



**ESRE Input to the European Commission  
for  
Horizon Europe “Space”  
Work Programme 2025**

Provided by ESRE

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**Table of content**

- List of abbreviations ..... 4
- Introduction..... 6
- 1. Access to Space ..... 8
  - 1.1. Innovative and adaptable GNC algorithms for expendable and reusable launchers..... 8
  - 1.2. Environmental impact of reusable launch systems ..... 9
  - 1.3. Reusable upper stage: recovery, reconditioning, recycling ..... 10
- 2. Communications..... 11
  - 2.1. Adaptive Physical Layer and Antennas of mega-constellations..... 11
  - 2.2. Satellites as Smart Intelligent Reconfigurable Secure and Reliable Network Nodes ..... 12
  - 2.3. Optical Transport Network in Space ..... 13
- 3. Earth Observation..... 14
  - 3.1 Interplay of biodiversity and geodiversity from ecosystem to landscape scale ..... 14
  - 3.2. Detecting environmental crimes using EO data ..... 15
- 4. Navigation ..... 16
  - 4.1. Building blocks for applications such as vertiports ..... 16
  - 4.2. PRS adoption in civil applications..... 17
  - 4.3. Resilience of GNSS..... 18
  - 4.4. LEO Position Navigation Timing ..... 19
- 5. Future Space Ecosystem..... 20
  - 5.1. Distributed payloads on-board clusters of small satellites ..... 20
  - 5.2. New concepts and system analysis of collaborative small satellite constellations ..... 21
  - 5.3. Autonomous systems for Automated Rendezvous and Docking (AR&D) ..... 22
  - 5.4. Robotic CubeSat missions for testing cooperative tasks..... 23
  - 5.5. Electric propulsion disruptive technologies ..... 24
  - 5.6. Space Robotic Assistance ..... 25
  - 5.7. Management and Coordination Activity for Future Space Ecosystem ..... 26
- 6. Space Science & Exploration ..... 27
  - 6.1. Innovative scientific instruments, exploration concepts and enabling technologies ..... 27

## List of abbreviations

<i>Abbreviation</i>	<i>Meaning</i>
ADCS	Attitude Determination and Control System
AI	Artificial Intelligence
ADR	Active Debris Removal
AO	Adaptive Optics
AR&D	Automated Rendezvous and Docking
COTS	Commercial-Off-The-Shelf
CAS	Commercial Authentication Service
DIAS	Data and Information Access Services
ECR	Electron Cyclotron Resonance
EDL	Entry, Descent & Landing
EGNSS	European Global Navigation Satellite System
EO	Earth Observation
EOL	End-Of-Life
EPIC	Electric Propulsion Innovation & Competitiveness
ESA	European Space Agency
ESRE	Association of European Space Research Establishments
EU	European Union
EVA	Extravehicular Activity
eVTOL	electric Vertical Take-Off and Landing
GBAS	Ground-based Augmentation System
GEO	Geostationary Orbit
GNC	Guidance, Navigation and Control
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HPT	Helicon Plasma Thruster
ILS	Instrument Landing System
IOD	In-Orbit Demonstration
IOV	In-Orbit Validation
IR	Infrared
IRIS <sup>2</sup>	Infrastructure for Resilience, Interconnectivity and Security by Satellite
ISL	Inter-Satellite Link
ISRU	In-Situ Resource Utilization
LEO	Low Earth Orbit
LIBS	Laser-induced breakdown spectroscopy
LIDAR	Light Detection and Ranging
LPV	Localizer Performance with Vertical guidance
MEO	Medium Earth Orbit
ML	Machine Learning
NASA	National Aeronautics and Space Administration
NBS	Natural Based Solution
OOS	On-Orbit Servicing
OSNMA	Open Service Navigation Message Authentication
PNT	Positioning, Navigation and Timing
PPU	Power Processing Unit
PRS	Public Regulated Service

ESRE input for Horizon Europe Space Work Programme

QKD	Quantum Key Distribution
RF	Radio frequency
R&D	Research and Development
SLR	Satellite Laser Ranging
SRIA	Strategic Research and Innovation Agenda
STM	Space Traffic Management
SWAP-C	Size, Weight and Power and Cost
TPS	Thermal Protection Systems
TRL	Technology Readiness Level
VHTS	Very High Throughput Satellites
VLEO	Very Low Earth Orbit
VTOL	Vertical Take-Off and Landing

## Introduction

ESRE has developed the present document as a contribution to the on-going definition and future implementation of the research related to space.

The main purpose of this document is to provide the European Commission with concrete and coordinated suggestions for the Space sector in support to the preparation of Horizon Europe work programme for 2025.

The thematic suggestions have in common that they are based on the Strategic Research and Innovation Agenda and on a roadmap (European Commission roadmap if not specified).

