IRUS Mission Update
Circular Economy (ORUM)

ISAM Workshop, ESTEC

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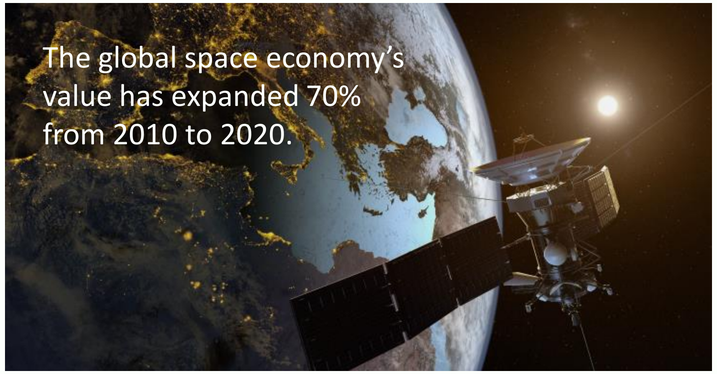
Astroscale – Led by Clear Opportunity

VISION

Safe and sustainable development of space for the benefit of future generations.

MISSION

Develop innovative technologies, advance business cases and inform international policies that reduce orbital debris and support the long term, sustainable use of space.



Situation

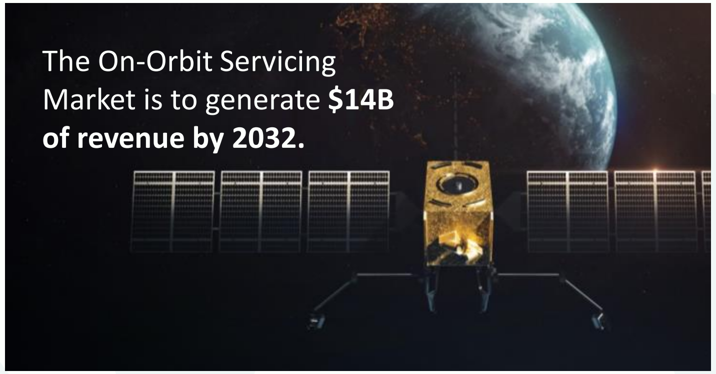
The global economy is more dependent on satellites than ever before for transportation, logistics, finance, agriculture, communications, and more.

Source: CNBC, "The space industry is on its way to reach $1 trillion in revenue by 2040, Citi says" | May 21, 2022

Problem

These satellites are not being refueled, recycled, repaired or removed, and are becoming orbital debris, putting the orbital environment and the global economy at risk.

Source: European Space Agency, "Space debris by the numbers" | August 11, 2020



Opportunity

Governments are already funding contracts to demonstrate debris removal/servicing and commercial industry players are looking for solutions that help keep the space environment safe.

Source: NSR IOSM 3-5, Morgan Stanley |
** $14bn represents cumulative revenue up to 2032.*

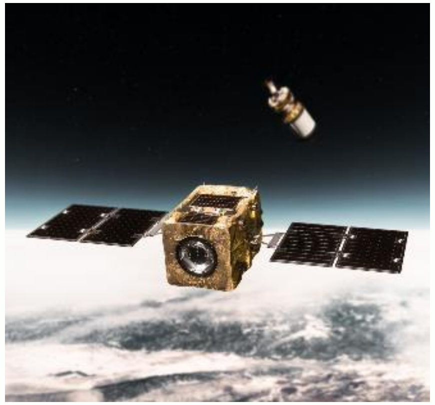
Multiple Capabilities, Multiple Orbits

Astroscale is the only company solely dedicated to providing on-orbit services across all orbital regimes

Life Extension, Fleet Management

LEX (GEO)

Keeping GEO satellites in operation after fuel depletion



In-Space Situational Awareness/Inspection

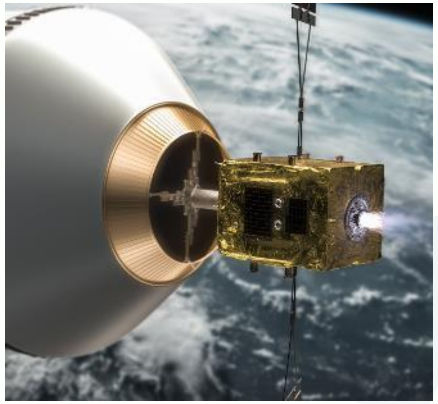
ADRAS-J, LEX

Surveying client objects and orbital environments at a variety of ranges

End-of-Life Services

ELSA-d, ELSA-M, LEX

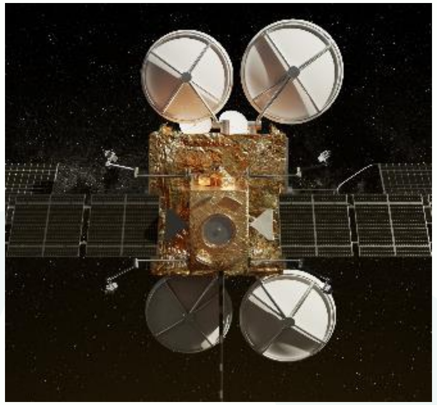
On-orbit maneuvers, last mile delivery, and de-orbiting prepared client spacecraft (docking plates)



Active Debris Removal

CRD2, COSMIC (UK ADR)

