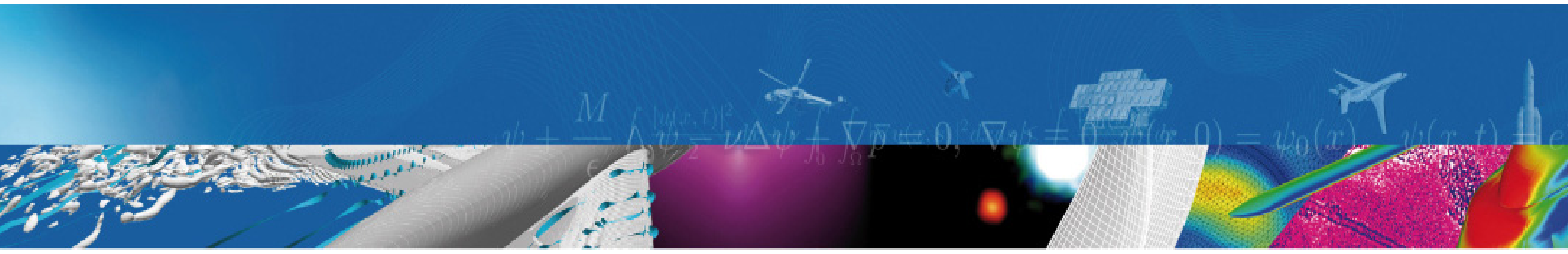


Strategic Scientific Plan 2015-2025

La recherche CARNOT pour les entreprises

ONERA

THE FRENCH AEROSPACE LAB

The SSP
ONERA's 2015-2025
Scientific Strategic Plan

Shaping the future:

from science to technology

What is the SSP?

The SSP, or Scientific Strategic Plan, is the strategic guideline document for ONERA's research activity for the period 2015-2025. The SSP expresses ONERA's ambition. Although containing no indication of means or of programming, it is intended to provide the basis for multiannual objectives and performance contracts. It takes into account the opinions and recommendations of the ONERA's High Scientific Council, as well as various external reports written at the request of official departments, and strategic meetings with government departments and industry.

The SSP is an essential part of the dialogue with the French State, the scientific community and industry. The SSP is structured on the basis of twelve scientific and technical challenges.

ONERA in 2015

2017 people
1501 scientists and managers
263 doctoral and postdoc students
256 rank A journal articles
340 communications
72 PhD theses
24 scientific awards
1186 technical reports
29 patents

ONERA's DNA

Created 70 years ago, ONERA contributes to advances in aeronautics, space and defense by conducting world-class research, achieving world-firsts, and developing current technology on most of the industrial platforms and products of this sector in France and in Europe.

From basic research to technological development, from modelling to advanced simulation, and from ultrafine experimentation to integral tests on real systems in flight or in large wind tunnels, and even demonstrators, it is this multidisciplinary research continuity, with a very strong orientation towards aerospace and defence issues, that forms the ONERA's real DNA.

TRL 2 to 6, the SSP's domain

The SSP concerns the TRL* from Level 2 up to Level 6, access to TRL 6 being enabled by the specific means available to ONERA: from large test facilities to airborne platforms for evaluating sensor technologies and flight systems, the ability to engage with partners in demonstrators, and proprietary technological means.

*TRL : *Technology Readyness Level* (degree of technological maturation)

- TRL 1: basic principles observed
- TRL 2: technology concept formulated
- TRL 3: experimental proof of concept
- TRL 4: technology validated in lab
- TRL 5: technology validated in relevant environment
- TRL 6: technology demonstrated in relevant environment
- TRL 7: system prototype demonstration in operational environment
- TRL 8: system complete and qualified
- TRL 9: actual system proven in operational environment

The SSP: an action tool

For ONERA, the SSP sets a challenging course for the future: the aims and orientations proposed should lead to new ideas, new technologies, and new scientific areas, as well as taking advantage the use of the latest scientific advances.

The purpose also is to develop multidisciplinarity and partnerships, in a cross-cutting way which now became inevitable because of the complexity of systems and their environment but also in front of the increasing requirements on the systems of tomorrow.

The SSP should also help to establish ONERA's annual objectives, by providing a long-term vision and enabling the definition of the most relevant indicators for its ambitions.

The SSP, a comprehensive view of what lays ahead for ONERA

In order to ensure the conditions for success in the mission entrusted to it by the French State, ONERA is positioning itself not only as a major player in research, but also as a consistency centre for research relating to the major objectives identified for the next 10 years and beyond.

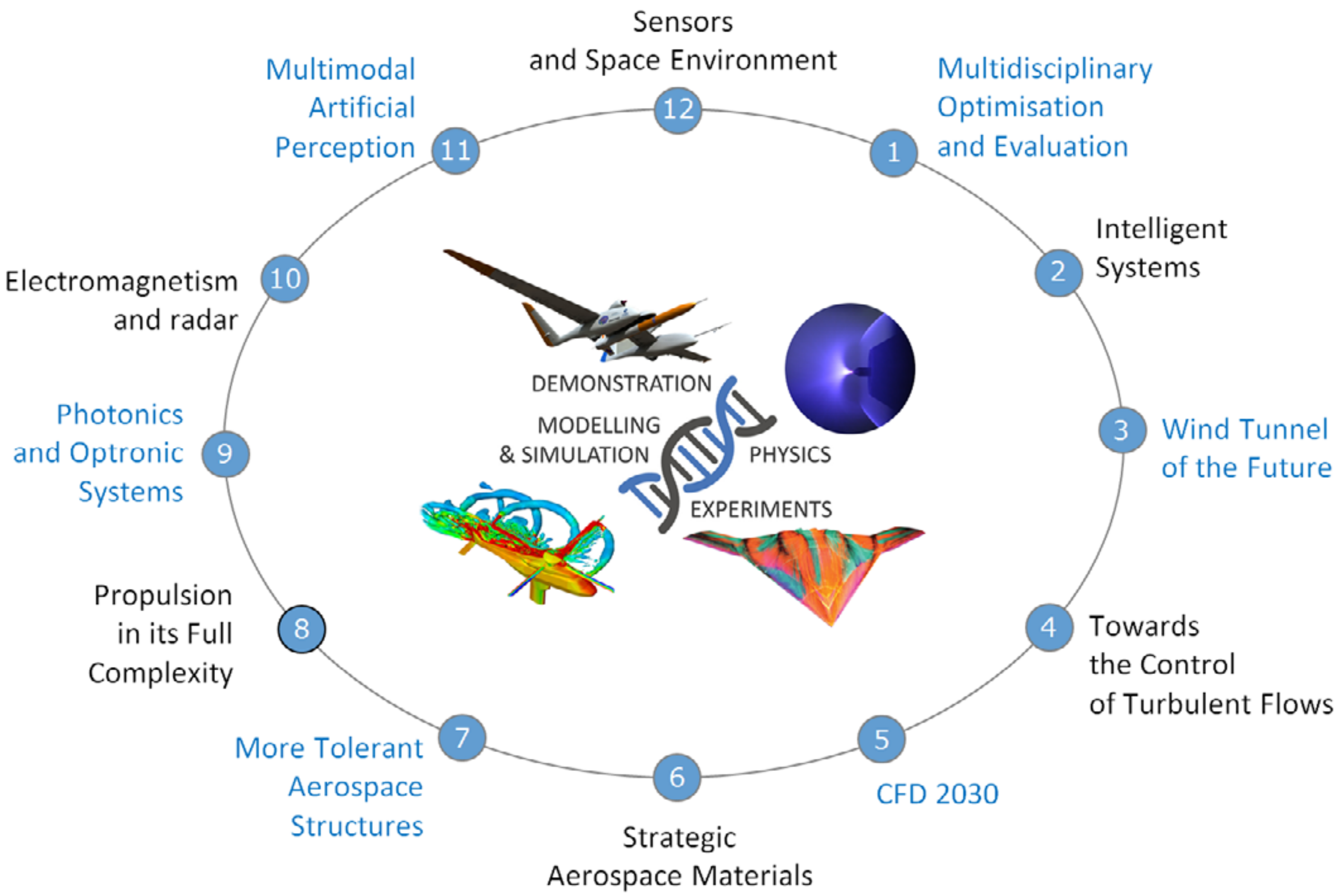
Because low and middle TRL research can not be other than collaborative, the need for a comprehensive vision and coordination is essential to focus resources - and the results - in the right directions and build roadmaps that can resist short-term pressures and continuous reorienting temptations.

Beyond the question of sizing resources, future major projects must, as from the lowest TRL, be conceived and designed by a community of players, each having a different legitimacy but sharing resources and means to achieve a same vision.

ONERA intends to play a central role in this, in line with its mission, and the SSP is the first of its tools.

