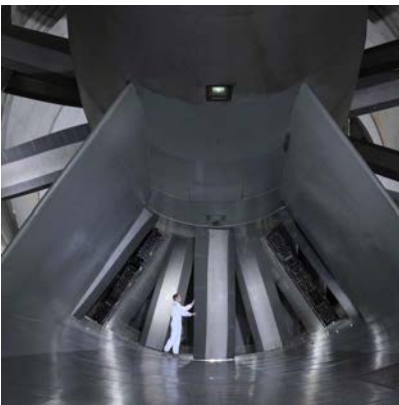


ANNUAL REPORT 2023



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ONERA is a central player in aeronautical and space research and employs over 2,100 people. Operating under the authority of the French Ministry of Armed Forces, its 2023 budget amounts to €294 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,
CEO OF ONERA

Edito

ONERA's 2023 annual report is a fine illustration of the major trends that have emerged in recent years.

The confidence of our partners is evident in all our areas of activity, and is reflected for the third year running in a new record order intake of €177m. This marks an exceptional year for both our scientific and wind tunnels departments. Three other all-time records were broken: orders from industry, from the DGA and by the Wind Tunnels Division. This confidence is also reflected in the very many visits, meetings and testimonies recounted throughout this report, starting of course with that of Mr Sébastien Lecornu, Minister for the Armed Forces, whom I would like to thank warmly for the interest he has shown in the institution and the employees who support these achievements.

The commitment of ONERA employees to allowing results described in this report is just as evident. This can be seen both in the scientific and technical achievements that meet the expectations of government and industry, and in the efforts made to achieve a positive economic result despite the severe constraints we have had to face, such as the additional costs of our energy bill. I would like to thank them warmly for their efforts. Artificial intelligence and quantum physics are two disciplines that many people are talking about, and they are part of our concrete successes. On the one hand, ONERA has signed an agreement with the DGAC/DSNA which will lead to the operational equipping of 4 of the 5 air traffic control sites in France with SINAPS air traffic management software using artificial intelligence. The Defence Innovation Forum was also an opportunity for ONERA to present the second-generation quantum gravimeters that will be fitted to some of the French Navy vessels in 2024.

ONERA is shining internationally, with a high success rate in European calls for tenders and confirmation of our position in calls for projects from the European Defence Fund. The signing of a new agreement on icing with NASA and the now traditional acquisition by NASA and the Jet Propulsion Laboratory of new accelerometers for space, as will be the case for ESA in 2024, are also remarkable successes. This report also highlights the American National Science Foundation's choice of ONERA's adaptive optics to improve the Gemini North astronomical telescope. And of course I am very proud that the International Forum on Aviation Research (IFAR), which now has 26 active members covering every continent, has elected me for a two-year term as its Chairman, which I am doing on behalf of ONERA. This illustrates their recognition of the value of ONERA's research and results in this field.

On 17 March 2023, we were particularly proud to host the visit from Emmanuel Chiva, Délégué général pour l'armement, and Damien Cazé, Directeur général de l'aviation civile. The visit took place at the Modane ONERA site, home to our very large strategic wind tunnels, which are also the greenest in the world. It was also an opportunity to receive a group of journalists. Discussions at the press conference organised for the occasion, as well as during the visits, highlighted ONERA's contribution to preparing the defence and aerospace industries of tomorrow.

The past year has of course been marked by the return of the Paris Air Show. What a pleasure it was to meet up again and show the whole defence and aerospace community our vision of the future with ESPADON, the hypersonic combat aircraft project, and GULLHYVER, an aircraft configuration contributing to the decarbonisation of air transport! We also unveiled the second edition of our roadmaps, which detail the ten areas of targeted research on which our researchers and engineers are working.

In 2023, ONERA created its first subsidiary ASTAREON, which aims to provide space surveillance services, building on the unique experience in Europe acquired with GRAVES, which has been operational since 2005. This is a major step into the world of start-ups and New Space.

In a context of fierce competition for recruiting, ONERA continues to attract talents: 214 new employees have joined ONERA in 2023, which I am delighted about because we need them! Along with those who have gone before them, they will be writing the pages of the future of defence, aeronautics and space that have only just been sketched out. The more than 18,000 applications received in 2023 for the positions we had open also illustrate our attractiveness, which is just as strongly confirmed at student level, with 128 students joining the ranks of our doctoral students.

ONERA is determined to do its bit for the nation at a time when the threats of a past are unfortunately resurfacing. ONERA is also responding to the challenges of decarbonising air transport. Wherever there are issues of sovereignty in the defence, aeronautics and space sectors, ONERA is on the front line, innovating on behalf of the State and industry.

I invite you to discover the highlights of 2023 in this annual report.

HIGHLIGHTS



Visit by the DGA, the DGAC and the press to Modane on 17 March 2023.

The Delegate General for Armaments and the Director General of Civil Aviation visit the large wind tunnels in Modane, in the presence of the press

On 17 March, Emmanuel Chiva, Délégué Général pour l'Armement, and Damien Cazé, Directeur Général de l'Aviation Civile, were in Modane for an exceptional visit, which generated a great deal of interest in the Office's activities. This dual visit by the most senior executives of the DGA, ONERA's defence supervisory body, and the DGAC, the French civil aviation authority, took place at a time when the wind tunnels are preparing to take up two major challenges: the decarbonisation of civil aviation, and the ramping up of defence programmes, including the renewal of deterrent vectors. Organised in conjunction with a press visit, the visit not only demonstrated the vital role of wind tunnel testing in preparing for the aeronautics and defence of the future, but also presented projects conducted jointly by the scientific departments and the wind tunnels (Superman, Aspic, E2IM - an innovative motive integration study, illustrating ONERA's know-how and innovative ideas in the field of combat aviation and the preparation of low-carbon aviation).

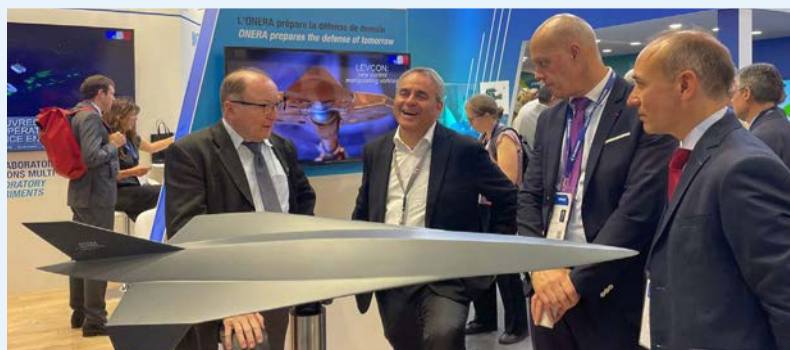
DEFENCE INNOVATION FORUM FROM 23 TO 25 NOVEMBER

The DGA asked ONERA to present five of its projects staged by the Defence Innovation Agency: quantum gravimeters, the bispectral camera based on freeform optics, observation from a nanosatellite using multi and hyperspectral imagery, the acoustic mask and the detection of explosives and firearms in real time in a flow of people.



A REAL SUCCESS FOR LE BOURGET 2023

Numerous innovations presented on the ONERA stand, including decarbonisation with the GULLHYVER configuration and the ESPADON hypersonic aircraft. Numerous visits from civil and military authorities, including Sylvie Retailleau, Minister for Higher Education and Research, Emmanuel Chiva, Delegate General for Armaments, Thierry Burkhard, Chief of Staff of the French Armed Forces and Xavier Bertrand, President of the Hauts-de-France region.



ONERA TAKES OVER THE PRESIDENCY OF IFAR

France and ONERA were in the limelight for a second time this year at the IFAR world summit (after the IFAR ECN event at Le Bourget), with Bruno Sainjon taking over the presidency of IFAR and ONERA presenting a brand new multilateral research project on the characterisation of the atmospheric environment in an airborne measurement configuration.



ONERA creates its first *New Space* subsidiary: Astareon

The creation of Astareon builds on ONERA's unique historical expertise in space surveillance, acquired with Graves. ASTAREON, a new player in NewSpace, will provide space surveillance services from 2024 to meet the growing challenges of space safety and security.





**Sébastien
Lecornu**

Minister of the
Armed Forces



**MINISTÈRE
DES ARMÉES**

*Liberté
Égalité
Fraternité*

In recent years, the international geostrategic situation has changed radically. Can we say that the context is worrying?

Indeed, until recently, we were used to successive crises, and I'm thinking of course of terrorism, conflicts in Africa, the Sahel and so on. Since February 2022, a chain of disruptions has been building up, in addition to the other classic threats that have not disappeared. What is most worrying today is probably the war on Europe's borders and Russia's aggressive behavior. The outcome of the conflict between Russia and Ukraine is taking an unknown pathway. If Ukraine disappears, who knows where Russia's ambitions will end?

Vladimir Putin's Russia is becoming increasingly aggressive towards us. This level of aggression has never existed before, and the risk is growing, a fact shared by all European countries. The Kremlin is playing with thresholds and multiplying threats, including blackmail over raw materials and hydrocarbons. We have recently witnessed disinformation operations at the heart of our democratic processes. This hybrid threat, which takes the form of cyber-attacks, disinformation campaigns and even aggressive action on our territory, is of great concern to us. It is therefore essential to approach the Russian threat with lucidity, and not to underestimate it.

What consequences or adaptations are needed for French defense?

It's crucial not to give up our ideal of peace, and to avoid all forms of naivety. Preparing for war, in a sense, is a means of preserving peace. Our first insurance policy is

our army, based on the fundamentals of the Gaullist model drawn up in the 1960s, i.e., an autonomous nuclear deterrent, a national employment framework for a combat-experienced army, clear alliances and a sovereign defense industry, inspired by dynamic, high-level research.

The page of peace dividends that saw our military capacities reduced in the wake of the fall of the Berlin Wall is well and truly behind us. Since 2017, a first military programming law (LPM) has acted on the recovery of our defense resources, executed under the authority of the President of the Republic. In 2023, Parliament adopted a new, highly ambitious LPM, which is having an impact, as France is back above the threshold of 2% of GDP devoted to defense, something that has not happened for several decades. I'm delighted. The defense budget will have doubled under Emmanuel Macron's two terms in office. But the real issue, for every NATO country, is to ensure that this spending is focused on material and human investments that are genuinely useful for our security. This is what France is defending with our allies, on the basis of our experience as an employment army.

Re-industrialization, modernization of our capabilities and rearmament of France: the first results are there. By 2023, over €20 billion worth of equipment has been ordered. Including 42 Rafales, 109 Caesar MkIIs, 420 Serval and 7 offshore patrol boats. All made in France!

More than ever, our nuclear deterrent has demonstrated its credibility. With the successful test-firing of an M51 strategic ballistic missile from the SNLE Le Terrible in April, and the successful test-firing of the first M51.3 in November, our deterrence is on a permanent footing.

“The importance of ONERA's work goes far beyond deterrence: innovation, innovation, innovation. technology is essential to all our armed forces”.

“ONERA is an asset that breathes innovation into our armies! And of course I expect you to strengthen your expertise”.

Why is research important in this new context?

2024 is the first year of application of the new military programming law passed last summer. Its success depends on the effort devoted to research and innovation! We have to take risks to ensure that France always has sovereign access to technologies, both current and future, in order to guarantee the reliability and superiority of our weapons for decades to come. The challenges are great and research is essential, whether in quantum mechanics, artificial intelligence, high speeds or stealth. Space is becoming a new terrain of conflict, and our means of knowledge, anticipation and action must be unfailing. These are all fields ONERA has developed world-renowned skills in. Taking risks is the very essence of our scientific research! We need to be daring, so that we can acquire ever more detailed knowledge of technical and tactical tools. I'd like to see a return to the pioneering spirit of the 60s, both within our defense industry and at the Direction Générale de l'Armement (DGA), and in all the Ministry's technical departments, including of course its scientific research.

In this context, how important do you think a scientific organization like ONERA is?

Since its creation on May 3, 1946, ONERA has played a key role in the French defense effort. Firstly, in revitalizing its aeronautical industry, both military and civilian. Secondly, in the establishment and maintenance of a credible nuclear deterrent, constantly maintained at an excellent level. Today, ONERA's contribution to the renewal of the two components of our deterrent system, within the framework of the LPM (law on military programming), should enable us to pursue our efforts to maintain the credibility of our deterrent. It's thanks to our investment in research that our deterrent is credible and recognized.

The importance of ONERA's work goes far beyond deterrence: technological innovation is essential to all our armed forces, to ensure that they remain world leaders. I'm thinking of the French Air Force, of course, with its major contributions to air-vehicle development, as well as to observation systems such as GRAVES, Nostradamus, hypervelocity and directed-energy weapon systems, and also to the French Army, with its detection systems, to the Gendarmerie on important topics such as drones, and



the Navy with quantum gravimeters. Our wind tunnels and the expertise of our scientists and technicians remain unique in the world. ONERA is an asset that drives innovation in our armed forces! And of course, I'd like to see you strengthen your expertise. Your role is vital: to innovate, to push the boundaries, to guide research, to be the State's expert for our future programs. I ask you to play this role for the SCAF (FCAS, the Future Combat Air System), as for the other defense programs in the third dimension.

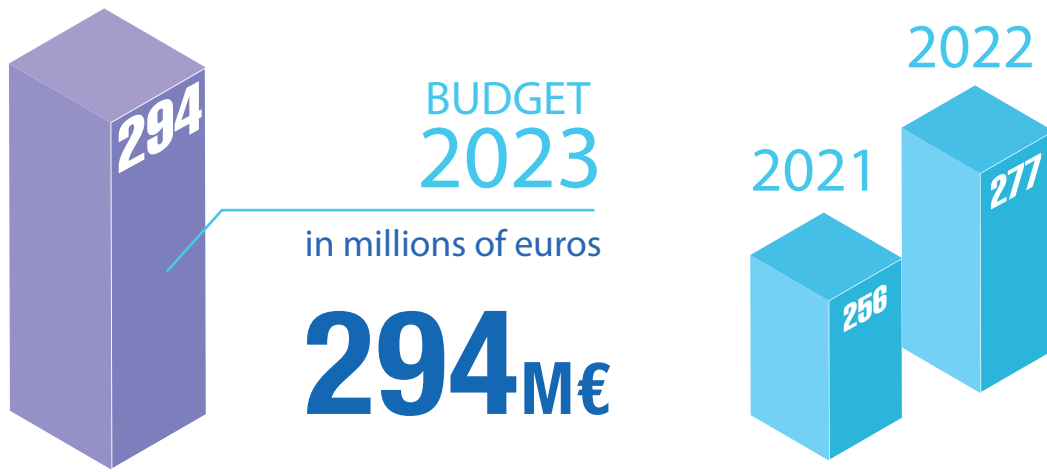
ONERA also plays a key role in France's international reputation, and is one of our export strengths: none of the Rafale, A400M or H-160 programs would have been a success without the innovation and expertise of ONERA, one of the world's most prestigious aerospace science centers.

That's why, despite the difficult budgetary context, I intend to continue the Ministry of the Armed Forces' support for ONERA, which goes far beyond what was set out in the COP (Contract of Objectives and Performance).

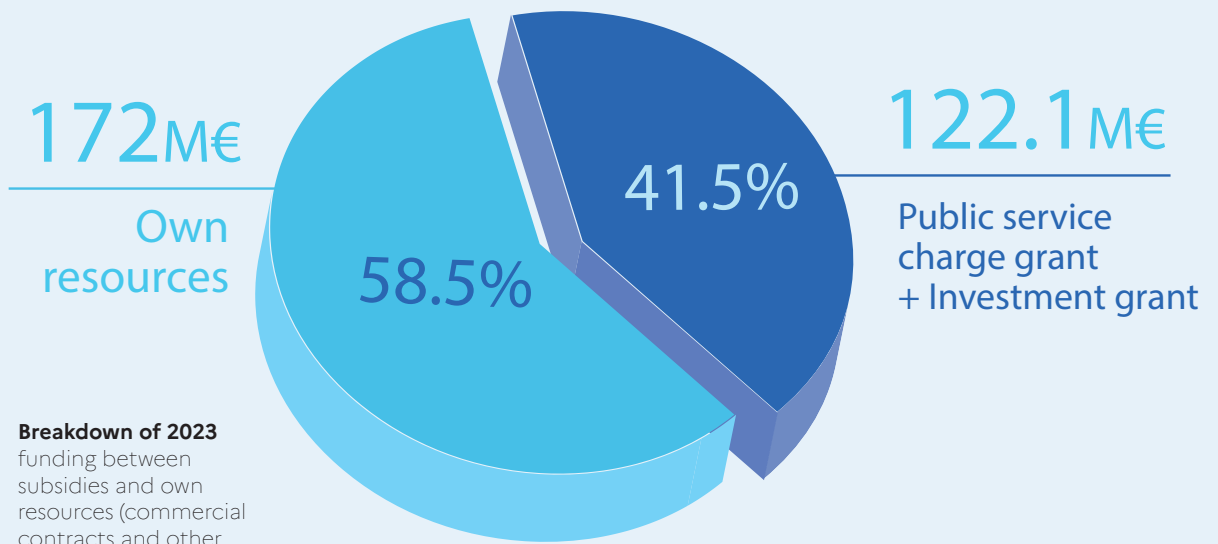
I reaffirm my support and remain attentive to your needs in a context that has considerably changed and in which your role is essential.

I know I can rely on ONERA, on your world-renowned scientific contributions - I'm thinking of course of simulation, modeling, experimentation and wind tunnel testing. Your role is vital to the credibility of our armed forces, and it needs to be reinforced. Instill a spirit of innovation and pioneering. So that France and its weapons remain at the top of the world

BUDGET ON THE RISE



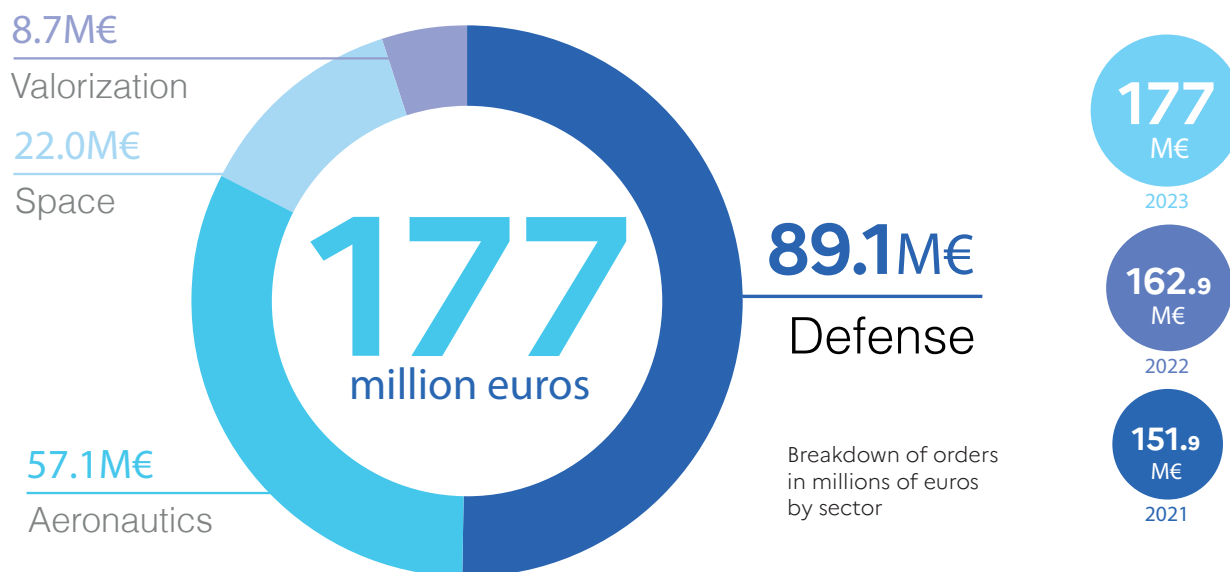
Placed under the supervision of the Ministry of Defence, from which it receives its subsidy, ONERA's budget comes partly from the Defence Innovation Agency and almost 60% from commercial contracts.



