

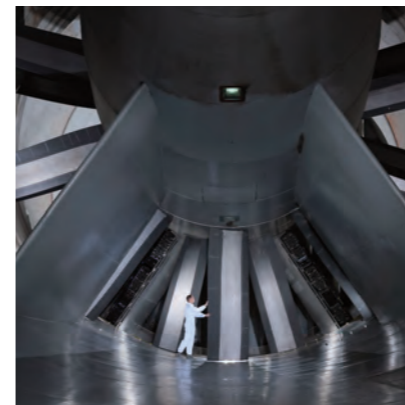
ANNUAL REPORT 2022



Contents

5	ONERA at a glance
6	Editorial from the CEO
8	Highlights
10	Testimonial by Emmanuel Chiva
12	Testimonial by Philippe Baptiste
14	Testimonial by Bruno Even
16	Key figures
18	CSR at ONERA
19	Human Resources
22	Awards
24	Highlights
30	Defense
34	Aeronautics
38	Space
42	Wind tunnels
46	Digital simulation
48	Valorization
50	International

Image credits: iStock – Sirpa Air/Anthony Jeuland – DGA Flight tests – Antoine Gonin – Philippe Choy/ONERA



The French
Aerospace
Lab



ONERA is a central player in aeronautical and space research and employs over 2,000 people. Operating under the authority of the French Ministry of Armed Forces, its 2023 budget amounts to €289 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.

Edito



BRUNO SAINJON,
CHAIRMAN AND CEO OF ONERA

Despite three years shaken up by the COVID-19 crisis and the war in Ukraine with an inflation that consequently triplicated over one year in 2022, ONERA has trustfully maintained its course, therefore testifying the resilience of our choices and directions. This solidity is acknowledged by our partners, who recognise and appreciate both our work and the deep commitment of ONERA personnel, starting by our supervising authority, the French Ministry of the Armed Forces.

As always, this annual report provides an opportunity to look back at the many successes of the past year.

In March, we signed a new five-year period “contract for objectives and performance” with the French Minister of the Armed Forces. Since then, our supervising authority has granted us an increased subvention for 2022 and 2023, in order to better cope with the inflation, as well as to increase the personnel capping we were initially facing. Let me express my deep gratitude for such an increase.

In 2022, our order intake set a new record, with €162.9 million. We therefore beat our previous record, which was amount up to €151.9 million and which was dating back of last year only. This success was built both upon the scientific departments and upon the Wind Tunnel division, and marked by two new records again, those of DGA order intake and those of orders received outside of France. The high level of activity generated by the order intake in 2022 and previous years, testifies the high level of confidence and the expectations placed on us by all our national and international partners, both state-owned and private. Thanks to the efforts of employees contributing to this activity, ONERA ended 2022 with a net carrying profit of €14.4 million.

The numerous awards received by ONERA and its researchers once again testify to the excellence of our scientific research. A selection of these awards are described in this annual report.

Two events were particularly striking in 2022. The results of the Microscope mission, revealed on 14 September, confirmed the intangibility of Albert Einstein’s equivalence principle with unparalleled accuracy of 2.7×10^{-15} . This extraordinary scientific adventure confirms ONERA’s world-leading position in space accelerometers. On the very same 14 September, the Association of Professional Journalists in Aeronautics and Space awarded ONERA and the Modane teams by its 2022 ICARE Grand Prize for having bailed out the large S1MA wind tunnel. A landmark recognition from the specialized media sector for this key flagship of the French industry, essential for our defense and our national industry. The next day, 15 September, the National Space Council, a department of the

White House, honoured ONERA with a visit to our headquarter in Palaiseau, on the occasion of the US delegation’s visit endeavouring to prepare the Comprehensive Space Dialogue with France.

We must also underline, among the many signs of ONERA’s scientific excellence presented in this report, the Group Achievement Award, which is an internal NASA award that was awarded in March to a mixed NASA-ONERA team for its work on icing, one of the major historical themes of our cooperation. In addition, let us underscore too that the award given out in November by the French Academy of Sciences to Silvia Feld-Payet for her work simulating material damage is the sixth accolade paid to an ONERA scientist by the Academy since 2018.

Committed toward the French Civil Aviation Authority (DGAC) and the industry in the governmental approach to accelerate the transition to carbon-free aviation, ONERA joined the Club for the Sustainable Development of Public Establishments at the end of 2022. Our approach responds to the societal challenges faced by the sector, supported by the government’s aeronautical incentive plan and by the European research programmes. Our commitment is influencing both the topics that our research are addressing on sustainable aviation (decarbonisation and reduced fuel consumption in particular) and the way we are embedding such consideration of environmental issues in our current working processes.

Giving prospects for future developments and providing tools and skills required for research to our partners is an essential mission for ONERA. Our roadmaps have been updated at the end of 2022 and will led to some public document by at the Paris Air Show – Le Bourget in 2023. These roadmaps are now the main steering tool for our scientific and technical operations, and essential for achieving our major purposes.

To conclude, ONERA continues to attract talent: I am pleased to report that no less than 194 new employees joined ONERA in 2022. Together with those who preceded them, these new recruits will write the pages of the future of aeronautics, space and defense.

Throughout this annual report, I invite you to discover ONERA’s highlights of 2022!

ONERA stays on course

COP 2022–2026 SIGNED WITH THE FRENCH MINISTRY OF THE ARMED FORCES

Florence Parly, French minister of the Armed Forces, and Bruno Sainjon signed the Contract of objectives and Performance (COP) on 3 March. This contract defines the framework for relations between the office and the State, represented by AID (Defense Innovation Agency) and the DGA (French Directorate General of Armaments), recognising the success of ONERA's transformation and its status as a key partner of the ministry and industry.



FINAL RESULTS OF THE MICROSCOPE MISSION REACH RECORD LEVELS OF PRECISION

The satellite equipped with ONERA's T-SAGE instrument has delivered its latest results and confirmed the equivalence principle with unprecedented accuracy of 10^{-15} . These results, which have been the subject of 200 publications in 25 languages, confirm ONERA's worldwide recognised expertise in accelerometers.



ALL TYPES OF COOPERATION WITH THE USA

Visit on 15 September by the delegation of the National Space Council, the highest authority in the US space domain, chaired by Mr Chirag Parikh, its executive secretary, based at the White House. On 20 October, 50 years of cooperation on helicopters between the US Army and the ONERA-DGA team were celebrated in Palaiseau.

NEW SUPPORT FROM THE DGAC FOR WIND TUNNELS



Following the visit by Pierre Moschetti, Deputy Director of Aeronautical Construction in June, the DGAC (Directorate General for Civil Aviation) granted a new subsidy to the wind tunnels directorate for the development of the SCAMPIS project: cooperation underway for more than ten years with the CEA's Electronics and Information technology Laboratory (CEA-LETI) for the development of high-performance and miniaturised acquisition systems.

LARGE MODANE S1MA WIND TUNNEL RECEIVES PRESTIGIOUS AWARD

On 14 September, the AJPAE – Association of Professional Journalists in Aeronautics and Space – awarded the ICARE 2022 price to the large S1MA wind tunnel. This is a recognition from the sector's press for this flagship of French industry, a must-have and essential contributor to industry and French defense.

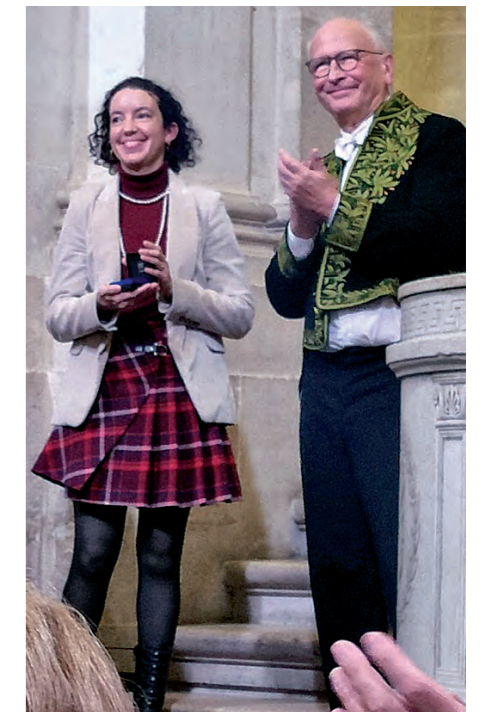


ONERA INAUGURATES ITS QUANTUM TECHNOLOGY LABORATORY, QTECH

QTECH's mission is to federate activities related to applications of quantum physics in the fields of aeronautics, space and defense. This cross-disciplinary laboratory, which involves around thirty ONERA researchers, also promotes exchanges with academic and industrial partners. ONERA inaugurated QTECH on 8 February 2022.

A PLETHORA OF AWARDS RECEIVED BY ONERA

First place in the Joseph Fourier international award, the Hope award from the Michelin Foundation - Académie des Sciences, the 3AF aeronautics award, eight thesis Prizes awarded issued to our alumni... Once again, in 2022, ONERA scientists were in the spotlight!



VISIT BY GENERAL MILLE, HEAD OF THE AIR FORCE AND SPACE ARMY PERSONNEL

On 30 November, General Mille came to discover ONERA by visiting various laboratories in Palaiseau: ramjets and electric propulsion resources in space. This visit also provided the opportunity to discuss space-related issues and the partnership with the École de l'air et de l'espace (Air and Space School).

NASA GIVES A GROUP ACHIEVEMENT AWARD TO AN ONERA TEAM

This very high-level award, which is usually used to honour an internal NASA team, recognises a joint NASA-ONERA team for the SUNSET 2 project (studying the effects of icing on delta wings). This cooperation is continuing with SUNSET 3, investigating the effects of icing on high-lift delta wings.



ONERA, BLAST'S BACKBONE

The acceleration programme dedicated to deeptech projects in the ASD sector has unveiled its second promotion. Among the 18 selected winners, ONERA is proud to count two of its researchers. The office plays a major role in BLAST: providing scientific support for project leaders.



ORDERS: A RECORD YEAR

A new record was set with €162.9 million in order intake; a success built up by both by the scientific departments and by the wind tunnel directorate, and marked by a second record, order intake outside France, which exceeds €50 million.



INTENSE DEFENSE COOPERATION PROGRAMMES WITH SINGAPORE

Numerous visits were organised: firstly Ambassador Teow Lee Foo, accompanied by Ms Yihui Chia, First Secretary in charge of Political Affairs, and William Peh, Adviser for Armaments and Defense Affairs; then General NG Chad-Son, Director of Defense Innovation; and finally several delegations within the framework of the SONDRRA quadripartite laboratory.

Emmanuel Chiva,
General Delegate
for Armaments



QUESTIONS TO

Oliver La Comie/ECPAD/French Armed Forces

“ONERA has always been a key partner of DGA for research and development in cutting-edge technologies”

We are witnessing the return of the “high-intensity war”. What challenges must be met and what role will ONERA play?

Faced with an increasingly wide range of threats, we are now globally designing our defense system in terms of capabilities, for example air combat capability, rather than programme by programme, thus promoting the launch of new solutions.

The challenge for the DGA is to set the rights directions structuring and coherent over time. We must be able to deal with both current and future threats, a high-intensity but also hybrid war, fairly conventional weapons combined with more innovative approaches such as cyber attacks. Preparing for the future is a strategic challenge. Defense innovation is also a major source of leverage to guarantee the operational superiority of the French armed forces and the strategic autonomy of France in the future. This approach is part of both a long-term strategy, to prepare for structural investments, to anticipate technological breakthroughs or to ensure our understanding of emerging strategic technologies, and a short-term strategy, to rapidly harness innovations on the civilian market.

ONERA will play an essential role to play through its various forms of intervention, whether by providing its expertise in support of state project management, through sub-contracted studies carried out for the benefit of industry, or through test and expert appraisals on themes calling on its many areas of expertise.

What role will ONERA play in terms of deterrence in particular?

In a context of renewed international tension and nuclear dialectics between States, it is more essential than ever for France to guarantee the credibility of its deterrence policy, to guarantee its security and ability to negotiate with other nations.

In this regard, the continuous adaptation of the oceanic and airborne components of our nuclear deterrence programme is one of the DGA's structuring missions, just like the anticipation of future threats and the development of breakthrough technologies that will enable us to stay one step ahead of our adversaries.

In the sensitive area of deterrence, ONERA has always been an unwavering partner of the DGA in terms of research and development of cutting-edge technologies. ONERA is a key player, acting as an incubator for new technologies, a design office, an expert, a co-project manager, a project owner assistant, and a tester. ONERA has been supporting deterrence systems for many generations.

ONERA can intervene in a wide range of fields: propulsion systems, aerodynamics, navigation systems, radar systems, instrumentation, performance evaluation, etc. It goes without saying that the DGA will continue to call on all these skills and I believe that ONERA will respond by mobilising its resources to meet the challenges of deterrence.

The concept of war is now reaching space: how can ONERA help prepare the necessary combat systems?

Thanks to its technical skills and knowledge of the aeronautical and space environment, ONERA is able to provide all its expertise to support the DGA's space programmes, in two main forms.

Works are expected to increase as part of the ARES (Action and Resilience in Space) programme, to which ONERA is already contributing, and ONERA will play an essential role as project management assistant.

For other space programmes, the DGA also calls on ONERA for the recognised excellence of its technical expertise. This is particularly the case in the fields of observation, for example to set up hyperspectral image processing, and to analyse physical phenomena in space. This expertise is essential not only to make the best use of space sensors during operational missions, but also to anticipate the risks faced in the demanding spatial environment, and thus better protect our satellites.

Artificial intelligence, quantum... Are we ready for the scientific changes ahead?

Artificial intelligence offers a range of innovative techniques in key areas supported by ONERA. In terms of priority applications, I would mention geospatial intelligence, space surveillance, monitoring of the operational environment, multi-sensor intelligence and new control, planning and navigation algorithms. In addition, the most recent machine learning approaches open up a range of options that are particularly rich in terms of improving the performance of our defense systems. I am therefore delighted that ONERA is a stakeholder of the Interdisciplinary Institute for Artificial Intelligence (3IA) in Toulouse, which addresses the topics of “safety and security of critical systems”, which are of major interest for defense purposes.

Just like AI, but with a more forward-looking perspective, the quantum shift brings many potential breakthroughs in sensors for electronic warfare applications, radars, navigation and geolocation in a scrambled environment, securing communication networks and cryptology. Quantum calculations can also be used to solve combinatorial optimisation problems that meet the need for operations planning or mission preparation, for example. ONERA is an essential partner in this field of innovation. ONERA has proven to be the world leader in onboard cold atom gravimeters with the first ever use case for quantum technologies in the maritime field. The establishment in 2022 of its QTECH laboratory to federate all its quantum activities, with a staff of around thirty and a scientific council chaired by Alain Aspect, is a very promising initiative for defense. ■

Philippe Baptiste,
CEO of the
National Space
Studies Centre



QUESTIONS TO

Christophe Peus / CNES

“ONERA has enormous potential to shape the space world of the future”

What role does France play for Europe in the *New Space* race? How can ONERA support the collective effort?

New Space initially took shape in the United States, and is now expanding rapidly throughout Europe. In this context, France is one step ahead in Europe with one startup created per week on average in the space sector. These players, which are as diverse as they are innovative, contribute to meeting the new challenges faced in the space sector.

Thanks to the skills of research laboratories, the experience of major historical industrial players, such as Airbus, Thales Alenia Space or ArianeGroup, and with the support of the France 2030 system, these startups benefit from the support of the entire ecosystem. These synergies are essential for shaping the space world of the future and staying at the forefront of innovation.

In this respect, CNES plays an important role liaising between manufacturers, startups and research organisations such as ONERA. Thanks to the skills of its teams, whose standards are recognised by all (with the Microscope project, the theory of general relativity was tested in space, as well as excellence in radars, work on combustion, codes and models, etc.), ONERA contributes directly to the collective effort in space, in terms of both civilian and military components. For all these reasons, its know-how can be rolled out and irrigate the entire ecosystem. Similarly, startups make laboratory research a reality. Thanks to these permanent interactions between the various stakeholders, we can all generate value together.

CNES is increasingly working with startups to promote innovations. What role can a research establishment such as ONERA play in this ecosystem?

ONERA can access exceptional technologies, knowledge, skills and know-how within its laboratories. New space players, which, by their very nature, are keen to take risks, can help us find markets and move from research to market. ONERA is a major player in the field of civilian and military aerospace research, enabling startups to expand, whether through innovative projects or by making available the scientific expertise of its research laboratories.

