# Paris-Saclay
# cradle of aerospace-security-defence


## Paris-Saclay, a region dedicated to innovation

With 15% of national research and 40% of public and private research jobs in the Paris Region, the Paris-Saclay science and technology cluster is one of the eight most powerful innovation clusters in the world, alongside Silicon Valley, Boston, Tech City London, Beijing, Bangalore, Skolkovo Innovation City in Russia and Israel's Silicon Wadi.

At the gateway to the French capital, this area, spreads from Massy to Versailles via Saint-Quentin-en-Yvelines and is home to an exceptional concentration of higher education establishments, public research laboratories, private R&D centres and innovative companies of all sizes and reputations.

This density of resources and potential partners makes Paris-Saclay one of the most attractive innovation clusters for investors, innovators and entrepreneurs from all over the world:

- integration at the heart of the Paris Region, Europe's leading economic region*;
- excellence in education and research to the highest international standards, supported by Université Paris-Saclay and the Institut Polytechnique de Paris;
- a wealth of major scientific facilities and multidisciplinary laboratories;
- concentration, excellence and diversity of industrial players and start-ups;
- a rare quality of life in a setting that enhances the natural environment.

Created in 2010 by the Greater Paris Act, the Établissement public d'aménagement Paris-Saclay (EPA Paris-Saclay) works with local players to steer and coordinate the development of the science and technology cluster and ensure its international reputation. The cluster's development strategy is based on three pillars: supporting innovation by leading a community of companies, start-ups and innovation centres; promoting the international appeal of the cluster and its Paris-Saclay Innovation Playground brand; and developing services to meet the needs of companies.

One of the most attractive innovation clusters in the world.

*Source: INSEE


With this in mind, EPA Paris-Saclay is mobilising and federating industrial and academic players around strategic sectors to strengthen the links between public and private research, encourage innovation and entrepreneurship and stimulate the region's economic growth. Six areas of excellence have been identified, analysed and mapped: aerospace-security-defence, agritech-foodtech, energy-city-environment, mobility of the future, health and digital technologies. The purpose of this document is to present the aerospace-security-defence sector of excellence.

## 6 STRATEGIC SECTORS

### Aerospace Security Defence

Airbus, Safran, Thales, Nexter, Arquus, etc.

**16*** start-ups
**68** laboratories and platforms

#NewSpace
#Cybersécurité

### AgriTech and Foodtech

Danone, Mondelez, Syngenta

**77*** start-ups
**110** laboratories and platforms

#AlimentsDuFutur
#NutritionSanté
#SmartFarming

### Energy City Environment

EDF, Bouygues, Colas

**47*** start-ups
**123** laboratories and platforms

#EnergyStorage
#Biofuel
#SmartGrids

### Mobility

Renault, PSA, Valeo, Fiat, etc.

**12*** start-ups
**46** laboratories and platforms

#VéhiculeAutonome
#Hydrogène
#SystèmesEmbarqués

### Health

Sanofi, LFB, IPSEN, GE Healthcare

**146*** start-ups
**346** laboratories and platforms

#Microbiote
#GeneTherapy
#Oncology
#SantéConnectée

### Digital technologies

Nokia, Ericsson, HP, Dassault Systèmes, etc.

**106*** start-ups
**252** laboratories and platforms

#IA
#Quantique
#IoT
#SmartManufacturing

*Currently listed on paris-saclay-startup.com

# Aerospace-security-defence, an historic sector facing new challenges

Paris-Saclay was the birthplace of civil and military aviation at the beginning of the twentieth century, and has been a major centre of French military research since the aftermath of the Second World War. It has always occupied a central position at the heart of the French aerospace-security-defence sector.

Today, with more than 60 major establishments, nearly 70 laboratories and cutting-edge technical platforms and around 30,000 jobs, this sector also remains one of the most dynamic in the region, benefiting from the prestige of historic players at the forefront of global innovation, such as **Thales, Safran, Airbus, Arianespace, Nexter, Arquus** and **ONERA**.

**NEARLY**

**70**

**LABORATORIES**

60 major establishments, more than 68 laboratories and technical platforms, 64 start-ups and around 30,000 jobs in Paris-Saclay.

This sector of excellence, which was founded on sovereign technologies linked to the defence and security of the French state, is now facing new challenges. The digital revolution has transformed the ways in which information is produced, distributed and consumed, and information management, and with it cybersecurity, has become one of the key security challenges facing both governments, with a view to preserving their sovereignty, and administrations and businesses, which have been faced with an increase in cyberattacks in recent years. In the space sector, the development of new technologies in the wake of the digital explosion, combined with the widespread democratisation of the use of space data – no longer reserved solely for state, military or scientific applications – are signalling the emergence of New Space.

At the heart of these new challenges, thanks to its historical roots in aerospace, security and defence and its undisputed leadership in digital technologies, the Paris-Saclay cluster of scientific and technological excellence has developed specific expertise in the two emerging sectors of cybersecurity and New Space, with an ever-growing number of particularly innovative start-ups.

To examine the main features of this aerospace-security-defence sector, the Établissement public d'aménagement Paris-Saclay, in collaboration with SATT Paris-Saclay, has launched a wide-ranging study.

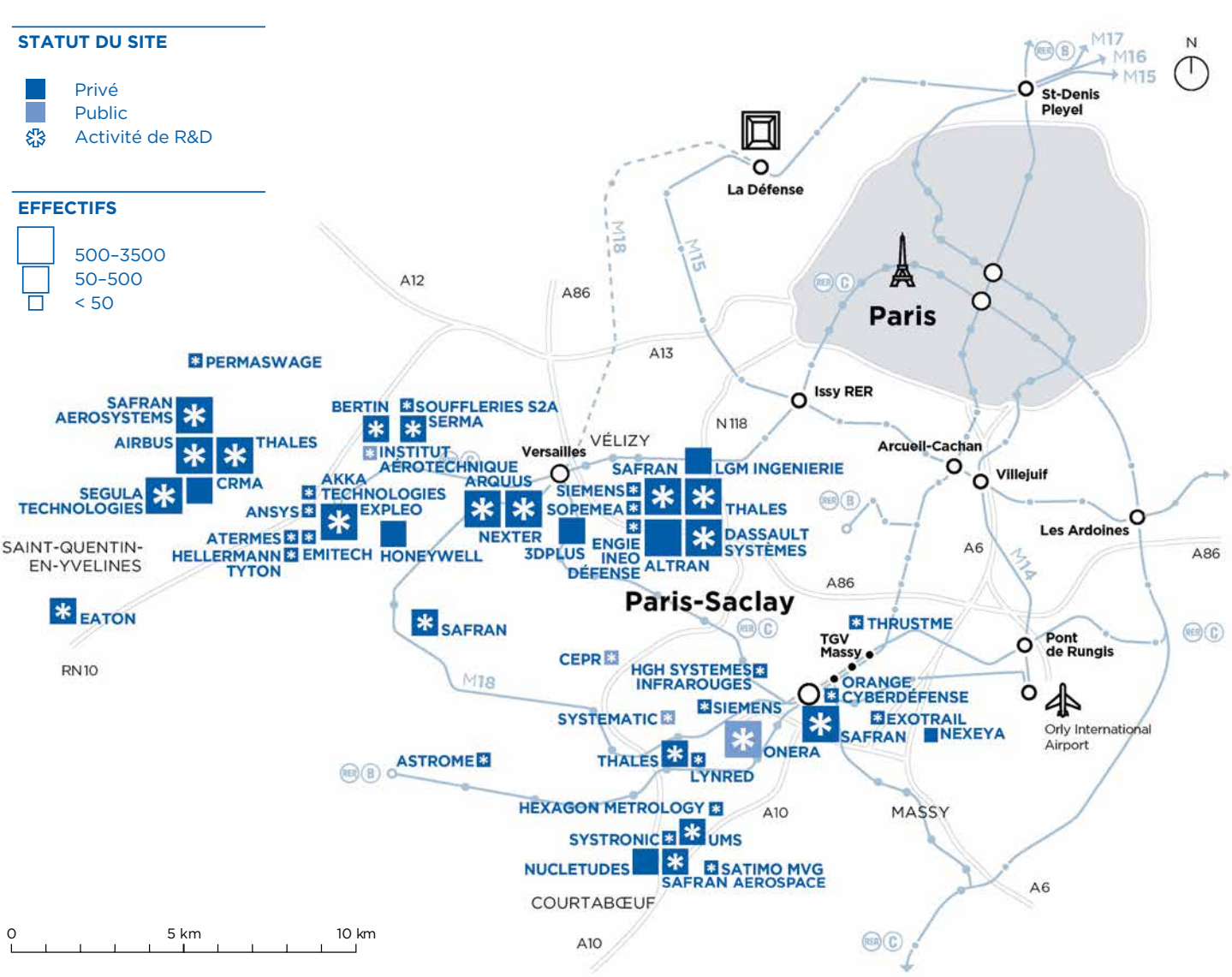

• **Fig.1** The spacedrop™ service offered by the start-up Exotrail, now a major player in the New Space originating from Paris-Saclay.

What are the key technologies deployed within this sector in the region? Who are the players who are bringing it to life at the heart of Paris-Saclay? How is it structured? What are its advantages? What is its capacity for innovation in the future?

The conclusions of this study, presented in this document, confirm Paris-Saclay's leadership in the aerospace-security-defence sector, bringing together not only world-class research bodies and laboratories, particularly in the military field, but also leading international industrial groups, cutting-edge higher education establishments and high-tech start-ups, i.e. world-class excellence in research, industry and innovation. The sector's strengths include excellent academic research at the crossroads of scientific disciplines, a dynamic innovation ecosystem and a position at the cutting edge of innovation in key digital technologies such as artificial intelligence, quantum computing, robotics, big data and optics and photonics, establishing Paris-Saclay as a pioneering centre of innovation in the technologies of tomorrow, where the future of New Space and cybersecurity is taking shape.

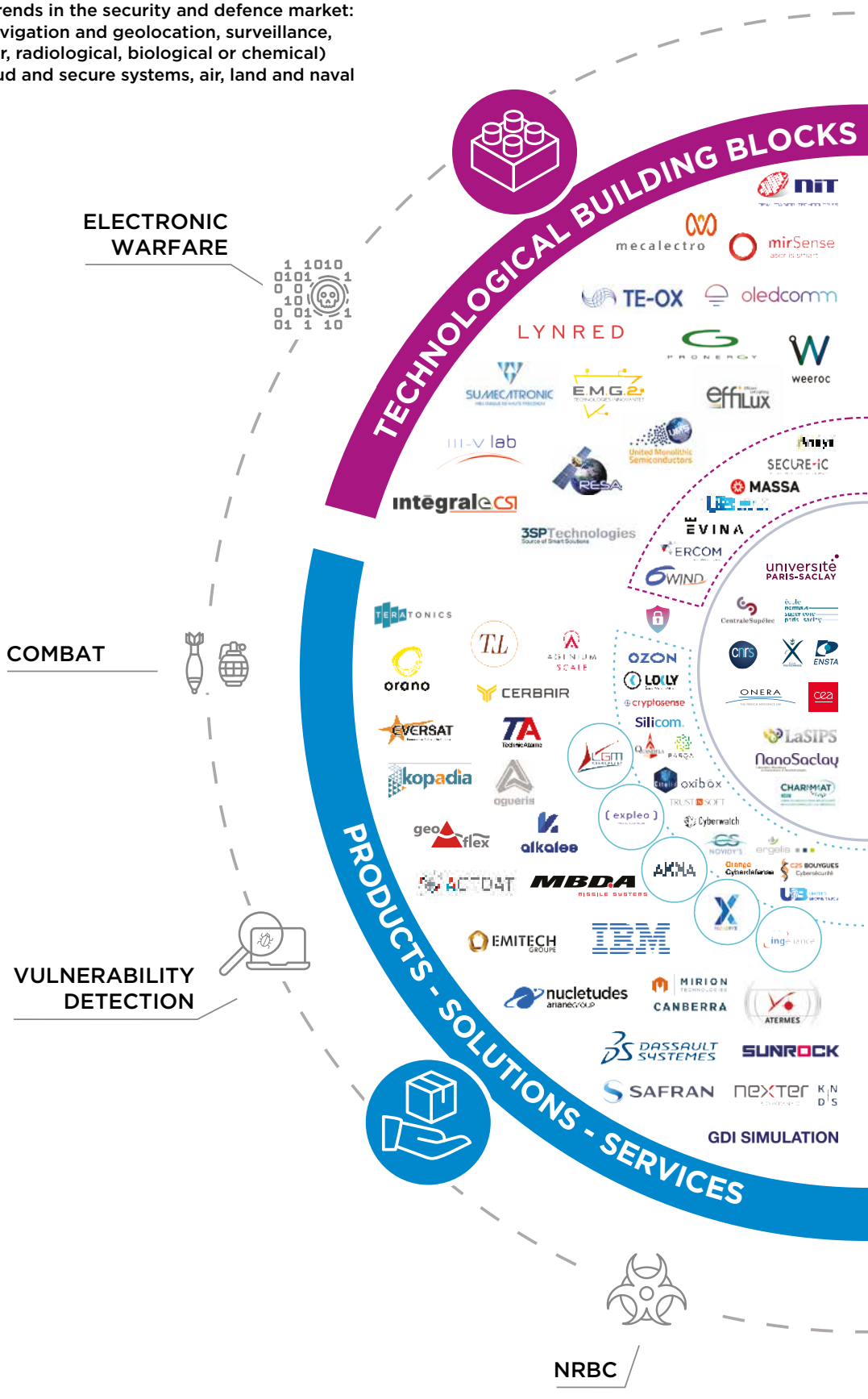
Paris-Saclay has always occupied a central position at the heart of the French aerospace-security-defence sector.

**The aerospace-security-defence sector in Paris-Saclay**



**Historically anchored in security and defence activities**

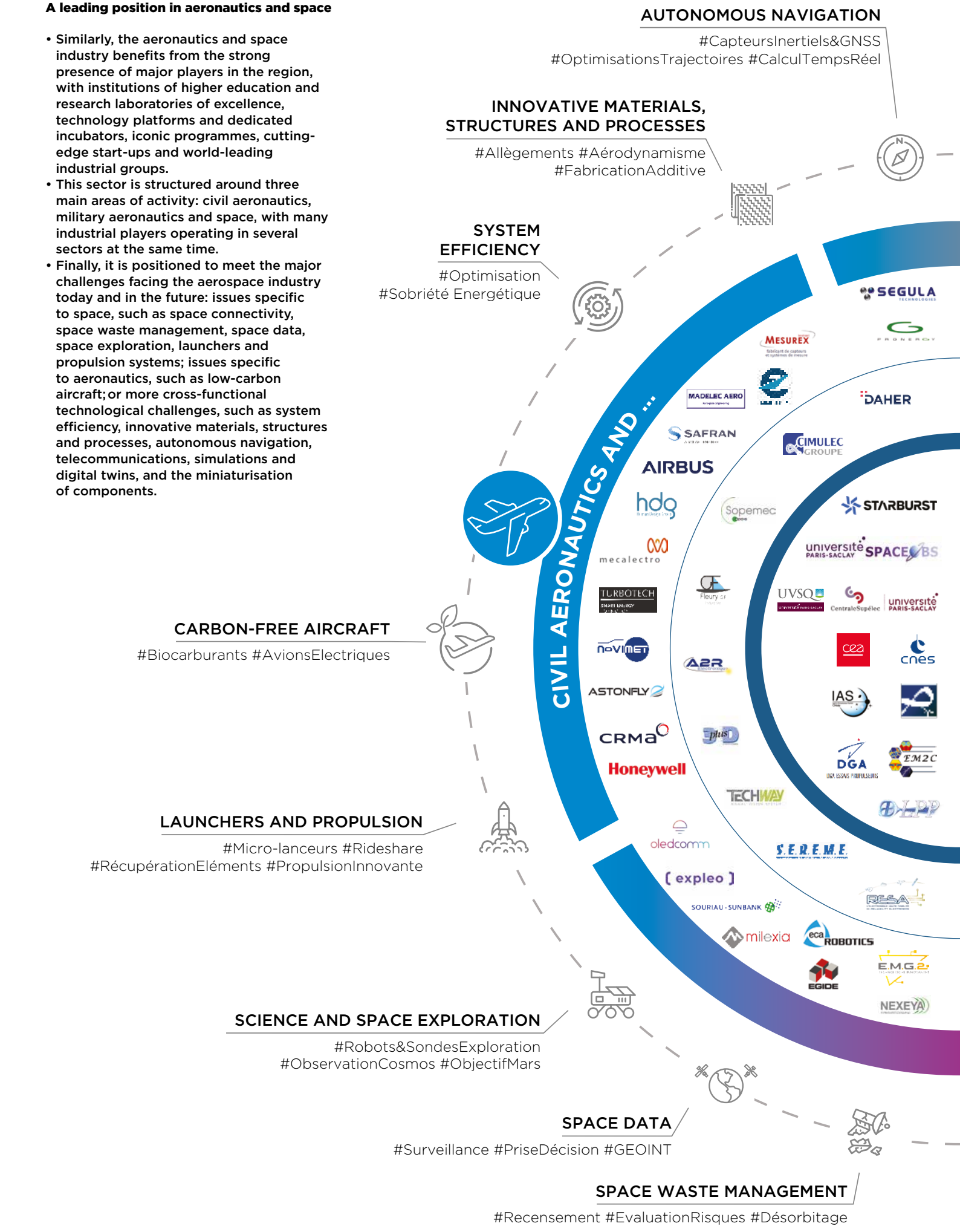
- In terms of security and defence, the Paris-Saclay science and technology cluster benefits from a rich ecosystem of players: prestigious higher education establishments and research laboratories, highly expert design and engineering firms, international industrial groups and high-tech start-ups.
- An ecosystem structured around the four key segments of the security and defence industry: technology building blocks; systems; products, solutions and services; and cybersecurity, which cuts across the other sectors.
- An ecosystem also positioned on key trends in the security and defence market: secure cities, critical infrastructures, navigation and geolocation, surveillance, communication systems, NRBC (nuclear, radiological, biological or chemical) protection, vulnerability detection, cloud and secure systems, air, land and naval combat, and electronics.




