THE GOVERNMENT
OF THE GRAND DUCHY OF LUXEMBOURG
Ministry of the Economy

LUXEMBOURG
SPACE AGENCY

NATIONAL ACTION PLAN
2020 - 2024

SPACE SCIENCE AND TECHNOLOGY

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INTRODUCTION

The National Action Plan for Space Science and Technology originated in 2005, soon after Luxembourg joined the European Space Agency (ESA).

This first official version of the Action Plan was endorsed by the Government in 2008. It was then revised in 2012 and 2016, as part of preparations for the ESA Ministerial Council meetings held in Naples and Lucerne.

The strategic objectives as originally stated remain unchanged:

- contribute to the diversification and sustainability of economic activities in Luxembourg;
- consolidate and enhance existing skills and expertise in media and satellite communications services;
- strengthen the competitiveness of companies and public research organisations in the space sector;
- develop skills and expertise in the space sector and enhance the integration of Luxembourg players in international networks.

In addition, as part of the Space-Resources.lu initiative, **a specific national strategy** has been developed and implemented since 2016, by the Ministry of the Economy.

It is important to note that the **National Action Plan** for Space Science and Technology only covers activities related to the SpaceResources.lu initiative implemented as part of ESA. This includes ESA programmes, or those falling within the scope of the LuxIMPULSE national programme. All other activities fall within the remit of the Luxembourg Space Agency (LSA).

While the LSA is now an integral part of the Ministry of the Economy, the plan is for the agency to become a legal entity in its own right, as stated in the most recent government programme.

There have been several major events since the last version of the action plan in 2016.

First, the Luxembourg Space Agency was founded in September 2018. The agency's duties and responsibilities are consistent with the space policy set out above. The main objective being to develop Luxembourg's space ecosystem, with the aim of facilitating the diversification of the national economy.

The next event was the appointment of a new chair to ESA's Ministerial Council in Seville. On 27 and 28 November 2019, a Franco-Portuguese Co-Chair was elected for a period of 3 years.

Lastly, the preparation of the next Multi-annual Financial Framework of the European Union ended with a partial agreement on the implementation of a European Union space programme.

GNSS and Copernicus remain the core components of the EU space programme and will be supplemented by two new components: **the space surveillance and tracking system (SST) and the governmental satellite communications service (GOVSATCOM)**. The total budget earmarked for the purpose amounts to around 16 billion euros.

The European Union is playing an increasingly important role in the space sector, and Luxembourg's involvement in these initiatives promises to provide new opportunities for Luxembourg businesses in the future.

ACHIEVEMENTS SINCE 2016

At the ESA Ministerial Council meeting in Lucerne in 2016, Luxembourg made new financial commitments to ESA programmes, agreeing a total contribution of 123.5 million euros to the mandatory and optional programmes proposed at the time.

Luxembourg also earmarked 115 million euros for the LuxIMPULSE national programme, implemented through ESA.

Unfortunately, following the Lucerne discussions, the Asteroid Impact Mission (AIM) Programme did not materialise due to a lack of financial resources. As a result, Luxembourg's planned 15 million euros contribution to the programme was not used.

Generally speaking, the financial resources invested in ESA programmes have helped to support research and development projects focused on new technologies, services and applications. It has also aided the development of products and components for future space infrastructure, several examples of which are given below.

For the SpaceResources.lu initiative, announced by Minister Étienne Schneider on 3 February 2016, a number of actions have been undertaken at political, legal and regulatory levels. Work has also been done in research and higher education, alongside economic and financial efforts.

SPACE RESOURCES INITIATIVE RESULTS **2016 - 2020**

Key results from the last four years include:

- Creation of an "Advisory Board on Space Resources."
- Organisation of several specialist conferences in Luxembourg (e.g. "Mining Space Summit" and "Space Resources Week").
- Signing of many agreements with other countries (USA, China, Japan, the United Arab Emirates, Belgium, Poland, Czech Republic, Portugal, Australia/New South Wales).
- Signing of agreements with globally recognised organisations such as ESA, NASA, DLR and EIB.
- Adoption of the Law on the Exploration and Use of Space Resources.
- Active involvement in "The Hague International Space Resources Governance Working Group" and on the United Nations Committee on the Peaceful Uses of Outer Space.
- Launch of an "Interdisciplinary Space Master" at the University of Luxembourg, incorporating classes related to space resources.
- Signing of agreements with numerous companies for the development of economic activities in Luxembourg.
- Launch of various research and development projects with companies and public laboratories.

The SpaceResources.lu strategy is built on the following five pillars:

1
To ensure national political support and promote international cooperation

2
To build an attractive legal and regulatory framework

3
To promote long-term development by supporting public research and education

4
To offer dedicated support for private sector research and development activities

5
To develop long-term financial instruments tailored to the needs of private companies

As a reminder, the aim of Space-Resources.lu is to promote the peaceful exploration and sustainable utilisation of space resources. The initiative aims to put in place a comprehensive ecosystem for the development of private economic activities related to the use of space resources.

In just a few years' time, the Grand Duchy of Luxembourg has become a key player on a global level, recognised for its ambition in the area of space resources utilisation.

Since the launch of the Luxembourg Space Agency, most of the actions planned as part of the Space-Resources.lu initiative have been implemented by the Agency, with the focus of such actions being not just space resources, but the space sector as a whole.

However, the SpaceResources.lu initiative remains a flagship programme for the Agency, and there are plans to implement actions specifically dedicated to the development of space resources. In particular, research and development projects with companies and public research laboratories will continue to be supported.

To further strengthen Luxembourg's standing in the areas of space resources, there are also plans to launch a "**European Space Resources Innovation Center**," in partnership with ESA.

The center will focus on the following activities:

- Research and development related to space resources
- Provision of dedicated testing facilities
- Business support and incubation
- Knowledge management
- Community management and organisation of specialised events

The center will facilitate a number of activities planned as part of the SpaceResources.lu initiative. It will also widen the scope of the project at the European and even global level. Other partners may join the center over the coming years.

It will also widen the scope of the initiative to a European and even global level.

The next chapter presents various projects to illustrate the range of activities implemented in recent years. The selected projects also demonstrate the impact on Luxembourg's space sector as a whole, as well as the new opportunities generated by participating in ESA programmes.

European Space Resources Innovation Center signing ceremony

ESA PROGRAMMES

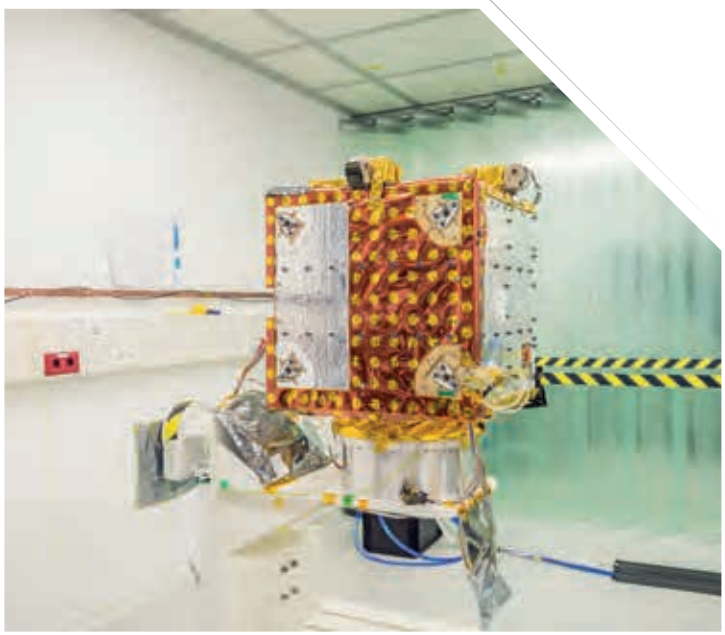
INFRASTRUCTURE PROGRAMMES

SAT-AIS (E-SAIL)

As part of this flagship programme for Luxembourg since 2012, **LuxSpace** – a Luxembourg satellite integrator – and **exactEarth** – a Canadian provider of Automated Identification System (AIS) services – have teamed up to develop a microsatellite (E-SAIL) with the aim of identifying and tracking ships around the world.

The satellite provides far better detection capabilities than its predecessors and is now ready to be delivered. Launch on the Vega rocket is scheduled for 2020. It will be the first satellite of this kind manufactured in Luxembourg.

Maritime surveillance microsatellite, ESAIL - LuxSpace



Govsatcom Precursor (PACIS-1)

Govsatcom Precursor has been a critical additional component in Luxembourg's strategy to establish itself in the field of government telecommunications. The project, involving SES and LuxGovSat, has resulted in the development of an innovative system for pooling and sharing secure satellite communication systems and services. In addition, SES provides institutional and commercial users with the option of conducting demonstrations of secure services. In this respect, SES will be performing pre-operational activities on the new secure functionalities and facilities. The project is scheduled to end in June 2020. It will enable SES and LuxGovSat to offer secure communication capabilities and services as part of the future EU GOVSATCOM programme.

ScyLight (QUARTZ)

ScyLight (QUARTZ)

ESA and a consortium led by SES are currently developing a system designed to enable the production of cryptographic keys in space and their secure transmission, by laser, to users on Earth. QUARTZ is a perfect illustration of the potential of collaboration between scientific research and private sector requirements, with the support of the ScyLight programme, to develop future applications. The preliminary design review has been finalised. Completion of the project (including the demonstration phase) is scheduled for June 2021.

The project will enable SES to offer encryption capabilities as part of the **European Union's Quantum Communication Infrastructure (QCI) programme**.

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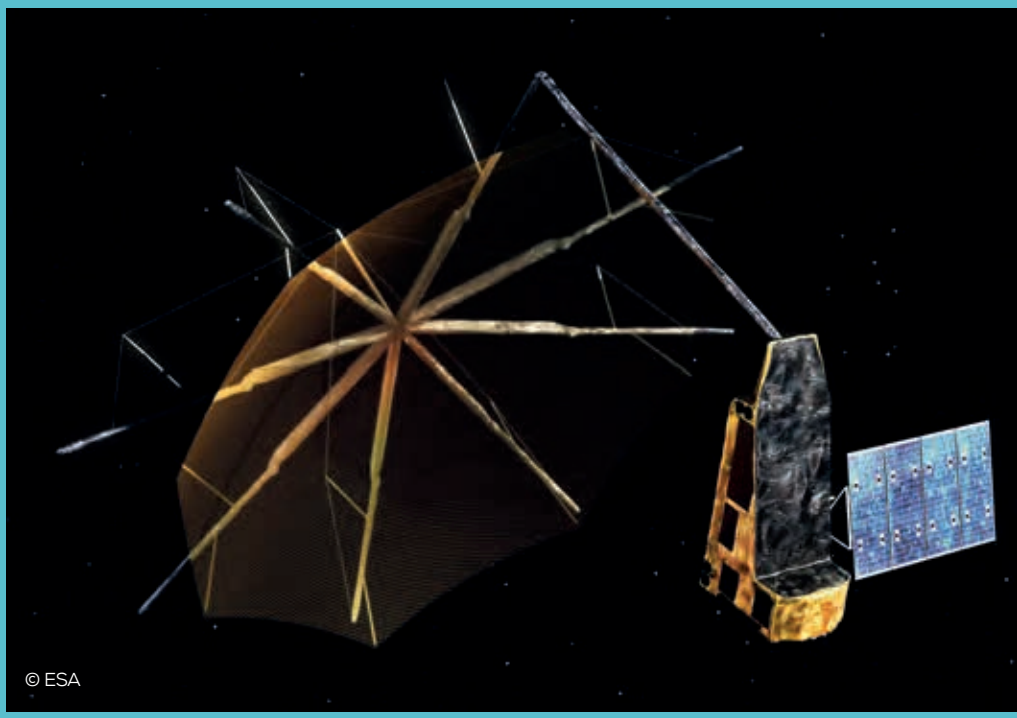
EOEP - BIOMASS

Selected as ESA's seventh Earth explorer mission in May 2013, the Biomass mission will provide crucial information about the state of our forests and how they are changing. The data will improve our knowledge of the role forests play in the carbon cycle. A European consortium with significant experience in this area has been set up, which includes **HITEC Luxembourg** who is developing and calibrating in-situ transponders.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Small Geostationary Satellite (SGEO)

SGEO is an ESA programme aimed at developing the new generation of small telecommunications satellite platforms for geostationary orbit. SGEO was successfully launched in January 2017. LuxSpace was involved in the consortium to design the on-board communication subsystem (TT&R) and to develop the mission simulator. On the back of these achievements, LuxSpace recently signed two commercial contracts related to German satellite projects.

TECHNOLOGICAL DEVELOPMENT SUPPORT PROGRAMME

Blackcoating

The materials department of the **Luxembourg Institute of Science and Technology (LIST)** is working on the development of a "blackcoat." This type of coating includes among its properties, the capacity to completely absorb light and thereby avoid parasitic light. One of the main applications will be telescopes, the aim being to improve the clarity of images. Compared to existing technologies, the LIST technology can be used to apply the coating to surfaces as curved as screw pitches. The effectiveness of the technology has been demonstrated through ESA's GSTP Programmes. The next stage will be industrialisation. One of the partners and likely future client is a major player in the space sector: **Thales Alenia Space**.

NATIONAL PROGRAMME

In 2009, Luxembourg entered into an agreement with ESA to handle the technical and contractual management of the **LuxIMPULSE programme**, the aim of which is to develop technologies, undertake market research and study new concepts. This is a critical step, taken at a national level, to prepare Luxembourg's operators for competition on the international stage.

The LuxIMPULSE programme has also proved very useful in putting in place partnerships with major European contractors. In particular, the projects carried out with **Thales Alenia Space** have helped to establish **Euro-Composites, GRADEL and HITEC Luxembourg** as future suppliers.

The following paragraphs describe a number of flagship projects carried out with Luxembourg companies.

