GSTP ANNUAL REPORT 2021

Cover: An artist’s impression of the Picasso satellite in orbit.

GSTP
ANNUAL REPORT 2021

A GSTP activity with has developed an innovative lattice structure for a compliant mechanism using additive manufacturing that has reduced mass by at least 50%.

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MISSION

In space, spare parts and repairs are hard to come by, so any technology sent into its unforgiving environment must have proven itself on Earth through a series of increasingly more intense tests.

The General Support Technology Programme (GSTP) is one of ESA's key instruments for assuring European competitiveness in the global market, creating jobs and keeping Europe at the forefront of technological innovation.

As ESA defines its goals into the next 10 years it is prioritising maintaining and growing Europe's role in the space economy. This means working with European stakeholders and with companies of all sizes involved in the space industry. ESA's technology development activities, especially those in GSTP, are embedded into the wider space R&D landscape in Europe, reflecting the maturity of the sector, recognising increasing private sector role as well as the substantial investments in space technologies at national level.

For almost 30 years the GSTP has been developing leading-edge space technologies that enable missions and support the competitiveness of European industry. For ESA to be Europe's leading space power in 2035, it starts today with the activities being developed by GSTP right now.

GSTP IN NUMBERS

26

All ESA Member States (Participating, Associate and Co-operating) choose to contribute to the optional GSTP as they recognise its benefits

29%

Of GSTP's portfolio is invested in activities with SME's.

3.5M

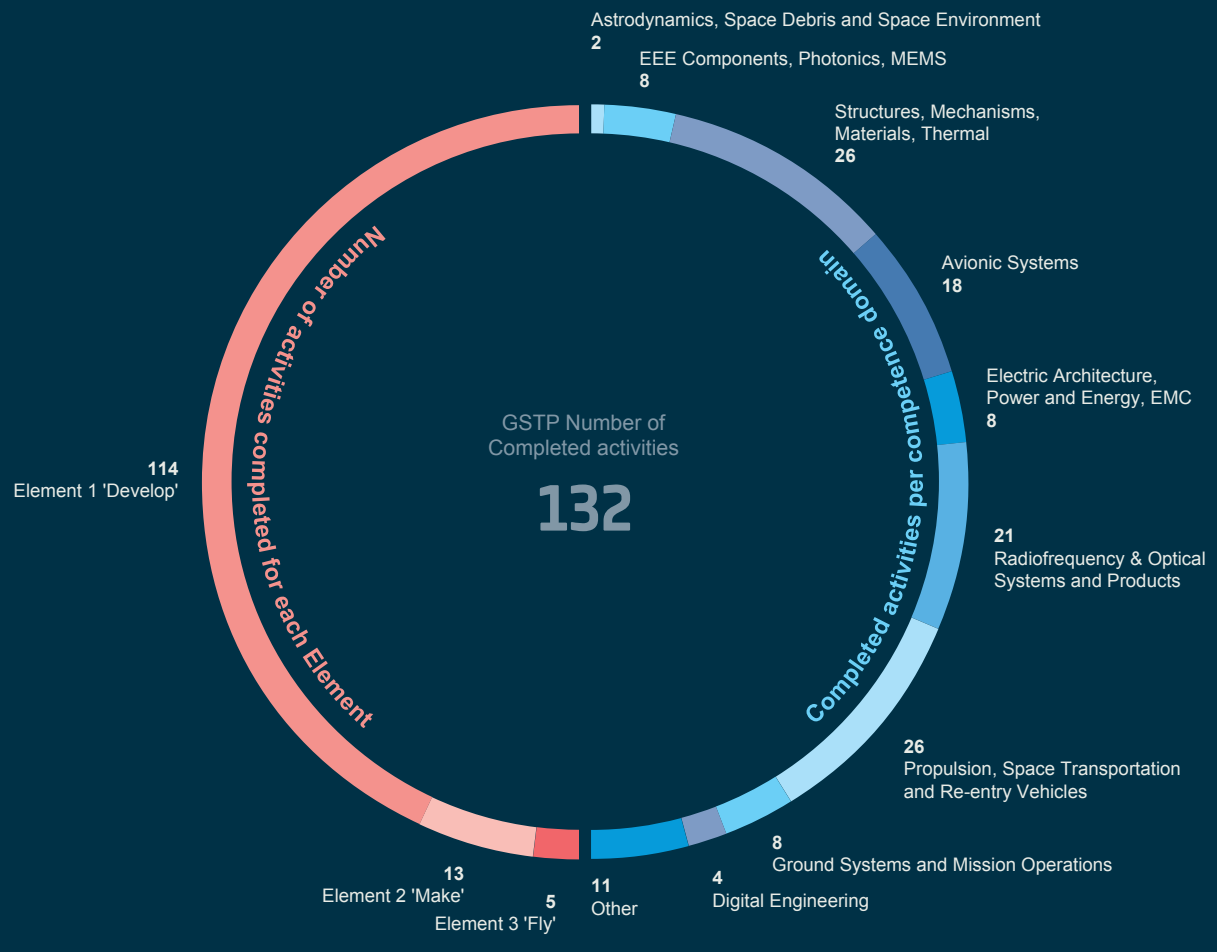
Every €1 invested through GSTP in European space industry encourages €3.5 in investment.

157

GSTP Number of Initiated activities

131M

GSTP Annual Commitment amount



GSTP AND UK BUILD EUROPE'S FIRST WIDE-ANGLE CORONAGRAPH

United Kingdom

A recently closed activity in GSTP Element 1 has developed Europe's first wide-angle coronagraph. This fundamental instrument for researching space weather, takes an image of the solar corona, by blocking the sun itself – similar to how the sun is seen during an eclipse.

These images are vital for tracking Coronal Mass Ejections and understanding related space weather phenomena.

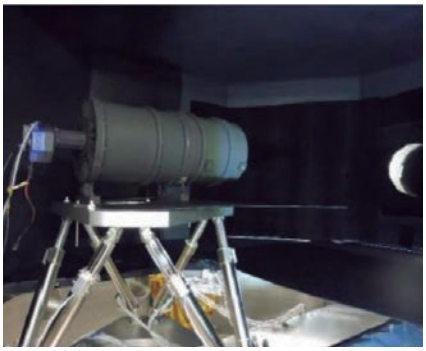
Currently two ESA missions, Solar Orbiter and Proba 3, are carrying coronagraphs, but they respectively have a narrower field of view, or the concept requires two spacecraft flying in formation. While interesting for science these are less useful for operational space weather forecasting.

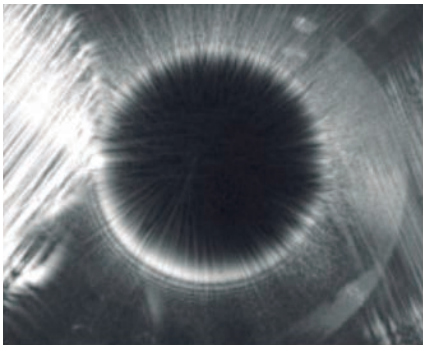
The newly developed Solar Coronagraph for OPErations (SCOPE) aims to provide imaging from very close to the Sun, where the corona is relatively bright, to around 30 solar radii, where the corona is very faint to track Coronal Mass Ejections (CMEs) using a single telescope.

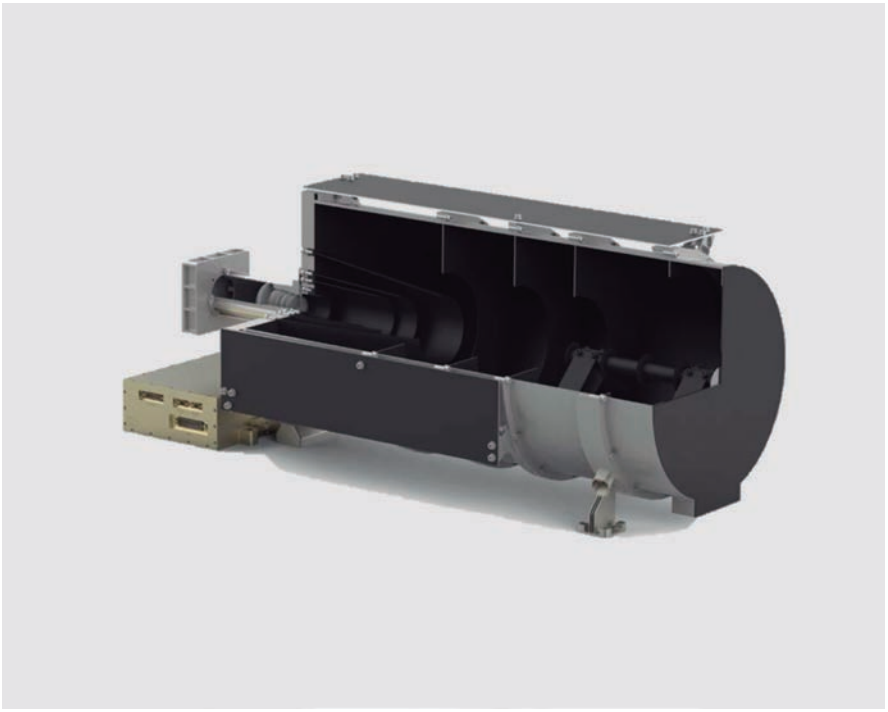
The activity found that the only way to be certain the technology functioned was to build it through an iterative process of continuous testing and redevelopment.

The design consists of a white-light telescope with focusing optics, essentially a camera and an external occulter. This occulter is comprised of a stack of discs that blocks out the central sun itself from the image. The complexity for the design came from both reducing the size of the technology and in trying to prevent the structure holding the occulter disc and its housing from interfering with the image, through diffraction and reflection of the light. To reduce the stray light bouncing off the structure and the disc, it was important to get this exactly right. The activity found that often the testing results didn't meet the simulated ones. It was discovered that minute imperfections in the testing site apparatus were producing anomalies when the light source used to simulate the corona reflected back and forth off of the instrument and the mirror used for focus the light – causing an additional stray light source in the images. Repeatedly conducting real-life tests was the only way issues like this could be found, resolved and retested.

The technology is now at TRL 4, with the eventual intention to be fully verified for future ESA Space Weather missions as part of the Space Safety Programme.







DEVELOPING THE TECHNOLOGY NEEDED FOR REMOTE SENSING MARINE LITTER

Portugal

An activity with GSTP Element 1 and Portugal, has developed a spectrometer that could be used to detect plastic marine litter from drones or planes.

Marine litter causes enormous damage to ecosystems and has become a concern for human health, since plastic has been found entering the food chain.

To try to solve this, research and industrial communities are now working on systems for detecting and/or capturing marine litter debris. Satellite-based detection approaches, in particular, are still in the early stage of their development and need to be validated with ground truth data and observations.

The activity placed three 10x10m targets covered in different types of common plastics into a bay in the Azores (see image), and was able to identify the relevant spectral bands a spectrometer would need for the detection of this plastic marine litter. It also identified the spectra datasets at different altitudes and the data processing techniques and algorithms needed for the detection of plastic marine litter.

GSTP AND THE ESA STRATEGY

FOCUS FOR FUTURE

Into the future, GSTP will continue to build on the work it is already doing to meet the goals of CM22 and AGENDA 2025. One of the main ways will be with individualised key focus areas, enhancing cooperation with each Participating State.

GSTP will mainly focus on increasing the number of activities and improving the implementation rates. It will also be expanding the use of the Frameworks to support the establishment of expertise across Europe. This is in relation to the new thematic areas, in particular artificial intelligence, advanced propulsion, cybersecurity, digitalisation and quantum technologies.

To encourage uptake of the Frameworks the de-risk and building blocks have been published as an OSIP channel and on ESA-STAR, easing access to templates and information and also streamlining the procurement process.

The Programme's legacy of reinforcing European industry will only strengthen, especially regarding its reputation as the ESA Technology Programme which works the most with SME's, with around 29% of the portfolio invested in activities with small and medium entities.

GSTP is also in a unique position to leverage dedicated opportunities for In-Orbit Demonstration, including onboard micro-satellites & CubeSats through its Element 3, FLY. This in turn will help establishing capabilities across the European space industry and encourage new products for the market.

HOW HAS GSTP MET THE GOALS OF SPACE 19+?

STRUCTURED EXCHANGE AND INTERACTIONS WITH INDUSTRY

- Preparation of Compendia
- Focus on Artificial Intelligence, Operations Innovation, Cybersecurity and Advanced Manufacturing

UNPRECEDENTED SUPPORT FROM DELEGATIONS

SUPPORT COMPETITIVENESS WITHIN THE EVOLVING EUROPEAN SPACE SECTOR

- Segmentation of Element 2 to accommodate market oriented activities, strategic activities and national priorities

FURTHER FOSTER TIMELINESS AND REACTIVENESS, REDUCING RISK, BUILDING CAPACITY

- Improve Frameworks
- Use of OSIP for pre-proposals and streamline ESA-STAR

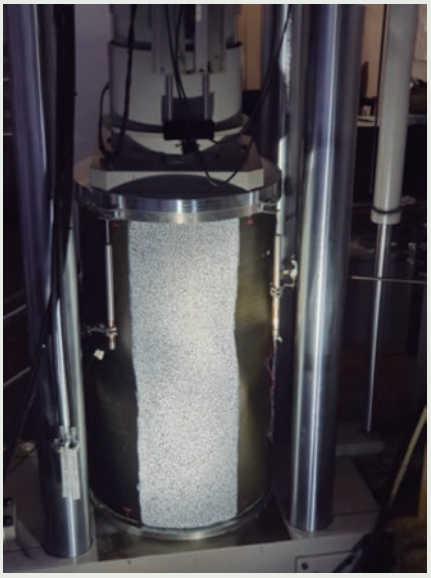
IMPROVED PROCUREMENT TIMELINESS

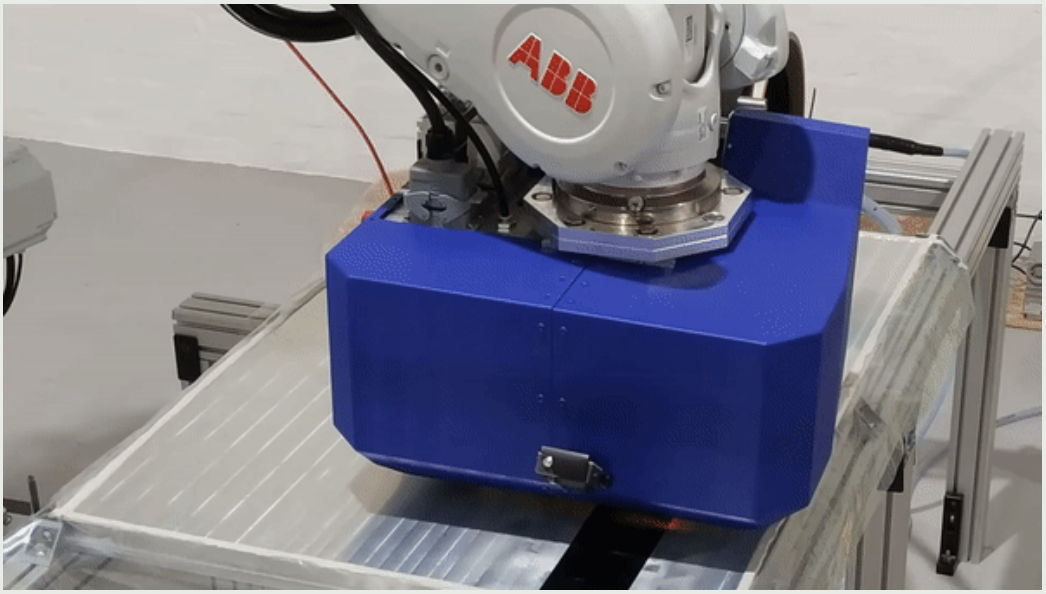
FACILITATE IN-ORBIT DEMONSTRATION

- Several in-orbit demonstrations in preparation/development

11 NANO/MICRO SATELLITE MISSIONS

A GSTP Element 1 de-risk activity with the UK has developed Rapid Tow Shearing (RTS), the world's first composites automated deposition technology that can steer tapes with no defects. This project sets out to prove the benefits of fibre steering on cylindrical space structures, such as launch vehicle interstages, which include a reduced sensitivity to typical imperfections as well as improved performance in terms of buckling load and stiffness, ultimately leading to lighter designs. These benefits are not achievable with state of the art technologies such as Automated Fibre Placement (AFP).





