THE SPIRIT OF SPACE
In 2017, CNES’s mantra was inventing the future of space. What is it for 2018?

In 2018, we’ll be continuing to execute our Innovation & Inspiration objectives and performance plan. That means in each of our five domains of activity—Ariane, science, Earth observation, telecommunications and defence—we’ll be putting more emphasis on disruptive programmes like low-cost launchers, Mars sample return, climate actions, Internet for all and military payloads of the future. And we’ll be launching three fundamental missions: InSight with the United States to probe the origins of Mars, BepiColombo with Europe and Japan to unveil the secrets of Mercury, and CFOSAT with China to observe the oceans and monitor climate. We want our fellow citizens to be able to gain more benefits from space, and we want to see the spirit of space reaching into all areas of society!

How is CNES positioning itself in today’s fast-shifting space landscape shaped by a multitude of players, space agencies, multinationals and start-ups?

CNES is constantly adapting to the new challenges of space. We’re executing France’s space policy and, more than ever before, fulfilling our role as the backbone of Europe’s space programme at both the European Space Agency (ESA) and the European Commission. And we’re pursuing our partnerships of excellence with the United States, India, China, Japan, Russia and most of the world’s other space powers. In France, CNES is doing great work driving innovation for jobs, as evidenced by the exceptional partnerships we’ve forged in all our areas of activity. Working with scientists, institutions and industry, and through our commitment to the success of Europe’s space programme and our many international collaborations, CNES today occupies a unique position in the global space arena.

Since COP21, the role of satellites supporting climate actions is clear to all. How is CNES contributing to this effort?

CNES has been a key player in this fundamental area for our planet’s future for many years. Following on from the extraordinary results accomplished by TOPEX/Poseidon and the Jason series of satellites, which revealed the yearly rise in sea level of 3.2 millimetres, we are now setting our sights on greenhouse gas emissions, with MicroCarb to measure carbon and MERLIN methane. For COP21, we federated the world’s space players around climate actions with the Mexico Declaration in 2015 and the New Delhi Declaration in 2016. And in December 2017, the Paris Declaration was adopted at the One Planet Summit initiated by President Emmanuel Macron. This coordination effort is extremely important.

Space exploration is a focus of international scientific cooperation. What is France’s place in this great endeavour to advance knowledge?

France is playing a central role. We’re actively involved in ESA’s science programme, supplying sophisticated
We’re hearing a lot these days about a digital revolution. What is CNES doing to take up this new challenge?

CNES has been a precursor in this area from the outset, devising one of the most sophisticated information systems in the world for launch vehicles, satellites and data processing. The Toulouse Space Centre has developed unique expertise in big data, notably for the Gaia astronomy mapping mission, which demands huge amounts of computing power. And in 2017 we created a dedicated directorate to drive the agency’s digital transformation, because we’re seeing phenomenal shifts in this area. We’re forging new partnerships in this same direction, for example with French national railway operator SNCF to connect its trains, with autonomous vehicles for which Galileo’s unique accuracy is going to be a game-changer, and in the domain of health, where space is also fuelling many applications, as we saw during Thomas Pesquet’s mission aboard the International Space Station.

Through mini-, micro-, nano- and now pico-satellites, miniaturization has been making inroads into manufacturing for some years now. What does that imply for CNES?

Satellite manufacturing is indeed undergoing a seismic shift. Where once we were building satellites weighing several tonnes, we’re now seeing new payloads weighing often no more than a few tens of kilograms. They don’t do quite the same thing, but their missions are often the same. CNES paved the way with the Myriade bus around which the Microscope and Taranis satellites are built. Today, we’re moving a step further. For the follow-on to Argos, we’ve begun development of the ANGELS nanosatellite, and post-Pleiades we’re moving forward with the CO3D optical constellation. These are very important challenges we face. We’re analysing what’s being done and developing the best technology for our missions, our industrial base and the ecosystem around us. Between traditional agencies and tomorrow’s start-ups, we want the best of both worlds.

It’s said that more than half of the jobs we’re likely to see in 2030 haven’t been created yet. Is space innovation creating new fields and opportunities?

Of course. What our people are doing today is very different to what they were doing yesterday and a long way from what they’ll be doing tomorrow. They come from many horizons, they absorb CNES’s DNA and then build on it to lay the foundations for the future. Our greatest strength is that we’re constantly evolving. Innovation, applications and digital technologies are the watchwords of this transformation. Look at how far we’ve come in recent years, but that’s nothing compared to what’s ahead. That’s how we always stay at the centre of the game!

Lastly, what would you say to convince a member of the young generation to join CNES?