The document is organised in six main activity fields, which are Access to space, Communications, Earth observation, Navigation, Future space ecosystem and Space Science and Exploration.

### ESRE

The Association of the European Space Research Establishments — ESRE — was formally established in March 2016 as an international non-profit organisation. Present member organisations of ESRE are the national space research centres CBK (Poland), CIRA (Italy), DLR (Germany), INCAS (Romania), INTA (Spain), NLR (Netherlands), ONERA (France) and VZLU (Czech Republic).

Through ESRE, these national space research centres strengthen their cooperation and propose European Research and Development (R&D) actions to advance science and technology both to support the competitiveness of the European space sector and to address the grand societal challenges.

<https://www.esre-space.org/>



## 1. Access to Space

### 1.1. Innovative and adaptable GNC algorithms for expendable and reusable launchers

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Access to Space

**Specific Challenge:**

Throughout Europe there is continuous efforts being made in the expandable and reusable launch systems scene, which are facing several specific engineering challenges, such as:

- Implementation and testing of adaptive flight software to ensure increased responsiveness for the vehicle;
- The growing need for fault-tolerant capabilities to guarantee mission safety and success even in off-nominal scenarios;
- Real-time data processing onboard launchers to perform robust corrections during flight.

**Scope:**

The scope of the present proposal is to identify and design onboard capabilities within GNC system development which will enable the advancement in the field of launch vehicle in European landscape moving from off-line and pre-computed capabilities into real-time computation and optimization algorithms and techniques.

**Expected outcome:**

The proposal shall assure fostering of collaborative research between European institutions and private entities with a clear contribution to:

- Europe's ambition of achieving independent access to space along with higher reliability and cost-effectiveness;
- EU Green Deal objective through the reduction of environmental footprint of space launchers by optimizing their trajectories and minimizing the amount of space debris generated for each mission;
- Europe's aspiration to strengthen the robotic and human space exploration capabilities for future Moon and Mars missions.

**Year of the call:** 2025

**Type of Action:** Grant – Research and Innovation Action

## 1.2. Environmental impact of reusable launch systems

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Access to Space

### **Specific Challenge:**

The main challenges to be addressed are:

- the accurate estimation of atmospheric emissions along the trajectory of a launcher (Indeed, one of the particularities of launch vehicle systems is to eject gases in the upper layers of the atmosphere, which implies large lifetime and a potentially significant contribution to the change of atmospheric and climate equilibria);
- assessing all other aspect of the environmental impact of the production and operation of launch vehicles, which cover a wide spectrum of effects.

### **Scope:**

Includes activities for:

- Evaluating launchers atmospheric emissions:
  - Differentiate the emission in different layers of the atmosphere;
  - Study the respective influences of the various propellants;
  - Study the consequences of propulsion mode change during a flight;
  - Assess potential ozone depletion.
- Estimating other effects of launch industry production and operation by means of a Life Cycle Analysis:
  - Potential degradation of air and water quality;
  - Influence on the biodiversity near the launch pads;
  - Pollutant emission near the manufacturing sites;
  - Energy consumption;
  - Emissions due to propellant synthesis.
- Transposing for that purposes some aspects of the methods implemented in the aeronautic field, in which this topic has been booming in the recent years (e.g. EU Clean Aviation program).

### **Expected outcome:**

Several outcomes are expected:

- Contribution to greenhouse effect mitigation;
- Prevention of the degradation of upper atmosphere equilibria;
- Permit the space sector to become environmentally sustainable in the context of its increasing development (mega constellations, space exploration...);
- Improve European competitiveness in the sector, producing and operating greener launchers.

**Year of the call:** 2025

**Type of Action:** Grant - Coordination and Support Action

### 1.3. Reusable upper stage: recovery, reconditioning, recycling

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Access to Space

**Specific Challenge:**

Recovery or reusability of the upper stage to prevent burning up material in the upper atmosphere or uncontrolled re-entry and crashing is becoming increasingly important with the growing number of yearly launches. For the upper stage, an emerging possibility is to reuse it in space, perhaps for interplanetary missions. For re-entry back to Earth, control of flight path and deceleration are important.

**Scope:**

- Mission design
  - Re-entry trajectory along with safe re-entry corridor need to be calculated;
  - Re-use in orbit will depend on the set-up and final state of the upper stage.
- Engine-related design
  - Engine architecture and components adaptations suitable for re-entry phase;
  - Intelligent engine controller design for adaptive mission scenarios;
  - Recovery methods of the upper stage lead to specific additional technologies and/ or propellants needed.
- Structural design
  - Control surfaces might be necessary or other means of control;
  - Landing systems such as deceleration devices and soft touch-down methods to be included;
  - Reusability in-orbit by making parts easily detachable to be investigated.
- Material selection
  - Light non-ablative materials to be used when re-entering;
  - Material which can either be used again (or the complete upper stage) or brought back to source material with low effort;
  - Material which can be recovered into a powder form for in-orbit manufacturing.

