# CNES MAG

EN FR

SPACE • INNOVATION • SOCIETY

#87
February 2021

## EXPLORATION

### MOVING UP A SCALE

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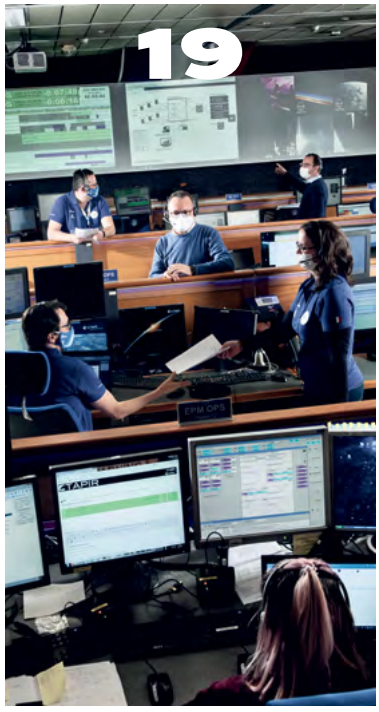
CENTRE NATIONAL D'ÉTUDES SPATIALES

# INSIDE

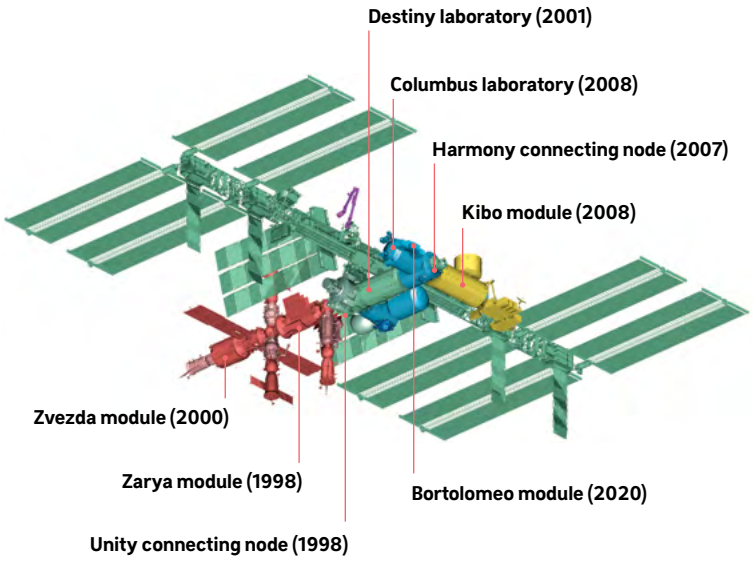


INSIDE






# ISS
## A 20-YEAR TEAM EFFORT




## PARTNERS

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## CONTRIBUTORS

### RÉMI CANTON

**With his deeply-rooted passion for space, Rémi Canton was cut out to be the link between Earth and the ISS.** As project leader for the Alpha mission and CADMOS Development Manager, he's readying and developing the experiments that CNES has entrusted to Thomas Pesquet. In this issue, he brings his infectious enthusiasm to this new scientific adventure for us.

### JEAN BLOUVAC

**As CNES's head of Exploration and Human Spaceflight,** Jean Blouvac is intimately involved in lunar programmes. Tomorrow, humans will be striking out into deep space. Jean is also France's representative on these matters within ESA, giving us his unique insight into Europe's roadmap for this international quest as well as that of competing nations.

### SÉBASTIEN BARDE

**Previously in charge of CADMOS during the Proxima mission,** Sébastien Barde is today deputy director of Science & Exploration at CNES, where he combines planning and operations tasks. Astronauts, science aboard the ISS and future robotic and human deep-space exploration hold no secrets for him, so he was the ideal person to guide us through the big programmes now taking shape.

### GUILLEMETTE GAUQUELIN-KOCH

**Guillemette Gauquelin-Koch takes a scholarly and human approach to science.**
CNES's head of life science programmes knows that space exploration is as uplifting for the mind as it is punishing for the body, which is why she's sharply focused on developing countermeasures capable of preventing physiological and psychological disorders in astronauts.

CNESMAG

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IMPRIM'VERT®

**How far will humans venture into space? And when they get there, what will they do and what will they discover?** These questions are no doubt the real reasons motivating human space exploration, which has been making the headlines recently in the world of space.

Today, we can reasonably hope to set foot on Mars within the next two to three decades. This endeavour will call for close international cooperation in overcoming all of the obstacles still in our path. The United States, China and with them Europe, Japan, Canada and other space powers will first be returning to the Moon before 2030 to establish a long-term base, as they already have on the International Space Station (ISS), which recently celebrated 20 years of uninterrupted human presence. This will enable us to fill the gaps in our understanding of the Moon and its resources, of how Earth formed, and above all to learn to live more self-sufficiently outside the protective shield of our planet's magnetic field.

In the meantime, Thomas Pesquet, France's tenth astronaut, will be going back to the ISS this spring on the long-duration Alpha mission. He will thus be playing an active part in readying for this return to the Moon—the chief goal of human space exploration for the coming decade.

**JEAN-YVES LE GALL**
CNES PRESIDENT


EXPEDITION 65

## NEW ISS MISSION

Thomas Pesquet is all set to depart on Expedition 65, the next mission to the International Space Station (ISS) scheduled for this spring. He will be the first European astronaut to command the SpaceX Crew Dragon spacecraft for NASA when it lifts off from the legendary launch base in Cape Canaveral, Florida. From the moment he began training for his flight, Thomas Pesquet was won over by the cockpit's futuristic design and the new space taxi's greatly enhanced features (see Q&A p. 13-15). Once aboard the ISS, he will be pursuing his objective of conducting fundamental research on the unique orbital laboratory. The Expedition 65 crew will be continuing experiments already underway as well as performing some 100 new ones, with the ultimate goal of future human space exploration in their sights.

**Thomas Pesquet in training at Johnson Space Center for an extravehicular activity (EVA).**

Future astronauts undergoing endurance and survival training.

SITS VAC

## SHOOTING FOR THE MOON

Do you dream of working in space? It takes courage, autonomy, audacity, adaptability... and endurance to be an astronaut. The same qualities are called for at each step on the way to becoming one, the first of these being the selection process. ESA is launching a campaign this year to recruit new European astronauts for future crewed space missions (see Horizons p. 30). If you think you have what it takes, a battery of psychotechnical tests awaits in addition to your qualifications and multilingual talents. Your psychological qualities, when working alone and in a team, your ability to stay calm on the job and your resilience will be key in overcoming all of the obstacles in your path on this marathon quest. So, persevere and if you feel the need for a lighter moment at any time, you can always turn to Marion Montaigne's comic book *Dans la combi de Thomas Pesquet* (Inside Thomas Pesquet's spacesuit).

FIND OUT MORE: WWW.ESA.INT/YOURWAYTOSPACE

**27,000**

**The name Alpha was chosen for the next ISS mission after a competition organized by ESA in partnership with CNES. The competition attracted 27,000 entries, Alpha coming up 47 times.**

HEALTH

## PREVENTION FIRST

Human spaceflights have got longer over the years, from just 1 hour 48 minutes for Yuri Gagarin to seven days for Jean-Loup Chrétien and six months for Thomas Pesquet. They have also ventured progressively further from Earth. Future crews on the Moon or Mars won't have the benefit of the protective shield of our planet's atmosphere, so the risks to their health from radiation—accelerated ageing, cell damage and more—need to be identified. Following a series of stratospheric balloon flights exposing cells to direct and indirect radiation in 2019, a new balloon-borne experiment is set to cover the same zone this year to establish the physical and biological dosimetry profile and thus compare results.
In partnership with Toulouse Rangueil University Hospital, CNES has initiated studies to gauge the impact of radiation on human cells. Long-duration confinement is of course another drawback of deep-space exploration. Ethological[1] and psychological studies are in development to measure its effects.

