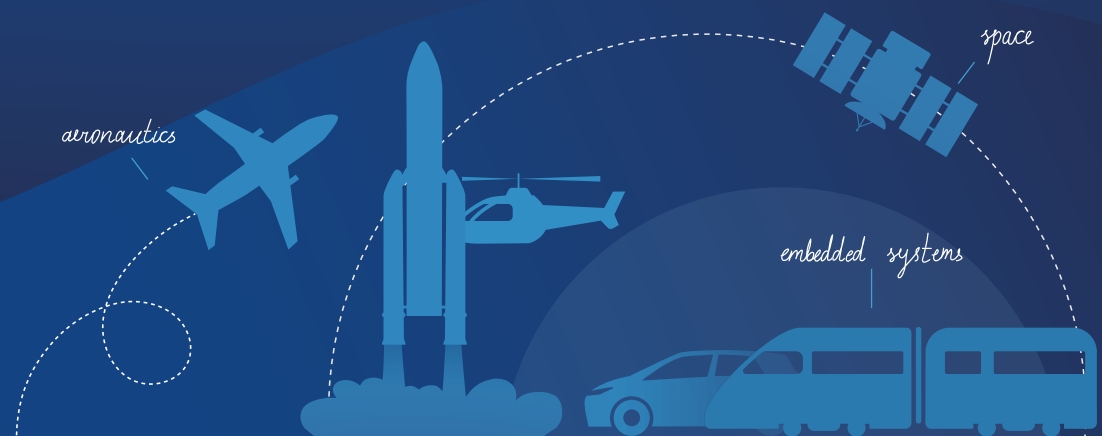
IRT SAINT EXUPERY

2018

ANNUAL **REPORT**



CONTENTS

2018 KEY FIGURES

TECHNOLOGY RESEARCH @ IRT

33 On going Projects

€332M Cumulative Budget (2014-2023)

172 Publications
180 Communications
294 Conferences
110 Technology Transfers

11 Platforms
51 Equipment

15 Patents

PEOPLE

320

153 IRT Secondments
167 IRT Contract Employees

18 Post-Docs
89 PhD Advisors
42 PhD Students
17 Technical Referents

MEMBERS & PARTNERS

103 Industrial Members
including
57 SMEs

53 Academic Members
including
30 Laboratories
23 Public Institutions

2013 — 2014 — 2015 — 2016 — 2017 — 2018 — 2020+

START-UP — RAMP UP — CRUISE MODE

FACILITIES

2,800 m² Bordeaux
10,900 m² Toulouse
200 m² Sophia Antipolis

1 Satellite Site

4,000 m² Offices
6,900 m² Technical Surfaces

Gilbert Casamatta
President

Ariel Sirat
Chief Executive Officer

2018 will go down as a year of exceptional achievements for IRT Saint Exupéry. It firstly reached its adult size with a yearly activity of circa €40M with 300 personnel, after a steep ramp-up started from scratch in 2013, strongly supported by our governance. IRT Saint Exupéry's teams and Platforms in Toulouse moved to their permanent facilities at B612 Building. This offers to IRT Saint Exupéry an exceptional tool to fulfill its R&T ambition, and gives institutional visibility. IRT Saint Exupéry also organized the 6th IRT's Forum which hosted more than 400 guests including two French ministers.

Based on its first projects, IRT Saint Exupéry highly developed its Artificial Intelligence (AI) activities on a key topic for applications to critical systems and functions in aeronautics and space, as well as in other industrial sectors such as terrestrial transportation. The DEpendable and Explainable Learning (*DEEL*) project, which started at the end of 2018, has not only reached a critical mass (+€15M) but now offers strategic partnership opportunities to address related scientific challenges both locally, with the Toulouse proposal for an AI institute (ANITI), and internationally, with one world class AI research center in the world, IVADO[1] in Montreal.

Regarding relationships with industrial Partners, IRT Saint Exupéry has initiated a deeper strategic dialog with CORAC[2], which unites French Public Authorities[3] and the main aeronautics industrial players. This will allow IRT to be better integrated in CORAC's technology roadmap, and to improve and accelerate the project proposal process with related industrial Partners. A first batch of project proposals started before the end of 2018, in particular in the fields of Advanced Materials and More Electrical Aircraft. The first European projects were also acquired, in particular in the Clean Sky Program.

The outlook for further development has led us to split our "Embedded Systems" Domain in two: "Systems Engineering & Modeling", to address the challenge of digital continuity in the product life-cycle, and "Intelligent Systems & Communications", to properly integrate communications and AI in our Members' products and services. The target is to double related activities by 2021.

The aforementioned achievements and changes clearly demonstrate that IRT Saint Exupéry is able to develop both its "ecosystem common house" model and to initiate new technology areas for the benefit of its Members. They also secured the roadmap for the "three thirds model" to be reached by 2025 to get sustainable financial support from the French Public Authorities.

We are confident that the 2019 assessment by HCERES[4] will be positive, and that this will contribute to putting IRT Saint Exupéry on an optimal trajectory to sustainability and world-class R&T excellence. It will be a just reward for our talented, inspired and hard-working teams.

1 Institut de valorisation des données (FR) - The institute for data valorization (EN) - Also in association with CRIAQ (Consortium for Research and Innovation in Aerospace in Québec)
2 COnseil pour la Recherche Aéronautique Civile (FR) - COuncil for Civil Aeronautics Research (EN)
3 The main changes to the initial model lie in IRT's ability to acquire public or private R&T contracts for one third of its business volume
4 which evaluates French research activities

Stéphane Mahdi-Pierazzi
Head of Materials Domain

If you please, draw me a new material... After another year of intense activities, we would like to believe that your material solution is in our technology box. Aside from the nod to Antoine de Saint-Exupéry's *The Little Prince*, materials represent a significant part of the cost of a structural element and have a significant impact on the long-term customer satisfactions. They also define the means of production and the ability of the industrial system to adapt to the demand. Materials research is an enabler to disruptive product developments. Innovative materials, processes and technologies that are certifiable, robust, high-performance and multifunctional, are at the heart of our value proposal. The Materials Domain aims to nurture ideas and innovations from laboratories, start-ups and SMEs and to co-develop them with material suppliers and manufacturers, thus facilitating rapid and mature technology transfer.

"Innovative materials, processes and technologies that are certifiable, robust, high-performance and multifunctional, are at the heart of our value proposition."

13
ON GOING PROJECTS

76
STAFF MEMBERS

122
PUBLICATIONS & COMMUNICATIONS

50
TRANSFERS TO INDUSTRIAL MEMBERS

HIGHLIGHTS

Materials Domain is composed of 76 staff members, including 43 research engineers & post-docs, 14 industrials on secondment, 7 platform engineers and 12 PhD students. This year highlight is the closure of most of the 1st generation of structuring projects (*CompinnovTP, CompinnovTD, SOFUSIN, METALTECHNICS, SALSA, Innovative Assemblies 1* and *SURFINNOV*). The results are summarized around three common thematics:

01
The choice of constituents, the transformation and the elaboration from raw materials which have allowed new levels of performance and functionality to be attained, as well as lowering costs. Examples are the development of slurry formulations for the impregnation of organic matrix composites (incl. fibers sizing and PAEK functionalization) and for ceramic matrix composites (oxide-oxide with stable shelf life). Also noteworthy is the substitution of components subject to special regulations (e.g. RoHS[1]) through the development of greener Aluminum and Titanium surface treatment processes to address anti-corrosion and Tribological properties.

02
Expertise, which aimed to optimize incremental or disruptive technologies[2] and develop processes that meet the needs of performance, robustness and optimized manufacturability. This axis has led to a better understanding of processes-microstructure-property relationships for organic and ceramic matrix composites, as well as products made from metal additive manufacturing or forging processes. The optimization of automated UV-curable paint and ink application process resulted in a time saving of several days over the manufacturing cycle. Lastly, the use of advanced statistical approaches (e.g. meta model) has also made it possible to determine the optimum parameters of plasma/laser surface preparations, and significantly increase the mechanical performance of adhesively bonded assemblies.

03
Finally, the co-development of digital material, processes and virtual testing solutions is enabling to reach additional levels of understanding. For instance, we have made significant progress in the modeling of the effects of fibers, multifunctional particles and consolidation parameters over the crystallinity rate of carbon-PAEK composites. The numerical chaining of additive manufacturing process-microstructure-properties of lattice structure simulations has allowed direct and full assessment of the effect of defects on the performance.

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1 Restriction of Hazardous Substances
2 Reduction of weight and recurrent costs

perspectives

The first results of the Materials Domain have been received positively and futher projects (2018-2021) are either in the process of being finalized or under discussion for a start in 2019. Materials technology bricks are essentially supporting OEM[1], their supply chain and CORAC[2] objectives:

01
Supporting the next generation of vehicles (e.g. materials and processes optimized for manufacturability such as additive manufactured primary structures, durable "net-shape" forged parts and composites at controlled cost), as well as disruptive vehicles (beyond 2030, e.g. thermoplastic composites elements including induction welded parts).

02
Reducing aircraft energy requirements (e.g. integration of more electrical, damping and thermal functions), and providing greener industrial solutions (e.g. Chromium6 free MAO[3] anti-corrosion coating and lead-free solder tab).

03
Enabling industry 4.0 thanks to the automation of complex processes (e.g. multifunctional painting and coating, structural welding and adhesive bonding), the application of big data technologies to Materials & Processes, and lastly the development of digital twins (chaining of simulations: From processes to materials to virtual tests).

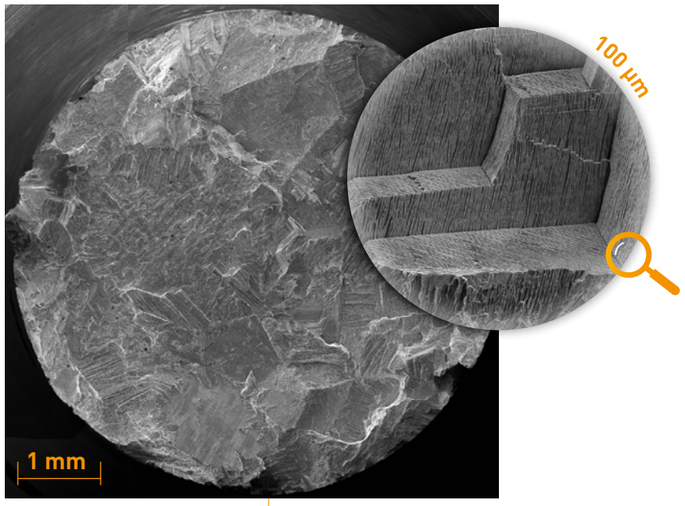
1 Original Equipment Manufacturer
2 COuncil for Civil Aeronautics Research
3 Micro Arcs Oxidation

LIGHTHOUSE INITIATIVE

This year, the Materials Domain has launched several Lighthouse Initiatives in order to achieve a high level of excellence and competitiveness. It hopes to strengthen its collaboration with academic and industrial Partners. The first one, emerging, addresses the simulation of materials, processes and tests. The second one, Factory of the Future, will allow agile development and rapid proof of concept of new technologies with a focus on short-term industrial needs. A third one, a priority, is dedicated to the development of multifunctional organic and ceramic composites.

The last Lighthouse Initiative aims to develop stronger ties with selected academic and industrial Partners on metallurgy with a focus on the durability of materials and structures made from special processes. This initiative, which aligns with the FIT's[1] positioning on the subject, is supported by major groups, mid-caps companies, SMEs and public institutions (PIA[2], Regional Authorities). The IRT Saint Exupéry plays a role in leading these working groups by centralizing and analyzing the needs and specifications of the industry, as well as by developing materials, processes, digital models and tests on a scale that enable instantaneous transfer of results to industrial Members. One of the first results is the launch of inter-IRT projects[3] (IRT SystemX and IRT Saint Exupéry) *DSL*[4] and *LASER*[5]. The aim of this work is to accelerate the development of lattice structures by developing design, sizing rules and simulation models.

1 French Institutes of Technology
2 Programme d'investissements d'avenir (FR) – Investments for the Future Programme (EN)
3 This collaboration between the IRT Saint Exupéry and the IRT SystemX is part of the Inter-IRT Coordination action on Additive Manufacturing launched in 2016 with IRTs Jules Verne, M2P, Saint Exupéry and SystemX. It offers to project's Members an access to the best expertise and therefore optimized efficiency
4 Durabilité des Structures Lattices (FR) - Durability of Lattice Structures (EN)
5 LAttices Structures for Engines and launcheRs



Fracture surface of a lamellar Ti-834 alloy tensile specimen after long term exposure to high temperature (5,000 hours - 500°C)

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Nathalie Schmitz
HEXCEL
Carbon Fiber and Thermoplastic Business Development Manager for Europe

interview

Hexcel Corporation is a leading advanced composites company, developing, manufacturing and marketing lightweight and high-performance structural materials for use in commercial aeronautics, space, defense and industrial applications. Over the year, we have collaborated with IRT Saint Exupéry's teams. Their multidisciplinary team is enhanced by experts, and they have proved to be very reactive. We became a Member in 2018 and partner of the *METEOR* project (coMpEtitive ThErmOplastic pRepreg, 2018-2021), providing Hexcel's specific product and expertise. IRT Saint Exupéry's Platforms are very specialized and it will be very interesting to have access in the future, within the framework of that project.

Michel Bouquet
Thermosets
Project Leader

Mathieu Chevalier
Thermoplastics
Project Leader

Gautier Mecuson
CMC
Project Leader

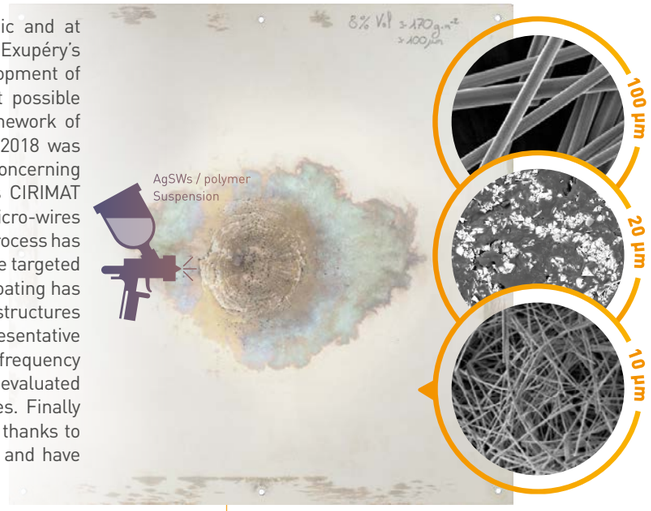
COMPOSITE MATERIALS & PROCESSES

The Competence Center's activities are focused on the development of high-performance and multifunctional composites based on thermostable organic and ceramic matrices. Research activities currently make it possible to work on the entire industrial value chain: From the choice of constituents to the generation of optimized prepreg architecture for cost, performance, structure-system integration or manufacturing process robustness requirements. In 2018, the *CMC OxVL, CompinnovTD, CompinnovTP* and *SOFUSIN* projects ended and enabled the formulation of aqueous suspensions for the production of ceramic and thermoplastic prepregs, the optimization of impregnation and induction welding processes and the integration of electrical-thermal-damping functions into materials and structures. All of them were supported by modeling and simulations. Representative technological samples of industrial applications were evaluated (lightning strikes and vibration tests, flat and L-angle elements welding, scale-up of multi-object fabrication in SiC composites). The *SOFUSIN* project, the first GIFAS[1] project dedicated to the dynamic induction welding process without susceptor, was completed with the welding of L-angles and a stiffened panel demonstrator. All these promising results have also made it possible to launch further *DEFLECT, METEOR, CMC OxVL2* and *CMC IN SERVICE* projects.

1 (FR) Groupement des industries Françaises de l'Aéronautique et du Spatial

DEVELOPMENT OF MULTIFUNCTIONAL ORGANIC MATRIX COMPOSITES TO IMPROVE PERFORMANCE AND MANUFACTURABILITY

The complementarity of actions, at the academic and at industrial levels, centered around IRT Saint Exupéry's unique Platforms and expertise, supports the development of innovative technologies and concepts and makes it possible to transfer them faster to industry. Within the framework of *SOFUSIN, CompinnovTP* and *CompinnovTD* projects, 2018 was rich in results. Significant progress have been made concerning the maturation of concepts resulting from previous CIRIMAT laboratory work. For example, the addition of silver micro-wires during the thermoplastic carbon fiber impregnation process has significantly increased the electrical conductivity of the targeted matrices. In addition, a sprayable epoxy conductive coating has been developed to protect aeronautical composite structures from lightning strikes and has been validated by representative tests. Another original concept, aimed at adding low frequency damping functions to composite structures, and was evaluated on the scale of representative technological samples. Finally piezoelectric particles concepts have been validated thanks to tests conducted in partnership with ISAE-SUPAERO and have demonstrated a substantial gain in performance.



Conductive lightning strikes protection coating

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thesis zoom

Vincent Bedel
2018 PhD, CIRIMAT Laboratory
& IRT Saint Exupéry

PhD Advisors:
Prof. Eric Dantras, scientist, CIRIMAT
Prof. Antoine Lonjon, scientist, CIRIMAT

PROCESSING AND OPTIMIZATION OF A CONDUCTIVE POLY(EPOXY) / SILVER SUBMICRONIC WIRES COATING FOR LIGHTNING STRIKE PROTECTION OF AIRCRAFT STRUCTURAL COMPOSITE PARTS

A conductive lightning strikes protection coating has been developed. Composed of a high-performance poly (epoxy) matrix and submicron silver wires with high aspect ratio (AgNWs), the physical structure, molecular mobility and conductivity by volume and surface have been characterized. Lightning strikes tests carried out on substrates representative of structures for aeronautics have shown the effectiveness of this coating to protect composite material structures impacted by lightning strikes.

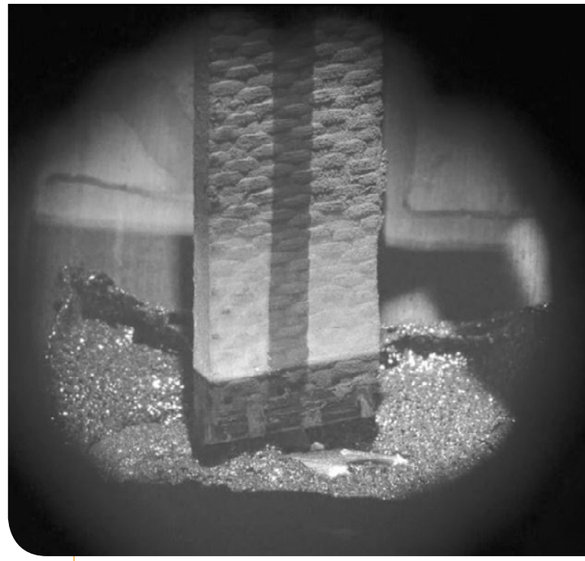
TRANSFERS AND PATENTS ON CERAMIC MATRIX COMPOSITES IMPREGNATION CONTROL AND OPTIMIZATION FOR ENGINE PARTS

One of the two founding ceramic matrix composite activities, *CMC OxVL* project, addressed the development of an oxide-oxide prepreg and associated scale-up technologies, and closed with two patents co-filed with Safran regarding:

01 The use of thermogel in slurry to control the rheological behavior during the process with a solid phase higher than 20°C and a liquid phase at lower temperature.

