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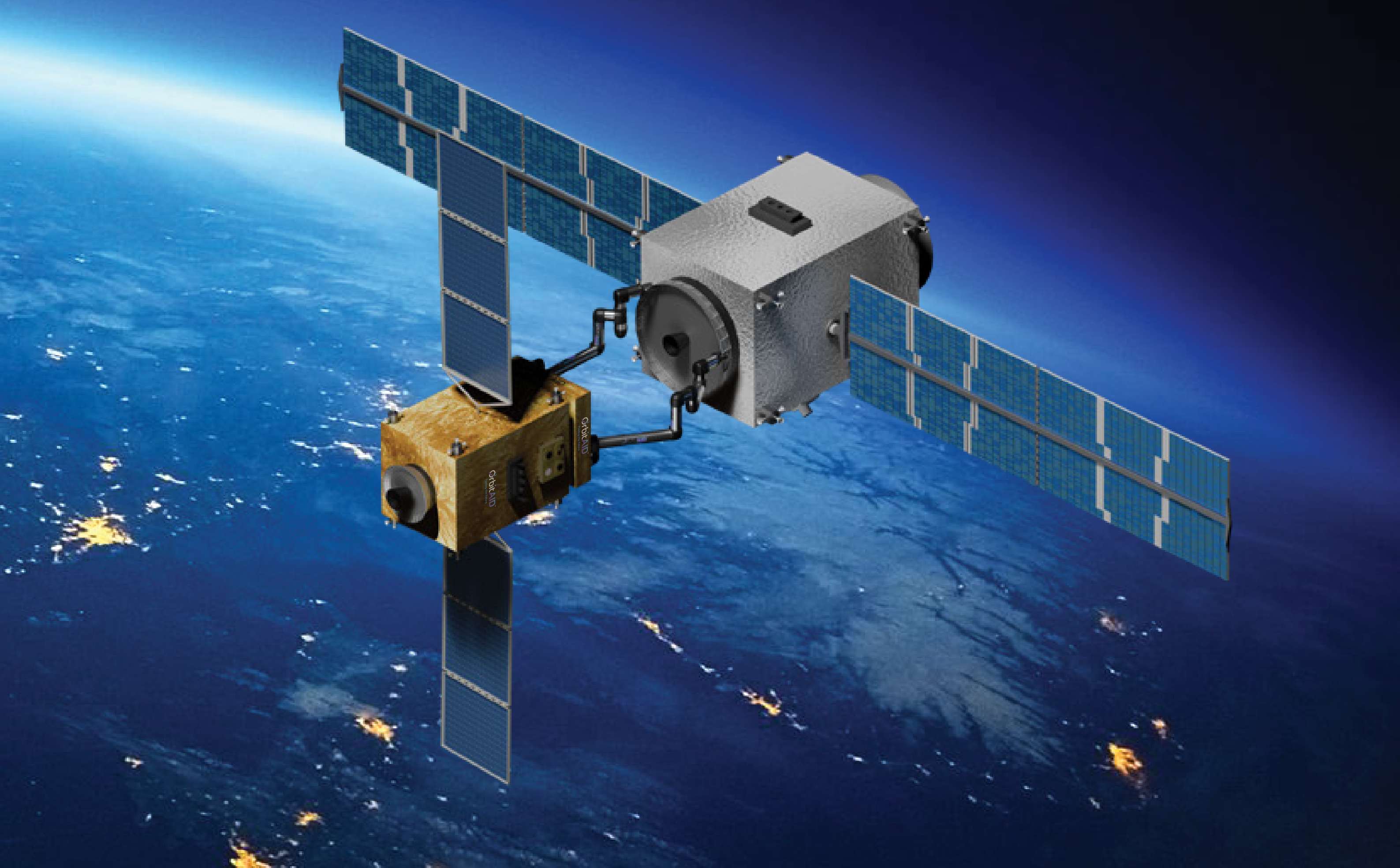
ADVANCING ISAM: BUILDING THE FOUNDATION FOR ON-ORBIT SERVICING & REFUELLING



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FOREWORD

The global space sector stands at the threshold of a structural transformation. What was once defined by access to orbit is now increasingly characterized by the ability to operate within it sustainably, flexibly, and at scale. In this context, In-Space Servicing, Assembly, and Manufacturing (ISAM) is emerging not as a peripheral capability, but as a foundational layer of the future space economy.

For India, this transition is both timely and strategic. The recent reforms aimed at liberalizing the space sector have marked a decisive shift in national approach, moving from a model of centralized capability to one that actively fosters private participation and innovation. This process of privatization has not only broadened the industrial base but has also redefined how we think about capability development: from isolated missions to integrated, lifecycle-driven systems.