The 12 challenges of the SSP

The SSP expresses ONERA's DNA through twelve scientific challenges, for the benefit of the Aerospace and Defence sector.



CHALLENGE 1

MULTIDISCIPLINARY OPTIMISATION AND EVALUATION

A digital platform for multidisciplinary optimisation and evaluation of innovative concepts

The challenge

Jointly optimising structural parameters, propulsion system parameters, guiding/piloting laws and embedded systems, as well as aiding in the evaluation of new concepts through interactive and immersive simulations, represent a dual challenge to manage the innovation process in the field of aerospace. This environment must also allow the expert assessment needs expressed by the authorities to be met.

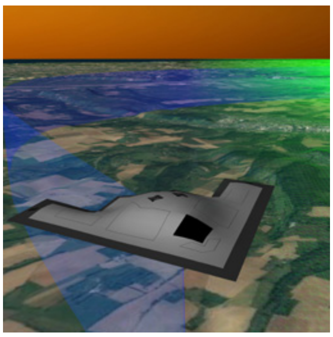
Multidisciplinary and multi-criterion design methods

Blade, ONERA's simulation lab

These methods, at the core of future developments, will cover the need for:

- parametric **modelling** of multidisciplinary and multi-fidelity systems implementing, in particular, model reduction and uncertainty propagation analysis methods
- design space **exploration** through multi-criterion optimisation techniques, seeking compromise between conflicting performance objectives, while respecting the constraints that must be met by the system by using the most advanced methods of each discipline
- strong **interaction** between engineers and the design process through data mining methods promoting the traceability of evaluated configurations, techniques for visualising results in spaces with large dimensions, and metrics that enable decision making
- **innovation** by including the modelling of the most advanced technologies through variable-fidelity methods

A distributed hybrid simulation environment



A simulation in Blade including a combat drone

This environment will extend the capabilities of current platforms – the Blade simulation laboratory, IESTA ATM systems and simulation with human/Pycshel system interfaces incorporating:

- formal **methods** for the **functional analysis** of mission objectives and of vulnerability to disruptions and hazards
- **human-system interaction** via physical interfaces and models supporting representations of the cognitive and physical activity of operators
- **data** from tests and from measurements by on-board piloting or sensor information processing computers
- system **behaviour observation** tools via the logical representation of their dynamics, data mining in large dimensions with uncertainties, and knowledge extraction

[Breakthrough (underway)] A multidisciplinary platform

The Acadia MDO/MDA platform will include multidisciplinary modelling, model reduction, uncertainty propagation and multi-objective optimisation tools. It will be used by defining a limited number of visible and attractive aeronautical platforms, such as the new transport aircraft architectures with blended wing body (BWB) or rotary wings, and distributed propulsion, convertible drone architectures and reusable launchers.

ONERA's assets

These developments will be based on leading work that has been carried out at ONERA in MDO/MDA for over a decade. The operational simulation means developed will benefit from the already substantial potential of the Blade simulation platform and ONERA's unique resources in terms of sensor models and associated processing models to achieve simulation with a high level of realism.

Ampere: light aircraft design with distributed electric propulsion

Priorities for 2020

- **Generation of probabilistic parametric models** to take into account random and epistemic uncertainties in dynamic systems and **related multidisciplinary sensitivity analysis methods** in the context of model-driven engineering
- **Accurate and robust alternative models** for time-managed simulation by generic regression and associated uncertainty measurement methods, and **tools for multidisciplinary optimisation with uncertainties**
- **Formal and statistical methods for the analysis of system architectures** in the assessment of functional and temporal performance, as well as for the characterisation of failure risks and the estimation of rare events
- **Distributed hybrid simulation with real elements** for the assessment of operational performance, incorporating components and physical measurements and making use of system autonomous behaviours and of data and behaviour representation means through virtual reality interfaces

Eole: automated and reusable aircraft demonstrator for placing small satellites in orbit

Partners

The DGA and DGAC. IRT St-Exupéry and SystemX collaborative projects, and bilateral collaboration with INRIA (Rocquencourt, Rennes and Sophia Antipolis), the CNRS (Saint-Etienne), and Georgia Tech. Some topics on model reduction will be worked on by ONERA/ISAE joint research teams.

CHALLENGE 2 SMART SYSTEMS

Designing safe and efficient smart systems

The challenge

The development of so-called "smart" systems is, in general, aimed at the achievement by these systems of significant capacity to adapt to variations in the environment in which they operate, as well as those in their intrinsic state.

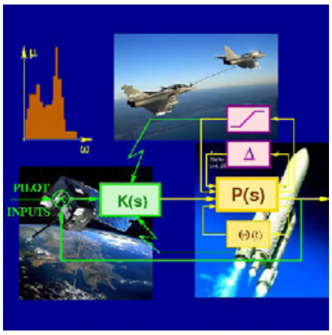
Designing functions related to autonomy


Cooperation between heterogeneous drones

Controlling the behaviour of complex dynamic systems when facing uncertainties and constraints of all kinds, operation non-linearities or even failures is done through the use of robust multi-loop control structures and, at a higher level, control loops referenced on exteroceptive sensors enabling a local relationship to be established between the system and its environment directly in the sensor space. The planning and supervision of missions must also be done by a decision-making level capable of reasoning based on incomplete and uncertain data.

The development of control architectures must be supported by consistent environments for modelling, synthesis assistance and performance analysis, as well as for the design of the computer platforms necessary for running them and for checking their implementation, taking into account developments in embedded computers.

Ensuring human-system integration



Control loop for aerospace systems

Taking into account cognitive, perceptual or sensorimotor aspects in human/system interactions is critical for the design and management of complex systems, whether for implementing fast control loops for these systems or for higher level functions (supervision, decision, etc.).

A better understanding of the man-machine interactions will lead to human-centred interfaces, monitoring and decision support tools, and distributed decision organisational practices (air traffic management, air-ground procedures), in order to reduce the cognitive and physical burdens of operators and to expand human capabilities by providing technologies and tools to assist operators.

[Breakthrough (underway)] A resilient drone - Dropter project

Adaptive control techniques can be found on board an aircraft drone, which enable it to continue flying despite any rudder or aileron actuator problem.
A scenario involving the loss of the speed measurement sensor is also envisaged, in which online techniques will enable the flight to continue safely. Vision referenced control approaches, which are also being studied for landing airliners, are also being put to use

ONERA's assets

The developments relating to this challenge will be based on unique expertise and means for automation, robotics and cognitive engineering (SMAC and MORE toolboxes, Genetic, etc.; testing means: drones and robots, and cognitive engineering laboratory).

Priorities for 2020

- **Development of system function specification and risk analysis methods** and tools for the formal analysis of operational concepts and regulations, probabilistic modelling and predictive evaluation of failures, and requirement verification
- **Controlling the quality and performance of IT platforms and embedded software**, by proposing programming methods for next-generation computers and networks
- **Optimising the behaviour of aircraft for optimal, reliable and secure inclusion in the airspace**, for new global air traffic management (ATM, UTM) concepts
- **Ensuring behaviour control and safe navigation of aerospace vehicles under all conditions**, by changing the control techniques for dynamic systems and the model adjustment and reducing methods, and by developing adaptive multi-sensor referenced control techniques
- **Incorporating human cognitive and sensorimotor functions in the design of control systems** for designing human-centred interfaces and decision support tools
- **Carrying out the preparation, supervision, and coordination of autonomous vehicle missions** with dynamic mission planning software architectures for multi-agent systems
- **Incorporating diagnostic inspections to optimise system operation and maintenance** through failure detection and reconfiguration methods and through methods for structure and component diagnostic inspection by analysing collected data

The security dimension aspect must be taken into account, especially through cyber-physical systems that are likely to be developed on a large scale.

Integration of human cognitive and sensimotor functions into the design of defence systems

Partners

The DGAC/DSNA; aerospace and drone system manufacturers; collaborations with the CNRS and INRIA, the ONERA /ISAE IECR, CEA-List, ICM, Crea, Enac, Irit, Laas, Isir, Lip6, Paris-Saclay University; NASA, DLR, and JAXA.

CHALLENGE 3 WIND TUNNEL OF THE FUTURE

Designing and preparing tomorrow's tests in large scale wind tunnels

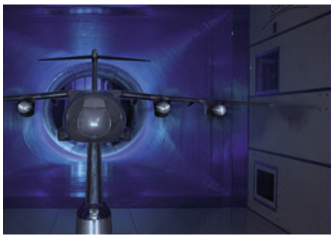
The challenge

It has two aspects. The first is the preparation of future development and validation tests, in a context where digital simulation, big-data, and test- calculation interaction both for operation and control will be under-going further new developments. The second is the scientific use of these great means, for both ONERA's challenges and also those of its scientific partners, complementing its research wind tunnels.

