

# CNES MAG

EN  
FR

SPACE • INNOVATION • SOCIETY

#95  
June 2023

**SPACE TRANSPORTATION**

**THE CRUCIAL CONNECTION**

  
**cnes**  
CENTRE NATIONAL  
D'ÉTUDES SPATIALES



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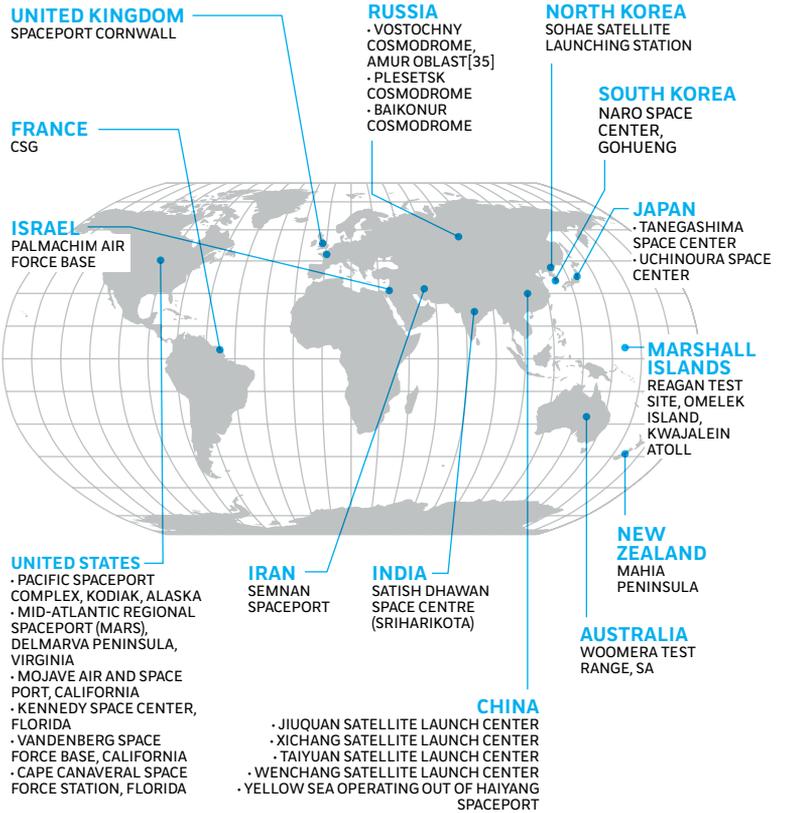


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## CONTRIBUTORS

**YANN  
GUÉLOU**



**A pyrotechnics engineer when he first joined CNES**, Yann Guélou has since occupied a number of posts in the field of space transportation. He currently leads activities tied to the French Space Operations Act. His broad vision of launchers and his network of experts were invaluable in putting together this issue.

**EMLINE  
DESEEZ**



**An engineer by training, Emline Deseez knows just about everything** there is to know about space transportation, a field she has been mediating as a communication officer for the last 10 years. Her in-depth knowledge of CNES's specialists and expertise in this area ensured that all aspects are covered in fine detail.



**AIMÉE  
CIPPE**

**In charge of innovation and planning in French Guiana**, Aimée Cippe was notably the Guiana Space Centre's first female Director of Operations. In this issue, she takes us behind the scenes to discover the different facets of Europe's spaceport and its projects for the future.

**PHILIPPE  
PUJES**



**In a career marked by a range of space-related posts at various public institutions**, Philippe Pujes is today in charge of launch systems programmes at CNES and France's delegate for space transportation on ESA's Executive Board. He brings the benefit of his strategic vision to CNESMAG, notably on the importance of sovereign access to space.

## CNESMAG

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## EDITORIAL



**Space transportation is the cornerstone of our strategy, the linchpin connecting ground and space systems, and a sovereign capability for nations that possess it.**

France has long been a key player in space transportation through its presence at the Guiana Space Centre, Europe's spaceport, and its expertise in launchers with the Ariane series.

Space transportation involves much more than just orbiting satellites; it is also a prerequisite for maintaining systems in space and sending human crews there.

It is also addressing society's concerns with regard to sustainable development and environmental conservation, pursuing projects to develop reusable launchers and to optimize and modernize ground support facilities.

Today, access to space and sustainable development are two of the four pillars of CNES's Objectives and Performance Contract with the government.

In this issue of CNESMAG we invite our readers to come with us on an adventure that we are continuing to write with our partners in Europe, to build the space transportation of the future.

We hope you enjoy the journey.

**MARIE-CLAUDE SALOMÉ**  
CNES DIRECTOR OF COMMUNICATION



## ARIANE 6

### FINISH LINE IN SIGHT

After a storied career of 117 flights, Ariane 5 is ready to bow out as Ariane 6 takes the stage in the months ahead for its maiden launch from the ELA-4 launch complex at the Guiana Space Centre. The new heavy-lift launcher built by ArianeGroup is competitive and versatile, designed to secure Europe's independent access to space and serve the needs of institutional and commercial stakeholders alike. In readiness for the event, the first months of this year have been devoted to wrapping up combined tests, putting all of the interfaces, communications systems, flight software and checkout equipment through their paces, as well as rehearsing tank filling and draining operations.

Aerial view of the Ariane 6 ELA-4 launch complex at the Guiana Space Centre.

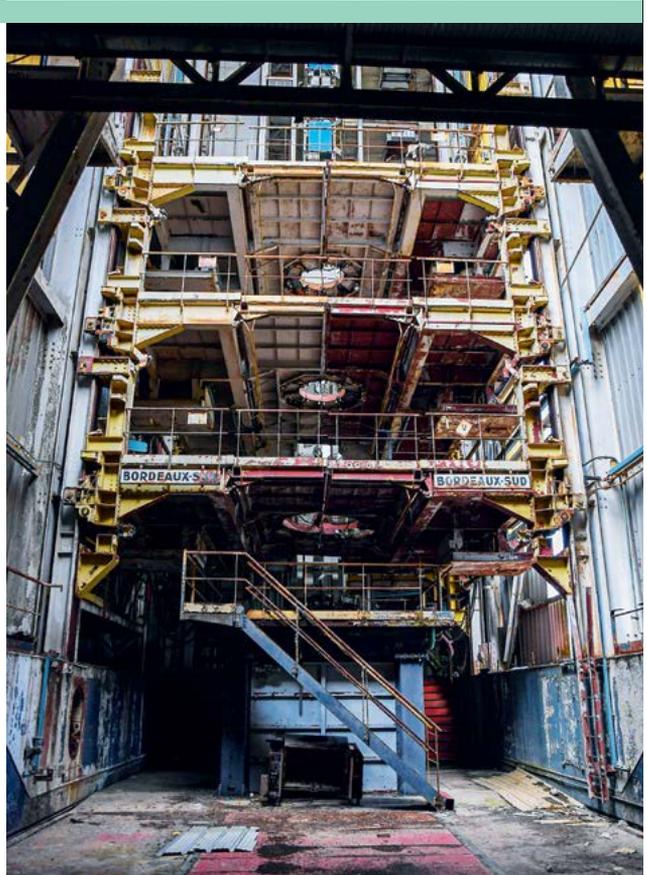


ROUNDUP

CSG

## ELM DIAMANT LAUNCH COMPLEX LOOKS TO THE FUTURE

**T**he first ever launch pad at the Guiana Space Centre, built for the Diamant rocket, was decommissioned four decades ago. Between now and next year, it will be getting a new lease of life as a multi-launcher complex under the moniker ELM<sup>1</sup>, initially comprising several separate launch areas and a suite of shared facilities—power, Wi-Fi, conventional fluids, etc.—for operators. CNES thus intends to meet the needs of the emerging micro- and mini-launcher market. Four launch zones have already been set aside and seven operators were down-selected last year. The remaining launch area will be assigned to the Callisto reusable first stage demonstrator (see page 28-29). For now, CNES is finalizing solicitations to select firms for the refurbishment of existing facilities scheduled to start this summer to accommodate Callisto, before undertaking a massive extension of the site. A first flight of the demonstrator is planned in late 2024 and a first micro-launcher flight in late 2024.