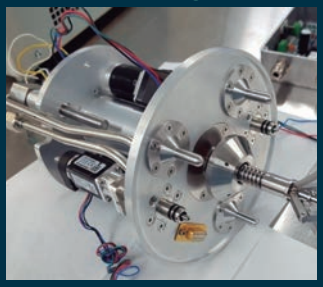
HOW IS GSTP EVOLVING TO MEET THE GOALS OF AGENDA 2025?

ACTIONS

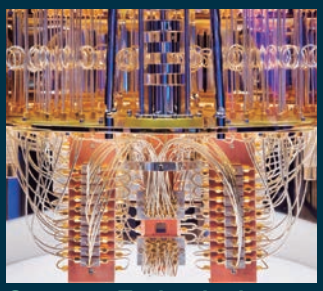
- Diversifying interactions with industry on technology themes
- Expanding frameworks to support company portfolios and exploit them further.
- Evolving Element 2 and Element 3 to expand and become more responsive
- Support the establishment of expertise within the strategic thematic areas: Innovative Propulsion, quantum technology, artificial intelligence and digitalisation, cybersecurity, in-obit servicing
- Promote cooperation between Member States

TECH THEMES

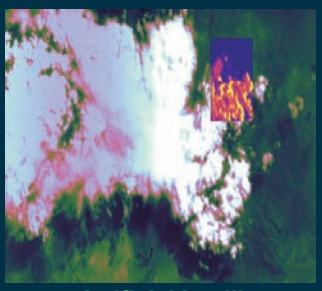
In Orbit Servicing



Cybersecurity



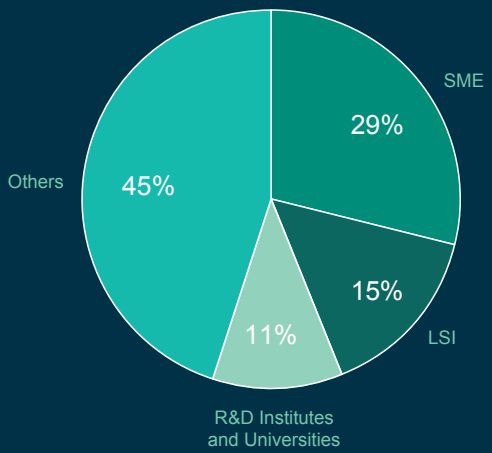
Quantum Technologies



Artificial Intelligence

PROJECTS

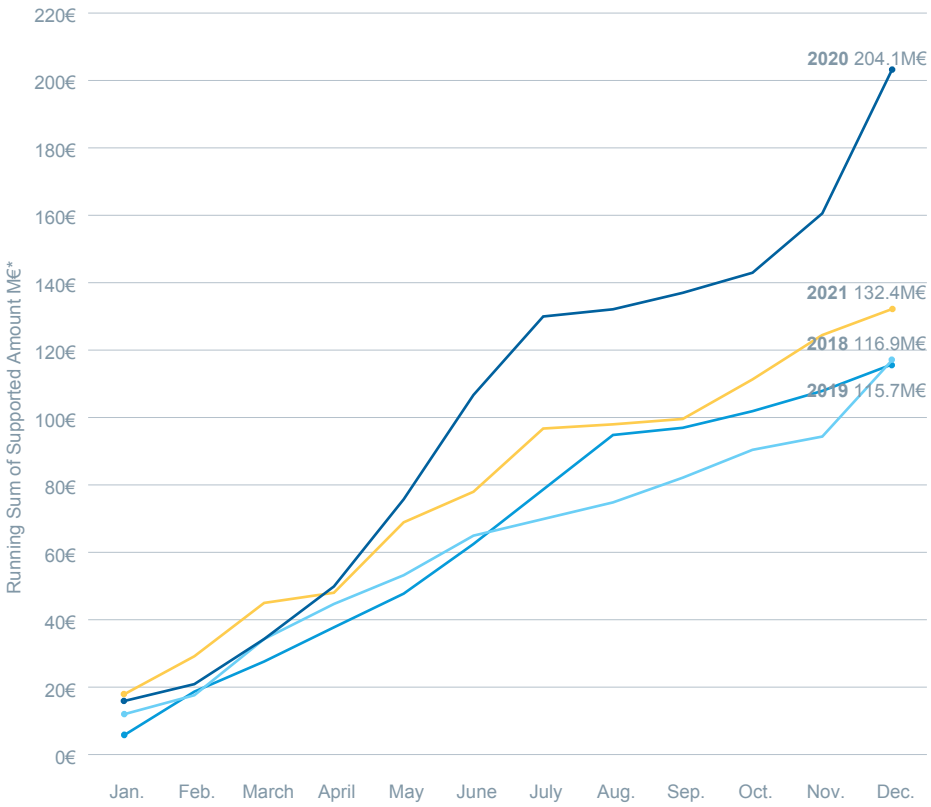
Interdisciplinary technology developments and demonstrations.



A YEAR IN REVIEW

OVERVIEW

- For GSTP, 2021 was a year of accomplishment. Over 132 activities were procured last year, representing over €131m.
- One such milestone saw delegations rain unprecedented support on the Programme's efforts to build their communication and improve the interactions with its partners in the European Space industry. These interactions were reinforced by the compendia and focus given to technology themes, which encouraged these partnerships, gave them a new structure and helped advance these exchanges.
- The introduction of the CSOC activities and Quantum Technology Framework and preparations for small satellite missions for in orbit demonstration, helped round out the Programme's sense of accomplishment.



GSTP Evolution - support levels over the year (January to December) comparing 2018/2019/ 2020/ 2021.

JANUARY

The year started strong with four GSTP activities already committed in the first half of January, representing over €2 million. In the Frameworks, the Building Block Framework saw two activity proposals, one in Norway and one in Estonia, under evaluation, with a few further activities intended for initiation following the outcome of the evaluation, while two de-risk activities were also notified “Sustainable Future” and “High-Efficiency Guide Star for Space Surveillance and Tracking”.

MARCH

TEC SHARING DAYS - The first online Technology Sharing Days were successfully held on 3rd March 2021, with over 300 registered participants. Fifty presentations from each of ESA’s 10 Competence Domains (CD) were presented, preceded by introductions from the CD leaders. Each session had between 50 and 80 attendees, many of whom participated in the question and answer sessions after the panels.

GSTP Compendia - 34 compendia activities were supported by Participating States in the first 6 months of 2021 with the first activity committed in March.

APRIL

The GSTP Element 1 work plan proposed 20 new activities and updates to four activities.

An update for the GSTP Element 3 work plan was submitted to the April IPC for approval adding one new activity to the previous Work Plan/Procurement Plan that builds upon the initial Work Plan/Procurement Plan (ESA/IPC(2013)63).

MAY

The activity Preparation of enabling space technologies and building blocks was held in May and the call for proposals was published in esa-star by the end of the month. This simplified the procurement process of the activities within this framework.

JUNE

In June 2021, the new, GSTP-funded, National Space Propulsion Facility in the UK was declared open. GSTP has invested around €4.5 million and overseen the design, assembly and commissioning of the facility – equipped to test-fire the most powerful classes of rocket engines used onboard spacecraft. This facility is just one of the many activities that GSTP and TDE invest in to ensure that future ESA missions will have the right technology available, at the right maturity, at the right time. Innovative propulsion is a focus of ESA's R&D strategy for the coming years, and spans from air-breathing rocket engines, to electric propulsion for extremely low orbits, to green propellants. From the largest test facilities to the smallest component, GSTP and TDE together have over forty ongoing activities in all areas of propulsion. Whether that is investigating ways of using the latest 3D printing techniques to build lighter and stronger components for the propulsion systems, or developing artificial intelligence programmes that will monitor the amount of fuel left in a propulsion tank. For more see page 26.

JULY

Procurement was initiated on 10 de-risk activities after they received support from the GSTP Participating States.

AUGUST

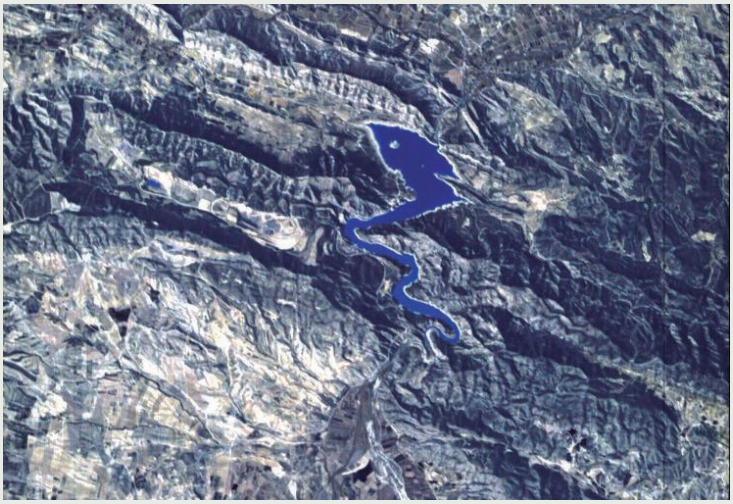
August 2021 saw the launch of three ESA CubeSats, two of which were developed through GSTP's Element 3 – Fly. SunStorm, an activity with Finland, and RadCube, an activity with Hungary, will demonstrate miniaturised space weather instruments for use in later operational space weather missions. SunStorm, a two-unit CubeSat, hosts a new solar X-ray flux monitor that will detect coronal mass ejections from the Sun which threaten satellites and terrestrial power and communications networks. RadCube is a three-unit CubeSat built through a collaboration that will demonstrate a new CubeSat platform and a new space weather in-situ monitoring instrument called RagMag. The instrument consists of a radiation telescope and a magnetometer that will be deployed on the end of a boom system. It carries an experiment to show how radiation in space damages electronics, which will lead to safer components and spacecraft.

Launch of Sunstorm and Radcube to demonstrate miniaturised space weather instruments. Funded by GSTP in collaboration with Finland and Hungary.

SEPTEMBER

Lithuania is the latest Associate Member to join the GSTP (with €1.5M Euro of Subscription). GSTP now has 26 Participating States, including the 22 Member States, Canada, Slovenia, Lithuania and Latvia.

September also saw the first ever online Space, Engineering and Technology Final Presentation Days. With 423 registered participants, the event saw nearly 200 people a day viewing the sessions. On Day 1 attendees were welcomed with a speech that focused on how we will meet the aims of Agenda 2025, followed by a panel discussion about advanced propulsion. Day 1 continued with this theme, with four panels inviting speakers from across Europe's space industry to present their GSTP and TDE activities. These panels ended with upbeat discussions and debates about the details of the activities and next steps. Day 2 saw a lively keynote as the topic moved to optical and hyperspectral imaging. Across five panels, fifteen activities were Presented by external companies.



The blue of the Calanda reservoir amid the rugged landscape of northeastern Spain, as seen by ESA's oldest – and one of its smallest – Earth-observing missions, Proba-1, midway through its 15th year of operations.

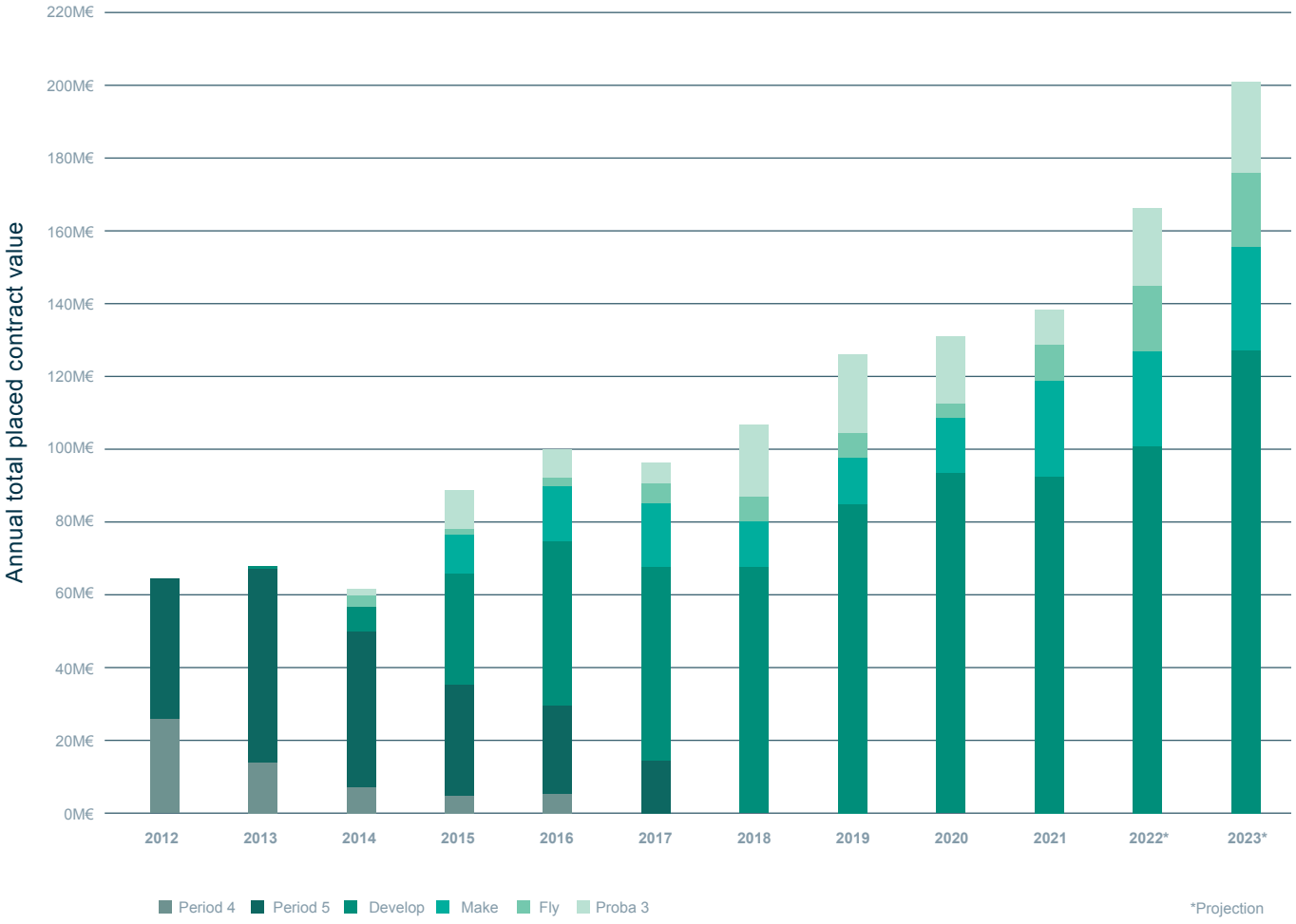
OCTOBER

This month saw the celebration of Proba-1's 20th year in orbit. Its two imaging instruments – the Compact High Resolution Imaging Spectrometer (CHRIS) and the panchromatic High Resolution Camera (HRC) – have provided more than 1000 images of more than 1000 sites.

DECEMBER

After a record year, Element 2 is projected to place contracts for 20-30 activities in 2022.

GSTP GROWTH


Annual total placed contract value
220M€
200M€
180M€
160M€
140M€
120M€
100M€
80M€
60M€
40M€
20M€
0M€
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022*
2023*
Period 4
Period 5
Develop
Make
Fly
Proba 3
*Projection

ASPHERIC MIRRORS FOR SPACE FOR TELESCOPES AND OTHER INSTRUMENTS

Belgium

An activity with GSTP Element 1 and Belgium, has demonstrated recent manufacturing developments could mean aspheric mirrors can now be used, and tested, for space.