CLOUD & SECURITY
SECURE CITY
CRITICAL INFRASTRUCTURES
SYSTEMS
NAVIGATION
SURVEILLANCE
COMMUNICATION SYSTEMS
BLAXTAIR
SEGULA
Hyperpanel
DIGINEXT
Infrared Systems
THALES
egidium
SAFRAN
NBC sys
ANSE
SIMPULSE
COBHAM
MBDA
APILOG Automation
ATEMPO
AIRBUS CYBERSECURITY
ECA GROUP
Roxel
exotrail
CHAPSVISION
NOKIA
THRUSTME
Develyn
UVSQ
HENSOLDT
noxant
PhonOptics
Kleverware
ES GROUP
Inria
SystemX
quantum PARIS-SACLAY
ALL4TEC
innov+
EATON
ubble
AIRCAPTIF
DigiCosme
UNIRIS
storit
KRONO-SAFE
SHERLOCK
LSARS
VENTURE ORBITAL SYSTEMS
AEROMAPPER
SPHEREA
ionosys
ISD
aeroaccess
Procegin
share my space
Flyinstinct
ARQUUS
OEM DEFENCE SERVICES

**A leading position in aeronautics and space**

- **Similarly, the aeronautics and space industry benefits from the strong presence of major players in the region, with institutions of higher education and research laboratories of excellence, technology platforms and dedicated incubators, iconic programmes, cutting-edge start-ups and world-leading industrial groups.**
- **This sector is structured around three main areas of activity: civil aeronautics, military aeronautics and space, with many industrial players operating in several sectors at the same time.**
- **Finally, it is positioned to meet the major challenges facing the aerospace industry today and in the future: issues specific to space, such as space connectivity, space waste management, space data, space exploration, launchers and propulsion systems; issues specific to aeronautics, such as low-carbon aircraft; or more cross-functional technological challenges, such as system efficiency, innovative materials, structures and processes, autonomous navigation, telecommunications, simulations and digital twins, and the miniaturisation of components.**




TELECOMMUNICATIONS
#EcouteElectronique #Cryptographie
SIMULATIONS & DIGITAL TWINS
#Conception #Essais
MINIATURISATION OF COMPONENTS
#Instrumentation #Electronique
SPACE CONNECTIVITY
#ConstellationsSatellites #InternetSpatial
MILITARY
SPACE
NEW SPACE
ingeliance
EMITECH GROUPE
EVERAXIS
SPHEREA
SUMECATRONIC
SUPRAERO
CHELTON
Nexess
TECMATEL
Space Connect
COBHAM
intégralecs
NANOLAB
senior Aerospace CALORSTAT
Roxel
ESTACA
INSTITUT POLYTECHNIQUE DE PARIS
THALES
cnrs
ONERA
ENSTA
SAFRAN
LATMOS
PIT
AIRBUS DEFENCE & SPACE
nucletudes
PERMASWAGE
Paris-Saclay HARDWARE ACCELERATOR
DASSAULT SYSTEMES
SONDRA
STARSEM
EVERSAT
GROUP
EUROSATCOM
SAFRAN
LAMECO
ADVANTEC
HORIBA Scientific
arianespace
imagine optic
exotrail
THRUSTME
SIRIUS
KRONO-SAFE
hemeria
SPACEABLE
share my space
kanop
geoflex
Descartes Underwriting
AMPHITRITE
unseenlabs
Space Sense
arkane
PRELIGENS
GeoWatch Labs
delfox

# A history of aerospace-security-defence at the heart of Paris-Saclay

One of the sector's key assets in Paris-Saclay is its strong regional roots in security, defence, aeronautics and space.

The Paris-Saclay science and technology cluster benefits from the long history of French military research, with world-class laboratories, the presence of international industrial leaders, prestigious higher education establishments, highly-experienced design and engineering offices, emblematic innovation programmes and high-tech start-ups, and a particularly rich ecosystem whose strength lies in the concentration of its players, the density of its skills and the synergies deployed between players, disciplines and technologies.

Today, the aerospace-security-defence sector includes more than 60 major establishments, nearly 70 laboratories and cutting-edge technical platforms, nearly 65 start-ups and accounts for around 30,000 jobs.

## A long-standing position in sovereign technologies

**Modern civil and military aviation was born on the Saclay plateau at the beginning of the twentieth century**, with the flight of **Clément Ader** in his Éole 3 at Satory in 1897. Due to a lack of controllers, it was not certified as aviation's first powered flight. However, ten years later, a few kilometres away, aviation and then aeronautics developed on the plateau, with several aerodromes, assembly workshops, hangars, offices, testing grounds and flying schools. In 1907, the Toussus-le Noble airfield was used by **Robert Esnault-Pelterie,** and in 1909 the Buc aerodrome was built under the direction of **Louis Blériot**. Around 1917, the **Farman brothers** built the Mérantais aerodrome in Magny-les-Hameaux, followed by the Guyancourt aerodrome in 1930. A veritable new industry was thus established.

In the aftermath of the Second World War, civil and military aviation on the Saclay plateau underwent major changes. In 1948, the **Office national d'études et de recherches aérospatiales (ONERA)** took possession of the Palaiseau fort to bring together its research capabilities and develop major test facilities. It developed alongside the **Centre d'essais des propulseurs (CEPr)** for testing engines in flight conditions, a laboratory set up by the Ministry of Defence around the Saclay ponds. At the same time, aeronautical innovation continued on the plateau, with players such as **Airbus** and **Safran**, which had based its research centre in Châteaufort.

Paris-Saclay represents a unique network of establishments and companies dedicated to security, defence and aerospace.

• **Fig. 2** Buc aviation meeting: Ms Bolland and Maïcon, 6 October 1920.

# 1945

## THE CEA MOVES TO THE SACLAY PLATEAU

It was followed by the CNRS in 1946 and ONERA in 1948.

It was at this time, in the service of defence, that the history of the Saclay plateau really began, when in 1945 Raoul Dautry and Frédéric Joliot-Curie proposed the creation of the **French Atomic Energy Commission (CEA)**.

The centre opened its doors in 1952, just as France's first five-year nuclear plan was getting under way. At the time, the CEA was a major centre for experimentation and was headed by **Frédéric Joliot-Curie,** the first High Commissioner for Atomic Energy. At the same time, in 1946, the **French National Centre for Scientific Research (CNRS)**, also headed by Frédéric Joliot-Curie, moved to Gif-sur-Yvette and became the second pillar of the Saclay plateau.

In the 1950s, this vast area became the scene of nuclear research, as well as fundamental and applied science. These research activities attracted students, and soon the most prestigious establishments were opening premises close to internationally renowned researchers. Bures-sur-Yvette became home to some of the laboratories of the **University of Paris** in 1955. In just a few years, the **Faculté des sciences de Paris,** the **Ecole Supérieure d'Optique,** the **Ecole Polytechnique** and the **ENSTA** were created or moved to the area. They will soon be joined by other leading centers of scientific learning. And so, following in the footsteps of the CEA, the first laboratories of France's very largest companies were set up in close proximity. In 1968, **Thomson-CSF,** now Thales, built the first private research centre in the region. **Sagem Défense Sécurité, EADS** (the future Airbus Defence and Space) and **Arianespace** will follow.

Today, Paris-Saclay is one of Europe's leading nuclear research and development centers. Also home to the Versailles-Satory defence cluster, it is based on sovereign technologies linked to the defence and security of the French state. Today, it represents a unique network of establishments and companies dedicated to security, defence and aerospace.

• **Fig. 3** First construction of the CEA site at Bruyères-le-Châtel in the Paris-Saclay area.

## The heart of French military innovation

Although the Paris-Saclay science and technology cluster was largely built around defence and security activities, particularly nuclear, with the establishment of the CEA in 1945, it remains today at the heart of French military innovation.

The **Versailles-Satory military site** is an undeniable asset among the region's strengths. It is made up of two entities. The Satory-Est site is a military camp that is home to various operational and logistical organisations and formations of the **French Army** and **Gendarmerie Nationale,** including several residential areas housing almost 5,000 defence personnel and their families. The Satory-Ouest site encompasses a business park that is home to a large number of industrial companies working in land armaments technologies, including sector leaders Arquus and Nexter. With its special runways and integration benches, the Satory site is particularly well suited to manufacturer testing. It is also a hotbed of innovation for the French Army, as illustrated by the **Vulcain project**, which involves identifying and testing military robots developed by cutting-edge industries with a view to integrating them into attack and defence tactics by 2040.

The Paris-Saclay scientific and technological cluster remains at the heart of French military innovation.

## CEA-DAM at the forefront of nuclear simulation

Created in 1958, the CEA's Military Applications Division (CEA-DAM) has three main missions: to meet the challenges of nuclear deterrence; to monitor, analyse and intervene for defence and security; and to contribute to research excellence and industrial competitiveness. Since the creation of the DAM, its activities have been shared with those of the armed forces. While logistical support for operations is the responsibility of the armed forces, it is up to the DAM to prepare the experiments, carry out the measurements during the tests and make use of the results. Since the end of field trials, simulation has taken over. The DAM has therefore built major simulation facilities: the Megajoule Laser (Le Barp), the Epure X-ray facility (Valduc), the RES test reactor (Cadarache) and the EXA1 supercomputer (Bruyères-le-Châtel). This latest addition to the DAM's large-scale instruments, located in the heart of Paris-Saclay, was launched in September 2021. Built in partnership with Atos, it is the first exascale supercomputer, capable of processing one billion billion operations per second. The DAM and Atos built three supercomputers before completing this one. The first partition of the EXA1, known as the CEA-HF, is capable of 35 million billion operations per second. To date, it is the largest High-Performance Computing (HPC) system in the world. Already ranked 14th in the world's TOP 500 calculators, this tool has the most sustainable energy technology to date. Equipped with CPUs, it is cooled with warm water, which helps to control energy consumption and therefore costs. A new, much more powerful partition is scheduled for mid-2023. Finally, the DAM is responsible for the nuclear engineering of France's military infrastructures, from creation to dismantling.

• **Fig. 4** Commissioned at the end of 2021 by the CEA-DAM in the heart of Paris-Saclay, the first partition of the new EXA1 supercomputer, known as "CEA-HF", is based on Atos's BullSequana XH2000 product.

Alongside **Arquus,** Europe's leading armoured vehicle manufacturer, whose vehicle testing department is based at Versailles-Satory, and **Nexter,** the leading land defence company, whose general management and research-development-engineering, logistics support, maintenance and operations support divisions are also located at Versailles-Satory, other leading manufacturers have chosen to locate their innovation centres at the heart of Paris-Saclay. This is particularly true of **Thales,** one of the world leaders in cybersecurity, which set up one of its largest research sites in Palaiseau in 2005, and **Safran**, a leading supplier to the aerospace and defence industries, which has several sites in the heart of the region. Nearby, **MBDA,** Europe's leading designer of missiles and missile systems, employs 3,000 people in research and development at Plessis-Robinson. Many of the main members of **GICAT,** the **French Land and Air Defence and Security Industries Group,** are based in Paris-Saclay.

In terms of public research, the Paris-Saclay science and technology cluster has been home to prestigious organisations from the outset, including **ONERA** (Office national d'études et de recherches aérospatiales since 1948, and the **CEA** (French Atomic Energy Commission), whose **Military Applications Division** (CEA-DAM) was set up in 1958 and is now based at Bruyères-le-Châtel.

Leading manufacturers in the security and defence sector have chosen to locate their innovation centres in the heart of Paris-Saclay: Arquus, Nexter, Thales, Safran, MBDA.

## MBDA Group: Europe's leading missile manufacturer

Following the merger of Matra BAe Dynamics, Aerospatiale Matra Missiles and Alenia Marconi Systems, MBDA was created in 2001, specialising in missiles and missile systems. Based mainly in the Paris region – as well as in various European countries and the United States – and now number two on the world missile market and the leader in Europe, MBDA equips all three types of armed forces (sea, land and air). In addition to missiles, the Group has developed specific expertise in air defence systems against small aircraft such as mini- and micro-drones, thanks in particular to the industrial partnership that led to its creation. Its experts also create all types of drones: space-based, underwater and/or weapon-carrying. The complementary nature of its product range means that it can meet the needs of armed forces around the world for countermeasure and counter-mining systems, as well as more general detection systems (radar). Finally, MBDA has its own munitions dismantling plant.
Group management and R&D are based in Plessis-Robinson. This proximity to Paris-Saclay has long encouraged the Group's researchers to collaborate with local research teams. A number of partnerships have been developed, such as the one with CEA-List to correlate satellite images with missile vision.
The Group also has a framework contract governing its long-term relationship with the CEA. Finally, the Group is working with IRT System X and the Systematic competitiveness cluster.
The cooperation between MBDA and the scientific network of Paris-Saclay is therefore historic and set to last.

Similarly, **DGA Essais propulseurs** (Direction générale de l'armement) has been based on the Saclay plateau for over 70 years, working on behalf of weapons programmes and the world's leading aerospace manufacturers. Some of the biggest players in defence innovation are also represented in the region, including **Innovation Défense Lab,** an innovation accelerator for the whole of French defence, which was created by the **Defence Innovation Agency, GINCO,** one of France's eight technical innovation clusters of Defence Procurement Agency dedicated to NRBC (nuclear, radiological, biological or chemical) techniques, as well as **DGA Maîtrise NRBC** at Vert-le-Petit and the **French Armed Forces Biomedical Research Institute** (IRBA) at Brétigny-sur-Orge.

In addition to its scientific and technological excellence, Paris-Saclay is also particularly renowned for its interdisciplinary and collective initiatives, which help to build bridges between scientific and technological disciplines and encourage cross-disciplinarity between its stakeholders. In the field of defence and security, two initiatives are particularly exemplary. The first, **GAI4A** (Groupement académies, industries, ingénieurs d'Île-de-France pour l'innovation au profit de l'armée de Terre) was created in 2021 by **Université Paris-Saclay,** the **Defence Innovation Agency,** the **Institut Polytechnique de Paris,** the **French Army** and **GICAT** to promote cross-disciplinary partnerships and projects with the aim of creating an innovation cluster in the field of land and air-land equipment.

# 2 ESPECIALLY NOTEWORTHY INTERDISCIPLINARY AND COLLECTIVE INITIATIVES: GAI4A AND CIEDS

## GAI4A, the new innovation cluster for land and air forces

In March 2021, Université Paris-Saclay, the Defence Innovation Agency (AID), the Institut Polytechnique de Paris, the French Army and GICAT (French Land and Air Defence and Security Industries Group) signed the birth certificate of GAI4A on the Versailles-Satory military site. This "Groupement académies, industries, ingénieurs d'Île-de-France pour l'innovation au profit de l'armée de Terre" ["Association of academies, industries and engineers in the Paris region for innovation to benefit the French Army"] has been set up to foster cross-disciplinary partnerships for innovation projects in the field of land and air-land equipment. How can we not take advantage of the wealth of interests of the various players and their research in the vicinity of Versailles-Satory? The first GAI4A project was launched at the end of 2022 and includes teams from Arquus, the French Army's leading supplier of land vehicles, based at Versailles-Satory, the IBICS (Informatics, Bioinformatics, Complex Systems) research laboratory at the University of Evry Paris-Saclay and the Innovation Group of the French Army's Technical Division, the STAT. Its aim is to optimise energy consumption in the defence sector, particularly in military vehicles. In addition to this first project, GAI4A has a number of other ambitions. The synergy between the civil and military worlds should, very soon, make on-board systems on platforms lighter, increase the capacity to detect swarms of drones, enable optimised management of autonomous vehicles and robots, help secure ultra-high-speed mobile connectivity devices (5G/6G) or the widespread use of additive manufacturing (3D printing), etc. In addition, there are plans to set up a technology platform within Paris-Saclay – probably on the Versailles-Satory plateau – on shared premises with several clusters: studies, demonstration areas, military testing and experimentation grounds, *showroom*.

The second, the **CIEDS** (Interdisciplinary Centre for Defence and Security), one of the four interdisciplinary centres of the Institut Polytechnique de Paris, was also set up in 2021. Developing projects in several research areas – additive manufacturing, digital security, robotics and artificial intelligence, energy optimisation and propulsion or quantum technologies – it aims to meet the technological needs of the defence sector. In order to strengthen the links between researchers, students from the Institut Polytechnique de Paris, companies, funding structures and the Ministry of the Armed Forces, it has also created the **Industrial Partnerships Club**, which provides privileged access to its results and protected technologies.

