ANNUAL REPORT

2019

ONERA

THE FRENCH AEROSPACE LAB

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ONERA: the French aerospace research center

ONERA, a central player in aeronautics and space research, employs approximately 2,000 people. Under the supervision of the Ministry of the Armed Forces, it has a budget of 237 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.

BRUNO SAINJON,
CHAIRMAN AND CEO OF ONERA

2019 was a year marked by progress made on all fronts, sometimes in a spectacular fashion. The visit from the French Armed Forces Minister, Florence Parly, on January 10, extensively documented in the 2018 annual report, was the kick-starter, not least in terms of recognition of our excellence. The aeronautical medal for collective performance that we received from the hands of the Minister is a prime illustration of this. We are particularly proud of the four scientists who were rewarded by the Science Academy; of our winner of the ICAS "John J. Green Award"; of the three female PhD students of ONERA to have acquired an Amelia Earhart Fellowship (out of 30 granted worldwide) from Zonta International; of the three teams rewarded with the "best paper awards" from EREA; in short, we take great pride in all the prizes, awards and distinctions heaped upon our scientists and doctoral students. These examples, along with so many more that can be read about in this annual report, serve to illustrate the extent to which our scientific excellence is recognized both nationally and internationally.

This recognition is also manifest in the parliamentary reports, when these reports address the question of ONERA's contribution to the civil and military aerospace sector. This recognition reflects on each and every ONERA employee, and it is something to be proud of. Recognition is also a real asset when it comes to facing adversity, to which I can testify every day right now, writing these words as I do in the midst of the COVID-19 crisis, while the ONERA staff maintain exemplary diligence, standing shoulder-to-shoulder with our partners.

On the financial side, the exceptional measures announced by the Minister, Ms Florence Parly, back in January, concerning the consolidation project for our activities in the Ile-de-France region and the modernization of the wind tunnels, heralded the launch of these two major structural operations for ONERA. I wish once more to thank her for these tokens of recognition and confidence. I am also grateful to our parent ministry for raising our grant for public service charges to €110 million in 2020 and 2021 (instead of, respectively, €106 million and €107 million). This increase will go some way to plugging the pay gap compared to the rest of the aerospace sector. This therefore constitutes a strong signal of recognition, which acknowledges our excellence, both scientific and technological. It also makes it an appreciable contribution to increasing our appeal on a labor market that is tight across the entire aerospace sector.

As well as our positioning among the best in the world, 2019 generated very good economic results, with ONERA posting a net consolidated income of €9.7 million, considerably up on 2018 (€2.6 million). We recorded €124 million in orders, admittedly slightly down on 2018 (€126 million), but at a level still close to an historic high. It was a year in fact in which the reduction in orders for wind tunnel tests (€14 million, compared to €28 million in 2018) could be offset by orders placed with the research departments, in particular in the field of defense. The reinforcement of our links with the regions was manifested through increased efforts in support for our scientific investments, the most significant being in the Occitanie region, with €10 million in funding going into a new €14 million platform, testimony to the heightened interest in our activities across the nation.

Last but not least, 2019 was another Paris Air Show year, and our stand once again met with great success. The show provided an opportunity in particular to forge new international partnerships. This international openness, already outlined above in terms of its scientific dimension, is also illustrated in this annual report through the testimonials from Pascale Ehrenfreund, CEO of the DLR, Sergey Chernyshev, Chair of IFAR, and Cheong Chee Hoo, Chair of DSO. ■

The Armed Forces Ministry supports ONERA

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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DES ARMÉES

Visit from the Armed Forces Minister, Florence Parly

In January 2019, the Minister announced five measures which demonstrated just how confident the Government is in ONERA for preparing the sky of tomorrow. Regarding the budget, she announced an exceptional envelope of €160 million for consolidating the three Ile-de-France centers on the Saclay plateau and a €47 million loan from the European Investment Bank for modernizing the wind tunnels. A revision of the COP* was also for the first time announced. The last announcements concerned two different but equally noteworthy items: the aeronautical medal bestowed upon ONERA, and the famous Christmas bonus brought in by the French President in December 2018.

* Objectives and Performance Contract

Parent ministry announces its intention to increase grant to €110 million

This is an increase that represents an extra €7 million compared to the last 2 years of the COP, which stood to amount to €106 million and €107 million respectively. This constitutes a first line of response to the human resource issues highlighted by ONERA.

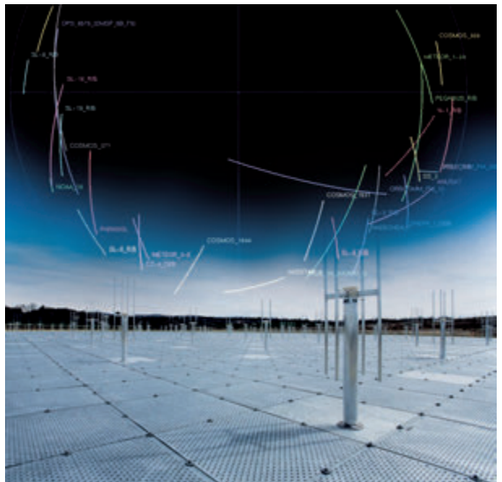
These issues had, moreover, been debated by the legislators, who had called, in July and the fall of 2019, for a revision of the ONERA COP, so that the resources allocated to it match the challenges that it needs to face.

ONERA: major partner for the new space defense strategy and doctrine

On July 25, 2019, at the Lyon Mont Verdun base, the Armed Forces Minister, Florence Parly, gave a detailed description of the new space defense doctrine that had been announced several days earlier by President Macron, and in which ONERA has an important part to play.

Among the three lines of approach of the new strategy, the capacity component directly concerns ONERA, with a new "Space control" weapons program. The Minister spoke of the successor to the ONERA GRAVES space surveillance system and power lasers, another field: "in which the expertise of ONERA and its scientific excellence are recognized, and which will no doubt be called into action."

ONERA was also an exhibitor at the Defense Summer Schools, putting on show a mockup of its GRAVES space surveillance system, at the request of the DGA.



Paris Air Show: technological innovations are central to the challenges of the aerospace sector

For this 53rd edition of Air Show, ONERA perfectly fulfilled its role as expert for the State and bridgehead between upstream and applied research for industry, with 6 topics concerning topical issues in the sector. ONERA's work generated particular interest, moreover, with the signing of five international cooperative agreements (with DNR, JAXA, CNRC, NASA and EREA) and 110 media features (including on M6, Figaro TV, France Info, Europe 1 and RFI).

Philippe Beaumier, director of aeronautical programs at ONERA, presents the Dragon project to Ms Élisabeth Borne, French Transport Minister.

Exceptional loan from the European Investment Bank

As announced by the Armed Forces Minister, Florence Parly, on her visit to Palaiseau on January 10, 2019, the European Investment Bank (EIB) signed off, in April 2019, a €47 million loan with ONERA for modernizing its fleet of wind tunnels, the largest in Europe. The signing took place in Modane-Avrieux, on a visit to the large wind tunnels, and this funding is allocated to ONERA in the framework of the European defense and security initiative. It is the first loan that the EIB has granted in Europe to a defense organization. It will be used for consolidating the wind tunnel infrastructures and modernizing the metrology instruments. This loan is testament to a strong degree of support for ONERA.

ONERA's vision for preparing the future; publication of the roadmaps

Everything that flies in France and in Europe has passed, to a greater or lesser degree, through the hands of ONERA. And tomorrow? What scientific avenues are to be followed to prepare the sky of the future? In 2019 ONERA published its digest called The ONERA scientific and technological roadmap, to explain the 10 topics that it intends to explore.

Drones, military space, respect for the environment, artificial intelligence, air combat systems: these are among the topics for which ONERA proposes a scientific strategy, as discussed in this document. In its capacity as expert for the State and expert for the aerospace and defense industry, its mission indeed is to anticipate and take account of a certain degree of risk in exploring new and sometimes bold topics.

> We have a results-oriented program that runs along 3 broad lines: implementation of the roadmaps, reinforcement of the system aspects, and consolidation of the State expert role of ONERA.

Interview with Franck Lefèvre, new general technical director at ONERA

What assets do you bring to your job of supporting the various departments of ONERA?

I joined ONERA in 2009 to take charge of the optics department, then in 2017 I took over as director of the defense programs. This career path has given me an intricate understanding both of the issues within the departments and vis-à-vis contacts outside of ONERA. As director of the defense programs, I had a programmatic vision, and multiple close interactions with industry and the main clients of ONERA.

So you know all about ONERA, but do you also have previous experience elsewhere?

Indeed, not all of my career has been spent at ONERA, since I first earned my spurs in industry, in the field of low-level-light night vision, at a company today called Photonis. Following a thesis on solid-state physics, I joined Safran/Sagem in the R&D lab, working on infrared vision, guidance and navigation systems. This industrial experience helped open the doors, in 2002, to the DGA, where I was hired to work in the Force Systems and Prospective Systems Analysis Division (Direction des systèmes de force et de la prospective). I then had a stint on the Mission for technological research and innovation (MRIS), where I dealt in particular with European and international relations, and in this way, over the years, I have built up a solid aeronautics and defense culture.

What will be your first major project as general technical director?

I want to work closely with the departments and with the three program divisions, so that actions are initiated rapidly. Central to my concerns are the roadmaps, which offer a structured scientific and technical framework for the years to come and which, above all, establish the list of objectives to be attained and the future partnerships that ONERA intends to forge. This latter point is important, as I want the departments to be able to draw on partnerships that offer contractual cooperative frameworks that are both simple to deploy and efficient, for the technical and budgetary monitoring of projects. The second important point for the roadmaps is that they need to live! The work on their application that is to be undertaken is not intended to be exhaustive and definitive. The roadmaps constitute a common thread for all our research work, but they do not cover all of ONERA's activity. Last but not least, the highly programmatic vision of the roadmaps must not exclude creativity and the spirit of initiative. These two aspects are complementary and tie in with a multidisciplinary dynamic that is vital to the system approach that I wish to develop.

How does ONERA's organization meet the needs of stakeholders outside ONERA?

Our vision and our "SYSTEM" skills, which I wish to develop further, should enable ONERA to play a major role in the future major programs in the aeronautical, space and defense fields. Upstream research is increasingly irrigated by these major programs, and our global approach will enable us, one, to secure new contracts and, two, to consolidate and substantiate still further our State-expert status. This is a pragmatic program that follows on logically from the 2017 reorganization and is therefore broken down along three broad lines: the implementation of the roadmaps, the reinforcement of the system aspects, and the consolidation of ONERA's expert role vis-à-vis the State.

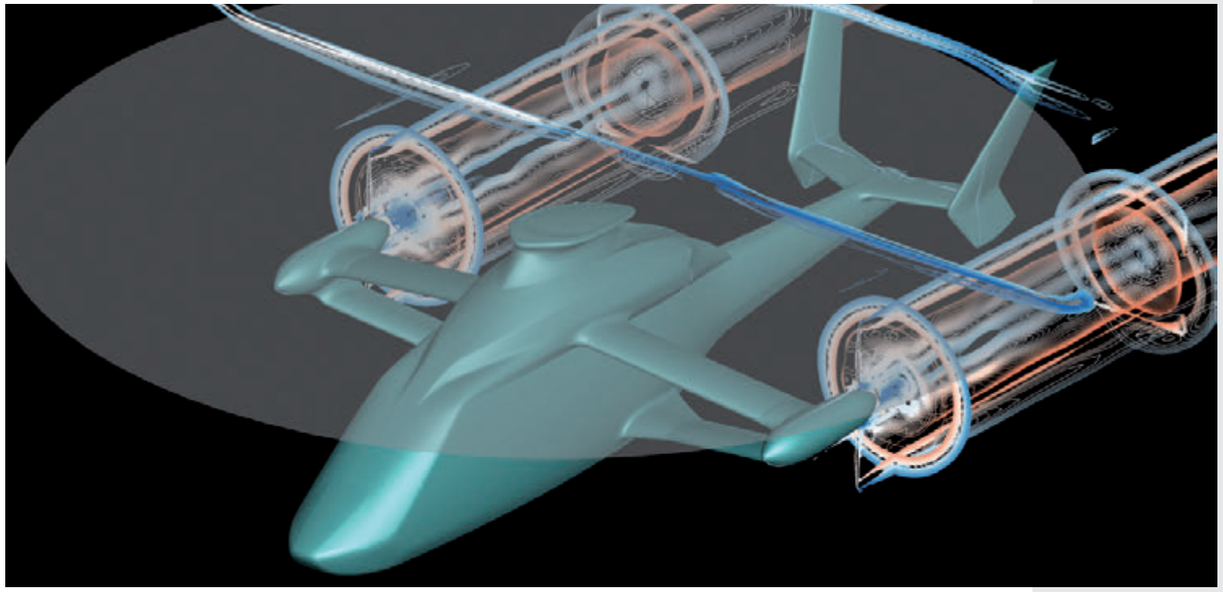
Aside from the organizational aspects, however important they may be, can you tell us a little about the engineers and researchers at ONERA?