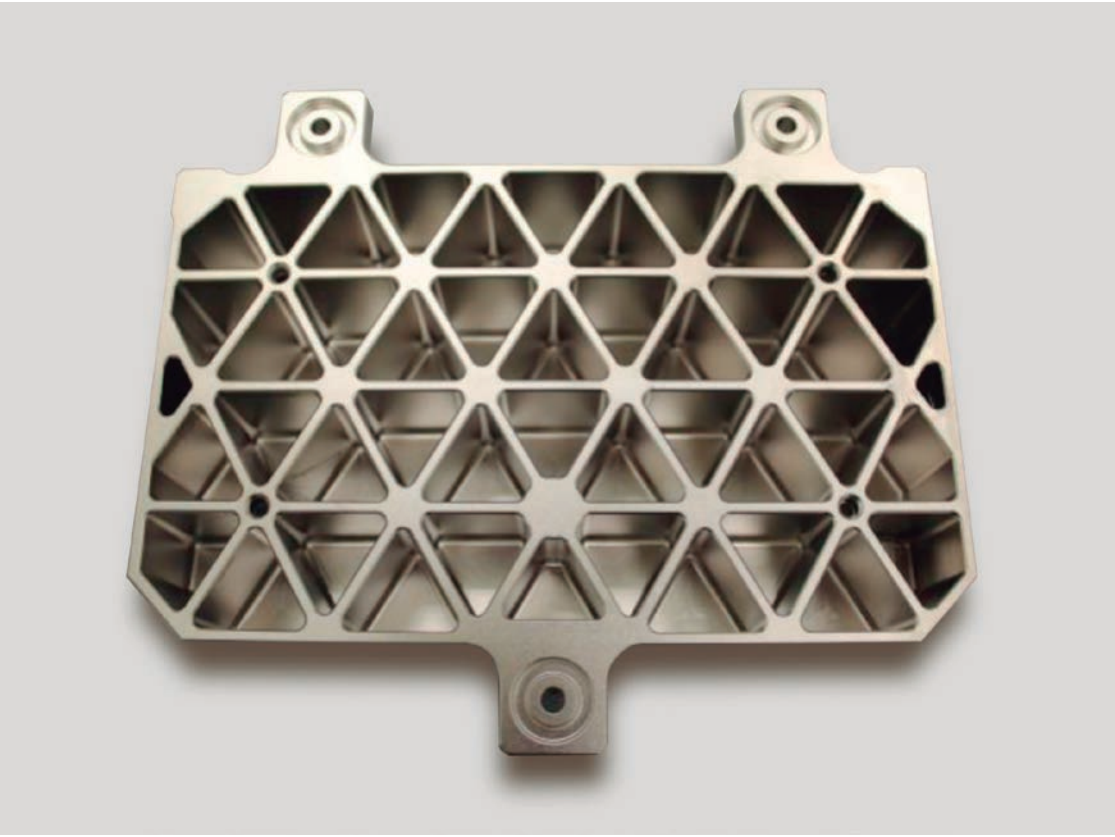
The activity was able to develop and improve technologies and processes (such as polishing) that will enable manufacture and production of lightweight, highly aspherical, metallic optical mirrors with the accurate surface shape and low roughness needed for high performance optical systems, such as telescopes and high-resolution spectrometers.

These designs have been increasingly investigated in the build of compact, lightweight and high performance space-based instruments. But the effort and time needed to polish these mirrors to meet the requirements for highly-detailed space instruments has meant their reliability has been hard to predict. This has led to uncertainty in lead time and cost. Now, advances in melt-spinning technology, the development of new aluminum alloys and changes to manufacturing methods for metallic mirrors manufacturing has opened new possibilities for fully-metallic instruments with challenging designs.

These developments mean instruments such as compact spectrometers, large field-of-view telescopes or relay systems, could be developed using only metallic materials, making them better able to withstand cryogenic temperatures.

The activity studied different materials and ways of polishing them to understand how best to manufacture these mirrors. Eventually, lightweight mirrors of 10cm square and 20cm by 10cm were made using an aluminium alloy, AlSi40, plated with Nickel-Phosphorous, and their structure and longetivity evaluated through a test campaign.

The largest mirrors survived the thermal and vacuum cycling tests before the performance of the mirror in cryogenic conditions was evaluated, using real-time monitoring of the surface error as the mirror was subjected to temperatures ranging from 295 to 200 Kelvin.The activity was able to successfully develop two mirrors that met the strict requirements of optical instruments.



NEW PULSE TUBE CRYOCOOLER DESIGNS MEET PERFORMANCE REQUIREMENTS FOR SPACE

Netherlands

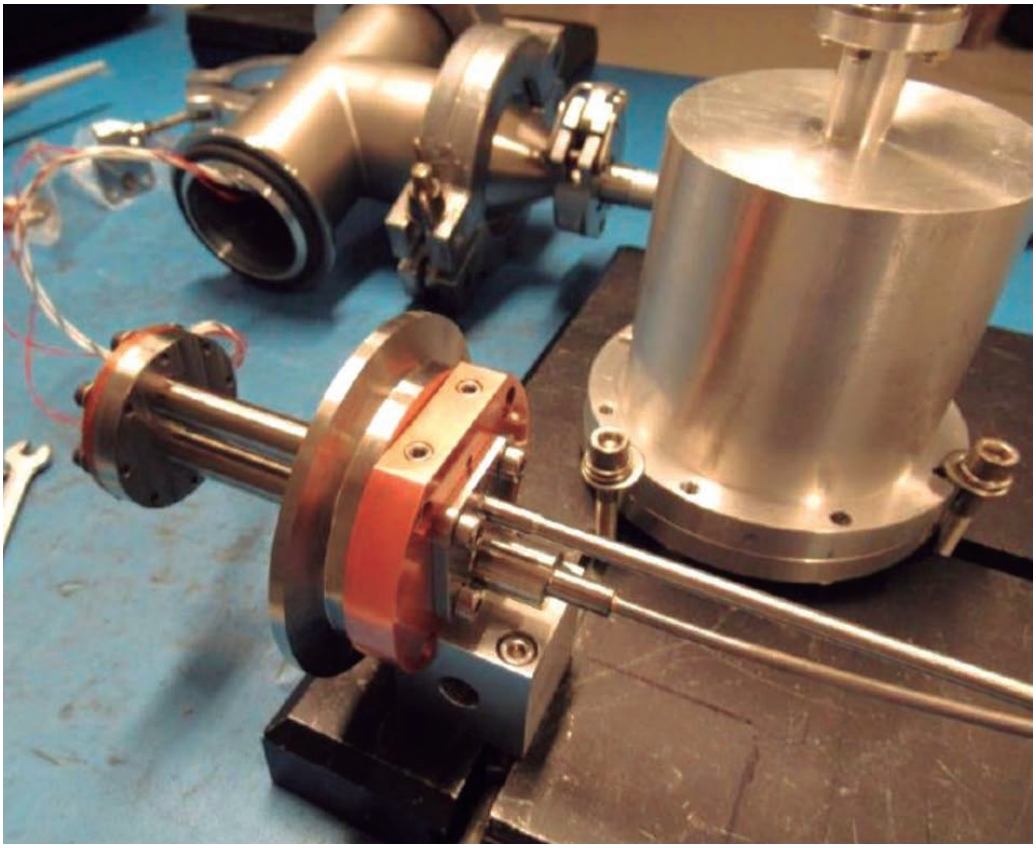
There is an increasing need for ever smaller pulse-tube coolers. These coolers have the characteristics necessary for space applications because the absence of moving parts in the cold finger makes them extremely reliable and any induced vibrations are typically smaller and easier to control.

But these types of cooler are less efficient and have a lower power density. Typically, this is resolved by increasing their drive frequency, to reduce amplitudes and displacements, which means that the coolers are smaller.

Unfortunately, at higher frequencies the thermal and flow losses increase as well. A new de-risk framework activity has investigated these losses, together with ways to improve optimisation.

Three potential cold finger configurations were designed and met performance requirements. The designs chosen will be beneficial for a wide range of coolers, from high-end 'full space' coolers to series produced 'COTS+' coolers for low-cost missions.

The activity investigated design options for miniaturisation of pulse-tube cold fingers, and simulated and optimised for efficiency before experimentally verifying the predicted performance through breadboard testing.



Photograph of the breadboard during assembly. The cold finger is not yet wrapped in Mylar nor placed in the vacuum vessel.

A MAP OF GSTP ACROSS EUROPE

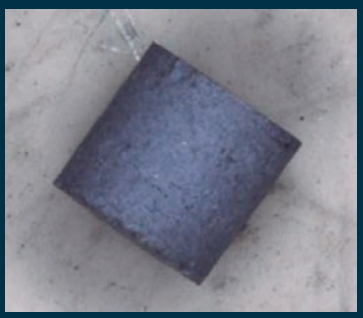
ACTIVITIES ACROSS ALL PARTICIPATING STATES

CANADA

The spatial distribution and quantity of in-situ lunar resources, such as water, ice and ilmenite, is currently highly uncertain. The VMMO (Volatile and Mineralogy Mapping Orbiter) is a low-cost 12U Cubesat that includes both the Lunar Volatile and Mineralogy Mapper (LVMM) science payload, a GNSS technology demonstrator, and the supporting 12U Cubesat platform. This GSTP activity addresses the need for mapping these lunar volatiles at relatively high spatial resolution in permanently-shadowed regions by using active single-mode fiber-lasers.

FRANCE

The BRAVE series of reprogrammable FPGA's represent an entirely new area of development for microelectronics. These high performance, very advanced electronics could revolutionise the manufacturing process and performance of multiple missions. Alongside their development there is a current industry initiative to standardise avionics systems. As part of this venture, GSTP Element 2 has initiated an activity to develop a standardised box, which will contain all the different computer modules, such as power boards, and ensure they are all compatible. This activity is expected to be one of the first onboard computers to use the BRAVE Ultra FPGA technology, and will certainly be the first in Europe.

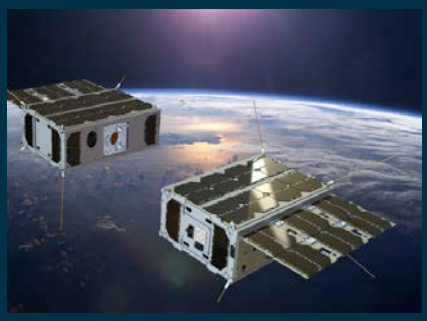


UK

Over the past decade, a new and innovative European radioisotope power technology based on americium-241 has been successfully developed. Radioisotope heater units and generators rely on the provision of americium-241 radioisotope material to provide energy. A GSTP Element 1 activity with the UK has advanced the manufacturing capability of 241AM radioisotopes. This sets up an independent European capability in radioisotope power sources that will enable a range of deep space and planetary/lunar missions that are currently impossible without outside nuclear technologies.

GREECE

An activity with GSTP Element 1 and Greece has developed a generic alarm management system. Currently, spacecraft operation teams are usually notified of non-nominal conditions when specific system parameters exceed preset threshold values, alerts that do not offer operators a deeper insight into a system's condition. The Advanced Alarm Management System will: Enhance alarm generation and notification system through advanced processing of the data using industrial grade Complex Event Processing (CEP) technologies. It will also develop a system that can provide contextual information about the monitored system that will arrive alongside the alarm on mobile applications.



DENMARK

RACE is a GSTP Element 3 funded, in-orbit demonstration mission (IOD). The satellite will fly in low Earth orbit to demonstrate, for the first time, the capability of nano-satellite systems to perform close proximity operations (rendezvous, docking or close fly around) with different targets, using critical miniaturised technologies. These technologies are currently under development in Europe such as relative navigation sensors, control actuators, and docking mechanisms. The most recent activity confirmed the technical and operational feasibility of the mission, taking into account the ongoing GSTP technology development of the 6 degrees-of-freedom cold gas propulsion system. RACE phase A/B has been completed.

GERMANY

Compliant mechanisms are well known in space applications under different configurations and categories, from flexure joints and pivots to special spring elements or actuation devices. A GSTP Element 1 activity with Germany designed three preliminary motion transformation concepts using AM: a roto-translation, a rotation reduction and a gimbal design.

AUSTRIA

The first steps have been taken to establish a non-explosive, harmless Indium-based 100W electric propulsion system for small and medium satellites. The activity successfully developed a breadboard that included all necessary functions for controlling a micro thruster, including temperature sensing and control, generation of the high voltage supplies for the ion emitter and extractor as well as heating and bias voltage supply for the charge balancing.

ROMANIA

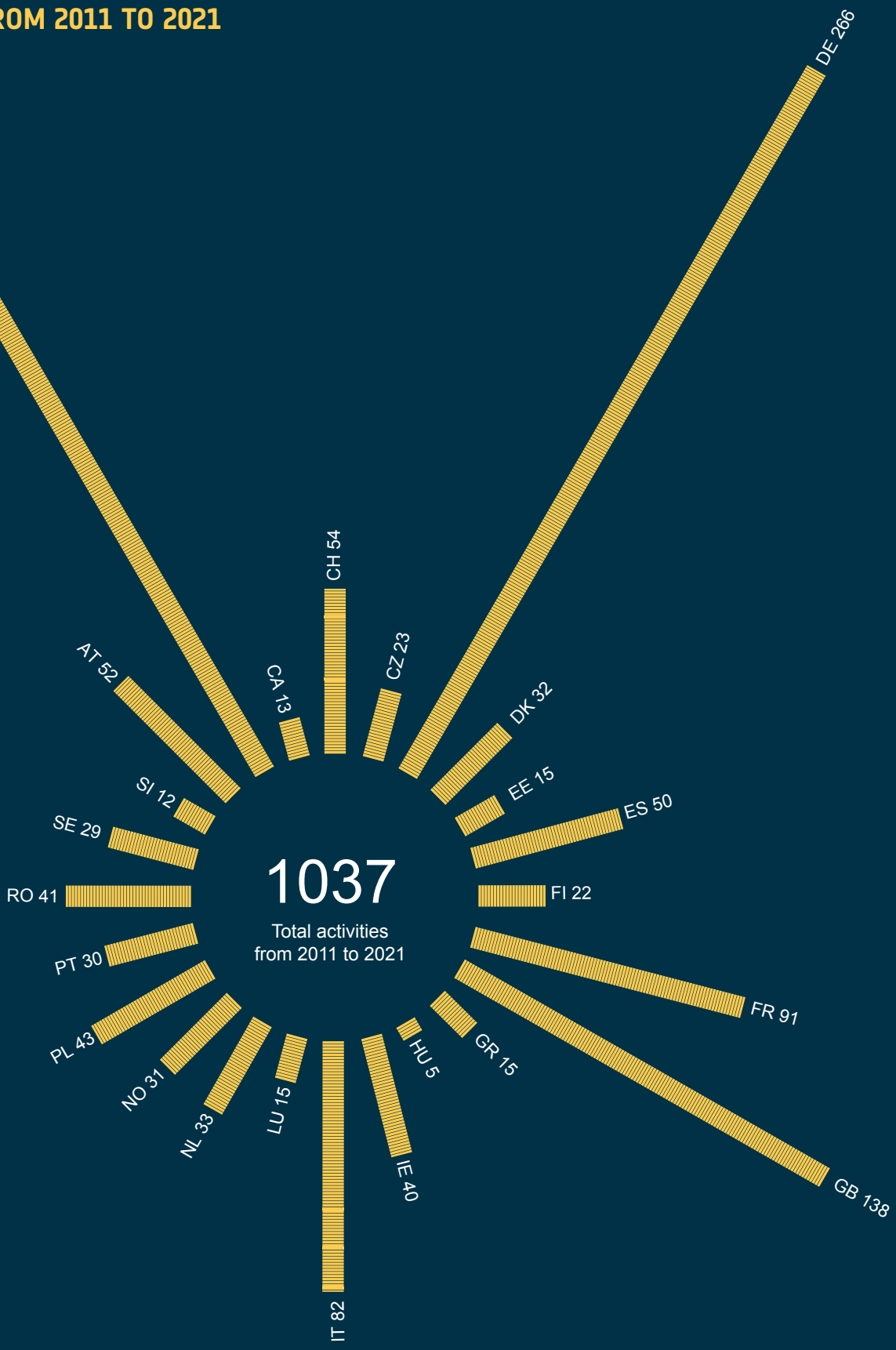
A new activity with GSTP Element 1 and Romania has developed a GNSS receiver based on COTS components that can achieve positioning accuracy to less than 10 cm without trading a loss in robustness.

Called OrbFIX, this GNSS receiver for space can produce high positioning precision in the vital low volume, mass and power consumption required for small satellites. At the same time, it is being produced for low cost, making it affordable despite its advanced technology.

