IRT SAINT EXUPÉRY

Annual Report 2021

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technological axes

our key competencies

Claude Girard
General Secretariat for Investment

preface.

Facing unprecedented health, economic and social crisis affecting both our companies and our citizens, France had to show resilience and mobilize its strengths to contain the effects, while preparing for the future. In this context of urgency, planning the years to come was difficult but more than ever necessary for the aeronautics sector, which was hardly affected.

To achieve this, France has a major asset: the « Programmes d'Investissements d'Avenir » (PIA) since 2010, and now the « France 2030 » plan. For more than ten years, the PIA has contributed to the emergence of a greener, more competitive, and more techno-logical economy, promoting new forms of solidarity. As a powerful tool for investment in innovation, the PIA and France 2030 plans are naturally mobilized during crises to support our economy and contribute to the emergence of the France of tomorrow.

It is during this period that IRT Saint Exupéry transformed itself to meet both the adaptation of the financial model required by the French Government by 2025 and the challenges of the aeronautics, space, and embedded systems sectors. The challenges of sovereignty and environmental impacts are now unavoidable and IRT Saint Exupéry is organized to meet them with its ecosystem. I would also like to warmly thank the founding members for their mobilization during the crisis, despite the halt in air traffic and the brutal slowdown in the economy, which today allows IRT Saint Exupéry to address the challenges of tomorrow.

All of these changes, driven by the commitment of Magali Vaissière, President, and the dynamism instilled by Denis Descheemaeker, General Manager since December 2019, are also reflected today in an evolution of the graphic identity of IRT Saint Exupéry -symbolically representing this bridge between the academic research and the industry.

I am therefore delighted and honored to preface this annual report, which illustrates a year rich in achievements and reaffirms the unfailing support of the French Government, led by the General Secretariat for Investment, to the models of the IRT and ITE, brought together under the FIT association.

Claude Girard
Director of the Research Valorization Program
General Secretariat for Investment

edito.

Within our historical sectors, which are experiencing a very important transformation, particularly influenced by the major environmental and sovereignty objectives, 2021 has been a transition phase for IRT Saint Exupéry. We have revisited our global strategy, the associated organization around 4 technological axes supported by 12 key competencies. This work has led us to redefine our roadmaps to actively contribute to the achievement of these major objectives, in collaboration with our industrial and academic members.

Within the framework of the FIT[1] association, we are expanding this strategic reflection to set out an ambitious vision for 2030 for all the IRTs and ITEs that have already demonstrated their strong added value for the French collaborative technological research.

Today, thanks to the maturity and strength of our organization renewed in 2021, we want to make IRT Saint Exupéry an essential player in the aerospace industry, in France and internationally, thanks to our multidisciplinary expertise.

With this objective in mind, we have expanded our activities in the space sector, both nationally and in Europe. We have contributed to the ambition of decarbonizing aeronautics in line with the structuring approach of CORAC[2], but also with start-ups as part of the MAELE[3] call for projects organized by the Occitanie Region and the Aerospace Valley competitiveness cluster. We have diversified our activities into new synergistic sectors such as health with the IUCT-Oncopole of Toulouse thanks to the very significant results of our work in Artificial Intelligence.

We have closely supported our industrial, academic, and institutional members in the Occitanie, Nouvelle-Aquitaine, and Provence-Alpes-Côte d'Azur regions, all of whom are committed to the future of IRT Saint Exupéry's sectors, and we would like to thank them for their unfailing support and their renewed confidence.

Our ambition for 2022 is to consolidate our transition by defining 8 positioning of excellence to better meet our missions: to create a link between the public and private research by carrying out integrated collaborative research projects and to promote French technological research to develop our ecosystem.

Wishing you a good reading,

Magali Vaissière, President of IRT Saint Exupéry
Denis Descheemaeker, CEO of IRT Saint Exupéry

[1] French Institute of Technology
[2] Conseil pour la Recherche Aéronautique Civile
[3] Mobilité AErienne Légère et Environnementalement responsable

Absentees :
Lionel Cordesses, Smart Technologies Director
Christophe Moreno, Sophia-Antipolis site manager

mission

For almost 10 years, the IRT Saint Exupéry has been carrying out its missions entrusted in 2013 by the French government under the «Programme d'Investissement d'Avenir».

Promote French technological research for the benefit of the industry established on the national territory.

Develop the local ecosystem for aeronautical & spatial sector and critical systems.

Create a link between public and private research in order to bridge the two worlds and ease the transfer and implementation of research within the industry.

Realize research projects from the industrial needs, integrated, with an upstream contribution from the academic community, supported and funded par the French state and the industrial members.

IRT Saint Exupéry is committed to the future of the industry by structuring itself around 4 major technological axes:

- Greener technologies
- Advanced manufacturing technologies
- Smart technologies
- Methods & tools for the development of complex systems

For

Aeronautics **Space** **Embedded Systems**

& our synergy markets

Defence **Health**

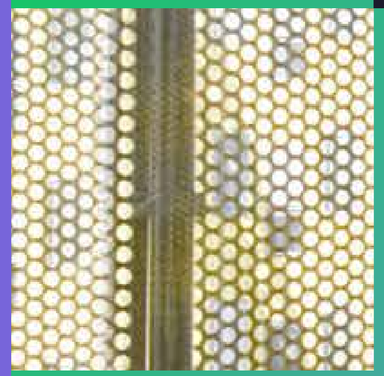
€37M
annual budget

39
ongoing projects

367
patents & technology transfers

3
start-ups creation

11
technological platforms



348
employees

382
publications & communications

including

131
people on secondment

217
IRT employees

including

36
PhD students

since 2013

227
members

including

174
industrial members

53
academic members

read more

greener technologies.

greener technologies.

Lionel Bourgeois
Technological Director

The **«Greener Technologies»** axis addresses technological challenges to reduce CO_2 emissions based on the ambitious objectives set by the International Air Transport Association (IATA) and in line with the research programs of major aeronautical and space industry customers.

We are contributing to the development of solutions that will enable the replacement of systems historically powered by hydraulic and pneumatic energy with new solutions based on electrical energy while addressing the major challenges in this field, which are reliability, and weight. We are also preparing the technological solutions of tomorrow that will enable the electrification of propulsion systems. Voltage rise, reliability and densification are the key elements to achieving this.

For this, we rely on all the skills of IRT Saint Exupéry in the fields of electricity, materials, artificial intelligence, and multi-physics modeling.

«We conduct tests, provide tools such as demonstrators, databases, optimization algorithms, methodologies and recommendations within the ambitious project of decarbonization.»

Find out more about our key competencies by clicking here

challenges

Reduce carbon emissions from target sectors through the development of **innovative technologies**

Accelerate the development of technologies and industrial **transfer**

objectives

Improve the product life cycle.

- Reduce the consumption of materials
- Reduce maintenance and increase durability
- Reduce the energy consumption of products & systems

Enable increased electrification of systems.

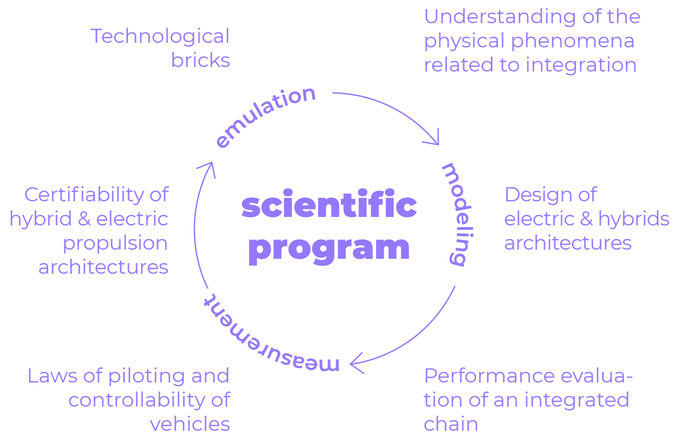
- Master EMC (electromagnetic compatibility)
- Increase the electrical power
- Increase the power density
- Increase the reliability of electrical functions

Reduce the mass and volume of products.

- Increase the power density of electrical equipment
- Develop lighter, iso performance or improved performance manufacturing processes
- Use lightweight materials with combined functions

FIL-AE: a structuring approach for the electrical aeronautics sector

In 2020, while the aeronautics sector was experiencing an unprecedented crisis linked to the COVID-19 pandemic, ISAE-SUPAERO, ONERA, and IRT Saint Exupéry initiated a joint reflection with the aim of proposing an ambitious program to accelerate the transition to the decarbonized aircraft of the future and to enable France to maintain its status as a pioneer in aircraft development. These discussions led to the launch of the FIL-AE (Filière de l'Aéronautique Electrique) initiative. An important step in this initiative was taken in 2021 with the implementation of a scientific program endorsed by the industrial members of CORAC. FIL-AE has also seen the integration of new key members of the French research landscape, such as the CEA and the LAPLACE, and LAAS-CNRS laboratories.



The HIGHVOLT project

The Highvolt project ended in November 2021 after 4 years of work. This 10M euro project, brought together 15 industrial members and 3 laboratories to meet two objectives:

- To improve the understanding of physical phenomena present within electromechanical chains under high voltage (partial discharges, space charges, aging, electric arcs, etc.)
- To verify the performance of current systems when confronting future voltage levels

Among the outstanding results of the project, we can mention the prediction of partial discharges[1], the study of electric arcs under representative conditions[2], the aging with high voltage measurement automation[3], and finally the development of cutting-edge laboratories.

