Indian Council of World Affairs

INDIA'S SPACE AND SATELLITE DIPLOMACY

Developing Partnerships *in* Blue Economy *and* Climate Change *in* The Global South

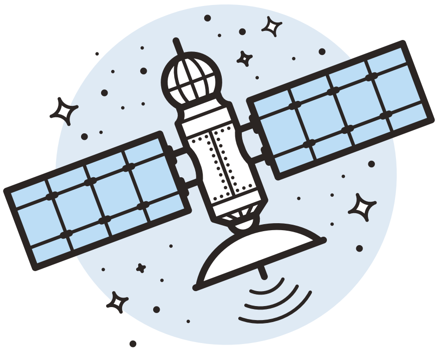
INDIAN COUNCIL OF WORLD AFFAIRS

SAPRU HOUSE, NEW DELHI

2025

Indian Council of World Affairs

INDIA'S SPACE AND SATELLITE DIPLOMACY



Developing Partnerships *in* Blue Economy *and* Climate Change *in* The Global South

Indian Council of World Affairs
Sapru House, New Delhi

2025

ISBN : 978-93-83445-89-9

Disclaimer: The views, analyses, and recommendations in this publication are those of the authors.

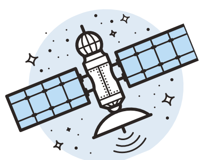
CONTENTS

Foreword

Space and satellite research, a new frontier of diplomacy, is an endeavour of a collective journey, which is not for and of any single country or group of countries. India's space diplomacy does not emanate out of a prestige driven or a competition driven objective, but key focus has been to use this frontier technology for developmental purposes and human upliftment through sustainable methods. It is pivotal that developing countries engage in space diplomacy—leveraging space science and technology to bolster foreign policy and development partnership objectives and domestic space capacities for realising their development targets— not to be left out from the benefits it offers. Indeed, it has been a challenge for less developed economies and politically unstable geographies, to pursue, invest or develop space science and technology, which demands economies of scale which India can afford. India has brought forth the true story of how a newly independent country with a fledgling economy can dream and pursue a space program from scratch, turning into a success story of providing the most dependable as well as economical space program in the world. No country has yet been able to replicate our lunar mission which successfully achieved its objectives at such minimal cost.

Though India's space program has many dimensions, this publication makes an attempt to identify the role India's space program has played in climate action and in the sustainable development of 'blue economy', especially in the context of countries in the Global South. India has already developed a robust technological knowhow, showcasing how tools such as satellite imagery and remote sensing are revolutionizing sectors like fisheries, maritime navigation, meteorology and marine biodiversity conservation. By leveraging these technologies, stakeholders can enhance operational efficiency, monitor ocean resources, and develop sustainable practices that support both economic growth and environmental health.

Monitoring climate change is another critical aspect where India's space program has been playing a crucial role. It is not only involved in gathering and analysing satellite data in tracking climate patterns, it is also involved in studying sea-level rise, soil studies, forest management, weather monitoring and forecasting and the overall health of marine environments. Such empirical evidence not only informs



policy decisions but also underscores the necessity of international collaboration in data sharing and capacity building.

India's exploration of space is not a new and sudden endeavour. Scholars from ancient India had a strong interest in space and astronomy, with detailed celestial observations and cosmological ideas documented in texts such as the Vedas and Puranas, dating back to the Vedic period (1500-600 BC). This knowledge was used for timekeeping, rituals, and tracking the movements of celestial bodies like the sun, moon, and stars. Renowned astronomers like Aryabhatta expanded on these ideas, calculating the earth's circumference and suggesting a helio-centric model, showcasing India's major contributions to the understanding of the cosmos throughout history. Building on such ancient wisdom and knowledge, visionaries of modern India envisaged to develop modern India's indigenously owned space research program with a focus on telecommunications and meteorology. The philosophical underpinnings of India's modern space programme is derived from ancient Indic thought which seeks to understand and conceptualize the cosmos to harness it for human benefit and for the benefit of human relations.

