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Enabling a European In-Space Transportation ecosystem

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Abstract

The boom of NewSpace and its start-up ecosystem, alongside the evolution of the space market linked to constellations and to new destinations as the Moon and Mars, is challenging the traditional space transportation approach based on "point-to-point" missions with tailored launchers. ESA market and system studies [1] indicate that the most cost-effective and performant space transportation system on the 2025-2050 horizon could rely on an optimised fleet of reusable launchers injecting payloads on high parking orbits, combined with a "hub and spoke" space logistics network to reach the final orbits (e.g. constellations phasing, exploration missions…) and provide transportation support for in-orbit servicing. Such an ecosystem will be a system-of-systems involving a portfolio of interoperable In-Space Transportation Vehicles (ISTVs) integrating standardised interfaces to ensure their interactions.

To foster the emergence of such a European in-space transportation ecosystem, that is considered as a potential game-changer for access to space, ESA Future Space Transportation is enabling its required space transportation capabilities, as rendezvous & docking and in-orbit refuelling, using incremental In-Orbit Demonstrations over the coming years.

Following a competitive tendering, five parallel contracts are on-going on the Phase 0/A studies of Proof-of-Concept 1 (PoC-1) on in-orbit rendezvous and docking [2]. Their objective is to perform a state-of-the-art survey then trade-off on the enabling interfaces (mechanical & electrical docking interfaces, operational & GNC protocols, communication standards…), to foster a convergent approach on their standardisation, and to perform the conceptual design of the PoC-1 system-of-systems for its In-Orbit Demonstration between two ISTVs. These contracts are led respectively by D-Orbit, OHB System, S.A.B. Aerospace, Thales Alenia Space, and The Exploration Company as Prime contractors.

This paper provides a synthesis of the outcomes of these Phase 0/A studies on PoC-1: in-orbit rendezvous and docking. The considerations and designs of the required interfaces will be presented and discussed, to pave the way for the standardisation of these building blocks that are cornerstones for the emergence of this end-to-end space transportation ecosystem. The ESA roadmap on in-space transportation will be continued with the next steps of PoC-1 up to its In-Orbit Demonstration (IOD) and the launch of first phases of PoC-2 on in-orbit refuelling for reusable space tugs.

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1. Introduction: towards an end-to-end space transportation ecosystem

1.1 Transformation of the SpaceTech sector

The aerospace sector is facing a landslide change. On the one hand, the SpaceTech sector is transforming, with an aggressive competition worldwide, an acceleration of space exploration, and a booming NewSpace economy with more venture capital & private investment. On the other hand, we are at the dawn of an emerging orbital space economy, with an ever-increasing LEO transportation and servicing with constellations deployment, and an upcoming in-orbit servicing revolution.

In this context, ensuring an autonomous and competitive access to space is key for Europe.

ESA has a decisive role to play in enabling this evolution. Indeed, the Agency is transforming accordingly, by shifting from a role of administration of the European space sector, to being in the driving seat of a competitive SpaceTech ecosystem, acting as a facilitator for this ecosystem, a key technology enabler and an anchor customer.

Our objective is to ensure the European industry has the required capabilities, building blocks and interfaces to access and be competitive on the space transportation markets and ensure an autonomous access to space for Europe, notably the new game-changing ones of Space Logistics.

1.2 A paradigm shift, from point-to-point missions to “hub & spoke” space transportation network

The boom of NewSpace and its start-up ecosystem, alongside the evolution of the space market linked to constellations and to new destinations as the Moon and Mars, is challenging the traditional space transportation approach based on “point-to-point” missions with tailored launchers.

ESA market and system studies [1] indicate that the most cost-effective and performant space transportation system on the 2025-2050 horizon could rely on a routine access to space with reusable launchers injecting payloads on high parking orbits, combined with a “hub and spoke” space logistics network to reach the final orbits (e.g. constellations phasing, exploration missions…) and provide transportation support for in-orbit servicing.

Such an ecosystem will be a system-of-systems involving a portfolio of interoperable In-Space Transportation Vehicles (ISTVs) integrating standardised interfaces to ensure their interactions. These ISTVs will be able to dock with target spacecraft and cargo in-orbit, to take-over payloads, to carry them up to their final orbit and to refuel themselves on orbital propellant depots.

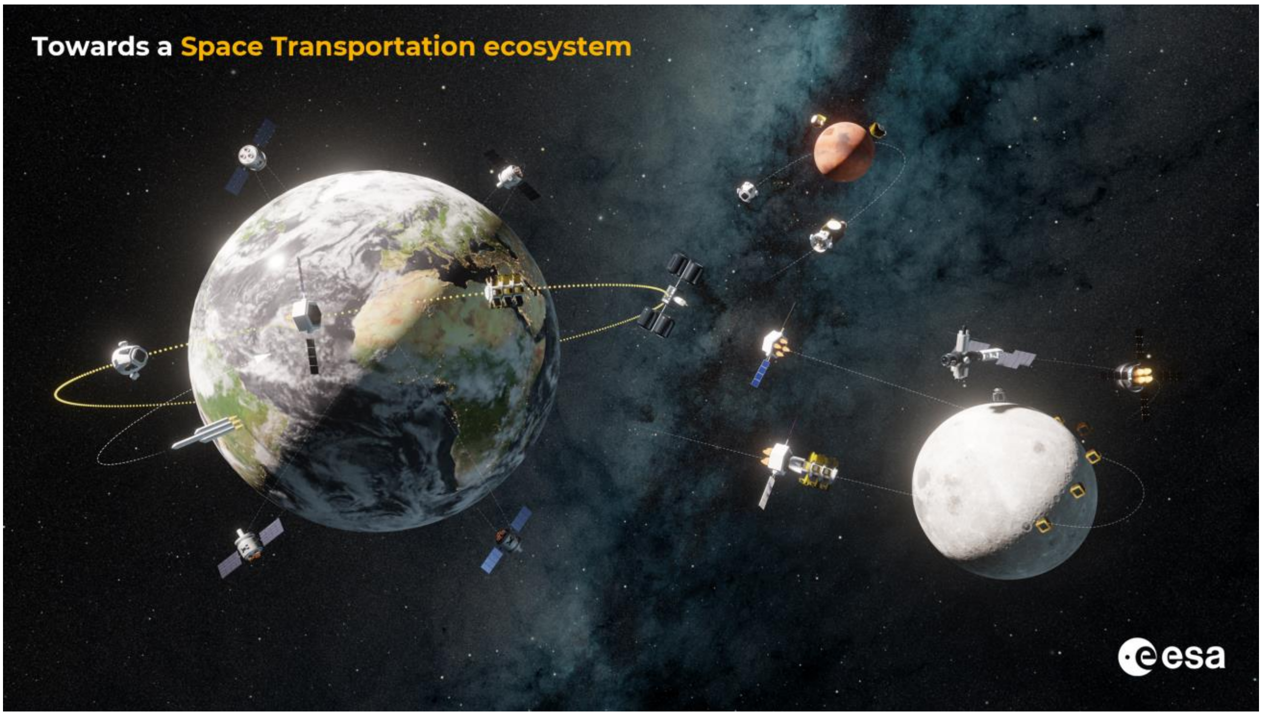

Figure 1: Artistic view of the future space transportation ecosystem

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The two following capabilities are the enablers for the shift from a "point-to-point" scheme (see fig. 2 below) to a "hub-&-spoke" space transportation network (depicted in fig. 3):

1. In-orbit rendezvous and docking: to enable the docking of the ISTV (for example space-tug) with its target payloads in high-parking orbit and/or with an orbital propellant depot,
2. In-orbit refuelling: to enable the refuelling of the ISTV when needed, transforming it into a reusable space-tug, that will stay in space to perform numerous missions over its lifecycle.

