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SPACE ● INNOVATION ● SOCIETY

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GALILEO

A CONSTELLATION OF SERVICES

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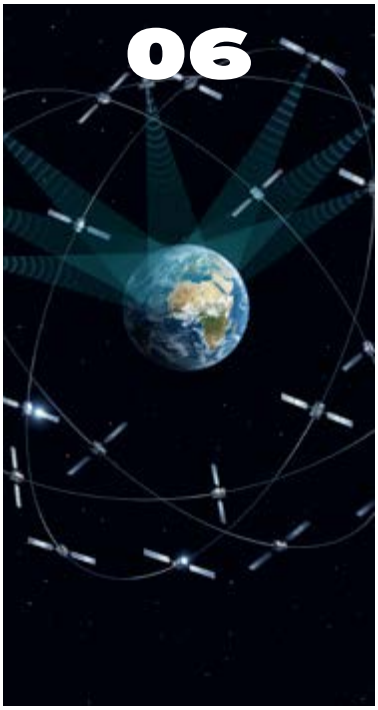
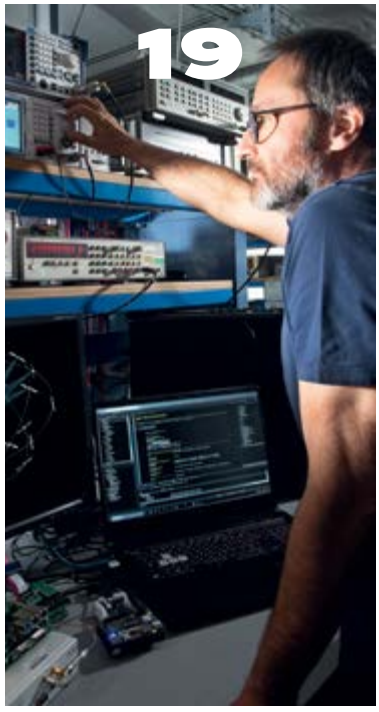
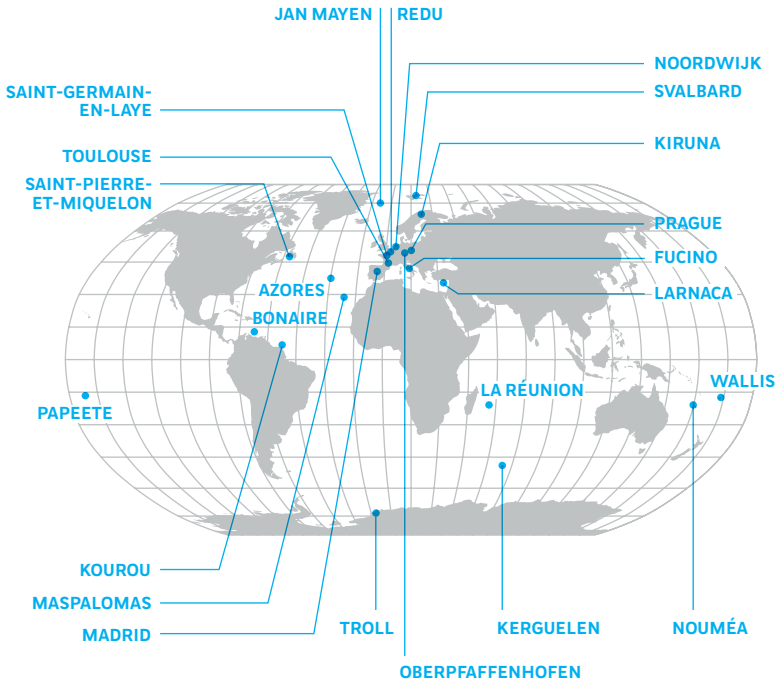
INSIDE



INSIDE



THE GLOBAL NETWORK OF GALILEO SITES AND GROUND STATIONS



PARTNERS

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JEAN MARÉCHAL

Jean Maréchal knows a thing or two about satellite navigation, from the core of systems to operational services, design to development, and EGNOS to Galileo. Previously a national expert seconded to the European Commission, he's today in charge of CNES's Navigation programme. For this issue, he gave generously of his time to pass on his encyclopaedic knowledge of the subject.

CHIARA SCALEGGI

For nearly ten years now, Chiara Scaleggi has been devoting her boundless energy and enthusiasm to the international COSPAS-SARSAT programme. She's now going one step further, leading the SAR-Galileo project at CNES, looking to save even more lives in the future. Inside, she shares with us the promises these new services hold.

MARC JEANNOT

Having spent many years working in the field of space navigation, Marc Jeannot has made the EGNOS, Galileo and GNSS constellations his domain of excellence. This engineer and former national expert seconded to the European Commission explains how everything works, from the space and ground segments to receivers and orbits.

JEAN-PIERRE DIRIS

As the Head of CNES's Telecommunications and Navigation projects sub-directorate, Jean-Pierre Diris knows all of Galileo's assets. He also knows the flaws that expose it to jamming, spoofing and other malicious acts. For CNESMAG, he guides us through work now underway to guarantee data security.

CNESMAG

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IMPRIM'VERT

First conceived in the United States over 60 years ago through the TRANSIT military project, satellite-based navigation is today an essential global resource. The civil services it enables have been adopted on a massive scale by citizens and businesses alike, who rely on them to fix their position in space and time at any moment. Europe decided 20 years ago to secure its technical, economic and strategic sovereignty with this apparently simple yet vital service. Today, thanks to Galileo and EGNOS, it can call on a range of high-quality services, and more now in development are on the way.
In this issue of CNESMAG we look at the contributions of France and CNES to these two European systems: the invention of Galileo's signals, operation of the search-and-rescue service, global verification of navigation performance and industrial infrastructure developments to name a few. We'll also discover ambitious projects pushing the boundaries of technology and demonstrating the feasibility and benefits of new concepts like services underpinned by constellations in low Earth orbit.
In the field of satellite navigation, France has proved itself an outstanding performer and an innovative and resolutely European player.
I hope you enjoy reading the magazine.

MARIE-CLAUDE SALOMÉ
CNES DIRECTOR OF COMMUNICATION

GALILEO

A CONSTELLATION FOR INDEPENDENCE

On 15 December 2016, the European Commission issued the declaration of initial Galileo services, giving users the ability to combine the constellation's signals with those from other satellite navigation systems. In November 2021, the Commission put in place an enhanced operational capability through the Open Service Definition Document (OS SDD) that establishes Europe's independence in space-based positioning, navigation and timing. This document enables users to opt for Galileo services. The two latest satellites launched in December have further enhanced the robustness of the system that now counts a constellation of 28—a launch that came in the nick of time, as two months later Russia suspended all Soyuz operations at the Guiana Space Centre and recalled its teams working there.

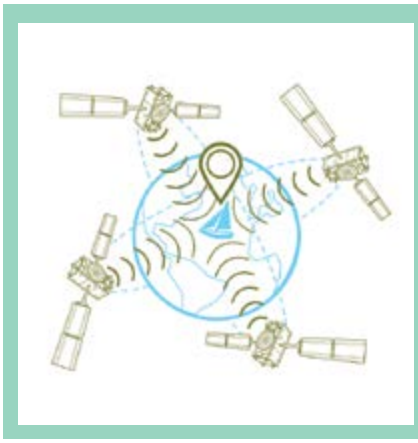
Artist's impression of the Galileo constellation.

SOYOUZ/ARIANE

REFLECTING ON A DECADE OF LAUNCHES

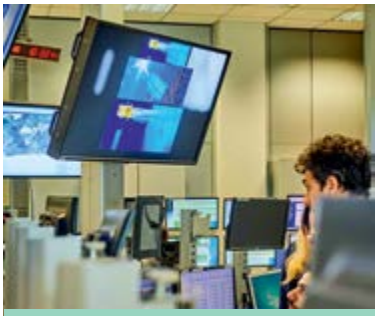
It has taken 10 years to get the 28 satellites of the Galileo constellation into orbit. Out of these, there are 24 'operational' satellites and one on-orbit spare ready to take over in the event of a hitch to guarantee service continuity. At the Guiana Space Centre, Soyuz and Ariane 5 have shared the workload to meet the launch schedule, with Soyuz able to orbit two satellites at a time and Ariane 5 four, thanks to the adaptability and flexibility provided by its ES variant specially designed for this purpose. The satellites were positioned alternately by CNES in Toulouse and ESOC[1] in Darmstadt, Germany. World geopolitical events have since compromised the launch manifest, forcing the next flights originally planned on Soyuz in April and October this year to be scrubbed. As Ariane 5 production has now shut down, Ariane 6 will be launching the satellites no earlier than the first half of 2023.