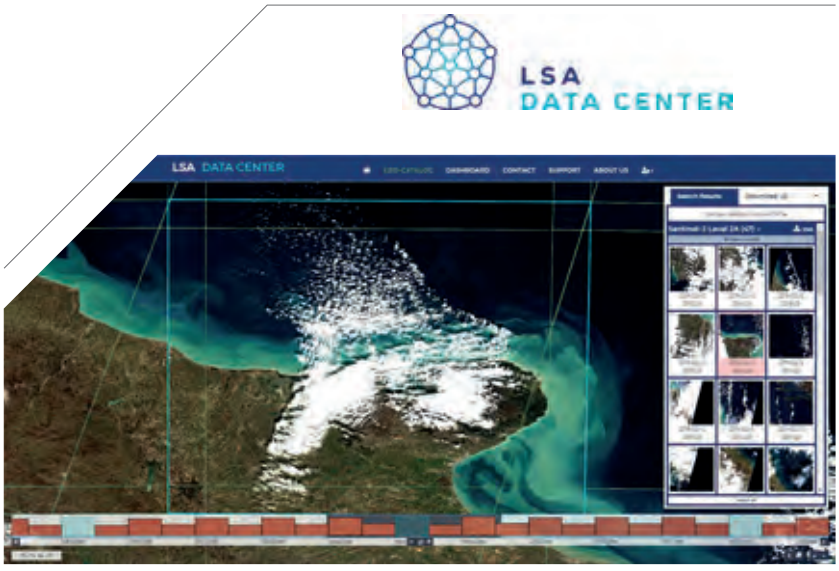
EarthLab Luxembourg - Max-ICS Platform

The initial aim of **EarthLab Luxembourg** was to establish a portfolio of services based, among other things, on Earth observation space data, for the insurance market (natural and industrial risk management). Thanks to the support of the national programme, not only has this goal been achieved, but new expertise, and therefore new services, have also been developed in the area of artificial intelligence.

LSA Data Center

The **LSA Data Center** is a key component of the Luxembourg Space Agency, aimed at facilitating access to Copernicus space data. Developed as part of the national programme by a Luxembourg consortium led by **adwaïsEO**, the Center provides fast and reliable access to data flows from the Sentinel satellites of the **European Earth Observation Programme**.

Following its recent launch, the Center is attracting significant interest from both institutional and commercial bodies. In particular, it will enable Luxembourg government agencies to meet their obligations under European regulations such as the Common Agricultural Policy.



KLEOS Space

Kleos Space provides geolocation services and develops space infrastructure for geo-intelligence applications. Current developments in this area relate to the manufacture in space of composite materials equipped with antennas. As part of its work in this area, Kleos Space is collaborating with **EmTronix**, a Luxembourg company specialising in the development of electronics, and with the **Luxembourg Institute of Science and Technology (LIST)**. The project is currently underway, and the initial results have been encouraging for future institutional and commercial activities. Their first satellite will be launched in 2020.

KLEOS Space

© Kleos Space

SKILLS DEVELOPMENT

Developing the skills and expertise of our current and future workforce is a cornerstone of the development strategy for the space sector, and of the SpaceResources.lu initiative in particular.

This will require the promotion of scientific and technical careers among future generations of students, whether at primary, secondary, university or post-university level.

Education is a key area of investment because of its critical importance to the industry's competitiveness and the development of the future workforce that Luxembourg's space strategy requires.

That is why, in June 2018, Luxembourg announced the creation of a **Luxembourg European Space Education Resources Office (ESERO)**.

The Luxembourg Science Center acts as Luxembourg's ESERO, thus joining a network of around twenty ESA Member States already active in this area.

The initiative uses the significant interest in space, as well as the richness of the topic, to offer an innovative take on teaching and learning in Science, Technology, Engineering and Mathematics (STEM) subjects.

The project is aimed specifically at primary and secondary school teachers, and its activities are structured around three key areas: teaching and learning resources, school projects and teacher training.

The ESERO programme provides content and activities that align with current teaching and learning methods in primary and secondary schools. The teaching and learning materials developed enable teachers to make STEM classes interesting, interactive and attractive.

Since the launch of the project, more than 260 teachers and 110 future teachers have taken advantage of the project's learning resources.

ESERO has also developed a wide range of teaching and learning resources, 16 of which have been translated into German and 15 into French. The resources were recently presented to the teaching community during training sessions.

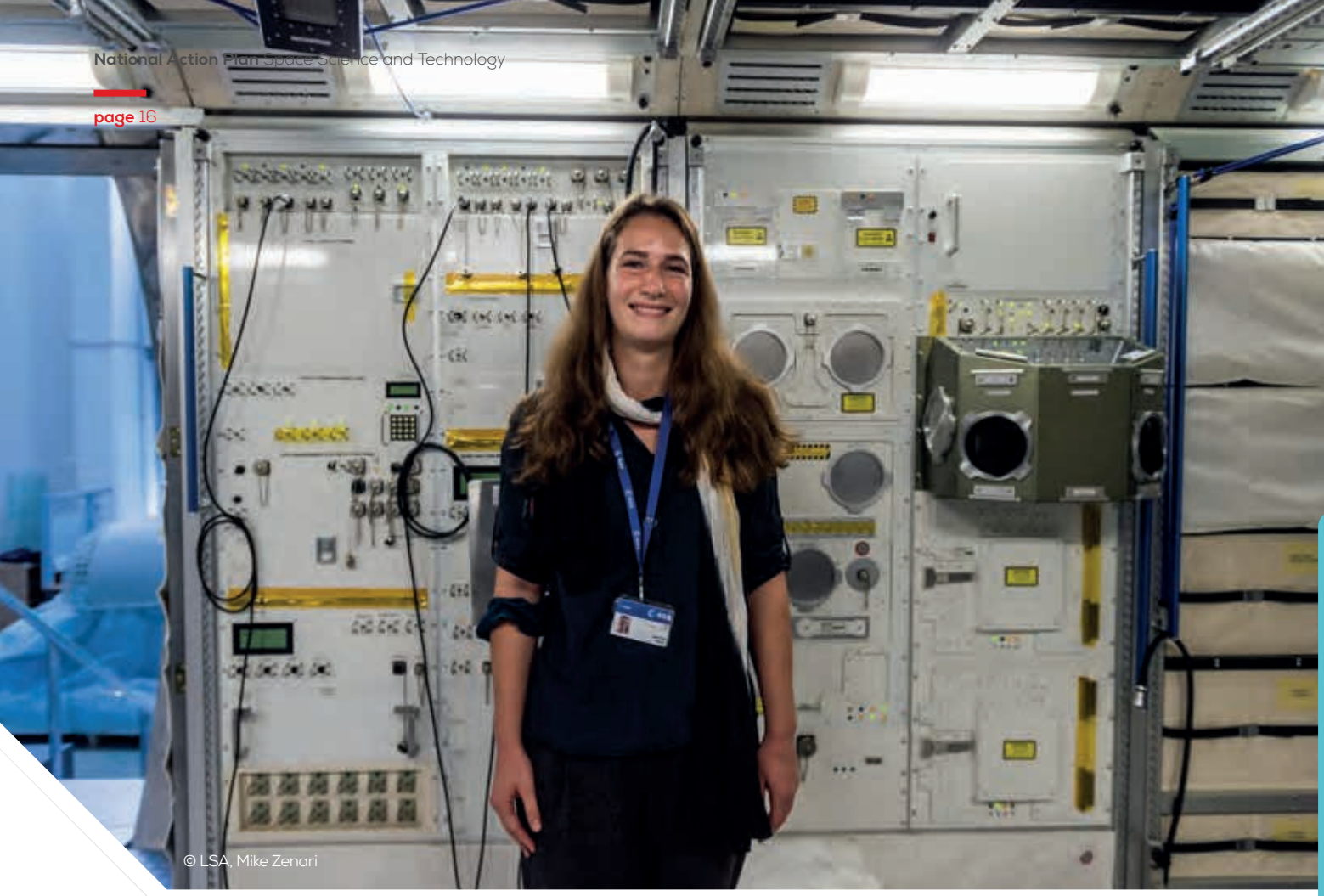
Alongside the ESERO initiative, the LSA is also supporting the **Luxembourg Tech School (LTS)**, an extra-curricular initiative aimed at students aged 15-19.

Launched in 2016, the initiative is a collaborative project between the *Service des médias et des communications du Ministère d'État* (SMC), the *Service de Coordination de la Recherche et de l'Innovation pédagogiques et technologiques* (SCRIPT), the IT service provider CGI, and the LSA.

LTS projects are offered to the Lycée Michel-Rodange high school, the Athénée de Luxembourg, the Lycée Aline Mayrisch, the Lycée des Arts et Métiers, the European School, the Lycée des Gargons in Esch, the Lycée Josy Barthel in Mamer and the Lycée Edward Steichen in Clervaux.

The aim of the initiative is to help students develop their skills and ideas through practical learning activities, based on projects in areas such as new technologies, Big Data, artificial intelligence and space.

A dedicated 12-week module on



Marthe Faber, LuxYGT

space resources has been developed. It includes topics ranging from the basics of space exploration to robotics, including mission planning and the design of spacecraft and small moon robots.

Students attend a series of practical sessions to learn about the basics of certain technologies with a view to subsequently applying their knowledge to a specific project.

At the university level, the LSA signed an agreement with the University of Luxembourg in September 2018 to put in place a specialist Masters programme, the **"Interdisciplinary Space Master" (ISM)**.

The aim of the ISM is to train talented individuals in Luxembourg and thereby support the development of the space sector. The course teaches the basic practical skills currently sought by space companies operating in Luxembourg, as well as key economic and entrepreneurial skills.

The ISM was launched at the start of the 2019/2020 academic year, and the first cohort consists of 12 students from 10 different countries. The complete course lasts two years and concludes with a thesis written as part of an internship in a company.

Financial support provided by the LSA will enable the university to recruit several professors in new areas and to set up specialist laboratories.

In the years to come, the LSA will continue to support the university to develop new expertise, with the aim of offering an internationally recognised programme.

For young graduates looking to gain professional experience in the space sector, Luxembourg has put in place the **Luxembourg Young Graduate Trainees (LuxYGT)** programme, which offers young graduates the chance to work at ESA for 2 years – a key foundation for training future recruits looking to work for businesses operating within the sector.

The programme enables young people to gain experience in the development and running of space missions by taking responsibility for the implementation of a practical project while also benefiting from the support of a tutor drawn from ESA staff.

allowing young graduates to gain experience which will be vital for their future career.

Each year, a call for applications is issued, with the average number of applications totalling around 12. At the end of the selection process, 4 or 5 candidates are offered a position at ESA.

Alongside the LuxYGT initiative, Luxembourg also takes part in the **Alpbach Summer School**. The summer school has been organised every year since 1975 by the Austrian Space Agency and is co-financed by ESA and its Member States. It has a long tradition in the area and enjoys an excellent reputation for science education and space technologies. Each year, 60 science and engineering students and graduates from ESA Member and Cooperating States are given the opportunity to attend the event. Over the course of ten days, participants attend conferences on various aspects of space science and technology, while working intensively on defining and designing a space mission under the supervision of scientific and technical experts.

8

Luxembourg currently has 8 young graduates working within ESA.

To provide young engineers and researchers with an opportunity to participate actively in the Summer School, the LSA has established a cooperation agreement with the Luxembourg National Research Fund aimed at doctoral and post-doctoral students. Since Masters students are also eligible to attend the Summer School, further cooperation has been agreed with the GLAE to ensure funding and the participation of Masters-level engineering students. Each year, two students from Luxembourg are given the opportunity to attend the summer school.

In cooperation with the Ministry of Education, the LSA has also organised an interdisciplinary competition called "Living and Working in Space". The aim of the competition was to encourage young people across all age groups to express their creativity and thereby promote interest in STEM subjects. The competition got underway with training sessions and practical workshops delivered to around forty teachers to support them in carrying out the project with their classes.

Over a period of five months, space became a key learning topic for more than 400 students. Students made full use of their creativity to build rockets, small lunar robots, a Martian base and a space station (among other creations). During Asteroid Day, students were invited to present their creations to the jury and astronauts attending the event.

Various **other events**, including the Makerfests, Science Week and the Cyber Security challenge, have been supported with a view to raising awareness of space careers among students.

LEGAL FRAMEWORK

Luxembourg is a signatory to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies and the Convention on the International Liability for Damage Caused by Space Objects. A system of concessions is in place for the authorisation of space activities.

A law on the use of space resources adopted in 2017 introduced an authorisation and supervision system in Luxembourg. The law is aimed at regulating the use of space resources and is the first legal framework of its kind in Europe.

A draft law on space activities was introduced in the Luxembourg Parliament in 2018 to strengthen the authorisation and supervision system prescribed by the international treaties to which Luxembourg is a party. Among other things, it provides for a national register of space objects. In addition, a draft law was also introduced on the accession of Luxembourg to the Convention on Registration of Objects Launched into Outer Space.

INTERNATIONAL COOPERATION

Luxembourg is keen to reaffirm its commitment to, and the necessity of, international cooperation in the space sector, especially regarding the exploration and use of space resources.

Since 2016, a number of bilateral agreements have been signed to this end:

- Memoranda of understanding with Japan (2017), Portugal (2017), the United Arab Emirates (2017), China (2018), Poland (2018), the Czech Republic (2018) and the United States of America (2019).
- A joint declaration with Belgium in 2019.

These agreements generally aim to express an intention to collaborate, which includes the exchange of information and expertise, a scientific and technological cooperation, and exchanges on legal matters related to the use of space resources. These agreements represent a first step in discussions between Luxembourg and other countries sharing the same vision. Common projects will be the subject of an implementation agreement specific to each activity.

As part of bilateral agreements, the LSA has also organised a number of workshops and meetings with representatives of partner countries, in order to share their respective policies and present the development of their sectors. The LSA also invites representatives of partner countries to events held in Luxembourg, such as the NewSpace Europe conference, Space Resources Week and the Space Forum.

The LSA has also ensured active involvement in various events and conferences abroad, such as International Space Exploration Forum (ISEF-2) in Tokyo and the International Astronautical Congress (IAC) in Adelaide in 2017, Bremen in 2018 and Washington in 2019. These events are an opportunity to strengthen international ties and forge new relationships.

In terms of governance and international relations, Luxembourg has been actively involved in international fora and communities to progress with a framework related to the exploration and use of space resources.

At the level of the United Nations, the question of space resources is handled by the **United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)** in Vienna, as a specific point on the agenda of its Legal Subcommittee.

Work is currently underway, and an increasing number of countries are expressing interest in establishing an international framework in the future.

At the Legal Subcommittee meeting held in April 2019, Luxembourg presented the SpaceResources.lu initiative and the vast opportunities related to the exploration and use of space resources.

Luxembourg is actively involved in the work of COPUOS on the 2030 Agenda for space, discussions on the guiding principles and long-term viability of space activities and various high-level fora.

Luxembourg has also been actively engaged in the work of the "Hague International Space Resources **Governance Working Group**" since it was set up in 2016.