Exploring new configurations, and extending flight envelopes

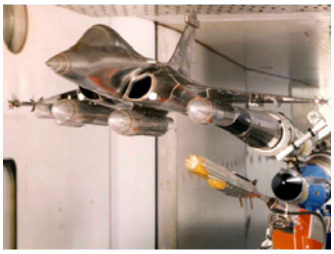
Breakthrough technologies for the civilian and military aircraft of 2030 and beyond must be developed, evaluated and validated using high-capacity wind tunnels, both for civilian aircraft and defence, which involves combat aircraft, combat drones, missiles and engines.

Validation of numerical simulations by calculation/experiment hybridisation


The low speed A400M in the F1 wind tunnel at Fauga-Mauzac

ONERA's large wind tunnels, top level worldwide, are preparing for the future by exploring new configurations, mastering new metrologies and developing the hybridisation of experiments with numerical simulations, together with ONERA's departments.

The role of testing in wind tunnels in the design of new formulas should assert itself as their representativeness with regard to actual conditions increases, reducing in-flight testing and the associated costs.


Missile trajectography with Rafale (S2MA wind tunnel)

ONERA's assets

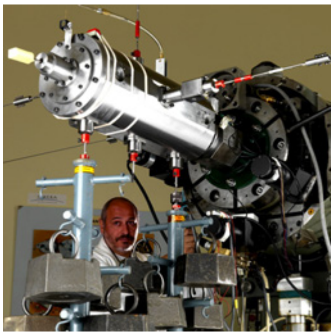
- A fleet of wind tunnels covering all needs
- A dynamometric system manufacturing workshop of the highest level
- Advanced metrology

[[Breakthrough (underway)] CFD-test merging assimilation

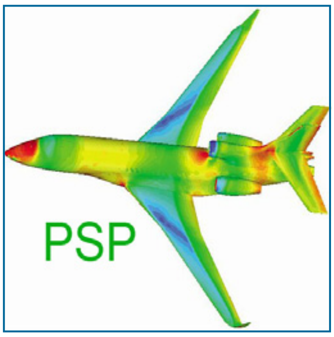
The future is the combined use of CFD and testing. This association will enable the wall of difficulties that theory has come up against to be overcome. For calculations and tests carried out on a same configuration, the use of "merging-assimilation" helps theory to improve - or adjust- its models and to create the missing link where calculations are uncertain or the model is too simplified.

Priorities for 2020

- **Knowing how to explore new civil and military aircraft configurations**
  Testing configurations involving engines with very high dilution rates, or even without fairing, evaluating the performance of propulsion solutions with airframe boundary layer ingestion (BLI concept), and incorporating physical phenomenon control technologies, such as transition, separation and acoustic emissions, while promoting increased productivity and supporting new approaches in the design of aeropropulsion formulas.
- **Developing advanced aeroacoustic means for controlling aircraft noise**
  Offering aeroacoustic testing capabilities in a closed test section with all of the specifications usually required.
- **Taking into account, as from the wind tunnel testing stage, dynamic effects in the flight behaviour of aircraft**
  Supporting numerical calculations for arising dynamic phenomena and for an accurate definition of flight envelopes, thanks to the miniaturisation and densification of sensors and signal processing chains
- **Making use of measurement- simulation dialogue to enhance test reliability**
  Developing calculation/experiment hybridisation to correct conditions in wind tunnels, to identify sensitive areas to concentrate measurements in and to adjust production calculations.
- **Bringing wind tunnel testing closer to in-flight testing**
  Better simulating actual flight conditions by developing active control technologies based on MEMS to improve transition techniques and aimed at experimental simulation with aeroelastic similarity.



Wind tunnel force measuring device



Falcon 7X model covered with pressure-sensitive paint, during a test

Partners

The entire network of ONERA's partners in the fields of measurement, simulation and hybridisation

9

CHALLENGE 4

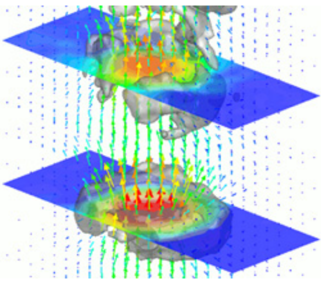
CONTROLLING TURBULENT FLOWS

Controlling unsteady flows, for turbulence management

The challenge

In terms of aerodynamics alone, or when coupled with other fields (aero-thermics, aero-acoustics, aero-thermodynamics, diphasic fluid mechanics, icing, etc.), the modelling of fully developed turbulence, as well as that of the transition to turbulence, is a challenge that affects all aeronautical applications.

A strategic issue for all aeronautical applications



Turbulence in 3D, thanks to PIV3D and its computers

Overall performance forecasts (drag, flutter, aircraft manoeuvrability), of wall heat transfers (cooling film, hot spot on a vane, thermal protection sizing), engine efficiency (injection, mixing), environmental pollution (noise and chemical pollutants generated by engines, internal noise), and safety aspects of air transport (stall, icing) depend directly on the representativeness of turbulence, whether in an experiment or in a numerical simulation.

Understanding, experimentation, simulation, modelling... and control

Laminar tail fin in S1MA

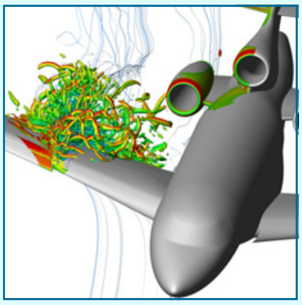
This modelling work is based on the combined use of research wind tunnels and multi-level digital simulations, from the "exact" resolution of equations by so-called direct simulation (DNS), to that of equations filtered at various levels (LES, DES, RANS).

Mastering the physics of turbulence, detailed experiments, detailed numerical simulation and modelling thus open the way to controlling flows through the development of actuator, sensor and control loop technologies.

ONERA's assets

- World-leading specialists in modelling, simulation and experimentation on turbulence and flow control for aeronautical applications.
- Powerful simulation tools (software and internal computers) and a fleet of test facilities covering a wide range of TRL.

[Breakthrough] The ZDES method

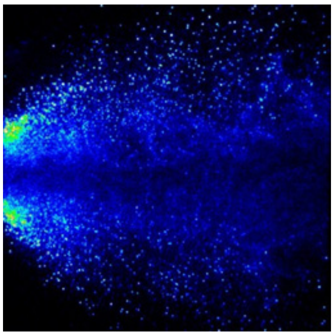


The prediction of the aeroacoustic sources responsible for noise is an example of a situation in which accurate knowledge of the fluctuating field in a turbulent flow is vital. To meet this challenge, ONERA has developed a multi-resolution method called ZDES (Zonal Detached Eddy Simulation). This method makes possible the coexistence in the same simulation of time -inexpensive averaged modelling and more advanced modelling to solve turbulent fluctuations.

Priorities for 2020

- **The development of metrology and experiments for aerodynamics, aerothermochemistry and aeroacoustics**

  Time-resolved 3D PIV, BOS and digital holography for density, pressure-sensitive paint for forces on walls, acoustic antennas, laser-induced fluorescence, and diffusion or spectroscopy methods for combustion, combined with the most advanced signal and image processing methods, as well as embedded methods, to reduce complexity and therefore information storage.



Dispersion of kerosene droplets in a combustion chamber (LIF)

- **Complexity reduction**

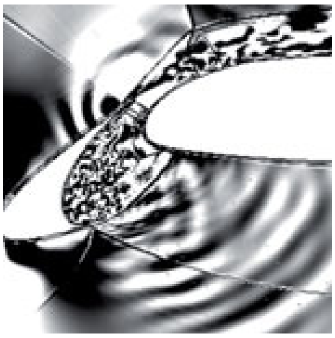
  Proper Orthogonal Decomposition and Dynamic Mode Decomposition for energetic and spectral classifications, as well as new approaches, to be incorporated into digital platforms for embedded processing limiting information storage.

- **Joint development of actuators and models to control phenomena**

  Exploring and implementing flow control to optimise aerodynamic efficiency, using new sensors, actuators, control laws and digital tools.

- **Construction of transition and turbulence models on physical bases**

  Modelling instabilities, the initiation and development of the transition to turbulence and modelling the turbulence (dynamic and thermal) developed as a function of poorly known parameters: surface condition, type of external disturbance, slow unsteadiness through dedicated experiments and digital approaches. Integrating the models into the platforms.



Numerical simulation of the production of acoustic waves

- **Prediction and control of noise, icing and vortices**

  Based on experiments and interoperable modular digital tools: understanding and reducing the impact of noise sources and vortex signatures of aircraft; ice accretion control, optimising the powers used (de-icing, anti-icing); gaining maturity with regard to transient modelling.

