Earth observation

A driver for India's development

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pwc

SIAINDIA
SatCom Industry Association

Preface

Our reliance on EO data and technologies has never been more wide ranging, and they have the potential to play a vital role in the fabric of our society. For instance, EO data is increasingly utilised to enhance agricultural and resource management practices, allowing farmers to oversee their lands and livestock more precisely across larger areas. Additionally, EO plays a crucial role in natural disaster response and climate science, aiding in the modelling and mitigation of severe weather events such as cyclones, floods, and droughts, which have considerable economic and social impacts on communities. In India, the economic advantages derived from EO data are substantial, greatly contributing to national development.

It is within this context that India's 'Decadal Vision and Strategy for Indian Space Economy' report released by IN-SPACe projects market potential worth USD 8 billion for EO in 2033 with a growth rate of 28%.[1] India is heavily reliant on EO data for various critical needs, including weather monitoring, climate change monitoring, agriculture sector applications, urban planning, transport, infrastructure and most importantly national security. Building sovereign capability to ensure assured access to EO data is essential for India's national interests. This includes enhancing capabilities in climate monitoring, disaster management, agricultural planning and defence operations. In addition to these, various other sectors such as infrastructure, energy and mining, and finance and insurance can greatly benefit from EO data-based applications. Developing expertise within the nation to meet these needs in the coming decade is crucial. In this regard, key value propositions of EO-based applications have been detailed in this thought leadership. It also delves deeper into how an EO platform may support the acquisition, processing and analysis of data. Establishing such a platform would enable the downstream capability, while also supporting India's sovereign needs, strengthening international relationships, and contributing to socioeconomic development.

EO stands at the forefront of the ongoing efforts being undertaken to understand and sustainably manage Earth's resources. By advancing EO capabilities and fostering a robust data platform, India can pave the way for a future where informed decision making drives sustainability and resilience. The insights and innovations detailed here emphasise the profound potential of EO to not only enhance quality of life but also to secure a sustainable future for generations to come.

Vishal Kanwar
Executive Director – Aerospace, Defence and Space
PwC India

1 https://www.inspace.gov.in/inspace?id=inspace_decadal_vision_strategy

Message from PwC

In this era, technology shapes the future of a nation. With advancement in space technologies, the role of EO in the development of a nation has become crucial. This paper provides a view on the potential impact EO applications can have on India's development.

With its ambitious space programme, India has emerged as one of the leaders in the exploration and utilisation of space technology. India has made great strides across sectors from agriculture and urban planning to environment and disaster management. This paper covers the utilisation of EO data in driving informed decision making and the revolutionary impact of the same across various industries.

The insights covered in this paper address some of the most pressing challenges faced by the country. EO data enables efficient planning and improvement in productivity. Moreover, it represents a paradigm shift in our approach to development. It is evidence of both human ingenuity and the ability of science and technology to build a more sustainable future.

We need to enhance collaboration to take bigger steps in exploring and innovating in the field of EO.
The technology holds the key to driving progress and improving lives across the globe.

Pallab De
Partner and Leader, Operations and Manufacturing Consulting – Aerospace and Defence
PwC India

Message from SIA-India

Advancements in science and technology have changed the way we interact with our world. Interestingly, EO data-based applications have emerged with the potential to drive development and address challenges. It is heartening to note PwC India's initiative in bringing out a paper covering the role that EO-based applications can play in driving the development of our nation.

It is critical to recognise the impact that EO-based applications will have on the development of our nation. India's space programme, with its array of spacecraft, has become a beacon of progress. It demonstrates how strategic investments in technology can drive sustainable growth across diverse sectors.

In this context, it is necessary to explore the multifaceted applications of EO. At the macro level, EO optimises governance and monitoring of climate change, whereas at the micro level, it supports in evaluating key assets and infrastructure for their vulnerability to natural hazards and potential for operational disruptions.

The potential of EO-based applications to revolutionise development practices is immense. I hope this paper will inspire further collaboration and innovation in this field.

Dr. Subba Rao Pavuluri
President, SIA-India

Executive summary

EO through satellite technology has become an indispensable tool for understanding and managing the Earth's resources and environments. By providing comprehensive, real-time data on climate, land use, biodiversity, and more, EO enables better decision making and supports efforts towards sustainable development. This capability is crucial for addressing complex global challenges such as climate change, natural disasters, urbanisation, and resource management, making EO an essential component of modern governance and economic strategy.

By providing critical data and insights for agricultural activities, EO enhances crop management practices and yield predictions, contributing to food security and economic growth. Similarly, EO data enhances consumer solutions, improves transport efficiency, boosts agricultural productivity, optimises energy and mining operations, aids disaster management, and supports infrastructure development. Additionally, EO supports the development of applications to monitor environmental health and inform risk assessment in the insurance and finance sector.

Several trends have been identified that significantly impact the field of EO. Technological advancements have led to more sophisticated and cost-effective satellites, enabling higher resolution and more frequent data collection. The proliferation of small satellites, or CubeSats, has democratised access to space-based data, while improvements in data processing and AI are enhancing the ability to analyse and interpret this information rapidly and accurately. Additionally, increased international collaboration is expanding the scope and utility of EO, fostering shared knowledge and resources among countries and organisations.

EO directly supports several of the United Nations' SDGs. For instance, it plays a crucial role in climate action by monitoring greenhouse gas emissions and climate patterns. It aids in the development of sustainable cities and communities by providing data for urban planning and disaster management. In agriculture, EO supports zero hunger through precision farming techniques that improve crop yields and resource efficiency. Moreover, EO is vital for clean water and sanitation by monitoring water bodies and detecting pollution, thus ensuring sustainable water management.

While the impact of EO spans numerous use cases, it is also critical to understand the value chain of the data supporting these use cases. The value chain spans multiple stages, from data acquisition by satellites to processing, development of information, and application of big data analytics to derive insights. This chain creates numerous opportunities for value creation across various sectors.

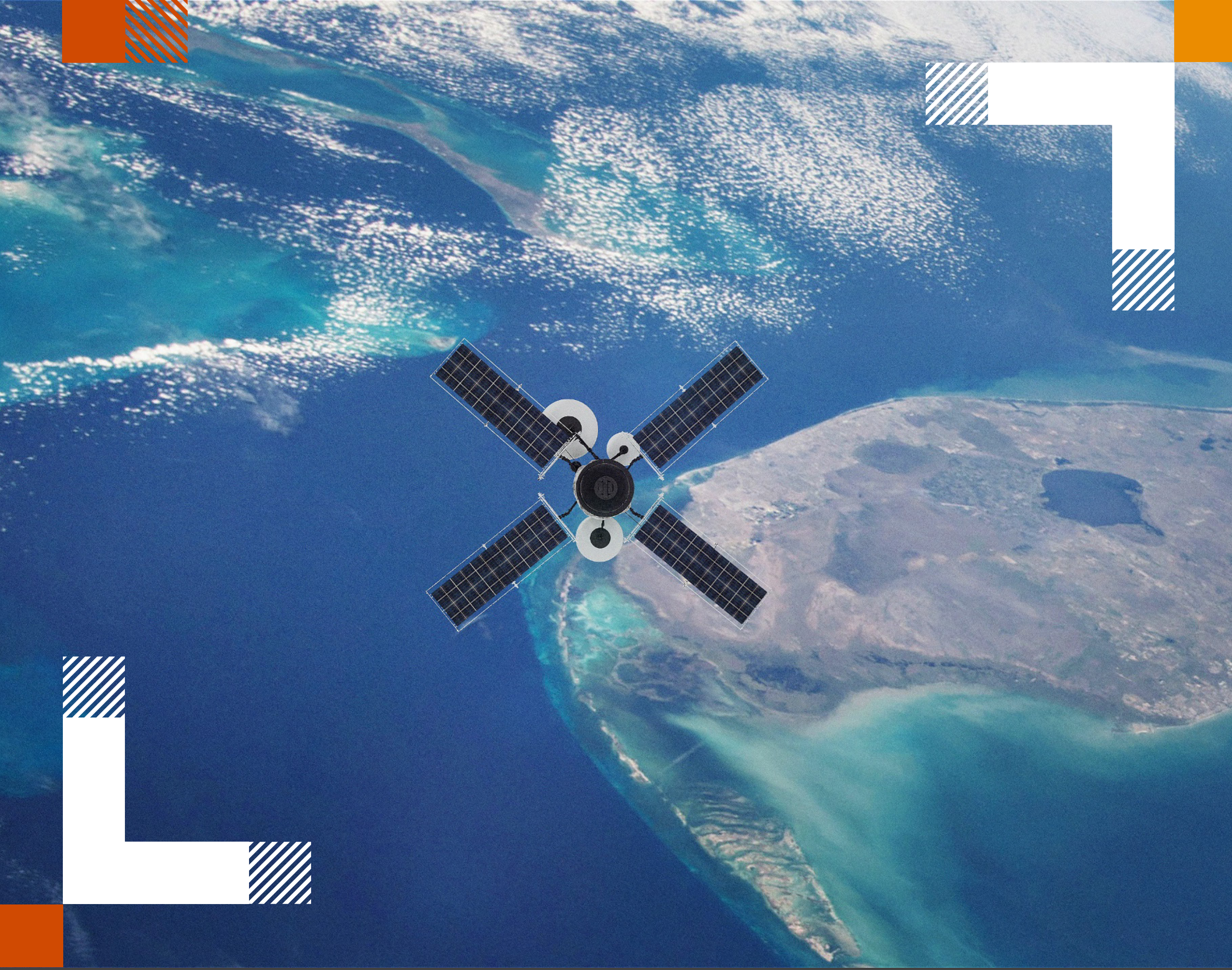
Despite its numerous advantages, the field of EO faces several challenges. Data privacy concerns, the increasing congestion of the Earth's orbit, and the need for robust regulatory frameworks are significant issues that must be addressed. Additionally, there is a need for efficient data integration and interoperability among different EO systems to maximise the utility of the data collected.