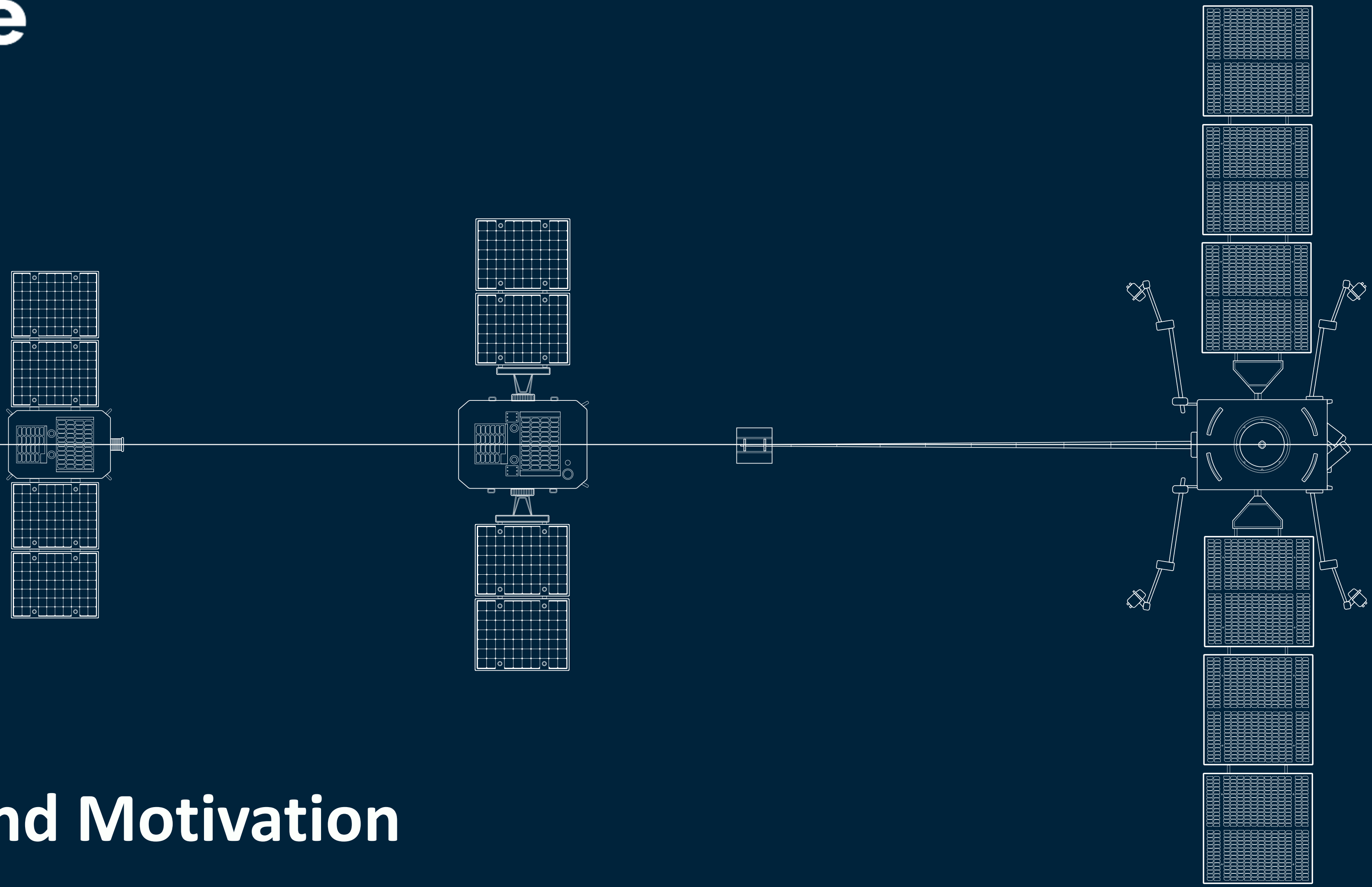
Reducing current debris by de-orbiting objects unprepared for servicing



Refurbishing, Upgrading, Refueling, Maintenance

IRUS, LEX (+ELSA-M variants)

Upgrading, refurbishment, refueling, repair, or assembly on-orbit



IRUS Context and Motivation

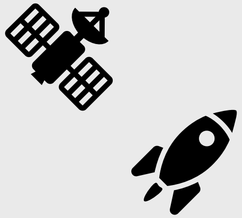
Context and Motivation

No commercial industry on Earth, except the space industry, is built on single use and disposal.

Logistics / Energy / Communications / Infrastructure Value Chain

Research & Development → Test & Manufacture → Sales → Operations → **Post-sales Servicing and Support (Repair, Inspection, Maintenance, Disposal)**

Spacecraft Value Chain

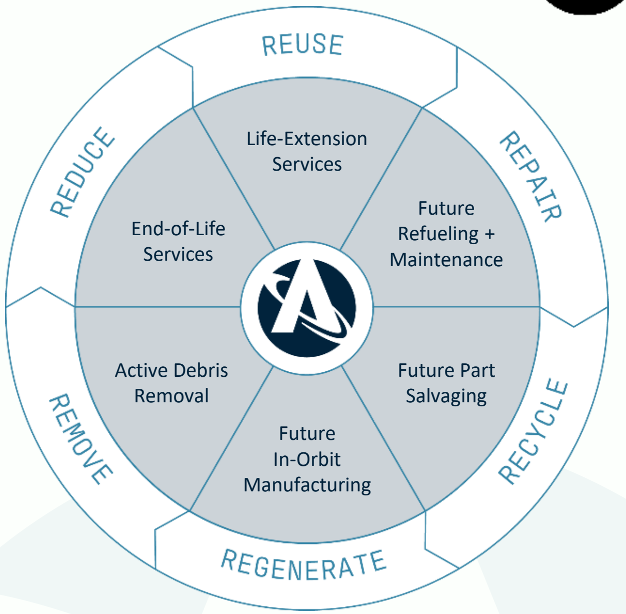


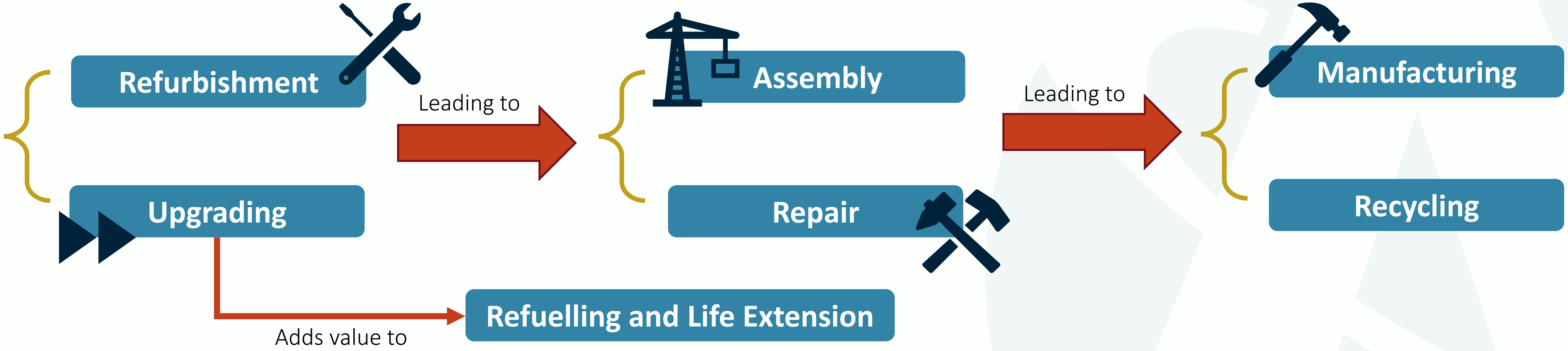
Research & Development → Test & Manufacture → Launch → Operations → *Debris Removal, Situational Awareness, Life Extension, Orbit Adjustments, Refueling, Maintenance and Repair*

