CNES MAG

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SPACE • INNOVATION • SOCIETY

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BALLOONING

A FRENCH FLAIR

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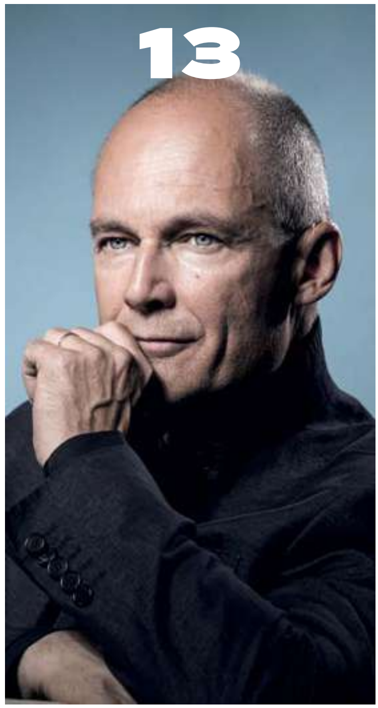
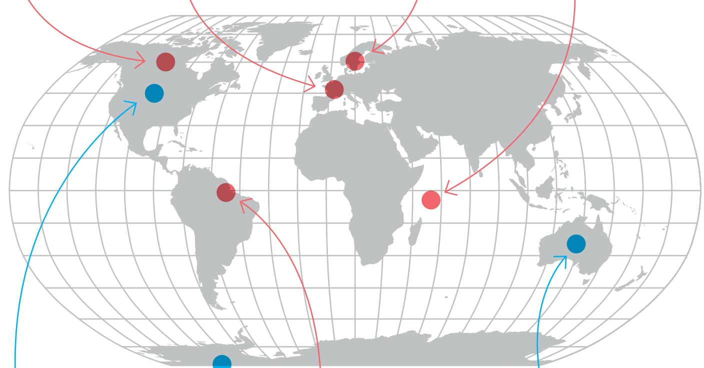
CENTRE NATIONAL D'ÉTUDES SPATIALES

INSIDE



INSIDE



Official launch bases
Occasional launch sites

PARTNERS

In this issue: European Space Agency (ESA) p. 8, 11, 31; CNRS, the French national scientific research centre p. 7, 9, 29; Inserm, the French national institute for health and medical research p. 8, 24-25; IRAP astrophysics and planetology research institute p. 9, 12, 23; CEA, the French atomic energy and alternative energies commission 9, 23; National Aeronautics and Space Administration (NASA) p. 11; INSU, the French national institute for universe sciences at CNRS p. 22; LPC2E, the environmental and space physics and chemistry laboratory p. 24; LMD dynamic meteorology research laboratory p. 23, 29, 31; LATMOS atmospheres, environments and space observations laboratory p. 23, 29; LAM astrophysics laboratory, Marseille p. 23; Thales Alenia Space p. 18, 26; World Meteorological Organization (WMO) p. 29.

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VINCENT DUBOURG

With his hand firmly on the tiller of CNES's Balloons sub-directorate, Vincent Dubourg likes the diversity his job offers, covering everything from project development and partnerships to technology and management. Unsurprisingly, he was our main source for this issue of CNESMAG. He has also pulled off the challenge of building a strong, united, highly skilled and agile team from the four corners of the globe.

STÉPHANE LOUVEL

Job title: stratospheric ZPB mission leader. Where: the great outdoors! Stéphane Louvel travels the world from the tropics to the Arctic, supervising and organizing extra-large balloon flight campaigns. It's a job that demands meticulous attention to detail and unwavering commitment. This year, he'll be spending his summer in Kiruna. He took us behind the scenes checking the payloads for the Klimat mission.

JEAN-CLAUDE RUBIO

With his sights trained on the future, Jean-Claude Rubio has given the legacy launch base in Aire-sur-l'Adour a new lease of life by making it available to new users. This experienced, digital-savvy educator has opened it up in particular to young university students and their experiments. He also knows how to fire the imagination of schoolchildren with virtual trips in the world of lighter-than-air vehicles to inspire future vocations.

STÉPHANIE VENEL

Strateole-2 project leader
Stéphanie Venel knows an extremely testing flight campaign awaits her this autumn, when the stratosphere above the Equator will be pushing balloons and teams to their limits. This is the price to pay for advancing our knowledge of greenhouse gas transfers. For CNESMAG, she gives us the inside track on this unique international scientific campaign.

CNES MAG

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IMPRIM'VERT

EDITORIAL

The intense heat, droughts, storms and typhoons disrupting the planet's delicate climate balances come with critical risks for populations. For the past 60 years, balloons have proved a platform of choice, complementing satellites with their unique ability to stay aloft for long periods at altitudes of 20 to 40 kilometres and collect in-situ data on winds, greenhouse gases, aerosols and radiation. They can even carry telescopes weighing several hundred kilograms to observe the universe from above the dense layers of Earth's atmosphere.

Ever since its inception, CNES has gained world-renowned expertise in scientific ballooning that today is being leveraged through the top-flight technical resources, laboratories and testing equipment at the disposal of its balloon projects sub-directorate. This expertise makes CNES a linchpin of flight campaigns around the world. This year, balloon teams will again be conducting two major campaigns to advance science: in August, Klimat will be deploying exceptional resources to analyse winds in the mid-stratosphere from Kiruna, Sweden, while this autumn Strateole-2 will be pursuing research into the atmospheric dynamics of the intertropical zone from Mahé in the Seychelles.

With the advent of NewSpace, the stratosphere is becoming a strategic destination for new observation and surveillance applications, with start-ups, large primes and institutional players all coming on board. CNES's roadmap charts a course for developing balloons with even better performance to drive forward great projects in the years ahead.

MARIE-CLAUDE SALOMÉ
CNES DIRECTOR OF COMMUNICATIONS

2021

TAILWINDS FOR CLIMATE SCIENCE

French balloon teams are at the ready, with two major climate science campaigns going ahead this year. In August, Klimat in Sweden is taking advantage of the light summer winds to deploy an exceptional range of resources including large zero-pressure balloons, small dilatable balloons, instrumented aircraft and ground systems. This campaign is complementing long-term analysis of the mechanisms at work in the mid-stratosphere. On the other side of the globe, in the Seychelles, Strateole-2 is set from October 2021 to April 2022 to pursue investigations underway since 2005. The objective will be to study the cyclical winds at the Equator and measure the chemical composition of the upper troposphere and lower stratosphere (see Timeline p. 28-29). Meanwhile, the FIREBall campaign—flying a balloon-borne telescope with ultraviolet detectors—put on hold during the COVID-19 pandemic—is gearing up to resume. CNES is supplying the pointed gondola for this French-U.S. mission.

Inflating an auxiliary balloon for the Strato-Science flight campaign (Timmins, 2018).

AIRE-SUR-L'ADOUR

A BALLOON BASE FOR OUR TIMES

In 1965, CNES took over the reins of the Aire-sur-l'Adour base from the national scientific research centre CNRS to conduct balloon launches. The light winds in this part of Southwest France and the proximity of aviation firm Potez made the base suitable for launching very large balloons. But by the 2010s, urban sprawl had begun eating into its safety zone, compromising stratospheric zero-pressure ballooning operations. To exploit the eight-hectare site more efficiently, CNES thus changed tack to focus on greenhouse gas emissions, consolidating its offering, accommodating light balloons and becoming a key contributor to the fight against climate change. Flights in the atmosphere gave scientists in-situ measurements to complement satellite and aerial data, while yielding indications about greenhouse gas distribution. MAGIC (see box p. 25) is one of the balloon campaigns that Aire-sur-l'Adour is hosting today. A K_a-band antenna is also set to clear the way for new downstream services at the base, for example for agriculture. Master's degree students can also test experiments that meet criteria defined by a selection committee.

4,000

CNES has been designing and operating balloon systems to support science and technology for close on 60 years, conducting some 4,000 flights in that time.