To effectively manage the vast amounts of data generated by EO, a comprehensive EO platform is proposed. This platform would facilitate the collection, processing, and analysis of satellite data, ensuring it is accessible and usable for various stakeholders. By integrating advanced data analytics and AI, the platform would enhance the ability to derive actionable insights from EO data, supporting informed decision making across sectors. This centralised approach would also promote collaboration and data sharing, driving innovation and maximising the impact of EO on sustainable development and economic growth.

In conclusion, by leveraging the latest technological advancements and addressing key challenges, EO can support in adding significant economic value by improving agricultural efficiency, optimising urban planning, enhancing disaster response, and conserving natural resources, thereby fostering a more resilient and prosperous economy.

Table of contents

Table of figures



1. Understanding (EO)

1.1. Introduction

India has always acknowledged the potential of space to power its economy and society, democratising development by making data available through the concept of space to all. The 'Decadal Vision and Strategy for Indian Space Economy' report defines the vision for the Indian space sector as follows: 'To make India a dominant Space power, which accelerates India's growth through space applications on Earth, strengthens capabilities in Space, creates socio-economic benefits and capabilities for growth.'[2]

EO will be a crucial domain of our space ecosystem to achieve the vision. It refers to the use of remote sensing technologies to monitor land, oceans and the atmosphere. EO satellites use payloads that utilise technologies like optical, thermal or radar sensors to gather imaging data of Earth's characteristics. Post processing and analysis of this data can provide a range of applications for users across sectors such as agriculture, environmental monitoring, disaster management, energy and mining, oil and gas, transportation (including rail, road aviation), and insurance and finance. Globally, EO data-based applications have become an indispensable tool, leading to the launch of approximately 1,460 satellites in the last two decades.[3]

With the launch of the Bhaskara-1 satellite in 1979, India embarked on its EO journey. Today, India has one of the largest constellations of remote sensing satellites in operation. As India observes an era marked by rapid technological advancements, the EO space segment has tremendous potential. This paper provides an overview of EO and its contribution in the development of different sectors.

1.2. Key trends in EO

The field of EO is experiencing unprecedented growth and innovation, driven by a confluence of technological advancements, increasing demand for geospatial information, and expanding applications across various sectors. This section delves into the key trends shaping the landscape of EO, examining both the demand and supply sides of the industry, and highlighting notable developments and emerging opportunities.

Increasing demand for EO data-based applications across sectors

- Democratisation of the use of EO outside of expert communities
- Increasing interest in ESG
- New emerging analytics markets
- Strong interest from military
- Growing interest in non-imagery EO data & information

Increased data availability given the increase in EO satellites

- Satellite miniaturisation offering increased flexibility and coverage
- Satellite constellations for continuous monitoring
- Emergence of new business models for rapid market expansions

Increased reliance on space-based data by governments and changing geopolitics

- Wars and geopolitical risks fueling interest in earth observation
- Insurance players investing in satellite data exploitation
- 100% FDI in space sector
- New space policy
- New regulations opening opportunities (e.g., Liberalised National Geospatial Policy)
- Remote sensing beyond LEO

Figure 1: Key trends in EO

[2] https://www.inspace.gov.in/inspace?id=inspace_decadal_vision_strategy
[3] https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Earth_observation_inspires_global_inventiveness

Increasing demand for EO data-based applications across sectors

The **democratisation of EO** data availability outside expert communities has reshaped how individuals, organisations, and communities access and utilise geospatial information for diverse purposes. With advancements in technology and the increasing availability of open-access satellite data and tools, the barriers to entry in the field of EO have significantly lowered.

There is significant momentum in utilising EO technologies for **ESG** monitoring. Advances in satellite technology and remote sensing are enabling more precise and comprehensive tracking of environmental indicators such as deforestation, water quality and carbon emissions.

The trend of the **emerging analytics market in EO** are characterised by the rapid evolution and adoption of advanced data analytics techniques tailored specifically for processing and interpreting geospatial data. As the volume and variety of EO data continue to increase exponentially, driven by advancements in satellite technology and sensor capabilities, there is a growing demand for innovative analytics solutions to extract valuable insights from these rich datasets. Emerging analytics technologies such as machine learning, deep learning, spatial analytics, and predictive modelling are being increasingly applied to address a wide range of challenges across various sectors, including agriculture, urban planning, disaster management, environmental monitoring and infrastructure development. Moreover, military organisations worldwide are leveraging cutting-edge technologies such as AI and big data analytics to enhance their EO capabilities for ISR missions.

There is a **growing interest in non-imagery EO data** and information which reflects a broader recognition of the diverse array of data sources beyond traditional satellite imagery that hold immense potential for understanding and monitoring our planet. This trend is driven by advancements in sensor technology, data collection methods, and data integration techniques, which enable the acquisition and analysis of multidimensional data sets at unprecedented scales and resolutions.

Increased data availability given the increase in EO satellites

The trend of **satellite miniaturisation** in the EO industry is revolutionising how space-based data is collected, enabling more agile and cost-effective missions than ever before. Miniaturised satellites, such as CubeSats and Microsats, leverage advancements in electronics, propulsion, and manufacturing techniques to pack sophisticated sensing and communication capabilities into smaller form factors. This trend is driving a shift away from traditional, large and expensive satellite platforms towards smaller, more numerous satellites. These satellites offer increased flexibility, rapid deployment and improved coverage for EO applications. Additionally, satellite miniaturisation is lowering the barriers to entry for space exploration and Earth monitoring, empowering universities, startups, and developing countries to participate in the space industry and contribute to scientific research and societal benefits. As the technology continues to mature and miniaturised satellites become more capable, the trend of satellite miniaturisation is poised to accelerate, unlocking new opportunities for innovation and collaboration in EO and beyond.

The growing interest in **constellations in EO** satellites represents a paradigm shift in how satellite-based observation systems are designed, deployed and operated. Traditionally, EO satellites operated as standalone platforms, capturing data over specific areas at scheduled intervals. However, the emergence of satellite constellations involves the deployment of multiple small satellites in interconnected networks, working collaboratively to provide continuous global coverage of the Earth’s surface. Today, India has one of the largest constellations of remote-sensing satellites in operation.[4] This trend is fuelled by advancements in miniaturisation, standardised satellite platforms, and improved communication technologies, enabling cost-effective deployment and operation of large-scale constellations. As the demand for timely and actionable geospatial information continues to grow, the trend of using constellations in EO satellites is poised to play a central role in shaping the future of remote sensing and geospatial intelligence.

[4] https://www.isro.gov.in/EarthObservationSatellites.html#:~:text=Starting%20with%20IRS%2D1A%20in,remote%20sensing%20satellites%20in%20operation

New delivery models such as cloud services, in the EO industry are reshaping how satellite imagery and geospatial data are accessed, processed, and utilised. Cloud-based platforms offer scalable, on-demand access to vast repositories of EO data, providing users with the ability to rapidly analyse, visualise, and extract insights from petabytes of satellite imagery and related datasets. These platforms leverage cloud computing infrastructure, distributed processing algorithms, and advanced analytics tools to deliver high-performance geospatial processing capabilities to a diverse range of users, including government agencies, commercial enterprises, research institutions, and individual developers. Moreover, new business models are emerging. Market fragmentation due to a variety of solutions has led to the evolution of downstream business models, from traditional single-image purchases to subscription/volume based.

