

CNES MAG

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SPACE • INNOVATION • SOCIETY

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CHALLENGE

INVENTING THE FUTURE OF SPACE

A vibrant, stylized illustration of space exploration. The background is a dark blue space filled with stars and a large, glowing orange and yellow sun or planet. Several futuristic spacecraft are depicted in various orientations, some with solar panels and antennas. The style is modern and graphic, using bold colors and geometric shapes. The overall composition is dynamic and futuristic.

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CNES



**NEW SPACE POWERS
SET TO JOIN THE
BIG PLAYERS**



CONTRIBUTORS



LILIANE FEULLERAC

A stalwart of CNESmag,

Liliane Feuillerac is a journalist with a cutting style who keeps a laser focus on what's going on at CNES. Always on the look-out for original initiatives, leading-edge technologies and future projects, she shows in ROUNDUP and CNES IN ACTION how the space agency is readying today for the challenges of tomorrow.



MARIE-CLAUDE SIRON

As a copywriter at CNES's Communications Directorate,

Marie-Claude Siron knows all about science outreach. With her natural altruism, friendly disposition and ability to empathize, she has conducted many moving and sincere interviews for the HORIZONS section of the magazine. For this issue, she met the president of a non-profit association, an artist and a young research scientist.



LÉONARD DUPOND

We love Léonard Dupond's graphic universe, so we gave him 'carte blanche' to illustrate this issue. Heavily influenced by the circular motifs of the architect David Wright, he drew inspiration from the space propaganda matchboxes of the Soviet era—a reference to constructivism that is particularly apposite here.



GÉRARD AZOULAY

At the head of the Observatoire de l'Espace, CNES's arts and science laboratory, Gérard Azoulay pursues an original approach to promoting knowledge and creations in relation to the world of space. When artists and creators discover the space adventure, they are at once enraptured and enthusiastic about such a wonderful and unknown material that becomes a powerful and fertile source of inspiration for their work. All of this and more is on view in INSIGHTS and HORIZONS.

CNESMAG

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EDITORIAL



Space plays a central role in our daily lives and seems nowadays to be everywhere we look. Indeed, we have not seen such a keen interest in space since the late sixties. The black-and-white pictures of that era remain etched in our memories, showing the Vietnam War sound-tracked with Nancy Sinatra's voice and the United States setting foot on the Moon. Fifty years on, the colour pictures we now see of crews aboard the International Space Station and from probes exploring the solar system are no less compelling. But in the intervening years space has shifted up a gear, as **innovation** has revolutionized launchers and satellites, our planet's **climate** has come under constant surveillance from Earth orbit and Mars has become the new frontier of space **exploration**. We may have come a long way in that time, but it hasn't been all plain sailing and the advances achieved are the result of our continuous efforts to adapt to a fast-changing context. CNES is pursuing these efforts with all of its institutional, science and industry partners because, faced with the rise of emerging nations and the all-pervading influence of the United States, we must stay ahead of the game and above all we must keep **inventing the future of space**.

JEAN-YVES LE GALL
CNES PRESIDENT

The background image is a composite of two scenes. The upper portion shows a massive, dark grey space station or planet with several large, glowing blue engines or thrusters. The scene is set against a deep blue, star-filled sky. The lower portion shows a desert-like landscape under a bright orange and yellow sunset. Two small, dark figures in futuristic suits stand on the ground, looking up at a large, white, angular object in the sky.

CINEMA

Art and science on the same bill

What will the 28th century hold in store? It might look something like the next blockbuster from filmmaker Luc Besson, *Valerian and the City of a Thousand Planets*¹. But before the film hits our cinema screens in July, a taste of its atmosphere will be on display in CNES's pavilion at the Paris Air Show, where the agency will be partnering with the film's production company EuropaCorp to recreate the world imagined by Christin and Mézières, the authors of the comic strip on which the film is based, while promoting its new mantra—"Inventing the future of space"—in a dynamic and original way. CNES will be showcasing its current and future programmes with innovative, interactive and spectacular features alongside sets and visuals from the film. All will be revealed on 19 June at Le Bourget!

1. In cinemas on 26 July



ROUNDUP



PROMETHEUS SIGHTS ON COST SAVINGS

Next-generation space launchers will need to bring costs right down without compromising on performance. CNES and Airbus Safran Launchers (ASL) are rising to this major challenge with a new engine called Prometheus¹ that will reduce tenfold the cost of building an engine equivalent to Ariane 5's Vulcain. Based on a simplified architecture, optimized industrial organization and new fabrication processes, the methane- and oxygen-fuelled prototype is built around cost-saving technologies like additive manufacturing (also known as 3D printing). The project is also leveraging innovative methods like intensive numerical simulation, rapid prototyping and concurrent testing. Finally, Prometheus is paving the way for future reusable systems, as it plans to re-fly up to five times without being requalified—another way of cutting launch costs.

1. Precursor Reusable Oxygen METHane cost Effective engine propUlsion System

CALLISTO REUSE DEMONSTRATOR



Standing only 13 metres tall and spanning 1.1 metres, Callisto will be a 'miniature' spacecraft.

In successfully recovering rocket first stages, the United States has put reusability back on the map. Meanwhile, CNES and its partners have been working on this concept since 2015 with the Callisto demonstrator. While the spectacular stage recovery phase has so far captured all the attention, ground operations are an equally vital part of the economic equation. Callisto is designed to explore all of these parameters. The small reusable first-stage rocket must be capable of flying, returning and re-flying several times. Its home base will be the historic sounding rocket launch pad in Kourou, French Guiana, specially refurbished for the purpose. Aspects studied by this complex and original project will include launch trajectories, range safety, diagnostics and predictive maintenance. First tests are planned in 2020.



2,500

Luc Besson's new film uses special effects in more than 2,500 shots.

In 2004, an ESA brochure highlighted how space technologies have infused cinema and literature.

<https://www.esa.int/esapub/br/br205/br205.pdf>



ROUNDUP

Ny-Ålesund on the Norwegian island of Spitsbergen, seen by Pleiades 1A.



NEW PROPELLANTS

BOOSTING PERFORMANCE WHILE PRESERVING THE ENVIRONMENT

One thing Valerian doesn't need to worry about is getting his skyjet airborne; the special effects team takes care of that. Back in the real world, it's not so simple. To produce thrust, a launcher uses chemical propellants to drive its rocket engines. Current propellants like liquid oxygen, kerosene and monomethylhydrazine work well with today's high-performance engines, but they still have drawbacks, among them their low density and very low operating temperatures (as low as -252°C for liquid hydrogen). CNES, the national scientific research centre CNRS, Airbus Safran Launchers (ASL) and Lyon University have therefore set up a joint research unit unique in France to address this problem. The unit is working to develop new, non-toxic propellants that afford better performance and a low environmental footprint. Research is focusing on metastable molecules at ambient temperature combining excellent energy performance with high density. Such molecules could ultimately point the way to more-compact launcher architectures and simpler engines.

SATELLITE IMAGERY

MAKING IT SIMPLER

The COP 21 confirmed what CNES already knew, i.e., that satellite imagery is crucial to climate monitoring. Leading the way in high-resolution imaging of the planet, the Pleiades satellites record pictures of exceptional detail. Tomorrow, consumer climate applications won't require the same level of precision. The large volumes of data generated will be stored more simply, more cheaply and in more-versatile fashion, for example on the kinds of sensor arrays found in our cameras and smartphones.

MAJOR LEAPS IN SPACE TRANSPORTATION

1952



Véronique, France's first launcher, sends aloft scientific instruments to an altitude of 70 kilometres.

1965



France's **Diamant** rocket puts the Asterix A-1 satellite into low-Earth orbit to test its viability.

1979



Ariane 1 puts a satellite weighing one tonne into geostationary orbit to offer commercial telecommunications services.

1988



Ariane 4 accomplishes the first dual launches for a new generation of telecommunications satellites.



Naïo Technologies has conceived a tracked robot to help vineyards and nurseries automate labour-intensive tasks like weeding.

