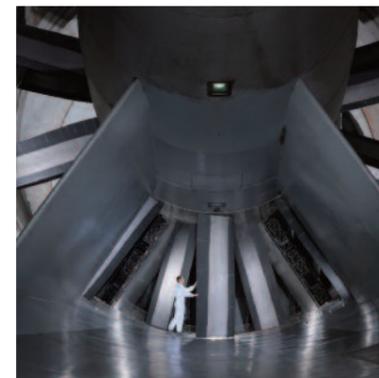


# ANNUAL REPORT 2021



## Contents

<b>05</b>	<b>ONERA at a glance</b>
<b>06</b>	<b>Introduction by the CEO</b>
<b>08</b>	<b>Highlights</b>
<b>10</b>	<b>Contribution from Thierry Burkhard</b>
<b>12</b>	<b>Contribution from Damien Cazé</b>
<b>14</b>	<b>Contribution from Guillaume Faury</b>
<b>16</b>	<b>Key figures</b>
<b>18</b>	<b>Human resources</b>
<b>21</b>	<b>Awards</b>
<b>22</b>	<b>Key developments</b>
<b>28</b>	<b>Defense</b>
<b>32</b>	<b>Aeronautics</b>
<b>36</b>	<b>Space</b>
<b>40</b>	<b>Wind Tunnels</b>
<b>44</b>	<b>Numerical simulation</b>
<b>46</b>	<b>Commercialisation</b>
<b>48</b>	<b>International</b>



The French  
Aerospace  
Lab



ONERA is a central player in aeronautical and space research and employs over 2,000 people. Operating under the authority of the French Ministry of Armed Forces, its 2022 budget amounts to €266 million, over half of which comes from study, research and testing contracts. As the government expert in aerospace technologies, ONERA strives to prepare tomorrow's defenses, address the aerospace challenges of the future, and boost the competitiveness of the aerospace industry. It boasts skills in all disciplines and technologies used in aerospace applications.

All the major civil and military aerospace programmes in France and Europe are rooted in ONERA's DNA, including Ariane, Airbus, Falcon, Rafale, missiles, helicopters, engines, radars, etc.

Its world-renowned, prize-winning research scientists mentor many doctoral students.



BRUNO SAINJON,  
CHAIRMAN AND CEO OF ONERA

## Introduction

Firstly, I would like to point out how proud I am of the conduct of ONERA employees throughout 2021, another year marked by the pandemic. Not only have we correctly integrated the best practices developed in 2020, which enabled us to survive the first waves, but we have performed even better! Like in 2020, no outbreak of Covid-19 occurred within our walls and despite the pandemic, in 2021, we recorded both scientific and economic results of the highest level that the Nation can expect from ONERA. This annual report illustrates these wonderful success stories.

It is an ongoing priority to maintain our research at the highest scientific levels. And what better than the awards and distinctions received to illustrate our results. Our research scientists have been honoured with prestigious awards, which we invite you to discover in this annual report. These awards are emblematic of our scientific excellence; they show the way for our young research professionals, in particular our doctoral students, who have also won many awards. Certain events are of particular note. I'd like first to speak of the election of ONERA to the vice-presidency of the International Forum for Aerospace Research institutes (IFAR), which means that it will assume the presidency in Autumn 2023. Truly international recognition of the importance of ONERA by its peers! Next, I would like to mention the distinction of three ONERA research scientists winning the all the medal places for the "EREA best paper award". It is also with great satisfaction that we learned of our appointment as an expert advisor to the European Commission\* in order to reinforce the competitiveness of the aerospace and defense sector, or our participation as one of the two representative of research institutes to the new governing council of Clean Aviation, the successor programme to Clean Sky. Lastly, our integration into the strategic committee of the DGAC as a representative of the French scientific community in aviation, is another reason for immense pride.

Our efforts are also much appreciated by decision-makers who honour us with their trust. As it has become a tradition for our annual report, we have included testimonials to which I am very sensitive. These are from General Thierry Burkhard, Army chief of staff, Damien Cazé, Director General of Civil Aviation and Guillaume Faury, CEO of Airbus and president of GIFAS. These are essential partners for us, as their support encourages us to constantly improve.

This support is closely linked to the trusting relationship built up with our partners and to which I am very attached. The tangible results are visible in remarkable economic performance. Firstly, orders recorded by ONERA have reached record levels that seemed unbeatable, but we recorded €151.9 M, exceeding the previous record of €139 M dating back to 2008. This excellent level was achieved through major orders from the DGA and DGAC, in which I see a mark of their trust and support. It concerns scientific departments such as wind tunnels, where the recognition of international clients is also notable. Net earnings are also very good at €9.4 M which will enable us to distribute a bonus payment of €250 to each of our employees. The amount remains modest, but this hasn't been possible for some time due to the lack of a bonus agreement. We are therefore now enjoying the benefits of the pay agreements signed in 2020 which I spoke of in our previous annual report. They have enabled us to revamp career prospects and have largely contributed to achieving new hiring records: 166 in 2020 and 167 in 2021. Our economic recovery is also enabling us to invest in new capacities, including the PRISME project to group Greater Paris activities into one site in Palaiseau. We invested €40.1 M in 2021 for all projects, which will the uplift in orders demonstrates a real positive momentum, at least in the short term. It is also and above all the employees of ONERA who guarantee this future, while the dynamic recruitment approach contributes significantly by bringing in new and not-so-new talent to join us in designing the future of defense and aerospace.

Surviving the tough times due to the Covid-19 pandemic put ONERA to the test, but we have been able to count on the support of the DGA and today we come out of it matured, backed by the trust of our partners, more than ever motivated to fly the flag of French aerospace and defense research. Please enjoy reading this annual report to see for yourself.

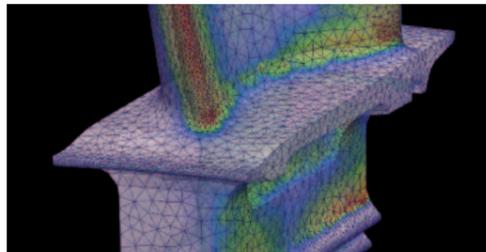
\*Directorate General of the European Commission for Defense, Industry and Space

# A rich year despite strong turbulence



## Aviation recovery plan and zero-carbon aviation

If the Government's aviation recovery plan offers ONERA the essential means to prepare for green aviation by 2035, we have already studied disruptive concepts for a number of years, as shown by the ENERGIA projects (jointly with Airbus, Safran and Dassault on alternative fuels), E2IM (wind tunnel tests and numerical simulation of an aircraft concept with different engine positions) and IMOTHEP (electrical technologies for electrical hybrid propulsion), selected by the European Commission and coordinated by ONERA.



## The ADAMANT "industrial chair": cooperation between the defense innovation agency, Safran and ONERA

Equally funded by the Ministry of armed forces via the defense innovation agency (AID) and Safran, the purpose of this chair is to develop materials more rapidly, by integrating specific decision support systems.

## The DGA and ONERA boost their cooperation in armament programmes

On 5 May 2021, Joël Barre, Chief Executive of the DGA, represented by Cécile Sellier, Technical Director of the DGA and Bruno Sainjon, Chairman and CEO of ONERA, signed a partnership agreement to provide ONERA with a high level of skills over the next ten years to the benefit of the Ministry of armed forces. The aim: face major challenges in military aviation and aerospace.



## ONERA distinguished in the EDIDP\* programme

The European Commission selected six of the eight EDIDP projects proposed by ONERA. This European programme for industrial defense development aims to promote projects related to the development of defense equipment and technologies to strengthen the European defense industry.



\* European Industrial Development Programme



## ONERA vice-president of IFAR

Bruno Sainjon was unanimously elected to the vice presidency of IFAR (International Forum for Aviation Research). This is a strong mark of recognition and esteem for all the scientific staff of ONERA, expressed by the 26 largest worldwide aviation research centres (including NASA, JAXA, TSAGI, DLR, etc.).



## PYCOFIRE: new test resources for aviation fire safety

It is intended to assess the environmental performance and fire safety behaviour of new aircraft materials. Officially launched on ONERA's Fauga-Mauzac site by Nadia Pellefigue, vice president of the Occitanie Regional authority in charge of higher education, research, Europe and international relations, Slawomir Tokarski, Director of European territorial cooperation and Bruno Sainjon, CEO of ONERA, this collaborative laboratory will be unique in the world.

## Environmental impact: Aviation & Climate convention

In 2021, the Pierre-Simon-Laplace Institute and ONERA signed a research convention on modelling and forecasting the effective impact of non-CO2 effects, in particular on contrails generated at cruise altitude. This five-year research programme is funded by the DGAC.



## ONERA, expert advisor to the European Commission

The appointment of ONERA as part of the DG DEFIS expert panel reflects recognition for its skills in multi-disciplinary research to the benefit of innovation in the space, defense and aviation sectors. Objective: bolster European competitiveness and resilience while advising the Commission.



## ONERA presents its innovations to the Aéroclub of France

On 8 and 9 July, ONERA organised an exhibition to showcase its innovations, including key deterrent technologies, the preparation of zero-carbon aviation and future satellite communications.



## Airland robotics: ONERA alongside the Army

ONERA took part in the Airland battle robotics day; the ideal opportunity to launch the VULCAIN project organised by the Army alongside the GICAT, industrial partners and the Saint-Louis Institute. The aim: by 2035-2040, imagine the role of robotics on the battlefield. ONERA developed the algorithm components for autonomous decision-making and coordination of multiple robots, delivering its expertise on embedded sensors.



## ONERA at the 2021 defense innovation forum

As the original role of ONERA is to work on the defense of the future, it naturally exhibited several projects: MUST, on improving the autonomous coordination capacities of multi-robot systems, very long range radar and advanced alert systems against ballistic missiles and space monitoring, in cooperation with Thales, an innovative thesis on improving flight quality using airflow control, and the ADAMANT chair on new materials for future aircraft jet engines.





# Thierry Burkhard

ARMY CHIEF OF STAFF

## High-intensity is back. How can ONERA help armed forces?

In this early 21st century, Russia's offensive in Ukraine underlines the limits of multi-lateralism and legal international regulatory tools. In a world governed by constant competition extending to all areas, strength has once again become a conflict resolution method and we are observing a real war at the borders of the European Union. If it takes two to make peace, one is enough to make war! We need to be ready to engage in a high-intensity conflict. But our aim is firstly to "win the war before the war", as soon as conflict arises, by discouraging adversaries to take further steps towards opposition and confrontation. This all depends on the credibility of our armed forces, where ONERA has a crucial role to play in their reinforcement.

This issue of credibility can be seen in the aviation sector. In high-intensity situations, control of the skies is contested. In Ukraine, Russia has not achieved air supremacy and at this stage only has local air superiority. The issue - to gain air superiority - is high and to meet it, French armed forces depend on capacities centred for the most part around the Rafale. In the future, the FCAS will be the focal point.

The FCAS is an ambitious project and represents a challenge in many fields where ONERA can contribute skills for us: propulsion, sensors and electronic warfare, systems of systems or the "combat cloud". High-intensity also involves the development of new capacities such as hypersonic weapons and directed energy weapons. I am counting on ONERA to support our progress in these fields.

## What you have mentioned about air superiority can undoubtedly be transposed to space, as this field is now at the heart of operations. What can ONERA contribute to the space defense strategy?

The aim of the space defense strategy is to ensure our capacity to act from, in and towards space. ONERA is already the parent and manager of the GRAVES system used to monitor space and share information with our partners. It must help us to design the successor to GRAVES to improve our monitoring capacity. In particular it provides details of how our competitors are manoeuvring - I'm referring to the multiple unfriendly approaches by the Russian satellite Luch Olymp.

## In parallel to these potential high-intensity confrontations, external operations will remain. Do you have any specific expectations?

Preparing for high intensity engagement does not herald the end of OPEX nor of our commitment on our national territory. Armed forces protect France and its population against the dangers of the world and help to protect them against the dangers of daily life. To accomplish this mission, we need

high-performance equipment that gives us the ascendancy over adversaries, whose capacities are in constant evolution themselves.

In this respect, ONERA is active in multiple fields. We can mention land and underwater robotics, remote detection of combat gases - the Syrian example shows that more than ever we need to be prepared to face this threat -, the combat against UAVs and UAV swarms, the detection of improvised explosive devices, etc. Going further, ONERA develops technology components such as sensors, data fusion and AI techniques, which will be integrated into our weapons systems and contribute to improving their performance.

In terms of autonomous lethal weapon systems, France's position is clear: we will not use fully autonomous systems. However, we need to explore the technologies to learn to defend ourselves against adversaries who make different choices. We are developing lethal weapon systems that incorporate autonomy (SALIA) to make use of the potential of AI in certain use cases. These SALIA systems must preserve the role of human command (responsibility, situational assessment, decisions to assign in a limited time-space and under strict conditions the performance of tasks founded on decision-making autonomy).

More globally, and because it is a fundamental aspect, I expect from ONERA is that it continues to contribute to defense innovation and helps to maintain our systems at the highest level of excellence.

## Historically, ONERA contributes to deterrence. What do you expect of it?

ONERA work benefits two areas. For seaborne operations, it takes part in the development cycle of ballistic missiles and the launch tests conducted by the French Navy and the DGA. In terms of airborne nuclear, its role is even more important as the ramjets used on the ASMP and which are still used on the ASMP-A were built in Palaiseau.

The scientific specialists of ONERA currently work alongside the industrial operator to develop hypersonic missile. I would like to thank them for their commitment and motivation. ONERA strives to maintain these singular skills at their best level to ensure the credibility of our deterrent, keystone of our defense strategy. ■

“What I expect from ONERA is that it continues to contribute to defense innovation and helps to maintain our systems at the highest level of excellence.”



Photo credit: D. Bascou / DGAC

“ONERA is perfectly positioned to be closely involved with the government.”