**Expected outcome:**

- Sustainable use of available materials, to reduce space debris generation;
- Maximize the efficiency of launchers;
- Pave the way for recycling methods and procedures to be put in place for space applications (i.e. Lunar base or in-orbit stations) and interplanetary missions (i.e. source material for Mars missions).

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 2. Communications

### 2.1. Adaptive Physical Layer and Antennas of mega-constellations

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Foster competitiveness of end to end systems and associated services

**Specific Challenge:**

With the new space changing era, first generation of global mega-constellations are being deployed. The main challenge to be addressed is to provide the best compromise between user needs (high availability, minimum data rate) and operator interest (high throughput, low interference). The main goal to be followed are to improve performances of satellite communication systems using high frequencies such as Ka-bands for user links and Q/V/W bands or Optics for the feeder links, for mega-constellations using radio links with VLEO/LEO/MEO satellites.

**Scope:**

Benchmarking from big Very High Throughput Satellites (VHTS) systems has to be considered as state-of-the-art reference.

- Extension to W-band and Optics for feeder links in complement to Q/V band
  - Propagation channel characterization, modelling and forecasting;
  - Fade Mitigation Techniques with focus on smart gateway diversity techniques;
  - W-band Radio Frequency (RF) components.
- Interference management for Ka-band user links
  - Interference detection and rejection techniques;
  - Generic sharing studies between LEO/MEO/GEO.
- Wide bandwidth antennas:
  - Optical beamforming;
  - Integration / accommodation into large moving platforms aircraft, trains, ships etc.);
  - Flat Phased Array Antennas (especially for automotive and for small mobile platforms such as eVTOLs with reduced SWAP-C constraints).

**Expected outcome:**

- Growth of the commercial market for the next generation of mega constellations;
- Improve full sovereign institutional communications taking into account that IRIS<sup>2</sup>, first generation, will have limited performances;
- Pave the way for the design and development of a new generation for IRIS<sup>2</sup>, providing higher data rates, higher reliable and resilient links.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 2.2. Satellites as Smart Intelligent Reconfigurable Secure and Reliable Network Nodes

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Foster Competitiveness of space systems

### **Specific Challenge:**

The upcoming deployment of IRIS<sup>2</sup> constellation will pave the way for multi-orbit satellite communication systems. Future communication satellites shall be thus regarded to as intelligent, reliable and secure network nodes which are part of a fully integrated global network combining space and terrestrial connectivity. In this context, also a new role for geostationary satellites as enablers for autonomous space network operations shall be addressed.

### **Scope:**

To optimize performance (especially in terms of latency), resource usage and increase resilience and dependability, many access and core network functionalities traditionally implemented in the ground segment shall be brought to space.

- Long-term secure multi-orbit satellite communication system that is resilient against current and potential future threats like e.g. quantum computers;
- Modular, flexible and distributed network architectural concepts aiming at intelligent, reliable and secure network nodes in space;
- Advanced concepts to optimize access and core network functionalities deployment in space given the always tight mass and power budgets of communication payloads;
- Optimized radio resource management, routing, handover, mobility management and networking protocols for ubiquitous and secure connectivity;
- Edge Computing enabled payloads combined with Artificial Intelligence (AI)/ Machine Learning (ML) techniques.

### **Expected outcome:**

- Improve and enhance the performance of IRIS<sup>2</sup> first generation (integration with terrestrial network, provision of resilient, secure and reliable connectivity);
- Contributions to the 6G standardization process.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

### 2.3. Optical Transport Network in Space

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Foster competitiveness of end to end systems and associated services

**Specific Challenge:**

The upcoming deployment of IRIS<sup>2</sup> constellation will pave the way for multi-orbit satellite communication systems. Optical communication links are a promising candidate for setting up inter-satellite connections as backbone networks. Quantum Key Distribution (QKD) between satellites and ground enable global secure communication systems. In addition, optical feeder links, both to LEO- and GEO-satellites, have the potential to overcome bottlenecks which are existing with radio-frequency technology. Moreover, they inherently offer increased robustness against jamming.

**Scope:**

- Optical inter-satellite- and feeder-links beyond the existing State-Of-The-Art (for instance, with higher data rates);
- Smart / Compact Optical Ground Stations (Adaptive Optics (AO), Predistortion, multi-purpose – e.g. QKD-enabled);
- Photonic Integrated Circuits (space...);
- Low SWAP-C (Size, Weight and Power and Cost) Laser Communication Terminals;
- Routing and Switching;
- High Speed On-Board Data Handling and Processing;
- Integration with upcoming QKD (space & ground) infrastructure.