Increased reliance on space-based data by governments and changing geopolitics

The ongoing **wars and geopolitical risks** have sparked a growing interest in EO technologies as valuable tools for monitoring and understanding the situation on the ground. Satellite imagery and remote sensing provide critical insights into the dynamics of a conflict, including troop movements, infrastructure damage, and humanitarian impacts. By analysing high-resolution satellite imagery, researchers, journalists, and humanitarian organisations can track the progression of conflicts, identify areas of concern, and assess the effectiveness of ceasefire agreements and peacekeeping efforts. Additionally, EO data can support humanitarian aid efforts by providing accurate and up-to-date information on displaced populations, damaged infrastructure, and areas in need of assistance.

Today, **insurers are investing in satellite services,** underscoring the growing recognition of the value of space-based assets in managing and mitigating risks across various industries. As the demand for innovative risk management solutions continues to grow, the trend of insurers investing in satellite launches is expected to accelerate, driving further advancements in space-based technologies and collaboration between the insurance and space industries.

India's announcement of **100% FDI** in the space sector signals a significant step towards liberalising and opening the space industry to foreign participation and investment. This move reflects a broader trend of governments recognising the potential of space exploration, satellite technology, and related services as drivers of economic growth, innovation, and international collaboration. By allowing 100% FDI, the government aims to unlock new opportunities for growth and development in the space economy.

Moreover, with the introduction of the **Indian Space Policy 2023** and 'Decadal Vision and Strategy for the Development of the Indian Space Economy', the space industry is set to grow exponentially. In 2022, Ministry of Science and Technology notified an NGP 2022, with the goal of making India a world leader in the global geospatial sector. The policy is aimed to set up high-resolution topographical survey and mapping, with a high-accuracy DEM by 2030.

Additionally, the trend of deploying satellites into HEO for EO is emerging as a promising approach to enhance remote sensing capabilities. HEO satellites, with their unique elliptical trajectories, provide prolonged coverage over high-latitude regions, which are often underserved by traditional geostationary or LEO satellites. This orbit allows extended dwell times over specific areas, enabling detailed and continuous observation of dynamic phenomena such as polar ice melt, weather patterns and natural disasters. Furthermore, HEO satellites complement existing LEO and geostationary systems, providing a more comprehensive global observation network.

1.3. Impact on SDGs

EO technologies, especially those utilising satellite data, have seen tremendous growth in recent years. These technologies provide critical data for monitoring and managing natural resources, environmental changes and human activities on a global scale. As the world increasingly focuses on sustainable development, EO plays a pivotal role in achieving the United Nations' 17 SDGs. This section explores the impact of EO on these goals, highlighting the specific SDGs that benefit the most and detailing the nature of these impacts.

Sustainability goals positively impacted by EO

EO technologies significantly contribute to achieving several of the 17 SDGs. The most directly impacted goals include:

1

No Poverty:
EO technologies help monitor and analyse poverty indicators by providing data on land use, agricultural productivity, and natural resources. This data aids in developing targeted poverty alleviation programmes, improving resource allocation and assessing the effectiveness of interventions.

2

Zero Hunger:
EO data supports agricultural monitoring, crop yield prediction and early warning systems for food security. By providing real-time information on soil moisture, weather patterns, and crop health, EO helps optimise agricultural practices, reduce food waste, and ensure efficient food distribution.

3

Good Health and Well-Being:
EO technologies contribute to health and well-being by tracking environmental factors that affect health, such as air quality, water quality and vector-borne disease patterns. This information supports public health initiatives, disaster response and disease prevention efforts.

6

Clean Water and Sanitation:
EO data enables the monitoring of water bodies, water quality and the impact of human activities on water resources. This information is crucial for managing water resources, ensuring safe drinking water and planning sanitation infrastructure.

7

Affordable and Clean Energy:
EO supports the development of clean energy by identifying appropriate locations for projects such as solar and wind farms. It also helps monitor the environmental impact of energy production and optimise energy infrastructure.

11

Sustainable Cities and Communities:
EO technologies facilitate urban planning and management by providing data on land use, infrastructure development, and environmental quality. This data helps create sustainable, resilient and inclusive urban environments.

13

Climate Action:
EO is critical for monitoring climate change indicators such as greenhouse gas emissions, deforestation and glacial retreat. This data supports climate action by informing policy decisions, tracking progress and identifying areas requiring urgent attention.

14

Life Below Water:
EO technologies help monitor ocean health, including coral reefs, marine biodiversity and pollution levels. This information is essential for protecting marine ecosystems, managing fisheries and mitigating the impact of human activities on oceans.

15

Life on Land:
EO data supports the conservation and sustainable management of terrestrial ecosystems by monitoring deforestation, biodiversity and land degradation. This information aids in protecting natural habitats, restoring degraded land and promoting sustainable land use practices.

Key examples where EO has supported the above-mentioned SDGs have been captured below.

Key case studies

Geospatial data plays a crucial role in addressing food security (**Goal 2**) by providing essential insights into agricultural productivity, land use patterns and environmental conditions. The International Fund for Agricultural Development uses geospatial data to identify vulnerable areas, targeting poor rural communities, analysing climatic hazards and impacts, as well as assessing the state of natural resources. This data-driven approach supports the formulation of its country strategies.

Geospatial data provides valuable insights into public health, environmental factors, and social determinants of health, thus playing a critical role in ensuring healthy lives and promoting well-being (**Goal 3**). During the COVID-19 pandemic, WHO leveraged geospatial technologies for vaccine distribution, planning and monitoring. This technology helped WHO find disease clusters and improve deployment for emergency services.

Thus, the growth of EO technologies offers significant benefits for achieving the United Nations' 17 SDGs. By providing accurate, real-time data on a wide range of environmental and social indicators, EO supports informed decision making, effective resource management, and targeted interventions. As EO technologies continue to advance, their role in promoting sustainable development will become increasingly vital, helping to address global challenges and build a more sustainable future for all.

1.4. EO space value chain

The EO value chain can be segmented into three key phases: upstream, midstream and downstream. Each phase plays a pivotal role in ensuring the efficient collection, processing and delivery of EO data to end users across various sectors.

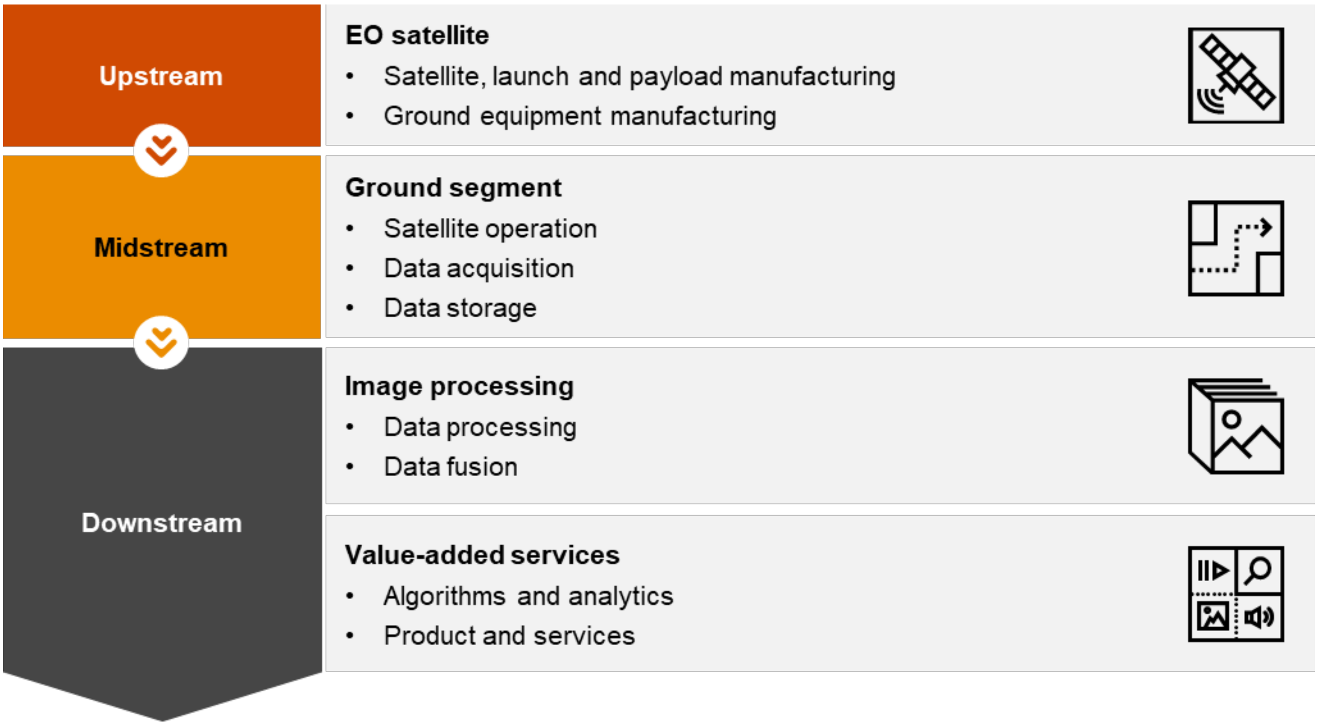


Figure 2: EO space value chain

The upstream segment involves the manufacturing and integration of space assets for EO. This includes the development of satellite buses, which house essential systems like power, communication and propulsion. It also involves creating EO payloads such as multispectral, hyperspectral and SAR sensors, which capture a variety of data types from the Earth's surface.

