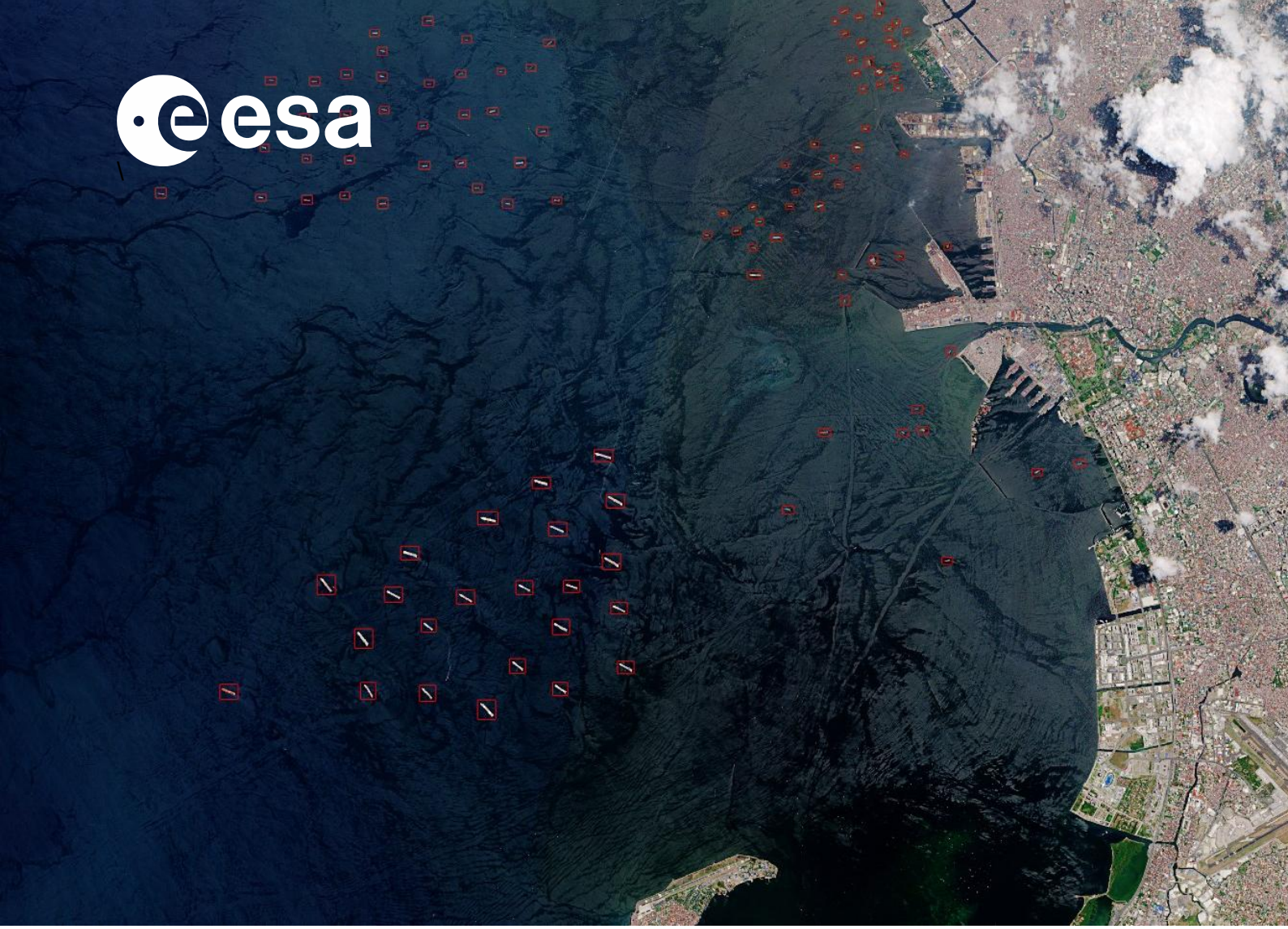


IMPACT ASSESSMENT OF ESA EARTH OBSERVATION EARLY R&D ACTIVITIES

Φsat-2 Mission

know.space

March 2025

Earth Observation holds untapped potential in expanding our understanding of the planet …

An improved understanding of the Earth's systems – including weather, climate, and ecosystems and their respective interactions – is crucial for predicting and mitigating the impacts of global changes on humanity. Earth Observation (EO) data is vital for informed decision-making, providing evidence to support global environmental strategies, enable policy actions and monitor progress at all geographic scales.[1] EO data advances the UN's Sustainable Development Goals (SDGs) by driving solutions in areas such as urban planning, agriculture, water management, and disaster reduction, highlighting its impact beyond environmental applications.

EO has transformed how global challenges are addressed, but opportunities remain to further leverage its potential. Key obstacles include data accuracy, limited observation frequency causing data gaps, standardisation, and the ability to derive actionable insights. Artificial intelligence (AI) offers solutions through dataset streamlining, identifying patterns, and providing predictive analytics based on time series and auxiliary data. AI also enables rapid data analysis for swift responses to extreme weather events and integrates EO data with real-time alerts to aid emergency services and tackle issues like illegal deforestation and pollution, improving policy enforcement and mitigation strategies.[2]

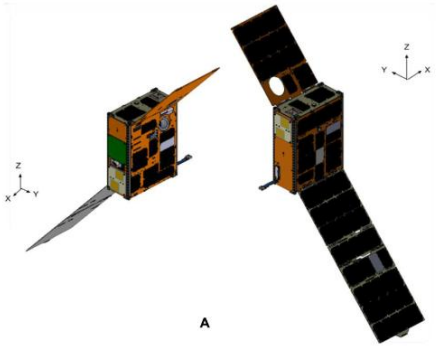
Traditional methods of data collection, downlinking the data to Earth and analysis are often time-consuming and labour-intensive. AI processing on board the satellite (i.e., in space) can greatly accelerate the whole value chain, as only the valuable, leverageable data needs to be downlinked to Earth. Faster, real-time analysis and therefore faster information delivery could unlock novel applications and services and reach end-users whose data needs are not currently fully met. This approach not only enhances efficiency but also minimises the large human capital resources required, enabling faster decision-making.