1. Ethology is the scientific and objective study of animal behaviour under natural conditions, including that of humans.

CARDIOMED

## AFFAIR OF THE HEART

Microgravity modifies the distribution of fluids in the body. One such change is that blood flow can be reversed in the upper body, with potentially severe consequences. The French-Russian Cardiomed device applied 10 clinical protocols to monitor cosmonauts' cardiovascular function in space, measuring their blood flow, heart rate and blood pressure. A report detailing the results obtained with the device in nearly 10 years operating on the ISS was authored at the age of 92 by Adilya Kotovskaya[1] from IMBP, the Russian space medicine institute. Just two weeks later, in March 2020, the CNES teams with which she worked to design the device were devastated to learn of her passing. CADMOS and IMBP are now working on a new-generation Cardiomed device for the ISS capable of gauging the effects of a long stay in microgravity conditions, notably on the spine (vertebral compression fractures, back pain), blood flow in the brain and high blood pressure.

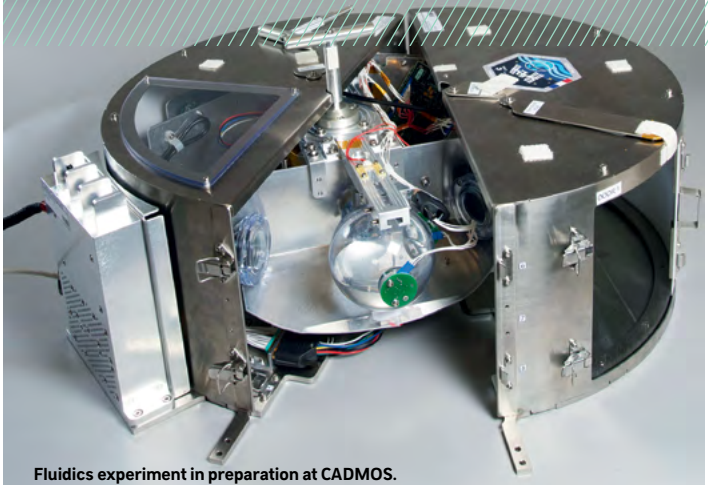
1. Former physician of Yuri Gagarin

DECLIC

## BACK TO THE ISS

Could liquids like water in microgravity, in a supercritical state, meet the challenge of recycling waste here on Earth without emitting carbon dioxide? Housed inside a science rack on the ISS, the DECLIC[1] mini-laboratory conceived by the CADMOS centre for the development of microgravity applications and space operations has been studying this phenomenon since 2009 using three inserts[2] activated in turn for periods of three to six months. DECLIC is currently being refurbished after its laser broke down and is scheduled to return to the station this spring and stay there until at least 2024. The science programme is set to be extended on the strength of its results. CNES and NASA will be working together along the same lines to incorporate two new inserts in the DECLIC-EVO programme: Aerosol, to gain new insights into cloud mechanisms, and SCOW, to study oxidation of organic waste in supercritical water.

1. DEvice for the study of Critical LIquids and Crystallization.
2. ALI (Alice Like Insert), HTI (High Temperature Insert) and DSI (Directional Solidification Insert).



Fluidics experiment in preparation at CADMOS.

PROXIMA

## SUSTAINED SUCCESS

Each ISS crew leaves behind 'science in progress' on board the station. The Proxima mission's EveryWear experiment is one example among many. This application developed by CNES collects physiological data to monitor astronauts' health, as well as supporting Aquapad to test the microbiological quality of the crew's drinking water and Vascular Aging to measure arterial stiffness using the ECHO ultrasound scanner during the Proxima mission. In fact, EveryWear has proved such a success that ESA has adopted it and is discussing future upgrades and utilization with the other ISS partner space agencies. It has already been deployed for ISRO[1]'s Gaganyaan project and NASA's Orion spacecraft and Gateway lunar platform. Another success is the Fluidics experiment developed by CNES with Airbus Defence & Space, which is studying capillary wave turbulence in microgravity on the station, where it has been active for three sessions per year. The Perspectives virtual-reality device, meanwhile, is used once a month to investigate how cognitive functions are altered in microgravity.

1. Indian Space Research Organisation

**60 years**

**12 April 1961, Yuri Gagarin became the first man to see Earth from space. Selected from a field of 20 candidates to fly the Vostok 1 mission, he completed a single orbit around our planet in 1 hr. 48 min. (full flight time). The fantastic Cold War feat would be hailed around the world. In 2021, as plans are being laid to fly crewed missions to the Moon, the scientific community will be commemorating the 60th anniversary of Gagarin's historic flight.**

**22 tonnes**

**A crew of six astronauts on a three-year mission to Mars would need about 22 tonnes of food to survive.**

**578 people**

**have flown in space. Only 65 of these, just over 10%, are women. The 578 'lucky few' come from 38 different nations.**

## FRANCE AND HUMAN SPACEFLIGHT


**1980**

CNES organizes first French astronaut selection

**1982**

Jean-Loup Chrétien becomes first French astronaut in space on Salyut 7 space station


**1985**

French astronaut Patrick Baudry flies on STS-51-G mission (U.S. Space Shuttle Discovery)


**1988**

Jean-Loup Chrétien performs first extravehicular activity by a French astronaut on the Aragatz mission


**1996**

Claudie Haigneré becomes the first female French astronaut to fly in space, on the Cassiopée mission

**1998**

ESA creates the European Astronaut Corps (EAC), incorporating CNES's own astronaut corps

**2001**

First French mission to ISS (Andromède)

**2025-2027**

Three European astronauts scheduled to fly to the Gateway lunar outpost

DRAGON FOR THE ISS

## SUCCESS CONFIRMED

SpaceX's Dragon spacecraft has been ferrying supplies to the ISS since 2012. On 30 May 2020, the U.S. firm launched its Crew Dragon on a first crewed test flight. This version of the spacecraft features a number of enhancements for rendezvousing and berthing with the station, as well as the system for propelling the crew capsule to safety in the event of a launch abort. Since this qualification flight, SpaceX has accomplished the first operational mission last November with a crew of four astronauts on board, and the next flight will be taking Thomas Pesquet to the ISS. Crew Dragon will now be used for all station crew rotations and ultimately fly to more-distant destinations like the Moon.

GAGANYAAN

## A HELPING HAND FROM FRANCE

In 2022, India will be sending its first three astronauts into space aboard the Gaganyaan[1] spacecraft. France is contributing its expertise through CNES to ISRO to ready for this five-to-seven-day sojourn. CNES's MEDES space clinic is providing special training for the Indian space agency's physician and helping to devise a nutrition programme for the crew during their spaceflight. The CADMOS centre for the development of microgravity applications and space operations and the European Astronaut Corps (EAC) are also in on the act, training Indian engineers in crewed spaceflight mission control, flight tracking and handling of emergencies. The Indian astronauts will also be using gear tested and still operating on the ISS, like Aquapad and EveryWear (see p. 9), while CNES will be supplying French-made fireproof bags to protect hardware from shocks and radiation during transport.

1. 'Sky craft' in Sanskrit.

PERSEVERANCE

## THINKING AHEAD

Launched with the Mars 2020 mission last July, the Perseverance rover will be hunting for signs of ancient life on the red planet—starting in February—and studying in particular the effects of the Martian environment on materials used in spacesuits. It will also be collecting and caching samples to be brought back to Earth by future missions in the early 2030s, a key step for future Mars exploration plans. But the Mars 2020 mission is also laying the groundwork for human exploration of the red planet. On Mars, crews will have to use local resources, notably to produce oxygen. And while planting trees won't be an option, Perseverance's MOXIE instrument will employ solid electrolysis to generate oxygen from carbon dioxide molecules. MOXIE is a demonstrator designed to validate the technology concept and only capable of providing 10 grams of oxygen per hour intermittently. Oxygen will be vital not only for future Martian explorers, but also to produce engine propellant in situ for the return trip to avoid adding weight to the payload.

