

Inventing  
the future of space



  
**cnes**  
CENTRE NATIONAL  
D'ÉTUDES SPATIALES

- 02 • 03 Inventing the future of space
- 04 • 05 A fast-changing environment
- 06 • 07 Europe, ESA and the European Commission
- 08 • 09 CNES's role and missions
- 10 • 11 Innovation
- 12 • 13 Climate
- 14 • 15 Exploration
- 16 • 17 Launchers
- 18 • 19 Science
- 20 • 21 Earth observation
- 22 • 23 Telecommunications
- 24 • 25 Defence
- 26 • 27 Applications
- 28 • 29 Cooperation
- 30 • 31 Inspiration
- 32 • 33 CNES centres



INTERVIEW WITH

**Jean-Yves Le Gall**

*CNES President*

**How is CNES gearing up to remain relevant in the fast-changing space arena?**

The space sector is indeed undergoing seismic shifts. Europe is still the world's number two space power, but new players are arriving on the scene and we see them as opportunities to develop the future of space. That is why, alongside our traditional programmes, we have initiated a 'market pull' approach to invent the systems of tomorrow. This approach constitutes the roadmap for our new Directorate of Innovation, Applications and Science created in 2016.

# “ Inventing the future of space ”

**What is CNES's place alongside an increasingly mature and innovative space industry, particularly with the advent of NewSpace?**

We need to be present wherever space technologies and spin-offs are likely to bring better results and foster synergies. Enabling industry to benefit from the results of our efforts is clearly part of our mission. As for NewSpace, we don't perceive it as a threat but as a great opportunity that we intend to grasp with both hands. With all of these new players now emerging, space is becoming a remarkable tool and its potential is being turbo-charged by the digital revolution. Through our projects and partnerships, our role is to pursue and step up the scientific and technological cooperation that is deep in our DNA and to maintain our position as a pivotal player. The success of our programmes means that partners all over the world are eager to work with CNES.

**Is our agency still a driving force to be reckoned with against these new and ever-more-dynamic players?**

CNES is still a driving force at the forefront of innovation. We are central to discussions regarding efforts to curb climate change, notably with MicroCarb and MERLIN, materialized through the Declarations of Mexico and New Delhi.

And today, CNES is seen as a climate-driven space agency. In December 2016, we were the main contributor at the ESA Ministerial Conference in Lucerne where Europe reached key decisions for its future. Ariane 6 and Vega-C, the pursuit of ExoMars, Europe's participation in the International Space station and the future of telecommunications and Earth observation are all endeavours in which CNES is playing a lead role. This versatility and diversity is our great strength.

**The agency's agreement with the government is entitled Innovation & Inspiration. How is CNES applying these values every day?**

These are our signature values. They reflect our priority of making innovation central to everything we do, which more than ever is going to prove vital to ready ourselves for the profound shifts the space sector is experiencing worldwide. We have engaged several new-generation projects in each of our areas of excellence: Prometheus for launch vehicles, Mars 2020 for science, SWOT for Earth observation, Internet for all in telecommunications, Syracuse 4 for defence, and much more besides. This structural commitment to innovation is backed by our ability to inspire, notably by engaging younger generations to see the career perspectives that space offers.

**CNES has been very active in the international arena in recent years, with a series of cooperation agreements. What results do you hope to achieve from this policy?**

As the cost of getting into space comes down, new players are ramping up their presence and CNES is forging partnerships with them in pursuit of a threefold aim: to get involved in projects that we would otherwise be unable to fund alone, to understand and learn from new approaches, and to help our industry to break into these markets by encouraging potential customers to 'think France' as a reflex response. And as such collaborations often start through scientific programmes, they also allow us to reaffirm the importance we attach to science.

**How can we sustain our expertise in this broad collaborative landscape?**

Today we have renowned expertise that we must sustain while constantly adapting to changes in the space sector, because space is clearly a business that is evolving. Our specialists now working on electric satellite propulsion were not working in that area ten years ago. And for launchers, with Ariane 6 we have reinvented the Ariane programme-something that seemed impossible only 30 months ago. It is through this ability to evolve and adapt that we will invent the future of space.

”

# A fast-changing environment

## A NEW WORLD SPACE ORDER

In recent years, the level of competition in the launch services market has risen steadily with new entrants coming mainly from the US private sector, but also from China, India, Japan and Russia.

In response, Europe took strategic decisions in 2014 in Luxembourg and in 2016 in Lucerne to develop a new launcher, Ariane 6, set to enter service in 2020 and offer a flexible, high-performance solution at a much lower cost per kilogram in orbit than the current Ariane 5.

Competition is also ramping up once again in the much-sought-after satellite market, as new players with big budgets acquire large satellites and others seek to procure cheaper systems.

Alongside these highly competitive markets, international cooperation is increasingly the norm for programmes like Mars exploration and the International Space station.



**The space sector is seeing significant shifts.**



PPS1350-G plasma thruster.

## A range of satellites and constellations

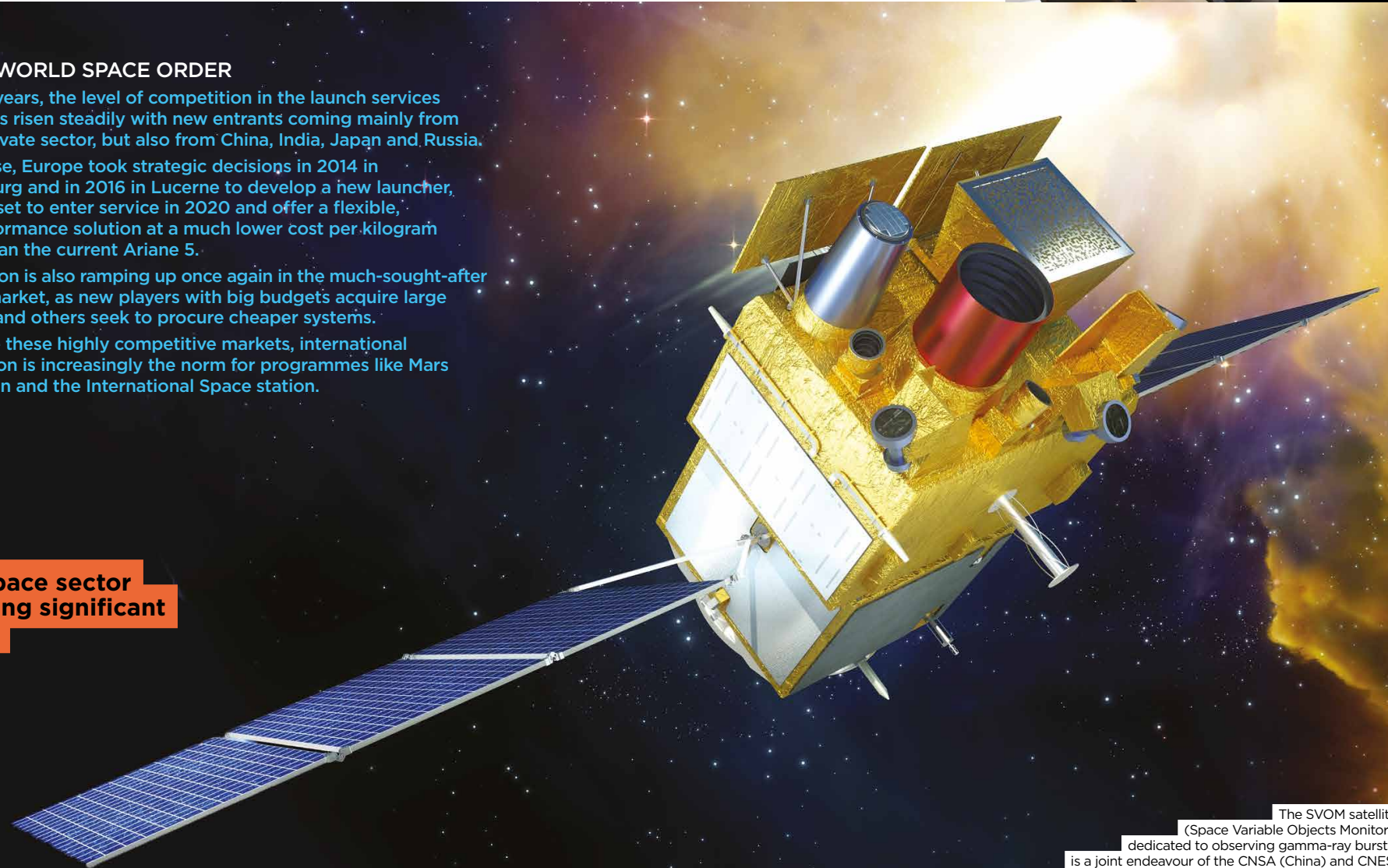
The world's leading operators are now choosing a new generation of electric-propulsion satellites in the 4.5-to-5.5-tonne category. This is the rationale underpinning the Ariane 6 programme.

