Italian Aerospace Research Centre

FLY HIGH
FLY FAST BUT
FEET ON THE GROUND

Overview of the activities and facilities of the **Italian Aerospace Research Centre**

THE ITALIAN AEROSPACE RESEARCH CENTRE (CIRA)

Is a private-public company, located in Capua, Campania, whose shareholders are the National Research Council (majority shareholder), the Campania Region and Italian aerospace industries.

The Italian Government entrusted CIRA with the implementation and management of the National Aerospace Research Program (PRO.R.A.), thanks to which CIRA has outstanding aerospace research infrastructures and scientific skills that contribute to making it an internationally recognized and appreciated Centre of excellence in aeronautical and space disciplines.

The approval (in 2020) of the New PRO.R.A. marks the beginning of a new multi-year cycle made of strategic research and technological development projects and new laboratories and test facilities in the field of: sustainable, resilient and safe air transport, advanced air mobility with autonomous and/or remotely-piloted aircrafts, innovative propulsion systems, access to and exploration of space, Earth Observation and suborbital and stratospheric flights.

TOWARDS A NEW GENERATION WING FOR REGIONAL TP AIRCRAFT

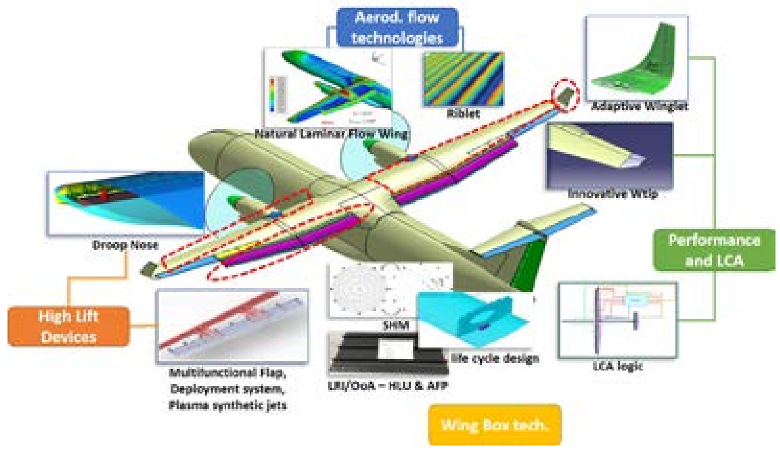
The regional aircraft market continues to be a key growth sector within commercial aviation, contributing significantly to efficiencies in the airline networks and ensuring safe and seamless mobility, while respecting environmental obligations.

The role of Clean Sky's Regional Aircraft programme is to validate the integration of innovative and affordable technologies in future regional aircraft platforms.

The Project AirGreen 2 aims to develop and demonstrate innovative concepts and methodologies enabling the realization of a wing of new generation. This wing will be characterized by: an innovative structure, as a result of an improved life cycle design; a high level of adaptability, enabling load control and alleviation strategies, and enhancing the aerodynamic performance at the different flight regimes; an innovative aerodynamic design, oriented to the preservation of the natural laminar flow and for the drag reduction.

CIRA, project leader, is involved in the development of a new concept of Morphing Winglet that meets the requirements provided by Leonardo. Implementing a unique design, the Winglet features two independently movable morphing surfaces, capable of increasing the aerodynamic efficiency of the wing by actively controlling the loads at the wing interface. The Winglet will be tested in flight by Leonardo after qualification through full scale ground tests.

AIRGREEN2 is a project co-funded by the European Union under the Clean Sky 2 Programme



Technologies Developed within the AIRGREEN2 Project for the New Generation Wing

Full Scale Morphing Winglet Ground Structural Demonstrator

REVOLUTIONIZING SMALL AIR TRANSPORT FOR A GREENER FUTURE

Exploiting Small Air Transport (SAT) can help achieve the mobility goal of a 4-hour door-to-door travel time and leverage Europe's dense airport/airfield infrastructure, with several benefits, such as reduced fuel consumption, reduced turnaround times, and improved economic viability. To support the SAT growth and the integration in the SESAR ATM environment, new technological solutions reducing the SAT operating costs are needed and the implementation of single pilot operations is crucial.

The COAST project aims delivering key technology enablers for the affordable cockpit and avionics for aircraft with 1 to 19 passengers and small cargo aircraft, all belonging to the CS-23 category (EASA certification). In addition to improving affordability, some of these technologies have the potential to reduce aircraft-related emissions by allowing optimized flight profiles.

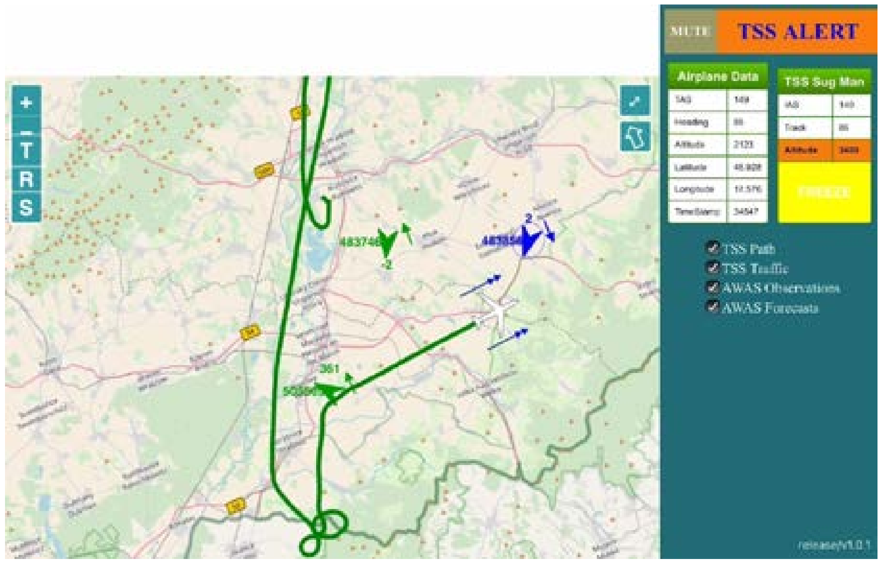
CIRA is involved in this project as leader of specific technologies such as:

Tactical Separation System (TSS), which is an Automatic Dependent Surveillance-Broadcast (ADS-B) based advanced self-separation system to extend traffic situational awareness. The system provides the pilot, through dedicated graphical human-machine interface, with suggested maneuvers aimed to maintain the required separation minima.

Advanced Weather Awareness System (AWAS), which provides complete awareness of weather situation with (both observed and forecasted) information assisting the pilot in avoiding entry into atmospherically dangerous areas.

These systems have been successfully demonstrated in real flight trials in the year 2021 and now CIRA is working on the evolution of these technologies to be included in the Integrated Mission Management System (IMMS).

The COAST project is co-funded by the European Union under the Clean Sky 2 Programme
The consortium consists of four EU partners: Honeywell CZ, CIRA, Łukasiewicz – Institute of Aviation (ILOT) and Rzeszów University of Technology (RUT).



Tactical Separation System (TSS) pilot's interface. Example of Single-pilot decision-making support technologies developed by CIRA

FLYING IN COMFORT: HOW THE CASTLE PROJECT ENHANCES PASSENGERS' WELL-BEING DURING FLIGHTS

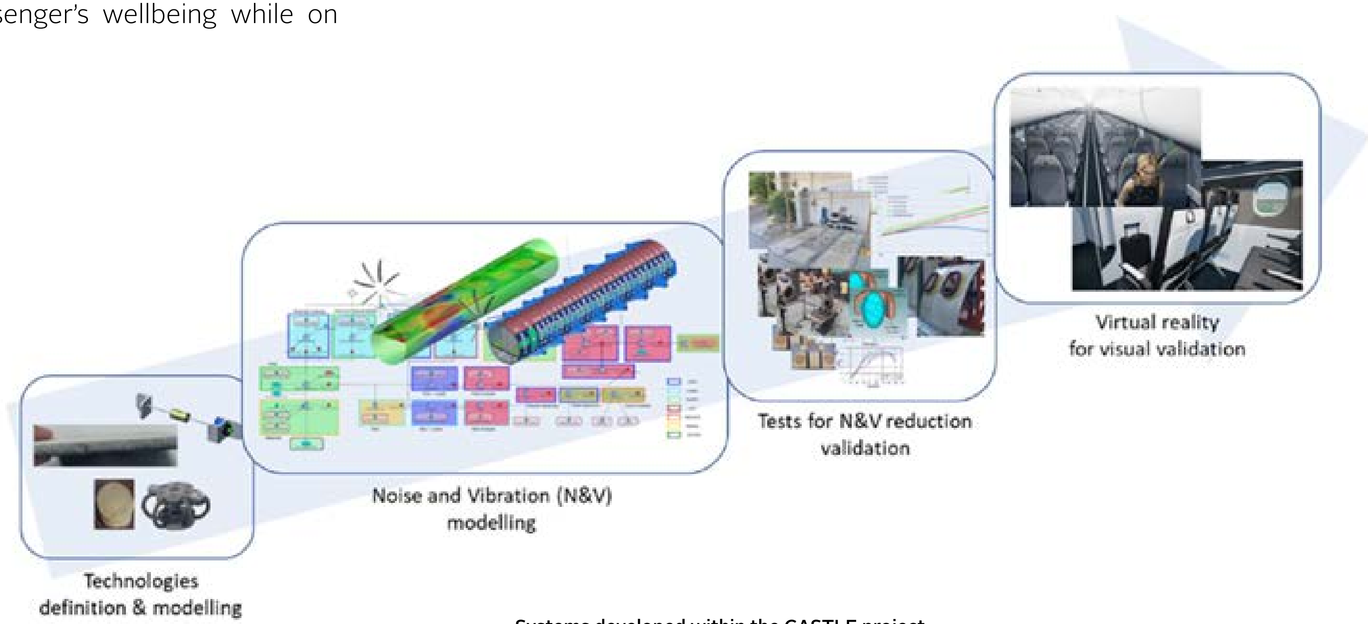
The CASTLE Project (CAbin Systems design Toward passenger welLbEing) aims to develop and demonstrate an improved and optimized cabin environment through an innovative human-centric design approach in order to increase passenger's well-being and making the travelling time more effective and productive for both business jet and regional aircraft. The investigated technologies and design solutions aim at constructing full-scale test benches representative of the aircraft cabin, including major cabin items associated to passenger's and service areas.