1. Ensemble de Lancement Multilanceurs.

# €50 MILLION

Budget for construction work at the ELM Diamant launch complex, funded out of the France 2030 plan.

CMIN22

## EUROPE REAFFIRMS ITS SPACE AMBITIONS

**M**eeting in Paris on 22 and 23 November 2022, ESA's Ministerial Council decided to expand Europe's space ambitions with a budget of €16.9 billion over the next three years, 17% more than the previous budget voted in 2019. Ministers notably confirmed the absolute necessity for Europe to assure its independent access to space through a budget line of €2.8 billion for space transportation, to enable it to sustain the ramp-up of Ariane 6 and Vega-C, while also laying foundations for the future with the modernization of the Guiana Space Centre and the Prometheus and Themis projects.



## ROUNDUP



First hot-fire test of the Prometheus engine at the Vernon facility.

### REUSABLE LAUNCHERS

## THEMIS AND PROMETHEUS ON THE STAND

Last year, two future standard-bearers of spacefaring Europe came together on the test stand at ArianeGroup’s facility in Vernon outside Paris. Prometheus, the low-cost variable-thrust reusable engine initiated by CNES and developed by ESA, was mounted on the T1B test stand for the Themis programme designed by ArianeWorks (CNES/ArianeGroup). The objective was to validate ground operations for the European reusable first stage demonstrator and to conduct the first hot-fire tests of Prometheus, which got underway in September.

### First hop tests around the corner

For Prometheus, the next step will be the demonstration test campaign scheduled late this year on the P5 test stand at the German space agency DLR’s facility in Lampoldshausen prior to scaling up production. The two protagonists will then be pursuing their path together with a series of low-altitude “hop tests” in Kiruna using the T1H vehicle, scheduled in 2024.

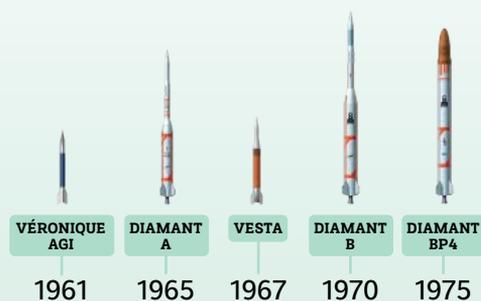
# €15 MILLION

invested by France under its France 2030 plan to ready the T1B test stand in Vernon.

## SUPER-HEAVY LIFT IN SEARCH OF HIGH THRUST

Recent years have been marked by the arrival of super-heavy-lift space launchers capable of lofting payloads of more than 50 tonnes into low Earth orbit and sized with human spaceflight missions in mind. In this context, CNES and its partners have begun working on the kind of high-thrust engine concepts needed to build these giants, with the aim of pushing the levels of thrust currently provided by the most powerful European engines from 100 up to 200 tonnes. To accomplish this aim, a number of technological obstacles will first have to be overcome to enable development of staged combustion concepts. Preliminary work is ongoing since 2021 with ArianeGroup and envisioned engine configurations include an evolution—currently at the design stage—of the Prometheus engine and a high-performance configuration. The first engine tests incorporating subsystems to support this upgrade are planned for early next year at the Vernon test facility.

## EUROPEAN LAUNCHERS





**4.000**  
**PEOPLE**

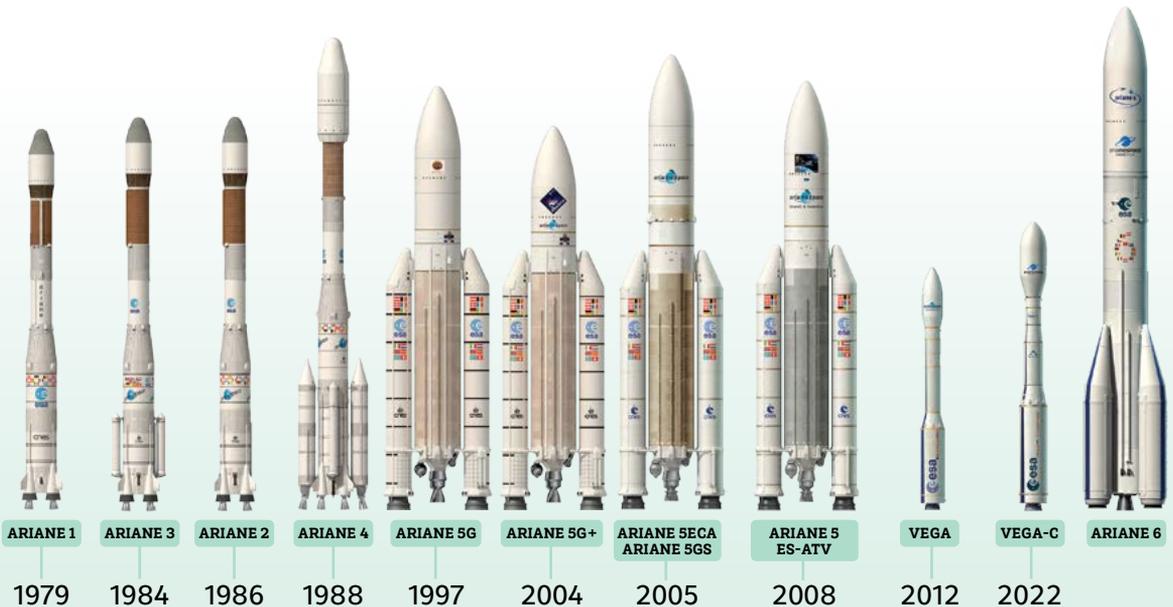
from 13 countries have worked on the Ariane 6 programme

**PERSEUS**  
**STUDENT PROJECTS ALL SET TO GO**

**S**ince 2005, the PERSEUS programme has been attracting thousands of students to careers in space transportation through educational space projects in partnership with universities and non-profit associations. This year the adventure will involve no fewer than 300 young students on seven main projects, several of which are converging towards the design of a reusable sounding rocket demonstrator (DREAM'ON challenge). Among the calendar highlights are the successful validation in February of the liquid oxygen and ethanol propellant tanks designed by SME CMP Composites for the Astreos sounding rocket project, the launch of the fourth version of the SERA rocket in May, the C'Space summer space event in July, and of course qualification of the launcher for Astreos scheduled for the end of the year.

**90%**

The Guiana Space Centre intends to meet 90% of its energy needs with renewable energies by 2030

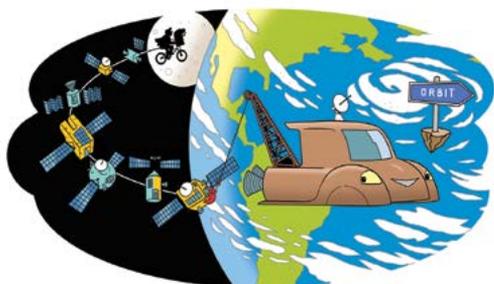




## ROUNDUP

### FUTURE SPACE LOGISTICS

**R**ide-sharing offers satellite operators a significantly cheaper way of getting into space, but it sometimes comes at the price of a shorter lifespan due to the onboard energy required to reach the right orbit. A solution is now in sight with in-space mobility services capable of taking payloads to their destination. CNES has been actively



exploring this emerging market since 2020, positioning itself as a customer for space tug service demonstrators. After a request for proposals issued mid-2022 under the France 2030 plan, two firms have been selected: Exotrail for its SpaceVan™ concept designed for small satellites (see *CNESMAG 94*) and Thales Alenia Space for its Astarte project focused on geostationary satellites. The first in-orbit demonstrations are planned next year.



Envisioned Ariane 6 configuration for crewed flights.

### FORESIGHT WHAT FUTURE FOR EUROPEAN HUMAN SPACEFLIGHT?

**S**ince development of the Hermes space shuttle was halted in 1992, Europe's involvement in human spaceflight has refocused on the International Space Station (ISS) and the Orion spacecraft. But the very ambitious Moon and Mars programmes the United States and China have been pursuing for several years now are changing the game. At last year's Space Summit in Toulouse, President Emmanuel Macron called on Europe to set out its space exploration and human spaceflight ambitions. ESA subsequently put together a High-Level Advisory Group (HLAG) tasked with conducting an in-depth assessment and making recommendations. The group's findings were recently laid out before member states to prepare for the next Space Summit this autumn in Spain.

