Mechanical Engineering). Specific curricula are entirely taught in English.

Ph.D. PROGRAMS

Ph.D. is the highest level of university education and can be accessed after the Master of Science. The three-year research program is accessed through a competitive examination and it is reserved to a limited number of participants.

DIMA offers three Ph.D. programs (Aeronautical and Space Engineering, Industrial and Management Engineering, and Theoretical and Applied Mechanics).

PROFESSIONAL MASTER PROGRAMS

The one-year Master Programs can be accessed after the Master of Science. They offer highly specialised courses, designed to meet the current demands of the industrial world.

DIMA offers five Professional Master Programs in the fields of Energy, Space, Aeronautical, and Inventive engineering.





Academic Council
Aerospace Engineering
Chair: Prof. Guido De Matteis
www.ingaero.uniroma1.it

Aerospace industry has attained a role of primary importance both in Europe and worldwide as a driving force of economic growth and as a technologically intensive supply chain bringing about innovation in a great number of industrial sectors. All the main industrialized countries now consider aerospace industry as a strategic sector in terms of added economic value, social relevance and contribution to the general well being and safety of its citizens. As such, aerospace industry is in continuous search for talented and motivated young engineers to be employed in a European or international context and, for this to be feasible, requires constant and widespread access to an up-to-date knowledge base for the efficient training of its employees.

In this context, we view our Aerospace Engineering program here at Sapienza as a tight-knit community of students and professors that on the one hand operates in close collaboration with industry personnel, research centers and institutions, and on the other hand is setting the following standards for the educational system: Aspire, reach and maintain levels of excellence – Promote and reward a sense of responsibility, the value of knowledge and passion for studies and research – Maintain a pioneering spirit with respect to the constant development of technology – View the aerospace sector as a unique opportunity for students and researchers to contribute to crucial technological challenges in communications, space exploration and safety – Promote international and multicultural exchanges in view of the globalization of the technological markets – Promote awareness of the social and environmental implications of research and development activities.

accreditations



Academic Council
Aerospace Engineering
Chair: Prof. Guido De Matteis
www.ingaero.uniroma1.it



Bachelor Degree in Aerospace Engineering

The aim of the curriculum is to give the students a solid basic grounding in mathematics and physics and ensure that they have knowledge of the fundamental aspects of the required disciplines of Aeronautical Engineering and Space Engineering. The experimental and numerical workshop modules help to develop interdisciplinary and applicable skills that are also useful for the industry. Upon completion of the Personal Study Plan, the student will be prepared to operate effectively in the job environment. The general education provided by the course, together with the independent work, enables the graduate to acquire further specific skills. At the same time, the 3-year Degree Course has the essential function of preparing students for the Graduate Degrees in Aeronautical Engineering and in Space and Astronautical Engineering.

∞

Master of Science Degree in Aeronautical Engineering

The MSc Degree in Aeronautical Engineering takes the students to an advanced level of disciplinary and professional training and specific engineering skills, enabling them to address complex problems that require the analysis, development, simulation, and optimisation of the various components of a fixed or rotating-wing aircraft. The learning process focuses primarily on the most advanced research and design tools and on the innovation in the aeronautics industry with particular reference to improved efficiency, reduction of weight, and of chemical and noise pollution.

Building upon with the solid foundation of the Bachelor's Degree Course, the two further years of the Graduate Degree deepen the same methodologies and applications.

∞

Master of Science Degree in Space and Astronautical Engineering

The MSc Degree in Space and Astronautical Engineering equips the students with advanced disciplinary and professional training and specific engineering skills, enabling them to address complex problems that require the use of modern methods of analysis, design, simulation, and optimisation. The course also provides an appropriate level of expertise in basic space access technologies, the utilisation of terrestrial orbits, and space exploration, with particular reference to the systemic and scientific aspects of launch vehicles, interplanetary missions by astronautical vehicles, and manned space missions. The student learns to use the most advanced research and design tools for innovation in the space industry, e.g. improving the performance of launch systems to reduce the cost of entry into orbit per unit mass of payload, payload mass reduction (for platforms, sensors, and power units), and increasing the efficiency and utilisation of the available on-board power. These areas of investigation are re-elaborated in relation to a human crew, placing particular emphasis on life support technologies and systems in space.



Aerospace Engineering course is entirely taught in English (MSc Degree)



Academic Council

Mechanical Engineering

Chair: Prof. Franco Rispoli

www.ingmecc.uniroma1.it

Mechanical Engineering Degree have been established at Sapienza University of Rome in 2000, as a natural evolution of the historical five-year *curriculum studiorum* in Mechanics, one of the pillar of the engineering culture of the former School of Engineers of papal Rome founded by Pope Pius VII in 1817, which in 1824 merged with the University of Rome.

With an eye to the modern view of Mechanical Engineering, the present Course keeps the original educational spirit and objectives, combined with the innovation in the teaching approaches, designed to transfer the academic research to teaching experiences and methodologies. Our School preserves and advances knowledge in the fields of mechanical engineering and shares this knowledge with students, providing them with background knowledge and technical skills, teaching them how to approach new scientific challenges with innovation-oriented thinking. Presently the School has more than 70 faculty members, including full and associate professors and researchers. The School of Mechanical Engineering offers training to professionals with advanced university education in planning, designing, and managing complex activities associated with the development of scientific and technological research and the promotion of research in a broad range of disciplines. The educational goals are pursued by strengthening mathematical skills and advanced physical understanding, in order to tackle complex mechanical problems ranging from the design of systems and machines (conceptual and detailed design), of processes, the development of technologies, systems, manufacturing processes as well as production and management, organization and safety of the associated industrial and technological innovation.

accreditations



Academic Council
Mechanical Engineering
Chair: Prof. Franco Rispoli
www.ingmecc.uniroma1.it



Bachelor Degree in Mechanical Engineering

The Bachelor in Mechanical Engineering prepares individuals to apply mathematical and scientific principles to the design, development, and operational evaluation of physical systems. Students are also concerned with the flow of matter, such as air and water, and the transfer of heat. Practical applications, theory, computer simulated coursework and evaluations are all methods used to develop skills. Core curriculum covers mathematics, design, engineering concepts, and many others allowing for a diversification of information.

With a Bachelor in Mechanical Engineering program, students are prepared for professional practice in an era of rapidly advancing interdisciplinary technology. Those holding a Bachelor in Mechanical Engineering degree can have careers in industry and government in areas related to fluid, solid, thermal, and mechanical systems. Many students pursuing a Bachelor in Mechanical Engineering continue on to the graduate program.

Master of Science Degree in Mechanical Engineering

The Master of Science in Mechanical Engineering aims at training young engineers with an advanced education, providing them with skills in designing, planning, and managing complex activities of research and development in an industrial environment. This goal is achieved by means of a broad training proposal based on advanced mathematics and physics, and professional expertise targeted to the solution of complex engineering problems concerning the design of processes, plants, systems, devices, and machines. Engineering Design professionals educated at Sapienza can work as technology specialists in a wide range of fields, including manufacturing, mechatronics, transportation (automotive, naval, aeronautical and railroad), conventional and renewable energy production, biomechanics and many others. In these settings mechanical engineers are responsible for design, testing, management, research and development.



Mechanical Engineering
Design course is entirely
taught in English
(MSc Degree)

PhD Programs

Aeronautics and Space Engineering Chair Prof. Mauro VALORANI

<https://web.uniroma1.it/aerophd/>

The PhD program in Aeronautics and Space Engineering represents the highest level of university education in the aerospace engineering field offered by Sapienza. The PhD program aims at developing the skills needed to carry out high quality research activities in the aerospace field. The characteristics of pure and applied research in the aerospace industry have led to a strong link between major companies and national and international institutions, particularly those with head offices in Lazio. In this collaboration several scholarships have been funded by major corporations and companies in the sector such as ESA, ASI, Thales Alenia Space, Avio, Telespazio, Elv, Selex, etc.

The main areas where research is carried out by faculty and students of the PhD program are: numerical and experimental fluid dynamics, aeroelasticity, dynamics and control of aerospace structures, design and testing of materials and innovative structures, flight mechanics, space missions, combustion, efficiency and emission control in aircraft engines, space propulsion, design of launchers, turbomachinery for aviation and space, dynamics and control of helicopters.

Theoretical And Applied Mechanics Chair Prof. Antonio CARCATERRA

<https://web.uniroma1.it/dottomta/>

The PhD program in Theoretical and Applied Mechanics deals with rigorous theoretical, numerical and experimental approaches to solve new problems of Applied Mechanics. Applied Mechanics actually combines concepts and techniques from Theoretical Mechanics and other branches of Mathematics to attack complex problems of interest for engineering, thus contributing to the growth of new theories and mathematical constructions inspired by issues arising from emerging technologies. Aim of the program is providing the student with a sound basis of mechanics and the related mathematical foundations needed to independently attack and solve new research problems. In this framework, students are called to master and develop innovative experimental and numerical techniques instrumental to the application of original theoretical insights to emerging fields. The program is based on a first block devoted to fundamental aspects, two parallel blocks dealing with experimental and numerical methods in mechanics, respectively, and a third block dealing with specific applications. The research focuses on a specific branch of applied mechanics (solid mechanics, fluid mechanics, mechanical systems) and culminates in the final Doctoral Thesis.

PhD Programs

**Industrial And Management
Engineering**
Chair Prof. Massimo TRONCI

<https://web.uniroma1.it/ingindgestphd/>

The PhD in Industrial and Management Engineering plays an active role in the development of the innovation cycle, going deep into the following fields: innovation-evolution cycle of products, processes and organizations, in terms of economic, environmental and social sustainability; techniques of evaluation and transfer to stakeholders of the developed methodologies; network of companies, harmonizing and governing requirements through models of coordination, collaboration, sharing of risks and rewards; network of innovation, to meet strategic and tactical competitiveness and sustainability of different organizations; implementation of pilot projects at various levels. The approach of the PhD course can lead to significant results that support the industrial and economic development process, both at a level of individual companies or networks. The PhD Program in Industrial and Management Engineering, giving advanced skills in the field of innovation, meets the need to create a profile of PhDs to act in the areas of research and development, design and management of innovative production and service systems with a vision that ensures the consistency of the technological choice with the business strategies of different industries.

Professional Masters

Satellite Systems and Services
Chair Prof. Paolo GAUDENZI

<http://www.mastersatelliti.it>

The Master course in Space Systems and services, organized with the support of space agencies, space companies, and public bodies aims at developing an advanced professional education and training activity in cooperation with the academia. The Master responds to the need for advanced education in the space sector, especially towards the development of both technical and management capabilities and skills. The Master is oriented in particular towards the new markets of the “space based” services in the area of remote sensing, telecommunication, and navigation that are very promising in terms of benefits for the population and for the improvement of its daily life standards. The course encourages the international dimension of the educational process. Lectures are coming from universities, companies and space agencies from all over the world. The Master is organized in two semesters: the first is devoted to regular classes in which theory, applications, case studies, and teamwork activities are combined. At the end of the semester the students prepare a technical and economical proposal for a complete satellite system meeting the requirements of a proposed mission. The students spend the second semester performing an internship in a company under the joint tutorship of a University professor and a company manager. The course is taught in English and in Italian.

Professional Masters

Space Transportation Systems

Chair Prof. Marcello ONOFRI

<https://web.uniroma1.it/mastersts>

This Master Course aims at filling the gap between industrial needs and educational programs offered by the European Universities involved in the Space Transportation sector. In the job market, a high demand exists for the profile of a System Engineer with expertise in Space Transportation/ Analysis and Design of space vehicles and launchers. Despite these needs, the curricula of the European universities cover only partially the specific needs of this sector. This training course for graduate students is founded upon one of the pillars of the European space policy, which is precisely to guarantee independent access to space, so as to consolidate its leading position in the international scenario. STS Master is a highly innovative initiative, unique in the EU context, which is aimed at fostering: the assessment of transversal skills and promote the professional development; the hiring of young graduate engineers in European and Italian industries and in Space Agencies; the relationship between education and industry, which is the founding concept of the Master; the best specialists in the field of Space Transportation Systems both from Universities and Industries are involved in the planned activities and will share their experience with all trainees.

Civil Aviation Management

Chair Prof. Claudio SCARPONI

<http://www.masteraviation.it>

The main target of the Master is the advanced education of young people, who have a Master Degree in Engineering, towards high-level Management jobs in Civil Aviation environment. The Master is jointly organised by Sapienza Mechanical and Aerospace Engineering Department (DIMA), Italian Civil Aviation Authority (ENAC), Rome Society of Professional Engineers and with the contribution of Centro Studi Demetra. All these contributors guarantee to the attendants to gain specific competences that allow them to obtain good job opportunities in airlines, certified maintenance companies, airports, handling companies, and also in National and European regulators. It is a one-year, full time study course (1500 hours, including an internship at an aviation company), directed to students interested in developing a solid professionalism in the field of Civil Aviation, both in Italy and in Europe. Furthermore, the Italian Civil Aviation Authority (ENAC) provides the attendants with a special reduction of the number of years needed to obtain significant job positions in aviation companies.

Professional Masters

Energy Efficiency and Renewable Energy Sources

Chair Prof. Franco RISPOLI

<https://web.uniroma1.it/masterefer>

The Master in Energy Efficiency and Renewable Energy Sources is aimed at professionals who want to increase their knowledge in the energy field, focusing on resource use, environmental sustainability, energy efficiency and energy production from renewable sources.

The Master is addressed to engineers and professionals such as architects, physicists, chemists, science graduates, and economists.

The Master is composed of 11 modules and provides technical in-depth analysis including different aspects of the sector within context of short, medium and long terms. Technical requirements of energy plant, methodologies and interventions for energy efficiency, plant management, and waste-to-energy are the main topics of the Master in Energy Efficiency and Renewable Energy Sources. Furthermore, Master topics are deeply correlated with the new ICT technologies, with the perspective of smart city, Big Data, and the Internet of Things. The Master modules are organised in technical inspection, exercises and projects providing more practical details of the proposed materials. An entire module is dedicated to job-market orientation and evolution.