NEWSPACE

## THE BOLDNESS OF YOUTH

**Guy Laliberté, founder of the Cirque du Soleil, became the seventh space tourist on his Soyuz flight.**

Bored with the seaside and mountains? NewSpace[1] players guarantee you a whole new experience with a flight or stay in space. Between 2001 and 2009, seven space tourists embarked on this unique adventure. Today, space tourism projects are burgeoning but most are still hitting the glass ceiling that is the Karman line 100 kilometres above our heads. SpaceX's Crew Dragon, Blue Origin's New Shepard capsule and Virgin Galactic's spacecraft are all announced for 2022. Looking further ahead, SpaceX plans to take tourists on trips to the Moon, possibly accommodating them for example in a BEAM[2] module developed by Bigelow Aerospace in partnership with NASA, prefiguring the first space hotels. CNES, meanwhile, is leveraging its balloon expertise, working with Zephalto (see Spinoff p. 36) to put together a bold and viable space tourism project.

1. NewSpace or entrepreneurial space encompasses a range of private initiatives driving a paradigm shift in the space industry.
2. Bigelow Expandable Activity Module.

# #COMMUNITY

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

## @ASTRO_DANYBOY

Daniel Chrétien, blog editor at http://space-kiwi.fr & @RevesdEspace. Space news, China space programme and NewSpace watcher. Space is friendship

Weiss: less than one month after Prime Minister Modi's announcement of India's intention to send its own astronauts into space, an agreement on human spaceflight has been reached with CNES.

## @THOM_ASTRO

@ESA astronaut, spacecraft pilot in training for #MissionAlpha, patron of @ONG_ASF

How it started:

How it's going:

## @VIDALFREDERIQUE

Minister for #HigherEducation, #Research and #Innovation - @sup_recherche

Report in pictures on the #GenerationISS competition with @Thom_astro. More than 130 entries for art, technology and science projects. Congratulations to all the talented laureates who'll now be refining their projects with help from @CNES before flying them to the ISS!


## @REVESDESPACE

#Space news, events and articles at http://reves-d-espace.com (in French)

Call for candidates! @esa is opening applications for a new astronaut selection in mid-February. If you're thinking of applying, I'd like to hear your reasons to write some articles and follow you through the process. Message to all you girls out there: go for it!


Q & A

# THOMAS PESQUET

EUROPEAN ASTRONAUT THOMAS PESQUET will be embarking this spring on his second mission to the ISS. We caught up with him to talk about crewed space exploration now and in the future, and how the space station can aid this endeavour.

## You're all set to return to the ISS. Has preparing for this Alpha mission been like for your previous Proxima mission?

**Thomas Pesquet**: No, not quite! Obviously, all sojourns on the station share many things in common. The science programme may evolve, but the business of living in space, fixing things when they go wrong and so on stays the same. When you can draw on experience from a first mission, those aspects of training require less work. The main difference this time is the transportation to the ISS. For my first flight, I spent a lot of time in Russia preparing to be the co-pilot in the Soyuz spacecraft, with 76 sessions in the simulator at Star City! This time I'm at SpaceX's facility in Hawthorne, California, in a more modern environment and with a new spacecraft, the Crew Dragon. Like with a new aircraft, you have to re-learn all the systems and procedures, how to handle emergencies and all that. And of course the spacesuits are different, too.

## How are you feeling about this second stay on the ISS?

**T.P.**: It's a bit like a second parachute jump! As I recall, the first time is easier, because you've decided to make the jump but you don't yet realize what you've let yourself in for. The second time round, you know exactly what to expect, it's a magical experience, but you're also conscious of what's hard about it, being away from your family and so forth . So, I'm just as excited as last time, only with a little more perspective. And, perhaps selfishly, this time I want to take everything in and make more time for myself to simply contemplate the Earth.

"The ISS is a key waymarker on the path of space exploration."

## What kind of ties do you have with CNES?

**T.P.**: With its long human spaceflight legacy, CNES is working on this mission alongside ESA. As a Frenchman in the European Astronaut Corps, I'm proud to be wearing a French flag on my left sleeve. Personally, I have very special ties with CNES, as that's where I began my career as an engineer. I subsequently had the opportunity to become an airline pilot and so I took a different path, but I still feel like I belong there a little and I'm in regular contact with the agency's teams.

## Besides the specific goals of the Proxima and Alpha missions, what for you is the overriding ambition of the ISS?

**T.P.**: For me, the ISS is a key waymarker on the path of space exploration, combining the two virtuous goals of exploration and science. It's first of all a means to learn how to live in low Earth orbit and rehearse the techniques and operations we'll one day need to set up a base further afield, starting with the Moon. Certain experiments on the station are designed directly to pave the way for crewed exploration, like remotely controlling robots with a view to guiding Moon rovers from the future Gateway platform. But the ultimate destination is Mars, to learn how life forms and above all how it disappears. We know Mars has been stripped of its atmosphere and liquid water. Could that happen to Earth? At a time when concerns about the environment and the future of our planet are growing, that's a big question. At the same time, the ISS offers a unique outpost for fundamental research by enabling investigation of phenomena otherwise hidden by Earth's gravity.

## What are the biggest obstacles to be overcome for future crewed space exploration?

**T.P.**: The main challenge is actually sending humans. Take a mission to Mars, for instance. The crew will be subjected to pretty high doses of radiation once outside the protective shield of the Van Allen belt. That means the spacecraft will need its own shielding, making it heavier and harder to launch. Also, Mars' atmosphere isn't dense enough to allow braking or the use of a parachute, unless it's absolutely huge. But there's enough of an atmosphere to burn a spacecraft without a heatshield. This is an amazingly complex equation that we know how to solve for a one-tonne rover like Curiosity or Perseverance, but not yet for a 40-tonne crewed mission.

# THOMAS PESQUET

EUROPEAN ASTRONAUT

**"The ultimate destination is Mars, to learn how life forms and above all how it disappears."**

Propulsion is the key and we're working on that, because if we fly a lot faster we're exposed to the same radiation but for a shorter time, and the crew will need less water, food and oxygen. Given some of the technologies now being developed, we can be optimistic about that one day being possible.
The other major obstacle is psychological, as no human has ever been completely out of sight of Earth. For Mars, we'd be gone for 600 days. If the slightest thing goes wrong, whether it's a hitch with an engine or raging toothache, the shortest way back is to loop around Mars and return. Missions lasting 200 days on the ISS are a good start to train for such situations. Living aboard the station shows just how important it is to have a tightly knit team, which is often down to small details. That's why astronaut selections seek to recruit people who show empathy, are patient and able to lead when needed or follow someone else's lead when the circumstances dictate. The other key is to preserve the bond with families, albeit virtually.

## Would you like to go on such a mission?

**T.P.**: I'd love to. It'll be the most incredible adventure of the 21st century! If we're ready to go in 20 years' time, I'll be nearing the end of my career but I'll have plenty of experience. That said, it's like entering the Vendée Globe solo round-the-world yacht race: it's not a decision to be taken lightly, but with your nearest and dearest.

## Do you think there's a limit to how far we can explore in space?

**T.P.**: Yes, Mars is the limit today, because we can't fly fast enough to go any further. To give an idea, a commercial airliner flies at an altitude of 10 kilometres, the ISS is at 400 kilometres, the Moon is 400,000 kilometres away and Mars 40 to 400 million kilometres depending on where it is on its orbit. So that's a thousand-fold increase every time, the distances are pretty mind-blowing but we can go there. Beyond that, the next destinations are exoplanets light-years away, and to get there we'd have to fly so fast that the distances would be compressed. Or maybe we could freeze the passengers, but now we're talking science-fiction!