After successfully concluding the Preliminary Design Review, the very promising receiver was tested to withstand radiation, in a thermal-vacuum chamber, in a stratospheric balloon and in a GNSS simulator, replicating operations in a Low-Earth Orbit.

Next, the OrbFIX receiver will be developed up to TRL 8, going through critical design, testing and qualification procedures.

NUMBER OF ACTIVITIES INITIATED PER COUNTRY FROM 2011 TO 2021

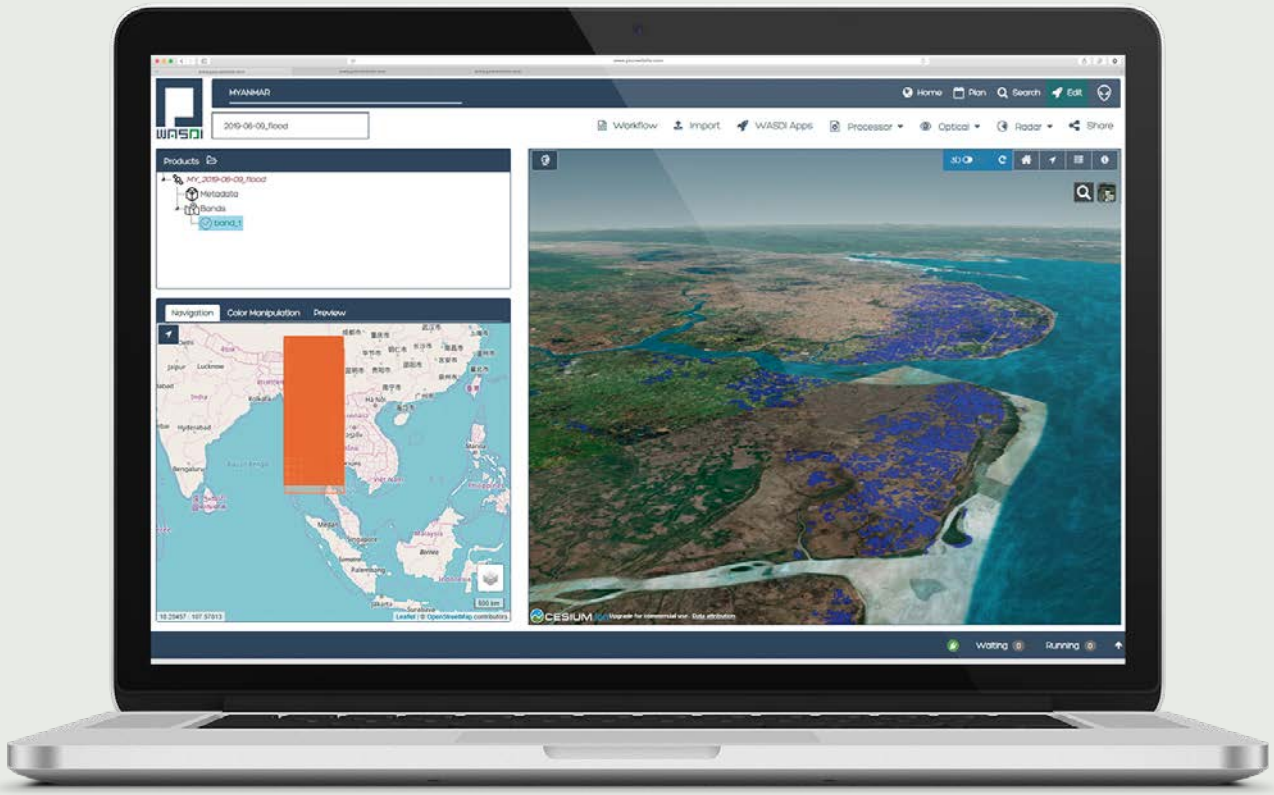


In-cloud image processing used for civil protection and employed by World Bank.

An in-cloud image processing software built by a GSTP Element 1 activity with Italy has already been employed by the World Bank. Currently, the tools available on the market to view, edit and process Earth Observation images are mostly desktop-based. But, as high performance computing progresses, there is more and more need for Earth Observation image processing to be moved onto the cloud, to minimise data transfer.

This new activity wanted to implement a tool that can let Earth Observation image experts work directly in the cloud without needing to download and process images on their PC first. Called WASDI, the prototype is already available online: users can register to access the platform, create their own workspaces, search and import Earth Observation images from different catalogues, manipulate images, create and run workflows, publish images on maps and search for new possible acquisitions in the future.

Users can also develop their own processors and deploy the algorithms on the cloud. The WASDI prototype has also been installed on the Copernicus satellite system. At the same time, WASDI is hosting operational Earth Observation services for the Italian Civil Protection (floods, forest fire) and pre-operational services for the World Bank (Continuous Flood Monitoring System for Risk Transfer).



IN FOCUS: PROPULSION

One of GSTP's most innovative activities is the SABRE (Synergetic Air-Breathing Rocket Engine) air-breathing propulsion engine, which is designed to offer hypersonic flight and cheaper and more reliable access to space.

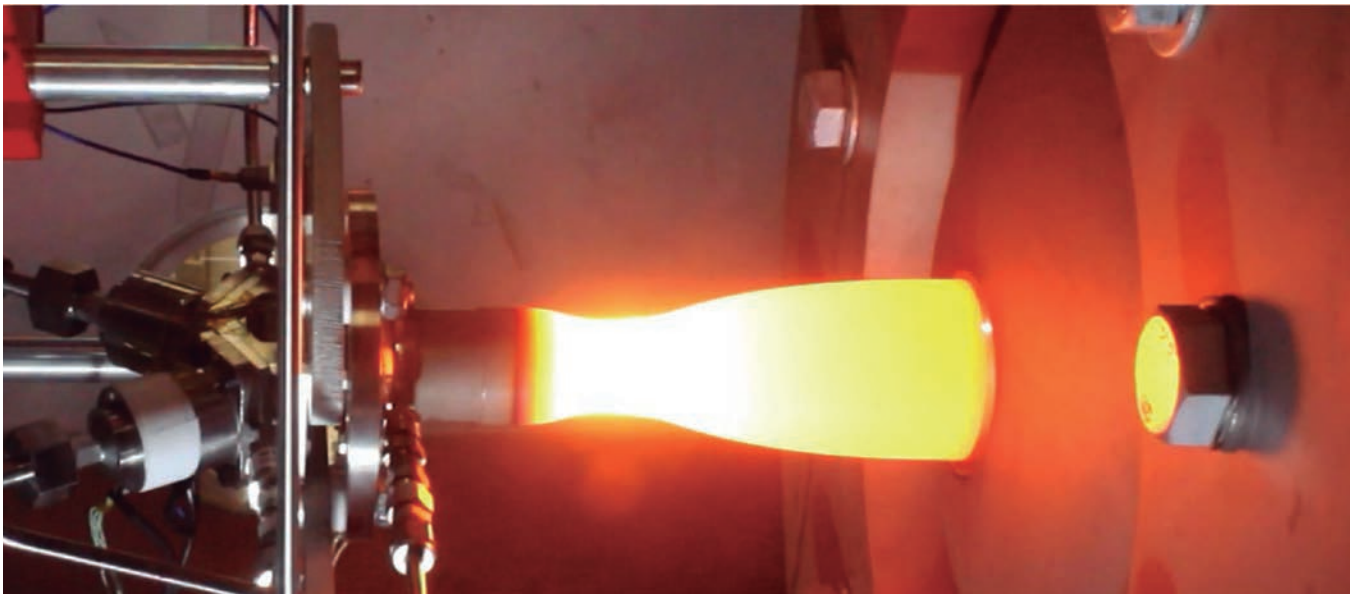
GSTP has invested €10 million into the SABRE engine, a UK activity, which is uniquely designed to scoop up atmospheric air during the initial part of its ascent to space, at up to five times the speed of sound. At around 25 km altitude, it would then switch to rocket mode for its final climb to orbit. The SABRE engine is intended for future, more sustainable, reusable launch vehicles, which would operate like aircraft. Since it would carry less bulky oxygen supplies onboard, such a vehicle could deliver the same payload to orbit of a half the vehicle mass of current launchers, as well as potentially offering a large reduction in cost and higher launch rate.

At the cutting-edge, GSTP is investing in activities such as INVICTUS, which is currently under approval. INVICTUS plans to take advantage of hypersonic propulsion engines like SABRE, to become a flying test bed for industry and academia to launch and test new components for future missions more easily. ESA is aiming for INVICTUS to be flying within the next four years.

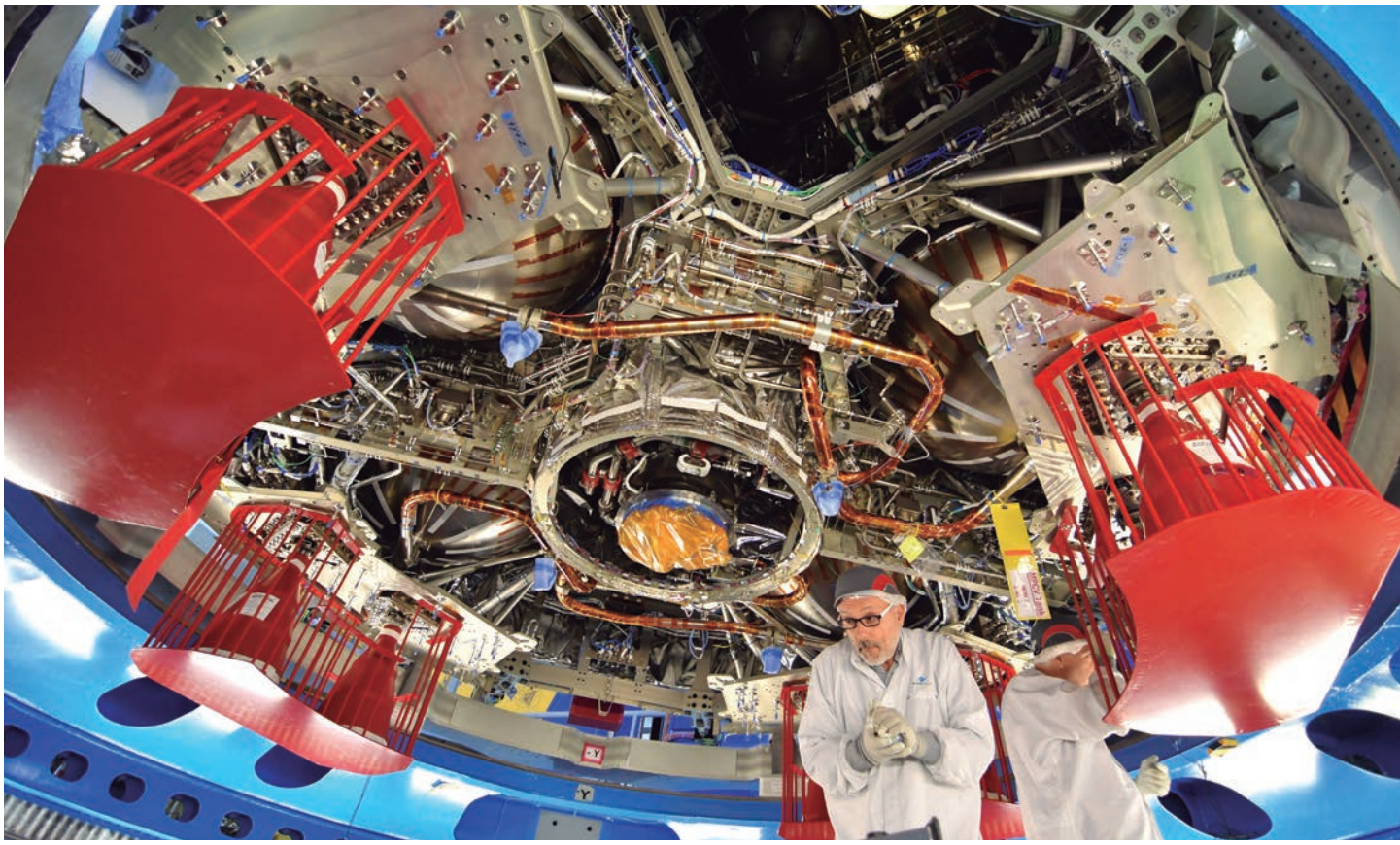
While there is considerable interest in engines, facilities and large projects, propulsion systems cannot run without fuel, which is notoriously heavy, difficult to transport and often explosive or toxic.

From the largest test facilities to the smallest component, GSTP and TDE together have over forty ongoing activities in all areas of propulsion. Whether that is investigating ways of using the latest 3D printing techniques to build lighter and stronger components for the propulsion systems, or developing artificial intelligence programmes that will monitor the amount of fuel left in a propulsion tank.

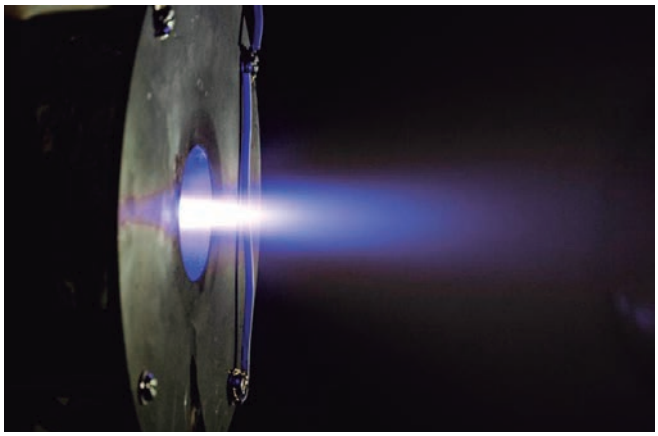
Medium Altitude Development Testing at National Space Propulsion Test Facility at Westcott UK.

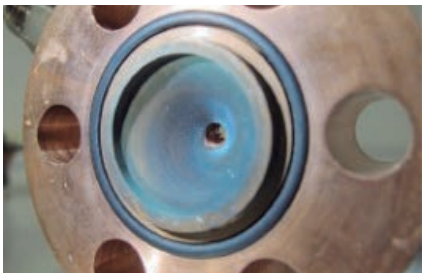


A de-risk activity with Germany developed a propulsion valve capable of replacing the current product with a European solution that is smaller and more lightweight. It will be applied as part of the European Service Module (ESM) development for the Orion project.



The Helicon Plasma Thruster (HPT) is a concept of electric propulsion which generates thrust by electrodeless acceleration of plasma. An activity with Spain designed, manufactured, assembled and tested a breadboard for a Helicon Plasma Thruster Unit.





A de-risk activity with the UK is developing a European High Performance Green Propellant. Swirl pattern of ammonia injection seen on the inlet to the arc-chamber here during testing for the activity.

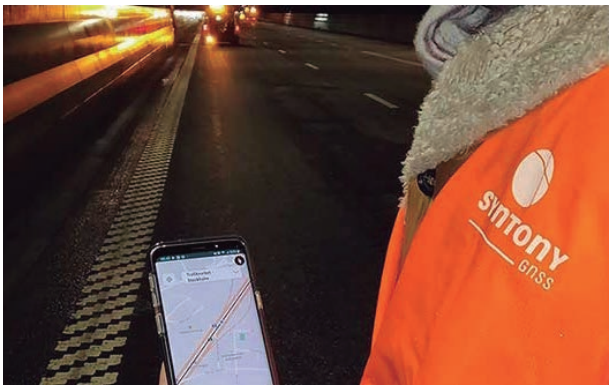
€4.5M National Space Propulsion Facility declared open. Funded by GSTP with UK

SUBWAVE+NAVIGATION UNDERGROUND

France

A GSTP Element 2 activity with France, has taken an existing product used to help signals from satellites reach underground and developed and improved it for navigation purposes.

The product, called SubWave, is for underground geolocation where GNSS signals from satellites cannot be received. It allows the navigation signals to be received with the user's normal smart phone even underground, for example in metro or road tunnels. But there is currently a drawback, which can lead to significant errors in the position being shown. Now, an improved system called SubWave+, has significantly reduced these errors, developing this system into a marketable product. SubWave+ is a substantial improvement in the system as it brings the accuracy from 10m down to few meters. It extends the location service to cover metro or subway stations and their tunnels, is designed to be compliant with any GNSS receivers and enable a seamless transition between indoor and outdoor. The developed product is already being sold to worldwide customers.



