CNES MAG

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SPACE ● INNOVATION ● SOCIETY

#77
July 2018

MINIATURIZATION

SMALLSATS STEP UP TO THE PLATE

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CENTRE NATIONAL D'ÉTUDES SPATIALES

INSIDE

PARTNERS

Mentioned in this issue: p. 6/10/26 European Space Agency (ESA); p. 10 Comat (equipment designer and supplier for space and industry), Air Liquide and start-up ThrustMe, a spin-off from the Ecole Polytechnique's research centre; p. 10 Syrlinks (firm specializing in RF communications and geolocation); p. 11 Sodern (ArianeGroup subsidiary specializing in optronics) and 3D+ (electronic component manufacturer); p. 16 CLS (Collecte Localisation Satellites), a CNES subsidiary; p. 18/36 Aerospace Valley competitiveness cluster; p. 22-23 Thales Alenia Space; p. 28 ISAE/Supaero (the world's leading aerospace higher-education institute) and ENAC (French national civil aviation school).

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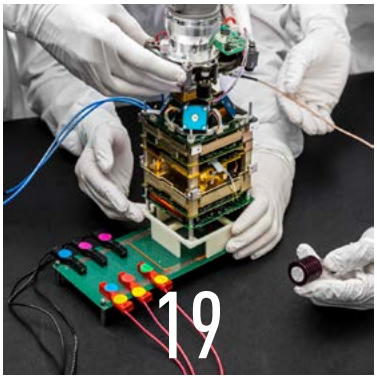
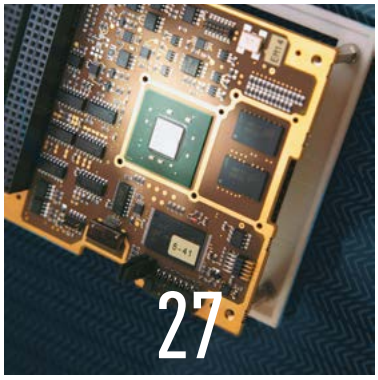
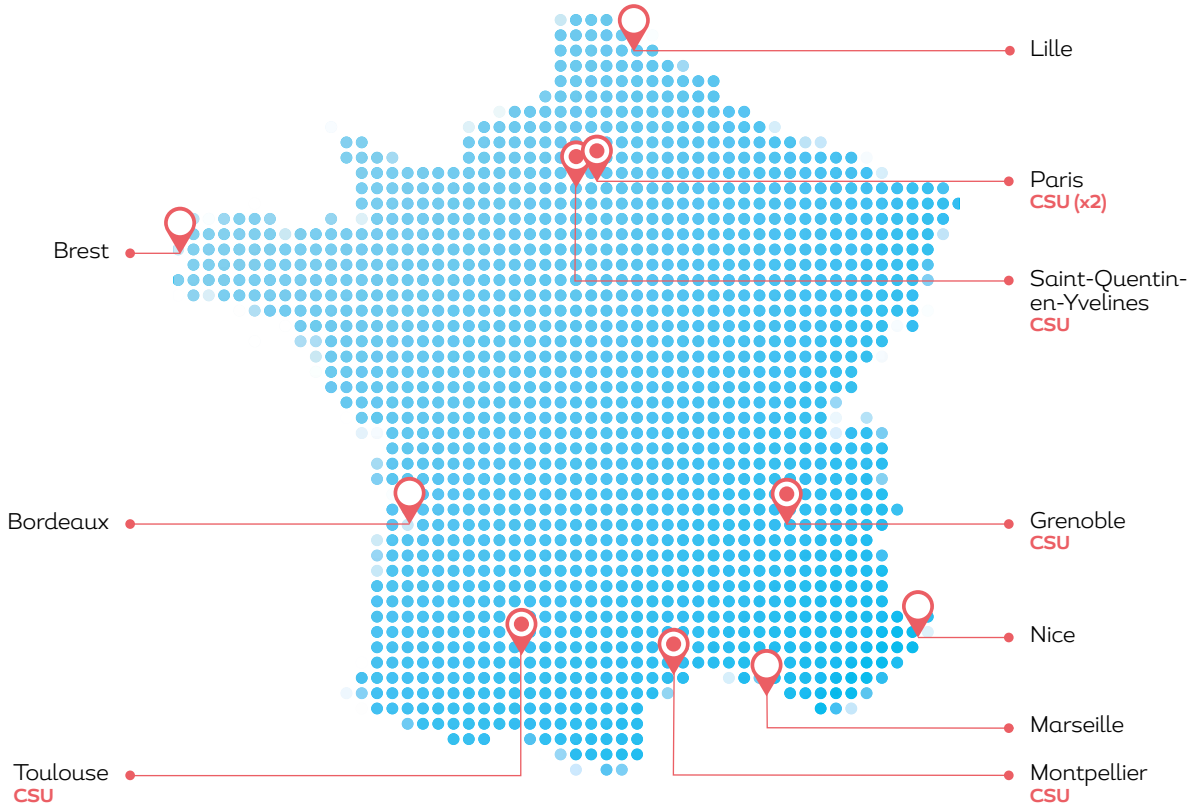




THE JANUS NETWORK

19 higher-education institutions in 10 French cities, including 6 university space centres (CSUs)



CONTRIBUTORS

AMÉLIE PROUST

Amélie Proust is a committed woman whose work has always centred on humans and our planet. So it's not surprising that today she's in charge of science communication at CLS. She's a strong voice for protected species and all those who work at sea and rely on the Argos system. For this issue, she recounts a moving meeting with Abdoulaye Seck.

ALEXANDRE OLLIER

Alexandre Ollier is an alumnus of the ETPA photography and game design school, where he was awarded the special jury prize in 2015. He's an artist/photographer with an eye for detail and the sensibility of the moment. Invited to the ImageSingulières photography festival in 2017, this aesthete has an equal penchant for technical aspects and taking the shot. All of his photos have soul, as in the opening article of CNES in Action.

OLIVIER PASCAUD

Olivier Pascaud is a portrait photographer who likes his subjects. For him, photography is a chance to meet some fascinating people. He captures a look, an expression or an attitude to reveal their innermost nature. Pacôme Révillon's human qualities shine through in the portrait he took for Q&A.

THIBÉRY CUSSAC

CNES's nanosatellite project leader

Thibéry Cussac embarked on the adventure after a long career as an engineer working on several missions. He knows all about miniaturization for large satellites. Today, he's in charge of the CNES-Nexeya technical platform and is supporting the firm up to the launch of ANGELS, the first French nanosatellite.

CNES MAG

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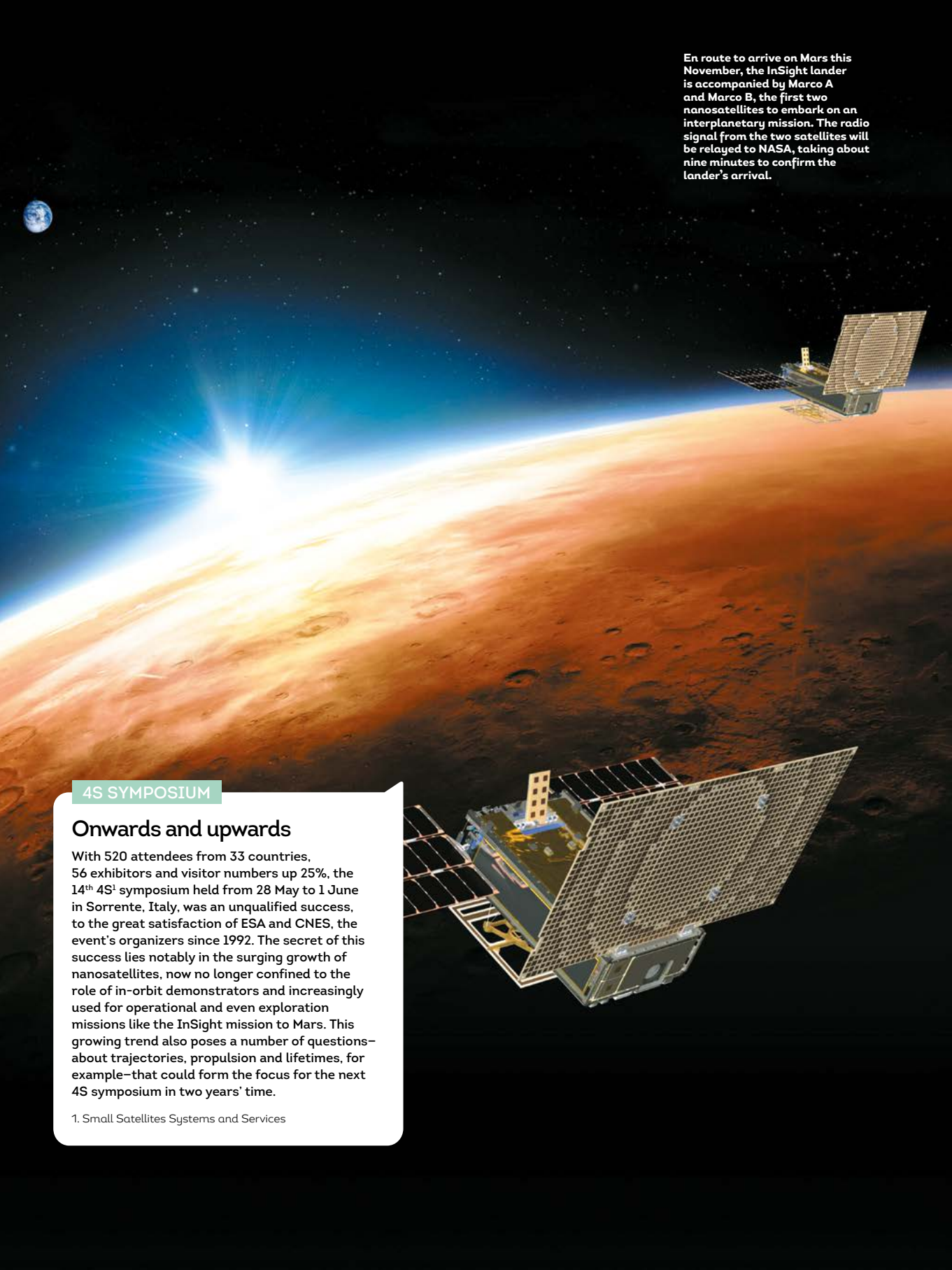
EDITORIAL