## Damien Cazé

DIRECTOR GENERAL OF CIVIL AVIATION

**The DGAC and ONERA have become much closer over recent years. How so? In your opinion, what role does research play?**

Aviation is a particularly high-tech industry and research has always been a major differentiating factor in terms of competition: an industrial operator using the best technologies has a considerable advantage over its competitors. Indeed, to make aircraft more environmentally sound and safer, innovation by research is indispensable. The position of ONERA is especially strategic and these past years has been bolstered by direct support for fundamental research topics of public interest, such as flight safety (crashes, fire resistance, certification of multi-core computers, etc.). This new type of support has met with a certain degree of success, both with industrial partners who are monitoring the work, and internally to ONERA, as the number of these “PHY agreements” continues to rise. Using its skills across all traditional scientific fields, from fundamental physics to aviation systems, while retaining its capacity to explore new technologies, ONERA is perfectly positioned to be closely involved with the government to supply the information and tools required to orient public policies. It can also be involved in all steps of the research process, including modelling, simulation and testing. This makes it a supplier of the methodology and means to validate these steps. ONERA is one of the essential keys in the France Relance recovery plan: in 2021 the DGAC supported ONERA to the order of €49 M in “purchase orders” (31 new agreements and tranches), both on internal projects and projects involving industrial partners. 2021 was therefore a record year for new contracts between ONERA and the DGAC. This closer involvement strengthens the role of ONERA as a government expert, for example on decarbonisation, encompassed by the Climate and Resilience law.

**What will be the priorities for the DGAC? What do you expect from ONERA?**

The Covid-19 crisis enabled the commitment to a complete overhaul of the aviation sector, its decarbonisation, a dynamic process supported by the DGAC. ONERA is at the heart of this revolution: its studies on production channels for sustainable aviation fuels, the properties of the emissions from these new fuels or the physical and chemical phenomena at the origin of the climate impact of aviation are eagerly awaited by all European players. The Office must communicate regularly on progress in its work, with real objective scientific data useful to the debate. In parallel to this expected creativity, ONERA maintains its internationally renowned level of scientific excellence on historical incremental innovation projects (materials, aerodynamics, airframe), also needed to improve the performance of the new generation of commercial aircraft. ONERA must listen to the needs of industry as this is a major issue today: a zero-carbon aircraft is an efficient aircraft above all.

**What vision of aviation do you have for the next twenty years? What will France’s role be?**

When faced with the crisis, worldwide but especially in France and in Europe, the aviation industry was able to re-examine itself and undertake a transformation, even a revolution, in which France has a major role to play. A historical country in terms of aviation and world leader in commercial aviation, it hosts a large part of the design and production activities for Airbus aircraft, which themselves account for over half the commercial market, along with engines from the Safran / General Electric joint venture CFM, which are fitted on over 60% of the world’s short- and medium-range fleet. The responsibility of both France and Europe in contributing to the decarbonisation of the industry is therefore considerable. The response to this issue is threefold: decarbonisation, industrial and technological excellence, and new mobilities. Decarbonisation, as the aviation sector is one of the most advanced on this key matter and has always aimed for exemplary conduct. Industrial and technological excellence as a zero-carbon aircraft must be competitive to ensure an impact on worldwide aviation emissions. New mobilities, because sustainable urban mobility programmes are becoming an increasingly important issue. The French players in the aviation sector and naturally the DGAC also have acknowledged this responsibility and through the expertise provided by ONERA, are making the efforts necessary to the reforms and growth of our industry, but also to the defense of France’s positions in Europe and in the world. In practice, the institutional support plans set up to respond to the crisis have encouraged this revolution: while conserving safety as a priority, we now need to envisage disruptive innovations to meet the requirements of improved environmental performance. At the start of the next decade, I strongly hope that we will make highly decarbonised short- and medium-range aircraft and zero-emission regional aircraft. In less than twenty years, I hope that our aviation industry will have brought zero-emission short- and medium-range aircraft into service. ■


**AIRBUS**

# Guillaume Faury

CHAIRMAN AND CHIEF EXECUTIVE OFFICER OF AIRBUS

**Together, Airbus and ONERA have written some of the best parts of the story of French aviation. What is your view of this collaboration?**

When you look at the last decades of French aviation, both Airbus and ONERA are naturally closely involved. We are proud of the success of the A320, A350, A380 or the A400M military aircraft and it is important to underline that ONERA research has contributed to it by our side. In effect, you have the multi-disciplinary expertise that is essential to resolve all the cross-functional issues of an aircraft builder such as Airbus. I'd like to touch on two examples in particular which demonstrate the extent of our collaboration. Firstly, very recently, the first flight of an A319neo with 100% sustainable fuel, where ONERA analysed the fuel compatibility with the aircraft systems. In the decarbonisation efforts currently in progress, ONERA brings its expert knowledge in combustion phenomena and its test resources. Another example dates from 2010, when Airbus Helicopters officially unveiled the new Blue Edge rotor blade, produced through its collaboration with ONERA (and the DLR). This innovation was then integrated on the H160, the latest of the Airbus range, to reduced perceived noise by 50%. At the time ONERA put its whole panel of testing tools and resources at our disposal to develop new more aerodynamic forms of blades, enabling the rotor to generate less noise and better fuel consumption performance.

**What challenges must Airbus prepare to face?**

This period is marked by complexity, uncertainty and volatility, leading all players in the sector to reinvent themselves and innovate. We are at a major turning point: today, rather than speaking of improving or rationalising existing systems, we must change paradigm and work on disruptive projects. To achieve zero-carbon, innovation is fundamental. Beyond the immediate measures we must take to decarbonise our sector, notably the use of sustainable fuels, we need to rethink the design of aircraft over the long term. For example, the use of hydrogen requires that we rethink the configuration of our aircraft. Airbus has already started working with multiple partners on the matter, as the effort must be collective.

**How can ONERA support Airbus in facing these challenges??**

To paraphrase Bruno Sainjon, I'd say that "Innovation is not possible without research." Whether in aerodynamics, materials, combustion, flight controls, physical environmental phenomena, or many others besides, our engineers and those of ONERA have proven that working together was a win-win situation. In continuity of this collaboration, I refer most especially to the field of numerical simulation. ONERA has developed software platforms (elsA for aerodynamics) which we use, and we are currently working together on the next

step. I'd also like to underline the quality of the dialogue between the research engineers of ONERA and Airbus engineers. In terms of future aircraft, ONERA brings its expertise in the management of complex scientific and technological project, notably its wind tunnels. I hope they will enable us to test our designs in as realistic conditions as possible. Today, having a solid ally is essential to face the huge challenges that our sector is facing. This is why Airbus and ONERA will always fly in the same direction.

**You are also the President of GIFAS, what role does ONERA play?**

Within GIFAS, which I have presided since July 2021, I can count on the expertise of ONERA to support CORAC efforts towards zero-carbon air transport by 2050. ONERA produced a detailed quantitative analysis of the evolution of CO2 emissions from aviation worldwide over the 2018-2050 period. This forward-looking analysis is based on simulations of various decarbonisation trajectories that are part of the CORAC roadmap and provides a tool to assess the relevance and effectiveness of the technology, operations, and energy solutions, as well as the deployment schedule. ■

“Alongside those of ONERA, our engineers have proven that working together was a win-win situation.”

# Key figures 2021



**INVESTMENT**  
**€40.1 million**  
(€36.2 million in 2020)

split between:

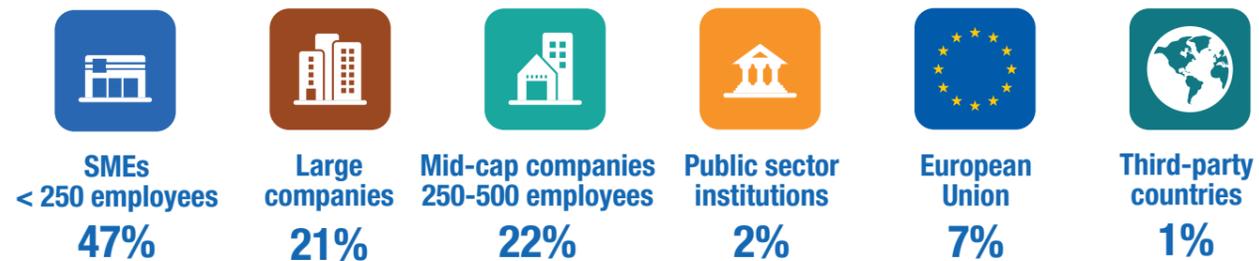
- **€31 million** on current operations;
- **€7.3 million** for the ATP programme to upgrade wind tunnels, following the grant of a loan from the European Investment Bank (EIB);
- exceptional grants: **€0.2 million** from the DGA for work to reinforce the large wind tunnel in Modane and **€1.6 million** for the PRISME project to consolidate the three Île-de-France centres.

## PROCUREMENT

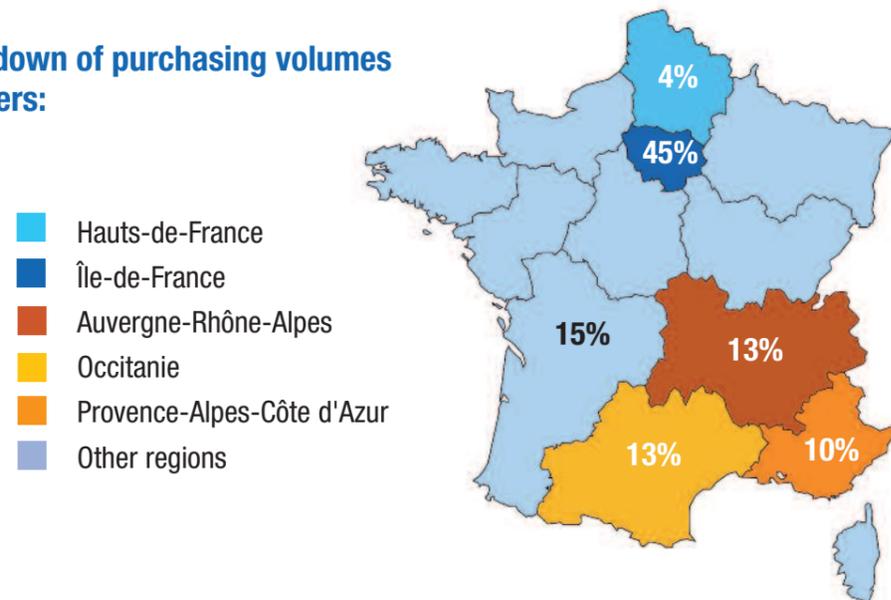
ONERA works mainly with SMEs in all its centres, across all regions.

In 2021, ONERA did business with **1,590 SMEs** (1,620 in 2020).

Breakdown of purchasing volumes by size of business, 2020:



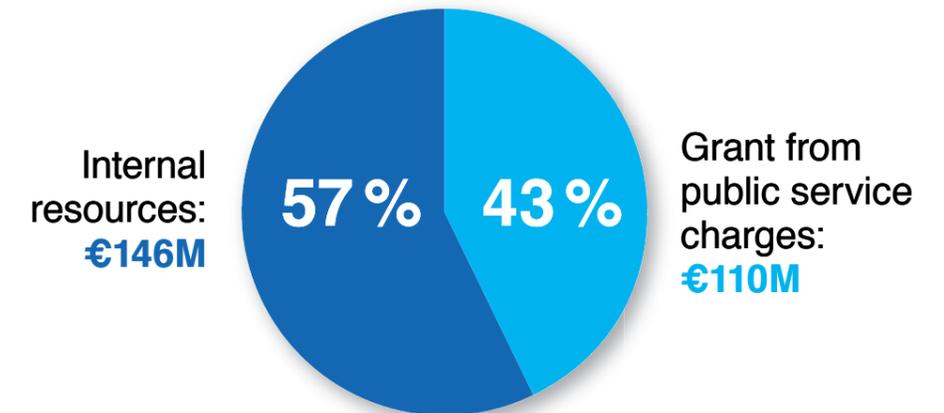
Regional breakdown of purchasing volumes with SME partners:



2020 BUDGET  
**€ 234 M**

2021 BUDGET  
**€ 256 M**

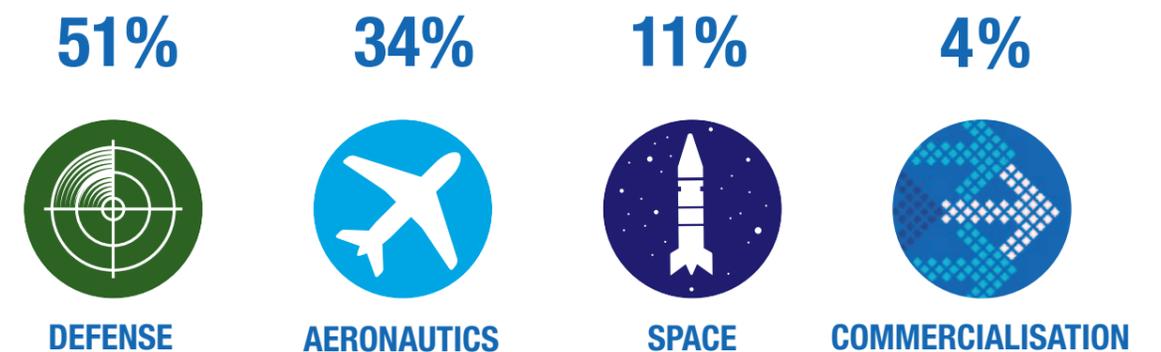
2022 BUDGET  
**€ 266 M**



Net income:  
**€9.4M**

Order book value:  
**€151.9M**

Breakdown of contractual activities by purpose:



# ONERA PEOPLE



## 2,123 employees

1,304 engineers and management  
 246 technicians • 184 employees • 1 worker  
 350 doctoral students • 23 post-doctoral researchers  
 36 work/study students • 272 interns  
 25% women  
 Gender equality index: 94/100



268 communications in conventions  
 with publications  
 334 peer-reviewed journal articles  
 1,006 technical reports



71 doctoral theses defended  
 113 scientists holding approval to direct  
 research (HDR)  
 11 approvals to direct advanced research

## WANTED

### Talented people to prepare the skills of the future

**D**espite the pandemic we have witnessed recently, ONERA has always kept its sights on the future by continuing to hire varied candidate profiles, whether for its scientific departments or its support departments. Indeed, to meet the objectives of the Government aviation recovery plan, industrial and institutional partners are all the demanding of contributions from ONERA. ONERA will not ignore the well-being of its employees nonetheless.