Space is an exciting place to be and there’s no doubt we’re seeing renewed interest in what we do all over the world. Why join CNES? Because we combine everything that’s best about our partners. Youngsters can build their career with CNES because we give free rein to their creativity while offering them a certain degree of stability. What’s more, and all opinion polls confirm this, today’s youth are looking for careers that give them a strong sense of identity. That’s exactly what they’ll find at CNES, where everyone embraces the spirit of space.

1 January 2018

“Thank you again to CNES for having me here in Kourou. Thank you for your commitment to serving French and European space excellence over the decades.”

Thank you to CNES for having me here in Kourou. Thank you for your commitment to serving French and European space excellence over the decades.

EMMANUEL MACRON
President
Emmanuel Macron visiting the CSG
27 OCTOBER 2017

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“We must be present wherever space technologies are likely to foster synergies”

Competition in space is fierce and traditional industry leaders are feeling the heat from some especially innovative newcomers. Since its inception in 1961, CNES has played a pioneering role in space and today is helping to develop new technologies and spawn a broad range of applications.

By forging European and international partnerships and by working to extend French industry’s influence, CNES is shaping, consolidating and supporting France’s strategic choices in areas like climate action, development of ever-more-sophisticated launchers and manufacturing of electric-propulsion satellites. The agency’s tireless diplomatic efforts make it a prime mover behind all European and international decisions.
Fuelling industrial development to serve institutional and social needs while bolstering business competitiveness is central to France’s space policy and CNES’s strategy. In contributing to this goal, CNES is executing an industry and technology policy upstream with manufacturers and downstream with the service sector, with a special focus on SMEs and mid-tier firms. Its ambition is to encourage its international partners to ‘think France’ as a reflex response and turn to French manufacturers for their space applications. CNES is also supplying a range of solutions around the world that demonstrate the benefits of space, like humanitarian emergency response containers and a reconstruction observatory in Haiti, agricultural monitoring in Côte d’Ivoire and Senegal, forest mapping in Gabon and water resource monitoring in the Congo Basin. The space agency is able to set up such large-scale projects through partnerships with French manufacturers and development aid bodies like the French development agency AFD and the World Bank.

International relations are all about diplomacy, and space is no exception due to its dual civil-military nature and clear strategic import. In a balanced spirit of sharing, CNES develops a broad palette of cooperative undertakings ranging 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 U.S., Russian, Japanese and Indian space sectors, they assist France’s ambassadors in all matters pertaining to space.

Through its investments, Europe is a leading provider of launch services for telecommunications payloads and satellite prime contractors that hold 40% of the global commercial market.
“Innovation is ingrained in CNES’s DNA and we are always striving to do things better, faster and cheaper.”

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, most would not see the light of day without international partners. 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 shape and execute France’s space policy, and true to its vocation, CNES is constantly reinventing space. After inventing the Ariane family of launchers, today its teams are federating European efforts around the key projects set to shape the future.
A driving force for spacefaring Europe

In 1965, in making France the world’s third space power after the Soviet Union and the United States, CNES showed its determination to join the big players. The agency has pursued this ambition ever since, through its involvement in the large-scale projects led by ESA. From the development of Ariane to the Galileo satellite navigation system, which underpin our independence, to the ExoMars rover, the Athena observatory and the Euclid mission, spacefaring Europe is engaged in many cooperative endeavours. Indeed, it is involved in ambitious projects outside its own borders.

A tool for economic diplomacy

In the international arena, CNES is pursuing and developing its cooperation with the world’s leading space powers (United States, India, China, Japan and Russia). It is also very active working with emerging nations such as Chile, Mexico, Thailand, Indonesia, Morocco and Singapore to further the French government’s economic diplomacy and in climate actions. It signed 23 agreements in 2016, 32 in 2017 and more are already in the pipeline for 2018.
Europe, ESA and the European Commission

“In federating the efforts of scientists, agencies and industry, CNES has found a winning formula for Europe.”

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 space launch capability and is helping to ready new generations of space systems and develop an international cooperation strategy.
Satellites will make up the final constellation of Europe’s Galileo navigation system.

**ESA’s extraordinary success**

Exploration is a focus of the space community’s efforts, and to venture farther afield ESA is seeking to develop new engines to enhance its future launchers. To this end, it is working with CNES and industry to develop Prometheus, a reusable low-cost engine, and the Callisto demonstrator, scheduled to undergo its first tests in 2020. But it is also looking beyond launchers. Other missions like InSight to probe the interior structure of Mars (2018), Euclid to study dark energy (2021), Athena to map hot and energetic regions of the Universe (2030) and JUICE to explore Jupiter and its icy moons (2022) are in development, while Mars 2020 is set to unveil the red planet’s remaining secrets.