While the space sector is currently undergoing major changes, I strongly believe that contributors such as ONERA and CNES, historical partners in the field of space research, must continue to mobilise their strengths to respond to the emerging challenges of the sector. This is a great opportunity to contribute to France's reputation in the space sector. ONERA has enormous potential to shape the space world of the future.

Where do competitiveness, innovations... and science fit in? What scientific challenges must CNES and ONERA face together, whether for civilian or military applications?

In our industries, innovation, science and technology are closely intertwined. ONERA has recorded multiple scientific successes in this respect. I am pleased to now mention the results of the Microscope mission, which have led to numerous national and international media articles and which confirm the extensive scientific cooperation between CNES-ONERA and ONERA's leading world role in the field of space accelerometers. This excellence is also reflected in the excellent results achieved by ONERA's teams in European calls for projects. In addition, the science and technologies performed in our laboratories not only irrigate startups, but they are also innovative products in the New Space world that we are increasingly using in scientific projects.

In terms of current scientific challenges, I would particularly like to mention the low orbital constellations that have boomed in recent years and which can be seen as emblematic of New Space. Constellations led to a fully-fledged Copernican revolution in how we design a mission, and are at the heart of the challenges faced in today's space world. These constellations play a considerable role in the IoT (Internet of Things) and telecoms, but they are also used for Earth observation and scientific missions. They are also required to play a key military role.

I am convinced that CNES and ONERA can rely on these innovative startups in all fields. Although this approach clearly involves risks (which must be controlled), we have the means to accelerate developments and reduce costs.

I also consider that the safety of space operations is one of the major challenges facing us in the coming years, in both civilian and military contexts. To meet this crucial challenge, which includes protecting space systems from orbiting debris or space weather, we need ONERA, the startup ecosystem, industrial contributors, and the EU-SST (European Science and Surveillance Tracking). This widespread cooperation is necessary to meet the challenge of ensuring safe space operations. ■

**Bruno Even,
Chairman of Airbus
Helicopters, Chairman
of the CORAC
Steering Committee**



QUESTIONS TO

Diane Bond/Airbus Helicopters

“ONERA plays a decisive role in managing the upcoming revolution”

The CORAC (French council for civil aviation research) brings together all French players in the air transport sector. What role does ONERA play in CORAC?

Let me refer to a specific example. Studies attempting to forecast decarbonisation in the aviation sector are often quite complex to analyse and compare, are subject to increasing media coverage, and even misinformation, and are embedded in a growing flood of political announcements focusing on ever-more ambitious carbon targets (Paris Agreement, the French low carbon strategy (SNBC), the European Green Deal, etc.), in particular with the objectives of “net zero emissions” by 2050, announced by the European Union and the ICAO (International Civil Aviation Organisation).

It therefore appeared essential for CORAC to refer to a logical and educational analysis of variation in airborne CO₂ emissions, based on independent and referenced publications. ONERA's role was decisive in carrying out this prospective analysis on simulations of the different decarbonisation trajectories. ONERA demonstrated, on a geographically relevant, i.e. global, scale, how aviation CO₂ could vary in different scenarios based on traffic levels, technologies, operations, the incorporation of sustainable fuels, etc., over the coming decades, and compared the results to relevant CO₂ targets for 2050. This approach is essentially scalable, but it supports CORAC's research strategy by providing its private and public stakeholders with a tool for assessing the relevance and effectiveness of technological, operational and energy solutions and their implementation schedule.

What major challenges lie ahead of us when outlining a carbon-free aviation sector?

As we pull out of the Covid crisis and exacerbated international competition, the 2023–2027 period will be crucial for the French aeronautics sector as it aims to prepare for the launch of new programmes and to reinforce its global leadership. On this basis, from 2023, the aim is to continue with the process of reducing risks and increasing technological maturity started in 2020, thanks to the support of the State, via the stimulus plan and France 2030, and thus confirm the decarbonisation trajectory as modelled by ONERA with different scenarios. CORAC established its strategy and roadmap based on this independent study, integrating its assumptions and the associated R&T schedule. This approach is only feasible thanks to the relationship based on trust established with ONERA, and thanks to the exceptional scientific and technological skills of its teams. France can boast one essential asset, ONERA, allowing the nation to combine technological progress with performance and competitiveness, not forgetting safety.

For the entire French aeronautics sector, it is also a matter of transforming the approach to future programmes in a competitive and independent manner.

How will ONERA be able to help the aeronautics sector?

Thanks to its expertise covering a unique technological spectrum in France, ONERA can play a decisive role in facing this upcoming revolution. As I have already mentioned, this approach critically underlies industrial and technological sovereignty, and we must work together to meet the objective of carbon neutrality in air transport by 2050.

Through its work, ONERA helps to make this possible with concrete and intermediate achievements:

- an ultra-simple hybrid helicopter by 2030;
- an ultra-simple business jet from 2030;
- a regional aircraft and a next-generation, ultra-simple and carbon-free short- & medium-haul aircraft by 2035.

These three major lines have been deployed and the priorities for 2023 have been clearly announced:

- the transition to new low-carbon energy sources;
- ultra-frugal systems reducing energy consumption by 20–30% thanks to technological breakthroughs in the field of engines, airframes, and operations;
- changing development processes and the industrial system for a rapid launch phase at the right level of maturity and with a ramp-up allowing for integration into fleets fast enough to meet decarbonisation objectives.

The entire aeronautics sector is actively involved and ONERA's expertise and skills are essential. There are key disciplines for which ONERA's know-how will directly contribute to project management. I am mainly referring to aerodynamic modelling and wind tunnel tests, engine modelling and tests, and expertise in high electrical powers, among other aspects. ONERA can deal with both subjects in their entirety in a technological field (simulation, technical testing, re-adjustments, extrapolation, etc.), and multi-disciplinary aeronautical subjects. This demonstrates the immense technical and technological expertise available to the aeronautics sector, and unique in France.

This expertise is essential, as the entire industry must transform in order to retain its know-how, and develop future products meeting environmental challenges with competitive technological solutions, which will probably be groundbreaking compared with existing solutions to successfully decarbonise the aviation sector. Industrial and Technological excellence in France and Europe depend on this approach. ■

Key figures 2022



INVESTMENTS
€49.5 M
(€40.1 M in 2021)

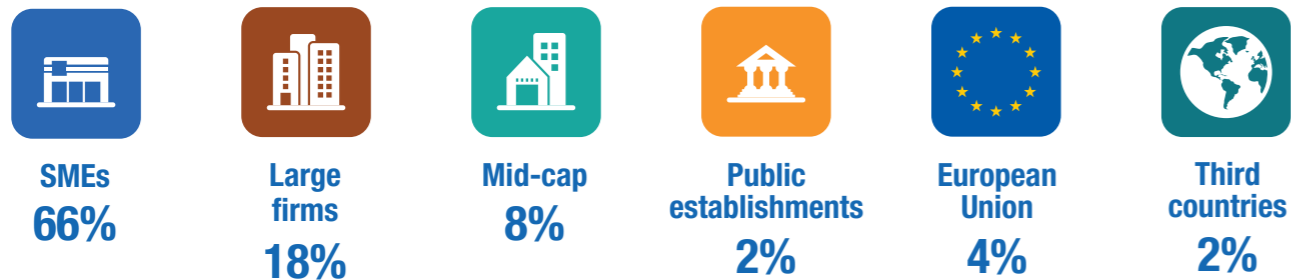
- €35.1 M for routine operations;
- €0.6 M for the Aero Testing Programme (ATP) for the modernisation of wind tunnels, following the loan granted by the European Investment Bank (EIB);
- exceptional grant: €3.8 million for the PRISME project bringing together the three Île-de-France (Paris) sites.

PROCUREMENT

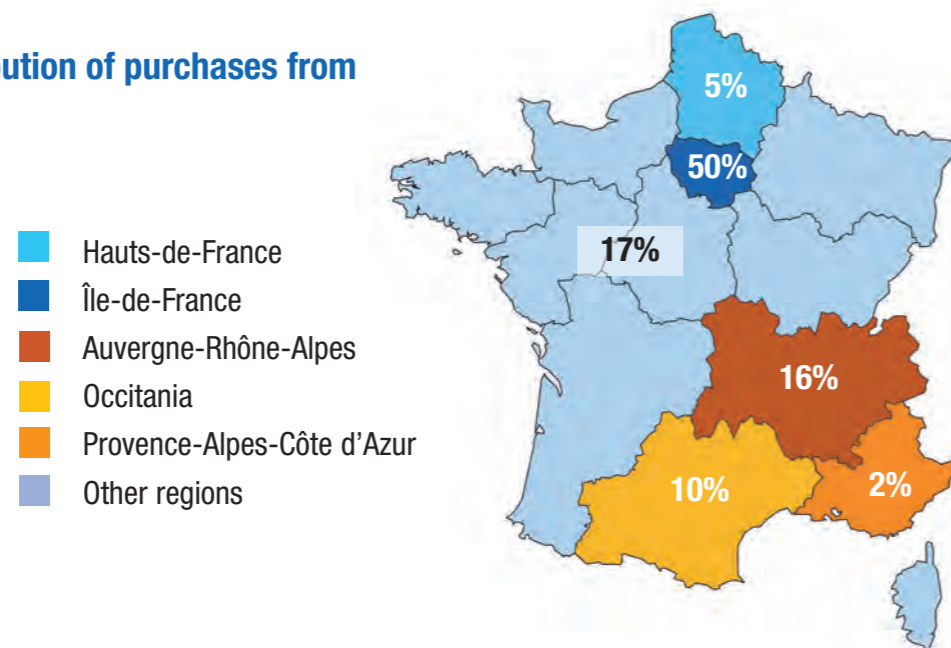
ONERA mainly works with SMEs in all its centers across all regions.

In 2022, ONERA signed a contract with 1,840 SMEs (1,590 in 2021).

Breakdown of purchases by type of business in 2022:



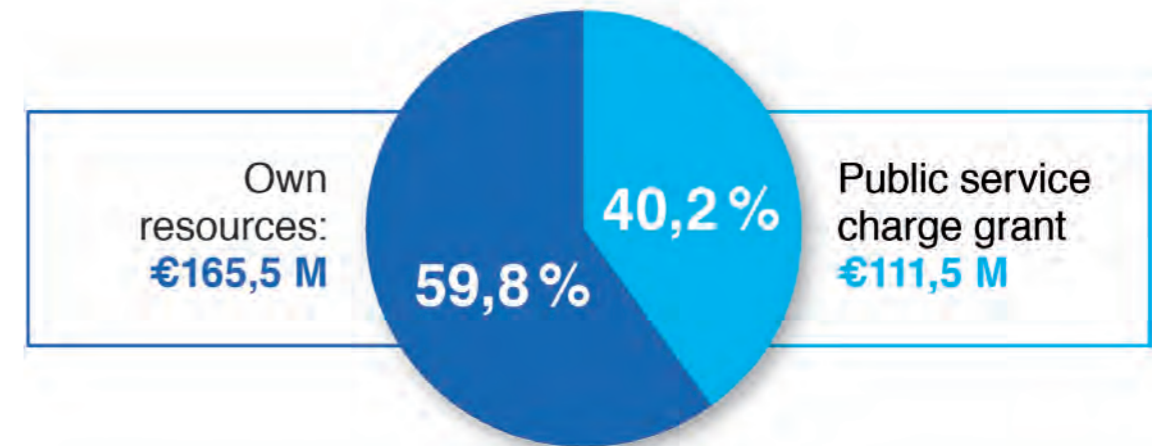
Regional distribution of purchases from partner SMEs:



2021 BUDGET
€256 M

ACTUAL 2022 BUDGET
€277 M

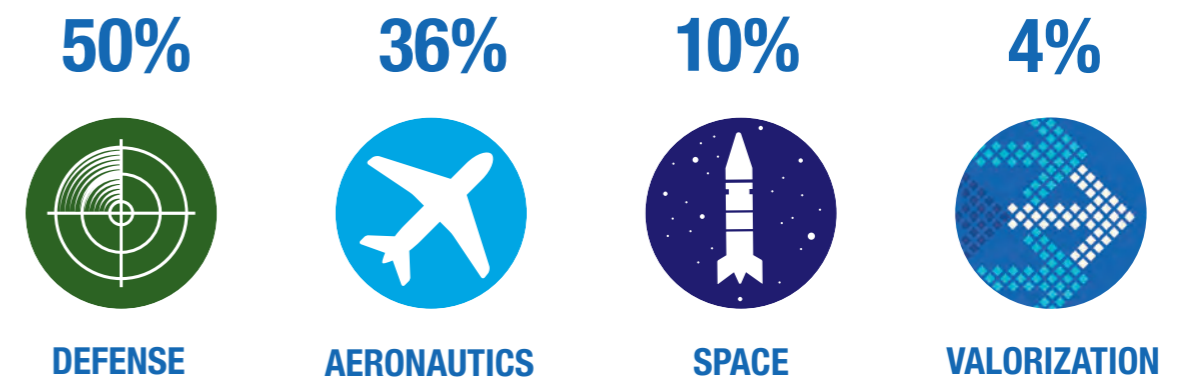
2023 BUDGET
€289 M



Net income:
€14,4 M

Orders:
€162,9 M

DISTRIBUTION OF CONTRACTUAL OPERATIONS BY ACTIVITY:



Corporate Social Responsibility: ONERA is committed.



Social challenges are numerous today: protection, ethics and climbing the social ladder, training and education. ONERA's management has been supporting all of these values for several years now. ONERA managers believe that investing in social impact provides an opening for development moving towards sustainable and profitable growth. This approach also provides a real opportunity to invest in our society and for future generations.

In December 2022, ONERA strengthened its commitment to CSR initiatives by joining the Club for the Sustainable Development of Public Establishments and Public Companies. On this basis, ONERA combines its research into sustainable aviation (decarbonisation, reduced energy consumption and optimised airport traffic in particular) with the consideration of environmental issues in its current operations (less business travel, digital footprint, greater responsible purchasing, ensuring staff awareness, recycling, etc.).

Gender equality

ONERA is a partner of the "Elles bougent" association, and for this reason, regularly presents scientific professions and careers to high school students, aiming to arouse their interest in the Industry of the Future.

Disabilities

ONERA is heavily invested in raising awareness among its staff about disability. Several initiatives were dedicated to the subject in 2022: active participation in the 26th edition of the European Week for the Employment of People with Disabilities (EWEPD), and distribution of information on the day of deaf and hearing-impaired people through testimonials from the staff concerned.

The benefits of the green transition are undeniable. Here at ONERA, this objective takes shape with compliance in the work environment itself, the adoption of eco-gestures on a daily basis, the smart use of digital technologies, as well as the adoption of mobility plans at ONERA centres.

Environmental footprint

In addition to reminders of good practices in the responsible use of digital technologies, for example, ONERA goes one step further and has a direct impact on the daily lives of its employees: in 2022, all employees were provided with a metal bottle featuring a logo. This initiative aims to drastically reduce the number of cups and water bottles used each year.

Sustainable mobility

Another example: in order to promote green mobility and cat-sharing for its employees, ONERA set up a widespread "Mobility" survey in 2022. This complements the initiatives launched in previous years: raising awareness among motorists and cyclists about better road sharing, setting up areas and equipment dedicated to cyclists (shelters, tyre inflation stations, showers, etc.), and reimbursing bicycle safety accessories.

Awareness of the fight against global warming

A webinar on the theme "Understanding ONERA's carbon footprint" was organized in January 2022.

PRISME: plans to consolidate Ile-de-France sites

For employees at the Île-de-France centres, combining the Meudon and Châtillon sites at Palaiseau implies a significant reduction in greenhouse gas (GHG) emissions by reducing energy consumption and operating expenses. Reducing GHG emissions is indeed an integral component of the PRISME project.

Sustainable aviation

ONERA has adopted a global approach to reducing the environmental footprint of future aircraft, and coordinates all the issues relating to the propulsion system of (mainly civilian) aircraft, and the environmental impacts generated by aircraft. Current major challenges in this respect:

- reduced consumption, CO₂ emissions and pollutants (NO_x, CO, particles, etc.) by improving engines, exploring new propulsion architectures and using alternative fuels;
- reduced perceived noise;
- understanding of the atmospheric impacts of air transport (air quality and total impact on climate change, in particular due to the generation of condensation trails).

