Digitalisation for Commercial Space solutions

Space Partnership recommendations for Horizon Europe Work Programme

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Preamble

The Globally Competitive Space Systems partnership is about to be launched in 2024, with moderate budget prospects and a short window of operations, targeting the calls 2025, 2026 and 2027 of the Horizon Europe work programme.
In light of the challenging calendar and budgetary environments, the partners propose to focus the efforts of the first version of the partnership (as implemented in Horizon Europe) on activities pursuing the following objectives:

- Address up to date challenges for commercial space solutions
- Achieve synergetic developments across the areas covered by the partnership scope
- Promote high yield, low risk, short timeline developments and deployments
- Target rapid deployment towards high TRL and demonstration activities
- Promote the involvement of all partners, large and small, institutes and corporate entities, demonstrated our capacity to work together at European scale
- Enable a scalable building blocks approach, towards a ready-to-bid status (possibly through demonstration missions) for commercial markets in the medium term.

With these objectives in mind, the partners propose to focus the first three years of the partnership on cohesive activities in the domain of digital developments under the grand heading of **Digitalisation for Commercial Space solutions.**

The Digitalisation goals will be articulated around the following main domains:

- **Collaborative and synergetic Earth Observation and Satcom missions for Space solutions**
    - **Satellites as Smart Network Nodes:** this domain will support the realization of key competitiveness development goals identified in the Partnership scope, covering the commercial communications including the seamless integration with terrestrial networks. The domain (further described herewith) will enable to roll out and demonstrate key space and ground technology building blocks in state-of-the-art areas such as cloud in space and edge computing, network protocols (5G&6G), distributed systems, automatic/intelligent data processing, inter-satellite links, innovative resources management software and orchestration of multi orbit space assets.

- **Digitalization to maximize Observation imagery performance and timeliness:** this domain will address end-to-end commercial observation systems. In particular, it will enable the maturation of the most time-efficient high power end-to-end processing chains, together with significant imagery performance enhancements.

- These two subdomains are fitting the corresponding sections of the Space's Strategic Research and Innovation Agenda. However, as far as possible, the space partnership endeavours to address them jointly to reinforce their synergies and to foster market-demanded innovations edging from such a combined approach

- **Digital solutions for launcher autonomy for space transportation systems, design and simulation tools**: focusing on a narrow scope of activities supporting competitiveness innovations for space transportation services, and aiming at enabling technologies able to support a wider range of new systems and services. The domain (further described herewith) would support four key development areas, eco-design software tools enhancing reconfigurability in orbit, on-board system autonomy, digital avionics and proof of concept and designs for new transportation systems and means (, orbital fuel depots, etc.)

The focus on digitalisation answers most of the requirements for the current Partnership while allowing the participation of a wide range of actors and fits with the budget envelope considered. Most of the demonstrators envisaged could be realised on ground or via a testbeds approach taking benefit of available in space infrastructures.

Collaborative Earth Observation and Satcom missions for Space solutions

Background

Satellites as Smart Network Nodes (Cloud/Edge computing, ISLs, AI/ML, real time, tasking, …)

The satellite Telecom market moved from a stable landscape with established value chain actors and roles to a moving environment similar to the terrestrial telecom market. Indeed, new entrants in the value chain have established themselves as disruptive and daring suppliers of new services targeting Earth observation, space data transfer, broadband and narrowband (IoT and mobility) applications for professional and consumer markets (B2B, B2G and B2C). The introduction of multi-orbit/multi-payload systems provide an additional challenge for orchestration and seamless integration into the network. In the future, assets in space will require new capabilities to cope with the continuous demand shift of consumers such as a seamless as possible integration of space networks with the terrestrial networks.
New entrants are combining manufacturer, operator and service provider ambitions, blurring traditional industry boundaries. This positions them to better respond to the challenge of tremendous data volume increase (especially driven by higher spatial and spectral resolution, HD video traffic etc.) and leverage on the deployment of newer standards such as 5G and 6G. Satellite operators will target increased flexibility and lower total cost of ownership to enhance their competitiveness in the global telecom landscape. Ownership itself is being challenged,

with new approaches around satellite as a service, offering access to space infrastructure without the need to effectively own payloads or satellites.