#### Technology building blocks within reach

CNES and several of its partners—ESA, ArianeGroup and Airbus Defence & Space—had already initiated work in 2020 to study the possibility of launching a crewed mission with Ariane 6 from the Guiana Space Centre. Their investigations revealed that Europe already has most of the elements needed for human spaceflight, except for extravehicular spacesuits and launch escape systems. At the end of last year, ESA decided to extend these initial studies through a working group, in which CNES is involved, tasked with informing policymakers at the European Space Summit.

## NEW ERA AT THE CSG A DEDICATED NEW GENERATION TEAM

**F**our years ago, ESA's member states gave the go-ahead for the CSG-NG (for New Generation) programme to refurbish the Guiana Space Centre by 2024 and modernize it, make it more attractive, reduce costs and decarbonize operations. This colossal project—encompassing the operations centre, heating, ventilation and air conditioning, power systems, tracking systems, infrastructures and cross-functional digital base—is being led in Kourou by a dedicated six-strong team. Its role is to orient tasks for each of these components and orchestrate their

implementation. For this the team is calling on all of CNES's expertise, working with representatives of all categories of user at every step of the programme, applying agile methods to nurture cooperation between multidisciplinary, self-organizing teams.

### Down to work

After being held up by the COVID

pandemic, CSG-NG is now advancing at a good pace, with 90% of the programme's elements underway by the end of the first half of 2023. Initial work will refurbish drinking and fire hose water piping with the roll-out of connected infrastructures, and construction of the future operations centre will begin at the start of the second half of the year.



# 34 FTE

(full-time equivalent) staff were directly involved in the CSG-NG programme in 2022 (including the lead team).



## INNOVATION NEW BIRD IN KOUROU

**I**n recent months, the sounding rocket launch pad at the Guiana Space Centre has been pressed back into service to study how to accommodate the Mésange (meaning *blue tit* in French), a suborbital rocket 3½ metres high and 15 centimetres in diameter capable of reaching an altitude of 100 kilometres. Mésange is the result of a research effort at Opus Aerospace, a French start-up that was a laureate of a CNES R&D challenge in 2021 focused on reusable upper stages for future European launchers. The aim of the challenge is a heat shield produced by additive manufacturing that protects the small rocket's fairing. It has received €100,000 in funding from CNES. Scheduled to launch this year, Mésange will be the first of Opus Aerospace's rockets to fly, and most certainly not the last, as the start-up, which has already successfully hot-fire tested a liquid propellant rocket engine, is concurrently developing a micro-launcher named Sterne (French for *tern*).



## # COMMUNITY

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



**@SRETAILLEAU**

Minister for Higher Education & Research



The Guiana Space Centre in Kourou is Europe's spaceport. Its unique facilities make it a core element of our sovereignty.



**@ISAE\_ENSMA**

Aeronautical and space design engineering school

Their names are Maël, Nathan, Ugo and Maxime, engineering students at @ISAE\_ensma taking part in the #LanceLeFutur [Launch the Future] competition organized by @CNES. Their brief? To imagine, invent, model and prototype tomorrow's space transportation. <https://tinyurl.com/4m95ufsz>



**@THOM\_ASTRO**

Astronaut 🇫🇷 🇫🇷 spacecraft pilot, back on Earth after #MissionAlpha, patron of @ONG\_ASF



The CSG, Europe's spaceport! So amazing to see the launch pads rising out of the lush green forest. After the success of the Ariane series, the base is gearing up for the future, and Europe is increasingly envisioning its own crewed space capsule, launched from French Guiana!



**@THALES\_ALENIA\_S**

Official account of Thales Alenia Space. Joint venture between @thalesgroup |67% and @leonardo\_live |33%.

"Europe's #space sovereignty is predicated on a strong, independent, competitive and innovative space industry." P. Cexus. "There are 3 types: economic, industrial and employment sovereignty." #LTSF2022





Q & A

**JOËL  
BARRE**

WORKING AT CNES AND WITH POLICYMAKERS, INDUSTRY AND THE MILITARY, JOËL BARRE HAS DEVOTED MOST OF HIS CAREER TO SPACE. He gives us his take on launchers as the cornerstone of space strategies and the key to independent access to space.



## Q & A

### **What are the stakes for France of having a space launch capability?**

**Joël Barre:** Assured access to space is crucial to our sovereignty, first and foremost from an economic perspective. After telecommunications, we're now seeing vigorous growth in space applications for Earth remote sensing, especially for monitoring the environment, which has become an imperative for society. Access to space is also a priority for our security and defence, in the field of communications, intelligence and weapon system guidance. France is the main driver behind this independent space launch capability. In the 1970s, Ariane 1 was born out of this desire to achieve strategic independence from the United States. And for satellite launch, our nation applies a strict policy of European preference.

**"The big challenge facing the next generation of launchers is to work with industry in order to drive down launch costs."**

### **And the major challenges for spacefaring Europe?**

**J. B.:** From the commercial and strategic standpoint, our main

competitor is the United States. To maintain its own assured access to space, Europe needs to be more competitive. That's the goal of the Ariane 6 programme and of Vega-C, which will soon be taking over the mantle from Ariane 5, Soyuz and Vega. We need a range of launchers covering all bases: a heavy-lift launcher to loft large satellites into geostationary orbit, a medium-lift launcher and a light launcher for low Earth orbits. European industry must pursue its efforts in this respect and share the financial burden of these programmes. The big challenge facing the next generation of launchers is to work with industry in order to drive down launch costs.

### **What are you hoping for from Ariane 6?**

**J. B.:** To see it in service soon! In 2014, we set ourselves the target of making Ariane 6 40% to 50% cheaper to launch than Ariane 5, with the same level of performance. This new programme was also intended to replace Soyuz, but we obviously couldn't have foreseen the context of insecurity in 2022 and that the Russian launcher would cease operating from French Guiana. We therefore focused on schedule, while retaining the same propulsion concept. After Ariane 6's maiden flight, there'll be lessons to be learned for the next generation, in terms of how the programme is apportioned between member states, ESA, CNES and other national agencies, and industry. The idea of a "fair contribution" advocated at the time by the former ESA Director General

Jean-Jacques Dordain will most surely have to be put back on the table. In other words, work should be allocated in accordance with each nation's industrial know-how and capabilities, and member states will be asked to fund whichever one is chosen.

### **What innovations have marked the space sector in recent years?**

**J. B.:** The main leap forward has come in accomplishing partial reusability after launch, a technology introduced by SpaceX with its Falcon 9 vehicle to bring down the cost of launching. Europe must pursue its research and development efforts to give Ariane 6's successor this capability. We're also seeing a plethora of mini-launcher projects designed to put small satellites weighing a few hundred kilograms into low Earth orbit. Each of these innovations is also driving construction of new launch bases, for example in Scandinavia and the United Kingdom.

### **In this context, how can we consolidate the Guiana Space Centre's position?**

**J. B.:** The Guiana Space Centre (CSG) must also provide facilities to accommodate mini-launchers. It has much to offer, with available space and the ability to supply energy and safe operating conditions, plus the advantages conferred by its exceptional near-equatorial location,



## Q & A



### JOËL BARRE

NEW NUCLEAR  
INTERMINISTERIAL DELEGATE

**“The fact that space pollution may become an obstacle in the future to governmental, military and commercial uses of space makes it a strategic issue.”**

which enables eastward launches into geostationary orbit for telecommunications satellites and launches into polar orbits for Earth-observation satellites. The base is also inside a French zone and enjoys sheltered weather conditions. In all, Europe’s spaceport has everything required to compete in this new mini-launcher market.

### **What about the ecological transition?**

**J. B.:** The CSG must be a beacon on these issues and lead the way with renewable energies like biomass and solar. Pollution from launches is limited and closely monitored, and CNES regularly releases the results of its tests showing that the impacts on flora and fauna in the vicinity of the launch pads are under control.

### **And space pollution?**

**J. B.:** Proliferation of space debris in low Earth orbit is a major concern. Moreover, the fact that space pollution may become an obstacle in the future to governmental, military and commercial uses of space makes it a strategic issue. Europe must acquire its own space surveillance capability. Giving satellites the ability to de-orbit at the end of their lives could be a solution. The leading space powers also need to get round the table to agree on applying international rules of the road. That will be one hell of a challenge!