### A dynamic, proactive recruitment policy

To handle an extensive workload, ONERA opted for a resolutely proactive hiring policy, resulting in the recruitment of 167 people in 2021.

Space surveillance, optics, flying taxis, artificial intelligence, laser communication, flying wings, hydrogen-fuelled commercial aircraft and more... Just some of the fields addressed by ONERA and which need more talented people. At the start of the new 2021 academic year, ONERA went to meet future employees at multiple employment and hiring forums such as the Salon de l'emploi, APEC Connect, ESTACA, ISAE ENSMA and the Perspectives forum for Lyon higher education establishments.

ONERA is strongly committed to young people: support, training, management of young research engineers and technicians are integral parts of ONERA's missions and mobilise all internal stakeholders in achieving training objectives in and by research. In 2021, ONERA recruited 84 people under 25 years of age, across all contracts, including 70 doctoral students.

## 167 recruitments

including 100 engineers,  
 33 administrative employees /  
 management and 34 technicians

Hiring figures by region:

Hauts-de-France: 9

Île-de-France: 106

Auvergne-Rhône-Alpes: 18

Provence-Alpes-Côte d'Azur: 4

Occitanie: 30

114 permanent and 37 fixed-term  
 contracts

16 work/study placement students



# Well-being at work

## More flexibility in work organisation

During lockdown, many ONERA employees got a taste of working from home, and a remote working agreement was signed on 22 October 2020. It addresses both occasional remote working, relating to specific individual or collective situations and regular remote work, an individual work organisation method, which was requested by many employees. In 2021, almost 70% of employees made use of regular remote work, with several configurations available to them.



## Towards greater parity

In 2021, ONERA scored 89/100, up 5 points in relation to the good score achieved in 2018 (84/100) and stable in relation to 2019 (89/100). ONERA is fully engaged in promoting gender equality: negotiations were opened in 2021 to update its gender equality agreement.

ONERA is convinced that professional equality is a decisive factor in cohesion and performance, so we have been committed to it since 2006. The new 2021 version of the agreement goes beyond the obligations set out by the French Labour code and is integral to the promotion of diversity. In October 2021, a partnership was created with the "Elles bougent" association, which encourages young women to envisage scientific and technical careers.

Moreover, the agreement foresees the improvement of female presence in the research sector, with the opening of specific negotiations (three meetings held in 2021).

Parenthood measures have also been put in place for people having taken full-time parental leave.



## Action in favour of disabilities

Social insertion and non-discrimination against people with disabilities (whether physical or mental) are strong principles at ONERA.

The Office once again demonstrated its commitment by contributing to the national awareness campaign to support the employment of people with disabilities at the 25th annual European Week for employment of people with disabilities (SEEPH) in November 2021.

ONERA is also fully active alongside Agefiph, the association managing the fund for professional insertion of people with disabilities and committed to building a disability-friendly approach. Disability correspondents play a determining role: supported by the occupational health team in each centre and the ONERA social department, these relays are available to provide explanations, advice and support to employees in completing required formalities, whether in adapting work-stations, retention at work or career development.



# Awards on a regular basis

ONERA's research engineers are recognised every year by the national and international scientific community for their contributions, both to research activities and applied projects. In 2021, several awards were won:

Forest McFarland award from SAE International (Society of Automotive Engineers) presented to Philippe Villedieu of the multi-physics department for energy work



"This award recognises my extensive involvement in organising the SAE 2019 international conference on icing in aviation, for which I was joint chairman with my colleague Vince LoPresto. I am very happy, as it acknowledges the important role played by ONERA in the international scientific community concerning aircraft icing. Therefore I see it as a collective award for the whole ONERA team."

Technical Fellow Award from the Vertical Flight Society presented to Arnaud Le Pape from the programme technical department



"This award reflects my whole journey and my contributions to the helicopter field. From a scientific and technical standpoint, I am very proud of the numerical simulation work done on the aerodynamics of rotary wings. This award also underlines the international dimension of my career, as I have been lucky enough to work with peers in Europe and the USA, on large projects that I coordinated. I obviously owe a lot to ONERA and the colleagues I still work with for these opportunities."

URSI-France medal from the French national scientific committee on radio science presented to Jean-Philippe Parmantier from the electro-magnetism and radar department



"This medal honours the work done with my ONERA colleagues on electromagnetic topology. It is a great honour for me to see my name in the middle of the prize winners: some have been my teachers (J.-C. Bolomey and P. Degauque) and have helped forge my scientific aspirations for EMC (electromagnetic compatibility). It is the first time that this discipline has been recognised in the radio science community and I was able to express its immense richness in my presentation at the awards ceremony."

The ONERA Academy of science award for mechanical sciences in aeronautics and aerospace is presented each year. The 2021 winner of the fourth edition is Anthony Gravouil, professor in structural mechanics at INSA in Lyon.

ONERA doctoral students regularly receive awards for their presentations to forums, their publications, or more generally for their scientific results. At ONERA, an internal doctoral student award for each scientific field encourages doctoral students to undertake scientific research.

# 2021 Highlights

## Atmospheric propagation New measurement methods



ONERA has acquired two new troposphere measurement methods as a basis for analysis of the satellite propagation channel: an optical disdrometer measuring drop size distribution on the ground and a water vapour profiling radiometer. This new radiometer can characterise the W band channel in the absence of rain to make comparisons with optical channels. These new means are used in addition to the tropospheric propagation measurement resources in the Ka and Q bands recently acquired by ONERA (three new satellite beacon receiver stations). The first two stations (20 GHz and 40 GHz) were installed on the site of the French joint department for Joint Directorate of Infrastructure Networks and Information Systems (DIRIS) in Fort-de-France, and the last (20 GHz) on the Aviation navigation department (DSNA) site in French Guiana. On the Toulouse site, these atmospheric analysis instruments complete the Astra-ttB and Alphasat operational stations. A “supersite” for the Alphasat propagation campaign where different instruments are operated simultaneously is now operational at the ONERA centre in Toulouse.

## Composite materials New equipment: manufacture of complex parts with built-in sensors



ONERA recently acquired an autoclave where it could build complex forms and “smart” specimens, equipped with sensors to monitor the state of the structure. By blending the benefits of conventional vacuum bag methods with better management of vacuum and pressure levels, the autoclave method has made it possible to manufacture organic and ceramic composite parts, in “S” or “U” forms. Sensors are useful both to guarantee the manufacturing process is completed correctly and to monitor any damage to the parts once in service. They are inserted without causing the slightest structural defect. These parts were highlighted in the European SuCoHS project (Sustainable and Cost Efficient High Performance Composite Structures demanding Temperature and Fire Resistance), the aim of which is to develop composite parts that resist extreme conditions (high temperatures and fire); the DGAC PHYDEFECT project which aims to assess the relevance of SHM (Structural Health Monitoring) sensors to characterise the initial defects of industrial parts; and the CNES/ONERA joint interest programme which aims to anticipate the use of composite parts for reusable launch vehicles.

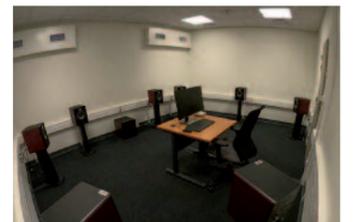
## Supersonic aircraft Unique expertise in Europe to design an aircraft with low sonic boom

As part of the H2020 RUMBLE project (Regulation and norm for low sonic boom level), where ONERA is a main partner, tests carried out in the S2MA wind tunnel at Modane-Avrieux enabled us to validate the signature of a low sonic boom supersonic aircraft. The aim: characterise pressure disturbances causing the sonic boom phenomenon felt on the ground. These tests use very small-scale mock-ups (20 cm long) to measure pressure disturbances as far from the aircraft as possible, without being hampered by interactions between the shock waves and the wind tunnel walls. A specific measurement system has been developed and the design required technical discussions with NASA. It consists of a long, slim rail fixed to the side wall of the wind tunnel, on which around fifty instationary pressure sensors are mounted, and used to measure disturbances when the mock-up is placed in the test section (using a motorised robot arm). The data are essential to foresee the sonic boom on the ground after propagation in the atmosphere.



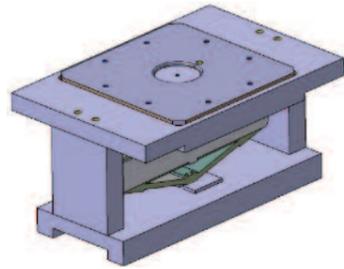
The mock-up tested is a demonstrator concept of a low-boom supersonic aircraft designed jointly with Airbus, Dassault Aviation and the DLR. The work has earned ONERA unique expertise in Europe in the design of low-boom supersonic aircraft forms and in the experimental characterisation of its “bang signature”.

## Aircraft noise Better understanding of acoustic discomfort



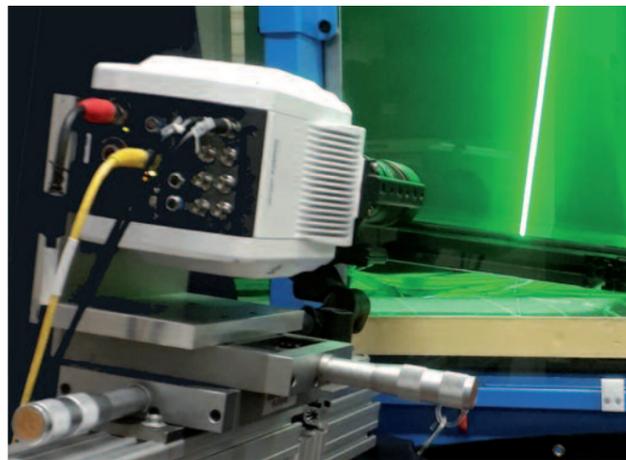
A new sound lab has been installed at ONERA to better understand the discomfort generated by aircraft noise as they pass by. It will be used in perception tests, with participants sat in the centre of the room and asked either to consider sounds directly (at various levels, frequencies, repetitions, etc.), or to perform independent tasks, to assess the extent to which the sounds played influence their capacity to complete the required task. The aim is to contribute to defining acceptability criteria (e.g. for UAVs), identify the noise components that actually cause discomfort, or work towards more appropriate certification metrics. Two studies are of benefit to this equipment; the DGAC CIGALE project which aims to link the discomfort felt when an aircraft passes to individual and societal factors totally independent of the noise, and the DGAC MOTUS project, which aims to analyse the detectability of a helicopter in an urban environment and assess the discomfort generated by different noise reduction technologies.

**Aerodynamics**  
**Fluid actuators to improve the aerodynamic performance of aircraft**



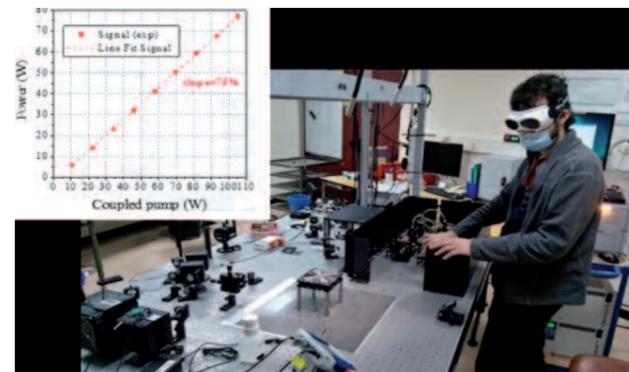
ONERA has developed a new fluid actuator which creates an ultra-efficient synthetic jet that reaches high aspiration-suction speeds to control fluid flow. This study was carried out as part of the SYNJETtC project (European Clean Sky 2 partnership) jointly with SME Cedrat Technologies. It has enabled the development of a “synthetic” jet, - piston oscillating in a cavity - which creates compression / aspiration phases. The piston movement is generated by a piezo-electric actuator, which is simpler to use on an aircraft than a conventional control, as it needs neither a compressor nor air supply from engines, nor heavy and complex piping, simply an electrical power supply. Until now, this technology had limited performance levels in terms of aspiration and blowing speeds. The new ONERA actuator reached peak speeds (Mach =1), the initial objective. Over time, this type of actuator could raise the performance of wing rudders or the tail fin and therefore reduce their surface area, delay separation, or control the noise generated by engine jets or cavities.

**Reynolds turbulent boundary layer**  
**Creation of an unrivalled experimental database**



For the Frottement research project on friction, a special database was created during a major particle image velocimetry (PIV) project conducted in the large boundary layer wind tunnel in Lille. The purpose: understand and model turbulent friction. A turbulent boundary layer several centimetres thick was generated under a favourable pressure gradient, then an unfavourable one. A large PIV field was created using ten cameras and the data input into a high-resolution database. Friction measurements using very high-resolution TR-PIV (Time Resolved PIV) were also carried out for comparison with other more conventional methods (hot film sensor, MEMS friction sensor, luminescent film, etc.) to make progress on friction measurement in finer boundary layers. This type of optical measurement is extremely rare on worldwide level. The database will now be used by ONERA to validate the models used.

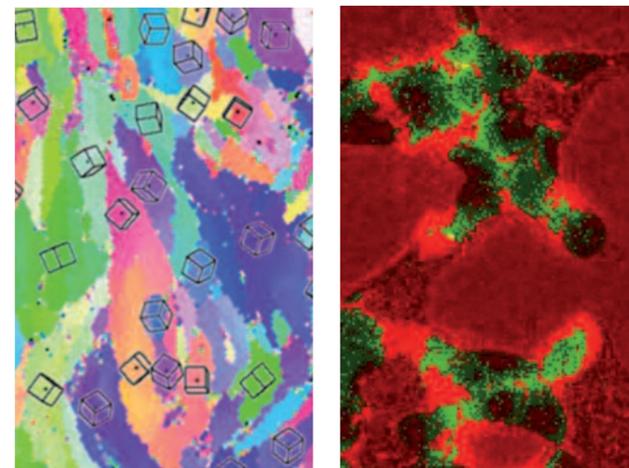
**Technologies**  
**Efficiency record for a fibre laser**



To extend the range of transportable laser systems, for example for optical telecommunications in open areas (and access to broadband) or defense systems (to develop laser weapons), “full-fibre” lasers open the possibility of delivering high-intensity beams with a robust system in harsh environments. Using numerical simulations of laser amplification, ONERA designed the architecture of a “full fibre” laser, which is very promising in terms of efficiency and maximum power. The amplifying medium is a holmium-doped silica fibre and the reflectors at each end are fibre Bragg gratings. The optical pumping energy is provided by thulium-doped fibre lasers, where the fibres themselves are pushed by laser diodes. Modelling showed the conversion efficiency between pump laser and signal laser from 50% (current state of the art) to over 70%, fact validated by the production of iXblue fibres, which also funded a doctoral thesis.