1 European Space Operations Centre.



4

The minimum number of satellites that must be in view for Galileo users to determine their position. To meet this requirement and ensure global coverage, a constellation of at least 24 satellites is needed.



PERFORMANCE

A SYSTEM UNDER CLOSE WATCH

How do we ensure from here on Earth that everything in the Galileo constellation 23,000 kilometres above our heads is running smoothly? Answer: by maintaining a constant check on performance parameters defined by each EU member state. The slightest glitch—temporary loss of service, a clock malfunction, reduced precision or any problem with user protection—is closely tracked. And to guarantee that performance checks are objective, this mission has been entrusted to CNES, whose expertise and independence are widely renowned, as it has been doing the same job since 2009 for the EGNOS system used by civil aviation. To accomplish this mission, the agency is working under an agreement with EUSPA[1], for which it is leading two consortia, one of nine and the other of 19 public institutes representing ten European nations.

1 EU Agency for the Space Programme

ACCURACY

APPROACHING ONE CENTIMETRE

Galileo's one-metre accuracy is already outstanding. Now, it is set to improve even further with precise point positioning (PPP) technology promising centimetre accuracy for certain applications. The patented prize-winning method invented by CNES engineers works by applying corrections to the raw data from onboard atomic clocks, orbital parameters and so on. These corrections are then sent to the receiver to enhance data quality. PPP technology works with all GNSS[1] constellations, but Galileo's specific frequencies optimize it, particularly its third E6 civil signal, which provides more measurements to make solutions converge faster. While the convergence time for GPS is estimated at ten minutes, for Galileo the process is completed in near-real time, taking no more than ten seconds. Formed in 2015 to spin off the PPP service at the end of the development phase, start-up Geoflex now offers solutions for a broad spectrum of sectors including the maritime, aviation and construction/civil engineering industries (bridges and structures), land planning and railways.

1 There are four GNSS (Global Navigation Satellite Systems) constellations: Galileo, GPS, Beidou and Glonass.

RECEIVERS

ON EARTH AND IN SPACE

Initially designed for use here on Earth, GNSS receivers are also flown on satellites, and have been since the 1990s for certain missions. What's new today is their growing use in space on the back of burgeoning demand from nanosatellite programmes and missions in low Earth orbit (LEO). Whatever a satellite's orbit—low or medium Earth or geostationary—it can only gain from incorporating such a receiver, which ensures more accurate onboard orbit determination and timing synchronization. By increasing the number of satellites within view, Galileo is helping to boost their performance, paving the way for new multi-constellation and multi-frequency functions. For military satellites, Galileo also offers the benefit of greater independence and security. However, these onboard receivers have to be custom-built to satisfy the tough technical specifications—radiation, power consumption, orbits, high dynamics, etc.—of operating in space, so their design is altogether different from that of an everyday smartphone receiver.

POSITIONING

GUIDE: THE CERTIFICATION EXPERTS

The GUIDE laboratory runs geolocation tests in real-life conditions to check positioning system performance and signal integrity. Requests for certification come from receiver manufacturers with an eye on the quality of their products, as well as from users of high-precision agricultural robots and the automotive and rail industries, for example. To verify and characterize positioning systems' reliability and accuracy, GUIDE puts them through their paces inside a vehicle in constrained environments like urban canyons and tunnels. Scenarios can then be re-run in the lab to confirm performance levels statistically. GUIDE also collects GNSS signals to characterize improvements from augmentation systems like EGNOS, which deliver real-time corrections to enhance positioning accuracy. On the strength of this expertise acquired from its fruitful collaboration with CNES, GUIDE is since 2021 one of only two geolocation laboratories accredited to the European EN16803 standard.

1 m

The current positioning accuracy of Galileo. This parameter is measured independently and performance is checked by CNES, in particular at the reference station in Toulouse.

80 ms

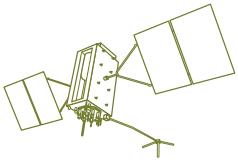
23,222 kilometres is the altitude of the Galileo satellites' orbit. Their signals reach receivers in near-real time, taking 80 milliseconds to 0.1 seconds.

3,000,000,000

Galileo-enabled smartphones as of mid-April 2022.
Source: https://www.usegalileo.eu/accuracy-matters/EN

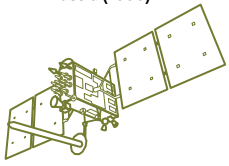
THE FOUR GNSS CONSTELLATIONS

GLOBAL POSITIONING SYSTEM (GPS)
United States (1995)



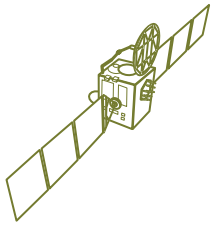
Operational satellites: 31
Orbit: 20,200 km
Accuracy: 1.7 m
Services: positioning, navigation and timing (PNT)
Funding: military

GLOBAL NAVIGATION SATELLITE SYSTEM (GLONASS)
Russia (1995)



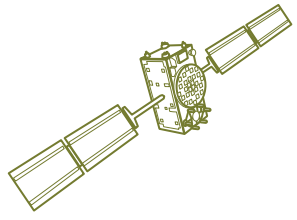
Operational satellites: 22
Orbit: 19,100 km
Accuracy: 6.6 m
Services: PNT
Funding: military

BEIDOU
China (2020)



Operational satellites: 24
Orbit: 21,500 km
Accuracy: 1.7 m
Services: PNT + high accuracy (HAS)
Funding: military

Galileo
Europe (2022)



Operational satellites: 24
Orbit: 23,222 km
Accuracy: 1.0 m
Services: PNT + HAS + authentication + worldwide location of distress beacons + return link
Funding: civil

SECURITY

KEEPING THE AIRWAVES CLEAR

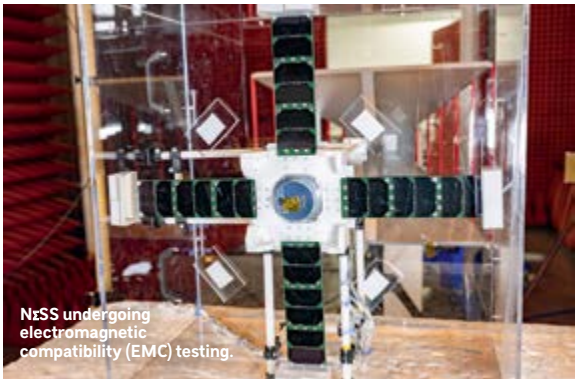
In France, GPS jammers are illegal and anyone caught owning or using them is liable to a fine. For these little devices don't only jam your GPS; they can also interfere with other GNSS receivers in businesses, aircraft, cars, boats and TV antennas sometimes hundreds of metres away, and even obstruct emergency services. Obsolete or defective equipment can also inadvertently jam systems. Whatever the source, the French frequencies agency ANFR runs tests and dispatches its field teams at the first sign of an anomaly. With Galileo now operational, it's taking the opportunity to recall certain rules, including where users are operating in the same frequency band. ANFR is fulfilling this role for France, but a working group is also looking at establishing a set of common rules and best practices to protect frequencies across Europe.

NAVWAR

INNOVATING TO COMBAT INTERFERENCE

Navigation warfare (NAVWAR) already existed as a concept before the conflict between Russia and Ukraine, but current events have highlighted the need to protect space-based navigation assets. From the start of hostilities, news agency AFP reported increased interference with GPS signals used for air navigation. Jamming and spoofing impact both civil and military applications. The NΣSS technology demonstrator developed by CNES in partnership with the Ministry of Armed Forces will be launched into low Earth orbit this year.
This pocket-sized (30 cm x 10 cm), featherweight (6 kg) nanosatellite conceived with start-up U-Space is set to demonstrate technology able to detect and pinpoint interfering transmitters operating in GNSS frequency bands. The French government is also addressing this issue through its recovery plan, with funding for two dual-use projects supported and led by CNES and the French defence procurement agency DGA. The first, DIEGO, will test new technologies to achieve closer surveillance of interference in GNSS frequency bands. The second, SICUT, is a demonstrator in low Earth orbit led by a consortium of French SMEs and manufacturers[1] designed to augment signals for Galileo's Public Regulated Service (PRS) and make them more robust.