LIGHT DILATABLE BALLOONS

SMALL BUDGET, BIG DEMAND

They may be relative featherweights, but light dilatable balloons occupy an important place in CNES's panoply of lighter-than-air vehicles. Their closed latex, helium-filled envelope—spanning as much as 1 metre 50—expands as it ascends up to 30 kilometres into the stratosphere. Flights carrying three to four kilograms of scientific experiments can be conducted in no more than two to three hours from launch to landing. Offering affordability—envelopes cost less than €200—and good payload capacity, light dilatable balloons are sought after by scientists and students alike. With more than 150 balloons launched since 2012-2013, sustained growth in demand is now stabilizing at around 30 balloon launches a year, three to four for student projects.

BALLOON BASES

RELEASES AT ALL LATITUDES

Be it in Sweden, Canada, Brazil or Australia, it's more the latitude than the country that dictates where launch bases are sited for very large stratospheric zero-pressure balloons. Their location needs to fit science goals while assuring good flight trajectories and safe, wide-open spaces for mission recovery. Indeed, balloon launch bases are operated under specific agreements. As a member of the EsaPac consortium, CNES has preferential access to the Esrange[1] Arctic base in Kiruna, Sweden. The French and Canadian space agencies also have a 10-year cooperation agreement set to be renewed in 2022, covering operations at the Timmins base in Canada. But to meet strong demand from the scientific community, this offering is set to be expanded with a new equatorial base in the state of Tocantins, Brazil, a longstanding partner nation. Ultimately, instituting a three-year cycle with these bases would give scientists observations at all latitudes. Alice Springs, a tropical base in the heart of Australia, could accommodate one-off astrophysics missions. CNES has access to this base managed by CSIRO[2] under a bilateral agreement.

1. European Space Range.
2. Commonwealth Scientific and Industrial Research Organisation.

BIOLOGY

NEW DIRECTION FOR BALLOONS

Hellish cosmic radiation poses a major obstacle to the human dream of deep space exploration. Human cells have in fact already flown in the stratosphere, in 2019. Inserm, the French national institute for health and medical research, protected them with different kinds of shielding and then entrusted them to CNES for testing. A 12-hour flight at an altitude of 40 kilometres and −40°C confirmed that even when protected, the cells suffer from the effects of radiation. A new experiment named Bernadotte is scheduled this August from Kiruna, Sweden. Paraffin, lead and aluminium shielding will protect skin, heart, eye and bone cells lofted into the stratosphere. One type of shielding will even be using pieces of fabric from Thomas Pesquet's spacesuit to guide the choice of materials for future astronaut crews. This balloon-borne biology experiment calls for special attention, as recovering, transporting and carefully conserving the samples in strict conditions—at a temperature of at least −16°C to avoid damaged cells rebuilding themselves—from the Arctic polar circle to Inserm's laboratories will be a challenge in itself.


PILOT gondola ready for the off.

FROM PILOT TO CO-PILOT

PEERING DEEPER INTO THE GALAXY

In 2017, the IRAP astrophysics and planetology research institute, the French atomic energy and alternative energies commission CEA, the national scientific research centre CNRS and CNES conceived PILOT[1], a scientifically ambitious and technologically complex mission to gain new insights into the role of the galaxy's magnetic field in star formation. The 83-centimetre telescope was equipped with instruments able to record cosmic emissions. Three survey campaigns later, it has accomplished its mission and science teams are now sifting through the 23 hours of data collected in optimal conditions. Co-PILOT is poised to pursue this success story. This new mission will reuse the same telescope and cryogenic cooling system, but the instrument will be reconfigured to operate in different frequency ranges. Co-PILOT will thus yield new observations of the distribution of the dark molecular gas that partly determines how stars form in galaxies like ours.

1. Polarized Instrument for Long-wavelength Observations of the Tenuous interstellar matter.

479

The EOLE programme was the first to test the science value of balloon survey campaigns. From September 1971 to June 1972, a flotilla of 479 superpressure balloons was released into the southern hemisphere jet current at an altitude of 9,000 metres. The balloons drifted for several days, tracked by a weather satellite. Source: LMD dynamic meteorology laboratory

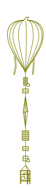
680

In 2019, during the pre-Strateole-2 campaign, eight stratospheric superpressure balloons clocked up 680 flight days, an average of 85 days per balloon. Staying aloft for up to four months, they could circle Earth three times.

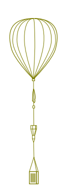
1 KG/1 M³

A simple rule of thumb to know how much helium is needed to inflate a balloon: 1 m³ of gas to lift 1 kg of mass.

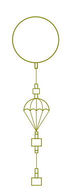
BALLOON PANORAMA



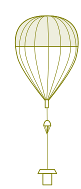
Stratospheric zero-pressure balloon (ZPB)
Volume: de 3,000 to 1,200,000 m³
Gas: helium
Payload capacity: several tonnes
Ceiling altitude: 40 km
Flight time: a few hours to several days



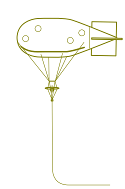
Stratospheric superpressure balloon (SPB)
Volume: 900 m³
Gas: helium
Payload capacity: up to 60 kg
Ceiling altitude: 30 km (daytime)
Flight time: several months



Light dilatable balloon
Volume: more than 500 m³
Gas: helium or hydrogen
Payload capacity: less than 4 kg
Ceiling altitude: 30 km
Flight time: 2 hrs



Infrared Montgolfier
Volume: 45,000 m³
Gas: hot air
Payload capacity: 60 kg
Ceiling altitude: 30 km during daytime, 20 km at night
Flight time: several weeks



Aeroclipper
Volume: up to 70 m³
Gas: helium
Payload capacity: 50 kg
Ceiling altitude: 50 m maximum above seas and oceans
Flight time: up to 30 days

NOSYCA

VERSATILE COMMUNICATIONS

Whether aloft for a few hours or several months, in the interests of science and safety balloons are always closely tracked and in constant contact with their control centre on the ground. The five key functions to be fulfilled are communication, location, dropping of ballast, release of gas and separation at the end of the flight. Since 2012, CNES has been using its NOSYCA[1] system to provide better control and telemetry/ telecommand, and to optimize ground-to-balloon communications. Today, the principle of a separate system for each balloon family is a thing of the past. The flight computer in new-generation gondolas is no longer designed as a monobloc unit but rather as a suite of functions that can be transposed and reused for any type of lighter-than-air vehicle. This approach affords numerous advantages, cutting costs through the use of off-the-shelf products, enabling recurring functions to be regularly upgraded or innovating with new ones, breaking down silos between disciplines and optimizing qualification and team interventions.


Strateole-2 flight campaign (Seychelles, 2019).

1. New Operational SYstem for the Control of Aerostats.

HEMERA

SENDING EUROPE STRATOSPHERIC

CNES formed the HEMERA consortium in 2018 for the Horizon 2020 programme, with a view to federating European suppliers of scientific balloons and their users. As a result, Europe's scientists are now able to acquire measurements from the stratosphere. France and Sweden are coordinating to fly experiments for other nations. HEMERA is seeking to exploit synergies between measurements and data sharing. The consortium has already proved its vitality, with 39 experiments from 13 countries selected after a request for proposals. Flights spread over 2019 to 2022 cover a range of fields, including astrophysics, the atmosphere and the magnetosphere. Certain payloads are absolute jewels of technology, while others explore scientific niches. In some cases, balloon flights serve as precursors for a larger-scale satellite mission dedicated to studying climate change. This initiative confirms European interest in stratospheric science.

VASCO flight campaign dedicated to studying variability in ocean-atmosphere exchanges in the Indian Ocean (Seychelles, 2007).

