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nasscom

Exploring opportunities for Indian downstream spacetech

October 2023

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राज्य मंत्री
संचार
भारत सरकार
Minister of State
for Communications
Government of India

MESSAGE

I extend congratulations to the Indian Space Policy Association (ISpA) on their second anniversary. I am also happy to release this report - "Exploring Opportunities in Indian Downstream Spacetech" during the event – Indian Space Conclave 2023.

Growth of India's private space ecosystem over the past few years has been remarkable. There are around 200 startups in the sector which is indicative of our capabilities and potential within the Indian private space industry. Bridging the digital divide has been foremost priority of the Government under the leadership of the Hon'ble Prime Minister Shri Narendra Modi ji. Space sector has potential to address such telecommunications needs of the country, particularly in remote and inaccessible areas. It can bring socio-economic changes, enhance the competitiveness and productivity of other existing sectors.

This report presents a good analysis of the potential and challenges within the Indian downstream space sector. It outlines specific focus areas, including agriculture, disaster management, education, health, urban planning, satcom, navigation etc. This report also highlights transformative potential of SATCOM technology in India, which will enable crucial services like telemedicine, e-learning, and e-commerce in even the most remote areas. Report also highlights many other specific areas which are poised to significantly contribute to India's economic growth, aligning with the overarching vision of an AatmaNirbhar Bharat.

India continues to leverage its space capabilities in many sectors including defence, and scientific exploration. It is also on the track to achieve new milestones and solidifying its position as a spacefaring nation. This forward momentum is not only propelling India towards self-reliance in space technology but also paving the way for ground-breaking discoveries and technological advancements that will benefit humanity.

(DEVUSINH CHAUHAN)

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भारतीय डाक
India Post

Foreword

Dr. Pawan Kumar Goenka
Chairman, IN-SPACe

The Indian space sector has witnessed remarkable achievements in the recent years, such as the successful launch and landing of Chandrayaan-3, the first Indian mission to explore the lunar south pole, and the development of various satellites and applications for socio-economic benefits. These achievements have not only enhanced our national pride and prestige, but also demonstrated our capabilities and potential in the upstream space sector, which involves the design, development and launch of space systems.

However, the full potential of space for creating impact on Earth is realized using the downstream sector, which involves the utilization of space data, products and services for various end-user applications. The downstream sector has immense scope for innovation, entrepreneurship and value creation, as it can cater to diverse sectors such as agriculture, disaster management, education, health, navigation, communication, entertainment and many more. The downstream sector can also contribute significantly to the national goals of inclusive development, digital transformation and self-reliance.

The downstream space sector, with its potential to generate real-world applications and solutions, holds the key to advancing socio-economic progress. IN-SPACe is committed to enable downstream space segment to reach the last mile of the remote areas and taking multiple initiatives like the Seed Fund Schemes, which fosters innovation in critical sectors such as agriculture (a starting point).

As we embark on this journey, we are committed to providing the necessary training and resources to empower individuals and organizations to harness space technology for the benefit of all. Initiated short-term domain-specific credit courses, in collaboration with ISRO and NSDC, exemplify this commitment. We believe that by equipping our Indian workforce with the knowledge and skills required to leverage space technology, we pave the way for a more inclusive and empowered society.

This report, which estimates market sizes for specific downstream use-cases, comes at a pivotal moment for the Indian space sector. It complements our initiatives in the downstream sector and provides valuable insights into the potential of downstream applications. This report equips stakeholders with the knowledge needed to make informed decisions and drive the growth of the space economy.

I extend my heartfelt congratulations to the Indian Space Association (ISpA) on their second anniversary. Their unwavering commitment to advancing the interests of the Indian space community has been instrumental in shaping the sector's trajectory.

Let us continue to strive for a resurgent, AatmaNirbhar Bharat, where the limitless potential of space is harnessed for the greater good of our nation and its people.

Foreword

Jayant D Patil
Chairman, Indian Space Association (ISpA)

Since the launch of Aryabhata in 1975 announcing India's entry into Space, to the latest successes of Chandrayaan - 3 and Aditya – L1, India recorded benchmark accomplishments to establish our prowess by showcasing unmatched frugal approach, consistency, unmatched safety track record, and efficiency by pursuing self-reliance over this journey. Also, India demonstrated ability to build sophisticated infrastructure at its space port, ground systems, DSN network and exploited these with clear mission to serve the common man not only in India but for the mankind. Over the years India emerged the partner of choice for many countries with space aspirations. Thanks to ISRO for ably spearheading India's ambitions in Space & in the process establishing an Indian ecosystem for the Space Industry. While announcing the Space reforms, our Hon Prime Minister envisioned India attaining a share of Global Space Commerce befitting the maturity India has attained.

Recent announcement of Indian Space Policy marks the dawn of a new era enabling the private sector to foray into the entire gamut of the space ecosystem, from building, launching & operating satellites for earth observation, navigation, communication as also unshackling to build new business models through innovation, entrepreneurial thinking and imagination where "Sky is not the Limit". For India to realize the incredible future potential in the Space Tech sector the participation of private entities shall play a crucial role & the Indian Space Association is at the fore front of leading the synergy between the Private sector & the Government.

Since its establishment following the National Leadership's advice to build a Space sector specific association, the Indian Space Association has been steadfast in its commitment to promote, actively engage with, and facilitate the involvement of private enterprises in the space sector. ISpA mission of disseminating knowledge, information, and technology within the space industry, continues to benefit its ever-expanding and diverse community of membership and industry at large.

The overarching vision of IN-SPACe has been to handhold the fledgling Industry, foster collaboration wherein governmental entities and private sector stakeholders work in unison and regulate the Space activities reflects the National leadership's out-of-the box thinking and commitment to see the same succeed. Towards this ISpA collaborated with nasscom and Deloitte to unveil the untapped potential of the Space sector and foster synergy between government entities and private enterprises within the domain of space tech.

ISpA has great pleasure to announce the release of this comprehensive report. This report titled **"Exploring opportunities for Indian downstream spacetech"** represents yet another significant stride in the direction of paving way to untap India's potential through synergy across Industry sectors.

The report throws light on the rapidly growing space economy of India & the potential that can be realized by private players in harmony with the government bodies. The report focuses on the downstream segment of the Indian space value chain & explores the vast use cases that exist within the downstream segment by exploiting the Global leadership position of India in IT & ITES sectors hand in hand with earth observation, satellite communication, navigation, positioning & timing services. The report dives further into specific use cases that promise significant commercial & revenue potential to chase. It also delves upon certain regulatory, business & technology challenges that need focused attention and resolved.

ISpA with the knowledge partners hope that the report shall enlighten the reader on the various commercial & business services to pursue to unlock the potential of Indian space economy

Foreword

Lt Gen Anil Kumar Bhatt
Director General, Indian Space Association (ISpA)

It is with great pleasure that we release this report on the occasion of ISpA's 2nd Anniversary and the Indian Space Conclave event 2023. This momentous occasion marks another significant step in our collective journey towards propelling India to the forefront of the global space ecosystem.

The Indian Space sector has witnessed remarkable growth and achievement over the past few decades. In recent years, India has also made impressive strides with in space exploration, culminating in the successful Chandrayaan-3 mission to the Moon and Aditya-L1 mission, which garnered global acclaim. The emergence of private players and startups in the space sector has added a new dimension, fostering innovation, competition, and collaboration. This dynamic ecosystem is poised to play a pivotal role in shaping the future of space exploration and commercial activities. This inclusivity is driving technological advancements, economic growth, and job creation, aligning with the vision of an 'Atma Nirbhar Bharat' or self-reliant India.

The downstream sector of India's space industry is making a substantial impact on economic growth. Through applications like satellite communications (SATCOM), remote sensing/earth observation (EO), and positioning, navigation, and timing (PNT) and strategic usage of space downstream sector has opened up new avenues for economic development. From the diverse potential use-cases of 200 identified from the above 4 areas of the downstream sector, few use-cases, around 25, are identified based on 3 parameters – Impact, commercial viability, and technological feasibility in the next 5 years. This report deep dives into those focus use-cases and highlights the emerging use-cases in future.

This report on **"Exploring opportunities for Indian downstream spacetech"** aims to provide a comprehensive overview of the current state and future prospects covering the following aspects:

- A use case analysis & market analysis that estimates the size and growth of the focussed areas prioritizing specific use cases for downstream space applications across various sectors such as agriculture, disaster management, urban planning, health, education, finance etc,.
- Key trends, policies landscape, challenges, value creation models and highlights recommendations for developing a vibrant and sustainable downstream space ecosystem in India.

We believe that the downstream Space sector has the potential to transform the Indian economy and society by enabling new solutions for existing and emerging challenges, enhancing productivity and efficiency, creating new jobs and skills, fostering innovation and entrepreneurship, and strengthening national security and strategic interests. We hope that this report will serve as a valuable resource for all stakeholders who are interested in exploring and leveraging the opportunities offered by the downstream space sector in India.

Let us forge ahead with a renewed sense of purpose and determination. Together, we have the power to chart a course that will not only define the future of the Indian space sector but also leave an indelible mark on the global stage. I extend my heartfelt congratulations to each member of ISpA for their unwavering dedication, and I look forward to the strides we will make in the years ahead.

May the foundation day continue to serve as the bedrock to connect all stakeholders of this industry and allow them to propel India to new heights.

Foreword

Achyuta Ghosh
Sr. Director & Head of Insights
nasscom

National Association of Software and Service Companies (nasscom) in collaboration with Deloitte and ISpA is delighted to launch this report to showcase that space sector has come very long since its conception in 1960s and the possibilities it encompasses for future of Indian space economy if used to its maximum potential.

Until now, most of the contribution of space technology has been from the upstream segment of value chain through satellite manufacturing, launching etc., India's new space policy opened opportunities for space technology to serve even the downstream segment. Also, emergence of New Space India not only increased the scope to service the market but also created opportunities to invent technologies. Access to ISRO assets is encouraging many private players to make use of space technology available in various forms to even target markets that are not served by space technology.

Going forward, space technology in India will penetrate much deeply into various other sectors like maritime, aviation, agriculture, energy, telecom etc. to make them more profitable by supporting them in making business decisions with the help of satellite imagery, scale their services to remote areas through satellite communication and data from PNT satellites can be leveraged to provide navigation and location-based services. The "Exploring Opportunities for Indian downstream space-tech" report focusses on the downstream segment of space value chain by deep diving into three major areas Earth observation, satellite communication and positioning, navigation, and timing services (PNT) and the potential value that these areas can create. This report analyses areas of investments for space-based players in the market and highlights downstream applications in various sectors for businesses to gain more insight on using space technology to grow. By synthesizing these insights, the report not only offers valuable guidance to investors seeking opportunities in the downstream space sector but also provides entrepreneurs with a roadmap for directing their resources within the current technological and commercial landscape.

Ultimately, it highlights India's burgeoning space economy, emphasizing the immense potential for private players in satellite communication, earth observation, positioning, navigation, and timing and strategic defense services. Let's get together for India's journey toward self-reliance in space, meeting global demands, and illuminating the vast business opportunities within the Indian space economy.

Foreword

Sreeram Ananthasayanam
Partner, Deloitte

In the dawn of the Indian NewSpace era, we find ourselves at a momentous juncture where the democratisation of space is no longer a distant aspiration, but a tangible reality. The profound impact of the space sector on socio-economic development cannot be overstated. Over the past six decades, India's space programme has been instrumental in addressing critical challenges facing our nation, creating an ecosystem that continues to yield innovative solutions. From informing farmers about best practices based on climatic conditions to disaster relief and prediction measures, the country's interest has always been at the heart of the space programme. It will continue to persist in this era of NewSpace.

This report, written in collaboration with nasscom and ISpA, offers an overview of the downstream market's potential. It also covers specific use cases within key satellite application areas of Earth Observation, Satellite Communication and Positioning, Navigation and Timing along with strategic defence applications. This report deep dives into specific use-cases (about 25 of the 200+ possible use cases) identified by mapping their technological feasibility, impact, and commercial viability considering the current capabilities of countries and industries in space. The commercial market potential of the identified use cases for the next five years has been derived on the basis of the current technology landscape and business models identified from multiple industry sources. These are indicative in nature and provide only a directional view of the market potential.

As we embark on this journey of discovery and progress, we acknowledge the immense potential that lies within the downstream sector. Together, we stand poised to unlock a future where space is not just a realm of scientific exploration but a catalyst for unprecedented socio-economic growth.

Executive summary

> "...But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society."
>
> **–Dr. Vikram Ambalal Sarabhai**

The fundamental purpose of India's space programme has been solving the real problems of man and society. Over the past six decades, this purpose has created an ecosystem that continues to generate solutions that address the country's critical socio-economic and strategic challenges.

In general, this mature ecosystem can be classified into the following segments:

01. **Upstream:** Manufacturing, launching and operating space assets
02. **Downstream:** Using and applying data and insights from space in solving problems on Earth through applications
03. **Auxiliary segment:** Non-core service areas for the space sector and products/services that are spin-offs from space technologies and used in other sectors

In recent years, the domestic ecosystem has transformed basis investments into the sector, technologies and co-operation and critical actors driving growth and innovation. To further this transformation and achieve self-reliance, the space sector has been liberalised to allow non-government entities to participate in a gamut of core space activities through the Indian Space Policy, 2023. Construed as a watershed moment for India's space ambitions, the policy is not only an approach for the future but also a testimony to the advent of India's NewSpace era.

The advent of NewSpace; primarily the entry of private players and capital into core space activities to complement government efforts through a regulatory regime; is expected to shift the priorities and benchmarks for the sector and its prominent actors to the extent that commercial value creation, economy of operations and return on invested capital may evolve to become critical determinants of NewSpace's success in India.

At the basic level, solving socio-economic and strategic challenges in the backdrop of commercial considerations requires the enabling of tangible business and governance benefits through the downstream sector. In other words, downstream applications are the most critical revenue- and impact-generating segment of the space economy that can support, sustain and further advancements in other segments.

Although non-space and space-based technological advancements and newer business models are fuelling opportunities through downstream applications, competition from terrestrial alternatives and a suboptimal ability to promote adoption applications are critical challenges for the sector. In fact, without a calibrated approach to mitigate these challenges, future projections of the size and nature of the space economy and its potential may not materialise and remain mere projections.

According to the age-old adage, "What gets measured, gets managed," measuring the downstream market potential of the Indian market is mission critical for India's space ecosystem. Sizing the potential of the downstream market for space applications has been a challenging task for several reasons, including the boundary conditions to measure, sectors to study, availability of data and consensus on the approach and methodology to adopt.

This report attempts to determine the potential market value for the downstream segment along three major satellite application areas: earth observation (EO)/remote sensing, satellite communication (SATCOM) and positioning navigation and timing (PNT). The sectors and corresponding use-cases covered in this report are in no way exhaustive.

Figure 1: Downstream segment: sectors and use-cases considered for market value estimation

Before delving into the market potential, this report details the context and details of the space value chain in India. Further, it specifies the study areas and methodology adopted for the study.

The market potential was evaluated by carefully considering the challenges faced by all stakeholders, i.e.

01. Technology providers and end-users
02. The focus areas requiring solution development
03. Penetration that may ultimately lead to value creation.

Moreover, the report details the use-cases driving value creation. Finally, the study identifies and documents the critical challenges that may act as a deterrent from realising value creation.

In the same vein, it is fundamental to recognise that space has been and will continue to be a dual-purpose sector combining commercial possibilities with implications for national security and strategy. With technological advancements, securing space assets and ensuring sustained access to space are new additions to the traditional dimensions of leveraging space for national security, truly making space the fourth warfare domain in addition to land, air and sea.

For this purpose, the report lists the key areas of defence space for India and the impact it can have on India's national security considerations. In this context, it is imperative to note that attributing market values for strategic use-cases can be misleading because their criticality and sensitivity far outweigh their market potential. Hence, for strategic use-cases, the focus areas for NewSpace have been highlighted; in time, it is expected that substantial value creation for the NewSpace ecosystem will be a by-product of securing India's strategic objectives.

The report also has a section on **"The Emerging Indian Private Space Ecosystem: Opportunities, Challenges & Way Ahead"** solely and exclusively authored by Wing commander Satyam Kushwaha (Retd), Director, ISpA, where he details out new trends, challenges and future opportunities for the emerging private space ecosystem.

Figure 2: Space Defence Sector: Key Strategic Use-cases

* Internet of Battlefield Things (IoBT), Internet of Military Things (IoMT)

Overview of global space economy

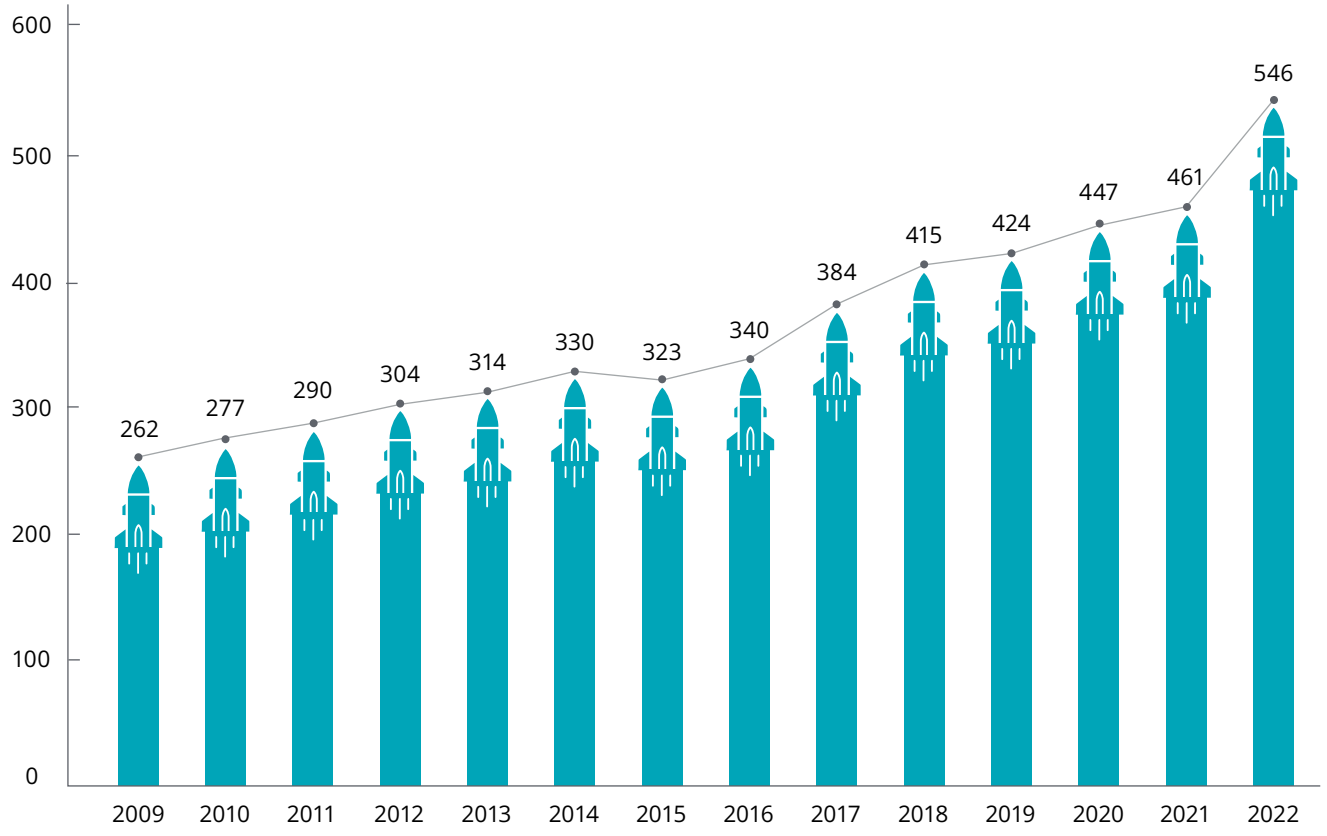
Global landscape of the space sector

Nations around the world have recognised the strategic and economic importance of space. Therefore, the sector has evolved from the exclusive purview of governments to a dynamic, synergistic collaboration between public and private entities.

Over the past two decades, there has been a new movement towards innovative start-ups, novel business models and increased accessibility and utilisation of space. Consequently, globally, the space industry is experiencing a renaissance with innovative technologies, cross-border collaboration and new business models reshaping how we explore, utilise and benefit from space.

This shift is driven by technological advancements such as reusable technologies, miniaturisation of avionics and growing demand for satellite services, leading to the deployment of large numbers of small satellites, transforming how we communicate, navigate and gather information from space. Moreover, this facilitates commercial returns from space, allowing entry of commercial players into the space industry.

Figure 3: Space economy size (in USD billion) - year on year



Source: Compilation from Space Foundation: https://www.spacefoundation.org/2022/07/27/the-space-report-2022-q2/

Space value chain

Although headline numbers and launches captivate public imagination, they are part and product of a high-functioning value chain with a complex interplay between engineering, technology and commerce. Global consensus on segmenting the space value chain is evolving; there are several approaches to categorising space activities.

For this report, the Organisation for Economic Co-operation and Development's (OECD) framework has been adapted to include space and ground system operations in the midstream segment as part of the upstream segment.[1]

Table 1: Space Value Chain[2]

Upstream Segment

This segment refers to all activities, products and infrastructure ensuring the development, testing, launching, operations and monitoring (including space situational awareness) of space assets. It includes emerging areas of leveraging in situ usage of space viz., space tourism, space-based manufacturing, space mining, etc. This also includes applications like ground stations and space assets monitoring which are typically classified under midstream.

Downstream Segment

Primarily sub-segmented into Earth Observation(EO), Satellite Communication(SATCOM), Positioning, Navigation & timing (PNT), this segment refers to all applications, services and devices relying on satellites to create business value. This includes dual-purpose services and applications that cater to strategic requirements.

Auxiliary Segment

Primarily referring to activities, products and services derived from space technology in other sectors, such as manufacturing and health. It includes additional space-related activities such as space insurance and awareness, education and training.

Upstream (includes midstream)

Figure 4 : Overview of Up-Stream segment

Satellites, launch vehicles & their components: From materials supplies, design, development, testing till integration into launch vehicle

Activities related to the design, manufacture, test and operation of satellites and launch vehicles constitute the upstream segment. Organisations working on realization of propulsion systems, guidance, navigation, payloads, avionics, control systems, power & thermal systems and structural elements, are all part of this upstream sub-segment.

Space infrastructure development

This upstream sub-segment involves the development of critical space infrastructure, including launch pads, facilities, satellite launch services supporting for the launch of satellites into orbits. Providers offering telemetry, tracking, and communication centers play a crucial role in real-time monitoring and control of spacecraft.

This also would cover space technology parks, which supports innovation by offering research and incubation facilities, educational resources etc. These parks also fast-track the commercialization of space innovations, ensuring regulatory compliance and stimulating economic growth in the sector.

Development of hardware & software for assisting spacecraft launch

This sub-segment focuses on the development of ground support equipment, and relevant software required for space systems testing and simulation. It incorporates the planning and execution of launch operations, supporting & ensuring the smooth deployment of spacecraft into their intended orbits.

Space stations, space tourism, In-orbit services & space manufacturing activities

This sub-segment deals with services that cater to usage of space for commercial purposes viz., space situational awareness (SSA), space tourism, space manufacturing and in-orbit services to extend or de-orbit the satellites.

Downstream

Figure 5 : Overview of Downstream Segment

Earth Observation (EO)

This sub-segment includes services for storage of satellite data, data analysis and development of applications, platforms and APIs needed to provide insights from satellite data either to end-conusmers or business in sectors like agriculture, infrastructure development, insurance etc.

Positioning, Navigation & Timing Services (PNT)

This covers Global navigation satellite system (GNSS) data service providers, development of GNSS applications, platforms and APIs to provide the insights and integration of GNSS data to other sector applications. It also includes GNSS services used for tracking of assets, navigation services on air, land and sea, time synchronization for networks etc.

Satellite Communications (Satcom)

This sub-segment focuses on products and services that uses communication satellites for services like broadcasting, communication, internet connectivity to the end-consumers and businesses. It also covers the satellite communication gateways services and satellite based IoT applications.

Space bases services catering to strategic purposes

This sub-segment is dedicated to services and applications that serve national security and strategic interests. It capitalizes on the dual-use capabilities of space-based products and services, fostering an interplay among Earth Observation, PNT, and SatCom.

Auxiliary

Figure 6 : Overview of Auxiliary Segment

Space insurance services

The space insurance industry plays a crucial role in facilitating the growth of the space sector and promoting investment in space ventures. By offering financial protection to the uncertainities within space, space insurance services help manage the risks involved in complex and expensive space missions. This support empowers space companies and agencies to confidently pursue ambitious commercial and exploration missions.

Space education, training & outreach programs

As the Indian private space industry expands, the demand for skilled professionals in various space-related fields becomes crucial. Companies in this segment provide space education and training programs, equipping students, engineers, and professionals with the necessary knowledge and expertise to excel in the space domain. These programs cover diverse subjects such as satellite technology, space missions, satellite data analysis, and space policy.

Collaborations and technology transfers

Collaborations, technology transfers, and space technology parks are pivotal in advancing India's space industry. Partnerships among private firms, research entities, and government bodies foster innovation and solve critical challenges. Technology transfers boost the inception and commercialization of novel space solutions through the exchange of intellectual property.

Commercialization of spin-off products

These are innovations and technologies that were originally developed for space missions but find commercial applications on Earth. For instance, advanced materials developed for spacecraft can be used in sectors like aerospace, automotive, and construction, while space-derived data processing algorithms can be utilized for image analysis, environmental monitoring, and artificial intelligence applications. Commercialization of these spin-off products not only drives revenue for the companies, but also brings space technology benefits to various terrestrial sectors.

Key drivers/trends and impact across the space sector value chain:

Figure 7 : Segment wise key drivers and impact

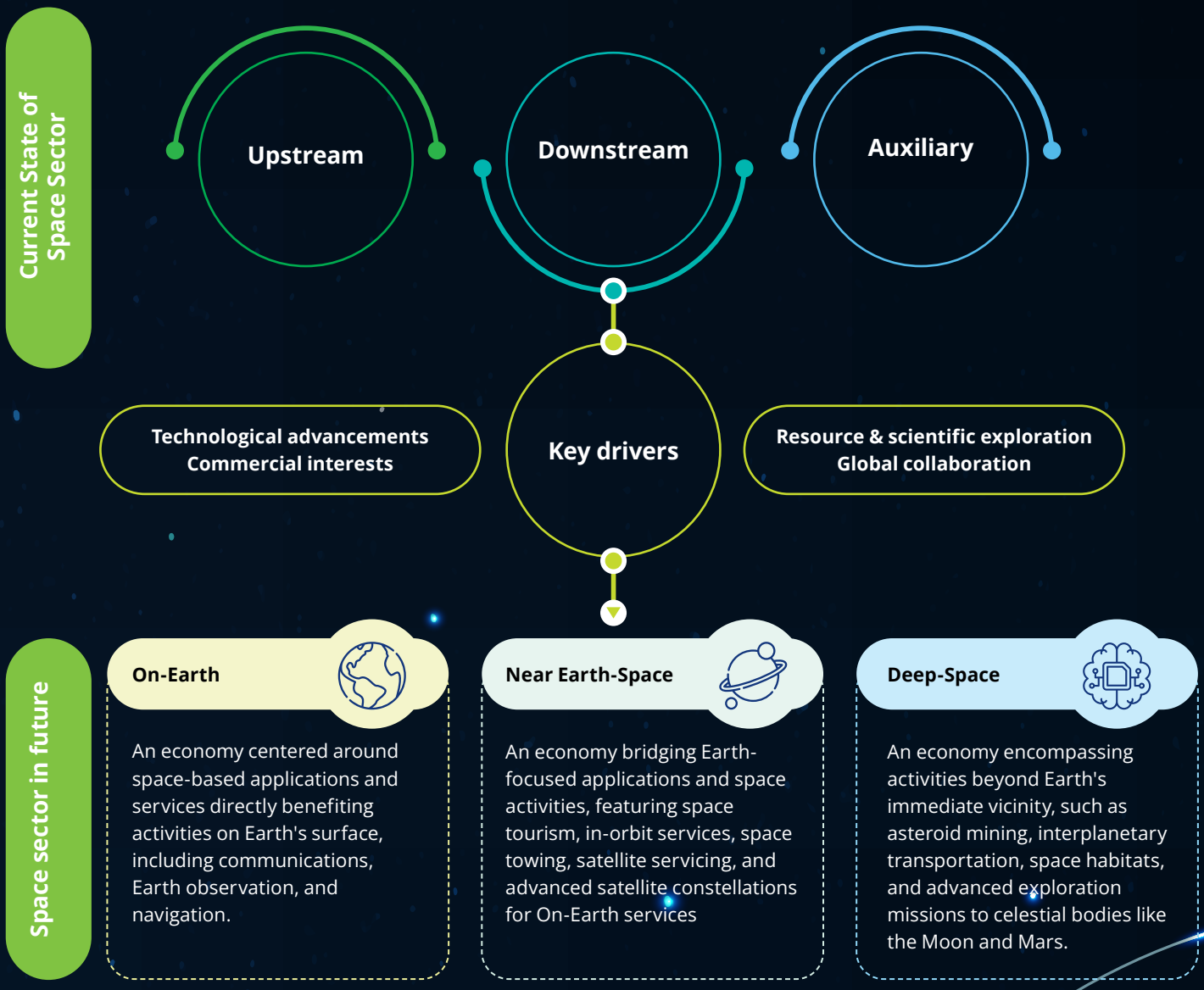
Source: https://www.euroconsult-ec.com/press-release/value-of-space-economy-reaches-424-billion-in-2022-despite-new-unforeseen-investment-concerns-2/

The shift toward the future of the space economy

With the successful launch of Chandrayaan-3 and the growing interest in space exploration, future segmentation in the space sector is poised for significant evolution. While India has traditionally excelled in earth-focused applications such as SATCOM, navigation and EO, the recent success of Chandrayaan missions indicates a shift towards deep-space exploration. This evolution will likely lead to balanced segmentation, emphasising on-earth and Near Earth-Space economies and the burgeoning focus towards the deep-space economy.

Similarly, globally, the current status of the space sector, typically segmented into upstream, downstream and auxiliary segments, is poised for significant transformation as space technologies advance and space utilisation diversify across various sectors. The emerging use-cases and evolving business models, such as space tourism, mining and manufacturing, are reshaping the landscape of the industry. This transformation will likely lead to a nuanced segmentation of space-based businesses into on-earth, near-earth-space and deep-space economies. This segmentation reflects the increasing integration of space technologies in various facets of life and the pursuit of new opportunities beyond our planet. These business models are driven by a combination of commercial interests, resource exploration, scientific curiosity and technological advancements, which contribute to a rapidly changing space industry.

Figure 8: The Future Evolution of the Space Sector Economy



Source: Adapted from Deloitte xTech Futures: Spacetech Report

Takeaways for 'Global space sector & Space value chain'

- **The global space industry has undergone a revival in the past two decades : Space is no longer the exclusive domain of Governments, and it is set to be driven by synergistic efforts between public and private sector due to its strategic and economic significance.**
- **Definition :** There is no consensus on the boundaries and segmentation of space economy. In general, the space value chain can be segmented into Upstream, Downstream and Auxiliary and every segment is influenced by a diverse set of factors, including technological advancements, commercial interests, policy mandates etc.
- **Dependency:** The space industry's various segments are interconnected. For instance, advancements in upstream technologies drive increased opportunities in the downstream segment for commercial applications and vice versa.
- **Value:** The projected impacts underscore the importance of concrete and measurable results in the space industry. While rocket launches and satellite imagery garner attention, the true commercial value lies in areas that directly affect daily life and various industries, including decision-making, resource management, and education
- **Innovation:** India's recent success with Chandrayaan highlights the industries transition from traditional Earth-focused applications to a more balanced segmentation that includes a growing emphasis on deep-space exploration. This shift is driven by a combination of commercial interests, resource exploration, scientific curiosity, and technological advancements.

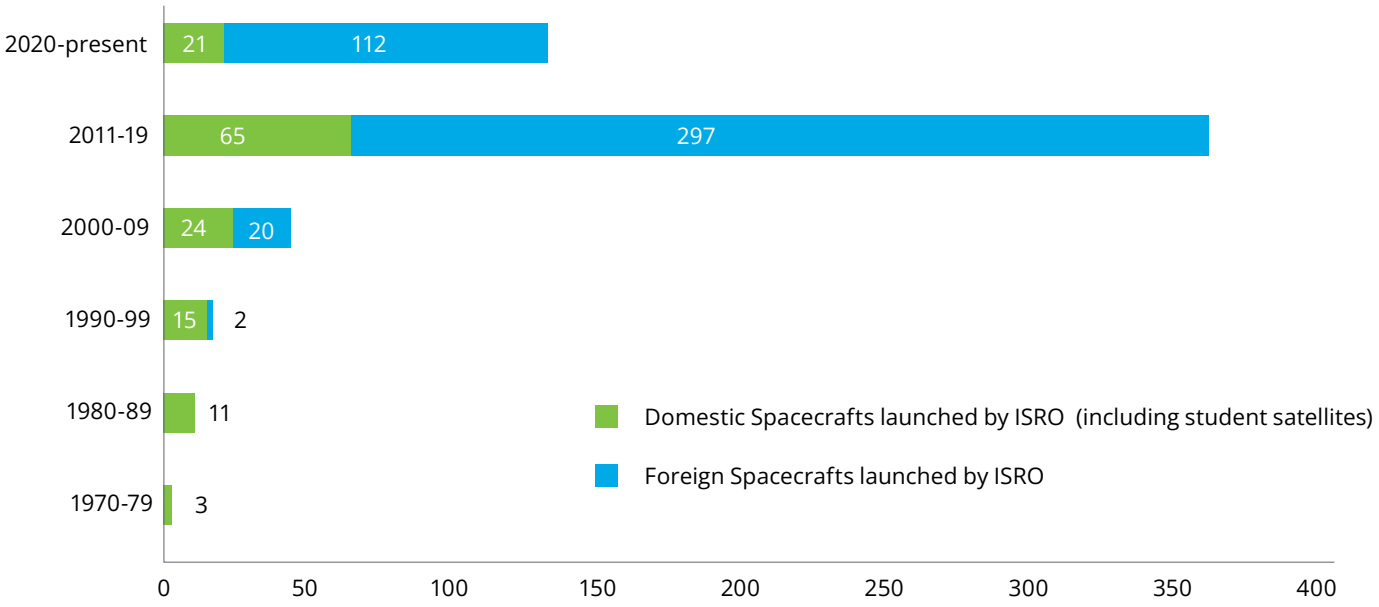
From Thumba, Beyond Chandra: The India space story

India's space odyssey

From the launch of Aryabhata in 1975, which marked India's first foray into space, to the triumphant success of Chandrayaan-3, which has demonstrated India's capabilities further in the list of spacefaring nations, India's vision for the space sector has been marked with a clarity, conviction and purpose that resonates with the country's economic realities and general ambitions.