Mini-, micro-, nano- and pico- are the new prefixes ruling the world of satellites today. Why? Because space too is riding the wave of the digital revolution and its stupendous technological advances. Where not so long ago we were lofting full-blown telescopes into space to observe our planet or survey the stars, today a mini-camera weighing only a few grams is capable of sending back fantastic pictures. This evolution is akin to that of the amateur photographer, once weighed down with their 1-kg camera and 30-cm zoom lens but now taking hundreds of photos with their smartphone. And this miniaturization trend is also modifying the world of telecommunications with a profusion of projects turning to small satellites. The consequences of this revolution are considerable, as they are driving down the cost of getting into space, with the result that more and more nations now have their own satellites and private space projects are on the up, fuelling exponential growth in the range of space applications. In short, we are seeing the same kind of revolution that transformed the information technology industry just 20 years ago, as miniaturization is now changing the playing field in space.

JEAN-YVES LE GALL
CNES PRESIDENT



En route to arrive on Mars this November, the InSight lander is accompanied by Marco A and Marco B, the first two nanosatellites to embark on an interplanetary mission. The radio signal from the two satellites will be relayed to NASA, taking about nine minutes to confirm the lander's arrival.

4S SYMPOSIUM

Onwards and upwards

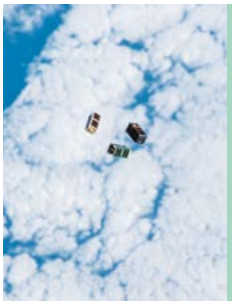
With 520 attendees from 33 countries, 56 exhibitors and visitor numbers up 25%, the 14th 4S[1] symposium held from 28 May to 1 June in Sorrente, Italy, was an unqualified success, to the great satisfaction of ESA and CNES, the event's organizers since 1992. The secret of this success lies notably in the surging growth of nanosatellites, now no longer confined to the role of in-orbit demonstrators and increasingly used for operational and even exploration missions like the InSight mission to Mars. This growing trend also poses a number of questions–about trajectories, propulsion and lifetimes, for example–that could form the focus for the next 4S symposium in two years' time.

1. Small Satellites Systems and Services

NANO CLUB

TOWARDS A NATIONAL INDUSTRY

The Nano Club is an open structure created in 2016 at the last Toulouse Space Show to federate players from the public and private sectors focusing on satellites in the under-50-kilogram class. As the leader of this initiative, CNES is looking to foster sharing of experience and encourage stakeholders from academia, institutions and industry to work together, with a view to nurturing a national nanosatellite industry. A survey of European stakeholders was completed in 2017, followed by thematic workshops on payloads, launchers and technologies to address their concerns. At the end of March 2018, the club's annual seminar welcomed some 60 participants in Paris, where it was decided to create a platform for exchange. Above all, this momentum is driving the partnership between CNES and Nexeya, which has paved the way for the French ANGELS industry demonstrator (see CNES in Action p. 22).



6,200

More than 900 cubesats have been launched since 1998 and a further 1,000 are expected to reach orbit between now and 2021. Aerospace analysis firm Euroconsult estimates that 6,000 small satellites are likely to be launched over the next decade.

NANOSATELLITES

MEET THE FAMILY

Nanosatellites come in various sizes, from pocket satellites to picosatellites or cubesats (see p. 9). Besides their small form factor and low power consumption, they share many other features, such as a very low cost and limited lifetime (six months to three years on average). They therefore fully embrace the ethos of the French Space Operations Act (FSOA), which stipulates that once a satellite on a trajectory less than 600-650 kilometres from Earth reaches the end of its life, it must re-enter the atmosphere in less than 25 years. Most nanosatellites are operating without propulsion in low Earth orbit, but in the not-so-distant future they could be used in higher orbits and even for deep-space exploration missions. What's certain is that with burgeoning applications driven by the Internet of Things (IoT), climate monitoring and Earth observation, the future for these new 'service providers' looks bright.

CAREER

SPACE BROKER

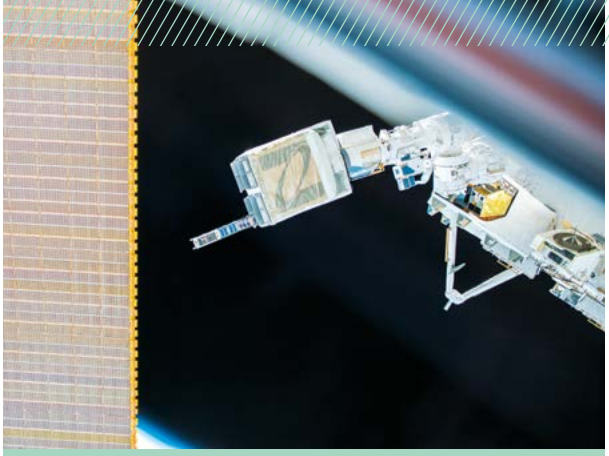
Need a nanosatellite for a commercial application or technology demonstrator? For all logistical and administrative matters, a space broker can help! This isn't a new line of work, but it wasn't that common until now. A broker is the contact between a client and a launch services operator. Ahead of any inquiry, they book launch capacity—for example, 50 slots on Vega—and then offer it on the Internet. But as well as the launch slots, they also sell shipping and integration of the nanosatellite, supply ground station services and more. As they work with several providers, they can put you on the first available launch that fits requirements. While launch services operators and satellite clients were for a time a little wary, these new professionals have today succeeded in gaining their trust while helping to massify launch requests.

NOIRE

A NEW WINDOW ON THE UNIVERSE

In radioastronomy, NOIRE[1] is no longer just the colour black in French but a concept that could revolutionize space-based observation. There are currently no antennas large enough to survey the sky at low frequencies, that is, under 300 MHz. An interferometric array of 7,000 ground-based antennas is capable of 'imaging' the sky at these frequencies, but it can't actually 'see' anything below 300 MHz because of Earth's ionosphere. The NOIRE concept turns the problem around by deploying a radiowave observatory in space far enough from Earth to avoid interference from human radio transmissions. It will accomplish this using a 'swarm' of nanosatellites placed varying distances apart to form a synthetic antenna array spanning several hundred kilometres. Each satellite will form a separate sensor and together they will scan the sky with unprecedented spatial resolution. Developed within CNES's PASO[2] orbital systems architecture department, the project recently entered the technology maturation phase.

1. Nanosatellites pour un Observatoire Interférométrique Radio dans l'Espace
2. Plateau Architecture Systèmes Orbitaux



ISS

CUBESAT LAUNCH BASE

The crew of the International Space Station (ISS) aren't all alone, as they're regularly resupplied by cargo flights, which in recent years have also started ferrying cubesats. From its outpost in low Earth orbit, the ISS has become a launch base for these small satellites. Cubesats are deployed from the station by a robotic arm attached to the Japanese Kibo module, interfacing with deployers designed by U.S. firm NanoRacks. Each deployer accommodates up to six cubesat units, depending on their configuration (6x1U, 3x2U, 2x3U, 1x6U). The arm can handle up to eight deployers, so the station is able to launch 48 units in one go. The wait to deploy a cubesat from the ISS is usually one to three months. In April 2017, 28 cubesats were orbited for the QB50 project, two of them—X-Cubesat and Spacecube—for the Janus student nanosatellite project (see the tweet from Thomas Pesquet p. 12).

1U, 2U, 3U

The basic nanosatellite unit is 1U, i.e. a cube of 10 cm x 10 cm x 10 cm, weighing no more than 1.33 kg and consuming no more than 1 W. Satellites may be made up of multiples of this unit. For example, a double cubesat (2U) is 10 cm x 10 cm x 20 cm, weighs 2.66 kg and consumes 2 W.

