CNES MAG

SPACE ● INNOVATION ● SOCIETY

SPECIAL ISSUE EN FR

#90
November 2021

60 YEARS

FOR THE FUTURE

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

INSIDE

CNESMAG

CNESmag, the magazine of the Centre National d'Etudes Spatiales, 2 place Maurice Quentin. 75039 Paris cedex 01. For all correspondence, write to: 18 avenue Edouard Belin. 31401 Toulouse cedex 9. Tél. : +33 (0)5 61 27 40 68. Internet: http://www.cnes.fr. This review is a member of Communication&Entreprises. Subscriptions: https://cnes.fr/reabonnement-cnesmag. **Publication director:** Philippe Baptiste. **Editorial director:** Marie-Claude Salomé. **Editor-in-chief:** Brigitte Alonzo-Thomas. **Proofreading:** Céline Arnaud. **Editorial staff:** Brigitte Alonzo-Thomas, Liliane Feuillerac, Dominique Fidel. **Photos and iconography:** Marie-Claire Fontebasso. **Photo editor:** Thierry De Prada. **Photo credits:** p. 1 CNES/ESA/Arianespace/CSG video and photo department/S.Martin, 2019; p. 3 La Poste/CNES/D.Ducros; p. 4 CNES/C.Peus, 2021; p. 6 CNES 2021, distribution Airbus DS; p. 7 CNES/A.Ollier; p. 8 (top) C.Virmontois - (bottom) CNES/E.Grimault; p. 9 Espace Patrimoine Safran; p. 11 P.Nayler; p. 12 NASA/JPL-Caltech/Univ. of Arizona; p. 13 ESA/Rosetta/MPS for OSIRIS Team/MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA; p.14 (top) ESA/ATG Medialab - (bottom) ESA/M.Cowan; p. 15 ESA/DLR/Fur Berlin; p. 17 S.Maurice; p. 18 NASA; p. 19 CNES/ESA/Arianespace/CSG video and photo department; p. 20 (top) ESA/Gaia/DPAC - (bottom) ESA, GG BY SA 3.0 IGO; p. 21 ESA; p. 23 C.Cornuat/French Embassy in the US; p. 24 NASA Modis; p. 25-27 Getty Images; p. 29 CLS; p. 30 Getty Images; p. 31 CNES 2019, distribution Airbus DS; p. 32 (top) CNES/Mira Production - (bottom) CNES/P.Cocquerez; p. 33 CSG video and photo department/L.Mira; p. 35 D.Korber; p. 36 CNES/C.Peus; p. 37 CNES/SIGMA; p .38 Planète Sciences/Agence TL - T.Labois; p. 39 French Air Force/J.L.Brunet; p. 41 ESA/N.Imber-Vier; p. 42 CNES/ESA/NASA; p. 43 NASA. **Illustrations:** Jean-Marc Pau. **Webmaster:** Sylvain Charrier, Mélanie Ramel. **Social media:** Mathilde de Vos. **English text:** Boyd Vincent. **Design and pre-press:** Citizen Press – Camille Aulas, David Corvaisier, Fabienne Laurent, Alexandra Roy. **Printing:** Ménard. ISSN 1283-9817. **Thanks to:** Cecile Angelelis, Jacques Arnould, Kader Amsif, Jean Blouvac, Typhanie Bouju, Eric Boussarie, Eric Brel, Olivier Bugnet, Rémy Canton, Thierry Chapuis,Jean-Marc Charbonnier, Selma Cherchali, Florence Chiavassa, Philippe Collot, Evelyne Cortiade, Sophie Coutin-Faye, Audrey Decrock, Serge Delmas, Emline Deseez, Vincent Dubourg, Sandra Dusses, Pascal Faucher, Valérie Foix, Marie-Laure Gouzy, Aurélie Jeanne, Nathalie Journo, Sandrine Lafont, Carole Larigauderie, Olivier Lamarle, Brice Lamotte, Alice Lebreton, Samuel Mamou, Jean Maréchal, Jean-Youri Marty, Vincent Meens, Eric Médaille, Anne-Marie Medinilla, Laurence Monnoyer-Smith, Christian Mustin, Pascal Noir, Amélie Proust, Gilles Rabin, Sandrine Richard, Sylvain Rouzaud, Michel Sarthou, Arnaud Sellé, Lionel Suchet, Christophe, Sophie Tiget, Claire Tinel, Venet, Nicolas Verdier, Cédric Virmontois.

PEFC 10-31-2690

IMPRIM'VERT

STAMPS
COMMEMORATIVE ISSUE

To mark the anniversary of its inception, La Poste has issued a special commemorative stamp in its history collection. Designed by David Ducros, the stamp combines Earth and the Universe in shades of blue. Ariane 5 lifts off majestically with Mars in the background, while the Perseverance rover drives the SuperCam instrument around the red planet. In the foreground, French astronaut Thomas Pesquet reminds us of the role of humans in the space adventure. 504,000 stamps printed in plates of 15 went on sale in October at an international face value of €1.50. And the collaboration between CNES and La Poste isn't set to end there: for all you collectors out there, the next special issue plans to mark the maiden flight of Ariane 6.

BOX SET
THE ART OF SPACE

For its 60th anniversary, CNES decided to delve into its archives and has come up with a selection of stunning historical and artistic photos. *À la conquête du Cosmos*, the coffee-table book in which they are collated, is packed with emotions shared over six decades of space adventures. Each page pays tribute to the pioneering men and women who made it all happen, as well as to science and technology. Each photo comes with an accompanying commentary. The elegantly designed box set marks a milestone and the preface by CNES Chairman & CEO Philippe Baptiste sets our sights on the future—the conquest of the cosmos is only just beginning.

À la conquête du Cosmos, under the direction of Alice Leroy - Published by Flammarion – On sale in bookshops

1 9 December 1961, President Charles de Gaulle signed into law the statute creating CNES, taking France into the very select inner circle of world spacepowers. 60 years is something to celebrate, so we've put together a special redesigned anniversary issue of CNESMAG for the occasion.

We could have taken the easy way out, simply reviewing the highlights of the last six decades of human and scientific adventures or compiling a long list of all the major advances that we owe in some way or other to CNES. But we decided to take a different perspective. In setting the bar for this issue, we had a single objective in mind: to show you how CNES has always strived to shape the future. Be it in new technologies, space exploration, satellite data exploitation or climate science, in all its fields of expertise our agency has constantly pursued a forward-looking vision. It is our great ability to adapt and anticipate that has enabled us to spot emerging needs and challenges early on and conceive the solutions to match them.

In the six sections that follow, you'll discover or rediscover CNES's avant-garde vision and see how we've helped change the world. Through historical content, eyewitness accounts from our people and interviews with personalities from outside the agency, we've imagined this issue as a deep dive into France's storied space programme.

And because no anniversary would be complete without remembering past highlights, the timeline at the end of the magazine sets out some of the milestones that have marked CNES's history.

I hope you enjoy reading this CNESMAG.

MARIE-CLAUDE SALOMÉ,
CNES DIRECTOR OF COMMUNICATION

PHILIPPE BAPTISTE

CNES Chairman & CEO

You were appointed to head the agency earlier this year. How do you see CNES at 60?

Philippe Baptiste: I'm extremely proud to be leading this agency. Looking back at what my predecessors have accomplished over these last 60 years, I see just how far we have come in space. CNES has been a pioneer in every field and succeeded in adapting to each new challenge. It was the prime mover behind the birth of the French and European space industry and the formation of firms like Arianespace, Spot Image and CLS. It has achieved some great firsts, making it a go-to partner for the world's leading space agencies. With its track record and forward-looking vision, CNES is a scientific and technological jewel in the crown for our nation. In a fast-moving sector, we need to continue evolving our processes and organization while remaining faithful to our heritage. Our manufacturers are honing their expertise and gaining maturity, so let's put our faith in them and focus our efforts on new areas where things are more complex and not so mature. Let's help the new entrepreneurs now entering the marketplace to upskill by contracting with them. This calls for a very flexible mindset.

How do you see the global space arena evolving between cooperation and competition in the years ahead?

P. B.: The right balance between competition and cooperation is quite easy to find, working sector by sector. In the fields of launchers and telecoms we're facing fierce global

"CNES is a scientific and technological jewel in the crown for our nation."

competition fuelled largely by national governments. New commercial challenges are emerging around the Internet of Things (IoT), Earth observation and other areas, but there are also whole fields of scientific investigation where cooperation is our watchword. CNES, in line with the Ministry for Europe and Foreign Affairs, has always worked with all nations. We fully intend to pursue foundational collaborations with our European, American, Japanese and Indian partners, and to a certain extent with China also.

You're a strong advocate of a European constellation. Can you detail your vision on this?

P. B.: Low-Earth-orbit constellations are a major strategic challenge to deliver Internet everywhere in near-real time. This will be crucial for our defence and homeland security, as well as for numerous commercial applications, like for example autonomous vehicles. What's at stake is at the intersection of digital and space. Not having our own constellation in the future will mean depending on other big players, and that's not something we can entertain.

You also stress the importance of satellite data utilization. Why is this a priority in your view?

P. B.: We need to convert businesses, manufacturers and local government to satellite data to fuel new services that are going to revolutionize applications. Satellite data are the black gold of the 21st century. CNES's job is to qualify them and bring together entrepreneurs from very different horizons to spawn new ideas and services. This is the philosophy behind our Connect by CNES initiative, which we need to step up a gear.

The world is also seeing far-reaching changes driven by growing climate and social concerns. What does this mean for CNES?

P. B.: All research work on climate and biodiversity relies on satellite data. Without them, we have no way of measuring our planet's health. Weather forecasters and scientists building climate models are seeking ever-more precise observations, so it's absolutely vital that we invest massively in these areas.
As for corporate social responsibility (CSR), we're having to address the same issue as all large organizations: that of curbing our carbon footprint. We already have some great projects underway, notably in French Guiana to develop biofuel feedstocks in the near future.

What is your vision of CNES's role in furthering space exploration and France's scientific reach?

P. B.: CNES doesn't decide to embark on exploration missions alone. They are conducted through ESA or in partnership with other space agencies, and overseen by scientific committees. It's the job of CNES's teams to make them possible. That's why extending France's scientific reach relies as much on the prowess of our scientists as it does on our ability to devise instruments and conceive systems to be operated in space. Today, the big question is our place in human deep-space exploration, a field where Europe has never had its own independent programme. At a time when the leading spacepowers envision establishing bases on the Moon and even Mars, it's important to know where Europe will stand looking forward.

In conclusion, what message would you like to convey to the new generation that is discovering our rich 60-year space heritage and will have to invent new applications and meet new challenges?

P. B.: The conquest of space is a fabulous human adventure driven by passion. Our role today has changed and our role in the future is a new chapter to be written. So do science and technology and join us with your new ideas.

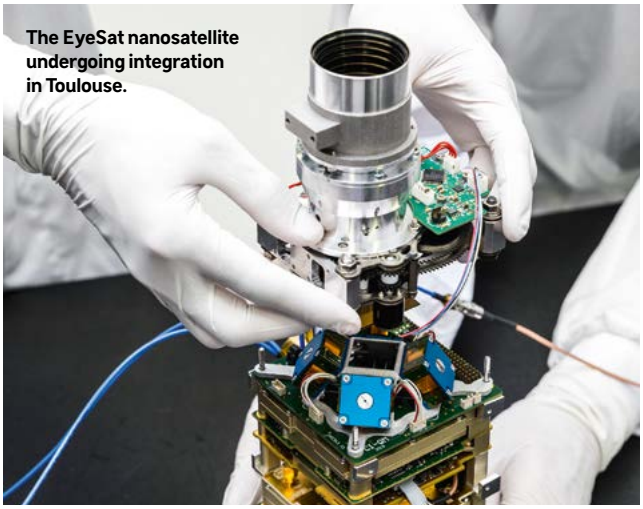
"The conquest of space is a fabulous human adventure driven by passion."