The midstream segment focuses on the operational aspects of EO, including ground stations, satellite operations and data acquisition. Ground stations receive data transmitted from satellites and manage satellite operations, including tasking for specific observations and continuous monitoring. This segment also encompasses the storage of acquired data for further processing and utilisation.

Finally, the downstream segment involves processing raw imaging data into usable formats. This includes calibration, correction and georeferencing to ensure spatial accuracy. The processed data is then transformed into advanced products and services, such as value-added services, information products and actionable insights, which are delivered to end users in various sectors like agriculture, urban planning and disaster management.

Hence, it is crucial to align the participants across the value chain to foster collaboration, innovation and informed decision making within the space sector. In this regard, SIA-India has taken an initiative to create a database to highlight industry capabilities.[5] The database will boost visibility and partnership potential with key government and private stakeholders.

[5] https://forms.office.com/pages/responsepage.aspx?id=4ZhFQ1bkCEmOk5fyaqzFNqF5n7zZkiJAjsnslbHj96FUQ1ZLTU9IMzc4VUxHUVJBOTI5MEczNElCNi4u

1.5. EO data value chain

As part of the EO data value chain, data acquisition is the initial phase where information about the Earth's surface and atmosphere is collected using a variety of sensors and platforms. Satellites, aircraft, drones and ground-based instruments are among the primary tools used for this purpose. Satellites play a crucial role due to their ability to provide global coverage and revisit frequency. These satellites are equipped with sensors capable of capturing electromagnetic radiation across different wavelengths, including visible, infrared and microwave.

During data acquisition and aggregation, these sensors record electromagnetic radiation emitted or reflected from the Earth's surface and atmosphere. The data collected encompasses a wide range of information, such as high-resolution imagery, spectral signatures and geospatial data. Depending on the sensor's characteristics and mission objectives, data acquisition focuses on specific parameters like land cover, vegetation health, atmospheric composition or oceanic conditions.

Additionally, as part of data acquisition and aggregation, the raw data undergoes various preprocessing steps to correct for sensor artefacts, atmospheric interference and geometric distortions. Once processed, the data is transmitted to ground stations or stored onboard for later retrieval.

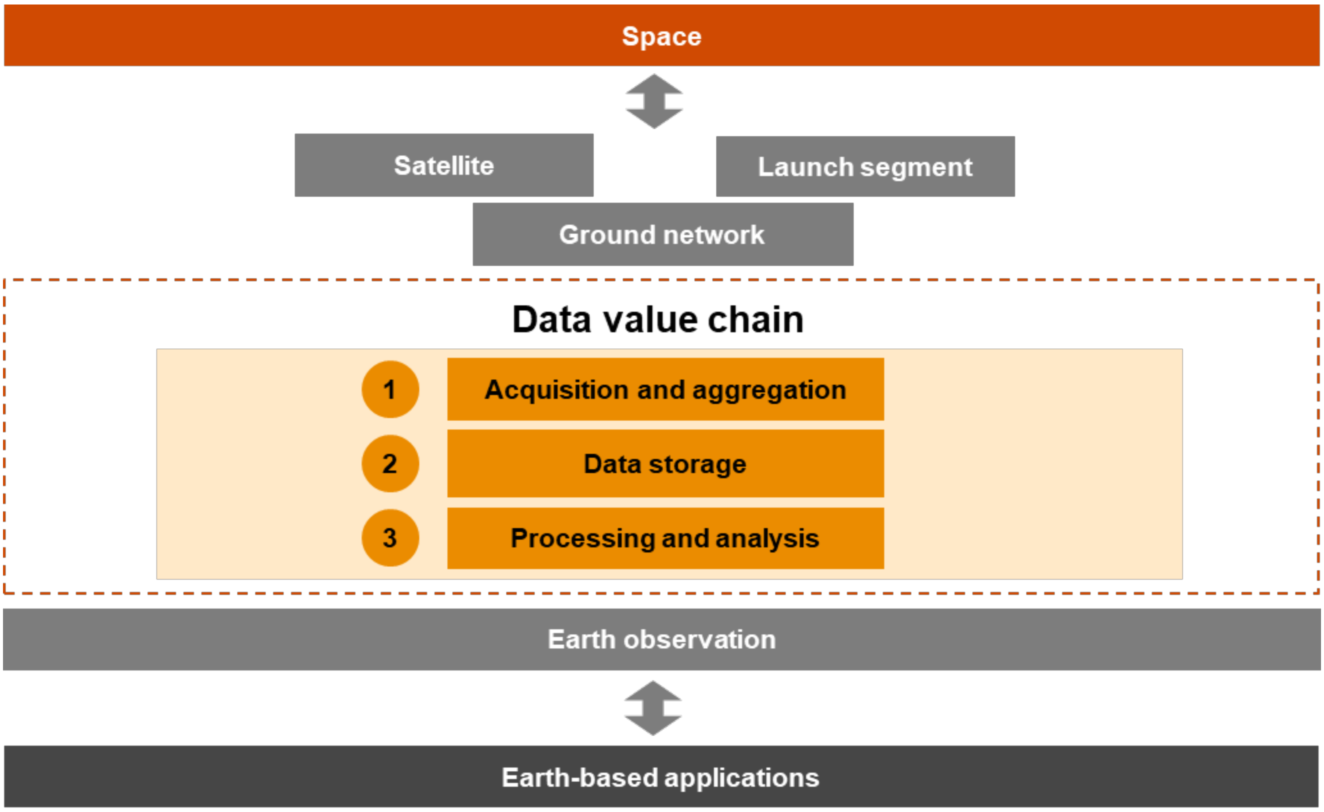


Figure 3: EO data value chain[6]

The last phase of the data value chain involves processing and analysis. This phase involves the application of various computational techniques and algorithms to analyse the data and uncover patterns, trends, and relationships. This includes querying the data to retrieve specific information, correlating different datasets to identify spatial or temporal relationships, and fusing multiple data sources to gain a comprehensive understanding of a particular phenomenon. Change detection techniques are also commonly employed to identify and quantify changes occurring over time, such as land cover changes, urban expansion or environmental degradation.

6 https://www.inspace.gov.in/inspace?id=inspace_decadal_vision_strategy

1.6. EO market size

The EO market encompasses a wide range of technologies, services, and applications related to the collection, analysis, and dissemination of data about the Earth's surface and atmosphere. With continued innovation and the development of more sophisticated remote sensing satellites, India's position in the global remote sensing market is poised for substantial growth. From its market size of USD 521 million in 2022, the industry is expected to grow with a robust CAGR of around 28% over the next decade.[7] Factors contributing to this growth include advancements in satellite technology, expanding satellite constellations, and the proliferation of remote sensing applications.

Key segments within the EO market include satellite imagery, aerial photography, LiDAR, radar imaging and geospatial analytics services. Additionally, the market encompasses various downstream applications such as agriculture, forestry, urban planning, infrastructure development, defence and maritime surveillance. Government agencies, commercial enterprises, research institutions and non-profit organisations are among the major consumers of EO data and services.

The increasing availability of high-resolution satellite imagery, coupled with the growing demand for real-time monitoring and analytics, is expected to further drive market expansion in the foreseeable future. This huge potential is attributed to the utilisation of EO data across different sectors, which has been detailed in the next section.