Breakdown of 2023 funding between subsidies and own resources (commercial contracts and other public funding)

NET INCOME : 4 M€

RECORD-BREAKING ORDERS



ORDERS BY SECTOR

50.3%

Defense

32.3%

Aeronautics

12.4%

Space

5%

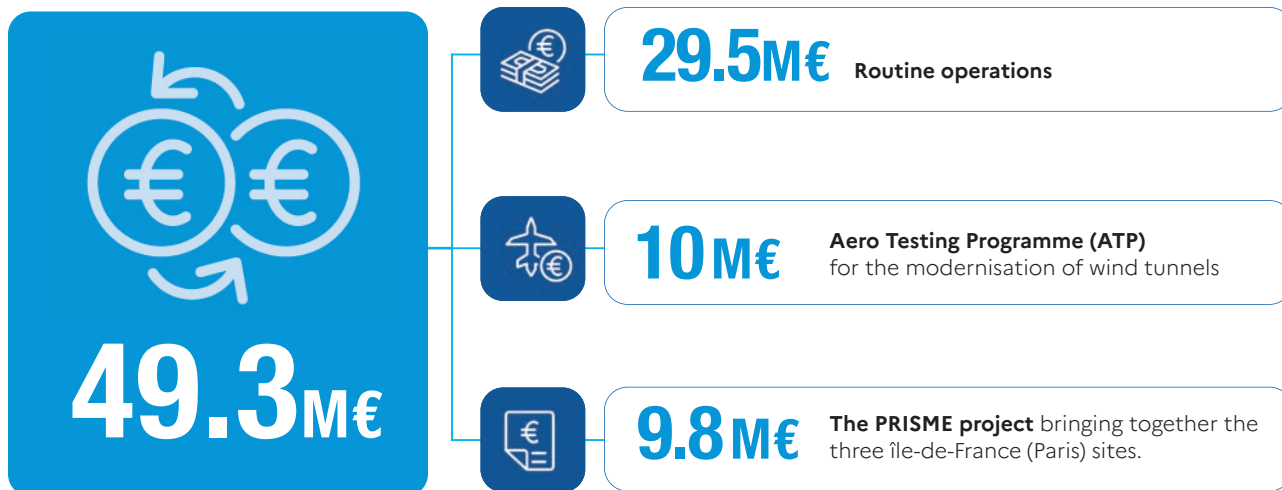
Valorization

Percentage breakdown of order value by field.

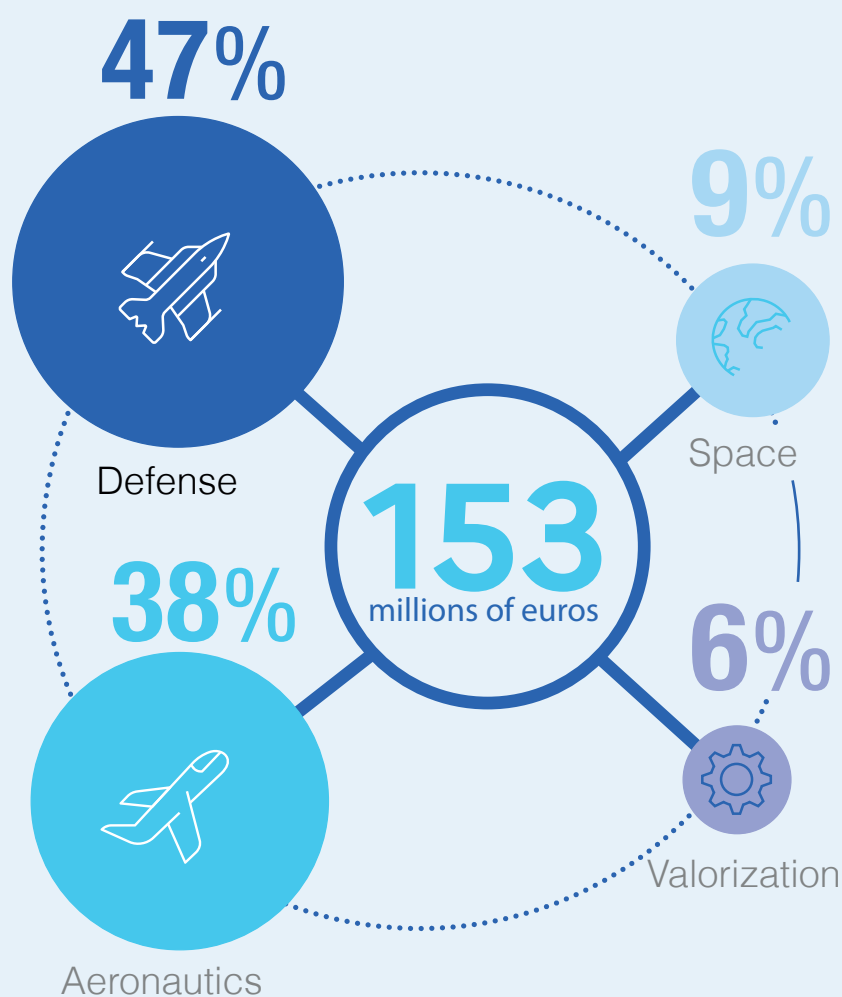
Order intake by customer in M€



INVESTMENTS



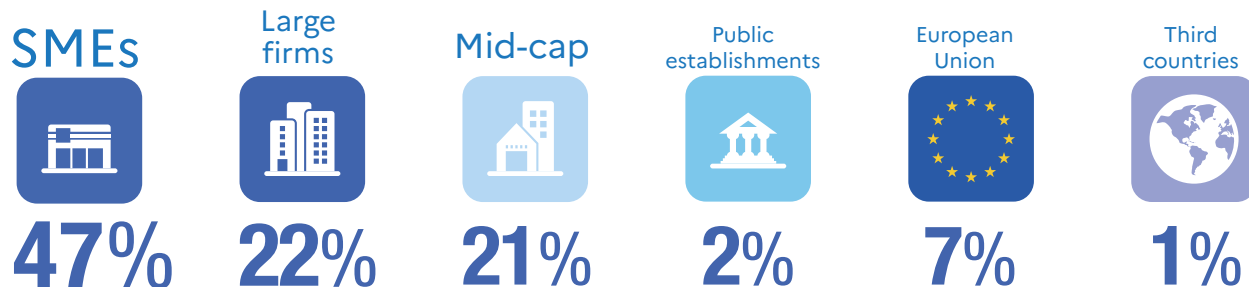
DISTRIBUTION OF CONTRACTUAL OPERATIONS BY ACTIVITY



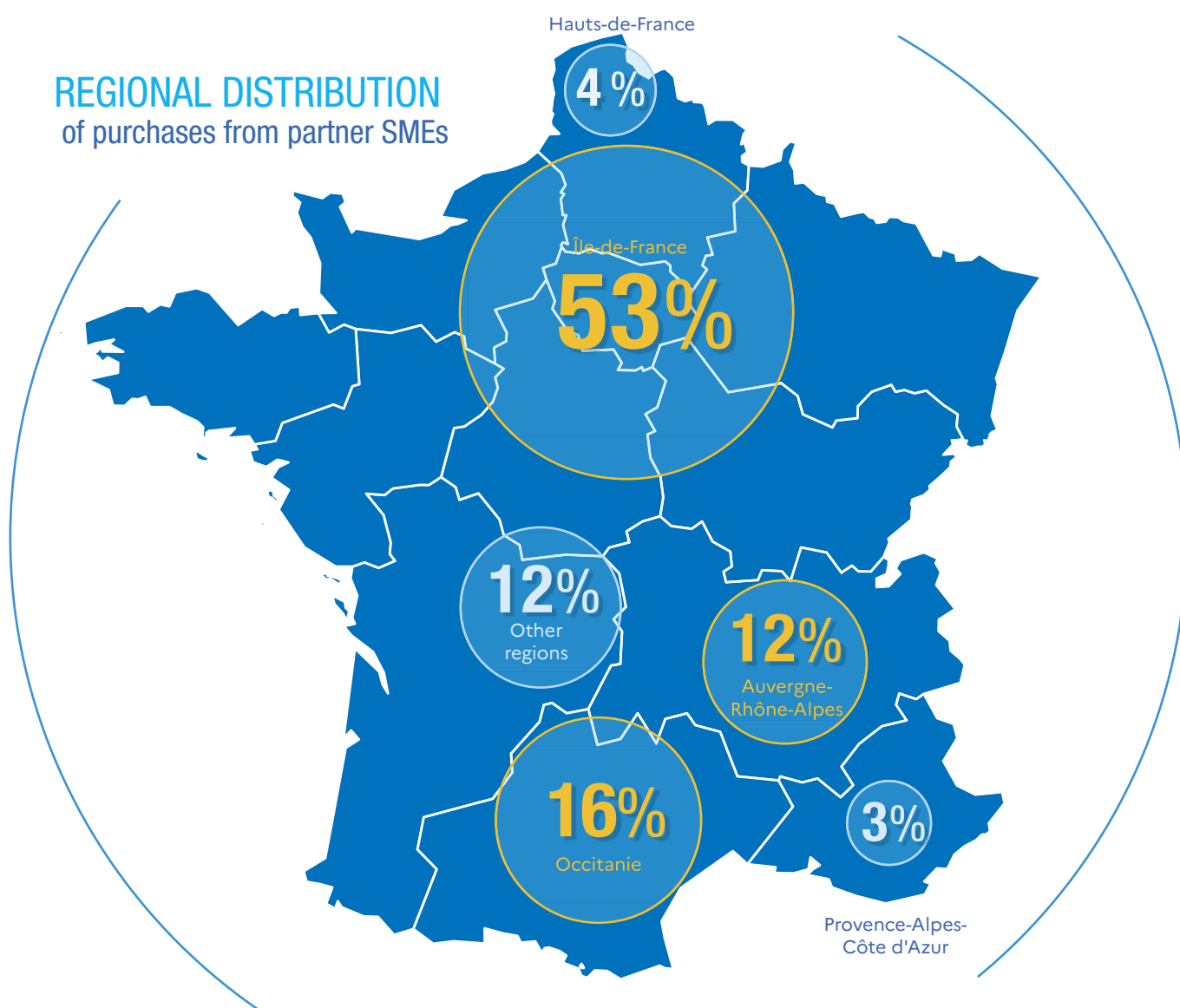
PROCUREMENT

L'ONERA works mainly with SMEs in all its centres, across all regions. In 2023, ONERA will have signed contracts with 1932 SMEs (1840 in 2022).

Breakdown of purchases by type of business in 2023



REGIONAL DISTRIBUTION of purchases from partner SMEs



Enriching and developing the skills of ONERA teams

The Office's research and innovation rely on the expertise of its employees. That's why training and career management are an absolute priority

Investing in key skills to stay at the forefront of the latest advances

As a government expert in Defence, Aeronautics and Space, ONERA invests in developing the skills of its employees. In 2023, ONERA will record a 10% increase in the number of hours of training, targeting priority areas in line with its strategic orientations of ONERA's strategic orientations: artificial intelligence, nuclear defence and quantum physics. Partnerships with other research bodies such as CEA/DAM have been set up to accelerate the development of these skills. In-house training is also a key means of sharing knowledge.

In 2023, 3,895 hours of in-house training were provided in 59 sessions led by 45 in-house trainers.

Protecting and promoting knowledge

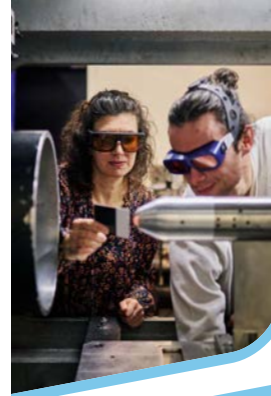
ONERA supports its teams in protecting and promoting their work by registering patents, software, Soleau envelopes, invention briefs and trademarks, and helps employees to become entrepreneurs through technology transfer.

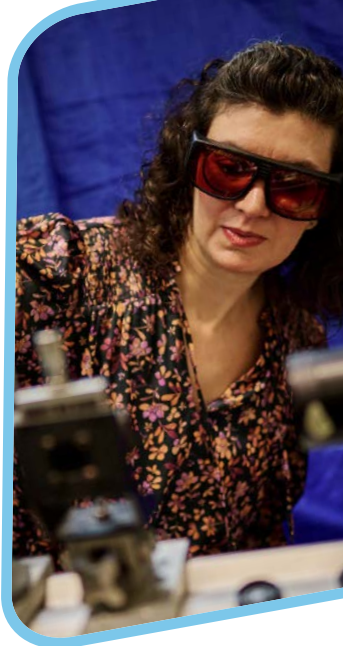
Encouraging young talent

In 2023, ONERA launched the "springboard project" scheme, which will enable newly recruited young engineers and technicians to carry out personal scientific projects in line with ONERA's research strategy. This programme, the first projects of which will be awarded in 2024, aims to encourage initiative by offering the means to put a scientific and/or technological activity into perspective, on a subject of the employee's own initiative.

Training the experts of today and tomorrow

As part of its mission of training through research, ONERA is committed to training new generations of researchers. In addition to hosting trainees/doctoral students (to be specified quantitatively), ONERA employees are encouraged to contribute to teaching at schools and universities. In 2023, nearly 10,400 hours of teaching were provided by ONERA teams. ONERA's knowledge and skills are also shared through the ONERA Academy®, which will eventually offer a catalogue of professional training courses for companies.





2,157 employees

- 1,703 engineers and executives
 - 181 employees
- 34 work-study students
- 238 technicians et 1 worker
- 26 % women
- gender parity index: **95/100**

390* communications at congresses with publications

335* publications in peer-reviewed journals

121 scientists with habilitations to lead research (HDR), including 6 presented to juries in 2023

- 376 doctoral students
- 16 post-doctoral students
- 243 trainees

89* PhD defended

978* technical reports

* Preliminary figures

SCIENTIFIC AWARDS

International Astronautics Prize

Awarded to **Manuel Rodrigues**,
by the Société Astronomique de France (SAF).

EREA AWARDS 2023

2 ONERA publications on the podium

At the annual EREA (European Research Establishments in Aeronautics) event, the best publication prizes were awarded to two teams including ONERA researchers, in 1st and 3rd place.

1st prize: ONERA-DLR team, author of the paper "Aeroelastic tailoring of a wind-tunnel model for passive alleviation of static and dynamic loads". The team is made up of Nicolo Fabbiane (ONERA), François-Xavier Irisarri (ONERA), Johannes Dillinger (DLR), and Arnaud Lepage (ONERA).



"ONERA Académie de Sciences" award

The ONERA 2023 award « ONERA-Sciences mécaniques pour l'aéronautique et l'aérospatial » : **Véronique Lazarus**, professor at ENSTA/IPP in solid mechanics. Since 2018, this prize has alternately rewarded researchers in fluid mechanics and solid mechanics for outstanding work in aeronautics and aerospace.



Thesis prize AMPEREE

Awarded to **Vincent Andraud** by the SEE (Société de l'électricité et de l'électronique)

First edition of the "ONERA Internal Awards"

The aim is to reward engineers and technicians who, through their scientific and/or technical excellence, contribute to ONERA's dynamism and reputation. These prizes, awarded every 3 years, in synchrony with the mandate of ONERA's High Scientific Council (HCS), are as follows:

Technical Achievement Award

Accelerometer team: Manuel Rodrigues, Bruno Christophe, Joël Bergé, Damien Boulanger, Mickael Chavagnac, Ratana Chhun, Marine Dalin, Phuong-Anh Huynh, Vincent Lebat, Françoise Liorzou, Alexandre Rebray, Nicolas Tanguy, Judicaël Bedouet, Patrice Carle, Stéphanie Lala. This prize rewards all the team's achievements in space accelerometry.

In addition, as part of this prize, a special mention was awarded to the HORUS project team, comprising Marlon Botte, Laurent Marcellin, Fabien Méry and Rémi Roncen, for the design and production of an innovative reference acoustic source adapted to wind tunnels.

Young Talent Prize

Michaël Scherman for his work on Raman spectroscopy, particularly as applied to measurements in reactive flows.

Scientific Research Prize

Sébastien Deck for his work on the modelling and simulation of turbulence applied to the ASD field.

Doctoral student prize

Each year a jury selects the best 3rd year thesis in each scientific field. The aim is to encourage doctoral students, provide them with a reference that can be used later on, and highlight outstanding work that could be the subject of special promotion.

2023 Prize-winners: **Dijwar Yilmaz** [DPHY], "Synthesis and characterisation of self-healing polymer materials in a radiative space environment" - **Hanae Labriji** [DTIS], "Shadow imaging of satellites" - **Bruno Mangin** [DAAA], "Modelling acoustic propagation in the presence of a complex geometry and a heterogeneous flow" - **Lisa Audouard** [DMAS] "Design and characterisation of ultra-high-temperature materials with gradient properties" - **Alexandre Suss** [DAAA], "Coupling Boltzmann and Navier-Stokes lattice methods for unsteady aerodynamic simulations".

Strong commitments

Scientific chairs

ONERA has set up an internal system of Scientific Chairs, designed to structure collaborative research projects between ONERA and academic and/or industrial players in areas of high strategic importance and major industrial and societal significance.

These scientific chairs also serve to promote technology transfer between research and industry, as well as the development of training initiatives.

Three chairs will be inaugurated in 2023:

- **MUSIC** – - holder **Élise Colin** – “New satellite image processing for the analysis of global dynamics”, with DLR, CentraleSupélec, Sonda, Kanop and Telecom ParisTech.

- **PROVE** – **Denis Sipp** – “Hybrid physical models for green aeronautical propulsion”, with INRIA and the Nouvelle Aquitaine region.
- **Seeing through the fog** - holder **Serge Meimon**, with the Institut Langevin (ESPCI Paris, CNRS).



Élise Colin

Denis Sipp

Serge Meimon



European Research Council (ERC) grant to Rémi Roncen for the POROLEAF project

Rémi Roncen is one of 400 scientists selected by the European Research Council for 2023.

A young ONERA researcher specialising in combustion and aeroacoustics in porous media, he has been awarded an **ERC Starting Grant** for his research project on the **dynamics of immersed flames in porous materials (POROLEAF)**, a little-explored area at the interface of the various physics of energy. He got a €1.5m grant over 5 years, which will enable him to take on three PhD students and two post-docs.

HONOURS

Riad Haidar, Chief Scientific Officer of ONERA, has been appointed as member of the CNRS Scientific Council

The CNRS Scientific Council has been renewed for a five-year term in 2023. Comprising 30 members, it ensures the consistency of the CNRS's scientific policy in liaison with all the scientific advisory bodies of the National Scientific Research Committee.

In July 2023, ONERA and CNRS also strengthened their collaboration by co-signing a framework agreement for cutting-edge aerospace research.

Antoine Godard, Scientific Director of the Physics division, has been elected as incoming President of the Société française d'optique.

Denis Gély, ONERA, has been appointed as distinguished member of one of the most important professional associations in the aerospace sector: the AIAA (American Institute of Aeronautics and Astronautics).



Riad Haidar



Antoine Godard



Denis Gély

HIGHLIGHTS

2023



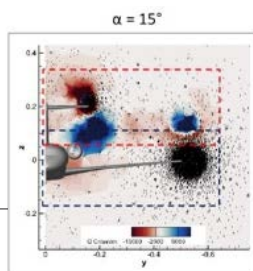


Vein reference configuration. Flow speed: 60 m/s.

New aircraft configurations: the benefits of soufflerie testing right from the preliminary design stage

Thanks to 3D printing (rapid, low-cost manufacture of modular models with good geometric accuracy), tests in the soufflerie can be used from the pre-project phase of a new aircraft concept. A test campaign was conducted in the Lille windtunnel in collaboration with Dassault Aviation, as part of the NACOR (New Innovative Aircraft Configurations) project of the European CleanSky2 partnership, to measure the impact of different fuselage widths and tailplane variants on the aerodynamic performance and flying qualities of a wide-body business jet.

PIV identification of wingtip and empennage trunnions.



The introduction of a wide fuselage requires a global re-optimisation of the configuration: This pre-design phase therefore requires the evaluation of a large number of varied geometries. The manufacture of parts using rapid prototyping has made it possible to combine 3 fuselage widths, 4 types of tailplane and 2 engine positions.