EXPLORATION

PLANETARY BALLOONS

Releasing a balloon into the atmosphere of Mars or Venus is not something from the realm of science-fiction. A balloon would even afford a number of advantages: it's faster than a rover, drifts with the winds and can acquire images near the surface and readings to measure the atmosphere's dynamics. Indeed, in 1985 Russia inserted two balloons into the atmosphere of Venus for its Venera programme with a contribution from France. Major obstacles to planetary ballooning nevertheless remain, including their ability to withstand harsh environments, acid rains or long-duration stowage of envelopes inside interplanetary probes, for one to ten years depending on the destination. Deploying and inflating a balloon during its parachute descent are also real hurdles to be overcome. But CNES has been involved in a number of preliminary projects over the last 20 years: Mars 1996 with Russia, European Venus Explorer with Europe in 2011 and Titan Aerial Explorer with Europe and the United States in 2010 and 2012. These collaborations were pursued under NASA's Flagship and ESA's Large Mission requests for proposals.

Exploring Titan with a hot-air balloon.

PHYSALIA

IN THE EYE OF THE STORM

The eye of the storm is in fact the glass ceiling we have to break through to delve deeper into such tropical phenomena that are intensifying as a result of climate change, and to better predict their intensity and trajectory. It's hard to measure atmospheric pressure inside a storm from conventional remote-sensing platforms in Earth orbit. An aeroclipper balloon drifting at the air-sea interface could be a good candidate, but existing models are too heavy and not sensitive enough to wind due to their tapered shape. CNES's balloon fab lab is therefore seeking to develop this concept with a new profile. It has developed different models that are smaller but with high wind sensitivity, to be sucked into the storm faster. Very promising tests have already been completed on the miniaturized gondola that will measure atmospheric pressure, ocean temperature and other parameters, confirming that the model can withstand a storm and does not pose a danger if it lands on a beach. The profile of the final vehicle is in the process of being stabilized and it will be tested on water this year.

COMMUNITY

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

@F_BIERRY

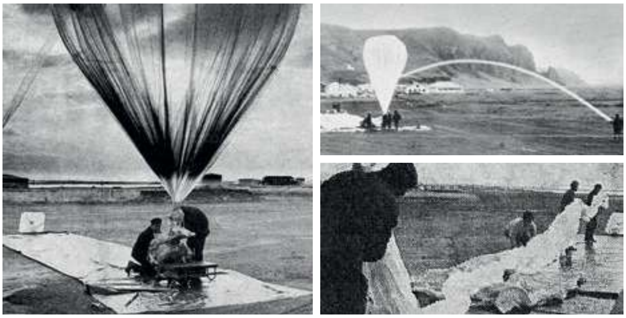
President of the Alsace European authority (CeA) and Vice President of the Assembly of French Departments (ADF)

[#sciences] Sending a sounding balloon 26,000 metres into the stratosphere! That's the feat pulled off last week by a junior high school class in Alsace (#collège Charles-Walch, Thann) with their technology teacher, @CNES and the @PlaneteSciences #Alsace association

@STRATOBALLOON

Stratospheric balloons past and present. A website devoted to documenting their use in scientific research, the military and aerospace

Very rare images of French stratospheric balloons operating in Iceland, circa 1967-1968. Every year in the late 60s CNES made these launch expeditions to the island to perform X-ray measurements at altitude in the auroral zone and to study solar X-rays. #BalloonImageOfTheDay



@IRAP_FRANCE

IRAP astrophysics and planetology research institute. Studying the universe from the centre of the Earth to the outer reaches of space

#Kiruna, a launch base well known to the science teams at @IRAP_France, and the #PILOT team @CNES

@LOUVELSTEPHANE

Mission leader for stratospheric zero-pressure balloon flights conducted by CNES for Europe's scientists

Ten light dilatable balloons launched from #CNES Aire-sur-l'Adour carrying experiments to analyse the composition of the atmosphere + SAFIRE's Falcon 20 acquiring additional measurements. A trial run before flights for the Klimat campaign in Kiruna this August.

CNESfrance @CNES YouTube CNES

Q & A

BERTRAND PICCARD

AS A SEASONED BALLOONIST, ALL-TERRAIN ADVENTURER AND VISIONARY ECOLOGIST, BERTRAND PICCARD KEEPS A KEEN INTEREST IN FRENCH BALLOONING ACTIVITIES. He talked to CNESMAG about the people who changed his life and those he thinks will change the world.

Microlights, paragliders, balloons, aircraft... Where does your passion for aviation come from?

Bertrand Piccard: No doubt from the examples and inspirations encountered when I was a child. In 1931, my grandfather Auguste was the first man to reach the stratosphere, a feat accomplished in the pressurized airtight cabin he invented to show it was possible to fly at very high altitude, where the air is less dense. I was also fortunate to live in Florida from 1968 to 1970. Thanks to my father, who was an oceanographer involved in building the lunar module for the Apollo programme, I saw six Apollo launches—a life-changing experience for an 11-year-old—and got to meet the first Mercury, Gemini and Apollo astronauts—the real "right stuff"—and even Charles Lindbergh himself! Meeting those pioneers gave me a taste for exploration and pushing limits. I learned to fly at the age of 16 and after that I grasped every chance I could to fly something new. The family tradition caught up with me in 1992, when a Belgian balloonist asked me to team up with him for the first transatlantic balloon race. He chose me because I was a qualified doctor and for my expertise in hypnosis, which he reckoned would be a secret weapon for managing our stress, sleep, vigilance and so on. And it must have helped, because we won the race!

> "CNES gleans fundamental scientific knowledge to reveal what's happening and accelerate actions to protect the environment."

You first circled the globe in 1999 with Breitling Orbiter 3, after two failed attempts in 1997 and 1998. How do you view that period now looking back?

B. P.: Staying aloft for 42,714 kilometres over 19 days, Breitling Orbiter 3 is the longest flight—for distance and duration—in the history of aviation. A record achieved in a balloon, a nod to my grandfather. Twenty years on, everything has become more complicated since 11 September 2001: each flight has to meet tight, standardized security requirements that leave little room for adventure. When you think about it, Breitling Orbiter was a really romantic project, as we departed with the hope we would reach our destination! I was always greatly amused by the specialists who affirmed I'd never make it; it's so typical to judge a project possible or not on the basis of what we know rather than with a disruptive mindset. No balloon at the time had stayed aloft for more than a few days, six for gas-filled balloons and two and a half for hot-air balloons. But we combined the two in a hybrid Rozière balloon, a system invented by Jean-François Pilâtre de Rozier in 1784, which cost him his life. Unlike our competitors, we had a found a way, thanks to a thermodynamic study at EPFL in Lausanne, to triple the lifetime of helium by insulating the balloon not at night but during the daytime so that the Sun wouldn't overheat the helium, which we kept warm at night with propane burners.

Do you keep an eye on French ballooning activities?

B. P.: Of course! Especially because while my grandfather invented the pressurized cabin, his twin brother Jean-Félix invented the plastic stratospheric balloon! Such balloons are an extraordinary technology capable today of circling the globe two or three times. For me, the only thing missing is a human in the loop! Indeed, if the third attempt with Breitling Orbiter had failed, I'd planned to try again with a balloon like those flown by CNES.

You subsequently switched from balloons to planes and in 2003 developed Solar Impulse. How did you come up with the idea of a solar plane?

B. P.: After accomplishing my dream of circumnavigating the globe in a balloon, I wanted the next flight to be fundamentally useful. When I landed with Breitling Orbiter 3 in the Egyptian desert, my propane tank was virtually empty. It's said that the sky's the limit, but that's not true: fuel is! So, I felt that I needed a new paradigm, to fly without fuel and free myself from all limits. That's how the

BERTRAND PICCARD

ALL-TERRAIN ADVENTURER
AND VISIONARY ECOLOGIST

"If the third attempt with Breitling Orbiter had failed, I'd planned to try again with a balloon like those flown by CNES."

dream of Solar Impulse took shape, a plane flying only on solar power, generating and storing its own electricity in batteries during the daytime to be able to fly at night. I wanted to show that we can achieve things thought impossible with clean technologies and renewable energies, working from the principle that if I could fly like that, then we can use clean technologies here on Earth in our daily lives.