The Group's aim is to develop building blocks which could provide a basis for a future international framework for the peaceful exploration and use of space resources. Luxembourg has provided financial support to the second phase of the Working Group in collaboration with the University of Luxembourg. This phase ended in November 2019 with a list of 20 "building blocks".

Luxembourg is actively involved in common projects with the European Union. As part of the "**Science meets Parliaments/Science meets regions" initiative**, the European Commission, the University of Luxembourg, the LSA and the LIST co-organised a conference entitled "Space solutions for sustainability on Earth."

Held at Luxembourg's Chamber of Deputies, the aim of the conference was to raise awareness of the use of data from the European Copernicus and Galileo space programmes to support environment policies.

Since 2019, the LSA has been a member of the **International Astronautical Federation (IAF)**, an organisation bringing together key academic, institutional and industrial players involved in the space sector. The association has 200 members from over 50 different countries. Each year, the IAF organises the International Astronautical Congress, one of the most important international congresses in the field. The most recent edition, held in Washington, was attended by nearly 6,000 delegates.

PROMOTION AND COMMUNICATION

Over the last three years, communication activities have intensified, focusing on the following strategic objectives:

- To establish Luxembourg as a European hub for the development of the commercial industry.
- To promote the space ecosystem and the entire value chain.
- To promote the SpaceResources.lu initiative internationally.
- To present the national space policy as well as the values of the Luxembourg Space Agency and of Luxembourg as a country.
- To inform about opportunities and needs within the industry, with the aim of developing the Grand Duchy's talent pool, especially its engineering, research and business capabilities, while supporting students at all levels, from primary school to young graduates and professionals.
- To promote the development of partnerships and an international approach by cooperating with other agencies such as ESA on communication relating to the space industry in both Luxembourg and Europe.

The commercial side of the space industry and the topic of space resources are gradually taking centre stage, resulting in constant coverage in the international media outlets. Luxembourg is widely viewed as a pioneer and as a reference in the field.

Media relations have given rise to coverage in international newspapers and on radio and television outlets including the *Financial Times*, the AFP, BBC 4 (Today), the BBC World Service, the *Wall Street Journal*, Reuters, the *New York Times*, *Les Échos, De Tijd* and *L'Écho*, to name but a few.

Key media events include national press conferences, on-site visits to ESA and space sector businesses with the press and numerous press conference.

During economic missions abroad, meetings with the press have been held with leading media organisations from countries including the United States, the United Kingdom, France, Belgium, Germany, China, South Korea and Japan.

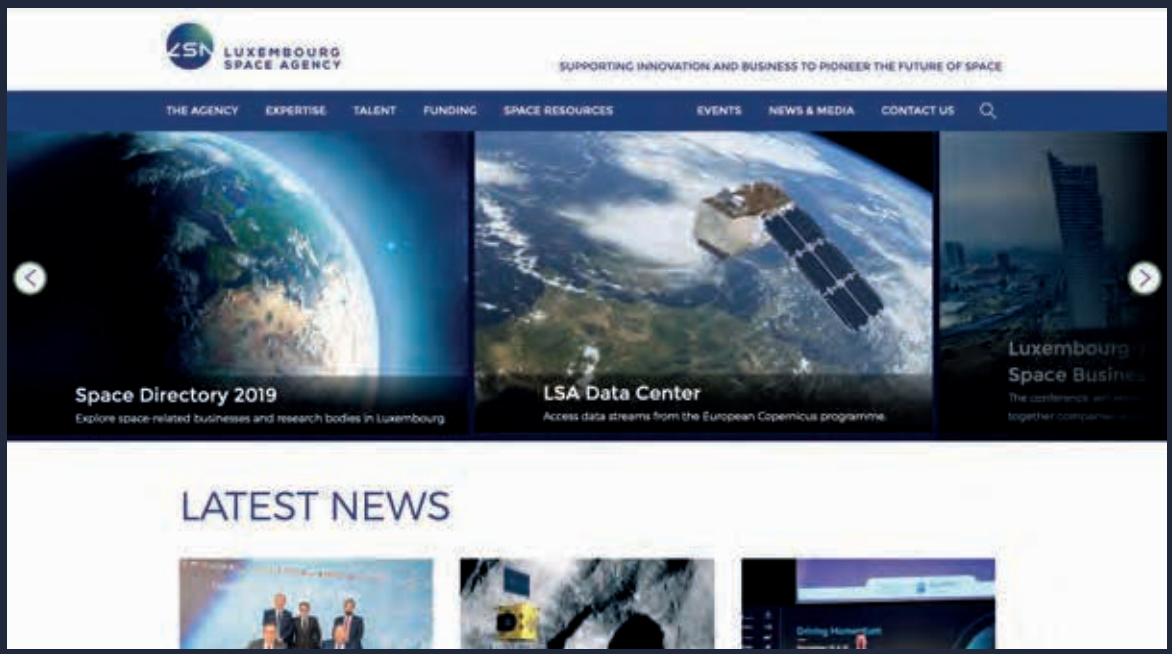
The brand of the Luxembourg Space Agency was presented as part of the launch of the agency in September 2018. The SpaceResources.lu brand will continue to be used and is now promoted by the LSA.

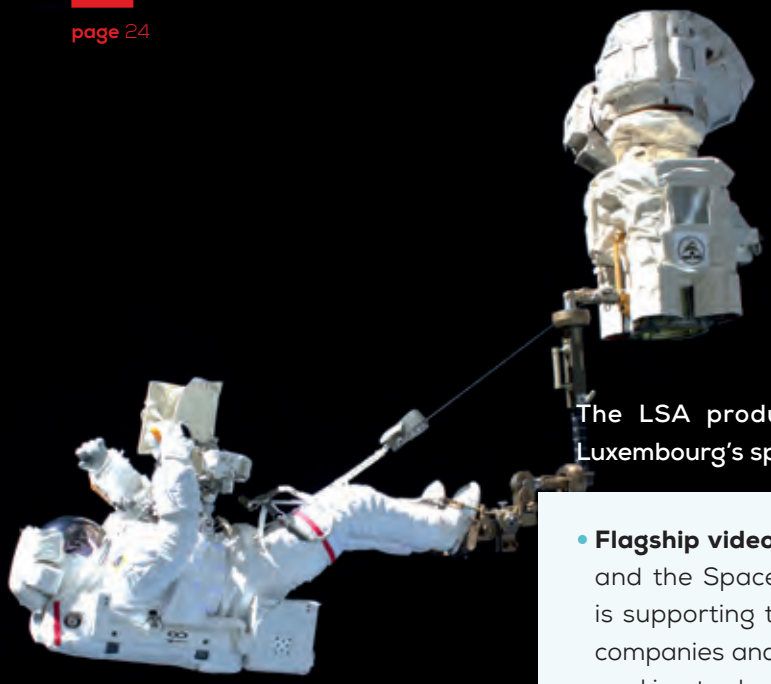
Each year, the LSA publishes the '**Space Directory**', which provides an up-to-date picture of Luxembourg's space industry.

The directory is designed to highlight the capabilities of Luxembourg's existing space industry. A digital version is available on the LSA's website. Most of the actors included have earned a reputation that extends beyond Luxembourg, their expertise being fully recognised by the international space community.

A year after the launch of the Luxembourg Space Agency, the SpaceResources.lu and space-agency.lu websites were merged. The agency's new website is a comprehensive reference point for anyone with an interest in Luxembourg's space sector.

The website contains digital content on the agency's mission, news, Luxembourg's space policy and legal framework, the 'Space Directory', education and training, and funding programmes. The new website also includes interviews with key players in the Luxembourg space sector and a calendar of events.





The LSA produces five kinds of videos aimed at promoting Luxembourg's space sector.

- **Flagship videos**: "Luxembourg, the place for space development" and the SpaceResources.lu launch video show how Luxembourg is supporting the future space economy. It presents Luxembourg companies and research centers operating in the space sector and working to develop tools and services aimed at understanding and addressing our future. Both videos offer an inspiring insight into the space resources initiative and Luxembourg's thriving space sector.
- **Face-to-face interviews with business leaders and experts**: The videos are published monthly along with articles on the LSA website.
- **How-it-works**: In this series, the LSA delves into the detail of the science and technology applied by companies operating in the space sector in Luxembourg.
- **Conference videos**: These present the main announcements and discussions from conferences organised by the LSA or in which it has taken part.
- **Animations**: An animation on space resources and the space resources value chain is currently in production.

The agency prioritises digital communication and disseminates a wide range of information on social media on a daily basis. The space agency is present on **Twitter, LinkedIn, Facebook, YouTube** and **Instagram**. The number of followers increases every month.

Lastly, the LSA organises many **conferences and events in Luxembourg** with the aim of raising awareness about Luxembourg's space sector. Key events include: **NewSpace Europe, Space Resources Week and Asteroid Day**. Representatives of the space agency have also taken part in space industry events in, among other places, the United States, the United Arab Emirates, Poland, the Czech Republic, France, Belgium, China, Japan, South Korea and Germany.

Visits by astronauts and international representatives also led to the organisation of a "**Space Talk**", held recently at Kinepolis.

DEVELOPMENT OF THE SECTOR SINCE 2016

Since the foundation of SES in 1985, the growth of the space sector in Luxembourg has been driven by key expertise in satellite telecommunications and media, along with the corresponding ground infrastructure.

The area remains in the lead, but is offset by the arrival of new actors operating in highly diverse areas ranging from Earth observation and, more specifically, geoinformation services, to the exploitation and use of space resources.

AISTECH LUXEMBOURG

Founded in 2017, Aistech Luxembourg is a subsidiary of Aistech Space focused primarily on Big Data, with the aim of providing services to decision-makers in business, government and other organisations using Earth observation data.

ANISOPRINT

Anisoprint is an SME founded in Luxembourg in 2018. The company designs and supplies equipment, software and 3D printing devices capable of producing optimised parts based on composite materials with high-performance physical and mechanical properties, for the space industry.

BLUE HORIZON

Co-founded in Luxembourg in 2017 by the OHB group and LuxSpace, Blue Horizon specialises in biotechnology and life sciences. The company focuses on the development of life support systems for space and terrestrial applications. These activities mainly take the form of the development of small and medium sized bioreactors.

DATABOURG

Founded as a startup in 2017, Databourg is a spin-off of the Interdisciplinary Centre for Security, Reliability and Trust of the University of Luxembourg. Operating in the downstream sector, Databourg provides value-added data. The company's core expertise involves locating the position of terminals on the ground and providing network diagnosis services to tele-communication satellite operators. Databourg has also developed algorithms capable of correlating the intensity of telecommunications satellite signals with weather conditions in distinct areas.

DEEP SPACE INDUSTRIES EUROPE – BRADFORD GROUP

Acquired by Bradford Space in 2018, the company's main aim is to develop small-satellite subsystems for exploration missions in "Deep Space", but also low-Earth orbit exploration. The approach is firmly Deep-Space oriented and geared towards the commercialisation of low-cost products to meet demand in an institutional, and above all, commercial market.

GOMSPACE LUXEMBOURG

GomSpace Luxembourg was founded in 2017 as a subsidiary of the GomSpace group, with the aim of developing an operations center for nanosatellites constellations. The Luxembourg entity also operates instruments on board its nanosatellites and is responsible for providing data distribution services to users and customers of GomSpace.

HYDROSAT

Hydrosat Europe is a subsidiary of Hydrosat Inc. in the United States and was founded in Luxembourg in 2018. The Luxembourg entity provides value-added Earth observation data for the agricultural and humanitarian sectors. The data it provides enable farmers to optimise irrigation and crop harvest cycles and to identify in advance the potential effects of drought in certain regions of the world.

ISPACE EUROPE

ispace Europe was founded as a result of the Space Resources. lu initiative launched in 2016. The Luxembourg company is a subsidiary of the Japanese entity, ispace Japan, operating in the field of lunar exploration. In Luxembourg, the company is focused, among other things, on developing software designed to plan lunar missions and the autonomous navigation system of the exploration rover to be used for lunar exploration missions. The collected data will be used to identify areas on the Moon which contain water in the form of ice and will subsequently be commercialised.

KLEOS SPACE

Kleos Space S.A. specialises in geo-intelligence using Earth observation technologies. By detecting signals originating from vast maritime areas, Kleos Space satellites are capable of geo-locating unidentified ships which would be undetectable using conventional identification tools. Kleos Space was founded in 2017.

MAANA ELECTRIC

Maana Electric is a startup dedicated to developing technologies designed for manufacturing solar panels using in-situ resources. The products developed by the company could be used in remote regions of the world and on the Moon, for the purpose of generating solar energy.

ispace Europe

MADE IN SPACE EUROPE

Made In Space Europe is a subsidiary of the US company Made in Space US. The company's goal is to develop and commercialise a robotic arm capable of being used for a wide range of space-related applications, such as the maintenance of orbiting satellites and the automated use of space resources. The Luxembourg entity of Made in Space was founded in 2018.

MOLECULAR PLASMA GROUP

Founded in 2016, Molecular Plasma Group (MPG) is a Luxembourg company that has developed coating solutions at the molecular level, capable of being applied to a wide range of surfaces and materials in ambient conditions. Treatment with this technology can be used to characterise the surface of an inert material and to achieve improvements such as anti-corrosion and hydrophobic characteristics. It can also improve the adhesive capacity of a surface, for the purpose of gluing together different materials.

3D printed human skin and bones, Blue Horizon, Luxembourg

ODYSSEUS SPACE

Odysseus Space was founded in Luxembourg in 2019 as a subsidiary of the company incorporated in Taiwan. The company has relocated its head office to Luxembourg. Its engineers develop optical telecommunication solutions for small satellites. Innovative technology developed by the company provides a wide range of benefits compared to conventional radio-frequency communication methods. The telecommunication equipment developed by Odysseus Space applies above all to satellite communications from "Deep Space".

OFFWORLD

Founded in 2016, OffWorld is a subsidiary of OffWorld Inc, which is currently at the prototype stage of development with its first mining robots. The Luxembourg entity is committed to developing a fleet of robots for mining purposes, in space. Working with minimal human supervision, the robots tasks could include the extraction and production of fuel.

OQ TECHNOLOGY

Founded in 2017, this startup has the commercial aim of supplying the world with the first universal, Plug & Play IoT. OQ Technology seeks to develop and use a low-cost satellite infrastructure to connect sensors, devices and units of measurement in remote and largely off grid regions with limited mobile or Wi-Fi coverage.