These tests showed that the T-tail is the configuration which appears as least sensitive to variations in fuselage width. Aircraft stability is degraded when other tailplane geometries are combined with wide fuselages. Increasing fuselage width has a non-linear negative effect on the overall stability of the configuration. The integration of experimental data into the rapid design codes has also made it possible to enrich the tailplane design models.

Aeronautical structures: Bird impact tests on laminar wing structure protection systems



The air cannons at the Lille centre's high-energy impact test facility were used - for the first time in the laboratory - to simulate a bird strike. The aim was to assess the performance of a protection system against this type of threat, developed by AERNNOVA to

protect the wing's main spar.

The HLFC-Win project (financed by the European Union as part of the CleanSky21 programme) is dedicated to the design and manufacture of an aircraft wing structure based on Hybrid Laminar Flow Control (HLFC) technology. The ONERA centre in Lille has a facility comprising 3 air cannons capable of achieving impact speeds of up to 220 m/s.

Mounted on a system of elevating rails allowing the point of impact on the target to be adjusted, they are activated according to the size of the projectiles in question. This test device is regularly used for problems involving impacts from ice, composite debris or tyres.

To meet the projectile size requirements (a 4-pound bird made of substitute material - gelatin), the tests were carried out with the largest diameter gun, at different speeds (maximum 140 m/s. 2)

Quantum: First meeting of the QTech laboratory's scientific council

The scientific council of the QTech laboratory (ONERA's transverse laboratory for quantum technologies) held its first meeting on 24 January 2023, with a board chaired by Alain Aspect (Nobel Prize in Physics 2022) and comprising Cyril Allouche (ATOS), Fabien Bretenaker (CNRS, LuMIn), Fabrice Devaux (UFC-Besançon, FEMTO-ST), Eleni Diamanti (CNRS, LIP6), Pierre Rouchon (Mines ParisTech) and Sébastien Tanzilli (CNRS, Institut de Physique de Nice). The laboratory's 4 main areas of research were presented: quantum computing, quantum communications, quantum optonics and atomic sensors. The Board particularly appreciated the dynamism of the QTech laboratory after only one year of existence, as well as the laboratory seminar. It made a number of recommendations to help the most forward-looking activities get off the ground, in particular quantum computing and quantum optonics. The board will meet once a year to monitor the laboratory's progress.

Human factors: Experimental campaign

As part of a thesis being carried out in ONERA's Information Processing and Systems Department, a helicopter flight test campaign was conducted with the aim of characterising and modelling the biomechanical activity of the pilot's arm. The aim is to contribute to the development of methods for assessing the flying qualities of helicopters, by introducing new techniques for the analysis and biomechanical modelling of piloting activity (by integrating them into the existing normative approach). During these flights, the acquisition of kinematic, electromyographic and subjective data (responses to established questionnaires) aimed to characterise the cognitive cost inherent in the piloting activity during manoeuvres where the difficulty of the task was manipulated.



Optics: First infrared image with a microbolometer with a pixel pitch of 8.5 μm



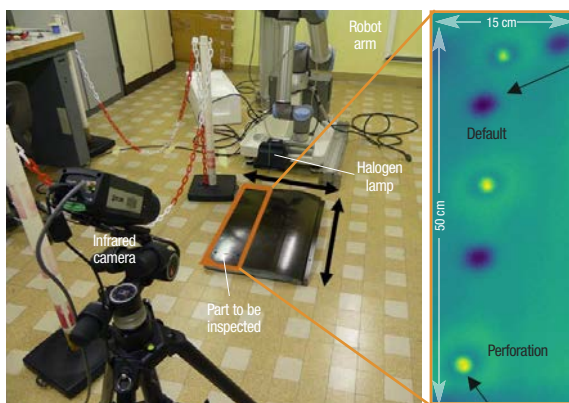
European "thermal vision augmented awareness" project.

An initial infrared image using a microbolometer with a pixel pitch of $8.5 \mu\text{m}$ was obtained using an optical solution proposed by ONERA as part of the European "thermal vision augmented awareness" project run by the JU (Joint Undertaking) ECSEL. The aim of this project was to integrate thermal imaging into the automotive sector to monitor the passenger compartment and provide driving assistance, two essential elements of future mobility. Application to the industrial automotive market meant that the 12 partners had to target low-cost thermal cameras. Over the 41 months of the project, the key technology was the development of microbolometer detectors with a very small pixel pitch of $8.5 \mu\text{m}$, reconciling performance and cost. ONERA was involved in the optical part of the project, designing complementary lenses for microbolometer detectors with these severe constraints. To achieve this, ONERA studied solutions using chalcogenide glasses with a high refractive index, as well as solutions compatible with wafer-based optics manufacturing methods. The project has led to a breakthrough in the development of perceptive systems for autonomous driving.



First infrared image with a microbolometer with a pixel pitch of $8.5 \mu\text{m}$ (QVGA (320x240pixels), optics with a focal length of 3.9 mm open at F/1.2).

Health inspection: An autonomous method for inspecting aeronautical parts

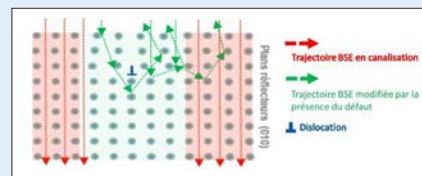


ONERA has implemented strategies for automating non-destructive inspections of metric aeronautical parts, with the aim of making maintenance operations faster and more reliable. ONERA's Non-Destructive Testing (NDT) laboratory recently acquired a 6-axis robotic arm on which an on-board thermal exciter, of the halo-gen lamp type, can scan complex-shaped structures, such as a fuselage section, using a 'Dirac comb' (a succession of flashes). The maps are

acquired using an infrared camera placed in front of the robotic arm. The processing used, based on a decomposition into singular values and extraction of the resulting orthogonal functions, makes it possible to generate real-time imagery of the defects being sought, at low cost. The immediate prospect is to install a second, visible camera on the arm and to propose an inspection approach combining infrared and visible imaging to further optimise the NDT process. This work was carried out as part of the DGAC EXAM project, in cooperation with Airbus.

Materials : Original SEM imaging technique for dislocations

With the aim of increasing the range of characterisations carried out by ONERA's Scanning Electron Microscopy (SEM) laboratory, an imaging technique that makes it possible to observe dislocations has been successfully implemented on one of the microscopes. ECCI (Electron Channeling Contrast Imaging) now makes it possible to observe dislocations on a massive sample thanks to the channeling phenomenon. When the atomic planes are carefully aligned with the electron beam, the incident electrons are said to be 'channelled' and little of the BSE signal (backscattered electrons) is sent back to the detector (red trajectories). The presence of a dislocation will disrupt the arrangement of atomic planes locally. As a result, the electron trajectory is modified, resulting in an increase in the number of BSE electrons returned to the detector, making the crystalline defect visible in the acquired image. This technique, which complements transmission electron microscopy (TEM) analyses, can be used on the vast majority of alloy families, with the advantage of being able to analyse larger areas non-destructively, thereby improving our understanding of damage mechanisms.



Energetic materials: New capabilities for multi-mechanical characterisation of propellants

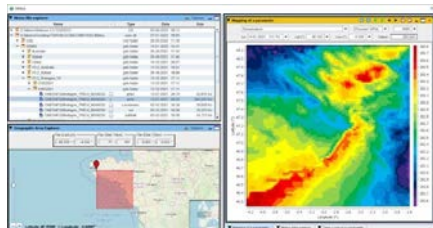


ONERA has just installed a new quasi-static test machine and camera system in the pyrotechnics zone, in order to characterise the mechanical behaviour of propellants under controlled experimental conditions of temperature and hygrometry.

The aim is to control combustion, and in particular to optimise the physico-chemical formulation of new propellants, in all phases of propelled vehicle flight. The quasi-static test machine provides conventional machine data (force and displacement of the jaws) and the camera system measures local mechanical fields. This is a rare procedure for studying propellant materials in pyrotechnic zones.

This is all the more important as the quantification of deformations requires a very fine pattern to be deposited on the propellant, which constitutes a set of reference points whose movement in space can be tracked by the CIN software. During an initial campaign, this very fine pattern was successfully produced, which constitutes a real advance and enables ONERA to meet its own needs for characterising the mechanical response of representative energetic materials, and those of its customers.

Optronics: Qualification by the DGA of the MATISSE 3.6 code, coupled with Météo France forecasts



The DGA has declared MATISSE 3.6 (the atmospheric radiative transfer code developed at ONERA for over twenty years) to be the new reference version, which can be distributed to DGA, industrial and academic establishments that request it, subject to a licence.

This new version offers the possibility of taking as input the outputs of Météo France's forecasting models. Then it is possible to predict the 24-hour performance of the inherent or apparent temperature contrast between two natural or manufactured materials, or radiative quantities, for mission preparation (tactical decision support, etc.). Another feature enables performance statistics to be produced for a given geographical location anywhere in the world, over a time span of 4 years, using replay data from Météo France models. This version will be accompanied by a specific data production service for MATISSE available from Météo France. It also includes a new thermal module for contrast calculations fed directly by weather data. The first MATISSE training course will be given as part of ONERA Academy.

Quantum technologies: First microwave field measurements with cold Rydberg atoms

The first microwave field measurements using cold atoms placed in a Rydberg state have just been carried out at ONERA. In such a state, a negatively charged valence electron is in an orbital a long way from the positively charged nucleus. The atom then has a large electric dipole, making it highly sensitive to the surrounding electric fields, which means that a set of laser-cooled atoms can be used to make precise electromagnetic field measurements. This technique also has other advantages over conventional methods based on conductive antennas, such as being self-calibrating, having a sensor size that is independent of the wavelength to be measured, and being tunable over a wide frequency range from around 100 MHz to THz. This measurement technique, known as 'trap loss spectroscopy', had never been used before to measure electromagnetic fields. It offers a better linearity of the scale factor compared with the usual techniques used in thermal vapours, as well as the possibility of measuring both the frequency and the amplitude of the microwave field from the respective amplitudes and positions of the two peaks.

Remote sensing: Lidar for sensing 500 meters underground

As part of the Calisto 2 contract with Andra (Agence nationale pour la gestion des déchets radioactifs), ONERA has successfully carried out initial in situ tests at the underground research laboratory at its Meuse/Haute-Marne centre to remotely characterise the atmosphere (hydrogen, oxygen, nitrogen, relative humidity) in a storage cell demonstrator for high-level vitrified waste. Under the experimental measurement conditions (open cell), the atmospheric lidar developed by ONERA was used to determine the composition of the air, without revealing any concentration gradient. This atmospheric lidar detects Raman scattering by molecules of hydrogen, oxygen, water vapour and nitrogen to deduce their concentration. The Cigéo (Centre industriel de stockage géologique) project involves storing French high-level and long-lived intermediate-level radioactive waste at a depth of 500 metres. During the operating period of Cigéo (final sealing scheduled for 2150), it is planned to monitor changes in the atmosphere of certain instrumented control cells.



Top left to right: alignment of the emission/reception system with the green pointer, beam deflection mirror and lidar positioned to fire into the cell. Bottom: ONERA-Andra teams.

Hot materials: New crystallographic analysis capability at ultra-high temperature



(Anton Paar)

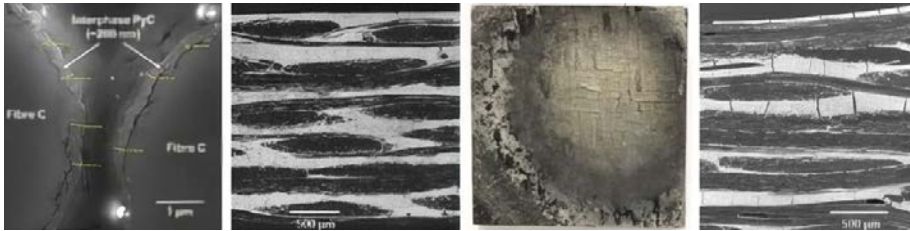
HTK 2000 N high-temperature chamber.

Within the X-ray diffraction (XRD) laboratory, ONERA has set up a device for the in situ study of the evolution of the structural and crystallographic properties of materials, up to 1600 °C in air, nitrogen or helium, as well as up to 2300 °C in vacuum.

In-situ temperature-resolved XRD analysis can be used to study numerous physico-chemical phenomena including the crystallisation of nano-materials and thin films, the recrystallisation and growth of grains (crystallites), the stability and/or transition of phases or even the precipitation and oxidation of materials. The coefficient of thermal expansion can also be determined from these analyses.

An initial experimental campaign has made it possible to study the formation of a hafnia-based ultra-refractory phase, used as a thermal barrier in materials with a gradient of ultra-refractory properties. These materials, currently under development (CNES R&T and ONERA-CNES thesis), are intended to be used as alternatives in satellite propulsion systems. In situ XRD analyses up to 2000 °C have provided a better understanding of the physico-chemical mechanisms acting during the crystallisation and synthesis of these phases, their crystallographic structures and their stability, contributing to the optimisation of the elaboration process.

Materials: Ultra-refractory materials for applications in extreme conditions



(From left to right) PyC interphase - cross-section of a UHTCMC composite after processing - surface and cross-section of the composite after an oxidation test at surface and cross-section of the composite after a 5-minute oxidation test at 2200°C in air

ONERA is developing ultrarefractory materials for applications at temperatures above 2000°C in an oxidising environment. They offer high mechanical performance while retaining good resistance to oxidation.

Their performance has been enhanced by working on the quality of impregnation of the fabrics by the matrix and by introducing a PyroCarbon fibre/matrix interphase obtained by gas phase deposition. Mechanical tests confirmed the essential contribution of this interphase to the material's non-brittle mechanical behaviour. At the same time, work has shown their good resistance under air at very high temperatures. Further developments are envisaged to increase the strength of these composite materials: incorporation of new types of matrix based on studies of monoliths. These are virtually unavoidable solutions for a large number of current and future needs.

Structural health: sensors characterised under cryogenic conditions

The issue of hydrogen storage tanks requires structural health monitoring (SHM) approaches to be adapted to cryogenic conditions. ONERA

has measured the properties of ultrasound sensors in a rarely used temperature range (between 300 K and 15 K), thanks to the acquisition of a liquid helium cryostat, which enables SHM sensors to be subjected to temperatures down to 10K. Instrumentation with the cryostat will make it possible to check the behaviour and durability of the sensors in this extreme environment, but above all to calibrate them in temperature in order to take account of any drifts in their response and to trace the acoustic and thermomechanical quantities whose evolution is monitored during a flight or mission. An initial campaign of thermal cycling has made it possible to measure variations in impedance and therefore in the properties of the ultrasonic sensors. The set-up developed will eventually be used to characterise other types of sensor, such as FBGs (Bragg grating optical fibres), or to study changes in the properties of systems during thermal cycling at very low temperatures.



Characterisation of an SHM sensor in a liquid He cryostat environment

Hypersonics: Validation of on-board electronics in the wind tunnel



The ability to process and transmit flight data to the ground is of paramount importance to the CEA in the context of ballistic missile flight tests. The CCF12 campaign, carried out in collaboration with CEA/CESTA in an ONERA hypersonic wind tunnel at Meudon, enabled ground validation of the operation of a UATE (Onboard Acquisition and Processing Unit) designed by CEA for use in flight. This compact unit supplies power to the sensors and then conditions,

digitises and processes the signal. Digital frames are then emitted by the box to transmit only the most relevant data. This makes it possible to take maximum advantage of the limited data rate offered by telemetry during flight tests. The campaign validated the good behaviour of the on-board electronics (robustness and performance in a representative environment). The reduced measurements were compared with those from ONERA and CEA reference acquisitions, validating its performance and the relevance of on-board processing.

Optics: Nanocarb airborne campaign to measure greenhouse gases

For the purposes of an airborne campaign, ONERA and the University of Grenoble Alpes have co-developed Nanocarb cameras, very compact spectro-imagers, dedicated to the measurement of a specific gas, CO₂ and CH₄.M. Carried out with the CNRS, Météo-France, CnesSafire and the Service des Avions Français Instrumentés pour la Recherche en Environnement, the campaign, co-financed by the CNES, aimed to demonstrate the ability of Nanocarb cameras, combined with a hyperspectral camera, to detect the CO₂ plume emitted by a thermal power plant.

The campaign measured the plume emitted by the Belchatów power station (Poland), one of the largest coal-fired power stations in Europe. The hyperspectral images acquired by the Fenix hyperspectral camera, operated by ONERA, will provide additional information on aerosol content and ground reflectance.



Photo of the Belchatow power plant (Poland) taken on 8 October 2023 from the instrumented aircraft.

Optical propagation: NATO SET-304 measurement campaign a success

A multi-instrument experimental campaign was carried out at the ONERA Fauga-Mauzac laser base as part of the NATO SET-304 group. The aim was to improve control of the phenomena affecting the propagation of an optical wave through turbulence. Various experiments were carried out during the 5 days of data acquisition: test pattern imaging to develop innovative processing methods, wavefront analysis on extended and moving objects, characterisation of the effects of turbulence on the propagation of optical beams, subjects which benefited from the unique resources of ONERA's laser base (scintillometry, characterisation of meteorological conditions). The group included teams from FFI (Norway), FOI (Sweden), Fraunhofer IOSB (Germany), TAI and TUBITAK (Turkey), DRDC (Canada), US Army (USA), TNO (Netherlands) and ONERA.

Robotics: ONERA takes part in the COHOMA II challenge

ONERA took part in the CoHoMa II challenge, as part of a team made up of ISAE-Supaero, ENAC, LAAS-CNRS and Scalian.

This challenge, organised by the Battle Lab Terre of STAT (the French Army's technical section), aimed to provide operators in an armoured vehicle with a system enabling them to deploy air and ground robots around their vehicle to monitor the situation, identify threats and move forward securely in their environment. ONERA was able to highlight its work on decision-making autonomy and human-system interaction during the visit by General Pierre Schill, Chief of Staff of the French Army.

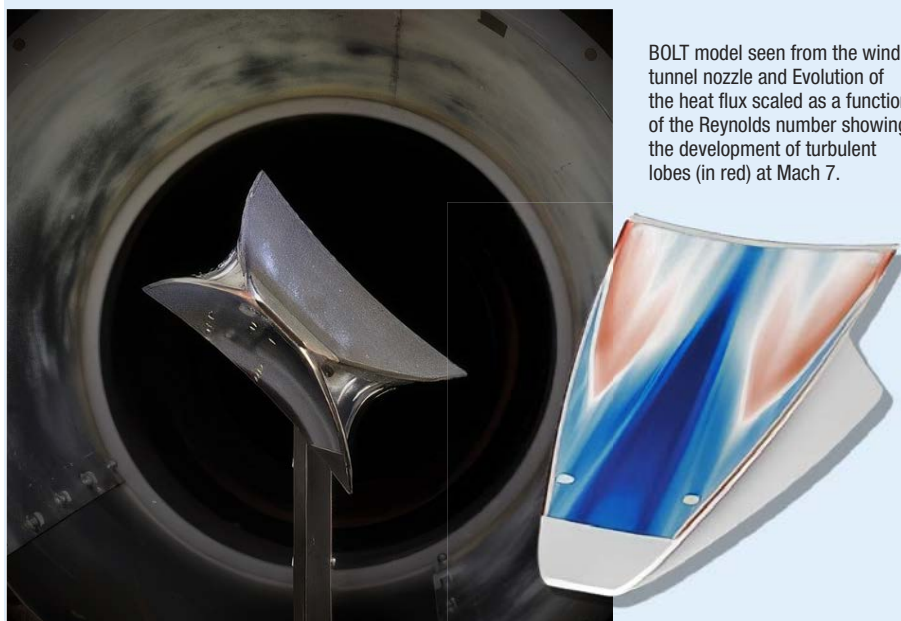


The team presented the various technological building blocks developed for the challenge: work on autonomous navigation, autonomous fleet movement, decision-making autonomy and control-command and decision-support systems for operators. ONERA's participation was particularly noteworthy, confirming its role as an expert in the field of autonomous robotic systems, combining research and experimental capabilities.