02 The tack time optimization on an oxide prepreg by using slurry composition for matrix impregnation.

The *SiC MI* project, whose objective is to develop industrial processes for internal SiC parts of engines, resulted in another patent co-filed with Safran. It addresses on tooling enabling the impregnation of several samples in one go. The concept was co-developed by Safran and IRT Saint Exupéry. The tool was validated and tested thanks to IRT Saint Exupéry's innovative Platforms. Finally, the visual *in-situ* observation of the impregnation process of liquid silicon alloy at very high temperature (> 1,400°C) directly into the furnace has led to a better understanding and control of each step of the melt infiltration process (silicon alloy fusion, capillarity impregnation, solidification, interaction alloy-sample).



Melt infiltration in situ observation

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CERAMIC MATRIX COMPOSITES DEVELOPMENT PROJECTS

In 2018 the focus was on SiC MI development with special attention to the scale-up of the slurry injection and of the melt infiltration processes. The effect of the SiC Particle Size Distribution (PSD) on the material quality has been demonstrated, and the next step will consist in finding the right level of PSD for material optimization (i.e. a compromise between slurry injection, melt infiltration and final material properties). It is noteworthy that the tooling cleaning process after injection and a non-destructive infra-red spectroscopy characterization method (CNRS collaboration) have also been investigated. Moreover, X-ray tomography data reduction work for Non-Destructive Test method is still ongoing with the start-up company Voxaya.

Tomography on oxox CMC sample

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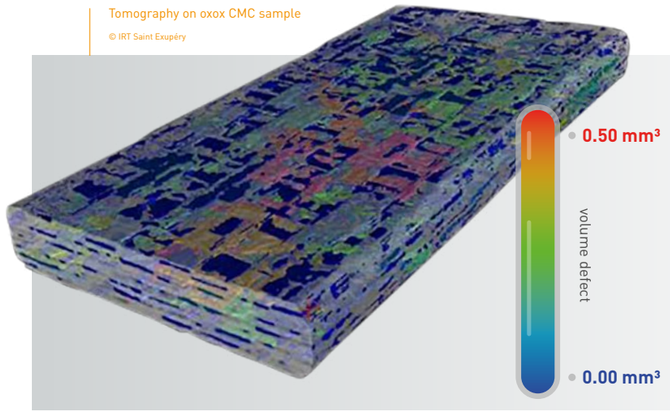


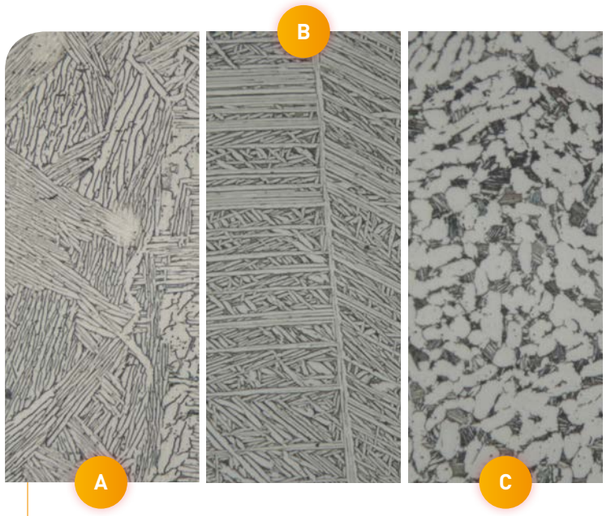
In terms of new projects, the *CMC OxVL2* project has been launched for a duration of two years. The goal is to develop an optimized oxide/oxide towpreg suitable for the Automated Fiber Placement. *CMC IN SERVICE*, a four years project, has started in June 2018 and aims to develop a new thermo-mechanical test bench for the *in-situ* assessment of ceramic matrix composites in representative engine environment.

Simon Pérusin
Head of Metallic Materials & Processes Competence Center

METALLIC MATERIALS & PROCESSES

The Competence Center's activities are focused on four research areas: the development of metallic alloys transformation processes (e.g. forging, thermal treatments, additive manufacturing), physical metallurgy, durability and ageing of materials and structures, and the process simulation and modeling of the thermomechanical behavior. At the end of 2018, the workforce consisted of 20 research engineers and technicians (20% of whom were seconded from industry) and 3 PhD students. 2018 was marked by numerous technology and knowledge transfers, particularly in the fields of Titanium alloys forging, thermal ageing and metal additive manufacturing. Two theses were defended in the field of damage tolerance and stability of aluminum alloys microstructures.

TITANIUM ALLOYS FOR HIGH TEMPERATURE AERONAUTICS APPLICATIONS



Microstructure generated on Ti6242 alloy (a) β forged, (b) β annealed (c) α/β forged

The enhancement of aero-engine efficiency requires an increase in their working temperature, thus affecting surrounding aero-structure components. As Ti64 has reached its service use temperature limit, about 350°C, and Ni-based alloys are heavier materials, the goal of the study was to develop alternate titanium solutions. Work focused on three titanium alloys already used by motorists for engine applications. Target microstructures likely to provide mechanical properties consistent with aero-structures requirements have been identified as well as associated thermomechanical routes to achieve them. Trials have been performed on industrial forging facilities to accelerate the technological transfer. In this way, 10 material/microstructure combinations have been produced and characterized before and after 5,000 hours of exposure at 500°C. Hundreds of microstructural and mechanical characterizations at both room and high temperature led to the selection of two candidates for industrial applications that comply with targeted properties throughout the service life of structural parts.

Antoine Casadebaigt
1st year PhD Student,
CIRIMAT Laboratory
& IRT Saint Exupéry

PhD Advisor:
Dr. Daniel Monceau,
Research Director, CIRIMAT

thesis zoom

HIGH TEMPERATURE OXIDATION OF THE Ti64 ALLOY PRODUCED BY ADDITIVE MANUFACTURING

The first aim of the thesis is to investigate the influence of surface and metallurgical state on oxidation and mechanical properties of Ti-6Al-4V titanium alloy manufactured by Laser and Electron Beam Melting processes. Our first studies have showed that the surface state does not influence the oxidation kinetics of the Laser Beam Melted Ti-6Al-4V alloy. The second year will be focused on the influence of oxidation up to 600°C on the mechanical properties of this Titanium alloy.

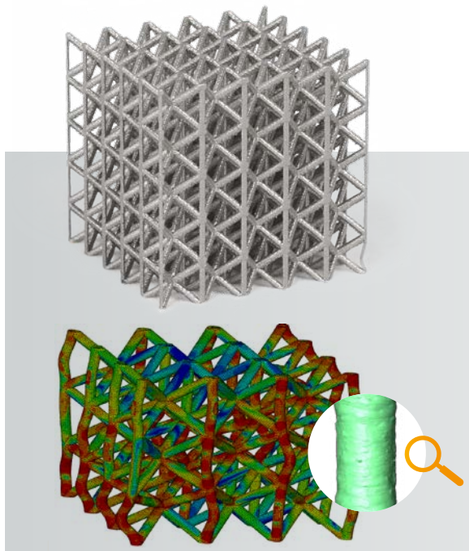
OLLOPA - OPEN-ARCHITECTURE PLATFORM FOR LASER POWDER BED FUSION AND IN-PROCESS ANALYSIS

The development of monitoring devices becomes crucially important in laser beam melting processes due to high process complexity and the high value of the products obtained. An open-architecture Platform, called *OLLOPA*[1] was designed collaboratively at the IRT and I2M institute. The experimental bench enables off and co-axial monitoring using multiple sensors for *in-situ* analysis. In addition, pre- and post-mortem evaluation of the powder bed layer by layer is possible. The objective is to understand the laser-powder interaction, calibrate sensors and develop machine learning algorithms for in-process material quality evaluation. For instance, photodiodes are implemented and signals can be interpreted as indicators of the change of absorptivity of the laser beam by the powder bed, plasma and molten pool as well as the evolution of the temperature field and droplet ejection. Materials, sensors, data mining, decision making, process strategy and part properties can be studied and optimized around the *OLLOPA* Platform.

Open-architecture pLatform for Laser pOwder bed fusion and in-Process Analysis

1 Open-architecture pLatform for Laser pOwder bed fusion and in-Process Analysis

ARCHITECTURAL MATERIALS: DESIGN, MANUFACTURE AND CHARACTERIZATION



Lattice structures offer a very high specific stiffness allowing drastic mass reduction. Additive manufacturing processes such as laser beam melting, are enabling the design of lightweight components that include these architectures. The aims of the *LASER*[1] project is to develop industrial predictive numerical models of the mechanical behavior of lattice structures that are intended for integration in engine and launcher components made of nickel-based alloy 718. An original multiscale approach is being conducted, linking process parameters with microstructures and the constitutive behavior of the constituent struts and nodes and finally with the macroscopic compression and shear behavior of the structures. The multiscale modeling and simulations are validated against the experimental data obtained from X-Ray micro-tomography and 3D-Digital Image Correlation techniques.

The LASER project is closely linked to the *DSL*[2] project at IRT SystemX which focuses on statistical quantification of defects and stochastic simulations. A collaborative framework has been set up between our two institutes.

1 LAttices Structures for Engines and launcheRs
2 Durabilité des Structures Lattices (FR) - Durability of Lattice Structures (EN)

Experimental and numerical multiscale analysis of alloy 718 BCCZ lattice structures

Thomas Delsol
Head of Innovative Assemblies & Surfaces Competence Center

INNOVATIVE ASSEMBLIES & SURFACES

2018 was marked by the creation of a new Competence Center bringing together Surface Treatment and Innovative Assembly activities, with surface preparation as the common base. This year, the 1st generation of projects ended with the first transfers of results to industrial Members, in particular through TRL Gates[1] passed by project Members. These very positive results have enabled the launch of the *Oxymore*, *SP²RINT* and *Innovative Assemblies 2* projects. In addition, we have started new activities on multifunctional coatings with the *FREEzING* project and printing solutions for conductive inks as alternatives to electrical wiring in aircraft with the *ELIPSE* project.

1 Technology Readiness Level

SURFACE PREPARATION AND META MODELS

Experimental work on the laser or plasma surface preparation before adhesive bonding of composite or metallic materials was carried out in conjunction with advanced statistical tools and methodologies. Screening tests and design of experiments have been constructed on the basis of criteria including the key process parameters and assembly key characteristics.

Then, the development of meta models made it possible to establish relationships, and determine the optimum between process parameters and performance (e.g. becoming a preliminary tool for design offices). The approach was validated thanks to a sensitivity study performed at the component level. Lastly, an Efficient Global Optimization enrichment technique has been implemented for laser experiment designs to determine a robust operating optimum.

Atmospheric plasma equipment for surface preparation

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Marie Laveissière
2018 PhD, CIRIMAT Laboratory & IRT Saint Exupéry

PhD advisor:
Prof. Laurent Arurault, Scientist, CIRIMAT

thesis zoom

ELABORATION AND CHARACTERIZATION OF COATINGS PREPARED BY PLASMA ELECTROLYTIC OXIDATION ON Ti64 TITANIUM ALLOY

The subject of this PhD, between CIRIMAT Laboratory and IRT Saint Exupéry, was to prepare coatings using Plasma Electrolytic Oxidation to improve Ti64 titanium alloy tribological behavior. Understanding of correlation parameters between the process and the coatings properties has led to the preparation of a coating with a friction coefficient below 0.3 and a wear loss inferior to 0.01 mm^3 after 100,000 cycles, demonstrating a significant improvement in surface mechanical properties of the Ti64 substrate. These promising results have led to a new IRT Saint Exupéry project in 2018 in order to optimize process parameters and ensure a transfer to an industrial scale demonstrator.

INNOVATIVE ASSEMBLIES: TECHNOLOGY TRANSFERS TO INDUSTRIAL MEMBERS

The work on statistical methods has led to the development of a methodological guide for industrial Members, thus facilitating its introduction into proprietary technological developments.

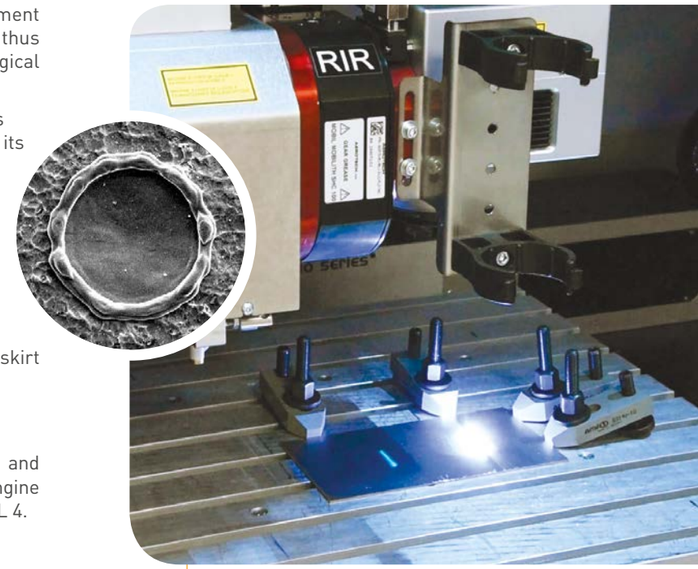
ArianeGroup, with the support of the IRT Saint Exupéry's project team, conducted an evaluation of the TRL[1] using its own analysis grids:

01 Hyperjoints technology for applications to payload-bearing structures passed a TRL 3.

02 EB² Rings technology for applications such as skirt connection of launchers passed a TRL 3.

03 Surface preparation before bonding (laser and atmospheric plasma) for applications such as engine components or solid propellant engines passed a TRL 4.

1 Technology Readiness Level



UV & IR Lasers equipement for surface preparation

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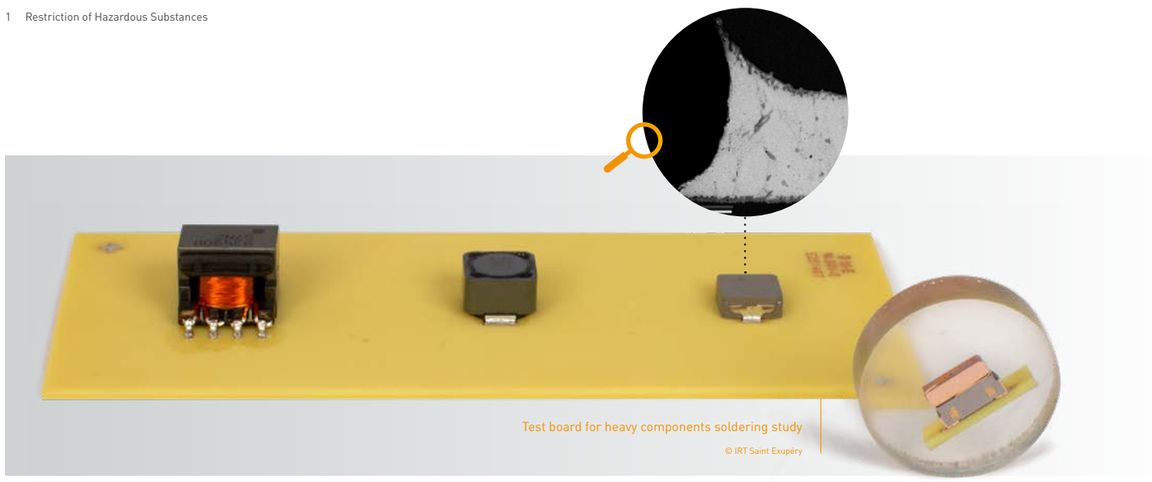
INVESTIGATING A NEW WAY TO ENHANCE SOLDER RELIABILITY

SP²RINT project is part of the innovative assemblies thematic. It brings together development activities and characterization in the field of interconnection materials for electronics. The project aims to comply with restrictions on the use of hazardous substances in European electronics such as RoHS[1] directive, while answering to technical and industrial challenges related to these soldering and assembly materials: Relaxation of the constraints of double-sided printed circuit design and improvement of the thermomechanical ageing of SnAgCu solders.

The approach relies on the use of metal-organic compounds as additives to a solder paste. The concept resulted in a patent being co-filed with CIRIMAT Laboratory. Besides solder pastes for Surface-Mount Technology assembly, the project has considered another type of joining material, intended for power electronics. These highly thermally conductive silver-based assemblies are processed at low temperature without involving any nanomaterial handling.

1 Restriction of Hazardous Substances



Test board for heavy components soldering study

© IRT Saint Exupéry

TECHNOLOGICAL PLATFORMS

Laurent Ferres
Head of Bordeaux Facilities

Jean-Marie Des
Head of Materials Platforms

This offer is based on strong technical expertise as well as on the use of disruptive and differentiating equipment of IRT Saint Exupéry Materials Platforms.

As part of the implementation of a Materials Technological Platform Service, IRT Saint Exupéry is now providing companies access to the following equipment and expertise:

- Elaboration of innovative materials such as multifunctional thermoplastic or thermosetting organic matrix composites, ceramic matrix composites, metallic additive manufactured parts and forged parts.
- Implementation of "proof of concept" prototypes manufactured with these materials and processes.
- Multifunctional "build-to-spec" coatings such as paint, ink, sol-gel, or green coating in substitution of non-REACH[1] compliant ones such as Chromic Anodic Oxidation.
- Definition of innovative thermal post-treatment (development of new thermomechanical routes).
- Materials characterization and analysis including non-standard mechanical tests, impact testing, damage tolerance studies modeling, failure analysis, etc.
- Direct provision for confidential use of IRT Saint Exupéry equipment to industrials.
- Training, supporting with material expertise or technology transfer (scale-up).

1 Registration, Evaluation, Authorization and Restriction of Chemicals

INNOVATIVE ASSEMBLIES

Integrated laboratory for assembly studies installed on the Bordeaux Platforms. This unique assembly line covers all the range from upstream to downstream operations for the next generation of high performance assemblies and adhesively bonded structures.

TECHNICAL FEATURES

- Lasers (UV & IR)
- Atmospheric plasma technologies
- KUKA© Robot for technological samples
- Automated Adhesive Dispensing System
- Climatic chamber
- Characterization

KUKA© Robot
© IRT Saint Exupéry

Injection moulded part
© IRT Saint Exupéry

CERAMIC COMPOSITES

This Platform prepares the industrialization of ceramic composite processes in both oxide and carbide bases. All process steps are covered from formulation to consolidation.

TECHNICAL FEATURES

- Injection moulded part with a capacity of 20 bars
- Melt infiltration furnace (Volume: (450 mm)3 and T°max: 1,600°C)
- Characterization means: rheometer, granulometer, sedimentometer
- Mixers, US probe, moulds

Thermoplastic composites impregnation line
© IRT Saint Exupéry

ORGANIC COMPOSITES

This Platform is dedicated to the implementation of "built-to-spec" high-performance multifunctional thermoplastic composites and assembly process by induction welding technology.