As a newly independent nation state, India's focus was not competing with spacefaring nations on human-crewed space missions/space warfare but to use space for socio-economic development. These ambitions evolved in sync with India's growing prowess as an economic powerhouse. Aspirations for far-space explorations to Mars and the Moon translated into successful missions. Therefore, India's posture as a spacefaring nation grew steadily to meet demands beyond India and explore beyond the Moon and Mars.

Figure 9: Spacecrafts Launched by ISRO: Decadal count



Source: https://www.isro.gov.in/SpacecraftMissions.html

Quick recap

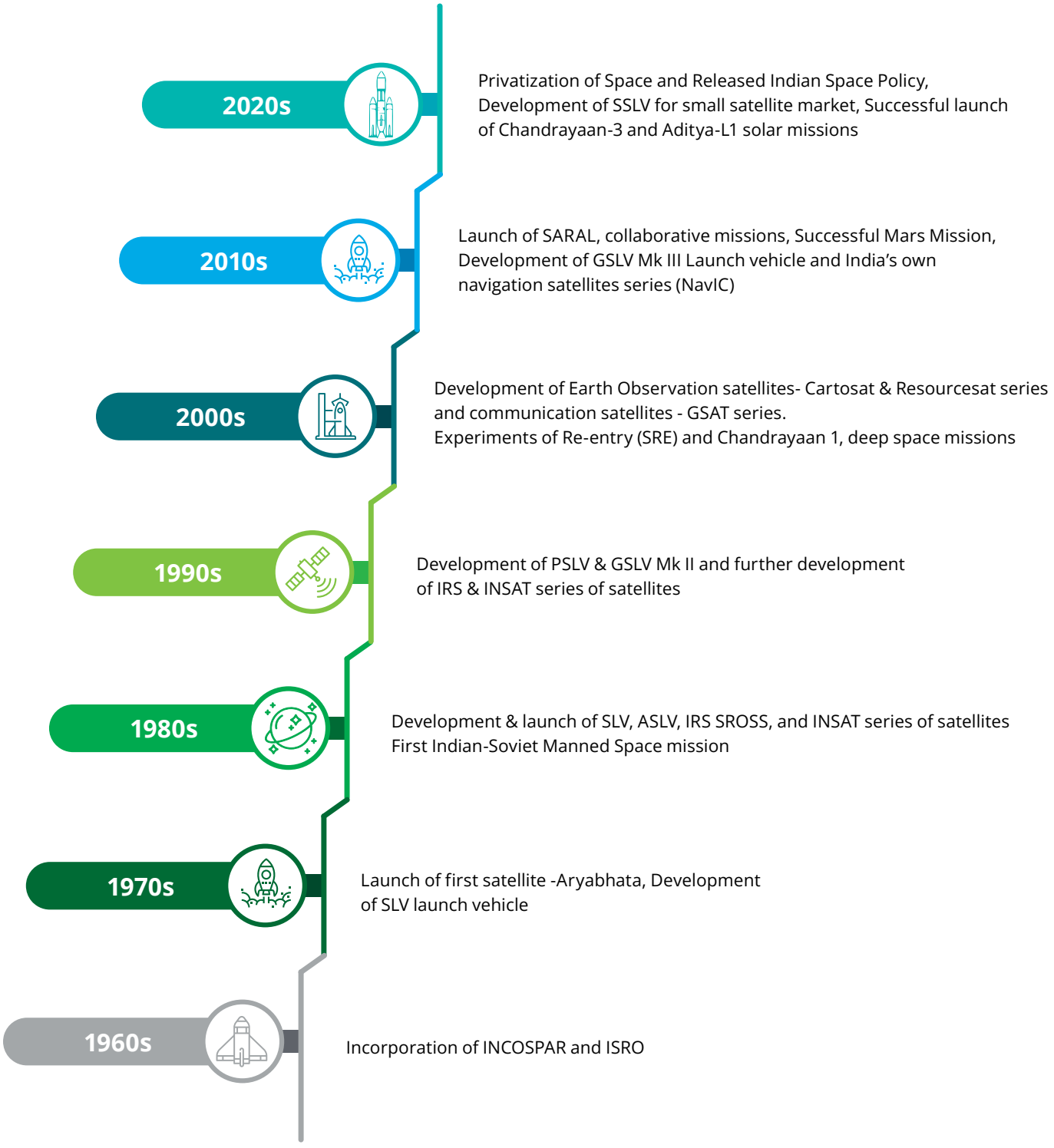
India's journey in space, which began in the 1960s, is a resplendent odyssey of technological prowess and monumental achievements that have etched India's name in the annals of global space exploration. Guided by the visionary pursuits of the Indian Space Research Organisation (ISRO), this trajectory has been marked by a number of significant milestones, pioneering satellites, rockets and space exploration programmes and transformative technological leaps. These achievements have not only enriched scientific understanding but also brought about a paradigm shift in the nation's technological capabilities, global recognition, forging a profound impact on the nation and its people.

The Rohini satellite series, which began in 1980, had remote sensing and communication capabilities. The successful operationalisation of the satellite launch vehicle (SLV) in 1983 solidified India's prowess in space transportation. The development of VIKAS engines and the introduction of the Polar SLV (PSLV) and Geosynchronous Launch Vehicle (GSLV Mk II) in the 1990s propelled India to the forefront of the international satellite launch market. Further, PSLV's production-oriented approach for launch vehicle systems enabled private players to contribute, reducing the turnaround time for building launch vehicles and attracting commercial satellite players.

The development of the INSAT and IRS satellite series revolutionised telecommunications, remote sensing and weather forecasting. Meanwhile, further progress in the Resourcesat, Cartosat, GSAT and NavIC series further solidified India's space prowess, offering vital services such as agriculture, navigation, tele-health and tele-education, rural connectivity, infrastructure, resource planning and monitoring and environmental management.

The development of the INSAT and IRS satellite series revolutionised telecommunications, remote sensing and weather forecasting. Meanwhile, further progress in the Resourcesat, Cartosat, GSAT and NavIC series further solidified India's space prowess, offering vital services such as agriculture, navigation, tele-health and tele-education, rural connectivity, infrastructure, resource planning and monitoring and environmental management.

Figure 10: Indian Space Programme Odyssey



The Chandrayaan and Mangalyaan missions discovered water molecules on the moon in 2008 and 2013, respectively, ushering in a new era of deep-space exploration. In 2014, the development of the Geosynchronous SLV Mark III (GSLV Mk III) paved the way for large satellites, advancing India's human spaceflight endeavours.

Advancing beyond satellite programmes, this space odyssey has extended to transformative ventures such as reusable launch vehicle technology (RLV) and the ongoing Gaganyaan programme. These programmes demonstrate India's commitment to sustainable, cost-effective human spaceflight endeavours. The recent development plans of Small SLV (SSLV) to capture the emerging global small satellite market demonstrate India's pursuit towards capturing the changing global space landscape. Future missions such as Aditya-L1, NISAR, SPADEX, Shukrayaan (Venus orbiter), XPoSat (X-ray astronomy) and Mangalyaan missions exemplify India's relentless pursuit of excellence in space exploration.

Journey of Indian Space Programme

India's space journey	1960s– 1990s	1990s–2019	2019 onward: Towards NewSpace
Signature missions	Technology demonstration of satellites and launch vehicles. Satellites: Launch of Aryabhata, to build experimental satellites such as Rohini and the INSAT and IRS series Launch Vehicles: Development of sounding rockets to SLV and ASLV	Major development of launch vehicles such as PSLV, GSLV Mk II and Mk III. Satellites: Development of the INSAT, IRS, GSATs, NavIC, Resourcesat and Cartosat series Demonstration of reusable launch vehicles technology and human space missions Space exploration missions such as Chandrayaan and Mangalyaan.	The paradigm shifts towards new launch vehicle development for capturing small satellite commercial market and advanced space missions such as Chandrayaan 3, NISAR, Aditya and Spadex missions . Privatisation of the space sector, allowing launch of private satellites, launch vehicles, space exploration activities such as asteroid mining, lunar missions and space application development by private players With advanced technologies like 3D printing of engines, reusable launch vehicles, plasma and nuclear propulsion, ISRO, along with Non-Government Entities (NGEs), would become capable of futuristic missions for deep-space explorations, in-space manufacturing and space mining. Increased efforts will be made to reduce space debris and build edge computing to enhance space-based utilisation and integration.
Space applications	Origin of remote sensing for EO and space-based SATCOM services since 1980s	**Earth Observation:** Remote sensing for major applications such as agriculture, climate and infrastructure planning. **Communication:** GEO based communication for broadcasting and Internet services **Navigation:** Developed indigenous NavIC series	With evolving commercial space-based use-cases: High-resolution remote sensing for agriculture, space-based monitoring, planning and real-time insights Low-Earth Orbit (LEO) based communications Improved PNT services

India's space journey	1960s– 1990s	1990s–2019	2019 onward: Towards NewSpace
Major players	ISRO and Government: ISRO was the main driver and government funding was the main source.	ISRO and government: Continue to be the main player with increased collaborations with private industries. PSUs and private players acting as major suppliers for all ISROs missions	ISRO and government: Continued leadership, with an increasing emphasis on collaboration with private players. Private Players: Emergence of start-ups and private companies offering launch services, satellite manufacturing and applications.
Budgets[3] and financing for space sector players	Average annual budget around INR 100–200 crores	Average annual budget around INR 5,000–10,000 crores	Increased allocation by public investments for space sector growth, with average annual budget around INR 10,000–13,000 crores.*
Regulations	As the Indian space sector was in its nascent phase including only government bodies, no regulations were needed. Establishment of ISRO: 1969: Formation of ISRO as the national space agency, emerging from INCOSPAR Space Commission: 1972: Creation of the Space Commission, which oversees ISRO's activities	Liberalisation of sector: 1990s, opening of the space sector for private participation and encouraged industrial growth. Antrix Corporation: 1992: Formation of the commercial arm of ISRO, Antrix Corporation, for satellite services and technology transfers. Started policies initiatives such as SATCOM Policy in 1997 and Remote Sensing Data Policies from 2001, to streamline, regulate and promote the use of space assets and data for the nation's building activities and commercial activities such as broadcasting.	Establishment of NSIL in 2019 and IN-SPACe in 2020. Department of Space (DOS) released the National Geospatial Policy in 2022 for democratisation of data and commercialisation of geospatial services. The Indian Space Policy 2023 outlines the stakeholders' roles in space activities. Expected to release Foreign direct investment (FDI) Space policy for boosting private investments and space activities bill to legitimately regulate and promote space activities.

* https://www.thehindu.com/business/budget/budget-2023-department-of-space-gets-12500-crore-8-less-than-previous-year/article66458858.ece#:~:text=The%20biggest%20cut%20is%20for,in%20the%20previous%20Budget%20estimate.

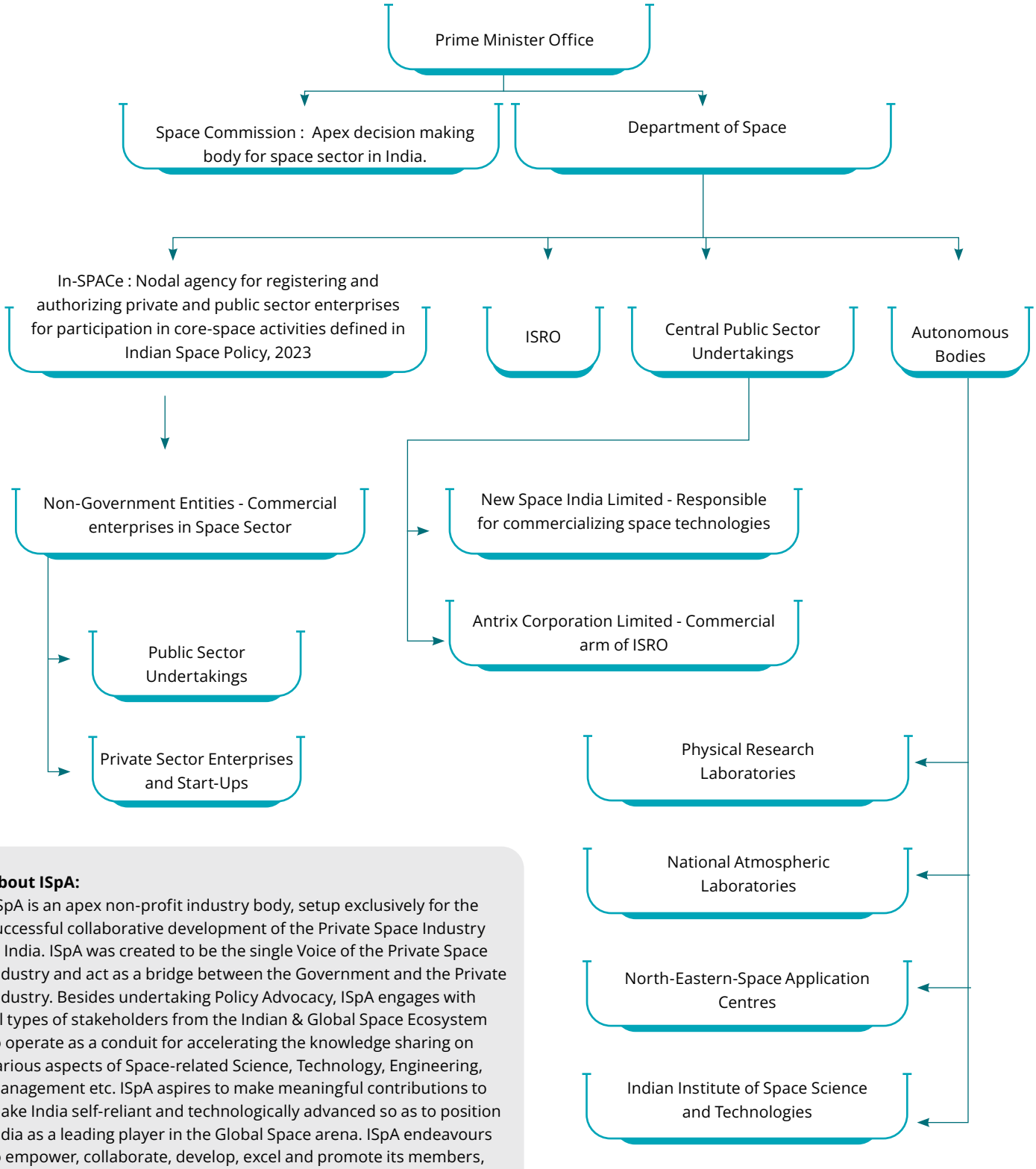
The advent of the NewSpace era

The NewSpace era is a paradigm shift in India's space journey. Prominently referring to the advent of private sector enterprises in core end-to-end space activities, it also signifies a significant shift in the regulatory approach of the sector, permitting private capital to supplement government efforts.

Formalised through the Indian Space Policy, 2023, these game-changing levers viz., regulations, financing, technology and private participation have given NewSpace a lot more momentum and opened previously unimaginable growth opportunities. In contrast to the traditional model, with government agencies as the primary drivers of space activities with ambitious goals and cutting-edge technologies, NewSpace will be driven by the private sector and start-ups, evidenced by the fact that the number of registered space start-ups has increased from one in 2014 to more than 190 as of 2023.[4]

Figure 11: Key Drivers Enabling the Advent of NewSpace Era

Figure 12: India space sector landscape



About ISpA:

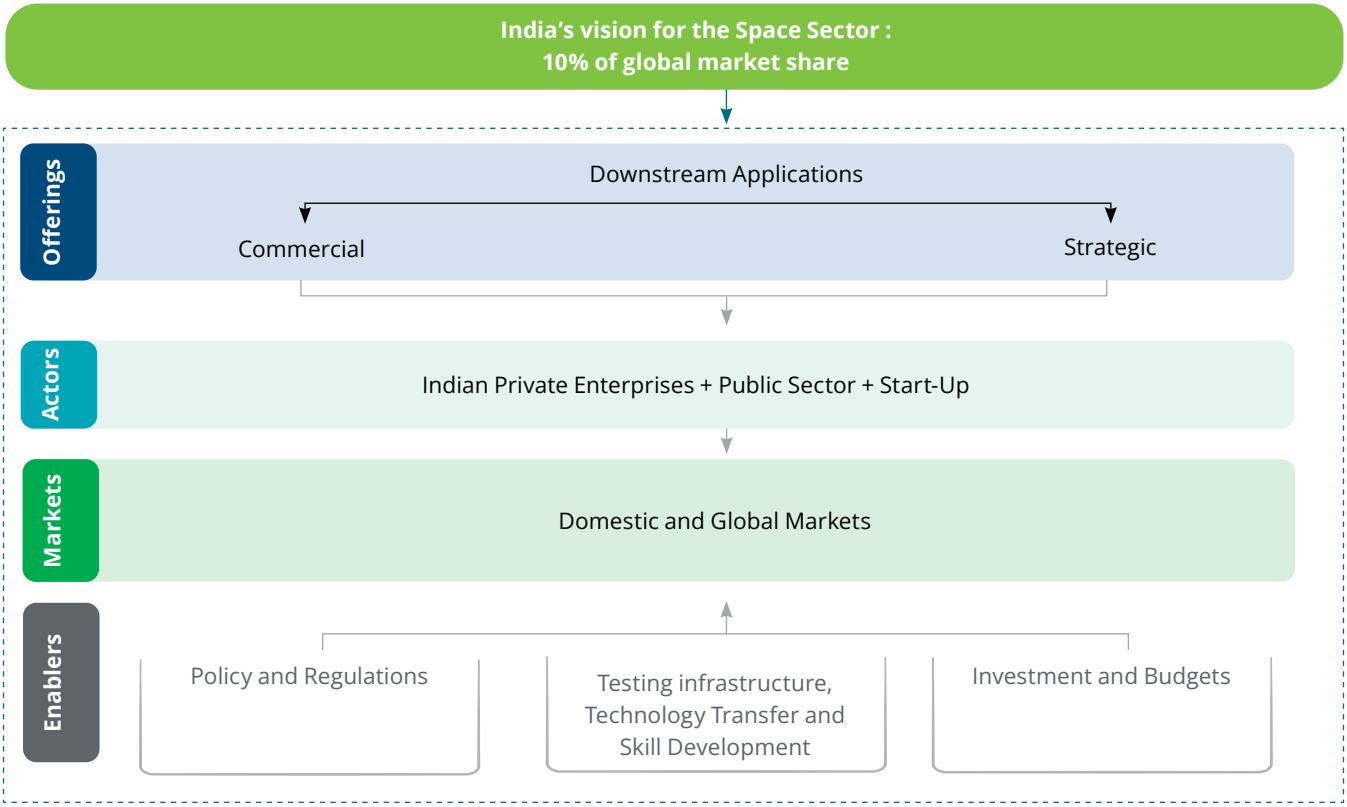
ISpA is an apex non-profit industry body, setup exclusively for the successful collaborative development of the Private Space Industry in India. ISpA was created to be the single Voice of the Private Space Industry and act as a bridge between the Government and the Private Industry. Besides undertaking Policy Advocacy, ISpA engages with all types of stakeholders from the Indian & Global Space Ecosystem to operate as a conduit for accelerating the knowledge sharing on various aspects of Space-related Science, Technology, Engineering, Management etc. ISpA aspires to make meaningful contributions to make India self-reliant and technologically advanced so as to position India as a leading player in the Global Space arena. ISpA endeavours to empower, collaborate, develop, excel and promote its members, associate organisations, academia, entrepreneurs, and start-ups by facilitating them with a platform to coalesce and create an enabling environment for strengthening the private as well as the public industry in the Indian Space sector.

Source: https://ispa.space/aboutus.html

Future of Indian space sector

Despite all of the above, the Indian space industry represents only 2% of the global market.[5] ISRO has a vision of increasing the sector's global market share to 10% to advance India's space activities and compete with other spacefaring nations.[6] While ISRO has the leading share of satellites and launch vehicles, recently the Indian private sector has also made forays into these activities. Several significant developments that have gradually emerged are important to India's future plans for the space sector and the realisation of its vision:

Figure 13: Critical Matrix of India's Space Vision



01. Proliferation of downstream applications: From television to mobile connectivity and remote sensing for agriculture and disaster management, expanding space assets provides a variety of socially beneficial and revenue-generating applications, increasing the demand for additional space assets.

Regardless of the application and purpose, so far, monetisation and revenue generation for the sector has largely been driven by downstream applications. With miniaturisation of satellites, lowering of launch costs and advancements in enabling technologies, viz., cloud computing, AI/ML, 3-D printing, etc., downstream applications offer increased possibilities to service user demands. Simultaneously, competition from terrestrial alternates for remote sensing, communications and navigation is expected to impact the overall offerings and business models.

Space for Strategic Purposes: Categorised as the fourth operational domain, space has always been a dual-purpose sector. In a multipolar global order where strategic priorities are re-aligned dynamically, the impetus on "space for security and security for space" is set to develop into critical sub-segments within downstream applications. Beyond technological advancements, several recent developments viz., India signing the Artemis Agreements, Initiative on Critical and Emerging Technologies, etc. are mission critical signals to the Indian market.

Table 3: Indian private companies that have launched spacecraft

Name of the Company	Number of Spacecrafts Launched till Date
Pixxel	2
Azista BST Aerospace	1
Digantara	2
Dhruva Space	3
Antaris, XDLINX Labs and Anant Technologies	1

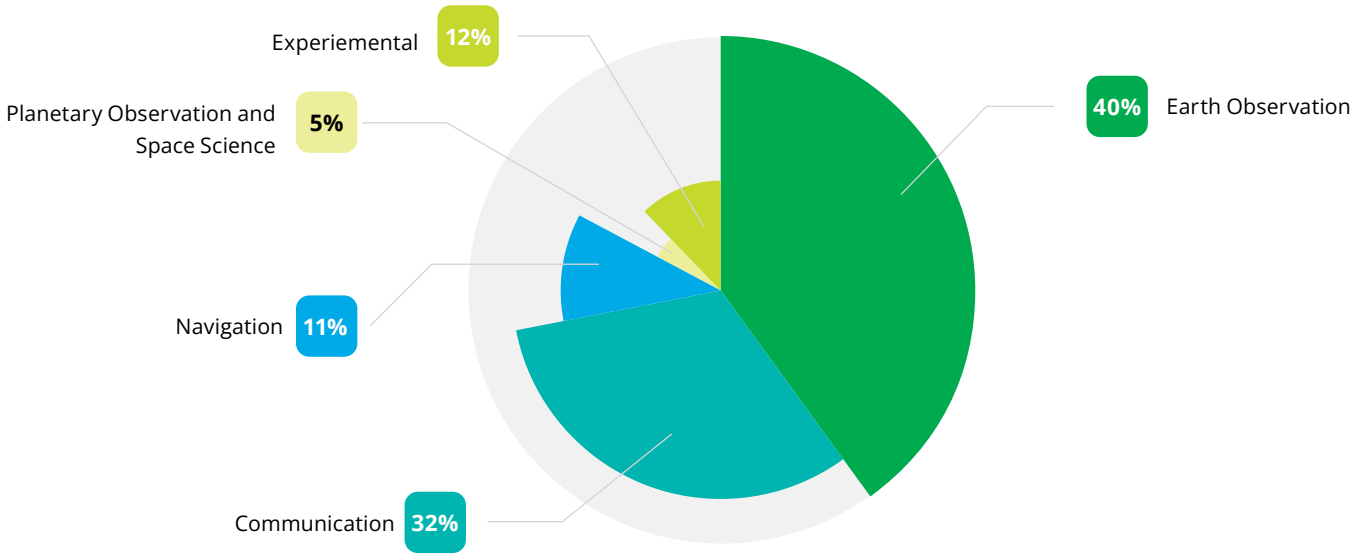
02. Private presence: Until recently, India's space exploration efforts were spearheaded by ISRO and other government entities. The private sector that started as a trusted ancillary ecosystem to ISRO now covers the gamut of the space technology ecosystem, from manufacturing and operating launch vehicles and satellites to providing downstream services.

The peaking interest of private enterprises[7] coupled with timely regulatory and policy reforms has placed India in a unique position to realise its future potential in this sector. Alongside allowing non-governmental entities to participate in end-to-end core space activities, the Indian Space Policy, 2023 aims to establish a symbiotic relationship between private and public sectors by creating new government entities to perform specific roles for the Indian space technology sector, moving ISRO's role towards a focus on research and development in advanced technologies and development for long-term projects, such as Chandrayaan and Gaganyaan.

03. New geographies: With complex supply lines and the ability to provide services beyond national borders, space has always been global. However, real globalisation of space has been a recent phenomenon with several new countries establishing national space programmes/agencies and placing assets into orbit[8]. The new space race is evidence of the shift in perception of the space sector in several geographies from a research and development domain to a growth-promoting economic sector. Enabled by conducive policy ecosystems, this opens-up new markets for private and public Indian space players to cater to the global economy, which, by various market estimates, is projected to reach USD 1 trillion by 2040.[9]

The interplay of the above factors will play a central role in India achieving its vision for the space sector.

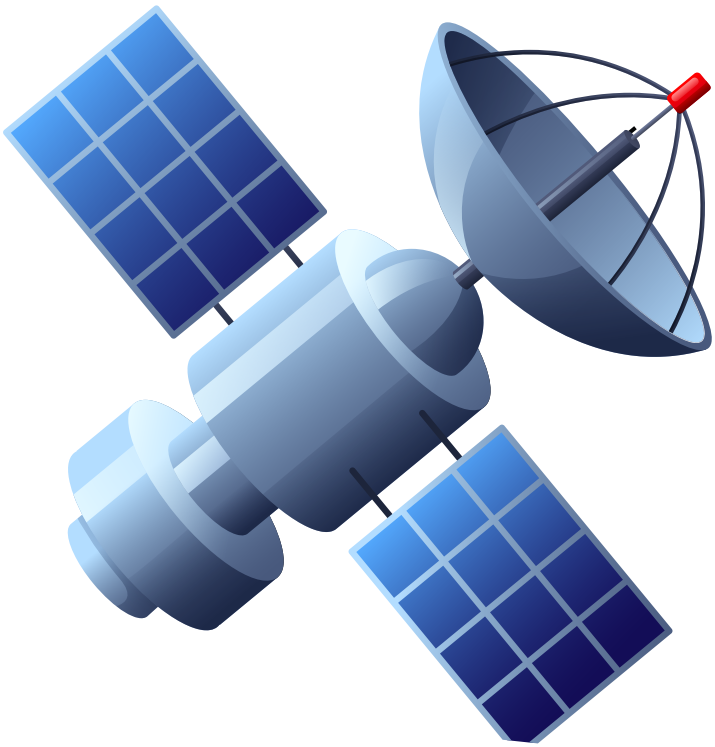
Figure 14: Application-wise Split of Indian Spacecrafts Launched by ISRO



Source: https://www.isro.gov.in/Mission.html

Takeaways for 'Indian space odyssey'

- **Focus on socio-economic impact from inception:** India's space journey, from its early days with Aryabhata to recent successes like Chandrayaan-3, has been characterized by a clear focus on socio-economic development rather than competing in manned space missions.
- **Global recognition:** India has achieved significant milestones, including the Rohini satellite series, successful satellite launches, and exploration missions like Chandrayaan and Mangalyaan, which have enhanced its global recognition and technological capabilities.
- **Diverse services utilizing space:** India has developed a wide range of space-based services, including telecommunications, remote sensing, weather forecasting, agriculture, navigation, healthcare, education, and environmental management.
- **NewSpace era in India:** The advent of the NewSpace era in India involves private sector participation in space activities, marked by regulatory changes and the growth of space-related startups, signaling a shift from government-driven efforts. Despite achievements, India's space sector holds only 2% of the global market share. To compete globally, India aims to capture 10% of the global market share and is looking to expand into downstream applications and strategic space applications.
- **Emergence of private sector ecosystem:** Private enterprises have expanded their roles in the space technology ecosystem, from manufacturing and operating launch vehicles and satellites to offering downstream services. The Indian Space Policy, 2023, aims to establish a symbiotic relationship between the public and private sectors.
- **Future prospects of global space economy:** Space is becoming a global economic sector with the establishment of national space programs in various countries. India's space players, both public and private, have the opportunity to cater to the global space economy, projected to reach USD 1 trillion by 2040.



Scope and approach

The scope of the report is limited to exploring opportunities in the downstream market (Indian market alone), majorly classified into: **Earth Observation, Positioning Navigation and Timing, Satellite Communication and Defense-Space.**

Figure 15 : Scope and approach

Scope : Ground-up estimate of serviceable market through critical use-cases in downstream segment of Space Value Chain

Upstream

- **Satellites and Launch Vehicles:** Design, Manufacturing, Assembly and Testing.
- **Space Infrastructure Development:** Launchpads, Launch services, Telemetry and Tracking, Communication Centres.
- **Hardware & Software Spacecraft launch:** Ground support equipment, station and services for simulation and testing for launch operations and deployment of satellites into orbits.
- **Space stations, space tourism, In-orbit** services & Space Manufacturing activities: In-situ usage of space for commercial purposes

Downstream

- **Earth Observation/Remote Sensing** applications and services
- **Satellite Communication** applications and services
- **Positioning, Navigation and Timing (PNT)** applications and services
- Space applications and services for **strategic purposes**

Focus Geography - India

Auxiliary

- **Space Insurance Services:** Insurance for space assets and operations
- **Space Education, Training and Outreach Programmes**
- **Collaboration and Technology Transfers**
- **Commercialization of spin-off products** in other sectors

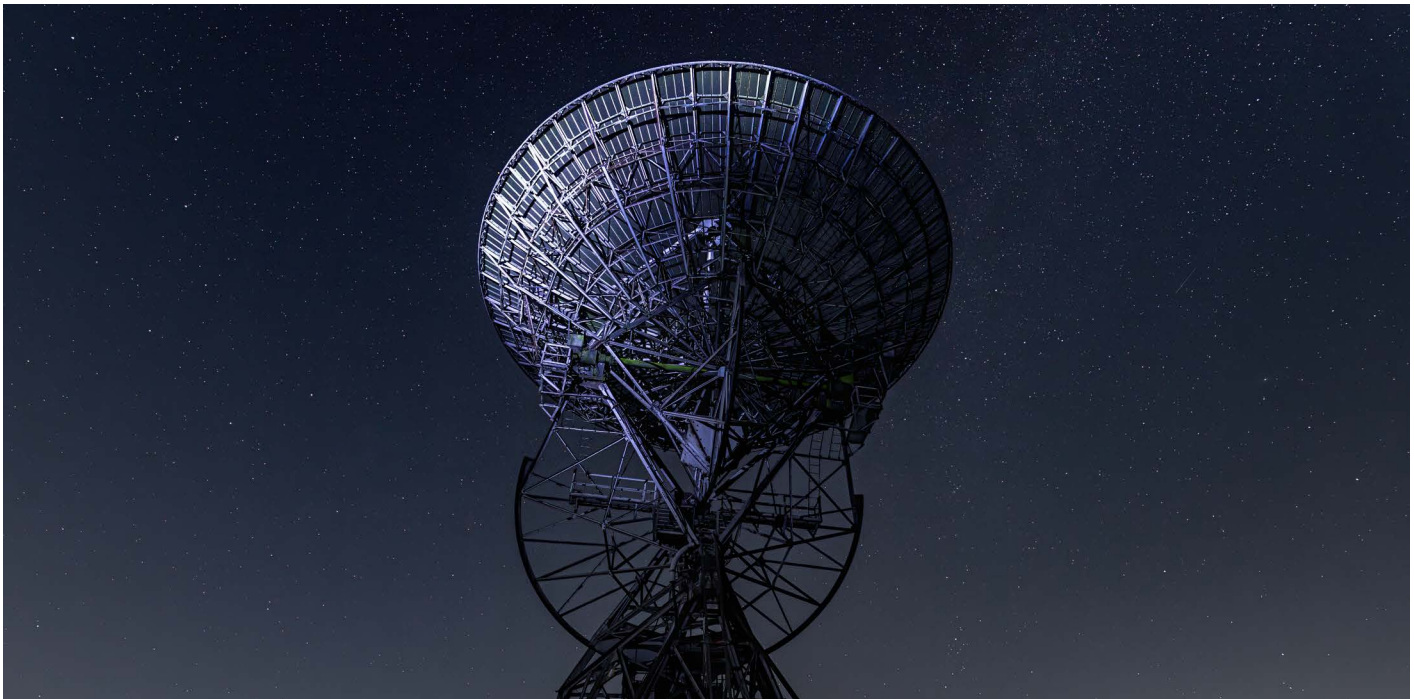


Figure 16 : Overall approach

Identification of focus sectors and value driving use-cases in every sector against downstream sub-segments in alignment with market movements.

