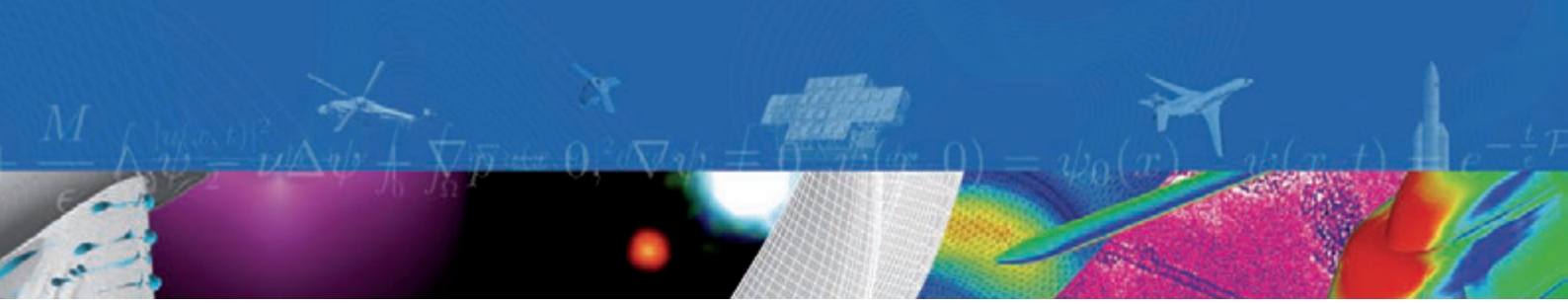


ANNUAL REPORT

2012

ONERA

THE FRENCH AEROSPACE LAB

r e t u r n o n i n n o v a t i o n

ONERA

THE FRENCH AEROSPACE LAB

Skill and creativity, our watchwords in 2012

The creativity of our scientists, engineers and technicians reached an all-time high in 2012, as the achievements recorded in this report show.

Our exceptional results are the product of our people's skills and expertise of course, but they also reflect the rejuvenation of our workforce, with the hiring of many talented young people, and close cooperation with industry.

We are more active than ever in export markets such as the United States, Russia, India and China, and a number of our research proposals in Europe were chosen.

The defense industry's recognition of our skills and critical facilities for military program development supports the sustained contribution of our expertise and technologies.

Research & Technology (R&T) is a constant key to the development of both civil and military aerospace programs.

At ONERA, we will continue to do our utmost for the customers and partners who place their trust in us.

Denis Maugars
Chairman and CEO
of ONERA

The leading aerospace and defense research organization in France

ONERA

THE FRENCH AEROSPACE LAB

return on innovation

To maintain our scientific and technical leadership, ONERA invests in fundamental research and spurs innovation. We are developing the defense technologies that will underpin tomorrow's strategic and tactical systems. We are also working on the enabling technologies for tomorrow's commercial aircraft, to reduce fuel consumption and noise, while further improving safety.

ONERA is a multidisciplinary organization that brings together the talents of 2,109 people, including top experts in energetics, aerodynamics, materials, structures, electromagnetism, optics, instrumentation, atmosphere and space environments, complex and onboard systems, information processing and long-term design.

We are Europe's leading center of expertise for aeronautical wind tunnels.

Results-oriented, ONERA conducts research in true project mode, based on professionalism, scientific excellence, impartial expertise and confidentiality. Half of our business comes from commercial contracts with firm deadlines, awarded under competitive conditions. Our annual budget is 243 million euros, including 23 million euros to keep our plant and equipment state-of-the-art.

ONERA works for both government and private industry.

Key Figures - 2012

2,109 employees:

1,528 engineers and management staff,

including **263** doctoral candidates

280 interns

23% women

107 new hires,

including **97** engineers and management staff

408 papers given in conferences publishing their annals

240 articles published in peer-reviewed journals

1,145 technical reports

76 doctoral theses submitted

€243 million budget

including

€23 million in capital expenditures

€115 million in contracts awarded

€109.7 million in grants

53% contract business

ONERA

THE FRENCH AEROSPACE LAB

Management Commitee

Left to right:
Thierry Michal, General Technical Director;
Véronique Padoan, Director of Human Resources;
Emmanuel Rosencher, General Scientific Director;
Patrick Wagner, Director of Computing, Engineering and Testing Facilities;
Denis Maugars Chairman and CEO;
Michel Humbert, Director of Business Development and Commercialization.

Scientific and Technical Organization

SCIENTIFIC BRANCH	SCIENTIFIC AND TECHNICAL DEPARTMENTS	Share of science/technology workforce
Fluid Mechanics and Energetics	> Applied Aerodynamics > Fundamental and Experimental Aerodynamics > Fundamental and Applied Energetics > Aerodynamics and Energetics Modeling > Computational Fluid Dynamics and Aeroacoustics	27%
Physics	> Theoretical and Applied Optics > Electromagnetism and Radar > Instrumentation and Sensing > Space Environment	25%
Materials and Structures	> Aeroelasticity and Structural Dynamics > Composite Systems and Materials > Metallic Structures and Materials > LEM: Laboratory for Microstructural Investigations*	12%
Information Processing and Systems	> Long-term Aerospace Planning** > System Design and Performance Evaluation > Information Processing and Modeling > Systems Control and Flight Dynamics	17%
Computing, Engineering and Testing Facilities (GMT)	> Modane-Avrieux wind tunnels > Fauga-Mauzac wind tunnels > Design, Engineering and Manufacturing > Software Products and Services	19%

* a joint ONERA-CNRS unit ** entity working for all ONERA departments

2012 Highlights

JANUARY

Buffet'n'Co, a project to control aircraft buffeting

ONERA carried out a wind-tunnel demonstration of closed-loop buffeting control, using small fluid jets on the upper surface of the wing, designed to delay the appearance of this dangerous phenomenon. Buffeting is an aerodynamic vibration that limits the flight envelope at high lift coefficients during cruise flight.

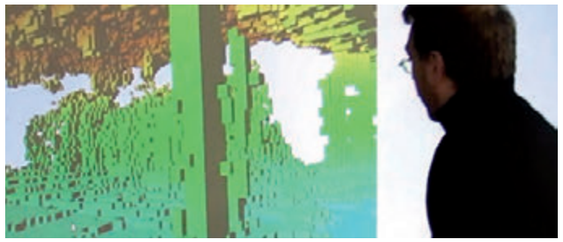
Extreme materials for hypersonic missiles

ONERA has developed a cost-competitive, high-temperature material that will push back the thermal limits on hypersonic flight. This spectacular achievement earned ONERA's research team the MBDA Innovation award.

ONERA chosen to evaluate NATO ACCS for France

French defense procurement agency DGA has awarded ONERA a third contract (2012-2013) to carry out the expert evaluation of the NATO Air Command and Control System (ACCS), clearly recognizing our expertise in this area. The ACCS will replace national air defense systems in NATO countries with a single system that handles mission planning, programming and conduct.

FEBRUARY



Parallel processing boosts microdrones' artificial vision

ONERA's Spider research project culminated in a successful demonstration of vision-based flightpath analysis and modeling, on a microdrone operating in an unknown environment. Another promising result is the development of an innovative process for the co-design of 3D sensors by exploiting the "depth from defocus" principle (patent filed in October 2012).

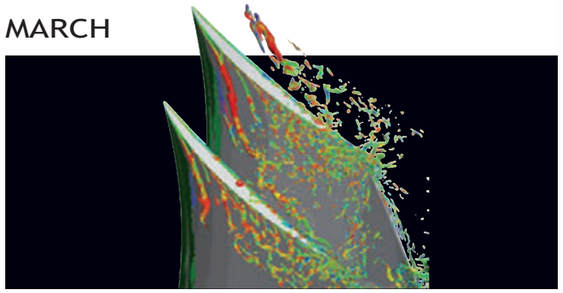
The smallest cryogenic infrared camera in the world

A doctoral student at ONERA has fabricated a compact infrared camera, suitable for volume production, earning the ONERA 2012 thesis award. This invention marks a technological breakthrough, with the complete optical system integrated in the cryogenically-cooled infrared detector.

