ESA Φ-week 2021

Hybrid event – October 11–15 2021

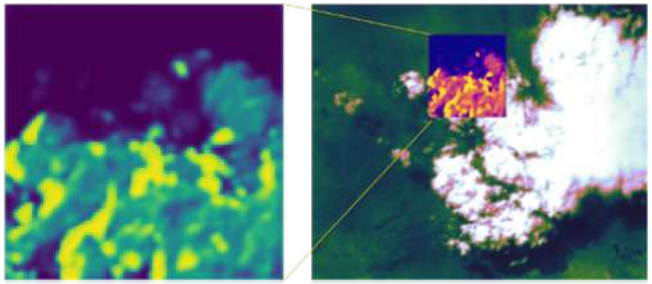
Summary and recommendations to ESA

Version 009

Summary – main topics

During the biggest Φ-week ever, themed around the **New Space economy**, ESA and the worldwide EO community focused on bringing space even closer to the forefront of addressing society's biggest challenges, such as the climate crisis, while boosting the economy through transformative initiatives in New Space, AI and quantum as well as cognitive computing. In the recaps in the following slides, some specific recommendations from the sessions have been highlighted and will be shaping future work plans.

After a successful Φ-sat-1 experiment onboard the FSSCat mission, we looked into the future of the Φ-sat-2 mission



ϕ-week 2021 statistics

Overall

- Registered Participants: 3876
- Abstracts Submitted: 200
- Invited keynote speakers: 105
- e-Poster Presentations: 126
- e-Exhibition booths: 35
- Side events: 30

Brella

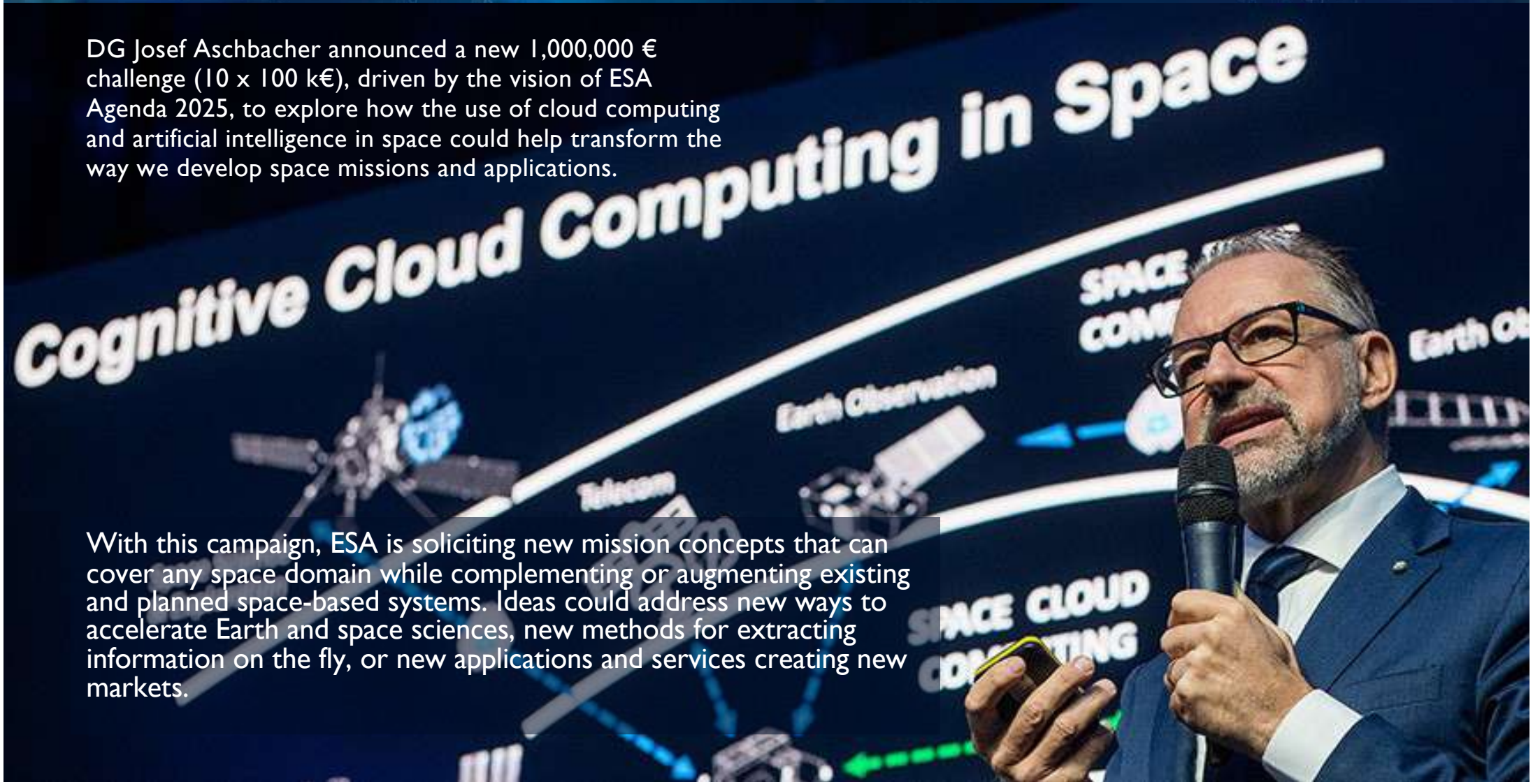
- Attendees through Brella: 1884
- Active during the week: 1799
- 1:1 Chat messages: 1411
- Meeting requests: 454