TECHNICAL FEATURES

- Twin screw extruder
- Sizing pilot
- Impregnation line
- Draping and consolidation
- Automated thermoplastic composite induction welding robot
- Material health analysis and characterization

Coatings automation
© IRT Saint Exupéry

MULTIFUNCTIONAL COATINGS

This Platform is dedicated to the study and optimization of multifunctional coatings including application key process parameters (ink, paint, green surface treatment and so forth...) for all types of substrates.

TECHNICAL FEATURES

- Paint booth equipped with 6-axis robot
- Automatic or manual paint guns
- Inkjet printing
- Plasma surface activation
- Plasma electrolytic oxidation device
- Analysis and characterization test devices for coatings

Laser Metal Deposition - BEAM Modulo 400
© IRT Saint Exupéry

ADDITIVE MANUFACTURING

Thanks to this Platform, IRT Saint Exupéry is able to produce prototypes according to customer specifications and carry out the thermal treatments, material analyses and characterizations needed to validate these manufactured parts in accordance with customers' requirements.

TECHNICAL FEATURES

- Electron Beam Melting and Laser Metal Deposition machines
- Heat treatment (including Hot Isostatic Press)
- Analysis and characterization of metallic parts and materials
- Implementation of tests representative of complex in-service conditions on materials or mechanical parts

Régine Sutra-Orus
Head of More Electrical Aircraft Domain

"We aim to optimize more electrical aircraft solutions, to prepare hybrid / electric propulsion and to combine all possible convergences of different industrial sectors."

8 ON GOING PROJECTS

75 STAFF MEMBERS

154 PUBLICATIONS & COMMUNICATIONS

26 TRANSFERS TO INDUSTRIAL MEMBERS

The More Electrical Aircraft Domain's activities are split into three areas:

- More electrical aircraft optimization through prototypes, tools and methods. Research focuses on the interaction, integration and optimization of all electromechanical chain components.
- Enabling innovative solutions for electric and/or hybrid propulsion aircraft by mastering high voltage (aeronautical embedded) electrical systems, and by focusing on dielectrics and conductors, which are the major challenge.
- Combining and leveraging the know-how and the innovations introduced in different industrial sectors (e.g. railway, naval, energy, automotive, and consumer) in order to establish the physical understanding and the methodological frameworks to meet the most demanding aerospace standards of reliability, maintainability, availability and safety.

HIGHLIGHTS

In 2018, More Electrical Aircraft Domain significantly increased staff recruitment (from 45 to 110 employees in a scientific field that is hindered by a severe labor shortage) in order to carry out three structuring projects launched in 2017: *E-PowerDrive*, *Highvolt* and *Feline*.

First international development actions have been achieved. Noteworthy in the partnership agreement with Kyutech[1]. Within the framework of this agreement, an IRT research engineer was hosted in Japan for one year to work on Field Grading Material solutions as part of the team of Professor Masayuki Hikita, one of the founding fathers of the study of dielectrics.

Similarly IRT Saint Exupéry hosted Brazilian Professor Lenin Morais as part of the *CAPES COFECUB* project, for which the partnership between LAPLACE laboratory, two universities in Brazil (UFMG[2] and UNIFEI[3]) and IRT Saint Exupéry has been selected. His work focuses on power electronics.

Finally, the Domain was selected by the ESOF[4] committee to lead the session "More (All) Electric Aircrafts Enabled by Power Electronics Revolution using Disruptive Semiconductor Technology." This event included, among others, keynote speeches from Yannick Assouad, CEO of Latécoère (France), and Dushan Boroyevich, Professor at Virginia Tech University and Director of the CPES[5] (USA).

1 Kyushu Institute of Technology
2 Federal University of Minas Gerais
3 Federal University of Itajubá
4 EuroScience Open Forum
5 Center for Power Electronics Systems (Virginia Tech)

perspectives

In the years' ahead the More Electrical Aircraft Domain will focus on:

- Consolidation of the Domain's positioning on high value-added themes such as by master of the high voltage in aeronautical embedded systems, reliability of COTS[1] components and optimization of electromechanical chains.
- Continued development of international partnerships with research laboratories and universities, including CPES, Nottingham, Manchester and Fraunhofer and with other institutes such as ONERA, and VEDECOM[2].
- Contributing to transversal projects within IRT Saint Exupéry in order to offer multi business technological solutions. The ambition is to offer a Platform and Databases of multiphysical models (electrical but also EMC[3], thermal, mechanical, etc.) based on the global optimization methods developed by the IRT Saint Exupéry Embedded Systems Domain.
- Development of multifunctional materials for electrical performance by introducing conductive materials into structural materials. The potential of the additive manufacturing applied to electrical engineering materials will also be evaluated.

1 Commercial Off-the-Shelf
2 Institut pour la transition énergétique [FR] - French institute for energy transition [EN]
3 Electromagnetic compatibility

LIGHTHOUSE INITIATIVE

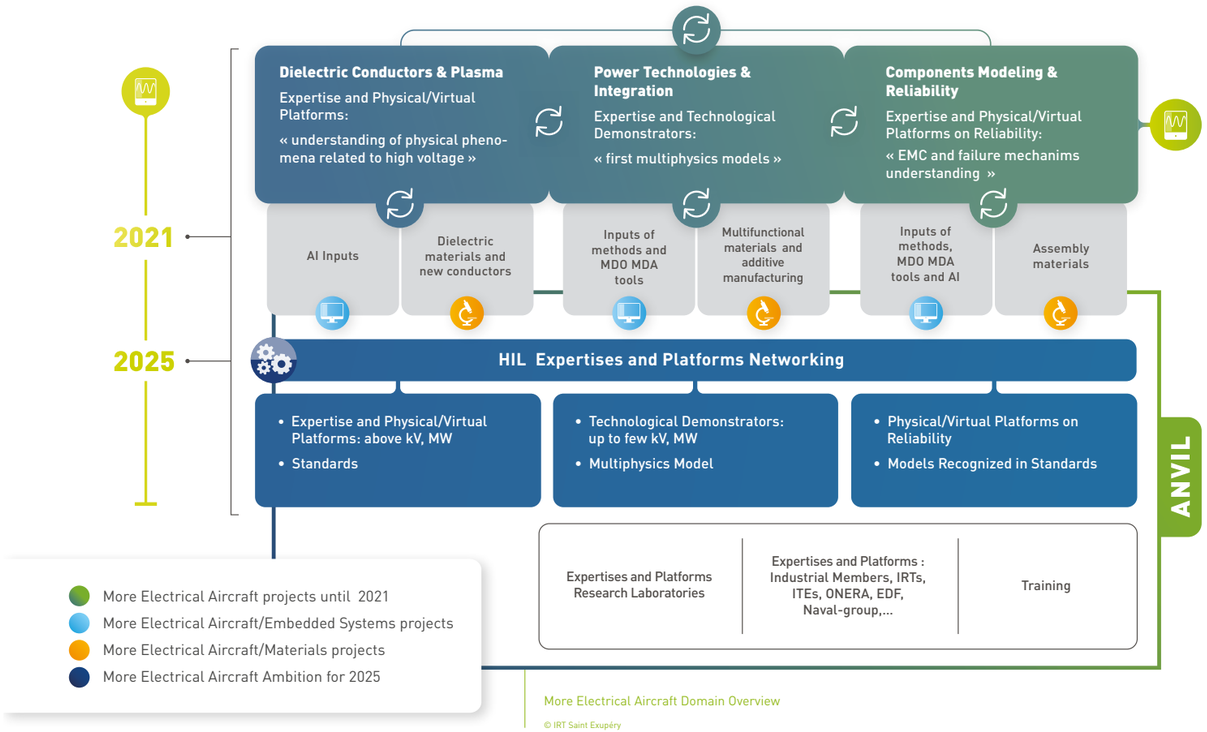
In 2019, the More Electrical Aircraft Domain will set up the *ANVIL*[1] project on hybrid and electric vehicles. This is a structuring project at the national level to deal with the international competitiveness of electrical engineering applied to aeronautics' needs but also for the future means of transport.

This project has an ambitious technological and scientific program based on breakthrough solutions and methods such as additive manufacturing for electrical engineering, multidisciplinary optimization methods, big data and deep learning solutions applied to electrical engineering, etc. World-class physical and virtual testing facilities such as networked Platforms and "hardware in the loop" solutions will be installed at the IRT Saint Exupéry.

This project will trigger strong cross-sector synergies through five areas:

- Integration of power electronics based on disruptive components (wide bandgaps).
- Manage COTS components' reliability to reduce costs management and development.
- Checking ageing of components and in particular of insulators.
- The need for energy storage capacity.
- The development of mechatronic and multiphysics optimization solutions.

1 Ambition interNationale pour Véhicules hybrIdes ou éLectriques [FR] – International ambition for electric or hybrid vehicles [EN]



More Electrical Aircraft Domain Overview

Philippe Manfé
LEROY-SOMER
Electromechecanical & Materials Laboratory Director

interview

A major player in electromechanical drive systems, electronic converters and energy conversion, Nidec Leroy Somer is preparing future technological breakthroughs to offer more efficient, reliable and competitive solutions.
Nidec Leroy Somer is involved in the *HIGHVOLT* and *E-PowerDrive* projects of IRT Saint Exupéry on the main lines dedicated to controlling the life span of electrical machine insulation systems and optimizing electronic machine and converter assemblies.
This partnership with the IRT Saint Exupéry, which exploits strong synergies in the aeronautics, automotive, rail and industrial sectors, makes it possible to pool skills and access specific high-tech equipment. It is fully in line with Nidec Leroy Somer's innovation strategy by providing three PhD engineers and involving experts.

Laurent Albert
Head of Dielectrics,
Conductors & Plasmas
Competence Center

DIELECTRICS, CONDUCTORS & PLASMAS

The path towards more electrical aircrafts and hybrid/electrical airplanes requires higher voltage levels. High voltage matters are well understood in terrestrial applications, but not for embedded electrical components where size and mass constraints lead to extreme stresses on electrical systems. Evaluating and controlling electrical risks may be separated into several different research topics, notably: Partial discharges, space charges, electric arcs, electrical ageing and dielectrics. Competence Center's activities seek to provide our industrial Partners with deliverables that are essential for robust product development, including: design guidelines, test procedures, databases, simulation tools, test resources, norms and standards.

POWER SUPPLIES SPECIFICATIONS FOR ELECTRICAL AGEING

Picture of a formed wound motorette to be characterized under ageing due to partial discharge

© IRT Saint Exupéry

Innovative test rigs are currently being engineered and will be deployed in the *Highvolt* project for the characterization of electrical phenomena responsible for the ageing of Electrical Insulation Systems of an electromechanical chain. Among them, two tailor-made power supplies have been specified and designed this year.

The first one generates a 10 kV sinusoidal signal at 10 kHz on six channels at the same time with a power of 2 kVA per channel. Such an electrical source is necessary to speed up the electrical degradation occurring within representative specimens of formed and random wounds, and thus, shorten the lifetime for observing failure in laboratory.

The second tailor-made power supply can provide a 4 kV bipolar square signal at 100 kHz with a rise time of 1 µs, on five independent channels of 0.5 kVA each. It is made to accelerate the ageing under partial discharges of aeronautics wiring and connectors.

With these two power supplies, the *Highvolt* project aims to establish new scientific models of electrical degradation and thus forecast the component lifetime in real life.

Bouazza Taghia
3rd year PhD Student,
LAPLACE laboratory
& IRT Saint Exupéry

PhD Advisors:
Prof. Hubert Piquet, Scientist, LAPLACE
Prof. David Malec, Scientist LAPLACE

thesis zoom

MODELING AND OPTIMIZATION OF ELECTROMECHANICAL CHAIN TO PREVENT PARTIAL DISCHARGES IN AERONAUTICAL ACTUATORS

A fast and precise wide band frequency model of transient overvoltage has been developed. Experimental validations have been performed on 15 kW industrial equipment fed by 540 Vdc, according to: Inverter technologies (IGBT and SiC), harness length and harness shielding. To prevent the premature failure of the motor insulation due to partial discharges, three solutions have been evaluated in terms of weight: Reducing the inverter switching speed, reinforcement of the insulation and passive filters.

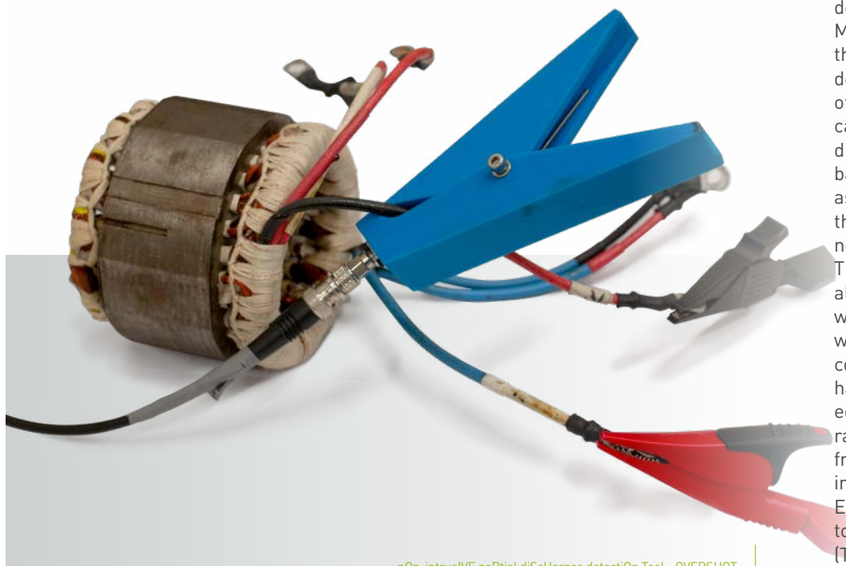
SAE HIGH VOLTAGE WORKSHOP

IRT Saint Exupéry organized and held an SAE[1] High Voltage workshop on July 10 -11, 2018. More than 100 attendees were at IRT Saint Exupéry, coming mainly from the international aeronautics industry (United States, England, Germany, Italy, Brazil, Japan, France, etc). Experts discussed their progress in several fields: materials development (new dielectrics like Field Grading Materials), high voltage testing methodologies and high voltage electrical components challenges (cables, interconnects, electric motors, power electronics, protective devices and arc fault detection). The participants took the opportunity to visit the IRT Saint Exupéry partial discharges laboratory and electric arcs Platform.

This event was a first step in one of the Competence Center's goals: To help industrials align on common new standards for high voltage matters.

1 International Society of Automotive Engineers

PARTIAL DETECTION TOOL TRANSFERRED WITH TOULOUSE TECH TRANSFER



nOn-intrusIVE paRtial diScHarges detectiOn Tool - OVERSHOT

© IRT Saint Exupéry

One of the great challenges regarding partial discharges concerns their detection, especially under Pulse Width Modulation (PWM) voltage. To address this problem, IRT Saint Exupéry has developed a detection tool which consists of a sensor and a denoising system called OVERSHOT (nOn-intrusIVE paRtial diScharge detectiOn Tool). This tool is based on a capacitive coupling as well as on a wavelet processing to extract the partial discharge signals from the noise associated with inverter switching. The main advantage of this tool is that it allows on-line and non-intrusive testing which allows other tests to be conducted without changing the nominal operating conditions. The operation of this tool has been validated on various industrial equipment (aeronautics, automobile and railway) and has aroused strong interest from IRT Saint Exupéry's Partners in tooling up this system. IRT Saint Exupéry has decided to transfer this tool with SATT[1] Toulouse Tech Transfer (TTT) to increase the TRL[2] and make it marketable.

1 Société d'accélération du transfert de technologie (FR) - Acceleration Society of Technology Transfer (EN)
2 Technology Readiness Level

Fabio Coccetti
Head of Components Modeling & Reliability Competence Center

COMPONENTS MODELING & RELIABILITY

The massive insertion of commercial off-the-shelf (COTS) components of power electronics, digital electronics and energy storage into the industrial supply-chain is a major challenge currently faced by the aerospace and automotive sector. The intrinsically low maturity of emerging technologies, combined with severe environmental application profiles, imposes a systematic and accurate assessment of the associated Reliability, Availability, Maintainability and Safety (RAMS).

Component Modeling & Reliability Competence Center addresses this issue by tackling the understanding of the underlying phenomena and the development of knowledge, methodologies and tools, such as to lay the basis of an innovative and cost-effective framework to address predictive reliability, obsolescence management, virtual prototyping and certification support.

FRAME METHOD - FAILURE RISK ANALYSIS METHODOLOGY

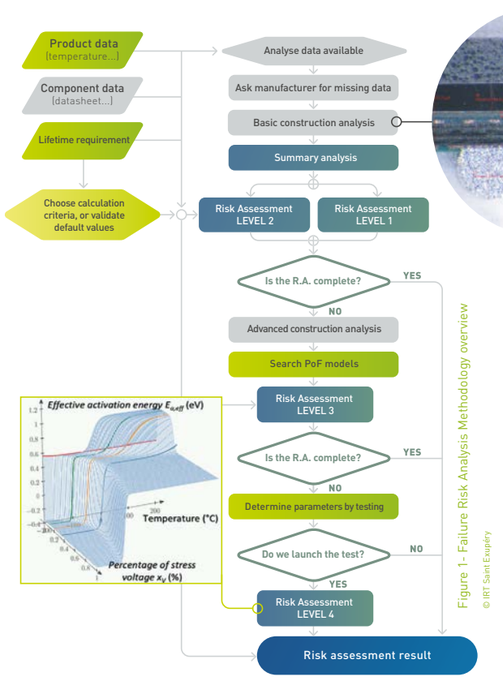


Figure 1- Failure Risk Analysis Methodology overview
© IRT Saint Exupéry

The FRAME method is based on a high level approach originally introduced by the aeronautical community (GIFAS - 2015) to address the selection of emerging COTS[1] components via an educated guess of the risk level based on available knowledge.

The method has been deeply revised in order to provide a formally sound and generally applicable engineering tool to carry out a critical estimation of component lifetime for a given mission profile. It follows a four-fold risk level assessment that starts with the situation in which the component manufacturer directly provides either the final lifetime estimation (level 1 – figure 1) or all necessary data to carry out the analysis (level 2 – figure 1). This latter is by far the most favorable scenario, since it endows the user with the highest degree of flexibility and control to carry out its own multiple scenario estimation. In the most likely situation where no data from the manufacturer is available, a progressive involvement of laboratory resources (construction analysis) and previous knowledge (specialized literature) is needed to carry out the analysis (level 3 - figure 1). Finally, the most time- and resource-consuming scenario occurs in the case of emerging components (e.g. 16 nm FinFET[2] or GaN HEMT[3]) for which very little knowledge is available. Here in-depth analysis (construction) and experimental lifetime methodology need to be implemented (level 4 - figure 1). Innovative experimental methodologies, such as the multiple stress conditions and multiple failure mechanisms methodology introduced in the past and currently being investigated, may represent cost effective reliability tools.

