Guidance Document for the EU ISOS Pilot Mission

IN-SPACE OPERATIONS & SERVICES 4 INFRASTRUCTURE

ISOS4I

ACT IN SPACE

HORIZON-CL4-SPACE-2025

Version 1.0

Disclaimer

This is the full version of the guidance document as the technical annex to the upcoming calls for Horizon Europe (Cluster 4 Work Programme 2025). The purpose of this release is to publicly communicate on the EU's ambitious goals on ISOS, and more specifically on the concept of the ISOS Pilot Mission the EU is initiating. It provides technical and programmatic orientations to the community with a view to inform and facilitate collaboration among stakeholders, agencies and institutions.

It includes the mission boundary conditions with provisions for coordination, project management and project implementation, and a section with high-level requirements for the pilot mission that will be applicable for the call and awarded projects.

The document was prepared and endorsed by the European Commission in close cooperation with the Pilot Mission Advisory Group (PMAG) in April 2025. The PMAG is composed of public authorities and agencies from interested Member States and EEA countries[1] *and is chaired by the European Commission.*

It is planned to establish a European Commission Expert Group on ISOS and the Pilot Mission by summer 2025. Once established, this expert group will take over all functions of the PMAG; in this event all references to the PMAG will refer to that expert group.

This guidance document for the ISOS Pilot Mission may evolve in the future in close coordination with the expert group, also considering inputs from the selected grants and EU/EEA stakeholders.

[1] AT, DE, ES, FI, FR, ES, IE, IT, LT, LU, NL, NO, PL, PT, SE, SK

HISTORY OF CHANGES		
Version	Publication date	Changes
Pre-release	19.03.2025	• Pre-release version (without high-level requirements)
1.0	30.04.2025	• Full version with high-level requirements • Addition of repair services as an example under section 4.5 • Clarification with regards to prevention of an arms race in outer space under section 4.5 • Addition of refuelling/recharging use-case to the baseline demonstration and clarification on definition of cooperative client in section 4.6 • Addition of 'AC' under section 4.7.2.3 • Addition of a dedicated point on satAPPs component grants in section 4.8

1 Introduction

1.1 Scope and applicability of the document

This document provides guidance to applicants by providing detailed information on the **objectives**, the **boundary conditions**, and **high-level requirements** of the envisaged In-Space Operations and Services (ISOS) pilot mission. The document also contains the **mission statement** and **perspectives for ISOS** as a new strategic priority for the European Commission. With that this guidance document complements and details the work programme topic descriptions.

The guidance document is **applicable to** the following call topics[2]:

- Horizon Europe Cluster 4 Work programme 2025
    - Call topics HORIZON-CL4-2025-02-SPACE-21/-22/-23/-24
    - ISOS Pilot Mission Coordination and Support Action

Furthermore, it is meant to serve as a **reference document for other EU programmes and calls relevant to ISOS** (e.g., Horizon Europe EIC Work Programme 2025 - Accelerator Challenge Space: Innovative in-space servicing, operations, robotics and technologies for resilient EU space infrastructure; the European Defence Fund), in order to explore synergies and steer interoperability and future interfacing and plug-in opportunities.

1.2 The ISOS Pilot Mission as seed for a future service infrastructure in space

'**Act in Space**', i.e. being able to conduct operations and services in space related to servicing, assembly, manufacturing, removal and logistics with a high degree of system autonomy, is a **key future strategic capacity for the EU** as a space power. Due to its dual-use potential by nature, In-Space Operations and Services (ISOS) are of strategic importance to **ensure EU's freedom of action in space** and increase the **sustainability, competitiveness, resilience and safety** of space and EU's **space infrastructure**, and **generate new markets** for an in-space economy. Moreover, it is essential to **reduce technological dependencies** in an area where the pace of innovation and technological maturation remains essential**.** As global competition intensifies, it is necessary to **maintain Europe's capabilities** on par with competitors.

Dedicated R&I actions related to In-Space Operations and Services and linked enabling and critical technologies were conducted in H2020 and Horizon Europe and as well as in other programmes making use of EU funding (e.g., Recovery & Resilience Facility) are still ongoing. Several activities are also ongoing at national level and within ESA programmes.

The **ISOS pilot mission will demonstrate an adaptive and scalable concept comprising in the beginning four mission components**, i.e. **Servicing**, **HOST**, **Logistic** and **satAPPs** (Figure 1), starting with technology and first service demonstration. With this seed point, the European Commission will enable beyond technological and service demonstrations, also operational demonstrations and will boost the **generation**

[2] The document will also apply to potential future ISOS-related topics in Horizon Europe.

of business and innovative applications in space, leading to services **addressing commercial and governmental use-cases** and the EU policy priorities provided before.

Moreover, the envisaged concept allows a **simplified plug-in of other developed technology, applications or services** funded through EU, national and ESA programmes. **Co-funding by private organisations** can be considered as a contribution in-kind, proving that risk is shared with the private sector and demonstrating the added value of the industrial proposals. Also, without prejudice to the scope of the ISOS pilot mission, the **plug-in of commercial services** offered by private entities is possible, to accelerate the growth of available services and capabilities for Europe in space, respectively.

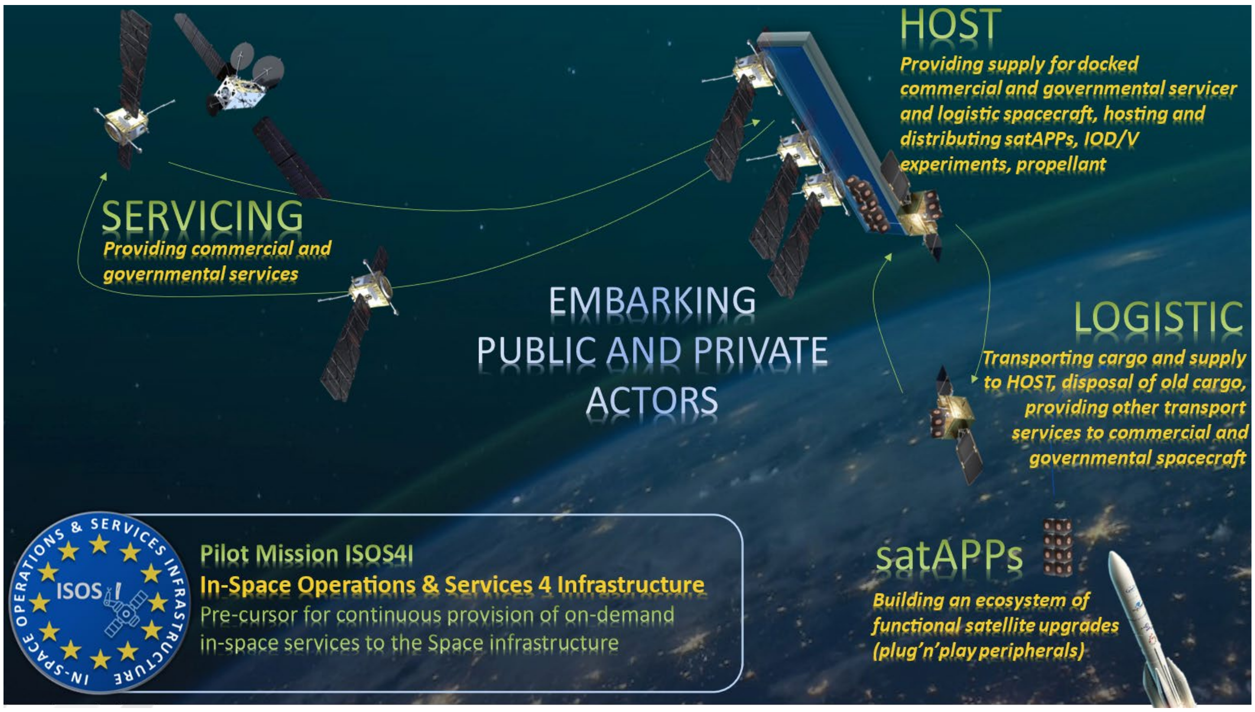

FIGURE 1 ISOS4I CONCEPT

With its pioneering and strategic orientation, the ISOS pilot mission will create **visibility**, **federate the ISOS ecosystem** by stimulating interoperability and generating **demands to industry** and **providing openness for embarking private and public actors, offering services in space.**

Moreover, the pilot mission will intrinsically mature and demonstrate technologies highly relevant for **science and exploration** activities (e.g., robotics, autonomy, assembly and manufacturing), and could with its logistic and HOST component also serve as a bridge (e.g., warehouse/logistic node) to initiatives beyond Earth orbits, although this is not a design driver.

The pilot mission will focus exclusively on civilian use-cases **but synergies with other sectors should be explored**, both in terms of technologies and future services, bearing in mind the dual use of ISOS. This could enable the acceleration of the development and implementation of the pilot mission while avoiding unnecessary duplication. This is of particular interest with regards to applications requiring higher system autonomy e.g., robotic servicing, enhanced space-based surveillance, assembly of large structures in space.

The unique mission concept allows public and private actors to step in and expand the range of capabilities provided by the ISOS ecosystem. It promotes interoperability between mission components, thereby creating added value through the sharing of capacities between the different elements of the ISOS infrastructure. This offers enormous opportunities also for Start-ups as well as for established companies working in the ISOS domain, which is a core area in the NewSpace arena. That will be also supported through the Digital EU Space Ecosystem[3].

The above-mentioned ambition is codified by the boundary conditions and high-level requirements of the ISOS pilot mission provided in this document.