What did the successful flight of Solar Impulse in 2015-2016 change for you?

B. P.: Let me tell you a story. In 2018, Tom Enders, the boss of Airbus at the time, told me his engineers had advised him on three occasions not to help me; first because they thought I'd never be able to build the plane, and second because it would never fly and if it did would most likely crash... But when I succeeded in circling the globe, those same engineers said "we've got to develop electric aircraft programmes"! The flight therefore showed the great potential there is to be exploited in this domain.

As an advocate of clean technologies, you've also founded the World Alliance for Efficient Solutions. What are your goals?

B. P.: I find we spend too much time talking about problems and not enough about solutions. That's why I founded this Alliance, as I was crossing the Atlantic with Solar Impulse, to bring together people producing clean technologies and those looking to use or fund them. More than 3,500 firms have joined today and the solutions it's promoting prove that we can reconcile economic development and job creation with preserving the environment.

Do you think CNES and more broadly the space sector in general have a role to play in achieving cleaner and more sustainable lifestyles?

B. P.: CNES gleans fundamental scientific knowledge to reveal what's happening and accelerate actions to

"The longest flight—for distance and duration—in the history of aviation was made with a balloon."

protect the environment. Today's technologies are what are going to enable us to develop all sectors cleanly and sustainably, and space is a fine illustration of that. When you're in orbit, 100% of your energy is renewable and 100% of your waste is recycled, which is exactly what we need to do here on Earth.

PROFILE

1985
European hang-glider aerobatics champion

1992
Wins first transatlantic balloon race

1999
Circles globe in a balloon

2015-2016
Circles globe in Solar Orbiter aircraft

2016
Founds World Alliance for Efficient Solutions

STRATOSPHERIC ZERO-PRESSURE BALLOON

In 2015, this 40-metre-high 'bubble' inflated with 3,000 cubic metres of helium carried aloft the PILOT mission from the Timmins base in Canada. On reaching 40 kilometres, its envelope had expanded to a surface area of 45,000 square metres, equivalent to seven rugby pitches, a volume of 800,000 cubic metres, a height of 100 metres and a diameter of 140 metres. The flight train would have been higher than the Eiffel Tower! The ballast dropped from the gondola maintained the balloon at its maximum altitude day and night. Able to stay aloft for a few hours to several days, stratospheric zero-pressure balloons offer a large payload lift capacity—more than a tonne for PILOT—and great versatility for science and technology experiments, model space shuttles and even rockets.

IN PICTURES

STRATOSPHERIC SUPERPRESSURE BALLOON

This stratospheric superpressure balloon being prepped at the U.S. McMurdo base in Antarctica is one of 19 released into the polar vortex for the international Concordiasi campaign. These closed balloons are still fairly floppy on the ground, expanding and reaching their full volume at the end of their ascent and then remaining at a constant ceiling altitude of 20 kilometres for up to four months before bursting. Able to carry a maximum payload of 50 kilograms, these balloons enable scientists and climatologists to measure movements of air masses, their temperature, pressure, humidity and air quality, as well as the role of the ozone layer. Concordiasi has delivered new insights into the polar atmosphere and helped to monitor Earth's climate.

Label

Balloons are also attracting interest for their commercial potential. The airships of the Flying Whales consortium are already under study to carry heavy loads, Thales' Stratobus is seeking to develop surveillance and telecommunications applications, and Zephalto is set to innovate with near-space tourist flights. All of these players prove the sector's inventiveness and vitality. But they need support. That's the mission of bodies like public investment bank Bpifrance, competitiveness clusters and Europe, whose backing is conditional on the approval of subject matter experts. CNES fulfils this function, combining intellectual property for large balloons with its decades of field experience. It offers advice to firms and is the gateway to secure funding—a role it is set to strengthen as the single operator for the space ecosystem under the government's economic stimulus plan.

107

DAYS

That's the longest flight duration recorded in 2020 for the Strateole-2 test campaign in the equatorial lower stratosphere (see Timeline p. 28-29).

RECORD

1 million cubic metres is the volume of the largest balloon built for CNES, the size of the Stade de France stadium! Launched since 1982 from the Aire-sur-l'Adour base, this stratospheric zero-pressure balloon was too long for the launch area and teams had to use the airfield's runway. It reached an altitude of 47 kilometres.

1 mm

As tiny as it may seem, a hole less than one millimetre in a Strateole-2 balloon shortens the flight by one month.

KLIMAT

115 people from more than 20 European universities and research laboratories will be gathering at the Esrange launch base in Kiruna, Sweden, for the Klimat flight campaign to collect measurements in the stratosphere on climate change.

1770

THAT'S WHEN THE FIRST HOT-AIR OR GAS BALLOONS WERE FLOWN.

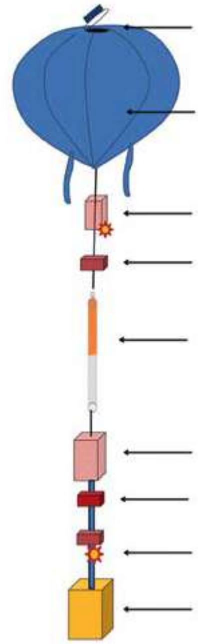
The first flight with a passenger carried Jean-François Pilâtre de Rozier and the Marquis of Arlandes in November 1783, from the Château de la Muette in Paris with King Louis XVI in attendance. The flight lasted 25 minutes and the balloon rose to an altitude of 1,000 metres, staying aloft for eight kilometres. The first scientific ballooning programmes started in the 1960s and were soon subsumed by CNES.

BALLOONING

A CORE CNES COMPETENCY

THE ONLY VEHICLES CAPABLE OF PROBING THE ATMOSPHERE IN SITU FOR LONG PERIODS AT ALTITUDES UP TO 40 KILOMETRES, BALLOONS ARE A DOMAIN WHERE CNES HAS EXCELLED FROM THE OUTSET. ADAPTABLE, MODULAR AND REUSABLE, THEY HAVE PROVED CRUCIAL TO A GROWING NUMBER OF SCIENCE AND ENGINEERING DISCIPLINES. CNESMAG INVESTIGATES.

Prepping a superpressure balloon for the Strateole-2 flight campaign (Seychelles, 2019).



The 100-to-150-metre flight train is what connects the balloon's envelope to the payload. The first element underneath the envelope is the identification and location system. Below that, the separation system is commanded from the ground to terminate the flight. These are followed by the parachute and housekeeping gondola, which notably takes care of flight control and data reception and transmission. Lastly, the strobe light ensures the balloon is seen at night.

Archimedes hit on the principle of buoyancy in his bath and Joseph de Montgolfier drew inspiration from his discovery in 1783, applying it to air. And for the last 60 years, CNES has been exploiting the principle to drive its scientific ballooning activities, earning the agency world renown in the process.

Balloons and satellites have been cohabiting in perfect harmony at CNES since 1962. This is no surprise, for contrary to appearances they have much in common. "If you think of the balloon envelope like a launcher, then buoyancy is what propels it and the gondola is like the satellite and payload," explains Vincent Dubourg, who heads CNES's Balloons sub-directorate. The difference is that with balloons, these three components stay locked together from the beginning to the end of the flight.

7 times

Helium
is seven times less dense than air. A balloon envelope containing 100 m³ of the gas could therefore get airborne carrying an adult of average build.

And if balloons are complementary to other vehicles, it's also because they have their own preferred 'hunting ground' at altitudes between 20 and 40 kilometres above Earth, flying higher than aircraft but lower than satellites, and staying aloft longer than rockets that ascend through this layer of the atmosphere too quickly.