INTERNET OF THINGS A NEW WORLD BECKONS

A connected watch able to close your window shutters is no longer the preserve of science fiction and more to do with machine-to-machine (M2M) technologies or the Internet of Things (IoT). Connected objects are linked to central servers and can also communicate through networks with a range of devices in a more interoperable and less centralized way. This burgeoning ‘new world’ is set to rise exponentially with the advent of 5G. CNES has been a pioneer of data collection with its Argos system for nearly 30 years and is now working with subsidiary CLS on new technologies to increase its capacity and functionality.

4.0

Launch vehicles are evolving and so, too, is the Kourou launch base. The Guiana Space Centre (CSG) is exploring modern industry 4.0 techniques, for example optimizing manufacturing facilities, incorporating the Internet of Things (IoT) in production cycles and providing digital aids for operators. New methods already being used include collaborative digital modelling during industrial ramp-up, connected sensors and aggregation of previously separate functions.

x1,000

That’s the gain in transmission speeds achieved by geostationary communication satellites in the space of 20 years, going from one gigabit per second (1 Gbps) to several hundred Gbps today. And tomorrow, we can expect to reach speeds of one terabit—1,000 billion bits—per second.

269

CNES received 770 proposals in response to its 2017 call for projects, 648 from outside the agency. In all, 269 innovative projects have been down-selected matching its eight chief R&T goals, which include future avionics, next-generation atomic clocks (Galileo NG) and supporting the competitiveness of telecommunications for export markets.



1996

Ariane 5 gets a new architecture with different models (GS, ECA and ES) able to serve a range of missions.



2020

Offering the same level of reliability as Ariane 5, **Ariane 6** brings down launch costs with a new industrial set-up and technologies, offering two configurations tailored to the institutional and commercial markets.



Ariane Next paves the way for reusable launchers designed for a series of orbital missions.



ROUNDUP

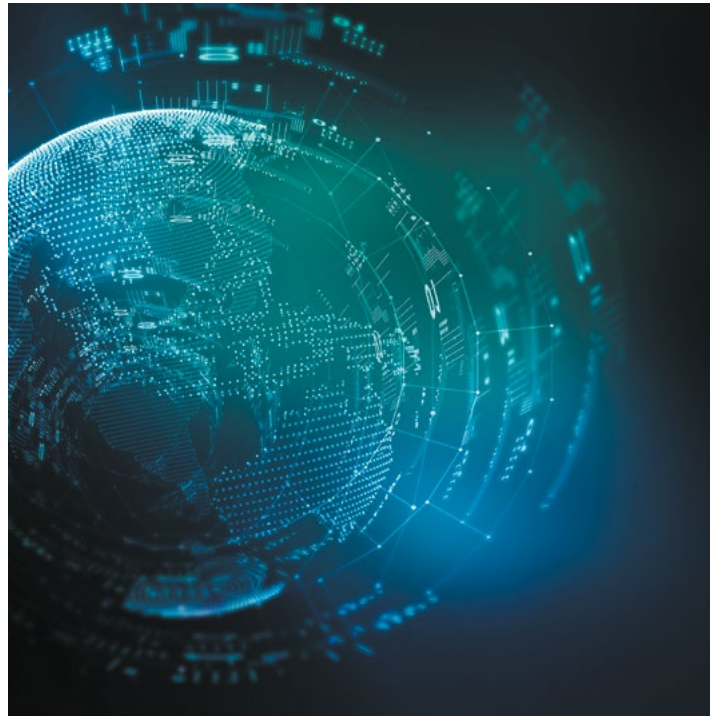
SECURITY

AVOIDING THE PITFALLS OF A CONNECTED WORLD

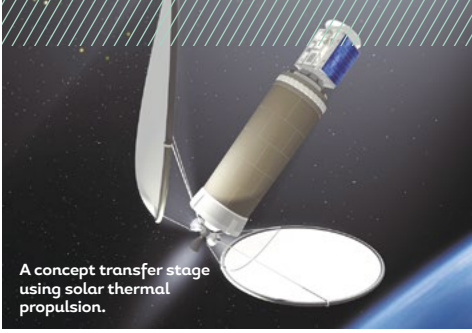
Living in today's connected world is not without risk. Ground networks maintained by organizations in third-party nations and 'visited' by hackers need to be highly secure, and in the future private satellite networks will even be essential. Working with the Ministry of the Interior and the Ministry of the Environment, CNES has identified new secure satellite telecommunications needs for crisis management, which will have to complement or stand in for existing terrestrial infrastructures. Multi-site service demonstrations have already been run in 2015 and 2016 with the Sextant station at the Toulouse Space Centre and on the Athena-Fidus dual-use satellite operating since 2014. But new R&D work will be necessary to cope with growing security needs. The European Commission is addressing this issue through the Govsatcom project to which CNES is contributing, with a view to assuring secure and independent communications for the European Union.

OBSERVATION

VIRTUAL EARTH SOON A REALITY



As new constellations of remote-sensing satellites in low-Earth orbit start to come on stream, navigation systems will be constantly updated. A profusion of low-cost imagery is also going to impact other sectors, like for example unmanned aerial systems (UAS) and satellites operating in tandem, which will gain in autonomy. Much is also expected of a 'virtual Earth' updated with metric-resolution imagery in real time, ten times more powerful than anything Google Earth can offer today. Associated tools will enable users to search this repository of data by content, monitor environmental parameters (forests, mangroves, erosion, etc.), track economic indicators or inform decisions. This virtual Earth will also form the foundation for innovative services like those proposed by Qwant, the French search engine backed by CNES.



A concept transfer stage using solar thermal propulsion.

ADVANCED CONCEPTS A MINE OF INSPIRATION

CNES is keeping a close eye on unusual, futuristic technology concepts. Some, like space elevators or magnetic solar sails, have real potential but still need time to mature. Among the advanced concepts being touted, laser propulsion could offer a way to clean up space debris, while nuclear electric propulsion (NEP) could power heavy loads faster and further into the solar system. CNES and its European and Russian partners are working on NEP technology demonstrators through the Democritos¹ consortium.

1. DEMOnstrators for Conversion, Reactor, Radiator and Thrusters for Electric Propulsion Systems

ANTENNAS INNOVATION AND PERFORMANCE

A satellite-tracking ground antenna is most often pictured as a barrel-mounted mobile dish. But other solutions are now emerging, like the innovative new concept that CNES and Thales Alenia Space (TAS) have developed for Cospas-Sarsat¹ ground antennas to be deployed to track the Galileo satellites. Unlike traditional motor-driven antennas, these new beam-forming antennas are 'steered' electronically to track 20 Galileo satellites at the same time and provide wider coverage for detection of distress beacons, thus speeding dispatch of rescue services. CNES worked with TAS during the operational validation phase of the prototype and the first series model is scheduled for delivery at the end of this year.

1. Global search-and-rescue system



ROUNDUP

3D PRINTING MADE IN SPACE HERE WE COME

In 2014, NASA fabricated the first 3D object on the International Space Station (ISS) using an additive manufacturing (AM) tool. Also known as 3D printing, AM technology is gaining ground over traditional reductive machining due to its adaptability and low cost. It consists in fabricating parts and complex systems by adding successive layers of material, thus simplifying the production process. CNES had previously started R&T work in this area and has now decided to take things a step further, setting up a dedicated team, getting involved with working groups in France, forging close ties with stakeholders and defining a strategy with ESA and French manufacturers. AM parts are already being used on the Ariane 5 launcher and on satellites. Growth prospects are good and plans are being laid to scale up the technology. 'Made in Space' is set to become the new challenge and several European initiatives have been launched. Looking further ahead, making parts directly in space appears totally feasible, possibly even from lunar dust.



Mock-up of a launcher made using additive manufacturing.



COMMUNITY

Every day, CNES engages with you on social networks and you share your thoughts and questions with us. Join the conversation!

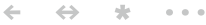


@ CYRILLE VANLERBERGUE

Science and Medicine editor at Le Figaro. Yachting and ocean racing aficionado.



The Ariane 6 construction site in French Guiana is just amazing! Carved out of the granite.



