

ANNUAL REPORT

2017

ONERA

THE FRENCH AEROSPACE LAB



## ONERA: the French aerospace research center

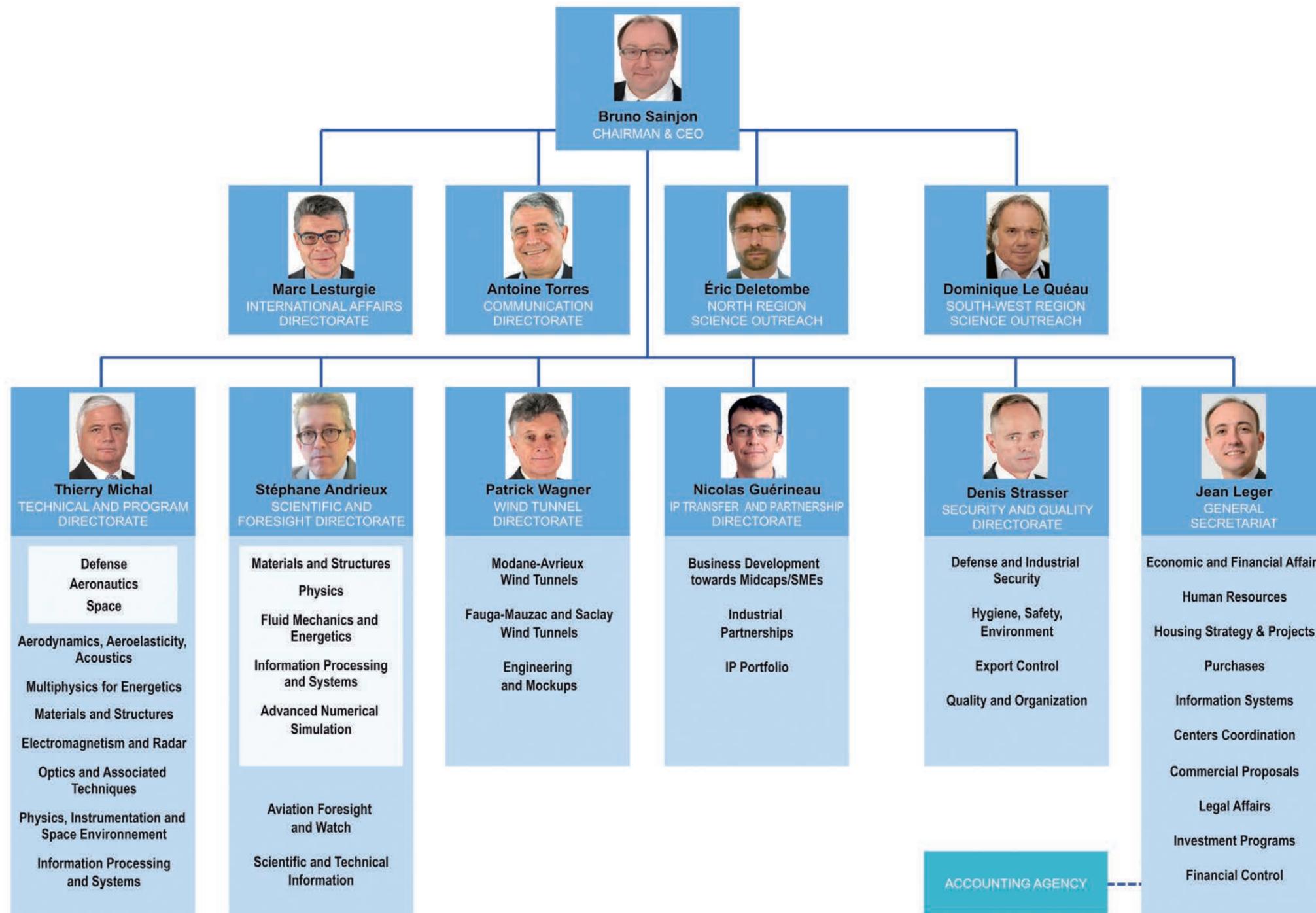


ONERA, a central player in aeronautics and space research, employs approximately 2,000 people. Under the supervision of the Ministry of the Armed Forces, it has a budget of 228 million euros, of which more than half comes from commercial contracts.

As a government expert, ONERA prepares tomorrow's defense, meets future aerospace challenges and contributes to the competitiveness of the aerospace industry.

It masters all of the disciplines and technologies in this field.

All major civil and military aerospace programs in France and Europe include some of ONERA's DNA: Ariane, Airbus, Falcon, Rafale, missiles, helicopters, engines, radars, etc. Its researchers, who are internationally recognized and have often received awards, train many doctoral students.



# Edito

BRUNO SAINJON, CHAIRMAN AND CEO OF ONERA

**2017** is the first full year of the new Objectives and Performance Contract (COP) signed with the Government on December 14, 2016. In this first year, ONERA has met its objectives set by the COP with very good results, both scientific and economic. These successes were achieved thanks to the work done by ONERA employees and the strong support of the Ministry of Defense.

As the first important milestone of the COP, a new organization is now in place. It gives more visibility to our interlocutors and improves our efficiency. Since the Paris Air Show, we have seen how the new ministers and elected officials of both chambers, as well as our partners, appreciate our contribution to defense, aeronautics and space.

2017 ended with a net accounting profit of €7.6 million, while the budget voted by the Board of Directors foresaw a slight deficit. As in the two previous years, this performance is credited with the substantial savings achieved, but also an exceptional grant (€10 million in 2017) from the DGA. In addition, we recorded €113 million in orders placed in 2017, which confirms the return of the trust of our partners. Also worth noting is the resumption of orders for wind tunnels for the amount of €23 million, the highest since 2012, while the soil stabilization works for the S1MA wind tunnel continue and are showing encouraging signs of stabilization.

These good results encourage us to continue the activities undertaken by addressing three major issues: our economic balance, which remains fragile, must be consolidated, our Île-de-France locations must be regrouped, and we must finally strengthen the attractiveness of ONERA to continue to recruit and retain talent.

The Paris Air Show was an opportunity to show our successful achievements and our vision for the future of aerospace. Agreements have been signed with many of our foreign counterparts, thereby contributing to our future successes. Thus, in 2017, out of €113 million in orders placed with ONERA, €24.1 million came from foreign customers, including €7.9 million from the European Union (Commission, ESA). For wind tunnels, out of €23 million in orders placed, €11 million concerned foreign countries.

In this annual report, you will find a dynamic and resolutely forward-looking ONERA, at the service of its defense, aeronautics and space partners. We turned the floor over to them, and their words confirm our progress. They are also a testimony to the individual and collective value of ONERA employees and their work. ■

# Key figures

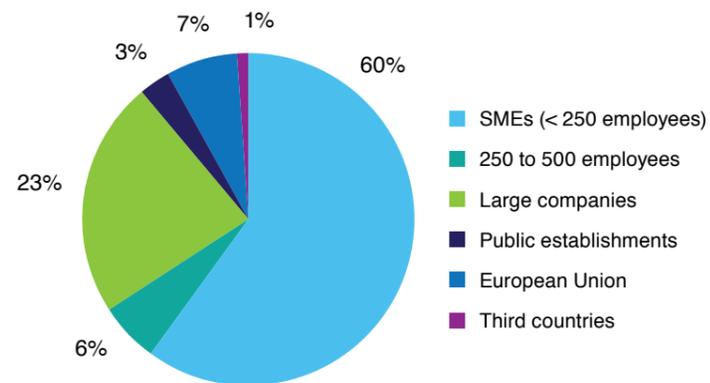
## Investments in 2017: €25.8 million (€21.3 million in 2016)

ONERA has a complete and varied experimental resource park, suitable for each stage of the research process. These installations require a constant renovation and maintenance effort, for ONERA to maintain its level of excellence. In 2017, ONERA spent **3.2 million euros** to strengthen its S1MA wind tunnel in Modane.

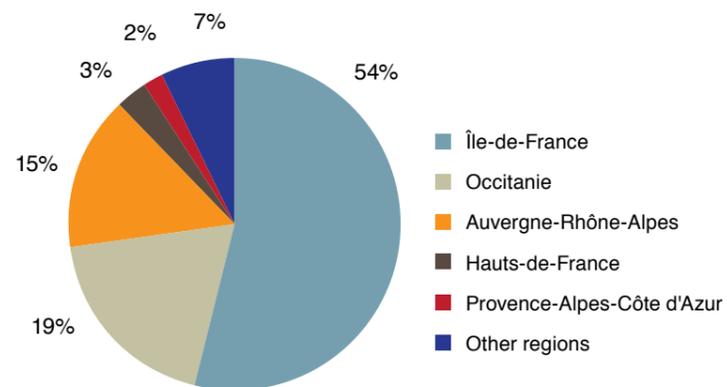
## Purchases

ONERA works mainly with SMEs at all of its centers, in all regions.

Breakdown of the amount of purchases by type of business in 2017

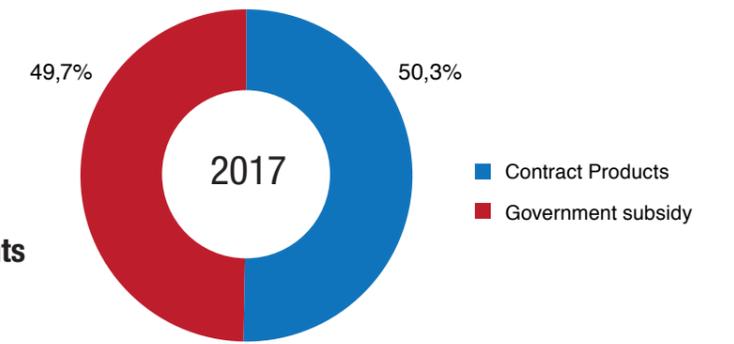


Regional distribution of the amount of purchases from partner SMEs



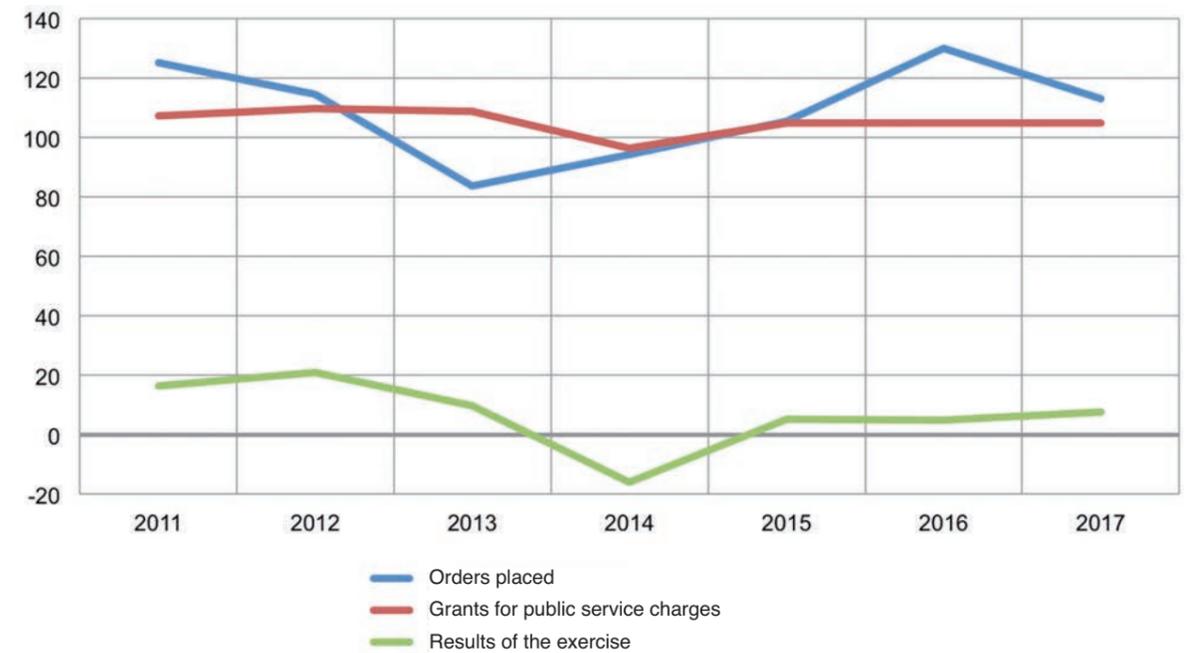
## €228 million budget

€114.7 million in grants from the Government, including €104.7 million from the SCSP\* and €10 million in exceptional grants

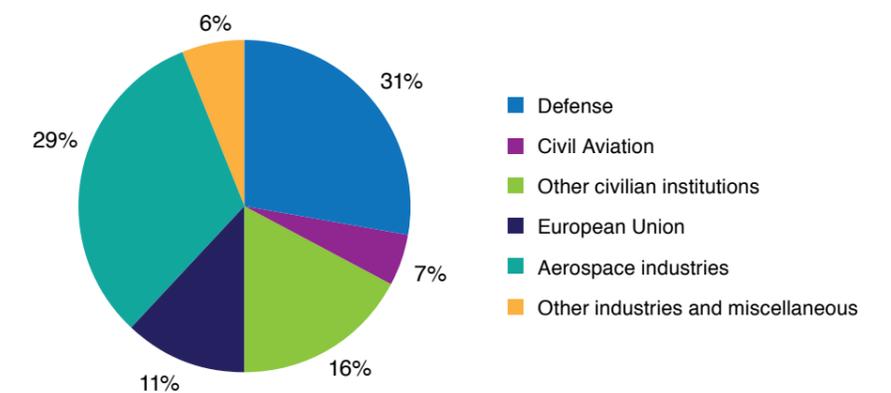


\*Subvention pour Charges de Service Public: Grants for public service charges

## Contractual production: €104 million



## Contractual production by activity area in 2017





**1,960** collaborators

**1,477** engineers and executives

**291** PhD students

**24** post-docs

**215** trainees

**25%** women

**108** recruitments, including 67 engineers and executives

**327** presentations  
in refereed congresses

**248** publications  
in peer-reviewed journals

**1,125** technical reports

**72** theses

**9** habilitations to direct research

**93** HDR

## Training future researchers

Training through research is one of the seven missions listed in ONERA's statutes.