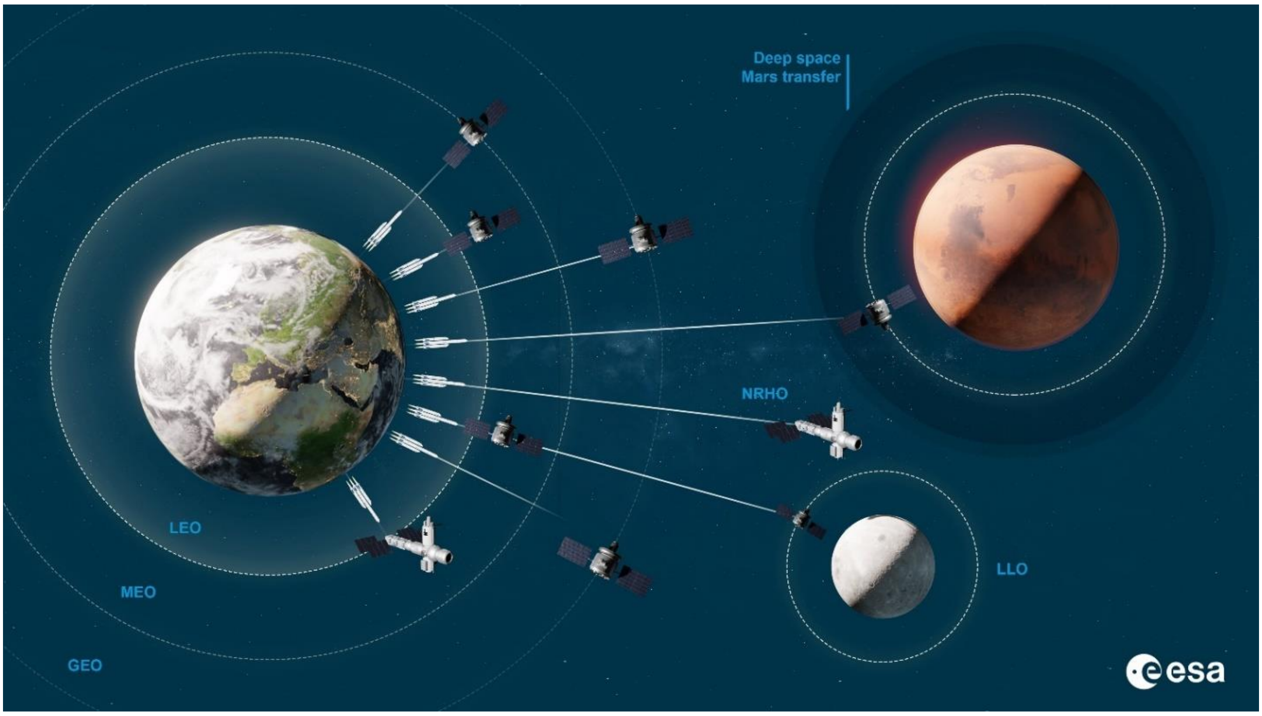

Figure 2: ↑ Traditional point-to-point missions with expendable launchers

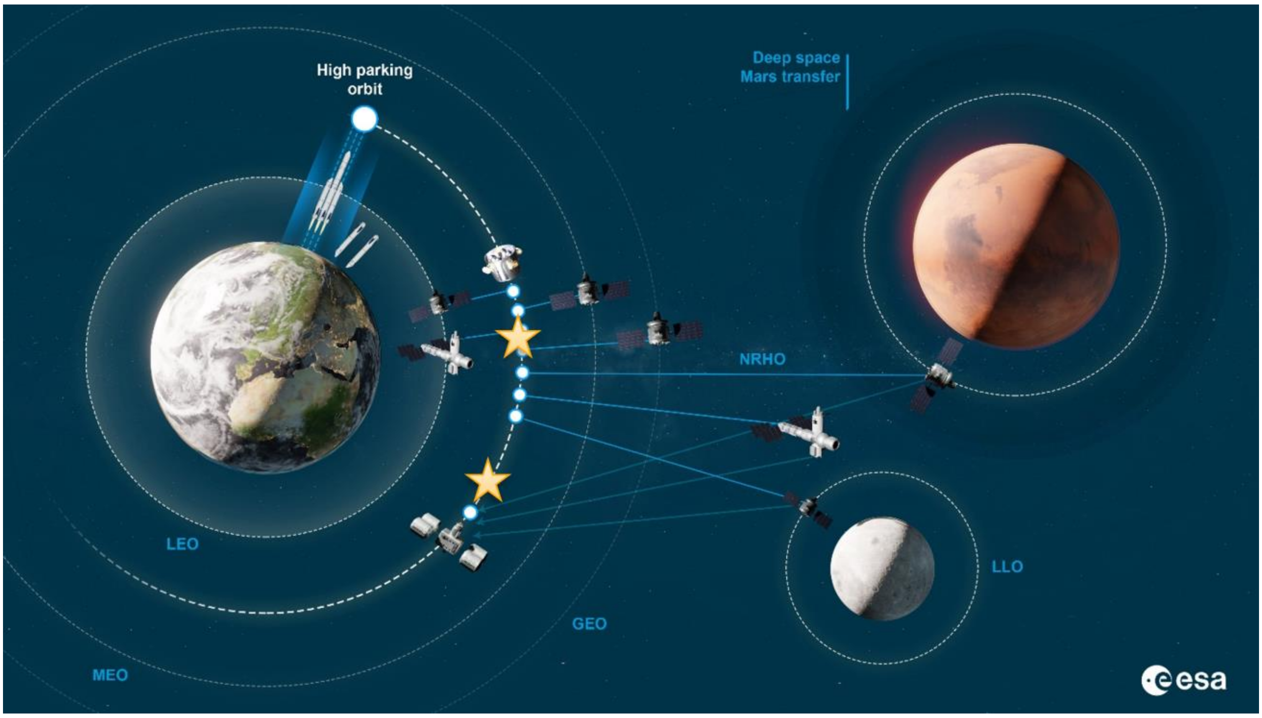

Figure 3: ↑ Upcoming end-to-end transportation ecosystem, with routine access to high parking orbit by reusable launchers and "hub-&-spoke" network of in-space vehicles with reusable space-tugs

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1.3 Key enabling interfaces and building-blocks

An increasing number of European SpaceTech players have existing or planned capabilities to provide in-space transportation services, with motorised dispensers, orbital transfer vehicles and/or kick-stages. ESA is welcoming these developments, that are driven by providing added value on the commercial and institutional markets, and attracting institutional fundings, national funding and/or private investments. This market-driven and entrepreneurial approach is a key factor for fostering a flourishing, robust and competitive in-space transportation ecosystem for Europe.

These vehicles, called In-Space Transportation Vehicles (ISTVs), are the backbone of the ESA venture towards enabling the In-Space Transportation ecosystem. The objective of this venture is to enable this ecosystem to reach its next level and to allow the European industry to address the full potential of the in-space transportation market and associated orbital economy.

Indeed, without proper interfaces to be able to dock and to refuel, the ISTVs remain expandable, used in one-shot missions to dispatch their original payload as a last-miles delivery service.