India has shown a strong commitment to advancing space diplomacy and promoting sustainable development, contributing to its own progress while also supporting the growth of other countries in the Global South. India considers its Space Research Program as a "Common Heritage of Mankind" highlighting the shared responsibility of nations to safeguard and manage global resources such as oceans and space, where many nations have been at the receiving end of tech denial by the developed West. India's own experience in this regard has shaped its world view regarding technology and international relations. India seeks to share the strengths of the network of space institutions that it has developed over the decades pan-India with its friends in the Global South to collective advantage. India's satellite diplomacy is based on the principle of development partnership which is based on trust, understanding the requirements of the development partner and working together so that such partnership ultimately leads to human capacity building, ease of living, and enhanced well-being, care for the future and sustainable development, maintaining a human-centric approach, aspiring for common prosperity and growth. This positive narrative of mutual growth and cooperation is a path that India has been following, sharing its expertise where required, thus enhancing the access to knowledge and domain expertise.

India has partnership space programs with diverse nations like Bhutan and Brunei, having ground stations in both the nations, while it has been building a Mega ISRO Ground Station in Vietnam for ASEAN countries. It is also exploring areas of partnership and seeking avenues of collaboration with countries like Kenya in developing and expanding Africa's space capabilities. ISRO has collaborated with Latin American countries, including Mexico and Brazil, on space projects. ISRO has also been a reliable, viable and cost-effective option when launching nano, micro and other satellites for countries of the Global South. Though space is a dual use sector, India has primarily worked in this sector though the lens of promotion of science and technology for development, human well-being and prosperity. India's space diplomacy similarly has worked to achieve shared developmental objectives and build a common narrative of mutual trust and cooperation.

This publication brings together three papers, which makes a holistic attempt of bringing scholars, practitioners as well as experts analysing India's space program and how it has expanded to bring into its fold countries of the Global South. The publication will prove to be useful to scholars and practitioners alike who are studying the evolution of India's space program, its satellite diplomacy and the growth and cooperation it has achieved or is striving to achieve in the areas of climate change and blue economy.

The Preparation of this publication has been coordinated by Dr. Dhrubajyoti Bhattacharjee, Research Fellow, ICWA and Mr. Keshav Verma, Research Associate, ICWA.

Ms. Nutan Kapoor Mahawar
Additional Secretary
Indian Council of World Affairs
Sapru House
New Delhi

April 2025

INDIA'S SPACE COLLABORATION IN GLOBAL SOUTH

Dhrubajyoti Bhattacharjee *and*
Keshav Verma

India's space program is among the oldest and most developed in the world. It has transformed from a baseline scientific undertaking to a significant player in international space relations. India, as an emerging power in space, considers its space capabilities as important instruments for addressing issues like climate change and the blue economy. Understanding the history of India's vision in space reveals how its achievements in space technology have been linked with socio-economic progress, international and multilateral relations, and regional and international cooperation.
India has not only advanced space technology for itself, but through its strategic engagement with the Global South, India leverages space technology for development. India has helped many developing countries, especially with issues related to climate change and sustainable development of oceans.

Beginning of India's Space Program

The development of India's space program began with the initial steps of space research in the country, preceding the formation of the Indian Space Research Organization in 1969. Development of India's space program began with Vikram Sarabhai, known as the father of India's space program. The Indian National Committee for Space Research (INCOSPAR) was founded in 1962 under Sarabhai's leadership.[1] This organization was later changed into ISRO-Indian Space Research Organisation. The aim was very precise: Satellites in the orbit shall be used for the socio-economic growth of the country. As a difference from several other space programs across the world which stemmed out of prestige-driven objective in a cold war dynamic. India's key focus was deploying satellites from a civilian developmental purpose. Sarabhai's vision was centred on the need for communication satellites and satellite-based meteorology as well as mapping of the earth's resources.

Sarabhai was a strong advocate for the growth and advancement of a nation. He believed that the further development and modernization of the country relied heavily on technology, especially space technology. His beliefs were in accordance with those

1 ISRO. n.d. "About Indian Space Research Organisation". https://www.isro.gov.in/profile.html.

Sarabhai was a strong advocate for the growth and advancement of a nation. He believed that the further development and modernization of the country relied heavily on technology, especially space technology.

of Prime Minister Jawaharlal Nehru, who was keen on making science and technology and a scientific temperament the focal point of reconstruction in India after gaining independence. As a result, the country's objectives for modernity, escaping the underdevelopment trap, progress and international recognition came to be associated with its endeavours in space.