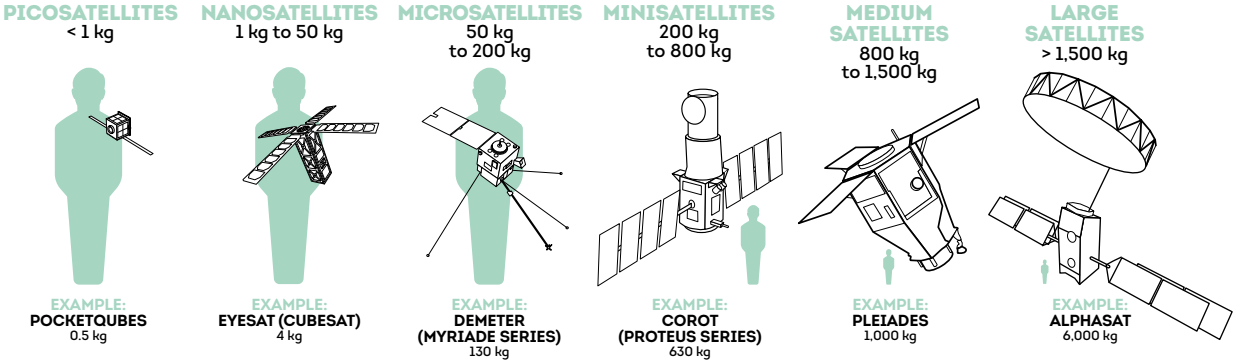
888

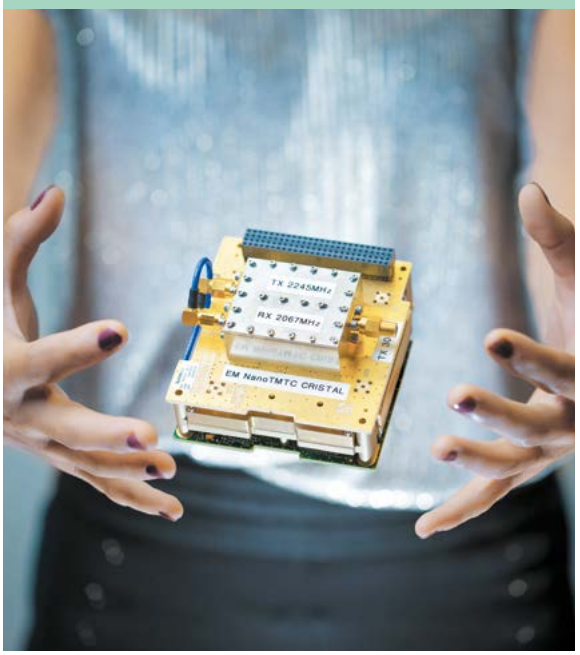
Nanosatellites launched piggyback in nearly eight years—257 had been launched before September 2017.

QB50

Partly funded under the European Union's 7th Framework Programme (2007-2013), QB50 is a project to deploy a constellation of 40 student cubesats. Each cubesat built by a university will carry a scientific instrument to study the thermosphere.

SATELLITES OF ALL SIZES





COMMUNICATIONS

HIGH-PERFORMANCE MODEM

Prototyped for the Janus project, the new telemetry-and-telecommand nanotransmitter/receiver is operating on several international, ESA and CNES missions. Built by Syrlinks, this high-performance modem developed by CNES's research-and-development teams relies on new-generation components and large-scale integration of radiofrequency functions. It supports Earth-to-space and inter-satellite communications (between satellites in low Earth orbit) and deep-space exploration missions, for communications between an orbiter and several small landers. An inter-satellite ranging function has now been added from a CNES demonstrator and the space-to-ground version is also compatible with the ranging function. The range of applications of these technologies also limits development risks for systems designed for microsatellites like those built around the Myriade Evolutions bus.

SENSOR

NAVIGATING IN SPACE

Like shepherds, satellites rely on the stars to guide them. Their star tracker is pointed at the celestial vault to keep the satellite correctly positioned. But fitting an entire constellation with star trackers is costly. French firm Sodern has therefore developed an affordable new-generation star tracker called Auriga, re-using a 'building block' developed by 3D+ for CNES's research and technology programme. This component features a number of functions as well as the star tracker. Preliminary studies verified the star tracker's viability and fit to requirements. While Auriga may be a low-cost product, it nevertheless relies on proven expertise tested on previous generations of star trackers, and it has succeeded in allying lightness and compactness with a competitive cost. CNES has provided support to Sodern throughout the development process, with the result that the firm has been contracted to supply 1,800 star trackers for the 900 minisatellites of the future OneWeb constellation.

GEOLOCATION

CHIPS GETTING SMALLER

To reduce mass and cost, CNES is looking to achieve economies of scale that go to the core of subsystems, notably in electronic chips. Boosted by applications like mobile telephony, latest-generation chips have seen major evolutions in integrated circuits and ever-smaller feature sizes. Like for mobile phones, these improvements are driven by compactness and weight, with processor mass halved and weight gains cascaded down to every subsystem element. Such electronic components, used initially for nanosatellites, can also be adapted to microsatellites in CNES's Myriade and Myriade Evolution series.

ENERGY

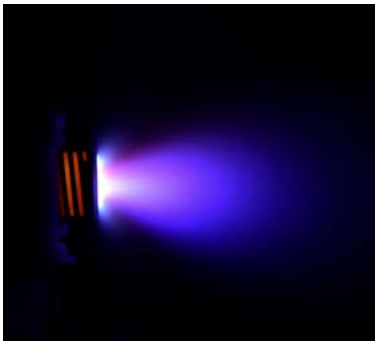
THE RIGHT BALANCE

A service life of two to three years isn't very long, and a nanosatellite faces the same constraints in orbit as a larger spacecraft, having to maintain its systems in good working order and ensure a constant supply of power to its payload. The key is the power consumption/size ratio, which must be carefully tailored to mission requirements. CNES achieves this by 'resizing' the solar array: where a telecommunications satellite will be carrying thousands of photocells, a nanosatellite makes do with just tens. Another vital auxiliary system is the storage battery. Here, CNES uses commercial-off-the-shelf lithium batteries for their compactness and low cost. On the electronics side, integrated circuits now pack a number of power control functions into a tiny space. In this very dynamic research sector, circuit boards could soon be replaced by embedded software functions that will bring a 20-to-30% gain in available space. All of these technologies will naturally be tested aboard the ANGELS demonstrator.

PROPULSION

ELECTRIC ON THE UP

Satellites don't fly, but they do manoeuvre with their thrusters. Today, nanosatellites operating in low Earth orbit need propulsive assistance. Research is underway to find alternatives to chemical thrust systems, which are powerful but heavy and burn a lot of fuel. Cold-gas propulsion hasn't proved very effective, and for now electric propulsion is gaining the upper hand. While electric thrusters may lengthen time to orbit, they dispense with the need for fuel tanks and piping and drastically reduce mass. French firms Comat and ThrustMe have established themselves in the microthruster market for nanosatellites and CNES is helping them to develop their business. Comat is investing in development of a new thruster technology from its own R&T for small satellites. Air Liquide has also developed a valve prototype with CNES designed to miniaturize electric propulsion systems.



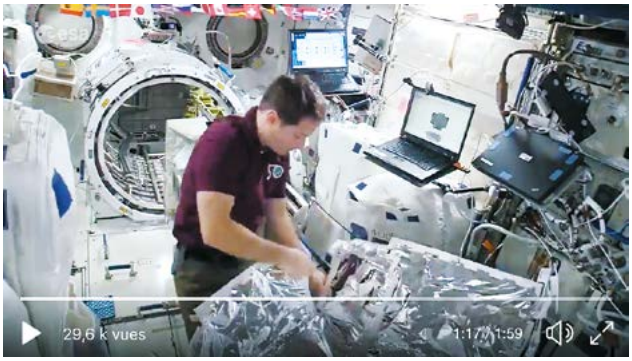
#COMMUNITY

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

@THOM_ASTRO

Européen Français, pilote de vaisseau spatial à l'ESA de retour de 6 mois de mission sur l'ISS / ESA Euro-French spacecraft pilot, back from 6-month ISS mission

Preparing to release #Cubesats: see the final episode as I install the deployment system. http://bit.ly/2kSS6JT



@WAKKA44

Space and the conquest of space - Co-Administrator /Moderator of the http://www.forum-conquete-spatiale.fr/ Author of a blog on the the @NASA_Orion http://www.developpement-orion.over-blog.com programme.

[#India] #PSLVC37 launch with onboard camera followed by impressive release of 101 nanosats.

https://youtu.be/tiOVJvvQLjc

@PLASMARMUSE

Doctepreneur! PhD student in plasma physics for propulsion at @LabPhysPlasmas & @ThrustMe_ | Back from @NASAJPL & @ESA_Tech | French Point of Contact @SGAC.

Project viva for #IonSat propelled #CubeSat at @Polytechnique this afternoon! A project I've been supervising since last September with a great group of students from @AstronautiXSC.

@MATTHIEU_COMPIN

Nanosatellite engineer and project leader at @ISAE_officiel on long-term secondment from #CNRS.

Recap in pictures of phase D key milestone review for the #EYESAT #cubesat led by @CNES through the Janus programme with #students from @Univ_Toulouse @enacfrance @ISAE_officiel 🔩 Launch 🚀 between October 2018 and March 2019.

CNESfrance @CNES YouTube CNES

Q & A

PACÔME RÉVILLON

EUROCONSULT CEO AND SPACE SYSTEMS ANALYST, Pacôme Révillon believes the pace of innovation we're seeing in the nanosatellite market is unprecedented in the space era. And thanks to nanosatellites, getting into space has never been easier.

Q & A

HOW DID SMALL SATELLITES FIRST COME INTO BEING?

Pacôme Révillon: The first smallsats were conceived in the 1990s at universities and engineering schools in Japan, the United States (MIT), the United Kingdom (Surrey) and France (Supaero). At that time, they still weighed several hundred kilograms and lacked true operational capabilities. They were placed in low Earth orbit to enable students to gain a handle on certain space functions, from initial concept through to data collection. Launches were sometimes paid for by partner government agencies. It wasn't until around 2010 that commercial projects to build cubesats weighing 10 to 50 kilograms really started to ramp up. A small satellite (up to 500 kilograms) costs at least $1 million, but launching it can cost up to ten times that amount. Such satellites are currently being launched as auxiliary passengers with other payloads, but new dedicated launchers are in development.

HOW HAVE THEY EVOLVED SINCE THEIR BEGINNINGS?

P.R.: Constellations of small satellites replicated tens or even hundreds of times are the main evolution. Satellites in geostationary orbit are too far from Earth to collect certain kinds of data, whereas nanosatellites are able to revisit regions of interest frequently and communicate with each other. While the larger and more powerful satellites in a constellation handle communications, the smaller ones collect data and beam them back to stations on the ground. They're focused on satellite imaging and applications related to the Internet of Things (IoT).