In-Orbit Servicing

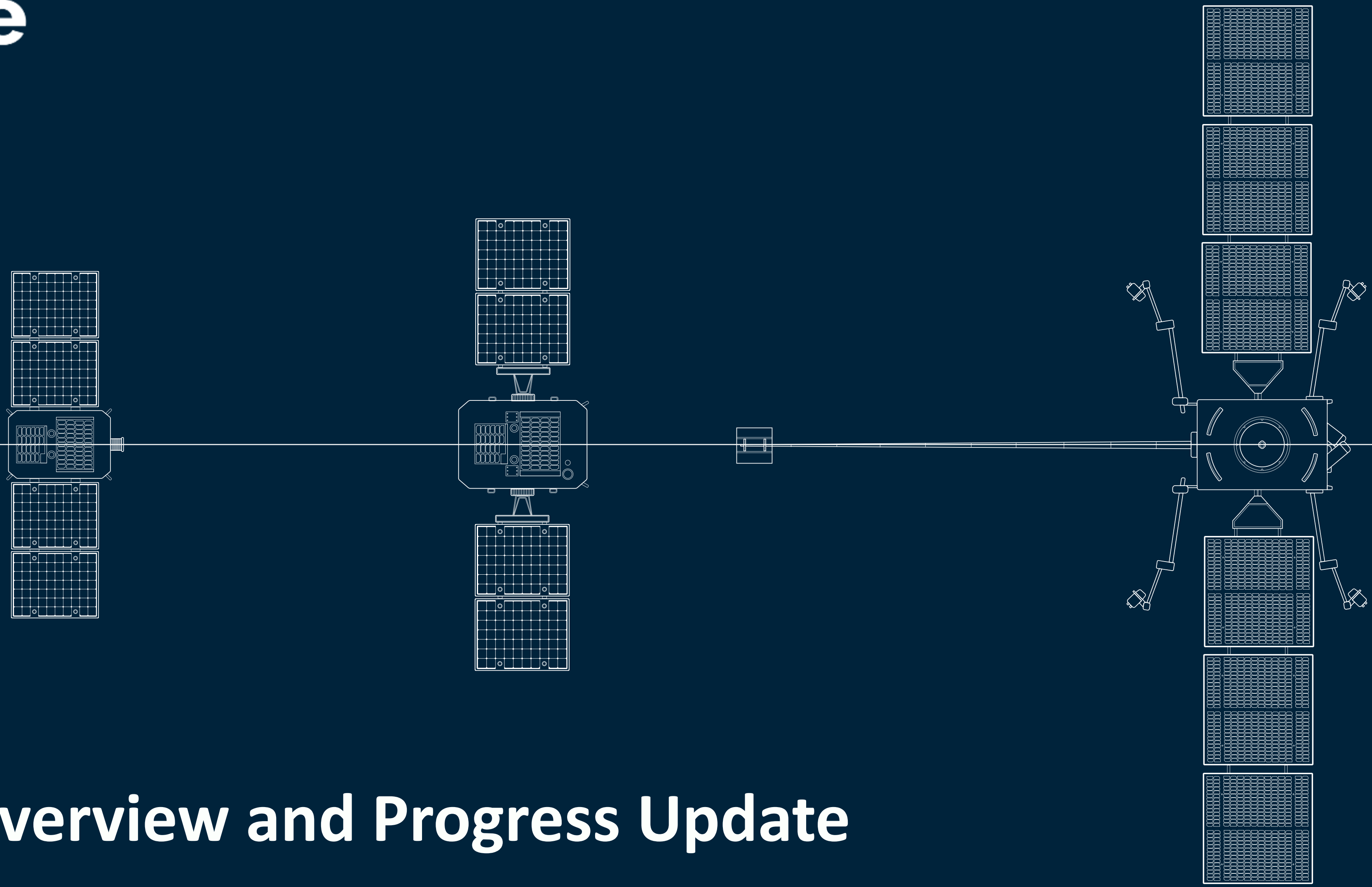
Context and Motivation

- A market for in-orbit servicing, assembly, refurbishment, manufacturing, and recycling are all part of the future of the space economy
- IRUS is paving the way for In-orbit Refurbishment and Upgrading Services
- **Refurbishment:** swapping out a damaged component with a new one
- **Upgrading:** replacing a component with another component that has improved capabilities.





IRUS Mission Overview and Progress Update



IRUS Overview and Progress Update

IRUS (In-orbit Refurbishment and Upgrading Service) is being developed as part of the ESA Circular Economy Programme (ORUM). Wider ESA COSMIC Programme.

The **client satellite** for the initial mission is BAE Systems' modular P30 platform.

We have begun **forming partnerships** with selected **robotics and interface companies.**

Progress update: IRUS was awarded an ESA's CDF session in Q1, which helped develop the mission concept. We are currently planning for the next phase, which will focus on designs for the interconnector, Servicer and container, in addition to business case development.

Service Level Objectives

Develop a **technically** and **economically** viable CONOPS that enables **refurbishment of multiple clients** in the context of future commercial constellation services.

Mature the **business model** considering the full lifecycle costs of refurbishment and upgrading services developing the **future circular space economy**, including market analysis, pricing policies, and commercial feasibility.

Define an **initial interface** that will enable a **standardised docking** approach between the servicer and the client.

Servicer Spacecraft Objectives

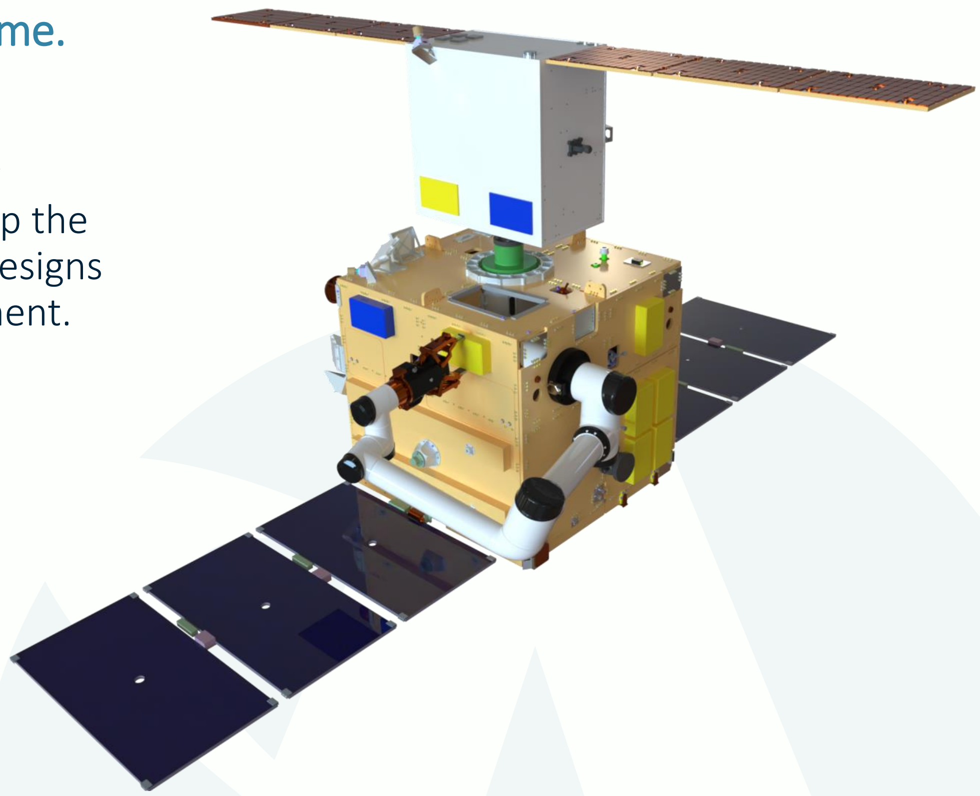
Develop an initial servicer spacecraft design that enables **targeted component refurbishment and upgrading** of the client spacecraft, leveraging relevant design considerations from the COSMIC platform.

Define a set of **functional requirements** and **operational constraints** for a robotic arm that features a **compatible standardised end-effector** that can be used for future refurbishment and upgrading missions.

Client Spacecraft Objectives

Develop an initial **client spacecraft** design focused on specific containerised units that enables **targeted component upgrading** by a robotic servicer.