Hypersonics: A better understanding of the luminous-turbulent transition

The physical understanding of this subject is an important issue for the design and performance prediction of hypersonic missiles and gliders. The experimental campaign on the BOLT (BOundary Layer Transition) body, carried out in partnership with CEA-CESTA, in an ONERA hypersonic wind tunnel, aimed to analyse the boundary layer transition on a complex three-dimensional geometry. Various measurement techniques (infrared thermography and high-frequency pressure sensors, up to 300 kHz) highlighted the different stages of the transition, as a function of Reynolds number and Mach. The excess heat flows at the wall, associated with the change from laminar to turbulent state of the boundary layer, were measured by an infrared camera, while unsteady sensors were used to provide a local description of the appearance, linear amplification and non-linear evolution of transitional instabilities. These measurements, the most detailed to date within the community, are the fruit of ONERA's expertise in infrared measurements and high-frequency parietal pressure fluctuations.

This campaign was carried out as part of an international NATO collaboration.



BOLT model seen from the wind tunnel nozzle and Evolution of the heat flux scaled as a function of the Reynolds number showing the development of turbulent lobes (in red) at Mach 7.

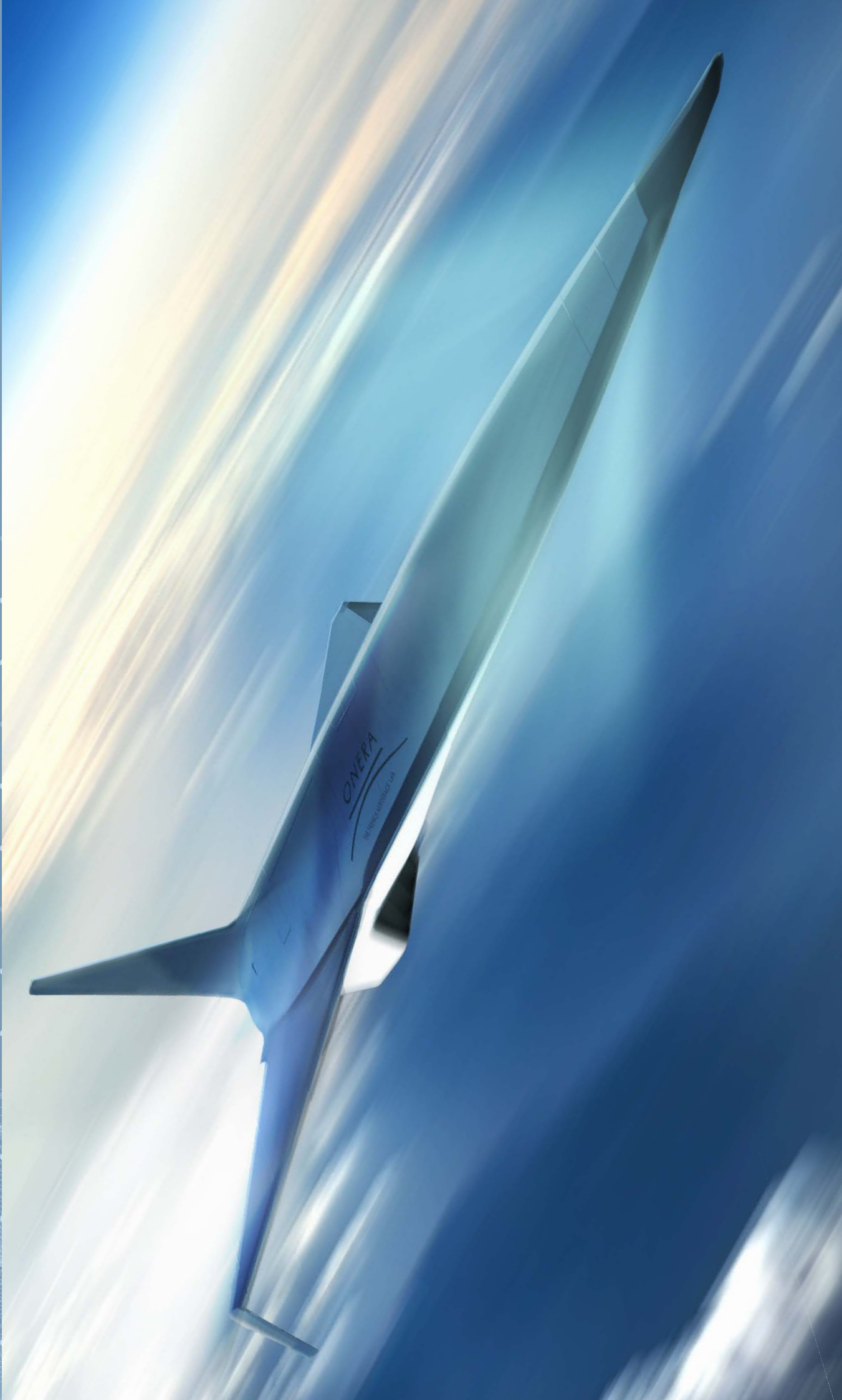
Space: New vacuum thermal analysis capability

ONERA has a thermal vacuum chamber to simulate the thermal conditions encountered in the vacuum of space. It allows the device under test to be subjected to a temperature profile over the range [-35°C, +80°C], while maintaining a secondary vacuum (pressure of less than 1.10⁻⁵ mbar) during the test. Allowing the temperature of the specimen to drop below the dew point temperature without any risk of condensation on the electronics, it is possible to carry out performance tests as well as vacuum qualification tests. This environment, which is representative of the vacuum of space, will enable the thermal sensitivities of the electronics housings of ONERA's ultra-sensitive accelerometers to be finely characterised, enabling their performance to be improved.

Compatible with the dust control specifications of the European (CNES, ESA) and international (NASA) space agencies, as it is located in an ISO 8 room, this enclosure can also accommodate small payloads or an entire CubeSat (up to 6U).



DEFENSE



ONERA A KEY PLAYER IN HYPERSONICS

Since the 1950s, ONERA, as an operator under the aegis of the Ministry of Defence, has been conducting the research needed to provide France with cutting-edge equipment. Its work is part of the 2019-2025 military programming law. It covers active stealth, multi-sensor data fusion, decision-making autonomy and, of course, reaching very high speeds for missiles and aircraft. In the field of hypersonics, ONERA can draw on its expertise in aerodynamics, propulsion, materials, thermics and stealth. At ONERA, hypersonics is mainly driven by the activities carried out for the benefit of our two airborne and ballistic components, but it also concerns related fields such as hypersonic aircraft and gliders.

ESPADON

military hypersonic aircraft project: designing the future and anticipating the threat

With the ESPADON federative research project, ONERA is fulfilling its mission of forecasting and analysing the technological obstacles to be overcome in order to create a disruptive military aeronautics of the future and to counter the new threats facing our future defence systems.

As a State operator under the supervision of the Ministry of Defence, ONERA helps to ensure that France has the best aeronautical and space equipment. As part of its mission to develop and guide aerospace research, it is a key partner of the Ministry of Defence and the aerospace industry. For example, the ESPADON FRP, commissioned by the DGA (Direction Générale de l'Armement), focuses on the design of a hypersonic military aircraft.

Through this project, ONERA is fulfilling its missions of :

- Monitoring and expertise for the benefit of the State and the armed forces;
- Innovation and foresight.

This project is based on ONERA's experience of aerobic hypersonic flight, developed since the 1950s, while benefiting in situ from all the skills needed to design an aircraft. It thus enables a global study combining aerodynamics, propulsion, materials, sensor design and systems of systems.

The ESPADON FRP is first and foremost a case study enabling us to imagine the contexts of use, the missions and the probable capabilities of such an aircraft, and thus to define the potential threat to our current and future weapons systems. With the Espadon project, ONERA aims to identify the key technological building blocks to be mastered, and even to propose technological roadmaps.

Through this project, ONERA is consolidating its role as an expert for the DGA and the armed forces.

ONERA took part in the test flight of the V-MAX hypervelocity glider

On 26 June 2023, the DGA carried out a flight of the V-MAX. Several ONERA teams are involved in this programme right up to the exploitation of the flight results. Sébastien Lecornu, the French Minister for the Armed Forces, congratulated the teams from DGA, ONERA and ArianeGroup on their work.

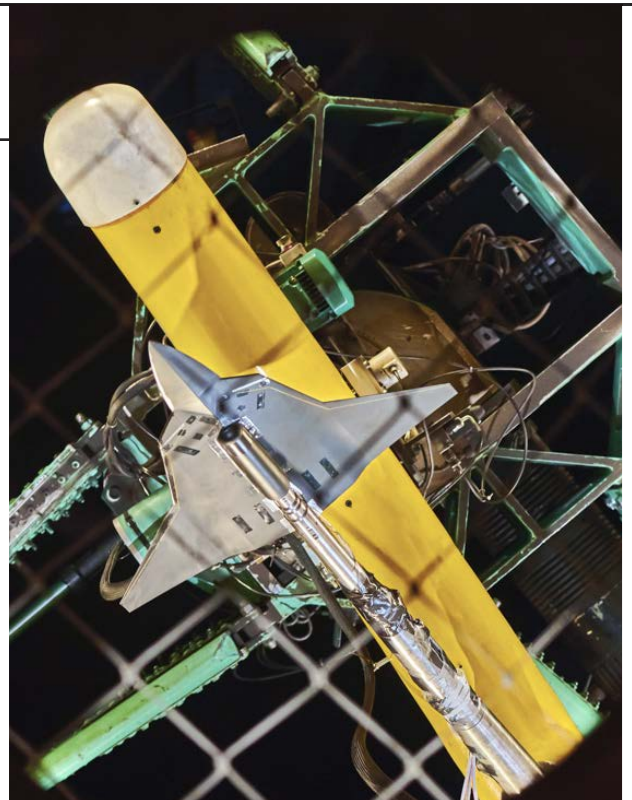


The SUPERMAN project

To provide the best possible support to its partners, ONERA carries out its own projects to advance its knowledge. The SUPERMAN upstream research project, conducted with internal resources, aims to extend its knowledge of the manoeuvrability of future combat aircraft concepts.

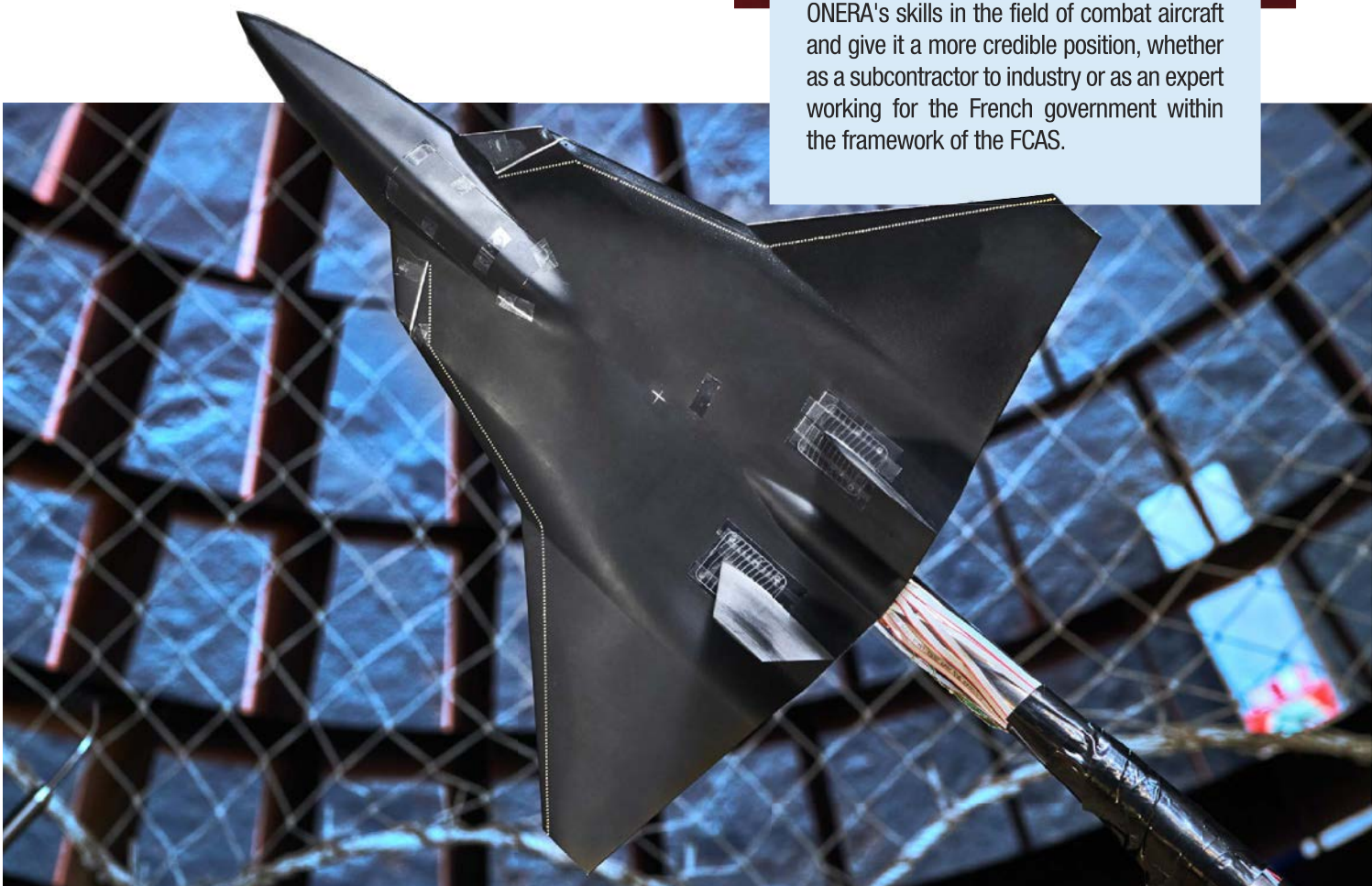
A generic shape, which could be representative of a future combat aircraft, has been defined. It will be used to experimentally characterise vortex flows at high incidence in order to establish the link between vortices and aerodynamic forces.

The low-speed wind tunnels at Lille L1 and SV4 are ideal for this purpose and provide additional information. The PQR set-up in L1 (P: roll rate, Q: pitch rate and R: yaw rate) allows rotational movements to be imposed on the model about each of its axes, and the rotating balance in the SV4 vertical wind tunnel allows the effects of rotation about the wind vector axis to be documented.



Preparing for the future

In particular, this project will strengthen ONERA's skills in the field of combat aircraft and give it a more credible position, whether as a subcontractor to industry or as an expert working for the French government within the framework of the FCAS.



SPACE SURVEILLANCE, ONERA A KEY PLAYER

GRAVES: a major strategic asset

Developed by ONERA in the 2000s, thanks to its expertise in information processing and radar, the GRAVES (Grand Réseau Adapté à la Veille Spatiale) space surveillance system maintains a catalogue of objects in low orbit, between 400 and 1000 km in altitude. It went into operational service in 2005, giving France an autonomous and sovereign source for establishing the space situation, and enabling it to engage in more balanced discussions with the major space powers.

In order to guarantee the system's operation until 2030 and to adapt it to changing operational requirements, the DGA called on ONERA to tender for a contract to renovate and improve the system (obsolescence management, improved signal processing and detection capacity, updated tracking and orbital analysis algorithms). The firm phase of this contract was delivered to the DGA at the end of June 2023 and accepted. Work is continuing to further improve the system's capacity.



Evolution of the global space scene

At the same time as this renovation work, the space environment has changed considerably with the arrival of the New Space dynamic: multiple players have entered the space market, which has multiplied the number of objects in orbit tracked by the system. Additional work has therefore been decided to enable the system to cope with the strong future growth in the size of the catalogue it maintains.

These activities require major modifications to the architecture of the processing system. The schedule has therefore been adapted to best meet the operational constraints in an incremental approach, the aim being to enable the Air Force to continue its mission throughout the work. By developing new algorithms and new computing architectures, ONERA is working to ensure a controlled transition to an even higher-performance system.

For more than 20 years, successive notifications and uninterrupted collaboration between ONERA, the DGA and Air Force operational staff have underlined the recognition of ONERA's expertise.

ASTAREON

On 30 May 2023, ONERA created ASTAREON, its first subsidiary, to capitalise on its historic expertise in space surveillance, which is unique in Europe. ASTAREON, a new player in NewSpace, will provide space surveillance services from 2024 to meet the growing challenges of safety and security in space.

ASTAREON draws on ONERA's expertise and know-how. Engineers with expertise in the GRAVES space surveillance system and associated operations form the core of ASTAREON's technical expertise. From the beginning of 2024, ASTAREON will market surveillance data on objects in low-Earth orbit, based on the first MEDOC passive reception station developed by ONERA. This station uses the GRAVES signal to autonomously detect and restore the orbits of objects in low-Earth orbit. After the first signals are received in October 2023, qualification at the beginning of 2024 will make it possible to provide a highly competitive commercial service, based on a technologically mature solution.



NEW GENERATION OF RADARS: KEEPING ITS TEST FACILITIES UP TO DATE

Surface wave radar (SWR)

The surface wave effect enables coastal HF radars to observe maritime zones beyond the horizon. Between 2007 and 2010, ONERA installed an initial demonstrator at the DGA centre in Biscarrosse (detection of small targets in sea clutter). In 2011, a version with a linear synthetic antenna was installed at DGA's Levant Island site. The synthetic antenna's operation and performance were validated, but the site did not allow continuous H24 transmission.



SWR Salins reception antennas with solar panel.



Row of 6 transmitting antennas.

In order to provide comprehensive statistics, ONERA will start installing a SWR at the Salins du Midi site in Aigues-Mortes in 2021. The principle of the synthetic antenna has been extended to a 2-dimensional version. This will enable the beam to be formed in elevation, thus significantly reducing ionospheric clutter, and increasing the total number of antennas in the virtual array without the array becoming too long.

The radar, which is isolated, covers an area of several square kilometres and is located in a Natura 2000 classified zone. ONERA has developed low-profile antennas using optical fibres to transmit analogue signals over long distances. The basic transmitting antenna consists of a pair of T-shaped antennas in end-fire configuration. Eighteen antennas of this type were installed during 2023, and the complete transmission system

is being finalised in early 2024. The complete radar will be ready for trials in April 2024, when military manoeuvres will be carried out in the Gulf of Lion as part of the DGA SURMAR study.

Anti-drone warfare

SAP is representative of the needs of today's armed forces: innovative solutions that have been validated by the armed forces and can be rapidly industrialised.

The DIAMOND module developed by ONERA, the heart of the SAP (Single Air Picture) software, was successfully deployed at the 2023

Rugby World Cup as part of the stadium protection system against malicious drones. The aim of this software is to present a single drone aerial situation to the defence and security services in charge of protecting major events. The Rugby World Cup provided an opportunity to test all the anti-drone components that will be deployed for the Paris 2024 Olympic and Paralympic Games.

The added value demonstrated by SAP is its ability to optimise the conduct of anti-drone



NOSTRADAMUS

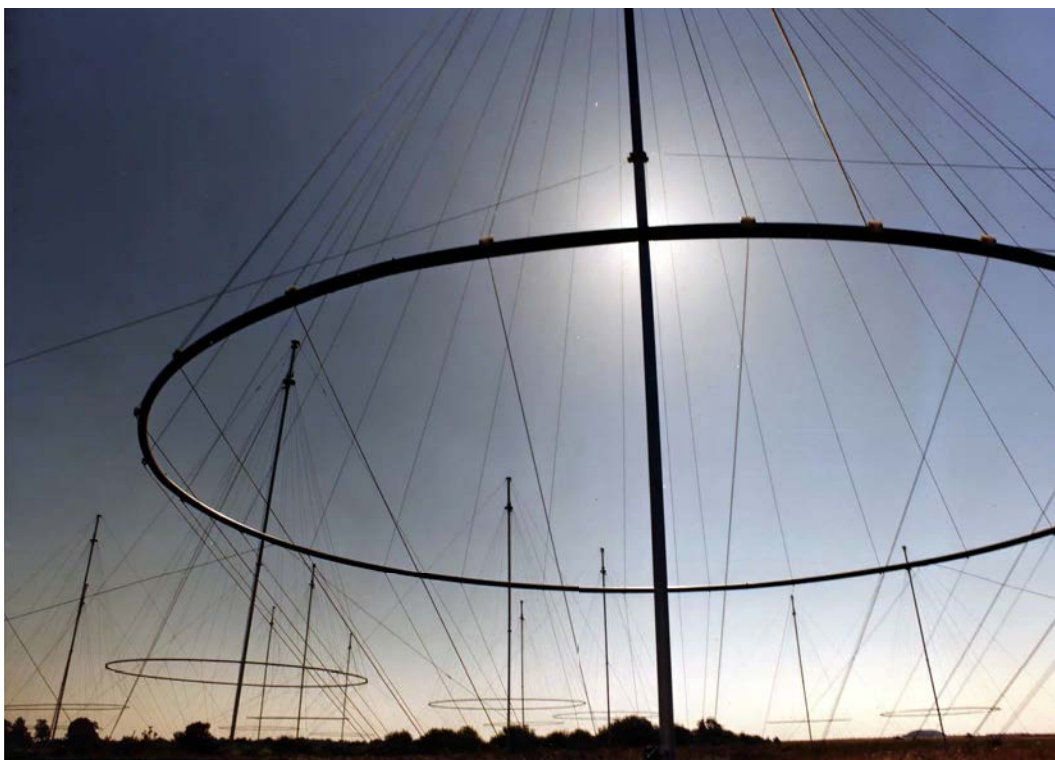
ONERA has expertise in the field of skywave over the horizon (OTH) radars operating in the HF band.

