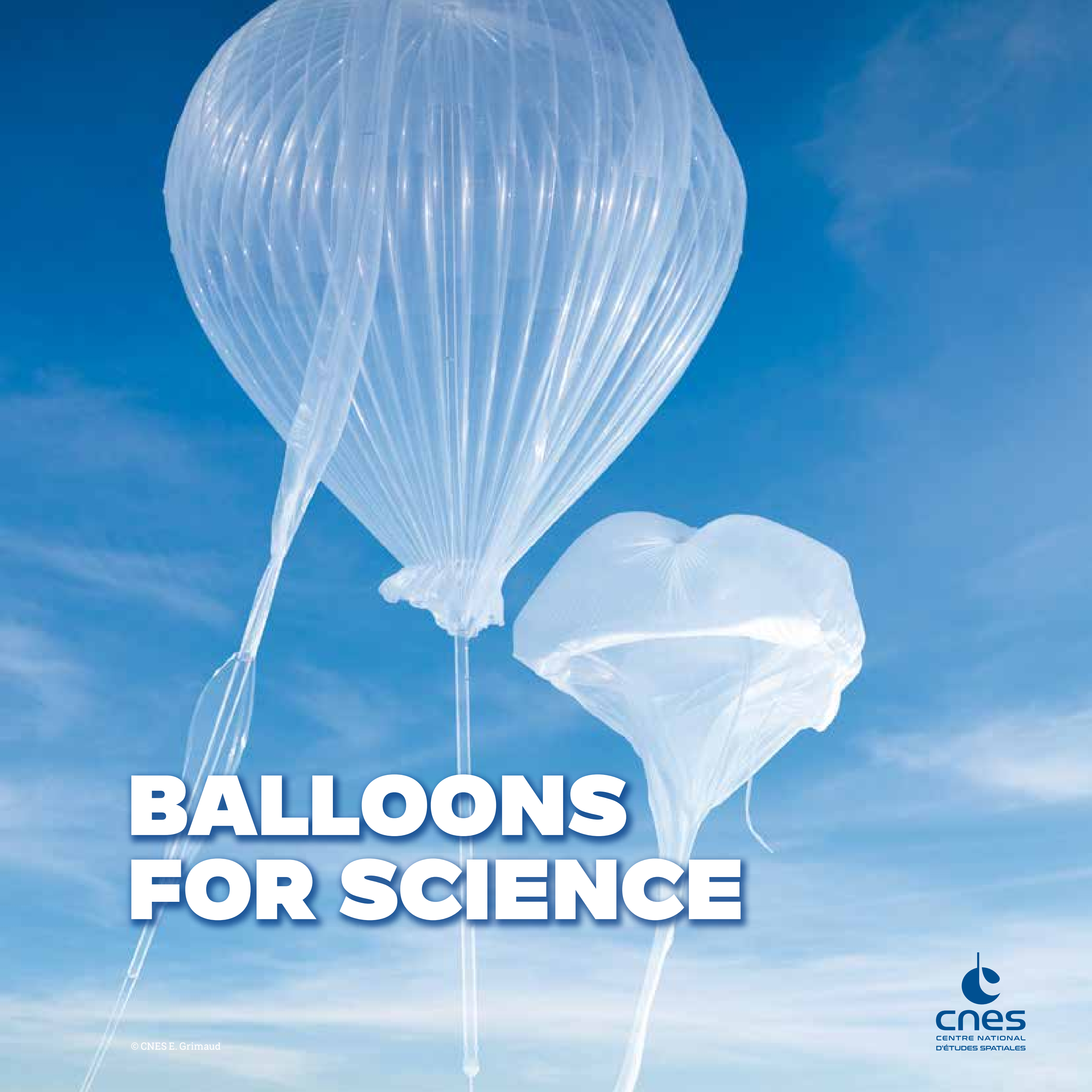
BALLOONS FOR SCIENCE



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CENTRE NATIONAL
D'ÉTUDES SPATIALES

BALLOONS FOR SCIENCE

summary

science

BALLOONS

A GREAT ADVENTURE

CNES, experienced in stratospheric balloons

CNES is the public institution in charge of drafting and submitting national space strategy to the French Government, and is then tasked with implementing it. For the last fifty years, it has been one of the two foremost experts worldwide in the design, development, launch and operation of stratospheric balloons.

Imagining Space in France and Europe for the next two decades is the day-to-day work of engineers at the French Space Agency, CNES (Centre National d'Études Spatiales). Its mission is to put space technology at the service of society by finding innovative technological responses to meet current needs, and by anticipating future changes.

To this end, CNES coordinates upstream scientific work with the laboratories, and cooperates downstream with the industrial world, making it possible to constantly develop advanced technologies.

CNES activities are organised along five main lines:

- access to space
- Earth, the environment, the climate
- applications for the general public
- the sciences of the universe and preparation for the future
- security and defence.

CNES takes part in the programmes run by the European Space Agency (ESA), to which it is a major contributor, and plays an important role within the framework of major international schemes.

WHERE DO CNES BALLOONS START THEIR JOURNEYS?

CNES has launched balloons from the four corners of the Earth

Arctic Site between 90°N and 66.33°N (Arctic polar circle)

- 1 *Kiruna (Sweden)*
- 1 *Andoya (Norway)*
- 3 *Ny Alesund Spitzberg (Norway)*

Northern mid-latitude site between 66.33°N (Arctic polar circle) and 40°N

- 4 *Aire sur l'Adour and Gap Tallard (France)*
- 5 *Leon (España)*
- 6 *Timmins (Canada)*

Northern Tropical Site between 40°N and 15°N (Tropique du cancer à 23,27°N)

- 7 *Trapani (Sicily)*
- 8 *Hawaï (USA)*

Equator between 15°N and 15°S (Equator at 0°)

- 9 *Kourou (Guiana, France)*
- 10 *Mahé (Seychelles)*
- 11 *Teresina (Brazil)*
- 12 *Cotonou (Benin)*
- 13 *Goa (India)*
- 14 *Latacunga (Equateur)*
- 15 *Diego-Suarez or Antsiranana (Madagascar)*
- 17 *Niamey (Niger)*
- 18 *Zinder (Niger)*
- 19 *Guam (Pacifique)*

Southern Tropical Site between 15°S and 40°S (Tropic of Capricorn at 23.27°)

- 20 *Bauru (Brazil)*
- 21 *Mendoza (Argentina)*
- 22 *Pretoria (South Africa)*
- 23 *Alice Springs (Australia)*
- 24 *Noumea (New Caledonia)*
- 25 *Sao José dos Campos (Brazil)*

Southern High Latitude (> 50°S) and Antarctic (Antarctic polar circle) and 90°S (South Pole)

- 26 *Ushuaia (Argentina)*
- 27 *Kerguelen (France)*
- 28 *McMurdo (USA)*

A european reference in balloon activity

For almost 60 years, CNES has been developing a first- rate balloon activity, the largest in the world after the United States. In five decades, CNES has launched over 4,000 balloons for the benefit of an extensive international scientific community. These are free balloons, with no link to the ground, unmanned, but carrying automatically-operating scientific instruments

At a European level, CNES is the only organization which brings together all the essential skills necessary to develop, qualify, design, manufacture, release and operate balloons. With its balloon programme, CNES takes part in scientific and technological collaborations with other countries such as Germany, Italy, Sweden, Norway, and Canada, the United States, Japan and Brazil

© Illustration Nou Thierry

HOW DO THEY BECOME LIGHTER THAN AIR ?

No pilot, no engine, no fuel, just some gas in a plastic bubble... yet sufficient for balloons to soar with the greatest of ease.
There must be an explanation... right, Archimedes?

Balloon flight seems to be the most natural form of flight, and the easiest to understand.
It is also one of the most fascinating, due to its simplicity. Yet it took until 1782 for the principle discovered by the Greek scientist Archimedes (287 to 212 B.C.) to be applied to air, with Joseph Montgolfier's discovery.

The balloon's "engine"... is Archimedes' Principle of buoyancy

The principle of balloon flight simply takes up a principle stated by Arch imedes more than twenty centuries ago: any body immersed in a fluid is buoyed up by a force equal to the weight of the volume of fluid displaced. Consequently, we can consider that our balloon is simply a bubble of light gas immersed in the heavier ambient air.

The other forces applied to the balloon are the friction of air on the envelope (if the balloon has vertical speed), and its weight.

If the balance of these forces is positive, the balloon goes up, if it is negative, it comes down. If it is nil, the balloon remains in a state of equilibrium. It "floats", neither ascending nor descending.

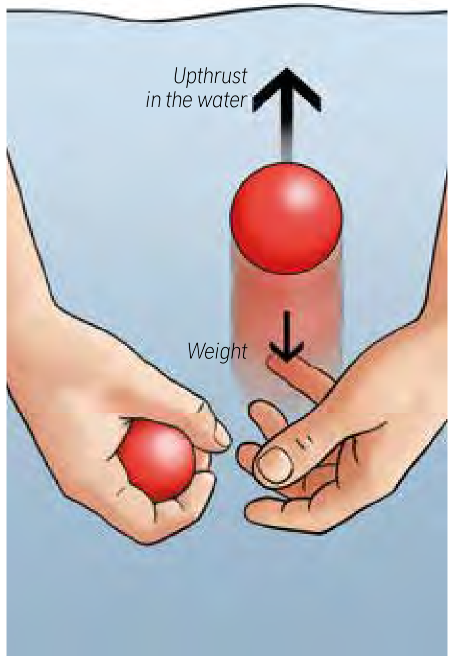
© Illustration Nou Thierry

**Lighter than air...
but mighty strong**

Irrespective of the balloon model, buoyancy remains the one and only engine.

To lift a person aboard a gondola off the ground, simply anchor the gondola to an envelope containing a bubble of gas less dense than the air in the atmosphere, such as helium, which is seven times less dense than air.
Each cubic metre of this gas only weighs 180 g and can lift a weight of about 1 kg!
Therefore, a balloon whose envelope contains about 100 m^3 of helium can go up with an adult on board. Other carrier gases are also used: hot air for recreational Montgolfiere balloons, hydrogen in gas balloons and scientific balloons (also helium).
As hot air has a low carrying power (about 270 g/m^3 at sea level for a 110°C inside air temperature), Montgolfiere balloons have to be very big: 3,000 m^3 and 25 m in height to lift five people.
The higher the altitude, the lower the density of the air, which means that the buoyancy decreases. The higher a balloon is intended to fly, the greater its volume will need to be. Some of the balloons developed by CNES are over one million cubic metres in volume.

A simple way of demonstrating Archimedes' Principle.



Here is a very simple experiment: plunge a Ping-Pong ball down to the bottom of a sink full of water and release it. The ball immediately shoots up to the surface, pushed by the pressure of the water exerted on it. The other forces to which the Ping-Pong ball is subjected are its weight and the friction with the fluid. The upward force is Archimedes' Principle of buoyancy. It is equal to the weight of the displaced fluid. In our example, the weight of the ball is lower than the force of buoyancy: the ball goes up.