Partners

Paris-Saclay, Toulouse and Lille ComUEs, Pprime, LMFA, IMFT, Imperial College, Caltech, NASA, JAXA

CHALLENGE 5

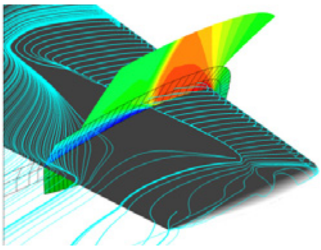
CFD 2030

Developing the computational fluid dynamics of 2030 for aerospace

The challenge

Developing a comprehensive simulation strategy based on building modular models and simulations, chained or coupled, validated by experiments at all levels, using very high performance computing capabilities.

Software interoperability and hybridisation are a priority

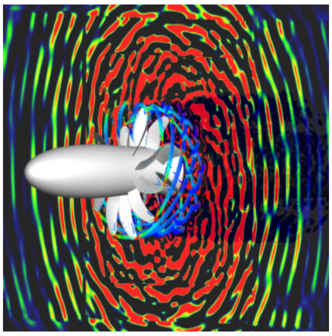


ONERA's software Aghora prefigures the CFD of the future

elsA for fluid mechanics; Cedre for combustion, aero-thermics and aero-thermomechanics; Sabrina, Space for aero-acoustics, as strategic tools for ONERA and its industrial partners.

They capitalise on an expertise in simulation and physical modelling validated by ONERA's multilevel experimental potential. A priority for ONERA is to develop, based on an architecture of components that are interoperable among themselves and with the outside, a consistent software offering that "hybridises" its unifying software and the best research software developed in-house or by its partners.

Systems that are easy to use and suitable for large computers



Aero-acoustic numerical simulation of a CROR double propeller

ONERA ELSA
ONERA CEDRE

elsA and Cedre, Onera's two great "codes" for aerodynamics and propulsion

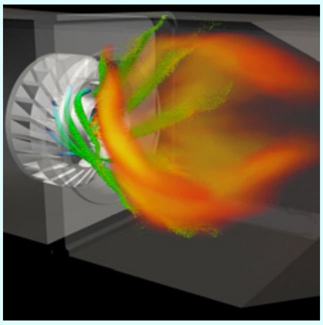
ONERA is also preparing for the future by developing and consolidating a robust and reliable class of numerical methods, coupled multiphysics, multi-model and multi-scale construction and simulation methods that can be integrated into modelling systems that are easy to use and suitable for the architectures of large computers.

These new methods, based on both digital and physical aspects, will be gradually integrated into future multiphysics platforms made available to manufacturers.

ONERA's assets

- Validated, recognised and interoperable aerodynamic (elsA) and multi-physics (Cedre) platforms.
- A wide range of expertise covering all CFD core fields (software engineering, numerical analysis, physical modelling, experimentation-

[Breakthrough] Cedre multi-physics simulation



Simulation in fluid mechanics requires models describing the physics of chemistry, thermodynamics, and aerodynamics, as well as interaction models: thermo-chemistry, aerothermodynamics, liquid-gas, radiative transfer, etc. Cedre, with its specialised "solvers", considers all of these physics and their interactions. It can be coupled to other software relating to more distant physics: mechanical or acoustic structures, for example.

Priorities for 2020

- **Integration of CFD platforms for research and industry**

  Software architecture with interoperable components coupling ONERA platforms to each other and to the outside, for multidisciplinary simulations, dealing with a large number of configurations, either steady or unsteady. Gradually integrating the necessary auxiliary approaches for optimisation and assimilation.

- **Accurately taking into account geometric complexity**

  For increasingly detailed mesh configurations, the development of a structured/unstructured hybrid solver for aerodynamics, the exploration of breaks through methods like finite elements, with various turbulence models.

- **Error and uncertainty management for the incorporation of CFD into certification processes**

  Code checking-validation, implementation of error estimators, development of estimation and uncertainty propagation methods, and wind tunnel testing, in collaboration with industry, in order to quantify the uncertainties and biases due to operational and geometrical parameters.

- **Coupled and validated multiphysics multiscale models**

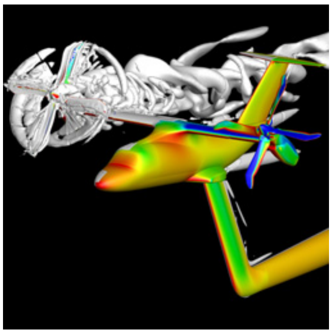
  Conducting hybrid RANS/LES simulations on complete objects (thruster, from the air intake at the engine outlet up to the condensation trails), based on a communication standard between codes and meshes, running in a HPC environment.

- **Leveraging experiment-simulation coupling beyond validation and understanding phenomena**

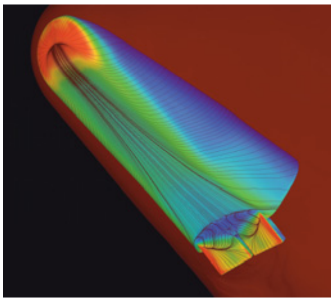
  Developing and directing experiment-CFD hybridisation to refine the understanding of flows, regulating measurements and making them more comprehensive, until air data representative of the model in flight is obtained.

- **Managing exascale computing for numerical simulation**

  Preparing for the arrival of exascale computers through multi-core orientation of the codes and the use of accelerators, in a research approach with manufacturers and accessing national and European infrastructures.



elsA numerical simulation for the European project Nicetrip



Numerical simulation of the atmospheric re-entry of the PreX demonstrator (ESA)

Partners

Cerfacs, Coria, Paris Saclay, Toulouse and Lille ComUEs, Bordeaux University, IMFT; Airbus and Safran groups.

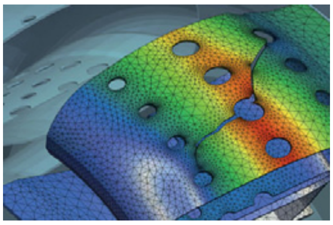
CHALLENGE 6 STRATEGIC AEROSPACE MATERIALS

Developing strategic aerospace materials

The challenge

This challenge relates both to the scientific and technological aspects of the development of materials for the aerospace industry, in order to ensure France's strategic independence and to strengthen its global leadership.

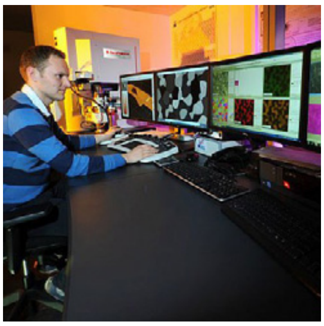
Ensuring France's strategic independence & strengthening its global leadership



Crack propagation with ONERA's Zset Zebulon code

The development of new materials requires long-term investment, and the research, which is necessarily multidisciplinary, covers a very wide range: electronic properties and atomic structure of materials, from the conception, preparation and characterisation of metallic, ceramic or composite materials, to the functional and mechanical behaviour of components in their environment.

All air transport challenges relate to the field of materials



Scanning Electron Microscope (SEM) and microanalysis systems (EDS-WDS-EBSD) for microstructure and alloy chemistry studies

This challenge focuses primarily on air transport challenges, that is to say, the reduction of CO_2, effluents and noise, as well as reliability, but also on those of defence or dual defence/civil challenges, such as exploiting space, increasing competitiveness in terms of cost and performance, and on the development of core skills.

ONERA's assets

- Only French research centre to have all of the means for the design, development, characterisation and modelling of alloys for aerospace applications and their protective systems.
- Advanced capabilities for the physical-chemical, microstructural and thermomechanical characterisation of materials in their environment
- An internationally recognised multidisciplinary skill base focused on the incorporation of the relevant physics into the multi-scale and multi-physics modelling of materials, and on experimental validation
- A historic and strategic partnership with the French aerospace industry

[Breakthrough] Transparent ceramics

ONERA is developing highly transparent ceramics with excellent thermo-mechanical properties, from hot-pressed alumina (Al_2O_3) and spinel ($MgAl_2O_4$) powders.

Defence Applications range from missile windows, transparent to visible and infrared light, to ballistic-resistant windshields for combat helicopters. With a thickness three times smaller, these ceramics offer shielding capabilities equivalent to that of conventional bulletproof glass.

Priorities for 2020

- **Development of the next generation of materials for jet engines and thermal protection systems**
  Developing new ways of manufacturing innovative materials from powder metallurgy, such as additive manufacturing processes, and mastering material-process coupling. Jointly developing structural materials and their environmental protection systems.

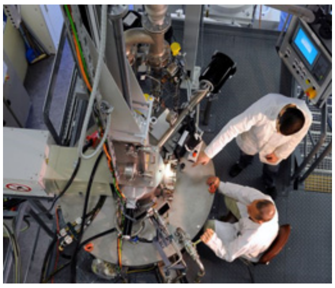
- **Designing, characterising and modelling innovative materials for sound absorption**
  Developing new absorbing materials and metamaterials, with physical properties that are adjustable via their internal architecture using 3D printing and various methodsof powder compaction.