### **What are the stakes of human spaceflight?**

**J. B.:** Human spaceflight touches on the societal and almost philosophical question of humankind’s vocation to explore the universe. It also has science value, as we’ve seen with medical experiments aboard the International Space Station. And human spaceflight has the power to inspire young people. As a former head of the French

defence procurement agency, I’m obviously delighted to see Sophie Adenot, our first female helicopter test pilot, selected to join ESA’s astronaut corps. What’s more, it’s striking how the invasion of Ukraine hasn’t disrupted ISS operations for Russia, the United States and Europe—a fine example of international cooperation that must be perpetuated.

### PROFILE

#### **1988-1995**

Head of Helios military observation satellite programme at DGA, the French defence procurement agency.

#### **1997-2001**

Director of Programmes and Industrial Affairs at CNES.

#### **2001-2007**

Head of Snecma’s Space Propulsion Division.

#### **2007-2012**

Director of the Guiana Space Centre.

#### **2012-2017**

Associate Director General, CNES.

#### **2017-2022**

Head of DGA.



## IN PICTURES

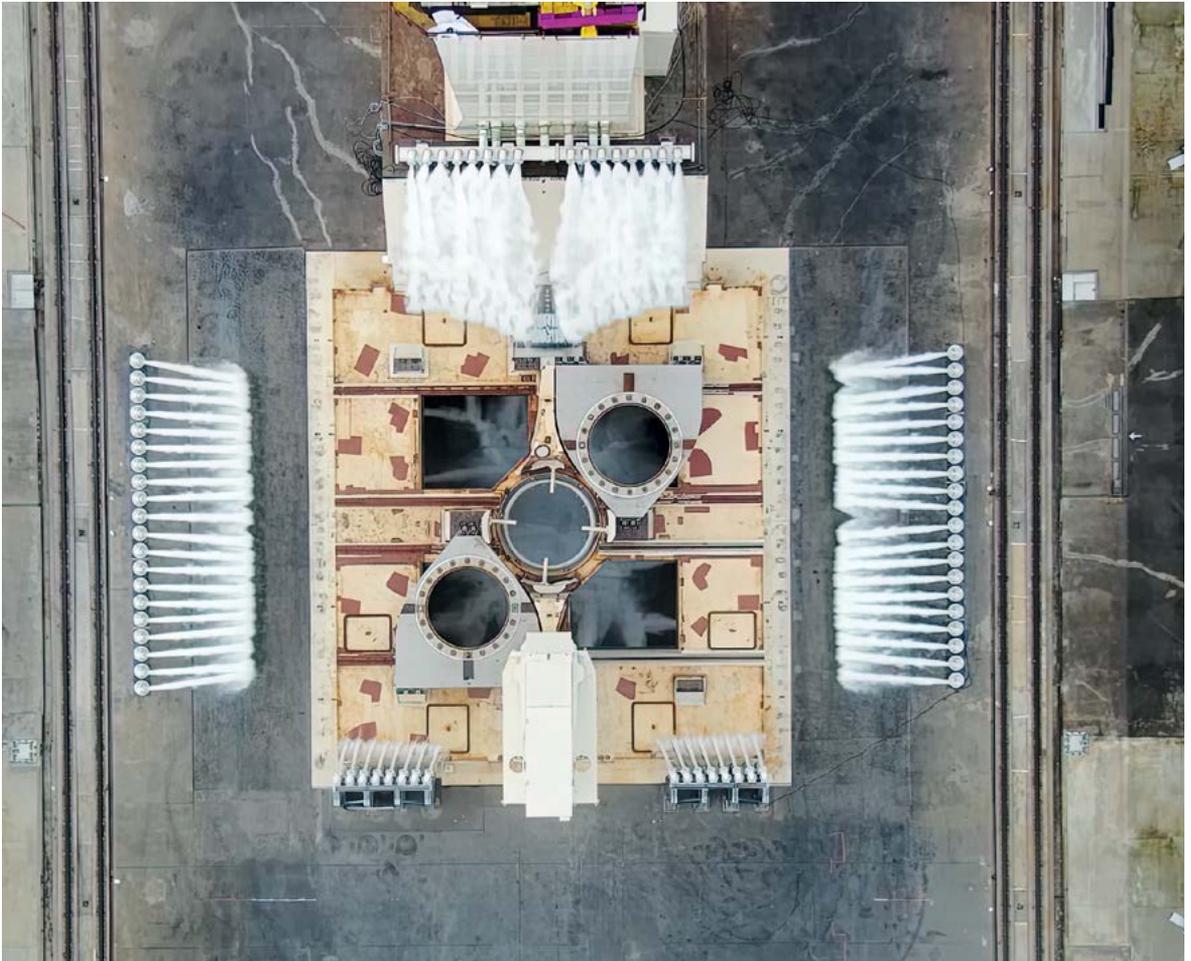


### PROPELLANTS UNDERGROUND

Until they combust together to power Ariane 6 away from the pad, the launcher's propellants are kept well apart. Liquid oxygen (LOx) is stored to the south-east of the launch table and liquid hydrogen (LH2) to the west. Each one is piped to the engines through its own dedicated 20-centimetre vacuum-jacketed feedline to keep it cold. In total, each litre of propellant travels about 300 metres from the storage tanks to the launch pad foundation, then another 100 metres inside the foundation and up through the mast to the cryogenic arms and mini-masts.



## IN PICTURES



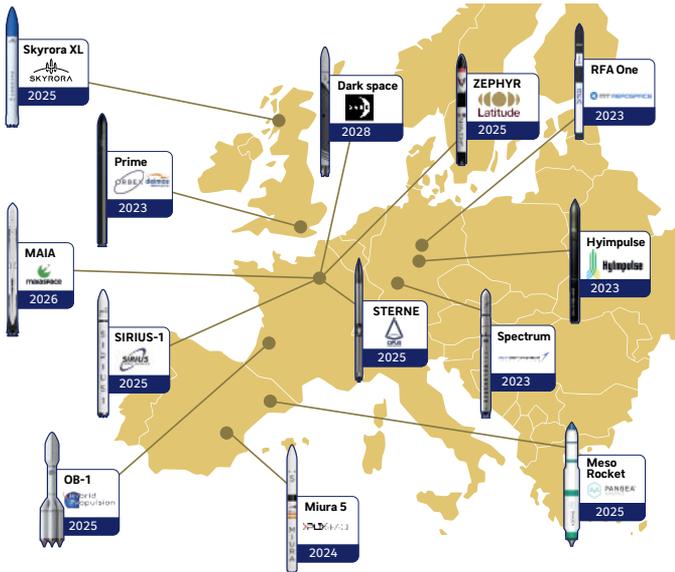
### **FLOODING ELA-4**

Like all launch pads, ELA-4 has a water deluge system to suppress noise and protect the launch table and ground installations from flames at lift-off. First, spray systems are activated 30 seconds before lift-off to cool the blast and flame deflectors in the central flame trench. Then, at lift-off, the water deluge system kicks in, with much higher flow pressures: approximately 15 cubic metres per second for the flame trench and double that for the 72 nozzles flooding the launch table. All these systems are managed by a central programmable logic controller, which required a month of qualification testing.



## IN FIGURES

# MICRO- AND MINI-LAUNCHERS IN DEVELOPMENT IN EUROPE



# 116

**SUPER-heavy-lift and heavy-lift** launchers flew in 2022. Ariane is classed in this top category of vehicles. They were complemented by medium-lift (39) and light and ultra-light (31) launchers.

# €1.1 billion

**New funding for launchers approved by Germany, Italy and France at the opening of the ESA Ministerial Conference** last November to guarantee the ramp-up and future evolutions of Ariane 6 and Vega-C.

# 186

**LAUNCHES** recorded across the globe in 2022. Of these, 97 were institutional and 89 commercial.



# \$9.6 billion

Generated by the global launch services market in 2022.