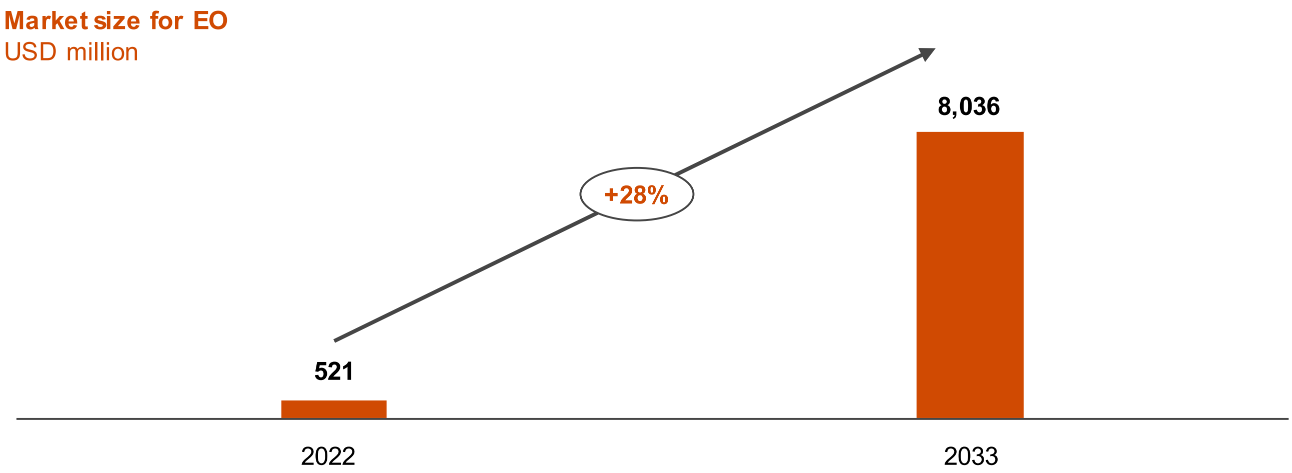


Figure 4: EO market potential

7 https://www.inspace.gov.in/inspace?id=inspace_decadal_vision_strategy

2. EO – a driver for development

2.1. Contribution of EO across sectors

EO, facilitated by advancements in satellite and remote sensing technologies, has revolutionised various industries by providing valuable insights into our planet's dynamic systems. The multifaceted data acquired through these observations plays a pivotal role in enhancing operational efficiency, resource management and risk mitigation across diverse sectors. From consumer solutions to disaster management and for agriculture to finance – the impact of EO is profound and far-reaching. The following sectors are the key contributors to the USD 8 billion market potential of EO. This comprehensive overview delves into how EO can transform key industries and drive innovation for a sustainable future.

Consumer solutions:

EO data enables businesses to offer consumer-centric solutions by providing valuable insights into consumer behaviour, market trends and geographical preferences. For instance, companies can analyse satellite imagery to assess population density, urban expansion and infrastructure development which can help in location-based services, targeted advertising and market expansion strategies.

Transport:

EO enhances transportation systems through improved route planning, traffic management and infrastructure maintenance. Satellite imagery helps monitor road conditions, predict traffic congestion and assess the impact of weather events on transportation networks. Additionally, satellite navigation systems like GPS facilitate precise vehicle tracking, navigation, fleet management and also help in optimising logistics and reducing fuel consumption.

Agriculture, forest and fisheries:

EO plays a crucial role in optimising agricultural practices, forest management and fisheries monitoring. Satellite imagery provides valuable data on crop health, soil moisture and vegetation dynamics, enabling farmers to make informed decisions regarding irrigation, fertilisation and pest control. Similarly, remote sensing aids in forest inventory, deforestation monitoring and biodiversity conservation efforts. In fisheries, satellite-based monitoring systems track vessel movements, detect illegal fishing activities and assess marine ecosystems' health which helps organisations and governing bodies in promoting sustainable fisheries management.

Energy and mining:

EO supports efficient energy production and responsible mining practices by providing insights into resource exploration, environmental impact assessment and infrastructure monitoring. Satellite imagery helps in identifying potential sites for renewable energy projects such as solar and wind farms, assessing geological formations for mineral exploration and monitoring the environmental impact of extraction activities. Additionally, remote sensing data aids in pipeline monitoring, power grid management and disaster resilience planning in the energy sector.

Disaster and emergency management:

EO is instrumental in disaster preparedness, response and recovery efforts by providing real-time monitoring, early warning systems and damage assessment capabilities. Satellite imagery enables rapid assessment of disaster-affected areas, identification of infrastructure damage and coordination of rescue and relief operations. Moreover, remote sensing data aids in monitoring natural hazards such as wildfires, floods and earthquakes, facilitating proactive risk management strategies and enhancing community resilience.

Climate service and environment monitoring:

EO contributes to climate research, environmental monitoring and climate change mitigation efforts by providing comprehensive data on atmospheric conditions, land cover changes and ecosystem dynamics. Satellite observations help track global climate indicators, monitor deforestation rates and assess the impact of human activities on ecosystems. Additionally, remote sensing data can support carbon monitoring, air quality analysis and water resource management enabling policymakers to formulate evidence-based climate policies and conservation strategies.

Infrastructure:

EO supports infrastructure planning, development and maintenance by providing geospatial data, urban mapping and infrastructure monitoring services. Satellite imagery aids in site selection for infrastructure projects, land use planning and infrastructure asset management. Furthermore, remote sensing technologies facilitate the monitoring of critical infrastructure such as bridges, dams and roads for structural integrity, ensuring public safety and resilience against natural disasters.

Insurance and finance:

EO enhances risk assessment, underwriting and claims management processes in the insurance and finance sectors by providing geospatial intelligence, hazard mapping and catastrophe modelling services. Satellite imagery helps assess property exposure to natural hazards, quantify risk factors and streamline insurance pricing strategies. Additionally, remote sensing data support post-disaster damage assessment, claims validation and risk transfer mechanisms, enabling insurers and financiers to mitigate losses and enhance financial resilience.

The following section provides more details on the value proposition, use cases and key users of each sector.

2.2. Users and value propositions across sectors

2.2.1. Consumer solutions

EO data provides valuable insights into consumer demographics, behaviour and preferences enabling the sector, its associated value propositions and use cases. Satellites equipped with EO sensors gather data on population density, urbanisation trends, and consumer habits, thereby helping the consumer solutions sector to understand the market and customise their offerings. Key users within the consumer solutions sector include game developers, government bodies, companies in consumer products, retail, banking and insurance. Let us look at some of the value propositions and use cases of EO in the consumer solutions sector.

a. Value propositions and use cases

Broadcasting, entertainment and advertising industries leverage EO data in several ways to enhance their operations and offerings. EO data helps in creating visually immersive content by providing high-resolution satellite images for documentaries, news broadcasts and entertainment programmes. This enables broadcasters to offer the audiences a more engaging and realistic viewing experience. In the entertainment sector, EO data contributes to the development of realistic virtual environments in video games and virtual reality experiences which enhances immersion and gameplay. Moreover, advertising agencies utilise EO data for targeted marketing campaigns, leveraging insights into consumer demographics, behaviour and preferences based on the location. For example, retailers can use EO data to identify high-traffic areas or popular tourist destinations and target consumers in these locations with customised promotions or discounts.

b. Case study

Space industries of the US and Europe are collaborating to utilise satellite images that will help them in building enhanced digital twins of the Earth and of cities by providing higher quality texture assets and mapping the Earth's landscape (natural or man-made, e.g. cities, infrastructure). An example of this is the creation of digital twins of the Earth using satellite imagery for metaverse technology. By providing businesses with access to detailed and dynamic representations of the world around us, this collaboration empowers them to create more immersive, personalised and impactful experiences for consumers, driving growth and differentiation in an increasingly competitive market landscape.

2.2.2. Transport

Transportation plays a vital role in connecting people, goods and services across the globe, driving economic growth and social development. From monitoring traffic flow and optimising routes to supporting navigation and infrastructure planning, EO satellites empower transportation stakeholders to make informed decisions and improve the resilience and reliability of transportation networks.

Ministries of transport, civil aviation, railways along with ports, shipping and waterways leverage satellite data for infrastructure planning, management and monitoring, ensuring safe and efficient transportation networks. Airport operators, including the AAI, utilise EO satellites to enhance airport operations, airspace management and safety protocols. EO satellites play a transformative role in shaping the future of transportation, driving innovation and facilitating seamless mobility in an increasingly interconnected world.

a. Value proposition and use cases

Enhancing traffic management by leveraging EO satellites can revolutionise transportation systems across railway, maritime and air domains. By integrating satellite data with GPS-based toll systems, toll operators gain real-time insights into road usage patterns, enabling more accurate levy charges and effective congestion control measures. In aviation, performance-based navigation with GNSS and SBAS enhances access to small and medium airports, thereby improving flight efficiency and safety. For instance, in maritime transport, satellite imagery can provide real-time information on vessel locations which can optimise shipping routes and prevent collisions.

b. Case study

Land-use and environmental considerations are critical to ensuring the safe operation of airports. EO-based imaging data supports planning professionals in land and airspace planning, landside access planning, noise monitoring, environmental regulations compliance, wildlife management etc. The imaging data also support obstruction analyses to meet all aviation regulations. Such a solution generates validated electronic airport layout plans, designed to help prepare compliance data for submission to the civil aviation authority.