In this project CIRA is involved as leader of some specific technologies and design solutions enabling the development of an innovative cabin environment in terms of comfort for passenger's wellbeing while on board of a regional aircraft.

These solutions combine environmentally friendly materials and technologies for the reduction of noise and vibration.
Passive and active solutions for noise and vibration were investigated to optimize the cabin with respect to key comfort drivers and psychoacoustic criteria and the down-selected technologies have been successfully demonstrated at a high Technology Readiness Level (TRL) in 2022.

CIRA also supported the design of the innovative cabin items with fully immersive simulations and a visual validation in a virtual reality environment realized with a Head Mounted Display (HMD).

The Project is co-funded by the European Union under the Clean Sky 2 Programme. The CASTLE consortium consists of 11 EU partners: GEVEN (leader), ACUMEN, CIRA, DEMA, INVENT, NOESIS, PGA, POLITO, SIEMENS, UNIBO, UNINA.



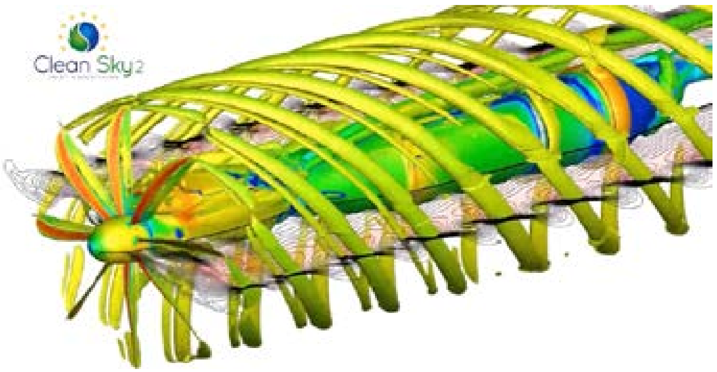
Systems developed within the CASTLE project

REDUCING CABIN NOISE IN TURBOPROPS: THE IRON PROJECT'S MISSION

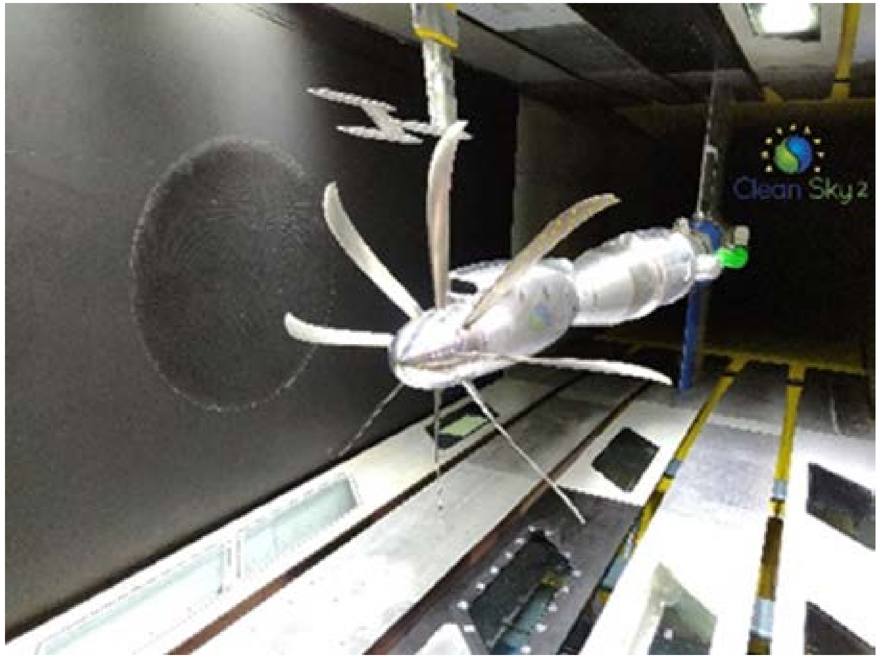
Turboprop aircraft typically produce around 95% of their thrust from a propeller, with a jet exhaust providing the rest. With this split it won't be a surprise that most of the noise arising by a turboprop is generated by the propeller itself. As the propeller spins, the speed at which the tips are moving is high, sometimes transonic, and the disruption to the airflow creates pressure fluctuations that result in a series of low frequency tones that the human ear is more sensitive to, leading to the perception of a noisier cabin for passengers.

This is why CIRA, together with the other IRON project partners, aims to carry out design studies of innovative propeller concepts in order to significantly reduce noise levels without degrading aerodynamic performance.

Out of the five designs developed by IRON partners during this process, two designs achieved the highest scores and were selected for comparative wind tunnel testing against a baseline model.



IRON is a Clean Sky2 project coordinated by CIRA, with Leonardo serving as the topic leader. The project also benefits from support and contributions from several core partners, including GE Aviation Advanced Technology (AAT) Dowty Propellers, CENAERO, Royal NLR, ONERA and Avio Aero.



High-speed wind tunnel installation and corresponding digital-twin used in CIRA computational fluid-dynamics and aero-acoustic simulations, for one of the three tested turbo-prop configurations

THE INTEGRATED SIMULATION FACILITY: A CIRA ASSET FOR SUPPORTING THE EUROPEAN DAA SYSTEM VALIDATION ACTIVITIES.

There is a general consensus among experts that we will see a growth of certified remotely piloted aircraft systems (RPAS) for civil and commercial purposes. Safety of these operations will be a critical issue as increasing numbers of unmanned vehicles enter civilian airspace. In this context, a Detect and Avoid (DAA) system represents the most critical enabling technology to guarantee an equivalent level of safety of manned aviation. Various international research projects, standards and regulations supporting studies have addressed and are still working on the development and full validation of a DAA system (in Europe both SESAR as far as EDA and EDIDP funded programs).

The CIRA Integrated Simulation Facility (ISF) has been used in the Real-Time Simulations (RTS) with the Human-In-The-Loop validation activities of large DAA programs, such as URClearED (coordinated by CIRA), ERICA, and EUDAAS, for the development of a European DAA System.

ISF is a structured simulation facility fully developed and managed at CIRA for Real-Time validation of avionics systems for General Aviation and RPAS aircraft, encompassing high fidelity simulators of GA aircraft, rotorcraft, TUAV/MALE RPAS, GNSS SBAS/GBAS navigation systems, air transport system and ATCO Controller Working Position, U-Space drones and services, with the capability to integrate in the loop pilots, remote pilots and ATCO through fully functional Human Machine Interfaces.

Remote Pilot and ATCO perform Real-Time Simulation in URCLEARED Project

SCALED FLIGHT TESTING: THE COMPETITIVE EDGE IN INVESTIGATING DYNAMIC AIRCRAFT BEHAVIOUR

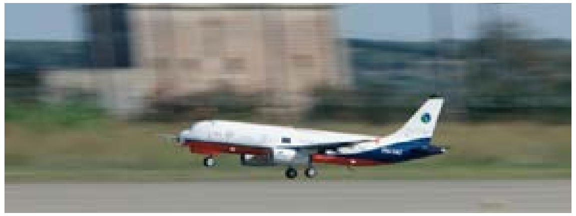
To achieve a climate-neutral air transport system by 2050, new disruptive technologies and aircraft architectures will need to be introduced, developed and tested. The Scaled Flight Testing represents a viable and competitive strategy to investigate the impact of new technologies/architectures on the real scale aircraft's dynamic behaviour. It can complement other design & verification strategies such as numerical simulations, wind tunnel testing and other ground testing.

The demonstrator developed in the SFD (Scaled Flight Demonstrator) Project represents a dynamically scaled version of an existing, full scale aircraft, featuring a wingspan of 4 metrAes, a take-off mass of 140 kg, and a cruise speed of 85 kts.