It is within this evolving ecosystem that enterprises such as OrbitAID assume particular significance. As one of the early movers focusing on on-orbit servicing and ISAM-related capabilities, OrbitAID represents a new generation of Indian space actors, those that are not only responding to existing market needs, but are actively shaping emerging ones. Their work reflects an important transition in mindset: from designing systems for deployment, to designing systems for endurance and sustained utility in orbit. This shift is critical. The challenges confronting the space domain today, orbital congestion, asset obsolescence, and the growing imperative for sustainability cannot be addressed through traditional approaches alone. ISAM offers a pathway to mitigate these pressures by enabling satellite life extension, in-orbit repair, modular upgrades, and, in the longer term, the assembly and manufacturing of complex structures in space. In doing so, it redefines infrastructure itself, not as static hardware, but as dynamic capability.

At the same time, the emergence of ISAM raises important questions for policy and governance. Servicing missions, by their very nature, involve proximity operations, shared orbital environments, and potential dual-use implications. These realities necessitate a re-examination of existing regulatory frameworks, particularly in areas such as authorization, liability, safety standards, and ongoing supervision. A forward-looking policy architecture must therefore balance two imperatives: enabling innovation and private sector growth, while ensuring responsible and secure operations in an increasingly contested domain.

India's strengths position it well to navigate this balance. Our demonstrated capability in cost-effective engineering, combined with a rapidly maturing private ecosystem and a more enabling regulatory posture, provides a strong foundation. However, leadership in ISAM will depend not only on technological progress, but on the ability to align policy, industry, and strategic intent in a coherent manner.

This paper makes a valuable and timely contribution to that effort. By examining the policy contours and ecosystem requirements of ISAM, it provides a structured lens through which India's opportunities and challenges can be understood. Importantly, it situates emerging private sector efforts, including those of companies like OrbitAID, within a broader national and global context, highlighting the pathways through which India can translate early momentum into sustained leadership. As we look ahead, it is imperative that ISAM be recognized as essential infrastructure for the next phase of space development. The opportunity before India is not limited to participation-it extends to shaping norms, setting standards, and contributing to the architecture of the future space economy.

I commend the authors for their thoughtful and forward-looking work. It is my hope that this paper will serve as a catalyst for informed dialogue, progressive policymaking and continued industry innovation in this critical domain.

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I. INTRODUCTION

The global space sector is at a crucial point, transitioning from a launch-dominated sector to a more complex in-space economy. For decades, the primary focus of space activity was on the design, manufacture and deployment of satellites, with launch serving as the central value driver. However, as orbital environments become increasingly congested and significant, this model is rapidly evolving. The next phase of space development is being defined not by access to orbit alone, but by the ability to sustain and optimize assets once they are already there. In-Space Servicing, Assembly, and Manufacturing (ISAM) has emerged as a critical pillar of this transformation, enabling a shift from disposable satellites to serviceable, upgradeable and longer-lasting space infrastructure.

Within this evolving shift, ISAM occupies a foundational role. Capabilities such as life extension, on-orbit refueling, repair, relocation, and debris mitigation are no longer futuristic innovations, they are becoming essential enablers of space and economic sustainability. Satellite operators are increasingly recognizing the ability to extend mission lifetimes or adapt assets in orbit which can significantly enhance return on investment while reducing the need for frequent replacements. At the same time, governments and international bodies are placing growing emphasis on responsible space operations, particularly in light of rising space debris and the risks posed to critical infrastructure. ISAM, therefore, sits at the intersection of commercial opportunity and strategic necessity.

For India, this transition presents a rare and time-sensitive strategic opportunity. The country has already demonstrated global competitiveness in launch services through cost efficiency and engineering excellence. More importantly, India is now witnessing the rapid maturation of its private space ecosystem, supported by policy reforms and institutional mechanisms such as IN-SPACe. This emerging industrial base, combined with a strong talent and experience in complex space missions, provides us a robust foundation for entry into the ISAM domain. Crucially, India is young and fluid, not constrained by massive investments in traditional space architectures only, to the same extent as more established spacefaring nations. This creates the possibility of leapfrogging directly into high-value segments of the in-space economy, rather than following a linear path.

The argument of this paper is straightforward. ISAM should be treated as a strategic infrastructure capability, and its development should be approached as an ecosystem-building exercise rather than a series of isolated technological efforts. This requires coordinated action across policy, industry and institutional frameworks.