# €593 billion

**Invested by European nations in maintaining and developing** the Guiana Space Centre.

# €3.2 billion

As the second largest contributor to ESA, just behind Germany, France will be providing €3.2 billion of the €16.9 billion in funding secured at the 2022 Ministerial Conference—€600 million more than in 2019.



# SOVEREIGN SPACE ACCESS

EUROPE'S FUTURE LAUNCHERS WILL BE REUSABLE AND MODULAR, IN MINI AND MICRO FORMATS, AND BE CHEAPER AND MORE ECO-FRIENDLY THAN EVER BEFORE. BUT THEY WILL STILL BE SERVING OUR CONTINENT'S INDEPENDENCE AND GLOBAL REACH.



## CNES IN ACTION



Europe's Ariane and Vega launcher family.

**F**rance's space sector supports some 70,000 jobs and 1,700 firms across its ecosystem, generating revenues approaching €11 billion for manufacturing industry<sup>1</sup>. As impressive as those numbers may sound, they don't reflect the true importance of space. "Assured access to space is key to France and Europe's sovereignty," notes Carine Leveau, CNES's Director of Space Transportation. "In recent decades, space has become a core element of strategic and military independence, an essential cog in our industrial and economic sovereignty, a powerful lever for advancing science and a



**Target  
turnaround**  
time between  
launches from  
the CSG by 2030,  
versus 11 today.

fundamental tool to gain new insights into the major environmental and climate challenges we face." So, what is the role of launchers in all this? "They form the foundation for everything else. Launchers are the necessary condition to stay competitive and maintain our sovereignty in space," in the words of President Emmanuel Macron addressing the informal meeting of European ministers in charge of space in February last year.

### REAFFIRMING EUROPEAN SOLIDARITY

None of this is new. "But recent shifts in the global landscape subsequent to the COVID-19



## CNES IN ACTION

pandemic and above all the war in Ukraine underline more than ever before the importance for European nations of maintaining assured access to space,” affirms Philippe Pujes, in charge of launch system programmes at CNES. In this respect, the agreement reached by France, Germany and Italy last November augurs well for the future. It reaffirms the principle of European preference for space launch, guarantees the future operation of the Ariane 6 and Vega-C launchers, and envisions giving micro- and mini-launchers access to ESA’s institutional launch market. “This is a big step forward at a time when the world of launchers is undergoing deep economic, geopolitical and technological transformations,” says Carine Leveau.

### GEARING FOR THE FUTURE IN UNCERTAIN TIMES

With competition hotting up from major space powers outside Europe and from private players, a burgeoning number of payloads of all sizes employing increasingly diverse technologies, and the climate imperative, CNES and its partners in Europe are today feeling their way forward in a challenging and fast-moving landscape. These elements have been incorporated into the agency’s Objectives and Performance Contract (OPC) with the government and the many actions already undertaken by its teams. One of the top priorities is to get operations for Ariane 6 and its ELA-4 launch complex off to a successful start. The aim is also to give the sector more scope to compete globally by nurturing new French players, particularly in the micro- and mini-launcher segment. A series of measures have already been adopted to this end, especially for infrastructures and the space industry ecosystem. According to Philippe Pujes, “these small launchers will also allow us in turn to test technology building blocks needed to respond to the key challenge of reusability that we’ve been exploring for several years now with our Prometheus low-cost reusable engine project and the Callisto and Themis reusable launcher stage demonstrators.” CNES is also seeking to consolidate the position of the Guiana Space Centre (CSG) as

### Syracuse 4A & 4B

## SERVING FRANCE'S MILITARY SOVEREIGNTY



**On the night of 23 to 24 October 2021, the Syracuse 4A satellite was sent into orbit from the Guiana Space Centre. It will soon be joined by its twin Syracuse 4B, set for launch on the final flight of Ariane 5. These two latest satellites in the Syracuse series will support secure broadband communications for armed forces around the globe from ground, air, sea and submarine platforms. The new generation of French military communications satellites will offer data rates up to three times faster than their predecessors, as well as better security, anti-jamming and protection against cyber threats.**

Europe’s spaceport, with major transformation plans designed to ramp up launch cadences while drastically reducing the base’s environmental footprint. “Last November, the ESA Ministerial Conference approved funding of €593 million from European nations to maintain and develop the CSG, taking the total investment in our spaceport in Kourou to €900 million,” adds Carine Leveau, who sees this as “a strong signal for the future”.

1. Source: French Space Economy Observatory and INSEE national statistics office.



CNES IN ACTION

# What future

## FOR THE CSG?

**Offering even greater flexibility and availability, more attractive, more competitive and with a smaller environmental footprint, the Guiana Space Centre (CSG) is making a major transformation.**



Over the course of its venerable 60-year history, Europe's spaceport has constantly evolved to serve the needs of space stakeholders. In the era of New Space and its myriad players, the launch base is now set to undergo a new transformation to make it more attractive than ever before. "The unprecedented number of small satellite and nanosatellite operators now coming onto the scene is forcing the CSG to develop capabilities to accommodate micro- and mini-launchers," explains its Director, Marie-Anne Clair. "That's why we're building the new ELM multi-launcher complex on the site of the former Diamant launch facilities, which will also be used for the Callisto and Themis demonstrators. These new entrants also have new ways of working and different expectations, so we're having to change our methods and infrastructures to boost the centre's availability and launch capabilities, while cutting maintenance costs significantly."

These are the guiding principles behind the two large-scale modernization programmes undertaken in recent years. The first, dubbed CSG New Generation, plans in particular to build a new operations centre optimized to ramp up launch cadences and accommodate more launchers.



Artist's impression of the future Operations Centre at the Guiana Space Centre.



Earthworks for the new Operations Centre at the Guiana Space Centre.



## CNES IN ACTION



### Propellants

## MOVING TOWARDS BIOMETHANE AND GREEN HYDROGEN

**The question of what kind of fuels Europe's future launchers will use is central to the CSG and CNES's energy transition.** For several years now, two projects to develop low-carbon fuels are underway at Europe's spaceport, applying the same strategy of deploying virtuous ecosystems in close partnership with local firms. Named Hyguane and led by ESA, the first of these is coordinating CNES and industry players—Air Liquide, Sara and others—to scale up a green hydrogen production process. This will involve building a pilot facility combined with a dedicated solar farm and employing electrolysis<sup>2</sup> technology, with the capacity to produce 130 tonnes of hydrogen a year. The project also entails a packaging facility that will open the door to both stationary (fuel cell) and mobile (vehicle) applications. A centre of excellence offering training, intelligence and outreach is also planned in French Guiana. The second project involves biomethane production by a plant to be built near the CSG. This facility will use feedstock from local agricultural waste and/or landfill gas, employing a circular economy rationale. Initially intended to provide propellant for the Themis demonstrator, it could subsequently supply future micro- and mini-launchers. A request for proposals is set to be issued soon.

2. Process that separates hydrogen molecules from water using electricity

The second, given the go-ahead by the ESA Ministerial Conference of November 2022, is focused on making the base more flexible and embracing the digital transformation to boost its competitiveness. It also includes a strand devoted to the base's sustainable development and energy transition.

"This third aspect is central to CNES's strategic priorities, as we have a duty to set an example for the rest of the space sector, but it's also of prime importance for the environmental and economic future of French Guiana," says Marie-Anne Clair. Continuing the ambitious policy it has pursued for many years to preserve biodiversity inside the base's 660-sq.km footprint, the CSG is

now engaging a pro-active energy transition strategy with the clear goal of operating the space centre on 90% renewable energies by 2030, while drastically reducing consumption. This will involve construction of two solar farms and two biomass energy generation plants, as well as achieving big savings in heating, ventilation and air conditioning, optimizing and modernizing the centre's buildings, and use of low-carbon fuels.



Ariane 6's core stage is assembled horizontally, unlike Ariane 5's.