Can't make it to the World Expo[1] in Dubai? Then this very-high-resolution image takes you there. Since 2011, the Pleiades VHR satellites (70-cm resolution) have been combining 3D viewing, agility and civil and military applications.

1. Until 31 March 2022.

TECHNOLOGY

BE IT FOR IMAGING, NAVIGATION, TELECOMMUNICATIONS, LAUNCH VEHICLES OR OTHER FIELDS, THE TECHNOLOGY BREAKTHROUGHS LED BY CNES HAVE LEFT NO CORNER OF SPACE UNTOUCHED. WHILE SUCH ADVANCES ARE ALREADY VISIBLE HERE ON EARTH, THEY ARE ALSO FUELLING THE SPACE PROGRAMMES OF TODAY AND TOMORROW.



The EyeSat nanosatellite undergoing integration in Toulouse.

A LEGACY OF INNOVATION

In 1962, the fledgling space agency was tasked with steering a sustained technology effort. CNES received the message loud and clear and advancing technologies would become its trademark and guiding motive.

It was at the dedicated test centre in Brétigny-sur-Orge that President Charles de Gaulle first set France on course for space. Six years later, in 1968, the centre relocated south and the Toulouse Space Centre was born, with a mandate to address major engineering challenges. By the 1980s, the SPOT-1 imaging satellite—conceived and designed to observe cities, roads, crops and natural disasters—had revolutionized Earth remote sensing. The subsequent return on investment has been impressive, paving the way for the Pleiades satellites (Pleiades-NEO, CSO, etc.) and their illustrious Sentinel descendants for Europe's Copernicus environment-monitoring programme, as well as a new generation of high-resolution military and Earth-imaging satellites. A decade later, the TOPEX/Poseidon and Jason-1, 2 and 3 altimetry satellites would begin measuring sea level variations (see Planet p. 32). With SWOT, radar interferometry is set to extend altimetric observation to surface waters, while the IASI infrared interferometry instrument is lending greater accuracy to weather forecasts and atmospheric chemistry measurements. And tomorrow, MicroCarb will acquire data on CO_2 exchanges in the atmosphere with its spectrometer.

25 cm

In 1986, SPOT-1 afforded an image resolution of 10 metres. In 2002, SPOT-5 took it to 2.5 metres. Soon, the very-high-resolution THR-NG satellite will be capable of achieving a resolution of 25 to 30 centimetres.

A broad palette of technological expertise

Geolocation, meanwhile, is today no longer the preserve of GPS. The European Galileo system uses a new method to calculate position fixes with patented navigation signals, reducing error margins to achieve near-centimetre accuracy. Back in 1979, employing quite different technologies, Telecom-1 beamed telephony and television into French homes. Since 2015, new generations of communications satellites are helping to eliminate "notspots" where coverage is poor. Closer to the present day, broadband modems, fast-broadband transmission and increased satellite capacity continue to optimize communications.

CNES is a past master in the art of devising new concepts and systems, but it also knows when to latch on to beneficial advances in technology. From the 2010s, it played its full part in nanosatellite or miniaturized equipment projects (see CASPEX p. 8) that have since deeply transformed the space market. And in the domain of launchers, ArianeGroup is shaping the future at its facility in Vernon outside Paris with the Prometheus engine, laying the groundwork for the technologies that will power rockets with cleaner fuel and at lower cost (see p. 9).

CNES's ability as both a space agency and technical field centre to give expert advice, conduct feasibility studies and verify the suitability of a technology or material—in short, to innovate—makes it unique in Europe. It initiates early-stage R&T, R&D and platforms that in turn fuel technology research. Downstream of space systems, it encourages data uptake and in some cases makes data available free of charge. These technologies are not only effective down on Earth, they are also supporting current and future robotic exploration programmes, and further ahead, crewed deep-space missions now in the pipeline (see Exploration p. 10).

MINIATURIZATION

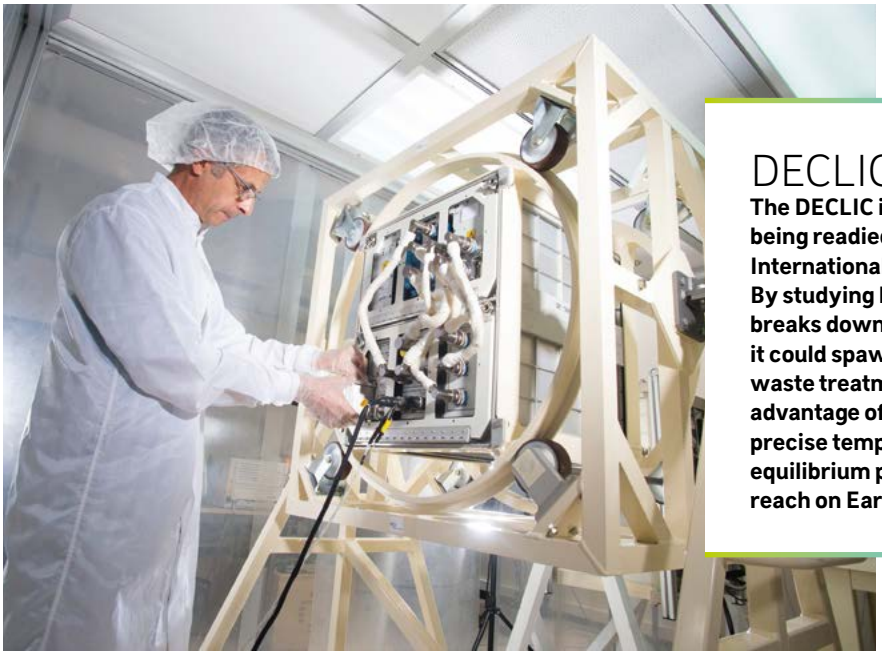
CASPEX IN THE BIG LEAGUE

Don't be fooled by its small size: CASPEX—for Colour CMOS Camera for Space Exploration—has a big future ahead of it. With CNES as prime contractor, the camera measuring three centimetres on a side was conceived in 2014 to the specifications of the SuperCam instrument on the Perseverance rover. This called for innovative miniaturized systems, some of which came from off the shelf, like its imaging sensor based on mobile phone technology. Vibration, radiation and extreme temperature excursion tests confirmed its ability to withstand conditions on Mars. CASPEX also comes with its own complete microsystem, programmable array and non-volatile random-access memory (NVRAM) to be able to adjust images. On SuperCam, it has certainly proved its worth. Built around commercial products, it has enabled substantial savings without compromising on performance. The mini-camera will be on the United Arab Emirates' Rachid lunar rover set to depart in 2022 and on the Japanese Martian Moons eXploration (MMX) mission. It is also the core component of the more than 2,000 Auriga and Sodern star trackers selected for the One Web constellation.

600,000

CATALOGUE.THEIA-LAND.FR

Earth observation generates
copious amounts of data, be it on soil moisture, glacier elevation or—in the near future—surface waters. The Theia data hub's new online portal affords access to 600,000 digital products derived from such data for scientists and government departments.



DECLIC

The DECLIC instrument is seen here being readied for its return to the International Space Station (ISS). By studying how organic material breaks down in supercritical fluids, it could spawn applications for waste treatment. On the ISS, it takes advantage of the critical point—a precise temperature and pressure equilibrium point impossible to reach on Earth due to gravity.

LAUNCHERS

A WELL-MANAGED LEGACY

The plume of smoke that shrouds the pad at lift-off is just the visible side of years of technology research required to send a 750-tonne launcher into space. And this research challenge is something CNES has been working on for decades.
The agency's Viking engine, which traces its heritage back to sounding rockets, was the first to break onto the scene. Using storable chemical propellants, it powered the first stages of Ariane 1 to 4, whose third stage was powered by a small cryogenic engine, the HM7. In 1973, to keep pace with the competition, Europe set in train the Ariane 5 programme to build a sophisticated space launcher able to loft payloads of up to 10 tonnes, with a new cryogenic engine—Vulcain—to power it. Drawing on the expertise gained from Viking and HM7, two solid-propellant boosters were conceived to get the launcher off the ground, while Vulcain, burning liquid oxygen and hydrogen stored at very low temperature, would power the rest of the ascent. The enhanced Vulcain 2 variant was used on Ariane 5 ECA launchers, while the very latest Vulcain 2.1 variant—the most powerful liquid-propellant rocket engine in Europe—will be used on Ariane 6.

FAST FORWARD

GREEN LAUNCHER PROPELLANTS

Since 2017, a significant research effort has been channelled into production of green launcher propellants to meet environmental requirements in line with Europe's REACH regulation[1]. Bio-methane belongs to this new generation of fuels. As well as its green credentials, it has the added advantage of being able to be produced in French Guiana, in close proximity to the launch complexes, using local industrial, household and plant waste, supplemented if needed by fuel crops that won't harm local farming. A preliminary project encompassing the biomass concept, production facility and feedstock supply process preceded the definition phase kicked off in April this year. Construction could get the final go-ahead by the end of the year. The sustainably designed facility could ultimately morph into a regional project supporting a local circular economy.

1. Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), EU Regulation n°1907/2006, effective since 2007.

ANTOINE RESSOUCHE

Co-founder and chief technical officer, U-Space

"Little did I know when I joined JANUS that I would stay for 8 years"

Snubbed by NASA and seen as little more than a "learning toy" by industry, cubesats initially found it hard to gain traction at the turn of the century. Today, these nanosatellites originally conceived to give students hands-on experience with space technologies are proving popular with universities and science teams for their standard features and low-cost, rapid development. From 2012, CNES latched onto the idea with its JANUS student nanosatellite programme, since renamed Nanolab Academy. One of the first to benefit from the programme was Antoine Ressouche, then a student at ENAC, the national civil aviation school. "Without really knowing what I was letting myself in for, I joined the EyeSat pilot project to design and develop through to launch a nanosatellite to observe the zodiacal light. In the end, I stayed with it for eight years. I started off as a mere intern and then was eventually offered an engineering post at the Toulouse Space Centre supervising students' work." In all, some 250 people took part in the EyeSat adventure, with 15 to 20 students per year relaying each other every six months. That level of turnover posed quite a challenge for the young engineer, calling on all his educational and project management skills. The programme came to an end in December 2019 when EyeSat was sent into space by a Soyuz launcher. But Antoine Ressouche's love affair with space didn't end there, as today he's part of the executive team at U-Space, a start-up specializing in the design and construction of nanosatellites, alongside two partners he met through EyeSat. The fledgling firm has got off to a strong start, recently winning a contract to build the NESS demonstrator for CNES and a nanosatellite for the French aerospace research agency ONERA.

Q & A

"FAST-BROADBAND INTERNET FOR ALL IS BECOMING A REALITY"

PETER NAYLER

Business Development Manager, EASii-IC

"CNES played a key role helping us to flesh out the design of this new generation."

Which of your firm's products is serving space technologies?

Peter Nayler: We started out designing integrated circuits for the medical, aviation and automotive industries, before turning to more-complex integrated circuits for space applications. In 2020, we acquired part of STMicroelectronics' businesses, notably its satellite communications products and in particular Oxford, a miniaturized IC conceived by CNES. This chip processes signals received by an antenna. It can be used in most satellite Internet terminals or decoders for the consumer market and supports data throughput equivalent to optical fibre.

What needs is this new-generation chip seeking to meet?