Define an initial mechanical, electrical and thermal **interface** between the client spacecraft bus and the **containerised subsystem.**



Deciding Which Components to Upgrade

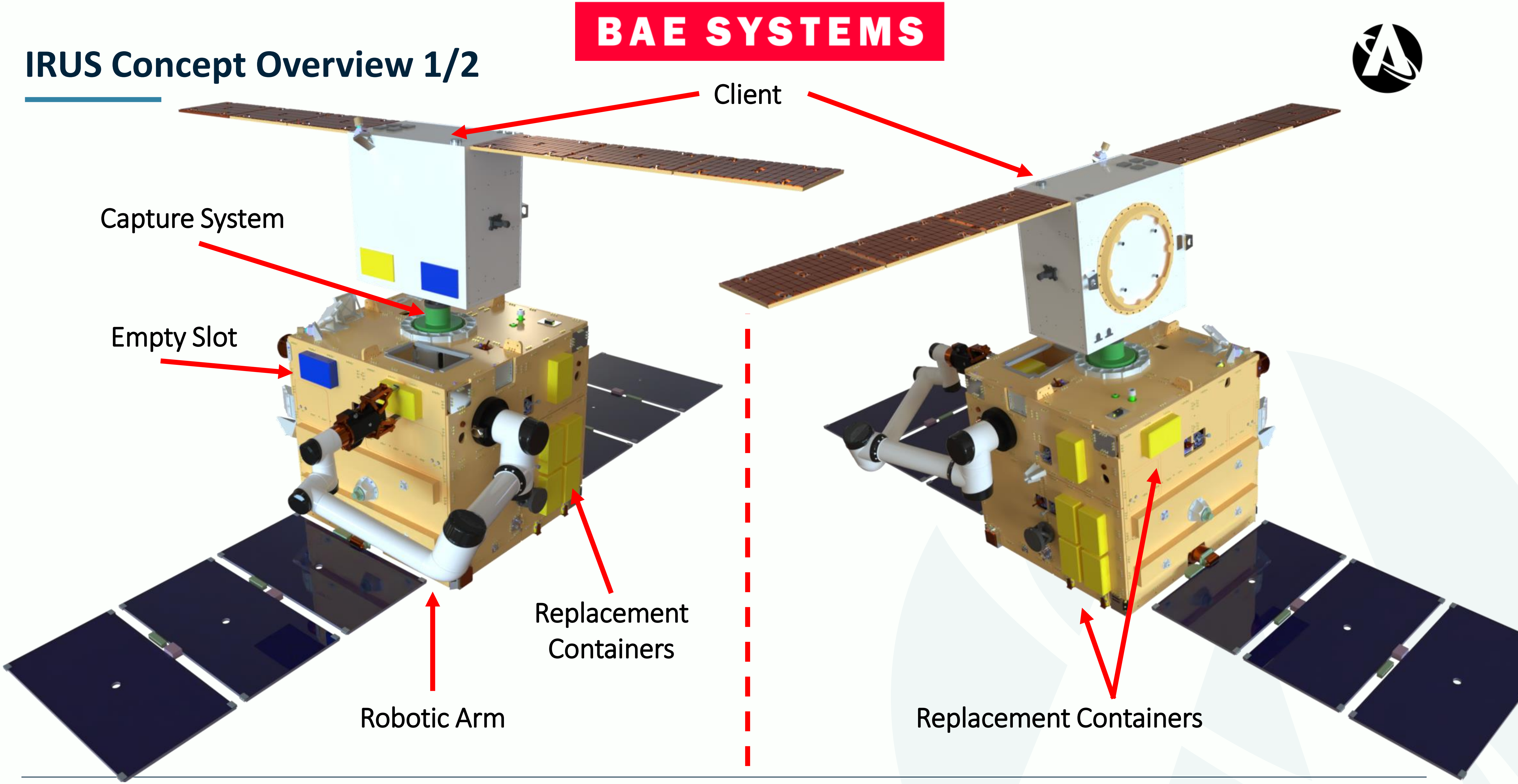
Various components were considered in terms of 'serviceability' and modularisation.

Our fault tree analysis showed batteries and on-board computer failures have knock-on effects on every other subsystem. And may be upgradable in 3-5 yrs.

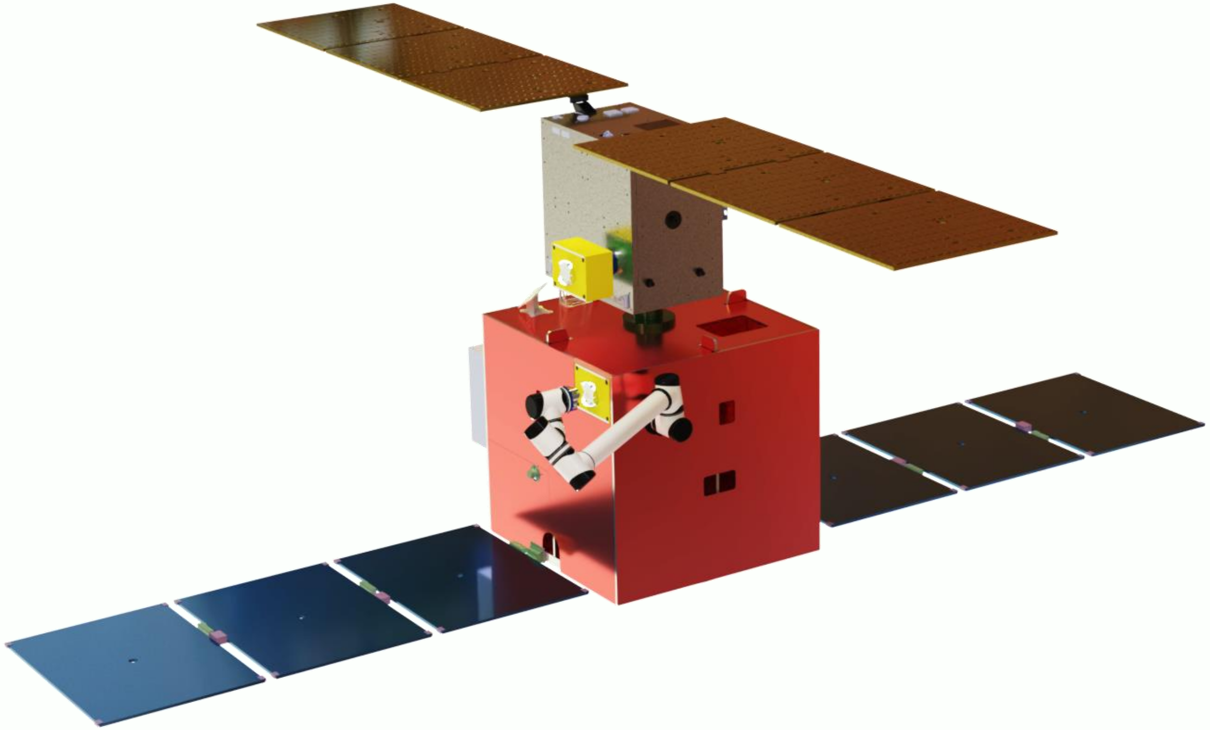
These components are serviceable and modularisable, but other options may be possible.