ONERA personnel



2,135 employees

- 1,679 engineers and executives
- 181 employees
- 31 work-study students
- 244 technicians and workers

26% women

Gender parity index: 94/100

118 scientists with habilitations to lead research (HDR) including 5 presented to juries in 2022

- 341 doctoral students
- 19 post-doctoral students
- 242 trainees

419 communications at congresses with publications

265 publications in peer-reviewed journals

863 technical reports

85 PhD defended



ONERA strengthens its employer brand

ONERA asserts its identity, and defends its culture and values as an employer keen to share the enthusiasm of its teams.

This project was proposed and led by the HRD, and mainly owes its success to the employees involved. On this basis, the five values highlighted are: **passion and discipline, innovation, commitment, integrity, and shared aims.** Charlotte Haurie, ONERA HR Director, explains: "To highlight our ability to attract, retain and convince the talent of the future, we need to leverage our unique strengths, by defining a stand-out employer promise: experience aerospace and defense excellence."



A boost for the recognition of researchers

In 2022, ONERA modified its research sector to promote dynamic research. Three grades were created: research officer (CR), second-class research director (DR2) and first-class research director (DR1).

74 engineers were appointed as CR, 70 DR2, 24 DR1 and 76 research supervisors at level 1. They joined the brand-new group of research directors and officers, now including 251 research engineers, representing an increase of almost 50% compared to 2021.

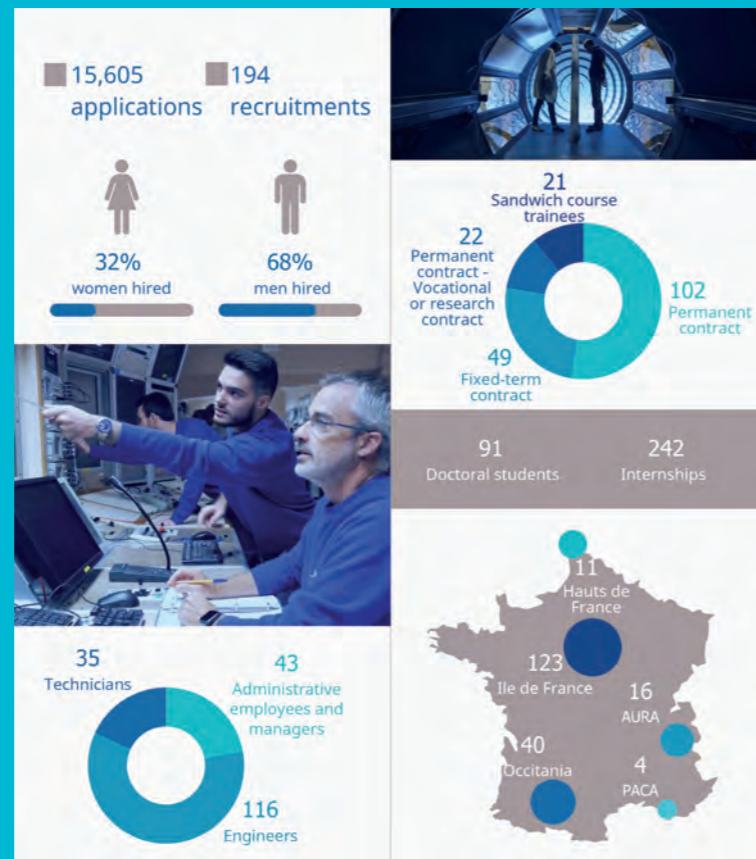
Among the innovations brought about by the new agreement are earlier recognition at the start of a career and more women in the sector. These targets have been met for the first year! This last point is of great importance to ONERA following on from its commitment to greater diversity.

In 2022, ONERA's professional equality index – 94/100 – remained stable compared to 2021.

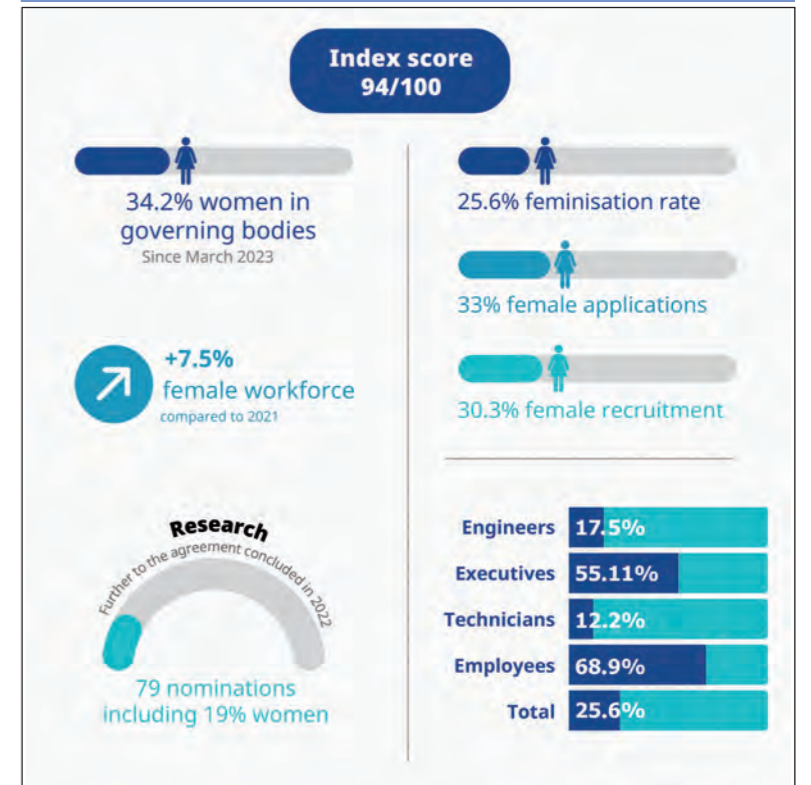
While women and men are treated in the same way, efforts have been made in recent years, in many areas, to consider a wider range of factors than just remuneration: recruitment, promotion, work/life balance. 26% of ONERA personnel were female in 2022, however this figure rises to 34% for the company's governing bodies.

Recruitment: 2022, a new record year for ONERA

In line with the strong growth recorded throughout the aerospace and defense sectors, ONERA's recruitment dynamics are healthy: 159 recruitments in 2020, 167 in 2021, and 194 in 2022. Firstly, the government's support plan has put carbon-free aviation at the top of its list of priorities, and ONERA's skills are and will be essential in this context. Secondly, ONERA has a well-filled order book, demonstrating the high level of confidence of its customers and partners. Good economic health reflected in new skills requirements in all ONERA's scientific and technical departments and support services.



Professional gender equality assessment – 2022



Scientific awards are now a tradition for ONERA's research engineers

Every year, ONERA's engineers and technicians are recognised with prestigious scientific awards. Riad Haidar, Chief Scientific Officer since January 2022, is proud of, but expected, this observation: "ONERA's core activity revolves around science, and the Office has always ensured that its staff can continue to improve their knowledge and push the boundaries of knowledge through their fundamental research work. This approach is what makes the parallel dialogue with applied research so exciting and fertile. I will continue to promote these dynamics."



Atos – Joseph Fourier prize

This international prize, awarded by Atos in partnership with GENCI (major intensive computing hardware), rewards scientific work in the field of advanced computing and artificial intelligence, with a focus on decarbonisation.

In 2022, the first prize was awarded to a team from the Multi-physics department for energy: **Jean-Christophe Hoarau, Jean-Luc Estivalèzes, Luc-Henry Dorey, Davide Zuzio**. The simulation that earned them this prize is the most accurate model of an atomised liquid jet to date with 3 billion points, and 40 million computing hours using 86,000 processors. This model generated 40 terabytes of data that can be used by other researchers. This work was part of a project aiming to better understand combustion.

Other scientific awards related to ONERA

In 2022, the Nobel Prize for Physics was awarded to **Alain Aspect**, a familiar ONERA face. He has held various positions here, as Chairman of ONERA's Scientific High Council (2004–2006), member of ONERA's Scientific and Technical Council (1998–2002) and member of the assessment and orientation council of the Physical Measurements department (1999–2003). Today, he is the chairman of the scientific council for the QTech laboratory* (ONERA's quantum technology laboratory).

In particular, he encouraged the development of research on cold atoms at ONERA, which led to the GIRAFE gravimeter, the first quantum sensor. The first laser subsystem of the devices developed by ONERA in this context were able, in particular, to be tested in collaboration with Alain Aspect's team at the Optical Institute Graduate School.

The ONERA Mechanical sciences for aerospace award from the French Academy of Sciences was awarded in 2022 to **Mickaël Bourgoïn**, CNRS Research Director at the Physics Laboratory (CNRS/ENS Lyon).

Since 2018, this award has been alternately awarded to researchers in fluid mechanics and solid mechanics for outstanding research in the aeronautics and aerospace sectors. This award is part of the Mechanical and computer sciences section of the French Academy of Sciences, whose members form the award jury, which independently selects the winner.

Mickaël Bourgoïn, a researcher in fluid mechanics, is interested in the transport of fields and particles in complex flows, particularly turbulent flows.

Hope Michelin Foundation Award – French Academy of Sciences

This award goes to a young scientist having contributed a major innovation in the field of materials, in relation to sustainable mobility.

The 2022 winner is **Sylvia Feld-Payet**, a research engineer in ONERA's Materials and Structures department. Her research focuses on numerical methods used to simulate material damage and failure as well as compare these simulations with experimental results. This work improves the predictive nature of the simulations and should allow manufacturers to reduce the mass of parts with equal resistance.



3AF aeronautical award

In 2022, the French aeronautics and astronautics association (3AF) awarded two titles to ONERA staff.

Laurent Cambier, Scientific Director of the Advanced Numerical Simulation (SNA) field, was awarded the Aeronautics Prize for the quality of his work on modelling and numerical simulation in aerodynamics. His contributions to the aeronautical industry include: Canari, ONERA's first calculation code solving the Navier-Stokes equations for turbulent compressible flows, elsA (aerodynamics simulation software package), which can be used with planes, helicopters, missiles, space launch vehicles and all types of turbomachinery.



2022 Highlights

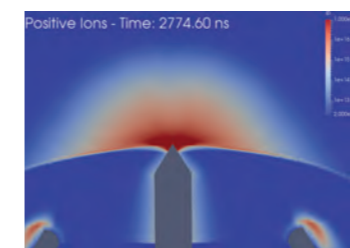


Aerodynamics Managing aerodynamic interactions for the helicopters of the future

Combined helicopters such as the Airbus Helicopters RACER or the Sikorsky S-97, with additional rotors and/or wings, can separate the propulsion and airfoil systems, thus combining speed and comfort. ONERA conducts digital and experimental studies to understand the aerodynamic interactions at stake. As part of the DGAC CHARME project, which aims to characterise these interactions, tests in the low-speed wind tunnel at the ONERA centre in Lille were used to obtain data on wake interactions, and in particular their impact on blade loading and rotor performance.

Alongside this campaign conducted on the specific INTROH test bench (1:7.7 scale Dauphin 365N model and propellant which is representative of the dimensions of the Eurocopter X3 prototype), numerical simulations were conducted with different levels of precision, after the validation of models and computing practices, improving the optimisation of configurations. In addition, phenomena likely to generate noise were also identified, making them easier to manage.

Simulation of plasma effects Proven and recognised expertise

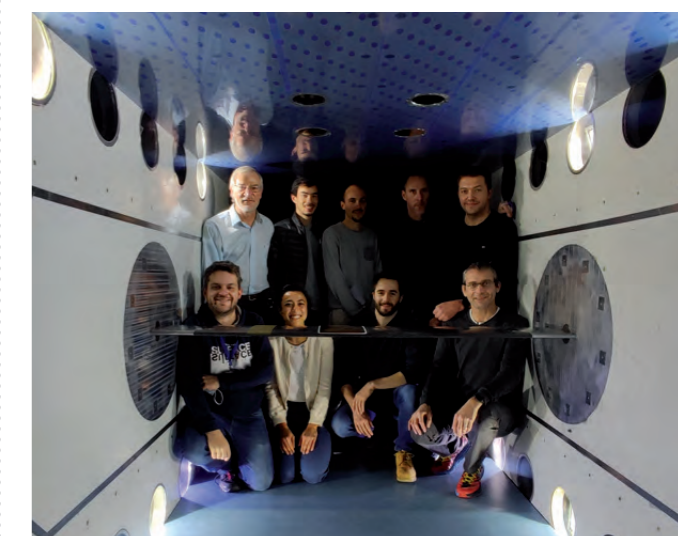


The excellent capability of the ONERA COPAIER code (*COde Plasma Instationnaire pour l'aERodynamique* - Unsteady plasma for aerodynamics code) to simulate plasma discharges within airflows and to help understand the electro-hydrodynamic (EHD) force was proven

As part of our cooperation with Airbus Central Research and Technology on ion thrusters. The simulation of a crown discharge on a wing profile perfectly replicated the effects observed in the laboratory, representing a major breakthrough. Works conducted as part of the European CTFF (Control of the Turbulent Friction Force) project. These works explained the inversion of flow induced by an axi-symmetric actuator. Also, the simulation of a point-type non-equilibrium plasma discharge in a supersonic airflow has, for the first time, demonstrated the coupling between the load separation effects and the carrier flow.

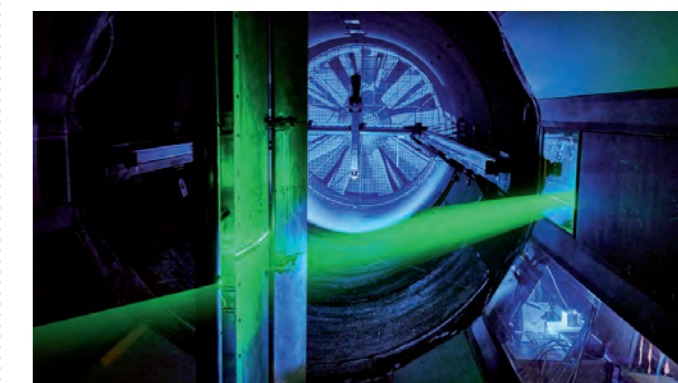
Laminar wings An outstanding database

In this way, a detailed and very high quality database on the physics of laminar-turbulent transitions on a transonic profile was experimentally produced in ONERA's S2MA wind tunnel as part of the NACOR project. For this project, launched in 2015 within the Airframe-ITD Clean Sky 2 platform, ONERA leads the TechnoStream Advanced laminarity. Four ONERA scientific departments are collaborating in this large-scale campaign, called STUNTT (Surface imperfection and UNsteady motion impact on Transition onset), dedicated to investigating several scientific barriers specific to laminarity technologies. The first part of testing concerned the assessment of 2D surface defects on the laminar-turbulent transition of the high Reynolds limit layers and at transonic speeds. The second part was aimed at studying the forced movement of the profile on the laminar-turbulent transition mechanism.



Aerodynamics Measurements taken in the L1 wind tunnel for a motorised Krueger slat

The European UHURA project (Unsteady High-lift Aerodynamics – Unsteady RANS) aims to develop and validate the numerical computing tools required to predict the performance of wings equipped with a Krueger-type mechanism. ONERA, a major partner in the project, used its test resources and know-how in aerodynamic measurements for tests on a mockup equipped with a motorised Krueger slat in the L1 wind tunnel of the Lille centre. The objective of these tests is to characterise the flow that develops on the lower surface of the wing when deploying and retracting the mechanism, with the purpose of validating the digital simulations conducted by ONERA and by other partners. This high-lift system has great potential for maintaining an extended laminar flow zone on the wings of civilian planes, thanks to the elimination of grooves and discontinuities in the leading edge region, compared to a traditional slat.

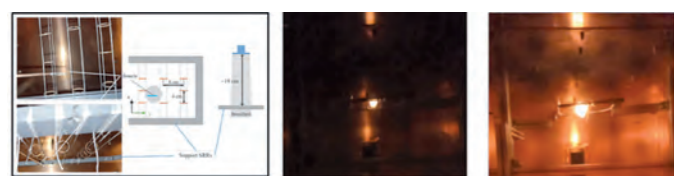


Engines

A world first: microwave time reversal ignition

The re-ignition of an aerobic aeronautical combustion chamber is a key element in the design of an engine for safety and operability reasons. The current system with an arcing spark plug has drawbacks, therefore new concepts are being studied that are more efficient and more durable.