1.3 Towards a new in-space economy – beyond the ISOS pilot mission

The pilot mission will introduce a **more sustainable infrastructure and operations**, and – as a **pre-cursor element** deployed by 2030 – pave the way to **a future adaptive service infrastructure fully integrated in the Space ecosystem of space-based services.** Therefore, the mission components are intended to stay operational in space beyond the pilot mission demonstration phase. The future service infrastructure (Figure 2) can provide **on-demand commercial and governmental services** to European (and international) space infrastructure, including the EU flagships. **It is important to note that the future adaptive service infrastructure will not be part of the ISOS pilot mission.**

The paradigm shift towards adaptive space systems builds on automation and robotics, AI and modular and reconfigurable spacecraft infrastructure with space assets prepared for in-space operations and services. An indispensable building block to enable this kind of activities is the ability to relocate supplies, propellants and other types of consumables also in significant quantities, autonomously, between different points and assets in space. Together with other enabling technologies such as electric propulsion, they will change how space assets are designed, produced, tested, transported, and operated. Different means realised with AppStore-like principles will benefit the future space ecosystem and foster a circular economy.

Autonomous, robotic, real-time and onboard decision-making ISOS technologies illustrate their potential use for both governmental and commercial purposes. ISOS, leveraging in-space servicing, assembly, manufacturing, and logistics technologies will foster the sustainability, flexibility, reliability, safety, security of space missions. **ISOS is bridge building and an essential step towards a new in-space economy with economical viable services. Such a new in-space economy will be boosted with orbital ISOS services, but it can also expand beyond Earth orbits (e.g., the Moon and beyond)**.

Appropriate regulation and standardisation are crucial for the growth of global ISOS. While first guidelines and standards are already emerging, further efforts will be necessary to consolidate them towards meaningful standards required for a thriving in-space economy. A comprehensive regulatory framework that provides the foundation for a new ecosystem, stimulating market growth and fostering cooperation between market players is considered necessary.

At the same time, actions are initiated towards preparing future assets for services to raise demands and stimulate market generation, providing technological and financial benefits. In-space maintainable assets

[3] https://digital-space-ecosystem.eu

will give a huge boost to the sustainability and resilience of the space infrastructure and operations in space. This paves the way towards a more competitive and sustainable in-space ecosystem.

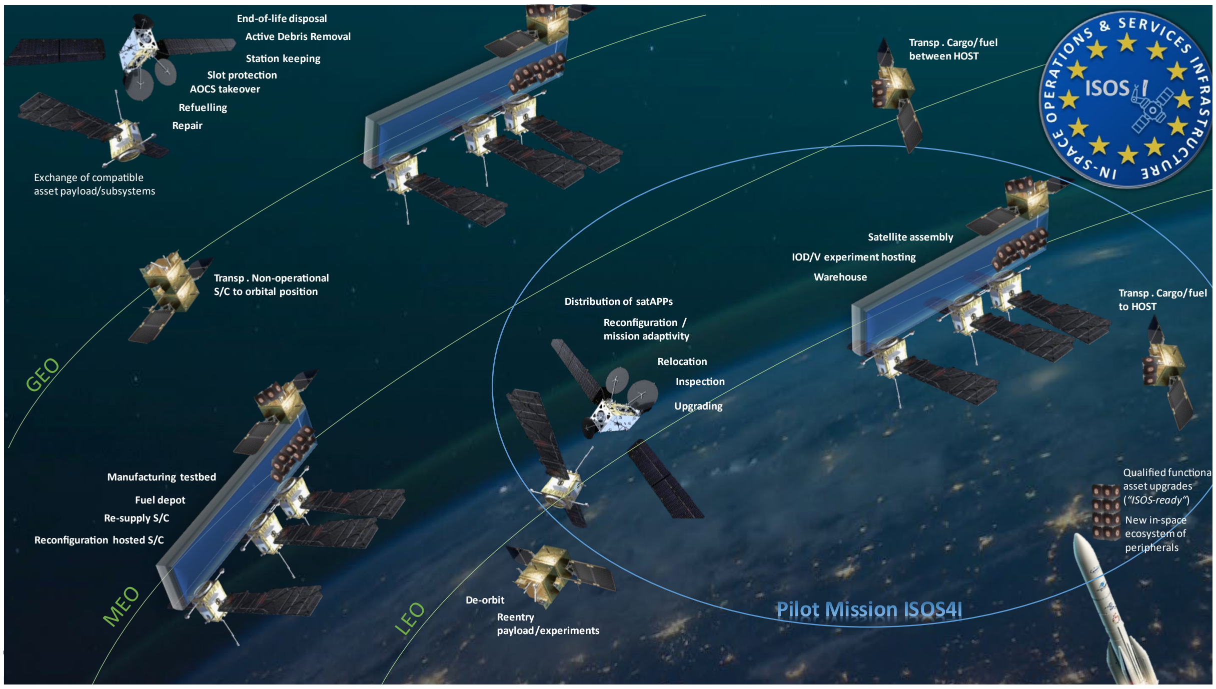

FIGURE 2 FUTURE ISOS SERVICE INFRASTRUCTURE IN THE EARTH ORBITS

2 Mission Statement

To be prepared for sustainable and competitive activities in space, the EU strives to **attain the strategic capacity to ‘Act in Space’**, i.e. being able to implement and perform operations and services in space related to **servicing, assembly, manufacturing, removal and logistics** through a service infrastructure with a high degree of system autonomy. ***In-Space Operations and Services*** **(ISOS)** increase the **sustainability**, **safety** and **competitiveness of space infrastructure** as well as enhance the **resilience of assets.**

To achieve this strategic capacity, the EU introduces a **pilot mission** which shall demonstrate in space the necessary **seed components, technologies, services and operations for a future adaptive service infrastructure** to provide **on-demand** maintenance, upgrade, removal and logistic services in space available to the European in-space ecosystem, driving the generation of a **new in-space economy,** enhancing **in-orbit demonstration and validation capabilities through such infrastructures,** and maximising the use/exploitation of space technologies that respond to EU technology sovereignty and EU technology non-dependence.

The pilot mission is to be **designed, developed and executed as a precursor action for governmental and commercial use-cases**, consisting of **mission components** that can be used beyond the mission lifetime, paving the way for the development of a **new strategic paradigm** within the next decade for the benefits of the EU, its Member States and other partners. Safety and reliability, as well as interoperability and scalability through modular design concepts are key for achieving this.

The mission demonstrations will be planned to be achieved by 2030, exploiting previous R&I efforts and showcasing know-how and competences developed through EU, Member States and ESA funding with a **pioneering and novel operational mission concept featuring robotic and digital solutions**, that is offering manifold opportunities for cooperation and that is unique worldwide. The mission shall focus on **application and service demonstration** considering relevant technologies and operations, enabling **governmental and commercial usage**.

3 Mission objectives

High-level objective

To **introduce the 'Act in Space' strategic capacity for the EU** by deploying and demonstrating seed components for a sustainable, modular and competitive *in-space operations and services infrastructure* that is designed to provide a wide spectrum of services to governmental and commercial users and assets, including the EU Space infrastructure.

Specific objectives

- To design, manufacture, launch, and operate on-orbit the following **mission components**:
  - **Servicing:** able to provide autonomous services (including robotic) to client spacecraft
  - **HOST:** able to host and provide supply for docked servicer and logistic spacecraft, stockpiling and assembly of satAPPs, hosting IOD/IOV experiments
  - **Logistic:** able to transport cargo, fuel and supply to the HOST, including the satAPPs
  - **satAPPs:** building an ecosystem of functional and composable plug'n'play modules for satellite upgrades, payload exchange and IOD/IOV experiments
- To demonstrate as a minimum the following **ISOS use-cases**:
  - Life extension, End-of-Life disposal, cargo/fuel transport, inspection, IOD/IOV experiment hosting, satellite relocation, payload exchange, upgrade and reconfiguration, on-orbit assembly, introduction of a new ecosystem of plug'n'play peripherals (satAPPs).
- To conduct specific operations that include interactions among the components, demonstrating a significant increase in **sustainability, safety and resilience** of space infrastructure;
- To demonstrate in **operational scenarios** the robustness of advanced **digital, robotic and autonomous** operations, as well as the modular (plug & play) philosophy increasing the **competitiveness** and driving the generation of a **new in-space economy**;
- To foster **scalability and interoperability** by designing and implementing the above-mentioned components as **precursor elements** that can be used and complemented with additional capabilities for further governmental and commercial use-cases beyond the pilot mission;
- To contribute to **EU technology sovereignty** by integrating, maturing and demonstrating technologies from the EU/EEA supply chain, and offering **enhanced IOD/V opportunities** making use of the HOST component, expanding the EU IOD/V capabilities.

4 Boundary Conditions

The boundary conditions represent general mission and system constraints that are policy driven and of highest importance for the mission and system development, deployment and operation. Therefore, they must be considered and implemented in the projects.

4.1 Mission title

The preliminary title, acronym and logo of the ISOS pilot mission is pre-defined and given as follows:

Mission title	In-Space Operations and Services 4 Infrastructure
Mission acronym	ISOS4I
Mission logo	

4.2 Mission architecture

The mission architecture described in this part introduces the **generic functions of the components** comprising the pilot mission ISOS4I. It must be noted that **the architecture is not limited to the mission baseline demonstration** (section 4.6), and objectives respectively, but is open to other use-cases.

ISOS4I will be composed of the following **4 mission components**, that **comprise the space segment** of the mission architecture for specific purposes:

- **Servicing component (SC)**: This component will deliver different services in space to governmental, institutional or commercial satellites, addressing specific use-cases, ranging from inspection to relocation, robotic manipulation and refuelling of client spacecraft. It may consist of different types of commercial or governmental servicer spacecraft addressing additional use-cases.
- **HOST component (HC)**: The HOST "*Hub for Operational Services and Testing*" will provide supply for docked servicer and logistic spacecraft, host IOD/V experiments (enhancing the European Commission's IOD/V initiative) and a robotic testbed for on-orbit assembly/manufacturing. The HOST will be designed as a scalable, modular, flexible platform component, equipped with robotic manipulation capabilities, and satAPPs-compatible slots and refuelling capability (for the HOST and docked servicer/logistic spacecraft). After the pilot mission, the HC capabilities could be extended and reconfigured to meet different demands (e.g., governmental and commercial SC/LC docking slots, IOD/V segment, specific robotic/manufacturing testbeds, warehouse/stockpile, etc.).