THE STRATEGIC OPPORTUNITY

The global space sector is at a crucial point, transitioning from a launch-dominated sector to a more complex in-space economy. For decades, the primary focus of space activity was on the design, manufacture and deployment of satellites, with launch serving as the central value driver. However, as orbital environments become increasingly congested and significant, this model is rapidly evolving. The next phase of space development is being defined not by access to orbit alone, but by the ability to sustain and optimize assets once they are already there. In-Space Servicing, Assembly, and Manufacturing (ISAM) has emerged as a critical pillar of this transformation, enabling a shift from disposable satellites to serviceable, upgradeable and longer-lasting space infrastructure.

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1.1. RISING DEMAND

This shift is further accelerated by the rapid proliferation of large-scale satellite constellations, which fundamentally alter the economics of space operations. (Kulu, 2024). Unlike traditional single-satellite missions, constellation architectures involve hundreds to thousands of satellites operating as coordinated fleets, where performance and lifecycle management must be optimized at a system level rather than on an individual asset basis. In such environments, even marginal improvements in satellite longevity or functionality can generate significant value across the constellation. This creates a strong economic rationale for ISAM capabilities, including life extension & repair.

Moreover, constellation operators face continuous pressures related to collision avoidance and system degradation over time. (National Aeronautics and Space Administration [NASA], 2025) The conventional model of replacing failed or aging satellites through repeated launches becomes increasingly inefficient and cost-intensive at scale. Orbital servicing introduces an alternative paradigm based on fleet maintenance rather than fleet replacement, enabling operators to reduce launch dependency, and enhance overall system resilience. In addition, the scale of constellation deployments amplifies the importance of risk management. Failures within a congested orbit can have drastic effects, including service disruption and increased collision risk. Servicing capabilities, particularly those related to inspection and repair, provide a mechanism to mitigate such risks proactively. Over time, this is likely to influence not only operational strategies but also financial models, including insurance structures and asset valuation, as serviceable constellations are perceived as lower-risk and more adaptable. (European Space Agency [ESA], 2024) Taken together, the rise of constellation-scale operations transforms orbital servicing from a niche capability into an economic necessity. It shifts the focus from discrete mission success to continuous system optimization, reinforcing the central role of ISAM in enabling sustainable and economically viable space architectures.

1.2. INDIA'S POSITION

India is particularly well-positioned to capitalize on this transition due to a lot of factors . The country's demonstrated strength in cost-efficient space engineering provides a strong foundation for delivering competitively priced ISAM solutions in a market that remains highly cost-sensitive. At the same time, India's deep and expanding pool of engineering talent, spanning aerospace, robotics, software, artificial intelligence, aligns closely with the interdisciplinary demands of ISAM . Perhaps most significantly, the rapid emergence of a private space ecosystem, multiplied by recent policy reforms, is creating a dynamic environment for innovation. Startups are already developing capabilities in propulsion, space situational awareness, and small satellite systems, all of which are directly relevant to ISAM applications. (Ernst & Young LLP (2022)). This growing industrial base enhances India's ability to move quickly and scale new solutions without being constrained by legacy structures.

Taken together, these factors create a compelling opportunity for India to leapfrog into a high-value segment of the global space market. Unlike traditional launch services, which are becoming increasingly commoditized, ISAM represents a frontier domain with significant technological barriers and long-term revenue potential. Early movers in this space are likely to shape industry standards and secure a disproportionate share of future value. For India, the ability to align its cost advantages, talent base and emerging private sector with a clear policy vision could enable it to transition from a cost-effective launch provider to a key architect of the in-space economy. This is not merely an opportunity for incremental growth, but a chance to redefine India's position in the global space hierarchy.

2. CURRENT STATE OF ISAM ECOSYSTEM IN INDIA

The development of In-Space Assembly and Manufacturing (ISAM) technologies demands a highly specialized and advanced set of capabilities that extend far beyond what a conventional satellite manufacturing ecosystem is typically designed to support. Core competencies required in this domain include autonomous rendezvous and proximity operations, precision docking mechanisms, robotic manipulation in microgravity environments, on-orbit refueling systems, and sophisticated autonomous decision-making software. Each of these areas represents a technological frontier, where even the most advanced global space programs are still engaged in iterative development, testing and in-orbit demonstrations. These are not mature, commoditized technologies but rather evolving capabilities that require deep technical expertise and sustained investment.

2.1. HISTORY OF INDIA'S SUPPLY CHAIN ECOSYSTEM

For India's emerging ISAM sector, the challenge is significantly amplified by structural and historical factors. The domestic space ecosystem has had very limited time and relatively few structured opportunities to build such capabilities from the ground up. Unlike countries with long-standing commercial space industries that have gradually diversified into advanced mission profiles, India is attempting to make this transition within a compressed timeframe. This creates a situation where both capability development and market creation must occur simultaneously, placing additional pressure on all stakeholders involved.