The NOSTRADAMUS demonstrator is the first generation of transhorizon radar developed with DGA funding. With this sensor, ONERA has a unique, complete and autonomous tool, capable of detecting targets beyond the horizon.

ONERA is constantly upgrading its resources: it has developed a second generation of trans-horizon radar, the PEGASE demonstrator, also with DGA funding: for this new bistatic structure, the NOSTRADAMUS reception system has been modified for continuous operation. The performance of PEGASE has been analysed for long-range aerial surveillance and ballistic surveillance applications.

In 2023, as part of the same drive to modernise its facilities, ONERA has initiated an internally-funded project to improve the sensor's performance, sensitivity and availability. It thus remains a major French player in the field of HF skywave radar for the detection of moving targets at long range.

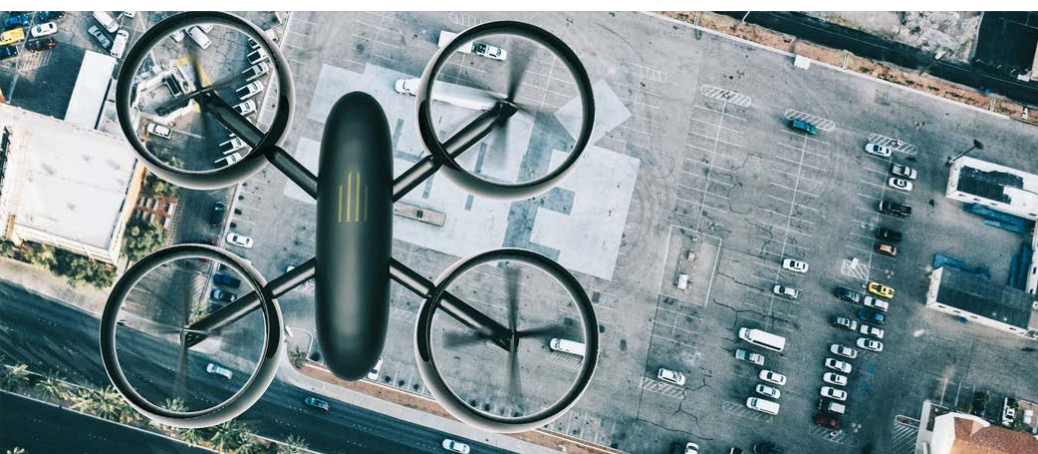
The demonstrator has gone 'all digital' for transmission and reception, demonstrating the contribution of innovative, low-



cost technologies. Multi-function and multi-channel applications could be envisaged, with multi-frequency, multi-code, simultaneous or interleaved operation for radar surveillance, multi-sector listening or new (hybrid) configurations.

Work has also been carried out to adapt the sensor to new climatic conditions (reduced temperature rise in the pits during the summer).

At the same time, ONERA is involved, as technical leader, in the European iFurther project to develop a network of HF sensors for surveillance of European borders.



operations, by providing a real-time overview of known drones (media, security and defence forces) and, where applicable, malicious drones that could disrupt the smooth running of a major event.

This software will continue to evolve over the coming months to provide other functionalities requested by operational staff to deal with the rapidly changing drone threat.

AERONAUTICS



REDUCE OUR ENVIRONMENTAL FOOTPRINT OF TRANSPORT AIRCRAFT

Reducing fuel consumption

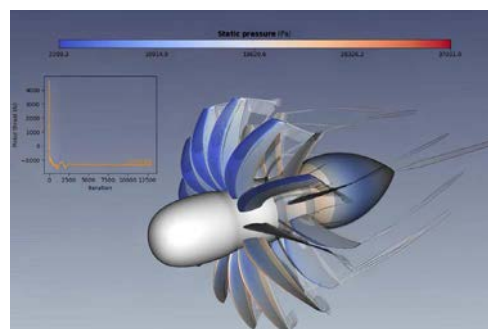


ONERA is carrying out research on high bypass ratio engines (open fan in particular) and on the aspects of engine integration and high aspect ratio wings. All these technologies have been integrated into the GULLHYVER aircraft configuration, presented at the 2023 Paris Air Show. This open-fan concept, powered by hydrogen and equipped with a high aspect ratio

wing, uses a non-sheathed propeller engine.

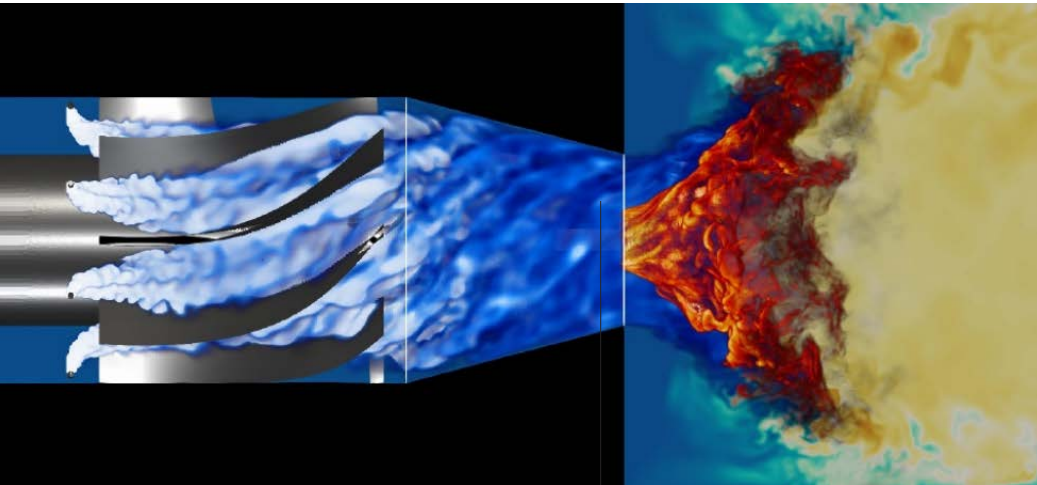
The explorations are based on a multidisciplinary dimensioning process, which makes it possible to identify the benefits of each of the new technologies studied separately, but also the additional gains linked to their simultaneous and complementary use in a realistic configuration.

The issue of long wings is also being studied in the AWATAR (Advanced Wing MATuration And integRation) project, coordinated by ONERA, the aim of which is to develop key technological building blocks for future certification processes. Starting on 1 January 2024, this project aims to bring to maturity a promising wing concept with a very high aspect ratio and guyed wing architecture, laminar sections in the outer areas, integrated de-icing systems, and optimised integration of a USF (Unducted Single Fan) type system



Numerical simulation of an open-fan configuration.





High-pressure aeronautical hydrogen/air vortex injector with pure hydrogen injection pilot.

Reducing carbon intensity

This second lever is driving research into new fuels: the impact of the use of synthetic fuels (biofuels and electrofuels) on fuel systems and emissions, and longer-term studies into completely carbon-free fuels such as hydrogen in the fields of combustion (NOx control in particular) and hydrogen-materials interactions. ONERA is studying these two themes via the PHYDROGENE and PHYDROMAT DGAC agreements, which are in line with the roadmap defined by CORAC (decarbonisation of air transport) to explore the potential application of hydrogen in aeronautics.

Notified in June 2023, the DGAC PHYDROMAT project focuses on understanding hydrogen embrittlement mechanisms in alloys. The aim is to study the effects of embrittlement caused by the penetration of hydrogen into the material. In 2023, initial electrochemical loading tests and thermal desorption spectroscopy analyses demonstrated the validity of the experimental method. In addition, the work required the development of numerical calculation tools that will be used in the remainder of the project.

The objectives of the DGAC PHYDROGENE project are to study turbulent hydrogen/air combustion and to develop an optimisation methodology that will ultimately accelerate the design process for hydrogen injectors compatible with future

regulatory requirements for NOx reduction and operability. In 2023, the first high-fidelity simulations of the MICADO configuration (bench and ONERA injector, inlet air temperature and chamber pressure representative of a real aeronautical engine) enabled us to highlight a particular flame structure and to understand the mechanisms contributing to its stabilisation.

Finally, the first version of a complete single-fidelity functional optimisation chain was set up.

Another way of reducing carbon emissions is to electrify aircraft propulsion. For 3 years, ONERA coordinated the IMOTHEP project (selected by the European Commission as part of Horizon 2020). In 2023, a final workshop was organised: around sixty participants from all backgrounds, covering 18 projects from the H2020/Horizon Europe and Clean Sky2/Clean Aviation programmes, shared their vision of hybrid propulsion and its prospects. The discussions highlighted that short-range applications (commuter and regional) are the primary target for hybridisation in the coming years

EFFICIENCY, SAFETY AND CERTIFICATION OF THE AIR TRANSPORT SYSTEM

The risk of fire

Aeronautics is undergoing a major transformation, with electrification, sustainable alternative fuels and hydrogen: the aircraft of the future will carry an even greater density of energy within ever lighter structures, probably made of composites. Fire safety will be a key stage in the deployment of these technologies.

Outcome of the PHYFIRE2 agreement

The aim was to reduce risk by developing increasingly high-performance structural materials. The agreement ended in November 2023 with a double day of exchanges. In particular, ONERA made progress on the characterisation and modelling of thermo-mechanical properties at temperature, as well as on innovative approaches to predicting phenomena such as delamination by coupling Z-set (mechanics and cracking) and MoDe-TheC (thermal and thermodegradation).



PyCoFiRe

In 2023, the completion of the acceptance of this new fire test platform means that it can be scheduled for inauguration in 2024. PyCoFiRe will be used to experimentally simulate spray fire incidents (immediate ignition of a paraffin mist resulting from a leak in a fuel line) and pool fire incidents (fuel leak draining and accumulating in the lower part of the compartment before igniting) in 2 engine compartment models located in a fire zone (FAN and CORE). PyCoFiRe will also be able to simulate incidents without fire that could lead to a similar level of thermal aggression. The Occitanie region has awarded ONERA a grant of more than €10m in ERDF funding out of a total budget of €14m.

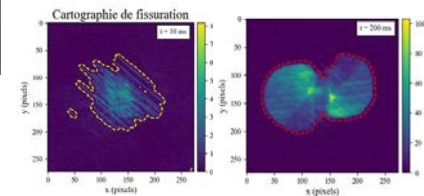
Lightning risk

New types of damage detected in composite materials

ONERA has obtained new results characterising the effects of lightning on composite materials. This work, supported by the DGAC, France Relance and Next Generation EU, via the PHYLIGHT2 agreement, highlights a new type of damage. Intra-ply tearing was identified by in-situ thermography on thermoplastic carbon fibre composite panels during the 2023 test campaign on the ONERA GRIFON test bench.



Banc GRIFON. À droite : plaque après foudroiement - Ci-contre : cartographies thermiques à $t = 10$ ms et $t = 200$ ms et estimation de l'aire d'endommagement.



Flight limit risk

Études et essais sur le flottement

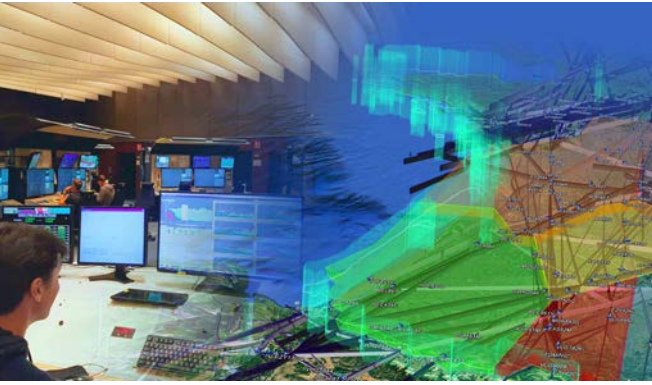
A sophisticated system to eliminate flutter

A team of European researchers, including engineers from ONERA, has taken up one of the key challenges of aeroelasticity: eliminating the phenomenon of flutter by means of an active control system. This is the aim of the European FLIPASED (Flight Phase Adaptive Aero-Servo-Elastic Aircraft Design Methods) project, conducted as part of a partnership between DLR, SZTAKI (the Hungarian Institute of Computer Science and Control), ONERA and TUM (Munich University of Technology).

To prevent this phenomenon using active systems, the principle was to use aircraft control surfaces, sensors and intelligent control laws. The aim was to determine the extent to which this principle of active flutter control could free up the design of an aircraft and ultimately reduce its weight.

Several stages were necessary: developing tools for modelling a flexible aircraft, control algorithms to make it fly beyond its natural float entry speed, and validating these tools using a low-cost, low-risk demonstrator.





SINAPS, artificial intelligence applied to air safety

In December 2023, the French Directorate of Air Navigation Services (DSNA) adopted SINAPS, an AI tool for optimising airspace for air traffic, the result of collaboration between ONERA and the DSNA. Developed by ONERA as part of the European SESAR programme, this algorithmic engine is an innovative tool based on "tailor-made" artificial intelligence that provides operational staff with decision-making support for managing control sector configurations.

UAVS

Onera contributes its expertise to the French government and fosters industrial innovation. Its multi-disciplinary approach and 30 years' experience in aerial robotics, combined with a large fleet of UAVs, are key assets that enable Onera to work on the main challenges in this field: it is conducting research into safer, more efficient UAVs, and into the surveillance of malicious UAVs.

Aerology - Effect of wind on the flight dynamics of a drone



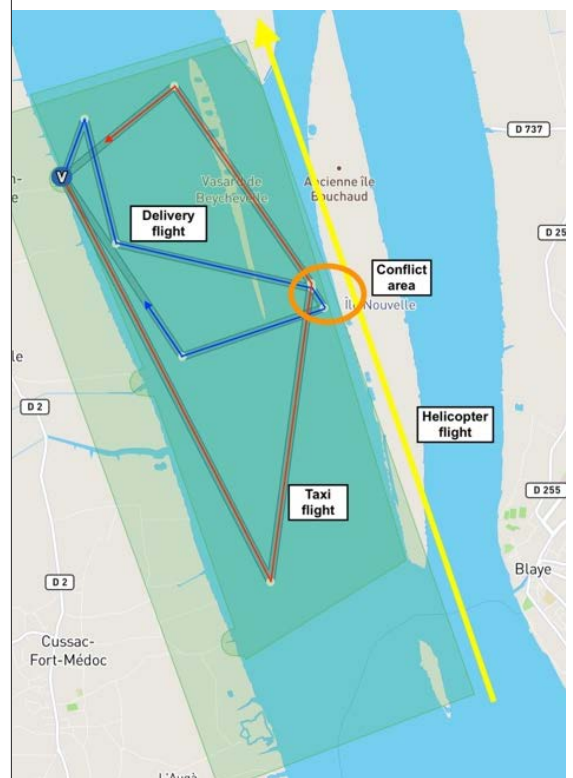
Regulation of drone operations and urban air mobility require methods for analysing the effects of wind, and proposing ways of reducing the risk associated with this hazard.

Tests to measure the effects of rotor interactions on a small drone subjected to the effects of wind have been carried out in the free flight laboratory at the Lille centre (laboratory equipped with a gust generator). 12 cameras measure the position and attitude of objects with great precision.

The tests show that in interaction with the wind, the motor speeds of rotors located upstream of the flow are lower than those located downstream. They pave the way for the establishment of drone flight models in a disturbed environment, which will make it possible to predict trajectories and make progress on the issue of flight safety.

Deconfliction: TIND'AIR

A demonstration of conflict management between different types of aircraft has confirmed the feasibility of tactical deconfliction for the future controlled airspace system. The main objective of the EU-SESAR TINDAIR project was real-time conflict resolution between UAVs, eVTOLs and manned aircraft in controlled airspace (U-Space) to ensure flight safety. Several scenarios including a situation not foreseen in the flight plans were used to test how well the system works, detecting and managing conflicts by taking priorities into account and generating rerouting and holding orders.



NOISE REDUCTION

Human sciences: understanding the nuisance caused by aircraft noise

Reconciling studies on human factors with those on acoustic factors is becoming a major concern when it comes to assessing the annoyance caused by aircraft noise. This is the aim of CIGALE (Conciliation des études sur la Gêne Aéroportuaire en Laboratoires et des Enquêtes de terrain), a DGAC project led by ONERA (2019-2023), in partnership with the MSHS-T (CNRS) and Airbus Aviation.

6 profiles of local residents have been identified on the basis of non-acoustic factors (rather positive or rather negative attitude towards air traffic, coping strategies, etc.).



A listening test was carried out in ONERA's new listening room at Châtillon. The idea was to read short stories during which the test subjects were exposed to different noise scenarios (aircraft passing overhead at different noise levels). After each scenario, the participants noted the impact of the noise on their activity.

Result: the positive or negative nature of the profile seems to have an impact on the level of annoyance experienced, without influencing the strategy of their response to the acoustic factors. The results need to be transferred to the operational world so that the annoyance of local residents can be better taken into account.

Technologies: testing "acoustic" liners on helicopter fenestrans

Since 2021, ONERA has been participating in the DGAC MOTUS project (Minimisation of the Operational Acoustic Impact of VTOLS in Urban Conditions), by designing an acoustic liner adapted to the fenestron diffuser, to accentuate the initial noise reduction.

The liner proposed by ONERA is based on an ONERA-patented surface treatment concept called LEONAR (Long Elastic Open Neck Acoustic Resonator), which provides acoustic efficiency at frequencies well below those of conventional liners within defined integration constraints.



SPACE



ONERA has confirmed its position as a key player in the space ecosystem, thanks to its long history of work and its in-depth knowledge of the disciplines needed to solve its partners' problems. This role will be strengthened by the new situation imposed by Newspace and the preparation of future European work programmes in the space sector.

SPACE MISSIONS

ONERA on board the JUICE mission



For ESA's latest space mission, JUICE, which will be successfully launched in April 2023, several challenges have been met thanks to ONERA: the design of innovative instruments and the assessment of certain aerospace environments and their consequences on onboard systems.

The aim of these instruments is to gain a detailed understanding of plasma interactions between Jupiter and its main icy moons: ONERA has modelled the neutral, ionised and electromagnetic environments of Ganymede, as well as their impact on the probe's measurements, in collaboration with a number of CNRS laboratories.

ONERA has also contributed to studies into the survival of the satellite and its payload in Jupiter's hostile space environment. In collaboration with ESA, CNES and various European manufacturers of the satellite and payload, in particular Airbus Defence and Space, ONERA has applied its expertise to the effects of the space environment (numerical simulation and experimental characterisation). JUICE solar cells were tested for Airbus Defence and Space using ONERA's MIRAGE electron and proton irradiation facility, a unique facility: NASA has

asked to re-use these results for the Europa Clipper mission. MIRAGE was also used to test onboard solar sensors.

Microscope 2

By testing the equivalence principle to an accuracy of 10-15, MICROSCOPE has not only confirmed the theory of General Relativity, but has also made it possible to exclude parts of space from the parameters of competing theories. For example, MICROSCOPE has made it possible to constrain the intensity and range of a possible fifth force behaving like gravity, as well as the possible mass of particles predicted by string theory (and as yet unobserved). As this type of particle is a candidate for dark matter, several teams of scientists have launched a search for it. ONERA is aiming to improve the MICROSCOPE results by a factor of 100, which would provide a new test of General Relativity, and new constraints on this type of dark matter. The MICROSCOPE 2 project, which is just getting underway, is based on the MICROSCOPE model, and the instrument will be improved to significantly increase the accuracy of the measurements.