[1] CEOS (n.d). CEOS EO Handbook –The Important Role of Earth Observations. Available at: https://eohandbook.com/eohb2011/important_role.html
[2] MEWS Partners (2024). Illuminating Earth: How AI Enhances Satellite-Based Observations. Available at: https://www.mews-partners.com/en/illuminating-earth-how-ai-enhance-satellite-based-observations/

… further enhanced by the use of AI to enable data processing onboard the spacecraft …

Φsat-2 (PhiSat-2) is an ESA demonstration mission, funded through the FutureEO[3] (Block 1) programme with DPTD[4] (Discovery, Preparation and Technology Development) co-funding. The mission received €3m in ESA funding (including launch and 1 year of operations) and launched in August 2024. Flying in Low Earth Orbit (LEO), ESA's Φsat-2 satellite aims to demonstrate how AI technologies can be used to advance Earth Observation by processing images using AI *on-board*, thus directly in space and in real-time. By analysing data in-orbit, the systems on board Φsat-2 reduce delays associated with waiting for satellite-to-ground station contact, which can be between 30 and 40 minutes away. This process filters out unusable data, such as cloud-covered images, allowing the satellite to transmit only high-quality data back to Earth. The successful demonstration of Φsat-2 will showcase the feasibility of low-cost EO missions through improved efficiency of data transmission and supporting quicker decision-making through the provision of actionable information at lower bandwidths.

Figure 1: Φsat-2 6-U CubeSat in deployed configuration



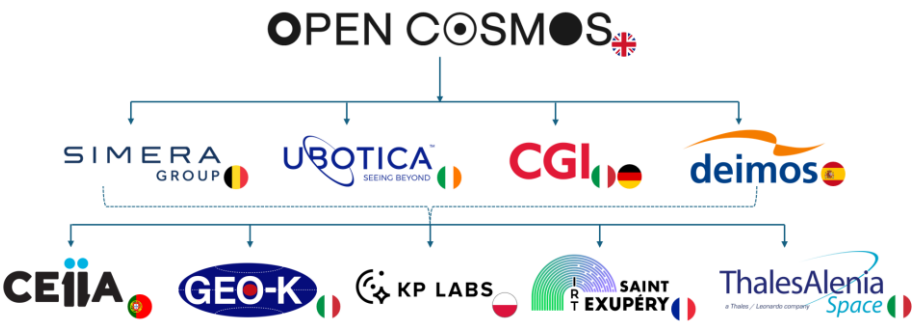
Source: eoPortal[5]

The lead contractor, Open Cosmos (GB), in conjunction with Ubotica (IR), Simera Sense (BE) and Deimos Space (ES), provided the 6U CubeSat platform that runs AI applications, which can be easily uploaded and operated remotely from Earth. Still in the space segment, the NanoSat MO framework, which facilitates the integration and operation of AI applications, was integrated by CGI (IT-DE) as part of the payload. Data dissemination will also be handled

[3] The ESA FutureEO programme is a long-term initiative aimed at developing innovative EO technologies, missions, and applications. It focuses on developing research, including promoting the use of new observation techniques. By supporting early-stage research and development projects, and exploring novel mission ideas, FutureEO seeks to maintain European leadership in EO.
[4] ESA's Discovery, Preparation and Technology Development (DPTD) activities conduct preparatory analysis to shape the Agency's future by studying new mission concepts, supporting strategic planning, and demonstrating the feasibility of innovative projects. They also explore breakthrough ideas, implement interdisciplinary research, and test new working methodologies to drive paradigm shifts and long-term advancements.
[5] eoPortal (2023). PhiSat-1 & -2 Nanosatellite Mission. Available at: https://www.eoportal.org/satellite-missions/phisat-1#spacecraft

by CGI through their Insula system. The satellite is equipped with a multispectral camera to capture images across seven bands, ranging from visible to near-infrared wavelengths. There are 6 applications running on-board Φsat-2, helping fulfil the objectives of this on-board AI demonstration mission, with 4 selected at proposal-level and a further 2 that were selected through the OrbitalAI challenge.[6] The providers of AI applications include CGI (IT-DE), CEiiA (PT), GEO-K (IT), KP Labs (PL), IRT Saint Exupéry (FR) and Thales Alenia Space (IT).

Figure 2: Consortium diagram



Source: know.space based on ESA and Φsat-2 consortium data

Φsat-1, launched in 2020, was the predecessor mission to Φsat-2, developed and funded by ESA. It was the first European satellite[7] to demonstrate how AI in space can be used to improve the efficiency of sending EO data to Earth. In line with ESA's Open Data Policy, the Φsat-2 mission will provide free and open EO data for all users. This includes both on-board camera processed images and data extracted from these images from application providers.

The Φsat-2 mission is currently in its commissioning and payload calibration phase, which will be followed by AI applications fine-tuning (for 2-6 months), wherein the applications will be refined. Routine operations will commence in mid-2025 (for 6-10 months) before Φsat-2 enters its decommissioning phase. The mission will demonstrate the feasibility of running an entire data processing chain on board the satellite, from Level 0 to level 1C and further through the AI applications.[8] The modular nature of the AI software means that these applications can upload, update and upgrade their tasking in-flight. The Φsat-2 mission is among the first to showcase the latest advancements in AI processing on board satellites for EO, paving the way for the implementation of similar AI-driven data processing structures on future EO operational missions.