In collaboration with other countries like the Soviet Union, the United States, and France, India was able to achieve basic capabilities in space technology. One of the most significant advances in space technology came with the creation of the Thumba Equatorial Rocket Launching Station or TERLS in 1963, which aided launch of sounding rocket.[2] This garnered interest in India's prospective plans in space, which furthered the country's international cooperation, ensuring the acquisition of important knowledge and resources without relying on one specific nation.

The SITE (Satellite Instructional Television Experiment), which was executed in collaboration with NASA, was one of the remarkable milestones achieved during the early years of the Indian space program in 1975.[3] It aimed at telecasting educational programs for the rural populace in India, thus, setting the framework for the use of satellites in advancement of education and improvement of life standards. Other later initiatives such as the STEP (Satellite Telecommunication Experiments Project) and the INSAT (Indian National Satellite) systems further strengthened India's leadership in the use of space technology for socio-economic advancement.[4]

2 ISRO. n.d. "Sounding Rockets" https://www.isro.gov.in/soundingRockets.html.

3 Karnik, Kiran. 2016. "Early Experiments with Technology - The Hindu." The Hindu. 2016. https://www.thehindu.com/opinion/op-ed/Early-experiments-with-technology/article10322024.ece.

4 ISRO. n.d. "Genesis." https://www.isro.gov.in/genesis.html.

Development of Space Diplomacy

The space diplomacy of India has seen decades of change and evolution, marked with significant events and developments of importance. Currently, under the leadership of Prime Minister Narendra Modi, India seeks to expand its initiatives to function as a core of international space diplomacy. PM Modi has not only aided the development of technologies related to space but serves as a great re-strategizer of Indian space diplomacy on the global stage. Regarding PM Modi's vision for the Indian space program, it heavily focuses on the development of Global South through space diplomacy always prioritizing shared technology, building strategic trust, and shared capacity development leveraging India's growing strengths and leadership in the sector.

The recent phase of space diplomacy of India marks the growing augmentation of satellite collaborations in the context of cooperation as well as problem solving at the global stage. India's satellite systems and space technology capabilities, especially in the field of satellite earth observation, can be matched to the requirements of many developing countries. This is specially the case about India's initiatives towards aiding other countries in the assessment and management of climate change, natural resources, blue economy and development.

Perhaps one of the most important strands of space diplomacy of India has been aiming towards the support of mitigation and adaptation measures for climate change in the Global South. The Indian Space Research Organisation has made significant strides in designing and building Earth Observation Satellites capable of providing critical data for monitoring ecological changes. For example, the Indian Remote Sensing satellites that were deployed during the late 1980s. Their function extended well

The recent phase of space diplomacy of India marks the growing augmentation of satellite collaborations in the context of cooperation as well as problem solving at the global stage.

beyond the management of disasters, agriculture as well. Today, these systems are an integral part of the infrastructure of many countries in Africa, Southeast Asia and Latin America, providing data that help in mitigating the terrible consequences of disasters, controlling deforestation, and managing waters.

India has been actively engaging with the world through the United Nations Framework Convention on Climate Change (UNFCCC) as well as the Paris Agreement, where satellite data is important in emission tracking, temperature monitoring, and ecosystem health assessment. Sharing her satellite data and technology, India has shown resolve in providing climate action support to developing nations, most of the time, the most susceptible to the impacts of climate change.

In addition to the impacts of climate change, India is also making strides in the blue economy through space diplomacy. The blue economy involves the sustainable resource use of ocean resources and is of great importance not only for island nation states but also coastal countries, particularly those in the Global South. India's space program has been a boon for these countries as the Oceansat satellites provide important data for monitoring various marine ecosystems, ocean current assessment, and sea-level rise evaluation. Such data is critical for these countries whose economy is reliant on climate-sensitive industries like fisheries, tourism, and shipping.