1 Commercial Off-The-Shelf
2 Fin field effect transistor
3 Gallium nitride high-electron-mobility transistor

Yuanci Zhang
3rd year PhD Student,
IMS & IRT Saint Exupéry

PhD Advisors:
Prof. Jean-Michel Vinassa,
Director of IMS
Prof. Olivier Briat, Scientist, IMS

thesis zoom

PERFORMANCE AND AGEING QUANTIFICATION OF ELECTROCHEMICAL STORAGE ELEMENTS FOR AERONAUTICAL USAGE

Electrochemical storage elements are becoming one of the promising candidates for aircraft electrification. Therefore, a deep understanding of the failure mechanisms and reliable models is indispensable. For this, a non-isothermal Ragone plot has been established by considering the thermal effect for the first time in different temperatures and multiple power levels. It will be helpful as a conception tool for the selection of Li-ion cell during a system design process. In addition, a qualitative and quantitative method based on Incremental Capacity has been investigated in order to identify the degradation modes and estimate the State Of Health for Li-ion batteries.

RESTRUCTURING AND CAPITALIZATION OF PROJECTS RESULTS ACCORDING TO RAMS APPROACH

Competence Center's added value is based on the understanding and modeling of physical phenomena to meet RAMS requirements. Inputs for a given application or a mission profile are components (or cells in the case of batteries) and electronic boards or stacks, with their specificities in terms of assembly and interconnection solutions. Previous knowledge is a considerable resource that requires continuous updating.

The heart of the approach (figure 2) is the construction of a behavioral model that is built by coupling theory with Computer Aided Design (CAD) tools and validated through experimentation. The key role of these models are in their ability to yield Constant Failure Rate (CFR) and/or End-Of-Life (EOL) estimations, hence providing a powerful tool to carry out diagnosis and analysis for the components under consideration. Added value and assets targeted by this approach are in the deployment of these models to enable:

01 Rapid prototyping through Design for Reliability (DfR), EMC[1] assessment or exploration of new technologies.

02 Lifetime and obsolescence management through accurate status estimation of ageing or damaged components.

03 Certification support with simpler and/or more effective qualification approaches.

04 This flow of actions can in principle also be reversed in order to carry out a synthesis approach where from a given performance such as specifications, lifetime or standards, the most suitable components (cells) and boards (stack) could be identified.

1 Electro Magnetic Compatibility

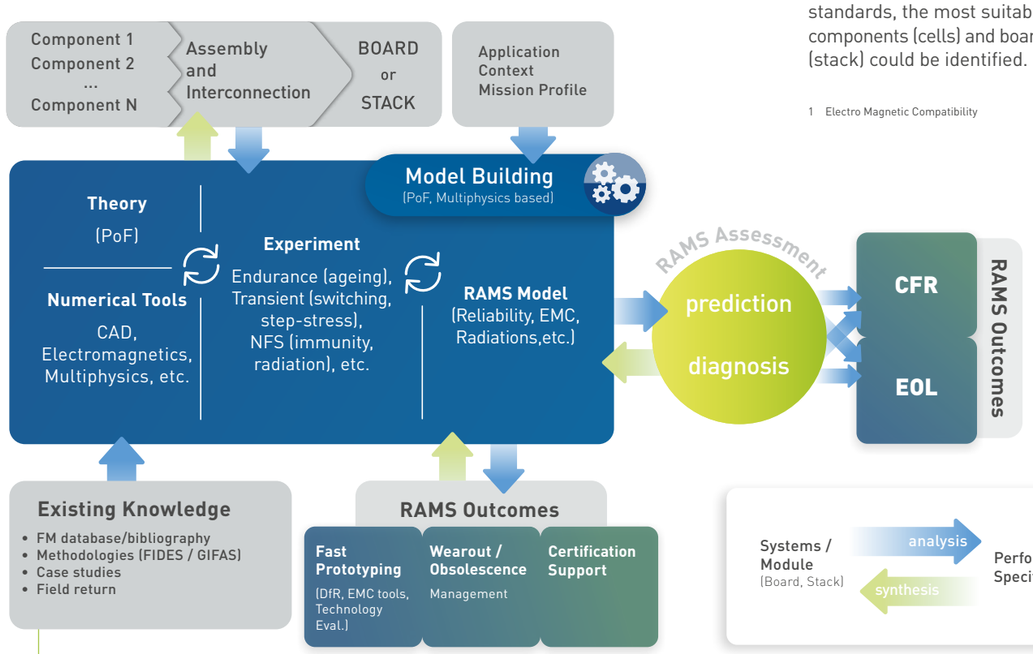


Figure 2- Restructuring of the Components Modeling & Reliability competence Center according to a RAMS approach
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A TRANSFER TO STANDARDIZATION ORGANIZATIONS

The IRT Saint Exupéry became a Member of AFNOR in 2018 and since April 2018 has chaired the UF47A committee, a mirror committee of subcommittee 47A of the International Electrotechnical Commission (IEC) dedicated to integrated circuits. Its representative, André Durier, seconded by Continental to the IRT Saint Exupéry since 2014, has been actively involved in the work of various Working Groups (WG) since 2009. In particular, he was a driving force in drafting the third version of the Committee Draft (CD) IEC 62433-6 on the behavioral model of integrated circuits at electrostatic discharges (ESD) and electrical fast transients (EFT) submitted in June 2018. The expertise and involvement of the IRT Saint Exupéry was recognized in August 2018 with the election of Mr. Durier as convenor of WG9 dealing with methods for measuring the electromagnetic emission and immunity of integrated circuits. He represented France at the 82nd IEC General Meeting held in Busan, Korea in October 2018.

Dominique Alejo
Head of Power Technologies & Integration Competence Center

POWER TECHNOLOGIES & INTEGRATION

More electrical aircraft requires a high level of performance and integration of power electronics to enable the electrification of non-propulsive functions and systems. That means, a higher power density and efficiency, a reliable and efficient cooling system, while meeting network quality standards with an acceptable level of reliability. In line with research works carried out by the first generation of projects such as *Integration, Double & Bump* and *Apsitherm*, the Domain launched the *E-PowerDrive* project to develop optimized dimensioning methods for electromechanical systems. Wide gap components, such as silicon carbide and gallium nitride, have been integrated into power electronics, combined with advanced converter topologies. This has an effect on the emissions of electromagnetic disturbances conducted and radiated as well as on the losses in the electrical machines that have begun to be characterized. As the size of the chips decreases, the Competence Center is seeking to integrate them into electronic cards thanks to *PGIP* project. Finally, the SoCool project developed an efficient cooling system to extract, transport and dispose of heat losses.

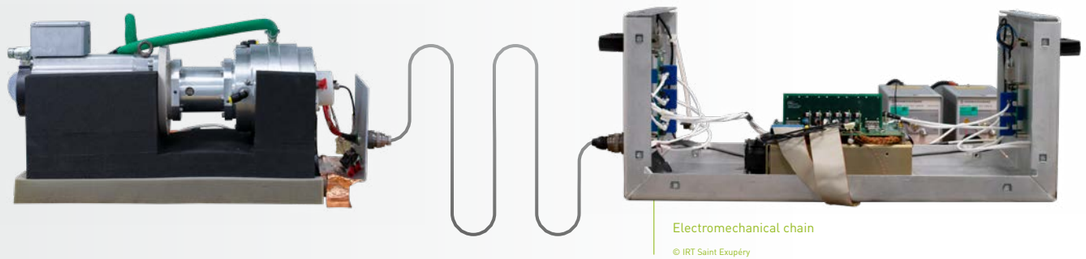
DESIGN OPTIMIZATION OF ELECTROMECHANICAL POWER CHAIN WITH A SIC BASED INVERTER FOR AERONAUTICS

Today in the Power Electrical Drive (Power converter, cable and motor), the filter accounts for 30% of the total weight. Current converter innovations with wide bandgap interrupters (SiC and GaN) increase filters' weight for high switching frequency. These filters are designed for EMC standard[1] between the converter, the cable and the motor.

Objective of IRT Saint Exupéry's research is to increase electrical drive's power density by reducing filters weight. It needs to work for the whole system in order to optimize and share these filters between the converter, the cable and the motor.

More Electrical Aircraft Domain has developed overvoltage, common mode and design filter models in order to optimize filter weight. This approach enabled a weight reduction of 24%. A 15kW electrical drive in a Faraday cage has been developed in order to validate this optimization. This electrical drive has a SiC converter, a different length cable shielded or not shielded, and an aeronautical synchronous motor. Nowadays, IRT Saint Exupéry is developing a future Platform at 70 kW with a multi level converter and a multidisciplinary design optimization approach in order to optimize the EMC, as well as thermal and mechanical aspects.

1 Electromagnetic compatibility - RTCA DO-160G standard and overvoltages limits



Electromechanical chain

Victor Dos Santos
3rd year PhD Student,
LAPLACE & IRT Saint Exupéry

PhD Advisors:
Prof. Bruno Sareni, Senior Scientist, Laplace
Dr. Nicolas Roux, Associate Professor, Senior Scientist, Laplace

thesis zoom

ELECTROMECHANICAL DRIVE MODELING AND PARAMETRIC OPTIMIZATION IN ORDER TO MINIMIZE THE COMMON MODE CURRENT

The work carried out at IRT Saint Exupéry led to a better understanding and modeling of the conducted electromagnetic interferences in an electromechanical chain using SiC wide bandgap semi-conductors. Different filtering solutions have been implemented: external and internal passive filters. Finally, sensitivity studies and an optimization were accomplished dedicated to the resolution of a multi objectives problem (mass, losses) and multiple constraints (network quality and stability, EMC, thermal, etc.) in order to minimize the mass of the converter.

The results of Victor Dos Santos' thesis research earned him the first place in the GEET Doctoral School Congress Contest in the electrical engineering session, which took place at Jean Jaures University Blagnac IUT, April 5.

HIGH PERFORMANCE AC/AC POWER CONVERTER WITH SIC ELECTRONICS FOR AERONAUTICS

AC/AC power converter with SiC electronics

The *Cascade* project objective was to demonstrate design feasibility of a SiC AC/AC[1] converter for aeronautics applications like power supply equipment in aircraft. In such applications, a high level of performance in terms of efficiency, weight and network on the input stage were requested to comply the DO160 requirements. The tasks consisted in the preliminary design of different conversion stages of the power converter. Then, architecture was defined and the component was bonded with SiC interrupter technology. After simulation, the prototype was built, the design of both hardware and software was validated with a specific control loop. An experimental test bench was developed in order to validate features. This converter has very interesting performances with a system power efficiency of around 97.4% and a 2 kW/kg power density with a forced air cooling. A transfer to an industrial Partner is under discussion.

1 Alternative Current to Alternative Current

STUDIES OF COOLING SOLUTIONS FOR ELECTRONIC COMPONENTS

As the development of electronic components moves forward, thermal engineers are confronted with a constant increase in heat flux densities. To ensure optimal and long-lasting performance for electrical equipment, it is essential to develop cooling mechanisms to make them more efficient, less bulky and lighter. IRT Saint Exupéry aims to improve both thermal transfer and energy transportation. In 2018, teams worked on a power device in order to increase contact thermal efficiency between the dissipating component and its support. They have also improved support material thermal conductivity and attempted to intensify the thermal exchanges by forced convection. In addition, they have led research on two-phase cooling systems and tested a new prototype of 20 W/cm² two-phase micro-heat exchanger with a heat transfer coefficient of 20 kW/m²/K. They also tested a multi-source loop heat pipe with three independent hot sources and two independent heat sinks. Other test benches and models designed to increase maturity level and to improve integration of their systems are expected by October 2019.

Cooling test bench

TECHNOLOGICAL PLATFORMS

Pascal Frey
Platforms Engineering Project Leader

Nicolas Chadourne
Head of More Electrical Aircraft Platforms

More Electrical Aircraft Domain's Platforms enable different physical phenomena and technological bricks to be studied. These Platforms have been built to optimize More Electrical Aircraft solutions, to prepare hybrid/electrical propulsion.

Physical Phenomena Understanding Platform enables the characterization and study of damages caused by partial discharges or electrical arc phenomena under various conditions, for electrical components.

Electromechanical Chain Integration Platform is based on a motor driven by a power converter. It enables tests and characterization of individual cooling technologies, soft magnetic materials, power converters, motors, or the complete electromechanical drive.

Starting from 2019, new equipment will be provided:

- Power supplies with higher voltage, Pulse Electro Acoustic test bench and test chambers simulating various conditions will be integrated to characterize electrical component ageing.
- An automatic test bench will be developed to characterize wide bandgap components or power converters,
- Near field Scanner Platform will be implemented; this system will allow researchers to measure the electromagnetic field emitted by electronic mock-up

All these equipment can be available for industrial or academic needs with the support of More Electrical Aircraft Platform's team and Domain's experts.

HYSA – HYROGEN STORAGE SOLUTIONS

In collaboration with LAPLACE laboratory, the *HYSA* Platform enables researchers to characterize charge and discharge performances of hydrogen storage solutions (tanks) as well as the performances of their coupling with a Low Temperature -Proton Exchange Membrane (LT-PEM) type fuel cell system. The characterization makes it possible to evaluate the capacity of the reservoir to provide a flow of hydrogen as a function of time for different gas temperatures. Thus, for a given flow rate, the bank makes it possible to determine the evolution of the gas outlet pressure when the reservoir is subjected to different temperatures, and from an initial state of charge.

TECHNICAL FEATURES

- Up to 15 bar of pressure (storage) / 5 bar (fuel cell)
- Include temperature and H_2/O_2 flow monitoring
- Flow control from 0 to 50 NL per min
- Electrical power up to 5 kW
- Stack currents up to 700 A
- Temperatures from 30°C to 80°C

Hydrogen storage solutions Platform
© IRT Saint Exupéry

Electric arcs Platform
© IRT Saint Exupéry

Partial discharges detection Platform
© IRT Saint Exupéry

UNDERSTANDING PHYSICAL PHENOMENA

This Platform is dedicated to the reproduction and study in a controlled environment of phenomena occurring in and around electrical systems, such as arcs and partial discharges. From 2019, ageing equipment associated with electrical and climatic constraints will also be added. This Platform is designed for the testing and development of new components as well as for the characterization of existing systems compared to existing standards.

TECHNICAL FEATURES

- Power sources from 115 to 230 Vac, 40 Hz to 800 Hz, 28 Vdc, ±270 Vac, max available power = 180 kVA
- Fast video recording up to 3,600 frames per second at 1,024x1,024
- Partial discharge internally developed test system
- Combined altitude (100 mbar), and vibration (2G) test chamber
- Electrical tests up to 10 kV with sine or PWM waveforms
- Electrical recorders, wide-bandwidth oscilloscopes, voltage and current probes

Hysteresigraph with single sheet tester
© IRT Saint Exupéry

Electrical motor test bench
© IRT Saint Exupéry

ELECTROMECHANICAL CHAIN INTEGRATION

From the electrical source to the mechanical load, this Platform includes all the equipment needed to test components or a complete electromechanical chain. Now covering a power range of up to 15 kW, its capabilities will be increased to 50 kW by the end of 2019 with an electromechanical chain demonstrator fully assembled in a Faraday cage. For power electronics, this Platform can also be used as a development and test environment for wide bandgap component based converters.

TECHNICAL FEATURES

- Power electronics laboratory with various power sources, passive loads, latest generation electrical measurement devices and power analyzers
- Hysteresigraph with single sheet tester, Epstein frames and two-dimension measuring systems
- 30 m^2 Faraday chamber
- One laboratory fully dedicated to the analysis and prototype building of two-phase cooling loop systems
- One electrical motor test bench, up to 24,000 rpm, 25 kW

Calixte Champetier
Head of Embedded Systems Domain

Embedded Systems Domain's business volume grew strongly in 2018, as a result of sustained project development activity in 2017. This has enabled us to reach the critical mass and pursue sustainable growth in the medium and long term. Several projects that are nearly finalized have provided significant results and have started being transferred to industrial Members. A major effort has been devoted to renewing these projects by setting up new structuring projects to strengthen our four Competence Centers. Embedded Systems Domain will be divided into two main Domains: Systems Engineering & Modeling, and Intelligent Systems & Communication. These Domains will be effective in early 2019.

"To support and accelerate Domain's development, it was decided to split it in two: Systems Engineering & Modeling and Intelligent Systems and Communications."

12 ON GOING PROJECTS

101 STAFF MEMBERS

76 PUBLICATIONS & COMMUNICATIONS

34 TRANSFERS TO INDUSTRIAL MEMBERS

HIGHLIGHTS

Embedded Systems Domain teams in Toulouse and Sophia Antipolis have been strengthened. In Sophia Antipolis, the new team is working on secure avionics architectures in operation, and on real-time embedded image processing based on neural networks (figure 1).

Methodological research in collaborative engineering and systems optimization has been fruitful. The implementation of this research work on representative case studies and demonstrators convinced IRT's industrial Partners of their validity. Transfers have already started and will continue in early 2019.

Research in Artificial Intelligence has addressed cutting-edge topics (data assimilation, unsupervised learning techniques, multi-agent systems hybridization and neural networks) and delivered results for image processing algorithms and mission profile optimization. Moreover, the Embedded Systems Domain has united academic and industrial actors to open up a new field of research on explainable, dependable and certifiable Artificial Intelligence with very high ambitions (see page 25).

All these results were delivered with the expected level of maturity thanks to the completion of technological Platforms: In particular, *GEMS/SPIRO* (MDO[1]), *AIDA* (MBSE[2]), *ELLA* (optical telecommunications) and *AGATA-NEO* (satellite operations).

1 Multidisciplinary Design Optimization
2 Model Based System Engineering

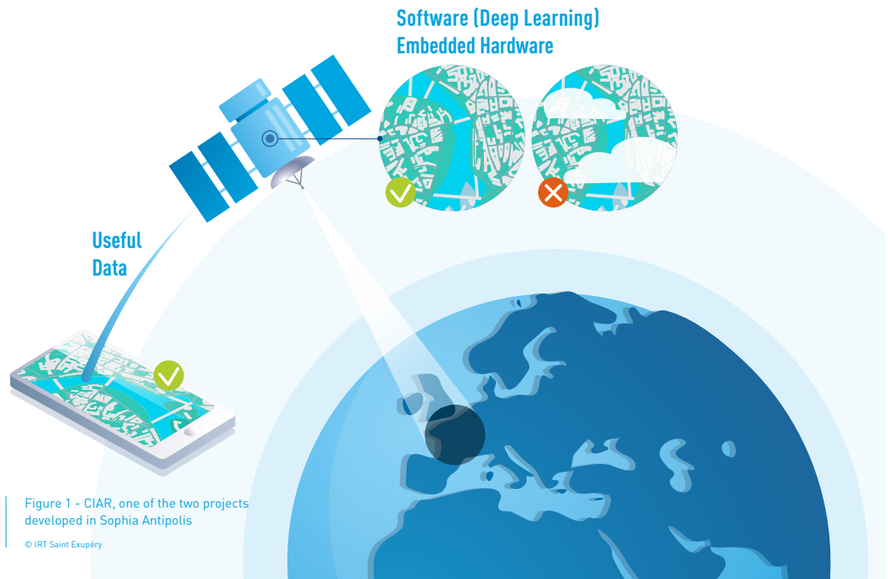


Figure 1 - CIAR, one of the two projects developed in Sophia Antipolis

perspectives

The year 2019 will see a strong development of Domain's activities. To support and accelerate this development, it was decided to split the Domain in two: Systems Engineering & Modeling, which will be managed by Marie-Hélène Deredempt, and Intelligent Systems and Communications, which will be managed by Lionel Cordesses.