I intend to focus in particular on the human resources that need to be in a position to address ONERA's challenges, of course, but also capable of supporting the departments and program divisions in many aspects: forward planning, contracts, legal, hiring, to name but a few. It is therefore important to construct, in collaboration with the HR department, a mechanism for closely monitoring the activity and skills acquisition of new employees during the first two years, with respect to the criteria applicable when the post was first taken up. This also presupposes reflection on the part of the departments, which need to conceive job vacancies according to their long-term needs, the tasks to be undertaken and the skills to be acquired. Long-term objectives must not be sacrificed on the altar of short-termism. This exercise, no matter how difficult, is essential for coordinating the activities of the departments. Here is my diagnostic: the time constants are shorter than before, and this obliges ONERA to make sure it has the means to be more reactive, in order to stay in the race. ■

A special relationship providing a united front and facilitating research

Prof. Pascale Ehrenfreund,
Chair of the DLR Executive Board
(German Aerospace Center)

Aerodynamic simulation of the RACER high-speed helicopter demonstrator (ONERA image)



What best characterises the bilateral partnership between DLR and ONERA?

We have long cooperated with France and French research institutes. This partnership with France is Europe's largest, and cooperation with ONERA forms a fundamental part of it. We have a long history of cooperation, in a number of fields of aeronautics including civil transport aircraft, measurement techniques, vibration tests for new aircraft, and a specific helicopter programme whose 20th anniversary we have just celebrated. New areas of cooperation have also recently been added, extending the scope of our partnership, particularly in the space field on themes such as new launcher concepts. In addition, the theme of artificial intelligence applied to aerospace is an important theme that features in the bilateral research agenda of both our countries.

On the European scene, what is the impact of this special relationship, particularly in the civil aeronautics field?

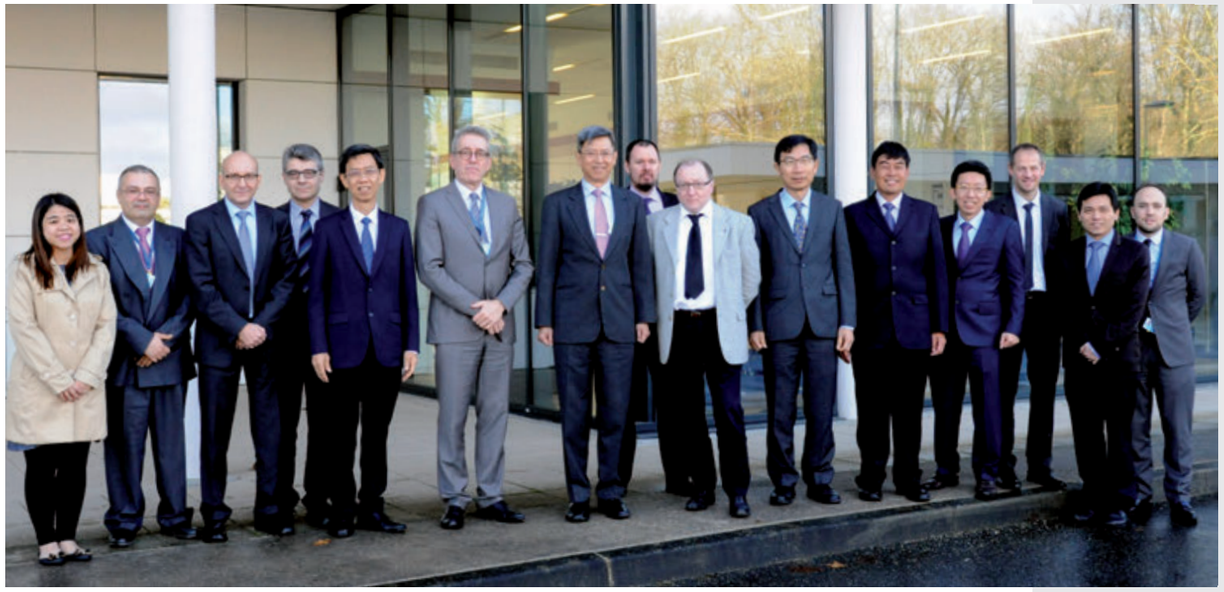
DLR and ONERA are both involved in the majority of European projects in the aeronautical field, and our chances of success are significantly increased when we share expertise and develop synergies. We are also heavily involved, alongside other European institutes, in EREA (the Association of European Research Establishments in Aeronautics), which serves both as a forum for discussion with the European Commission and a tool to coordinate the work of its different members. ONERA and DLR, which were among the association's founder members, have both on several occasions chaired the association, whose effectiveness and visibility is well-established.

Will the upcoming "Horizon Europe" framework programme change this relationship?

We are continuing to work with other European partners to defend the need to have a level of resources in the next framework programme suited to the needs of research centres. ESRE (the Association of the European Space Research Establishments), like EREA, is the physical embodiment of the desire to structure the research carried out by European institutions like ONERA and DLR. I have had the privilege of chairing ESRE for the last two years and ONERA will take over from 2020, further evidence that team work is the winning formula for our two organisations! ■

From collaboration on radars to an international world-class laboratory

Mr Cheong Chee Hoo,
CEO of DSO National Laboratories in Singapore



How did you hear about ONERA and what ONERA represents for you?

Collaboration with ONERA started from early work in radar research. As a young DSO engineer back then working on radar development, I had the chance to work with ONERA on some of these radar projects. I was deeply impressed by the professionalism of ONERA researchers and the rigour of their work. Our collaboration with ONERA has come a long way. The strong partnership is evidenced by not only the growing number of collaborative projects, but also the many ideas seeded through fruitful interactions and lasting friendships forged between our researchers and engineers. ONERA is, and will continue to be, one of our key R&D partners.

Collaboration started with the radar area. What about the expectation on the enlargement of the area?

Over the years, DSO and ONERA have developed a close working relationship in radar research. By harnessing the rich experiences and deep expertise of both ONERA and DSO, we were able to advance topics of mutual interest quickly. In the same vein, our cooperation has expanded beyond radar research to tap on our collective strengths in new cutting edge technology areas. I look forward to deepen and broaden our cooperation further, and to transit valuable research outcomes into innovative solutions.

SONDRA is a unique model of alliance between our two countries. Could you brief on the benefit of this alliance?

With mutual interests and commitment to extend our collaboration to upstream research, SONDRA was set up in 2004. SONDRA is a research alliance born out of great synergies between the Centrale Supélec, ONERA, National University of Singapore (NUS) and DSO. NUS and Centrale Supélec are top notch academic institutions partnering in a double degree programme, whilst ONERA and DSO are like-minded defence research institutes pursuing rigorous applied research. By tapping on research talents and expertise from both countries, SONDRA has fostered a rich research environment for upstream R&D benefitting both countries. Today, SONDRA is a world-class centre for graduate education and research. Singapore and French researchers have regularly embarked on cross-exchanges since SONDRA's inception, and this has fertilised innovative research outcomes for both DSO and ONERA. I look forward to deepening our collaboration further. ■

Issues in aviation: exchanging to move forward

Prof. Sergey L. Chernyshev,
Chair of IFAR and scientific director of TsAGI

Could you briefly comment on what is IFAR and when ONERA came in?

IFAR, the International Forum for Aviation Research, is the world's only aviation research establishments network. IFAR aims to connect research organizations worldwide, to enable the information exchange and to develop a shared understanding on challenges faced by the global civil aviation research community. IFAR develops views and recommendations, on future research strategies and facilitates partnerships. IFAR focuses on non-competitive research and development related to global technical challenges such as those pertaining: emission, noise, safety, efficient operations and steps to reduce the impact of aviation on climate and the environment. IFAR aims also on exchange, education and promotion of youth scientists. ONERA is a major partner of IFAR since its Establishment in 2008 and hosted the 2nd IFAR summit in Paris (2011).

IFAR has been created to foster bilateral and multilateral collaboration. How would you describe the relevance of ONERA in that respect?

Among the 26 IFAR partners, ONERA is one of the most active in terms of generating new ideas, topics and the working approach. The French aerospace Lab provides its scientific leadership in many cooperation endeavors. For the last decades ONERA has been collaborating with DLR, NASA, JAXA, etc. and certainly TsAGI, addressing various challenges in aeronautics such as flight safety, greener aviation, next generation supersonic transport and focusing on some common research and technology priorities for instance, icing, noise, flow control technologies, new structure concepts. ONERA participation in IFAR activities is vital for the success of our organization. We, all the members are learning from each other and I would like to say that ONERA's rich experience in fostering international cooperation inspire us. ONERA is very pro-active in developing IFAR members common view on various existing global challenges: aviation impact on climate change, urban air mobility, greener aviation, faster than sound air travel, etc. No doubt that ONERA should be one of the key players for the framework of Horizon Europe.

And what about the bilateral cooperation between TSAGI and ONERA?

We are very proud of the wonderful history of ONERA and TsAGI cooperation that goes back to the 1960s, when the first generation of supersonic aircrafts Concorde and Tupolev Tu-144 were about to make their maiden flights. Over half a century ago two research centers established joint ONERA-TsAGI scientific seminar that is still alive. The seminar format was reshaped in 2001 to, not only present new scientific results, but also to discuss research priorities for cooperation. The leadership of our centers and scientists get together to meet once a year in France or in Russia. ■

Key figures 2019

INVESTMENTS
€33.1M
(€23.2M in 2018)

breakdown:

- **€24.45M** for current-account transactions;
- additional grants: **€2.14M** from the DGA for the reinforcement work on the large wind tunnel in Modane, and **€0.63M** for the PRISME project, consolidating the three centers of the Ile-de-France region.

The European Investment Bank (EIB) granted an exceptional loan of **€5.88M** for the ATP program of wind tunnel modernization.

PURCHASES

ONERA works in the main with SMEs in all its centers, in every region.

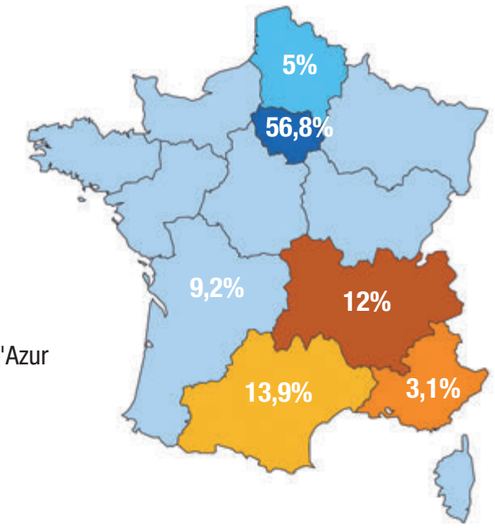
In 2019, ONERA signed contracts with 1,776 SMEs (1,730 in 2018).