Moreover, India's investment in ocean resources is linked to global issues as part of their development strategy for countries in the Southern Hemisphere. While some nations struggle with ocean-related issues, India has satellite solutions and has thus enhanced her leadership in space diplomacy. The partnership of India with countries like Sri Lanka, Maldives along with some African countries showcase how far space technology can go in solving common problems of managing marine resources, climate change, and adaptation. India's diplomacy in space has several core policy drivers, which include nurturing relations with emerging economies and other international actors regardless of their development stage and fostering bilateral and multilateral diplomatic dialogues.

Understanding how deeply rooted the principles underlying India's space diplomacy are, one can clearly see the intent of how India formulates its international engagements in the space sector:

- **Trust and Collaboration:** One of the main features of India's space diplomacy is the focus on trusting relationships and cooperative frameworks. For a long time, India has advocated that space technology should be utilized for peaceful objectives and no one nation should be disadvantaged in the advancement of space technology. India's policy of multilateral cooperation rather than competition among countries has helped promote a sense of trust among the developing nations. India, through its offer of technology transfer, capacity-building programs, and satellite data-sharing agreements, has shown that it is willing to work together with other countries to address their challenges.

- **Development Partnership:** India's space program has been development-focused from the very beginning and rests on deploying science for development and human upliftment. This is evident in the strides made by India using space-based technologies for disaster management, monitoring agricultural productivity, and even providing telemedicine services. India's approach to space diplomacy reflects its broader philosophy of South-South cooperation, where the focus is on mutual growth and shared benefits. In catering to the developmental needs of other nations, India is a lead player in the Global South which has established itself as a development partner while

> For a long time, India has advocated that space technology should be utilized for peaceful objectives and no one nation should be disadvantaged in the advancement of space technology. India's policy of multilateral cooperation rather than competition among countries has helped promote a sense of trust among the developing nations.

In catering to the developmental needs of other nations, India is a lead player in the Global South which has established itself as a development partner while itself trying to combat poverty, inequality, climate change, and many other issues.

itself trying to combat poverty, inequality, climate change, and many other issues.

- **Human-Centric Approach:** One of the key features of Indian space diplomacy is the human-centric approach, which means that people are placed at the centre of space initiatives. The space program of India goes beyond merely advancing technological prowess; it strives to utilize such technological advancements to address real-life issues. From enabling access to educational materials through satellites to assisting various countries during natural disasters, the objectives of Indian space diplomacy have always been to enhance and secure the lives of people, especially in developing nations. This approach has allowed India to forge very deep and lasting friendships with African, Asian, and Latin American countries.

South Asia

India directs its space diplomacy towards the use of space to foster development and relations with other countries, especially those nearby, to address regional issues. In the course of time, India has used its space program to assist South Asian countries in several ways including providing satellite communication, Earth observation, and meteorological services. All this is possible due to

From enabling access to educational materials through satellites to assisting various countries during natural disasters, the objectives of Indian space diplomacy have always been to enhance and secure the lives of people, especially in developing nations.

The GSAT-9 satellite has benefited Afghanistan, Bangladesh, Bhutan, the Maldives, Nepal, and Sri Lanka, countries which acknowledge India's role as a regional space leader.

India's desire for regional cooperation aimed at sustainable development in South Asia and its desire to share its technological strengths with its neighbours as a mark of good – neighbourliness.

India positioned satellite "GSAT-9, the South Asia Satellite" in 2017, as a tool to augment the South-Asian Association for Regional Cooperation (SAARC) nations.[5] Such measures aim to boost India's persisting goal of becoming the key regional power in terms of space technology as well as modern services. GSAT-9 was built with special features in communication, broadcasting, and even in telemedicine. With increased capacity for telecommunications, and broadcasting services, the satellite serves South Asian nations effectively and assists in disaster management during times of emergency. This just shows the leap in space diplomacy as they move forward to using satellite systems for more tele-communications-based solutions and active participation at solving regional issues. The satellite is intended to foster better communication, particularly for remote and underserved regions, while also

https://danielmarin.naukas.com/files/2017/05/f0902.jpg

5 ISRO. 2017. "GSAT-9." 2017. https://www.isro.gov.in/GSAT_9.html.

offering critical services like disaster management during emergencies. The GSAT-9 satellite has benefited Afghanistan, Bangladesh, Bhutan, the Maldives, Nepal, and Sri Lanka, countries which acknowledge India's role as a regional space leader.