The Highvolt 2 project, which started in October 2021, aims to study combined aging and develop innovative insulating material solutions.

[1] « PDIV Numerical And Experimental Estimation In A Needle/Dielectric Film/Plane Configuration » - C. Van de Steen; C. Abadie; G. Belijar

« Partial discharge detection, Experimental-Simulation Comparison and actual limits » - C. Van de Steen; C. Abadie; G. Belijar

[2] « Caractérisation de l'impact sur son environnement d'un arc électrique amorcé entre des câbles en conditions aéronautiques » - T. Vazquez

[3] « Ageing study in aircraft electromechanical chain: systems modeling for property evolution monitoring » - S. Pin; G. Belijar; L. Fetouhi; Leroy Somer; C. Van de Steen; L. Albert

« PD energy as a marker of low-voltage insulation aging » - M. Szczepanski; L. Fetouhi; M. Sabatou; S. Pin; G. Belijar

« Ageing in aircraft electromechanical chain: design of thermal cycling bench for winding elements » - S. Dreuilhe; S. Pin; L. Fetouhi; S. Stemmer; G. Belijar; L. Albert

The SiCRET project: at the heart of the energy transition

The SiCRET (SiC (MOSFET) Reliability Evaluation for Transport) project team continues its studies on the reliability of Silicon Carbide power electronic devices. At the heart of the transition to electric mobility, this project aims to enable the deployment of a «reliable» SiC MOSFET technology in the transport sector but also to create an increasingly autonomous ecosystem at the national and European levels.

The project brings together the main players in the electrification value chain in various fields (Supergrid Institute, Safran, Alstom, Vitesco Technologies, Liebherr) sharing the same major requirements: reliability and cost.

The project relies on the proximity of device suppliers, especially through a major collaboration agreement with ST Microelectronics for medium voltage (1200V) and Mitsubishi for high voltage (3300V). The industrial needs of these partners are complemented by the expertise and technological research of the main public laboratories in the field: AMPERE in Lyon, IES in Montpellier, LAAS-CNRS, and LAPLACE in Toulouse.

The transfer and capitalization of the know-how generated by the project are ensured by three industrial test centers: Supergrid Institute in Lyon, Nucletudes in Paris, and Alter Technology in Toulouse. Finally, the panel of experts is completed by the expertise and investigation capabilities of the French Ministry of Defense (DGA) and IRT Saint Exupéry, which hosts the infrastructure and staff. This guarantees a qualitative and collaborative work environment in order to successfully meet the objectives of the SiCRET project.

read more

ongoing projects 31st December 2021

SiCRET
Evaluation of the maturity of Silicon Carbide (SiC) power semiconductor technology

SOCOOL 2
Rising maturity of thermal cooling solutions: two-phase loops

OCEANE
Optimization of the high power electrical chain, development of predictive models and Multidisciplinary Design Optimization tools (MDO) for the optimal dimensioning of the electrical chain, evaluation of future DC/AC converters of very high power

EF-MAHPCO
Evaluate the implementation of thermal insulating layers between the composite part and the hot titanium part

HIGHVOLT 2
Improved understanding of the physical phenomena associated with strong electric fields (partial discharges, surface discharges, space charges, electric arcs), evaluation and control of their consequences on the reliability of systems, identification and development of solutions to improve the performance of systems beyond the state of the art

SOLER
Study of the lifetime of electronic components assemblies on printed circuits made with new generation lead-free soldering creams (SAC+ type)[1]

[1] Tin-Silver-Copper

European projects

IMPERIAL
Development of an innovative power converter able to provide power transmission, monitoring, diagnostics, and communications. The system will be highly efficient, reliable, compact, and lightweight, contributing to higher, more efficient, and environmentally friendly performance for future large aircraft

DCADE
Evaluation of potential technologies that will allow the use of higher voltage converters while maintaining power density, as well as arc detection techniques that will increase the safety of high-altitude operations

RECET4RAIL
Development of new technologies for the train traction drive subsystem

HYPNOTIC
Development of a set of bidirectional converters acting together as a single device

projects completed in 2021

HIVACS
Exploring and optimizing the design of future aerospace cable systems to enable the aerospace industry to meet the high power design requirements of future aircraft programs

HIGHVOLT
Study of the physical phenomena amplified by the increase of the voltage and the use of «large gap» components

advanced manufacturing technologies.

advanced manufacturing technologies.

Emilie Herny
Technological Director

The **«Advanced Manufacturing Technologies»** axis develops solutions to improve the performance and competitiveness of manufacturers, from the design to the manufacture of critical parts or systems.

Our solutions can be «targeted» on one element of the value chain or «global» on the entire chain. In this approach, our activities are mainly focused on the development of new manufacturing technologies, the optimization of processes or the production chain, and the control of the behavior of materials and structures.

We propose a disruptive approach by coupling multi-physics modeling tools and/or artificial intelligence to the world of materials and processes, to take advantage of the transversal synergies offered by all the competencies of IRT Saint Exupéry.

«We provide proof of concept, based on environmentally friendly solutions.»

Find out more about our key competencies by clicking here

challenges

Improve the **competitiveness** of our industrial partners through the development of **innovative and cost-effective technologies**

Accelerate the development of technologies and transfer to the industry

objectives

Development of new manufacturing technologies.

- Develop innovative materials and processes
- Develop hybrid manufacturing technologies
- Develop the multifunctionality of materials and structures

Optimization of manufacturing processes & production line.

- Reduce material costs
- Reduce manufacturing, repair, and maintenance costs
- Reduce development and qualification cycles

Control of the behavior of materials and structures.

- Master the processes (reliability and robustness)
- Master the life cycle (initial and residual) of structures
- Mastering the long-term evolution of material properties

LMD-powder process: the DePÔz project has reached a new level of technological maturity through the design and manufacture of a unique demonstrator in record time.

The DePÔz demonstrator illustrates the growing maturity of the LMD-p process through the development of design and manufacturing rules, making IRT Saint Exupéry a major player in the industrialization of this technology. It is the result of a collaboration between IRT Saint Exupéry and the AddUp Company. It allows one to demonstrate process abilities but also to highlight its limits linked to its actual maturity level. This part gathers various complexities inherent to the LMD-p process, such as intersections, changes of a section, overhang zones, elbow zones, or functionalization on thin freeform surfaces.

read more

METEOR Project: a technological breakthrough in the production of high-performance thermoplastic prepregs and composites.

2021 was marked by the successful conclusion of the METEOR project, which aimed to optimize the quality and cost of producing high-performance composites from competitive thermoplastic semi-finished products 100% sourced from the French supply chain.

The project team focused on optimizing the entire value chain, from resin synthesis and grinding processes to optimize the morphology of the prepregs used to make composite parts for aerostructures.

Among other things, this project has enabled the French prepreg industry to demonstrate its skills, reduce costs and move towards a less energy-consuming technology!

read more

Launch of COBRA & CODEX projects

The COBRA (COntrolled Bonding for Reliability of Assemblies - on the robustness and performance of innovative assemblies) and CODEX (on dismountable bonding) projects launched in 2021 are a continuation of the projects on innovative assemblies previously carried out.

Launch of the OXYGEN project

The OXYGEN project, launched in 2021, deals with ceramic matrix composites for dual applications in aerospace and defense. It is a continuation of the «Oxyde Voie Liquide 1» and «Oxyde Voie Liquide 2» projects conducted in the context of the development of lower-cost ceramic materials. This project marks our first collaboration with the CEA DAM («Direction des applications militaires»).

Platforms Zoom:

new LMD-W equipment unique in Europe

New equipment has been added to our metal additive manufacturing platforms. It is a unique additive manufacturing machine in Europe, using metal wires, based on LMD-w (Laser Metal Deposition-Wire) technology. It will soon join our Toulouse platforms.

ongoing projects 31st December 2021

COMPINNOV HT
Replacement of metal parts by high-temperature composites for aeronautical structure applications

COMPINNOV TP2
Understanding between carbon/thermoplastic prepreg architectures, processability (consolidation and assembly), and impact on mechanical properties

C3N
Removal of technological barriers related to the replacement of low-carbon steel used for the lining of HA (high activity) cells by a Ceramic Matrix Composite material (CMC)

CMC en service
Removal of technological barriers related to the characterization of CMC technological samples in a representative engine environment

CMC SiCMI 2
The rise in the maturity of SiC-SiC[1] CMC materials for the needs of civil aeronautics

ACDC
Development of composite materials and structures for noise reduction and vibration control in the cabin and nacelle environment

OXYGEN
Development of oxide CMC for high-temperature applications (from 700°C to 1000°C)

VITAL
Generation of composite material design qualifiers by virtual testing

ASSEMBLAGES INNOVANTS 2
Determination of critical parameters to enable the maturity of innovative assembly technologies

COBRA
Increased maturity and automation of innovative assembly processes

CODEX
Development of removable bonding solutions for the automotive, aeronautics, and space industries

SPRINT
Development and characterization of lead-free solder creams with improved thermomechanical properties

ELIPSE
Characterization and maturation of non-contact printing processes of electrical tracks on the aircraft structure or cabin trim panels

FREEzING
Development of multifunctional surface coatings for aeronautical parts

GLAD
Development of functionally graded materials and properties through the use of the LMD-p (Laser Metal Deposition - with powder) process

WALLSAPP
Increasing the maturity of the design and manufacture of thin structures (with dimensions less than 1mm) by metal additive manufacturing processes

MATILD
Increasing the maturity level of the LMD-p (Layer Metal Deposition - powder) process for aerospace applications