Live streaming

- Monday, 11 October: 1771
- Tuesday, 12 October: 1390
- Wednesday, 13 October: 1397
- Thursday, 14 October: 1277

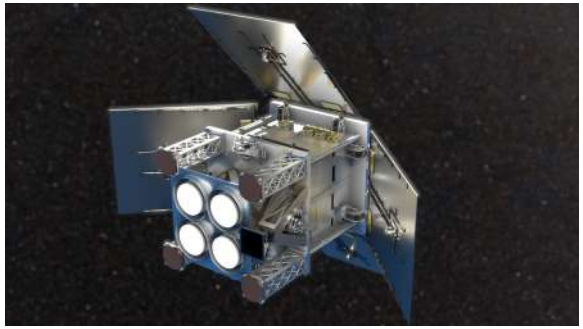
Key announcement – the age of AI and edge computing in space has come

DG Josef Aschbacher announced a new 1,000,000 € challenge (10 x 100 k€), driven by the vision of ESA Agenda 2025, to explore how the use of cloud computing and artificial intelligence in space could help transform the way we develop space missions and applications.



With this campaign, ESA is soliciting new mission concepts that can cover any space domain while complementing or augmenting existing and planned space-based systems. Ideas could address new ways to accelerate Earth and space sciences, new methods for extracting information on the fly, or new applications and services creating new markets.

Contract signature events



AI4EO Solution Factory (link to news article)

Under the Investing in Industrial Innovation (InCubed) programme, a Public Private Partnership co-funding programme run by the Φ-lab, ESA and DFKI Germany (the German Research Centre for Artificial Intelligence) signed the AI4EO Solution Factory contract to support a new development initiative focused on Artificial Intelligence for Earth Observation (AI4EO). The AI4EO Solution factory will receive EO business problems from its customers and will develop and deliver AI-powered solutions, typically for downstream business cases.