For an equal displaced volume, this buoyancy will be much lower in air, but it still exists. Air is lighter than water.

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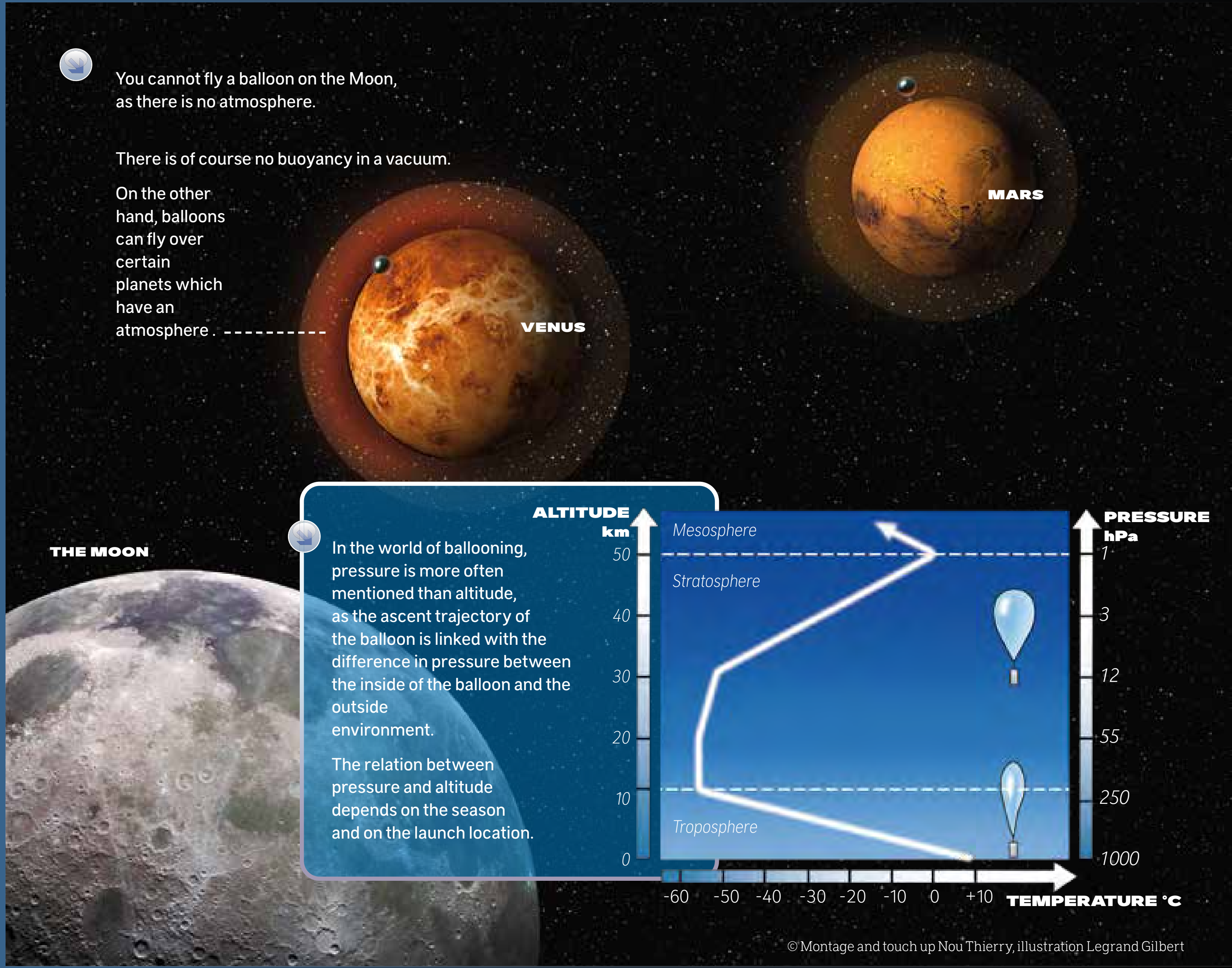
Mais comment font-ils pour s'envoler ?

DES BALLONS POUR LA SCIENCE

>> Le saviez-vous ?



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BALLOONS: OVER 200 YEARS OF HISTORY

The first balloons went up in the 18th century.
Who could have predicted that more than 200 years later, balloons would still be used to enable men to reach the skies, in a simple, cost-effective manner? Balloons are used for scientific and exploratory flights, recreational trips, sports, aerial advertising, etc.

>1770

At the end of the Age of Enlightenment (18th century), hot-air balloons and gas balloons, both very similar, were discovered almost simultaneously.

1782

On 15 November 1782, Joseph Montgolfier found that a shirt hung up over a fire with the collar done up started to inflate. He then built a one-cubic meter cube made of taffeta, which rose up on being heated. Then one experiment followed another, leading up to the first balloon flight which marked the birth of aerostation.

1783

On 4 June 1783, ascent of the first hot-air aerostat, called "Montgolfiere", at Annonay (Ardèche). There are still no passengers on board at this point.

1783

On 21 November 1783, in the presence of King Louis XVI at the Château de la Muette, a thick crowd witnessed a historic event: the world's first trip through the air with passengers: Jean-François Pilâtre de Rozier and the Marquis d'Arlandes, from La Muette to the Butte-aux-Cailles (8 km).
The flight lasted for 25 minutes, and the balloon reached an altitude of 1,000 m.

Ten days later, on 1 December 1783, Jacques Charles and Marie-Noël Robert flew over the gardens of the Tuileries in Paris in a gas balloon filled with hydrogen.
Very soon after, balloons were used for demonstrations during fairs, for military purposes (tethered balloons were used for spying behind enemy lines during battles or sieges, etc.) for scientific applications (atmospheric chemistry, tests on organisms).

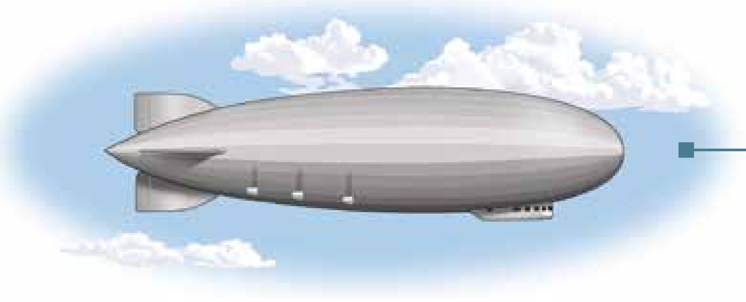
1794

As early as 1794, tests using military tethered balloons with observers on board were conducted successfully. The first company of balloonists was created, and carried out observation missions during battles against the Austrians (Maubeuge, Charleroi, etc.).
The enemy was bewildered and demoralised on finding that all their actions where seen by the French from their flying observatory.

1870

During the siege of Paris in 1870 (the period known as the Commune), gas balloons made it possible for the city to break out of its isolation and send mail to the outside. Key political figures such as Léon Gambetta were also able to escape.

In the mid-19th century, the first true airship, or dirigible, was made in France, thanks to Henri Giffard. He used a small steam engine to drive the propeller. His balloon took off from Paris on 25 September 1852, and landed in Trappes after a 27 km flight. However, the weight of the engines made its practical use impossible.
The dirigible made giant strides thanks to the invention of the internal combustion engine; particularly worthy of note is the epic saga of the Zeppelins, which were used very early on for regular transatlantic flights, or for military purposes in a way that was to make a lasting impression.
The early 20th century was the golden age of dirigibles. These airships remained in use until the early 50's.



*The Jet-stream *is a strip a few hundred kilometres wide located at an altitude of 10 km. The wind speed inside this current is about 200-300 km/h.*

1950

Between 1950 and 1960, a little-known competition took place over balloons between the USSR and the United States. Performances unimaginable up till then were achieved through the production of polyethylene-type thin films. Records were broken several times a year.
The highest manned balloon flight is from that period: over 34,000 m!

1960

In the early 60's the French scientific balloon programme got underway, and was quickly incorporated into CNES.

1999

Latest feat to date: a non-stop round-the-world flight in a manned balloon, by Bertrand Piccard and Brian Jones in 1999: 46,759 km in almost 20 days*.

BALLOONS RISE, SCIENCE MOVES FORWARD

Being better suited and more efficient than planes, satellites or sounding rockets to explore the atmosphere, balloons just keep soaring higher, leading science towards new horizons.

WHY USE BALLOONS?

> Balloons are considerably cheaper than satellites.

> The onboard instruments which can be heavy and bulky, do not need to be able to withstand the accelerations, vibrations and mechanical shocks experienced in a launcher on take-off.

> Balloons are subjected to a far less hostile atmospheric environment than the space environment beyond the Earth's atmosphere.

> Gondolas and onboard instruments can often be recovered and re-flown.

> A balloon launch can take place from a great variety of sites without heavy infrastructure, unlike sounding rockets and space launchers.

> Easy launch from just about anywhere, according to scientific requirements.

Scientists are particularly partial to balloons.
The reason is that balloons constitute a truly unique exploration, measurement or experimentation tool. For almost a century now, they have been mostly used for studying the atmosphere or for astronomy.
Their main advantage is that they alone can explore certain parts of the atmosphere, such as the stratosphere, a region lying at an altitude between 15 and 40 km, too high for planes, inaccessible to satellites, and which sounding rockets go through too fast.
Balloons can therefore be used to complement satellite observations and measurements taken from the ground.

Improved knowledge of our planet and its weather patterns.