[6] The OrbitalAI Challenge enabled organisations to develop in-orbit Earth Observation (EO) data processing solutions using cutting-edge AI. The top two teams will focus on ESA's Φsat-2 mission, including having their solutions launched into orbit and receiving additional prizes such as research opportunities and computational resources.
[7] eoPortal (2023). PhiSat-1 & -2 Nanosatellite Mission. Available at: https://www.eoportal.org/satellite-missions/phisat-1#%CF%86sat-2
[8] Level 0 indicates raw, unprocessed data that requires further processing to extract useful information.
Level 1C indicates data aligned to actual geographic coordinates, corrected for sensor errors. See more details: https://www.earthdata.nasa.gov/learn/earth-observation-data-basics/data-processing-levels

… providing actionable insights to improve life on Earth …

The Φsat-2 satellite hosts AI applications that enhance disaster response, environmental protection, and security. AI application providers within the consortium will benefit from their double role of being both subcontractors and end-users, as they will initially be the first to exploit the data. Among the AI applications (see Annex A: List of AI applications on-board Φsat-2 for exhaustive list), several have direct societal benefits that will actively improve life on Earth.

For example, 'Street Map Generation' by CGI converts satellite imagery into detailed maps, helping emergency teams navigate disaster zones during floods and earthquakes. 'Autonomous Vessel Awareness', developed by CEiiA, uses machine learning to monitor vessel activity, aiding in the prevention of illegal fishing and improving maritime security. Environmental monitoring is also strengthened with 'Marine Anomaly Detection' by IRT Saint Exupéry, which identifies threats such as oil spills and harmful algae blooms in real time, helping protect marine ecosystems. Meanwhile, 'Wildfire Detection' by Thales Alenia Space tracks and classifies wildfires, providing crucial data to firefighters for faster containment. Together, these AI applications on board the Φsat-2 satellite enhance crisis management and support global conservation efforts.

… delivering potentially valuable socio-economic benefits.

While on-board AI processing, as being demonstrated by Φsat-2, is still within the early stages of adoption and commercialisation, ESA funding has already led to some important benefits for the contractors involved. These include skills development, catalysing follow-on funding, and enhancing European competitiveness.

Progressing technological maturity

ESA funding has enabled critical progression in the on-board AI capability in Europe, with AI applications reported to reach full technological maturity upon successful demonstration of the Φsat-2 mission.

ESA funding is driving technological progress by enabling critical developments in on-board AI processing capability. This funding bridges a key gap in European space technology, ensuring proper de-risking and making on-board AI suitable for potential commercialisation and adoption within the EO community for future missions.

Currently, the consortium is operating at differing levels of technology maturity and readiness (see Key priority indicators for TRL breakdown), with several hardware and software systems

having already reached TRL 9. Most contractors reported usage of 'off-the-shelf' components for hardware systems, making relevant customisations for the Φsat-2 mission. This approach facilitates faster turnarounds and enables quicker launch timelines. TRL for AI applications remains lower than that of hardware/software systems. On average, AI applications have started at TRL 4-6 and will reach TRL 9 by the end of the mission, as they still require thorough testing and validation in space to ensure functionality and reliability.

The Φsat-2 mission brings key technological advancements through AI applications that improve efficiency and data quality. 'Cloud Detection' by KP Labs processes images in orbit, ensuring only clear, usable images are sent to Earth. This reduces unnecessary data transmission, optimising bandwidth and improving image availability for various applications. Meanwhile, 'On-Board Image Compression and Reconstruction' by GEO-K significantly reduces file sizes before downlinking, allowing for faster data transfer and increased image storage. Once received, the images are reconstructed using a dedicated decoder, ensuring high-quality results. Together, these AI applications should help make EO data more efficient, cost-effective, and impactful, ultimately supporting a more informed and responsive approach to global challenges.

The successful demonstration of the Φsat-2 mission will therefore showcase the enhanced reliability and scalability of the AI applications and the hardware/software subsystems.

Upskilling and strengthening the workforce

ESA funding has enabled contractors across the consortium to improve their technical (e.g., systems engineering, AI software, end-to-end development) and project management (e.g., ESA processes, strategic business development and management of human resources) skills.

Across the consortium, teams reported that ESA funding has enabled them to enhance their project management and technical skills. Through activities carried out for the Φsat-2 mission, teams have not only improved their competencies but also catalysed a spillover of knowledge to other areas of their respective organisations.

The scale and end-to-end systems integration of Φsat-2 resulted in an increase in capabilities for the hardware systems providers in the consortium – including running different software on a unique platform, which fostered skills in systems engineering, system level integration, customer applications integration, chaining, L1 image processing, and AI applications training. On the other hand, for AI applications providers, enhancement of technical skills notably included AI processing techniques, knowledge instillation approach, and extending board compatibility. A major learning for contractors on the Φsat-2 mission has also been

the notion of working with limited resources (systems that have strict limitations of processing power, memory and energy efficiency as on Φsat-2).

The consortium reported that the need for synchronisation and timely communication enhanced their project and partner management skills. This was also attributed to the complexity of the mission and its numerous milestones, operating within a big consortium, complemented by the rigour and quality standard upheld by ESA. Open Cosmos noted that working on Φsat-2 made their team 'leaner' whilst interacting with commercial customers, i.e., more effective in presenting important information, helping them grow in the commercial sector.