Digitalization to maximize Observation imagery performance and timeliness

The EO commercial market is two-fold. On one hand, end-to-end operators are developing or procuring their space assets, and selling data and analytics solutions. On the other hand, manufacturers are selling end-to-end (E2E) infrastructures to commercial (or public) operators or through G2G agreements across the World (Export to governments looking for sovereign E2E assets). The downstream imagery data and analytics market is a very complex target (congested, segmented/captive, still in need of customer evangelisation/education), most of the vertically integrated end-to-end operators now also diversify to selling infrastructure; this is notably the case in the USA and in China. The competition on the E2E infrastructure market is thus getting harsher inside Europe and world-wide; customers are looking for the best value for money, the value being measured in terms of resolution and timeliness (including freshness of the information). Competitive differentiators will benefit from data and analytics rapidity of execution, data availability for user/customer insights, and data/analytics earliest delivery to the user/customer, notably thanks to edge-computing. The integration into a global networked digital workspace with computing, cataloguing, repositories, analytics capabilities will drive future EO systems competitiveness.

Digital trends

In Communications satellites

On-board satellite data processing capabilities, coupled with enhanced ground data processing capabilities have become core enablers thanks to the digitalisation of the satellite payloads. Smart and cost-effective solutions are growingly in demand from by satellite operators and service providers as they face the increasing market pressure. The future satellite networks will need to adapt to evolving mission requirements as well as more complex multi-orbit/multi-payload space infrastructure. These types of space network will require new technologies that enable and facilitate the integration into the ground network architecture. Key technology enablers are optical inter satellite links, digital processors, hybrid antennas, on board and space software, high-performance space-to-ground links. The success of a space network will also require agile and dynamic routing of the traffic and adoption of proper terrestrial standardized communication protocols. This traffic processing capabilities is required by almost all the mission types from any kind of orbit: data security, broadband connectivity, data and/or TV broadcast, network backhauling, Internet of things and machine to machine networks, secured governmental applications, data transfers, etc.

In Earth Observation satellites

New concepts for multi-layers (various orbits with satellites and High-altitude platform station HAPS) multi-sensors (e.g. hyperspectral, thermal, optical and radar) allowing freshness up to persistence of the observations create needs for increased data integration, using digital/SW solutions.

Synergies

Enhanced robustness and Cyber Security are also needed, for system resilience and data integrity. Increased connectivity between satellites themselves and ground enables responsiveness and resilience, and optimisation of board vs. ground data processing, with cloud for global system competitiveness.

It will be important that the Space Partnership also works on the AI/ML chain covering both imagery and signal data. This is needed for operational on-board intelligence and autonomy, starting with the availability and access to validated training data for new AI/ML algorithms to AI/ML training infrastructure (which today depends a lot on non-European resources) to actual inference software frameworks.
Today most of the underlying technology and data needed to successfully implement new AI/ML algorithms – which are needed to reach desired on-board intelligence / autonomy – are either simply not or highly limited available or heavily depends on non-European Infrastructure (Training Computer resources and inference frameworks). It is therefore important to address those topics within the overall objectives.

To ensure European competitiveness for the worldwide market and its forthcoming requirements, the industry needs to further develop a systemic approach which will allow massive tasking of satellites by end-users, therefore demanding generalization of communications capabilities and standards between EO and communication satellites, on-board treatment of data, agile and collaborative management of request. It will be required to improve the industrialization and the whole value chain aspects to reduce the production cost and achieve lower system life cycle costs. New digital approaches need to be adopted to increase efficiency in the satellite development and in the Assembly Integration and Test (AIT) operations.