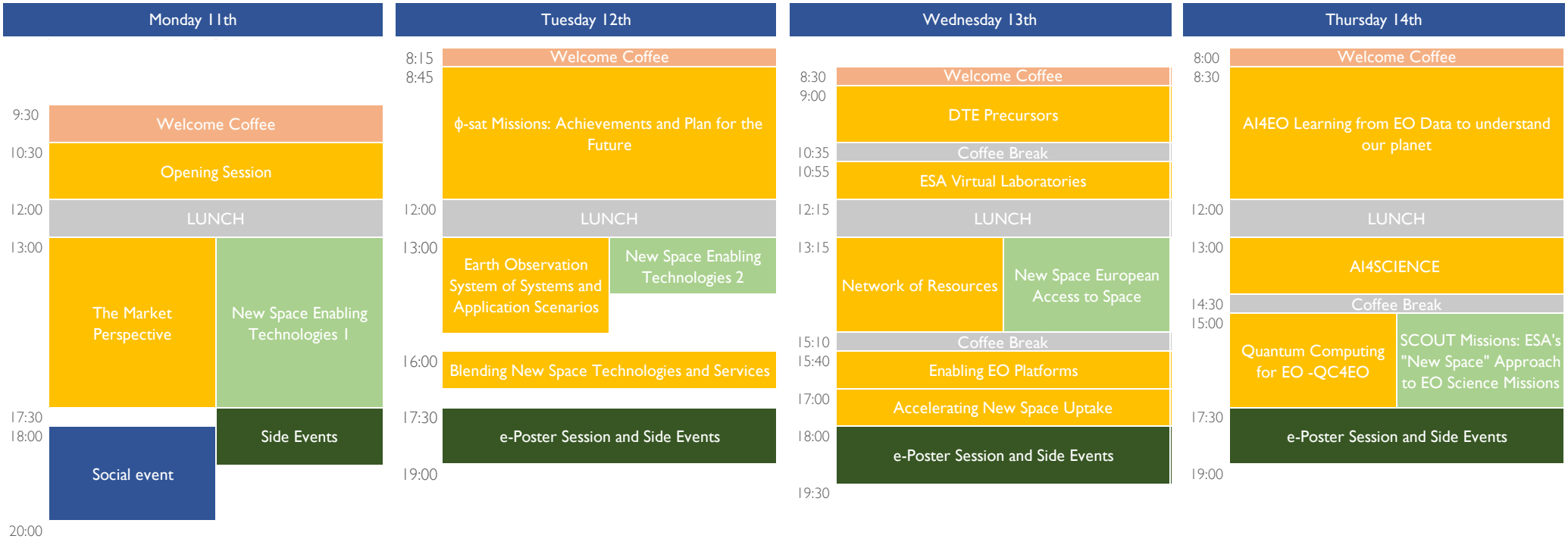
HydroGNSS (link to news article)

Under the Scout framework, an EO framework complementary to the science-driven Earth Explorers, ESA and SSTL signed the HydroGNSS contract worth €24 million. Embracing the concept of New Space, HydroGNSS is a micro-satellite utilizing GNSS Reflectometry (GNSS-R) to observe essential climate variables relevant to the hydrological cycle.

ICEYE (link to news article)

ESA and ICEYE signed a contract to include the ICEYE X-band SAR satellite constellation as a new Copernicus Contributing Mission, the first example of New Space implementation in Copernicus, complementing the existing commercial Copernicus Contributing Mission data offer with further innovative SAR data.

Programme



In addition, Friday 15 October was fully dedicated to side events from 09:00 to 19:00. Running throughout the week, these specialised sessions delved into an extremely broad range of EO-related subjects, including the Space App Camp, Rapid Action on COVID19 with EO (RACE), data quality, intellectual property and AI for InsurTech, to name a few.

Opening Session

- Monday 11 October – 10:30-12:00
- Live on the dedicated web platform **Brella** for registered attendees
- Live on **ESA Web TV** for non-registered attendees
- **Programme** including: J. Aschbacher (ESA DG), T. Tolker-Nielsen (Acting D/EOP), E. Kavvada (European Commission), K. Peeters (EIB), M. Boggett (Seraphim Capital) and R. Modrzewski (ICEYE) – Moderator: I. Lung (ESA)

OUTCOMES

- **508 unique views** on **Brella + 775** on **ESA web TV**
- Average watch time of 00:19:10 on ESA web TV
- ESA Portal articles announcing the session here **(2088 views)** and about the outcomes here **(1717 views)**
- 2 articles published on ESA intranet for staff and contractors
- **Full replay videos** available online
- Social Media and Press coverage (#Phiweek)

The Market Perspective

Key Messages

- This session, involving market leaders exploiting EO data & VAS (such as Shell, SCOR, SAP, Primo Space Fund, etc.) confirmed EO industry growth in several indicators, with more data & VAS diversification and offering specialisation. EO remains a niche market (4% of the space market) and its growth (7% future 10Y CAGR) is driven by downstream data and services, as upstream and other activities will deliver a limited growth. While the global data market is highly consolidated, the service market is more fragmented, but in consolidation as well.