RSS-HYDRO

RSS-Hydro is a Luxembourg startup working to develop remote sensing methods for identifying flood risk areas. The flood maps developed by the company take into account topologies and weather conditions in near real time, providing numerous benefits compared to conventional maps. These services represent a major asset for the insurance industry. The company was founded in 2017.

SKYFLOX

Skyflox has been operating in Luxembourg since 2018. The company has developed Earth observation technology capable of being fitted on board airliners with the aim of providing high-resolution observation data with a high revisit rate.

SPARC INDUSTRIES

Founded in 2017, SPARC Industries is a startup which provides R&D services for all institutional and commercial applications of plasma physics. This includes the development of simulation tools as well as the development of a new plasma thruster. SPARC Industries targets both the space and terrestrial markets with the potential to require gas and plasma flow simulation services and maintenance services for neutron generators.

SPIRE GLOBAL LUXEMBOURG

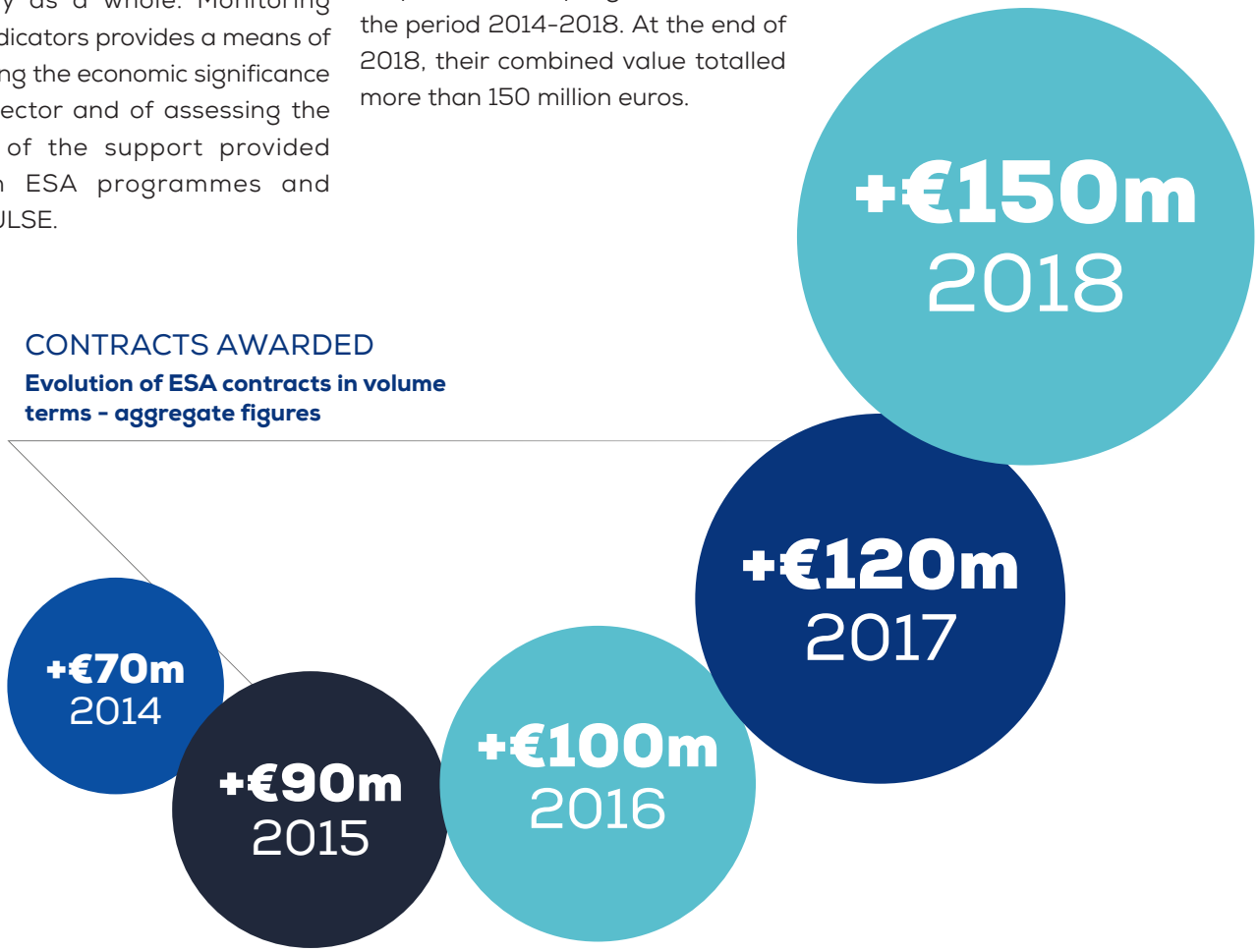
Founded in 2018, Spire Global Luxembourg specialises in the predictive analysis of satellite data used to tackle problems in the air, weather and maritime fields. In particular, Spire Luxembourg focuses its work and activities on the growth market of Big Data for maritime applications and weather forecasting.

IMPACT ASSESSMENT

It is important to be able to measure the impact of previously described supporting actions on Luxembourg's space industry. For this, the LSA has a monitoring system in place, capturing indicators such as turnover, employment and the size of the space sector relative to the economy as a whole. Monitoring these indicators provides a means of evaluating the economic significance of the sector and of assessing the impact of the support provided through ESA programmes and LuxIMPULSE.

As part of the impact assessment, we also examine the financial impact of ESA programmes on Luxembourg companies.

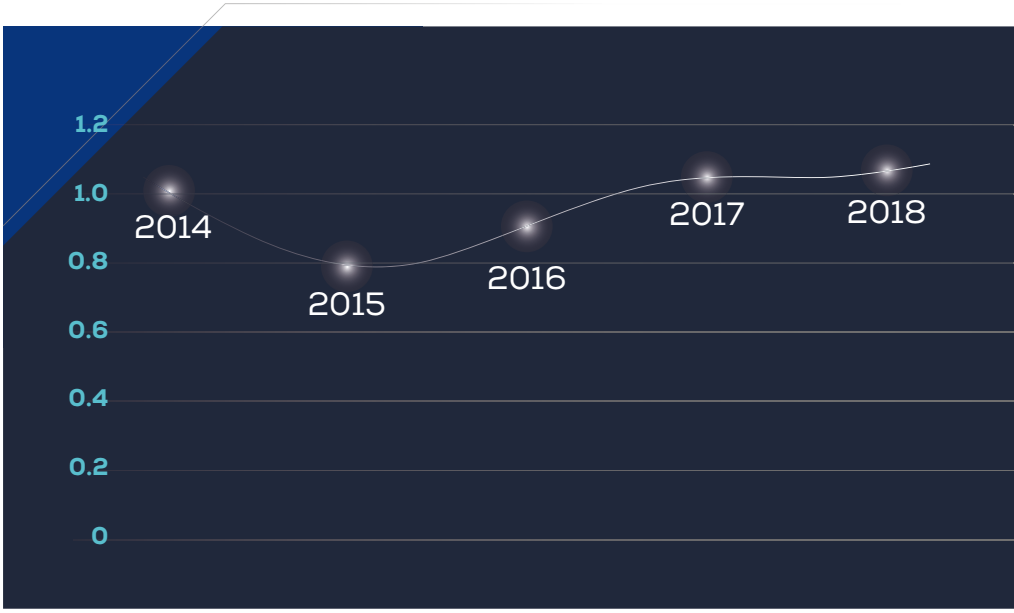
The graph below shows the aggregate value of contracts awarded to Luxembourg companies as part of ESA programmes over the period 2014-2018. At the end of 2018, their combined value totalled more than 150 million euros.



GEOGRAPHICAL RETURN COEFFICIENT

Evolution of Luxembourg's geographical return coefficient

Geographical return is also a useful indicator for monitoring the use of Luxembourg's financial resources in ESA programmes. ESA collects all relevant data relating to contracts awarded to companies and research laboratories in Member States with the aim of compiling statistics.



The agency calculates the coefficient over a limited period of time and produces its statistics on a cyclical basis. The last period began in 2000, at a time when Luxembourg had a cooperation agreement in place on telecommunications programmes but was not yet a full-fledged member. The statistics run up to 31 December 2014.

Since 1st January 2015, a new geographical return coefficient has been calculated, based on the contracts awarded from that date onwards. The coefficient has been increasing constantly since 2015, which is a positive, and since 2017 it has again exceeded the threshold of 1. This upward trend was confirmed in 2019, with the initial figures indicating a geographical return coefficient of 1.04.

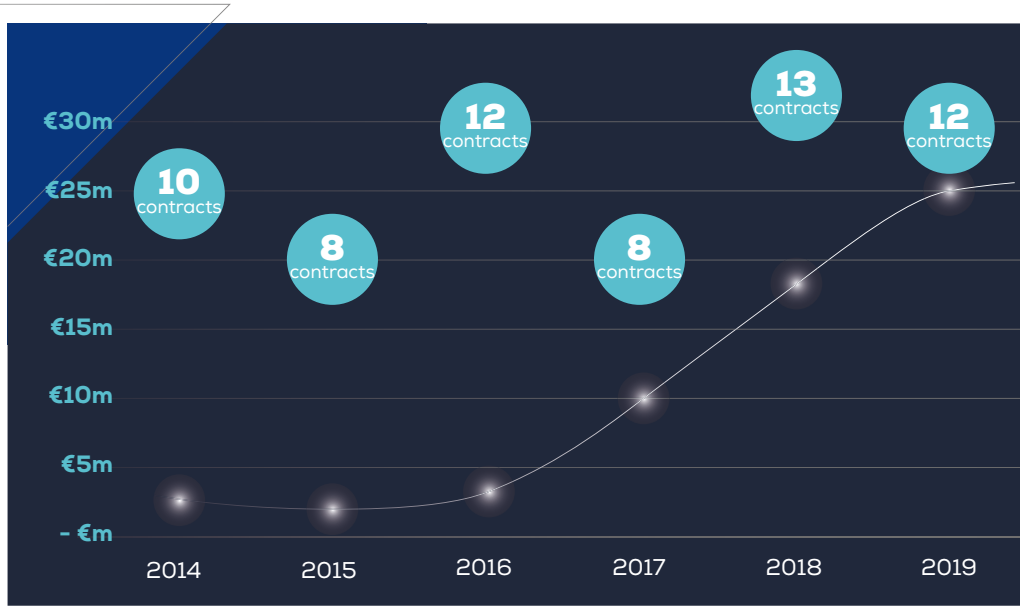
Besides the contracts awarded as part of ESA's Optional Programmes, Luxembourg operators also benefit from the LuxIMPULSE national programme.

The figure below shows that the LuxIMPULSE programme grew significantly between 2014 and 2018, with the total value of contracts coming to more than 18 million euros in 2018, compared to just 3 million euros in 2014.

The number of contracts signed has remained relatively stable (8 to 13 projects annually), meaning that the value of individual contracts is growing and becoming increasingly significant.

LuxIMPULSE

Evolution of the number of projects and of the value of contracts awarded to companies through the LuxIMPULSE programme



In order to provide a more accurate assessment of socioeconomic impacts than the financial data set out above, data on companies operating in the sector were also collected with the aim of defining key indicators such as the number of operators within the sector, the number of jobs and the gross value added. The collected data show that the number of companies operating in the sector doubled between 2012 and 2018, notably as a result of the emergence of many new companies between 2016 and 2017.

The total number of jobs in the sector rose from 639 to nearly 840 over the same period. It is important to note that these figures do not include jobs at the LIST public research center or the University. In employment terms, this represents a 31.6% increase.

While SES remains the largest employer, the number of staff in other companies within the sector almost doubled over the period 2016-2018, reaching a total of more than 270 jobs.

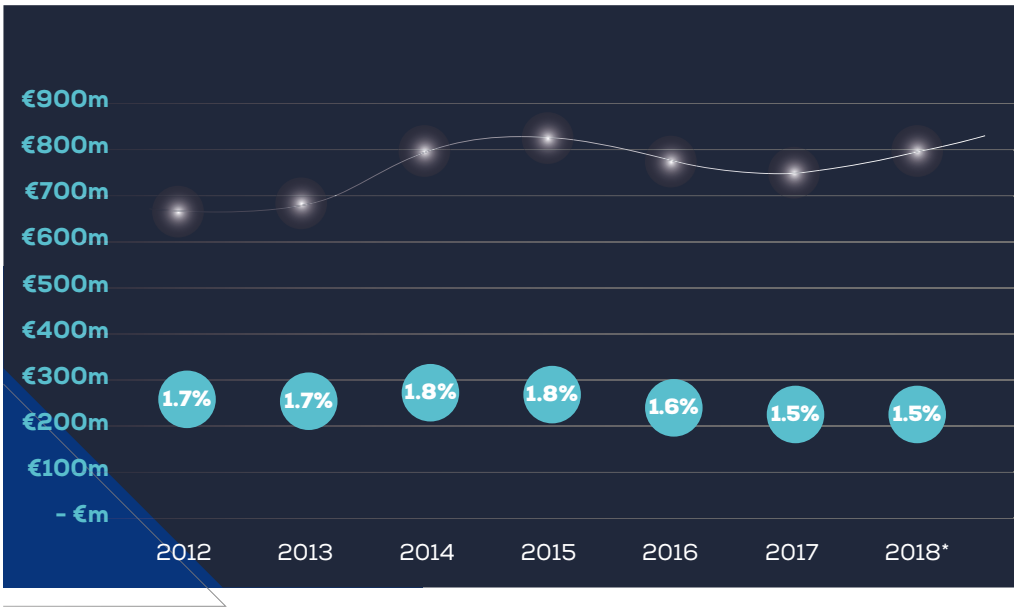
KEY FIGURES

	2012	2013	2014	2015	2016	2017	2018*
Number of companies	16 0.1%	18 0.1%	18 0.1%	19 0.1%	22 0.1%	30 0.1%	32 0.1%
Number of employees	639 0.2%	634 0.2%	598 0.2%	618 0.2%	648 0.2%	723 0.2%	840 0.2%
Value added at factor cost	670.8 1.7%	694.8 1.7%	803.3 1.8%	823.3 1.8%	777.7 1.6%	753.8 1.5%	800.8 1.5%

**preliminary figures*

Source : Calculations by the Competitiveness Observatory and ESA on the basis of data obtained from a questionnaire submitted to companies and data filed with the Trade and Companies Register (RCS-LBR).