**Expected outcome:**

- Improve and enhance the performance of IRIS<sup>2</sup> first generation (system performance, payload volume, integration with the ground segment, on-board-processing, as well as integration with the ground segment).

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

### 3. Earth Observation

#### 3.1 Interplay of biodiversity and geodiversity from ecosystem to landscape scale

**Based on roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Foster competitiveness of end to end systems and associated services

**Specific challenge:**

Rapid environmental changes impose the need for quantitative and comprehensive scientific information that supports policies aimed at managing biodiversity, geodiversity, climate change impacts, and to implement nature-based solutions supporting sustainable development.

Currently, the loss of biodiversity is one of the global environmental concerns. On the other hand, the variety of abiotic features and processes of the land surface and subsurface, usually indicated as geodiversity, is crucial also for preserving high biodiversity and ecosystem functioning.

**Scope:**

- Develop comprehensive and interoperable databases, consistent data reporting and standardized models of geodiversity and its interplay with biodiversity;
- Apply geosystem models to complement ecosystem models, developing examples of new coupled geodiversity-biodiversity ecosystem models;
- Develop comprehensive and parsimonious measures of geo-system and ecosystem structure, function, integrity, and risks;
- Contribute to model building addressing cross-scale geosphere-biosphere interactions (digital twin) and models upscaling from in-situ to regional and global ones;
- Address long-term and large-scale environmental, ecological and social challenges;
- Involve existing data sets and Copernicus services (e.g. EO Sentinel satellite data) using modern data processing and handling techniques such as Machine Learning (ML) and artificial intelligence (AI) and cloud computing possibilities such as European DIAS services.

**Expected outcome:**

- A better understanding and quantification of the direct drivers of geo- and biodiversity;
- Development of an interconnected vision of geo- and biodiversity processes, supporting integrated policies at regional, EU and global levels;
- Develop strategies for managing protected areas and their networks;
- Foster the incorporation of geo- and biodiversity concepts, ecosystem services, natural capital and nature-based solutions (NBS) into public and business decision-making.

**Year of the call:** 2025

**Type of Action:** Grant - Research and innovation action

### 3.2. Detecting environmental crimes using EO data

**Based on roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Foster competitiveness of end to end systems and associated services

**Specific Challenge:**

Environmental crime is a growing problem that significantly impacts EU citizens' everyday lives, with negative impacts on human health, security, economy, society and culture. Furthermore, environmental crime can be accompanied by corruption, money laundering and even financial terrorism.

**Scope:**

- Carrying out usability tests of satellite and aerial data with various spatial and temporal resolution;
- Development of advanced target detection techniques for EO;
- Development of advanced classification techniques for EO data based on machine learning and/or AI;
- Data fusion of EO data (satellite and aerial) with administrative databases;
- Development of a prototype monitoring.

**Expected outcome:**

- Developing methods to chase environmental crimes;
- Foster cooperation with the administration and environmental crime enforcement authorities.

**Year of the call:** 2025

**Type of Action:** Grant - Research and innovation action

## 4. Navigation

### 4.1. Building blocks for applications such as vertiports

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Copernicus and EGNSS – Development of applications

**Specific challenge:**

The emergence of unmanned and autonomous air transport means a change from controlled, open sky environments, to vertical take-off and landing in urban, densely populated areas. Current navigation technologies and standards used in civil aviation (e.g. GBAS, ILS, LPV-200) are either not suitable or not adequate for this application. The rapid development of technologies and standards supporting such operations is therefore of vital importance.

**Scope:**

- Development of navigation and sensor technologies for “last mile” aerial navigation;
- Application of new or existing standards toward vertical take-off and landings in urban environment;
- Ground-based GNSS augmentation;
- Resilience, accuracy, integrity;
- System assessment how LEO-PNT will impact and affect VTOL in urban, densely populated areas.

**Expected outcome:**

- The adoption of both autonomous and unmanned aerial transport will have a major impact on our economy (economic boost to the transport and logistics sector);
- Opening new methods of green and sustainable transport in urban areas;
- Speed up the adoption of sustainable transport;
- Increased or faster adoption of new ground-based navigation augmentation in traditional manned civil aviation.

**Year of the call:** 2025

**Type of Action:** Grant - Innovation Action

## 4.2. PRS adoption in civil applications

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** EGNSS Evolution of space & ground infrastructures

**Specific challenge:**

Public Regulated Service (PRS) is a major investment done by all European countries in unison. This investment is only worthwhile if the system is actually used. Currently, most countries are initially aiming at an adoption of PRS primarily for military use cases. PRS was however also designed to enable civil use, for example for civil services such as police, or critical infrastructure. This call item will help to speed up the overall adoption of PRS in European Member States, as well as encouraging the adoption of additional civil use cases.