## NewSpace

Today, space agencies have been joined by a wave of new investors in space. New players from the Internet sphere are among the 100 or so mostly US private firms driving a new paradigm known as NewSpace. Fuelling their ambitions are two aims—to connect and observe—and a single guiding purpose: to embrace the digital revolution. Innovation is the only way for Europe and France to meet this new challenge.

## Launchers: costs coming down and projects burgeoning

New designs, simplified architectures and optimized production processes are driving fierce competition in the launch services sector. To stay competitive, spacefaring Europe has responded with Ariane 6, a new launcher that CNES and France have been instrumental in shaping.



The SVOM satellite (Space Variable Objects Monitor), dedicated to observing gamma-ray bursts, is a joint endeavour of the CNSA (China) and CNES.

# Europe, ESA and the European Commission

**35,000**

**JOBS SUSTAINED  
IN EUROPE BY THE  
SPACE SECTOR**

Since 1975, the European Space Agency (ESA) has been conducting European space policy. ESA today has 22 member states and its leading contributors are France and Germany, represented by their respective agencies CNES and DLR. In this role, CNES guarantees Europe's independent access to space and helps prepare new-generation space systems and develop international cooperation.

Space policy is now a competency of the European Union and the European Commission is closely involved, alongside CNES and ESA, in Europe's two flagship space programmes: Galileo for geolocation and Copernicus for environmental monitoring.



**Europe is the world's number two space power.**



Jason CS  
after Sentinel 3.

## Lucerne: Launchers, ExoMars, ISS and satellites

CNES and its French partners are developing a range of instruments for future large-scale missions to Mars, as part of European and international team efforts. At its latest ministerial conference in Lucerne, Switzerland, at the end of 2016, ESA confirmed funding for ExoMars. This programme will land a European rover carrying unique scientific instruments to search for traces of life on the surface of the red planet.

## Infrastructures: launchers, science, applications and exploration

The European Space Agency (ESA) is pursuing a number of other projects encompassing launchers, the advancement of science, applications and exploration.

## Galileo, Copernicus and Horizon 2020

These projects are helping to maintain Europe's position as the world's number two space power, as demonstrated by the successes accomplished by Galileo, for which initial services have been officially announced with the first 18 satellites now in orbit, and by Copernicus through the PEPS Sentinel Product Exploitation Platform.

## European space strategy: consolidating the bedrock of new ideas

With Thomas Pesquet, ESA's tenth French astronaut to fly in space, currently aboard the International Space station (ISS) for a six-month mission, Europe also extended its contribution to the station through to 2024 in Lucerne, a decision that shows Europe's attachment as partners of the United States, Russia, Japan and Canada to crewed space exploration.

## New investment responsibilities and risks

When, at the end of 2014, Europe gave the go-ahead for Ariane 6, it called at the same time for a restructuring of the space launch sector. To achieve the desired level of competitiveness, it recommended simplifying the sector's organization and asking industry to shoulder more of the financial risks involved, from production through to marketing.





# CNES's role and missions

CNES plays a key role in the French, European and international space arena, driving initiatives, stimulating new proposals and providing technical expertise to support the design, development and operation of space systems. While some programmes remain within national boundaries, many more would not see the light of day were it not for international partnerships.

CNES thus represents France on the European Space Agency's Council. It is also a partner in several commercial enterprises, giving government support to strategic activities.

Founded to implement France's space policy and true to its vocation, CNES is constantly reinventing space. After creating the Ariane family of launchers, today its teams are federating European efforts around Ariane 6 and conceiving the key projects that will shape the future.

## Industry

At the crossroads of research and industry, France is helping prime contractors and smaller firms alike to break into export markets. At any given time, there are constantly 40 or so projects under study or in development, covering satellites, launchers, systems and subsystems.

## Innovation

CNES and rail operator SNCF are working on innovative solutions under a partnership agreement intended to improve the travel experience for passengers and citizens.

## Research

CNES is also working with research organizations, as research and innovation are vital to boost the competitiveness of the French and European

space industry. The agency intends to step up its research partnership efforts, be it with French aerospace research agency ONERA, national scientific research centre CNRS or CEA, the French atomic energy and alternative energies commission. Healthcare will also be included, CNES having signed a framework agreement with INSERM in 2016.

2,500

MEN AND WOMEN WORKING AT CNES, WITH A PASSION FOR SPACE AND ITS INFINITE INNOVATIVE APPLICATIONS FOR SOCIETY.

The world's 2<sup>nd</sup> space budget

With €35 per capita per year, France's civil space budget comes second only to the United States (€50), ahead of Germany (€20) and the United Kingdom (€8).

2017 budget:

€2,334m

- Contribution to the European Space Agency: **€833m**
- National programme: **€728m**
- PIA future investment programme: **€91m**
- Own funds: **€682m**



CNES is driving all of France's space projects.



4 centres of excellence

### Paris Les Halles

is CNES's Head Office, responsible for mapping out French and European space policy and crafting and coordinating CNES's national, European and international programmes.

### Paris Daumesnil

is home to the Launch Vehicles Directorate (DLA), which has been developing Ariane launchers for over 40 years. Its specialists are working tirelessly to secure the future of European launchers within an integrated team with ESA.

### The Toulouse Space Centre

(CST) is the agency's biggest technical and operational field centre. Its engineers conceive, design, develop, build, position, control and operate orbital systems. Their work also involves fostering the use of satellite data for the benefit of all and innovating and creating to imagine tomorrow's space systems.

In French Guiana, teams at the **Guiana Space Centre** (CSG) are in charge of launching all European launchers. Ideally located near the equator, Europe's spaceport is a major asset for the European space programme.

1961

Inception of CNES.

1965

France becomes the world's third space power with the launch of Diamant carrying the Asterix satellite.

1979

First Ariane flight from the CSG.

1986

SPOT paves the way for space-based Earth observation.

1995

Helios gives France's military the capability to anticipate global crises.

2003

Ariane 5 begins a series of 76 straight successful launches (as of end 2016).

2006

CoRoT discovers planets outside our solar system.

2014

The Rosetta-Philae mission reaches comet Churyumov-Gerasimenko after a 10-year journey.

2015

The COP21 in Paris sets satellites the task of monitoring climate change.

2016

CNES creates a new directorate of Innovation.

2017

Space enters the digital age.

# Innovation

Innovation is the process of transforming and adapting existing technologies. CNES is continuously stimulating space innovation to help French industry stay ahead in the competitive global market.



Multi-spot-beam antenna for future telecommunications satellites.

## Space, more a means than an end

Innovating is probably the trait that best defines what CNES has accomplished since its inception in 1961. Today, the agency is continuing efforts alongside industry and institutional partners to transform the space sector, underpinned by its *Innovation & Inspiration* objectives and performance plan.



