

**Enabling the New Space Economy:
ISAM as a Pillar of Orbital Sustainability**

November 2025

Servicing | Sustainability | Financing the Future



Acknowledgement

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IIFCL PROJECTS LTD

Foreword



The dawn of the New Space Age has redefined humanity's engagement with outer space. What was once an exclusive pursuit of a few national space agencies has transformed into a dynamic and inclusive global ecosystem, driven by technological innovation, commercial ambition, and collaborative partnerships. As the boundaries of exploration expand and the economic potential of orbital activities becomes increasingly evident, it is imperative that sustainability and responsible utilization form the foundation of all space endeavours.

In this context, **In-Space Servicing, Assembly, and Manufacturing (ISAM)** has emerged as one of the most transformative developments of our time. By enabling spacecraft to be repaired, refueled, upgraded, and even assembled in orbit, ISAM represents a fundamental shift in the way we design, operate, and sustain our space infrastructure. It promises to extend the life of valuable space assets, reduce orbital debris, and catalyze new business models that will define the next era of the space economy. ISAM is not merely a technological innovation—it is a strategic imperative for ensuring the long-term viability and sustainability of our activities in space.

This report, “Enabling the New Space Economy: ISAM as a Pillar of Orbital Sustainability,” captures this transformative vision with clarity and depth. It reflects the collective understanding that the path towards a sustainable and self-reliant space future lies at the intersection of policy, technology, and finance. Through a comprehensive exploration of global frameworks, pioneering case studies, and innovative partnership models, the report highlights how ISAM can reshape the global space ecosystem and secure India's leadership in this emerging frontier.

The collaboration between the **Indian Space Association (ISpA)** and **IIFCL Projects Ltd (IPL)**, as highlighted in this report, represents a timely and strategic convergence of capabilities. ISpA, as the apex industry body representing the Indian space sector, continues to serve as a bridge between government, industry, and academia—driving policy advocacy, fostering innovation, and building platforms for international cooperation. IPL's expertise in structuring and financing Public–Private Partnership (PPP) projects, particularly in infrastructure development, brings a vital dimension to realizing India's vision for ISAM. Together, we have the opportunity to design sustainable financial and operational frameworks that will empower India's public and private stakeholders to co-develop, deploy, and sustain in-orbit servicing and manufacturing missions.

The international policy landscape for ISAM is evolving rapidly, with nations such as the United States, the United Kingdom, Japan, and members of the European Union formulating their own strategies to promote responsible and interoperable ISAM activities. This report situates India's emerging efforts within this broader global context, identifying opportunities for alignment, collaboration, and leadership. India's inherent strengths—cost-efficient engineering, mission reliability, and a rapidly maturing private space ecosystem—make it well-positioned to become a trusted global partner in shaping sustainable orbital operations.

Through a detailed examination of case studies such as NASA's Hubble Space Telescope servicing missions, Northrop Grumman's Mission Extension Vehicles, and the SPIDER (OSAM-1) program, the report illustrates how

ISAM technologies are already transforming the economics of space. These missions demonstrate that on-orbit servicing and assembly are no longer conceptual aspirations but operational realities. The insights drawn from these examples provide invaluable lessons for India and other emerging spacefaring nations as they embark on their own ISAM journeys.

Equally important is the report's focus on developing viable Public-Private Partnership models for ISAM. The challenges of financing, risk management, and long-term mission assurance require innovative frameworks that blend public policy support with private sector agility. The proposed PPP models, risk allocation mechanisms, and financing frameworks outlined here are designed to ensure that India's ISAM initiatives are sustainable, scalable, and globally competitive. They also reflect our shared belief that public-private collaboration is not just an option, but a necessity for building a resilient and inclusive space ecosystem.

As we look to the future, the principle of sustainability in space must remain at the forefront of every mission and initiative. Space is a global commons—finite, fragile, and vital to modern civilization. Our ability to safeguard this environment will determine the longevity of space-based services that underpin communication, navigation, climate monitoring, and national security. ISAM offers us a means to move from a “use and discard” paradigm to one of “repair, reuse, and renew.” It embodies the very essence of sustainable innovation, aligning technological advancement with environmental stewardship.

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Foreword



The global space sector is witnessing a transformative era—one that redefines the very nature of exploration, collaboration, and sustainability. As the world moves toward a new paradigm of orbital infrastructure, In-Space Servicing, Assembly, and Manufacturing (ISAM) emerges as the cornerstone of a resilient and sustainable space economy.

India stands uniquely positioned in this evolution. With decades of achievements in satellite development, launch systems, and remote sensing, the nation now enters a phase that demands integration of technology, finance, and policy. ISAM represents not just an engineering challenge, but an opportunity to embed sustainability, reusability, and long-term economic value into every orbital mission.

This report—developed collaboratively by the Indian Space Association (ISpA) and IIFCL Projects Ltd (IPL)—lays out the financial, institutional, and policy frameworks necessary to translate ISAM into reality. It draws upon international precedents such as NASA's Hubble Servicing Missions, Northrop Grumman's MEV program, and NASA-Maxar's SPIDER initiative to demonstrate that sustainability in orbit is achievable when innovation and financing move in tandem. The contributions of India's private sector, especially OrbitAID Aerospace with its pioneering work on the Standardized Interface for Docking and Refueling Port (SIDRP) and AayulSAT mission, reflect the nation's growing capacity for indigenous innovation in sustainable orbital operations.

At IIFCL Projects Ltd, we believe that the future of India's space ecosystem lies in the creation of a structured financial foundation—through PPPs, blended-finance mechanisms, and sustainability-linked instruments—that can de-risk innovation while ensuring accountability. The proposed Space Sustainability and ISAM Financing Facility aims to catalyse this transformation by aligning capital with purpose and growth with responsibility.

As India advances its leadership in the global space ecosystem, our approach must remain anchored in one essential principle: **to design, operate, and steward space in a manner that safeguards the long-term stability and sustainability of the orbital environment.** By leveraging India's strengths in engineering, remote sensing, launch vehicle capabilities, and its emerging PPP-driven financing architecture, the nation is well-positioned to set new benchmarks in responsible space operations. Through coordinated efforts between government, industry, and financial institutions, India can ensure that ISAM evolves not only as a technological breakthrough, but as a model for sustainable growth. This collective vision—shaped by ISpA and IIFCL Projects Ltd—offers a clear pathway to a future where every mission enhances resilience, protects orbital assets, and strengthens India's role as a champion of sustainable space development.

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Enabling the New Space Economy: ISAM as a Pillar of Orbital Sustainability

Abstract

This report explores the role of In-Space Servicing, Assembly, and Manufacturing (ISAM) in enabling a sustainable and resilient new space economy. As operations expand into the cislunar domain, and as orbital infrastructure becomes increasingly commercialized, ISAM technologies support asset life extension, modular infrastructure, and on-orbit manufacturing. The idea of this report is to understand the purpose of space sustainability and in-orbit servicing.

Building upon this foundation, the report underscores the strategic potential of the collaboration between the Indian Space Association (ISpA) and IIFCL Projects Ltd (IPL) in advancing ISAM (In-Space Servicing, Assembly, and Manufacturing) capabilities. ISpA's leadership in policy advocacy and its sustained engagement with diverse stakeholders serve as a catalyst for facilitating the exchange of knowledge, technological advancements, and best practices within the space domain. When combined with IPL's expertise in structuring public-private partnerships, particularly in the space sector, this collaboration can effectively leverage India's strengths in cost-efficient engineering, rapid scalability in satellite and launch vehicle manufacturing, and evolving PPP models. Together, these competencies create a robust framework for co-developing servicing missions, harmonizing regulatory standards, and designing innovative financing mechanisms that embed sustainability into orbital infrastructure from inception. This partnership positions India's space sector to play a leading role in shaping the future of the global new space economy.

1. Introduction

1.1. Sustainability in Space Industry





Space plays an increasingly crucial role in our daily lives, and the issue of space debris looms large on the horizon. Imagine a scenario where everyday services like TV, navigation, weather forecasting, and online banking are disrupted due to a satellite collision. This is a rising concern and that is why the government is taking bold steps to mitigate the risks associated with space debris by investing in national capabilities and international cooperation.

The space industry is experiencing unprecedented growth, with over 11,000 active satellites in orbit and 18,000 more projected by 2030. This surge, driven by commercial constellations and deep space ambitions, has intensified concerns about orbital congestion and space debris. According to European Space Agency's (ESA's) 2025 Space Environment Report, over 1.2 million debris objects larger than 1 cm are estimated to be in orbit, enough to cause catastrophic damage. Traditional space operations follow a linear model: launch, operate, and discard, which is not viable in terms of sustainability. Satellites often become defunct after their mission ends, contributing to a growing debris field that threatens future missions and risks triggering the Kessler Syndrome, a chain reaction of collisions².