Breakdown of purchases by type of business 2019

SMEs < 250 employees	Large companies	Mid-tier 250 to 500 empl.	Public establishments	European Union	Third countries
60,5%	18,2%	10,4%	5,7%	3,6%	1,6%

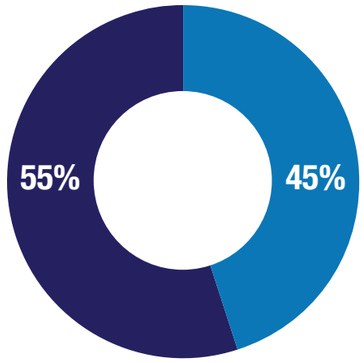
Regional distribution of purchases from partner SMEs

- Ile-de-France
- Occitanie
- Auvergne-Rhône-Alpes
- Hauts-de-France
- Provence-Alpes-Côte d'Azur
- Other regions



BUDGET
€237M

Own resources:
€132M



Public service charge grant:
€105M

Net income for the year:
€9,7M

Orders:
€124M

Contractual production by activity area

DEFENSE	AERONAUTICS	SPACE	VALORIZATION
52%	36%	8%	4%

Men and women of ONERA

1,968 staff members

1,504 engineers and executives
298 doctoral students
25 post-docs
223 trainees
25% women
Women-men parity index: 89/100

171 hirings,
including 123 engineers and executives

315 presentations in refereed congresses

243 publications in peer-reviewed journals

1,068 technical reports

87 theses

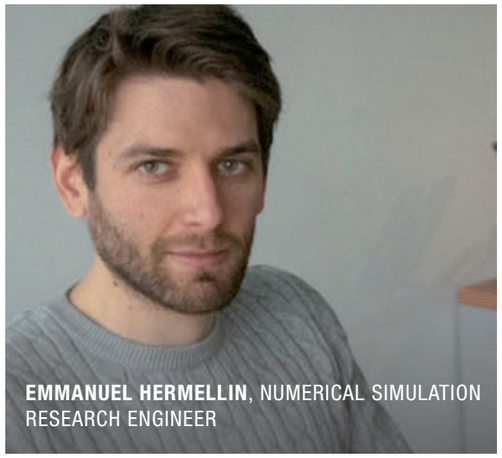
12 habilitations to direct research

102 HDR doctors

7,700 hours of teaching per year
in colleges and universities

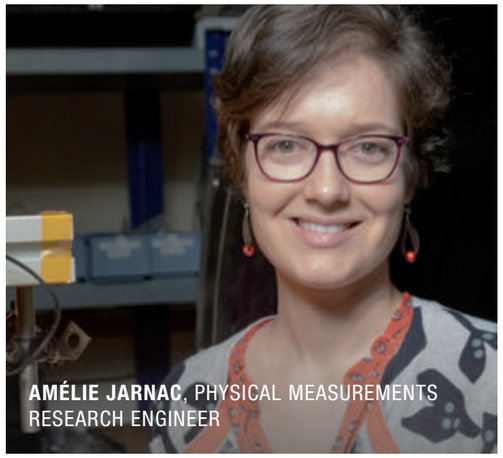
Choosing research

Upstream research or applied research? Experimental tests or digital tests? State expert or industrial partner? Ile-de-France or the provinces? Why not yes to both?! This is the atypical stance of ONERA, making it attractive for new recruits and encouraging the allegiance of its already incumbent scientists. Here are two career choice testimonials:



EMMANUEL HERMELLIN, NUMERICAL SIMULATION RESEARCH ENGINEER

"I've always been interested in the aerospace sector and when, for family reasons, I started looking for a job in the Ile-de-France region, I remembered just how much I had enjoyed my Masters' internship in the ONERA center in Salon-de-Provence. In my time there I had appreciated the genuine research work that I'd carried out to develop a computer code. It was, moreover, the doctoral students who showed me the ropes about procedures and how research work was carried out: the sense of collaboration is ubiquitous at ONERA.
The recruitment process then followed a fairly classic path, involving tests with the HR department and interviews with the scientific managers. I'd like to underline the really good feeling I had with all my contacts, in particular the scientific director of the information processing and systems field, who made it clear to me that, at ONERA, basic research got the respect it deserved! Sure, there are deadlines to respect for the manufacturers, but upstream studies are indispensable, since there is always a scientific study underlying a contractual delivery. Also, and this was vitally important for me, I knew that I would be abie to teach.
As of today I don't yet have defense habilitation - it is still an ongoing process - but I get to do lots of different things. Providing support for various people in various scientific departments is highly stimulating. The needs are different, but each time the common denominator is galvanizing: the work we do is laying the groundwork for the spatial technologies of tomorrow. For example, I am working on the SpaceLab, which brings together professional experts and users around a common software platform. This involves developing or integrating the many design, simulation and mission-tracking tools, and capitalizing on ONERA know-how in the field of space, within a single platform."



AMÉLIE JARNAC, PHYSICAL MEASUREMENTS RESEARCH ENGINEER

"I began my career in the academic environment, pursuing a PhD at the University of Lund, in Sweden, then at Synchrotron SOLEIL. I then looked for a job linked to research in the French scientific ecosystem, and this led me to ONERA, which had posted a job vacancy on its website, so I went for it! This resulted in several interviews with the various scientific managers, and each time I sensed a real open-mindedness and people with a ready ear, who were looking for 'someone who had done something different'.
Beyond this highly positive human dimension, I discovered a stimulating work environment, with cutting-edge instrumentation, such as the Micronewton scales for satellite thrusters and the GRIFON test bench for studying lightning. You don't find these kinds of resources everywhere. The management of projects ranging over several levels of technological maturity is also highly motivational. I find ONERA's positioning ideal for me, comprising as it does exploratory research, via which you can expand on your basic knowledge, and application-oriented research. I'm still in my early days at ONERA, but through observing how the teamwork drives everyone on to better themselves, the cutting-edge expertise of the engineers, the issues surrounding societal research and the organization into departments which encourages collaborcollaboration, I find it suits me down to the ground."

Unprecedented raft of awards

From left to right: Manuel Rodrigues, Mrs Touboul, Laurent Mugnier, Denis Sipp and Pierre Touboul

ACADEMY OF SCIENCES AWARDS

Four ONERA scientists were rewarded by the French Academy of Sciences, the prestigious institution whose mission consists in encouraging the spirit of research to contribute to progress in the sciences and their applications.

The Servant Prize went to **Pierre Touboul** and **Manuel Rodrigues** for their major contribution to the Microscope mission: they developed the T-SAGE instrument, used for testing the general theory of relativity in space.

The Paul Doistau-Émile Blutet Prize went to **Denis Sipp** for his aerodynamics research, which is world-leading. His fundamental research into hydrodynamic instabilities and how to control them have had a profound impact on our understanding of the transition to turbulence.

The Lazare Carnot Prize went to **Laurent Mugnier** for developing powerful methods for the deconvolution of images enabling optimum exploitation of expensive instruments, such as the European Very Large Telescope or the future James Webb Telescope in space.

Theses awards

AMELIA EARHART PRIZE

3 ONERA doctoral students received this prize, awarded by the Zonta International club, for their thesis work.

Marine Ruffenach, for her thesis on the modeling of proton sensors, for studying an energy range that is still little observed, using detectors that are lighter, more precise and less energy-intensive and which could, ultimately, be miniaturized to be carried on nanosatellites or CubeSats.

Eva Borakiewicz, whose CIFRE thesis is funded by Airbus, for her research path and her thesis on the development of a method for predicting virtually the propagation of damage on the stratified composite materials of aircraft. The objective is to improve numerical simulation software.

Jahnavi Kantharaju, for her thesis on the experimental analysis of the dynamics of vortex structures that are formed in jet flows. The fields of application are propulsion and combustion.

Cécile Ghouila-Houri, doctoral student in aerodynamics between 2015 and 2018, received the thesis prize from the CNRS Research Federation on Terrestrial Transport and Mobility.

The prize-winners. Top photo: Marine Ruffenach, second from the right.
Bottom photo: Jahnavi Kantharaju and Eva Borakiewicz.

Rémi Roncen and **Florian Monteghett**, doctoral students in, respectively, acoustics of porous materials and numerical aeroacoustics, are the winners of the 2019 thesis prize from the Isae-Supaero Foundation.

Thibault Désert received the Pierre Maury Prize from the Academy of Sciences of Toulouse for his thesis: "Aeropropulsive study of a rotary-wing micro-drone for Martian exploration".

Other scientific awards

Valérie Rialland, specialist in infrared signatures, received, with the NATO AVT-232 group, the AVT Team Panel Excellence Award from the STO – NATO's scientific and technological organization – for her work on the aerothermochemistry of thruster jets, and the infrared emission from aircraft jets, surfaces and cavities.

Pierre Bourdon, specialist in laser dazzle, received, in the framework of the NATO SET-198 group, a Scientific Achievement Award for his work on visible laser dazzle.

Yoko Watanabe, winner of the ICAS John J. Green Award, designed to reward young professionals in the field of aviation who have contributed to promoting international cooperation between scientists. Yoko has been coordinator of the EU-Japan H2020 VISION project (improving aircraft faults tolerance).

Jean-Philippe Parmentier received the Carl E Baum Memorial Medal (Summa Foundation, USA) for his work on the electromagnetic topology.

Louise Sévin was recipient of the CNES young researcher days prize for "Ultra-high-temperature materials: thermomechanical optimization of FGM composites", as was **Laurie Paillier** for "Propagation channel models with adaptive optics for satellite-ground optical links".

The GARTEUR Award, bestowed upon the AD/AG52 working group on the topic "Surrogate model-based global optimization methods in aerodynamic design", rewards **Gérald Carrier**, **Jacques Peter** and **Didier Bailly**, from ONERA, for their involvement.

Best paper Awards

In 2019, ONERA took the top 3 spots in the EREA Best Paper Awards.

Fulvio Sartor and **Julien Dandois** for "CFD Benchmark of Active Flow Control for Buffet Prevention".

Jean-Marc Biannic and **Clément Roos** for "Robust Autoland Design by Multi-Model H∞ Synthesis with a Focus on the Flare Phase".

Timothée Achard and **Christophe Blondeau** for "High-Fidelity Aerostructural Gradient Computation Techniques with Application to a Realistic Wing Sizing".

Rodrigo Caye Daudt received the Best Student Paper award from the EarthVision workshop for the article: "Large Scale Computer Vision for Remote Sensing Imagery".

Michael Lienhardt received the Best Paper Award for his article: "Static Analysis of Featured Transition Systems".

Vincent Corbas and **Anthony Bourdelle** received the Best Student Paper Award for their respective sessions: Propulsion Physics and Flight Physics at the EUCASS 2019 Congress.

Distinctions

Jean Leger, General Secretary of ONERA, was made Knight of the National Order of Merit.

Franck Lefèvre, general technical director of ONERA, was made Knight of the Legion of Honor.

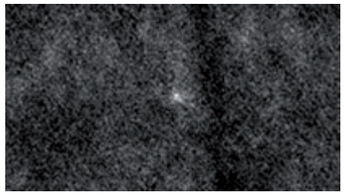
Stéphane Andrieux, general scientific director of ONERA since 2015, is one of the sixteen new members of the Academy of Technologies elected in December 2018 and decorated in March 2019.

Annick Loiseau was appointed to the CNES Scientific Programs Committee for her expertise in nanosciences and nanomaterials, in line with the Order signed by the Minister for Higher Education, Research and Innovation and the Armed Forces Minister.

Nicolas Bérend (emeritus member), **Claudine Besson**, **Anne Denquin** and **Denis Gely** (senior members) were honored at the graduation ceremony of the 3AF (aeronautics and astronautics association of France).

Bruno Chanetz was appointed Chair of the High Scientific Council of the 3AF.