In Europe's next space geodesy mission

ESA has called on ONERA, world leader in space accelerometry, to supply 3 "new generation" accelerometers for each of the 2 satellites due to be launched around 2032. These new MicroSTAR accelerometers, developed with ESA since 2022, should achieve performance of the order of 0.1pico-g on all 3 axes, and pro-

vide angular accelerations at levels of precision never before achieved.

This activity is being carried out in parallel with the supply of 2 accelerometers to the JPL (Jet Propulsion Laboratory) and NASA for the future GRACE-C mission, which will be launched at the end of 2028. NGGM and GRACE-C will form the MAGIC constellation of 4 satellites, dedicated to mapping the Earth's gravity field and its evolution with unprecedented precision

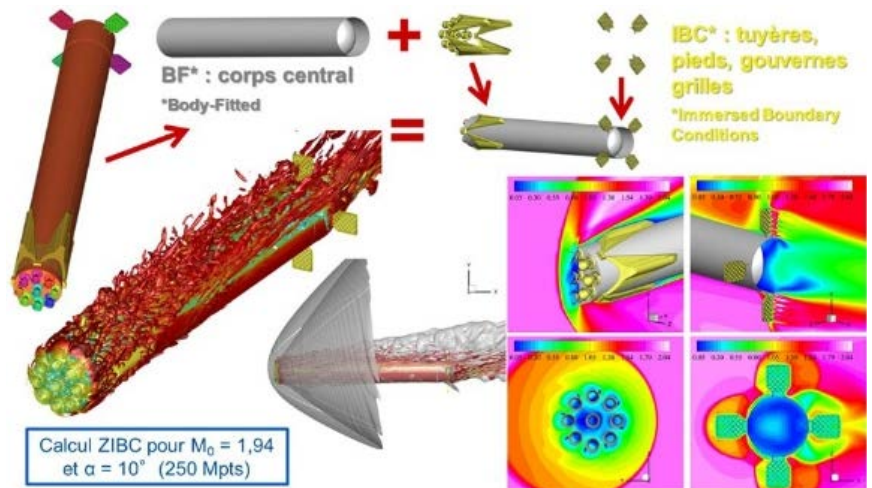
ONERA at the heart of one of the largest telescopes in the US

ONERA and its partners have won an NSF (US National Science Foundation) tender worth more than \$10 million to design the adaptive optics (AO) for the Gemini North astronomical telescope. As part of an international consortium led by Macquarie University in Sydney, ONERA and its partners, the Marseille Astrophysics Laboratory, the Observatoire de Haute Provence, the SME ALPAO and the start-up Space ODT, will begin designing a laser-assisted tomographic AO system. This is the new generation of AO for one of the world's largest and most powerful astronomical telescopes. GNAO (Gemini North Adaptive Optics) will incorporate the very latest innovations in the field, freeing it from the deleterious effects of atmospheric turbulence and enabling it to reach its diffraction limit (and therefore its ultimate performance) over almost the entire sky. This success, achieved in a highly competitive international environment, is the culmination of more than 30 years of unique expertise at ONERA and places its teams at the forefront of the field worldwide.

Reusable launchers: a new strategy for their simulation

ONERA has carried out the first massive ZDES unsteady numerical simulations in the design phase of a reusable launcher prototype. The aim is to study, for a post-Ariane 6 reusable launcher concept, the poorly understood sequence of physical phenomena encountered during flight, which could potentially damage performance and flight control (CNES R&T programme).

These simulations will also enable digital simulation strategies to be adapted, to reduce development cycles in the design phase and the associated costs. The ZIBC (Zonal Immersed Boundary Conditions) strategy, developed at ONERA, successfully combines an advanced turbulence modelling method (ZDES approach) and an immersed boundary conditions (IBC) technique.



The simulations go right down to the technological details, such as the grid control surfaces, which are particularly difficult to reproduce numerically (thin walls). They have made it possible to locate and quantify the maximum fluctuating pressure levels in the engine bay, feet and grid control surfaces, which will

make it possible to assess the structural stresses with a view to sizing new-generation reusable space launchers.

GROUND-SATELLITE LINK

RADIO FREQUENCY & RADAR

Radio propagation: characterisation of the multi-frequency propagation channel in a tropical region

As part of the joint programme of interest on radio frequency electromagnetic propagation (PIC PERF) with CNES, ONERA, in collaboration with the DSNA (navigation services directorate) in Guadeloupe, carried out an Earth-space propagation experiment with the Eutelsat E65WA satellite. This experiment made it possible to collect attenuation measurements at 12 GHz, 20 GHz and 40 GHz, H24, 365 days a year, for 3 consecutive years with an exceptional availability of over 95%, which is a world first. The results obtained in this region of the world, which is subject to very heavy rainfall, show that in order to avoid link interruptions lasting more than 8 hours a year, margins of 4 dB in Ku band, 13 dB in Ka band and more than 35 dB in Q band are required, i.e. practically three times those usually encountered in Toulouse in temperate regions.



11.2 GHz, 19.7 GHz and 39.8 GHz beacon receivers and tipping bucket rain gauge.

Modernisation of NOSTRADAMUS

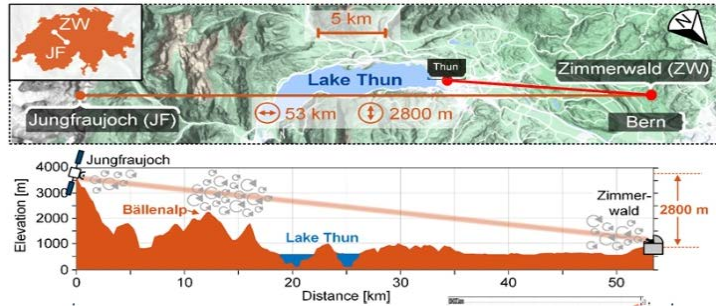
ONERA, with internal funding, has decided to modernise its NOSTRADAMUS over the horizon radar system. The modernization of the demonstrator consisted in making it fully digital (transmission and reception), by demonstrating the contribution of innovative low-cost technologies ("radar waveform generation by digital synthesis", "digital broadband reception" and "distributed synchronization" over long distances and for a large number of nodes).

OPTICAL LINK

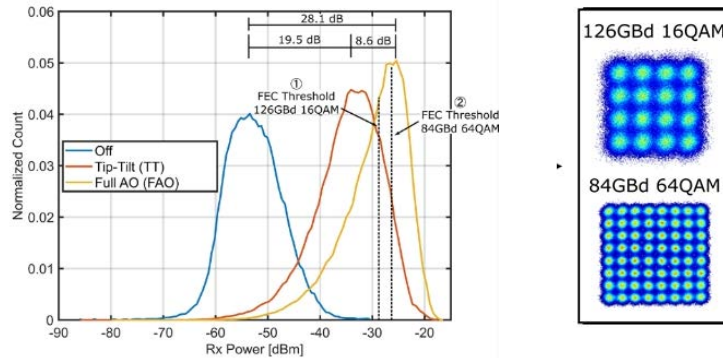
World record during VERTIGO tests: adaptive optics achieve Tbit/s on a 53 km coherent optical link.

The aim of the VERTIGO project was to make progress on all the essential building blocks for very high-speed ground-GEO optical links. This project enabled ONERA to work with several major players in optical telecommunications, including Thales Alenia Space, the project leader, and ETH Zürich (Institute of Electromagnetic Fields). ONERA contributed its expertise in the turbulent channel (correction by adaptive optics and in situ turbulence metrology).

The keystone of the project was the establishment of a high-speed link, with a single-channel data rate of 1 Tbit/s, achieved using sophisticated coherent modulation formats, a record for such a line of sight: 53 km between two sites. This record performance was made possible by the adaptive optics correction provided by ONERA's ground station, comprising the FEEDLIO bench (adaptive optics and 35 cm telescope).



Geometry of the line of sight during VERTIGO field trials in July 2022 in Switzerland.



Coupled flux enhancement with adaptive optics - comparison in the following modes: no correction ("Off"), simple pointing correction ("Tip-Tilt TT") and global correction with adaptive optics ("Full AO (FAO)"). The thumbnails on the right show an example of constellation in the coherent 16QAM and 64QAM formats, in cases corrected by adaptive optics.



New FEELINGS ground station

ONERA has acquired a new means of characterising the optical propagation channel in the atmosphere, using a device that it designed and which is unique in Europe: FEELINGS (Feeder Links optical Ground Station). Developed by its optics department, using its own investment budget, FEELINGS is designed to understand the effect of the atmospheric channel on optical links, and in particular the feeders (highly capacitive data links) that will supply telecoms satellites in geostationary orbit with data of all kinds, so that this data can then be relayed to other satellites, to the ground or to other types of carrier. At the end of October 2023, FEELINGS received a key component, the 60 cm telescope, giving ONERA the capacity to track satellites with optical precision into low-Earth orbits (LEO). The telescope has already demonstrated an absolute pointing capability better than one arcsecond on designation, offering the possibility of open-loop LEO satellite tracking with decametric precision. The station will be officially inaugurated in spring 2024.

NEW SPACE

Reception of the 1st set of measurements of the ionosphere

ONERA's CUIONO payload has successfully received and sent back radio waves emitted from Earth. It received a radio signal emitted from the Crucey testing facility (Eure-et-Loir) and sent this signal back to the LATMOS station (Atmospheres and Space Observations Laboratory). This device, one of the modules of the InspireSat-7 nano-satellite launched on 15 April 2023, was designed to characterise the state of the ionosphere, by studying the disturbances it causes to radio waves.

CUIONO is a technical feat, having been developed in less than 2 years by adapting pre-existing components.

Successful mechanical integration

In collaboration with ISAE-SUPAERO, and thanks to ERDF funding, ONERA was responsible for the design of the 3U CREME (Cubesat for Radiation Environment Monitoring Experiment) nanosatellite, produced by U-SPACE. The mechanical integration of the ONERAD payload took place in December 2023. This autonomous payload consists of the radiative particle detection heads and its electronic data acquisition and processing chain. Technological advances include the miniaturisation of the radiation monitor (in terms



of size and weight), the design of the electronic cards using components that are tolerant to space radiation, and the design of the European digital core that meets the requirements for withstanding space radiation in the usual orbits. ONERA was also involved in taking account of severe thermal constraints to optimise the production of ONERAD.

FLYLAB mission: experimenting in Space

This flying laboratory is made up of 2 nanosatellites, equipped with 100% ONERA payloads, which aim to carry out innovative scientific demonstrations in optics, radar and systems, developed rapidly and at an affordable cost.

At the end of 2023, ONERA carried out the preliminary definition review of the platforms for the two nanosatellites with

the supplier. The design of the platforms was carried out under ONERA supervision, and is based on its specifications, as well as the definitions of the mechanical, thermal, electronic and software interfaces of the payloads of the two nanosatellites. Two "flats" - table-top models of the satellites - have been delivered to ONERA to enable the teams to develop the payload software modules in a representative environment. The launch is scheduled for 2025.

Studying the space environment

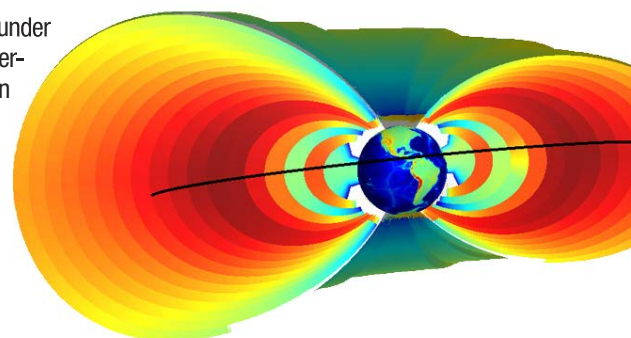
ONERA is working on the CROCUS (ChaRging On CUbeSat) project, in partnership with the École Polytechnique Space Centre (CSEP), which aims to study the electrical charge induced by the space environment, validate a new generation of payloads, and demonstrate the effectiveness of an ONERA electron emitter in limiting the negative charge of satellites. The instruments will be integrated on a CubeSat 3U satellite, for injection into a low sun-synchronous orbit. Regular passes through auroral zones, which are known to produce high levels of charge, will enable the satellite to detect and characterise electrostatic discharges and improve our understanding of electromagnetic coupling phenomena with the platform. Launch scheduled for 2026.

SPACE WEATHER

ONERA takes part in space weather in Europe

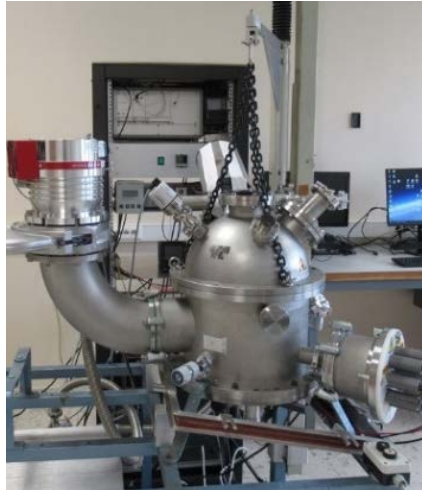
As part of the ESA ESOC Space Situational Awareness Program, ONERA has developed two prototypes offering users of the ESA Space Weather portal information and alerts dedicated to radiative risks on space missions. The aim of these prototypes is to assist satellite operators and designers in the rapid analysis of potential risks, in real time.

This prototype provides alerts for the next 3 days, depending on the satellite orbit under consideration, relating to two major risks: degradation of the solar panels and the internal load. ONERA codes are used to reconstruct and predict the radiative environment in the orbits of interest. The second prototype, RB-IND (Radiation Belts Activity Indices), also offers a three-colour risk indicator for the effects of solar panel degradation, as well as surface and internal load degradation. Its main aim is to use the most accurate in-situ measurements to provide the most appropriate information on the risks incurred in the preceding days.



LUNAR DUST: Dusting off the lunar missions

ONERA has been working on the subject of electrostatic charging and dust adhesion in space for nearly 10 years, and has an original range of experimental equipment and key skills that are fuelling a wide range of studies for ESA and the EU. The DROP platform houses a dust deposition chamber, validated on a series of powders simulating lunar dust, as well as a vacuum chamber reproducing the lunar environment. This platform is used to characterise adhesion strength and to test electrodynamic decontamination. It was used to validate a system manufactured by the equipment manufacturer COMAT to protect optics as part of a study carried out for ESA, as well as to validate the centrifuge used to characterise the



adhesion of lunar dust stimulants to technical space materials.

Major upgrades to the SPECTRO laboratory's measurement bench are also underway to meet new requirements for characterising the adhesion of space-grade materials and studying the degradation of thermo-optical properties, coatings and solar panel cells, and to provide reference measurements.

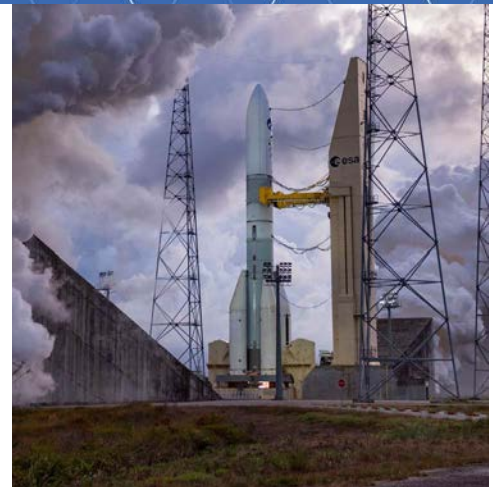
This experimental park is associated with a modelling capability, in particular 3D numerical modelling of dust layers (SPIS software, Spacecraft Plasma Interaction System), ESA's reference software for the study of electrostatic charge, for which ONERA is the main developer.

ONERA is currently using all these resources to design and test a dust detector as part of the DUSTER project (2023-2024) funded by the European Union.

ACCESS TO THE SPACE

Ariane 6: Contribution to the preparation of the maiden flight

As part of the combined tests aimed at qualifying the Ariane 6 launcher before the maiden flight, ONERA assisted CNES during the so-called "short" and "long" tests of the Vulcain2 main engine. Its rocket propulsion laboratory (LPF) was responsible for instrumenting the launch pad with heat flux and temperature sensors, in particular to validate the operation and durability of the jet containment system (water torus, nitrogen torus and jet guide). The LPF team designed and then manufactured these instruments so that they could provide robust measurements in this ultra-severe environment, with its extreme temperature effects, supersonic jets and very high-speed water flow. The LPF laboratory also took part in installing the sensors and checking that they were working properly on site in Kourou. ONERA's measurements were a success from start to finish.



Instrumentation for measuring temperature in the jet guide.



Heat flow measurement block on the VULCAIN 2.1 engine before shipment.

Ariane 6 launcher at ELA4 during long fire test (ArianeGroup).

ONERA'S LARGE WIND TUNNELS

S1MMA

AT THE SERVICE
OF AERONAUTICAL
INNOVATION
AND DEFENSE

F1

2023, a year with even more orders heralds a period of high activity

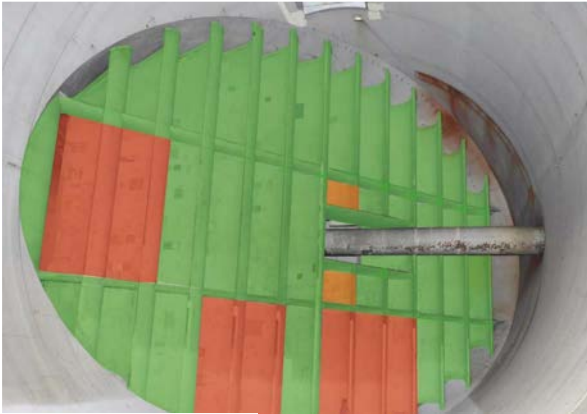
2023 ended with a record order intake for the Wind Tunnels division (€37.5m), surpassing the 2009 figure, the highest level recorded in recent years. This is mainly due to the ramp-up of defence programmes, as well as work linked to the decarbonisation of civil aviation, and in particular to new engines and engine integrations, the first tests of which were carried out in 2023 in the large S1MA wind tunnel. These tests mark the start of a long series of highly complex tests and confirm, if confirmation were needed, the importance of having launched the rescue plan for S1MA. On the Defence side, 2023 was mainly marked by emblematic tests in the gust wind tunnels relating to deterrence and sovereignty. The S2MA high-speed wind tunnel and the F1 and CEPRA 19 wind tunnels were mainly used by foreign customers and for Rafale export activities. In addition to this intense contractual activity, we also carried out major capacity development work, financed by the ATP project and DGAC agreements.



Ecoengine tests to S1MA.

ATP programme continues to maintain and modernise large wind tunnels Wind tunnels

2023 was also a record year in terms of activity and commitments for the ATP investment programme, launched in 2019 to keep the infrastructure of the major wind tunnels operational, increase their productivity and modernise them to meet the future testing needs of defence and civil aeronautics.



Work to replace the first elbow of the S1MA wind tunnel.

The project to replace the first elbow in the S1MA wind tunnel (which deflects the flow leaving the test section by 90 degrees towards the fans) has come to fruition with the launch of production of the 12 blades that make up the new elbow, which will be almost 150 m long and weigh more than 50 tonnes. Final installation of the new elbow in S1MA is planned for 2024.

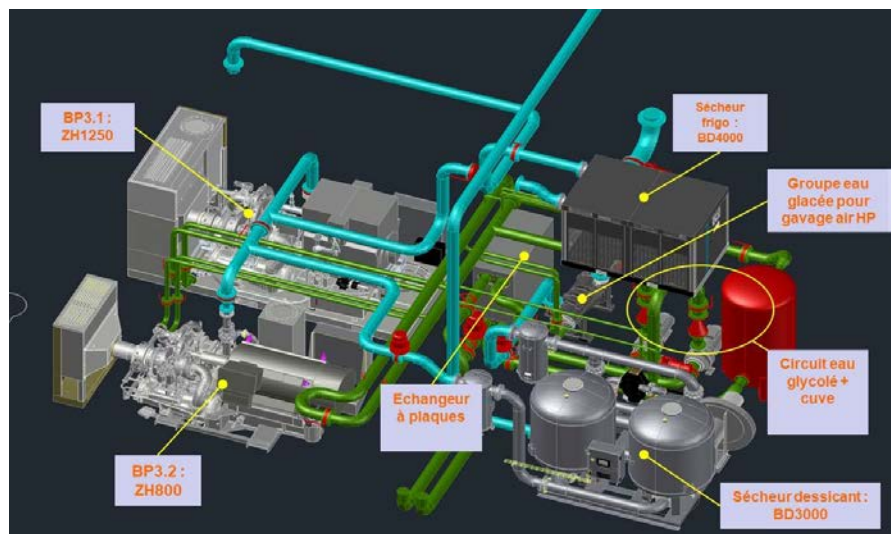


New DSMA HP air tank.