Primary research: Stakeholder interviews from industry, Government and Start-Ups for data gathering, demand assessment and assumptions validation.

Mapping of current value chain of the sub-segments: identification of challenges (technology, business and adoption), trends and global benchmarking to define the problem for market creation.

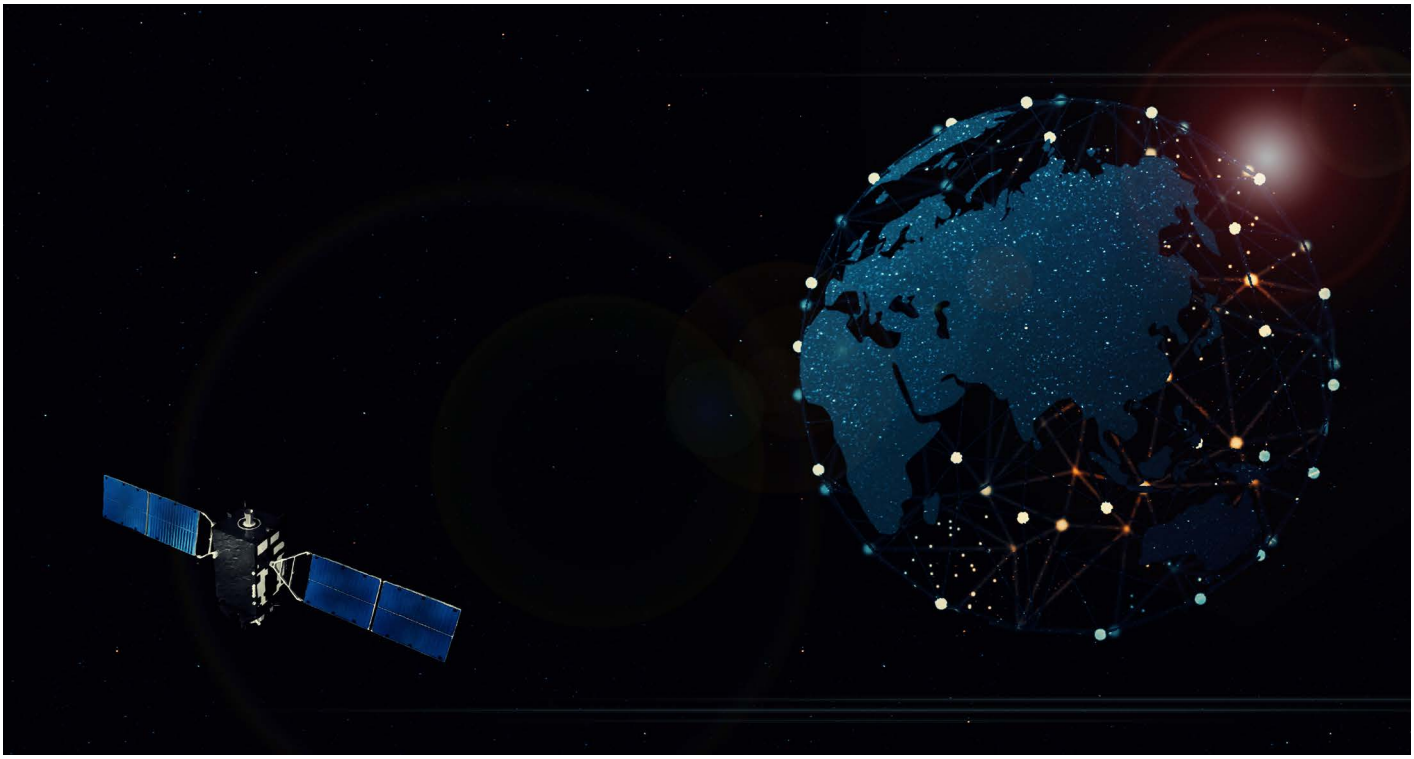
Market size estimation and adoption rate modelling to arrive at serviceable market size across the identified sectors and use-cases.

Focus sectors and use-cases

Considering the multitude of downstream use-cases that have emerged across the sectors utilizing space assets for the improvement of our day-to-day lives and the accelerated pace with which the current value-chain is progressing, a universe of possibilities for sectors currently serviced by downstream technologies was developed.

Universe of possibilities through space technologies:

Imagine a future where precision agriculture enables farmers to maximise crop yields while reducing costs, minimising environmental impact and trade on carbon credits. A world where cities are defined by night-time light (NTL) and urban administration uses real time satellite data to alleviate traffic congestion, predictive maintenance of utility infrastructure etc. Imagine remote villages gaining access to telemedicine and quality education through satellite-powered connectivity, resulting in a significant increase in the rates of healthcare and literacy. This transformative potential enabled by the interplay of services among EO, PNT, and SATCOM becomes increasingly paramount.



Indicative and non-exhaustive

Figure 17 : Universe of earth observation

Natural Resource Management

Mineral exploration
Mine disasters
Harmful gases monitoring from mines
Vegetation around mines
Assets monitoring
Mine exploitation/illegal activities
Locating slicks
Detecting hydrocarbon leaks and recurrence
Evaluating leak magnitude
Oil and gas seeps
Decision making in oil exploration
Post drilling estimation
Oil and gas mapping
Assets monitoring
Oil Spill Detection

Sustainability & Biodiversity conservation

Larch mapping
Deforestation monitoring
Forest carbon sequestration
Monitoring vegetation status
Investigating global temperature trends
Solar radiation monitoring
Monitoring Snow and ice
Evaluating sea-level changes
Management of agricultural practices
Monitoring fire events and fire emissions
Monitoring aerosols and water vapor
Improvement of climate projections
Monitoring & protecting protected areas
Endangered Species Conservation
Land-cover classification and protection
Determination of species habitat/ distribution

Agriculture

Crop Identification
Crop Production forecasting
Assessment of crop damange
Crop Disease detection and control
Crop Yield Modelling And Estimation
Soil Mapping
Monitoring of Droughts
Flood Mapping And Flood Monitoring
Land Mapping
Nitrogen Management
Weather Monitoring
Irrigation Management
Horticulture crop area assesment
Integrated watershed management
Crop Insurance

Urban Planning and Development

Master Plan Development
Traffic and Accident Management
Property Taxation
Water distribution infrastructure monitoring
Seweage infrastructure monitoring
StormWater drain management
Urban heat island : Prediction and Monitoring

Infrastructure Planning and Development

Predictive Maintenance
Asset mapping
Engineering and Topographic surveys for planned assets
Monitoring of asset utilisation
Asset health monitoring
Constuction progress monitoring
Parametric Insurance

Logistics Improvement

Public Transportation planning & monitoring
Transportation, freight monitoring, management and taxing
Traffic and Accident Management
Hazardous Goods monitoring (Petro-chemical & Gas)
Road Maintenance
High value cargo monitoring

Disaster Management : Prediction and Post-Disaster Management

Volcanos
Active faults and Earthquakes
Landslides
Floods
Icemelts
Tsunami
Cyclones
Fire accidents (urban and forest)
Road accidents
Plane crashes
Ship Wrecks

Blue Economy (Fisheries, oceanography)

Fish Detection & forecasts, Potential Fishing zones
Fishing Grounds properties
Measuring ocean temperature
Measuring of Turbidity & Wave characteristics
Updating fishery Inventories
Oil pollution detention
Measuring the fishing grounds
Weather forecasting
Suspended sediment concentration

Other Areas (Taxataion, Banking, Financial and Insurance Services)

Asset & Resource Mapping: Digitizatization of land records, assets and Tracking
Forecasting Ocean resources and assistance
Supply chain monitoring and taxing
Transportation, freight monitoring and taxing
Cross-borders trade monitoring and taxing
Maritime frieght taxing
Intelligence for Trading
Natural resources(Mining, oil, fishing) tax cross-verification

Indicative and non-exhaustive

Figure 18 : Universe of satellite communication

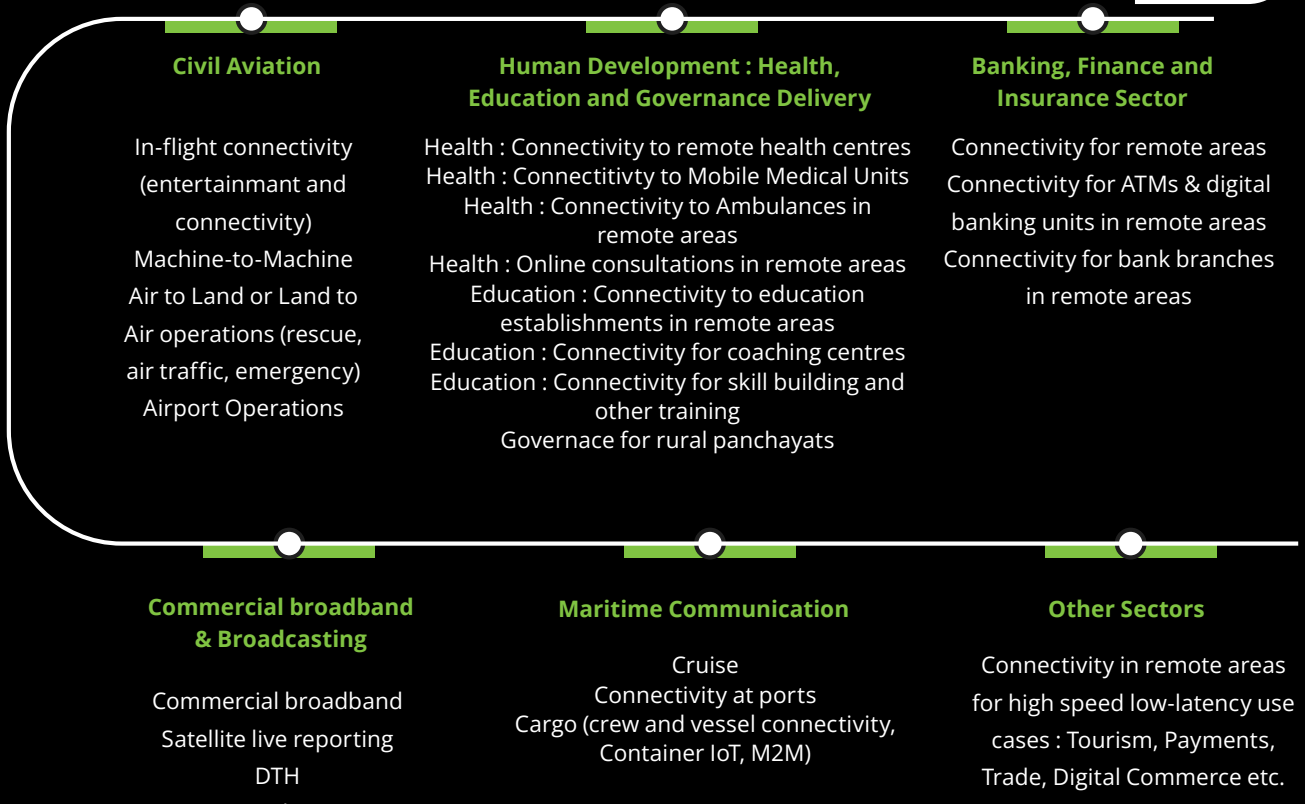
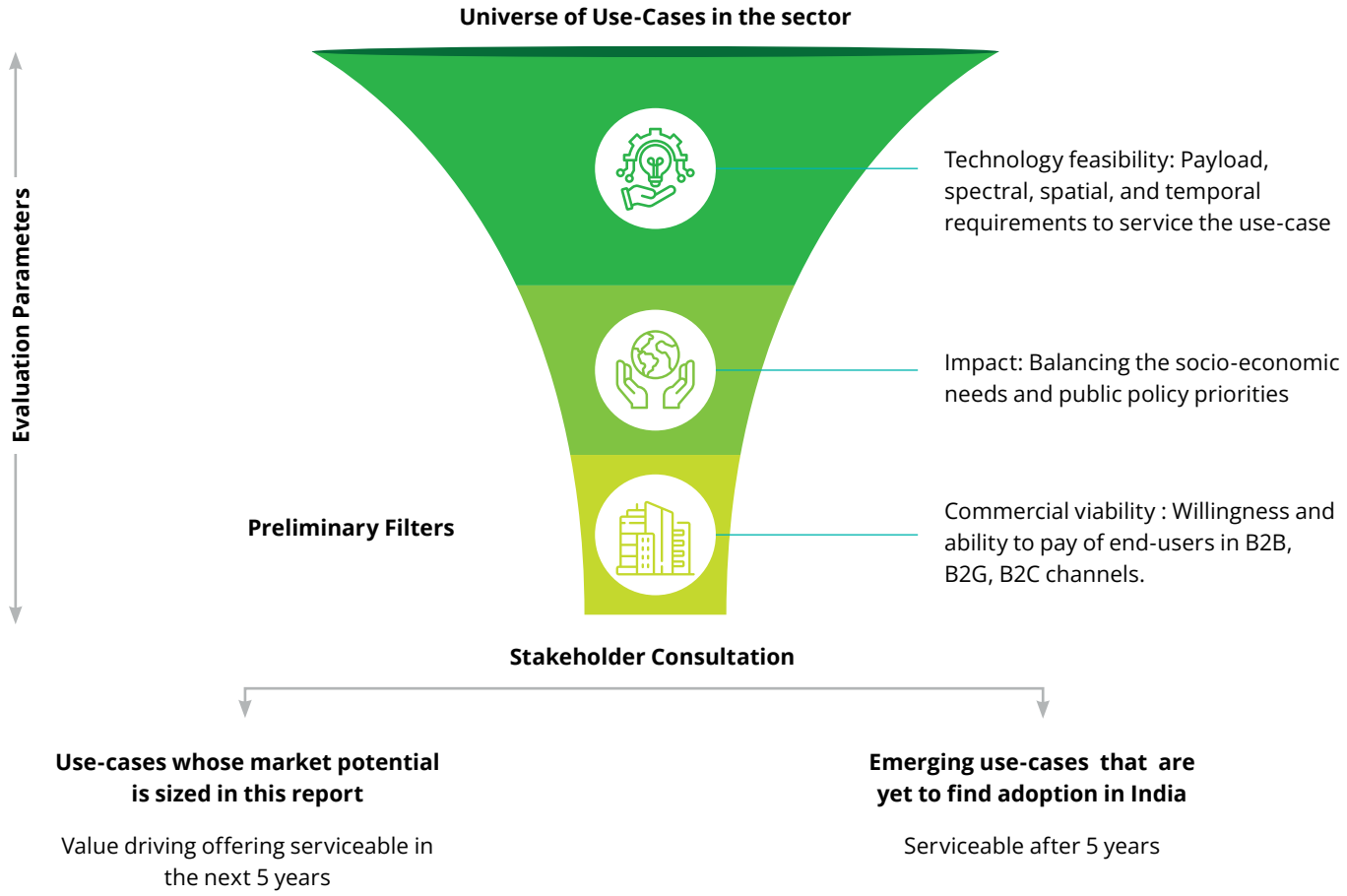


Figure 19 : Universe of PNT

Value-driving offerings/use-cases

While the possibilities are plenty, it is imperative to underscore that data, observations and capabilities from space assets must be packaged into specific service offerings that can create value to end-users. Such service offerings are subject to both demand and supply considerations. Hence, every possibility was evaluated against multiple parameters along the fault lines of technical feasibility, commercial viability, and impact to arrive at service offerings/use-cases that have commercial potential in the next 5 years.

Figure 20 : Approach for identification of serviceable offerings/use-cases (for defense use-cases, commercial viability was not considered)



Through a combination of consultations and secondary research, the following are the serviceable offerings/use-cases that are deep-dived for the purposes of the report.

Figure 21 : Offerings/use-cases for earth observation

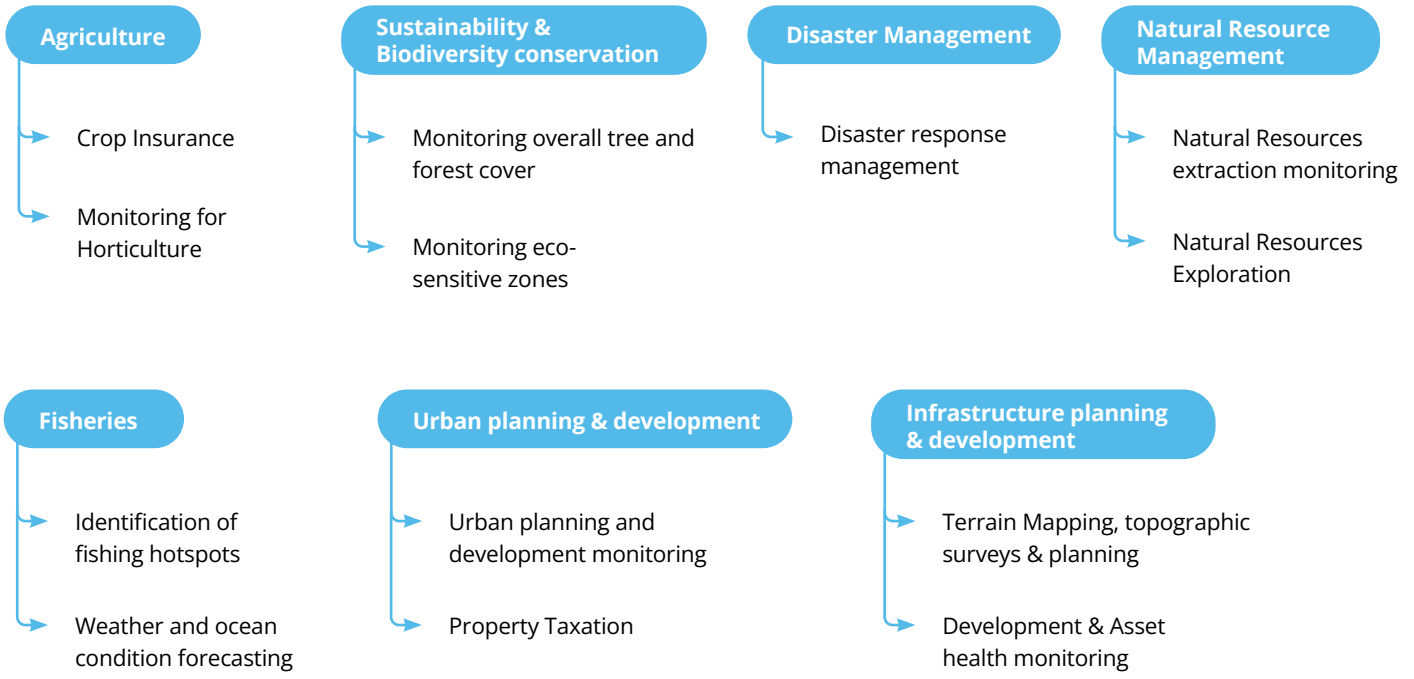


Figure 22 : Offerings/use-cases for satellite communication

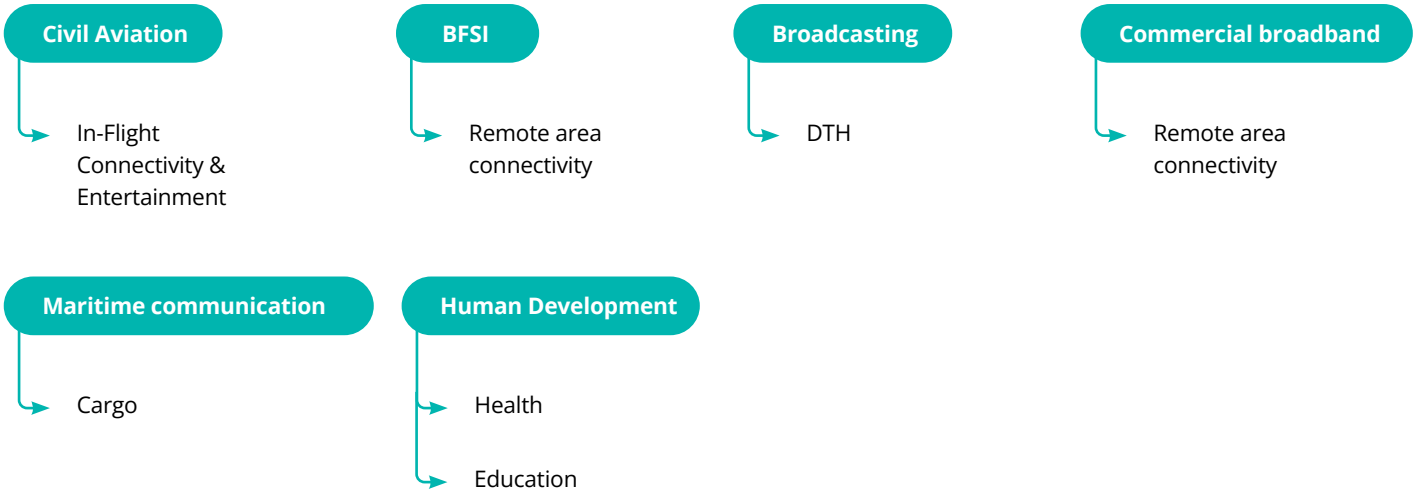


Figure 23: Offerings/use-cases for PNT

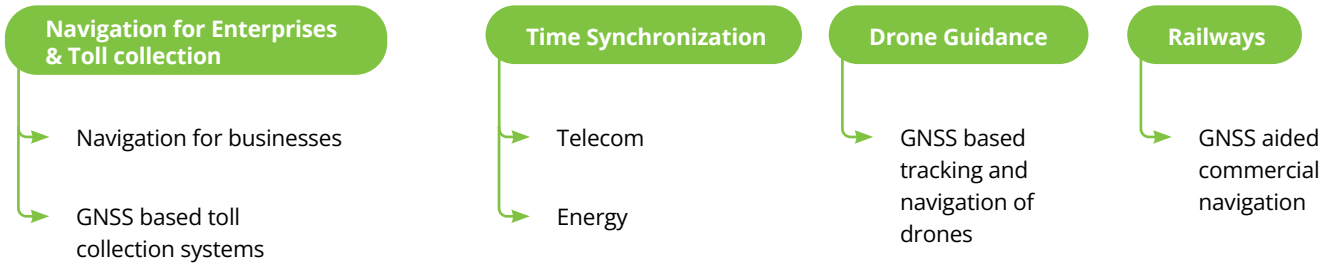
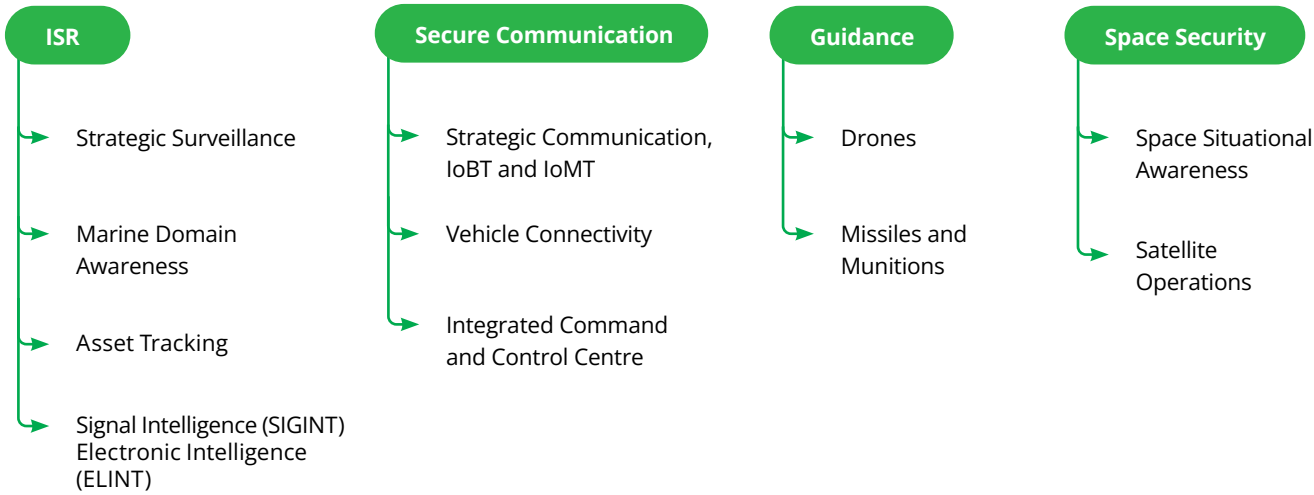


Figure 24 : Offerings/use-cases for defense-space

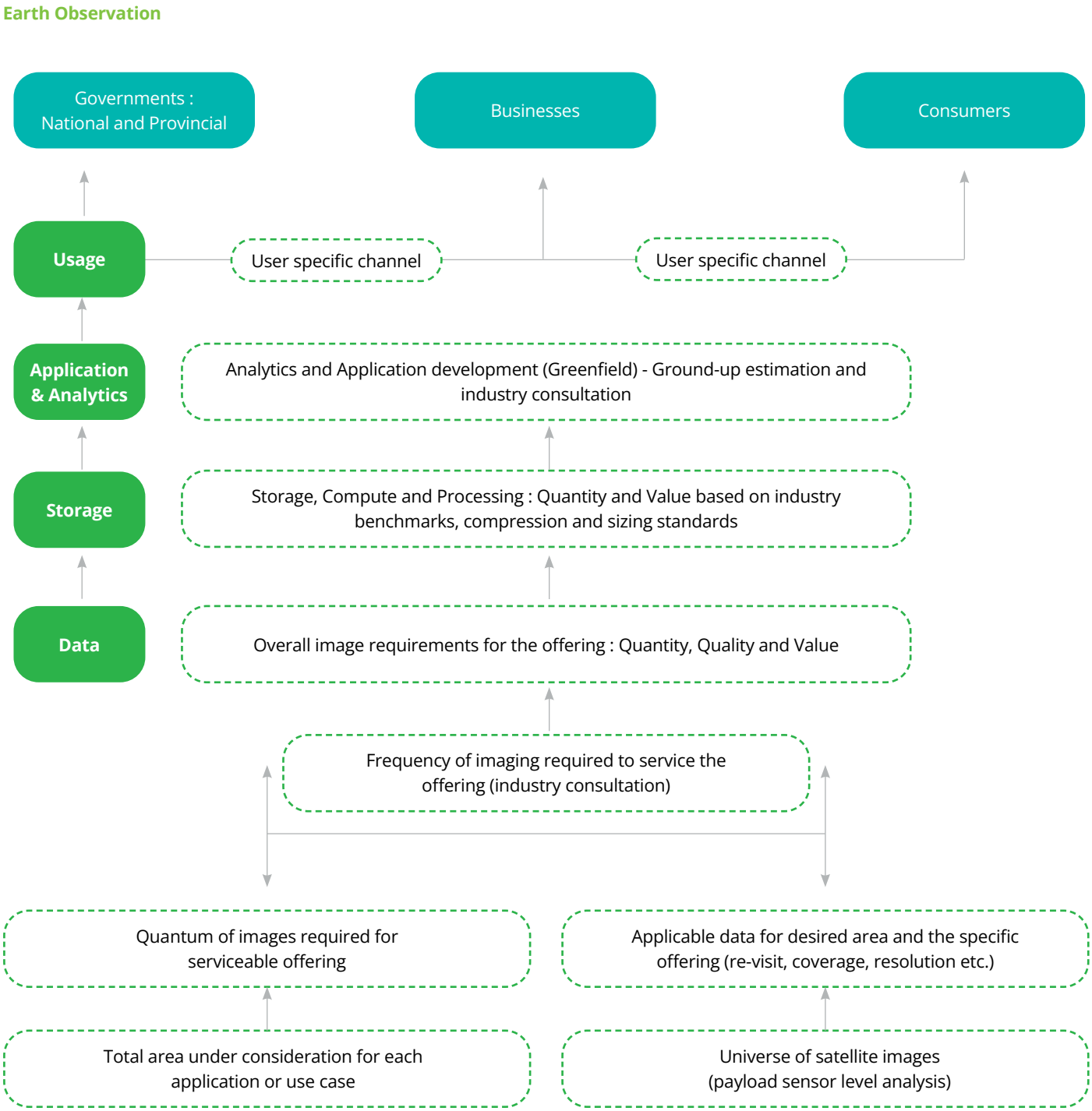


Approach for market potential estimation

The methodology of sizing the markets for various use-cases under consideration used mixed techniques. **It is pertinent to note that the potential market value is for the specific service offering/use-case in the specific sector and need not be the overall potential of the sector. As technology matures and business models evolve, it is all but certain that the overall potential will grow manifold.**

In the case of EO, modelling incorporates the cost of relevant imagery (influenced by revisiting time, resolution, availability of data through public sources, maturity of domestic companies to service use-cases, etc.), and the associated cloud and application development and maintenance costs.

Figure 25 : Approach for earth observation market



For SATCOM, the current number of subscribers to digital communication services has been extrapolated as potential markets for future services in SATCOM, a relatively more mature market in the downstream. Where terrestrial alternatives may hold substantial market power, satcom projections have been modified accordingly.

Figure 26 : Approach for SATCOM market

For PNT services, the recent emphasis from the government for self-reliance in the geospatial segment, coupled by the completion of the NavIC regional constellation, has enabled us to draw parallels with a wide range of use-cases that use global positioning system (GPS) data or receivers.

Figure 27 : Approach for PNT market

Access to GNSS

The use-cases considered will require physical gateways to access GNSS services such as NavIC, GPS, GLONASS etc., With further adoption of PNT, equipping the consumers of the services will form a considerable chunk of the market

Applications for tracking, navigating, and timing

Mapping services, tracking logistics and a variety of synchronization applications contribute to the PNT market. The price points associated with developing platforms and software services tailormade for specific industries and clientele on top of the open and largely free architecture of GNSS services have been considered when sizing the market

Takeaways for 'Scope & Approach'

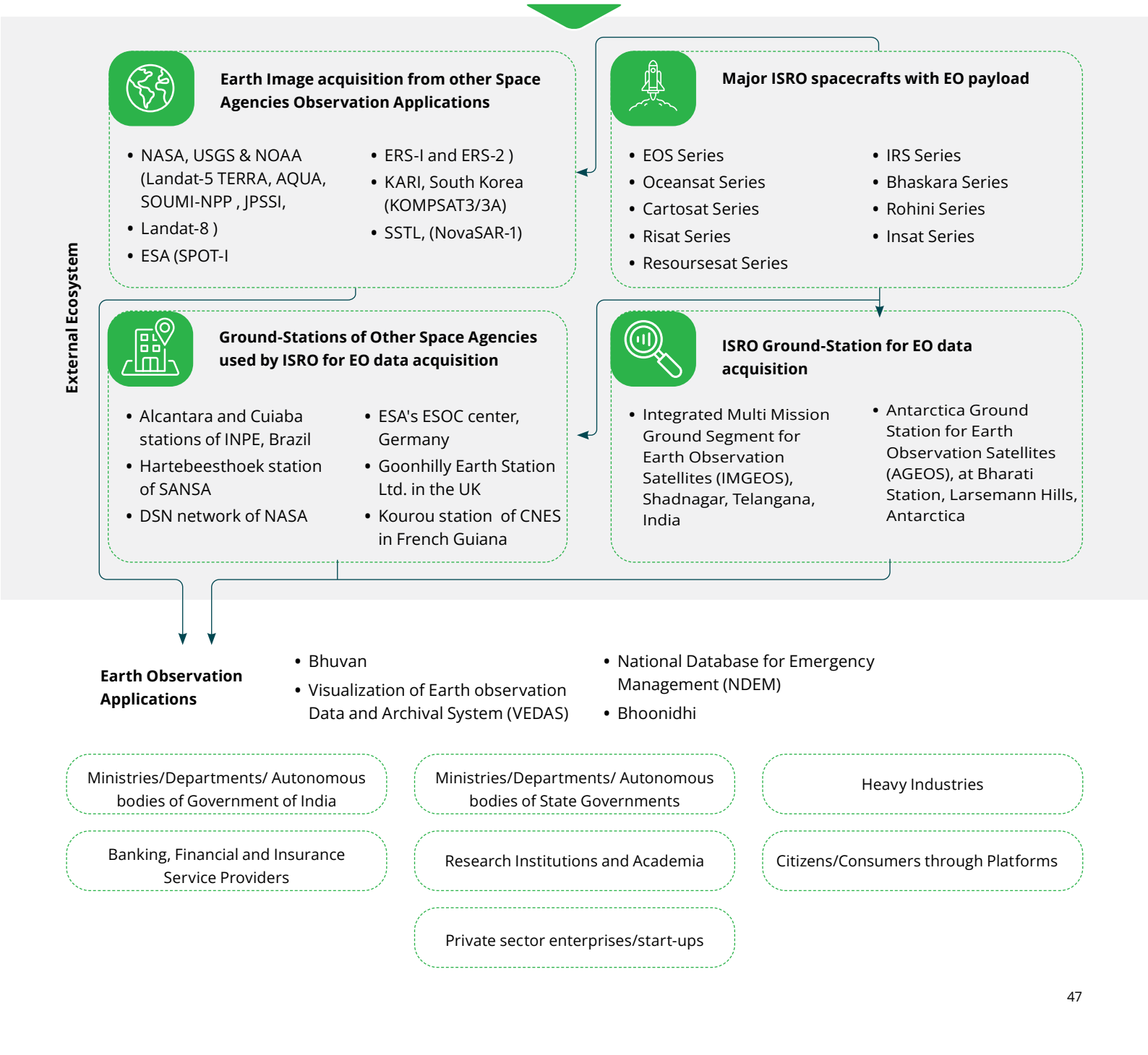
- **Value creation:** The primary source of commercial value in the space industry in the coming years is expected to be the application of space-based infrastructure and services to businesses outside the space sector and to people's everyday lives.
- **Expanse of diverse use-cases of downstream segment:** There are nearly 200 diverse use-cases identified within the downstream segment of the space industry, spanning Earth Observation (EO), Positioning, Navigation, and Timing (PNT), Satellite Communications (SATCOM), and strategic Defense applications.
- **Approach of identifying focused use-cases:** From the universe of use-cases, few focused use cases are identified by using multiple parameters along the fault lines of technical feasibility, commercial viability, and impact and arrived at service offerings/use-cases for the next 5 years.
- **Downstream segment potential to create huge impact:** The downstream segment of the space industry, with its synergy between EO, PNT, and SATCOM, has the potential to drive significant economic growth, particularly in a country like India with a mature software industry.
- **Democratization of space-based services:** The downstream segment has the unique ability to democratize access to space-based services, benefiting ordinary citizens, small businesses, and local communities. This democratization can lead to innovations that uplift lives and foster progress.