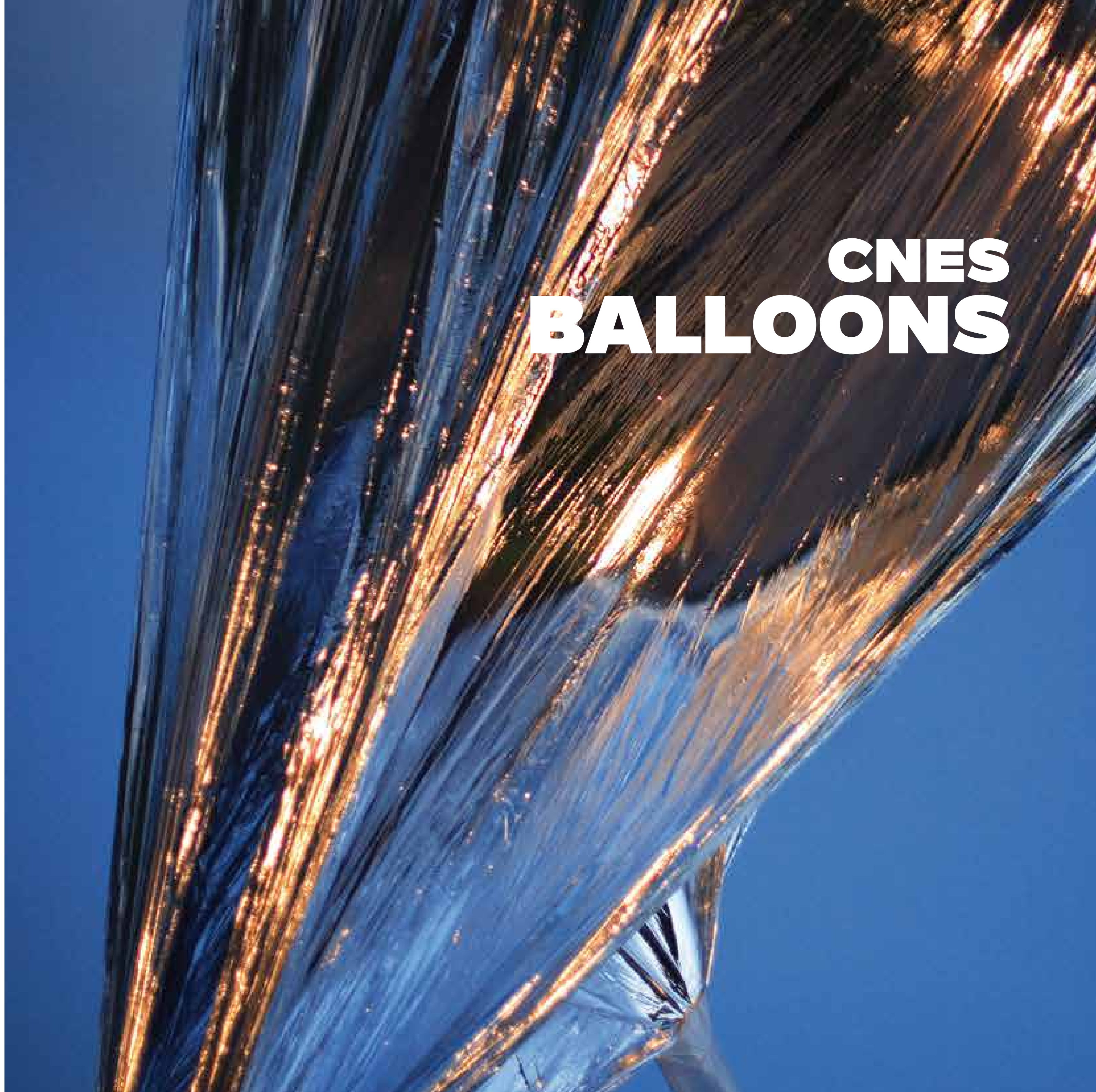
By drifting through the atmosphere, balloons can be used to study physical and chemical phenomena and take air samples. They have been used to study the ozone layer, search for greenhouse gases and particles, and even to improve our understanding of the monsoon patterns in India and Africa.

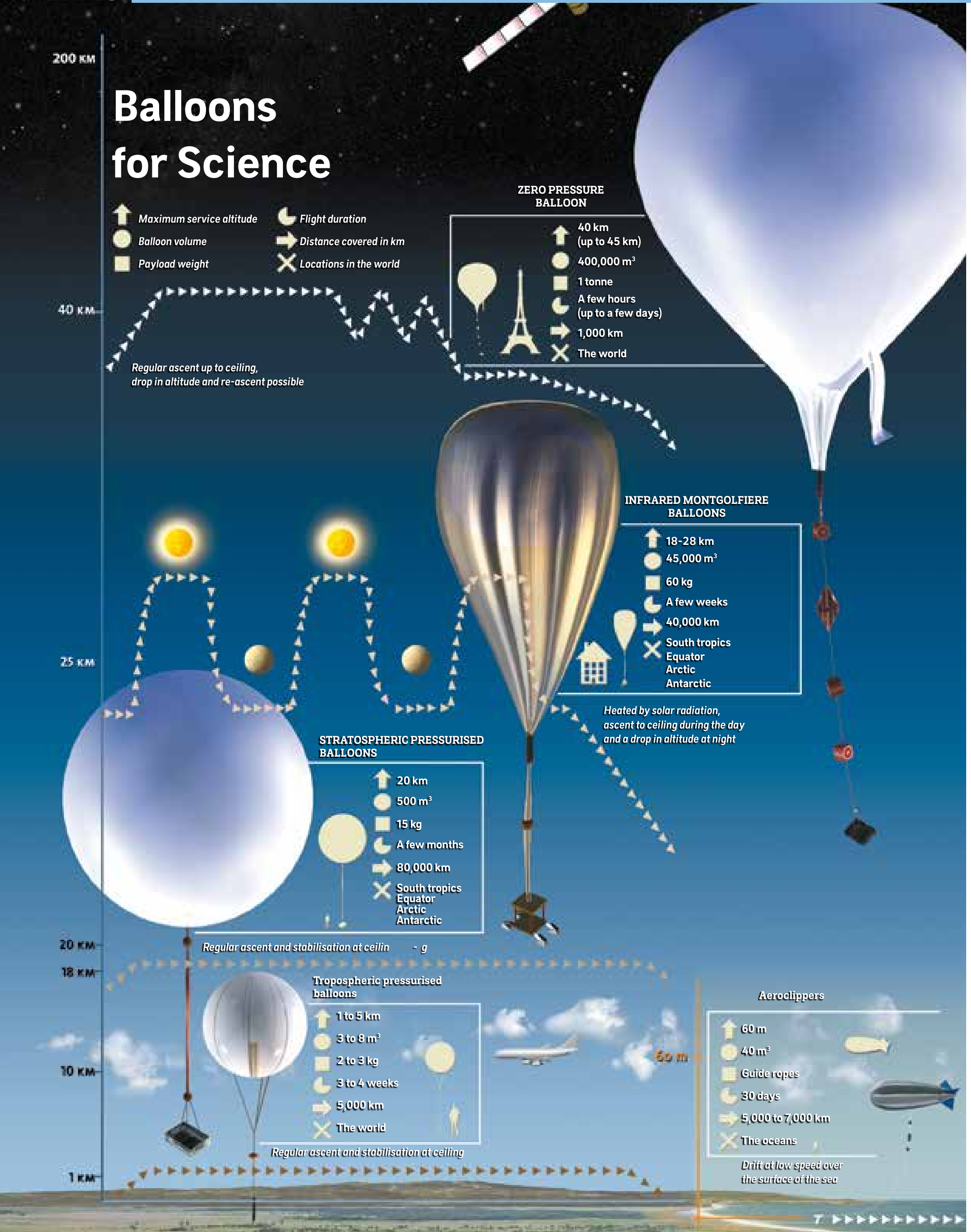
Ideally suited to test satellite equipment.

The scope of application for balloons was broadened through the development of space activities. Balloons are also useful from a technological point of view. Instruments or equipment, designed to be integrated on board satellites, such as cameras, star trackers, solar cells, are tested with balloons at very high altitudes.

Astronomers, astrophysicists, biologists... all on board for using balloons!

Balloons meet the needs of many scientific families. For instance, astronomers use balloons launched beyond the dense layers of the atmosphere to capture invisible radiation which hardly reach the ground, like infrared or ultraviolet, or never reach it at all, like X and Gamma rays. Astrophysicists take advantage of certain flights to validate instrumentation techniques while collecting important scientific data. In addition, balloons can be involved in certain interplanetary missions to Mars, Venus or Titan, one of Saturn's moons.



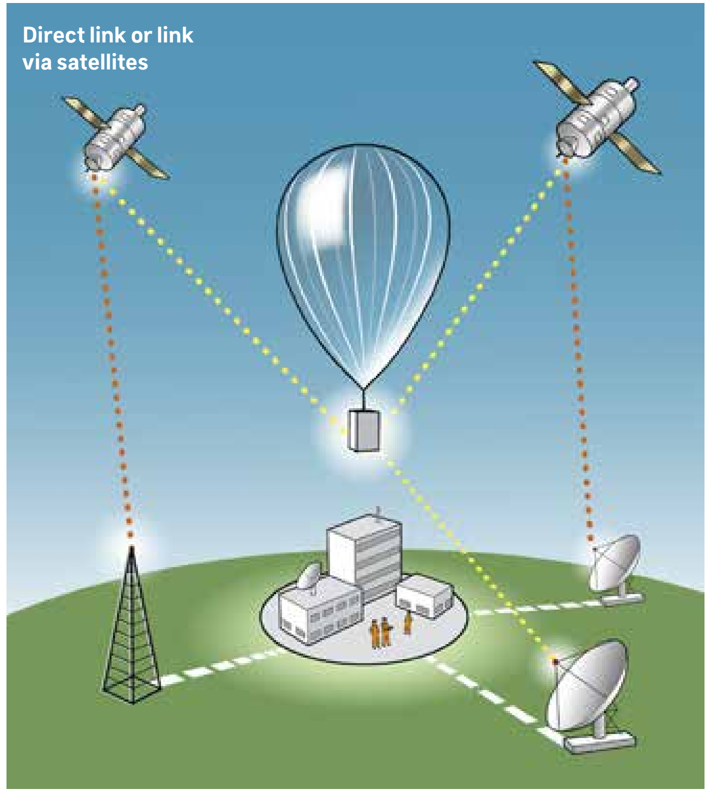


Not all balloons are designed for the same purpose. Every scientific area determines its own requirements, which entail specific constraints. The weight of onboard instruments, the altitude selected to conduct studies, the flight duration, etc. all constitute parameters which vary from one scientific mission to the next. CNES therefore designs and operates several types of balloons. This means that France is one of only a few countries with a mastery of all the techniques required by balloon flights for scientific or technological purposes.

UP, UP AND AWAY… "HIGH" PERFORMANCE

How exactly are balloons controlled?

Balloons flying at stable altitudes or at constant vertical speeds, winds blowing in every direction, and yet everything comes back to ground in predetermined areas. What's the secret? Balloons and people talk to each other. Les ballons dialoguent avec les hommes.



Balloons have gondolas which are constantly connected to a ground control centre. These gondolas are used to operate onboard actuators to release either gas or ballast. This makes it possible to control the ascent or descent of the balloon from the ground.

The control centre, on the other hand, has all the tools required for drawing up accurate weather forecasts. In addition, software packages are used to simulate the balloon behaviour in order to anticipate its motion.
The operators combine all these data and means together to best make use of the winds in order to reach a landing zone free from dwellings or people.

The reliability of balloon control systems such as NOSYCA (Nouveau SYstème de Contrôle d'Aérostats) has been ensured to guarantee that the balloon can always be controlled, including in case of failure. For instance, the links between the control centre and the balloon can be established in several different ways, as shown on the drawing (direct link, or link via satellites). Finally, onboard experiments use these links between the balloon and the ground to transmit their measurement results throughout the flight. In this way, researchers too can interact with their experiments, like the pilot with his balloon.