Mistigri, a space-based observation instrument

ONERA produced and operated an end-to-end simulator to design the Mistigri high-resolution observation instrument for French space agency CNES. This new instrument will be dedicated to the study of the environment in the infrared band, including vegetation profiles and the detection and forecasting of thermal islands in urban settings. The simulator core is the Matisse radiation transfer software developed by ONERA.

MARCH



Enhanced aerodynamic calculations for turbomachinery compressors

The use of multi-scale modeling of flows, integrating blade-casing clearance in turbomachinery compressors, paves the way for more accurate performance forecasts. This major advance in technology will enhance prediction capabilities for operational configurations of all types of turbomachinery.

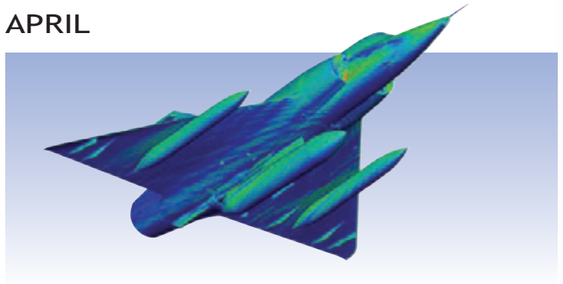
Tracking NOx emissions from aircraft

Predicting the generation of polluting emissions in aircraft engines is an extremely complex task. ONERA has set up a multidisciplinary project called "Cleaner", based on our Cedre software, to simulate these emissions in tomorrow's combustors. The results of this computer simulation, which match experimental measurements, are excellent.

ONERA leads European project to reduce orbital collision risks

The European project P²-ROTECT, coordinated by ONERA, addresses the growing problem of collisions between objects in orbit. Participants in an initial workshop presented the three ways of decreasing space systems' vulnerability to orbital debris: prediction, protection and debris reduction. They also shared the initial results of the development of a computation tool for this task.

APRIL



Spectacular reduction in radar signature computation time

Using an innovative mathematical formula, ONERA has achieved a spectacular decrease in the time needed to calculate radar cross-section, and is now among the world leaders in this field. The new method was tested on a computer-simulated warplane, reducing overall calculation time 22-fold over conventional methods!

More realistic aerodynamic simulations

ONERA's aerodynamic simulation software, elsA, has taken a major step forward in the quality of its predictions. The ability of this kind of software to numerically represent the influence of small devices and details on airflow is a key to increasing aircraft manufacturers' competitiveness.

Simulating the propagation of EM waves between space and Earth

ONERA has delivered a toolbox to the European Space Agency (ESA), capable of simulating the effects of signal propagation affecting land-based SAR (synthetic aperture radar) observation and radio occultation systems. It also developed the initial licenses for Sistar, a troposphere attenuation simulator for radio-communication systems, subsequently transferred to Thales Alenia Space, Eutelsat and SES Astra, within the scope of the ONERA-CNES commercial spinoff agreement.

MAY

First Ecosse tests to prevent overheating of fan casing a success

ONERA's engineers have built a simplified full-scale model of the fan casing on the new CFM International LEAP turbofan engine, instrumented to characterize and optimize the natural and forced convection ventilation of accessories. Following the successful first series of tests, Snecma will continue testing to study different configurations.

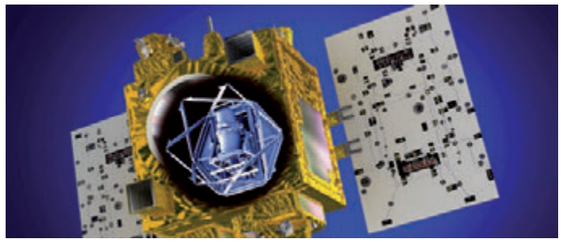
Air Transport Systems 2050 – Phase 2

ONERA published this document, including recommendations for the new Strategic Research & Innovation Agenda from ACARE (Advisory Council for Aeronautics Research in Europe), which will define the priority air transport research objectives for Europe through 2050. Coordinated by ONERA, this study was conducted by seven European aerospace research establishments through their association, EREA.

Photon sorting, a world first at ONERA

ONERA's scientists have sorted infrared photons according to their wavelengths, meaning down to a micrometer. The sorting is done by nano-antennas located on a single surface, a technique which could lead to pixels as small as a wavelength. This technique offers unrivaled sensitivity and resolution.

JUNE



European leader in micro-newton thrust measurement

After more than a year of continuous measurements, ONERA has completed thrust readings on the 13 cold gas thrusters to be used on ESA's Gaia mission, designed to provide a 3D map of our galaxy. Because of the accuracy of these measurements, to within a fraction of a micro-newton, ESA has pre-selected ONERA to qualify the 20 ultra-precise thrusters on the upcoming Microscope mission.

Expert analysis for robotized border monitoring system

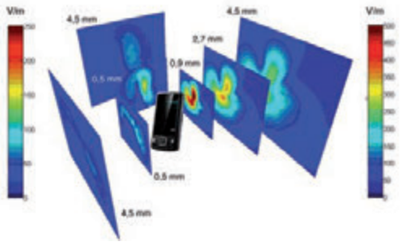
The system developed for the European project Talos has undergone a final demonstration. ONERA was in charge of modeling the optical sensors in the land robots (CCD, infrared cameras and laser rangefinders), and assessing their performance in the field. It also set up a subsystem simulation, involving drones and observation towers.

CFD boosts Ariane 5 performance and reliability

ONERA's ongoing developments in computational fluid dynamics (CFD) have continuously improved the European launcher Ariane 5 since the 1980s. Over the years these calculations have become more accurate, and integrate unsteady conditions plus technological details. These numerical simulations are pivotal tools to help understand the phenomena involved, whether for propulsion (Cedre code) or aerodynamics (elsA), with meshes based on some 100 million data points.

2012 Highlights

JULY



ONERA invents instant photography for EM waves

The EMIR method produces images that show the precise intensity of electromagnetic waves, as well as their emission direction. The successful development of this method called on the convergence of several ONERA specialties, namely electromagnetism, materials and infrared optics.

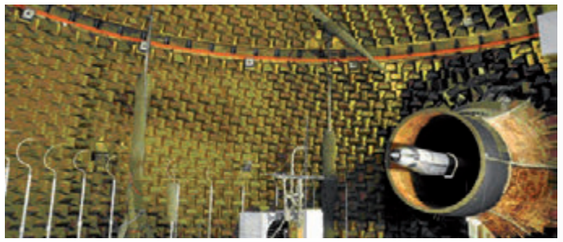
S4MA wind tunnel ready to host tomorrow's hypersonic vehicles

After extensive reconfiguration, the S4MA wind tunnel was to be ready for hypersonic tests in the first quarter of 2013. Final adjustments and airflow tests in the empty test section validated the performance of the aerodynamic system, determined the degree of heating of the different components more precisely and refined the automated airflow sequence.

Helicopter dynamic stall: better understanding, better simulation, better control

The Simcos program, developed jointly by ONERA and German counterpart DLR, explored the numerical simulation of dynamic stall, enabling it to more accurately predict performance, develop and test airflow control devices, and explore various technological solutions. ONERA worked on deployable vortex generators (DVG), which "reattach" the airflow to the blade.

AUGUST



Tackling jet noise with wind tunnels, measurements and ONERA software

The Exejet series of tests in the CEPRA19 wind tunnel has come to an end. A joint ONERA/Safran/Airbus program, financed by French civil aviation directorate DGAC, it collected extensive data on jet noise produced by commercial turbofans, and compared results from different nozzles. Velocity measurements via PIV (particle image velocimetry) were particularly instructive, thanks to Folki, an ONERA image processing software.

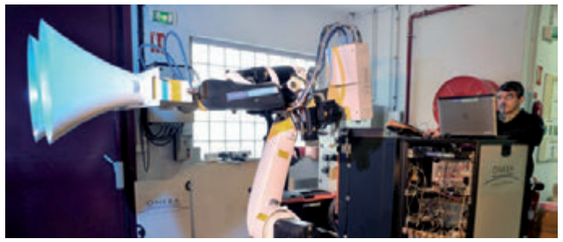
An active role in early Ariane 6 studies

Whether on the digital or experimental front, ONERA is very actively involved in the entire development process for solid rocket motors intended for the next-generation Ariane 6 launcher. It has carried out simulations using Cedre software, as well as five model firing tests to check instabilities (pressure oscillations or thermoacoustic instability).