**Lucerne: launchers, ExoMars, space station, satellites...**

CNES and its European and international partners are developing a range of instruments for future large-scale missions. At the ministerial conference in Lucerne, Switzerland, at the end of 2016, ESA secured funding for the ExoMars 2020 mission that will land a rover carrying unique scientific instruments to search for traces of life on the surface of the red planet. The Lucerne conference also reaffirmed Europe’s commitment to Ariane 6 and gave the go-ahead for construction of a new ELA4 launch complex in French Guiana, overseen by CNES. Other key decisions were reached on Europe’s participation in the International Space Station (ISS) and on development of ever-more-sophisticated satellites, to extend the heritage of past successes.

**The European Commission’s political ambition**

The Space Strategy for Europe, adopted by the European Commission on 26 October 2016 and designed to inform the EU’s actions in space for the years ahead, was largely based on France’s proposals advocated by CNES. The success of Thomas Pesquet’s mission on the ISS holds out new opportunities, and it is in this spirit that Europe has committed to continuing its participation in the station through to 2024, sending a strong signal that marks its attachment to human spaceflight with its partners the United States, Russia, Japan and Canada.

**Galileo, Copernicus, Horizon 2020**

These three flagship projects are helping to maintain Europe’s position as the world’s number two space power, amply demonstrated by the success of Galileo (with initial services declared on 15 December 2016) and Copernicus (with six Sentinel environmental-monitoring satellites now in service).
A new world space order

“CNES is the hub of a growing network of partners.”

United States, Europe, China, India, Japan, Russia

The level of competition in the launch services market has risen steadily with new entrants coming from the U.S. private sector, as well as from China, India, Japan and Russia. This led Europe to take foundational decisions in Luxembourg in 2014 and in Lucerne in 2016 to ready a new launcher, Ariane 6, which by 2020 is set to offer a flexible, high-performance solution at half the cost per kilogram into orbit of the current Ariane 5.

Competition is also ramping up again in the much-sought-after satellite market, as emerging nations with big budgets buy large satellites and others seek to acquire less costly systems.

Alongside these highly competitive markets, international cooperation is increasingly the norm for programmes like Mars exploration and the International Space Station.
New entrants on the space scene

More and more nations are being attracted to space technologies and their economic and social spin-offs. For example, Gabon, Mexico, Chile, Indonesia, Thailand, Morocco and Argentina are all ready to develop their own projects, and CNES has signed international agreements to help them.

NewSpace: connecting and observing

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 private firms around the world driving a new paradigm known as NewSpace. Their twofold ambition is to connect and observe. Innovation is the only way for Europe and France to meet this new challenge.

A revolution for satellites and launchers

New designs, simplified architectures and optimized production processes are fuelling fierce competition in the launch services sector. To stay competitive, spacefaring Europe has responded with Ariane 6, a new launcher that France has been instrumental in shaping. Driven by demand from the big telecommunications operators, a new generation of electric-propulsion satellites is also emerging. Here again, French industry is gaining a strong foothold in these new markets with support from CNES.

French firms are working with CNES in the space sector, for a budget of €648 million (2016). In total, this represents 2,314 firms (€907 million) across all sectors.

Applications: more a means than an end

Innovating is probably the trait that best defines what CNES has accomplished since its inception in 1961, sustaining its continuing efforts alongside industry and institutional partners to transform the space sector. This is the rationale underpinning the agency’s 2016-2020 objectives and performance plan, entitled “Innovation & Inspiration”.

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To stay competitive in the commercial space launch services market, Europe decided at the end of 2014 to reinvent Ariane with a sixth version of the launcher. Overseen by ESA, integrated teams working with CNES and contractors are pooling the technologies and experience acquired through 40 years of success to significantly reduce production and operating costs.
**Ariane 6 and Vega-C**

With its reignitable upper stage, Ariane 6 will be better suited to new generations of satellites. Employing two solid rocket boosters or four, the new launcher will offer the flexibility that government and commercial launch markets demand.

In addition to Ariane 6, Europe has decided to evolve its Vega light launcher to better cater for government 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. The P120C will be tested in 2018 at the Guiana Space Centre.

**New developments**

In French Guiana, CNES’s Launch Vehicles Directorate (DLA) is in charge of the overall design of launch facilities at the Guiana Space Centre and is managing construction of the ELA4 launch complex for Ariane 6. Work is progressing well and the operating licences were delivered in 2017.