**Scope:**

- (Technical) concepts to allow PRS in civil use;
- Concepts to treat a PRS receiver as a black box, removing or lightening the security requirements for PRS receivers in non-controlled environments;
- Evaluation of PRS versus Open Service Navigation Message Authentication (OSNMA) and Commercial Authentication Service (CAS) for specific applications and use cases;
- Alternative PRS concepts such as snapshot receivers for use in civil applications;
- Civil use cases for PRS suitable for society transformation;
- Build on top of previous funded R&D projects related to PRS civil applications (HORIZON-EUSPA-2023-SPACE-01-44) to widen the adoption of PRS among new user communities;
- Foster cooperation among PRS Participants, especially in terms of support and knowledge transfer from those with more experience to others with lack of adoption.

**Expected outcome:**

- Increase the value of PRS and provide better return-on-investment (civil applications will typically increase safety and security in society, increasing the resilience of both civil services as well as critical infrastructure);
- Acceptance and stronger support for future evolutions of the PRS system.

**Year of the call:** 2025

**Type of Action:** Grant - Coordination and Support Action

### 4.3. Resilience of GNSS

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Copernicus and EGNSS – Evolution of services

**Specific challenge:**

Safety critical applications in transportation as well as security related applications and critical infrastructure rely more and more on GNSS for positioning, timing and synchronization. Therefore, availability, integrity and authenticity of GNSS signals is a must. However, we see an increase of threats to GNSS by jamming and spoofing caused by several kinds of actors reaching criminals over terrorists to state actors. A combination of two capabilities is needed to handle this threat: 1) reliable detection, identification and localization of jamming and spoofing events and sources, 2) the toughening and hardening of GNSS receivers against aforementioned threats. This call item invites proposals that address these shortcomings by coming up with proposals for new architectures and building blocks which can be applied in different combinations for a large variety of applications. This includes topics such as:

**Scope:**

- Technologies for localization of jamming and spoofing sources both from space, air and ground;
- Scalable heterogenous architectures for localization of jamming and spoofing sources bringing different technologies (space/air/ground) together, e.g. including monitoring stations with common reference time via fiber link;
- Assessment of vulnerability of critical applications by jamming and spoofing threat;
- Resilient GNSS receivers against jamming and spoofing, e.g. including steerable antenna, beamforming techniques;
- Galileo capabilities, such as multi-frequency signals and open services devoted to authentication (namely OSNMA and CAS), shall be exploited for detection and protection against jamming and spoofing.

**Expected outcome:**

- More commonly available resilient receivers to be adapted within critical infrastructure and similar applications;
- Establish monitoring activities possible to better detect and pin-point localization of jamming or spoofing sources.

**Year of the call:** 2025

**Type of Action:** Grant - Innovation Action

#### 4.4. LEO Position Navigation Timing

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** EGNSS Evolution of space & ground infrastructures

**Specific challenge:**

Out-of-domain solution based on LEO satellites can enhance GNSS services by broadening the delivering Position Navigation Timing (PNT) solutions to urban, national critical infrastructure where reception of typical GNSS signals is hindered due to signal obstruction or higher spatial diversity is needed. Both payloads and ground segment technologies should be pursued to introduce new applications and drive constellation population.

**Scope:**

- System analysis about pros and cons of dedicated constellations vs. signal-of-opportunity driven approaches;
- Receiver for PNT applications using LEO constellations;
- Small laser satellite ranging system on LEO satellite for precise time transfer and ranging;
- Orbit determination and time synchronization including scientific applications;
- Orbital debris, space traffic management and collision avoidance;
- Constellation Management, Control & Autonomy.

**Expected outcome:**

- Specific LEO-PNT target high precision applications, robustness against attacks or low signal environments;
- Rise of interoperability and complementing GNSS;
- Laser ranging time transfer offering precise time comparisons could be made more accessible and not only limited to geodetic SLR specific observatories.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 5. Future Space Ecosystem

### 5.1. Distributed payloads on-board clusters of small satellites

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Future Space Ecosystem

**Specific Challenge:**

Clusters of small satellites implementing fractionated systems and instrumentation open a wide field of opportunities for next-generation Earth Observation, Communications and Science systems, as they have the potential to improve mission capabilities, flexibility and robustness compared to large monolithic satellite systems, at lower cost.

**Scope:**

The topic is devoted to key technologies enabling applications of distributed miniaturized payloads for missions related to Earth Observation, Science and Telecommunication. This include both the payloads themselves and the subsystems and technologies required for the missions:

- Development of an efficient and stable formation flying control system for nanosatellites compatible with Earth Observation requirements;
- Development of a highly-accurate Attitude Determination and Control System (ADCS) for nanosatellites which enables coordinated pointing of the fractionated instrument constrained by the formation flying and which paves the way to reach high spatial resolution on ground;
- Development of a multi-node Inter-Satellite Link (ISL) equipment for nanosatellites control and coordination;
- Development of a fractionated instrumentation based on miniaturized payloads for Earth Observation.