P. N.: Space telecommunications is a very fast-moving sector. New generations of antenna have emerged to replace traditional parabolic antennas, receiving signals with new technical characteristics. So we're adapting our Oxford chip to serve this future market. Oxford-2 will speed up signal processing and deliver optimal data for Internet and for video applications through a decoder. And things are set to evolve further with the advent of 5G and connected aircraft and ships. We're continuing to work with CNES to develop a forward-looking vision.

Has this collaboration changed your relationship with CNES in any way?

P. N.: CNES came on board very early on in the development of Oxford, working with STMicroelectronics and now with us. With an eye on the future, Oxford-2 has for example been optimized for low-Earth-orbit satellites. CNES played a central role helping us to flesh out the technical design of this new generation, fostering partnerships with key stakeholders. It's clearly a very important partner for us and our ambition is for EASii-IC to become a leading player in the French and European space industry.

KEY DATES

1986
BSc in Electronics and Communications from the University of Sussex

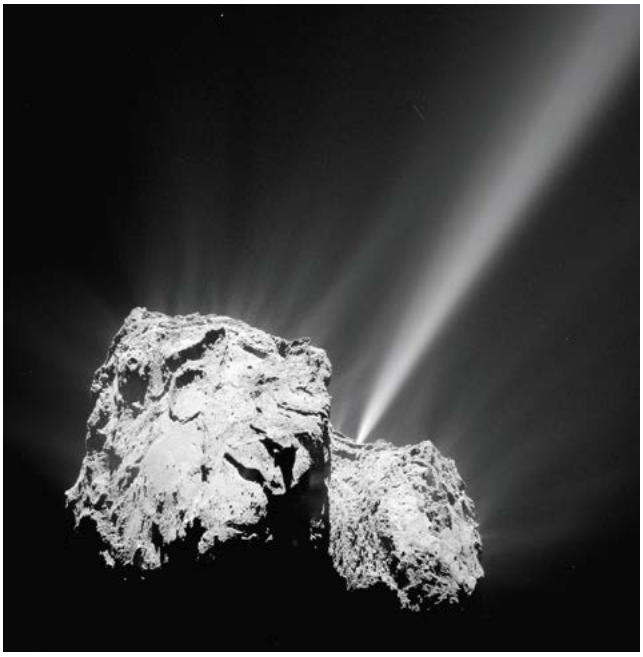
1999-2003
Radiofrequency Applications Manager (cellular terminals) at STMicroelectronics

2019
Business Development Manager, EASii-IC

Did water once flow on Mars? These delicate interlacing patterns of clay-bearing minerals confirm that it did. In 2005, Europe's Mars Express probe found patterns like these at 20 sites that scientists are still investigating.

EXPLO RATION

A LOT HAS BEEN WRITTEN ABOUT SPACE EXPLORATION AND THE MOMENTOUS DISCOVERIES AND REVOLUTIONS IT HAS SPARKED. FROM SATURN TO MARS AND THE SUN, AND IN THE FUTURE BLACK HOLES, CNES HAS WORKED TIRELESSLY TO DEEPEN OUR UNDERSTANDING OF THE UNIVERSE.



EXPANDING OUR HORIZONS

Humans have set foot on the Moon and rovers are currently trekking across the surface of Mars. While exploring the outer reaches of deep space remains an endeavour fraught with danger, it is a tantalizing prospect inspiring an increasing number of European missions.

Discovering the universe is seldom a journey we make alone. Despite this, in 2001 France decided to embark on a stellar seismology mission led by CNES. CoRot would subsequently identify numerous exoplanets, since catalogued and published in 2018. But CoRot remains an exception; France usually takes part in astrophysics or deep-space exploration missions within the framework of the European Space Agency (ESA). Indeed, space science is one of ESA's mandatory programmes to which all member states contribute in proportion to their GDP. This mandatory pooling of resources has proved most effective, enabling missions that would be too complex or costly for any one nation to undertake alone.

2012

This is when

the Curiosity rover's SAM instrument confirmed that water once flowed on Mars after probing clay-bearing rocks.

Springboard for science and industry

Once a mission has been selected for its science value, it's time to get technical. France is called on to develop instruments, sometimes as principal investigator, thereby involving French scientists and research laboratories, notably the national scientific research centre CNRS and its ten institutes. For example, in 1997 Cassini-Huygens (NASA/ESA) studied the environment of Saturn and its moons Titan and Enceladus with a French suite of instruments designed to analyse their chemical composition. In 2018, BepiColombo (ESA/JAXA[1]) set out on its journey to map Mercury, with six out of its 16 science instruments conceived by eight French laboratories. And in 2014, France and Germany supplied the MASCOT lander and instruments that contributed to Japan's successful Hayabusa 2 mission. Europe is now supporting a project bringing together European astronomers and physicists to study the "dark universe" with Euclid, a cosmology mission scheduled to launch in 2022 to map hundreds of millions of galaxies in three dimensions. Up to 500 research scientists in France could be involved. CNES is supporting them as a member of the consortium tasked with providing the ground segment—telemetry and tracking stations, etc.—and leading development of a spectrometer. Further down the line, around 2034, the Cosmic Vision programme's Athena mission plans to probe black holes with its new-generation X-ray telescope, a revolutionary instrument for which CNES has been given sole contractual responsibility.

1. Japan Aerospace and Exploration Agency

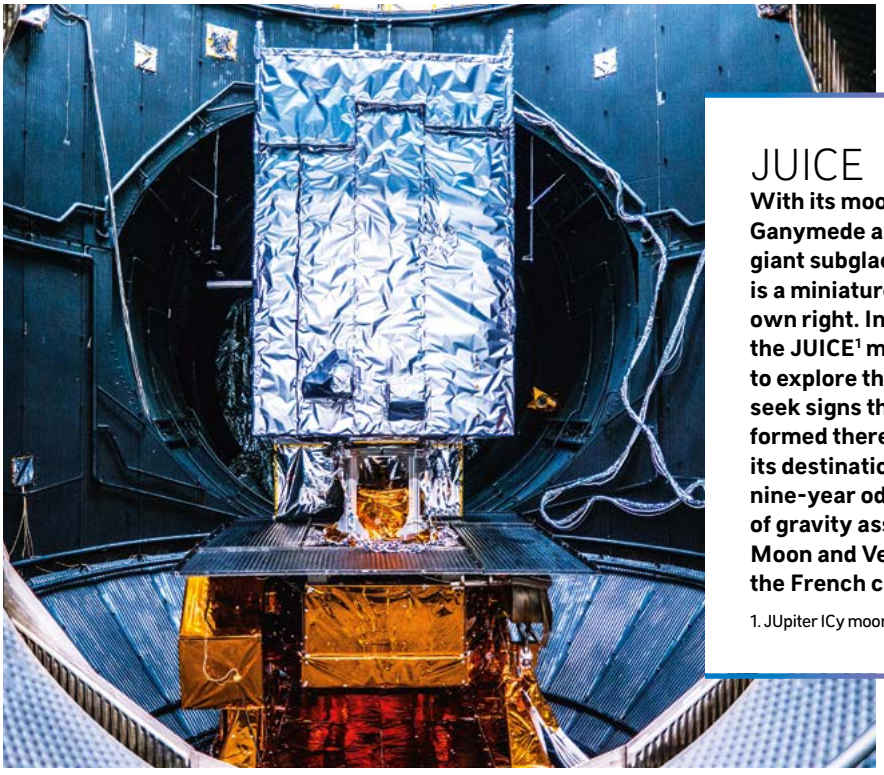
SUN

BURNING BRIGHT

The Sun's light carries the energy that shapes our climate and sustains our plants. However, it remains something of an enigma, even if since 1990 a series of missions —Ulysse, SOHO, STEREO—have approached it. From an already scorching 5,000 to 6,000°C at its surface, temperatures rise to a million degrees in its corona for reasons we still can't explain. To probe deeper into this phenomenon, the United States and Europe have dispatched two new missions: Parker Solar Probe (NASA), launched in 2018, is investigating the solar corona with a suite of instruments including contributions from France, while Solar Orbiter (ESA), launched in 2020, is observing the Sun at unprecedented resolution with ten instruments to attempt to gain new insights into our star and its environment. It will later turn its attention to the Sun's poles.

4,838

How many of them are there outside the solar system?
Extrasolar planets—or exoplanets—still hold many secrets. In 2006, CoRot was designed to prove their existence; by September 2021, 4,838 had been catalogued.



JUICE

With its moons Io, Europa, Ganymede and Callisto and their giant subglacial oceans, Jupiter is a miniature solar system in its own right. In the autumn of 2022, the JUICE[1] mission will depart to explore the Jovian world and seek signs that life might have formed there. It will arrive at its destination in 2031 after a nine-year odyssey and a series of gravity assists from Earth, the Moon and Venus. CNES is leading the French contribution.

1. JUpiter ICy moons Explorer

Selfie of the Curiosity rover from the surface of Mars.

ROBOTICS

THE NERVE CENTRE OF EXPLORATION

End 2003, the French OMEGA and SPICAM spectrometers on ESA's Mars Express probe began analysing the soil and atmosphere of Mars. They would be followed by ChemCam and SAM on Curiosity (NASA, 2011), SEIS on InSight (NASA, 2018) and SuperCam on Perseverance (NASA, 2020). French research laboratories have been working on the core instruments of Mars missions for close on 20 years. Europe's ExoMars, which is being accomplished in two phases, is a fine example. French manufacturers built the Trace Gas Orbiter (TGO) launched in 2016 that is successfully observing Mars' atmosphere and serving as a communications relay for other missions. Now, French laboratories are working on four of the instruments for the Rosalind Franklin rover set to depart in September 2022 and arrive at Mars in 2023. The sequel will be written in 2030 with the return of samples from the red planet (see opposite). Across the space community, robotic exploration is seen as the prelude to the holy grail of human exploration of Mars.

FAST FORWARD

LOOKING FOR LIFE

How did life take hold on Earth? Did it emerge elsewhere? To find out, scientists are hunting for other planetary environments conducive to the development of lifeforms. Exploration of the solar system conducted for over half a century—with Venus Express, BepiColombo to Mercury and Huygens to Saturn's moon Titan—is ongoing, but it's Mars that's focusing our attention. In addition to being relatively easy to reach, the red planet holds layers of sediments indicating that water once flowed in abundance on its surface. Current missions are engaged in a treasure hunt for biosignatures in the form of minerals or organic molecules. The Perseverance rover is coring rocks in target areas to acquire samples for their geological and exobiological value. These samples will be preserved inside sealed tubes for later collection by another rover and then placed into Mars orbit for return to Earth. This is the ambitious goal of the ESA/NASA Mars Sample Return mission (MSR) scheduled for 2026-2031.

PHILIPPE GAUDON

Former CNES Rosetta project leader

"With Philae, the unexpected happened"

1 2 November 2014: Philae is all set to rendezvous with comet J67P/Churyomov-Gerasimenko, or Chury to friends. For Europe's tiny lander, it's the culmination of a seven-million-kilometre odyssey that began in March 2004, riding on the Rosetta probe. But the journey's epilogue had some surprises in store. "It wasn't for lack of planning. We'd been in orbit around the comet for four months, observing it up close and spending days discussing the best place to land and the best trajectory to get there," recalls Philippe Gaudon, then Rosetta project leader at CNES. "But the unexpected happened and two of the devices activated on landing failed to work." So, instead of landing softly, Philae bounced off the surface, although fortunately its ten scientific instruments sustained no damage. "After two long nailbiting hours, the module came to a standstill and for 60 hours we received some wonderful pictures and a wealth of data that scientists are still poring over today." But once Philae had drained its batteries, there wasn't enough sunlight in the area where it had come to rest to recharge the lander. And as it was lying on its side, communication with Rosetta proved problematic, although contact was briefly established on a few occasions before a final transmission on 9 July 2015. In September 2016, Rosetta flew over Chury again and was able to snap a picture of Philae's resting place. "We bid farewell to Philae that day, but its legacy is immense: the extremely complex molecules detected during its 60 hours of transmission appear to confirm that comets seeded the oceans and therefore life on Earth." An immense legacy indeed.