Contractors gained valuable technical and project management skills through their interactions with ESA, and their specific involvement in this mission. Some contractors reported spillover of knowledge from ESA, allowing them to resolve technological issues, and increasing their understanding of quality assurance for specific software solutions and mission development. For example, Simera Sense reported that the customisations requested by ESA on the thermal management of their imager enabled them to enhance their existing knowledge, improving their current and future product offerings. From a business development perspective, understanding ESA's strategic outlook on AI integration in space technologies was insightful to them. They also identified that working on Φsat-2 has allowed them to understand the expectations, standards and workings of the Agency, which will help them to anticipate needs and make the organisation more efficient when delivering future projects with ESA.

Contractors have also contributed to the publication of scientific research in the field of on-board AI processing for EO. This has elevated their technical skills by fostering rigorous research, critical analysis and sharpening their ability to communicate intricate technologies developed on Φsat-2 effectively. Moreover, it has helped strengthen the empirical research foundation of the field, fostering innovation and informing future developments within the industry. This is evidenced by the consortium publishing articles and research papers in reputable journals such as IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing and on the SPIE Digital Library (see Annex C: Publications and conferences).

Fostering the development of students and early-career professionals

This activity has allowed at least 11 early career professionals to be involved in the Φsat-2 mission across the consortium, equipping them with valuable experience and technical knowledge/training, overall supporting the talent pipeline of the European space sector.

ESA funding has enabled the contractors to support the growth and development of students and early-career professionals, promoting skill development, hands-on learning, and a pathway for long-term professional advancement. This helps grow the talent pipeline of the European space industry.

Indeed, whilst most contractors reported their team being mostly composed of mid-senior to senior professionals, there were still at least 11 students/young professionals involved across the consortium. Early career professionals working on Φsat-2 gained valuable experience on the application of academic knowledge in a real-world environment. This has enabled them to leverage their enhanced technical (including systems engineering, GIT, AI applications integration) and project management skills to secure promotions in more senior roles within their organisations or obtain roles in other organisations.

Creating and supporting jobs

This ESA-funded mission has enabled the creation of at least 7 jobs and has supported more than 90 jobs across the consortium, enhancing contractors' capacity and competitiveness within this emerging field.

This ESA-funded mission has enabled the consortium to support the workforce and facilitate job creation in the European space sector**,** with over 90 jobs supported and at least 7 jobs created across the consortium.

For example, the role of CGI as software integrations framework provider and AI applications provider enabled them to support 10 to 15 FTEs, including roles such as data scientists, software engineers, engineers to integrate applications into the framework, and cloud architects. Similarly, Simera Sense reported that their involvement in Φsat-2 supported jobs across the space industry value chain – including 3 people in the electro-optical team, 2 in the software team, 3 in the production team, 2 in the testing team and 3 involved in logistics and shipping. The team that worked on the development of their imager for Φsat-2 itself involved mid-senior employees that had at least 3 to 5 years of experience.

End-to-end mission involvement enabled some consortium members to recognise the need for dedicated processing teams. For example, CEiiA reported the creation of a dedicated data

processing team (whose flagship project was Φsat-2 and has since engaged in other missions), thanks to the organisation's involvement in this mission.

The newly created roles are a long-term asset, as they directly contribute to building organisational capacity for future projects and help companies become more competitive in the rapidly evolving on-board AI domain.

Strengthening European competitiveness

The ESA-funded demonstration of on-board AI processing capabilities for EO has enabled the consortium to have a 'first mover advantage' in Europe, facilitating the capture of European market share, and position themselves as fully integrated providers of AI solutions for EO.

ESA funding has allowed Europe to be one of the early adopters of the on-board AI processing capability, which is becoming increasingly important in the space domain due to requirements for faster processing times and quicker extraction of actionable insights. Φsat-2 is demonstrating the capabilities of technology not yet available on the market, giving the consortium a head-start for when satellite operators seek its commercial adoption. This will help the contractors be more competitive in securing demand when it materialises, both in Europe and globally. The global market size for AI in Remote Sensing and Earth Observation is currently projected to expand at a compound annual growth rate of 27.5% by 2030.[9] The capture of global and European EO market shares may be facilitated by credibility and trust built by the successful completion of the ESA-funded demonstration of the on-board AI processing capability.

Open Cosmos and Ubotica reported a 'first mover advantage', highlighting that being one of the first to demonstrate on-board AI processing has increased their competitiveness for future offerings of this product/service. Ubotica, originally an embedded systems and AI company, has furthered their exposure and learnings as a space company through Φsat-2. Having participated in this end-to-end mission, they expanded their heritage and expertise in EO, helping to establish themselves in the rapidly evolving space sector.

Knowledge of integrating diverse AI processing solutions and having a demonstrated platform that can run AI applications enabled the hardware-provider contractors to position themselves well for future success with commercial customers. CEiiA reported that their organisation recognises the value of on-board AI capabilities, and is now considering its use in upcoming missions. By launching their current satellites with idle GPUs, they are ensuring the possibility of future integration of AI applications and on-board processing (once demonstrated on Φsat-

[9] Future Data Stats (n.d.). Artificial Intelligence in Remote Sensing and Earth Observation Market Size: Global Report 2023-2030. Available at: https://www.futuredatastats.com/artificial-intelligence-in-remote-sensing-and-earth-observation

2). They also noted that there might be a possibility of including the on-board AI processing on one of their components on the Atlantic Constellation[10].

Open access to Φsat-2 data also lowers entry barriers for SMEs in the EO/space sector, promoting transparency and collaboration, enhancing competitiveness and benefitting the entire European space ecosystem.