- EO can provide benefits to businesses with three main impact lines: revenue (with innovative offerings and business models); EBITDA (Earnings Before Interest, Tax, Depreciation and Amortization), by improving the operational excellence; and ESG (Environmental and Social Governance), by supporting the implementation of a sustainable business). Key factors for EO adoption seem to be awareness (significant amount of effort in explaining products); expectation management (no overselling); perception of market players of cost/benefits ratio; and resiliency (as some industries are slow adopters).

- On the investor side, the New Space economy is clearly an opportunity for private investors, and venture capital deals are taking off also in Europe, even though currently Europe is about 1/15 of USA ($3B cum. fund raising 2011-20). In investment assessment VCs' key criteria are: excellent teams, visionary but pragmatic, addressing a market sector with high growth potential, while the technical aspects (and risks) are important but secondary to these.

Recommendations to ESA

- Continue strengthening relationships and collaborations with private investors.
- Continue working across technology borders to foster transformational innovation.
- Continue supporting start-ups and SMEs on the various steps on their development path with specific and tailored action.

New Space Enabling Technologies – EO Payloads

Key Messages

- Expanding range of RF and optical instrument technologies (from components to full payloads)
- New Space: smaller/cheaper than traditional space → easily scalable to (large) constellations
  - more focused and faster pace, but something must give in (quality, redundancy, coverage, calibration, lifetime, or …)
- New players & new business models (out of the box) → new opportunities
- A lot already done well: e.g. technology, new InOrbitDemo (IOD) programmes (e.g. GSTP Fly, Scouts, InCubed, Φ-sat), workshops / networking, …

Recommendations to ESA

- Setting requirements – need to have more iterative processes, to balance resources priorities vs quality/risk
- Need agile interaction approaches (not just contractually) on key areas (not all of them within ESA – use the strongest part of each partner): networking, technical expertise, adapt to end-user needs case by case
- Adapt reviews for New Space to its paradigm (faster/riskier technology and system development, but still with a controlled approach)
- Add mission opportunities to gain experience (both at industry and within ESA) → competitiveness
  - Lessons Learnt → adapt fast (more iterations): i.e. keep the momentum

3 ESA overview + 6 RF Instruments + 9 Optical Instruments

New Space Enabling Technologies – CubeSat + SmallSat Systems

Key Messages

- Technology is an enabler, but many more dimensions are key
- Under more demanding cost-schedule → system simplifications, less redundancy, higher risk
- New ways of collaboration Institution-Industry → shift from sat products to data-service driven
- Demonstrated capacity to build IOD/IOV with acceptable performance/reliability → risk / control shift
  - (true for the mature New Space, not for newcomers)
- Next challenge after IOD/IOV: increase "availability" to become EO operational (max revisit time, timely data delivery) → new customers. This has started with the implementation of 2 Scout missions providing science data as a service.
- Technology develops faster than there are IOD/IOV opportunities
- High standardization achieved for CubeSats, but far more challenging for SmallSats (it is an issue for equipment suppliers)
- Downstream technology will also mature with standards that enable incremental services
- A lot already done well: e.g. technology, new InOrbitDemo (IOD) programmes, help to network, …

Recommendations to ESA

- Adapt reviews for New Space to its paradigm (as in previous slide)
- Add more adaptability to take into account cost/schedule constrains, as well as emerging technologies and risk (like in ESA WG on COTS components)
- Add more IOD/IOV opportunities to gain experience (both at industry and in ESA) → convergence in Engineering/Risk Approaches
- Support incremental steps / scalability to grow from IOD/IOV towards higher "availability" → operational – serving new-user needs → sustainability