Installing transmitter.

Underground testing.

A SATELLITE FOR EVERYONE

Spain

Developing a high-performance, but low cost satellite with very high resolution products would open the Earth Observation market to a new audience, creating a path for new applications and ultimately encouraging competitiveness.

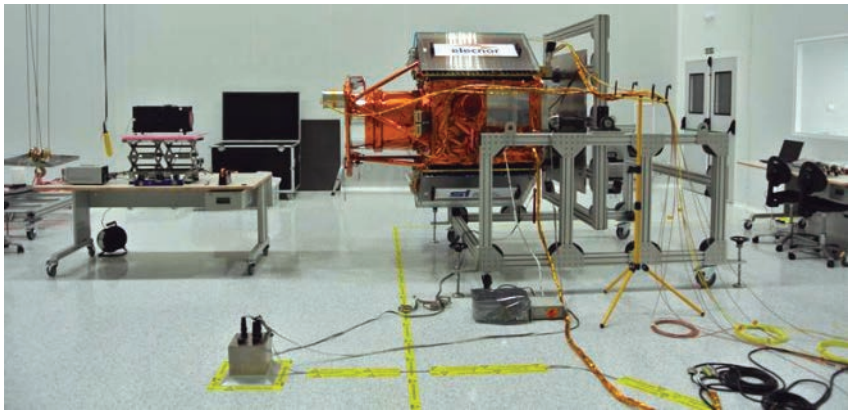
These products are currently not often covered by the space industry and access is very limited. As such a new low cost satellite, with turnkey technology could open the market considerably.

A new activity, with GSTP Element 2 and Spain, has developed a spacecraft to do just that.

The seven phases of SAT4EO opened the market with low cost solutions, merged optical very high resolution products with low-cost microsatellites, aligned the spacecraft with the current market, improved know-how, performance and covered a variety of different applications – from natural disaster, to energy through to natural resources and security.

The activity intended to deliver a fully qualified satellite that could eventually be modified in future iterations for customers or tailored to industries.

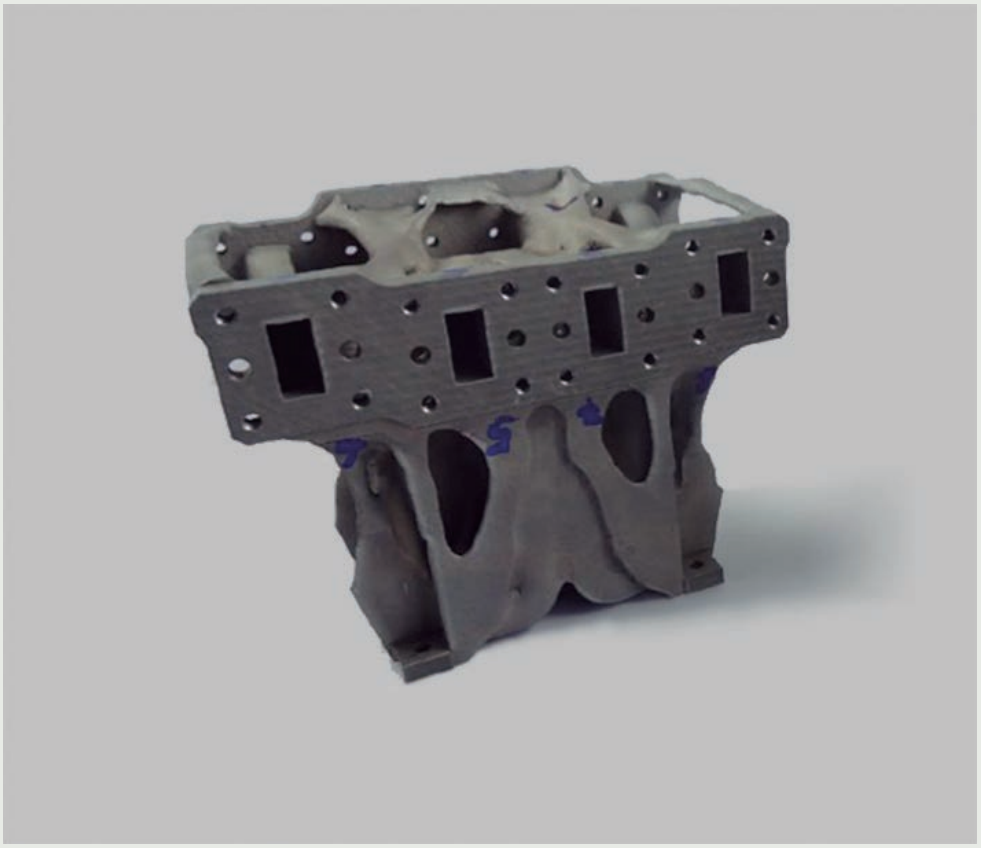
To reach this point, a variety of technologies had to first be developed or bought, from a high-resolution optical payload, to a data handling subsystem, attitude and orbit control subsystem, and a new propulsion subsystem.



Based on the complexity of the two most critical technologies, the High Resolution Optical Payload and the Imager Processor, and their current TRL status, a dedicated plan was needed for their development. The activity chose to utilise already existing technology for the High Resolution Optical Payload, to build on the extensive experience of the design, alignment and bonding of components such as primary mirrors or lenses to advance the TRL level quickly.

All four critical technologies are still progressing through design, product and readiness reviews, with the intention of having a fully developed spacecraft platform and payload to be launched by 2024.

An activity with GSTP Element 1 and Germany has shown how additive manufacturing can increase the complexity of RF microwave filters and how several functions can be included into a single monolithic structure.

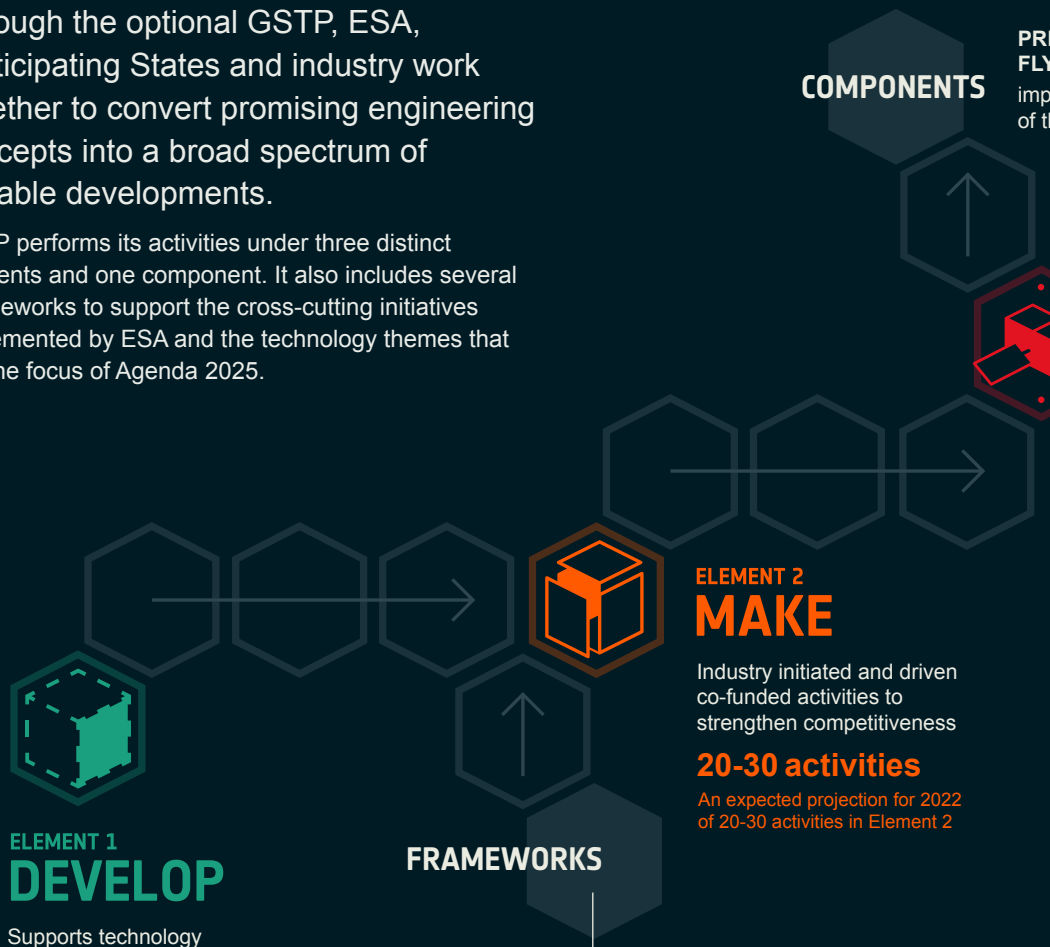


ELEMENTS AND FRAMEWORKS

GSTP STRUCTURE

Through the optional GSTP, ESA, Participating States and industry work together to convert promising engineering concepts into a broad spectrum of useable developments.

GSTP performs its activities under three distinct elements and one component. It also includes several Frameworks to support the cross-cutting initiatives implemented by ESA and the technology themes that are the focus of Agenda 2025.



COMPONENTS

PRECISE FORMATION FLYING COMPONENT
implements phases C/D/E of the PROBA-3 mission

ELEMENT 3
FLY

Implements in-orbit demonstrations of technologies in need of acquiring flight heritage

ELEMENT 2
MAKE

Industry initiated and driven co-funded activities to strengthen competitiveness

20-30 activities
An expected projection for 2022 of 20-30 activities in Element 2

ELEMENT 1
DEVELOP

Supports technology developments, building blocks and ESA technology targets

FRAMEWORKS

- Frameworks used in 21 Participating States.
- Activities are supported on a case-by-case basis or through tailored calls, addressing specific themes and/or types of entities.
- De-risk and building block frameworks are published as an OSIP Channel and on ESA-STAR, easing access to templates and information and also streamlining the procurement process.
- GSTP number of activities completed and initiated per framework: de-risk, building block, advanced manufacturing and quantum technologies.

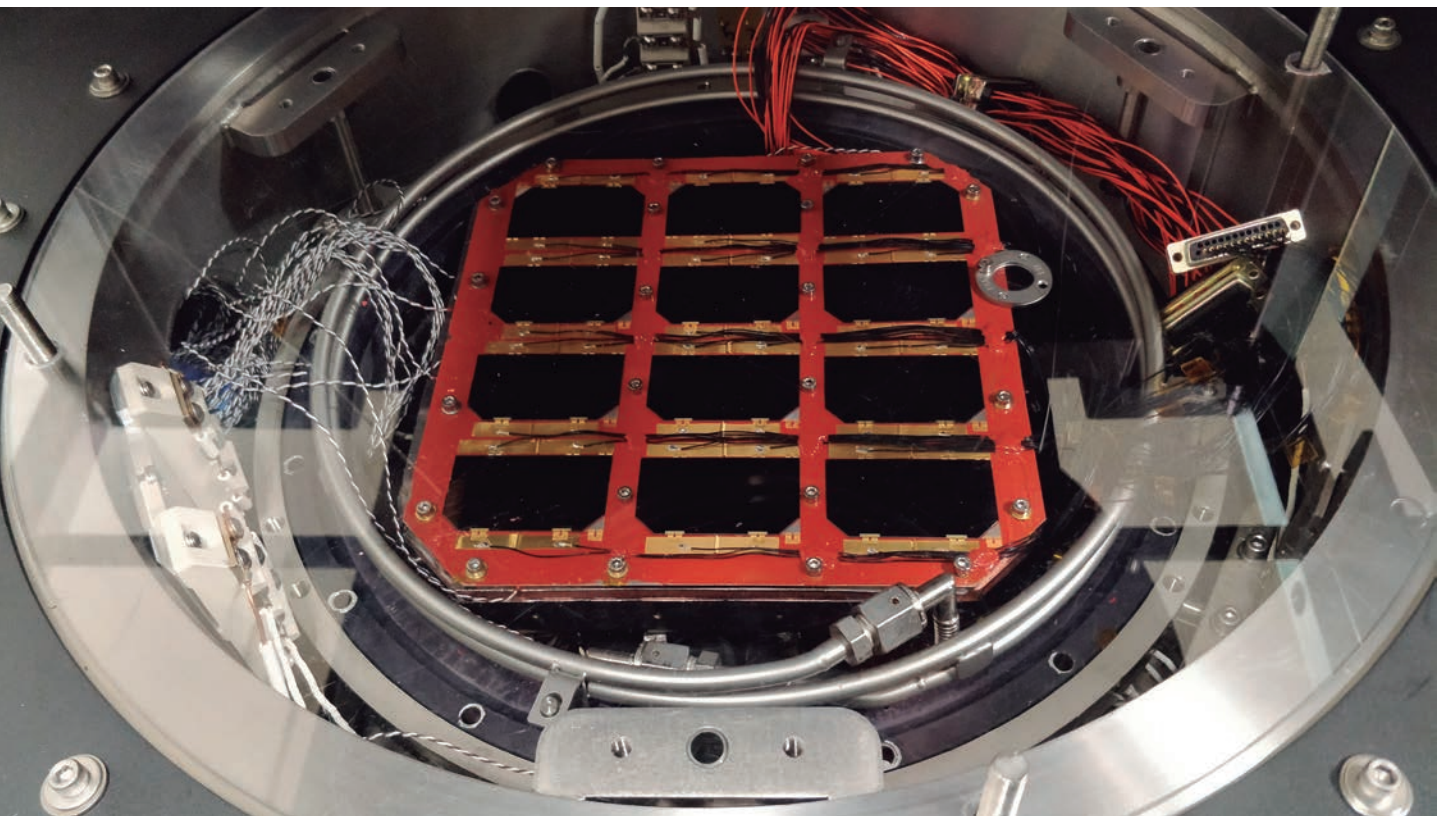
Framework	2021 Completed	2021 Initiated
De-risk	42	41
Building Blocks	12	19
Advanced Manufacturing	6	0
Quantum	0	1

STRINGS OF SUN-POWERED CELLS

Italy

A recent activity with GSTP Element 2 and Italy, has taken their most up-to-date and lowest cost solar cell and qualified it for use in space missions.

The cell, which is the size of a business card, is, in its simplest form, able to provide electricity after it is exposed to light. But just one of these cells is unable to produce enough to be able to do much. Interconnectors enable these cells to attach to each other, forming a grid or strings of these tiny cells, building up until they are able to generate enough current and voltage for multiple different needs. The strings of cells can be bonded to spacecraft or instrument panels until an entire array is built. Individually, the cells are protected by a very thin (100-150 microns thick) glass, which protects them from radiation and other dangers in the harsh space environment. The activity developed these low-cost cells by optimising the manufacturing process. While this means the cells are slightly less efficient than similar ones on the market, their lower cost means they can be benefit at the power generator level. In particular, for Low Earth and Geostationary Orbit (LEO and GEO) satellites and missions, where the solar arrays have to be less expensive while maintaining their reliability.

