

ANNUAL REPORT

2018

ONERA

THE FRENCH AEROSPACE LAB

Table of contents

3	ONERA at a glance
4	Editorial
6	Key moments
10	ONERA centers
12	Testimonials
18	Key figures
20	Human resources
21	Awards and distinctions
22	Highlights
24	Roadmaps
26	Defense
30	Aeronautics
34	Space
38	Drones
40	Valorization
42	Wind tunnels
44	Numerical simulation
46	International



ONERA: the French aerospace research center



ONERA, a central player in aeronautics and space research, employs approximately 1,950 people. Under the supervision of the Ministry of the Armed Forces, it has a budget of 236 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.

editorial



BRUNO SAINJON, CHAIRMAN AND CEO OF ONERA

As an exception, in addition to the activities and results of 2018, which was an extraordinary year for ONERA, this annual report will include a major event that took place in 2019. Indeed, on January 10, ONERA was honored to welcome Ms. Florence Parly, Minister of the Armed Forces, who announced that the government will finance the consolidation into a single place of our facilities in the Île-de-France region on the Saclay plateau, to the tune of €160 million, as well as having given the green light for a €47 million loan for ONERA from the European Investment Bank (EIB) to modernize our wind tunnels. The first major investment in the field of defense made by the EIB will therefore be in France, in ONERA.

The minister also wanted to point out the government's recognition of ONERA by collectively awarding it the aeronautical medal. This honor is all the more remarkable because it is the first time that an organization that is neither a military body nor a DGA or DGAC school collectively receives such a recognition. Finally, the minister requested that ONERA's Objectives and Performance Contract (COP), signed at the end of 2016, be updated to take into account a military programming law, voted in at the end of 2017, which is much more ambitious in ONERA's areas of activity (aeronautics, space, deterrence, innovation, etc.), and very good results obtained by ONERA over the period. In this report, you will also discover that ONERA achieved first-class scientific results and also good economic results in 2018. In fact, a net accounting profit of €2.6 million, obtained without any exceptional operating grant, was achieved in 2018 thanks to new efforts to limit

expenses. We recorded €126 million in orders placed, which is greater than the total achieved in 2017 (€113 million) and close to the highest historical levels, thus confirming the renewed confidence of our partners. The portion of orders placed by foreign customers rose sharply to €31 million (€24.1m in 2017). This is now a very large portion of our economic balance (€130m over the last five years) and I invite you to discover this aspect in the "International" pages. For the wind tunnels, the increase has also been remarkable, having recorded €28 million. This is a sharp increase compared to 2017 (€23m), which was however the highest since 2012.



These results make it possible to envisage the future with confidence and, if the COP talks have a favorable outcome, this newfound tranquility will motivate our scientists to propose even more defense and aerospace innovations for the future. We will build this future together with the Defense Innovation Agency, which, within the DGA, is now in charge of overseeing ONERA. Our contribution to the success of the first Defense Innovation Forum marked our first joint key moment.

I have described in figures the confidence that our government and industrial partners have in us. What better than to turn the floor over to them, so that they can express their perception of ONERA's role. Thus, in this annual report you will find interviews with Mr. Joël Barre, Delegate General for Armaments, Patrick Gandil, Director General of Civil Aviation, and Eric Trappier, Chairman of GIFAS. These testimonies, like that given by the Minister of the Armed Forces on January 10, are an incomparable motivation for ONERA teams. ■

“ Innovation isn't a gadget, it's a necessity [...]. ONERA is highly relevant for these modern armed forces. ”

Florence Parly, Minister of the Armed Forces, visits ONERA

Florence Parly visited the ONERA Center in Palaiseau to announce an unprecedented budget effort. This is a strong sign of recognition for the French aerospace research center, which had not received its supervising minister for almost twenty years.

It was at ONERA that the Rafale, Airbus, Mirage, Ariane, missiles, helicopters, and radars were "conceived, tested and improved", the Minister of the Armed Forces reminded us during her address to almost all of the staff of ONERA's center in Palaiseau. The speech was geared toward expressing recognition, but not only that. The minister explained that "innovating is not a gadget, but rather a necessity", and that therefore she was counting on ONERA to continue its indispensable work in this direction: "ONERA is highly relevant for these modern armed forces. It is one of the spearheads, one of the pioneers."

At this key moment for the future of ONERA, she was accompanied by Mr. Abdel-Kader Guerza, Palaiseau Sub-Prefect, Ms. Amélie de Montchalin, representative of the sixth constituency of the Essonne, Mr. Jean-Pierre Madika, Deputy Mayor of Palaiseau, Mr. Joël Barre, Delegate General for Armaments, Ms. Caroline Laurent, Director of Strategy of the DGA, and Mr. Emmanuel Chiva, Director of the Defense Innovation Agency.

Two announcements that show that the government trusts ONERA to prepare future skies

The minister announced an unprecedented budgetary effort to support ONERA: an exceptional budget of 160 million euros to enable the consolidation of the three Île-de-France sites on the Saclay plateau into a single facility in Palaiseau and, as a second show of strong support, the exceptional loan of 47 million euros from the European Investment Bank to modernize ONERA's wind tunnels.

Consolidation of ONERA's centers in Île-de-France into a single facility

Nearly 600 people currently work at the Palaiseau center. In the long term, nearly 1,200 will work on the Saclay plateau, where ONERA's innovation is very relevant.

Modernization of the wind tunnels

The objective is to enable the DGA, the industrialists and ONERA's researchers to meet the challenges of future programs. This decision by the Ministry of the Armed Forces to support ONERA's wind tunnels proves their essential character and the need for France to have large wind tunnels, both for future weapon systems and for supporting export markets.

Aeronautical medal

Recognition by the government was also symbolized by the aeronautical medal, awarded to ONERA by the minister, who explained: "This is an award that is very significant to me, saluting more than 70 years of expertise, audacity and success for French aeronautics thanks to ONERA, and which I know also foretells many years of success."



Florence Parly
Ministre des Armées
ONERA - 10 janvier 2019

Parliamentarians take action to aid ONERA

Very good scientific and economic results were achieved in 2017 and 2018, with the reaffirmation of its missions, of its strategic role and of its international influence... the observations made in parliamentary reports were all positive (Ms. Lardet, reporter at the National Assembly, Mr. Allizard, Mr. Boutant and Mr. Vial, senators), but also warned of the inadequacy of the resources allocated to ONERA considering its increasing volume of activity and the missions that are required of it.



Joint research federation ONERA / ISAE-SUPAERO / ENAC

On May 14, 2018, Bruno Sainjon, Chairman and CEO of ONERA, Olivier Lesbre, Director General of ISAE-SUPAERO, and Olivier Chansou, Director General of ENAC, launched a joint research federation in the field of "Design, certification and operations of future aerospace systems" to facilitate the exchanges and scientific collaboration that have existed for several years between the three institutions.



ONERA, a major partner of NASA



NASA has renewed its confidence in ONERA: the Super Star accelerometers, which have again been supplied by ONERA to NASA's JPL, measure the drag due to the residual atmosphere in low orbit. Knowledge of this parasite drag guarantees the accuracy of the mission's gravity measurements. ONERA and NASA have also signed a partnership on the supersonic bang.

UAV show 2018

During this ninth edition of the first European professional drone show, ONERA presented its interdisciplinary expertise on drones. Bruno Sainjon opened the event.



They visited ONERA

General Mandon, head of personal staff of the President of the Republic, General Lanata, Chief of Staff of the French Air Force, Admiral Coindreau, Vice-Chief of Staff of the French Armed Forces and General Friedling, Chief of the Joint Space Command, visited ONERA. This is a strong sign of the interest of the armed forces in the research center.

Defense Innovation Forum

ONERA presented eight projects during the first edition of this forum organized by ONERA's new supervisory body, the Defense Innovation Agency:

- the ROS (surface wave radar);
- the FLOAT project (Feasibility of an optical link in a turbulent atmosphere);
- 3D lidar technology;
- the SYSIPHE spectral imaging system;
- the infrared camera TEMOIN;
- additive manufacturing for metallic materials;
- the CAMELOTT project: MEMS sensors and actuators for the closed loop flow separation control of a flap.





Thanks to the exceptional financial support of €160 million from the Ministry of the Armed Forces, ONERA can launch its project of consolidating its three Île-de-France centers into a single facility. This consolidation has several objectives: a better synergy between the scientists and thus increased efficiency, time and cost savings, and improvement of working conditions.

ONERA'S FACILITIES' NEW LAYOUT

KEY FIGURES

Budget: €160m

Project duration: around 5 years

Palaiseau: 3 main buildings

X-ENSTA-ONERA cluster: 1 building

Lille: 1 extension

What real estate changes will there be?

The project includes, at Palaiseau, the construction of three new main buildings; at the *École Polytechnique (X)*, the construction of a building integrated into the future X-ENSTA-ONERA mechanical cluster, to which the research wind tunnels of Meudon will be transferred; in Lille, the construction of an extension allowing the model workshops to be grouped together. The whole consists of nearly 40,000 m².

What will the budget, calendar and workforce be?

The cost of the project is currently estimated at €160 million, of which €130 million are being financed by the sale of the Meudon and Châtillon land, and €30 million are being directly financed by the Ministry of the Armed Forces. This unprecedented investment is a further sign of the Ministry's confidence in ONERA. The project is scheduled to end in 2024 and will benefit all of ONERA: the real estate division, of course, as well as all of its supporting departments, and all research departments and services that will be consolidated in Palaiseau. In all, nearly 700 additional people will transfer to the largest center for aerospace research in France, under better working conditions.

A facility in the heart of the Saclay plateau

The enhancement of ONERA's facility in Palaiseau, as well as the integration to the future X-ENSTA-ONERA mechanical cluster, will consolidate the anchoring to the Saclay plateau research cluster: this will enable the development of research activities and will expand the opportunities for undergraduate and graduate training – including internationally – and enhance ONERA's attractiveness to both researchers and students.

ONERA Palaiseau

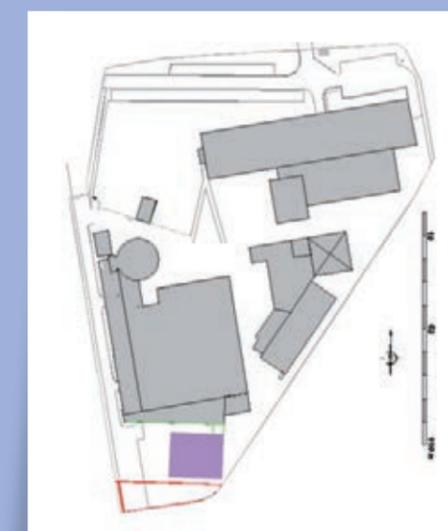


■ New buildings

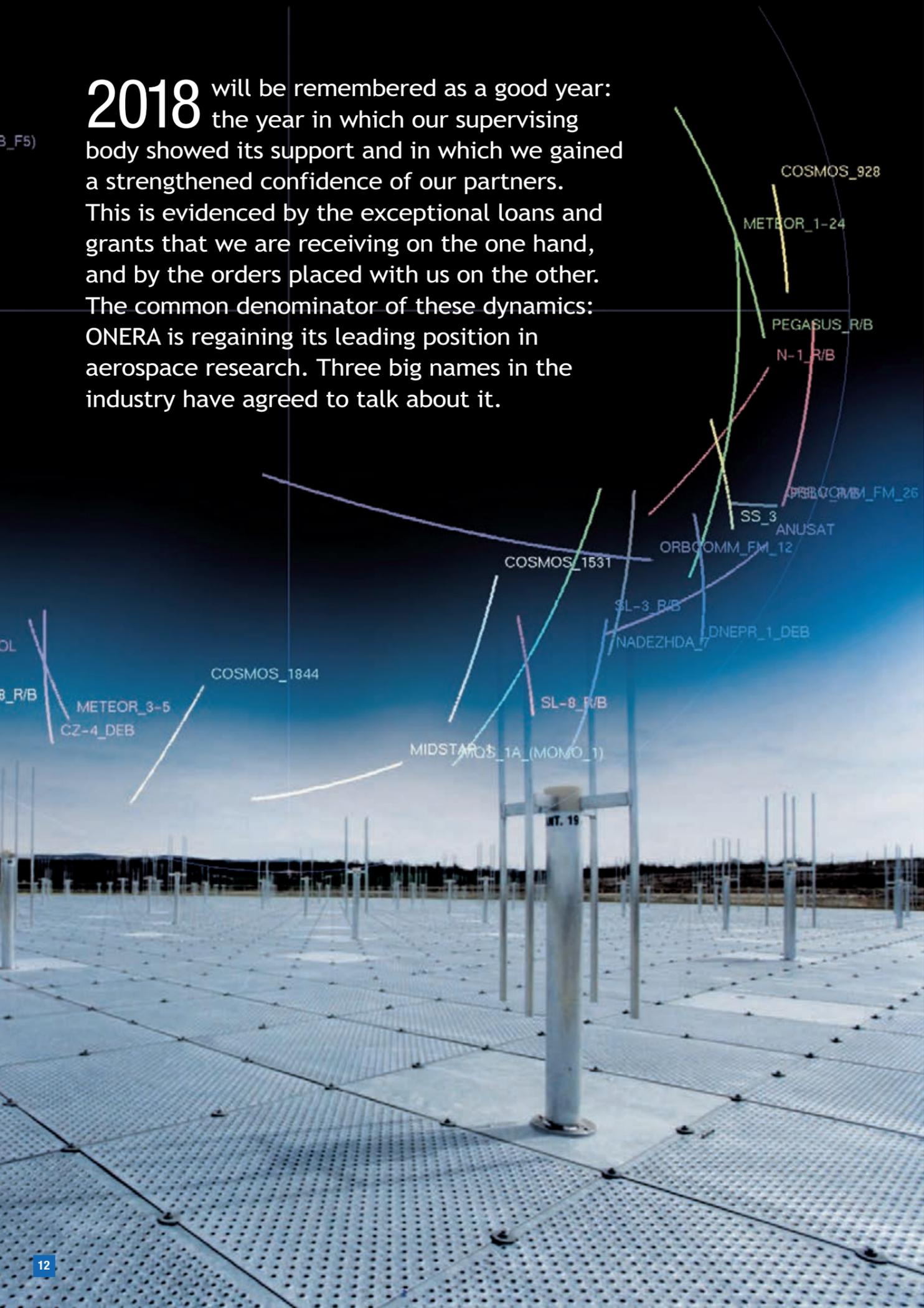
X-ENSTA-ONERA Saclay



ONERA Lille



2018 will be remembered as a good year: the year in which our supervising body showed its support and in which we gained a strengthened confidence of our partners. This is evidenced by the exceptional loans and grants that we are receiving on the one hand, and by the orders placed with us on the other. The common denominator of these dynamics: ONERA is regaining its leading position in aerospace research. Three big names in the industry have agreed to talk about it.