As part of the project, CIRA dealt with:

- Development of a Ground Remote Piloting Station (GRPS) to be embedded into the overall Ground Control Station from which the SFD is controlled. The aim is providing the remote piloting crew with all flight information data needed for a comfortable and safe flight. The GRPS, being a flight simulator, is also used to train the pilot and to minimize the risks associated to each planned flight mission.
- Development of a Guidance, Navigation and Control System (CNG) that facilitates the execution of flight experiments and guarantees a good quality of flight data produced. The GNC system allows the aircraft to autonomously fly through assigned circuits and to automatically execute pre-scheduled maneuvers.
- Mission Flight Test (MFT) campaign preparation and execution carried out at Grottaglie airport in Italy. The 19 flights, for a total of more than 8 hours of flight time, allowed verification of system functions, the tuning of the GNC, the calibration of the air data system and more important, the recording of the aircraft dynamic responses to many different inputs on the control surfaces to achieve a thorough parameter identification process.

Scaled Flight Demonstrator is a Clean Sky 2 project (Large Passenger Aircraft platform). The partnership includes Airbus, CIRA, Royal NLR and ONERA



The Scaled Flight Demonstrator during a take-off at Grottaglie Airport

Guidance Navigation and Control System: autonomous flight and automatic maneuvers during real flight data acquisition operations at Grottaglie Airport

THE FUTURE OF MAINTENANCE FOR UAV: AUTONOMOUS STRUCTURAL ASSESSMENT THROUGH SHM SYSTEMS

An attractive option for maintenance of structural integrity of UAVs is the use of structural health monitoring (SHM) systems. The aim of SHM is the autonomous structural airworthy assessment of individual vehicles, alerting for maintenance actions only as needed. Among the available SHM technologies, fiber optics sensing and, in particular, the use of multiplexed fiber Bragg gratings (FBGs) offer the main advantage of being quite flexible and tolerant to environmental conditions and electromagnetic interferences. In addition, their small diameter allows for easy embedding within large composite-material-based structural components, such as many UAV wings.

RESUME (Real-Time Health & Usage Monitoring Systems for UAV) is a joint cooperation between Israel and Italy to demonstrate the feasibility for the application of Real-Time SHM systems on-board of an UAV aircraft.

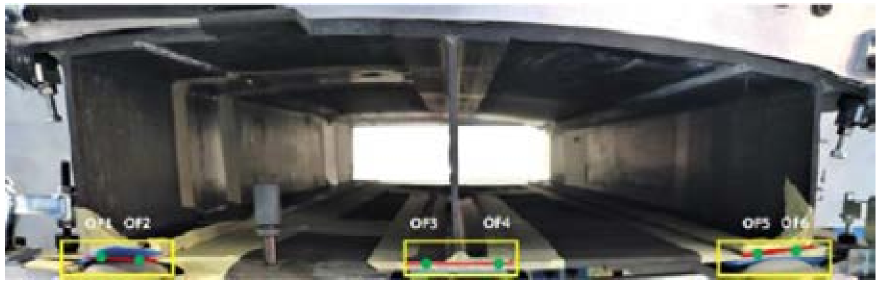
The proposed system is based on a real-time module, allowing for management of data provided by a four-channel interrogator and redistribution of this information to different SHM algorithms, with the aim of detecting the possible presence of flaws. In the described setup, SHM algorithms developed by CIRA (Italian Aerospace Research Centre) and IAI/TAU (Israel Aerospace Industries/Tel-Aviv University) were simultaneously deployed, operating concurrently on the same data.

Test article equipped with FBG technology

The generated output is managed by a real-time module, which transforms the results into sound (or even visual) cues to attract the attention of a generic user. In this regard, the measure of the actual real-time system considered herein is the difference between the instants correlated to two consecutive outputs; such a time interval was evaluated to typically be approximately one second.

Tests are being executed on a composite beam, with the aim of testing a real-time SHM system to detect the possible presence of a flaw. The system has proved its capability to detect damage with a good estimation of the damage length. The tested applications confirmed that the proposed SHM system is able to point out the "edge" of a damage region, which is intended as the starting (or ending) point of the occurring fault.

The project is funded by MOD of Italy and Israel. According to the PA 2019/3, Italian MOD has assigned the contract to the RTI composed from Piaggio and CIRA



Fibers Optics installed on portion of Full-Scale Wing Box

MONITORING SKIN/SPAR BONDING LINES OF CFRP WING BOXES: ADVANCEMENTS IN TECHNOLOGY

The OPTICOMS project aims to develop design and manufacturing processes for the future wing of Piaggio Aero aircraft. Within the project, CIRA is leading the development of a Structural Health Monitoring System that aims to monitor the bonding lines between skin and spars using distributed Fiber Optics technology.

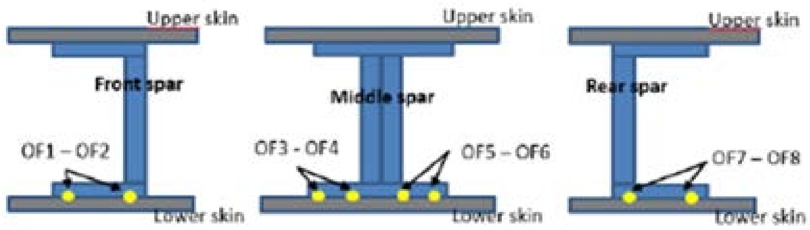
The activities in this project are primarily focused on three main objectives:

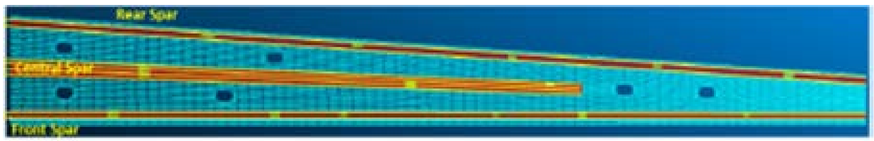
Exploring the capabilities of SHM system concepts that use distributed fiber optics and a proprietary SHM algorithm.

Gradually increasing the complexity of test articles using a building block approach.

Gaining experience in optical fibers deployment and embedding processes, with the ultimate goal of defining specifications for an industrialization procedure.

OPTICOMS is a research project co-financed by the European Union under the Clean Sky 2 programme.





Fiber Optic Locations embedded inside the structure

T-WING: AN INNOVATIVE COMPOSITE WING FOR THE NEXT GENERATION CIVIL TILTROTOR

T-WING is a project that aims at the development, up to TRL6, of the wing of the Next Generation Civil Tiltrotor Technology Demonstrator, developed by Leonardo.

The design of the wing was driven mainly by aeroelastic requirements, which required a tailored composite layup to maximize wing-box structural stiffness whilst minimizing weight penalty. For what concerns the manufacturing and assembly, the innovative composite wing is characterized by innovative features such as a highly integrated upper skin concept, a modular tool chain and no-gap approach for the Nacelle Primary Structure Installation.

T-WING Consortium has been working on the wing since 2016, from consortium building-up to the wing delivery as a result of 8 years of hard work. The project kick-off was held in 2018, and over the years the main milestones were successfully performed, until the main milestone of delivery of the wing assembly complete with Nacelle Primary Structure to Leonardo in Cascina Costa, that was achieved on 9th May 2023.

The Next Generation Civil Tiltrotor is one of the two Integrated Aircraft Demonstrator Platforms of Clean Sky 2 Fast Rotorcraft. The partnership involves CIRA (Project Coordinator), MAGROUP, OMI, MAREGROUP, IBK-INNOVATION, UNINA

Wing flight article prior to delivery

Wing flight article delivered to Leonardo in Cascina Costa and installed on the NGCTR-TD fuselage

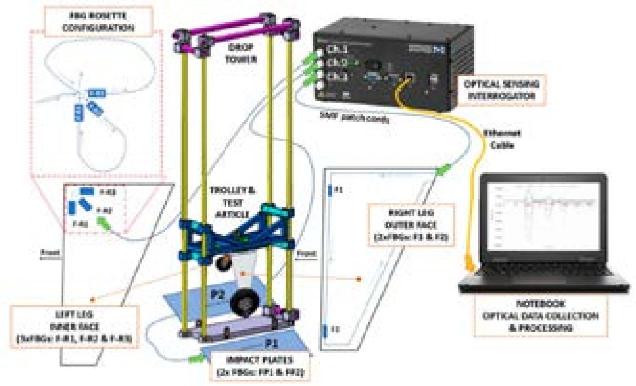
ADVANCED TECHNOLOGY FOR SAFER LANDINGS, THE ANGELA PROJECT'S SMART LANDING GEAR SYSTEM

During their lifetimes, landing gears shall resist any operational load, both in normal and extreme conditions. Distributed sensor nets can be integrated into smart landing gears with different objectives, which may include the following: weight on wheel, weight and balance assessments, hard landing detection and even flight management and control or wheel dynamometers. At present, for instance, there are no assessed direct methods for determining whether a landing gear was overloaded during landing or ground manoeuvres; currently, airlines rely on a combination of pilot's judgment and recorded data.