The LAPLACE laboratory at the Federal University of Toulouse and ONERA have proposed an original solution based on the time reversal of microwaves. With this approach, energy is injected into a combustion chamber, which is controlled in space and time by the temporal shape of the microwave energy injected into the chamber. The collaboration is part of the JETRRIM project supported by the STAE foundation (Sciences et Technologies pour l'Aéronautique et l'Espace [Science and Technology for Aeronautics and Space]) and a thesis co-led by the two entities. This work demonstrated, for the first time at international level, that the plasmas generated by microwaves in the gaps of the resonant rings can effectively ignite kerosene spray. The ability of time reversal to selectively ignite certain SRRs suggests the prospect of an agile energy deposition system allowing for easier ignition or combustion control.



Cosmic radiation

4th mission at the Concordia research station, Antarctica



Cosmic radiation can alter some types of data and impair the operation of on-board electronic systems. ONERA is working to better understand this radiation in order to plan ahead for its effects on new technologies. As part of the CHINSTRAP polar project supported by the French Polar Institute Paul-Emile Victor, a neutron spectrometer was installed by ONERA in 2015 at the Concordia research station in Antarctica. Its special feature: quantify neutrons while characterising their energies. A significant contribution compared to standard instruments, which are limited to flow measurement. In addition to instrument calibration operations, a new signal control and processing system was installed for this 4th polar mission led by ONERA. This new system incorporates a self-restart mode, auto-configuration and daily data transmission. Thanks to this work, the neutron spectrometer is now operational and long-term observations are feasible.

Helicopters

Improved landing on frigates thanks to flow control



One of the most difficult manoeuvres faced by pilots is landing on frigates. Highly turbulent areas in the superstructure's wake generate disturbance which is severe on the flight deck in terms of both direction and intensity. Tests were carried out in ONERA Lille's L2 low-speed wind tunnel as part of a thesis, in cooperation with Naval Group and the Laboratory for automation, mechanical engineering and industrial and human computing (LAMIH). The purpose of these tests was to identify flow behaviour on the flight deck for the different flow control strategies using continuous blowing. This involves analysing the aerodynamic nuisance to be reduced. One other key factor must also be considered: the rotor enters the area interacting with the ship's wake. On this basis, the rotor must be considered during testing. Naval Group's digital simulations can be validated by installing pressure sensors in several areas of the model, while studying the flows over the flight deck. The tests will be used by ONERA to improve the landing simulator. These tools (experimental, digital, simulator) can be combined in order to gain an objective view of the pilot's workload.

Satellites

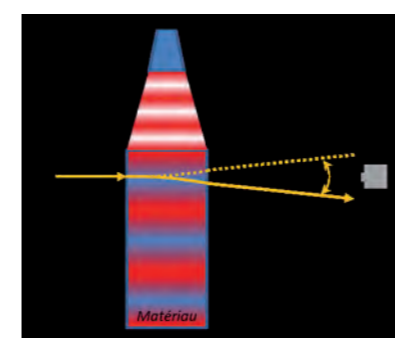
High risk of anomalies: Airbus welcomes ONERA's expertise

A satellite's environment induces strong voltage differences for various elements located close to each other, for example between a solar cell and its protective glass cover, or between a cable's insulation and its conductive core, or between a structural metal component and insulating paint. These differences can induce generally-accepted levels of electrostatic discharges, but which are not acceptable for the power system (solar cells, cables, connectors, etc.), as these levels could destroy the system and threaten the mission. Such effects are studied at ONERA: qualification and risk reduction tests are conducted to the benefit of space agencies and manufacturers. ONERA carried out tests for Airbus DS on some components of this power system, in the JONAS ionospheric simulation chamber by generating, on sample surfaces, electrostatic discharges which are representative of phenomena observed in flight, and by analysing, based on electrical and optical diagnostics, the potential formation of electric arcs. Thanks to this series of tests, a risk presented by an anomaly observed on the ground can be removed, thereby avoiding delays in the launches of two telecommunications satellites. Airbus DS has praised the excellent cooperation with ONERA, built up over more than 30 years.



Transparent materials

Development of a mirage-effect thermal diffusivity meter



III. ONERA has developed a diffusimeter as part of an upstream study programme (PEA) for these materials.

In the aerospace industry, windows are subjected to high temperatures. Complete characterisation is vital for assessing their behaviour. Thermal conductivity is a key parameter: the flash method developed at ONERA and used for several decades is reliable and robust, but hard to apply to transparent materials in IR bands II and

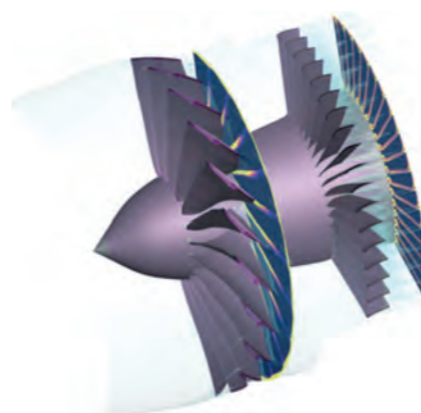
Robotics on land

Successful first milestone reached for the EDA/ARTUS project

ONERA participates in the ARTUS (Autonomous Rough-terrain Transport UGV Swarm) project, which started in early 2021 and is one of the projects selected by the European Defense Agency (EDA) in the framework of the PADR (Preparatory Action on Defense Research). The aim is to develop, over two years, a fleet of autonomous terrestrial robots able to provide logistical support to armed forces operating in difficult terrain. In 2021, a first demonstration of mono-robot autonomous navigation with obstacle avoidance enabled the green-lighting of an initial version of the system interfacing the combat management software developed by Diehl with the fleet navigation algorithm developed by ONERA, onboard a Ziesel robot mule. In 2022, the system was used for the coordinated navigation of three terrestrial robots interacting with a geolocated operator.

Aerodynamics

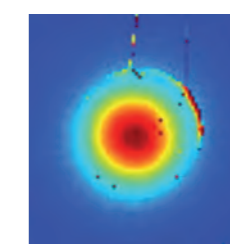
First: application of the exergy balance analysis to turbomachinery



This method developed by ONERA has been extended to rotational configurations, and applied to complex flows in turbomachinery for the first time. This is a "far field" method, based on an exergy balance, a thermodynamic quantity representing the potential to extract mechanical work from the fluid system. This method is implemented using the FFX (Far-Field eXergy, ONERA) software, which has, until now, been used for planes. The formulation of the FFX software has recently been extended to rotational configurations as part of Ilyès Berhouni's thesis (DGAC SUBLIME project) and validated on a propeller configuration and a compressor rotor. In the DGAC IDEFFIX project led in collaboration with Safran Aircraft Engines and Airbus, the exergy balance was initially applied to the NASA SDT engine wind tunnel configuration (calculations were run with the elsA software). This approach made it possible to characterise performance using innovative metrics: the flow of mechanical and thermal exergy through the engine. It also helped identify and break down areas with an irreversible loss of exergy, a key element for aircraft and engine manufacturers.

Health check

Characterisation of the durability of ultrasonic sensors



The DGAC MIND (Individualised conditional maintenance) project, led by AIRBUS, aims to characterise and model the ageing of ultrasonic sensors intended to be embedded on the metal structures of civilian aircraft for Structural Health Monitoring (SHM).

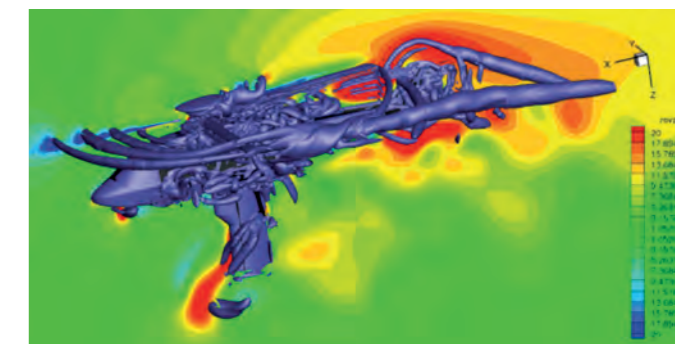
While simulations run with the CIVA code (developed by the CEA) had revealed a loss of the sensors' ability to detect cracks, ONERA

obtained innovative experimental results identifying the effect of ageing on the impedance of ultrasonic sensors and on the wave propagation field. The challenge is to propose experimental and numerical protocols to predict sensor drift when subjected to temperature cycles (between -55°C and +85°C) for several thousand flight hours in order to avoid triggering maintenance operations that would unnecessarily immobilise the aircraft.

Helicopters

New simulation tools to accelerate helicopter design processes

The closure of the DGAC CHARME project implemented with Airbus Helicopters and involving three ONERA scientific departments has made it possible to validate the improvement of aerodynamic, aeromechanical, acoustic, and aerothermal simulation tools, which are particularly critical in reducing the time and cost of designing helicopters. The physical phenomena faced by helicopters are more complex than those faced by planes and are therefore, for current simulation tools, more difficult to predict. The CHARME project focused on three areas: securing the rotor design, securing fixed parts subjected to aerodynamic interactions, and implementing methods in an industrial environment. ONERA and Airbus Helicopters teams worked together to improve and validate a wide range of simulation tools ranging from low- to high-fidelity.



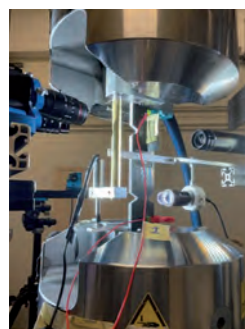
Lightning

New method used to analyse direct effects on composite materials

ONERA improves the understanding of the damage to carbon fibre composite panels and aeronautical rivets by comparing experiments with digital models. Thanks to the works completed pursuant to the DGAC PHYLIGHT2 convention, ONERA was able to assess the potential of phase contrast X-ray imaging combined with ONERA's multilateral offset interferometry technique, to characterise composite wafers struck by lightning. With this approach, one single image can identify the spatial orientation of the weave, thanks to the phase gradient images, and thus the damage induced in the different weave directions can be detected. This analysis is run in cooperation with the CEA-List. Radiography with absorption and phase contrast at the edge of a current injection point revealed, for the first time, and as part of a common CEA/ONERA thesis, various types of damage.

Composite structures

New analysis techniques for technological specimens



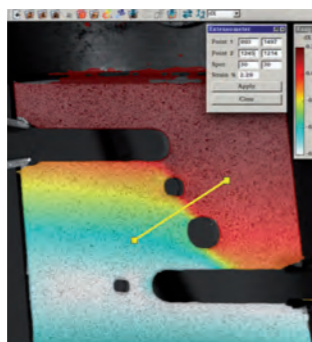
As part of the study "Evaluation of advanced methods for justifying composite structures" carried out in partnership with the Ariane Group, ONERA has set up a series of tests to validate the material models developed at ONERA focusing on behaviour, damage and failure. The definition of the structure tested on a traction machine integrates the specific geometric features of industrial parts. Beyond the geometric definition, the originality of the study lies in the experimental techniques (instrumentation and post-analysis) which

combine ONERA's know-how and allow test results to be compared with simulations. Damage was monitored by two acoustic emission sensors and six video cameras. The measurements taken can be used to quantify the specimen's overall behaviour and to observe, at the scale of the composite weave, the appearance of the first cracks, and monitor cracking, under a load, until the specimen fails.

Solid mechanics

Scale, an open source software platform, for test-model-calculation dialogue

The Escale software platform, developed at ONERA to meet its needs in terms of test-model-calculation dialogue in the field of solid mechanics, has been available since February 2022. Escale was developed to meet the need for tool capitalisation and pooling, and is a software library that includes data processing and analysis modules which can generate synthetic images, measure kinematic fields, detect cracks, identify behavioural law parameters and compare test results with calculations. In addition, interfaces allow for dialogue between these internal modules and external software.



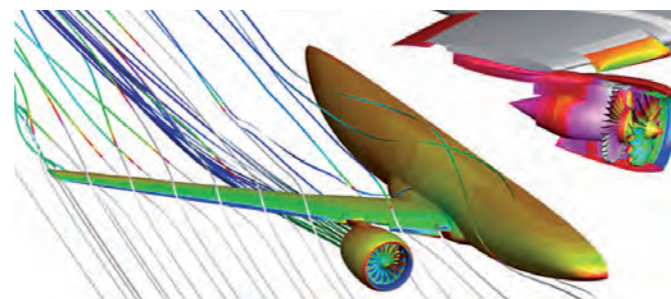
Aerodynamics

Data assimilation used to enrich fluid metrology

ONERA's multi-disciplinary team has developed an original data assimilation method allowing for the reconstruction of all the physical quantities of an instantaneous fluid field, based on a set of point velocity measurements. This approach, based on digital optimisation techniques, aims to determine flow acceleration, in order to minimise the gap between the measured speed field and a reconstructed speed field. This is a real step forward, with existing reconstruction techniques requiring multiple instantaneous speed measurements and therefore more complex and costly hardware. The effectiveness of this method was primarily demonstrated on a cylindrical air jet experiment, based on a field of scattered speed vectors measured by Particle Tracking Velocimetry (particle tracking between two points in time). This work (article published in Measurement Science and Technology) paves the way for potential applications with more complex flows, especially at high speeds, or characterised using other types of measurements, for example pressure or temperature.

Greener engines

Pioneering calculation for a complete motorised plane with a rotating fan

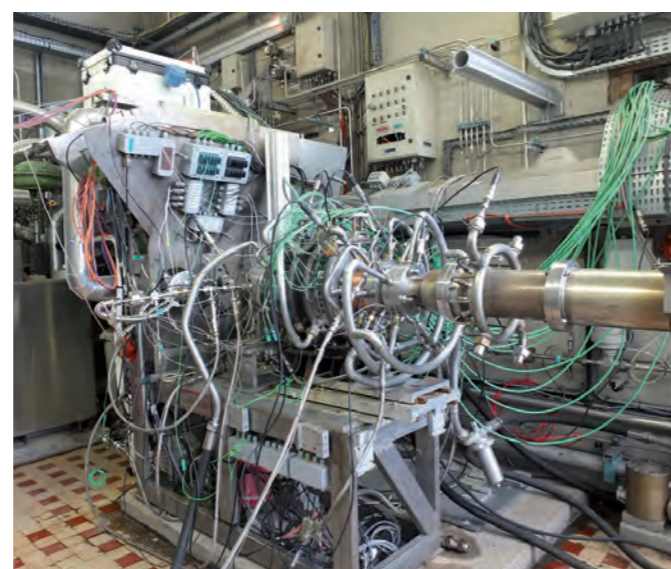


As part of the European Clean Sky 2 ADEC project, in the LPA (Large Passenger Aircraft) platform, numerical simulations were used to reproduce the flow around a complete plane, modelling both the external aerodynamics of the airframe and the internal aerodynamics in the secondary engine flow. These calculations take into account most of the components of a civilian transport plane: the wing, fuselage, slats and flaps in the take-off position, the engine pylon and nacelle, as well as the components inside the secondary flow of the UHBR engine, the rotating fan and the OGV (Outlet Guide Vanes). These calculations, both stationary and unsteady, were made possible thanks to the many features of the elsA software, including significant meshing activity to generate each element. The test case, NOVASPIRE, was the outcome of cooperation between many European partners: a merger between one of the NOVA configurations, the plane demonstrator designed by ONERA, with the ASPIRE engine, resulting from a previous partnership with Airbus, the DLR (German aeronautics and astronautics centre) and NLR (the Netherlands).

Satellites

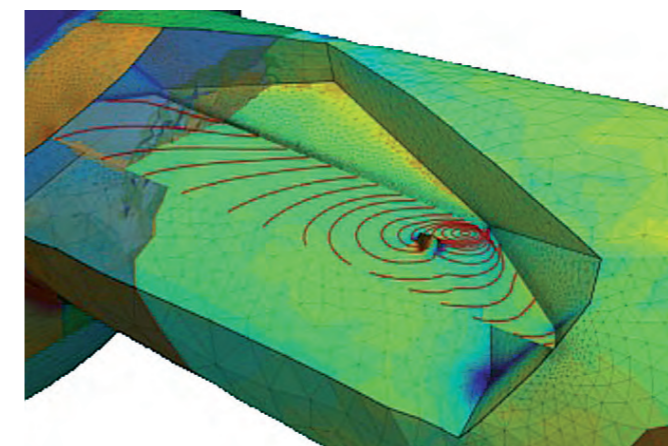
Materials with resistant property gradients in extreme environments

Thanks to tests conducted on ONERA's MASCOTTE combustion bench, the resistance of materials with property gradients have been validated up to flame temperatures of 3200 K in the presence of water vapour. These refractory materials, which combine a structural metal with ceramics, are developed and optimised by ONERA within the framework of the ONERA/CNES common interest programme "Green Monergol based Orbital-Propulsion System". These materials are designed to withstand the extreme temperatures of combustion chambers in future thrusters used to reposition satellites. For these tests, the fully water-cooled combustion chamber of the MASCOTTE bench was adapted to place the samples directly in the flame. Several gradient configurations were tested with excellent results.