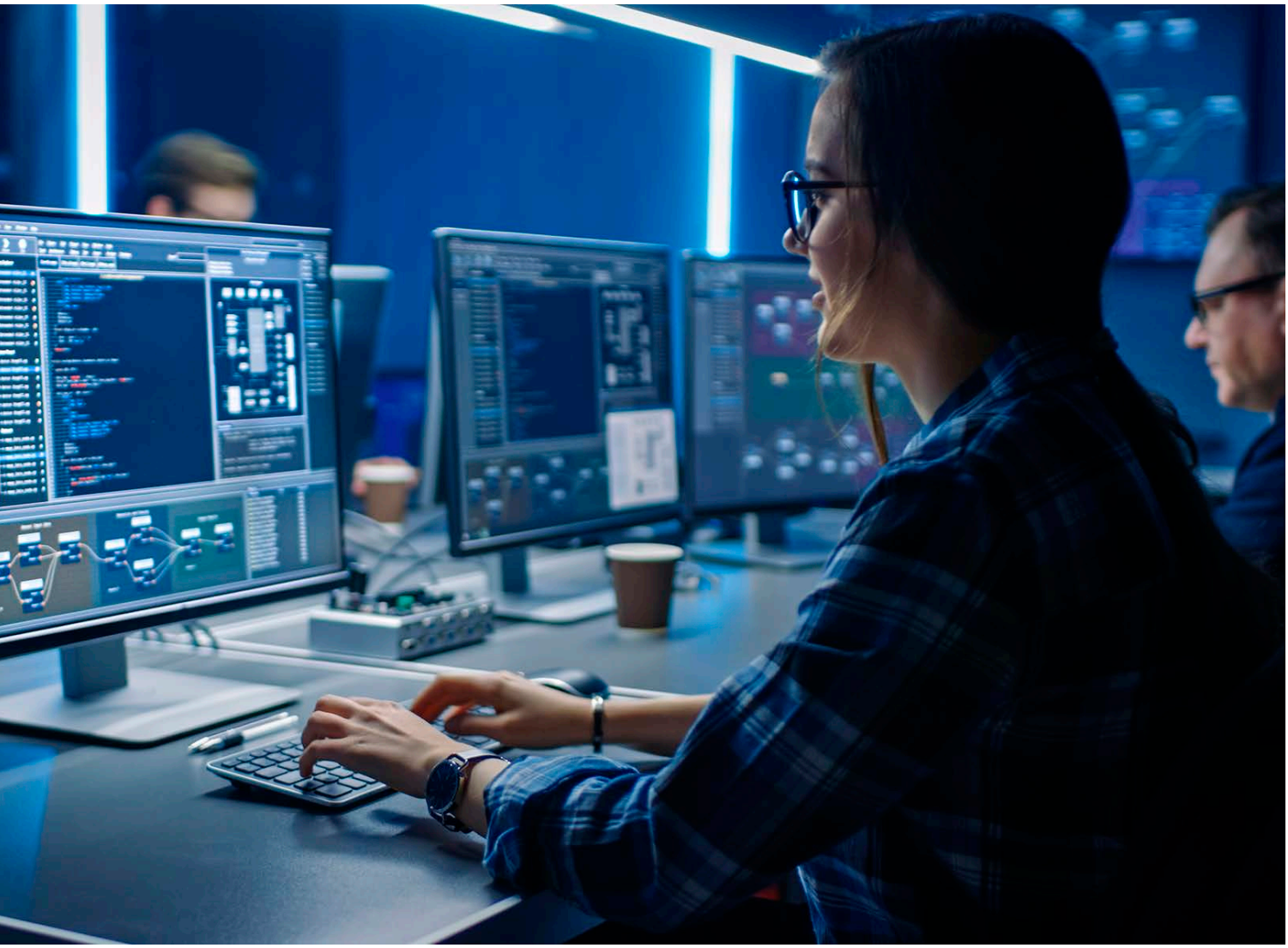


CYBERSECURITY

Funded by GSTP as part of ESA's cybersecurity project.

A large contract in phase B/C/D/E has been funded by GSTP as part of ESA's development of the Cyber Security Operational Center (C-SOC) project, to tackle building a cybersecurity 'fence' around ESA's ground and space assets. C-SOC aims to increase the cyber resilience of ESA and to ensure adequate monitoring of the security and operational environment, while also making a set of fully validated security measures available to protect space infrastructures. In addition it will act as an enabler for cyber industry competitiveness. As part of the contract different developments will be undertaken via GSTP and TDE regarding:

- secure systems,
- safe operations,
- data transmission and
- safe management of constellation like projects.
- These developments will be distributed over the strategic cybersecurity building blocks.



SUPPORTING SMALL MISSIONS

The best place to test new space technologies is in space. New technology products have to be tested in orbit, particularly when there is a high risk associated with the use of the new technology and so it can get flight heritage.

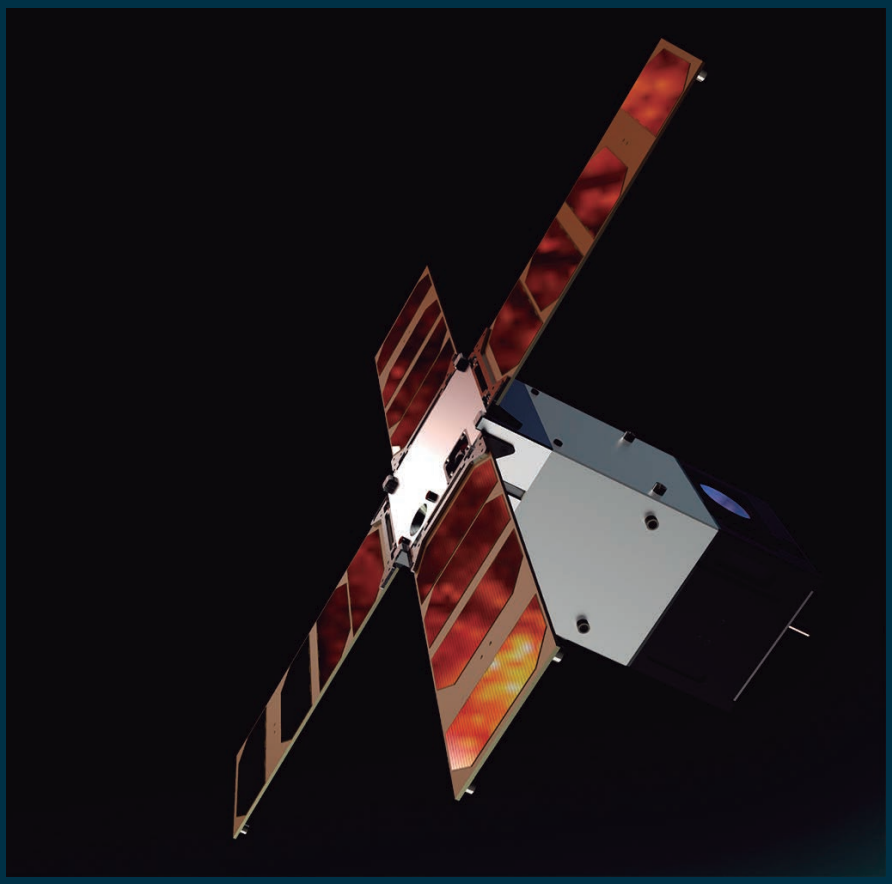
Recently ESA has been utilising CubeSats, tiny, low-cost satellites to give early orbital access to Europe's most promising technology innovations.

Nanosatellites typically weigh between 1 and 10 kilograms and follow the popular CubeSat standard, which defines the outer dimensions of the satellite within multiple cubic units of 10x10x10 cm.

Due to their high degree of modularity and extensive use of commercial off the shelf subsystems, CubeSat projects can be readied for flight on a much more rapid basis compared to traditional satellite schedules, typically within one to two years.

These flight-testing missions include:

- **SIMBA** and **Picasso** (2020) looking at the power of the Sun and ozone distribution
- **GomX-5** (2023) will test constellations for high speed communication links
- **M-Argo** (2025) will rendezvous with asteroids
- All of these small missions are funded through GSTP and its Element 3, Fly.

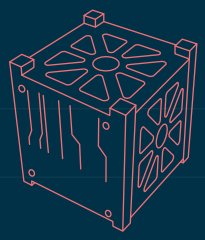


Around the same size as two big Harry Potter paperbacks, ESA's Sun-watching Sunstorm CubeSat has produced its first solar X-ray spectrum, coming just over a week after its launch to orbit aboard a Vega rocket.

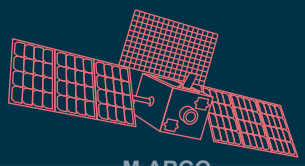
GSTP MISSIONS

IN ORBIT PLANNED

2024

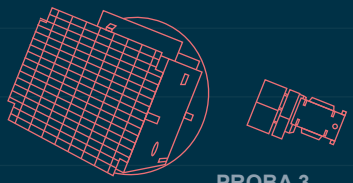


PRETTY
2023



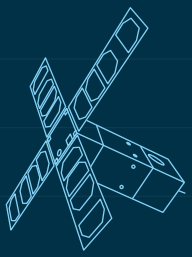
M-ARGO
2025

2021

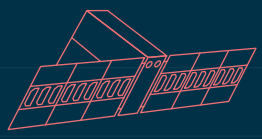


PROBA 3
2023

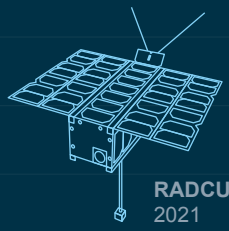
2018



SUNSTORM
2021

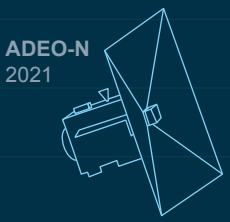


GOMX-5
2023

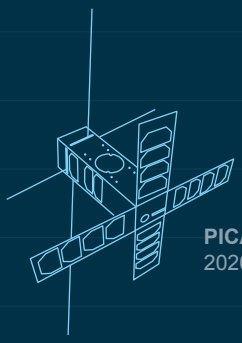


RADCUBE
2021

SIMBA
2020



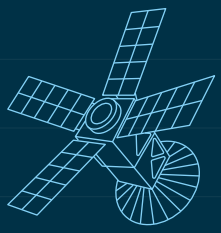
ADEO-N
2021



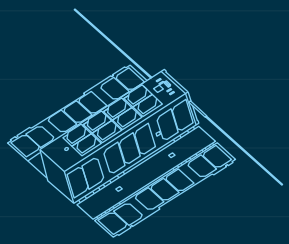
PICASSO
2020

2009

GOMX-4
2018

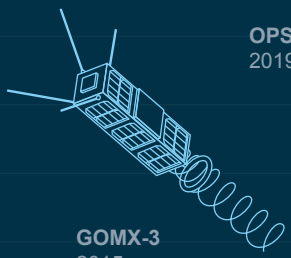


QARMAN
2019



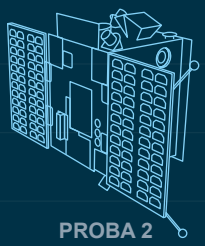
OPS-SAT
2019

PROBA V
2013

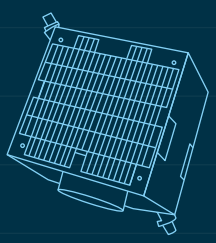


GOMX-3
2015

2005

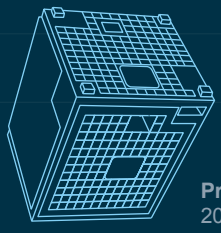


PROBA 2
2009



SLOSHSAT
2005

2001



Proba 1
2001

PROJECTS IN ORBIT

Proba-1 is a small satellite that has remained operational for 20 years, and celebrated its anniversary in October 2021.

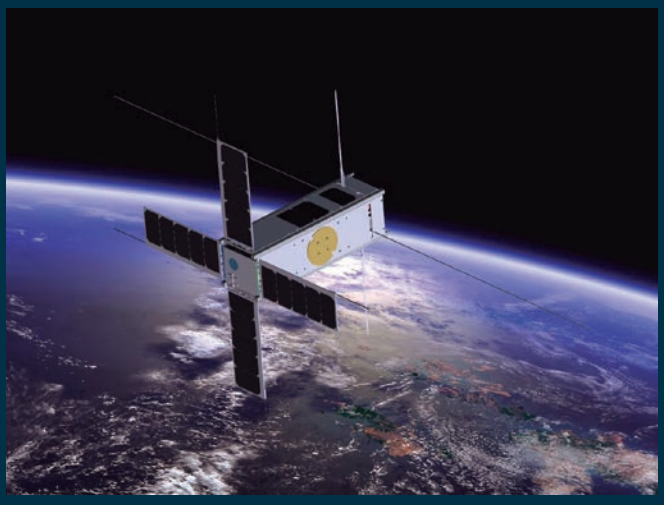
Proba-2 is a small satellite investigating space weather.

Proba-V is a small satellite that has completed the operational mission phase and has entered the experimental phase.

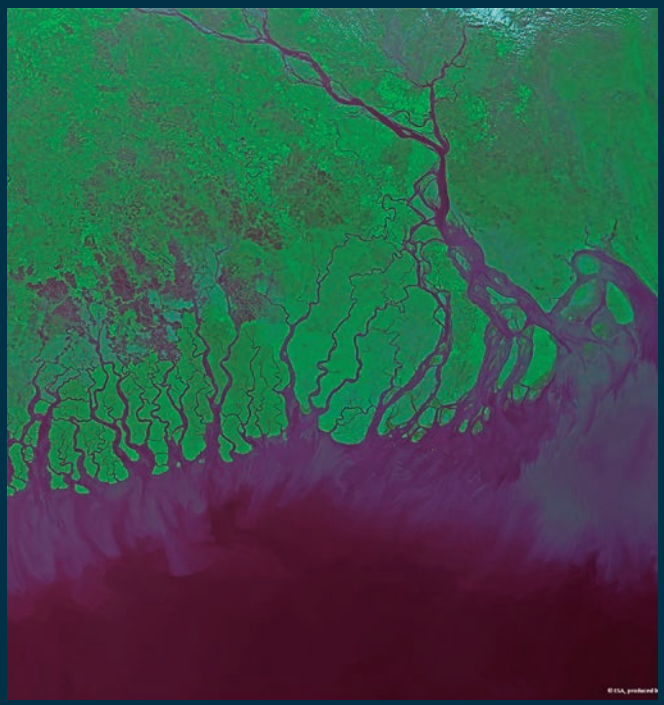
PICASSO CubeSat hosts a cut-down spectrometer for monitoring the atmosphere, as well as sampling probes (called 'SLP') to measure space plasma around the nanosatellite.

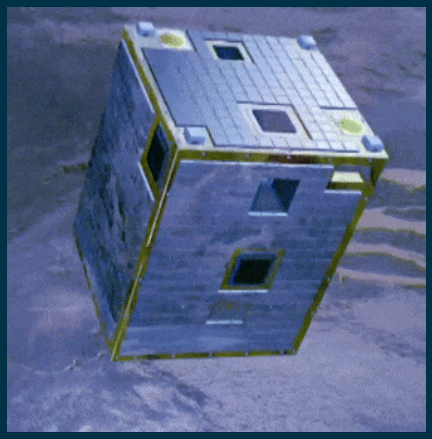
SUNSTORM CubeSat launched in 2021 and demonstrates a highly miniaturised solar X-Ray Flux Monitor (XFM) for space weather monitoring and forecasting.

PICASSO CubeSat



Proba-2 used its SWAP imager to capture the Moon passing in front of the Sun in a near-totality. SWAP views the solar disc at extreme ultraviolet wavelengths to capture the turbulent surface of the Sun and its swirling corona.





Proba-V images the Ganges Delta, the world's largest delta, in the area of Bangladesh and India. This Proba-V Vegetation image was acquired on 2 February 2014 at 100 m spatial resolution.