ZERO PRESSURE BALLOONS (ZPB)

JOURNEY TO THE HEART OF THE STRATOSPHERE

In the "balloon" family, they're the oldest, but also the largest.

Zero Pressure Balloons (ZPB) are the most commonly used balloons for short flights. They have an opening in the bottom part, or more precisely "sleeves" for the release of excess gas once the balloon has reached the required altitude. Once in a state of equilibrium, the balloon remains at a constant altitude in the daytime. At night, when the temperature is lower, the balloon tends to come down. It is therefore kept flying via ballast off-loading operations, in order to make up for the loss of aerostatic lift. This explains the limited lifetime of these balloons (1 hour up to approximately 40 hours), since after a certain number of switches from day to night, the necessary ballast is lacking.

Thin and light, but able to lift several metric tonnes

ZPBs are nothing new. The first models were launched in 1947 in the United States. In France, the first launches by the French National Centre for Scientific Research (CNRS) and then by CNES, did not take place until the 60's. Since these first flights, designers have made considerable changes to the balloons. The objective, flight after flight, was to increase the payload mass, the flight time and the altitude reached . Today, there are several models of zero pressure balloon. The envelopes for these balloons, manufactured by CNIM AS (Ayguesvives, in Haute-Garonne, France), are obtained by hot-sealing of gores of polyethylene, a translucent plastic material. Polyethylene can be amazingly thin: for the largest balloon ever made (1.2 million m3), the thickness of the polyethylene was 0.015 mm, finer than a human hair!

And yet, whatever their dimensions (from a few thousand cubic metres to more than a million cubic metres), these balloons are highly efficient.

They can take up loads ranging from a few dozen kilos to a few metric tonnes. The largest balloons can lift up gondolas of about two metric tonnes to an altitude of 40 kilometres.

BALLOONS FOR SCIENCE

A journey to the heart of the stratosphere

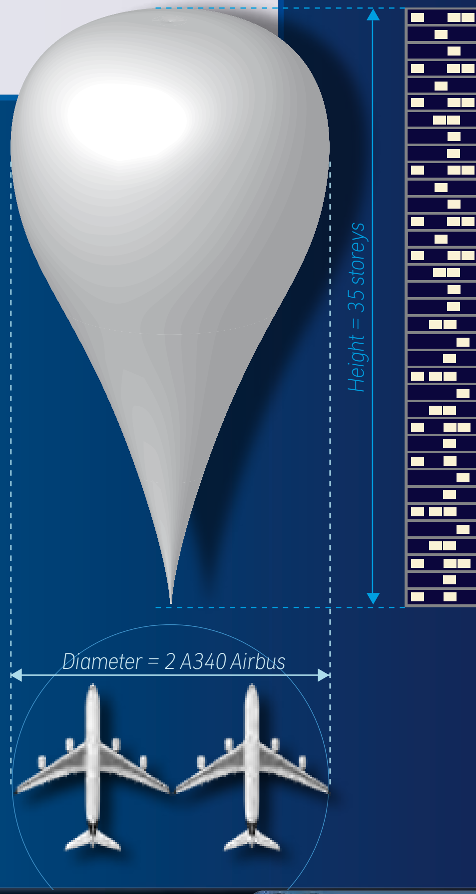
>> DID YOU KNOW?

ZPB facts and figures

Volume of the envelope: **from 3,000 to 1,200,000 m^3**
Carrier gas: **helium**
Weight carried: **several metric tonnes**
Maximum service altitude (where the balloon stays): **from 15 to 40 km**
Flight duration: **7 hrs up to a few days**

The largest French balloon ever made to date is simply gigantic.

A volume of **1,2 million m^3**, a maximum **diameter of 148 m** (twice the wingspan of the Airbus A340), **108 m high** (the equivalent of a 35-storey building) and the capacity to lift **a lead of 750 kg to an altitude of 45 km d'altitude.**



INFRARED MONTGOLFIERE BALLOONS (MIR)

EFFICIENCY DAY AND NIGHT

In flight, this infrared Montgolfiere balloon descends, then rises up, then falls a little lower again, and so on... a bit like a yoyo with scientific leanings.

In 1977, French researchers from the CNRS Aeronomy Department came up with the idea for a Montgolfiere design capable of long flights through the stratosphere.
This concept was then developed by CNES under the name of Infrared Montgolfiere Balloon or MIR. The principle of this balloon, supported by hot air rather than helium or hydrogen, is particularly ingenious. Its envelop is heated naturally, by the sun during the day, and at night (and here is why this balloon is particularly original), by the infrared radiation from the Earth.
Unlike other balloons, which irreversibly gradually lose their gas in flight, and then start to come down, infrared Montgolfiere balloons run on air that can be renewed at will.

In other words, they can "recharge their batteries" in flight.

Since daytime radiation is greater than night-time radiation, the balloon goes up. At night, the MIR starts to come down, but is "held up" by the infrared radiation captured by an aluminised film. The balloon eventually reaches a critical level (altitude of about 16 km), from which it becomes impossible to find a stable flight altitude, unless the rising sun starts to re-heat the MIR, which will then start to rise again.
In this way, without any human intervention, the MIR balloon continues to move up and down naturally between a ceiling (during the day) and a floor (at night). It also moves along with the winds.

Why are MIR balloons so popular with scientists?

The flight principle of an infrared Montgolfiere balloon presents many advantages to the scientific community.

> They guarantee longer flight times than the majority of other balloons: between fifteen and twenty days on average. On the other hand, it depends on the latitude, the season, and the cloud cover (especially at night: the thicker the cloud cover, the more it absorbs terrestrial infrared radiation, and the higher the risk of the balloon falling).

> MIR balloons are more efficient than satellites for chemical and meteorological observations below 20 km, because of the clouds and atmospheric absorption.

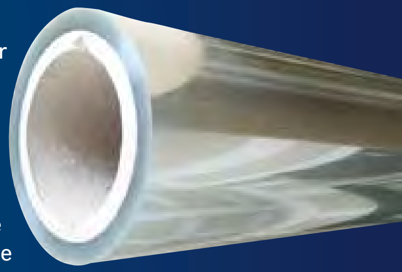
> They are used, among other things, to measure the daily rate of ozone depletion in an air mass, to assess the performance of weather models in the stratosphere, or to observe the amplitude of orographic waves on the highest mountains on Earth.

But how do they manage to take off?

BALLOONS FOR SCIENCE

>> DID YOU KNOW?

From a technical point of view, MIR balloons are exclusive to France. Their envelope comprises two types of plastic film: polyester with a thick-ness of 0.012 mm covered by a thin layer of aluminium on the upper part, to absorb the terrestrial infrared radiation; and polyethylene with a thickness of 0.015 mm on the lower part.



MIR facts and figures

Volume of the envelope: **45,000 M³**
Carrier gas: **ht air (helium for take-off)**
Weight carried: **60 kg**
Maximum service altitude: **30 km (day) 20 km (night)**
Flight duration: **several weeks**

PRESSURISED BALLOONS (SPB - BLPB)

A LONG VOYAGE THROUGH THE STRATOSPHERE

CNES has become world-renowned in the field of stratospheric pressurised balloons. Today, SPBs constitute one of the best ways of conducting long flights, perfectly suited to certain scientific missions.

Stratospheric pressurised balloon (SPB) heing released.

On the Esrange launching pad.

Stratospheric pressurised balloons (SPBs) are of interest to researchers studying the atmosphere and who want to find out about the movements of air masses, their temperature, their pressure, the moisture content, or to those who wish to study the quality of the air or the role of the ozone layer... SPBs are used as platforms to carry measuring instruments.

High-strength balloons

These balloons, with pressurised envelopes, are used for long flights. Their volume, which is kept constant due to the gas being retained in an air-tight envelope, enables them to stabilise at a specific maximum altitude (through equilibrium between the buoyancy and the weight carried). However, keeping this volume constant requires material able to withstand stresses of several metric tonnes per square metre, which are generated by the difference in pressure between the inside and the outside of the envelope. The material used is a polyester about 1/20 of a mm thick.

The flight time is only limited by changes in weather conditions in the fly-over area, and by gas losses from the envelope. These balloons require the greatest care, from their production to their deployment on site, as the smallest microleak may cause quick loss of the vehicle, and therefore mission failure. The largest envelopes currently reach 12 metres in diameter. Designers are still exploring ways of possibly broadening the diameter, and therefore increasing the load or the altitude.

>> DID YOU KNOW?

BALLOONS FOR SCIENCE

BLPBs, another type of pressurised balloon

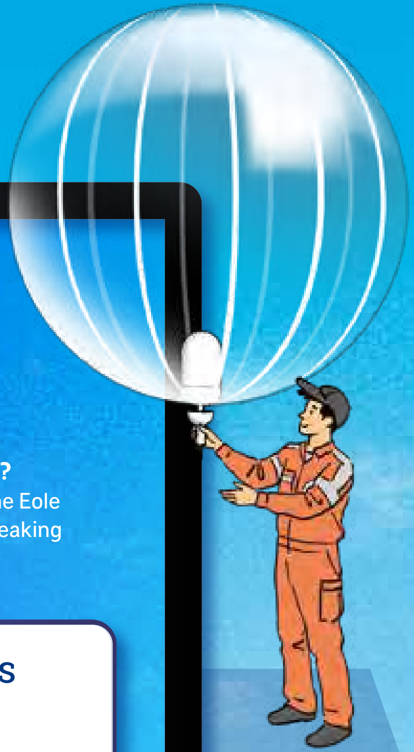
BLPBs (boundary layer pressurised balloons) are a variant of SPBs.

These smaller, lower-flying balloons with a diameter of 2.5 m behave as veritable atmospheric air mass tracers.
They are highly valued by scientists for the study of intense meteorological phenomena (monsoons, cyclones, depressions, etc.).
These simple-looking balloons are jam-packed with concentrated technology; the combination of the low weight they can carry (a few kilograms) and their long lifetime (a few weeks) means that designers are obliged to miniaturise the instruments and control devices as much as possible.

CNES is working on even smaller balloons, the NANOs, which can be launched in formation to provide the scientific community with an even more efficient tool to collect samples from the lower layers of our atmosphere.

An SPB never leaves on its own.
Generally, campaigns are conducted with a flotilla of these balloons (a few dozen).

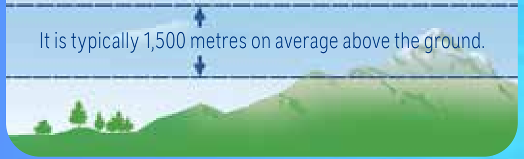
Over 600 days, ...any higher bids?
The longest flight took place during the Eole campaign: it lasted a world-record breaking 605 days.