To enable the in-space transportation ecosystem to its full potential, the baseline ISTVs shall evolve from expandable spacecrafts to reusable space-tugs that can perform several missions over their lifetime and provide space transportation support to in-orbit servicing. To do so, the baseline ISTVs shall first integrate the required building-blocks to enable the key capabilities of (1) in-orbit rendezvous and docking and (2) in-orbit refuelling, as described below:

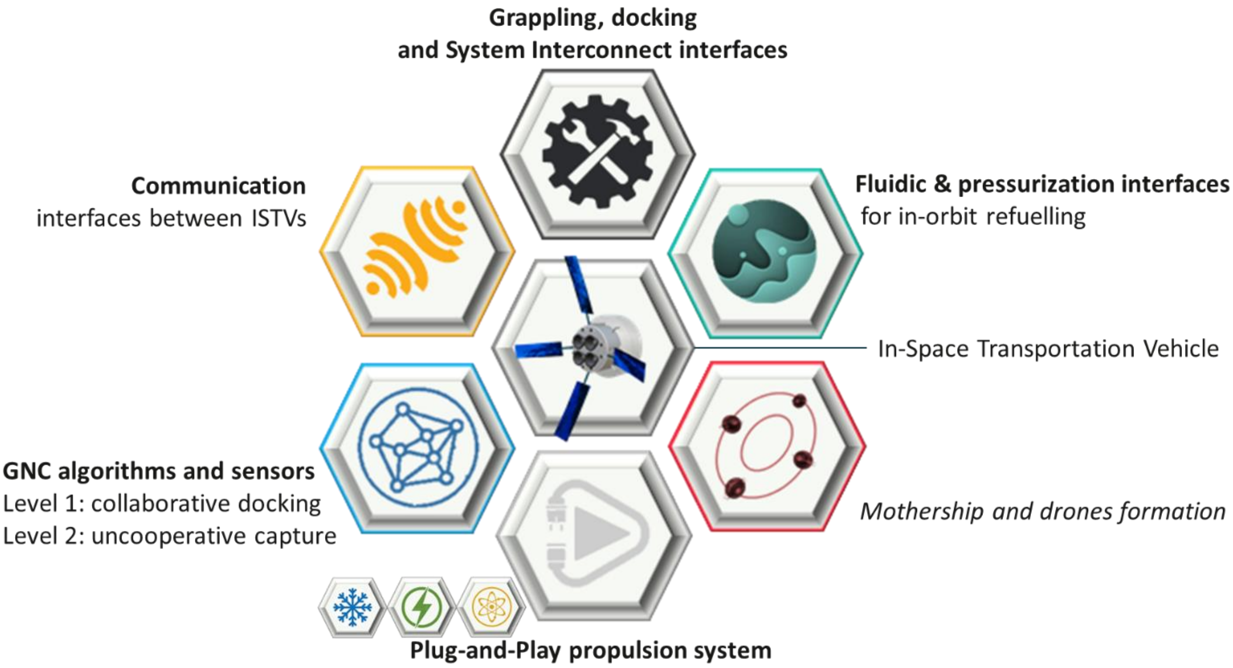

Figure 4: Key enabling interfaces and building-blocks for in-space transportation

Once this first basis of reusable space-tugs is reached, it will be possible to add extended features, as swarm control for spacecrafts orbital management, mothership & drones formation flying, capture of non-cooperative targets and plug-&-play propulsion systems with a lean integration in different platforms configurations.

The future orbital market might not be ruled by a “winner takes all” approach, but rather by an ecosystem of actors providing unbundled added-value services in orbit. In this perspective, the following considerations shall drive the development of these enabling interfaces:

- Ensure interoperability between spacecrafts and payloads from different countries and manufacturers to perform the required interactions in this ecosystem,
- Ensure the modularity of the interfaces to address different ranges of spacecrafts and missions,
- Provide the ecosystem with efficient and proven interfaces meeting its needs, as Components off-the-Shelf (COTS) to integrate in its vehicles to address new markets,
- Define the good-enough set of guidelines and shared designs to foster both relying on existing solutions and promoting innovation and evolutions.

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As a result, fostering standardization, dissemination and adoption of the enabling interfaces is key to enable this ecosystem. This is exactly what we intend to tackle in the in-space transportation venture.

To meet these objectives, ESA is promoting coopetition within the European SpaceTech ecosystem, encouraging:

- competitiveness to access new markets,
- and collaboration between actors on these interfaces to enable together the extension of their respective playgrounds and the European in-space economy.

By teaming up for developing key enablers, the European space industry might obtain competitive advantages on the worldwide space competition and unlock access to new promising markets. Once the European guidelines and enabling building-blocks are agreed-upon with a significant group of SpaceTech players, each of these players will be able to benefit from them and integrate them as COTS in their space logistics projects, whatever their source of funding is (ESA, European Commission, national agencies and/or private fundings).

Then these standards might be disseminated for adoption on the worldwide market, or adaptors between standards might be designed to ensure international interoperability.

1.4 An incremental roadmap of In-Orbit Demonstrations to enable in-space transportation

ESA is aiming at transforming the vision above in reality, with its venture on in-space transportation Proof-of-Concepts (PoCs), that is now in full-swing implementation. Through this venture, the Agency acts as enabling partner to de-risk these space transportation capabilities and foster standardized interfaces using incremental In-Orbit Demonstrations (IOD) over the coming years. Each PoC focuses on one key enabling capability for in-space transportation and will indeed identify and mature the required critical building-blocks and culminate at In-Orbit Demonstrations between ISTVs.

The two first in-space transportation Proof-of-Concepts are currently being implemented, to ensure the acquisition of these key transport capabilities, namely PoC-1 on in-orbit rendezvous and docking and PoC-2 on in-orbit refuelling.

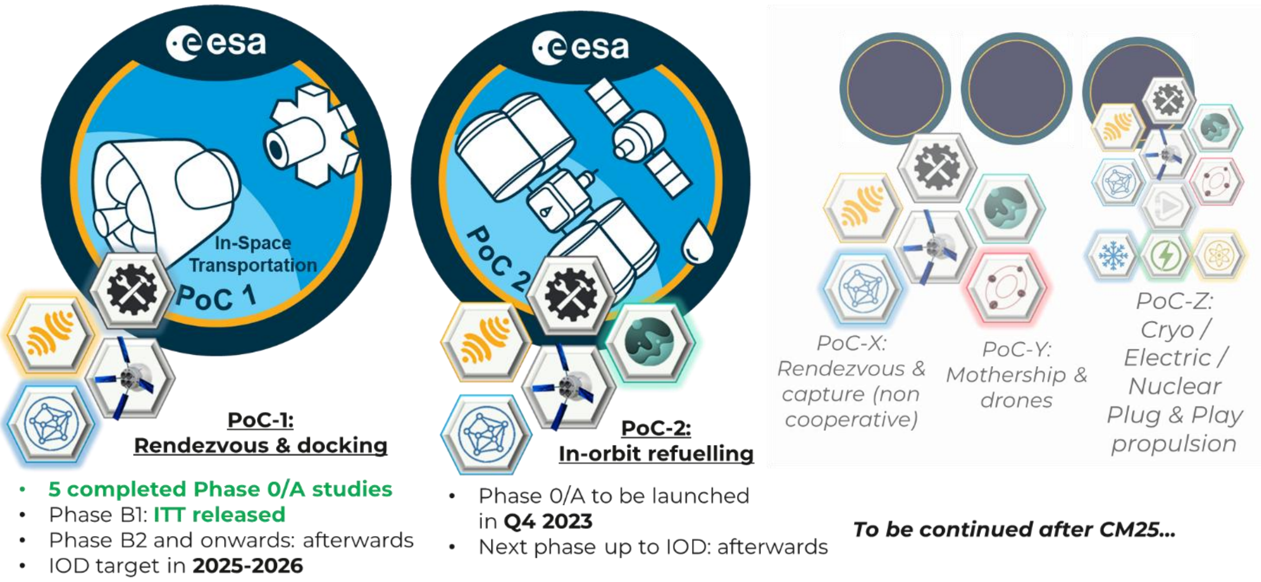

Figure 5: Incremental roadmap of In-Orbit Demonstrations

The PoC-1 aims at demonstrating the key enabling transport capability of in-orbit rendezvous and docking between two orbital systems, compatible with payload transport and cargo transfer. It will be based on one or two ISTVs allowing to carry out the demonstration. Its first objective is to define and mature enabling capabilities for in-space transportation:

- Operational guidelines and GNC-related constraints for automatic rendezvous & docking between cooperative vehicles,
- Interfaces for grappling, docking and System Interconnect (with a potential option on refueling) between the vehicles, compatible with high thrust maneuvers for in-space transportation,

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- Communication interfaces for data exchanges between the spacecrafts.

The first validation of these interfaces and capabilities will be performed on the ground. It will be followed by the in-orbit demonstration of rendezvous and docking between two vehicles, validating in-flight the designed interfaces and the associated enabling capabilities.