Thanks to the excellence of its researchers, ONERA is the reference government expert



Joël Barre,
Delegate General for Armaments



What does the DGA expect from ONERA?

Since its creation, ONERA's expertise has greatly benefited weapons programs, and therefore the armed forces. Alongside the DGA, which oversees it, ONERA participates in planned innovations for major aerospace weapon programs. Thanks to the excellence of its researchers, ONERA is the reference government expert in terms of science and technology in the fields of aeronautics and space. ONERA's wind tunnels are unique in Europe and strategic for the aerospace industry, both military and civilian. In order to keep them at the best worldwide level, ONERA launched an ambitious operation in 2018 to renovate all of its wind tunnels, in conjunction with the consolidation of its Île-de-France sites into a single facility. These projects must be completed according to the defined schedule, to face future challenges. In addition, the favorable context of the new military programming law (2019-2025), and the appearance of new strategic challenges in space, which has become a new theater for confrontations, are an opportunity to strengthen ONERA's missions.

How do the DGA and ONERA work together?

ONERA plays a vital role for the armed forces: on the one hand, it provides a testing capability that is essential for major programs and, on the other hand, its scientific expertise makes it possible to clarify the structuring choices relating to the preparation of future aeronautical and space defense systems. To ensure the adequacy of ONERA's activities to the needs of the ministry, the DGA oversees ONERA and establishes, through the Objective and Performance Contract (COP), the needs for preparing tomorrow's defense. Seven government representatives, among which three from DGA, meet at least three times a year at the ONERA's board of directors.

What can you tell us about the Defense Innovation Agency?

The Defense Innovation Agency, which is attached to me, was created on September 1, 2018. This agency, which serves all players of the Ministry of the Armed Forces, coordinates all areas of innovation that are useful for defense; its mission is to promote the emergence of new forms of innovation. I encourage the agency to maintain a privileged link with ONERA, because ONERA is both an innovation generator in the fields of aeronautics and space, and a scientific expert that evaluates lines of technical innovation. ■

ONERA must occupy a strategic position in France's public research

Éric Trappier,
Chairman of the French Aerospace
Industry Association (GIFAS)



What are the main areas of cooperation between ONERA and industry?

The existence of a national aerospace research institute, with a broad expertise spectrum, is a veritable asset for the French industry. ONERA is also a member of GIFAS, and is an active contributor to the various GIFAS commissions and work groups, to which it contributes its specificity. ONERA's expertise in the development and validation of models encompasses a number of sectors of interest to the industry: aerodynamics, propulsion, optical and radar signal propagation, stealth, high-performance materials, multi-disciplinary coupling, etc. ONERA's expertise in the control of the dynamics of aircraft and space systems, launchers and satellites is also highly appreciated. On topics such as fundamental aerodynamics, new launcher concepts, and artificial intelligence, ONERA is recognized as a proposing force that is essential for preparing the future of an entire sector. Finally, the wind tunnels and, more generally, ONERA's large test facilities are unique in Europe and are essential to our industry: we salute the actions of ONERA's chairman, who allowed a €47 million loan to be obtained from the EIB to maintain and develop the wind tunnels.

How has the relationship between ONERA and the industry evolved in recent years?

Aware of ONERA's strategic role, GIFAS manufacturers issued in 2015 a series of recommendations concerning the adaptation of ONERA's research offer to changes in the sector. These recommendations have indeed been followed, and the cooperation between ONERA and industry has considerably strengthened. As proof of this, ONERA researchers are heavily involved in the CORAC's (Council for Civil Aeronautical Research) projects, whether in preparing for the long-term future or in very specific topics that ONERA has recognized and undisputable expertise in, such as icing, lightning or the environmental impact of air transport. Similarly, partnerships have recently developed with prime contractors in the space sector, an area in which ONERA has a very broad spectrum of expertise; ONERA is

thus an important player in the government-industry dialogue on space. This more assertive position and ongoing dialogue have had the tangible effect of increasing the volume of studies and research directly benefiting industry over the past three years. This currently represents more than a third of ONERA's external resources.

How does the industry view ONERA's position in French and European research?

ONERA must occupy a strategic position in French public research, establishing structuring partnerships with major players such as the CNRS (French Center for Scientific Research), CEA Tech (the French Atomic Energy and Alternative Energy Commission technology research unit) or colleges like X (École polytechnique) and the ISAE SUP'AERO. The industry also wishes ties with the IRT Saint-Exupéry to be consolidated.

At the European level, ONERA has repositioned itself more firmly in major partnerships, such as Clean Sky, as well as with regard to space technologies, such as optical telecommunications and robotics. In general, it is essential for ONERA to reaffirm its mission of representing and defending the interests of French aerospace research at the institutional level in Europe, and to remain a high-level interlocutor of the German DLR. ■



ONERA's scientific research, supported by the DGAC, explores key topics

Patrick Gandil,
Director General of French Civil Aviation Authority



What does ONERA represent for you?

For over 70 years, ONERA has supported the French aeronautical industry, providing its expertise on a wide range of topics. From my point of view, its primary contribution is its work on aviation safety. ONERA's scientific research, supported by the DGAC, explores key topics such as fire and crash resistance, and the study of icing phenomena and wake turbulence, etc. The results obtained are directly transmitted to our aeronautical industry, which derives applications to improve the safety of its products. This expert role is evident in the position taken by ONERA in the Council for Civil Aeronautical Research (CORAC). The CORAC gathers all French players around a common roadmap and synchronizes their R&T so that the desired technologies will be mature when a program kicks off. The most innovative among them have benefited from it.

What are ONERA's advantages for this role of expert?

Its wind tunnels are one of ONERA's greatest assets. I had the opportunity of visiting the Modane site, which houses the largest wind tunnel in Europe, called the S1, an extraordinary tool that, coupled with the expertise of ONERA's teams, enables complex tests that are essential to aircraft design, even in this digital age. I am proud that the DGAC was able to contribute to the sustainability of this site by financing S1's new giant fans and the adjustments to this wind tunnel. Acoustic tests of engines with very high dilution rates, which the next generation of aircraft should be equipped with, will be carried out in it. The wind tunnel plan, financed by the European Investment Bank (EIB), will allow further progress.

Can you tell us about one of the increasingly important topics of the moment, drones?

ONERA also plays a very important role in the civil drone sector. When the DGAC set up the Council for Civil Drones, my teams went to see those of ONERA and discovered a wealth of knowledge and skills, since they had already been working on this subject for fifteen years. We therefore

strongly rely on its expertise to help the sector to develop through training, through the analysis of drone architectures and of the technologies needed for new uses (urban air mobility), and to prepare future certification methods. ONERA is a partner in our two main activities: a R&D project on avionics for high-performance drones and a prospective study on the use of drones for urban logistics. I also entrusted it with the task of carrying out, together with the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR), reliable tests on the dangerousness of small drones impacting people, whose results are expected by this spring.

The DGAC, like the French aeronautical industry and, I hope, the civil drone industry, will find in ONERA a partner that will facilitate the success of its projects.

Key figures 2018

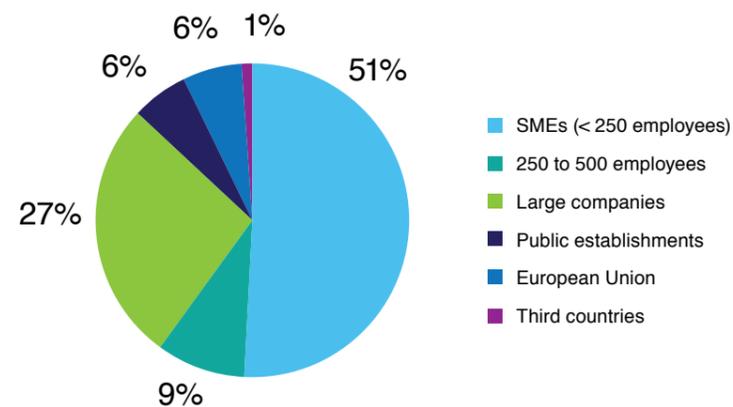
2018 INVESTMENTS
€23,2 million
 (€25,8 million in 2017)

ONERA has a complete and varied set of experimental resources, suitable for each stage of the research process. These facilities require constant renovation and maintenance for ONERA to maintain its level of excellence. In 2018, ONERA allocated 2.3 million euros for the S1MA upgrade operations at Modane.

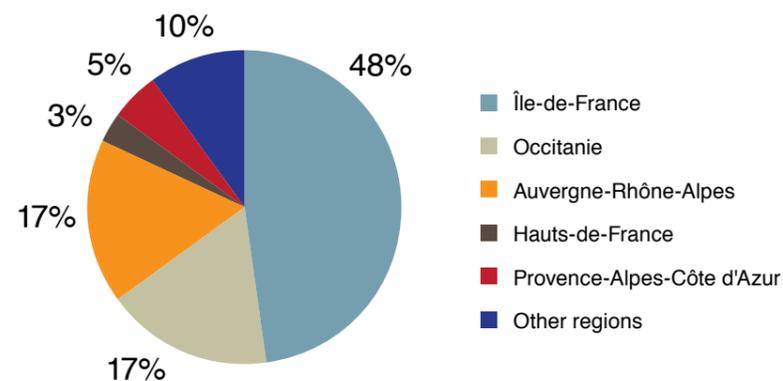
PURCHASES

ONERA works mainly with SMEs at all its centers, considering all regions combined.
In 2018, ONERA signed contracts with 1,730 SMEs (1,579 en 2017).

Breakdown of purchases by type of business

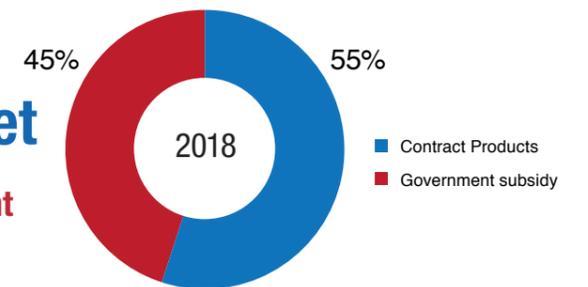


Regional distribution of purchases from partner SMEs

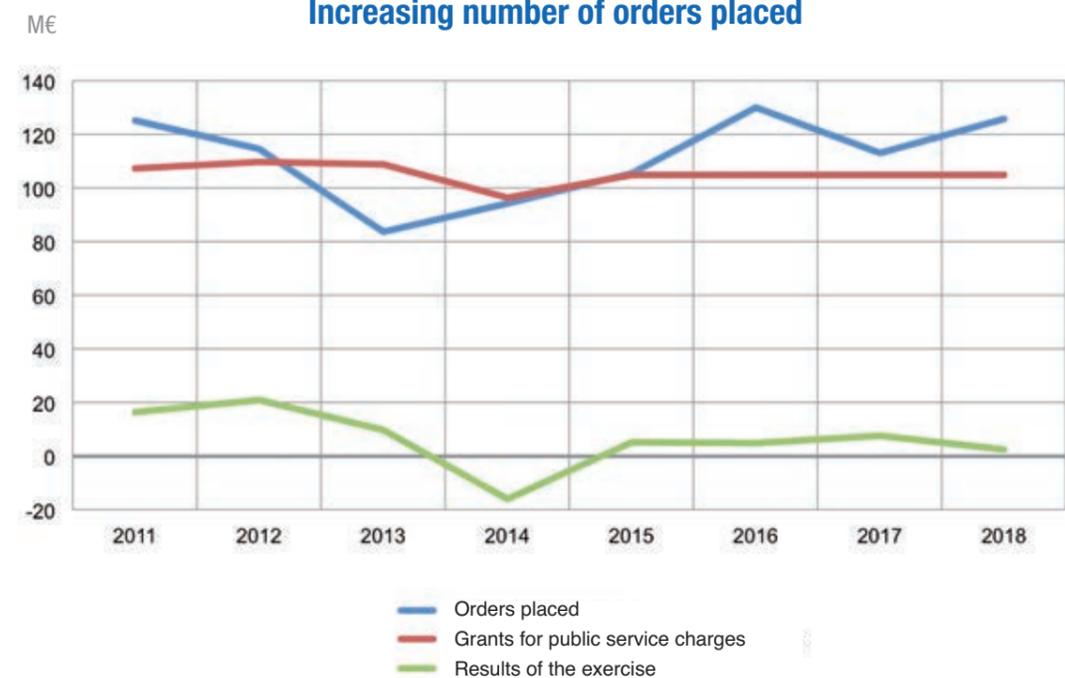


€236 million budget

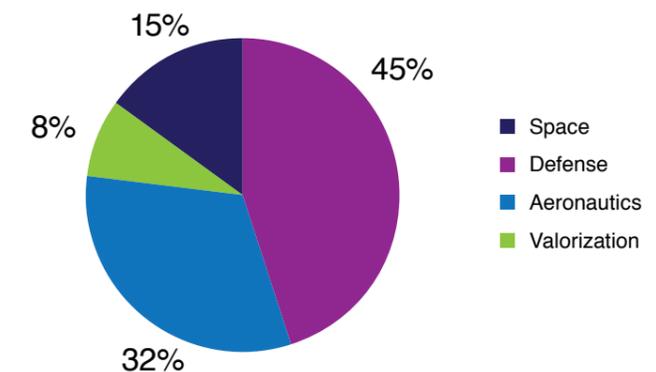
€105m in grants from the government
 €126m contractual production



Increasing number of orders placed



Contractual production by activity area



Human Resources 2018



1,965 collaborators

1,512 scientists and executives

291 doctoral students

22 post-docs

215 trainees

25% women

376 presentations in refereed congresses
219 publications in peer-reviewed journals
1,209 technical reports
87 theses
5 habilitations to direct research
97 HDR
7,770 hours/year of teaching at colleges and universities

140 recruitments, including 92 engineers and executives

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 rewarding to train doctoral students, post-docs and trainees because they offer access to the resourcing of ideas and methods.