To address this, the industry must transition towards a sustainable, circular space economy, where resources are reused, refurbished, and recycled in orbit. European Space Agency (ESA) defines this as a system enabling the refurbishment, manufacturing, and recycling of space systems using advanced in-orbit servicing technologies. ISAM (In-Space Servicing, Assembly, and Manufacturing) is central to this shift. ISAM enables:

- Satellite life extension
- Orbital construction
- In-situ manufacturing
- Reducing launch frequency
- Enhance mission flexibility
- Supports long-term space sustainability

ISAM offers a wealth of opportunities for the Indian Space sector – from extending the working lives of satellites by refuelling and repairing them, to the manufacture of large structures in space including space stations and space-based solar power farms. The sector can also take advantage of microgravity conditions to manufacture products that simply cannot be created on earth including novel pharmaceuticals and new composites and alloys.

Through collaboration and innovation, Indian leadership in building a thriving space economy can be secured, leaving a legacy of prosperity whilst delivering environmental, economic, scientific and other benefits for the country and the wider global population.

1.2. Importance of ISAM in the Future of Space Economy

The exponential growth of space activities over the past two decades has transformed outer space into a critical domain for scientific exploration, economic development, and national security. However, this expansion has also introduced pressing sustainability challenges, including orbital congestion, space debris accumulation, and the inefficiency of single-use spacecraft.

ISAM offers a transformative solution to these challenges. By enabling the maintenance, construction, and production of space infrastructure directly in orbit, ISAM shifts the paradigm from “launch-and-dispose” to a more circular and resilient space economy. These capabilities not only extend the operational life of satellites and reduce the frequency of launches but also support the development of

large-scale structures that are impractical to launch from Earth. ISAM encompasses a suite of advanced technologies, including autonomous robotics, modular spacecraft design, additive manufacturing, and AI-driven navigation systems which facilitate satellite servicing (e.g., refuelling, repairs), orbital assembly of complex structures (e.g., antennas, telescopes), and manufacturing using in-situ resources or recycled materials.

The strategic importance of ISAM is underscored by its potential to reduce mission costs, enhance flexibility, and mitigate space debris through proactive asset management. Moreover, ISAM supports long-duration missions and infrastructure development for lunar and Martian exploration, aligning with broader goals of space sustainability such as Space Debris Mitigation.

This report explores ISAM's role in advancing space sustainability, analyzing its technological foundations, policy landscape, economic implications, and strategic relevance. Through case studies, expert insights, and forward-looking recommendations, it aims to provide a comprehensive roadmap for stakeholders across government, industry, and academia. Ultimately, it advocates for ISAM as a cornerstone of a sustainable and inclusive space future and future space economy.

1.3. Strategic Objectives of the Report

The objectives are designed to provide a comprehensive understanding of ISAM's role in shaping a resilient, efficient, and environmentally responsible space ecosystem. Specifically, the report seeks to:

- i. **Position ISAM as a Pillar of Space Sustainability-** Establish ISAM as a foundational capability for reducing space debris, extending space asset lifespans, and enabling circular space operations.
- ii. **Promote Strategic Autonomy and Infrastructure Resilience-** Emphasize ISAM's role in reducing Earth-dependence, enhancing mission flexibility, and enabling autonomous infrastructure development for deep space missions. ISAM enhances mission flexibility, allowing for in-situ repairs, upgrades, and reconfiguration of assets without the need for costly relaunches. It supports redundancy and resilience, ensuring that critical systems can be maintained or replaced in orbit, even in the event of failure. Ultimately, ISAM contributes to strategic autonomy by empowering nations and commercial actors to build, maintain, and evolve space infrastructure independently, fostering a more robust and secure space ecosystem.
- iii. **Support Circular Space Economy-** Provide a roadmap for integrating ISAM into a closed-loop space ecosystem, where assets are reused, materials are recycled, and orbital logistics are optimized for sustainability and mission resilience. By facilitating on-orbit manufacturing and component-level recycling, ISAM supports the creation of modular, adaptable infrastructure that can evolve with mission needs. This approach aligns with the principles of a circular economy, promoting long-term resilience and environmental stewardship in space. ISAM can help establish resource recovery systems for placed satellites and debris, turning obsolete hardware into usable material. The integration of ISAM into orbital logistics also enhances mission planning efficiency, reduces operational costs, and supports the development of self-sustaining infrastructure in cislunar and deep space environments.
- iv. **Analyze the Technological Foundations to Drive Investment and Innovation-** Highlight ISAM's market potential to attract investment and stimulate innovation in robotics, autonomous systems, and in-orbit manufacturing technologies.



- v. **Establish Metrics for Sustainable ISAM Operations-** Propose measurable indicators for evaluating the environmental, economic, and operational sustainability of ISAM activities, enabling data-driven decision-making and accountability.
- vi. **Catalyze Investment and Industrial Momentum-** Encourage Public Private Partnership (PPP) model of investment in ISAM technologies and foster partnerships between space agencies, commercial entities, and academic institutions to accelerate development and deployment.
- vii. **Influence Policy and Regulatory Evolution-** Advocate for the creation of international norms, licensing frameworks, and safety protocols that support ISAM activities while ensuring responsible behavior and long-term orbital stewardship.
- viii. **Shape the Global Discourse on Space Sustainability-** Contribute to international discussions on sustainable space development by offering a strategic, technology-driven perspective centered on ISAM, aligned with global sustainability goals. It should include awareness campaigns, workshops, and capacity building initiatives for ISAM projects.

1.4. Challenges to Overcome

- (a) **Finance**
 - **High upfront costs:** Developing and deploying ISAM technologies and infrastructure requires significant initial investment.
 - **Uncertain return on investment:** The long-term economic benefits of ISAM are still being explored, making it challenging to secure funding from investors and stakeholders.
 - **Lack of established business models:** ISAM is a relatively new field, and viable business models for commercial operations are still emerging.
- (b) **Technology**
 - **Technological complexity:** ISAM involves various advanced technologies, which require extensive research and development.
 - **Compatibility and standardization:** ISAM systems need to be compatible with different spacecraft designs, which requires standardization and collaboration.
- (c) **Commercial**
 - **Market demand and acceptance:** The commercial viability of ISAM depends on the demand for services from satellite operators and space agencies, which are influenced by factors such as cost-effectiveness, risk perception, and regulatory considerations.
 - **Competition from traditional approaches:** ISAM must compete with other approaches to satellite replacement and maintenance, which may be more established and less risky.
- (d) **Regulation**
 - **Legal and policy frameworks:** ISAM operations raise various legal and policy questions related to liability, ownership, and responsibility, which require clear regulatory frameworks.
 - **International cooperation and governance:** ISAM requires international cooperation and governance mechanisms to ensure compliance with international laws and treaties.

2. International Policy Frameworks for ISAM

Several countries have taken proactive steps to develop national strategies, licensing frameworks, and regulatory mechanisms to support and shape ISAM activities.

2.1. United Kingdom

- i. The United Kingdom (UK) has positioned itself as a forward-thinking leader in ISAM policy, combining strategic ambition with regulatory modernization. Its approach is characterized by clear legal frameworks, industry-government collaboration, and a vision for global competitiveness in space sustainability and servicing technologies through regulatory modernization and public-private partnerships.
- ii. **National Space Strategy and Space Industrial Plan:** The National Space Strategy and Space Industrial Plan identify ISAM as a priority capability area. These documents articulate the UK's ambition to:
 - Build one of the most innovative and attractive space economies globally.
 - Develop resilient national space capabilities, including ISAM.
 - Promote space sustainability through servicing and debris mitigation.
- iii. **UK Space Agency's ISAM Roadmap to 2035:** At the ISAM 2025 Conference in Belfast, the UK Space Agency (UKSA) highlighted a strategic roadmap aiming to:
 - Deliver safe, reliable, and repeatable in-orbit services by 2035.
 - Develop a competitive ISAM supply chain and skills base.
 - Position the UK as a global leader in In-orbit Servicing, Assembly & Manufacturing.

2.2. Europe

- i. The EU Space Act is a legislative initiative by the European Commission that introduces a harmonised framework for space activities across the Union. The Act introduces robust rules for tracking space objects and mitigating space debris, preserving Europe's secure and uninterrupted access to space.
- ii. **Clean Space Initiative:** ESA's Clean Space Initiative is a cornerstone of Europe's approach to sustainable space operations. It is structured around four roadmaps:
 - **Eco-design** – Integrating environmental considerations into spacecraft design.
 - **Green Technologies** – Promoting low-impact materials and systems.
 - **Space Debris Mitigation** – Developing guidelines and technologies to prevent debris generation.
 - **Space Debris Remediation** – Active removal of debris using ISAM capabilities.