Until the liberalization of India's space sector in 2020, the development of advanced space technologies was almost entirely concentrated within the Indian Space Research Organisation (ISRO). The organization functioned largely as a closed and vertically integrated system, where most critical technologies were developed internally, tested within its own programs, and deployed without extensive collaboration with private industry. While this model ensured reliability and mission success, it did not foster a broad-based industrial ecosystem capable of independently developing and scaling advanced technologies. Technology transfer to the private sector was limited, and opportunities for co-development were relatively scarce.

The opening of the space sector through the establishment of IN-SPACe marked a significant and necessary policy shift. It created a regulatory and institutional framework for private participation and signaled the government's intent to build a more inclusive and commercially vibrant space economy. However, this transition also meant that startups and emerging companies were effectively starting from a very low baseline in terms of technical capability, infrastructure, and experience. Building advanced ISAM technologies under such conditions is inherently challenging, particularly when compared to more incremental innovations in traditional satellite systems.

This compressed development timeline poses a particular problem for ISAM because the subsystems required for life extension, servicing, and in-orbit operations are among the most technically demanding in the entire space domain. Technologies such as high-precision propulsion systems capable of fine impulse control, LIDAR-based proximity sensors for accurate distance measurement, force-torque sensors for robotic manipulation, radiation-hardened processors for reliable computation in space, and autonomous navigation software require years of sustained effort. These systems must undergo extensive ground testing, environmental validation, and multiple iterations before they can achieve the level of reliability required for space missions. In addition, they require mission heritage, which can only be built through successful deployment in real operational environments.

2.2. CURRENT SUPPLY CHAIN ECOSYSTEM FOR ISAM

However, when the focus shifts specifically to ISAM-related subsystems, a clear mismatch between available capabilities and required technologies becomes evident. The rapid growth of India's commercial space sector over the past five years has been driven predominantly by the Earth Observation segment. Strong demand from government agencies, agricultural monitoring initiatives, defense applications, and disaster management programs created a relatively well-defined and accessible market for Earth Observation satellites. As a result, most private investment and product development naturally gravitated toward subsystems optimized for Earth Observation missions.This has led to the emergence of a supply chain that is largely calibrated to meet the needs of the Earth Observation industry. For example, sensors have been optimized for imaging payloads, satellite buses have been designed primarily for sun-synchronous orbits, and ground station networks have been built around high-throughput data downlink requirements. While these capabilities are valuable, they do not directly translate to the needs of ISAM missions. The requirements for ISAM are fundamentally different and significantly more complex.

The absence of these mission-specific components within the domestic ecosystem creates a significant bottleneck for the growth of the ISAM industry in India. Startups and companies working in this domain cannot afford to wait for several years while suppliers develop and qualify new technologies, especially when they are simultaneously under pressure to demonstrate their own capabilities to attract funding and secure contracts. This creates a dependency on external sources, which introduces additional challenges.

Beyond the issue of capability mismatch, the broader supplier base for space-grade hardware in India remains relatively limited and fragile. Only a small number of companies are currently engaged in the manufacturing of critical components, leading to capacity constraints and reduced flexibility. When demand increases or when multiple programs require similar components simultaneously, there are few alternative suppliers available. This results in extended lead times, increased costs, and potential compromises in quality assurance processes.

For ISAM startups that are operating under tight timelines and competitive pressures, these constraints can be particularly severe. Delays in component availability can disrupt development schedules, increase project risks, and affect the ability to secure follow-on funding. As a result, many companies are compelled to import key subsystems, particularly advanced sensors and specialized electronics, from international suppliers. While this approach can address immediate needs, it also introduces long-term risks related to cost volatility, supply chain disruptions, and strategic dependency.

Encouragingly, some Indian companies have begun to address these gaps by developing indigenous alternatives to critical subsystems. These efforts reflect a growing recognition of the importance of self-reliance in advanced space technologies. However, most of these products are still in the early stages of development and demonstration. Transitioning from prototype to production involves significant challenges, including scaling manufacturing processes, ensuring consistent quality, and achieving the level of reliability required for repeated space missions.

The gap between demonstrating a technology in a controlled environment and delivering it consistently across multiple missions at commercial scale is substantial. It requires not only technical refinement but also robust supply chains, quality control systems, and customer validation. At present, India's ISAM-relevant suppliers are still in the process of bridging this gap. Until this transition is successfully achieved, the growth of the ISAM ecosystem will continue to face structural constraints that limit its ability to scale and compete globally.

