CRAFTING THE EUROPEAN EARTH OBSERVATION ECOSYSTEM 2040+

Workshop: 11.02.2025 – 12.02.2025

Towards a Next-Generation Earth Observation Ecosystem

As we look to the future, Earth Observation must evolve into a more adaptive, integrated, and intelligent ecosystem to effectively monitor human activities and understand critical planetary processes. In this context, the European Earth Observation Ecosystem 2040+ represents a proposed cross-cutting vision for the future of Earth Observation in Europe. To achieve this vision, the development of the next-generation EO Ecosystem represents a fundamental step in creating a more cohesive, interoperable, and user-driven framework. The architecture is designed to leverage synergies across institutional, commercial, and international EO systems while maintaining a strong focus on scientific integrity, operational efficiency, and stakeholder-driven evolution.

The EO Ecosystem is considered from a holistic system-of-systems perspective leveraging cross system/mission synergies instead of individual EO missions. This vision is structured through the following core questions:

- **What should our European Earth Observation Ecosystem look like in 2040+?**
- **Which future operational or scientific users' needs will drive the definition of future system-of-systems?**
- **How do commercial Earth Observation data providers fit into the overall picture?**
- **How do we verify the performance of the system?**

With this in mind, ESA hosted a workshop to establish a "European Blueprint for Earth Observation" that can guide future preparation for Europe in Space. The Blueprint is designed to identify and group activities within all EO programmes (science, commercial and operational nature), to identify gaps in the system against the future needs for scientific research and development, innovative new EO mission ideas and technologies, and mission data

exploitation with applications that address new Earth system science and deliver societal benefits.

The workshop was an important milestone to discuss different scenarios (e.g. Will Earth Observation boom or bust?) and consolidate inputs and seek feedback on the shape and content of the European Blueprint for Earth Observation. Its objective was to identify and prioritise actions to implement in order to sustain, operate, and evolve the performance and capacity of Earth Observation in Europe as the most advanced living systems-of-systems in the world in support of European citizens and policies.

The Workshop was attended by around 200 participants representing the user community, industry actors and delegates.

To set the scene on day 1, several keynote presentations were given. Key messages include:

1. **From exploring to understanding:** there are still essential knowledge gaps in our understanding of the Earth System, also within the Essential Climate Variables. We need to continue to discover the unknown.
2. **From monitoring to action and economic benefits**: the focus of European EO should expand to addressing climate adaptation beyond the downstream into action and supporting policy-related decision making, by positioning itself as a champion of integration of space applications and striving to maintain a strong policy and user focus.
3. **From Kyoto to Kiev**: Europe remains highly vulnerable to foreign influence, affecting both its internal and external decisions. It still lacks the key features needed for autonomy in space affairs. Additionally, it lags in using space for military, security, and diplomatic purposes.
4. **Towards coherent and calibrated datasets**: the European EO Ecosystem must ensure the authenticity and performance certification of EO data through reference-class satellite missions and robust calibration standards, forming the backbone of the European EO Authentication and Measurement Performance Certification Service (AMPCS).

On day 2, different splinter discussions were organised:

The European EO Ecosystem in 2040+ System-of-systems view

This splinter discussion addressed three key topics: The definition of the EO Ecosystem, the foreseen evolution of EO in 2040+, and the use of the EO Ecosystem Blueprint.

1. **Definition of the EO Ecosystem**

Participants identified key components of the European EO ecosystem, including Observations (97%), Satellite Missions (81%), Payload Specific Ground Segment (73%). To integrate these elements into a cohesive system, a user-centric approach is essential, prioritizing user needs, policy requirements, and continuous feedback. Federated systems and interoperability will drive integration, with AI accelerating insights and addressing observation gaps. Ensuring sustainability requires economic viability, inclusive governance, and diverse data policies.

2. **EO Evolution by 2040+**

EO's future holds both promise and challenges. Advances in technology will enable faster, more integrated systems, enhancing global collaboration on climate action through open data policies. Institutional-commercial partnerships will improve EO's role in daily life, fostering transparency and accessibility. However, risks include private sector dominance through data access control, slow bureaucratic adaptation, and geopolitical tensions disrupting cooperation. Climate change could also drive global conflicts over resources.
Key priorities will include continuous monitoring of Essential Climate Variables (ECVs), sustainable infrastructure, improved data accessibility, and AI-driven automation. Agility, multi-year funding, and strong public-private partnerships will be critical to EO's long-term impact.