2.2.3. Agriculture, forestry and fisheries

In agriculture, forestry and fisheries, EO satellites have emerged as a key tool for enhancing productivity, sustainability and resilience. In agriculture, satellite data enables farmers to monitor crops and optimise irrigation leading to higher yields and decreased impact on the environment. In forestry, satellite imagery aids in monitoring deforestation, forest health and biodiversity which enables organisations to plan conservation efforts and sustainable forest management practices more effectively. Similarly, in fisheries, satellite observations help monitor ocean temperatures, sea surface conditions and fish stocks, facilitating sustainable fisheries management and marine conservation. Key users of EO data in this sector include farmers, agricultural cooperatives, ministries, government bodies and fishermen.

a. Value proposition and use cases

In precision farming, self-driving tractors with automatic steering systems streamline core agricultural tasks, allowing farmers to focus on other tasks like strategic decision-making and planning which can maximise their productivity. Satellite monitoring of farm equipment enables real-time reporting of key metrics such as location and hours of operation, optimising equipment usage and reducing downtime.

Utilising EO-enabled variable rate application enhances performance and reduces agricultural inputs by tailoring resources to specific crop needs, thereby promoting resource efficiency and minimising the sector's environmental impact. By leveraging satellite data, farmers can easily locate the nearest cold storage and other facilities for storing the harvested crops.

b. Case study

Companies provide satellite-based crop health monitoring services and field mapping services to identify underperforming locations on the field where plant water stress is low and plant growth is not normal. Such companies also offer interconnected app ecosystems facilitating mapping and monitoring of fields to provide uninterrupted crop health satellite data even during cloudy weather through SAR imagery.

2.2.4. Energy and mining

EO satellite technology is reshaping the energy and mining sectors by offering unparalleled insights for asset management and resource optimisation. From site selection to environmental monitoring, EO data enhances the decision-making processes with real-time information. Companies leverage this technology to streamline operations, mitigate risks and drive sustainable practices. Energy operators, mining companies, and oil and gas firms along with traders, investors and other stakeholders in the energy and mining sectors are leveraging EO satellite technology to gain a competitive edge.

a. Value proposition and use cases

The value proposition of EO satellite technology in the energy and mining sectors is both multifaceted and impactful. In area surveying, including site selection, EO satellites offer unparalleled capabilities for comprehensive, cost-effective, rapid assessment of potential project sites. By providing high-resolution images and detailed terrain mapping, these satellites enable informed decision-making, reducing risks associated with site selection and facilitating the identification of optimal locations for energy and mining operations. For example, EO data aids in identifying optimal sites for resource exploitation as showcased by a project where solar irradiance and wind speed data informed the selection of prime locations for wind and solar farms, maximising energy output.

b. Case study

Companies have developed network of hyperspectral earth imaging satellites as well as analytical tools to extract insights to evaluate the use of high-resolution satellite imagery in mining operations. This imagery reduces the disturbance caused by exploration activities, and helps in tracking the operational and environmental performance of mining operations, and monitoring biodiversity and vegetation health around closed sites. As result, efficiency and sustainability in operations can increase.

2.2.5. Disaster management and emergency response

As the frequency of natural and man-made disasters increases, the need for effective disaster resilience and emergency response systems becomes more critical. EO technologies, particularly those based on satellite data, have emerged as invaluable tools in enhancing the efficiency and effectiveness of these systems. The key users of EO in disaster management and emergency response are disaster management departments, emergency responders and NGOs.

a. Value proposition and use cases

EO technologies offer several advantages in the preparedness phase, including satellite-based population counting, vulnerability analysis, early warning systems and post-event analysis. These early warnings allow authorities to issue timely alerts and take preventive measures.

Disaster management and emergency response could be enhanced by EO in several ways. During the critical search and rescue phase, EO technologies provide situational awareness, enhance emergency communication and support geo-positioning and fleet management solutions. These capabilities are crucial for locating survivors, coordinating rescue efforts and managing resources effectively.

b. Case study

An American geospatial analytics company provides satellite-based global geographic monitoring and communication services which gives users a constellation of satellites in LEO. These satellites help generate reports on wireless signals that support emergencies and provide data analytics services across industries. It also provides situational awareness and collects information for planning mitigation, timely monitoring of the situation and emergency response.

2.2.6. Infrastructure

The infrastructure sector is the backbone of modern economies, encompassing a wide range of activities from urban planning and construction to maintenance and risk management. The integration of EO technologies in the infrastructure sector has revolutionised this sector by providing valuable data and insights for various stakeholders. The key users of EO in the infrastructure sector are ministries and government bodies, state government, municipal corporations, real estate corporations and engineering companies.

a. Value proposition and use cases

EO technologies enhance infrastructure planning through detailed urban analysis, smart streetlight management, vegetation monitoring and urban land use mapping. Monitoring the health and extent of green spaces is crucial for sustainable urban planning. EO data provides precise information on vegetation cover which helps the infrastructure organisations and governing bodies in managing urban green spaces effectively. EO technologies also help in the detailed mapping of urban land use and land cover, including classification of built structures, building heights and urban infrastructure such as roads.

b. Case study

An international financial institution is collaborating with the European Space Agency to use EO data for LULC assessment, topological analysis, flood history and risk assessment, imperviousness estimation, unplanned settlements monitoring and more such use cases.

2.2.7. Environmental monitoring and impact assessment

EO technologies have become critical tools in environmental monitoring and impact assessment, providing comprehensive data which can help in sustainable development and environmental protection initiatives. This section explores the application of EO in various sectors, emphasising its importance for key users such as the ministry of environment and other government bodies, state governments, municipal corporations, ministry of transportation, ministry of civil aviation, AAI, airlines and railways and how EO can contribute towards effective environmental management.

a. Value proposition and use cases

EO technologies provide crucial insights into the environmental impact of infrastructure projects and help stakeholders make informed decisions to mitigate the adverse effects of their projects. This includes assessing changes in land use, water quality and biodiversity. EO data is also used to monitor the release of harmful toxins into water bodies and detect aquifer overexploitation in urban areas. This information is vital for managing water resources and ensuring the availability of safe water. EO technologies detect, collect and interpret information related to various air pollutants, including their origins, movement and potential health risks. This helps in implementing air quality management strategies and reducing pollution levels.

b. Case study

Consumer solutions based companies are utilising EO to measure the growth of trees planted in sourcing regions as a part of their ESG programmes. This initiative focuses on demonstrating the amount of carbon being removed from the atmosphere and helps organisations realise their net zero emission goals.

2.2.8. Insurance and finance sectors

The insurance and finance sector are increasingly leveraging advanced technologies to improve their services, enhance decision-making processes and manage risks more effectively. EO technologies, particularly those which utilise satellite data, are proving extremely valuable in these industries. The key users of EO in insurance and finance are banks and insurance organisations, agri-stakeholders, infrastructure sector and insurance buyers.