The main innovation challenges facing the defence and security sectors today include the development of emerging defence technologies with support for the micro- and nanoelectronics industry, quantum technologies and the energy sector, the deployment of additive manufacturing and digital twin technologies, nuclear, radiological, biological and chemical (NRBC) defence, autonomous robotics for land combat and cyberdefence, all areas in which the Paris-Saclay science and technology cluster has developed specific and internationally recognised expertise over the years.

The Paris-Saclay science and technology cluster has developed specific, internationally recognised expertise in security and defence.

• **Fig. 5** An AMX-56 Nexter (Leclerc tank) at high speed.

## Nexter: France's leading systems integrator for the army

Nexter's history is rooted in the creation of the first arms factories in France in the seventeenth century. As a direct result of this knowledge, Nexter (formerly Giat Industries) became widely known in 2005 as the manufacturer of the Leclerc MBT tank, the French Army's flagship piece of equipment. This was followed by the VBCI (armoured combat vehicle), the Caesar artillery system and the Aravis 4x4. The Serval armoured vehicle, Nexter's latest achievement, began to be delivered to the French Army in spring 2023 as part of the Scorpion programme. The aim of this armament programme is to modernise and renew France's inter-army battle groups, in particular through the use of innovative technologies.

For the French land defence architect and systems integrator, Scorpion represents a €330m contract.
In 2015, Nexter founded the European joint venture KNDS through its merger with KMW, a major German arms manufacturer. Nexter, whose head office is based in Versailles, near the Satory military zone, offers its customers a complete range of systems (armoured, artillery or weapons systems and turrets) as well as munitions and equipment for on-board electronic systems, optics, mechanics and NBC (nuclear, biological and chemical) protection. Its Managing Director, Nicolas Chamussy, is a graduate of the École Polytechnique and the ENSTA, both based in the heart of Paris-Saclay.

## A concentration of global industrial leaders

Attracted by the presence of internationally renowned research organisations, particularly in the nuclear, military and space fields, and of leading engineering schools, stimulated by major facilities open to industrial R&D and innovative interdisciplinary programmes, many companies have, over the years, established themselves at the heart of the Paris-Saclay science and technology cluster.

In terms of **security and defence**, this industrial fabric is characterised first and foremost by the presence of major integrators such as **Airbus, Dassault Aviation** and **ArianeGroup,** as well as major equipment manufacturers such as **Goodrich, Thales** and **Safran**. These groups are present both through their head office and research and development activities, and through their major production sites. Alongside these global players, the sector includes a large number of SMEs and ISEs, as well as start-ups from public research or local companies. **104 industrial players** of all sizes have been identified in Paris-Saclay. Alongside these companies, a large network of industrial subcontractors supplies the sector, with 1,400 establishments, mainly SMEs, in mechanical engineering, metal processing and electronics. Finally, a large number of design offices assist all the players in the industrial value chain.

The security and defence industry is also divided into four main sectors:

**104**

**INDUSTRIAL PLAYERS OF ALL SIZES**

104 groups, ISEs, SMEs, EPICs [state-funded industrial and commercial establishments] and micro-enterprises were listed in the region in the security-defence sector.

### Safran: aviation has always been at the heart of our business

Safran is currently the world's leading aircraft engine manufacturer, but its roots go back to the very end of the nineteenth century, when France was one of the crucibles of this new industry. It powered Roland Garros's first flight over the Mediterranean in 1913. The Group, which took the name Safran in 2005 after the merger of Snecma and Sagem, is now ready to conquer the space market. With major operations in Saint-Quentin-en-Yvelines, Évry-Courcouronnes and Les Ulis, the Group has a strong presence in Paris-Saclay. While Safran focuses on the design and manufacture of aircraft, helicopter and rocket engines, it also produces aircraft equipment (nacelles, wiring, landing gear, interior equipment), communications systems (test instrumentation, telemetry, space communications) and defence systems. It has distributed the CFM56, the world's best-selling commercial aircraft engine, and equipped French Air Force aircraft such as the Mirage 2000. Safran uses all the tools at its disposal, such as the Factory Lab platform in Paris-Saclay and the CampusFab training centre in Essonne, to bring about technological breakthroughs. This appetite for innovation goes hand in hand with a desire to work more closely with the region's academic players, in particular as part of the work carried out by Safran Tech, its research and technology centre, based in Paris-Saclay. Safran cooperates with the CNRS, ONERA and CEA, as well as with local universities and engineering schools. To complement these partnerships, the Group has created a number of industrial chairs. With over 80,000 employees worldwide – including 43,000 in France – it remains the leading specialist in its fields.

• **Fig. 6** The new-generation LEAP-1A engine developed by the Safran Group, chosen to power the Airbus A320neo.

companies that develop technological building blocks, the major systems integrators that integrate them, companies that develop products, solutions or services based on these building blocks or systems and, finally, across the board, cybersecurity players. In terms of developing **technological building blocks**, the SME **III-V Lab**, for example, is a key player in the region. Founded in 2004 in Palaiseau by the **Alcatel** and **Thales** Groups, joined in 2010 by the **French Atomic Energy Commission** (CEA), the company, which develops strategic III-V semiconductor electronic components for European aerospace and security equipment manufacturers, is now at the forefront of the European industry. In the same field, **UMS - United Monolithic Semiconductors -** is just as emblematic. Based in Villebon-sur-Yvette, the company specialises in the design, manufacture and marketing of semiconductors for European equipment manufacturers in the security, defence and space sectors. As far as **systems** are concerned, the region's strength lies in the presence of major groups such as **Bowen, Thales** and **Spherea** in electronics, **Safran, Cobham, Airbus Defence and Space** and **ECA Robotics** in communications systems, **Hensoldt, HGH Systèmes Infrarouges, CS Group** and **Lynred** in surveillance, and **Orano, Bertin Instruments** and **NBC Sys** in the NRBC (nuclear, radiological, biological and chemical) sector. Last but not least, the region also boasts some big names among the developers of **products, solutions and services**, including **Engie, Dassault Systèmes, Orange Cyberdefense, C2S Bouygues Cybersécurité, Proengin, Arquus, Nexter and MBDA**.

Over the years, many companies, including world leaders, have established themselves at the heart of the Paris-Saclay science and technology cluster.

The security and defence sector also boasts some particularly promising

## Arianespace, the world's leading satellite launcher


**Founded in 1980, Arianespace is now the world's leading satellite launcher. The company has four launchers in its catalogue (Ariane 5, Ariane 6, Vega and Vega C). As an integral player in the New Space revolution, Arianespace, thanks to its Ariane 6 launcher, will soon be offering a new service: the deployment of a wide range of small satellites thanks to its MLS (Multi-Launch Service) system, from CubeSats to MicroSats. This is the response that all the start-ups have been waiting for. At the same time, over the next five years, the number of satellites in low-Earth orbit is set to increase tenfold. Traffic management in space will then take on a whole new significance. This is why Arianespace has signed a partnership agreement with SpaceAble, a start-up supported by IncubAlliance Paris-Saclay, which offers a new service and technologies designed to make low-Earth orbit more reliable and ensure its sustainable use. With its headquarters in Évry and its Ariane 6 launcher assembled in Les Mureaux, Arianespace has naturally turned to the local research and innovation ecosystem through a number of partnerships. For example, it plays an active role in the curriculum of two space studies programmes, at ESTACA and the École Polytechnique. In 2023, the latter brought together its three space activities (AstronautiX, the space student association; the CSEP, a group of students, engineers, teacher-researchers, space agency and industry representatives; and the ESDS chair, the result of the combined sponsorship of ArianeGroup and Thales Alenia Space). At ESTACA, the space course gives students access to solid training provided by engineers affiliated to major institutes and highly specialised industrial companies such as Arianespace, ONERA, CNES and Safran.**

start-ups, such as **MirSense** and **Almae Technologies**, both of which have emerged from III-V Lab. The first has the ambition to revolutionise the laser spectrometry market with intelligent, cost-effective laser solutions. The second designs and manufactures photonic components essential to next-generation telecoms and datacom infrastructures and, more broadly, to all future connectivity solutions. Other start-ups include **New Imaging Technologies (NIT)**, a pioneer in *Wide Dynamic Range* solutions *and* now one of the world's leading suppliers of camera and detector solutions for security and surveillance applications, and **Weeroc, WIN MS, Isybot, Ubble, Innov+** and **Teratonics**.

When it comes to **aerospace**, the sector is above all characterised by the importance of the Paris Region, Europe's leading aerospace region, with 105,000 jobs linked to this industrial activity. Among the companies listed are a number of major groups, including **Safran, Thales, Dassault Aviation, Airbus, Air France Industries** and **Collins Aerospace**. The region boasts some outstanding production sites, including **Airbus Helicopters** at Dugny and **Ariane 6** at Les Mureaux. With 28,000 researchers, the Paris Region accounts for 43% of France's aerospace R&D budget, making it the world leader in maintenance, aeronautical equipment, business aircraft, modelling and simulation tools, propulsion and launchers.

## Thales at the heart of advanced technologies

The Thales Group has the distinction of being one of the world leaders in a large number of advanced technology fields. Defence, communications, aerospace, shipbuilding, deep tech, etc.: the French group offers a comprehensive range of services covering a broad spectrum of aerospace-security-defence activities. Founded in 2000, Thales is now present in 68 countries and employs no fewer than 77,000 people worldwide. The Group's raison d'être, "Building a future of trust together", sums up the nature of its various markets. In 2007 – with the transfer of Alcatel-Lucent's transport, security and aeronautics businesses – it became one of the world's leading specialists in mission-critical information systems, with a focus on three markets: defence, aeronautics and security. Its capabilities also extend to the naval sector (a stake in DCNS), identification (acquisition of Gemalto), semiconductors (creation of III-VLab), lasers (via the MirSense start-up, a spin-off from III-V Lab), underwater detection, quantum physics and drones (partner in a centre of excellence dedicated to the drone sector at Brétigny-sur-Orge). Today, its activities are divided between aeronautics, where it equips two out of every three aircraft in the world and 40% of the world's air traffic controllers; defence and security, in particular by equipping armies and/or navies in some fifty countries; digital identity and security, with data protection and encryption, identity management and control, and security for connected objects; ground transport, satellites and space exploration. Based in Élancourt for decades, the Group's teams work in constant collaboration, particularly with the École Polytechnique, which has a Thales Chair in Complex Systems Engineering. Thales's main research centre is located directly on the École Polytechnique campus.

**• Fig. 7**
Thales laboratory in Palaiseau.

At Paris-Saclay, **79 companies** have been identified in the aerospace sector. Nearly half of these are SMEs. They operate mainly in the civil aviation, space and military aviation sectors, with a very strong presence upstream of the value chain in design, research, development and engineering activities, as well as in the manufacturing of parts and components. Among the world leaders present in the region are **Airbus Defence and Space** at Élancourt, **Safran Aérospatiale** at Plaisir, **Arianespace** at Evry, **Dassault Systèmes** at Vélizy-Villacoublay, **Thales** at Massy, **Roxel** at Plessis-Robinson and **Daher Aerospace** and **Daher Technologie** at Paray-Vieille-Poste.

The presence of these industrial leaders is a particularly structuring force for Paris-Saclay. The prestige of some of these players, world leaders in their fields, such as **Thales, Safran, Airbus, Arianespace, Nexter, Arquus** and **MBDA,** confirms Paris-Saclay's historic industrial roots in the aerospace-security-defence sector.

**79**

**COMPANIES IN THE PARIS-SACLAY AEROSPACE SECTOR.**

The prestige of some of these players, world leaders in their fields, confirms Paris-Saclay's historic industrial roots in the aerospace-security-defence sector.

## Airbus conquering space and defence

The European flagship of commercial aviation is no longer a household name. Its success speaks for itself. On the other hand, its space, defence and security activities are less well known to the general public, even though they are of major importance. Airbus Defence and Space is one of the Group's subsidiaries, dedicated to military aviation, drones, missiles, space launchers and satellites. The entity and its divisions develop solutions tailored to their customers' needs in these areas. Space, climate research, deforestation monitoring and secure communications are just a few examples of the company's expertise. With 6,000 employees in France, this subsidiary is well represented throughout the country and has two major sites: Toulouse and above all Élancourt, a municipality in the Saint-Quentin-en-Yvelines Conurbation Community. Secure mobile radio communication systems for law enforcement and emergency services (Tetra, Tetrapol and P25 technologies) are developed, marketed and installed in this region. Other activities include the protection of highly sensitive government and military data, maritime traffic surveillance, drones and the design and production of tools for space exploration. Lastly, Airbus has set up a cybersecurity centre here, integrating teams from its dedicated subsidiaries, Airbus Protect and Stormshild. As part of international projects, staff are also actively involved in creating military solutions based on new technologies such as the Multi-Domain Combat Cloud and the Future Combat Air System. In this field, where there is a shortage of trained professionals, Airbus CyberSecurity has set up its cybertraining centre on the École 2600 campus. Every year, work-linked students are trained to become cybersecurity analysts in the aeronautical sector (RNCP-certified).

## Excellent research and training capacity

Alongside this historic industrial fabric, Paris-Saclay boasts an exceptional research and training capacity at the crossroads of scientific disciplines.

At the heart of Paris-Saclay's academic excellence: prestigious national research bodies, such as the **CEA** (French Atomic Energy Commission) with, in the military field, its **Military Applications Division – CEA-DAM –** but also **CEA-List**, a leader in cybersecurity; the **CNRS** (French National Centre for Scientific Research) which, in the space sector, implements the major research programmes defined and supported by **CNES** (the French national space agency), particularly in conjunction with the **European Space Agency (ESA)** and, of course, **ONERA** (Office national d'études et de recherches aérospatiales), which has unique aerospace testing and expertise resources.

Paris-Saclay also has a large number of expert laboratories. In terms of security and defence, there are four **laboratories of excellence (LabEx)** whose research is linked to security, defence and cybersecurity issues: **LabEx CHARMMAT** (chemistry of multifunctional molecular architectures of materials), **LabEx LaSIPS** (systems and engineering laboratory of the Saclay plateau), **LabEx NanoSaclay** (laboratory of excellence in nanosciences and nanotechnologies) and **LabEx DigiCosme** (laboratory of excellence in digital sciences).

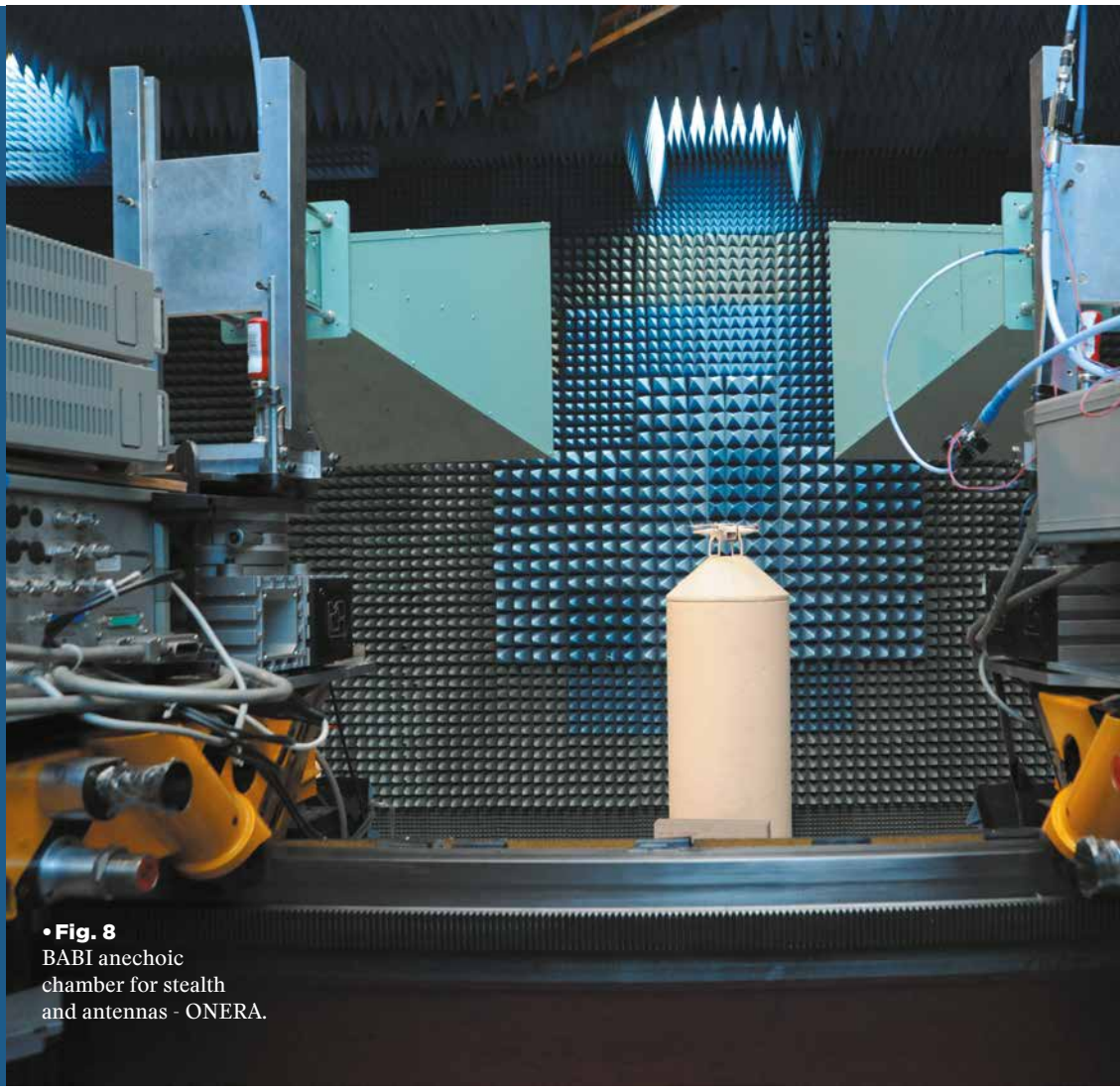
**4**

**LABORATORIES OF EXCELLENCE (LABEX)**

whose research is linked to security, defence and cybersecurity issues: LabEx CHARMMAT, LabEx LaSIPS, LabEx NanoSaclay, LabEx DigiCosme.