  Developing, characterising and modelling the behaviour of low-density materials that are resistant to very high temperatures
  Developing alternative solutions to conventional alloys aimed at achieving density gains of 20 to 25% by combining refractory, and thus heavier, elements (Nb) with light elements (Ti, Al, Si). Enhancing the toughness of ceramic materials by introducing fibres or by acting on their microstructure.

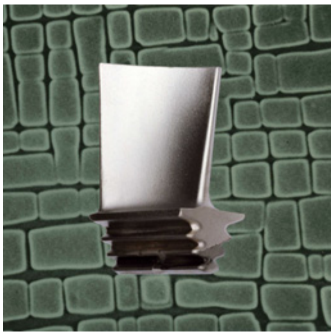
- **Making nanostructures and nanomaterials based on interdisciplinary and experimental expertise**
  Making carbon-based nano-hetero-structures to combine, modify, and exalt the properties of this type of nanomaterials. Direct control of the properties at the nanoscale opens up entirely new perspectives.

- **Mastering multi-scale and multi-physics modelling of materials in complex environments**
  Developing the modelling of physical phenomena, ranging from the atom to the industrial part: alloy design, mechanical behaviour, aging in service, and resistance to extreme conditions.

- **Accelerating the maturation of new materials by optimising simulation-experimentation dialogue**
  Dramatically reducing the time for the development and introduction of new materials by optimising the interactions between experimentation and modelling.



Spray tower to develop materials through powder metallurgy and to develop parts through additive manufacturing



Turbine blade and microstructure of the nickel-based superalloy (AM1)

Partners

Safran, Dassault Aviation, MBDA, Thales, DCNS. Instituts Carnot, Cnes, IRTs, Cetim. Partenaires académiques en IdF, Flagship Graphène.

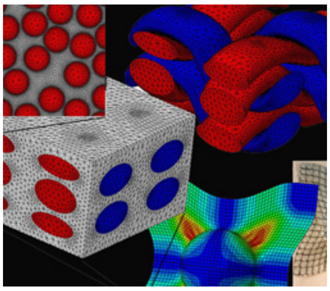
CHALLENGE 7 MORE ENDURING AEROSPACE STRUCTURES

Designing lighter and more environment-tolerant aerospace structures

The challenge

The challenge deals with the scientific and technological problems at the structure scale, and is intended for all aerospace systems: vectors, platforms, and launchers. While civil applications are largely predominant, there are many dual applications. Our research is aimed at preparing and facilitating the work of manufacturers by enabling the design of optimised structures to ensure the necessary level of performance and safety. They also explore the principle and potential of breakthrough technologies.

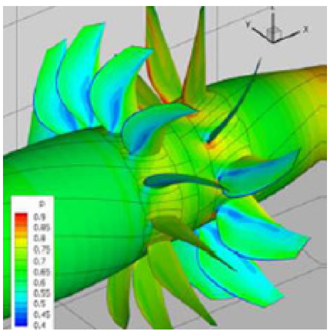
Improving safety, durability, and integrity


Cascading multiscale model of the behaviour and damage in 3D woven composites

Future structural solutions must be lighter and "greener", in order to reduce consumption and emissions, to increase their performance as well as to better meet lifecycle challenges.

Sized relative to normal, limit, extreme or accidental loads, they must ensure at least the same level of safety, durability and integrity. They must not only be resistant, but also be tolerant and adaptable to their natural (aerodynamic, hydric, thermal, icing), mechanical (vibrations), operational (marine, electromagnetic) or aggressive (impacts, lightning, fire, corrosion, abrasion) environment.

Aiming beyond current concepts and developing innovative solutions

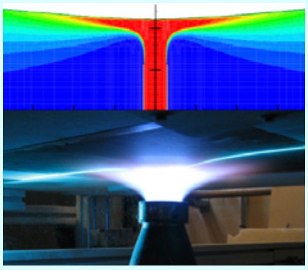

Simulation des couplages aéro-élastiques statiques sur un *counter rotative open rotor*

In order to achieve significant gains, the aerospace industry must aim beyond current concepts and develop innovative solutions. The feasibility, relevance and viability of which will be necessary to demonstrate and prove numerically and experimentally in the light of reasoned test matrices, if not at scale 1, at least on demonstrators and models that can be tested in ONERA's laboratories and wind tunnels.

ONERA's assets

- Expertise and test facilities that are unique in France, for example, the resistance of structures to impact or crash; and large-scale ground vibration tests (GVT) on aircraft;
- Strongly multidisciplinary knowledge and skills;
- International reputation and visibility, close collaboration with the DLR on aeroelasticity, resistance to impact and crashes

[Breakthrough] Materials and fire

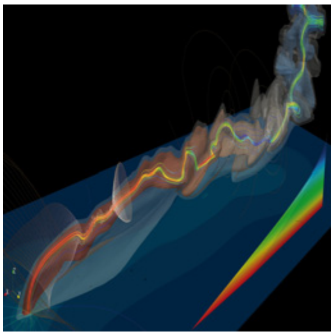


While the fire certification of aerospace materials is established experimentally by standard fire testing (ISO and FAR standards), ONERA is conducting research to understand the physical phenomena involved, ensure better management of safety margins and anticipate new challenges.

Priorities for 2020

- **Development of composites that are resistant to lightning and fire, and evaluation of the effectiveness of their protection**
  Dealing with fire and lightning from a detailed understanding of the physico-chemical mechanisms of the composite material. A "damage tolerance" type approach is used, validated through multi-physics calculations and realistic laboratory tests.
- **Modelling and prediction of the behaviour and lifetime of assemblies**
  Modelling the behaviour of metallic, composite or hybrid assemblies, taking into account the physico-chemical and metallurgical material reactions in assembly processes and predicting their evolution over time.
- **Predicting the lifespan of structures for mass and maintenance cost reduction**
  Treating microstructural heterogeneities, processing-related defects and multiphysics couplings in life prediction models.
- **Identifying, studying and validating future structural concepts**
  Integrating innovative solutions to structures (passive or active), such as health control, functional hybrid structures, integrated actuators, and architectured or functionally gradient materials to optimise aerodynamic flows.
- **Optimising structures in their natural, vibrational, operational or aggressive environment**
  Optimising increasingly lighter aerospace structures, guaranteeing safety (crashworthiness and resistance to impact, avoidance of of aeroelastic instabilities) and taking into account nonlinear physical phenomena.
- **Assessing and dealing with lightning risks**
  In-flight measurements that can be integrated on civilian aircraft, development of validated models, measurement of electrical parameters at the composite/assembly/mounting level, and characterisation of the connection impedances on a complete aircraft.

Crash tower to measure the resistance of structures to crashes



Crash tower to measure the resistance of structures to crashes

Partners

Manufacturers: Airbus, Alstom, Dassault, DCNS, Airbus Helicopters, Safran, Thales; institutions: DGA/TA, École Polytechnique, Ensta, IRT Saint Exupéry.

CHALLENGE 8

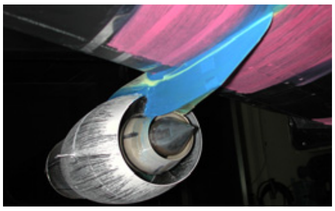
PROPULSION IN ITS FULL COMPLEXITY

Meeting the most stringent propulsion system requirements

The challenge

More reliable, less polluting and less noisy aerobic, liquid or solid propellants, for aircraft engines, helicopters, drones, rockets, missiles, satellites: a considerable interdisciplinary challenge for multi-physics simulation and experimentation-validation, which will be addressed in close cooperation with industrial partners.

A challenge for simulation and experimentation-validation



Wing-nacelle integration. Visualisation with viscous coatings (S3CH wind tunnel, Meudon)

ONERA's assets

- Experience and expertise, integrating "modelling simulation validation experiment physics"
- Metrology and development capabilities
- Interaction with industry (understanding needs and constraints, and supporting development and transfer)

Civil aviation, missiles, launchers, satellites, ... all propulsions

The M1 bench for studying combustion chambers (realistic conditions of cruising flight)

Priorities for 2020

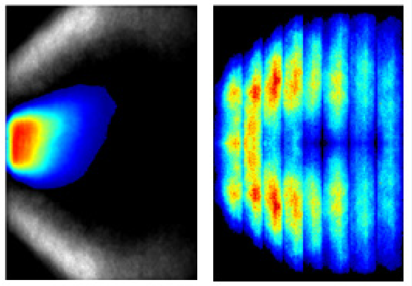
- **Supporting developments in civil aviation propulsion systems**

  In aerodynamics: supporting the industry in its efforts to increase jet engine dilution rates and compression ratios, and the use of alternative fuels, for the development of innovative helicopters and for greater control of the various noise sources, in the context of a greater airframe-propulsion system integration capable of ingesting the viscous regions of the airframe (BLI concept). In thermomechanics: developing and testing high performance materials and new cooling techniques. In the longer term: assessing more electrical hybrid propulsion solutions, in terms of performance and on-board energy management, in partnership with the CEA.