## ESA is about to engage a new astronaut selection process. Any advice for candidates?

**T.P.**: (Laughs) Take your marks on the starting line! No, seriously, I would say that 100% of candidates selected tried their luck. So give it your best shot, and even if you don't think you're up there with the best, send in an application anyway.

### PROFILE

**2001**
Graduates with a degree in aeronautical engineering

**2002-2004**
Works on space mission autonomy at CNES

**2005**
Airline pilot

**2009**
Joins ESA's European Astronaut Corps (EAC)

**2016-2017**
First stay on ISS (Proxima mission)

## DESTINATION WEIGHTLESSNESS

A parabolic flight on the Airbus Zero-G is no joy ride. For passengers, mostly scientists, it's a memorable experience far from the confines of the lab. Pitched up 50° from horizontal, the aircraft has you floating around from floor to ceiling for 22 seconds of weightlessness. And it does that 31 times. Parabolic flights highlight phenomena otherwise masked by Earth's gravity. The Airbus Zero-G tests experiments selected by space agencies covering a broad spectrum from medicine and biology to mechanics and space technologies and more besides. Brought into service by CNES in 1989 and operated by Novespace, this one-of-a-kind aircraft offers excellent conditions for experiments at a lower cost. It has even been used by filmmakers to give extra realism to space scenes.

## SPACE CLINIC

Do you fancy lying in bed for a few days with your head tilted back 6° or in dry immersion, as shown in the photo here? Such bedrest studies help scientists to understand the physiological effects of weightlessness and to test mitigation and countermeasures like artificial gravity. This year MEDES will be conducting the first European dry immersion study on an exclusively female panel of volunteers. In 2022, a new bedrest study will look at the potential of artificial gravity using a short-arm centrifuge. A centrifuge like this could be flown on future spacecraft to help limit the kind of disorders induced by weightlessness.

# Heart under close watch

**After a spaceflight, even a short one, the heart's left ventricle contracts by about 12 to 15%, and its wall loses an equivalent amount of mass through lack of physical activity.** To monitor astronauts' cardiovascular system, the Cardiospace device has been installed on China's Tiangong 2 space station and Cardiomed in the Russian module of the ISS.

# 100 m²

Since 1986, CNES has tasked its Novespace subsidiary with organizing parabolic flights to simulate weightless conditions. Such flights are cheaper and more flexible than going to the ISS, which is why they are so popular with scientists. Until 1997, experiments were flown aboard a Caravelle. From 1997 to 2014, an Airbus A300 qualified for zero-gravity operations took over, flying more than 13,000 parabolas over 102 flight campaigns. Since May 2015, a refurbished Airbus A310 is providing this service, offering research scientists and engineers 100 $m^2$ of floor space and a volume of 200 $m^3$. This Airbus Zero-G aircraft accommodates up to 40 passengers and 12 scientific experiments. Since 2013, Novespace has started offering first 'weightless' flights for the public under certain conditions through Avico.

# ISECG

**Going from low Earth orbit to the Moon or Mars is a big step for space exploration,** which is why space agencies are joining forces within an international body called ISECG[1]. An initial roadmap established in 2018 was updated and rounded out in September 2020 for lunar exploration. While in no way binding, this blueprint sets out a shared vision and plan for what each agency can do and the timeframe and resources required for doing it. The partners—now 26, up from 14 previously—are working to give form to this collaboration. For example, ESA has committed under the roadmap to stepping up lunar exploration with a service module for NASA's Orion spacecraft and the system for communicating with Earth.

1. International Space Exploration Coordination Group

# Pricing

**The terms and conditions for space tourism flights (fitness, training, etc.) are not yet known, but the price tag is.** With Blue Origin, a five-minute flight at an altitude of 100 kilometres is expected to cost €250,000. Virgin Galactic will likely offer a flight to 80 kilometres for the same price and flight time. And a ticket with SpaceX for a 31-day stay on the Moon will probably set you back €100 million! So mass space tourism is still a long way off.

# 8,413

**Working as an astronaut is a life-enhancing experience.** In 2008, for its last astronaut selection, ESA received 8,413 applications from which six candidates were chosen, among them Frenchman Thomas Pesquet. Will this record be broken by the class of 2021?

# 2hrs30

## ABOARD THE ISS,

**exercising is vital to combat the effects of weightlessness.** Astronauts do physical exercise for 2 hours and 30 minutes a day, six days a week. And despite these efforts, they lose about 2.4% of their initial weight for every 100 days in space. A mission to Mars could thus mean 15% of their body mass will be lost.


## MAINTAINING

# THE BOND

**THE TANTALIZING PROSPECT OF LONG-DURATION HUMAN SPACEFLIGHT HAS NEVER BEEN CLOSER, BUT THERE ARE STILL COLOSSAL CHALLENGES TO OVERCOME BEFORE SENDING HUMANS TO LIVE ON THE MOON OR MARS. FRANCE IS CONTRIBUTING ACTIVELY TO INTERNATIONAL EFFORTS TOWARDS THIS AIM, NOTABLY THROUGH ITS CADMOS CENTRE.**

Sixty years after Yuri Gagarin's historic feat inside his cramped capsule, today's astronauts aboard the ISS have the luxury of 400 sq.m. of living space and functional facilities to go about their daily tasks. Looking back, CNES has been instrumental in making the station what it is today. In 1983, France was among the first to back the concept of a "permanently manned Earth-orbiting station" advocated by NASA. CNES would subsequently lend its expertise in physiology to advance the project through three key actions. In 1989, it created the MEDES space clinic, a unit like no other in Europe, to study the effects of weightlessness on astronaut crews (see box p. 21). Then, in 1993, it set up the CADMOS centre for the development of microgravity applications and space operations (see p. 23) to prepare and monitor experiments on the space station. And in the 2000s, it developed the control centre for ESA in Toulouse for the five Automated Transfer Vehicles (ATVs) that would ferry supplies to the ISS between 2008 and 2014. In 2008, the first ATV Jules Verne would carry the European Columbus space physiology module installed on the station by French astronaut Leopold Eyharts.

**3,000**

**In its 20-year existence, the ISS has hosted more than 3,000 scientific experiments. As well as these "tenants", it has accommodated 241 astronauts from 19 countries on short missions.**

## SHARED ACCOMMODATION

The ISS has been manned continuously since 2001 and is "kind of like an orbital co-ownership where each partner has built a section of the apartment," notes Sébastien Barde, CNES's Deputy Director of Science & Exploration. The station's

**The International Space Station.**

**The Orion capsule and service module after integration at NASA's Kennedy Space Center.**

modules are arranged around a Russian side and a so-called "Western" side co-managed by four partners: NASA for the United States, ESA for Europe, CSA for Canada and JAXA for Japan. Time on the station is allocated to each partner in proportion to their funding commitments. Through ESA, to which it is one of the three key ISS contributors, France is apportioned crew time and hardware for certain experiments prepared by CADMOS. Seven experiments were developed in 2017 for the Proxima mission under this arrangement and a dozen new ones are set to be added for the upcoming Alpha mission. CNES is also able to perform science and technology research through bilateral partnerships like for Cardiomed (see Roundup p. 8) with Russia and DECLIC (see Roundup p. 8) with the United States.