Materials and structures

ONERA dynamically reconciles dislocations and crack propagation



New research, generated by modelling hydrogen embrittlement phenomena in next-generation aeronautical engines, has revealed similarities between dislocations and cracks (unavoidable and omni-present small-scale defects in metallic structures). The analogies highlighted relate to the theoretical analysis of dislocation dynamics and the 3D simulation of crack propagation by adaptive finite elements. As a result, significant new results were published in two articles in a reference journal for materials mechanics.

Aeroelasticity

Targeting the stratosphere!

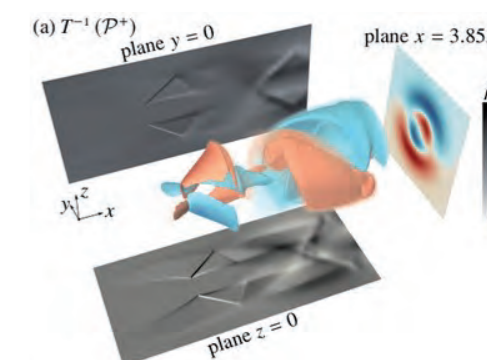


ONERA carried out an exhaustive GVT (Ground Vibration Testing) campaign in Meudon for the SolarStratos aircraft of the Swiss structure, SolarXplorers. At stratospheric altitudes (targeted by this aircraft), the flight envelope approaches the "coffin corner", a particularly dangerous zone at the boundary between stalling and flutter. In order to ensure the absence of aeroelastic instabilities, it is essential to identify the structural dynamic behaviour of the aircraft, the "modal model", beforehand. Several test configurations were investigated in order to provide all the data necessary for flutter calculations. In addition to analyses for the SolarStratos aircraft, this GVT contributed to the evaluation of new developments and methodological tools aiming to improve operational efficiency and the quality of analyses: this tool can provide information on the geometry of a high aspect ratio aircraft (span of 25 m), a first step for future research programmes on new groundbreaking transport aircraft configurations.

Supersonic jets

Three disciplines unveil their 3D dynamics

Underexpanded supersonic jets, found in a variety of aeronautical and aerospace applications, have complex unsteady dynamics. ONERA conducted an unparalleled analysis to identify the 3D structure of the density field of such a jet. Measurements obtained using a state-of-the-art optical technique – holographic interferometry – were re-used with advanced mathematical analysis. Instantaneous flow observations were used to reproduce the main coherent dynamics of the supersonic jet. This jet exhibits helical instability, and the direction of rotation changes stochastically. This work is the outcome of extensive cooperation between several ONERA teams, each of which has provided its expertise in turbulence, optics and image processing, thus giving new insight into the mechanisms governing the dynamic behaviour of such jets. This work was published in the Journal of Fluid Mechanics.



Deterrence

Sipa Air - R. Nicolas-Nelson



On 3 March 2022, Florence Parly, French Minister of the Armed Forces, and Bruno Sainjon, Chief Executive Officer of ONERA, signed the Contract of Objectives and Performance (COP) for the 2022-2026 period. This contract structures relations between ONERA and the State, recognising its status as a key partner of the French Ministry and the defense industry.

Deterrence

Under the aegis of the DGA, ONERA is at the heart of developments in the airborne nuclear component, supporting MBDA in preparing for successive generations of high-speed missiles. Today, ONERA complements its support by providing assistance to the project owner, making it the DGA's preferred contact over the entire life cycle of the programme.

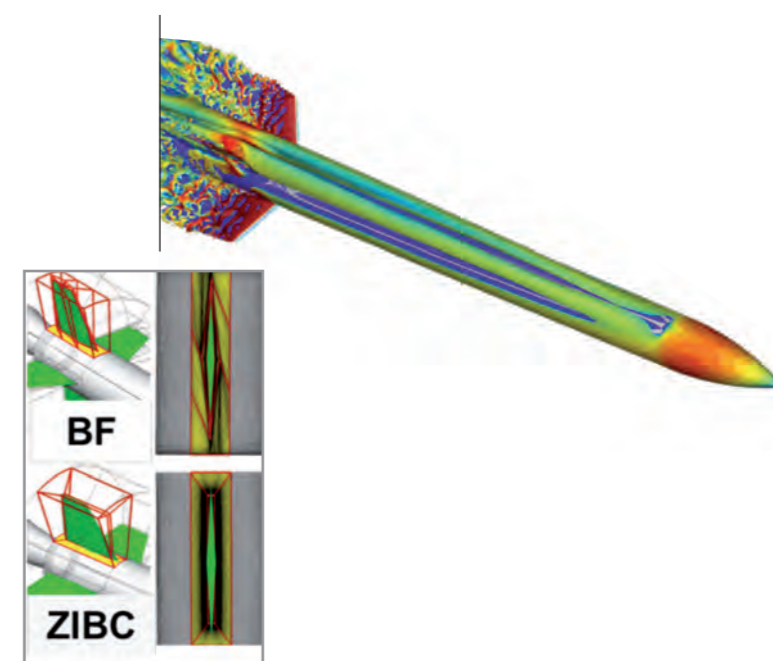
For example, in 2022, ONERA took responsibility for hybrid thruster fire tests, using new propulsion test equipment with an altitude simulation proposed by DGA Missile tests, as part of the development of sea-land strategic ballistic missiles (MSBS). Objective: cover all problems envisaged for the propulsion components of the upper parts of the M51 missile. Altitude is simulated using an open vein concept, increasing test capacities and significantly simplifying the architecture and operation.

As this architecture had never been tested in France, the DGA decided to finance the design of a model, in order to consolidate its operating principle, which led ONERA to carry out fire tests in a hybrid propulsion system in 2021 and in a solid propulsion system in 2022.

The precise prediction of aerodynamic performances for complex geometries is a major challenge in this field. ONERA's performance in terms of numerical simulation is remarkable. Past achievements: an unsteady aerodynamic simulation of a generic missile in crosswind, using an advanced digital simulation strategy, the ZIBC (Zonal Immersed Boundary Conditions), which combines speed with precise results. Thanks to this made in ONERA methodology, preparation time for simulations based on realistic geometries can be significantly reduced, however the calculation is far more complex. This technical obstacle was removed by ONERA with the development of a specific algorithm.



DGA-Espace en vol



The FCAS: Future Combat Air System

As an ambitious project, FCAS brings challenges in many fields, in which ONERA can provide its expertise: propulsion, sensors, electronic warfare, systems of systems, and the “combat cloud”. ONERA is both a government expert and a sub-contractor for Dassault Aviation.

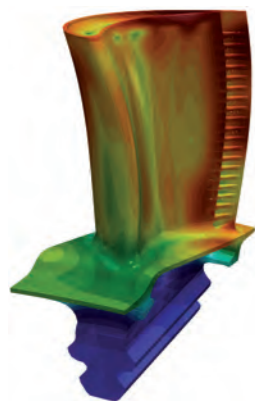
From 2021, the foundations were laid with the signature of the ONERA-DGA partnership agreement, which includes a specific agreement on the FCAS.

ONERA has worked for Dassault Aviation on the air inlets, as airflow can detach downstream of impact marks in supersonic conditions. To improve both performance and surge margins, ONERA explored the potential benefits of a technology based on porous walls. In addition, Dassault Aviation supported the development and validation of the ZDES (Zonal Detached Eddy Simulation) turbulence modelling technique for air intakes.

The first FCAS tests were conducted early 2022 in the transonic

and supersonic veins of the Modane S2MA wind tunnel. ONERA wind tunnels are recognised for their quality measurements, particularly high incidence measurements.

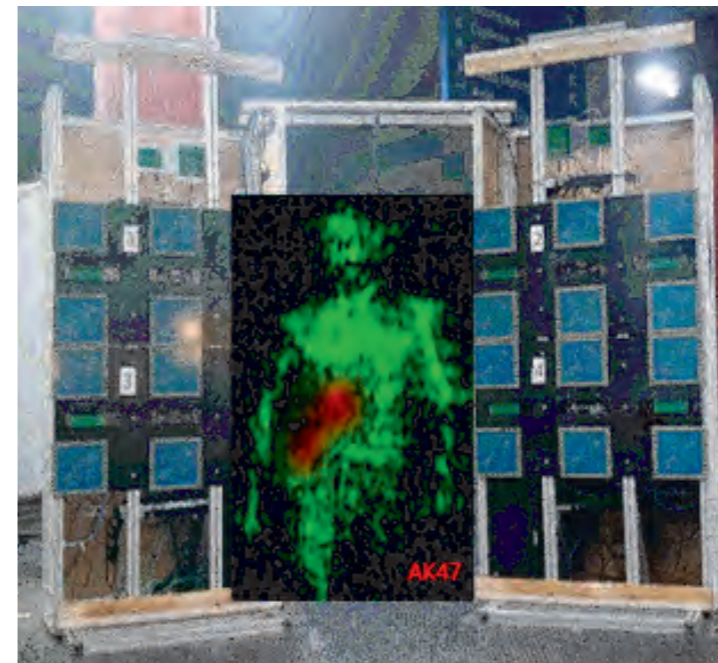
At the same time, ONERA’s upstream research project, SUPERMAN, aims to expand knowledge on the manoeuvrability of future combat aircraft concepts. A generic shape, which could be representative of the New Generation fighter (NGF), was defined. This shape can be used to experimentally characterise vortex flows in high incidence conditions in order to establish the link between vortexes and aerodynamic forces. The Lille low-speed wind tunnel is ideal for this purpose, as it provides the necessary data by applying oscillations to the model thanks to a dedicated device: the PQR assembly (P: roll rate, Q: pitch rate and R: yaw rate), which can be used to input rotational movements to the model in several directions.



Furthermore, as part of the ADAMANT project (acceleration of the development of alloys and multilayer systems for use with new turbines), supported by Safran and the Defense Innovation Agency (AID), ONERA has successfully tested a method based on artificial intelligence, providing predictions of the hot properties of materials, based on data shared with Safran, with a view to designing new alloys. Recent machine learning techniques have been used to design monocrystalline nickel-based superalloys for the high-pressure turbines used in future engines.

Finally, as part of the BECAR-Occitania project (combustion test benches for future aeronautical combustion chambers in Occitania), funded by the DGAC, the ERDF (European Regional Development Fund) and the Occitania Region, ONERA is upgrading its combustion test benches (pressure, temperature, and flow rate), to achieve the performance levels required to prepare for the engines of the future (civilian and military projects). For example, BECAR strives to equip ONERA with a new altitude test bench, HARP (re-ignition at altitude).

Safety: the MIC imaging radar successfully detects explosives and firearms in the crowd



A technological demonstration of the detection of explosives and firearms in real time and in a continuous flow of people was conducted by ONERA and its partners, late May 2022, in Italy, as part of the NATO-SPS DEXTER (Detection of EXplosives and firearms to counter TERrorism) programme. This demonstration, during which journalists, technical experts and guinea pigs blindly tested the system in the Roman metro system, successfully closed a one-month test campaign. With a success rate of 95%, the DEXTER system MIC (Microwave Imaging Curtain) radar demonstrator has proven its unique performance.

From 2018 onwards, NATO and the SGDSN (French Secretariat general for defense and national security) commissioned ONERA to lead a consortium of Ukrainian and South Korean universities, in partnership with the German researchers at Fraunhofer-FHR, to implement and test a radar demonstrator for detecting firearms hidden under clothing by pedestrians.

Defense robotics: ONERA demonstrates the value of its algorithms



In May 2022, the Battle Lab Terre, supported by AID and the French Ministry of the Armed Forces, organised the CoHoMa (human-machine cooperation) challenge, a competition designed to fuel reflection on new combat capabilities supported by automated, land-based and airborne systems.

ONERA was in charge of the land robots and coordination part (in collaboration with ENAC and ISAE-SUPAERO). On this basis, ONERA was able to test its control and command know-how for autonomous robotics, and was honoured by the organisers with two awards: “experimentation” and “control & command”. ONERA’s robotics researchers are behind some remarkable innovations, including: software architectures for autonomous decision-making (mono and multi-robots); vision-referenced navigation (mono and multi-robots); remote control and remote operation of machines (terrestrial and air) with adjustable autonomy.



Aeronautics

Decarbonisation: ONERA on all fronts

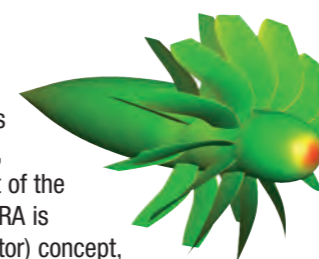
The European and international objectives to ensure the climate neutrality of commercial aviation by 2050 are at the heart of ONERA's strategy, alongside extensive involvement with industrial operators working with disruptive technologies in national and European programmes, and active attempts to adapt the knowledge base and tools required to reach maturity for the new generation of aircraft. The projects behind the 2020 aeronautical stimulus plan share the same ambition.

These environmental objectives are targeted by line no. 2 of ONERA's roadmap.

AIRCRAFT ENGINES

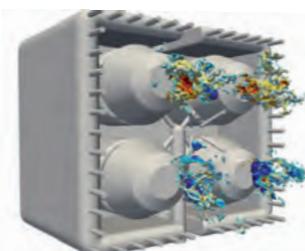
Energy efficiency

The increase in dilution ratio achieved thanks to the open rotor (USF) increases the propulsion efficiency of the engines, thus reducing fuel consumption. As part of the European Clean Sky 2 partnership, ONERA is studying the ORAS (Open Rotor and Stator) concept, an early stage USF.



Reducing CO₂ emissions

With the open-rotor, hydrogen could potentially be the second technological breakthrough, provided the combustion chamber and injection system are redesigned. Thanks to the government stimulus plan, ONERA is adapting its combustion test resources with the BECAR project. In 2022, advanced optical test benches were installed to improve measurement techniques and extend their capabilities to high pressures and temperatures.



In particular, in 2022, ONERA successfully tested a low NO_x injector designed by its teams as part of the DGAC HYPERION project.

Hydrogen: multiple skills for a transversal project

In addition to the work carried out on the aircraft configurations most compatible with hydrogen propulsion systems, our teams focus on two areas of research: combustion and hydrogen-material interactions.

In terms of combustion, in addition to the points mentioned opposite, ONERA develops injector design methodologies and tools, as per the DGAC PHYDROGENE agreement notified late 2022 (in cooperation with CERFACS for digital approaches).

In terms of materials, work on the impact of hydrogen will begin in 2023 aiming to study the embrittlement of alloys in a hydrogen atmosphere and the oxidation of turbine blade materials at the combustion chamber outlet. ONERA is also a partner of the DGAC STOHYC project and provides its expertise in the design of cryogenic storage tanks based on composite materials. Clean Aviation's HYDEA and CONCERTO projects will also address the issue of risk management.

Finally, the Cirrus H2 project, led by ONERA in partnership with Airbus, Safran, Dassault Aviation and IPSL, is studying the impact of the use of hydrogen as a fuel in turbojets on the formation and initial properties of condensation trails.

Sustainable Aviation Fuels (SAF)

SAF (Sustainable Aviation Fuels) are an essential foundation for decarbonisation. Their 100% paraffin composition is studied as part of the DGAC VOLCAN project with Airbus, Safran and Dassault Aviation. ONERA also assesses their impact on the formation of condensation trails and on fuel systems.

Propulsion materials

The ADAMANT project, supported by the Defense Innovation Agency (AID) and Safran, studies new nickel-based superalloys for future engine programmes. In addition, how diffusion, oxidation and mechanical forces interact in titanium alloys is covered by the DGAC PHYDOM agreement, which studies lower operating temperatures.

Finally, the DGAC ATLAAS project, led by Safran, focuses on design techniques for large aeronautical structures, in particular how calculation and test results correlate, using advanced instrumentation.