3. BUILDING AN ISAM FOUNDATIONAL LAYER IN INDIA

While the challenge of building a robust supply chain for In-Space Assembly and Manufacturing (ISAM) is not limited to one geography but is instead a global concern spanning regions such as Japan, Australia, the United States, Europe, and the United Kingdom. India faces a particularly unique situation shaped by the historical evolution of its space ecosystem. The Indian space sector has for decades, been largely oriented toward Earth Observation missions, resulting in a strong but specialized industrial base. While this has enabled significant achievements, it has also meant that emerging domains like ISAM do not yet have a naturally aligned supply chain. This creates both a constraint and an opportunity because the foundational capabilities exist but must be strategically redirected and expanded to meet the requirements of ISAM. Without structured and deliberate intervention, relying solely on market forces will not be sufficient to sustain or scale this industry in India.

3.1. GOVERNMENT DIRECTION

Firstly, clear and consistent direction from the government must be treated as the highest priority in enabling the ISAM ecosystem. Unlike mature sectors such as Earth Observation, where demand, supply chains, and institutional frameworks are already well established, ISAM is still in a nascent phase and requires active nurturing. This direction must go beyond high-level policy statements and translate into tangible signals that reduce uncertainty for all stakeholders involved. One of the most critical signals is the assurance of long-term procurement commitments from strategic end-users, including defense organizations and national space agencies. Such commitments act as demand anchors and give confidence to startups, manufacturers, and investors that there will be a viable market for ISAM technologies in the future. In addition to procurement signals, the government should also expand targeted innovation initiatives tailored specifically to ISAM. This includes designing dedicated challenge programs similar to existing innovation frameworks but with a sharper focus on in-space servicing, assembly, and manufacturing technologies. Seed funding schemes from agencies such as IN-SPACe and other relevant bodies should be structured to support early-stage experimentation and prototyping. By doing so, the government enables all stakeholders in the ISAM ecosystem including startups, component manufacturers, end-users, and investors to align their internal priorities and allocate resources toward developing capabilities in this domain. Over time, such coordinated signaling can create a self-reinforcing cycle of innovation and investment.

3.2. ISAM SUPPLY CHAIN DATABASE

Secondly, there is a pressing need for the government to systematically identify and address the gaps within the Indian supply chain ecosystem for ISAM. At present, there is no comprehensive mapping of the components and sub-systems required for ISAM missions, which makes it difficult to assess where domestic capabilities exist and where dependencies on external sources remain. Initiating the development of a dedicated and dynamic database of these components would be a critical first step. This database should not only catalog existing capabilities but also highlight areas where technological development is needed. Importantly, this effort should be approached with a holistic mindset, viewing ISAM as an integrated system rather than a collection of isolated components.

Building on this understanding, targeted policy interventions can be introduced to strengthen domestic manufacturing capabilities. Production Linked Incentive schemes can play a pivotal role in encouraging manufacturers, testing facilities, and startups to invest in ISAM-related technologies. These incentives should be designed to support both new entrants and existing companies that are willing to extend their expertise from adjacent domains into ISAM. At the same time, establishing robust frameworks for quality assurance and standardization is essential. High standards and certification processes will ensure that ISAM companies can reliably source components when required, thereby reducing delays and enhancing mission reliability.

3.3. BRIDGING EARTH OBSERVATION SECTOR TO ISAM

To address immediate gaps, the current ecosystem, which is heavily oriented toward Earth Observation, can be leveraged as a starting point. Many Indian companies already possess strong capabilities in areas such as satellite subsystems, electronics, materials engineering, and software. The key challenge lies in identifying the difference between these existing capabilities and the specific requirements of ISAM-oriented subsystems. This involves understanding the additional functionalities, performance parameters, and reliability standards needed for in-space operations such as robotic assembly, servicing, and manufacturing.Once these gaps are clearly defined, targeted interventions can be implemented to facilitate the transition.

Specific grant programs and funding mechanisms should be designed to support startups and existing vendors in developing ISAM-compatible technologies. These programs should provide clarity in terms of eligibility, funding timelines, and expected outcomes, enabling participants to plan their development efforts effectively. In many cases, companies may choose to invest their own internal resources to bridge these gaps, particularly if there is sufficient confidence in future market demand. By creating an environment where both public and private funding can coexist and complement each other, the transition toward an ISAM-ready ecosystem can be significantly accelerated.