2019 highlights

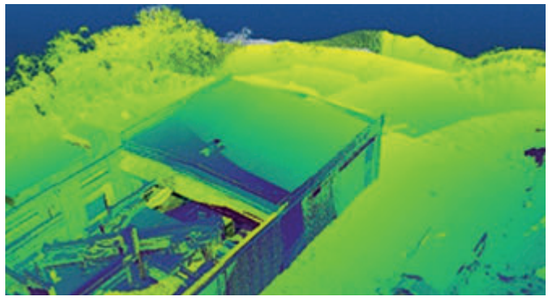


Aircraft debris retrieval | Helping the BEA by means of the ONERA detection system

ONERA came to the aid of the BEA (investigations and analysis bureau) of Airbus and Engine Alliance to find the fan hub of the A380 in Greenland. While an initial campaign of visual search by helicopter had only found the light items remaining on the surface, the heavier items had sunk into the ice and then been covered by snow. ONERA offered the use of its SETHI radar (experimental microwave imaging remote detection system), an airborne system dedicated to imaging, featuring high-performance SAR sensors and optronic sensors. In February 2019, after 10 months of effort, the fan hub was found thanks to the localization of three points brought to light by the analysis tools developed by ONERA for the mission.

Applied mathematics | a new lab

The aviation and space applied mathematics laboratory was created to bring together the ONERA community of mathematicians and computer scientists and encourage the pooling of their work. This discipline is involved in all fields of physics and plays a key role in the development of numerical simulation tools. It is about working on the upstream development of computer codes, to design ever more efficient methods and algorithms and significantly increase the simulation capacities of the departments.



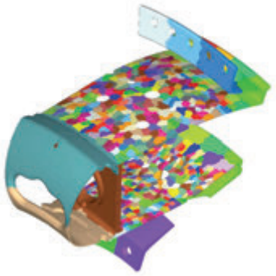
Drones | Onboard high-resolution 3D laser imaging

As part of the European INACHUS project, the purpose of which is to assess the damage and plan the rescue measures following a catastrophe, by means of methods and tools for helping locate victims under the wreckage, ONERA has developed multi-rotor drone solutions equipped with 3D laser imagers and the associated processing. Successful testing has made it possible to obtain initial real-time mapping via 3D LiDAR, work that will serve to help in planning the deployment of the rescue services and in assessing the structural damage, in order to prioritize intervention and optimize the assistance response times.

ONERA TERRISCOPE

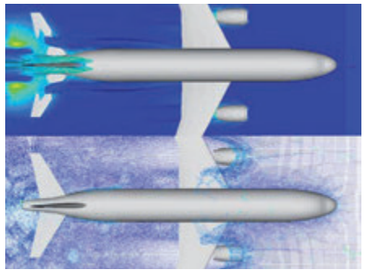
Airborne remote detection | inauguration of the Terriscope platform

Terriscope is a pooled airborne optical remote detection search platform for characterizing the continental environment and surfaces from aircraft and drones, using latest-generation optical sensors. This unique passive and active optical remote detection resource is of interest both for scientific research and for work linked to surveillance, security and defense. In addition to the input from ONERA, the platform has been funded to the tune of €4.7 million by the Occitanie region, including €2.3 million in European FEDER funds, and is supported by four manufacturing companies: LYNRED, BOREAL, M3 SYSTEMS and LEOSPHERE.



Materials | high-fidelity simulation of combustion chambers

The computation of a portion of a combustion chamber containing 1,200 micro-perforations was conducted in the framework of the SEMAFOR project (Simulation and experimental analysis of material failure in large scale yielding) of the ANR (French national research agency). These new high-fidelity simulations will enable manufacturers to refine the design of combustion chambers. The behavior of a chamber made of cobalt superalloy, subjected to extreme temperatures, was simulated with the Z-set computer code developed by ONERA and the Materials Center of Mines ParisTech.



Structural dynamics | numerical simulations of ditched landings

A structural model of a short-haul and medium-haul aircraft has been developed in the framework of the ADAWI project (ONERA-DLR collaboration) for simulating ditched landings. It has been able to bring to light differences in the global behavior of the aircraft. This cooperation is being continued via the RADIAN (Robust Aircraft Ditching Analysis) project, which is intended to simulate the ditched landings of a generic aircraft in different sea conditions. A major part of the project is also devoted to the validation of the simulations by means of comparisons with the different experimental results produced at ONERA.

Numerical simulation | ONERA joins the consortium for processing uncertainties

This consortium for developing the OpenTURNS open source software library enables the processing of uncertainties in numerical simulation. The consortium also includes EDF, AIRBUS, IMACS and PHIMECA. It should encourage exchanges and best practices among the community of researchers and enable pooling of the tools and the exploitation of the results. ONERA's participation in this development ties in logically with the "uncertainties" investigations of the ONERA applied mathematics lab.

Multidisciplinary optimization | ONERA contributes to NASA software

XDSMjs, a library enabling visualization of MDO (MultiDisciplinary Optimization) processes, developed by ONERA in open source, has just been integrated in the latest version of the OpenMDAO open source framework of NASA Glenn. OpenMDAO is used by ONERA for the preliminary project design of aircraft and launchers. This integration extends the collaboration forged for several years with NASA Glenn and the University of Michigan in this field, and confirms ONERA's status as a major contributor to OpenMDAO.

Innovation | a new means of measuring electromagnetic fields

The patent: "Sensitive component for device measuring electromagnetic fields via thermoflorescence, corresponding measurement and manufacturing processes" was filed jointly by ONERA, INSA and the CNRS. It concerns the development of the EMVi technique for mapping electromagnetic environments and consists in measuring the heating of a resistive film by thermofluorescence. The targeted applications are the characterization of antennas and the evaluation of electrical or magnetic fields across a wide frequency band.

Distributed propulsion | maiden flight of an aircraft mockup with eight propellers

In October 2019, the distributed propulsion demonstrator, developed in the framework of CEDAR (Chair for Eco-Design of AiRcraft), made its maiden flight and checked, in real-life conditions, its onboard systems and its flight characteristics. This demonstrator ties in with a thesis co-supervised by ONERA and Isae-Supaero. Objectives: to propose a co-design method for both conceiving the engine control laws and sizing the vertical stabilizer, while respecting flight quality and security constraints. It also aims to provide a point of comparison with a flight-proven solution on a demonstrator.

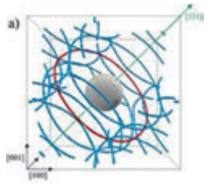
© Alseamar

Drones | centralized missions management

Three Alseamar SeaExplorer underwater gliders have been piloted by a centralized missions control system developed by ONERA. To mitigate the positioning uncertainties, their limited power and their random movement on account of the diversity of their missions (defense, industry and environment), testing in real-life conditions was conducted to test the initial supervision and planning strategies. It demonstrates the possibility of reducing the workload of human pilots of underwater gliders while increasing the efficiency of multi-drone missions in terms of duration, energy and the use of payloads.

Event | first international aerospace conference by ONERA and Paris-Saclay University

In November 2019, ONERA, Paris-Saclay University and the Northeastern University, with the support of the Federal University of Toulouse, organized a Franco-American scientific conference – Future of Innovation in Aeronautics and Aerospace – with a dual objective: enabling scientists and research lecturers to present their research, and identifying topics for collaboration and discussing opportunities for partnerships, including with industry, both nationally and internationally.



Materials physics | modeling of hot isostatic pressing

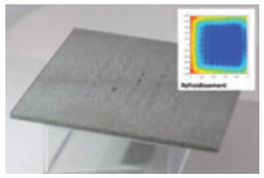
Flight security depends in part on the reliability of aircraft engines, in particular the blades of the turbine in the hot part of the engine. To improve their resistance, they are solidified in the form of nickel-based superalloy monocrystals, elements that contain micropores, significantly reducing their service life. This defect can be eliminated by hot isostatic pressing, a process conducted at very high temperatures, and which can damage the blades. In the framework of the European MICROPORES-HIP project, funded by the ANR and the DFG*, ONERA modeled the contribution of the plastic activity in the annihilation of the porosities. The model is therefore capable of reproducing the complex behavior of the dislocations.

* German research foundation

Composites | ONERA science in the software

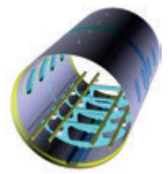
In terms of materials and structures, ONERA boasts many digital competences and is involved in the development of several software applications such as Z-set and Europlexus. It also makes advanced use of industrial codes (Abaqus, MSC Nastran, Hyperworks suite from Altair) and develops lots of business software around these codes. The latest, codeveloped by ONERA, is the Cetim* QSD software, the fruit of several years of pooled research into the manufacturing of thermoplastic composite structures. It is dedicated to the optimization of stratified composite structures.

* Technical center for the mechanical industries



Engines of the future | transpiration materials for combustion chambers

As part of the MOSART project, funded by the DGA, and conducted in conjunction with Safran, SIMap and SinterTech, ONERA has designed and characterized porous materials obtained by means of additive manufacturing. The targeted application is the replacement of the multi-perforated walls of aeronautical combustion chambers. Aerothermal tests have demonstrated improved cooling efficiency in the leading-edge zone. The prospects may involve producing materials via LBM (Laser Beam Melting), with the advantage of greater finesse in the porous architectures generating more efficient cooling. It has been selected as "flagship project" by the ANR (national research agency).



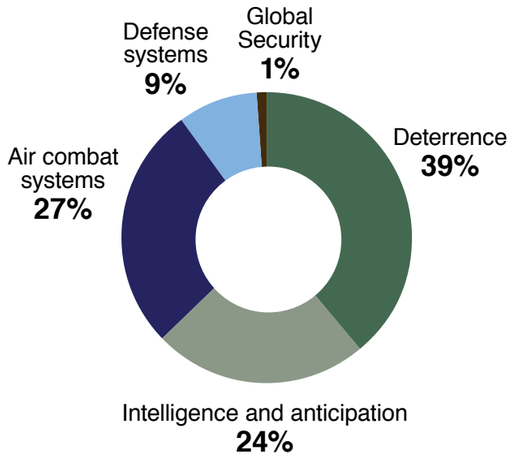
Electromagnetics | end of the European EPICEA project on composites

This project, for which ONERA is the European coordinator, deals with the problem of the effects of severe electromagnetic environments deriving from cosmic radiation on composite aeronautical structures, and the modeling of these effects on systems. ONERA's efforts have been focused on the electromagnetic coupling on complex wiring harnesses and the study of small footprint antenna concepts, installed on massively composite structures. A modeling platform was produced, and the developments were applied and validated by comparison with measurements on a section of a business jet fuselage, made available by Bombardier Aerospace and equipped with prototype wiring produced by Fokker Elmo.

Defense

Innovation in the service of defense

Scientific excellence, the multi-disciplinary skills of its teams and excellent knowledge of operational requirements make ONERA a genuine "tool for innovation" in the service of Defense. Whether for technological or system innovations meeting the needs of the armed forces, eliminating risks for the benefit of the French DTIB or expertise in the service of the weapons programs, ONERA is at the service of Defense across the board.