1 ESA overview + 1 Equipment supplier + 3 CubeSat + 1 SmallSat Integrators + 1 AI On-ground for Emergency use

Φ-sat Missions: Achievements and Plan for the Future

Key Messages

Two main key messages came out from the Φ-sat session:

- The inflight results of the Φ-sat-1 were above the expectation, demonstrating the enabling capability of onboard AI while also experimenting a New Space way of working for ESA with a dynamic and very interdisciplinary team spread over different sites and organization units.
- With Φ-sat-2 ESA will continue innovating in the field of AI and of new way of configuring satellites through the use of apps, like in our mobile phones.

Recommendation to ESA

Maintain support to quick and low-budget demonstration of innovative applications in EO using Φ-sat missions

EO System of Systems and Application Scenarios

Key Messages

The speakers from the EO value-adding industry confirmed the synergy and complementarity across public EO missions and private commercial assets.

The public EO satellites predominantly apply an open and free data policy, along with global coverage, high frequency of observations and the assurance of long-term continuity. They also strive to reach the best level of absolute calibration for their measurements, acting as 'reference' missions.

The presentations showed how this scenario acts as a solid basis for private investments both in the space segment and in the downstream application development. This subsequently springboards the integrated utilization of public and commercial data for tailored applications responding to specific user needs.

Recommendations to ESA

- Continue facilitating the ongoing applications development process.
- Continue, when necessary, leveraging on both the public EO missions and the private commercial assets.

DTE Precursors

Key Messages

- The session presented results of the precursor studies launched by ESA in preparation of the Digital Twin Earth implementation, exploring some of the main scientific and technical challenges in building a digital twin of Earth.
- Digital Twin Antarctica - a twin of the Antarctic ice sheet system, its hydrology, surrounding ocean, atmosphere, and biosphere was built, harnessing satellite observations, numerical simulations, and AI. The system was used to track the whereabouts of melt water on and under the ice sheet, and to explore how fringing ice shelves melt under various hydrology scenarios.
- Digital Twin Food Systems simulate agricultural activities and interactions within ecosystems on a daily basis
- Digital Twin Hydrology developed a 4D reconstruction of dynamic hydrology at unprecedented resolution through the integration of EO and an advanced modelling system
- Digital Twin Climate Impacts - initially focused on African drought, the Digital Twin utilises an innovative combination of EO, environmental modelling and Machine Learning to bring enhanced decision support capabilities directly to our stakeholders
- Digital Twin Forest will provide a reconstruction of the forest system at levels of detail not possible with generic land surface models
- Digital Twin Ocean will focus on exploring the potential of artificial intelligence to learn directly from its data, from the past and the behavior of the Earth system to predict the future to forecast oceanic events.

Recommendation to ESA

Continue the development of the Digital Twin Earth Precursors

ESA Virtual Laboratories

Key Messages

- The session explored the latest advancements in collaborative Earth system science research, offered by the combination of Open data, Open Tools and Virtual Laboratories.
- Achieved scientific results, new functionalities available as well as the future pathways and trends in the various research infrastructure and collaborative tools were presented.

Recommendations to ESA

Continue and advance the development of Open Innovation tools, enabling collaborative Earth System Science research, such as:

- Atmosphere Virtual Laboratory
- Cryosphere Virtual Laboratory
- Agriculture Virtual Laboratory
- Ocean Virtual Laboratory
- (Deep) Earth System Data Lab