## ONERA, defence and aerospace expert for the State and industry

ONERA – Office national d'étude et de recherches aérospatiales – is a key player in aeronautics and space research, employing more than 2,000 people. Under the supervision of the Ministry of the Armed Forces, it has a budget of 289 million euros (2023), more than half of which comes from study, research and test contracts. As a government expert, ONERA is preparing the defence of tomorrow, meeting the aeronautics and space challenges of the future, and contributing to the competitiveness of the aerospace industry. It masters all the disciplines and technologies in the field. All the major civil and military aerospace programmes in France and Europe carry a part of ONERA's DNA: Ariane, Airbus, Falcon, Rafale, missiles, helicopters, engines, radars, etc. Recognised internationally and often awarded prizes, its researchers train many doctoral students.



**• Fig. 8**
BABI anechoic chamber for stealth and antennas - ONERA.

On the aerospace side, there are almost 1,000 researchers and more than 250 PhD students working in 11 particularly outstanding academic and public research structures. These include **Latmos** (the Atmospheres, Environments and Space Observations Laboratory), based in Guyancourt since 2009 and employing more than 200 researchers with expertise in the study of the physical and chemical processes of the Earth's, planetary and stellar atmospheres, and in the interaction between the Earth's atmosphere and surfaces (oceanic and continental surfaces). Its excellence makes the **Université de Versailles Saint-Quentin-en-Yvelines,** to which it belongs, Europe's leading university in atmospheric sciences according to the Shanghai Academic Ranking of World Universities*.

The **PIT** (Plateforme d'intégration et de tests) and **IAS** (Institut d'astrophysique spatiale) platforms are two other outstanding structures. They are founding partners of the **national GIS (scientific interest group) Paradise** (platform for applied research and development activities in ground and space instrumentation), which brings together France's main integration, testing and calibration resources for instrumentation in the sciences of the universe. The first, at Guyancourt, is a technical platform shared by the Université de Versailles Saint-Quentin-en-Yvelines and the CNRS. As part of the GIS Paradise, it provides instrument integration and mechanical testing facilities, in particular to simulate launches, atmospheric re-entry and orbital situations.

**1,000**

**RESEARCHERS AND MORE THAN**

**250**

**PHD STUDENTS**

work within 11 academic and public research structures with a particularly strong focus on aerospace.

*2022 Academic Ranking of World Universities (ARWU)

## Latmos: simulating and analysing complex data from the solar system

The Atmospheres, Environments and Space Observations Laboratory, or Latmos, is a joint research unit specialising in the study of the physical and chemical processes at the heart of the atmospheres of the Earth and other planets in the solar system. Latmos also analyses the link between these atmospheres, surfaces and oceans, as well as the interplanetary environment. With this in mind, its team of over 200 people are studying the various physical and chemical processes present in all layers of the Earth's atmosphere, as well as exchanges between the atmosphere and the Earth's surface. Researchers are also analysing the planets and small bodies in the solar system. Finally, Latmos research includes the physics of the heliosphere and exosphere of planets and plasmas in the solar system. The laboratory was created in 2009 when the Aeronomy Department merged with certain parts of the Centre for the Study of Terrestrial and Planetary Environments. It is placed under the quadruple supervision of the Université de Versailles Saint-Quentin-en-Yvelines, the CNRS, CNES and Sorbonne University. A member of the Institut Pierre-Simon-Laplace, it has two sites: Guyancourt and Paris. The strength of Latmos lies largely in its ability to create and use instruments on the ground (stations) or in orbit (balloons, aircraft, satellites) capable of collecting a unique set of data. Following the launch of UVSQ-SAT in 2021, the first nanosatellite to study the climate sent into space by a French university, Latmos successfully launched its successor, Inspire-Sat, on 15 April 2023. In addition, thanks to its modelling and digital simulations, the laboratory supports a large number of research campaigns. This is the case of JUICE, the latest major mission launched last April from Kourou to study Jupiter. In addition to the digital tools needed to prepare for the mission, the laboratory plans to analyse the observations gathered over the three-and-a-half years of the mission.

The second, at Orsay, brings together nearly 150 researchers in astrochemistry, astrophysics, cosmology, solar and stellar physics, planetology and instrumentation. Finally, the astrophysics department of the **Irfu** – the Institute for Research into the Fundamental Laws of the Universe of the **CEA** – is one of France's leading space laboratories, with European and world-class expertise in instrumentation and modelling. It has been involved in a number of major programmes, including **Euclid** and the **James Webb Space Telescope** (JWST), the most powerful space telescope ever designed.

Alongside these fundamental and applied research activities, Paris-Saclay is also training the talents of tomorrow. Ranked **1st in the world in mathematics**, **9th in physics** and **29th in telecommunications engineering** according to the Shanghai ranking, Paris-Saclay benefits from excellent multidisciplinary and cross-disciplinary teaching provided by prestigious universities and schools of engineering – **CentraleSupélec**, the **École normale supérieure de Paris-Saclay**, the **Institut d'optique Graduate School**, the **École Polytechnique**, **ENSTA ParisTech**, **Télécom Paris** and **Télécom SudParis** – all of which are major assets in the region's security and defence sector. Within Université Paris-Saclay, four *Graduate Schools* also have a number of applications in this field: Computer and Digital Sciences, Engineering and Systems Sciences, Physics, as well as its Institute of Light Sciences.

There are currently more than 65 aerospace training courses offered by 18 organisations, preparing future researchers, engineers and technicians for the industry. Among the region's top-quality training courses in the space sector, **ESTACA** (École supérieure des techniques aérospatiales et de construction automobile) in Montigny-le-Bretonneux offers its future engineers over 400 hours of training, provided by experts from CNES, EADS, ONERA, Arianespace and the Safran group. **ENSTA** (École nationale supérieure de techniques avancées) offers a Master's degree in meteorology, oceanography, climate and engineering for space observations (MOCIS), while **CentraleSupélec** offers a Master's 2 in aeronautics and space. **Université Paris-Saclay** offers a number of courses related to the aerospace sector, including a Master's 2 in tools and systems for space astronomy (OSAE), a Master's degree in aeronautical and space systems engineering (ISAS) and, more recently, a Master's 2 in challenges of space and new applications – New Space. Lastly, the **Campus des métiers et des qualifications aéronautique et spatial (Aeronautics and Space Professions and Qualifications Campus),** run by the **Université d'Évry**, brings together companies, training and research organisations and key players in the region to work together to match training, skills and jobs, particularly in 4.0 design, production and maintenance.

• **Fig. 9** A weekly work session at CentraleSupélec, as part of the Nanolab Academy/CNES programme.

**65**

**TRAINING COURSES**

offered by 18 organisations preparing future researchers, engineers and technicians for the aerospace industry.

## CNRS: when space is analysed up close

For almost 50 years, the CNRS and CNES have been working together on research into the Earth's environment and the universe beyond Earth, under a framework agreement on scientific cooperation signed in 1976 and continually extended since. In this context, the CNRS provides scientific support for the major programmes defined and supported by CNES, as well as their scientific exploitation. These programmes may be specific to CNES, or linked to those of the European Space Agency (ESA), or may be the result of bilateral agreements, such as with NASA. These research projects cover a wide range of fields, from the creation of on-board instrumentation on satellites, interplanetary probes or balloons, to the development of innovative methods for analysing observations (in astronomy and astrophysics as well as Earth observation). The CNRS's flagship laboratories in astrophysics, space research and instrumentation, which support or contribute to these scientific projects, are largely located in Paris-Saclay. This is the case for Latmos in Guyancourt and the Space Astrophysics Institute in Orsay. The École Polytechnique is home to some of the teams from the Dynamic Meteorology Laboratory and all those from the Plasma Physics Laboratory. The technical division of the CNRS's Institut des sciences de l'Univers (INSU) is also based in the area, on the CNRS campus at Gif-sur-Yvette. The INSU leads and coordinates national and international research into Earth sciences, as well as studies of continental surfaces and interfaces, the oceans, the atmosphere, astronomy and astrophysics.

**INTERVIEW WITH ANTOINE MINIUSSI,** NANOSAT SYSTEMS ENGINEER, ONERA

# Supporting the new challenges in aerospace

While New Space reflects the emergence of brand new entrants to the launcher and satellite market – including start-ups – it is nonetheless dominated by long-standing players in the aerospace industry. Just like the Office national d'études et de recherches aérospatiales (ONERA), where Antoine Miniussi, nanosat systems engineer, works. He explains how ONERA is participating in this sector by sharing its unique testing resources and aerospace expertise. This is despite the differences in timing between that imposed by R&D and the more iterative, risk-taking approach adopted by start-ups.

ONERA is recognised as a major and historic player in aerospace R&D. How has it tackled the issues and challenges of New Space?

AM ONERA's vocation has always been to support manufacturers (large and small) in the aerospace sector by carrying out R&D work in partnership and as a subcontractor. It's with the same philosophy that we approach our relationships with the players in New Space, including the start-ups with which we've already got into the habit of collaborating by giving them the benefit of our expertise and know-how. While it's one thing to work with large industrial companies such as Thales, Airbus, etc., which are capable of making major investments, it's quite another to do so with start-ups which, by definition, have fewer resources, both financial and human, as well as less time, etc. New Space is therefore forcing us to review some of our operating methods. Work has been carried out internally to identify ways in which we can be more agile and better meet the expectations of these new contacts, who more often than not need rapid responses to their problems.

Listening to you, this New Space, which is presented as being driven by new private "entrants", also offers you new opportunities ...

AM Yes, and this ability to change and interact with new people is what I like about ONERA. It's true that the Office has been in existence for over seventy years, and with research and innovation in its DNA, it's constantly adapting. Since its initial core business (aerospace and defence), it has evolved by opening up to other areas of expertise, while at the same time becoming involved in new industrial sectors, starting with the space industry in the 1960s. There is no doubt that a new sector is emerging with the arrival of new players, which we need to take into account, especially as it is attracting many young engineers and start-ups. Most of the people we talk to are aged between 20 and 30 ... They're not all experts, but they're passionate and keen to invest in New Space. They have questions that we need to be able to help them answer.

This New Space is defined as the entry of the space industry into the era of miniaturisation of launchers and satellites, and the democratisation of access to digital data and its processing by AI. Is that how you would characterise this sector?

AM There is the dual logic of miniaturisation and democratisation, but New Space is far from being just that. I'll refrain from giving a canonical definition, as there are several, but fundamentally, this New Space is first and foremost a new approach based on gaining speed, even if it means taking more risks. Until now, it was accepted that space programmes necessarily took time to complete, if only to validate the right options. The promoters of the New Space approach take it upon themselves to push testing less far, to devote less time to it, and to proceed by iteration, in other words by trial and error. A philosophy that's financially viable because the miniaturisation of equipment – which we'll come back to – reduces manufacturing costs. As far as possible, New Space players use off-the-shelf technologies, available commercially in large quantities and at lower prices than custom-designed technologies.

A philosophy that you have made your own?

AM No, far from it. ONERA remains committed to R&D, with all that this means in terms of timing: we take the time to innovate and de-risk new technologies as much as possible before passing them on to industry. I would add that our vocation is to develop tailor-made technologies, which necessarily takes time. We are, however, relying on what New Space has to offer for these developments. As our logo suggests – at least this

is how I interpret it – our vocation is first and foremost to build bridges between research and industry, while respecting the time frames of both. And this remains true in the age of New Space.

What assets and resources do you have to offer the New Space players?

AM Our primary asset is our multidisciplinary approach. Our research covers fields as diverse as optics, electromagnetism and radar, physics, materials, information processing and systems, aerodynamics and energy. Although ONERA is organised around seven different scientific departments, they all know how to work together to solve our partners' cross-disciplinary problems. ONERA also has a wealth of technological and human resources, so much so that I spent a year and a half making an inventory of them. Firstly: dedicated test facilities, enabling a variety of experiments to be carried out, such as electric propulsion tests to measure very precisely the small thrusts of mini-propulsion units; electrostatic discharge benches, vibration benches, a thermal vacuum chamber, and the PESO bench for testing technologies for the autonomy of small space systems. Not forgetting the SpaceLab, an advanced digital simulation laboratory currently under development, which will simulate the space environment, mission control and satellite constellation management. These are complemented by *hardware* – infrared and visible cameras, radars, atomic oxygen sensors, electrostatic discharge mitigation systems, accelerometers – and *software* – satellite flight control software, space system design software, etc. Finally, the third category of resources: algorithms for simulating fluid flow around a launcher and rarefied atmospheres at high altitude.

Are you taking part in any missions aimed directly at New Space?

AM Yes, they range from the study of the ionosphere to the radiation belts, Earth observation and technical means of mitigating the effects of electrostatic discharges within satellites. These missions or studies are based on the technological building blocks developed in recent years – on-board cameras, for example – which have been hardened to withstand the demands of space, such as radiation. We also take part in research projects directly involving New Space players.

Right here, in the Paris-Saclay ecosystem?

AM Yes. Here's one example: the CROCUS (ChaRging On CUbeSat) project, carried out in partnership with the École Polytechnique space centre, with the aim of studying electrostatic discharges in satellites, validating a new generation of payloads and demonstrating the effectiveness of an ONERA electron emitter in limiting the negative charge of satellites. Another example is the FLYLAB mission, which is paving the way for Earth observation (visible and infrared) and formation flying techniques.
We are also working with Latmos, a laboratory at the University of Versailles-Saint-Quentin, on the CUIONO payload for the INSPIRE-SAT7 nanosat, and the ASTERIX nanosat, which aims to measure the Earth's radiative imbalance by designing two onboard cameras developed by us.

How can a New Space start-up approach you? Have you set up a "one-stop shop" to direct them to the right person?

AM Within ONERA, I'm the ideal person to talk to. They can contact me directly or see me at trade fairs. The cross-disciplinary ONSATLab (for ONERA Satellite Laboratory), which is currently being set up, will soon be a key contact for New Space players, start-ups and others. Its website (w3.onera.fr/nanosat/) already gives an overview of our nanosat activities at ONERA. ONERA is also taking part in BLAST, a programme to support and accelerate deep-tech start-ups in the aeronautics-space-defence sector, launched in 2020. We devote around a hundred hours to each of them.
I'm supporting two of them personally, giving them the benefit of my technical expertise.

To what extent do you take account of growing concerns about sustainability and energy efficiency?

AM These are major issues to which I am personally very sensitive. Like its work for the aeronautics industry, ONERA is involved in R&D that meets environmental constraints. For example, in 2021, ONERA acquired a space simulation bench, ERIS, dedicated to the study of electric space propulsion. Another example: in 2015, ONERA began work on the HYPROGEO project, designing and testing a hybrid engine demonstrator. What's more, our space missions are constrained by France's 2008 law on space operations – the only law to date that obliges operators to de-orbit their satellites at the end of their life in order to guarantee a clean space environment.

Interview by Sylvain Allemand

## A dynamic innovation ecosystem

The aerospace-security-defence sector has a long history in the region, and remains particularly dynamic, with a growing number of start-ups and innovative projects, particularly in the new areas of cybersecurity and New Space.

These projects benefit from the many facilities dedicated to innovation and the creation of innovative businesses in Paris-Saclay. Incubators are run throughout the region by the schools, such as the **X-UP** and **Pépinières X-Tech** incubators at the École Polytechnique, the **503 Entrepreneurship and Innovation Centre** at the Institut d'Optique and the **CentraleSupélec incubator**.