**Materials**  
**New scanning electron microscopy chemical and crystallographic analysis system**

The micro-structural characterisation of materials at scanning electron microscopy (SEM) scale is based on instrumental techniques that are constantly evolving. In this way, ONERA has just acquired a new system coupling chemical analyses by energy-dispersive X-ray spectroscopy and crystallographic analyses by electron backscatter diffraction. The performance improvements are significant compared to the standard equipment. The context of use of this new resource mainly relates to the characterisation of the chemical and crystallographic micro-structure at micron and sub-micron level for new metal, ceramic and composite materials used in aeronautical and space applications. It also addresses the analysis of relationships between crystallographic and micro-mechanical properties of these same materials.



**Combustion**  
**High-resolution visualisation in a supersonic airflow**



Tests aiming to define the characteristics of liquid fuel injection in a supersonic airflow were carried out in the LAPCAT test section of the ONERA centre in Palaiseau. High-resolution visualisations of the liquid jets enabled the collection of new details on the atomisation and deformation of the liquid structures produced, according to the temperature and speed of the supersonic airflow. The wealth of information provided in these images should help to improve the description of phenomena related to this type of injection. It should also help to validate the numerical approaches used with the CEDRE code, as this type of airflow can be met in the combustion chambers of scramjets.

**Flight tests**  
**New artificial intelligence in onboard instruments**

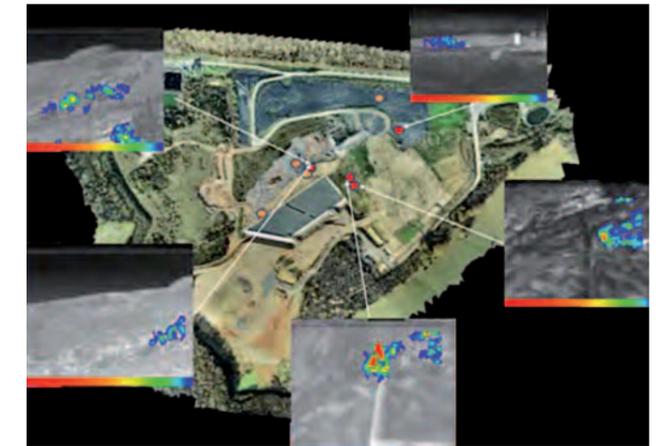
A new technology has been developed to non-intrusively acquire the flight parameters of a helicopter. Developed by ONERA, EPNER (test and acceptance pilot training school) and the Innovation Flight Test Lab of DGA Flight tests, the work has been done under a cooperation agreement between ONERA and DGA/EV (flight tests). The principle is to acquire a video sequence of the aircraft dashboard using a camera fixed to the pilot’s chest, identify the dials on the image and estimate the needle positions to transpose them into numerical values. The difficulties exist in the uncontrolled image acquisition mode (vibrations, variable illumination, reflections, pilot movements, low-cost sensor, etc.) and the diversity of the dials. We were able to develop a generic approach using adjustment and form recognition techniques. The approach was assessed on the first datasets to demonstrate the feasibility of the technology. The highly promising results obtained open the way to conducting flight tests or acceptance tests without intrusive modifications to the aircraft.



**Space telecommunications**  
**Successful propagation test using Ka band in Guiana**

ONERA and the CNES successfully conducted a Ka band propagation test in at the Kourou space centre in French Guiana, to analyse the impact of the atmosphere in equatorial regions on high-frequency (20 GHz) satellite communications. The ground segment comprised a Ka band radio frequency signal reception station, a rain meter and a GNSS receiver. Three years of data were collected with very good availability, as they were deemed over 99.5% usable. Analysis of the data produced a statistical distribution of the impact of equatorial rainfall on rain-induced attenuation of radio frequency signals in this frequency band. This is one of the two reference databases for these latitudes. It serves to improve the long-term characterisation of the propagation channel and at the same time, to improve the modelling of the behaviour of this channel over time.

**Pollution**  
**Success for ONERA measurements of low methane emissions**



A programme to characterise the fugitive methane emissions on a waste landfill site was undertaken jointly with Suez and institutional partners as part of the Trace chair (LSCE-CEA, TotalEnergies-LQA). ONERA deployed two of the instruments developed in the Naomi partnership with TotalEnergies: the Vega fibre Lidar system and the Simagaz multi-spectral imaging system, the first compact multi-spectral camera to offer quantitative visualisation of a methane gas cloud and its evolution over time. The Vega Lidar is the first capable of simultaneously measuring the methane concentration and wind speed at several metres from the zone in question from a mobile platform. The aim is to enlarge the scope of application of these instruments. The initial promising results show the interest of these systems to the environmental monitoring and inspection of polluting human activities.

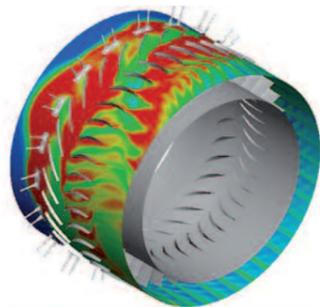
**Materials**  
**Low-speed / low-energy impact tests on composites**

ONERA conducted real-time monitoring of damaging mechanisms during a low-speed / low-energy impact test on latest-generation laminated composite plates. These tests were conducted as part of the MARCOS2 project funded by the DGAC and involving ONERA, Dassault Aviation and the ENPC. They last just a few milliseconds and present the original aspect of multiple instruments with the ultra-rapid test resource of ONERA Lille to perform the stereo-correlation of images and infra-red thermography. The tests served to define the complex damage scenario for these materials. A low-speed / low-energy impact test bench was raised upward to install the instrumentation in an optimised position. Two generations of different materials were tested, enabling us to demonstrate the benefits of these new-generation composites, particularly impressive in terms of impact.



## Aerodynamics

### Better design of aircraft engine operability limits



The European Clean Sky 2 project ACONIT (2020-2023) involving ENSAM (École Nationale Supérieure d'Arts et Métiers), ONERA, the Bundeswehr University of Munich and CTEC (Cedrat Technologies) aims to develop fluid control technology for industrial use in aircraft engine compressors, to reduce the margin on pumping. ONERA numerical simulations using the elsA software and validated by exper-

iments showed the beneficial effect of fluid actuators to delay the pumping phenomenon in the jet engine compression stages, and thereby increase the operational range of the engine. While only one cell was observed to separate in the experiment, the simulations enabled us to understand rotor stall mechanisms in the absence of fluid control. elsA is able to reproduce the single-cell rotating stall observed during these tests. Simulation of stall control also demonstrated the beneficial effect of fluid control: actuators modify the airflow inside the compressor, delaying rotating stall by pushing it to lower engine speeds. This will enable the engine to be used at higher efficiency levels, with lower fuel consumption, and over a wider operating range.

## Falcon 6X

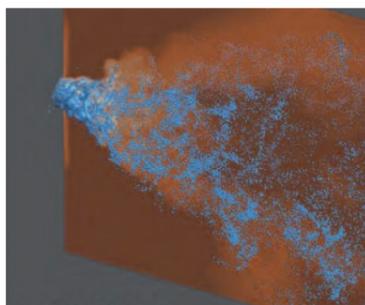
### ONERA know-how in ground vibration tests



The Dassault Aviation Falcon 6X flew its maiden flight on 10 March 2021. ONERA contributed to the ground vibration test programme using its expertise, its software upgrades (new ONERA FRF Synthesis software to adjust and correct automated response output and MMB (Modal Model Builder) to manage the database for sorting and selecting the best examples) and instruments. This is the first case of application of the partnership agreement between ONERA and Sopemea on this subject. 620 synchronous measurement channels, registering the responses of 546 accelerometers fixed to the aircraft, and 16 exciters installed covering 29 excitation sites were installed. Six structural configurations (fuelled or not, rudder settings) were subject to excitation. A database of 130 vibration modes was provided to the aircraft building, enabling them to correct the mathematical model. This is precious to verify the absence of a risk of aero-elastic destabilisation in its flight domain and to anticipate the amplitudes of vibrations and loads to which the aircraft could be exposed.

## Combustion

### First hi-fidelity numerical simulation in a ramjet injector



We conducted hi-fidelity numerical simulation of the liquid kerosene flow inside a ramjet injector. The adoption of this approach is a first with ONERA's calculation code for combustion, CEDRE, on such a complex injection nozzle. Over time, the aim is to reproduce the formation of the liquid layer at the injector outlet to help us understand its

operation and to provide input data for the deployment of simulations on chamber configurations using these injectors. The current study represents a first step towards this objective and the interest of the approach will be verified by comparison with experimental data recently acquired on the LACOM bench of the ONERA centre in Fauga-Mauzac.

## Laser

### A first for ONERA/LMD in remote detection of CO<sub>2</sub>

In January 2021, ONERA and the LMD lab for dynamic meteorology succeeded in creating a hybrid laser amplifier for the first time at 2  $\mu$ m. The laser will serve as a transmitter in a Lidar system to measure atmospheric CO<sub>2</sub>. This amplifier goes beyond 1 mJ for 200 ns pulses at a repeated frequency of 1 kHz. This performance and the robust optical architecture open the way to onboard applications that are particularly simple to deploy. It is a hybrid amplifier, where a low-power laser beam is firstly amplified in optical fibre amplifiers, which are free of alignment constraints and robust against vibrations but are limited in power. Then it passes through a crystalline amplifier capable of supplying higher power than that available in a full-fibre architecture. A simple and efficient solution to ramp up fibre laser sources.

## Optics

### First infra-red image with a Freeform optics system

Freeform optics have no axis nor centre of symmetry (principle of varifocal lenses) and enable a higher number of degrees of freedom in optical design. The benefits include improved opening, performance and compact size of imaging systems. The equipment housing this architecture developed by ONERA was designed to eliminate the adjustment of mirrors. The panchromatic objective was evaluated in distant infra-red: it forms a focal length of 20 mm and occupies a volume of 1 L, confirming the expected qualities of compactness. This project is part of a doctoral thesis co-funded by the French defense innovation agency (AID). The demonstrator was funded under the internal FREEGO project, jointly with Opus for the mechanical parts and Gaggione for the mirrors.



## Climate change

### ONERA Lidars in a methane analysis programme

ONERA took part in the MAGIC Arctic programme (Monitoring of Atmospheric composition and Greenhouse gases through multi-Instrument Campaigns) organised in Scandinavia which features many lakes, wetlands and peat bogs, making it a natural methane hotspot. ONERA and the DLR conducted an innovative experiment to measure the methane level from an ATR42 aircraft and the profile of the atmospheric wind field directly below the aircraft. The simultaneous and co-localised measurement of these two values serve to characterise the dynamic nature of the methane sources. To measure the wind field, ONERA deployed its Doppler LIVE Lidar, while the DLR team used the CHARM-F Lidar to measure the air column of CH<sub>4</sub> and CO<sub>2</sub>. Precious and original data were collected to enable progress in climate sciences. Organised by the CNES and the CNRS, the campaign brought together 17 labs and seven different countries. The aim was to measure the emissions and atmospheric dynamics of methane, a powerful greenhouse gas contributing to climate change.

## Simulation tool

### Success of EMPRISE scene model

The COMAREM/EMPRISE project team was congratulated by the DGA and by industrial operators MBDA and Thales LAS at the final demonstration of the PATMAR tool for sea patrol simulation. The demo features the EMPRISE (electromagnetic image and signal production system) scene model, used as a reference for scene simulation in the electromagnetic environment. Its development is part of the 2017 COMAREM reference framework agreement on the environment, which stipulates that ONERA ensures project management of the reference work in partnership with subcontractors for software developments and creation of virtual field databases (Scalian-DS, Oktal-SE and FWD). The final version of the PATMAR software and the first version of STIMUSAR (imaging radar application) were forwarded to MBDA and Thales in June 2021.



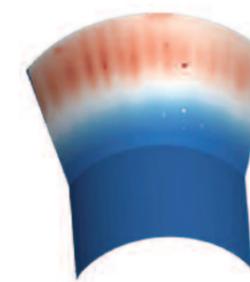
## Electric aircraft

### ONERA Power

Using its CRIPTE calculation code acknowledged as the reference tool for its capacity to model electromagnetic compatibility (EMC), ONERA validated an original statistical optimisation method coupled with a guided electrical propagation model to complete the installation of electric wiring bundles to ensure EMC safety. The Clean Sky 2 project ANALYST (EM compatibility Analysis & Statistical Techniques in aeronautics) aimed to determine the optimal separation distance between two parallel cable bundles to make them compatible with EMC requirements. The aim for SAFRAN E&P: use a calculation model to work more soundly with integrators. ONERA coordinated the project and a consortium comprising Italian firm IDS, the SME AxesSim and Aquila university (Italy). The aim was to extend the capacity of the tool to branched topologies and optimise the content of cable bundles in terms of EMC and also heat considerations. It will deliver solutions that are compatible with the dimensions of future aircraft.

## Hypersonic

### Innovative infra-red measurement programmes in the R2Ch wind tunnel



The prediction of aerothermal flows is a critical element in the design of heat protection systems for hypersonic aircraft. ONERA conducts research using the R2Ch gust wind tunnel at Meudon and has just completed the test programme for the Cylinflar research project co-funded by the CEA. The aim is to make progress on understanding of the standard form of a re-entry vehicle. The prediction of these heat fluxes is critical for the design of thermal protection

on hypersonic vehicles (the transition causes the appearance of a significant local thermal flux at the end of the interaction zone. In addition to being higher than the levels observed in turbulent cases, this exhibits strong transversal irregularities). The test programme enabled us to make instantaneous infra-red measurements with innovative post-processing, which delivered response elements on the origin of these irregularities.