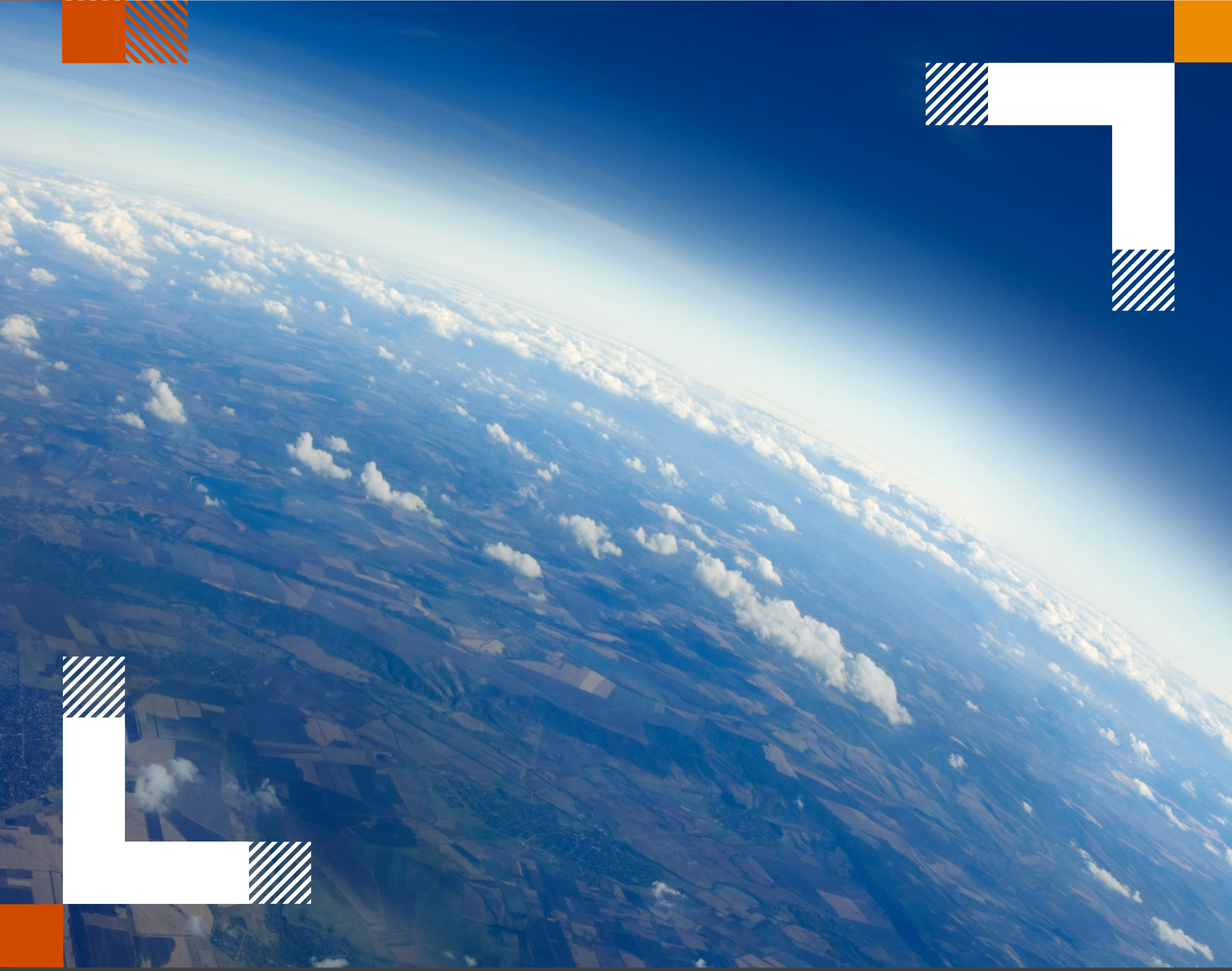
a. Value proposition and use cases

EO technologies provide detailed, accurate data which enhances risk modelling and intelligence and allows insurers and financial institutions to make informed decisions. EO data can be used to develop statistical indices which can understand thresholds and deviations in various parameters such as weather patterns and environmental conditions. These indices help calculate insurance premiums more accurately by reflecting the actual risks involved.

EO enables efficient claim management by providing precise impact assessments and validating claims, leading to faster and fairer compensation. It enables insurers to compare the losses listed in claims against actual damage observed through satellite imagery. This helps in accurately determining compensation, reducing fraud and ensuring that claimants receive fair settlements.

b. Case study

Global companies, are using satellite imagery in the index-based micro-insurance market. Satellite data is used to accurately determine the drought index which is used to develop a risk profile and price insurance policies. Such mechanisms enable the development of improved insurance products and ease the claims verification process.



3. Enabling EO in India

3.1. Key challenges

As India strengthens its capabilities to support and enable the EO domain, it faces the following hurdles in optimising EO's potential:

01	**Gaps in existing infrastructure for supplying structured and the reliance of private players on other international agencies:** While, collaborative ventures enable cost-sharing, data-sharing and technology transfer, they also entail complex negotiations, coordination and regulatory compliance. Additionally, India faces challenges in ensuring access to low and competitive pricing due to gaps in the infrastructure and the reliance on international agencies for satellite imagery data. This data is essential for promoting widespread adoption and commercialisation of EO services.
02	**Need for data sets which are compatible with AI and ML to enable efficient analysis and interpretation:** It is critical for India to ensure the compatibility of data sets with AI and ML algorithms to extract meaningful insights and facilitate decision-making across diverse sectors, including agriculture, urban planning and disaster management. However, achieving this compatibility requires standardisation of data formats, metadata, and processing protocols as well as the development of specialised algorithms tailored to EO applications.
03	**Increasing requirement of EO and constellations to meet growing demand and coverage requirements:** The demand for EO satellites and constellations continues to rise, driven by the need for comprehensive and real-time monitoring of various phenomena, including environmental changes, natural disasters and urban development. This increase in demand necessitates substantial investments in satellite infrastructure and launch capabilities in India along with the development of advanced technologies to support data processing, storage and transmission.

3.2. Proposed EO platform

An EO platform will encompass five broad layers, supported by upstream for access to data. The output from this platform may aid in application development for different users across various user segments.

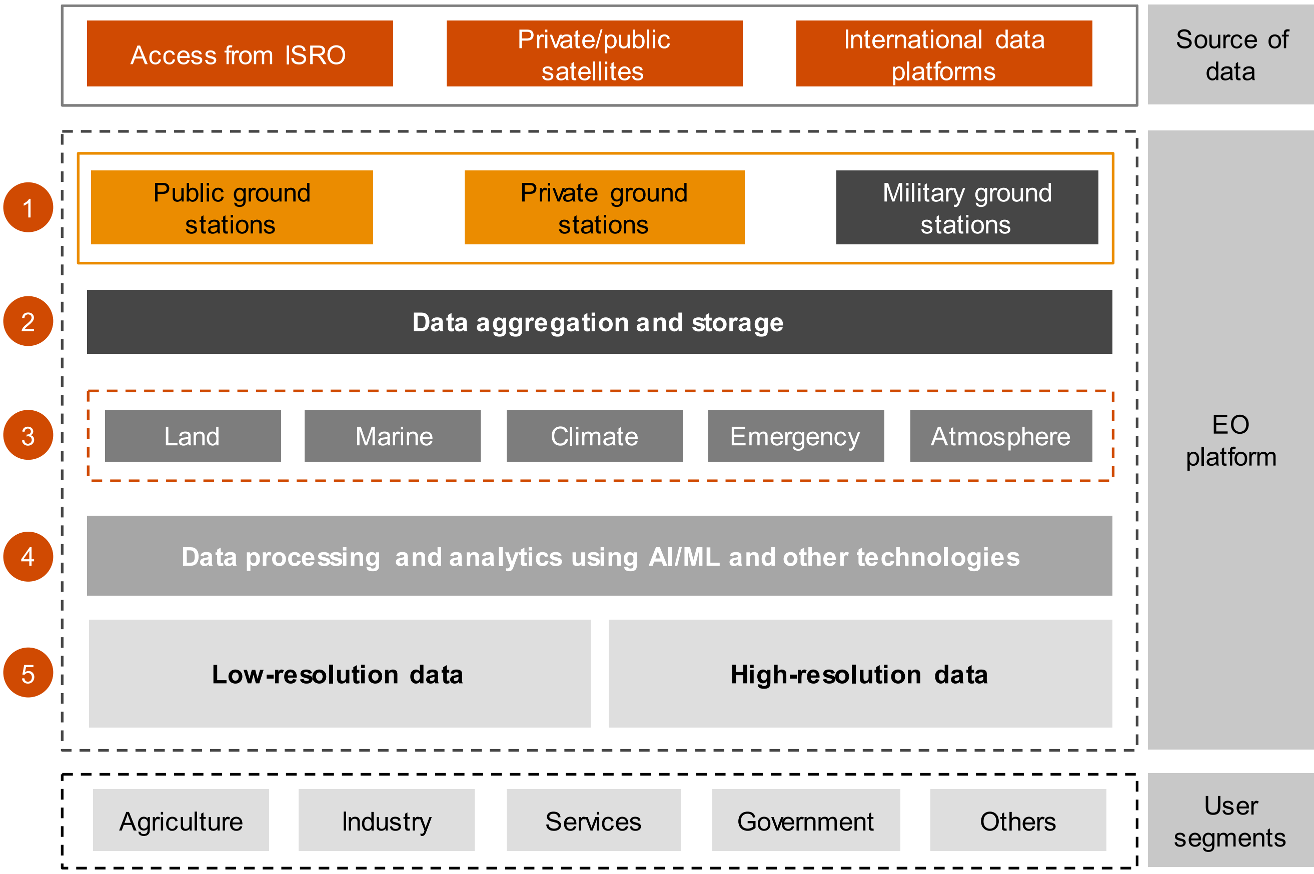


Figure 5: Envisioned EO platform[8]