In 2018, ONERA had **291 doctoral students**, and **87 theses** were presented. To supervise them, it had **97 HDR doctors** (*Habilitation à Diriger des Recherches: habilitation to direct research*), that is to say, researchers with sufficient professional and scientific background to master a research strategy in a scientific field.

SCIENTIFIC AWARDS

Aymé Poirson Award 2018, awarded to **Riad Haidar** by the Academy of Sciences, as an expert in the field of applications of science to industry.

Chairman Award, received by **Quentin Gallas** and **Ronan Boisard** from the European Rotorcraft Forum International Committee (ERF 2017) for their article and presentation "Forces on Obstacles in Rotor Wake – A Garteur Action Group".

CSMA Junior (national symposium on structure calculation) Best Code Award, presented to **Christophe Bovet** for "Adaptive multipreconditioned domain decomposition method for poorly conditioned AMP-FETI problems (in Z-set/Zebulon)".

Collective SET Panel Excellence Award, presented to **Stéphane Barbé** for his work in the NATO SET-209 group on the use of human signatures for threat identification.

CEM 2018 Doctoral Award, presented to **Matthieu Patrizio** at the 19th International Symposium & Exhibition on Electromagnetic Compatibility, in Paris, for "Optimizing the performance of the Discontinuous Galerkin method in the resolution of unsteady 3D Maxwell equations".

FRTTM (*Fédération de Recherche Transports Terrestres Mobilité: Land Transport & Mobility Research Federation*) Creativity Award, presented to **Gabriele Perozzi**, PhD student, for her work titled "CW-Quad Toolbox – Controls: sliding mode controls, Hinfinit control, PID control, Wind estimator for Quadrirotors".

TSAGI-ONERA Award, presented to **Rémi Roncen** and **Fabien Mery** in Moscow for their LoLS project: "Low-Frequency Liner Study".

POSTERS

Best Student Poster Award, presented to **Jean-Charles Mateo Velez** at the 15th Spacecraft Charging Technology Conference, SCTC 2018, for his work "On the use of a detailed electron emission model for spacecraft charging at low energy".

Best Poster Award, presented to **Marc Villemant** at the SCTC 2018 (29/06/2018) for his work "On Testing materials under electron spectra representative of GEO worst-case environments for surface charging".

Best Poster Award presented to **Antoine Lacour** for his thesis work carried out as part of the ANR-funded project Turbo-Ahead (Safran, ICPE, LSPM, and ONERA) at the IChemE international congress (South Korea, 5-9 December 2018) on high-entropy alloys for turbine engine applications.

3AF AWARD

2018 Excellence in Science Award, presented to **Alexandre Bresson**, Yannick Bidel and Nassim Zahzam by the French Aeronautics and Astronautics Association for "Cold Atoms".

Anne Denquin was elected President of the 3AF Materials Technical Committee.

DISTINCTIONS

Pascal Crozier, aeronautical medal, by Decree of 30/01/2018.

Franck Lefèvre, Knight of the Legion of Honor, by Decree of 31/12/2018.

Jean Leger, Knight of the National Order of Merit, by Decree of 15/05/2018.

BEST PAPER AWARDS

Best Student Paper Award, presented to **Baptiste Fix**, an ONERA doctoral student, at the defense and security optonics congress OPTRO 2018 organized by 3AF, for "Nanostructured diode for infrared photodetection through nondegenerate two-photon absorption".

Best Paper Award, presented to **Adrien Langenais** at the CNES Young Researchers' Days in Toulouse.

EREA Best Paper Award, 2nd place, presented to **Maxime Fiore**, **Olivier Vermeersch**, **Maxime Forte**, **Grégoire Casalis** and **Christophe François** for "Characterization of a highly-efficient chevron-shaped anti-contamination device" in Experiments in Fluids, 2016.

Best Student Paper Award, presented to **Claire Li** at the PIERS Conference in Singapore for her work "Far-Field to Near-Field Investigation of Thermal Radiation Emitted by a Single Optical Nanoantenna" (ONERA-ESPCI thesis).

Safety Track Best Paper Award, presented to **Xavier Olive** at the ICRAT (International Conference on Research in Air Transportation), in Barcelona, for the article Quantitative Assessments of Runway Excursion Precursors using Mode S Data.

Best Paper Award, presented to **Jean-Luc Hantrais-Gervois** at the NATO AVT-284 Research Workshop on "Advanced Wind Tunnel Boundary Simulation" for "A Methodology to Derive Wind Tunnel Wall Corrections with RANS Simulations".

Best Paper Award at the RFIAP 2018 Congress (*Reconnaissance des Formes, Image, Apprentissage et Perception: Recognition of forms, image, learning and perception*) in Marne-la-Vallée, presented to **Marcela Carvalho**, **Bertrand Le Saux**, **Pauline Trouvé**, **Frédéric Champagnat** and **Andrés Almansa** for the article "Monocular depth estimation by neural network and the contribution of defocus blur".

CFPT 2018 Best Paper Award (French Conference on Photogrammetry and Remote Sensing in Marne-la-Vallée), presented to **Élise Koeniguer**, **Jean-Marie Nicolas**, **Béatrice Pinel-Puysegur**, **Jean-Michel Lagrange** and **Fabrice Jabez** for the article "Visualization of changes in radar time series: REACTIV method evaluated globally using the Google Earth Engine".

Young Researcher Award, presented to **Fabrizio Pagano** at the 7th International Conference on Fatigue of Composites (Vicenza, Italy) for the article "Fiber-Dominated Fatigue Failure in CFRP Composite Laminates".

ISIF 2018 Jean-Pierre Le Cadre Best Paper Award at the 21st International Data Fusion Conference (Cambridge) FUSION 2018, awarded to **Jean Dezert**, **Albena Tchamova**, ext., and **Deqiang Han**, ext., for "Total Belief Theorem and Generalized Bayes' Theorem".

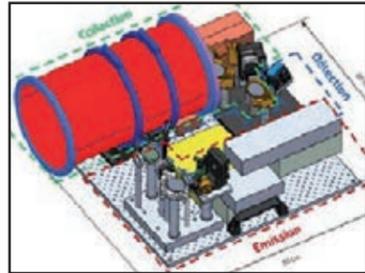
CNAM IFAC Young Author Award, presented to **Elinirina Robinson**, **Julien Marzat** and **Raissa Tarek** at the 10th IFAC Symposium on Fault Detection, Supervision and Safety for Technical Processes (SAFEPROCESS 2018) for "Model-Based Prognosis of Fatigue Crack Growth under Variable Amplitude Loading".

Best Student Article, 2nd prize, awarded to **Cécile Ghouila-Houri** at the 2018 Flow Control Conference AIAA for "High temperature gradient wall shear stress micro-sensors for flow separation control".

Best Paper Award, presented to **Frédéric Boniol**, **Youcef Bouchebaba**, **Julien Brunel**, **Kevin Delmas**, **Claire Pagetti**, **Thomas Polacsek** and **Nathanael Sensfelder** at the 37th AIAA / IEEE DASC (Digital Avionics Systems Conference), in London, September 23-27 for "PHYLOG: a model-based certification framework".

Collectively, ONERA received the aeronautical medal on January 10, 1919, from Florence Parly, Minister of the Armed Forces.

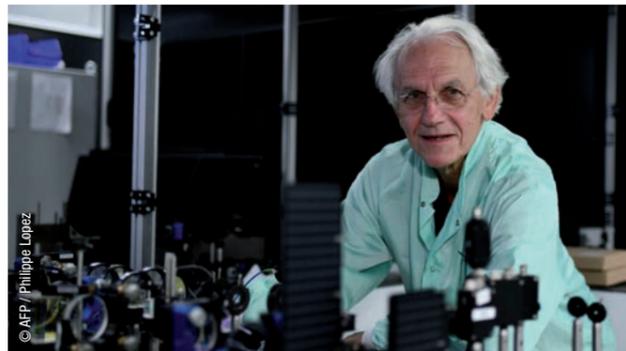
2018 Highlights



Environnement | Soot aerosol lidar measurements

A first experimental demonstration of soot aerosol measurements was conducted by short-range (from 3 m) and high-spatial-resolution (<1 m) lidar. The Colibris lidar thus made it possible to

measure the radiative properties of carbonaceous aerosols resulting from the combustion of kerosene and diesel fuel. This new instrument will consolidate ONERA's position on the characterization of the environment, particularly with regard to particulate effluents from aeronautical combustors.



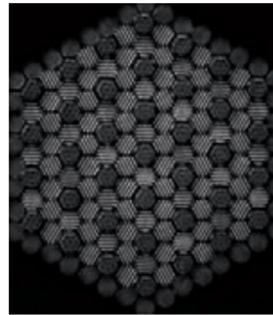
Laser | ONERA supports the 2018 Nobel Prize winner in his quest for extreme light

Gérard Mourou was rewarded for a technique called frequency-drift amplification, which triggered an increase in the importance of ultra-short-pulse lasers. Since the 1990s, ONERA has accompanied him: an interferometer patented at ONERA, based on the interference of three and then four waves, was shown to have qualities that are suitable for the metrology of the beams emitted by this type of laser. Several world premieres were achieved at the CUOS (Center for Ultrafast Optical Science) under the direction of Gérard Mourou. The success of this new measurement resource has led to the creation of the SME Phasics, which offers it under an ONERA license.



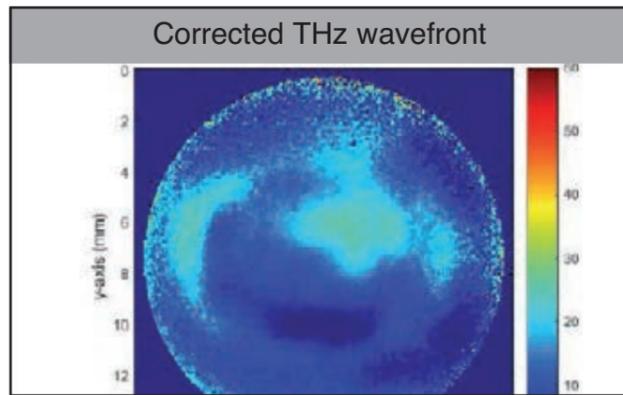
Optical metrology | 3D reconstruction of flows using digital holography

For the analysis of complex aerodynamic phenomena, ONERA tested a multidirectional digital holographic interferometry bench with 6 simultaneous lines of sight, based on interferometry. As a light source this bench uses a frequency-doubled pulsed laser with a coherence length of the order of 3 meters. Applications are related to flow control and boundary layer manipulation by jets, and the 3D reconstruction of supersonic flows.



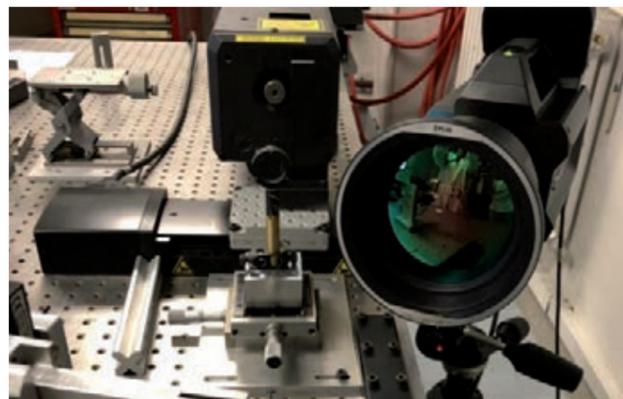
Ultra-intense lasers | ONERA makes an essential contribution to a new generation of lasers

ONERA designed, constructed and used a wavefront analyzing interferometer, which achieved, for the first time, an absolute measurement of the quality of a laser wavefront resulting from the amplification and coherent combination of laser beams for the new architectures, likely to produce these ultra-intense lasers. The interferometer was implemented on the first prototype of this new generation of lasers, called XCAN (LULI laboratory, École Polytechnique).