3. **EO Ecosystem Blueprint – objectives**

The EO Ecosystem Blueprint defines a strategic roadmap as a living document, ensuring alignment with scientific, operational, and commercial needs. It must outline roles, optimize mission planning, and drive collaboration through resource federation and open data policies. Standalone missions and redundant infrastructure will be phased out in favour of user-driven, cloud-based solutions. Sustainability will shape mission planning, reducing duplication and enhancing coordination across agencies and commercial entities.
To maximize impact, the ESA Blueprint should align with global strategies like the UN SDGs,

Paris Agreement, and Copernicus Strategy, while fostering collaboration with key space agencies and research initiatives to ensure EO's continued relevance and effectiveness.

The Role of FRM and Reference Measurements for Performance Certification and Monitoring within the European EO Ecosystem

The splinter discussion aimed at defining the role of Fiducial Reference Measurements (FRM) and Reference Measurements within the growing EO Ecosystem.

1. **Ensuring Data Quality and Interoperability**

Key to using data from the multiple new sources of EO is a good understanding of their characteristics, how they are calibrated, and their quality and technical capabilities. Additionally, interoperability between satellites/products will allow to extend dramatically the opportunities for applications (agriculture, water use, forest and vegetation monitoring, pollution monitoring, climate applications…). Therefore, harmonisation in Calibration and Validation approaches are fundamental to trust data accuracy and characterisation.

2. **EO Product Certification and Qualification**

EO Product Certification or Qualification falls under three main domains: data authenticity, data content and performance measurement, fitness for purpose. The recommended approach to certification is a levelled approach, which will improve accessibility to the scheme whilst retaining scheme rigour, retain differentiation between products with different quality specifications, and improve the quality of data products over time. There is a consensus to go toward product certification to increase confidence in EO data, which requires the use of a Cal/Val reference, i.e. a Fiducial Reference Measurement (FRM) with SI-traceability.

3. **Establishing an EO Authentication and Measurement Performance Certification System**

ESA should therefore design, develop, implement and operate a European EO Authentication and Measurement Performance Certification System (AMPCS). This System would guarantee certification of EO measurement performance uncertainty with well documented traceability to SI standards, allowing to set and assess standards and quality level of emerging EO data providers.

It is necessary that FRMs are planned and integrated in a satellite programme from the beginning of the development phase (Phase 0/A/B/C/D), operated and maintained in Phase E.

User Expectations and Requirements

This splinter discussion aimed at fostering a dialogue with various Earth Observation users, to collect their expectations and requirements for a future EO Ecosystem.

1. **Priorities for the future EO ecosystem**

The user consultation highlighted several priorities for the EO ecosystem towards 2040, including **climate science, data record continuity, facilitation of commercial applications, multi-mission approaches, and the development of user-friendly data portals**. An important aspect is ensuring that the EO Ecosystem meets the needs of a broad and diverse user base, ranging from modelers who require raw Level 1 data to policymakers seeking actionable insights.

The discussion outlined the importance of maintaining a diversity of measurement techniques, orbits, and approaches to capture a more comprehensive view of Earth's systems. At the same time, smarter satellite tasking (e.g. tip and cue) and decision-making using AI and edge computing were identified as key innovations to improve EO efficiency. A holistic approach to EO was encouraged, ensuring that observations cover not only the atmosphere but also the sub-surface, oceans, and Earth's core.

One of the key challenges discussed was the discrepancy between the policy-related reporting needs (which parameters, how often, which accuracy) and EO capabilities, underscoring the need for stronger dialogue to align data collection with policy and operational needs. Direct engagement with end users was also emphasized as essential, recognizing that different sectors have varying levels of maturity in EO adoption. Another priority was ensuring the availability of test data and infrastructure for training datasets, as well as implementing mechanisms to guarantee data integrity and traceability. The long-term continuity of EO data was highlighted as critical, with a strong focus on maintaining long time series and ensuring interoperability for diverse exploitation needs.

2. **Role of ESA in structuring the ecosystem**

EO is pivotal in various areas such as regulatory enforcement and decision support, therefore ESA should take a leading role in standardization, calibration and certification efforts to ensure data compliance with legal mandates, both in terms of authenticity and performance.