Expected outcomes (Objectives of the call)

In Communications satellites

Objectives are:

- To enable the European Space Industry to maintain a significant share of the global connectivity market by increasing the performance of space satellite networks, new type of control and ground segments being fully integrated into the terrestrial networks. This will also be needed in enabling the European Space Industry to maintain its global leadership role in Earth observation missions and systems.
- To target new commercial services and applications enabling a digitalisation of space solutions. Such solutions could be addressing in synergy the requirements of data transfer for analytics and observation system, and deploying a 5G/6G network in space, enabling massive data repatriation, direct to device services (D2D, i.e. satellite communications with unmodified smartphones) and non-terrestrial network (NTN) integration, Quantum applications, … A continuous development of key technology stacks will ensure European sovereignty in the future and will strengthen the industry against the competition from USA, China and others.

In Earth Observation satellites

Objectives is:

- To develop advanced Earth observation payloads, technologies and processing means (on ground and in space), for all types of observation missions.

Digitalisation is a major enabler for enhancing the value of an E2E EO system. Indeed, processing applied to the multi-sensor data, on-board or on-ground, with or without calling for IA, can significantly enhance the resolution of the final data set and resulting image/analytics (e.g. digital SAR back-end electronics, optical images post-processing etc.). Besides, persistent imagery modes (e.g burst, video) require new generations of digital processors and on-board memories. Furthermore, digital optimisation of the data flow (autonomous decision, selective downlink, ground-segment efficiency) directly improves the E2E timeliness of an EO system (from request to delivery). Lastly, the enhancement of E2E data resilience and integrity calls for digital technologies on-board and, on the ground, end-to-end objectives.

Operational objectives

In Communications satellites

- Improving ground and space data distributed computing and processing
- Edge computing/cloud capacity close to the payload (ground-space segments optimisation)

In Earth Observation satellites

- Digitally enhance EO imagery performance and mission timeliness
- Advanced EO-payload systems and technologies, including onboard and ground processing

Synergies

- Direct tasking by end-users and on-board treatment of data
- Harmonisation of building blocks interfaces
- Enhancing data security and system resilience in Space and Ground Infrastructures
- Advanced space network architectures allowing, through in-orbit resources sharing, for lowering the environmental impact of future missions.

Development goals

- Mid to High TRL targets for developments, with a need for a quick raising of the Low to Mid TRL levels for critical technologies of EO & Satcom required building blocks
- On-ground and in orbit demonstration and/or market readiness
- Focus on software and digital tools (e.g algorithms), supporting HW (e.g processors, electronics) from design to operation phases

Scope (Development activities)

The areas of R&I, which need to be addressed to tackle the above expected outcomes are one or several of the following ones:

For Communications satellites

- End to End Mission capabilities
    - Satellite network interconnectivity
    - Seamless integration into the terrestrial networks
- Energy efficient connectivity and compatibility with 5G & 6G waveforms.
    - Constellation and Network software management system
    - Optical communication
- Satellites as network nodes in a distributed system
    - Flexible and modular testbed: Multi-orbit and terrestrial integrated satcom architecture
    - Need common protocols across the comms chain. (similar to SDA standard but for civil)
    - Faster reaction time between the acquisition and the availability of data
    - Ubiquitous use of orbital resources

  - Distributed computing – do the computing where the data is, how best to combine final result

Earth Observation satellites

- On-board processing to optimize EO missions' performance or timeliness
  - Standardized software framework to host embedded edge-computing applications (AI, Machine Learning, ...)
  - Data/signal image processing to optimise algorithms, AI-based or not (e.g addressing compression, autonomous action, front-end/back-end performance etc.)
  - Enhanced downlink and uplink capabilities (e.g. for better reactivity)
- EO ground segment interfaces and data flows standardisation and adoption (evangelisation)
  - Development of ground-segment digital building-blocks in coherence with adopted standards
- Smart multi-source EO intelligence information fusion
  - Innovative intelligence information extraction and fusion exploiting multiple data sources (EO sensors and other space-based data along with ground-based data)