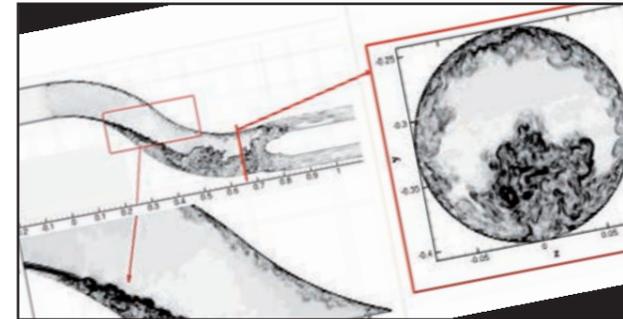
Adaptive optics | First experiment in the terahertz domain

ONERA made an intermediate wave loop between microwaves and infrared waves, in collaboration with the Onde Matière Aquitaine Laboratory. The quality of the terahertz phase was improved by a factor of 10. The phase corrector is a very-large-stroke deformable mirror usually used in astronomy, and the analysis is done through an optical scan of the terahertz wave. The next step: to demonstrate the beam phase and amplitude correction, in order to improve current non-destructive testing techniques.



Non-destructive testing | Microcrack detection by laser thermography

Microcracks, observable by scanning electron microscopy, but not detectable by conventional non-destructive testing means, were revealed by laser thermography. The principle: to detect, with an infrared camera, the thermal gradient induced locally by a crack in a material scanned by a laser beam. This exceptional result is a major breakthrough in fault detection in structures.



Aerodynamics | Better prediction of flow distortions in UCAVs

Due to stealth constraints, there is frequently a boundary layer detachment in the air intake ducts of combat drones. This detachment causes dynamic distortions that are detrimental to the engine. As part of ONERA's OPA-UCAV research project, the ZDES Mode 3 method was applied for the first time to a complex internal aerodynamics geometry. This has significantly improved the prediction of these dynamic distortions in curved intake ducts.

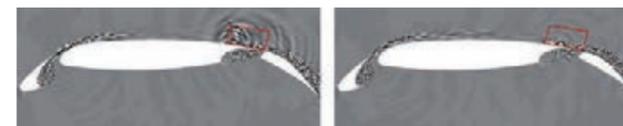


Materials | Acquisition of a new sintering machine

ONERA has acquired an electric sintering machine: its 40 kA and 250 t capability will enable the production of 0 mm to 300 mm parts, making the machine almost unique in France. This system allows parts (metals, ceramics, etc.) to be heated quickly up to very high temperatures (2,500° C), to obtain dense parts made of ultra-refractory materials while maintaining a fine microstructure to improve their physical properties, such as their mechanical properties.

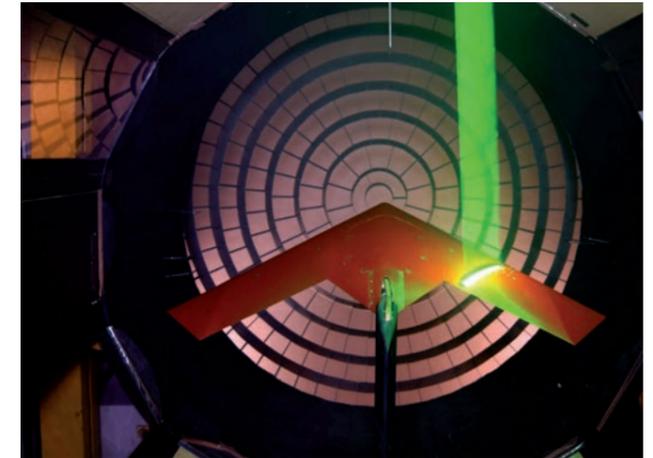
Materials | 30th anniversary of the microstructure laboratory

The LEM is a joint CNRS-ONERA research unit that conducts fundamental studies establishing the link between physical mechanisms and the macroscopic behavior of materials. An impressive performance was revealed at the time of this anniversary, with the publication of 131 articles in peer-reviewed international journals, the presentation of 103 invited lectures, and the supervision of 31 doctoral students and 14 post-docs by about ten permanent researcher over the last five years.



Digital aeroacoustics | Silent generation of turbulent fluctuations

Satisfactory resolution of turbulent dynamics in the boundary layer requires the injection of fluctuations upstream of the area of interest. Conventional methods of generating artificial turbulence are too noisy for the prediction of aeroacoustic sources. ONERA has developed a method for coupling source terms and dynamic forcing, which has enabled the first RANS/LES hybrid simulation of a turbulent boundary layer without wall pressure corruption by the input condition.



Innovative metrology | Three-dimensional PIV on a semi-industrial scale

ONERA carried out a three-dimensional 3D particle velocimetry campaign around a combat drone model in the L1 wind tunnel at the Lille center. Beyond metrological control, this first use of 3D PIV enabled data to be collected to develop methods for the determination of volumic pressure fields from velocity fields. This work is being carried out as part of the ANR-funded project Astrid Evapor in partnership with the Pprime laboratory.

Fluid Mechanics | Creation of Lille laboratory

LMFL is the result of the merger of two research entities: the University of Lille's "Rotating and Turbulent Flows" team and ONERA Lille's "Experimentation and Flight Limit" unit. The laboratory comprises 38 permanent staff and about 25 doctoral and post-doctoral students, at Lille's Arts et Métiers sites and at ONERA's sites, as well as on the Villeneuve d'Ascq campus: Centrale Lille, the CNRS and Lille university. Four scientific topics will be addressed: turbulent flows and control, measurement and analysis of data, rotating flows and flight dynamics in an unsteady and inhomogeneous environment.



Human factors | ONERA's dedicated test facilities

Cognitive engineering activities are underway at the Salon-de-Provence to assist operators in conducting complex operations. ONERA relies on comprehensive test facilities (information processing and system control, interactive simulation, etc.). It conducted a flight test campaign with the company AVDEF to study pilot behavior under stress (3D camera in the cockpit aimed toward the crew and associated with a human body pose estimation software to measure the pilot's posture by reconstituting the orientation of the head, torso and upper limbs).

Radar | On-board pods for passive-mode radar data

The Salon-de-Provence center has retained its privileged relationship with the Air Force Research Center (CREA). In 2018, they cooperated using the ONERA BUSARD motorglider to acquire data using Digital Terrestrial Television (DTT) transmitters to detect aircraft in the vicinity of the radar receiver.

ONERA's Roadmaps

2018 has been largely devoted to drawing up ONERA's roadmaps, the main objective of which is to structure a large part of the scientific activity for the years to come.

Identifying obstacles to overcome them

Roadmaps are therefore the central tool for programming activities. They cover the major applicative purposes – aeronautics, defense and space – and also identify the challenges specific to ONERA, to enable it to better carry out its missions in the years to come. Indeed, identifying fields of research to invest in also means identifying the skills that ONERA's scientists must maintain, complete or acquire.

Meeting external needs

The roadmaps have been designed to be an effective means of communicating with stakeholders, as part of the ongoing dialogue with the entire sector, through participating in the various CORAC and CoSpaCe instances, and with ONERA's supervising body, the Defense Innovation Agency.



Questions to Stéphane Andrieux,
Chief Science Officer of ONERA

Do roadmaps have both an internal and external dimension?

Internally, it is indeed essential to question our expertise and our ambitions, because this will allow us to adapt and enrich our offer. Only a clear and detailed vision of our objectives could help us. However, roadmaps are not just an inventory of our professions, far from it.

If you had to summarize the roadmaps in two words, what would they be?

First, "vision". In 2015-2016, we developed our scientific strategic plan (SSP), that is, our major scientific orientations. It made sense to break it down into major lines of research directly related to the roadmaps.

The second key word would be "creativity", because although roadmaps point to concrete targets, we rely on the creativity of our scientists to figure out how to achieve them. It's their day-to-day work: pushing the frontiers of knowledge to lift obstacles.

Do roadmaps also address ONERA's partners?

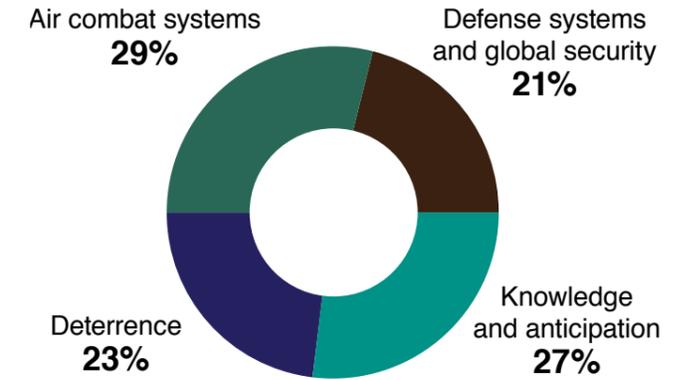
ONERA is not intended to replace industrialists. In this sense, roadmaps are not industrial design programs for industrial purposes. However, we have been listening to the needs of our sector, in order to focus our research on what will be useful to prepare the skies of tomorrow. However, we will also call upon our scientific partners for the most scientific of the obstacles. Our supervising body also impatiently awaits our roadmaps, which we wished to be ambitious in our role of government expert.

Illuminating the future of aerospace with clear, formalized and shared objectives

Defense

Innovation for defense

In 2018, the defense activity was very important: ONERA played a major role in the field of deterrence and as an expert in the digital simulation of a combat scene environment.



Distribution of ONERA's defense activities in 2018



Optical communication: long-range broadband at sea

Funded by the DGA for three years, the FLOAT project (feasibility of a turbulent optical link in a turbulent environment) has been successfully completed, proving that a high-speed, long-range optical communication system can operate in a maritime environment. The demonstration revealed a 20km laser telecom link above the sea, with extremely low information loss rates and large data rates. The role of ONERA has been twofold: to develop optical transmission and reception modules, with the challenge of pointing the emission towards the reception to within a few microradians, and to maintain this line of sight despite turbulence, device vibrations and atmospheric refraction. ONERA has also been able to put to good use its knowledge of atmospheric propagation phenomena for the sizing of an optimized system battling severe turbulence conditions. This project was presented at the 2018 Defense Innovation Forum.



Space surveillance: extending the performance of the GRAVES system

ONERA, together with its partner Degréane Horizon, is continuing the renovation of the GRAVES system: the 2018 success of the detailed design review for the new system validated the technical choices. Since then, ONERA has been working hard to build, test and integrate this technical solution, and to prepare for its implementation on the reception site, the first to be renovated. ONERA has implemented exceptional resources for studying new antennas in order to evaluate system performance extension solutions. The irregularity of the network required an innovative calculation method and the power of the SATOR supercomputer, in order to compare the different options and to provide the DGA with the best elements of choice.

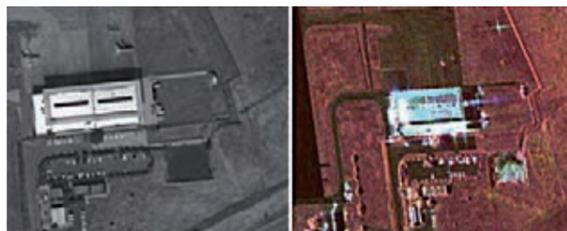


Radar: airborne SAR campaign for the French Navy

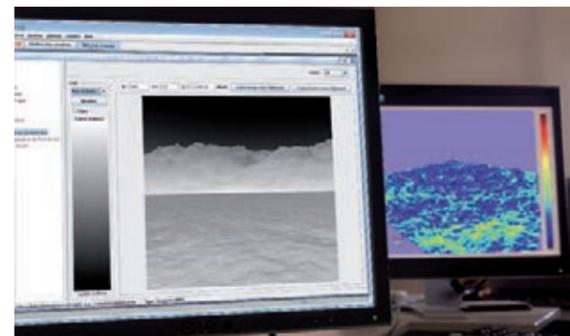
The frigate *Auvergne* (US Navy picture)

ONERA has implemented its airborne SETHI-RAMSES NG resource for a very high resolution SAR measurement campaign, on two Navy frigates – the *Chevalier Paul* and the *Auvergne*. The data collected during seven flights, including some at night, are very rich: they will enable the characterization of the radar response of these vessels according to the observation configurations, and the comparison of the models and experimental measurements. This campaign took place within the framework of the DGA COMAREM contract – Knowledge and reference modeling of the maritime electromagnetic environment.

In 2018, Sethi's spectral coverage was extended to infrared (new optronic sensor and infrared camera increasing the spectral coverage to the LWIR domain). The new pod configuration has obtained EASA certification, allowing it to fly without restriction on the Falcon 20 of the company AVDEF, with the Sethi device on board.