Earth observation

The use of remote sensing data and applications to mitigate critical governance and business challenges can be traced to the genesis of India's space programme: The success of the pilot to use remote sensing to identify coconut wilt disease in Kerala in 1970 paved the way for the development of the Indian Remote Sensing satellite series[10].

Over the past five decades, India's EO capabilities have grown to enable the use of remote sensing data and applications in critical sectors such as agriculture and fisheries development, disaster management, biodiversity conservation and extraction and exploration of natural resources.

Figure 28: Earth observation: current ecosystem in India[11]



Trends

At the same time, the overall pace of technology maturity, the increasing realisation on the importance of using satellite-based remote sensing data and applications in routine business and governance operations positively influence the global technology and business landscape of remote sensing to deliver reliable imagery and analytics.

Figure 29: Global trends in earth observation

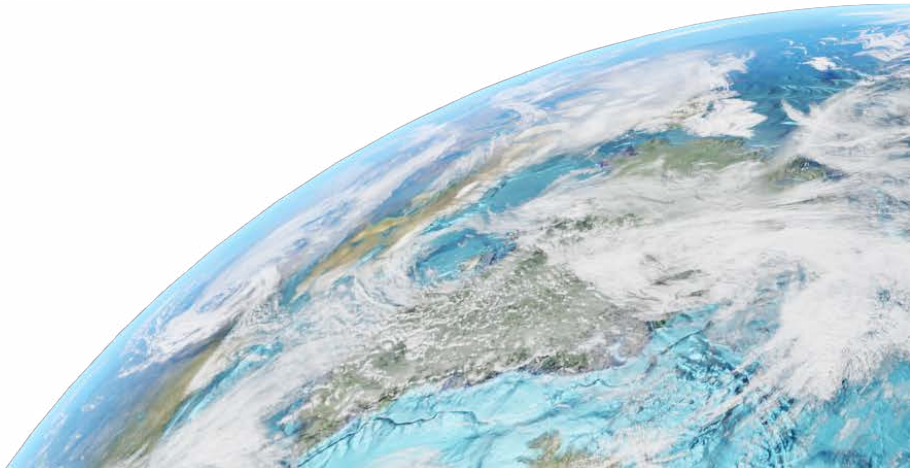
Governments across the world are liberalizing the space to allow for private participation in all segments of remote sensing - design and operations of space assets to building commercial applications.

There is an evolving global consensus that remote sensing data and applications be considered as public goods to be collectively used for achieving sustainable development.

The business models are also evolving with lines between design and operations of space assets and application blurring quickly. Application companies and users are increasingly inclined towards owning and operating own assets and vice-versa.

Along with the lowering cost of launching and operating LEO based space assets, cloud-based storage and processing of data; emerging technology developments viz., muti-sensor(optical +SAR) payloads, edge computing in space, hyperspectral imagery etc. have great disruptive potential by providing high resolution and reliable imagery.

With increasing penetration and ease of use of terrestrial alternates viz., UAV imagery, remote sensing solutions can evolve into a single package with combination of satellite based and earth-based imagery standardised and processed through AI/ML models to solve specific business and governance needs.

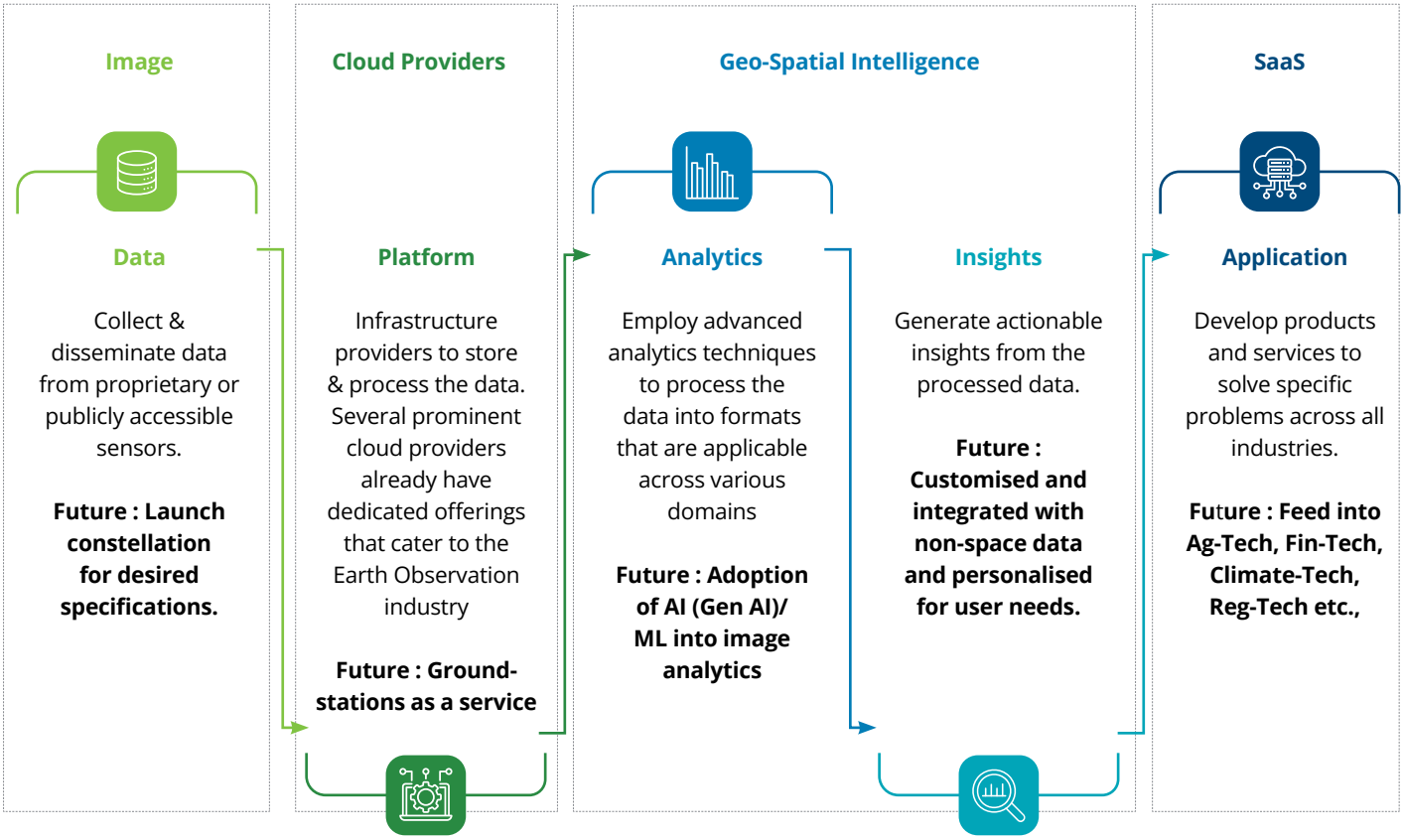


Value creation

As more organisations become aware of the relevance of data-based decision-making, EO data will gradually become part of their portfolio. Hence, earth observation/remote sensing applications may venture beyond the space industry.

However, to enable data-driven decision-making, the information must be timely and relevant to the government and businesses. The ecosystem would benefit from sensors tuned to these requirements and providing data in a persistent manner and an analytics ecosystem that is agnostic to the source of the data and can readily provide insights.

Figure 30: Evolving ecosystem of earth observation (adapted from terrawatch space)

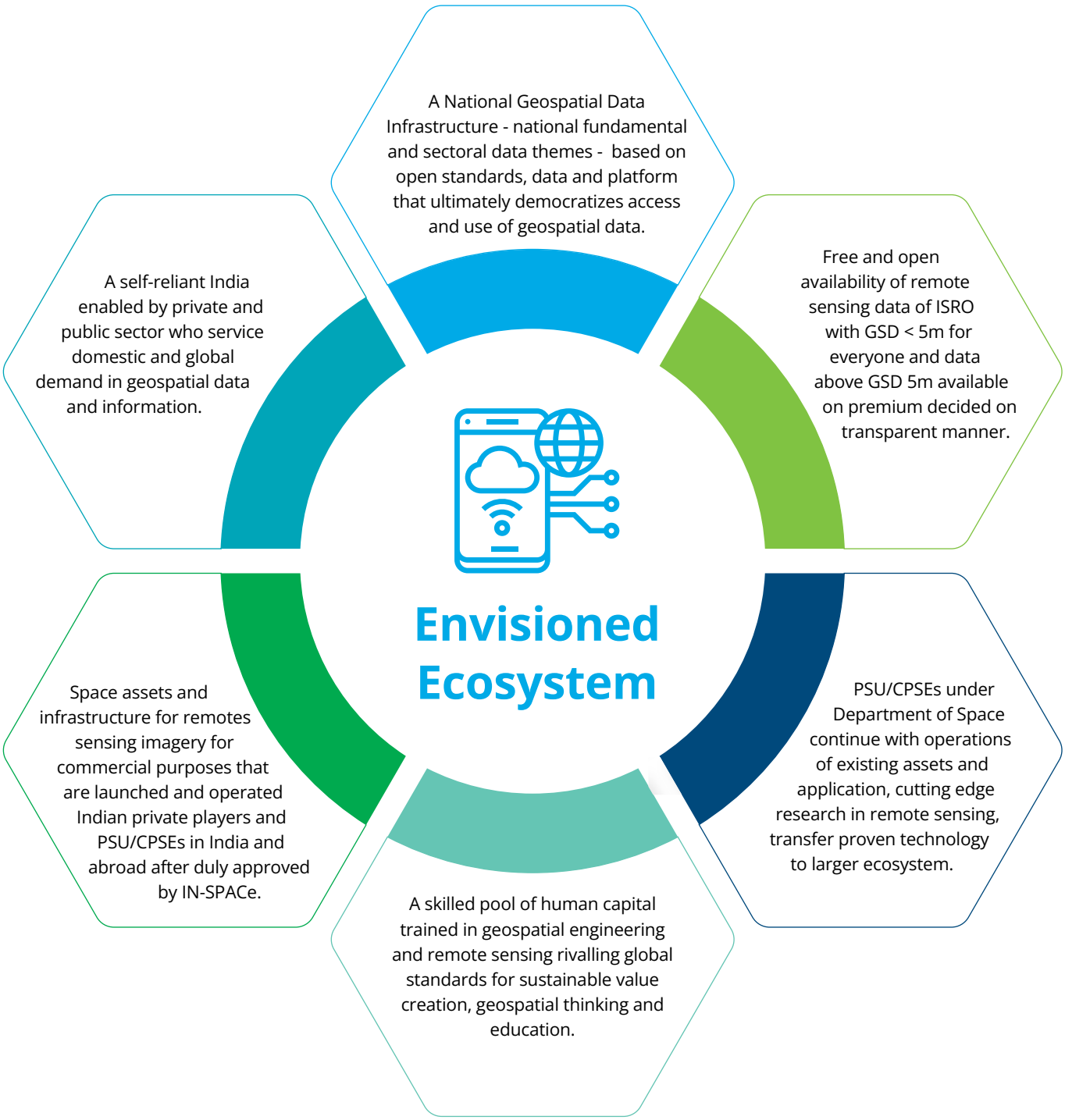


Source: https://newsletter.terrawatchspace.com/p/the-state-of-commercial-earth-observation

Policy landscape

To enable India to keep pace with global trends and emerging technology developments, the Department of Space, Government of India and the Department of Science and Technology, Government of India have unveiled a new strategy and vision for India's remote sensing ecosystem through synergistic propositions envisioned through the India Space Policy, 2023 and the National Geospatial Policy, 2022 [12,13]. The policy states that IN-SPACe will be the single-window agency for all authorisations regarding the dissemination of high-resolution satellite imagery for EO purposes. Additionally, IN-SPACe has been tasked with facilitating the accessibility of imagery for public and private entities.

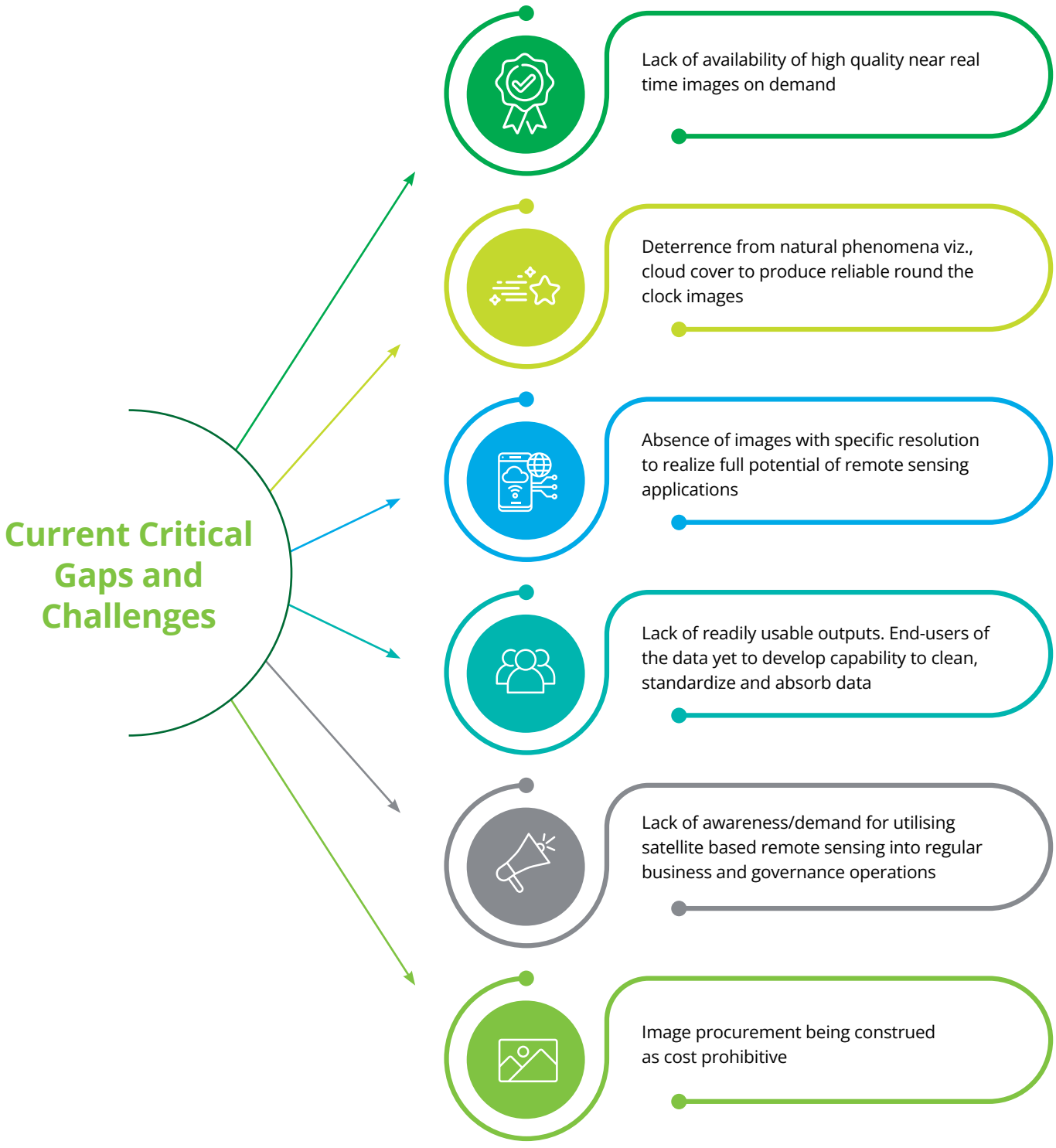
Figure 31: Policy landscape for earth observation



Challenges

Despite a mature ecosystem servicing complex use-cases supporting an enabling policy landscape, several critical gaps and challenges deter large-scale EO adoption of business and governance operations.

Figure 32: Key challenges and gaps in satellite-based remote sensing



Several private companies in India have launched their own constellation of satellites due to the lack of datasets related to key Indian industries. This ranges from companies that are solely data providers to companies that only perform analytics on processing-ready satellite image data and provide insights to companies that offer the full stack of these services. The fusion of multiple types of data from multiple types of sensors in space will be essential for holistic, user-relevant information. Open-source tools, such as the World Meteorological Organisation's OSCAR, can assist in identifying gaps in the current imaging ecosystem and in planning missions that meet the necessary commercial specifications or scientific requirements[14].

Furthermore, the adoption of EO will depend on the level of abstraction in end-user applications (such as GPS-based services), while maintaining accuracy in the information (something many still yearn for from weather data services). In an ideal future scenario, a mature EO market will no longer see itself as part of the space industry, but much like other information management services today, augment itself into various facets of business and everyday life.

Focus sectors and select value-generating use-cases

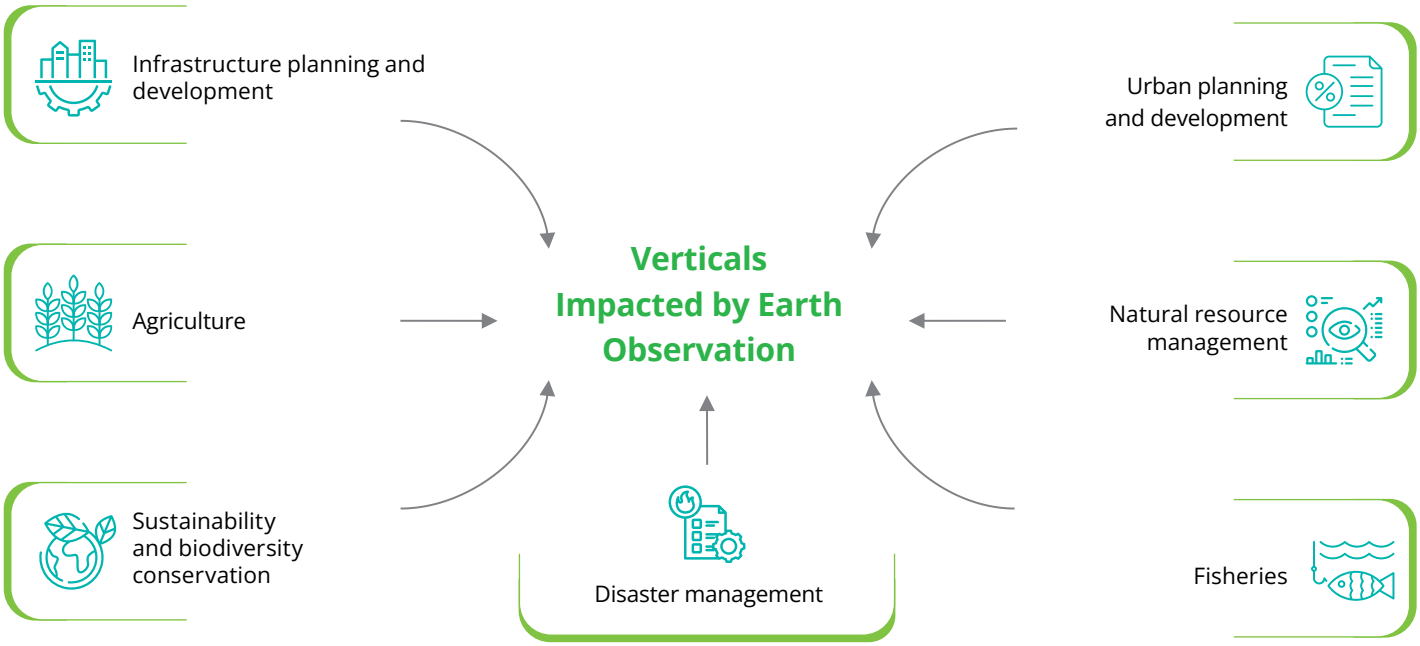
The major value creation areas are expected to be

- Image generation and sourcing will fulfil gaps in near real time and on-demand availability, required resolution, etc. to service use-cases complemented by terrestrial sources.
- First-level storage, retrieval and processing of images through cloud infrastructure to service business requirements.
- Application and Analytics on imagery to deliver business and consumer ready critical insights that can mitigate actual business and governance challenges.

As the maturity of the user-facing applications increase, it is possible to enable business-to-consumer models that can be anchored by governments and large enterprises thereby augmentation the monetisation potential.

EO can also enable a number of use-cases that were not quantified for the purposes of this study. Despite the fact that their current commercial opportunity or technical challenges make it difficult to estimate their market potential, they have the potential to have an enormous impact. Using EO data for futures trading, image analytics for detecting animal movement, disaster prediction, monitoring ocean health, quantifying natural capital, etc., are a few examples of this impact.

Figure 33: Non-exhaustive list of where EO will add value



Takeaways for 'Earth Observation'

- **Early stages of Indian remote sensing:** India's engagement with remote sensing and Earth observation dates back to its early space program in 1970 when it used remote sensing to identify coconut-wilt disease, leading to the development of the Indian Remote Sensing satellite series.
- **Impact of remote sensing:** Over the past five decades, India has significantly expanded its Earth observation capabilities, utilizing remote sensing data and applications in various sectors including agriculture, disaster management, biodiversity conservation, and natural resource exploration.
- **Increasing interests for data driven insights:** Increasingly, organizations worldwide recognize the importance of data-driven decision-making, which is driving the integration of Earth observation data into routine business and governance operations, expanding its relevance beyond the space industry.
- **Policies landscape:** To align with global trends and emerging technology developments, India has introduced new policies, such as the Indian Space Policy, 2023, and the National Geospatial Policy, 2022, which aim to streamline remote sensing activities and facilitate access to high-resolution satellite imagery.
- **Current challenges:** Despite progress, challenges remain, including data gaps, the need for data fusion from various sources, and the importance of maintaining accuracy in information. However, the Earth observation market in India is expected to grow significantly, with potential value creation areas including image generation, storage, retrieval, processing, application, and analytics, as well as the possibility of business-to-consumer models and numerous unexplored use-cases

Focus Sector: **Agriculture**

As one of the initial use-cases of the remote sensing programme of India, use of agriculture for remote sensing in India has diversified and grown over the years. NRSC has developed applications to generate insights at sub-district level for several business-critical areas viz., crop intensification, yield estimation for crop insurance etc. In the recent past, many emerging players are servicing the sector by enabling several stakeholders viz., farmers, Governments, banks, insurance providers etc. with applications leveraging space data for informed decision making.[1]

Key Characteristics of the sector and implications for EO market

With an average size of 1.08 hectares, the operational landholding is fragmented wherein ~46.93% of holding is less than 2 hectares	**Less than 1m resolution imagery** is required to deliver actionable insights to the last-mile users
The average monthly income per farmer household is INR 10,218	Propensity to pay by last-mile users may be less
The sector is replete with inter and intra-regional variations inter alia cropping patterns, intensity, irrigation, availability of farming inputs and access to markets	Requires an **integrated approach** to generate insights through multi-modal datasets viz., space, UAVs, field surveys etc

Key Challenges

Technology

Of the major parameters that are generally monitored through satellites, payload capable of generating highest **quality data is available for Evapotranspiration and Vegetation Greenness - Normalized Vegetation Greenness Index.**

Lack of **indigenous, near real time imagery and required resolution** to enable full potential of remote sensing

Business

Poor penetration of EO applications owing to lack of direct-to-consumer channels and ability to pay by last mile users viz., farmers

[1]https://pib.gov.in/Pressreleaseshare.aspx?PRID=1562687
https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1909208#:~:text=Farmers'%20income%20is%20estimated%20through,survey%20conducted%20in%202018%2D19.
https://space.oscar.wmo.int/gapanalyses
https://pmfby.gov.in/stateWiseDataPage

Value Drivers

- Lack of mature B2C channels would mean that financial institutions, large argi-industries and governments are likely to be the largest consumers for this sector
- Actionable insights will depend on having high spatial, spectral and temporal data of farmlands. Currently the ecosystem that can deliver all of them is disaggregated

Emerging Use-Cases

- Assessment of crop damage
- Crop Disease detection and control
- Soil Mapping
- Monitoring of Droughts
- Nutrient Management
- Precise and realtime weather Monitoring
- Irrigation Management
- Integrated watershed management

Focus Use-Cases

- Crop Insurance: Currently, only 22% of the farmers and 30% of the Gross Cropped Area are brought under crop insurance in India. With PM-Fasal Bhima Yojana and Weather Based Crop Insurance Scheme, Government of India aims to increase the insurance penetration. Also, vagaries of weather and connected global supply chains will have a sizeable impact on agriculture commodity pricing and farmer income making crop insurance more mission critical
- Monitoring for Horticulture: With increasing income, consumer preference for horticulture products is increasing. Stressed for area available for cultivation enhanced EO based yield improvement insights will be a game-changer for this high value sub-segment which also may have a higher propensity to pay

EO for crop insurance and monitoring for horticulture have a market potential of ~**USD 1.35 billion over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Biodiversity Conservation**

The Indian landmass has a rich wealth of wetlands, forests, biosphere reserves and glaciers etc., World over, combating climate change will be critical in sustaining lives and livelihoods from catastrophic climate change events. The country's progress is contingent on having access to clean air & water, fertile lands and having a symbiotic relationship with our environment.

Key Characteristics of the sector and implications for EO market

IUCN has provided categories of Vulnerable, Endangered and Critically Endangered for landmasses that need protection	Based on IUCN's classification, regulations will mandate incremental precision in monitoring
Aichi Biodiversity targets enlisted 10 variables[1] across species traits, ecosystem structure and ecosystem function that will require constant monitoring	Several critical climate variables still don't have appropriate instruments for measurements over India
Computer vision techniques can detect elephants, flocks of birds, whales, etc., provided the sensor has sufficient resolving capability[2]	Comprehensive observations will require multi-sensor systems and compute heavy deep learning techniques

Key Challenges

Technology

Suitable instruments to persistently monitor critical variables viz., snow and glacier runoff

Hyperspectral imagery, L-band SAR and LiDAR measurements are considered the best standards for conservation applications. Access to such data and insights over the Indian region is still limited

Business

Persistent monitoring of vast areas comes at a significant cost. Emphasis on cost-effective options viz., cloud computing etc., can make actionable analytics commercially viable

[1]Environmental science: Agree on biodiversity metrics to track from space, Andrew K Skidmore et. Al.
[2]Applications of Satellite Technologies for Biodiversity Conservation, Chris Williams

Value Drivers

- The lack of persistent insights from hyperspectral and SAR data can be bridged by the private space industry
- Apart from monitoring ecologically sensitive zones, GoI has made a commitment to reduce the Emissions Intensity of the GDP by 45% by 2030. Satellite imagery can play a pivotal role in tracking these metrics

Emerging Use-Cases

- Tracking and monitoring endangered species
- Forest carbon sequestration
- Investigating global temperature trends
- Monitoring snow and ice
- Evaluating sea-level changes
- Monitoring aerosols and water vapor
- Larch mapping
- Sea algae detection
- Oil spill/Gas leak detection

Focus Use-Cases

- Monitoring of overall Tree and Forest Cover, Biosphere Reserves and Wildlife Sanctuaries: With close to 25% of the Indian landmass comprising of Trees (with 17+ states having over 33% of their area under forest cover), moderate resolution imagery can inform policymakers of land use patterns and achieve goals such as doubling protected environments
- Monitoring of Eco-Sensitive Zones: These relatively smaller, very sensitive areas will require high resolution imagery for precise monitoring to detect minute changes in boundaries, swamp cover, tree cover etc., apart from more advanced applications such as detection of fires or animals

EO for monitoring ecologically sensitive areas has a market potential of ~**USD 302 million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Disaster Management**

Climate change events have already started to impact weather conditions around the world. Given the increasingly unpredictable nature of catastrophes occurring in the last few years, earth observation can be crucial to prepare and plan for disasters, detect and monitor hazards in near real time and conduct damage assessment & recovery planning.

Key Characteristics of the sector and its implications for Earth Observation

The range of disasters occurring can be wide-ranging. Their detection is contingent on observation of several inter-linked factors. Eg: Glacier melting's effect on river water levels	No singular approach for space-based observations will be sufficient. Instruments will have to be fine-tuned and deployed specifically for each event
ISRO is a member of the International Charter: Space and Major Disasters along with 17 other space agencies[1]	Sharing of satellite imagery amongst signatories is free of cost in the event of a disaster
95% of coastal districts and 75% of all districts in India are vulnerable to extreme climate change events[2]	High-resolution imaging may not always be feasible, even if the data is free the cost of storing and processing them can be significant

Key Challenges

Technology

Data latency due to unavailability of space-based sensors delivering near-real time data can hinder attempts to analyze damages to large areas

Integration and interpretation of satellite data with ground-based observations can be complex. More so when insights from such data will be required in the preparatory or monitoring phases of disaster response strategies

Business

Identifying and catering to the requirements of the competent entities who require timely insights is important for realizing commercial value. Such entities may include national, state and district disaster management authorities.

[1]https://disasterscharter.org/
[2]https://www.hindustantimes.com/india-news/75-districts-in-india-vulnerable-to-climate-crisis-face-risk-of-floodsreport-101635272597188.html

Value Drivers

- The current range and power limitations of drones may not make them as resilient as satellite imagery in the event of large-scale disasters
- There is no comprehensive service that can fuse all related EO data with PNT data that can be critical in the times of disasters. Private players may bridge this gap

Emerging Use-Cases

- Predicting forest fires
- Estimating trafficability of terrains
- Snow cap/glaciers melting rate
- Intensity of volcanic activity
- Monitoring ship/ plane wrecks
- Riverbank monitoring for flood-predictions
- Reconstruction planning
- Hazard zoning and Epidemic outbreak monitoring

Focus Use-Cases

- Disaster Response Management: While satellite imagery may also be used for prediction of natural disasters before they occur, the focus of this exercise has been on applications that will better serve the response of governments and civil society to disasters. In the event of floods, earthquakes, landslides, forest fires, droughts or cyclones & tsunamis satellite imagery can and have been used to coordinate relief efforts and assess damages to property and lives

EO for disaster response management has a market potential of **~USD 311 million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Natural Resources**

Extraction of non-renewable resources is currently pivotal for sustaining the modern way of life. The act of mining, drilling, processing and consuming these minerals has an irrevocable toll on the environment and in turn, on people. Earth Observation can help ensure that these activities are carried out legally and sustainably. If extraction is inevitable for the moment, being able to do so responsibly is vital for India's socio-economic development in the coming years.

Key Characteristics of the sector and its implications for Earth Observation

Exploration and monitoring the extraction of natural resources encompasses all minerals which includes fuel, atomic, major and other minor minerals	Their dispersion will be across varied terrains & landmass, calling for different approaches for detecting and monitoring them
Government of India has set ambitious target for the sector to boost India's economic growth[1]	Commercially viable imaging to service India's entire landmass and evolving requirements needs to be developed
Indian states and the central government are losing out on significant revenue due to illegal mines[2]	The 7 states that contribute to more than 97% of the country's mineral reserves will require persistent monitoring

Key Challenges

Technology

To track illegal mining and transportation activities, high-resolution imagery will have to be generated and operationalized

Hyperspectral imagery is considered the best standards for conservation applications. Access to such data and insights over the Indian region is still limited

Business

Baseline data has already been generated by Geological Survey of India's geochemical and geophysical mapping. The challenge remains in spotting the best possible sites within already identified areas to minimize wastage and disruption to the surrounding environment

[1]https://www.livemint.com/industry/energy/india-to-see-58-billion-investment-in-upstream-oil-sector-hardeep-singh-puri-11673613295699.html
[2]https://www.deccanherald.com/opinion/editorial/identify-illegal-mines-plug-revenue-loss-1194293.html#:~:text=The%20Comptroller%20and%20

Auditor%20General,due%20to%20illegal%20mining%20there.

Value Drivers

- Most exploration surveys are carried out across vast scales of area. Satellite imagery can ensure precision in allocating resources to the right spots
- Monitoring operations for this industry will not only demand fusion of multiple types of data, but also integration of EO insights from PNT services

Emerging Use-Cases

- Mine disaster prediction
- Emission monitoring from mines
- Environmental impact around mines
- Locating slicks
- Detecting hydrocarbon leaks and recurrence
- Activity in mining sites for futures trading

Focus Use-Cases

- Natural Resource Extraction Monitoring: Illegal mining continues to plague several regions of India. This includes violation of mining leases, rat hole mining etc., amongst other unscientific practices. Apart from aiding in assessing the environmental and social impact of mining activities, earth observation can also help track unauthorized extraction of resources
- Natural Resources Exploration: Novel sensors being used for earth observation can reveal mineralogical variations in the earth's surface. This method may prove to be cost-effective and non-invasive

EO for monitoring resource extraction and exploration has a market potential of ~**USD 1.2 billion over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Fisheries**

Earth observation using remote sensing in India has grown over the years. It is well known that changes in ocean conditions directly impacts fluctuations in fish stocks. By using remote sensing technology for determining changes in temperature, colour, wind speed etc., fisherman can directly improve productivity along with reducing operational costs. Mariculture has huge potential to create sustainable livelihoods for marine fishers. Collection and analysis of data by using transponders & satellites are one of the crucial aspects to help in precision fishing.