**40**

**INNOVATION CENTRES IN THE PARIS-SACLAY REGION.**


## BLAST programme: French ASD *deep-tech* start-ups have their own acceleration programme

In November 2020, the Starbust accelerator, SATT Paris-Saclay, ONERA and the École Polytechnique launched the BLAST *(Boost and Leverage AeroSpace and defence Technologies)* programme. France's first acceleration programme dedicated to deep-tech companies in the aeronautics, space and defence sectors, its aim is to help around twenty emerging disruptive technology companies and research programmes to emerge and thrive each year. This unique programme will also bring together all the players in the ASD ecosystem, from major industrial contractors to investment funds. The aim is to nurture a new generation of French start-ups and consolidate a pool of deep-tech start-ups capable of participating in future aerospace and defence programmes, at both national and European level. The programme's key themes include low-carbon aviation, new urban and regional air mobility platforms, autonomy, artificial intelligence, secure cloud communications and space in the broadest sense.
In 2021, twelve start-ups and eight research programmes were selected. They covered topics as varied as the creation of a prototype individual flying capsule to relieve traffic congestion in urban areas (Caps), a naval drone (Seaproven) to collect oceanographic data, and a research project on gas leak detection using infrared cameras (ONERA).
The second class, in 2022, also brought its share of cutting-edge creations, including DisAltek, a project to detect illegal discharges using satellite images and recognition algorithms, Octofan, a giant drone powered by hydrogen, and VeriQloud, a quantum cybersecurity solution. For the 2022 edition, CNES and the MBDA group joined the initial partners, driving and supporting the programme. The Ministry of Defence's Defence Innovation Agency, OVH Cloud, Naval Group, Thales Alenia Space and Safran are also keeping a close eye on the start-ups we support. The BLAST programme aims to give a new impetus to the development of this particularly buoyant sector.

• **Fig. 10** The 2022 winners of the BLAST programme.

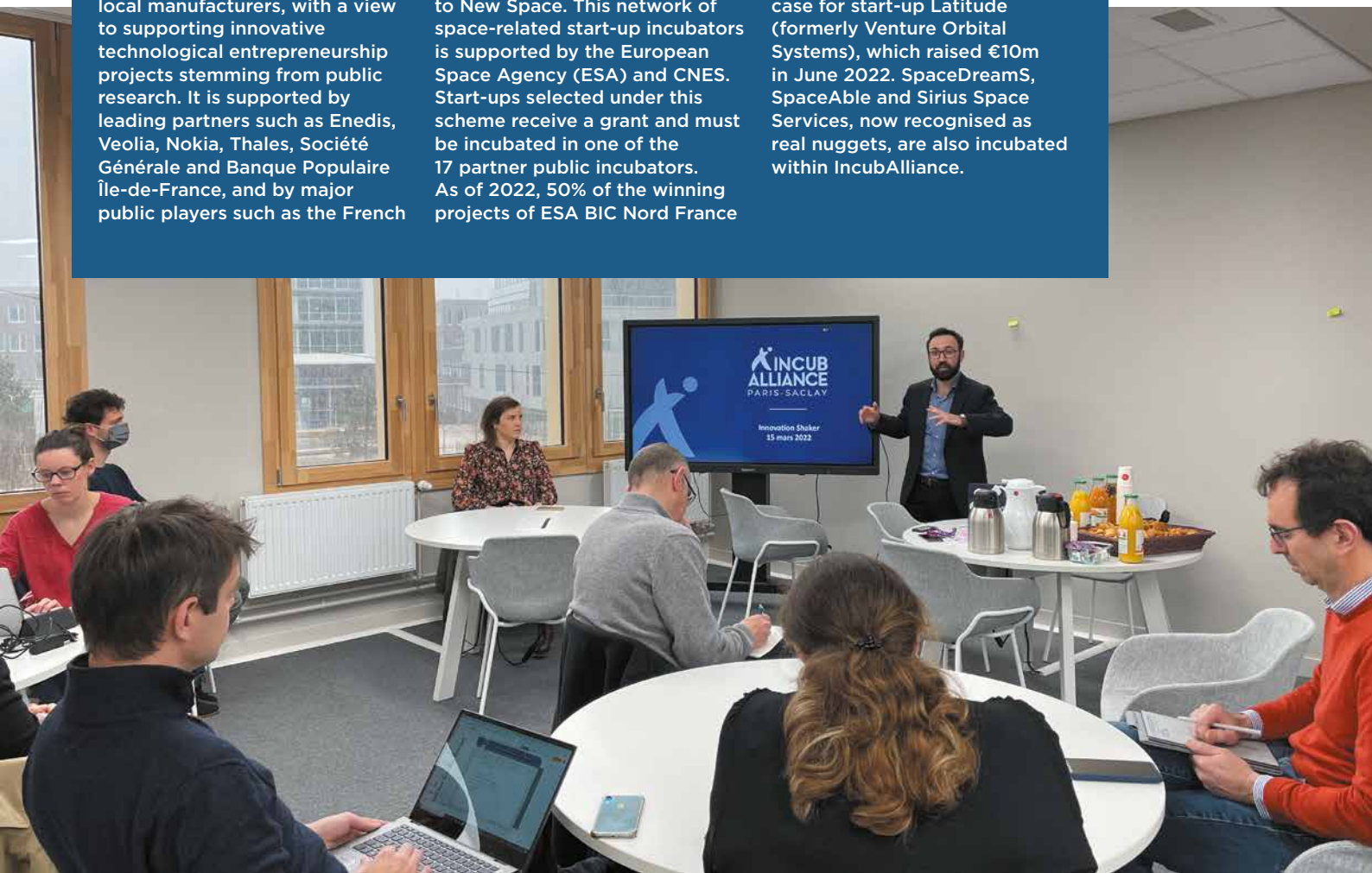
Accelerators and incubators have also been set up by public and private bodies such as **IncubAlliance, WILCO, Hardware Accelerator, SATT Paris-Saclay** and **Playground Paris-Saclay,** the new innovation cluster for the region. *iLabs, fablabs* and experimentation centres such as **Software République** are also dedicated to developing innovative technologies. Finally, the **Paris-Saclay SPRING** has been organised every year since 2019 and is now a real showcase for scientific and technological innovation in the Paris Region, along with other events.

Within the aerospace-safety-defence sector, various programmes have been launched, such as **BLAST,** France's first programme dedicated to deep-tech companies in the aerospace and defence sectors. Launched in November 2020 by **Starbust**, the consortium leader, **SATT Paris-Saclay**, **ONERA** and the **École Polytechnique,** it supports around twenty start-ups or research projects each year. Similarly, since 2018, the Paris-Saclay **IncubAlliance** incubator has been accredited as a partner incubator of **ESA BIC Nord France,** a network of space-related start-up incubators, for the incubation of New Space start-ups selected by the **European Space Agency** (ESA).

Start-ups and innovative projects benefit from a number of facilities dedicated to innovation or to the creation of innovative companies within Paris-Saclay.

## IncubAlliance, France's leading technology incubator

Founded in 2000 in the heart of Paris-Saclay, IncubAlliance is recognised as one of France's leading deep-tech incubators. Its creation was called for by the region's prestigious higher education and research establishments, as well as by local manufacturers, with a view to supporting innovative technological entrepreneurship projects stemming from public research. It is supported by leading partners such as Enedis, Veolia, Nokia, Thales, Société Générale and Banque Populaire Île-de-France, and by major public players such as the French Ministry of Higher Education, Research and Innovation, the European Union and local authorities. Following its accreditation as an incubator partner of ESA BIC Nord France in 2018, the structure has begun to welcome projects related to New Space. This network of space-related start-up incubators is supported by the European Space Agency (ESA) and CNES. Start-ups selected under this scheme receive a grant and must be incubated in one of the 17 partner public incubators. As of 2022, 50% of the winning projects of ESA BIC Nord France had chosen IncubAlliance. What is special about these start-ups is that they require substantial investment and, at the same time, need to raise funds and grow their workforce. IncubAlliance supports them in both these areas. This was the case for start-up Latitude (formerly Venture Orbital Systems), which raised €10m in June 2022. SpaceDreamS, SpaceAble and Sirius Space Services, now recognised as real nuggets, are also incubated within IncubAlliance.




• **Fig. 11** Innovation Shaker event by IncubAlliance and French Tech Paris-Saclay.

**INTERVIEW WITH ARIELLE SANTÉ**
MANAGING DIRECTOR OF INCUBALLIANCE

# Supporting New Space start-ups

In 2018, IncubAlliance was accredited as a partner incubator of ESA BIC Nord France. As such, the Paris-Saclay deep-tech Incubator is authorised to incubate New Space start-ups selected by this network. Arielle Santé, its Managing Director, and Fabrice Daumard, one of IncubAlliance's start-up managers and the person responsible for this scheme within IncubAlliance, tell us more, including the advantages of IncubAlliance's involvement in the Paris-Saclay ecosystem.

Could you start by explaining what IncubAlliance is all about?

AS Created in 2000, IncubAlliance is a public incubator set up under the Allègre law. Supported by the French Ministry of Higher Education, Research and Innovation, its mission is to promote technologies from academic laboratories. At the beginning, we weren't yet talking about deep-tech technologies, but the technologies were already deep tech. IncubAlliance is a not-for-profit association under the law of 1901, financed mainly by public subsidies (from the Ministry, the Paris Region, the CPS and Europe). Unlike private incubators, we don't want to take an equity stake in the start-ups we incubate. So we can let them grow at their own pace, without being constrained by the need for a return on investment. We really are positioning ourselves as a trusted third party for start-ups.

How did you react to the emergence of the New Space sector, one of the characteristics of which is that it is driven by private players who don't necessarily have anything to do with academic research?

AS That's a good question. This gives me the opportunity to point out that IncubAlliance, as an entrepreneurial player in academic research, also selects projects with no direct links to this research, as long as they remain deep-tech projects with a high technological content. Our aim is to connect them to the laboratories and ecosystem of Paris-Saclay. Our starting point is that innovative entrepreneurship thrives on the diversity of the start-ups we incubate.

A mix of project leaders from public research and project leaders from the private sector is all the richer for it. What's important is that the people we incubate exchange ideas on the issues surrounding innovative entrepreneurship, rather than those specific to a single technological field. Start-ups run by private players in the New Space sector also have their place at IncubAlliance. We are also a certified Incubator partner of ESA BIC Nord France.

> **We really are positioning ourselves as a trusted third party for start-ups.**

What does this cover?

AS ESA BIC Nord France is a network of space-related start-up incubators (BIC stands for Business Incubation Centre) supported by the European Space Agency (ESA) and CNES.
This system is all the more valuable in that it also mobilises the expertise of the ESA and CNES.
Why Nord France? Because this network covers the northern half of France, from Brest to Lille, via Orléans, Paris and the Paris region.
Its counterpart, ESA BIC Sud France, covers an area from Bordeaux to Chambéry, including of course the Toulouse ecosystem. In both cases, the start-ups, previously selected by the ESA BIC jury, receive a grant and must be incubated in one of the network's partner incubators. Currently, seventeen public incubators can incubate projects selected by ESA BIC Nord France. IncubAlliance is particularly well positioned. In 2022, no less than 50% of the winning projects from ESA BIC Nord France chose to be incubated with us (i.e. six out of twelve).

What are the specific characteristics of these start-ups, between those involved in the design of micro-launchers and those focused on nanosatellites?

FD The New Space universe covers a wide range of start-ups and technologies, not just the ones you mentioned. They include, of course, all activities relating to launchers, space access and satellite deployment services, but also everything to do with Earth observation, activities in space (such as satellite constellations, orbital stations), etc.
There are a number of reasons why a start-up may be created in New Space: either a market study, or an innovative technology derived in whole or in part from academic research, and so on. While retaining this special link with academic research, our mission is to help project leaders to adopt an entrepreneurial approach.
These start-ups also require substantial investment, especially when they are involved in building micro-launchers or constellations of nanosatellites. Their workforce is set to grow rapidly, in line with their engineering needs. Start-ups incubated with us have gone from a handful of people to several dozen in less than two years. It is understood that, within this time frame, they may still be a long way from generating sales. Our support must therefore include a sizeable human and financial dimension, whether in the form of subsidies and/or fund-raising. Having said that, the context has been particularly favourable for New Space start-ups in recent years, with the sector now fully recognised as an industry of the future.

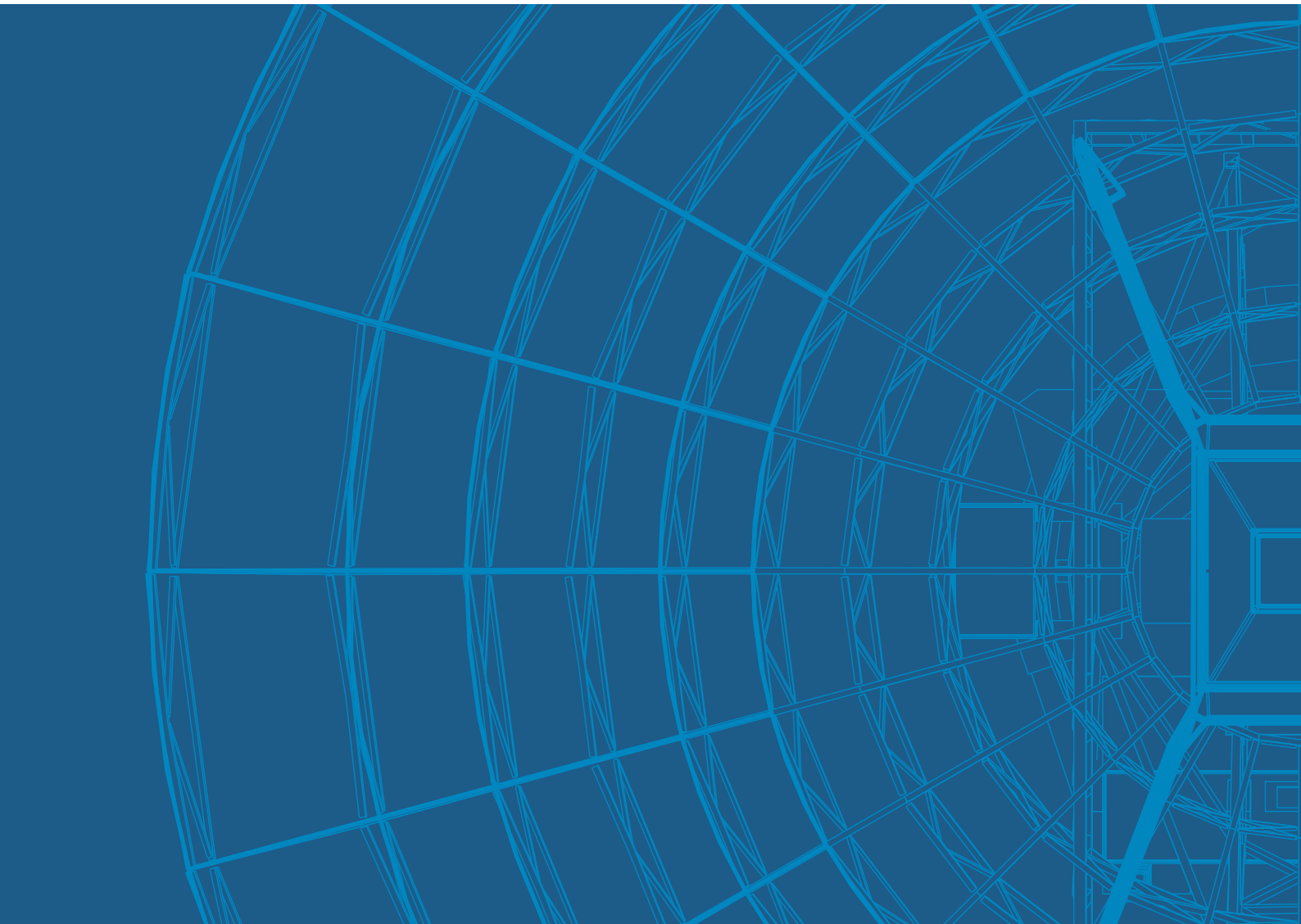
**Inb 2022, no less than 50% of the winning projects from the BIC Nord France chose to be incubated at IncubAlliance.**

How is IncubAlliance's place in the Paris-Saclay ecosystem an advantage for the start-ups you incubate?

AS Even if the Paris-Saclay ecosystem (which, it should be remembered, includes the Saint-Quentin-en-Yvelines conurbation) does not have the same historical influence as that of Toulouse in the space sector, there's no doubt that a sector is well and truly taking shape, covering the entire chain: academic research, experimentation platforms, start-ups and industrial production players. We ourselves interact with all these players, as well as others such as the Astech competitiveness cluster, Airbus Développement and others.
For the 2023 Spring 50, half (five out of ten) of the start-ups selected in the New Space category are supported by IncubAlliance. Allow me to quote them: Constellations Technologies, DISAITEK, ASTROLAB, Opus Aerospace and Space Quarters, which has just joined us.
And that's not all: our incubatees and alumni also include other (future) start-ups such as SpaceDreams, Spaceable, Sirius and Latitude [ex-Venture Orbital], which raised €10 million in June 2022.
Finally, we take part in major New Space events: "Space Connect", as sponsor and chair of the Pitch Jury [to find out more: https://spacecon.io] and ActinSpace, this time as a member of the Hackathon jury [https://actinspace.org]. So, yes, we are fully integrated into the Paris-Saclay ecosystem and the New Space ecosystem in general.