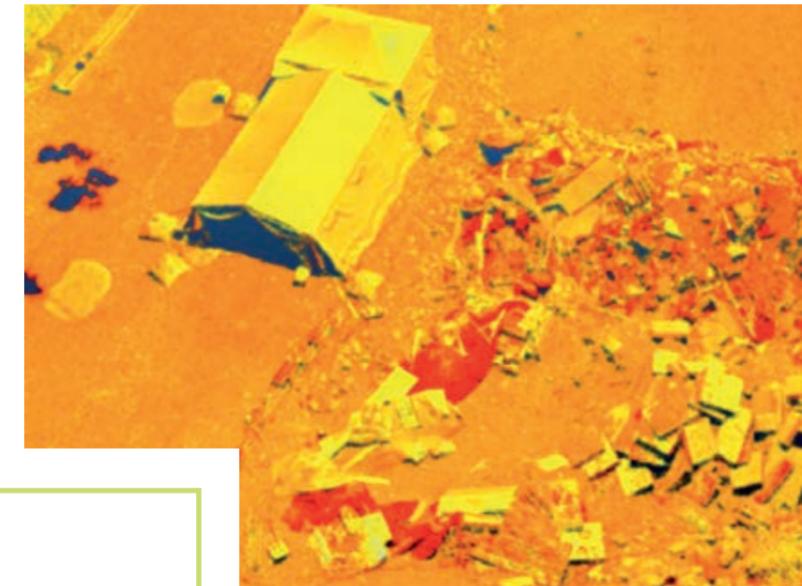
Optronics: version 3.5 of the radiative transfer code MATISSE



Version 3.5 of MATISSE, a code of reference for the digital simulation of combat scene environments, was delivered to the DGA. Thanks to the many data included (atmospheric profiles, clouds, aerosols, backgrounds, etc.), this software can be easily used for engineering calculations. It can also be integrated into simulations and performance forecasts. MATISSE is, for example, used for missile programs, as well as in the scene generation tool used by the DGA.

Laser imaging : assessing damage and planning rescue operations

As part of the European project INACHUS, which is aimed at developing a high-resolution 3D laser imaging system to be carried on board a drone, ONERA worked on the 3D mapping of large areas to plan the deployment of rescue operations, evaluate structural damages to prioritize their intervention, and to locate victims with the aim of optimizing assistance times. Thus, ONERA has developed and implemented two multirotor drone solutions equipped with passive and active imaging sensors.



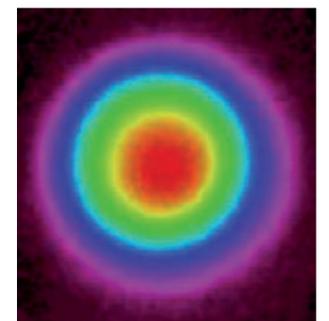
© Bertin Technologies

Multispectral imaging: continuation of the partnership with Bertin Technologies

The research and industry partnership agreement with Bertin Technologies on multispectral infrared instrumentation for the remote detection of gases entered its second year. This three-year research program called CUBIX (payloads based on multi-spectral imagers), is aimed at developing new spectro-imaging instruments based on innovative optical concepts, allowing the system's mass and volume to be reduced. This will enable Bertin Technologies to remain a leader in remote chemical detection. At the end of the first year, Bertin praised a very satisfactory collaboration, as well as the scientific quality of ONERA's work.

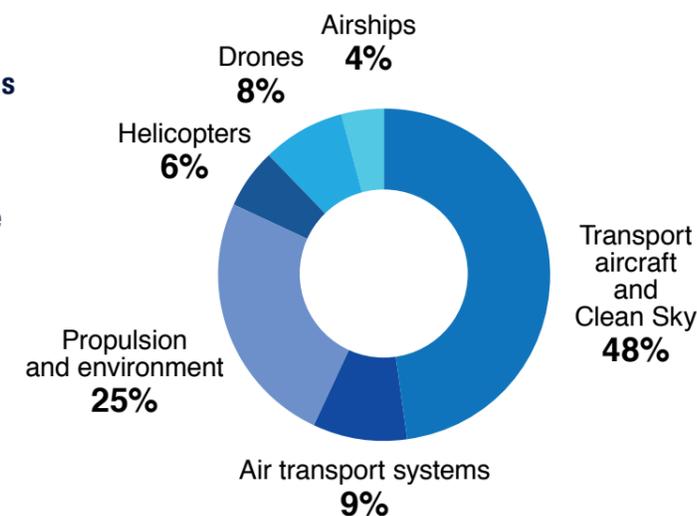
Laser weapons: ONERA's partnership with the TALOS consortium

Set up in response to the European Defense Agency's 2018 call for tenders, the TALOS consortium relates to energy weapons with laser-based sighting. Led by the company CILAS (ArianeGroup), this consortium, worth €5.4 million, will start in April 2019 for a period of three years. Its purpose is to establish the technological roadmaps for the development of European anti-structural laser weapon systems in the medium term, and to produce the first demonstrations of key components. Among the 17 European partners, ONERA will study the increase in importance of fiber lasers for laser weapons, using its numerical simulation methods to define the optimal fiber laser source architectures and to evaluate the expected performances. As a second step, experimental testing of high-efficiency fiber laser amplification stages will be conducted.



Preparing the new generation of aircraft

In 2018, the most striking highlight was the strong increase in "transport aircraft" activities under the triple influence of the Clean Sky activities, the successes encountered in the European H2020 calls for tender, and the growing involvement of ONERA in several agreements established by the DGAC. The significant increase in activities on airships is also worth noting.



Distribution of ONERA's aeronautical activities in 2018

Aircraft safety: ONERA's world-renowned icing expertise

ONERA has developed a new generation of digital tools that are more precise and interoperable with other codes. In 2018, it was involved in all H2020 projects selected on this topic:

- The MUSIC-HAIC project, which it coordinates, on the development of 3D models for icing under crystal conditions;
- The SENS4ICE project on innovative icing detection technologies;
- The ICE-GENESIS project, on the modeling of icing under snow and de-icing conditions; this project will be supported by the construction of the icing wind tunnel, financed by the DGAC* (AIRBUS coordination).

The PHYSICE-2 project, also funded by the DGAC, relates to research on the understanding and modeling of icing or de-icing. ONERA will continue its collaboration with NASA via the SUNSET2 project on the study of aerodynamic degradations due to icing for a swept wing.

*Directorate General of Civil Aviation



Airships: wind tunnel testing of FLYING WHALES

As part of a 48-month "industry research partnership", signed in 2013, ONERA and FLYING WHALES conducted wind-tunnel tests on a LCA60T airship model. The goal: to study the airship aerodynamics to make corrections before the transposition to real flight conditions. ONERA is involved in many areas such as system studies, flight dynamics, aerodynamics, and even environmental conditions.



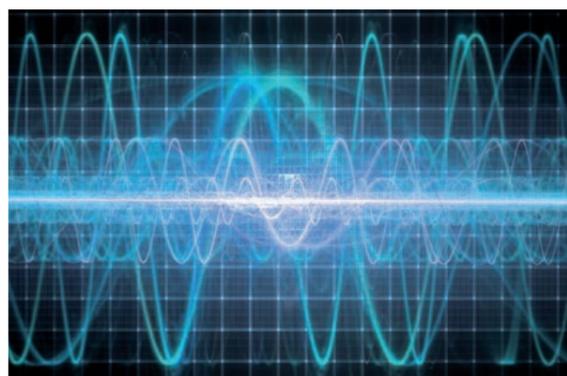
Noise reduction: ONERA on several fronts

The European project ANIMA presented in Brussels

This H2020 project, led by ONERA, focuses on managing the noise impact around airports. ANIMA was presented to the European Parliament in March 2018, in front of around fifty deputies. It is supported by EREA (Association of European Research Institutions in Aeronautics) and constitutes the "noise" component of the European initiative Future Sky, which is aimed at addressing the challenges faced by air traffic and its growth over the years to come.

NASA and ONERA are working together on an issue that divides the international scientific community

ONERA and NASA are actively discussing the modeling of acoustic liners, a tricky point for reducing fan noise. One solution to reduce this noise is indeed to line the engine nacelle with these absorbent materials, whose acoustic properties must be analyzed precisely. Expected advances: the consolidation of numerical simulation models for estimating noise pollution in engines, in which acoustic waves propagate simultaneously in all directions.



Electromagnetic compatibility: new test bench for powerful electronics

ONERA is carrying out work to reclaim EM phenomena due to the increase in the power of this equipment, and to revisit the current avionics standards. A 5 kW brushless test bench has been developed using components from the electric bike market. The objective: to validate innovative experimental methods for the electromagnetic characterization of power systems.



Air traffic control: dynamic sectorization in real time

As part of the dynamic sectorization work carried out in collaboration with the DGAC and the CRNA/SO*, ONERA has implemented the SINAPS platform with actual data from the Bordeaux Air Traffic Control Center to evaluate what is happening in real time. The SINAPS platform indicates what strategy must be adopted to constantly adapt to changing air traffic and to the available resources.

*Southwest en-route air navigation center



Lightning: new instruments to better analyze the risk

ONERA is developing sensors to better characterize the atmospheric environment and understand the threat of lightning. They were tested in flight as part of the ANR-funded* EXAEDRE project by approaching storm clouds as closely as possible on board the Safire Falcon 20. Sensors developed by ONERA were deployed: a new type of lightning imager based on an interferometry system for detecting and locating lightning bolts, and four lightning detectors on the aircraft.

*French National Research Agency

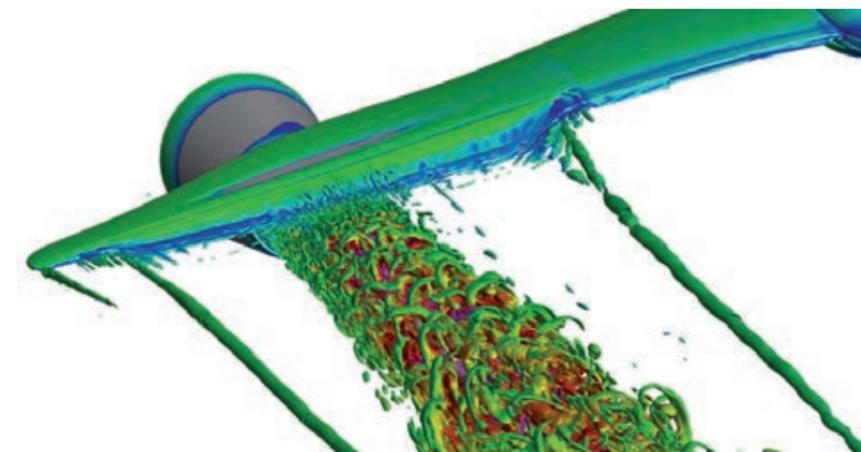


Aerodynamics: innovations and new resources to conquer laminarity

As part of the Clean Sky 2 AIRFRAME-ITD platform and the Technology Stream "Advanced Laminarity" under the responsibility of ONERA, a workshop gathering some thirty partners (including Airbus Commercial Aircraft, Dassault Aviation, the DLR and SAAB) enabled discussions on the flight test analyses conducted by Airbus Commercial Aircraft on the BLADE A340-300 demonstrator equipped with two laminar sleeves on the outer parts of the wings. A test campaign was also conducted in ONERA's F2 wind tunnel combining suction and a passive device in order to control the appearance of the laminar-turbulent transition on the dividing line of a swept wing.

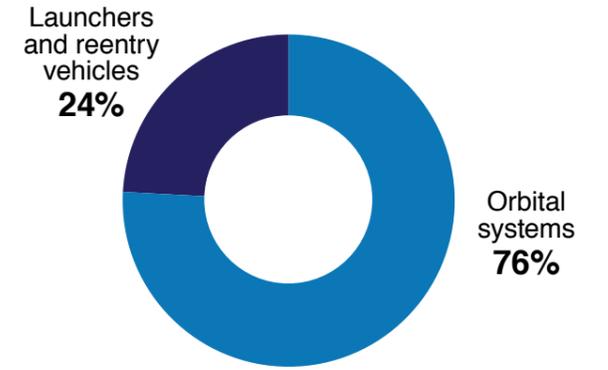
Aerodynamics: numerical analysis to predict stall

The turbulent boundary layer developing on a wing profile was simulated using the ONERA FAST HPC computation code and the ONERA CASSIOPEE pre- and post-processing tool. The resolution needed to digitally capture the phenomenon requires a one billion point mesh and ONERA's very large computing resources.



ONERA in the construction of the French and European space strategy

In 2018, ONERA is in high demand to prepare the French and European space strategy. In particular, it has signed two cooperation agreements with major players in the field, Airbus Defense & Space and Thales Alenia Space. ONERA has also had great success in Brussels, and has been asked by DGA to work on the future generation of space surveillance systems.



ONERA's space activities in 2018

SPATIAL ACCELEROMETRY: A GLOBALLY-RECOGNIZED EXPERTISE



Bruno Christophe and Bernard Foulon, in front of an accelerometer from the Grace Follow-On mission

Two satellites of NASA's Grace Follow-On mission for measuring the Earth's gravity field, which were launched in May 2018, are equipped with ONERA electrostatic accelerometers. During the Grace mission in 2002, ONERA had already supplied accelerometers, which worked without incident for 15 years. Their role is to measure the residual drag of the satellites. Michael Watkins, director of NASA's JPL, thanked ONERA more than warmly, describing the team as "world leaders in the area of borne accelerometers".



CNES President Jean-Yves le Gall congratulates ONERA

On the occasion of the withdrawal from service of the Microscope mission satellite, the ONERA team was warmly congratulated by Jean-Yves Le Gall: "... I would like to take this opportunity to thank and congratulate all of the teams that participated in this extraordinary adventure, and in particular to pay tribute to the remarkable work of Pierre Touboul, the scientific leader of this mission. On October 15 and 16, 2018, the satellite was taken out of orbit using an innovative system of inflatable sails as air brakes. In less than 25 years the orbit will reach the dense layers of the atmosphere, where the satellite will disintegrate. Scientific teams have one year to complete the analysis.