Inventive Engineering

Chair Prof. Antonio CARCATERRA

<https://web.uniroma1.it/masterie>

The Master in Inventive Engineering provides students with the opportunity to acquire in-depth knowledge in developing advanced multidisciplinary technologies, planning and development of new technical products, identification of strategies focused on intellectual property, rights protection, sustainability, and market analysis of the new products. The Master program is composed by theoretical courses held by experts and in industrial innovation projects in collaboration with partner companies. The Master course is addressed to students interested in developing practical skills in the following fields:

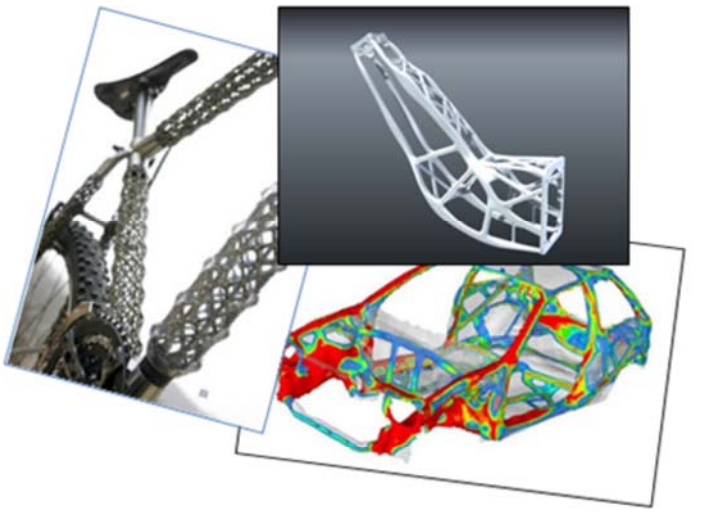
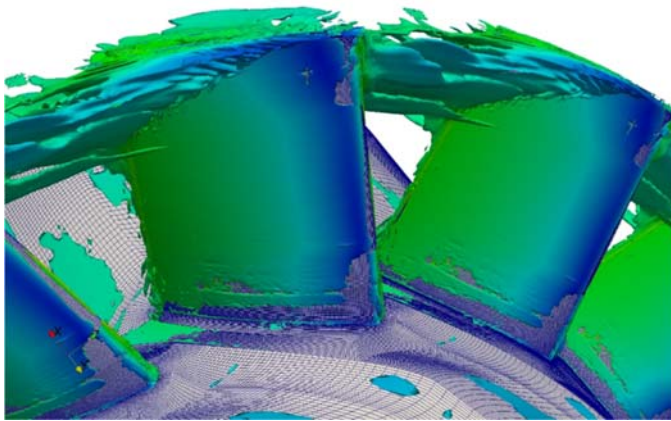
- development of inventive engineering skills and capacity of synthesis.
- development of integrated multidisciplinary technologies
- product engineering
- development of patent application and IP in general
- development of innovative processes at the industrial level
- international strategies and policies for technological innovation
- systematic innovation management
- industrial spin-off management

RESEARCH

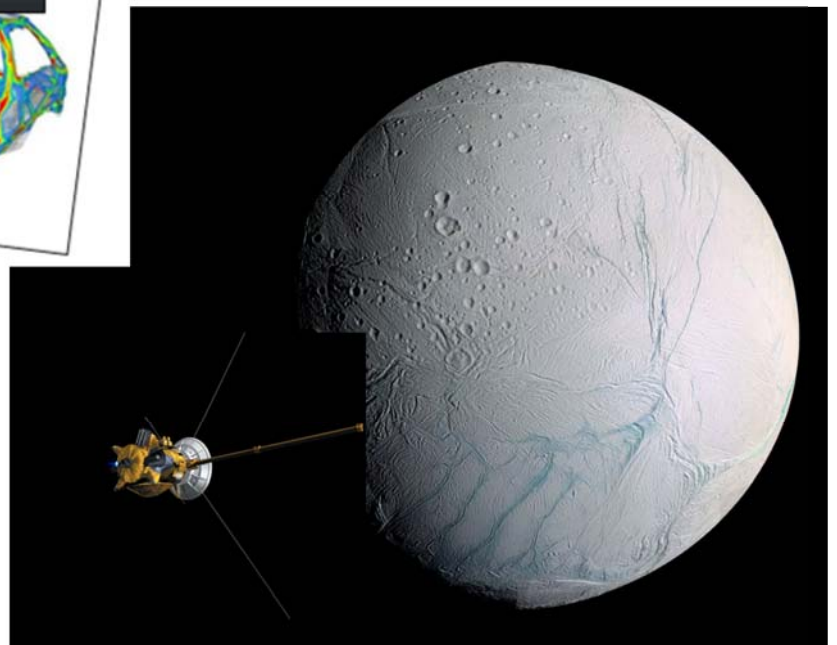
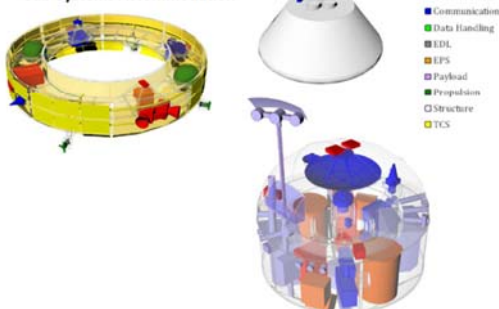
Our research activities are organized in areas, according to the so called Academic Disciplines defined by the Italian Government.

DIMA supports research with infrastructural facilities and labs.

Numerous collaboration with foreign universities and research agencies, as well as companies interested in the progress of science and technology reflect our reputation and our values: integrity, autonomy, ambition, teamworking, transparency, and excellence.



Sub-Systems Accommodation



ACADEMIC DISCIPLINES

According to the Italian Government definitions, DIMA works on the following Academic Disciplines (Settori Scientifico Disciplinari—SSD):

ING-IND/03 Flight Mechanics

ING-IND/04 Aerospace Structures and Design

ING-IND/05 Aerospace Equipments and systems

ING-IND/06 Fluid Dynamics

ING-IND/07 Aerospace Propulsion

ING-IND/08 Fluid Machinery

ING-IND/09 Energy Systems and Power Generation

ING-IND/12 Mechanical and Thermal Measurements

ING-IND/13 Applied Mechanics

ING-IND/14 Mechanical Design and Machine Construction

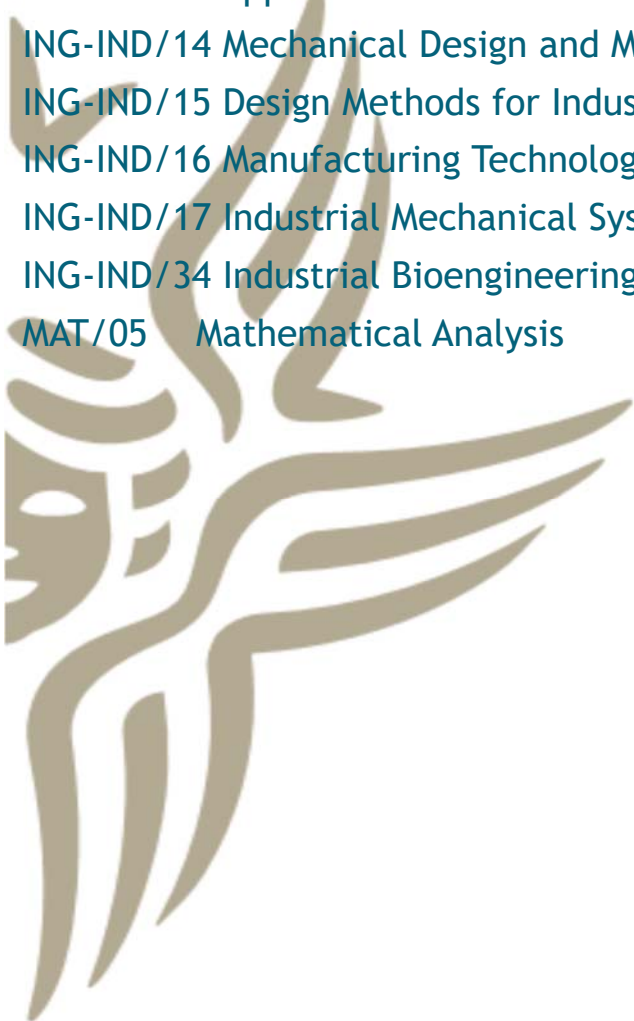
ING-IND/15 Design Methods for Industrial Engineering

ING-IND/16 Manufacturing Technologies and Systems

ING-IND/17 Industrial Mechanical Systems Engineering

ING-IND/34 Industrial Bioengineering

MAT/05 Mathematical Analysis



ING-IND/03 FLIGHT MECHANICS

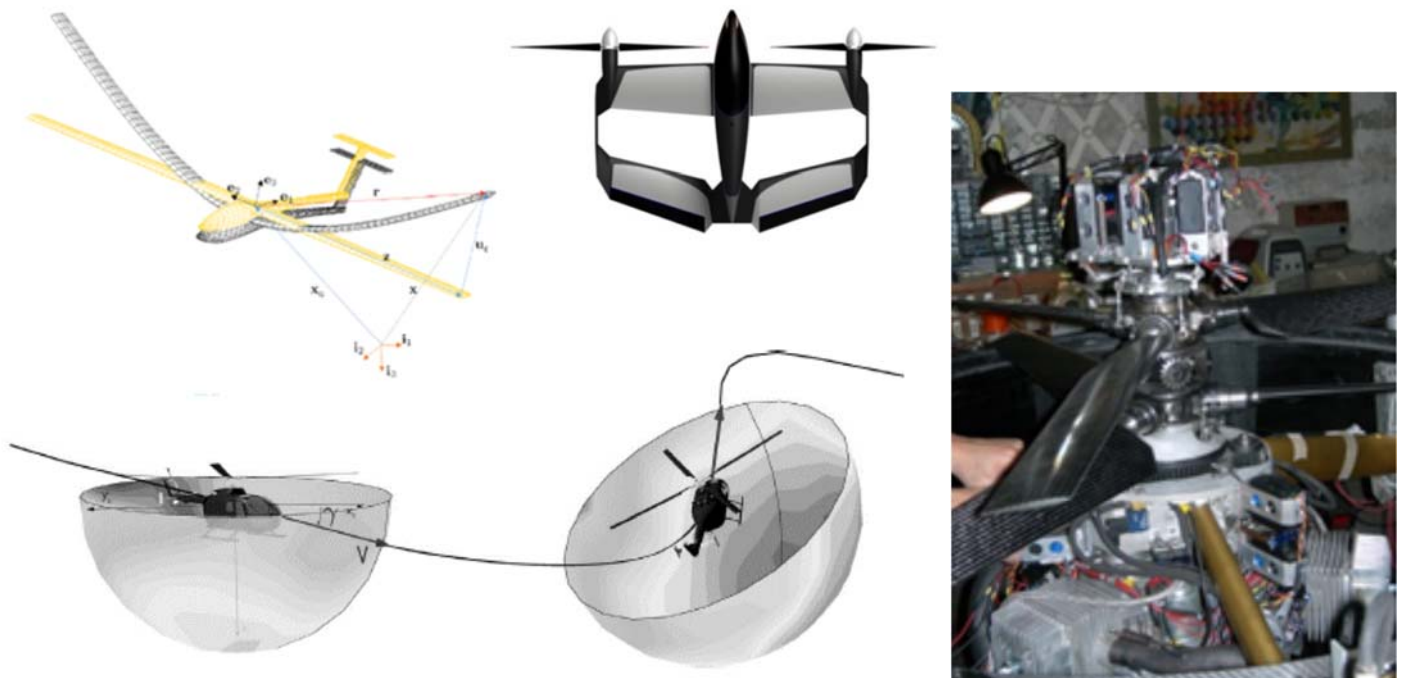
The research activities of this discipline include:

AVIATION

- ◆ Inverse simulation techniques as a support for helicopter modeling and the determination of guidance and control laws for minimum-noise-impact maneuvers
- ◆ Analysis of helicopter performances and stability
- ◆ Highly flexible modeling and stability analysis for aircraft
- ◆ Development of guidance and control systems for small fixed and rotary wing UAVs
- ◆ Aerodynamic modeling for the study of dynamics and driving test of unmanned re-entry vehicles
- ◆ Methodologies for determining rotational and non-stationary stability derivatives

SPACE

- ◆ Analysis and design of systems for setting and control of satellite balance
- ◆ Development of optimization methods for spatial trajectories, both direct (meta-heuristic / developmental) and indirect, with special attention to three different types of applications:
 - ◆ ascensional problem of multi-stage launchers subject to various constraints (e.g., dynamic pressure, heat flux, falling point of the exhausted stages);
 - ◆ interplanetary trajectories that take advantage of multiple gravity assists, with impulsive or finite-thrust models;
 - ◆ terrestrial missions, characterized by a very high number of revolutions, typical of satellites with electric propellers (characterized by low values of thrust and high specific impulse).

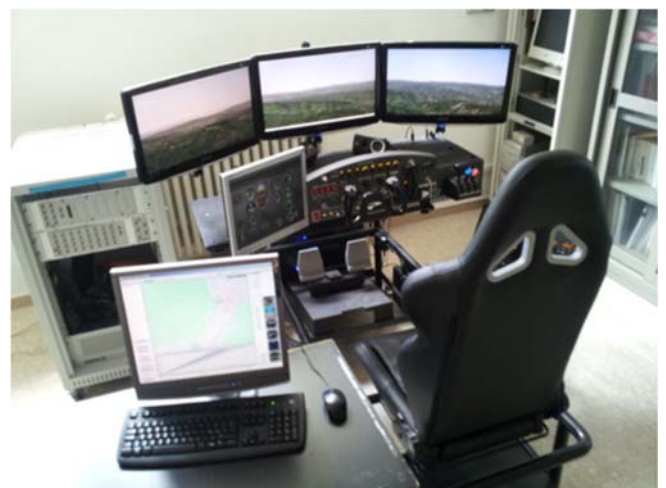


Flight Dynamics Labs (LAPIS) Activities

- ◆ Development of fixed and rotary-wing UAVs (Unmanned Aerial Vehicle) : design and construction of small aircraft (drones) with innovative features, equipped with thermal or electric propellers;
- ◆ Autopilot Design: drive and control algorithms developed through an automatic SW generation and implementation on the on-board computer;
- ◆ Aircraft modeling and flight simulation by a real-time simulation system, with a realistic cockpit for the human-machine interface study.
- ◆ Design, prototyping and validation via simulation of systems for determining balance control of nano satellites.

Lab equipment:

- ◆ Fully instrumented UAVs for GN&C test and validation using scale models;
- ◆ dSPACE equipment for rapid prototyping of flight control and hardware-in-the-loop simulation systems:
 - ◆ dSPACE modular system based on DS1006 Processor Board, 2.5 GHz and various cards(I/O Serial Interface Board, Digital I/O Board, A/D and D/A Board, Timing and Digital I/O Board etc.)
 - ◆ dSPACE System DS1103 PPC Controller Board, single-board system with real-time processor and comprehensive I/O
 - ◆ dSPACE MicroAutoBox II system
- ◆ CPU boards, GPS, I/O, power supply in PC/104 format for embedded computer realization
- ◆ Inertial navigation system C-III MIGTS - Systron Donner Inertial Division
- ◆ Professional Flight Console with hand wheel and pedals by Precision Flight Control Inc., with digital avionics and navigation system emulation by Garmin GNS 530W for single-engine, twin-engine propeller and turbojet .
- ◆ MathWorks Family products (Matlab, Simulink and toolboxes); products by dSPACE and applications for aerodynamics analysis (Tornado, VSAERO).



ING-IND/04

AEROSPACE STRUCTURES AND DESIGN

The research activities cover emerging issues in the field of Aerospace Structures and Design in theoretical, numerical, experimental, and planning aspects related to the aviation and space industry.

The main research activities are:

- ◆ Aeroelastic modeling of fixed wings, rotary wings and launchers. Integrated aircraft design with MDO approaches (multidisciplinary Design-Optimization) and MOO (Multi-Objective Optimization). Analytical and numerical methods for nonlinear aeroelastic systems.
- ◆ Development of experimental modal analysis methodologies. Development of structural updating methodologies. Vibration Reduction.
- ◆ Structural dynamics and inverse problems applied to multidisciplinary design. Dynamic, guidance and control of complex structures and multibody systems in the space environment. Realization of experimental testbed for the study of autonomous robotic systems.
- ◆ Advanced/active aerospace structures in composite materials. Wireless structural monitoring with use of wavelet transform and developing of self-powered sensors. Multiphysics Analysis, Finite Element modeling, and verification of real structural elements. Newly developed Space Missions and procedures of concurrent and cost engineering.
- ◆ Mechanical characterization of composites with natural fibers. Partially "green" composites

Labs

Structural Dynamics Lab

Development of experimental modal analysis technique based on both input/output and output-only measurements. Identification of structural dynamic properties from flying test and GVT of fixed and rotating wing vehicles. Environmental testing for design qualification and flight acceptance of space structures and mechanical components undergoing severe vibration levels. Vibration reduction methods via PZT patches passively used. Development of sensitivity-based structural updating techniques and structural damage identification methods.

Aerospace Composite Material Lab



Design, manufacturing and testing of high performance composite materials for aerospace applications. Embedding of sensors/actuators for health monitoring. The laboratory is equipped with the following facilities: autoclave for vacuum bagging technique with 440mm diameter, and 770mm length, curing cycle with programmable logic controller for temperatures up to 200°C, pressures up to 8 atm and 10mbar of vacuum; tooling facilities for post-processing of composites; ultrasonic device for non-destructive testing with linear phased array probe with 64 transducers at 3.5MHz and encoder. The Lab is involved in the development of natural fiber composites for aeronautics and other fields of application.