- **Contributing to the design of propulsive solutions for new missile and for the future European launcher**

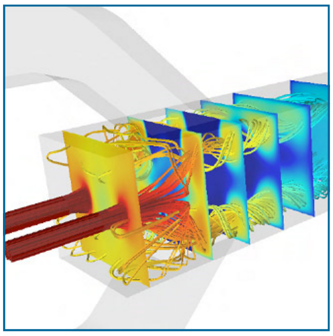
  Control instabilities, attachment and combustion stabilization in ramjets and scramjets, as well as structure cooling technologies for high-speed endurance. Supporting Ariane 6 and its evolution. In liquid propulsion, the idea is to predict the combustion chamber thermal load in order to control liquid oxygen atomization and to estimate the stabi-

[Breakthrough (underway)] Combustion under severe conditions



Qualification of an injector on the M1 test bench for Safran Aircraft Engines, applying PLIF giving the spatial distributions of the OH and kerosene (left) and CO (right), at a pressure of 4.5 bar.

lity margins and lateral loads. In solid propulsion, the idea is to control solid rocket engine pressure oscillations, to improve the robustness of ignition techniques and to develop thrust control means. Finally: to explore breakthrough technologies, such as the use of plasmas to control combustion, the use of green fuels and propellants (REACH compatibility), hybrid propulsion and detonation wave propulsion. All of this research is based on advanced multi-physics numerical simulations taking into account complex geometries, or even scalable in the case of solid propulsion.



Cedre numerical simulation of combustion in an ONERA research ramjet

•Modelling multiphysics couplings to understand the deformation and damage mechanisms and the microstructural evolution of materials and components

Studying the structure and the microstructural evolution of materials through multi-physics and multiscale approaches, based on multi-physical simulations and on chemistry-material and fluid-material interaction models. Use of advanced metrology (optical, spectroscopic, etc.), and development of coupled numerical methods. Setting up a multi-criteria optimisation approach involving aerodynamic performance, structural quality, durability and damage resistance objectives.

Solid propulsion tests in Fauga-Mauzac

•Controlling material/environment interactions

Pushing the limits of component heat resistance domains by testing new refractory materials, thermal barrier deposits or the cooling of architected porous materials, while assessing the thermal degradation of fuels and its impact on circuits. Designing thermo-structural (CMC, ultra-refractory) materials for hypersonic propulsion and proposing new theoretical approaches to support the introduction of blades with larger diameters made of 3D woven composites.

•Developing advanced propulsion for satellites

Making use of present and future test facilities (Cassiopée bench) for low thrust and high altitudes, as well as mastering advanced diagnostics (laser induced fluorescence, micro-Newton balance), while studying plasma physics and global satellite-thruster-space environment interactions, in order to review orbital transfer strategies.

Testing of a CROR engine model in the S1MA wind tunnel

Partners

DGA, Cnes, DLR. Centrale-Supelec, Coria, Cerfacs, CEA, Safran Aircraft Engines, Safran Helicopter Engines, Safran Tech, Airbus Safran Launchers, MBDA.

CHALLENGE 9

PHOTONIC AND OPTRONIC SYSTEMS

Taking advantage of the diversity of optical and optronic observations

The challenge

Currently, the optical and optronic industry produces both large terrestrial, space and airborne observation means, and consumer items used on a daily-basis, such as miniature cameras. This panorama can be misleading: optics and optronics are not yet mature disciplines that we can no longer expect incremental changes in.

Considering data processing as from the design stage of systems

Wide-field curved-sensor infrared camera demonstrator (Temoin DGA project with Sofradir)

Recent or future developments will lead to a broadening of their application scope. These developments are of different orders, such as, for example:

- the drastic increase in performance of current systems
- the development of devices to access new features (3D imaging, passive imaging in new spectral and hyperspectral domains)
- reduction of the cost of development and possession, of the mass and size of equipment for their generalisation to still inaccessible fields (robotics, domotics, environment, etc.)
- consideration of the data-processing function as from the design stage of optical systems, leading to increased performance and a reduction in the constraints and costs with regard to the instrumental part

Widespread use of simulation for design, development, and acceptance

Optronic sensor integration into the pod of ONERA's Busard motorglider

- the coupling optronic and electromagnetic systems to develop new products, and new campaigns
- the widespread use of simulation to design, develop and perform the acceptance of new optronic devices, particularly in the field of defence.

ONERA's assets

The teams have extensive experience in infrared optics. They have recently developed expertise in sub-wavelength optics, plasmonics and nano-optical technology. In the hyperspectral domain, they have proven their capacity to construct a camera with unmatched performance and to process data to take full advantage of the observation wealth. Adaptive optics remains an international flagship.

[Breakthrough] Adaptive optics for astronomy

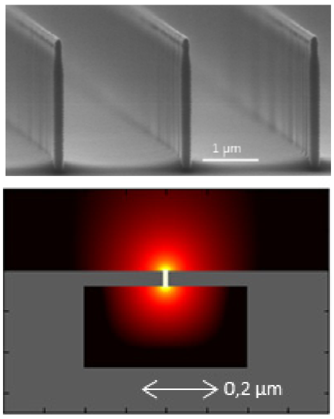
ESO's Very Large Telescope in Chile was equipped with ONERA's NAOS system in 2001, on an 8m telescope, which led to the first direct observation of exoplanets.

Then, the VLT instrument SPHERE was equipped with SAXO in 2014 (first light in 2015), to create a true extrasolar planet imager.

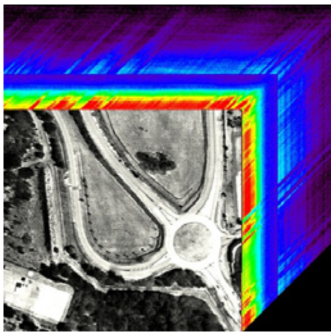
Next challenge: the adaptive optics (AO) of the European Extremely Large Telescope (eELT), which will be equipped with a 39 m mirror.

Priorities for 2020

- **Increasing the spectral and spatial resolution of active and passive remote detection**
  For defence, safety or the environment: object identification, overcoming difficult battlefield conditions, surveillance or expert assessment of characteristic event scenes, mapping in water, vegetation, pollution, urban environments, etc.
- **Develop angular high-resolution imaging at diffraction limits**
  Characterise and model optical propagation through atmospheric turbulence. Correct observations: application for space observation, defence, telecommunications and in the medical field.
- **Mastering miniaturised optical functions and the nano-photonics**
  Focusing light energy, varying its orientation, polarisation, and frequency; designing new thermal sources, new photodetectors for IR cameras, for the analysis of chemical components, and many other applications.
- **Development of new laser sources and their applications: lidar, counter-measures and spectroscopy**
  Increasing the power of lasers. Their agility and frequency stability are applied in anemometry, active or 3D imaging, CBRN threat or pollution detection, etc.
- **Mastering the co-design of new optical sensors and their integrated processing**
  Taking into account the sensor requirement functional description and the associated processing as from the design stage of the sensor.
- **Developing the most accurate simulation of the environment and signatures for sensors**
  Through numerical and experimental developments, making simulation chains more representative by incorporating the environment, the target and the sensor for a more accurate assessment.



Sub-wavelength structures interacting directly with photons



Stack of images of the same scene at different wavelengths, forming a "hyperspectral image"

Partners

The Latmos and the Paris, Grenoble, Aix, and Nice observatories; IRFU, IOGS, CEA-Leti; Sofradir, Total, Leosphere, Tosa or Sagem D & S and many other industrial partners; the Minao joint laboratory with C2N for nanotechnology.

CHALLENGE 10 ELECTROMAGNETISM AND RADAR

Increasing the accuracy and diversity of electromagnetic observations

The challenge

The use of electromagnetic waves in sensors and controlling their effects in operational systems remain a major challenge in light of recent technical advances in terms of equipment, and digital signal or information processing. Unconventional technologies (meta-materials, passive-active coupling, etc.) offer new degrees of freedom to shape the waves and sensors of tomorrow. Increased knowledge of the environment will in addition enable a more dynamic adaptation of the sensors to the context of use.