In return, for its engineer-researchers, it is enriching to train PhD students, post-docs and trainees because they offer access to the resourcing of ideas and methods.

In 2017, ONERA had **291 PhD students**, and **72 theses** were presented. To supervise them, it had **93 HDR doctors** (habilitation to direct research), that is to say, researchers with sufficient professional and scientific background to master a research strategy in a scientific field and formally admitted by university to officially advise PhD students.

## Scientific Awards

Zonta International Amelia Earhart Fellowship Scientific Award, awarded to **Narindra Ranaivomiarana**, currently working on a PhD thesis, for her work on Topological Optimization of Composite Aeronautical Structures.

Garteur Excellence Award, awarded to **Franck Simon** and to the work of Action Group HC / AG 20, dedicated to the improvement of acoustic comfort inside the cabin of a helicopter: Simulation methods and experimental methods for new solutions for internal noise reduction.

Young Investigator Award, awarded during the CNES Young Researchers' Days, to **Marina Gruet**, for her work on the Prediction of Radiation Belt Dynamics from the Alpha\_m Magnetospheric Index, and to **Adrien Langenais**, for his research on the adaptation of aeroacoustic methods and tools for jets interacting with space launchers.

SET Panel Excellence Award, awarded to **Pierre Bourdon**, for his work in the NATO SET-198 group on the Vulnerability of the Human Eye to Laser Glare, a group in which twelve nations participated, and whose activities were completed by 2016.

Individual Scientific Achievement Award, awarded by the NATO Scientific Council to **Luc Vignaud**, ONERA engineer working in the Department of Electromagnetism and Radar, for his contribution, in recognition of 16 years of successful activities in NATO's SET (Sensors and Electronics Technology). This is the first time that this distinction has been awarded to a person rather than to a group.

## Posters/Video Animations

Most Artistic Flow Visualization Animation, an award presented during the FDTC/MSTC Flow Visualization Event at the AIAA Aeroacoustics Congress in June 2017, was awarded to **Adrien Langenais** for a video designed in association with the CNES, on code coupling applied to the simulation of space launcher jet noise on takeoff.

Student Poster Session First Prize, awarded to **Ariane Emmanuelli**, for her presentation: Indirect combustion noise in a stator row: 2D modeling and CAA study. Powder and Sintered Materials Symposium 2017 (May 3-5, 2017, in Toulouse) Best Poster Award awarded to **Virgil Malard** by the French Ceramics Group and the French Society of Metallurgy and Materials, for his work on the study of a Nb-Si alloy microstructure in different manufacturing states by powder metallurgy.

Third Best Poster Prize in the 2017 National Composite Days organized by the Association for Composite Materials, awarded to **Yann Todeschini**, **Cédric Huchette** and **Cédric Julien**, for their work on understanding the damage and rupture mechanisms of composite materials manufactured by the QSP process.

## Best Paper Awards

EREA Best Paper Award 2017, awarded to **Frederic Moens**, for his publication: Comparison of Optimization Strategies for High-Lift Design - DeSiReH Project (FP7), at the EREA Annual Event in Brussels.

EREA Second Best Paper Award 2017, awarded to **Olivier Vermeersch** and **Maxime Fiore**, in representation of **Maxime Fiore**, **Olivier Vermeersch**, **Maxime Forte**, **Grégoire Casalis** and **Christophe François**, for the article: Characterization of a highly efficient chevron-shaped anti-contamination device, published in Experiments in Fluids, 2016, at the EREA Annual Event.

Award for the Best 3AF Presentation, awarded to **Pierre Grenson** and **Philippe Reulet** at the 3AF 51th International Conference on Applied Aerodynamics, for their presentation: Flow dynamics and head transfer on an impinging heated jet for a small nozzle-to-plate distance and high Reynolds number.

Award for the Best Presentation by a Researcher Under 35, to **Ye-Bonne Koyama**, for the presentation: Experimental/numerical investigation of a leading-edge vortex on a propeller blade, at the 17th ONERA/DLR Symposium.

Best Student Paper Award presented to **Gabriele Perozzi**, during the 7th Edition of the EUCASS European Conference, for her presentation: Wind rejection via quasi-continuous sliding technique to safely control a mini drone.

Best Student Paper, presented to **Claire Li**, at the PIERS Conference in Singapore, for her presentation: Far-field to Near-field Investigation of Thermal Radiation Emitted by a Single Optical Nanoantenna.

Best Student Paper Award, presented to **Khanh Linh Nguyen** at the SPIE Remote Sensing Conference in Warsaw, for the article: Measurement of the spatial distribution of atmospheric turbulence with SCINDAR on a mosaic of urban surfaces.

Best Paper Award, awarded to **Abigaël Taylor**, at the International Conference on Radar Systems, in Belfast, UK, for the article: Reducing false alarm rate by testing proportionality of covariance matrices, co-written with **Hélène Oriot**, **Frédéric Brigui** and **Laurent Savy**.

Best Paper Award, presented to **Maxime Bucher**, **Stéphane Herbin** and **Frédéric Jurie**, for their article Generating Visual Representations for Zero-Shot Classification at the International Conference on Computer Vision 2017, in Venice.

Young Visionary Award, awarded to **Sara Correyero-Plaza** and her co-authors from the *Universidad Carlos III de Madrid*, for the article: Innovative Electric Propulsion trends, concurrent mission design and enabling technologies for a bold CubeSat Lunar Positioning System, at the 35th International Electric Propulsion Conference, in Atlanta.

RADECS Award, presented to **Pablo Caron**, for the article: Physical mechanisms inducing electron Single Event Upset, co-written with **Christophe Inguibert**, **Laurent Artola**, **Nathalie Chatry**, **Nicolas Sukhaseum (TRAD)**, **Robert Ecoffet** and **Françoise Bezerra (CNES)**, during the conference: Radiation Effects on Components and Systems, in Geneva.

## D I S T I N C T I O N S

**Bruno Sainjon**  
Commander of the National Order of Merit,  
by Decree of 06/11/2017

**Christian Colas**  
Officer of the National Order of Merit,  
by Decree of 04/11/2017

**Antoine Torres**  
Officer of the National Order of Merit,  
by Decree of 06/11/2017

**Pierre Bourdon**  
Knight of the National Order of Merit,  
by Decree of 12/10/2017

**Anne-Marie Naldi**  
Knight of the National Order of Merit,  
by Decree of 02/05/2017

**Stéphane Andrieux**  
Officer of the Order of Academic Palms,  
by Decree of 03/08/2017

**Pierre Caron**  
Knight of the Order of Academic Palms,  
by Decree of 11/01/2017

**Riad Haidar**  
Knight of the Order of Academic Palms,  
by Decree of 03/08/2017

**Hélène Piet-Lahanier**  
Knight of the Order of Academic Palms,  
by Decree of 03/08/2017

**François-Xavier Roux**  
Knight of the Order of Academic Palms,  
by Decree of 03/08/2017

**Juliette Ryan**  
Knight of the Order of Academic Palms,  
by Decree of 03/08/2017

**Catherine Tessier**  
Knight of the Order of Academic Palms,  
by Decree of 11/01/2017

**Muriel Brunet**  
Aeronautics Medal,  
by Decree of 26/01/2017

**Laurent Serre**  
Aeronautics Medal,  
by Decree of 22/08/2017



## INNOROBO trade show: excellent visibility of ONERA's work in robotics

ONERA presented its recent work in autonomous navigation, mission planning and onboard perception of aerial, ground and submarine robotic systems. Among visitors to the ONERA booth: Valérie Pécresse, president of the Île-de-France regional council, Xavier Bertrand, president of the Hauts-de-France regional council, and Arnaud Montebourg, who was, as Minister of Industry, behind the *Nouvelle France Industrielle* plan, in which robotics occupies an important place. During the General State of Robotics event, which took place on this occasion, ONERA made several interventions that were noted.



## Explaining ONERA and its challenges to parliamentarians

As part of the preparation of the 2018 Finance Act, ONERA's chairman was twice heard in the National Assembly and once in the Senate: proof of parliamentarians' interest in ONERA, and a unique opportunity to present to them in detail the situation and prospects of the research center.



## Arianespace and ONERA sign a partnership agreement



Signed in Paris between ArianeGroup Executive Chairman Alain Charneau and ONERA CEO Bruno Sainjon in March 2017, the partnership agreement defines the most effective ways to collaborate. With the aim of meeting global competitiveness challenges, in the fields of space and defense technologies, this partnership is intended to throw light on the basic research developed by ONERA in the fields related to strategic and space transport systems and technologies.

## Paris Air Show 2017:

### ONERA invites its partners to "invent the future of aerospace together"



Resolutely open to international visitors, the ONERA stand and the message chosen reflected the establishment's new organization around three program directions: defense, aeronautics and space. The importance of the collaborations was thus put forward, as well as the renewed confidence of the government partners (DGA, DGAC and CNES) and the industrialists. ONERA's presence alongside the DGA and the industrialists on the stand of the Ministry of the Armed Forces, alongside the CNES on the GIFAS Paris-AirLab space, in the AIRCAR cluster, or with the Réplic'Air association, illustrated this dynamic.



## ONERA participates in the first two scientific councils of the gendarmerie

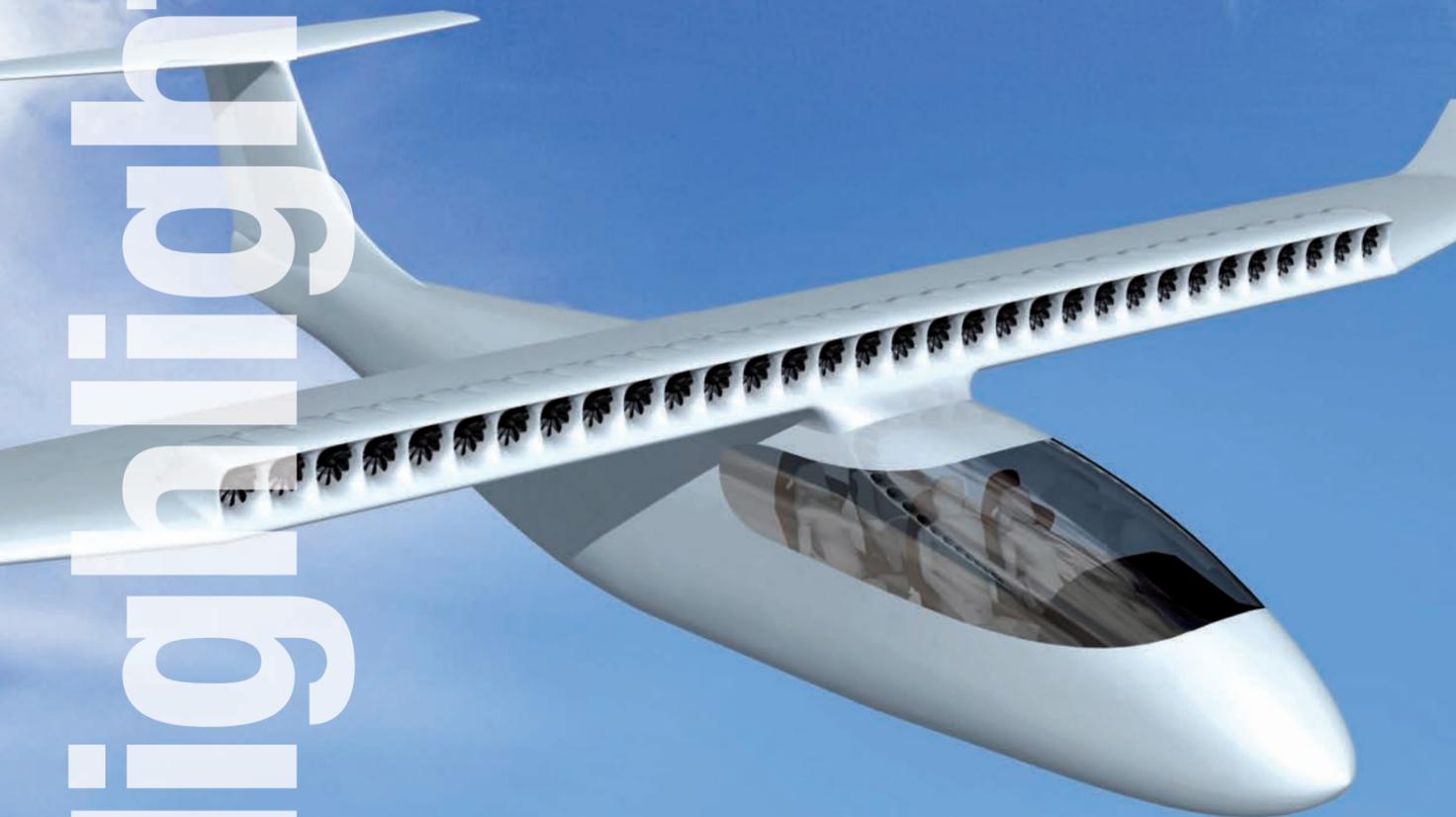
These councils bring together representatives of universities, public scientific institutions (ONERA, CNRS, CEA, etc.), the DGA, the CNIL, and the ministerial delegation for security industries and cybercrime, as well as external personalities. ONERA's participation underlines its willingness to collaborate with the Gendarmerie. Ever since the first flyovers of sensitive facilities by pirate drones in 2014, a partnership agreement had been signed. ONERA's goal is to provide the National Gendarmerie with scientific expertise in various fields: drone systems, biometrics, land and air robotics, site protection and surveillance, laser, radar, scrambling, speech processing or stealth technologies, etc.



## SGDSN visit to Palaiseau

Louis Gautier, Secretary General of Defense and National Security, visited the ONERA center in Palaiseau accompanied by several of his close collaborators. He underlined the "very remarkable presentation of the capacities and works of ONERA, whose performances are essential for our defense and our aeronautical industry".