2.3. United States

- i. **ISAM National Strategy (April 2022):** The ISAM National Strategy, developed by the National Science and Technology Council (NSTC), outlines the U.S. government's vision to lead globally in In-Space Servicing, Assembly, and Manufacturing (ISAM) capabilities. It identifies six strategic goals:
 - Advance ISAM R&D – Foster innovation across robotics, autonomy, and modular systems.
 - Expand Scalable ISAM Infrastructure – Develop testbeds, launch platforms, and orbital facilities.
 - Accelerate Commercial ISAM Industry – Support startups and incentivize private investment.
 - Promote International Collaboration – Align with allies on standards and joint missions.
 - Prioritize Environmental Sustainability – Integrate debris mitigation and lifecycle planning.
 - Inspire the Future Space Workforce – Build educational pipelines and interdisciplinary programs.
- ii. **ISAM Implementation Plan (December 2022):** The ISAM Implementation Plan operationalizes the strategy through 28 discrete activities across federal agencies. Key highlights include:
 - Standards Development: Encourages adoption of interoperable servicing interfaces and safety protocols.
 - Infrastructure Gap Analysis: Identifies needs for ground and orbital ISAM testing facilities.
 - Mission Planning: Supports NASA and DoD in developing ISAM-enabled architectures.
 - International Engagement: Promotes ISAM norms through bilateral and multilateral forums.
 - Workforce Development: Funds educational initiatives and interdisciplinary training.
- iii. The U.S. also supports industry-led initiatives like Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) and Consortium for Space Mobility and ISAM Capabilities (COSMIC), which develop servicing standards and coordinate ISAM capabilities.

2.4. Japan

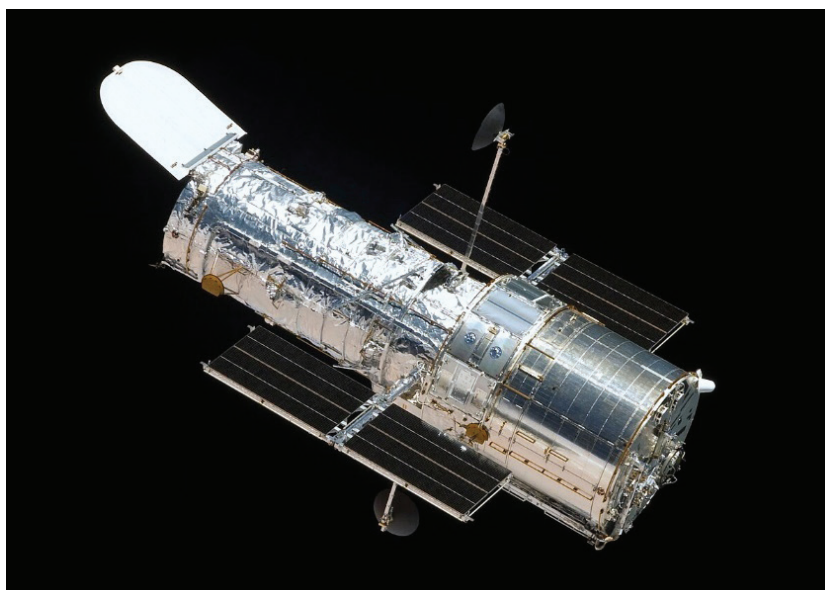
- i. Japan has issued Guidelines in 2021 for Licensing Spacecraft Performing On-Orbit Servicing. These guidelines ensure safety, transparency, and accountability in ISAM missions and reflect Japan's commitment to enabling commercial servicing technologies. The guidelines include the following aspects of ISAM:
 - Rendezvous and Proximity Operations (RPO)
 - Servicing Activities (e.g., refueling, repair, inspection)
 - Separation and Disposal Procedures

- ii. **International Standardization Strategy (2025):** Japan's government launched a strategy to align domestic ISAM standards with global norms. It emphasizes interoperability, safety, and resilience. Key goals of this strategy include:
- Promoting interoperable docking interfaces
 - Establishing safety protocols for servicing operations
 - Defining data exchange formats for autonomous systems

3. ISAM Case Studies

3.1. Case Study 1: NASA's Hubble Space Telescope Servicing Missions

The Hubble Space Telescope (HST), launched in 1990, is one of the most iconic astronomical observatories in history of mankind. Orbiting the Earth at an altitude of ~547 km, Hubble has provided unprecedented views of the universe. However, its long-term success was made possible by a series of servicing missions conducted by NASA, which involved astronauts performing complex repairs and upgrades in space.



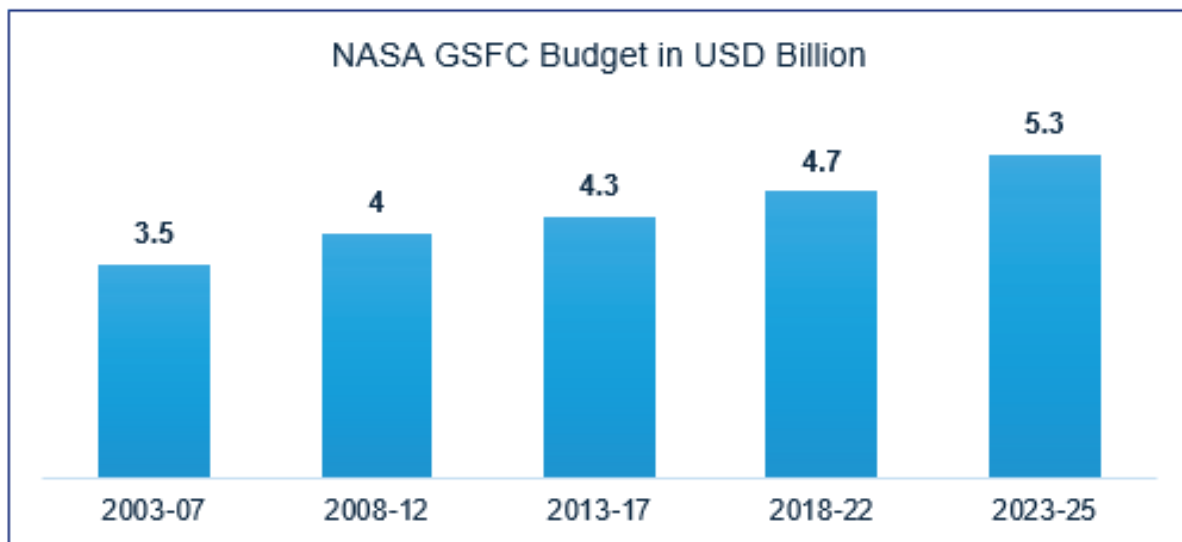
Geared-up Hubble Space Telescope in Orbital Motion
Source: [newscientist.com/article/2141982](https://www.newscientist.com/article/2141982)

NASA Goddard Space Flight Center (GSFC) and Space Telescope Operations Control Center (STOCC): GSFC is the lead NASA center responsible for the management, operations, and servicing of the Hubble Space Telescope. It oversees mission planning, hardware development, and coordination of servicing missions. Located within GSFC, STOCC serves as Hubble's mission control. It handles real-time spacecraft operations, monitors system health, and executes commands for scientific observations. STOCC played a central role during all five servicing missions, ensuring seamless coordination between astronauts and ground systems.

Annual Budget Scale and Distribution- GSFC operates with an annual budget nearing \$5 billion, making it one of NASA's largest and most economically impactful centers. In FY2023, the direct budget was approximately \$4.2 billion, with an additional \$850 million allocated through interagency agreements. Over 80% of GSFC's budget is invested directly into American businesses, academia, and nonprofit organizations, reflecting its commitment to national economic stimulation. Based on NASA's official



reports and publications, below is the year-wise summary of NASA Goddard Space Flight Center (GSFC) budget allocations from 2003 to 2025:



NASA GSFC Budget Allocation in USD Billion (2003–2025)

3.1.1. Need for Servicing Missions

Shortly after launch, Hubble Space Telescope was found to have a flawed primary mirror, which severely limited its imaging capabilities. This defect catalyzed the development of a servicing strategy using the Space Shuttle program. Over a period of 16 years from 1993 to 2009, NASA GSFC executed five servicing missions (SM):

- **SM1 (1993):** SM1 was a rescue mission to protect NASA's \$1.5 billion investment in Hubble. Installing corrective optics restored the telescope's viability, saving the program and NASA's reputation.
- **SM2 (1997):** Delaying the need for a costly replacement for technical upgrades in Hubble to remain competitive with ground-based observatories.
- **SM3A (1999):** Reducing long-term software maintenance costs, based on a cost-effective life-extension strategy.
- **SM3B (2002):** Maximization of scientific return per dollar by simultaneous operation of four Hubble instruments for boosting productivity.
- **SM4 (2009):** Ensuring continued scientific output without launching a new telescope, making SM4 a strategic investment in financial sustainability and cost avoidance.