Major work has also been undertaken in 2023 to improve compressed air generation and storage capacities, which are essential for the operation of the facilities and for testing. At the Fauga-Mauzac centre, the contract for the new BP3 low-pressure air plant was launched and will be completed in 2024. This is essential if the F1 wind tunnel is to continue to operate productively.

At the Modane-Avrieux centre, the installation of a new 270 bar high-pressure air storage tank, with a capacity of 40 m³, will increase the centre's high-pressure air capacity by around a third, and in particular its capacity for testing turbine-powered models.

These works, which illustrate only some of the projects currently underway, will improve the availability of the wind tunnels, reduce maintenance periods and increase the range and quality of the measurements carried out there.



DSFM BP3 air handling unit. Centrale d'air BP3 du DSFM.

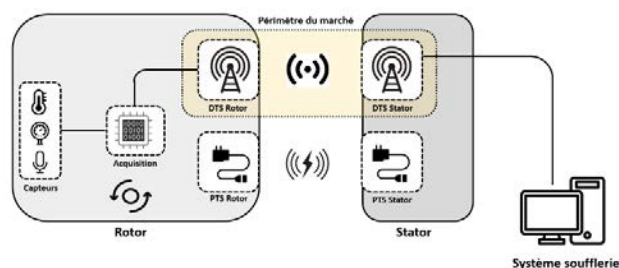
Increased support from the French Civil Aviation Authority (DGAC) to innovate and prepare wind tunnels for testing future civil aircraft engines

Two new investment projects have been launched in 2023 with the support of the DGAC.

- The first, DPTS (Data & Power Transmission System), aims to remove a major technological barrier that currently limits the quantity and quality of measurements that can be made on the rotating propellers of a wind tunnel model. To this end, DPTS will be demonstrating two wireless data transmission systems that can be installed in the rotating parts of the models. The aim of these systems is to enable the transmission of a high rate of measurement data in a reduced volume and operating at rotational speeds of several tens of thousands of revolutions per minute.
- The second project, GREENER, is the first stage in an ambitious plan to enable new measurement techniques and new technologies for wind tunnel models to be applied in the large S1MA and F1 wind tunnels. The first part of this work involves the deployment

of particle image velocimetry (PIV) and stationary and unsteady pressure measurements on the surface of the models using pressure-sensitive paints (PSP), making it possible to overcome temperature variations. The second part covers the improvement of acoustic measurement capabilities, both at low and high speeds. The final part involves improving technologies for wind tunnel models, such as the motorisation of multiple moving surfaces.

The aim of all this work is to enhance the test capabilities of S1MA and F1, in particular to meet the future test requirements of new Open fan engines.

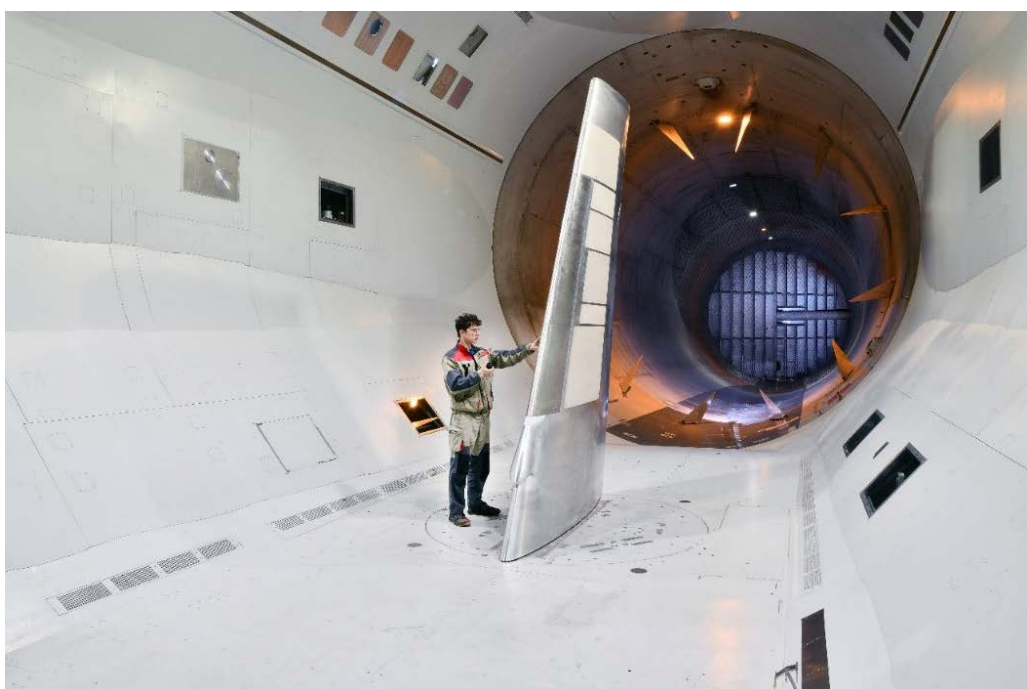


Test at S1MA: laminar airfoils to reduce fuel consumption?

A test in the large S1MA wind tunnel at the Modane centre was carried out to validate the technologies required for laminar wings to reduce fuel consumption in future transport aircraft (HLFC-Win project).

A large-scale mock-up (4.5 m wingspan), representative of a transport aircraft wing section, was blown in December 2023. This test was the culmination of the European HLFC-Win (Clean Sky 2) project, in which ONERA was coordinating the wind tunnel test activities. The aim was to validate technologies that are essential for enabling future transport aircraft wings to maintain a laminar flow over as large an area as possible, thereby reducing friction drag.

These hybrid laminar flow technologies (HLFC) combine aerodynamic shapes that generate pressures favourable to laminar flow with suction at the wing skin through micro-perforated porous sheets in the leading edge region to further delay the transition of the boundary layer to a turbulent state.



Validating these technologies for high-speed flows and therefore high-sweep airfoils is a challenge that requires large-scale experimentation, which is made possible by the characteristics of the S1MA wind tunnel, in particular its size.

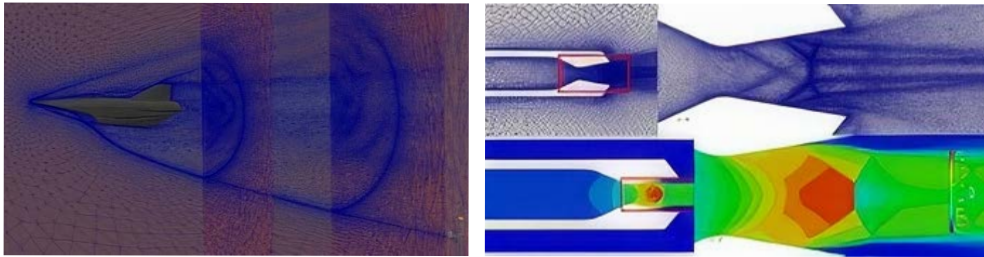
HLFC-Win model in the S1MA wind tunnel.

DIGITAL SIMULATION

ONERA SOFTWARE IN CONSTANT EVOLUTION

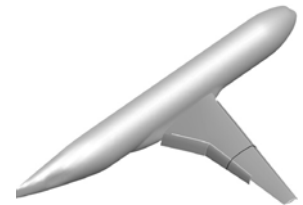
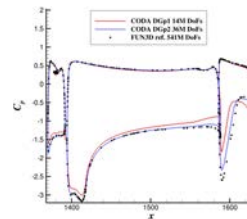
Aerodynamic simulation: SoNICS and CODA take it one step at a time

The construction of SoNICS (Safran-ONERA), the new-generation aerodynamic simulation software that will replace elsA from 2026, is continuing, mainly as part of the DGAC SONICE project. After demonstrating its high performance in terms of calculation time on CPU and GPU processors, numerous simulations with mesh adaptation were carried out in 2023, enabling automated calculations from CAD to post-processing, and in particular a drastic reduction in the mesh generation stage. The targets for 2024 are many and varied: taking into account multi-species flows, using automatic differentiation for shape optimisation or stability analysis and, more generally, continuous functional enrichment in both numerical and modelling terms..



Mesh adaptation using SoNICS (ONERA-Safran) and Feflo.a (INRIA) software: Hypersonic aircraft (left) - Over-extended nozzle (right).

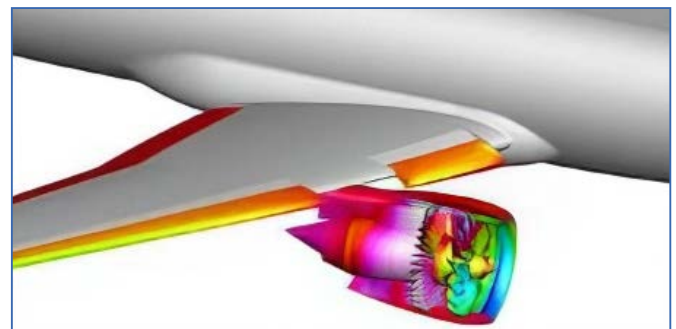
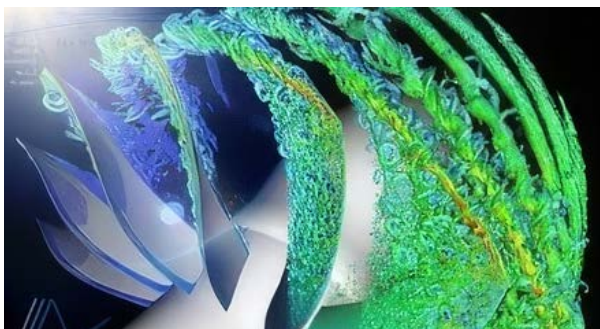
At the end of 2022, Airbus, DLR and ONERA renewed their commitment to the collaborative development of the next-generation CODA code for a further five years. The routine use of CODA in industrial design at Airbus by the end of 2024 is one of the objectives. In 2023, work on improving accuracy continued and led to very good results on aircraft cases. Significant progress was also made on the so-called "immersed boundary" methods for calculating frosted surfaces, as well as on the "discontinuous Galerkin" (DG) methods applied to hyper-supported configurations.



Comparison between two CODA calculations using the DG method (14 million and 36 million degrees of freedom) and a simulation using the "Finite Volumes" method carried out with the FUN3D code (NASA) on 541 million points.

elsA continues to grow

At the same time, the elsA software continues to be enhanced to meet the short-term needs of users. For example, in 2023, Safran's design offices have welcomed the availability of particularly effective non-reflective boundary conditions. Advanced demonstrations have also increased in all areas: high-fidelity simulations and complex geometries.

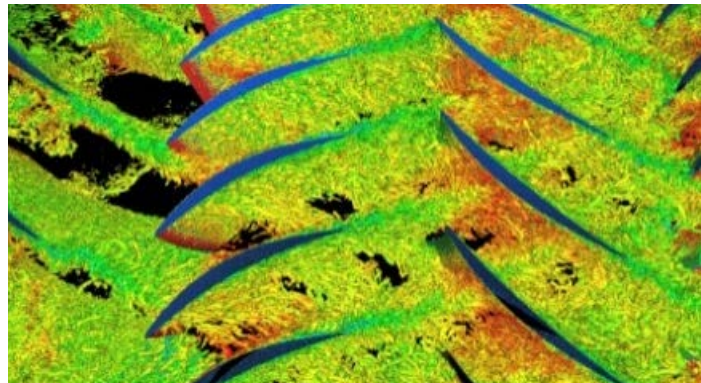


elsA simulations (from left to right): first unstructured mesh ZDES simulation of an open-fan propeller (DGAC MONICA); RANS simulation of the ASPIRE turboprop installed on the NOVA aircraft with a hypersurface device (Clean Sky 2 ADEC).

High-fidelity simulations with FAST software

Unsteady numerical simulations of the "large-scale simulation" type have made it possible to faithfully reproduce the highly complex vortex flow in the CREATE compressor, developed by Safran Aerospace Engines. These calculations pave the way for the creation of reliable numerical databases with a view to improving the modelling of turbulence in turbomachinery.

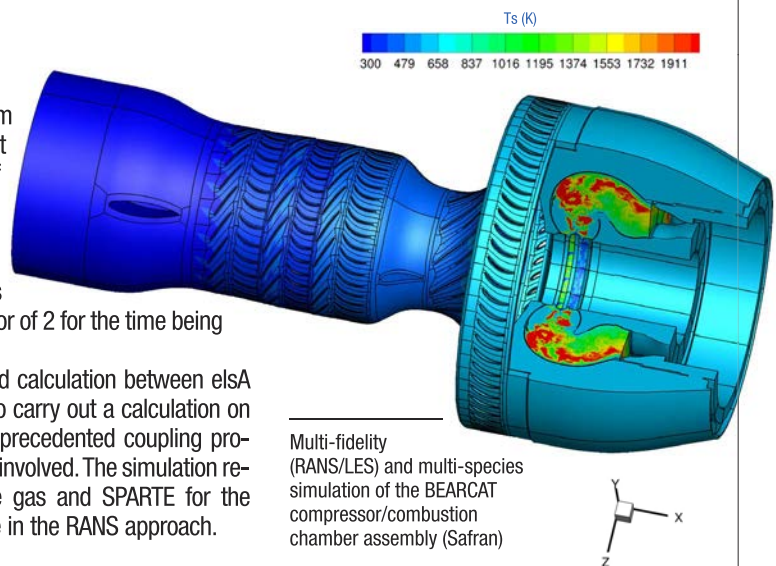
Visualisation of turbulent flow in the centre of the vein. FAST simulation on 1.4 billion meshes.



Energy and Propulsion: software CEDRE

The CEDRE software is ONERA's digital simulation platform for energy used by major manufacturers in the sector. It deals with the complex flows encountered in the field of power generation and propulsion, taking into account a wide variety of physico-chemical phenomena and the associated coupling mechanisms. Key achievements in 2023 include improved robustness of numerical methods for two-phase flows and a CPU performance gain of a factor of 2 for the time being on a limited scope of the code.

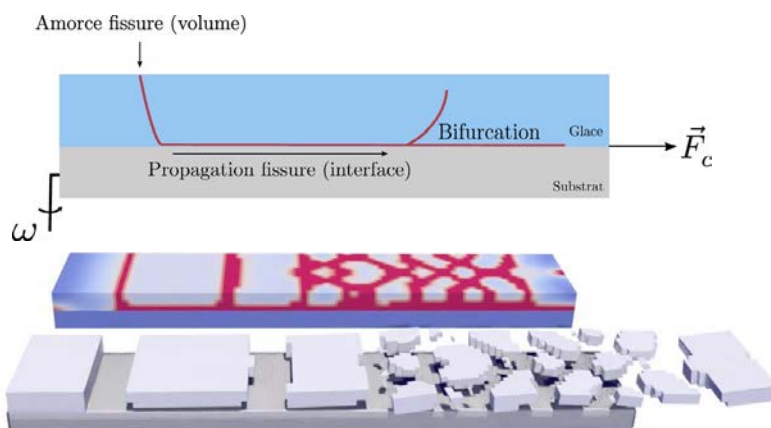
In addition, as part of the DGAC ATOM contract, a coupled calculation between elsA and the 'pythonised' version of CEDRE made it possible to carry out a calculation on the BEARCAT engine configuration. This complex and unprecedented coupling provides a detailed understanding of the physical phenomena involved. The simulation requires the use of two CEDRE solvers (CHARME for the gas and SPARTE for the particles) in the LES approach, coupled with the elsA code in the RANS approach.



Multi-fidelity (RANS/LES) and multi-species simulation of the BEARCAT compressor/combustion chamber assembly (Safran)

Materials and structures: the software Z-set

ONERA has been working for many years on the Z-set code (in partnership with École des Mines and Transvalor). It is used to assess the service life of the most critical parts at the design stage, depending on the type of materials used, using high-fidelity calculations dealing with systems of equations with tens, or even hundreds, of millions of unknowns.



Recent developments in the code (Python coupling interface, phase-field modelling, high-performance parallel computing) allow new types of applications such as the simulation of ice detachment and cracking on aircraft engine fan blades.

In parallel, ONERA is developing a new-generation code, A-set, which will benefit from the advances made in Z-set. A-Set is being developed with academic and industrial partners and, thanks to financial support from the DGAC, is adapted to today's hybrid computing architectures, aimed in particular at integrating complex, more physical and more accurate multi-scale models.

Simulation of ice detachment on a specimen under the effect of centrifugal force in mixed failure: phase field model (in the volume) coupled with cohesive zone model (at the blade-ice interface).

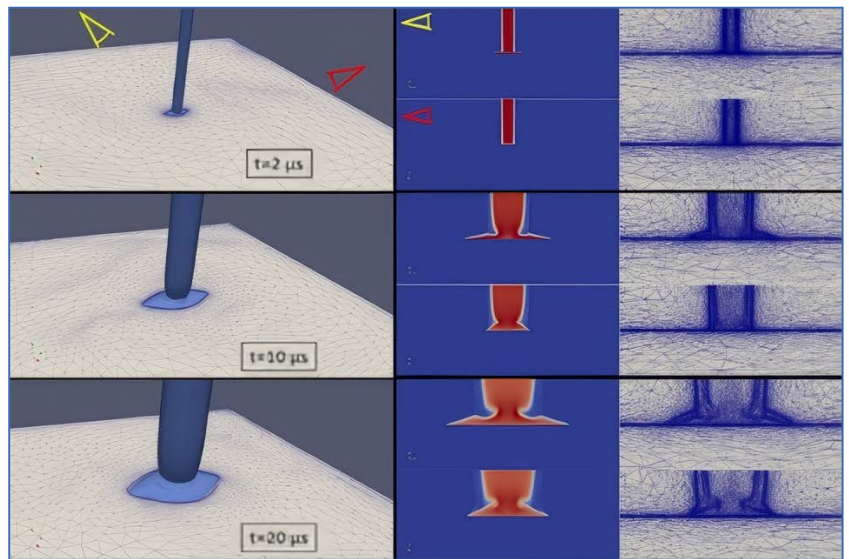
Transverse software ecosystem

ONERA is continuing to set up ORION, a vast software ecosystem for multiphysics simulation. The challenge is to adapt software, at the lowest possible cost, to the architecture of future Exascale machines, capable of performing more than a billion billion operations per second. To create the ORION ecosystem, ONERA is taking steps to modularise and modernise the architecture of simulation software from different disciplines and to facilitate multiphysics coupling.

Simulating lightning strikes: the TARANIS code

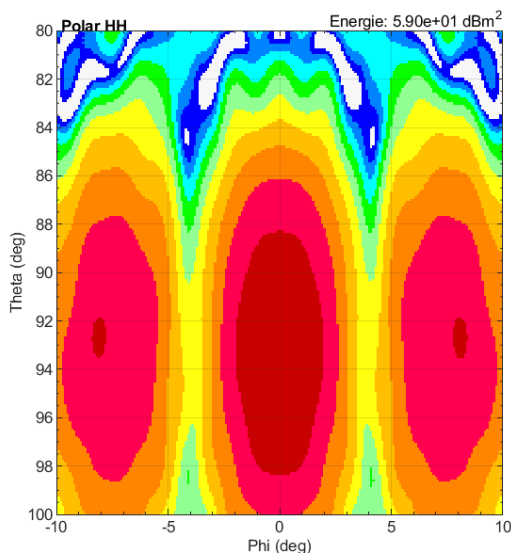
Taranis is an unstructured MHD (MagnetoHydroDynamics) code for simulating electric arcs, such as lightning strikes, and plasmas. In order to simulate 3D lightning strike scenarios on complex geometries, Taranis was coupled with INRIA's anisotropic mesh adaptation tools, centred around the feflo.a anisotropic remesher.