Smart Structures Lab

SMART-LAB

Development of active structures for vibration control, health monitoring and shape morphing in aerospace systems. Exploitation of piezoelectric materials for wireless sensors networks and energy harvesting capabilities. Vibration control of active structures, active control of composite structures, electro-active polymers, smart thermal protection system. The laboratory is equipped with the following facilities: LMS SCADAS III advanced platform for data acquisition and analysis for vibration engineering, electrodynamic shaker, electronic equipment for circuit design, breadboarding and testing, equipment for piezoelectric material treatment, telecom devices for wireless network communications.

Computational Mechanics Lab

Numerical simulations of aerospace structures by finite element procedures for nonlinear analysis (large displacements, large strains, material nonlinearity e.g. rubber) and multiphysics (thermal and thermoelastic analysis, piezoelectric analysis).

Computational Space Robotics and Multibody Dynamics Lab

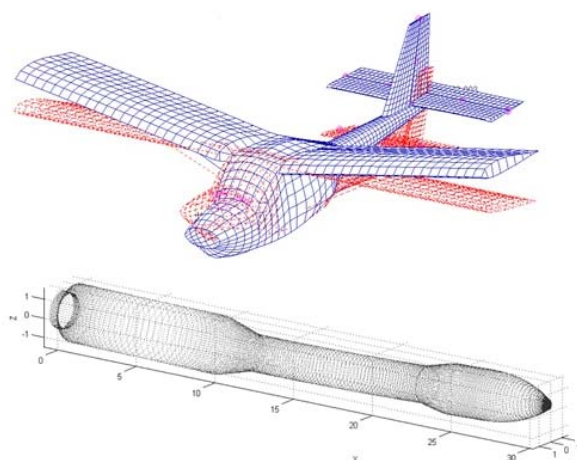
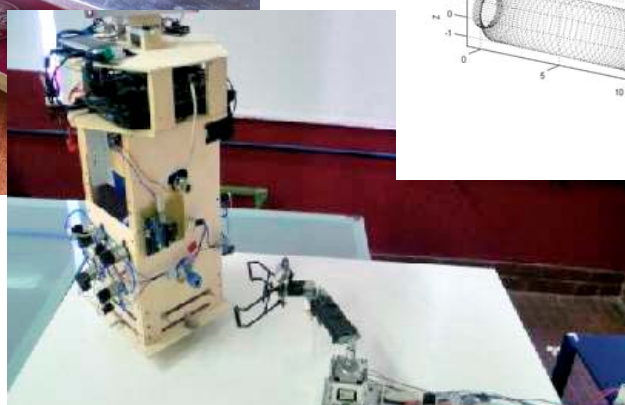
The activities of the laboratory are relevant to the development of space manipulators and robotic arms from the mechanical, dynamical, and control point of view. Interactions with autonomous space systems are also investigated, studied, and simulated numerically and experimentally.

Computational Dynamics and FSI Lab

Development of multidisciplinary reduced-order models (ROM) for the dynamics of aerospace structures and for the solution of stability and response problems induced by fluid-structures interactions (FSI) in aircraft, launch vehicles, and rotorcraft. Use of ROMs for multidisciplinary design and optimization (MDO) of innovative aircraft configurations.

Concurrent Engineering Lab

Preliminary design of satellite systems in the frame of multidisciplinary analyses and pre-phase A sizing criteria in a concurrent engineering SW and HW environment.



ING-IND/05

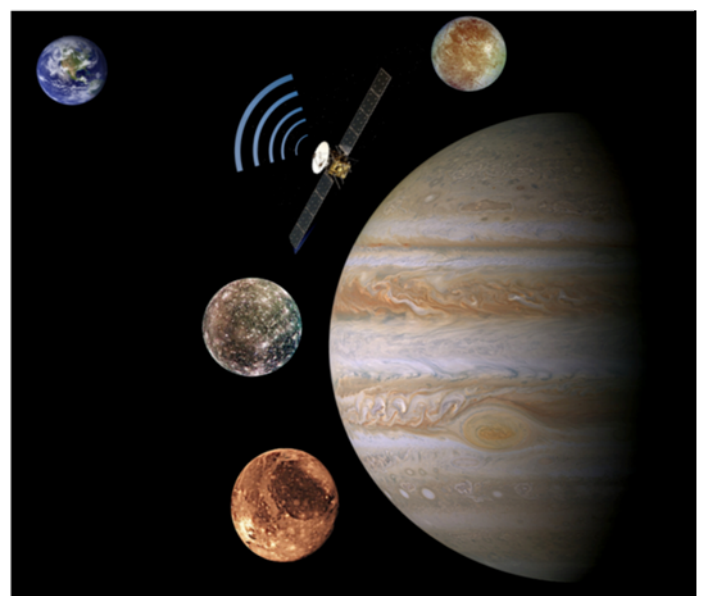
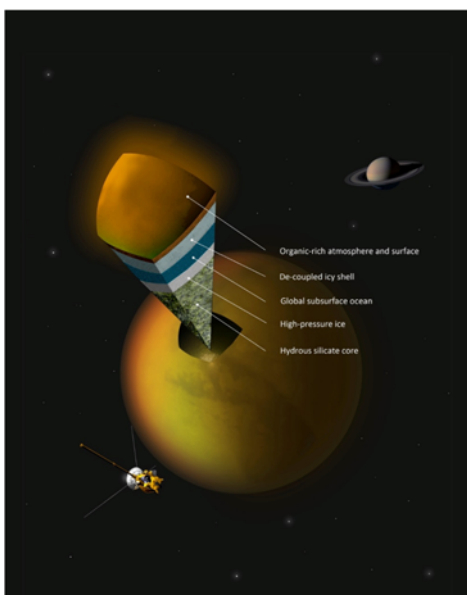
AEROSPACE EQUIPMENTS AND SYSTEMS

Definition, development, and data analysis of the radio science and space geodesy experiments, especially in the context of planetary missions:

- ◆ Cassini: analysis of the Doppler data of Cassini space probe, in orbit in Saturn system. Determination of the gravity field of Titan, Enceladus, Rhea, and Dione. Determination of tidal deformations of Titan. Search for internal oceans in the bodies of the Saturn system. Numerical simulations of gravity field of Saturn and its satellites for future phases of the mission. Development of dynamic models of the Saturn system.
- ◆ Juno: planning of the radio science experiment of Juno mission (NASA) to Jupiter. Numerical simulations of the orbital phase for the determination of Jupiter's gravity field and its tidal variations.
- ◆ BepiColombo: development and management of radio science experiment MORE for BepiColombo mission (ESA) to Mercury. Numerical simulation of orbital phase for gravity field, tidal effects, and rotational state determination.
- ◆ JUICE: Development and management of radio science experiment 3GM of the JUICE mission (ESA) to the satellites of Jupiter. Numerical simulations of the gravity field and tidal effects of Europa, Ganymede and Callisto. Search for internal oceans on the moons of Jupiter. Support to the industrial development of scientific payload of 3GM experiment.
- ◆ Delta-DOR: Maintenance and development of new features of the ESA correlator DeltaDOR. Codes for data processing in wideband configuration using multiple receivers. Development of correlation algorithms in low levels conditions of the signal-to-noise ratio. Code Development to support the CCSDS standard for the inter-agency exchange of DeltaDOR data.

Space debris: analysis of optical measurements of objects in Earth's orbit to identify their dynamical and physical properties. Goals: supporting the collision avoidance maneuvers, and characterization of the debris environment in space.

On-board systems: realization of automatic landing support systems for manned and unmanned aircrafts and to the realization of components for micro- and nanosatellites. Specific focuses: space surveillance, space debris mitigation, systems and components on board.



Aerospace Systems Lab

Development of techniques for the analysis of optical measurements of Earth orbiting objects. In particular, the activity aims at the dynamical (trajectory and attitude motion) and physical (material, colour, shape, area-to-mass ratio) characterization of space debris.

To achieve space debris optical measurements the laboratory produces and operates observatories dedicated to space debris measurements. Astrometry and photometry is accomplished by exploiting a network of small observatories deployed all over Italy, multicolour photometry and spectroscopy is performed from the Loiano observatory in Bologna and in collaboration with the Cerro Tololo observatory of the University of Michigan.

Moreover, the laboratory of Aerospace-systems design, manufactures and tests components and subsystems for aircraft and spacecraft. In particular the activities in this field involve a system for supporting landing of airplanes, helicopters, and drones based on optical tracing of the target and systems for testing microsatellite components as vacuum chamber and Helmholtz coils for simulating variable magnetic fields.



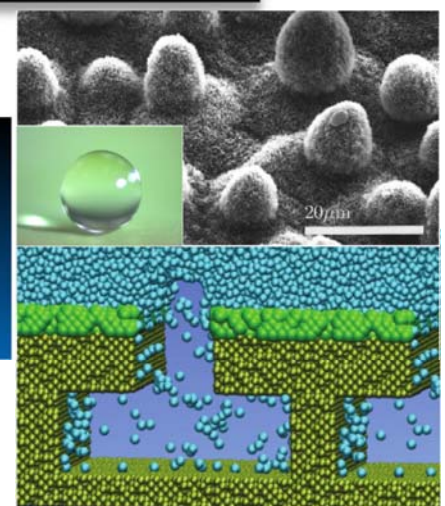
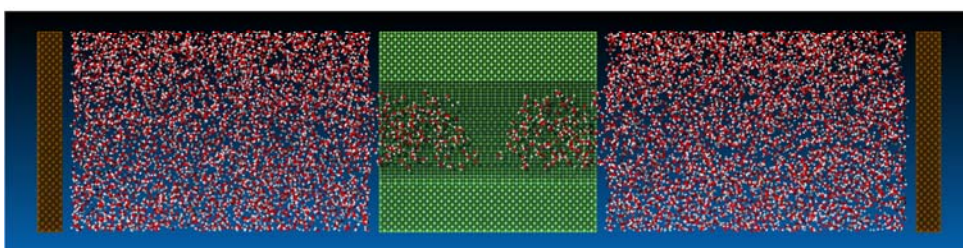
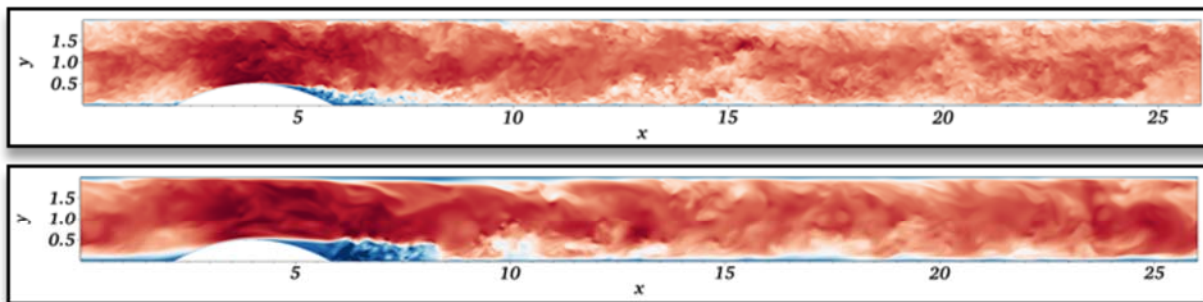
Radio Science Lab

The Radio Science Lab is active in radio science experiments, precision tracking systems, planetary geodesy, and orbit determination. The laboratory hosts a network of high-power computers for the processing of tracking data used both for scientific investigations and deep-space navigation. In the period 2011-2013 twelve people (graduate students, postdocs, and research assistants) worked in the lab. The team has joined flagship missions of NASA and ESA planetary exploration program, such as Cassini (ongoing, in orbit around Saturn), Juno (now in cruise to Jupiter), BepiColombo (to Mercury, launch in 2016), and JUICE (to the Jovian satellites, launch 2022). The lab participates in these missions with flight hardware and data processing of radio science and planetary geodesy investigations. These activities are carried out in an international context, with extensive collaborations with academic and scientific institutions, and aerospace industries.

Over the past years the Radio Science Lab took part in industrial studies (often with the role of prime contractor), with the participation of prominent European aerospace industries (such as BAE Systems and Thales Alenia Space). Of special relevance was the development of the Delta-Differential One-way Ranging (DDOR) correlator, a crucial asset for Europe's access to deep space. This operational tool for the navigation of ESA's planetary probes was entirely developed by the lab's personnel.

ING-IND/06 FLUID DYNAMICS

- ◆ Analysis of the interaction between vortices and blades in helicopters in motion and of the consequent generation of noise. Experimental aeroacoustics analysis of free jets interacting with solid surfaces.
- ◆ Numerical simulation of nucleation, turbulent transport, and collapse of cavitation bubbles. Multiscale cavitation and multiphase flows. Superhydrophobic surfaces: wetting/dewetting. Turbulent modulation by inertial particles. Experimental activities: laser induced cavitation, cavitation-enhanced drug delivery, experimental microfluidics. After-implant hemodynamics.
- ◆ Numerical simulation of high-Reynolds number wall-bounded flows. Drag reduction and heat transfer in turbulent channel flows. Analysis and control of transitional flows on lifting surfaces. Control of shock wave/turbulent boundary layer interactions. Computational aeroacoustics. Supersonic turbulent boundary layers. Compressibility effects in roughness-induced transition.
- ◆ Turbulent combustion. Analysis of solid propellant rocket motors. Fluid dynamic effects of distributed combustion in solid propellant engines. Aluminium particles combustion: modeling and numerical simulation.
- ◆ Fluid-particle interactions in turbulent flows with applications to propellers and microflows. Optical techniques for multiphase flows in two-way coupling regime. Single point and multi-point measurements. Experimental study of turbulent jets. Experimental and numerical analysis of free-surface flows. Hydroelasticity in sloshing tanks and wave impact for shallow-water condition: experimental and numerical analysis. Two-phase flows in T-junction microchannels.
- ◆ High performance computing for computational fluid dynamics. GPU-accelerated flow solvers for direct numerical simulation of turbulent flows.



Aerodynamics

- ◆ **Subsonic Wind tunnel**, with a circular cross-section of about 1 m in diameter and a maximum air velocity of 50 m/s. Equipment: Multi-hole Pitot Tubes, Pressure Gauge, Particle Image Velocimetry System (PIV), Continuous and Pulse Laser, High-Speed Video Camera (up to 100,000 frames per second), PIV, video and photo cross-correlation video camera Commercial camera, 30-frame lenses and video camera, Laser Doppler Anemometer (LDA) systems, Hot Wire Anemometer (HWA) and Ultrasound Anemometer (UA), three-component dynamometer scale. Oil Pressure Generator (Laskin nozzle). Models of wings and ailerons, wind turbines (HAWT and VAWT), cars, MAV, and other geometries.
- ◆ **Anechoic wind tunnel**, with a standing chamber connected to a high pressure system. The section of the chamber is circular (diameter 50 cm) and the velocity of an input jet can range from 50 m/s to more than 450 m/s depending on the jet output diameter. Equipment: 8 microphones (1/4 in Bruel-Kjaer 4939) connected to a PULSE X-3570 scan system. Set of Absolute and Differential Pressure Gauges (MKS). Set of air and nitrogen flow meters (MKS). Nozzles of various sizes and shapes.
- ◆ **Shrinkage in water**, with a maximum speed of 10 m/s and an outlet section of 2 cm in diameter, has a square cross-section measuring area of 50 cm side and 80 cm length.
- ◆ **Water duct**, with a maximum output speed of 1 m/s and an outlet section of about 2 cm in diameter, has a square cross-section measuring area of 80 cm side and 120 cm length.
- ◆ **Water-jet orifice**, continuous and pulse configuration with a 3 cm output diameter, with a square cross-section area of 50 cm side and 60 cm length. It is equipped with remotely controlled linear gear to generate pulsed flows with assigned forcing.

Other equipment: magnetic flow-meters for water pipes.