HIPPOME
Study and development of HIP (Hot Isostatic Pressure) treatments for nickel-based superalloys processed by LBM (Laser Beam Melting) additive manufacturing and elaborated by MIM (Metal Injection Molding)

LASER
Development of numerical tools and methodologies for the design of lattice structures made by additive manufacturing

MAMA
Development of disruptive forging and closed die-forging processes for the manufacture of primary aeronautical parts in TA6V titanium alloy

EF HYDROPLANE
Definition of a future project to develop material and process solutions for hydrogen distribution in future generations of aircraft

[1] Silicium carbide

European projects

ReCHycle
Development of a CMC demonstrator for optimized gas flows in metallurgical blast furnaces

DEFLECT
Functionalization of composite materials for the manufacture of electrical enclosures to house and protect on-board electrical and avionics devices

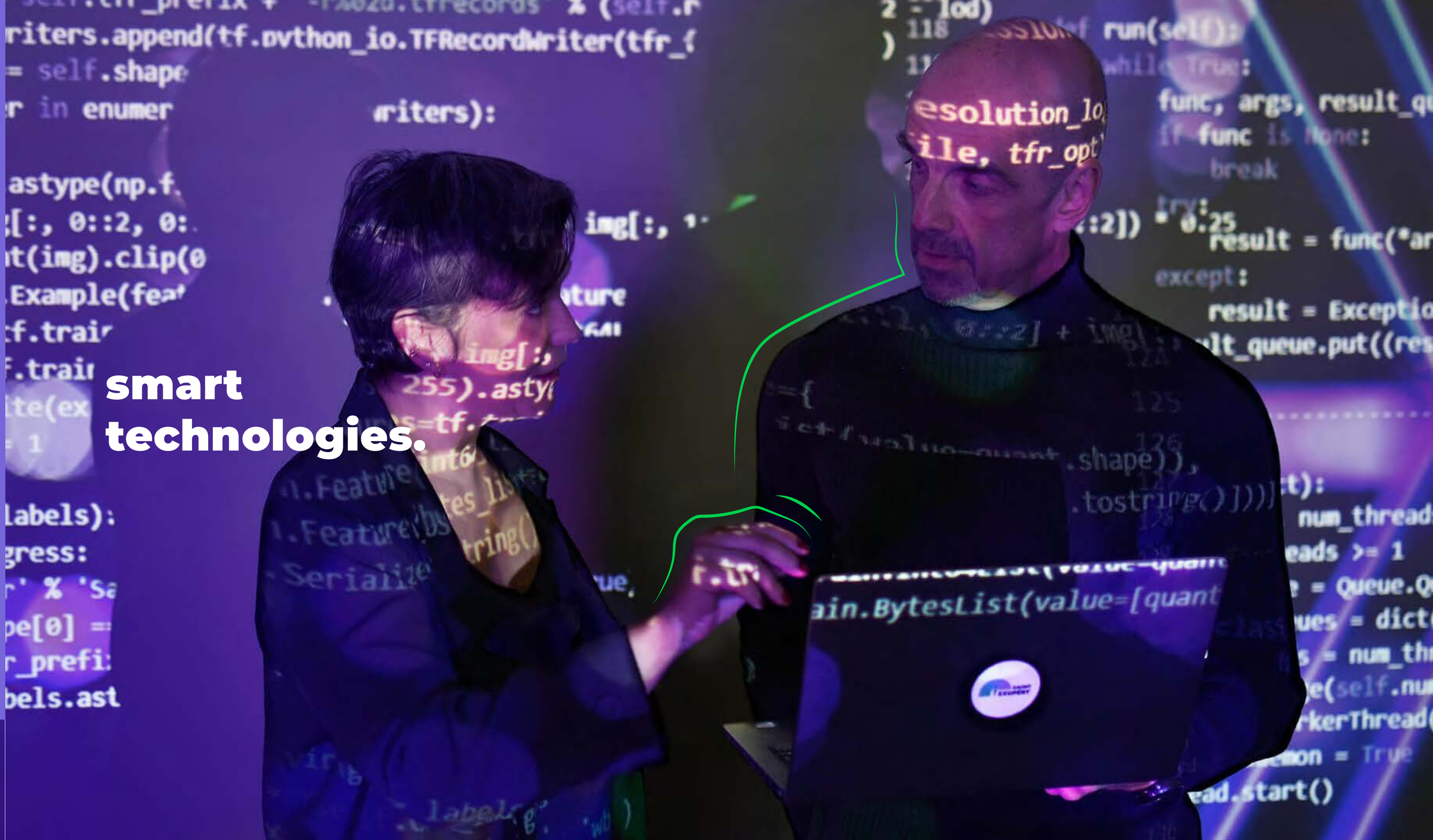
projects completed in 2021

ANDDURO
Understanding and improvement of powder bed metal additive manufacturing technologies by laser fusion or electron beam

DEPOZ
Understanding and improving Laser Metal Deposition (LMD) additive manufacturing technology

METEOR
Development and study of competitive thermoplastic semi-finished products, compatible with non-autoclave processes and coming 100% from a French supply chain

OXYMORE
Optimization of the micro-arcs oxidation process for aeronautical applications (nacelle air inlet lips, seat rails, valve bodies)


smart
technologies.

smart technologies.

Lionel Cordesses
Technological Director
& IEEE Senior Member

The **«Smart Technologies»** axis develops Artificial Intelligence and connectivity technologies for systems.

We also develop and evaluate AI-based solutions for planning and decision-making in complex and uncertain environments: satellite constellations, sensor networks, or air operations. In most of the critical systems on which we work, the collaboration between Human and Machine takes a predominant place.

Similarly, connectivity technologies are ubiquitous: we are focusing on applications involving a non-terrestrial segment such as satellite or a high-altitude platform to increase the coverage of digital services in areas without infrastructure (5G, IoT).

Finally, we use AI to improve communications, just as we use techniques from real-time communications to improve AI!

In the same spirit of cross-fertilization, some of the robust AI techniques that we develop serve other axes of the IRT Saint Exupery and increase the added value of the solutions developed for industrials such as AI to simplify system engineering, AI to control processes with ceramic matrix composites or AI to detect and locate electrical arcs in an aircraft electrical network

Finally, we have recently applied these same robust and explainable techniques to the most critical system of all: human health! Collaborations and research in partnership with key players in the sector are coming up in 2022.

« Everybody - or almost everybody - does Artificial Intelligence (AI). Our difference: we invent and deploy robust and explicable AI for critical systems with the best laboratories in the world »

Find out more about our key competencies by clicking here

challenges

Development of **robust and explainable** Artificial Intelligence (AI) bricks

Increased **coverage** of communication systems

Certification of systems including AI

objectives

Increase the performance and ubiquity of digital services, especially non-terrestrial ones.

- Connectivity
- Observation and detection

Plan and decide in complex environments.

- Planning and decision
- Efficient and embedded AI

Invent & deploy certifiable Artificial Intelligence.

- Machine learning and certification
- Qualification environment

5GMED Project: innovation, connectivity, challenge.

The European project 5GMED was launched in September 2020 for three years and a total budget of 15 million euros. The objective of the project is to test on a 40 km cross-border corridor (freeway + railroad), between France and Spain, innovative services using the 5G telecom network and AI, with a particular focus on service continuity when roaming between the two countries.

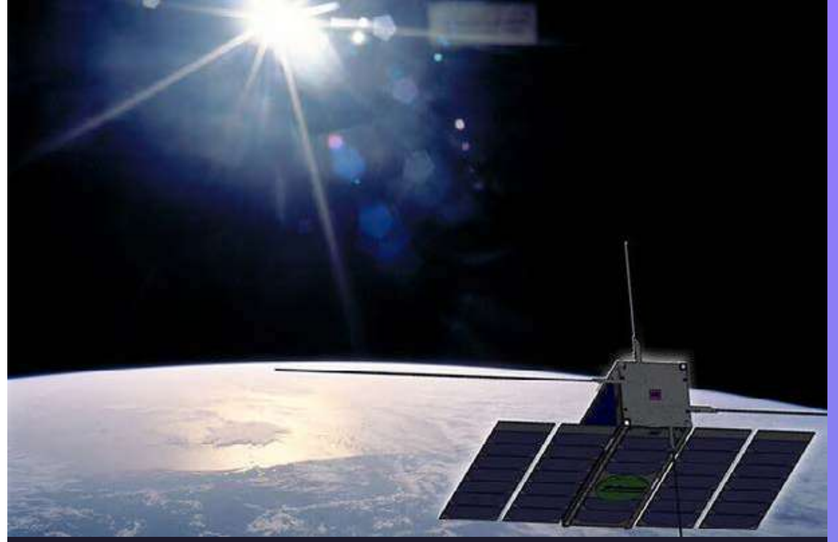
IRT Saint Exupéry, responsible for the initial definition of services and tests for each use case, uses its skills in 5G and satellite networks as well as in AI to develop AI modules for detection, optimization, prediction, and testing of a satellite slice before its implementation in the train.

read more

Creation of the Advanced Master «Artificial Intelligence & Business Transformation»

Since the end of 2017, we have been working together with ISAE-SUPAERO and Toulouse Business School to create a specialized training program on the understanding of AI, its impacts, and its modes of operation in the company. The very favorable context of the 3IA institutes, including ANITI in Toulouse, and of the emerging professions has confirmed the creation of this program. The first courses of this specialized master's degree in «Artificial Intelligence & Business Transformation» have been taught at ISAE-SUPAERO since October 2021. IRT Saint Exupéry contributes mainly on 2 subjects: the application of the acquired knowledge in the framework of concrete use cases and the subjects of certification and robustness of artificial intelligence. These sessions are supervised by IRT Saint Exupéry staff (DEEL project). This strong partnership with ISAE-SUPAERO demonstrates the complementary of our two institutions and our ability to train experts who meet the needs of industry in the face of international challenges.

read more



CIAR Project: Two premieres in Artificial Intelligence on-board satellites

The CIAR project (Chaîne Image Autonome et Réactive - Responsive and Autonomous Imaging Chain) is studying technologies to deploy Artificial Intelligence (AI) for image processing on embedded systems (satellites, delivery drones, etc.). Three interdependent challenges are addressed:

- Defining use cases and building relevant image databases.
- Designing AI that is both performant and well suited to embedded systems constraints.
- Optimizing the selected algorithm and embedding them in hardware targets.