INTEGRATING ENGINES IN A PLANE AIRFRAME

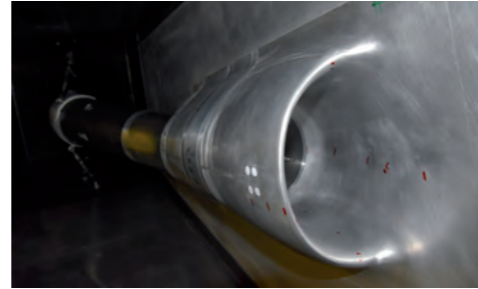
Improving aerodynamic efficiency: high aspect ratio wings

ONERA is working on the aerodynamic optimisation and overall performance of a plane with high aspect ratio wings, based on its digital simulation capabilities, thanks to the performance of its computing codes. ONERA is particularly considering aeroelasticity and load control (development of control laws).

ONERA is considering the concept of wing struts in terms of the complete plane (multi-disciplinary design process) in order to identify the inherent benefits. The wing strut with an aspect ratio of 19 was defined as a reference. The detailed aerodynamic design is partly based on an optimisation process.

Targeting more efficient engine integration systems

In terms of boundary layer ingestion, ONERA conducted wind tunnel tests within the framework of the DGAC SUBLIME convention to analyse the impact of more embedded engines: upstream distortion tests in the air inlet, characterisation of surging and the aeroelasticity of the fan.



ENVIRONMENTAL AND CLIMATE IMPACT

ONERA is working on improving our understanding of the impacts of aviation on the atmosphere and climate. The challenge: better understand the non-CO₂ effects (NOx and condensation trails) and the radiative disturbance induced by the condensation trails and cirrus clouds generated. The aim is to reduce uncertainties around the impact of aviation on global warming.

Research is primarily conducted under the Climaviation Convention (2021–2026), with the Pierre-Simon-Laplace Institute and with the support of the DGAC.

Research is also being conducted as part of the OCTAVIE (Occitania Region) project on estimating the impact of a trajectory on the climate taking into account non-CO₂ effects and on developing trajectory optimisation algorithms.

In order to better characterise the radiative properties of condensation trails, ONERA is studying the development of an onboard micro-lidar system, for example.

In the field of reducing polluting emissions in airport environments, ONERA has continued to develop simulation codes to characterise the dispersal of pollutants at an airport with a high spatial-temporal resolution and thus contributes to the characterisation of engine emissions. ONERA is a partner of the European AVIATOR project in particular.



ONERA, a benchmark player for the DGAC

Around fifteen conventions have been notified to ONERA by the DGAC aiming to expand knowledge of the multiple physical phenomena involved in aeronautics. Environmental safety and new mobility are both complex themes which ONERA could analyse in more detail thanks to its multi-disciplinary approach and its long-standing experience in these fields. Thanks to the support of the DGAC, ONERA is preparing the sky of the future.

PHYDOM: study on how diffusion, oxidation, and mechanical forces interact in titanium alloys

SUBLIME: study on boundary layer ingestion for civilian transport aircraft

PHYDIAS 2: study on how to manage drone-related risks

PHYDEFECT: study on the acceptability of defects when manufacturing composite parts

GIS 2: study on the impact of drones on people

GVT NEXT: advanced Ground Vibration Testing (GVT) methodologies

PHYCIEL: study on requirements when integrating electrical components

PHYDROGENE: study on understanding the combustion mechanisms of hydrogen engines

PHYLOG 2: study on certification options for software-hardware architectures

PHYSAFE 2: study on the crash properties and survivability of aeronautical structures

PHYLIGHT 2: study on lightning strike risks for aircraft

AIR CONDITIONING: study on the impacts of emissions other than CO₂ on the climate

BECAR: new measurement techniques for combustion studies

PHYFIRE 2: studies on fire risks



OTHER EXAMPLES OF ONERA'S WORK TO MAKE AVIATION... "GREENER"

Airport environment: measurement campaigns to better understand emissions

Using an A340 operated by the Iberia airline, equipped with Rolls-Royce engines, ONERA and its partners succeeded in very precisely identifying the type of emissions according to the type of fuel, and the influence of atmospheric conditions on the development of the plume and the impact on air quality in the airport zone. ONERA has been developing its expertise for several years: instrumentation, modelling and characterisation of emissions according to fuel type, combustion conditions, and external factors. Campaigns were carried out as part of the European AVIATOR project led by INTA - *Instituto nacional de técnica aeroespacial* -, Spanish space and aviation agency.

World-leading laser ignition

To develop new, more efficient and sustainable designs, ONERA is working on a laser ignition system, which has been tested successfully. This system can be used to recreate altitude conditions which are representative of the re-ignition of an aerobic aeronautical combustion chamber.

The laser igniter has reached a TRL of 5, establishing a global benchmark.

This work is being carried out as part of a cooperation programme between LOMA (Aquitaine's wave and material laboratory), ONERA and the company Fibercryst (DGA financing).

...SAFER

Ensuring the safe integration of drones in air traffic

A demonstration of how to avoid crossing drone trajectories in an emergency situation was successfully provided in July 2022. This was one of the final demonstrations of the EU-SESAR TINDAIR project, aiming to demonstrate how to manage conflict between drones, eVTOLs and manned aircraft in controlled airspace in urban environments.

For a scenario including the detection of future conflict and an autonomous emergency landing, ONERA has integrated the USSP system on board, and developed a planner that continuously re-plans diversion routes during the mission.

Flight controls: mini-sticks with haptic feedback for enhanced safety

This technology improves situational awareness, crew coordination and reduces the workload of pilots, as demonstrated by the EFAICTS project carried out using ONERA's PycsHel simulation bench in 2022. This European Clean Sky 2 project launched by ONERA, led by Safran E&D, and the DGA-EV (flight tests) as a sub-contractor, aimed to improve pilot/copilot interactions and interactions between the crew and the on-board systems. A rotary wing research simulator with a bi-pilot configuration has now emerged, integrating a large number of flight control systems and features.

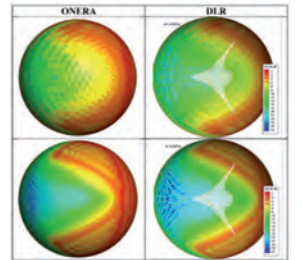
Helicopters: understanding transmission system cracking mechanisms

Tests under multi-axial loading have been used to develop more precise models of transmission system cracking. These transmission systems are subjected to extreme mechanical loads: an appropriate design and forecast life are essential to ensure the operating safety of the aircraft, as these parts are critical elements in the power transmission system. With Airbus Helicopters, ONERA is attempting to better understand cracking in planetary gears. The work carried out as part of a CIFRE thesis (Industrial training agreements based on research) helped to understand and model such cracking.

... LESS NOISY

13 dBA noise reduction for a flying wing type long-haul aircraft

ONERA and the DLR have demonstrated the effectiveness of innovative noise reduction technologies based on meta-materials and high-lift profiles, with flying wing type aircraft configurations. As part of the European H2020 ARTEM (Aircraft noise Reduction Technologies and related Environmental iMpacT) project, ONERA assessed the acoustic footprint on the ground of a long-haul BWB design at take-off and landing, using its CARMEN code (radius-based acoustic codes used to model and estimate nuisances).



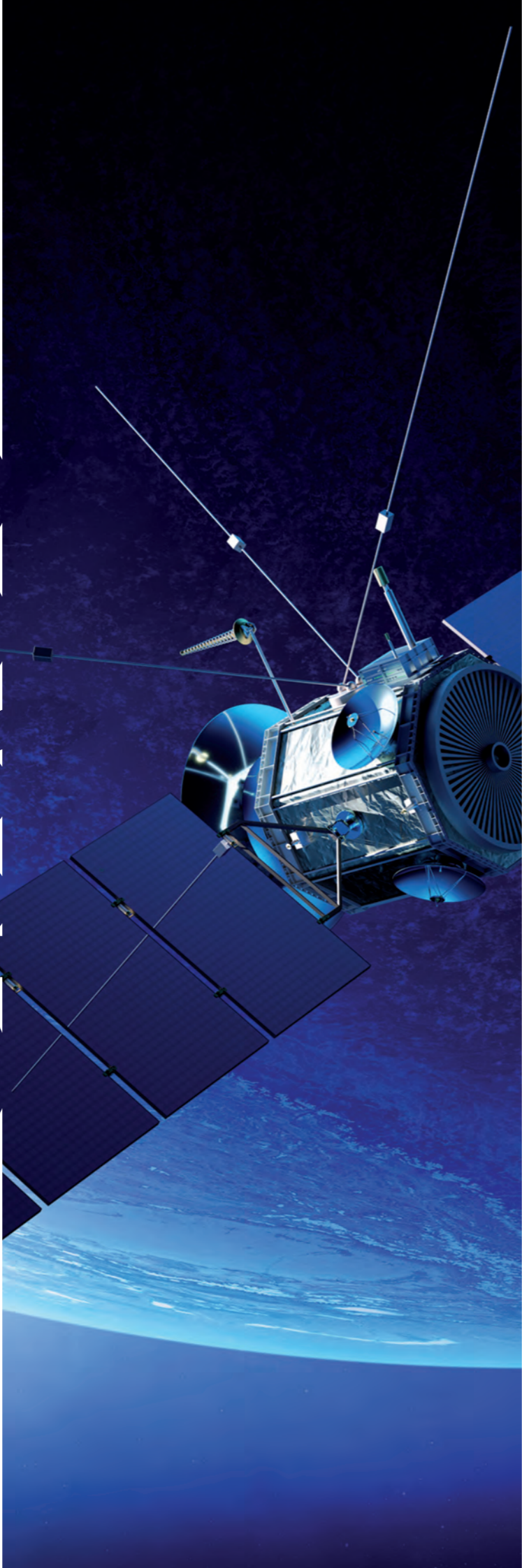
Creating a VTOL acoustic reference base (Vertical Take-off and Landing)

Noise is a major issue in the deployment of flying taxis. ONERA participated in an acoustic measurement campaign for VoloCity VC 2X in March 2022.

Objective: measure noise and record acoustic signals in the different flight phases. These measurements, combined with those taken by the other project partners (DGAC, RATP, NoiseParif), provide a shared reference base. ONERA will use this base to improve noise forecasting tools and carry out initial perceptual tests in order to identify acceptability criteria.



Space

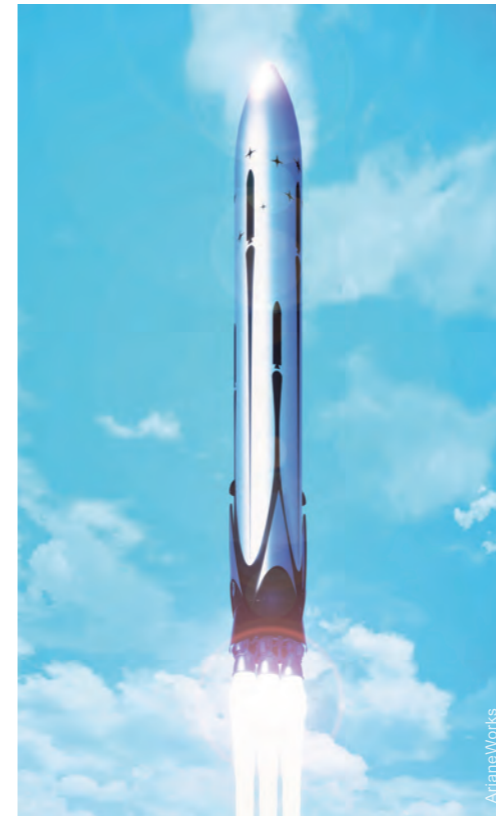
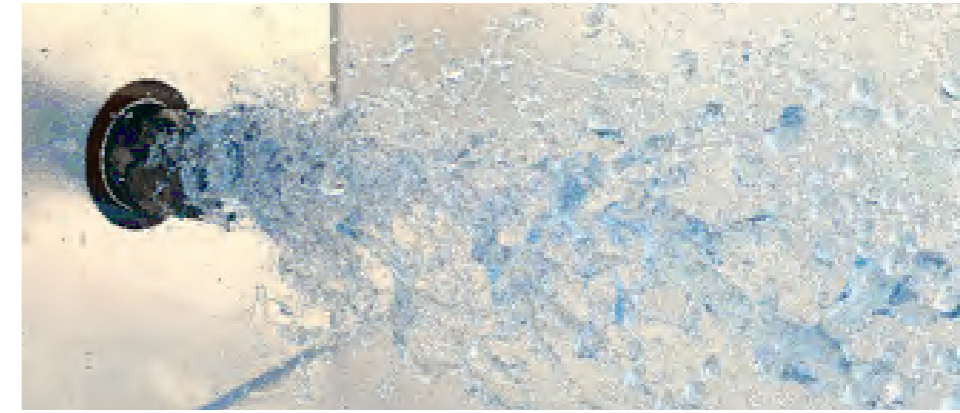


In 2022, ONERA's role in the space ecosystem grew, with success in national and European calls for projects, contracts concluded with major manufacturers and startups in New Space, continued cooperation with CNES, etc. ONERA is a major player in this ecosystem thanks to its wide range of skills, which allow it to play a central role in influencer groups such as COSPACE, a state-industry consultative committee working in the space sector, at national level, or with the preparation of future European work programmes in the space sector.

ACCESSING SPACE

Space launcher propulsion

As part of the second part of the programme of common interest (PIC), ONERA-CNES C3PO (Cryotechnic Combustion CH₄ plus Oxygen), signed with CNES in 2022, on the modelling of oxygen-methane pair combustion for the future Prometheus engine of the ESA (European Space Agency), ONERA carried out an unprecedented calculation: a simulation with unparalleled precision of the atomisation of a liquid jet. This type of simulation illustrates ONERA's work on understanding combustion instabilities in a liquid propellant rocket. This calculation was awarded first place for the Atos – Joseph Fourier Prize (see Awards pages).



Systems

ONERA managed the definition and validation of an SHM (Structural Health Monitoring) system, dedicated to monitoring the health status of a tank as part of the Themis Initial Phase project. ONERA has notably worked on the installation of sensors on the launcher's stage, prior to the tests to be organised in Sweden (technological validation in a cryogenic environment).

Reusable launch vehicles

In partnership with CNES, within the framework of the RLV (Reusable Launch Vehicles) programme of common interest (PIC) and an associated thesis, ONERA develops experimental and digital approaches aiming to design and qualify a system of SHM sensors which could be used to monitor the structural health of launchers, and validate reuse. One of the major challenges involves modelling the durability of these sensors, under conditions which are representative of launch vehicle environments. These activities will continue as part of the Horizon Europe SALTO project, which started at the end of 2022.

For the Horizon Europe ENLIGHTEN project, launched late 2022 and led by ArianeGroup, ONERA is using its artificial intelligence skills to design a health monitoring solution for the electrical systems in the Prometheus engine used in next-generation reusable launch vehicles. ONERA will primarily use its new algorithms to diagnose electrical components. When embedded, these algorithms will make it easier to detect failures and facilitate decision-making in operational phases, improving the level of safety and reliability of systems.

ULTRA-SENSITIVE ACCELEROMETRY: ONERA AS A PARTNER IN SPACE MISSIONS

Final results of the Microscope mission with record-breaking precision

The mission confirms the equivalence principle (EP) with an unparalleled accuracy of 10^{-15} and demonstrates that the bodies fall into the vacuum under the same acceleration, regardless of their composition or mass. As early as 2017, the initial results of the CNES Microscope satellite, equipped with ONERA accelerometers, had improved the precision of the EP test to the level of a global reference. Since that time, 15 times more measurements were accumulated prior to satellite deorbiting, and have since been analysed: the scientific team has pushed the limits of the test even further, achieving 10 times better results than in 2017. By comparing the free fall accelerations of two bodies with different compositions, the teams were able to demonstrate that the relative difference between these bodies is less than 10^{-15} .

In 2022, Manuel Rodrigues, ONERA project manager for the Microscope mission, which was a total success, was elected chairman of the Committee on Space Research (COSPAR) "fundamental physics in space" committee, for a period of four years.



ONERA accelerometers for international missions

ONERA's expertise in ultra-sensitive accelerometry has established its position as the referral point for several other international missions: the ESA's Next Generation Gravity Mission (NGGM), NASA's Mass Change Mission (MCM), and a potential future ultra-precise navigation mission.

GROUND-SATELLITE LINK: ONERA AT THE CUTTING-EDGE OF INTERNATIONAL RESEARCH

Radar communication

In 2022, ONERA achieved a world first: the characterisation of the propagation channel in the Ku, Ka and Q bands simultaneously. This experiment was performed within the framework of the ONERA-CNES PERF PIC (radiofrequency electromagnetic propagation).