**Expected outcome:**

- Enhanced mission capabilities and flexibility;
- Higher robustness and resilience.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 5.2. New concepts and system analysis of collaborative small satellite constellations

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Future Space Ecosystem

### **Specific Challenge:**

Currently few satellite constellations are in operation. The most notable applications for which satellite constellations have been established are in the domains of navigation and communications. With regard to small satellite constellations, it is important that Europe is not dependent on international partners. The focus should be on reusable resources, cost-effective solutions or more dedicated mission profiles.

### **Scope:**

- Analysis of the needs, from mission, to technical and operational needs;
- Technologies (not limited to): satellite positioning, pointing accuracy, orbital control, power density/distance, in-orbit replacement (upgrades), operations/constellation management (scheduling), on-board autonomy (AI/Machine Learning), EOL procedure, debris mitigation, STM;
- COTS products, which could necessitate a technology push or revision to ensure the required quality;
- Modular constellation design, whereby each satellite has a dedicated functionality (e.g. space-based solar power, space telescope);
- In-orbit servicing of satellites;
- Space debris removal systems (i.e. pick-up satellites + main disposable unit);
- Combined fabrication systems (split factory functions over multiple small satellites).

### **Expected outcome:**

- Enabling new constellation types to be exploited for European interests (Earth Observation constellations for coverage and/or accuracy);
- Pioneering new space applications with global coverage (Lagrange point swarms);
- Enables supporting infrastructure for future Lunar and Mars missions (Lunar orbiting systems (GPS/LO), Mars orbiting system (GPS/MO/weather));
- Boosting the European space economy and expanding cooperation between European partners.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

### 5.3. Autonomous systems for Automated Rendezvous and Docking (AR&D)

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Future Space Ecosystem

**Specific Challenge:**

New, ambitious space missions, such as Active Debris Removal (ADR) and On-Orbit Servicing (OOS) missions, will rely extensively on the advancements in space robotics. The main challenges of these missions are autonomous rendezvous, proximity operations and interaction with either cooperative or non-cooperative objects.

**Scope:**

- Analysis of lighting conditions impact on guidance, navigation and control system dedicated to AR&D missions;
- Preparation of database with test results of AR&D technologies done on different testbed systems both on Earth as well as on orbit;
- Analysis of the stability of AR&D control systems in different mission phase (e.g. contact between target and chaser), improvement of performance, robustness, and reliability of the control systems dedicated for proximity operation of spacecraft's;
- Improvement of control system operate during contact between target and chaser mechatronic subsystems;
- Miniaturization and accommodation of mechatronic devices on CubeSat platforms;
- Miniaturization and accommodation of vision sensors on CubeSat platforms;
- Improvements of path planning algorithms to include autonomous obstacle mitigation during path realization;
- Improvements of navigation filters to include nonlinear behaviour of systems;
- Development of sensors suites dedicated to rapidly changing lighting conditions;
- Validation of testbed systems dedicated to AR&D missions.

**Expected outcome:**

- Increase the level of autonomy of robotic systems;
- Increase the involvement of Europe's terrestrial robotics industry in space developments;
- Foster cooperation between international industry, scientific, and engineering teams.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 5.4. Robotic CubeSat missions for testing cooperative tasks

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Future Space Ecosystem

### **Specific Challenge:**

Cooperative satellites will enable many new applications through in-orbit assembly and maintenance of large space systems, such as giant telescopes, antennas and radar systems, without the constraints of monolithic deployable systems (fairing size, launch mass).

### **Scope:**

Proposed missions should address one or several of the following issues:

- Aiming for a centimetre relative position knowledge accuracy on a 6U CubeSat or smaller and provide sufficient  $\Delta V$  and impulse control to match operational mission duration, typically resorting to electric propulsion or enhancing the current liquid propulsion systems;
- Following Horizon 2020 PULSAR and Horizon 2020 MOSAR projects, further work is needed on critical scenarios, for example desaturation using electric propulsion and constraints on structures and materials caused by the space environment. Missions involving a number of CubeSats could address robustness, scalability and safety issues regarding mission planning, resource management and coordination of the formation flying architecture;
- Close proximity maneuvers, in order to demonstrate the ability to deal with unaccounted perturbations, either by considering communications delay with the ground in the formation control, or by relying on independent on board sensor systems to monitor the safety of the operations and allow autonomous disengagement;
- Specific key subsystems must be demonstrated such as optical or radar sensors, on-board intelligence for autonomous operations, inter-satellite communications and sensing, etc.;
- Other related space operations can be relevant, e.g., on-orbit servicing for inspections, maintenance and refuelling, Earth Observation payloads including geometry dependent measurements such as payloads which use time-differences, Earth Observation sensor fusion, secondary platforms in interplanetary missions for mission risk mitigation and for support to the main spacecraft.