For several years, the CIAR team has been collaborating with the European Space Agency (ESA) on the OPS-SAT mission. On March 22nd, 2021, the team successfully uploaded a neural network on the FPGA embedded in this satellite. This illustrates the ability of IRT Saint Exupéry to tackle all these technical challenges.

read more

DEEL program: Toulouse and Montreal join forces to develop AI for critical systems

Resulting from a rich collaboration between academic and industrial partners, the DEEL project aims at developing an Artificial Intelligence (AI) that would be dependable, robust, explainable, and certifiable, applied to critical systems in the field of aerospace and transportation.

A new step in the collaboration between the French and Quebec sides of the DEEL (DEpendable and Explainable Learning) project has taken shape with the signature of an international collaboration agreement between the various project actors. This signature will allow the development and expansion of existing collaborations between the organizations.

In Quebec, the DEEL project is led by the Consortium for Research and Innovation in Aerospace in Quebec (CRIAQ) and the Institute for Intelligence and Data (IID) of Laval University, with the collaboration of the Institute for Data Development (IVADO). In France, the DEEL project is supported by IRT Saint Exupéry and ANITI, the Interdisciplinary Institute of Artificial Intelligence of Toulouse.

Launched in 2018, the DEEL (Dependable and Explainable Learning) project addresses the scientific and technological challenges of securing the use of Machine Learning in critical systems. Within this framework, a team of 30 experts is working on the challenges of certifying systems with AI. Read their white paper.

ongoing projects 31st December 2021

PEP_hiTE
Implementation of a platform to evaluate the performance of collaboration between humans and autonomous agents including AI in the context of military and civil aeronautics

SODA2 *(under construction)*
preparation of future defense systems involving artificial intelligence for the optimization of ground-air defense strategy

MINDS
Artificial intelligence for the evolution of space observation systems: planning of massive and heterogeneous constellations and bimodal semantic analysis of satellite images and text

NS3
Scientific and technological simulations and modeling of an innovative concept of high resolution and small size imager for mobile, airborne, and space applications

ELLIOT
Definition of a communication protocol and removal of technological barriers that allow an IoT service with wide geographical coverage from low-cost nanosatellites in low orbit

CIAR
Introduction of artificial intelligence technologies for image processing in embedded systems (satellites, robots, drones, etc.) to make them more autonomous and responsive

PHOEBUS
Methods and equipment for the verification of high-capacity communication satellite payloads (VHTS[1]) exploiting photonic technologies and overcoming the limitations of electrical-only solutions

DEEL
Creation of explainable and robust machine learning theory and algorithms to meet the challenges of qualification and certification of AI-embedded critical systems

SUPERG
Study of 5G/Satcom integration. Realization of a platform for orchestration and acceleration of virtual network functions for Satcom and 5G for software-driven networks

SB
Establishment of community management of access to data and services for the environment, sharing of resources (data, calculations, storage, AI algorithms). Application use case: coastal submersion and erosion

RAPTOR
Definition of an embedded subsystem to conduct a rendezvous mission with more or less collaborative space targets, as well as a multi-objective optimization planning tool

APISS *(under construction)*
Implementation of a standardization reference for embedded sensor solutions based on photonic technologies

ENVIA *(under construction)*
Realization of automatic control based on reinforcement learning for autonomous vehicles placed in an uncertain environment. Use case: the LCA60T airship from Flying Whales.

European projects

5G MED
Deployment of a telecom and computing infrastructure (5G-SA and AI) along a France/Spain cross-border corridor. Test of use cases: innovative train and car in real conditions.

[1] Very High Throughput Satellite

projects completed in 2021

EF-SUCRE
AI evaluation and quantification of the comprehensibility of textual user queries, from the perspectives of semantic analysis and pragmatic analysis

NEWCAST
The growing maturity of technologies that increase the energy and spectral efficiency of satellite links, up to a demonstrator level

methods & tools for the development of complex systems.

methods & tools for the development of complex systems.

Christophe Lemort
Technological Director

The **«Methods & Tools for the development of complex systems»** axis proposes a set of solutions to facilitate the development, optimization, and architecture verification of critical systems.

Our solutions aim to improve the quality of the design phases, increase system control, and reduce recurring costs and the duration of the architecture and development phases.

Our approach takes into account the entire life cycle of complex and critical systems. It starts from the design phase thanks to multidisciplinary, optimized, iterative, and efficient engineering and extends to the operational deployment phase thanks to the use of digital twins.

We develop a 100% numerical approach by integrating multidisciplinary optimization, model-based systems engineering (MBSE), and the time guarantees required for critical systems.

Because of the transversality of our activities, we address all the other axis of IRT Saint Exupéry and support the fields of electricity, materials, and artificial intelligence by proposing complementary solutions to achieve their objectives.

«The transversality of our skills allows us to address the entire range of our members' activities.»

Find out more about our key competencies by clicking here

challenges

objectives

Create methods and tools for the development of **digital twins** to improve the efficiency of complex systems

Design **complex systems** in an optimized, iterative, and fast way

Certify and qualify **critical embedded systems**

Enable digital and collaborative systems engineering.

- Get a unified vision of a complex system based on heterogeneous data, methodologies, and tools.
- Improve coherence between different disciplines or in extended enterprises
- Adapt to the rise of artificial intelligence

Develop and transfer robust multidisciplinary optimization.

- Accelerate the digital transformation of system design and development phases
- Improve design efficiency and robustness through new multidisciplinary optimization and uncertainty propagation methodologies
- Implement artificial intelligence and multidisciplinary optimization in the development of digital twins

Design efficient & secure hardware and software architectures.

- Propose methods to meet certification objectives in distributed or artificial intelligence contexts
- Guarantee the temporal properties of new implementation models (GPU, FPGA, TSN)
- Optimize the use of material resources

2 key competencies at the heart of the R-EVOL project

For several years, the digitization of processes and systems has become a strategic issue. This transformation aims to create synergies between the different actors, improve the robustness of design processes, and make the most of systems in operation. Within this global approach, the R-EVOL project is developing advanced MultiDisciplinary Analysis and Optimization (MDAO) methodologies for the design phase, by studying the advantages of using system engineering models as a support for the definition of MDAO processes.

The project started in 2020, is an example of the coherence of the approach carried out within the «Methods and tools for the development of complex systems» axis. It takes advantage of the skills of the «Multidisciplinary Optimization» team and the «Systems Engineering» team.

It is also a project of strong transverse interest within IRT Saint Exupéry, as these MDAO techniques are applied in the application areas of electrical system optimization, heat exchanger design, and «virtual testing» for materials.

GEMSEO

GEMSEO: a disruptive tool for the multidisciplinary designer

GEMSEO software developed by IRT in 2015 became open source in May 2021. Using a disruptive approach based on MDO formulations, this software bridges the gap between the best algorithms developed by researchers and industrial design problems.

Among the different examples of use, Airbus presented in November 2021 at the COP26, its platform SoSTrades, whose digital core is GEMSEO. This platform is designed to evaluate different scenarios by integrating and coupling biophysical models (energy - economy - climate - natural resources) and aiming at finding compromise solutions for energy transition and climate issues. The associated hard high-dimensional problems to solve challenged the limits of GEMSEO numerical algorithms and led our researchers to improve the graph algorithms, linear and non-linear solvers, coupled-adjoint techniques, and the overall GEMSEO software performance.

read more

The S2C project

The increasing use of models in the development phase of complex systems is an opportunity to extend digital continuity to new disciplines.

The S2C project is working to characterize the necessary exchanges between MBSE system engineering models and MBSA safety analysis models. For this, the team is working with the authors of the «Model-Based Safety Assessment» annex of the future ARP4761A[1], used in civil aeronautics. A complementary methodological guide is being written to help manufacturers make the transition from more traditional approaches such as fault trees (FTA). The MBSA also facilitates the link with the MBSE. To align practices, the project is exchanging with the ATLAS program, which aims to promote the emergence of standards for model interoperability.

[1] Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

The ATIPPIC project

The emergence of «NewSpace» and satellite constellations is leading the industry towards new satellite concepts with reduced size, mass, and power consumption. Lower production costs and reduced integration times create a double challenge: avoid the costly development of specific components and maximize the integration of functions on a single board.

The ATIPPIC project studied a generic avionics architecture based on COTS (off-the-shelf components) applicable to the micro-satellite domain.