- **Logistic component (LC):** This component will provide transport services in space of cargo, i.e. satAPPs, fuel and other consumables. It will bring supply taken over from launcher to the HC. While for the pilot mission one single logistics spacecraft is foreseen, the ISOS LC may consist of different types of logistic spacecraft addressing additional use-cases such as last-mile delivery services or logistic services beyond Earth orbits or return to earth of cargo/experiments and disposal services.
- **satAPPs component (AC):** This component will create an ecosystem of composable and exchangeable functional satellites modules that can bring additional functionality to satellite platforms (based on the plug'n'play principle), host experiments for IOD/V or fuel for life extension. A satAPP is a composable and exchangeable functional satellite module that can be connected to other satAPPs or a spacecraft prepared with a specific USB-like interface (Universal Service Interfaces - USI).

The mission architecture of ISOS4I is given in Figure 3. It consists of a space segment, a ground segment, and a launch segment. Illustrations of the above-mentioned mission components is given in Figure 5.

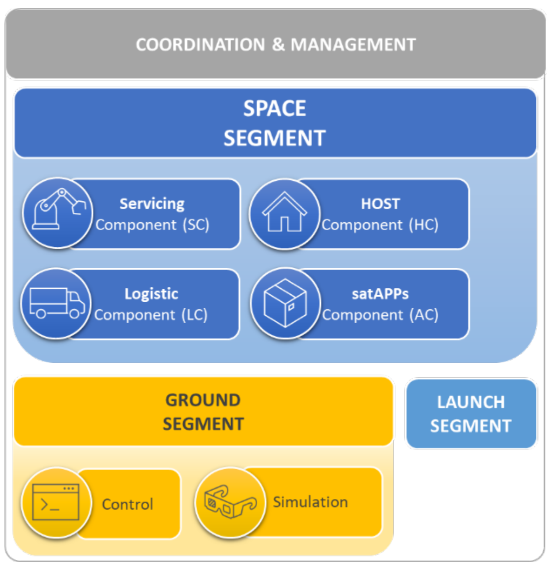

FIGURE 3 ISOS4I MISSION ARCHITECTURE INCLUDING MISSION COMPONENTS

The **mission coordination and management** aspects are reflected in the tasks of the ISOS Pilot Mission Coordination and Support Action (CSA), that will drive the coordination between the mission components aiming at -among others- ensuring the interoperability between them (in close coordination with the PMAG) and at preparing the deployment plan and operational sequences of the overall pilot mission.

The **ground segment** covers all the mission operations as well as simulators supporting both, development and mission operations.

Each of the projects implementing the four components of the space segment should identify and consider specific needs for ground segment and launch segment. These needs will be consolidated by the CSA and should be considered and managed in an integrated manner in the design, with well identified tasks in the components grants and the CSA.

4.3 Mission schedule

The target for the **full demonstration mission deployment is 2030**. A deployment plan will be prepared by the CSA taking into account the readiness of the different mission components.

The implementation will start with Horizon Europe funding, specifically through the Cluster 4, Destination 5 Work Programme 2025. Other Horizon Europe instruments (e.g., EIC) may contribute to the mission with components or dedicated developments as well.

The Work Programme includes topics for the development of the four components up to detailed design, with all technologies demonstrated at TRL6.

The Commission, in close cooperation with the PMAG and taking into account recommendations from the CSA will define the next steps and scheduling for the further maturation of the components as well as mission integration, deployment and operations, without pre-empting the decisions for the next MFF.

Precursor activities testing and demonstrating in space elements/technologies and functions of the above scenario with test/demonstrative assets or in non-critical orbits (e.g., graveyard orbits) are encouraged because they are considered useful to validate technologies and concepts and enable useful real data collection that can be used for finetuning, considering that. in some cases, some legal frameworks already require such preliminary tests/IODs. They may be realized with co-financing from other sources (private or public) as an added value and they should be considered in the mission schedule, however they shall not jeopardise the overall mission objectives and schedule, nor shall they preempt decisions related to interoperability aspects of the pilot mission.

The ISOS4I mission shall have the priority in using mission components for the baseline demonstration (section 4.6), should they have additional operational tasks, either commercial or governmental. In other words, **ISOS4I is to be treated as main customer**. This means that: i) the ISOS4I pilot mission has priority over other missions using the components; ii) the design of the components shall primarily satisfy all the high-level requirements of the pilot mission to conduct the baseline demonstration; ii) additional use of the components must not create delays or jeopardise the pilot mission with its deployment and demonstration plans or increase costs/time, rather be beneficial for a future service deployment. Any contract related to the use of the mission components before the ISOS4I mission completion and outside the scope of the ISOS4I mission, shall acknowledge the above elements, shall not contain contradictory clauses and shall be agreed with the European Commission and in coordination with the PMAG. Such elements will be reflected in the contractual arrangements for the ISOS4I implementation next phases (i.e., beyond Detailed Design).

4.4 Additional contributions and Intellectual Property

Additional public or private contributions to the pilot mission are possible and welcome in principle to ensure timely and smooth implementation and execution of the pilot mission. Contributions could be done in different ways such as direct co-funding, in-kind contributions or system/technology plug-ins to the mission (e.g., funded through other programmes).

In all cases, the following important aspects must be considered:

- For the completion of the detailed design phase and relevant to the evaluation, grant preparation and management of the component grants, any additional contribution (private or public) shall be reflected in the relevant proposals and grant agreements (e.g. work packages, tasks, milestones, deliverables, risk management) and as such be governed by the applicable rights and obligations (Horizon Europe legal base, Article 9.2 of the Horizon Europe Model Grant Agreement, "Third parties giving in-kind contributions to the action"). As a general point, it must be ensured in all mission phases, that all contributors are able to meet the necessary timelines for delivery of their contributions in order not to jeopardise the mission implementation.

- Potential additional co-funding or in-kind contributions by Member States/EEA countries should not be perceived as a means to influence the selection of proposals for mission components, the prioritisation of mission scenarios and the IP ownership scheme. All such aspects (including any potential background IP contributed in-kind to the proposals) will be objectively evaluated with the applicable instruments (starting from Horizon Europe evaluation procedures and legal base).
- Any additional contribution should not pre-empt later usages and exploitation of the designed components (i.e., after the completion of the ISOS4I pilot mission), and should be in line with the provisions of this guidance document.
- Contributions, especially in-kind contributions or system/technology plug-ins must be compatible with the described mission architecture and concept (and their evolution). Dedicated tests shall ensure that all contributions meet mission-specific requirements.

For the finalization of the detailed design phase of the mission implemented through Horizon Europe grants, the provisions in Article 16 of the Horizon Europe Model Grant Agreement shall apply (relevant to protection, exploitation, transfer and licensing, access rights to results and background).

Intellectual Property (IP) rights and ownership must be clearly defined in terms of fully delivering the detailed design of the components as well as ensuring the availability of results to the next mission phases (for instance through cost-free IP licensing or transfer arrangements). Contractual arrangements beyond the detailed design phase will contain applicable IPR clauses for the mission implementation up to completion and if applicable for a possible later transition towards a larger service infrastructure in space.

The CSA must have the necessary and sufficient visibility of the IP landscape and of any co-funding and in-kind contributions applicable to the mission components, and consider them in the System Risk Management plan, Pilot Mission minimum cost estimate and cost impact assessment as well as the mission deployment plan.

4.5 Main mission and system design driver

The ISOS4I pilot mission is an EU-driven mission contributing to various policy drivers (see below), designed to address governmental and commercial use-cases. The European Commission in close coordination with the Member States/EEA countries (through the PMAG) will ensure an efficient and coordinated approach with regards to alignment of activities at European level.

The main policy drivers of this mission are to boost:

- **Sustainability**: offering solutions for maintenance and repair services, e.g., for life extension and repair of defects
- **Competitiveness**: introducing a new in-space economy, on-boarding new commercial entrants and offering solutions for enhance operational flexibility and mission adaptivity to the assets, e.g., through plug'n'play upgrades and relocation or platform reconfiguration services

- **Resilience**: offering solutions for inspection, damage assessment, repair and maintenance, refuelling, upgrading and reconfiguration of assets
- **Safety**: enhancing the safety of space assets and critical infrastructure, e.g., through debris removal

The pilot mission should be envisaged, setup and implemented in such a way that allows:

- **Exploitation and further maturation of current European R&D achievements in the field of ISOS**
    - Building on ongoing and past R&I funded by EU, ESA or national programmes or through private investments with no IPR related or other restrictions or limitations regarding its application within the ISOS Pilot Mission.
- **Support of New Space and innovative actions and the offering of opportunities to multiple actors of the value chain**
    - Promoting inclusiveness and ecosystem creation
- **The EU acting as anchor customer**
    - Uptake of EU/EEA technology and services, ensuring sovereignty and non-dependence, as well as fostering of creation of new business opportunities and the evolution of the space infrastructure
- **High-visibility and high-impact at worldwide level through a unique and pioneering concept**
    - An EU-led pilot mission showcasing opportunities for commercial or governmental actors in the context of a new in-space economy.
    - Building bridges with European relevant initiatives while setting the state of the art for the future with a forward-looking concept enabled by digital and robotics capabilities
    - The demonstration shall allow building confidence on the feasibility of ISOS-based business-based ISOS and creating with high visibility material for the larger public and decision-makers
- **Strengthening EU strategic autonomy, direct contributions to the EUSSSD**[4]
    - fostering synergies between civil and governmental sectors
- **Consideration of service demonstration on institutional assets**
    - EU/EEA or other institutional or commercial assets, non-prepared for ISOS at the time of the demonstration (through dedicated interfaces) e.g., approaching the end of their lifetime, can be considered to be part of the baseline demonstration with the explicit agreement of the owner of the asset.[5]
- **Interoperability and expandability**
    - The mission should be conceived and implemented as a seed for further services and demonstrations beyond the baseline scenario demonstration, via mission plug-ins. Moreover, the infrastructure will serve as a seed for a possible future flagship for servicing EU and MS/EEA infrastructure.
    - A dedicated *Pilot Mission and Future Space Ecosystem Plug-in Specification* will be released at later stage so that commercial actors may have the possibility to plug-in new services to further evolve the ISOS ecosystem. This document will be elaborated by the

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[4] EU Space Strategy for Security and Defence - European Commission

[5] At this stage, it must be noted that an operation towards any asset in space is not allowed unless there is a dedicated agreement or request from the owner of the asset.