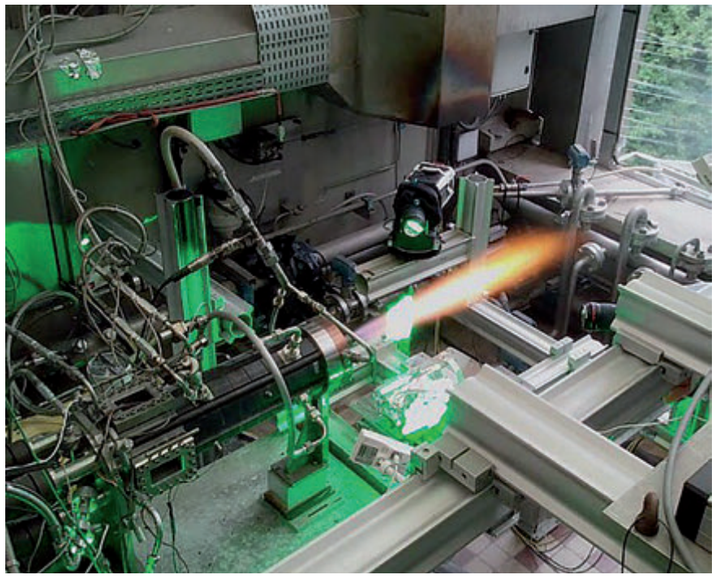
Breakdown of ONERA defense activities in 2019

Combating drones: ONERA coordinator of a cross-disciplinary project

In January 2019, ONERA launched the SHIELD R&D project, which it coordinates. Scheduled over 2 years, the project is of interest to the entire national community concerned with combating drones, both civil and military. Its objective is to put in place a platform for studying and evaluating new technologies dedicated to the detection and neutralization of UAVs. The challenges consist in identifying and improving the sensors, evaluating the fusion architectures and coming up with innovative processing, to propose a complete system suited to drone neutralization.
Four scientific departments of ONERA are involved: "optics", "electromagnetics and radar", "information processing and systems" and "aerodynamics".

GRAVES, the first European space surveillance system: ONERA to further upgrade the system

The DGA has asked ONERA for the latest version upgrade of the system, to bring it up to its maximum performance levels. Unique in Europe, it enables the Air Force to monitor satellites in low orbit (1,000 km). Following on from the renovation phase of the reception site from 2016 to 2019, this new step concerns the transmission site. This step-by-step process guarantees maintained continuity of the surveillance mission for the Air Force and the new space command, with no alteration to detection. For improved performance, the DGA has indeed selected the most ambitious production option, proposed by the ONERA scientists using exceptional computation tools and resources.



Early warning: culmination of the ONERA "Ballistic missile signatures" project

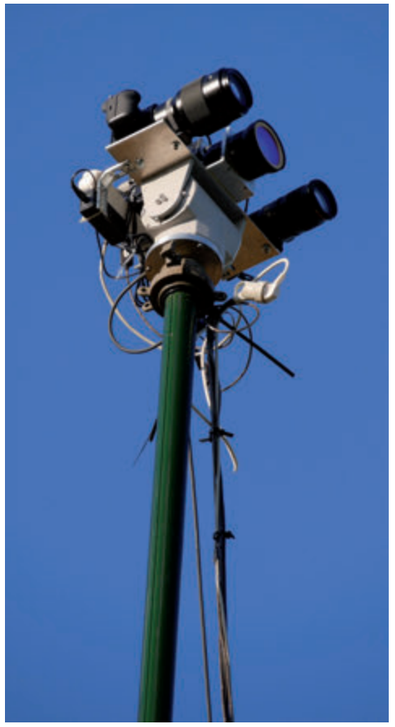
The SIMBA (infrared and radar signatures of ballistic missiles) project has concluded with highly positive results, hailed by all the partners. This interdisciplinary project has supplied the elements of an infrared and radar signature model for ballistic missile jets, used for sizing and analyzing the performance of a future warning system. In particular, various experimental campaigns were conducted on the ONERA test benches: PIV (Particle Image Velocimetry), PLIF OH (Planar Laser Induced Fluorescence of OH) and multi-spectral images of propellants in combustion, along with numerical simulation, to produce the first reactive jet calculations and their infrared and radar signatures.

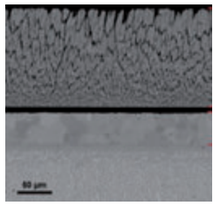
Military intelligence: success of the Sysiphe tests campaign

Version 3.5 of MATISSE, reference code for the numerical simulation of the combat scene environment, has been delivered to the DGA. Including a wealth of data (atmospheric profiles, clouds, aerosols, backgrounds, etc.), this code is easy to use in engineering calculations. It can also be integrated in performance simulations and forecasts. MATISSE is, for example, used for missile programs, and in the scene generation tool used by the DGA.

Optronics: success of the EVALOP measurement campaign

Funded by the DGA, the objective of this campaign, conducted in Djibouti, was the acquisition of color and near-infrared visible images of military and civil, armed or unarmed, personnel and vehicles in a desert environment. The tests were carried out on scenarios similar to operational scenarios. They required the development of performance modeling resources, image simulation resources and resources for evaluation in the lab or in the field. The database will enable the modeling resources to be validated by comparing the scope provided by the perception metrics with the subjective scores obtained by means of psycho-visual experiments involving field experts.





Hot materials: towards a new system for turbine blades

Funded by Safran Aircraft Engines from 2016 to 2019, the AGATHE (Advanced Gas Turbine with High Efficiency) project is part of the DGA TURENNE (new-generation turbine and regulation) project, aimed at developing the new-generation turbine technologies for future fighter jet engines (new version Rafale and SCAF), in particular the new materials system for high-pressure turbine blades. ONERA has proposed six new nickel-based single-crystal superalloy grades, with high mechanical performance at very high temperatures and high resistance to the environment. A new alloy and a new heat barrier composition are already integrated in the new material for the latest-generation HP turbine blades, to be assessed in engine tests as part of a new DGA contract.

Electromagnetic environment: a captive balloon for measuring it

To face the increased density of electromagnetic emissions, the armed forces need to obtain optimized and innovative means of detection and location. The CERBERE project, conducted by Ineo Defense and ONERA for the DGA, is intended to demonstrate the performance of a signal intelligence solution on a captive balloon carrier. In the June 2019 tests campaign, ONERA studied all the aspects of the carrier and designed the networks of antennas and certain specific processing algorithms, leveraged by Ineo Defense in the payload. ONERA also took charge of all the test logistics and the procurement of the carrier. The project results will be taken into account for guiding the future electronic intelligence and warfare programs conducted by the DGA on behalf of the armed forces

Military intelligence: high-resolution satellite imaging

The objective of the DGA OBSSAT study (high-resolution observation from satellites in low orbit with adaptive optics) is to demonstrate, with the aid of the ODISSEE adaptive optics bench from ONERA and the MeO telescope of the Côte d'Azur observatory, the possibility of supplying satellite video sequences in low orbit, with a quality level exploitable for military intelligence. Enhancements to the ODISSEE facility and the post-processing algorithms have made it possible to obtain videos of excellent quality. The performance of the experimental system makes it possible to envisage its use in space surveillance.

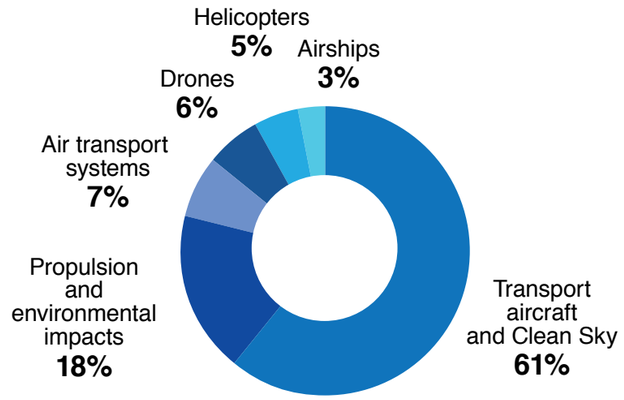
Combating drones: assessment of deep learning techniques

In the framework of the thesis: "Selection and recognition of drones via deep learning", co-supervised by ONERA, a drones measurement campaign has been conducted to develop, in real-life situations, the recent neuronal network techniques by adapting them to radar signals. Around a dozen drones were used, along with many bird signals. In addition to common birds, for greater realism, ONERA worked with falconers to collect signals from falcons flying at altitudes and distances similar to drones.
This database is richly diverse in terms of trajectories (straight lines, climbs/descents, circles, pivots, free trajectories, etc.), weather, radar signals (HH/VV polarization) and environment (different heights, etc.). It will enable development of the classification algorithms (distinguishing between targets: birds/drones, or between drones), as well as the most realistic simulation possible of signals via neuronal network methods.

Aeronautics

Preparing the sky of tomorrow

Among the civil aviation activities, the proportion of ONERA's work on protecting the environment has increased. This trend is consistent with the strategy pursued by the manufacturers, by Europe and by the institutional bodies, and with today's societal concerns.

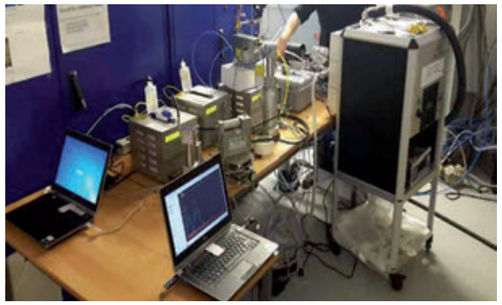


Répartition des activités aéronautiques de l'ONERA en 2019

Aerodynamics: boundary layer inspection tests

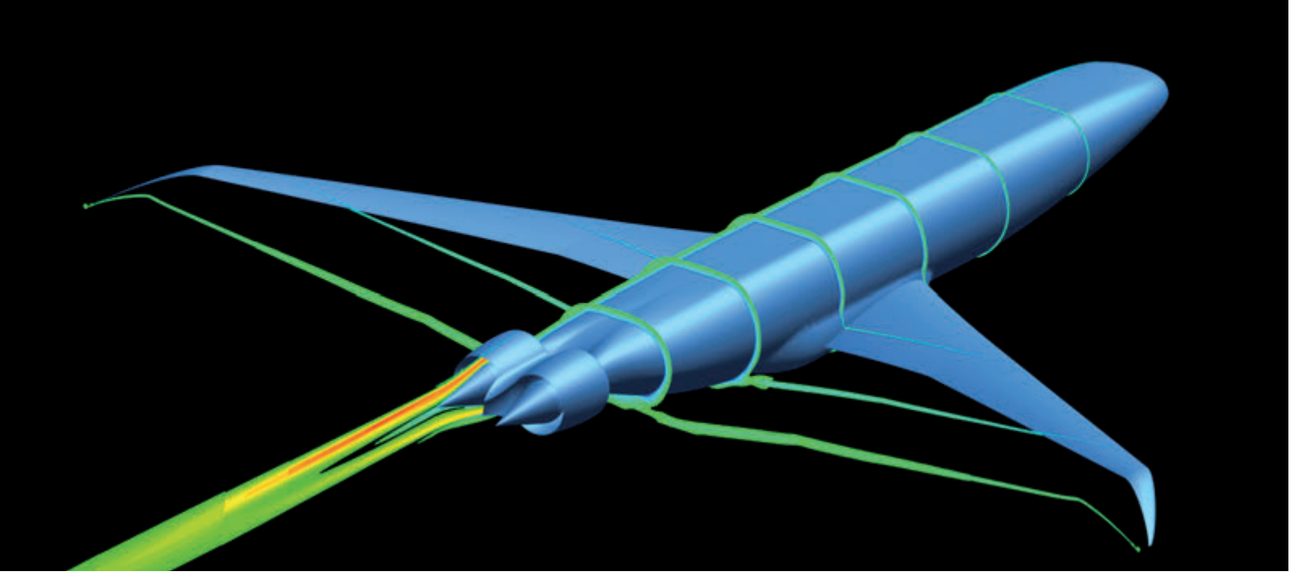
For the first time, the combined efficiency of a passive anti-contamination system and active parietal suction system was studied in an inspection campaign of the laminar / turbulent transition on the split line of a wing. The tests were carried out in the wind tunnel in the framework of the Nacor* project, the joint response from ONERA and the DLR to the Airframe ITD (Innovative Technology Development) of the Clean Sky 2 program. The successful results of the test campaign will feed into all the laminarity activities carried out in Europe as part of Clean Sky 2.