"EXPLORING THE SOLAR SYSTEM IN SEARCH OF WATER AND LIFE"

SYLVESTRE MAURICE

Astrophysicist and planetologist at the IRAP astrophysics and planetology research institute

"My office has been on the red planet for nearly 10 years now!"

What were—or still are—your main fields of study?

Sylvestre Maurice: My specialist field is planetary surfaces. A lot of my work involves looking for water and evidence of habitability at different places in the solar system: for example, Saturn, Jupiter, Mercury, Mars and the Moon. I'm also an instrument specialist; our team designed and is operating ChemCam and SuperCam, the two laser cameras on the Curiosity and Perseverance Mars rovers. They were both developed in France, in partnership with the Los Alamos National Laboratory (LANL), for the Jet Propulsion Laboratory (JPL) in Pasadena, California.

What have been the great discoveries of your career?

S. M.: To this day, my fondest memory remains the Lunar Prospector mission. In 1999, it led to the discovery of hydrogen indicating that water ice was present at the Moon's poles. There were just four of us analysing the data. A team that small would be unheard of today! I subsequently contributed to other discoveries like hydrated phases at Mars' equator with the Mars Odyssey mission and water ice at Mercury's poles on the Messenger mission. But the life of a scientist isn't all plain sailing and I've had my fair share of setbacks: for example, I wasn't able to identify water molecules on the first mission to Saturn's magnetosphere. There's of course the Curiosity adventure, which has proved that Mars was habitable in its ancient past. And since February this year, Perseverance is hunting for signs of life.

How did CNES contribute to these advances?

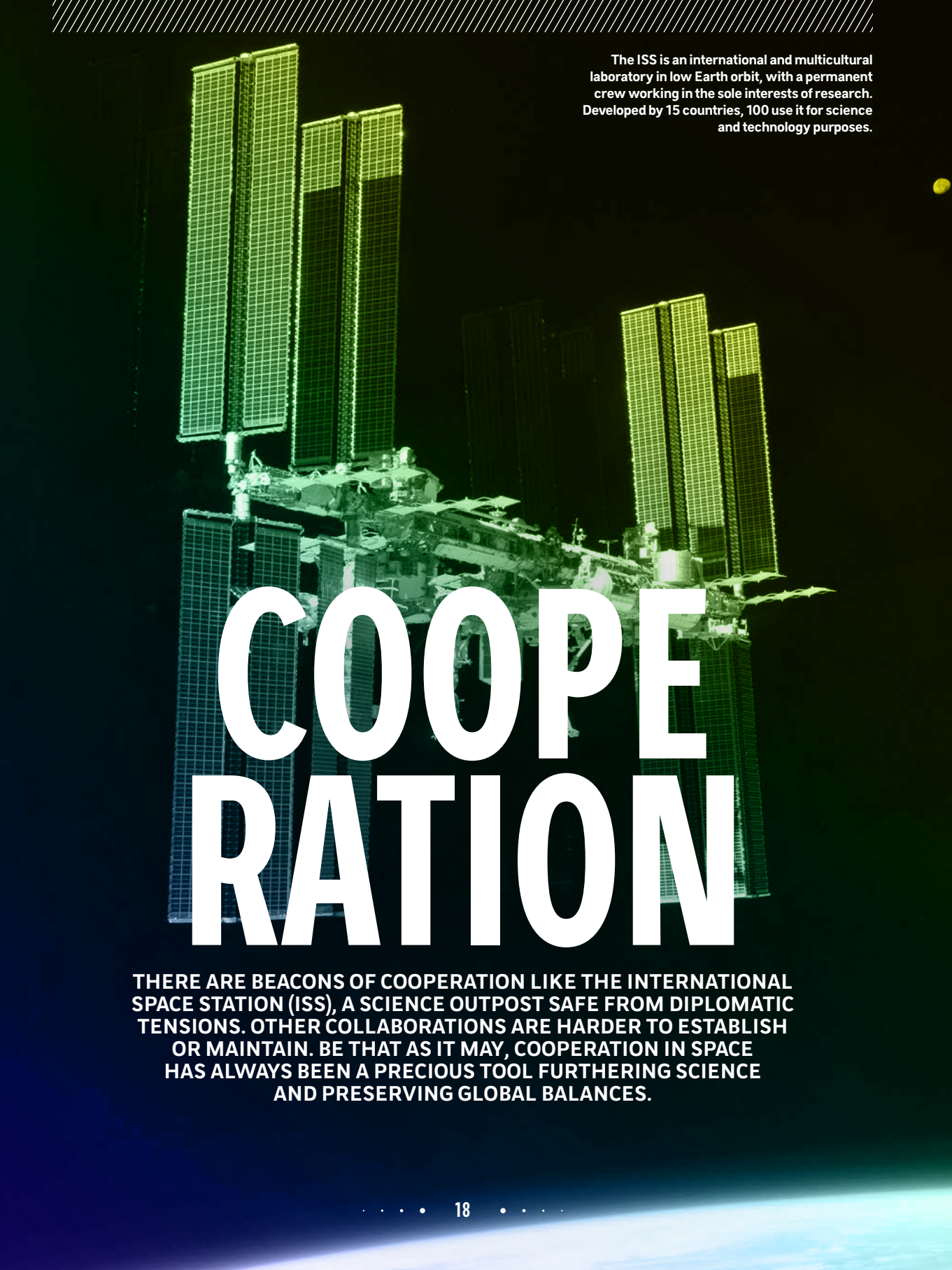
S. M.: Since the first joint studies in 2001, which led to today's Martian survey campaigns, the ties forged between our research teams at CNRS and universities and those at CNES have become so close that many of my American colleagues don't even know I'm from IRAP! Some 70 people from CNES worked on SuperCam, specialists in mechanisms, components, quality and so on. They supplied several subsystems, starting with its laser and camera. Today, we're operating these instruments together every day on Mars. More broadly, CNES guarantees us access to space and we have agreements with multiple partners to fly the instruments we build. All in all, I feel I'm in a privileged position, with a foot in academia and a foot in the day-to-day operations of a space agency, which gives me the best of both worlds!

KEY DATES

1994
PhD in astrophysics (Paul Sabatier University, Toulouse).

2001
Mars Odyssey mission; discovers hydrated minerals at Mars' equator.

2012
Curiosity rover lands on Mars carrying ChemCam.



The ISS is an international and multicultural laboratory in low Earth orbit, with a permanent crew working in the sole interests of research. Developed by 15 countries, 100 use it for science and technology purposes.

COOPERATION

THERE ARE BEACONS OF COOPERATION LIKE THE INTERNATIONAL SPACE STATION (ISS), A SCIENCE OUTPOST SAFE FROM DIPLOMATIC TENSIONS. OTHER COLLABORATIONS ARE HARDER TO ESTABLISH OR MAINTAIN. BE THAT AS IT MAY, COOPERATION IN SPACE HAS ALWAYS BEEN A PRECIOUS TOOL FURTHERING SCIENCE AND PRESERVING GLOBAL BALANCES.

Soyuz makes its first flight from French Guiana on 21 October 2011.

NOT SO MUCH A STRATEGY, BUT A MINDSET

In deciding to craft its own space policy, France had to find its place between two ambitious behemoths, the United States and the Soviet Union. In the interests of research, it chose to work with both. It has since forged multiple partnerships around the globe.

Space cooperation is always motivated by programmatic, scientific or industrial interests. For example, Russia's Soyuz launcher has been accommodated at the Guiana Space Centre (CSG) since 2011, where it takes advantage of optimal operating conditions and rounds out Europe's range of launch vehicles. Generally speaking, CNES seeks agreements in priority areas such as space exploration, the environment, Earth observation and telecommunications, but that's not all. As a government agency it is a key cog in French diplomacy, with eight permanent offices at the embassies in Tokyo, Berlin, Washington, Beijing, Abu Dhabi, Moscow and Bangalore, and at the European Union in Brussels. Its space advisors are vital local contacts supporting European and international actions. And through its status as an industrial and commercial agency, CNES is helping to open up international markets to French manufacturers, SMEs and start-ups.

90%

Today,
France is conducting 90% of its missions with European or international partners.

Cooperation is king

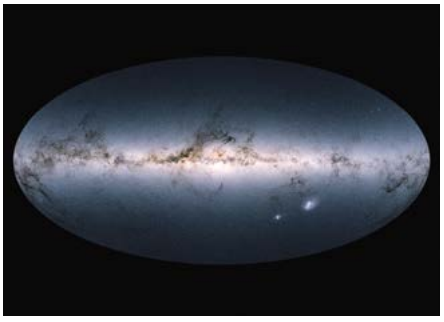
From its inception in 1961, CNES worked to forge close ties with its longstanding partners: with the United States in 1963 to support French engineers working on the FR-1 satellite, the USSR in 1966 with the first intergovernmental accord on the exploration and peaceful use of outer space, India in 1964, Japan in 1996 and more recently China. New partnerships are also being developed with new space players like the United Arab Emirates (on Emirates Lunar Rover), Korea (with KASS, Korea's 'Galileo'), Israel (VENµS) and Morocco (Irrisat).

But the most emblematic example of all is the cooperation with neighbouring nations that sowed the seeds for a truly European space programme. Alongside Germany, France was a prime mover behind the European Space Agency (ESA), founded in 1975. Today, with 22 member states, ESA is leading Europe's space ambitions and CNES remains a core player and one of the main contributors. France is also supporting the European Union's growing space ambitions. This European framework favours French participation in large-scale missions.

Besides scientific and/or economic concerns, some cooperation initiatives are driven by a more geopolitical vision. Satellite data are vital to aid development of regions of the globe like Africa and South America or to support sectors like water resource management, environmental conservation or healthcare. Kenya, for example, is tackling elephant poaching with satellite data, while Nigeria is employing them to monitor how its forests are managed. Partnerships are also motivated by international solidarity, for example to further the United Nations Sustainable Development Goals (SDGs).