In 2018, fluid, mechanical and electrical processes will be nearing completion and technical qualification tests will get underway. The BAL launcher assembly building should also be ready for tooling to be installed. The first phase of the launch system’s validation tests will start in Europe and then be pursued in French Guiana in 2019.

**An efficient launch base**

The Guiana Space Centre has been operating Ariane 5, Soyuz and Vega since 2011, confirming its expertise and efficiency year after year. The future ELA4 launch complex is the ninth designed and built by CNES at the launch base since 1967.

**Prometheus and Callisto charting the course ahead**

At CNES’s initiative, six nations—France, Germany, Italy, Belgium, Sweden and Switzerland—have decided to fund the prototype of a new engine called Prometheus, planned to be ten times cheaper than Ariane 6’s engines and designed to power the launchers of the future.

This demonstrator developed with ArianeGroup is based on a radically new design using methane propellant to simplify its 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 future launchers.

Alongside Prometheus, the Callisto project kicked off with international partners in 2017 intends to assess technical and economic issues related to reusability, with a flight demonstration scheduled for 2020. Callisto aims to study and mature technologies for returning the first stage of a launcher with a soft, pinpoint landing, and to conduct several flights with the same demonstrator. As Callisto will be a small vehicle powered by a low-thrust engine, it will not be fully representative of a reusable first stage. However, its conceptors believe it will yield significant gains for a very small investment. If reusable launchers become the benchmark in years to come, Europe will be able to use the results from Callisto to develop a much larger demonstrator powered by Prometheus engines.
Space is 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 are testing Einstein’s theories and could totally transform our understanding of the Universe and rewrite the textbooks on physics. They are central to CNES’s mission, vision and strategy.
**CNES (Microscope) and ESA (JUICE, Euclid and Athena)**

*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 mission and responsible for its control centre. Five French instruments will be on the European *JUICE* mission to explore Jupiter and its icy moons. CNES is supplying one of the instruments (MAJIS) and helping to develop the other four. *Euclid* is set to study dark energy. Teams are working on this mission at 12 French space research laboratories, which are developing its instruments and ground segment. *Athena* is an ESA space observatory designed to study the hot and energetic Universe. CNES is working with research laboratories to supply the mission’s X-IFU instrument, a spectrometer that will acquire highly detailed images.

**Funding for infrastructures**

CNES is supporting the development of numerous French contributions to ESA’s PHARAO, BepiColombo and ExoMars science missions. In 2016, it organized two project reviews in response to a request for proposals. Out of 30 projects submitted, nearly one-third were led by a French research laboratory. To support innovation for instrument concepts and to mature technologies for missions in the next decade, CNES also assisted an R&T action relating to cryogenics.

**Research excellence**

Working with leading research institutions and laboratories is vital to pierce the secrets of the Universe. CNES is forging closer ties with several research units of excellence, in particular the French national scientific research centre CNRS, the French atomic energy and alternative energies commission CEA and the French aerospace research centre ONERA. It organizes regular high-level gatherings and establishes the formal process for engaging projects with partner institutions. CNES has also signed a framework cooperation agreement with INSERM, the French National Institute for Health and Medical Research.

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

International cooperation is required to accomplish exploration programmes like SVOM, Mars 2020 and MMX, and to manage the International Space Station. Japan, China, Russia, the United States, India, Singapore, the United Arab Emirates, South Korea, Mexico and Australia are among the myriad nations with which CNES works in partnership throughout the year. Some of these cooperation agreements go back years, while others are more recent, giving nations with growing economies the chance to get into space and access new technologies.

This cooperation will be stepped up in 2018 through new agreements and projects geared towards the challenges and strategies of each of the partners.
“Only satellites can offer solutions to preserve our planet.”

Keeping watch over ‘spaceship Earth’ is a pillar of France’s space policy. Climate is a global concern, ideas abound and the environment poses many challenges that go beyond achieving competitiveness. Taking the lead on this issue, CNES has succeeded in federating more than 60 of the world’s space agencies behind a common approach.
A climate-focused agency

CNES is concentrating its efforts to raise awareness among space players, get them to speak with one voice on climate and work towards a common goal. The universal agreement signed in 2015 at COP21 in Paris was a defining moment. The New Delhi Declaration committing the world’s space agencies to use satellites to monitor greenhouse gases and the Marrakesh Declaration focused on preserving our climate, particularly in the area of water resource management, have helped to highlight climate issues and encourage all concerned to take them on board.