Network of Resources

Key Messages

- The keynote speech by Marie-Francoise Voidrot, European Director Innovation Program at OGC, summarised the recent European initiatives such as Copernicus+ Open data policies pre-2014, NextGEOSS in 2016, Interoperability in 2018 and the Engagement of users in 2019.
- The importance of interoperability and user engagement were highlighted as key aspects to ensure users have access to cost-effective multiple resources and data often spread over different locations and mainstream technologies. The development of cloud technologies to use available scalability of resources in a cost-effective way, to optimise software architectures / data access / storage so as to avoid waste of resources was also presented. Highlight: infrastructure and related offers by providers need to be as user-centric and tailorable as possible.
- Presentations of their Platform services were also given by 7 onboarded providers. Feedback from providers and their users is that they appreciate the new Network of Resources (NoR) portal, the simplified mechanisms for interfacing with NoR and the streamlined sponsoring mechanism. In some cases the user projects need a higher level of funding than currently available.
- Price models moving from fixed temporal / subscription to pay per use have been done in many services but fine 'tuning' is ongoing.
- NoR initiative and portal help to provide marketing of the various onboarded resources

Recommendations to ESA

- Within the Network of Resources, need to have 'flexible sponsoring limits' / higher sponsoring fund limits for specific criteria of sponsoring requests e.g. projects that commit to make available the processed results or developed algorithms to be hosted within the NoR.
- Promote further the Network of Resource, the portfolio of European resource and platform services available on the NoR portal and the sponsoring / funding initiative.

New Space European Access to Space

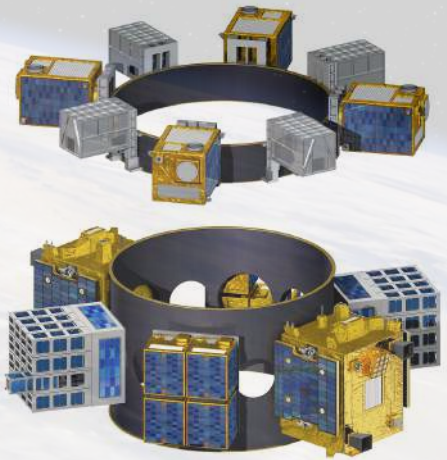
Key Messages

Starting from 2022, the European portfolio of possibilities for access to space will drastically increase. Multiple launch sites will have their maiden launch in the next two years in many European countries such as UK, Norway, Sweden etc. Many micro-launcher developers will have major stepping stones in the near future.

Overall, all the major actors in this field are incrementing their offer in terms of access to space, leading to a landscape for the New Space companies that want to base their business on in-flight assets that gives them more and more possibilities in a competitive environment.

Recommendation to ESA

Keep supporting access to space for the New Space community.



Enabling EO Platforms

Key Messages

- Cloud based EO platforms offered to the community in Europe are advancing and now offer a convenient abstraction layer to petabyte-scale EO data archives and to the computational resources. Platform business models are diversifying and address better the community and industry needs. Community-developed analytical capabilities and workflows at different levels of maturity can now effectively be made available to other users.
- Nevertheless, the European offering suffers from fragmentation and redundancies that should be addressed and potentially consolidated.

Recommendations to ESA

- As to the fragmentation and redundancies in the European offering, the key elements to address this include advanced federation concepts, harmonised interfaces and strategic alignment.
- Further efforts are required to evaluate and align about interfaces facilitating interoperability and federations (i.e. APIs, protocols, standards).
- For the DestinE initiative, aspects of federation, interoperability and community engagement will be critical to its success. The effective handling of reference data and related data engineering tools will also be important.

Accelerating New Space Uptake

Key Messages

This session looked at how an increasing number of European smallsat developers/operators are using private sector investment to develop, launch and operate dedicated EO satellites and deliver focused commercial services to clearly defined customer groups.

However, in many cases the data from these systems are also of potential interest to stakeholders that cannot be effectively engaged in the short term or which may not be addressable under conventional business models.

ESA has already set up some projects to test whether ESA-funded actions to specify demonstration exercises can accelerate wider uptake among such customers of the data and services provided by the New Space operators. This leads to increased commercial revenue streams and a more attractive investment proposition for future financing rounds.

The scope of this session was to investigate with the key players if and how this model can be expanded and what other actors would need to be engaged.

AI4EO Learning from EO data to understand our planet

Key Messages

The session, involving a diversity of speakers, leading various AI fields (e.g. from Tu Berlin, AIRI, NASA, Uni Twente / Munster) highlighted the super rapid evolution and uptake of AI by the community, enabling new science, new predictions and new applications capitalizing on the power of Machine Learning (ML), being automated, data-driven and scalable.