1. Hemeria, Thales Alenia Space and Syrlinks


NΣSS undergoing electromagnetic compatibility (EMC) testing.

LEO

NEW ORBITS, NEW SERVICES

In fuelling the development of nanosatellites, miniaturization has made low Earth orbit (LEO) a very attractive proposition. With OneWeb, O3b, Starlink and tomorrow the EU Secure Space-based Connectivity System (ESSCS), LEO constellations are set to go forth and multiply. Previously sought after for telecommunications, orbits between 400 kilometres—the altitude of the International Space Station—and 2,000 kilometres are today opening up to new services. LEO is especially conducive to positioning, navigation and timing (PNT) and synchronization services, as the signals are closer to Earth and therefore stronger and more resistant to jamming. Constellations in LEO are currently the subject of numerous studies, notably at Thales Alenia Space, and could offer services to boost GNSS signals from satellites operating in medium Earth orbit (MEO, at 20,000 kilometres). They could also help resolve issues like obtaining position fixes indoors or in constrained environments. Fitted with specially designed antennas, satellites could even keep a check on GNSS signals from space.

LEO PNT, an example of a constellation of 160 satellites in low Earth orbit.

REGINA

A GLOBAL NETWORK SERVING SCIENCE

In 2012, CNES and France's national mapping, survey and forestry agency IGN created REGINA[1], a network of 38 stations with antennas, receivers and related equipment. These stations receive signals from GNSS constellations all around the globe, including from regional systems like QZSS in Japan and IRNSS in India, as well as from satellite-based augmentation systems like EGNOS for civil aviation. REGINA thus collects a wealth of data and sends it to the mission centre at CNES's field centre in Toulouse, which then forwards the information in raw or processed form to IGS[2], a databank for generating Earth science products and services. In 2016, REGINA was upgraded to receive new signals, notably from Galileo. Its multi-constellation capability and global coverage make it the keystone of CNES's navigation efforts, enabling the agency to supply new institutional users like EUSPA[3] as well as scientists and precise positioning service providers.

1. REseau GNSS pour l'IGS et la NAvigation
2. International GNSS Service
3. EU Agency for the Space Programme

#COMMUNITY

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

@THIERRYBRETON

EU Commissioner

A sea rescue... from space! Glad our #Galileo satellites could help save @KevinEscoffier during the #VendeeGlobe yacht race. Three of the navigation system's satellites picked up the signal from his locator beacon to provide his precise position. @JeanLecam

@SPACEARTH_IN

Our mission: putting French and European space to work for citizens.

Finding your way before 1995: 🗺️
Finding your way today: 🤳
Every day, 2.3 billion users are taking advantage of the Galileo navigation system's 28 satellites. Learn more about Galileo here 👋:
http://spacearth-initiative.fr

@SEBMAYOUX

Serious crime fiction writer

France's #overseas territories are vital to the EU's technological sovereignty: the spaceport in Kourou, French Guiana, the research bases in the French Southern and Antarctic Lands... and #Galileo, the European satellite navigation system that recently arrived in the #Kerguelen Islands.

@EUROPAWIRE

Press release distribution & #newswire service for #Europe & the #EuropeanUnion.

The 3rd #HackathonCASSINI: participants will be using the wealth of data from the #Copernicus, #Galileo and #EGNOS programmes to come up with revolutionary solutions for the future of #tourism.

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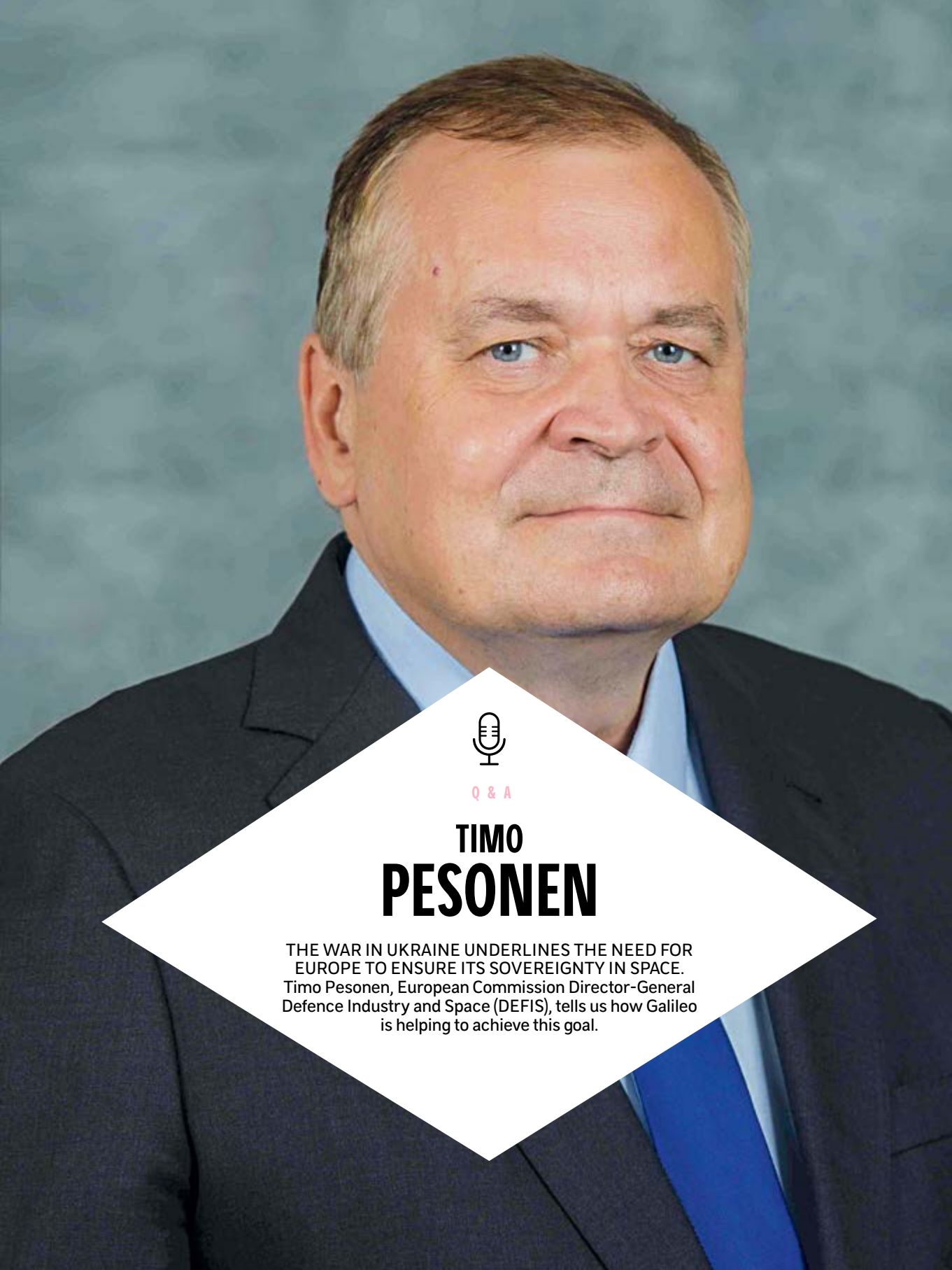


Q & A

TIMO PESONEN

THE WAR IN UKRAINE UNDERLINES THE NEED FOR EUROPE TO ENSURE ITS SOVEREIGNTY IN SPACE. Timo Pesonen, European Commission Director-General Defence Industry and Space (DEFIS), tells us how Galileo is helping to achieve this goal.

Is Galileo supporting the response to the current invasion of Ukraine by Vladimir Putin in any way?

Timo Pesonen: Galileo isn't serving any specific purpose with respect to the invasion of Ukraine right now. On the other hand, the dramatic events unfolding there confirm the utility of its future Public Regulated Service (PRS) for projecting European forces. For example, Galileo PRS receivers in aircraft and weapon systems will offer sufficient robustness to counter the kind of jamming attempts we're seeing in certain parts of Ukraine. More broadly, this invasion is a reminder that we must protect our space assets to guarantee our independence. Our space defence strategy will draw on the lessons learned from the current situation.

From a wider perspective, how is this programme helping the European economy? Is it vital to Europe's sovereignty?