SPB facts and figures

Volume of the envelope: **900 m³**
Carrier gas: **helium or hydrogen**
Weight carrier: **up to 60 kg**
Maximum service altitude: **18 to 30 km (day)**
Flight duration: **a few months**

In meteorology, the term **atmospheric boundary layer** is used to refer to the layer in the atmosphere where wind circulation is affected by the relief.



A long journey in the atmosphere

AMMA: African Monsoon Multidisciplinary Analysis

The purpose of the AMMA mission is to better understand the mechanisms at work in the African monsoon, in order to more accurately predict its variations and repercussions on the climate (local, regional, worldwide) and on the populations. Part of the campaign took place in Cotonou (Benin) to study the flow and outbreak of monsoons.

AEROCLIPPERS

ACROSS THE SEAS AND THE OCEANS

It is not required to take off, just to move over the surface of the sea and perform a whole series of measurements. Its name is Aeroclipper, and it looks like a small, semi-tethered airship.

The Aeroclipper, first tested in 2004, is a weather balloon designed to study the marine surfaces and the lower layers of the atmosphere.
In practical terms, it is a balloon which drifts along with the wind at a height of 50 m maximum. Below its helium-inflated envelope is a small atmospheric gondola which performs meteorological and/or scientific measurements in the lower layers of the atmosphere. The balloon is stabilised by a guide rope, with a rope attached and floating at the surface of the water. An ocean gondola at the end of the guide rope is used to take measurements at the surface of the seas and oceans.

Thanks to the capacity of the two gondolas, this balloon is ideal for the study of atmosphere - sea water coupling phenomena.
The measurements are then transmitted by satellite to a control station.

Performing measurements in inaccessible areas.

The Aeroclipper offers a number of advantages allowing it to perform unprecedented scientific measurements.

- It is perfectly suited to taking long-term measurements (up to 30 days) without a break.

- It performs its measurements in regions where few traditional means are used (ships, aircraft).

- It can be used to supplement satellite data collected in sensitive regions such as the Indian or Pacific Oceans.

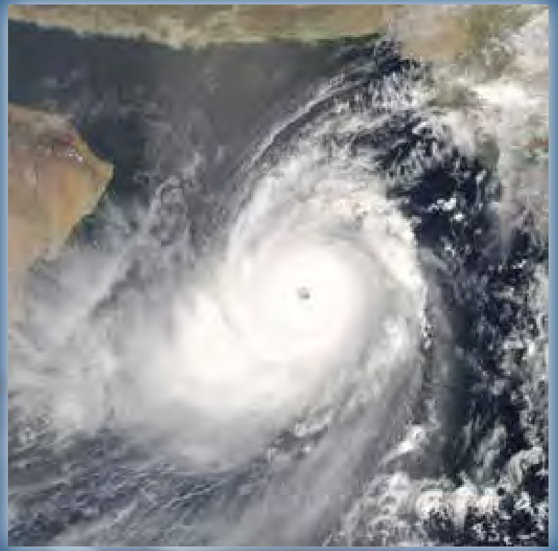
- In addition to the position and usual atmospheric parameters, it also measures the wind speed on the balloon, the displacement speed in the water mass, the temperature and the water salinity.

Drifting above the seas an the ocdeans

>> DID YOU KNOW?

Always on top.

The ocean gondola is equipped with sensors to measure the temperature at depths of 10 cm and 40 cm.



In the eye of the storm.

After being trapped by cyclone Dora in 2007, two aeroclippers managed to keep contact with the ground for close to a month, including from the centre the cyclone itself!

This was a world first, and scientists are hopeful that they will be able to repeat this achievement to collect a wealth of data of major importance to understanding the way a cyclone behaves and changes.

PLANETARY BALLOONS

THE PLANETS SEEN FROM BALLOONS

Sending balloons to fly over planets?
Incredible but true.
And this is not just some harebrained project. It is reality.
Certain planets have an atmosphere through which balloons can fly.

Flying over Mars or Venus in a balloon. A mad notion, worthy of Jules Verne. And yet in June 1985, the former Soviet Union actually took up the challenge. The Vega 1 and 2 space probes released two pressurised balloons into the atmosphere of Venus. They drifted for two days at an altitude of about 50 km. Today, CNES is working on several projects to explore Venus and Titan using balloons.

Why fly over planets with balloons?

The scientific instruments on board the gondolas are used to make measurements in various fields (imaging, meteorology, atmospheric chemistry, radiation, etc.).
These data are then sent to earth via an on-board telemetry/ telecommand relay.
A balloon is often more efficient than a vehicle moving around on the planet's surface. Obstacles can often hinder the progress of the vehicle, which moreover cannot take pictures apart from when it is landing with a parachute.

Flying a balloon in this environment is no easy task…

And yet, solutions must be found to improve the balloon's resistance to the atmospheric environment of the planet by improving the composition of the material used for the balloon envelope. This atmosphere can be hostile, as on Venus, due to the presence of clouds of sulphuric acid, or on Titan, where the temperature can drop down to -170°C at the Montgolfiere balloon flight level. However, the trickiest and most difficult phase remains the deployment and inflation of the balloon in a few minutes, while the interplanetary probe drops down, hooked to its parachute system, into the atmosphere of the planet.

The planets seen from balloons

BALLOONS FOR SCIENCE

>> DID YOU KNOW?

Several types of balloons can be considered, depending on the atmosphere encountered.

In order to fly for several days over Mars, a pressurised balloon, closed and filled with helium, must be used to withstand the transition in temperature at sundown, which would cause the balloon to descend again.

On Venus, a pressurised balloon filled with helium is another possibility. And for Titan, Saturn's moon, it is possible to use a Montgolfiere balloon filled with "air" from the planet, provided this air is warmed up by a "heater" inside the balloon.

Projects for the future?

Europe and Russia are exploring the possibility of sending a balloon into Venus' atmosphere at some point in time between 2015 and 2025.

CNES, in collaboration with ESA and NASA, is working on sending a Montgolfiere balloon into the atmosphere of Titan.

A TYPICAL LAUNCH

THE BALLOON SOARS INTO THE AIR

An eye-witness account...

Here are the different steps of a typical zero pressure balloon launch. A minute-by-minute account of the event, giving a good idea of all CNES balloon launches.

On the eve of the launch, the scientific team confirms that the instrument is ready to fly.

H-3

D-day at H-3. Weather briefing.

The person in charge of "weather forecasts" at the centre confirms that conditions are favourable. He goes over the flight profile: the required maximum altitude of 31,200 m will be reached in 1hour 40 mins, then there will be a slow descent prior to separation. It is planned for the balloon to land in a safe area. The simulation, correlated with an analysis of the risks calculated all along the planned trajectory, confirms that the flight is feasible.

H-2H45

The launch team move in.

Start of the validation tests on the gondolas for command, control and communication with the scientific gondola. The auxiliary balloons used to hold the gondola during the launch phase are filled with helium.

H-1H45

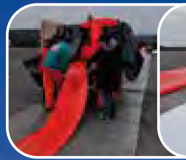
The control gondola is brought out to the launch pad.

The flight train is assembled with the gondola and the last technical tests are conducted.

H-1H30

The experiment is transferred to the launching pad.

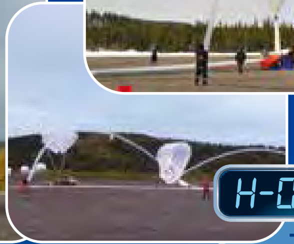
The gondola, over 100 kg in weight, is suspended under the auxiliary balloon. The tests on the radiofrequency connection between the gondola and the mission centre can now take place in flight configuration.



H-1

The main balloon is unfolded.

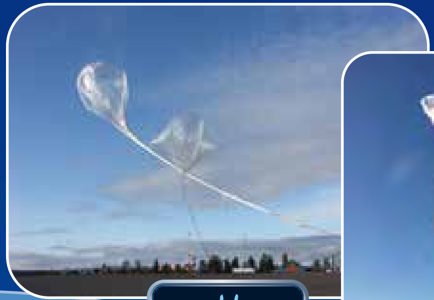
The envelope is taken out of a wooden crate, and placed on a long protective mat. It is handled with gloves. Its volume is 50,000 m³. It weighs 238 kg. The weight of its ballast is 100 kg.



H-0H30

Time to inflate.

Two technicians fill the balloon with helium for 15 min. 740 m³ of gas fill up a bubble 23 m high.



H

Release 5 minutes ahead of schedule!

The balloon is released and flies up. The ascent of the balloon is monitored from the operation room, and the trajectory is followed by means of the various GPSs (20 m precision in 3D). The retrieval teams have already been sent to the estimated landing site. The balloon ascends at a rate of 5 metres per second, in accordance with the flight plan and with the scientist's criterion. Everything is going according to plan. The measurements are about to start.

Photographs taken from the ground using a telephoto lens.

H+1H30

The balloon reaches its maximum service altitude

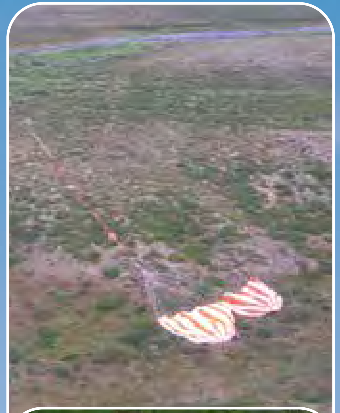
The balloon has reached an altitude of 31,200 m, 30 km west of the launching pad. The ascent phase is about to end, as the maximum service altitude has been reached. The collection of scientific data starts.

H+5

Scientific measurements completed

The operation room identifies a suitable landing site compliant with safety rules. The air navigation control centres are informed and give their approval. The retrieval teams head for the landing sites in order to secure the area.

The order is given to separate the gondola from the envelope. The descent of the two mobile elements (envelope and gondola with its parachute) is monitored in real time down to the ground.



H+5H30

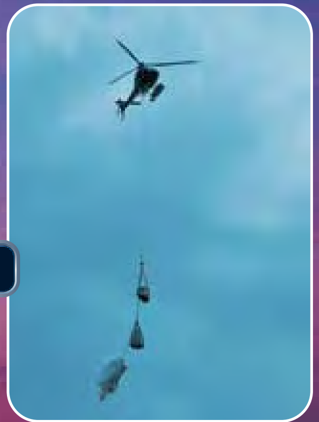
The envelope lands 35 km west of the launching pad.

The recovery team starts to deactivate the electronic gondola, and then loads everything into a trailer.

H+6

The scientific gondola lands in a grove 4 km away from the envelope.

The second teams moves in and secures the area. They disconnect the electronic units and ask the operation room for helicopter assistance to recover the gondola...



H+10

1 hr after the early morning mist has cleared, the helicopter can finally take off and get on site.

The components are recovered in great condition and are sent to the launching pad.

The envelopes are recovered for environmental reasons. These will be disposed of and never reused.

MAJOR CNES CAMPAIGNS

Launched in 2007, the Vasco programme brings together boundary layer pressurised balloons (BLPBs) and Aero-clippers. Objective: to gain a better understanding of the interactions between the atmosphere and the Indian Ocean.