ONERA mentors junior rocket scientists

Engineers from ONERA are taking part in the rocket launch portion of the student space research program Perseus (CNES), by mentoring engineering students from ISAE in aerodynamics and propulsion. The students built and successfully launched two rockets this year, each one carrying a scientific mini-payload. These highly enriching experiences often cement a student's career choice.

SEPTEMBER



Consert: checking out aircraft radar stealth on the ground

Consert is a robotic demonstrator for the local measurement of radar cross-section, designed and developed by ONERA under contract to the DGA. It is used to measure the radar signature of very stealthy aircraft on the ground, without needing an anechoic chamber. Its portability and operational flexibility make this innovative instrument a very powerful test device.

Kudos for a thesis on the digital optimization of superalloys

Guylaine Boittin's doctoral thesis brought together metallurgists and mechanical engineers from ONERA to study the digital optimization of a superalloy microstructure and thus increase its fatigue resistance and lifespan in turbine blades. This thesis won international scientific recognition during the prestigious Superalloys conference.

A major step towards new-generation combustors

At the end of 2012, work by ONERA helped Snecma make a major advance in the development of a new design for low-NOx combustors. This technology should eventually replace conventional combustors to help aircraft engines meet upcoming emission standards.

OCTOBER

Ramses-NG long-range tests a success

ONERA's new airborne radar test platform, Ramses-NG, equipped with X-, L- and UHF-band components, plus visible and hyperspectral cameras, has just passed a new milestone. By integrating a higher-performance X-band sensor, it can now illuminate and track a target at a range of 45 km in side-looking mode.

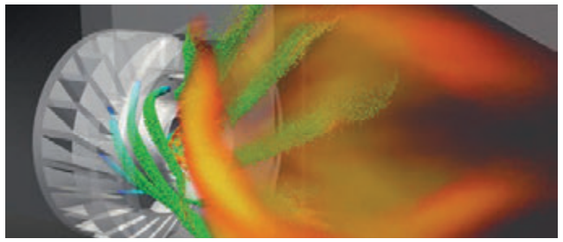
Promising results for ONERA's lidar vibrometer in urban environments

The Urbasis instrument, developed by ONERA with ISTerre, was used to measure micrometric vibrations on buildings in Grenoble at a range of several hundred meters, and reconstruct their mode shapes. This makes it very promising for seismic diagnoses of buildings, dams, bridges and other constructions, based on its high-speed operation from a single, remote viewing point.

A mirror that's 85% empty

ONERA teamed up with French national scientific research agency CNRS to produce an astonishing mirror that's 85% empty and yet totally reflecting, based on the interactions between light and matter at a microscopic scale. The mirror can also absorb certain wavelengths. Its spectacular optical properties and very light weight make it a key component in future photon sources or sensors.

NOVEMBER



Cedre energetics and propulsion software wins award

The French Academy of Air and Space has recognized Cedre, the benchmark energetics and propulsion software developed by ONERA, used widely for both research and by the aerospace and defense industries. Applications include all turbomachinery, scramjets and ramjets, liquid rocket engines and solid rocket motors.

First "Action" demonstrator: successful cooperation between a drone and terrestrial robot

ONERA's Ressac helicopter drone and the CNRS Mana terrestrial robot have carried out an autonomous urban zone control mission as part of the "Action" advanced research program, including the cooperative exploration of the zone and target tracking after position-determination. Used in the field, the drone could draw up a local map, for example, enabling a blocked robot to take another path.

S1MA wind tunnel enhances performance and productivity

As part of the European project ESWIRP, the first tests to control the Mach number in the test section of the S1MA wind tunnel were very satisfactory. Any differences were countered very effectively up to Mach 0.86; beyond that, they could be diminished further, and improvements are planned. The upshot is higher test productivity and enhanced airflow quality in the wind tunnel.

DECEMBER

ONERA research engineer wins award for work on laser detection of pollutants

The French federation of scientific societies awarded its Edouard Branly prize to Myriam Raybaut, a specialist in laser physics, for her development of laser devices (NesCOPO type optical parametric oscillator) used for the detection and measurement of natural or man-made pollutants.

ONERA teams up with Steel Electronique for NASA

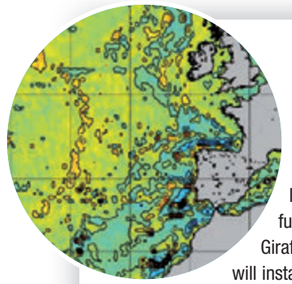
ONERA, the world leader in the development of ultrasensitive accelerometers, has renewed its confidence in Steel Electronique, a small French company specialized in high-tech electronics. The company's electronics will be used on ONERA instruments for NASA's Grace Follow-On terrestrial gravity measurement mission, slated for 2017.

Joint research agreement with Leosphere

Leosphere, a small but fast-growing company that builds and sells atmospheric measurement lidars, is bolstering ties with ONERA, which is accelerating its research on new wind lidars, in particular to develop long-range instruments to increase flight safety at airports.

First person: researchers and their projects

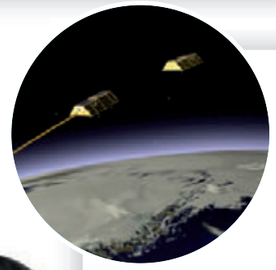
ONERA's researchers build foundations for the future of aerospace. While each itinerary is different, in terms of the disciplines practiced and the projects developed, there are still points in common, in particular the pride of working on major projects to help society, and the motivation of being able to call on outstanding facilities. We asked six scientists who have a passion for their profession to share their thoughts and experiences.



ALEXANDRE BRESSON
RESEARCH ENGINEER, PHYSICS, OPTICS AND LASERS, GIRAFE PROJECT MANAGER

"The Girafe project was launched in 2002 to design and build a shipborne cold atom gravimeter. Over the last ten years, I've had the satisfaction of being involved in all phases of research, from fundamental to applied, culminating in the construction of a demonstrator. Girafe-2 has now been launched, and we're developing the technology that we will install on a ship for operational measurements. I had to form a team to get to that point. In the beginning it was only half time for one person, since I was working on another project at the same time. Today, there are four of us working on the project full time. The fact that both CNES and the DGA were interested in our work made us even more motivated."

See further details of this project on page 24.

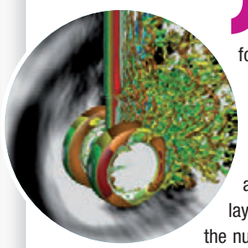


BRUNO CHRISTOPHE
RESEARCH ENGINEER, SPACE ACCELEROMETRY, GRACE FOLLOW-ON ACCELEROMETER PROJECT MANAGER

"It's very stimulating to design and build one of the critical instruments on NASA's Grace Follow-On mission. I'm very proud of being able to contribute to a project that helps evaluate climate change. I'm also very proud that NASA called on us again after the initial Grace mission, further recognition of our world-class expertise in accelerometry. Not to mention that this is a rather atypical project, and one in which we're going to take charge of the technology from A to Z, from design to delivery, and then operation. As researchers, it's exceptional when we can go all the way to ensuring the full operational maturity of a technology. Plus, this is the first time I've been in charge of such a large program, and I greatly appreciated both the personnel and project management aspects."

See further details of this project on page 42.

ERIC MANOHA
RESEARCH ENGINEER, AEROACOUSTICS, LAGOON PROJECT MANAGER



"The Lagoon project, completed in 2012, focused on reducing landing gear noise. It was very much a fundamental research project, since we established an experimental database using a simplified gear layout, to validate the numerical simulation methods applied to aeroacoustics. Launched back in 2006 and funded by Airbus, this was a real multidisciplinary project, and generated benefits for the global aeroacoustics R&D community. In fact, NASA chose this method as a test case for an international benchmark, to compare different techniques for predicting the noise generated by landing gear and high-lift devices."

See further details of this project on page 34.

DIDIER LOCQ
RESEARCH ENGINEER, METALLIC ALLOYS, DARTAGNAN PROJECT MANAGER

"Dartagnan is a DGA fundamental research project, combining ONERA, Snecma and the Ecole des Mines de Paris engineering school, which aims to develop new superalloys for turbine disks. From the management standpoint, it was a very exciting challenge to coordinate three major players with different yet complementary approaches. It was also very satisfactory to see the DGA, impressed by our results, quickly green-light the second phase. This time the objective is to bench test the new disk superalloy. Furthermore, and this is especially motivating, if we successfully complete this development, it will be the second superalloy for this type of application to be developed in France in the last 25 years. And that's quite an achievement!"