This coupling was used to produce the 3D calculation below, showing the development of an impulse lightning arc foot on an anisotropic CFRP composite material. A characteristic 3D diamond-shaped structure, observed experimentally, was thus obtained. The adaptation made it possible to carry out this highly multi-scale calculation with only 300,000 nodes, reducing the mesh size by a ratio of 100.



Taranis / feflo.a. calculation of the interaction of a lightning arc foot with an anisotropic CFRP, ONERA, 2023. F. Pechereau*, J. Vanharent†, G. Puigt‡, F. Tholin*, A. Loseille† and F. Alauzet‡. *ONERA/DPHY, †INRIA/Projet GAMMA, ‡ ONERA/DMPE.

Radar simulations: optimising calculations for better representativeness



With the EMPRISE project, ONERA is developing a new generation of "radar" scene simulators that combine models of large terrain scenes (land, surface, sea) in which targets and radar carriers can move.

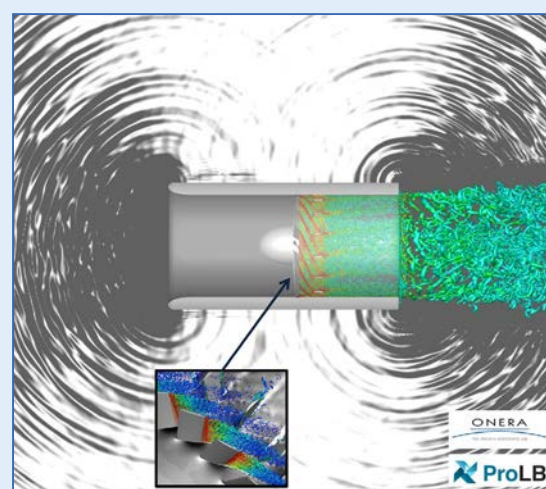
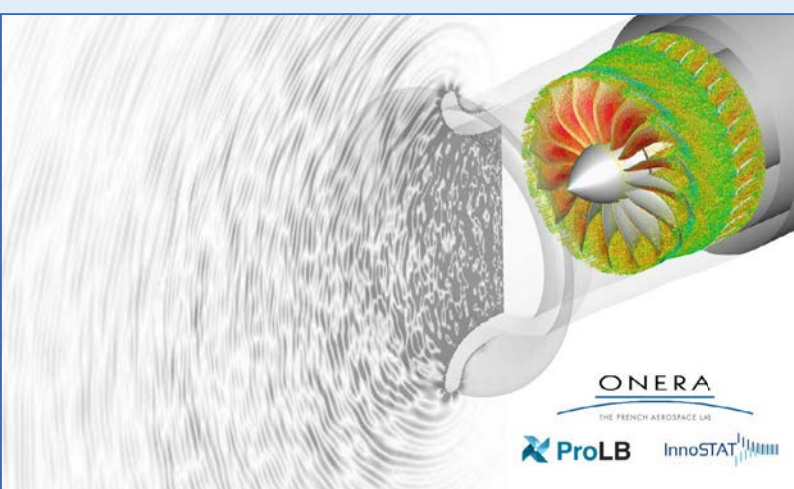
Some of the simulation data is uncertain, and it is necessary to determine the statistical characteristics to ensure it is as representative as possible. The production of metamodels (with OpenTURNS) requires learning bases, a challenge for 'high-fidelity' simulators, which capture the laws of physics in fine details: for this, ONERA uses its Maxwell3D solver, which it has greatly optimised. So while high-performance computing is often aimed at the challenge of extreme simulations, optimisation is essential when calculation plans require thousands of calculation points.

Calculation performed with 40401 calculation points for the linear system to be solved.

A DYNAMIC ECOSYSTEM

Renewal of an agreement on *Lattice Boltzmann* methods

ONERA has renewed for the period 2024-2028 its research collaboration agreement with the consortium comprising Airbus, Aix-Marseille Université, CS Group, Centrale Lyon, Renault and Safran for the development of ProLB™ software. This software is based on the Lattice-Boltzmann approach, which has proved its worth for processing complex configurations in unsteady fluid mechanics and aeroacoustics. ONERA is carrying out upstream research on this approach and is contributing to the development and validation of the ProLB™ software, as illustrated by the result below.



On the road to Exascale



France has been officially chosen to host and operate a new European Exascale supercomputer at the CEA Bruyères-le-Châtel centre in 2023, and ONERA has decided to join the consortium formed for this purpose. The privileged access from 2026 to unprecedented computing capacities (more than 1 Exaflops, or one billion billion operations per second) will enable ONERA to fully play its role as a trailblazer for the future of the aerospace sector. To prepare for Exascale computing, ONERA is involved in the NumPEX (Numerics for Exascale) national research programme, with a digital demonstrator of a prototype aircraft with a new configuration, as part of the move towards low-carbon aviation.

ONERA's strong presence in the quantum computing ecosystem

Although quantum computing is still at a very early stage and can only lay the first foundations, and there is still a long way to go before we can deal with industrial cases, ONERA is getting into the swing of things on the subject so that in the long term aeronautics, space and defence programmes can benefit from digital simulations that are both less energy-intensive and faster.

In particular, ONERA is seeking to assess the potential of quantum computing for the numerical resolution of partial differential equations for numerical simulation in aerodynamics and combustion. To this end, ONERA is taking part in two PAcK Quantique (PAQ) projects in the Ile-de-France region, in cooperation with the start-ups Quandela and Pasqal and the manufacturers Airbus and MBDA, as well as the VulQain project, financed by the AID, led by the start-up ColibriTD and also involving the company Eviden.

ONERA is also leading a GIFAS working group on quantum technologies, which issued its recommendations in March 2024, including the field of quantum computing.

VALORIZATION

While aeronautics, space and defence research is ONERA's primary mission, transferring the results of its research to industry is a major national challenge. ONERA's mission is to promote its expertise and accelerate innovation projects. This is the mission of the Development and Intellectual Property Division (DVPI).

ONERA ACADEMY®

The ONERA Academy® project, launched in 2022, reflects ONERA's desire to set up a structured continuing education offer, and thus to propose new ways of promoting ONERA's offer in line with its missions.

In 2023, the ONERA Academy® brand was registered, the general terms and conditions of sale for the training courses were validated as well as the registration forms and the course agreement.

ONERA has chosen to give priority, initially, to the "development" of training courses on the use of "in-house" software, tested and fine-tuned in-house to test the concepts, excluding the major codes. These training courses will constitute an initial catalogue of training offers: ONERA has a genuine repository of almost 600 codes developed by the scientific departments.

The CASSIOPEE (CFD Advanced Set of Services In an Open Python Environment) training course, to be run from 19 to 21 September 2023 with partner ANDHEO, in conjunction with the Aerodynamics Department, has been divided into 3 one-day modules. These are a set of Python modules offering pre-, co- and post-processing services for CFD calculations (eISA, Cedre, etc.);



The success of this training course, which brought together both ONERA learners and external learners, enabled ONERA to be declared a Training Organisation by the Ministry of Labour, Employment and Integration, and to quickly plan new sessions.

Encouraged by the keen interest shown by future participants, the 2nd test course is scheduled for March 2024. This 100% ONERA training course (organised by the optics department) will focus on the MATISSE software, a radiative transfer

code enabling advanced modelling of the Earth for the Imaging and Simulation of Scenes and their Environment).

At the same time, LMS (Learning Management System) software was implemented at the end of 2023 to manage professional training and thus meet quality requirements (Qualopi in particular) and administrative requirements, such as the annual remote declaration of the BPF (pedagogical and financial report) tracing training activity.

In 2024, ONERA Academy® will continue to be rolled out, with an expanded catalogue to meet the needs of ONERA's partners. The aim is to obtain Qualiopi certification, which will attest to the quality of the professional training process.



THE DX400 PROJECT

AUTONOMOUS AND ELECTRIC AIR MOBILITY

The DX400 project involves the development of an eVTOL (electric Vertical Take Off and Landing) cargo drone, with high elongation and high payload capacity. It responds to an emerging market need and is part of the carbon neutrality programme scheduled for 2040.

In 2023 the work was carried out as part of an innovation project funded by the DVPI, following on from the work carried out in 2022. This work consolidated the aerodynamic formula of the DX400 and the design of its propulsion system.

The DX400 has a hybrid electric propulsion system, distributed over 4 pairs of

counter-rotating propellers providing lift in eVTOL mode and a propulsive propeller for cruising flight. The system is designed to remain resilient in the event of 2 simultaneous electric motor failures. A patent has been filed for this concept in 2023.

In addition, in 2023, a maturation dossier financed by SATT Paris Saclay has been drawn up: it finances the development of the DX400's hybrid propulsion core on a ground test bed installed at the Fauga centre. An agreement between the SATT and ONERA also provides for the hiring of two engineers on fixed-term contracts for the duration of the project (18 months).

The start-up Windair, as third-party operator, has signed a term sheet with

the SATT allowing it to exploit this technology (DX400 programme sponsor).

Initial work will begin in 2024, involving the integration of the main components of the DX400 propulsion chain on a ground test bed at Le Fauga.

ONERA's FdR 1.1 (Aircraft Electrification) has proposed integrating Windair's DX400 project into its programme, as a collaborative project led by an industrial partner. ONERA and Windair will be working to set up a framework partnership agreement in the first quarter of 2024. Collaborative work planned for 2024 includes wind tunnel tests on a 1/3 scale model of the aircraft, followed by preparations for a reduced-scale flight demonstration of the DX400 (by 2025).

INTELLECTUAL PROPERTY INDICATORS 2023

11 new patent applications

13 new invention declarations

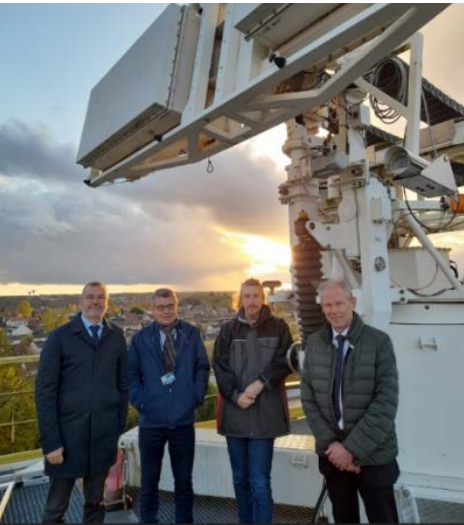
55 new software registered

97 licence agreements in progress

12 new Soleau envelopes

14 new licences
2 brands

INTERNATIONAL



NATO visits ONERA



On 9 November, ONERA welcomed the Director of NATO's Collaborative Support Office, John-Mikal Stordal, and his deputy, General Philippe Montocchio, to Palaiseau.

Testimonial to the NATO S&T community: "CSO Deputy Director, Maj Gen (rtd) Philippe Montocchio, and I had the honour of visiting ONERA – the French Aerospace Lab at their facilities just outside Paris. (...) Philippe and I met with some of their world-class scientists and engineers, and got a first-hand look at some of the unique research they are undertaking. ONERA, when created in 1946, was given the task to elevate France to the world's top table of S&T excellence in aeronautics and transferring their S&T results to the French national defense and aeronautical industry. Nearly 80 years later, it's safe to say that ONERA has been an overwhelming success".

ONERA and NASA sign new icing research agreement



On 20 June in Palaiseau, at an ONERA-NASA meeting, Robert A. Pearce, Associate Administrator of NASA, and Bruno Sainjon, CEO of ONERA, signed an agreement continuing their cooperation on the study of the aerodynamic effects of icing. The aim is to compare aerodynamic measurement data and simulation data for a High Lift Common Reference Model (HL-CRM) aircraft placed in an artificial ice environment. Tests are planned in NASA's transonic wind tunnel and in the ONERA-F1 pressurised wind tunnel.

ONERA and IFAR invited to the ICAO Council for an "innovation" session



On 20 and 21 March, IFAR was invited by ICAO to present the results of their first collaboration on the new topic of urban mobility by UAV. This was an opportunity for the IFAR network to submit the final report of this "Urban Air Mobility Scientific Assessment" study to the ICAO Secretary General. 80 researchers from IFAR member institutions took part, working closely with ICAO experts. The event also provided an opportunity to launch discussions on future cooperation.

EUROPE

Circular economy: ONERA co-organises a major event at the Paris Air Show



ONERA and NLR, respectively chairing and co-chairing the EREA* "Future Sky Circular Aviation" theme, have co-organised with the EC* an event entitled "ReThink Aviation - ReUse, ReCycle, RePair, ReBuild" at the Paris Air Show. This is an important topic for ONERA, which is already active in a number of 'circular' practices: the development of processes that consume less raw materials and energy, the recycling of aeronautical-grade alloys, increasing the

lifespan of parts and components, the repair of engine parts, eco-design, etc.

GARTEUR celebrates its 50th anniversary

The 50th anniversary of GARTEUR (Group for Aeronautical Research and Technology in Europe) took place on 5 and 6 October at the Italian Air Force Academy in Pozzuoli.



ONERA as a player in European space policy

ONERA is increasingly consulted by DG DEFIS (EC*) on space policy issues. These consultations are generally channelled through ESRE*, of which ONERA is a founding member. On 30 June, ONERA and ESRE presented their recommendations to Mr Christoph Kautz, Head of Unit B1 "Secure Connectivity and Space Surveillance" and Mr Guillaume de la Brosse, Head of Unit B2 "Innovation and New Space", from DG DEFIS. On 18 July, they held discussions with Guillaume de la Brosse and his team on the EC's plans to establish a regulatory framework to ensure the security and resilience of growing space traffic.

* ESRE: European Space Research Establishments Association - UPS: Université Paris-Saclay - EREA: Association of European Research Establishments in Aeronautics - EC: European Commission - DSO: Defence Science Organisation, Singapore - DG DEFIS: Directorate-General for Defence Industry and Space, European Commission. DSO: Defence Science Organisation, Singapore - DG DEFIS: Directorate-General for Defence Industry and Space, European Commission.



Young Researchers" seminar at the Paris Air Show and IFAR: 19 nationalities represented to work on sustainable aviation!

The week of the Paris Air Show provided the opportunity to organise a "young researchers" seminar based on the ECN (Early Career Network) model, which has finally been held face-to-face after several years at Covid-19: an exceptional opportunity for France, ONERA and IFAR to enable young researchers of 19 different nationalities to work together on the future of low-carbon aeronautics, and more specifically on the optimisation of a generic hybrid aircraft. In partnership with Paris-Saclay University, the week was organised around conferences, collaborative work, presentations at the Paris Air Forum and a visit to the Paris Air Show. ONERA's initiative has prompted other IFAR members to set up a new ECN event in 2024.

Cooperation with Singapore: visit from the Singaporean Permanent Secretary for Defence, Melvyn ONG

Melvyn ONG, Permanent Secretary (Defence Development), a rank equivalent to that of Secretary of State in the Singapore Ministry of Defence, visited the Palaiseau site. Meetings and technical visits took place, including a tour of the Modane wind tunnels by Ms NG Keng Bee, director of the DSO UAV laboratory, and annual meetings of the ONERA-DSO cooperation and SONDRALAB laboratory boards. 2023 was also marked by the confirmation of interest in new subjects, conducive to broadening and perpetuating cooperation between ONERA and the DSO.



MIFJC reaches cruising speed!



ONERA is a founding and permanent member of the Maison Irène et Frédéric Joliot-Curie (formerly CLORA since 2022). Created to promote French science and innovation in Brussels, the MIFJC brings together 25 research institutions:

12 of them (including ONERA) have a permanent office there. Membership, occupation of premises, events: the MIFJC is a success. One of ONERA's highlights was the organisation of a day dedicated to space infrastructure data.

ONERA is a key player in the Clean Aviation partnership

ONERA is a major player in the European Clean Aviation partnership: it is a founding member. It is a partner in 8 (out of 20) projects started in 2023, and in 3 projects selected in 2023 (including a project in coordination on the wing of the future short/medium range aircraft).



Visit from the Japanese agency for the development of aeronautics

On Monday 30 October, ONERA welcomed to Palaiseau a delegation from the International Aircraft Development Fund (IADF), the agency in charge of propulsion and environmental development strategy.



INVESTMENTS

Investing to build the futur

In 2023, major investments have been made with an objective unchanged since the creation of ONERA: to remain at the cutting edge of experimental know-how.



PyCoFire (total value €15.80m)

multi-physics department for energy

As part of the drive to improve aircraft safety and assess their environmental performance, involving more and more composite materials, the PyCoFiRe (Pyrénées Composite Fire Research) project aims to develop a platform bringing together resources for characterising the fire resistance of new materials, with a view to understanding and modelling their behaviour.

This platform brings together resources that are representative of the industrial specificities of fire in open or confined environments, in close collaboration with manufacturers Airbus, SAFRAN and ArianeGroup. Two benches, FAN and CORE-EXTINCTION, are installed at the LACOM on the ONERA Fauga-Mauzac centre, for the study of fire propagation in turbomachinery. They complement the Burn-Through research bench dedicated to studying the fire resistance of materials and panels under biaxial stress.

The project is 65% funded by the ERDF and the Occitanie region, topping up the €2.15m in industrial co-funding. Acceptance of the test platform was completed in 2023.

€15,80 M



SCHEMAX simulator (total cost €1.79m)

information processing and systems department

The aim is to improve the performance of systems combining humans and machines, as well as flight safety and operational performance, thanks to an interactive simulation research cockpit supported by virtual reality techniques, which is installed at the ONERA centre in Salon de Provence.

A bridge between fundamental research and industry, SCHEMAX is an experimental platform that is unique in Europe. It incorporates complex biometric acquisition tools for characterising biological signals, which are essential for

developing cognitive and sensorimotor models as part of the design of intelligent systems that ensure human-system integration. In this way, SCHEMAX meets the needs of academic research in the fields of civil aeronautics and defence. The latest sensors and biometric acquisition systems will be installed and calibrated in early 2023, so that the test platform can be used immediately in the TOUCANS project and the MEDIEVAL PST.

€1,79 M



€1,70M

ERIS housing (total cost €1.70m) physics department

The ERIS project (Equipement de Recherche pour l'Instrumentation et la Propulsion des Satellites - Research Equipment for Satellite Instrumentation and Propulsion) is a response to national interest in new applications for electric satellite propulsion.

Its dimensions (4 m long and 2 m in diameter) are suited to the study of thrusters in the 2-3 kW range, with a view to supporting the development of ECRA (Electron Cyclotron Resonance Acceleration) thrusters. Delivered to ONERA in Palaiseau on 2021, in a bay specially fitted out and consolidated because of its unusual mass and dimensions, the acceptance tests for the space simulation facility were successfully carried out in 2022-2023.



€1,88M

HF21 base (total cost €1.88m) electromagnetism and radar department

The HF21 project involves the development of an all-digital high-frequency base for transmission and reception, in order to provide an autonomous radar.

This new equipment opens the way to new research topics, such as operation in MIMO (Multiple-Input Multiple-Output) mode, and enables advanced studies to be made of the ionosphere, while retaining the optimised detection capabilities of the NOSTRADAMUS and PEGASE radar systems. The equipment will be finalised and tested in 2023, with commissioning scheduled for the second half of the year.



€2,50M

TOSSCA earth-satellite optical links (total amount €2.50m) optical department and associated techniques

Satellite-to-ground optical links are envisaged for future TeleMeasurement Payloads from Low Earth Orbit (TMCU) ground observation satellites and for the provision of Internet access: geostationary satellites are used as communication relays.

To establish a high-availability broadband link with this type of satellite, we need to control propagation: this is the challenge of TOSSCA (Transmissions Satellite-Sol Corrigées par Optique Adaptive), which is organised into 2 parts:

- the development in 2019-2020 of an Innovative Platform for the Development of Adaptive Optics Concepts for Optical Links (PICOLO);
- the construction in 2021-2022 of a FEELINGS ground station demonstrator to validate the technological building blocks for FEEDER GEO links.

In 2023, the FEELINGS station will be installed on the Fauga site, and tested before going into operation in spring 2024.



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



In 2023, the certification audit led to the
renewal of ONERA's ISO 9001-2015
certification for 3 years.



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