The project focused on the use of COTS for the onboard computer, the various sensors (star sensor), actuators (inertial wheel), GPS, etc. The centralization of the avionics functions and the respect for the temporal constraints were detailed to guarantee the operation of the system. The ability to detect, isolate, and reconfigure in case of failure has been addressed at different levels of the architecture.

ongoing projects 31st December 2021

ARCHEOCS
Design and optimization of critical software systems deployed on single and multi-card architectures equipped with complex SoCs

EASYMOD
Definitionofappropriateandaccepted interaction modes by system architects and engineers to improve the acceptability and wide deployment of modeling and increase the efficiency and productivity of system engineers

EDEN
Evaluation and design of the bricks of a deterministic, modular, standardized, and multi-sector (automotive, aeronautics, or space) embedded communication architecture based on the TSN (Time-Sensitive Network) standard

R-EVOL
Contribution to digital continuity through MDO concerning systems engineering.
Development of innovative capabilities to improve the efficiency and robustness of MDO processes. In particular, the development of multi-fidelity and uncertainty propagation aspects in MDO processes

S2C
Establishment of numerical continuity between system definition and safety analysis

SPOC
Evaluation of software and hardware implementation test architectures for embedded Machine Learning models supporting future space or airborne optical payloads

VITAL *(contribution)*
Contribution via GEMSEO to the quantification and propagation of uncertainties to study the impact of the variability of composite material properties for aeronautical structures

TeePee4Space (ESA project)
Evaluation of mass and power budgeting analyses on a set of distributed and heterogeneous MBSE models to leverage digital continuity in an extended enterprise environment

ELMASAT (ESA project)
Model-based engineering approach for availability assessment of satellite systems embedding electronic COTS

European projects

MADELEINE
Development and validation of multidisciplinary design tools for optimization.
Special attention is given to multidisciplinary optimization, understanding of multi-physics phenomena, simulation of manufacturing processes, and transition to High-Performance Computing (HPC)

RHEA
Use of multidisciplinary optimization for the design of future-generation aircraft with ultra-high-aspect-ratio wings. In this context, we are in charge of the implementation of the global process, interfacing to GEMSEO different models based on physics

NEXTAIR
Enable the digital transformation of future-generation aircraft through the development and demonstration of new numerical methods combining the most advanced high-fidelity modeling capabilities with Machine Learning techniques. NextAir will enable robust design and fielding of future-generation climate-neutral aircraft configurations with improved operational reliability and smart maintenance technologies

RECET4RAIL *(contribution)*
Contribution through MDO approaches to the study of new additive manufacturing technologies applied to the development of traction systems in the railway field

projects completed in 2021

ATIPPIC
Definition of a highly integrated avionics architecture based on COTS for the small satellite platform market

our key competencies.

composite materials.

Toulouse team

Bordeaux team

R&T Fields

- Multifunctional materials
- Design & manufacture of prepregs with optimized architecture
- Induction welding processes
- Virtual material, manufacturing and testing
- Innovative ceramic composite material and processes

Our «Composite materials» competence center Our competence center meets the challenges of industrial competitiveness to develop lighter aeronautical and spatial structures that are both resistant and multifunctional, by using high-performance composite materials. We focus on the development of materials from thermostable organic matrices (PEEK, PEKK, PAEK, and high-temperature polymers), to thermoplastics or thermosets and ceramic matrices resistant at very high temperatures (aluminum oxide Al2O3, silicon carbide, vitroceramics, etc.). The applications targeted are the critical mechanical structures of aircraft, launchers, satellites, and motors whose reliability has to be guaranteed.

We design and develop new multifunctional composite materials with managed architectures, and we also operate on a semi-industrial scale. Going beyond the technological error testing approach often found in industry, we develop digital tools and methodologies to design and manufacture high-value-added materials and structures.

This enables, for instance, to reduce design and qualification phases for industrial understanding (virtual testing) of the influence of setting parameters of development means on the microstructure and properties of materials (virtual manufacturing).

Eventually, we also help technicians, engineers, and PhDs to develop their skills, and train Ph.D. students for careers in the formulation and implementation of new generation high-performance composites.

« Composite Vitrimers » webinar

On June 22, 2021, the teams of the composite competence center organized in collaboration with Ad'Occ and Aerospace Valley a webinar on the theme of vitrimers composites*. Our academic and industrial members were able to discuss this interesting topic with interventions from CNES, a key player in the space sector, and SOLVAY, a leader in the advanced materials and chemistry sector. Patricia Sandré and Mathias Destarac concluded this session with a presentation of the EVERGREEEN project conducted within IRT Saint Exupéry and focused on this theme.

* Cross-linked polymer which, when cold, has the characteristics of a thermosetting polymer but which, when hot, can be shaped like a thermoplastic polymer

Creation of a Research Group on Ceramic Matrix Composites (CMC)

The GDR (Research Grouping) has been set up by the LCTS (University of Bordeaux/CNRS) in 2019. In this context, the steering committee of this GDR has decided to define a common French strategy on CMC, in co-piloting between the LCTS laboratory and IRT Saint Exupéry at the end of 2021.

Composed of the main contributors/users in the field of CMC (university laboratories, contractors, manufacturers, and developers) this community aims to build a common strategy at the national level.

2020 → 2025

- Process control
- Functionalization of materials & structures
- Process optimization
- Multifunctional solutions & greener composites
- Disruptive processes & materials for future transportation
- On-demand composite (reduction of costs & cycle)

surfaces & assemblies.

Toulouse team

Bordeaux team

R&T Fields

Towards greener & multifunctional coatings

Automatic deposit of paints & inks

Innovative assemblies

Nowadays, reduction of manufacturing costs and product maintenance, the adaptation of processes to new legislation (especially environmental regulations) is mandatory as well as weight reduction, multifunctionality, or improvement of products' in-service robustness and durability. These challenges put surface and assembly technologies at the heart of today's R&T as they are involved at several levels of the manufacturing process of aeronautics and space products and have a significant impact on pieces of equipment/systems' total costs.

The «Surfaces & Assemblies» competence center design, develop and operate up to a semi-industrial scale to implement new innovative coatings & assembly processes. Understanding the impact of process parameters is supported by using modeling tools: the technologies that we develop are, thus, transferable and adaptable to the specific needs of the aeronautics and space industries.

The applications targeted are mainly structural parts or sub-assemblies of aeronautics systems as well as launchers and satellites.

For this purpose, we operate to favor the development of stronger skills for technicians, engineers, and Ph.Ds. We also train Ph.D. students for career opportunities in surfaces and assemblies technologies with a strong emphasis on the automation of processes.

Technical day «Surfaces & Assemblies»

On September 23, 2021, was held «Surfaces & Assemblies Day» organized by our teams in Toulouse and Bordeaux. On the program: thematic workshops led by our research teams and our academic partners, and intended to cross the needs and expectations of the industry with the current and future research areas of IRT Saint Exupéry. With the participation of all the major players in the Aerospace industry (Airbus, Airbus Helicopter, Thales Alenia Space, Safran, Ariane Group, Liebherr, CNES, Socomore, Stelia) and with the support of our academic partners (LGC, I2M, CIRIMAT, LAPLACE, ICA, ISAE SUPAERO, ENIT), this meeting was a success.

Collaboration with ITE NOBATEK/INEF4

The NOBATEK/INEF4 Institute for Energy Transition (ITE) and IRT Saint Exupéry have collaborated on the prototyping and manufacturing of a first series of thermal solar panels integrated into a facade. The ITE NOBATEK has developed an innovative technology of solar thermal collectors integrated into a metal cladding called BATISOL®.

Within the framework of the PLATSOLAR project for the optimization of this system, ITE NOBATEK and IRT Saint Exupéry have collaborated to carry out the application of glue on the aluminum panels using a pneumatic gun. The objective was to demonstrate the ability to carry out the gluing of these parts in a controlled way by the use of automatable techniques. It also adapts or develops the parameters of glue deposit with the adhesive used by NOBATEK on about fifty sensors. This gluing was carried out with the 6-axis robot (KUKA) of IRT Saint Exupéry.

2020

Mastery of assembly processes & coating

Robustness of processes & coatings

Functionality

Multifunctional, durable & maintainable solutions

New technologies, coatings & assemblies for the transportation of the future

On-demand coating & assembly (robustness & reliability)

2025

metallic materials & processes.

R&T Fields

- Thermomechanical processing of metallic alloys (special processes)
- Physical metallurgy
- Durability of materials and structures, aging
- Modeling & simulation

The «Metallic materials & processes» competence center plays an essential role in the development and qualification of materials and processes that contribute to the technical and economic competitiveness of metallic solutions in the structures and systems of aircraft, satellites, launchers, and turbine engines.

Our experts aim at bringing together, in the same team, scientific and technological skills that are both multidisciplinary and complementary. The mix enables us to transfer the results of research projects more rapidly to the industry. The range of competencies includes experts in physical metallurgy, process simulations, thermomechanical modeling, special processes, and physicochemical characterizations.

Through our strategy, we focus on eco-design, sobriety, and sustainability of metallic materials, structures, and systems. The development of tailor-made materials with specific properties (like architecture or functionally graded materials) supports our strategy, as well as material savings, streamlined structures, increased use of recycled materials, or deployment of repair solutions for high-added-value components.

Launch of a thesis on the development of functionally gradient materials (FGM)

2021 saw the launch of the thesis work in collaboration with the Carnot Interdisciplinary Laboratory of Bourgogne (ICB) on the development of high-temperature corrosion-resistant gradient materials for the energy production field.

Initial work has identified optimal process parameters for LMD (Laser Metal Deposition) fabrication of multi-material systems, composed of low alloy steel and nickel-based alloys. First results on the corrosion behavior of these systems have also been obtained.