# 2017 Highlights

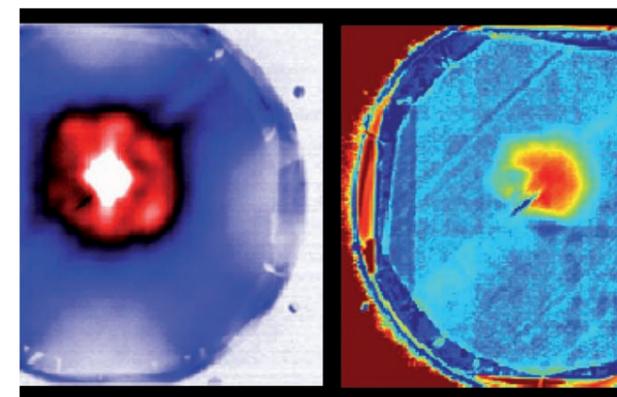


## Space physics: Microscope delivers its first results

Microscope is the CNES scientific mission dedicated to the testing of the principle of equivalence, for which ONERA has the scientific responsibility (instruments, scientific mission center, PI, etc.), together with the OCA (CNRS) and the ZARM (Germany). The first results demonstrate, with unequaled precision, that is  $2 \cdot 10^{-14}$ , that bodies fall in a vacuum with the same acceleration, whatever their composition. This is a new confirmation of the general relativity established by Albert Einstein.

## High-performance computing: ONERA in the United States for Super Computing 2017

As part of the collaboration in the Intel Parallel Computing Centers, ONERA has been selected to present, on the Intel stand, its experience of modernization of industrial code, on the occasion of the global event of HPC, in Denver, Super Computing 2017.

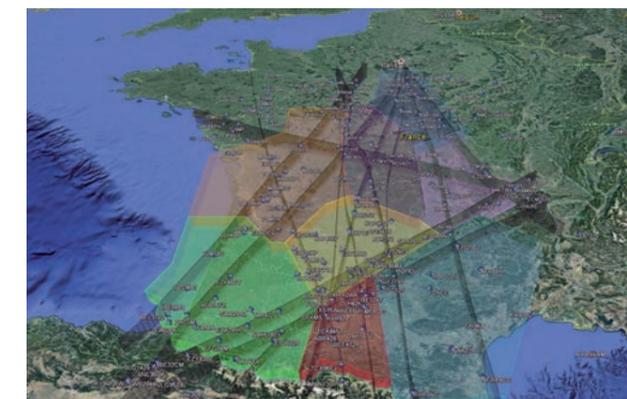


## Composite materials: first dynamic characterization by infrared thermography

For the ONERA Thermosolex project, on damage monitoring in composite material dynamics (impact, lightning, fire, complex mechanical loads, etc.), ONERA has managed to monitor, for different speeds, the evolution of the matrix cracking rate of a laminated composite material under dynamic loading. This scientist breakthrough opens up new composite research perspectives.

## Two ONERA engineers selected in reference technical committees

Nathalie Bartoli and Peter Schmollgruber were selected as experts in the Multidisciplinary Design Optimization (MDO) and Aircraft Design technical committees of the American Institute of Aeronautics and Astronautics (AIAA). They will contribute in particular to the animation of the topics and to the organization of the Scitech and Aviation conferences.

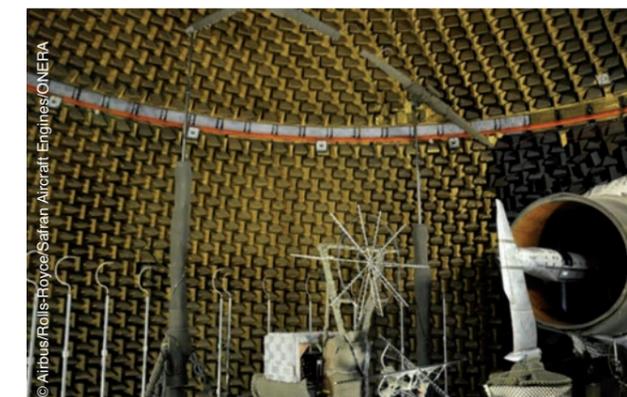


## ONERA collaborates with air traffic controllers

As part of the SESAR program to modernize ATM (Air Traffic Management) systems, ONERA is working with the Air Navigation Services Directorate (DGAC / DSNA) on dynamic sectorization. Objective: to provide decision support tools based on optimization algorithms.

## The E-Break project winner of the Stars of Europe 2017 trophy

This project is aimed at developing the technologies behind a new generation of turbojet engines that are both more fuel-efficient, environmentally friendly and less expensive to manufacture. ONERA has contributed to this by developing an optimized latest-generation TiAl-based alloy, replacing the nickel-base superalloys of aeronautical engines.

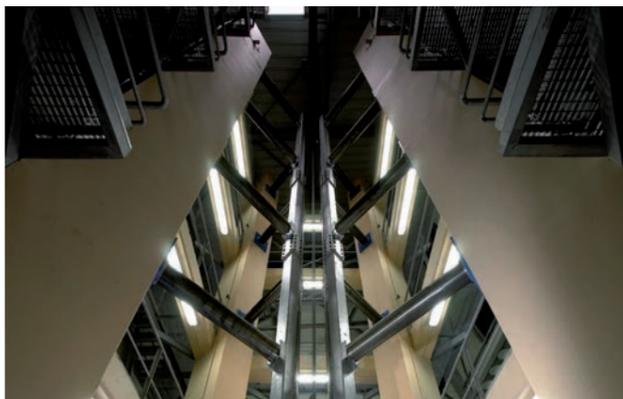


## End of the Jeronimo project on jet-wing interaction noise

This European project is aimed at improving the knowledge on jet-wing interaction noise, which is greatly amplified when the nozzle is close to the wing (which is the case of future-generation engines). On the program: eLSA numerical simulations and a major test campaign in the Cepra 19 acoustic wind tunnel, with far-field measurements, wing pressure sensors and two microphone networks.

## Hybrid propulsion: an innovative combustion chamber

The Hydroprogeco project, funded by the EU's H2020 program, is aimed at developing a hybrid propulsion engine for satellite positioning. ONERA has designed an innovative combustion chamber called a "compensated regression" chamber. A demonstrator was developed and tested at ONERA, raising the TRL from 1 to 4 in less than three years.



### Innovative test campaign with ONERA's crash tower

Thanks to the development of a specific carriage to increase speed, the most important tests in terms of impact speed (17 m/s) and impact energy (> 150 kJ) have been achieved with the Lille crash tower. Conducted for the FUI\* Ballo project, these tests are aimed at validating the resistance of different helicopter tank fuel configurations, compared to the standards in force.

\* Fonds unique interministériel – Single interministerial fund

### World breakthrough in laser metrology to analyze solid propellant flames

Supported by the CNES, an ONERA thesis proposes an original measurement technique for solid propulsion, in which the very intense fluorescence signal of aluminum makes it possible to follow the agglomerates formed during combustion in real time. ONERA therefore has a relevant resource for the fine analysis of solid propellants in combustion and plasmas.



### Space environment: new resources for surface analysis

The Alchimie bench, in which ONERA has invested, makes it possible to analyze the surface of materials using an ion source, and to probe their thickness. It provides a better understanding of surface phenomena for applications such as electronic emission, aging, erosion, contamination, etc.). Potential customers: space agencies and industrialists in the sector.

### Instructive distributed propulsion tests

The internal project AMPERE defends two key technologies for the future of hybrid-powered aircraft: the aerodynamic effects of multiple propellers and piloting techniques combining traditional control surfaces with distributed propulsion. Conducted on an ONERA model, the tests showed the efficiency of the technology. The acquired database will be able to confirm the aerodynamic behavior to develop suitable control processes.

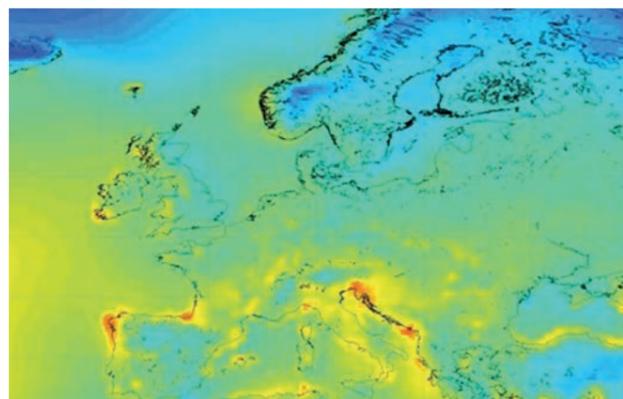


### ONERA upgrades its Sethi airborne test facility

The Sethi-2020 investment program has enabled digital acquisition and tracking systems to be replaced, allowed the remote sensing platform transmitters/receivers to be upgraded and made it possible to acquire new, more accurate computers. Funded with ONERA's own funds, the program will enable the acquisition of a new optronic sensor and new laboratory qualification resources.

### First discovery of an exoplanet with ONERA's adaptive optics

ESO's European Very Large Telescope, equipped with the SPHERE instrument and its ONERA adaptive optics system, links discoveries, in particular, a giant extrasolar planet. The real-time correction of the adverse effects of atmospheric turbulence (nanometric precision) is one of the keys to this performance.

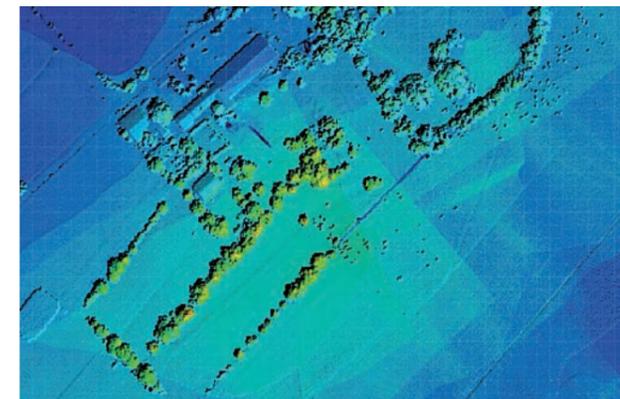


### ONERA statistical model becomes a global standard

This model was adopted in March 2017 by the International Telecommunication Union as a global standard: it allows the calculation of rainfall intensity, which is the basic input data for rain attenuation forecast models for Earth-Space, Earth-aircraft and terrestrial links. The work was conducted by ONERA as part of an ONERA-CNES common interest program.

### Space/Earth optical communications: ONERA honored in Japan

Together with its partners, ONERA was rewarded during an international workshop for the success of the Domino project (optical demonstrator for high-speed transmissions in orbit), funded by the CNES and carried out by the OCA, ONERA, Thales Alenia Space and Airbus Defense and Space. The demonstrator established in 2015 the first corrected optical links for atmospheric turbulence effects using ONERA's adaptive optics.



### The Terriscope platform strengthens its capabilities with hyperspectral imaging and 3D laser

For this platform of optical instruments and drones, dedicated to imaging and airborne measurement for the study of the environment and territories, ONERA has equipped itself with the best state-of-the-art very-high-spatial-resolution resources through a hyperspectral imager for aircraft (50 cm spatial resolution over the entire spectral range) and high-performance 3D lidar imagers for aircraft and drones.

### Success of the Stealth Materials and Smart Structures event

Co-organized by ONERA and the DGA, the MAFUSI thematic days gathered more than 250 people (industrialists, DGA, research centers, university laboratories, etc.), from the 7th to the 9th of November 2017, around the topics of structure health inspections and additive manufacturing, radar stealth, optics, acoustics and windows. The objective: to draw up an inventory of the issues, the latest advances and perspectives.



### ONERA leader in the Semantic3D benchmark for the interpretation of laser scenes

Three ONERA engineers presented at the Eurographics congress an artificial intelligence method (deep learning) for the classification of 3D point clouds: SnapNet. Developed within the framework of the ONERA DeLTA project and the European FP7 Inachus project, it ranked first in the Semantic3D benchmark, which concerns urban data interpretation (automatic discrimination of buildings, roads, etc.).

### Remote sensing: airborne monitoring of water leaks

Project H 2020, WADI – Water-Tightness Airborne Detection Implementation – is studying the feasibility of an airborne service for monitoring water leakage during transportation in rural areas. ONERA conducted preliminary tests to determine the optimal optical wavelengths, using its Busard air platform equipped with pods carrying hyperspectral and infrared cameras. The results are convincing: leaks were observed and confirmed by image processing. Once the wavelengths of interest are determined, a prototype with multi-spectral and infrared cameras will be developed for aircraft and UAV platforms provided by partners.

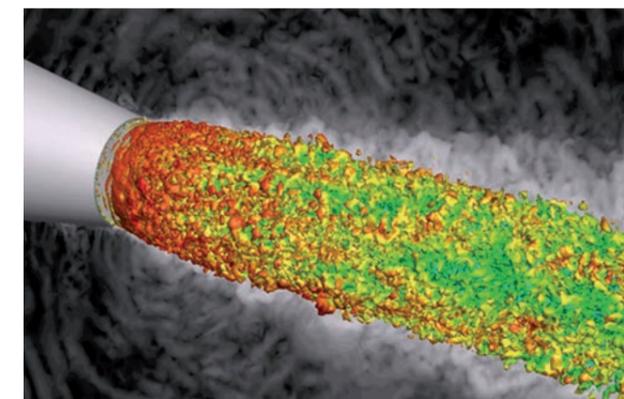


### Big data: launch of the Medusa project

ONERA has been engaged by local authorities to lead this project. Objectives: planning of urban development and monitoring of "smart cities". In 2017, a database construction campaign on the Saclay plateau, with an order for several very-high-resolution optical satellite or radar data sets. Preliminary results on structure monitoring from space have been published and supported by on-site measurements by experts.

### ONERA, one of the main contributors to a NASA code

It is mentioned in the reference magazine Aerospace America, together with NASA and other US and European laboratories. Its contributions to the Open MDAO code: the definition of new components in the framework structure, the proposal of associated methods and the production of a multidisciplinary aircraft design test-case. These are being carried out for an ONERA project aimed at providing it with a multidisciplinary design workshop.