* New innovative Aircraft COnfigurations and Related issues



Drones: ONERA, key player and national benchmark body

ONERA is naturally involved in many activities associated with drones: PHYDIAS convention on the safety of drones and CONCORDE convention on design and analysis methods for drone systems and their certification (both at the request of the DGAC). In 2019, thanks to funding from FEDER and the Occitanie region, ONERA finalized production of Terriscope, the pooled platform for airborne optical remote detection research. On the manufacturers' side, ONERA is involved, for example, in the SNCF-Altametris partnership, DROSOFILES, on the inspection of railway lines. Various other projects, representative of ONERA's multidisciplinarity, concern the following fields: take-off / landing standardization, risk management, avionics for safety, payloads, autonomy, etc.



Engine installation: more efficient aero-propulsive configurations

ONERA has just completed the second phase of the Nautilius project, under direct contract from Airbus, aimed at assessing its patented BLI* engine installation concept. The work consisted in pursuing the aerodynamic design and fine-tuning the propulsive yield gain forecast. The optimization of the fan/straightener stage helped limit the deterioration of its yield in the presence of the distortion generated by the boundary layer ingestion developed by the fuselage. This work will be continued in the framework of the European Clean Sky 2 project, with the integration of other disciplines such as aeroelasticity and acoustics.

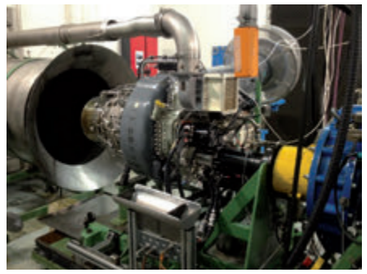
* Boundary layer ingestion

Turboprops: designing a propeller

Safran has unveiled the TechTP demonstrator, equipped with a high-performance and silent propeller designed by ONERA. ONERA's contribution to the design of this 2.5 m-diameter propeller, equipped with seven blades and spinner, offer significant noise reduction – 4.5 dBa – while maintaining efficiency. The CO2 emissions and the fuel consumption will be reduced by 15%. These successful results have been obtained thanks to the skills of ONERA in aerodynamics, acoustics, materials and energetics. This work was conducted in the framework of the European Clean Sky 2 partnership, and more specifically the ANTARES project, coordinated by ONERA from 2017 to 2021.

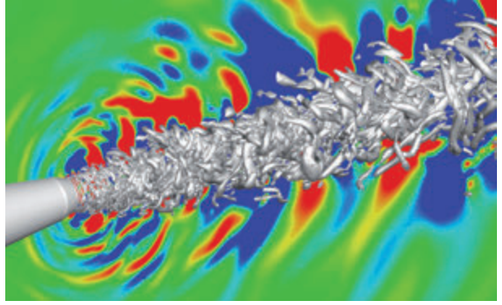
A revolution in aircraft propulsion: hybrid electric propulsion

At the head of a consortium of 27 European partners and 6 international partners, ONERA successfully submitted the IMOTHEP project (Investigation and Maturation of Technologies for Hybrid Electric Propulsion) on hybrid electric propulsion in the framework of Horizon 2020. IMOTHEP will look in depth into the electrical technologies for the hybrid electric propulsion of commercial aircraft, in relation to the design of innovative configurations developing new synergies between airframe and propulsion. The objective: to surpass the emission reduction levels for commercial aviation that can be hoped for from the development of conventional technologies by 2035. IMOTHEP receives funding of €10.4 million from the European Commission.



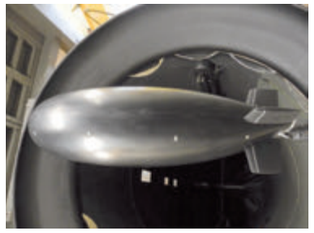
Reducing emissions: advanced measurement techniques

ONERA possesses cutting-edge resources for characterizing helicopter engine emissions. In 2019, ONERA conducted monitoring of particulate and gas emissions (CO2, CO and SO2) from the engine exhaust, using advanced experimental techniques, in partnership with Safran Helicopter Engines. This measurement campaign was carried out in the framework of the European ANTARES project of the Clean Sky 2 - Engines ITD (Integrated Technology Demonstrators) partnership. These techniques contribute to demonstrating and validating technological developments that meet the environmental objectives of ACARE (Advisory Council for Aeronautics Research in Europe).



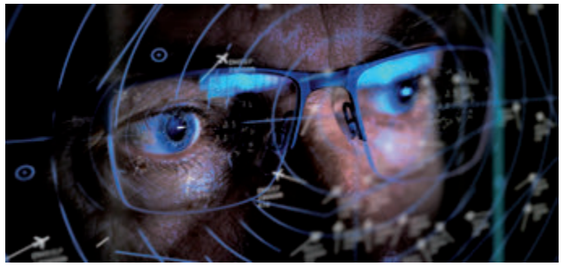
Noise from transport aircraft: ONERA gets the thumbs up from the European Commission

Aviation noise comes from two main sources: the noise of air friction on the aircraft in flight (aerodynamic noise) and the engine noise. As part of a European RFP (H2020), ONERA is involved in the three chosen projects. On the INVENTOR project, which it coordinates, it will provide its expertise on aerodynamic noise (landing gear, slats, flaps, etc.). Its expertise will also be brought to bear on jet noise, for the DJINN project, and on advanced engine installation for the ENODISE project. Each time, ONERA's contribution has proved decisive, thanks to the variety and complementarity of the engineering-research specialities, in particular the various numerical simulation techniques in aerodynamics.



Airships: wind tunnel tests for the revival of the sector

Several wind tunnel test campaigns have enabled analysis of airship aerodynamics in the framework of various projects, such as the stratospheric airship (Stratobus project for Thales Alenia Space: an airship dedicated to transporting heavy loads), and the LCA60T project (ONERA / Flying Whales partnership), on a generic ellipsoid form in the framework of the Cifre Flying Whales - ONERA thesis on the modeling of non-homogeneous flow effects. The purpose of all this work is to build up models of behavior in a highly extended flight domain, and it will feed into the work conducted on flight simulators. This experimental work is accompanied by numerical computations.



Air traffic management: "SINAPS Open Days"

The SINAPS (SWIM INAP Services) platform, a decision-making aid tool for the dynamic configuration of control sectors, was presented to the air traffic controllers. It has been developed by the DSNA* and ONERA in the framework of the SESAR** project to help in the optimization of an air traffic control room. This innovative tool proposes a set of services that are permanently adapted to the growth in air traffic and to the available resources, to propose an optimal configuration for the sectors to be employed in ATC. This project is cited as exemplary, since ONERA has the skills and test resources (numerical and experimental) required for conducting projects on artificial intelligence, human-system interfaces and onboard systems.

** Direction des services de la navigation aérienne*

** Single European Sky ATM (Air Traffic Management) Research

Aerodynamics: active control of flows to reduce drag

An airstream separation control test campaign on a business jet vertical stabilizer was carried out in the wind tunnel (DGA RAPID ASPIC project in partnership with the SME, CEDRAT). The objective was to increase the lateral force generated by the stabilizer by eliminating extreme separation that appears on the rudder at high deflection angles. This control would enable the stabilizer surface area to be reduced, thus reducing aircraft drag by around 3%.

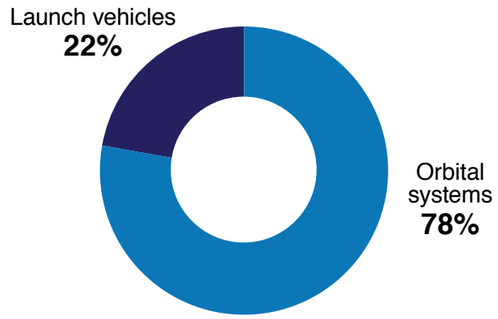
Clean Sky: involved beyond the environment alone

ONERA is involved in five broad thematic platforms. Here are three examples of projects on which it is working: firstly, IDEA (Innovative DEsign of acoustic liners for Air conditioning System), for which it characterized the noise sources for a new air-conditioning system for the more-electric aircraft (jet pump). It designed, manufactured and tested a prototype liner for reducing noise propagation. Secondly, EFAICTS (Ergonomic impact & new Functions induced by Active Inceptor integration in CockpiTS): ONERA developed and integrated a system of active mini-controllers for the coupling functions, to improve pilot/copilot and crew/onboard system interactions. Thirdly, ANALYST (ANALYsis Statistical Techniques in aeronautics): ONERA modeled the wiring architectures to optimize the segregation distances between routes in an aircraft via statistical approaches.

Space

Space research of the future: ONERA on all fronts

The year 2019 will remain a year of intense preparation for the future in the field of space research: reinforced exchanges with the historic partner, CNES, along with preparation of the European Horizon Europe space research program and the ESA Space19+ ministerial conference. Between promoting upstream research projects at national or European level, and pursuing applied research projects for industry, ONERA has been engaged on all fronts.



Breakdown of ONERA space activities in 2019

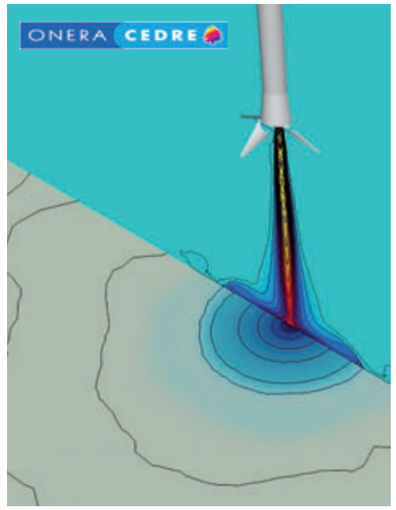
LAUNCH VEHICLES

Collaborations: ONERA a major player within ArianeWorks

In 2019, the CNES and ArianeGroup signed an agreement protocol in Paris for the implementation of an acceleration platform, ArianeWorks, designed to prepare the launch vehicles of the future, which are to be partially reusable, and in particular the Themis demonstrator. Spearhead for the topic and backed by its expertise in multidisciplinary optimization, ONERA, which has supported ArianeGroup and the CNES throughout the development of Ariane, has chosen to join up with ArianeWorks, to provide its expertise, with special emphasis on monitoring the health of structures, a key element when considering reuse.

Ariane 6: heat flow measurement on the Ariane 5 launch pad

For optimized design of the Ariane 6 launch pad, the ESA asked ONERA to measure the heat flows linked to the impact of the hot jets, charged with alumina particles issuing from the solid fuel engines. ONERA produced the measurement system suited to this harsh environment and validated it in laboratory testing. The measurements were then sent to the Guiana Space Center (CSG) for integration by the CNES, enabling the specified flows for Ariane 6 to be updated. In light of this success, it is envisaged putting them in place in certain zones deemed sensitive of the ELA4 launch pad for the first flights of Ariane 6.



Numerical simulation: landing of the future launch vehicle

In late 2019 ONERA made the first landing simulation of Themis using the CEDRE code, enabling the establishment of a reference database for the instantaneous heat flows and their integral, on both base and feet of the stage and on the ground. These data will then be used to size the heat protections required for the various elements.

SEVERAL STRUCTURAL COMMON INTEREST PROGRAMS (PIC)

PIC C_3PO: cryogenic combustion of CH4 plus oxygen

In November 2019, ONERA and the CNES entered into a 4-year commitment with this PIC in the field of methane/oxygen combustion. Tests on the MASCOTTE combustion bench and ambitious simulations with the CEDRE code (based on the new models consolidated via testing) will be conducted by the ONERA combustion and physics experts using innovative measurement techniques. Four theses will also ensure a scientific approach in support of the development of ESA's reusable low-cost engine demonstrator, Prometheus.