This work is part of the competence center's strategy to develop customized materials.

Example of gradient materials developed by LMD (LaserMetalDeposition) and characterized in the framework of Agathe Curnis' thesis (supervision Aurélien Prillieux - IRT, Ioana Popa - ICB, Sébastien Chevalier - ICB)

2020

- Development of hot forming processes
- Process hybridization
- Innovative design & materials
- Intelligent mechanical structures
- Materials & structures of the future
- Eco-design, sobriety, durability, reduction of costs & cycles

2025

high voltage energy.

The «High voltage energy» competence center aims to respond to the challenges of reduction of the environmental footprint of transport through electrification solutions. Indeed, we focus on the increasing need for electrical systems, for which either non-propulsive or propulsive energy is leading to a significant rise in electrical power need, and therefore in the voltage level. In addition, densification is essential to allow a drastic reduction in the weight and volume of electrical equipment and systems. Indeed, these performance indicators raise non-negligible constraints when it comes to embedded applications: some, such as electric fields, increase considerably due to the small distance between them. These electrical constraints, combined with the harsh environments of aeronautics and space (temperature, pressure, etc.), aggravate phenomena detrimental to the integrity of electrical systems, such as partial discharges or electric arcs.

Therefore, we research, characterize, and model these physical phenomena (partial discharges, surface discharges, space charges, electric arcs, and electrical aging of insulators). In addition, we examine the application of suitable innovative dielectric materials (polymers, polymer matrix composites, etc.).

In a quest to increase power, we are also focusing our efforts on the study of electrical currents. To minimize the weight of onboard electrical components, our teams focus their research on innovative electrical conductors.

HIVACS project

The European HIVACS project, which was coordinated by IRT Saint Exupéry, was officially closed in July 2021.

The HIVACS project focused on the development of cable systems for safe and efficient power transfer for aircraft electric propulsion. The project also developed a series of simulation tools and experimental test benches that can be used for future cable development.

The project, conducted alongside Nexans, the University of Manchester, and the University of Toulouse, has produced relevant results in the following areas:

- Improved electro-thermal models to predict the maximum current a cable is capable of carrying with modeling capabilities demonstrated for unshielded cables and the next generation of shielded cables expected to be used in future aircraft.
- Partial discharge testing and modeling show the difficulties in providing consistent PDIV (partial discharges inception voltage) results in a way that could lead to changes in future standards.
- A better understanding of aging mechanisms, including thermal degradation of insulation and implications for future aerospace systems.
- New perspectives in cable design and manufacturing.

read more

R&T Fields

Evaluation of the impact of voltage on components

Controlling the impact of voltage

Reduction of the impact of electrification on the weight

2020 — Understanding of physical phenomena — Means & methods of measurement — Modeling — Ageing — Health Monitoring — Tension rise — 2025

high reliability energy.

R&T Fields

Reliability (qualification support, robustness, durability) of power components, digital components, energy sources and storage, electronic/electrical assemblies and interconnections

EMC : predictive behaviour of an electronic board (emission and immunity)

Immunity to natural radiations (neutrons, protons, heavy ions, etc.)

The core of the «High reliability energy» competence center is the challenge of transport electrification, and, more generally speaking, the increase in energy density and electronic functions miniaturization (be they digital or power). This results in the massive insertion of commercially off-the-shelf components (COTS) and the underlying technologies into the supply chain of high-end applications such as automotive, aeronautics, and space alike. The main challenge hindering their deployment in these severe environment operations is to assess their reliability (qualification, failure rate, and service lifetime), or more properly speaking their “dependability”*.

Through our research, we aim to lay down innovative resources (tools and methodologies) and dedicated expertise (experimental and numerical means) to meet the challenges of this changing paradigm. The core of our activities is represented by the fundamental knowledge and understanding of the underlying Physics of Failure (PoF) or/and the Physics of Fault.

COTS components based on emerging technologies can be dedicated to different functions: electrical power (non-propulsive and propulsive), digital (calculation and memory), analog (radio communications and radar detection) and optics (communications and detection), storage and energy sources (batteries, fuel cells, and supercapacitors).

Our approach is essentially based on the analysis, understanding, and modeling of failure/fault mechanisms induced by the combination of usage driving conditions (stimulus) and working environmental parameters, which may be extreme and include electromagnetic compatibility (EMC), and natural radiation immunity.

NRTW: reliability at the heart of embedded electronic devices

Since 2019, IRT Saint Exupéry is an ambassador of the French Center for Reliability, a national group of experts in the reliability of electrical and electronic systems). In this context, the NRTW (National Reliability Technology Workshop) 2021 symposium took place on October 13 and 14 in Toulouse within the B612 building, in association with the CFF (French Reliability Center) and the NAE (Normandie AeroEspace). This annual event brings together national players in the field of system and component reliability: a unique opportunity to strengthen synergies and the European influence of this network around technical exchanges on reliability in the context of the miniaturization of electronics.

Two employees awarded at international events

Catherine Ngom, a doctoral student, received two awards at the RADECS2020 event, for Best Paper and Best Presentation, for her work on «Characterization of the sensitivity to singular effects due to radiation of GaN (Gallium Nitride) power components sold by charge injection with laser pulses».

Pierre Roumanille, a research engineer, received the «Best Paper Award» at the ESREF2021 event for his scientific paper on the subject of «Reliability and failure analysis of lead-free packaging and assembly», studied within the FELINE project at IRT Saint Exupéry.

read more

2020

Analysis of failure modes & their effects

Characterization adapted to emerging technologies (e.g. SiC or GaN)

Fine modeling of the reliability of the component at the module/board level

Failure Risk Assessment Methodology (FRAME) for given usage profile

Qualification, robustness & durability of embedded electrical systems

2025

high density energy.

R&T Fields

Integrated demonstrators

Technological bricks

Methods & tools

The **«High Density Energy»** competence center operates to develop and concretize solutions concerning the switch to electric vehicles. Indeed, to keep them competitive compared to other energy sources (pneumatic, hydraulic, etc.), we focus on finding a way to increase the power density of electrical systems.

Moreover, the whole set of technologies and design methods needs to be revised to:

- increase the voltage to reduce the cable mass;
- use higher performance electronic components (wide gap components) to reduce losses;
- better integration of the components and equipment to master mass constraints, electromagnetic compatibility (CEM), network quality, reliability, thermal control, or costs.

Throughout our research, we concentrate on electromechanical conversion chains, electronic power converters, and electric motors, developing technologies (power modules, filters, inductances, printed circuit board, drivers, thermals, materials, etc.) and the methodologies required to optimize them (MDO/MDA) on different criteria (mass, thermal control, CEM, etc.). In other words, we aim at helping increase the power density of electronic circuits between 2 to over 10 kilowatts/kg and of electric machines between five to over 15 kilowatts/kg.

In synthesis, we deal with voltages of less than a kilovolt for applications of a few hundred kilowatts (small carriers), but also with voltages of between 1 and 3 kilovolts for applications of over a million watts (propulsion, major carriers).

EpowerDrive project

The Epowerdrive project was officially closed in December 2021. We have transferred to our members all the methodological and technological bricks that have been developed through the work carried out during these 4 years:

- Optimization tools for the power chain converters, cables, and motor thanks to the Gemseo platform
- Design of very high-efficiency large gap SiC and GaN converters including many innovative technological bricks
- Characterization of ferromagnetic materials used at high frequency

2020 — Characterization of the electrical chain — Innovative converters — Densification solutions — High-power converters — Integration increase in power density — 2025

smart connectivity & sensors.

Toulouse team

Sophia Antipolis team

R&T Fields

- Digital & analog communications
- Systems & networks
- Remote sensing

To meet the challenge of global and ubiquitous access to digital services, the **«Smart connectivity & sensors»** competence center focuses its research on the development of sensing and communication technologies that enable the continuity and reach of these services based on airborne or space-borne relays. Our experts also study the use of embedded sensors to provide improved monitoring services for industrial and natural environments.

The overall objective is to increase networks' capacity and range while seeking to optimize their availability and security. We aim at allowing the whole value chain of the aerospace and transport industries (operators, system manufacturers, equipment suppliers, and component suppliers) to develop their market by reducing the risks linked to the introduction of new technologies while favoring standardization initiatives.

Our main activities focus on the development and use of digital technologies in telecommunications, and intelligent embedded processing close to the sensor. They apply to systems with distributed architecture, connecting intelligent remote devices to centralized or cloud infrastructures.

For telecom activities, the targeted markets are verticals (transport, industry 4.0, defense, and civil security...). The primary topic is to contribute to the development of Non-Terrestrial Networks (NTN: satellites, HAPs[1], UAVs[2]) driven by 5G/6G standardization works. To respond to 5G or Internet of Things requirements, our works are looking to design and optimize end-to-end system architecture with an NTN segment, through the use of virtualization technologies (NFV[3]) network programming (SDN[4]), and service orchestration.

For sensing activities, we targeted are New Space and aeronautics markets. Here, the objective is to improve the autonomy, compactness, and consumption of embedded monitoring systems to deliver reliable detection services.

The applications linked to connectivity are backhauling of 5G networks, direct access to satellite for mobile, and universal support of the Internet of Things with worldwide cover.

The applications concerned for remote sensing are autonomous guidance for satellites, environment monitoring (gas concentration), and aircraft health monitoring.

5G-NTN workshop

On September 30, 2021, the Super-G project team gathered more than 50 participants for a workshop dedicated to the potential applications of «Non-Terrestrial Networks» 5G.