European Commission (in close cooperation with the PMAG) based on industry recommendations.

Considering the ambitious timeline, technologies and capabilities already available or in a development phase will be preferably considered and traded-off with respect their compliance to meet the objectives and requirements of the ISOS Pilot Mission.

Finally, the **mission should be compliant with applicable legal frameworks**, namely national space laws that may apply depending on the actors involved, and the forthcoming EU Space Act, as well as the UN Space Debris Mitigation Guidelines[6]. Additionally, the mission and all involved actors (governmental, institutional and private) should consider the prevention of an arms race in outer space (PAROS) in all its aspects, which is essential for strengthening international security and stability and for safeguarding the free exploration and long-term use of the space environment for peaceful purposes[7].

If not covered already by the applicable legal frameworks, measures for safety of operations should be considered, such as subscription to an SSA/Collision Avoidance service, TM/TC for supervision of operations and health monitoring, etc.

4.6 Baseline demonstration and use-cases

The following **baseline demonstration** -that is derived from the mission objectives and **composed of scenarios A and B**- will be **implemented in LEO**, allowing the demonstration of the indicated civil use-cases that can be available to private, public, institutional, and governmental actors:

A) A sequenced operation including all four components (after commissioning):

1) **A logistic operation** supplying the HOST platform with functional modules (satAPPs, incl. experiments), and fuel;
    - Demonstrating cargo/fuel transport
2) **A HOST-based manoeuvre** that displaces satAPPs across the platform and assembles a small functional asset based on satAPPs with robotic means, and refuels and recharges a docked servicer/logistic spacecraft;
    - Demonstrating satellite assembly, IOD/IOV experiment hosting (as satAPPs) and warehousing
    - Demonstrating refuelling and recharging
3) **A servicing operation** implementing satellite upgrade and maintenance using the satAPPs hosted on the platform;
    - Demonstrating upgrade, reconfiguration, mission adaptivity, distribution of satAPPs and introduction of a new ecosystem of plug'n'play peripherals

B) A servicing operation to a cooperative[8] client (non-prepared):

- Demonstrating rendezvous, inspection, berthing or docking, AOCS takeover and relocation or End-of-Life disposal.

[6] https://www.unoosa.org/res/oosadoc/data/documents/2010/stspace/stspace49_0_html/st_space_49E.pdf
[7] https://www.eeas.europa.eu/delegations/un-new-york/eu-statement-%E2%80%93-un-general-assembly-1st-committee-outer-space-0_en?s=63
[8] Not necessarily fully functional

Scenarios A and B can be carried out in parallel or in succession. The completion of both scenarios (A and B) corresponds to a successful mission demonstration, fulfilling all ISOS4I mission objectives.

This baseline demonstration will drive the definition of the high-level requirements for the mission and its components. However, it must be noted that the components may be designed with more capabilities than required to perform the baseline demonstration, as long as this does not significantly increase implementation costs and create a risk to the mission as a whole. This will allow the further use of the infrastructure according to additional use-cases in the future.

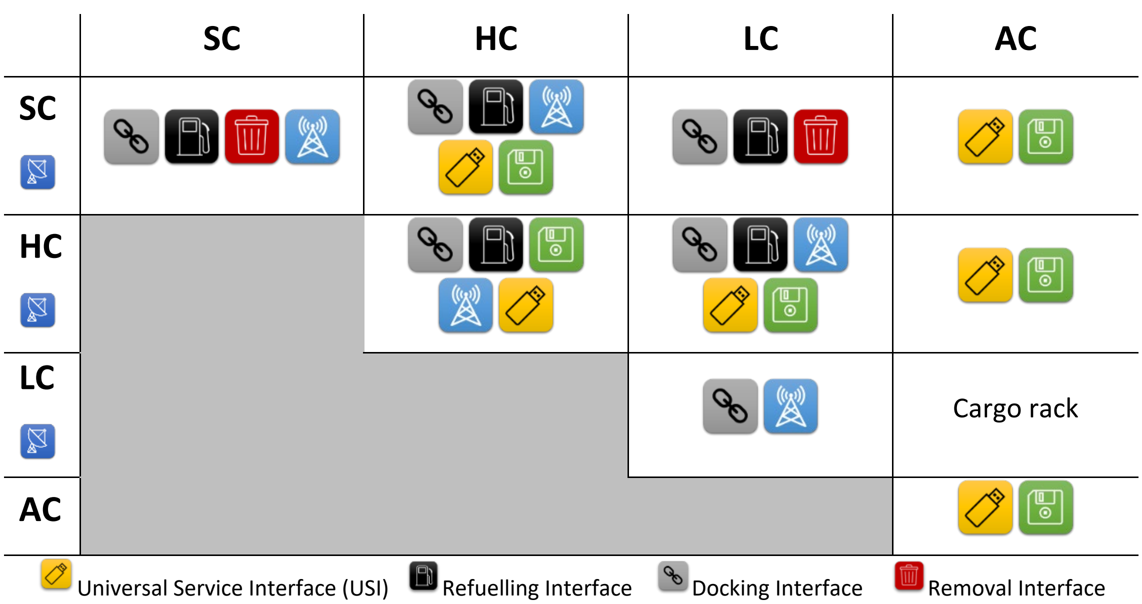
4.7 System interoperability and expandability

Interoperability between the mission components is an integrated and essential part of the pilot mission. Thereby, **interoperability and modularity shall be ensured by defining the interfaces, procedures, protocols and formats that are common across the mission components and future plug-ins**. Following these definitions, a rapid implementation and deployment is in principle possible (provided that developments are done efficiently), and an extension of the service infrastructure beyond the pilot mission can be easily achieved.

The **preliminary elements provided in the following subsections are to be considered as a starting point** for the elaboration on the interfaces, procedures, protocols and formats. **All mission components, and in particular the CSA are tasked to work on this elaboration in close cooperation with the PMAG.**

4.7.1 Interoperability matrix

The following **mission component interoperability matrix** provides a **preliminary baseline configuration** of interfaces, protocols and format types that the mission components should consider in their system designs and the CSA in the overall mission design:



Communication protocol compliance Software format compliance Ground Communication Link

This component interoperability matrix shall be further elaborated by the CSA. Applicable requirements for the mission components are provided at the high-level requirements, however this preliminary matrix should also be considered to derive the system designs.

4.7.2 Interoperability aspects

4.7.2.1 Spacecraft Service Interface

In principle, four types of **Spacecraft Service Interfaces (SSI)** for spacecraft can be distinguished:

- **Universal Service Interface (USI)** - an active element that allows a multifunctional connection - that combines three elements (mechanical, power and data connections: "USB-like") while allowing for the optional inclusion of thermal connection - between a spacecraft and functional elements or among functional elements;
- **Docking Interface** – an active element that allows a controlled, stable mechanical connection between spacecraft (e.g., servicer and client spacecraft);
- **Removal Interface** – a passive element that allows a stable connection between the servicer spacecraft and the client object for the purpose of object removal;
- **Refuelling Interface** - an active element that allows the transfer of propellant (i.e. fluid and/or gas) in space.

It is noted that similar interfaces combining some of the functions described above are also possible depending on their use-case (e.g., prepared/unprepared clients), as long as interoperability according to Interoperability matrix above is ensured.

Moreover, in specific cases, USIs can also be used as end-effector of a robotic manipulator as long as they fulfill the required functions of the ISOS Pilot Mission.

The following specifications should be considered in the elaboration on Spacecraft Service Interfaces (SSI) between all mission components and the CSA. The CSA will further elaborate and assemble the consolidated interface requirements in coordination with the PMAG:

- The docking and refuelling interface should be the same for SC, HC and LC.
- As a principle, the HC should allow the support of multiple EU-based USI solutions (such as SIROM, HOTDOCK, iSSI), provided that the chosen solution(s) are of sufficient maturity to reach TRL 6 at the end of the detailed design phase.
- The AC should support by design satAPPs series based either on multiple EU-based USI solutions (such as SIROM, HOTDOCK, iSSI) or a single USI solution in its baseline configuration provided that the chosen solution(s) are of sufficient maturity to reach TRL 6 at the end of the detailed design phase.

Figure 4 displays the principle of an SSI-driven system and value chain, in which satAPPs (and functions delivered through them respectively) can be transferred between the mission components using same USIs, and other mission components can interoperate through dedicated interfaces. The ISOS4I mission will give chances to multiple USIs to be considered. Therefore, the HC as central element of this chain must support multiple USI solutions. Later it is expected that commercial actors will decide on the most competitive solution(s).