## HIGHER, FURTHER, LONGER

The ISS will continue to operate in low Earth orbit for a few more years yet, as will the future Chinese Space Station (CSS). But in the near term, crewed exploration is poised to venture further afield to the Moon and ultimately Mars, and possibly to near-Earth objects. These destinations are already being surveyed by a range of robotic missions, "which are stepping stones for crewed missions" says Jean Blouvac, who heads CNES's

Deep-space exploration

## INVENTING A NEW LIFE

**Deep-space exploration by humans poses a number of challenges.** The first of these is their very survival, as explorers on the Moon or Mars must not receive radiation doses above what crews are exposed to on the ISS. CNES is contributing actively to research efforts in this domain. For example, the Cerebral Ageing and Lumina experiments (see Materials p. 27) on the upcoming Alpha mission will seek to better measure this risk. The other challenge is the ability to live self-sufficiently, as there will be no emergency medical evacuations, no click & collect meal service and no readily available raw materials like water, fuel and oxygen either. Crews will have to produce everything themselves in situ. For Mars, an initial solution could come from the Perseverance rover (see Roundup p. 11) which is carrying a concept to validate oxygen production. Waste management poses an even bigger conundrum. Trash on the ISS is taken away by cargo supply spacecraft, but the weight and cost penalties make this an unviable option for the Moon, Mars or a near-Earth object. Last but not least, precisely assessing the mental impacts of living in close confinement on interplanetary missions is not easy—an aspect the MEDES space clinic has been looking into since 2003 with its confinement campaigns.

**2.6**

**German and Chinese researchers recently published the results of the experiment conducted by the Chang'e 4 lunar lander and rover. They estimate radiation on the Moon's surface is 2.6 times higher than what ISS crews are exposed to.**

**The European Heracles lander delivers supplies for astronauts to the surface of the Moon as part of the U.S. Artemis programme.**

Exploration & Human Spaceflight programme. Some nations like the United States, China and India are well advanced with their crewed exploration plans. But what about Europe? "Its role is to contribute to these missions and ensure they complement each other," says Blouvac. Under a bilateral agreement with NASA, ESA is building habitation and refuelling modules and supplying communications for the future Lunar Orbital Platform-Gateway (LOP-G). Europe will be sending three astronauts there as well as for the U.S. Artemis programme that plans to send a multinational crew to explore the Moon, using the Gateway as a staging post from 2024.

The China National Space Administration (CNSA) is also operating its Chang'e 5 lunar sample return mission. Its follow-up robotic mission, Chang'e-6, will be carrying the French DORN experiment, a radon detection instrument developed with support from CNES by the IRAP astrophysics and planetology research institute. The ability to detect this gas is a prerequisite for establishing a sustained human presence on the Moon.

Mars exploration, currently limited to robotic missions, is also advancing nicely. CNES is involved with the Mars Express (2003), Mars Science Laboratory (2011) and InSight (2018) programmes. The Mars 2020 mission is the first step in the ultimate challenge of sending crews to the red planet (see Roundup p. 11), while Mars Sample Return (MSR) is an even more complex endeavour holding all the hopes of the international space community. If these missions succeed, they will usher in a new age of deep-space crewed exploration. CNES is always ready to innovate and plan future manned bases, and is set to host a SpaceShip model space base (see Timeline p. 28-29) at its field centre in Toulouse.

**8.3%**

**The ISS**

**comprises a Russian side and a so-called "Western" side co-occupied by the United States (76.6%), Japan (12.8%), Europe (8.3%) and Canada (2.3%), where each partner uses the orbiting laboratory in proportion to their investment (construction, operations, fixed costs, etc.).**

# CADMOS

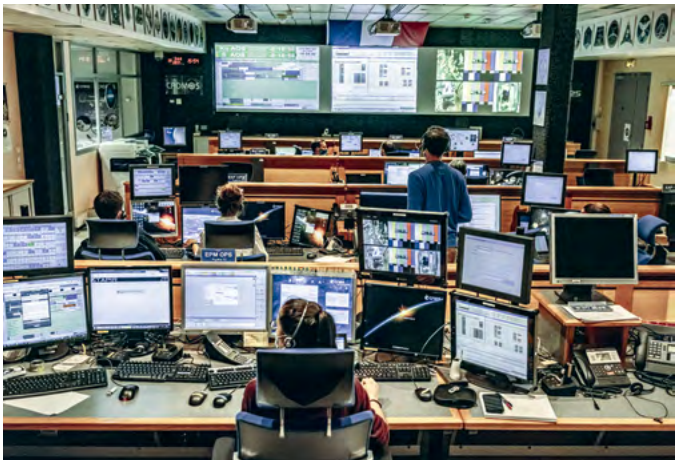
## **CONNECTING** SCIENCE AND SPACE

**CADMOS is the go-to contact for research scientists and astronauts alike, preparing, planning and monitoring microgravity scientific experiments. It is in charge of parabolic flight campaigns and above all a support centre for the ISS.**

In 1975, the Soviet Union and the United States sent aloft their first joint space mission, carrying with it some biology experiments provided by CNES to study the effects of weightlessness. In 1982, Jean-Loup Chrétien departed for the Salyut 7 station loaded down with 500 kilograms of scientific instruments for French and soviet researchers. In 1993, CNES replaced such one-off operations with a longer-term, more structured policy, bringing together the know-how of its microgravity project teams under one roof at its Toulouse Space Centre within a novel unit designed to provide technical and operational support for experiments in weightless conditions. The CADMOS centre for the development of microgravity applications and space operations was born.

### INSPIRING ORGANIZATION

In 1998, ESA adopted this support centre concept to provide a link between scientists, experiment designers and the astronauts called on to perform them with its European network of User Operations and Support Centres (USOCs). Given its expertise in human physiology, neuroscience, fundamental science, materials science and technology applications, CADMOS naturally joined this network as the French USOC. When Europe's Columbus laboratory was installed on the ISS in 2008, CADMOS stepped up another gear, becoming one of the four European Facility Responsible Centres (FRCs). In this capacity, it was put in charge of the European Physiology Module (EPM) facility, an instrumented 'toolbox' for monitoring astronauts' cardiovascular and muscular systems. CADMOS also retains its national prerogatives, preparing and operating experiments developed by CNES or through bilateral cooperation arrangements, like for example DECLIC (see Roundup p. 9), tele-operated from the centre where scientists can control their experiments in real time. DECLIC is activated and then switched off for sequences of three weeks, operating for six full months through the year with CADMOS serving as control centre.



**92**

**minutes**

**The ISS takes just 92 minutes to circle Earth at a speed of 28,000 km/h or 7 km/sec. The crew thus sees the Sun rise and set 16 times a day.**

### END-TO-END EXPERTISE

"The scientists sure know their stuff, but not necessarily the procedures. That's why CADMOS is

MEDES

## INNOVATING TO EXPLORE

**While the space adventure remains the stuff of dreams, weightlessness is not without risks.** The MEDES space clinic, CNES's health subsidiary, detects these risks, studies their impacts on astronaut health and devises and tests countermeasures. For ESA, it assists in astronaut selection, preparation and health monitoring. It conducts ground studies using clinical simulations of weightlessness that serve as benchmarks for planning future missions. And it lends CADMOS its expertise in physiology to prepare programmes and support experiments on the ISS. Drawing on its 30-year research heritage, MEDES is now embarking alongside the European space community on the new challenge of long-duration human space exploration. "To preserve astronauts' health and performance on these future missions, we'll not only have to limit the side effects of weightlessness but also handle psychological and radiation risks," notes MEDES's director Audrey Berthier. "The crew's ability to handle any medical issues will be vital once they're on their own. To meet these new challenges, we need to develop innovative medical research and technologies," she adds. MEDES's teams of physicians, physiologists, engineers and IT experts are on the case "to help advance space research and accelerate health innovations here on Earth."

involved right from the early stages of designing an experiment to provide valuable insight into its technical feasibility," notes Rémi Canton, CADMOS Development Manager. "Where needed, before engaging the development phase, CADMOS designs and develops custom equipment and operating procedures." "For a virtual reality experiment, for instance, it can determine if a headset is the most appropriate device or not," adds Mauro Augelli, CADMOS Operations Manager. "It can even go one better and conceive modifications to meet the experiment's expectations. The strength of CADMOS is this end-to-end expertise from conception through to construction and dissemination of science data."