Marie-Hélène Deredempt
Head of Systems Engineering & Modeling Domain

Lionel Cordesses
Head of Intelligent Systems & Communications Domain

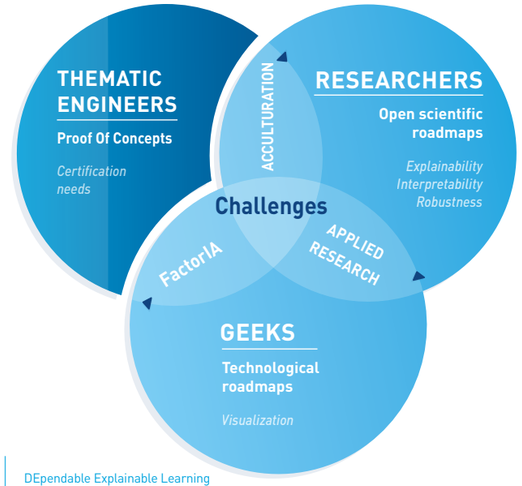
The first quarter of 2019 will focus on the implementation of these two Domains and new projects that will structure their roadmaps, such as collaborative system engineering (*S2C* project, follow-up to *MOISE* project), optimization of complex systems (*R-Evol* project), artificial intelligence for critical systems (*DEEL* project), data science for the development of high added value services (*SB* project in connection with the *Littoral+* project for an innovative territory in the Occitanie region), and 5G technologies for space telecommunications (*SUPERG* project).

The French-Quebec partnership with IVADO[1] and CRIAQ[2] is developing and will be effective thanks to the *DEEL* project. This collaboration will be strengthened by setting up new projects thanks to the impending creation of an IRT Saint Exupéry branch in Montreal. The future branch will serve as a gateway to the local ecosystem, rich in know-how for the areas concerned. Moreover, the Domain will strengthen its emerging transatlantic collaborations on systems engineering and certification at the University of Michigan, Georgia Tech, Berkeley and AVSI[3]. Finally, every opportunity will be studied to develop links with French and European laboratories and institutes, which are already effective on a number of subjects such as Multidisciplinary Design Optimization and Telecommunication.

1 The institute for data valorisation
2 Consortium for Research and Innovation in Aerospace in Québec
3 Aerospace Vehicle Systems Institute

LIGHTHOUSE INITIATIVE

Artificial Intelligence (AI) techniques are widely used by the Big Four tech companies for consumer applications: Customer segmentation, speech recognition, recommendations, etc. These applications are low-risk: If a given recommendation is incorrect, the operator does not lose money. These same techniques, however, are not fit to be used in critical systems. IRT Saint Exupéry has therefore set up the DEpendable & Explainable Learning (*DEEL*) project to connect internationally recognized Partners such as IVADO and CRIAQ in Montreal to the Toulouse academic ecosystem for the aeronautics, space and automotive industries. With a budget of more than €30M, *DEEL* is a five-year international project which brings together researchers, thematic engineers, and computer scientists. It aims to provide robust, explainable AI techniques that are designed to be certified and allow collaborative learning. Co-located on two sites, *DEEL* innovates by its integrated operation where PhD students, researchers and industry experts collaborate in agile mode to solve these ambitious scientific challenges.



DEpendable Explainable Learning (DEEL) project overview

Bruno Darboux
AIRBUS
Aircraft Systems Engineering, VP Strategy and Programs

interview

We are well synchronized with the IRTs, that have adopted technology roadmaps well aligned with those defined together within the CORAC for the complete civil Aeronautics French ecosystem. The results are there, and commensurate with our investment .
For example, the collaboration of academic and industrial partners on the *MDA MDO* project delivers readily useable methods and tools, exploiting advanced scientific knowledge.
And the *MOISE* project invents the multi-partner digital backbone that we strive to set up. This domain of Systems Engineering, that needs cross fertilization and collaboration to define powerful and standard solutions, is well addressed by the IRTs. We will continue to support with energy the development of initiatives in this field, and will ensure that our collaboration remains a success.

Grégory Flandin
Head of Intelligent Systems
& Data Competence Center

INTELLIGENT SYSTEMS & DATA

In 2018, Intelligent Systems & Data teams gave rise to four new projects including a flagship international collaboration (*DEEL* project, see page 25). Each project is associated with a major lock on Artificial Intelligence (AI) and Big Data.

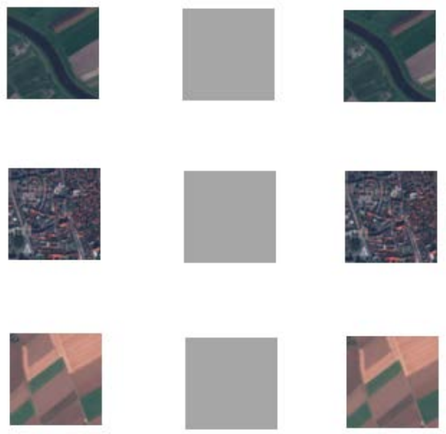
DEEP4CAST project, a data assimilation project, hybridizes methods based on physical modeling (partial differential equations) and their numerical solutions with data-based approaches such as Deep Learning. It is expected to result in gains in performance over conventional methods, and in robustness over data-based methods.

CIAR project, related to Earth Observation (EO), aims to implement machine learning solutions near the sensors. Algorithms will be designed to be embedded in the next generation of EO satellites.

SB project will create value by fusing data between silos such as weather forecasts, *in situ* sensors (IoT), and satellite images. An environmental cockpit monitoring, predicting and warning about the ecological conditions of a territory will be designed. AI methods will support environment models.

ROBUSTNESS OF NEURAL NETWORKS TO ATTACKS

Neural networks have shown impressive results in many different tasks in computer vision such as object detection, image recognition and segmentation. The Competence Center is focusing now on the downside of these networks such as their lack of robustness. Imperceptible perturbations of the input (image, sound) can confuse the network and completely change the prediction. This kind of input, which is called "Adversarial Example," can be designed by an attacker to deceive neural networks. The resulting misclassification could threaten the security and safety of critical systems. It investigates different attack strategies in order to propose new kinds of learning techniques to avoid this weakness of neural networks. The approach is to find the balance between the accuracy of the neural network predictions and the domain where the network is valid. In the article "Flexible Unsupervised Neural Network," in the framework of *SYNAPSE* project, the problem has been described as a dual game between the learning network and an attacker that is trying to deceive it. After training, the network was resilient against 99.5% of DeepFool's attacks on standard benchmarks.



Left Colomn - An image well classified by the neural network
Center Colomn - A tiny perturbation created specifically using the image on the left
Right Colomn - The resulting perturbed image wrongly classified.
Even imperceptible perturbation can deceive the neural network

thesis zoom

Eduardo Sanchez
2nd year PhD Student, IRIT
& IRT Saint Exupéry

PhD advisor:
Dr. Mathieu Serrurier, Lecturer,
IRIT

CHANGE DETECTION IN TIME SERIES USING MONO AND MULTI-SENSOR SATELLITE IMAGES

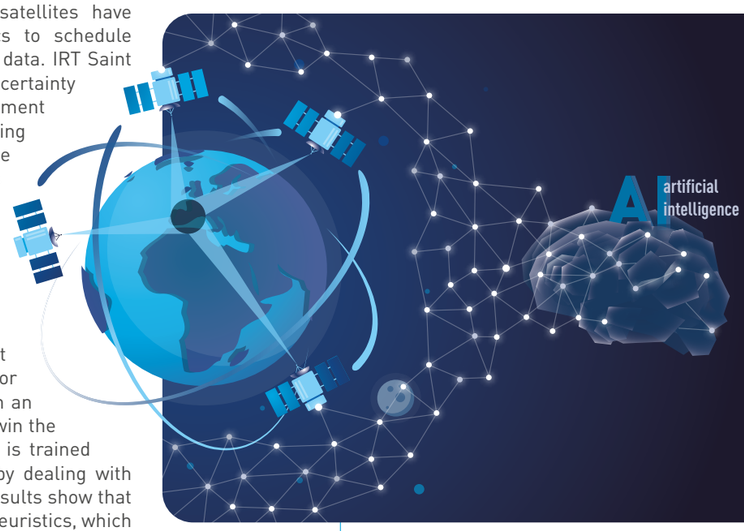
My PhD thesis focuses on learning a suitable data representation of satellite images time series in an unsupervised manner. By leveraging large amounts of unlabeled satellite data, we propose a model based on deep learning algorithms capable of learning spatio-temporal representations. The novelty is that the representation space is constructed by combining Generative Adversarial Network (GAN) and Variational Auto-Encoder (VAE) constraints. Since these representations capture meaningful attributes of data in an unsupervised way, they can be leveraged to perform multiple tasks such as image classification, image retrieval, image segmentation, object detection and change detection. For instance, by using our representations we achieve an accuracy of 94% at image classification of the EuroSAT dataset, which is close to the best state-of-the-art supervised methods, but with far fewer constraints in the learning process.

USING ARTIFICIAL INTELLIGENCE REINFORCEMENT LEARNING FOR SATELLITE MISSION PLANNING

Earth Observation satellites are used to take cloud-free images on a continent-wide scale, covering up to several millions square kilometers. Complexity of acquisitions scheduling increases exponentially considering interoperability of several satellite constellations and weather forecast data. To satisfy cloud-free images, selecting the right shot with the right satellite at the right time is therefore crucial in order to deliver images to the customer as fast as possible.

For decades, legacy Earth Observation satellites have been programmed with simple heuristics to schedule acquisitions regarding short-term weather data. IRT Saint Exupéry is developing algorithms for uncertainty planning with the cutting-edge Reinforcement Learning technology. Reinforcement Learning has proven to be of great value since these algorithms have mastered several games such as Pong on Atari 2600, AlphaGO and, more recently, StarCraft. Such Artificial Intelligence is capable of learning how an agent will behave to win the game. The learning process is achieved by playing games over and over.

Considering these trends, the IRT Sait Exupéry team has developed a simulator based on Open AI Gym framework in which an AI agent controls the satellites. In order to win the game of mapping a large area, this agent is trained to cover the area as quickly as possible by dealing with short- and long-term weather forecasts. Results show that Reinforcement Learning is beating human heuristics, which are the state-of-the-art algorithms of legacy systems.



Satellites tasking with Reinforcement Learning

IMPROVING WEATHER FORECAST WITH DEEP LEARNING – *DEEP4CAST* PROJECT

The quality of weather forecast models has a direct impact on various industrial sectors. For example, in the domain of wide-range satellite coverage, it is essential to rely on quality cloud prediction in order to build smart scheduling of image acquisition. Those models are currently constrained by their numerical resolution and their computational cost. In *Deep4Cast* project, the goal is to evaluate how deep learning algorithms (convolutional and recurrent network) can help overcome these limitations at different scales: Statistical post-processing of ensemble model, hybridization of physical model or nowcasting model. For statistical post-processing the goal is to correct errors of the model by learning the relation between output of numerical model (ARPEGE) and observed data. Deep learning methods based on both convolutional and fully connected methods have been developed on these outputs, considered as images in a 0.1°x0.1° resolution, leading to encouraging results (figure 1). Those algorithms will further be applied on larger amounts of data. This project is being carried out with the CERFACS, CIMI, Météo-France and STAE.

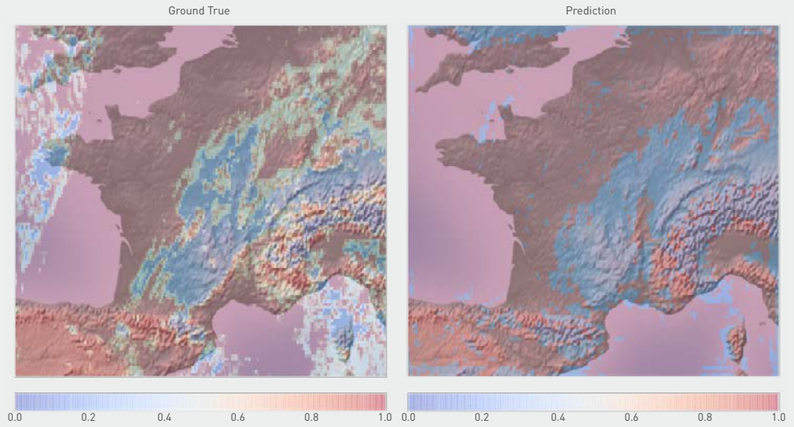


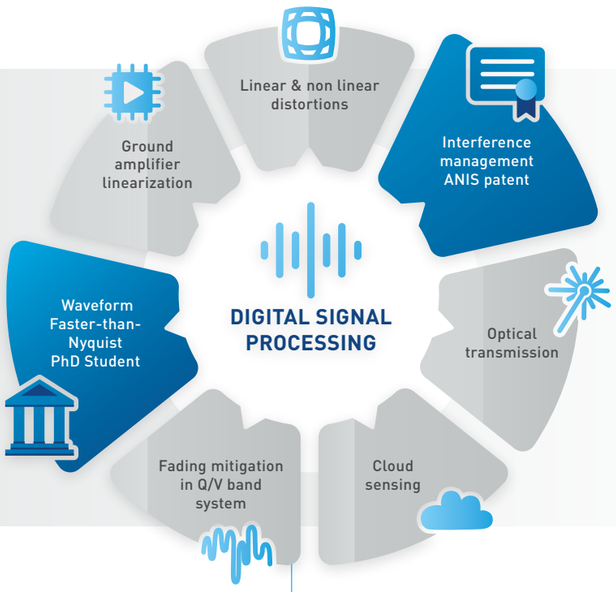
Figure 1 - Cloud cover forecast

Jacques Decroix
Head of Digital Signal Processing Competence Center

DIGITAL SIGNAL PROCESSING

The purpose of the Competence Center is to develop innovative digital and analogue models to be implemented into the functional chains of future communication or observation systems. The applications mainly target the space industry in the broad sense, i.e. including the on-board and ground segments, but may also cover other similar needs in the medium term. The technologies involved range from photonics to digital radio operating on processing Platforms that are representative of future missions. The technical skills deployed cover a wide spectrum, from algorithmic study to real-time digital implementation, in order to provide proof of the concept of feasibility, and anticipate technological challenges such as very high speed optical digital transmissions, virtualization of ground communication segments, and massive processing of observation data driven by the digital transformation of industry.

ANIS PATENT, AN ALTERNATIVE ARCHITECTURE OF A SATELLITE ACCESS SYSTEM TO REDUCE INTERFERENCE



Digital Signal Processing Competence Center's activities overview

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In 2018, three actions initiated as part of the *ALBS* project have been implemented. Firstly, the ANIS patent filed in March 2016, related to the proposal for an alternative architecture of a satellite access system to reduce interference caused by frequency reuse, has been the subject of an official request for transfer to Airbus Defence & Space and Thales Alenia Space, which will thus be able to exploit this patent for commercial purposes. Secondly, the thesis initiated at the end of 2014 on the study of a waveform with high spectral efficiency based on the «Faster-than-Nyquist» temporal compression method was successfully defended on October 11 at ENSEEIHT in Toulouse. IRT Saint Exupéry intends to put the results of this thesis to use through the *NEWCAST* project and propose a compatible receiver architecture for this technique. Finally, IRT Saint Exupéry has acquired a new research Platform, the *ELITE* bench (Telecom Link Emulator), which brings together all the functionalities of a satellite access gateway and will serve as a means of validating the telecom processing chains studied at the IRT Saint Exupéry. For more information you can refer to the Platform area p. 35.

Karim Elayoubi
3rd year PhD Student,
ISAE-SUPAERO
& IRT Saint Exupéry

PhD Advisors:
Prof. Angélique Rissons, ISAE-SUPAERO
Prof. Jérôme Lacan, ISAE-SUPAERO

thesis zoom

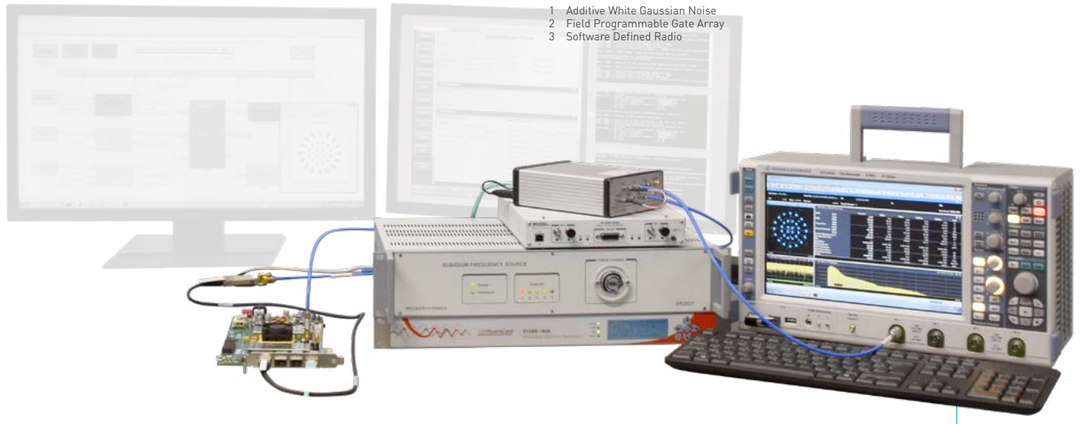
MODELING OF FREE SPACE OPTICAL COMMUNICATION THROUGH THE ATMOSPHERE FOR SATELLITE FEEDER LINKS APPLICATION

Due to expected capacity bottlenecks of exploited microwave technologies, feeder links for data relay or broadband access systems will require the implementation of high capacity optical communication links between space and ground. Various test benches have been developed in order to characterize different modulation and detection techniques for optical communication systems prior to being incorporated into the conceptual design of future 1-Tb/s ground-space optical links.