IRT Saint Exupéry has set up the Super-G project, which focuses on the integration of satellites in the context of 5G with 4 industrial partners: Airbus Defence and Space, QoS Design, Thales Alenia Space, and Viveris. The project was launched in February 2019 and will be completed in June 2022. This project addresses the architecture and solutions to support satellite backhaul in a 5G compliant context and leads the development of the platform dedicated to the virtualization of «Satcom» network functions.

[1] High Altitude Platforms
[2] Unmanned Aircraft Vehicles
[3] Network Function Virtualization
[4] Software-Defined Network

2020

Broadband communication/ satellite: capacity optimization, interference management

Environmental monitoring: embedded and real-time AI for image processing, cloud detection

5G NTN Backhauling by satellite: network virtualization, slicing

Environmental monitoring: gas detection

5G NTN direct satellite access: multi-connectivity, network security

Embedded system monitoring: multi-sensor photonic network

Advanced 5G/6G: satellite/network fusion

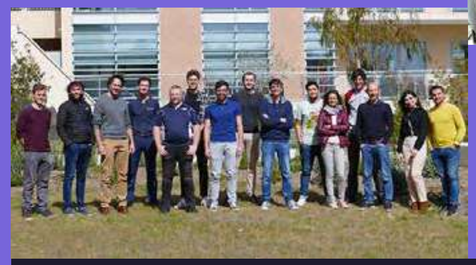
Space surveillance: autonomous guidance & multisensor fusion

2025

advanced learning technologies.

Toulouse team

Bordeaux team



Sophia Antipolis team

R&T Fields

Frugal AI & lifecycle management

Optimization & decision-making

Man-machine interactions

In a fast-moving digital world, driven by Data and Machine Learning techniques, the **«Advanced learning technologies»** competence center uses artificial intelligence to solve complex industrial problems. We accompany the need for novel and fitted AI-based architectures taking into account operational locks to roll out these techniques.

Given the market uncertainty and agility of the major digital operators, a lot of industrialists are forced to bypass their usual patterns and invest in less mature technologies to remain competitive.

Our objective is to gather common investments in AI and capitalize on R&T in a competitive sector undergoing deep restructuring. As we are fully aware of the need to provide reliable and explainable AI, we tackle problems in which data frugality, embedding AI, Man-Machine interactions, and decision-making raise challenges.

Born to serve spatial applications, our competence center keeps widening its application sectors to fully reach the aerospace and transportation industries, as well as the health sector.

Confiance.AI

Technological pillar of the «Grand Défi : securing, certifying and making reliable systems based on artificial intelligence», the Confiance.ai program, launched in January 2021 and supported by IRT SystemX, unveiled its first results during the 1st annual day held in Toulouse on October 6, 2021, at our premises.

This program, which brings together Airbus, Air Liquide, Atos, CEA, EDF, Inria, Renault, Safran, Sopra Steria, IRT Saint Exupéry, Thales, IRT SystemX, and Valeo, among others, is structured around five themes: characterization of AI, trust-based AI by design, data and knowledge engineering, mastery of systems engineering based on AI, and trust-based AI for embedded systems. It involves more than 400 people over 4 years on the sites of Paris Saclay (site of the IRT SystemX) and Toulouse (site of IRT Saint Exupéry) for a budget of 45M€.

With more than 400 participants, this event brought together world-renowned speakers such as Yoshua Bengio (Scientific Director, Mila Institute) and Maximilian Poretschkin (Director of the AI Certification Project, Fraunhofer IAIS) for workshops and presentations on the key themes of the program.

read more

2020

Satellite planning, environmental cockpit, satellite imaging (supervised learning), embedded AI

Operations support, multi-mission planning, imaging (frugal learning & representation learning), embedded AI

Collaborative learning, reactive & autonomous planning, multimodality lifelong learning, embedded AI

Autonomous system, teaming with robust assistants, few shot learning

2025

AI for critical systems.

R&T Fields

- Removing bias and sensitive information from datasets in machine learning
- Theorical guarantees for generalization
- Robustness via detection and adaptation to unknown data
- Explainability

Recent progress in Artificial Intelligence, especially in Machine Learning, has aroused unprecedented interest in these technologies. Many industrial sectors are now considering using them. However, this has led to strong scientific obstacles. Machine learning, especially deep neural networks, can perform well enough to consider critical applications such as autonomous vehicles, predictive maintenance, and medical diagnosis, but their theoretical properties are not well-known yet.

These scientific challenges make it difficult to meet the industrial constraints required for a general application such as certification, qualification, and explainability of algorithms. To this end, the **«AI for critical systems»** competence center aims to create knowledge on:

- Standards, regulations: how to determine new certification guidelines that will increase confidence in complex and adaptive systems;
- Defining the algorithmic and mathematical challenges of integrating machine learning (including neural networks) algorithms in critical systems
- Developing new algorithms and mathematical frameworks with improved properties regarding certification and qualification
- Development process (design pattern) and incremental maintenance/correction of AI-based systems;
- Embedding AIs: quantifying/reducing neural network implementation, assessing performances, regarding specific infrastructures/material targets.

Mobilit.AI: the challenges of Artificial Intelligence for critical systems

The 2nd edition of the MobiliT.AI Forum, an international event organized by IVADO, IRT Saint Exupéry, IID, CRIAQ & ANITI, took place from May 10 to 12, 2021 in a 100% virtual format between France and Quebec. It gathered 450 participants around 13 conferences, 3 round tables, 4 tutorials, virtual stands, and scientific posters.

The 2022 edition will be held in Quebec City (Canada) on May 17, 18, and 19. This 3rd edition of the forum will bring together about thirty speakers on various topics, ranging from certification issues of AI to its implementation in embedded systems or the challenges related to its explicability.

read more

the DEEL project @NeurIPS 2021!

5 scientific publications from IRT Saint Exupéry, ANITI, and the University of Toulouse, published in the framework of the DEEL project, have been selected for the prestigious NeurIPS[1] 2021 conference, proof of the quality of the work in artificial intelligence carried out by the teams!

[1] Neural Information Processing Systems is a scientific conference in artificial intelligence and computational neuroscience held annually in the United States

2020

Machine learning & certification:
Bias, explainability & robustness toolboxes, metrics, white paper issues in certifiable AI

Qualification environment:
Simulation environment

Machine learning & certification:
theoretical guarantees

Qualification environment:
Sim to Real
Knowledge transfer

Machine learning & certification
Causality
LAN & automatic
Robust control in an uncertain environment, embarkation on the LAN

2025

systems engineering.

R&T Fields

Collaborative model-based engineering

Smart interfaces

The «Systems engineering» competence center meets the challenges of competitiveness in the aeronautical, space, and automobile industries – namely, cutting the costs of development, manufacturing, and product maintenance. To this end, we must master increasingly complex technologies that give the product a high level of capability of operating unattended while, at the same time, ensuring its operating safety and reliability.

The very core of our research revolves around engineering processes, methods, and tools that favor collaboration between the systems engineering team and other disciplines, such as safety, software, hardware, simulation, Verification & Validation (V&V), and manufacturing, in the frame of the extended enterprise.

Our objective is to provide new ways of working for systems engineers by using new technologies (e.g. AI, touch screen) or by contributing to global digital continuity. However, as these collaborations are essentially human-based, analysis of humans' behavior during these interactions is mandatory for them to be improved.

The specificity and differentiation of our competence center concern two points:

- Incorporation of the multidisciplinary nature of the profession and organization in an extended company;
- Compatibility with the regulatory aspects in force, such as certification.

The objective is also to develop industrialists' competence in the Model-Based Systems Engineering (MBSE) profession.

Presentation of the S2C project results to the Occitanie SdF Working Group

On October 1, 2021, the S2C (System & Safety Continuity) project presented its first results to the Occitanie Operational Safety Working Group, composed of industrials and academics interested in this topic.

This action is in line with the project's large-scale dissemination objectives. It was also an opportunity to present the risk management methods developed by three other competence centers (High Reliability Energy, AI for critical systems, and Critical Embedded Systems).

2020

MBSE analysis in extended enterprise

MBSE & MBSA consistency

MBSE & MBSA coherence

Intelligent interfaces for model design

Systems engineering for AI-based systems

Architecture & optimization of complex systems

2025

multidisciplinary optimization.

R&T Fields

Developments in methodology

Development of GEMSEO software

Applications

The objective of the **«Multidisciplinary optimization»** competence center is to address four major industrial challenges: shortening the design and development cycle, mastering products for their entire life cycle through the interconnection of systems and digital continuity, ensuring the flexibility and adaptability of the design processes necessary to face market changes, and finally, accelerating the introduction of new technologies in products. It is, therefore, necessary to develop an ambitious conception and simulation program.

Our activities are thus dedicated to the development of process automation technologies encompassing a wide range of disciplines and parameters, as well as enabling the smooth reconfiguration of these processes. We also fully contribute to digital continuity, building a bridge between Model-Based System Engineering (MBSE) and MDO domains. This allows ensuring the consistency of MDO problem formulations and solutions with the top-level program objectives and system requirements. Finally, our experts focus on developing robust and efficient multidisciplinary optimization methodologies and tools, taking into account uncertainty quantification that can be scaled to industrial applications.

While our scope of application is to design aircraft, generic developments are and can be adapted to other fields – space, automotive, rail, naval, energy – and even more remote applications such as healthcare, climate, and other systems, like means of production.