Key Characteristics of the sector and implications for EO market

The coastal economy sustains over 4 Mn fishermen. India is the second largest fish producing nation in the world and has a fleet of 2,50,000 fishing boats.[1]	Less than 5m resolution imagery is required to deliver actionable insights to the last-mile users. Inland farms will require different resolution
India has remarkable marine position with 7,517 kilometers of coastline. Nine of India's states have access to the coastline	Propensity to pay by fishermen may be very less
Use of remote sensing for studies of freshwater fish habitat is a relatively nascent field of study	Needs fishermen friendly apps with multi language model along with features that can be subscribed for a monthly fee

Key Challenges

Technology

Lack of indigenous, near real time imagery and required resolution to enable full potential of remote sensing. Cost of high-resolution imagery and data processing can still be a barrier for many players, especially those with limited resources. Finding ways to make technology more affordable and accessible is important

Business

Poor penetration of EO applications owing to lack of direct-to-consumer channels and ability to pay by last mile users viz., fisherman in India

[1]https://www.downtoearth.org.in/news/environment/indian-blue-economy-is-thriving-but-country-needs-to-be-careful-about-marine-litter-87813#:~:text=India%20is%20the%20second%2Dlargest,6%20per%20cent%20at%20present.

Value Drivers

- Much like agriculture, the adoption of intelligence from satellite imagery might be low in the B2C segment. However, organizations that collectivize fishermen, provide relief efforts and provide financial support to fishermen can benefit from EO

Emerging Use-Cases

- Sea temperature monitoring
- Forecasting potential fishing zones
- Measuring turbidity and wave characteristics
- Suspended sediment concentration
- Precise and realtime weather Monitoring

Focus Use-Cases

- Identification of Fishing Hotspots: Currently, there are few key players that are trying to reach out to fisherman & educate them about how they can use apps developed to increase productivity & reduce operational costs while at sea
- Weather and Ocean Condition Forecasting: Earth observation satellites can provide real-time and accurate data on weather conditions such as wind speed, wave height, and sea surface temperature. This information is crucial for fishermen to make informed decisions about when to go out to sea, helping them avoid hazardous weather conditions that could endanger their lives and boats

EO for fishers to detect hotspots and get weather updates has a market potential of ~**USD 29 million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Urban Planning and Development**

Globally, utilisation of satellite imagery for urban planning and development is witnessing an uptick to the extent several international organisations are contemplating the very definition of urban areas based on nighttime light analytics from satellite imagery. Urban development has been a cardinal pillar to India's remote sensing programme with several Government initiatives viz., AMRUT etc., relying on earth observation data.

Key Characteristics of urban sector in India and its implications for EO

India's urban landscape is very diverse with extremely hyper-local challenges and characteristics including land-use planning, utilisation, congestion, climatic conditions etc.[1]	Servicing requirements through pure-play satellite imagery may not render outputs to suffice requirements. Integrated approach of fusing images from varied sources would create key-differentiation
Although 31% of India's population lives in urban areas, majority of urban population is housed in the major urban agglomerations and Tier I towns which creates uneven distribution	It is imperative to recognize that a one-size fits all approach will not work. Not every urban settlement requires satellite-based approach for master plan development/land-use monitoring etc.

Key Challenges

Technology

Several (non-space) companies have started to publish tools for monitoring land use. This may drive adoption of their cloud services to develop tools and services for urban and regional planning[12]

Given the density of buildings in Indian cities, only high-resolution imagery from LEO, fused with drone-based imagery and data from door-to-door surveys can provide a holistic picture

Business

While the required imagery can be procured cost-effectively, the real value creation requires improved and actionable insights generation within a multi-stakeholder ecosystem

[1]https://www.livemint.com/Politics/4UjtdRPRikhpo8vAE0V4hK/How-much-of-India-is-actually-urban.html

Value Drivers

- High resolution imagery can inform administrators and empower citizens to monitor how cities are planned and renovations are executed. This application is also ideal for the usage of drones (where permitted), so the best services will offer a combination of satellite and drone imagery

Emerging Use-Cases

- Monitoring and mitigating urban heat islands
- Disaster resilient city planning
- Monitoring encroachment of lakes and public commons
- Planning and monitoring city repairs and upgrade programs
- Transport route planning
- Heat signature of buildings to track activity

Focus Use-Cases

- Urban Planning and Development monitoring : As India's urbanization expands, master plan requirements increase. Along with planning, land-use and urban sprawl monitoring will be crucial use-cases that can be serviced through remote sensing
- Property Taxation: Geo-tagging of urban commercial and residential properties along with periodic updating to be inputted as critical parameters into property tax collection and monitoring systems

EO for urban development and taxation has a market potential of **~USD 251 million over the next 5 years.**

Note: Emerging Use Cases have not been sized
Note: The market potential was calculated only for select urban areas i.e., urban areas more than 50 sq.km. as per census 2011

Focus Sector: **Infrastructure**

Use of satellite imagery for terrain mapping and topographic surveys, project development monitoring and asset utilization/ health monitoring has been in use since the launch of Resourcesat series of ISRO. As Government of India reinvigorates India's infrastructure with new expressways, high-speed rail corridors, modern airports, sustainable energy production, re-imagined coastal economy through ports, the utility of satellites in infrastructure planning, development and monitoring is set to spike.

Key Characteristics of sector in India and its implications for EO

- **Roads:** 47.85% growth in National Highways over the last 8 years with peak per day road creation reaching 36.5 km/day in 2020-21
- **Railways:** Apart from impetus to high-speed corridors, target for new track at 19 km/day
- **Ports:** Master Plan Development of 1.1 lakh hectares of port land for industrial development
- **Airports:** Vision to establish 220 new airports
- **Renewable Energy:** Target to achieve 500 GW of renewable energy

In addition to accomplishments and overall vision of Government of India, the overall planned outlay for these critical sub-segments is ~USD 150 billion.[2]

As Governments and infrastructure companies would require innovative approaches for planning and monitoring, this segment will be a pre-dominant business-business segment

Key Challenges

Technology

Even very high-resolution satellite imagery cannot compare with drone-based imaging on spatial resolution. Augmenting both datasets can bring down the cost of drone operations while retaining persistence of imaging

While recent years have seen the availability of many high-resolution datasets, their potential for urban mapping has not been fully explored. It can be partially ascribed to their accessibility as they are mostly commercial data[1]

Business

Coordinating between urban & regional planners, administrators and earth observation insight providers will be key to realizing tangible value in this segment. Imagery alone won't suffice

[1]https://doi.org/10.1016/j.isprsjprs.2023.05.028
[2]https://m.economictimes.com/small-biz/sme-sector/gati-shakti-with-ulip-budget-wants-to-put-150-billion-logistics-sector-in-the-fast-lane/articleshow/89313268.cms
https://newsonair.gov.in/News?title=Road-Transport-and-Highways-Ministry-says%2C-construction-of-National-Highways-witnesses-47.85%25-growth-in-last-eight-years&id=453463

Value Drivers

- Infrastructure planning, development and monitoring has typically been the most difficult aspect of governance to overhaul. Through reliable and persistent imagery, insights from satellite data can provide an effective means to monitor large-scale projects, provided governments adopted the same

Emerging Use-Cases

- Asset Utilization monitoring
- Parametric insurance for construction
- Predictive maintained and asset health monitoring
- Satellite image based Building Construction Information Model

Focus Use-Cases

- Terrain Mapping, Topographic Surveys and Planning : Engineering Surveys and Project Planning already rely on satellite imagery. Being able to generate actionable insights that can inform the departments driving initiatives such as Gati Shakti can boost the effectiveness of the capital expenditure. This can aid in the better planning of roads, ports, industrial zones, power grids etc
- Development & Asset Health Monitoring: Centralized monitoring of highways (and related industries) would require the imagery of close to 8,000 sq. km of area each year. Satellite imagery may prove to be the most cost-effective method of validating the progress and health of such expensive initiatives

EO for mapping, surveying and asset monitoring has a market potential of **~USD 62 million over the next 5 years, for new infrastructure development**

https://www.deccanherald.com/india/railways-plans-to-lay-19-km-new-track-per-day-1198311.html#:~:text=Indian%20Railways%20has%20set%20the,in%20the%202022%2D23%20fiscal.
https://infra.economictimes.indiatimes.com/news/aviation/india-will-have-220-airports-in-next-2-3-years-says-scindia/100825757#:~:text=Scindia%20outlined%20the%20objective%20of,airports%20in%20aIndia%20to%2030.
https://economictimes.indiatimes.com/industry/transportation/shipping-/-transport/chunk-of-1-10-lakh-hectares-land-with-ports-to-be-utilised-to-develop-industries-shipping-minister/articleshow/76921592.cms?from=mdr
https://economictimes.indiatimes.com/industry/renewables/india-to-achieve-500-gw-renewables-target-before-2030-deadline-rk-singh/articleshow/103936965.cms?from=mdr

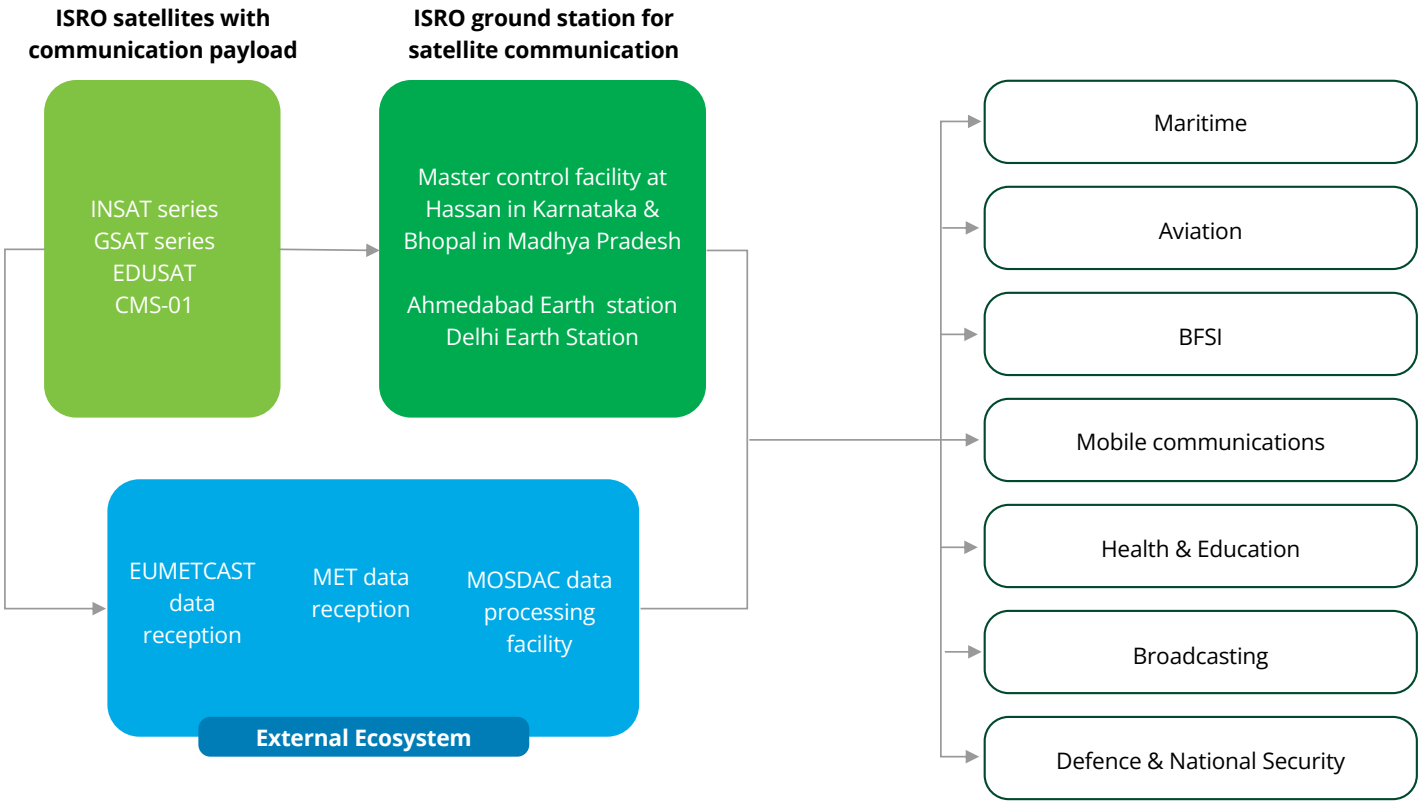
Note: Emerging Use Cases have not been sized
Note : The market potential was calculated only new/greenfield infrastructure development. Monitoring of existing infrastructure was not considered for estimating market potential

Satellite communications

ISRO's history with indigenous SATCOM began with the Ariane Passenger Payload Experiment, an experimental communications satellite sent into its GEO orbit in 1981 on an European Space Agency(ESA) flight. However, India's attempt to put a communication satellite for use due in 1982 suffered a setback as INSAT-1A failed in its orbit. SATCOM as a service were then realised in 1983 with the INSAT 1B satellite. Since then, India's communication market has matured greatly – from providing Doordarshan on television to connecting rural and remote areas through satellite broadband through BBNL. This journey has played a pivotal role in commercialising telecommunication, broadcasting and now the broadband market.

Broadcasting and telecommunications have long seen applications, with broadcasting being the traditionally commercially viable use-case with private players' participation and telecommunications restricted for strategic purposes. In an effort to facilitate satcom for the greater good, the government has loosened certain regulations and processes. Recognising this and the fact that SATCOM has unrivalled advantages over traditional terrestrial networks, especially in remote and inaccessible regions due to its ability to transcend geographical barriers (including hilly terrains, islands and sparsely populated areas), private players are eager to enter the market. A handful of major private entities are launching their own constellation of satellites to serve land, sea and air. The government has also extended its satellite Internet service through the BharatNet project in collaboration with private players to serve around 7,000 gram panchayats at reasonable costs, empowering citizens with access to valuable online resources. By ensuring spectrum allocation is consistent with global best practices, the government can further expand market access for new entrants and allow incumbents to thrive in the sector.

Figure 34: Space ecosystem for satellite communication



Trends

Conventional GEO orbits are giving way to MEO and LEO for the commercial use-cases to help reduce latency. As new assets get deployed and technology advances, the world moves into a phase of rediscovering capacity for newer use-cases. India had set its eyes on pioneering the narrowband Internet of things (IoT) space with the world's first ever service provided by BSNL; however, it seemed ahead of its time.

Figure 35: Global trends in satellite communications

1

Satellite IOT

Considering that IOT devices will only increase in number with time and there is a good possibility of these devices being in areas with less or no access to terrestrial networks, satellites are the only other alternative to deliver connectivity to such IOT devices. Once, satellites can get connected to IoT sensors, there are numerous applications that are significant to their respective fields, real-time asset tracking and monitoring, remote infrastructure monitoring, remote healthcare, transportation, and fleet management are some of them.

2

Satellites enabling 5G ecosystem

NTN technology that has the ability to enhance 5G network to ensure service continuity in moving platforms like train, airplanes etc. and mission-critical communications, guarantee network connectivity in un-served or underserved areas where terrestrial network Is not present or is cost ineffective. Many big companies have their NTN modem technology and chips to make satellite connectivity available on cellular and IoT devices. This is still an untraversed market that can disrupt telecommunications market.

3

Very High Throughput Satellites

Having greater data transmission capabilities compared to traditional satellites can meet increasing demands of data-intensive applications and services. Advanced technologies like software-defined radios and multi-spot beams can transmit several hundreds of gigabytes of data per second and increase frequency in frequency bands.

4

LEO Satellites

Apart from 84% of satellites in space being LEO, they operate with low latency and high bandwidth. Hence, they can move faster, operate at lower altitudes, and can provide good connectivity with low power. LEO satellites could be the best choice of communication in the brink of emergency or disaster.

Value creation

SATCOM is a government regulated service and operates in different bands with each band catering to a different application, and it dictates the spectrum allocation. The primary value creation lies in end-user services such as telecommunications, broadcasting, Internet services, etc. and these have been the traditional avenues.

Figure 36: Each band serves a different sector based on its requirements

L (1-2 GHz)	S (2-4 GHz)	C (3.6-4.2 GHz)	Ku (12-18 GHz)	KA (27.5-29.5 GHz)
Used for GPS Signals (NAVIC)	Used for Broadcast and Mobile Satellite Services	Used by Broadcast Sector (TVRO)	Used by DTH Sector	Identified by ITU for Satellite Services
NAVIC coverage (up to 1,600 km with1 m or 3 ft accuracy)	NAVIC Also uses S band	(Serves Over 210 Mn HH in India)	71 million active DTH subscribers in India	200+ Satellites withTBPS capacity world overs

Sourced from SIA India

However, there lies a host of untapped markets around in-flight connectivity, logistics and OTT, among others. New models such as bundling services such as broadband and TV over satellite connections can see potential growth in the years to come. OTT players too have expressed the need to allocate satellite bandwidth for streaming, especially to cater to the rural areas[15].

Policy landscape

Indian Space Policy 2023 has set the provision for satellite players to obtain frequency and orbital slots from agencies other than the Department of Telecommunications' wireless planning and coordination wing exclusively, thereby improving the ease of doing business in a rather regulated and stifled category.

The Satellite Reforms 2022 document released details for simplifying the process and enhanced the scope of licences to cover M2M/IoT services. Licence fees, MPVT (Mandatory performance verification testing) and Network Operations and Control Center (NOCC) charges have been exempted.

01. The global mobile personal communication by satellite policy licence is given by the government to private players allowing them to provide SATCOM services in licensed serviced areas. Three large players already have this licence to offer services in India.
02. The new 2023 space policy allows non-government entities to offer space-based communication services through self-owned or procured or licensed Geo-Stationary Orbits (GSO)/ Non-Geo-Stationary (NGSO) communication satellites.
03. TRAI (telecom regulatory authority of India) is still deciding between the regulation method to allocate spectrum through auction or nonexclusive shared spectrum.

Challenges

Figure 37: Key challenges in satellite communication

High cost of data

The cost of service is very high today compared to terrestrial broadband connections, ~5 times more, unaffordable for common man.

Limited data offering

Most of the satellite interenet service providers impose data caps on their monthly plans, and hence, data-intensive activities like video streamikng, downloading large files etc., will not be feasible.

Spectrum allocation

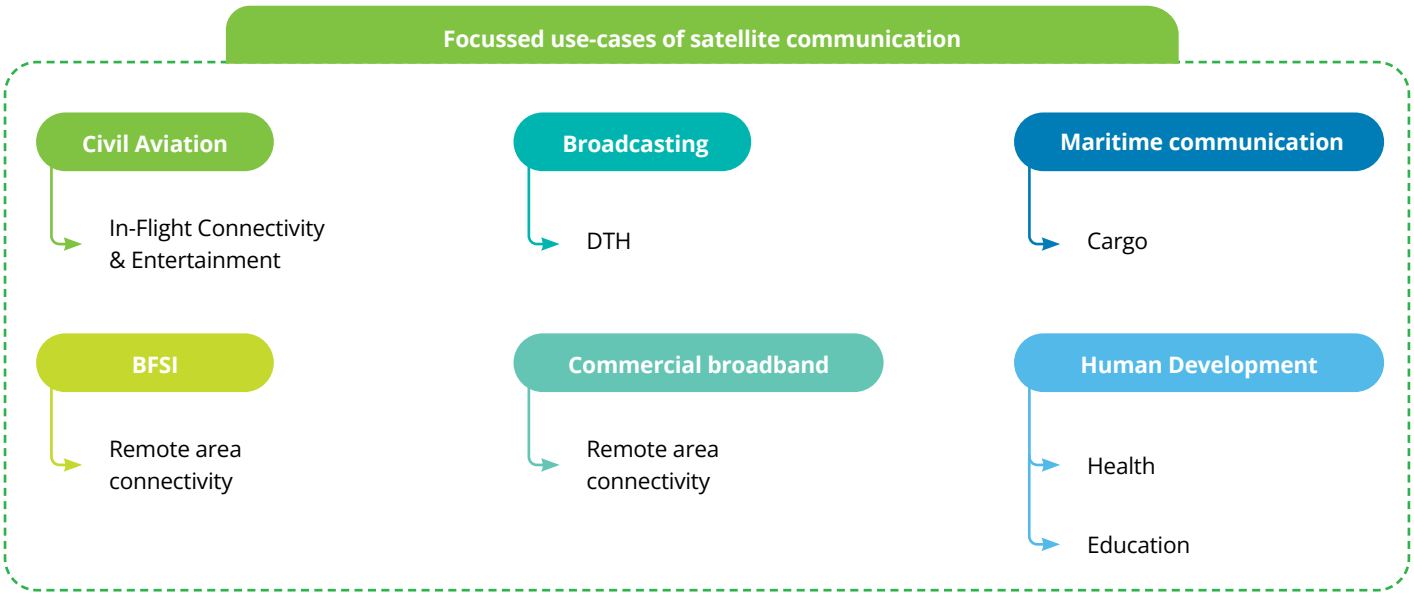
Governing & regulatory bodies can bring spectrum allocation & adequacy in-line with global test practices allowing new players to enter the market as well as existing ones to flourish, resulting in market stabilization and lowering of cost.

Latency concerns

Satellite internet suffers from high latency issues, as it relies on signal transmission over long distances. A noticeable delay can be observed compared to terrestrial broadband services

Figure 38: Non-exhaustive list of sectors where satcom will add value

Focus sectors and select value-generating use-cases



Takeaways for 'Satellite Communication'

- **Early era of Indian SATCOM:** India's satellite communication journey began with the launch of APPLE in 1981, and it has since evolved significantly, playing a pivotal role in the commercialization of telecommunications, broadcasting, and broadband markets.
- **Shifting trends in SATCOM:** The industry is shifting towards Medium Earth Orbit (MEO) and Low Earth Orbit (LEO) satellites to reduce latency. Trends include Satellite IoT, satellites enabling the 5G ecosystem, Very High Throughput Satellites, and the prominence of LEO satellites.
- **Evolving business models:** While traditional avenues like telecommunications, broadcasting, and internet services remain significant, there are untapped markets such as in-flight connectivity, logistics, and Over-The-Top (OTT) services. Bundling broadband and TV over satellite connections is also a potential growth area.
- **Policies Landscape:** Recent policy changes, such as the 2023 space policy and satellite reforms in 2022, are aimed at simplifying processes and encouraging private sector participation. These changes include exempting certain fees and allowing non-government entities to offer space-based communication services.
- **Current challenges:** Challenges include the high cost of satellite data compared to terrestrial broadband, limited data offerings due to data caps, the need for improved spectrum allocation practices, and addressing latency concerns in satellite internet services.

Focus Sector: **Commercial Broadband**

Using satellite internet to connect rural India is a transformative initiative that addresses the critical issue of the digital divide in the country. With a vast and diverse geographical landscape, India's rural areas have faced challenges in accessing reliable and high-speed internet connectivity. Traditional terrestrial infrastructure has limitations in reaching remote and sparsely populated regions, making satellite internet a viable and effective alternative.

Key Characteristics of the sector and implications for SATCOM Market

India is marked by the presence of various players, including government-owned entities, private internet service providers (ISPs), and mobile network operators	To bridge this Digital Divide, the government, under the scheme of BharatNet project, aims to provide internet services to all 2.5 Lakh Gram Panchayats
Driven by affordable smartphones and accessible data plans, India has achieved a 52% internet penetration rate, with over 760 million active users. Of these, 360 million are from urban areas, and 400 million are from rural areas	So far, 1.95 Lakh GPs have been connected by OFC and made service ready. For 7000 GPs and sites that are remote and inaccessible for OFC infrastructure, satellite-based internet will be provided

Key Challenges

Technology

LEO satellites have shorter lifespans than GEO satellites due to atmospheric drag and orbital debris, which degrade their performance and raise collision risks

Adverse weather conditions, such as heavy rain or storms, can temporarily affect satellite signal quality, leading to potential service disruptions

Business

Navigating complex regulatory frameworks and significant upfront infrastructure costs of terminals and gateways

https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1884072
https://www.thehindu.com/news/national/over-50-indians-are-active-internet-users-now-base-to-reach-900-million-by-2025-report/article66809522.ece

Value Drivers

- With the Urban internet penetration reaching a plateau, Rural India is set to drive the next leg of growth. By 2025, ~56% of new internet users will be from rural India, with a projected total of 900 million internet users in the next two years

Emerging Use-Cases

- Connected Vehicles exchanging information for navigation and safety
- Connecting smart home devices and industrial IoT devices anywhere in the world
- Direct connectivity with cellphones

Focus Use-Cases

- Remote Area Connectivity: Using satellite internet for rural connectivity is a revolutionary approach that addresses the digital divide prevalent in remote and underserved areas. Traditional terrestrial infrastructure faces limitations in reaching these regions, making satellite internet a game-changing solution. LEO based satellite internet providers and newer high throughput ground terminals may overcome traditional issues of limited bandwidth associated with VSATs

Satcom for broadband connectivity in remote areas has a market potential of ~**USD 263 Million over the next 5 years**

Note: Emerging Use Cases have not been sized

Focus Sector: **Broadcasting**

Broadcasting dates to 1990s when it was introduced through television (Doordarshan), over the time this technology has evolved with many other uses like satellite radio, DTH, and DSNG (digital satellite news gathering). Today, there are 898 satellite TV channels, 7 DTH, 1 HITS operators and many MSOs catering to ~101 Mn households.

Key Characteristics of the sector and implications for SATCOM Market

OTTs are posing a stiff competition to broadcasting companies in acquiring newer consumers	Entertainment broadcasting services will have to be bundled with OTT content to keep acquiring customers
No geographical disadvantage as service can be extended to global audience without much difficulty	Revenue is generated in satcom market by leasing C and Ku-band transponders to service providers

Key Challenges

Technology

Performance is affected by extreme weather conditions like rains and storms, as signals are not received well by antennas.

Business

OTTs, video on-demand, and music apps are capturing market share from DTH and Radio, targeting medium to high income groups

Cable, DTH and Radio from Prasar Bharati is freely available, capturing users from low-income group making them unavailable to the market

https://www.trai.gov.in/sites/default/files/Annaul_Report_23022023_0.pdf
https://www.exchange4media.com/media-tv-news/dth-players-on-ott-what-lies-beneath-the-shift-123625.html
https://www.thehindubusinessline.com/info-tech/can-ott-platforms-displace-cable-tv-and-dth/article29516596.ece

Value Drivers

- Increasing adoption of entertainment services in rural India.
- Extending satellite bandwidth to OTT players has the potential to increase the market size for broadcasting as the demand is shifting

Emerging Use-Cases

- Ultra-High-Definition Broadcasting
- Video on Demand Services
- Integration with smart appliances
- Personalized content streaming
- Interactive TV

Focus Use-Cases

- DTH: Market for DTH is to remain consistent in the coming years, having said that there is heavy competition from OTT players for the market to grow any further. Satellite communications as a technology cannot save DTH market from getting saturated because we see a change in viewing habits of users to OTT. Players in this market have to come up with strategic pricing as subscriber base for pay DTH is expected to go down

Satcom for DTH has a market potential of **~USD 12.69 Billion over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **BFSI**

Satellite communication has a lot to offer for BFSI sector, satellite connectivity is suitable for back-up connections, connect remote and rural areas to be able to access digital business units and better in-branch connectivity. It is a great opportunity for BFSI and government to use satellite connectivity to digitalize underserved and remote areas.

Key Characteristics of the sector and implications for SATCOM Market

- Connectivity has become the core for efficient functioning of BFSI sector not only to extend services to customers but also for internal operations → High throughput terminals offer reliable and persistent connectivity 24*7, anywhere in the world
- With most population shifting to online/digital payments BFSI are forced to provide mobile applications and net banking → Banking has been one of the early adopters of satellite internet with the help of Indian government

Key Challenges

Technology

ATMs are powered by fiber broadband connection because there is sensitive data transmission and most of them have satellite connection as a backup option

Business

Most banks already use terrestrial networks because of huge data transmission, which cannot be always fulfilled by satellite connectivity

Cost of satellite internet is high

https://dbieold.rbi.org.in/BOE/OpenDocument/1608101727/OpenDocument/opendoc/openDocument.faces?logonSuccessful=true&shareId=12.
https://www.livemint.com/money/personal-finance/online-payments-in-india-how-upi-is-changing-the-face-of-digital-payments-11687241104262.html

Value Drivers

- Reports indicate that 70% of new ATMs in the country are in rural areas, reflecting a growing demand for financial services. Rural India presents an opportunity to expand BFSI penetration through satellite communication and internet services

Emerging Use-Cases

- Network redundancy for urban bank branches, ATM machines and digital payment gateways
- Detailed telematics from insured vehicles or assets to verify claims
- High Frequency Trading
- Enhanced mobile banking facilities such as video calling branches from remote areas for queries

Focus Use-Cases

- Remote Area Connectivity: There was a surge of micro-ATMs in remote and rural areas from 2020 to make banking available and banks have been increasing the count of ATMs in rural areas with each year (there are 55451 ATMs and 1419271 micro-ATMs in rural India), and this requires connectivity in these areas, satellite connectivity could be a better solution

Satcom for BFSI in remote areas has a market potential of **~USD 43 Million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Maritime**

Satellite based communication & internet has the potential to provide critical communication services & connectivity to the maritime sector which has no other substitute since traditional connectivity doesn't serve commercial & consumer activities carried out on sea. Carrying out financial transactions, connectivity for passengers & crew members, equipment monitoring, leisure & entertainment, cargo tracking, etc are few of the wide applications SatCom has for Maritime sector

Key Characteristics of the sector and implications for SATCOM Market

Approximately 95% of India's merchandise trade is done through its 200 major & non major ports, with non-major ports contributing to 45% of the overall traffic & major ports contributing 55%	Cargo shipping emerges as a use case with massive potential for satellite communication services
Growth rate for cargo vessels in India stands at a CAGR of 2.08%	High adoption rates will drive business in the future
As of 2022, Ministry of Ports, Shipping & Waterways recorded the Indian cargo fleet at 1520 ships	The hardware component for satellite communication in cargo ships has a potential to reach USD 3.6 Mn

Key Challenges

Technology

SatCom internet services have had limited bandwidth in the past, wide scale adoption & subsequent revenue has a dependency on the reliability & bandwidth of the technology

Business

In comparison to leisure, entertainment & recreational use cases, where the propensity to purchase is dependent on the pricing, commercial use cases such as cargo shipping is likely to have higher propensity to purchase

https://www.ibef.org/research/case-study/india-s-maritime-sector
https://www.ibef.org/industry/ports-india-shipping
https://shipmin.gov.in/sites/default/files/ISS%202022%20_31032023.pdf

Value Drivers

- Access to reliable & quality internet services can drive efficiency in commercial use cases where communication & connectivity proves to be an essential service. While for other use cases where maritime activities are more recreational in nature, satellite-based internet services can unlock significant value through leisure & entertainment purposes

Emerging Use-Cases

- Remote ship diagnostics
- Integrated fleet management
- Precise weather monitoring
- Autonomous ship navigation
- Port operations and logistics monitoring
- Optimizing ship routes for fuel efficiency and safety

Focus Use-Cases

- Cargo: With ~95% of India's merchandise trade being conducted through its ports; cargo emerges as an important & significant use case within the maritime sector in India. Due to its nature of being a critical commercial activity, the propensity to purchase is likely to be higher for the cargo use case

Satcom for cargo ships has a market potential of **~USD 195.4 million over the next 5 years**

Note: Emerging Use Cases have not been sized

Focus Sector: **Civil Aviation**

Satellite communication emerges as a vital response to the modern-day passenger's need of always staying connected to the internet. SatCom allows passengers in civil & commercial airlines to access internet for leisure, entertainment & staying connected to the internet. For Airlines, the in-flight connectivity & entertainment use case emerges as a value-add service that has the potential to contribute significantly towards overall revenue.

Key Characteristics of the sector and implications for SATCOM Market

The number of passengers in flights are expected to grow at a rate of 13% annually	People in the age group 20-39 make up majority of the passengers & are also likely to drive adoption for in flight connectivity
India is expected to add approximately 100 aircrafts every year giving a growth rate of ~12%	By 2028, the country is projected to double its aircraft fleet size to ~1300
Directorate General of Civil Aviation reports 190 Million total passenger traffic for 2022-23 and the growth rate for domestic passengers at 8.9%	The market for SatCom in Aviation is expected to grow owing to the growing traffic in domestic passengers

Key Challenges

Technology

Limited bandwidth causes slow internet due to congestion from multiple users, worsened by remote areas and bad weather affecting satellite coverage. LEO based constellations may overcome this

Aircraft design, including metal composition, hampers in-flight WiFi coverage. Interference from onboard systems, devices and external sources worsens connection quality

Business

Poor speeds & bandwidth can cause dissatisfaction & frustration amongst passengers paying for in flight internet services

https://www.dgca.gov.in/digigov-portal/?page=jsp/dgca/InventoryList/dataReports/aviationDataStatistics/airTransport/domestic/yearly/26/Fleet/ALL%20SCHEDULED%20INDIAN%20AIRLINES/ALL%20SCHEDULED%20INDIAN%20AIRLINES%201.10.pdf&mainnull
https://www.dgca.gov.in/digigov-portal/?page=jsp/dgca/InventoryList/dataReports/aviationDataStatistics/handbookCivilAviation/HANDBOOK%202022-23.pdf&main4252/4205/sericename

Value Drivers

- In-flight connectivity can act as a strong differentiator in a highly competitive industry like Aviation. Prioritizing customer centricity has been a key focus area for airlines. In-flight Wi-Fi keeps passengers connected, allowing them to work, communicate, and stay entertained during flights, enhancing overall satisfaction.