ESA

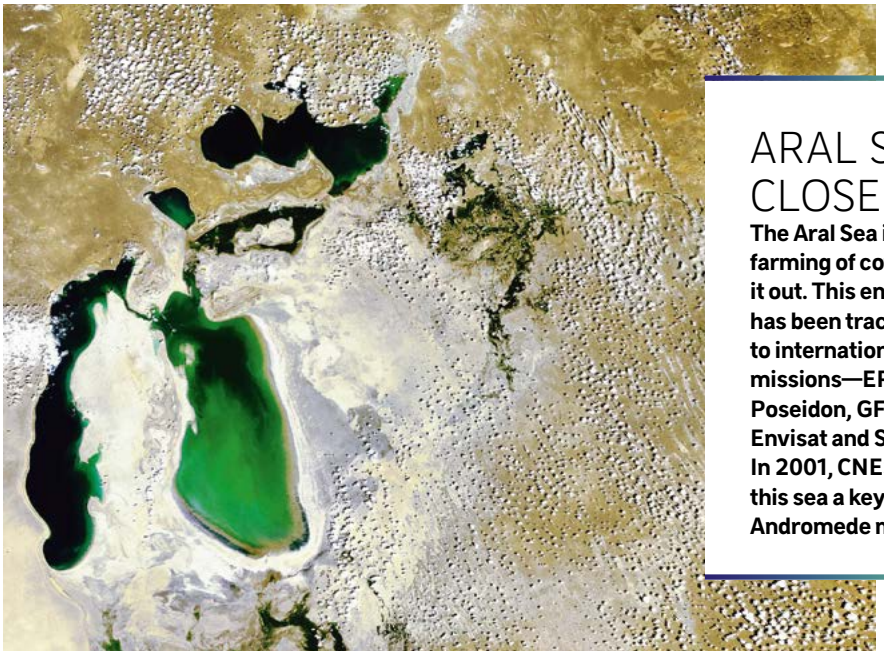
HIGH ADDED VALUE



France has long advocated space as a symbol of European construction, deciding very early on to put its science and engineering expertise to work for Europe. Since ESA's inception, CNES has been closely involved in shaping and executing European space policy. Ariane has been the flagship of this effort, and for good reason: the prestigious line of launchers has guaranteed Europe's independent access to space while meeting a large share of global demand for commercial satellite launch services. Meanwhile, Galileo has given Europe a geolocation system that affords unrivalled precision and Copernicus is surveying the planet in fine detail. ESA's scientific missions are a clear illustration of the value of pooling talents and know-how, be it Rosetta and its unlikely rendezvous with a comet (see Standout story, p. 16), BepiColombo's close approach to Mercury, Solar Orbiter's high-risk encounter with the Sun (see p. 14) or the Mars Express odyssey. Others like the Gaia galaxy mapper are one of the decadal Cosmic Vision programme's ambitious small-, medium- or large-class missions, and the list doesn't end there.

225

Cooperation agreements
signed over the last ten years by CNES. Of these, 126 are still active, 80 were signed with Asian nations and 70 with North America. In all, 41 countries are concerned.



ARAL SEA UNDER CLOSE WATCH

The Aral Sea is dying due to intensive farming of cotton crops that is drying it out. This environmental disaster has been tracked largely thanks to international space cooperation missions—ERS-1 and 2, TOPEX/Poseidon, GFO, Jason-1, 2 and 3, Envisat and Sentinel, to name a few. In 2001, CNES even made monitoring this sea a key area of study for its Andromede mission aboard the ISS.

Lunar-orbiting Gateway.

EXPLORATION

GETTING READY TO TAKE HUMANS TO MARS

Within a few decades, human exploration crews will set foot on the red planet. But before we get there, work to ready for that moment is underway on the ISS and will continue in the future on the Moon to test the capabilities required to survive on the journey to Mars. To do that, we must first get to know our natural satellite better. Besides its European collaborations, France expects between now and 2024 to be contributing to several pathfinder robotic missions. For Rachid, the United Emirates lunar rover planned to set down on the Moon in 2022, CNES is supplying its CASPEX cameras (see p. 8). For China's Change'6 lunar sample return mission, it will be providing an instrument to measure surface radon emissions. And across the Pacific, the United States plans in 2024 to send a mission to probe the geophysics of the Moon's mantle, for which a seismometer derived from SEIS will be delivered to the Jet Propulsion Laboratory (JPL). A magnetometer has already been delivered to the University of California, Berkeley (UCB) for the LuSEE[1] mission to study the electric and magnetic fields on the lunar surface. Work focused on health is also anticipated on the future Gateway lunar outpost.

1. Lunar Surface Electromagnetics Experiment.

FAST FORWARD

PROTECTING OUTER SPACE

Declared "the province of all mankind", outer space is a bit like a co-working space. Since 1967, the world's nations exploring it for scientific purposes have abided by an international treaty signed at the initiative of the United Nations. Founded on the principle of non-appropriation, this treaty states that "the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries". But the rise of New Space[1] and planned lunar and Martian sojourns are changing the game. Should we see in this trend a risk of natural resources being appropriated for commercial gain? For the time being, exploitation of such resources is still at the project stage, but what of the future? Who does space belong to? We could take our cue from regulations governing the inalienable resources of the ocean depths or envision concession-type systems. Now is the time to reflect and chart the course ahead.

1. New Space or entrepreneurial space encompasses a range of private initiatives driving a paradigm shift in the space industry

PATRICK CASTILLAN

Former CFOSat project leader at CNES

"We had no idea how our Chinese colleagues operated"

Jiuquan, Inner Mongolia, 29 October 2018, 00:47 UTC. *Sān, èr, yī…*(3, 2, 1). The Long March 2 launcher soars skyward from the pad, carrying a satellite called CFOSat, for China France Oceanography Satellite. "A perfect launch, in a pristine sky," Patrick Castillan, CNES's project leader, fondly recalls from that morning in the Gobi Desert, a day marking the culmination of an unforgettable adventure. It all began 12 years earlier with an intergovernmental accord between Paris and Beijing to cooperate in space. The scientific ambition was equal to the high political stakes. "The choice was made to go with a really innovative project to simultaneously observe waves and winds," explains Castillan. It was also a human challenge to get teams from such different cultures to work together in the long haul. "We had no idea how our Chinese colleagues operated, other than the usual clichés. It has to be said that we were wracked with uncertainty." But everything turned out fine, and both sides learned to adjust to each other's way of doing things. "On the French side, we spent a lot of time discussing to explore all possible options, whereas our Chinese partners preferred to move forward quickly, looking to be efficient and responsive rather than exhaustive. We learned a lot from working with them, and over time we found ourselves on the same wavelength. This adventure changed all of us and personally it taught me to stay calmer when things don't go according to plan. That's definitely something I brought back from China!" And as for CFOSat, it is still delivering data to fuel the great work being done by the mission's operations and science teams.

Q & A

"TRUST AND RECOGNITION ARE THE KEYWORDS OF OUR RELATIONSHIP IN SPACE WITH THE UNITED STATES"

NICOLAS MAUBERT

Space advisor at the French Embassy in the United States and CNES representative in Washington D.C.

"We must continuously cultivate our excellent relations with the United States"

What context did you find when you arrived in Washington in the summer of 2019?

Nicolas Maubert: The Trump administration had already taken important decisions for space, resurrecting the National Space Council and signing a number of key executive orders aimed at establishing a human presence on the Moon, opening up space to private players and creating a Space Force. This series of measures really gave structure to U.S. and world space policy. The United States were seeking to reaffirm their leadership in space, and that momentum has been sustained since Joe Biden has been given the keys to the White House. In two years I've also seen the massive influx of private players and the ramp-up of nations like China, of course, as well as nations with space ambitions like Australia, South Korea and Luxembourg.

How is the relationship between the United States and France evolving on space matters?

N. M.: France and the United States are longstanding partners who have been working together in space ever since CNES's inception. Even today, one-third of the agency's agreements are with NASA or the National Oceanic & Atmospheric Administration (NOAA). The watchwords of the transatlantic relationship in space are trust and recognition. But despite our close relationship, we must never forget that here it's America First, particularly in a tight economic context, as the recent Australian submarine contract affair has shown. We therefore have to keep in mind that our excellent relations with the United States aren't set in stone and need to be cultivated all the time.

Do you think space cooperation can continue to be an ally of diplomacy?

N. M.: I firmly believe that space cooperation remains a great tool for diplomacy. This is nothing new: ever since the Cold War, space has always been a domain where consensus is easier to achieve, with shared stakes—notably scientific stakes—even when we're not on good speaking terms in other areas. Space also offers an excellent pathway for broader discussions. Indeed, the first conversation between Emmanuel Macron and Kamala Harris was for the landing of Perseverance on Mars, which is pretty symbolic! Since then, the National Space Council—headed by Kamala Harris—has advocated for a French-U.S intergovernmental summit on space, which is a very positive sign for our diplomatic relations.

KEY DATES

2003
Joins Galileo programme at Thales Alenia Space and then ESA

2013
Joins CNES as technical and operations manager at the Guiana Space Centre

2019
Appointed space advisor to the French Embassy and CNES representative in the United States

With 20 cyclones, nine of them reaching hurricane force, 2020 proved a record year. Satellite data for weather alerts are vital for mitigating the consequences and protecting populations. The IASA interferometry instrument has been improving forecasts for more than 20 years.

SPIN OFF

SPACE HAS LARGELY SUCCEEDED IN MAKING ITSELF INDISPENSABLE, THANKS TO TECHNOLOGIES THAT ARE NOT ONLY ADVANCING SCIENCE BUT ALSO SERVING INCREASINGLY USEFUL APPLICATIONS IN OUR DAILY LIVES—JUST THE KIND OF TECHNOLOGY SPIN-OFF THAT CNES IS WORKING TO SUSTAIN.

SPACE FOR EVERYONE

Mapping the skies has been ingrained in our culture for as long as we can remember. In recent years, technology, satellites and data derived from space have made it a feature of our daily lives.

These days, space is everywhere we look. Take our smartphones' geolocation system, capable of telling us where we are to within a few tens of centimetres and how to get where we want to go. We pretty much take this for granted as one of the most common applications of space technology there is. And space-based experiments have not only advanced scientific knowledge; they have also been spun off into highly useful applications. The miniaturization of electronics driven by the race to the Moon in the 1960s subsequently spawned today's personal computers, tablets and e-book readers, while survival blankets and fire-fighting suits adopted the kind of composite materials used to insulate satellites.

2,000

Weather forecasts,
LEDs, shape-memory pillows and high-tech ski masks are just some of the more than 2,000 products and services derived directly from space technology.

The utility of microgravity

By enabling us to operate in weightless conditions, the International Space Station (ISS) has given a big boost to research. Recent examples include the Perspectives experiment to learn more about the central nervous system, and Aquapad, which has led to the development of a water quality tester. Proving just as useful on the ground as in orbit 400 kilometres above our heads, this unit designed with BioMerieux is set to be deployed to test potability in developing nations.

But if there's a domain where space technology spin-off has amply demonstrated its utility to populations, it is health. CNES has been instrumental in this regard, creating the MEDES space medicine and physiology institute in 1986 to monitor astronauts' health and opening its in-house CADMOS centre for the development of microgravity applications and space operations in 1993. Today, telemedicine is helping to address the issue of medical deserts, largely thanks to experiments conducted on the ISS. Electrocardiograms, for example, have been tried and tested there, while EveryWear kept a close check on the vital signs of astronaut Thomas Pesquet with its suite of smart wearable sensors.

Space serving the planet

Space has also become a fixture of the navigation-mobility and environment-agriculture sectors. In another domain, CNES and CMA CGM, a shipping company seeking to develop sustainable logistics, have conceived a smart routing solution to make shipping 'greener' and more fluid. And of course space is a prime purveyor of objective indicators to keep track of climate change effects.

Space also proves a precious aid to emergency relief and rescue services by supplying maps and other information about disasters zones, as it did this September in the United States in the aftermath of Hurricane Ida. And last but not least, space spin-offs are fuelling both traditional businesses and New Space start-ups, bringing a real boost for the economy.

GEOLOCATION

GALILEO SURGES AHEAD

GPS was the moniker on everyone's lips, and it was American; but that was then and this is now. Since 2016, Europe has developed and fielded Galileo, its own independent 24-satellite global positioning system. CNES was a precursor in this domain, inventing the Precise Point Positioning (PPP) method in the 2000s and positioning the Galileo satellites up to 2018. Today, the agency is coordinating performance monitoring for ESA's member states, managing several tracking stations in Kourou, French Guiana, and exploiting satellite data for search and rescue through the Cospas-Sarsat system. As well as playing a key role in interministerial coordination for Galileo, CNES is also keeping a close eye on new solutions likely to benefit industry. Under the government's stimulus plan for space initiated in April 2021, it is now working on specific complements to fly on nanosatellites in low Earth orbit for secure applications. Today, two billion smartphones are compatible with the four positioning systems in service—Galileo (Europe), GPS (United States), Beidou (China) and Glonass (Russia).