Potential route to commercialisation

Consortium members are able to begin progressing towards commercialisation through products / services enabled by the potential successful demonstration of the onboard-AI processing capability on Φsat-2.

The Φsat-2 mission, while not directly targeting commercialisation, aims to demonstrate the potential of on-board AI capabilities to the consortium and other commercial developers. This demonstration mission is already establishing a pathway to commercialisation, enabling consortium members to integrate the capability within their existing products.

On average, the contractors identified data-centric products as the pathway to commercialisation, leveraging off-the-shelf instruments and platforms for faster mission deployment. Open Cosmos noted that their involvement in Φsat-2 revealed a substantial market for implementing the on-board AI capability, benefitting their data tool, Data Cosmos.[11] The team reported that, as data volumes grow, expanding the capabilities of AI applications will be essential for managing it effectively. This will also increase the functionality of DataCosmos and enable the creation of new products. They also reported that learning on the Φsat-2 project has helped their image processing team speed up ground processing, enabling faster delivery to commercial customers.

Commercialisation hinges critically on both market demand and the availability of follow-on funding to advance the on-board AI processing capability further. Nevertheless, the consortium acknowledged how ESA funding played a pivotal role in de-risking the early stages of development for this capability. This support has positioned consortium members to compete effectively for larger commercial opportunities and ESA missions, potentially paving the way for the integration of this capability into future EO missions.

Furthermore, public availability of Φsat-2 data will facilitate the creation of new EO data-based products and services, in turn supporting further adoption of the on-board AI capability, expanding its market potential. Across the consortium, contractors highlighted that potential

[10] The Atlantic Constellation is a flagship project for developing a constellation of small satellites for Ocean, Earth and Climate monitoring.
[11] DataCosmos, a service provided by Open Cosmos, is a tool that allows data to be turned into actionable information to suit all user needs. See more detail: https://www.open-cosmos.com/data-and-services

end-users of this data could include public institutions in need of remote sensing data for wide-ranging applications, including cloud-free images that can be used to enhance defence and national security, disaster management, environmental safeguarding.

Creation of new partnerships and collaborations

ESA's role as facilitator has enabled the creation of partnerships and collaborations across the consortium. Whilst some have resulted in further collaborations, most partnerships are seeking further funding or mission opportunities to realise this benefit.

ESA funding has fostered at least 3 new partnerships, and several key networks developed across the consortium. Whilst most contractors had prior relationships with ESA, this mission catalysed several new connections within the consortium.

As the lead contractor, Open Cosmos played a central role in facilitating communication and coordination among subcontractors, laying the groundwork for these connections. Several subcontractors indicated that they are actively exploring prospective partnerships with each other to further advance and enhance the on-board AI processing capability. For example, the team at GEO-K are currently engaged in formal discussions regarding a potential collaboration with KP Labs, catalysed by their interaction on Φsat-2 (but not directly related to it). Additionally, Ubotica reported some spillover of knowledge to the AI applications providers on the operation of the on-board AI processing system and integration of AI applications into said system, as a result of their collaboration on the mission.

Overall, the consortium reported that coordinating with Open Cosmos helped them establish a strategic connection with the lead contractor. In particular, Ubotica highlighted the establishment of a key partnership with Open Cosmos, having already launched a satellite (CogniSAT-6) with on-board AI capabilities together, with more collaborations in development. Similarly, Simera Sense also reported that their long-time collaboration with Open Cosmos evolved from just a supplier relationship to a close partnership due to enhanced technical knowledge of each other's capabilities, in part thanks to their collaboration on Φsat-2.

While the majority of contractors reported successfully establishing valuable networks and fostering collaborations within the consortium, they acknowledged that fully materialising these partnerships would require additional funding or follow-on mission opportunities.

Enhancing reputation and visibility

As ‘first movers’, contractors across the consortium reported an increase in their organisation’s reputation and visibility in the EO domain. Many teams also highlighted the value of having gained trust and visibility from ESA.

As highlighted earlier, ESA funding has enabled the consortium to establish themselves as ‘first movers’ in the field of on-board AI processing for EO. This unique capability sets a new benchmark for satellite operations. Across the consortium, teams reported that being involved in Φsat-2 had a positive impact on their reputation and visibility, including within ESA. A key outcome of the increase in reputation and visibility has been follow-on opportunities secured by some contractors, enabling them to expand the scope of their activities and impact.

This further highlights the ‘stamp of approval’ benefit of having worked with ESA, showcasing the proven reliability of the developed technology and reinforcing the companies’ heritage and credibility within the industry. For example, CEiiA emphasised that working with ESA was pivotal for their organisation, as ESA’s reputation validates the collaboration. They highlighted that ESA’s robust technology development processes ensure reliable de-risking and facilitate the exchange of knowledge between the organisations and the Agency.

Participation in Φsat-2 has not only fostered cross-border collaboration but also served as a powerful platform for organisations to enhance their visibility and credibility on both national and international scales. For Simera Sense, a Belgian company with technical headquarters in South Africa, their involvement in the ESA-funded Φsat-2 mission has highlighted their capability to operate on a global stage, showcasing their expertise and strengthening their standing within both regional African and European markets. This is evidenced by their participation in local South African engineering conferences and roundtables communicating their work on Φsat-2. They also reported gaining further visibility within ESA, enabling them to informally assist another organisation with ESA’s technology development processes, having gone through it successfully themselves.