Timeline of Servicing Missions of NASA for Hubble Space Telescope since its Deployment

Source: newspaceeconomy.ca/2023

3.1.2. Commercial Objectives of Servicing Missions

- SM1 (1993): To justify continued investment in Hubble by correcting its optical flaw through cost-effective modular upgrades, thereby preserving the value of NASA's \$1.5 billion investment in the telescope. It was achieved by leveraging private contractors for rapid hardware fixes. The mission justified continued investment in Hubble and validated modular servicing design, which encouraged future commercial servicing models.
- SM2 (1997): Strengthening NASA's procurement partnerships with U.S. industry for high-performance components, thereby extending mission life without the cost of a new observatory.
- SM3A (1999): Cost-effective rapid mission planning, highlighting NASA's agile contracting and budgeting capabilities. It aimed to rapidly restore Hubble's operational capability with a \$136 million mission budget, using off-the-shelf commercial components and a faster onboard computer to reduce long-term software maintenance costs.
- SM3B (2002): To maximize scientific output per dollar by installing the advanced components, all while managing the risks and costs of Hubble's first full power-down.
- SM4 (2009): To extend Hubble's operational life into the 2020s through a final investment in new instruments (WFC3 and COS), in-orbit repairs, and sustainability upgrades, ensuring continued scientific returns without the cost of a replacement telescope.

3.1.3. Funding of Servicing Missions

- Instead of replacing Hubble, NASA chose to invest in modular servicing, which proved to be significantly cheaper and more sustainable than launching a new telescope.



Servicing Mission	Budget Amount	Source of Information
SM1, 1993	\$629 million	NASA Technical Mission Report for STS-61
SM2, 1997	\$581 million	GAO Report GAO-05-34
SM3A, 1999	\$172 million	NASA STS-103 Mission Overview
SM3B, 2002	\$706 million	NASA SVS Archive for SM3B
SM4, 2009	\$1.1 billion	NASA Science Mission Overview for SM4
Total Estimate of All Servicing Missions	\$3.2 billion	

3.1.4. Procurement Process of Servicing Missions

- NASA's Procurement Strategy: NASA's Office of Procurement oversees all procurement activities and procurement strategies, across its centers.
- Contracting Authority: NASA Goddard Space Flight Center (GSFC) served as the contracting authority.

Procurement Process of Servicing Mission 1 (SM1):

Mission	Selected Contractor	Selection Process	Contract Type
SM1 	- Ball Aerospace (COSTAR and WFPC2) - Tinsley Laboratories (Precision Corrective Mirrors for COSTAR) (Coherent TIOS) - Lockheed Martin (Shuttle Integration)	- Competitive bidding - Sole-source bidding - Empanelment with NASA	Cost-plus-fixed-fee modular contract, Modular Subcontract, Task order under an existing IDIQ (Indefinite Delivery, Indefinite Quantity) contract.
SM2 	- Ball Aerospace (NICMOS and STIS) - Lockheed Martin (Spacecraft systems engineering and hardware refurbishment) - United Space Alliance (Shuttle operations and logistics)	- Competitive bidding - Continued engagement through contract extension - Sole-source bidding	Cost-plus-fixed-fee modular contract, Task order under an existing IDIQ (Indefinite Delivery, Indefinite Quantity) contract, Cost-reimbursement contract with award and performance fees.

Mission	Selected Contractor	Selection Process	Contract Type
SM3A 	- Lockheed Martin (Mission planning, shuttle integration.) - Honeywell Technology Solutions (Systems engineering, avionics) - L3 Space & Navigation (Manufacture and redesign of gyroscopes) - Ball Aerospace (Fine Guidance Sensor (FGS) refurbishment) - IBM Federal Systems (New onboard computer) - Raytheon (Solid State Recorder and S-Band transmitter systems) - United Space Alliance (Shuttle operations and astronaut EVA training)	Sole-source bidding for all contractors	Cost-plus-fixed-fee contract, Sole-Source, Cost-Reimbursable Cost-Plus-Award-Fee (CPAF), Cost-Plus-Incentive-Fee (CPIF)
SM3B 	- Ball Aerospace (Advanced Camera for Surveys) - ITT Industries (Components for NICMOS Cryocooler) - Raytheon Technologies (Power Control Unit) - Lockheed Martin (Shuttle integration, mission planning) - Honeywell Technology Solutions (Systems Engineering and avionics) - L3 Space & Navigation (Gyroscopes and reaction wheel assemblies) - United Space Alliance (Shuttle operations, astronaut training, and EVA simulations)	Sole-source bidding for all contractors	Cost-Plus-Award-Fee (CPAF), Cost-Reimbursable, Cost-Plus-Fixed-Fee (CPFF), Cost-Plus-Incentive-Fee (CPIF)

Mission	Selected Contractor	Selection Process	Contract Type
SM4       	- Ball Aerospace (Wide Field Camera 3 and repairs of the Advanced Camera for Surveys) - ITT Industries (Components for NICMOS Cryocooler, Thermal insulation systems and cryogenic engineering) - Raytheon Technologies (Power Control Unit and power distribution; Avionics support) - Lockheed Martin (Shuttle integration, mission planning) - Honeywell Technology Solutions (Systems Engineering and avionics) - L3 Space & Navigation (Gyroscopes and reaction wheel assemblies) - United Space Alliance (Shuttle operations, astronaut training, and EVA simulations)	Sole-source bidding for all contractors	Cost-Plus-Award-Fee (CPAF), Cost-Reimbursable, Cost-Plus-Fixed-Fee (CPFF), Cost-Plus-Incentive-Fee (CPIF)

3.1.5. Achievements of Servicing Missions

Cost Sustainability Achieved: Cost of Hubble servicing missions versus the estimated cost of building and launching a new Hubble-class telescope:

Mission	Estimated Budget (USD)
Servicing Mission 1 (SM1)	\$629 million
Servicing Mission 2 (SM2)	\$581 million
Servicing Mission 3A (SM3A)	\$172 million
Servicing Mission 3B (SM3B)	\$706 million
Servicing Mission 4 (SM4)	\$1.1 billion
Total Cost of Servicing Missions	~ \$3.2 billion

New Hubble-Class Telescope (1990 cost)	\$4 billion
Cost of New Hubble-Class Telescope (modern cost with adjusted inflation)	\$10 billion
Estimated Savings by Servicing	~ \$7 billion (~70%)

By servicing the Hubble Space Telescope (HST) instead of replacing, NASA saved approximately \$7 billion, achieving an 70% cost reduction compared to launching a new similar mission at today's rates.

Lifespan Extension of Hubble Space Telescope

Event	Year	Expected Life	Actual Outcome
Launched	1990	~15 years	Needed servicing by 1993
After SM4 (Final Servicing)	2009	+5 years (to 2014)	Operated through 2025 (and counting)
Total Operational Life	1990–2025+	~15 years planned	35+ years achieved

Source: Self-assessment and calculations by IPL

Through these servicing missions, the Hubble Space Telescope (HST) exceeded its original design lifespan by more than two decades, demonstrating the strategic and economic value of ISAM technologies in extending a space asset without replacement.

3.1.6. Key Learnings and Outcomes

	Outcome	Learning
Cost Saving	By servicing the Hubble Space Telescope instead of launching a replacement, NASA saved approximately \$7 billion, achieving a 70% cost reduction compared to the estimated cost of a new mission with similar capabilities at today's rates.	These savings can be redirected toward critical R&D, new scientific missions, or technology development, reinforcing the economic viability of ISAM. It also demonstrates how servicing existing assets can be more sustainable than replacement.
Life Extension	The HST has exceeded its original design life by over two decades, thanks to multiple servicing missions. This extended operational life was made possible through on-orbit repairs and upgrades, a core capability of ISAM.	This not only maximized the scientific return on investment but also prevented the telescope from becoming space debris, aligning with long-term goals of orbital sustainability and asset preservation.

3.2. Case Study 2: Mission Extension Vehicle (MEV-1 & MEV-2)

The Mission Extension Vehicle (MEV) program by Northrop Grumman represents a pioneering step in commercial satellite servicing. MEV-1 and MEV-2 are robotic spacecraft designed to extend the operational life of geostationary satellites by docking and providing propulsion and attitude control.

Many geostationary satellites face premature retirement due to fuel depletion, despite having fully functional payloads. MEV addresses this gap by offering life extension services, reducing the need for costly replacements and minimizing space debris.

The primary goal of MEV-1 and MEV-2 was to demonstrate the feasibility of autonomous rendezvous and docking in GEO. Specific objectives included extending satellite life by 4–5 years, establishing the servicing model for commercial use, and laying the groundwork for future robotic servicing missions.