"ONE OF THE CHALLENGES FOR THE DECADE AHEAD IS GOING TO BE HOW WE MANAGE SPACE DEBRIS."

WHAT DIGITAL APPLICATIONS DO NANOSATELLITES SUPPORT?

P.R.: The IoT is one of the three applications served by these constellations. Small satellites enhance the transfer of data acquired by space sensors to ground, for example for trains, ships, aircraft and soon maybe connected cars. The second application is Earth observation, offering almost permanent coverage of the globe. This smart economy monitors industrial activity or crop yields, and provides more frequent indicators than bulletins from statistics institutes. It helps to manage natural disasters in real time and is supporting 'smart cities'. The third application is broadband communications, since nanosatellites orbiting closer to Earth reduce latency and offer better continuity of service more cheaply than terrestrial networks.

WHO ARE THE PLAYERS IN THIS SECTOR?

P.R.: The first space start-ups emerged in the United States. Now, the number of players is growing because the technology barriers to entry are perceived as being lower. Some players have specialized in building nanosatellites, while others are focused on services. These start-ups are adopting a new approach to engineering processes, but they still need to demonstrate the viability of their business model. The 'legacy' players can't stand idly by, so consolidation and concentration of the industry will most likely come about through partnerships and acquisitions. Indeed, constellations are relying on research funded partly by government, which is starting to warm to this approach. In the United States, NGA, the military agency in charge of collecting geospatial intelligence, is starting to test the capabilities of constellations. In Europe, CNES and ESA are also working on ambitious projects. Despite these trends, traditional systems aren't going away yet, as certain missions still call for high degrees of stabilization and precision.

"THE SMALLER NANOSATELLITES GET, THE MORE FRAGILE THEY ARE."

PACÔME RÉVILLON

EUROCONSULT CEO

"CONSTELLATIONS COULD ACCOUNT FOR 70% OF DEMAND FOR THE 2017-2026 PERIOD."

WHERE DO YOU SEE THE MARKET GOING FROM HERE?

P.R.: A market survey conducted by Euroconsult estimates the number of launches since 2014-2015 at 900, and expects to see 6,000 in the decade ahead—that's several hundred launches a year—generating a satellite construction and launch market worth $8.8 billion. Out of 133 satellites launched in 2016, 60% were smallsats. The main launch vehicle was Atlas V, with 37 launches, and the top operator was Planet, with 36 satellites. Constellations could account for 70% of demand for the 2017-2026 period. One of the challenges for the decade ahead is going to be how we manage space debris. If more satellites started being lost as a result of collisions in space, governments would need to set drastic launch rules, and that would imply complex international agreements.

WHAT ARE THE CONSTRAINTS OF MAKING SATELLITES SMALLER?

P.R.: For cost reasons, miniaturization means choosing between components built specifically for space or for the consumer electronics market, which increases the risk of failures. Ultimately, more and more constellations will be deploying more nanosatellites than they need, 90 or 100 instead of 80. Large satellites carry redundant systems that back each other up in the event of a failure. But what you gain with a network of small satellites, you may lose in performance. Today, constellations of small imaging satellites offer a resolution of up to one metre, whereas larger satellites are able to reach a few tens of centimetres. And the smaller nanosatellites get, the more fragile they are. A commercial constellation is looking at a service life of at least three years.

HOW IS FRANCE POSITIONED IN THIS MARKET?

P.R.: Alongside government initiatives in which CNES is involved through its research-and-development efforts, French players are following the cubesat trend. I'm thinking of new players like Nexeya, and big industrial groups operating on their own or in partnership, like Airbus with One Web and Thales Alenia Space with Spaceflight Industries. One of the first operators to invest in this domain is Eutelsat, which has ordered a small satellite to test IoT applications. It's therefore becoming easier to get into space. Satellites and improved ground terminals will deliver more data for analysis and applications through the development of artificial intelligence. The pace of innovation we're seeing now has rarely been so fast since the start of the space era in the 1960s.

Profile

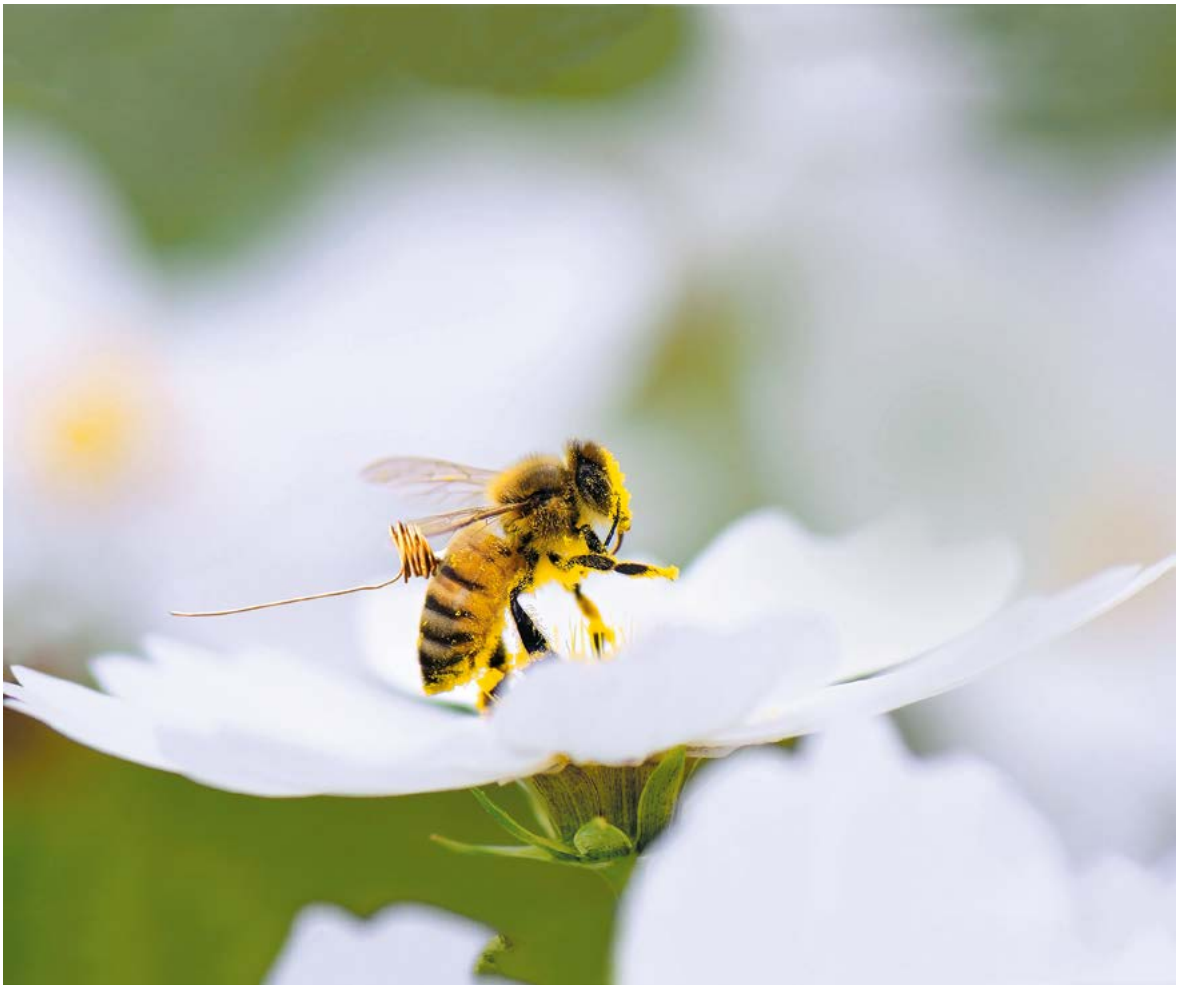
1999
Graduates from Supaero aerospace engineering school

2000
Joins Euroconsult as consultant

2003
Becomes CEO of Euroconsult (present in 60 countries)

2006
Launches Earth-observation expert consulting service

2015
Launches aeronautical connectivity expert consulting service



CUCKOOS AND BEES

Biodiversity is dying. In France, one-third of bird species have disappeared in less than 15 years. CNES subsidiary CLS is studying threatened species to understand why. And for this task, miniaturized transmitters are a boon to scientists. For example, a cuckoo weighs 110 grams on average. By fitting it with an Argos transmitter weighing 5 grams, CLS is able to track its migratory paths and wintering sites. But 5 grams is still too heavy in some cases. With transmitters weighing just 2 milligrams, CLS could track pollinating insects like bees, which are particularly in danger. Sounds impossible? The smallest smartphone today weighs 4 grams, so for CLS, a 2-milligram transmitter is achievable.

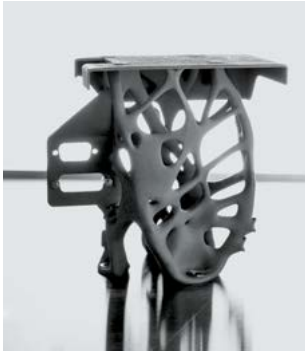
DISTRESS ALERTING FOR ALL

Whether on the Vendée Globe or the Route du Rhum yacht races, Argos transmitters are today found only on the boats of the world's top skippers competing in the most extreme conditions. But not for long! Previously the preserve of a sporting elite, Argos is now looking to bring its location and distress alerting system to a wider audience in combination with the international Cospas-Sarsat system. How? Using a built-in miniaturized modem, sportsmen and sportswomen of all abilities will soon be connected and their adventures tracked anywhere in the world. They'll be able to stay in touch with loved ones, post their travels on social media and request assistance wherever they are. Coming in 2021!