The R-EVOL project

Building a bridge between Model-Based Systems Engineering and MDO domains, this project fully contributes to digital continuity.

In addition, innovative techniques are developed to enhance the efficiency, robustness, and reliability of the MDO processes, while extending MDO capabilities to multi-mission and propagating uncertainties throughout the processes to open the door to routine industrial use of MDO.

2020

MDO formulations & automatic design space exploration

GEMSEO Open Source

Mixed discrete-continuous variable optimization for solving architecture choice & decision-marking problems

MDO under uncertainty

Digital twin

Full life cycle numerical continuity for complex systems

2025

safety-critical systems.

R&T Fields

- Real-time computing
- Dependable computing architectures
- Time predictable communications
- Embarcability & verification of machine learning applications

Independently from the industrial domain – automotive, aerospace, medical, etc. –, most of the functions performed by embedded systems depend on high-performance, complex computation and communication architectures leveraging the latest technologies in chip design and networking.

In this context, the **«Safety-critical systems»** competence center addresses the ever-renewed challenge of exploiting those technologies efficiently, i.e., maximizing safety and the use of the available resources while minimizing the development effort.

To accomplish this goal, our competence center carries out research around three main axes:

- real-time, to ensure that services will be delivered in a predictable and deterministic time;
- hardware/software co-design, concurrency, and distribution to ensure that the processing capabilities of the hardware will be exploited efficiently;
- dependability, to ensure that the system will behave as intended, with the appropriate level of reliability and availability in the presence of physical or intentional faults.

For each of these axes, we propose our expertise on the various elements involved in computing architecture, including the processing units (SoCs[1], FPGAs[2], GPUs[3], neural network accelerators...), the real-time operating systems, and hypervisors, the communication networks, and the tools/technologies used to build an executable code out of a model (a C program, a machine learning model).

Embarcability & verification of machine learning applications

Based on our research activities on hardware architectures for «real-time» computing, and relying on the «Artificial Intelligence for Critical Systems» competence center, our objective is to help industries to find appropriate and safe solutions for the deployment of machine learning algorithms on embedded platforms.

This activity is based on our expertise in machine learning algorithms, deployment tool chains (e.g. TFlite[4], TVM[5], etc.), and hardware platforms. Beyond deployment issues, our research activities also focus on the definition and formalization of verification and validation activities of systems integrating machine learning algorithms by combining model-based system engineering techniques and formalization of reasoning using «assurance cases».

[1] Systems on Chips
[2] Field-programmable gate arrays
[3] Graphics Processing Units
[4] [5] TensorFlow Lite & TVM : frameworks open source de deep learning

2020 → 2025

- Formal methods for critical embedded hardware & software
- Deterministic & predictable hardware & software
- Deterministic & predictable hardware, software & communications
- Deterministic & predictable distributed systems
- AI-based reliable embedded systems
- High-performance, deterministic & predictable distributed embedded systems

our technological platforms.

Our technological platforms, mainly based on our Toulouse and Bordeaux sites, offer a complete range of differentiating and multidisciplinary equipment addressing our 4 technological axes.

Physical or virtual, our platforms are developed and used in our research projects to meet the current and future needs of industrials and academics. Our research teams benefit from a complete in-situ environment for the development of their R&T work.

Our experimental platforms

- Composites platform
- Metallic materials platform
- Surfaces & assemblies platform
- Characterization, control & testing platform
- Conductors & dielectrics platform
- Components platform
- Converters & power modules platform

Our numerical platforms

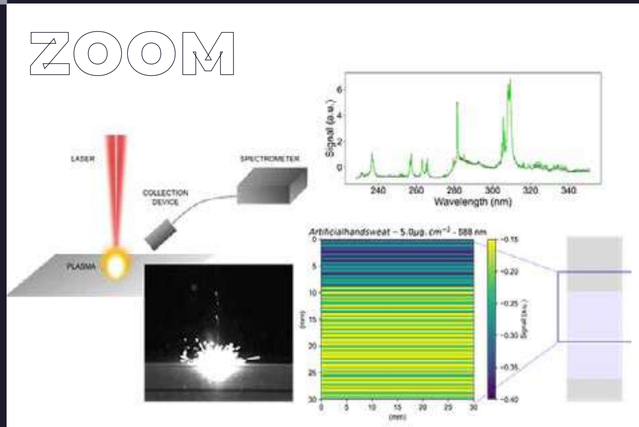
- Systems engineering & modeling platform
- Communications platform

Evolution of the sizing driver

A DSC (Differential Scanning Calorimetry) and a Rheometer-DMA (Dynamic Mechanical Analysis) have been acquired through the COMPINNOVHT project for thermal, rheological, and mechanical analysis of polymers used in the manufacture of prepregs on our pilot line, which has been upgraded to be able to process thermoplastic, thermoset, and vitrimer resins.

LIBS *in-situ*

LIBS (Laser Induced Breakdown Spectroscopy) in situ developed by and at IRT Saint Exupéry is a non-destructive testing method based on the spectroscopic analysis of the plasma generated during a surface preparation by laser. As a complement to the video monitoring of the laser treatment, it to combine the preparation and the online monitoring of the surface contamination before bonding, thus making the process more reliable.



Datacenter

We offer computing machines equipped with recent GPUs (about 600 CPU cores + 38 GPUs), centralized management of users and projects, controlled-access storage spaces, and virtualization capabilities. We host the developments around the 5G core of the SuperG and 5GMed projects, the OpenCloud developments (SB project), as well as the majority of the activities around AI (DEEL, Confiance.ai, Minds, Dcade, Amimaia, and Raptor projects).

Offers & expertise

Our equipment can also be used for research services. Coupled with the expertise of our engineers, experts, and technicians, our platforms allow us to meet the needs of research and development, but also training on state-of-the-art equipment.
Our strength lies in the integrated collaborative environment and the synergy of the treatment of issues: this multidisciplinarity allows us to test processes and technologies on equipment and to understand their interactions, ensuring the optimization of our partners' projects.

Our technological platforms allow us to carry out customized research work, respecting the specific needs of each of our partners. We adapt to the expectations of each client, to the level of maturity of its technology, and also to its size, thus allowing start-ups, very small companies, and SMEs to access unique development resources.

R&T services

Consulting & Expertise
Feasibility study
Engineering :
guidelines, models,
database, standards & techno-
logy maturity evaluation

platforms services

Characterization
Model & simulation
Optimization
Access to our plateforms &
equipement
Training

read more

virtual tour

check out our technological platforms in Toulouse →

check out our technological platforms in Bordeaux →

Thanks to our members & partners.

SMEs, Mid-cap company and industrials members & partners

ACTIVEEON – ACXYS – ADDUP - ADVANS GROUP – AEROCONSEIL - AIRBUS DEFENSE & SPACE - AIR LIQUIDE – ALSTOM - ALTER TECHNOLOGY FRANCE ALTRAN – ANDRA - APSI3D – APSYS - ARIANE GROUP - ARKEMA FRANCE – ASTC – ATOS - AUBERT & DUVAL – AVIACOMP - CAPAERO - CAPGEMINI DEMS FRANCE - CENAERO FRANCE SAS – CERFACS – CETIM – CHOMARAT – CIMULEC – COMAT - CONTINENTAL AUTOMOTIVE FRANCE - CONTINENTAL DIGITAL SERVICES - CS GROUP FRANCE – DASSAULT AVIATION – EIKOSIM – ELEMCA - ELEMENT MATERIALS TECHNOLOGY – ELLIDISS - ELVIA PCB - EPSILON INGENIERIE – ERNEO - ESSEX-IVA - EXPLEO – FUSIA - GEO4I - GIT SAS - HEXCEL COMPOSITES - HEXCEL REINFORCEMENTS – HUTCHINSON – ICAM – INATYSCO – INS - INSIDE TOULOUSE - INVENTEC PERFORMANCE CHEMICALS - IREPA LASER - ISP SYSTEM - KRONO-SAFE – LAAM – LATECOERE – LATELEC – LGM – MAGELLIUM – MBDA - MECAPROTEC INDUSTRIES - MITSUBISHI ELECTRIC EUROPE B.V. - MOTEURS LEROY SOMER SAS - MY DATA MODELS - NAWA TECHNOLOGIES – NEXANS - NEXIO TECHNOLOGIES - NIDEC MOTEURS LEROY SOMER SAS – NUCLETUDES - OERLIKON AM GMBH - OERLIKON BALZERS FRANCE - OPT'ALM - PFW AEROSPACE GMBH - PORCHER INDUSTRIES – PROTECNO - QOS DESIGN – RADIALL – RECAERO - RENAULT SOFTWARE LABS - SAMARES ENGINEERING - SCALIAN DCP – SCIAKY - SD TECH MICRO - SEG DIELECTRIQUES - SERMA INGENIERIE – SII – SNCF – SOBEN – SOCOMORE – SOURIAU - SPACE CO DESIGN EUROPE – SPASCIA - SPECIFIC POLYMERS - STEEL ELECTRONIQUE - STELIA AEROSPACE - STTS GROUP - SUEZ EAU FRANCE - SUPERGRID INSTITUTE - SYNOPSIS – SYRLINKS – TEAMCAST – TECHFORM – TELESPAZIO - TFE ELECTRONICS - THALES CANADA INC. - THALES DMS FRANCE - THALES SERVICES NUMERIQUES – TRAD - VITESCO TECHNOLOGIES - VIVERIS TECHNOLOGIES – VOXAYA

Academic, public and institutional members and partners

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