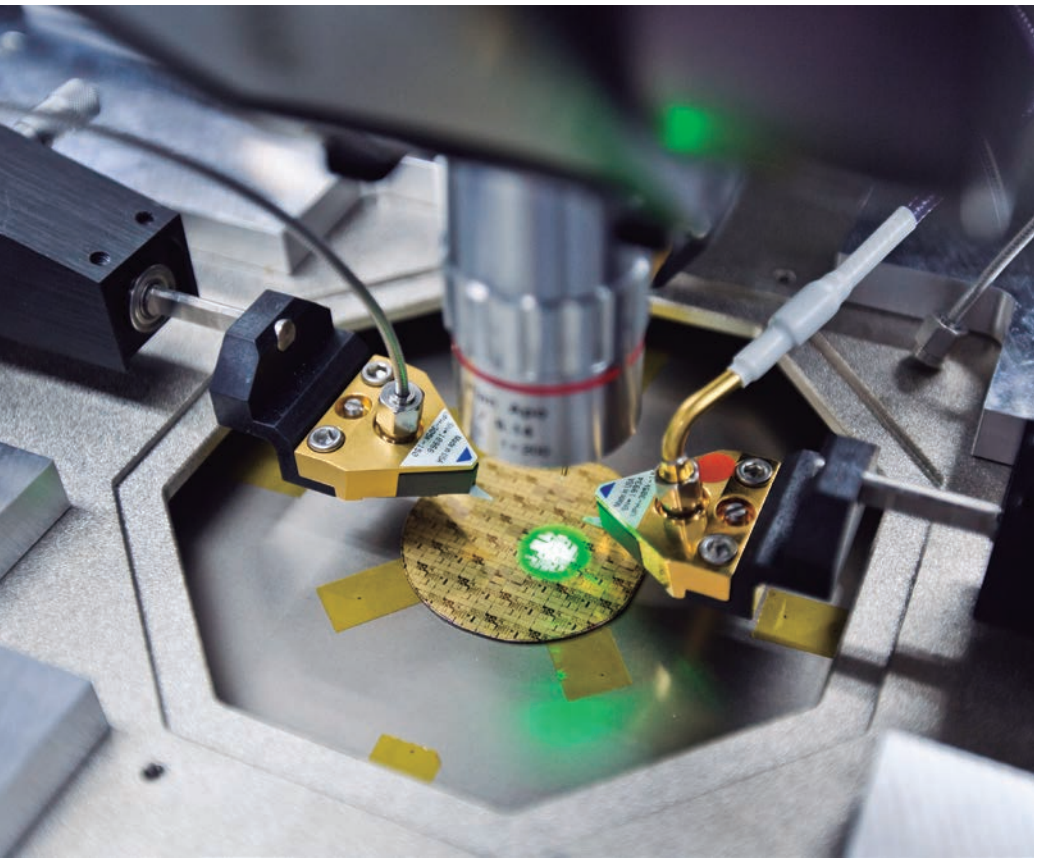
CAN INTEGRATED AVIONICS FROM THE AVIATION INDUSTRY BE APPLIED TO SPACE?

Czech Republic

Integrated Modular Avionics (IMA) is a concept developed for the aeronautics industry to manage the growth in functionality and efficiency required as the industry grows. Integrated Modular Avionics for Space (IMA-SP) is a spin-in of the corresponding concept for spacecraft avionics.

IMA-SP is foreseen as a possible technical solution for future missions, specifically for scientific missions. This is because combining different software criticality on the shared hardware reduces the computing power needed, reduces the complexity of software needed and prevents one application crashing, which affects other running applications.

Recently, ESA has launched several studies to explore possible solutions to implement IMA-SP in a form of separation kernals – a way of providing the basic functionality needed to enforce time and space partitioning without affecting communications between the applications in different partitions. These studies defined the roles and interfaces needed for software development in a partitioned environment.



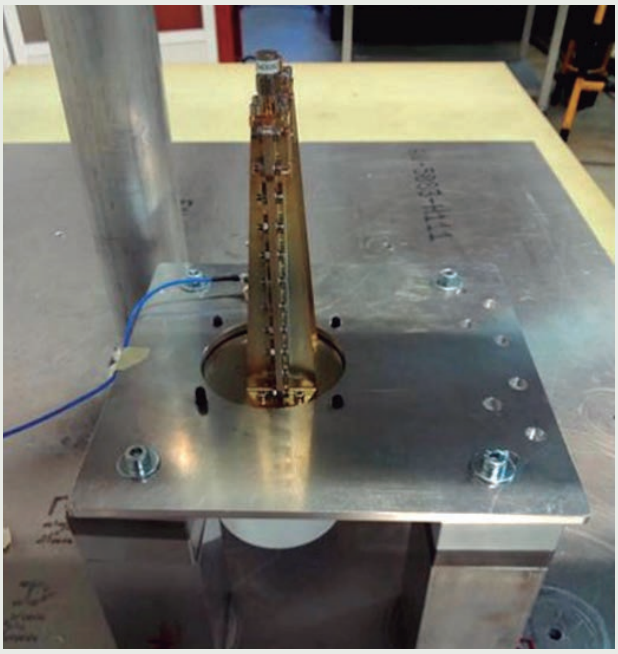
A GSTP Element 1 activity with Czech Republic, has built on this framework to further develop IMA-SP processes and roles and understand how they can be implemented and integrated. The activity defined a use case for in-flight hosting of a payload to demonstrate the feasibility of the concept.

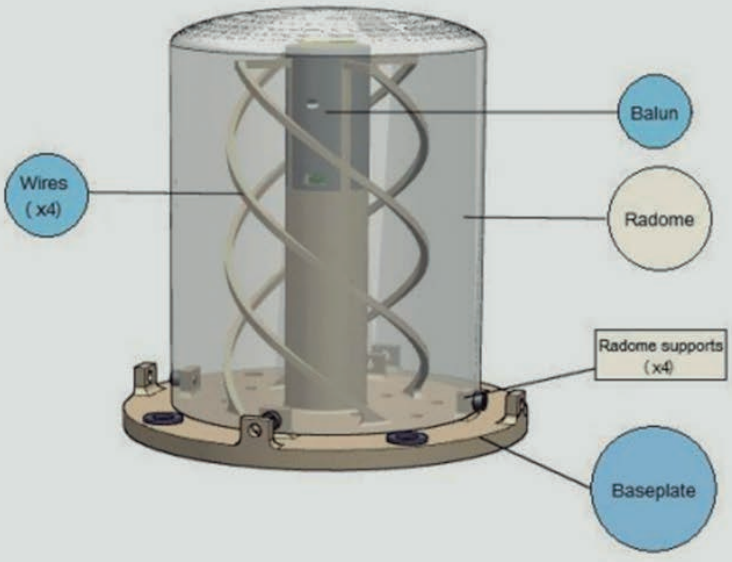
Generally speaking, the environment is not an easy one to master as it encompasses an entire on-board software. This software then has additional partitions to separate the demonstration and test environments. Finally it also has to integrate the payload software. All of these elements are largely outdated today and were not meant to be maintained over so many years.

Notably, the GSTP activity was based on a single core processor, which limits utilisation of multiple applications. But recently multi-core processors have spread around the world. If the multi-core processor is used, more interesting scenarios can be considered, such as having the IMA-SP Platform executed on one dedicated core, while the remaining cores can be utilised by payloads that may reduce the risks found in partition scheduling.

A 3D printed corkscrew antenna

GSTP with Spain, have built a radiating helix antenna using innovative Advanced Manufacturing technologies as an alternative to traditional manufacturing methods. Metallic 3D printing was shown to produce antenna with similar performance to those already in use.





ANNEXES

CONTRACTED ACTIVITIES

ELEMENT 1

DEVELOP

G61e-006SY	Space Servicing Vehicle close-range Multi-Spectral Camera EM
G617-241TAfa	De-risk assessment: Evaluation and solution of critical questions regarding the use of Solid Rocket Motors (SRM) as key components of deorbiting systems for satellites
G617-241TAfg	De-risk assessment: MOB - Moisture And Outgassing Barrier Next-Generation Of Stable CFRP Structures In Space
G617-241TAfj	De-risk assessment: Implementation of Sum-Int ADC IP-core into radiation-tolerant FPGA and performance evaluation
G617-241TAfk	De-risk assessment: 22N Thruster Maturation
G617-241TAfn	De-risk assessment: Development of a compact receiver back end for optical deep space communication
G617-241TAfp	De-risk assessment: Prediction of life time of soldered electronic assemblies for space, based on thermo-mechanical simulations
G617-241TAfr	De-risk assessment: Development of a High-Speed, High Accuracy, Multi-Physics Propagator
G617-241TAft	De-risk assessment: Hollow cathode based charge neutralisation for e-beam AM study
G617-241TAfu	De-risk assessment: Validating a novel MWIR sensor and data
G617-241TAfz	De-risk assessment: RAD Cam
G617-241TAga	De-risk assessment: Neuraspace proposal for Collision Avoidance Market Approach
G617-241TAgb	De-risk assessment: Software TDI and spectral filters on COTS sensors for cost efficient hyperspectral Earth Observation
G617-241TAgd	De-risk assessment: 3D Printed Catalyst Development
G617-241TAge	De-risk assessment: TTE memory Cpcimm
G617-241TAgf	De-risk assessment: Controlled Polymer Ablation CPA
G617-241TAgj	De-risk assessment: Additive manufacturing of soft magnetic material for satellite actuators - AMMMSA
G617-241TAgo	De-risk assessment: High-Efficiency Guide Star Laser for Space Surveillance and Tracking
G617-241TAgs	De-risk assessment: Improvement of Reliability and Lifetime for Rotary Type Stirling Coolers
G617-241TAgt	De-risk assessment: Intelligent Space Camera
G617-241TAgu	De-risk assessment: Sustainable Futures for Space Logistics
G617-241TAgv	De-risk assessment: Velocity assisted devices for suborbital vehicle
G617-241TAgw	De-risk assessment: Modular ADCS
G617-241TAgx	De-risk assessment: Equatorial Satellite Constellation Derisking
G617-241TAgy	De-risk assessment: De-risking of Cloud-native and Analytics-optimized access to hyperspectral data
G617-241TAgz	De-risk assessment: SY1201 ASIC for Radiometer Receivers
G617-241Taha	De-risk assessment: Development of Machine Learning Models for Predicting the Evolution of Satellite Collision Risk in Time
G617-241TAhb	De-risk assessment:Gyroc VTVL Platform Development and Flight Testing
G617-241TAhh	De-risk assessment: GaN-based digitally controlled modular PCDU
G617-241TAhi	De-risk assessment: IR-Camera development for formation flying, docking and SSA applications
G617-241TAhj	De-risk assessment: AFO: ADEO - Follow On
G617-241TAhk	De-risk assessment: MMU-NXT Mass Memory
G617-241TAhl	De-risk assessment: Reaction Wheel Family
G617-241TAhm	De-risk assessment: Preparatory activities for Improvement of a chemical propulsion component
G617-241TAhn	De-risk assessment: AGILE TT&C Transponder
G617-241TAho	De-risk assessment: MicroIntegrated Laser Building Block
G617-241TAhp	De-risk assessment: Independent High Perofrmance readiator development - IRAD
G617-241TAhq	De-risk assessment: Power Management Components for the New-Space Market
G617-241TAhs	De-risk assessment: Actor-based, asynchronous simulation framework for functional verification
G617-241TAht	De-risk assessment: Phase and strain monitoring during direct metal deposition of Ni-superalloy by in-situ neutron and synchrotron diffraction (PhaNi-Neutron)
G617-241TAhu	De-risk assessment: Torque Motor Valve De-risk Development
G617-241TAhw	De-risk assessment: Maximum Impulse Bit Extension for Green Bi-Propellant Thrusters
G617-248EE	Spenvis-NG interfaces, tools and models
GT1A-307MS	Copper alloys for additive manufacturing
GT1A-309MS	Development of new metallic alloys for additive manufacturing
GT1A-309MSb	Parallel Contract: Development of new metallic alloys for additive manufacturing
GT1A-312MS	Joining Solutions for Additive Manufacturing
GT1A-314MS	Finishing technologies for additively manufactured complex parts
GT1A-317SW	Application of machine learning and artificial intelligence technologies for process data analysis
GT1A-318MS	Development of a digital twin for advanced manufacturing processes
GT1A-325EF	Enhanced RF/microwave parts by using advanced manufacturing techniques
GT1A-401MS	Density-based topology optimization strategy methodology for RF components manufactured by AM
GT1I-302ED	Machine learning application benchmarking on COTS inference processors
	Machine learning application benchmarking on COTS inference processors - Parallel contract
GT1I-304ED	Machine Learning-based on board autonomy, failure prognostics and detection
	Machine Learning-based on board autonomy, failure prognostics and detection (parallel Contract)
GT1I-306ED	Robust machine learning systems for dependable space applications
GT1O-306GD	GT1O-306GD Ground segment operations automation using artificial intelligence
GT1O-310GD	GT1O-310GD Augmented and virtual reality support tool for ground station equipment and telescopes
GT1O-311GD	GT1O-311GD Test automation exchange framework
GT1O-318OP	Continuous integration of operational products
GT1Y-002IS	Cyber Safety and Security Operational Centre (C-SOC) Phase 2
GT1Y-303ES	Cybersecurity by design for mixed criticality embedded systems
GT11-002MM	Development and evaluation of curved silicon 2D array
GT11-400MT	Engineering Qualification Model of a Small Scale Cooler System
GT11-401EO	Novel reference/calibration system to measure spectral radiance on the range 4 µm to 100 µm

GT11-403ES	Development of a 1.2 Gbaud - 26 GHz payload data transmitter EQM
GT11-404EO	MUltisource data package tools and SErvices (MUSE)
GT12-010MM	Trapped Ion space optical clock physics package TISOC-PP
GT13-402SA	LIDAR Hazard Map Algorithms for Planetary Landing
GT13-403ES	GNSS L-band antenna for lunar relay satellites
GT14-016ST	Development of an European low cost separation system for small satellites
GT14-401MM	Flight Demonstrator for the TEMPUS PRO Integrated Physiological Monitoring Unit
GT14-402MS	Applied NDI methods for quality assurance of high density AM mission critical parts
GT17-009ED	Definition and validation of an European source of flip-chip bump services for 28nm and lower technology nodes
GT17-058GS	Water cooled 5-10kW X-Band Solid State Power Amplifier (SSPA)
GT17-065GE	SSE4Space - Secure Systems Engineering for Space Missions
GT17-081GR	Development of an enhanced spacecraft fragmentation code
GT17-137TIao	Preparation of enabling space technologies and building blocks: AI-enabled robotics SW suite for autonomous collaborative ISRU
GT17-137TIar	Preparation of enabling space technologies and building blocks: Science Application Store for ESA Data Labs
GT17-137TIav	Preparation of enabling space technologies and building blocks: SPACEPANEL Manufacturing process for space-graded sandwich panels (Aluminum and CFRP)
GT17-137TIaw	Preparation of enabling space technologies and building blocks: Passive Propagation Resistant Battery
GT17-137TIax	Preparation of enabling space technologies and building blocks: Chamber design and experimental evaluation for a 6kN storable propellant engine
GT17-137TIaz	Preparation of enabling space technologies and building blocks: Standard hybrid 15W DC/DC converters - Development and qualification
GT17-137TIba	Preparation of enabling space technologies and building blocks: Injector design and experimental evaluation for a 6kN storable green propellant engine
GT17-137TIbb	Preparation of enabling space technologies and building blocks: Stepper Motor Project
GT17-137TIbc	Preparation of enabling space technologies and building blocks: Multi-Needle Langmuir Probe
GT17-137TIbd	Preparation of enabling space technologies and building blocks: 6kN liquid rocket engine
GT17-137TIbe	Preparation of enabling space technologies and building blocks: Core vehicle main structure and tanks manufacturing and integration
GT17-137TIbf	Preparation of enabling space technologies and building blocks: Operations, ground support, test site and reusable testing platform infrastructure concept and sizing
GT17-137TIbi	Preparation of enabling space technologies and building blocks: Automated Manufacturing for Space hardware
GT17-137TIbk	Preparation of enabling space technologies and building blocks: GNSS-AI on-EDGE - Onboard detection of GNSS signal disturbances by DNN
GT17-137TIbl	Preparation of enabling space technologies and building blocks: Development of grid-stiffened cylinders for space transportation applications
GT17-137TIbm	Preparation of enabling space technologies and building blocks: ORBFIX Phase 2
GT17-137TIbp	Preparation of enabling space technologies and building blocks: Test facility for 25kN Lox & LNG engine
GT17-137TIbs	Preparation of enabling space technologies and building blocks: GPS Guided Parafoil Descent System
GT17-137TIcd	Preparation of enabling space technologies and building blocks: Absolute Localisation for Planetary Exploration Rovers (ALPER)
GT17-154MS	Lithographic Manufacturing of Monolithic Ceramics for Stable Structures in Space Follow-up-Phase 1
GT17-183MP	Numerical and Experimental Validation of Spacecraft Demise during Atmospheric Re-entry
GT17-187MMc	Quantum Technologies for Space: Active Alignment System for Quantum Communications
GT17-304ED	Alternative test methods for COTS
GT17-312MS	Smart NDT system for complex shape polymer matrix composite space structures and assemblies
GT17-315MS	Pointing mechanism for electric thruster propulsion for nanosats
GT17-323MT	Towards a thermal digital twin
GT17-327ED	Strategies for reliable on-board reconfiguration of FPGAs
GT17-340EP	Advanced multi-junction solar cells focusing to cost reduction
GT17-341EP	Power unit for high power radars and altimeters, improving the dynamic performance under pulsed operation
GT17-342EP	N channel Latching Current Limiter
GT17-343EP	New packaging techniques to increase power density of power control and distribution units
GT17-382EO	3D visualization of fluid surfaces (3DFLUS)
GT17-385SY	Model-based system engineering for AIV (MBSE 4 AIV)
GT17-400MS	Dry lubricant composite for deployment mechanisms with initial low friction (A3Lub2)
GT17-403MP	Electric propulsion diagnostic package flight model
GT17-404ST	National Technology Transfer Activities
GT17-407MS	Compact Reaction Wheel Technologies for High Accuracy Smallsat Missions
GT17-410SW	Solar Polarimeter - Critical Technology Development
GT17-411MP	Miniature ion thruster, neutralizer and harness development/ qualification and pointing mechanism integration
GT17-413SD	Software technologies supporting CREAM
GT17-416MM	Thermal infrared imaging camera for small satellites (SATIRIM 2)
GT17-417ES	Configurable Space Security Module - Stage 1
GT17-419GD	GT17-419GD Deployment model for Control Centre operating heterogenous missions
GT17-421MT	Mechanically pumped miniature cooling loop for small satellites
GT17-422QQ	Independent Software Verification and Validation (ISVV) activities for RTEMS Symmetric multiprocessing (SMP)
GT17-426ES	Real-Time flexible reconfigurable Waveform Testing Platform (WTP)
GT17-428MM	Manufacturing, test development and evaluation of a monolithic, rad-hard ECM LVDS component family
GT17-441SW	Ground Software Systems Performance Validation
GT17-442SW	System validation and CDM viewer development
GT18-003EP	Radiation Monitor System in a Package
GT18-009EP	3D Ionospheric Modelling