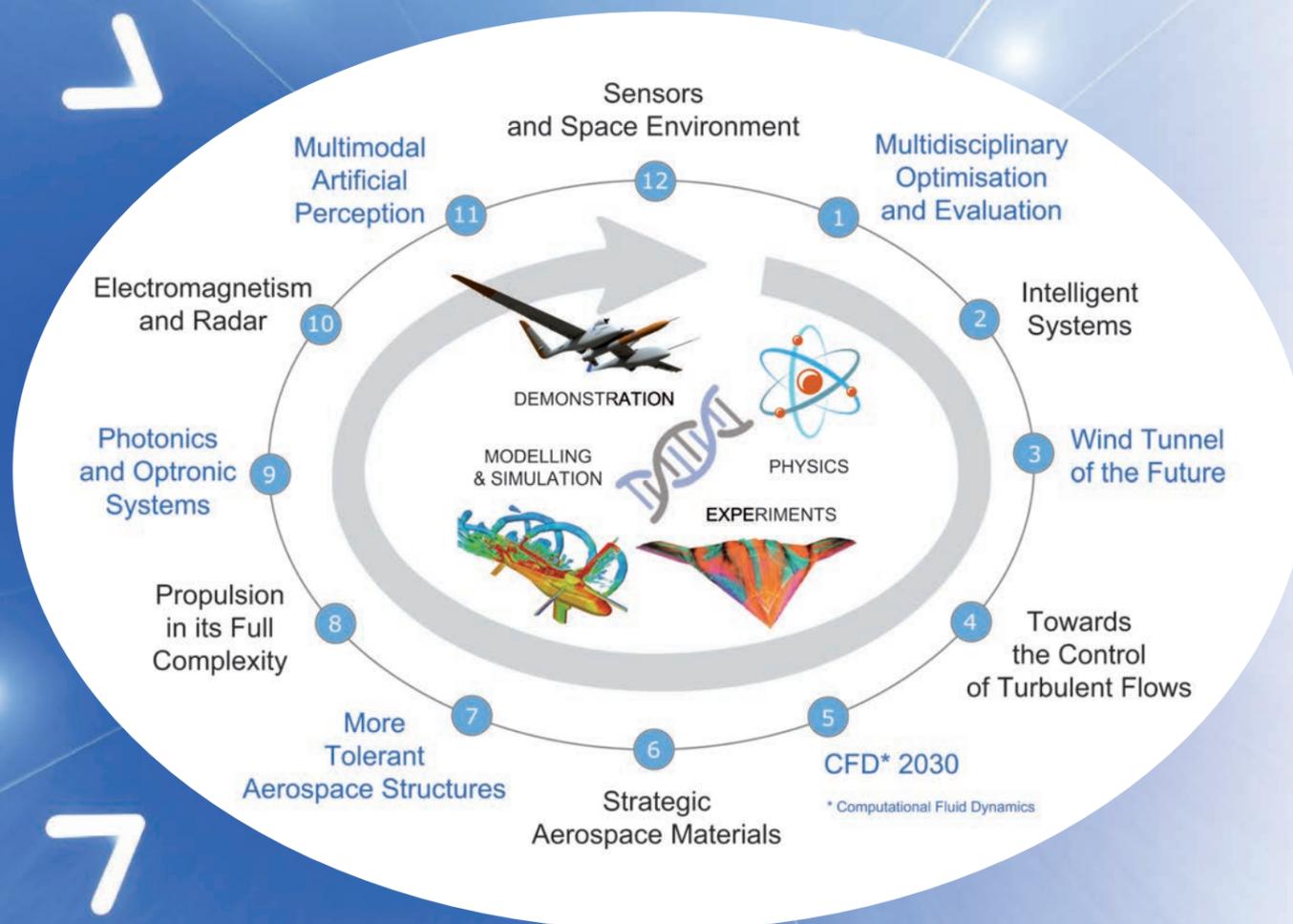
### Numerical simulation code: finer simulation of turbulence

The internal project REALITY, aimed at strengthening the robustness and efficiency of the Aghora CFD research code and broadening its scope, should allow the most accurate simulations, through advanced turbulence modeling. Significant milestones have been achieved, including the ability to simulate highly unsteady turbulent flows with high-precision diagrams, representative of the problems faced in industry.

### ONERA at the top of laminar-turbulent transition modeling

ONERA participated in NASA Langley's workshop on turbulent laminar transition modeling in CFD codes, in order to present its state-of-the-art approach and tools. ONERA's high level of expertise has been widely welcomed. These features are available in the elsA software.

# Strategic research at ONERA: The technologies of tomorrow are being prepared today



**S**trategic research is financed by ONERA with its own funds, using the subsidy for public service that it receives from the Government.

This research is mainly in the form of projects that are often highly multidisciplinary. Their animation, steering and evaluation are carried out by the Scientific and Foresight Directorate, in accordance with the 12 scientific challenges defined in the scientific strategic plan.

This research is fertile ground for training through research (300 PhD students at ONERA).

Scientific outreach is ensured by publications in journals, by participation in conferences and workshops, etc., and by the publication of AerospaceLab Journal, ONERA's half-yearly scientific journal, which presents its state-of-the-art research. Open to external contributions, more than 4,000 subscribers receive it.

In 2017, as part of ONERA's reorganization, five scientific areas were defined. They are divided into 54 research topics that will feed the roadmaps, which are the vectors of ONERA's scientific strategy.

## Fluid mechanics and energetics

In aerodynamics, we study and model the fundamental phenomena that limit the performance of aircraft, such as turbulence, detachments, vortices, noise sources, and shock waves, as well as their coupling with the behavior of structures. Noise contribution is also an important research topic. In energetics, the development of more efficient and environmentally friendly propulsion systems is dependent on controlling the different types of combustion, and on designing and characterizing new fuels. This field also covers research on the coupling of different physics, such as the behavior of materials subjected to intense heat flux or to the formation of ice on sensitive aircraft surfaces.

## Materials and structures

The scientific process begins at the finest scales, in order to understand the basic mechanisms involved and to determine the models and key parameters, as well as the change-of-scale approaches. The development of new materials, the construction of behavioral laws, and the modeling of aging or damage phenomena constitute the second major line of research, which must be associated with observation methods, particularly in field theory, and with the development of in-service monitoring or manufacturing process control resources. Couplings with aerodynamics, thermal phenomena or electromagnetism must be taken into account: their modeling, their numerical simulation using high-performance computing and, of course, experimentation constitute the third major line of research in the field. The development of the link between calculations and tests is essential here.

## Physics

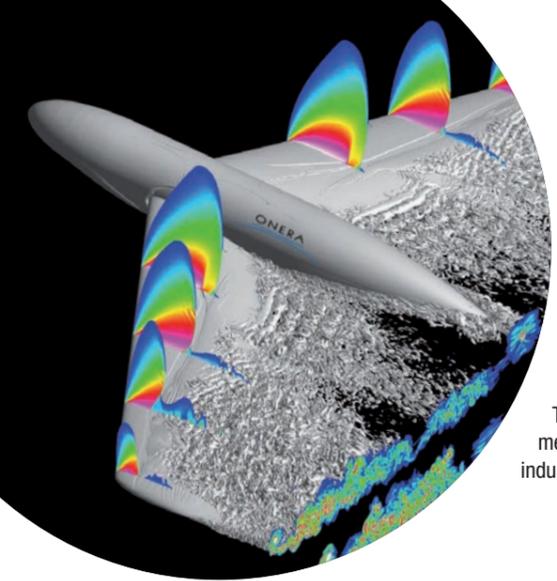
The activity is aimed at designing and implementing measurement and observation systems for both defense and civilian aerospace applications. It ranges from fundamental components to integrated systems in their environment. These resources must meet the observation, detection, identification and measurement challenges being the least intrusive possible, at increasingly greater distances, faster, and with constantly improving resolution and experimental robustness, in order to better understand the physics underlying the phenomena observed.

## Information Processing and Systems

Much of the research is focused on the design of aeronautical and aerospace systems, and of defense, surveillance and security systems, as well as on the deployment of these systems in complex missions, on the processing of big data from embedded sensors and on the development of knowledge about large-scale phenomena. Many of these works lead to experimental developments: minidrones and drones, land and submarine robots, flight control interfaces, smart sensor networks, and so on. Others lead to software platform developments – air traffic, battle lab, MDO design, etc. – for creating digital models and for evaluating operational performances by physical simulation.

## Advanced numerical simulation

This field includes the entire research and development process associated with ONERA's scientific and technical production that is done in the form of software. It thus covers, for all physics disciplines, modeling research, algorithmics and applied mathematics studies, high-performance computing related problems, the couplings between different physics, model reduction techniques, and uncertainty consideration.



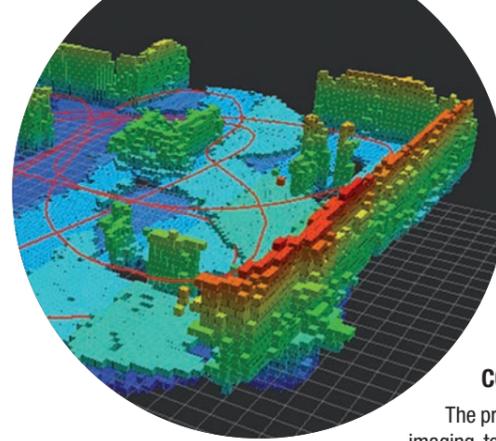
**CFD 2030**

**ADER – Development of innovative shape optimization methods**

ADER has made it possible to develop and validate a numerical tool (adjoint solver) able to efficiently optimize, from the point of view of aerodynamics, the shape of objects forming part of rotary machines like compressors or turbines. Incorporated into ONERA's aerodynamic code elsA, the tool has also benefited from the activities of the IRT St-Exupéry (Toulouse). > [1 presentation](#)

**HARP2 – Hybrid CFD strategy for simulating complex configurations**

The HARP2 project allows ONERA's aerodynamics code of elsA to work with unstructured and hybrid meshes, which are much better suited than conventional structured meshes to the simulation of complex industrial flows. > [1 thesis, 2 presentations](#)



**PHOTONICS AND OPTRONIC SYSTEMS**

**FanToMas – Optics: design and implementation of new FTM techniques**

The FTM technique (a technique based on the use of a modulation transfer function) makes it possible to measure the ability of a detector or an imaging system to restore the details contained in an observed scene. The project has enabled ONERA to be an expert for the DGA in the use of this technique and has resulted in collaborations with the academic world and the industrial sector. > [1 publication and 1 presentation](#)

**COPIE3D – Exploring deep imaging**

The project has made it possible to identify the performance and application possibilities of sensors used in optical imaging, to develop treatments that improve the accuracy of these sensors and to produce demonstrators using optical imaging systems. COPIE3D has benefited from a collaboration with the Fresnel Institute. The concepts developed are transposable to multi-spectral imaging (use of spectral bands going beyond the optical band). > [1 thesis, 2 publications and 5 presentations](#)

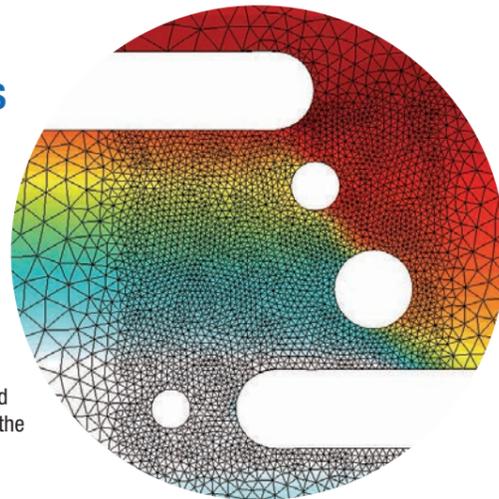
**STRATEGIC AEROSPACE MATERIALS**

**LOCOMOTION – Mechanical behavior of a material in an aggressive environment**

The project improves the reliability of testing resources for evaluating the hardness of a material, or more precisely its elasto-visco-plasticity, by indentation (observation of the effect of penetrating the material with an object). The testing resources makes it possible to test materials in a high-temperature and/or chemically aggressive environment. > [1 scientific presentation](#)

**MECHANICS – Test-calculation dialogue platform**

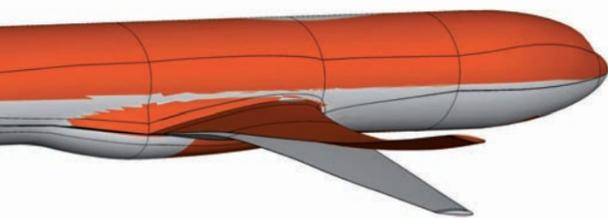
A computer platform makes it possible to optimize the results of mechanical tests (on a solid subjected to constraints), more particularly field measurements, during the simulation of the behavior of solid objects subjected to constraints. > [1 thesis, 4 publications, 9 presentations](#)



**MORE ENDURING AEROSPACE STRUCTURES**

**HYBRID STRUCTURES – Design of cofabricated composite/metal structures**

The project demonstrates that it is possible to improve the mechanical strength of a metal panel using a technique consisting in direct polymerization on the panel, that is to say, without using an adhesive or assembly elements, or a composite stiffening material. The project resulted in academic collaboration with the Luxembourg Institute of Science and Technology and an industrial partnership with MecanOLD, the space equipment supplier. > [3 publications, 4 communications](#)



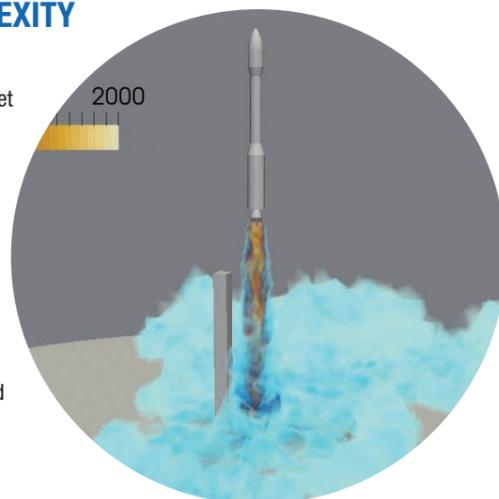
**PROPULSION IN ALL ITS COMPLEXITY**

**AJIL – Controlling the acoustic environment of launchers**

The project led to the implementation of an aeroacoustic simulation method for the engine jet noise of a rocket on takeoff. This method is based on the strong coupling of an unsteady flow simulation (LES) method and an acoustic simulation method (CAA). The work has contributed to the development of a joint interest ONERA-CNES program and will be extended to the simulation of civil aircraft engine jet noise. > [1 thesis, 1 publication, 6 presentations](#)