T. P.: Galileo is a key element of our sovereignty. By supporting our ability to act and decide independently, it's driving development of whole swathes of the economy like air, maritime and road transport, logistics, precision agriculture, public works and network synchronization. It's also helping to mature new technologies like autonomous vehicles that need to know their exact position at all times. And it's a global system delivering positioning and timing information from anywhere in the world. Without Galileo, our economy would be dependent on systems operated by foreign powers. We're clearly seeing the consequences today of any form of dependence, in the energy sector for example.

Besides supplying operational navigation services, let's not forget that a space programme like Galileo taps into a rich pool of talent. It's also enabling the European Union to acquire the know-how it needs to maintain in Europe to secure supply chains in high-value sectors like electronic chips, atomic clocks, launchers and active antennas. Sovereignty is also about those kinds of things.

> "Without Galileo, our economy would be dependent on systems operated by foreign powers."

What are Galileo's strengths and where can it improve?

T. P.: Galileo is designed for civil purposes, which is important because that means structuring how we manage end-users' needs through the EU Agency for the Space Programme (EUSPA). However, Galileo's dual-use status also serves military purposes, as set out recently in EUSPA's Governmental Market Report. This civil rationale affords more flexibility to adjust the mission and services compared to the United States' NAVSTAR programme [Editor's note: the original name for GPS], conceived by and for the military, which is much less able to accommodate civilian needs. Galileo in fact offers a much wider range of services than other providers, with three open frequencies (E1, E6 and E5), authentication, a High Accuracy Service (HAS), integrity messages, a search-and-rescue return link, and soon an Emergency Warning Service (EWS) and improved encryption.

The recently renewed governance structure ensures effective sharing of responsibilities between the European Commission in charge of the programme, EUSPA as operating agency and ESA as design authority. However, the Commission isn't ruling out mechanisms like public-private partnerships tailored to other components of the space programme where contributions from the commercial sector are planned for example.

What future prospects do you envision for Galileo? How will it evolve to address new challenges in Europe?

T. P.: Galileo has anticipated several trends in satellite navigation. First, we're seeing growing demand for robustness, which can be achieved through frequency diversity—Galileo offers users several frequencies—power levels, different degrees of

TIMO PESONEN

EUROPEAN COMMISSION
DIRECTOR-GENERAL DEFENCE INDUSTRY AND SPACE (DEFIS)

"Galileo has anticipated several trends in satellite navigation."

signal and message authentication, and encryption. Galileo already provides these features and its second generation promises to deliver more with even better performance.

Better positioning accuracy is crucial for precise applications like autonomous vehicles or precision agriculture. Galileo is already a step ahead here with its ultra-precise atomic clocks and HAS (20 centimetres) set to enter its operational phase in the near future. New 5G and 6G mobile networks, miniaturized inertial sensors and quantum technology are other emerging areas where we're working to develop combined usage with Galileo.

The pace of change in recent years in the downstream sector requires systems to be increasingly agile and adaptable. The second generation of Galileo is designed to meet this need, for example through the ability to reconfigure certain functions on the satellites.

Lastly, the arrival of large low-Earth-orbit constellations is undoubtedly going to revolutionize satellite navigation. The second generation of Galileo will be able to operate with these systems.

What role does an agency like CNES have to play in this context?

T. P.: The European Union needs to be able to rely on national agencies with expertise in satellite navigation. CNES, through its participation in the programme's governing bodies, is helping the European Commission to pilot its implementation and is closely involved in shaping the R&D. This pivotal role is vital in managing the Galileo programme effectively. Indeed, CNES frequently assists the Commission with national experts seconded for missions of several years.

CNES is also supporting services validation or extending European technology outside the EU through its own initiatives like demonstration platforms.
And let's not forget CNES's special expertise in search and rescue so vital to Galileo's MEOSAR component.

PROFILE

1997
Permanent Adviser of the Committee of EU Affairs of the Government of Finland

2015
European Commission Director-General Communication (COMM)

2020
European Commission Director-General Defence Industry and Space (DEFIS)

OPTIMIZING RAIL TRAFFIC

Led by a consortium[1], the Loc4Rail project aims to replace the balises and axle counters along railway lines with an on-train location system. Funded by ADEME, the French agency for the ecological transition, under the government's PIA future investment programme, this hybrid solution will combine inertial sensors, augmented GNSS signals and precise network mapping to pave the way for the new ERTMS[2] standards that will assure interoperability across all of Europe. Demonstrations will be continuing up to the end of this year.

1 CNES, iXblue, SNCF, Geoflex
2 European Railway Traffic Management System

SAFER LANDINGS

The approach phase is always the trickiest for an airliner, as its trajectory may vary right up to the last moment due to weather conditions or instructions from the control tower. The EGNOS civil aviation navigation system augments the accuracy and reliability of GNSS signals to ultimately make landings safer. Powered since 2010 by GPS, EGNOS is now evolving with the new V3 version set to enter service in 2028 that will rely on Galileo to serve all European airports. Selected by ESA, Airbus Defence & Space is developing this next generation of Europe's system.

Ephemeris

One notable advantage that Galileo has over GPS is the refresh rate of its ephemerides, which continuously define the satellite's time and range parameters and send them to receivers. GPS refreshes these parameters every 24 hours, whereas Galileo does it every ten minutes. The constellation is also interoperable with other satellite navigation services, consolidating its near-metre accuracy and even centimetre accuracy for professional users.

11

IT HAS TAKEN
11 launches to place the 28 satellites in the Galileo constellation into orbit, 24 of them operational.

SYNCHROCUBE

The Synchrocube nanosatellite project launched in 2002 by a consortium[1] of French manufacturers has big ambitions for a small satellite. Looking to become a complementary solution to the GNSS network, it will pack innovative technologies into a small form factor, including a microwave receiver the size of a cigarette packet. The system will provide robust synchronization when GNSS signals are unusable as a result of atmospheric disturbances, masking, being indoors or jamming. Synchrocube prefigures a type of future constellation in low Earth orbit which, once complete, could serve sectors like energy, telecommunications, smart transportation and finance to name a few. It was one of the first projects selected and funded by the government's recovery plan for space and is therefore being supervised by CNES. The first satellite in the series is scheduled to launch in 2023.

1 U-Space, Syrlinks, Anywaves, Comat and Microtec

99.7%

Percentage of global coverage as of December 2021 where Galileo's Open Service (OS) was available.

2,000

OPERATIONAL SINCE 1979, COSPAS-SARSAT TODAY SAVES MORE THAN 2,000 LIVES EVERY YEAR. With its global coverage and return link service since 2020 via SAR-Galileo (see Timeline p. 28-29), it's now set to save even more.

An infinite number of users can benefit from Galileo's freely accessible "open" signals.

EUROPEAN CHAMPION

WITH GALILEO, EUROPE ENGAGED A MAJOR EFFORT IN THE 2000s TO RESTORE ITS SOVEREIGNTY IN SATELLITE-BASED NAVIGATION. TODAY, THE CONSTELLATION IS ESTABLISHING ITSELF AS THE BEST POSITIONING SYSTEM ON THE MARKET—AN ACCOMPLISHMENT FOR WHICH CNES'S EXPERTISE HAS BEEN INSTRUMENTAL.

Radio-navigation laboratory at the Toulouse Space Centre.

Prepping Galileo FOC satellites at the Guiana Space Centre.

The days when we found our way with a map unfolded on our lap are long gone. And GPS soon will be too, for while it remains a familiar fixture around the world, in Europe Galileo is now firmly in the co-driver's seat. When the European Union gave the official green light to build Galileo on 19 July 1999, it saw the future constellation as a means of affirming its sovereignty and strategic independence, freeing itself from the inherent risks of dependence on the U.S. GPS, such as flex power, regional service variations and deliberate jamming. The other equally legitimate motive was that GPS was originally conceived by the U.S. Army in 1973, deployed in 1990 for military purposes and extended to civil applications. The EU took an altogether different tack, opting from the outset for a civil system, with civil funding and under civil control, and a service reserved for government and military requirements. In the GNSS ecosystem, Galileo is the outlier, as the Chinese Beidou (2018) and Russian Glonass (2011) constellations are also under military control.

EUROPE'S UNIQUENESS

All global positioning systems are built around the same architecture, with a constellation of satellites in medium Earth orbit (MEO) between 19,000 and 23,000 kilometres beaming radiofrequency signals back to Earth. "The principle of a constellation is that you always have four satellites in view. The 24 Galileo satellites are in three different orbital planes, and in the optimal redundant configuration there will be 10 satellites in each of these planes," explains Jean Maréchal, who heads CNES's Navigation programme.