In addition to the GSAT-9, India's space collaboration extends to various other domains. For example, through bilateral and multilateral agreements, India has provided satellite data and services for weather forecasting, agriculture, education, and healthcare. These efforts demonstrate India's broader goal of using space technology to promote inclusive development and capacity-building across the South Asian region.

India has actively engaged itself in the global satellite-aided search and rescue program known as COSPAS-SARSAT.[6] Under this program, India offers distress alert and position location services to its neighbours like Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka, and even Tanzania. Additionally, India has supported regional meteorological instrumentation with the project SAARC STORM (Severe Thunderstorms: Observations and Regional Modelling).[7] This project of scientific collaboration includes other SAARC members Bangladesh, Bhutan, Nepal, and India, and seeks to improve forecasting of severe storms.

Sri Lanka has participated actively alongside India in various of its space-related projects. The initiative of ISRO's support to Sri Lanka's space program showcases the increasing importance of space diplomacy towards bilateral relations. Also, the support of India to Sri Lanka is immense in terms of sharing data related to Earth observation, more specifically in agriculture, management, water resources, and disaster management. In case of the Maldives, the support which India has provided for the country is focusing on the enhanced protection of the rising seas and extreme weather conditions. As an island nation Maldives depends largely on space borne technologies for tracking environmental changes; India extends helps to the country by providing the satellite imagery and data required to monitor the increase

6 ISRO. n.d. "Satellite Aided Search and Rescue." https://www.isro.gov.in/SatelliteAidedSearchAndRescue.html.

7 SAARC Disaster Management Centre. n.d. "Implementation of SAARC-STORM Project | SAARC Disaster Management Centre (IU)." https://saarc-sdmc.org/implementation-saarc-storm-project.

India has also under-taken the responsibility through the collaborations under COSPAS-SARSAT of providing support for search and rescue operations to the remote communities of people living near the coastal areas thus enhancing the security of life.

in the level of seas, coastal erosion, and other climate change impacts. India has also under-taken the responsibility through the collaborations under COSPAS-SARSAT of providing support for search and rescue operations to the remote communities of people living near the coastal areas thus enhancing the security of life.

India has helped Nepal to bolster its meteorological capabilities through its space initiatives. Given Nepal's difficult geography, India's skilful technologies for monitoring and predicting severe storms have been beneficial. These collaborations assist in timely disaster response to floods and landslides that are frequent in Nepal. India has also helped Nepal cope with the changing climate by providing her satellite data for disaster management and resource monitoring. With Bhutan, the impact of India's space collaboration has been evident in the technological advancement of the country and disaster management's operational capacity. India offered initial support in the launch of Bhutan's Satellite "Bhutan-SAT" and has played a continuous role in supplying high-resolution resource management images.[8] These developments have immensely helped Bhutan in monitoring severe weather events which are crucial for agriculture and disaster management in the mountainous region.

The Information Fusion Centre – Indian Ocean Region (IFC-IOR) leverages space technology to enhance maritime security and assist South Asian countries and beyond in addressing regional challenges.

8 Ministry of External Affairs. 2022. "Launch of India-Bhutan Satellite." 2022. https://www.mea.gov.in/press-releases.htm?dtl/35924/Launch_of_IndiaBhutan_Satellite.

> India also actively maintains and establishes ground stations throughout Southeast Asia for the remote tracking and telemetry of satellites.