VASCO (2006-2007)

EVERYTHING THERE IS TO KNOW ABOUT THE INDIAN OCEAN CLIMATE

Launched in partnership with the Laboratoire de Météorologie Dynamique (Laboratory for Dynamic Meteorology, or LMD) and the Laboratoire d'Océanographie et du Climat, Expérimentation et Approches Numériques (Oceanography and Climate Laboratory: Experiments and Digital Monitoring, or LOCEAN) part of CNRS, Vasco is one of the most extensive CNES balloon campaigns. The region concerned is the Indian Ocean. The Vasco objective? To enable scientists to improve seasonal forecasts in the Indo-Pacific area.

What's behind El Niño?

This campaign was designed to answer the countless questions about this oceanic region, where major weather events bringing monsoon rains occur over several thousands kilometres, for a period of 30 to 60 days. Why do these disturbances then move eastwards during the summer in the southern hemisphere, and occasionally trigger this abnormal hot current, known as an El Niño event, upon reaching the West Pacific? Why, during the northern summer, do these disturbances move up north and affect the Indian monsoon? Could water and energy exchanges between the ocean and the atmosphere be at the root of these disturbances in the rain patterns?

Two types of balloon in action

The Vasco campaign mobilised considerable operational resources, such as oceanographic ships and drifting buoys, but also tropospheric balloons. Two types of balloon were used: Aeroclippers, which simultaneously took measurements at the surface of the ocean and in the atmospheric surface layer, and boundary layer pressurised balloons (BLPBs), flying at an altitude of 1,500 m, whose aim was to study large-scale tropospheric movements.

Recent BLPB and AéroClipper campaigns

"As early as 1973, CNES developed low-altitude balloons for flying in the lower layers of the atmosphere, in order to study the local meteorological phenomena such as the monsoon in India or Africa, Cévennes events in France or cyclones. The Tropospheric tracer balloon family (TTB) includes Pressurized Boundary Layer Balloons (BLPB) and the AeroClipper."

The objective of the BLPB HyMeX (Hydrological cycle in the Mediterranean eXperiment) flights was to collect meteorological data in the atmospheric boundary layer above the Mediterranean Sea, at an altitude of around 1000 m. These data improve knowledge of air / sea interactions and flows and help extend the ability to predict high-impact meteorological events (Cévenol episodes).

Two operational periods took place:-

- September to– November 2012 : 16 balloons were launched from Mahon airport (Minorca).
- February to March 2013 : 15 balloons launched from the Candillargues airfield (south of France).

The objectives of the BLPB ChArMEx (Chemistry-Aerosol Mediterranean Experiment) flights were to study the plumes of pollutants exported from the northern shore of the Mediterranean basin, and the radiative impact of the dust plumes from the African continent on the Mediterranean region. been completed with the addition of an ozonometer or an optical particle counter (LOAC) to the basic configuration of the BLPB.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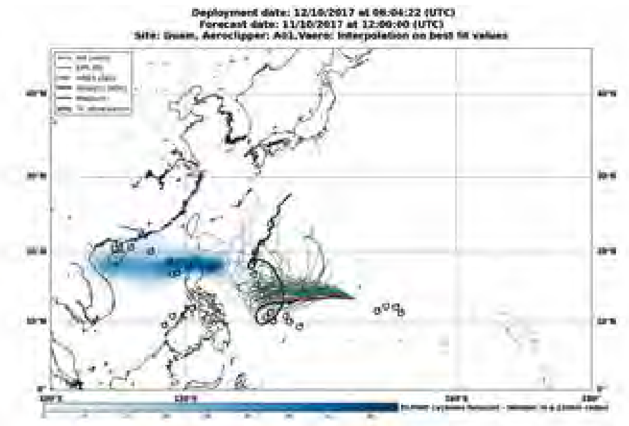
Two operational periods took place:

- June-July 2013 : 14 balloons were launched from the Mahon airport (Minorca) – flight altitude : 2500 m ÷ 3000 m.
- July-August 2013 : 9 balloons launched from Ile du Levant (south of France) – flight altitude ~ 1000 m.

The AeroClipper campaigns (post VASCO): Following the development of a new AeroClipper blimp balloon, sea system tests from Port Camargue were organized to validate its aerodynamic behavior.

The last AeroClipper campaign was conducted on the island of Guam (US territories in the West Pacific) in 2017 for the LMD. The objectives were multiple:

- Operational validation of the Guam site, very conducive to the passage of cyclones nearby.
- Characterization of vehicle performance for the study of cyclones, in particular its penetration speed.
- Validation of the model for forecasting the trajectory and "capture" by a cyclone, developed by the LMD.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MIR (February 2001)

A RECORD 3 TRIPS

ROUND THE WORLD IN 71 DAYS

In February 2001, an infrared Montgolfiere balloon made history with a flight of unequalled duration. New evidence of the extreme reliability of these ingenious balloons.

After leaving Pretoria (South Africa) on 8 December 1988, an infrared Mont-golfiere balloon made an astounding two trips round the world in fifty days. However, one of the three infrared Montgolfiere balloons launched on 15 February 2001 from Bauru (Brazil) did even better: 3 round-the-world trips in 71 days. A record, historic achievement. The other two infrared Montgolfiere balloons clocked up flight times of 48 and 40 days.

Beyond the achievement, scientific breakthroughs

The success of these flights confirmed the ability of the infrared Montgolfiere balloon vehicle to carry out scientific missions on ex-changes between the troposphere and the stratosphere in tropical and equatorial regions. In addition, these flights opened up perspectives for new missions involving vertical atmospheric soundings in areas that are hard to reach. These soundings are used to validate high-altitude weather forecasts, and certain satellite measurements of the composition of the atmosphere.

Eole campaign

(1971-1972)

RIDING THE WIND

The Eole campaign (1971-1972) **was one of the most important CNES missions not only in terms of pressurised balloons, but also of the exploration of the atmosphere. This Franco-American programme made scientists aware of how efficient the use of balloons and space resources could be.**

STRATEOLE VORCORE (August-November 2005)

STUDY THE HOLE IN THE OZONE LAYER

The goal of the Strateole Vorcore campaign, which was conducted in the harsh conditions of Antarctica, was to study the variations in the hole in the ozone layer. A flotilla of around twenty pressurised balloons was mobilised in order to bring this important scientific mission to a successful conclusion.

Between 20 August and 11 November 2005, from the American base of McMurdo in Antarctica, a team from CNES and the Laboratoire de Météorologie Dynamique in Palaiseau conducted a very original campaign called Strateole-Vorcore. This aim of this project, sponsored by the National Science Foundation and the Paul Émile Victor Institute, was to study the variations in the hole in the ozone layer at the polar vortex (the polar vortex refers to the circulation of stratospheric air masses around the North and South Pole).

Paths of 20 balloons in simultaneous flight around Antarctica.

Why choose the McMurdo American base in Antarctica?

The choice of the McMurdo American base in Antarctica, at the foot of Mount Erebus, at latitude 78° south and longitude 167° east, was conditioned by several factors. First, this station is protected from katabatic winds, the violent gusts of the Antarctic continent caused by the unusual relief. Also, balloons released just 1,300 km from the South Pole can be injected straight into the heart of the polar vortex. Finally, this base is located on Ross Island, on the edge of the pack ice, and is accessible by boat in summer, and by (heavy) aircraft at the end of winter. This is a unique location in Antarctica, which made flights possible right from the end of winter.

27 balloons in the skies over Antartica

Over two months, 27 pressurised balloons, 10 m in diameter, were launched in very harsh conditions, to fly over the continent of Antarctica for several months, always following the same air masses. On completion of the programme, more than 150,000 observations had been made, corresponding to 1,575 days of observation in total.

An undeniable scientific success

Prior to the Strateole-Vorcore programme, McMurdo had never seen such an extensive operation carried out in winter conditions. It was a success, from and a logistical, operational and scientific point of view. This campaign opened up a new vision of the polar stratosphere, and made a significant contribution to our knowledge of the stratospheric vortex dynamics.
Since then, a new balloon campaign called Concordiasi has been proposed to increase the scientific knowledge of this region of our planet.

AMMA - AFRICAN MONSOON MULTIDISCIPLINARY ANALYSIS (2002-2007)

A HUMANITARIAN CAMPAIGN

In 2006, about sixty African, American and European organisations, including CNES, joined forces to help West Africa towards a better understanding of and better preparation against the monsoon phenomenon. CNES took over all the balloon activities for this crucial programme, aimed at improving the quality of life for the populations.

How to better predict the monsoon's variations and repercussions on the climate at a local, regional or global scale and on populations?

To answer these questions of great concern, and above all to better understand a phenomenon which makes it difficult to set up agricultural strategies and which directly affects the populations, around sixty European, African and American laboratories rallied around the AMMA programme, launched in 2001 by French researchers.

An international effort at sea and in the air

The year 2006 marked the apex of the programme, with a series of intensive observations, particularly from space. No fewer than thirty countries joined forces through numerous organisations. Major resources were mobilised for a large-scale analysis of the ocean and the atmosphere. Five research aircraft were deployed from Niamey, Ouagadougou and Dakar to carry out dynamic and atmospheric chemistry measurements. Instrumented balloons took off from three platforms: Cotonou, (Benin) (BLPB), Zinder, (Niger), (SPB with dropsondes) and Niamey, (Niger) (ZPB) to take additional measurements. In the course of campaigns conducted by three ships on the ocean in the Gulf of Guinea, the atmospheric flow, the temperature, the water salinity and the sea currents were measured.

Three balloon launch campaigns took place to study monsoon flows and their apparition, and also observe the upper troposphere, the lower stratosphere, and the atmospheric environment. These balloons were also equipped with instruments for measuring temperatures, wind speed, moisture content and atmospheric pressure.

Satellites were also in on the action

The space industry was also called upon to supply satellite data, Spot, Vegetation, Meteosat, Noaa, Envisat, A-train... About thirty satellite resources in total were mobilised for the 2006 campaign.

STRAPOLETE (summer 2009)

STUDYING THE OZONE LAYER

The radiation balance of the stratosphere is conditioned by its chemical composition: ozone content, greenhouse gas content, aerosol content. It depends on the latitude and the season. The disturbance to this balance caused by human activities has already modified the wind patterns, and consequently the surface temperature in the polar regions.

The Strapolete programme is a large-scale balloon campaign which took place from 20 July to 15 September 2009, in Kiruna (Sweden), as part of the International Polar Year. Its mission was to conduct an in-depth study of the arctic stratosphere in summer to better understand the ozone layer depletion processes at the North Pole.
In other words, this mission was to clarify the role clouds in the stratosphere play in modifying the ozone layer at the North Pole and the ozone-climate interactions.
This was the first time that measurements of the polar stratosphere (altitude of between 17 and 40 km) were taken in summer. Scientists traditionally spend more time studying the formation of the hole in the ozone layer at the end of winter, but they wanted to complete their data with summer measurements in order to better describe and understand the overall phenomenon.