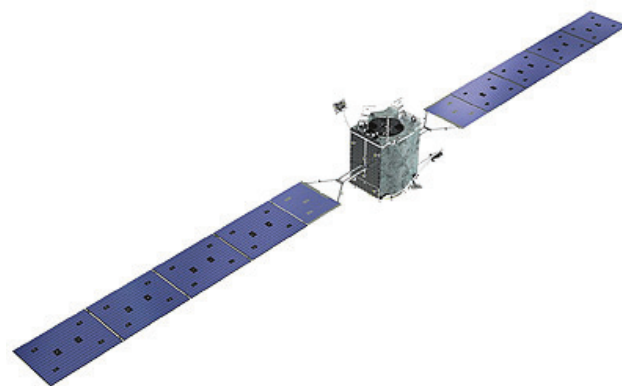


Illustration of MEV (Mission Extension Vehicle-1) for life extension services for in-orbit satellites
Source: space.skyrocket.de

3.2.1. Commercial and Economic Objectives of MEV-1 and MEV-2

- To delay costly replacements, thereby maximizing return on investment (ROI).
- To validate the business model for on-orbit servicing, encouraging future investments and partnerships.
- To validate a fleet-based model, where one MEV can serve several satellites over its lifetime, reducing per-client costs.
- To introduce circularity in financial planning and investment cycles in the satellite industry, by extending satellite lifespans.
- To postpone capital expenditures on new satellites and optimize existing assets.
- To transform space operations to a sustainable, service-based economy.

3.2.2. Need of the MEV Missions

Replacing a GEO satellite typically costs \$250–\$500 million, including manufacturing, launch, and insurance. Satellites nearing end-of-life often still have fully functional payloads but lack fuel for station-keeping. Implementation of MEV missions were expected to allow operators to continue revenue generation from these assets without capital reinvestment. Satellite operators operate on long investment cycles. MEV missions were expected to allow them to defer large capital outlays, freeing up resources for new technology development, market expansion, and debt management or shareholder returns.

3.2.3. Funding of MEV Missions

- The MEV missions represent a commercial-first approach to ISAM, proving private investment and customer-driven revenue approach to sustain complex space operations.

- The cost to build and launch each Mission Extension Vehicle (MEV) was estimated to be between \$60 million and \$80 million.
- The funding was done by Northrop Grumman's internal capital, reflecting a strategic investment in commercial satellite servicing.
- 'Intelsat' was the anchor customer for both MEV-1 and MEV-2. It agreed to pay \$13 million per year for a five-year life extension, totaling \$65 million per mission. These payments covered operational servicing and docking & propulsion support.
- Both MEV-1 and MEV-2 were not funded by any government organizations.

Component	Estimated Allocation
Spacecraft Design & Manufacturing	\$30–\$40 million
Launch Services	\$15–\$20 million
Mission Operations & Ground Support	\$10–\$15 million
Licensing & Regulatory Compliance	\$2–\$5 million
Contingency & Insurance	\$3–\$5 million
Total Estimated Cost	\$60–\$80 million

3.2.4. Procurement Process for MEV Missions

- Northrop Grumman Innovation Systems (formerly Orbital ATK) served as the prime contractor for both MEV-1 and MEV-2.
- The procurement process was managed by SpaceLogistics LLC, a wholly owned subsidiary of Northrop Grumman, responsible for mission execution.
- Vendors were selected based on technical capability and cost-effectiveness.
- Procurement Strategy: Northrop Grumman followed a commercial procurement model, which included:

Stage	Description
Supplier Registration	Vendors registered via SAP Ariba Network to be eligible for procurement opportunities.
Request for Proposal (RfP) Issuance	RfPs are issued to pre-qualified vendors based on technical and mission-specific needs.
Proposal Submission	Vendors submitted detailed proposals including technical specs, cost estimates, and compliance documentation.
Bid Evaluation	Proposals are evaluated based on: • Technical merit • Cost competitiveness • Past performance • Compliance with Northrop Grumman's standards.
Contract Award	Contracts were awarded to vendors offering the best combination of technical capability and commercial viability.

Mission Objective	Selected Contractor		Contract Type
Spacecraft Design & Manufacturing	Northrop Grumman Innovation Systems (formerly Orbital ATK) (Prime Contractor)		Internal Development (No external contract)
Mission Operations & Servicing	SpaceLogistics LLC (Mission Operator)		Internal Subsidiary Agreement
Launch Services	Intelsat (Anchor Customer)		Firm-Fixed-Price (FFP)
RPOD Sensors & Docking Systems	Jena-Optronik GmbH (Technical Supplier)		Cost-Plus-Fixed-Fee (CPFF)
Client Satellite Interface Coordination	International Launch Services (ILS) (Launch Provider (MEV-1))		Technical Interface Agreement (Non-contractual)
Quality Assurance & Compliance	Arianespace (Launch Provider (MEV-2))		Flow-down Clauses in Subcontracts
Insurance & Risk Management	Space Systems/Loral (Maxar Technologies) (Satellite Manufacturer (Intelsat 901))		Negotiated Commercial Agreements
Licensing & Regulatory	Airbus Defence and Space (Satellite Manufacturer (Intelsat 10-02))		Internal Legal & Compliance

3.2.5. Achievements of MEV Missions

Cost Sustainability Achieved: Cost of MEV servicing missions versus the estimated cost of launching two new satellites:

Mission	Estimated Budget (USD)
Servicing Mission 1 (MEV-1 for IS-901)	\$70 million
Servicing Mission 2 (MEV-2 for IS-10-02)	\$70 million
Total Cost of Servicing Missions	\$140 million
Original Satellite Cost IS-901	\$250 million
Original Satellite Cost IS-10-02	\$250 million
New Satellite 1 (IS-901, adjusted to inflation)	~ \$452 million
New Satellite 2 (IS-10-02, adjusted to inflation)	~ \$424 million
Total Cost of New Satellites	\$876 million
Estimated Savings by Servicing	\$736 million (~84%)

Source: Self-assessment and calculations by IPL

By servicing the satellites instead of replacing them, Northrop Grumman and Intelsat saved approximately \$736 million, achieving an 84% cost reduction compared to launching new satellites at today's rates.

Lifespan Extension of Satellites:

Event	Year	Original Expected Life	Actual Outcome
Intelsat 901 Launched	2001	~15 years	Fuel depletion by 2019
MEV-1 Docking & Servicing	2020	+5 years (to 2025)	Operational through 2025
Total Operational Life (IS-901)	2001–2025	~15 years planned	24 years achieved
Intelsat 10-02 Launched	2004	~15 years	Fuel depletion by 2021
MEV-2 Docking & Servicing	2021	+5 years (to 2026)	Extended to 2026, contract renewed to 2029
Total Operational Life (IS-10-02)	2004–2029	~15 years planned	25 years achieved

Through MEV servicing missions, both satellites exceeded their original design lifespans by nearly a decade, demonstrating the strategic and economic value of ISAM technologies in extending satellite utility without replacement.

3.2.6. Key Learnings and Outcomes

	Outcome	Learning
Cost Saving	By servicing the two Satellites instead of launching a replacement, Northrop Grumman saved approximately \$736 million, achieving an 84% cost reduction compared to the estimated cost of a new mission with similar capabilities at today's rates.	These savings can be redirected toward critical R&D, new scientific missions, or technology development, reinforcing the economic viability of ISAM. It also demonstrates how servicing existing assets can be more sustainable than replacement.
Life Extension	The two Satellites have exceeded its original design life by over a decade, thanks to these MEV missions. This extended operational life was made possible through on-orbit repairs and upgrades, a core capability of ISAM.	This not only maximized the scientific return on investment but also prevented the satellite from becoming space debris, aligning with long-term goals of orbital sustainability and asset preservation.

3.3. Case Study 3: SPIDER (OSAM-1)

The On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1) mission was NASA's flagship initiative to demonstrate autonomous robotic servicing and assembly in space. A key payload of OSAM-1 was SPIDER (Space Infrastructure Dexterous Robot), developed by Maxar Technologies in collaboration with NASA. Its core function included the Assembly of a Communications Antenna. SPIDER would assemble seven reflector elements into a 3-meter Ka-band antenna capable of transmitting data to ground



stations. The OSAM-1 mission faced technical, cost, and schedule challenges, leading NASA to cancel the project in 2024. However, SPIDER introduced first-of-its-kind robotic assembly capabilities in orbit, setting a technological benchmark for future ISAM missions.

3.3.1. Commercial and Economic Objectives of SPIDER Mission

- Build large space structures in orbit, reducing the need to launch them fully assembled from Earth.
- Create new business opportunities in satellite servicing and space infrastructure for private companies.
- Lower long-term costs by enabling repairs and upgrades of satellites instead of replacing them.
- Support future space missions (government and commercial) with flexible, modular construction capabilities.
- Showcase the value of public-private partnerships in advancing space technologies and markets.