@ SPACEUP FRANCE

The next event organized by SpaceUp France will occur on February 4 and 5, 2017 @ISAE_officiel in #Toulouse, France. <http://www.spaceup.fr>



@tyrower now talking about how to interest kids in space with #astropi and #ARISS - #SpaceUpTLS

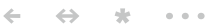


@ RÉMI GOURDON

EE grad student @INP_ENSEEIHT and @GeorgiaTech. Open Source supporter. Space addict! @ISUnet #SSP15 alumn. #SpaceUp participant. Tweeting also @techforspace.



Now some NewSpace & CubeSats figures & pictures with @plasmarmuse ! Aerospace startups are a real thing, check out @Thrustme2. #SpaceUpTLS

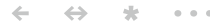


@ SÉGOLÈNE ROYAL

Minister of the Environment, Energy and Maritime Affairs, in charge of International Climate Relations, COP21 Chair



Proud to kick off development of #MicroCarb and help build a shared vision of our 🌍 and work together to protect it



@ THOMAS PESQUET

Européen Français, pilote de vaisseau spatial à l'ESA en mission pour six mois sur l'ISS / Euro-French spacecraft pilot at ESA, now on 6-month ISS mission



The Kerguelen Islands, at the end of the Earth. Not for holidaymakers, but for scientists and engineers, notably from @CNES





Q & A

PHILIPPE STARCK

A TALENTED AND VISIONARY DESIGNER, Philippe Starck is also a resolutely forward-looking citizen of the Universe who draws inspiration from space. Leaving the engineering and science challenges to the experts, he gives us his personal vision of a responsible and democratic use of space for the future.



Q & A

WHAT PROJECTS DID YOU WORK ON WITH VIRGIN GALACTIC?

Philippe Starck: I was given the role of artistic director. I designed the logo around an iris representing curiosity and adventure, which to me define how the human spirit has evolved over millions of years. My goal was to endorse the approach adopted by Virgin Galactic¹. Some may have seen the company as a billionaire's 'plaything', but what interested me was the idea of opening space up to a wider public. Today, it's the preserve of experts and the military, but to me it's the stuff of dreams and I believe we need to reappropriate space together and significantly reduce the cost of getting into space. In 2001, the first suborbital flights were on offer for \$35 million; today, the price has come down to \$200,000. Providing more choice will give more people a chance to attain the dream of space.

WHAT PLACE IS THERE FOR DESIGN IN SPACE?

Ph. S.: The space adventure captured my attention at a very young age, but I didn't understand why American astronauts all looked handsome and elegant in their white spacesuits and anodized decor. I was influenced by the new aesthetic of their mission environment. On the other hand, Russia's cosmonauts looked really drab in their khaki outfits and grey decor. They had an air of desolation that was the complete opposite of how

I dreamed of space. I learned only many years later that NASA had employed an artistic director, the eminent Raymond Loewy², to work with its engineers. What he achieved shows it's possible to create something that's visually appealing even in the most constrained environments.

WHAT DO YOU THINK A FUTURE MARTIAN BASE SHOULD LOOK LIKE?

Ph. S.: Taking his cue from a theory expounded by Democritus, Jérôme Monod said that "everything in the Universe is the result of chance and necessity". For a Martian base, necessity will be what's dictated by the obstacles scientists planning missions and crews living there will have to face. I guess things like aesthetics won't be foremost in their minds. But before we start dreaming about a Martian base, we should think about certain rules required to avert all possible danger. There are two aspects I would underline in particular: waste and pollution. In the early years of the space adventure, our attitude was kind of "after us, the deluge" and we turned space into a vast waste tip. Today, it's estimated that 500,000 of our 'throwaways' are circling Earth. That's morally and pragmatically

inconsiderate. Pollution and waste issues are really much more important than aesthetics, so we need to start thinking now about regulations and codes to govern building on Mars and avoid 'cluttering' its surface.

SCIENCE-FICTION FILMS ALWAYS PORTRAY A VERY 'CLINICAL' AND FUNCTIONAL ENVIRONMENT. DOES THAT REPRESENTATION SEEM RIGHT TO YOU?

Ph. S.: The first science-fiction films, notably the pioneering films inspired by the novels of Philip K. Dick, were predicated on a pristine, unreal space environment. Gradually, they then started to depict a more Earth-like reality, with more-everyday stock imagery. As the space adventure continues to evolve, we'll soon be seeing more-human-like images, with pictures of girls, children and so on.

WHAT DOES THE MANTRA 'INVENTING THE FUTURE OF SPACE' MEAN TO YOU? HOW ARE YOU HELPING TO INVENT THAT FUTURE?

Ph. S.: We have no choice but to invent the future of space. We are at one with space and it's our territory to explore. The only limit

"INVENTING THE FUTURE ONLY STOPS WHERE OUR VEHICLE CAN TAKE US NO FURTHER. AND EACH TIME WE MOVE FORWARD IN THIS RESPECT, WE GET A LITTLE CLOSER TO INFINITY."



Q & A



PHILIPPE STARCK

A TALENTED AND
VISIONARY DESIGNER

“BEFORE WE START DREAMING ABOUT A MARTIAN BASE, WE SHOULD THINK ABOUT CERTAIN RULES REQUIRED TO AVERT ALL POSSIBLE DANGER. THERE ARE TWO ASPECTS I WOULD UNDERLINE IN PARTICULAR: WASTE AND POLLUTION.”

is our ability to push back the frontier a little further every day. Each generation has adopted its own vision of infinity, and maybe there are several infinities, but inventing the future only stops where our vehicle can take us no further. And each time we move forward in this respect, we get a little closer to infinity. My contribution as a designer is a pretty modest one. I'm doing my best, but my job is to improve lives, that's all. On the other hand, I'm making quite a strong human contribution in that I'm trying to be a trailblazer. I communicate about the need to advance 'bionism'³, for example. We were 'born' four

billion years ago when the first bacteria came to life and we will disappear in four billion years' time when the Sun implodes. Embracing bionism is unavoidable if we're to continue evolving.

DO YOU THINK THE FUTURE OF HUMANKIND LIES IN SPACE?

Ph. S.: We are meant to travel, and to go further we need to travel lighter. We have an inherent awareness, an undefined urge to rid ourselves of what we don't need. The space adventure is one of those transitions that lead us to do that. Increased miniaturization and e-technologies illustrate a clear trend: a chip is an object that packs ten times more capability into a small space.

DO YOU THINK ART CAN INSPIRE SPACE SCIENTISTS LIKE SPACE CAN INSPIRE ARTISTS?

Ph. S.: Yes, because scientists are creators too. There are pictures and science-fiction scripts that have inspired certain kinds of research. I think it's harder to use the power of science to create art, but where they differ is in how free they are: scientists have their hands tied by so many functional constraints, whereas artists are free to dream.

HOW DO YOU SEE THE ROLE OF SPACE AGENCIES IN INVENTING THE FUTURE OF SPACE?

Ph. S.: A space agency is an association of skills from all

horizons. It has a broad, impartial and scientific vision. And that vision must remain extremely clear. Space agencies should be given more of a voice because they have the most interesting things to say. Science can also be pure poetry. I'm really interested right now in the work of Thibault Damour, which I think proves that. To me, conceiving the demise of the Universe through the barely audible 'background noise' of emptiness is the height of poetry.