See further details of this project on page 26.

MURIEL BRUNET
SPECIAL ADVISOR, "AIR TRANSPORT SYSTEMS", COORDINATOR OF THE ATS2050-2 STUDY FOR EREA

"Coordinating this second phase of the study concerning tomorrow's air transport systems was motivating on three different levels. First, it involved seven research centers in Europe, and about 30 persons. We were able to organize the study the way we wanted, with a collegial working atmosphere, similar to what you'd find in an association. Secondly, we were able to perform the analysis without being constrained by financial considerations. It was a purely intellectual exercise, enabling us to really look at all the technological possibilities without this restriction, especially in terms of certification. Thirdly, it was highly gratifying to conclude this study with a presentation to the French Senate."

See further details of this project on page 38.

SEBASTIEN DECK
RESEARCH ENGINEER, NUMERICAL AERODYNAMICS, SPECIALIST IN AIRFLOWS AROUND LAUNCHER EXHAUST SYSTEMS

"I loved working on the pressure oscillations around the exhaust system of the Ariane 5 launcher, because this work is really at the crossroads between a scientist's theoretical research and the industrial application that's the specialty of engineers. Our task was to understand the physical phenomena that could potentially disturb the operation of a launcher, and either to control these phenomena or at least to accurately predict them. I was able to develop and apply new methods. Today, looking back from a distance of ten years, I can see the increasingly prevalent role played by ESA on this type of technical exercise. Alongside my regular contacts with French space agency CNES, my work with ESA allowed me to work with counterparts across Europe."

See further details of this project on page 36.

The federated research project Spider (French acronym for "onboard dynamic interpretation and perception systems for the urban environment") aims to develop innovative vehicle-mounted artificial vision functions. Kicked off in 2009, this project closed out on a high note in 2012 with a second-place thesis award, and above all a breakthrough in understanding: these "artificial eyes" have to be produced by a co-design approach combining specialists in artificial vision, optics and control systems.

Expanding knowledge to build foundations for the future

Research on artificial vision kicked off in the early 1980s, and has benefitted from the tremendous growth of embedded processing power, expressed in quotidian objects ranging from cars to smartphones. Today, our main challenge is to integrate this artificial perception power in dynamic systems that interact with their human users, including robotic systems, android type robots or microdrones.

Through the Spider research project, ONERA's researchers initiated an innovative co-design methodology, bringing together specialists in optics design, artificial vision and autonomous system control. This approach draws on examples from nature, because perception in animals is always connected to their motor capabilities, giving them highly complex functions with minimal resources – just look at the extraordinary flight capabilities of a simple fly!

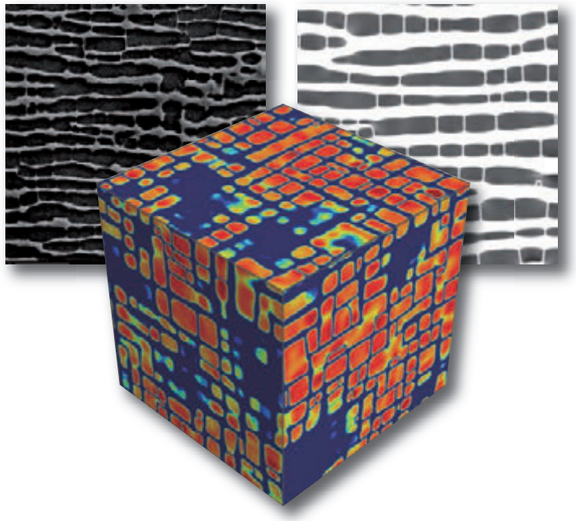
The Spider program ended in 2012, achieving major scientific advances such as the development of an innovative 3D sensor co-design process, based on the "depth in defocus" principle (patent filed in October 2012). Other advances include the production and demonstration of a flightpath analysis function, real-time modeling of an unknown environment by a microdrone using artificial vision, and a contribution to the production of a focal plane array lidar sensor for obstacle detection.

EXPLORATORY RESEARCH

AGENCE NATIONALE DE LA RECHERCHE ANR

France's National Research Institute, known by its French initials ANR, has regularly recognized the excellence of ONERA's exploratory research, encouraging its innovative approaches through the national research support program, Blanc.*

Contribute to forward-looking programs



In 2012, within the scope of the ANR's Blanc research initiative, ONERA took part in a research project dubbed Couphin, the French acronym for "coupling between phase fields and continuous crystalline plasticity." It aims to develop a modeling method that will describe the aging of metallic alloys used in turbomachinery. A new model coupling thermodynamics and mechanical behavior was developed through this project. For the first time, ONERA is offering a way to model microstructural changes according to the thermomechanical conditions inside the turbomachinery. This type of model could be used to predict the behavior of a microstructure in equipment under operation.

* The ANR's Blanc program is designed to give a significant boost to ambitious scientific projects that provide a competitive edge in international markets, and are based on an approach different from the conventional research process.

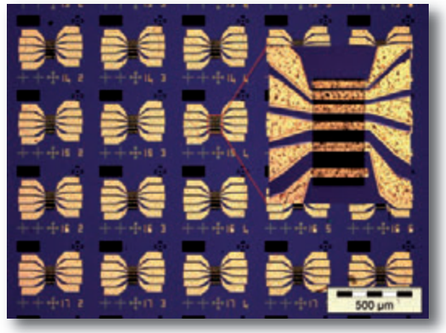
INSTITUT CARNOT ONERA-ISA

The 34 institutes that have earned the Carnot label cover a large majority of industry research needs identified by public authorities. The Carnot label reflects the research volume performed for industry, and the professionalism of the contractual partnership with these enterprises. Counting some 19,000 researchers, the network of Carnot Institutes represents 15% of public research in France, and 50% of research contracts financed by industry. The main objectives are now to develop this contract-based research and transfer the resulting technologies to industry, with a particular focus on innovative small and medium-size technology companies.

ONERA's Aerospace Engineering Systems unit (ISA), which earned the Carnot Institute label, invests in a number of projects to support industrial applications, such as the following:

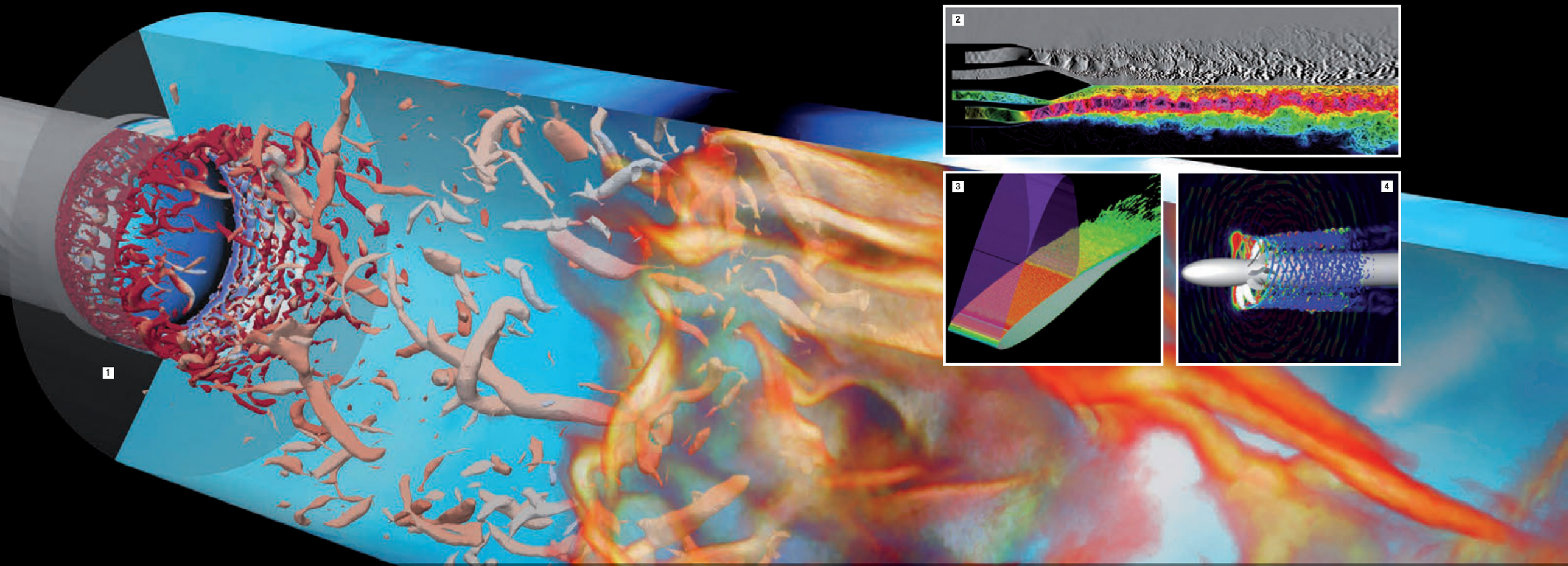
> **Antares**, an optronics project developing plasmon resonant antennas, a nano technology that paves the way for a new class of detector: ultra-sensitive infrared detectors that can be used at room temperature.