[8] https://www.inspace.gov.in/inspace?id=inspace_decadal_vision_strategy

The EO platform would source its data from a wide array of space assets including satellites and other space-based instruments operated by ISRO as well as those from private and public sector entities and international data platforms. The platform is proposed to have several interconnected layers, each with a specific function to ensure the efficient and accurate delivery of data to various user segments. Some of the layers are:

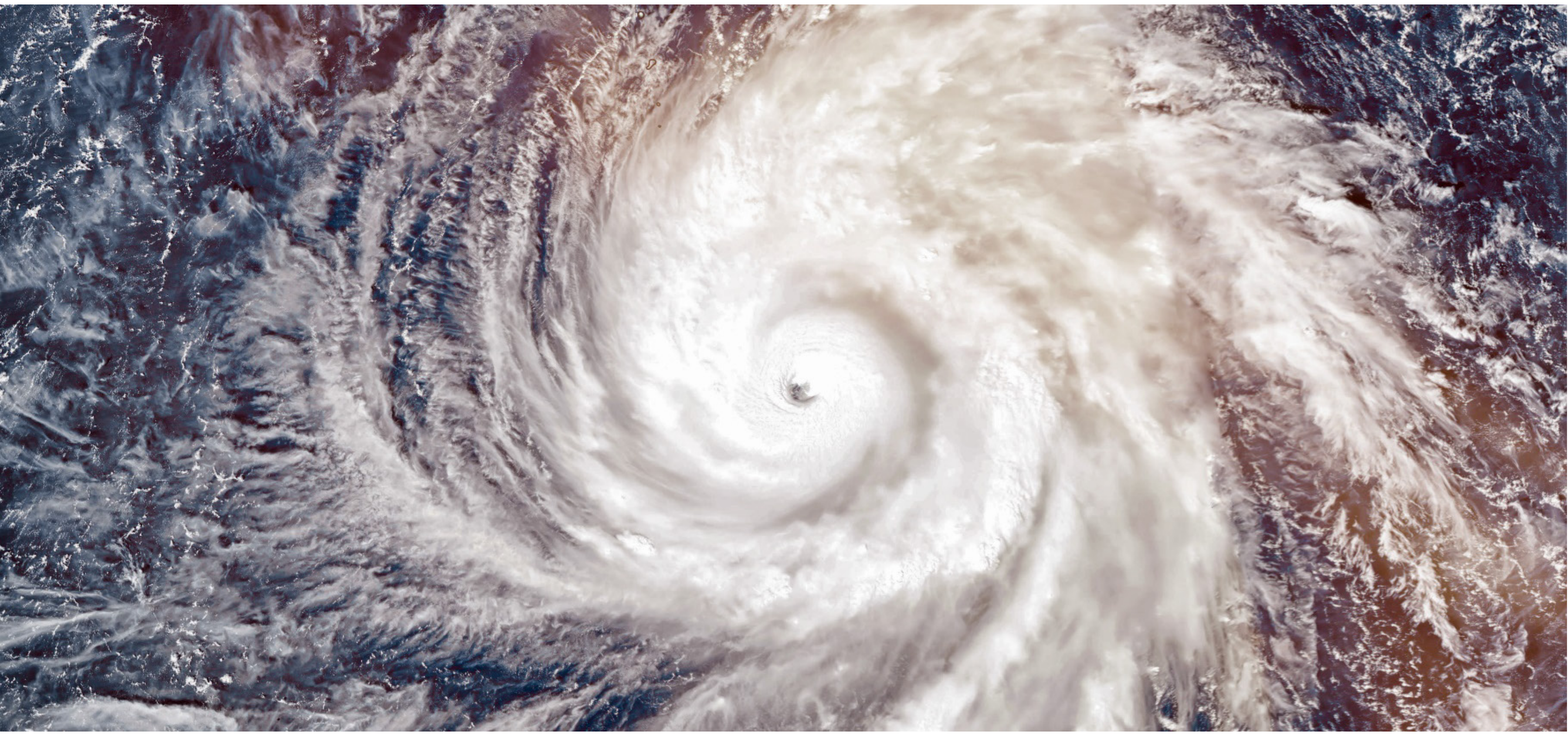
1	**Ground stations:** The initial layer of the EO platform would include ground stations. These stations would be a part of a network which include facilities from public, private and military sectors. The stations would play a critical role in receiving data transmitted from the space assets, acting as the first point of contact for the data collected from space.
2	**Data aggregation and storage:** The next layer would involve the aggregation and storage of data. This layer would collect data from all the ground stations, integrate it and store it in centralised repositories. This aggregation would be essential for managing large volumes of data and ensuring its availability for further processing.
3	**Data classification layer:** After data storage, the platform would include a data classification layer. In this layer, data would be categorised and tagged with metadata which identifies various types of data such as land, marine, climate, emergency and atmospheric data. This metadata tagging would help in organising the data and making it easier to access and analyse for specific applications.
4	**Data processing and analysis:** In this layer, the platform would employ advanced technologies such as AI, ML and other emerging technologies to process and analyse raw data. This step would be crucial for converting the raw data into meaningful information that can be readily used by various applications to derive actionable insights.
5	**Segregation of data:** The processed data would then be segregated into low-resolution and high-resolution data suites. This segregation would be tailored to meet the needs of different user segments, ensuring that each user group receives data that is most relevant and useful for their specific requirements.
6	**User segments**: Finally, the EO platform would disseminate the processed and classified data to various user segments. These segments would include agriculture and allied sectors, industries, services, and government and other sectors. Each segment would utilise the data for a range of applications, from agricultural planning and industrial monitoring to emergency response and environmental management.

3.3. Additional recommendations to support EO in India

Given below are a few recommendations to further strengthen the EO ecosystem in India and support the establishment of the proposed EO platform:

1	**Establishment of additional EO satellites through PPP:** Expanding the network of EO satellites will address existing data gaps and provide comprehensive information in a timely manner. Collaborating with private sector partners can accelerate the deployment and innovation if the platform by leveraging private investments and expertise.
2	**Managed services model for non-strategic ground segment operations:** Outsourcing non-strategic ground segment operations to managed services providers can enhance efficiency, reduce costs and allow ISRO and other government entities to focus on strategic and high-priority tasks.
3	**Establish a CoE for algorithm development (including AI/ML):** A dedicated centre for algorithm development will drive innovation in data processing and analysis and help in enhancing the utility of EO data. AI and ML will help in generating advanced, automated data insights and improve decision-making capabilities across various sectors.

The detailed study and analysis undertaken highlights the vast potential applications of EO technologies across various industries and how they can drive economic growth and sustainability in India. In this regard, PwC has leveraged its extensive experience in the space sector to comprehensively understand the EO domain and meticulously identify over 200 use cases that could encourage the advancement of EO enterprises over the next decade.



Glossary

Sr. no.	Acronym	Full form
1	AAI	Airports Authority of India
2	AI	Artificial intelligence
3	API	Application programming interface
4	CAGR	Compounded annual growth rate
5	CoE	Centre of excellence
6	DEM	Digital elevation model
7	EO	Earth observation
8	ESG	Environmental, social and governance
9	ETL	Extract, transform and load
10	FDI	Foreign direct investment
11	GNSS	Global navigation satellite systems
12	GPS	Global positioning system
13	HEO	Highly elliptical orbits
14	HTML	Hypertext markup language
15	ISR	Intelligence, surveillance and reconnaissance
16	ISRO	Indian Space Research Organisation
17	LEO	Low earth orbit
18	LiDAR	Light detection and ranging
19	LULC	Land use/land cover
20	ML	Machine learning
21	NavIC	Navigation with Indian Constellation
22	NGO	Non-governmental organisation
23	NGP	National Geospatial Policy
24	OEM	Original equipment manufacturer
25	PPP	Public-private partnership

Sr. no.	Acronym	Full form
26	R&D	Research and development
27	ROI	Return on investment
28	SAR	Synthetic aperture radar
29	SBAS	Satellite-based augmentation systems
30	SDG	Sustainable Development Goal

Notes

About SIA-India

SatCom Industry Association (SIA-India) is a not-for-profit body created to represent the interests of the satellite communication ecosystem in India.

As a dynamic, not-for-profit space sector association, SIA-India is dedicated to advancing sectoral interests, accelerating industry growth, and catalysing innovation through strategic engagements with key governmental and global stakeholders, policymakers, regulatory bodies, and standardization entities, aiming to create a vibrant and innovative ecosystem.

As 'Thought leaders' for the satellite communications ecosystem, we aim to present the industry's interest at the highest Government levels for policy-making, regulatory and licensing matters.

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