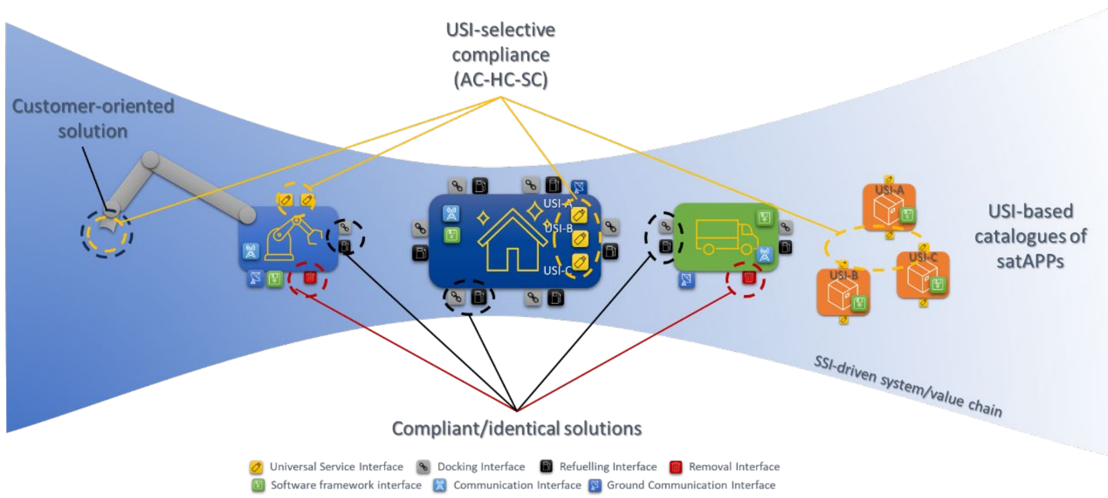
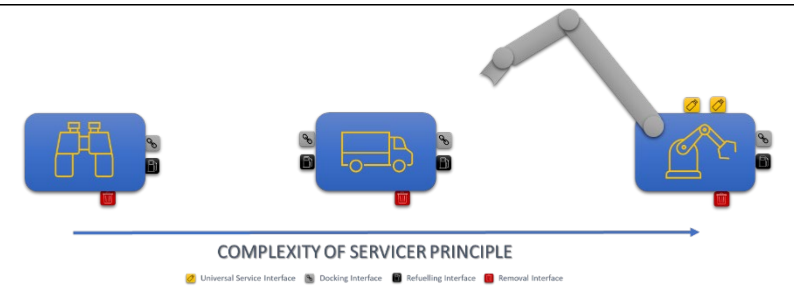


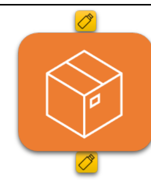
FIGURE 4 SSI-DRIVEN SYSTEM AND VALUE CHAIN

In Figure 5 illustrations of the four mission components are given including potential interface configurations.

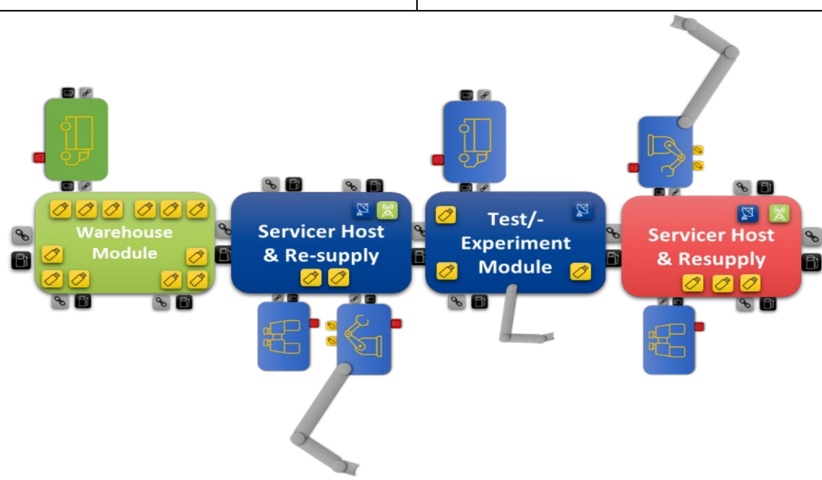


Different types of servicer spacecraft for the Servicing Component

Logistic spacecraft for the Logistic Component



satAPPs component



Example illustration of the HOST component (with docked servicer/logistic spacecraft)

FIGURE 5 EXAMPLE ILLUSTRATIONS FOR THE FOUR MISSION COMPONENTS OF THE PILOT MISSION

4.7.2.2 Software aspects

The following specifications shall be considered in the elaboration on the software compliance between all mission components in close coordination with the CSA and the PMAG. The CSA should further elaborate a full set of requirements related to software interoperability aspects and assemble the consolidated interface requirements. As a starting point the following requirements shall be considered:

- The software framework of the HC shall support data exchange between AC, SC, LC and the HC (wired and/or wireless).

- The software framework of the HC, SC shall allow the addition of new capabilities and capacities on-board through other HOST segments and satAPPs (plug'n'play principle).
- The software framework of the HOST component shall foresee sufficient on-board data processing capacity for IOD/V purposes.

4.7.2.3 Communication architecture (including ground segment)

The following specifications shall be considered in the elaboration on the communication architecture, and protocol compliance, respectively between all mission components in close coordination with the CSA. The CSA will further elaborate and assemble the consolidated interface requirements:

- The overall setup of the communication architecture (and protocols) shall allow a communication between the HC, SC, LC and AC.
- The HC, SC, and LC should have separate communication links to the ground segment.

4.8 Coordination, project management and project implementation aspects

This section highlights the different coordination mechanisms, management structures and project management requirements that should be put in place relevant to the PMAG, the CSA and the Grants implementing the four components ("Component grants").

The governance, relations and interdependencies among different actors and actions are displayed in Figure 6.

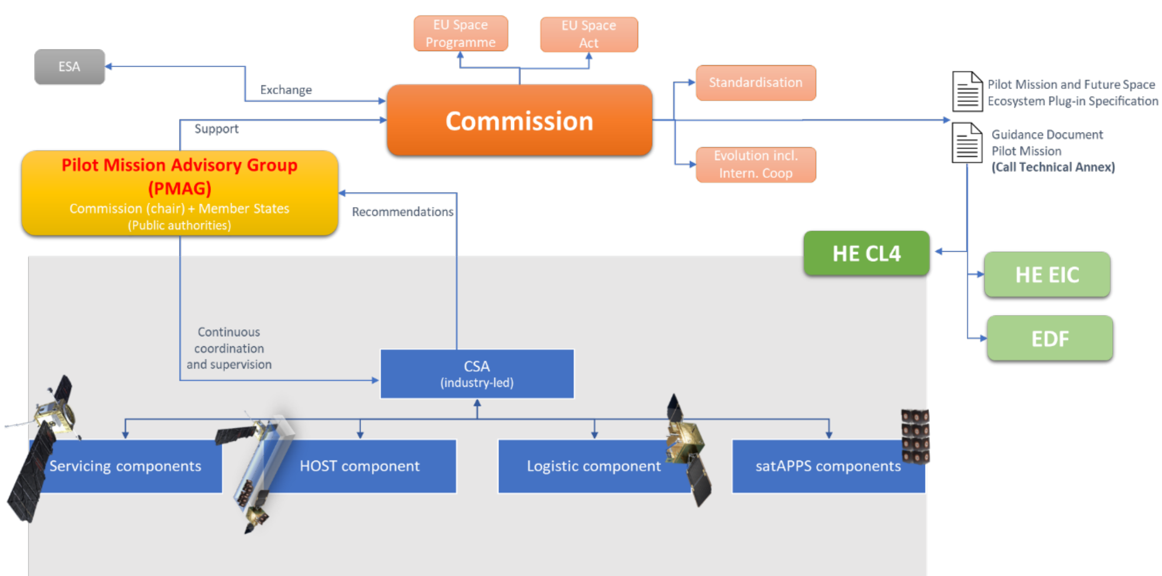


FIGURE 6 ISOS4I MISSION IMPLEMENTATION GOVERNANCE AND INTERCONNECTION SCHEME

The following considerations shall be taken into account by the proposals for the Component grants and the CSA and by the respective projects.

Actions Management

- The CSA grant will be managed by DG DEFIS and with continuous coordination and supervision provided by the PMAG. The grant will provide full access of the planned deliverables to the PMAG. DG DEFIS will provide for the necessary confidentiality arrangements.
- The CSA grant and Component grants will be Linked Actions as per Horizon Europe Model Grant Agreement. The collaboration among the linked actions will be formalised by a collaboration agreement that will be prepared by the CSA grant. The collaboration agreement will include collaboration provisions for:
    - access to documents and information sharing, including a clear identification of the necessary and sufficient Component grants documentation the CSA will need to access in order to be able to coordinate the Pilot Mission and components toward Detailed Design
    - key milestone review (e.g., System Requirements Review, Preliminary Design Review, Critical Design Review etc.) procedures for the components grants with regards to the CSA participation to the review boards
    - interoperability and definition of common interfaces;
    - standardization approach and activities;
    - dissemination and communication in terms of ensuring coherence and joint actions toward the Pilot Mission;
    - intellectual property arrangements and conflict resolution regime
- Beneficiaries of the Component and CSA grants will be invited to register and participate to the new ISOS hub of the Digital EU Space Ecosystem[3]

Key Milestone Reviews

- Component grants shall organize key milestone reviews, including at least System Requirements Review, Preliminary Design Review and Critical Design Review (achieving the completion of detailed design with all technologies at TRL6 and a ground demonstrator). The review board for each grant shall consist of internal experts from the consortium as well as external experts proposed by the consortium and in agreement with the Commission services. PMAG delegates may also be nominated as external experts contributing to the review process. Component grants should include in their workplan a presentation and feedback session with the PMAG before the completion of key milestone reviews.