## Active optical instrumentation

### First worldwide demonstration of a DIAL HDO Lidar



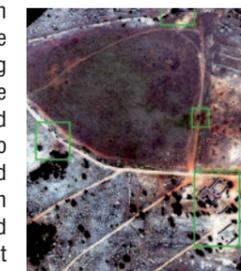
As part of the ANR WAVIL project, ONERA and its partners (LATMOS coordinator, LSCE, INSU and GSMA) developed a differential absorption Lidar (DIAL) to measure water vapour and its isotope HDO. Until now it was only possible to make this measurement with local gas sensors, therefore point by point, yet measurement using Lidar provides a concentration profile

with a range in the kilometres. The development of this Lidar based on a parametric source technology patented by ONERA and used to process water vapour and its isotope HDO successively, opens perspectives for better understanding of the water cycle. Preliminary experiment results have been produced. They confirm the predictions of the performance calculations.

## Hyperspectral imaging

### ONERA expert in scene interpretation

ONERA presented many results obtained in processing hyperspectral data, notably those obtained by the SYSIPHE airborne imaging system, to provide assistance to Defense image analysts. The image analysts showed interest in information by their capacity to more rapidly direct the search for targets and elements of interest in a very high-resolution optical image and by their capacity to respond to new operational demands. Significant progress was made in irregularity detection, anti-deception and camouflage busting, detection, characterisation and quantification of gases released by industrial sites and suitability of ground surfaces for vehicles. The HYPEx-IR contract supported by the DGA and in cooperation with the main government stakeholders in the field (BRGM, CEA, CNES), enables us to demonstrate and quantify the added value of hyperspectral data in relation to the images usually seen by the armed forces.



# Defense

The intrinsic mission of ONERA is to prepare the defense systems of the future. Authorities and partners have again shown their trust in us.

## Closer cooperation between DGA and ONERA



The DGA and ONERA boosted their cooperation to the benefit of the Ministry of armed forces. In May 2021, a partnership agreement was signed with the purpose of providing for the next ten years a high level of skills to ONERA, with a view to the major challenges ahead in terms of military aviation and space. ONERA has a public service mission to assist national institutions as an expert in the aerospace industry. The DGA is desirous of bolstering its links with ONERA while using its technical skills and its test resources that are unrivalled in France.

This agreement extends the scope of technical cooperation between the DGA and ONERA, especially on strategic military orientations, technological innovations, future technical capacities as well as all expert advisory and contracting authority support activities to the benefit of defense projects. It serves to coordinate expert advisory activities and to adopt consistent skills strategies and ensure the effectiveness of respective investments by the DGA and ONERA. It also facilitates cooperation between the DGA and ONERA centres of expertise.



“ONERA was created 75 years ago almost day for day. It has remained faithful to its original mission, and I am proud of this innovative partnership, which confirms our public service mission to the benefit of the armed forces and our European DTIB. This agreement confirms ONERA's key role as a government expert in military aerospace.”

**Bruno Sainjon,**  
Chairman and CEO of ONERA



“This partnership between the DGA and ONERA is an integral part of strengthening high-level public technical expertise of the Ministry of armed forces, complementing that of industry and serving the national and European defense system.”

**Joël Barre,**  
Chief executive of the DGA

## ONERA serving the airborne deterrent component

Under the auspices of the DGA since the 1980's with the ASMP, up to now with the preparation of the ASN4G, ONERA is central to changes in the airborne nuclear component, supporting MBDA to prepare successive generations of high-speed missiles. Its research firstly enabled the entrenchment of ramjet technologies and the bases of hypersonic propulsion, then the in-depth exploration of the combined-cycle aircraft engine. Today, ONERA completes its support with assistance to the contracting authority, which makes it the preferred partner of the DGA throughout the lifetime of the programme.

### ONERA's strengths, built up and maintained over the long term

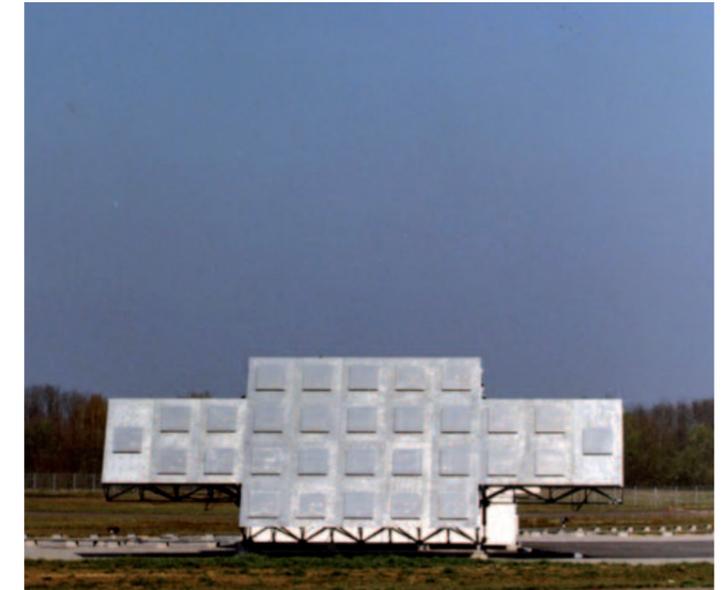
ONERA consistently carries out work very upstream to develop its expertise in physical phenomena. In the upstream design phase: design studies are generally conducted jointly with MBDA by prospective work funded by the DGA to prepare the next generation of vectors. In the programme phase: as a government expert, ONERA assists the DGA in its project management and also conducts wind tunnel tests for MBDA that are required for development.

### A methodological challenge: manage aero-propulsive balance

- Expertise in all disciplines involved (aerodynamics, propulsion, materials and structures, stealth, guidance, navigation, pilot control, future threat assessment, performance analysis, etc.).
- Propulsion test benches covering all flight conditions up to approx. Mach 7.5.
- Wind tunnels for all aerodynamic tests required (Mach 10 to 12).
- CEDRE aero-thermo-chemistry calculation code, the key-stone to assessment of aero-propulsive performance and continually enriched.

## Space, new arena for military confrontation

ONERA has key skills in all fields of space defense. With the design and production of the GRAVES system which has been operational since 2005, it offered France a strategic capacity of autonomous surveillance of low orbits. ONERA completed the system upgrade (new receiver antennae) to ensure its operation until 2030 while improving its performance. ONERA also develops technologies used to image satellites, using its expertise in adaptive optics to offer high-resolution image sequences. The investigation of future systems based on ISAR radar processing (inverse synthetic-aperture radar), is central to ONERA's work as part of the EDIDP (European Industrial Development Programme) SAURON project, funded by the European Commission.



### European defense industry: ONERA at the centre

The European Commission selected six of the eight EDIDP projects proposed by ONERA. The EDIDP European programme for industrial defense development aims to promote projects related to the development of defense equipment and technologies to strengthen the European defense industry.



## Anti-UAV defense

### Notable progress on the Single Air Picture project

The Single Air Picture (SAP) project entrusted to ONERA by the French defense innovation agency (AID) must demonstrate the feasibility of a decision-support system by data aggregation and fusion, presenting a dynamic situation of UAV and manned-aircraft traffic. For the Rugby world cup in 2023, the aim is to provide the CDAOA (French air defense and air operations command) with an initial version of the system providing a display of all UAV traffic, and for the Paris Olympic and Paralympic games in 2024, a unified vision of UAV and general aviation traffic.

An important phase was completed successfully; the validation of a message format to be applied when data are exchanged between anti-UAV defense systems.

### ONERA passive radars: improved performance in UAV detection

The experiments organised in 2021 with academic and industrial partners on a military airfield aimed to assess the first components of the SHIELD laboratory dedicated to anti-UAV defense. The initial results exceeded all expectations as the ONERA passive radar detected UAVs in real time at a distance of 4 km from the receiver antenna. Also, the ONERA acoustic sensor detected UAVs at low altitude in real time, with the detection and description reported at a distance of 1.3 km from the C2. Lastly, the data fusion module built into the C2 developed at ONERA served to track and classify the targets presented in the scene, while enabling control of the optronic sensors deployed by Exavision.

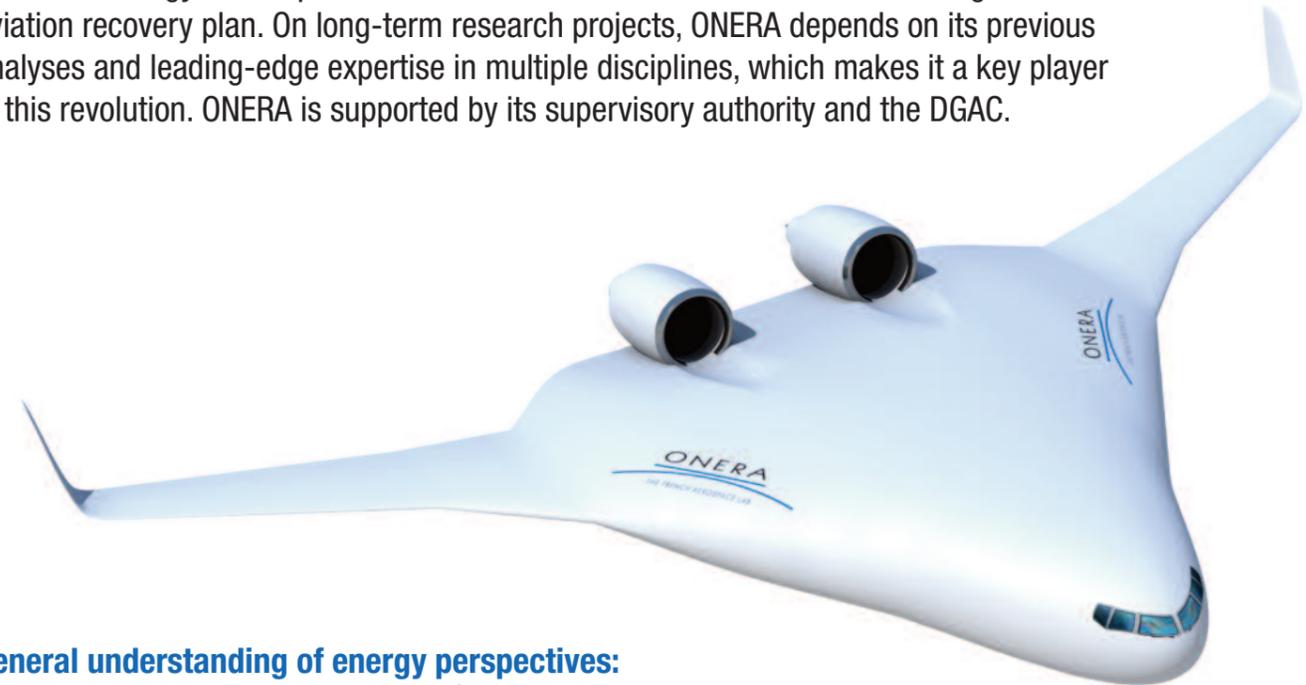


### Gas detection: efficient ONERA instruments

Two test programmes demonstrated the potential of ONERA instruments. Firstly, on French Navy anti-pollution projects, ONERA installed the SIMAGAZ instrument for sea trials to observe gases evaporating during chemical accidents. ONERA delivered visual displays of evaporation enabling the characterisation of different gases (butyl acetate, acetone, heptane). Secondly, with the support of the DGA NRBC experts and on invitation by the French Army, a programme was successfully completed in June 2021 and opened up many operational perspectives. The SPICE Lidar programme enabled us to validate the robustness of technology components developed by ONERA and Thales R&T, as well as the quality of the integration achieved by the Teem Photonics firm. Other possibilities of use for this technology are under investigation.

## Towards zero-carbon aviation

ONERA's strategy is a response to the societal issues of the sector and of the government's aviation recovery plan. On long-term research projects, ONERA depends on its previous analyses and leading-edge expertise in multiple disciplines, which makes it a key player in this revolution. ONERA is supported by its supervisory authority and the DGAC.



### General understanding of energy perspectives: ONERA on the move with the ENERGIA study

This DGAC-funded project managed by ONERA with Airbus, Safran and Dassault Aviation had several objectives in sight: build a common vision of the energy outlook for decarbonisation solutions and conduct a non-aircraft analysis (resources, environmental benefits, economic aspects, production channels and their obstacles). The channels analysed are biofuels, hydrogen,

e-fuels and methane. The conclusions of the study show the need to combine several solutions together, to make extensive efforts in developing the production of biomass and zero-carbon electricity, to maintain a critical vision of energy efficiency and operational efficiency, and to ensure technology intelligence.



### Investments to test new fuels: BECAR project

ONERA initiated a major investment project on its research test benches for future projects relating to new fuels (SAF, H2). Thanks to joint funding from the DGAC and the Occitanie regional authority / REACT-EU, the M1 and MICADO combustion benches at the Palaiseau centre (chamber sector injectors) and the Toulouse combustion benches (ignition) will be adapted and completed to be able to conduct experiments on the new fuels.



## ONERA, fundamental member of the Clean Aviation partnership

The European Commission announced an objective of zero emissions by 2050 (the Green Deal). In this context, ONERA is behind the initiative creating the partnership for Clean Aviation in 2021. The initiative depends on three pillars: Hybrid electric regional aircraft, Ultra-efficient SMR aircraft et Technologies for H2-powered aircraft.

### Towards 100% sustainable fuel?



The French Ministry of Transport, Airbus, Dassault Aviation, Safran and ONERA jointly worked on the VOLCAN project (flight with new alternative fuels), the aim of which is to enable aircraft to use pure synthetic fuels (biofuels or e-fuels) over time. They completed the first flight of a single-aisle aircraft carrying unmixed sustainable aviation fuel over the Toulouse region on 28 October 2021. An Airbus A319neo test aircraft with CFM LEAP-1A engines operated successfully with 100% sustainable fuel. ONERA was responsible for analysing the compatibility of the fuel with aircraft systems and for preparing, analysing and interpreting the results of the impact tests using 100% sustainable aircraft fuel on emissions and contrail formation.