ADAPTIVE OPTICS FOR SPACE

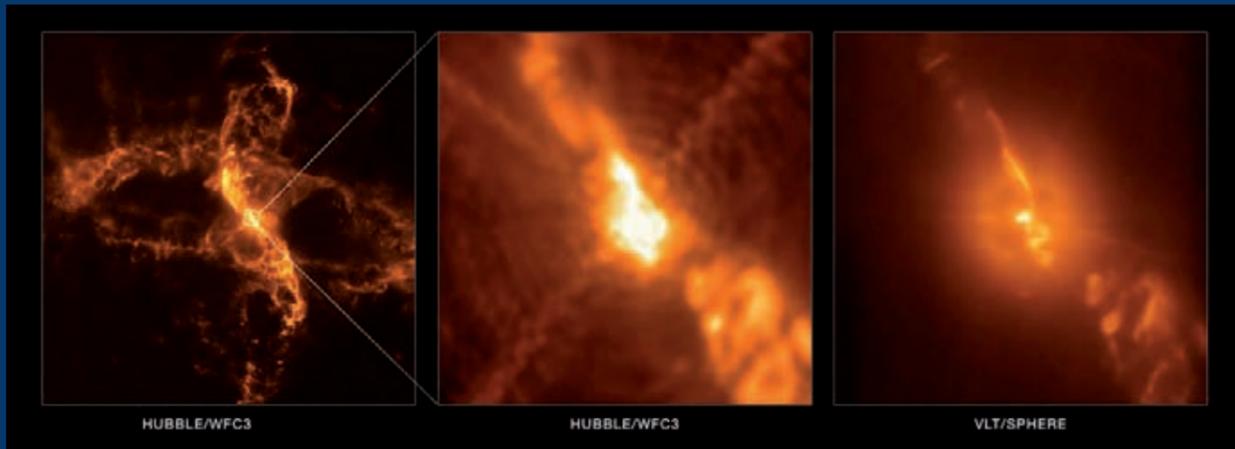
ONERA is contributing to the development of the Extremely Large Telescope (ELT)



With its 39 m diameter primary mirror, the ELT's very high-resolution spectral imager is the largest optical telescope ever built. Developed by the Southern European Observatory (ESO), the HARMONI instrument will achieve exceptional performance that will answer fundamental questions, such as the formation and evolution of the first galaxies in the universe. ONERA, in partnership with the Marseilles Astrophysics Laboratory (LAM), has developed adaptive optics modules for observation with very high spatial resolution.

SPHERE delivers new exceptional results

The "planet hunter" instrument SPHERE, ESO's Very Large Telescope, provided unique images: dust disks and exoplanets. Astronomers captured the spectacular details of the turbulent stellar relationship in the R Aquarii binary star with unprecedented clarity, even compared to Hubble telescope observations. This achievement is largely due to the unique performance of the SPHERE extreme adaptive optics system, designed by ONERA.



Support to industry: two flagship cooperation agreements

Although different, the two agreements share a common goal: to strengthen and structure joint activities. **With Airbus Defense & Space**, the agreement covers around fifteen technical topics in the fields of future science, observation and telecommunication missions, particularly with the constellations, to respond to the rapidly changing space sector. **With Thales Alenia Space**, the research topics of common interest identified at kick-off are telecommunications, optical imaging, and knowledge of the space environment.

ONERA INNOVATES TO FIGHT CLIMATE WARMING

The SCARBO project highlighted in Nature

The objective of the project is the monitoring of greenhouse gas emissions from space. Most existing satellites have masses between 200 kg and over one ton, whereas the SCARBO satellites offered by Airbus Defense & Space, equipped with a very compact spectral-imager designed by ONERA and the IPAG (Grenoble Institute of Planetology and Astrophysics), will be miniatures. A consortium of eight European organizations is working on the project, led by Airbus Defense & Space. ONERA is involved in building the instrument and in the data processing.



Propulsion: a world first on an ONERA bench

As part of the European project H2020 HYPROGEO, completed in 2018, the satellite hybrid engine demonstrator, designed and tested at ONERA, ran for five minutes with constant thrust: it is the longest hybrid propulsion test ever performed. ONERA designed an innovative axial combustion chamber with compensated regression. This progress was praised by the European Commission at the final meeting, and the project received a Stars of Europe Award in the "Innovation" category over more than 50 projects. As a major advancement compared to the existing state-of-the-art, it raised the TRL level from 1 to 4 in less than three years.

Stratospheric airship: continuation of the Stratobus project

Subcontracted for the project, ONERA delivered the Stratobus project's dynamic behavior simulation tool to Thales Alenia Space. Additional aerodynamic activities were also carried out. ONERA will be subsequently involved in the following activities: experimental and numerical aerodynamics (envelope and propellers), dynamic behavior simulation, robust control laws and operation in degraded mode, and, optionally, mast behavior, icing, lightning, etc.



ALTAIR: a European project for launching small satellites

The European project H2020 ALTAIR, which is studying a future system for launching small economically competitive satellites, has made it possible to define an original concept of a large drone carrying a hybrid propulsion rocket. ONERA coordinated all of the system's design work (carrier, launcher and ground segment), as well as the definition of the business model and a development plan proposal. The European Commission has selected the ALTAIR project for continuation.

Drones

A dual role before the DGAC: expertise and research

Having started in 2018, the first part of the DGAC drone convention, PHYDIAS, foresees that ONERA will continue to carry out work of interest for the entire sector, along two lines:

- Research work for everyone's benefit, on human factors, the "U-space" (organization of the low-altitude airspace for drones), risk analysis tools and methods, and the certifiability of adaptive systems and perceptual systems;
- Expertise for the benefit of the DGAC, on the challenges related to new applications and to the development of new regulations to make them possible.

In a context of regulatory changes and at the request of the DGAC, work began in 2018 on the analysis of a falling drone impacting a person.



Receipt of new helicopter and airplane drones

ONERA has a fleet of aircraft that enable it to mature the algorithms, methods and technologies that it develops up to the level of a demonstration in a real environment. In 2018 it acquired two new helicopters and a new airplane.

- The Yamaha Fazer-R helicopter drone, designed to replace the Yamaha Rmax, have a rotor diameter of 3 m, and can carry a payload of around 25 kg.
- The fixed-wing drone, a K75 by the company Deimos, weighs 75 kg and can carry around 30 kg.

These aircraft will make it possible to validate advanced approaches to navigation, guidance and control, in particular robust and adaptive control, based on detailed modeling of their flight dynamics. Sophisticated sensor tests will also be conducted: radar systems or optronic systems such as lidars or multispectral sensors. A variety of missions are envisaged: long-range surveillance, parcel delivery, agricultural applications, defense missions, etc.



The increase in importance of both civil and defense drone applications continues: ONERA plays a key role, both as an expert for the French government and as an innovator for industry. Due to the complementarity of its various scientific departments, its activities cover almost the entire technical spectrum and benefit many applications. In the civil area, ONERA is very strongly involved with the French Council for Civilian Drones, led by the DGAC.

Navigation based vision

The H2020 Vision project, in partnership with Europe/Japan, offers advanced steering, guiding and navigation systems to improve airliner flight safety and to validate these solutions on experimental platforms. One of the scenarios considered involves the use of visual information to assist navigation during the airplane final approach in the event of a sensor failure (GPS or ILS). At the beginning of March 2018, ONERA successfully completed the first flight of the K50 (50 kg) fixed-wing UAV, which was fully-instrumented by ONERA, in the presence of the Japanese industrial partners of RICOH Co. Ltd., which are developing a stereovision sensor. ONERA will merge these measurements with other sensors to provide the autopilot with a robust navigation solution. Following the first flight in March, two in-flight test campaigns with the K50 were carried out by ONERA in June and December.



Advanced use of 3D lidars on drones

ONERA has developed and implemented two multirotor drone solutions:

- The ReSSAC-M600, for high-resolution 3D mapping using a RIEGL VUX lidar (the rendering is available a few minutes after landing);
- The ReSSAC-S900, which enables 3D maps to be reconstructed and retransmitted in real time to the operator using a Velodyne 3D lidar (the merging of visible and infrared images from the on-board sensors is also transmitted in real time and remotely).

The applications are numerous and have in particular been successfully deployed as part of the PRF DROPTER project, which is aimed at making UAVs reconfigurable in the event of hazards while mapping a site. In addition, the H2020 project INACHUS, completed at the end of 2018, was aimed at developing methods and tools to help locate victims under the rubble in the event of a disaster. ONERA has worked on 3D mapping of large areas to plan the deployment of rescue operations, evaluate structural damages to prioritize their intervention, and to locate victims to optimize assistance planning.

Drones for defense

ONERA is involved in various topics related to defense.

- A first expertise contract for the DGA was completed at the end of 2018, within the context of the development of a European MALE drone. ONERA contributed to the first phase of the project, which in addition to France involves Germany, Italy and Spain.
- In early 2018, the DGA notified Airbus Helicopters and Naval Group of a contract for the study of the future navy drone: SDAM (Airborne UAV System for the Navy). ONERA will be present to help overcome any technological challenges.



ONERA DRONES SCIENTIFIC DAYS

In November 2018, the event gathered around a hundred people to discuss various aspects of UAV research: uses, design methods, payload technologies, navigation systems and even human/system interactions. With a great number of interventions, these days enabled the sharing of the latest research, as well as the generation of new ideas.

Valorization

180 patent families
160 software applications
350 Soleau envelopes filed

ONERA has a department dedicated to the valorization of intellectual property. Indeed, ONERA's patents, software, know-how, expertise, R&D and technical resources appeal to manufacturers beyond the aeronautics, space and defense sectors and, in particular, VSEs, SMEs and intermediate-sized enterprises (ETI).

START - U P S

In 2018, the IMPULSION device was set up: its purpose is to support ONERA scientists who want to create their own start-up based on a technology that they have developed. Two projects are currently in the maturing process and should end in 2019. Another striking fact: within the framework of the Lab2Biz program, an innovation developed by an ONERA researcher to replace the current Pitot tubes with a plasma device was selected by the students of a HEC MBA to support a business creation project.

ONERA, a partner of SMEs

The valorization of our research results is based on R&D contracts with our industrial partners, particularly SMEs. 50% of the 80 industrial partners surveyed in 2018 are small businesses or SMEs, with which the activities carried out amount to €1.5 million (figures from 2018). Due to its position as leader of Carnot AIRCAR, which gathers eight Carnot institutes, ONERA has implemented concrete actions to better prospect and contract with SMEs/intermediate-sized enterprises (ETI) in the aeronautical field.

Technology transfer

In 2018, there were 38 operating license agreements (patents, software and know-how), of which over 50% are being conducted with SMEs and 15% with VSEs, which generated €850,000 in revenue from exploitation licenses.

IN 2018, PARTNERSHIPS THAT CONTINUE TO BEAR FRUIT...

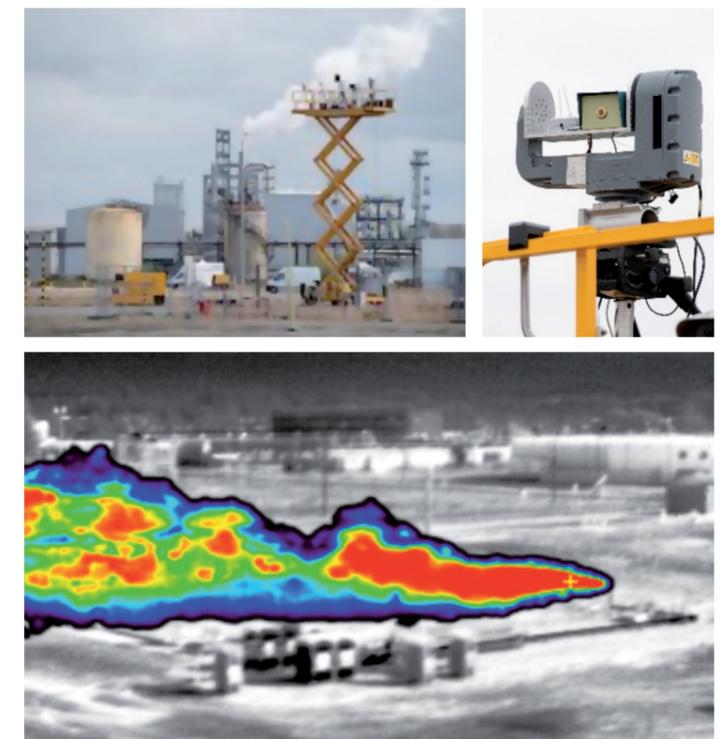


SNCF Réseau: embedded intelligence for rail infrastructure monitoring

As part of the DROSOFILES PRI (Research Industry Partnership), a fourth indoor flight demonstration was successfully conducted to demonstrate the advanced remote operational capabilities of a multirotor drone for inspection missions indoors or in congested environments. Several flight scenarios have been validated within the SNCF Réseau technicentre. People with various profiles, such as remote pilots and non-expert engineers, were able to test these features. The remote operation mode demonstrated makes it possible to control the direction and the advancement speed of the drone on a set trajectory, as well as the yaw angle. The vision algorithms on board the drone enable its location without GPS, as well as collision avoidance with obstacles not foreseen during the definition of the set trajectory. The DROSOFILES PRI resulted in a successful collaboration with SNCF Réseau and its subsidiary Altamétris.