In 2018, the space sector generated over 800 million euros of gross value added, representing nearly 1.5% of the country's total gross added value. Gross value added increased by 21.7% in absolute terms between 2012 and 2018, although its share in the total economy (% of total gross value added) fell slightly, particularly following the growth in GDP (total economy), which is increasing more rapidly than the gross value added generated by the space sector.



PROPOSALS FOR THE FUTURE

The proposals set out in this chapter have been compiled from the results of several inputs. The first are regular exchanges with ESA services to identify potential opportunities for operators in the Luxembourg space sector.

Further consultations have been undertaken to determine the necessary levels of investment. This has taken two main forms:

(i) the "*Groupement luxembourgeois de l'aéronautique et de l'espace*" (GLAE) recently issued a "position paper" providing a consolidated view of the group's members.

(ii) one-to-one interviews with major players have served to further refine this information.

A more detailed description of the programmes referred to below can be found in the appendix.

ACTIVITIES PROPOSED WITHIN ESA

The proposed contribution to ESA programmes is based, on the one hand, on the need to ensure the continuity of the programmes in which Luxembourg is already involved and, on the other, on the interest of Luxembourg operators in taking part in new programmes, to consolidate existing expertise but also, and above all, to develop new expertise.

ESA programmes are classified under four main programmatic pillars:

The same classification is used in the following pages.

SCIENCE AND EXPLORATION

Human and robotic exploration programme

ESA's envelope programme (E3P) addresses both human and robotic exploration.

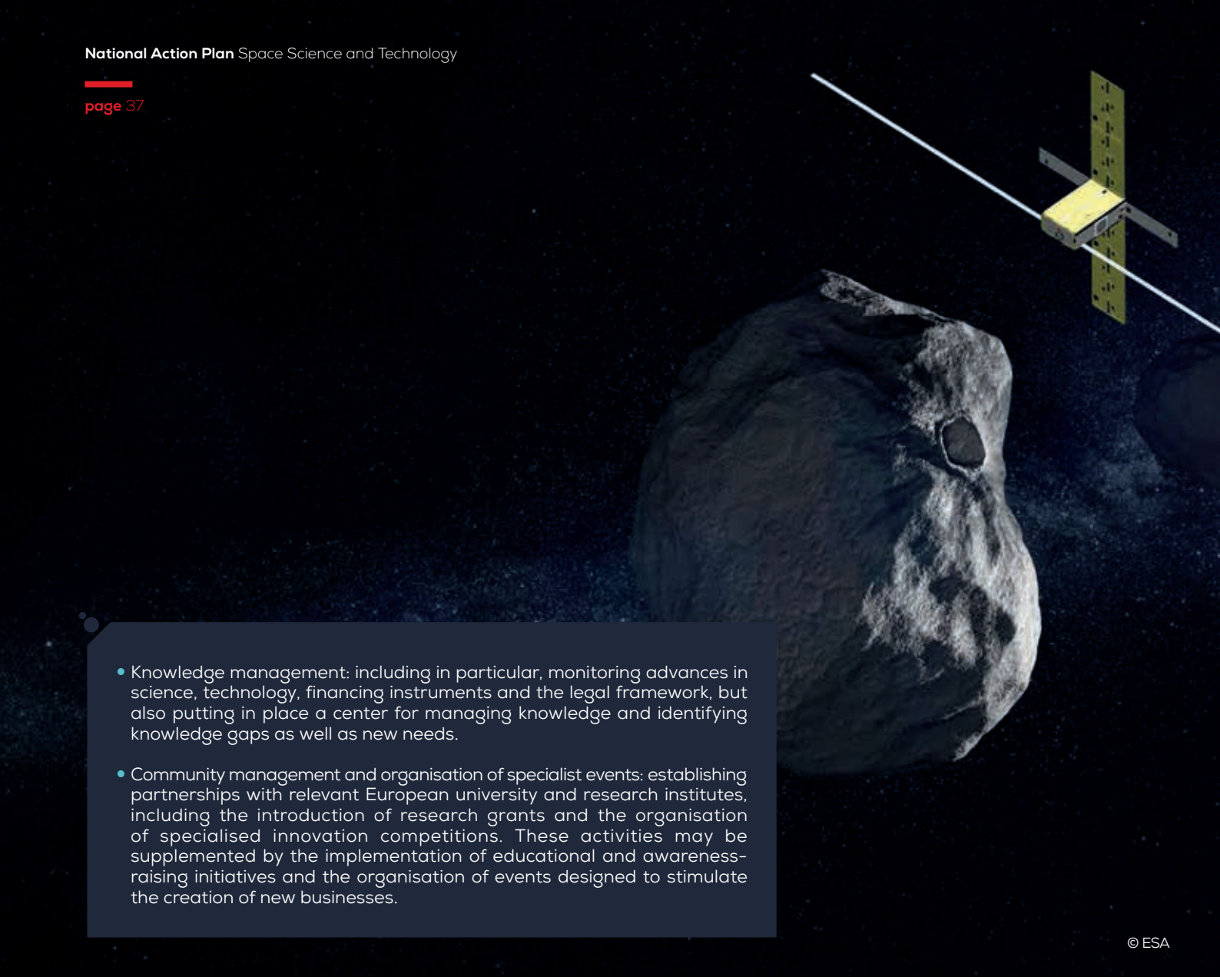
Luxembourg joined the programme with a particular focus on the development of lunar activities. This will support the SpaceResources.lu initiative and associate ESA with it.

For the space resources component, the E3P programme includes the following objectives:

- Enhance the potential of space resources, stimulate sustainable space exploration and identify the main resources.
- Create new scientific and economic opportunities for European industry and universities.
- Generate technological advances and innovation for sustainable activities in space and also on Earth.
- Involve new industrial players.
- Establish ESA's role as a member of the wider community of international actors, both public and private, and to create new international and commercial partnerships.

In addition, and in order to enhance Luxembourg's standing in this area, there are plans to launch a "**European Space Resources Innovation Center**" in partnership with ESA. The center will be dedicated to the following activities:

- Research: includes research and development activities and the advancement of technologies used across the entire value chain of space resources. The aim is to advance in-situ use of resources for long-term exploratory missions.
- Business support and incubation: includes evaluating the value chain of space resources, mapping and identifying key players at the European and global levels, conducting economic and market research and the creation of new partnerships aimed primarily at the non-space industry.



- Knowledge management: including in particular, monitoring advances in science, technology, financing instruments and the legal framework, but also putting in place a center for managing knowledge and identifying knowledge gaps as well as new needs.
- Community management and organisation of specialist events: establishing partnerships with relevant European university and research institutes, including the introduction of research grants and the organisation of specialised innovation competitions. These activities may be supplemented by the implementation of educational and awareness-raising initiatives and the organisation of events designed to stimulate the creation of new businesses.

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The European Space Resources Innovation Center will provide a base for pursuing a range of activities falling within the scope of the SpaceResources.lu initiative, while also adding a broader dimension with expansion at the European and even global level. Discussions with ESA are at an advanced stage.

Contributions to the lunar component of the E3P programme and to the European Space Resources Innovation Center will help to support the research and development projects of Luxembourg companies and public research laboratories by including them in projects at the European level. Examples include **Blue Horizon**, who are developing biological infrastructures allowing sustainable life for long journeys in space, thereby generating economic benefits in the medium term as well as significant environmental benefits. For **ispace Europe**, the aim is to support the development of their services in the area of carrying capacity and payload operations to the Moon and beyond. And for **Maana Electric**, who plans to manufacture solar panels using lunar regolith with an immediate application on Earth, using sand.

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The contribution to the Human and Robotic Exploration Programme amounts to a total of €16 million.

Hera scan of "Didymoon"

SAFETY AND SECURITY

Space Safety Programme

The **Space Safety Programme** aims at protecting our planet and, mankind, along with our space and ground infrastructure, against threats from space.

The programme addresses space weather and planetary defence issues, together with problems related to space debris and protection of the space environment.

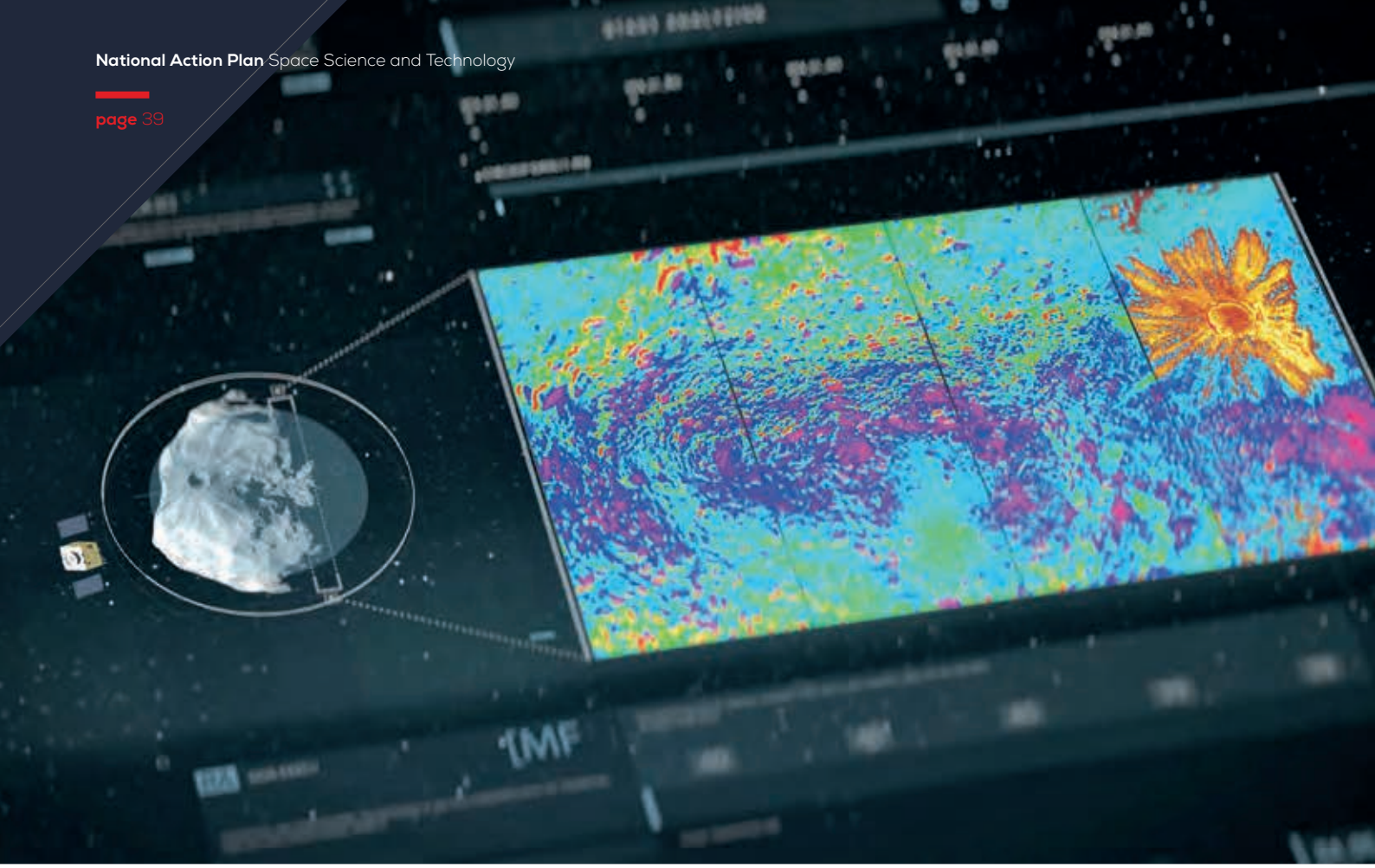
It is based around five key areas of activity: core activities required for each of the above tasks and four cornerstones (an operational space weather mission, a planetary defence mission, a space debris removal demonstration mission and, lastly, an automated collision avoidance system).

Luxembourg's interest in the programme is directly linked to its own programme dedicated to the exploration and utilisation of space resources. While the objectives of the programmes differ, there are synergies to be gained.

Whether in terms of planetary defence or the exploration and utilisation of space resources, we need to establish a catalogue of asteroids and other celestial bodies with a view not only to drawing up an inventory but also to describing their composition as accurately as possible. The degree of reliability in terms of composition matters for planetary defence since it will help to better predict the trajectory of near-Earth objects presenting a risk to our planet, and is also important for the SpaceResources.lu initiative since it helps to target asteroids of potential commercial value.

Therefore, there is a common interest in developing space observation means such as telescopes and Deep Space exploration missions. Both are targeted by the core activities for planetary defense on one hand and by the HERA planetary defense mission on the other hand.

This latter replaces the AIM mission that Luxembourg had supported during the ESA Council at Ministerial level in 2016 but had not materialised. The aim of the HERA mission is to characterise the binary asteroid Didymos after the impact of its Moon by the NASA's Double Asteroid Redirection Test (DART) mission.



During previous periods of the programme, some development activities for a Fly Eye telescope had been initialised with **HITEC Luxembourg** with the aim to contribute to a future European planetary defense system. Since then, the European Union decided on a component of its space programme dedicated to space surveillance and tracking including near Earth objects and therefore will become a major customer for this kind of infrastructure. It is therefore important to continue supporting these activities in ESA.

Our contribution to the **HERA mission** will relate specifically to the development of one of the two CubeSats (Juventas), which the mother ship will carry to Didymos. The Juventas spacecraft's mission will be to characterise the main asteroid and its Moon. This will enable us to develop our "Deep Space" expertise with **GomSpace Luxembourg** as well as expertise in low-frequency radar with **EmTroniX**. We will also benefit from the data acquired by Juventas as well as those obtained by the second CubeSat. The aim is to feed this data into the database of the European Space Resources Innovation Center.

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The contribution to this Space Safety Programme amounts to a total of €14 million.

APPLICATIONS

Earth Observation

The aim of the Earth Observation Programme is to maintain Europe's leadership in the surveillance of our planet's segment and to advance science and research in our understanding of our Earth as a system. It also seeks to create commercial opportunities in the downstream sector of geoinformation services. This second commercial objective of the programme continues to be the primary driver of our contribution. This is especially the case today as it is fully in line with the digital transition objectives, one of the Luxembourg's current top priorities.

The Earth Observation Programme's upcoming period includes plans to extend existing programmes and to launch new programmes or programme components.

Those of particular relevance to Luxembourg's strategy are:

- The Earth Observation Envelope Programme (FutureEO).
- The fourth segment of the Copernicus Space Component (CSC-4).
- The Global Development Assistance (GDA) Programme.
- The Incubed+ Programme.
- The Arctic Weather Satellite (AWS) Programme.