Further, the **Information Fusion Centre – Indian Ocean Region (IFC-IOR)** leverages **space technology** to enhance maritime security and assist **South Asian countries** and beyond in addressing regional challenges. IFC-IOR tracks vessels in real-time using satellite-based AIS (Automatic Identification System) and Remote Sensing integrated with Geospatial Intelligence.[9] This enables nations to monitor their Exclusive Economic Zones (EEZs) and mitigate maritime crimes such as illegal fishing, smuggling, and piracy. The centre's data enables provision of high-resolution imagery and weather forecasting, which are critical during responding to disasters and ensuring maritime safety. For other South Asian countries with limited access to such infrastructure, IFC-IOR serves as a force multiplier, empowering these nations with critical intel and timely warning systems to enhance their maritime domain awareness and decision-making. This integration enables overarching improvements in the Indian Ocean's regional security, economic development, and environmental safeguarding. Space based assets are critical to cooperative frameworks on maritime domain awareness and their effectiveness and India is making its contribution in the IOR and Indo-Pacific towards this end.

Southeast Asia

India has enhanced its collaboration with Southeast Asian countries over the years, focusing on sharing technology, building capacity, launching satellites, and developing infrastructure. The ISRO has been instrumental in promoting regional cooperation to strengthen the space capabilities of Southeast Asian countries.

India also actively maintains and establishes ground stations throughout Southeast Asia for the

9 Rai, B Ranjit Commodore. 2024. "Guardians Of The Indian Ocean: How India's IFC-IOR Is Transforming Maritime Security – Analysis – Eurasia Review." Eurasiareview. 2024. https://www.eurasiareview.com/08082024-guardians-of-the-indian-ocean-how-indias-ifc-ior-is-transforming-maritime-security-analysis/.

remote tracking and telemetry of satellites. The Telemetry, Tracking, and Command (TT&C) station in Brunei is a prime example. Established in 2000, the station operates under a bilateral agreement signed in 1997.[10] In 2018, a new MOU was made allowing ISRO to augment and maintain the station in addition to training Brunei nationals in satellite technology. India is also setting up a ground station in Vietnam that will serve ASEAN countries such as Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam as a remote sensing data reception, processing, and dissemination centre.[11] The station will provide crucial data for planning and managing disasters, monitoring the environment, and agricultural forecasting.

The cost-effective satellites and launchers from ISRO have increased its popularity among Southeast Asian countries. Even Singapore has become a large centre for space activities with Singaporean satellites launched by ISRO. Singapore now ranks third for ISRO's satellite launching services.[12] The India-Singapore Technology Summit of 2022 boosted collaboration even further through an MoU regarding collaboration on space technology, fostering innovation for the future in satellite technology and space exploration.[13]

Indonesia is also collaborating with India. The India-Indonesia space cooperation has deep roots, dating back to the late 1990s. Key milestones include the establishment of Telemetry, Tracking, and Command (TTC) Stations in Biak, Indonesia, and multiple MoUs that have expanded the partnership over the years.[14] On March 19, 2024, India and Indonesia inked the Implementation Agreement for the Transfer of Title of Integrated Biak Telemetry, Tracking, and Command (TTC) Facilities. This collaboration

10 Space Watch GLOBAL. 2018. "Sultanate Of Brunei To Host Indian Satellite Tracking And Telemetry Station - SpaceWatch. GLOBAL." Space Watch GLOBAL. 2018. https://spacewatch.global/2018/09/sultanate-of-brunei-to-host-indian-satellite-tracking-and-telemetry-station/.

11 Kumar, Chethan. 2021. "Space Diplomacy: India Building Ground Station for Asean Countries in Vietnam." The Times of India. 2021. https://timesofindia.indiatimes.com/india/space-diplomacy-india-building-ground-station-for-asean-countries-in-vietnam/articleshow/84066043.cms.

12 Wikipedia. n.d. "Space Collaborations between Singapore and ISRO."https://en.wikipedia.org/wiki/Space_collaborations_between_Singapore_and_ISRO.

13 "DST-CII India - Singapore Technology Summit." n.d. 2022. https://www.ciihive.in/Login.aspx?EventId=ISTSummit.

14 Space News. 2002. "ISRO Signs MOU with Indonesian Space Agency -." 2002. https://spacenews.com/isro-signs-mou-with-indonesian-space-agency/.