1. Virgin Group company founded by Richard Branson to operate commercial suborbital spaceflights.

2. French-born industrial design pioneer who spent his entire career in the United States.

3. According to Starck, 'bionism' is finding inspiration in living matter to design technology better suited to humans.

Profile

1979

Founds Starck Products, his own design company

2006-2007

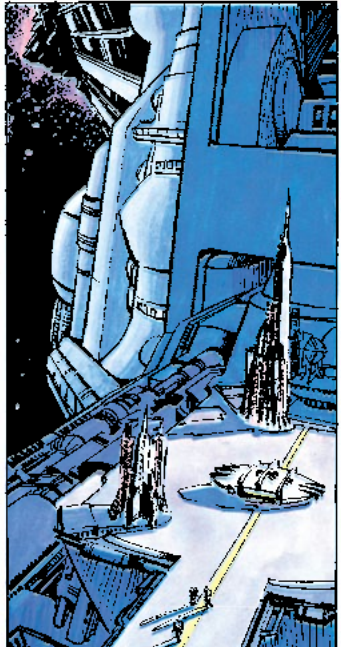
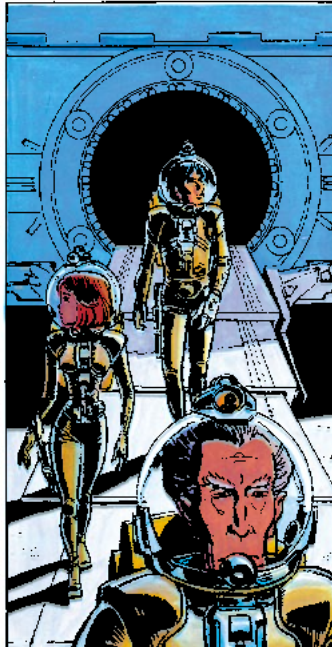
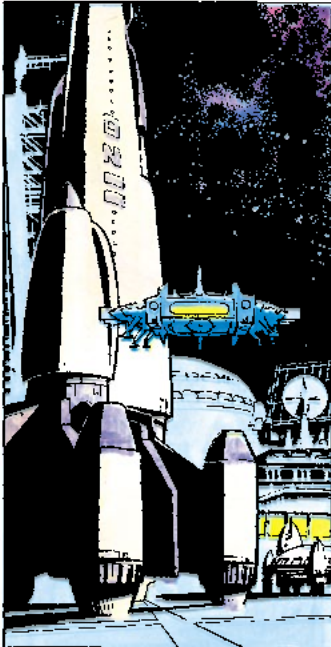
Artistic director for Virgin Galactic

2009

Ambassador for the European year of creativity and innovation



IN PICTURES



FROM THE DRAWING BOARD...

“Drawing a futuristic series that takes place in space isn’t at all easy. And when we created Valerian¹ in 1967, there were very few representations of space for us to go on. Stanley Kubrick’s 2001: A Space Odyssey came out a year later, Star Wars 10 years later. So we had to start almost from a blank sheet and find the right graphic resolutions. Little by little, things fell into place. The illustrator is sort of like a film director; this extract from Ambassador of the Shadows, where there was no dialogue, gave me free rein to do some really spectacular artwork with Pierre Christin’s script.”

Jean-Claude Mézières

1. Science-fiction comic series by Pierre Christin and Jean-Claude Mézières, published by Dargaud



IN PICTURES



...TO THE SILVER SCREEN.

"I'm really keen to see how Luc Besson is going to adapt and recreate the atmosphere of the comic series, and we'll only see that once the film has been edited and the special effects added. I feel he should be completely free to imagine his own version of Valerian. There would be no point in just following the comic strip like a storyboard. So I didn't work directly on the film; even if Luc consulted us and asked us to read the script, it's his film. Seeing our creation on cinema screens really is a dream come true!" Jean-Claude Mézières



IN FIGURES

1 PPM

MICROCARB IS SET TO undertake the massive task of mapping sources and sinks of carbon gas around the globe. The satellite's instrument has been made extremely compact—small enough to fit inside a 12-bottle crate—without compromising on precision, which will be on the order of 1 ppm¹ with a pixel size of 4.5 km x 9 km.

1. Greenhouse gas molecules per million

OTOS



With OTOS, CNES is developing innovative technologies geared towards designing instrument systems in novel ways, employing features like active optics or very-high-rate telemetry for new operating modes in future very-high-performance optical satellites. The goal is to be able to fabricate small instruments in record time and fine-tune their performance in orbit.

20 petabytes

THAT'S THE AMOUNT OF EARTH-OBSERVATION DATA ESA is expecting to hold in its archive by 2020, enough to fill four million DVDs. Copernicus is set to generate 13 terabytes a day (5 petabytes a year), while the SPOT data archive (from the SPOT 1 to SPOT 5 satellites since 1985) is about 15 Pb.

25 kW



Ubiquitous Internet connectivity—at sea, on the train, in the home—is the new paradigm. To support this trend, satellite-based systems are now expected to offer mobility, availability and more data-transmission capacity.

CNES is pursuing this goal with projects like Neosat to develop geostationary spacecraft buses with a capacity up to 25 kW, and THDSat to conceive new payloads and ground networks, while projects like FLIP¹ and SMILE² are seeking to boost service flexibility.

1. Flexible Innovative Payload

2. Satellite Mobile Innovation, Laboratory and Engineering

Patents

CNES files 40 or so patents every year.

In 2016, the agency came 30th in the rankings established by INPI, the French national industrial property institute. Its aim is to enable businesses to use this 'grey matter' and leverage space technologies. In six years, CNES has filed—on its own or with partners—295 patents, of which 55 in 2016 alone.

BILLIONS

Thousands of Argos transmitters have been deployed in the last 30 years. In the coming decade, billions of objects will be connected...



CNES IN ACTION

STAYING AHEAD OF THE GAME

NEW SPACE AGENCIES AND AN INCREASING NUMBER OF AMBITIOUS GAME-CHANGING PLAYERS ARE ENTERING THE INTERNATIONAL SPACE ARENA. FOR CNES, THIS NEW PARADIGM OFFERS AN OPPORTUNITY TO REINVENT ITSELF WHILE REMAINING AT THE FOREFRONT OF INNOVATION AND INVENTING THE FUTURE OF SPACE.



CNES IN ACTION



he world is changing, and with it the space sector. The first sign of this shift began to take shape some 15 years ago. “Lowering the barrier to entry into space has spurred a

growing number of nations to step up their space efforts,” notes CNES’s President Jean-Yves Le Gall. India, Brazil, South Korea and Mexico have gradually established their presence alongside the world’s historic space powers. The latest to join this select club is the United Arab Emirates, with a new space agency formed in 2014. Another more recent sign is the arrival on the scene of the Web giants looking to connect everything—our homes, cars, tablets, watches—everywhere over 4G and 5G networks. To achieve this ambition, space has become their holy grail and the new competitive frontier. And today, access to space is no longer the preserve of government agencies. Since the successes SpaceX has accomplished with its Falcon 9 launcher, it’s clear that private firms have the ability to transform the playing field and exploit space for mercantile purposes. These new entrants are pursuing an original and dynamic approach that is driving the NewSpace¹ paradigm now stimulating the space economy.

TIME FOR RESTRUCTURING...

Jean-Yves Le Gall sees this shift in the space landscape “as an opportunity to reinvent ourselves through innovation and inspiration,” two values that have guided the agency since

its inception in 1962 and which today run through its 2016-2020 objectives and performance plan. These are values that apply across the board to CNES’s core domains of science, Earth observation, launchers, telecommunications and defence, as well as to its more recent areas of research (see Round-up p.6-11). The agency’s recent restructuring is designed to put them into practice. The Directorate of Innovation, Applications and Science (DIA) created last year has been tasked with thinking outside the box with a view to boosting the new space economy and spurring new uses of space applications. In less than a year, it has already forged partnership ties with a range of users, among them the French national rail operator SNCF. It’s also looking to establish a market mindset, as today technologies—no matter how inventive—are no longer ‘sold’; rather, the key is to find an innovative technology and match it to a specific need. The new Directorate of Orbital Systems (DSO) is faced with another challenge: to develop disruptive technologies and processes to keep pace. In other words, costs need to come down, performance needs to be optimized and development cycles need to be shortened while retaining the same level of excellence. To serve the profusion of new applications, huge constellations of mini-satellites are poised to be orbited (see. p.22-23) and CNES is going to play a major role here. Last but not least, the new Directorate of Digital Technologies and Operations (DNO) is leading the agency’s drive to fully embrace the digital transformation. Satellite data are set to become the ‘black gold’ of the 21st century, and receiving, analysing and exploiting them in real time will be one of the biggest challenges in the years ahead.