EXPORT

Helping French SMEs and mid-tier firms gain a foothold in the fiercely competitive international nanosatellite market is the aim of the Newspace Factory collective formed by the Aerospace Valley competitiveness cluster. The collective comprises 20 promising firms that have received support from CNES for their research and development. In March, nine of them were at the Satellite 2018 conference in Washington D.C. to showcase their expertise. On 29 June, in Toulouse, Newspace Factory organized a workshop on the potential of smallsats for SMEs, mid-tier firms and research laboratories.

COMETS



CNES's COMET expert communities—formerly CCTs or technical expertise communities—were first formed in 1998. Today, there are 20 of them bringing together 3,000 experts from academia, industry and institutional partners. Structured by theme, they began looking at nanosatellites and cubesats in 2016, and a series of seminars has since addressed equipment, technologies, architectures and operational concepts. Upcoming events will focus on microthrusters, the avionics and electrical architecture of nanosatellites and operations for cubesat constellations. These eminently cross-cutting investigations will subsequently pool their results to fuel the agency's knowledge base.

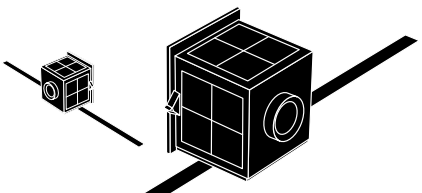
LEARN MORE: COMET-CNES.FR

3%

FOR A LONG TIME, THE ONLY WAY TO TRACK BIRDS WAS TO RING THEM.
Argos transmitters changed all that, rewriting the history of wildlife migrations, and now their miniaturization is set to mark the next step. It's estimated that the maximum for a transmitter fitted to a bird is 3% of its weight. Each gram saved means nearly 1,000 additional species that can be tracked by satellite.

€200K

Cubesats are proving attractive because they're cheap to produce. For the single-payload cubesats built by university space centres, the cost is estimated at €200k for a 1U cubesat, €400k for a 2U cubesat and €1,500k for a 3U cubesat, not including supervision and launch costs. In France, the cubesat industry is still nascent, but U.S. firm Planet, which has built more than 300 3U Earth-imaging cubesats, indicates a cost of €100k per satellite (not including launch).



NANOSATS

SPRINGBOARD TO SPACE

CNES HAS A LONG HISTORY OF INVOLVEMENT WITH MINIATURIZATION, HAVING BUILT FROM SCRATCH A SERIES OF STUDENT NANOSATS THAT TODAY IS IRRIGATING THE SPACE ECOSYSTEM. AND SINCE 2016, THE AGENCY HAS BEEN WORKING TO LAY THE FOUNDATIONS OF A NEW INDUSTRY AND BUSINESS TO MEET NEW DEMAND WITH NEW STAKEHOLDERS, PLAYING A PIVOTAL ROLE SHAPING THE MAJOR SHIFTS BEING DRIVEN BY THE INFINITELY SMALL.

Like the photography, information technology and telephony industries, space is leaning towards ever-smaller form factors. But CNES isn't a recent convert to this trend. Back in 1986, the SPOT 1 satellite, a behemoth weighing nearly two tonnes at launch, heralded a revolution in Earth observation. Twenty-five years later, Pleiades afforded far superior resolution while weighing less than one tonne. And today, the satellites built around the Myriade and Proteus spacecraft buses that are performing world-class missions tip the scales at just 100 to 500 kilograms.

For the Toulouse Space Centre, miniaturization is therefore nothing new; it's simply accelerating now that nanosatellites are arriving on the scene. This is because the cost of designing and launching satellites is encouraging manufacturers to make them smaller. With shorter development cycles of one to three years, nanosatellites are easier to design and operate than large satellites, offering a better return on investment. And that's not the only reason for going small. "*It's not conceivable in the near future that we'll be sending spacecraft weighing several tonnes to Mars*," explains Marie-Anne Clair, CNES's Director of Orbital Systems. With the current state of the art, we can envision a mothership orbiting Mars and releasing nanosatellites around the red planet to study it up close.

Mock-up of the Eyesat nanosatellite presented by a student from the Janus programme.

NEW EMULATION

Miniaturization also has the benefit of spurring emulation, and not only in the space sector. "*It's currently a big area of cooperation*," confirms Marie-Anne Clair, for miniaturizing doesn't necessarily mean reducing size and mass to the detriment of functionality; rather, it means constantly looking to pack as much as possible into the smallest space within each system or subsystem, instrument and innovative or disruptive technology, reaching into all areas from propulsion and power systems to sensors (see Roundup p. 10-11). CNES, meanwhile, is making interesting advances in this field, like the Ninano board tested on Eyesat (see Materials p. 27) or the Argos Neo micro-transmitter on the ANGELS[1] demonstrator (see p. 22), leveraging the efforts of its research-and-technology teams and COMET expert communities (see In Figures p. 18). Wherever possible, it also seeks opportunities to spin off technologies, substituting commercial-off-the-shelf products for their 'space-hardened' equivalents. As early as 2012, through its Janus[2] student nanosatellite project, CNES conceived its first cubesats (see p. 24). And since 2016, the agency has laid the foundations for a commercial line of nanosatellites in partnership with the Nexeya group, with which it will be flying ANGELS in 2019.

MINIATURIZATION AND STANDARDIZATION

One thing's for sure: industry has great expectations for nanosatellites, and with good reason. Manufacturers can't mass-produce six-tonne satellites, but they can develop series of hundreds of spacecraft weighing 1 to 40 kilograms. And these 'smallsats' have a bright future in the burgeoning services market. Operating alone or in constellations, combined with artificial intelligence or not and offering a precious revisit capability, they're ideal for numerous environmental missions such as monitoring climate, gauging water resources or tracking deforestation. Miniaturization is spurring not only research and industry, but also the employment market. The launchers sector, for example, is undergoing a major rethink and buzzing with new concepts. In response to new needs, miniaturization is also creating new and sometimes surprising careers (see Brokers, p. 8). Next year, CNES will therefore be watching how ANGELS fares intently. "*We won't be tearing up the laws of physics and nanosatellites won't do everything,*" warns Marie-Anne Clair. "*Optical imaging missions will still call for complex instruments, so the Pleiades and Sentinel Earth-observing satellites and the CSO military imaging satellites are as essential as ever, but there's no doubt that miniaturization offers space a new boost for the entire ecosystem.*"

VIDEO

ANGELS
The nanosat revolution

1. Argos Neo on a Generic Economical and Light Satellite
2. Jeunes en Apprentissage pour la réalisation de Nanosatellites au sein des Universités et des écoles de l'enseignement Supérieur.

This Cygnus radiofrequency antenna designed for nanosatellite applications was developed through a CNES R&T action.

OPTICAL INSTRUMENTS

MINIATURIZATION IN MOTION

Nanosatellites aren't the 'be-all and end-all'. For example, they can't be adapted to the size of the systems needed for optical imaging instruments to collect signals at a sufficient level of spatial resolution. The solution in such cases lies in understanding exactly what's required in terms of image quality and measurement physics. In this respect, work to miniaturize active optics has enabled a technology leap leading to smaller space telescopes. Likewise, the MicroCarb satellite's innovative dispersive grating spectrometer designed to map greenhouse gases is able to concentrate different spectral bands on a single detector, thus halving its mass and volume.

Part of the ANGELS engineering team at work at Nexeya, a specialist French electronics firm and lead contractor on the project.

ANGELS
BEST IN CLASS

Next year, the ANGELS cubesat will be launched with the dual goal of demonstrating the reliability of miniaturized technologies in flight and inaugurating a line of nanosatellites built in France through a public-private partnership.

Combining the efforts of research and industry, CNES and French firm Nexeya have worked together to produce ANGELS, a 12U cubesat weighing 20 kilograms. With the small satellite market now really starting to take off, it was time for France to commit itself to the commercial nanosatellite adventure. The agency therefore issued a request for proposals in 2016 for the ANGELS project, and Nexeya, a firm specializing in the design and development of electronic equipment, was selected as prime contractor.

DEDICATED TEAM AND FACILITY

The two partners decided on an original way of working to assure the project's success. Nexeya and its consortium have teamed with seven subcontractors—Erems, Steel, DHV, CS-SI, Spacebel, Saft and Meca-

no-ID—and ten first-tier suppliers, while CNES is providing funding and human resources. In all, the ANGELS team comprises 22 people from Nexeya, CNES and subcontractors. To make this joint endeavour work effectively, a project platform has been set up at Nexeya's facility. "*This platform is the cornerstone of the ANGELS development effort*," says Thibéry Cussac, project leader at CNES. It's a unique arrangement enabling short, collegial decision cycles and a true sharing of cultures. The result is edifying: the preliminary definition review, for example, was held barely seven months after the start of the study phase and ANGELS was built in 33 months—a record for the space industry.

DEMONSTRATOR AND PRECURSOR

Initiated by CNES in 1978, Argos is still among the world's leading data collection and location systems today. A lighter version, Argos Neo, will be flying on ANGELS. One of its first missions will have a strong operational focus, as Argos Neo will be taking over from a number of satellites now reaching the end of their service lives—Metop, JPSS and SARAL—to assure coverage of Argos transmitters.

Developed by Thales Alenia Space and Syrlinks, Argos Neo had to adapt to the size and mass constraints of a cubesat. CNES therefore sought the best trade-off, reinvesting the results of its most innovative research-and-technology projects and, wherever possible, integrating standard commercial-off-the-shelf components and equipment to reduce costs, key to developing a viable industrial process.

All of these efforts are geared towards the true challenge of making ANGELS the best product in its class. Leaving technology aspects aside, ANGELS marks a new approach to the governance of large space projects. Above all, with CNES's support it is lending a helping hand to manufacturers and suppliers in the French cubesat industry. Ultimately, Nexeya is looking to deliver more than 50 satellites a year.