1.5 Implementation timeline and procurement

The overall implementation process of the venture on in-space transportation PoCs has been unfolded as follow:

- The structuration of the PoC-1 content has been shaped based on the insights form the markets analyses and system studies on future space transportation with the industry, notably space logistics system studies and Post-NESTS (New European Space Transportation Services) studies.
- A preliminary Request For Information (RFI) has been concluded to gather the commercial interests, potential technical contributions, motivations, and competences of the interested parties. The content of the PoC-1 has been refined accordingly and the fields-of-interest from subcontractors have been identified by the primes.
- A pitch-day has been organized to allow short pitches of the key enabling providers over the value chain for potential interested primes, for fostering matchmaking within the industrial ecosystem.
- A competitive tendering process has concluded in the placement of five parallel contracts for the Phase 0/A studies PoC-1, that have now been successfully completed.
- During the unfolding of the project, after the Mission Key-Points, a standardization convergence workshop has gathered the five consortiums to foster convergence on their approaches on the enabling capabilities.
- The next phases B1 and subsequent phases up to IOD will be procured in two-steps approach, with a target IOD in 2025-2026.
- A similar process will be implemented soon for the launch of PoC-2 on in-orbit refuelling.

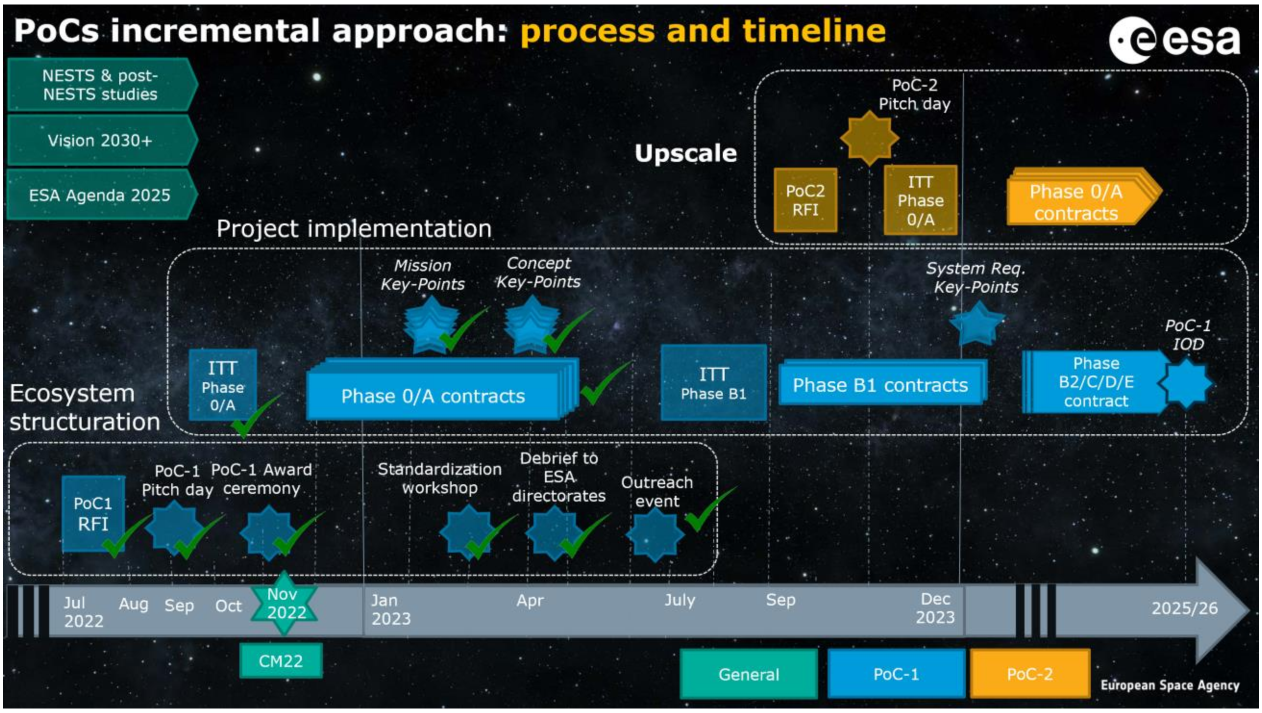

Figure 6: Implementation timeline and innovative procurement process for in-space transportation PoCs

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1.6 ESA Transformation in motion

In line with the transformation of the European SpaceTech sector facing a fierce global competition, ESA is also implementing a transformation at different levels including technological, business and implementation process. It becomes clear that the role of ESA is shifting from the administration of a sector to the facilitation of a SpaceTech ecosystem coupled with an awareness of the autonomous access to space for Europe. This ecosystem should benefit from the strengths of the established and the new players alike, inclusion of new players from non-space sector as well as new ways of funding. It is also important to foster team spirit towards Space Team Europe, based on “coopetition” (meaning cooperating while being in competition) within European stakeholders, to build worldwide leadership position for European companies.

ESA has its role to play there, as only together European ecosystem can be successful to tackle such international challenges. A common purpose is to ensure the European industry has the required capabilities and building blocks to access and be competitive on the space transportation markets and ensure an autonomous access to space for Europe. In this context ESA Future Space Transportation is accompanying the industry by de-risking these technical building blocks.

The PoC-1 venture has been a test case for new tools of ecosystem structuration (see Fig 6) in support of project implementation process. By now is has successfully demonstrated:

- Acceleration in ESA decision making and implementation of programmes,
- Matchmaking between primes and key technology providers, established and new players alike, through RFIs, pitch-days and open competition procurement,
- Implementation of common vision by embracing industry roadmaps both commercial and institutional and steer them towards a common goal. This process has been stimulated also by open exchanges and wide communication during award ceremony, standardization workshop and outreach event, putting the basis for the future “coopetition” spirit.

2. Synthesis of the Phase 0/A studies on in-orbit rendezvous and docking

2.1 A top-notch team of Space Logistics players

Following the competitive procurement process presented above, five parallel contracts have been awarded and successfully completed on the Phase 0/A studies of PoC-1 on in-orbit rendezvous and docking. These contracts have been led respectively by D-Orbit, OHB System, S.A.B. Aerospace, Thales Alenia Space, and The Exploration Company as Prime contractors. The associated consortiums are depicted in the figure below.

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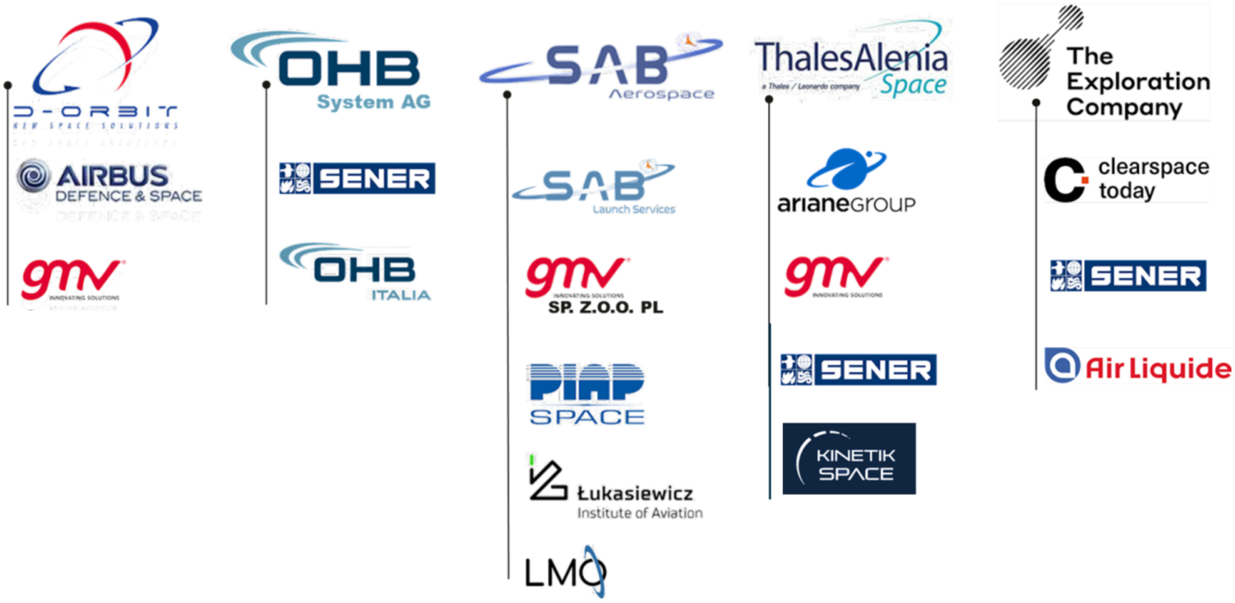

Figure 7: Awarded consortiums of the Phase 0/A studies for PoC-1 on in-orbit rendezvous and docking

Building a European end-to-end space transportation ecosystem requires an inclusive and collaborative approach across Europe, joining European industrial forces to foster interfaces standardization and interoperability between ISTV. In this respect, it is highly appreciated that the consortiums gather European actors with well-developed industrial expertise as well as new space actors, aiming for innovative concepts and strategic partnerships. Also, the consortiums have regrouped Primes with proven System Engineering experience for enabling in-space transportation ecosystem and key technologies providers for overcoming the associated technical challenges.