MISSIONS DEDICATED TO ASTRONOMY

CLOSER TO THE SKY

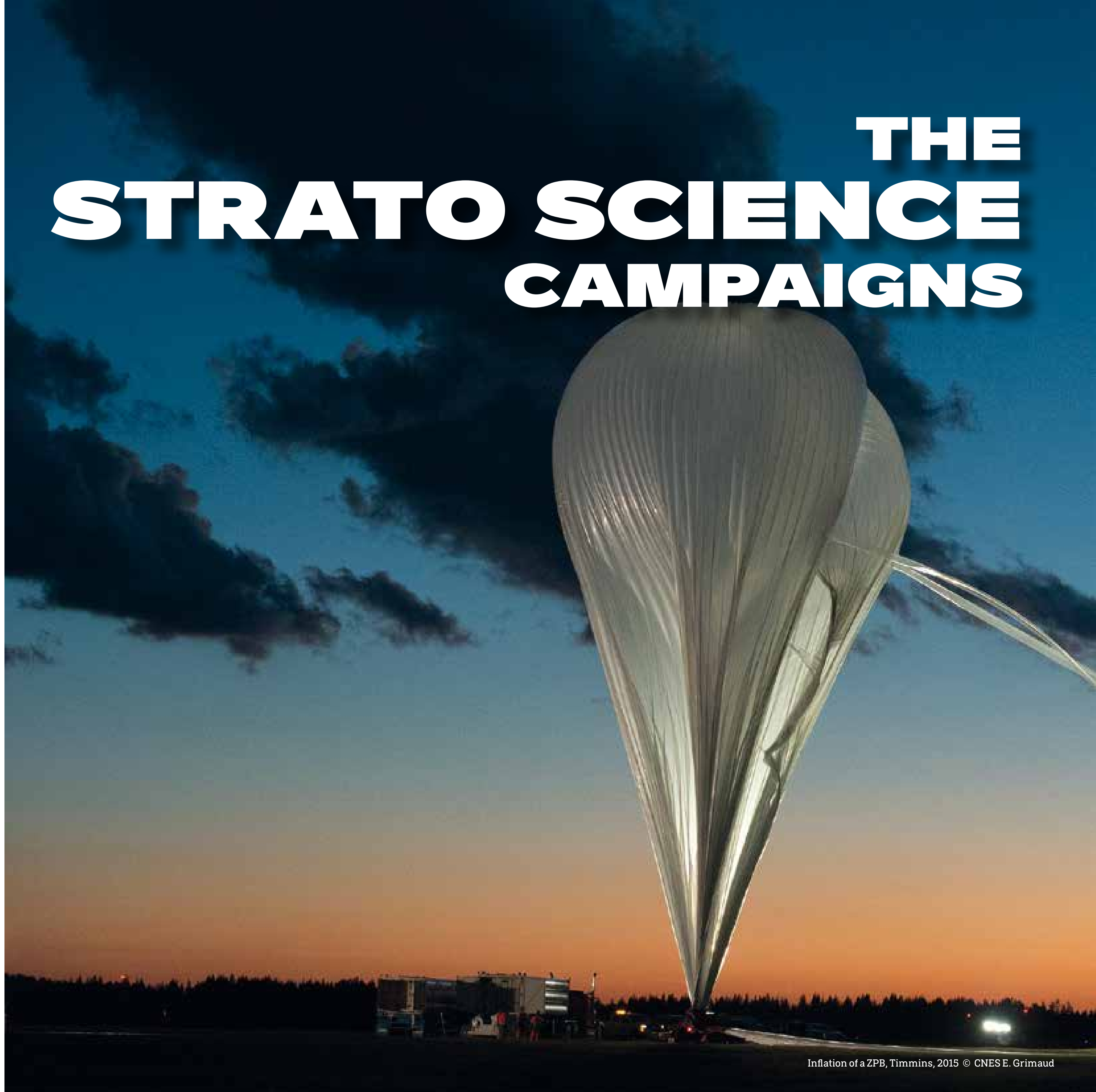
From Pronaos through Archeops to Pilot

Over the last few years, submillimeter astronomy on board stratospheric balloons has been a part of major projects, such as Pronaos and Archeops. It will once again be at the fore with the Pilot project. Pronaos was developed by CNES and CESR (Centre d'Étude Spatiale des Rayonnements - the French Space Radiation Research Centre) in Toulouse, IAS (Institut d'Astrophysique Spatiale – the Space Astrophysics Institute) in Orsay and SA (Service d'Aéronomie – the Aeronomy Department) in Verrières. The three-tonne gondola carried a telescope two metres in diameter pointed at five arcseconds. Pronaos flew in 1994, 1996 and 1999 with a one million-cubic meter balloon, reaching an altitude of about 37 km. These flights made it possible to obtain remarkable results on the interstellar galactic environment and the relic radiation. Archeops is the result of international collaboration between France, Italy, Russia and the United States... It is also a submillimeter astronomy experiment more specifically dedicated to the mapping of relic radiation. After two test flights in 1999 and 2000, Archeops took off three times from Kiruna (Sweden): first in January 2001, and then in the winter of 2002.

Pilot is a stratospheric balloon astronomy project whose purpose is to measure the polarised emission of interstellar dust in the far infrared and submillimeter wavelengths. These observations will enable us to study the magnetic properties of interstellar dust particles, to characterise the magnetic field of our galaxy, and to improve our understanding of the role the magnetic field plays in the formation of stars. Lifted up to 40 km by 800,000 cubic meter balloon, the telescope, one metre in diameter, will scan the galaxy and the diffuse clouds outside the galactic plane. This project is being developed by CNES, CESR, IAS and CEA (Commissariat à l'Énergie Atomique – the Atomic Energy Commission) in Saclay.

Fireball (2007, 2009, 2018), a campaign dedicated to astronomy

Fireball is a balloon project involving CNES, the Astrophysics Laboratory in Marseille and several American partners, including the Columbia Science Balloon Facilities (which is part of NASA). As part of this project, CNES has been entrusted with the study and manufacture of an astrophysics gondola weighing more than 2 tons, capable of carrying a telescope with a primary mirror of 1m and a focal length of 2.5 m. Operating in the UV range, Fireball looks for warm dust filaments close to galactic clusters. The fine pointing stage allows for fields of view with a precision of a few arcseconds under a stratospheric balloon at an altitude of 40 km.



THE STRATO SCIENCE CAMPAIGNS

Inflation of a ZPB, Timmins, 2015 © CNES E. Grimaud

In order to meet the requirements for balloon flights from the French, European and international scientific community, CNES organizes an annual Zero Pressure Stratospheric Balloon campaign (ZPB) from partner sites at different latitudes.

Some figures

7 flight campaigns were carried out between 2013 and 2019 :

A total of 30 ZPB flights

> 2013: Timmins, 2 flights

> 2014: Timmins, 7 flights

> 2015: Timmins, 6 flights

> 2016: Kiruna et Aire, 3 flights

> 2017: Alice Springs, 3 flights

> 2018: Timmins, 5 flights

> 2019: Timmins, 4 flights

> 2021: ZPB flights and 10 SB flights foreseen at Kiruna

Number of participants on site during a balloon launch campaign: up to 140, including 20 to 30 CNES staff, 15 partners from the site, and about one hundred persons from the scientific teams

Average duration of a balloon campaign: 40 days

Quantity of freight shipped to the launch site: 110 tons by sea containers

These campaigns also give the opportunity to operate sounding balloons (SB) in particular and SPB (Super pressure balloons), as well as measurements from the ground or from instrumented airplanes, to complete the harvest of scientific data.

Since 2013, the launch bases mainly used are those of Timmins (48 ° N, Ontario, Canada, managed by the Canadian Space Agency), and Kiruna (68 ° N, Sweden, managed by the Swedish Space Corporation).

In 2017, the campaign took place in Alice Springs, Australia, in collaboration with CSIRO and NASA, to allow the PILOT telescope to observe the southern sky and Magellan clouds.

By 2024, CNES plans to have access to a Brazilian site at equatorial latitudes, in the region of Tocantins, to meet the expectations of scientists wishing to investigate intense convection phenomena in these regions.

THE LAUNCH BASES FOR THE STRATO SCIENCE CAMPAIGNS

EUSO BALLOON

Embedded under a stratospheric balloon, the EUSO Balloon project aims at demonstrating the possibility to detect space cosmic rays entering the Earth's atmosphere. EUSO Balloon (for Extreme Universe Space Observatory) is an exploratory balloon mission. Its objective: to validate a technique - potentially more effective from space than from the ground - for detecting ultra-energetic cosmic rays as they pass through the atmosphere. This involves testing the proper functioning of an ultra-sensitive and ultra-fast optical instrument prototype, performing UV background noise measurements and attempting to detect the first light showers.

© CNES

EUSO Balloon's first flight was successfully carried out on August 24, 2014 from the Timmins balloon launch base, in Ontario, Canada. The telescope was carried under a 400,000 m³ ZPB (Zero Pressure Balloon), flying at an altitude of 40 km before landing in a small lake. As the gondola of this flight was waterproof, the instruments were not damaged. A 2nd flight was carried out in April 2017 from New Zealand with a ULDB (Ultra Long Duration Balloon) also called SPB (Super Pressure Balloon). The EUSO Balloon mission was approved and funded by CNES, in collaboration with several French and foreign laboratories. Placed under the responsibility of IRAP (Institute for Research in Astrophysics and Planetology), and designed with the collaboration of the APC laboratory (Astro Particle and Cosmology) and the LAL (Laboratory of the Linear Accelerator), the scientific instrument was aboard a waterproof gondola partly designed by CNES.

Objectives	To validate the detection of high energy cosmic rays from space, using the atmosphere as a detector.
Concept	A balloon borne telescope able to detect the fluorescent light produced by the entry of cosmic rays in the atmosphere
Launch dates	1st flight August 2014, Canada, 5 hours / Second flight in april 2017 from New Zealand
Partners	CNRS (France), University of Tübingen (Germany), INFN (Italy), UNAM (Mexico), Universities of Alcala and Madrid (Spain), Riken Institute (Japan), University of Chicago (USA), NCNR (Poland).
Carriers	Open stratospheric balloon (BSO)
Fly Duration	5 hours for the first flight 14 days for the second but in bad altitude and cloudy conditions

THE THREE FLIGHTS OF THE PILOT TELESCOPE

PILOT is an international project led by CNES and IRAP to measure the submillimeter polarized emission from interstellar dust for the first time on three stratospheric balloon flights achieved between 2015 and 2019..