Requirements

- Component grants shall elaborate a comprehensive list of Functional, Implementation and Demonstration and Operational requirements starting from and ensuring compliance to the Boundary Conditions and list of high-level requirements provided in this document (delivered at M3).

Key technology and service provider group

- The setup and operations of the Key technology and service provider group should be part of the CSA workplan. The group should be setup at M1 in order to allow the real-time centralised monitoring and coordination of the Mission and the Components grants. The group will have a fundamental role to allow the CSA to fulfil the tasks related to Interoperability and Standardisation.

CSA mandatory deliverables

The following documents should be included in the CSA workplan:

- Collaboration Agreement (delivered at M1)
- Detailed system architecture (delivered at M12)
- Mission Coordination Report (delivered every 6 months)
- Interoperability Requirements including component interoperability matrix consolidation (see section 4.7.1), starting from the preliminary requirements in section 4.7.2 (delivered at M6)
- Proposal for USIs consolidation, i.e., selection of a single USI European solution or approach allowing compatibility with multiple solutions (required for the HC) (delivered at M6)
- Proposal for a Pilot Mission and Future Space Ecosystem Plug-in Specification (delivered at M9)
- In-space services product tree – functional specification of the pilot mission system (delivered at M6)
- Professional video to visualise and promote the ISOS pilot mission (delivered by M3).
- Consolidated Ground and Launch segment needs (delivered at M12).
- Integrated CONOPS for the different ISOS pilot mission components according to the baseline demonstration scenarios (delivered yearly).
- Pilot Mission minimum cost estimate (incl. cost breakdown) delivered after completion of key review milestones of all Component grants (delivered after SRR, PDR and CDRs). The Commission has estimated that a budget in the order of 500 M€ should be necessary and sufficient for the mission, however this does not preclude that the CSA may arrive to a different cost estimation with the right justification, while taking into account that the cost envelope shall be minimized.
- CONOPS for three potential use-cases addressing the servicing of EU space assets, in the context of realising the baseline demonstration scenario B in section 4.6 (delivered at M6).
- Pilot Mission evolution plan towards a potential future flagship (delivered at M18)
- Proposal for the implementation, deployment, funding and system governance scheme for the ISOS pilot mission under the next MFF (delivered at M6);
- System Risk Management plan (delivered yearly)
- List of technology dependencies (non-EU) assembled from Component grants (delivered at M12)
- Mission Deployment plan including references to mission components and related interdependencies (delivered yearly)
- Proposal for an as much as possible integrated ground demonstrator bringing together the different mission components at the end of their detailed design phase (delivered at M9)

satAPPs Component Grants

- Each satAPP component grant shall design (and test) at least three satAPPs, with at least one being an IOD/IOV satAPP.

Intra-EU transfer of defence-related products

- If the implementation of the action requires the Intra-EU/EEA transfer of defence-related products[9] used or generated by the action, the beneficiaries remain fully responsible to plan and implement their action in a way that ensures the exercise of the rights by the granting authority/other EU bodies, in accordance with the Grant Agreement. This includes the possible transfer of defence-related products by the beneficiaries to other EU bodies for checks, reviews, audits and investigations. Considering the granting authority's obligations towards other EU institutions and bodies, the Commission may need to retransfer such defence-related products to them, notably in the framework of audits performed by the European Court of Auditors (ECA). In such a circumstance, the Commission would duly inform the relevant competent national authorities about the list of the concerned defence-related information prior to the transfer. Please note that the granting authority will not retransfer the defence-related products to any other third parties to the grant agreement, unless explicitly authorised in writing by the competent national authorities.

[9] listed in the Common Military List of the EU and in the Annex to Directive 2009/43/EC and falling under the export or transfer control of national authorities.

5 High-Level Requirements

The high-level requirements (HLR) represent requirements that must be fulfilled by the designed system for the ISOS4I mission. The below list comprises requirements that must be considered and **complemented by requirements stemming from the boundary conditions above** to further specify the mission and system design. A complete list of high-level requirements must be derived by each project in the beginning.

5.1 Servicing Component

This section contains **high-level requirements specifically for the servicing component (SC)** of the ISOS4I pilot mission.

5.1.1 Functional Requirements

ISOS4I-SC-100	**Minimum service provision functionality for cooperative, prepared and non-prepared clients**
Description	The designed SC shall be able to perform servicing operations to cooperative, prepared and non-prepared clients, by demonstrating at least: • inspection service, • AOCS takeover, and • relocation or End-of-Life disposal service, pursue a client upgrade/reconfiguration service with satAPPs (only for prepared clients).

ISOS4I-SC-101	**Distribution and deployment of satAPPs**
Description	The designed SC shall be able to transport satAPPs from the HC to client spacecraft and deploy them with robotic means.

ISOS4I-SC-102	**Client upgrade/reconfiguration service**
Description	The designed SC shall be able to transfer satAPPs from the SC to a prepared client spacecraft by robotic means, whereby satAPPs will be connected through USI.

ISOS4I-SC-103	**Rendezvous and close-proximity manoeuvres**
Description	The designed SC shall be able to perform safe rendezvous and close-proximity operations to the client spacecraft in all illumination conditions.

ISOS4I-SC-104	Inspection service
Description	The designed SC shall be able to perform inspection manoeuvres incl. fly-around of a target object, i.e. client spacecraft (or debris object at later stage).

ISOS4I-SC-105	Berthing or docking to the client spacecraft
Description	The designed SC shall be able to • grasp and berth the client spacecraft to the servicer spacecraft, or • dock to the client spacecraft, or • both, to establish a stable connecting between both spacecraft for further upgrade and maintenance tasks.

ISOS4I-SC-106	AOCS takeover service
Description	The designed SC shall be able to take over the AOCS for the client spacecraft through • its own on-board capabilities, or • through dedicated satAPPs installed to the client.

ISOS4I-SC-107	Relocation/end of-life disposal service
Description	The designed SC shall be able to relocate a cooperative client spacecraft • to another orbit, or • to perform an end-of-life disposal operation with this spacecraft.

ISOS4I-SC-108	Interoperability with ISOS4I components
Description	The SC shall consider by design the defined interface, protocol and software format compliance given in the above interoperability matrix (section 4.7.1), being able to, as a minimum • dock-undock with the HC, • be refuelled and recharged by the HC • communicate with the HC, • exchange data with the HC and/or AC either by TLC module or physical connection (e.g., through USI), • be removed from orbit by another SC through a removal interface.

ISOS4I-SC-109	Robotic capabilities
Description	The SC shall be able to perform robotic manipulation for the defined baseline demonstration and use-cases (section 4.6). The robotic capabilities shall be able to provide a rigid, robust and safe physical mating with target objects.

ISOS4I-SC-110	Robotic end-effector
Description	The robotic manipulator shall be equipped with a suitable end-effector able to securely grasp a client spacecraft launch adapter ring (LAR) and a removal interface on the client. Moreover, the end-effector shall be able to grasp, release, and connect satAPPs using a USI.

ISOS4I-SC-111	Health monitoring
Description	The SC shall be able to monitor its health status, with the required sensors capabilities to implement the safety of its mission and proper FDIR activities, especially during the critical phases of a service operation.

ISOS4I-SC-112	Communication links
Description	The SC shall consist of communication links to the HC and ground segment, as required, including for safety-critical operations. Moreover, the SC shall be able to securely communicate and receive with/from ground during all phases of the service operation, in compliance with applicable regulatory frameworks.

ISOS4I-SC-113	Mission safety
Description	The SC shall be compliant with applicable safety standards and regulations. Specifically, the SC shall be compliant with the Debris mitigation guidelines[6] and applicable regulations (i.e. national and EU Space Act -when in place-).

ISOS4I-SC-114	Monitoring of the service operation
Description	The SC shall be equipped with at least an additional monitoring camera for the purpose of • monitoring the service operation and • for public outreach.

5.1.2 Implementation Requirements

ISOS4I-SC-200	SC deployment
Description	Should the SC component be deployed prior to other mission components, it shall remain operational for the completion of the whole ISOS4I baseline demonstration.

ISOS4I-SC-201	Operational lifetime
Description	The operational lifetime of the SC resulting from the design has to comply with the overall mission deployment plan and shall be of at least 5 years to allow addressing further use-cases (beyond the pilot mission).

ISOS4I-SC-202	EU/EEA technologies
Description	EU and EEA technologies at component level shall be preferred. Any choice of non-EU/EEA technology shall be justified as long it is free of non-EU export restrictions (such as ITAR).

ISOS4I-SC-203	Development Approach
Description	The SC development approach shall perform in its development logic a verification, validation and ground demonstration of its performance and its services by exploiting a Hardware-Software simulation environment. The software framework shall include provisions for the associated software-in-the-loop and hardware-in-the-loop test infrastructures.

ISOS4I-SC-204	Docking and removal interface coherence across components
Description	The docking interface used in the SC shall be the same as for the HC and LC. The removal interface used for the SC shall be the same as for the LC. The interface harmonization across the mission components shall be driven by the CSA.

ISOS4I-SC-205	Software Framework
Description	The software framework of the SC shall allow the addition of new capabilities and capacities on-board, including through satAPPs (plug’n’play principle).

5.1.3 Demonstration and Operational Requirements

ISOS4I-SC-300	Validation of technologies and service operation
Description	The SC shall demonstrate each of its services in the full representative environment and validate on orbit technologies and service operations -that are used for the first time for ISOS- on a test/demonstrative asset prior a service provision to an operational asset.