Component	Servicing Considerations	Path to Replaceability
Battery 	Li-ion batteries deteriorate over time even if inactive. Mechanical deformation of Li-ion batteries can result in shorting, leakage, venting and smoke emission. The impact on the client spacecraft when the existing battery is removed must be considered.	Must replace case with standardised unit container. Design/selection of suitable containers (refurb units) that can be manipulated in-orbit. Analysis of impact on other subsystems (particularly thermal) and on technical budgets.
Onboard Computer (OBC) 	Replacement of an individual processor chip is a delicate process that is not currently suited to the modular container approach. Replacing an entire OBC board offers the capability to upgrade multiple elements at once, e.g., installing a better performing processor along with a new mass memory unit with improved capacity.	The several data inputs/output for an OBC could be simplified with an interface board outside the SRU. The OBC will need a power interface with the platform. The next phase will determine whether this could be transferred over the same interconnector as for data. Analysis of impact on other subsystems (particularly for thermal and power) and on technical budgets.

IRUS Concept Overview 1/2

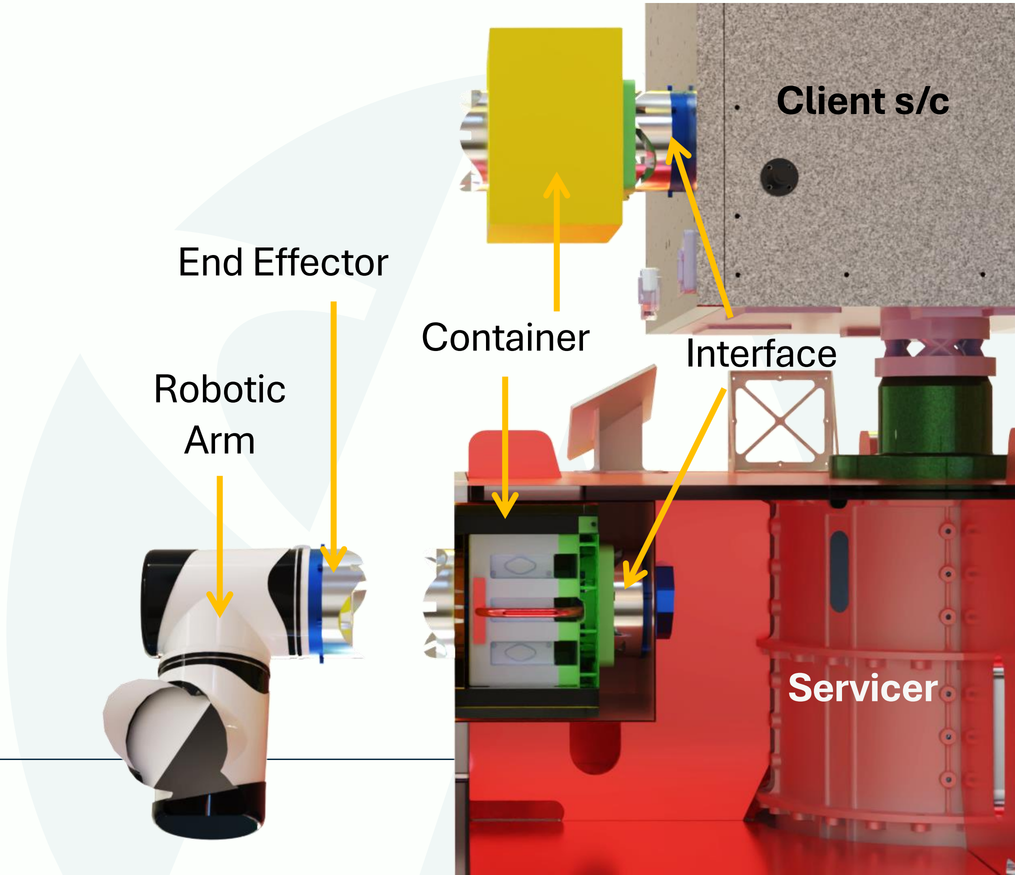


IRUS Concept Overview 2/2

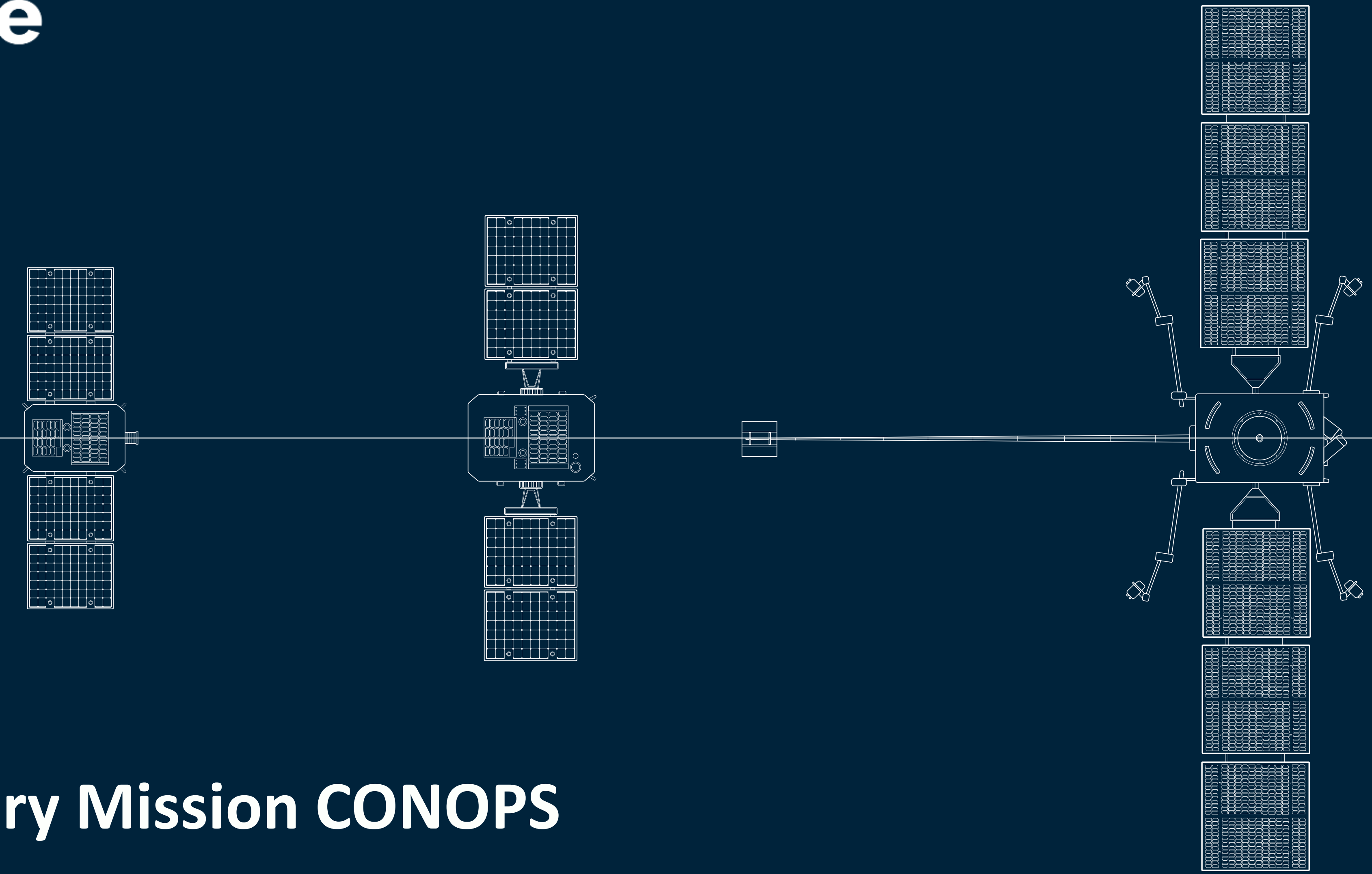


Key client spacecraft assumptions:

- Cooperative, active and prepared.