ELEMENT 2
MAKE

GT21-076ES	ONEO
GT21-099ED	Generic Universal Processing Module (UPM) Product Development
GT21-103EF	Efficient Information-Preserving Image Compression for Space Applications EIPICSA
GT26-081EF	On Board Solid State Power Amplifier Modules for Galileo Transition Satellites
GT26-109EF	Broadband L-Band Preliminary Design Development for a Broadband Amplifier in L-Band for Navigation
GT27-063MS	Innovative Large Flexible Reflectors (REF-FLEX)
GT27-066EP	Development of one axis solar array drive assembly for CubeSats (SADACUBE)
GT27-072EP	Standard Mechanism Drive Electronics (sMDE)
GT27-075MT	Thermal switch simulation models
GT27-080ED	RTU Product Extension
GT27-082MS	Micro-control moment gyroscope attitude actuator
GT27-085EP	PVA Flexible Development
GT27-086ED	6 Gigabits European Space Serializer-Deserializer (SERDES) under TSMC65 technology
GT27-087EP	PCDU Product Extension
GT27-088ED	Development of a multi core LEON5FT Space grade Microprocessor GR765
GT27-089MP	BOOST - Breakthrough Opportunity Of the NPT30-I2-1.5U System
GT27-090ED	Development of a ruggedized frequency doubler
GT27-091ES	Relay Communication Technologies
GT27-092SA	Enhancing the robustness of the Auriga Star tracker
GT27-093EP	New Evolutions and EGSE Product Enhancements
GT27-094EP	Plug & Play Solar Panel for Smallsats
GT27-097MP	Improvement of the PPS Product Line Technologies
GT27-098EP	Improved Ge wafer technology for multijunction solar cells (IMAGER V)
GT27-101SW	Development of Real-time operating system for ARM microcontrollers
GT27-102ES	GNSS Receiver Multi-Constellation, Multi-Frequencies associated with an Orbital Navigator
GT27-104ST	Safeguard Localization and Autonomous Decision Unit (SLADU)
GT27-106EP	Low Power PPU
GT27-111MS	Thruster Pointing Mechanism Development

ELEMENT 3
FLY

GT37-001SYr	Neptuno
GT37-004SP	ProbaV -Companion CubeSat (Phases D/E1)
GT37-009MP	Development of the Space Rider Observer Cube Phase B1

CLOSED ACTIVITIES

ELEMENT 1

DEVELOP

G61A-006QT	Powder Metallurgy Based Materials for High Wear Resistance, High Hardness and High Temperature
G61A-021QT	Primary Structures made by Additive Manufacturing
G61A-025MS	Development of Design Methods for AM including CAD Design / FEM analysis / Manufacturing features
G61A-027MS	Development of embedded thermal functions in structural parts using 3D printing
G61A-029ET	Development of one single part integrating waveguide filter, bends, coupler, supporting structures by Additive Manufacturing
G61A-032MM	Development of low areal density Aluminium alloy mirrors using Additive Manufacturing
G61A-033MSb	Parallel - Development of a Compliant Mechanism Based on Additive Manufacturing
G61A-036QTe	Optical payload with additive manufacturing - Assessing the use of Advanced Manufacturing to improve and expand space hardware capabilities
G61A-036QTg	Assessing the use of AM: Potential of AM applied to filling tubes
G61A-036QTj	Assessing the use of AM - 3D Printed Solid Antenna Mesh Reflector
G61A-036QTk	Assessing the use of AM: AM Process Development for Manufacturing a Closed Pump Impeller
G61A-036QTl	Assessing the use of AM: AM of a Flywheel for High Performance Reaction Wheel
G61A-036QTm	Assessing the use of AM: Printed component for New Orbital Infrastructure pumps system
G61C-007QT	Surface Engineering for parts made by Additive Manufacturing (Step 1)
G61C-021EP	Spacecraft power system passivation at end of mission 3rd Batch 2013 (Mid year Priority)
G61C-052EC	Development, test and qualification of demisable magnetorquer - Phase 1
G601-69EC	Second Generation APS improvements for flexible low cost and mass sensors LCMS2
G611-031EP	SOLAR CELL INTERCONNECTOR DESIGN OPTIMIZATION FOR SURVIVING HARSH FATIGUE ENVIRONMENTS
G611-047EO	Quality Control Metadata Management System for Land Monitoring Services (QC-MMS)
G611-049EO	Atmospheric Missions DAta packaging (AMIDA)
G614-004MP	Experimental characterisation of transient flow phenomena in cryogenic Fluids
G614-013MP	Launcher payload fairing transparency preliminary assessment
G617-107MS	MATS - Multilayer Adaptive Thin Shell Reflectors for Future Space Telescopes
G617-150SW	Development of Partitioned Prototype Application - IHPA
G617-167EE	Supra THz receiver Front-End
G617-169QT	Preliminary reliability assessment of a European 0.25 ym GaN HEMT process
G617-206SW	Applicability of Mutation Testing method for Flight Software
G617-223QT	SPACECAP STACK DEVELOPMENT TO MARKET & QUALIFICATION ACTIVITY
G617-230SId	Assessment studies for synergy between technology developments in terrestrial sectors and the space sector - Electronic components with improved radiation resistance based on isotopic enriched elements
G617-234MM	Radiation testing of optical coatings for space
G617-241TAad	De-risk assessment: Liquid Oxygen Turbopump
G617-241TAam	De-risk assessment: LIDAR for Exploration
G617-241TAao	European High Performance Green Propellant - Assessments to Prepare and De-Risk Technology Developments - G617-241TAao
G617-241TAaq	De-risk assessment: GSTP Aerial Recovery
G617-241TAbc	Experimental Feasibility Study of the Conical Pump as a Satellite Propulsion Booster - Assessments to Prepare and De-Risk Technology Developments - G617-241TAbc
G617-241TAbg	De-risk assessment: Graphene-based materials with improved gas barrier properties for space applications
G617-241TAbk	De-risk assessment: 6KN Engine - NAMMO UK
G617-241TAbm	De-risk assessment: 60kN Kerosene pump
G617-241TAby	De-risk assessment: Helix Antenna
G617-241TAbz	De-risk assessment: u should be greek micro symbol
G617-241TAcb	De-risk assessment: Satellite Test bed for EGNSS based Vehicle Localization Validation (STEV)
G617-241TAch	De-risk assessment: Powder Characterization
G617-241TAci	De-risk assessment: Deep-space optical communication system (DOCS)
G617-241TAco	De-risk assessment: 2D Lightweight Materials and Coatings for EletroMagnetic Interference Shielding Applications
G617-241TAcw	De-risk assessment: Norwegian engine operating on green storeable propellant - expro
G617-241TAcx	De-risk assessment: Development of mission compatible aerospace diaphragms and bladders
G617-241TAcz	De-risk assessment: Spectrometer for Marine Litter
G617-241TAdh	De-risk assessment: Quantifying Effect of Protuberances and Interfaces from an Aero-Thermo-Structural Design Perspective
G617-241TAdi	De-risk assessment: Plasma Focus Thruster
G617-241TAdn	De-risk assessment: LEROS ACE-25 Engine Development
G617-241TAdp	De-risk assessment: Next Generation Remote Interface Unit Architecture
G617-241TAdq	De-risk assessment: High-Performance Pulse-tube Cold Finger
G617-241TAds	De-risk assessment: Generic flexible Nanosat platform for IOD and IOV services - Scenario 1
G617-241TAdu	De-risk assessment: Generic flexible Nanosat platform for IOD and IOV services - Scenario 3
G617-241TAdv	De-risk assessment: Generic flexible Nanosat platform for IOD and IOV services - Scenario 4
G617-241TAdz	De-risk assessment: Novel Cooling and Pressurisation Cycle for a Rocket Engine Suited to SmallSat Launch Applications
G617-241TAeb	DE-RISK ASSESSMENT: MPCV-ORION EUROPEAN PROPULSION VALVE - EXPRO
G617-241TAef	De-risk assessment: Fuel Cell application for future missions
G617-241TAei	De-risk assessment: Technology Enhancement Evaluation of STT S-Band Transceivers
G617-241TAek	De-risk assessment: Machine Learning to support Threat & Vulnerability Management
G617-241TAel	De-risk assessment: Computer Module Maturation Campaign
G617-241TAem	De-risk assessment: Smart Tanks for Space
G617-241TAen	De-risk assessment: 12U Chemical Propulsion System
G617-241TAep	De-risk assessment: Highly efficient computer-generated holograms for space applications
G617-241TAeq	De-risk assessment: Fiber-steering for lightweight & cost-efficient space structures
G617-241TAes	De-risk assessment: Helicon Plasma Thruster
G617-241TAeu	De-risk assessment: Hyperboloid Rocket Thrust Chamber Technology (HYPE)
G617-241TAew	De-risk assessment: High data-rate bus for Cubesat
G617-241TAf	De-risk assessment: Long-life Valve

G617-241TAfk	De-risk assessment: 22N Thruster Maturation
G617-241TAgb	De-risk assessment: Software TDI and spectral filters on COTS sensors for cost efficient hyperspectral Earth Observation
G617-241TAge	De-risk assessment: TTE memory Cpcimm
GT617-244EC	Second Generation APS improvements for flexible low cost and mass sensors LCMS2
G617-249SW	SAVOIR Electronic Data Sheet Definition
G617-273ED	GR740 Next Generation Microprocessor Flight Models (NGMP Phase 3)
G617-278ED	Sensing element replacement and magnetometer requalification
GT1A-004MS	Novel structural components for launchers/satellites applications using additive manufacturing technologies
GT1G-004SW	RE-ISSUE - Performance Analysis EGS-CC based applications
GT1Y-001IS	Cyber Safety and Security Operational Centre (CSOC) Phase 1
GT1Y-001IS	Cyber Safety and Security Operational Centre (CSOC) Phase 1
GT1Z-502ET	Design and development of a reconfigurable Telemetry Transmitter for Earth Observation Satellites
GT1Z-505MS	Ceramic structures sizing and verification method improvements
GT1Z-505MS	Ceramic structures sizing and verification method improvements
GT11-016MM	MicroMHiDe: Technologies for Microsatellites Multispectral High Definition Imager.
GT11-019EO	End-to-end Instrument Performance Simulator upgrade of the SEOSAT/Ingenio mission.
GT11-020EF	Advanced Antenna Modelling Tool for Performance Verification and Diagnosis
GT11-022EO	ESE Ergonomic User Interfaces (ESE-ERGO)
GT13-008EP	Americium Fuel Pellet Development & Medium Scale Plant Design
GT14-010DV	Recovery of re-entry vehicles and launcher stages by means of the Mid-Air Retrieval technology
GT17-044EF	Fast Diagnostic Methods for Large-Scale Full-Satellite Antenna Measurements
GT17-057GI	GT17-057GI - C2LOCO Generic MCS / EGSE for smallsats and low cost operations
GT17-108SW	ISVV for evolutions in SW development methods & processes
GT17-113ES	VDES pre-operational demonstration for navigation augmentation and VHF maritime spectrum monitoring
GT17-117MP	Spacecraft Propulsion Component Developments - The re-qualification of propellant filter
GT17-122MP	High Altitude Test Facility - Realization Phase
GT17-132MM	NEWSI for Detection of hidden defects in composites and metals - to improve confidence in structural integrity.
GT17-133EP	Metal-Wrap-Through (MWT) Multi-Junction Solar Cells
GT17-137TIah	Preparation of enabling space technologies and building blocks: ATENA - AIT/AIV and Operations based on OTX
GT17-137TIam	GT17-137TIam - Preparation of enabling space technologies and building blocks: Satellite Operations Simulator For Cyber Exercises
GT17-137TIau	Preparation of enabling space technologies and building blocks: EGS-CC consolidation: provision of minimum viable product
GT17-137TIbl	Preparation of enabling space technologies and building blocks: Development of grid-stiffened cylinders for space transportation applications
GT17-137TIf	WeatherCubes demonstrator
GT17-137TIh	Preparation of enabling space technologies and building blocks: Multi-beam uplink antenna demonstrator
GT17-137TIk	Preparation of enabling space technologies and building blocks: PVA Flexible Pathfinder
GT17-137TIl	Preparation to prepare enabling technologies and building blocks: WARP
GT17-137TIu	Preparation of enabling space technologies and building blocks: BBK Platform Electronics for Observation & Navigation
GT17-137TIx	Preparation of enabling space technologies and building blocks: Optical Head for an Instrument
GT17-144MP	Development of a flight Electric Propulsion Diagnostic Package (EPDP) for EP satellite Platforms
GT17-146GI	Proactive Performance Monitoring Engine using Predictive Machine Learning Techniques for Systems evaluated on Space and non-Space use cases
GT17-155SA	Space Missions Global Optimisation for Spacecraft Guidance
GT17-156ES	Software-Defined Radio TT&C Modem for RF-SCOE and Ground Segments
GT17-158MP	Mono- and Bi-Propellant Flow Characterization in Generic Propulsion Systems
GT17-178MM	Automotive LiDAR technology for Space applications - RE-ISSUE
GT17-442SW	System validation and CDM viewer development

ELEMENT 2
MAKE

G627-019ET	Class 3 S-Band TTC EQM transponder development
G627-072EP	Qualification of Low Cost Solar Cells at Bare and SCA Level
G627-089ED	Extreme Rapid Mass Memory Unit
GT26-022ES	AsteRx 2020
GT26-024ES	Subwave+
GT27-009MM	MICA Optical characterization of high-precision mirror.
GT27-012SW	Multi-Purpose Interface Platform (MPIP) for EGSE
GT27-014EP	UniverSAS Power Supply Extension
GT27-018MS	Development of Large-Class 3D Printing by means of ``VARIOCLAD`` Laser Metal Deposition
GT27-026MT	HiPeR-AdPack Technology Development
GT27-050MS	MW1000-DX High Torque Reaction Wheel
GT27-086ED	6 Gigabits European Space Serializer-Deserializer (SERDES) under TSMC65 technology
GT27-090ED	Development of a ruggedized frequency doubler

ELEMENT 3
FLY

G637-001TFaa	Phase A study for VMMO Lunar Cubesat
G637-001TFac	E.inspector phase A
G637-001TFx	Phase A/B study for Belgian IOD Cubesat Mission
G637-006MM	VIRSI Hyperspectral Imaging In-Orbit Demonstration
GT37-001SYh	Phase A Study for LUMIO Lunar Cubesat

Participating states:
Austria
Belgium
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Luxembourg
Netherlands
Norway
Poland
Portugal
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United Kingdom
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Lithuania
Slovenia