1,280

CNES's portfolio of patents covers
a broad range of applications, with more than 400 patent families in France and 1,280 patents granted worldwide.

CONNECTED BEEHIVE

Helping beekeepers to monitor temperature, humidity and vibrations in hives to take close care of their bees is one of the initiatives being supported by Connect by CNES, a sustainable development programme aimed at boosting uptake of space-derived data and services by public companies and stakeholders. As early as 1986, CNES formed Novespace to spin off space technologies to industry and promote weightlessness as a new research tool.

IoT

CONNECTING THE GLOBE

Whether it's to plan inputs in a farmer's field, keep track of herds or inspect turbines in a wind farm, a revolution is underway in the Internet of Things (IoT). For satellites give us the ability to acquire data anywhere, including where terrestrial infrastructures are lacking—a great asset for businesses with operations at multiple sites around the globe. Key stakeholders in this new world, CNES and its subsidiary CLS have conceived Kineis, a prime player in the New Space movement (see Q&A p. 29). Drawing its heritage from the Argos system, Kineis is set to fuel uptake of low-throughput, space-based IoT with its constellation of 25 nanosatellites. While they may be built around different technologies, terrestrial and space-based IoT are by no means incompatible—in fact, they even complement one another, as whatever the technology, all connected objects can link to the same data and service platforms.

FAST FORWARD

SPACE TENDING TO OUR HEALTH

Arbocarto: behind this unusual name is a preventive healthcare programme supported by CNES that aims to map densities of tiger mosquitoes in infested regions in real time. The programme is in development in France. But it's not alone: using Sentinel-2 data, ClimHealth is being trialled in Cambodia. Based on the same principle, it generates risk maps to counter environmentally sensitive diseases like leptospirosis, borne by rats. Besides preventing diseases, communications satellites can play a key role supporting medical staff and taking clinical diagnosis and telemedicine to remote populations in poor or war-torn nations. CNES is working hard to enable such solutions to be developed. Its MEDES subsidiary is already reinvesting its observations in community healthcare to combat chronic illnesses or the effects of ageing.

STANDOUT STORY

CLÉMENT BARON

CTO of Agreenculture

"CNES played a key role in Agreenculture's development"

In 2015, Clément Baron was an engineer at CNES's Launch Vehicles Directorate (DLA). Six years on, he's chief technical officer (CTO) of Agreenculture, a Toulouse-based start-up specializing in robotic farming solutions, a career change that came about thanks to a great opportunity grasped with a little help from CNES. "It all started when I was reunited with an old friend from my student days who had a project for a weeding robot he was developing," he says. "I advised him to add an inertial management unit (IMU) to the GPS-based system he'd envisioned. Two weeks later, he'd already purchased the IMU and an intern was working on it. That really impressed me and I liked the real-world side of what he was doing, so I gradually bought into the project alongside him." When Clément Baron went to the person in charge of the spin-off unit at CNES that helps employees looking to create space technology start-ups, the idea received a warm reception. The agency would then provide its support in various forms, accommodating the project within the ESA BIC incubator, funding testing and validation of the robot's positioning systems at the GUIDE-GNSS laboratory, and subsidizing the application to join an ESA research programme. "Not to mention another key factor, which was everything I learned during my time at DLA, not only from a technology perspective but also how to manage complex projects." Now with 45 employees, the young firm is set to start selling robots capable of centimetre precision to till soil and weed vineyards autonomously. It also provides the robot's 'brain' and software environment. And it's already charting its course for the future: "If everything goes according to plan, we're looking to sell our robots to cereal growers and market gardeners."

"CREATING HIGH-ADDED-VALUE SERVICES FROM SATELLITE DATA"

CHRISTOPHE VASSAL

CEO of CLS and Chair of the Kineis supervisory board

"CNES is a fantastic technical mentor and a strategic foundation for our international development."

How did it all start for CLS?

Christophe Vassal: CLS, for Collecte Localisation Satellites, is a subsidiary of CNES and Belgian investment firm CNP. It was incorporated in 1986 to operate the Argos satellite-based system conceived by CNES to locate and collect data from transmitters on land and at sea. In the early years, our business was mostly focused on data collection from oceanography buoys and wildlife tracking. In 1991, CNES tasked us with operating altimetry satellites and we became specialists in space oceanography. Some years later, we acquired a radar satellite data company to round out our portfolio. Today, we use 400 satellites to develop space solutions to study and protect our planet, and for sustainable resource management.

With Argos and now Kineis, you've gone from strength to strength. What's the secret behind this success?

C. V.: I think our strength lies in our in-depth knowledge of needs in the field and our ability to create high-added-value services from satellite data and combine them with artificial intelligence tools. That enables us to address real-world concerns driven by the challenges facing us with regard to the environment, energy, infrastructures, maritime safety and security, transport and logistics, and so on. For example, our biodiversity department offers services for tracking wild herds and studying their behaviour using collars with embedded AI and connected to satellites. We overlay these data on information about environmental conditions and human activities to build decision-support tools for land planning. Kineis, our joint subsidiary with CNES, marks a new stage in our development strategy. By 2023, our ambition is to boost uptake of the Argos system through low-throughput connectivity that is affordable and easy to integrate. The Argos system today connects to 20,000 transmitters; with Kineis, there will be several million.

What in your view is the recipe for successful space technology spin-off?

C. V.: I think the watchword is mutual trust, and in that regard CNES has always been a consummate partner, helping us to conceive space applications while going along with our choices at every step of the way. It has played a visionary role in developing CLS and space applications serving humans and the planet. Today, we're striving to do the same thing with Kineis and the other start-ups we're working with.

KEY DATES

1992
Start of space oceanography business

2000
Start of ocean monitoring business, using radar services

2023
Launch of Kineis IoT constellation of 25 nanosatellites

Our house is burning while we look the other way! Human populations and biodiversity are under threat. The latest IPCC report released in August has once again raised the red flag, basing its conclusions on satellite data that are the only way to obtain a full picture of Earth and its diverse components.

PLANET

FRANCE HAS BEEN SURVEYING EARTH FROM SPACE FOR 60 YEARS. ONLY SATELLITES CAN PROVIDE AN OBJECTIVE PICTURE OF THE COMPLEX PROCESSES PLAYING OUT THERE. CNES STORES AND PROCESSES THESE PRECIOUS DATA SO THAT THEY CAN SERVE US ALL.

Mayotte, Petite-Terre, seen by Pleiades.

A CLOSE EYE ON OUR PLANET

Earth observation is part of CNES's genetic make-up. The expertise acquired through 60 years of remote-sensing missions has made France a leading world power and is boosting its research laboratories and manufacturers.

CNES cultivates many fields of expertise and Earth observation leverages every link in the agency's chain of competencies. From waves to data and photons to applications, this holistic approach is the result of a long legacy of innovation in which optical systems are the standout. Each pixel of an image corresponds to a precise physical value that allows us to finely characterize our planet's lands, oceans and atmosphere. It has led to world firsts like Meteosat (1977), SPOT-1 (1986), TOPEX/Poseidon (1992), Jason (2001) and IASI (2006), and the quality of these data has convinced international space bodies to reinvest them in Copernicus.

27

As of 1 July 2021,
27 leading institutions in the field of Earth observation had signed up to the Space Climate Observatory (SCO), which has already accredited 36 projects.

Why observe Earth anyway?

Generating data is fine, but actually making use of them is even better. CNES grasped their potential for developing applications that serve the planet very early on. Data inputs include visible and thermal infrared radar or 3D imagery at local, regional or global spatial and temporal scales. Once processed and archived, such imagery is made available to research communities and public and professional institutions through data and service hubs (see Theia p. 8).

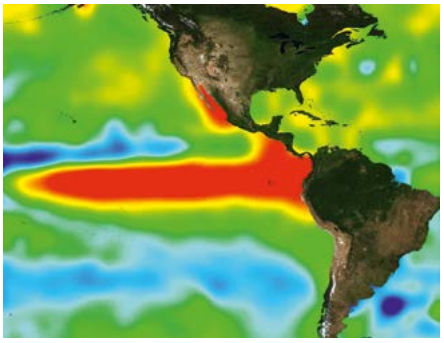
Combined with in-situ and aerial data, satellite imagery is helping to analyse climate change and is a valuable tool for land planning (to combat urban heat islands, measure air quality, etc.), managing natural hazards (flooding and wildfires) or monitoring fragile environments (coasts, estuaries, mangroves, etc.). Satellite data are also serving healthcare (see p. 27), mobility and biodiversity. In the years ahead, other applications are set to come on stream thanks to future missions like SWOT (hydrology of lakes, rivers, dams and reservoirs), Trishna (water status monitoring), CO3D (3D mapping of Earth's land surfaces), MicroCarb (CO_2) and MERLIN (methane).

For the Pleiades civil/military satellites, CNES innovated. The ORFEO Toolbox software has federated a community of users and regularly supports developments for new services—a systematic 'downstream' focus that CNES is also proposing for SWOT, CO3D and Trishna.

With its stellar track record in Earth observation, France deservedly occupies a leadership position in climate science and was instrumental in securing the legally binding Paris Agreement on climate change in 2015. In 2017, the One Planet Summit brought together the heads of the world's space agencies to create the Space Climate Observatory (SCO), a strategic and diplomatic tool intended to inform public policy on climate change. And as far back as 2000, France was already one of the founders behind the International Charter Space and Major Disasters (see Q&A p. 35).

ALTIMETRY

SURVEYING THE OCEANS



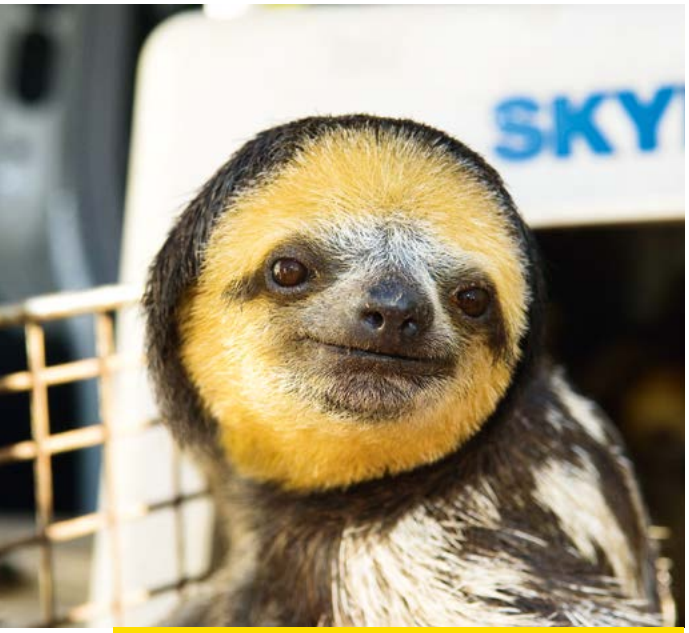
El Niño phenomenon observed by Jason.

From its orbital perch, an altimeter bounces a signal off the ocean surface to acquire an instantaneous measurement of sea-surface height. It was on this principle that in 1992 CNES and NASA based TOPEX/Poseidon, a satellite that would revolutionize the science of oceanography. To be able to determine the satellite's exact orbit, CNES, the space geodesy research centre GRGS and the national mapping, survey and forestry agency IGN also invented the DORIS[1] system, which enables precise and stable sea-surface height measurements. The dynasty of three Jason satellites would take the accuracy of these measurements to just one centimetre. Today, the European Copernicus programme's Sentinel 6 satellite is continuously measuring mean sea level. The long time-series of data now available to scientists are helping them to study tides, waves and ocean winds and currents. The current fleet of satellites encompasses 11 missions and unites Europe, the United States, India and China. Their data are analysed daily by an international community of more than 500 research scientists and have fuelled the development of numerous marine applications such as tidal zones and levels, iceberg detection and management of coastal risks.