Jason and SWOT, Megha-Tropiques, CFOSAT, MicroCarb and MERLIN

While the U.S. and European operational climatology and oceanography agencies are working on the successor to the Jason series of satellites, CNES and NASA are innovating with the SWOT programme to measure surface water and ocean topography. Operational since 2011, the French-Indian Megha-Tropiques mission is designed to study the water cycle and energy exchanges in the intertropical belt. This mission is being pursued with instruments supplied by CNES and input from the French weather service Meteo-France.

CFOSAT. This French-Chinese science mission is set to measure the speed and direction of ocean surface winds. CNES is supplying part of the instruments. The satellite is scheduled to launch in 2018.

MicroCarb. Able to detect carbon gases with great precision, MicroCarb will help scientists to better understand the planet’s major ecosystems and gain a clearer picture of its carbon budget at regional scales.

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

Leading-edge technology and coordination

With its unique fleet of six families of Sentinel satellites, the European Union’s Copernicus Earth-observation and monitoring programme generates huge and continuous volumes of high-quality data now available through CNES’s PEPS Sentinel Product Exploitation Platform. This platform is set to evolve in 2020 into DIAS, an integrated European system involving big data and cloud computing providers to bring these data and processing capacity to citizens, scientists and manufacturers worldwide.

Global coverage with CO3D

Engineers, cartographers, scientists and salespeople everywhere will find a new solution to their needs with CO3D. By 2022, this constellation of optical mini-satellites offering submetric (50 cm) resolution will produce precise 3D elevation data and offer global coverage, providing continuity with Pleiades.

10 Terabytes of data generated every day by the Sentinel-1A/1B, Sentinel-2A/2B and Sentinel-3A/3B satellites.
Fuelled by the flood of unprecedented innovations and exponential growth in demand for connectivity, satellite telecommunications is a burgeoning field. Whether for the Internet, high-definition television, mobility or geolocation, technologies conceived by CNES are underpinning an increasing range of new services. To help this sector of excellence and French industry to stay ahead, the agency is investing massively in fast broadband and electric propulsion.
New systems: VHTS, constellations

The satellite telecommunications sector receives government funding through the PIA future investment programme for the foundational projects CNES is executing. The agency is working with manufacturers to design various orbital systems aimed at achieving a factor-of-five reduction in the cost per gigabyte.

Better geostationary satellites

To meet increasing demand for uninterrupted Internet connectivity, CNES is developing new-generation geostationary spacecraft buses optimized for electric propulsion, as well as very-high-throughput satellites (VHTS) using innovative technologies.

Cheaper low-Earth orbit satellites

Low-Earth-orbit (LEO) constellations are well suited to meeting growing demand for Internet connectivity. The cost of manufacturing such constellations comprising tens of satellites weighing 10 to 200 kilograms is coming down all the time. CNES is leading the GEICO research project that seeks to give them more innovation and flexibility.

ANGELS for nanosatellites

Nanosatellites could potentially spawn a market worth $800 million in the years ahead. To structure the national ecosystem needed to build these satellites, CNES has launched development of the ANGELS demonstrator (Argos Neo on a Generic Economical and Light Satellite) planned to launch in 2019.

Galileo is ‘go’

In December 2016, Europe’s Galileo geolocation system began offering initial services (including search and rescue), giving receiver manufacturers the signal to ramp up production.

Technologies and equipment: electric propulsion, optical payloads

To maintain their edge in such a dynamic market, French manufacturers will be able to leverage innovative technology building blocks to stay competitive. By 2020, electric propulsion will equip the Neosat spacecraft buses CNES is developing with European partners to enhance their performance and make them lighter and cheaper. The optical payload on THD-Sat is another innovation that will employ a portion of the electromagnetic spectrum largely unused until now, providing an ideal complement in remote areas unserved by fibre-optic coverage.
Optical high-resolution imaging, signals intelligence and highly secure telecommunications all help to maintain peace and guarantee citizens’ security. The French Ministry of the Armed Forces and CNES are conducting programmes and funding R&T projects to bring France’s military effective, reliable and affordable space systems, and to maintain French industry’s competitive edge.
**Ongoing programmes: CSO, CERES, Syracuse 4**

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

**Syracuse 4.** Fielding two satellites built around new-generation electric spacecraft buses, the Syracuse 4 programme is set to take over from Syracuse 3 in 2020. CNES has responsibility for early-stage development of technologies and is supporting development of the space side of the programme.

**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.

**Full panoply**

The challenge is to develop systems geared towards military needs while bringing civil users the benefits of innovative imaging and telecommunications technologies. Such dual-use systems are able to meet operational needs and boost the competitiveness of France’s sectors of excellence, especially in the domain of very-high-resolution optical remote sensing.