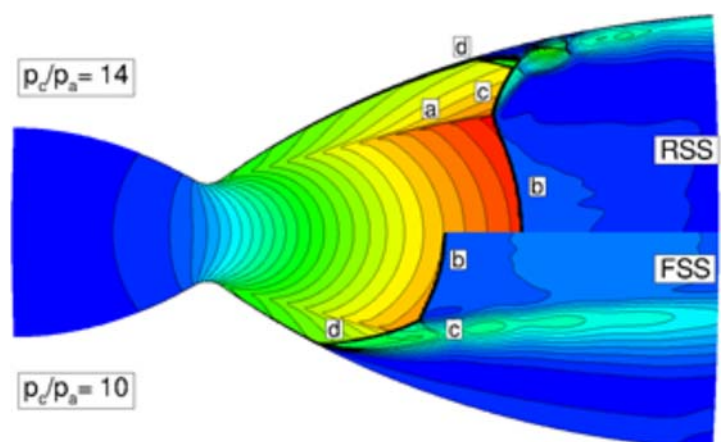
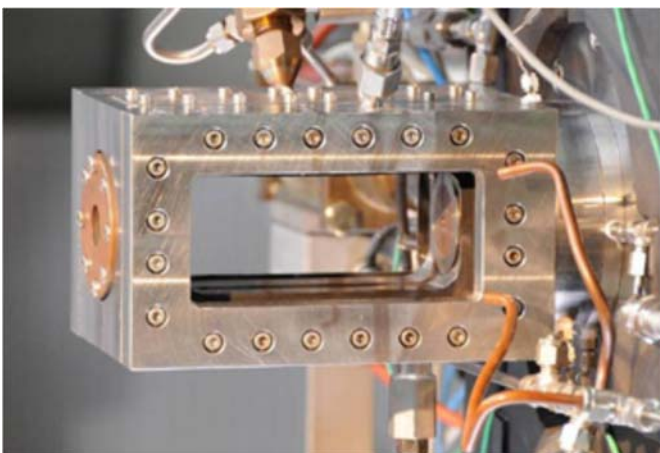


ING-IND/07

AEROSPACE PROPULSION

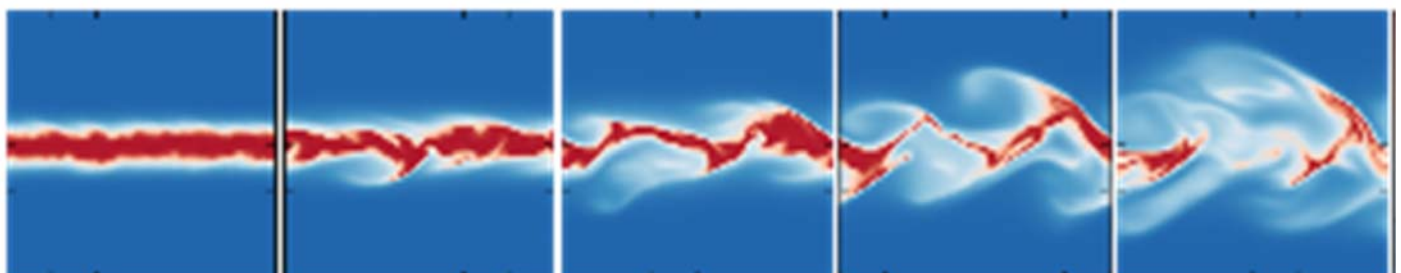
Methods

- ◆ Fluid dynamics of propulsion systems: development and validation of RANS-based CFD models; study of chemical-physical properties and modeling of fluids in supercritical conditions; cavitation modeling for cryogenic fluids including Thermodynamic Suppression Head effects; modeling of liquid propellant injection; modeling of pressure oscillations in solid rocket motors.
- ◆ Heat Transfer: numerical modeling of the evolution of supercritical fluids in ducts with heat transfer deterioration; modeling of wall heat transfer in liquid rocket engines; fluid-surface interaction models including catalysis, pyrolysis and ablation; modeling of gas and soot thermal radiation in turbulent combustion; modeling of surface kinetics of active and passive oxidation of carbon and silica thermal protection systems of reentry vehicles.
- ◆ Combustion: RANS modeling of turbulent combustion of compressible flows in supercritical conditions; LES modeling of turbulent combustion of compressible flows in supercritical conditions; DNS modeling of premixed laminar and turbulent flames in the presence of instabilities; modeling of the ignition transients of solid rocket motors; modeling of the combustion surface evolution of solid rocket motors; modeling of internal ballistics of solid rocket motors by 3D unsteady simulations; flameless oxidation combustion modeling; experimental study with PIV techniques of turbulent premixed flames.
- ◆ Propulsion system analysis: intrusive and non intrusive methodologies to analyze systems with uncertain parameters; development of system analysis software for engine parametric analyses and startup transients; reduced order models for the study of thermoacoustic and low frequency instabilities.
- ◆ Algorithms: automatic generation of simplified (skeletal) and reduced kinetic models for detailed chemical kinetics; feature detection and sensitivity analyses in reacting flows on the basis of time scale diagnostics; integration methods for multi-scale problems (stiff differential equations) with deterministic and uncertain parameters; mesh generation by conformal mapping; adaptive mesh resolution using wavelets; analysis of numerically generated time series using wavelets.



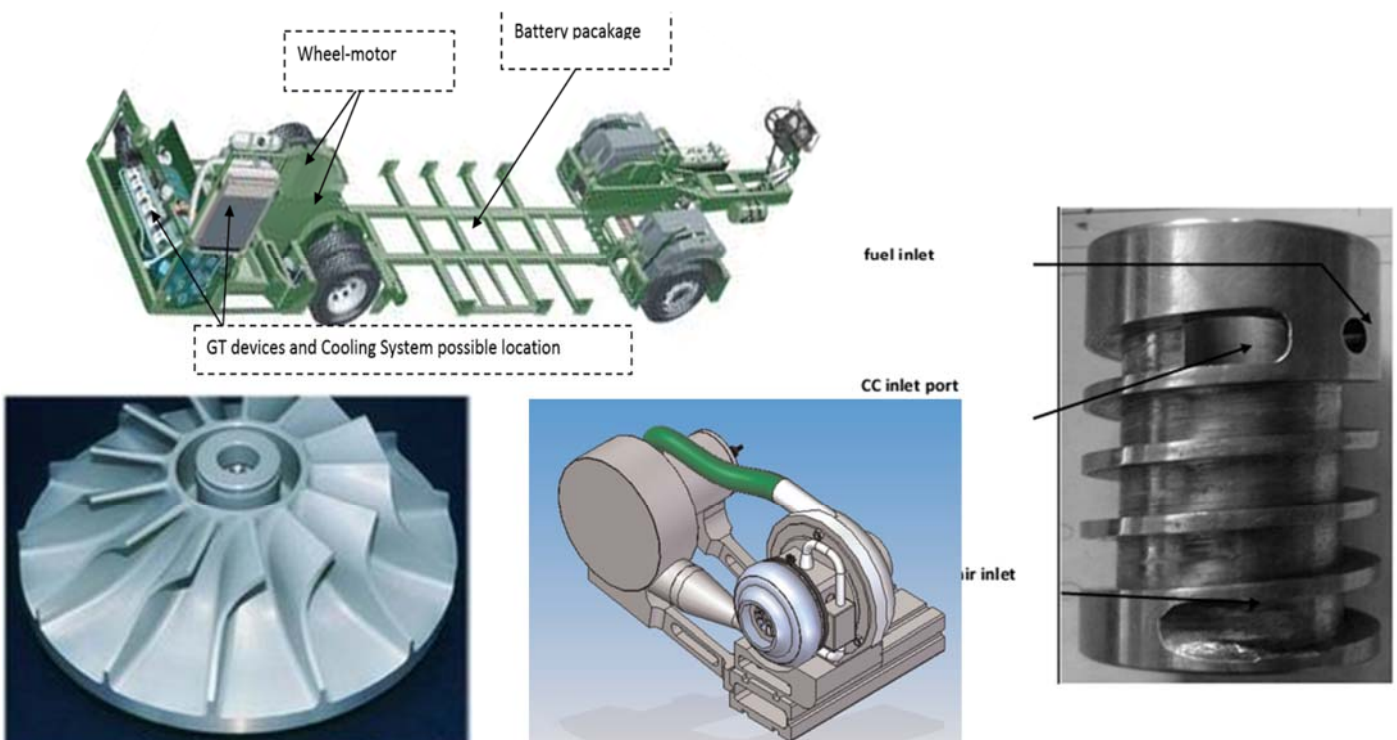
Applications

- ◆ Liquid rocket engines: modeling of turbulent combustion in the thrust chamber of liquid rocket engines in super-critical conditions; numerical modeling and RANS / LES simulations of the thrust chamber of a liquid rocket engine (LOx/LCH₄); analysis of ignition processes in combustion chamber by means of deposition of energy with laser pulse; analysis of thermal loads in thrust chambers of liquid rocket engines; analysis of regenerative cooling systems with super-critical methane; RANS and DES analyses of separated flows for propulsion applications (air-intakes, nozzles); modeling of cavitation in turbopump inducers for liquid rocket rockets; simplified models of liquid rocket engine components for system analysis; feed systems for liquid rocket engines.
- ◆ Solid rocket motors: study and analysis of the ignition transient of solid rocket motors of VEGA launcher; study and analysis of pressure oscillations in solid rocket motors of VEGA launcher; models for performance analysis of the solid rocket motors of Vega; modeling the evolution of propellant grain surface; ablation modeling for nozzle walls based on pyrolyzing and non-pyrolyzing materials.
- ◆ Hybrid propellant rockets: flow/surface interaction modeling for solid and paraffinic fuels; combustion modeling and performance analysis; ablation modeling for nozzle walls based on pyrolyzing and non-pyrolyzing materials.
- ◆ Aircraft engines: off-design performance analysis of gas turbine engines with uncertain parameters.
- ◆ Prediction and measurement of pollutants: generation of simplified/reduced chemical kinetic mechanisms for application in aviation, energy, and automotive including pollutants (NO_x), PAH and soot predictions. [Experimental techniques for soot concentration measurement].
- ◆ Space Propulsion: design, test and in-orbit demonstration of a cold gas micro-thruster.
- ◆ Mission Analysis: exploration on Mars and Venus through ISRU (In Situ Resource Utilization); propulsive solutions for return missions of planet surface samples; mission analysis of single-stage-to-orbit vehicles.
- ◆ Re-entry vehicles: modeling the active and passive oxidation of carbon and silica thermal protection systems of reentry vehicles.

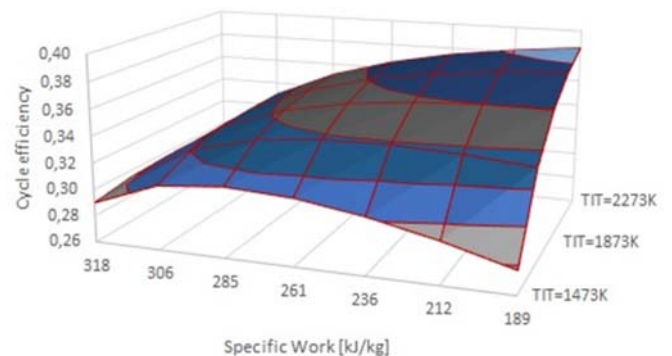
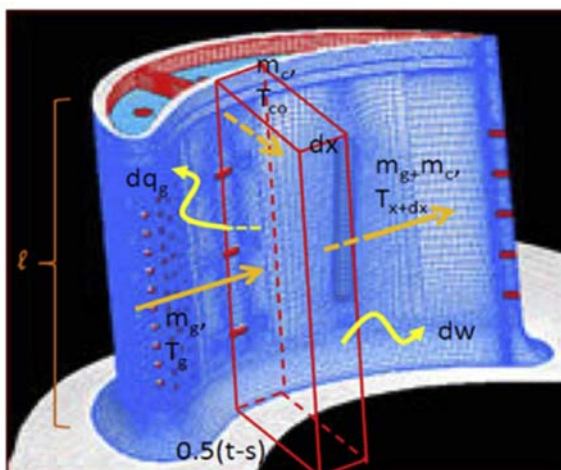
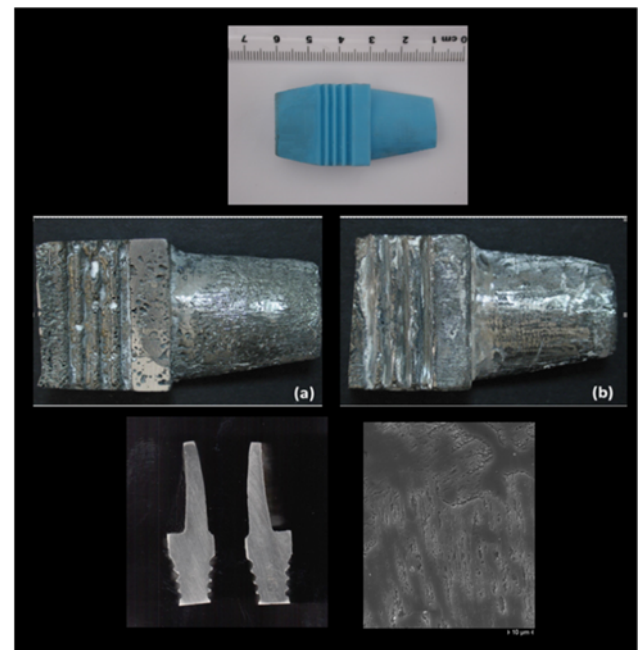
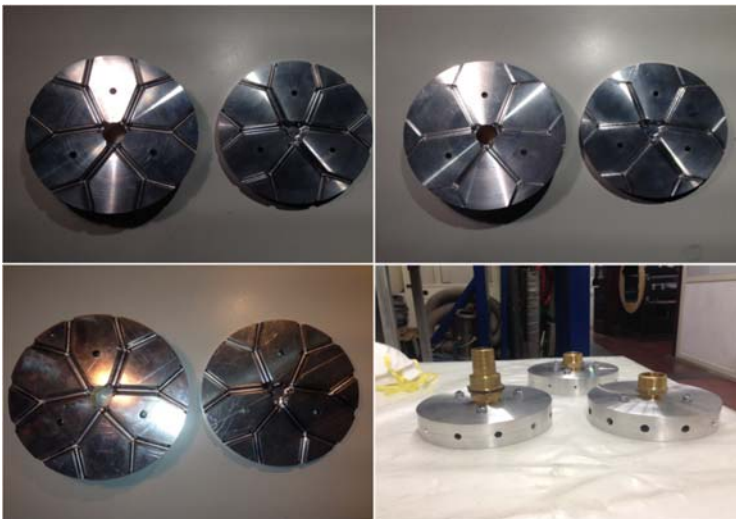


ING-IND/08 TURBOMACHINERY

- ◆ **UMGT:** A study on the miniaturization of a complete turbogas set (UMGT, Ultra-Micro Gas Turbine) was launched, based on the intuition of Richard Feynmann in 1959, and is in principle based on simple considerations of scale, which demonstrate that, ideally, the smaller the turbomachinery, the higher its power density. Zero- and one-dimensional studies were complemented by thorough process simulations to try to identify the most likely efficiency ranges.
- ◆ **UAV:** Design of a hybrid propulsion system based on a recently developed, high efficiency micro-turbine which can be used to power an electric generator, thus providing a significant range/mission time extension. Noise and cruising characteristics are strongly improved.
- ◆ **HYBRID VEHICLES:** conceptual study, design, development and fielding of a road prototype of a new concept hybrid vehicle, with a series arrangement and endowed with a small Gas Turbine set as a thermal engine.
- ◆ **ORGANIC RANKINE CYCLE (ORC):** complete pre-industrial feasibility analysis of "on-board" installations of innovative and patented Organic Rankine Cycle recovery systems a) as a bottoming unit to an I.C.E. (diesel turbocharged and naturally aspirated); b) as a bottoming to a micro-TG; c) as a general low-Temperature heat recovery system in remote power stations.
- ◆ **CFD OF TURBOMACHINERY COMPONENTS:** Specific and detailed studies on viscous turbulent diabatic flow in turbomachinery channels, both fixed and rotating, both axial and radial.
- ◆ **EXPERT SYSTEMS IN THE DESIGN OF THERMAL MACHINERY:** complete preliminary design of turbomachinery (compressible & incompressible, axial or radial, single or multi-stage) performed by an "intelligent expert system" endowed with a set of design rules of qualitative and quantitative type.