A HOST OF ADVANTAGES

Inflated with helium and lighter than air, a balloon "flies freely with the air masses and is an ideal tool for investigating inside the atmosphere," says Vincent Dubourg. It carries experiments that can be developed and executed within a short timeframe: a balloon project takes two to three years, where a satellite takes five to 15 years. Launching doesn't require the heavy infrastructure of a spaceport, clean room or test rig. And as no fuel is needed,

balloons are also cheaper and more environmentally friendly. Everything is modular, from envelopes and flotillas to the flight train. This adaptability is helping to keep balloon teams on their toes in readiness for future space missions.
CNES has a vast array of balloons large and small, open and closed, which it operates from the Equator to the polar circle. Stratospheric zero-pressure balloons are for short flights carrying heavy loads. The balloon maintains a constant altitude during the day and descends at night as temperatures drop (see In Pictures p. 16). Closed stratospheric superpressure balloons, on the other hand, can stay aloft for several weeks or months at the same ceiling altitude over long distances (see In Pictures p. 17). Last but not least, boundary layer superpressure and aeroclipper balloons that look like airships (see Roundup p. 9), borne by the winds at the sea-air interface, scout the

Pointed gondolas

CNES LEADING THE WAY

Green-lighted on the recommendation of the CTB[1] balloon engineering committee, balloon missions are driven by science or technology goals. So the instrument payload has to be designed and operated to serve these goals as effectively as possible. In some cases, instruments need to be pointed very precisely at the area of interest or a specific part of it, but the flight environment can sometimes thwart the best attempts to achieve this. CNES's Balloons sub-directorate has therefore come up with new gondolas able to overcome such effects, using digital command modules, new-generation gyros, multi-star trackers and optimized ground-to-air links. For PILOT, a new star tracker has been tested (see Materials p. 27) to measure the balloon's attitude night and day—a technology investment that makes CNES the world leader in pointed gondolas today.

1. Comité Technique Ballons (CNES/CNRS-INSU).

FIREBall's pointed gondola at the LAM astrophysics laboratory, Marseille.


Kasa flight campaign (Kiruna, 2016).

3

Range safety regulations
at heavy balloon launch bases are very strict. The risk of hitting someone on landing must be less than 3 in 100,000.

lower layers of the atmosphere and the ocean boundary layer for weather forecasters and scientists. For most balloons, the ability to recover and reuse them is a big plus point. After the flight is terminated, the envelope isn't reused but recovered. All other equipment and instruments are geo-locatable and recovered, reconfigured and reused on future projects.

DANCE WITH THE WINDS

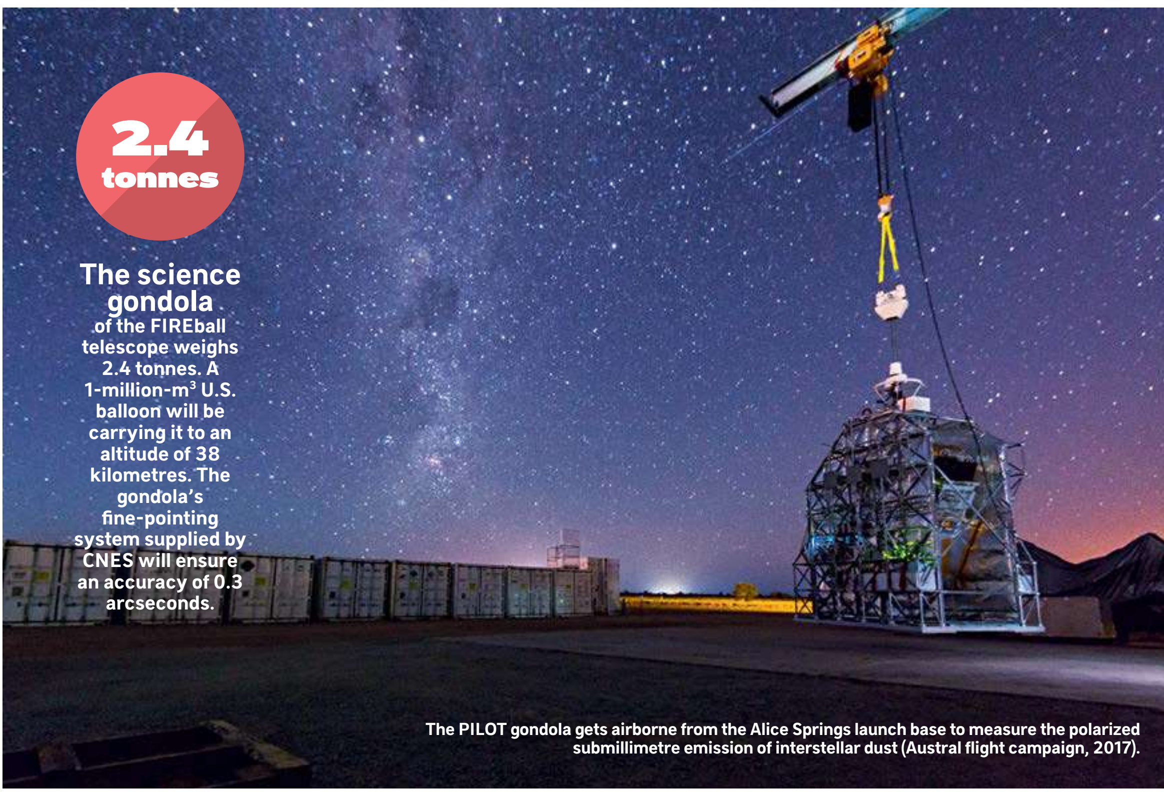
As the team leader and funder of balloon flight campaigns, CNES is involved in selecting projects submitted. A specific committee, the CTB, is in charge of planning and scheduling. On the basis of recommendations from scientific committees and technical experts, it assesses the utility and science or technology value of each proposal against current areas of investigation and whether it could be extended by a satellite mission.

The know-how of balloon teams guarantees flight safety as required by regulations, under which CNES has delegated self-certification responsibility. The agency defines the stringent conditions and measures that must be scrupulously applied. "Balloon teams are responsible for everything they send aloft and everything they retrieve," confirms Vincent Dubourg. Balloons also play a fundamental role for students. "Balloon experiments are developed by undergraduate students destined to work in the space industry," says Dubourg. "They get a real kick out of being in the field and actually building a flight system."

Balloon flight campaigns are therefore great showcases for what CNES does and a permanent source of innovation, constantly seeking to improve payload pointing precision (see box p. 21), develop new materials, optimized flight computers and new gondola designs, and reach into new fields of science. All in all, scientific ballooning has a bright future to look forward to.

Probing
INSIDE **THE ATMOSPHERE**

Balloon flight campaigns to which CNES has contributed have revealed insights into many key components of Earth's climate mechanisms. But balloon missions are also capable of diversifying—from astrophysics to biology—to the great benefit of the international scientific community.



2.4 tonnes

The science gondola of the FIREball telescope weighs 2.4 tonnes. A 1-million-m^3 U.S. balloon will be carrying it to an altitude of 38 kilometres. The gondola's fine-pointing system supplied by CNES will ensure an accuracy of 0.3 arcseconds.

The PILOT gondola gets airborne from the Alice Springs launch base to measure the polarized submillimetre emission of interstellar dust (Austral flight campaign, 2017).

Aeronomy, astronomy, meteorology and climatology are just some of the diverse domains in which balloons have brought real added value over the last 60 years. In-situ experiments in the stratosphere and throughout a balloon's descent yield precise readings of concentrations of water, methane, carbon dioxide, ozone, nitrogen oxide, aerosols and other parameters that play a role in climate disruptions. These precious data are downlinked to ground or recorded for retrieval post flight, informing the work of the international scientific community. CNES has been working in the field of balloon-borne research for many years, partnering public laboratories like LPC2E[1], LMD[2], LATMOS[3], IRAP[4], LAM[5],

Releasing a superpressure balloon for the AMMA campaign from Cotonou. The mission's goal was to understand the mechanisms driving the African monsoon and how they affect local, regional and global climate and populations (Benin, 2006).

ONERA[6] and CEA[7]. This longstanding partnership has been marked by the agency's active involvement in large-scale international campaigns. Half a century ago, in 1972-1973, the French-U.S. EOLE mission confirmed the utility of balloons as tracers of air masses and winds for aeronomy and meteorology research, paving the way for future scientific flights.