Interview by Sylvain Allemand

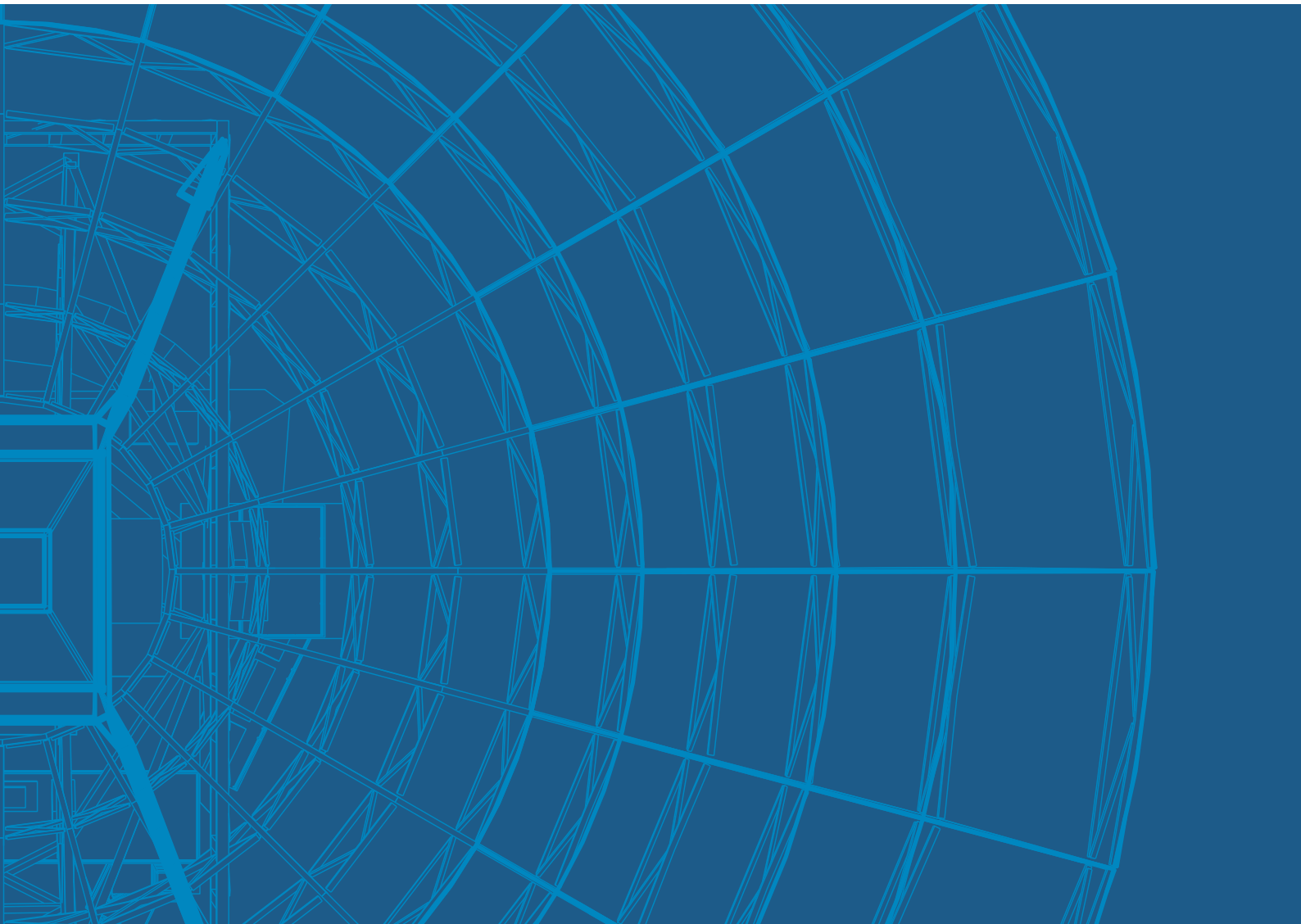
# Paris-Saclay, a forerunner in the technologies of tomorrow



By virtue of its size, the wealth and weight of its players, the density of the skills deployed and the significant cross-fertilisation of disciplines favouring some of the most disruptive innovations, the Paris-Saclay science and technology cluster occupies today a leading position in the aerospace-security-defence sector.

It is also at the heart of tomorrow's security, defence and aerospace challenges. Its strengths include a position at the forefront of innovation in digital technologies, the presence of renowned scientists and a very strong impetus for innovation and the creation of high-tech start-ups.

All these strengths make Paris-Saclay a pioneering innovation cluster in emerging fields that represent the future of the sector: cybersecurity and *New Space.*



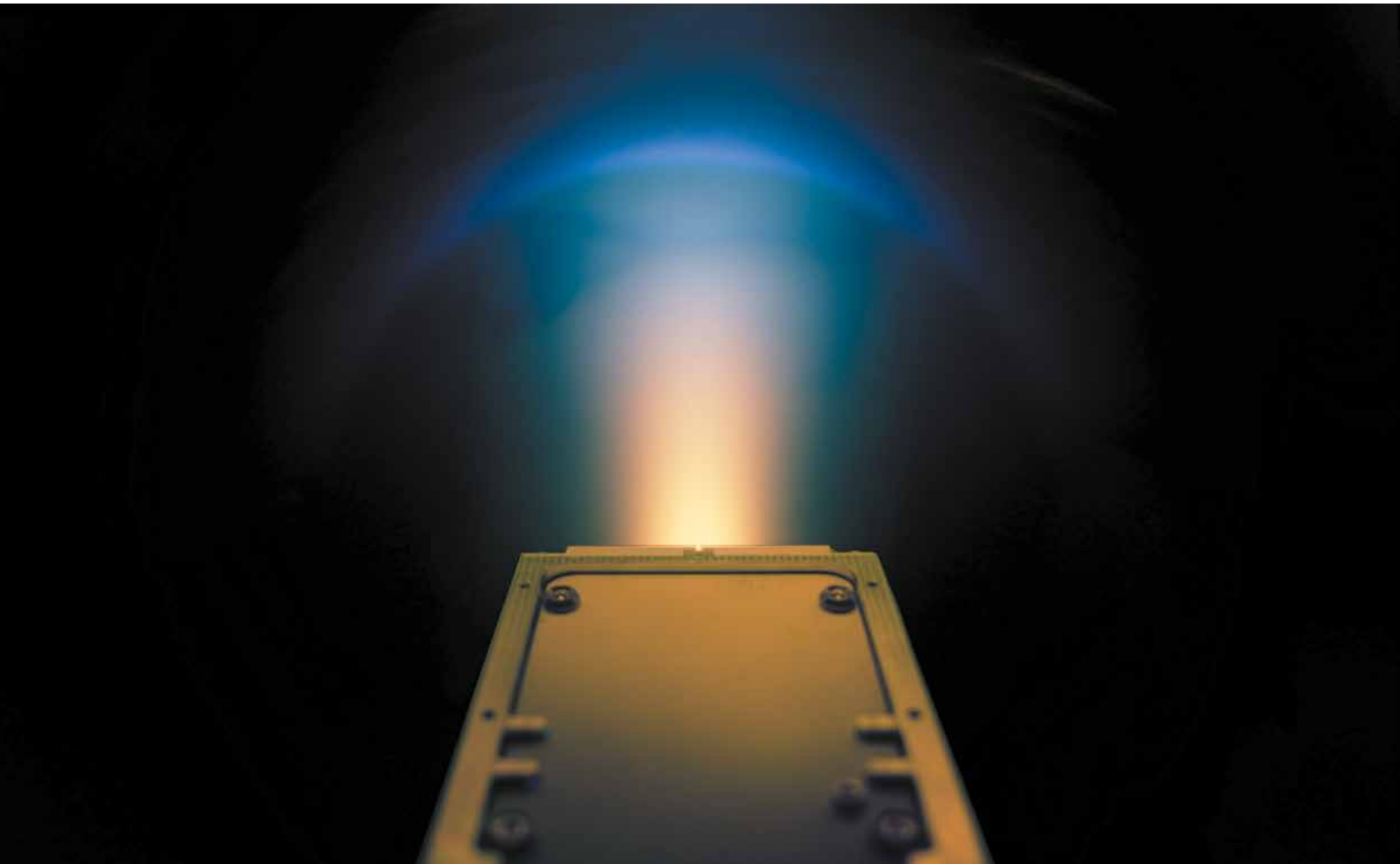
## The new challenges facing aerospace-security-defence

Aerospace-security-defence has always been a sector of excellence at Paris-Saclay, and has relied over the years sovereign technologies linked to the defence and security of the French State. Today, the entire industry is faced with new challenges, as well as a shift from applications that were originally security- and defence-related to applications that are now dual-use or specifically civilian.

In the security and defence sector, since the digital revolution transformed the way information is produced, distributed and consumed, information management has become one of the priority security issues, not only for States, with a view to defending and preserving their sovereignty, but also for economic and industrial activities. The increase in cyberattacks on public authorities and businesses in recent years has demonstrated the extent to which security issues are now, above all, cybersecurity issues.

In addition to the key markets in the security and defence sector, which today include communication systems, surveillance, electronics and optronics, critical infrastructure security (government or military sites, airports, ports and transport networks, public sites, industrial facilities), urban security, navigation, nuclear, radiological, biological or chemical (NRBC) issues and combat, the issues of detecting vulnerabilities in information systems, assessing their risks and developing secure systems, infrastructures and clouds are becoming increasingly important.

In the space sector, the development of new technologies due to the



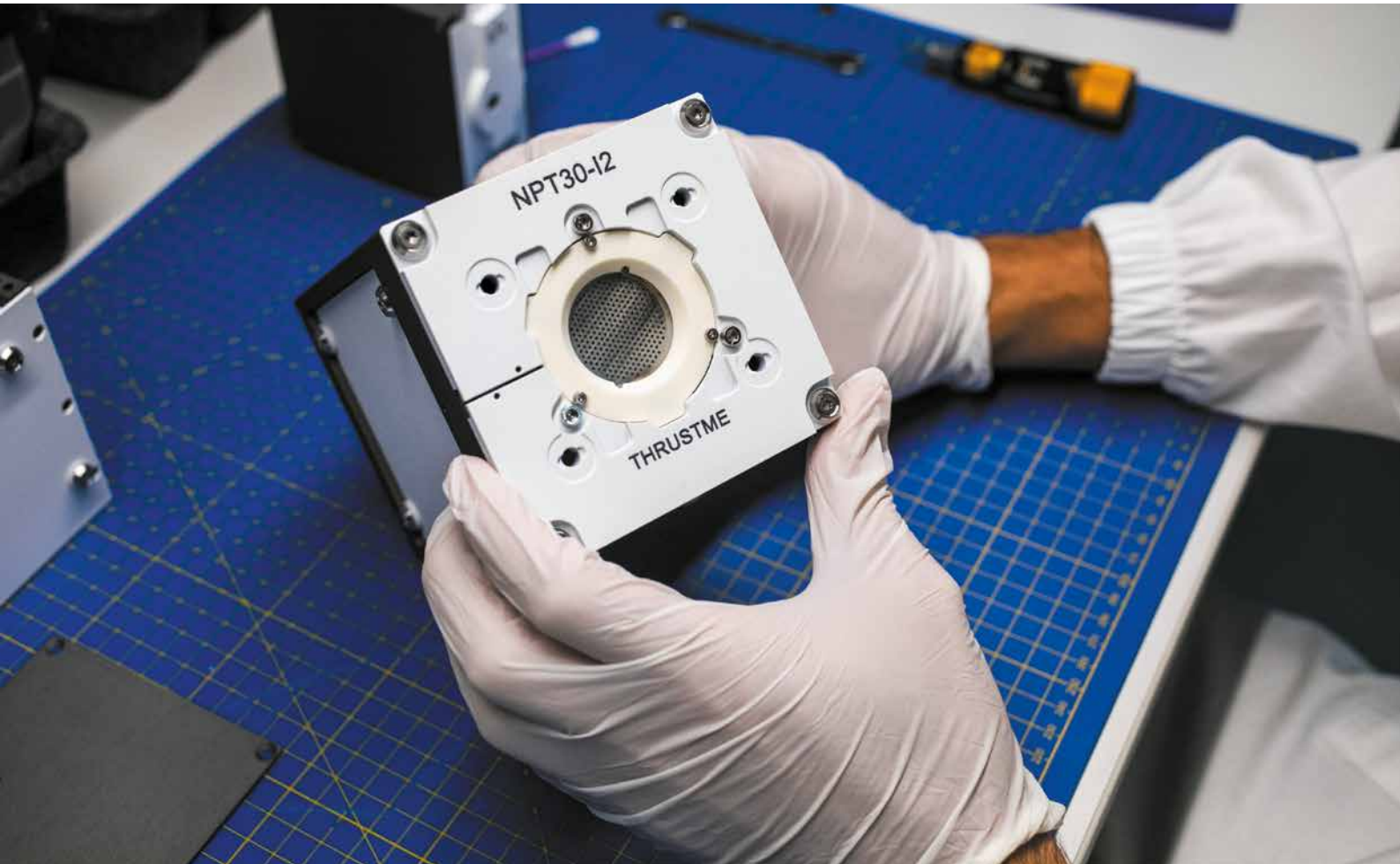
• **Fig. 12** The NPT 30-I2 propulsion system developed by the start-up ThrustMe for miniaturised electric propulsion for launching nanosatellites.

booming digital sector, such as artificial intelligence, quantum computing, big data and cloud computing, combined with a strong democratisation of the use of space data, no longer reserved exclusively for military, state or scientific applications, but now increasingly for dual and civil applications, has led to the advent of New Space, a real paradigm shift. The new challenges facing this emerging sector include the development of new launchers, in particular micro-launchers or micro- and nanosatellites and innovative propulsion systems such as reusable launchers, connectivity and the space internet with satellite constellations, space waste management and the new use of space data, in particular by private companies, for surveillance, decision-making or geo-intelligence purposes in the mobility, health or environmental sectors.

The advent of *New Space* represents a real paradigm shift.

The Paris-Saclay cluster of scientific and technological excellence is at the heart of these new challenges, thanks to its historical roots in aerospace, security and defence, as well as its leadership in digital technologies, which are at the heart of the current revolution. The cluster has developed specific expertise in these two emerging sectors – cybersecurity and New Space – making it a true pioneer. In terms of cybersecurity, the Saint-Quentin-en-Yvelines Conurbation Community is now home to a large number of companies in the digital security sector and is increasingly structured to offer specialist training in this area. In the New Space sector, Paris-Saclay has generated over the years many highly promising start-ups, notably in propulsion and telecommunications.

• **Fig. 13** The deep-tech start-up ThrustMe, founded in 2017, is an expert in electric propulsion for nanosatellites.



**INTERVIEW WITH THOMAS GARNIER**
CO-RESPONSIBLE FOR THE SPACE SECTOR AT ESTACA

# Training for the new professions in New Space

An alumnus of ESTACA (École supérieure des techniques aérospatiales et de construction automobile), Thomas Garnier has helped to overhaul this engineering school's space programme, drawing on his involvement in the Paris-Saclay ecosystem, as well as his own experience of innovative entrepreneurship. He is also a research engineer at Latmos, and has taken part in setting up master's degrees in partnership with Université Paris-Saclay and CentraleSupélec. in his view, training is all the more important because New Space is already leading to the emergence of new professions.

How has ESTACA negotiated the "turning point of the New Space era, building on its expertise in space?

TG Let's face it, apart from Elon Musk and Jeff Bezos, the traditional players in the space industry, including us, have been slow to deal with the consequences of this turning point, which began in the 2000s. In the space sector, our training focused on the engineering of launchers and large satellite platforms. However, it became clear that they could only meet some of the needs of the market, and the dominant position held by ArianeGroup, one of our strategic partners along with CNES, was called into question. At the same time, we were seeing the emergence of new professions.
In response to this new context, we have undertaken a reform of the three-year training programme for our space industry. To do this, we took the time beforehand to survey several categories of people: our industrial partners and training experts, but also our young alumni – those who graduated less than five years ago – not forgetting our students, so that they could help us identify any gaps between the training they received at ESTACA and what they were asked to do during their internships. Significantly, the results of our various surveys converged on what we should be focusing on in terms of guidelines, themes and options for adapting our programme to the new needs of the market, and preparing our students for the emerging professions – those of New Space, in other words, but also of Next Space, which is set to take hold over the next thirty years.

What are the main changes in your training programme?

TG The first decision was to hold more than half of the courses in English, as the final year at ESTACA is spent almost entirely in this language. A number of new courses have been introduced in the form of options that students choose as part of a pathway, similar to what happens at American universities.

**We have undertaken a reform of the three-year training programme for our space industry.**

There are two categories of options in the final year of study: majors and minors. The first are concerned with "advanced satellites"[1] – dealing in particular with their miniaturisation and on-board instrumental performance – and "advanced launchers" – looking at the new types of launcher being deployed in Europe and around the world, how they can be reused in whole or in part, and the challenge of 3D metal-printed thrusters. These are all themes that our teaching didn't cover until now. The minor options, *"Space Exploration"* and *"Human Spaceflight"*, deal with the following themes: space exploration and robotics; all aspects of manned flight: space tourism, suborbital space transport, manned flight by agency, civilian or commercial astronauts. All these aspects mean that many professions need a better understanding of the human body as it moves through space. We prepare our students for this by developing the study of "terrestrial analogues", i.e. extreme environments in sport, the military and medicine that simulate the experience of space on Earth. Added to this is the "Defence and Space" option, offered in French and reserved for students of French nationality, which aims to train our students not so much in the militarisation of space as in the importance of space data (Observation and Telecom) in the world of defence, the emergence of cybersecurity applied to space defence, and the challenges of linking space-based and terrestrial defence bodies.