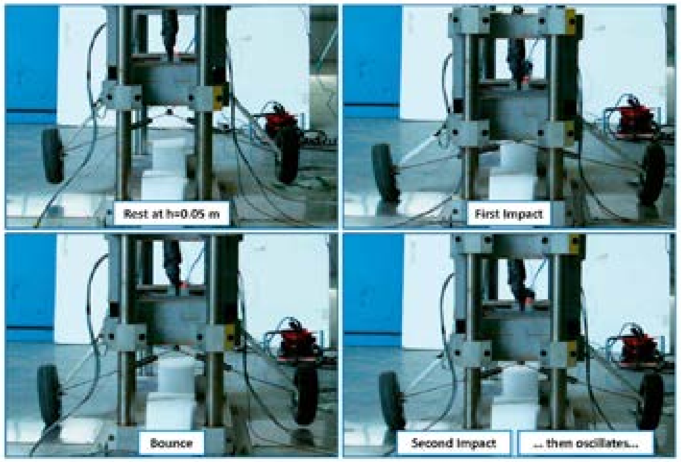
Fibre optics technology has proven to be a potentially excellent technique for monitoring the health state of landing gear systems. The advantage of using fibre optic sensors are directly related to the immunity to electromagnetic interference, small size, light weight, durability and high bandwidth, which allows for a great number of sensors to operate in the same system and to be integrated within the structure.

The Smart Landing Gear System is one of the innovations developed in the framework of the ANGELA project. This activity foresees the design and assessment of a Smart Landing Gear system for Hard Landing detection, based on Fibre Optics to be integrated into the Landing Gear structure.

Angela is a project funded by CleanSky2, in the Fast Rotorcraft Innovative Aircraft Demonstrator Platform.



FBG-based hard landing monitoring system test rig



Drop tests on a landing gear equipped with FBG sensors to monitor strains at different impact velocities

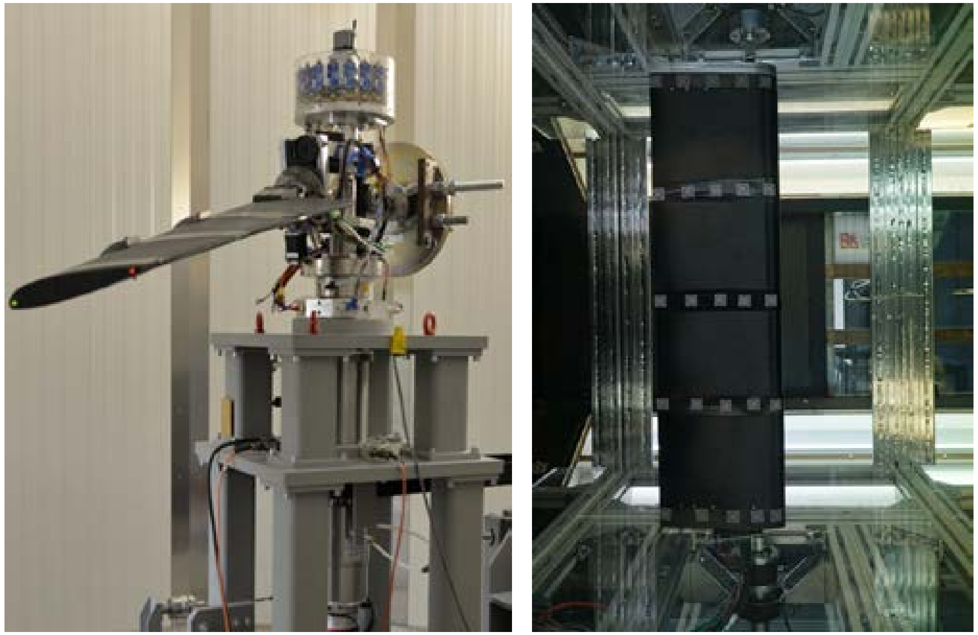
SABRE'S MORPHING TECHNOLOGIES TO IMPROVE ROTORCRAFT PERFORMANCE AND SUSTAINABILITY

SABRE (Shape Adaptive Blades for Rotorcraft Efficiency) aimed at mitigating the rotorcraft environmental impact through morphing technologies applied to the main rotor. The research strategy foresaw the estimate of morphing system impact on performance and the development and demonstration of the proposed concepts. Blade chamber, twist, chord and stiffness parameters were investigated with the aim of making them adaptive.

CIRA developed an original adaptive twist system based on Shape Memory Alloy (SMA) technology and capable to increase in pitch ward direction the original twist, to improve performance in hover and vertical flight, regimes generally penalized by the conventional design in favor of others, as cruise, more extended. Moving from requirements at rotorcraft level, the most suitable morphing architecture was selected, modelled and optimized.

The numerical predictions were validated through a prototype characterized at laboratory level. After having passed this phase and on the basis of the lesson learned, the demonstration in representative environment was faced. Two further full scale protypes were manufactured and tested at the wind tunnel plant of the University of Bristol and at the whirl tower facility of DLR, proving the achievable aerodynamic benefits and the capability of the system to work in representative conditions. The promising results led CIRA to apply for a patent.

SABRE is a project funded by H2020. The Consortium involves the universities of Bristol (leader), Swansea, Delft and Munich and the research centers of CIRA and DLR



Whirl tower and wind tunnel tests of the SMA blade twist prototype

AN EUROPEAN “CORE SPECIALIZED” WIND TUNNEL

The Icing Wind Tunnel is one of the largest wind tunnels in the world for aerodynamic and ice testing. With its three different closed test chambers and the “open jet” test chamber it is able to simulate speeds up to Mach 0.7 and altitudes of 7000 m, with minimum temperatures of -40 °C. The IWT is also unique for its capability of simulating speed, altitude, humidity and temperature at the same time. It has been operational since 2003 and is mainly used for aerodynamic and ice experimentation activities, with the aim of demonstrating the “compliance” of ice protection systems with the reference certification standards FAR PART 25 and FAR PART 29 APPENDIX C. IWT is already successfully integrated into the main industrial research and development programs of the national, European and world manufacturing industry.

The cooling of the flow is obtained by means of a heat exchanger placed at the end of the diffuser in the return circuit of the tunnel: the minimum temperature that can be reached and controlled is -32 ° C for the MTS (Main Test Section), ATS (Additional Test Section) and Open Jet, and -40 ° C for the STS (Secondary Test Section). A pressurization/depressurization system also allows to reach and control the static pressure in the test chamber between 0.39 and 1.45bar. This allows both to carry out tests at altitudes up to 7000m, and to increase the maximum number of Reynolds in aerodynamic tests.

The generation of the cloud for the simulation of ice accretion on the test model is ensured by the Spray Bar, a system consisting of 20 horizontal bars, aerodynamically profiled, and placed, equally spaced in height, in the calm chamber of the tunnel circuit.

TEST SECTION	DIMENSION (M)	SPEED (MACH)	TEMPERATURE (°C)	ALTITUDE (M)
MAIN	2.25 x2.35	0.41	-32 < Ts < +40	7000
SECONDARY	1.15 x 2.35	0.7	-40 < Ts < +40	7000
ADDITIONAL	3.60 x 2.35	0.25	-32 < Ts < +40	7000
OPEN-JET	2.25 x 2.35	0.34	-32 < Ts < +40	7000

Characteristics of the three test chambers and the Open Jet.

Up to 50 nozzles can be installed on each bar, for a total of 1000 available positions, fed with air and water under pressure for the generation of the droplets constituting the cloud.

The test activity is naturally accompanied by an engineering capacity aimed at developing and operating measurement techniques in the field of aerodynamics as well as developing new technologies for cloud generation and measurement.

Main measuring instruments/techniques available:

- Droplet sizing techniques (PDPA/LDS/ADA/PDI, FSSP, OAP, HSI)
- LWC/TWC measurements (icing blade, hot-wireDMT-LWC100, SEA LWC probe, Multiwire probe, Robust probe)
- Cloud Uniformity measurements (icing grid, cylinders)
- Ice accretion (manual ice tracing, ice thicknesses, laser scanning)
- Infrared thermography
- Particle Image Velocimetry
- Laser Doppler Velocimetry
- Hot-wire anemometry
- Pneumatic measurements

Icing Wind Tunnel aerial view

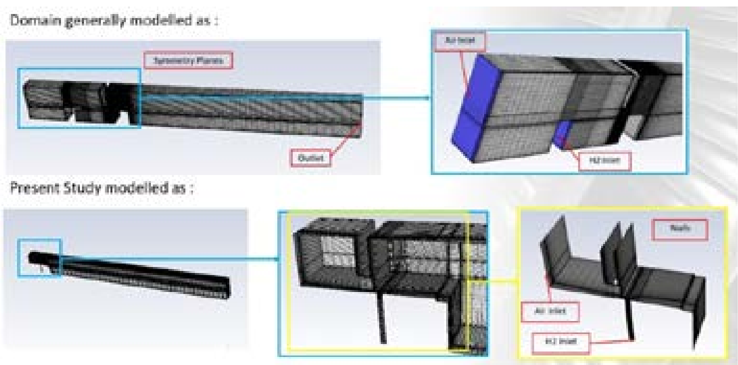
JSF inlet installed in the MTS

THE FUTURE OF SUSTAINABLE AIR TRAVEL: EXPLORING THE POTENTIAL OF HYDROGEN-POWERED ENGINES

The use of hydrogen as an alternative fuel in the combustion chamber of an aircraft turbine engine would offer a practical solution to reducing levels of emissions which contribute to atmospheric pollution. In recent years various designs of the basic system component of such an engine have been proposed being described as the hydrogen micromix combustor.