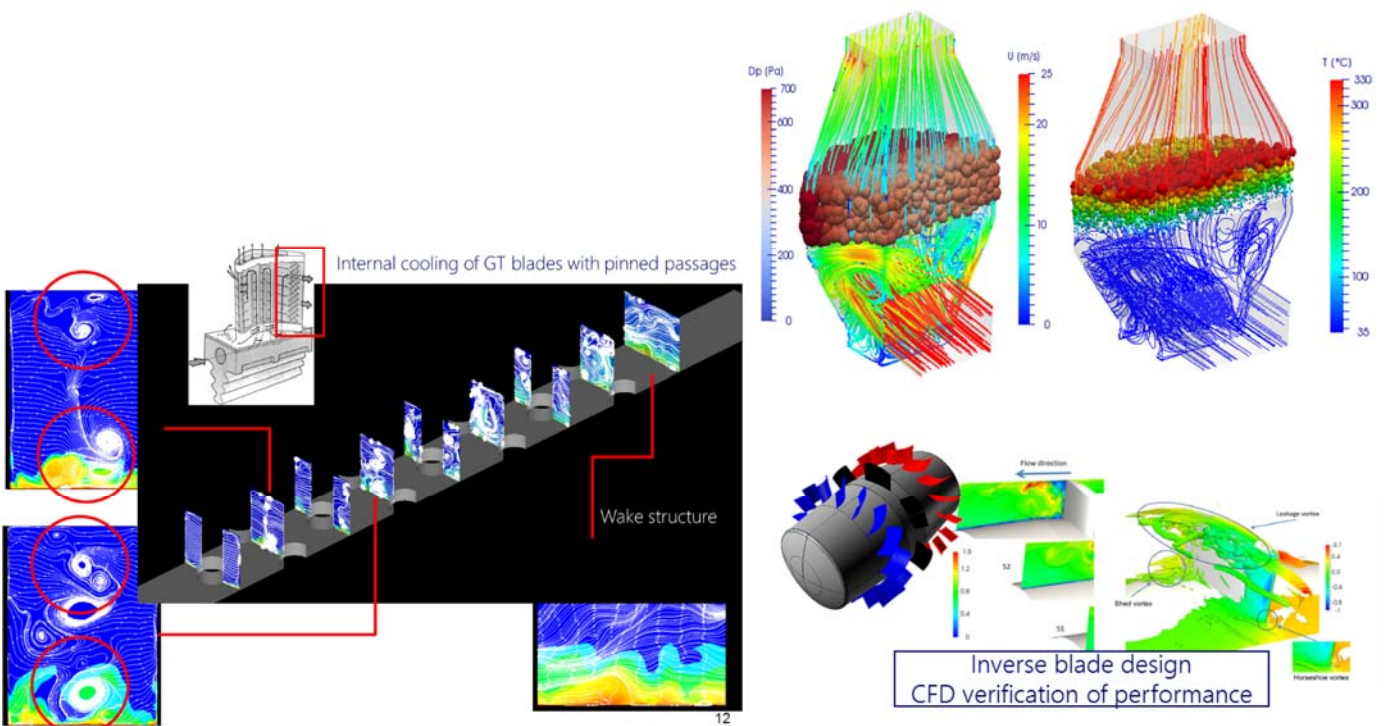


- ◆ **OTHER TOPICS IN TURBOMACHINERY:** blade cooling; thermo-fluid behavior of a gas turbine blade with ceramic porous coating; general features of the entropy generation rate in TM channels; a novel concept of a vortex-based highly compact combustion chamber for a micro TG; heat recovery systems for a UMTG; super-compact modular heat exchanger for UMTG.
- ◆ **EXERGY-BASED SYSTEM ANALYSIS:** Extension of the concept of ECS by including communities, industrial sectors, regions, and entire nations. A novel and highly sophisticated exergy-based analysis (Extended Exergy Accounting) was formulated, developed and applied to several real cases.
- ◆ **THERMO-ECONOMICS:** The tool of Thermo-Economics was applied to novel studies of innovative ECS (gas flaring in oil refineries, energy conversion from renewable sources, etc.)



ENERGY SYSTEMS AND POWER GENERATION

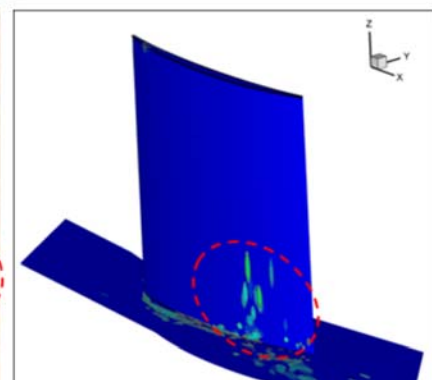
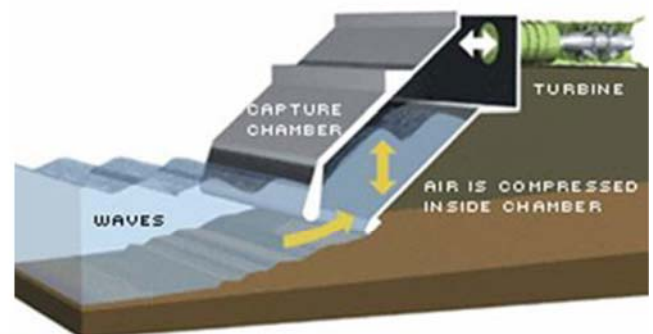
- ◆ Thermo-computational fluid dynamics of turbomachinery. Analysis, development, and implementation of numerical models (U-RANS based) for the description of turbulence and heat transfer in turbomachinery applications. Analysis and implementation of simulation approaches (Large Eddy Simulation -LES) for turbulence and heat transfer in turbomachinery applications and in general industrial applications.
- ◆ Forecast of fouling and erosion caused by dispersed particles, for industrial applications. Analysis, development and implementation of multi-phase models (Lagrange) for particle-loaded flows in industrial applications (two methods are considered: particles-cloud and single-particle monitoring). Modeling of particles impact on solid walls: elastic and elasto-plastic impact model; influence of temperature; adhesion of particles; erosion.
- ◆ Study of energy systems based on conventional and renewable energy sources. Renewable Sources: concentrating solar power, biomass, organic fraction of municipal solid waste, gasification. Development and implementation of numerical models of power systems with Aspen Tech, CHEMCAD and TRNSYS softwares. Gasification of biomass for the production of hydrogen-rich syngas with a low CHAR content. Experimental analysis and software modeling of the Life Cycle Assessment of distributed energy systems; cogeneration.
- ◆ Experimental study of fuel cells performance. Analysis, testing and optimization of direct methanol fuel cells: study of the performance of the whole system; Micro-PIV investigation of CO₂ bubbles generation and dynamics in the micro channels of the cell. Analysis, testing and optimization of solid-oxide fuel cell fed with syngas produced from biomass gasification.
- ◆ Experimental study of recycled materials for liquid hydrocarbons absorption. Testing of properties of crude oil absorption by waste materials from recycled tires; Full-scale testing and process optimization.



ING-IND/09

ENERGY SYSTEMS AND POWER GENERATION

- ◆ Solar cooling: micro absorption machine for solar thermal systems.
- ◆ Biomass: experimental numerical analysis for the conversion of multi-fuel gas turbine groups (with particular attention to the burners) to vegetable oils or biogas. Study and optimization of digesters operating parameters. Study of ozonation of different types of biomass, and other pre-treatments designed to improve energy efficiency (use of microwaves and two-stage systems).
- ◆ Smart Grid: management of electrical loads as a function of tariffs and availability of autoproduction from renewables.
- ◆ Sustainable buildings: integration of systems, active and passive interventions for energy efficiency
- ◆ Storage systems for electricity from renewable sources: study of mechanical systems for small power generation.
- ◆ air quality monitoring: statistical investigations, Simulation models of pollutants dispersion into the atmosphere; analytical techniques for sources separation; short and long term forecast models; pollution abatement and air treatment systems; Environmental impact assessments.
- ◆ Cryogenic Machines: Pulse Tube and reverse cycle Stirling type and absorption systems; Stirling: development of a new hybrid heater for solar applications, based on research activities with the Bruno Kessler Foundation (TN).
- ◆ Pulse Tube: evaluation and characterization of thermo-acoustic processes during operation.
- ◆ Realization of high vacuum systems for applications in cryogenics and energy conversion



Cryogenics and Stirling Engine

Experimental activities: the laboratory has been active for over 20 years for the study and testing of closed cycle Stirling machines. There is also a complete test-bench for the measurement of the various functional parameters and the analysis of Stirling engine cycle and cryogenic thermoacoustic machines. The lab is supplied with a National Instrument acquisition bench, a high-vacuum pump, a vacuum chamber for cryogenics (volume=3 dm³) with a chilled water auxiliary circuit for thermal stabilization. There is also a specific library and a rich collection of Stirling machines prototypes .

Engine test room

The engine test room has three test benches, one with hydraulic brake suitable for teaching, a tilting scale for torque and power measurements; the other two benches are for eddy currents for the testing of internal combustion engines up to a power of 80 kW. Equipped with external conveyors and refrigeration circuits of flue gas it can also accommodate test-benches for Stirling machines (with 25 kW dynamo-brake) and microturbines. According to necessity can also be installed on a test bench burners up to a power of 60 kW.

Other available equipment includes a BOSCH gas analyzer, a unit for measuring the indicated cycle, and an AVL balance for the fuel.

A facility for the preparation of prototypes is also available.



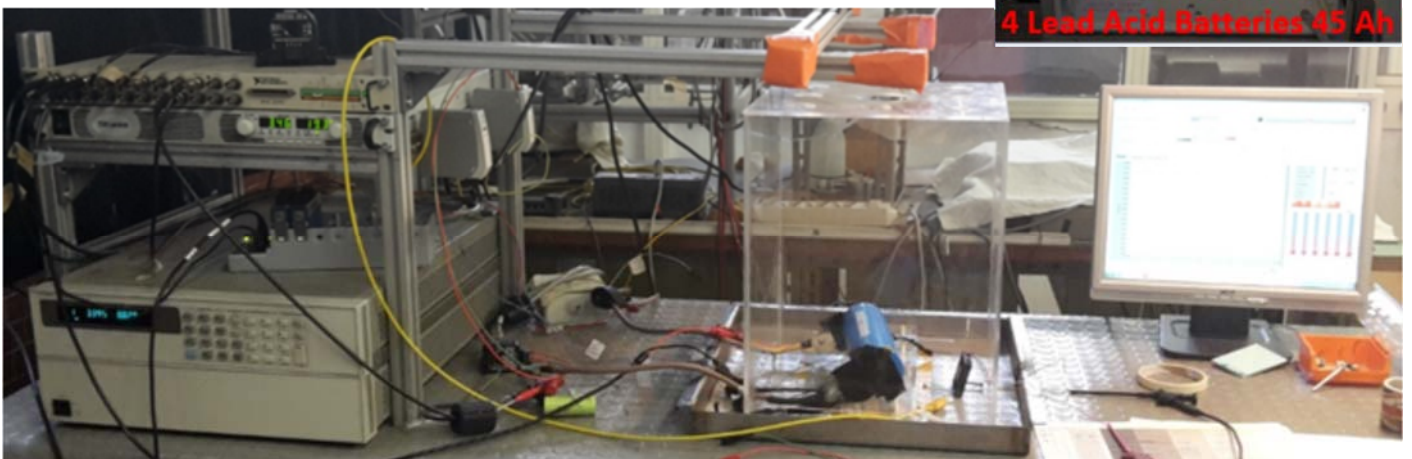
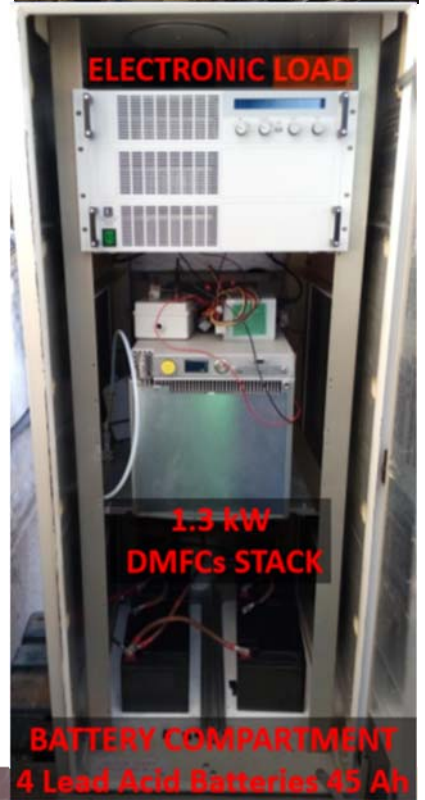
Biomass Laboratory

The DIMA biomass lab is equipped with a bench scale fluidized bed gasifier (10 kW). The experimental setup, shown in Figure, is mainly composed by a screw feeding system for the biomass, a bench scale fluidized bed gasifier, gas and steam supply systems, systems for the removal of the particulate from the gas, a gas cooling system and metering and analysing systems for the gas produced. Wood-gas composition is measured with an on-line GC, while heavy hydrocarbons are sampled at regular interval and successively measured in a GC-MS. Several research activities were carried out by using the fluidized bed gasifier: a) evaluation of wood-gas from different feedstocks (i.e. changing humidity, biomass type); b) development of improved catalysts for tar reduction; c) development of efficient traps for heavy metals dispersed in the biomass; d) development of carbon capture techniques aiming at assessing negative emission schemes.



Fuel Cell Laboratory

Design, manufacturing and testing of fuel-cell based on energy conversion systems. V/I, power curves, impedentiometric analysis and contact resistance measurements for single MEA. Fuel-cell stack design testing and optimization. Design of Direct Methanol Fuel-Cell systems for APU or UPS applications. Design of PLC for fuel-cell systems. PIV analysis of two-phase flows for flow channels optimization. Testing of Direct Methanol Fuel Cell single MEA, working in passive configuration, for low power electrical devices.



MECHANICAL AND THERMAL MEASUREMENTS

The research focuses on the validation and design of measurement chains both for industrial and biomechanical applications: from signal transduction to signal acquisition and processing, seeking to preserve the quality of information.

In the field of **mechanical industry**, the group is specialized in:

- ◆ Installation of strain gauge bridges for the measurement of deformations, vibrations, and stress of structures and/or mechanical parts, as well as for *ad-hoc* realization of load cells.
- ◆ Installation of interferometric or reflection optical benches for studying micro-deformations of structures.
- ◆ Laser scanning of mechanical or structural parts for both monitoring and reverse engineering.
- ◆ Installation of stress measurement chains, using multi-component load cells.
- ◆ Rotary torque measurements for the characterization of rotary actuators and braking systems.
- ◆ Installation of thermal gradients measurement chains, both for environment and mechanical parts, including thermocouples, PT100, surface thermometers, thermistors, thermal imaging cameras.
- ◆ Characterization and real-time monitoring of energy production systems (catalytic converters) and the use of hydrogen (fuel cells).
- ◆ Development of benches for function monitoring and incipient fault detection of ions and lithium polymer batteries.