PRE-DISTORTION SIGNAL: HOW TO REGAIN CAPACITY IN A DISTURBED LINK

In order to meet the ever-increasing demand for satellite throughput, high efficiency APSK modulation orders have been introduced in the latest revision of the DVB-S2X standard, posted in 2015, along with tighter roll-off factors of 0.05 and 0.1, leading to an increase of about 15% in achievable spectral efficiency in the AWGN[1] channel. Nevertheless, non linear distortions caused by the on-board high power amplifier (HPA), especially when driven close to saturation, as well as linear distortions induced by the payload channelizing filters (IMUX, OMUX), unravel these benefits unless mitigated. In this context, IRT Saint Exupéry has developed a powerful pre-distortion technique, based on the so-called small variation algorithm (SVA). Following the intensive software simulation campaign carried out last year, a proof of concept demonstration was completed in 2018 using in-house FPGA-based[2] hardware pre-distortion mock-up and SDR[3], allowing researchers to confirm that achievable spectral efficiency can be increased by up to around 12% thanks to the SVA mitigation technique.

1 Additive White Gaussian Noise
2 Field Programmable Gate Array
3 Software Defined Radio



SVA Pre-distortion technique proof-of-Concept demonstration

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ELITE TRANSMISSION PLATFORM: A REFERENCE TOOL FOR EVALUATING SATELLITE LINK PERFORMANCE

Elite transmission Platform

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The IRT Saint Exupéry has just acquired a new satellite link test facility, the *ELITE* bench (Telecom link emulator) made up of measurement equipment as well as products from IRT's Partners, which, once integrated, form a bidirectional communication Platform compliant with the ETSI DVB-RCS2 standard usable in a laboratory environment. *ELITE* will enable researchers to assess the behavior and performance of new digital functions, developed at IRT, focused on new waveforms or channel correction devices, in order to optimize the capacity and robustness of broadband satellite links. These functions, resulting from modeling and simulation work on advanced algorithms, are first implemented in FPGAs as technological building blocks and then inserted in the functional chains of the bench to characterize their impact on link quality. This tool enables users to compare different architecture options and select the most efficient one, with no need to set up real links. This facility installed and qualified in 2018, is operational, and will be open to any IRT Partner that wishes to benefit from a validation environment for its research needs.

Anne Gazaix
Head of Multidisciplinary Design Optimization Competence Center

MULTIDISCIPLINARY DESIGN OPTIMIZATION

Multidisciplinary Design Optimization (MDO) is the application of digital optimization to the design of systems based on multiple disciplines. A major challenge remains to apply MDO techniques to industrial design processes based on high fidelity simulations, handling challenging configurations in terms of geometrical complexity and interacting components, and using many historically separated and sequentially optimized disciplines. MDO activities started in early 2015 at IRT Saint Exupéry with the objective of taking a significant step towards the deployment of MDO methods in the industry.

During this four-year period, both innovative methodologies and a software Platform have been developed. In 2018, these capabilities have been successfully applied to a complex engine pylon aero-structural optimization test case, representative of the industrial constraints. The results demonstrate the feasibility of applying MDO processes to industrial design problems, and the benefits of solving these problems in a holistic manner.

INNOVATIVE MIXED CATEGORICAL-CONTINUOUS OPTIMIZATION METHODOLOGIES

Efficiency of existing algorithms that can solve large-scale mixed discrete-continuous optimization problems is limited. In the case of aircraft structural design, the number of structural elements combined with the number of available materials and cross-sections, leads to a combinatorial explosion of the possible structural configurations. The major objective of this work is to build a methodology that solves such problems efficiently. The computational cost is driven by the number of structural analyses relying on finite element models. As a first approach called Hybrid B&B, a new hybrid formulation involving the branch-and-bound algorithm and gradient-based algorithm has been implemented. It allows to identify design subspaces that do not contain the global optimum, and avoids their exploration. Thus, compared to an enumeration of continuous optimizations, this approach offers a global optimum with a limited computational cost. However, it will not scale up to an industrial case. This is why a second formulation, called Bi-level, has been implemented. Continuous variables are handled in a lower-level optimization problem, where discrete variables are fixed by an upper-level optimization problem that handles discrete variables. In this upper-level problem, a linearization is performed with respect to the discrete variables. This allows to significantly reduce the computational cost, comparing to Hybrid B&B and Genetic-based approaches. On the figure 1, it can be seen that the exponential computational cost's scaling of Hybrid B&B with respect to the number of structural elements is reduced to a near-linear scaling by the Bi-level methodology. These results have been realized as part of P.-J. Barjhoux's PhD Thesis.

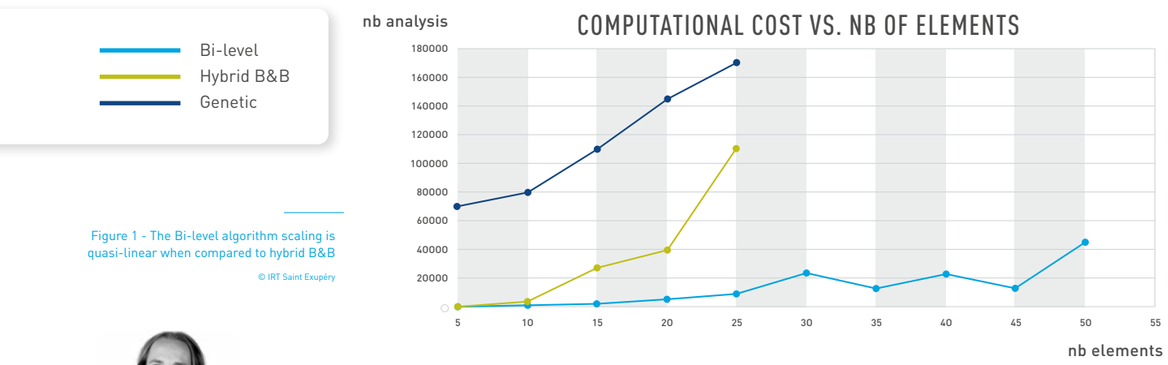


Figure 1 - The Bi-level algorithm scaling is quasi-linear when compared to hybrid B&B

Romain Dupuis
3rd year PhD Student, CERFACS & IRT Saint Exupéry

PhD Advisor:
Dr. Jean-Christophe Jouhaud, Senior Scientist, CERFACS

thesis zoom

SURROGATE MODELS COMBINED WITH MACHINE LEARNING TO CAPTURE COMPLEX PHYSICAL PHENOMENA - APPLICATIONS TO AERONAUTICAL INDUSTRIAL CONFIGURATIONS INVOLVING AERODYNAMICS AND AEROTHERMAL EFFECTS

Simulating aerodynamics along the aircraft mission requires numerous calculations due to the large range of operating conditions. Surrogate models are a classical solution to mitigate such a problem. However to cope with the different flow regimes, it is necessary to develop a new approach that is able to combine local surrogate models in an adaptive and consistent manner. Machine learning algorithms are used as a powerful solution to identify the appropriate subsets. These techniques are applied to an industrial aerothermal simulation.

GEMS: A DISRUPTIVE TOOL IN THE SERVICE OF THE MULTIDISCIPLINARY DESIGNER

System design is usually expressed as the search for the best compromise between different disciplines involved in system performance (e.g. aerodynamics, structure, thermal engineering). The designer's job consists in judiciously choosing the optimization formulation, i.e. the layout of the iterative calculations to be performed for a guaranteed and rapid convergence towards a robust optimum, the choice of optimization algorithms, the set of constraints to be taken into account, the possibilities of model reduction, etc. However - it is a mathematical certainty (see the "no free lunch theorem"!) - there is no single formulation that can effectively solve any optimization problem. As a result, designers need a tool that allows them to test different formulations as easily and quickly as possible. For this purpose, the IRT Saint Exupéry has created GEMS (Generic Engine for MDO Scenarios). It is a Python library that allows designers to describe very simply the mathematical formulation of their problem (or better to choose an existing formulation in its formulations library), and which, according to this formulation, automatically generates the sequence of calculation, data transfer and management of the underlying IT infrastructure that will provide the result of the desired optimization and will display all the information that is useful for the designer. The first transfers to industrial Partners are ongoing and in addition, IRT and its Partners have decided to distribute GEMS in open source, which will make it possible to amplify the generation of knowledge and the transfer to industry of good techniques and practices in multidisciplinary optimization. The following XDSM[1] diagrams (figure 2) present two different formulations corresponding to the resolution of the same design problem (see the "Sobieski's SSBJ use case[2]"). The difference between both formulations is the sequence of operations and the data exchanged between the components. The "art" of a MDO designer is to select the most appropriate MDO formulation for his design problem. IRT Saint Exupéry has developed a new bi-level formulations family, illustrated in the second diagram, in order to satisfy the constraints associated with an industrial deployment.

1 eXtended Design Structure Matrix
2 Sobieszczanski-Sobieski, J. and Agte, J.S. and Sandusky, R.R. Jr. Bi-level integrated system synthesis (BLISS)." In Technical Report TM-1998-208715, NASA, Langley Research Center, 1998.

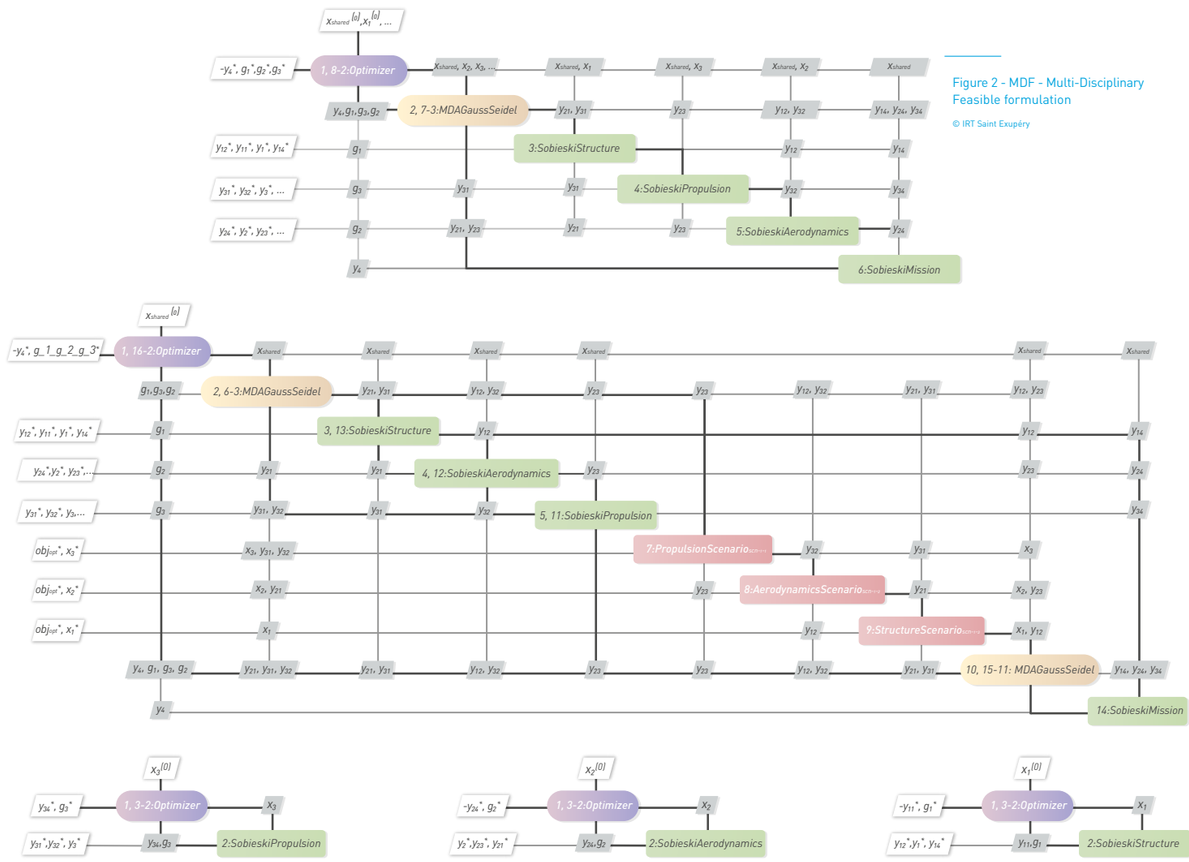


Figure 2 - MDF - Multi-Disciplinary Feasible formulation

Figure 2 - Bi-level formulation proposed by IRT Saint Exupéry to satisfy the constraints associated with an industrial deployment

Patrick Farail
Head of Systems Engineering Competence Center

SYSTEMS ENGINEERING

Systems Engineering Competence Center performs research work relating to processes, methods and tools to optimize and facilitate activities for system, software and hardware architects, as well as verification and validation managers, with the goal of reducing costs and development cycles. Our activities involve mainly critical, dependable systems for which it is necessary to overcome methodology barriers in order to introduce new architectures and/or complex new functions.

The *RESSAC* project demonstrated that the overarching properties approach for system certification is not entirely conclusive. In order to address the identified gaps, it was decided to study the use of a Safety Case approach in close collaboration with the OPWG group led by the FAA[1] in the United States. The recommendations were provided to the ASD[2] for presentation to EASA[3]. The year 2018 also saw significant progress in the work of the *MOISE* project, with the definition of promising new approaches to collaborative systems engineering, both to ensure multi-business synchronization within a company and to define the first services for exchanging modeling elements in an extended enterprise.

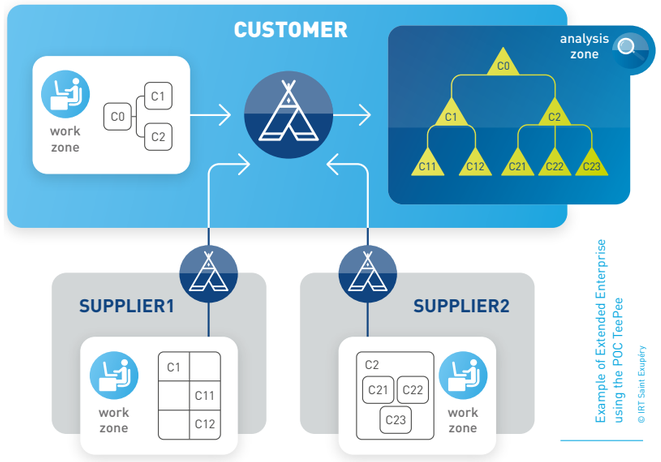
1 Federal Aviation Administration
2 Aeronautics, Space, Defence and Security
3 European Aviation Safety Agency

MODELS AND INFORMATION SHARING IN EXTENDED ENTERPRISE

Significant benefits are expected from an increased use of models for Systems Engineering, including unambiguous communication between stakeholders, digital continuity of engineering data along the development process, and access to higher levels of abstraction allowing users to better represent and handle system complexity. However, such gains imply significant changes in ways of working, and therefore pose new challenges.

MOISE project is devoted to the study of Model-Based System Engineering (MBSE) in the Extended Enterprise (EE), and has tackled several of these challenges. Some of the main outcomes are tangible contributions towards digital continuity within the EE and across engineering domains.

Despite the inescapable heterogeneity of data, methods and tools existing within and between companies, we proposed to take advantage of the structuring of system engineering digital data inherent in the MBSE approach.



Example of Extended Enterprise using the POC TeePee
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As a proof of concept, we developed TeePee, an exchange Platform that aggregates heterogeneous engineering data and allows for constituting a unified vision of structural architecture while handling confidentiality constraints. In particular, we succeeded in building a unified view for two classes of problems (breakdown structures and interfaces) from scattered contributions expressed with several methods, in various modeling tools. This opens the way for new analytical capabilities using systems engineering data, and therefore faster and more consistent interactions between Partners of the EE.

Renan Leroux-Beaudout
3rd year PhD Student, IRIT & IRT Saint Exupéry

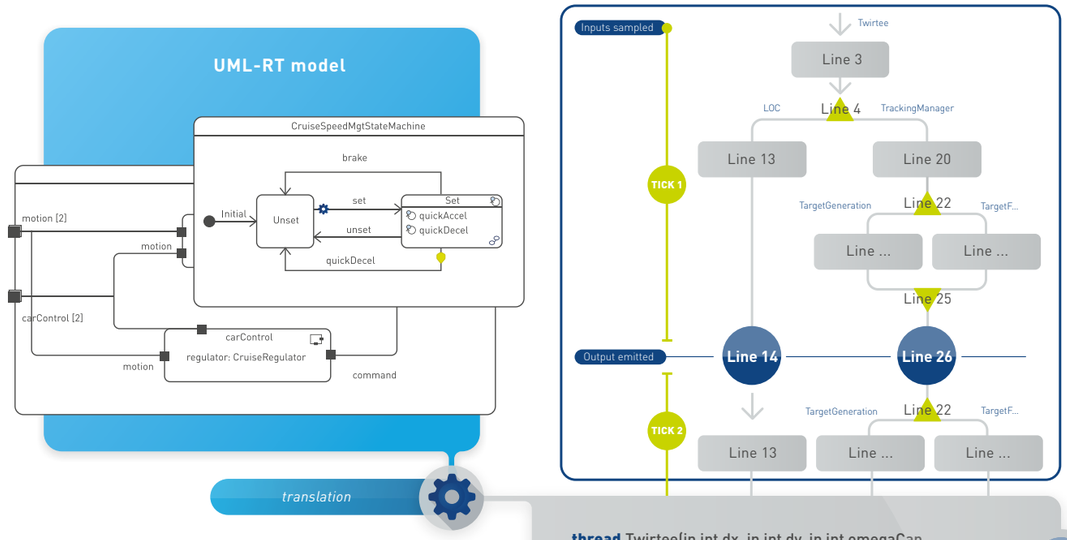
PhD Advisor:
Dr. Marc Pantel,
Associate Professor, IRIT

thesis zoom

MODEL-BASED SYSTEMS ENGINEERING FOR SYSTEM SIMULATION

Simulation is essential for the development of critical systems. The validation and verification activities of the different types of models produced during the development of a system require the construction of many simulators dedicated to the different points of view and phases of development. The purpose of this thesis is to propose and validate a method for the development of such simulators from system models (by applying an MBSE approach) and validation and verification requirements. It integrates the constraint of intellectual property protection in an extended enterprise context. Special attention has been paid to the consistency of the different simulators associated with the different points of view, the reuse of elements between each other and the management of simulators throughout the development and maintenance of systems.

TOWARDS A DETERMINISTIC REAL-TIME COPROCESSOR



Until recently, IRT Saint Exupéry's ability to keep up with the ever increasing complexity of software applications has relied essentially on technological improvements, including a regular increase in component density and clock frequency. But this strategy has reached its limit. To get around the power wall, processing units have to be multiplied and combined, and complex micro-architectural mechanisms must be combined to optimize their uses. That way, performances increase strongly, but predictability, repeatability, and temporal determinism – three major properties of any safety critical real-time system – have been strongly reduced.

To conciliate performance and determinism, the *CAPHCA* project extends and combines two academic technologies: ForeC, a synchronous programming language similar to Esterel developed by INRIA and the University of Auckland, and FlexPRET, a processor developed by the University of Berkeley. A first SoC integrating multiple FlexPRET cores connected by a simple TDMA[1] bus – MultiPRET – has been designed, and several improvements of ForeC have been proposed to enhance its capability to deal with industrial applications. Software and hardware-level determinisms are combined through an optimal time-triggered translation of ForeC source code that leverages the specific timing instructions of the MultiPRET SoC. In addition, a transformation from the architectural language UML-RT to ForeC has been prototyped as another means to favor the industrial acceptability of the ForeC/MultiPRET Platform.