3.4. SETTING UP NATIONAL ISAM TESTING INFRASTRUCTURE

Finally, one of the most critical and challenging aspects of building an ISAM ecosystem is the establishment of specialized testing and validation infrastructure. ISAM technologies require highly sophisticated facilities that can simulate the conditions of space and enable the testing of complex operations such as rendezvous, proximity operations, and docking. This includes air-bearing facilities, which allow for the simulation of microgravity conditions, as well as dedicated robotic arm testing environments and advanced cleanroom facilities for integrated system testing. While India has developed substantial infrastructure for satellite Assembly, Integration, and Testing, these facilities are not fully equipped to meet the unique demands of ISAM.

To address this gap, the creation of a national-level ISAM infrastructure facility would be highly beneficial. Such a facility would serve as a shared resource for startups, research institutions, and established companies, enabling them to test and validate their technologies without the need for significant individual capital investment. This, in turn, would accelerate development timelines and reduce barriers to entry for new players. However, establishing such infrastructure is a capital-intensive endeavor and therefore requires a collaborative approach. Partnerships between government agencies, universities, and private companies can help distribute the financial burden while ensuring that the facility meets the needs of a diverse set of users.

In conclusion, while the challenges associated with building a robust ISAM supply chain are significant, they are not insurmountable. With clear policy direction, targeted investments, systematic mapping of capabilities, and the development of specialized infrastructure, India can position itself as a key player in the global ISAM landscape. The transition will require sustained effort and coordination across multiple stakeholders, but the potential benefits in terms of technological leadership, economic growth, and strategic capability make it a worthwhile endeavor.

4. MARKET CREATION & POLICY FRAMEWORK

A fundamental constraint in the emergence of an orbital servicing ecosystem in India is not just manufacturing, but the absence of a clear market. ISAM is an emerging technology, where supply-side is outpacing the demand, creating a coordination failure between capability development and commercial market. (Cavaciuti, Davis, and Heying (2022)). In such conditions, the role of the government as an anchor customer becomes decisive not only to generate initial demand and risk benchmarks for the market.

For India, this extends beyond simply funding demonstration missions. In-SPACE can actively shape market structure by embedding servicing requirements into public satellites , effectively mandating or incentivizing serviceability across future missions. This creates a guaranteed demand while simultaneously expanding the addressable market for private providers. In parallel, early-stage public procurement of services such as life extension or in-orbit inspection can help establish reference contracts, which are critical for unlocking private financing in a capital-intensive sector. A key, often overlooked lever is the integration of ISAM into financial and risk frameworks. If servicing capabilities are recognized by insurers and financiers as mechanisms for risk reduction through asset recovery, repair, or life extension this can materially lower insurance premiums and improve asset valuations. Such shifts would transform ISAM from a discretionary capability into an economic necessity. Policy can accelerate this transition by working with insurers, regulators, and satellite operators to formally recognize servicing as a risk mitigation tool.

Finally, market creation must be viewed not as a one-time intervention, but as a phased process. Initial demand will be state-driven, but over time should transition toward commercial operators, particularly constellation providers, for whom fleet-level optimization creates strong economic incentives for servicing. (Cavaciuti, Davis, and Heying (2022)). The objective of policy, therefore, should not be to sustain the market indefinitely, but to catalyze a self-sustaining demand cycle where demonstrated value, reduced risk, and standardized practices drive organic growth.

4.1. STANDARDIZATION

Equally critical is the need to structurally embed servicing capability into the satellite lifecycle through standardization. At present, the lack of interoperability between satellites and servicing systems represents a fundamental bottleneck that limits scalability, increases mission complexity, and raises costs. Without common technical standards, each servicing mission risks becoming a one of a kind operation, undermining the economic viability of the entire ecosystem. A policy-driven transition toward "serviceable-by-design" architectures incorporating standardized docking interfaces and modular subsystems can fundamentally change this dynamic. However, standardization should not be viewed merely as a technical exercise, but as a strategic market-shaping tool. By defining common interfaces and protocols early, India has the opportunity to influence emerging global norms, positioning its industry within future international supply chains and reducing dependence on external standards.

Importantly, standardization enables scale (CONFERS, 2019). As more satellites adopt compatible designs, servicing operations can transition from one-off missions to repeatable, cost-efficient services. This creates network effects: each additional serviceable satellite increases the value of the servicing ecosystem as a whole, strengthening the business case for further adoption. Over time, this can shift ISAM from a niche capability to a default feature of satellite design. There is also a regulatory dimension to standardization. Mandating or incentivizing serviceable designs for certain classes of satellites particularly those in congested orbits can align commercial incentives with larger sustainability goals. Standardization can thus serve as a bridge between economic efficiency and responsible space operations, enabling effective end-of-life management, and orbital traffic coordination.