The **FutureEO** envelope programme aims to secure the research, development and innovation activities necessary to achieve the objectives of the European Earth observation strategy (EO EUROPE 2040). FutureEO prepares the future missions developed by ESA, including, in particular, the Earth Explorer, Sentinel and weather missions, and provides technological developments for the national and commercial missions of ESA Member States.

FutureEO also aims to develop innovative data access and data use services, to improve the understanding of the terrestrial system and to generate in particular impartial global information on climate change.

FutureEO incorporates new approaches such as artificial intelligence, small satellites, high-altitude platforms and big data analysis.

The programme is of particular interest to Luxembourg for several reasons. Although our involvement in research and operational missions remains limited, it will enable us to support the diversification of the activities of **HITEC Luxembourg** towards on-board equipment.

Above all, FutureEO is a suitable complement to the commercial applications line of the Telecommunications programme. It supports the development of the downstream sector of value-added geoinformation applications and services for companies such as **EarthLab Luxembourg**, **Hydrosat, space4environment** and **SPIRE**, as well as **LIST/ ERIN**. Beyond the products developed, the programme also promotes advances in the analysis of big data and the artificial intelligence techniques that such analysis requires.

In 2017, Luxembourg set up the **Luxembourg Space Agency Data Center**, with the aim of facilitating access to data that are essential to the development of the downstream sector. Today, this includes the data from the Copernicus Sentinel-1 and -2 satellites, although the Center intends to expand the current offering.

It is therefore vital to continue to have access to such data, but also to innovations in the matter of accessing Earth observation data and above all, to be a stakeholder in invitations to tender involving **adwaïsEO** on behalf of the Centre with the aim of promoting the latter.

The **Copernicus programme** aims to ensure the continuity of Earth observation capabilities through the Sentinel Next Generation missions and the High Priority Candidate missions.

This ESA programme involves developing the first units, with the subsequent units being funded in full by the European Union. Copernicus will therefore enable to establish some of our key operators, such as **adwaïsEO**, **LIST/ ERIN**, **LuxSpace** and **SES**, placing them well for contracts to produce recurring activities. Given the underlying economic impact, there is significant backing for the programme among Member States.

The **Global Development Assistance (GDA)** project aims to meet the geoinformation needs of international financial institutions with responsibility for development aid. By positioning Luxembourg on this element, we will be able to give greater visibility to our operators in this market segment, including **adwaïsEO**, **Blue Horizon**, **LIST/ERIN**, **space4environment** and **SPIRE**.

The **Arctic Weather Satellite (AWS)** programme will enable us to consolidate **GomSpace's** role as an operator of small satellite constellations.

Lastly, the **InCubed+** initiative – a continuation and extension of InCubed – is the component of the programme focused on commercial matters and therefore remains an attractive programme for our ecosystem as a driver of growth.

Telecommunications and Integrated Applications

The **Advanced Research in Telecommunications Systems (ARTES)** programme is of critical importance to Luxembourg.

Luxembourg's space sector developed out of the commercial satellite telecommunications industry of the '70s and '80s, and was driven by the success of SES. Today, SES remains a major player in the sector, and it is important to maintain the pace of innovation in order to keep and even increase the market share of space operators while facing competition from terrestrial network operators.

The ARTES programme is subdivided into strategic programme lines and generic programme lines.

The strategic lines are designed to meet the priorities of Participating States at the national and European levels:

- Space for 5G
- Space Systems for Safety and Security (4S)
- Optical Communication – ScyLight.

The generic lines are designed to address long-term objectives and are as follows:

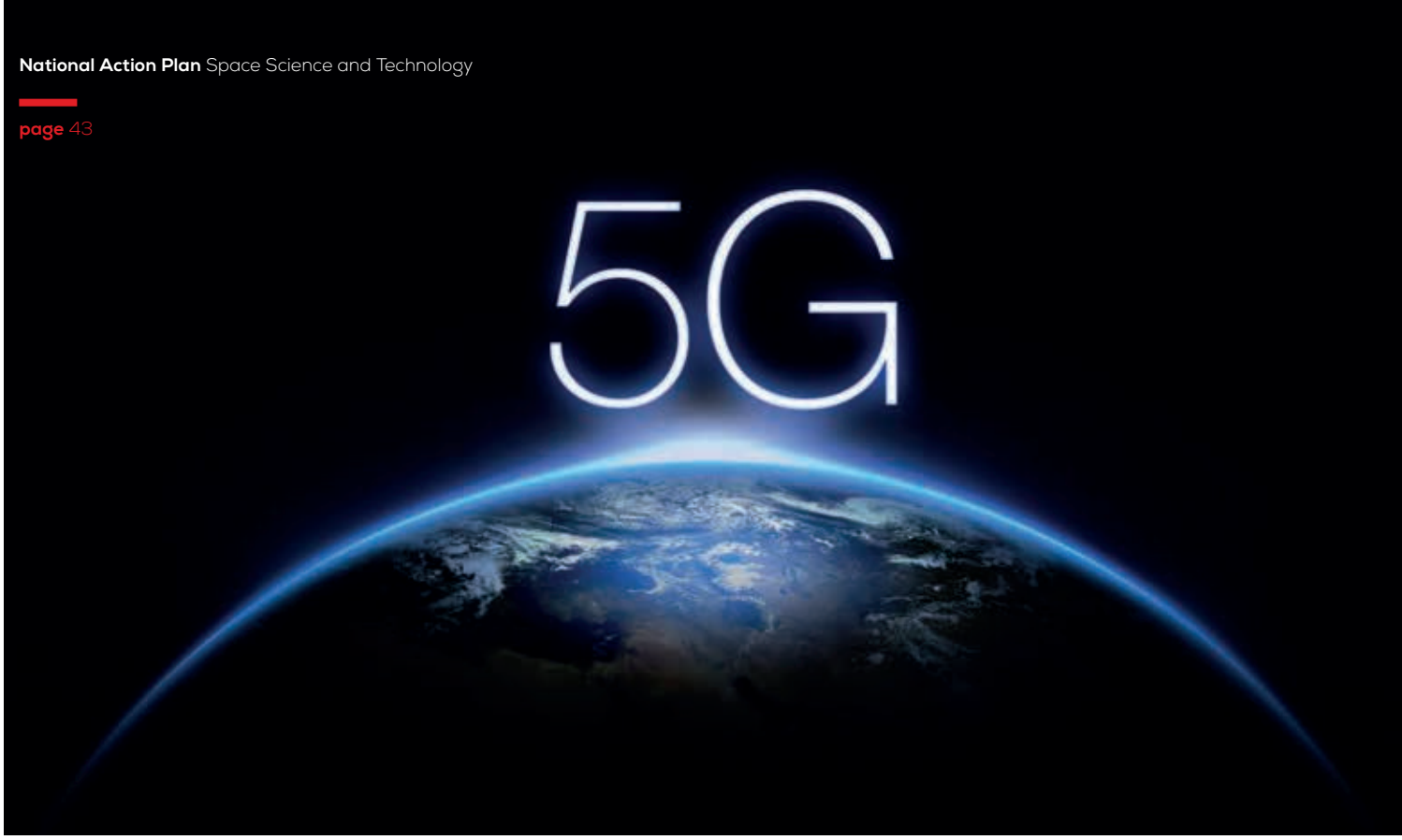
- Future Preparation.
- Core Competitiveness.
- Partnership Projects.
- Business Applications – Space Solutions.

The **Space for 5G** strategic line is vital for the future of space telecommunications and critical to the digital transition. The advent of 5G as the new standard for next generation mobile telecommunications favours the development of a network of networks, combining a range of different technologies including terrestrial mobile systems, Wi-Fi and satellite technology. It therefore represents a major opportunity for the future of space telecommunications, and this strategic line will aim to ensure that satellite networks are fully included in the definition of the 5G standard.

It is only natural for **SES**, the global leader in satellite telecommunications services, to seek to position itself in this area in line with the preliminary studies conducted during the previous programme period, as well as the **SnT**, a benchmark for R&D in the field of telecommunications.

The **Space Systems for Safety and Security** strategic line **(4S)** is a response to the fact that our economy and society depend on key infrastructures that are often themselves dependent on telecommunication networks and services. Consequently, the security, reliability and resilience of these networks and services is becoming increasingly critical. A range of activities within 4S addresses governmental telecommunications, following on from the precursor services developed by **SES** and **GovSat**.

This strategic line aims to prepare the industry and operators for the future **EU GOVSATCOM programme** and, more generally, for the commercial secure satellite telecommunications market.



Here too, Luxembourg University's Interdisciplinary Centre for Security, Reliability and Trust **(SnT)**, along with **LIST/ERIN** and **SPIRE**, have identified activities of potential relevance to their development.

The **Optical Communication – ScyLight** strategic line aims to establish industrial excellence in, and dominance of, the optical communications market. The goal is to achieve unprecedented levels of transmission rates, data security and resilience. A first project (QUARTZ) was developed during the previous period, by **SES**, **LuxTrust** and **itrust**. For this project, a demonstration in low or medium orbit is planned for the next round.

The **Future Preparation** generic line is meant to run mission and system feasibility studies to regularly update the ARTES programme and identify the technological studies necessary for its implementation.

Contributing to this line gives access to the entire programme. Therefore, we consider it as a mandatory contribution, which is why we do not expressly require companies and public research bodies to express their interest in the matter.

The **Core Competitiveness** generic line represents, the core of the ARTES programme. Its aim is to maintain and improve the capabilities and competitiveness of the industries of Participating States in the global space telecommunications market.

Core Competitiveness is based around two components: Advanced Technology (development of new technologies and techniques) and Competitiveness and Growth (development of products for use in the commercial and/or institutional market).

These technologies and products cover both the space and ground segments and key players such as **SES**, **SnT**, **HITEC Luxembourg**, **Kleos** and **Gomspace** will have the opportunity to develop technologies that will serve as the basis of their future commercial products.

The generic line **Business Applications - Space Solutions** (BASS) is aimed at the commercial exploitation of data, space capabilities and resources. The proposed instruments are grouped into two core components: Applications Activities (development of sustainable commercial space applications that meet users' needs) and Space Solutions (activities aimed at promoting the economic development of the space sector in Participating States).

This line has always been important to Luxembourg but has become particularly significant in recent years due to Luxembourg's commitment to digital transition. In particular, this line allows for the development of the artificial intelligence techniques required to exploit big data sources as well as the development of the downstream market for value-added

applications and services using these techniques for the benefit of society as a whole. **Blue Horizon**, **HITEC Luxembourg**, **Kleos**, **LIST/ ERIN**, **LuxSpace**, **Skyflox** and **SPIRE**, and any new players will have the opportunity to increase their share in downstream activities.

This line also includes the implementation of technology transfer activities through technology brokers. The latter assess market needs in areas of potential for the exploitation of space technologies. They identify opportunities in terms of specific technology transfers and forge links between industrial entities and technical resources, whether from the space sector or elsewhere. **Creaction** is the technology broker for Luxembourg.

There are a series of additional contributions in the following existing programmes, aimed at, either supplement the contribution to cover costs at completion, or for new activities. These include the SAT-AIS, EDRS Global and NEOSAT programmes with, in particular, **HITEC Luxembourg** for the supply of additional ground stations as part of the EDRS programme.

85

The contribution to these programmes amounts to a total of € 85 million.

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ENABLING AND SUPPORT ACTIVITIES

General Support Technology Programme (GSTP)

ESA's **GSTP** programme is the Agency's programme for developing technologies other than those targeting telecommunications. It provides support to companies by helping them convert engineering concepts into potentially marketable products.

The programme covers almost the full range of technological maturity, including in-orbit demonstrations. It includes three elements related to the level of technological maturity, with the first element focusing on the least mature technologies and the third element focusing on in-orbit demonstration and small missions.

It often happens that the proposed activities correspond either to the R&D needs of Luxembourg companies or to the priorities of our research bodies. As a result, participation in the programme serves to ensure that both are technologically at the edge and competitive and thus, able to provide products and services that meet market expectations.

As mentioned above, the third component of the programme also covers small missions. Thus, the **M-ARGO mission**, which is a natural fit in our SpaceResources.lu initiative as an asteroid exploration mission, will naturally be implemented through this element.

Unlike Juventas, which will travel with the HERA mission, M-ARGO will develop technologies that will be essential for a CubeSat to travel to "Deep Space" and to reach an asteroid completely autonomously. Once on site, M-ARGO will use its suite of instruments to characterise the physical properties of the asteroid. These data will then feed into the European Space Resources Innovation Center. Phase A is already underway at **GomSpace** and was completed in May 2020.

10

The contribution to this programme amounts to a total of € 10 million.

LUXIMPULSE NATIONAL PROGRAMME

National initiatives will be implemented primarily through the LuxIMPULSE national programme.

This concerns not only the Space-Resources.lu initiative but also more traditional projects and any New Space projects falling outside the scope of the initiative.

To this end, the programme will be provided with **additional funding of 80 million euros** to both continue supporting technological developments decided in recent past years and support the growth of the sector and new entrants.

For example, **GRADEL** will develop and validate a process known as *"xFK in 3D"* in collaboration with their partner AMC, thereby enabling the production of ultralight structures for space applications. The technology will be used to put high-performance composite fibres only where they are needed, using an exclusively digital approach for the definition and simulation of the structures. Weight savings of up to 70% are possible, as well as the integration of additional technical functions, all of that by reducing the degree of complexity, thereby enabling competitive solutions to be offered to its customers.

Orbitare, currently in the process of being set up in Luxembourg, will develop and provide a low-cost IP messaging service (email, messaging and images) for remote regions, based on a small constellation of nanosatellites. Its customers will include hikers and sailors.

SPARC Industries will develop software capable of simulating plasma physics with a high degree of accuracy for both space and non-space applications.

There are, of course, also plans that are relevant to the Space-Resources.lu initiative. R&D projects with companies and public research laboratories will continue to be supported through the LuxIMPULSE programme, notably for prospection, extraction and processing of space resources. This will require the development of new expertise in remote sensing, materials, robotics and autonomous systems.

Thus, **Maana Electric** will initially be supported by the national programme to develop its autonomous solar panel production system from *in-situ* resources (regolith on the Moon and sand on Earth). This innovation will also enable the production of inexpensive and environmentally friendly solar panels, generating little waste compared to current processes.

Deep Space Industries - Bradford Space will develop sub-systems for low-cost space exploration platforms.