### Hydrogen research

As part of the HYPERION project financed by the DGAC and managed by Safran with Airbus and Ariane Group (2021-2022), ONERA is responsible for summarising the concepts applicable to hydrogen injectors, the numerical evaluation of two injector designs (using its CEDRE calculation code for combustion) and for complementary experiments on its MICADO bench (adaptation of the bench as part of the BECAR project referred to above). The aim of HYPERION is to identify possible solutions for the propulsion system of an LH2 aircraft and the required technologies, and to prepare a future ground demonstration. Moreover, in partnership with Airbus, Safran and Dassault, ONERA is managing the CIRRUS H2 project also financed by the DGAC (2021-2023). The purpose of the project is to analyse the formation and properties of condensation trails generated by the combustion of hydrogen. The project also aims to explore experimental approaches for in-situ data acquisition used to validate numerical studies.



### Understand the climate impacts of aviation

In parallel and in partnership with the IPSL, ONERA has undertaken a five-year research programme (2021-2026) - Climaviation -, financed by the DGAC. The aim of the programme is to understand and quantify the climate impacts of aviation and to study strategies to minimise these impacts. ONERA provides expertise on the formation mechanisms and on modelling condensation trails, as well as a wider range of skills in the fields of observation, emissions inventories or ATM to define minimisation strategies.

## Noise



### Final conference of the ANIMA project "A new approach to aircraft noise management"

The ANIMA project (Aviation Noise Impact Management through Novel Approaches) ended in December 2021 with a conference on the project results held in Brussels. For four years, the project was coordinated by ONERA and marked the landscape. ANIMA brought together specialists in aircraft noise with human science experts, players in the air transport sector and property managers around airports, to deliver a holistic response to the issue of noise, discomfort and the related health impacts.

Beyond the traditional approach to reducing noise at source, the ANIMA consortium - associating 22 partners from 11 different countries - has produced a methodology and tools to enable airport managers and air transport authorities to implement efforts jointly with local residents, concluding in balanced consensus. Most results are freely accessible on the project noise platform <https://anima-project.eu> or via OpenAIRE.

## UAVs

At the 2021 UAV Show, ONERA chose to promote two subjects.

- **The PHYDIAS convention**, funded by the DGAC, devoted to UAV system safety design and analysis methods. Initiated in 2018 for three years, PHYDIAS enabled us to work on the risk assessment of UAV operations and systems, the impact of air measurement on low-altitude traffic, human factors and remote operation, autonomous avionics and guarantees on image processing by onboard cameras;
- **The SAR-Light project for imaging radar sensors for UAVs, aiming to evolve to a fully integrated sensor.**

ONERA's new UAV programme director Fabrice Cuzieux presented the multiple offering of the Office, evoking priorities in terms of UAV certification and certifiability.



In 2021, a UAV impact study on humans on the ground was undertaken using the ONERA-Lille catapult. Initial AUV impact tests were carried out with UAVs launched at speeds of 15, 20, and 30 m/s to analyse the influence of higher speeds on impact criticality. The aim was to improve understanding of energy dissipation phenomena within the structure during an impact. The original nature of the study lies in the numerical experimental dialogue (on the impacting UAV (ONERA work) and on the people impacted - using dummies - (work done by Gustave Eiffel university).

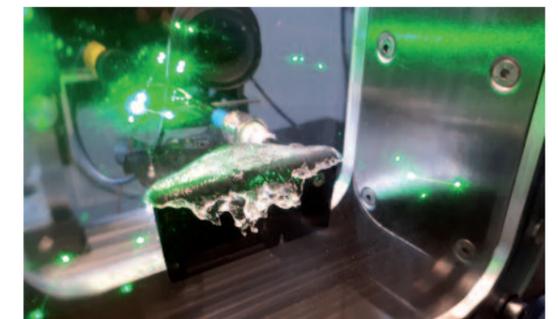
The B20 catapult, a historical experimental resource in the Lille centre for free flight tests, was adapted for the specific needs of the study. The experiment protocol must consider a wide variety of UAV topologies (multi-rotor and fixed-wing) and envisages an infinite number of initial orientation configurations on impact.

This research is undertaken as part of the DGAC GIS II study (Ground Impact Study) lasting four years.

## Icing

### First steps of the ONERA icing wind tunnel

ONERA's icing wind tunnel has provided precious results for the analysis of accretion of large droplets on aeronautical structure walls. As documentation on this issue is sparse, the new data will support modelling efforts. The research wind tunnel was brought into service in 2020 at the Toulouse centre. It features an original design with a vertical test section which enables us to analyse the accretion of droplets on a wall. Droplets are present in drizzle or sleet and represent a risk for transport aircraft. This risk must be controlled in the aircraft certification process. Future studies will focus on the accretion of droplets in negative pressure conditions, related to the H2020 ICE-GENESIS project and the description of the mechanical properties of ice as part of an internal research project. The icing wind tunnel will be used to produce ice samples in different airflow conditions.



# Space

## ONERA at the centre of European space research

Thanks to stronger skills and resources, ONERA undertakes research that directly benefits the European industrial fabric via partnership agreements with major clients, as well as SMEs and start-ups, in the course of activities within the France 2020 recovery plan. The CNES and ESA have also renewed their trust on key topics, such as the preparation of future space missions: on-orbit assembly, controlled re-entry of space debris, high-precision accelerometry for terrestrial gravity field measurements, space communications, etc. ONERA is positioned as a world leader in emerging technologies within the European space community.

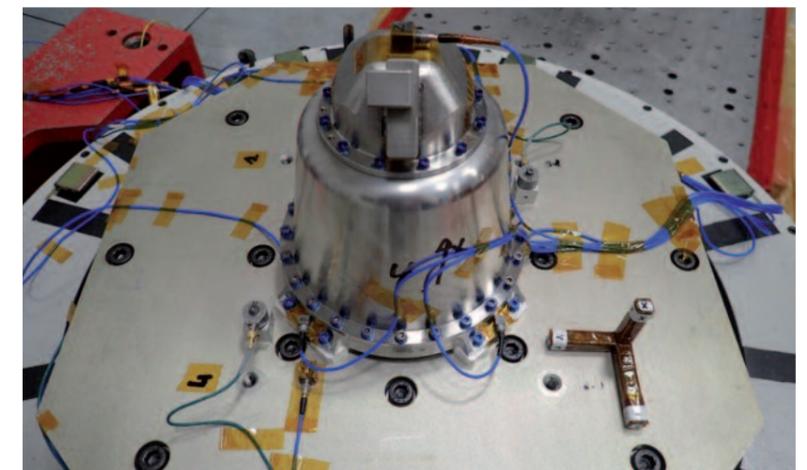
### Orbital systems: closer cooperation between CNES and ONERA

As part of the framework agreement renewed in 2020, two new common interest programmes involve the two organisations on future topics: on-orbit assembly and the controlled re-entry of space debris.

**COSOR-2 PIC**, the second phase of the COSOR PIC programme (orbital system controls), must develop robustified non-linear command techniques for varied uses: consideration of complex and difficult-to-foresee behaviours such as those induced by the sloshing of liquid propellants in satellite tanks, control of robotic sub-systems in real time, etc. The second phase of work planned to last five years should contribute to developing advanced control in the presence of disturbances for autonomous on-orbit assembly, opening the way to design new-generation space systems.

**LEONIDAS PIC** (experimental and numerical degradation study of space debris During Atmospheric entry) is devoted to analysing the aero-thermo-dynamic degradation of debris during re-entry to the atmosphere. The reduction of risks for people and property is vital, especially in light of the greater presence of debris in low orbit, related to the dynamic of NewSpace and the arrival of large constellations. This new PIC programme aims to improve understanding and modelling of material behaviours in atmospheric re-entry and to develop new materials to improve the degradability (Design for Demise) of satellite structures.

### Space mission: ESA renews its trust in ONERA



One of the future ESA space missions is MAGIC (Mass change And Geoscience International Constellation) which aims to monitor changes to the Earth's gravity field and to produce crucial information to assist in monitoring climate change. ONERA is recognised the world over for its expertise in ultra-sensitive accelerometers used on projects such as CHAMP (CNES/DLR), GRACE (NASA/DLR), GOCE (ESA), MICROSCOPE (CNES) and GRACE-FO (NASA/Germany). Once again it received order for an instrument, signing a €1.9M contract with ESA to raise the technology maturity of the MicroSTAR accelerometer. The requirement is to verify the resistance of the accelerometer and its performance in re-created actual conditions (ONERA test resource).

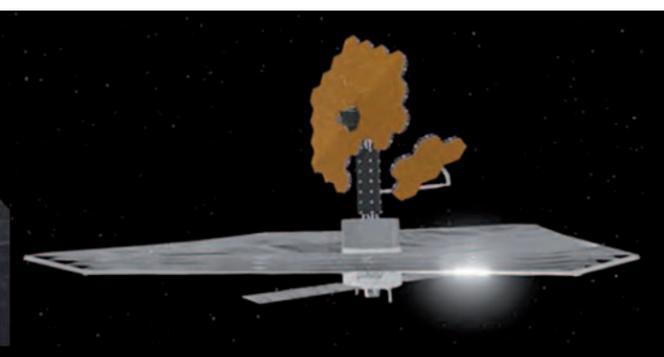
### Space telecommunications: new measurement instruments, full range

As part of the PERF 2 common interest programme signed in 2020, ONERA and the CNES regularly conduct experiments on satellite communications. In 2021, two significant events occurred: firstly the acquisition of new measurement instruments for the troposphere (disrometers) by ONERA for the description database of the Toulouse satellite propagation channel, which completes ONERA's measurement instruments for tropospheric propagation in the Ka and Q bands. The Astra-3B (2009) and Alphasat (2015) atmospheric measurement stations are now complete and operational. Furthermore, ONERA and the CNES successfully conducted a Ka band propagation test in at the Kourou space centre, to analyse the impact of the atmosphere in equatorial regions on high-frequency (20 GHz) satellite communications. Analysis of the data produced a statistical distribution of the impact of equatorial rainfall on rain-induced attenuation of radio frequency signals in this frequency band.



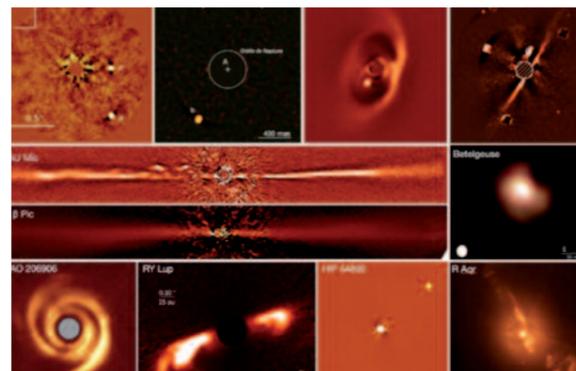
### Space operations: European PULSAR project for robotised on-orbit assembly

The H2020 PULSAR project (Prototype of an Ultra Large Structure Assembly Robot) aimed to demonstrate the capacity to autonomously assemble large structures in space. Over the 25 months of the project, the eight partners built three further demonstrators used to build a telescope in space. With its experience in Attitude and Orbit Control Systems (AOCS), ONERA was one of the main contributors. It notably developed onboard attitude controllers to stabilise the satellite during deployment, assembly, and observation operations. The PULSAR demonstrators showed that the components required for autonomous assembly reached a sufficient level of maturity to be included in the development process for new missions.



### Astronomy: SPHERE, 20 years of challenges and success stories with ONERA

ONERA is a member of the SPHERE consortium, which has celebrated its 100th scientific publication. ONERA was responsible for building the SAXO extreme adaptive optics system which serves to correct atmospheric disturbances and instrument vibrations with peerless accuracy. The SPHERE exoplanet imaging system (Spectro-Polarimetric High-Contrast Exo-planet Research), installed in the Very Large Telescope of the European Southern Observatory (ESO) is a genuine scientific, technological and human adventure that started around twenty years ago. These hundred scientific publications represent an important step for the consortium, made possible by the investment of its members who have contributed to the design, construction and scientific deployment phases over the past five years. Some remarkable results: first image of a multi-planet system around a sun-type star, images of protoplanetary disks produced by young, newly formed stars, intriguing unique structures identified around a near star, etc.

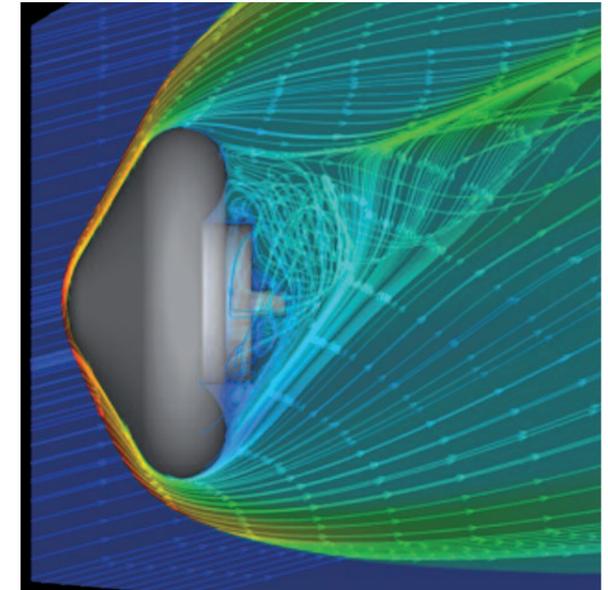


### Space solar panels: launch of EMAGS4 project

The EMAGS4 project on the design and modelling of arcs on solar generators is the fourth phase of ESA projects started in 2000. In contrast to Opus 3 co-funded by the DLR and the CNES, the EMAGS4 project is fully financed by France (CNES) and bring TAS and ADS to work with ONERA. The aim is to experimentally study and model the propagation of discharges on flexible solar panels and to deduce the definition of electrostatic risk qualification methods suited to new solar panel designs.

### Atmospheric re-entry: ONERA method for inflatable heat shield

The European EFESTO project (European Flexible hEat Shields: advanced TPS design and tests for future in-Orbit demonstration) aims to develop an inflatable heat shield compacted inside the vehicle during flight and deployed on the mission return journey. Using its CEDRE code which simulates a gaseous environment at several thousand degrees around a complex geometry (up to nine metres diameter for the Mars mission), ONERA develops new calculation and analysis resources enabling suitable re-entry for large-dimension vehicles. For the design, ONERA also proposed an innovative simulation methodology, based on the explicit calculation capacities of the Altair RADIOSS software, and which is inspired by airbag designs in the automotive sector. Two test programmes served to validate the technologies and thermal models. This project was subsidised by the European Union as part of the H2020 programme. Partners on the project managed by DEIMOS Space include CIRA, Aviospace, the DLR and Turin University.