Emerging Use-Cases

- Near real time tracking of aircraft systems by ground control
- Providing precise weather updates to the cockpit
- Access to the all modes of digital payments on flights
- Transmitting near real-time observations from aircrafts, UAVs and guiding them
- Medical consultations for passengers and crew in the event of an emergency

Focus Use-Cases

- In-Flight Connectivity & Entertainment: With a healthy growth rate in passengers & India's aircraft fleet, in-flight connectivity & entertainment has the potential to generate significant revenue

Satcom for in-flight connectivity has a market potential of **~USD 240 million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Education**

Leveraging satellites for delivery of education services has been an integral part of India's space programme. Apart from enabling education broadcasting through INSAT series, the launch of GSAT-3 (EDUSAT) in 2004 marked the launch of an extensive payload to provide two-way communication to classrooms focusing on rural areas. With India's focus on the digital delivery of education and the upcoming launch of LEO satellites, it is expected that satellite broadband for education will drive major value creation for the sector and provide access to high quality digital education

Key Characteristics of the sector and implications for SATCOM Market

Students and Teachers prefer dynamic, two-way communication channels for effective and engaging learning through digital channels.	Satellite broadband for education can enable two-way interactions which can make learning more live and engaging.
Providing internet to schools has been identified as one of the first requirements to ensure decent and pleasant service conditions at schools by New Education Policy, 2020	Through ICT @ SamagraSiksha, Government of India is providing recurring monthly expense support to schools for providing internet connectivity.
Regional Distribution : More than 80% of schools and 60% of colleges in India are located in rural areas.	India's largest segment of students are in rural areas where market focus has been limited.

Key Challenges

Technology

Largely enabled by GEO constellations which have high launch costs, Satellite Broadband for education use-case was limited high latency, low throughput, bandwidth and upgrade challenges.

The advent of LEO/MEO based constellations have the potential to mitigate these challenges.

Business

Owing to regulatory uncertainty, many global and domestic players refrained for active participation in the sector.

https://www.education.gov.in/sites/upload_files/mhrd/files/statistics-new/aishe_eng.pdf
https://dashboard.udiseplus.gov.in/#/reportDashboard/sReport

Value Drivers

- There's already precedent for introducing live interactive content, several states have dedicated programs for satcom in schools
- Satellite internet providers may focus on aspirational districts in hilly and underserved locations. Only 34% of schools in India currently have internet connectivity

Emerging Use-Cases

- Interactive virtual classrooms
- Accessing open-source learning content
- Tailoring content for the specific needs of each classroom
- Flexible learning, revisit course materials as needed

Focus Use-Cases

- Internet Connectivity for Schools : India has improved internet connectivity at schools from 6.20% in 2012-13 to 33.91% in 2021-22. Despite this sustained growth almost 9.84 lakh schools are yet to receive internet connectivity. Almost, 72% of unconnected schools belong to 15 states of which majority of them have terrain and geographical challenges in way of enabling sustained land-based connectivity. Additionally, more than 75% of Government schools across regions are yet to receive internet connectivity. Connecting these remaining schools in light of the advancements in technology and favourable policy climate, presents the most significant value creation potential in education through satellite communications.

Satcom for internet in schools has a market potential of **~USD 179 million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Health**

Satellite-based connectivity for health traces its origin to ISRO Telemedicine pilot project, in 2001. Enabled by GSAT and INSAT series, ISRO's telemedicine initiative (through V-SAT) has grown to establish connectivity between remote/rural hospitals with super-specialty hospitals, connectivity for continuing medical education (CME) for medical students, connectivity for telemedicine units, connectivity to hospitals during disasters etc. With a strong reliance on constant connectivity, patients can receive enhanced medical care through the use of wearable health devices, advanced medical imaging technologies, and state-of-the-art robotic surgery techniques.

Key Characteristics of the sector and implications for SATCOM Market

Beyond hospitals, connectivity for primary health centers, community health centers and sub-centers is critical for ensuring access to healthcare in the hinterlands	The rate at which satellite broadband is being offered will be unfeasible for most health centers in the country. Newer models that caters to these segments must be envisioned
Several initiatives viz., National Ambulance Services, National Health Mission mandating norms for deployment of MMUs etc., have emphasized the importance of emergency response services and last mile connectivity for healthcare delivery	India's fleet of mobile & medical units have shown steady growth. It is expected the fleet of mobile vehicles will now move towards augmenting quality delivery and increase in possible services that can be provided.

Key Challenges

Technology

Largely enabled by GEO constellations which have high launch costs, Satellite Broadband for health was limited by high latency, low throughput, bandwidth and upgrade challenges.

The advent of LEO/MEO based constellations have the potential to mitigate these challenges.

Business

Owing to regulatory uncertainty, many global and domestic players refrained from active participation in the sector.

Several policy reforms viz., TRAI's initiative on spectrum auctioning, Indian Space Policy, 2023 have the potential to provide regulatory clarity.

https://nhm.gov.in/index4.php?lang=1&level=0&linkid=457&lid=686
https://main.mohfw.gov.in/sites/default/files/rhs20-21_1.pdf
https://vahan.parivahan.gov.in/vahan4dashboard/vahan/view/reportview.xhtml

Value Drivers

- The Ayushman Bharat Digital Mission under the National Health Authority already has the mandate of equipping the health providers with a host of digital systems
- All such services will require reliable internet connectivity. Current public VSAT internet providers offer speeds only up to 2Mbps

Emerging Use-Cases

- Remote consultations & monitoring of patients
- Remote surgery
- Real time tracking of medicine & vaccine storage and distribution
- Health chatbots for reminders to take medication and health tips in local languages

Focus Use-Cases

- Internet Connectivity for Hospitals: Apart from enabling connectivity at PHCs in rural/remote regions, linking sub-centres, community health centers can have a transformative effect in providing healthcare services.
- Internet Connectivity for Mobile Medical Units and Ambulances: 30-40% of Mobile Medical Units and Ambulances are deployed in focus states of National Health Mission and most of the regions have terrain and geographical challenges. Providing sustained internet connectivity to medical vehicles in such remote/rural regions can augment quality of critical healthcare services.

Satcom for internet in hospitals, mobile medical units & ambulances has a market potential of **~USD 306 million over the next 5 years.**

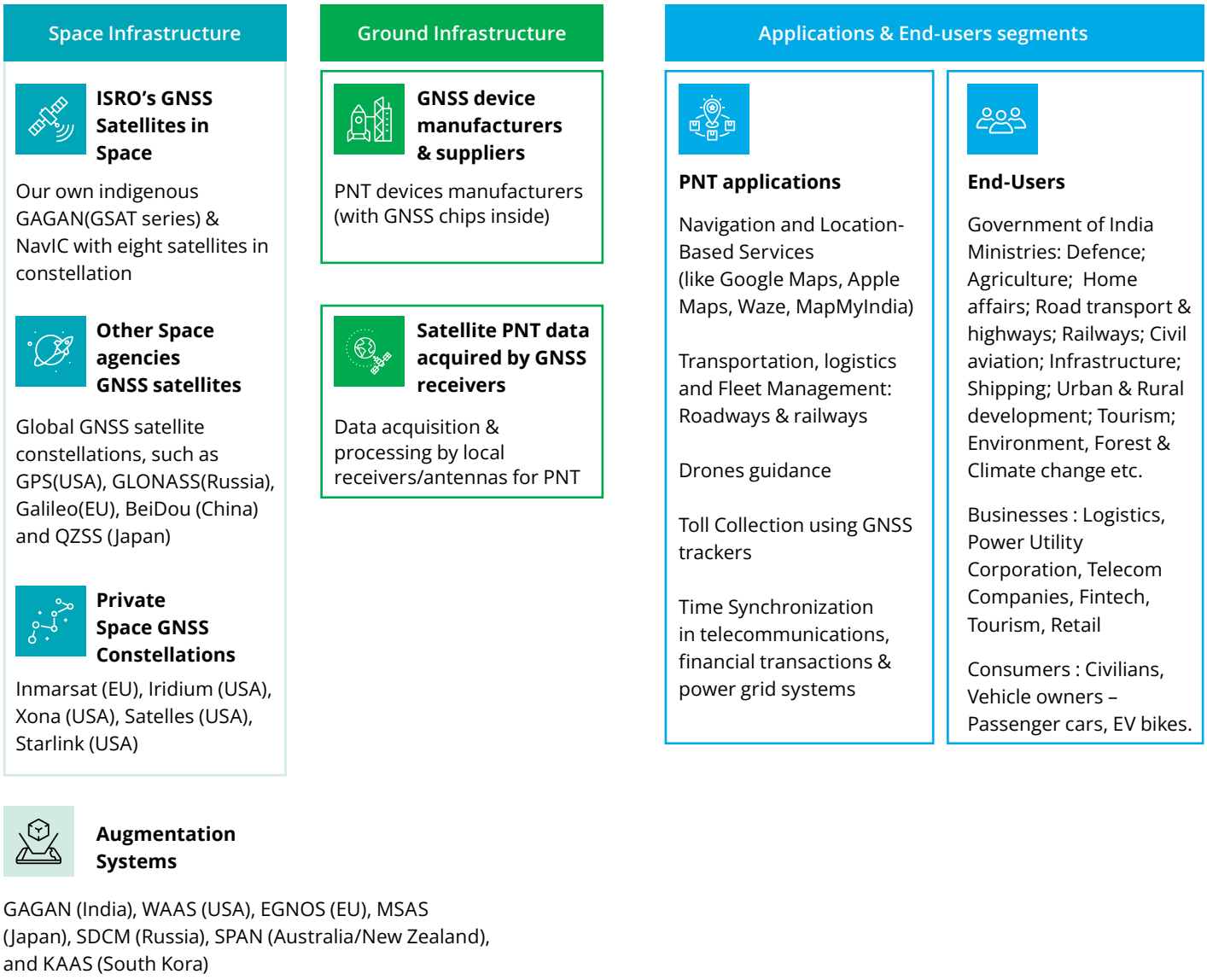
Note: Emerging Use Cases have not been sized

Positioning, navigation & timing services

Positioning, navigation & timing services

As the most omnipresent "space" service, PNT services influence every facet of our lives, permeating realms ranging from transportation and communication to sustenance and exploration. PNT services, whose origins can be traced to the GPS, have been a game-changer for the geospatial world and are now regarded as a strategically important asset for global commerce, resulting in the proliferation of Global Navigation Satellite System (GNSS) constellations. This proliferation points to the demand (impacted by commercial and strategic reasons) for persistent PNT services, without reliance on any one single entity.

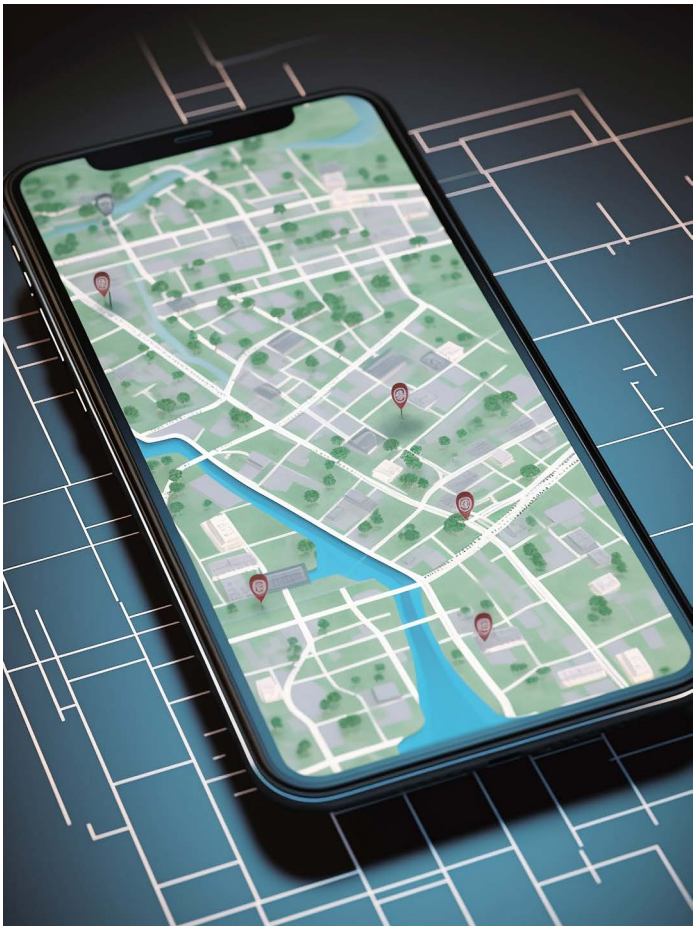
Figure 39: Landscape of the GNSS infrastructure in space and PNT value chain



PNT value chain			
PNT devices Manufacturers / Suppliers	PNT data Augmentation, Analytics & Integration	PNT Solutions	
		Industry specific solutions (B2B)	Consumer centric applications (B2C)
Manufacturers embed PNT technology into devices, vehicles, and equipment to enable accurate positioning and timing capabilities.	PNT signals are collected from satellites and augmented with correction data to enhance accuracy and reliability through differential corrections and filtering techniques	Software solutions integrate PNT technology into various sectors, including transportation, agriculture, logistics, mining, and for optimizing operations and enhancing services	PNT enabled applications provide end-users with accurate location and timing information tailored to their needs viz., tracking\, navigation etc.,
Types of current business models			
Direct sales of PNT devices, OEM partnerships	Subscription Services, Pay-as-you-Go, PNT analytics & insights as a solutions, Custom-tailored solutions	Subscription Services, Enterprise Licensing	App Monetization, Licensing APIs

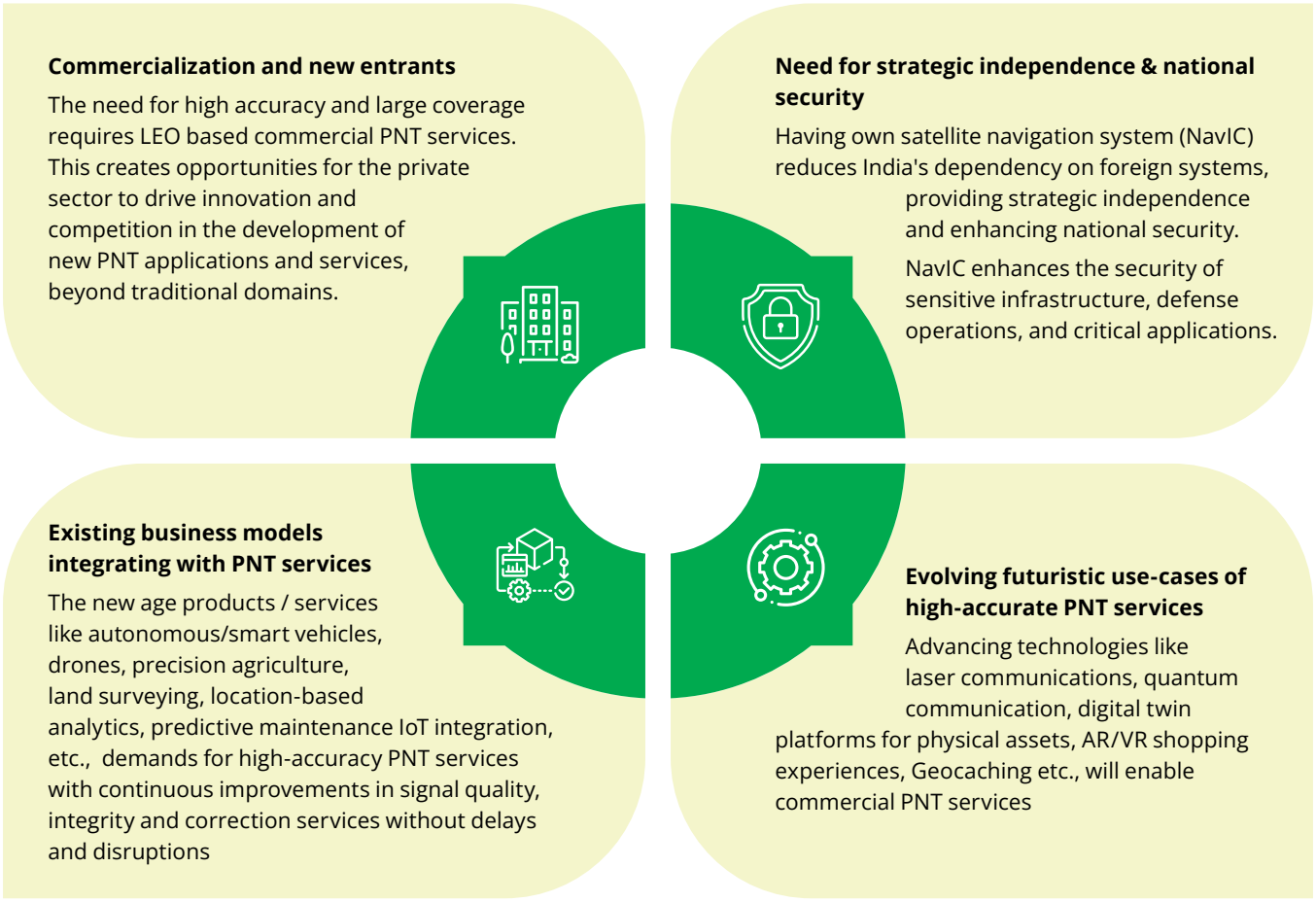
Similar to other segments of the downstream space industry, the adoption of PNT services is determined by how their data can be utilised to meet the needs of all other industries. For instance the success and adoption of GPS. can be attributed to its ability to abstract away the extremely complex technical aspects underlying its services and enabling and enabling user centric applications viz., mapping, delivery and ride sharing, logistics etc., that consumers use on a daily basis have relied on ultra-precise satellite data to support daily activities.

The potential size of the PNT service market will be significantly influenced by the compatibility of upcoming services within a mature ecosystem and their user-friendliness.



Trends

Figure 40: Overview of Trends, PNT



Value creation

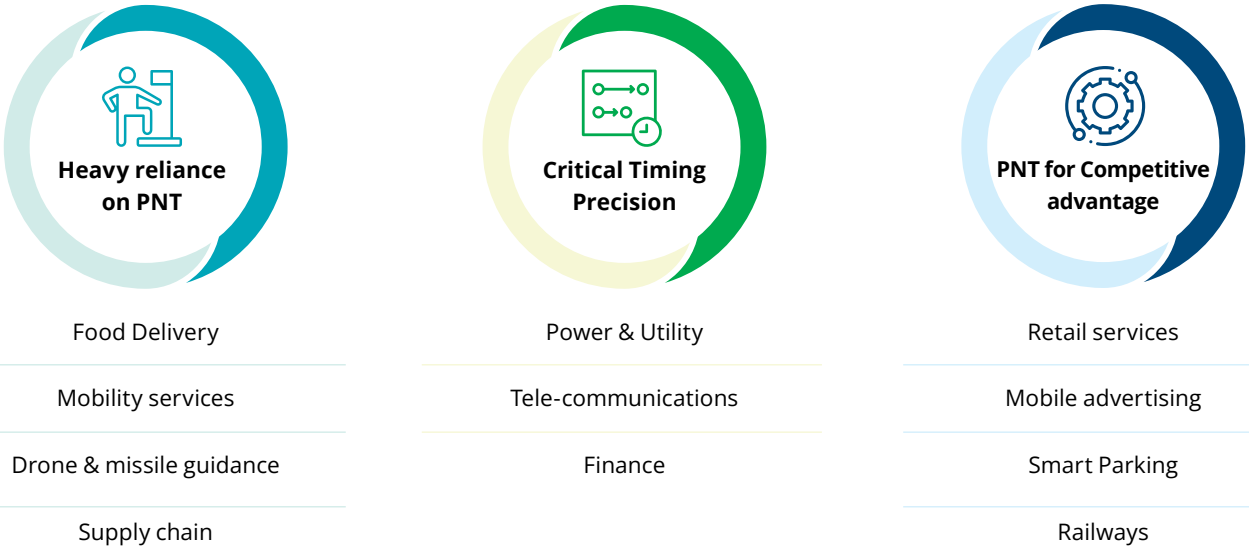
Despite the widespread availability of GNSS services, there are several challenges that are specific to India, including the following:

- The lack of an accuracy better than 20 m in the Indian region[16] deters the development and usage of applications that require precise positioning, e.g. drone guidance, logistics, transport toll collection, etc.
- Lack of reliability due to interruptions in GPS signals[17] in equatorial regions.

NavIC, India's own regional navigation service, seeks to bridge these gaps in the GNSS ecosystem catering to India. Companies in the downstream that leverage NavIC and other services to provide more accurate and relevant data to other industries will realise significant value in the coming years. This demand pipeline is also supported by the government's intention to have all major smartphones augment NavIC capability[18], and all major airlines in India use GAGAN for their navigation[19]. The demand pipeline, which is also supported by GoI's intention to have all major smartphones to have NavIC capabilities and all regional airlines use GAGAN for their services, also has the potential to boost the chip-manufacturing ecosystem in India.[20]

In addition to mitigating the challenges and complementing GPS capabilities, NavIC offers a short messaging service for users in the Indian region through IRNSS-1A and 1E satellites. A web-based interface for Internet message submission has been developed[21]. This messaging service, which will function independently of ground-based telecom connectivity, is already in use by the Indian National Centre for Ocean Information Services to broadcast Potential Fishing Zone messages, Cyclone & High wave alerts, etc. to fishermen across the country.

Figure 41: Evolving ecosystem and emerging use-cases of PNT
Credit: Geospatial World[22]



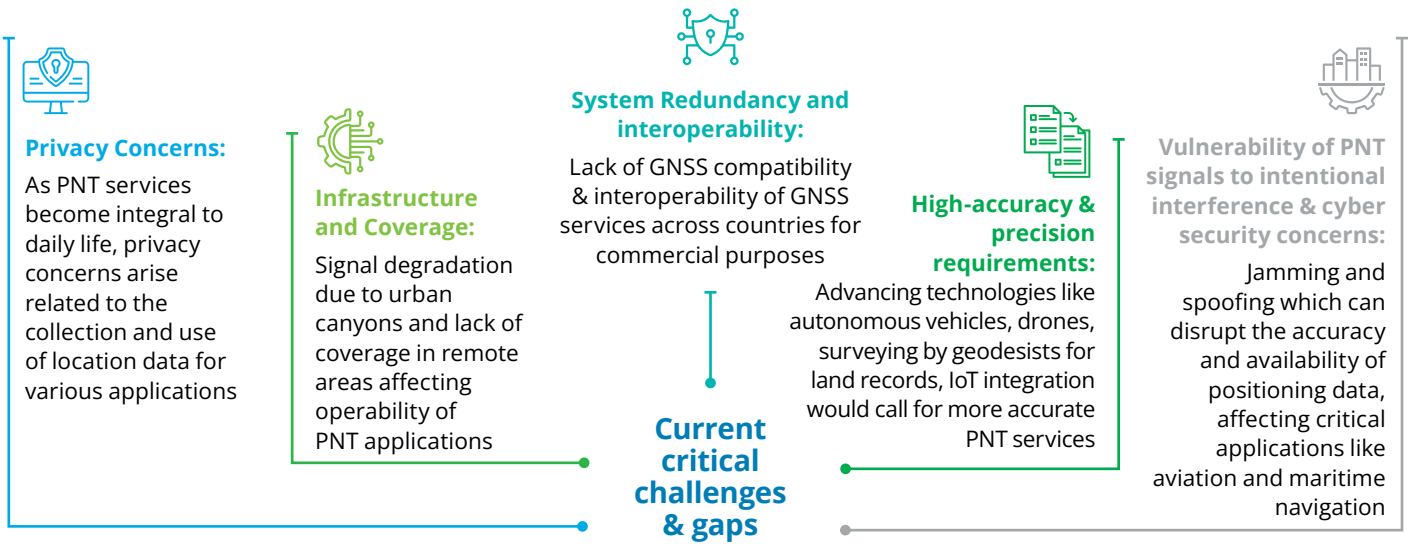
Policy landscape

To further the development and usage of domestic products and services, the Government of India has unveiled critical policy reforms and undertaken several initiatives:

01. The new Indian Space Policy of 2023 defines that free-to-air civil navigation signals shall be broadcast to all users within the service region free of cost by the satellite navigation systems.
02. Section 8(6 & 7) of the policy creates a mandate on the DoS to ensure sustenance, promotion and standardisation of existing and future satellite constellations, satellite control centres and ground segments for continuous and guaranteed availability of free-to-air and secured navigation signals as well as space-based augmentation signals.
03. The Geospatial Policy, 2022[23] places the responsibility of PNT infrastructure to DOS on matters of IRNSS and Survey of India (DoST) on matters of Continuously Operating Reference Stations (CORS).

Challenges

Figure 42: Key Challenges, PNT

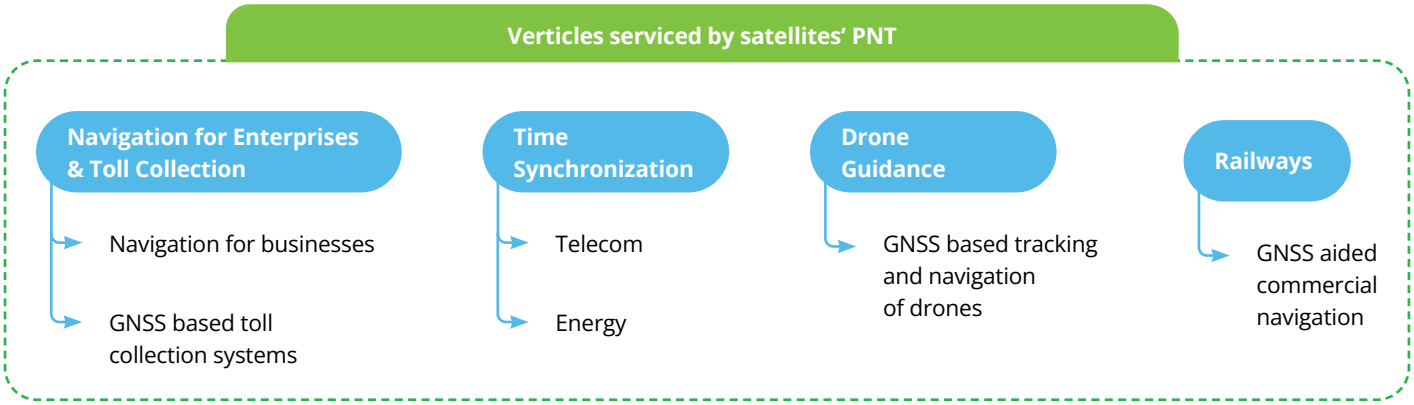


Focus sectors and value-generating use-cases:

The major value creation areas are expected to be

- Commercial navigation services will form one of the largest slices of this pie.
- Emerging use-cases such as drone guidance and mechanisms for toll collection using GNSS services, time synchronisation for power and telecom are also expected to create significant value.

This evaluation considers some of the commercially viable use-cases that already have technological solutions available in the market to a large degree. However, more use-cases can have a significant impact in this sector, some of them include PNT for shipping lanes, maritime search and rescue operations, verifying financial transactions, airport operations, supply chain management, etc.



Takeaways for 'PNT'

- **India PNT program - NavIC:** PNT services, originating from GPS and now including regional systems like India's NavIC, are considered strategically critical assets with applications spanning transportation, communication, defense, and more. They play a pivotal role in various industries and are essential for global commerce.
- **Trends in PNT:** Key trends include the commercialization of PNT services with private companies entering the sector, the need for strategic independence and national security through regional navigation systems, integration of PNT services into new-age products like autonomous vehicles and drones and evolving futuristic use-cases driven by advancing technologies.
- **NAvIC services in India:** India's regional navigation system, NavIC, addresses specific challenges in the Indian region, such as accuracy and reliability. Companies leveraging NavIC and other PNT services for accurate data provision stand to gain significant value, especially with government support for smartphone and aviation adoption.
- **Policies Landscape:** The Indian government has introduced critical policies to promote PNT infrastructure, ensure the availability of navigation signals, and standardize satellite constellations. These policies are aimed at fostering the development and usage of domestic products and services.
- **Current challenges of PNT:** Challenges include vulnerability to interference, infrastructure and coverage gaps, system redundancy, high-accuracy requirements, and privacy concerns. The market for satellite-based PNT services in India is expected to reach USD 2.15 billion, with value creation in commercial navigation, emerging use-cases like drone guidance and toll collection, and potential applications in shipping, financial transactions, airport operations, and supply chain management.

Focus sector: **Navigation for Enterprises & Toll Collection**

Map platforms have changed the way we commute, as individuals we take navigation for granted (just as weather information, that it will always remain free to access on a smartphone). For an enterprise to use it at scale and customize it for their needs however, it remains an expensive affair. Novel methods of tracking vehicles on highways can also enable toll collection mechanisms with minimal infrastructure.

Key Characteristics of sector and its implications for PNT market

Most vehicles (including 2-wheelers) are opting for maps to be integrated onto their in-vehicle infotainment systems	Adoption at scale in India may lower market rates for enterprise grade map platforms
The B2B space is still largely competitive in India, driven mainly by pricing and other considerations	Open-source solutions or digital public goods for mapping can enable businesses to innovate
The government is already mooting GPS based toll collection systems to replace existing toll plazas[1]	There is significant demand for new mechanisms that enable tracking vehicles for tolls with a privacy first approach

Key Challenges

Technology

Enterprise grade applications will need to support features like route optimization, geofencing, and asset tracking[2].

With the exponential rise of digital commerce in India, map platforms will need to cost-effectively handle large number of requests, suitable for businesses with high traffic.

Business

GPS based tolling would require specialized devices that enables distance-based fees rather than fixed slabs. But to be effective, it'd need to overcome privacy concerns & enforcement mechanisms, all while implementing as quick as FASTag did

[1] https://www.ndtv.com/india-news/gps-based-toll-system-in-6-months-to-replace-all-toll-plazas-nitin-gadkari-3892054
[2] https://mapsplatform.google.com/

Value Drivers

- Catering to the specific requirements of Indian logistics businesses
- Adoption of NavIC services for better accuracy in and around the Indian region

Emerging Use-Cases

- Intelligent traffic management systems
- 3D Navigation Services
- Building products on top of open-source geospatial applications
- Taking NavIC services beyond India
- Driving related data for predictive maintenance and targeted advertising

Focus Use-Cases

- Navigation & Tracking for Logistics Movement: The rise in the adoption of navigation systems to monitor and optimize material movement when coupled with technological advancements (high speed connectivity) creates considerable growth avenues.
- GNSS based toll collection systems: Replacing conventional toll plazas can ensure seamless movements of vehicles, reducing congestion and wait times. As the trend of urbanization increases, services such as electronic road pricing (already in use in other global south countries) may be increasingly adopted, with the help of PNT technologies.

PNT for Navigation & Tracking for Medium and Large Logistics Operators as well as GNSS based toll collection has a market potential of **~USD 1.2 billion over the next 5 years**

Note: Emerging Use Cases have not been sized

Focus Sector: **Time Synchronization**

A variety of strategic tasks require precise Timing & Sync, which is essential. This is true particularly for Critical Infrastructure (CI), a system or asset necessary for preserving such fundamental society functions as human health, safety, and economic and social well-being. This Timing & Sync function in CI is frequently provided using GNSS, through direct access to Coordinated Universal Time (UTC).

Key Characteristics of sector and its implications for PNT market

Close to 1 lakh base stations (or cell towers) are being added in India year-on year. Driving demand for sync of timeslots and handovers between other stations.	Telecom and satcom applications require timing accuracy in the order of microseconds, and nanoseconds
On an average, approximately 300 power substations are being added each year	Upgradation of energy networks will increase GNSS penetration in the sector
Financial services use transfer protocols such as Network Time Protocol (NTP) and Precision Time Protocol (PTP) for keeping time in computer networks.	GNSS Finance Timing & Sync is already a mature market. PTP might go on to be the global standard for keeping time in computer networks

Key Challenges

Technology

Little to no private sector involvement in realizing the NavIC constellation. This creates a dependence on ISRO for guidance and validation of the hardware that enables time sync

SAC/ISRO has developed NTP servers that operate on NavIC. Availability of PTP services however is unclear

Business

SAC's low-cost receiver doesn't have the tri-band capabilities (2 NavIC + 1 GPS) which offer highest precision. Adoption of such tri-band devices at scale will be required prevent monopoly of GPS.

[1] https://www.euspa.europa.eu/sites/default/files/GNSS_timing.pdf
[2] https://www.unoosa.org/documents/pdf/icg/2019/icg14/19.pdf

Value Drivers

- Being able to deliver the precision of atomic clocks at scale
- With more and more devices and applications taking on autonomous functions, time-keeping and sync will be critical for them to cooperate with each other

Emerging Use-Cases

- Verifying financial transactions
- Vehicle to Everything (V2X) communication
- Smart city infrastructure
- Augmented and Virtual Reality
- Wireless timing for industrial applications

Focus Use-Cases

- Telecom: SATCOM, Professional Mobile Radio & Digital cellular networks all rely on GNSS timing functions. With every base station required to confirm the network synchronization quality, each of them will have to be equipped with devices to handle the timing data. This sector will draw the majority demand for GNSS timing & sync devices.
- Energy: As per ISRO that all power stations are already using phase measurement units (PMU) which are synchronized using GPS. NavIC timing receivers are slowly being installed across grid sites. They will be used for time stamping of power grid phaser measurements for grid control, measurement and monitoring applications.