Signing of the C3PO PIC by Thierry Michal and Jean-Marc Astorg, CNES launch vehicles director

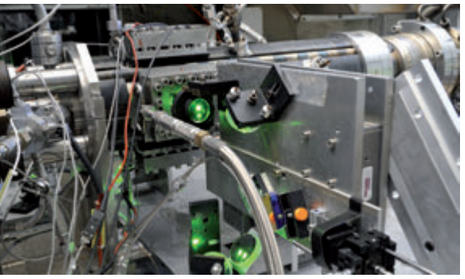
MATEO PIC: mitigation of optical turbulence

For superfast communications, optical transmissions present themselves as an alternative to radio frequencies, in the context of saturated available bandwidth and competition for the allocation of frequencies with the ground infrastructures, 5G in particular. Drawing on a decade of research and theses at ONERA, the MATEO PIC addresses this challenge by studying superfast optical links to telecommunication satellites, along with the rapid transfer to the ground of data from the future Earth observation constellations. Signed in late 2019 for a period of 5 years and supported by €1.5 million in shared funding, the PIC will relate in particular to the modeling and mitigation of the optical communication channel, with a significant experimental component.

Signing of the MATEO PIC by Thierry Michal and Jean-Claude Souyris, CNES/DIA vice-director

PERF PIC2: radio frequency electromagnetic propagation

Signed in January 2020, this follows on from PERF PIC, and confirms the intention of the CNES and ONERA to establish a structure of pooled R&D for 5 years, with experimental campaigns on every continent and modeling of the ground-satellite propagation channel, work carried out by the ONERA electromagnetic and radar department.



Satellites: new materials for future thrusters with green propellants

Tests conducted on ONERA's Mascotte combustion test bench have enabled validation of the temperature resistance of new materials, known as functionally gradient materials (FGM), designed for the combustion chambers of future green propellant thrusters for holding satellites in orbital position. These materials, which combine ceramics with a refractory metal, are developed by ONERA in the framework of the ONERA/CNES program of common interest (PIC): "Green monopropellant propulsion". The Mascotte test bench has enabled these innovative materials to be tested in real-life conditions of use and to validate their resistance to flame temperatures reaching 2300 K.

Space launch: successful jettisoning of a reusable airborne launch vehicle demonstrator

At the Guiana Space Centre, the reduced-scale demonstrator of an airborne launcher system for small satellites, EOLE, developed by ONERA, the CNES and Aviation Design, successfully jettisoned an inert launch vehicle mockup, proving that this innovative airborne launch system works. This latest experimental campaign has been a success, with automatic "out-of-sight" flights culminating in the jettisoning of the launch vehicle mockup, validating the avionics technologies and the separation/jettisoning technique in automatic mode. This is the ultimate stage in the European ALTAIR project, funded by the European Union (with a contribution from Switzerland).

Altair

EARTH OBSERVATION

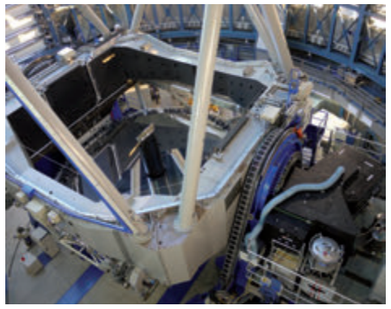
As part of the consolidation of its relations with the big French manufacturers in the space field, ONERA was involved in 2019 in 2 major projects financed by the Future investments program, coordinated by the SGPI (General secretariat for investment) and operated by Bpifrance.

Constellations of Earth observation satellites: LICHIE project

The LICHIE project is backed by a consortium led by Airbus DS and concerns the upstream chain relating to Earth observation satellite constellations. ONERA, which has invested €2.4 million in the project, provides its information processing and optics skills for application in, one, the design and manufacturing of the satellites and, two, the management of the constellation. This involves implementing a dual methodology encompassing instrument design and complexity of the serial manufacturing process, while taking into account requirements concerning the variability of the instruments and optimizing the time and cost of production.

Automatic 3D geospatial information production: AI4GEO project

This concerns a major challenge for many booming sectors of activity, such as self-driving vehicles, economic intelligence and urban development. This project, coordinated by a consortium headed up by CS, aims at putting in place new value-added services using innovative methods suited to 3D imaging. ONERA, the CNES and the IGN will provide their data and know-how in artificial intelligence and geospatial data processing for the production of semantic 3D information. They will provide the link with the SMEs concerned. Signed up to in December 2019, the AI4GEO project contract represents an investment of €30 million over 4 years, and is funded to the tune of €13.5 million.



Adaptive optics: high-resolution image of the smallest known planet

Thanks to the SPHERE adaptive optics instrument developed by ONERA, which equips the Very Large Telescope, a new picture of Hygiea, the smallest dwarf planet in the solar system, has been taken. Coupled with the MISTRAL image processing algorithm, also developed by ONERA, the SPHERE instrument enables image capture with a sharpness and resolution never before obtained from the ground. Based on the images obtained by the SPHERE instrument, according to the study in Nature Astronomy of 28 October 2019, it turns out that this is in fact an enormous spherical asteroid. Discovered in 1849, Hygiea had never before been photographed in high resolution.

Lidar: measuring greenhouse gases

Funded by the European Union to the tune of €3.37 million, the H2020 LEMON project, coordinated by ONERA, started up in 2019 in the framework of a consortium composed of FRAUNHOFFER (Germany), the CNRS, the KTH (Royal Institute of Technology, Sweden), SPACETECH (Germany), the UiB (University of Bergen), INNOLAS (Germany) and L-UP. The objective of the project is to develop a differential absorption LIDAR for sampling greenhouse gases (carbon dioxide and methane) and water vapor from space, and to test the device in airborne conditions. The project will also enable definition of the roadmaps and experience required for its application to a space mission. It will take us beyond the current satellite projects, which deploy either passive sampling systems (spectrometers) or active systems based on LIDAR for a single greenhouse gas (Merlin satellite for methane).

Optical communications: very high data rates thanks to adaptive optics

Conducted on behalf of the European Space Agency, the Feedelio project (Optical feeder-link for next-generation telecommunication satellites) aims to demonstrate the benefits of adaptive optics for correcting the effects of atmospheric turbulence for the future superfast laser links between ground and geostationary satellite. With the bandwidths for RF telecom links reaching saturation, these links are of fundamental importance, since they could operate at any point on the globe. ONERA therefore conducted an extremely innovative experiment in 2019 on a 13 km link between a ground station simulator and a satellite simulator. The results demonstrate for the first time the benefits of adaptive optics for bidirectional links between the ground and geostationary satellites, constituting an important milestone in the validation of such links.

Experimental test resources suited to every problem

Launch of the icing wind tunnel

To address the stiffening of the regulations, ONERA, the scientific benchmark body for icing certification, launched construction of a research wind tunnel. On March 15, 2019, ONERA and DGAC laid the foundation stone for this facility that they have together co-financed. Objective: improving air safety.

Unique capacities

- Air temperature: as low as -40°C
- Altitude simulation: 11,000 m
- Test section dimensions: 10 cm x 20 cm, 4 mobile bulkheads and wide optical accesses

Patrick Gandil, DGAC director general, Nadia Pellefigue, vice-president of the Occitanie region, and Bruno Sainjon, ONERA

ONERA, a government expert

In 2013, DGAC entrusted ONERA with conducting research into the understanding and modeling of the fundamental physical ice forming processes, and their consequences on an aircraft's components (PHYSICE research convention, then PHYSICE 2, in 2016).

Cutting-edge test facility

Having such a facility will serve two objectives: firstly, understanding the physical phenomenon in order better to combat it. It will enable experimental data to be acquired for the development and enhancement of the computer codes, also developed by ONERA. Secondly, it will enable development of measurement techniques and the testing of the efficiency of new ice-repellent materials.

ONERA's globally recognized icing expertise

In the '90s, ONERA proposed computer codes for simulating icing. More recently, it has developed a new generation of digital tools that are more precise and interoperable with other codes. In 2018, it was involved in all the selected European H2020 projects on this topic:

- MUSIC-HAIC project, which it coordinates, on the development of 3D models for icing in crystal conditions;
- SENS4ICE project on innovative ice detection technologies;
- ICE-GENESIS project on the modeling of icing in snow conditions and SLD (project coordinated by Airbus) for which the new icing wind tunnel will be used.

Furthermore, ONERA will be continuing its collaboration with NASA, with the SUNSET 2 project on the study of deteriorated aerodynamic performance due to icing.

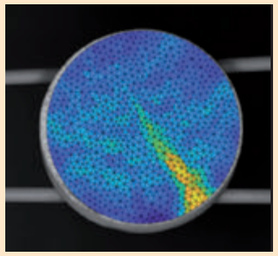
Focus on some cutting-edge tests in the field of materials

Testing high-temperature materials

Extreme temperature conditions (above 1500°C) to which missile or combustion chamber materials are subjected require lab testing.

An innovative test bench

ONERA has designed a laboratory test bench with controlled bulkhead temperature gradient, with injection of CMAS (calcium-magnesium-aluminosilicate), for reproducing real-life conditions to better understand the mechanisms of the deterioration of fan blades, situated in the hottest parts of engines. This bench stands out in comparison to other test resources available in France through the use of a power laser as heating mode and the possibility of injecting pollutants (sand, volcanic ash, etc.). On the basis of this laboratory resource, an industrial-style mechanism could be developed for campaigns to select new materials.

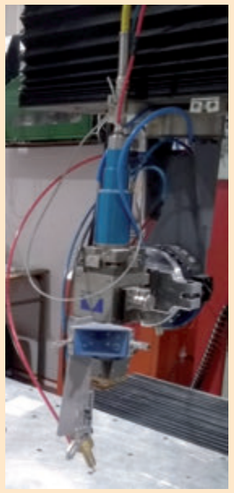


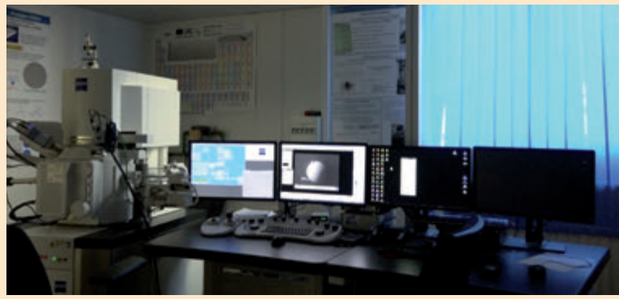
Measuring displacement fields via digital image correlation

Access to field measurements, vital for better understanding of the reactions of materials exposed to extreme temperatures, remains a major challenge. The integration of the thermo-optical properties of materials and the development of algorithms for correcting images acquired during tests conducted on the ONERA laser test bench have made it possible to obtain robust field measurements in detecting the propagation of a fissure at very high temperatures. No such results had ever previously been obtained.

Additive manufacturing: a single-stage process

ONERA and IREPA-LASER have explored the feasibility of producing dense ceramic parts in a single stage via the CLAD process of direct additive laser construction. The production of the first eutectic ceramic walls, the nanometric structure of which enables optimization of their resistance and hardness properties, constitutes a major feat. It holds out promise for the production of parts with complex geometric structures in polymers or in metal, and large parts consisting of several compounds. This work was done in the framework of the Carnot CLADIATOR inter-institutes project.





Microscopy: a new scanning electron microscope

ONERA has acquired a new scanning electron microscope and a heating stage for micromechanical testing. Equipped with three main new features, this new microscope complements the existing resources, and will enable observation and crystallographic analysis via EBSD of non-conductive samples without metallization, along with the implementation of hot micromechanical tests.
It can also be used for efficiently implementing the ECCI (Electron Channeling Contrast Imaging) technique for viewing and characterizing crystalline faults, such as dislocations.