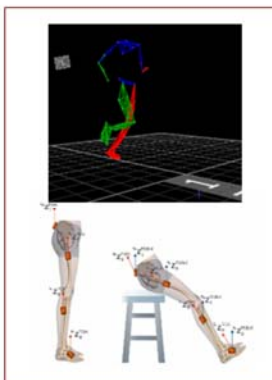
In the field of **experimental biomechanics**, the focus is on

- ◆ Metrological characterization of optoelectronic systems and force platforms for the analysis of human kinematics and kinetics.
- ◆ Development of 1-, 2-, and 3-degrees of freedom robotic devices for the balance rehabilitation.
- ◆ Development of wearable lower limb exoskeletons for hemiplegic children.
- ◆ Development of advanced and specific biomechanical models, such as the foot-ankle complex.
- ◆ Use and adaptation of robotic devices for the study of motor control in healthy or pathological subjects.
- ◆ Development of portable and low-cost solutions for natural or haptic interfaces for home rehabilitation.
- ◆ Development of solutions for biomechanical assessment in sports.
- ◆ Development of measurement methods and experimental protocols for *ex-vivo* characterization of muscle and connective tissue transgenic mouse.
- ◆ Creation of a muscle tissue engineered (X-MET), grown *in-vitro*.

The Mechanical Measurements Laboratory includes 14 computer stations, 7 workbenches, a welding station and 2 benches under extractor hood. The instrumentation, both for basic and for specific applications includes:

- ◆ **Essential Equipment:** Measurement chains for strain gauges, thermocouples, piezoelectric accelerometers, electromagnetic exciters, bench power supplies, signal generators, power amplifiers, multimeters, digital oscilloscopes, sensors for measuring temperature (thermocouple, PT100, etc.), sensors for displacement measurement (LVDT, linear and rotary encoders, potentiometers, absolute and incremental encoder), speed and acceleration (tachometers and capacitive and piezoelectric accelerometers), sensors for force and torque measurement, sensor for pressure measurement (piezoresistive sensors), Inspire 3D printer S250, FARO measuring arm.
- ◆ **Energy Systems measurements instrumentation:** 4-channel Micro Gas Chromatograph, Power-train "tank-to-wheel" fully instrumented with catalytic reformer and PEM fuel cell for global efficiency measure. Thermal imaging camera, FLIR, bench with power supply and electronic load for measuring the efficiency of lithium batteries, system for measuring the efficiency of the PV panels (with pyranometer).
- ◆ **Biomechanics Measurements instrumentation:** System of twelve IMU sensors for motion analysis, 6-cameras optoelectronic system for motion analysis, two 6-components AMTI force platforms, 16-channels EMG system, robot for upper limb rehabilitation, pressure matrix suitable for posturography, two biaxial electrogoniometers, robot for ankle rehabilitation.
- ◆ **Industrial Bioengineering Section - Clinical Ultrasound Imaging:** Ultrasound probes, ultrasound test object, low-frequency ultrasonic cavitation sonicator, linear and angular micro-positioners.

MOTION ANALYSIS

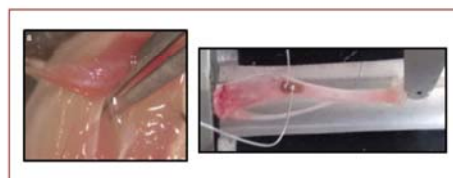
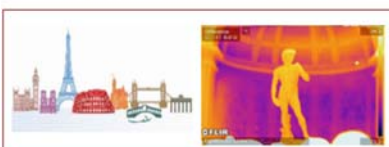


ROBOT MEDIATED THERAPY

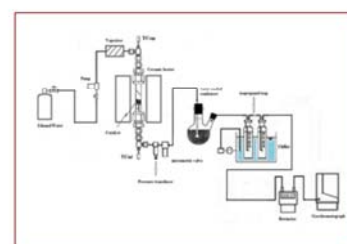


BATTERY PERFORMANCE

CULTURAL HERITAGE



TISSUES STRAIN



HYDROGEN PRODUCTION

ING-IND/13 APPLIED MECHANICS

- ◆ Vibroacoustics - non linear models + random loads (Statistical Linearization - Statistical Perturbation)
- ◆ High frequency vibroacoustic (Uncertainty propagation - Statistical Energy Analysis - Force identification)
- ◆ Medium-high frequency optimization using Statistical Energy Analysis (SEA) model - application: noise reduction on aeronautic and aerospace structures
- Tribology and contact mechanics
- ◆ Friction induced vibrations, contact damping and contact instabilities
- ◆ Friction and wear
- ◆ Numerical contact simulation and experimental contact instrumentation
- ◆ Control Robotics Mechatronics - Isotropic compliance
- ◆ Identification Substructuring - Experimental dynamic substructuring (dynamic behavior of complex mechanical systems)
- ◆ Micronano Mechanics - Theoretical and experimental research in micro electro mechanical systems (MEMS)
- ◆ design and fabrication MEMS-based devices
- ◆ development of a new concept CSFH (conjugate surface flexure hinge)
- ◆ Signal Processing and Detection
- ◆ Damping Dissipation - damping control and energy harvesting - Variational Approach to Optimal Control - Variational Feedback Control (VFC)
- ◆ Metamaterials - dynamic problems for metamaterials (wave propagation, piezoelectric mechanical structures for vibration control, active vibration control)

Multiphysics

Technology Application

- ◆ Vehicles (new Methods for crash detection, damage detection) - Vehicle control systems - smart tire Early Stage Damage Monitoring and Detection
- ◆ Aerospace - Bearings damage - Brake noise and performances
- ◆ Biomechanics



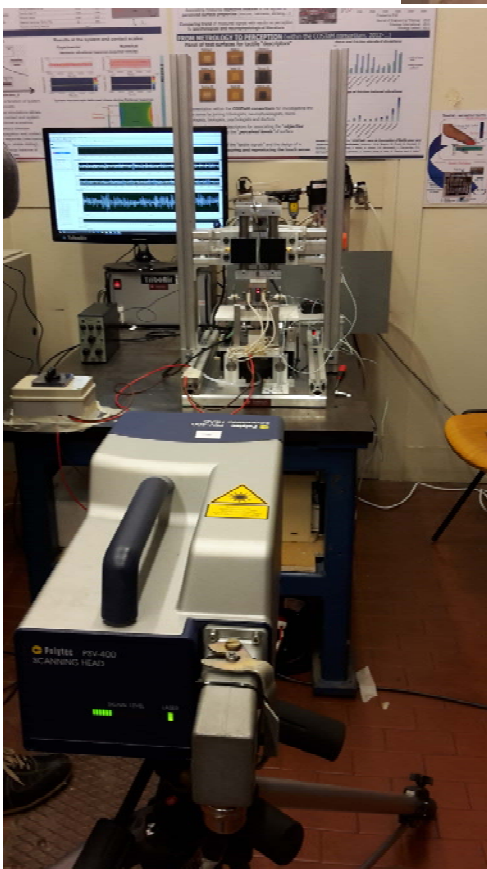
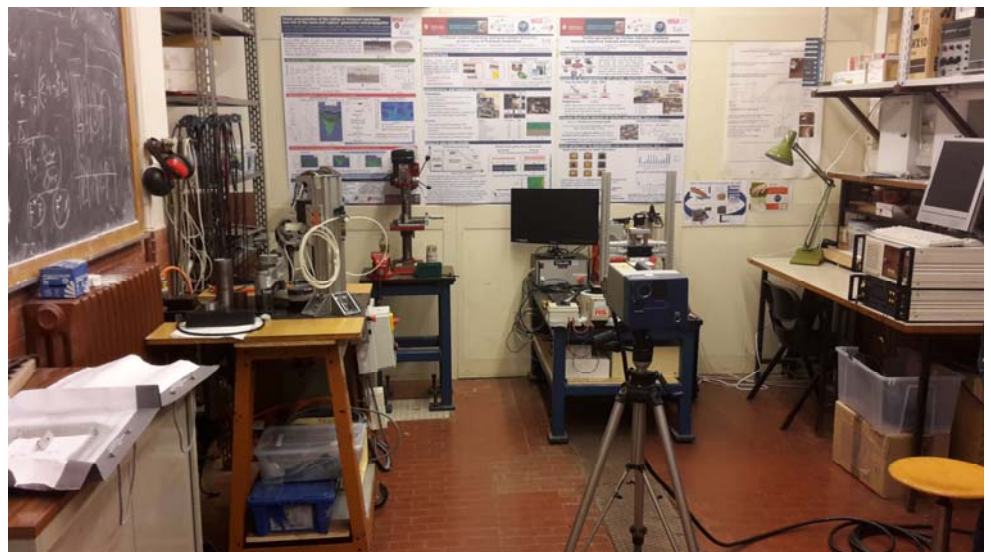
Vibroacoustic and Contact Mechanics

The vibroacoustics and contact mechanics laboratory is developed around the main experimental research topics of the applied mechanical group: vibroacoustics, tribology, biomechanics, and dynamics of mechanical systems.

Different test benches were developed within the laboratory for dynamic and tribological characterization of systems.

The lab has a wide range of vibration transducers, dynamic exciters, force transducers, microphones and two dynamic acquisition / analyzers.

A tribometer and a laser scanning vibrometer are also present.



ING-IND/14

MECHANICAL DESIGN AND MACHINE CONSTRUCTION

The research activities can be grouped into three major fields:

- ◆ **Advanced mechanical characterization of engineering materials.**

The research topic aims at the experimental characterization and numerical modelling of the structural behaviour of materials, focusing on large strain elastoplastic description, ductile damage accumulation, and fracture prediction. Investigated materials range from isotropic and anisotropic metal alloys (Steel, Titanium, Aluminum) to composites, and additive manufacturing alloys. Experiments are devised to induce complex stress states in material samples through multi-axial tests, mainly executed using a standard axial machine and a custom made bi-axial tension-torsion machine, both available in the Lab. Numerical models, to be used within Finite Element codes, are taken from the literature or developed on purpose. They are calibrated and validated using the experimental results. Over the years, the research results have been applied for the structural integrity assessments and design of several actual applications of structures such as: offshore and onshore oil and gas pipelines, similar and dissimilar welded joints, crash dampers, sheet metal stamping processes, and more.

- ◆ **Full field strain measurement using optical techniques**

The validation of theoretical/numerical models which describe material behavior can greatly benefit from a full-field local comparison between measured and computed strains. In this context optical techniques provide contactless non-invasive information of the strain distribution on the surfaces of material samples or actual parts. In this regard, an original white light speckle image correlation method algorithm was developed, which granted accurate measurements in a very wide deformation range (from 10^{-5} to 10^0 m/m). The technique was profitably applied to the study of the behaviour of different kinds of materials like metals, composites, biological tissues, and artworks.

- ◆ **Experimental and numerical methods for the restoration of Cultural Heritage.**

A long-standing collaboration with the "*Istituto Superiore per la Conservazione e il Restauro*" of Rome offered the group a chance to give an engineering support to the study, preservation and restoration of cultural heritage, particularly of canvas paintings. In this regard experimental techniques and numerical Finite Element models, usually employed in industrial engineering, were used to estimate the state of stress and pre-tensioning of important artworks such as: "L'annunciazione" by Antonello da Messina, Caravaggio's "La resurrezione di Lazzaro" and Raffaello's cartoon for the painting of the fresco "La Scuola di Atene". Results contributed to the assessment of the overall wear and aging effects of the paintings under study.

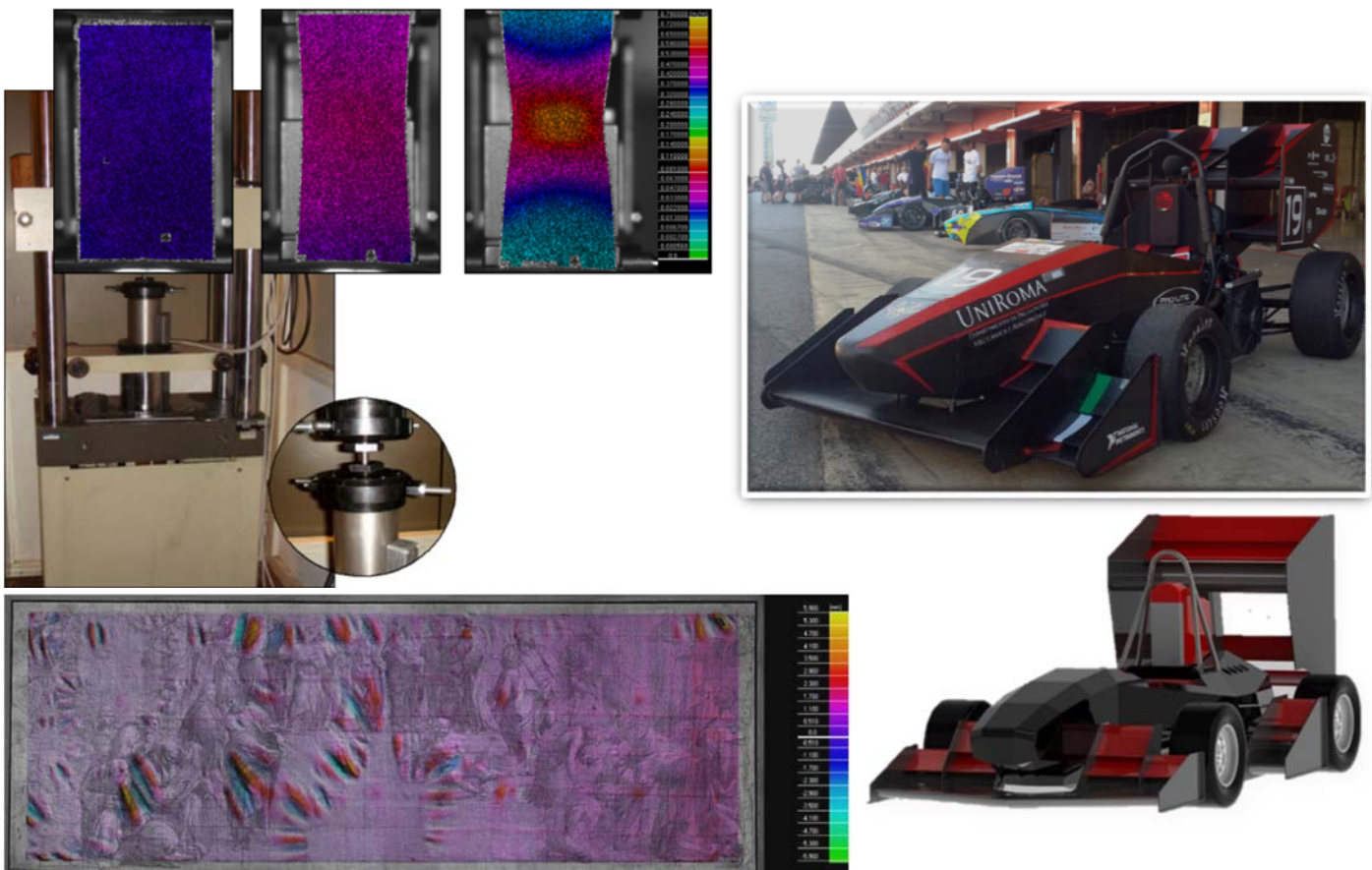
◆ Testing facilities

An hydraulic MTS testing machine, for axial tensile/compressive static and fatigue loads up to 250kN. The equipment is controlled by a 407 MTS hardware while load signal, crosshead displacements and specimen elongation data are collected by a National Instrument card and Labview software.

A tension-torsion custom designed electro-mechanical testing machine is available, based on a Schenck-Trebel four-columns frame, which allows axial and torsional loads up to 100kN and 1000Nm, respectively. Loads are acquired by a custom-made biaxial load cell, while displacements and rotations are recorded by means of digital encoders embedded in the actuators. The real-time control is provided by a National Instrument FPGA card programmed in Labview environment. The two axes can be independently loaded or displacement controlled. The equipment, in conjunction with proper specimen geometries, allows the execution of multiaxial tests characterized by very different loading conditions and stress states.