This technology requires the design and development of a safe mechanism for hydrogen combustion which avoids auto-ignition and flashback and permits the initial balance and mixing of a hydrogen-air mixture to produce thrust from the combustion of hundreds of miniature low temperature diffusion flames which produce extremely low levels of NOx.

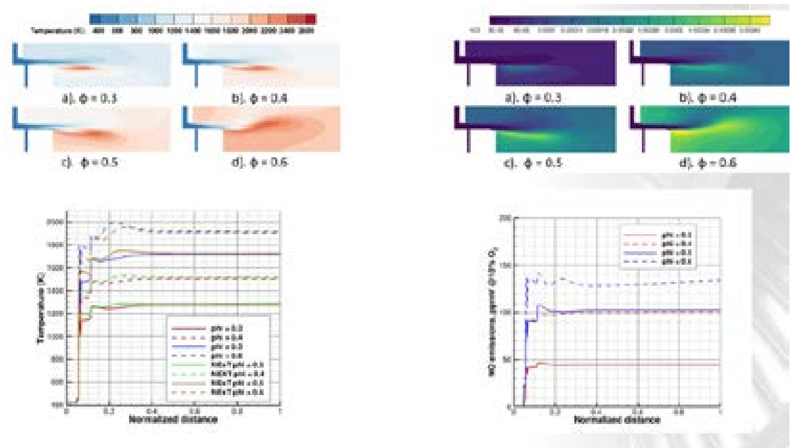
Of particular interest is the development of such hydrogen combustion technologies also operating at high chamber pressures of 15 to 20 atmospheres which are relevant to the development of future ultra-high bypass ratio engines which are envisaged to come into service around 2050.



Parametric Studies and Simulations of a Hydrogen Micromix Combustor

Current work at CIRA is associated with theoretical and numerical studies of various micromix combustor configurations operating at both low (2.5 bar) and high (15 bar) pressures suitable for APU (Auxiliary Power Unit) and Aero-engine combustion chambers, respectively.

CIRA is also chairing the GARTEUR Exploratory Group for Hydrogen Combustion (AD-EG83) involving various Italian national and International organizations from both industry and academia. The aim is to create a GARTEUR Action Group to develop and validate numerical tools suitable for the design of future hydrogen combustion powered aero-engines.

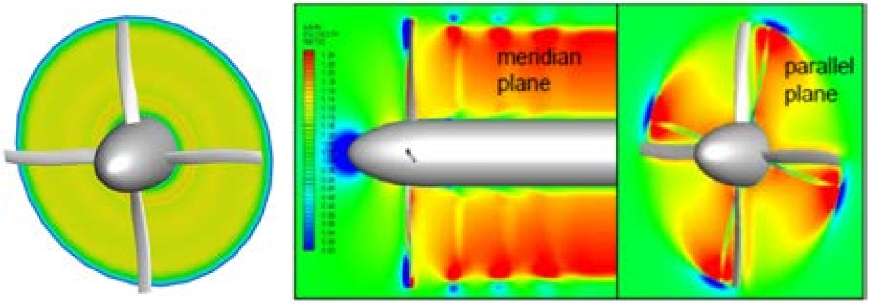


Results for Different Equivalence Ratios and Temperatures with CIRA code NEXT

REDUCING FUEL CONSUMPTION AND EMISSIONS WITH VENUS' INNOVATIVE DISTRIBUTED ELECTRIC PROPULSION TECHNOLOGY

The Distributed Electric Propulsion (DEP) is an innovative technology which, applied to fixed-wing aircraft, can enable a significant reduction in the fuel consumption, in the emission of CO_2 and NOx and in the noise, with advantages in terms of costs, competitiveness and reduced environmental impact.

The VENUS (inVestigation of distributEd propulsion Noise and its mitigation through wind tUnnel experiments and numerical Simulations) project aims at improving the knowledge about the aerodynamic and aeroacoustic performance of a wide range of DEP configurations through numerical simulations and wind tunnel test experiments. The ultimate goal is to improve the future design of new aircraft configurations for regional air transport. Another important aspect of VENUS is its commitment to providing open access to all the models, data and documents produced by the project. This allows other institutions to validate their in-house developed methods and establishes an "open test-case" that is unique in the aircraft design landscape within Europe.

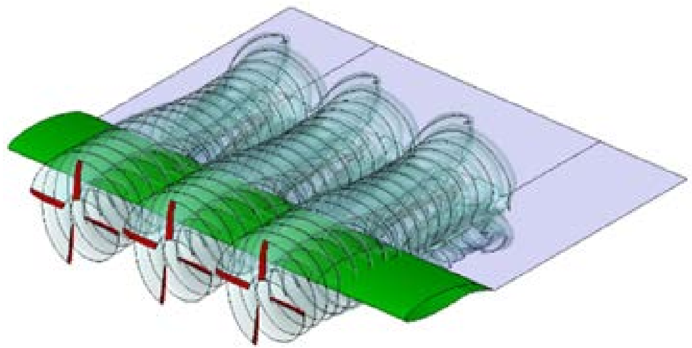


Design and CFD validation of the isolated propeller

CIRA is strongly involved in several technical activities concerning: the literature review about the advantages and disadvantages of the different DEP configurations; the identification and selection of a reference aircraft configuration and scaling considerations; the aerodynamic and acoustic design of the isolated propeller and of the multiple propellers combination; contributes to the selection of suitable noise mitigation technologies.

Furthermore, CIRA carries out numerical simulations before the experiments; contributes to the wind tunnel test matrix definition; participates in the analysis of the experimental database acquired during the wind tunnel test campaign; validates the numerical simulations by using the experimental data and performs numerical simulations to extrapolate aerodynamic and aeroacoustic performance in flight conditions.

VENUS is a Clean Sky project (H2020). The project is coordinated by Università Roma Tre and involves NHOE, CIRA, Eligio Refraschini from Italy; IBK-Innovation GmbH & Co. KG from Germany.


Layout optimization of the multiple propellers combination

THE FUTURE OF EARTH OBSERVATION AND TELECOMMUNICATIONS - A LOOK AT THE CIRA HYBRID HIGH ALTITUDE AIRSHIP”

The interest in long endurance Unmanned Stratospheric Platforms for Earth observation and Telecommunications (also known as HAPS) has increased in the last years, because they represent a valid complementary solution to satellites and RPAS (Remotely Piloted Aerial System).

HAPS can fly at an altitude of about 18-20 km, well above commercial air traffic, where weather is quite calm and temperature is approximately constant. For these reasons, convective phenomena have lower magnitude and the intensity of winds is lower than at the other altitudes. These considerations motivate the interest in this part of the stratosphere.

Unlike LEO satellites and RPAS, HAPS can maintain station like a Geostationary Satellite, thus they can provide continuous coverage of the same area for several months (persistence) at a fraction of the cost of a geostationary satellite.

The CIRA Hybrid High Altitude Airships represent a completely new aerospace configuration, exploiting at the same time aerodynamic and aerostatic forces to balance the weight. This approach permits the design of Platform with payload range of 25-150 kg using off-the-shelf available technologies.

CIRA Hybrid High Altitude Airship, capable of generating extra lift with a wing airfoil, will be one of the three stratospheric platforms to be developed within the EuroHAPS Project (consortium coordinated by Thales Alenia Space).

THE CUTTING-EDGE RESEARCH OF THE CIRA EARTH OBSERVATION LAB

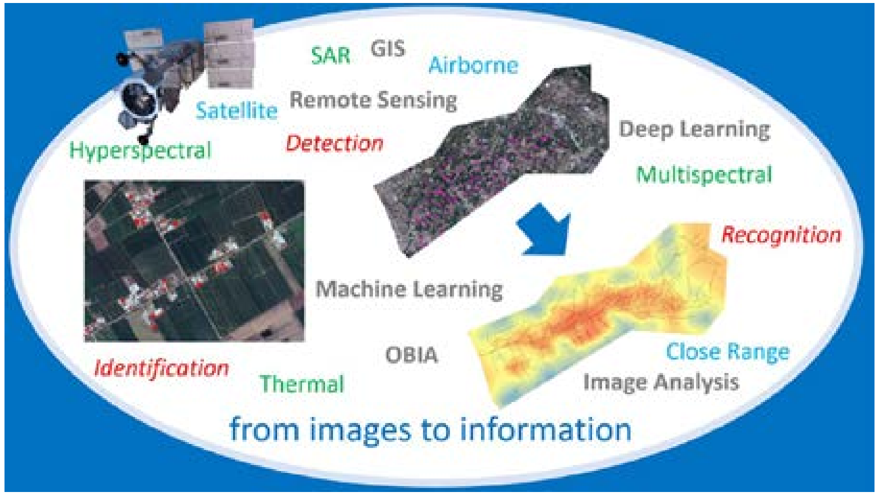
The CIRA Earth Observation Lab was established to provide access to aeronautical and space technologies for Earth observation and land monitoring. This is achieved through the development of technology demonstrators that utilize existing technologies while also advancing new ones.

The Lab focuses on two main research areas:

- the development of technologies for processing Earth observation data with high spatial and temporal resolution, catering to various applications such as security, agriculture, and the environment;
- the exploration of innovative methods for processing and correlating images acquired from satellite, pseudo-satellite, and aerial platforms (manned or unmanned).