**CYPRES – Combustion simulation in space thrusters**

The project led to the creation of a computer tool that reports the evolution of the internal geometry of a solid propellant rocket engine, following the consumption of the propellant. Other applications are conceivable, such as shape optimization, simulation of the shape evolution of objects subjected to icing phenomena, or the automatic generation of meshes for numerical simulations. These works are part of an ONERA-CNES joint interest program and have benefited from a collaboration between ONERA and the INRIA. > [1 publication, 3 presentations](#)



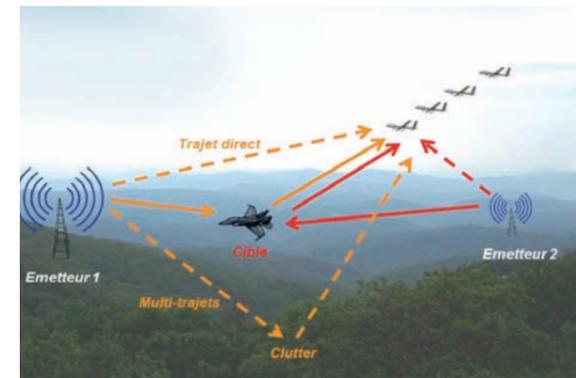
**INTELLIGENT SYSTEMS**

**VESTA – Mastering the complexity of future air transport systems**

ONERA has developed software platforms, demonstrators and databases. These achievements have resulted in three DGAC contracts and participation in SESAR 2020, as well as collaborations with ENAC, DGAC, Thales Avionics, Airbus, CERFACS, INERIS, CNRM and the Midi-Pyrénées Observatory-Aerology Laboratory. > [1 post-doc, 1 presentation, 1 book, 2 publications](#)

**DORADA – Low-altitude target detection system**

The objective was to evaluate the feasibility of a discrete radar detection system carried by a set of fixed-wing drones operating in coordinated flight. A passive radar testing resource for detecting low-altitude targets has been implemented on fixed-wing drones. This resource can be used to evaluate industrial applications of the detection technique. > [9 presentations](#)



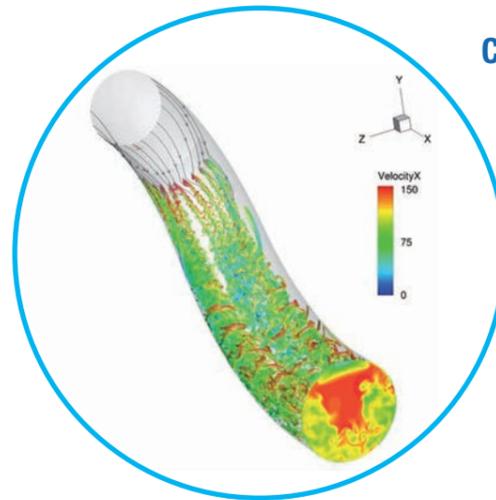
**CONTROLLING TURBULENCE**

**OPA-UCAV – Combat drones: tools for optimization and flow control**

ONERA has acquired a unique know-how on the optimization of control devices, turbulence modeling, and the coupling between the air intake flow and the compressor flow to improve the aerodynamic performance of combat drone air intake systems. > [2 publications and 2 presentations](#)

**FLEURIE – Fast laser fluorescence imaging method for *in-situ* diagnostics of unsteady flows**

ONERA is developing innovative solutions for the analysis and non-intrusive measurement of chemical species in flows subject to complex physics. These flows are subject to a complex physics that includes, among others, turbulence, mixing phenomena, and possibly chemical reactions. > [1 thesis and 4 presentations](#)



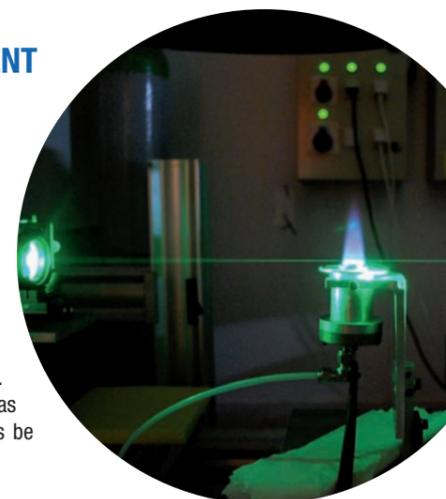
**SENSORS AND SPACE ENVIRONMENT**

**Ultra Cube – Non-intrusive measurement method in flows**

ONERA has developed two femtosecond laser metrology benches (measurement systems) based on Raman absorption and scattering to improve the quality - rate and spectral coverage - of measurements in flows. These benches will be used as part of the EU Horizon 2020 projects for research and innovation, with the collaboration of the DLR and the CNES. The method is also relevant to the fields of nano-material and biological object microscopy. > [2 theses, 2 publications, 6 presentations](#)

**ORESTE – Protection of new generation satellites**

As part of the positioning of geostationary satellites by electric propulsion, ONERA has evaluated the effects of the space environment and thruster plasma. It has created an extreme environment database that will make it possible to design the radiation hardening of embedded systems. ONERA has also adapted its laboratory resources. For the purposes of the R & T contracts signed with the CNES, a pilot prototype of the Spacesuite software suite has been developed with the SME Artenum. Industrial qualification tests of components and materials can thus be performed. > [6 presentations, 5 publications](#)





“ ONERA’s primary mission is to be an expert for the Government and to remove technological obstacles.

”



Bertrand Michelet,  
supervisor at ONERA for the DGA



#### How are research activities with ONERA organized?

ONERA's primary mission is to be an expert for the Government and to remove technological barriers. We know that it has the knowledge. It therefore proposes scientific research lines, which we would not always be able to follow without it. Thus, ONERA ensures and proposes, and the DGA specifies its priorities. It is indeed necessary for research programs to be in the field of interest of the DGA, and to aim for application purposes: ONERA must keep ahead of our needs, by presenting its competences. It is highly likely to respond to these thanks to its proven expertise, which is, paradoxically, too little known even to its supervising body. ONERA is now more proactive with regard to this point, further improving an already very good relationship.

#### You say that ONERA is more proactive. How does this being done?

ONERA is competent on many issues that concern the DGA, not just aeronautics. Examples include the fields of materials, radar, optics, ultra-sensitive accelerometry, etc. However, very often, a technology developed on a particular problem remains dormant, due failing to imagine the interest that it could hold for other areas of defense. The mission of the new defense program line is thus to be in permanent contact with us, to make us aware of this multidisciplinary approach, to maintain detailed knowledge of our needs, and to guide ONERA's developments accordingly. It is a question of maintaining a bilateral and very individualized dialogue, complementary to a more global communication, such as during technical review days.

#### What role do you play in this device?

I do not intervene in the technical aspect. My role is rather to make sure that all of the conditions for the dialogue with ONERA are met, whether they may be administrative or organizational, so that both parties only have "science and technology" to discuss. I check that the line is "interference-free", so that this permanent interaction can proceed well – a liaison officer role, sort of. ■

The missions of the new ONERA program lines, set up as part of the reorganization in 2017, can be summarized using four verbs:

**facilitate, outline, coordinate and represent.**

Their role is to facilitate dialogue with industrial and institutional partners, to outline their long-term needs in ONERA's program, to coordinate activities and proposals from several departments, and finally to represent ONERA in various areas.

The Defense Program Directorate is part of this dynamic: to be the privileged interlocutor of ONERA's supervisory body, the DGA (Directorate General of Armament), and defense sector customers.

# ONERA, expert for the Government and alongside the defense industry

## ONERA develops testing facilities suitable for very high temperatures



For MBDA, ONERA has developed and validated a new infrared measurement bench. In the case of missile applications with infrared homing, it is indeed important to know the thermal properties of potential dome materials. Measurements of thermal diffusivity, spectral emissivity and specific heat, among others, at temperatures of up to 1000°C or more, are also already available at ONERA.

## Successful lidar measurement campaign for the remote sensing of chemical weapons



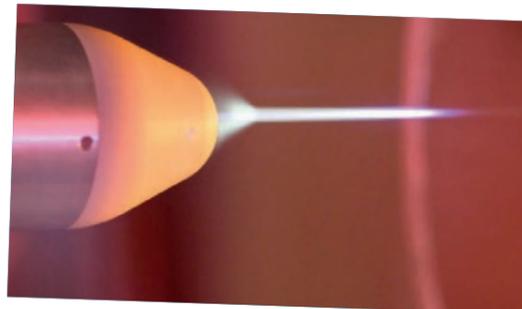
The ONERA MICLID lidar (Mid-Infrared Chemical Lidar) has been used successfully to remotely detect sarin gas and yperite in realistic tests conducted in August 2017. These results validate the approach taken by ONERA, based on the conversion of laser to infrared radiation from non-linear crystals (OPO – Optical Parametric Oscillator – technology). MICLID was developed by ONERA, in partnership with the KTH (Royal Institute of Technology, Sweden) and the VVU (Military Research Institute, Czech Republic), on behalf of the European Defense Agency (EDA).

## Validation of the organization for carrying out future tests for Dassault Aviation



A first test campaign carried out on ONERA's Paris aircraft, in Meudon, is the culmination of a process of resource and skill pooling between the ONERA and SOPEMEA teams working in the field of aircraft ground vibration tests, which began following the signing of the ONERA-SOPEMEA convention in November 2016. The tests carried out made it possible to check the complementarity of the teams and to validate the organization for carrying out future tests for Dassault Aviation. A delegation from the aircraft manufacturer was able to witness the capabilities of the team.

## Missiles: "laser pole" to reduce the sonic boom



The use of telescopic poles on a missile reduces drag in supersonic flight, replacing the shock wave that would occur in front of the warhead in its absence by a shock wave at the tip. ONERA, in collaboration with the Applied Optics Laboratory, in May 2017, performed the first experimental demonstration of the "laser pole" concept in its Meudon wind tunnel. This concept uses the filamentation property of femtosecond lasers to create a plasma filament upstream from a body in supersonic flow. The plasma thus created heats the gas and induces a significant perturbation of the shock wave. This phenomenon, predicted by numerical simulation, was revealed for the first time in a dedicated experiment using the EnstaMobile laser, as part of a DGA-ASTRID contract. This demonstration opens up promising application perspectives for the control of supersonic flows.

## Zone surveillance: launching of the SAFIR project



ONERA's Information Fusion System for Sensor Networks, SAFIR (Système Onera de Fusion d'Informations pour les Réseaux de capteurs), is a software platform designed to receive and process heterogeneous data from abandoned sensors – optronic, radar, seismic, and acoustic. It tracks the tactical situation of the scene in real time, tracking and classifying targets and assessing the threat. This last point is the subject of research to adapt this type of network to combatting drones. In September 2017, ONERA participated in perimeter surveillance field tests conducted for the Army, together with the company ARDANTI Défense at the Mourmelon camp, which allowed it to test the data fusion module and to gather feedback from the operatives, who were keenly interested.

## Very long range radar: ONERA conducts the first tests on a calibration sphere



The DRTLTP is a risk-removing demonstrator aimed at confirming the feasibility of a complete advanced warning radar (for the detection and tracking of ballistic missiles) and at specifying its performance. The radar concept is based on state-of-the-art technology, which ONERA is contributing to enrich: active electronic scanning antenna, digital reception channel, etc. In collaboration with Thales, via a contract awarded by the DGA in 2011, an important system integration stage was completed at the end of 2017 at the DGA's Hourtin site. After the qualification of the equipment and the integration of the software, the entire set of equipment set up in a structure nearly twenty meters high, representing 1/8<sup>th</sup> of a full radar potential, enabled the first measurements to be obtained. This opens up an experimental phase to qualify and validate the demonstrator performance, and to anticipate the future performance of a complete operational system.

“ Our collaboration is historic, natural and strategic. ”



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# Aeronautics

**A**ircraft, rotary wing aircraft, propulsion and environment, air transport system, drones, elsA software platform: the new **Aeronautics Program Directorate** is dedicated to spreading the word about ONERA's multidisciplinary. Like the defense and space program directorates, it is the privileged interlocutor of the industrialists in the sector.



Benoit Guyon,  
Director of R&T partnerships  
at Safran



**How would you describe your collaboration with ONERA?**

ONERA is the largest research organization in the sector. Collaboration between us is, in this sense, natural, as well as being historical. It is, however, especially strategic, because ONERA has completely integrated Safran's problems, particularly for two reasons: it has a deep knowledge of our subjects thanks to common experience, and it really focuses on applied research. Unlike a university seeking to "push the frontiers of knowledge", ONERA uses its leading-edge knowledge for the applied needs of its partner.

**What do you think the new organization and program lines, including the Aeronautics Program Directorate, will contribute for Safran?**

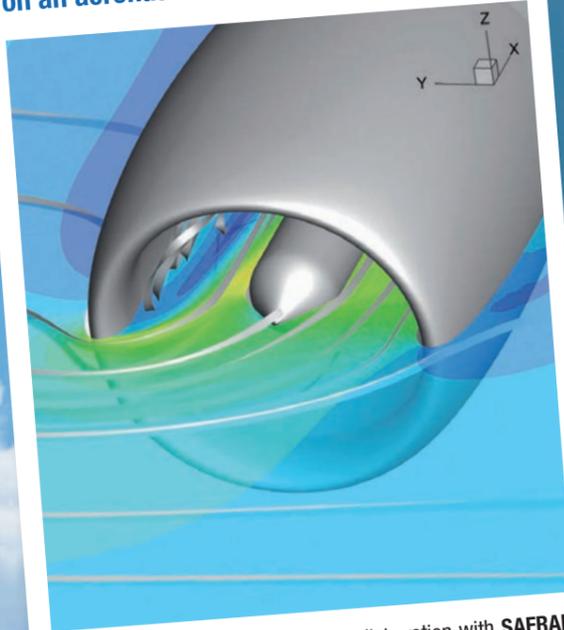
The Aeronautics Program Directorate will be able to set the course, to ensure that ONERA's research is consistent with our needs. It will become a link between Safran, which it knows all the problems of, and ONERA's scientific departments, which have a more detailed and technical approach. This conductor role therefore does not interfere with the discussions that we have with ONERA scientists on specific issues related to the work in progress.