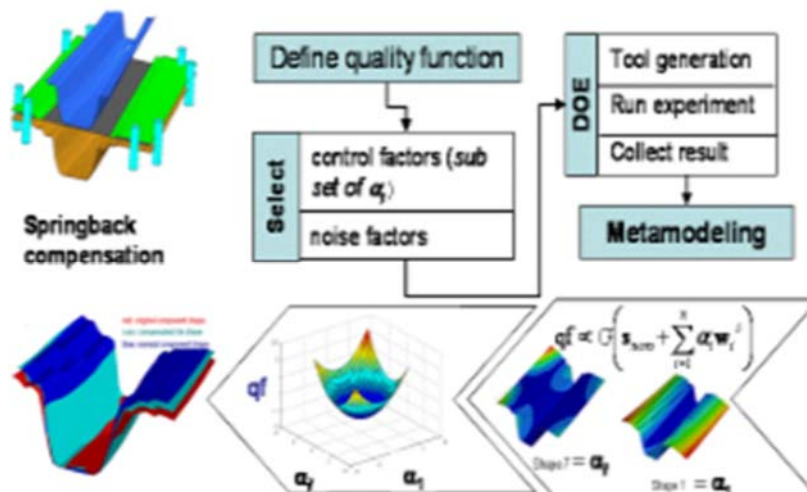
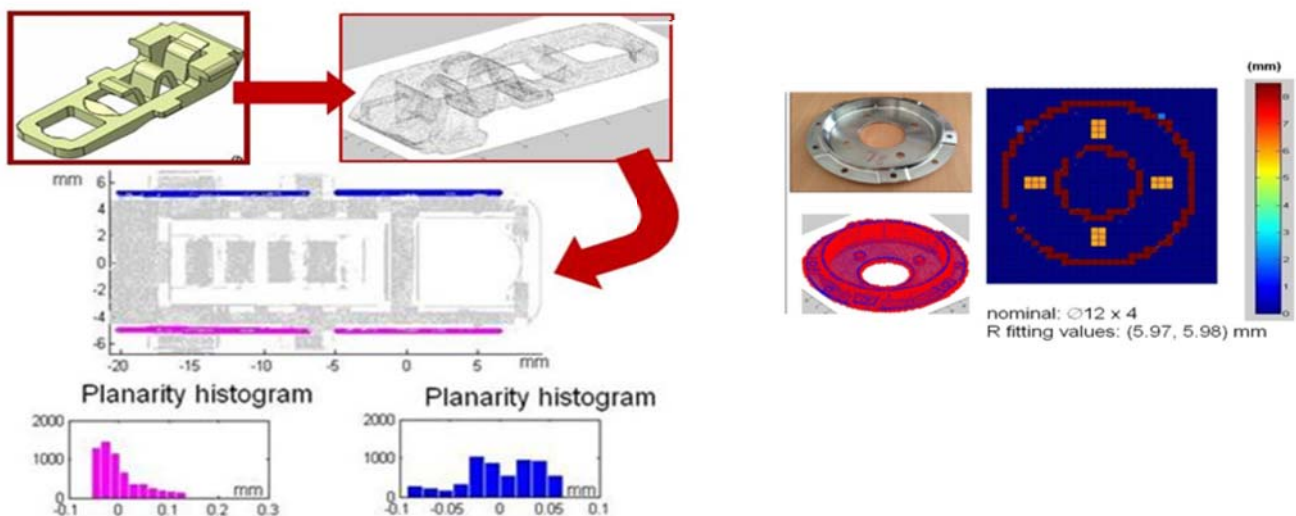
◆ Digital image acquisition equipment for DIC analysis

The group has a consolidated expertise in surface strain measurements relying on the "*white light speckle image correlation*" technique. A high resolution digital image acquisition framework can be used for the experimental activities, based on 2208×3000 pixel PixeLink cameras, controlled by a personal computer through a FireWire high speed connection. The system can be used with different testing machines available in the lab. The acquired data can be properly post-processed to quantify full-field displacements of the specimen with a spatial resolution up to a fraction of a pixel and strains during test execution.



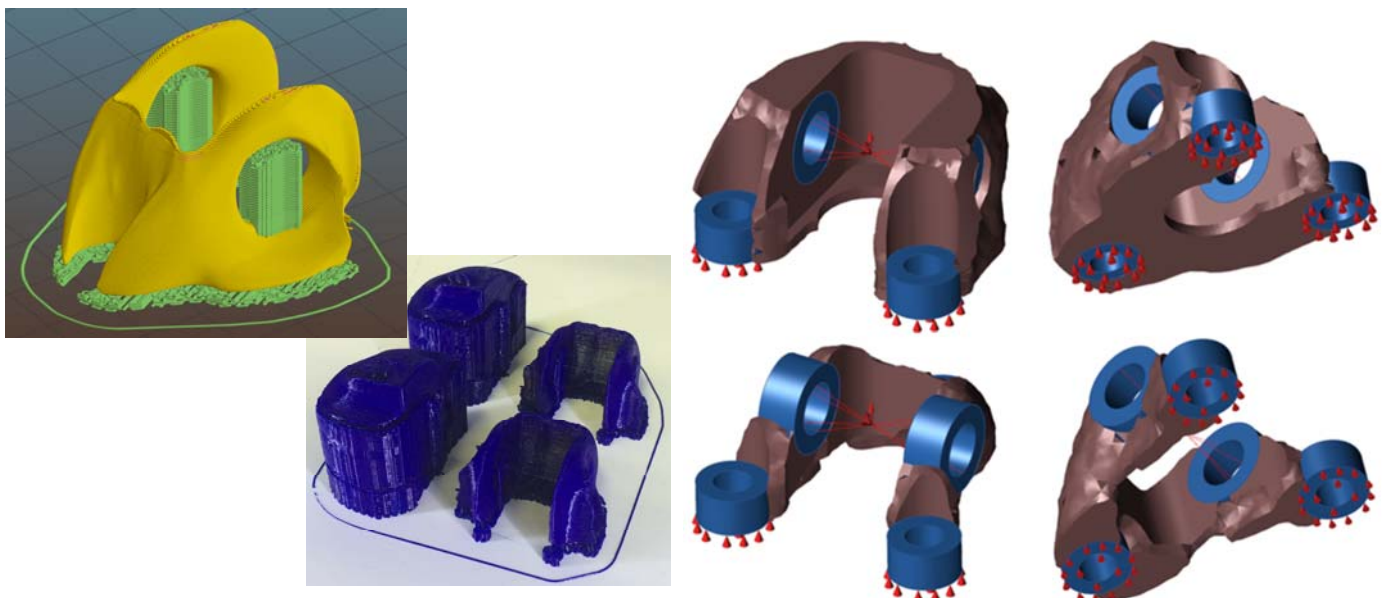
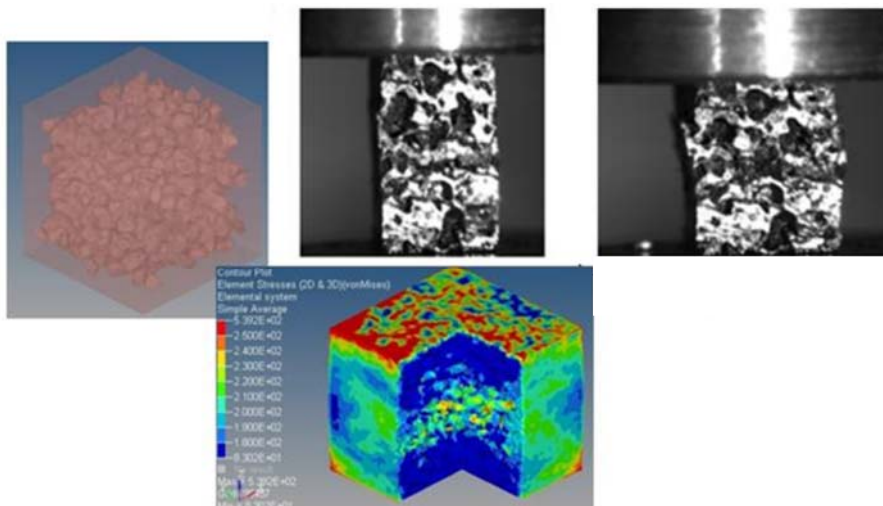
ING-IND/15 DESIGN METHODS FOR INDUSTRIAL ENGINEERING

- ◆ **Reverse Engineering:** acquisition and post-processing for the detection of shape, development and tuning of automatic systems for the analysis and control of the acquired surfaces (springback study of printed sheets, analysis of the damage of pipeline tubes, verification of electromechanical components).
- ◆ Methods to support CAD-CAE archaeological investigation, restoration, and conservation
- ◆ Computer Aided Tolerancing & Inspection Development of algorithms for verification of geometrical tolerances from Reverse Engineering clouds.
- ◆ **Product Lifecycle Data Management:** Study of expert systems for managing optimization processes in developing product-process (design alternatives study for bending and hydroforming tube duct discharge) and quality control (tolerances occurring in the development of processes for injection molding).
- ◆ **Virtual prototyping** of crash phenomena and cold forming processes.



ING-IND/15 DESIGN METHODS FOR INDUSTRIAL ENGINEERING

- ◆ CAETools with particular interest to their integration into the robust design (**Robust Design**) and in integrated design product-process (Design for Additive Manufacturing, design and verification of cold-molded components, cold-rolled optimization, hydroforming of tubes and sheets).
- ◆ **Topological optimization** and CAD-CAE tools for Additive Manufacturing.
- ◆ DOE planning of experiments applied in optimization studies and analysis of product (eg. Search of predictive methods in the context of the dynamics of toothed belts, structural verification of bent tubes, and development of response surfaces for the optimization of printed sheets, cold rolling and crash phenomena).
- ◆ Analysis of images applied to the study of aluminum foams. Characterization and control of cellular materials by means of the combined study of morphological analysis of cells and mechanical response.



ING-IND/16 MANUFACTURING TECHNOLOGIES AND SYSTEMS

Research activities are mainly focused on the use of additive manufacturing processes, laser power processing, and surface technology, which can range from surface finishing processes to functional film deposition processes.

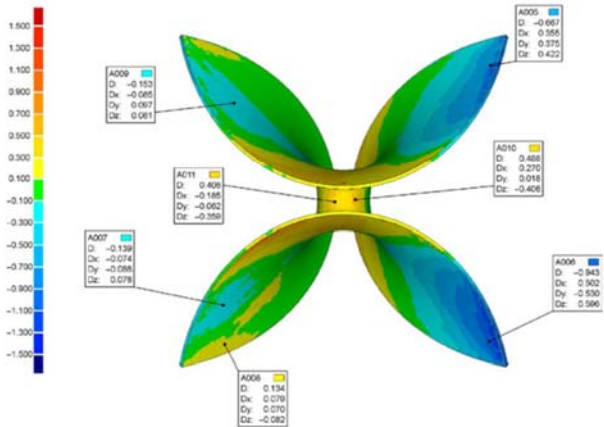
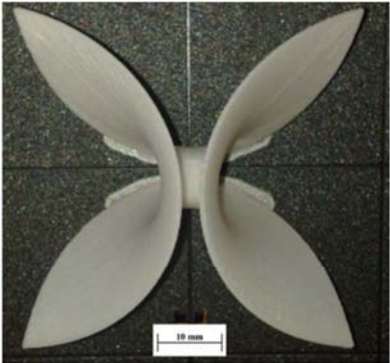
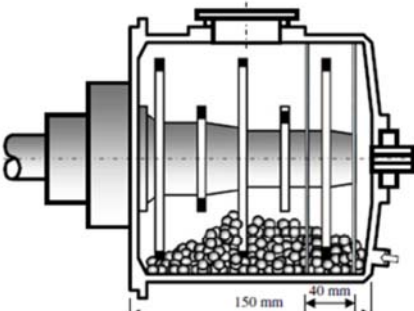
Over the years, the group has developed specific skills in the field of:

- ◆ Production of prototypes and components by additive manufacturing, with Fused Deposition Modeling technology and development of a rapid prototyping experimental apparatus;
- ◆ Machining with numerical control systems of free-form mechanical components;
- ◆ Finishing of manufactures and prototypes produced using traditional and non-laser (FDM) technologies by mass-finishing techniques;
- ◆ Manufacturing of metal foams for salt infiltration;
- ◆ Reverse engineering of complex geometry components;
- ◆ Laser thermal treatments aimed at increasing the mechanical and / or tribological properties of ferrous materials, metal metallic composite materials (hardening, surface aligation, etc.); Densification treatments of thermoswitch coatings, surface finishing of metal substrates or sintered components; Surface cleaning treatments (delamination, oxide removal, etc.);
- ◆ Recycling polycarbonate from electronic waste (optical media such as CDs and DVDs);
- ◆ Folding and shaping aluminum and stainless steel sheets with complex shapes and identification of innovative forming strategies;
- ◆ Aesthetic welding for conducting light alloys and precious metal alloys;
- ◆ Metal-polymer hybrid laser joints for applications in automotive, biomedical, food and pharmaceutical packaging;
- ◆ Analysis and modeling of laser processes using artificial intelligence techniques and numerical simulation to optimize them by identifying process windows;
- ◆ Deployment of organic or inorganic organic or organic hybrids for the production of aesthetic and functional coatings.

Manufacturing Technology Lab

In addition to standard support equipment, such as rugosimeters, microscopes, data acquisition systems, the technology and processing systems laboratory, the following equipment is dedicated to scientific and technological research in the field of mechanical machining:

- ◆ CNC milling machine
- ◆ centrifugal disc finishing plant - ECO MAXI range available in "Magnetic", "Wet & Dry" and "Basic"
- ◆ FDM additive manufacturing system
- ◆ Rofin-Sinar DL015 Diode Laser Source - 1500 W Wave Length 940 nm, spot size 3.8x1.2 mm²; Size of the laser head 580x180x155 mm³;
- ◆ Forced ventilation stove (model FD 53 Binder), volume 53 liters, equipped with electronic control system APT.line™, which guarantees temperature accuracy and reproducible results; Temperature range: from + 5 °C above room temperature up to 300 °C.

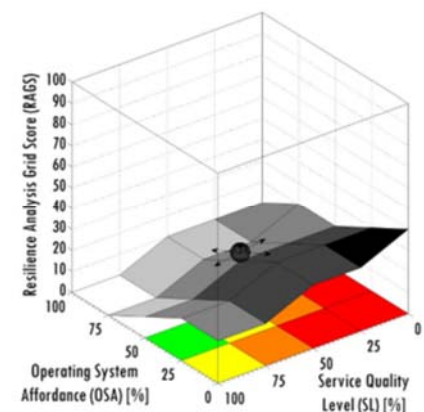
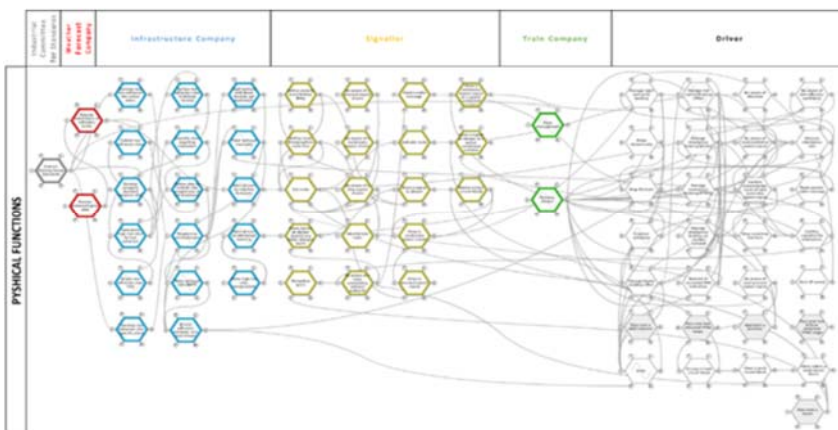


ING-IND/17 INDUSTRIAL MECHANICAL SYSTEMS ENGINEERING

The Industrial Systems Engineering area addresses a broad range of topics from production design to operations management. Analytic and theoretical models, simulation techniques and data-driven tools are developed to propose new opportunities for innovation, competitiveness, effectiveness, efficiency, and sustainability, practically relevant to decision makers in business and society.