> **Work on a probabilistic and statistical approach to evaluate fatigue in composite structures**. This could be used to develop a method that would integrate fatigue factors in composite material structures very early in the process, right from the preliminary design phase.



Supercomputing power for enhanced simulation

In 2012, ONERA was eligible for nearly 10 million hours of computer processing time at the National Supercomputing Center, part of French atomic energy agency CEA, which it used to simulate a wide variety of fluid mechanics phenomena. This status validates both the pertinence of ONERA's research and the excellence of our researchers.



Control

combustion instabilities 1

Combustion instabilities in the liquid rocket engines powering the current Ariane 5 and upcoming Ariane 6 could imperil the payload. While the principle behind this phenomenon is known, involving a cascade of physical mechanisms (droplets, turbulence, combustion, acoustics), we still have to come up with a more refined forecasting tool. ONERA, which has worked on this subject for over 20 years, knows how to reproduce in digital form the phenomena seen during ground tests. Our ability to calculate airflows inside these engines will be a considerable advantage in further development of the current generation of engines, and the design of tomorrow's engines.

Analyze

unsteady turbulent flows in engine exhausts 2

What happens in the exhaust of a commercial aircraft engine? How are the different flows mixed, and how can we characterize them? The ONERA calculation seen here, using a strioscopic visualization of turbulent unsteady flows, enabled researchers to integrate the thermal effects of the hot jet from the combustor. The long-term objective is to further improve the prediction of the development of these jets to simulate acoustic propagation – an extremely complex calculation that required 1 million hours of computing time on the supercomputer at the French atomic energy agency CEA.

Predict

buffeting in an airfoil 3

The phenomenon known as buffeting can be very dangerous for an aircraft, and aviation authorities demand that manufacturers design in sufficient safety margins to avoid its appearance. So when engineers design a wing airfoil, they have to know when it appears, and for what reasons. ONERA calculated the transonic airflow around a wing airfoil undergoing buffeting, at the IDRIS scientific IT research center, highlighting the separation instability mechanism created by the interaction between the shock layer and the turbulent boundary layer on the upper surface of the airfoil.

Evaluate

the aerodynamic noise of an open-rotor engine 4

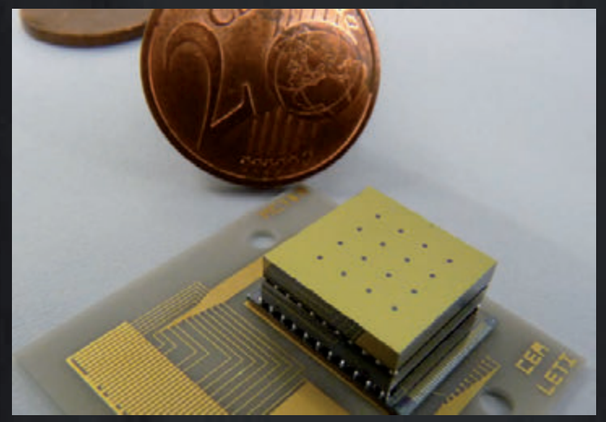
To better understand the complex aeroacoustics in a counter-rotating open rotor (CROR) engine layout, which generates significant noise, ONERA simulated the propagation of sound waves around this system. This is an especially complex calculation because of the interactions between the two large fans rotating in opposite directions. It required a highly sophisticated Chimère type moving mesh, an area of expertise for ONERA's aerodynamicists, with some 480 million points.

RAMSES-NG, a new airborne imaging system

ONERA is actively working on tomorrow's defense systems. Ramses-NG, for instance, is a major upgrade to the Ramses radar imaging system, incorporating significant improvements in radar imaging. It plays a key role in specifying and validating new operational systems that use imaging equipment.
Ramses-NG was developed jointly with industry for defense applications, but can also be used in the security sector (zone surveillance) and for environmental monitoring (remote sensing for climatology, agronomy, etc.).

Ramses-NG is a new-generation airborne imaging and surveillance system. It comprises two pods mounted under the wings of a Mystère 20 operated by the DGA's flight test center, and incorporates high-performance SAR (synthetic aperture radar) detectors, with the possibility of adding optronic sensors. It offers new or enhanced long-range imaging capabilities, including off-axis sighting, spotlight mode and complementary radar/optronic imaging, plus the ability to install models from industry for testing.
Ramses-NG's ability to create databases and explore the environment will enable today's armed forces to draw up specifications for their future operational systems, to optimize them to match operational scenarios, or to test system and equipment models for industry. In addition, this ONERA testbed can be used to meet specific operational requirements.

The smallest cryogenic infrared camera in the world



ONERA has developed an infrared camera that marks a total breakthrough versus current models, as part of a DGA-financed fundamental research project dubbed Temoin (the French acronym for "MEMS technologies for integrated nighttime optronics"). The aim was to develop a high-performance camera that could be used in surveillance or flight control aid applications.

ONERA's infrared "camera on a chip" marks a complete break with current infrared systems. The complete optical system is actually integrated in the cryogenically-cooled infrared detector itself. The camera is extremely compact – only 4 mm long – and offers a wide field of view, equal to about 120°, and could be produced in volume, like semiconductor wafers.

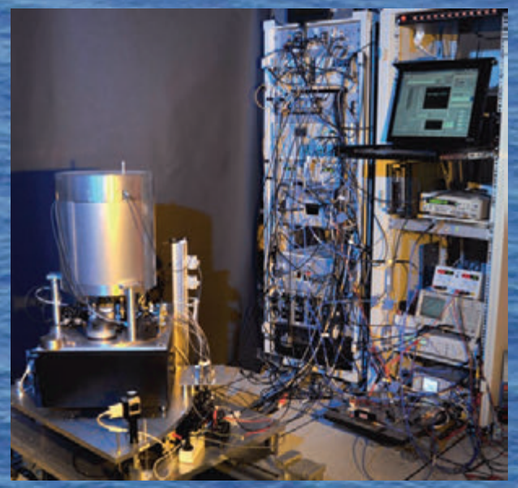
ONERA's camera is the smallest of this type in the world. Because of its compact design, it provides infrared observation capability even to vehicles with little payload capacity, such as microdrones or land robots.

This achievement is all the more impressive since in fact it originated with a doctoral thesis at ONERA, which won ONERA's doctoral student award for the research work, carried out in conjunction with the Leti electronics and IT lab at French atomic energy agency CEA.

A follow-on project, Temoin-2, was launched in 2012 and will finance the development of an operational demonstrator based on the same principle.