Across the consortium, other contractors have reported an increase in organisational reputation and visibility, including participation in conferences and outreach events since the start of the mission (see Annex C: Publications and conferences). The contractors have also engaged audiences through social media, advertising their specific applications or technologies on their company websites or on LinkedIn. Dissemination efforts are anticipated to accelerate further once mission data becomes available, building on the momentum already established before and shortly after launch.

Securing follow-on missions / funding

ESA funding has enabled contractors to secure follow-on mission contracts and funding to further advance on-board AI capabilities, as evidenced by private funding secured for CogniSAT-6 and ESA funding for the NanoMagSat and Ciseres missions.

Securing follow-on missions and funding is a critical benefit that enables sustained growth and development for contractors. It provides the financial and strategic support needed to build on initial successes, and supports organisations to remain competitive and position themselves to capture future market share. Several contractors have already secured follow-on opportunities due to their involvement in Φsat-2.

Ubotica leveraged their relationship with Open Cosmos on Φsat-2 to successfully launch CogniSAT-6 in 2024 – a co-funded EO mission that provides Live Earth Intelligence. The mission design was driven by Ubotica, with Open Cosmos leading the construction of the spacecraft and design of the bus[12]. It aims to advance AI processing capabilities and its applications to benefit the field of EO and support numerous sectors including agriculture, disaster response, maritime monitoring and energy infrastructure.

Additionally, Open Cosmos have secured ESA funding worth €34.6m[13], for the development of the NanoMagSat constellation to enhance our understanding of Earth's magnetic field and ionospheric environment.[14] They attribute this to the trust and visibility acquired through Φsat-2 and other ESA missions to which the organisation has successfully contributed. Other contractors have similarly been able to secure follow-on opportunities with the Agency. For example, building on their work for Φsat-2, Deimos Space secured ESA funding for the Ciseres mission – a small satellite mission designed to significantly improve crisis response times using AI, as part of ESA's Civil Security from Space (CSS) programme.[15] Additionally, the company has been awarded a contract through ESA's InCubed programme to qualify an offering they developed – Insight4EO[16] – an advanced on-board processing solution for Earth Observation satellites.

There is also clear evidence that Φsat-2 has acted as a catalyst for fostering international collaborations, driving new partnerships and expanding global networks. For example, IRT Saint Exupéry are in discussions to embed their AI application on South Australia's Kanyini[17]

[12] Ubotica (2024). Ubotica's CogniSAT-6 Mission Launches on SpaceX Transporter 10, Delivering Unprecedented Live Earth Intelligence. Available at: https://ubotica.com/cognisat-6-launch-spacex-transporter-10/
[13] The European Space Agency (2024). ESA awards development contract for NanoMagSat. Available at: https://www.esa.int/Applications/Observing_the_Earth/
[14] Open Cosmos (2024). ESA Approves Development of NanoMagSat Constellation. Available at: https://www.open-cosmos.com/news
[15] The European Space Agency (2024). Ciseres: AI-powered satellites for rapid disaster response. Available at: https://vision.esa.int/ciseres-
[16] The European Space Agency (n.d). Insight4EO. Available at: https://incubed.esa.int/portfolio/insight4eo-d2/
[17] SmartSat (n.d). Kanyini: SA Space Services Mission. Available at: https://smartsatcrc.com/research-programs/

mission. If it materialises, the organisation will not be receiving any funding, the focus being more around a collaborative effort to integrate their application.

Would these benefits have been realised without ESA?

Whilst there is recognition that the development of on-board AI capabilities would have happened at some scale without the intervention of ESA, it is unlikely that the scope of benefits achieved through this mission would have been realised. ESA's role is crucial in driving innovation, accelerating the adoption of this technology and capturing the European and global market share.

"Working with ESA is important, as it helps prove a company: it teaches you massively and increases the visibility of the company to secure further projects. It is unclear whether this would have happened without ESA, but it is clear it would not have happened at this scale." – Open Cosmos.

Contractors highlighted that the role of ESA as a facilitator of collaboration was crucial to the development and success of this mission, and that collaboration with other consortium members would have taken a lot longer to realise without the introductions facilitated by ESA. There is now greater awareness of the advantages of on-board AI capabilities within the EO community itself. This can be attributed to the production of scientific research, dissemination of findings at conferences and EO-specific community outreach, including by ESA through the OrbitalAI challenge[18].