### TWIN EXPERIMENTS

Astronauts are briefed on each operation they will have to perform once aboard the ISS and backed up 24/7 by the 50-strong team at CADMOS. And that's not all: for each experiment on the station, an identical 'twin' experiment is run at CADMOS on the ground. When, on the ISS, the EveryWear application collects Thomas Pesquet's physiological data, they are instantly relayed to CADMOS, which can then uplink commands or respond in the event of a hitch. At the end of the mission, CADMOS also has the task of recovering biological samples from the landing site and bringing them back to the laboratory, completing data gathering on the ground after each flight and archiving and distributing data to scientists that need them. And while it has its 'hands on the wheel' before, during and after each mission, the centre knows when to call on its partners. Health aspects are entrusted to the MEDES space clinic via an integrated team of ten people, while research laboratories and manufacturers translate the recommendations and adaptations for each experiment into the required protocols and hardware.


**The Edible Foam bag that will be used for the Food Processor experiment on the Alpha mission is checked out.**

# Alpha mission

## PAVING THE WAY FOR HUMAN EXPLORATION

**While clearly a follow-on to the Proxima mission, Alpha nonetheless features a number of innovations. Among the 12 new scientific experiments conceived by CNES that it will be taking to the ISS, some are designed specifically to lay the groundwork for human space exploration.**

The name 'Alpha' was chosen from thousands of other proposals for its universal nature, as the word is pronounced the same in almost all languages. "It also refers to Alpha Centauri, the star system closest to Earth, next to Proxima Centauri in the same constellation," explains astronaut Thomas Pesquet. Just as the two stars are related to one another, so the Alpha mission intends to pursue the work of its predecessor. Indeed, one-off experiments are now something of an exception on the ISS. As Thomas Pesquet's guided tour in our Insights section on page 35 makes clear, experiments are being handled, equipment is operating and astronauts are at work in every one of the station's modules, applying the protocols established on the ground by control centres like CADMOS.

## THE ADVENTURE IS JUST BEGINNING

With human exploration of the Moon and Mars now a tantalizing prospect, all of this work for the ISS crew is taking on extra significance. The new physiological issues the crews of these future missions will encounter guided the choice of experiments for the Alpha mission. Twelve of them have been conceived and constructed by CNES, and some will complement Proxima experiments still underway on the station. Lumina (see Materials p. 27) will measure radiation levels, Dreams will seek to gauge the impact of confinement and weightlessness on sleep and Pilote will employ virtual reality to improve haptic assistance and reproduce the sense of touch during robotic tasks. Cerebral Ageing, meanwhile, will study the effects of weightlessness on the brain. With an eye on preparing for long-duration space missions, experiments like Telemaque (using acoustic tweezers to hold or move small objects without touching them) and Immersive Exercise (to improve conditions for daily exercising) are intended to add a little extra spice to astronauts' daily lives. Food Processor will seek to develop food self-sufficiency, while Renewable/Edible Foams will replace petroleum-based packing foam. Lastly, Active Packaging is setting out to test new types of packaging capable of extending the shelf life of fresh produce.


**Left: Oculus Quest virtual-reality headset and cycling shoes for the Immersive Exercise experiment.**
**Top right: qualification model of the sleep headband for the Dreams experiment.**
**Bottom right: laboratory model of the acoustic 'tweezers' for the Telemaque experiment.**

## A TIGHTLY KNIT FRENCH TEAM

CNES isn't facing the challenges of this new mission alone and is leading a highly talented French team of research laboratories and universities with which CADMOS has forged close ties, such as Sorbonne University, the Hubert Curien Laboratory, the national scientific research centre CNRS, Paris Descartes University, the Institut Pasteur, Sup'Biotech and Toulouse University Hospital. CADMOS has also called on its network of key space manufacturers supporting research and designing systems and equipment carefully tailored to the experiments' requirements. Partner firms with extensive experience of space missions, like Erems, Comat, Dreem, Henaff, IXblue and FIT Immersion, have also worked to the exacting specifications of an equally exacting mission.


**The Alpha mission badge has 17 different flat colours to reflect ESA's commitment to pursuing the 17 United Nations Sustainable Development Goals (SDGs).**

# Light shield

**IN SPACE, ASTRONAUTS—AND OBVIOUSLY ANY FUTURE SETTLERS—NEED ABSOLUTELY TO BE PROTECTED FROM HIGH-ENERGY IONIZING RADIATION. This small unit measuring barely 30 centimetres on each side could be the alerting system to give them early warning of a solar flare. Developed by the CADMOS centre for the development of microgravity applications and space operations in partnership with IXblue and the Hubert Curien research laboratory, Lumina is an optical-fibre active dosimeter. Its unequalled precision and stability enable it to continuously monitor doses of received radiation by measuring fading in the optical fibre. This is achieved by two diodes that send a light signal, one at a visible and the other at an infrared wavelength, into two coils of optical fibre (2 and 7 km long!); a photodiode then measures the light reaching the other end of the coil. Lumina will depart for the ISS this spring as a demonstrator on the Alpha mission.**


1

## EUROPE'S THIRD SPACESHIP

Coordinated by ESA, the SpaceShip network came into being in 2012. After those in Germany and the United Kingdom, focused respectively on astronauts and robotics, SpaceShip France will embody a lunar or Martian type of space base. Relying heavily on start-ups and postdocs, in addition to traditional space exploration players, it seeks to inspire talents and excellence, federate synergies between space and non-space initiatives, industry and research, and support development of mature and innovative solutions.

2

## 13 TECHNOLOGY LINES OF ACTION

Given its home-grown expertise, France has chosen to develop 13 of the 93 technologies identified as necessary to establish a permanent base on another planet: habitation, energy and storage, radiation shielding, environmental control and support, robotics, digital, health, nutrition, agronomics, recycling, in-situ resource utilization, control centre and guidance/navigation. CNES is already working with more than 40 partners from all horizons to nurture, mature and qualify innovative technologies.

**HOW WILL FUTURE SPACE EXPLORERS LIVE SELF-SUFFICIENTLY WHEN DAYS OR MONTHS AWAY FROM EARTH? TO ANSWER THIS QUESTION, FRANCE IS DEVELOPING SPACESHIP FRANCE, A MODEL SPACE BASE CONCEIVED TO SUPPORT INNOVATION AND FOSTER COLLABORATIVE LEARNING.**

## 3 BASED IN TOULOUSE

SpaceShip France is a prototype of a European space base accommodating four to six people planned to be set up at CNES's Toulouse Space Centre this year. There will be 450 $m^2$ of solar-powered modules and a Martian terrain for partners' immersive experiments. For example, in the in-situ resource utilization zone, some of the 'crew' will be doing 3D printing with lunar basalt, while others will be testing bacteria as a means of recycling protective foam from cargo supplies into something totally new and possibly even edible!

## 4 FOCUS ON NUTRITION

SpaceShip France will trial a hydroponic[1] greenhouse developed in partnership with a start-up specializing in indoor crops, notably using hermetically sealed containers in total darkness. Crops grown in this greenhouse will complement astronauts' freeze-dried rations and contribute to their well-being. It will also house a circular aquaponic[2] system to rear fish that will diversify the crew's daily diet while producing fertilizer from their ammonia-rich excrement (see Insights p. 34).

1. Hydroponic crops are grown with their roots in a nutrient-rich solution rather than in soil.
2. Aquaponics is a method of rearing fish and growing plants in the same system where fish excrement serves as a source of nutrients for the plants.