ANGELS.

2.5 kg

The Argos Neo

payload is much lighter than its predecessor: offering the same level of functionality, it is roughly 10 times lighter and consumes 3 times less power than Argos.

22 x 22 x 35

Dimensions

of ANGELS in centimetres. The generic bus derived from this prototype is designed to accommodate a range of cubesats from 6U to 27U (10 to 45 kg) capable of operating for 2 to 3 years.

OUTREACH FROM SMALL BEGINNINGS TO GREAT CUBESATS

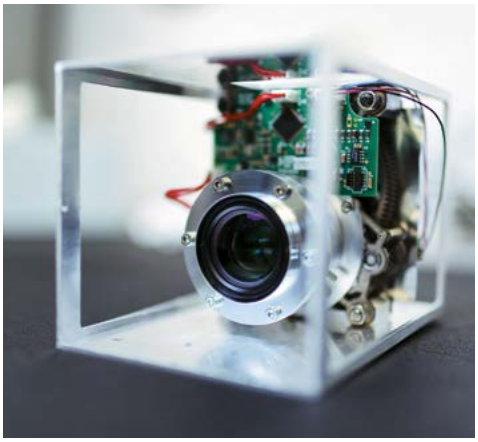
Launched by CNES in 2012, the Janus initiative has given many students the chance to engage with space by conceiving cubesats. Today, several start-ups have even been formed in the wake of Janus projects.

The student cubesat adventure began quietly in 2006 with the aim of getting budding scientists and engineers interested in space research and engineering. It set out to achieve this aim by building nanosatellites. In its role as a programme leader, CNES launched the Expresso initiative, providing its experts to manage the project and partly funding the construction of a cubesat. The University of Montpellier served as the pioneer and began building Robusta 1A, which failed to accomplish its mission but nevertheless re-entered the atmosphere, proving the worth of a complete educational programme mobilizing all university disciplines. In 2009 and 2010, two other international projects adopted the same modus operandi: Baumanets 2 with Moscow's Bauman University and the University of Montpellier, and then Pratham with the Indian Institute of Technology Bombay (IITB) and Paris Diderot University.

DOING SCIENCE

In 2012, CNES structured and beefed up these initiatives through the Janus project, its chief goal being to get students interested in scientific disciplines related to space (mechanics, thermal systems, avionics, attitude control, power systems, propulsion, ground and flight software and processing systems, etc.). The second goal was to orbit demonstrators of interest to science and industry. "*In place of practical work, CNES encouraged universities and engineering schools to create their very own space centres*" (see map p. 3), explains Alain Gaboriaud, Janus project leader at CNES. "*Students can work there with engineers and educators to conceive, integrate and operate cubesats, which means they must have technical resources and facilities at their disposal.*" Like a control centre on university premises? For Alain Gaboriaud, this goes without saying: "*It's a great exercise for getting a handle on how to manage an exacting space project with complex specifications.*" Conceived in no more than five years, a cubesat must serve to 'do science'. Robusta 1A was to test the behaviour of electronic components in space. XCubesat (from the Ecole Polytechnique) and Spacecube (from the Ecole des Mines) are studying the ther-

The Ecole Polytechnique's XCubesat and the Ecole des Mines' Spacecube in the thermal vacuum chamber at the integration and test platform at the University of Versailles Saint-Quentin-en-Yvelines (UVSQ).



Eyesat's IRIS optical instrument.

mosphere, while Entrysat will analyse atmospheric re-entry conditions and Eyesat (see Timeline p. 28-29) will capture zodiacal light. Robusta 1B, meanwhile, will observe the impacts of space radiation.

LINK IN THE ECOSYSTEM

In less than six years, Janus has become a fully-fledged player of the space ecosystem. Montpellier, the first university space centre in France, today has a technology platform and is developing its own 1U and 3U cubesats, working with industry through its Van Allen foundation. Several Janus alumni are also spinning off the results of their experience, surfing the nanosatellite wave to break into the space market. For example, Toulouse-based start-up U-Space is now supplying complete cubesat-based space systems. Such systems are also giving a boost to established equipment manufacturers offering subsystems like Anywaves (see Spinoff p. 36) and to nanosatellite bus prime contractors like Nexeya.

LAUNCHERS

MICRO-LAUNCH PROVIDERS **MANOEUVRING FOR POSITION**

The emergence of small satellites is forcing the launch services market to adapt fast. To meet demand, several systems are being studied, offering highly variable prices and services.

What do you prefer: bus, taxi or car-share? Each solution has its advantages. The same could be said for launching nanosatellites: having boosted the industry and service sectors, they're now set to boost the launch services market. Small satellites represent a growing market for launchers, but the jury is still out on which mode of launch is best. The requirements, however, are clear: what's needed is more agility, better availability and a premium service offering support tailored to the customer's profile. The global launcher ecosystem is adapting to this new and demanding market fast and in various ways. Today, we're seeing a shift mainly towards passenger satellites orbited on legacy launchers. The solutions now being proposed to offer an operational service are micro-launch vehicles and subcontracted ridesharing.

DIFFERENT FORMULAS, PRICES AND SERVICES

The United States was first off the pad in the domain of micro-launchers with Rocket Lab and in ridesharing and mission management with Spaceflight. India and Russia recently demonstrated their capabilities, deploying a remarkable number of small satellites on a single flight with their PSLV and Soyuz vehicles. China and Europe are also now lining up to join the fray. A new 'taxi' service is gaining traction with the development of multiple commercial micro-launch

– CONTINUED P. 26

Ariane 6.

vehicles, Rocket Lab being the best example. These flexible and exclusive taxi services come at a high price. But they afford real advantages, as they are able to offer short waiting times and match launches to demand. The prospects are looking good, too, with 100 such projects in the pipeline and more than €1 billion invested.

Rideshare and piggyback formulas, on the other hand, rely on traditional launchers like Soyuz, Atlas or Falcon 9, using payload adaptors. They need to evolve further, but they offer the advantage of low cost, although there are drawbacks, in particular their fixed launch manifests, trip sharing and the inability of nanosatellites to control their orbits precisely. But lessons learned show that the piggyback formula is a good one and institutional launchers regularly carry this kind of passenger.

EUROPE RARING TO GO

Europe, meanwhile, is exploring several avenues. With support from CNES and industry, ESA is overseeing the creation of a dedicated launch service for small satellites that will offer regular flight slots on Ariane 6 starting in 2021 and Vega in 2019. ESA and the European Commission are also supporting development of micro-launcher technologies, the aim being to foster a fertile ecosystem for these new players. CNES will not be funding any micro-launcher developments, but it is encouraging any private initiatives in France that could meet the demand from small satellites, or could benefit from technology spin-offs and create jobs. Economic uncertainties remain, however, for while the nanosatellite market is currently booming, nobody can be sure of what the future holds.

103

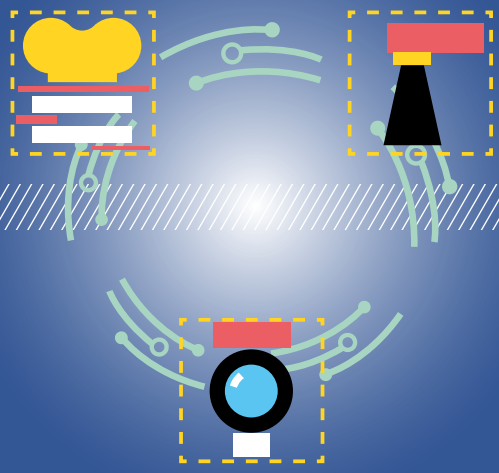
Record number

of nanosatellites deployed in a single launch, by the Indian Space Research Organization (ISRO). The nanosatellites were launched for foreign nations with a combined total weight of 664 kg.

MASTER CARD

DEVELOPED BY CNES'S RESEARCH-AND-TECHNOLOGY TEAMS, THE NINANO BOARD IS THE BRAIN OF EYESAT, A JANUS PROJECT NANOSATELLITE. Ninano addresses two key aspects at the same time. The first is economic, as the agency has opted to replace more-expensive space-hardened components with low-cost commercial-off-the-shelf equivalents delivering a high level of computing power. Associated failure risks have been analysed and will be mitigated. The second aspect is technological: in addition to all of the usual bus management functions, Ninano provides many other features like mission management and science data processing. As a result, it limits the number of onboard systems required. Built by Steel, Ninano will be making its first flight on Eyesat, but it is already attracting interest from other industry projects.

EYESAT



RECAP

WHO **DOES WHAT**

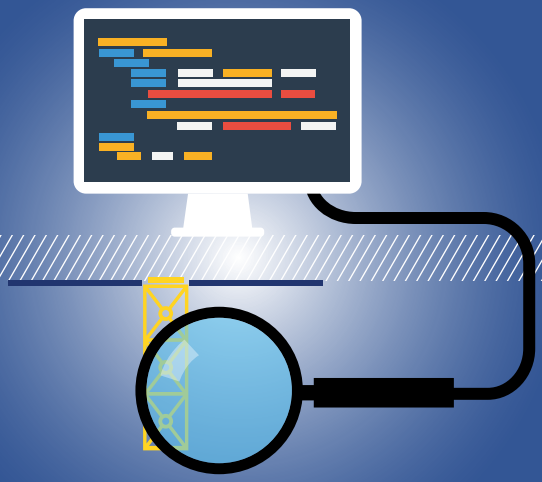
Building a triple cubesat in less than five years takes a lot of organization. Student interns from university space centres and engineering schools working at CNES's Toulouse Space Centre or partner research laboratories (IRAP and LATMOS) outlined the mission, under the supervision of a project leader and experts from CNES and the ISAE/Supaero aeronautics and space institute and ENAC, the French national civil aviation school, for engineering activities. Leveraging research-and-technology work at CNES and on the Janus programme, manufacturers then conceived the technology building blocks that have since evolved into commercial-off-the-shelf products. Subsequently, ISAE/Supaero will manage the satellite once it's in orbit and ENAC the payload.