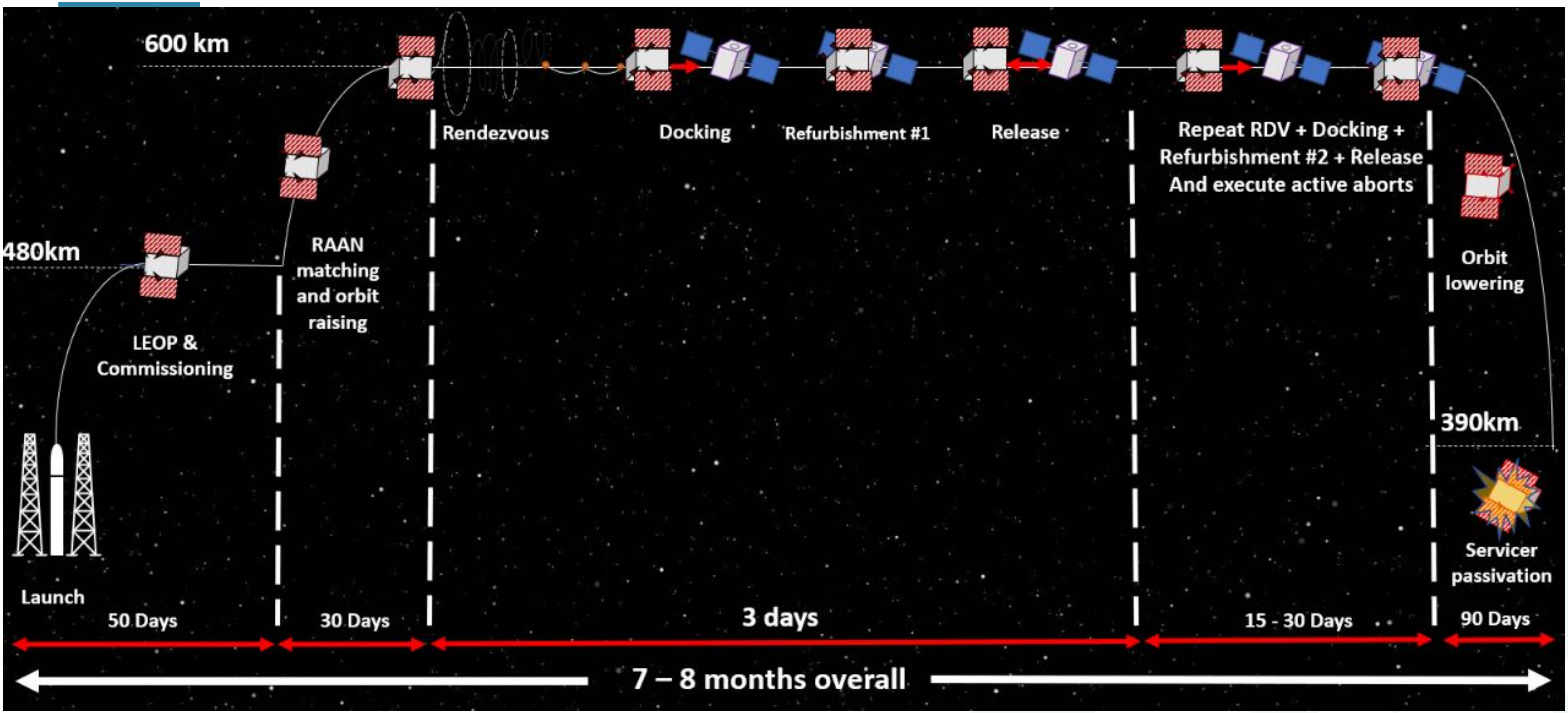


We are keen to engage with other potential client platform providers.



IRUS Preliminary Mission CONOPS

IRUS Initial Mission CONOPS



IRUS Mission Profile

IRUS is planned to launch in the next 5 years (~2030) and will demonstrate the following, thus proving a foundation for future in-orbit refurbishing and upgrading services:

IRUS will demonstrate...	Reasoning
Two client approaches	Increase the level of heritage.
Successfully capture a client tumbling at 0.5 deg/s	Expected max tumbling rate for an active cooperative client.
The capability to control the stack.	Critical for mission safety.
The refurbishment of at least one **cooperative client**	Keep the mission cost down with a single client.
The refurbishment of 2 priority component types	Increase the level of heritage.
At least one successful active abort while hard docked to the client and the subsequent recovery	Critical for full mission safety.
The capability to safely release the client.	Critical for full mission safety.

Rendezvous & Aborts

- As opposed to ELSA-M, in the case of IRUS the client is assumed to be active, in control of its attitude and capable of communicating its location
- This simplifies and shortens the rendezvous approach which can start a few km behind the client
- The servicer can use the GPS location of the client down to a couple hundred meters where platform sensors will begin identifying client features and switch to relative navigation
- The close approach and proximity operations phases are conducted using vision-based navigation
- Crucially, the propellant budget must account for several aborts at different stages in the rendezvous approach to ensure a safe mission
- Experience from missions such as ADRAS-J will help efficiently scale the budget for aborts and recoveries.