Within these research lines, there are several specific subtopics that are particularly relevant to this proposal. These include:

- integration of diverse remote sensing data sources (e.g., multispectral, hyperspectral, thermal infrared, SAR) from various aerial platforms (e.g., satellite, pseudo-satellite, unmanned aerial platforms), as well as proximal sensing data;
- design and prototyping of Earth observation products with high levels of automation, leveraging artificial intelligence technologies such as machine learning and deep learning;
- utilization of chemical-physical and statistical models to establish correlations between spectral responses and observed phenomena.

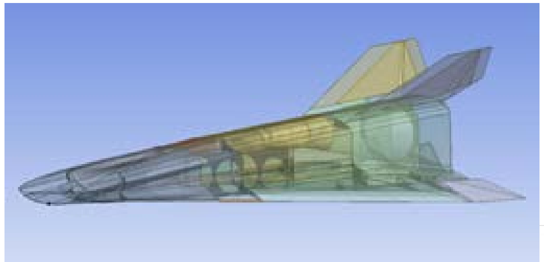


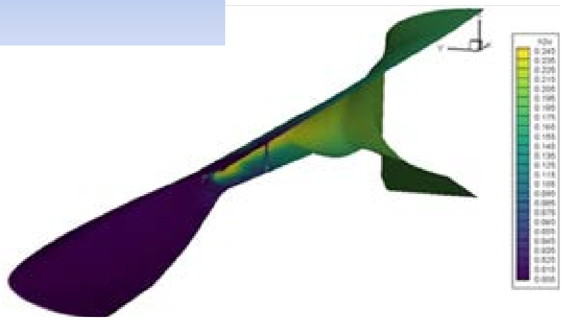
SPACE-IPERSONICA: THE PROJECT AIMED AT THE FUTURE OF HIGH-SPEED TRANSPORT

The SPACE-Ipersonica project, dedicated to the hypersonic flight for future high-speed transport vehicles, aims to design a Scramjet Hypersonic Experimental Vehicle (SHEV) able to perform a propelled levelled flight at 27÷32 km and Mach 7÷8.

The project faces the following main technological challenges:

- increase the Technology Readiness Level (TRL) of the breakthrough technologies on board;
- strengthen Italian knowledge and capability on CMC materials carrying on the collaborations currently underway on other projects;
- design and realization of the combustion chamber maybe exploiting the Italian know-how and technologies even from other fields of application.



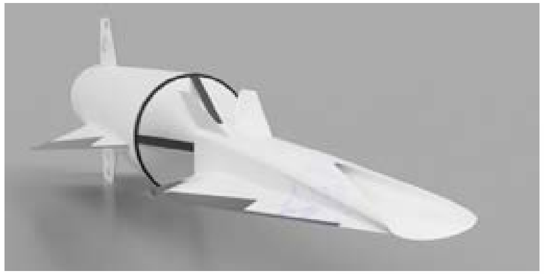


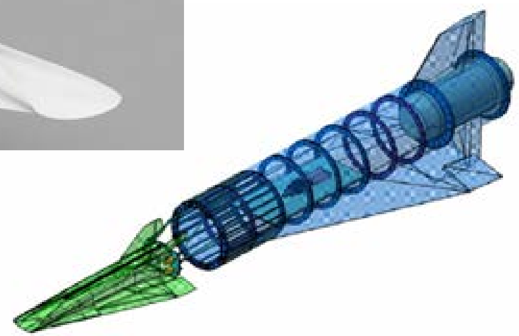
Configuration of the scramjet demonstrator (left) and propulsive flowpath CFD (right);

The vehicle concept starts from the preliminary results reached on the HEXAFLY project (EC FP7) scramjet hypersonic configuration, and modified to simplify the housing of the internal equipment and to solve some structural criticalities.

The baseline mission scenario foresees an air-launch from a carrier aircraft; the hypersonic demonstrator is released at subsonic velocity connected to a launch vehicle before the latter's booster fires to begin the climb and acceleration to target altitude and Mach number. Then, the hypersonic demonstrator is separated from the launch vehicle and the experimental mission can start with the ignition of the scramjet. After scramjet shutdown the demonstrator glides down to Mach 2 (end of mission).

The project has been approved by the national program PRORA up to the CDR (foreseen in 2028) and co-funded by the Italian Space Agency (ASI) up to the PDR (foreseen in 2025).





Scramjet demonstrator connected to Launch Vehicle.

FLYING FASTER THAN SOUND WITH HYPERION

The Hyperion project arises from the air defence need to develop systems capable of reaching every point of the airspace, up to 100km of altitude, in extremely short times, thus to counter the massive use of hyper-fast weapon systems (winged aircraft and hypersonic cruise missiles) that is foreseen in the near future.

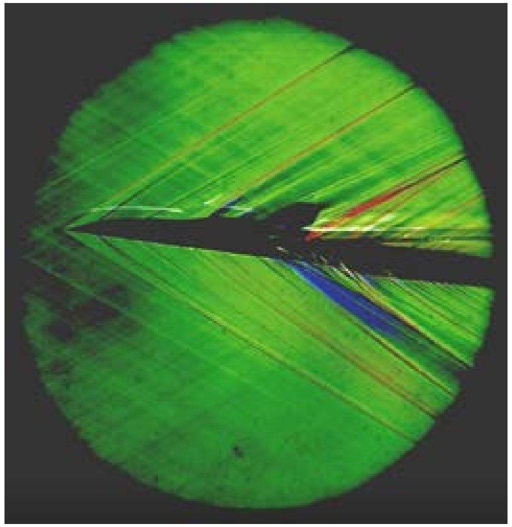
Hyperion is a supersonic aircraft, with hybrid turbo-ramjet/rocket propulsion, for reconnaissance and/or interception functions, designed to carry on repeated suborbital flight missions during a single flight, without limitations on the launch site typical of other systems (launchers and rockets, for example).

Its capabilities include:

- horizontal take-off/landing from/on "short" runways <1000m with engines operating in turbojet mode;
- subsonic climb up to the operating altitude of 10km of altitude (speed of 200m/s);
- acceleration through the transonic regime up to Mach <5 and ascent along a trajectory at constant dynamic pressure with engines in ramjet mode;
- suborbital jumps towards the Karman line at an altitude of 100km, thanks to the help of a booster (liquid or hybrid rocket);
- possibility of air-launching at high-altitude (50-70 km) a second stage for the insertion of small payloads in LEO;
- gliding descent and turbojet propelled horizontal landing.

HYPERION is funded by the Italian Ministry of Defence. The consortium is composed by DAC (coordinator), CIRA, MBDA ITALIA S.p.A., CALTEC, with the support of a number of SMEs and universities

Experimental Test at CIRA PT1 wind tunnel



Experimental Test at INCAS trisonic wind tunnel

SPACE RIDER: RETURN, RELOAD, RELUNCH

Space Rider aims to provide Europe with an affordable, independent, reusable end-to-end integrated space transportation system for routine access and return from low orbit. After launch on Vega-C it will stay in low orbit for about two months. Experiments inside its cargo bay will allow technology demonstration and benefit research in pharmaceutics, biomedicine, biology and physical science. At the end of its mission, Space Rider will return to Earth with its payloads and land on a runway to be unloaded and refurbished for another flight.

A key technology for sustainable space transportation system is ISiComp®, the reusable ceramic matrix composite made in Italy, born from the partnership between CIRA and Petroceramics. Based on a time and cost-effective process, ISiComp® can withstand temperature up to 1650 °C while preserving very high structural performance. Specifically conceived for aerospace applications, the material is the core of ESA Space Rider Thermal Protection System, being designed and developed by CIRA.

The reusability of the material has been fully demonstrated through an extensive test campaign in the SCIROCCO Plasma Wind Tunnel of CIRA, where the full envelope of six Space Rider mission has been reproduced. Following a complete design loop and a series of characterization and development tests, full scale demonstrators of the most critical TPS components have been manufactured: Body Flap, Nose, Flat and Curved Tiles of the belly. Qualification phase is now ongoing by first part of 2024.

THE INTERSTAGE 2/3: A REVOLUTIONARY GRID COMPOSITE STRUCTURE FOR VEGA-C LAUNCHER

The long-standing collaboration between CIRA and Avio has led to the development and qualification of the Interstage 2/3 for the VEGA-C launcher, which proposes a GRID composite structure that complies with key requirements and driving factors, including high manufacturing and structural efficiency (i.e., minimum cost and mass) as well as high strength and stiffness under compressive and bending loads.

The Interstage 2/3, the structure that interfaces the Z40 second stage with the Z9 third stage on the VEGA-C launch vehicle, was designed to fulfil the following main functions:

- to transmit the thrust from the second stage SRM to the launcher third stage;
- to provide a sufficient overall stiffness;
- to house and protect equipment items and components;
- to guarantee the separation of the second stage.

The Grid technology here referred is based on a refined version of the early Filament Winding approach and is probably the most efficient design and manufacturing solution to address heavily-loaded axisymmetric shell structures for space applications. In the last years, CIRA has developed methods to optimize this design concept and patented a specific manufacturing process, which is based on the automated “Parallel Winding” of dry carbon fiber tows supported by a Robotic cell. The process is completed with Resin Infusion under vacuum bag and oven (or autoclave) cure.