Such combination of key stakeholders and players of the SpaceTech ecosystem has been a strong asset for the quality of the project outcomes and for building a collaborative momentum to transform this vision into reality together.

2.2 Objectives and content of Phase 0/A studies

The overarching objective of PoC-1 is to analyse, mature and then demonstrate in-orbit the operational guidelines and enabling rendezvous and docking interfaces that would be used as building-blocks in the future within a European space transportation ecosystem.

PoC-1 will culminate into one In-Orbit Demonstration with a dedicated ISTV and Customer Vehicle, with the objective to design and demonstrate interfaces that are not only relevant for this case, but that will be standardised and used in a wider frame. These guidelines and enabling interfaces shall indeed be used by different companies and integrated in different vehicles and spacecrafts. PoC-1 is not only about performing one demonstration, but also about enabling all the others with relevant interfaces for in-space transportation at large.

The following in-space transportation scenario are considered as use-cases for the use of PoC-1 as an enabler for the in-space transportation ecosystem:

- Use-case 1: An ISTV docks with its target payload* in high parking orbit *(*target being payloads for Space Transportation, as non-active satellites, before entering into operations)*
- Use-Case 2: An ISTV docks with an orbital propellant depot and refuels,
- Use-Case 3: An ISTV docks with an In-Orbit Servicing Vehicle to handover its cargo towards in-orbit assembly or maintenance.

Each consortium has met the objectives of the PoC-1 Phase 0/A study as follow:

- Consolidated the Technical Requirement Specification of the Space Logistics PoC-1, considering the core and add-on functionalities expected by ESA,
- Selected the ISTV and Customer vehicle for PoC-1 and refined accordingly the Concept of Operations for the PoC-1 In-Orbit Demonstration,
- Performed the trade-off and conceptual design of the required interfaces between ISTVs, (mechanical, electrical, docking, communication, cooperative GNC…), and proposed the logic for dissemination and standardization within the space logistics ecosystem,

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- Performed the conceptual design of the PoC-1 System-of-Systems covering the two ISTVs and encompassed their interfaces,
- Defined the roadmap for the next steps up to PoC-1 In-Orbit Demonstration and the associated costing, planning, risks assessments, organisation, and industrial work breakdown,
- Established the Technology Identification and Maturation Plan for PoC-1.

2.3 Core functionalities of PoC-1 IOD

The PoC-1 In-Orbit Demonstration will be performed with a relevant ISTV and a Customer Vehicle to unfold the following operational features:

- Launch of the ISTV and Customer vehicles by a European launch service provider,
- Last-mile delivery of the space vehicles up to the selected location for rendezvous and docking demonstration,
- Performance of collaborative approach, rendezvous, and direct docking between the two vehicles,
- Test of in-orbit communication between the ISTV and Customer vehicles,
- Test of a coupling operation between ISTV and Customer vehicles, hereby testing and validating in-flight the matured grappling, docking and System Interconnect interfaces,
- Performance of translational and rotational maneuvers in all directions in space (high thrust maneuvers),
- Detachment of the ISTV from the Customer vehicle,
- Performance of at least one other coupling operation between the ISTV and Customer vehicles,
- Disposal and end-of-life for the two ISTVs compliant with the French Space Operations Act (see [3]).

On top of these operational features, the ISTV shall be designed to accommodate experimental payloads for alternative GNC testing and to share sensors measurements data for further ESA studies to test GNC functions.

2.4 Concepts of in-orbit rendezvous and docking from the Primes

During the Phase 0/A studies, each consortium has selected the reference ISTV and Customer Vehicle to perform the intended PoC-1 in-orbit demonstration of in-orbit rendezvous and docking. They have established accordingly their conceptual designs of PoC-1 System-of-Systems (covering the two vehicles, their space segments and ground segments and their interactions and interfaces) and refined their mission and Concept of Operations (ConOps). The following illustrations depict the variety of ISTVs and Customer Vehicles considered by the Primes for their respective in-orbit rendezvous and docking demonstrations.

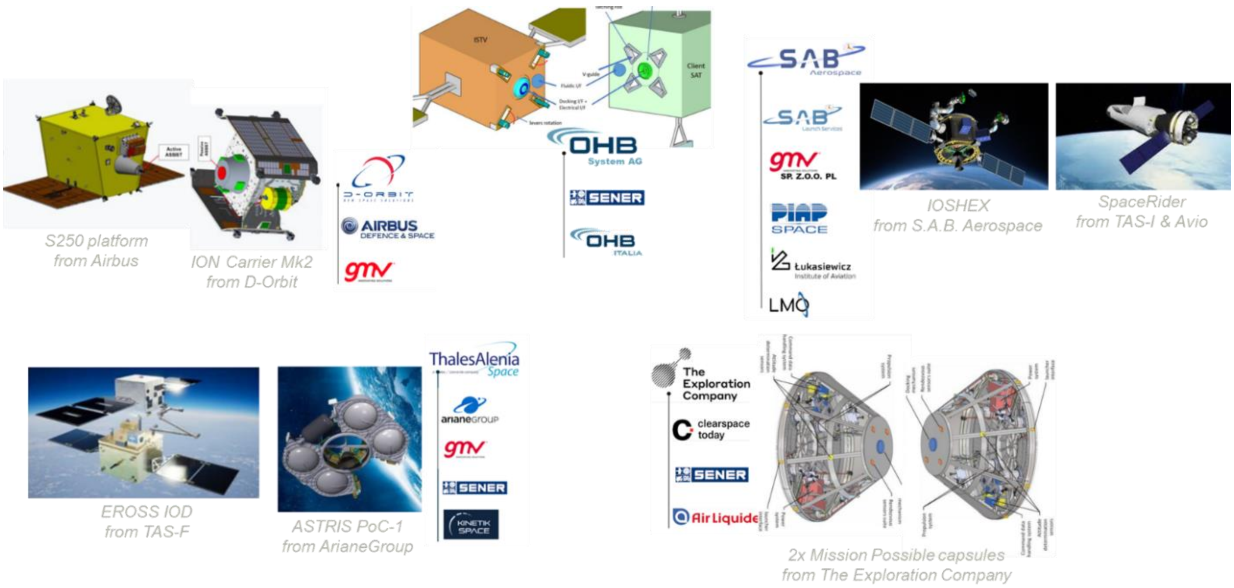

Figure 8: ISTVs and Customer Vehicles of PoC-1 concepts by the five consortiums

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2.5 Rendezvous: operational guidelines and GNC-related constraints

The five consortiums have displayed diverse yet convergent roadmaps towards in-space transportation and an interesting portfolio of spacecraft applications for their intended in-orbit rendezvous and docking demonstration. From this diversity of consortiums and spacecrafts, the steering of these projects has notably aimed at fostering convergence on enabling capabilities and interfaces. The consortiums have multiple applications but share one common purpose on agreeing upon the just-enough set of guidelines and design principles to allow interoperability and enable together the in-space transportation ecosystem.