ISOS4I-SC-301	Baseline demonstration for the SC (on orbit) as part of the sequenced operation (A)
Description	The SC shall perform the baseline demonstration scenario A.3 including the following main steps: 1. Undock from HC and RPO to a client spacecraft 2. Inspection manoeuvres of the client spacecraft 3. Grasping/berthing or docking to a client spacecraft 4. Upgrade of the client spacecraft with a satAPP 5. Client spacecraft to reconfigure (applying and demonstrating the new functionality provided through the satAPP) 6. Safe release of operational client spacecraft

ISOS4I-SC-302	Baseline demonstration for a servicing operation to a cooperative, non-prepared client (B)
Description	The SC shall perform the baseline demonstration scenario B including the following main steps: 1. RPO to a cooperative, non-prepared client spacecraft 2. Inspection manoeuvres of the client spacecraft 3. Grasping/berthing or docking to the client spacecraft 4. Demonstrate AOCS takeover for the client spacecraft 5. Relocate client spacecraft to another orbit or perform end-of-life disposal

ISOS4I-SC-303	Ground and Launch segment
Description	The SC shall identify its specific needs for ground and launch segment that shall be coordinated with the other ISOS4I components and consolidated with the CSA, in order to align the interlinked verification and validation activities and operations during the development, deployment and operational phase. Moreover, it shall aim at reducing the overall mission cost through more efficient use of ground segment resources and minimisation of launches by using European launchers.

ISOS4I-SC-304	Initial resources
Description	The SC shall have sufficient resources on board to perform the complete baseline demonstration without resupply from the HC.

ISOS4I-SC-305	Design of SC operations
Description	Servicing operations shall be designed aiming at minimizing impact on the client's operation (downtime) and the risk for incidents (e.g., damage of client and/or servicer spacecraft) by following applicable standards and regulations, as necessary.

5.2 HOST Component

This section contains **high-level requirements specifically for the HOST component (HC)** of the ISOS4I pilot mission.

5.2.1 Functional Requirements

ISOS4I-HC-100	Minimum service provision functionality
Description	The designed HC shall be able to provide the following basic functionality from the beginning at least: • Providing re-supply for SC and LC (i.e. fuel, power) through dedicated docking ports; • Hosting IOD/V experiments based on satAPPs (i.e. IOD/V satAPP modules); • Robotic testbed for on-orbit assembly; more specifically, on-board robotic management of the HC, and management of satAPPs, assembly/disassembly, incl. transfer to/from SC, and LC, • Extendibility of the HOST by additional HOST segments.

ISOS4I-HC-101	HOST Modular design
Description	The HC shall be based on a modular design, i.e. being extendable at later stage with additional HOST segments that can serve more specific needs (e.g., a dedicated warehouse segment, IOD/V segment, etc). The HC segments shall consider by design the defined interface, protocol and software format compliance given in the above interoperability matrix (section 4.7.1), allowing to • transfer fuel between the segments, • transfer data between the segments, • transfer power between the segments, • dock/undock the segments.

ISOS4I-HC-102	Number of docking ports for SC and LC
Description	Each HOST segment shall by design consider at least 2 docking ports for both, the servicer and logistic spacecraft. The baseline configuration of the HC shall foresee in total at least 4 docking ports for servicer and logistic spacecraft. Moreover, a HOST segment shall consist of 2 ports for additional HC segments.

ISOS4I-HC-103	Configuration of the spacecraft docking ports
Description	A spacecraft docking port shall allow • a stable mechanical connection (with a docking interface) between a spacecraft and the HOST, • transfer of fuel (refuelling) between HOST and docked spacecraft either with a dedicated refuelling interface or in combination with the docking interface, • transfer of data and power (recharging) between HOST and docked spacecraft, using a USI solution. HC docking ports for servicer/logistic spacecraft shall have the same design, and the docking interface used in the HC docking port shall be the same as for the SC and LC. The interface harmonization across the mission components shall be driven by the CSA.

ISOS4I-HC-104	Robotic capability on the HOST
Description	The HC shall be equipped with a robotic manipulation capability on-board to: • Manage HC embedded autonomous functionalities, such as SC and LC resupply/unload cargo, management of IOD/V experiments • Management of satAPPs, such as transfer satAPPs between the HC, and SC/LC, relocate, assemble/disassemble satAPPs on the HC Moreover, the robotic manipulator shall be compliant to interface with an USI, being able to grasp, release, transfer, and connect a satAPP as well as to adapt the end-effector, to be able to perform specific tasks for maintenance of spacecraft docked to the HC if needed.

ISOS4I-HC-105	Resupply of docked SC and LC
Description	The HC shall be able to refuel and recharge docked servicer/logistic spacecraft.

ISOS4I-HC-106	Safety manoeuvres
Description	The HC shall have propulsion capabilities to be able to prevent critical damages caused by space debris.

ISOS4I-HC-107	Number of satAPPs slots
Description	The HC shall foresee at least 9 slots for satAPPs, allowing the support of multiple EU-based USI solutions (such as SIROM, HOTDOCK, iSSI).

ISOS4I-HC-108	Interoperability with ISOS4I components
Description	The HC shall consider the defined interface, protocol and software format compliance given in the above interoperability matrix (section 4.7.1), being able to • let SC and LC dock • refuel and/or recharge docked spacecraft • communicate with the SC, LC, • exchange data with SC, LC and AC either by TLC module or physical connection (e.g., through USI) • be expanded by additional HC segments.

ISOS4I-HC-109	Health monitoring
Description	The HC shall be able to monitor its health status, with the required sensors capabilities to implement the safety of its mission and proper FDIR activities.

ISOS4I-HC-110	Communication links
Description	The HC shall consist of communication links to the ground segment, SC and LC, as required, including for safety-critical operations. Moreover, the HC shall be able to securely communicate and receive with/from ground during all phases of its service operations, in compliance with applicable regulatory frameworks.

ISOS4I-HC-111	Mission safety
Description	The HC shall be compliant with applicable safety standards and regulations. Specifically, the HC shall be compliant with the Debris mitigation guidelines[6] and applicable regulations (i.e. national and EU Space Act -when in place-).

ISOS4I-HC-112	On-board supervision capability
Description	The HC shall be equipped with monitoring cameras for the purpose of • monitoring the HOST operations, • inspecting the HOST (e.g., for damages) • providing video streams of major functional areas, e.g., warehouse, docking ports, experiment slots, and • for public outreach.

5.2.2 Implementation Requirements

ISOS4I-HC-200	Operational Lifetime
Description	The operational lifetime of the HC resulting from the design has to comply with the overall mission deployment plan and shall be of at least 10 years to allow addressing further use-cases (beyond the pilot mission).

ISOS4I-HC-201	EU/EEA technologies HC
Description	EU and EEA technologies at component level shall be preferred. Any choice of non-EU/EEA technology shall be justified as long it is free of non-EU export restrictions (such as ITAR).

ISOS4I-HC-202	HOST Component Development Approach
Description	The HC development approach shall perform in its development logic a verification, validation and ground demonstration of its performance and its services by exploiting an HW-SW simulation environment. The software framework shall include provisions for the associated software-in-the-loop and hardware-in-the-loop test infrastructures.

ISOS4I-HC-203	Supported USI
Description	The HC shall support the storage of satAPPs through plug'n'play principle based on multiple EU-based USI solutions (such as SIROM, HOTDOCK and iSSI).

ISOS4I-HC-204	Initial HC configuration
Description	The initial HC configuration (for the baseline demonstration) shall consider at least 2 segments.

ISOS4I-HC-205	Software Framework
Description	The software framework of the HC shall allow the addition of new capabilities and capacities on-board, including through satAPPs or other HOST segments (plug'n'play principle). The software/hardware framework of the HC shall foresee sufficient on-board data processing capacity for IOD/V purposes.

5.2.3 Demonstration and Operational Requirements

ISOS4I-HC-300	Baseline demonstration for the HC (on orbit) as part of the sequenced operation (A)
Description	The HC shall perform the baseline demonstration scenario A.2 including the following main steps: 1. Transfer of satAPPs from docked LC to HC stock area (warehousing) 2. Place a satAPP with an IOD/V experiment to a free slot on the HC 3. Relocate 3 satAPPs on the HC from the stock area (at the HC) and assemble them to a single unit (functional asset) 4. Demonstrate basic functionality of the assembled asset 5. Disassemble functional asset and relocate the satAPPs back to the stock area 6. Transfer of a satAPP to a docked servicer for the initiation of scenario A.3 7. Refuel and recharge a docked pilot mission component spacecraft

ISOS4I-HC-301	Ground and Launch segment
Description	The HC shall identify its specific needs for ground and launch segment that shall be coordinated with the other ISOS4I components and consolidated with the CSA, in order to align the interlinked verification and validation activities and operations during the development, deployment and operational phase. Moreover, it shall aim at reducing the overall mission cost through more efficient use of ground segment resources and minimisation of launches by using European launchers.

ISOS4I-HC-302	Initial resources
Description	The HC shall have sufficient resources on board to perform the complete baseline demonstration scenario without resupply from the LC.

ISOS4I-HC-303	Design of HC operations
Description	HC operations shall be designed aiming at minimizing the risk for incident (e.g., damage from/to satAPPs and/or docked spacecraft) by following applicable standards and regulations, as necessary.

5.3 Logistics Component

This section contains **high-level requirements specifically for the logistic component (LC)** of the ISOS4I pilot mission.

5.3.1 Functional Requirements

ISOS4I-LC-100	Minimum service provision functionality
Description	The designed LC shall provide end-to-end cargo transport and logistics, including delivery of satAPPs, fuel, and other cargo as potentially needed, ensuring seamless integration with the HC and SC in LEO.

ISOS4I-LC-101	Rendezvous and docking operations
Description	The designed LC shall be able to perform rendezvous and docking to the HC.

ISOS4I-LC-102	Transfer of fuel to the HC
Description	The LC shall provide fuel transfer to the HC, either by transferring special propellant modules from LC to HC (e.g., with support of HC'S robotic means) or by refuelling the HC directly through the docking port (ISOS4I-HC-103).