This know-how has been efficaciously applied for the Development and qualification of the Interstage 2/3 which successfully completed its inaugural flight from Europe’s Spaceport in French Guyana on 13 July 2022.

Interstage 2/3 developed within the VEGA C Program in partnership with Avio

INFLATABLE HEAT SHIELD, AN ENABLING TECHNOLOGY FOR ATMOSPHERIC RE-ENTRY AND SPACE EXPLORATION

The utilization of Inflatable Heat Shields (IHS) has emerged as a transformative solution for re-entry applications on both Earth and Mars. IHS holds great potential for facilitating the safe reentry of various space systems elements, such as launcher stages, ISS cargo payloads, and reusable satellites, in Earth scenarios.

Additionally, IHS's inherent scalability aligns well with the anticipated surge in missions for large-scale robotic and human exploration on Mars in the coming decades, enabling precision landing and high-mass delivery.

EFESTO and EFESTO2 have played a key role in advancing the field of Inflatable Thermal Shields in Europe. The EFESTO project, conducted from 2019 to 2022, focused on ground-based technology development and successfully facilitated the growth of know how pertaining to IHS. The consortium achieved an increase in the Technology Readiness Level (TRL) of key IHS technologies from 3 to 4 through the implementation of a comprehensive range of activities. These included mission and system-level conceptual design, the design, manufacturing, and testing of Flexible Thermal Protection Systems (FTPS), as well as the design, realization, and testing of a half-scale Inflatable Structure (IS) demonstrator.

Inflated structure of the Half Scale model Inflatable Heat Shield before testing

Inflatable Heat Shield during the static test campaign executed at CIRA

Inflatable Heat Shield with flexible TPS

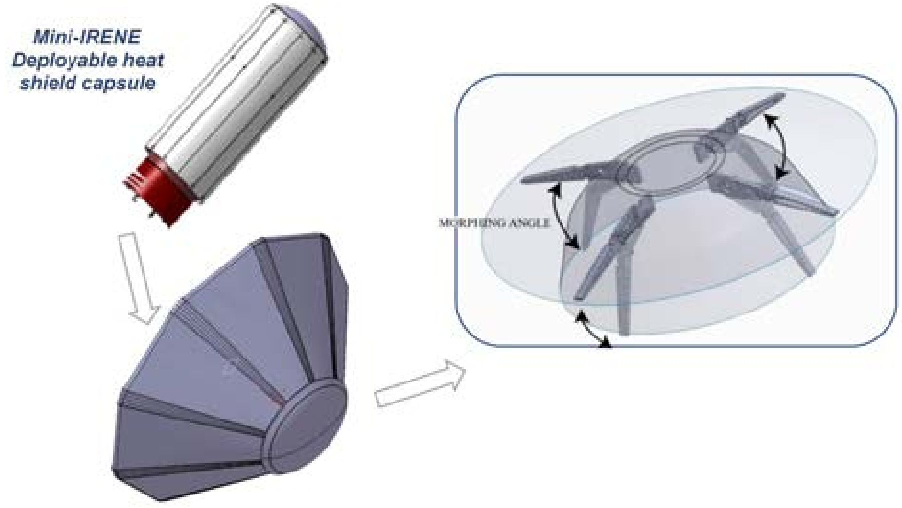
MORPHING DEPLOYABLE RE-ENTRY AEROSHELLS FOR CUBESAT AND SMALL SATELLITE MISSIONS

Morphing technology is increasingly emerging as a novel and alternative approach for performing the controlled re-entry and precise landing of space vehicles by using adaptive aeroshell designs. The ability to conduct a controlled re-entry of small Satellite payloads may contribute to broaden the mission capabilities of CubeSat class spacecrafts, such as the return of scientific samples and payloads from Low Earth Orbit, or the deployment of low-cost sensors on other planetary bodies, by ultimately supporting the development of Low Earth Orbit Space commerce.

Within the SPLASH project (Self-DePloyable FLexible AeroSHell for de-Orbiting and Space Re-entry), CIRA is coordinating a scientific and technological cooperation between Italy and Brazil to develop a mechanically-deployable re-entry module with morphing capabilities that may be incorporated within a standard form factor (12U) of a CubeSat design. The entry system is a mechanically-deployable system consisting of ribs and struts supporting a mechanism that deploys a load-bearing flexible skin after launch. The main design objective is, thus, used to expand the mechanism to a larger diameter by using a single translational actuator in order to protect the payload during entry and, once deployed, adapt the aeroshell shape by morphing flap segments via an SMA-based actuation.

This offers considerable benefits over traditional rigid aeroshells including higher volume, mass and payload form factor, more accurate guidance trajectories, and improved landing accuracy by using aerodynamic drag. Additionally, lower peak decelerations, heat loads, and fluxes can be effectively achieved to protect the payload from the re-entry environment.

The SPLASH project is funded by the Italian Ministry of Foreign Affairs and International Cooperation (MAECI) and by Brazilian CONFAP.



Mechanically deployable morphing aeroshell concept

MINI-IRENE MISSION: A SUCCESSFUL RE-ENTRY FLIGHT OF A DEPLOYABLE HEAT SHIELD CAPSULE

Mini-IRENE, acronyms of Italian RE-entry NacElle, is a capsule launched with a Maser Sounding Rocket in November 2022 from the Launch Base of the Swedish Space Corporation in Esrange. The flight has represented the clou of the Mini-Irene Flight Experiment (MIFE) project, aimed at increasing the ripeness of an innovative technology for atmospheric (re-)entry up to TRL 6.

The innovation of the IRENE concept stems from a deployable heat shield, resulting in a very low ballistic coefficient, allowing the exploitation of off-the-shelf materials for the thermal protection system. In fact, the low ballistic coefficient, leads to acceptable heat fluxes, mechanical loads and final descent velocity.
The first goal of the IRENE program is to develop a low-cost re-entry capsule, able to return payloads to Earth from the ISS and/or short-duration, scientific missions in Low Earth Orbit (LEO).

The MIFE (current phase of the IRENE program) objectives were to design and test a Ground Demonstrator for the thermal qualification in a Plasma Wind Tunnel, and realize a Flight Demonstrator to be qualified in a sub-orbital flight with a sounding rocket.
All the qualification tests have been performed successfully. The ground demonstrator was qualified in CIRA' Scirocco Plasma Wind Tunnel for the thermal loads of a specific re-entry mission; the Flight Demonstrator has achieved the two main objectives of the sub-orbital flight after ejection from the sounding rocket, namely the verification of the stability in every flight regime and the resistance of the heat shield under the thermal and mechanical loads due to the impact with the atmosphere.

Such technology has been developed by ALI consortium, CIRA and University of Naples, as part of the wider IRENE program. The project is funded by the Italian Space Agency (ASI) and managed by the European Space Agency (ESA) in the framework of a GSTP (General Support Technology Program)

Real footage taken by the Mini-Irene Camera during the Re-Entry.
By side the Ground Demonstrator of the Qualified Deployable Heatshield

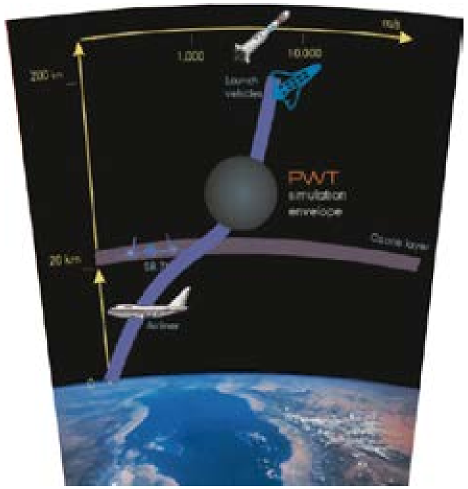
SCIROCCO AND GHIBLI: A POWERFUL PAIR OF PLASMA WIND TUNNELS

The SCIROCCO Plasma Wind Tunnel is a 70MW arc-jet facility. Its primary mission is to simulate the thermo-fluid-dynamic conditions on Thermal Protection System of the space vehicles re-entering the earth atmosphere, on models in scale 1:1 up to 600mm.

SCIROCCO is a high enthalpy hypersonic wind tunnel at the boundaries of state of art technology. Main characteristics are below summarized.

SCIROCCO DATASHEET			
Arc Heater electrical power (max.)	**70MW**	**Air Mass flow**	**0,2 – 3,5kg/s**
Total enthalpy (bulk)	**2,5 – 45MJ/kg**	**Test duration**	**Up to 25min.**
Heat Flux[1]	**125 – 3000kW/m^2**	**Test Chamber size**	**9,2m (H) x 5m (D)**
Flow speed	**2000 – 7000 m/s**	**Nozzles Diameter (m)**	**0,9; 1,5; 1,35; 1,95**

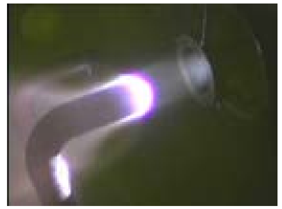
[1]: on a 100mm dia. fully catalytic cold wall probe



The GHIBLI Plasma Wind Tunnel is a 2MW arc-jet facility. Its primary mission is to simulate the reentry thermo-fluid-dynamic conditions on the material of which the Thermal Protection System of space vehicles are made. The size of the material samples is around a few centimeters.