**Our chief mission is to invent.**



## A dedicated directorate

Formed in 2016, CNES's new Directorate of Innovation, Applications and Science (DIA) plays a key role shaping the agency's strategy. In the current climate of innovative disruption, its job is to think outside the box and to survey, stimulate, develop, support, energize and build up all sources of innovation and creative talent—in other words, to create synergies between all present and future users of space technologies.

## New players and methods

To implement its 'economic booster' strategy, CNES is embracing changes in the world of space and crafting satellite-based solutions to meet society's and the nation's sovereign needs. In so doing, it aims to advance scientific knowledge of our planet and the Universe, while building bridges between stakeholders.



**We have engaged several new-generation projects in each of our domains of excellence.**



## Disruptive approaches: low cost and constellations

Using methods inherited from the new economy, new operators are applying disruptive approaches to a sector that until now has done things in very traditional ways. Building on existing technologies, some of these operators are conceiving new concepts, while others are trading size for numbers and sending fleets of nanosatellites into orbit.

## Moving with the digital revolution

With big data technologies gaining traction all the time, the vast volumes of data that missions like the GAIA astrometry satellite and the Sentinel Earth-observing satellites will be handling in the future are driving a quantum leap in data management systems towards the kind operated by today's Internet giants. CNES has upgraded its information system working closely with the agency's space project teams to ready for this challenge.



Data storage arrays for the GAIA mission at the Toulouse Space Centre.

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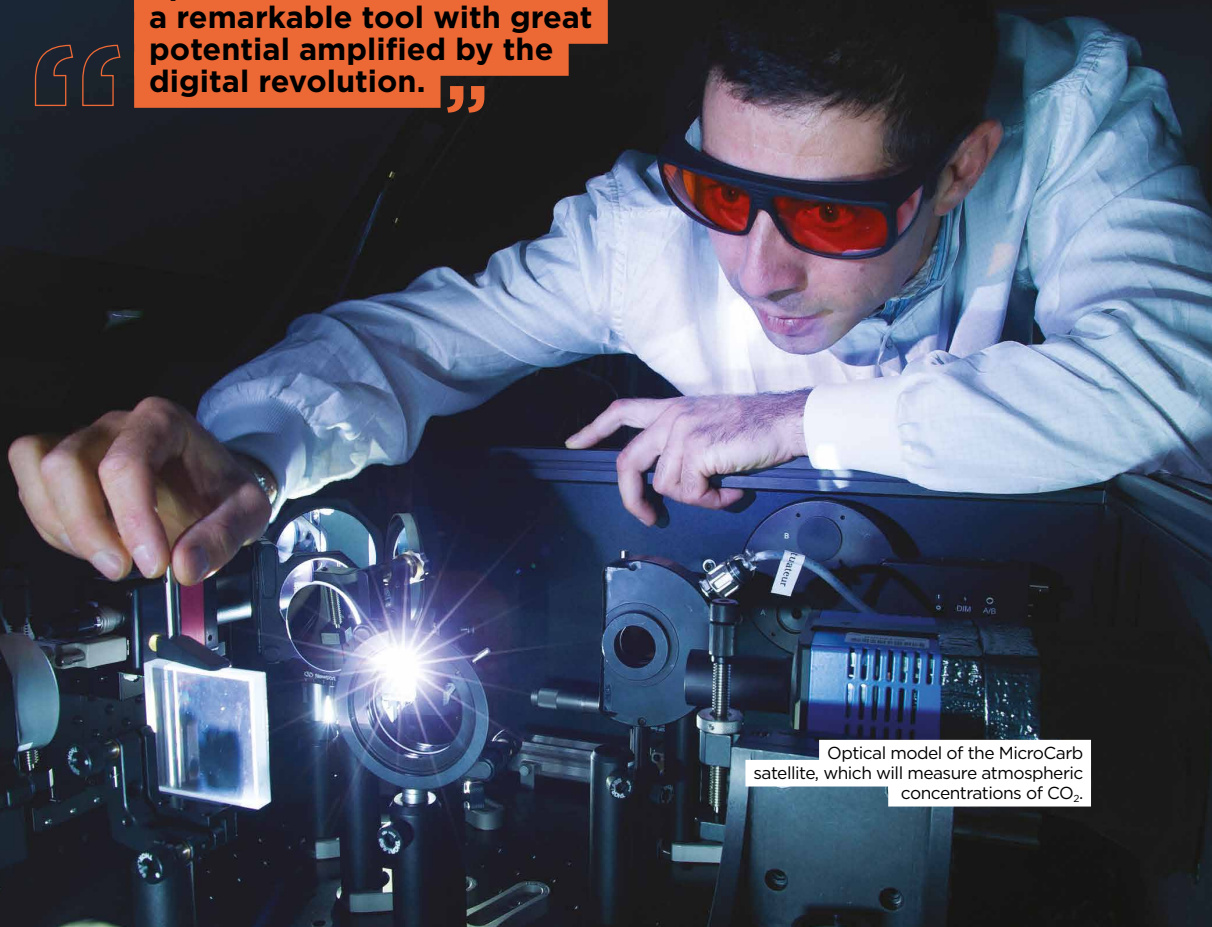
## KEY TECHNOLOGIES

FOR THE FUTURE OF SPACE WERE PRESENTED BY CNES'S EXPERTS AT THE AGENCY'S FIRST INNOVATION DAY IN 2016. NOTEWORTHY EXAMPLES WERE COMPOSITE AND THERMOPLASTIC MATERIALS, HIGH-DENSITY GREEN PROPELLANTS, ACTIVE OPTICS AND BIG DATA FOR SPACE APPLICATIONS.

# Climate

Climate change is a reality we have to face. To seek the solution, we need to precisely measure the factors driving it, like for example the concentration of greenhouse gases in the atmosphere, and to observe its impacts on temperatures and oceans. Satellite-based instruments are the best way to do this.

Space has become a remarkable tool with great potential amplified by the digital revolution.



Optical model of the MicroCarb satellite, which will measure atmospheric concentrations of CO<sub>2</sub>.

## 26

OUT OF 50  
**ESSENTIAL CLIMATE**  
VARIABLES CAN ONLY  
BE MEASURED FROM  
SPACE.

### Sharing data and results

Studying climate to curb the warming trend that is affecting all of us is a global task. International cooperation and coordination are therefore crucial to support sharing of data and results.

### CNES leads the way on climate

CNES is concentrating efforts on climate monitoring since the COP21 closed on 12 December 2015 in Paris with a historic universal agreement to tackle global warming. At the agency's initiative, in April 2016 in New Delhi the world's heads of space agencies approved a joint declaration committing to develop satellites to measure and mitigate greenhouse gases in the atmosphere. Two such projects are MERLIN to measure methane concentrations and MicroCarb to monitor levels of carbon dioxide. And in November 2016 the Marrakesh Declaration at the COP22 consolidated space's role in preserving our climate, particularly in the crucial area of water resource management.



### A new global ecosystem

Many nations have decided to build dedicated remote-sensing satellites in support of efforts to curb rising greenhouse gas emissions. This new global ecosystem reflects the new level of climate awareness. CNES is playing a key role with MERLIN and MicroCarb. All of these missions are designed to precisely map greenhouse gases.



# 5

**FRENCH INSTRUMENTS** WILL BE FLYING ON THE EUROPEAN JUICE MISSION TO EXPLORE JUPITER AND ITS ICY MOONS. CNES IS IN CHARGE OF THE MAJIS INSTRUMENT AND IS CONTRIBUTING TO THE DEVELOPMENT OF THE OTHER INSTRUMENTS.