ALL AROUND THE WORLD

And there have been plenty of balloon campaigns since, combining with other assets to help analyse destructive climate mechanisms like El Niño (VASCO in 2005-2007) or the African monsoon (AMMA in 2002-2007). Strateole Vorcore (2005), meanwhile, was driven by the first investigations of the Antarctic ozone hole, a globally significant change that is still focusing scientists' attention today. Strateole-2 (see Timeline p. 28-29), in partnership with the United States, will logically be delving deeper into these phenomena. From the southern and northern tropics to the Arctic, the Equator and mid-latitudes, balloons offer an exceptional tool for the scientific community to reveal the inner workings of an increasingly critical global climate picture.

While atmospheric sciences form the bulk of balloon teams' schedule, lighter-than-air vehicles are also valuable assistants for astrophysicists. Telescopes flown above the dense layers of the atmosphere are able to sense radiation obscured from the ground. Dedicated flight campaigns have served demanding areas of research like the interstellar galactic medium (Pronaos), interstellar dust (PILOT) and filaments in the warm-hot intergalactic medium (FIREball). Balloon observations complement satellite data to yield new clues or consolidate our understanding of how the galaxy works.

Since 2019, a new chapter is opening for CNES in the field of biology with balloon-borne experiments for Inserm, the French national institute for health and medical research, on irradiation of human cells (see Roundup p. 8). The agency even envisions flying balloons beyond Earth, with future missions on Mars, Venus or any other planet with an atmosphere. They will of course have to cope with local conditions and be able to withstand sulphuric acid clouds on Venus or frigid temperatures of –170° on Titan, for example.

10 days

The Opportunity rover

on Mars has traversed 45 kilometres in 15 years and Curiosity 23 kilometres in 8 years. The latest rover, Perseverance, could drive as far as 200 metres daily. In comparison, with the winds on Venus a balloon could circle the entire planet in just 7 to 10 days.

1. Environmental and space physics and chemistry laboratory.
2. Dynamic meteorology research laboratory.
3. Atmospheres, environments and space observations laboratory.
4. Astrophysics and planetology research institute.
5. Astrophysics laboratory in Marseille.
6. French national aerospace research centre.
7. French atomic energy and alternative energies commission.

Klimat

A RECORD-BREAKING CAMPAIGN

This large balloon science campaign operated by CNES this August promises to "aggregate exceptional resources" in the words of Stéphane Louvel, the mission's leader. Two HEMERA stratospheric zero-pressure balloons (see Roundup p. 10) will be released from the Kiruna base in Sweden to study atmospheric chemistry and gas and aerosol concentrations. CNES will be at the controls for two other stratospheric zero-pressure balloon missions, Xenon and Super Climat. Xenon will be carrying Bernadotte, an experiment for Inserm (see Roundup p. 8), and BRAD, an instrument to measure the radiation environment. The MEDOR solar array will also be tested under the gondola. Once validated, this technology could reduce the number of batteries required for future missions. Super Climat will be going after atmospheric gases using air coring techniques, accompanied by ten light dilatable balloons from the MAGIC campaign. The balloons' latex envelope bursts on reaching 30 kilometres and the gondola then collects pressure, humidity, temperature and greenhouse gas data as it descends. Combining data from stratospheric zero-pressure balloons, light dilatable balloons and aircraft in the SAFIRE fleet should improve models for predicting and understanding our climate.

13,000 m³

That's the volume of helium required for the entire Klimat flight campaign. CNES is supplying two trailers with a useful volume of 8,000 m³ at 300 bars, and the Swedish Space Corporation (SSC), which manages the base at Esrange in northern Sweden, is supplying 5,000 m³ at 180 bars.

100 tonnes

15 containers will be required to accommodate all the launch equipment. More than 100 tonnes of equipment will be shipped on site, from the balloons to their scientific gondolas and the control centre.

Balloons

LEAP-AHEAD TECHNOLOGIES

In addition to their relatively low cost and rapid results, balloons are perfect testbeds for new technologies before flying on satellites or scaling them up.

The main advantage of a balloon flight for often heavy technology experiments or models is of course its cost. Indeed, a balloon-borne experiment can be flown 40 times more cheaply than on a satellite. The second advantage is that results are quick: stratospheric zero-pressure balloon flights only last a few hours and the payloads are recovered and their data exploited immediately. Lastly, balloons are a precious ally for calibrating and validating instruments. For example, in 2014 EUSO Balloon tested a new technique for detecting cosmic rays as they traverse the atmosphere. In 2015, the Climat campaign flew 12 scientific instruments to inter-calibrate and compare them as they measured the same atmospheric variables.

In 2017, CASOLBA sent aloft 60 solar cells from six European and American manufacturers to calibrate them in real-life conditions before scaling up to series production for future satellites. Calibration/validation applies not only to instruments but also to data acquired by satellites on orbit. A stratospheric balloon provides a means to confirm or disregard such data. For example, in 2005 the Envisat satellite probed the ozone layer. A CNES balloon collected in-situ measurements of the same gas using an atmospheric sounder that was an exact replica of the one on the satellite, to complement and compare data acquired. In all, three of Envisat's atmosphere-sounding

Future

NEW HORIZONS

CNES is getting behind projects with the potential to drive growth for balloons. While Google's Loon project to deliver Internet access proved an economic failure, it was nevertheless a clear technological success through its development of manoeuvrable balloons. CNES is confident these small balloons can be reconfigured to find new fields of application (see Spinoff p.36). Likewise, the development of an intelligence, surveillance and reconnaissance (ISR) product line should open up new horizons for balloons, like the Stratobus airship programme. Thales is planning to operate this HAPS (High-Altitude Platform System) stratospheric airship for security and surveillance purposes. Another area with good potential is the use of balloons as aerostatic cranes for reusable launcher demonstrators. As reusable launchers will have to be put through their paces during atmospheric re-entry, reduced-scale balloon-borne models would be a first step to test processes. The balloon would 'hoist' the demonstrator and then release it from a height of 20 or 30 kilometres. It would currently appear to be the only platform capable of performing such manoeuvres.

instruments were tested at least once using a balloon-borne demonstrator. A similar technique was employed in 2010 to help calibrate/validate data from the IASI[1] instrument operating on polar weather satellites. Balloons may not attract much attention, but they are nonetheless a technology testing platform like no other.

1. Infrared Atmospheric Sounding Interferometer.

Stars in broad daylight

TO STUDY THE POLARIZED EMISSION OF GALACTIC DUST, THE PILOT TELESCOPE HAD TO PULL OFF THE CHALLENGE OF ENABLING EXTREMELY PRECISE POINTING NIGHT AND DAY. **No star trackers at the time could offer this capability, and for good reason: during the daytime and at an altitude of 25 kilometres, stars are lost against the blue sky in the glare of the Sun's rays and Earth's residual atmosphere. CNES's engineers took a multidisciplinary approach to the problem and found the solution in a hybrid combination of an optical sensor and balloon-borne gyro. Estadius[1] is the autonomous multi-star tracker resulting from this research, providing a very precise pointing attitude across the entire celestial vault. A low-cost device built from commercial-off-the-shelf components, Estadius was responsible for PILOT's excellent pointing performance on its two previous science flights.**

1. Estimateur STellaire d'Attitude DIUrne Stratosphérique is a high-precision patented device. The same basic principles were applied for the Gysele gyro-star tracker on France's Yoda space surveillance satellite.

TIMELINE

CLIMATE

1

TWO CIRCUM-NAVIGATIONS, FOUR MONTHS ALOFT

Eight un-instrumented trial flights tested the mission concept in 2019 and 2020. These are now set to be followed by two phases of science observations three years apart. The first[1] will be starting this October from the equatorial launch base in Mahé, Seychelles. Twenty superpressure balloons will be sent aloft for four months, circling the Earth twice to gather information from around the globe. Once all administrative clearances have been obtained, they will overfly 96 countries along the Equator. CNES first innovated with this type of aerostat in 1971, with an unexpandable airtight envelope suited to long-duration flights in the lower layers of the stratosphere. Half a century later, they are still operating and capable of flying as far as 80,000 kilometres.