Optical communication

In 2019, with the FEDELIO project (Optical feeder link for next generation telecommunication satellites), conducted on behalf of ESA, ONERA demonstrated the contribution of adaptive optics with pre-compensation for the effects of atmospheric turbulence. In 2022, a new record for data transmission via a very high-speed ground-ground laser link through the atmosphere was achieved as part of the European VERTIGO project: 1 terabit/s over a single wavelength, and a distance of 53 km and 2° elevation.

ONERA has also acquired state-of-the-art resources: it developed the FEELINGS (FEeder LINKs Ground Station) demonstrator as part of its investment programme, to establish two-way ground-satellite geostationary links known as "GEO feeder links". ONERA aims to develop and validate new scientific concepts to improve the performance of these links, in order to develop industrial stations for use in future ground-to-space optical networks. The objective: to establish a GEO feeder link with a geostationary satellite before late 2023 and test a downlink with an LEO satellite in 2024.



New Space

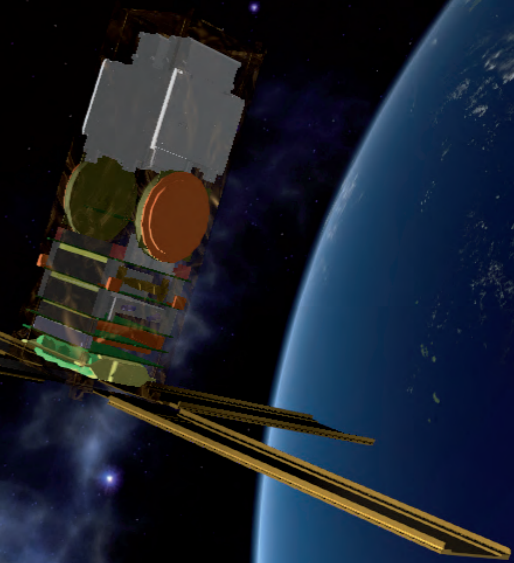
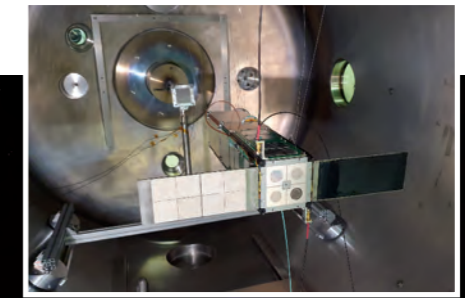
Nanosatellites are at the heart of the New Space approach, and simplify the process of conducting scientific experiments in space. ONERA's multi-disciplinary approach is a major asset.

CU-IONO, the first New Space payload developed at ONERA, will be deployed in 2023 on board the LATMOS INSPIRE-SAT7 mission (Atmospheres Laboratory, Space Observations). This payload will measure the electronic density of the ionosphere in order to measure the terrestrial radiative balance.

The CROCUS (ChaRging On CUbeSat) project run in partnership with Ecole Polytechnique's space centre (CSEP), aims to study electrostatic discharges in satellites, validate a new generation of payloads, and demonstrate the efficiency of an ONERA electron emitter to limit the negative charge of satellites.

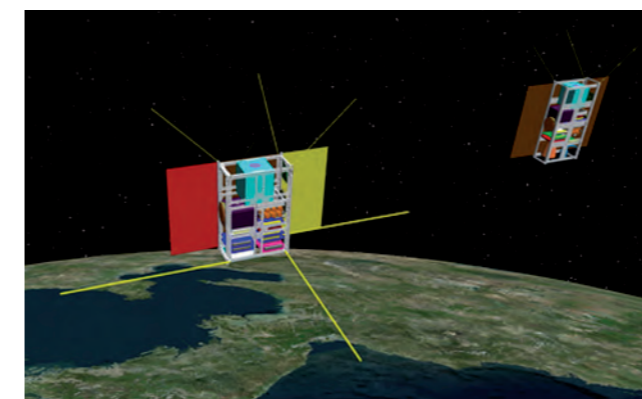
The CREME (Cubesat Radiation Environment Monitoring Experiment) project, partially funded by the Occitania region and dedicated to space weather, run in partnership with ISAE-SUPAERO, the U-SPACE company, and the SMEs, EREMS and TRAD and 3D-PLUS, aims to produce a monitor with a reduced footprint for use studying radiation belts.

Since the launch of the BLAST programme in 2020, linked to the Starburst accelerator, ONERA has supported several New Space startups.



A flying laboratory for multi-domain experiments: the FlyLab mission

The FlyLab mission comprises two nanosatellites, which fly in tandem in a low heliosynchronous orbit. ONERA will thus obtain a "flying laboratory" for demonstrations in orbit, allowing for missions in the fields of optics, radars, or systems. The satellites will carry two optical payloads for Earth observations and a companion satellite with visible and thermal infrared capabilities. They will also carry a radio receiver to study the impact of the ionosphere on HF signals, and an L-band transponder, to receive and retransmit signals. ONERA will also use algorithmic bricks to ensure the agility and autonomy of satellites during relative flight manoeuvres. The FlyLab will also be used, in interaction with other projects, to evaluate the performance of monitoring systems, enrich optical and radar signature databases, and validate propagation models. ONERA works with SMEs to supply equipment.



Lightning and Electromagnetic Compatibility (EMC)

ONERA has been working with CNES on the lightning protection of launch sites for 25 years: defining systems on the one hand, and running experimental evaluations on the other hand. This second role led ONERA to Kourou in 2022. Objective: to test the behaviour of the lightning protection system of the Ariane 6 launch pad, by injecting impulse currents into the pylons (lightning rod). Furthermore, ONERA runs other experimental and digital analyses on the vulnerability of ground pyrotechnic links to lightning strikes.

ONERA's major wind tunnels serving innovation in the aeronautical and defense sectors

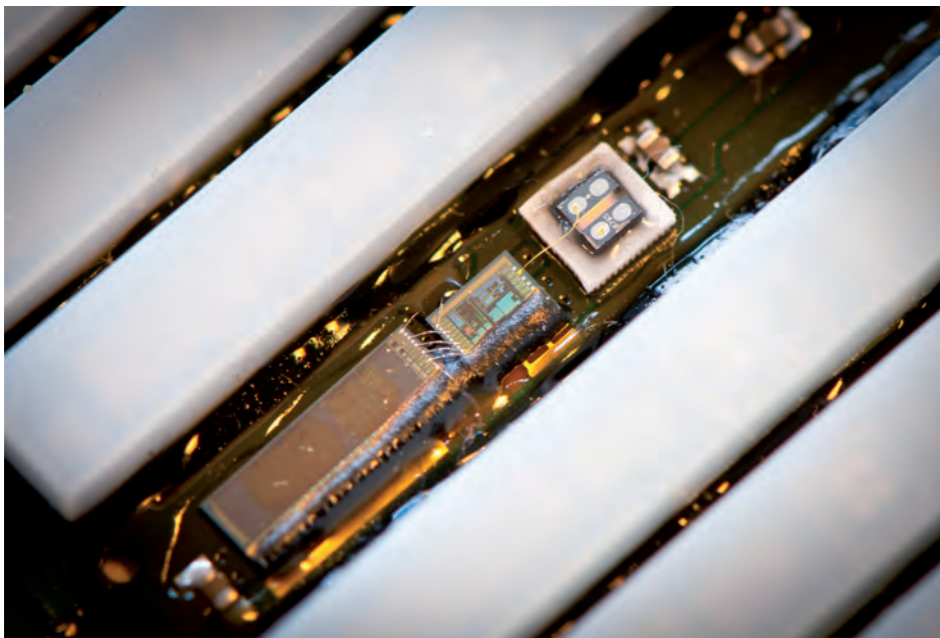
2022, another year full of orders

2022 confirmed the trend observed in 2021 : an excellent level of orders received combined with sustained testing, particularly in the high-speed wind tunnels in Modane. Also, significant development work continued as part of the ATP investment programme and DGAC* agreements. With almost €30 million in orders, the Wind Tunnels Division has recorded its best figures since 2009, with a wide variety of customers worldwide.

*Direction Générale de l'Aviation Civile: Directorate General for Civil Aviation, French civil aviation authority.

DGAC supports the innovations of the Wind Tunnel division: the SCAMPIS project

In June 2022, DGAC notified a subsidy contract intended to finance the work required for the SCAMPIS project, developed by the Wind Tunnel division as part of a partnership. This subsidy will allow for the continuation of the project, which is expected to replace the "large" pressure measurement equipment, currently installed in the models, with miniaturised systems. These systems will be equipped with electronics fitted as near to the measure point as possible, and will be able to achieve unsurpassed measurement performance, especially in terms of bandwidth. The SCAMPIS project will lead to a change in approach: the extreme miniaturisation of the electronics and pressure sensors used, will allow these devices to be installed directly on the model's surface, where the measurement is required; by acquiring the signal and converting it to digital format as near to the sensor as possible, a digital signal can be transmitted, eliminating both the noise problem and the complexity of pneumatic connections.



Wind Tunnel Division prepares future developments for carbon-free aviation

As part of the aim to reduce the environmental footprint of aviation, the Wind Tunnel Division is preparing tests for new engines and engine integration in the S1MA large wind tunnel. To this end, in 2022, the Fauga-Mauzac teams carried out maintenance work on the turbines intended for the test bench, which will enable the next generation of engines for short- & medium-haul aircraft to be studied in wind tunnels. S1MA will host several engine designs from 2023 and for several years. Prior to these tests, the windtunnel facilities will be adapted, thanks to the support of the engineering office and the WindTunnel division model workshop.

The continued modernisation of large wind tunnels

Thanks to the funding of the European Investment Bank and the subsidies granted by the DGAC in addition to its own funding, ONERA's Wind Tunnel Division has launched an extensive investment programme to ensure the long-term survival and modernisation of its facilities. In 2022, the Wind Tunnel division carried out a large paint job on the S1MA circuit, the condition of which threatened the very operation of the wind tunnel.



S2MA's control room was modernised to improve test ergonomics and prepare for the renovation of the measurement system. S3MA has been equipped with a new variable Mach nozzle control system, which can not only improve Mach number control but also boost test productivity.



These works only illustrate some of the activities in progress to improve the availability of our wind tunnels, reduce maintenance periods, and increase the extent and the quality of the measurements.



Boeing, NASA and Airbus attend the first tests of the high-lift reference model

In April 2022, the large low-speed wind tunnel, F1, welcomed Boeing, NASA and Airbus for the first tests of the high-lift reference model LRM-HL (Large Reference Model - High Lift). This large-scale model is the “new kid on the block” of the large reference models designed and manufactured by the Wind Tunnel Division model workshop. This model complements the reference models (clean wing surface) for ONERA’s three

large strategic wind tunnels: S1MA, S2MA and F1 and is part of the NASA “Common Research Model-High Lift” (CRM-HL) ecosystem, an international initiative aiming to bring together the efforts of the aerodynamics community in terms of modelling flows around an aircraft geometry equipped with highly realistic high-lift devices for flight conditions during take-off and landing. As the first high-lift reference model (full aircraft) and the first test of this type at high Reynolds numbers, the campaign at Fauga-Mauzac attracted great international interest focusing on the F1 wind tunnel.

Other test campaigns followed, primarily to characterise the wake behind the model in great detail, using laser Doppler velocimetry. This data will be used to validate new computing codes developed at ONERA, and new drag analysis methods based on the air velocity distributions.

ONERA stands out for its highly specialised flutter tests

In 2022, S2MA hosted flutter trials as part of the European Clean Sky 2 project. These tests are intended to investigate the aeroelastic stability of a new configuration of business aircraft tail fuselage. A model fitted out with large numbers of instruments was placed in a test section on an assembly allowing it to start fluttering: when aerodynamic forces combine with the elastic response of the structure, strong vibrations can occur, and can sometimes amplify very quickly until the assembly is destroyed. The flutter tests in the S2MA wind tunnel precisely reproduced the conditions in which fluttering starts for several model configurations, in order to improve digital aerodynamic and aeroelastic prediction methods. Improving our understanding of flutter enhances flight safety, and also the design of aircraft structures (weight reduction, costs, consumption, etc.).



Ceremony held to celebrate the contribution of the Wind Tunnel Division to the KF-21 programme

ONERA’s Wind Tunnel division was invited to the official celebration of the first flight of the KF-21 fighter aircraft, developed by KAI in South Korea. During an event bringing together different wind tunnel test service providers, ONERA was thanked for its significant contribution to the aerodynamic validation of the design of the KF-21 in Modane. Thanks to ONERA’s expertise and ability to meet the customer’s requirements, this major stage of the KAI project was completed within a very short timeframe.



KAI KOREA AEROSPACE INDUSTRIES, LTD.



Large S1MA wind tunnel receives prestigious ICARE award from the Association of Professional Journalists

The Association of Professional Journalists in Aeronautics and Space (AJPAE) selected the large wind tunnel, S1MA, for the ICARE 2022 award. This decision was intended to reward the contribution made by this industrial asset and ONERA personnel to research and development in the aeronautical and aerospace industries. More specifically, this award reflected the efforts made to save the wind tunnel, which was threatened by ground subsidence, and to modernise the facility as part of the large-scale ATP investment programme supported by the European Investment Bank.

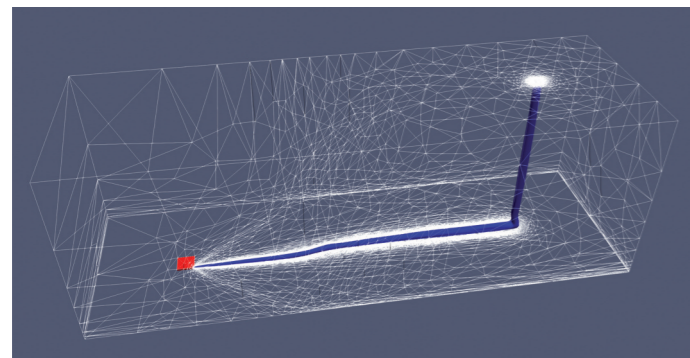
In order to celebrate the event, the award ceremony was simultaneously organized in S1MA windtunnel in Modane (pictured in the settling chamber) and at the Aeroclub de France.



Numerical simulation: increasingly powerful software

Agreements and signatures

Airbus, the DLR (German centre for aeronautics and astronautics) and ONERA renewed their commitment to the collaborative development of the new generation CODA code for five further years at the end of 2022. This agreement follows on from the first agreement signed in 2017. The aim is to extend the capabilities of the code to current and future Airbus projects. It could also help study even more radical concepts, such as the flying wing, with an unprecedented degree of speed and precision. In 2022, robustness and accuracy were significantly improved.



3D view of a 400 A continuous arc in air flow travelling at Mach 3 over a distance of 2 m and attached at its base by a conductive material (red square)

In addition, as part of the framework agreement signed with INRIA (French Institute for Research in Computer Science and Technology) in October 2022, the joint INRIA-ONERA Gamma0 team on the adaptation of meshes was created on 01/01/2023. The example opposite is obtained with the unstructured parallel 2D/3D Taranis code, which solves the resistive "magneto-hydro-dynamics" equations coupled with a compressible fluid model, in order to better understand the complex interaction between a lightning arc and different types of metallic and composite materials.

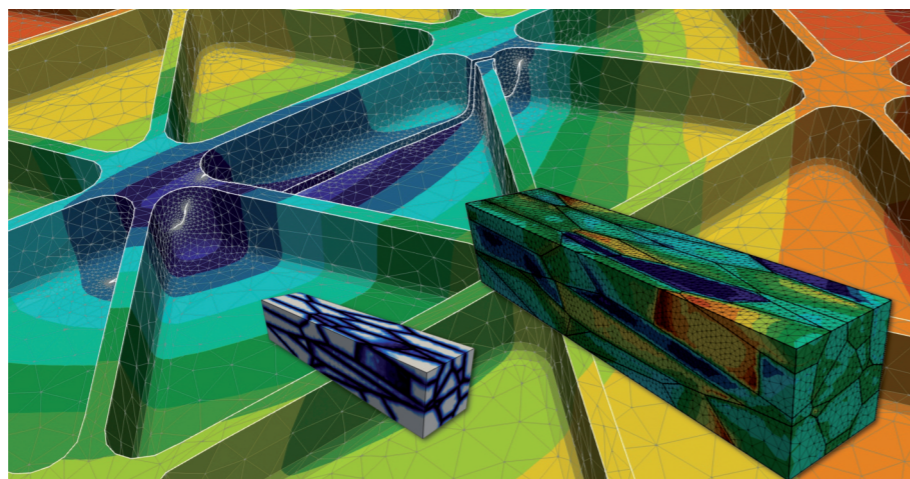
THE ONERA APPROACH: A MULTI-DISCIPLINARY PLATFORM

ONERA is attempting to harmonise its physics solvers and their software interfaces. This "shared platform" dynamic (one of the objectives of the roadmaps structuring ONERA's scientific strategy) will boost the efficiency of the development process for solvers for the different physics equations managed by ONERA and improve the consideration of ONERA's and its partners' high-performance multi-physics numerical simulation needs through the interoperability of these solvers.