3.3.2. Need of the SPIDER Mission

- SPIDER aimed to assemble large structures in orbit, eliminating the need to launch them fully built, thus avoiding the high cost of escaping Earth's gravity.
- SPIDER's in-space assembly capabilities were expected to reduce launch costs significantly by eliminating the need to send fully assembled large structures from Earth, which is one of the most expensive aspects of space missions.
- The mission was also part of a public-private partnership, combining NASA's resources with industry contributions to reduce taxpayer burden and accelerate innovation.

3.3.3. Funding of SPIDER Mission

The SPIDER mission, part of NASA's OSAM-1 (On-orbit Servicing, Assembly, and Manufacturing-1) program, was funded through a combination of government and industry investment, structured as a public-private partnership.

- The mission was funded by NASA's Space Technology Mission Directorate (STMD) under its Technology Demonstration Missions program.
- NASA awarded \$142 million contract to Maxar Technologies to develop the SPIDER payload.

3.3.4. Competitive Solicitation Process (Procurement Process) for SPIDER Mission

S. NO.	Step	Description
1.	Announcement of Opportunity (AO)	NASA issued a Tipping Point solicitation inviting proposals for technologies with commercial and NASA mission relevance.
2.	Proposal Submission	Companies submitted proposals via NASA's NSPIRES portal, detailing technical plans, commercial viability, and cost structures.

S. NO.	Step	Description
3.	Evaluation Criteria	Proposals were judged on technical merit, commercial potential, cost realism, management approach, and strategic alignment.
4.	Selection and Award	Maxar Technologies was selected and awarded a \$142 million contract to develop SPIDER.
5.	Partnership Execution	Maxar led the project, collaborating with Tethers Unlimited, WVRTC, and NASA Langley under a public-private model.

Detailed procurement process for other partners

Partner	Scope of Work	Procurement Strategy	Selection Criteria
 Maxar Technologies	Prime contractor responsible for designing, building, and integrating the SPIDER robotic payload.	Selected through NASA's Tipping Point competitive solicitation; awarded a \$142 million contract.	Technical merit, commercial potential, cost realism, alignment with NASA's ISAM goals.
 Tethers Unlimited	Provided the MakerSat device for in-space manufacturing of a 10-meter composite beam.	Subcontracted by Maxar; previously funded by NASA through SBIR grants.	Proven technology readiness, prior NASA collaboration, niche expertise in in-space manufacturing.
 West Virginia Robotic Technology Center (WVRTC)	Conducted independent verification and performance studies of SPIDER's robotic systems.	Subcontracted by Maxar; received approx. \$2 million for its role.	Technical capability in robotics, institutional credibility, experience with NASA projects.
 NASA Langley Research Center	Provided internal NASA support and technical expertise in robotics and ISAM systems.	Internal collaboration within NASA; not a contractor.	Strategic alignment with NASA's mission, inter-center cooperation, domain expertise.

3.3.5. Reasons of Failure

The SPIDER mission failed primarily due to massive cost overruns, technical delays, poor contractor performance, and a strategic shift in the space industry away from servicing unprepared satellites, making the mission economically and operationally unsustainable.

- **Massive Cost Overruns:** The mission was initially projected to cost between \$626 million and \$753 million, but ballooned to over \$2.05 billion, making it financially unsustainable.
- **Technical Challenges:** SPIDER's robotic systems were highly complex, and development faced repeated delays.
- **Poor Contractor Performance:** Maxar Technologies, the prime contractor, struggled to meet NASA's technical requirements and underestimated the scope of work. Deliverables were about two years behind schedule, and NASA had to provide additional labor worth \$2 million to support Maxar's efforts.
- **Fixed-Price Contract Limitations:** The contracts lacked incentive or award fees, limiting NASA's ability to motivate better performance or penalize delays.

3.3.6. Key Learnings and Outcomes

	Insight	Impact on ISAM and Space Sustainability
Funding and Resource Allocation	NASA's SPIDER mission was a flagship initiative to demonstrate autonomous robotic servicing and assembly in space. Although the procurement process was completed and contractors were selected, the mission was halted due to inadequate funding and technical readiness.	This highlights the critical need for dedicated funding streams and sustained investment in ISAM technologies. Without financial and technical continuity, even promising missions risk cancellation, delaying progress in space sustainability.
Strategic Planning and Technical Expertise	The premature termination of SPIDER underscores the importance of robust technical planning, risk mitigation, and cross-sector collaboration.	Future ISAM missions must be supported by interdisciplinary expertise, realistic timelines, and adaptive technology roadmaps to ensure successful execution and long-term viability.

3.4. Comparison of Case Studies

Space Program	Procurement	Design Risk	Ownership	Operations Risk	Maintenance Risk	Capital Risk
NASA Hubble Space Telescope	Cost Plus Contract	Private Player	Public Player	Private Player	Private Player	Public Player
MEV-1 & 2	Private Commercial Procurement	Private Player	Private Player	Private Player	Private Player	Private Player
SPIDER (OSAM-1)	Cost Plus Contract	Private Player	Public Player	Private Player	Private Player	Public Player

4. Industry Remarks



4.1 OrbitAID Aerospace

The satellite industry is shifting toward serviceable platforms, enabling on-orbit refuelling and upgrades. Proven missions like MEV show its feasibility. To support this, global standards for docking, safety, and data exchange are being developed. Early adoption of these standards helps manufacturers future-proof satellites, reduce costs, and improve sustainability through trusted international collaboration.

Steps Taken by OrbitAID

OrbitAID Aerospace has introduced the Standardized Interface for Docking and Refueling Port (SIDRP), a patented, lightweight (under 600 grams) modular interface designed for seamless integration with satellites. Its drop-in design allows easy incorporation into both new and existing satellite platforms without major structural changes, enabling efficient docking, refueling, and component exchange in orbit.

SIDRP works in coordination with OrbitAID's Tanker Satellite, which features a precision robotic arm. Together, they enable fully autonomous satellite servicing, including identification, approach, docking, and refueling. This integrated system marks a significant advancement in scalable On-Orbit Servicing and Refueling (OOSR) infrastructure, supporting the growth of India's satellite ecosystem.

Aspect	Details
Technology Introduced	OrbitAID Aerospace developed the Standardized Interface for Docking and Refueling Port (SIDRP), a patented, lightweight (<600g) modular interface.
Integration Capability	SIDRP can be easily embedded into new and existing satellites without major structural changes, enabling docking, refueling, and component exchange.



Supporting System	Works with OrbitAID's Tanker Satellite, equipped with a precision robotic arm for autonomous servicing operations.
Servicing Capabilities	Enables identification, approach, docking, and refueling of satellites autonomously.
Infrastructure Development	OrbitAID has built India's largest commercial RPOD facility for satellite servicing.
Mission Milestone	Preparing to launch 'AayulSAT' in November 2025, India's first dedicated OOSR mission.
Validation Efforts	Successfully conducted two zero-gravity missions to test SIDRP technology.
Current Industry Status	ISRO, NSIL, and startups lack post-launch servicing capabilities; while most satellites are single-use.
Strategic Opportunity	India can leapfrog into next-gen satellite design by integrating servicing interfaces early.
Global Alignment	Early adoption aligns Indian satellites with international standards and boosts India's position in global OOSR leadership.
Economic Impact	Potential to generate benefits across manufacturing, insurance, and mission planning, enhancing India's space economy.

Organizations like ISRO, NSIL, and private startups currently lack post-launch servicing capabilities. OrbitAID Aerospace is pioneering OOSR in India:

- Successfully conducted two zero-gravity missions to validate its proprietary SIDRP technology.
- Developed India's largest commercial RPOD (Rendezvous and Proximity Operations Docking) facility.
- Preparing to launch 'AayulSAT' in November 2025, India's first dedicated OOSR mission.

Limited adoption of serviceable satellite designs is due to unclear regulatory and technical frameworks. This gap presents a strategic opportunity for India to leapfrog into next-generation satellite design. Early integration of servicing interfaces can align Indian satellites with international standards, position India as a global hub for OOSR technologies, and generate economic benefits across manufacturing, insurance, and mission planning sectors.

Benefits of Interfaces

Standardized servicing interfaces in Indian satellites can offer major strategic and operational advantages. Refueling capabilities extend mission lifespans, reduce replacement launches, and lower insurance costs. They also support safer satellite disposal and debris mitigation, aligning with global sustainability goals. Modular upgrades allow in-orbit replacement of outdated components, improving flexibility and reducing costs. These features optimize launch infrastructure use and enhance return on investment. As the space economy grows, institutions like IIFCL and private investors can explore On-Orbit Servicing and Refuelling (OOSR) as a new financing vertical. This would support service providers, technology developers, and insurance products tailored for extended missions, positioning India as a leader in sustainable and economically efficient satellite operations.