# FRANK DE WINNE

**Head of the European Astronaut Centre**

## "We're looking for people who can learn a lot in a short time"


In spring 2021, after a rigorous selection process led by Frank de Winne, the European Astronaut Corps will have two, three or four new recruits. Previously an **engineer and senior test pilot in the Belgian Air Force, Frank de Winne was recruited by ESA in 2000 and became the first European to command the ISS**. "Candidates will be subjected to psychotechnical, psychological and medical tests," he explains. "Those on the final shortlist will have interviews with the Director of Human and Robotic Exploration, then with the ESA Director General." **Having served twice on the ISS, this experienced astronaut knows the array of aptitudes needed to meet the demands of the job**: engineer or scientist, polyglot, ability to work as a team across cultures, top physical condition and mentally tough, whatever happens. "We're looking for people who're stable, flexible and able to learn a lot in a short time, because the training is especially intense." Europe's priority is to operate in low Earth orbit in partnership with the United States' Gateway programme, so the 2021 cohort will almost certainly fly to the Moon. They might even set foot there, if the 2022 ESA Ministerial Council gives the go-ahead to cooperate with NASA on the Artemis programme. ESA has kept the same selection criteria as for 2008, with one important addition. Because the number of member states involved in Europe's exploration programme has doubled in 20 years, it needs to "**recruit career astronauts, with the assurance they'll fly in space, but also reserve astronauts in case a new opportunity arises,**" says Frank de Winne. The Belgian astronaut fell just short at the final hurdle of his first recruitment attempt in 1989. Today he says the invitation is open to all Europeans wanting to take part in this "fantastic adventure, where you learn so much about yourself as well".

# MIRIA RICCHETTI

**Researcher at the Institut Pasteur, Ricchetti group, stem cells and development unit**

"We're studying the long-term effect of cosmic radiation and oxidative stress"

She cites Louis Pasteur with a smooth Italian accent and sees mistakes as a necessary step on the path to progress. **A microbiologist by training, Miria Ricchetti developed an early interest in DNA, especially how it gets damaged and repairs itself.** Building on her most conclusive findings, she's focusing today on Cockayne syndrome, a neurodegenerative disorder in children characterized by premature ageing and other complications. "To understand this complex disorder, we need to study the underlying molecular mechanisms," she explains. Because taking even a tiny sample of human brain tissue isn't possible, and animal organisms don't respond to the disease in the same way, the researcher asked colleagues at the Sup'Biotech engineering school to generate cerebral organoids. "Discovered in 2013, organoids are artificially grown from a single cell—usually skin or blood—which is then reprogrammed in the laboratory. With their three-dimensional structure, which mimics brain functions, **cerebral organoids aren't a brain as such, but they offer a highly advanced experimental model of brain structure**." Because life in weightlessness alters an astronaut's body, **CNES is working with Miria Ricchetti to prepare and send a first batch of cerebral organoids for two months on the ISS**. Whether the experiment is included in Alpha or the next mission, it will have "dual benefits for space exploration," she explains. "Technologically, the process will give us cultures with much more elaborate and fully formed structures than an isolated cell and which can survive for almost a year with little input. Physiologically, it will be possible to study the long-term effect of cosmic radiation on these structures, which isn't reproducible on Earth, as well as the effects of oxidative stress."

# ALEXANDRA OPPENHEIM-DELAUZE

**CEO of COMEX (Compagnie Maritime d'Expertises)**

"Being immersed in water lets you move around in an environment similar to lunar microgravity"

**Alexandra Oppenheim-Delauze is a genuinely multi-talented and worthy successor to her grandfather Henri Germain Delauze, who founded COMEX in Marseille in 1961** to combine engineering with the underwater world—his profession and his passion for deep diving. An admirer of Delauze's ingenuity, his granddaughter describes him as a "visionary who devised a watertight, pressurized system enabling welders, for example, to withstand pressures at depth and stay there to work".

Since being immersed in water lets you move around in an environment similar to lunar microgravity, **the company soon signed up to the space adventure with ESA.** "It all began in the 1980s with our Gandolfi 'wet' spacesuit, designed to let astronauts train underwater and experience different degrees of gravity," she says. "The second version adapts to each person's specific morphology and further improves the sensation of microgravity, where movements may be slower, for example."

COMEX has been designing hypobaric and hyperbaric test platforms for over 50 years and has readily adapted to evolving ambitions in exploration. "**Europe is pushing companies to combine their expertise to serve a common endeavour to establish a lunar base before going to Mars**. To this end, we're working more on the engineering side of the space environment, for example with the Hydrosphere facility. Measuring four by six metres, this module developed for ESA makes it possible to create a vacuum and simulate space storms, which could damage robotic vehicles on the Martian surface."

Driven by values such as "our social responsibility", this singular CEO sees space exploration as a "human adventure, which everyone should have in their life". And that's how she leads the company: "to give people the opportunity to pursue the adventure as safely and effectively as possible".

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

ETHICS CORNER

J. A.

JACQUES **ARNOULD**

# AS WE BREATHE...

**After the aptly named Proxima mission, which taught us more about Earth, Alpha is focusing on the outer reaches of space. A chance to reflect on that impulse to explore which has guided and driven our species since it first appeared.**

Asked why he wanted to climb Everest, George Mallory replied: "Because it's there!" Nicely put—especially when we recall that the English climber was last seen on 8 June 1924 on the northeast ridge of Everest and that his body was found 75 years later on 1 May 1999 at an altitude of 8,300 metres. Astronauts often cite his famous retort. But it doesn't fully explain our fascination for the heavens or determination to explore space, whatever the cost.

## COSMIC BREATH OF FRESH AIR

For what Mallory said seems to imply he was driven by simple curiosity. Our pets show curiosity, as do shy creatures. But the impulse which has guided our species for thousands of years, maybe even since we migrated from Africa, that need to explore, is about more than just curiosity or even the need to survive and, with it, to conquer and colonize new places. What the tales of explorers reveal goes beyond the satisfaction of some animal curiosity or vital need. Rather, they reach into the realm of one of the most unique 'gifts' nature has given humans—the gift of imagination. In other words, our mind's ability to transcend the limits of the here and now to visit, inhabit and enjoy other places and other times, whether or not they actually exist.

Essentially, exploration is what happens when curiosity and imagination come together. And to continue the breathing metaphor, it's like a movement in two directions—breathing out, coming out of yourself, your boundaries and your knowledge to confront the unknown, often dreamt of in advance; then breathing in, taking in the air, the atmosphere of a new world, feeding off it and finding the strength to start again, or encourage others to do so.

Yes, we humans are full of imagination and we explore like we breathe; but we also breathe insofar as we explore. So, why not voyage into space for a big breath of fresh air?

NEUROSCIENCE

# ILLUSION
## A MAGICAL EXPERIENCE

Time, Grip, Grasp—several experiments on the ISS led by French scientists are studying the brain and central nervous system. But for the lay public, neuroscience might seem a bit 'barren'. To raise awareness about this complex discipline, CNES needed a clever trick. Illusion is specially designed for the Alpha mission. The pitch: ask Thomas Pesquet to perform magic tricks devised for weightlessness. For help, the CADMOS centre turned to world champion magician Yann Frisch, who says "what scientists learn by rationalizing, we learn by doing". Frisch designed and tested his illusions in the weightless conditions of parabolic flights, an experience the master of illusions won't forget in a hurry. "It's one thing to think conceptually about weightlessness, but quite another to experience it!"


**MUST READ**

### HUMANS AND SPACE: PHYSIOLOGICAL ADAPTATIONS

60 years after the first crewed spaceflight, there was no reference resource setting out the scientific benefits of human missions. At the cutting edge of science, the 17 chapters of this book offer an overview of the problems posed, research undertaken and progress still to be made.

***L'humain et l'espace*** – Ses adaptations physiologiques by Marc-Antoine Custaud, Stéphane Blanc, Guillemette Gauquelin-Koch and Claude Gharib – 344 pages – Published by BoD.