**Efficient organization**

France’s armed forces and CNES are working together in the field of space surveillance and tracking (SST) to make civil and military satellites more secure. Conjunction assessment data from our U.S. allies and from French military radars are processed by CNES’s specialists to keep them safe. To enable the European Union to achieve a first level of independence in this domain, five European nations have formed a consortium to supply SST services and study possible enhancements with funding from the European Commission.

**Disruptive programmes: OTOS**

OTOS is demonstrating technologies like active optics, a process that uses a compensating mirror to correct the imperfections of a telescope’s primary mirrors, with a view to maturing innovations in satellite optical remote sensing, a French domain of excellence. This process already traditionally used in astronomy could be adapted in space to enable industrial-scale production and thus shorten lead times and reduce costs. The results of OTOS are expected to feed into the next generation of Earth-observation satellites.

Since its inception in 1961, CNES has worked with the Ministry of Defence.
The talents that CNES’s people apply to conducting France’s space policy are forged by excellence and shared values. The agency’s 2,500 or so employees—70% of them engineers and executives, and 37% women—are all passionate about space and new technology applications. They work at CNES’s four centres of excellence, helping to extend the influence of French space policy and seeking solutions to meet the future daily needs of citizens, driven by a forward-looking vision.
New CNES recruits every year, mostly young engineers starting their career or with a few years’ experience behind them.

Head Office: space policy
(189 employees)

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. Every year, CNES signs tens of international agreements, laying the foundation for new science and technology partnerships. The agency also works of course with a broad spectrum of academic, scientific, industrial and business partners in France.

Toulouse Space Centre: orbital systems
(1,770 employees)

The Toulouse Space Centre (CST) is the agency’s largest technical and operational field centre. Its engineers conceive, design, develop, build, position, control and operate orbital systems. Their work also involves fostering uptake of satellite data for the benefit of all and innovating and creating to imagine tomorrow’s space systems. The CST’s teams are tasked with supporting all potential space user communities and encouraging adoption of space applications in our daily lives, by meeting, advising and training citizens and opening up new horizons.

Launch Vehicles Directorate: launch systems
(220 employees)

Paris Daumesnil is home to the Launch Vehicles Directorate (DLA), which is instrumental in operating Europe’s Ariane 5, Vega and Soyuz launchers. CNES is prime contractor for all of the launch facilities in French Guiana. Ariane 6, designed to bring down operating costs, is the next major challenge it is now working on. DLA’s experts are working tirelessly to develop this new launcher within an integrated team with ESA and industry partners. Drawing on its 40-year heritage, DLA is inspiring innovation and inventing tomorrow’s launchers.

Guiana Space Centre: launch operations
(285 employees)

The Guiana Space Centre (CSG) guarantees Europe’s independent space launch capability, under the watchful eye of CNES, ESA and Arianespace. The 1,700 people at the launch base come from 40 European firms and are working to get ready for Ariane 6 and Vega-C. At the CSG, CNES coordinates launch operations, prepares satellites and is responsible for range safety and ensuring compliance with environmental regulations. With its modern facilities, three operational launchers, 14-day turnaround between launches and the ability to conduct five satellite campaigns concurrently, the CSG is a key plank of Europe’s space strategy.
France’s space science communities are renowned as being among the best in the world. By pushing the boundaries of our knowledge, cutting-edge science is helping to create jobs in the space sector and boost economic growth in Europe. It is also spurring the market for new technologies that will be used in the innovative applications and services of the future.
France’s space industry alone employs 14,000 people, plus nearly 10,000 indirect jobs sustained by the space sector in French Guiana, and top posts in research laboratories at CNRS, and at CEA and CNES. This represents nearly 40% of the 40,000 jobs in the space sector in Europe.

CNES came second among the public enterprises ranked in a 2017 survey of the 500 best employers in France conducted by online statistics portal Statista on a sample of 20,000 employees.
Business, agriculture, fisheries, healthcare, the environment, security and science are just some of the myriad areas where space applications are delivering often unsuspected benefits to meet the multiple needs of the 21st century. More than ever, CNES is seeking to spur development of such applications that in some cases are set to become part of our daily lives.

“CNES must continue to deliver high added value in all areas of space.”
Serving increasing numbers of user communities

With advances in digital technologies, miniaturization and embedded smart systems, space is spawning a whole host of new businesses across a range of sectors. Informing land planning, improving safety for bathers, gauging occupancy of supermarket car parks, detecting pipeline leaks and anticipating epidemics are just some of the infinite applications being enabled by satellite data, which increasingly are becoming available to all and serving a wealth of ideas. CNES is driving home these messages and providing support to anyone who needs it to develop the space side of their project.