Policy and Regulatory Challenges

(a) Fostering International Collaboration

- India must develop clear and robust policies aligned with global standards to support innovation and partnerships.
- Strengthening ties through platforms like the Quad (India, USA, Japan, Australia) and with European Union nations can enable Knowledge Exchange and Resource Sharing.
- A regulatory sandbox model can help identify and address legal and liability gaps in OOSR missions.
- Joint training programs and workshops with international partners will build mutual trust, improve interoperability, and align operational standards.

(b) Domestic Policy Reforms for OOSR Advancement

India must refine its domestic policies to regulate and promote these technologies effectively. Aligning with the Indian Space Policy 2023 and IN-SPACe frameworks, the government should introduce comprehensive regulations tailored to OOSR operations. Key measures include:

- **Licensing for OOSR Missions:** Establishing a streamlined licensing process to regulate OOSR activities, ensuring compliance with safety and operational standards.
- **Liability Rules for Proximity Operations:** Defining clear liability frameworks to address risks associated with close-proximity operations, such as satellite servicing or debris removal, to mitigate potential conflicts and damages.
- **Mandatory Deorbiting and Post-Mission Disposal (PMD):** Enhancing PMD programs to mandate servicing interfaces for end-of-life satellite management, reducing space debris and aligning with international sustainability guidelines.
- **Incentives for Sustainable Practices:** Offering grants, tax benefits, and subsidies to encourage private companies to adopt sustainable OOSR practices, fostering innovation and environmental responsibility.

Conclusion

India is at a pivotal moment in advancing OOSR technologies, with OrbitAID Aerospace leading the way through innovations like Standardized Interface for Docking and Refueling Port (SIDRP) and the upcoming AayulSAT mission. While most Indian satellites are currently designed for single-use, OrbitAID's efforts demonstrate the feasibility and benefits of serviceable platforms. Standardized interfaces can extend satellite lifespans, reduce costs, and support debris mitigation, aligning with global sustainability goals. To fully realize these advantages, India must address regulatory gaps and align domestic policies with international standards. Strengthening global partnerships, introducing licensing frameworks, and incentivizing sustainable practices will be key. Early adoption of OOSR technologies can position India as a global hub for satellite servicing, unlocking economic opportunities across manufacturing, insurance, and mission planning. With strategic reforms and industry collaboration, India can lead the next generation of space operations, ensuring long-term orbital safety and economic efficiency.



4.2 UK Space Agency



Space sustainability is a priority for the UK, as per the National Space Strategy (2021), the UK's first Plan for Space Sustainability (2022) and, in 2024, the Space Industrial Plan included In-orbit Servicing, Assembly & Manufacturing (ISAM) as one of five specific capability goals where the UK seeks leadership. More recently, the Strategic Defence Review (2025) highlighted the need to develop Space Control capabilities, and by extension ISAM technologies, to defend UK space assets in an increasingly contested domain.

Although a nascent market, the UK Space Agency recognises the potential of ISAM to generate significant economic value and enhance the UK's sovereign space capabilities, including critical defence requirements. ISAM is the fastest growing segment of the global space economy, with In-Orbit Servicing alone projected to be worth USD26.1 billion in cumulative revenue between 2024 and 2034.

The UK is therefore investing in such technology capabilities which could be used for both civilian and defence purposes, e.g. by demonstrating rendezvous and proximity operations (RPO) through a national debris removal mission.

In the current geopolitical climate, these technology developments present a key opportunity for international collaboration and innovation across civil and defence space.

India has made notable progress in developing ISAM capabilities, particularly through ISRO's advances in docking and modular spacecraft technologies, demonstrated by the Space Docking Experiment (SpaDeX). With its strengths in cost-effective engineering and scalable manufacturing, India is well placed to contribute to sustainable space operations.

The UK, with its focus on space sustainability and emerging ISAM expertise, therefore thanks ISpA and IPL for inviting a UK contribution to this valuable report and looks forward to exploring opportunities with India to advance shared goals in space sustainability and ISAM.

5. Our Proposed Models to Promote PPP in ISAM

ISpA and IPL have identified ISAM as a strategic priority to ensure resilient, responsible, and innovative space ecosystems. Also, IPL, has a mandate to provide financial structuring, PPP advisory, and infrastructure financing for strategic sectors including space. This creates an opportunity for a collaboration, where IIFCL can serve as the financial enabler to support the ISpA's ISAM sustainability vision through innovative financing models, blended finance, and PPP frameworks.

5.1 Proposed PPP Models for ISAM

- Model A – Service-Based Concession for Orbital Infrastructure
- Model B – Build-Operate-Transfer (BOT) for Orbital Servicing Hubs
- Model C – Performance-Linked Public Procurement (Hybrid-Annuity ISAM Model)

Proposed PPP Model	Structure	Revenue Mechanism	Funding Mechanism	Strategic benefits
Model A – Service-Based Concession for Orbital Infrastructure	Long-term concession agreement for in-orbit services such as debris removal, refuelling, or life-extension, where the private operator develops and operates the servicing vehicle.	• Fixed annual availability payments from the government/ agency for readiness and capability maintenance. • Variable performance-linked payments tied to verified mission success (e.g., successful docking, fuel transfer, or debris removal).	Blended capital stack combining government viability gap funding (VGF), multilateral guarantees, and private debt/equity.	Establishes a recurring service market for ISAM, similar to long-term O&M PPPs in terrestrial infrastructure.
Model B – Build-Operate-Transfer (BOT) for Orbital Servicing Hubs	A private consortium designs, builds, and operates an orbital depot or assembly node for a defined term (e.g., 10–15 years), transferring ownership to the government/agency at the end.	Service charges for satellite docking, refuelling, and component replacement, benchmarked to avoid replacement costs of satellites.	• 40–50% government viability support or grant capital. • 30% private equity (OEMs, ISAM startups, insurers). • 20–30% MDB-backed debt.	Creates scalable infrastructure that underpins a circular space economy, where orbital nodes become economic assets generating continuous revenue streams.
Model C – Performance-Linked Public Procurement (Hybrid-Annuity ISAM Model)	Combines design-build contracts with long-term operational obligations. Payments are milestone-linked. • 40% on technology demonstration. • 30% on orbital deployment. • 30% spread as performance annuity over mission life.	• Variable performance-linked payments tied to verified mission success (e.g., successful docking, fuel transfer, or debris removal).	Public funding is released in tranches; private partner arranges interim finance against the future annuity stream.	Encourages cost discipline, innovation, and accountability while reducing immediate fiscal outflow.



5.2. Risk Allocation Matrix

PPP Model		Model A – Service-Based Concession for Orbital Infrastructure		Model B – Build-Operate-Transfer (BOT) for Orbital Servicing Hubs		Model C – Performance-Linked Public Procurement (Hybrid-Annuity ISAM Model)	
SN	Risk Type	Public Partner	Private Partner	Public Partner	Private Partner	Public Partner	Private Partner
1	Authorizations and Approvals	✓		✓		✓	
2	Design Risk (and linked defect/ delay)	Limited (if providing technology)	✓	Limited (if providing technology)	✓	Limited (if providing technology)	✓
3	Technology Risk (and linked defect/ delay)	Limited (if providing technology)	✓	Limited (if providing technology)	✓	Limited (if providing technology)	✓
4	Manufacturing Risk (and linked defect/ delay)		✓		✓		✓
5	Intellectual Property Risk (and linked defect/ delay)	Shared/ Transferable	Shared/ Transferable	Shared/ Transferable	Shared/ Transferable	Shared/ Transferable	Shared/ Transferable
6	Debt Funding		✓		✓		✓
7	Capital Contribution		✓	✓ (in the form of grants)	✓	✓ (in the form of grants)	✓
8	Repayment Risk		✓		✓		✓
9	Operational Costs		✓		✓		✓
10	Revenue Realization Risk		✓		✓	✓	
11	Testing and Operationalization		✓		✓	Limited	✓
12	Maintenance		✓		✓		✓

5.3 Key Enablers and Risk-Mitigation Instruments

- (1) Insurance-Linked PPP Mechanisms: Introduce an integrated space risk-pooling framework where orbital service providers subscribe to an insurance-backed network. This network prices risk dynamically based on satellite sustainability compliance (debris mitigation, safe disposal plans, etc.).

- (2) **Performance-Based Funding Windows:** Establish sovereign or bilateral innovation funds to co-finance ISAM PPPs, wherein disbursements are conditional on technical milestones verified through mission telemetry.
- (3) **Task-Force-Driven Implementation:** Each PPP project should be governed by a multi-agency task force including stakeholders from finance, insurance, regulatory, and technology domains.
- (4) **Regulatory Harmonization and Standardization:** Develop uniform standards for docking interfaces, liability coverage, and insurance premiums tied to sustainability indices.