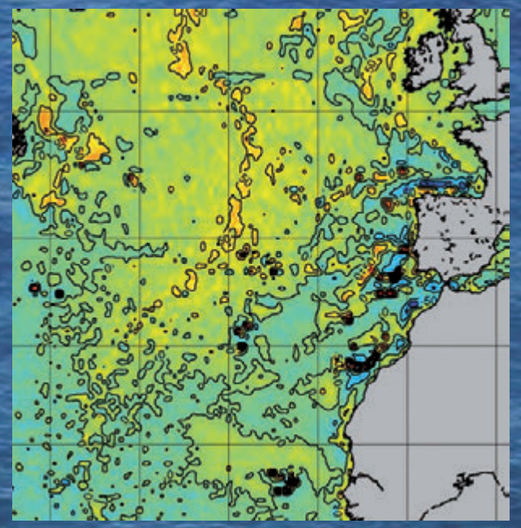
Know your position

ONERA has long experience in applying its multidisciplinary skills to complex projects. For example, by combining expertise in fundamental physics, metrology, microwaves, electronics, automation and above all lasers, ONERA produced the world's smallest onboard atomic gravimeter for French defense procurement agency DGA.



Starting in the early 2000s, ONERA teamed up with academia to push back the frontiers of our understanding of the fundamental area of atomic optics. ONERA was also developing in-depth expertise in laser technology at the same time, which could be used to cool atoms, with the application in mind of designing atomic inertial sensors (using laser-cooled atoms). Several prototypes of cold atom gravimeters were developed at ONERA for laboratory, space or defense applications.

The DGA kicked off its basic research program Girafe in 2007, moving further ahead in this area. The aim was to produce a demonstrator of an instrument to measure absolute gravity, using this technology. Performance specs were met, and ONERA started the follow-on project, Girafe 2, in 2012, to develop an instrument that could be installed on a ship. This new onboard instrument will have to be much smaller than the first generation, while meeting the navy's specific mapping requirements.



Optimizing alloys on the Rafale fighter to increase service life

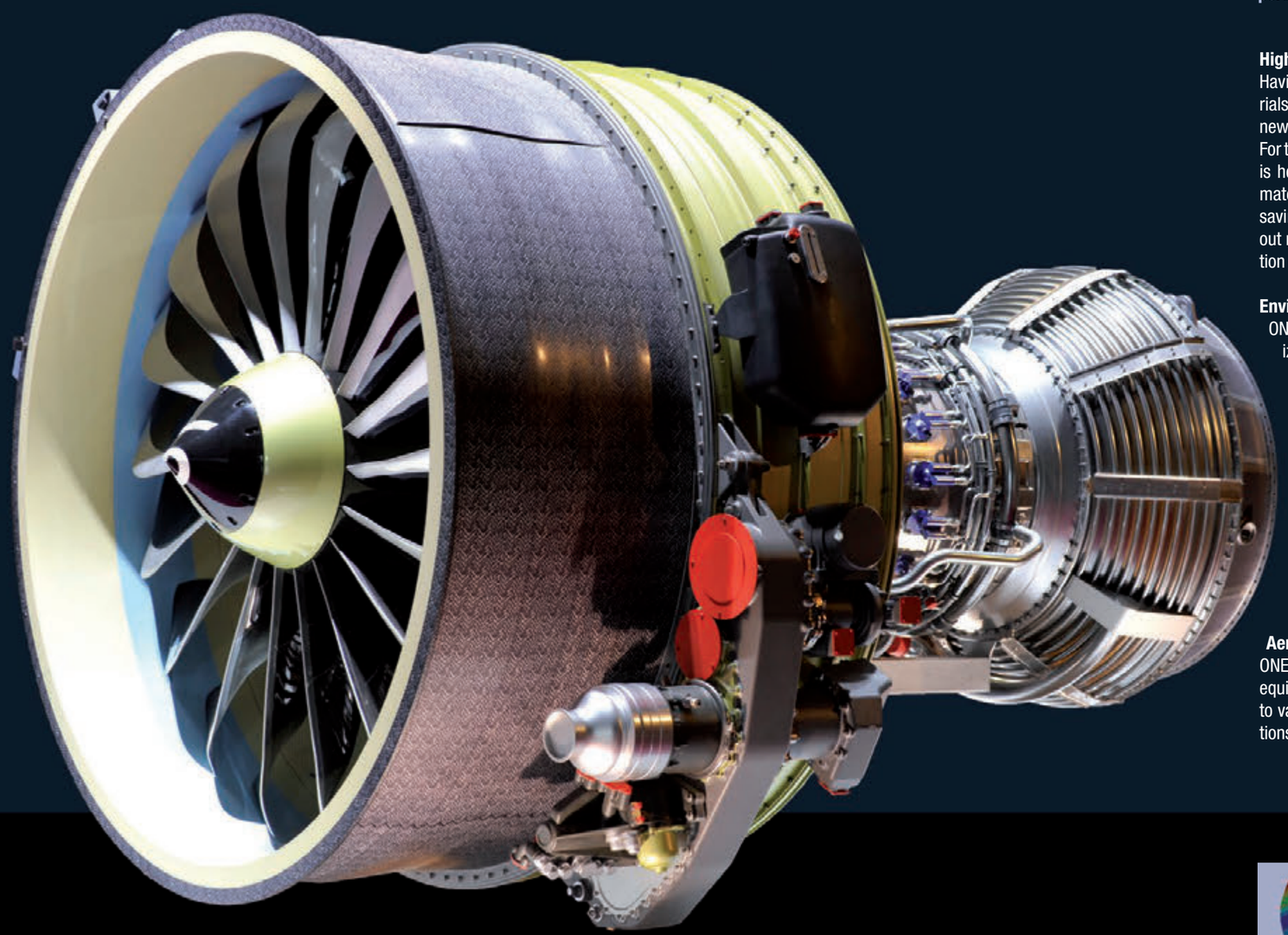
Acting as an expert advisor to French defense procurement agency DGA, ONERA came up with an innovative materials solution as part of a fundamental research program completed in 2012.

The Dartagnan project ("Rafale disk with improved fatigue resistance using a new nickel-based alloy") is designed to increase the service life of turbine disks on the Snecma (Safran) M88 engine that powers the Rafale fighter built by Dassault Aviation.

ONERA and Snecma teamed up to develop a brand-new superalloy, dubbed N19, using a very innovative approach. They first defined an appropriate microstructure by using both experimentation and computer modeling of the desired structure, enabling them to predict the lifespan of the part in question, which would be developed subsequently.

Full-scale demonstrators of disks made from N19 are now under development. They will be tested on a DGA test rig to validate the expected gain in operating life. Once in place, this advanced technology will help Snecma design and build engines with lower maintenance cost.

LEAP
Confirming our partnership with Snecma



The LEAP turbofan engine, successor to the world-famous CFM56, should enjoy similar global success. Snecma (a partner in CFM International with GE) has once again decided to call on ONERA to help it optimize the cold section of this new engine, and to meet the growing demand for an engine that combines cost-competitiveness, environmental-friendliness and flight safety. Snecma is counting on ONERA's multidisciplinary skills, spanning aerodynamics, aeroacoustics, aerothermodynamics, aeroelasticity, materials, electromagnetism and more, along with the two companies' shared expertise in experimentation and numerical simulation.

Higher efficiency

Having built up a broad understanding of the new 3D woven composite materials incorporated by Snecma, ONERA is developing specific models for these new materials to predict their failure points, and thus optimize their design.
For the advanced metals used on this engine, such as titanium aluminide, ONERA is helping to optimize them for use on the low-pressure turbine. These new materials offer half the density of conventional alloys, for even greater weight savings. The partners were able to meet their targeted objectives by carrying out mechanical tests concurrently with the development of powerful computation codes.

Environmental protection

ONERA is studying fan noise to make the blades even quieter without penalizing their performance. For the jet noise, ONERA can visualize the entire airflow, while precisely locating acoustic sources, combined with the computational fluid dynamics needed to analyze these flows. Experiments have been carried out on both ONERA's CEPRA19 wind tunnel, and Snecma's Race test rig, two of the few facilities in Europe dedicated to the study of aircraft noise.

Flight safety

ONERA is fully capable of evaluating the indirect effects of a lightning strike by using its powerful numerical simulation capabilities. We are also the national champion in the modeling of icing-related phenomenon – a skill applied to the development of LEAP.

Aerothermodynamics

ONERA calls on its Ecosse test bench to carry out characterization studies of equipment ventilation by natural and forced convection. This capability is used to validate the operation of the LEAP fan casing, depending on heating conditions, or to submit recommendations for changes in configuration.

Understanding lightning

ONERA is one of the world's acknowledged experts in studying the problem of lightning strikes on airplanes, helicopters, launchers and missiles.