TRIBUTE

Europe named its satellite navigation system after the astronomer Galileo Galilei (1564-1642). Galileo also made a significant contribution to navigation through his proportional compass, which improved measurements and calculations.

Rather than replicating GPS, the European Commission thus envisioned Galileo from the outset through the prism of its public utility, anticipating future growth in civil applications. Today, Galileo is driving economic development, and its evolving capabilities are serving industry, mobility, agriculture, healthcare, leisure pursuits and much more besides, while also paving the way for future innovations.

CUTTING-EDGE TECHNOLOGIES

Galileo is fully leveraging technology advances of recent decades. The satellites' maser atomic clocks (see Materials p. 27) provide unequalled stability and accuracy, and their reconfigurable systems can be evolved and reprogrammed on orbit.

Sharing one of its frequency bands with GPS ensures worldwide interoperability with GNSS signals, while the sophisticated ground infrastructure guarantees data quality and integrity. One of Galileo's distinctive advantages is its ability to quickly update orbit corrections and satellite clocks to deliver superior accuracy on the ground. The GIOVE A (2005) and GIOVE B (2008) demonstrators confirmed the technologies' feasibility and the four In Orbit Validation (IOV) satellites launched in 2011 and 2012 validated the system's performance; they are still operating as part of the constellation today.

CNES has channelled its experience acquired with EGNOS[1] into Galileo. EGNOS augments positional accuracy for civil aviation and has basically served as the blueprint for European satellite navigation. Starting in the 1990s, the agency was one of the first to work on this concept prefiguring Galileo services. The expertise it gained gave France more leverage to impose a specific signal for government services and thus ensure that civil signals would be more robust. CNES also shared with ESA the complex task of positioning the Galileo satellites up to 2018. Last but not least, it was behind the creation of COSPAS-SARSAT in 1982. This emergency rescue service, built around maintaining a permanent link between a system of distress beacons and satellites relaying distress calls to emergency responders, has saved thousands of lives. It was therefore only natural that the European Commission should entrust CNES with the SAR-Galileo Service Centre designed to make rescue operations more responsive (see Timeline p. 28-29). As it shifts into higher gear, Galileo, administratively managed and operated by EUSPA[2], is already present inside billions of smartphones.

1

nanosecond

A timing offset of just one nanosecond—one billionth of a second—translates into a positional error of 30 centimetres on the ground.

1. European Geostationary Navigation Overlay Service.
2. EU Agency for the Space Programme.

The SAR-Galileo team at work.

Positioning

EARTH IS THE COMPASS

Galileo is more than just a constellation of satellites. To work properly, it relies on continuous synchronous communications between space and Earth. Here's how.

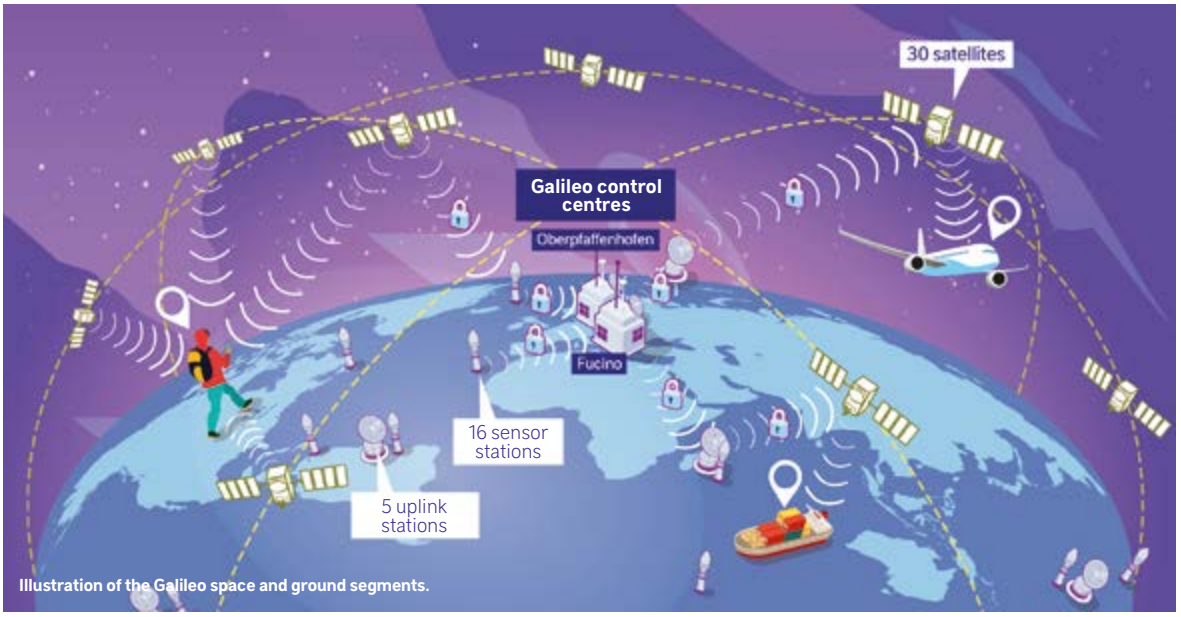


Illustration of the Galileo space and ground segments.

Galileo is the most accurate navigation system in the world today thanks largely to the symbiosis between two key components of its infrastructure: the space and ground segments.

The space segment is the tip of the iceberg and the best known, with the spectacular satellite launches that always attract wide media coverage. The satellites' payloads comprise four atomic clocks (see Materials p. 27) and systems for generating navigation signals and beaming them to ground. Each signal also contains the crucial information of the time it was sent. The tiny antennas inside our smartphones then receive and decode this signal, and record its departure and arrival times. They thus know how long the signal took to reach us and can deduce the distance—or range—from the satellite.

3

Frequency bands

used by Galileo, including E6 centred on 1.28 GHz, also used by ham radio.

CORNERSTONE OF THE SYSTEM

The ground segment helps our phones to measure this range. "It's the beating heart of the constellation, or its brain if you like," says CNES engineer Marc Jeannot. It consists of several complementary infrastructures that link the

satellites to you. On orbit, the satellite doesn't know its position. However, it sends a signal received in real time to 16 Galileo Sensor Stations (GSS) around the globe[1].
These signals are then relayed to the two redundant Galileo control centres in Italy and Germany for processing to determine the satellites' orbital position and establish what's known as their "ephemerides" containing orbit and time parameters. Lastly, these ephemeris data go through one of the five Galileo uplink stations (ULS). The series of two-way exchanges between ground and space underpinned by this sophisticated architecture delivers extremely accurate positioning to ensure good quality of service for users.

30

Optimal composition

of the Galileo constellation, comprising 24 nominal satellites and 6 on-orbit spares, expected to be reached by 2024.

The second generation of Galileo is already in the works. It will leverage innovative technologies to provide greater robustness, ten-centimetre and even centimetre accuracy (see Roundup p. 8) and less dependence on the ground through satellite cross-checking. Thales Alenia Space and Airbus Defence & Space are building 12 new satellites that will enter service progressively from 2025 onwards.

1. Kourou, Papeete, St-Pierre-et-Miquelon, Jan Mayen, Svalbard, Kiruna, Redu, Bonaire, Fucino, Réunion, Azores, Wallis, Nouméa, Kerguelen, Troll, plus one other currently being defined.

MEOLUT

SUPER STATION

To pick up distress signals sent through the Galileo SAR satellites and locate COSPAS-SARSAT beacons, conventional ground stations use parabolic antennas that can only receive a limited number of signals. In the Indian Ocean, the new MEOLUT[1] Next station—packed with technology innovations—will now relay all messages. Designed by Thales Alenia Space, this ultra-compact integrated system has a footprint of just six square metres, compared to conventional infrastructures the size of a football pitch. The new station can track up to 12 satellites instead of four previously and detect more beacons at a range of out to 5,000 kilometres. Extending the coverage area and limiting maintenance operations and costs, it will assure strategic surveillance of the Indian Ocean.

1 MEO Local User Terminal

Services

THE BEST IS YET TO COME

The Galileo system hasn't quite finished growing. Additional initially planned services are technically ready and being rolled out to broaden the range of users and applications. It will offer five services in all.