1. Doppler Orbitography and Radiopositioning Integrated by Satellite

STRATOSPHERIC BALLOONS

For the last 60 years, stratospheric balloon survey campaigns have been investigating Earth's upper atmosphere up close. Operating at an altitude of 20 to 40 kilometres, they see into the core of perturbing mechanisms. For example, the Strateole Vorcore campaign probed the ozone hole in the Antarctic in 2005, sending up 27 balloons and performing 150,000 observations in the space of just two months. In October this year, 20 superpressure balloons ventured inside the changing winds and high-altitude clouds of the equatorial skies.



GUIANA SPACE CENTRE

PROTECTING BIODIVERSITY

With its 16,000 hectares of savanna, its primary forest, 450 bird species and dozens of protected large mammals, the Guiana Space Centre (CSG) has been operating in an island of biodiversity spanning 66,600 hectares in total since 1968. As the base's 'landowner', CNES has undertaken to preserve this natural environment through management plans conceived in partnership with the French forestry commission ONF, which manages the forest. The base is not classed as a nature reserve and could therefore choose not to avail itself of the constraints that go with such a status; on the contrary, it has aligned its plans with the rigorous methodology this entails. Its 2021-2030 management plan, which recently came into effect, is set to step things up a gear. A yearly meeting of CSG and ONF will compare intentions against actions and verify that projects match what is possible to achieve. The CSG was invited to present its initiative as a beacon for others at the World Conservation Congress of IUCN[1] in September in Marseille.

1. International Union for Conservation of Nature.

FAST FORWARD

RALLYING CRY FOR RESPONSIBLE USE OF SPACE

On 10 February 2009, the U.S. Iridium and Russian Kosmos satellites collided with each other, generating a cloud of 2,200 debris objects of more than 10 centimetres. On 6 March 2021, a Galileo satellite performed its first-ever avoidance manoeuvre to steer clear of a space debris object. Space seems infinite to us, but do we need 'rules of the road' to operate there without risk? Today, there are 34,000 objects of more than 10 centimetres in low Earth orbit, 12% of them active satellites, and new constellations are being announced every day. The EU SST[1] consortium pools the resources of its member states and protects 228 satellites from collisions via CNES's COO orbit computation centre. But coordinating space traffic worldwide remains a true challenge. While the French Space Operations Act (FSOA)—for which CNES is the guarantor—sets rules for the use of space, it is in no way binding. Promoting virtuous practices worldwide and raising awareness among all users of space is therefore a matter of urgency.

1. EUropean Space Surveillance and Tracking.

BENOIT MEYSSIGNAC

CNES research scientist at the LEGOS space geophysics and oceanography research laboratory

"Between now and 2100, many island territories could be under threat"

In its latest report released in August this year, the Intergovernmental Panel on Climate Change (IPCC) indicates that sea level has risen about 20 centimetres since 1900, and that the rate at which it is rising has tripled in the last ten years. "We now know for sure that global warming is fuelling sea level rise, but it's not that long ago that the causal link between the two was established," says Benoit Meyssignac, a CNES research scientist at LEGOS, a joint research unit of which the agency is one of the overseeing bodies. That scientific certainty is down largely to the CNES engineers who have worked hard to perfect altimetry satellites—like TOPEX/Poseidon and Jason-2—to the point where they are able to deliver centimetre accuracy. Among them, Anny Cazenave, a former LEGOS research scientist, was the first to prove that rising sea level was indeed being caused by warmer waters and ice melt. Today, Benoit Meyssignac is following in her footsteps, albeit with a slightly different focus. "I've been able to isolate how much of sea level rise is due only to warmer water and I'm using my calculations to evaluate fluctuations in the planet's energy imbalance," he explains. This concept, which describes the excess heat in the Earth system due essentially to human activities, "is at the very root of climate change". For climatologists, the approach is opening up new horizons for observing, assessing and understanding climate. "We're currently working on the concept of the future Marvel mission designed to improve how we measure the variable gravity field so that scientists can see how the energy imbalance evolves over a period of ten years." A great asset to measure—among other things—the real impact of climate change mitigation policies.

Q & A

"MOBILIZING SATELLITES FOR DISASTER MANAGEMENT"

DEBORAH KORBER

Deputy head of the geographic information and geomatics unit (T12G) at the Ministry of the Interior

"In the last 20 years, the charter has been activated almost 700 times"

What is the International Charter Space and Major Disasters?

Deborah Korber: The charter was created in 2000 at the initiative of ESA and CNES to make it easier to get satellite data to crisis response teams in the event of a major natural or man-made disaster. Today, it's a worldwide organization federating 17 space agencies who contribute a constellation of some 70 satellites. In the last 20 years, the charter has been activated almost 700 times around the globe, so getting towards 40 times a year. Half of those activations were in response to flooding or coastal submersion.

How does it work?

D. K.: Only national crisis management units—in France, the COGIC interministerial crisis management unit—are authorized to task satellites through the charter. What this means in practice is that when a major disaster occurs or is about to occur, we first alert the charter representative at CNES. We then specify our exact requirements—area of interest, type of data, etc.—via a dedicated online platform. Imagery and data validated by the SERTIT regional image processing and remote sensing department are then delivered to us within 24 to 48 hours.

How does the Ministry of Interior use these data?

D. K.: When we receive the requested data, we feed them into the Synapse geographic information system to distribute them down the regional crisis management chain, which includes prefectures, defence zones, the COGIC and the interministerial crisis centre for a very serious event. If the charter has been activated in response to a disaster, satellite data serve above all to prioritize measures to protect people and infrastructures. But if the event has already occurred, imagery is used to plan operations for relief teams in the field, assess damage and later to aid reconstruction, etc. Last August, for example, the charter was activated immediately when a 7.2 magnitude earthquake hit Haiti. The COGIC was then able to organize the relief mission of ForMiSC, the French Army's civil protection response unit, using Pleiades imagery to identify the worst-hit areas and accessible roadways.

KEY DATES

2000
International Charter Space and Major Disasters is launched

2017
Charter activated in response to Hurricane Irma

2021
Activations in response to earthquake and floods in Haiti

Ever wanted to see a full-size rocket, or get close up to a satellite, drone or rover? The Paris Air Show is the world's largest event for discovering the mythical realm of spacecraft.

PERFOR MANCE

THE WORLD HAS CHANGED A LOT IN 60 YEARS—AND SO HAS CNES. AS NEW CHALLENGES HAVE COME TO LIGHT, THE AGENCY HAS ADAPTED AND RESPONDED QUICKLY TO SOCIETY'S EVOLVING NEEDS.

ONWARDS AND **UPWARDS**

CNES was founded by President Charles de Gaulle on 19 December 1961, above all to further a political commitment. Today, 60 years on, the agency has expanded its areas of expertise and grown in credibility and status, thanks to the conviction of its people. Here's the story behind the success.

CNES's initial mission was to "put France in the select club of world spacepowers, alongside the USSR and the United States". To achieve this, it had a total of just 17 staff—a small player in the big league! In 1962, a few programme objectives were agreed: probe deeper into the upper atmosphere, develop a launch vehicle (Diamant) and a first satellite (Asterix) and sketch the outlines of a future European space structure.

The newly formed CNES thus had a dual role of government agency and technical field centre mandated to "marshal energies and enthusiasm to create and grow a French space ecosystem". The aim was to connect the country's upstream science laboratories with its fledgling downstream space industry. In 1965, this initial mandate was achieved and France became the world's third spacepower.

300,000

Every two years,
more than 300,000 visitors converge on the Paris Air Show, an open showcase of a constantly evolving sector of industry.

No time to rest

Six decades later, CNES has reached a new dimension. Its activities today are spread across four sites: Head Office and the Launch Vehicles Directorate in Paris, the Toulouse Space Centre and the Kourou spaceport in French Guiana. Some 2,400 personnel are executing a coordinated space policy on a European scale. Its management model is based on the ISO 9001 and 14001 standards, with a particular focus on the "commitment of its teams to continuous improvement" and a "strong environmental dynamic". World-renowned for its expertise in space technologies, CNES is closely in touch with the world around it. To meet the new challenges we face as a society, the agency is always ready to adapt. In 2016, to keep pace with the digital revolution, the unprecedented increase in Earth observation data and the emergence of new consumer applications, it created its Innovation, Applications and Science Directorate (DIA). Then in 2020, it set up the Sustainable Development and Performance Directorate (DDP) to coordinate the agency's corporate social responsibility (CSR) policy. Now, in its 60th year, CNES is reorganizing again in response to a fast-changing space landscape. "The space industry can never rest on its laurels," says Lionel Suchet, Chief Operating Officer. "We're operating in a global market today, with a mix of private-sector and government initiatives and ever more players. As we always have done, CNES is keen to support this process of evolution." The close ties forged with the ecosystem contribute greatly to the French space sector's added value proposition. And to stay ahead in a competitive market being shaken up by New Space, development of the future reusable launcher demonstrator has been outsourced to ArianeWorks, an acceleration platform bringing together the convergent expertise of ArianeGroup and CNES. Its aim is to boost the innovation process and pave the way for the launch vehicles of tomorrow.

And the future promises to be just as exciting as the past. The major challenges ahead include making better use of space data and developing reusable launchers. Like the Roman god Janus, depicted as having two faces, CNES has one eye on its rich heritage, of which it is deeply aware, and the other on a fast-moving future world where space is set to become more important than ever.

TAGLINE

A SPACE OF PASSION

In 1962, CNES's first logo reflected France's ambition to achieve independent access to space. Once this had been accomplished, in the 1970s space became a tool for Earth observation and applications, symbolized by Earth in the logo. The agency reaffirmed this stance more recently through its new tagline, "Space for Earth". Since 2019, space has been playing an increasingly important role in our lives. As guarantor of data quality and facilitator of France's space ecosystem, CNES has reflected this in its new brand identity: "We are all explorers". The goal is to emphasize human values—pragmatism, passion and empathy—to get the public on board, share our excitement and make everyone explorers of the world today.

3

France's space policy
was initially under the authority of the Prime Minister. Over the years, the government departments overseeing this policy changed with the space sector's evolving direction and focus. Two have remained constant: Research and Defence. In April 2021, a third key ministry was added: the Ministry of the Economy, Finance and the Recovery.

SOWING SEEDS

Flying science experiments on balloons from the school playground, raising single-cell organisms ("blobs") on the ISS or launching mini-rockets—what better way to get young people excited about space? CNES's educational ambition has always been part of its roadmap and the agency puts on a whole host of fun and attractive programmes for students of all ages and levels.

SPACE COMMAND

A MILITARY ENTITY IN TOULOUSE

Will space be an arena where future wars are fought? We certainly seem to be heading that way. Space has become a "field of confrontation and conflict like any other," said the Minister for Armed Forces Florence Parly in 2019. Space Command was created to deliver an effective defence capability. This military entity is hosted at the Toulouse Space Centre, which has overseen construction of certain defence satellites (Helios, CSO, etc.) for decades and advises the French defence procurement agency (DGA). The 450 military personnel based in Toulouse will be able to count on CNES's expertise as they get to grips with new tools and develop new strategies. The standing up of the command on the agency's new-generation campus is in progress and should be complete by 2025. As a direct result, NATO is setting up a centre of excellence alongside it to play a role in training and the development of doctrines to be implemented as space becomes militarized.