DEMONSTRATOR

PAVING THE WAY **FOR NEW GENERATIONS**

The Eyesat demonstrator will assess the maximum performance achievable with a triple cubesat. It will mark the first flight for a nanotelescope (see opposite), for the processor on the Ninano board (see Materials p. 27) and for new radiofrequency boards. It will also test solar panel hinges made with a shape-memory composite. Reinvested in ANGELS, these new technologies will help French manufacturers to gain a foothold in the global cubesat market.

EYESAT'S EAGLE EYE IS SET TO SCAN THE ZODIACAL LIGHT, A PHENOMENON CREATED BY SUNLIGHT REFLECTING OFF INTERPLANETARY DUST GRAINS. AS WELL AS FLIGHT TESTING REUSABLE TECHNOLOGIES, THIS TRIPLE CUBESAT PILOT PROJECT WILL HELP TO REFINE MANAGEMENT METHODS FOR DEVELOPING CUBESATS FOR THE JANUS STUDENT SATELLITE PROJECT.



INSTRUMENT

AN XXS **TELESCOPE**

Eyesat will acquire a global colour picture of the Milky Way, for which it will be embarking a telescope scaled to its size. While the commercial-off-the-shelf optics weren't built specifically for Eyesat, they had to be adapted to its dimensions. The students designed and assembled the filter wheels and polarizing filters. The CMOS colour camera was produced by CNES's research-and-technology teams and French firm 3D+. The nanotelescope has already acquired night images of the sky background during testing at the Pic du Midi Observatory in the French Pyrenees.

INTEGRATION

LIKE **THE BIG BOYS**

How do you verify a cubesat's functions? Just like for larger satellites, through a series of tests to check out the star tracker, solar panels, optical systems and so on. Nothing is left to chance. Mechanical environment tests will be performed at ISAE/Supaero, after which Eyesat will be taken to the Versailles Saint-Quentin-en-Yvelines Observatory (OVSQ) for thermal vacuum testing. The flight computer will be validated on the hybrid BASILE digital simulation testbed, while the orbital environment and equipment will be simulated so that Eyesat thinks it's in orbit.

MATHILDA COUTURE

Student on the Janus programme

"We're making good progress, working together..."

For Mathilda Couture, developing a nanosatellite is most of all a fascinating thought process: "*You have to find ways to pack all the basic functions and tools into a tiny space*," she says. "*Right now, for example, we're trying to adapt the miniature screws we use to meet standards!*" **In her third and final year at the ICAM[1] engineering school in Toulouse, Mathilda has been on a six-month internship at CNES since February.** Already impressed by ICAM's emphasis on the "*mechanics of making things*", the young engineer was keen to get a place on the Janus programme via a "*practical placement focusing on AIT, or assembly, integration and testing*". **After competing in the French robotics cup, she joined the Eyesat student project to build a nanosatellite measuring just 10 cm x 10 cm x 33 cm.** "*Eyesat is an innovative telescope for studying dust particles in space, which you can't necessarily see with the naked eye, and building a 360° picture of the Milky Way*," she explains. "*The objective is to quickly and cheaply test solutions that can then be adapted for larger satellites or constellations.*"

This triple cubesat is being developed over five years, with over 170 students involved at different times ahead of launch in early 2019. "*Ten of us are assigned to different departments, responsible for the flight software, payload, power and so on, and we each have a specific CNES mentor*," continues Mathilda, who's in charge of AIT. "*It's an exciting way of doing things, and we're making good progress, working together.*"

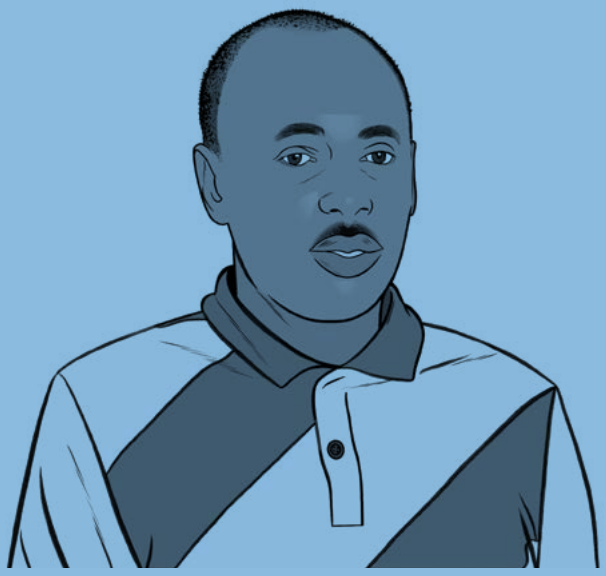
She plans to do a master's degree in management next year, but longer term wants to stay with the hands-on side of mechanical engineering, especially miniaturization, which she sees as a "*promising and innovative sector*". For Mathilda, there are no limits to miniaturization, "*we just need to find how to do it*"!

1. Institut Catholique d'Arts et Métiers

ABDOULAYE SECK

Coordinator of Dakar's local artisanal fishing council

"I look forward to announcing a year without fishing accidents in Senegal..."



Pushing their pirogue boats ever further from the coast, Senegal's traditional fishermen face danger every day. Abdoulaye Seck is a fisherman like his father, but gave up his boat in 2008. "*I don't bring fish home to my family any more, I buy them instead*," says the fishing boss, who oversees the local wholesale fish merchants and coordinates Dakar's local artisanal fishing council. "*Every village along Senegal's coast has its fishing office and representative, and we meet regularly with the local authorities to resolve any issues.*"

In Dakar, the size of the catch is seasonal and varies with the weather. "***With climate change, the guys are having to push out further and further to find the fish.*** *Species like yellowfin tuna, swordfish and marlin are now 35 kilometres out, sometimes more. And if they don't brave it, they won't be able to feed their families*," explains the coordinator. Yet their mobiles only have a range of 13 kilometres, so if they get into trouble they're stranded.

Already working to aid sustainable fisheries management, **CLS has offered to fit Senegal's artisanal fishing boats with Nemo location and data-collection transmitters.** This hybrid GSM device works via the Argos satellite system. Affording several months of autonomous operation, this small solar-powered transmitter will keep the fishermen connected with the shore, give them weather alerts and enable them to send a distress signal, wherever they are. **Nemo will also make it possible to gauge the impact of their fishing on natural resources.** The solution offers real hope for Abdoulaye Seck: "*What the fishermen need is reassurance. If we could be sure of contacting a boat within 15 minutes, this transmitter would enable rescuers to get to them quickly. It would boost their income, because they could go out further without worrying.*"

LAURENT JAVANAUD

Smallsat product line manager at Nexeya

"Nanosatellites open an incredible vista of possibilities!"

At Nexeya's Toulouse facility, the ANGELS (Argos Neo on a Generic Economical and Light Satellite) integrated team is working in an open-space office. Pinned imposingly on the walls between satellite posters is a set of A3 diagrams of their project: ANGELS, 22 cm x 22 cm x 35 cm. In late 2019, this 20-kg (wet weight) unit will replace the 40-kg Argos instrument on the SARAL-AltiKa satellite, now at the end of its life. ***"ANGELS is more reliable than a university cubesat and cheaper than a regular satellite, but it's real genius lies in miniaturization*** *— both of the bus, developed by Nexeya, and the Argos Neo payload, outsourced to Thales Alenia Space,"* says Laurent Javanaud, Smallsat product line manager at Nexeya. Directly inspired by NewSpace, ANGELS is a leap forward both technologically and organizationally. ***"Thanks to CNES's remarkable technical expertise, we're developing the satellite, ground segment and flight software concurrently.*** *CNES is overseeing the project as a whole and has implemented an integrated system of governance, which is proving highly effective."*

To meet the ambitious deadline, the team started by drawing up a framework allowing rapid, low-cost development in just two and half years. The critical design review is in October, followed by satellite assembly in April 2019. The complete system will be qualified from the control centre in line with the American 'test-as-you-fly' philosophy.

For Laurent Javanaud, who loves *"large-scale, innovative and multi-disciplinary projects,"* ANGELS is an exciting challenge: *"Built in partnership with local companies, it heralds a new field of French expertise.* ***More than a demonstrator, it'll be operational for at least two years*** *to prove that nanosatellites offer the reliability needed for commercial and security applications."*

Jacques Arnould,
science historian
and theologian,
CNES ethics officer.

ETHICS CORNER

JACQUES **ARNOULD**

MURMUR**ATION**

Advances in miniaturization mean we can now devise complex systems and place them in orbit. But will we know how to use them? What if those huge swarms of birds could tell us their secret?

Neil Armstrong's voice crackled through the speakers at NASA's mission control centre: "*Houston, Tranquility base here. The Eagle has landed!*"
The date is 20 July 1969. Just hours later, Armstrong took one of the most famous steps in human history, but it wasn't a solo achievement. To be first to put a crew on the Moon and bring them back safely, the United States raised a whole army of engineers and scientists. Yet by calling the Apollo 11 lunar module Eagle, they weren't just honouring one of their country's symbols, they also—albeit probably unconsciously—framed their feat in all the symbolism of a great discovery: like the solitary eagle, Armstrong and Aldrin were alone as they conquered the 'magnificent desolation' of the Moon.