### In search of our origins

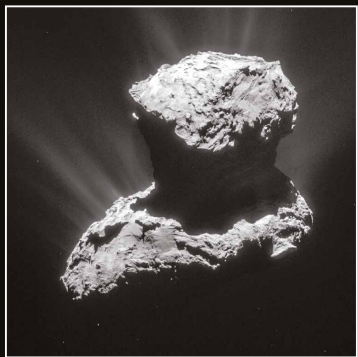
After a 10-year journey through the solar system, in November 2014 the Rosetta orbiter released its tiny Philae lander onto the surface of a comet 510 million kilometres from Earth. Among its many outstanding technological feats, the European mission succeeded in beaming back data from the surface of a comet's nucleus, revealing that while Earth's water was not seeded by these primordial celestial bodies, they do contain ingredients needed for life to emerge.

### What comes after the ISS?

For NASA, Mars is now the next destination after the ISS and work is focusing in both the public and private spheres on a new phase of space exploration. Following the latest technology and commercial developments, the trend is towards miniaturization and embedded smart systems, and on lowering the cost of satellites and launches.



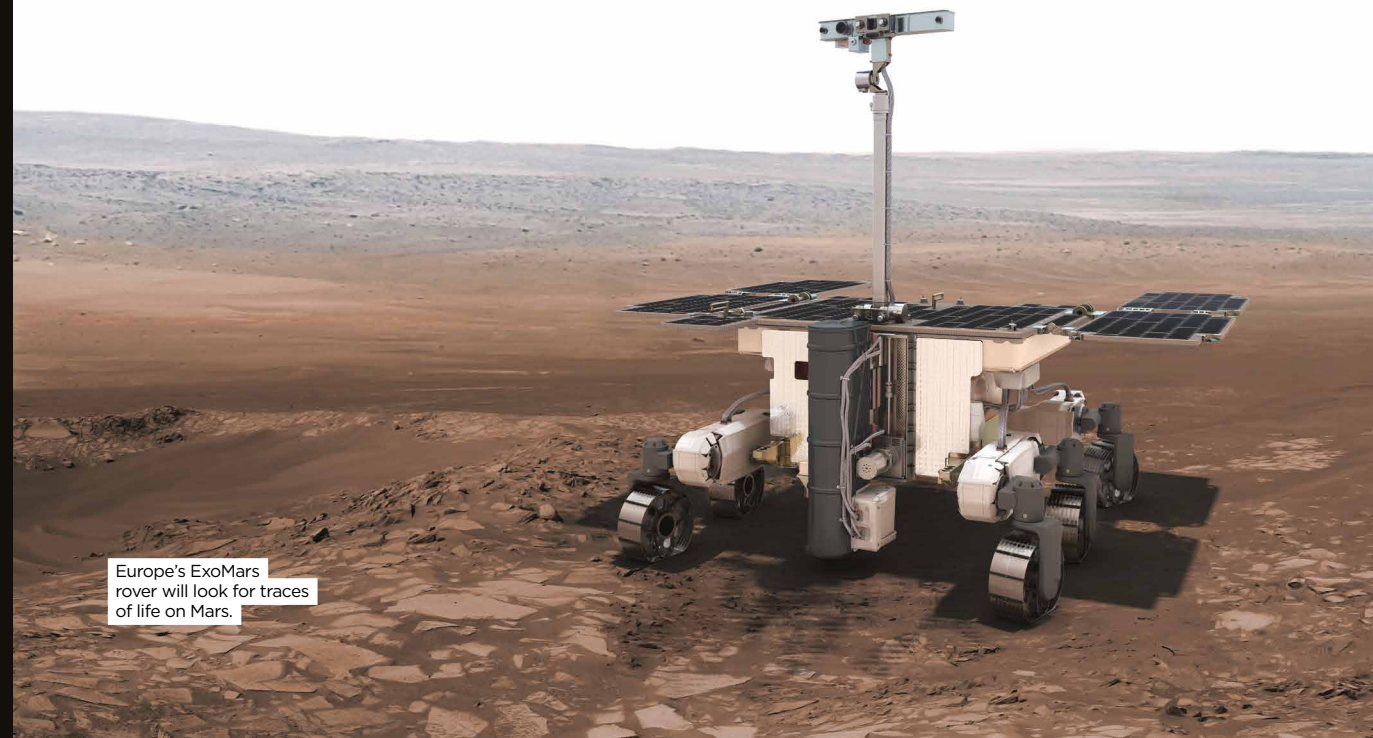
**Rosetta-Philae has commanded the international community's admiration.**



## Exploration

We are constantly seeking to unravel the many mysteries of the Universe. And CNES, from the first French satellite launcher to the spectacular success of Europe's Rosetta-Philae mission, is a cosmic explorer.

At a time when the cost of satellites and launches is coming down and launchers are offering more lift capacity, the influence of NewSpace and digital technologies is opening promising new vistas for space exploration. CNES's teams are continuing as ever to contribute to the most ambitious missions—the kind that can only be accomplished with international partners.



Europe's ExoMars rover will look for traces of life on Mars.



50%

**REDUCTION IN LAUNCH COST PER KILOGRAM FOR ARIANE 6 OVER ARIANE 5. TO CUT RECURRING COSTS, ARIANE 6 WILL BE ASSEMBLED HORIZONTALLY AND THEN ERECTED AT THE LAUNCH PAD.**

# Launchers



## STAYING WORLD NUMBER ONE

To remain competitive in the commercial space launch services market in which it is the world leader, Europe decided at the end of 2014 to reinvent Ariane with a sixth version of the launcher, a choice that France was instrumental in securing. Overseen by ESA, integrated teams working with CNES and contractors are pooling the technologies and experience acquired on Ariane and Vega to significantly reduce production costs and launch prices per kilogram.

With its reignitable upper stage, Ariane 6 will be better suited to new generations of satellites. The two versions of the new launcher—Ariane 62 with two boosters and Ariane 64 with four—will offer the flexibility that the institutional and commercial launch markets demand.

## Building ELA4 and enhancing the CSG's efficiency

As the authority in charge of developing launch facilities at the Guiana Space Centre (CSG), CNES is constructing the new ELA4 launch complex for Ariane 6. With this new launch capability, the CSG—which has been operating three launch complexes since 2011—is confirming its expertise and efficiency. CNES is adapting the (BEAP) solid booster test stand in readiness for qualifying the P120C booster.

## Ariane 6 and Vega-C

In addition to Ariane 6, Europe has decided to evolve its Vega light launcher to better cater for institutional needs. Both launchers will employ the P120C solid rocket booster, which will form the core stage of Vega-C and be used as a strap-on booster by Ariane 6.