5.4 Financing Framework for PPP-ISAM Missions

- (1) **Upfront Support:** Government seed funding for demonstration missions under a Technology Readiness Acceleration Facility (TRAF), supporting TRL 6–9 transitions. Recently, IN-SPACe has come up with Technology Adoption Fund (TAF) which helps in upgrading start-ups from TRL-3/4 to TRL-7/8 towards commercialization. This TAF fund is helping many start-ups to grow their companies towards commercialization.
- (2) **Credit Enhancement:** Deployment of first-loss guarantees and partial risk coverage through international financial institutions and export credit agencies.
- (3) **Revolving Sustainability Fund:** Creation of a dedicated Space Sustainability and ISAM Financing Facility jointly managed by public and private entities.
- (4) **International Participation:** Encourage co-investment through sovereign wealth funds and impact investors focusing on sustainable space operations.

5.5 Expected Outcomes

- Establishment of a market-ready PPP template for ISAM missions adaptable across refuelling, debris removal, and in-orbit manufacturing.
- Mobilization of private capital through blended finance and insurance-linked guarantees.
- Development of an industrial ecosystem comprising service operators, insurers, and AI-based monitoring networks.
- Creation of measurable sustainability metrics linking financial incentives to orbital behavior and mission outcomes.

6. Conclusion

India's space sector is entering an era defined not just by the number of satellites launched, but by the responsibility with which space is managed, serviced, and sustained. The evolution of orbital infrastructure has reached a point where innovation, sustainability, and financial foresight must converge to safeguard the long-term usability of near-Earth and cislunar domains. Within this landscape, In-Space Servicing, Assembly, and Manufacturing (ISAM) emerges as a transformative capability—one that redefines how nations design, operate, and finance their space assets. Far beyond a technological pursuit, ISAM represents the foundation for a self-sustaining, circular, and inclusive space economy that harmonizes commercial efficiency with planetary stewardship.



The global experiences detailed in this report—ranging from NASA’s Hubble Space Telescope Servicing Missions to Northrop Grumman’s Mission Extension Vehicles (MEV-1 and MEV-2) and NASA-Maxar’s SPIDER (OSAM-1)—illustrate the tangible economic and strategic dividends of sustainable space operations. The Hubble missions proved that intelligent design and modular servicing can extend operational life by more than two decades while achieving nearly 70 percent cost savings, underscoring that sustainability and fiscal prudence are not competing priorities but complementary imperatives. The MEV program validated the commercial logic of ISAM: through private investment and customer-driven models, it achieved 84 percent cost reduction compared to satellite replacement, establishing a repeatable framework for life-extension services that generate predictable revenue streams. Even SPIDER, despite its cancellation, provides enduring lessons in the necessity of resilient funding structures, adaptive procurement, and integrated risk management—all crucial components of a mature PPP ecosystem. Collectively, these case studies affirm that sustainability in space is inseparable from financial innovation and institutional foresight.

India’s proposed ISAM strategy builds precisely on this global learning curve. The adoption of Public-Private Partnership (PPP) models—whether in the form of service-based concessions, build-operate-transfer orbital hubs, or hybrid-annuity mechanisms—marks a decisive shift from one-time procurement to performance-driven collaboration. These models reward verified mission outcomes rather than expenditure, encouraging efficiency, innovation, and accountability. By embedding measurable sustainability metrics such as debris mitigation, asset reusability, and life-extension achievements directly into contract performance, PPP frameworks transform sustainability from an ethical aspiration into an enforceable economic principle. They also enable the private sector to invest confidently in high-risk, high-reward space technologies, while public agencies retain strategic oversight—thereby fostering a symbiotic ecosystem where risk and reward are equitably shared.

For ISAM to flourish at scale, sustainability must evolve into the core currency of the orbital economy. Establishing a Dedicated Space Sustainability and ISAM Financing Facility, as envisioned by IIFCL Projects Ltd, can institutionalize this transformation. The facility would mobilize blended capital from government, development banks, export-credit agencies, and private investors to support ISAM missions across their lifecycle—from demonstration and deployment to commercial maturity. By offering instruments such as first-loss guarantees, insurance-linked debt, performance-based disbursements, and revolving sustainability credit lines, the facility can de-risk pioneering missions while embedding sustainability compliance into their financing terms.

This institutional approach is reinforced by the partnership between the Indian Space Association (ISpA) and IIFCL Projects Ltd (IPL)—a collaboration that unites policy vision with financial architecture. ISpA acts as the convening platform that bridges government, industry, and academia, shaping the policy and regulatory environment needed to accelerate ISAM adoption. IIFCL Projects complements this mandate by structuring viable PPP frameworks, designing blended-finance models, and creating credit-enhancement instruments that transform emerging technologies into bankable opportunities. Together, they form the twin pillars of India’s space-finance ecosystem: policy stewardship and financial innovation, working in concert to turn sustainability into an investable proposition.

Within this ecosystem, OrbitAID Aerospace represents the spirit of India's private-sector ingenuity and its growing role in operationalizing sustainability. Through innovations such as the Standardized Interface for Docking and Refueling Port (SIDRP) and the upcoming AayulSAT mission, OrbitAID has demonstrated that serviceable satellite architectures and autonomous refueling systems are no longer conceptual—they are commercial realities. By developing India's first commercial RPOD (Rendezvous and Proximity Operations Docking) facility and aligning its technology with international standards, OrbitAID is establishing the foundation for a circular satellite economy. Its pioneering efforts exemplify how startups can complement national and institutional initiatives, transforming India from a technology adopter into a technology originator in sustainable orbital operations.

International collaboration will remain critical in this journey. Partnerships with the UK Space Agency, ESA, and global platforms such as CONFERS and COSMIC offer India opportunities to co-develop interoperability standards, undertake joint debris-removal missions, and design shared insurance and certification frameworks. Such alliances elevate India's role from participant to standard-setting in global orbital governance, reinforcing the principles of collective responsibility and sustainability that underpin the future of space.

The way forward lies in institutionalising a culture of orbital responsibility—through inter-agency coordination on sustainable finance, integration of sustainability metrics into licensing and procurement, educational programs in ISAM technologies, and the introduction of new financial instruments such as impact-linked bonds and space-sustainability credits. These measures will ensure that India's New Space Economy grows not merely in scale, but in substance—defined by durability, safety, and stewardship.

In this new paradigm, ISAM is more than a set of technologies—it is a philosophy of permanence. It reframes space not as an expendable frontier but as an enduring domain requiring care, maintenance, and shared accountability. By aligning technological ambition with economic logic and ethical governance, India can ensure that every mission launched adds not only to national capability but also to collective responsibility. The collaboration between ISpA and IIFCL Projects, backed by international partners and private innovators, positions India to craft a global benchmark for sustainable space finance—one that others can emulate in both form and spirit.

As we move into this decisive decade, the success of the New Space Economy will no longer be measured solely by the number of payloads in orbit, but by the sustainability of their presence, the resilience of their financing, and the inclusivity of the ecosystem that sustains them. By embedding sustainability into the very fabric of its financial and policy frameworks, India can lead a new orbital era—one where innovation serves responsibility, and where progress preserves the heavens as much as it explores them.



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About Indian Space Association (ISpA)



ISpA is the apex non-profit industry body dedicated to fostering the collaborative development of the private space industry in India. Acting as the single voice of India's private space sector, ISpA works as a bridge between the Government and Industry, driving policy advocacy, stakeholder engagement, and the exchange of knowledge, information, and technology across the Indian space ecosystem. Through its initiatives, ISpA seeks to advance India's self-reliance, technological innovation, and leadership in the global space domain.

About IIFCL Projects Limited (IPL)



IIFCL Projects Ltd. (IPL) is a wholly owned subsidiary of Indian Infrastructure Finance Company Limited (IIFCL), a Government of India Enterprise, to leverage its domain expertise for providing project advisory services including project appraisal and syndication services in infrastructure domain in India. Acting as a dedicated Financial & Infrastructure Advisory Company, IPL extends advisory support to the Central/State/ Local Governments & its bodies, Project Developers and Investors on the needs and priorities of infrastructure, impediments, policy, financing issues. IPL has been engaged for various assignments with the Department of Space (DOS), NewSpace India Limited (NSIL), and IN-SPACe. IPL has spanned key mandates including LVM-3 PPP Framework for NSIL, Earth Observation Satellite PPP Framework for IN-SPACe, Transfer of 10 in-orbit communication satellites to NSIL, Investment Incentive Scheme for IN-SPACe and Technology Adoption Fund (TAF) Scheme for IN-SPACe.



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