In its current configuration, Galileo delivers a free and universal Open Service (OS) for consumer-market applications such as positioning, driving aids and the Internet of Things (IoT), as well as for business services, transport, industry and more. It is interoperable with other satellite navigation systems, thus multiplying the number of signals and increasing their availability, notably in urban areas. While positioning performance with OS is assured, data integrity is not and there is no guarantee against users falling victim to malicious spoofing by hackers.

SPECIFIC VERSIONS ON THE WAY

To get around this flaw, Galileo will offer value-added satellite data authentication services[1]. In the maritime domain, for example, fishing vessels over a certain size must be fitted with a receiver so they can be tracked to check they aren't fishing in a no-take zone. But systems that generate GPS spoofing signals are widely available, making such checks inoperable. Galileo's signal authentication feature will resolve this issue. The service is technically ready and undergoing final validation to enter service in 2023. A free 20-centimetre High Accuracy Service (HAS) designed for professional receivers will also come on stream on this date. Meanwhile, the Public Regulated Service (PRS)—reserved for the military in France—will guarantee positioning accuracy, signal quality and transmission reliability using encrypted signals. Even if other navigation services are degraded, Galileo will nonetheless still be operational.

8 KG

SAR-Galileo payloads

may weigh only 8 kilograms, but they save human lives by instantaneously relaying a distress call from anywhere on Earth, and they only consume 3% of the satellite's power.

ENHANCING SAFETY

Several Galileo services have been designed with emergency response in mind. SAR-Galileo affords instantaneous global coverage and its return link feature will enable users with COSPAS-SARSAT locator beacons to be found faster. A service alerting populations in the event of a disaster will also be coming on line soon (see Timeline p. 28-29).
Lastly, Galileo is set to further boost the performance of EGNOS, which has been augmenting GPS for civil aviation for 10 years now, notably during airport approach phases with vertical guidance. The next-generation EGNOS, planned for 2028, will rely on Galileo to enhance safety during these approach phases for the Safety of Life service (see In Pictures p. 17).
And Galileo's growth won't stop there. Although it has already reached maturity, the system has been designed for just that. Certain potential features like PRS are already planned, and others like stronger anti-spoofing or access to synchronization are starting to emerge, while the second-generation satellites will employ electric propulsion, have more power and flexibility and enable faster signal acquisition.

1. Open Service Navigation Message Authentication (OSNMA) and Signal Authentication Service (SAS).

Saving lives

STRENGTHENING SEARCH AND RESCUE

Besides SAR-Galileo, the European Commission is seeking to foster new concepts to aid search and rescue—notably in remote regions—and is funding demonstrator projects to bring them on line more quickly as it seeks to make Europe and its industries pioneers in this global market.

For example, the Serenity project funded through the Horizon 2020 programme is working to define a return link service employing a second-generation beacon prototype to facilitate communications between emergency services and distress callers, providing key information such as the nature and location of the emergency. This service will be trialled with a demonstrator in real-life conditions at sea, with rescue teams responding to a distress call, complete with media coverage. As a member of the Serenity consortium, and supervisor and operator of the SAR-Galileo Service Centre, CNES will be helping to implement such demonstrators.

Kevin Escoffier is rescued during the Vendée Globe yacht race (30/11-1/12/2020).

Looking ahead

SERVICES **FOR ALL**

While vehicle navigation aids and smartphones account for 99% of the Galileo services market, they're far from being the only commercial applications out there. Numerous other user communities are now eyeing services offered by the European constellation.

We're all familiar with Google Maps and similar map-based applications, but the Galileo product catalogue is much broader than that. A wealth of applications is poised to take advantage of its excellent positioning, timing and synchronization features.

SERVING SCIENCE

Precision measurement is a staple of the scientific community. Reflectometry analyses reflected signals to gain insight into the characteristics of Earth's surface. Radio occultation precisely measures the layers of the atmosphere to improve weather forecasting models. Geodesy—the study of Earth's shape, size, rotation

and gravity field—will also benefit from more precise data. Just as geomorphology—the study of relief—climatology, oceanography, cartography and seismology all rely on Galileo's excellent performance. Even fundamental physics is getting in on the act, as redshift—a key element of Einstein's theory of general relativity—has been measured with five times more precision using two Galileo satellites: the last time it was measured was in 1976.

SUSTAINING THE ECONOMY

Tomorrow's world is likely to see a whole host of business applications now just beginning to emerge. Autonomous vehicles are going to require extremely accurate positioning, on the order of 20 centimetres or possibly even 10 centimetres. R&D institutes are currently working on such sustainable mobility solutions. By incorporating precise point positioning (PPP) on board satellites, it's possible to guide a bulldozer on a construction site with centimetre accuracy and to make port and airport approaches safer. Other applications include train fleet management, goods tracking, traffic control and vehicle guidance and identification. And future digital tachographs on trucks in Europe will use Galileo's authentication service.

OPEN CATALOGUE

Galileo is also a great timekeeper, enabling signals to be timed to within a billionth of a second to synchronize telecommunications networks and transactions, crucial for trading, finance, insurance and banking. Tomorrow, connected objects will need to know where they are at all times and to time-stamp their location. The Internet of Things (IoT) will support smart connections to collect data from sensors inside an object, machine-tool or robot. Galileo's interoperability will also foster more-hybrid solutions to improve positioning accuracy indoors or in so-called urban canyons.

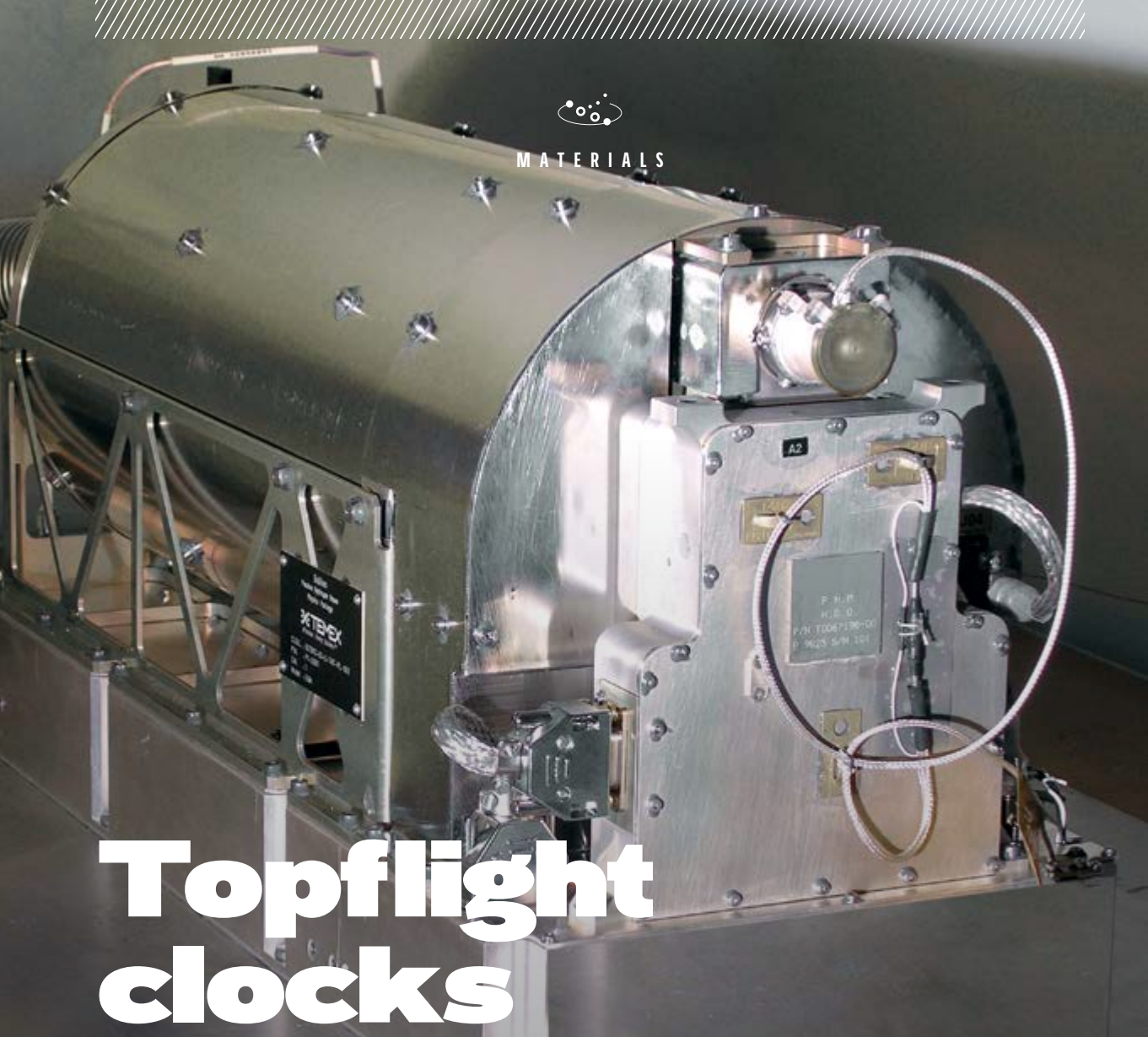
Positioning systems in low Earth orbit are also under study to provide alternative services when GNSS signals are inoperable. Such systems would afford the twofold benefit of being cheaper and quicker to deploy.