### Access to space

#### Propulsion: ONERA expertise serving Ariane 6 and future European reusable launch vehicles

The solid fuel engine P120C designed by Avio and the Ariane Group will be used as a top-up propulsion system for Ariane 6 and the first stage of the future Vega C launch vehicle. Via the CNES, ESA entrusted to ONERA an independent verification activity in supplement to the industrial work, on the prediction of instabilities potentially appearing during the combustion of the propergol fuel of the P120C. ONERA's expertise on the matter is renowned (hydrodynamic or thermo-acoustic instabilities). A new aluminium particle combustion model was developed and tested at ONERA. In addition, ONERA numerically simulated these



thermal instabilities (at different stages of the engine internal ballistic process). The amplitudes of instability calculated are very close to the measurements: the ONERA calculation procedure was therefore validated on an industrial engine. On the theme of space propulsion still, as part of the THEMIS INITIAL PHASE project, ONERA is managing the definition, implementation and validation of a Structural Health Monitoring (SHM) system dedicated to monitoring the state of health of a reusable launch vehicle fuel tank. The first phase of the project resulted in the selection of instrumentation comprising an optical fibre Bragg grating (FBG) and their characterisation at cryogenic temperature.

In 2021, ONERA deployed this instrumentation built into a demonstrator. The resistance and responses of sensors were assessed during liquid nitrogen filling tests and pressurisation tests conducted on the Ariane Group site. Analysis of temperature data and mechanical deformations recorded during the tests enabled us to validate the ice-resistance properties of the FBG and to develop a thermal-mechanical model of the tank behaviour, which is the first step in creating a digital twin.

### Space propulsion: new simulation chamber at ONERA

ONERA has installed ERIS, a space simulation test bench. This vacuum vessel comprises a main chamber measuring 2.3 m x 5 m, coupled to an auxiliary chamber measuring 1.25 m x 1.2 m via a full aperture gate valve, and is dedicated to experimenting with electrical propulsion for satellites.

Beyond the larger size of the test equipment, ERIS sets itself apart with the xenon pumping speed, which is increased by a factor of 20. This enables us to test electric thrusters in very good vacuum conditions. The performance levels are reached using an original architecture that maintains cryogenic temperatures on xenon condensation panels using closed-circuit coolants, which ensures recurrent and manageable maintenance costs. This vessel offers high-performance test conditions and will be ideal for the ECRA (Electron Cyclotron Resonance Accelerator) propulsion technology developed by ONERA. As was the previous vessel, this new resource will be available to start-ups in the space sector as part of ONERA's ongoing support efforts to their benefit.



# ONERA Large Wind Tunnels: very significant recovery in orders

**D**espite the Covid pandemic, 2021 saw a very clear upturn in wind tunnel activities, especially for high-speed testing, with €17.7 million in orders taken from national, international, industrial clients and government bodies. The international recognition of the quality of our services is growing. Also note a return of international clients with new defense projects in Modane and the arrival of new entrants in civil aviation at CEPR19.



NGF - Dassault Aviation / Eridia Studio / V. Almansa

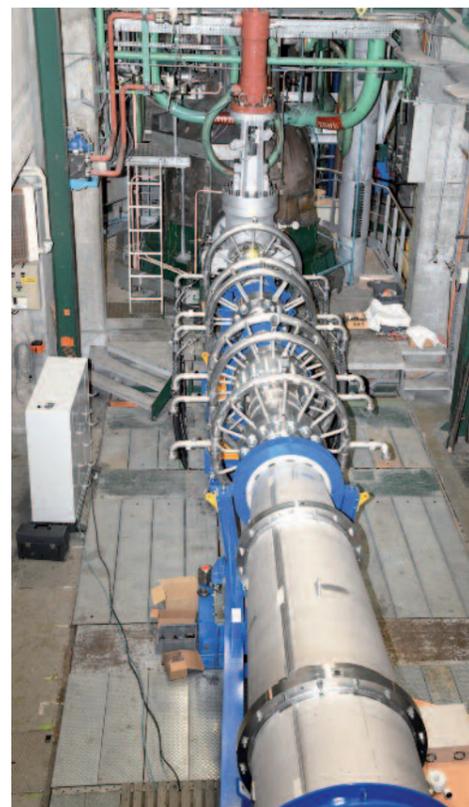
## First FCAS tests at Modane

In late 2021, the Modane wind tunnels hosted the first test programmes on the forms of the new generation fighter (NGF) as part of the FCAS project (future combat air system) in the transonic and supersonic test sections of the S2MA wind tunnel, with Dassault Aviation in charge. Full mock-up and air intake configurations were tested in the presence of Airbus German and Spanish partners. The quality of the measurements, notably of high incidence, is one of the renowned qualities of ONERA wind tunnels.



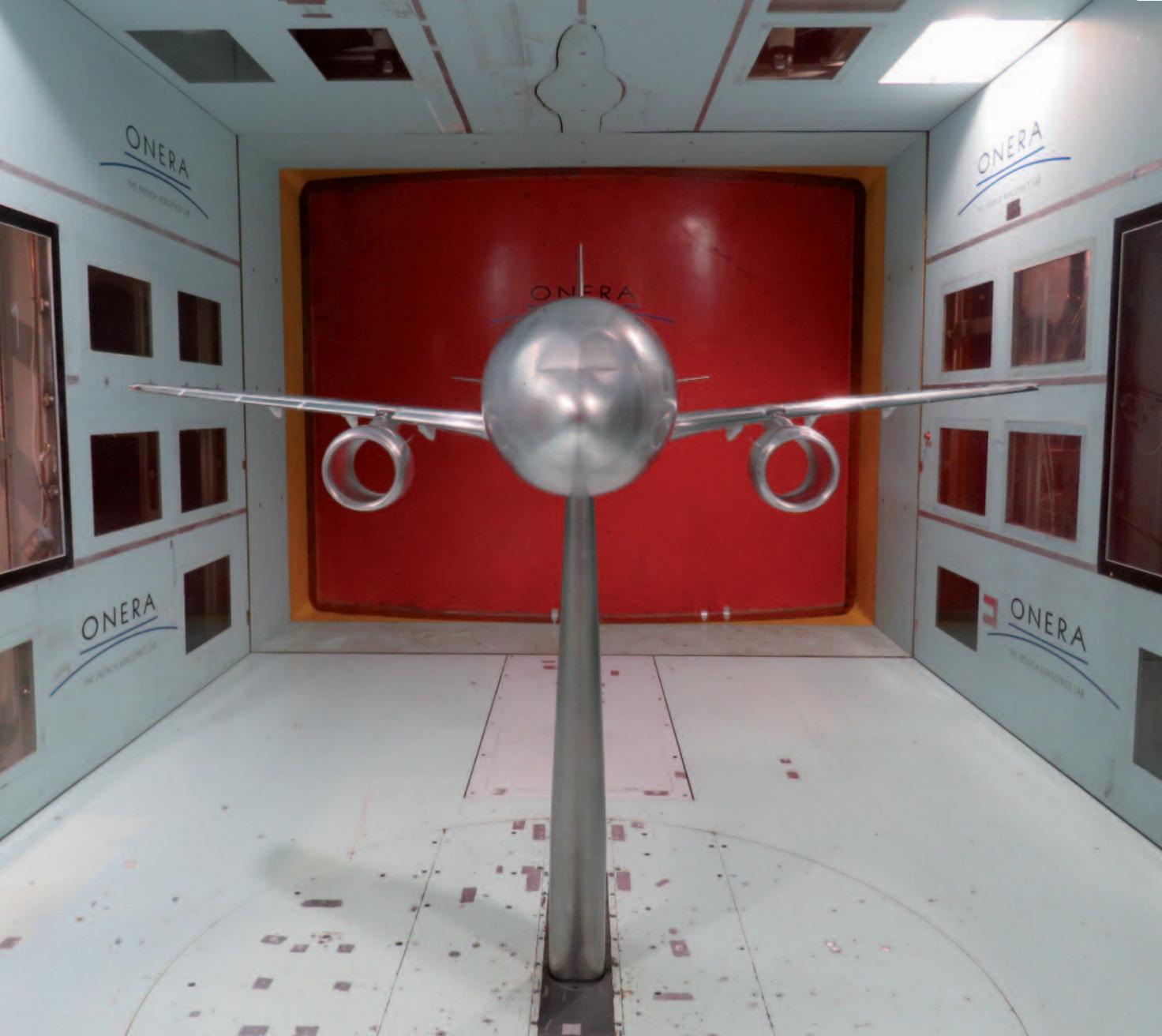
## Upgrade of S4A wind tunnel for deterrence

To meet the needs of deterrence tests, new nozzles were developed for the S4A to reach the higher Mach numbers. This is a complex field where regulations have evolved (pressure equipment). After significant work (replacement of aluminium balls in heater, mock-up injection table, etc.), the tests were successfully completed in late 2021. Since then, work has focused on the development of new M10/M12 nozzles.



## Combined tests at S1MA and F1 for business aviation

One of the main benefits of ONERA's Large wind tunnels is to propose complementary resources to complete tests across the whole spectrum of speeds, sometimes using the same mock-up. In 2021, Dassault Aviation completed the first tests to determine the performance of its latest business aviation aircraft at S1MA, then low-speed aerodynamic tests including acoustic measurements in the Fauga-Mauzac F1 wind tunnel.



### A range of reference mock-ups

The manufacture of the high-lift reference mock-up for the F1 wind tunnel was completed in early 2022. The “LRM-HL” mock-up (Large Reference model-High Lift) was fully designed and built by the Lille mock-up workshop using data provided by Boeing and NASA. Some mock-up forms were defined by ONERA and will be proposed to the rest of the CRM-HL international community (Common Research Model - HL). This achievement enables ONERA to have the first reference mock-up in high-lift version, which will be presented to Boeing and NASA during the Fauga tests in 2022. It completes the fleet of mock-ups built internally for ONERA’s three largest wind tunnels (S1MA, S2MA and F1): two plain mock-ups LRM-S1 and LRM-S2 intended for high-speed wind tunnels and an LRM-F1 plain mock-up for tests in the high-Reynolds number wind tunnel.

The LRM-S1 mock-up is also equipped with one of the latest developments of the mock-up workshop as part of the ATP programme: the motorisation of rudders with precision and stability that raise productivity in testing. With such mock-ups, not only the results of the large wind tunnel tests can be compared to other wind tunnels around the world to promote the quality of our services, but ONERA will also have reference mock-ups to calibrate wind tunnels or develop new test techniques.



### ONERA wind tunnels in European landscape

As part of Clean Sky 2, STUNTT (Surface imperfection and UNsteady motion impact on Transition onset) tests associated with the project on the Airframe Integrated Technology Demonstrator platform were conducted at S2MA in November 2021. These tests brought together different scientific departments of ONERA and the wind tunnel department. Their aim was to better understand the influence of surface imperfections on the boundary layer transition, both under static conditions and under forced pitch oscillations.

These tests will raise the maturity of metrology developments at the centre of tests on very long laminar airfoils foreseen in future Clean Aviation tests. Moreover, the extensive database of collected information will serve to validate current numerical developments in aeroelasticity.

### Continuation of ATP wind tunnel upgrade programme

The ATP programme intends to ensure the sustainability and modernisation of wind tunnels by preparing them for future programmes. In late 2021, almost 50% of the €47 million loan from the European Investment Bank had been committed. The modernisation of metrology tools made significant progress in 2021 as it is a key topic to ensure the quality of testing and a factor that differentiates us from other wind tunnels around the world. The improvement in optical metrology tools enables us to raise the quality and quantity of measurements, and also to characterise the airflows more accurately. Work on measuring the speed field by Particle Image Velocimetry (PIV) at S1MA reached a new level thanks to the completion of seeding tests. This enables us to envisage the deployment of this technique used in certain wind tunnels in a facility the size of S1MA by 2024.

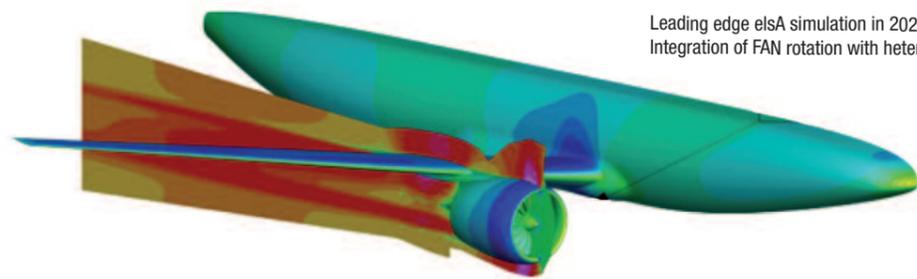
In terms of metrology of instationary effects, the development of pressure-sensitive paints has made considerable progress: application techniques have been developed and a lab working on the development and description of the paints is now operational in Modane. Following conclusive client tests, the use of this technique is planned on industrial scale for future contracts, especially on the FCAS programme. The uPSP is developed in partnership with Swiss laboratory CSEM and presents a major interest in determining shake limits and in enriching calculation codes. The use of these instationary pressure measurement techniques in wind tunnels will also be very helpful to increase the geometric density of instationary information, but also to reduce the test design times.

# Prepare future simulation to manage physical complexity

The national community depends on ONERA as it manages the development and constant update of large numerical platforms. This expertise extends across all domains useful to aerospace, enabling us to simulate complex issues and perform calculations that represent reality ever more closely.

## Aerodynamics: elsA optimised, SoNICS promising

SoNICS is the new-generation aerodynamic simulation software that will replace the elsA software by 2025. In addition to the functional scope of elsA (code validated on a very wide range of applications including aircraft, helicopters, turbojets, missiles, propellers, etc.), it will benefit from extended features such as the integration of multi-type airflows and the dynamic adaptation of meshing. Its revolutionary architecture offers enhanced capacities such as efficient alignment on heterogeneous computers, automated differentiation to optimise forms or stability analysis, and much easier cross-accounting between methods and models. The first 3-dimensional simulations conducted with SoNICS demonstrated a significant gain in calculation time, ten times better than elsA on CPU processors, and showed its capacity to draw benefit from the GPU technology. This progress was enabled with the financial support of the DGAC.