Since the initiative to propose a project is generally left to the industry or the public research organisations, it is difficult to anticipate all the activities that will be carried out as part of this programme. Other projects will be identified along the way and implemented in this context.

EDUCATION ACTIVITIES

In close partnership with ESA and the LSA, the **ESERO project** will continue to use space as a setting for teaching and learning about science and technology in schools. It will also offer training courses for educators, teaching and learning resources, and new practical activities, consistent with national school curricula.

Through its 2020-2022 programme, the ESERO project includes plans to offer 16 new training courses designed for a little over 320 teachers. These will extend and develop new teaching and learning resources and run school projects proposed by ESA, including: Astro Pi, CanSat, Moon Camp, Climate Detectives and MissionX.

ESERO will also seek to promote space careers and raise public awareness on the importance of space for society. Drawing on experts from industry and the world of research, the project will organise school visits to raise awareness among students and encourage them to choose STEM careers.

The educational programmes of the University of Luxembourg, notably the Interdisciplinary Space Master, will continue to benefit from the LSA's support over the years to come.

The LSA will continue to promote career opportunities in the space sector among young people. As part of these efforts, the next call for applications to the LuxYGT programme will be issued in 2020.

More generally, the LSA will continue to raise awareness among young people and to promote the importance of technologies related to space resources, in collaboration with national educational bodies, notably through initiatives such as the **Luxembourg Tech School** and other events.

PROMOTION AND COMMUNICATION ACTIVITIES

The LSA's communication and economic development activities play a key role in the government's efforts to position Luxembourg on a global level, to enhance Luxembourg's commercial space ecosystem and to promote the peaceful exploration and sustainable utilisation of space resources. These efforts will continue in the years ahead.

The aim is to further develop communication activities consistent with the government's global strategy with a view to repositioning Luxembourg and paving the way for the emergence of an autonomous space agency. Along the way, we will seek to boost awareness of space research, particularly particularly in the frame of the establishment of the European Space Resources Innovation Center.

The LSA will continue to organise events in Luxembourg and participate in conferences, international congresses and economic missions, all with the aim of presenting and promoting Luxembourg's space ecosystem among the international community.

INDUSTRY VISION

As it did in preparation for the 2016 ESA Council at Ministerial level, the **Groupement Luxembourgeois de l'Aéronautique et de l'Espace (GLAE)** provided an assessment of the space sector and issued proposals on what it sees as the appropriate approach for the future.

Before setting out its proposals, the GLAE thanked the government for its continued commitment to the development of the space sector and welcomed the creation of the Luxembourg Space Agency, as well as the significant funding commitments made available to further strengthen the existing ecosystem. It also acknowledged the regular and constructive dialogue between representatives of the LSA and the industry, providing a basis for the concerted development of the sector's prospects.

Lastly, it underlined the importance of the principle of 'fair return' as the basis of ESA's industrial policy since it guarantees an economic return for Luxembourg.

In its proposals, the GLAE emphasised that the end goal for Luxembourg must be the development of the ecosystem, the creation of high-value and recurring applications, products and services, and the development of commercial markets.

It encouraged operators to adopt a targeted approach, based on existing expertise, with the aim of developing a critical mass. The areas targeted are telecommunications and applications and the utilisation of space resources.

The GLAE also recommends using cross-cutting technologies such as artificial intelligence and machine learning to drive developments in the space industry and make the best use of synergies with other initiatives or sectors, such as the MeluXina supercomputer and the defence and security sector.

Bilateral cooperation with other countries or agencies is also seen as a key strategy for supporting the development of the sector.

The GLAE sees the Luxembourg Space Agency as a "one-stop shop" for the space industry and invites the government to further strengthen the agency to ensure its ability of addressing the growing challenges arising out of Luxembourg's space policy.

With respect to funding, the GLAE recommends ensuring the necessary financial resources through various instruments such as RDI funding, ESA programmes and the LuxIMPULSE national programme.

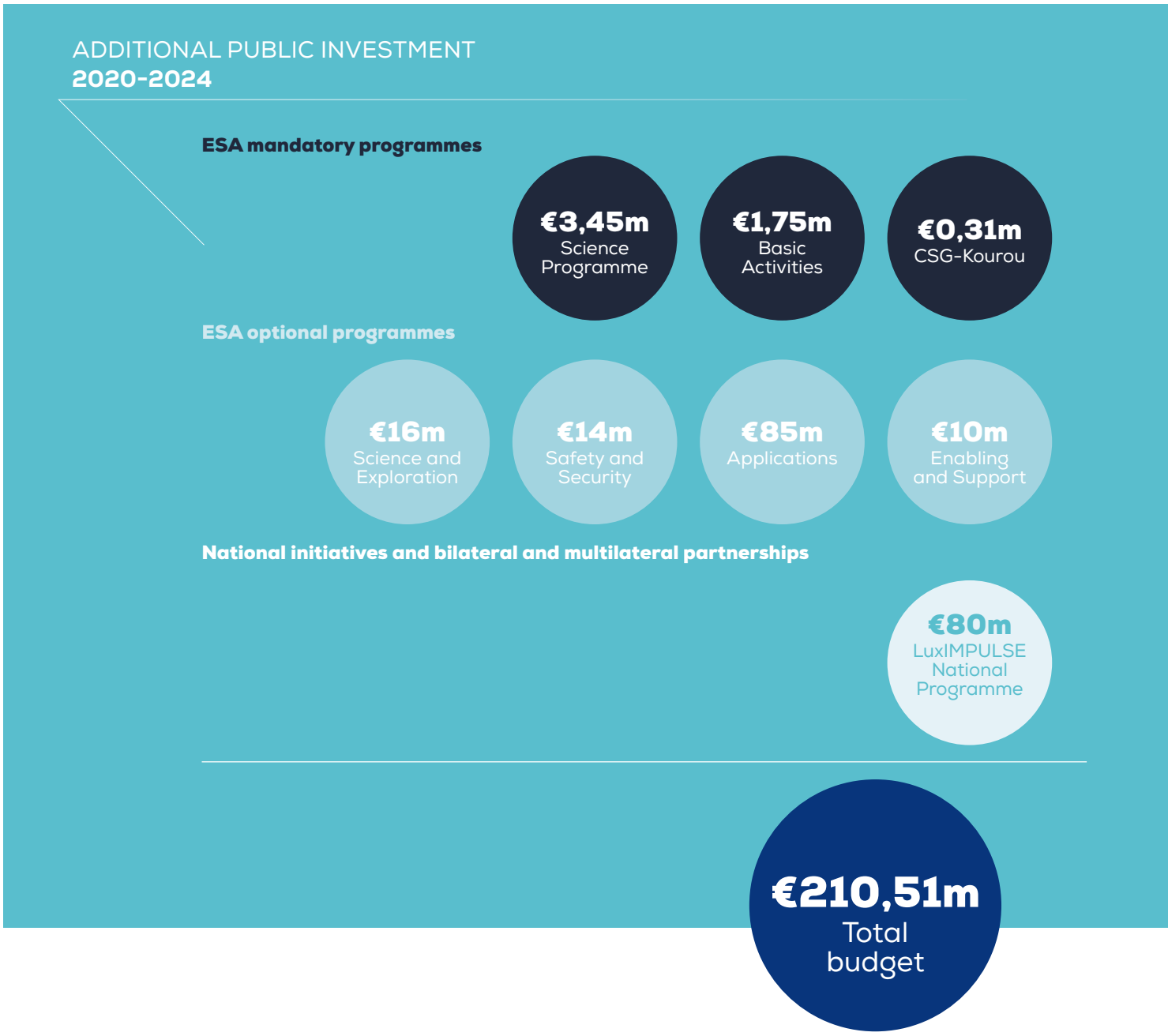
It also emphasised the importance of training and awareness-raising among young people and therefore recommends continuing with the young graduates programme at ESA (LuxYGT), and is also open to considering new training models. In addition, it very welcomed the setting up of the Interdisciplinary Space Master. Member companies of the GLAE are ready to welcome student interns as part of their training.

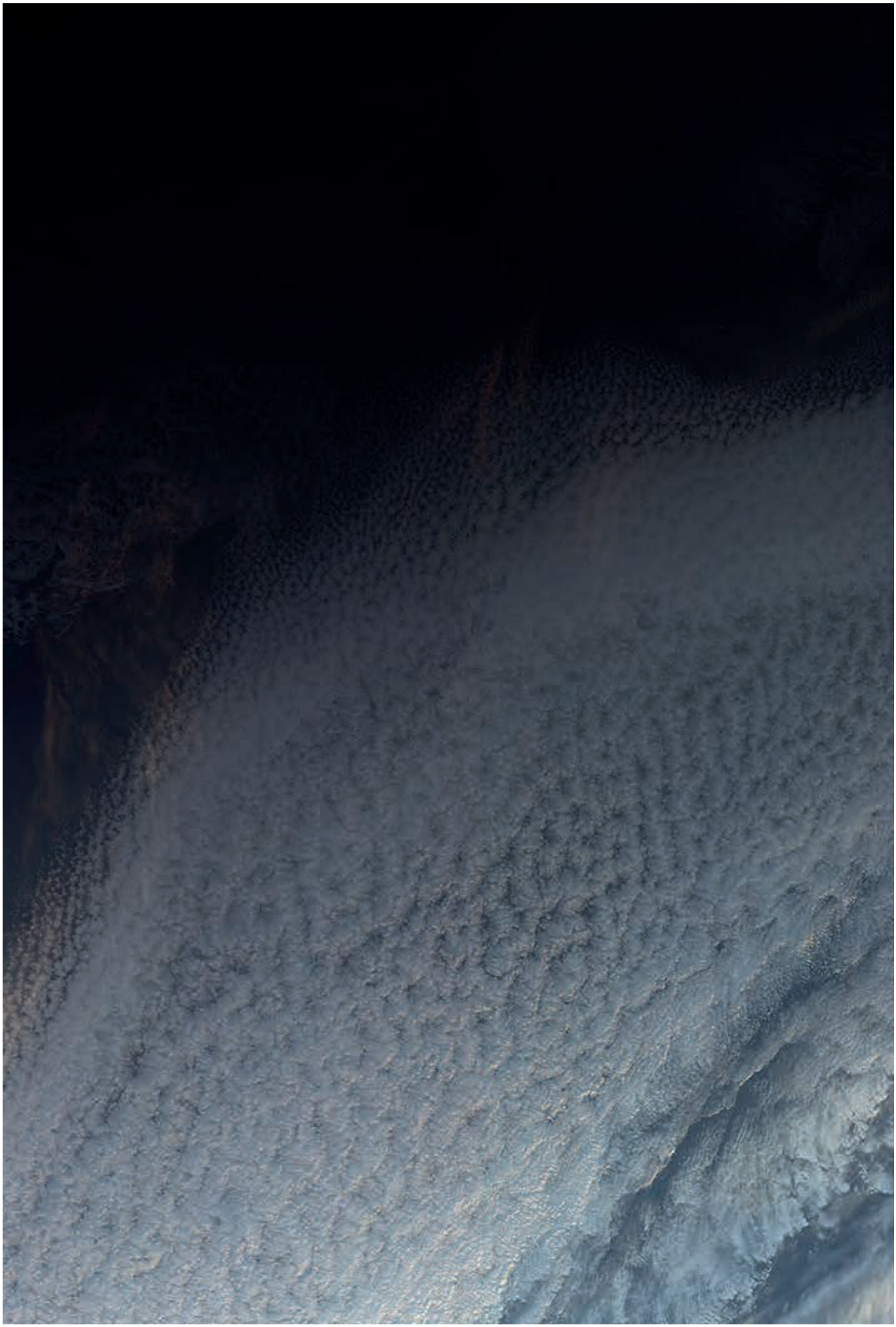
The GLAE also proposes to put in place an additional grant system to encourage young graduates to work for Luxembourg companies.

Lastly, the GLAE recommends persisting with efforts to promote the sector at several levels, whether internationally, within Luxembourg or, more specifically, among young people.

SUMMARY

The table below shows the additional public investment necessary for the implementation of the above-mentioned Action Plan over the period 2020-2024.





GLOSSARY

AIS	Automatic Identification System
ARTES	Advanced Research in Telecommunications Systems
ASI	Agenzia Spaziale Italiana
CGI	Centre de Gestion Informatique du SCRIPT
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EIB	European Investment Bank
EOEP	Earth Observation Envelope Programme
ESA	European Space Agency
ESERO	European Space Education Resources Office
GLAE	Groupement Luxembourgeois de l'Aéronautique et de l'Espace
GMES	Global Monitoring for Environment and Security
GSTP	General Support to Technology Programme
ISM	Interdisciplinary Space Master
LIST	Luxembourg Institute of Science and Technology
LSA	Luxembourg Space Agency

LTS	Luxembourg Tech School
LuxYGT	Luxembourg Young Graduate Trainees
PIB	Produit Intérieur Brut (Gross Domestic Product)
PME	Petite et Moyenne Entreprise (Small and Medium-Sized Enterprise)
PMI	Petite et Moyenne Industrie (Small and Medium-Sized Industry)
QCI	Quantum Communication Infrastructure
SCRIPT	Service de Coordination de la Recherche et de l'Innovation pédagogiques et technologiques
SES	Société Européenne des Satellites
SMC	Services des médias et communications du Ministère d'État (Media and Communication Services of the Ministry of State)
SnT	Interdisciplinary Center for "Security, Reliability and Trust", University of Luxembourg
STEM	Science, Technology, Engineering and Mathematics
TIC	Information and Communication Technologies
TRP	Technology Research Programme
YGT	Young Graduate Trainee

APPENDIX

DESCRIPTION OF ESA PROGRAMMES

The European Space Agency structures its programmes around the following 4 pillars:

I. Science and Exploration

II. Safety and Security

III. Applications

IV. Enabling and Support

A brief description of programmes of interest to Luxembourg is provided in the following paragraphs.

SCIENCE AND EXPLORATION

THE SCIENCE PROGRAMME

The Science Programme was at the origin of the first European space cooperation projects and has always been underpinned by dynamism and success. For more than 30 years, it has exemplified both the value of such cooperation and Europe's capacity for innovation. This is perfectly illustrated by the Giotto and Ulysses probes.

The Science Programme is a mandatory programme funded by all ESA Member States. It is the glue that binds research and industry together, even across national borders. It represents the foundation of future space programmes. But what is space science?