# Ariane 6 - ELA-4

## THE NEW DYNAMIC DUO

**Within the next few months, Europe's new heavy-lift launcher will be making its maiden flight from the ELA-4 launch complex. CNESMAG reflects back on the unique know-how and expertise that has gone into an extraordinary space adventure on which much is riding.**



NES was already advocating the development of a successor to Ariane 5 to assure Europe's independent access to space as early as 2009. After extensive studies and preliminary work, and the green light from

ESA's 20 member states in late 2014, the programme entered its operational phase in 2015 when the space agency chose ArianeGroup to develop the launcher and CNES its ELA-4 launch complex. CNES is assisting ESA with the programme's oversight and conducting combined tests. "The roadmap for Europe's future heavy-lift launcher was clear: it was to be modular, a lot cheaper than its predecessor and its upper stage needed to be re-ignitable to offer the ability to place several satellites into different orbits on a single launch and to de-orbit itself," notes Ariane 6 project leader Olivier Bugnet. For the launch



## CNES IN ACTION

complex, the key goal is to cut costs. “The idea was to share development costs, reduce recurring expenditures and optimize manufacturing processes,” says Pierre Guilhem, Ariane 6 Guiana Ground Support Systems lead.

To achieve these goals, development teams have employed innovative technologies and processes. New and faster fabrication processes have been adopted using less material, like additive manufacturing for the Vulcain 2 engine’s gas generator and friction-stir-welding for the cryogenic propellant tanks. All the stands for testing stages and conducting hot-fire tests have also been built on the same platform to reduce production costs and avoid hiatuses between test environments. “The layout of the launch complex has been rethought to require one less zone than for ELA-3,” adds Pierre Guilhem. “A horizontal assembly building was preferred to the conventional vertical method, thus achieving substantial savings. At the same time, a system to recover deluge water (see p. 16) and a waste water treatment plant have been added to free up the pad faster after a launch and limit the environmental impacts.”

Taken together, these design choices will significantly cut the cost of future flights. “We have a full manifest for several years, with 30 launches already scheduled, including 18 to deploy Amazon’s Kuiper constellation,” adds Olivier Bugnet. And the future is already in the making, as last November’s ESA Ministerial Conference confirmed the development of an upgrade to Europe’s new launcher.



**8**  
**years**  
That’s how long it took  
to build ELA-4.

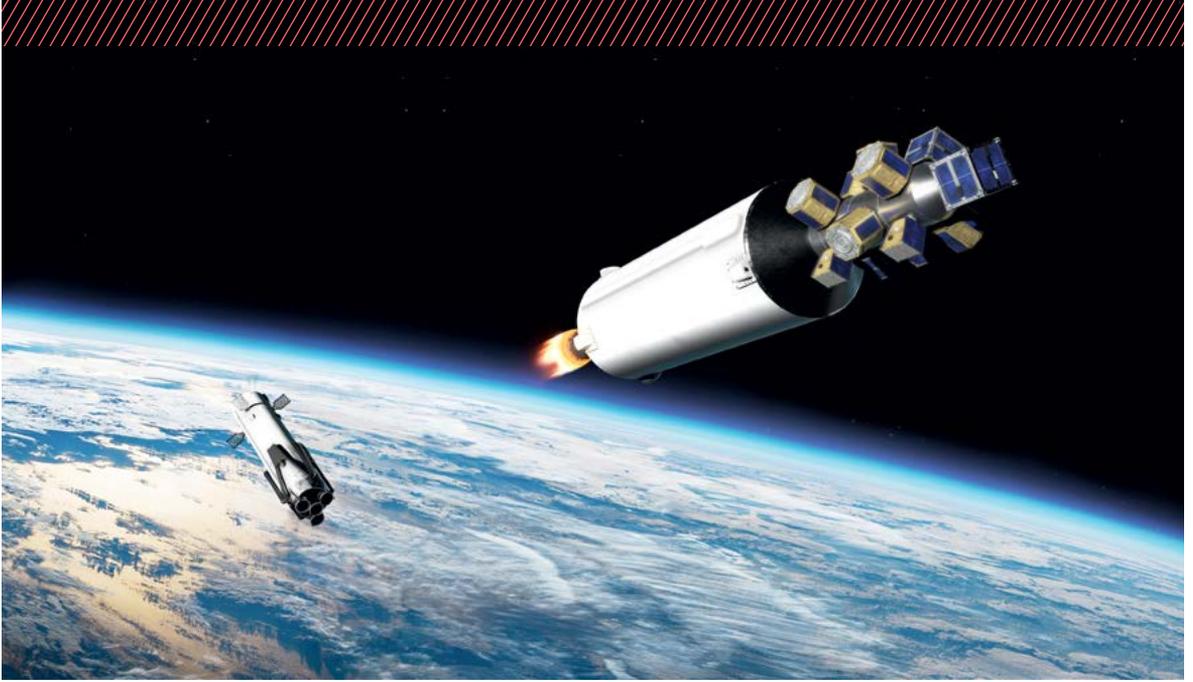
### Qualification



Hot-fire test of Ariane 6’s upper stage with its Vinci engine.

## THE “JOYS” OF INNOVATING

**Imagining new solutions is often quite exhilarating, but not without risk.** Developing Ariane 6 and its launch complex have been no exception, with obstacles amplified by the sheer scale of the project and its numerous partners, who needed to coordinate with clockwork precision. For the launcher, one of the main sticking points was undoubtedly the re-ignitable Vinci engine, requiring countless tests and fine-tuning to control how the cryogenic propellants behave during the ballistic flight phase when the launcher is operating in microgravity. The control station, hosting all of the hardware and software interfaces between the launcher and its pad, also reserved a few surprises. Several versions had to be developed before starting the myriad tests and analyses, due to the multiple safety parameters involved. But this particularly arduous phase is now nearing completion with the control station’s qualification review scheduled in April, clearing the way for the final stage of combined testing.



Artist's impression of a satellite orbited by a mini-launcher.

# Mini-launchers

## CARRYING HIGH STAKES

**In response to the rapidly emerging small launcher market, CNES is crafting a multi-layer support strategy.**

In its latest market intelligence report<sup>3</sup> charting the prospects for small satellites weighing up to 500 kilograms, Euroconsult anticipates more than 18,000 being launched over the course of the next decade, a third of them coming from Europe. This smallsat boom is also driving a multitude of micro- and mini-launcher projects, and CNES fully intends to grasp this opportunity to develop the Guiana Space Centre to cater for the burgeoning new market. The launch base in Kourou already offers a number of advantages, not least of which are its exceptional geographic location and unique expertise in launch systems and space-ground interfaces. It is also upgrading its facilities with the construction of a new multi-launcher complex (ELM) on the site of the former Diamant launch area, where four zones will be set aside for micro- and mini-launchers. To this end, a call for expressions of interest was issued in



**Billion**  
Estimated value  
of the small satellite  
market between  
2011 and 2020,  
according to  
Euroconsult.

December 2021 to down-select seven European operators, some of which will get the opportunity—after signing a preliminary agreement with CNES—to help Europe enhance its launch services portfolio from French Guiana. A first binding term sheet has already been signed with German firm Isar Aerospace. Since last year, CNES teams are also providing technical support to help five French start-ups develop their launcher, thus fulfilling one of the agency's key goals, which is focused on nurturing a new space ecosystem. Some of these start-ups could have reached a sufficient level of technology readiness in time to respond to a fresh request for proposals from French industry players that CNES will be issuing soon, which notably will offer funding support. First flights are planned in 2024.

3. Prospects for the small satellite market, Euroconsult, July 2022



MATERIALS



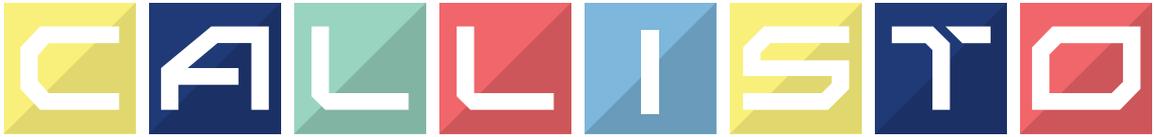
# A safety nanochip

ALTHOUGH ONLY A FEW MILLIMETRES IN SIZE, THIS NANOCHIP CAN ABORT THE CALLISTO REUSABLE LAUNCHER DEMONSTRATOR (SEE PP. 28-29) IF SOMETHING GOES WRONG IN FLIGHT. Employing microelectronics technology, it can be fabricated in large numbers at a competitive cost. It consists of several very thin layers of metal—aluminium and copper oxide—and a filament. As soon as an electric current flows through it, the nanochip catches fire. This in turn ignites a pyrotechnic system to puncture the launcher's propellant tank in the event of a safety issue. Developed by LAAS-CNRS<sup>1</sup>, the nanochip has been incorporated in a novel pyrotechnic system by Dassault Aviation. Unlike existing devices, this one is miniaturized and easily swapped in and out. In future, the technology could even find applications in our cars, as LAAS-CNRS teams are working on a prototype airbag igniter using this nanochip.