Participants at CNES’s Innovation Day

This year’s event, where CNES presented its R&T budget (around €20 million for 2017), attracted record numbers.



CNES IN ACTION



... TO STAY IN THE GAME

Fisheries, agriculture, construction and public works, security, transport and healthcare are just some of the domains for which satellite data are now a vital resource. To meet all of their needs, we will have to conceive and operate new satellites, manage massive flows of data, and create new applications and services. Synergies between space and non-space applications must therefore be sought to change how we work. The Innovation Day organized by CNES in February in Toulouse was a good illustration, bringing together the space community with research laboratories, contractors, SMEs and start-ups from outside the space sector. "We're used to working with big industrial groups, but now we must help start-ups to develop their

business; they've got ideas and they're creative, and they're going to imagine and drive forward future applications underpinned by space," affirms DIA's director Lionel Suchet. Mid-tier firms working across a more diverse range of domains and offering greater flexibility are the final link in this chain. CNES is however closely watching developments, as such a plethora of new applications is not without risk (see Ethics corner p.33) and space is a sensitive sector. It will also be assuring that regulations governing the use of space evolve within the framework of the French Space Operations Act (FSOA). A new chapter beckons for the agency.

1. NewSpace or entrepreneurial space are terms that have been coined to describe the emergence of a new privately funded space industry.

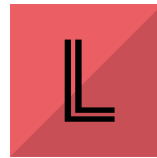


CNES IN ACTION

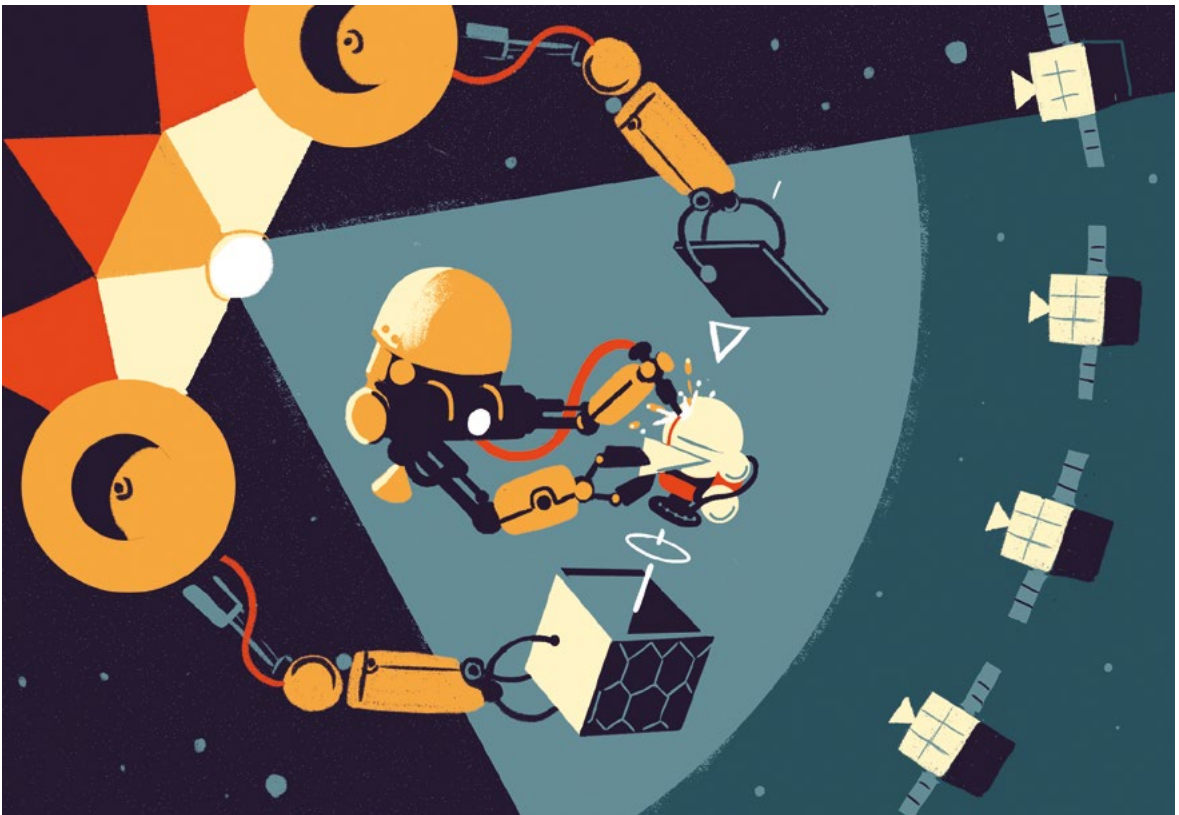
ORBITAL SYSTEMS

MEETING NEW MARKET CHALLENGES

Low-Earth orbit is set to be populated by constellations of thousands of small satellites. To gear up for this global revolution, CNES is helping manufacturers to adapt their production model and getting ready to apply the new rules of the game.



Low-Earth orbit (LEO) is becoming the new playing field for private players who see the opportunity to develop new markets there for global low-cost Internet services, non-stop Earth imagery and a myriad of other applications. This prospect is changing engineering practices, satellite technologies and space regulations in its wake. To reduce latency while gaining in flexibility and resolution, we need to orbit closer to Earth and embrace new concepts. In place of large monolithic satellites, new entrants and private players intend to employ constellations of small satellites weighing less than 150 kilograms—the size of a large washing machine—at altitudes between 700 and 1,200 kilometres.





CNES IN ACTION

CONSTELLATIONS ARE COMING

These 'flotillas' of satellites will offer the opportunity to ensure complete coverage of the globe and an uninterrupted supply of data. Custom-designed satellites must therefore make way for series production to bring down costs and shorten cycle times. While constellations are nothing new, they're being boosted by prospective sales of Internet services. Teledesic, the first large constellation project envisioned in the 1990s by Microsoft, was abandoned when the dot com bubble burst. Today, the strong dynamic driven by GAFA¹ is fuelling new and ambitious projects. Imagined by U.S. businessman Greg Wyler, the OneWeb constellation will initially consist of 672 satellites, with plans to grow to 2,000. SpaceX is also looking in the short term to establish a constellation of 4,425 satellites, and another longer term of 7,000 satellites, while Boeing is rumoured to be working on a constellation of several thousand satellites to support 5G services. CNES is watching this revolution with a close eye. To keep pace in this fast-moving context, it is aiding its SME and industry partners, who are going to need to ramp up their production model to turn out spacecraft at a rate of one or two small satellites a day, against one large satellite that currently takes 18 months to build.



Gain in latency
Low-Earth orbit (LEO) constellations are expected to reduce latency for Internet connections 40% compared to fibre-optic networks.

STAYING VIGILANT

Tasked with applying the French Space Operations Act (FSOA) on the government's behalf, CNES is taking a calm and clear-sighted approach to this proliferation of LEO satellites. The two most crucial issues are collision risks and clean-up at the end of satellite service life.

"Keeping thousands of small satellites on station in LEO is like moving from a country main road to a motorway, or finding yourself on the ring road in rush hour," says Philippe Marchal, Deputy Director of Orbital Systems (DSO). *"You need clear signage and new rules, and sometimes you have to manage problems with neighbours. How do you design an effective anti-collision system to ensure a smooth and safe flow of traffic? CNES is working on that."*

Keeping space clean is just as paramount. The small satellites making up these constellations are low-cost products with a limited service lifetime. How they will break up when re-entering the atmosphere therefore has to be factored in at the earliest stage of their design. That means using self-degradable materials to minimize risks on the ground. Here too, CNES is exercising its oversight and working with satellite manufacturers to address these new but crucial questions.

1. Google, Apple, Facebook, Amazon

ROBOTICS

SERVICING IN SPACE

Putting more small satellites in orbit obviously has the knock-on effect of increasing the risk of malfunctions.

Advances in robotics offer new solutions for conducting

maintenance in space. Tomorrow, robots could refuel, repair and upgrade satellites in orbit, enabling them to be recycled for other users. Only the future will tell if

such 'servicing' in space is a pipe dream or on the contrary a whole new off-planet economy.