Developing business and incubating start-ups

Innovation fires development. CNES files around 40 patents every year and grants licences to proponents of innovative projects. One example is Geoflex, which is using CNES’s precise point positioning (PPP) technology to offer a global satellite positioning service offering centimetre accuracy. Another firm using CNES patented technology is the start-up Flyops, which specializes in aviation solutions like air-to-ground communication and wireless connectivity for passengers. After starting life with a small team of just five people in 2015, today the firm has 36 employees.

As a hub of innovation, CNES is involved in a number of structures working to spin off space data and applications like the ESA-BIC incubators, national competitiveness clusters and the European Union’s Copernicus Relays. It is also providing its expertise and resources for testing the space component of a project.

Patents (for systems and launchers) have been filed over the last 10 years (57 in 2015 alone), a fine result showing the level of excellence that CNES seeks to maintain its edge in the global arena.

Partnerships with SNCF, INSERM, agriculture, fisheries, construction and public works

As with the agreement signed with INSERM, the French National Institute for Health and Medical Research and the leading biomedical research organization in Europe, CNES continues to forge partnerships in areas where space is proving highly valuable. In 2016, it signed a framework agreement with French national rail operator SNCF to install monitoring, geolocation and telecommunications systems. Research to be undertaken with the Department of Health (DGS) and the French armed forces medical office is going to help to further epidemiology, telemedicine and even satellite-assisted solutions for the visually impaired. And CNES’s subsidiary CLS is working to track the oceans and monitor illegal fishing.

Watching over Greater Paris

Technology transfer is an area where CNES has a proven track record. CLS subsidiary TRE Altamira was set up in 2000 with a licence for the Diapason radar interferometry software. In 2015, the firm won a satellite monitoring contract for the Greater Paris Express, measuring millimetre ground displacements either side of the rail corridor along some 200 kilometres of track and at 68 new stations in the Paris area.
With new applications and new players emerging all the time, space is a project booster. Pursuing a disruptive approach in line with its vocation to invent the future, CNES is gearing up to meet three structural challenges: innovation, climate and exploration.

“Space is everybody’s concern.”
The global climate challenge

As ice shelves melt, record floods sweep across the globe and a series of hurricanes hits the Caribbean, the link between increasingly frequent and destructive natural disasters and climate change is becoming more and more tangible. As a climate-focused agency, CNES is developing the satellite systems needed to measure climate variables, like the MERLIN and MicroCarb greenhouse-gas-monitoring missions.

Monitoring water resources

At COP22, seven French institutions including CNES officially grouped together to work on new approaches to monitoring water resources using satellite data.

Human exploration of space

With automatic space probes reaping an ever richer harvest of data, regular crewed space exploration is within reach. The International Space Station is set to continue operating through to at least 2024, providing a precious laboratory for experiments to further exploration and applications on Earth, notably in the domain of public health.
As a born innovator and visionary agency, CNES has evolved in recent years to establish a framework for spurring innovations and their applications, nurturing potential sectors of national excellence in the process. To this end, it is working on space projects to improve citizens’ lives and serve major economic and social needs.

“Satellite data is the black gold of the 21st century.”
Technologies

Disruptive approaches
CNES is adapting to the global environment. As low-cost systems and constellations fast become the norm, a disruptive approach is called for, building on existing technologies to conceive new concepts that are technically and economically matched to needs.

Organization: DSO (miniaturization), DLA (reusable), DNO (digital)
CNES began its restructuring drive in 2016. Formed to conceive the systems of the future, the Directorate of Orbital Systems (DSO) imagines and proposes disruptive technologies and processes designed to reduce costs, optimize performance and shorten lead times while retaining the same level of excellence. The Launch Vehicles Directorate (DLA) reorganized in 2017 to take on development of Ariane 6 and to ready the launchers of tomorrow with the Prometheus low-cost engine and the Callisto reusable stage demonstrator. And with the rise of big data driving an increasingly digital world, the Directorate of Digital Technologies and Operations (DNO) is engaging a digital transformation across the agency to receive, analyse and use a flood of satellite data in real time.

Applications

More a means than an end, new uses, new players
Space is going to prove vital to meet the challenges of the 21st century and compete effectively in the global economic race. Today, CNES is engaging efforts alongside industry and institutional partners to transform the space sector as it seeks to keep pace with the latest developments and maintain its edge.

Organization: DIA
Formed in 2016, CNES’s Directorate of Innovation, Applications and Science (DIA) plays a key role shaping the agency’s strategy to propose solutions and services for all sectors. DIA works in close collaboration with firms, applying a resolutely bottom-up approach to unearth potential applications and boost synergies, analysing different sectors’ needs and how space assets can serve them, and identifying the technologies and support required.