PNT for Telecom and energy has a market potential of **~USD 147 million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Drone Guidance**

Drones equipped with GNSS capabilities are more suitable for applications that require enhanced navigation and positioning capabilities While many basic drones may not need GNSS, the growth of the drone industry will be contingent on servicing more demanding applications. Some examples that require GNSS enabled drones include surveying and mapping, autonomous flight, delivery services, environment monitoring & strategic surveillance

Key Characteristics of sector and its implications for PNT market

Drones that are designed for indoor use or short-range flights can operate with their own sensors	Only a section of drones being manufactured will require GNSS services
While GPS receivers are considered power hungry for smartphones, drones physical flight requires several times more power[1]	Drone guidance can significantly be impacted by advances in GNSS technologies
Conventional radio altimeters and barometers are considered more accurate than GPS for altitude determination	GPS data will have to be fused with other sensors to provide reliable 3D navigation information

Key Challenges

Technology

Measures to overcome GPS spoofing needs to be overcome to increase the reliability of drones for sensitive applications

The GNSS based systems would have to be inter operable with emerging technologies such as visual positioning systems, optical flow and simultaneous localization & mapping[2]

Business

Complying with regulations that constantly update regions where drone operations are permissible will greatly benefit from augmentation of tracking and location services

[1]https://synrg.csl.illinois.edu/papers/drone-attitude-camera.pdf
[2]https://www.geospatialworld.net/prime/realigning-pnt-capabilities-with-future-needs/

Value Drivers

- Navigational units that can leverage the best GNSS signals for their region, while drawing minimal power, can overcome limitations of drones operating beyond line of sight

Emerging Use-Cases

- 3D Navigation Services for UAV and drone taxis/ ambulances
- Fusion of GNSS signals with information obtained from other sensors on the drone
- Autonomous navigation of swarms
- Overcoming GNSS spoofing

Focus Use-Cases

- GNSS based tracking and navigation of drones: India's thrust towards indigenization of UAV manufacturing has significantly multiplied the rate at which drones are being manufactured within the country. In the alternative of GNSS based systems, complex drone operations will require multiple operators depending on sophisticated sensors to guide the drones. While not comprehensive by itself, satellite-based data when augmented with the guidance systems can guide drones operations over long ranges.

PNT for GNSS based drone tracking and navigations has a market potential of **~USD 708 million over the next 5 years.**

Note: Emerging Use Cases have not been sized

Focus Sector: **Railways**

Railways transporting cargo and passengers to various locations covering most of the remote areas needs more attention for safety and serve passengers better by acquisition of train movement, emergency messaging to avoid accidents and avoid areas with possibility of natural disasters, providing updates on train movements accurately and tracking important assets in cargo and train. Today, GNSS is able to achieve this through a Real-time train Information system (RTIS).

Key Characteristics of sector and its implications for PNT market

Indian railways currently have 13215 stations increasing at an average rate of 3.334% every year	Railways is a huge market for PNT & Satcom due to its presence and volume of passengers that travel in trains considering it to be affordable compared to other land transport.
2700 locomotives have been installed with RTIS modules in phase 1, 6000 locomotives are to be fitted with these modules phase 2 by Indian Railways	There is a lot of scope of improvement for Railways to function efficiently for it to do so, PNT is the best alternative available terrestrial network connectivity is intermittent due to the moving nature of trains

Key Challenges

Technology
Wide scale adoption & deployment of the RTIS technology has a dependency on CRIS & ISRO

Business

Market is not liberalized for private players to enter the market. Making RTIS system data available for private players will help in building useful applications for passengers.

RTIS module installation has been done at a very small scale, there are still many locomotives without the system

Source
https://indianrailways.gov.in/railwayboard/uploads/directorate/cis/downloads/circulars/2019/RTIS%20Revised%20Estimate_190919.PDF

Value Drivers

- Real time navigation & monitoring of railways is going unlock significant value owing to the Indian Railways collaborating with ISRO to install RTIS (real time information system) modules in locomotives. The device utilizes GAGAN (GPS Aided Geo-Augmented Navigation System) to capture the train's position in real time

Emerging Use-Cases

- Integrated Control Centers with near-real time updates
- Monitoring train health for predictive maintenance
- Uninterrupted communication even through tunnels
- IoT based collision avoidance systems
- Seamless integration of train schedules with buses, flights etc.
- Retail and leisure offerings in trains

Focus Use-Cases

- GNSS Aided Commercial Navigation: It is highly critical to get real-time information on train movements enabling emergency services to avoid disasters and keep passengers informed of the movements to enhance their boarding experience and help them board on time. Real-time train information systems are deployed at a small scale by the government.

PNT for railways through GNSS aided navigation has a market potential of **~USD 45.5 Million over the next 5 years.**

Note: Emerging Use Cases have not been sized

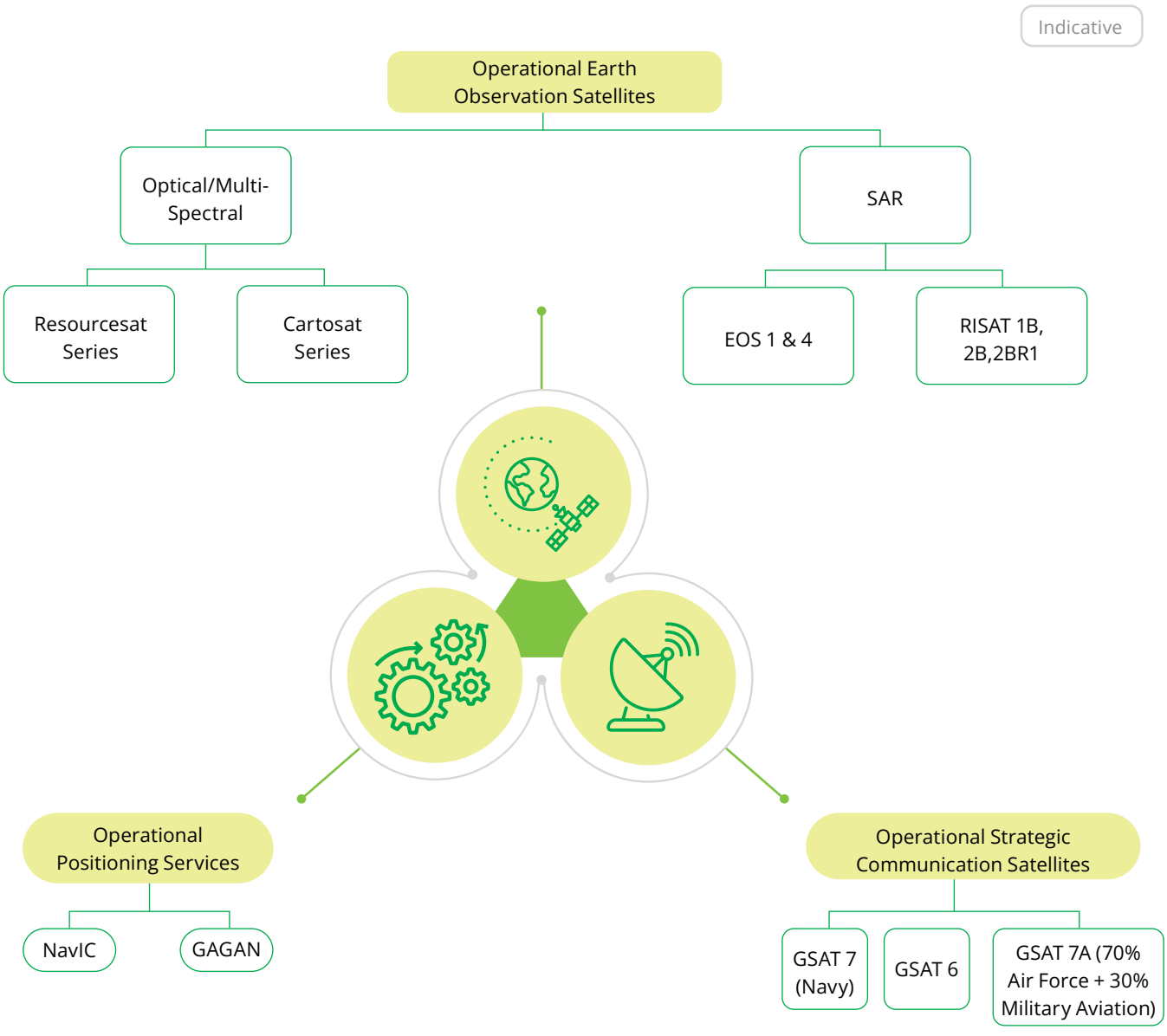
Defence space

Catering to strategic requirements

An aspect of the space sector that has been a constant since the dawn of the space age in the twentieth century has been the dual-use nature of space technologies, in which space capabilities complement the capabilities of countries to operate and monitor from land, sea and air.

While remote sensing satellites are important for monitoring urban development and the environment, they are also important for military surveillance. GNSS applications are central to both military navigation and coordination and to civilian services as well. Without secure SATCOM, security operations in India's diverse geography would be severely hampered.

Figure 43: overview of indian space assets currently catering to india's security needs (Future and past missions not included)



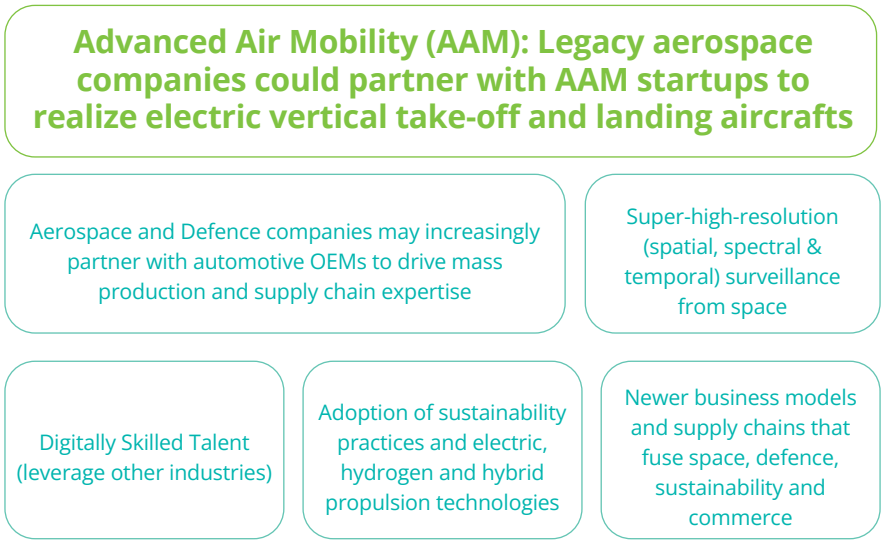
Source
https://timesofindia.indiatimes.com/india/after-navy-iaf-army-to-get-dedicated-satellite-gsat-7b-as-mod-inks-rs-3k-cr-deal-with-nsil/articleshow/99129740.cms?from=mdr

Trends

Indian start-ups have already received notable contracts from defence organisations in India and abroad to provide infrastructure and services to support Intelligence, Surveillance and Reconnaissance (ISR) activities[24].

Initiatives such as Innovations for Defense Excellence (iDEX) have provided a platform for start-ups, MSMEs, individual innovators and incubators to get initial funding and recognition from the Ministry of Defence[25]. Its approach of throwing open-ended problems for the industry to solve can be particularly useful for India's nascent space start-up ecosystem.

Figure 44: Trends in space for defense in India



Policy landscape

Given that outer space is not subject to national appropriation based on a claim of sovereignty and that space is regarded as the domain of all humanity, regulations governing defence space will always find a balance between national security concerns and international law. Additionally, the opening up of the sector to non-governmental entities adds a newer dimension of access to critical data to the private sector.

Some of the administrative and policy initiatives of the Government of India to find the balance with the utmost importance for India's strategic concerns:

- Following the demonstration of the Anti-Satellite (ASAT) capabilities and to further India's space security capabilities, Defence Space Agency (DSA) was established in 2019. Comprising members of all the armed forces, it is being supported by the Defence Space Research Agency on research matters.
- India is a party to all major international treaties/regulations related to outer space, including the Outer Space Treaty, the Rescue Agreement, the Liability Convention and the Registration Convention and has also signed the Moon Treaty. These treaties in effect ban the stationing of weapons of mass destruction in outer space, prohibit military activities on celestial bodies and detail legally binding rules governing the peaceful exploration and use of space.
- In the interest of national security, the new space policy of 2023 places restrictions on the dissemination of satellite imagery of India that has a Ground Sample Distance (GSD) better than 30 cm. IN-SPACe would need to authorise the same, while in other cases the policy states that only intimation would be required.

Challenges

However, there are critical challenges in the offerings of the space sector for defence, as identified in 2023[26]:

01. **Infrastructure:** With many of the imagers in space projected to meet their end of life soon, it is unclear how involved the nascent private space industry will be in realising the next version of imagers that will be used by the government. The consultation papers towards the same have been floated[27] and it is expected to create a pathway.
02. **Intellectual Property:** In previous efforts[28] of involving the private industry, Intellectual Property (IP) ownership proved to be more difficult than talent exchange. The true value for the commercial industry rests on the capacity to create and retain proprietary IP ownership. To indigenise the value chain for space situational awareness (SSA), signals intelligence (SIGINT), EO, etc., it is imperative to mitigate challenges around Intellectual Property Rights.
03. **Materials:** Recent trends of near-shoring of supply chains and in the case of India, a significant intent to indigenise the supply chains means that the space industry cannot simply copy-paste the processes conventional to the aerospace industry. This is particularly true for fuel cells[29], battery technologies[30], the solar industry[31] and even for rare earth metals[32]. Navigating around these constraints will be a defining hallmark for the space industry; while they are not explicit restrictions as of now, they will certainly hamper involvement with the defence and security establishments.

Table 4: Space for defence: ISR

Focus Area: **Intelligence, Surveillance and Reconnaissance**

The evolving global geopolitical dynamics that plays out in India's already volatile neighbourhood underscores the importance of securing India's ISR requirements through a multimodal and integrated approach where space-based assets and applications are used to deliver solutions with efficiency and efficiency. The privatisation of space sector in the face of ongoing impetus on defence modernisation opens several areas for improving capacity on space-based ISR.

Surveillance	Marine Domain Awareness	Asset Tracking	SIGINT
India's surveillance requirements hover over lakhs of sq. kms. across a varied terrain: LWE districts, areas within and beyond coastal and land borders[33]. Through several initiatives, viz., Comprehensive Integrated Border Management System[34] , Border Infrastructure and Management (BIM) scheme, Coastal Surveillance Network[35] , GoI is improving surveillance infrastructure, viz. fence, floodlighting, roads, border outposts, radar installation, etc. With the proliferation of hyperspectral imagery and high-resolution SAR imagery, some of the traditional challenges around reliability and frequency of satellite imagery will allow satellite-based surveillance to complement efforts to improve situational awareness along border areas and LWE districts. Beyond surveillance, EO data can provide valuable information such as the metrological conditions & trafficability of the terrain (determined by factors like snow cover), which require timely persistent observations.	Marine Domain Awareness has evolved to encompass national security in all its elements: territorial integrity, protection to cargo and shipping lines, ocean resources monitoring and exploration, environment and climate change, etc. The Indian Maritime Strategy (2015)[36] places MDA at the heart of the Information-Decision-Action[37] cycle, and several administrative, technological and multilateral cooperation initiatives have been undertaken to secure India's strategic autonomy in the Indian Ocean Region (IOR). Although the use of satellites (remotes sensing, secure communication and navigation) for MDA has been integral to India's MDA strategy, the upcoming ISRO-NASA (NISAR)[38] mission and the ISRO implementation agreement with CNES [39] France,for a constellation of satellites for MDA in IOR is expected to strengthen space capabilities for MDA. Additionally, RF based tracking capabilities can also open up solutions with commercial viability and potential that can cater to requirements of commercial shipping, fishing and ocean resource monitoring and exploration.	With applications beyond the strategic realm[40] , tracking objects such as aircrafts is critical for safe and efficient operations of aircrafts. The adoption of space-based tracking of aircrafts, enabled by Satellite Based Augmentation Systems and Automatic Dependent Surveillance-Broadcast (ADS-B), is increasing given the global coverage and reliability provided by such systems. As space becomes more democratic[41] , shielding access to military aircraft movements during training, testing and operations will also become more pronounced during peacetime. The recent announcement of the Indian Air Force[42] on its new satellite-based aircraft tracking system, which updates the location of a flying aircraft every 30 seconds, is a testimony to India's indigenous capabilities. As ISRO upgrades the NavIC constellation with second generation satellites[43], in conjunction with GAGAN, the public infrastructure required to enable downstream innovation will be in place.	Comprising of signal intercepting, communication between people (communications intelligence) and electronic signal intercepting (electronic intelligence), SIGINT is an integral part of India's intelligence infrastructure. Equipped to fuse and analyse multimodal data from air, surface (mobile + static), water and space, India has several operational intelligence platforms catering to varied needs: Programme Divya Drishti[44], Samyukta Electronic Warfare System[45] etc. With ISRO's EMISAT[46] spacecraft and private companies also planning to launch payload for RF tracking, India's space-based SIGINT capabilities have also been bolstered. As the maturity of space assets for SIGINT and ability to monitor improves, SIGINT capabilities for strategic purposes may also find commercial applications in areas of spectrum utilisation and monitoring for telecommunication, real-time location tracking for commercial shipping, maritime insurance, etc.

Table 5: Space for defence - strategic and secure communication

Focus Area: **Strategic Communication**

The recent Russia-Ukraine conflict has emphasised the need for a robust and secure strategic communication network strategy. As Network-centric warfare (NCW) has come of age, it is imperative to keep the tactical communication system capabilities sovereign and indigenous (if possible) for self-reliance while also maintaining flexibility for tactical interoperability. India with ISRO has ensured our sovereign capabilities through dedicated satellites for the Air Force and the Navy, and the army is set to join forces with a dedicated one for itself soon.

Strategic Communication	Connectivity of vehicles	Integrated command and control centre
Indian Navy: GSAT 7, also known as Rukmini, was India's first military satellite and is mainly used by the Indian Navy for communications between its fleet, or with terrestrial establishments within the IOR. It operates in the UHF, C-band and Ku-bands and has been operational since 2013. An upgrade to it, the GSAT-7R, has been sanctioned and is expected to be launched this year.[47] **Air force:** The next to join the constellation was the GSAT 7A also called the Angry Bird, catering specifically to the needs of the Indian Air Force. Launched in 2018, it operates on 10 channels within the Ku band. It also allows for the operation of Unmanned Aerial Vehicles (UAVs). The government recently approved the GSAT 7C for enhanced communications beyond the line of sight[48]. **Army:** Unlike the Airforce and Navy, the army has not had a dedicated communications satellite. However, in March 2023 the GSAT 7B procurement contract was made for INR 2,963 crore from NSIL. The new multiband satellite, expected to be handed over in 2026, will provide high throughput managing inter- and intra-service communications.[49] In the wake of the recent Russia-Ukraine war, India conducted a study of the war and as part of it did a complete operational test of all its SATCOM assets and personnel readiness, christened Operation Skylight[50]. The study on the Ukraine war has also led the army to engage with industry and academia to develop small-form factor hand-held satellite phones for easy use[51]. The focus is on design and development for portability of the terminals and sat phones, adapters for conversion of android devices, latency improvements to support mail/FTP and video services, among other enhancements to improve SATCOM between troops. Apart from government owned assets, private players are already working with all the three arms of the military on turnkey projects on satellite system integration.	Having defence personnel operating in some of the most difficult terrains such as the Himalayas and the hinterlands, satcom-on-the-move, vehicle tracking and equipment on board are of importance to India. As NCW becomes more prevalent, there is an increasing need for remote access and offensive capabilities. RUSTOM II or TAPAS is a prime example of SATCOM-enabled, pre-emptive-strike-capable UAVs. Even for UAVs without offensive capabilities, satellite links can improve their operational effectiveness by increasing their range via secure communication links. Despite the already existing satellite capabilities within the defence establishment, there is significant market value yet to be realised in the upkeep and security of these systems. The Ministry of Defence also recently launched a programme to increase indigenous development of satcom terminals for the Indian Navy. These will be housed in warships, submarines and naval planes[52]. Problems pertaining to product support for legacy systems and their sub-par data transmission rates have been cited as reasons for their upgrade.	India has had individual programmes across the three services like the AFNET and Integrated Air Command and Control System that facilitate real-time transport of images, data and voice, across satellites, aircraft and ground stations. With increasing adoption of information technology and even discussions of incorporating artificial intelligence into defence, a data deluge will occur, and it will be necessary to sort real-time information for decision-making and transmission to relevant parties on the frontline. The modern-day requirements of warfare would also mean interservice operability and secure data exchange at unprecedented speeds. The formation of DCA, DSA and the theatre commands validate this. Recently, the 8th defence India start-up challenge, in 2022, issued a design challenge for asset/convoy management platform that tracks satcom network footprint. This will be used by the Indian army to track troop and convoy movements.[53] Satellite services are imperative for providing seamless real-time communications support to the fighter and cargo fleets, ground radar stations, operational bases and Airborne Early Warning and Control System platforms. Military intelligence and operations require constant connection of the command centres with their edge devices. The adoption of the Internet of Military Things and Internet of Battlefield Things will heavily rely on SATCOM for persistent and reliable connectivity.

Table 6: Space for defence: guidance and navigation systems for strategic assets

Focus Area: **Guidance**

Space-based services, through GNSS and regional augmentation services, can be leveraged by aircrafts and projectiles to be guided to their intended targets.

Unmanned Aerial Vehicles	Missiles & Munitions
The use of unmanned aerial vehicles not only for assessments and monitoring but even for combat missions (precision strikes with minimal collateral damage, target decoys, etc.) is expected to increase, and indigenous capabilities and autonomy over all systems integral to the functioning of UAVs will be more pronounced than ever before. In line with the above, India's UAV capabilities have been significantly improved in the last decade, with DRDO Abyas, Ghatak, Archer and Rustom being some of the select examples. Additionally, due to concerted efforts by the Government of India, the UAV market has matured, with more than 100 Drones companies manufacturing over 200,000 components every year. The diversity of terrain in India's strategic realm and the mounting cyber warfare capabilities worldwide, necessitates secure communication and navigation system for UAVs. Although operationalised through ground-based systems, several critical use-cases leveraging UAVs including defence rely on heavy duty drones that require precision, reliability and security that cannot be guaranteed through exclusive ground-based approach. Specifically for drone guidance, the private sector has already developed solutions that utilise NavIC (along with other GNSS constellations) services[54]. Drones with 3D navigation capabilities can navigate complex terrains, thereby enhancing their surveillance capabilities. They can provide comprehensive reconnaissance data, thereby enhancing situational awareness and decision-making.	Strategic and guided missiles have always been integral to India's national security strategy and armoury. As a nuclear nation with Inter-Continental Ballistic Missiles (ICBM) capabilities, India is equipped with complete indigenous missile systems that can inflict massive and unacceptable damage. In addition to offensive capabilities, India has demonstrated antimissile systems capabilities to intercept and neutralise threats. The guidance systems for delivery, tracking and interception of payload are critical to the missile delivery and antimissile systems. While ground-based and satellite-based systems have been fundamental to missile navigation, guidance and tracking, there are a few critical areas where space-based systems are vital and innovation solutions in the area can augment national security. • **On the offence front:** Space-based services provide essential data for navigation, targeting and telemetry, which are vital for the successful operations of long-range missile systems as satellite-based systems provide greater accuracy. Additionally, it has become common practice during times of conflict to disable access to GNSS services so that long-range weapons cannot navigate properly[55]. Consequently, not only are satellite-based systems mission-critical, but access to the system during missions is also mission-critical, emphasising the importance of NavIC. • **On the counter-offensive front:** Early warning satellites can be used to track projectile kinetic weapons deployed. For instance, in addition to the space fence for SSA, the US Space Force has been seriously mooting satellites carrying Next-Generation Overhead Persistent Infrared Sensors in the GSO and another dedicated constellation for tracking missiles in the LEO[56].

Table 7: Space for defence: secure space operations

Focus Area: **Space Security**

With more than 8,000 satellites already in orbit[57], the rate at which it is increasing and the fact that ASAT capability exists with multiple actors, the protection of assets in space is vital for India's strategic and commercial objectives. The ability to apply SSA timely and reliably to operate satellites in a manner that prevents any mishaps, will be pivotal for the sector.

Space Situational Awareness

In the past, satellites collided with one another[58], with meteorites[59] and debris from launches[60]. Even far from Earth's orbits, the Chandrayaan-2 orbiter and the Lunar Reconnaissance Orbiter of NASA were expected to almost collide in 2021. It is now common knowledge that even after complying with all guidelines of the Inter-Agency Space Debris Coordination Committee, collision threats will continue to grow.

Given the enormous velocity at which objects in orbit travel, even the smallest of collisions can hinder or even completely compromise the functioning of satellites. In the lower earth orbits, where all commercial actors are eager to deploy assets in the interest of resolution and cost, this issue is exacerbated. ISRO predicts that there will be approximately 60,000 objects in LEO by 2021, all of which pose a threat to any assets in the region.

When you add to that the ASAT capabilities of several countries and the adverse impact space weather can have on electronic in space and power grids on earth, understanding the space environment is vital for maintaining the functionality and security of deployed assets in space and in earth.

ISRO in 2019 initiated the Network for Space Objects Tracking and Analysis (NETRA) project[61]. As of now, this network can spot, track and catalogue objects as small as 10 cm, up to a range of 3,400 km[62] and the equivalent orbit of around 2,000 km . Similar systems[63] by other agencies include such as the Space Fence operated by the Space Surveillance Network of the US Space Force[64].

Companies and research laboratories across the world are mooting newer technologies such as laser and neuromorphic sensors to more effectively track objects and provide timely data to satellite operators to make collision avoidance manoeuvre. In situ observations in space can provide a more comprehensive understanding of break-up events and potential impact scenarios. Some companies and space agencies are also developing novel technologies that will actively capture and deorbit debris from space.

Awareness of the activities of other space powers is an indicator of their strategic ambitions and is vital to national security considerations. With more ambitious programmes such as manned missions to space and deep-space exploration programmes being planned in India, SSA will be vital to ensure the sustainability of activities in space and national security.

Satellite Operations

Accurate functioning of spacecraft is contingent upon attitude stabilisation and control to ensure precise pointing of high-gain antenna to Earth for communications. Also, the heating and cooling effects of sunlight and shadow must be intelligently leveraged for thermal control and guidance[65]. This is critical in times of disasters and conflicts, when imaging satellites need to be manoeuvred away from their conventional orbits to collect data from the areas of interest.

As assets in space increase, operating satellites in efficient and safe manner becomes more complex. Currently, ISRO's Telemetry, Tracking and Command Network has established a network of ground stations in Bengaluru, Lucknow, Mauritius, Sriharikota, Port Blair, Thiruvananthapuram, Brunei, Biak (Indonesia) in addition to its deep-space Network Stations for satellite operations. With the advent of privatisation of the global space industry, several private sector players are also entering the realm of satellite telemetry, tracking and command (TTC) and other ground station operations.

There has been a drive to incorporate autonomous operations related to the security of satellites into their development. Satellites are equipped with onboard processing capabilities to perform tasks without ground control intervention.

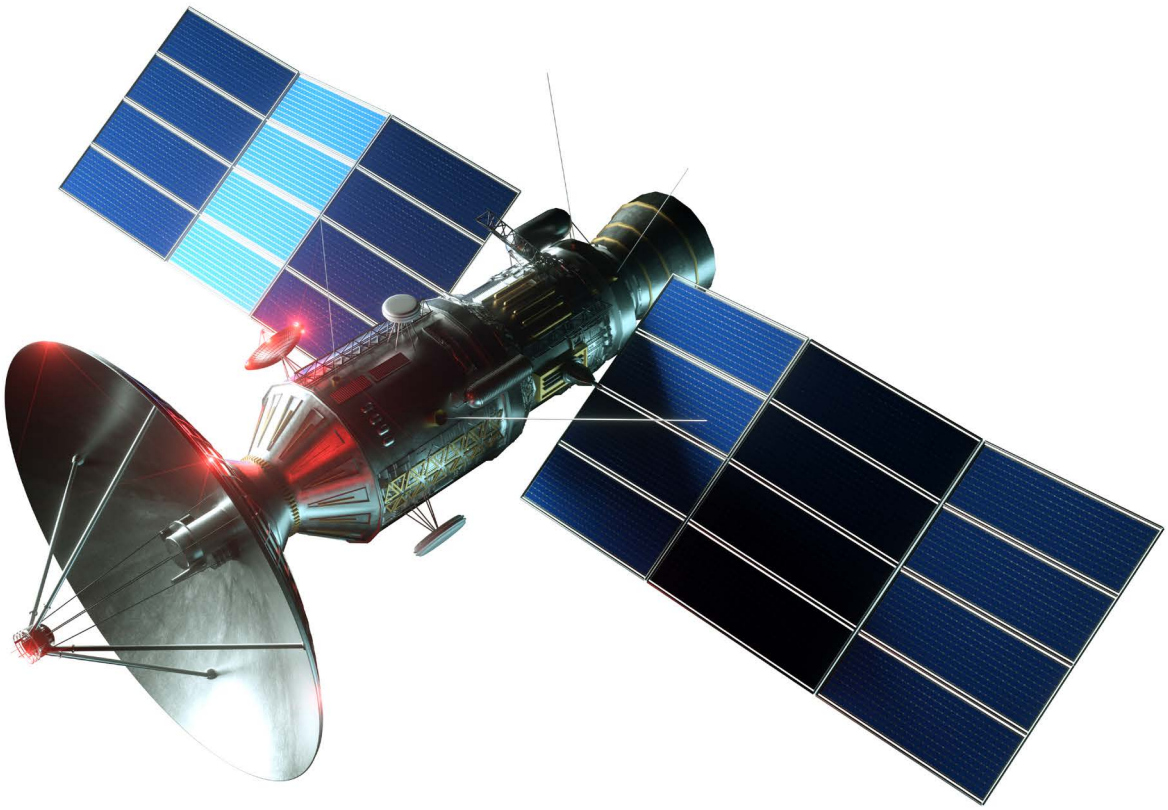
Some challenges that still concern satellite operations can be potentially resolved by involving the private space industry, namely:

1. **Security & Interference:** As with any communication system, TTC systems are potential cyberattack targets. These could range from attempts to disrupt communication links to more sophisticated attacks aimed at taking control of the satellite. By relying on RF signals to communicate with satellites, even unintentional interference from other satellites or ground-based sources could disrupt TTC operations.
2. **Scalability:** As satellite constellations grow larger, managing the TTC operations for all satellites becomes increasingly complex. This requires scalable systems that can handle the increased volume of data and the need to simultaneously command and control multiple satellites.
3. **Emerging Technologies:** The range and accuracy of tracking systems, the data rate of telemetry systems, the power & bandwidth of the control links are currently immutable constraints on the operations of satellites. Adoption of newer technologies such as free-space optical communication, AI-based predictive maintenance and cloud-based ground stations are expected to help bridge this gap.

v

Takeaways for 'Catering to strategic requirements'

- **Dual-use nature of Space:** Space technologies have a dual-use nature, serving both civilian and defense purposes. Remote sensing satellites, GNSS applications, and secure satellite communications are crucial for defense surveillance and national security, as well as civilian services like environmental monitoring and navigation.
- **Initiatives for supporting Indian space startups:** Indian startups have been receiving contracts from defense organizations, both in India and abroad, to provide infrastructure and services for Intelligence, Surveillance, and Reconnaissance (ISR) activities. Initiatives like Innovations for Defence Excellence (iDEX) have played a significant role in supporting startups in this sector.
- **Policies landscape:** India's space policies and initiatives strike a balance between national security considerations and international law governing outer space. India is complied with major international treaties related to space, prohibiting weapons of mass destruction in space and regulating peaceful space exploration. The 2023 space policy places restrictions on the dissemination of satellite imagery of India with a Ground Sampling Distance (GSD) better than 30cm in the interest of national security. Authorization from IN-SPACe is required for such imagery.
- **Current Challenges:** Challenges in the space sector for defense include concerns about infrastructure for the next generation of imaging satellites, issues related to intellectual property rights, and the need to navigate constraints in materials supply chains, including fuel cells, battery technologies, solar industry, and rare earth metals.



The emerging Indian private space ecosystem:

opportunities, challenges, and way ahead

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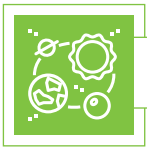

Introduction

The Indian space ecosystem is experiencing a transformative phase, driven by historic space reforms initiated by Prime Minister Narendra Modi. These reforms have ushered in a new era of space technology development, marked by remarkable achievements, such as the Chandrayaan-3 mission and successful launches by Indian start-ups. Investors now have greater confidence in the capabilities of young space entrepreneurs to create innovative space solutions. This article explores opportunities, challenges, and the path forward for India's private space sector.

India: A global opportunity destination

With its status as the world's most populous democracy, India offers a promising market and a testing ground for space technology due to its diverse landscape, languages, cultures, and socio-economic conditions. The country's youthful and digitally connected population presents significant opportunities for technology sandboxing and business innovation.

To effectively use this opportunity in space, technologists, investors, and the government must collaborate to integrate space technology with other ecosystems. This integration can unlock unprecedented business opportunities, improve sustainability, and enhance the quality of life for the common man.