### **Expected outcome:**

- Milestones for in-orbit demonstrations of complex space operations such as formation flying and large infrastructure assembly;
- Opening of new business opportunities and markets for European space industries, such as on-orbit servicing;
- Perform debris removal operations;
- Matching future needs following evolutions in international regulations,;
- Demonstration missions involving CubeSats in the near future as a testbed for key technologies;
- New product chains anticipating the future market trends.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 5.5. Electric propulsion disruptive technologies

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Future Space Ecosystem

### **Specific Challenge:**

The deployment of numerous smaller size satellites motivates the development of new solutions for satellite propulsion reducing the propulsion system size, weight, cost and complexity and increasing its modularity to facilitate its implementation on different platforms. Some earth observation activities require higher efficiencies from the propulsion system to compensate the atmospheric drag and would benefit from the higher autonomy granted by air-breathing electric propulsion system. Low power disruptive electric propulsion devices for satellites are emerging technologies that can answer these challenges and disrupt the status quo of the space sector.

### **Scope:**

Europe benefits from a very competitive landscape in electric propulsion disruptive technologies thanks to Horizon 2020 EPIC program. Some of these disruptive technologies have already demonstrated their performances in the laboratories thanks to this previous action. This action proposes to take disruptive electric propulsion technologies with a demonstrated concept and to bring it to flight ready prototypes. The action will focus on highly innovative electric propulsion technologies answering the challenges named above. The target technologies include cathodeless thrusters (ECR, HPT...), vacuum arc thrusters, pulsed plasma thruster, electrospray thruster. Several technical topics will be key in the selection of the technologies to develop. They should have one or several of the following specificity:

- the use of solid propellant, simplifying the fluidic subsystem, suppressing the gas tank and reducing size, weight and cost of the fluidic subsystem;
- being cathodeless, reducing the complexity, the weight and the cost of the PPU;
- being compatible or designed for air-breathing operation, allowing longer very low orbit mission.

The funded projects should focus on devices that already reached TRL 4. The scope of the action is to increase their TRL targeting TRL5-6 and a potential IOD/IOV.

### **Expected outcome:**

- Increase the TRL of selected technologies up to 5-6 and bring them to flying prototypes, paving the way to IOD demonstrations and triggering their industrialization;
- Take advantage of this ensemble of promising technology and allow Europe to be leader in the future space ecosystem.

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 5.6. Space Robotic Assistance

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Future Space Ecosystem

### **Specific Challenge:**

The primary goals of Space Robot Assistance are the deployment of robots as a vanguard for the preparation of orbital stations and planetary habitats, and as daily assistants of astronauts during orbital activity, and during the journeys to the Moon, Mars and beyond. AI-based contextual autonomy paired with intuitive and efficient human-robot interfaces should enable operation at any level of astronaut involvement, from deep immersion to full task delegation with minimal crew supervision. Applicable use cases are setting up experiments, station housekeeping, unloading new cargo arrival, serving as crew companion autonomously, and as avatar of ground crew and loved ones on Earth. Identifying and developing the most suitable modes and methods, as well as the necessary infrastructure, to assist astronauts with robots therefore are thus the key challenges of current space robotics.

### **Scope:**

- Modular designs
  - Provide easy scalability for fast upgradability/short design cycle toward different configurations, from simple or high functionality.
- Robot dexterity in microgravity intra-vehicular environments
  - Modular force-sensing actuated joints for space deployment;
  - Object handling for diverse on-station tasks;
  - Integrating propulsion and actuation functionalities for holistic approaches to trajectory and path planning together with object handling.
- Different robot command modalities
  - Autonomous robotic assistant with ground-supported and local AI;
  - Avatar (tele)robot to be operated from ground or by the crew with (but not limited to): haptic telepresence, shared control or supervised autonomy, task level command.

### **Expected outcome:**

- Increase the effective usage of space stations by robotic assistance;
- Improve astronauts comfort by carrying out background tasks for them;
- Reducing the overall costs by extending the usability of the station during un-crewed period;
- Demonstrate Europe's world leadership in dexterous space robotics;
- Give future space system a gateway to smoother, faster transition, from systems on ground to full Extra-Vehicular Activities (EVA).

**Year of the call:** 2025

**Type of Action:** Grant - Research and Innovation Action

## 5.7. Management and Coordination Activity for Future Space Ecosystem

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Future space ecosystem

**Specific Challenge:**

The main challenge to be addressed is to pave the way for enabling a sustainable, highly automated, flexible and economically viable space infrastructure, prepare to maximise commercial opportunities for European actors.