ELSA-M rendezvous and close proximity operations

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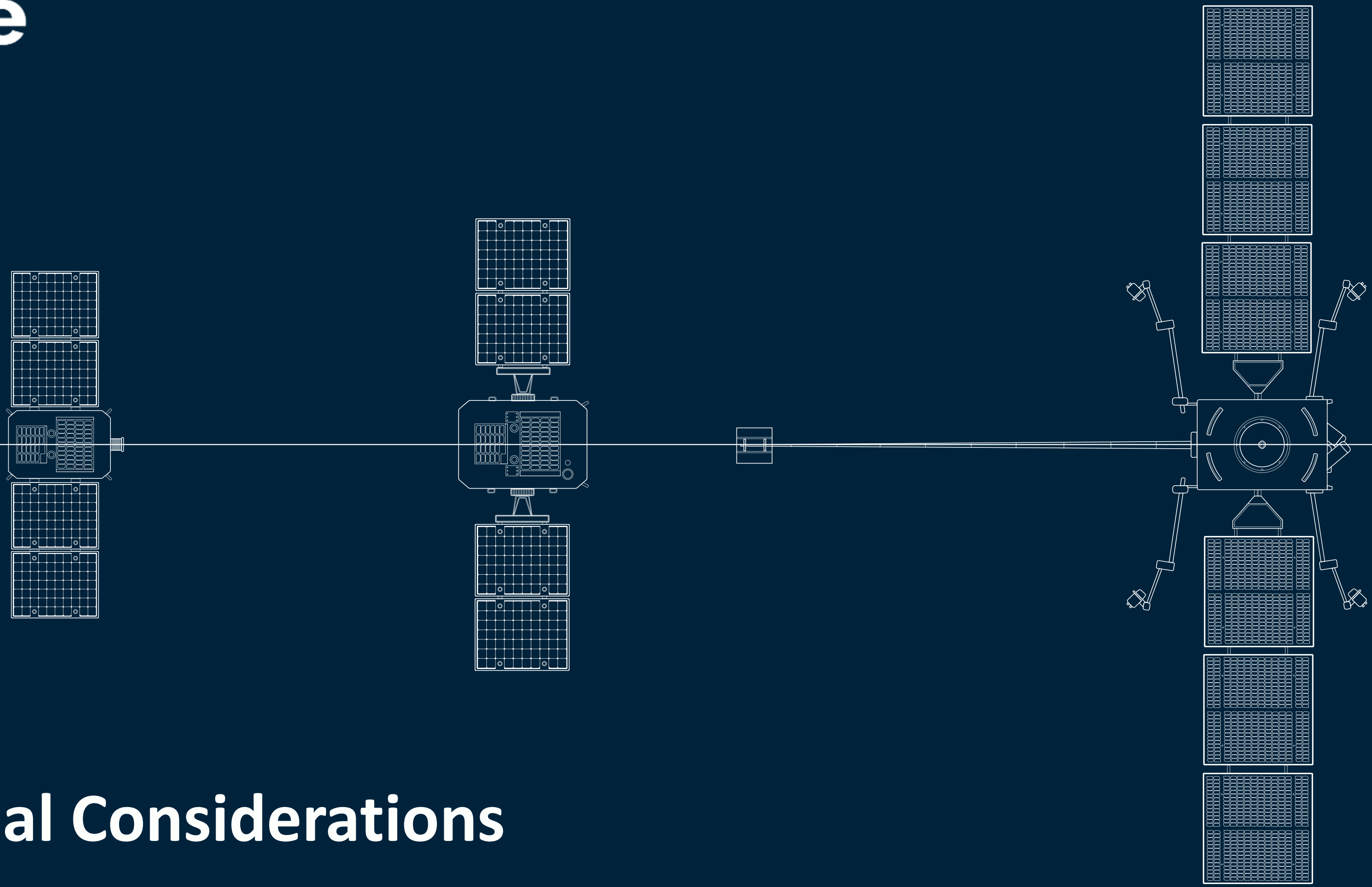
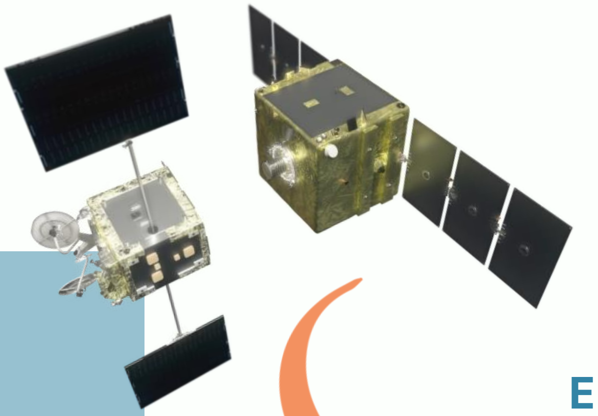


IRUS Commercial Considerations

IRUS is a Strategic Move to Unlock the Space Circular Economy

Enabled by on-going missions



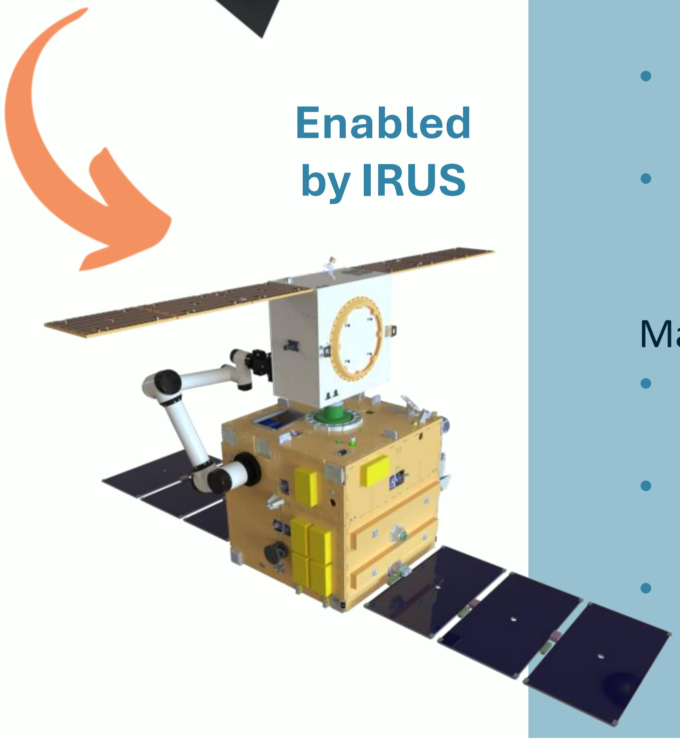
Core capabilities

- Heritage RPO and docking/capture
- Improved robotics
- Autonomous operations

Markets

- Active Debris Removal
- End of Life Services
- Life Extension
- Space Transport
- Inspection