The Galileo constellation thus offers a plethora of services set to fuel a whole host of applications limited only by users' imagination.

2.7

million

The passive hydrogen maser on the Galileo satellites provides a stability of roughly one-billionth of a second over 24 hours—in other words, a drift of one second every 2.7 million years.



Topflight clocks

GNSS SYSTEMS ARE BASED ON MEASURING SIGNAL PROPAGATION TIME. By synchronizing to within a few billionths of a second, they obtain a positioning accuracy on the order of one metre. Galileo achieves that kind of timekeeping accuracy using passive hydrogen masers and rubidium clocks. Each satellite carries two masers and two rubidium clocks. The masers deliver great performance but are very heavy and power hungry; the rubidium clocks are smaller but their performance isn't as good. So combining the two technologies is a good trade-off that avoids cluttering the satellite while ensuring redundancy to cover for any hitch. A first maser delivers the expected performance, and the second is there for back-up in the event of a malfunction. If both masers fail, the rubidium clocks are activated. This redundancy makes Galileo more robust to avoid interruptions in service to users.

1

EMERGENCY INFORMATION

Wherever they are in the world, a user in distress can activate their beacon and receive automatic confirmation through RLS[1] that they have been located. Now, the TWC[2] service is set to take this concept further, allowing them to tell search-and-rescue teams what kind of emergency they're dealing with (fire, flood, etc.), whether it's at sea or on land, if there are injuries and if so how many. They will thus be able to guide first responders and help them to organize rescue operations.

1 Return Link Service
2 Two-Way Communication

2

REMOTE BEACON ACTIVATION

The crashes of Air France flight AF447 on its way from Rio de Janeiro to Paris in 2009 and Malaysia Airlines flight MH370 in 2014 remain etched in our memories, not only because of the dramatic loss of lives but also due to the extremely complex search operations they entailed. The RBA service in an airliner's SAR emergency locator transmitter (ELT) will enable authorities to activate it remotely in flight and rapidly establish the aircraft's position or crash zone. Likewise, RBA will take over where sailors adrift at sea or lost explorers are unable to activate their locator beacon themselves.

WHEN A USER IN DISTRESS ACTIVATES THEIR COSPAS-SARSAT EMERGENCY BEACON, THEY KNOW THEY'LL BE DETECTED AND LOCATED BY THE SYSTEM'S RETURN LINK SERVICE (RLS). EXCLUSIVE TO GALILEO, THIS FEATURE PAVES THE WAY FOR NEW FREE GLOBAL SERVICES CURRENTLY IN DEVELOPMENT AT THE SEARCH AND RESCUE (SAR) GALILEO SERVICE CENTRE SUPERVISED BY CNES FOR EUSPA.

3 ALERTING POPULATIONS

Disasters like fires, earthquakes and tsunamis can be unpredictable. Using the SAR-Galileo return link, civil protection teams will be able to send early-warning messages to people in a potential disaster area via a Galileo receiver in a smartphone or terminal. The message will tell them what type of disaster to expect and if they need to stay indoors, leave the area or go to a precise rallying point, for example. This EWS[3] service is being defined in Europe and could be operational in 2024.

3 Emergency Warning Service

4 POSITION SHARING

Alerting first responders is of course important, but dispatching rescue teams can prove long and complex, and sometimes downright impossible. In such cases, the DPS[4] service proposes to alert users in the vicinity of a distress call so they can provide assistance more quickly. The recent example of yachtsman Kevin Escoffier saved by fellow competitor Jean Le Cam (see Horizons p. 31) during the Vendée Globe 2020 round-the-world race shows how this kind of solidarity can also save lives.

4 Distress Position Sharing

HÉLÈNE GAUTIER

Head of Navigation System & Projects department, CNES

"With my team, I've positioned 22 of the 28 Galileo satellites in orbit..."

Inspired by her father's career as a helicopter pilot, Hélène Gautier saw her future in the skies at a very early stage. **After graduating from the Sup'Aero engineering school in Toulouse in 1990, CNES was "the obvious choice"** for her first job, she says, starting in a department tasked with positioning geostationary telecommunications satellites and keeping them on station. These operations are designed to ensure that satellites reach their orbit and don't stray too far from their position. She would spend nine years there in a variety of engineering posts before becoming department head. End 2002, Hélène Gautier was put in charge of spaceflight dynamics for the ATV, Europe's International Space Station resupply spacecraft. "In 11 years, I was involved in the launches of the Jules Verne, Johannes Kepler and Eduardo Amaldi ATVs, and we shared some exciting times with our Russian and American colleagues." A new challenge presented itself in 2013, when she was asked to lead positioning operations for the Galileo satellites at CNES, a mission shared at the time with the European Space Operations Centre (ESOC). Hélène Gautier thus watched over 22 of the 28 satellites currently making up the European constellation, from Doresa to Ellen, each one with its own name. **"When at the end of 2018, CNES stopped conducting positioning operations for Galileo, I wasn't ready to say goodbye to the constellation,** so I took over responsibility for assessing the performance of GNSS systems—including Galileo—and the European EGNOS augmentation system." Today, Hélène Gautier heads up the agency's Navigation System & Projects department and her remit includes design support for navigation systems and contributing to projects like Loc4Rail with French railway operator SNCF. **"Although I miss the adrenalin of Galileo launches a little, I'm really enjoying this new job where I'm constantly discovering new facets of GNSS's utility...** I'm fortunate to still have so much left to learn after a 30-year career!"

JEAN LE CAM

Yachtsman

"Without COSPAS-SARSAT, Kevin Escoffier probably wouldn't be alive today..."

"Everything turned out OK in the end, and that's all that counts." **When he recalls the events of that 1 December 2020, Jean Le Cam's voice doesn't falter. He's not that kind. But the rescue of Kevin Escoffier wasn't for the faint-hearted.** At 14:48 on the 23rd day of the 2020 Vendée Globe round-the-world yacht race, the skipper activated his COSPAS-SARSAT locator beacon. Kevin Escoffier's *Imoca PRB* had literally just snapped in two in the middle of the Roaring Forties, and he barely had time to climb into his survival raft. Three minutes later, the signal from his beacon was located by CLS in Toulouse and three boats were alerted to assist him. "I was the closest, so I diverted from my route and when I reached the area at around 5 p.m., I picked up his AIS[1] signal. I soon spotted the raft with Kevin inside. I tacked away to start my recovery manoeuvre, but by the time I returned he was gone and so was his signal." Jean Le Cam would realize only later that Kevin Escoffier had drifted after turning off his AIS to save its battery. Picking out a small raft in a five-metre swell with night falling would be a miracle... and for the long hours that followed, Jean Le Cam feared the worst. "But during the night the race organizers located a new signal. **I eventually caught up with Kevin and was able to rescue him 11 hours after his boat sank. Without COSPAS-SARSAT, he probably wouldn't be alive today,** as indeed I probably wouldn't be myself if another PRB boat hadn't found me thanks to my locator beacon off Cape Horn in 2009," he says. **"Today, it's hard to imagine ocean yacht racing without satellites: we need them to communicate, to track race positions, to adjust our speed, to forecast the weather and surface currents...** They're vital crewmates for us."

1. Automatic Identification System.

JOSÉ IRIARTE

Founder and CEO or Stradot

"With our straddling valet robots, we're reinventing car parking..."