This objective has culminated at the standardisation convergence workshop where the five consortiums have shared their concepts of operations for PoC-1 and have been steered through collaborative design thinking to consolidate agreed-upon principles for interoperability.

Considering the in-space transportation use-cases, they have refined together with ESA a generic ConOps for ensuring safe and efficient in-orbit rendezvous and docking, and agreed on the "just-enough" set of operational guidelines to implement it, with associated GNC-related constraints on the target vehicle.

The following scheme presents the top layer of this reference ConOps for in-orbit rendezvous and docking as agreed-upon during this Standardisation workshop.

Common nomenclature, semantics, and definitions (notably on zones, phases, hold-points) have been agreed, coherent between projects and with international standards. The respective objectives have been broken down by phases with associated constraints and performances requirements. The operational guidelines and reference hypotheses have been discussed for guidance (on-board vs. ground-based), navigation (absolute or relative and types of measurements and sensors), types of control (closed- or open-loop control on attitude & position), control requirements on the customer (wrt. 3-axis attitude control and pointing), Inter-Satellites Link communication and content.

The objective is to set the "just enough" guidelines to ensure safe rendezvous, interoperability between spacecrafts and mission tailoring, while leaving open most of the GNC implementation to foster industrial innovation.

The following scheme presents the top layer of this reference ConOps for in-orbit rendezvous and docking as agreed-upon during this standardisation workshop.

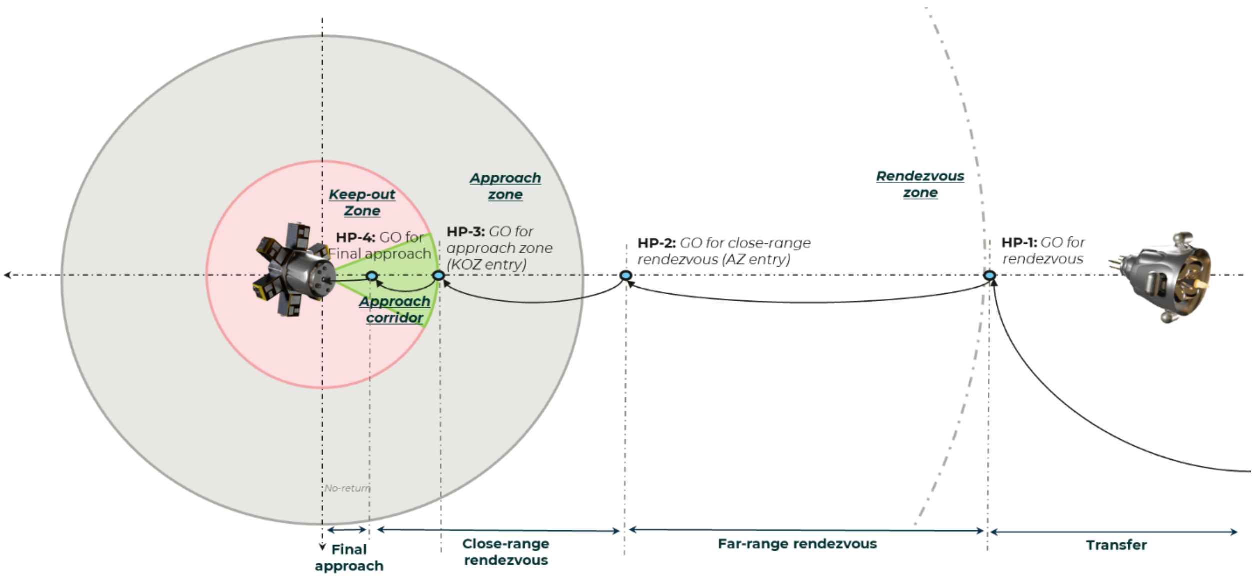

Figure 9: Scheme of generic Rendezvous ConOps - phases, zones & hold-points, as agreed during PoC-1 Phase 0/A standardisation workshop

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2.6 Docking: Grappling, docking and System-Interconnect interfaces

After final approach of the rendezvous phase, the ISTV shall perform the grappling and securing of the Customer Vehicle, considering the following definitions of these critical functions:

- Grappling: Act of first-time-connecting the ISTV to a prepared client spacecraft that has specific fixture by means of a device on the ISTV. In general, grapple systems are made of a gendered couple of gripper (normally placed on the ISTV) and grapple fixture (normally customer vehicle target). Grapple systems are designed to cope with quite wide ranges of relative distances/angles/rates between servicer and target.

- Securing of the Customer Vehicle: Act of setting the vehicle in a coupled configuration with the ISTV that can support all the following stacked operations. For in-space transportation, a very rigid link shall be established between the two vehicles to allow performance of high thrust maneuvers of the compound.

The docking corresponds to the combined act of grappling and securing of the Customer Vehicle to the ISTV by means of the same set of docking fixtures.

Once docking is performed, System Interconnect interfaces ensure mechanical, electrical, data, thermal and fluidic coupling between the two vehicles and/or with a payload. Such function shall cover bidirectional data transfer between the ISTV and Customer vehicle (health status, propellant loading, feedback, pressure, and temperature…).

The selected set of interfaces shall ensure several connection/disconnection sequences while remaining fully operational. They might also pave the way for latter in-orbit refuelling.

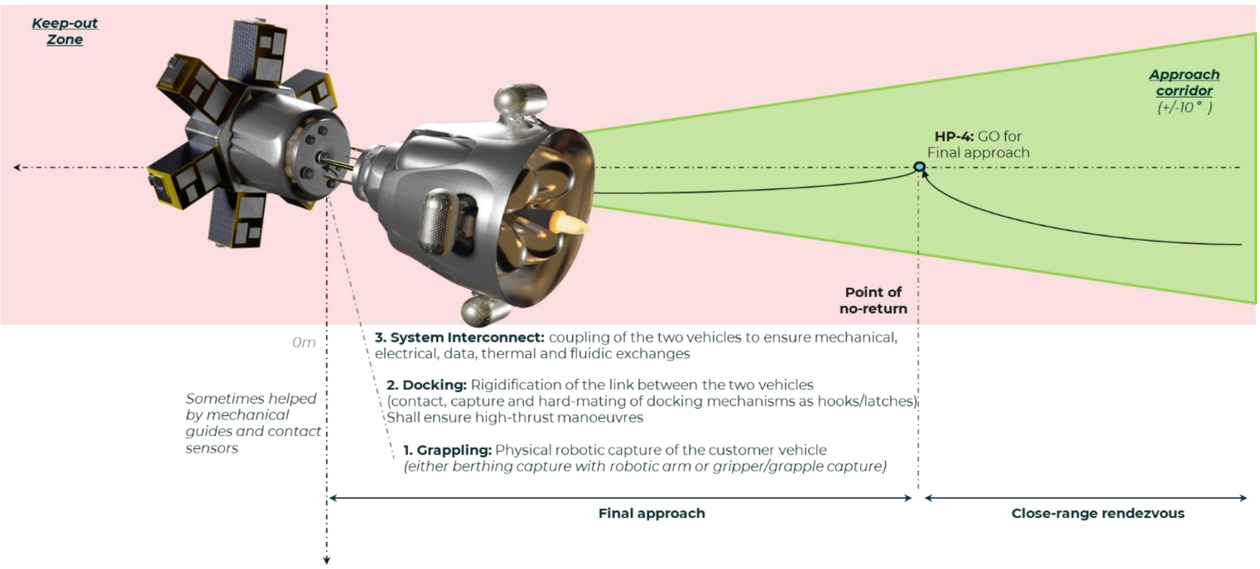

Figure 10: Scheme of final docking manoeuvre, grappling, docking and System Interconnect

One of the key topics from Phase 0/A studies was to perform a state-of-the-art and trade-off of the most promising grappling, docking and System Interconnect interfaces that would ensure these functions for in-orbit rendezvous and docking in relevant in-space transportation use-cases. Each consortium has established a detailed trade-off and concept file for these interfaces, including dissemination and standardization plan.