**What project(s) are you working on together today?**

A framework agreement binds Safran and ONERA since February 2008. It will also be, for the third time, renewed in November 2018. ONERA has in fact transversal and complementary skills in many areas that interest us. As proof, the last ONERA-Safran steering committee dealt with no less than eight topics, namely aerodynamics, acoustics, metallic materials, composite materials, combustion, innovative flight controls, future energy systems, and optronic systems. From this point of view, it is clear that the Aeronautics Program Directorate will help us to not only follow the various paths made simultaneously and in parallel by ONERA, but also to identify transversal interest research topics, if need be. ■

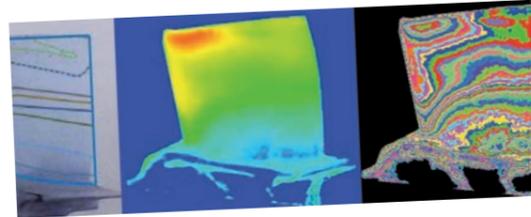
# ONERA alongside industry in the aeronautics sector

## Success of the EPiCE project regarding the characterization of the laminar zone extent on an aeronautical engine nacelle



The EPiCE project – carried out in collaboration with **SAFRAN Aircraft Engines** and financed by the program Investments for the Future – has enabled ONERA to consolidate its tools for detecting the transition zone between laminar and turbulent regimes through two complementary approaches: new tests in subsonic (ONERA F1) and transonic (ONERA S2MA) wind tunnels, and numerical simulations of test conditions. A laminar profile model, equipped with several demountable leading edge inserts reproducing the expected surface defects, was entirely designed by the ONERA model laboratory. The tests carried out included a large number of new metrological and technical innovations, such as the intensive and synchronized use of infrared measurements allowing the detection of the transition zone. The EPiCE project also enabled the creation of a new, high-quality database addressing the impact of surface defects on the extent of laminar areas on a nacelle under conditions close to flight (Mach and Reynolds numbers).

## Turbomachines: new generation thermosensitive paints for the measurement of very high temperatures



**Safran Helicopter Engines** placed an order with ONERA for a study to design irreversible thermoluminescent coatings capable of reporting the temperature experienced by engine parts (between 900 and 1300°C for turbine blades) during the design and certification tests. The aim was to identify, synthesize and optimize photoluminescent pigments and to design a suitable spectral analysis measurement chain. Heat-sensitive paints are the only solution available today for mapping temperatures in such a complex environment as that of an aircraft engine. The project resulted in a more environmentally friendly solution compatible with the REACH regulations (Registration, Evaluation and Authorization of Chemicals).

## ONERA contributions to the high-speed helicopter demonstrator Racer for Airbus Helicopters



Since July 2015, as part of Clean Sky 2, ONERA has been partnering with **Airbus Helicopters** to improve the aerodynamic performance and reduce the noise pollution of the high-speed helicopter that is the successor of the X3. ONERA participated in the design and optimization of propellers for the different phases of flight, allowing a significant gain in consumption during hovering and cruising flight. Another ONERA contribution is the optimization of the rear parts based on aerodynamic performance criteria and, in particular, vertical stabilizers ("X"-shaped), which are the subject of a patent application. Finally, together with the DLR<sup>1</sup>, ONERA evaluated and analyzed the acoustic characteristics of the demonstrator under a wide range of flight conditions.

<sup>1</sup> Deutsches Zentrum für Luft und Raumfahrt

## ONERA, coordinator of the butterfly project on buffeting



Coordinated by ONERA, this project involving **twelve European partners, as well as the Russian TsAGI**, is part of the overall work funded by the European Union for improving performance and reducing CO<sub>2</sub> emissions from commercial aircraft in cruising flight. One of the most significant achievements is the characterization and fluidic control of buffeting on a 2D laminar wing (ONERA wind tunnel tests and numerical simulations). At the end of the project, the representative of the European Commission acknowledged the success of the scientific work, and emphasized the involvement of Airbus and the good exchanges between Europe and Russia.

## Drones: regulatory experts at ONERA



As a member of the JARUS<sup>1</sup> Detect and Avoid group, ONERA received the other international experts for a week. The aim was to advance the drafting of the SORA document (Guidelines on Specific Operations Risk Assessment), a methodological basis for future drone operations.

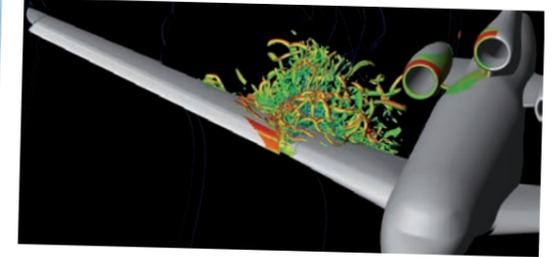
EASA<sup>2</sup> is therefore considering imposing it as a reference framework for taking into account the air and ground risks entailed by drone flight, with a view to issuing a permit to fly. ONERA contributes its expertise at the highest international level within the framework of JARUS, at the request of the **DGAC**<sup>3</sup>. This Cenacle gathers 51 national civil aviation authorities, EASA and Eurocontrol, to work on future drone unified regulatory frameworks for their certification and integration into airspace.

<sup>1</sup> Joint Authorities for Rulemaking on Unmanned Systems

<sup>2</sup> European Aviation Security Agency

<sup>3</sup> Direction générale de l'aviation civile

## Numerical simulation code: ONERA is preparing the future CFD together with Airbus and Safran



The ONERA CFD 2030 challenge is aimed at being at the forefront of CFD in terms of upstream methods, and at developing a unifying software for the entire fluid mechanics and energetics spectrum (aerodynamics, aeroacoustics, aeroelasticity, propulsion, etc.). The objective: maximum compatibility with the simulation chains of industrial partners, in particular **Airbus** and **Safran**.

ONERA and Safran are preparing a cooperation agreement to define and develop a common software platform, in which the elsA and CEDRE codes will interact. At the end of 2017, ONERA presented and launched an elsA upgrade project with Airbus and Safran. In parallel, ONERA will support Airbus in its next-generation CFD software project for use by design teams by 2025, which will be developed in cooperation with the DLR. 2017 ended with the signing of a tripartite cooperation agreement on this project, called NewGenCFD.

## Icing: between calculation and experimentation



ONERA is currently working on several projects funded or co-financed by the **DGAC**, including the PHYSICE research agreement, relating to icing physics. Moreover, in the GENOME project, ONERA recently conducted runoff and refreezing tests in a **DGA**<sup>1</sup> wind tunnel. In addition, ONERA has delivered to its industrial partners Versions 1.1 of the IGL002D and IGL003D calculation chains, which will enable the modeling of ice accretion on an unprotected surface. Versions 2.1 and 2.2, currently under development, will deal with the case of thermally de-iced surfaces.

As part of the CORICE project, work has been done to experimentally measure the adhesion and rupture properties of various accretion ice crystals produced in the DGA icing wind tunnel. ONERA is involved in numerous projects on icing at the French and European levels. A major player in this sector, his expertise covers experimental and numerical aspects, as well as icing modeling.

<sup>1</sup> Direction générale de l'armement



Given that the expertise and roles are complementary, everything takes place in mutual respect of our personalities.



Frédéric Pradeilles,  
CNES representative on the ONERA  
Board of Directors



**T**he collaboration between the CNES and ONERA has grown in recent years. In 2015, their two chairmen, Bruno Sainjon and Jean-Yves Le Gall, signed an updated framework agreement linking the two institutions. Coinciding with the arrival of Bruno Sainjon at the helm of ONERA, this signature marked a strong desire for collaboration between the two EPICs. This dynamic at the highest level allowed teams that already knew each other to focus on science. Objective: to prepare the future together and to advance research.

**The CNES and ONERA operate differently. How are the roles distributed?**

ONERA has its own laboratories and research facilities, while we are a program agency and an expertise center that makes its resources available to other laboratories. Therefore, we call upon ONERA for its ability to carry out work on its own. On our part, we contribute our ability to carry out project management and to build all or part of a satellite, as well as financial resources. Given that our expertise and roles are

complementary, everything takes place in mutual respect of our personalities. The many joint-interest projects (PIC) currently underway show that the CNES and ONERA need each other to make progress on common topics.

**You speak of "common topics". What projects are those?**

Although new players like SpaceX are taking up part of the international scene, we are seeking to jointly prepare the next generation of European launchers. For French and European sovereignty, it is essential to be able to conduct projects, with confidence.

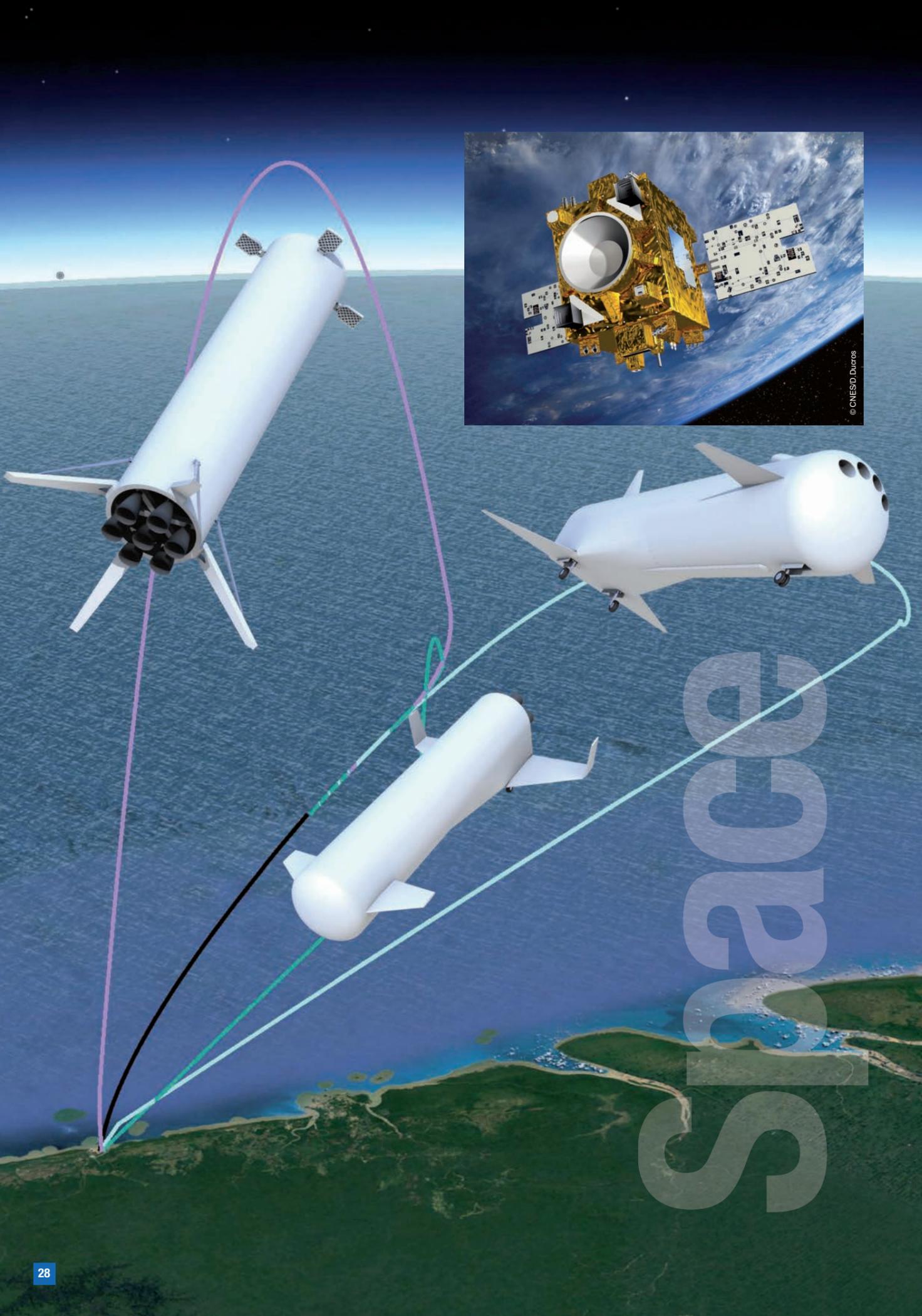
ONERA proposes R&T topics in other precursor areas, such as green space propulsion, environmental concerns also concerning space (development of a "green" monopropellant). We are also very interested in ONERA's specialized expertise on the propagation of electromagnetic waves, on Earth observation and on the space environment.

However, what particularly marked the year 2017, and which will continue in 2018, is the Microscope mission: while the best measurement of the principle of equivalence had not been exceeded for ten years, the first results of the CNES satellite MICROSCOPE, equipped with ONERA accelerometers, demonstrate with unparalleled accuracy that bodies fall in a vacuum with the same acceleration. Since the principle of equivalence remains unshakeable at this stage, this is a new confirmation of Albert Einstein's theory of general relativity, stated more than a century ago.

**Does the new space program line help you coordinate all of these topics and research projects?**

Absolutely. Its global vision is necessary, and it also plays a real animation role. Even though my colleagues and I are familiar with ONERA's various scientific departments, the space program line is obviously more aware of the research opportunities that could be pursued, and the latest technological bricks developed.

On a personal level, as a professor, researcher and engineer at the DGA, in industry and at the CNES, ONERA has always been part of the research ecosystem that I frequented. Its activities are multiple, and its added value for the aeronautical, space and defense sector is considerable. It is therefore perfectly legitimate to create the space program line to give an overview of so many gems. ■



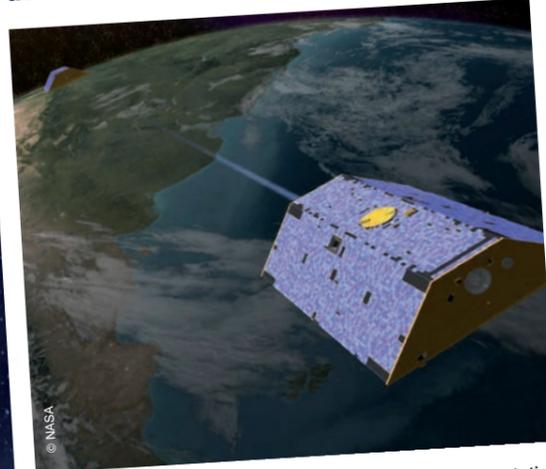
# ONERA alongside the space industry

## Placement in geostationary orbit by electric propulsion



Within the framework of the NEOSAT project, Airbus DS and Thales Alenia Space have the ambition to launch "all-electric" satellites, including their placement in geostationary orbit. This type of propulsion generates a feeble thrust, the transfer becomes slow (3 to 6 months to reach the targeted orbit) and the satellite crosses the hostile environment of the radiation belts, often violently disturbed by magnetic storms. ONERA has been commissioned to characterize the worst conditions of this space environment: it has created a tool to estimate the risk related to electrostatic charges inside and on the surface of the satellite. Airbus DS and Thales Alenia Space will use this tool to optimize the placement-in-orbit scenarios and the required shielding levels, giving them a competitive advantage. This work was conducted under a CNES "investment for the future" plan (PIA, Plan d'Investissement d'Avenir) contract.