For José Iriarte, satellites are old friends. It all began when he was an engineer working for Invap, a company involved in building satellites in Argentina. **When he came to France in 2013, it was to set up a new firm specializing in satellite guidance, navigation and control.** Two years later, he would find himself at Airbus OneWeb... Today, he heads Stradot, a Toulouse-based start-up developing valet robots for car parks. Does this mean he's lost interest in satellites? "Not at all, satellites are absolutely central to our project!" the entrepreneur confirms enthusiastically. Indeed, Stradot's robots are guided by a GNSS RTK system that corrects signals received from satellites—including Galileo's—to achieve centimetre accuracy. **This enables the robots to optimize parking space. Like the straddle trucks that handle containers in ports, they straddle parked vehicles, and lift and move them to park them behind one another.** A much better concept than existing solutions that require either large numbers of robots or a lot of space for manoeuvring... And space is precisely what Stradot is looking to save. "Today, it's estimated that a single parking space requires an area of roughly 25 square metres, more than twice the footprint of a medium-sized vehicle," says José Iriarte. "That equation just isn't sustainable when you look at the costs involved, the environmental challenge of trying to reduce land take and the planned numbers of park-and-ride facilities on the outer edges of large cities." **For now, the straddling robots are undergoing qualification in the fledgling firm's facility.** The first valet robots are scheduled to enter service with a first customer by the end of this year.

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

ETHICS CORNER

J. A.

JACQUES **ARNOULD**

HEIGHTENED AWARENESS

Earth's inhabitants have long used the stars to find their way about, but satellite navigation gives us new and unexpected responsibilities.

As we know, we're not the only ones to use the starry vault to move around the planet's surface or skies. But we're the first to put instruments in the skies to help us navigate and travel more safely and efficiently. I remember how enthusiastically my colleagues at CNES began to vaunt the merits of these instruments in the early 2000s, encouraged by the success of the American system—a success now shared. Already at that time, voices were raising concerns that these new tools and capabilities would bring with them new responsibilities that should give us pause for thought. The mayor who was told Europe's future constellation would help traffic move more freely in her city, known for its road congestion, might reply she was more concerned about actually reducing the huge volumes of vehicles and all the noise and pollution they cause. Or the manager of a road haulage company, interested in being able to track his vehicle fleet in real time, might say he saw a new responsibility on the part of his drivers—gone would be the days he had no idea what they were doing between depot and delivery.

GROWING RESPONSIBILITY

Years have passed, the systems in question have been brought into service and the range of applications has multiplied beyond all expectations: our societies are crisscrossed by an increasingly numerous and diverse array of "navigation pathways". And the two remarks I mentioned above are more relevant than ever—they highlight the need to think about these space systems and how we use them in terms of purpose and responsibility. Are we careful to ensure advances in navigation and the ever greater movement of people, goods and information are matched by a precise awareness of our objectives? Or are we simply dazzled and obsessed by the spectacle of all these flows? Are we aware that the global village these navigation routes serve is marked by a growing sense of individual and collective responsibility? We'll no longer be able to say we didn't know.

USERS

A SPACE RECEIVER **IN YOUR POCKET**

If you have a smartphone, then you have a space receiver. Without even knowing it, you're most certainly connected to Galileo. The vast majority of smartphones incorporate a chip that receives the most precise positioning signals, which obviously include those from the Galileo constellation.
The first Galileo-enabled smartphones arrived on the market in 2016; today, there are more than two billion of them around the world. According to the EU Agency for the Space Programme (EUSPA), some 900 models of smartphone sold in Europe are compatible with Galileo.

TERIA
THE GOLD STANDARD FOR CENTIMETRE GEOLOCATION

Initiated in 2005 by the French Order of Land Surveyors, Teria is both a company and a geolocation tool affording centimetre accuracy in real time for generating topographic and real-estate data. This benchmark solution has been using Galileo data since 2016 and is now being offered to other sectors in demand like mapping, agriculture, robotics, the Internet of Things (IoT) and geographic information systems (GIS). The firm has its own in-house R&D department, owns its entire infrastructure of receiving stations, servers, processing software and data distribution and sales channels, and provides training and technical support. It is involved alongside CNES in numerous European research programmes focusing on data integrity and structuring of future support networks. Teria has built itself an international reputation and is today the only French GNSS network management structure with ISO 9001 and ISO 14001 certification.

GALILEO
Fun fact

Thijs, Natalia, Adam, Anastasia, Doresa, Milena, Alba, Antonianna, Andriana, Tara, Samuel, Anna, Ellen… All the satellites in the Galileo constellation have their own name, given to them by a 9-to-11-year-old child from each EU member state after a drawing competition organized in 2011 by the European Commission for the launch of the first two satellites. For France, the winning entry was from Oriana.

COMPETITION

GET YOUR PROJECTS MOVING!

With Galileo, the catalogue of space applications is growing, and maybe you have a project to add to it. If it's innovative and employs the constellation's signals, the Galileo Masters could be the boost you're looking for (see Spinoff p. 36). This European competition takes the form of a call for ideas open to all natural and legal persons, consortia, SMEs, start-ups, universities, big corporations or research organizations. And the spectrum of sectors addressed is equally broad, ranging from the environment and agriculture to mobility, healthcare, leisure, disaster management, cybersecurity and more. The project entry form and submission procedure are available on line. Proponents selected are invited to present their projects at a special pitch day, with a first prize worth €10,000 on offer. The Galileo Masters "above all gives laureates visibility, a label of excellence and recognition of interest in their project," says Thierry Chapuis, CNES expert and the competition's contact for France. Selected projects may also receive tailored support through the agency's Connect by CNES programme. Entries can be submitted from April to July and the finalists will be announced in October-November.

LEARN MORE:
HTTPS://GALILEO-MASTERS.EU/

DAIRY

17 MAY 2022
Innovation Day
Pierre Baudis Convention Centre, Toulouse

6-20 JUNE 2022
Space Ambassadors training course
On line
Register at https://www.connectbycnes.fr/formation

28-29 JUNE 2022
ITSNT Symposium
On line
Register at http://www.itsnt.fr

ITSNT
2022 SYMPOSIUM

Postponed in 2020, the International Technical Symposium on Navigation and Timing (ITSNT) was held in virtual format in 2021, co-organized by CNES and ENAC, the French national civil aviation school. This year's symposium in June will also be virtual, with new and stimulating discussions between experts from the worlds of science, industry and institutions and students on topics like positioning in constrained environments, navigation systems and their performance, and air and land navigation. Like previous editions, the 2022 symposium will be inviting speakers from the European Union, North America and Asia.

EN

SPINOFF

NAV4YOU
BREAKING DOWN WALLS

In our ultra-connected world, a smartphone is all you need to know where you are. But what do we do indoors, when satellite positioning signals are masked? Nav4You has come up with an innovative solution optimized by Galileo.

Start-up Nav4You was born at the GEOLOC geopositioning laboratory headed by Valérie Renaudin at Gustave-Eiffel University in Marne-la-Vallée, just outside Paris.
In 2017, Johan Perul was conducting research there on autonomous location and multimodal transport. "There was no gold-standard solution for indoor positioning," he explains. In a closed environment, GNSS signals are often degraded, so he hit on the idea of packing everything into a portable all-in-one unit weighing just 200 grams. The small and light multi-sensor device combines the advantages of inertial (mobile) and magnetic technologies with the GNSS network, using artificial intelligence to optimize algorithms.

HIGH TECH MEETS HUMAN

Presented at the MALIN[1] indoor location challenge organized by French defence procurement agency DGA and frequencies agency ANFR, the concept came away with the top prize. In 2021, Nav4You was formed to foster the solution's development and operate it commercially. For this the start-up was able to employ GEOLOC's patents. The system is now in development for use by firefighters. "Every year, firefighters lose their lives because they couldn't be properly located when tackling a fire," says Perul. A Nav4You device fitted to their boot will change that. "Signal accuracy and robustness are valuable in all enclosed spaces," he notes.
Since its creation, the start-up has won many plaudits. Noticed during the Space Tour (see CNESMAG n°91) organized by French enterprise agency DGE and led by CNES, it received a helping hand from the government's recovery plan and was a laureate at the 2021 Galileo Masters challenge. This year it also obtained backing under the competitiveness element of ESA's Navigation Innovation and Support Programme (NAVISP). But its greatest reward is the market that now beckons. A collaboration with the Ministry of Armed Forces is under study to equip foot soldiers.

LEARN MORE:
HTTPS://WWW.NAV4YOU.FR

1. MAîtrise de la Localisation INdoor.

40%

Thanks to its algorithms and to artificial intelligence, Nav4You enables GNSS data to be picked up indoors 40% of the time.