Synergies

- Maturing high performance processing payload H/W to support space network capabilities including an improvement in downlink and tasking capabilities of the European infrastructure.
  - In-orbit re-configurability
  - Network resilience
    - Multi-band transmission
    - Interference: detect, identify, locate and isolate
    - Vulnerability assessment of spacecrafts systems
    - Space weather free communications
  - Data integrity
  - Data security
    - Low-cost Cyber Security
      - Genuine European low-cost solutions
      - Quantum technologies chips and sensors
    - Data encryption
  - Data authentication
  - AI/ML chain covering both imagery and signal data
- Maturing technologies and products improving system security and threats identification
  - Host/Network Intrusion Detection/Prevention Systems for space systems and networks (space segment)
  - Security engineering of space systems architecture (end to end)
  - Capability to safely operate systems by different users with strict security boundaries
  - Improve the interoperability of our systems to enhance their mutualisation in system of systems
- Resources usage optimization
  - Operational optimization: increase the mission envelope and lifetime thanks to a better knowledge of the system in real time based on digital twinning

- Design optimization: increase future systems efficiency thanks to a better use of the operational return of experience of legacy systems
- Advanced techniques for large system of systems or multi-missions' operations optimization

- Environmental impact minimization of future missions
  - Tools to support the measure of key environmentally driven criteria through increased resource sharing: minimization of the mass to be launched, development cycle reduction, digital nodes sharing through several missions, optimization of the ground systems for a lower environmental footprint, etc.

Digital solutions for autonomy for space transportation systems, design and simulation tools

Background

The European space transportation segment is undergoing radical transformations under the pressure of new players in the sector proposing disrupting new systems, particularly small and micro launchers, and with the expectations for the development of a wider array of new market segments for transportation to space, in space and between orbital locations.
Markets for new services are particularly driven by the emerging demand for last mile services, in-orbit operations, servicing and manufacturing, and the exploitation of new orbital locations beyond LEO.
The key challenge is to sustain a European space logistics service architecture of nodes and flows using as much as possible existing European transport systems commonalities and enhancing technology synergies and reuse.

The new space transportation services also shall be more sustainable with long term goals and SMART objectives, including synergies across systems, and ground facilities for a more efficient supply chain.
Another key area of development is improvement of space transportation autonomy, for more service agility and cost efficiency. More on-board autonomy, with self-managed decision processes, up to termination system as needed, trajectory auto-tuning for simplified/autonomous mission preparation.

Digital trends for new space transportation services

Access to space is now giving way to space logistics, driving innovation to new areas, such as new injection solutions, smart upper stages, transportation concepts to access new nodes, and calling for development of technologies and functional building blocks, with a focus on digital solutions for autonomy, FDIR[1], ground and board data fusion, autonomous navigation and mission planning, development of low cost/low mass sensors and efficient avionics, flexible mission software, etc.
Key areas for service improvement are health monitoring systems, enabling real time subsystem monitoring through all mission phases, including predictive maintenance and refurbishing in case of reuse, high speed sensor networks for on board real-time data feeds, enhanced ground-board high-data rate communication and multicore on-board computer and using Artificial Intelligence algorithms to process high volumes of data.

[1] Fault Detection Isolation and Recovery

Models for mission, system design and optimisation, able to integrate life cycle analysis, engineering and environmental models for optimisation of development through manufacturing and mission implementation.

Expected outcomes (Objectives of the call)

Operational objectives

- Improving space systems and launcher developments sustainability
- Reducing cost and operational constraints
- Improving monitoring and autonomy

Development goals

- Mid to High TRL targets for developments, with a need for a quick raising of the Low to Mid TRL levels for critical technologies
- On-ground demonstration and/or market readiness
- Focus on software and digital tools

Scope (development activities)

- Advanced technologies and digital sensors for new space transportation, such as:
  - Smart avionics with modularity and reusability drivers
  - Health monitoring system and smart sensors
  - Structural health monitoring addressing thermo-mechanical monitoring and damage detection
- Support the maturation of disruptive/game changing technologies as proposed by the Community

Work programme structuring with budget proposal

The tables are the current allocations of the 100M€ budget of EU funding, organised by topic and by year. For each topic and year, we propose a typical budget allocation per project (max and min project size) from which we derive the potential number of projects that could be funded under each call.