**Scope:**

Include activities to develop:

- Pathways to innovative and promising applications and services;
  - New Space approach
  - Advanced concepts and enabling technologies
  - Synergies
- Pathway for quick maturation and space qualification;
- Follow the projects related to the Future Space Ecosystem;
- Support to decisions (programmatic and strategy questions);
- Support to European Commission in the international dialogue;
- Support of European stakeholders.

**Expected outcome:**

- Future Space Ecosystem roadmap focusing on in-space services;
- Guidelines and standards;
- A suitable and sustainable framework.

**Year of the call:** 2025

**Type of Action:** Grant - Coordination and Support Action

## 6. Space Science & Exploration

### 6.1. Innovative scientific instruments, exploration concepts and enabling technologies

**Based on a roadmap:** Yes

**SRIA corresponding technology-based activity lines:** Contribution to space science

**Specific Challenge:**

Planetary exploration is experiencing a relevant time in which different approaches coexist: roadmaps for human exploration, large robotic missions to different bodies (e.g., Mars Sample Return), renewed interest for descent probes (e.g. for Uranus) or new concepts (e.g., aerial mobility, Dragonfly). Both robotic (specially in-situ) and human exploration require advanced scientific instruments not only with high performances, but also low power-demanding, miniature, or autonomous. Besides, innovative concepts and enabling technologies for exploring harsh environments or providing affordable, frequent access to selected destinations (Mars, Moon), as well as for giving answer to the numerous challenges of human exploration, must be targeted.

**Scope:**

The purpose is to boost the maturation of enabling technologies for the development of relevant scientific instruments that could provide breakthrough science in future missions. Building these instruments requires technology development efforts in advance to any potential mission scenario or, in other words, with a non-specific-mission approach. Nonetheless, the identification of scientific knowledge gaps the proposed technologies would fulfil, and/or future missions on which those instruments could be boarded is encouraged (especially if already foreseen in the main Agencies and international coordination groups' roadmaps).

Miniaturization, low power consumption and autonomy are particularly desirable aspects, as they facilitate the accommodation of scientific instruments in all kinds of platforms (from orbiters to rovers or small probes), while provide a natural synergy with the CubeSat market and New Space, which may increase their potential applications given their increasing role also in Space exploration.

At the same time, the moment for a new approach to in-situ planetary exploration has arrived. Being in the Mars Sample Return decade and with the reactivation of the ExoMars mission, the main efforts of NASA and ESA on the Martian arena will be devoted to those missions in the short and midterms. This entails a risk for a continuous robotic presence on the Red Planet.

Innovative concepts for reaching the Martian surface at low cost are needed to fill the gap. In a similar manner, missions to Ice Giants or Venus provide the best scientific return if they include descent probes capable of surviving extreme environmental conditions applicable to each case (temperatures, pressure, radiation, etc.). Exploration of Icy Worlds may require innovative means for reaching the subsurface, whereas mobility in different planets and moons can be achieved through aerial platforms. In summary, many innovative concepts are possible, such as penetrators, impactors, balloons and other aerial platforms, melting probes, etc. Also, collaborative, multi-probe or swarm concepts should be explored.

But not only robotic presence is of concern at this moment, when both NASA and ESA are targeting crewed missions to Mars and the Moon in the coming decades. ISRU technologies, innovative dust mitigation techniques and radiation shielding strategies should also be explored to alleviate the inherent risks of human missions. Further, the development of astronaut deployed or operated payloads is moving into focus.

Finally, key technologies that could enable the space exploration scientific missions should also be targeted. This may include (but is not limited to): extreme temperature electronics, optoelectronics, mechanisms; non-cooled IR-sensors; laser technology (for different applications: from LIDARs/altimeters to remote RAMAN or LIBS and others); compact Instrument Control Units and embedded software/processing capabilities for autonomous science; advanced EDL concepts (inflatable/deployable TPS, braking devices, etc.); high-pressure technologies to enable scientific sensors; sensing/processing technologies capable of withstanding high-g loads; innovative or advanced transducers/sensing principles; advanced optics for miniaturization, tuneable optical/IR filters, etc.

**Expected Outcome:**

- Maturation of enabling technologies for the development of both relevant scientific instruments and innovative mission concepts for space exploration;
- Development of scientific instruments for Space exploration, and especially miniature instruments for in-situ planetary exploration (landed assets, descent probes, aerial platforms, etc.);
- Definition/assessment/validation/prototyping of selected elements of innovative and/or low-cost robotic planetary exploration mission concepts;
- Increased collaboration of scientific, engineering and industrial teams both within and outside Europe across different domains;
- To strengthen European scientific excellence and support the development of leading edge scientific and technological research in Europe.

**Year of the call:** 2025.

**Type of Action:** Grant - Research and Innovation Action