FROM CONSTELLATION TO MURMURATION

Half a century later, the 'eagles' have folded their wings, waiting until they can fly to Mars. The focus now is on deploying space systems around Earth for the benefit of its inhabitants, taking advantage of technological innovations, especially miniaturization. And thanks to these advances, solitary flight has given way to formations or 'constellations' in engineering parlance.
Or 'murmurations', as our birdwatching friends might call them.
The secret of how thousands of birds perform this spectacularly choreographed aerial ballet still isn't fully understood. How do they communicate to alert each other of danger or a food source? How do they avoid mid-air collisions? And what influences their sudden shifts in direction? We still have much to learn about this phenomenon, where so many birds fly as one in perfect harmony, making its effect more useful, more efficient and more beneficial for the group as well as the individual.
Space murmurations—which are already happening in Earth orbit and will do even more in the future—are just as fascinating as their low-altitude counterparts. They fill us with awe, but scare us as well: what if they herald a frightening new reality, like something from a Hitchcock or Orwell novel? This is indeed a risk. It's important, therefore, to stay in control of the technological advances we make—and ensure they make sense. Our duty as well as our destiny is written in the course of the stars and the flight of the birds. So, it's up to us to write them in the sky, as we do on Earth.

CANSAT

SATELLITES IN A CAN

C'Space is a major national event for student space enthusiasts, with its programme of experimental rocket launch campaigns. Organized by CNES and Planète Sciences, C'Space has since 2009 hosted the highly original CanSat France competition. Teams must pack all the basic functions of a real satellite into a cylinder the size of a 33-cl-to-1-litre drink can. Each year, up to 10 of these tiny craft are put to the test by releasing them from a tethered balloon. For the 2018 contest, the CanSats must successfully deploy their structure during the descent or landing phase. As an option during the flight, they may also eject a scale figure of an astronaut with parachute. Eight teams are taking part, one coming all the way from Peru.

TOULOUSE SPACE SHOW

Nanosats in focus

For the first time, this year's Toulouse Space Show included a side event for international NewSpace players called Nanospace, focusing on the economic rationale behind nanosatellite projects and services. The event ran for the entire day on 27 June. The morning session reviewed the launch services offered by Rocket Lab, Arianespace, ECM Space, EXSpace and Spaceflight. The afternoon session looked at fundraising initiatives, with a first roundtable on venture capitalists, with representatives from Seraphim, Edgemore, GSV and CosmiCapital. A second roundtable reviewed feedback from start-up companies, with testimonials from Planet, Spire, Astrocast, OpenCosmos, ThrustMe and LeoLabs. A successful event, likely to be part of next year's programme.

#Must-read – According to essayist Elisabeth Dufourcq, *Homo sapiens* are far from losing the race against robots. And she proves it in *L'esprit d'invention : le jeu et les pouvoirs*, published by Odile Jacob, in which she retraces the great discoveries of human genius through the ages.

ARGONIMAUX

BASKING SHARKS JOIN THE PROGRAMME

At the request of APECS[1], the basking shark, that mysterious visitor to our shores, will join the small circle of species tracked by the ArgoNimaux education programme for marine ecology. CNES will make the tracking data available to teachers, along with—also new this year—the diving profiles of species already monitored, like the penguin and elephant seal. ArgoNimaux is set to benefit from advances in Argos transmitter miniaturization.

As well as tracking new species, miniature Argos transmitters will make it possible to study not just individual animals but whole groups. Coupled with sea temperature and other maps, these studies will provide valuable information for protecting biodiversity.

1. Brittany-based association for the study and conservation of selachians

2 G

Large mammals like the polar bear were the first to be fitted with Argos transmitters in the 1980s. More and more species can now be monitored thanks to miniaturization: the smallest solar-powered Argos transmitter weighs just 2 grams.

PRAGMATIC

NANOSAT IN KIT FORM

In the years ahead, the space sector will need a lot of new engineers. The 1U nanosatellite classroom kit is an ideal tool for learning at scale. This new resource, developed in partnership with the University of Montpellier, will be rolled out from September. It's part of the broader Pragmatic programme focusing on innovative and futuristic exploratory design projects, such as Mars drones and rovers. But Pragmatic is first and foremost a classroom support tool for higher education.

Through a series of teaching units, students are introduced to satellite system architectures and tasking. This module-based approach, developed in partnership with the École Normale Supérieure de Rennes, covers onboard power and data processing, testing, attitude control, satellite-to-ground communications and payload links. Good preparation for prospective job applicants, providing a solid grounding ahead of more ambitious, more rigorous industry projects.

DIARY

16-20 JULY 2018
C'Space
Camp de Ger military base Tarbes

EDUCATION

Perseus the teacher

Perseus[1] is a project designed by CNES's Launch Vehicles Directorate (DLA) for higher education students. Launched in 2005, it involves developing a set of demonstrators for a nanosatellite launch system. Timed to fit with the academic calendar, the project includes a number of highlights throughout the year, with student project presentation days, most recently at the University of Évry-Val d'Essonne on 16 June, project progress reviews and a seminar (the 14th edition is on 31 January and 1 February 2019). There are also live campaigns (in Sweden, for example), with the launch of the Sera 4 supersonic rocket in April 2019 and its Astres LOx/methane-powered evolution in April 2020 to meet the challenge of a demonstrator with a reusable first stage.

1. Projet Étudiant de Recherche Spatiale Européen Universitaire et Scientifique (European university/student space science research project)

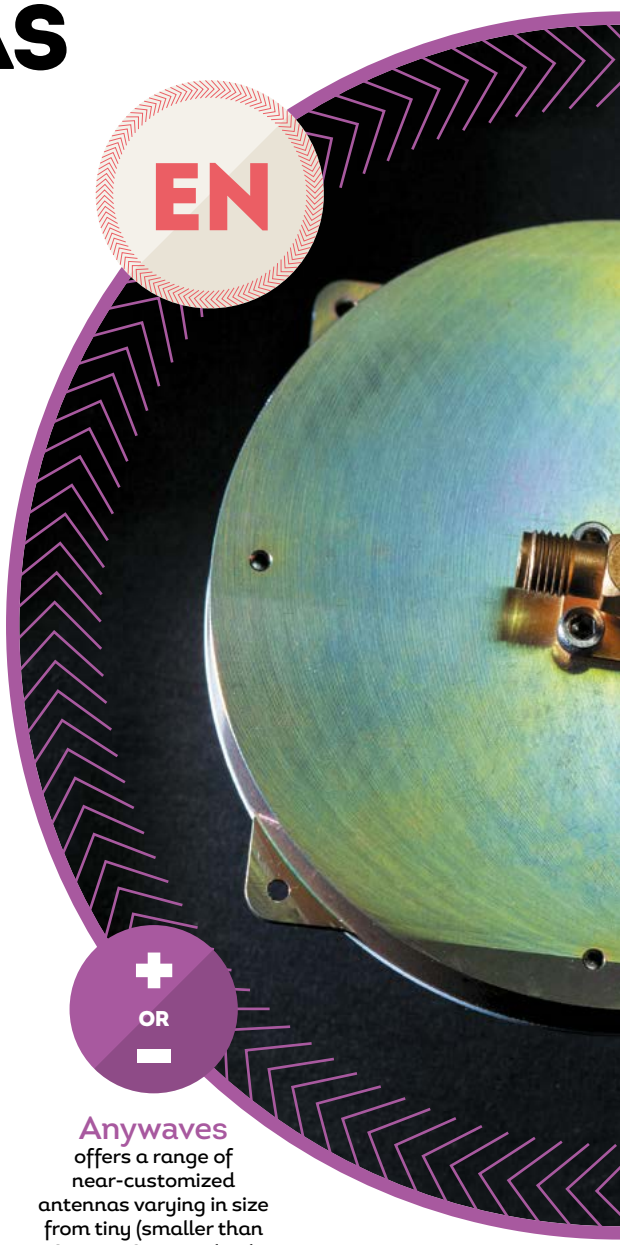
MINI-ANTENNAS
BIG RANGE, SMALL SIZES

Large, cumbersome satellite antennas are a thing of the past. Built on technologies spun off from CNES, Anywaves offers a range of antennas, some very small indeed. The young Toulouse-based start-up is today a European pioneer in this market.

Anywaves celebrated its first year in business this April, but founder Nicolas Capet is no novice in the field of antennas. Having worked as an engineer specializing in antennas and electromagnetism at the Toulouse Space Centre for seven years, he already has several patents to his credit. Indeed, he designed the innovative technology that gave him the idea of creating his own start-up.

WELL PLACED

Nicolas Capet has also been helped by his close knowledge of the space ecosystem and market. *"Anywaves is focused on the cubesat segment of the market. Even if this market doesn't pack a very big punch for the moment, it's starting to really take off. So it was vital to position the company quickly,"* he explains. Whether its patch antennas or flat antennas we're talking about, *"the important thing is that they offer a high level of performance, are ultra-compact and light."* The antenna on Eyesat, which was developed in-house at CNES, is a case in point. The other advantage that Anywaves offers is an additive manufacturing (3D printing) process that drastically shortens lead times. As a result, Anywaves is currently the only equipment manufacturer supplying antennas for nanosatellites in Europe. The start-up is already well established and looking to the future. In particular, Nicolas Capet is eyeing constellation projects and new space entrants with interest, as the potential market is global. And while it may be early days yet, Anywaves also isn't losing sight of the potential of small drones. Nicolas Capet therefore foresees a bright future. At the outset, his start-up employed just three people, and it has already created two new jobs. In July last year, Anywaves joined the ranks of the Aerospace Valley competitiveness cluster's ESA Bic Sud France incubator—a great springboard to success.



Anywaves offers a range of near-customized antennas varying in size from tiny (smaller than 10 cm x 10 cm and only a few centimetres thick) to simply small (25 cm x 25 cm).