FAST FORWARD

A GREENER, MORE VIRTUOUS SPACE

As a leading player in Earth observation, CNES is a public operator that also knows how to observe itself. So, before engaging in a CSR policy, it did some real soul-searching on all fronts. While CNES pays particular attention to the wellbeing of its staff in the workplace, it is equally concerned about its impact on the environment. It shares the national objective of getting on track for Net Zero. From refurbishing buildings to reducing business travel, everything is being done to reach zero greenhouse gas emissions by 2050. While it has a new Sustainable Development and Performance directorate and a newly appointed Low Carbon Project Leader, the task isn't easy for CNES, because some residual emissions can't be eliminated. An offset policy will therefore need to be put in place. But ultimately, CNES views these constraints as an opportunity to embrace new concepts and practices. Over the next five years, the Guiana Space Centre should be 90% converted to renewable energy—a way for CNES to promote a space economy in line with what our planet can sustain.

MICHEL MIGNOT

Former Director of the Guiana Space Centre (CSG)

"The first Ariane launch was one of the best Christmas presents ever!"

It all began in 1967. After graduating from the Arts et Métiers engineering school, Michel Mignot was hired by CNES to oversee construction of the launch facility for the Veronique sounding rockets. Two years later, he moved to French Guiana with his family, where he was responsible for the construction and testing of the Diamant rocket facility. The CSG had only been inaugurated a year previously, and "Kourou was still a town of just 3,000 people, with constant building developments". In 1971, the Europa 2 rocket project ended after a launch failure. But CNES was keen to pick up again: were the Europa 2 facilities now available? They could be used for something else! And that something else was the LS3 launcher, soon to be renamed Ariane. "I was tasked with designing the ground infrastructure ahead of the first launch, which was planned before the end of the 1970s." Only there was a hitch: the new launcher was 50% larger than Europa 2, so the tower had to be raised and the launch pad foundation lowered to find the extra 15 metres. Ariane 1 was scheduled to lift off on 15 December 1979, but the launch was aborted. It finally made its maiden flight on 24 December, after two further delays. Michel Mignot had little time to savour the success, however, because for several months he had already been overseeing the design of the ELA 2 launch complex for Ariane 3 and 4. And it was the same for ELA 3: the design review was in 1985, before the first launch from the ELA 2. "CNES's strategy had always been to stay one step ahead." In 1991, Michel Mignot changed career path and was appointed Director of the CSG. He served in this capacity for eight years, a record that stands to this day. "I coordinated 77 launches—up to three a month—and managed integration of the Ariane 5 propellant and booster production plants at the site." He concludes: "But above all, I had the incredible opportunity to conduct the finest orchestra at the finest launch facility in the world!"

"PUTTING THE MAGIC BACK INTO SPACE, BALANCING BOLDNESS WITH REASON"

CLAUDIE HAIGNERÉ

Astronaut and former Minister for Research and New Technologies, then Minister for European Affairs

"Today, the approach to excellence is more professional"

Looking back, how do you see your experience at CNES?

Claudie Haigneré: It's been 25 years since the Cassiopee mission took me to the Mir space station. I have fond memories of the adventure, especially the camaraderie and French-Russian cooperation. A few weeks ago, I was back at the CADMOS centre for the development of microgravity applications, which helped me throughout preparations for the mission. It's great to see how much progress has been made. In the 1990s, we were really learning as we went along, in an almost artisanal way, in the noblest sense of the word. Today, that same sense of excellence is underpinned by a much more rigorous set of professional procedures and approaches, but without being overly rigid. Over the years, CNES has shown a great ability to adapt.

What do you think is the main ingredient of this adaptability?

C. H.: I think one of CNES's great strengths is how it has broken out of its comfort zone to engage with a much wider audience and range of issues. That's a hugely important cultural shift for a government agency. Space is now central to our societies, economies and diplomatic relations. Missions are no longer conceived as a purely scientific endeavour. As co-chair of the "Objective Moon" group at ANRT, the French research and technology association, I'm in regular contact with researchers but also with specialists in energy, digital, mobility and other sectors. And when CNES sets up an incubator like TechTheMoon, it shows how keen the agency is to embrace new sources of creativity.

How do you see the future of human spaceflight and France's role in it?

C. H.: I think that's a question we need to address first and foremost at European level. I don't think any one country can embark on a comprehensive Moon or Mars exploration programme. That said, I believe human spaceflight is crucially important for Europe and its place in a changing world. Personally, I'd like to see a new exploration strategy, with a specific and complementary ambition, alongside the two dominant players, the United States and China. The prospect of an independent human spaceflight capability is a geopolitical issue, which we need to re-examine in a clear-headed manner. I also think we need to put the magic back into space, balancing boldness with reason and the need to look ever-further ahead, which is inspiring, with the environmental imperatives dictating our immediate destiny.

KEY DATES

1996 then 2001
16-day mission on MIR, 10 days on the ISS

2002-2004
Minister for Research and New Technologies

2015-2020
Advisor to the Director General of ESA

TIMELINE

19 DECEMBER 1961

French statute 61-1382 is promulgated. Published in the Official Journal of 20 December 1961, it directs the creation of the Centre National d'Études Spatiales.

14 APRIL 1964

CNES chooses Kourou to replace Hammaguir (Algeria) as the location for Europe's future spaceport. The Guiana Space Centre (CSG) offers close proximity to the equator, a secure launch pad and access to all orbits.

1 OCTOBER 1964

Balloon launch base established in Aire-sur-l'Adour, Southwest France.

26 NOVEMBER 1965

Diamant, France's first space launcher, places the country's first satellite in orbit. With Asterix, France becomes the world's third spacepower.

1 MARCH 1968

The French government decentralizes: Toulouse becomes home to CNES's technical and operational field centre.

31 JULY 1973

Europe announces the development of a three-stage launcher, Ariane. The programme is delegated to CNES.

7 JULY 1995

Launch of the Helios-1A military observation satellite. It would be operational for 17 years.

JUNE 1998

Go-ahead for the Vega programme, a light launcher to complete Europe's line-up. Vega makes its maiden flight on 13 February 2012.

10 DECEMBER 1999

First commercial flight of Ariane 5. The programme had been approved on 5 November 1987.

7 DECEMBER 2001

Launch of Jason-1, the first of three satellites to study ocean circulation. The result of a historic cooperation with NASA, it monitors and forecasts "ocean weather".

TOP 10

From the outset, CNES has been committed to human spaceflight and stepped up to train and prepare astronauts for space. To date, 10 French astronauts have flown: Jean-Loup Chrétien (1982, 1988, 1997), Patrick Baudry (1985), Michel Tognini (1992, 1999), Jean-Pierre Haigneré (1993, 1999), Jean-François Clervoy (1994, 1997, 1999), Jean-Jacques Favier (1996), Claudie Haigneré (1996, 2001), Léopold Eyharts (1998, 2008), Philippe Perrin (2002) and Thomas Pesquet (2016, 2021). Of the 10, seven are from the military, three civilian. Nine are male, one female. Until 1998, CNES had its own astronaut corps. From 1998, it came under the responsibility of ESA, becoming part of the European Astronaut Corps (EAC). France hopes to see a new astronaut admitted to the corps after the selection process currently underway.

1978

Creation of Argos, a global satellite-based location and data collection system, dedicated to the study and protection of our planet, with a special focus on biodiversity. 100,000 species of animal have been tracked to date.

1979

Creation of Cospas-Sarsat, a satellite-aided system derived from Argos to detect and locate distress signals, by the United States, Canada, the USSR and France. Operational since 1985, it has saved 43,000 lives.

FEBRUARY 1979

Launch of France's first telecommunications satellite, Telecom-1.

26 MARCH 1980

Arianespace founded. Today, the company markets and operates Ariane, Vega and Soyuz launch services from French Guiana.

24 JUNE 1982

Jean-Loup Chrétien becomes the first French astronaut in space, on the French-Soviet PVH mission to the Salyut 7 space station.

1993

Creation of the CADMOS centre, which helps users on the Russian space station Mir, then the ISS, to conduct experiments in microgravity.

1989

Creation of the MEDES space clinic, CNES's health subsidiary.

1986

The SPOT-1 satellite revolutionizes Earth observation. Its imagery is processed and distributed by Spot Image, formed in readiness for this role four years earlier on 1 July 1982.

10 JANUARY 2004

Agreement signed by ESA, CNES and Roscosmos for Soyuz to operate from the CSG. After the Baikonur Cosmodrome in Kazakhstan is decommissioned, the first launch takes place on 21 October 2011.

2005

Creation of the GEIPAN unit to analyse unidentified aerospace phenomena (UAP).

14 JANUARY 2005

Europe's Huygens probe lands on Titan, Saturn's largest moon.

ATV

They were the Jules Verne (2008), Johannes Kepler (2011), Edoardo Amaldi (2012), Albert Einstein (2013) and Georges Lemaître (2014). The five Automated Transfer Vehicles (ATVs) were ESA's contribution to the ISS programme. Their role was to resupply the station and reboost its orbit while docked. They took over from the Russian Progress M resupply craft, no longer in service. Recognized for its expertise in orbital rendezvous, CNES was in charge of the ATV Control Centre (ATV-CC) from 2005 to 2015. The ATV was the first European spacecraft to perform fully automatic docking with an orbital station. It did so with an incredible centimetre precision.

TIMELINE

19 OCTOBER 2006

Developed by CNES in partnership with Eumetsat, the IASI instrument is flown on Europe's MetOp weather satellites. IASI is designed to measure over 25 atmospheric components with a high degree of precision.

27 DECEMBER 2006

Launch of the revolutionary CoRoT space telescope. In the next eight years, it identifies 34 planets outside our solar system.

11 FEBRUARY 2008

Europe's Columbus laboratory docks with the ISS.

9 MARCH 2008

Launch of the first ISS resupply spacecraft, the Jules Verne ATV.

14 MAY 2009

Two exceptional space telescopes, Herschel and Planck, are sent on their mission to observe the universe. Planck is the coldest satellite ever launched to detect the cosmic background radiation and Herschel the largest ever built.

17 DECEMBER 2011

Launch of the first dual-use (civil and military) Earth-observation satellite, Pleiades A. Its twin Pleiades B is orbited on 2 December 2012.

19 DECEMBER 2013

Launch of the GAIA telescope, which will map over 1 billion objects in the Milky Way and bring astronomy into the age of big data. France is in charge of processing the vast amounts of data.

3 DECEMBER 2014

Launch of Japan's Hayabusa-2 spacecraft carrying the French-German MASCOT lander, which touches down on asteroid Ryugu on 3 October 2018.

5 MAY 2018

Launch of the InSight Mars lander carrying the SEIS seismometer, its principal instrument, developed by France. InSight lands on Mars on 26 November 2018.

19 DECEMBER 2018

Launch of the first of three CSO (optical space component) military reconnaissance satellites. With this constellation, defence enters a new dimension.

30 JULY 2020

Launch of Mars 2020 carrying the Perseverance rover. It lands on Mars on 18 February 2021.

LATE 2021

Commissioning of the new ELA 4 launch complex with a horizontal integration and preparation facility for Ariane 6.

ARIANE, A PROUD LINEAGE

In 1979, Europe ended its reliance on the superpowers for access to space with Ariane 1. Ariane 2 and 3 were largely based on the original launcher. Ariane 4 took performance and launch rates to new heights. Perfectly tailored to demand, the new launcher gave Arianespace global leadership in commercial launch services. But as satellites continued to grow in size and mass, it was phased out in favour of the Ariane 5 heavy-lift launcher, with double the payload capacity. As well as orbiting mostly commercial telecommunications satellites, it delivered civil and military payloads (Helios-2B) and science payloads (Herschel and Planck telescopes). Ariane 5 also launched the five ATVs for rendezvous with the ISS. The next chapter will be written by Ariane 6, with the aim of drastically reducing costs in the face of fierce competition and new private operators.