There is therefore a continuous need to test/explore new emerging architectures/topologies of neural networks (e.g. graph networks) and new learning methodologies (e.g. reinforcement learning, contrastive learning, …).

However, with these new opportunities also come new challenges in terms for example of robustness, ability to generalize and handle noise and trust in the black box. To address some of the these, a few recommendations are made.

Need for "speed" in projects to capture the rapid developments in AI.

Recommendations to ESA

- Need to explore the wider domain of AI beyond Deep Learning. AI is not limited to Deep Learning (main focus currently) and need to explore new AI methodologies combining "Reasoning" together with Machine Learning.
- Need to address the issue of "noise" in the data. Need to "augment" traditional data sets by delivering and curating AI-ready data sets, providing annotations, accuracy level, capitalizing on existing initiatives such as BigEarthNet.
- Need for new synergy / enhanced sensing products (e.g. fusing multivariate multi-data sets, revisit of Sentinel archive with super-res).
- Need to address the challenge of "trustworthy" AI, providing insight into "explainability" of the algorithms, so "trust" can be gained in using the products.
- Need for "caution" in generating "global" products with AI, as workflow is very easy to be scaled but maybe the products are not of quality. Need for a lot of in-situ validation.
- Need for stronger links between the climate modelling, EO and AI e.g. constraining climate model with EO data in particular for air quality and atmospheric properties, building emulators of models more physics-informed AI surrogate models for rapid prediction.
- Need for developing "edge" computing or TniML applications. Need to provide small-scale Deep Learning models to speed up their implementation in field applications (e.g. Drones and UAV).

AI4SCIENCE

Key Messages

- On methods: AI for Earth Science field is going through a prolific proof-of-concept phase. Synergies between Earth Science, AI/ML and HPC are far from easy, but possible, with clear examples already available in the community as reported by Barcelona Supercomputing Centre.
- Deep Learning is dominating the field of detection (e.g. of extreme events) and current architectures give good results in classical problems (e.g. tracking hurricanes). Key missing pieces identified by Univ. of Valencia are: neural nets explainability and understanding from a causal perspective, as essential for analyses of events coupled in space and time and to be able to attribute the events to climate change.
- On systems and platforms: the availability of data in the cloud enables a more effective analysis and is much more conducive to doing AI and data-driven science.
- On Open Science, a key unsolved issue is reproducibility, as reported by NASA. Making AI code, workflow and data openly available is not enough to guarantee, reproducibility of an experiment's accuracy, partly due to the differences in the systems. A cloud-based system where one shares the code, data and services enables reproducibility.
- On applications: Microsoft's presentation on their Planetary Computer focused on the importance of Open Infrastructure that enables interoperability, and Open Software architectures that enable Open Science and fuels community contributed applications and innovation.

Recommendations to ESA

- AI is not limited to Deep Learning and we should be more concerned about explainability and understanding causality. All these elements call for interdisciplinary education on EO Open Data Science.
- Need to provide cloud-based systems where scientists can share the code, data and services in such a way to enable reproducibility. More emphasis should be put on data and software engineering for the creation of tools to foster reproducibility.
- Need to think in ecosystem terms: providing the data, infrastructure, models, APIs, apps, in an architecture that enables interoperability and Open Science, to create and empower an ecosystem that includes contributors of data, developers that create new models or applications, and consumers of data and applications (citizens, businesses, governments).

Quantum Computing for EO - QC4EO

Key Messages

The session involving speakers leading in the field (e.g. from CERN, IBM, ECMWF, AstroCENT) highlighted the very rapid evolution of Quantum Computing (QC), a new "computing paradigm" to address "exponential problems" and particularly suited to optimisation problems, molecular biology and chemistry. Regarding EO, the question remains open to where it could shine but the field of Quantum Machine Learning (QML) looks promising and some cutting-edge research on QML4EO was presented. Promising fields for QC exploration are: large optimisation problems, computational prediction kernels, image classification and analysis, synthetic images generation, variational post-processing of AI models inference, probability distributions generation and sampling. One big issue is the "encoding" of big data with modest number of qubits. The avenue of better understanding the role of QC and QML in EO, and where it brings a real "quantum advantage" mainly through a "hybrid" system of computing, should be further explored by enhancing dialogue between QC specialists and domain experts with knowledge of EO. It is foreseen that when QC will have more computing power it could disrupt the entire way to do AI through hybrid schemes (bits / qubits / neurons).