UNNATI (UNispace Nanosatellite Assembly & Training by ISRO) is an exemplary initiative for assisting developing countries in skill development through building microsatellites that are multifunctional and nanosatellite assembly, integration, and testing.

is important as it also makes two Indonesian satellites scheduled to launch in 2025 from the ISRO's PSLV, increasing India's reliability as a launcher for neighbouring countries space programs. During the visit of Indonesian President Prabowo Subianto in January 2025, both nations concluded an Inter-Governmental Framework Agreement on Cooperation in Outer Space for Peaceful Purposes, further emphasizing mutual collaboration in space science, technology, and satellite launches.[15]

Apart from satellite launches, India has been involved in the training and capacity building in construction of the satellites for the Southeast Asian countries. UNNATI (UNispace Nanosatellite Assembly & Training by ISRO) is an exemplary initiative for assisting developing countries in skill development through building microsatellites that are multifunctional and nanosatellite assembly, integration, and testing.[16] These activities help ASEAN countries to independently formulate their independent satellite programs which consequently gives them the ability to independently operate their space technology without reliance on foreign space institutions. Using ground stations, launching the satellites, building capacity, and collaborations, India has emerged as the foremost partner in the space industry for Southeast Asia. These partnerships advance the scientific space development in the region and enhance collaboration for humanitarian aid and environmental, technological advancement, and disaster management.

15 Ministry of External Affairs. 2025. "India-Indonesia Joint Statement on the State Visit of H.E. Prabowo Subianto, President of Republic of Indonesia (23-26 January 2025)." 2025. https://www.mea.gov.in/bilateral-documents.htm?dtl/38944/IndiaIndonesia+Joint+Statement+on+the+State+Visit+of+HE+Prabowo+Subianto+President+of+Republic+of+Indonesia+2326+January+2025.

16 ISRO. n.d. "UNNATI Introduction." https://www.ursc.gov.in/indounssp/.

Africa

India and Africa have been cooperating on space technology knowing its power in boosting their economies, undergoing digital transformation, and fostering sustainable development. Africa through the African Union has set up the African Space Agency (AsFA) which underscores the determination of the continent to apply space technology in driving development. It is projected that the African space market would grow by more than 16% to USD 23 billion by 2026.[17] This gives African countries reason to consider India as a strategic partner in space exploration and satellite technology.

Prior to this western partnership, there had been some collaboration going on between the South African National Space Agency (SANSA) and ISRO. Their Memorandum of Understanding (MoU), which was signed in July 2018, aimed at joint research and projects on application of space technology, remote sensing of the earth, satellite navigation, and planetary research.[18] One of the important breakthroughs of this partnership has been South Africa's contribution to ISRO's Mangalyaan Mars Orbiter Mission.[19] Mangalyaan was launched in 2013, and South African National Space Agency (SANSA) played a critical role for the mission's insertion into the orbit of Mars in 2014. This served as a good example of collaboration in space activities.

Mangalyaan was launched in 2013, and South African National Space Agency (SANSA) played a critical role for the mission's insertion into the orbit of Mars in 2014. This served as a good example of collaboration in space activities.

17 Space in Africa. 2022. "African Space and Satellite Industry Now Valued at USD 19.49 Billion Space in Africa." Space in Africa. 2022. https://spaceinafrica.com/2022/08/17/african-space-and-satellite-industry-now-valued-at-usd-19-49-billion/.

18 "South African, Indian Space Agencies Strengthen Their Mutual Cooperation." 2018. Engineering News. 2018. https://www.engineeringnews.co.za/article/south-african-and-indian-space-agencies-strengthen-their-mutual-cooperation-2018-07-30.

19 Rao, Sushil. 2013. "Mars Mission: India Gets Help from South Africa to Monitor 'Mangalyaan'." Times of India. 2013. https://timesofindia.indiatimes.com/science/mars-mission-india-gets-help-from-south-africa-to-monitor-mangalyaan/articleshow/26776024.cms.