The main fields of research are:

- ◆ **Design of industrial systems:** methodologies to efficiently design industrial systems and service, also including feasibility studies, life cycle design, manufacturing processes, general plant services, economic evaluation and investment risks, plant location analysis and plant layout design, environmental impact assessment, dimensioning of inventories and material handling systems, project selection and management.
- ◆ **Risk Management:** new models and methodologies to identify, assess, and manage risks, with specific innovation in the field of resilience engineering for complex systems.
- ◆ **Operations management:** tools and techniques to design, manage, control, and improve the production processes and infrastructures by an optimization approach, also including lean management, six sigma approach, and simulation modelling.

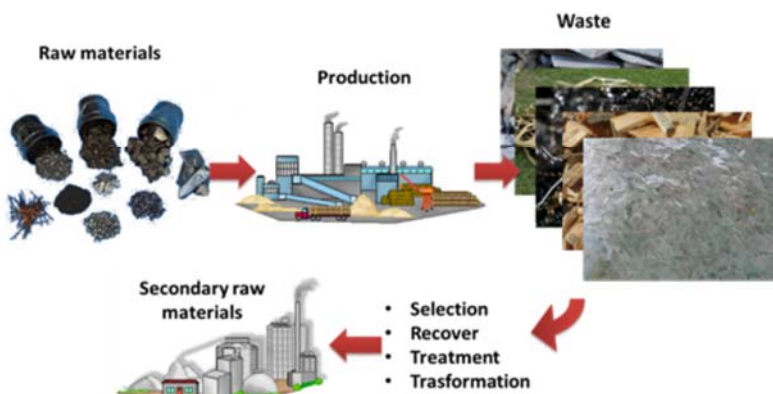
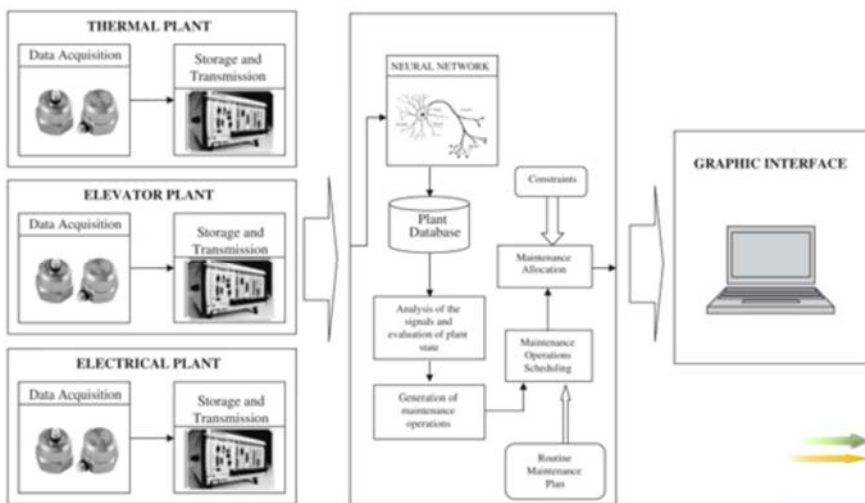


Logistics and Supply Chain Management: design, management, assessment, and improvement of logistics systems and supply chain, based on strategies to integrate companies with customers and suppliers, innovative tool to coordinate the planning of ordering, production, and logistics, rating model for supply chain performance, methodologies to reduce risks of disruption risks in the supply chain. Models, Governance-Risk Management-Compliance models.

ING-IND/17

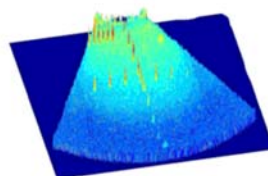
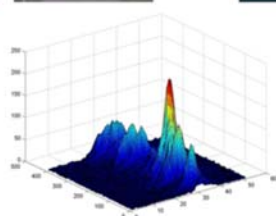
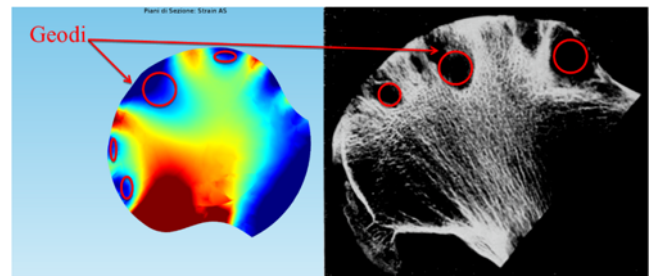
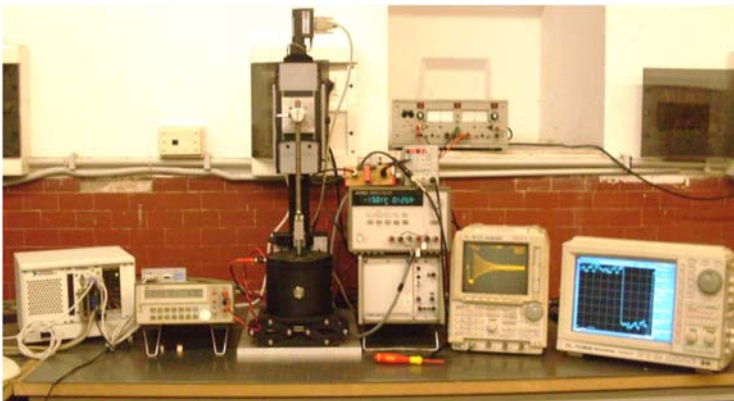
INDUSTRIAL MECHANICAL SYSTEMS ENGINEERING

- ◆ **Safety and maintenance:** methodologies and techniques for advanced maintenance and predictive safety, also including Tele-Maintenance, predictive Safety Intelligent System, ergonomics, resilience engineering applied to safety. Innovative models for spare parts management, also including the reduction of inventory costs, and logistics improvements.
- ◆ **Life Cycle Assessment and Management:** sustainability focus through the analysis and improvement of product, service, processes, management systems, supply chain, with Life Cycle approach, cost/assessment techniques, and end of life analysis.
- ◆ **Environmental and Quality Management:** business practices to increase stakeholders' satisfaction and reduce or prevent environmental pollution, achieved through management techniques. Total Quality Management and Excellence Models, Governance-Risk Management-Compliance models.
- ◆ **Industry 4.0 and production digitalization:** to enable the applications of IoT solution into productive systems, with specific frameworks and data-driven techniques to increase company performances, also including the analysis and management of the risks with the new digital opportunities.



ING-IND/34 INDUSTRIAL BIOENGINEERING

- ♦ Analysis of structure property relations and transport phenomena in nano-structured biomaterials
- ♦ Experimental analysis of low-frequency ultrasonic-induced cavitation phenomena for clinical use.
- ♦ Morphometric analysis of histological and ultrasound images of soft tissues (kidney, liver, thyroid).
- ♦ Tools for clinical evaluation of patients with facial paralysis.
- ♦ Tools for clinical evaluation of dysphagic patients.
- ♦ Modeling of Zinc Oxide Nanogenerators for Energy Harvesting.
- ♦ Evaluation of altered engine patterns in central nervous system disorders
- ♦ Study of the effects of Repeated Muscle Vibration (rMV) on cortical-muscular plasticity
- ♦ Analysis of sensors for detecting physical activity in 24 hours for the prevention of chronic diseases.



THIRD MISSION

Technology transfer
and societal impact



SUBJECT AREAS

The Department of Mechanical and Aerospace Engineering fosters the direct application, the promotion, and the dissemination of the scientific and technological knowledge for contributing to the societal, cultural, and economical growth of the society.

In this context, DIMA has a number of active collaborations and research grants with industrial partners and national and international agencies. DIMA has incubated some spin-off companies related to its research activities.

The research contracts are in the following areas, which often involve several of the academic disciplines to which each faculty belongs:

- ♦ **Automotive:** design of vehicles or vehicle parts; investigation of its fluid dynamics and materials; measurement of operation parameters, of vibrations, of noise, and emissions; realization of control systems.
- ♦ **Aeronautics and Aerospace:** space transport systems, satellite systems and services, control systems, simulation of flight mechanics, collision tests, aerodynamics analysis, ballistic tests and simulations, propulsion, modeling of systems or parts, wind-tunnel tests.
- ♦ **Biotechnologies:** simulation of bioreactors and fermentation processes.
- ♦ **Energy:** simulation and modeling, prototyping and management of energy systems and of individual plants for the generation of electricity, useful heat, or cogeneration, study of accumulation systems.
- ♦ **Quality:** analysis of industrial processes and risk analysis, safety and health management, quality control according to ISO standards, compliance management, models for the assessment of orders, compliance with safety regulations
- ♦ **Robotics:** modelling, simulation, and control of robots, design and modeling of components and systems (manipulation and motion-control systems, static components)
- ♦ **Nanotechnologies and MEMS:** micro and nanotechnologies for the development of new materials, biotechnologies, and micro and nanodevices; atomistic simulation of devices for specific functional and multifunctional applications.
- ♦ **Materials:** simulation and experiments on materials, preparation of testing specimens, microscopic analysis, comparative analysis of materials, component design
- ♦ **Technologies:** leveraging the broad expertise of its members, DIMA is active in the development and in the transfer of a broad spectrum of technologies
- ♦ **Green Engineering:** modeling and realization of prototypes of efficient energy systems, in particular based on renewable sources; simulation of processes and measurement of pollutant emissions. Assessment of low-impact energy carrier, recycling and energy re-use of wastes.
- ♦ **Biomechanics:** the expertise of DIMA in this area concerns the mechanics, fluid dynamics, and materials science as well as an established expertise in measurements and the design of biomedical devices.

The DIMA labs offer the possibility to perform a broad range of activities under contract, including specimen preparation, fluid dynamics tests, modeling of complex systems, and various types of measurements.

SPIN-OFFS

Spin-offs are the quintessential means of developing highly innovative businesses based on the research and knowledge base accomplished within the University. Sapienza fosters and promotes the birth of start-ups with the aim of transferring to the market patents, inventions, know how, or devices which are the result of scientific research.

With this idea, DIMA members have founded several spin-offs in diverse fields:

AIComply



(Contact Person: Prof. Massimo Tronci)

AIComply has the mission to develop and supply innovative services for Compliance Management in order to ensure the fulfillment of regulations or on a voluntary basis. The integrated approach is based

on a technological platform which accounts for multiple regulations ready to launch on the market. The goal of the service offered to the market is that of contributing to the evolution of static management systems of Compliance, moving towards an innovative Compliance & Risk Management, by offering methodological and technological support that, based on the output of processes, controls, and action plans, is capable of assessing the actual risk level to which the company is exposed.

SED Soluzioni per l'energia e la diagnostica



(Contact person: Prof. Alessandro Corsini)

The goal of SED is to develop and provide products and services for supporting the technologies for the diagnosis and prognosis of rotating machines, turbomachinery, and energy and power systems. In particular, SED is concerned with the development of the industrial production of on-time and on-line monitoring systems implementing new softwares for the diagnosis of unstable operation regimes and for their control by suitable actuators.

Smart Structures Solutions

(Contact person: Prof. Paolo Gaudenzi)



This spin-off stems from the idea of realizing monitoring systems for structural safety based on wireless communications and autonomous operation (i.e., without external electrical power supply). Smart structures technologies, which have been studied and developed in several international research centers including Sapienza, offer a number of technological solutions for both the choice of sensors and self-production of power, using energy harvesting methods and/or technologies.

CAESAR

(Contact Person: Prof. Enrico Sciubba)



The Spin-Off is a vehicle for the generation and dissemination of innovative ideas and projects in the field of Energy Conversion Systems and their components. Its main activity is designing and consulting on the operative features of conversion systems, to enact improvements to the general process efficiency, to optimize feasible configurations, to improve process simulators, to reduce the environmental footprint.

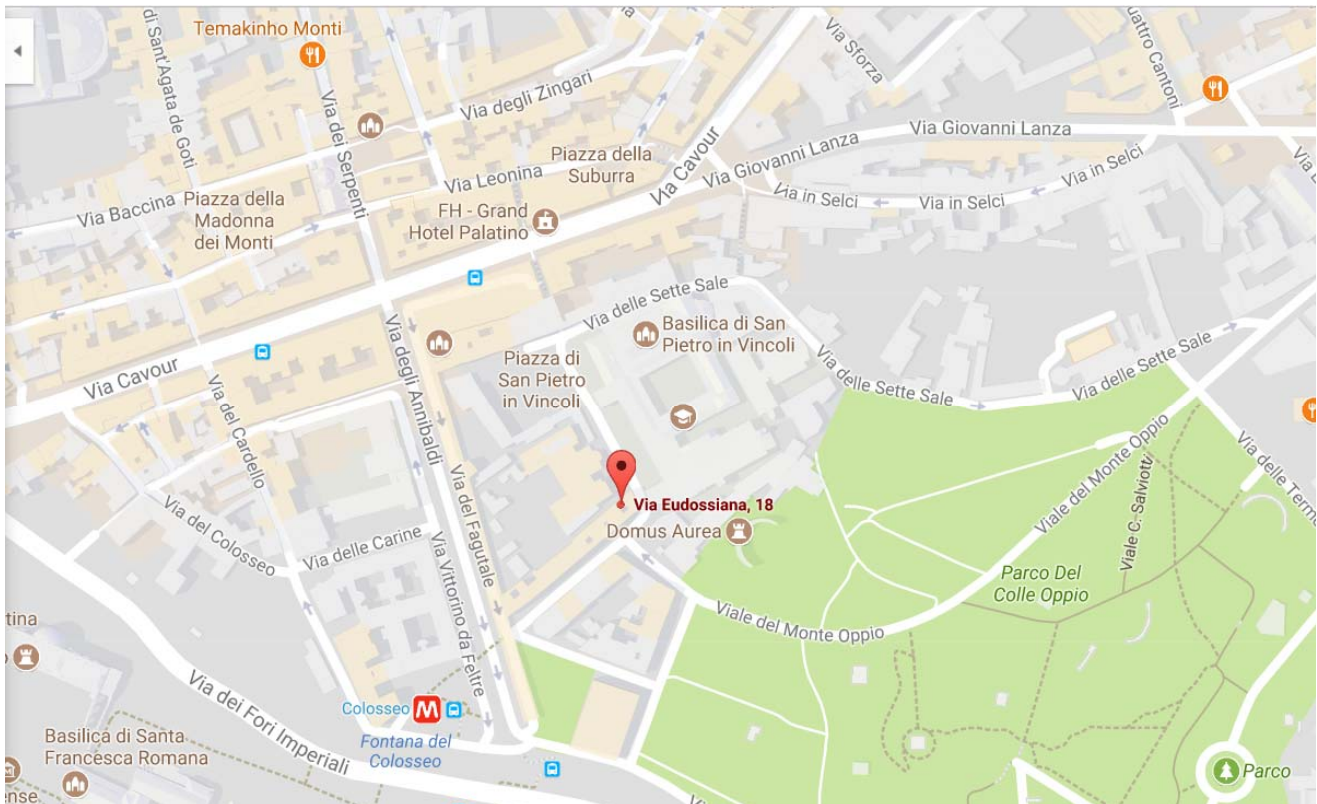
The central idea is to integrate the scientific activities proper of the academic world with the reality of the technological state-of-the-art, while keeping an eye on advanced implementations: the goal is to maximize the synergic effects of a close and structured cooperation between academic and industrial researchers.



WHERE WE ARE

DIMA is located in the Faculty of Civil and Industrial Engineering of Sapienza. Our location can be easily reached by bus/metro, by train, by taxi or by car.

Via Eudossiana 18—00184 Roma



Please check our website for further information:

www.dima.uniroma1.it

DIMA

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