CNES IN ACTION

THE FUTURE A HIVE OF INNOVATION

CNES has always worked closely with civil society and innovative firms gravitating around the space sphere. Today, this sphere is evolving with the arrival of new market entrants fuelling a new intermediate economy.

As the linchpin of Europe's space programme, CNES has always worked to establish strong ties with other space players, research laboratories and industry. Now, new entrants are expanding this circle. While the scientific and institutional partners of the early years remain contacts of choice, the agency has also forged links with public authorities and start-ups with a close interest in space. Setting its sights on the future, it now sees its role as a mediator between the space sector and potentially profitable new applications.

NEW, ORIGINAL MODELS

To anticipate all possible new developments, CNES is working to set up a future space-planning observatory called Spacibles. *"This observatory is designed to identify possible futures and think about how we want to shape them, as well as to conceive strategies to make them a reality,"* says Michel Faup, who leads up the Innovation and Long-Term Vision team at the agency's Directorate of Innovation, Science and Applications (DIA). The observatory brings together all ecosystem partners to form a long-term vision. Its first planning workshop at the end of the year is eagerly awaited. CNES is also reaching outside the space sector to other research laboratories and contractors, as well as to the general public and students. To this end,



Ultimately, this set of 50 cubesats¹ will serve to propose and validate new technologies in orbit. Their novel feature is that they are all being designed by universities. CNES is helping to build the constellation through its Janus student engineering programme which will supply four cubesats.

it has created a structure called Federation to map out the challenges facing us and the means to address them together, to which each member is contributing its expertise and enthusiasm. Start-ups are in the vanguard of these new entrants. CNES was already providing its support through competitiveness clusters, the ActInSpace competition, the ESA BIC incubator and Starburst, and since 2016 with CnesTim it has sought to form a closer relationship with them. As part of its mission, the agency is watching over these young firms to help identify their needs, strengths and weaknesses, with a view to energizing an increasingly competitive market—putting it at the heart of a hive of innovation buzzing with ideas.

1. Small cube-shaped satellite 10 cm on each side, weighing no more than 1 kg



CNES IN ACTION

LAUNCHERS ARIANE NEXT

Ariane 6 is well on track for its maiden flight in 2020, but CNES is already working on the launchers of the future. With Ariane Next, it is anticipating the new challenges that are going to govern space in the future.



here's more to inventing the future than simply calling up futuristic technologies. It also involves planning, thinking and acting differently, by combining engineering and ingenuity. This new approach is what India calls 'frugal innovation' or *jugaad*, the 'secret of success'. Far from being the latest fad, frugal innovation is a genuine business strategy and this is one of the approaches that CNES is experimenting for Ariane Next, the launcher of the future.

OPTIMIZING TO ADAPT

Ariane 6 will combine industrial efficiency, innovation and mature technologies. Entering service in 2020, it will significantly reduce space launch costs. But that's not enough; the next generation needs to make a quantum leap, with lower investment, short design cycles and even cheaper launchers. Frugal innovation will be the key to meeting this challenge, for example by cutting development times. Here, Ariane Next won't be starting from scratch; by relying on Ariane 6's design heritage and using simple technology prototypes, it should be possible to reduce them by half. It will also employ Prometheus (see Roundup p.7), a robust and reliable engine less sophisticated than Ariane 5's Vulcain workhorse, making it ten times cheaper and twice as quick to build. "By adopting flexible or reconfigurable solutions wherever possible, Ariane Next will be better adapted to the requirements of fast-changing markets," ex-



The estimated cost of launching to geostationary transfer orbit with Ariane 5 is €20,000/kg. Ariane 6 will reduce that by half. The target for Ariane Next is €5,000/kg.

plains Jérôme Vila at CNES's Future and Innovation for Launchers Sub-directorate. As well as proving flexible from a service standpoint, Ariane Next will also need to devise an agile production model to adapt capacity to fluctuating rates, ramping up to keep pace with launches of new constellations or on the contrary scaling back if the commercial market contracts.



CNES IN ACTION

BIG DATA ALL ABOARD THE DIGITAL TRAIN

Data are the 'black gold' of the 21st century now flooding the space sector. And there's more to come, which is why CNES has engaged a wide-ranging digital transformation.

Data from space have become the raw material fuelling our economies. How to exploit them fully is a key challenge, and as a pioneering space agency CNES is well aware of this fact. It is integrating new technologies to ensure the profusion of data from its multiple missions is rigorously managed. Augmented reality is entering the clean room (see Materials p.27), virtual reality is being used for predictive maintenance with connected embedded objects on spacecraft, and additive manufacturing (see Roundup p.7-11) is increasingly employed in satellites, launchers and more. Real-time processing is enabling immediate, predictive interpretations during launches. Multi-date, multi-mission processing chains are changing models and forecasts. Machine learning is attracting close attention as a means of saving engineers precious time that could be used more gainfully in analysing results. CNES is also applying artificial intelligence to deliver analysis, not before or after, but just when needed.

3,000

satellites

weighing 1 to 50 kg will be launched over the next 7 years, sending back exponential streams of data of all kinds.

CULTURE SHIFT

The agency is also looking at this phenomenon from a business perspective. It has engaged its digital transformation and is making a far-reaching culture shift, underpinned by collective intelligence, experimentation, cross-functional working and knowledge sharing. CNES is helping its teams to make this transition. "For such a culture shift to be successful, management has to fully embrace the transformation and provide leadership while encouraging innovation and creativity," says Cathy Lacomme-Verbiguié, Chief Digital Officer and Deputy Head of the Digital Enterprise sub-directorate at the Directorate of Digital Technologies and Operations (DNO). But this change isn't an end in itself and a virtuous process of continuous evolution must be instilled to adapt to new market requirements.





MATERIALS

AUGMENTING REALITY

ASSEMBLING A SATELLITE IS ANYTHING BUT CHILD'S PLAY. It's a critical phase involving thousands of components, complex processes and very tight safety standards, which is why CNES's assembly, integration and test (AIT) teams are experimenting with augmented reality to replace long and tedious paper procedures. Combining reality and computer-assisted design (CAD), augmented reality makes it possible to check that everything matches plans and drawings in the slightest detail. Capgemini has conceived augmented reality software¹ to support the various stages of assembly, inspection and testing, providing a precise baseline for teams. By tracking mistakes, enhancing safety and shortening integration time, augmented reality is proving a precious aid.

1. Built around technology developed by SME Diota



TIMELINE



FACT

UNEQUAL ACCESS

Only 0.007% of Earth's water is accessible for human consumption, and by 2025 nine billion people will be drawing on this scarce resource. To make matters worse, it's unevenly distributed around the globe. For example, Asia is home to 60% of the world's population but only has 6% of its water. Quality is another key factor, as every year 3.6 million people die through lack of potable water. And water is also a hot-button political issue, as with 323 cross-border catchments around the globe, sharing of resources is fuelling major conflict—a geopolitical situation that scarcity may make worse.



MANAGEMENT

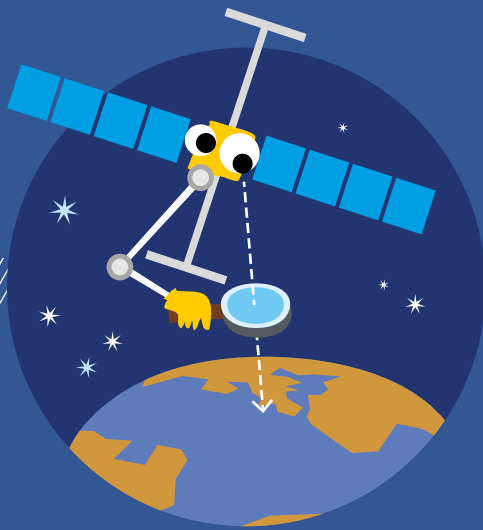
SENSING FROM SPACE TO THE RESCUE

Satellite imagery is clearly a great tool for predicting and managing water resources, as it offers a broad, synoptic picture of the reality on the ground. For example, it yields vital information about flooding, drought, crop monitoring and irrigation, and soil salinization. Analysis of such data informs action plans to monitor resources, mitigate risks and cope with the consequences of extreme situations. Satellite imagery is also diplomatically neutral, acting as a regulator by supplying objective data.