## The GRACE mission and its ONERA accelerometers celebrate their 15 years in orbit



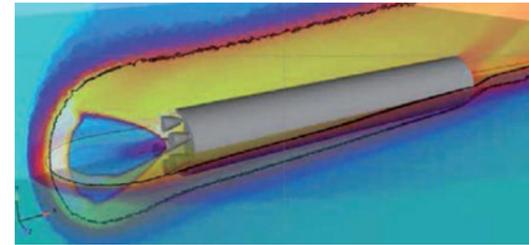
The two satellites of the NASA Grace mission have been rotating for 15 years, providing very precise information on the Earth's gravity field, and thus on the distribution of masses and their evolution in space and time. The environmental benefits are numerous, especially for climate change. On board both satellites, ONERA's essential accelerometers (one per satellite) have been operating without incident for 15 years. They make it possible to measure the very low drag of the satellites due to the residual atmosphere remaining in low orbit. The knowledge of this parasite drag guarantees the accuracy of Grace's gravimetric measurements.

## Launching of the SERA3 rocket probe



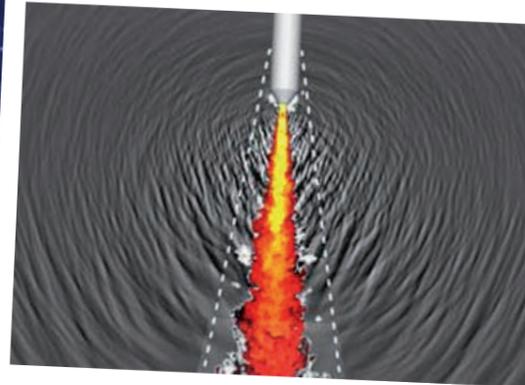
As part of the CNES Perseus project, the SERA3 rocket probe was successfully launched in April 2017 in Sweden. This rocket, designed and manufactured with the contribution of students, incorporates three Cesaroni engines. ONERA was responsible for the assembly and integration of these engines at the launch site. The reliability of their simultaneous ignition was an essential safety condition for the launch success, which was fulfilled thanks to the synchronous ignition technique defined by ONERA and validated in 2016 by two tests on ONERA's Fauga-Mauzac center propulsion bench. The propulsive behavior was nominal.

## First simulation in Europe of the toss back return of a launcher



Toss back return, that is to say, the moment when the launcher descends again, with its nozzle facing forward, braked by the successive re-ignition of one of its engines, was simulated with the ONERA code CEDRE. The results obtained make it possible to evaluate the flight range, where the engine ignition is useful for the stage braking. They will feed the overall trajectory and piloting models, and the sizing of thermal protections for the recovery of the vehicle.

## Numerical simulation of launcher jet noise



ONERA is mobilizing to improve the accuracy of numerical simulations of spacecraft thruster noise on take-off. It has set up a method using the ONERA CEDRE simulation software, dedicated to the simulation of a turbulent jet generating acoustic sources. The method is also based on the ONERA SPACE simulation software, which allows the propagation of acoustic waves in far field. A reference calculation of 290 million meshes yielded very good results. A best article award was presented at the CNES Young Researchers Days, in October 2017, for this methodological advance. This work was carried out within the triple framework of the joint interest program (PIC) ONERA-CNES Numerical simulation of launcher jet noise, the research project ONERA AJIL (adaptation of aeroacoustic methods and tools to interacting jets in launchers) and of a CNES-ONERA thesis project.

## Stratospheric balloons: modernization of the Eden testing resource



Thanks to the financing by the CNES of simulated characterization and aging resources, ONERA has modernized the envelope diffusion and brightness resource (Eden) enabling it to perform brightness and diffusion tests on gases of the various elements constituting stratospheric balloons. The amount of helium passing through the sample by diffusion or effusion is measured using a mass spectrometer. This modernization was achieved by replacing its thermal enclosure, optimizing liquid nitrogen consumption and reducing transient times. The extension of the temperature ranges (+80 to -110°C) and pressure ranges has been specified. For 50 years, ONERA has played a scientific support role for the CNES in the fields of material characterization and "balloon" subsystems.



We shared an intuition: what if drones could monitor railroad networks?



Nicolas Pollet,  
General Director of Altametris,  
a subsidiary of SNCF Réseau



**You say that "everything needed to be done from scratch", but you also speak of being quick: how is this possible?**

Partnership! That is the keyword. SNCF Réseau and ONERA are true partners, in the sense that we have come together with regard to skills. It is not a traditional provider-to-customer contract: we discovered the technological bricks and then mortared them together. The rapid maturation of the DROSFILES\* project for the monitoring of the rail network comes from ONERA's adaptability to the needs of its partner. Experts who seek, and find together.

**Can you tell us more about the DROSFILES project? How far have you got with it in 2017?**

SNCF Réseau is the manager of the national rail network, and consequently faces safety, operational quality and user comfort issues, as well as cost optimization issues. A drone, like a flying sensor, allows agile data collection for better infrastructure management. This is the job of ALTAMETRIS, a company of the SNCF Réseau group. This vast subject was structured in the partnership around six research topics, four of which are being addressed jointly with ONERA. We signed the PRI DROSFILES in 2014, and it is clear that, three years later, the results are already here. With regard to the first topic, risk analysis and simulation of drone operations, we jointly developed, on the basis of ONERA's BLADE software, a drone flight simulation tool allowing the quantified evaluation of the level of ground risk for areas flown over during non-sighted flight scenarios (a field in which ALTAMETRIS is a pioneer and has a solid experience). This is useful for mission preparation (flight authorization requests), flight plan optimization, or assistance with the design of secure UAV systems. These three security aspects are essential for structuring future regulations. With regard to the "sensor" topic, ONERA has developed optical payloads embeddable on UAVs to help detect defects in industrial equipment, particularly railway equipment. The first ground tests were conclusive. For data processing, deep-learning algorithms have been co-developed for the detection of industrial equipment, in particular rails, from airborne images or lidar point clouds.

\* Drones: observation systems for railways and for line inspection using sensors

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**T**he scientific and technological excellence developed for aeronautics, space and defense is offered to industrialists seeking innovation, whatever their activity sector.

**The IP transfer and Partnership Directorate's task is to support them.**

**Are you acquainted with ONERA? Railways and the sky would a priori have no reason to come across each other, right?**

I knew of ONERA as a government research organization, until I met Véronique Tanguy, from the DVPI, the partnerships directorate, in 2010. We each had the will to become acquainted with each other to know whether there were synergies. We first talked about "use cases" and then about "radar type sensors", before drones became the central topic. We shared an intuition: what if drones could monitor railroad networks? It turned out that the answer was yes, that the expertise in aeronautics could be used for railroads. However, everything needed to be done from scratch, and I did not know the multidisciplinary nature of ONERA. Véronique Tanguy therefore quickly arranged peer discussions, making it possible to accelerate the identification of collaboration leads and save time.



This is a good example of collaboration: we have provided data to test the algorithms, to make them robust and to validate their integration into the production line.

As for flight intelligence, the algorithms developed have made it possible to secure the remote operation of miniature UAVs for inspections indoors or in congested environments, and to automate the flight of UAVs for railroad track monitoring missions. In both cases, we organized flight validations on drones at industrial sites.

#### And from now on?

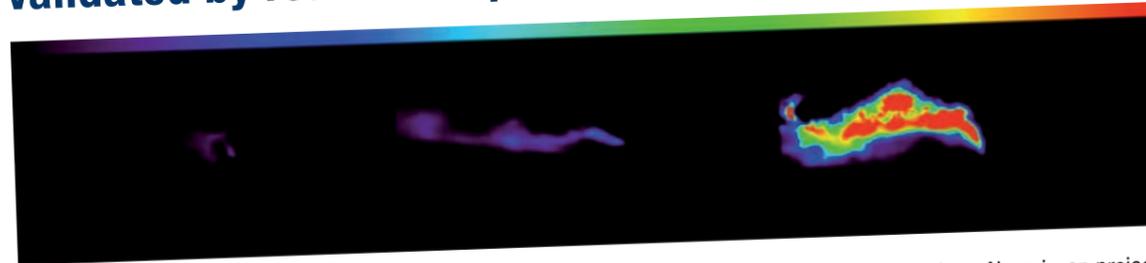
This "time spent together" since 2014 has allowed many successes in the topics worked on and beyond, by disseminating new skills within SNCF Réseau and ONERA. The DROSFILES project will continue in 2018, and we are already working on 2019. In addition, other more or less closely related topics are appearing, especially with the autonomous train. ■



# The ONERA-TOTAL collaboration initiated in 2014 continues in 2017



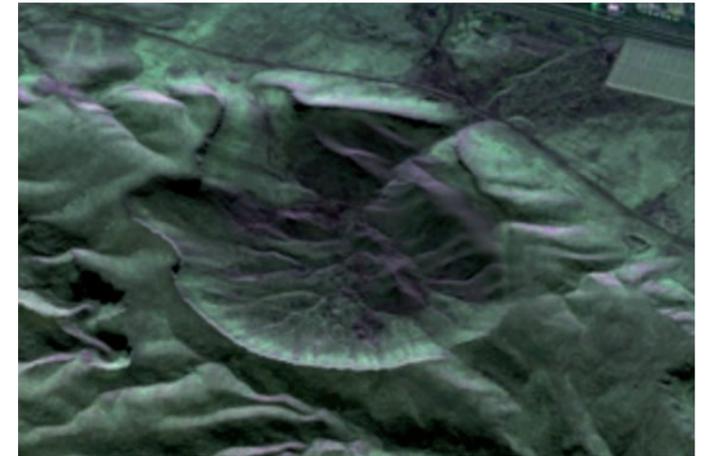
## Detection and quantification of gas flow validated by real-time optical resources



The aim of the Naomi gaz project is to provide real-time methane quantification to Oil & Gas operators during industrial or accidental emissions into the atmosphere. A measurement campaign, conducted in 2017 at the Lacq pilot site, has enabled the validation of optical systems developed by ONERA: they provide very accurate data for a wide range of gas flows. The performances of the spectral and lidar cameras developed by ONERA (SIM-ONE cryogenic multi-spectral camera, uncooled multi-spectral camera, Licorne wind lidar, etc.) were compared with the field data collected by TOTAL: the flow estimates provided by the NAOMI systems proved to be accurate.

In addition, two TELOPS hyperspectral instruments incorporating ONERA physical treatments have also been evaluated in terms of detection threshold and accuracy of the real-time methane amounts. This success paves the way for a wide range of applications: fugitive or accidental emissions. A large-scale campaign at the Lacq site is already scheduled for the end of 2018.

## Remote sensing: radar and hyperspectral imaging campaign



ONERA carried out an airborne acquisition campaign with the Sethi system in June 2017. The objective is to explore the potential of radar and hyperspectral imagery for the characterization of the geology of a semi-arid area. In order to aid TOTAL's team of geologists with regard to soil and rock analysis, ONERA deployed several teams with complementary skills:

- A system team for the operation of airborne equipment;
- Optical teams for proximity spectral measurements with two ASD spectroradiometers, in order to study their mineralogical signatures and multi-resolution topography measurements with a 3D lidar;
- A team of radar operators for the implementation of rock dielectric constant and soil moisture measuring instruments.

This unique set of collected data will allow to improve the systems of characterization of arid zones by satellite, airborne or drone remote sensing techniques.

## When a campaign meets another: first images of gas emissions obtained by the SETHI airborne resource



As part of the Lacq campaign, the Sethi airborne resource has made it possible, through hyperspectral imagery, to determine, during controlled emissions of methane, a quantitative

estimate of the flow of the latter. This breakthrough highlights the high potential of ONERA's testing system and quality of data post-treatment solutions developed by ONERA teams.

# Computation codes: a field that counts

A SCIENTIFIC FIELD IN ITS OWN RIGHT AT ONERA

**R**epresenting phenomena is becoming increasingly complex, because several physics are involved: besides fluid mechanics, it is essential to model elasticity, thermal aspects, acoustics, electromagnetism, etc. Because numerical simulation plays a major role, both for the development of knowledge and for the application work of our partners, it constitutes a scientific field in its own right for ONERA. A multi-physics simulation platform project, which will initially focus on fluid mechanics and energy, was launched in 2017.

## The multi-physics simulation platform in brief

It is a digital platform in which ONERA software will be interoperable. The goal: to simultaneously treat several different physical phenomena. By 2025, the platform will host software components associated with other physics too. ONERA will be able to fulfill three of its most important missions: improving the competitiveness of its industrial partners, responding to the sovereign demands (safety, environment, certification, etc.) and contributing to a thorough understanding of physics.

## New methods to advance research

Despite the huge advances in computational fluid dynamics (CFD), there are still considerable challenges in this field; transition, turbulence, and combustion: software still needs to reflect this physical reality better.

It is also necessary to make significant progress in controlling errors and uncertainties for the introduction of CFD into certification processes.

## A tool for non-specialists: a gain in competitiveness

Numerical simulation remains a specialist business. However, it must be controlled by non-specialists: the platform is aimed at lightening the level of expertise required to use this type of software, especially in view of growing multidisciplinary studies. In the industrial world, method teams provide the interface with design teams having access to an extremely limited number of simulation parameters.

Numerical simulation associated with a given field will also be used by non-specialists at ONERA, for multidisciplinary studies or for the development of joint experiment-simulation services.