Space science seeks to answer some of the most fundamental questions: how have the Earth and our solar system evolved? What is our place in the Universe? How did life appear? Are we alone?

Finding the answers to these questions means studying our solar system in a bid to understand the interactions between the Earth and other planets. Several missions have already improved our understanding of our solar system. The Giotto probe, which flew by Halley's Comet in 1986, showed the composition of its matter, based on analyses conducted by the probe as it travelled through the comet's tail. And, since 1990, the Ulysses probe has carried out surveys above the poles of the sun.

Another example is the Hubble Space Telescope, launched in 1990. Hubble is the most complex and technically advanced space observatory ever built. Its Faint Object Camera (FOC) produces highly detailed images of stars and detects objects beyond the reach of Earth-based instruments.

The aims of the most recent missions, including ExoMars TGO, BepiColombo and Gaia were, respectively, to study the atmosphere of Mars, to explore Mercury, to produce a 3D map of our galaxy. Meanwhile, Rosetta collected data on the core composition of Comet 67P/Churyumov-Gerasimenko and on its behaviour when approaching the sun.

Missions scheduled to launch in the years ahead cover aspects of space science including the measurement of the radiation emitted by very remote objects, the detection of extrasolar planets, the measurement of cosmic rays in the universe, the detection of gravitational waves, the study of Jupiter, the observation of millions of stars in our galaxy, the exploration of black matter and the study of the Sun.

These missions will help to improve our understanding of the origins of the Universe (Big Bang), its age and its expansion, of the formation of stars and galaxies, of the planets in our solar system and of our Sun.

THE EUROPEAN EXPLORATION ENVELOPE PROGRAMME

The European Exploration Envelope Programme (E3P) is ESA's exploration programme, focused on both human and robotic exploration. The programme is structured around four cornerstones:

- Low-Earth orbit (LEO) human exploration.
- Beyond low-Earth orbit (Beyond LEO) human exploration.
- Lunar robotic exploration.
- Mars robotic exploration.

The four cornerstones are framed by two cross-cutting programmes: Science in Space Environment (SciSpacE), incorporating scientific activities related to exploration, and Exploration Preparation, Research and Technology ExPeRT, incorporating all preparatory activities and studies.

ESA offers its Member States an ambitious programme balancing the three main destinations, i.e. low-Earth orbit, the Moon and Mars. To ensure the programme is financially sustainable, many of these missions are carried out as part of international partnerships, such as the *PROSPECT* and *ExoMars* missions, to be carried out with Roscosmos, the Russian space agency, and the *Mars Sample Return* and *ARTEMIS* missions in collaboration with NASA.

Space19+ came at a highly critical moment for space exploration, primarily because of the announcement by the US of its plan to return to the Moon with astronauts by 2024. Europe may take part in the adventure, but for it to play a significant role, it will need to commit to long-term collaboration that will undoubtly shape the European exploration programme for more than a decade.

It is also in the context of lunar exploration that ESA published its strategy on space resources in 2019. For ESA, space resources play a key role in sustainable exploration and will serve to carry out long-term human missions on the Moon. As part of this, ESA intends to launch a robotic mission to the Moon in the mid-2020s to demonstrate the potential for using space resources.

SAFETY AND SECURITY

SPACE SAFETY PROGRAMME

The aim of the Space Safety Programme is to contribute to the protection of our planet and mankind, along with our space and ground resources, against threats from space. The programme also ensures the continuity of the space surveillance programme (SSA).

The Space Safety Programme is structured around five major areas of activity, spread over 'core' activities and main cornerstones:

- Core activities focus on space weather and planetary defence, along with space debris and preservation of the space environment.
- The L5 mission – the first cornerstone – is an operational space weather mission aimed at the fifth Lagrange point, designed to provide faster and more accurate short- and medium-term weather forecasts.
- The HERA mission – the second cornerstone – is a planetary defence mission targeting the binary asteroid Didymos. The aim is to provide an accurate characterisation of the asteroid pair after impact by NASA's DART spacecraft, planned for 2022. This analysis will tell us how effective asteroid deflection by kinetic impact can be. It will supplement the asteroid detection and early warning activities by contributing to the development of deflection capabilities.
- The third cornerstone, dedicated to in orbit servicing and active space debris removal, aims to remedy the problem of space debris by planning a debris removal mission and supporting the emerging market of in orbit services.
- The automated collision avoidance system – the fourth cornerstone – is designed to ensure an anticipative approach to collision risk and the safety of mega-constellation operations.

APPLICATIONS

EARTH OBSERVATION

ESA's Earth observation Programme includes two main elements. The first is the science and research one which includes the *Earth Explorer* missions. The second, *Earth Watch*, is the one designed to facilitate the supply of Earth observation data to be used by operational services.

These elements are addressed across two major programmes:

- the Earth Observation Envelope Programme (EOEP)
- the Earth Watch Programme.

Although the *Earth Watch* element also addresses weather missions developed in cooperation with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the Sentinel missions developed as part of the European Union's Copernicus programme, these latters have their own dedicated programmes.

As well as launching new programmes, the current period of the Earth observation programme involves the continuation of a number of existing initiatives. This includes the extension of the Earth Observation Envelope Programme, the Copernicus programme and the elements of the Earth Watch programme, devoted to the continuation of Altius, Proba-VE and Incubed, to the Global Development Assistance (GDA), the Arctic Weather Satellite (AWS) and finally to TRUTHS.

FutureEO-1 Programme

Consistent with ESA's Earth observation strategy ("EO EUROPE 2040"), the Earth Observation Envelope Programme (EOEP) extends beyond EOEP-5 in the form of FutureEO.

A new period, known as FutureEO-1, lasting nine years (2020-2028), has been added to the EOEP. It consists of three independent segments, each lasting three years.

The first segment covers the funding period 2020-2022. It focuses on several activities of the current EOEP-5, but also introduces new concepts such as the implementation of a new type of research mission called "Scouts", investment in artificial intelligence for the effective recovery of ground segment data as well as data processing directly onboard satellites.

FutureEO-1 is designed to promote cross-fertilisation throughout the life cycle of Earth observation missions, from the design and definition of the mission to the development of missions and instruments. The programme also addresses data access and exploitation, which in turn feeds into the definition of the mission. FutureEO-1 provides a framework for meeting the needs and priorities of Earth observation data users more effectively.

FutureEO-1 focuses on the same objectives as EOEP.

These are:

1/ To secure the foundations required for the future Earth observation systems in Europe (technological and scientific maturation, end-to-end mission and system expertise, pre-development of instruments, system and architecture design studies, transition from science to applications).

2/ To deliver research missions as part of Earth science and to demonstrate the scientific relevance and utility of these missions.

3/ To further enable the development of the Earth observation downstream sector in order to build commercial opportunities and generate economic growth.

4/ To promote the expansion of the community of users of Earth observation data.

The programme's main activities are as follows:

- **Future missions**: Preparatory activities relating to innovative technologies, based on political priorities and the needs of the community of Earth observation data users.

  Increased support for the European space industry to prepare for all kind of missions and instrumentation, with the aim of increasing effectiveness and independence. This includes the development of the Sentinel family as part of the European Union's Copernicus programme and the definition of the Earth Explorer and meteorological missions.

- **Mission development**: Implementation and exploitation of world-class missions – the Earth Explorer family. Preparation of the transition from R&D to operational and commercial systems.

- **Mission management**: data acquisition, management, archiving and access for users. As part of FutureEO, these services will draw heavily on new methods such as artificial intelligence.
- **Earth Science for Society**: Involvement of users, scientific exploitation of data, development of services aimed at societal challenges, integration of data from small commercial satellites and high-altitude platforms.

Copernicus Space Component Segment 4.0 (CSC-4)

The fourth segment of the Copernicus space component is intended primarily, to ensure the long-term continuity of current observation capabilities. This will be achieved through Next Generation (NG) Sentinel missions and the deployment of High-Priority Candidate Missions (HPCM) for the observation and study of the climate. These are intended to meet both emerging user needs and the requirements of the European Union's new policies on climate change.

To lay solid foundations for these future developments, preparatory activities relating to the development of Copernicus are already underway as part of EOEP-5.

Other instrument for pre-development activities for the NG Sentinel and HPCM missions will be carried out as part of the FutureEO-1 programme.

Earth Watch - Altius Element

The revision of the ALTIUS element aims to include the supply of launch services, the preparation and execution of the launch phase, the start of operations in orbit and exploitation, for a period of 3 years.

Earth Watch - TRUTHS Element

The aim of this element is to cover the initial development phases of a small- to medium-size operational mission, known as TRUTHS. This mission is focused, for the most part, on the study of the climate and aimed at improving estimates of the Earth's radiative balance by one order of magnitude using direct measurements.

Earth Watch - AWS Element: Arctic Weather Satellite

AWS is a prototype satellite that will be developed with the aim of establishing a constellation of small satellites in polar orbit, designed to perform microwave sounding of the atmosphere of the Arctic region. The future operational constellation may be put in place at a later stage as part of a cooperation programme with EUMETSAT.

Earth Watch - Incubed+ element

In 2016, ESA launched the "Incubed" element to meet the challenge of the increasingly dynamic and commercial Earth observation market. In line with the success of InCubed, the InCubed+ element provides even faster co-funding solutions, as well as access to ESA's expertise in the fields of Earth observation and space technologies to help European companies stand out in this highly dynamic market. The programme focuses on commercial objectives, with activities defined on the basis of business opportunities within the industry.

Earth Watch - PROBA-VE element

The exploitation phase of the Proba-V mission, which began in 2013, has been extended twice. A third extension is planned, with a view to continuing the mission's activities beyond 2019. As part of this, Proba-V will continue the nominal phase of the mission until April 2020. This will be followed by an experimental phase aimed at compensating for the satellite's loss of capability by using two small companion satellites flying close to the Proba-V satellite.

Earth Watch - GDA Element: Global Development Assistance

The *Global Development Assistance* (GDA) element is designed to put in place the necessary technical developments to meet the geoinformation needs of international financial institutions. It will enable them to carry out their operational activities: planning, implementation, follow-up and assessment of development assistance/aid projects.

The technologies produced by the GDA element will also be of use to other development aid stakeholders in the broad sense. This will include, national agencies and ministries of European countries responsible for development aid and relevant authorities in developing countries.

Furthermore, the GDA element will be implemented in partnership with the World Bank and the Asian Development Bank as part of a joint initiative. This will entail participating organisations carrying out complementary activities, such as capacity building and skills transfer, using their own financial resources. This is intended to increase the impact of development aid.

TELECOMMUNICATIONS AND INTEGRATED APPLICATIONS

Luxembourg has been contributing to the **"Advanced Research in Telecommunications Systems" (ARTES)** programme since 2000, as part of a cooperation agreement with ESA.

The programme is organised into different elements, each with its own specific content and financing scheme. Some of the elements are dedicated to preparing future telecommunications applications, market research and technological pre-development, while others provide support for the development of new products or services.

The structure of the programme is based on a matrix, with Strategic Programme Lines (SPL) and Generic Programme Lines (GPL).

The **3 SPLs** are designed to achieve various economic and social objectives:

1. **Space for 5G**: The aim is to achieve the complete integration of satellites into the next generation of mobile networks;

2. **Space Systems for Safety and Security (4S)**: The aim is to provide secure and reliable support to social needs, such as key infrastructure for society and the economy, crisis management, maritime security and border control;

3. **Optical Communication – ScyLight**: The aim is to maintain Europe's industrial excellence and global leadership in optical communications technology.

The GPLs aim to achieve effectiveness optimisation and project implementation objectives through more conventional programmatic elements. There are **4 GPLs**:

1. **Future Preparation & Core Competitiveness**: Core Competitiveness is dedicated to the development, qualification and demonstration of products (addressed under the "Competitiveness and Growth" sub-element), or long-term technology development (addressed under the "Advanced Technology" sub-element).

   Here, "product" can mean a piece of equipment, belonging to the platform or payload of a satellite, but it can also be a user terminal or a full telecommunication system integrating a network with its respective space segment.

   Telecommunication applications are also covered.

   Future Preparation is meant to identifying future strategic development needs in the satcom sector. It includes preparatory activities dedicated to strategic analysis, market analysis, technology and system feasibility studies and the support of satellite communication standards.

2. **Partnership Projects (PP)**: This element aims to provide the satcom industry with an efficient framework to bring innovative products and systems into the marketplace through industry-generated public-private partnerships.

   They may address space and/or ground segments. Examples of recent and imminent launches include the European Data Relay System (EDRS), the satellite-based Automatic Identification System (SAT-AIS) and the New-Generation Platform (Neosat), which includes both Spacebus Neo (Thales Alenia Space) and Eurostar NEO (Airbus Defence & Space).

   Projects yet to be launched include Electra, Pacis-1 (Govsatcom Precursor) and QUARTZ (QKD). New PPs are on the table, including HyDRON, SAGA, Novacom and Sunrise Phase2.

3. **Business Applications - Space Solutions**: this element is dedicated to the development of sustainable businesses, services and applications that make use of space assets, for implementation across all market sectors from agriculture to transport and from energy to finance. It includes ESA's Business Incubation Center (ESA BICs) networks, innovation brokers and applications ambassadors.

ENABLING AND SUPPORT

GENERAL SUPPORT TECHNOLOGY PROGRAMME (GSTP)

Through this programme, ESA enables Participating States to encourage technological developments, bringing them to a sufficient level of maturity that they could be used in a future mission.

GSTP serves to strengthen and develop industrial expertise, ensuring that European industry maintains its position of strength in an increasingly competitive environment. It also offers the option of demonstrating, testing and qualifying technologies in orbit that cannot be qualified on the ground.

The programme's activities focus on topics such as Earth Observation, Science, Robotic Exploration, Human Spaceflight, Space Transportation, Navigation and Generic Technologies and Techniques.

The GSTP is based around the following three elements:

- Element 1 "Develop": Technology developments for future missions, ground applications and tools.
- Element 2 "Make": Development of market-driven technologies and products of strategic value from a competitiveness and sustainability perspective, co-funded with industry, and implementing national priority activities.
- Element 3 "Fly": In-orbit demonstration of new technologies, preparation of future missions and small missions.

The programme offers significant flexibility and enables Participating States to fund only activities in which they have expressed a specific interest.

Photo: LSA Data Center,
satellite image of Luxembourg,
Sentinel 2B

THE GOVERNMENT
OF THE GRAND DUCHY OF LUXEMBOURG
Ministry of the Economy

LUXEMBOURG
SPACE AGENCY