From now on, activities are focused on three main targets:

- synthesize MultiPRET on our target FPGA,
- propose a toolset supporting the extended version of ForeC,
- extend the ForeC translation process to exploit the flexibility of the FPGA and generate optimal inter-core communication topologies.

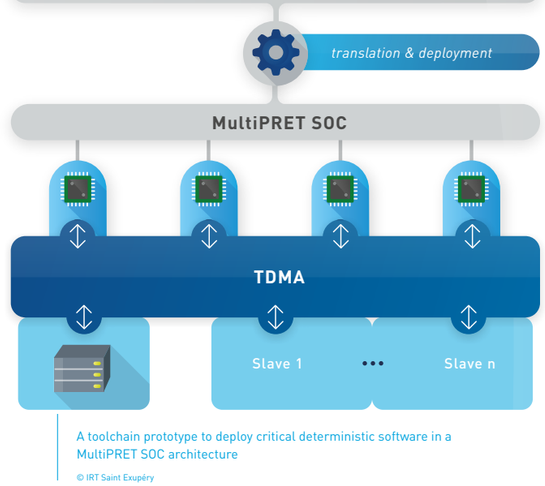
1 Time -Division Multiple Access

ForeC code

```
thread Twirtee(in int dx, in int dy, in int omegaCap,
out int v, out int omega){
shared inout Position position;
par{
LOC(dx, dy, position),
TrackingManager(position, v, omega),
...
);
}

thread LOC(in int dx, in int dy, out Position position){
[...]
}

thread TrackingManager(in Position position, in Path path,
out int v, out int omega){
[...]
}
```



A toolchain prototype to deploy critical deterministic software in a MultiPRET SOC architecture
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Yves Cerezal
Head of Embedded Systems Platforms

TECHNOLOGICAL PLATFORMS

Embedded Systems Domain's Platforms offer support to IRT Saint Exupéry projects and Members and can also offer services to other companies or SMEs. This offer is supported by the Digital Platforms activity which covers the needs in industrial IT and electronics for the three Domains of the IRT Saint Exupéry.

The Digital Platforms business provides software development, electronic development, system administration, bench support and procurement of hardware, software and components. This activity also provides a complete framework for project development: virtual machines, development environments, software forges and continuous integration tools to contribute to the quality of the developments carried out.

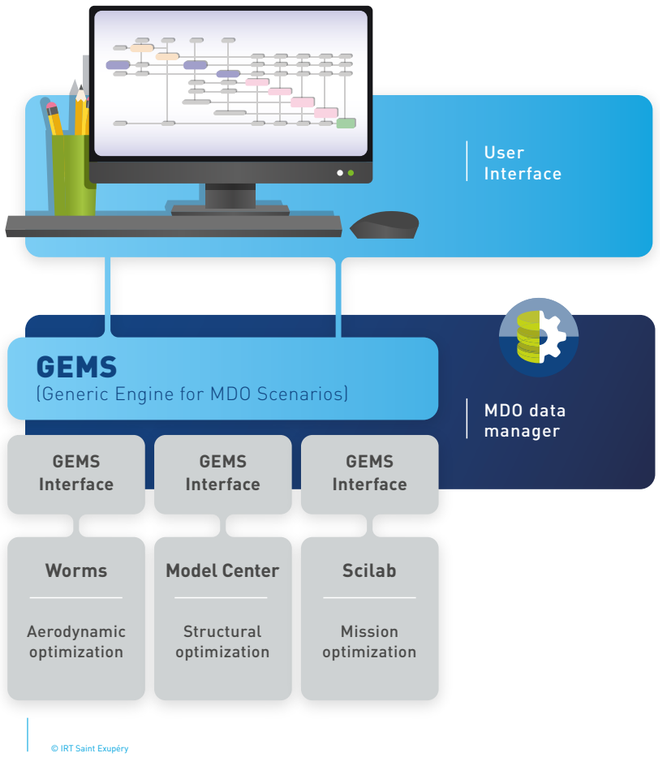
The proposed resources cover the four Competence Centers of the Embedded Systems Domain: multidisciplinary design optimization, intelligent systems, system engineering and digital signal processing. The following Platforms are examples of differentiating achievements in 2018.

SPIRO:
Software Platform for Industrial and Research Optimization

A user-friendly software Platform dedicated to Multidisciplinary Design Optimization (MDO).

SPIRO Platform architecture is based upon the GEMS kernel that dynamically creates MDO processes from a set of mathematical MDO formulations.

The *SPIRO* Platform can be used by research engineers through its generic Python API as well as by end-users through its graphical user interface.



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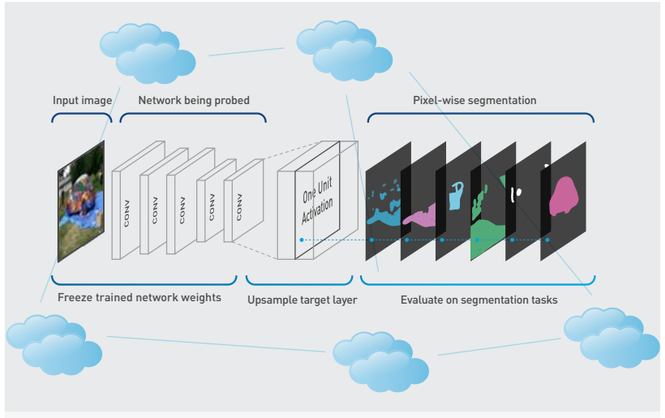
TECHNICAL FEATURES

- Supports full automation of MD design processes in distributed and multi-OS (Operating System) environments.
- Can be used for any type of models or physics through generic interfaces.
- Modularity: The component-based architecture allows the replacement of infrastructure-linked technologies such as HPC job submission or simulation workflow engine software.
- Extensibility: New optimization, DOE, coupling algorithms, surrogate models, visualization plots or MDO formulations can be easily added thanks to a plugin system.
- Can interoperate with any existing disciplinary applications within a consistent MDO process.
- Robustness: Proposes fault tolerance services that are robust to hardware and network interruptions as well as failed numerical simulations.
- Multi-fidelity: Can handle a large variety of models, from simple Matlab files to large scale industrial simulation processes.



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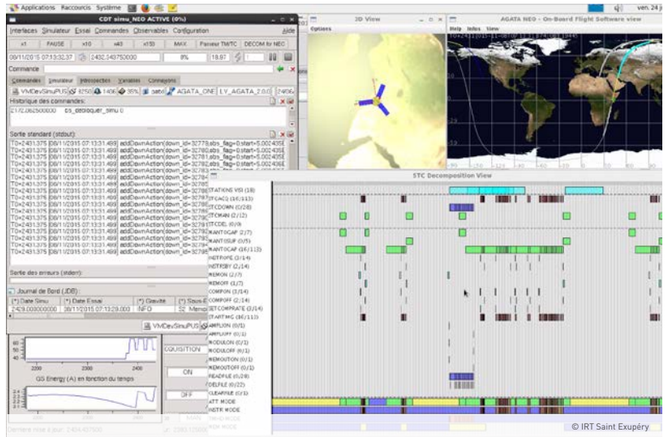

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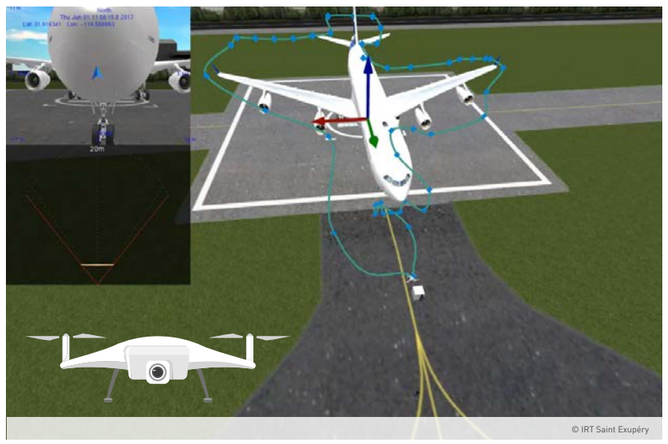

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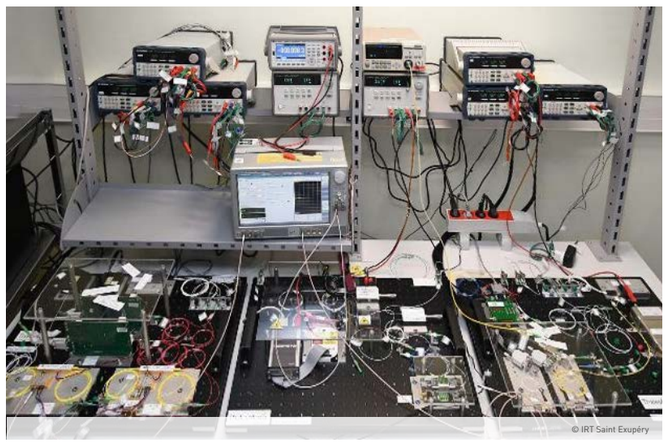

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CITADEL

Citadel is a Platform designed to facilitate the development of massive computing algorithms, artificial intelligence training in private infrastructures or in the cloud.

TECHNICAL FEATURES

- Big data processing
- Hybrid cloud management
- AI clusters deployment
- Image processing chains design

AGATA-NEO

Agata Neo demonstrates the feasibility of autonomous on-board planning, in terms of both image downloading and acquisition. The Platform integrates a full simulator which is available, and open for the evaluation of new planning algorithms.

TECHNICAL FEATURES

- On-board planning
- High fidelity simulator (board/ground, TM/TC)
- Algorithm benchmark
- Real time performance evaluation

AIDA

The IRT Saint Exupéry has developed industrial maturity models for *AIDA*, a four-engine pre-flight inspection drone for aircraft manufacturing, maintenance, etc. The objective is to provide a sufficiently complete, industrial scale case study, supporting future research work by IRT Saint Exupéry's Partners and initial or continuing training activities.

TECHNICAL FEATURES

- System architecture
- Functional safety analysis
- Simulation
- Available as open source in IRT Saint Exupéry's public forge.

ELLA TEST BENCH

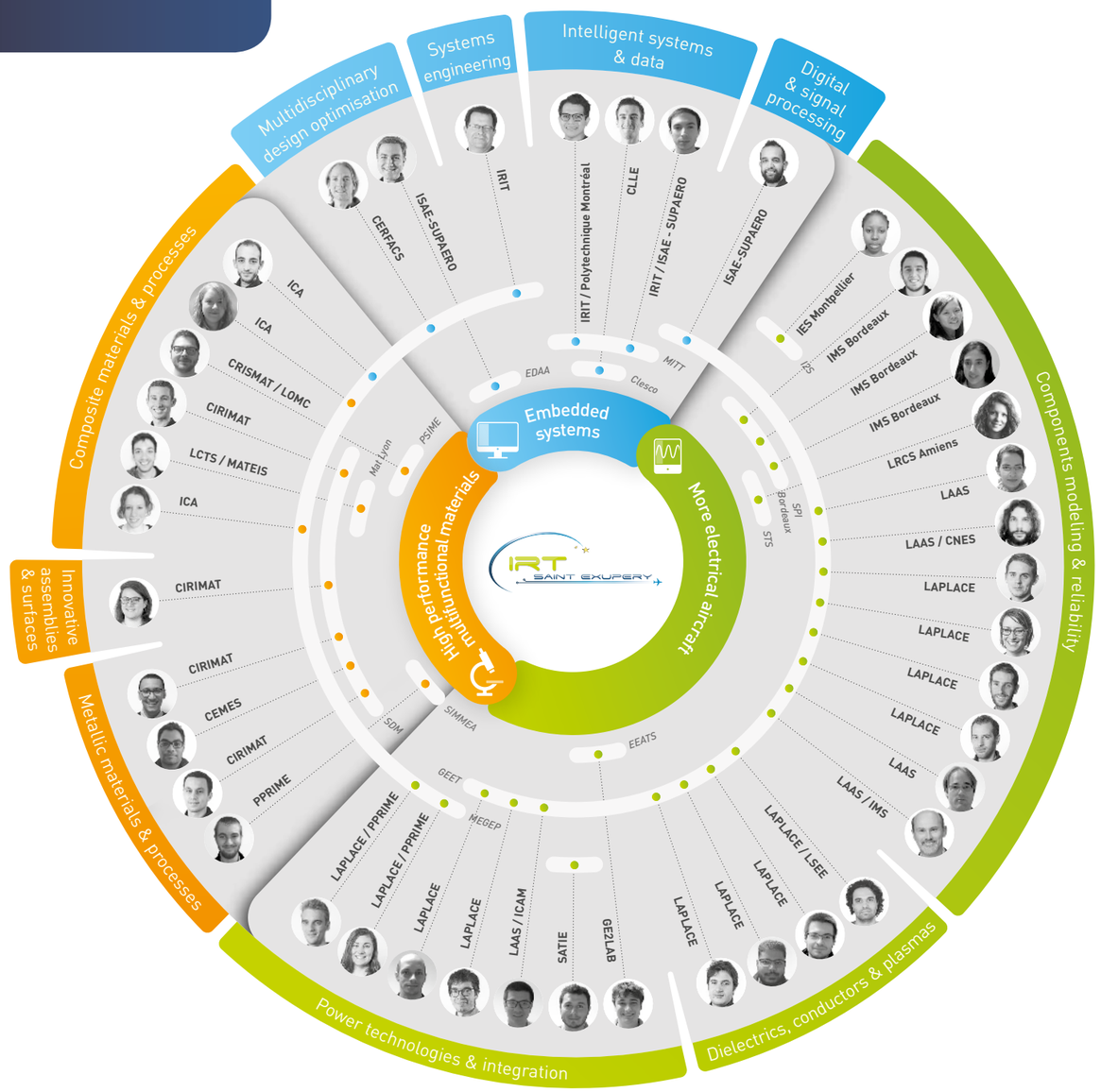
This bench, developed by the IRT Saint Exupéry and hosted by the ISAE-SUPAERO, enables the characterization of atmospheric disturbances on a laser telecommunication beam for tomorrow's satellite telecommunication needs.

TECHNICAL FEATURES

- End-to-end laser communication link emulation
- Atmospheric disturbances emulation
- Wavelength benchmarks
- Modulation benchmarks

Bertrand Girard
Scientific Director

All IRT Saint Exupéry PhD students benefit from its specific private-public environment. In particular their academic and industrial advisors ensure the highest scientific standards in parallel with the development of their awareness to the needs of industry, providing opportunities to expand their professional network.



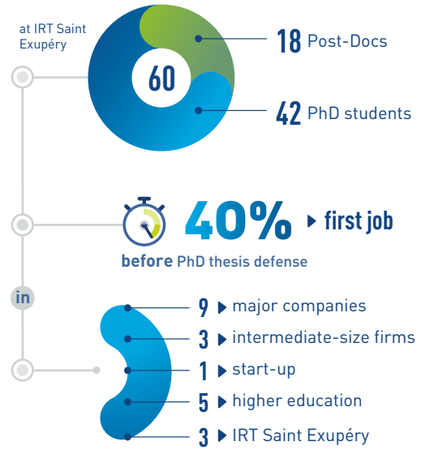
ANR · cnes · cnrs

École doctorales (ED) : CLESCO : Comportement, Langage, Éducation, Socialisation, Cognition ; EDAA : École Doctorale Aéronautique Astronautique ; EEATS : Electronique, Electrotechnique, Automatique & Traitement du Signal (Univ Grenoble-Alpes) ; GEET : Génie Électrique, Électronique, Télécommunications ; I2S : Informatique Stuctures Systèmes; Mat Lyon : Matériaux (Univ. Lyon) ; MEGeP : Mécanique, Énergétique, Génie Civil et Procédés ; MITT : Mathématiques, Informatique, Télécommunications de Toulouse ; Ondes : Ondes et Matières (Univ. Paris-Saclay) ; PSIME : Physique, Sciences de l'Ingénieur, Matériaux, Énergie (Normandie Universités) ; SDM : Sciences de la Matière ; SIMMEA : Sciences et Ingénierie en Matériaux, Mécanique, Énergétique et Aéronautique (Poitiers) ; SPI Bx : Sciences Physiques et de l'Ingénieur (Univ. Bordeaux) ; STS : Sciences, Technologie, Santé (Univ. Picardie)

As can be seen on the left-hand page, there were 42 PhD students, together with 18 Post-Docs, at IRT in 2018.

After 5 years, 21 PhD students, of the first two cohorts, have now defended their theses. Their employment placement is excellent: The average time between their PhD defense and their first job is one month, with 40% of them having their job contracts signed prior to the thesis defense. Students have found a variety of openings in the IRT Saint Exupéry's ecosystem as well as in companies outside IRT Members: Nine are joining major companies, three are in intermediate-size firms, one in a start-up, five in higher education and three at IRT Saint Exupéry.

While the laboratories on the Toulouse and Bordeaux sites, together with their immediate environments (85% and 7% respectively), were heavily involved in the first generation of projects, the new generation is shifting towards the national scene (after Poitiers, Amiens and Lyon: Sophia Antipolis, Grenoble, Caen, Saclay, Montpellier and Arras) and abroad (Montreal), while maintaining a strong local presence.



François Vernadat
STAE Foundation Director

FOCUS ON STAE FOUNDATION

Established in 2007, the STAE[1] Foundation associates 40 laboratories in the Toulouse Region. The objective is to contribute to the development of basic research in the fields of aeronautics, embedded systems, space and the Earth system.
Since May 2017, the STAE Foundation is hosted by the IRT Saint Exupéry.

1 Science and Technologies in Aeronautics and Space

The 2017-2020 roadmap provides:

- Financial support for basic research activities.
- The development of relations with Partners' eco-system.

The year 2018 was devoted to the implementation of the research programs provided for in the STAE roadmap.

In 2018, nine research projects worth €3M were launched. IRT Saint Exupéry is a Partner of two of them:

- *Deep4Cast* project: Towards a hybridization of physical models and learning techniques: application to numerical weather forecasting models.
  Partners: Cerfacs, IRIT, IRT Saint Exupéry and Metéo France
- *DAeDaLus* project: Debugging Architecture Description Languages.
  Partners: LAAS-CNRS, IRIT, IRT Saint Exupéry and ISAE-SUPAERO

4 working groups worth €200,000 started at the end of 2018.

On the occasion of the STAE Fall Meeting 2018, a booklet was published containing the summary sheets of each of these 23 actions (projects, springboards, working groups).

Ten springboard initiatives worth €700,000 have been launched.

Three of them involve the IRT Saint Exupéry:

- *DAAVVE* project: Dependable Adaptive Algorithm, V&V Engineering.
  Partners: IMT, IRT Saint Exupéry and IRIT
- *PGIP* project: Power GaN Inside PCB.
  Partners: LAPLACE and IRT Saint Exupéry
- *Toul-TIC* project: Toulouse–Theoretical Irradiation Center.
  Partners: Cerfacs, LAAS-CNRS, IMT and IRT Saint Exupéry

Patrick Martinez
Training Development Manager

Training @IRT

In 2018, the IRT Saint Exupéry developed its training activities, for its internal needs and its PhD students, or for the benefit of its academic and industrial Partners.