Recommendations to ESA

- Need to strongly engage / federate with nascent, but still fragmented, QC4EO community and build partnership.
- Need to further study "how and when can QC help EO to solve a practically relevant problem faster or better than any known classical algorithm on the best classical computer?"
- Need to explore "hybrid" approaches combining HPC with new computing paradigms such as QC but also neuromorphic computing to explore the strengths/weaknesses of QML4EO for a variety of tasks (e.g. data classification, synthetic data, simulations).

SCOUT Missions: ESA's "New Space" approach to Earth Science Missions

Key Messages

Scout is acknowledged by the European space EO sector as a key opportunity to deliver innovative science as a service to the scientific community.

The round table focused on the return of experience from the Prime Contractors involved in the first two running Scout missions (CubeMAP, HydroGNSS), to be used in the next Scout call, open to any bidders.

- The dialogue phase held with ESA during the tender phase was praised by Industry to prepare and adjust their ITT, build the industrial approach, identify the key topics.
- ESA's pragmatism and flexibility (e.g. tailored ECSS, use of COTS, project level reviews only) was acknowledged and praised by industry.

Recommendations to ESA

Scout attracts a lot of interest from industry. It is a real opportunity for ESA to develop innovation, science and support both industry and the science community.

- Need to brand and advertise Scout as much as possible, in preparation of the next Scout call, to further expand the interest and get many innovative and credible proposals. Need to identify and use synergies within ESA.
- It's important to further clarify what New Space means and implies to ESA. Practical steps have already been successfully taken within EOP (e.g. tailored ECSS for Scout missions, use of COTS, project level reviews only, streamlined activities, service contracts). Need to disseminate, consolidate and harmonise these steps at Agency level.
- Need to clarify ESA's internal approach and resilience to the increased risks inherent to a Scout mission.
- Need to capture lessons learnt from the first 2 Scout missions to be fed back into the next Scout call (already planned).
- It's key to remind industry that Scout missions are not scientific demonstrators but missions to deliver a service to the science community. Need to make the requirement to deliver science data as a service even clearer to future bidders.

Scouts have three key & challenging framework requirements: 36 months from KO to launch; industry cost below 30 M€; cost at completion below 35 M€.

- The implementation of a PATP during the tender phase till phase B/C/D/E kick-off was essential to progress on critical activities as the Scout schedules are quite constrained.
- Need to simplify the implementation of a PATP before kick-off for New Space in general and Scout in particular to progress critical activities in parallel to the bidding process and increase maturity for kick-off.

The partnership and risk sharing approach was acknowledged and praised by Industry. Supporting industry during the implementation phase while granting industry a more prominent role requires a hybrid contractual approach, implemented as a service contract. This approach raised many questions during the Scout-1IPRev.

- Need to clarify the notion and implementation of service contract in New Space within ESA.

Concluding remarks

The 2021 Φ-week highlighted the many challenges and opportunities related to the rapid evolution of EO, the amazing advances in technologies, in particular AI reshaping the whole value chain of EO services, the new exciting intersection and synergy between New Space and the operational programmes of EU and EUMETSAT to enhance EO, the development of new downstream real-time monitoring and forecasting services based on live Digital Twins of the Earth system and its components.

In this context of rapid evolution in the landscape of space with new players, "**innovation**" is more and more critical for Europe to keep a competitive edge.

Speed is of the essence and exploring the value of new digital technologies, computing paradigms, small-sats technologies is key to prepare for the future.

Also forging new **partnerships** with industry, academia and start-ups will be essential to deliver "innovation through collaboration".