Last but not least, we have also introduced practical courses on technical software directly from the space industry – until now, our students worked on generic programming, simulation or computer-aided design software. Software that is used in other industries such as aerospace and automotive. Our students now have access to a number of specific technical software packages – for launcher trajectory, satellite constellation management and satellite systems engineering for preliminary projects – with a view to working on applications with industrial players who use this software. In other words, we avoid training our students in proprietary tools that they would not be able to acquire for their future projects once they are in their companies.

One of the characteristics of New Space is that it is driven by innovative entrepreneurs and start-ups. Does your new curriculum include training in innovative entrepreneurship?

TG Our students, whatever their course of study, already have the opportunity to undertake an entrepreneurial project, which, under certain conditions, can even be part of their academic study project. Depending on the year, between five and ten students a year make this choice, making around fifty of the school's 400 students. Along with my colleague in charge of entrepreneurship at ESTACA, I support space-related projects by drawing on my own experience as an entrepreneur.

What did it involve?

TG In particular, I've had the opportunity to set up two start-ups working on technical products – online medical data software and a network of geographically distributed micro-data centres for intensive computing. I'm currently a research engineer at Latmos, the planetology laboratory at the University of Versailles-Saint-Quentin (UVSQ). The reason I mention this is because I think research laboratories are not so far removed from the world of start-ups: they give you a lot more freedom than you might think. In fact, I have no hesitation in recommending that students who want to gain experience at the start of their career should go and have a look around a laboratory, even if it's just for a work placement.
Coming back to innovative entrepreneurship, our students can of course take a Master's degree in entrepreneurship on leaving ESTACA (sometimes as a double degree in the final year), like the one I did at ESSEC-CentraleSupélec, or the new Master of Science and Technology (MSc&T Space Business Strategy) also set up by CentraleSupélec on business growth and development strategies in the space industry. These dual courses, sometimes as part of a double degree and sometimes after leaving the school, correspond to a real expectation on the part of our students. In the surveys we carried out with them and our alumni, we asked them if they would like to have experience in a start-up, including as an employee: over 50% said yes. A massive response, which we interpreted as a desire on their part for greater agility. To complement this development, ESTACA has set up a database of all the players in the space industry. This database is open to all outside ESTACA free of charge, and we hope that it can be used by all students and young professionals in the space industry looking for an internship or a job. It lists around 800 companies, including start-ups, alongside major groups and laboratories.

ESTACA is an integral part of the Paris-Saclay ecosystem. To what extent does this serve its ambitions for training in New Space?

**Adapting our industry to the new needs of the market, preparing our students for the emerging professions, those of New Space, but also of Next Space.**

TG ESTACA is an integral part of this ecosystem, interacting with various higher education establishments, as I have illustrated with the double-degree masters. On a more personal note, I'm also part of this ecosystem, running other courses at Université Paris-Saclay, including the Master's 2 in New Space that I launched two years ago with my colleague Philippe Keckhut, former director of Latmos and now Vice-President of Research at the UVSQ. I'm also in charge of the brand new Master's in Space Business Strategy project at CentraleSupélec. Together with our partners in the Paris Region, we also responded to the call for expressions of interest "Skills and Professions of the Future" by proposing, in partnership with Université Paris-Saclay, a research platform around aerial and space drones. Let's face it, it's not easy to create training courses for the professions of tomorrow, which, by definition, are not yet hiring. However, we're doing our utmost to fill the gaps by already offering training in the professions that will determine whether we can continue to send satellites into space in the near future, such as protection and the fight against space pollution caused by the proliferation of satellite debris.

Interview by Sylvain Allemand

## Recognised expertise in cybersecurity

At the heart of these new challenges, the Paris-Saclay cluster of scientific and technological excellence, and more specifically the **Saint-Quentin-en-Yvelines Conurbation Community,** has developed specific expertise in cybersecurity.

Over the years, the region has seen the emergence of a genuine industry, with leading companies such as **Airbus, Thales, Renault, Atos, C2S Bouygues** and **Orange Cyberdefense** heavily involved in this field. In 2014, Airbus, one of the world's leading industrial groups in digital research in the field of cybersecurity, relocated the activities of its subsidiaries **Airbus Defence and Space** and **Airbus CyberSecurity** to its Élancourt site. The company has also opened a cybertraining centre on the premises of the École 2600, a school dedicated to cybersecurity. Similarly, Thales, now a world leader in this field, has set up one of its largest research sites in Palaiseau in 2005, as a member of the **Thales Research & Technology** network. Built on the École Polytechnique site, it hosts more than 300 researchers and around 250 PhD students working on subjects related to securing military communications, space systems and large-scale government IT networks. This is also the case for **RTE,** the operator of the public electricity transmission network, which opened a national operational centre in Montigny-le-Bretonneux in 2021 to monitor all of the company's IT, telecoms and cybersecurity infrastructures. The same is true of **Atos**, which inaugurated the same year its new global R&D laboratory for quantum computing, cybersecurity and artificial intelligence in the town of Les Clayes-sous-bois.

The Paris-Saclay cluster of scientific and technological excellence, and more specifically the Saint-Quentin-en-Yvelines Conurbation Community, has developed specific expertise in cybersecurity.

## Atos shapes the information space

Founded in 1997, Atos has changed its scope several times since its creation, largely as a result of external acquisitions (Bull, Siemens IT Solutions and Service, etc.). Since then, the company has become one of the top ten secure digital services companies in the world. Its research areas cover strategic fields such as quantum computing, high-performance computing, edge computing, artificial intelligence and cybersecurity. In aeronautics, security and defence, digital technology is now an integral part of every stage of the process. In these areas, Atos is involved at every stage, from aircraft design and energy optimisation to monitoring the life cycles of equipment and parts. In 2021, ESA also selected Atos for an R&D project to improve the cybersecurity of satellite test platforms. Atos also announced its support for the creation of a joint cybersecurity unit by the European Commission at the end of 2021. In recent years, Atos has gradually chosen to focus its efforts on its "new" businesses: cloud, decarbonisation of the economy and cybersecurity. Its global R&D centre, which has been based in Les Clayes-sous-bois since 2021, is dedicated to cybersecurity, high-performance computing and quantum computing. Its 8,000 m² site is home to more than 350 engineers. This is the context in which Atos Quantum, Atos's quantum computing research programme and Europe's first major industrial programme in this field, is being carried out. This project has received a €5m investment from the Paris Region as part of its "Smart Industry" strategy. Projects dedicated to the fight against global warming are being developed here, thanks in particular to quantum computing and supercomputers. Atos is also planning to develop a "supercomputer brain". The company is already behind the creation of CEA-DAM's EXA1 supercomputer, the first in the exascale family.

## TrustInSoft: protecting critical software against cyberthreats

Since 2013, TrustInSoft has been developing solutions to validate mission-critical software used in sensitive environments, including the aeronautical, rail, military, nuclear, telecommunications, space, IoT and semiconductor industries. In particular, its products eliminate the entry points for attacks and guarantee a high level of security for the software code analysed, without the need to modify the development process. Incubated at the heart of Paris-Saclay within IncubAlliance when it was created, the start-up is now marketing TrustInSoft Analyzer, an advanced static source code analyser based on the Frama-C open-source platform. Resulting from joint work between the CEA and Université Paris-Saclay, this is one of the few tools to have passed the NIST(National Institute of Standards and Technology) analysts' evaluation, satisfying the ability to guarantee the immunity of the code analysed. With its roots in Frama-C, TrustInSoft Analyzer offers software designers and integrators effective security against potential vulnerabilities. Already recognised worldwide, it is now used by major names in the industry such as EasyMile, Mitsubishi Electric, Dassault Aviation and the IRSN, as well as operators of connected objects and semiconductor manufacturers. TrustInSoft also offers expertise in auditing the security of critical software components that are already in operation, and supports its customers in deploying their solution or Frama-C. The company was set up by two founders "made in Paris-Saclay" – Fabrice Derepas, who trained at the École Polytechnique and is a former CEA employee, notably at CEA-List, and Benjamin Monate, who trained at ENS Paris-Saclay and is a former CEA employee, with autonomous vehicle specialist Pascal Cuoq.

• **Fig. 14** CyberNDT, a solution developed by CEA-List to ensure the reliability, traceability and compliance of manual non-destructive testing (NDT).

Alongside these industrial giants, the sector also boasts an ever-growing number of start-ups at the heart of the ecosystem. Some, such as **Ozon, United Biometrics, Cryptosense** and **TrustInSoft**, specialise in vulnerability detection and risk and threat assessment, and have been recognised by the US Department of Commerce's National Institute of Standards and Technology (NIST) for their ability to provide the highest level of mathematical guarantees, or **Citalid,** a start-up founded by CentraleSupélec alumni, which has developed a particularly innovative technology for managing cyberrisks. In 2018, it won two innovation awards at the Assises de la Sécurité, which is among the most prestigious in France in this field. Others focus more specifically on secure cloud or the transformation of information systems and infrastructures. These include **Massa labs** and **Uniris**, which are active in blockchain technologies, **Kleverware, Storit, Alkalee** and **Snowpack, a** CEA spin-off that has developed an innovative solution for anonymising data, making it impossible to exploit network vulnerabilities by protecting the identification of users, devices and the content of communications.

**CEA-LIST BRINGS TOGETHER MORE THAN CYBERSECURITY EXPERTS IN**

**70**

**A PLATFORM THAT IS UNIQUE IN EUROPE.**

In the academic field, and even more so in training, Paris-Saclay is at the forefront of cybersecurity. To this end, the Saint-Quentin-en-Yvelines Conurbation Community is gradually building a centre of academic excellence. Now leading the way in the development of France's so-called "trust territories", the Conurbation Community will be hosting the first regional cyberincident response centre (CSIRT) in 2023, in partnership with the ANSSI (Agence nationale de la sécurité des systèmes d'information). In line with this development project, the region's leading higher education establishments offer dedicated training courses, such as **Université Paris-Saclay**, which offers an M2 in Content, Network and Telecommunications Security in Versailles, and the **Institut Polytechnique de Paris**, which offers a Master's in Cybersecurity, Threats and Defence. Specific schools have also been created, such as the first **European School of Cybersecurity** (EECS), which opened in 2021 in Versailles, the **École 2600**, created the same year in Montigny-le-Bretonneux, or the latest **IPSSI campus** dedicated to IT and cybersecurity. These courses are designed to meet the growing skills needs of companies. Between 2017 and 2021, the number of cybersecurity job vacancies in France doubled, and specialists predict that tens of thousands of jobs will be created in the very near future.

Finally, in research, alongside chairs dedicated to cybersecurity in partnership with the **Télécom Paris** and **Télécom SudParis** institutes (chairs in cybersecurity of critical infrastructures and responsible digital identity), the region also boasts cutting-edge organisations such as **CEA-List**, which specialises in the design, analysis and security of intelligent digital systems, and which brings together more than 70 cybersecurity experts in a platform that is unique in Europe. This platform works with around thirty major industrial players in the field, as well as the region's leading academic institutions. It is also involved in major French projects in the field, such as the Grand Défi Automatisation de la cybersécurité and Campus Cyber projects, and European projects such as Sparta.

## Florent Kirchner, a national coordinator for the 100% Paris-Saclay cybersecurity strategy

**Since last December, Florent Kirchner has been national coordinator of the cybersecurity acceleration strategy at the Secrétariat Général pour l'Investissement (SGPI), responsible for implementing the France 2030 cybersecurity mission. Since February 2023, he has also been France's representative on the Executive Board of the European Cybersecurity Competence Centre, and is working in parallel with the Cyber Campus at Paris-La Défense, as called for by the French President. National missions that confirm an exemplary track record at the heart of Paris-Saclay. After training at ENS Paris-Saclay and the École Polytechnique, Florent Kirchner, who has a doctorate in computer science, worked for many years at CEA-List. In particular, he directed the Laboratory for Software Safety and Security and the Cybersecurity programme. As part of his work, he has introduced various approaches to verifying very high-confidence software, in both academic and industrial settings. At the same time, he has initiated and managed a number of collaborations with international partners such as Airbus, Bureau Veritas, NASA and SRI International. More than ever, Paris-Saclay and cybersecurity go hand in hand at national level.**

# École 2600: training for data security professions

**Security management project manager, cybersecurity expert, security R&D engineer, systems security engineer, SOC manager, data, network and systems security manager ... there are many different professions involved in securing information and data. And demand from organisations looking for trained professionals is growing. École 2600 was created to give as many people as possible access to these professions of the future by training its students to become Data, System and Network Security Experts (RNCP Level 7/Bac+5). The skills acquired at the school cover a wide range of complementary areas, from auditing IT security to managing a technical team, defining an organisation's strategy, monitoring technology and designing secure solutions. Located at the heart of the Saint-Quentin-en-Yvelines cybersecurity cluster, École 2600 has also opted for inclusion by offering its courses on a three-year sandwich course basis. Partner companies (Atos, Diakse, RSM, Squad, Deloitte, Euro CRM, Patrowl, Zenetys, C2S Bouygues, Kyndryl, Plastic Omnium, Silicom, Thales, BSecure, Develter, i-Tracing and Red Alert Labs) quickly joined the 2600 Network. This enables companies that are sensitive to the notion of cyberprotection of data and systems to exchange information with each other and with the school on a regular basis, so that student training can be geared as closely as possible to their needs. Airbus CyberSecurity has even set up its cybertraining centre there. The school has also created a Community 2600 for its students and alumni. Cyberskills are being developed for the future, and links with the students trained are another guarantee of successful integration into the workplace. To date, 90% of students have found a job on leaving the school.**

• **Fig. 15** Some of the École 2600 students during the visit by Jean-Noël Barrot, Minister-Delegate for the Digital Transition and Telecommunications.

Paris-Saclay's interdisciplinary institutes are also involved in this area, such as the **Centre interdisciplinaire d'études pour la défense et la sécurité (CIEDS)** at the Institut Polytechnique de Paris and the **Institut de recherche technologique (IRT) System X**, which aims to accelerate the digital transformation of the region's industry and services. These academic players also benefit from a wealth of local talent, such as **Florent Kirchner**, who headed the Software Safety and Security Laboratory and the cybersecurity programme at CEA-List for many years, and who now coordinates the national cybersecurity strategy at the General Secretariat for Investment (SGPI), **Sara Tucci-Piergiovanni**, who works at CEA-List and is an international expert in the field of blockchain, and **Gilles Desoblin**, director of the cybersecurity and digital transformation programme at IRT System X.

The St-Quentin-en-Yvelines Conurbation Community is gradually building a genuine academic centre of excellence in cybersecurity.

## Future skills in New Space

Still in its infancy in France and around the world, the New Space sector involves a genuine change of model. Essentially made up of **new players from the private sector** who are not part of the traditional space industry – for the most part start-ups operating in the field of micro- and nanosatellites – the sector is characterised by both **technological and industrial acceleration** and the **democratisation of the use of space data**. This democratised and multifaceted use of spatial data is leading to the emergence of **new applications, more geared towards the civilian sector** and no longer strictly limited to military use, to help professionals and private individuals make economic and operational decisions in a wide range of fields, from health and mobility to environment and agriculture.

As the number of projects and players multiplies, thanks in particular to **advances in the miniaturisation of components,** a **sharp reduction in technological costs** and the promise of a **growing market**, particularly for small satellites, funding is accelerating around the world and in France, where between 2018 and 2020, some 35 start-ups raised a total of €260 million. France is focusing in particular on the key markets of reusable launchers and satellite constellations, as well as investment in new uses.

## Exotrail, space logistics in the hands of the transporter of tomorrow

With Exotrail, Paris-Saclay has a major player in New Space, and more specifically in the creation of electric propulsion systems. The deep-tech start-up, based in Massy and founded in 2017, sends mini- or nanosatellites into orbit via a propellant (spaceware®) based on the Hall effect (projection of a cloud of ions), which enables the orbits of these small devices to be changed. Right from the start of the project, another tool was added to the founders' thinking: an IT platform for managing space logistics and operations simulation software, spacedesign® and spacetower®. With them, satellite or launcher operators and those involved in access to space will be able to plan the movements and all the transport actions required for their space adventure to run smoothly. The first version of spacedesign® was launched in 2020. That same year, Exotrail was chosen to equip two Eutelsat satellites. A cargo ship (spacevan®), capable of transporting several satellites at the same time, and above all of dropping each one off at its specific destination, and for which a contract has been signed with CNES, is also under development. A real alternative to the thruster.

The start-up, a pure product of Paris-Saclay, began its activities on the premises of the Guyancourt Observatory.

The initial project was supported by the CNRS, the University of Versailles Saint-Quentin-en-Yvelines, Synchrotron Soleil and the École Polytechnique. It then benefited from the support of SATT Paris-Saclay through a maturation programme and was incubated by IncubAlliance. After raising €3.5m and €11m in two previous rounds, the start-up raised a third round in 2023, totalling €54m. This should enable it to increase its workforce, build a new production plant and set up branches abroad.

As part of **France 2030, the French government has earmarked €1.5 billion** for these issues, with a view to boosting the sector's competitiveness and creating a new ecosystem to drive economic growth.