360° effective calculations

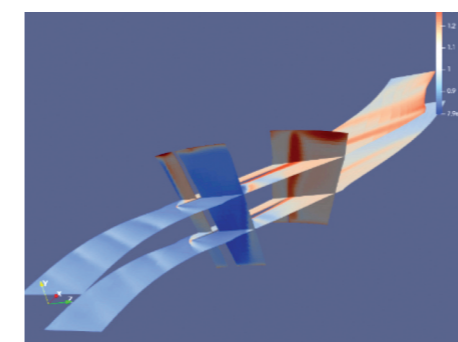
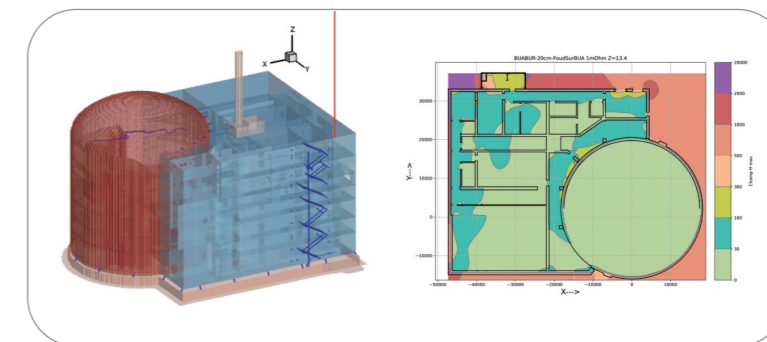
MATERIALS AND STRUCTURES

ONERA has been working for many years on the implementation of digital simulation tools for materials and structures such as the Z-set code (in partnership with the École des Mines). This type of tool can be used to assess, from the design phases, the lifetime of the most critical parts, depending on the type of material used, using high-fidelity calculations to resolve equation systems with several tens, or even hundreds, or millions, of unknowns. Within the ARIZE project, which is supported by the DGAC, ONERA is developing, with academic and industrial partners, the new generation A-set code, adapted to current hybrid computing architectures, aimed in particular at integrating complex, more physical and more precise multi-scale models, capable of significantly accelerating the deployment of decarbonised disruptive technologies in complete safety.



ELECTROMAGNETISM

ONERA has also been developing the ALICE FDTD code for many years. This code can solve Maxwell's equations using a "finite difference" scheme in the time domain. This code deals with large electromagnetic calculation scenes. In 2022, for CEA and TechnicAtome, ONERA digitally assessed the electromagnetic environments induced by lightning strikes on the Jules Horowitz nuclear reactor in Cadarache under construction. Due to the dimensions of the building and the complexity of its internal topology, a model comprising more than 2 million basic wires and nearly 251 million mesh points was required. The electromagnetic model has been validated by on-site measurements. Maps of the magnetic fields in the different building rooms, which could be used by the CEA and TechnicAtome, were obtained in this way.

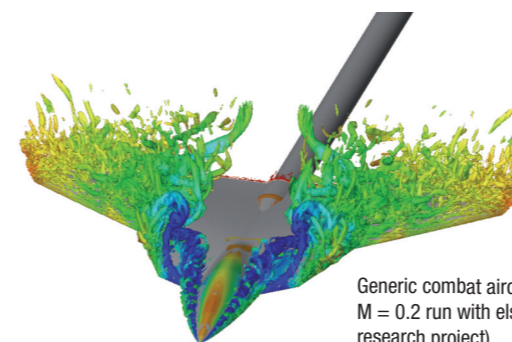


Implicit distributed parallel calculation of Rotor 37 with SoNICS. Comparison with the elsA simulation using partition parallelism (DGAC SONICE project)

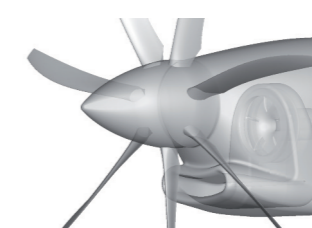
AERODYNAMICS

SoNICS next generation software reached significant milestones in 2022. Three-dimensional simulations demonstrated significant computing time savings and the code's ability to take advantage of GPU (Graphics Processing Unit) technology. Initial applications on turbomachinery, then calculations with an adapted mesh, were successful. SoNICS will ultimately benefit from extended functionalities compared to elsA, such as the inclusion of multispecies flows. This will enable significantly faster simulations and the software will be able to run efficiently on future hybrid computer architectures.

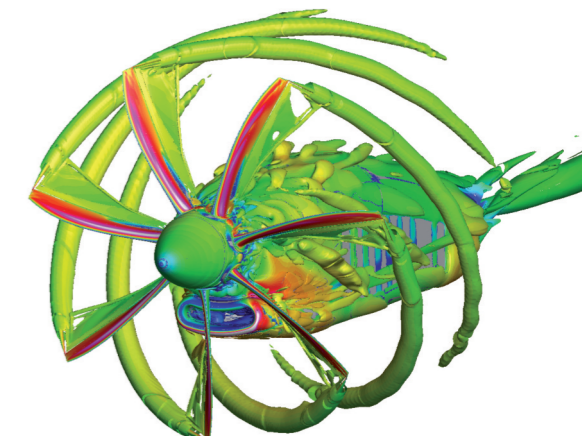
At the same time, elsA software continues to expand to meet the ever-increasing needs of users, particularly in terms of simulation complexity, both in the aeronautical and defense domains. Examples of such simulations proliferated in 2022.



Generic combat aircraft configuration at $M = 0.2$ run with elsA (SUPERMAN research project)



Unsteady aerodynamic interactions between the propeller, the nacelle, the air inlet and the centrifugal compressor of a turbopropeller (TechTP from Safran Helicopter Engines) run with elsA (EU Clean Sky 2 ANTARES project)



Advanced computing: first prize for ONERA

On 6 July 2022, ONERA won first place for the Joseph Fourier Prize, an international prize that rewards scientific excellence in the field of advanced computing and artificial intelligence. This simulation is, to the knowledge of ONERA, the most accurate existing model of the assisted atomisation of a two-phase coaxial jet. The model resolution is sufficient to include all the structures of interest in fiber regime atomisation.

This process is part of a project aiming to understand and control combustion instabilities in a liquid propellant rocket. Models calibrated using reference results are required in order to simulate large turbulence structures (LES for Large Eddy Simulation) for this purpose, and such results cannot be obtained using experiments under these extreme conditions.



BLAST programme: ONERA continues to support startups

ONERA is continuing to provide scientific and technical support for the projects selected for the BLAST programme – the first French incubation programme dedicated to Deep Tech companies in the aerospace sector. New space, carbon-free aviation and advanced air mobility are once again at the heart of this edition, which brings together ten startups and three researchers.

Projects supported by ONERA:

Sylphaero: plasma-based electric jet engines

Constellation Technologies: constellation of communication satellites in a very low orbit

Windlair: drone designed to carry heavy loads – High aspect ratio

Disaitek: Earth observations and AI to combat environmental crimes

Aerix Systems: omnidirectional propulsion drone for civilian and military applications

Spacelocker: pooled and multi-purpose satellite platform

Arkane: wireless smart sensor networks for aviation and space applications

Meoss: estimating local carbon flow segments and emissions using spatial data

Spaceblocs: SaaS solution allowing users to prototype and test space systems

Neamine: exploitation of rare metal resources available from earth-crossing asteroids

Static Engines: new definition of a low-power static engine

Matrix Gravity Waves: gravity wave control

ColibrITD: combustion modelling based on a quantum algorithm

2022 PI Indicators

16 new patent applications

11 new invention declarations

54 new software registered

88 licence agreements in progress

11 new Soleau envelopes

NumWorks software suite takes off

In December 2022, ONERA and the startup, Numworks Technologies, signed a licensing agreement for the co-development and use of the NumWorks digital platform.

In order to improve the modularity of simulation tools, an ONERA researcher created the NumWorks software workshop around twenty years ago, based on his electromagnetism expertise. This productivity tool, which has now reached maturity, is based on a large number of useful scientific calculation methods, and reaches performance levels previously unknown in the segment.

This is how ONERA's Maxwell3D code, built using "digital bricks" provided by NumWorks, can solve Maxwell's equations around 10 times faster than the market's leading commercial tools.

NumWorks Technologies is currently aiming to conquer the simulation software market for physics, and is targeting a position as a supplier of high-performance algorithmic components for publishers of scientific computing codes or industrial firms wishing to develop their own sector-specific applications in the NumWorks environment.



Technology transfers to make headlines



Late 2022, ONERA and SKYTED signed a patent licensing agreement to develop a silent mask allowing calls to be made with total discretion.

The SKYTED startup is based in Toulouse and has designed a new mask, offering a "silence bubble" for quiet, confidential calls in aeroplanes, transportation, open spaces and in the virtual world such as metaverse and online gaming.

The licensing contract provides for the integration of cutting-edge technologies to absorb the sounds produced by human voices: these technologies and this know-how were developed at ONERA for aeronautical applications, especially in next-generation aircraft jet engines. These technologies were used for a rather original application in this case.

"ONERA excels in scientific and technological research applied to the aeronautics, defense and space sectors. These cutting-edge research fields

lead to technological advances that could be used in other sectors. This transfer to SKYTED perfectly illustrates this point," explained Nicolas Guérineau, Director of Use and Intellectual Property.

"Voice reduction requirements are very similar to aeronautical issues in terms of aerology and acoustics. ONERA is therefore a natural partner for SKYTED," commented Stéphane Hersen, SKYTED CEO.

SKYTED is supported by Airbus Dev, the accelerator used by the European Space Agency and BPI Deep tech.

ONERA Academy®

The ONERA Academy® project, launched in 2022, reflects ONERA's aim to offer a structured continuous development training programme and thus to propose new levers for using ONERA's services in connection with its missions (2022–2026 COP). Several factors contributed to this range of options.

- ONERA must promote recognised skills in response to the current societal challenges in its sector: carbon-free aircraft, hydrogen, space data management, material constraints in aeronautics and digital simulation, etc.
- ONERA Academy® will thus promote the transfer of technologies to other sectors.
- Training culture is not new here at ONERA, an ideal environment for such an initiative (approximately 10,000 hours of training are provided by researchers every year). Some departments have already set up training courses for companies or administrations (primarily on software use).

To consider the other side of the coin, ONERA Academy® will bring benefits for researchers by helping them to enrich their activities. For ONERA, this approach will strengthen ties, and even create new relations with partners.

To get the ball rolling, ONERA decided to start by primarily developing training courses in how to use ONERA software, since it owns a library of over 550 codes developed by its scientific departments.

In 2022, legal, organisational and financial aspects of the ONERA Academy® project were set up internally. Partnership agreements with potential partners (ANDHEO, Ecole de l'air et de l'espace, INRIA, etc.) were also launched. Finally, two test training courses were selected for 2023: the CASSIOPE and MATISSE codes.



Intensive cooperation with Singapore

Numerous visits to ONERA by politicians and figures from the research sector highlighted the increased level of cooperation with Singapore. Since the creation of the SONDRRA radar laboratory 24 years ago, ONERA and Singapore have indeed maintained excellent relations.

In June 2022, several French and Singapore delegations met to discuss cooperation programmes within the SONDRRA laboratory. Specific meetings were organised at ONERA alongside the 5th SONDRRA seminar in Avignon. Ambassador Teow Lee Foo then visited ONERA in July 2022, just one year after arriving in Paris. She was accompanied by Ms Yihui Chia, First Secretary in charge of Political Affairs, and Mr William Peh, Adviser for armament and Defense Affairs.



General NG Chad-Son, Director of Defense Innovation of the Republic of Singapore, Ministry of Defense Deputy Secretary (Technology) and Future Systems and Technology Architect, also visited ONERA in November 2022. For his first trip to France since taking up his position, the General was interested in ONERA and the SONDRRA laboratory. He aimed to improve his understanding of the French defense and innovation landscape, and, of course, the cooperation programmes with Singapore.

Japan: the ONERA-JAXA relationship at its best

JAXA President, Dr Hiroshi Yamakawa, visited ONERA for the first time in 2022. This visit provided an opportunity for Bruno Sainjon, ONERA CEO, to sign a new bilateral agreement with his Japanese counterpart, in order to strengthen their cooperation in the aeronautical domain and especially in the space domain.



360° cooperation with the USA



The various visits by US bodies underscore the international impact of ONERA's work.

On 15 September 2022, the National Space Council (NSpC), the highest US space authority, visited the ONERA site in Palaiseau. The NSpC is a body of the Executive office of the President of the United States. The executive secretary of the NSpC, Mr Chirag Parik, is based at the White House and reports directly to Ms Kamala Harris. The NSpC addresses civilian and commercial policies involving international space and national security.

In October 2022, 50 years of cooperation in the field of helicopters between the US Army and ONERA were celebrated at the Palaiseau centre. DGA and ONERA hosted a delegation from the US Army as part of the AHFIR Rotary Wing Aeromechanics and Human Factors Integration Research cooperation programme for helicopters. This cooperation programme covers six areas of research: advanced rotors and high-speed rotors, hybrid design and configuration, pilot assistance and human factors, study of uncertainties for the aero structural analysis of vanes, and digital helicopter simulation methods.



ONERA-NASA cooperation: a new success story!

An ONERA-NASA working group was selected for the NASA Group Achievement Award. An internal NASA winner usually receives this high-level award. This award was granted to this joint NASA-ONERA team for the SUNSET 2 project, which involved around fifteen ONERA engineers from the scientific departments of energy, aerodynamics, and wind tunnels.

The SUNSET 2 project studied the effects of ice on delta wings, and led to the creation of several unique databases on the characterisation of icing effects on the aerodynamic performance of an aircraft. This project, which is part of a long-term cooperation programme, started in 2007 with the SUNSET 1 component, should continue with SUNSET 3, aiming to study the effects of

icing on high-lift delta wings. Furthermore, the signing of a framework agreement in April 2022, at the ICAO (International Civil Aviation organisation) meeting, confirmed the close partnership between the two establishments.

This framework agreement will facilitate the launch of new scientific cooperation initiatives. Bruno Sainjon and Robert Pearce, NASA Administrator, praised the continuity and success of the cooperation programme in several fields, such as icing and aircraft acoustics. This cooperation programme is set to expand to cover the new field of UAVs.



EUROPE

ONERA at the Governing Board of Clean Aviation

ONERA is a key player in the European Clean Aviation partnership (of which it is a founding member) and was entrusted with the role of representative (with DLR) of the research establishments that are members of the partnership in the Governing Board, at its launch at the end of 2021, and throughout 2022.



ONERA's Brussels office at the Maison Irène et Frédéric Joliot-Curie

In regards to the French Presidency of the Council of European Union, the CLORA became MIFJC to strengthen French participation in European research programmes, in particular Horizon Europe. This House aims to facilitate dialogue and cooperation with European institutions and strengthen cooperation between its members at European level. MIFJC is also a modern and suitable working place provided for ONERA teams dedicated to European matters.



ODAS 2022: ONERA rewarded



From 1st to 3rd June 2022, at the 22nd ONERA-DLR symposium, Samir Beneddine, an ONERA recipient, was rewarded for his presentation "Physical modelling using Deep Learning: mutual information maximisation to find optimal input features", describing a method for optimising the use of physical knowledge to improve the effectiveness of Deep Learning. Samir Beneddine is a researcher in the aerodynamics, aeroelastics and aeroelasticity department.

ONERA committed in European space research

ONERA chaired ESRE by the end of June 2022. During its mandate, ONERA organized a workshop on "Space-related challenge faced by the European Union". This workshop brought together officers of the European Commission, including Ms Catherine Kavvada, Director of division B (Innovation & Outreach) of DG DEFIS (Directorate General for Defense Industry and Space).



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



6 CHEMIN DE LA VAUVE AUX GRANGES - 91120 PALAISEAU - FRANCE - TEL.: +33 (0)1 80 38 60 60

www.onera.fr