A complementary pathway to standardization lies in the strategic development and promotion of India-origin interface standards and proprietary technologies. Rather than solely adopting externally developed protocols, India can pursue a dual approach: aligning with emerging global interoperability frameworks while simultaneously advancing indigenous solutions that can shape future norms. This includes technologies such as OrbitAID's Standard Interface for Docking & Refuelling Port (SIDRP), which provides a standardized, serviceable interface for next-generation satellites, enabling seamless docking, refueling, and in-orbit interaction. In parallel, solutions like OrbitAID's ARCAS system introduce backward compatibility into the ecosystem by addressing the large installed base of legacy satellites that lack servicing interfaces. By enabling the capture of existing adapter rings without requiring prior design modifications, ARCAS expands the scope of ISAM to include satellites that would otherwise remain non-serviceable, allowing them to access end-of-life management, life extension, and controlled de-orbiting services.

Together, such forward-looking and retrofit-compatible technologies create a more inclusive and scalable servicing architecture, bridging the gap between future-ready satellite design and legacy orbital assets. Strategically, this positions India not only as a participant in standard adoption, but as a potential exporter of standards and technologies, with the ability to influence global ISAM ecosystems while building domestic industrial depth.

Ultimately, the success of ISAM will depend not only on technological breakthroughs, but on the establishment of shared rules that enable interoperability, reduce uncertainty, and unlock scale. In this context, standardization is not a downstream activity, it is a foundational enabler of both market formation and long-term competitiveness.

4.2. POLICY APPROACH

In this context, the regulatory role of IN-SPACe is central to ecosystem formation. As the primary interface between government and private industry in India's space sector, IN-SPACe is positioned to move beyond a narrow authorization function and act as an ecosystem enabler. For ISAM, this entails developing a regulatory framework that is anticipatory rather than reactive one that provides clarity on mission approval pathways while remaining flexible enough to accommodate evolving technologies. This includes addressing issues such as proximity operations, interaction with third-party assets, liability attribution and compliance with international obligations. A predictable and transparent regulatory environment will be essential to unlocking both domestic and foreign investment in this domain.

To operationalize this framework, three policy priorities stand out. First, the development of ISAM-specific authorization regimes is essential. Servicing missions differ fundamentally from traditional satellite operations, involving active maneuvering, docking and physical interaction in orbit; existing licensing structures are not designed to accommodate these complexities. A tailored policy must therefore define clear criteria for authorization and oversight. Second, the establishment of technical standards for serviceable satellites is critical to ensuring interoperability and scalability. India has an opportunity not only to adopt emerging standards but to shape them, particularly if it moves early in deploying serviceable architectures. Third, targeted incentives for critical technologies are required to address capability gaps and reduce entry barriers. This includes support for R&D in robotics, autonomous navigation, in-orbit propulsion and high-reliability subsystems, as well as measures to strengthen domestic manufacturing of high-end components.

Ultimately, market creation and policy design must function as mutually reinforcing. Without early demand, private investment will remain constrained; without regulatory clarity, innovation will stall; and without standards, the ecosystem will fragment. A coordinated, forward-looking policy approach can enable India not only to participate in the ISAM market, but to shape its structure and capture long-term strategic value.

5. GLOBAL POSITIONING & ROADMAP

Building on a foundation of market creation and regulatory clarity, India must articulate a deliberate global positioning strategy that aligns its structural strengths with emerging gaps in the international ISAM landscape. Rather than competing head-on with capital-intensive, high-cost segments, India can position itself as a cost-efficient global hub for orbital servicing delivering reliable, scalable and competitively priced servicing solutions. This positioning leverages India's demonstrated advantage in cost effective engineering and systems integration, allowing it to offer ISAM services at price points that expand the addressable market, particularly for small and mid-sized satellite operators. In doing so, India can play a market-expanding role rather than a purely competitive one, lowering barriers to entry for servicing adoption globally.

At the same time, India is uniquely placed to emerge as a preferred partner for the Global South, in accessing and benefiting from ISAM capabilities. Many emerging spacefaring nations are entering orbit through small satellite deployments but lack the resources to build end-to-end lifecycle capabilities (International Telecommunication Union, 2023) . By offering affordable servicing solutions, technical partnerships, and potentially shared infrastructure models, India can position itself as an enabler of sustainable space participation for these countries. This approach aligns not only with commercial objectives but also with broader strategic and diplomatic goals, reinforcing India's role as a responsible and inclusive space actor. In effect, ISAM can become a tool of both economic expansion and geopolitical influence.