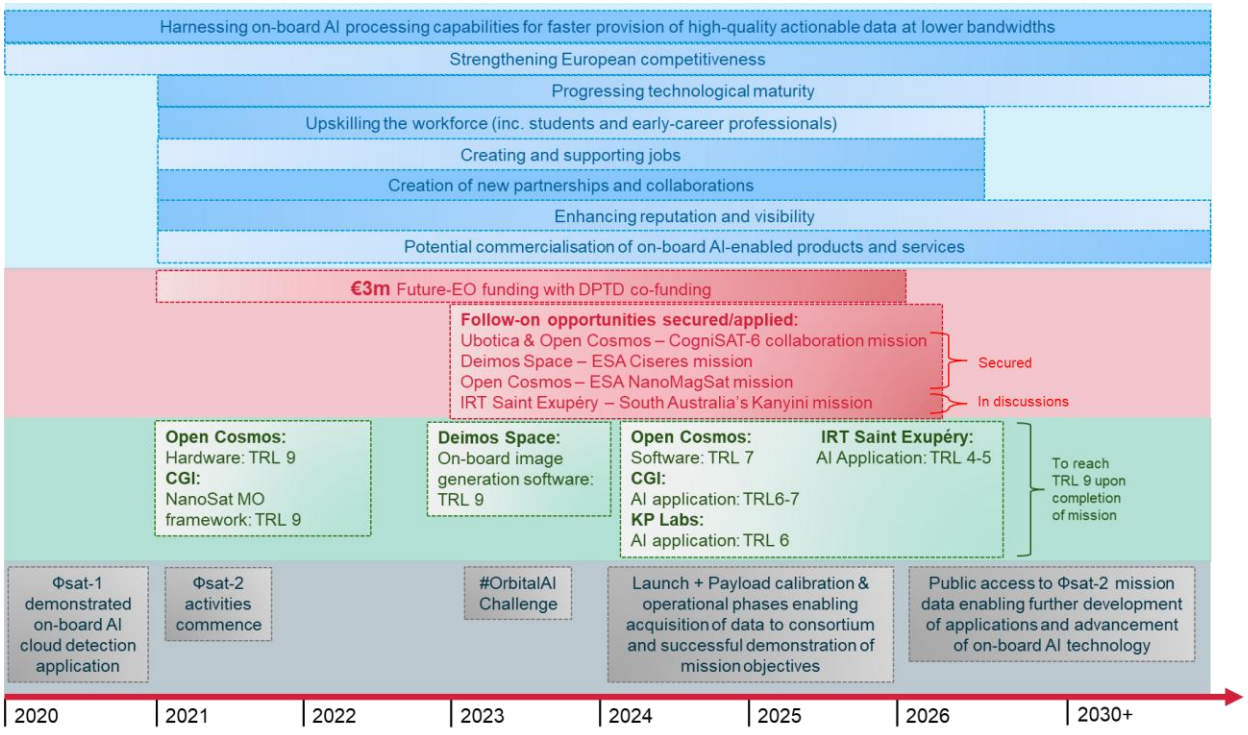
Next steps: Further development, further benefits

The immediate next step for the consortium is to ensure the acquisition of actionable data through the successful demonstration of onboard-AI processing capability on Φsat-2. This includes successful training of AI applications with acquired data to the point of complete reliability, without the need for cross-checks. Once the demonstration of the on-board AI capability is achieved, it will enable new partnerships for the use of raw and actionable data produced on this mission – as there is already commercial and institutional interest. Further benefits for contractors relate to advancing the development of this capability through follow-on missions and to capitalising on the key networks developed through the consortium's involvement in this mission.

A preliminary timeline overview of the ESA-funded 'Φsat-2 AI for EO' project and associated potential benefits is provided below. Some of the next steps and benefits outlined are dependent on the availability and timeliness of funding.

[18] The European Space Agency (n.d). #OrbitalAI Challenge. Available at: https://ai4eo.eu/portfolio/orbitalai-challenge/

Figure 3: Overview of the timeline of the Φsat-2 mission and the potential associated benefits



Source: know.space based on Φsat-2 consortium data

Key priority indicators

Programme	FutureEO (Block 1) activity with DPTD co-funding
Country	Consortium includes organisations from the United Kingdom, Ireland, Belgium, France, Germany, Italy, Portugal, Poland and Spain.
Activity cost	€ 3 million
Duration	1 year, including 6 to 10 months of operations
Lead contractor	Open Cosmos (GB)
Sub-contractors	Ubotica (IR), Deimos Space (ES), Simera Sense (BE), CGI (IT-DE), CEIIA (PT), GEO-K (IT), KP Labs (PL), IRT Saint Exupéry (FR), TAS (IT)
TRL progression	**Open Cosmos:** Hardware: Started at TRL 9 Software: Started at TRL 7; to reach TRL 9 at the end of the payload calibration phase. **CGI:** NanoSat MO framework: Started at TRL 9. Sat2Map AI application: Started at TRL 6-7; to reach TRL 9 by the end of the mission. **KP Labs:** Cloud detection AI application: Currently at TRL 6; to reach TRL 9 by the end of the mission. **Deimos Space:** On-board image generation software: Started at TRL 4; Achieved TRL 9 during course of the mission. **IRT Saint Exupéry:** Maritime anomaly detection: Currently at TRL 4/5; to reach TRL 9 by the end of the mission.
Spin-in into the space sector	-
Jobs supported/created	At least 90 jobs supported and 7 created
Strengthened collaboration with ESA	CGI, KP Labs, Ubotica, Deimos Space, GEO-K, IRT Saint Exupéry, Open Cosmos, Simera Sense and CEiiA reported strengthened collaboration with ESA.
Partnerships created	GEO-K with KP Labs; Simera Sense with Open Cosmos; Ubotica with Open Cosmos.
Follow-on opportunity/funding secured/applied	Secured: **CogniSAT-6** (Open Cosmos & Ubotica; undisclosed amount); **ESA NanoMagSat constellation** (Open Cosmos; €34.6m); **ESA Ciseres** (Deimos Space; undisclosed amount). In discussion for a flying opportunity: To embed AI application on **Kanyini** (IRT Saint Exupéry).

Annex A: List of AI applications on-board Φsat-2

The following are the 6 applications on-board Φsat-2 and their providers:

a) **Cloud detection:** Developed by KP Labs, this application allows Φsat-2 to solely downlink captured images that are not obscured by clouds, ensuring only clear, usable images are being sent back to Earth. This application can also classify clouds and provide insights into cloud distribution, which gives users more flexibility when deciding whether an image is usable or not.

b) **Street map generation (Sat2Map):** Developed by CGI, this application converts satellite imagery into street maps. This capability is valuable for emergency response teams, enabling them to identify accessible roads during natural disasters (e.g., floods and earthquakes).

c) **Autonomous vessel awareness (AVA):** Developed by CEiiA, this application employs machine learning techniques to automatically identify and categorise vessels in designated areas. It supports monitoring efforts for illegal activities such as unlawful fishing.

d) **On-board image compression and reconstruction**: Developed by GEO-K, this application significantly reduces file sizes by compressing images on-board. This enables an increase in the volume and speed of data downloads. Once downlinked, the images will be reconstructed using a dedicated decoder.

e) **Maritime anomaly detection:** Developed by IRT Saint Exupéry, this application leverages machine learning algorithms to detect anomalies in marine ecosystems, identifying threats such as oil spills, harmful algal blooms, and heavy sediment discharges in real-time.

f) **Wildfire detection:** Developed by Thales Alenia Space, this application uses machine learning to supply crucial real-time information to response teams. It provides classification reports that helps firefighters locate wildfires, track fire spread and identify potential hazards.