The proposal

The proposal detailed below takes into consideration the recommendations provided by DG DEFIS, where NSTS is less funded than Communisation and Earth Observation topics. The split considers 15% for NSTS and 85% for Communication and Earth Observation.

Note that in this proposal, the funding per call is defined
- with a growth curve for the Communication and Earth Observation topics
  - attributing 20% of the total budget for the call year 2025, allowing for 80% to be allocated on the 2026 and 2027 calls.
- with a major portion of the NSTS topic budget allocated in the first year to allow for fewer but still ambitious projects
  - attributing 2/3 of the total budget for the call year 2025, allowing for 1/3 to be allocated on the 2026 and 2027 calls.

TRL Targets

- Within each topic/call we propose to implement the budget via projects defined by Maturity target. i.e. as IA (innovation action) or RIA (research and innovation) type of instrument.
    - Low Mid TRL targets are up to TRL 3-5 (RIA)
    - Mid high TRL targets are up to TRL 6-8 (IA)
- In the proposal the theoretical budget split would be in the order of
    - 25% for low/mid TRL development targets (typically implemented via RIA type of actions)
    - 75% for mid/high TRL development target (e.g. IA type of actions).

Important: Low TRL activities should be selected among the most promising/disruptive candidates to answer the Partnership objectives. They should be further develop with the appropriate budget for maturation in the next iteration call(s).

The budget allocations

The elements defined above have been used to prepare the following tables allocating the budget envelopes to topics and calls, and deriving implementable proposal in terms of size and number of projects that could/would be funded within each call.

Budget allocation scheme per topic and call

The table below propose the budget allocation scheme reflecting the above proposal.

Budget (m€) repartition per call years and topics							
Topic n°		**Topic title**	**TRL target**	**2025**	**2026**	**2027**	**TOTAL (m€)**
Topic 1	EO / Satcom	Collaborative Earth Observation and Satcom missions for Space solutions	Low to Mid (RIA)	6	12	4	22
Topic 1	EO / Satcom	Collaborative Earth Observation and Satcom missions for Space solutions	Mid to High (IA)	11	26	26	63
Topic 2	NSTS	Digital solutions for autonomy for space transportation systems, design and simulation tools	Low to Mid (RIA)	3	-	-	3
Topic 2	NSTS	Digital solutions for autonomy for space transportation systems, design and simulation tools	Mid to High (IA)	7	5	-	12
		TOTAL (m€)		27	43	30	100

Budget allocation schemes per topic, call and project

The table below expand the budget allocation scheme to determine what could realistically be achieved in terms of number of projects and project size within each call.

Overview of the min/max budg. per project and min/max number of project				2025 budg./proj. (m€)		2025 # Proj.		2026 budg./proj. (m€)		2026 # Proj.		2027 budg./proj. (m€)		2027 # Proj.	
Topic n°		**Topic title**	**TRL target**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Topic 1	EO / Satcom	Collaborative Earth Observation and Satcom missions for Space solutions	Low to Mid (RIA)	1	5	1	6	1	2	6	12	1	2	2	4
Topic 1	EO / Satcom	Collaborative Earth Observation and Satcom missions for Space solutions	Mid to High (IA)	2	6	2	6	5	10	3	5	5	10	3	5
Topic 2	NSTS	Digital solutions for autonomy for space transportation systems, design and simulation tools	Low to Mid (RIA)	2	3	1	2	2	5	-	-	2	5	-	-
Topic 2	NSTS	Digital solutions for autonomy for space transportation systems, design and simulation tools	Mid to High (IA)	4	6	1	2	1	5	1	5	2	5	-	-