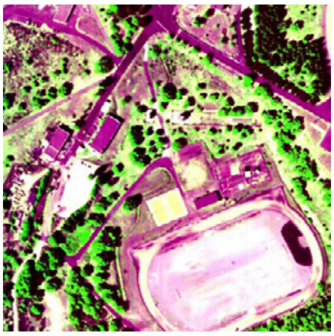
Making possible the transition to all-digital

Numerical simulation of surface currents on a Mirage III subjected to an EM wave

The apparently limitless advances in embedded or laboratory computers opens up new areas of investigation by enabling more realistic simulations (physical or statistical), in particular to calculate signatures, making possible the transition to all-digital radar. These changes will affect areas such as:

- Data acquisition at very high resolution by distributed agile multi-channel systems,
- Simultaneous, and very fast, use of big and multi-sensor data
- Simulation, embedded or not, of more complex and realistic scenes, up to decision support

Simulation, embedded or not, up to decision support



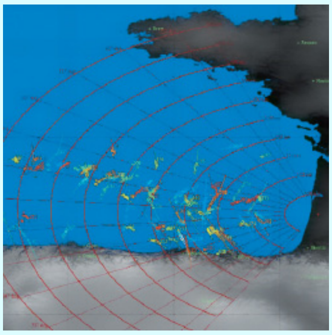
Airborne SAR Image (Sethi) discriminating vegetation

These developments will make it possible to rethink challenges such as smart antennas, distributed radar systems, electromagnetic compatibility, big data, real-time radar imagery, sensor qualification, etc.

ONERA's assets

ONERA is making progress in the areas of sky-wave or surface-wave transhorizon radar, passive radar, all-digital multifunction radar, SAR, and their applications. With a vast experience in propagation or antenna test means, simulations and physics, it is able to comprehensively address the

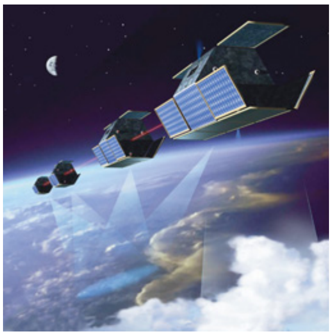
[Breakthrough] Surface wave radars



These radars emit waves that have the property of propagating over the sea surface, beyond the horizon. Surface Wave Radar (SWR) technology, transferred to Thales, is mainly used to monitor exclusive economic zones (EEZ, up to 370km from the coast). We can now track the trajectory and speed of vessels and detect abnormal behaviour.

Les priorités pour 2020

- **Improvement of radar techniques beyond the horizon**
  More energy-efficient architectures, new appropriate meta-materials and algorithms, such as for bi-statism, HV polarisation, use of GPU cards, or the use of several types of propagation.
- **Mastering the future multifunction digital radars, compact, agile and imaging**
  Self-adaptive radar systems, able to manage the allocation of resources in real time (polarisation, waveform, beams, etc.) and based on observations
- **Development of new applications and use of multi-source big data**
  Going beyond the monitoring function (detection, tracking, identification of moving objects, listening) to produce digital terrain models, considering the vegetation, and covered or buried objects
- **Modelling and control of propagation up to millimetric waves**
  Three areas emerge: characterisation of the environment and its spatial and temporal dynamics, modelling of the environment and propagation effects, specific processing techniques for corrections or simulations
- **Reduction of electromagnetic compatibility tests by simulation**
  The integration of modelling tools should enable a midsize plane to be fully simulated in around ten years
- **Modelling the targets and environments of future sensors or electromagnetic systems**
  The DGA has entrusted to ONERA the role of environmental benchmark consultant, with the purpose of conducting research, and building databases and models covering the variety of situations encountered.



ONERA Romulus concept: Earth observation with radar satellites in formation, to detect surface motion

Transmitting antenna of the Graves space surveillance demonstrator, now operated by the French Air Force

Partners

DGA, CNES, ESA and the Indian Space Agency; Thales and the SME Oktal-SE; Universities of Rennes, Limoges, Nice, and Toulouse, or other European universities; the École de l'Air; IFraunhofer (Germany), FOI (Sweden), and finally Singapore with the joint laboratory Sondra.

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CHALLENGE 11

MULTIMODAL ARTIFICIAL PERCEPTION

Controlling the robustness of artificial perception for the analysis of dynamic scenes

The challenge

Artificial perception is a central element in environmental monitoring, security systems, and the autonomy of aeronautical and aerospace systems. It includes spatial-temporal integration processes and data interpretation at various semantic levels that should allow the representation and analysis of dynamic scenes from systems of dynamically reconfigurable smart sensors.

La perception agile par des capteurs intelligents

Swarm of cooperating surveillance drones

The perception systems that ONERA is interested in are often systems on board various types of vehicles. They are therefore constrained by various factors (computer power, environment, communications, etc.). Nowadays, efforts are made to make them smart systems, based on communicating objects, endowed with a high capacity for analysis and decision-making, both to understand the environment in which they operate and to control the vectors that they include, in order to access information more actively and adapt treatment to the purposes.

L'interprétation interactive et le traitement des données massives

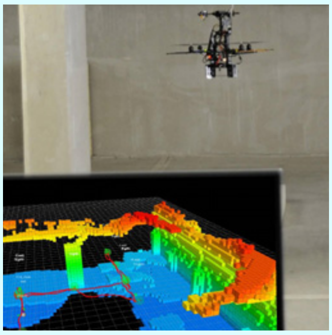
Automatic perception of an area of interest in a scene

Perception systems provide heterogeneous 3D data, often fused with opportunity and georeferenced data, to provide multi-scale representations of dynamic environments. Managing the fidelity of multiscale multiphysics representations and the service quality of data and interpretations leads to needs for learning more adaptive processing of big data, which is sometimes sparse and subject to uncertainties.

ONERA's assets

L'ONERA dispose d'une expertise métier très importante dans le domaine du traitement de l'information géophysique ainsi que pour les systèmes de surveillance et de sécurité. Il a fait également du domaine du traitement embarqué l'une de ses spécialités depuis de nombreuses années.

[Breakthrough] "Visual" drone navigation



A drone equipped with 3D vision and real-time computing capabilities builds its environment as a 3D model, in which it operates by visually assessing its position there. It can make decisions and develop navigation commands itself, according to the objectives of its mission, based on the analysis of its environment and on the detection of objects and events.

The areas of application are varied: monitoring and intervention on railway infrastructures, on EDF transformers, for the military, for construction, art structures, archeology, etc.

Priorities for 2020

- **Perception N-dimensional perception**
  Rendering a spatial-temporal digital representation of the world, with a scale and precision compatible with needs that can be as varied as autonomous navigation, geo-intelligence, multi-physics modelling of environments, surveillance, etc.
- **Data construction in a connected world**
  The hyper-connectivity of future systems is in line with massively heterogeneous architectures with a multi-level and multi-scale merging approach to be explored. It is strategic to know how to evaluate the relevance of information and the visual clarity of the producing sources.
- **Certification of perceptual systems**
  Meeting the safety requirements of autonomous systems based on the critical perception or merging functions, based on formal methods to qualify and certify the use of perception systems.
- **Semantic perception**
  Reducing the semantic gap in the field of vision by computer, studying its temporal dimension to face a triple equation: data, man-machine dialogue and optimal control of a perception system.
- **Global surveillance**
  Propose new remote sensing or video surveillance systems based on breakthroughs in the processing of big data and vector data: microsatellites, UAVs, balloons, etc.

Computer view of a surveilled urban area

The SNCF carries out research together with ONERA on its infrastructure surveillance concepts

Les partenaires

These developments are aimed at a wide range of civil and military applications. They will be the subject of a significant number of research collaborations, particularly with institutions grouped within Paris-Saclay University (Ensta, IOGS, Telecom-ParisTech, CEA-List, ENSC, etc.), as well as UMR-CNRS (Gipsa, Laas, Lip6, Isir, etc.).