1. The second phase is scheduled for 2024-2025.

2

TWO FLOTILLAS OF TEN BALLOONS

The 20 balloons won't be flying together but in two separate flotillas of 10. One, at an altitude of 18 kilometres, will collect in-situ measurements; the other, at 20 kilometres, will take remote readings. Two instruments in particular will gather temperature profiles over two kilometres to acquire very-high-resolution data and gain a deeper insight into the climate and refine weather forecasting models. Strateole-2 will notably measure wind intensity and direction, air pressure and temperature, concentrations of the main greenhouse gases—water vapour, ozone and carbon dioxide—and detect suspended ice and dust particles.

STRATEOLE-2 PLANS TO GO DEEP INSIDE THE SHIFTING WINDS AND VERY-HIGH-ALTITUDE CLOUDS OF THE EQUATORIAL LOWER STRATOSPHERE. FOR THIS UNPARALLELED EARTH-OBSERVATION MISSION ENGAGED BY FRANCE IN PARTNERSHIP WITH THE INTERNATIONAL SCIENTIFIC COMMUNITY, CNES WILL BE LAUNCHING BALLOONS FOR THE FIRST SESSION OF THE CAMPAIGN THIS OCTOBER FROM THE SEYCHELLES.

3 TWO GONDOLAS AND TWO CONTROL CENTRES

The flight train will comprise two gondolas. The first, EUROS, is a so-called 'housekeeping' gondola to track and control the flight in compliance with strict safety regulations from the control centres in Toulouse and Aire-sur-l'Adour. The second, Zephyr, will carry different combinations of two to three instruments from the 12 dedicated to science. These combinations will be defined by Albert Hertzog, the mission's principal investigator (see Horizons p. 31). Science operations will be handled by the LMD dynamic meteorology research laboratory and the LATMOS atmospheres, environments and space observations laboratory from the mission control centre in Palaiseau.

4 AN INTERNATIONAL SCIENTIFIC CONSORTIUM

Strateole-2 brings together several U.S. science teams and research laboratories from the French national scientific research centre CNRS. It is part of the World Meteorological Organization's SPARC[1] programme. Certain observations will be downlinked in near-real time to weather services around the world to improve forecasts. Strateole-2 will also validate measurements acquired by satellite-borne instruments as was the case in 2019-2020 for wind observations by the European Aeolus satellite. Once teams have finished poring over the data, they will be freely available to the world scientific community.

1. Stratosphere-troposphere Processes And their Role in Climate.

ISABELLE ZENONE

Lead engineer for stratospheric zero-pressure balloons at CNES

"The world of balloonists fosters a real sense of teamwork, with super-exciting technical challenges!"

"When I was little, I thought I was seeing UFOs flying overhead. In fact, they were balloons released from the Aire-sur-l'Adour centre, which were flickering in the sky," recalls Isabelle Zenone, originally from Tarbes, about an hour from the launch site. **Fascinated by these balloons, which gently rise towards space, the engineer with a degree in embedded IT systems was naturally keen to join CNES, where she first spent 10 years as an in-house project manager,** working with microsatellites and the PHARAO atomic clock. Then, in 2009, she moved to the Balloons sub-directorate, attracted by the exciting technical challenges, and she's now in charge of the largest models. "We're a small structure with a lot of opportunities," she enthuses. "We work with all kinds of other disciplines, and to coordinate them I have to get to know them all really well." To minimize costs and lead times, the engineering team has designed a specific balloon architecture, which lets them capitalize on each model they develop by making it adaptable and transferable from one series to the next. After a few years of "rethinking everything, especially to manage safety constraints, we're putting operational needs back at the heart of what we do," explains the engineer. **Each annual campaign now includes a host of innovations. This rapid pace of development meets short-term objectives and fosters synergies with operational personnel.** The developers regularly take part in balloon launch operations. "When they experience the realities of the field, they're always impressed by the skills of the operational team and how smoothly and efficiently they work," says Isabelle Zenone, who has implemented a ten-year technical roadmap. "I refine it each year, based on results, emerging needs and what we want to do, as it's important to give free rein to creativity!"

ALBERT HERTZOG

Strateole-2 Principal Investigator

"As they move through the air masses, balloons give us a new way of seeing the atmosphere."

Research lecturer at Sorbonne University in Paris and the LMD dynamic meteorology laboratory, part of the École Polytechnique engineering school in Palaiseau, **Albert Hertzog was introduced to balloons in 1999 during his postdoctoral research into the dynamics of the stratosphere, with the first long-duration Strateole-1 flights**. "It's incredible to work on observations made by balloons as they circle the planet," he says. "It's the reason I joined LMD." He became an avid user and is now Principal Investigator for Strateole-2. This is the fourth CNES balloon campaign in which he has taken part. While Strateole-1 was deployed in the polar regions, because it was primarily focusing on the recently discovered ozone hole, **Strateole-2 is moving to the Equator to better understand the distribution of greenhouse gases (GHGs) in the atmosphere,** in conjunction with other dynamics studies. "Drifting at an altitude of 18 to 20 kilometres, our balloons provide unique observations of this hard-to-observe area, where a major oscillation of the atmosphere occurs," explains the research scientist. "We're especially interested in the transport of water vapour from the lower layers to the stratosphere, which is much drier, but where vapour content is critical for the climate, because it's the most important GHG." **At the same time, Strateole-2 flights dynamically downlink their measurements to weather forecasting agencies.** All the data is made rapidly available to the international science community, which "uses it in ways we hadn't imagined. We also help validate instruments for future satellites, such as the first wind measurements by ESA's Aeolus lidar in 2019." A nice nod to this scientist, who began his career on ground lidar observations.

ANNE-SOPHIE LECTEZ

Head of balloon envelope mechanics at CNES

"To optimize a balloon, the challenge is to find the best trade-off between mechanical strength and lightness."

Sometimes thinner than a hair, the envelope must be resistant to any significant bending out of shape. Anne-Sophie Lectez specializes in this specific field of mechanics. Part of CNES's Balloons sub-directorate for four years, the engineer explains: "The mechanics of a deformable structure assumes that the distance between all the points around it will change. We observe how individual materials behave by applying a law of behaviour, specifically the relationship between the stresses applied and the distortions they create."

Thermoplastic polymers are the materials of choice for balloon envelopes. And for good reason: they change shape with temperature. These are plastic films 15 to 60 microns thick, such as polyethylene and polyethylene terephthalate, or PET, which are used in everyday life respectively for packaging and textile fibres. "The aim isn't to have an ultra-deformable material, but to be able to control how it changes shape."

Modelling is a powerful tool—initially to simulate the balloon in conditions as close as possible to reality on the ground, in flight and at various temperatures. "Next, we formulate simple and then increasingly complex hypotheses about a given law of behaviour, which we incorporate into a digital design of the entire balloon," she says. The results are validated through tests on a small balloon—or representative structure—fitted with target points whose positions are monitored to compare the theoretical results with the actual measurements. "The goal is to advance our knowledge by increasing the performance of the balloons and their range of applications," concludes Anne-Sophie Lectez, who joined CNES for "the wealth of modelling and experimental work, while keeping a foot firmly planted in real-world applications".

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

JACQUES **ARNOULD**

SIC ITUR AD ASTRA

Asked what balloons would be good for, Benjamin Franklin famously replied: "What good is a newborn baby?" In his view, lighter-than-air aircraft heralded a new era.