These trade-offs have been shared and discussed during the transverse Standardisation workshop that have regrouped all the consortiums with a collaborative design steering process. It has concluded that some excellent interfaces are existing in Europe and are likely to be promising candidates for standardisation, based on different main functions, for example:

- Grappling function: ASSIST - GMV
- Securing function: Gripper and Standard Gripping Fixture – PIAP Space
- System Interconnect function: SIROM – SENER
- Berthing function: robotic arm from Kinetik Space

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Figure 11: Promising interfaces candidates identified by the Primes, from left to right: ASSIST – GMV, Gripper and Standard Gripping Fixture – PIAP Space and SIROM – SENER

The standardisation workshop has also identified that no solution is yet fully compliant to all the needs and required features for the use-cases for in-space transportation. Notably, the required securing of the spacecrafts for performing high-thrust manoeuvres shall be covered. Moreover, some interfaces (as ASSIST and SIROM) were initially designed for being operated on robotic arms and/or for robotic operations and shall be completed to be applicable for direct docking use-cases.

A trade-off has also been performed between the two approaches of direct-docking and berthing with a robotic arm. Direct docking appeared as the most relevant for in-space transportation use-cases (with lower complexity and cost, potentially higher reliability over lifecycle). Berthing appeared to relevant in case of combination of use-cases in-space transportation and in-orbit servicing.

The outcomes and convergence points have been integrated into each project towards their finalisation at Concept Key-Points for each consortium. Some insightful concepts of modular interfaces configuration to tackle in-space transportation loads for different classes of spacecrafts and missions have been elaborated in the detailed PoC-1 Concepts Files.

In continuity with the outcome and trends from Phase 0/A studies, the upcoming Phase B1 will establish a ground-truth view on the technical capabilities and missing gaps of the considered candidates and will identify accordingly the gap-fillers, maturation and testing to achieve the required target capabilities. First preliminary designs will be established for the docking architecture and grappling / docking / System Interconnect interfaces, to ensure that the interfaces fully comply to the required in-space transportation use-cases, particularly with regards to the performance of high-thrust manoeuvres.

A particular attention will be granted to foster modularity, standardisation, interoperability, and lean interfaces between the ISTV and their building blocks, to ensure lean operations in the in-space transportation ecosystem, to promote synergies between actors, and to decrease the recurring costs.

A key focus in the following steps will be to fine-tune the standardisation and dissemination process for the selected solutions (as open Interfaces Control Documents, users-clubs…) to ensure their adoption within the space transportation ecosystem and steer the modification of these designs (as standardisation committees and collaborative evolutions processes). The mandatory objective is to define standards to ensure autonomous access to in-space transportation for Europe (as electrical plug standards). Growth potential can be proposed to allow interoperability of these standards to access worldwide markets (as electrical plugs adapters)

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3. Next steps towards enabling the ecosystem

3.1 PoC-1: In-orbit rendezvous & docking

The upcoming phase B1 of the venture aim at performing the preliminary design of PoC-1, considering the overarching objective of optimising the added-value of its IOD for enabling the European in-space transportation ecosystem at large. In this perspective, a special focus will be notably carried out on:

- Analysing the generic in-space transportation ecosystem and its types of spacecrafts and applications use-cases, that PoC-1 might be representative of. “Users-club” might be organized to gather insights and expectations from the European SpaceTech
- Consolidating the set of operational guidelines for ensuring safe and efficient rendezvous and docking fostering interoperability between spacecrafts, both in nominal and dysfunctional configurations,
- Performing the preliminary design of the GNC subsystem and refining the associated constraints on the Customer Vehicle,
- Performing first preliminary designs of the required interfaces to perform grappling, docking, and system interconnect functions meeting all the needs and required features of our use-cases,
- Refining and implementing the logic for dissemination and standardization within the Space transportation ecosystem,
- Performing the required de-risking and maturation of the critical enabling technologies for the IOD.

The Phase B1 might be open to parallel contracts, to pursue the spirit of coopetition that has proven its efficiency during the phases 0/A studies. The incremental procurement logic will progressively narrow down the PoC-1 concepts from five Phases 0/A to one actual PoC-1 IOD. In the meantime, the project will be supported by an ever-increasing group of SpaceTech representatives (through Users-Clubs, transverse Working Groups and Standardisation committees as described below) to ensure that the demonstration benefits to enabling the target ecosystem.

The final phases of the project up to PoC-1 IOD (phases B2 and onwards) will be procured afterwards, based on the momentum and insights gathered during the first phases.

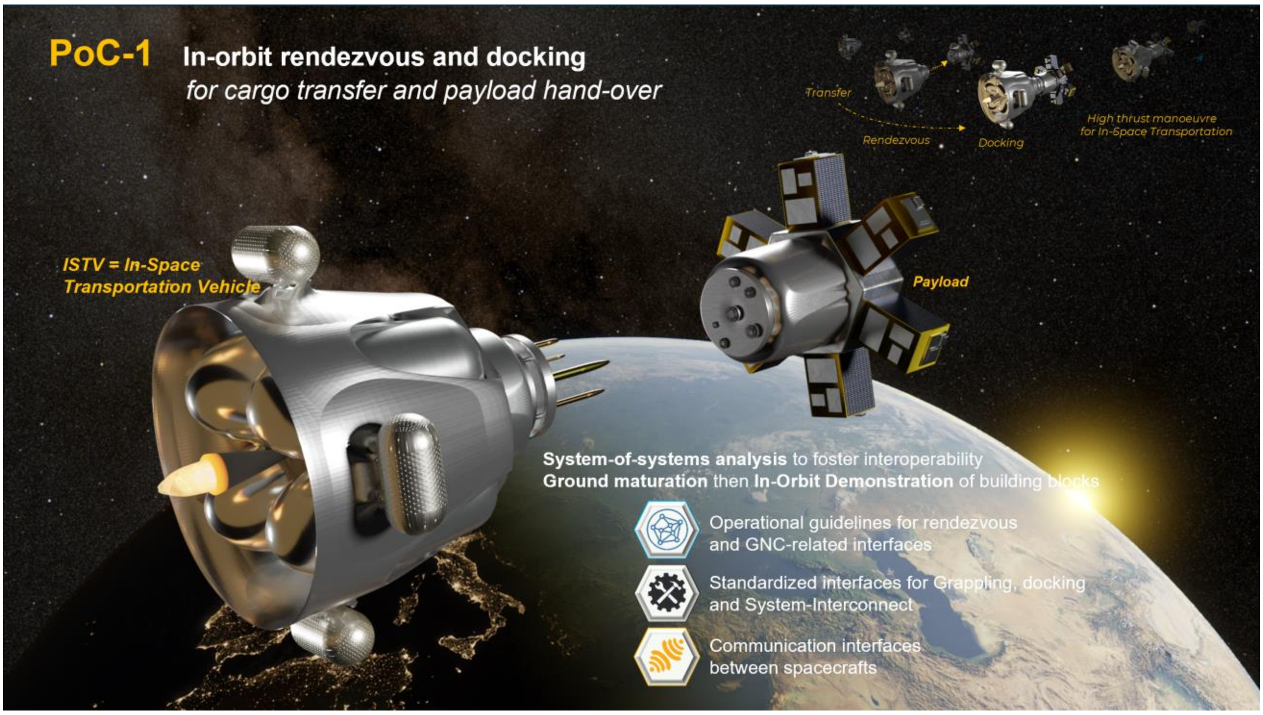

Figure 12: Artistic view of PoC-1 IOD on in-orbit rendezvous and docking, with its main content and ConOps

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3.2 PoC-2: In-orbit refuelling

Right after kicking-off the PoC-1 Phase B1 studies, ESA will initiate the incremental process on the following PoC in the in-space transportation venture, namely with PoC-2 on in-orbit refuelling.

Based on the capabilities and interfaces matured within PoC-1, PoC-2 will go one step further and will focus on enabling in-orbit refuelling with in-space cryogenic propellants management and transfer. Its objective will be to allow future ISTVs to refuel on orbital propellants depots and pursue their mission.