TOTAL: detection and quantification of methane and carbon dioxide by optical

A major test campaign took place in October 2018 at the Lacq industrial site on TOTAL's Transverse Anomaly Detection Infrastructure (TADI) testing platform. These tests were part of the NAOMI research and development agreement between TOTAL and ONERA. The goal: to detect, locate and quantify controlled gas emissions on industrial sites in real time. ONERA conducted lidar and spectral imaging measurements of CH₄ and CO₂ plumes. Various prototypes made by ONERA were deployed: the SIM-ONE laboratory cryogenic multispectral camera and its pre-industrial prototype SIMAGAZ; the GAZL multi-species lidar; the VEGA CH₄-wind lidar; and two hyperspectral imaging instruments (TELOPS) coupled with a real-time quantification ONERA software tool (IMGSPEC) for ground and airborne applications. The results achieved by ONERA and TOTAL, involving over 100 gas releases, are a real success: real-time monitoring and mass quantification for hyperspectral and multispectral imaging, plume localization and post-processing quantification for lidar systems. The transfer of ONERA expertise to the industry has already been launched both for the software developed – IMGSPEC – and for the innovative instrument concepts – the SIMAGAZ camera, the VEGA lidar and the GAZL lidar.



Photos © TOTAL

A CLOSER LOOK AT THREE SUCCESS STORIES



LEOSPHERE

LEOSPHERE, an innovative SME in the field of lidars, is a fine example of a SME that ONERA has supported since its creation 15 years ago: license agreement signed in 2006, first commercial successes in wind power since 2007 and in airport weather since 2010, and new prospects for development within the Finnish group VAISALA, which is the world leader in environmental and industrial measurement, in 2018.



FLYING WHALES

Launched in 2013, the SME Flying Whales is developing the airship aeronautical program LCA60T (Large Capacity Airship 60 Tons) for low-cost and point-to-point transport of heavy or bulky loads. ONERA and Flying Whales are actively collaborating to develop this giant of the air: ONERA is contributing in many fields, such as system studies, flight dynamics, aerodynamics, and even the environmental conditions.



MORPHÉE +

This young company created in 2018 offers an innovative product (fall detector and real-time actimetric monitoring of retirement home residents, while preserving their privacy) that resulted from radar technologies mastered by ONERA. This project was made possible thanks to the financing of the maturation phase by the SATT Paris Saclay, based on an ONERA proposal submitted in 2015. The product is currently being tested.



ONERA's Fauga-Mauzac center

Encouraging decision to financially support the upgrade of the ONERA large wind tunnels, providing confidence in the future of European aeronautics.



The new S1MA fans at Modane

The European Investment Bank has granted an exceptional loan of 47 million euros to ONERA to finance the ATP France investment plan, with the objective to upgrade some of its wind tunnel components, as well as to prepare them in assisting in the development of future aircraft. Covering eight wind tunnels that are considered as strategic, this loan is a positive sign to prove the essential need for France to operate very large wind tunnels for future weapon systems, as well as to maintain a world-leading aviation industry focus on export.

Having had its financing principle validated during ONERA's Board meeting in September 21, 2018, the ATP plan aims at enabling the DGA, the industry and ONERA's researchers to meet future challenges in aircraft configurations and make new programs more efficient. It will amount to €47 million covering procurement of major items for the wind tunnels, and will span over six years.

It will allow the upgrade of the facilities, enabling them to be operated in an efficient way in the long term. This is an opportunity to advance in major technical developments to better serve wind tunnel clients. Wind-tunnel test metrology of the future must be capable of assessing in detail new concepts that will:

- produce savings on fuel consumption ("buried" engines, "open-rotor" engines, Ultra High Bypass Ratio engines, flow control, etc.);
- increase stealth capabilities;
- push the limits of available flight speeds (missiles);
- create more competitive aircraft projects with optimized design in a world globalized market.

ONERA's large wind tunnels will thus have greater availability, responsiveness, productivity and quality.

Twenty-six major projects

These 26 projects involve the Modane S1MA, S2MA and S3MA wind tunnels, and the Fauga F1 wind tunnel, as well as the specialized wind tunnels: BD2 (nozzle thrust), S4B (turbofan propulsor simulator calibration) and S4A (very high Mach number, for space and defense) at Modane. Other wind tunnels will ultimately benefit from the technical advances developed under the ATP plan.

WIND TUNNELS ARE ESSENTIAL FOR THE INNOVATION PROCESS

Tests in large wind tunnels are necessary when mathematical simulation is no longer adequate. This is the case during the design phase of a new aircraft, or when evaluating leap-frog concepts. It's a real challenge to explore and understand scientific challenges, when working on flow physics. Finally, securing particularly critical flight phases calls for validation tests in wind tunnels.

In 2018, ONERA carried out 1,533 hours of wind tunnel testing

A closer look at the modernization of the large Modane S1MA wind tunnel

New fans for the S1MA

Following a design effort of almost twelve years and with the financial support of DGAC, the two fifteen-meter diameter counter-rotating fans (blades and hubs) were replaced. This is a first since the fans were commissioned in 1952. ONERA is very pleased with the achievements, with good mechanical behavior and very satisfactory results in operation.

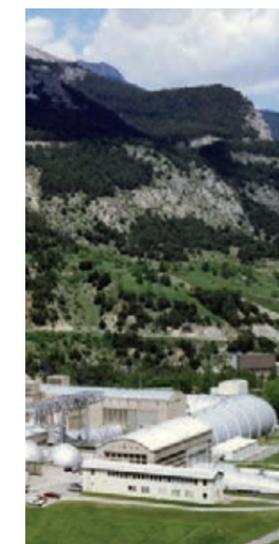
RAMSES: noise reduction for the next generation of aircraft

The RAMSES project (acoustic liners for wind tunnel measurements) is to serve the objectives set by ACARE* to reduce perceived noise by 50% by 2020. It is financed by DGAC for an amount of 3.85 million euros and for a period of 48 months. It's aiming providing the large S1MA wind tunnel with an aero-acoustic measurement capability and to carry out research on aircraft noise reduction over the entire flight envelope.

FUTUR S1: adapting the S1MA wind tunnel for future Ultra High Bypass Ratio engine tests

New engine configurations, such as very high dilution engines, will be studied in the S1MA wind tunnel, taking advantage of its large size. The purpose of the FUTUR S1 project is to prepare the S1MA wind tunnel to receive models and test benches capable of simulating the behavior of these new engine configurations. With a budget of six million euros, 50% is financed by the ATP plan and 50% by the DGAC.

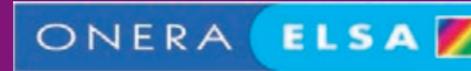
*Advisory Council for Aeronautics Research in Europe



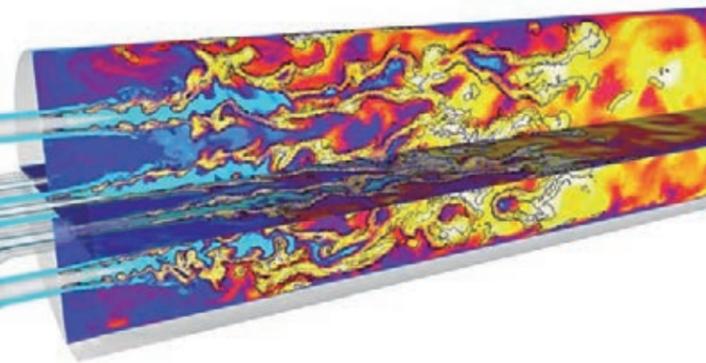
ONERA's computer codes continue to count



The CEDRE code is ONERA's multiphysics platform for energetics and propulsion. It is used by MBDA, ArianeGroup, Safran Aircraft Engines and DGA, as well as by ONERA'S research, including theses.

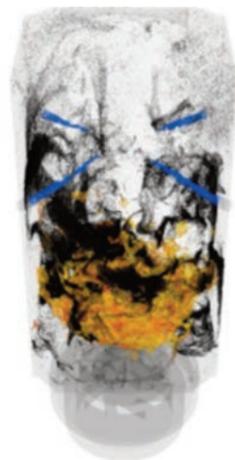


2018 is the year in which the third anniversary of the Airbus-Safran-ONERA agreement on the elsA software was celebrated, and was particularly fruitful for its development. These exceptional breakthroughs will ensure an important place for elsA in the worldwide CFD competition.



Thermal transfers inside rocket engine combustion chambers

As part of the work carried out with CNES on heat transfers in rocket engine combustion chambers, the evaluation of unsteady resolution methods - dedicated to heat flux restitution - made it possible to obtain temperature levels and flows in walls that agree closely with the experimental levels measured on the MASCOTTE bench of ONERA. Since each branch of physics is processed by a dedicated solver, this calculation involves a coupling between the CHARME solver for the gas phase and the SPIREE solver for the liquid oxygen droplets.



Soot prediction in aircraft engine combustion chambers

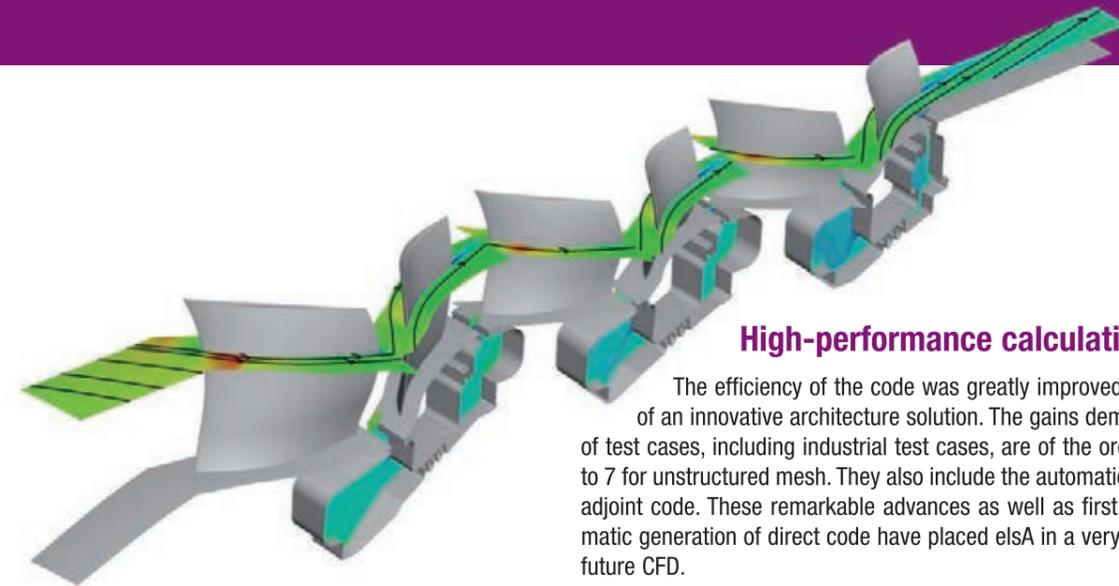
In order to respond effectively to the tightening of engine output soot emission standards, a special effort has been made in recent years to model these pollutants in combustion chambers. Thus, by coupling the CHARME solver - to deal with the

multi-species gas flow inside the chamber and integrating a detailed modeling of chemical mechanisms - with the SPARTE solver for solid soot particles, results that agree closely with experimental results were obtained on the DLR's FIRST configuration.



Acoustic environment at lift-off for space launchers

As part of the R&T work carried out with CNES on the acoustic environment at lift-off from space launchers, numerical simulation makes it possible to estimate the noise levels to which the launcher and the launch pad structures are exposed. The noise generated by a supersonic jet at Mach 3.1 is reproduced by the coupled use of the CEDRE code for the simulation of near-field acoustic sources, and of the SPACE code for far-field nonlinear acoustic propagation. It will then be possible to compare the results with the measurements made on the MARTEL bench.

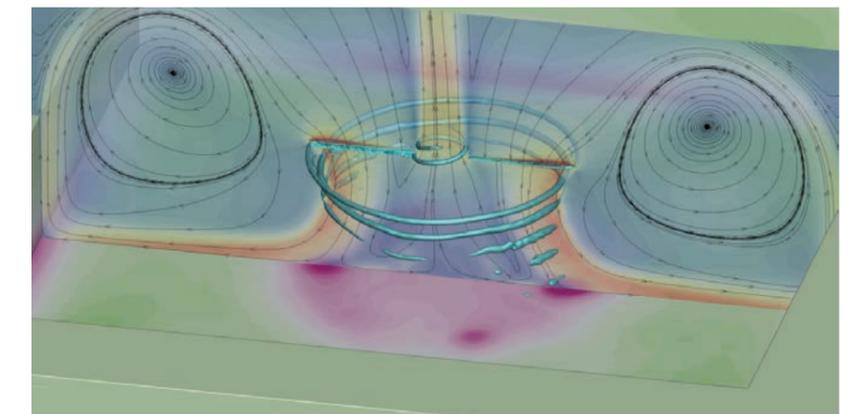


High-performance calculations

The efficiency of the code was greatly improved through the implementation of an innovative architecture solution. The gains demonstrated over a large range of test cases, including industrial test cases, are of the order of 3 for structured mesh, to 7 for unstructured mesh. They also include the automation of obtaining linearized and adjoint code. These remarkable advances as well as first demonstrations of the automatic generation of direct code have placed elsA in a very good position in the race for future CFD.