Louis XVI of France knew innovation when he saw it: after the first untethered flight by Pilâtre de Rozier and the Marquis d'Arlandes on 21 November 1783, the King was keen to reward the balloon's inventors, Joseph and Étienne Montgolfier, and ennobled them. Modern times owe more to engineers and scientists than to explorers and adventurers. The Montgolfier brothers adopted Virgil's lofty saying from *The Aeneid* as their motto: "Sic itur ad astra", or "Thus one journeys to the stars". I don't see in them any excessive pride or misplaced exaggeration. Like Franklin, they believed the invention of the balloon—which inspired a generation of scientists and excited the crowds in the late 18th century—marked humanity's effective entry into a new era: the conquest of air and space.

ONWARDS AND UPWARDS

Admittedly, it was hardly possible back then to distinguish between Earth's atmosphere and the vacuum of space. So, it was easy to imagine that balloons would one day carry humans to the Moon and beyond. In its 3 January 1808 edition, London-based satirical newspaper *The Examiner* made fun of Napoleon Bonaparte's cosmic ambitions: "Then, I will be able to form an army of balloons, of which Garnerin will be the general, and take possession of the Comet. That will enable me to conquer the solar system, after which I will go to the other systems with my armies and, at last, I think, I shall meet the Devil". In fact, Bonaparte had ordered the closure of the balloon factory and aerostat pilot academy in 1799 and given up on deploying his soldiers of the old guard to invade "the Comet". But the push to reach the skies had been set in motion by these lighter-than-air aircraft, as the Montgolfier brothers had foreseen.

After stoking fires to float the first balloons into the sky, aeronauts, aviators and astronauts alike have learned to master petrol and solid propellant; cotton and paper cloth have given way to steel and composite materials. Yet balloons haven't vacated our skies, before maybe one day helping us explore other planets. Without them, we wouldn't be able to study and understand the vast upper layers of the atmosphere—which our aeroplanes can't reach and our rockets pass through only briefly. With his black charcoal and white chalk, Odilon Redon was right: balloons are absolutely unique eyes turned toward both Earth and the stars.

CAREER

BALLOONIST: **A TEAM SPORT?**

Don't bother looking for 'balloonist' in any list of educational courses in France, because you won't find it. Launch manager Pierre Bergos agrees: he originally trained as a drafter/designer, and after four years in a design office he wanted a change of scene. "You learn most of it on the job," he says. "Balloon operations are a team sport." Mechanics, electronics, IT, communications and more—all these skills complement each other and are needed. "You have your own core knowledge, but you need to rely on others and learn from their expertise as well." Every day, balloonists are confronted with technical issues, scientific constraints and the vagaries of the weather, so a multidisciplinary approach is the only way to succeed. A launch campaign is a real education in social interaction. Back at the office, you might chat with colleagues for 10 minutes a day around the coffee machine. In the field, you're away from home for weeks, living and working with others in a whole new way. To stay motivated and work efficiently, there's no substitute for teamwork!

ZEPHALTO

Tourists in the stratosphere

Sometimes dreams do come true. For Vincent Farret d'Astiès, his dream is to "go and see the stars without polluting the skies and experience something truly beautiful in a clean natural environment". And he plans to share it with others, offering balloon flights at an altitude of 20 kilometres in a "comfortable, modular pressurized gondola, with extensive views of Earth's curvature". Drawing on his solid background as an aeronautical engineer, he founded his company Zephalto in 2016. After taking advice from CNES, he obtained backing from competitiveness clusters and the local space ecosystem. He has also invented and patented a solar-powered altitude regulator. The gondola is still being designed, but the balloon has already passed its first tests, with Vincent Farret d'Astiès successfully completing a smooth 300-kilometre flight in August 2020. The first tourists could take to the skies in Céleste, the name chosen for the balloon, as early as 2024. Tickets are available on presale.

LEARN MORE:
HTTPS://ZEPHALTO.COM/EN/BALLON

EDUCATION

YOUNG BALLOONISTS

Ah yes, Archimedes' principle—now there's a headscratcher! At CNES, we believe you have to see and do in order to understand, which is why we conceived a fun science education programme called "Un ballon pour l'école" (A balloon for school). Since 1992, we've conducted over 100 balloon projects every year with primary, junior high and high schools across France. CNES supplies the latex envelope of the light dilatable balloon, the flight train and parachute, transceiver and helium. We also provide a set of specifications to be adhered to. Volunteers from the Planète Sciences non-profit association then help with the design of the experiment gondola. Weather data, air humidity measurements, vibration propagation and ultraviolet radiation measurements and data transmission by radio—the "balloon for school" carries real science and technology experiments. As projects reach completion, school playgrounds and sports fields become launch bases. Inflation operations are carried out by a technician, then all students are balloonists for a day as they install the gondola and parachute ready for release. The balloon is fitted with a geolocation system and tracked throughout its 100-to-200-kilometre flight. The gondola is also locatable and quickly retrieved, so the data can be analysed. Each year, 2,500 young people take part in this exciting and inspiring educational initiative.

LEARN MORE OR SIGN UP:
WWW.PLANETE-SCIENCES.ORG/ESPACE/BALLON-STRATOSPHERIQUE/UN-BALLON-POUR-L-ECOLE

DIARY

AUGUST 2021
Klimat 2021 campaign
Kiruna, Sweden

OCT.-NOV. 2021
Strateole-2 campaign
Mahé, Seychelles

MAY 2022
25th ESA Symposium on European Rocket and Balloon Programmes and Related Research, organized by CNES and ESA
Biarritz, France
https://atpi.eventsair.com/QuickEventWebsitePortal/pac-symposium-2021/home1

FRENCH KNOW-HOW

CUSTOM-DESIGNED BALLOONS

CNIM Air Space, the successor to Zodiac Marine's space division—the legacy supplier of envelopes for French balloons—knows all about refinement. The polyethylene used for stratospheric zero-pressure balloons is close to a micron thick. Made by heat-sealing dozens of sections or 'gores' together, zero-pressure balloons can be up to 190 metres tall, so the production line stretches for 200 metres. Superpressure balloons are manufactured in a semi-cleanroom environment to ensure airtightness. CNIM Air Space is one of few companies with this kind of specialized facility and understands all the related procedures, constraints and quality certifications. Its experience has positioned the company as a partner on the HEMERA Horizon 2020 programme funded by the European Union (see Roundup p. 10). For this programme, it will be manufacturing a balloon of 900,000 cu.m. Challenges don't get much bigger than that!

EN

CNES MAKING MANOEUVRES

In 2014, Google's Loon initiative aimed to connect the globe with a fleet of balloons. While the Internet giant has since thrown in the towel, CNES is reinvesting its research efforts in a manoeuvrable balloon project.

Balloons drift with the winds, so to manoeuvre and change trajectory, why not simply change wind layer? "One way to do this would be by inserting a ballonet inflated with helium inside the superpressure balloon and filling the gap between the two envelopes with compressed air. As it gets heavier, the balloon would descend to a different wind layer and orient itself differently," explains Erwan Quévarec, head of CNES's Buoyancy Structures department. This would require a system to create the necessary exchanges, sucking in outside air to take the balloon lower and expelling air to ascend.

CHOOSING THE RIGHT ROUTE

By moving between air layers, a balloon would thus be able to stay aloft for longer over areas of interest. What's more, in the space of a four-month flight a balloon overflies many countries for which obtaining administrative clearances can be a long and painstaking process. A manoeuvrable balloon could thus skirt round a country it doesn't need to fly over. The reason balloons are launched from Sweden, the Seychelles or Australia is that weather conditions are a crucial factor. A manoeuvrable balloon could be released from a fixed, convenient base like Aire-sur-l'Adour, for example, and then transit to the area of interest, reducing operational constraints and costs. And lastly, such a balloon would pave the way for new commercial services like persistent surveillance of restricted areas. This new concept therefore charts a promising roadmap for CNES and the wider space ecosystem, backed by the government's economic stimulus plan—a welcome boost to put manoeuvrable balloons on course for success.

1 year

Work underway should enable manoeuvrable balloons to remain at their ceiling altitude for a year, considerably extending the range of expected services.