Numerical simulation: ever greater fidelity

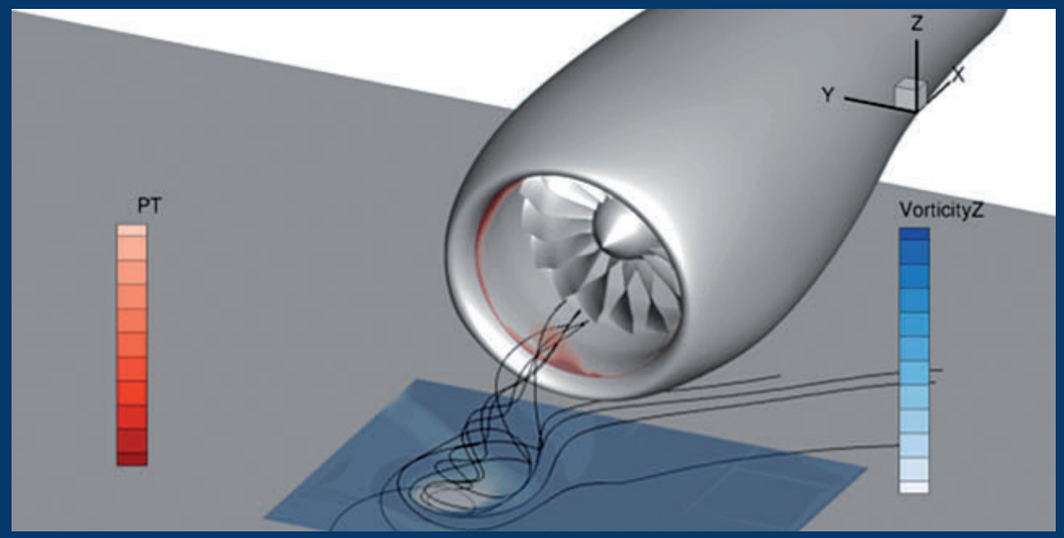
ONERA has a dual ambition for aerospace between now and 2030: being cutting-edge in terms of upstream methods, and developing a unifying software portfolio across the entire spectrum of fluid mechanics and energetics.

ORION multi-software platform

Following on from the signing of the cooperation agreement with Safran in early 2019, the ORION multi-physics numerical simulation platform will really come into its own in 2020. Its purpose is to streamline and pool the various ONERA codes and share the libraries (geometry, algebra, thermodynamics, etc.) for fluid mechanics, as well as for materials mechanics, acoustics, heat science, electromagnetism, radiation, etc.

Significant version upgrade

In the past two years, the efficiency of the elsA code for aerodynamics has been greatly improved. The demonstrated gains across a wide range of test cases are in the order of sevenfold.



News on agreements

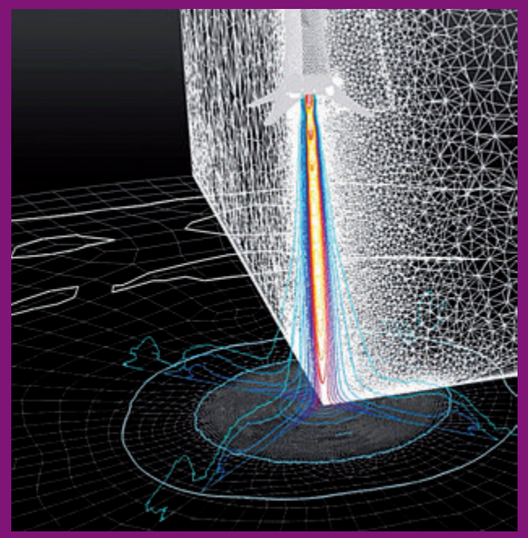
The cooperation agreement signed in 2015 between Airbus, Safran and ONERA for the development of the elsA software and its deployment in the industrial chains will reach its conclusion in April 2020. A new agreement between Airbus, the DLR and ONERA was signed in 2017 for the development of new-generation software called CODA. The work on this is ongoing.

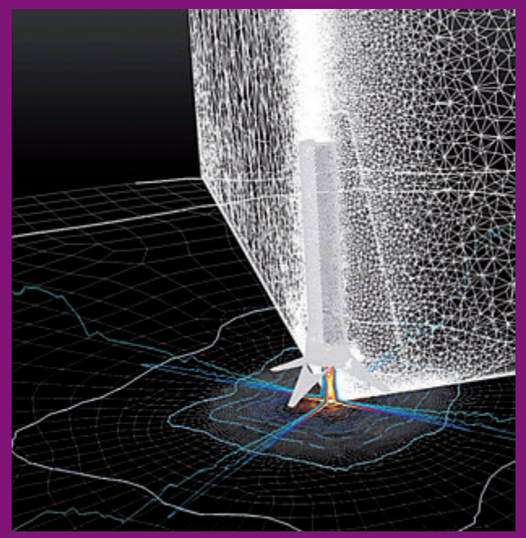
Safran chooses the software solution from ONERA for the future

By 2025, at Safran Aircraft Engines, Safran Helicopter Engines and Safran Aero Boosters, a new software solution is due to take the place of the elsA code, while benefiting from all the incredible benefits the latter had to offer. In an ever more competitive world, when it comes to the field of computational fluid mechanics, Safran invited competitive tendering from ONERA, along with NUMECA and ANSYS, in 2019, and ONERA met the challenge by delivering extremely conclusive demonstrations, thanks to the major improvements in the past two years to the elsA code, thanks to the progress made with the Cassiopée and ParaDigmA pre-and post-processing, and thanks to the total compatibility between these various software components. A software solution for the CFD of the future is due to be deployed by 2025 to replace elsA.

Future upgrades of Ariane: first landing simulation

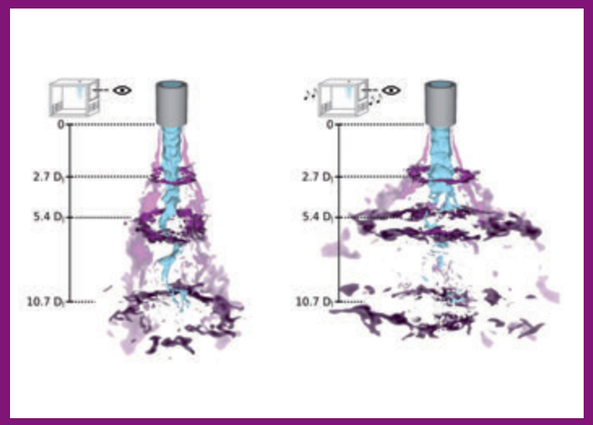
In the framework of the ArianeWorks THEMIS project, in late 2019 ONERA conducted the first URANS landing simulation of THEMIS, the low-cost and reusable rocket stage demonstrator, which paves the way for the future upgrades of Ariane. This simulation was done using, in particular, the functionality known as "conservative overlap meshing" (MCC - *Maillage Conservatif Chevauchant*), taking the hypothesis of constant deceleration for the last two to three seconds. This simulation made it possible to establish a reference database for the instantaneous heat flows and the integrals, on both the base and feet of the stage and on the ground. These data will be used to determine the dimensions of the requisite heat protections for these various items.





Rocket engine combustion: numerical simulation of noise

As part of the work conducted with the CNES on high-frequency combustion instabilities in rocket engine combustion chambers, it was demonstrated that the high acoustic levels encountered in engines could have a powerful impact on the atomization of the propellants. The instationary numerical simulation of an inert two-phase jet in the presence of acoustic excitation enabled the reproduction of the influence of the waves on the optimization process, observed experimentally by the CORIA laboratory. This computation involves a coupling between the CHARME solver, for the gaseous phase and the liquid core, and the SPIREE solver for the droplets.



Innovation through research

ONERA places its scientific progress at the disposal of any party in search of innovation. Whether for large, small, medium-size companies, or indeed startups, the ONERA DVPI (valorization and intellectual property division) offers access to its knowledge capital and test facilities for developing new products and services.

PARIS AIR SHOW 2019

ONERA's valorization activities got a high profile showing at the Paris Air Show 2019, where the emphasis was placed on partnership research with micro-enterprises and SMEs. Hence, ONERA, as coordinator of the AirCar aerospace branch, manned a stand dedicated to this topic, at which three partnership contracts were signed with micro-enterprises and SMEs. This collaborative dynamic was also plain to see on the institutional stand, which exhibited our activities with Flying Whales, and in the signing of a contract for a common lab with the company, Poly-Shape. These partnerships illustrate the valorization mission of ONERA, for exploiting its research results, and the wide variety of scenarios that can be put in place.

AC Innov

ONERA and AC Innov have joined forces to propose rhomboidal-wing UAVs designed for surveillance operations in harsh meteorological situations. To withstand these situations, which disrupt the trajectory of UAVs shaped like this, it is possible to make adjustments simultaneously to the front and rear wing curves, for increased maneuverability. ONERA has provided is expertise by means of very high fidelity computations (elsA software) to assess the aerodynamic performance of the different UAV versions. These computations have made it possible to obtain fine-scale modeling of the main physical phenomena concerning the configuration of rhomboidal wings, and therefore to assess performance precisely. In this way, it has been possible to accelerate the innovation process of the Reunion-based micro-enterprise, and two patents have already been filed.

Device-ALab

Since 2014, based on a classic customer/supplier relationship, ONERA has enhanced its instrumentation pool by purchasing high-performance thermal cameras from Device-ALab, for its field and airborne measurements. The idea naturally arose to structure a partnership in the shape of a formal framework agreement. This allows Device-ALab to benefit more easily from the expertise of ONERA, whose teams are both seasoned users who know the needs of the market and experts perfectly au fait with the available optics and sensor technologies.

Ascendance Flight Technologies

The purpose of the collaboration is to bring into service a hybrid propulsion VTOL for use as a flying taxi. The challenge consists in finding technological solutions for electric take-off and landing, to ensure less noise pollution and fewer greenhouse gas emissions in the urban environment, with the switch to cruise mode using combustion engine propulsion in order to profit from the autonomy offered by this system. ONERA has conducted aerodynamic and aero-acoustic studies of vertical propellers. Objective: validating the small acoustic footprint of the aircraft in the take-off and landing phases. Ascendance has in this way been able to benefit from ONERA's modeling capacities, in particular for the design of the propeller blades, and from a battery of specific tests.

ONERA TECHNOLOGY TRANSFER: BIRTH OF A STARTUP

ITAE Medical Research is the first startup born out of the framework of the IMPULSION mechanism put in place by ONERA in 2017, with the purpose of encouraging technology transfer and startup creation.
The microvasculoscope was unveiled in 2019, based on a technology developed in the ONERA optical laboratories. It is aimed at the medical sector.

An innovative diagnostic tool

With a real sense of entrepreneurship, Xavier Orlik, optics researcher at ONERA, and now CEO of the startup, ITAE Medical Research, wanted to use physics in the goal of developing new medical applications. With his associates, Élise Colin Koeniguer and Aurélien Plyer, of the information processing and systems department, he has created the microvasculoscope, which uses laser light and its polarimetric properties to detect skin cancers. "I knew," he says, "that cancer cells multiply more quickly, they need a high energy input, and therefore have denser vascularization, which is a peculiarity imperceptible to the naked eye."
The microvasculoscope was therefore born out of the original combination of these two techniques: interpretation of micro-movements for visualizing tumors, and use of polarimetry for deep detection of these agitations. With a very penetrative wavelength, optimized for red blood cell backscattering, the microvascularization is delineated, as being denser and more apparent around melanomas. It is even possible to see tumoral angiogenesis, i.e.: to see the tumor being nourished in real time and gradually growing.

Physicists serving physicians

Almost two fatal skin cancers in ten fail to be detected in a naked eye or dermatascope examination by a dermatologist. The microvasculoscope provides an image potentially capable of substantiating a more rapid and preciser diagnostic. The wavelength used can penetrate up to 3 millimeters in depth and in this way detect abnormal features more deeply than with the use of white light alone.

Through the IMPULSION mechanism, set up in 2017, ONERA supports startups deriving from its laboratories. The ITAE Medical Research startup was thus created at the initiative of a researcher from the ONERA optics department, for developing a new imaging instrument born of the marriage of optical technologies. The microvasculoscope will enable early detection and monitoring of skin cancers (melanomas, carcinomas, etc.), with the prospect of saving many lives.

ONERA

THE FRENCH AEROSPACE LAB

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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