India's commitment to inclusive development positions it as a pivotal player in serving the Global South while collaborating with the developed West. This inclusive approach, along with government support and project financing, creates an opportunity-rich environment for the emerging private space industry. Areas of intervention could include Sustainable Development Goals (SDGs) and Conference of Parties (COP) commitments.

Assessing industry and market potential

The availability of affordable miniaturised components and electronics has led to rapid growth in the space ecosystem. To ensure the space sector's sustainability, government support is needed for easy and affordable access to testing, validation facilities, and data buy-back programmes, especially in dual-use sectors. These sectors include remote sensing/Earth observation, Position, Navigation, and Timing (PNT), and satellite communications. Further, industry capability should be seen from the perspective of delivering space solutions that integrate various sectors and technologies. India possesses significant expertise in IT services, offering comprehensive capabilities that can outshine other space powers.

Rising global risks: The space industry's role in building resilient economies

Global instability and geopolitical conflicts disrupt supply chains, leading to economic hardships and increased resource costs. Space technology, particularly data-driven insights, can help create resilient and predictive economies by detecting, monitoring, and managing human activity, natural resources, and climate change on a global scale. Space data-driven decision support systems, powered by artificial intelligence, can enable proactive responses to various challenges, benefiting governments and industries alike.

Indian start-ups are building multi-sensor satellite constellations covering the electromagnetic spectrum. These constellations can enhance India's digital and data-driven economy by providing timely and accurate data for a wide range of applications.

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Space spectrum: Lifeline and oil for space-driven growth

The adequacy of the space spectrum, especially the 28 GHz band as allocated by the International Telecommunication Union (ITU) for space communications, is one of the most significant foundational enablers, to drive the nascent space industry of India. Given the unique monsoon-based climatic conditions, this spectrum band is best suited to support space-based communications, especially high-speed broadband (compared with higher frequency bands that face higher attenuation under monsoon conditions in the Indian subcontinent). The adequacy of this entire band is critical to meet the rising requirements of both strategic and civil domains. Given the large amount of direct and indirect benefits, the satellite industry in India eagerly awaits early policy directions for the retention of 28 GHz band for space communications, in harmony with ITU decisions. Furthermore, the space communication industry in India looks forward to the allocation of the space spectrum by administrative means to enable them to put maximum resources towards the creation of infrastructure across the breadth of the country for space communication utilisation.

It is opined that these two critical decisions would energise a strong market-friendly sentiment that would complement the rising positivity arising out of India's recent successes in space – announcement of Indian Space Policy 2023; Chandrayan-3; and deployment and performance of satellites made by Indian start-ups. Further, the announcement of a liberal FDI policy in the near future would be a huge enabler to add pace to the growth of the space industry in India. A combination of these could help catalyse the design, development, and manufacturing of ground equipment in India. This is a critical necessity for ensuring our "strategic sovereignty" and reducing the risk of supply chain attacks. If seen from a 25-year timeframe, the jump is expected when India starts indigenous designing and manufacturing of chips.

The analysis of the global space economy reveals that ground equipment manufacturing contributed 38.34 percent[1] to the total space economy of US$ 386 billion. This is significantly higher than the combined contribution of launch vehicles and the satellite manufacturing industry. The adequacy of spectrum and adherence to ITU standards (necessary for economies of scale), could help favourably kick-start space-related ground equipment manufacturing in India to make for the country and the world. Any deviations from ITU standards can weaken India's aspirations to be a manufacturing hub and ensure our dependence on foreign sources for the design and development of critical space-integrated communication equipment, infrastructure, and strategic electronics. Further, we would end up paying additional charges to foreign OEMs to design and supply equipment to suit Indian standards, should India not follow global standards. At this stage, India's strength in terms of vast geography and demography would be nullified if we do not seize the opportunity to focus on equipment manufacturing.

When seen from the strategic dimension, Indian aspirations to have an Aatmanirbhar Cyber Resilient Space Force, along with secure net-centric capability, to enable forces to seamlessly operate in any part of the globe would require adequate spectrum availability and indigenous ground equipment with Indian characteristics. Furthermore, for war-fighting in the present and future, armed forces would need secure high-bandwidth solutions that allow them to operate with full capabilities, in terrains including remote areas wherein space communications would be the only source of connectivity.

Similarly, when seen from a civilian perspective over a 25-year period, we must have adequacy of space spectrum to support the largest population. These multi-sectoral demands could include, inter alia, healthcare and telemedicine; e-governance; citizen-centric services; agriculture; resource mapping and extraction; weather; environment management; transportation; banking, finance and insurance; tele-education; disaster planning and relief; law enforcement; infrastructure development, monitoring and management, resource mapping and cartography; risk analysis as well as predictions for proactive decision making, and response to name a few critical ones. Given the huge scope, the government may consider developing space communications as infrastructure in mission mode, providing adequate incentives that could include administrative allocation of spectrum to allow private-sector resources to be devoted for developing such infrastructure. Spin-offs of such measures could include a large-scale increase of commercial activity, especially in under-served and un-served areas. This would yield tax benefits to the government in the long run.

[1]https://www.kratosdefense.com/constellations/articles/industry-report-highlights-what-happens-when-you-triple-on-orbit-capacity

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DefSpace challenges: Kick-starting space tech innovation and beyond

The monumental decision of the Ministry of Defence (MoD), Government of India, to go ahead with India's first and largest defence space innovation initiative for the private space industry at the behest of ISpA is a historic and path-breaking decision as part of the Aatmanirbhar Bharat Initiative. Launched by Prime Minister Narendra Modi, it lays the foundational canvas for the participation of the private space industry to develop full-stack capabilities in dual-use areas covering remote sensing/Earth Observation, communications, and PNT to serve the needs of the armed forces. The DefSpace programme provides the much-needed government support to create an ecosystem to develop foundational full-stack technologies to meet our space requirements for the strategic sector. Working for defence space was an exclusive domain for government agencies. However, given the reforms and mindset change, involving the private sector in meeting the requirements of the strategic sector in India signals the total "change of winds". The private space industry is now seen as a "partner" and "co-traveller" – a huge departure from the traditional "vendor" based approach. Such a huge programme could be successfully initiated, curated, and launched at a high speed within a short span through the collaborative efforts of stakeholders (that included MoD, DRDO, ISRO, ASI, iDEX, HQ IDS, DSA, IA, IN, IAF, and ISpA), various academic institutions, and ISpA. Besides sensitising the MoD on the strategic necessity to launch a funded defence space innovation programme, ISpA was engaged in the curation of the challenges by being the interface between stakeholders and the industry throughout the life-cycle of this programme. It is a work-in-continuum that needs to be strengthened and supported. This speaks a lot about the rising trust factor between the industry and the government as well as the improved collaborative climate within government agencies.

According to inputs gathered during various seminars and panel discussions, the DefSpace innovation programme is worth US$1.6 billion. Further, the armed forces are likely to procure almost US$ 80 billion worth of products; a significant portion of which is likely to be sourced from the successful outcomes of the ongoing DefSpace programme. This much-needed support from the MoD provides the initial momentum to the space industry. The industry now needs to be further accelerated with private investments to help scale up identified companies to serve both public and global requirements. MoD is also requested to tweak IPR policies for both iDEX and TDF schemes to make them more attractive for investors without compromising on national security aspects. Further, Defence Acquisition Procedures (DAP) may also be suitably modified to make them sensitive to the requirements of the space sector. New innovative business models could also be examined that could include Data-As-A-Service (DAAS), Platform-As-A-Service (PAAS), Analytics-As-A-Service (AAAS), and leasing of platforms. Further options include Government Owned Government Operated (GOGO); Government Owned Corporate Operated (GOCO); and Corporate Owned Corporate Operated (COCO) to mainstream adoption and expansion.

Government role in catalysing goal-oriented space technology innovation

The MoD's initiative is a great example of what can be done. It would be heartening to see how other infrastructure-intensive and services-oriented ministries could come up with their own consolidated challenges. These challenges could be centrally managed by IN-SPACe. For execution, IN-SPACe could take the lead and establish a Section-8 (not-for-profit) entity such as iDEX (with some structural and policy refinements to ensure a level-playing field and industry-friendly IPR guidelines) to kick-start goal-oriented funded innovation, focused towards the needs of the common man and strengthening government efforts to make India a US$5 trillion economy and beyond. The scope of ongoing initiatives of IN-SPACe could be expanded to accommodate this approach.

Various ministries could examine the possibility of using space technology to achieve their Vision 2047 spread over short-, medium-, and long-term plans. For example, more than 85 percent of the Indian population is engaged in contributing 17 percent to GDP. The ministries could engage with ISpA to help curate such challenges that would help increase the GDP contribution over time. Similarly, sectors affected by supply chain risks could look at developing technologies that would bring better predictability and enable response and real-time crisis management. Our commitments towards SDGs, COP, and reducing emissions are some areas that offer a huge opportunity for the industry to support government efforts. Additionally, the infrastructure sector holds huge opportunities where space technology could add value throughout the life cycle of projects.

The government can mandate the use of space technology derived data for implementation of such projects. A specific percentage could be decided during the tendering process (to be included as a bill of material) and form a part of project audits. The use of geospatial technology brings about a measurable impact in terms of reducing losses, removing duplication, and

boosting productivity. These need to be included as key result areas for each department and ministry. Similarly, the industry also needs to be encouraged to adopt and absorb space technology to become more efficient and sustainable. Ministries and departments could also consider integrating with space technology parks for spreading awareness, generating ideas, and tasking the industry to provide solutions.

We need to consider moving beyond the standard L-1 based tendering process for hi-tech solutions for various reasons. These could include providing a level-playing field for space heritage systems and innovative solutions by start-ups and dealing with uncertainties in estimates for new-gen technology development. The following approaches are proposed in this regard:

1. Quality Cost Based System (QCBS): This method could be examined where bids shall be evaluated both in terms of quality and quoted price. The weightage for quality is 70 percent and the weightage for cost is 30 percent. This would enable high TRL and space heritage systems to be evaluated on par with innovative start-up solutions. These are referred from www.gem.gov.in.
2. The "Cost plus Contract"[2] system: This system is proposed for consideration to support high-value R&D or for cases where enough data is not available to estimate the final cost accurately.

Developing Space Technology Parks (STPs)

While efforts are being made to set up space technology parks and industry parks, we could learn from Maruti's experience where the ecosystem was built to support the automobile industry. For the space sector too, an all-encompassing space infrastructure, including office space, workshops and labs, testing and validation infrastructure and production facilities (located or co-located in proximity), is needed. Additional support services in terms of incubation centres, legal and financial services, insurance, IN-SPACe, and NSIL liaison offices also need to be co-located. Single window clearances for the ease of doing business is a much-needed requirement to release the burden on young start-ups that operate in Lean, Mean, and Thin mode. Further, a central agency would be tasked to coordinate on the availability and use of testing and validation facilities to ensure a fair play in the allocation of such facilities through an online portal. Such a portal could help with the following – visualisation of facilities available; rules and regulations of operations; administrative formalities of facilitation of each facility; booking calendar; and visibility on pricing and online payment. Such an agency would directly liaise with stakeholders of the testing and validation ecosystem. These stakeholders would include ISRO, DRDO, CSIR Labs, NAL, HQIDS, Army, Navy, Air Force, HAL, C-DOT, CDAC, various laboratories, and research institutes run by the government. Defence services could also pitch in by facilitating the availability of test ranges for testing sensors using bronze to avoid local political interference to conduct such tests. Such ranges would need to be located in various terrains and climate zones to facilitate improving the effectiveness and operational performance of sensors and components under development. Given the mammoth scale of DefSpace challenges and solutions under development, strengthening human resources to support the industry would be important. Such human resources would also need to be integrated with STPs and testing locations in collaboration with academic institutions. A cluster approach, the Hub and Spoke mode, could be worked out for structuring such STPs. A network of STPs would form the breeding ground for taking the technology from "labs to space" and function as instruments to make India self-reliant and technologically advanced within the next two decades.

Resources and funding

The space sector is a capital-intensive domain. The life cycle of technology research, development, production, deployment, operations, and management is a high-risk and capital-intensive process. The process involves long gestation periods; ROIs are spread over a long period of time. Further, there is a heavy dependence on government-owned testing and validation infrastructure. Hence, high investments are needed in the space domain, especially where satellite and rocket hardware is involved (where funds up to or beyond INR 400-500 crore would be needed for series C/D level of funding or beyond).

At present, major challenges are faced in India for raising capital. Some of these include the following:

- High cost of raising capital compared with that for foreign companies located in the US
- Higher loss of equity during early-stage funding (resulting in the reduction in founders' equity to less than 20-30 percent by the time Indian space companies reach Series A funding)
- Further dilution of founder equity in the lower range of single digits at the stage of Series C/D level of funding
- Fewer Indian Venture Capitalists (VCs) who fund beyond Series A

[2]https://en.wikipedia.org/wiki/Cost-plus_contract

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A combination of these four factors would eventually lead to critical space companies being financially supported and controlled by companies or individuals outside the boundaries of India. It may be noted with concern that our start-ups groomed and nurtured with the government support are crucial to meet the strategic requirements of India. This would include the creation of national security linked infrastructure.

Given this strategic necessity, focused and urgent efforts need to be made to create Indian-owned financial institutions and instruments. This would essentially bring down the cost of raising capital to globally competitive rates and support the full funding requirements of the space ecosystem. Various options need to be energised. Some of these include the following:

- Using an IFSCA route through GIFT City
- Incentivising tax holidays/rebates for large business houses and institutions invested in the space domain
- Creating large collaborative investment pools supported by affluent business houses and companies (this would distribute risk and lower risk liability)
- The government-supported fund pool, front-ended by financial institutions/banks with additional contributions from VCs to support government-approved projects of iDEX, MoD (make series); and IN-SPACe
- The possibility of floating space Infrastructure bonds to fund specific dimensions of space technology for public good

Strategic electronics

Developing indigenous chip design and manufacturing capability would be a critical step in developing self-reliant strategic electronics manufacturing capability for India. While government efforts to help set-up semi-conductor capability are underway, these need to be strengthened in terms of scope and pace. Given the criticality of chip manufacturing to design and develop high-performance sensors and onboard processing systems, the space industry is looking to fast-track these efforts.

Conclusion

Given the potential and opportunities in the space domain, a focused “whole-of-nation approach” would be a huge enabler to the nascent high-potential space industry. The Indian industry's established track record in facilitating successful ISRO projects, combined with recent accomplishments by start-ups in deploying operational satellites in space, marks a positive stride forward. Government support, along with easy availability of capital, would be critical to fuel the space industry’s growth.

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Caveats and recommendations

Caveats

While there is a positive optimism around the sector with ambitious goals of attaining 10% of the global market share, it needs to be seen through the lens of realism to identify the issues and solve them to help attain the actual potential and probably beyond.

01. **Supply-demand mismatch:** One of the major concerns across the industry is the mismatch on the available tech and resources and the demands across on data, in terms of frequency, quality and accessibility. The space policy has created a mandate to make imagery from ISRO's satellites free and open and that high-resolution imagery, while free for the government, will be made available at a fair price to the industry. However, private players are of the opinion that the frequency of Indian datasets along with cloud and storage plug-in capabilities need improvement for them to have better accessibility to provide better services. ISRO and IN-SPACe have already taken cognizance of this, as they recently released a consultation paper for inputs from the industry to create a plan focusing on Public-Private-Partnership models for meeting the EO demands specifically. This could improve our self-sufficiency in the long run.
02. **Saturation of certain sections of the value chain:** A great deal of attention has been paid in India's initial period of private players entering the space sector to cater to the upstream segments, especially the manufacturing of launches and components. This made sense considering our cost advantage. Today, we have sufficient players within the launch manufacturing and services sector and focus needs to move towards other upstream services such as mission operations and control, SSA, in-orbit servicing and end-of-life servicing, among other services that can cater to different missions and generate regular revenue.
03. **Bridging the gaps:** Data aggregation and analytics is one of today's main gaps in the Indian space technology market. While quite a few companies are catering to specific use-case-driven analysis, a potential market exists for companies that could specialise in data aggregation and fusing data from multiple sources to derive useful insights to the end-users. In this regard, the cost of running analytics in the cloud is still quite high and expected to rise; this is a potential intervention point for the government or market to drive economies of scale.
04. **Value for money:** Justifying Return on Investment (ROI) is a sector-agnostic challenge, but it is profound within the space sector for the sheer cost of putting a resource in space and operating it. Although small satellites especially aimed at LEO have shorter lifespans, making the most of their 3–10-year lifespan is imperative. The government did ease a bit of the burden around Goods and Services Tax (GST) by exempting launch services. However, as the sector expands and more assets are placed in space, it will be important to standardise satellite specifications. When non-space alternatives exist, it will be necessary to develop new business models in order to maximise the return while maximising the value for end-users. There is also a lack of intent regarding legitimate use-cases, such as defence and insurance, for which a market exists. Governments could play a role in helping to alleviate some of these concerns by catering to some of them, particularly those regarding funding shortages and procurement cycles.

Recommendations

Figure 45: Caveats and recommendations for EO segment

NRSC and SAC have played critical roles in enabling use of remote sensing into everyday lives. As the nodal agency for image acquisition, NRSC also procures images from non-Indian sources and makes it available for industry and Governments. As the next logical step in this journey, **transition to public cloud** by NRSC can further innovation and help the nascent ecosystem to service use-cases efficiently and compete globally.

The most important area influenced by above reality is image pricing. In line with global practices, ISRO provides access to several governance critical images in an open, transparent and free manner. While the expectation is to enable affordable service delivery, viable businesses cannot sustain without credible revenue streams. As mitigation measure, in line with the IndiaStack approach and mirroring Bhoonidhi/ Bhuvan initiatives, **a digital public infrastructure for earth observation** is much warranted.

The role of State Governments has become more pronounced now than ever before. With the policy opening-up the sector, **the state governments have to play a vital role** as both enablers and consumers of earth observation-based services to nurture the nascent ecosystem

In all the focus sector basis the customer segmentation and business enablement considerations, it is evident that commercialisation possibilities are interspersed amidst non-commercial possibilities. This conundrum needs a focused and **calibrated approach to balance between commercial and social welfare objectives.**

While the overall policy approach is enabling, there are a few emerging inconsistencies that need early attention. **Clarity is required on the open, transparent and free availability to high resolution data** which is a pre-requisite for several use-cases.

Figure 46: Caveats and recommendations for SATCOM

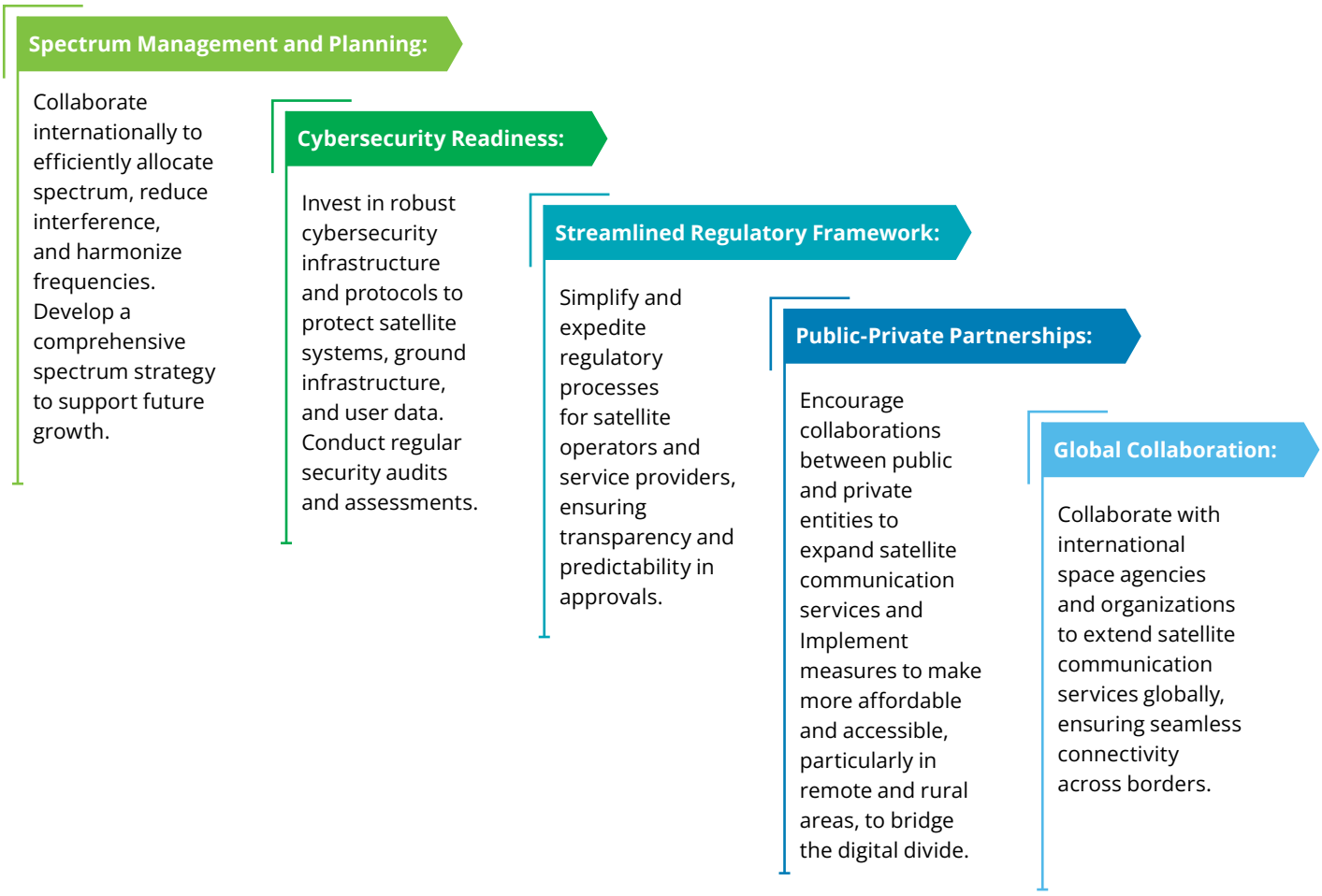
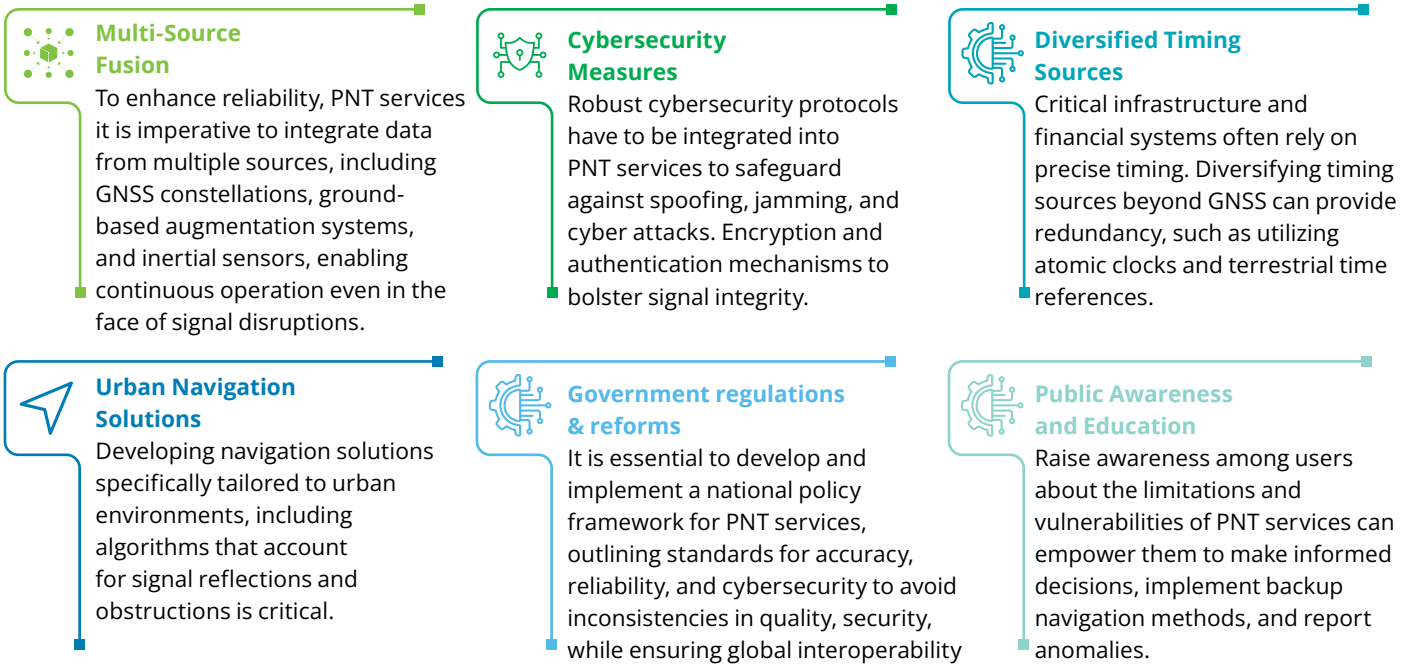


Figure 47: Caveats and recommendations for PNT segment



Takeaways for 'Caveats and Recommendations'

- The space sector faces the challenge of a mismatch between the available technology and resources and the demands for data, including frequency, quality, and accessibility. Efforts to improve accessibility and data quality are underway, including consultations for Public-Private Partnership (PPP) models to meet Earth Observation (EO) demands.
- The initial focus of private players in India was on upstream segments like launch and component manufacturing. With a sufficient number of players in these areas, attention should shift to other upstream services such as mission operations, space situational awareness, in-orbit servicing, and end-of-life servicing.
- The Indian space tech market lacks comprehensive data aggregation and analytics capabilities. There's potential for companies specializing in data fusion and deriving insights from multiple sources. Reducing the cost of running analytics in the cloud could further stimulate this market.
- The space sector faces challenges in justifying Return on Investment (ROI) due to the high cost of space resources. Standardization in satellite specifications and evolving business models can maximize returns while ensuring value for money. The government could play a role in supporting valid use cases like defense and insurance.
- With the space sector opening up, state governments have a crucial role to play as enablers and consumers of Earth observation-based services. Their involvement can nurture the growing ecosystem.

Conclusion

The Indian space sector is on the precipice of an industry-defining transformation moment. The Indian Space Policy, 2023, has broadly spelled out the contours of the transformation with non-government entities expected to play a major role in the transformation.

As mentioned in the report, the actual understanding of the space value chain is evolving dynamically, and it may unlock value that was previously considered impossible. A synergistic relationship exists between the various segments of the sector that can work in tandem to improve the overall size of the sector. For instance, as efficacy of downstream applications to service specific business and governance needs improve, it will naturally necessitate more launches and vice versa.

To that extent, the report has focused on only the downstream segment of the sector's current value chain through the prisms of applications and services by EO, SATCOM and PNT. While the focus of the report has been on identifying the downstream use-cases that are anticipated to generate long-term value for the sector, this is by no means an exhaustive list of possibilities, not even within the downstream segment.

As technology matures and newer business models are explored to service demands in various sectors within a commercially viable framework, it is expected that newer service delivery/business models will enable an increasing number of use-cases within the identified sectors.

Figure 48: Downstream Space Technology: Future Possibilities

	Models focused on aggregating offerings across a segment				
	Earth Observations	**Satellite Communication**	**PNT**	**Spin-off from Strategic use-cases**	
Focus Sector 1: Agriculture	Yield estimation Crop health monitoring Soil health status Moisture content	Remote Area Connectivity: Farmer handhelds Farm machines connectivity	Direct from farm procurement : Navigation Improved precision farming etc.	Weather forecasting and inputs from ELINT/ SIGINT	**Models focused on aggregating offerings across a sector**
Focus Sector 2: Health	Monitor conditions that facilitate spread of diseases Air & Water quality monitoring	Telemedicine Remote surgery Health outreach programs	Tracking medicine and vaccine distribution Timely medical help in the event of emergencies	Satellites developed for military communication can also connect doctors with patients in the event of a disaster	
Focus Sector 3: Disaster Management	Monitor evacuation efforts Post disaster reconstruction planning Disaster prediction	Coordination with response and relief personnel Send warning messages to unconnected areas	Tracking relief efforts When terrestrial networks fail PNT can guide satcom services	Insights on trafficability of roads is vital for defence operations. The same insights can inform disaster relief efforts	
Focus Sector 4: Mining	Identifying mineral deposits Detect illegal mining Track scale of mining operations and environmental impact	Remote operation of machines, reducing human presence Connect with sensors used in mines	Track location of miners, assets and mined materials Supply chain management	Geospatial tools used by the military for terrain analysis, hydrology, reflectance etc., are equally insightful for resource extraction	

As the number of Indian space assets increases, it is imperative to note that their ability to service global demand and markets also increases. Several Indian non-governmental organisations are already active in regions outside of India's borders.

In terms of supply chain connectivity and service enablement, space has always been a global domain. Consequently, it is also important to emphasise that the global space industry has been extremely active in recent years. This new wave of space, which is primarily driven by technological advances, is also characterised by the entry of new countries into the space sector, private capital and efforts complementing national space programmes and budgets to the extent that several market estimates predict the global space sector will surpass USD 1 trillion in the next two decades.

Over the recent years, the Government of India has undertaken several strategic initiatives to deepen partnership and cooperation with other space faring nations/ space programmes including but not limited to USA, Russia, France, European Space Agency, etc. In the same light, FDI policy for the space sector is also expected to be relaxed to attract foreign investments.

As paradigm shifts in terms of technology offerings, business models and new geographies, Indian space sector is expected to achieve Government of India's vision.

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List of abbreviations

ADS-B	Automatic Dependent Surveillance-Broadcast
AFNET	Air Force Network
ALOS	Advanced Land Observing Satellite
ASAT	Anti-Satellite Weapons
ASLV	Augmented Satellite Launch Vehicle
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVIRIS	Airborne Visible-Infrared Imaging Spectrometer
BBNL	Bharat Broadband Network Limited
BFSI	Banking, Financial Services and Insurance
BIM	Border Infrastructure and Management
BSNL	Bharat Sanchar Nigam Ltd.
BST	Berlin Space Technologies
CMS	Communication Satellite
CNES	Centre National d'études Spatiales
CORS	Continuously Operating Reference Stations
COSPAS	Cosmicheskaya Sistema Poiska Avariynyh Sudov
DCA	Defence Cyber Agency
DOS	Department of Space
DPIIT	Department for Promotion of Industry and Internal Trade
DRDO	Defence Research and Development Organisation
DSA	Defence Space Agency
EDUSAT	Educational Satellite
EMISAT	Electromagnetic Intelligence-gathering Satellite
ESA	European Space Agency
FDI	Foreign Direct Investment
FTP	File Transfer Protocol
GAGAN	GPS-aided GEO Augmented Navigation
GEO	Geosynchronous
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GSAT	Geosynchronous Satellite
GSD	Ground Sampling Distance
GSLV	Geosynchronous Launch Vehicle
GSO	Geostationary
GST	Goods and Services Tax
ICBM	Inter-Continental Ballistic Missile
INCOSPAR	Indian National Committee for Space Research
INR	Indian Rupee
INSAT	Indian National Satellite System
IOR	Indian Ocean Region
IRNSS	Indian Regional Navigation Satellite System
IRS	Indian Remote sensing Satellite
ISpA	Indian Space Association
ISR	Intelligence, Surveillance and Reconnaissance
ISRO	Indian Space Research Organisation

KOMPSAT	Korean Multi-Purpose Satellite
LEO	Low Earth Orbit
LWE	Left Wing Extremism
MDA	Maritime Domain Awareness
MEO	Medium Earth Orbit
MODIS	Moderate Resolution Imaging Spectroradiometer
MPVT	Mandatory Performance Verification Testing
NASA	National Aeronautics and Space Administration
nasscom	National Association of Software and Service Companies
NCW	Network Centric Warfare
NETRA	Network for Space Objects Tracking and Analysis
NGSO	Non-Geo-Stationary
NISAR	NASA-ISRO Synthetic Aperture Radar
NOCC	Network Operations and Control Center
NPP	National Polar-orbiting Partnership
NSDC	National Skill Development Corporation
NSIL	New Space India Limited
OECD	Organisation for Economic Co-operation and Development
OSCAR	Observing Systems Capability Analysis and Review
OTT	Over The Top
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PNT	Positioning, Navigation and Timing
PSLV	Polar Satellite Launch Vehicle
RISAT	Radar Imaging Satellite
RLV	Reusable Launch Vehicle
ROI	Return on Investment
SAR	Synthetic Aperture Radar
SARAL	Satellite with ARgos and ALtiKa
SARSAT	Search And Rescue Satellite-Aided Tracking
SATCOM	Satellite Communication
SIGINT	Signal Intelligence
SLV	Satellite Launch vehicle
SPADEX	Space Docking Experiment
SSA	Space Situational Awareness
SSLV	Small Satellite Launch Vehicle
TAPAS	Tactical Airborne Platform for Aerial Surveillance
TRAI	Telecom Regulatory Authority of India
TTC	Telemetry, Tracking and Command
UAV	Unmanned Aerial Vehicle
UHF	Ultra-High Frequency
USA	United States of America
USD	United States Dollar
VIKAS	Vikram Ambalal Sarabhai

About nasscom

nasscom is the industry association for the technology sector in India. A not-for-profit organization funded by the industry, its objective is to build a growth led and sustainable technology and business services sector in the country with over 3100 members. nasscom Insights is the in-house research and analytics arm of nasscom generating insights and driving thought leadership for today's business leaders and entrepreneurs to strengthen India's position as a hub for digital technologies and innovation.

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