GHIBLI is a high enthalpy hypersonic wind tunnel, whose main characteristics are listed below.

GHIBLI DATASHEET			
Arc Heater electrical power (max.)	**1,75MW**	**Air Mass flow**	**1 – 36g/s**
Arc Heater total enthalpy	**10 – 30MJ/kg**	**Test duration**	**Up to 25min.**
Heat Flux	**125 – 3000kW/m^2**	**Test Chamber size**	**2m (L) x 1,8m (D)**
Flow speed	**3000 – 5000 m/s**	**Nozzle Diameter (mm)**	**152**



At the Plasma Wind Tunnels complex there is a wide portfolio of instruments and measurement techniques ranging from non-intrusive diagnostics using thermography, pyrometry, spectroscopy and Laser Induced Fluorescence (LIF) to intrusive diagnostics with measurement of heat flow, temperatures, pressures, deformations and total enthalpy.

THE SPACE QUALIFICATION LABORATORY: OVER A DECADE OF EXCELLENCE IN AEROSPACE TESTING

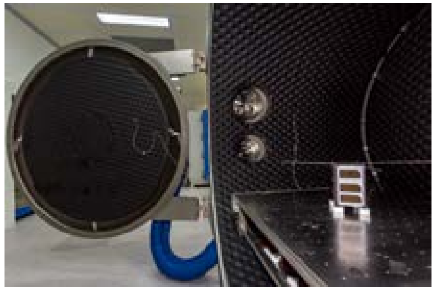
The Space Qualification Laboratory aimed at supporting aerospace companies in the design and testing of nano and micro satellites (up to 100 kg) and of electronic and mechanical components of space, aeronautical and military systems, providing service activities for qualification and acceptance to operational mechanical and environmental loads.

Major investments are underway to upgrade the laboratory's test facilities to include vibration tests on satellites weighing up to 2500 kg, acoustic excitation tests at launch with the DFAN technique and electromagnetic compatibility and susceptibility tests.

Test Lab facilities accommodate, in an ISO8 cleanroom environment, test articles at any technology readiness level and comply with ISO9001. The test facility and procedures fully comply with the main standards for qualification and acceptance tests in the space, military and aeronautical fields: ESA-ECSS-E-10-03A, MIL-STD-810-C/F/G and RTCA DO -160D.

The team has years of proven reliability and experience in qualification test field, gained by working on several national and international projects and within collaborations with private companies, research institutions and universities.

The Space Qualification Laboratory has a large portfolio of instruments and techniques for reproducing vibrational and environmental loads and for measuring, with surveys of static and dynamic accelerations, temperatures, pressures and humidity.



OFFERING NEW SOLUTIONS FOR ROCKET ENGINES: EFFICIENT, LOW COST AND ECO-FRIENDLY

Rocket engines must overcome significant challenges to meet the growing demand for new satellites. These engines need to be competitive, efficient, low-cost, reliable and eco-friendly according to the European Green Deal. The use of liquid (LRE) or hybrid hydrocarbons (HRE) in space propulsion systems shows promise as a potential solution for future launchers and transportation systems.

Methane is considered one of the most interesting solutions as propellant for LRE, coupled with oxygen, because of good performances, relatively easy storability, low toxicity, availability and production cost. At the same time, a renewed interest in the last years towards HRE turned on again, and specifically for paraffin-based fuels. High-Test Peroxide (HTP), which could be used as an oxidizer in combination with a paraffin-based fuel, could be also used as a monopropellant for low-thrust applications replacing hydrazine to overcome safety and environmental issues.

CIRA started activities on LOX/Hydrocarbons technologies with a mid/long-term R&D plan in synergy with MUR (Ministry of University and Research) initiatives and ASI (Italian Space Agency) programs. Several activities were performed in the framework of the HYPROB program, which included a specific line dedicated to Technological Demonstrators focused on LOX/CH_4 and paraffin-based hybrid rocket engines.

Further lines of the HYPROB program were dedicated to diagnostic, numerical modeling and facility development (H-IMP).

The HYPROB Demonstrator Line is divided in four main developments:

- Technologies supporting the development of third stage engines, by means of a 30 kN thrust-class DEMO design, manufacturing and testing;
- LOX/CH_4 breadboards supporting the DEMO development, to address the most critical design solutions, such as injection, combustion and cooling;
- Additive Manufacturing technologies applied to LOX/CH4 technology;
- Small-scale HRE studies, considering paraffin-based fuel and thrust-class up to 1000 N.

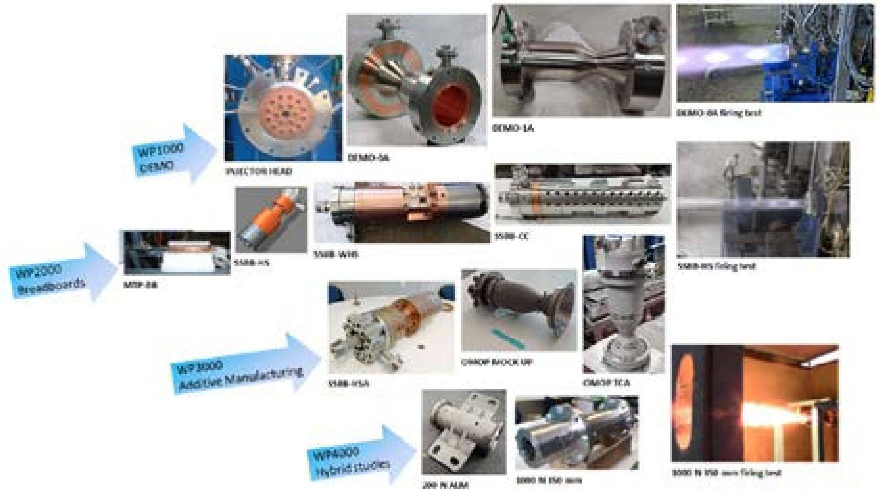
The results achieved include the creation and testing of breadboards, advanced manufacturing processes, and firing tests of the DEMO-0A. The study also involved numerous firing tests using gaseous oxygen and paraffin-based fuels to investigate critical issues related to small scale HRE studies. Advanced numerical methodologies were used in the different phases of development, from design verification to data assessment and rebuilding.

OFFERING NEW SOLUTIONS FOR ROCKET ENGINES: EFFICIENT, LOW COST AND ECO-FRIENDLY

Advanced chemistry models were also developed and validated with the numerous experimental data available. Moreover, some simulations on Solid Rocket Motors have been carried out by CIRA in order to support AVIO in the development of VEGA family launchers.

Further studies on LOX/LCH4 technology are currently carried out by CIRA within the TEME project (Technology for Methane). The analogue HREP project (Hybrid Rocket Engine Propulsion) is carried out to continue studies on paraffin-based fuel hybrid rockets, including also hydrogen peroxide for both mono- and bi-propellant applications.

In the framework of HRE studies, in the PHAEDRA project, financed by ASI and aimed to design a 10 kN class demonstrator based on paraffin fuel, CIRA has carried out the thermal protection system trade off and characterization by means of numerous firing tests with a 1000 N thrust-class oxygen-paraffin-based fuel hybrid engine (MTM) specifically designed by CIRA for the scope.



Main results achieved in the framework of the chemical propulsion programs

CIRA'S CUTTING EDGE RESEARCH ON ELECTRIC PROPULSION FOR NEXT GENERATION SPACE SYSTEMS

Electric propulsion systems use electric power to accelerate the propellant, providing much higher specific impulse (fuel efficiency) compared to chemical propulsion. This makes electric propulsion systems ideal for long-duration space missions, such as those required for interplanetary exploration or satellite station keeping. Space Electric Propulsion is considered one of the most promising technologies for the application of present and next future space systems.

CIRA, endorsed by ASI, launched a detailed development plan regarding an electric propulsion research program in 2015. This program allowed for the realization of the MSVC (Medium Scale Vacuum Chamber) facility in order to cover the R&D activities for the present class of EP thrusters (up to 5 kW power). MSVC operates R&D activities and integrate the other Italian space simulators, conceived as commercially oriented.

CIRA has also improved researchers' know-how on Electric Propulsion by developing advanced methodologies of design, analysis and testing of laboratory thrusters.

MEDIUM SCALE VACUUM CHAMBER (MSVC)	
Dimensions	(ab.) 1.9 m D (inner) x 4.0 m length
Vacuum	Up to $1e^{-8}$ mbar (ultimate pressure)
	Lower than $4.0e^{-5}$ mbar (@15 mg/s)
Applications	R&D purposes, equipped with advanced plasma diagnostics
Propellants	N_2, Ar, Kr, Xe

A low-power class Hall Effect Thruster, named CRHET-250, including a brand-new hollow cathode, has been designed, manufactured and tested to demonstrate a TRL 4. Moreover, diagnostic systems are available, such as High Speed Camera, Thermo-camera, Langmuir and Faraday probes.

Some new projects have been launched within PRO.R.A. to support research in the new commercial electric propulsion era, covering different areas of electric propulsion and improving the testing capability of the National and European sector.

Electric propulsion laboratory area with the Medium Scale Vacuum chamber.

CIRA Electric thruster (CR-HET 250) firing in the MSVC chamber.

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