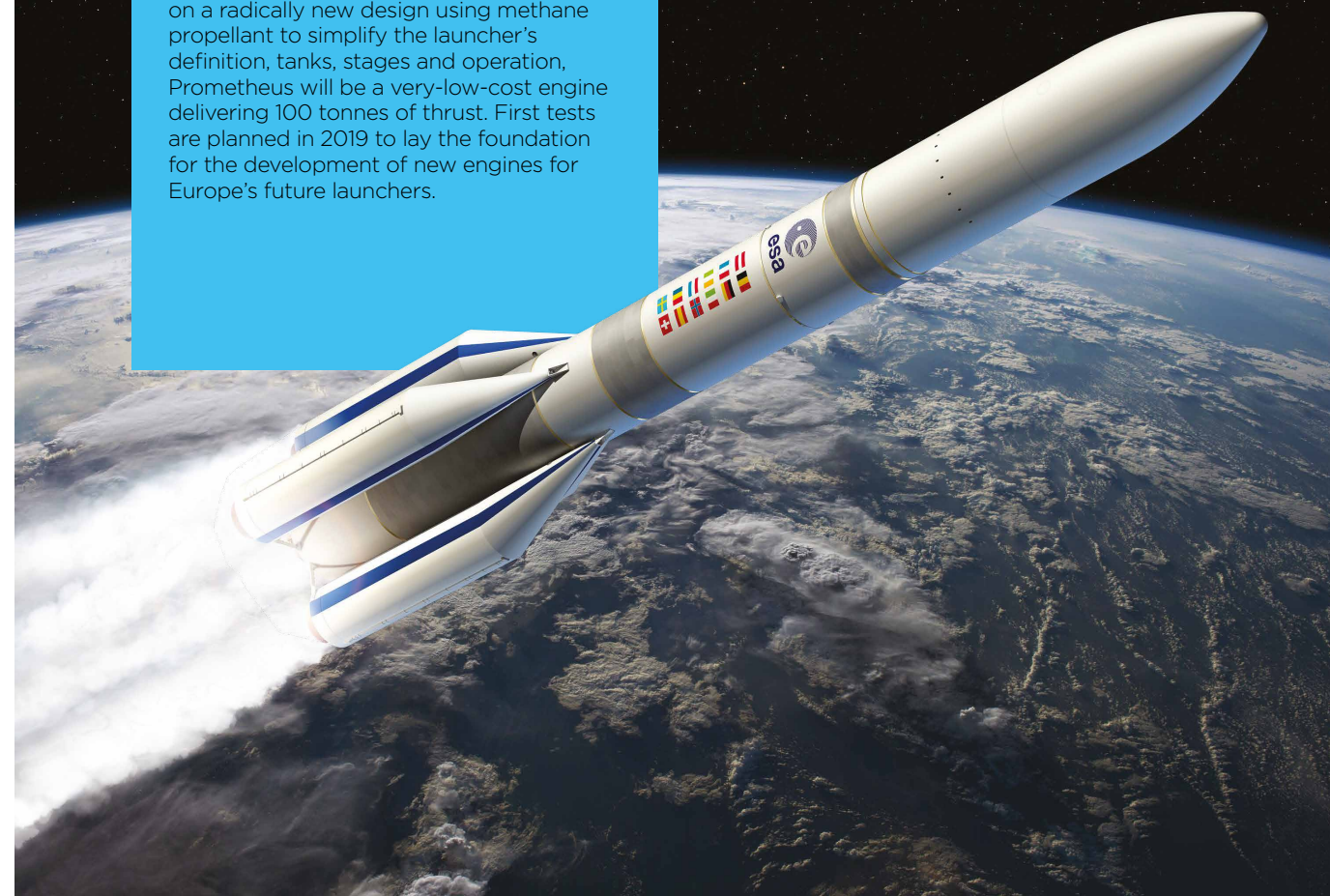
**Europe is building the Ariane 6 dream.**

## A reusable launcher

CNES is assessing the feasibility of a reusable launcher, with various recovery methods under study. Based on a novel design and technologies, a demonstrator called Callisto will be tested in 2019.

## Prometheus, a very-low-cost engine

In partnership with Airbus Safran Launchers, ESA, CNES is working to develop a new reusable engine called Prometheus. Based on a radically new design using methane propellant to simplify the launcher's definition, tanks, stages and operation, Prometheus will be a very-low-cost engine delivering 100 tonnes of thrust. First tests are planned in 2019 to lay the foundation for the development of new engines for Europe's future launchers.





Scientific cooperation is deep in CNES's DNA.

# Science

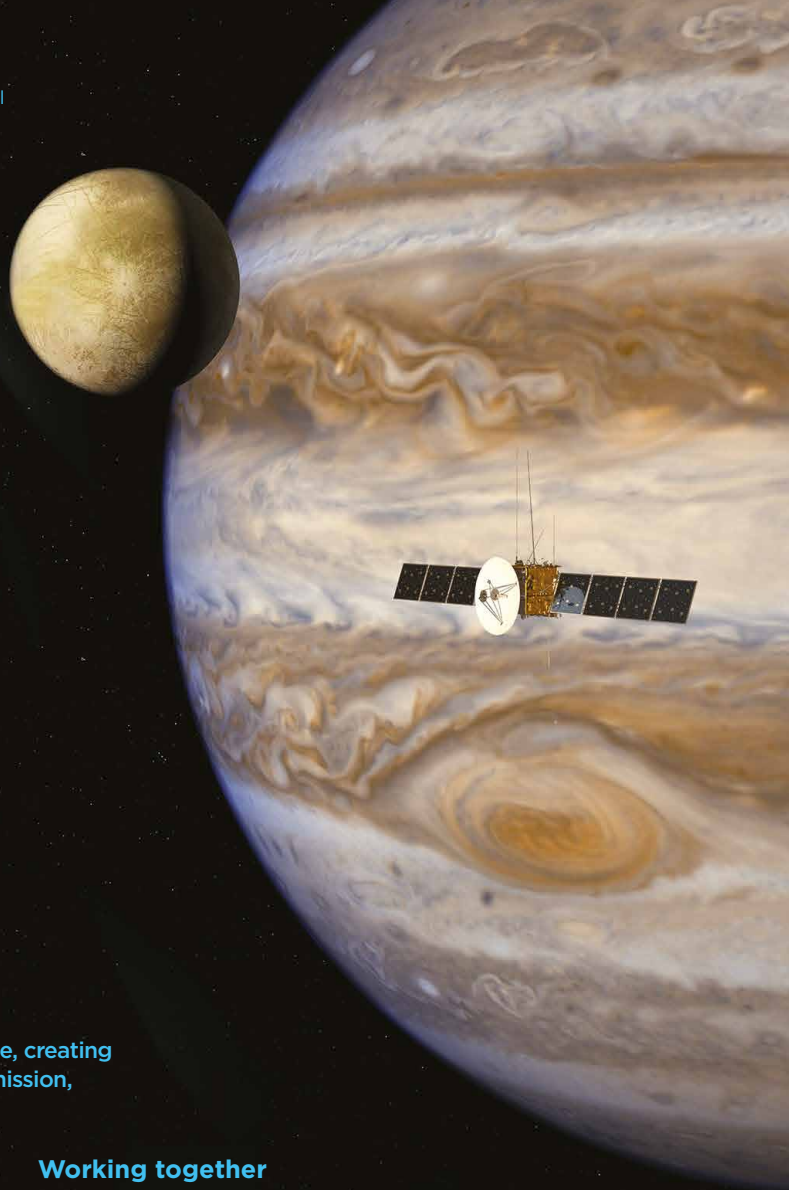
Science indisputably advances knowledge, creating value and jobs, and is central to CNES's mission, vision and strategy.

## Space, the new El Dorado for science

Far above the hustle and bustle of Earth's surface and the obscuring dust of its atmosphere, and free from the perturbing effects of its gravity, space is an ideal research laboratory that opens all kinds of possibilities. Projects like PHARAO and Microscope, led by CNES from conception through to completion, are testing Einstein's theories and could totally transform our understanding of the Universe and rewrite the textbooks on physics.

## Working together

CNES is innovating in Universe and Earth sciences to unlock the secrets of our Universe and the origins of life. Such space missions are often pursued in partnership by agencies, research organizations and industry.



The Microscope satellite in the anechoic chamber for radiofrequency (RF) testing.

## Outside Europe: United States, India, China, Japan, Russia and emerging nations

### Microscope

**Microscope** is a mission being pursued by European partners on a microsatellite from CNES's Myriade series. This fundamental physics mission was orbited atop a Soyuz launcher from French Guiana to verify Einstein's theory of general relativity. CNES is overseeing the project and is also operating the mission control centre.

### Instruments (Mars2020-SuperCam, SVOM)

The French-Chinese **SVOM** mission is designed to detect and study gamma-ray bursts (GRBs), the highest-energy phenomena known in the Universe. CNES is in charge of supplying two of the mission's four instruments, and of deploying and operating the ground VHF network. International cooperation now needs to step up a gear on exploration programmes like Mars 2020 and SuperCam, and to pursue operations on the International Space station. New avenues for cooperation are also under study with numerous new players on the space scene.

## Europe: ESA

The European **Euclid** mission is set to probe the secrets of dark energy. Twelve French space research laboratories are developing the mission's instruments and ground segment.