Translating this positioning into reality requires a phased roadmap. In the short term, the priority must be to establish technical credibility and reduce uncertainty through targeted pilot missions and policy clarity. Demonstration missions particularly those focused on rendezvous, docking, and life-extension are critical to validating indigenous capabilities and building confidence among potential customers and investors. In the Indian context, early private-sector initiatives such as OrbitAID's AayulSat mission have already contributed to the feasibility of satellite life-extension concepts, while its upcoming in-orbit servicing and docking missions of two satellites, target and chaser, which would dock and refuel, representing the next step toward operational capability. Together, these efforts signal the gradual transition from conceptual validation to applied ISAM operations within the Indian ecosystem. In parallel, regulatory frameworks must be operationalized with clear, time- sensitive authorization processes led by IN-SPACe, ensuring that firms can move from concept to execution without procedural ambiguity. Early government-backed missions will play a key role in anchoring demand and signaling long-term commitment.

In the medium term, the focus should shift toward scaling the domestic supply chain and deepening industrial capabilities. This involves moving beyond isolated technological successes to building an integrated ecosystem of component manufacturers, subsystem providers, and system integrators capable of supporting ISAM missions at scale. Targeted interventions will be required to strengthen domestic production of high-end components such as sensors, propulsion systems, and robotic interfaces while reducing dependence on imports and mitigating exposure to external export controls. At this stage, standardization efforts and industry-wide interoperability frameworks will also become increasingly important, enabling multiple players to participate in a cohesive and competitive ecosystem.

In the long term India should aim to evolve from a service provider to a builder of orbital logistics infrastructure. This includes the development of in-orbit platforms such as servicing hubs, propellant depots, and modular assembly nodes that support sustained operations in space. Such infrastructure would not only enable more complex ISAM activities but also anchor India's presence in the next phase of the space economy where value is derived from persistent capabilities rather than discrete missions. By aligning early policy choices with this long-term vision, India can ensure that its ISAM ecosystem evolves in a direction that maximizes both economic returns and strategic autonomy.

Taken together, this positioning and roadmap reflect a shift from reactive participation to proactive leadership. By leveraging its cost advantages, aligning with the needs of emerging space actors, and executing a phased capability build-up, India can establish itself as a central node in the global orbital servicing ecosystem shaping both its market dynamics and its governance frameworks over the coming decades.

II. CONCLUSION

The global space sector is undergoing a fundamental shift from a model centered on access to orbit to one defined by sustained operations and long-term value creation in space. As this paper has established, ISAM is central to this transition, enabling satellites to evolve from single-use assets into serviceable, adaptable, and longer-lasting infrastructure. In this context, ISAM is not a niche capability, but a foundational layer of the emerging in-space economy.

For India, this shift presents a timely strategic opportunity. The country's strengths in cost-efficient engineering, mission reliability, and systems integration provide a strong foundation for entry into the ISAM domain. The rapid growth of the private space ecosystem, supported by recent policy reforms and institutional support, further enhances India's ability to innovate and scale. Importantly, India is not as constrained by legacy systems as more established space powers, creating an opportunity to embed serviceability and flexibility into future space architectures from the outset.

However, technological capability alone will not be sufficient. As highlighted in this paper, the development of a viable ISAM ecosystem depends on the parallel evolution of markets, policy frameworks, and industrial capacity. The absence of a clear market remains a key constraint, requiring early government intervention to generate demand, reduce uncertainty and enable private sector participation. At the same time, standardization will be critical to ensuring scalability. Without interoperable systems and common interfaces, servicing missions risk remaining complex and costly, limiting their broader adoption. The role of supply chains is equally important. ISAM relies on advanced components such as propulsion systems, sensors, and robotic technologies. Strengthening domestic capabilities in these areas will be essential for reducing external dependencies and supporting long-term growth. A robust supply chain will enable India to transition from isolated demonstrations to a more integrated and scalable ISAM ecosystem. India's current capabilities, while still evolving, indicate strong forward momentum. Developments in small satellites, propulsion, and space situational awareness, combined with increasing private sector participation, provide a credible base for future expansion. The next step lies in translating this potential into operational capability through demonstration missions, regulatory clarity, and coordinated ecosystem development. Looking ahead, ISAM will also support more ambitious space activities, including deep space exploration. In-space servicing systems can act as "pit stops," enabling refueling, maintenance and reconfiguration of spacecraft, thereby reducing costs and increasing mission flexibility. Ultimately, ISAM represents more than a technological opportunity, it is a pathway for India to redefine its role in the global space ecosystem. With the right alignment of policy, industry, and strategic intent, India can position itself not just as a participant, but as a key enabler of the in-space economy.

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