## Capitalizing on ONERA's advantages in numerical simulation

ONERA software applications will be able to rely on the experimentation-modeling-simulation triad and on the availability at ONERA of in-depth multi-disciplinary skills. In addition, they will benefit from close relationships with industrial partners, allowing a detailed and evolving knowledge of needs, a rapid transfer of research to industry (with the software playing the role of a bridge) and validation by use on realistic configurations, which gives valuable feedback. The development by ONERA of its own software meets its need for research autonomy and capitalization of its scientific and technical heritage.

## MOSAIC

Safran has launched a simulation platform project, MOSAIC, to ensure that all of the software applications used by Safran in simulations involving CFD are interoperable. The technical choices adopted by Safran in the development of this platform correspond to the choices promoted by ONERA for several years in an internal program called NSCOPE. Discussions led to the recent signing of a joint declaration of intent expressing a clear desire for cooperation on the subject around common software elements, with ONERA aiming to achieve multi-physical reduction and capitalization "beyond CFD".

**T**ests in large wind tunnels are necessary when mathematical simulation tools become insufficient. This is the case for optimizing aerodynamics during the design phase of a new aircraft: the designers then seek to reduce the risks of a program and make their product more efficient and competitive. This is also the case when it is necessary to explore future concepts and meet scientific challenges involving the understanding of aerodynamic phenomena. Finally, the securing of particularly critical flight phases calls for validation tests in wind tunnels.

### Stabilizing the large S1MA wind tunnel

In recent years, the centerpiece of ONERA's experimental aerodynamic resources – the large S1MA wind tunnel in Modane – has suffered dents that put it at risk. The repair work started in March 2016 financed with a €20 million grant from the Ministry of the Armed Forces, and must be completed by the end of 2019. It is, at a higher level, a recognition of the usefulness of the S1MA wind tunnel.

Despite the filling of deep cavities, the denting continued. In July 2017, the creation of columns connecting the deep layers, the foundation and the girders of the building was decided to stop its progress. The whole seems stable, but remains under close monitoring.

### New fans

Thanks to nearly 12 years of design and manufacturing work, and to the financial support of the DGAC, the two counter-rotating fans (blades and hubs), which are fifteen meters in diameter, were replaced in the summer of 2017. This was the first time since its commissioning in 1952. The balance is very positive, with good mechanical behavior and very satisfactory operation results. The objective is to revitalize fans that were showing weaknesses that affected operations. The validations of the proper functioning of the S1MA wind tunnel against reference models will continue until mid-2018.



### The F1 wind tunnel, a world reference for landing and take-off configurations, celebrates its 40 years

In October 2017, the ONERA Fauga-Mauzac center celebrated the 40th anniversary of its F1 wind tunnel, by receiving institutional and local elected officials, customers and partners, as well as the families of the staff.

F1 is a pressurized low-speed subsonic wind tunnel with a high level of productivity, allowing the study of aircraft landing and take-off configurations at high Reynolds numbers. Its wide passage has been used for the largest international civil and military aircraft programs. Today, the quality, quantity and productivity of the measurements provided by this wind tunnel have earned it an international reputation. It is considered particularly strategic by the European aviation industry, as evidenced by the fly-over of the A350-1000 to celebrate its anniversary. It is an indispensable resource for evaluating breakthrough technologies required for noise reduction, lower consumption and increased flight safety. It will therefore be present for several more decades, at the service of aeronautics and its future challenges.

### New customers thanks to ground effect testing

The assembly for the characterization of ground effects on aircraft aerodynamics in the F1 wind tunnel was greatly improved in 2017. With the aid of an automated remote-controlled system, the height changing time went from 5 hours to 10-15 minutes. The F1 wind tunnel can simulate high Reynolds number flows, which, combined with a simple, efficient and productive feature for soil effect characterization, provides a very attractive new testing capability for industrial customers.



# ONERA in its local ecosystem

## LILLE

### Inauguration of the CONTRAERO wind tunnel platform



This regional platform, dedicated to the study of flow control, combines four wind tunnels of excellence located at ONERA, at the University of Lille/Centrale and Lille/CNRS, and at the Valenciennes University/CNRS, as well as a CNRS/IEMN micro/nano technology facility.

### Creation of the Lille Fluid Mechanics Laboratory

The Experimentation and Flight Limitation Unit of the ONERA center in Lille is part of the new LMFL-Kampé de Fériet laboratory (CNRS FRE 2017), which gathers Lille's historical academic partners in fluid mechanics (University of Lille, Centrale Lille, ENSAM Lille and CNRS). The scientific activities of the LMFL are supported by four scientific topics (turbulence and flow control, data measurement and analysis, rotating machines and flight dynamics).

## ÎLE-DE-FRANCE

### Exchanges between Paris-Sud University and ONERA



As part of the efforts to strengthen the links between the members of the Paris-Saclay University, ONERA and Paris-Sud University deepened their mutual knowledge in 2017.

Two meetings gathering Sylvie Retailleau, Chairman of Paris-Sud University, and Bruno Sainjon made it possible to identify the many scientific and technological fields of interest between the two institutions. Six main fields were selected: simulation, fluids and transfers, materials and mechanics, space, electromagnetism (including optics and photonics), and signals and systems. For each of these fields, Étienne Augé, Vice Chairman of Research and Innovation at Paris-Sud University, identified the laboratories with which ONERA could work. The international affairs directorate of ONERA and Paris-Sud University made good use of these meetings to share their vision of welcoming foreign PhD students.

## TOULOUSE

### Shared research: the Terriscope platform

Mainly financed by the Occitania region and by European Union ERDF funds, the joint research platform Terriscope, dedicated to airborne imagery for studying the environment and territories, was set up at the ONERA center in Toulouse for the operational phase, which will start at the end of 2018.



PROJET COFINANCÉ PAR LE FONDS EUROPÉEN DE DÉVELOPPEMENT RÉGIONAL

### ONERA has a university research school dedicated to aeronautical engineering with the ISAE and the ENAC

Launched in 2017, the return of the national call for projects related to university research schools (EUR) made it possible to achieve the EUR TSAE (Toulouse Graduate School of Aerospace Engineering). This associates participants in the ENAC and ISAE masters programs with ONERA research teams in Toulouse. In particular, it will contribute to increase the visibility and attractiveness of the Toulouse aerospace site to students from all over the world.



### Joint research federation between ONERA, the ENAC and the ISAE-SUPAERO

It establishes a collaboration in the field of "design, certification and operations of future aerospace systems", in order to synergize certain areas of scientific excellence of the three institutions, mainly those developed around Toulouse, with no exclusivity or strict exhaustiveness.

This federation is aimed, in particular, at developing a unified and tooled approach to the design, qualification, certification and operations of future aerospace systems, particularly for drone systems and their operations, and for air transport systems and their operations.



## SALON-DE-PROVENCE

### Constant proximity with the Air Force: experimentation on drone traffic management

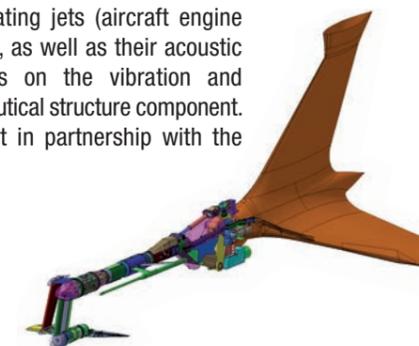
The ONERA center in Salon-de-Provence is located at Air Base 701. Frequent collaborations are taking place, as in 2017, for the needs of the Low Level RPAS Traffic Management (LLRTM) project: flight tests of an Air Force Jodel D-140R were conducted on the Provençal base, with the aircraft accompanied by a multi-rotor drone from the start-up Atechsys, equipped with a miniaturized identification device. The aircraft was equipped with a light aircraft airborne collision avoidance system (FLARM) patented by ONERA in 1998. The experiment was successful and new tests are planned for 2018. This project is being carried out with financial support from the PACA region and Bpifrance.



## MODANE

### ERDF and Auvergne-Rhône-Alpes Region grant award

The Auvergne-Rhône-Alpes region supports innovative and structuring projects by granting ONERA a grant from the European Regional Development Fund to develop the IJES (Installed Jet Effect Simulator) bench. It is a test bench that is unique in the world for simulating jets (aircraft engine nozzles) under cruising conditions, as well as their acoustic radiation and the consequences on the vibration and acoustic transmission on an aeronautical structure component. This operation will be carried out in partnership with the *École Centrale de Lyon*.



### "Mesures et démesures" exhibition in Chambéry

The CCSTI (Scientific, Technical and Industrial Cultural Center) in Chambéry hosted, from June 3 to September 2, 2017, this exhibition revealing the architecture of the Modane-Avrieux center, through large-format black and white artistic photographs by Antoine Gonin.



# ONERA intensifies its role on the international stage

INTERNATIONAL

## International mobility

In 2017, in order to promote scientific excellence and exchanges with its partners, ONERA set up a new mechanism for receiving foreign researchers and sending its researchers to organizations in other countries.

## Multilateral cooperation

### ONERA-JAXA-DLR: new agreement on the reduction of the supersonic boom

On the occasion of the annual meeting between ONERA, JAXA and the DLR at the end of March 2017 in Tokyo, the three research organizations signed a new tripartite research agreement on the reduction of the nuisances associated with the supersonic boom, which block the return of a supersonic transport plane following the ceasing of the Concorde program. To meet this technological challenge and prepare the implementation of regulations allowing supersonic overflight of inhabited land, the three partners combine their expertise.

- ONERA will contribute its expertise in digital simulation of the boom.
- JAXA will continue its research in concept validation (model) and boom prediction codes.
- The DLR will be involved in CFD near-field prediction and overall supersonic vehicle design, with a focus on drag-and-drag signature optimization and operational scenarios.

The bilateral cooperation between ONERA and JAXA from 2011 to 2016 on the configuration of a supersonic aircraft was already focused on the reduction of the sonic boom, but also on the reduction of the drag of the aircraft and the integration of the propulsion.

## Strengthening cooperation with Singapore



During the Second Advisory Board with the DSO, Bruno Sainjon and his Singaporean counterpart Mr. Cheong Chee Hoo recalled the strength and importance of the partnership, which focuses on radar (a historical topic) and optics (launched in 2015). As of January 2017, Mr. Cheong Chee Hoo was visiting the SONDRRA and ONERA joint laboratory. Professor Quek Gim Pew, accompanied by a delegation of members from the Singapore MinDef, the FSTD and the DSO, did the same a few months later.

WORLD

## International workshops in partnership with NASA



• Within the International Forum for Aviation Research (IFAR), ONERA is steering a sixteen partner group on aircraft noise reduction. In 2017, two multi-year international benchmarks were launched (one driven by NASA and the other by ONERA), aimed at improving the experimental and numerical characterization of acoustically absorbing materials. They complement those proposed by NASA and ONERA on aeronautical noise, as part of the AIAA (American Institute of Aeronautics and Astronautics).

• ONERA co-organized, together with NASA and the ISAE, the first European workshop dedicated to the OpenMDAO multidisciplinary optimization platform. Benefiting from the presence of the NASA Glenn team in charge of software development, this workshop gathered more than 60 representatives from research centers, European universities and the aviation industry.

• In 2017, ONERA continued its active participation in other workshops led by NASA. As part of the workshop dedicated to the modeling of turbulent laminar transition, ONERA successfully presented its approach and tools (advanced features of the elsA code).

## China



### ONERA and the CAE: new cooperation framework agreement

On the occasion of the Paris Air Show 2017, ONERA and its Chinese equivalent CAE (Chinese Aeronautical Establishment) signed a new framework agreement for cooperation in the aeronautics sector on June 20, 2017.

EUROPE

## ONERA at the heart of efforts to intensify cooperation for aviation

ONERA is in charge of the main part of the ICARE project (International Cooperation in Aviation Research), which is aimed at intensifying international cooperation with regard to research and innovation for aeronautics, between the EU and third countries. The project involves partners from the worlds of research, industry and aviation regulation.



## ONERA deeply involved in ACARE



ONERA has participated in all of the work groups of the ACARE (Advisory Council for Aviation Research and Innovation in Europe), which gathers the entire community (researchers, industrialists, airlines and airports). Result: the strategic agenda for research and innovation was updated and presented at the Paris Air Show 2017.

## Privileged dialogue with the European authorities (EU and AED)

Maintaining close relations with Europe is an important issue: ONERA actively participated in the development of EREA positions for the upcoming Framework Program (FP9) in the field of aviation and for the future Defense program. ONERA also proposed to its partners that a summary document be drawn up, to include the topic "aviation security" so that the European Commission takes this issue into account in FP9.



## SCIENTIFIC EXCELLENCE: SEVERAL AWARDS FOR ONERA

### GARTEUR Award: two ONERA researchers honored

At the board of GARTEUR (Group for Aeronautical Research and Technology in EUROpe), a network of scientific experts from seven countries that meets every two years, two "Action Groups" in which ONERA actively participated received a GARTEUR Award for their work in the fields of aerodynamics and helicopters. These awards emphasize the excellence of the work done and the quality of the results obtained.

### Young Researchers Award TsAGI-ONERA



The second edition of the prize was launched in 2017. Created in 2015 at the initiative of the chairmen of the two research organizations, the ONERA-TsAGI award rewards and supports a project by a team of young researchers from TsAGI and ONERA. It has several objectives, notably to encourage the emergence of innovative ideas and to promote collaborative projects.



### Best EREA publication 2017: ONERA doubly honored

At the annual EREA event, two publications by ONERA authors/co-authors featured on the first and second steps of the podium for the EREA Best Paper Award 2017.

### ODAS 2017 - 17th ONERA-DLR Symposium

In June, the 17th ONERA-DLR symposium was held to promote exchanges between young scientists from the two research centers. This year, focused on the topic of CFD and experimental validation, the ODAS Award 2017 was conferred to an ONERA doctoral student.



All major civil and military aerospace programs in France and Europe  
have some of ONERA's DNA: Ariane, Airbus, Falcon, Rafale,  
missiles, helicopters, engines, radars, etc.

Aircraft  
Helicopters  
Aircraft propulsion  
Space transport  
Orbital systems  
Missiles  
Drones  
Defense systems  
Security



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