**Athena** is an ESA space observatory designed to study the hot and energetic Universe. CNES is working with laboratories to supply the mission's X-IFU instrument, a spectrometer that will acquire highly precise images.



# Earth observation

## GLOBAL ENVIRONMENT AND COMPETITIVENESS

Keeping watch over 'spaceship Earth' is a pillar of France's space policy. But while climate is everyone's concern, environmental monitoring is a burgeoning field that also poses a competitive challenge. With the Pleiades system, French industry has established itself as the leader in the export market for high-resolution optical Earth remote-sensing systems. To maintain its technical and commercial leadership in this sector, support for innovation will need to step up a gear.



**Only satellites  
can offer solutions  
on a global scale.**



**CNES is today  
a climate-focused  
space agency.**

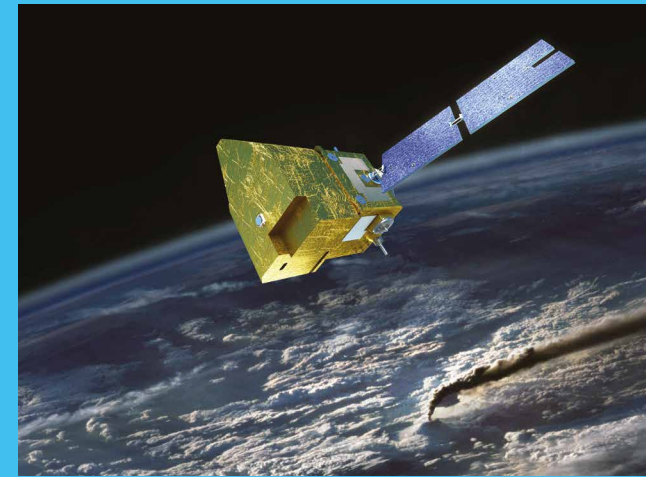
## MERLIN

In the wake of the COP21 conference, France and Germany are developing MERLIN, a small satellite built around CNES's new Myriade-Evolutions spacecraft bus packed with innovative technologies designed to measure atmospheric concentrations of methane with high accuracy.



## Jason and SWOT

The National Oceanic and Atmospheric Administration (NOAA) and Eumetsat, the U.S. and European operational climatology and oceanography agencies, have joined forces to conceive the successor to the Jason series of satellites, and so have CNES and NASA with the innovative SWOT (Surface Water and Ocean Topography) programme. Using a wide-swath K<sub>a</sub>-band radar interferometer dubbed KaRIn, this mission is set to deliver altimetry data with a resolution of 10 metres over land surfaces and 1 kilometre over open seas.



## MicroCarb

Able to detect carbon gas emissions with high accuracy, MicroCarb will help scientists to better understand the planet's large ecosystems and learn more about its carbon budget at regional scales. This project is also looking to lay the groundwork for a strategy and long-term vision within the framework of Europe's Copernicus programme. The first phase of the project is being funded through the government's PIA future investment programme, while subsequent phases will be pursued through European partnerships.



30

**SATELLITES WILL MAKE UP THE FINAL CONSTELLATION OF EUROPE'S GALILEO NAVIGATION SYSTEM.**



**We have helped to put French industry back in the game for electric-propulsion telecommunications satellites.**



# Telecommunications



The telecommunications satellite market—a domain where France excels—is riding on the wave of exponential growth in demand for Internet connectivity. CNES is conceiving satellites that offer ever more new services like broadband Internet, high-definition television, mobility and geolocation with Galileo. And to stay ahead, it is investing massively in electric propulsion.

## Electric propulsion

CNES is working with European partners to develop the new Neosat spacecraft bus, funded chiefly from the government's PIA future investment plan. This lighter and cheaper bus will deliver more performance, using electric propulsion and numerous other technological innovations. The first Neosat-based satellites have been ordered from Thales Alenia Space and Airbus Defence & Space for launch before 2020.

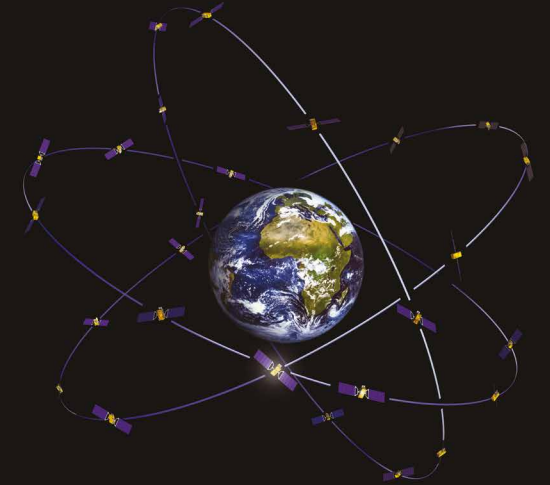
Complementing Neosat, the GEICO research and development programme is focusing on payload innovations to drive technological and market disruptions.

## Optical payloads

Using a portion of the electromagnetic spectrum largely ignored by telecommunications satellites until now, THD-Sat will provide an ideal complement in rural or remote areas unserved by fibre-optic coverage. Funded under the PIA future investment plan, this programme aims to build a national industry capable of deploying satellite fast-broadband Internet networks for operators.