1. Systems analysis and architecture laboratory.



## TIMELINE



# 1

## HISTORY

### THE FIRST EUROPEAN DEMONSTRATOR

CNES has been investigating reusable launcher concepts since the early 1980s. Some years later, in 2017 at the Paris Air Show, it signed a partnership agreement with two space agencies for a unique project in Europe and Japan: Callisto. Its goal is to fly a small reusable launcher demonstrator—just 15 metres tall—in real-life conditions. Callisto is not intended to be an operational vehicle, rather a pathfinder for the future Themis demonstrator and, ultimately, a commercial reusable launcher.

# 2

## LAUNCH

### A STORIED SITE GETS A MAKEOVER

The former Diamant launch pad, operational in the 1970s, is being given a new lease of life. Callisto will be launched and retrieved from this historic site at the Guiana Space Centre. Refurbishing the decommissioned launch complex is a virtuous approach, limiting land take and the need for new resources. Another advantage is that by launching Callisto from an active spaceport, all operations will be validated in the same conditions as for a commercial flight. Once the project is completed, this zone will accommodate commercial micro-launchers.



## T I M E L I N E

**CALLISTO IS A DEMONSTRATOR OF A REUSABLE LAUNCHER FIRST STAGE. IT WILL BE LIFTING OFF—AND LANDING—FOR THE FIRST TIME IN EARLY 2025 FROM THE REFURBISHED FORMER DIAMANT LAUNCH PAD. THIS UNIQUE EUROPEAN ENDEAVOUR IS PAVING THE WAY FOR FUTURE COMMERCIAL REUSABLE LAUNCH VEHICLES.**

# 3

## REUSE

### **TESTING NEW SYSTEMS AND OPERATIONS**

Launching rockets into space is something we've been doing for decades, but reusing them poses a real challenge. Callisto will be testing two crucial steps in the process.

Retrieving the launcher will require new systems: a variable-thrust engine, flight control surfaces and landing legs. Callisto will have to land upright with an accuracy better than 10 metres. The other key step is reuse, for which teams will be striving to assess the time, cost and human resources for re-flying the launcher.

# 4

## COOPERATION

### **AN UNPRECEDENTED INTERNATIONAL ALLIANCE**

Callisto in fact stands for Cooperative Action Leading to Launcher Innovation in Stage Toss-back Operations, embodying the cooperation that is one of the project's strengths. The demonstrator is a team effort by CNES, the Japan Aerospace Exploration Agency (JAXA) and the German space agency DLR. Such cooperation pools efforts, expertise and resources towards a common goal. For all teams involved, Callisto is a great and unique opportunity to share ways of working on a daily basis.



H O R I Z O N S

# MASSIMILIANO COSTANTINI

Head of the Guiana Space Centre's range safety unit

"Ensuring the safety of people and property during each launch..."



Kourou, 12 December 2017. Ariane 5 is all set for its 240<sup>th</sup> flight with a payload of four European Galileo satellites. Massimiliano Costantini is about to experience his first launch. "Five seconds before lift-off, the tension is palpable. Once the engine ignites, your brain resets and you have one thought—the mission," he recalls. After nine years at the Guiana Space Centre, he had risen through the ranks to become head of the range safety unit in 2020. A childhood dream: "I was passionate about everything that flies and developed a fascination for space technologies." He studied propulsion at the Polytechnic University of Milan. In 2014, he joined CNES in French Guiana as a computa-

tional modelling engineer in the ground safety department. He soon gravitated towards range safety—a crucial function at the launch base and a prerequisite for any launch, ensuring the safety of people and property. "It's the range safety engineer who hits the button to abort the rocket if anything goes wrong at any phase of the flight," he explains. On the night of 20 December 2022, Massimiliano is closely monitoring a Vega-C launcher. As it soars skyward, it starts to veer off course, so he hits the destruct button. "We're trained to think almost automatically," he says. Every week, his team uses a simulator to rehearse communications and the actions they may

have to take on launch day. "The instructor feeds faults and failures into the simulation, like drifting off course or a hitch with the tracking or telemetry systems." The simulator can generate any number of worst-case scenarios so the team can drill on what to do. Even after 27 launches, he still feels that 'adrenaline rush' as the countdown begins. Massimiliano also helps ensure each launcher complies with the French Space Operations Act (FSOA). "The arrival of micro-launchers opens a whole new paradigm for range safety. The challenge is to ensure the same levels of safety, while recognizing the economic and technological constraints around these launchers."



H O R I Z O N S

# LUCE FABREGUETTES

Head of ESA's Infrastructure and Value Chain Department, Space Transportation Directorate

"Offer competitive launchers in line with our public mission of access to space..."



Asked to describe her job, Luce Fabreguettes alludes to the Supports/Surfaces art movement, which originated in Montpellier and focused on materials as much as the finished piece. "I make sure the canvas, tools and brushes are available to everyone involved, so they don't have to worry about infrastructure, processes or safety issues," she says. This Montpellier native has been head of ESA's Infrastructure and Value Chain Department since 2020. "My job is to optimize the processes and resources needed for launcher production and launch facilities and find the right balance of public/private partnership to ensure our launchers are competitive, while fulfilling our public mission of access to space," she explains.

Before taking up this strategically important role, Luce Fabreguettes worked in pure engineering. In 1990, after graduating from the Ecole Centrale de Lyon engineering school, she joined Aerospatiale just as Ariane 5 was being developed. The second launch in its ECA variant was a fitting climax to many months of hard work. Luce was involved in the design of the Automated Transfer Vehicle (ATV), which resupplied the International Space Station. She was also involved in the early stages of the Vega launcher and in digitizing Soyuz operations. "After 15 years in the industry, I wanted to get a clearer picture of the expectations of customers and their passenger payloads," she says. Her assessment led her to Ariane-

space in 2005, then to ESA, where she worked on European space programmes. Her in-depth knowledge of launchers gives her real credibility with industry partners. "I'm less involved on the technical side now, but I'm still keen to understand it—I'll always be an engineer at heart," she adds. In 30 years, Luce has seen the increasing privatization of the sector and the emergence of new players in the micro-launcher and spaceport markets. "For geostrategic reasons, cooperation has become more selective," she observes. Added to that, there's the imperative to reduce our carbon footprint. "This complex environment calls for ESA and CNES to transform themselves and adopt a more sustainable way forward."



H O R I Z O N S

# EMMANUEL LACÔTE

Head of the future propellant chemistry laboratory

"Finding new liquid fuels to power the launchers of tomorrow..."



Green chemistry is predicated on a paradox: we need to develop new and more efficient molecules, while minimizing their impact on our health and environment. "To orbit a satellite, you need a specific amount of energy. Current solutions are toxic to a certain extent, so finding a green propellant would be the Holy Grail," says Emmanuel Lacôte, head of the hydrazines and polynitrogen energetic compounds research unit. Behind this rather cryptic name is a joint research unit set up by CNES, France's national scientific research centre CNRS, ArianeGroup and Claude Bernard Lyon I University. Since 2016, Emmanuel, an elemental chemistry researcher, has been working on the propellants

of the future. "Our goal is to find new liquid fuels to power the launchers of tomorrow." The challenge? Develop a breakthrough propellant. High-energy-density-matter (HEDM) propellants are one of the avenues being explored by the Ariane Ultimate initiative, led by CNES. "We're midway through the proof-of-concept phase," he adds. "We've inserted the chain of atoms needed for propulsion into a molecule. We now need to polish this rough diamond to achieve the target HEDM." Here, upstream research is determined by the industrial application, which means the propellant must have a high specific impulse value: "To find the right solution, we need to keep in mind the

particular constraints of space." Molecules with a higher energy density can be stored in a smaller tank. "If we can synthesize these molecules in large quantities, we could completely rethink launcher architectures and make them smaller, lighter and above all cheaper." The plan is to build a carbon-neutral reusable launcher with a low launch cost by 2040. "It's exciting to be doing impactful research that could help secure Europe and France's pre-eminence in space," he concludes.