**LUNAR HATCH**

### Fish farming on the Moon

Cyrille Przybyla is a marine biologist at Ifremer, the French institute of marine research and exploration. The Lunar Hatch programme, which he's developing with the help of CNES, Ifremer and the CSUM university space centre in Montpellier, addresses the problem of food self-sufficiency once on the Moon. Explorers will need to produce the animal proteins and omega-3 they need in situ. To this end, Lunar Hatch is looking at how to send fertilized fish eggs to a future lunar base. These farm fish would then be raised in a closed environment to save water. Fish farming in a closed system is also conducive to the production of microalgae, which could help feed them. Five fish species have already been selected.

**VYOMMITRA**

### A female humanoid in space

With her immaculate hair and neatly shaped eyebrows, Vyommitra is a female-looking humanoid robot designed by the Indian Space Research Organisation to function on its Gaganyaan crewed orbital spacecraft (see Roundup, p. 10). The choice of a prototype with a female face wasn't arbitrary, but supports a drive to increase the proportion of women in science. Let's hope this initiative leads to more aspiring female astronauts on future missions. For now, the first cohort was selected from military test pilots, all men!

**EDUCATION**

# ADOPT A BLOB!

**Better known as slime mould or simply "the blob", *Physarum polycephalum* doesn't have a brain but it's capable of learning, as CNRS, the French national scientific research centre, has been able to observe.** It moves, feeds and can defend itself. But will the blob respond differently in space? How will microgravity and radiation affect this organism's structure, behaviour and evolution?
To find out, the CADMOS centre for the development of microgravity applications and space operations in Toulouse will place this unusual 'lodger' under the watchful eye of Thomas Pesquet. The ESA astronaut will perform two scientific protocols. Exploration will study how blobs respond in an environment without food, while Exploitation will analyse their behaviour when food is available.
CNES's Youth and Education department is inviting middle and high schools to take part in this research, with pupils replicating the protocols in the classroom. Given the blob's nature, setting up the experiment on the ISS is a challenge in itself. Blobs will be delivered in a dormant state then rehydrated on the station and in classrooms from September 2021. A competition will also be run for participating classes, with the winners announced in late 2021.

FIND OUT MORE: **INFORMATION ABOUT RESOURCES AND EQUIPMENT FOR THE PROJECT CAN BE FOUND ON THE ALPHA MISSION WEBSITE, RELAYED BY CNES.**

GENERATION ISS

## WINNERS ANNOUNCED

The Generation ISS competition organized by CNES in conjunction with the Alpha mission offers young people a unique chance to see their experiments run on the station by Thomas Pesquet. The two winning projects were announced in June 2019 in the CNES pavilion at the Paris Air Show. TetrISS, devised by students at the Physical Measurements Technology Institute at Paul Sabatier Toulouse III University, focuses on 3D visualization of acoustic waves. Eklosion, by students at the Nantes Design School and Paul Sabatier University, is an experiment to grow French marigolds on Earth and the ISS to provide a 'travelling companion' for Pesquet by delivering messages from friends and family through sensorial experiences.

WORTH SEEING

### ISS photo gallery

The Cité de l'Espace theme park in Toulouse celebrated 20 years of the ISS in a unique way. On its website, it posted the portraits of the 64 crews who've performed the 64 missions to the station to date.
**Find out more at:** https://www.cite-espace.com/actualites-spatiales/iss-20-ans-expeditions

### ISS: take the tour!

Want to know more about how astronauts live on the ISS and what they do? Thomas Pesquet offers you a guided tour!
**Find out more at:** https://www.facebook.com/ESAThomasPesquet/videos/visite-guid%0C3%0A9e-aussi-exhaustive-que-possible-de-la-station-spatiale-international/621082794767864/

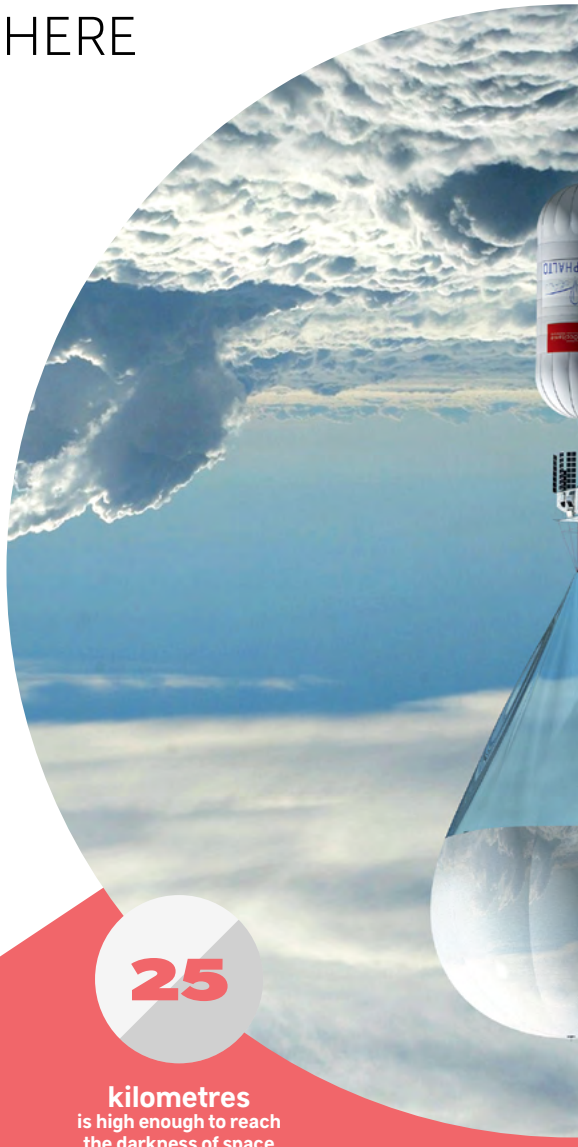
# CÉLESTE, HEADING FOR THE STRATOSPHERE

**Vincent Farret d'Astiès had a dream of contemplating Earth from space. To fulfil it, he designed a passenger craft capable of flying closer to the heavens. In 2016, he founded the start-up Zephalto to develop Céleste, a pioneering stratospheric tourism vessel.**

Halfway between a hot-air balloon and an atmospheric balloon, Céleste will soon be taking two to six people for several days to an altitude of 25 kilometres inside its pressurized capsule borne under a 140-metre-high balloon. "The capsule has large glass viewing panels for passengers to take in the ground panorama stretching for more than 1,000 kilometres before their eyes from the darkness of space!" says Vincent Farret d'Astiès. "Flights will take at least six hours, but it will also be possible to fly cruises lasting several days, for example to watch the Sun rise and set." Maybe the perfect backdrop for a very special marriage proposal or an unforgettable seminar!

## ECOLOGICAL AND INNOVATIVE

Céleste is fully solar-powered and has an altitude regulator to be able to ascend and descend at will, for example to adapt to air traffic or maintain a flight level. "CNES is drawing on its 50-year experience of stratospheric balloon flights to provide Zephalto with expertise and give them access to some of our testing facilities," says Jean Evrard, the agency's balloons expert. "We're supporting the start-up with flight physics and materials, notably to develop a reusable balloon envelope." In return, "Céleste will be able to fly technologies for CNES or research laboratories and support very sophisticated protocols applied by operators on board," notes Zephalto's Chairman & CEO. After its successful test flight on 21 August 2020, the start-up based in the Hérault department of Southwest France is now focusing its efforts on developing a gondola and enhancing the passenger experience in time for a maiden flight in 2024. It already has bookings from 250 people at a price tag of a few tens of thousands of euros.



**25**

**kilometres**
**is high enough to reach the darkness of space and contemplate the Sun, the stars, the colour shades of the Earth's limb and its curvature.**