Technology nuggets
To reward them for their efforts driving innovation, CNES distinguished five French firms—start-ups, SMEs and big groups—that were the most effective in 2016 spinning off the agency’s intellectual property: Airbus Defence and Space (algorithmic software and systems aboard the Pleiades satellites), Cap Gemini Technology Services (Pleiades tasking system), M3 Systems (GNSS software environment), MAP (paints and coatings for satellites) and Sodern (new-generation star trackers).

700 participants at CNES’s Innovation Day on 2 February 2017.
To understand, mitigate and cope with climate change, all nations need to start working together now. Setting in train an unprecedented global movement, 195 nations signed the Paris Agreement on climate in December 2015, for which CNES was instrumental in organizing the space contribution, as satellites are the only way to study climate on a global scale.

“A strong and united spacefaring Europe is vital to actively combat climate change.”

THREE STRUCTURAL CHALLENGES

Climate
Key role of satellites

Global temperature (Paris Agreement) and sea level
Out of the 50 identified essential climate variables (ECVs), 26 can only be measured from space. These include greenhouse gases, the main drivers of the global warming that is fuelling the alarming and accelerating rate of sea level rise of 3.2 millimetres a year. By committing signatory nations to curb their emissions, the Paris Agreement aims to keep the long-term rise in the planet’s temperature to 1.5°C and thus considerably reduce the risks and impacts of climate change.

Mapping emissions (MicroCarb for carbon, MERLIN for methane)
In 2016, at CNES’s initiative, 60 of the world’s space agencies signed the New Delhi Declaration through which they committed to developing a common system for measuring atmospheric concentrations of greenhouse gases in order to precisely map emissions and check compliance. The MERLIN and MicroCarb missions being developed by CNES to measure methane and carbon will be part of this global constellation.

International coordination

CNES focused on climate
Getting space assets to work together for climate research is a complex task that calls for close international cooperation and coordination. As a climate-focused agency, CNES’s determination in crafting and implementing the Paris Agreement makes it a prime mover in this crucial alliance for the future.

COP21, 22, 23, One Planet Summit (12 December 2017)
With the COP21 conference in Paris in 2015, COP22 in Marrakesh in 2016 and COP23 in Bonn in 2017, climate summits have followed each other recently in quick succession. To maintain the momentum and consolidate actions, CNES is involved in political initiatives like the One Planet Summit organized on 12 December 2017 in Paris at the behest of President Emmanuel Macron. Two years after the signature of the Paris Agreement, this gathering served to perform a status check and to secure the funding needed to make it work.
Burgeoning space applications and the reduced cost of satellites and launches are opening new vistas for space exploration. CNES’s teams are putting all their energy into the kinds of ambitious missions that can only be accomplished with international partners.

“Space, the final frontier.”
“Our aim on the ISS is to acquire the knowledge we need to innovate.”

THOMAS PESQUET

**Human spaceflight**

**Thomas Pesquet, beyond the ISS**

During his six-month stay aboard the International Space Station (ISS), Thomas Pesquet performed some 100 scientific experiments in microgravity, notably with the Everywear personal medical assistant, one of seven experiments designed for the mission by CNES. The agency has already reaffirmed its support for France’s astronaut on future crewed exploration missions, and is working closely with Europe to imagine post-ISS scenarios.

**Moon and Mars, public and private**

Whatever strategy the key players in space exploration choose to pursue in the future, international cooperation will be the order of the day. CNES is helping Europe to set its priorities and is involved in numerous programmes like the InSight and Mars 2020 rover missions with NASA, ExoMars with ESA and MMX with JAXA, all destined for the red planet. Working with Indian start-up Team Indus, CNES is taking part in the first private mission to the Moon. It is also working with ESA on the Orion service module for NASA.

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**Space probes**

**Shorter programmes, miniaturization, embedded smart systems**

Increased knowledge and the influence of NewSpace and digital technologies are leading us to see space exploration in a different light. To collect data vital to gain new insights into the cosmos, CNES is conceiving ultra-sophisticated instruments for various international space probes.

**Science survey review**

To establish the roadmap for its future scientific projects, CNES organized its Science Survey Seminar in 2014. A mid-term review of accomplishments for this five-year plan was held on 6 October 2017 to take on board recent developments in the space sector such as future launchers and satellites.

**500,000 Laser firings** performed by the French **ChemCam** instrument on the Curiosity rover exploring the surface of Mars since August 2012.