Simulations of complex geometries

The hybrid mesh simulation capability has been enhanced by its extension to low Mach flows and unsteady flows. The work carried out in Cassiopée related to the mesh intersection strategy will continue and has already shown its benefits, in particular for simulations on any meshes. In addition, the IBC method (Immersed Boundary Conditions), which makes it possible to dispense with part of the mesh, has proven to be a practical tool. Simulations of helicopter rotor aerodynamics when flying in a confined space in a yard, or near a building have been demonstrated, for example, with the external environment being modeled by IBC.

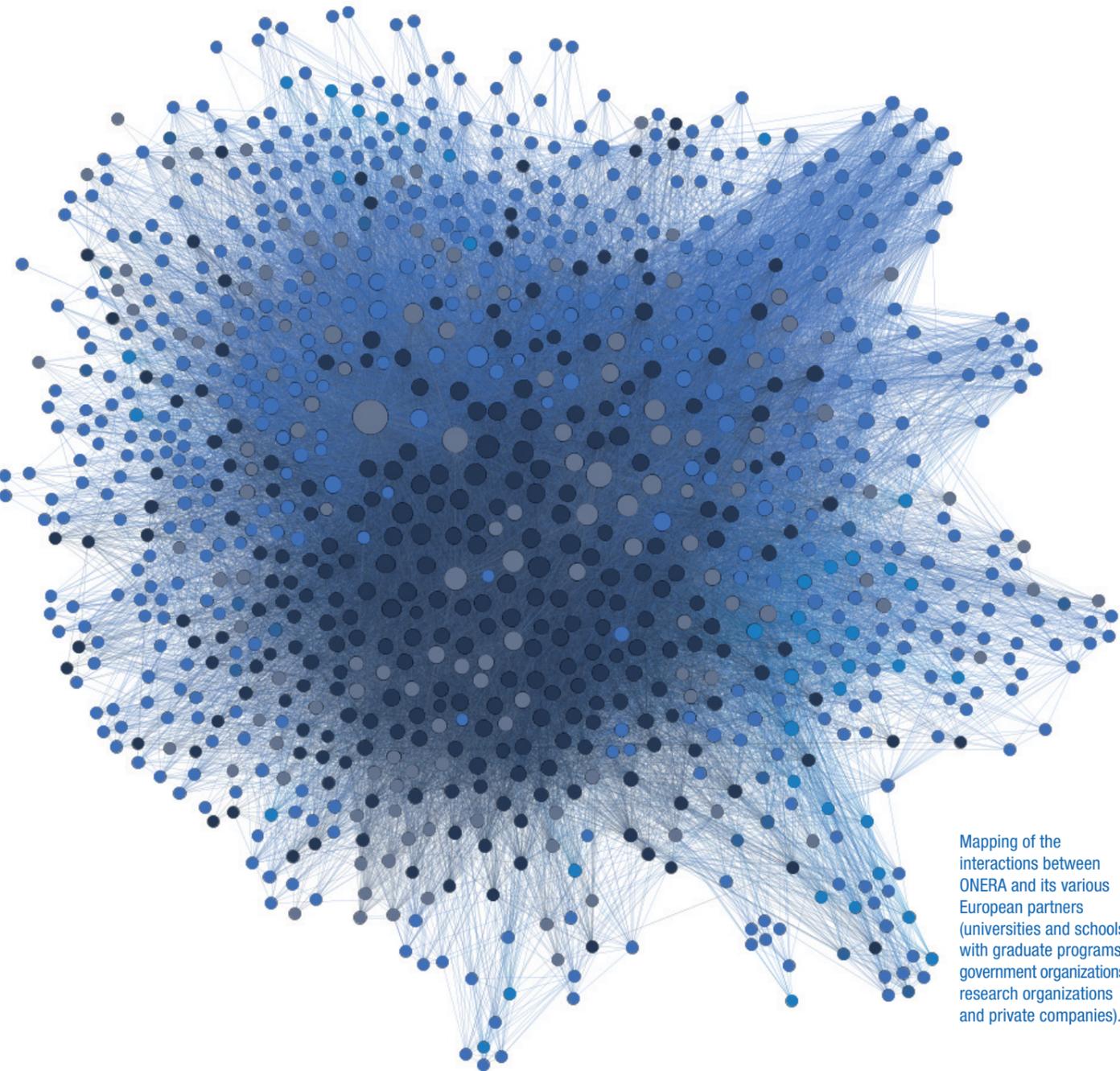


Modeling turbulence and transition

The use of advanced turbulence models with non-linear closures has led to significant progress in secondary flow simulation. The parabolic method and the laminar kinetic energy approach have been integrated into the software enhancing an already wide range for predicting laminar/turbulent transition. The first provides high-quality solutions for applications that are of interest to aircraft manufacturers, and the second improves flow predictions in turbomachines.

A key player in Europe

Thanks to its reputation, gained through the excellence of its work and its involvement in major European projects, ONERA interacts with many types of public and private European partners. ONERA is also involved in both the civil and defense fields. ONERA has just drafted in 2018, within EREA, a position paper on a transverse topic, air safety, intended to propose key elements to the European Commission for making the next multiannual research program. EREA, of which ONERA is a member, has also been invited to join the Stakeholders' Advisory Group on Aviation Security (SAGAS), whose mission is to advise the Commission on existing and future laws, as well as on political initiatives.



Mapping of the interactions between ONERA and its various European partners (universities and schools with graduate programs, government organizations, research organizations and private companies).

The many disciplines studied by ONERA have naturally created a place for it in many European projects. However, it is furthermore at the heart of a European network, supporting the governments.

SOME EXAMPLES OF EUROPEAN PROJECTS

SPACE

Three of ONERA's space projects were accepted at the time of the call to tender for H2020-SPACE-2018-2020, amounting to a total of more than €1.6 million in grants:

H2020 LEMON, coordinated by ONERA, for the development of an airborne differential absorption lidar to detect steam and greenhouse gases, and for the maturation for space of critical subsystems. The partners are: Fraunhofer, CNRS, KTH, SpaceTech, UiB, Innolas and L-up. The grant for this 48-month project amounts to more than €3.3 million for the consortium as a whole.

PULSAR, which is aimed at developing the technologies necessary for an autonomous robotic system to assemble a very large structure in orbit, over a period of two years, with eight partners. ONERA will work on the system specification, and will be in charge of developing the simulator and satellite attitude controllers.

EFESTO, a three-year project with six partners, is aimed at providing Europe with the innovative concept of a deployable and inflatable thermal protection shield. The principle: to land over two tons of cargo on the Martian surface, prior to inhabited missions, and to recover the upper stages of launchers within the framework of an orbital debris reduction policy. ONERA will evaluate, by simulation, the aerothermodynamic constraints on this shield and will analyze the degradation of the composites constituting the wall.

The European project H2020 **VERTIGO**, coordinated by Thales Alenia Space, is aimed at validating the technological contributions needed to achieve very high speed satellite/ground links. ONERA will contribute its expertise on the propagation channel and methods for correcting its effects. The technological developments will be validated as part of a long-distance optical link experiment under representative conditions: ONERA will supply the built ground segment. Interactions with the eight other European partners will make it possible to consolidate the understanding of the needs and will contribute to the developments in this area under the ONERA PARASOLS project.

AERONAUTICS

In the field of icing, ONERA – a reference in Europe – has developed a new generation of digital tools, more precise and easily interoperable with other codes.

In 2018, it became involved in all H2020 projects selected on this topic:

MUSIC-HAIC, which it coordinates, on the development of 3D models for icing under "crystal conditions";

SENS4ICE, on innovative icing detection technologies;

ICE-GENESIS, on the modeling of icing under snow conditions and de-icing; this project will be supported by the construction of the icing wind tunnel, financed by the DGAC* (Airbus coordination).

*French Civil Aviation Authority

MULTIDISCIPLINARY OPTIMIZATION

The €5.8 million European project H2020 **MADELEINE**, coordinated by ONERA and launched in 2018, is aimed at demonstrating the benefits of adjoint-based MDO (multi-disciplinary optimization) techniques for the design of civil industrial configurations. This project, which will last three years, involves fifteen partners. In addition to the coordination of the project, ONERA, a long-time expert on the subject, will be in charge of improving the adjoint system resolution methods, optimizing a civil aircraft wing aerostructure, and setting up an aeroacoustic adjoint and applying it to an isolated propeller configuration.

ONERA in the world in 2018

UNITED STATES: NASA AND ONERA, A RICH AND SUSTAINABLE COLLABORATION

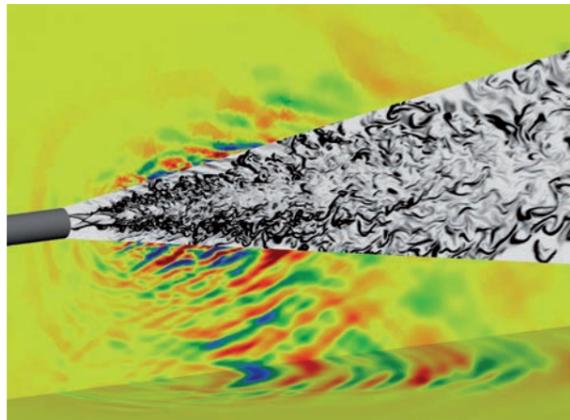
ONERA is currently the first foreign partner of NASA aeronautics. Having started in 1972 with work on the aeroelasticity of helicopters, the cooperation has since covered various topics: materials and structures, aerodynamics, human factors, icing, air traffic management, noise reduction, etc.

AVIATION NOISE

Supersonic bang

NASA and ONERA signed a research partnership in 2018 on supersonic bang as part of an extension of their cooperation on noise reduction and supersonic aviation research.

Simulation for the prediction of supersonic jet noise using the ONERA CEDRE code



Acoustic Liners

ONERA and NASA are actively discussing fan noise reduction by lining engine nacelles with absorbent materials called acoustic liners, whose acoustic properties must first be analyzed. ONERA and NASA are jointly addressing this issue. The modeling of the phenomenon will consolidate the physical models of the numerical simulation chains for estimating noise pollution from engine configurations, in which acoustic waves propagate simultaneously in all directions.

ICING

At the end of May 2018, ONERA's Chairman and members of the board of directors responded to NASA's invitation with a twofold objective: to reaffirm the importance of a historic partnership in a changing geopolitical context and to sign the renewal for two years of the Cooperation Agreement on Icing. This same year, ONERA also continued its collaboration with NASA on the SUNSET2 project, which studies the deterioration of the aerodynamic performance of a swept wing due to icing. A second test campaign took place in the Fauga-Mauzac F1 wind tunnel, and ice deposition shape calculations were done with ONERA's 3D code, then compared with NASA's calculation results.



SPACE ACCELEROMETRY

NASA has renewed its confidence in ONERA: the Super Star accelerometers re-supplied by ONERA to NASA's JPL can measure the drag due to the residual atmosphere in low orbit. Knowledge of this parasite drag guarantees the accuracy of the mission's gravity measurements.

A significant part of ONERA's activities takes place beyond our borders, and even outside of Europe. This constantly growing international activity includes participation in technical projects, bilateral scientific cooperation, and even lobbying activities. In five years, international orders reached €47.6 million for Asia, €10.3 million for the United States and €61.2 million for Europe. In 2018, contracts with foreign partners amounted to €30.4 million, an amount well above the average of the last five years (€132 million). This is a clear sign of ONERA's scientific excellence, which is recognized worldwide, as well as of its international influence.



RUSSIA: TSAGI CENTENARY IN MOSCOW

Bruno Sainjon awarded the Denis Maugars biennial prize to a French-Russian team of young researchers. This is a way to celebrate the durability of this cooperation on the aerodynamics of civil aircraft, launched 53 years ago. Awarded every two years to a team of young researchers (under 35), this prize is aimed at recognizing an innovative joint research project. In 2018, the selected project proposed an innovative concept of walls made up of non-periodic resonators capable of absorbing various frequencies for lining engine nacelles.



SINGAPORE: AN ESSENTIAL STOPOVER AT ONERA FOR HIGH-LEVEL SINGAPOREAN DIGNITARIES

In 2018, Singapore's Minister of Defense NG Eng Hen, on an official trip to France, took the opportunity to visit ONERA, as did Singaporean Permanent Secretary (Defense Development) NEO Kian Hong. ONERA and Singapore have been increasing their exchanges for twenty years now, ONERA resourcing new ideas from Singapore and transferring advanced know-how to this particularly dynamic country. The creation of the French-Singaporean radar laboratory, SONDRRA, in 2004, is the best example.

JAPAN: "MATERIALS" PARTNERSHIP BETWEEN ONERA AND THE TOKYO INSTITUTE OF TECHNOLOGY



This is an agreement with one of the most prestigious Japanese universities. It envisages exchanges of researchers and trainees in the field of materials, and more particularly the sending of students from TITECH to ONERA as part of their final training internship. Seminars have already been organized also.

THE ONERA WIND TUNNELS ARE RENOWNED WORLDWIDE

The wind tunnel tests constitute a very specific know-how of ONERA. Having been reserved for French aeronautics players for a long time, this highly sought-after expertise is now the subject of contracts with foreign customers. Indeed, for each new test, ONERA evaluates the context of the project, defines the suitable metrology, and provides the test data to the client.





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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