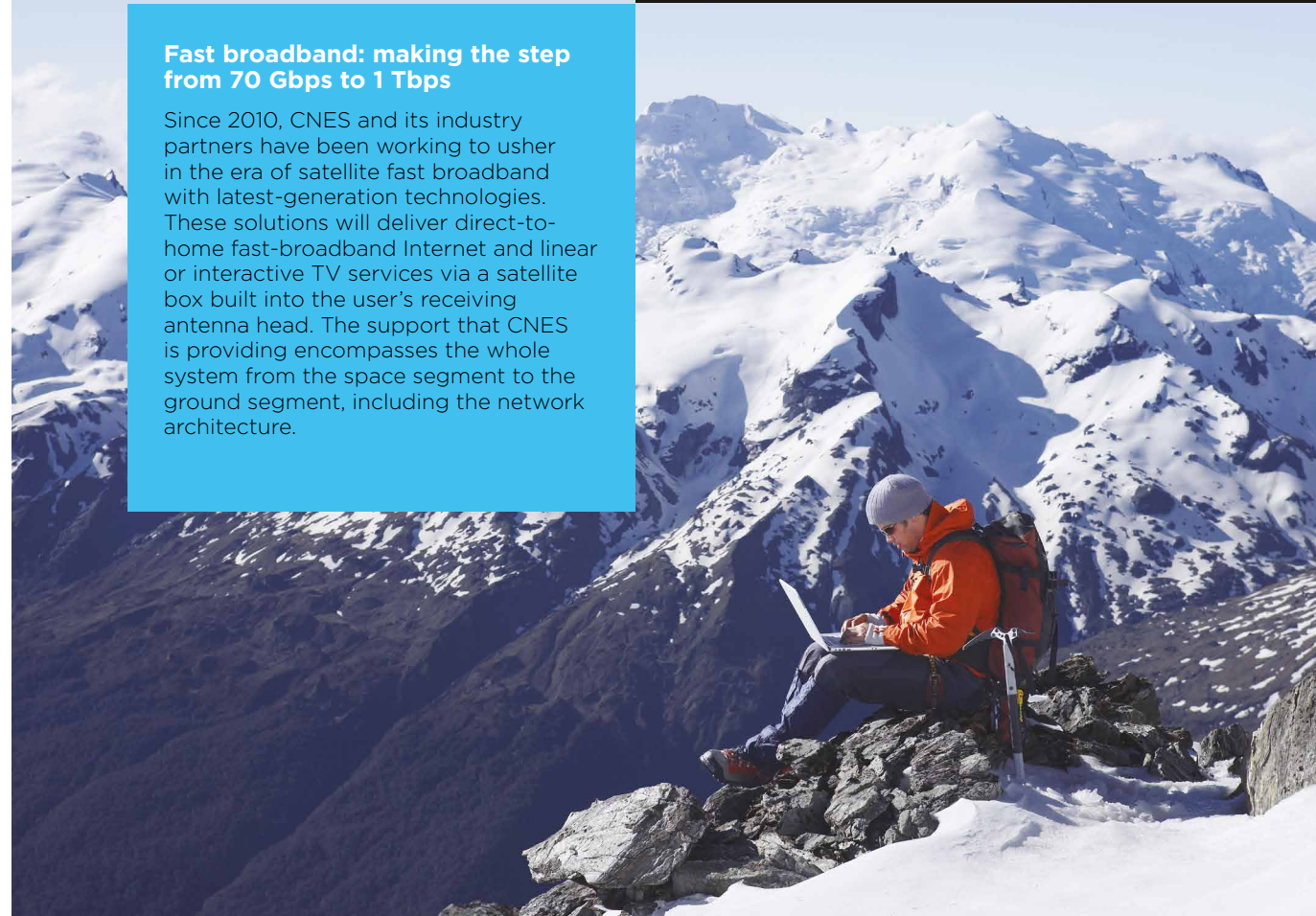
## Reducing costs

With ambitious projects and in particular satellite constellations in the works, the challenge facing industry is to achieve a factor-of-five reduction in the cost per Gbps. CNES is helping French equipment manufacturers and service suppliers to conceive and develop the new fixed and mobile technologies they will need to stay competitive.



## Fast broadband: making the step from 70 Gbps to 1 Tbps

Since 2010, CNES and its industry partners have been working to usher in the era of satellite fast broadband with latest-generation technologies. These solutions will deliver direct-to-home fast-broadband Internet and linear or interactive TV services via a satellite box built into the user's receiving antenna head. The support that CNES is providing encompasses the whole system from the space segment to the ground segment, including the network architecture.





# Defence

Optical high-resolution imaging, signals intelligence and highly secure telecommunications all contribute to guaranteeing peace and security for citizens. The Ministry of Defence and CNES are funding R&T projects to bring France's military effective, reliable and affordable space systems while sustaining the competitiveness of French industry. They are also working in partnership with European nations and the United States to offer them the best protection.

## Single response, dual use

Dual-use systems are geared both to military needs and to civil users of applications in security, mapping, precision agriculture, imaging, telecommunications and more. Such an approach goes hand in hand with the aim of making domains of excellence like high-resolution optical Earth observation more competitive.



## Ongoing programmes

### CSO

CSO is the optical space component of the future MUSIS optical and radar imaging system set to take over from the current Helios 2 system in 2019. Italy and Germany are supplying the new radar component. This constellation of three satellites will be more responsive, more agile and provide greater acquisition capacity, with a payload able to collect extremely high-resolution day-night optical and infrared imagery. Having initially been delegated oversight responsibility for the programme by the French procurement agency DGA, CNES will be controlling the satellites from an all-new tasking and command centre in Toulouse.

### CERES

The CERES mission is designed to strengthen our armed forces' signals intelligence (SIGINT) capabilities. Planned to enter service in 2020, this system will enable France to acquire SIGINT over regions that surface and aerial sensors cannot reach, free from legal overflight constraints and in all weathers.

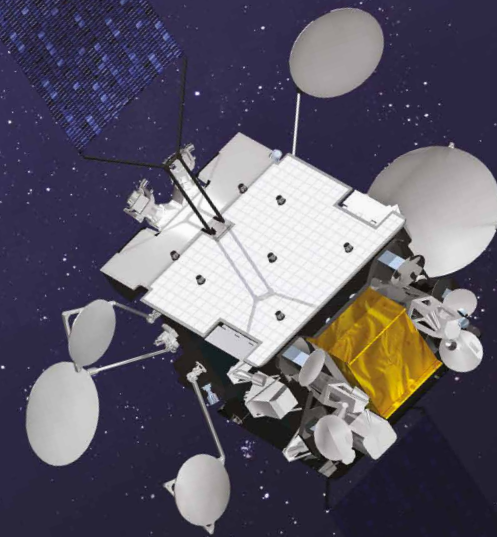
## Disruptive programmes

### Syracuse

The Syracuse IV defence programme is planned to take over from the Syracuse III system in 2020. The programme will field two satellites built around new-generation electric spacecraft buses. In addition to X-band communications, Syracuse IV will offer new military K<sub>a</sub>-band capabilities. CNES has responsibility for pre-development of technologies and is supporting development of the space side of the programme. The dual-use technologies under development are designed chiefly to improve the performance, jamming resistance and flexibility of the Syracuse IV payload.

### OTOS

An active optics system uses a compensating mirror to correct the imperfections of primary mirrors. This process already traditionally used in astronomy could be adapted in space to enable industrial-scale production and thus cut lead times and costs.



**Since its inception in 1961, CNES has always worked closely with the Ministry of Defence. The latest White Papers on national security and defence confirm space's role in delivering the capabilities our armed forces need.**



# Applications

Fisheries, agriculture, construction and public works, security, hazard management, land planning, natural resource management and monitoring and combating pollution are just some of the applications of broad benefit to wider society that are likely to take advantage of space technologies, and for which CNES has forged contacts.

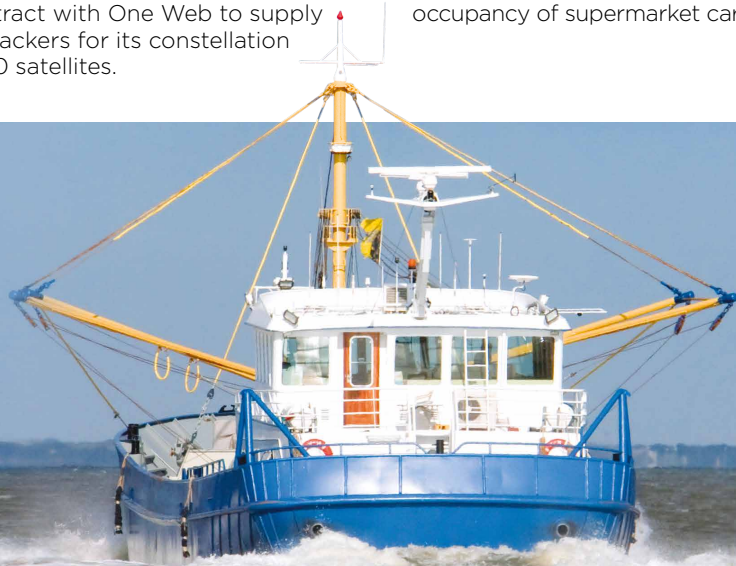
## Serving all space user communities

### Development supporting production

Barely larger than a 20-centime coin, the micro-camera conceived by CNES for the rover on NASA's Mars 2020 mission was developed in record time. Using a technology derived from this camera, French SME Sodern has signed a contract with One Web to supply star trackers for its constellation of 900 satellites.

### A wealth of applications

With advances in digital technologies, miniaturization and embedded smart systems, space is spawning a whole host of new businesses across a range of sectors. A good example is small nanosatellites weighing less than 10 kg, used to detect pipeline leaks or gauge occupancy of supermarket car parks.



**CNES needs to be present wherever space technologies are likely to bring better results and foster synergies.**



## Developing business and incubating start-ups

### More than 600 people at CNES subsidiary CLS

Formed in 1986 by CNES and Ifremer, the French institute of marine research and exploration, to study the ocean using the Argos data collection and location system, CLS (Collecte Localisation Satellites) is today the world leader in satellite-based Earth remote sensing and value-added services for environmental monitoring, sustainable marine resource management, maritime safety and tracking of single-handed yacht races. From its beginnings 30 years ago as a small firm with just 35 people, it has grown into an international group that today employs a 600-strong workforce around the world, developing applications and services for the benefit of the planet and its populations.