Beyond this function, ESA must also **accelerate the transition from EO research to operational services**, by creating a more agile ecosystem that can translate scientific discoveries into downstream services and actionable insights. As a trusted partner, ESA holds the influence necessary to open opportunities for the private sector, fostering innovation while maintaining high data integrity and quality assurance. Collaboration at both the European and institutional levels remains fundamental, requiring **clearly defined stakeholder roles** and strengthened formal and informal dialogue to structure the Ecosystem governance.

3. **Users outreach expectations**

ESA's role extends beyond technology development; it is also a policy driver and a role model for STEM and EO outreach, helping to build future expertise in the sector. ESA is expected to increase its involvement in **training development, policy and stakeholder engagement, as well as inspiring the next generation of EO scientists**.

These activities will allow to overcome technical barriers and increase data adoption by a variety of users. It will help to raise awareness of the opportunities Earth Observation services offer. Effective outreach is especially essential for engaging policymakers and government representatives: ESA's close ties with member states position it well to offer an introduction to EO applications and EO evidence-based decision making. This approach would be especially effective by targeting young career professionals.

Eventually, ESA should increase its efforts in attracting younger generations and school students to EO careers, by raising awareness of EO applications and developing educational resources and getting involved with science outreach programs.

The Role of a Constellation within the European EO Ecosystem

This fourth splinter discussion focused on collecting input from participants regarding the role of satellite constellations combining different EO systems in different ways through synergy in a Systems of Systems architecture.

1. **Need for Constellations**

Constellations have a recognized role in complementing backbone missions by enhancing revisit times, coverage, and resolution. They enable the provision of near real-time data, offering flexibility in tasking and reconfigurability. While backbone missions deliver stable measurements, constellations contribute adaptability, increased market opportunities, and enhanced performance in EO services

2. **Current and future use cases**

The user base for EO constellation systems spans across institutional, commercial, and security sectors, with a high demand from security and resilience applications. The use cases are broad and diverse, including extreme events, natural disasters, pollution monitoring, ecosystems, climate change, agriculture, and meteorology. An emerging trend is the aggregation of data from a combination of systems into information.

Looking towards the future, there is significant potential for EO applications to address pressing global challenges such as pollution, climate change, and the regulations related to these issues.

3. **Implementation Strategies**

Successful strategies to successfully develop constellations within the European EO ecosystem will include:

- Access to venture capital to enable investments with lower or no institutional support, as well as support in risk reduction for unconfirmed or potential new markets
- Supply chain standardization, simultaneously allowing vertical integration to allow for cost efficiency and implementation speed
- A special attention to knowledge transfer, synergies and interfaces between science advancement and downstream services
- Governance and coordination of commercial and institutional initiatives including dual-use capabilities

4. **Support from ESA**

ESA has an important role to play in supporting the development of future EO systems, and can assist in multiple ways including technology development, risk reduction, service and applications development, technical support and expertise to the industry, as well as financial support.

ESA's role also extends to fostering competitiveness within the market, providing certification services to ensure quality standards, and ensuring the overall integrity and reliability of the data generated by EO systems.

Conclusion

The European Earth Observation (EO) ecosystem must evolve to stay competitive, resilient, and impactful in tackling global challenges. EO 2040+ discussions emphasize the need for a system-of-systems approach, integrating institutional, commercial, and scientific domains. Federated platforms, standardized interoperability, and AI-driven automation will enhance data exchange, analytics, and decision-making. Open data policies, strategic investments, and global cooperation will strengthen Europe's leadership, while maintaining resilience amid geopolitical tensions is crucial.

Sustainability is an essential element, both in Earth monitoring and responsible space asset management. A public-private investment model will prevent fragmentation and ensure economic viability. EO must also address user needs by improving real-time capabilities for crisis response, urban monitoring, and security, resorting to cloud-based and AI-powered solutions. Beyond observation, EO should drive active climate adaptation, closing data gaps in Essential Climate Variables (ECVs) to support policy decisions.

ESA plays a key role as a facilitator, ensuring quality, reducing risk for new technologies, and harmonizing missions and data policies. The EO Blueprint must be a dynamic framework that adapts to technology, user demands, and policy shifts. On the other side the EO Blueprint needs to give a longer-term perspective and offer a certain degree of planning stability. Visionary leadership, collaboration, and long-term sustainability will be essential for Europe to maintain its strategic advantage and deliver critical insights for society and the planet.