ONERA inaugurated its "lightning lab" in 2012 to achieve a finer understanding of the direct effects of lightning strikes on aeronautical structures. This unique facility is dedicated to scientific research, in particular the diagnosis of the plasma generated by lightning, using spectroscopy, strioscopy, computed tomography or lasers.

The parameters being measured by this innovative facility will eventually enable engineers to optimize future generations of materials used in aircraft structures, while also reducing the time and cost of certification tests carried out by customers.

An analysis of structural damage mechanisms in this case is becoming even more useful because of the increasingly widespread use of composite materials on today's aircraft.

Europe is a leading global player in aerospace, and to preserve this leadership it has to deploy world-class research resources. The European Commission is providing financial support for large wind tunnels, so they can extend their range of services offered, improve service quality and availability, and harmonize expertise at different facilities. In October 2009, the EC launched a 48-month project dubbed ESWIRP (European Strategic Windtunnel Improved Research Potential), within the scope of its Framework Program 7 (FP7).

Europe supports the strategic S1MA wind tunnel

ONERA's S1MA wind tunnel in Modane, the most powerful in the world, is one of the three infrastructures chosen to receive support from the European Union through the ESWIRP project (along with LFF operated by German-Dutch consortium DNW, and the European Transonic Windtunnel, or ETW). ESWIRP investments were used to design, test and install a fine Mach number control system, to improve the quality of measurements in S1MA. Initial tests of the demonstrator in 2012 showed satisfactory control up to Mach 0.86. Above that speed, differences were reduced, but additional actions are under way to improve results.

In addition to improving efficiency and productivity, this system fosters greater teamwork between different research facilities. Researchers make joint use of the facility, allowing them to discover new techniques and technologies. In short, these investments will improve both the quality and quantity of services delivered.

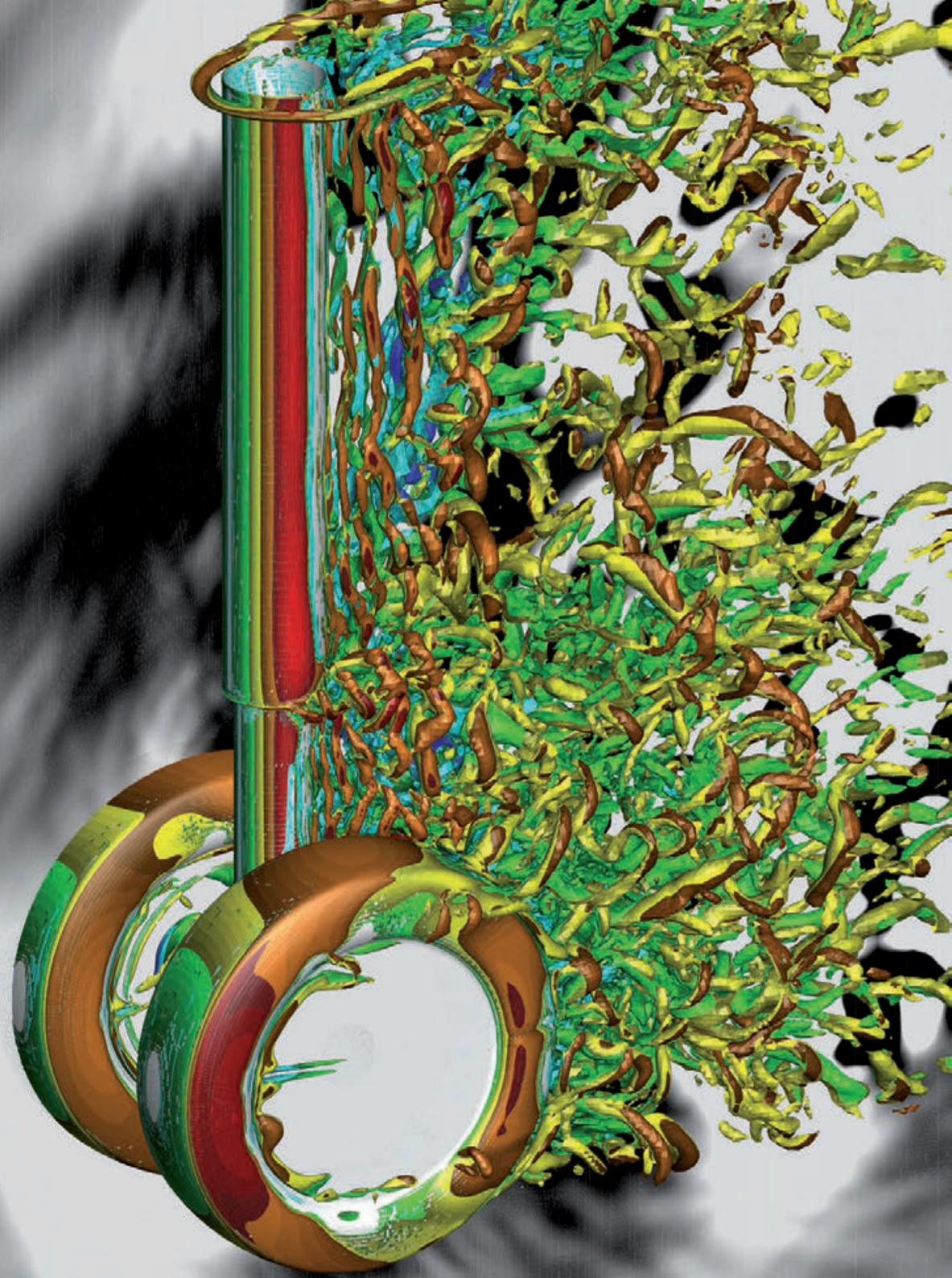
Simulating noise for quieter landing gear

50% **of the noise generated by a commercial jet as it approaches the runway comes from the landing gear. From 2006 to 2012, ONERA's aeroacoustics specialists teamed up with Airbus in the Lagoon project to successfully evaluate their numerical simulation methods applied to landing gear noise, calling on experimental data generated through this project.**

Experiments were carried out in the F2 subsonic wind tunnel in Fauga-Mauzac to study aerodynamics (using a simplified landing gear model with two wheels), and in the CEPRA19 wind tunnel at Saclay for aeroacoustic aspects.

On the digital side, ONERA used its computation codes to reproduce the unsteady aerodynamic flows around the Lagoon model (elsA code), enabling it to calculate noise (Kim code). This demands a tremendous amount of work, because landing gear are not inherently streamlined parts, so simulating their aerodynamics and aeroacoustics demanded complex meshes with some 40 million points and tens of millions of hours on ONERA's most powerful supercomputer. ONERA and Airbus are now considering a Lagoon 2 project that would apply the same approach to a landing gear with four wheels, thus making the physical and aeroacoustic aspects even more complex.

The Lagoon model was recently chosen by NASA for an international benchmarking initiative, in which a number of labs from around the world will be invited to compare their numerical simulation methods.



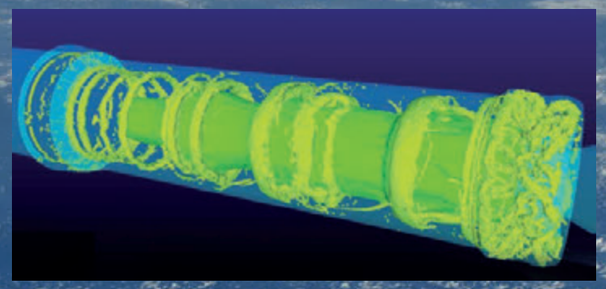
Europe is committed to maintaining independent access to space. The successor to Ariane 5 is already on track, with work beginning on Ariane 6. This new-generation launch vehicle should be more reliable, more robust and more competitive, while offering greater operational flexibility. French space agency CNES and solid rocket motor manufacturer Herakles are orchestrating this planned succession, with support from ONERA's constantly enhanced expertise. Our long-standing expertise in energetics and aerodynamics is a major asset in Europe's new space program.