The **challenges of this new sector are wide-ranging**, from the development of new launchers and innovative propulsion systems to the management of space waste and debris, the development of space connectivity and the new use of space data. Today, this data is used in a **wide range of applications**: traffic and transport (aircraft landing, road safety, navigation systems), security and defence (border surveillance, maritime surveillance), agriculture and fisheries (precision farming, crop development, drought monitoring) and communications and digital technology (satellite communications, Internet of Things).

With the emergence in recent years of a number of highly promising companies, particularly in the fields of propulsion and telecommunications, the emergence of the New Space sector is a reality at Paris-Saclay. Since 2010, **32** of the 70 French **start-ups** operating in the New Space sector – a third of the entrepreneurial sector – have come out of Paris-Saclay, 24 of which are considered to be pure players. They now employ over 1,500 people and have already raised €530m.

**32**

***NEW SPACE* START-UPS CREATED SINCE 2010 ARE FROM PARIS-SACLAY.**

• **Fig. 16** The mobility solutions offered by start-up Exotrail range from propulsion systems for small satellites to mission simulation and operation software, including orbital transfer services.

## Geoflex: entering the era of hyper-geolocation

Based in Massy-Palaiseau and founded in 2012, Geoflex exploits CNES research patents that increase the accuracy of ground-based data provided by Global Navigation Satellite Systems (GNSS). The company offers its customers "highly available and highly connected" information. The development of its research enabled it to bring its product range to market in 2018. Thanks to this hyper-geolocation technology, the start-up, which was incubated by IncubAlliance, quickly won a number of prestigious awards, including the Chinese Academy of Sciences' Innovation Award in 2018, the Innovation Award at the CES (Consumer Electronics Show) in Las Vegas in 2018 and an award at the Dubai World Challenge for its advances in autonomous driving.

Geoflex uses PPP-CNES (Precise Point Positioning) technology, which models GNSS satellite errors in real time using observations from a network of 80 ground stations. While GNSS networks are accurate to within 3 to 10 metres, the PPP-CNES network is accurate to within a few centimetres. It adapts to all types of GNSS: GPS (USA), Glonass (Russia), Galileo (Europe) and Beidou (China). The data obtained is streamed by Geoflex and synchronised with existing systems. Its customers come from a wide variety of sectors, including geospatial, construction, agriculture, defence and transport. The company also markets a wide range of GNSS-related hardware and software tools.

Some have developed highly disruptive technologies or particularly innovative systems. This is the case of **ThrustMe**, a spin-off from the École Polytechnique, which has developed a new iodine-based electric propulsion system for nanosatellites – a real feat in the space industry, and the Massy-based start-up **Exotrail**, which offers complete space mobility solutions for the propulsion, optimisation and innovative transport of small satellites in space. In the launcher sector, **Sirius Space Services**, based in Orsay, is developing a new launcher based on a rocket engine using liquid oxygen and liquid biomethane, while **Dark Space**, also based in Orsay, designs onboard launchers for nanosatellites.

Others are proposing new uses for space data, geared towards monitoring, decision-making and geo-intelligence applications. This is the case of **Preligens**, whose founders are from CentraleSupélec and ENS Paris-Saclay, which offers a pioneering technology for monitoring strategic sites using space imagery and artificial intelligence. The same is true of **SpaceSense**, a spin-off from the École Polytechnique, which offers a solution for analysing satellite images using artificial intelligence for applications in the insurance, agriculture, energy and infrastructure sectors, and **Geoflex**, based in Massy-Palaiseau, which offers cutting-edge hyper-geolocation technology that has won awards around the world for companies in the construction, transport, defence, agriculture and geospatial sectors.

With the emergence of a number of highly promising companies, particularly in the fields of propulsion and telecommunications, the emergency of the *New Space* sector is a reality at Paris-Saclay.


## Ane Aanesland, *New Space* in the feminine

In 2017, Ane Aanesland, a doctor of physics and international expert in plasma physics, founded the deep-tech start-up ThrustMe with Dmytro Rafalskyi, dedicated to the miniaturisation of rocket engines. In this way, it is capitalising on its experience developed at the École Polytechnique to launch engines for nanosatellites using solid iodine-based electric propulsion, rather than xenon, which is generally used in this type of propellant. This technology, developed at the École Polytechnique Plasma Physics Laboratory, was patented in 2014. The project then benefited from a maturation programme with SATT Paris-Saclay.
From the moment it was set up, everything accelerated for the young company. In 2017, it raised €1.7m, and in 2018 ThrustMe received €2.4m from the European Commission to market its propellants. In 2019, the first iodine thruster was fitted to an orbiting satellite, and in June 2022, the European Space Agency (ESA) asked the start-up to develop the propulsion system for the GOMX-5 demonstrator. ThrustMe builds ion engines and cold gas thrusters, which are sold worldwide. Small motors with low energy consumption, designed to make nanosatellites more durable. Given that 10,000 of them are likely to be launched over the decade 2020-2030, increasing their life expectancy will limit the number of satellites sent to replace them. What is more, the lower cost of propellant (the name given to the fuel used in propelled objects) opens up opportunities for a large number of small businesses. Until now, some of them have been held back by the size of the sums required for this item alone. They should now be able to take advantage of these simpler, more economical rocket engines. In 2019, Ane Aanesland was awarded the CNRS innovation medal.

Finally, in the field of new uses, **Share My Space**, a spin-off from the École Polytechnique and the CNRS and accelerated by SATT Paris-Saclay, is currently the only European company offering a complete space surveillance package. Detection of objects in orbit, real-time updating of the catalogue of space objects, data processing solutions, etc.: the start-up specialises in space debris mapping and risk management.

Alongside these innovative companies, the ecosystem is also taking shape through a new range of training courses dedicated to New Space. One of the region's top-ranking educational establishments, **ESTACA** (École supérieure des techniques aérospatiales et de construction automobile), has undertaken a wide-ranging reform of its space sector to prepare its students for emerging professions. **Université Paris-Saclay** has developed a Master's degree dedicated to the challenges of space and the new applications of New Space to meet the needs of the private sector and research laboratories. It has also launched its brand new Master's in Science and Technology "Space Business Strategy through Entrepreneurship and Sustainability" in 2023.
The **Nanolab Academy** project, a national programme to promote student space activities in conjunction with CNES, is also particularly active at Paris-Saclay, notably at the **École Polytechnique** and **CentraleSupélec**. Four student satellites in CubeSat format – EyeSat, Aerosat, X-Cubesat and soon IonSat – have been developed and launched as part of this programme. In January 2021, the University of Versailles Saint-Quentin-en-Yvelines launched **UVSQ-SAT,** the first climate study nanosatellite to be sent into space by a French university.

**PARIS-SACLAY HAS LAUNCHED AROUND**

**1/3**

**OF FRENCH CUBESATS OVER THE LAST DECADE.**

## Nanolab Academy: when students create nanosatellites

The Nanolab Academy project (ex-Janus/CNES) aims to train students in space technology in French schools and universities. Through this programme, CNES is offering them the opportunity to create and send into space their own satellite equipped with scientific instruments in "CubeSat" format. Since 2012, the University Space Centres (CSU) have been developing this type of project in conjunction with CNES, industry and students from leading engineering schools and universities.

• **Fig. 17** CentraleSupélec students carrying out tests on the premises of the Integration and Test Platform (PIT) as part of the Nanolab Academy programme.

At the Nanolab Academy, students are exposed to the logic of space project development and its implementation at every stage essential to the success of the project: project management, development plan, launch, reception and use of telemetry received. The programme also promotes scientific teaching by emphasising the experimental approach in the various space-related fields (mechanics, thermics, avionics, energy). Productive experiments that use new satellite and/or instrument technologies of interest to the scientific and industrial community. These are tested in orbit. At the heart of Paris-Saclay, the École polytechnique and CentraleSupélec have joined the Nanolab Academy programme.

**INTERVIEW WITH JEAN-LUC MARIA** CEO OF EXOTRAIL

# A New Space start-up “made in Paris-Saclay”

Logistics. It was with reference to this professional world and its solutions that, in 2017, Jean-Luc Maria co-founded Exotrail, a start-up focused on… space, initially offering software for designing space missions and electric thrusters for nano- and microsatellites. In just a few years, the young start-up has taken new steps forward, with new products now in its catalogue. This interview provides more details, including on the reasons for keeping Exotrail within the Paris-Saclay ecosystem, from which it emerged directly.

If you had to start by describing Exotrail?

JLM Exotrail was created in 2017, after a year and a half of gestation, by four people, all interested in the challenges of mobility in space, otherwise known as space logistics. Like companies in the traditional logistics sector, we help to organise the movement of objects, in this case satellites. It’s a challenge when you consider that the latter have multiplied to meet terrestrial, connectivity, observation and exploration needs. This is all the more true given that, since the early 2000s, the cost of access to space – for both satellites and launchers – has been falling. This is the same phenomenon that has occurred on land, with an intensification in the flow of goods and merchandise, against a backdrop of lower long-distance transport costs and the specialisation of companies in land, air and sea logistics.
My partners and I decided that there was an opportunity to create something equivalent in the space sector, convinced that there was room, in addition to the existing historical players – the satellite operators – for new companies to manage the mobility of objects sent into space.
However, we decided to develop our products step by step. The first, spacestudio™, is a space simulation software tool. It enables the mobility requirements of a satellite or satellite system to be calculated precisely, from design to end of life in space, and the mobility solutions to be selected that need to be implemented in order to make them move in space. The simplest solution is to install an electric thruster. This is the second product we proposed. We were encouraged to do so by the advent of a new era, that of smaller satellites, in other words nano- and microsatellites, which are intended to be placed at lower orbital altitudes but distributed in greater numbers – which is what constellation projects are all about. However, this trend has long been hampered by the difficulty of miniaturising engines. Exotrail was also born out of the desire to meet this need for efficient but smaller thrusters.

Where do you stand today?

JLM Building on the expertise and credibility we acquired with our first two products, and the income they are generating, we are now taking the next step by proposing to add two further mobility products. On the one hand, an alternative to the thruster: spacedrop™, an in-orbit transport service that uses the spacevan™ vehicle – in other words, a conveyor satellite that will be responsible for depositing all the small satellites it contains one by one into the right orbit after separating from the rocket.
This product is a response to the trend to reduce the cost of launches, by designing rockets on the model of cargo ships – they send several objects placed at their head, but to one and the same place. It’s a problem not unlike that of last-mile logistics, where a product has to be transported using smaller vehicles to reach its many final destinations. The launch of our first conveyor satellite is scheduled for October 2023.
Once the satellites are placed in space, we need to be able to communicate with them, retrieve their health data to check that everything is nominal, plan the movements they need to make (position correction, collision avoidance, orbit change, etc.),

and do all this as automatically as possible to limit operating costs. The other product currently under development, the fourth in our range, is another piece of software, no longer for design but for operation.
Naturally, we have no intention of stopping there. We already have other product ideas in mind, with the aim of eventually having a fleet of vehicles in space that satellite operators could mobilise when needed. All they would have to do is contact us and tell us what they need – inspect a fault on one satellite, refuel another, bring some satellites back down into the atmosphere at the end of their life so that they can burn up there and not add to the pollution in space. Along the same lines, we can also imagine a reusable conveyor satellite model. The range of possibilities in this area is particularly wide.

So, listening to you, space logistics are similar to terrestrial logistics. But how far can we push the analogy? After all, your environment is space! We have no doubt that you are facing challenges of an entirely different nature. By the way, do all the skills you bring to the table have anything to do with traditional logistics?

JLM (Smiling). Yes and no! The environment in space is indeed different from the environment as we know it on the surface of the Earth. We are projecting ourselves over longer distances, into the vacuum, confronting ourselves with variable levels of temperature, very low or very high; objects are exposed to radiation; maintenance operations are more complex. As a result, the logistical solutions are different; our thrusters are based on different technologies from those used on land. Conveyors have nothing in common with lorries, trains or ships either. That said, space logistics also shares skills in common with the world of traditional logistics, in this case the organisation and management of a fleet of vehicles. Fedex, UPS, Maersk, SNCF, etc. – all these major overland logistics operators have control centres from which they monitor their hundreds of ships, planes, trains and lorries, optimising their routes to consume as little as possible and deliver as quickly as possible. To do this, they draw on optimisation skills that are, in the final analysis, quite similar to our own.

Although you are based in Toulouse, you have chosen to remain part of the Paris-Saclay ecosystem by moving to Massy. What motivated this choice?

JLM Exotrail is a pure product of Paris-Saclay! After starting the project in Guyancourt (at the Observatory of Versailles Saint-Quentin-en-Yvelines), we moved to the École Polytechnique incubator for a few months. As I said, we have benefited from the SATT Paris-Saclay maturation programme. The project we submitted was supported by a consortium of leading research bodies and institutions in the ecosystem: the CNRS, the University of Versailles Saint-Quentin-en-Yvelines, Synchrotron Soleil and the École Polytechnique. It also happened that my partners and I were based near the Saclay plateau.
Naturally, when we set up the company, we canvassed the surrounding area for premises. These had to meet a number of criteria – be close to a railway station and an airport, etc. Hence the decision to base ourselves in Massy, a transport hub if ever there was one – the town is served by RER lines B and C, the TGV, and is close to Orly airport. We were lucky enough to find our current premises in an old industrial building – one of the few to have survived in Massy – perfectly suited to a business like ours, which involves a lot of machinery – we design, assemble and test our own thrusters! Even if we now have less interaction with the members of the consortium I mentioned – the company having now taken off – we remain attached to Paris-Saclay.

Can you tell us about your workforce and how it is changing?

**Exotrail is a pure product of Paris-Saclay. In particular, we have benefited from the SATT Paris-Saclay maturing programme.**

JLM We started at Paris-Saclay with six people – the founders and two SATT engineers. Our workforce has grown steadily since then – we've just passed the 100 employee mark, with the aim of reaching 150-160 by the end of 2023. The fundraising that we completed at the end of 2022 and announced at the beginning of February 2023 – the third since Exotrail was founded – should enable us to industrialise the production of our historical products by being able to scale up from the production of a few thrusters to several hundred. We're setting up a production plant right here in Massy, which means quadrupling the size of our premises – we're lucky not to have had to move. We also aim to bring our two latest products – the conveyor satellite and the operating software – to market and to internationalise the company. We've already recruited one person with a view to opening one or more offices in the United States in the summer of 2023, and soon in Asia.

Interview by Sylvain Allemand

## Photo credits

Cover: © Shutterstock
P3: © Shutterstock
P4-5: © EPA Paris-Saclay
P6-7: © EPA Paris-Saclay/ © Exotrail (Fig. 1)
P12-13: © Shutterstock
P14-15: © Agence Meurisse/ Creative commons (Fig. 2)/ CEA (Fig. 3)
P16-17: © CEA (Fig. 4)
P18-19: © Daniel Steger/Creative commons (Fig. 5)
P20: © Cyril Abad/CAPA Pictures Safran (Fig. 6)/© Arianespace
P22-23: © EPA Paris-Saclay/ Adeline Bommart (Fig. 7)
P24-25: © ONERA/Caroline Grippon-Lamotte (Fig. 8)
P26-27: © CentraleSupélec/ Nanolab Academy (Fig. 9)
P28: DR
P30-31: © Starburst (Fig. 10)/ © Incuballiance/Angela Riga (Fig. 11)
P32: DR
P34-35: © Shutterstock
P36-37: © ThrustMe (Fig. 12 and 13)
P38: DR
P41: © CEA-List/Cyrille Dupont (Fig. 14)
P42-43: © SGPI/Tristan Reynaud/ Sipa Press/© Jonathan Teboul/ Nonstoprod (Fig. 15)
P44-45: © Exotrail (Fig. 16)
P46-47: © ThrustMe/Frédérique Plas/© CentraleSupélec/Nanolab Academy (Fig. 17)
P48: DR
P51: © Shutterstock
P52: © Shutterstock

## Already published

Praxis No. 1 - Satory Ouest Versailles Charter/March 2013
Praxis No. 2 - Water management/July 2013
Praxis No. 3 - Mobility/October 2014
Praxis No. 4 - Biodiversity primer/January 2016
Praxis No. 5 - Innovation for all time/January 2019
Praxis No. 6 - Paris-Saclay, health excellence/December 2022
Praxis No. 7 - Paris-Saclay, a player in the energy transition/March 2023
Praxis No. 8 - Paris-Saclay, leader in digital technologies/May 2023

PARIS-SACLAY

**Établissement public d'aménagement Paris-Saclay**
6 boulevard Dubreuil
91400 Orsay
+33 (0)1 64 54 36 50
contact@oin-paris-saclay.fr

**www.epa-paris-saclay.fr**
**www.paris-saclay.business**
a programme: Paris-Saclay TV on TV78

facebook.com/ParisSaclay
@parisSaclay
paris_saclay
Établissement public d'aménagement Paris-Saclay
youtube.com/ParisSaclay
Paris-Saclay Innovation Playground
inno_playground

Editorial
**La mécanique du sens**

Conduct and preparation of interviews
**Sylvain Allemand**

Graphic design
**La mécanique du sens**

Print
**CIA Graphic**

Print run: 1,500 copies
2023