Annex B: Further socio-economic benefit examples

Benefit	Example
Fostering the development of students and early-career professionals	The team at Open Cosmos reported that the company has a high number of young engineers and had employed the support of 4 interns/recent graduates in the areas of systems and electronic engineering on Φsat-2. One employee that started as an intern with a background in physics now leads the image processing team within the organisation.
Creation and support of jobs	Open Cosmos reported that they hired 5-6 full-time flight software engineers to meet the needs of this mission as well as an increased number of projects. The core team at Open Cosmos working on this project included over 35 employees, with a mix of systems engineers, AIT (Assembly, Integration & Testing) engineers and flight software engineers. They also noted the creation of a dedicated image processing team to support on Φsat-2 and other current and future missions. CEiiA also reported a positive delta of 2 FTE (full-time equivalent) jobs created.
Upskilling and developing the workforce	Ubotica enhanced technical skills in systems engineering, thanks to their involvement in end-to-end mission integration on Φsat-2 and through better understanding ESA's technology development requirements. Interacting with ESA around their specifications for the mission has indirectly enabled Ubotica to be more effective in onboarding future customers as it has helped them understand how to extract the specific insights from the customer to effectively adapt their needs to a mission for the development of future AI processing software and processing platforms. Their learning and experience on Φsat-2 thus improved their competitiveness and efficiency on projects in the wider organisation.
Potential route to commercialisation	CEiiA are leveraging their involvement in Φsat-2 to develop a roadmap to provide future data monitoring services, specifically in the Exclusive Economic Zone (EEZ) of Portugal in the Atlantic Ocean. They highlighted the importance of creating agile processing in relaying important information, notably in the security & defence sector, which can leverage use of the on-board AI capability. They are also building a relationship with the Portuguese Air Force, as the AI applications for EO can be leveraged for ship detection in the Atlantic Ocean, monitoring illegal maritime activities and enhancing national security for the country.
Securing follow-on missions/funding	Open Cosmos also reported securing a mission contract with a commercial customer, as a result of AI processing knowledge developed on Φsat-2. Partly funded by ESA, this mission will be launching in 2026.

Annex C: Publications and conferences

Publications

- N. Melega, et. al. (2023). Consortium-wide: Implementation of the Φsat-2 on board image processing chain. Available at: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/12729/2679044
- Marin, et. al. (2021). CGI: Phi-Sat-2: Onboard AI Apps for Earth Observation. Available at: https://www.researchgate.net/publication/358278832_Phi-Sat-2
- T. Goudemant, et. al (2023). IRT Saint Exupéry: Onboard Anomaly Detection for Marine Environmental Protection. Available at: https://ieeexplore.ieee.org/document/10480531
- T. Goudemant, et. al (2024). IRT Saint Exupéry: On-Board Anomaly Detection for Efficient Marine Environmental Monitoring. Available at: https://zenodo.org/records/13850918
- E. Dunkel, et. al (2023). Ubotica: Benchmarking Deep Learning Models on Myriad and Snapdragon Processors for Space Applications. Available at: https://ubotica.com/wp-content/uploads/2024/07/Dunkel_et_al_2023
- N. Longépé, et. al (2024). Deimos Space: Simulation of multispectral and hyperspectral EO products for onboard Machine Learning application. Available at: https://www.researchgate.net/publication/382928716
- G. Guerrisi, et. al (2022). GEO-K: Artificial Intelligence Based On-Board Image Compression for the Φ-Sat-2 Mission. Available at: https://ieeexplore.ieee.org/document/10185543
- G. Guerrisi, et. al (2023). GEO-K: On-Board Image Compression using Convolutional Autoencoder: Performance Analysis and Application Scenarios. Available at: https://ieeexplore.ieee.org/document/10281562

Conferences

- Consortium paper presentation at the SPIE Remote Sensing Conference 2020 - Implementation of the Φsat-2 on board image processing chain. Available at: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/12729/2679044
- CGI: Paper presentation at the Space and Artificial Intelligence 2021 conference – Phi-Sat-2: Onboard AI Apps for Earth Observation. Available at: https://www.researchgate.net/publication/358278832; They will also continue further dissemination of their work on Φsat-2 at the Living Planet Symposium 2025.
- CEiiA: Disseminated their work on Φsat-2 at the European Space Conference 2023, the International Astronautical Congress in 2024 and will continue further circulation at the Living Planet Symposium 2025.
- GEO-K: Paper presentation on their work related to Φsat-2 at the 2023 IEEE International Geoscience and Remote Sensing Symposium: On-Board Image Compression using Convolutional Autoencoder: Performance Analysis and Application Scenarios. Available at: https://ieeexplore.ieee.org/document/10281562
- IRT Saint Exupéry: Paper presented on their work related to Φsat-2 at the Artificial Intelligence Platform (2024) in France: Onboard Anomaly Detection for Marine Environmental Protection. Available at: https://pfia2024.univ-lr.fr/Pr%C3%A9sentations