JACQUES ARNOULD

## SUCH A MAGNIFICENT VOYAGE

**Astronauts, satellites and probes are leaving our planet and heading for space in ever greater numbers. Never has there been such a fantastic destination. But what are they hoping to achieve?**

It all began in April 1610. After reading the account of Galileo's first astronomical observations the previous winter, Johannes Kepler enthusiastically announced the advent of space exploration: "As soon as someone demonstrates the art of flying, settlers from our species will not be lacking. Given ships or sails adapted to the breezes of heaven, there will be those who will not shrink from even that vast expanse. Therefore, for the sake of those who will presently be on hand to attempt this voyage, let us establish the astronomy, Galileo, you of Jupiter, and me of the Moon." This breathtaking prophecy would take three and a half centuries to be fulfilled, and with space transportation now entering a new chapter in its history, demand is greater than ever.

But Kepler was under no illusions: "I am aware how great a difference there is between theoretical speculation and visual experience; between Ptolemy's discussion of the antipodes and Columbus's discovery of the New World." And we cannot reflect on the art of space travel today without remembering its pioneers, its brilliant successes, but also the darker, murkier episodes of its history. Because they are human—dramatically human—

none of our conquests, none of our explorations, are without error or even fault.

### THEY WHO WOULD GO FAR...

This should not hinder our progress to the stars; rather, it should invite us to question our motives. If space, both near and far-distant, offers the most fascinating of destinations, this alone does not justify the efforts made and risks incurred to reach it. Norman Augustine, in his 2009 report to President Barack Obama, is right when he said: "[...] human spaceflight should begin with a choice of goals—rather than destinations [...] destinations should derive from goals and architectures should be weighed against those goals. We risk focusing on a destination without a clear understanding of why it was chosen, which can lead to uncertainty when the programme starts."

What Augustine says about human spaceflight is true for all space missions and forms of space transportation: we should not be blinded by the magnificence of space destinations. Instead, we must continuously question the goals we are pursuing—then the voyage will be even more magnificent!



EXHIBITION

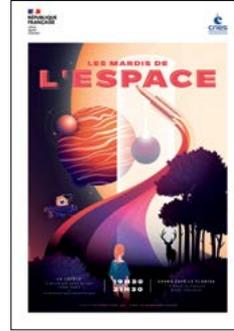
## SPACE MUSEUM MAKEOVER



Since August 2022, its doors have been closed for a major redesign. The Space Museum at the Guiana Space Centre (CSG) has been reinvented as an interpretation centre. “The key concept behind the new CSG Space Museum is two-way interaction,” says Marie-Françoise Bahloul, CNES project manager in Kourou. “We’re putting visitors in the driving seat to make learning a lot more fun.” In an immersive journey, young and old alike will relive the history of space exploration and developments at the Kourou spaceport. A dedicated gallery will feature 1/10 scale models of the iconic Ariane and Vega rockets. “The human aspect is front and centre of this makeover,” adds Marie-Françoise Bahloul. “Through video and audio testimonials, we’ll take visitors behind the scenes at the CSG and promote the 90 job functions and roles here.” Who has never dreamt of being an operator in the control room and clearing a launch to go? Choosing the right launcher for an Earth-observation mission and calculating the correct orbit? Or even hitching a ride on a satellite? A whole host of new features and installations await to inspire enquiring minds and revitalize our educational offering for local young people. All will be revealed when the new Kourou Space Museum opens in 2024.

PODCAST

## TUESDAY SPACE TALKS



What will the next generation of space launchers look like in 2030? What innovations will feature in tomorrow’s space transportation? And what role can France and Europe play on this front? These are just some of the topics discussed at the Space Tuesday

session in December 2022: “Space launchers of the future: towards independent and competitive access to space”. The event was organized by CNES, in partnership with the Science Bar. Hosted by science reporter Paul de Brem, it included short talks by three specialists from the sector about new types of propulsion, micro-launchers and eco-responsible launchers. Listen to the session as a podcast on all platforms, or on the CNES website.

MEET-UP

## AN ASTRONAUT AT PERSEUS



On 30 and 31 January, more than 80 people took part in the PERSEUS programme annual seminar. The event is designed to promote entrepreneurship

and careers in space for students from all backgrounds (see page 9). For this return to a physical venue after two virtual seminars, participants had the chance to meet Arnaud Prost, recently selected as an ESA reserve astronaut, and chat with him about his incredible career path, including a stint with PERSEUS. Hopefully inspiring vocations in space!



## INSIGHTS



**HAPPY BIRTHDAY!**

# C'SPACE TURNS 60

**The next C'Space student space projects event will take place at the Ger military camp near Tarbes in Southwest France, home to the 1<sup>st</sup> Hussard parachute regiment, from 15 to 22 July 2023.**

Organized by CNES, it will bring together about 60 volunteers from non-profit association Planète Sciences and 150 to 200 young people from across France for a week of rocket launches. Participants in the CanSat student competition will build satellites the size of a Coke can. Highlights at this 60<sup>th</sup> anniversary event also include mini-rocket launches at night and a roundtable discussion about space and the environment, hosted by astrophysicist Faustine Cantalloube and Lucie Poulet, a PhD student supported by CNES-CNRS for her research into growing vegetables in zero gravity. An extravaganza for space enthusiasts!



### BOOKS

#### SPACE FOR ALL

To engage youngsters and spark their interest in space culture, CNES supports the publication of illustrated books. One example is *L'EsPace*, part of the *J'ai tout compris* (All About) collection published by Privat. Fifty questions and answers to learn more about space and the challenges of space exploration. *Planètes*, the manga series by Makoto Yukimura, was also reviewed by CNES's scientists. And in *Mission EsPace*, the ninth volume of Violette Mirgüe's adventures, Marie-Constance Mallard sends her famous mouse into space from CNES's Toulouse field centre on a new mission: to bring back debris scattered around the cosmos. Three must-reads (in French).





SPINOFF

# SUPER-REFRIGERATORS AT SEA AND IN SPACE

**Air Liquide has developed a “super-refrigerator” capable of maintaining natural gas in a liquid state on ships or conserving samples aboard the ISS.**

**M**ore than 600 ships loaded with liquefied natural gas (LNG) are sailing the world’s oceans. To avoid boil-off, methane—the greenhouse gas that makes up 90% of LNG—must be kept in tanks in a liquid state, at a temperature of  $-162^{\circ}\text{C}$ . This proves quite a challenge when aboard ship. Air Liquide has developed its Turbo-Brayton system for this purpose. “The system re-liquefies boiled-off methane for reuse,” explains Benoît Hilbert, Air Liquide Advanced Technologies CEO. These easy-to-use units requiring minimal maintenance have come into widespread use over the last five years, with more than 140 already operating on LNG carriers.

## CONSERVING BIOLOGICAL SAMPLES

The units employ a principle known since the 18<sup>th</sup> century whereby a gas produces a cooling effect when it is compressed and then expanded. “At Air Liquide, this technology is operating here on Earth and in space,” notes Benoît Hilbert. Before installing them on LNG carriers, the company had already been using turbomachines since the 1970s to liquefy hydrogen and helium for scientific purposes. It then adapted the technology for space in the early 2000s for MELFI<sup>1</sup>, an ideal space “refrigerator” due to its compact turbomachinery, low vibration levels and great reliability. Three such units are used to conserve biological samples for science experiments aboard the International Space Station. “They keep them at a temperature between  $+4^{\circ}\text{C}$  and  $-95^{\circ}\text{C}$ ,” says Hilbert. In the future, the super-refrigerators could equip crewed scientific spaceflights, no matter how far from Earth.

1. Minus Eighty Degree Laboratory Freezer for ISS.



**8.5**

**Mass**  
in kilograms of a Turbo-Brayton unit aboard the ISS, capable of cooling to  $-95^{\circ}\text{C}$ .

**40**

**Weight**  
in tonnes of a Turbo-Brayton unit for an LNG carrier, operating at temperatures as low as  $-170^{\circ}\text{C}$ .