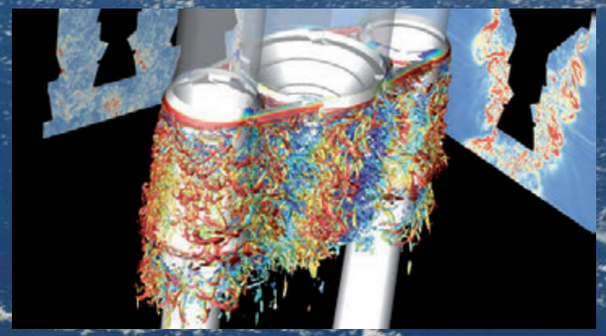
Ariane 6: capitalizing on ONERA's expertise

ONERA has been carrying out research since the 1990s to understand the pressure oscillations affecting Ariane 5. Today, this stock of knowledge underpins our active participation in the development of the new solid rocket motor intended for the first stage of the next-generation Ariane 6 launcher. The Demo IDC P180 project, coordinated by Herakles (Safran), achieved significant scientific progress in 2012. Five ground firing tests verified the absence of the hydrodynamic instabilities that cause pressure oscillations, and allowed the study of thermoacoustic instability likely to appear in this new motor. These types of tests provide invaluable aid in the design of the motor.

At the same time, ONERA performed 3D numerical simulations of the unsteady flows on Ariane 5, using its powerful Cedre computation code with a mesh comprising 20 million points.

ONERA has also developed significant expertise in the aerodynamics of launch vehicles. The investments made to develop Ariane 5's main-stage Vulcain 2 engine provide very solid foundations for the future, especially the development of a test bench to measure loads on the nozzle. These experiments validated the associated computer simulations using the ZDES code, and helped engineers better understand the physics behind the lateral loads affecting the launcher during liftoff.





ONERA & CNES: AN R&T PARTNERSHIP

In July 2012, ONERA and CNES signed a new framework agreement that will reenergize the long-standing collaboration between the two partners on space research and technology. New initiatives are under study to define joint programs that will match both CNES's R&T strategy and ONERA's strategic scientific objectives. For example, ONERA could contribute to these joint programs by transferring work planned for its own research programs.

How will we fly in 2050?

EREA

ONERA is a major player in long-term aerospace planning, with a dedicated multidisciplinary department. It was chosen by the Association of European Research Establishments in Aeronautics (EREA) to coordinate a study on the future of air transport: ATS 2050 (Air Transport System).

In December 2012 ONERA presented the ATS 2050 (phase 2) study to the French Senate. This study takes a detailed look at the long-term technological options for air transport, up to 2050, with a focus on five main areas: aircraft configurations, propulsion systems, air transport automation, airports, and aircraft subsystems.

The study's main deliverable is a list of well-founded recommendations on the priority research objectives to be promoted in Europe to pave the way for tomorrow's air transport system.

ONERA had already participated in the first ATS 2050 study in 2010, as an acknowledged multidisciplinary expert in this field. The first study identified five scenarios for the future development of air transport, to determine priority research goals.

Reflecting the many European research programs that it leads or participates in, ONERA also aims to define an initial framework for a long-term analysis of the situation.

Helping companies capitalize on ONERA's expertise

ONERA's job is to advance scientific knowledge, and this progress has contributed to the success of many aerospace programs. However, our broad knowledge base can also be applied to other sectors. ONERA regularly makes available its knowledge capital and test facilities to small and medium-size businesses.

Micro-energy sources

ONERA's Decawatt project is a micro-turbine concept, designed to bring this brand-new technology to maturity. It involves the development of a gas turbine less than 10 cubic centimeters in volume, developing 100 watts of power, the only one of its kind anywhere in the world in this power class.

This type of micro-energy source could well play a key role in a wide range of applications, including robotics, micro-drones and electronic systems for infantry soldiers.

Ten million times smaller than the jet engine on an A380 superjumbo, the Decawatt micro-turbine should generate its first watt in 2013.

Software and composite materials

Composite materials considerably reduce structural weight, which makes them very popular in aerospace applications. ONERA is co-developing a computation code, Zebulon, for the detailed analysis and design of composite parts and structures, to validate compliance with specifications.

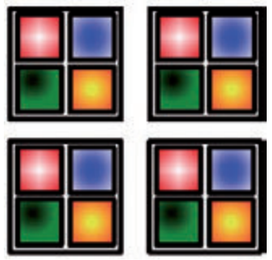
ONERA has now expanded its offering to include the custom-tailored design of parts, optimized right from the pre-design phase using innovative tools dedicated to composites and operating in conjunction with the Zebulon code. This saves considerable time in the design of structures that are both lighter and stronger, based on ONERA's proven expertise in design, experimentation and numerical simulation.

Icing detection

ONERA, teaming up with the company AER, has patented an early icing warning system for airport runways, based on our long-standing research into aircraft icing. When weather conditions are unpredictable, this system helps make decisions about whether or not to use deicing products on the runway – and it can also be used to ensure road safety.

This innovative system accelerates the formation of a layer of ice on a probe, whose temperature is slaved to that of the runway, and then analyzes how the thickness of this layer changes.

Very high resolution



ONERA has developed a technique for sorting photons according to their wavelength, accurate to within a micrometer. This system will revolutionize the traditional tradeoff between sensitivity and polychromy inherent in standard filtering techniques. ONERA's sorting method enables recovering and using all incident photons, while filtering "loses" these photons. The upshot is unrivaled sensitivity and resolution.

A technology demonstrator will soon be built, based on a discriminating vision camera that will provide information on "infrared color", and thus on the type of material or gas being observed.

Noise reduction

Reducing the noise of piston engines without losing power is a major challenge. ONERA has therefore designed a new noise-absorbent material, a micro-honeycomb structure. The structure is in fact made of very thin plates or tubes that, once assembled, absorb sound waves.

ONERA has also developed digital models to simulate the mechanical and acoustic properties of this material.

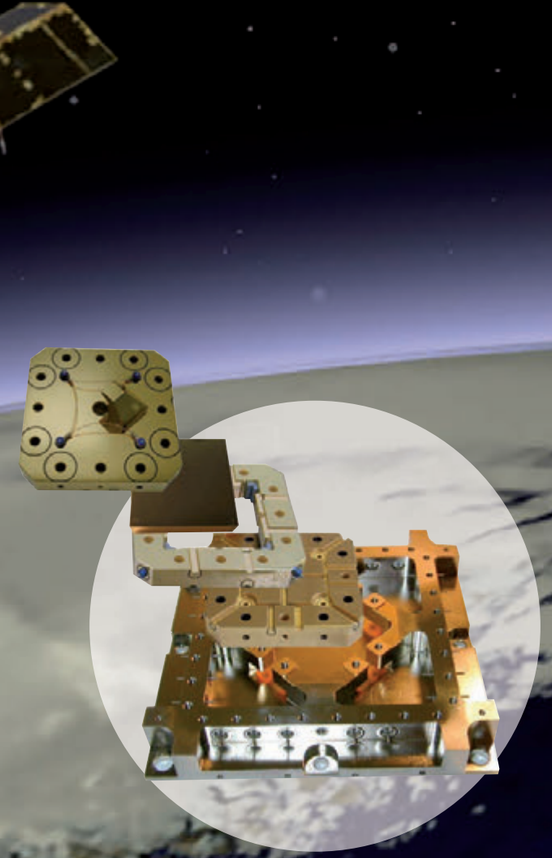
NASA chooses ONERA for Grace Follow-On mission

ONERA's reputation stretches well beyond the borders of France. In the United States, for example, NASA and JPL (Jet Propulsion Laboratory) are very familiar with and appreciate our expertise in spaceborne accelerometers.

In the late 1990s, ONERA built the ultrasensitive accelerometers for the original Grace mission (Gravity Recovery and Climate Experiment). This mission generated excellent results, especially concerning climate change, including monitoring of the Greenland ice cap, surveillance of marine currents and water resources (basin aquifers) – which is why NASA wanted to launch Grace Follow-On, an identical system that will ensure operational continuity for this vital data. The Jet Propulsion Laboratory in Pasadena, California, as project leader, once again called on ONERA, reflecting the relationship of mutual trust established during the first mission, and clear recognition of our unrivaled skills in space accelerometry. The contract kicked off in 2012, and the launch is slated for 2017.

ONERA AND NASA EXPAND COLLABORATION

ONERA has actively teamed up with NASA for many years, mainly working on icing and human factors. The two organizations recently added collaboration on acoustics, the ATM (Air Traffic Management) Environment, and ATM/Functional Allocation.



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