Objectives
Mesurer l'émission polarisée dans le submillimétrique des poussières interstellaires

Concept
Sciences & astrophysique

Launch dates
Septembre 2015 (Timmins, Canada), Avril 2017 (Alice Springs, Australie), Septembre 2019 (Timmins, Canada)

Partners
CNRS, CEA (France), La Sapienza University of Rome (Italy), Cardiff University (Wales)

Carriers
Balloon : ZPB of 800 000 m³

Flight duration
at least 24h at 40 km altitude for the scientific mission.

The PILOT project dedicated to studying the origins of the Universe measures the submillimeter polarized emission from interstellar dust in our Galaxy for the first time. Complemented by infrared measurements from the European Planck telescope between 2009 and 2013, these data will enable scientists to map the direction and intensity of the Milky Way's magnetic field and probe the magnetic properties of interstellar dust grains. They will prove very valuable in devising methods to subtract foreground polarized emissions for future cosmology missions designed to map the polarization of the cosmic microwave background (CMB), the cooled remnant of the first light to appear in the Universe after the Big Bang.

The PILOT instrument consists of a one-metre-diameter primary mirror, a photometer with cold optics, a rotating half-wave plate and a cryostat containing 2,048 bolometers cooled to 0.3°K. The instrument is embedded in a pointed gondola equipped with a daylight star tracker on an 800,000-m3 stratospheric balloon flying at an altitude of about 40 km to escape the obscuring effects of Earth's atmosphere. Two flights were made in 2015 and 2019 from Timmins, Canada, and the third one in 2017 from Alice Springs, Australia. Equipped with the NOSYCA new command-control system for aerostats, the flights went perfectly; Flight durations varied from 20 to over 30 hours.

CNES is funding and coordinating the PILOT system and is responsible for developing the gondola and the Estadius daylight star tracker that will help precisely point the instrument. The IRAP astrophysics and planetology research institute is in charge of developing the instrument, with support from CNES. The IAS space astrophysics institute is supplying the photometer, the French atomic energy and alternative energies commission CEA the focal plane, the University of Cardiff the cold optics, and the University of Rome the polarizer.

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FIREBall 2

© Mouser Williams

FIREBall 2

FIREBall (Faint Intergalactic Redshifted Emission Balloon) is a French-U.S. stratospheric-balloon-borne experiment conceived to detect the faint and diffuse emission of the intergalactic medium.

It is not from space but at an altitude of 40 km that the FIREBall experiment takes its measurements, installed in the nacelle of a stratospheric balloon. FIREBall, made up of a telescope with an aperture of 1 m and an absorption spectrograph in the ultraviolet, is to map the weak and diffuse emission of the warm intergalactic medium.

A first flight took place in 2007 at Palestine, Texas, and a second in 2009 at Fort Sumner, New Mexico. Following these flights, major modifications were made to the instrument and the gondola in order to improve the sensitivity of the device during future flights. A flight in the new con fi guration took place at Fort Sumner in 2018, which verified the excellent performance of the system and obtained the first scienti fi c results. After final adjustments, FIREBall is expected to return to the USA in 2022.

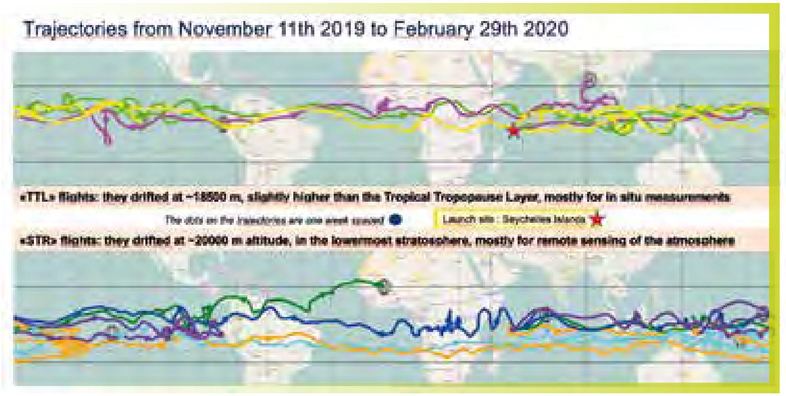
© CNES V. Dubourg

The intergalactic medium, which refers to matter located outside galaxies, provides the gas necessary for the birth and growth of galaxies. The energy released by this hot gas, which could represent 50% of ordinary matter in the universe, is extremely thin and can therefore only be measured through highly innovative instruments. Instruments like the one carried by FIREBall.
The FIREBall project is piloted by CALTECH, with flights being provided by NASA. The French partners of CalTech and NASA are the LAM (Laboratory of Astrophysics of Marseille), which has a great expertise in the field of UV astronomy under balloon, and the CNES, expert in the field of pointed pods. The CNES team is responsible for supplying the pointed nacelle, which presents unprecedented performance (0.3 arcsec) in balloon pointing precision, and the LAM, of the full spectrograph.

STRATÉOLE 2

STRATÉOLE-2, BALLOONS IN THE WIND

STRATEOLE-2 is a project designed to study atmospheric events above the equator. The project is led by France and includes researchers in the United States and other countries. It consists in launching several balloons capable of staying aloft at an altitude of 18 to 20 km high for over 3 months. The first science campaign is scheduled for winter 2021-2022, the second one for winter 2024-2025.



Earth's equator is where our planet's most powerful atmospheric events occur, and their effects can be observed as far as the polar areas. However, many of these events remain largely misunderstood and are consequently poorly represented in meteorology and climate models. To fill this data gap from a remote area note covered by other sensing systems, the Strateole-2 project plans to launch several balloons from the Indian Ocean. Two scientific campaigns are scheduled; one between October 2021 and April 2022, the other between October 2024 and April 2025.
Each campaign will launch 20 helium-filled transparent stratospheric superpressure balloons, spanning 11 to 13 meters and capable of staying aloft at an altitude of 18 to 20 km for over 3 months, thus circling the Earth along the equator 2 to 3 times to collect a wealth of data..

Some observations (temperature, wind, pressure) will be sent in near-real time to the World Meteorological Organisation (WMO) to improve weather forecast in tropical regions.

With its renowned expertise in scientific ballooning, CNES is playing a central role in the Strateole-2 project, working in close collaboration with several French and American laboratories, including the LMD dynamic meteorology laboratory, which is principal investigator on the project. The European Space Agency (ESA) also taking part in the mission to validate the Aladin instrument, launched in late summer 2018 aboard the Aeolus satellite. Other instrument calibration and validation operations are being discussed. Strateole-2 is also part of the WMO's SPARC climate programme..

Objectives
Studying interactions between the upper troposphere and the lower stratosphere over the equator

Concept
Climate and meteorology

Date of launches:
- Validation campaign (8 flights): Achieved November 2019 – February 2020
- 1st Scientific campaign (20 flights): October 2021 – April 2022
- 2nd Scientific campaign (20 flights): October 2024 – April 2025

Partners
- France : CNRS-LMD, LATMOS, GSMA, Météo-France, LPC2E and INSU-DT·
- USA : NSF (finances), LASP, NOAA, NorthWest Research Associates, Scripps Institution of Oceanography
- Indeia: NARL
- Australia: University of Adélaïde
- Italy CNR-ISAC

Balloon vehicle
Spherical super pressure balloon (SPB)

Flight duration
Up to 4 months for each flight

THE SOUNDING BALLOONS CAMPAIGNS (SB)

THE SOUNDING BALLOONS CAMPAIGNS (SB)

For the past ten years, with the help of the miniaturization of electronic systems, many scientific instruments have been able to reach very good performance while being greatly reduced in size, weight, power consumption and size.

Since 2018, MAGIC campaigns (Monitoring of Atmospheric composition and Greenhouse gases through multi-Instruments Campaigns) have used sounding balloons (SB), airplanes and ground resources to calibrate the greenhouse gas measurements made by the CNRS observation satellites and from ESA. The 2018, 2019 and 2020 editions took place in France, notably at Aire sur Adour (CNES), at GSMA Reims (CNRS) and at Trainou (CNRS).
The MAGIC campaign of 2021 is planned in the Arctic, mainly in Kiruna, during the KLIMAT campaign, to benefit from the additional measurements carried out by instruments flying under BSO, such as SPECIES of the LPC2E Orléans.
The instruments flying under sounding balloons for the MAGIC campaign : AIRCORE light, from LMD-CNRS Palaiseau : profile measurements by air sampling 0-30 km of CO_2, CH_4, CO, Temperature, H_2O, wind, isotopes of C, N_2O AMULSE, from GSMA-CNRS in Reims: a laser diode spectrometer for profile measurements 0-30 km of CO_2, CH_4, H_2O, Temperature.

Thus cubsats and nanosats weighing a few kilos have appeared in the world of satellites and occupy an increasingly important place in orbit observation systems; Likewise in the world of balloons, instruments weighing less than 3 kg can now accurately measure the atmospheric content of greenhouse gases and aerosols, and contribute to the study of climate change.
Thus, latex weather balloons (called light balloons in the regulations of the international civil aviation organization ICAO), capable of carrying 3 kg at an altitude of 35 km, are a method increasingly used by CNES and the CNRS during regular scientific measurement campaigns, carried out in particular from the CNES balloon operations center at Aire sur l'Adour and from certain CNRS and MétéoFrance sites.

These light balloons are also suitable for technological tests in the stratosphere of small instrumental systems, in particular developed by students who are thus trained to space technologies.

LOAC Instrument

Air Core-light
© LMD

Preparation of the AirCore payload © Alexandre Ollier

AMULSE Instrument © Alexandre Ollier

Launch of the AirCore experiment © Alexandre Ollier

Preparation of a SB launch in Aire sur l'Adour
© Alexandre Ollier

THE EUROPEAN HEMERA INFRASTRUCTURE

Inflation of a ZPB in Kiruna

HEMERA is a research infrastructure that allows European payloads to fly on board stratospheric balloons.

Further to two calls for proposals, 39 payloads from 14 European countries benefit from this infrastructure over the period 2019-2022. Adding them together, 1500 kg of high-tech experiments are carried out in the stratosphere. The flights are spread over 4 years (2019-2022) operated by CNES (France) and SSC (Sweden).

These flights are funded by the European Union's H2020 program.

HEMERA brings together 13 partners from 7 countries: Sweden, France, Norway, Germany, Italy, England and Canada.

CNES has a central role and coordinates this consortium.

In addition to payload flights, this H2020 project also supports the improvement of balloons and their payloads through joint research and development activities.

This European consortium plans to apply for a new European Union contract from 2023.

More information on the HEMERA website: https://www.hemera-h2020.eu/

Inflation of a ZPB in Kiruna

This brochure was updated in 2021 by Vincent Dubourg and the CNES Balloon team, in particular, Pascale Bez, Stéphane Louvel, Stéphanie Venel, Frédéric Thoumieux, François Vacher, Jean Evrard, André Vargas.

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https://ballons.cnes.fr/fr