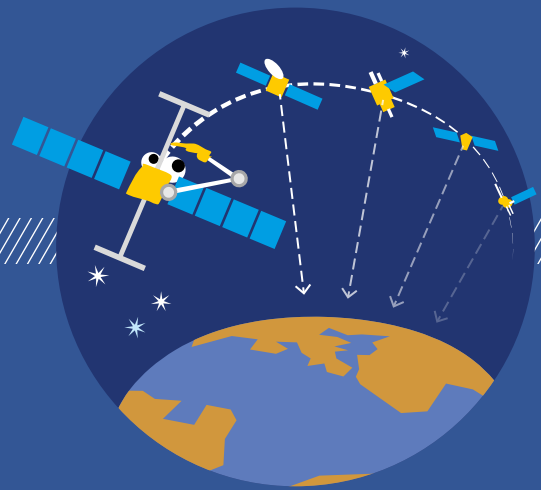
TIMELINE

THE COP 21 AND COP 22 PUT THE WORLD ON NOTICE THAT POTABLE WATER IS A COMMODITY UNDER THREAT. THIS “BLUE GOLD” IS SET TO REPLACE THE “BLACK GOLD” OF THE LAST CENTURY. WHILE THEY OBVIOUSLY CAN’T MAKE IT RAIN, SATELLITES ARE A PRECIOUS AID IN DELIVERING OBJECTIVE DATA TO INFORM MORE CAREFUL STEWARDSHIP OF RESERVES.



MONITORING SWOT ON WATCH

SWOT (Surface Water and Ocean Topography) is a joint NASA/CNES mission. The satellite’s two radar antennas perched at the end of a 10-metre boom—the size of a bus—will afford continuous coverage of a 120-kilometre swath where current radar altimeters can only ‘see’ strips of a few kilometres. SWOT will measure slopes and surface water heights and their variations in lakes, rivers and other water bodies. Such data will significantly improve hydrodynamic models used to monitor surface waters. A preparatory programme is helping future SWOT data users to gear up to supply new services.



LOOKING AHEAD PRESERVING WATER CAPITAL

To manage our planet’s water capital, we need to start planning SWOT’s successors now and combine measurements from other satellites like the Sentinel series and Pleiades to build up a spatial water database capable of underpinning long-term applications for tracking and preserving this vital resource. This strategy will follow the lead of the COP 21 and its Paris Pact on Water, and will support the United Nations’ active efforts to deal with the climate change threat, to which France can clearly be a key contributor.



HORIZONS

ROLAND LEHOUCQ

President of Les Utopiales

“Sci-fi is like a fictional laboratory speaking into our world today...”



Astrophysicist at the French atomic energy and alternative energies commission CEA, lecturer at the École Polytechnique engineering school and the IEP political studies institute (Sciences Po) in Paris, President of non-profit organization Les Utopiales and author of numerous books, Roland Lehoucq doesn't just make the most out of life; he devours it with passion! Can we study the 'shape' of the Universe? Is it finite, or without edges? These are the kinds of questions the researcher is asking. So, from science to science fiction, it's only one small step for someone with such a fertile imagination. Roland Lehoucq spends a lot of time pursuing his passion for science outreach and sci-fi. **For the last**

six years, he's been President of Les Utopiales, the non-profit organization supporting the annual international science-fiction festival in Nantes. Providing his intellectual imprimatur for the festival, Roland Lehoucq has brought more science to the programme while promoting science fiction, the only literary genre focusing on science and technology, as a catalyst for debate around its repercussions for humanity. **“It's a fantastic intellectual exercise to look ahead and anticipate the potential consequences of technological innovation,”** he says. *“Who'd have thought that, instead of Big Brother, today's digital technologies would spawn a generation of Little Brothers, all posting*

their thoughts and observations. Science fiction is entertainment, but it also makes you think. It draws inspiration from science to fill us with awe, while sounding a cautionary note about where it could lead. Sci-fi is one step ahead in space and time, like a fictional laboratory speaking into our world today.” Whether he's talking about Tintin, Superman or Darth Vader, they all offer a fun excuse for conversation about science. So, as a sci-fi enthusiast, what are his hopes for space exploration in the future? *“I'd love humanity to explore the solar system more extensively, then venture into deep space. But huge resources would be needed. And in the meantime, we need to better manage our own planet.”*



HORIZONS

BERTRAND DEZOTEUX

Creator of *Waiting For Mars*

“Artists aren’t scientists,
we’re here to share a perception...”



“Ordinary folk, not athletes, polyglots or real-life heroes”—that’s how Bertrand Dezoteux, creator of the *En attendant Mars* (Waiting for Mars) exhibition at a Parisian gallery in February, described the six people who took part in Russia’s Mars 500 experiment. Conducted in 2010, it simulated a mission to Mars in conditions close to reality, with a 520-day journey in the confined space of a mockup craft, complete with communication timelag.

Trained in digital imagery and animated film, Bertrand Dezoteux, whose other passions include cartoons and sci-fi, recreated their experience in an exhibition about the daily life of those pseudo-astronauts,

who never left Earth. A stationary voyage, with ordinary interiors, six volunteers in jogging trousers and vests, playing the guitar, slouched in an armchair or sat at the kitchen table, microwave on one side, broom on the other. A far cry from the polished image of sophisticated technologies and high levels of fitness and self-control we usually associate with space missions. The exhibition was accompanied by two short films about the fantastic and mundane aspects of the experiment.

“With the exhibition mannequins, I wanted to explore the sense of melancholy, which is a side of human space travel no one seems to talk about. As an artist, I was keen to get

inside the hearts and minds of these guys, who’re presented as superheroes. Artists aren’t scientists. We’re here to share a perception, something you feel.” That’s how Bertrand Dezoteux describes his artistic approach.

As the winner of a competition launched by CNES’s Observatoire de l’Espace as part of its ‘outside residence’ programme, and recipient of the Audi Talents Awards 2015 prize in the contemporary art category, he was invited to interview the Mars 500 participants in Russia, visit the facility, document their life inside the craft and draw inspiration from the film produced by the Russian space medicine institute (IMBP) in Moscow.



HORIZONS

DIANE DELBÈGUE

PhD student at Clermont-Ferrand Institute of Chemistry

“I want to improve
battery performance in space...”



Chemists and pastrycooks proceed in pretty much the same way, putting several things together and watching what happens! Third-year PhD student Diane Delbègue is both. She's working on a thesis jointly funded by CNES and the Auvergne regional council at Clermont-Ferrand Institute of Chemistry (ICCF). She also has a vocational qualification as a pastrycook, which she did as an external student during her master's degree. Her thesis title is “Lithium-ion battery with transition-metal fluoride cathodes”. For those of us without a PhD in chemistry, what does that mean? “I'm seeking to improve the performance of the batteries we send into space,” she explains. “A battery

is basically a positive electrode, a negative electrode and an electrolyte.

We're focusing on the positive electrode, which is currently the weak link in Li-ion battery performance

My goal is to develop new electrode materials. By incorporating fluorine into the positive electrode, we've already observed a 30% increase in battery life. But we need to understand more about the chemical mechanisms behind electrical discharge, because batteries discharge faster with time.”

It will take time before we know how these batteries perform in flight.

However, her research has attracted the attention of industry, where she plans to work after her PhD.

Diane is also a talented communicator, winning the prize for best poster at CNES's IC2 young researchers' forum in October 2016. Violinist and pastry maker when the mood takes her, she admits a weakness for red berry charlotte. So temptingly made that no amount of research into the lifespan of cream will make a slice last any longer!



ETHICS CORNER



JACQUES ARNOULD

POSSIBILITIES

Space isn't just a physical place. It's a whole set of technologies to be invented and developed, driven by the projects and endeavours we undertake. Thus, the future of space can be nothing other than human.