ESA structuration of PoC-2 will be established on the insights from its market analyses and system analyses with the industry, notably Post-NESTS (New European Space Transportation Services) studies, preliminary analyses on orbital propellant depots and taking into account Exploration perspectives. The procurement will be performed as follow:

- A preliminary Request for Information on in-orbit refuelling will be released on ESA Open Space Innovation Platform (OSIP), to identify interested parties and stakeholders (potential primes and enabling technologies providers), to align business and technical roadmaps and to consolidate accordingly PoC-2 content and objectives,
- A pitch-day will be organized to gather the relevant industrial forces and foster matchmaking between primes and key technologies providers,
- Then the Phase 0/A studies of PoC-2 will be launched, following a competitive tendering process, with the objectives of elaborating PoC-2 missions and concepts, maturing key enabling building-blocks and paving the way, if needed, to their standardisation.

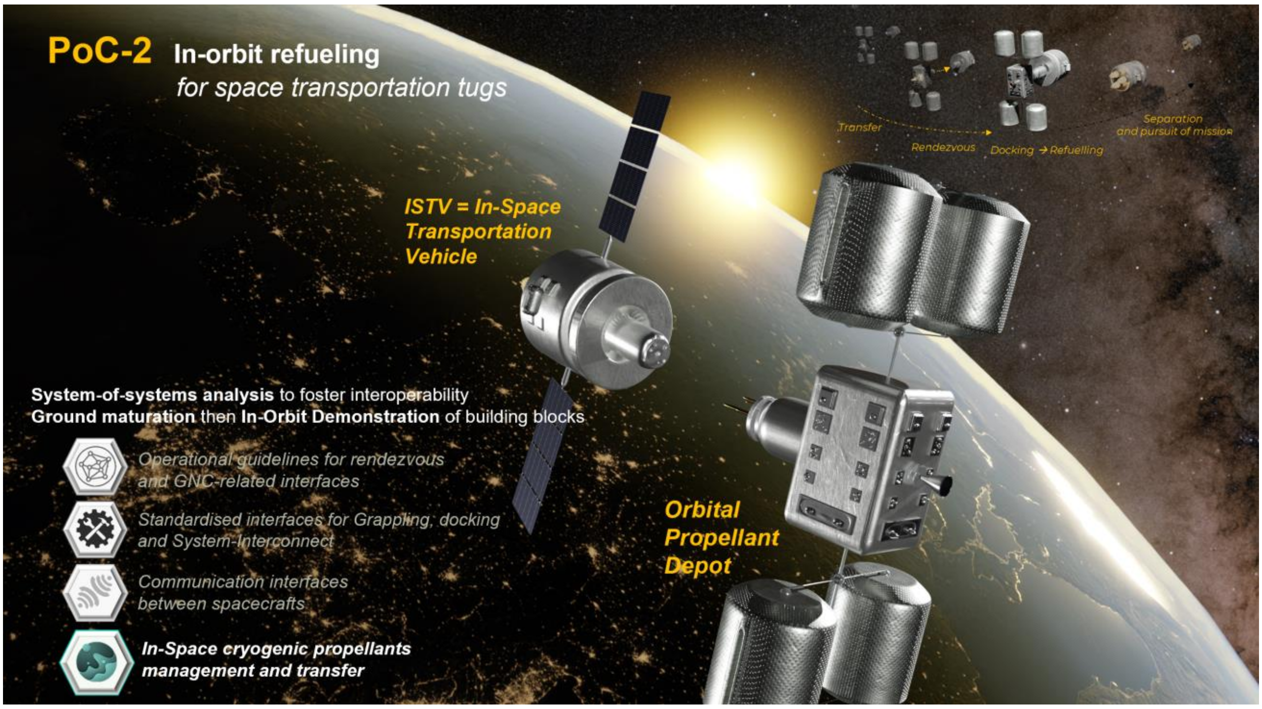

Figure 13: Artistic view of PoC-2 IOD on in-orbit refuelling, with its main content and ConOps

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3.3 Space Team Europe: towards standardized building-blocks and enabling the space transportation ecosystem

Beyond participating directly in the PoC-1 and PoC-2 contracts above, ESA intends to foster collaboration across the European ecosystem at-large, to accelerate the deployment of the in-space transportation ecosystem.

To do so, supporting the in-space transportations PoCs venture, ESA will organise the following activities:

- Transverse Working Group on In-Orbit rendezvous & docking: to foster collaborative progress on dedicated topics as (i) Rendez-vous & GNC, (ii) Docking interfaces, (iii) In-space communication,
- Users Clubs for In-Space Transportation: to gather stakeholders to collect needs, use-cases and parameters to take into account in shaping the ecosystem and enabling capabilities,
- Standardisation committee for enabling interfaces: to present the status on the enabling building-blocks, share interfaces control documents and agree on their evolutions.

One of the key take-aways from this venture so far has been this shared spirit of "coopetition" among the Primes and consortiums, to achieve together greater goals. It has proven that a key for the future of European access to space might be for Space competitors to collaborate on key strategic topics as these enabling capabilities and interfaces to unlock together their access to the future in-space economy.

We are building together this momentum and federating this European SpaceTech ecosystem, including Large Space Integrators, key technology providers, established and new players alike, Member-States, national agencies, and investors. Our common objective is for Space Team Europe to enable its autonomous and competitive access to space.

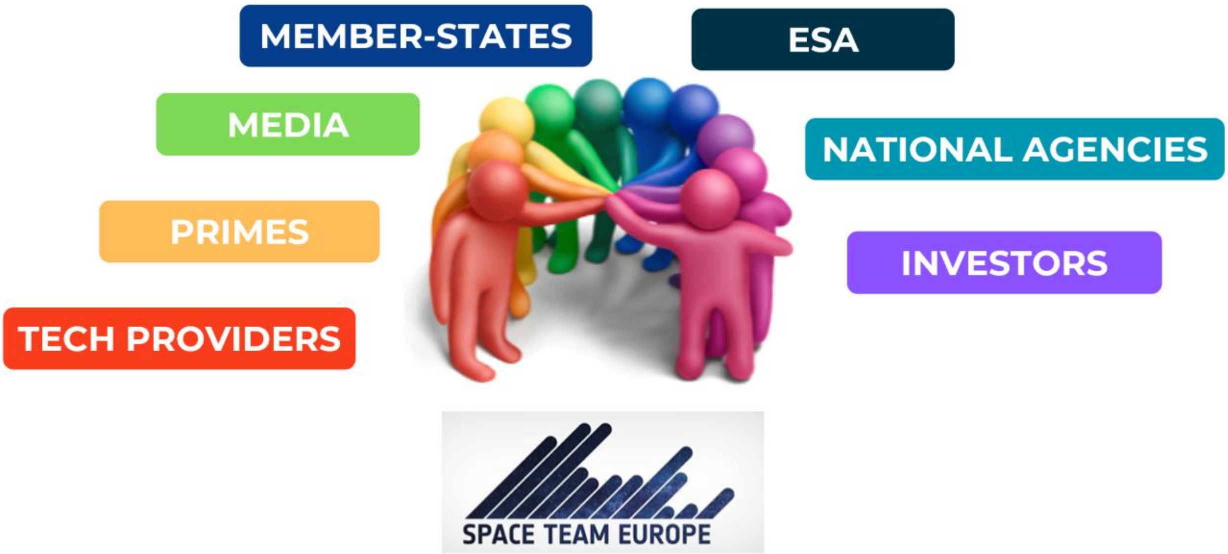

Figure 14: Space Team Europe

New actors and stakeholders are welcome to join this venture on in-space transportation. Feel free to reach out to do so.

References

[1] "ESA defines elements of future European space transportation solutions" https://www.esa.int/Enabling_Support/Space_Transportation/ESA_defines_elements_of_future_European_space_transportation_solutions

[2] "ESA sets sights on space transportation ecosystem" https://www.esa.int/Enabling_Support/Space_Transportation/ESA_sets_sights_on_space_transportation_ecosystem

[3] French Space Operation Act No. 2008-518 adopted on 3 June 2008, and related regulations and decrees.