ISOS4I-LC-103	Interoperability with ISOS4I components
Description	The LC shall consider by design the defined interface, protocol and software format compliance given in the above interoperability matrix (section 4.7.1), being able to • dock-undock with the HC • transfer fuel to the HC • be refuelled and recharged by the HC • communicate with the HC • exchange data with the HC either by TLC module or physical connection (e.g., through USI).

ISOS4I-LC-104	Communication links
Description	The LC shall consist of communication links to the HC and ground segment as required, including for safety-critical operations. Moreover, the LC shall be able to securely communicate and receive with/from ground during all phases of its service operation, in compliance with applicable regulatory frameworks.

ISOS4I-LC-105	Mission Safety
Description	The LC shall be compliant with applicable safety standards and regulations. Specifically, the LC shall be compliant with the Debris mitigation guidelines[6] and applicable regulations (i.e. national and EU Space Act -when in place-).

ISOS4I-LC-106	Transport rack
Description	The LC design shall consider in its design a dedicated transport rack for cargo, including satAPPs and fuel, to ensure a safe transport and simplify the unloading of the cargo at the HC (with its robotic means) as necessary.

ISOS4I-LC-107	Cargo transport cycles
Description	The LC shall be capable of transporting cargo from the launch vehicle separation point to the HC (for LEO). It shall also support multiple cargo transport cycles between the launcher and the HC, ensuring efficient and economically and environmentally sustainable transfer of satAPPs, ,fuel, and other supplies across repeated missions to maintain HC operational capacity and meet evolving mission demands.

5.3.2 Implementation Requirements

ISOS4I-LC-200	Operational Lifetime
Description	The operational lifetime of the LC resulting from the design has to comply with the overall mission deployment plan and shall be of at least 3 years to allow addressing further use-cases (beyond the pilot mission).

ISOS4I-LC-201	Implementation concept
Description	A mission implementation and deployment plan shall consider the operational concept for the LC beyond the ISOS4I demonstration phase.

ISOS4I-LC-202	EU/EEA technologies
Description	EU and EEA technologies at component level shall be preferred. Any choice of non-EU/EEA technology shall be justified as long it is free of non-EU export restrictions (such as ITAR).

ISOS4I-LC-203	LC Deployment
Description	The LC deployment shall be done by demonstrating its service in the full representative environment before delivering the relevant services.

ISOS4I-LC-204	Development approach
Description	The LC development approach shall perform in its development logic a verification, validation and ground demonstration of its performance and its services by exploiting a Hardware-Software simulation environment. The software framework shall include provisions for the associated software-in-the-loop and hardware-in-the-loop test infrastructures.

ISOS4I-LC-205	Docking and removal interface coherence across components
Description	The docking interface used in the LC shall be the same as for the SC and HC. The removal interface used in the LC shall be the same as for the SC. The interface harmonization across the mission components shall be driven by the CSA.

5.3.3 Demonstration and Operational Requirements

ISOS4I-LC-300	Baseline Demonstration scenario for the LC (on orbit) as part of the sequenced operation (A)
Description	The LC shall perform the baseline demonstration scenario A.1 including the following main steps: 1. Transport of cargo (i.e. satAPPs and fuel) from launcher to HC 2. Rendezvous and docking to HC 3. Transfer satAPPs and fuel to the HC (if needed with support of robotic means of the HC)

ISOS4I-LC-301	Ground and Launch segment
Description	The LC shall identify its specific needs for ground and launch segment that shall be coordinated with the other ISOS4I components and consolidated with the CSA, in order to align the interlinked verification and validation activities and operations during the development, deployment and operational phase. Moreover, it shall aim at reducing the overall mission cost through more efficient use of ground segment resources and minimisation of launches by using European launchers.

ISOS4I-LC-302	Initial resources
Description	The LC shall have sufficient resources on board to perform the complete baseline demonstration scenario without additional resupply.

ISOS4I-LC-303	Design of LC operations
Description	LC operations shall be designed aiming at minimizing the risk for incident (e.g., damage of cargo and/or HC) by following applicable standards and regulations, as necessary.

5.4 satAPPs Component

This section contains **high-level requirements specifically for the satAPPs component (AC)** of the ISOS4I pilot mission.

5.4.1 Functional Requirements

ISOS4I-AC-100	Basic functionality
Description	The designed AC shall be able to provide the following functionalities: • consist of composable and exchangeable functional satellite modules that provide certain function (determined through its payload) to the client to which they are connected • satAPPs are connectable to other satAPPs and to satellite platforms based on the plug'n'play principle through an USI, on ground and in space

ISOS4I-AC-101	satAPP function
Description	The function of a satAPP can be of different type, e.g. an operational payload, experiment, or other cargo.

ISOS4I-AC-102	Minimum number of USI per satAPP
Description	A satAPP shall feature at least 2 USIs to allow easy composability and manipulation by robotic means.

ISOS4I-AC-103	AC Interoperability with ISOS4I components
Description	The AC shall consider by design the defined interface, protocol and software format compliance given in the above interoperability matrix (section 4.7.1), being able, as a minimum, to exchange data with HC, SC and other satAPPs by physical connection (i.e. USI).

ISOS4I-AC-104	Form factor
Description	The dimensions of a standard satAPP (form factor 1 satAPP Unit, "sAU") shall be a multiple of the CubeSat standard in order to accommodate the necessary functions of the included payloads. Larger form factors, such as the 2sAU, 3sAU, 4sAU, etc., can be composed.

ISOS4I-AC-105	**Mission Safety**
Description	The AC shall be compliant with applicable safety standards and regulations. The AC (and any IOD/V experiment it may include) shall not cause any risk to the other pilot mission components.

5.4.2 Implementation Requirements

ISOS4I-AC-200	**satAPPs Operational Lifetime**
Description	The operational lifetime of satAPPs must comply with the overall mission deployment plan and shall be of at least 1 year.

ISOS4I-AC-201	**Implementation concept**
Description	A mission implementation and deployment plan shall consider the operational concept for the AC beyond the ISOS4I demonstration phase.

ISOS4I-AC-202	**EU/EEA technologies**
Description	EU and EEA technologies at component level shall be preferred. Any choice of non-EU/EEA technology shall be justified as long it is free of non-EU export restrictions (such as ITAR).

ISOS4I-AC-203	**Component Development Approach**
Description	The AC development approach shall perform in its development logic a verification, validation and ground demonstration of its performance and its services by exploiting an HW-SW simulation environment.

ISOS4I-AC-204	**Baseline USI**
Description	The AC shall be designed based on one or more EU-based USI solution (leading to a satAPP catalogue for each USI). The AC development shall be highly flexible with regard to the integration of different USIs.

ISOS4I-AC-205	**Catalogue of satAPPs**
Description	All designed satAPPs of the AC shall be entered in catalogues (databases) based on the types of USIs.

ISOS4I-AC-206	IOD/V satAPP
Description	At least one of the designed satAPPs shall be designed as an IOD/V satAPP, containing an experiment (with a minimum of TRL5/6 for the experiment).

ISOS4I-AC-207	Assembly satAPPs
Description	At least three of the designed satAPPs shall be intended for an in-space assembly demonstration, which shall result in a single functional unit consisting of three satAPPs.

5.4.3 Demonstration and Operational Requirements

ISOS4I-AC-300	Baseline Demonstration scenario for the HC (on orbit) as part of the sequenced operation (A)
Description	The AC shall demonstrate together with the HC in space that satAPPs are composable to each other to create a new functional chain. Specifically, on the HC, satAPPs shall be capable to be assembled to a single functional unit (functional asset) for demonstration. The AC shall perform the baseline demonstration scenario A.2 including the following main steps: 1. IOD/V experiment based on satAPPs connected to and operated through the HC 2. Transfer data between the satAPPs composed at the HC (functional asset)

ISOS4I-AC-301	Ground and Launch segment
Description	The AC shall identify its specific needs for ground and launch segment that shall be coordinated with the other ISOS4I components and consolidated with the CSA, in order to align the interlinked verification and validation activities and operations during the development, deployment and operational phase. Moreover, it shall aim at reducing the overall mission cost through more efficient use of ground segment resources and minimisation of launches by using European launchers.

ISOS4I-AC-302	On-ground demonstration
Description	It shall be demonstrated in lab that satAPPs are composable to each other, also to create a new functional chain. Specifically, each satAPP shall be tested in a ground demonstrator as part of a single functional unit featuring at least 3 satAPPs.

Annex

List of Acronyms

Acronym	Comment
AC	satAPPs component of the pilot mission
CDR	Critical Design Review
CSA	Coordination and Support Action
ECSS	European Cooperation for Space Standardization
EDF	European Defence Fund
EIC	European Innovation Council
ESA	European Space Agency
EUSP	EU Space Programme
HC	HOST component of the pilot mission
HE CL4	Horizon Europe Cluster 4
HLR	High-Level Requirements
HOST	Hub for Operational Services and Testing
IOD/V	In-Orbit Demonstration and Validation
ISOS	In-Space Operations and Services
ISOS4I	In-Space Operations and Services 4 Infrastructure
LC	Logistic component of the pilot mission
PDR	Preliminary Design Review
PMAG	Pilot Mission Advisory Group
R&D	Research and Development
R&I	Research and Innovation
RPO	Rendezvous and Close Proximity Operations
S/C	Spacecraft
satAPPs	Composable and exchangeable functional satellite modules
SC	Servicing component of the pilot mission
SRR	System Requirements Review
SSI	Spacecraft Service Interfaces
TLC	Telecommand
TLM	Telemetry
TRL	Technology Readiness Level
USI	Universal Service Interface (“USB-in-Space”)