How can we ignore the words of the wise teachers of civilizations past, who speak caution to those who pursued and still pursue dreams of conquering the world or, conversely, building huge grain stores for a future without risk? “*Vanitas vanitatis*,” says the writer of Ecclesiastes. “*All is vanity!*” Yet has Mother Nature not endowed humans with an imagination? A brain capable of thinking beyond the here and now and projecting into the future? So, why wouldn't we imagine our tomorrows, make plans, lay foundations and erect the scaffolding? In short, invent things before we build them? What kind of world would we be living in today if our ancestors had taken literally the words of that same Middle Eastern teacher, now enshrined in our dictionaries of quotations: “*Nihil novi sub sole – there's nothing new under the Sun*”? On the contrary, we stand on the shoulders of those who dared not only to face the uncertainty of their tomorrows but, more importantly, invented them.

THE DEMANDS OF REALITY

At the dawn of modern times, space offered those bold visionaries a seemingly boundless realm. At the end of Galileo's telescope, it stretched out like a new sea, inspiring their insatiable minds to dreams

of exploration and enterprise. A few centuries later, scientific progress on their side, the pioneers of astronautics sized up the technical challenges to be overcome, proposed hypothetical solutions and invented the first rockets. And in so doing, their tomorrows became our today. As historians and experts tell us, not all the promises of destinations and timeframes have been kept. That's not surprising when we remember that space isn't just a place, but a whole set of technologies. In other words, it's about what we do there and what we make it, according to our technical abilities, our political and economic decisions and our legal and ethical choices. However important our imagination, no invention can ignore, much less spurn, the demands of reality. Otherwise, it may forever remain a work of pure fabrication.

Invention requires us to think carefully, outline the possibilities and prospects and, perhaps, admit some of the boundaries and limitations. Space, as a place and a set of technologies, can't escape this human rule. Clearly then, inventing the future of space will be closely tied to our ability to invent the future of humankind.



INSIGHTS

YOUNG RESEARCHERS' FORUM PART 2

Through their research, PhD and postdoctoral students at laboratories in France make a key contribution to advances in space. In return, CNES supports them each year through thesis and postdoctoral contracts. For the last two years, CNES has brought them together at events called young researchers' days. At the IC1 open days on 14 and 15 March, CNES welcomed 60 new PhD students and 15 postdocs at the Toulouse Space Centre (CST) to show them round the facility and establish dialogue. They will be back at the CST for the IC2 event, 2 to 4 October, to present their own work.

BOOK *Turbulence in the Universe*



As we explore space, what if we find evidence of life, or proof that sentient beings exist on other planets? What would be the implications for our religions? Highly instructive and edifying like his successful previous books, author, scientist and theologian Jacques Arnould retraces the history of this age-old question.

Dieu, les extraterrestres et nous by Jacques Arnould - Published by Albin Michel - 279 pages - €19

NEWSSTAND Special issue of *Espace(s)*

Issue 14 of *Espace(s)* magazine is now out! The theme of the call for articles was "Space, a place of utopias". Outside the usual remit of science fiction, writers and artists offer a new take on the prospects for human life beyond Earth, from utopia to dystopia.



EVENT ACTINSPACE

To invent the future, CNES and ESA launched ActInSpace, an international space-themed hackathon. Candidates have just 24 hours to invent a future product using space data. The 2016 competition attracted 896 entrants from 12 countries, plus 208 start-up proposals. This year, the third edition will be officially launched at the Paris Air Show on 22 June in the presence of numerous overseas delegations. See you at the CNES stand. Don't miss it!

SIDÉRATION FESTIVAL SPACE UTOPIAS



On 24 to 26 March, CNES headquarters in Paris hosted the 7th Sidération festival, organized by the agency's Observatoire de l'Espace.

This diverse three-day event explored the promises of new societies, born out of the desire for a better life or the intent of one state to achieve dominance over others. It looked at all aspects of habitable space environments: poetic, domestic, political and utopian. Issues raised by the various artistic contributions included what kind of societies could be created in space, how socio-economic models might need to be reinvented and what off-planet cultural and tourist attractions might look like.



INSIGHTS

INSPIRATION

OPEN SPACE



Since 2000, the **Observatoire de l'Espace, CNES's art and science laboratory**, has been pursuing a highly original initiative to foster knowledge and creative design with a space flavour. It supports artists with an interest in the sector by providing input and inspiration for their work. *"We give them access to documentary and multimedia resources as well as opportunities to meet astronauts, researchers and historians,"* says Gérard Azoulay, Head of the Observatoire. *"We can also help arrange visits to dedicated facilities or make CNES's technical resources available."* The artists typically offer a critical and objective take on society. A prime example is the recent exhibition by Bertrand Dezoteux entitled

'En attendant Mars' (Waiting for Mars, photo above). Some have created a vision of space with real promise for the future, like *Télescope Intérieur* (Inner Telescope) by Eduardo Kac, an artistic experiment performed on the International Space Station by astronaut Thomas Pesquet. In the 19th century, space was limited to ground-based astronomy. Today, astronomy is just one field of space exploration. *"Space impacts all areas of human endeavour, from physics, biology, Earth science and medicine to history, philosophy, visual art, design and architecture,"* concludes Gérard Azoulay. *"Space inspires the imagination and, as such, is a rich source of inspiration for artists."*

➔ WWW.CNES-OBSERVATOIRE.NET/



DIARY

19-25 JUNE

52nd International Paris Air Show
Paris-Le Bourget
exhibition centre, France

2-4 OCTOBER

CNES young researchers' forum (IC2)
Toulouse, France

7 OCTOBER

Nuit Blanche festival
Paris, France

17-19 OCTOBER

2nd Ground Based Space Facilities Symposium
Toulouse, France
<http://gbsf2017.com>

28-30 NOVEMBER BiDS 17

Conference on Big Data from Space
Pierre-Baudis conference centre, Toulouse, France
<http://www.bigdatafromspace2017.org/>

BOOK

When nature inspires science

Like an encyclopaedia, this book sets out to tell us everything about a science inspired by plants and animals. Biomimetics is today more relevant than ever, even for studying comets up close.

Quand la nature inspire la science by Mat Fournier, illustrations by Titwane, published by Plume de Carotte, 2016 re-issue, 160 pages, €35



SPINOFF

ROSETTA LIVE

SPACE ENTERTAINMENT

3D interactive space video is coming to your screens! Jean-Christophe Barré, the designer of the Rosetta Live application, tells us how his invention is enabling a new way of sharing space experiences.



With a glint in his eye and his infectious enthusiasm, Jean-Christophe Barré just loves recounting his adventure. Before bringing his idea to fruition, he spent many hours in his job as an engineer watching Ariane 5 launches at Arianespace. After securing training leave, he did a

master's degree in Interactive Digital Experiences at the Ecole des Gobelins to learn all about interactive systems. He then developed his application, Rosetta Live, and embarked on a new career in space video.

INSIDE THE ROSETTA MISSION

Rosetta Live is a 3D interactive film created to watch the last hours of the Rosetta mission in September 2016. As well as charting the spacecraft's final minutes, the film retraces the 12-year space adventure of the Rosetta orbiter and its accompanying Philae lander, right up to the moment the orbiter made its controlled descent to the comet's surface. "The application turns your mobile device into a pair of interactive binoculars and takes you inside the Rosetta mission in 360°, using the actual trajectories and data from the spacecraft," explains the young engineer. The mission may be over, but the application has lost none of its appeal. Jean-Christophe Barré is now entering the commercial market and already has a version of Rosetta Live on the U.S. Steam digital distribution platform, thus providing a sure stream of revenue from downloads to generate a return on investment. Looking further ahead, he's working on a live screening of an Ariane 5 launch some time in 2018, as well as Ariane 6's maiden launch, with two goals in sight: "to match the level of video excellence achieved by SpaceX and to make the transition from self-employed entrepreneur to start-up." Space entertainment has a great future ahead of it.

EN

4.8/5

Average rating
given by mobile users of
Rosetta Live