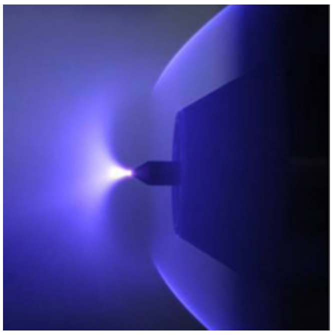
CHALLENGE 12 SENSORS AND SPACE ENVIRONMENT

Developing new sensors and mastering the disturbances of space environment

The challenge

The new sensors are breakthrough vectors through the use of new physical phenomena and/or technologies, for the entire system in which they participate, whether the latter may be atomic instruments or micro/nanosystems, for example. This challenge comprises four families of instruments:

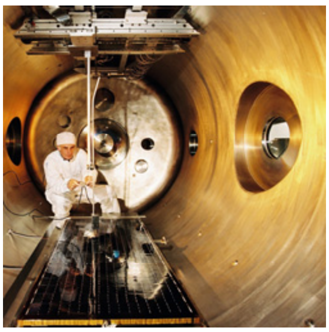
Breakthrough vectors through the use of new physical phenomena



Supersonic experimentation in the R1CH gust wind tunnel on drag reduction with plasma

- **ONERA's ultra-sensitive accelerometers**. Their improvement is necessary to meet the requirements of new space missions relating to fundamental physics and terrestrial or planetary geodesy
- **Manipulating cold atoms** has led to a real breakthrough in inertial techniques, creating new fields of research: accelerometry, gradiometry, and atomic gyrometry. A number of military, space and civilian applications are concerned, such as navigation or object detection
- **Resonant micro and nano-systems** are very effective in producing ultrastable clocks, inertial sensors, or miniaturised high-performance magnetometers; it is a case of juggling research on new concepts and multidisciplinary technological research
- **Managing plasma sources** is essential to achieve future instruments or equipment based on ion beams or electrons leading to a wide variety of applications: stealth, decontamination or flow metrology

Simulation, embedded or not, up to decision support



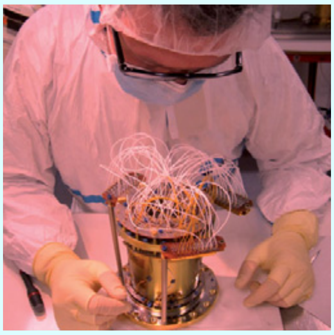
JONAS plasma chamber, enabling the production of an ionospheric-like plasma

The environment of equipment on-board satellites is a major concern. This applies both to objects (debris, satellites, etc.) and radiation. This aggressive environment leads to continuous degradation and failures and it is essential to study these, in order to anticipate or avoid them. Modelling radiation belts and understanding the possible degradation of components has become essential nowadays for space programmes.

ONERA's assets

Specific measurement means, digital tools for modelling and simulation, theoretical and experimental know-how to understand measurement systems and environments that are often complex for the field of aerospace. Result: an often international leadership.

[Breakthrough] Space accelerometry



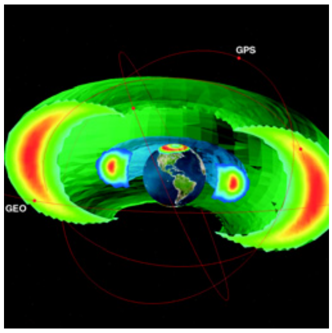
Ultrasensitive space accelerometers, which have been developed by ONERA for over 50 years, enable accelerations to be measured from the movement of a body levitating in an electrostatic field with a record accuracy of up to 10^{-15} ms^{-2}.

NASA, ESA, and CNES trust ONERA for geophysics or fundamental physics space missions such as the missions of DARPA, NASA, ESA and CNES: Champ, Grace, Goce, Microscope, etc.

Priorities for 2020

- **From pico-g to femto-g in Space**
  To better understand physics on Earth and the dynamics of its environment; fundamental physics may be shaken, depending on the results of Microscope, launched in 2016; accelerometers for dedicated space missions
- **Atomic interferometry and inertial sensors**
  Positioning applications, detection of underground gravitational anomalies, geodesy and fundamental space physics; Achieving the goal of having an operational instrument on board any vehicle
- **Inertial sensors to measure µg and µ°/s**
  Miniaturisation, in terms of resolution and stability, multi-axis, multi-sensor, integrated sensor processing, new materials and manufacturing processes
- **Robust and autonomous vector navigation**
  Developing expertise for the benefit mainly of the DGA, with a dual concern for reconfigurable configurations that make use of all available information
- **New plasma sources for defence and aerospace**
  Breakthrough applications for stealth, combustion, aerodynamics, decontamination, and satellite propulsion
- **Accurate and available space climate and meteorology**
  Joining the international effort (observation and modelling) to anticipate the risk of a critical solar geomagnetic storm
- **Nanoelectronics and devices able to withstand the space environment**
  Modelling to reduce experimentation: understanding and reducing component or equipment sensitivity as from the design stage
- **Achievement of a comprehensive space and debris surveillance architecture**
  Capitalising on ONERA's experience for a future monitoring system, undoubtedly European, to limit collision or re-entry risks.

Core of the atomic interferometer in the laboratory, with its operating and measurement windows



Salammbo physical model of Earth's radiation belts, a space weather tool

Partners

Depending on the fields: CNES, OCA, NASA-JPL, ESA, GFZ, Zarm, ENS, IOGS, Sirte, C2N (Paris-Saclay University), ESIEE, CNRS, DGA, and Shom.

GLOSSARY

A

ATM	Air Traffic Management

B

BLADE	Breakthrough Laminar Aircraft Demonstrator in Europe
BLI	Boundary Layer Ingestion
BOS	Background Oriented Schlieren

C

C2N	Centre for Nanoscience and Nanotechnology (CNRS, univ.)
CALTECH	California Institute of Technology
CBRN	Chemical, Biological, Radiological and Nuclear (defence)
CEA	French Alternative Energies and Atomic Energy Commission
CERFACS	European Research Centre Specialized in Modelling and Numerical Simulation
CETIM	French technical Centre for Mechanical Industry
CFD	Computational Fluid Dynamics
CMC	Ceramic Matrix Composite
CNES	French Government Space Agency
CNRS	French National Centre for Scientific Research
CORIA	Frennch laboratory Specialized in Aerothermochemistry
CROR	Counter Rotating Open Rotor

D

DARPA	Defense Advanced Research Projects Agency
DES	Detached Eddy Simulation (CFD)
DGA	French Defence Procurement Agency
DGAC	French Civil Aviation AUthority
DLR	German Aerospace Center
DNS	Direct Numerical Simulation
DSO	Defense Science Organisation (Singapour)
DSNA	Air Navigation Services Directorate (DGAC)

E

EM	Electromagnetic
ENAC	French Civil Aviation University
ENSC	French University in Cognitive Science
ENSTA	French University of Advanced Technologies
ESA	European Space Agency
ESO	European Southern Observatory

F

FOI	Swedish Defence Research Agency

G

GFZ	German Research Centre for Geosciences
GIPSA	Automatic Control, Signal & Images processing, Speech and Cognition Lab (CNRS)
GPU	Graphic Processing Unit

H

HPC	High Performance Computing

I

ICM	French Brain and Spine Institute
IESTA	Air Transport Systems Evaluation Infrastructure
IMFT	Fluid mechanics Institute of Toulouse de Toulouse (CNRS, univ.)
INRIA	French National Institute for Computer Science and Applied Mathematics
IOGS	Optics Institute Graduate School
IPSL	Pierre Simon Laplace Institute
IR	Infrared
IRFU	Institute of Research into the Fundamental Laws of the Universe (CEA)
IRIT	Toulouse Institute of Computer Science Research (CNRS, univ.)
IRT	Institutes of Technological Research
ISAE	Aerospace Engineering University
ISIR	Institute for Intelligent Systems and Robotics (CNRS, univ.)

J

JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory (NASA)

L

LAAS Laboratory for Analysis and Architecture of Systems (CNRS, univ.)
LATMOS Atmospheres, Environments, Space Observations Laboratory (CNRS, IPSL, univ.)
LEO Low Earth Orbit
LES Large Eddy Simulation (CFD)
LETI Electronics and Information technology Laboratory (CEA)
LIDAR Light Detection and Ranging
LIP6 Paris 6 Computer Science Laboratory (CNRS, univ.)
LIST Technological Innovation in Digital Systems Laboratory (CEA)
LIF Laser Induced Fluorescence
LMFA Fluid Mechanics and Acoustics Laboratory (CNRS, univ.)

M

MBDA Matra BAE Dynamics Alenia
MDA Multi-Disciplinary Analysis
MDO Multi-Disciplinary Design Optimization
MEMS Microelectromechanical Systems
MICROSCOPE Microsatellite to Test the Universality of Free Fall (Cnes, ONERA)
MINAO Laboratory of Micro and Nano Optics (ONERA, CNRS)

N

NASA National Aeronautics and Space Administration
NUS National University of Singapore

O

AO Adaptative Optics
OCA Côte d'Azur Observatory

P

PIV Particle Image Velocimetry
PLIF Planar Laser-Induced Fluorescence
PPRIME Instute of Research and Engineering for Materials, Mechanics, Energetics (CNRS, univ.)
SSP ONERA's Strategic Scientific Plan
PYCSHEL Prototyping and Design Bench of Systems for Helicopters (ONERA)

R

RANS Reynolds-Averaged-Navier-Stokes (CFD)
REACH Registration, Evaluation, Authorization and restriction of CHemicals

S

SAR Synthetic Aperture Radar
SHOM French National Hydrographic Service (MinDef)
SONDRA Supelec Onera NUS DSO Research Alliance
SUPELEC Computer Science and Energy University

T

TRL Technology Readiness Level (see p. 4)

V

VLT Very Large Telescope (ESO)

Z

ZARM German Center of Applied Space Technology and Microgravity
ZDES Zonal Detached Eddy Simulation (CFD)

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