### Agreement with Geoflex

Through a cooperation agreement signed on 18 June 2016, CNES granted Geoflex a licence to use its patented precise point positioning (PPP) technologies with a view to offering a global commercial operational service designed to augment satellite precise point positioning in real time to centimetre level.

### Partnering SNCF

National rail operator SNCF and CNES are working together on innovative solutions for rail services, for example leveraging the European Galileo satellite navigation system to modernize command-and-control systems, enabling fast-broadband connectivity on trains with new K<sub>a</sub>-band satellites, employing optical imagery to make the rail network safer and using radar for track surveillance.



### ESA BIC France

Working alongside ESA, CNES is involved in the Business Incubation Centre (BIC) programme to support firms spinning off space data and applications to offer new services and products in sectors outside space. In France, the ESA BIC Sud France programme is being led by the Aerospace Valley competitiveness cluster in association with CNES and encompasses five regional incubators. Since the centre's inception in 2013, more than 20 start-ups have been incubated with 130 new jobs.

40

**PATENTS ARE FILED BY CNES EVERY YEAR, WITH SIX IN 2015 RELATED TO THE #ACTINSPACE OPERATION, PUTTING IT 35<sup>TH</sup> IN THE RANKING OF INPI, THE NATIONAL INDUSTRIAL PROPERTY INSTITUTE, 10 PLACES HIGHER THAN THE PREVIOUS YEAR.**



**The success of our programmes means partners all over the world are eager to work with CNES.**

**CNES moving forward**

**Developing cooperation**

Once mainly a mark of sovereignty, space is today a key factor driving economic growth. As the ambassador for France's space efforts, CNES attends many conferences and events around the globe and meets with its fellow space agencies, thus maintaining close ties with the world's leading powers and defining a framework for cooperation with emerging players, notably in Southeast Asia, South America and Africa.

**Disruptive approaches**

Cooperation federates, strengthens relationships, shares knowledge and helps partners to keep pace in a changing world. By sharing costs and pooling talents, it shortens development cycles and enables the most ambitious projects. And by cultivating contacts with other cultures and methods, it encourages the disruptive approaches required to stay competitive.

**PIA3, Commission, Boosters**

The government decided in March 2010 to initiate its PIA future investment plan to ready France for the challenges that lie ahead. This plan is predicated on three watchwords: excellence, innovation and cooperation. The PIA3 plan renewed the government's commitment in 2016 to fund the innovative sectors—including a number of CNES programmes—that will fuel future growth and jobs.

**Think France**

CNES has forged lasting relationships with partners all over the world to make think France a reflex response, working with French industry to develop space applications, for example in the fields of space telecommunications in Brazil and the United Arab Emirates, Earth observation in Thailand and Mexico, and satellite navigation in South Korea.



SWOT is a French-US mission to study surface waters and ocean topography.

# Cooperation



Cospas-Sarsat is an international satellite-based search-and-rescue programme.

**Phylae-Rosetta, Herschel-Planck and Soyuz in Guiana are among the many successful team efforts to which France has contributed in recent years. Future joint projects next in line include Merlin, SWOT and CFOSat.**

**Working upstream from industry**

**Cooperation: creating wealth, lever effect and economic diplomacy**

International relations are all about diplomacy, especially where space is concerned due to its dual civil-military nature and clear strategic import. In a balanced spirit of sharing from which each party derives equal benefit, CNES develops a broad palette of cooperative undertakings from space missions to symposiums and academic collaborations. CNES's four advisors in Washington D.C., Moscow, Tokyo and Bangalore are constantly seeking to consolidate cooperation with the agency's longstanding partners. Working every day in close contact with the US, Russian, Japanese and Indian space sectors, they assist France's ambassadors in all matters pertaining to space.

**Ariane 6, electric propulsion, digital spacecraft buses, optical payloads and green propellants**

CNES is working closely with industry in a number of areas. While the development of Ariane 6 is focusing a lot of attention, electric propulsion, optical payloads, digital spacecraft buses and green propellants are equally important, and the latter in particular will be vital in pursuing efforts to curb climate change. As a climate-driven agency, CNES intends to play a pivotal role in this respect.

1,500

**JOBS WERE CREATED IN 2016 THROUGH INFUSING INSPIRATION INTO INDUSTRY.**

**50%**

**FRENCH INDUSTRY**  
GÉNÉRATE €6 BILLION  
EVERY YEAR, ROUGHLY  
HALF OF THE EUROPEAN  
SPACE SECTOR'S  
ANNUAL REVENUES.

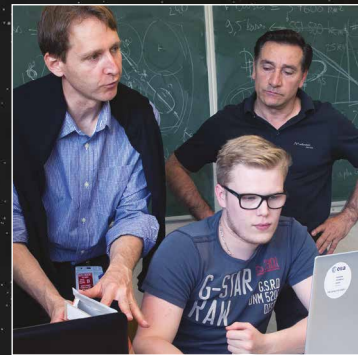
# Inspiration

CNES believes in innovation inspired by tomorrow's world, based on making the right choices and gearing up for the future in innovative sectors that are showing high promise or enabling disruptive generic technologies (micro- and nanotechnologies, electric propulsion, digital technologies, etc.).

To provide the fertile ground needed to seed development, CNES puts a great deal of effort into nurturing a downstream ecosystem built around space technologies and infrastructures. This ecosystem will rely essentially on a network of SMEs and mid-tier firms with the agility to respond to an evolving market, supported through actions implemented in partnership with established stakeholders like the CoSpace government-industry space coordination committee, competitiveness clusters, incubators and accelerators, and public investment bank Bpifrance.

## #ActInSpace: 208 start-up projects in a single weekend

That was the result of the challenge set by CNES and ESA to invent a new product for the future based on space technologies in just 24 hours. The second edition of the event attracted 896 candidates from 24 cities and 12 countries.



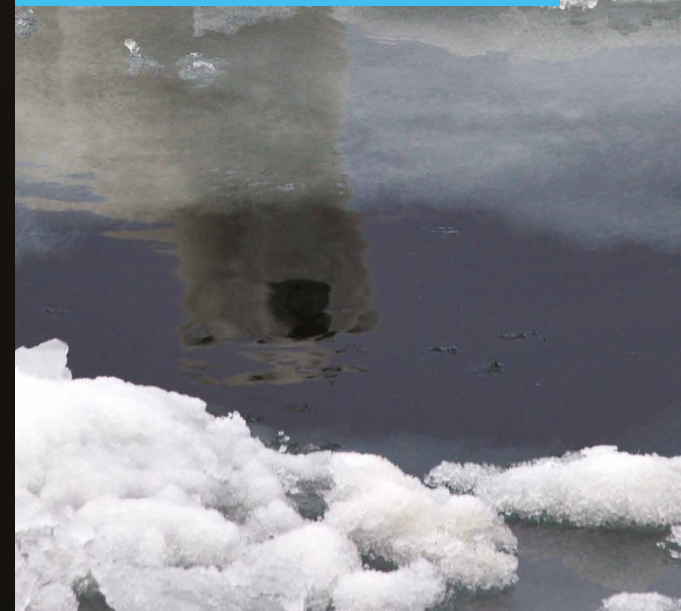
## Mars, the final frontier

As France's ambassador for crewed space exploration, Thomas Pesquet is conducting 62 experiments on behalf of ESA and CNES aboard the International Space station on a mission lasting from November 2016 to May 2017. Looking further ahead, CNES is leading the way in maturing the advanced technologies needed to accomplish the next exploration goal of an international mission to Mars.



## Climate

At the end of September 2016 in Guadalajara, Mexico, CNES took over the presidency of the International Astronautical Federation (IAF). This organization, which brings together representatives from the worlds of science, academia, space agencies and industry around the globe, this year opened its membership to players from NewSpace. After the Mexico and New Delhi accords, occupying such a pivotal position in the world space community will give CNES an even greater role coordinating international cooperation.





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