CONTRIBUTION TO TRAINING ACTIVITIES

During the 2017-2018 academic year, IRT Saint Exupéry's employees provided nearly 900 hours of training, for the benefit of academic Partners, and participated in various training councils. The Technological Platforms welcomed 24 interns, 9 work-study trainees, and visiting students from ICAM and INP Toulouse. In addition, IRT Saint Exupéry organized 22 training modules, totaling nearly 180 hours of teaching, for the benefit of its employees, PhD students and industrial Partners involved in various projects.

© IRT Saint Exupéry

ALTERNANCE AEROSPACE

In cooperation with "Campus des Métiers et des Qualifications," Aerospace Valley, UIMM Midi-Pyrénées, and with the support of GIFAS, the IRT Saint Exupéry was the driving force behind the implementation in 2018 of the "Alternance Aerospace" operation, to promote part-time training in aeronautics and space. "Alternance Aerospace" took place in two phases: a one-day recruitment fair and an online tool to bring together candidates, companies and training centers. For its first year, the operation was a success: 16 training organizations, 800 candidates, 20 participating companies, 650 job interviews.

© IRT Saint Exupéry

TRAINING SEMINAR

On November 21, the IRT Saint Exupéry brought together its academic and industrial Partners to explore and develops new ideas for training initiatives that its Partners would like to see in the future at the IRT Saint Exupéry. This seminar was attended by 50 people. The eight workshops made it possible to define many actions that IRT Saint Exupéry could develop with its academic Partners, for the benefit of industrial Members, higher education, and even a wider public. Subjects of the desired training courses were mainly focused on the strategic areas of excellence of the IRT Saint Exupéry such as electrical engineering for the vehicles of the future, additive manufacturing, artificial intelligence, and system engineering. In addition, expert missions have been suggested for the enhancement of digital training.

© Liebherr

AIDA

Aerospace Industry phD Acculturation

This program aims to introduce PhD students at the IRT Saint Exupéry to the world of industry in the fields of aeronautics, space and embedded systems. It enables them to discover the research work being carried out by industrialists, and the careers offered to PhD holders there. In 2018, an industrial visit was organized at Liebherr Aerospace for 25 doctoral and post-doctoral students.

Jean-Marc Heller
Head of Business Development & Communication

Patrick Zaffalon
Toulouse, Bordeaux & Sophia Antipolis Sites and Technological Platforms Director

EVENTS

2018 was a rich year in terms of ground-breaking events for IRT Saint Exupéry and its teams. Setting up staff and relocating Platforms from the Rangueil campus and installing additional equipment in the new B612 building provide very high visibility to go along with IRT's new obligations as the main occupant. This was followed by the organization of several notable events: the building's inauguration in June with Toulouse Métropole and the other tenants, in particular Aerospace Valley and ESSP[1] ; the Platforms inaugurated in September ; and the 6th National Forum of the eight IRTs, which was hosted this year in Toulouse in October. Not to mention opening to the general public. These efforts were all well-received, achieving both a high level of participation and general satisfaction.

1 European Satellite Services Provider

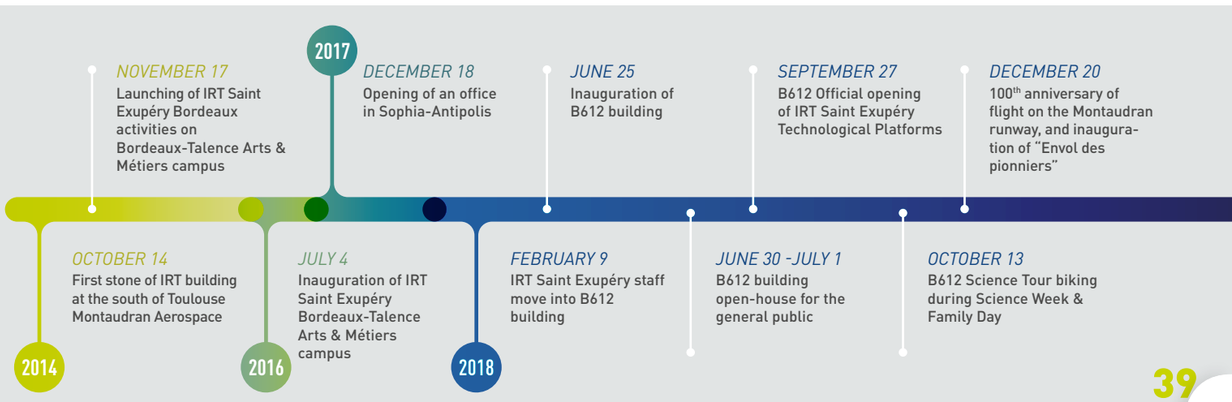
DESTINATION B612 :

IRT Saint Exupéry reinforces and expands its Technological Platforms as experimentation support for its major projects

2018 marks a milestone for IRT Saint Exupéry. The institute relocated to B612, Toulouse Aerospace's new flagship building in a fast-emerging zone whose innovation campus at the end of the legendary Aéropostale runway is dedicated to aeronautics and space R&T. Following two years of construction, the 25,000 m² high-tech vessel designed by the Khardam Cardete Huet architecture firm opened its doors. Nearly half of the heart of the building is occupied by IRT Saint Exupéry, covering five stories and a total surface area of 11,000 m². The building satisfies the particularly rigorous specifications required by IRT's Technological Platforms. Distributed across 7,000 m², the Platforms are adapted to the diversity and evolution of research work being performed, thanks to both physical separation and facility modularity. The "heavy" Platforms are located on the ground floor, with dimensions and a ten meter high ceiling compatible with very large sized equipment. Conditions for refreshing air can reach eight to ten times the volume for some rooms, such as those containing additive manufacturing machines. Observation devices such as electron microscopes are isolated from external vibrations. The electricity distribution network is also isolated to avoid electrical pollution for experiments on the More Electrical Aircraft Platforms located on level two. The roof is configured for the installation of large parabolic antennas. In addition to existing and relocated equipment, new machines have been added to IRT's resources, such as a Beam Modulo 400 additive manufacturing machine, hot isostatic compactor, new characterization equipment, and test benches for high-voltage applications aboard aircraft.

IRT Saint Exupéry's Technological Platforms visit in september
© ComSci

Inaugural plaque unveiling of the B612 building in June with (from left to right) Guillaume Boudy (France's Investment General Secretary), Yann Barbaux (President of Aerospace Valley), Georges Méric (President of Haute-Garonne County Council), Thierry Racaud (CEO of ESSP), Carole Delga (President of Occitania Region), Jean-Luc Moudenc (Mayor of Toulouse and President of Toulouse Métropole), Pascal Mailhos (Prefect of Occitania Region), Olivier d'Agay (Director of Succession Saint-Exupéry-d'Agay). © Toulouse Métropole



October 11, Toulouse - B612

6TH IRT FORUM ORGANIZED BY IRT SAINT EXUPÉRY

Over 400 participants at the heart of IRT Saint Exupéry's Technological Platforms

To demonstrate the strength of a collective effort on strategic issues, the morning focused on IRT villages organized by themes: Composite materials, additive manufacturing, artificial intelligence, cybersecurity, 5G/IoT and health. Many demonstrations, videos and samples were presented at the heart of IRT Saint Exupéry's Technological Platforms. With its Members and Partners from the French space, IRT Saint Exupéry also presented major innovations in the Space village.

A rich and intense plenary session with SGPI[1] and Ministry of Research and Innovation

During the plenary session, Vincent Marcatté, president of FIT[2], highlighted the quality of results presented with respect to ambitious objectives for 2018, with industrial transfers doubling in one year to reach 411. Guillaume Boudy, France's Investment General Secretary, said that IRTs are an instrument of technological sovereignty. Frédérique Vidal, French Minister of Higher Education, Research and Innovation pointed out that, on June 21 at IRT M2P in Metz, the French Prime Minister acknowledged the progress made by IRTs and proposed three measures: Bringing together IRTs and ITEs[3]; preparing a sustainable course beyond 2025 and supporting the "three thirds model" (State, industry and other funding sources); while finally relaxing employment regulations for public-sector researchers within IRTs.

IRTs reinforce sectors' competitiveness, the aeronautics example

Airbus conducts collaboration-oriented research in the aeronautics sector with four IRTs, Jules Verne, Saint Exupéry, M2P and SystemX. Examples of innovation acceleration through transfers to the industry has been given with Chantiers de l'Atlantique for IRT Jules Verne, Mentor Graphics (Siemens) for Nanoelec, Nexterfor M2P and Boehringer Ingelheim France for BIOASTER. IRTs build international partnerships as it has been pointed out by b<>com with the Fraunhofer Heinrich Hertz Institute (Germany), IRT Saint Exupéry, with IVADO and CRIAQ (Montreal, Quebec), the opening of a representative office in Singapore for SystemX or the Shift2Rail European Rail Initiative for Railenium. Through very appreciated three minutes PhD students work presentations, it has been demonstrated that IRTs contributes to scientific excellence. IRTs' vocation is to become the leading force in French technological research concluded Gilbert Casamatta, President of IRT Saint Exupéry and Vice-President of FIT.

1 Investment General Secretary
2 French Institutes of Technology Association
3 Institutes for Energy Transition

Official visit of IRTs Villages with (from left to right) Serge Prigent (team leader at IRT Jules Verne), Vincent Marcatté (President of b<>com and President of FIT), Gilbert Casamatta (President of IRT Saint Exupéry and Vice-President of FIT), Frédérique Vidal (French Minister of Higher Education, Research and Innovation), Philippe Baptiste (Cabinet Director of the French Minister of Higher Education, Research and Innovation) and Guillaume Boudy (France's Investment General Secretary) © L. Le Carpentier

Official visit of Space Village with (from left to right) Ariel Sirat (CEO of IRT Saint Exupéry), Guillaume Boudy (France's Investment General Secretary), Vincent Marcatté (President of FIT), Jean-Claude Traineau (Spatial Programs Director of ONERA) and Gilbert Casamatta (Vice-President of FIT) © L. Le Carpentier

March 6, Toulouse - B612

QUEBEC AND IRT SAINT EXUPÉRY AI AGREEMENT SIGNATURE

Partnership signature by (from left to right) Gilbert Casamatta (President of IRT Saint Exupéry), Gilles Savard (CEO of IVADO) and Denis Faubert (CEO of CRIAQ) in presence of (behind) Jean-Luc Moudenc (Mayor of Toulouse and President of Toulouse Métropole), Philippe Couillard (Prime Minister of Quebec) and Delphine Gény-Stephann (Secretary of State to the Minister of the Economy and Finance) © IRT Saint Exupéry

During the official visit to Toulouse by Philippe Couillard, Prime Minister of Quebec, IRT Saint Exupéry, CRIAQ[1] and IVADO[2], major players in the Quebec aerospace ecosystem and world-class research in artificial intelligence based in Montreal, committed to a five-year strategic partnership in the fields of aerospace, space and embedded systems. Artificial intelligence methods need to demonstrate their robustness and stability, with research work still in its infancy at the international level where IRT Saint Exupéry will bring its expertise, building on its success by combining big data and deep learning technologies and applying them to massive satellite imagery processing. The agreement promotes collaborative projects between the industry and French and Canadian academic communities, as well as exchanges of academic and industry research employees. The agreement will also develop cooperative links through strategic studies, courses, seminars and joint conferences. On March 6, Quebec and France adopted a roadmap outlining growth, innovation, digital technology and artificial intelligence that includes strengthening Franco-Quebec cooperation in those areas. Lastly, IRT Saint Exupéry is a major Partner in the Toulouse-based 3IA Interdisciplinary Institute of Artificial Intelligence, "ANITI", dedicated to hybrid AI.

1 Consortium for Research and Innovation in Aerospace in Quebec
2 The institute for data valorisation

2018

01 *JANUARY 24*
Toulouse - **Journée communications optiques en espace libre** by ISAE-SUPAERO

02 *FEBRUARY 20 -22*
Lyon – **ICIT** (International Conference on Industrial Technology)

JANUARY 31 - FEBRUARY 2
Toulouse – **ERTS²** (Embedded Real Time Software and System)

03 *MARCH 6*
Toulouse – **Signature of CRIAQ, IVADO & IRT Saint Exupéry partnership agreement on AI**

MARCH 22
Toulouse – **IRT Seminar** by Suresh Advani, University of Delaware

MARCH 27
Toulouse - **Organic Matrix Composite Technical Day** by Aerospace Valley

MARCH 29
Lille - **MT180 Hauts-de-France Region Final** by Caroline Gaya

MARCH 29
Toulouse - **Two-phase systems for power electronic thermal control –Technical Seminar** by the Thermal French Society

04 *APRIL 16-18*
Toulouse – **Eurosime** (International Conference on Thermal, Mechanical and Multi-Physics Simulation and Experiments in Microelectronics and Microsystems)

05 *MAY 15*
Saint-Orens-de-Gameville - **Alternance Aerospace recruitment forum**

MAY 27
Poitiers – **International Fatigue Congress**

MAY 31
Toulouse – **Enova/Technical Day Electronic Cards & Equipment: Integrated Signal & CEM**

06 *JUNE 12-13*
Arcachon - **Forum of the Aerospace Valley cluster members**

JUNE 12
Bouguenais – **Conference "The challenges of the more electrical aircraft"**

JUNE 26-28
Toulouse – **Toulouse Space Show**

JUNE 28
Toulouse - **Model Based Safety Assessment Workshop** by IRT Saint Exupéry/Onera

JUNE 29
Toulouse – **3rd PhD's Day** by IRT Saint Exupéry

07 *JULY 2-6*
Toulouse – **HTTP15** (International High-Tech Plasma Processes Conference)

JULY 9-14
Toulouse - **ESOF 2018 Euro Science Open Forum Toulouse / Science to Business / Round Table "More (All) Electric Aircrafts Enabled by Power Electronics Revolution using Disruptive Semiconductor Technology"**

JULY 3-4
Bordeaux - **International Conference on Industrial Laser Processing**

SEPTEMBER 18
Toulouse – **TechDay Continental**

09 *SEPTEMBER 25*
Toulouse – **Systems Engineering and Collaborative Engineering Workshop** by AFIS

SEPTEMBER 11
Varilhes –**Discovery Workshop on Functionalization of materials by addition of loads** by Ad'Occ

OCTOBER 11
Toulouse – **6th IRT Forum**

10 *OCTOBER 16*
Toulouse - **Airbus Airframe Xperience'18**

OCTOBER 2
Toulouse – **Café du quai « Transports du futur : l'expérimentation, un maillon entre recherche fondamentale et appliquée »** by CNRS Midi-Pyrénées with **"Le Petit Illustré"** la Dépêche du Midi co-publishing

11 *NOVEMBER 28*
Toulouse – **Fall Meeting STAE**

NOVEMBER 6
Toulouse - **Scientific day – Hardware interference and temporal determinism for modern SoC** by IRT Saint Exupéry and the CNRS GDR SOC2

12 *DECEMBER 6-7,*
Blagnac – **Intellectual Property Seminar** by Airbus

DECEMBER 4-5
Toulouse - **Aeromart**

FOUNDERS

PUBLIC INSTITUTIONS: Arts et Métiers ParisTech · ARMINES · INP Bordeaux Aquitaine · CNRT Matériaux · INP Toulouse · INP ENIT · INSA Lyon · INSA Toulouse · IRT Jules Verne · IRT M2P · IRT SystemX · ISAE-SUPAERO · MINES Albi-Carmaux · ONERA · Bordeaux University · Bretagne Sud University · Artois University · Haute-Alsace University · Toulouse Jean Jaurès University · Nice Sophia Antipolis University · Toulouse Paul Sabatier III University · Picardie Jules Verne University · UTBM (University of technology Belfort Montbéliard)

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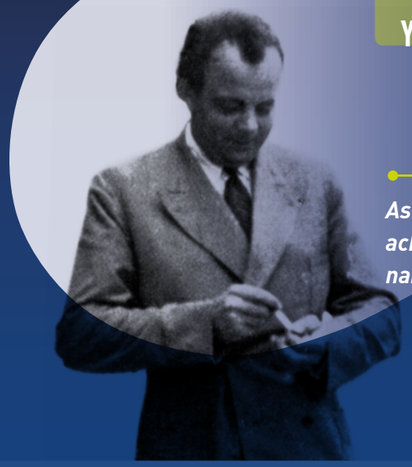
NETWORKS AND CLUSTERS: Aerospace Valley · Alpha RLH · Aquitaine Science Transfer · Astech · BAAS · FIT · Fondation Arts et Métiers · GIFAS · GIPI · SAFE Clusters · STAE Toulouse · TOMPASSE · Toulouse Tech Transfer

VALUES



> Your task is not to foresee the future, but to enable it.
>
> (Antoine de Saint Exupéry, Citadelle)

As a conclusion, IRT Saint Exupéry would like to dedicate these achievements to Antoine de Saint-Exupéry, to whom it owes its name, and most importantly the values on which it is built up.

Ingenuity, creativity and curiosity
"Your task is not to foresee the future, but to enable it."

Commitment, sharing, sense of responsibility
"To be a man actually means to be responsible, and feel that you are building the world by laying your foundation."

Orientation towards experimentation and action
"In real life there is no solution. Active forces do exist but you need to create them and solutions will follow."

Antoine de Saint-Exupéry

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Companies

Laboratories

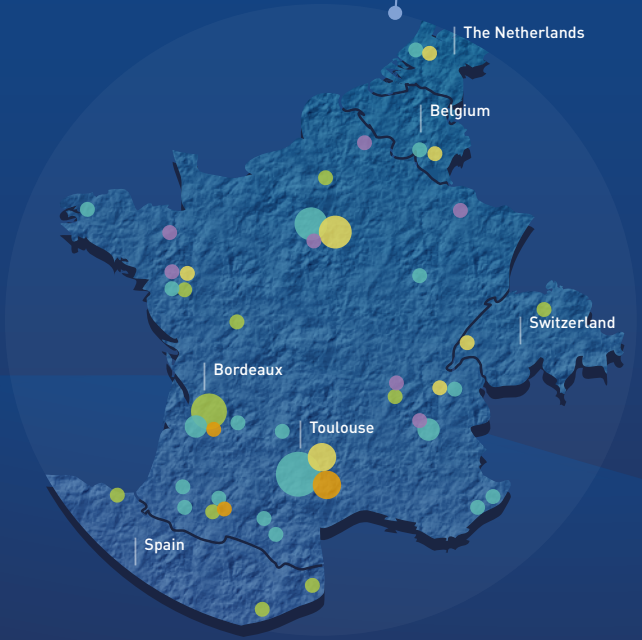
Platforms

ITAB (International Technology Advisory Board)

Other IRTs

International Members and Partners

National Members and Partners



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