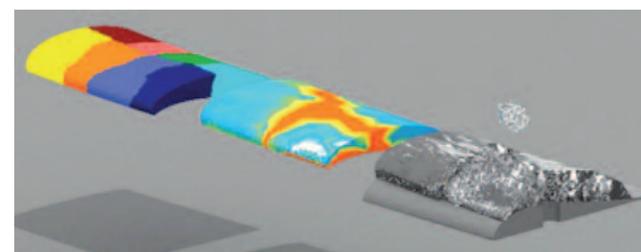


Leading edge elsA simulation in 2021: NOVA configuration with ASPIRE engine  
Integration of FAN rotation with heterogeneous speed values

## Materials

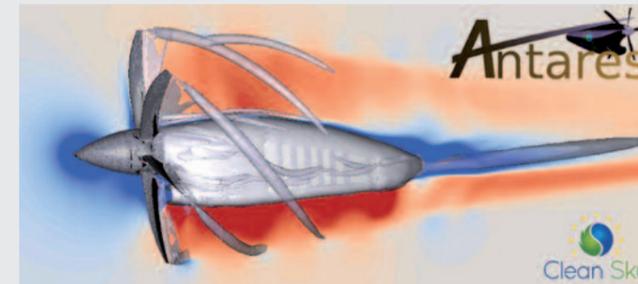
Numerical simulation of materials is particularly sophisticated when for example it involves the simulation of fractures: ONERA is an expert in this “boundary” science. In 2021, using the Z-set code it developed with Ecole des Mines, ONERA made calculations used to develop technology tests. For example, simulation by phase field and modelling cohesive zones of the separation of a block of accumulated ice enabled us to prepare a test in the icing wind tunnel of the ONERA Toulouse centre. Once the block of ice was formed on a profile, it involved the injection of pressurised air to cause the separation and study its properties in light of the freezing air conditions and the properties of the bearing surface.

This work was carried out as part of the TRICEPS PRF. ONERA is now building the next-generation finite-element successor for materials and structures: this is the ARIZE project started in 2021 with the support of the DGAC to develop the new A-set code.

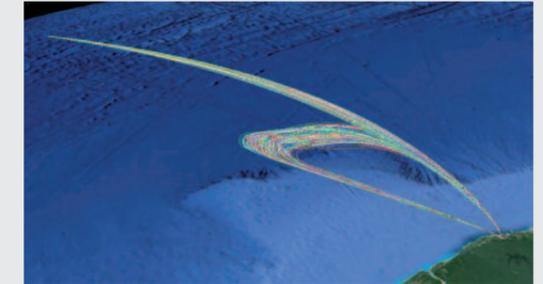


## SATOR: when young engineers propose original calculations

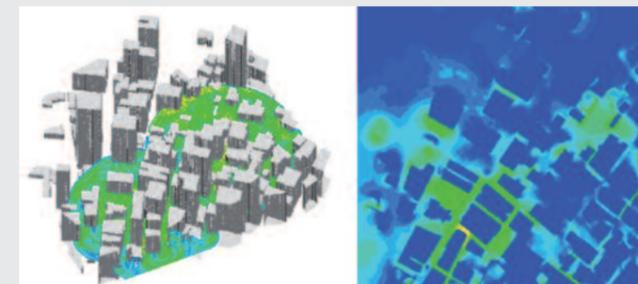
Preparing the future also requires us to implement “borderline” calculations which push back the boundaries of numerical simulation even further. On the occasion of upgrading its SATOR supercomputer, ONERA offered its young research engineers a vast amount of calculation hours for two months in Autumn 2021. This “major challenges for young researchers” event enabled us to offer 21 million calculation hours to 14 candidate applications. Also, an important challenge on the new TOPAZE machine owned by the CCRT and installed at the CEA took place over the same period, with an allocation of 40 million hours.



elsA simulation of the aerodynamics of the Tech TP turboprop engine demonstrator.  
Rocco Moretti – Aerodynamics, aeroelasticity, acoustics department



Study on the propagation of uncertainties on the performance of a reusable launch vehicle design. Mathieu Balesdent and Loïc Brevault – Information processing and systems department



Modelling an urban scene of electromagnetic fields radiated by 4G/5G antennae.  
Thibault Volpert, Ronan Cranny – Electromagnetism and radar department



FIRMAMENT (Fiber-regime atomization simulation for interfacial area quantification), calculation done at the CCRT. Jean-Christophe Hoarau, Luc-Henry Dorey, Jean-Luc Estivalezes – Multi-physics for energy department



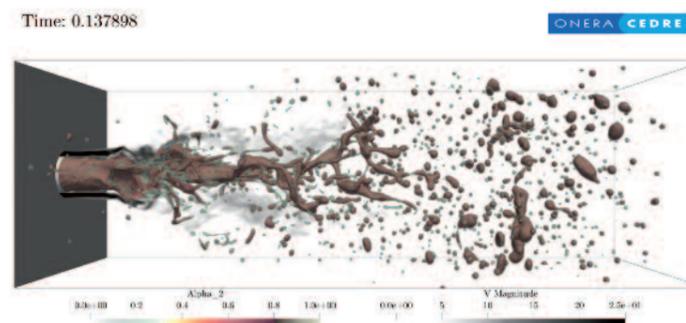
DNS simulation of results of a laminar-turbulent transition test on a symmetrical-axis compression ramp in hypersonic regime. Mathieu Lugin – Aerodynamics, aeroelasticity, acoustics department

## CODA, example of sustainable European cooperation

Developed in the course of a five-year cooperation agreement (2018-2022) between ONERA, DLR and Airbus, this new-generation aerodynamics code simulates fundamental or industrial configurations with specific applications for aircraft and helicopters. It enables simulations of great precision using the high order. Today, CODA is used at Airbus in the design calculation code for high-speed applications. Airbus has invested greatly in developing and validating the code. With its German counterpart, ONERA is also consolidating the partnership to develop methods and models and to jointly prepare several European projects (such as the EUROHPC NextSim project starting in 2021). These notable advances generate fruitful cooperation and are leading the CODA executive committee to prepare an extension to the initial agreement.

## CEDRE: continuously enriched software

CEDRE (calculation of two-phase reactive flow for energy) is the numerical simulation platform for energy at ONERA. It is used by major industrial operators in the sector, processes complex airflows encountered in the field of energy and propulsion, taking into account a wide variety of physical-chemical phenomena and the associated bonding mechanisms. For example, in the 2021 young researchers Challenge, using the CEDRE platform numerical methods were specifically designed to obtain robust - despite the conditions - and precise simulations to reproduce all the complex aspects of the airflow and the physical phenomena creating it. In this way, we obtained a simulation of two-phase reactive flows in the most extreme conditions such as those in rocket engine chambers.



## Innovation projects and support for start-ups: ONERA improves its track record

The 2017 launch of the internal innovation project accelerator (Impulsion) and the 2020 launch of the BLAST programme to support and accelerate Deep tech start-ups in the defense-aerospace sector, have enabled ONERA to slowly constitute a track record of successful technology transfers to start-ups it has helped to develop.

This is the case of three start-ups (VitaDX in 2016, Morphée+ in 2018 and Djeebox in 2019) which benefited from technology transfers from ONERA, and which have matured with the support of the SATT Paris-Saclay research foundation. Since 2019, four start-ups have seen the day from ONERA: ITAE Medical Research (2019), MOR Digital Systems (2020), NUMWORKS Technologies (2020) and ANYFIELDS (2021).

At ONERA, around fifteen innovation projects are in the maturing phase (including two with SATT Paris-Saclay).

Lastly, as part of BLAST (first year 2021-2022) ONERA supports each of the thirteen start-ups and proposed four innovation projects which are also following the programme. The involvement of 20 ONERA researchers opens up new perspectives on the role that ONERA can play for these emerging players in highly buoyant sectors (micro-launch vehicles, aerial mobility, electric aircraft, multi-spectral sensors, "flying donkey" UAVs). New possibilities for partnerships and technology transfer are emerging with these players.

This ramping up of innovation projects and start-up support programmes is mainly done using internal funds (with partial support from BPI France for BLAST and from SATT Paris-Saclay for the maturation of certain projects).

### ONERA at the centre of the BLAST programme



After the first call for BLAST candidate applications (June 2021), 12 start-ups and 8 researchers were selected to establish the first group of deep tech players who will be supported and accelerated under this programme. ONERA is pleased that four researchers from its labs are amongst those selected:

- **Aviation: Armin Taghizad** from the Information processing and systems department (development of a cargo UAV concept to transport heavy loads on long extensions)
- **Space: Nicolas Pelletier** from the Multi-physics for energy department (development of a reliable measurement system for very high thermal flows)
- **Defense: Guillaume Druart** from the Optics department (development of multi-spectral cameras to detect gas emissions for defense and security needs)
- **Enabling Technologies: Guillaume Vaudaux Ruth** (doctoral student) and **Adrien Chan Hon Tong** from the Information processing and systems department (development of algorithms to track the training of professional athletes using a video stream))

### Ideal support

ONERA has appointed thirteen scientific experts to drive start-ups towards success. A mentor is available to each of them to provide support on the scientific and technical aspects of their project.

These very varied and sophisticated deep tech subjects require precise knowledge that ONERA can bring to the start-ups. The scientific and methodological profile of the researchers selected is perfectly suited to the needs of the young companies.

Start-ups and projects supported by ONERA scientists:

- **Aviathor:** electric aviation
- **Beyond Aero:** hydrogen-fuelled business aircraft
- **Caps:** transport UAVs using artificial intelligence
- **Delfox:** AI decision-support platform for autonomous solutions
- **Hybrid Propulsion for Space:** hybrid micro-launcher
- **ICE Innovative Circular Engineering:** multi-performance green tech material
- **Miratlas:** atmospheric characterisation
- **Sea Proven:** constellation of autonomous surface vessels
- **StatInf:** statistical analyses for onboard systems
- **Venture Orbital System:** space launch vehicle for small satellites
- **Xinetis:** solar sail to remove end-of-life satellites from orbit
- **Rise:** optimisation software for regional aviation

Nicolas Guérineau, director of valorization at ONERA says:



“We are pleased to be able to contribute to this list of ONERA projects that have been selected and of which we are very proud.

We also intend to create a BLAST dynamic within ONERA based on the community of twenty or so researchers involved in the BLAST programme as project sponsors or scientific mentors for start-ups amongst the group. These experts will become ambassadors for the programme and the entrepreneurial approach within our Office.”

#### IP indicators for 2021:

15 new patent applications

18 new invention disclosures

20 new software solutions registered

81 new licensing agreements in place

6 new Soleau envelopes

# Valorization

# INTERNATIONAL

**O**NERA offers multiple disciplines which offer a transversal approach to scientific and technical challenges. Its contribution to the advancement of many work groups at European and International scale also offers it a political and strategic dimension. This specific aspect makes it a renowned, esteemed and essential player.

## Air traffic management: ONERA in SESAR 3

ONERA has participated in the SESAR R&D programme to revamp the air traffic management system since it was created (2008) and is a member of the new SESAR 3 partnership on the single European airspace, introduced in Brussels in 2021. Bringing together the EU, Eurocontrol, and over 50 different organisations (UAVs included), SESAR 3 will invest over €1.6 billion by 2030 to speed up the delivery of a resilient and sustainable Digital European Sky. ONERA contributes its multi-discipline expertise: trajectory planning, separation of 4D trajectories, organisation of airspace, operational concepts and modelling, human factors, safety, the environment, etc.



## ONERA assumes the presidency of the first worldwide aeronautics research forum IFAR

In October 2021, ONERA CEO Bruno Sainjon was unanimously appointed to the vice-presidency of IFAR (International Forum for Aviation Research) which groups together the 26 main aviation research centres around the world. This is a strong mark of recognition and esteem for all the scientific staff of ONERA, expressed by the largest worldwide aviation research centres. And even while worldwide aviation is experiencing a crisis phase where the exit lies in research, in particular its determinant role in decarbonising aviation.



## Introduction of the Horizon Europe programme: ONERA in the spotlight



For the launch of the Horizon Europe programme in May 2021 with the participation of Frédérique Vidal, French Minister for higher education, research and innovation, and of European commissioner Mariya Gabriel, ONERA was invited to showcase the H2020 project ALTAIR. A measure of interest and recognition for its research.

## Maison Irène and Frédéric Joliot-Curie: strong French presence alongside ONERA

Through multiple lobbying efforts in 2021, since 1st January 2022 CLORA has become Maison Irène and Frédéric Joliot-Curie (MIFJC). This new step involving the presence of French public research bodies in Brussels in line with the national action plan to improve French participation in the funding mechanisms for research and innovation and higher education (PAPFE) must bolster cooperation between the organisations involved at a time when the Horizon Europe programme is starting and as France assumes the presidency of the European Union.

## Successful virtual seminar between ONERA and the DLR on artificial intelligence



In 2021 as in 2020, the limitations imposed by the pandemic did not restrain the motivation of scientists from the DLR and ONERA to discuss topics fundamental to the virtual joint laboratory on artificial intelligence applied to aerospace, introduced in 2019. Over 50 scientists met online to discuss subject as varied as robotics in space, Earth observation, Computational Fluid Dynamics (CFD), advanced aeronautical systems and industrial systems management. Today, these topics are addressed using a hybrid approach, blending physical modelling and training using live data. Also note that a major new topic of this seminar addressed the interaction between humans and artificial intelligence.



## ONERA, expert advisor to the European Commission on the defense and aerospace industry

The panel of experts from the DG DEFIS selected ONERA, demonstrating their recognition of its already strong role in the defense sector, supported by the European Commission. The expertise of ONERA is effectively appreciated for its multiple

disciplines and transversal vision, which ensures clear advice. The aim of the Commission is to boost European competitiveness and resilience, by fostering innovation in the defense and aerospace sectors.



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



ONERA

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