Enabled by IRUS



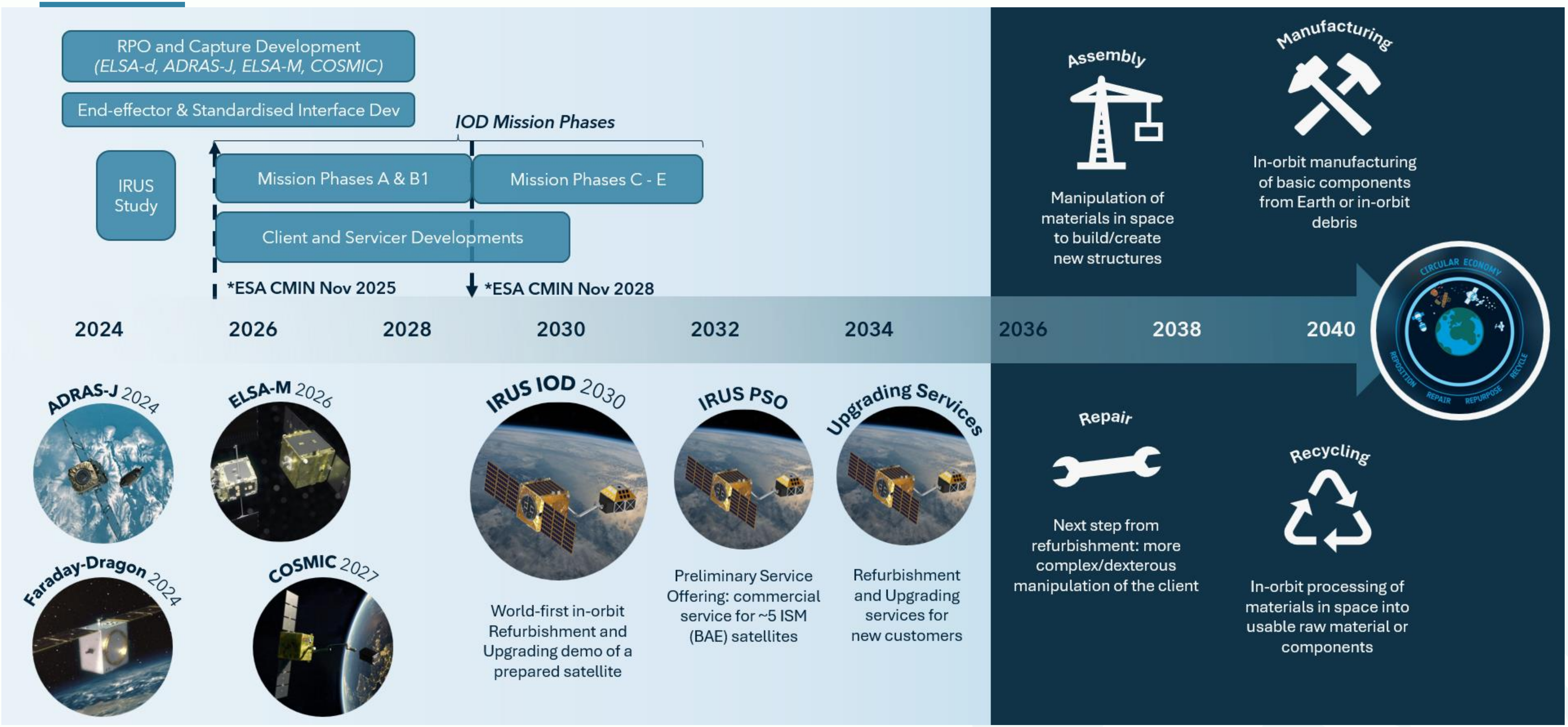
Core capabilities

- Next-level robotic manipulation
- Standardised interoperable interfaces
- Operations with a cooperative client
- Further heritage: RPO, capture, autonomous operations
- Developing critical understanding of the impact of robotics on whole service
- Enabling LOOP, ROBOFAB, and Recycling Space Plant

Market

- Commercial customer on-board from mission conception
- Significant value for LEO and GEO assets, especially constellations with a minimum of 3 spacecraft
- Incentivising future customers to prepare their assets

Commercial Development Roadmap



IRUS – Member State CMin 25 Approximate Asks

- Through CMin25, ESA plan to progress project to Phase B1 and unlock full mission funding at CM28.
- We require support to encourage ESA member states to back this crucial and enabling mission!
- We are keen to engage with suppliers of key enabling technologies for IRUS and future missions.

	Country	Ask (M€)
AT	Austria	-
BE	**Belgium**	0.5
CZ	Czech Republic	-
DK	Denmark	-
EE	Estonia	-
FI	Finland	-
FR	France	-
DE	**Germany**	1.5
GR	Greece	-
HU	Hungary	-
IE	Ireland	-
IT	Italy	-
LU	**Luxembourg**	1.0
NL	Netherlands	-

	Country	Ask (M€)
NO	Norway	-
PL	**Poland**	1.0
PT	Portugal	-
RO	Romania	-
ES	**Spain**	1.5
SE	Sweden	-
CH	Switzerland	-
GB	**United Kingdom**	6.0
CA	**Canada**	1.0
LV	Latvia	-
LT	Lithuania	-
SI	Slovenia	-
SK	Slovakia	-
Total		10.0 - 12.5M

Questions?

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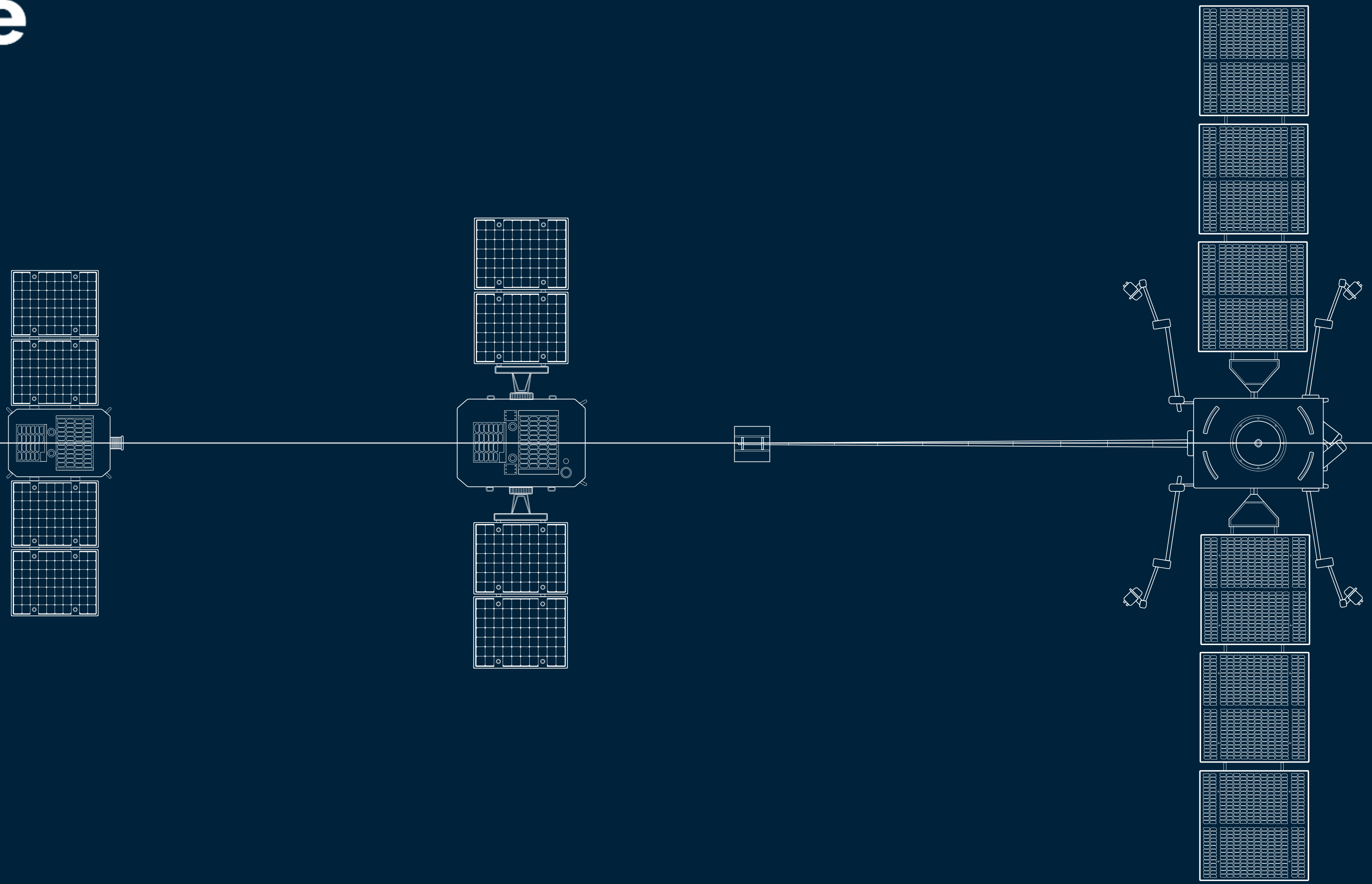

Annex Slides