Further, through the Memorandum of Understanding (MoU), Nigeria and India have formalized their partnership on the peaceful use of space. [20]This agreement advances India's ongoing developmental support program which has turned out to be beneficial for the space sector of Nigeria. Within the last 12 years, 45 Nigerian scientists have taken part in several ITEC (Indian Technical and Economic Cooperation) courses.[21] These courses offered by the Indian Institute of Remote Sensing (Dehradun), Geological Survey of India Training Institute, and Centre for Development of Advanced Computing (Noida) have increased the capacity of Nigeria in remote sensing, GIS, and even geo-informatics. Such transfer of knowledge is important for Africa's fight against disasters as well as for agricultural planning and resource monitoring.

One more of the prominent initiatives in the India-Africa space collaboration is the joint satellite project between India and Mauritius. Under the Memorandum of Understanding (MoU) signed between ISRO and Mauritius Research and Innovation Council (MRIC), the two countries are building a small satellite to be launched by ISRO early next year.[22] This agreement not only aids collaboration regarding the construction of the satellite but also allows Mauritius the right to use its ground station for other space related activities.

Apart from bilateral agreements, India's relationship with Africa in the domain of space technology is showcased through the large-scale digital infrastructure projects such as the Pan-African e-Network Project (PAENP).[23] PAENP aims to improve Africa's digital connectivity using satellites and fiber-optic technology. It utilized Indian space technology to tele-educate, provide modern medicine, and facilitate e-governance in multiple African countries. In 2018, India further advanced this

20 Ministry of External Affairs. 2020. "Signing of an MoU on Cooperation in Outer Space with Nigeria." 2020. https://www.mea.gov.in/press-releases.htm?dtl/32890/Signing+of+an+MoU+on+Cooperation+in+Outer+Space+with+Nigeria.

21 Indian High Commission to Nigeria. n.d. "India - Nigeria Partners in Progress.". http://hciabuja.gov.in.

22 Press Information Bureau. 2024. "Cabinet Approves Memorandum of Understanding between Indian Space Research Organization (ISRO) and Mauritius Research and Innovation Council (MRIC) Concerning Cooperation on the Development of a Joint Small Satellite." 2024. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1993364.

23 Ministry of External Affairs. n.d. "Pan African E-Network Project (PAENP)." 2009. Accessed April 12, 2025. https://www.mea.gov.in/Portal/ForeignRelation/Pan_African_e_docx_for_xp.pdf.

India and Africa's collaboration in space is part of a wider South-South partnership, which seeks to promote and develop shared opportunities. There is a great potential for value addition in telecommunication, navigation, and environmental monitoring both regions can achieve by combining India’s space technologies and Africa’s growing interest in utilizing satellite technology.

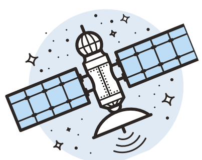
initiative into the second phase, e-VidyaBharati and e-Arogya Bharati (e-VBAB), strengthening Africa’s digital cooperation with India.[24] India’s PAENP and its successor programs have greatly advanced socio-economic growth within the African countries by improving access to quality education and healthcare services.

Africa is increasing its digital and technological capabilities, and India’s role is expected to expand as a fundamental partner in the region. India and Africa’s collaboration in space is part of a wider South-South partnership, which seeks to promote and develop shared opportunities. There is a great potential for value addition in telecommunication, navigation, and environmental monitoring both regions can achieve by combining India’s space technologies and Africa’s growing interest in utilizing satellite technology. This cooperation not only enhances diplomatic and economic relations but also strengthens the position of space technologies as instruments for achieving sustainable development in the Indo-Pacific and the areas extending beyond it.

The space cooperation between the Indian and Africa is further illustrated through the Indian private companies’ new involvement in the region. Recently, Memorandum of Understanding (MoU) between SIA-India and the Ghana Space Science and Technology Institute was signed which promotes satellite manufacturing, launching services, and other innovative uses.[25] Such

24 Embassy of India to Asmara, Eritrea. n.d. “E-VidyaBharati AarogyaBharati (e-VBAB) Network Project.” https://eoiasmara.gov.in/evbab.php.

25 Iderawumi, Mustapha. 2024. “GSSTI and SIA-India Partner to Advance Space Technology and Development -.” Space in Africa. 2024. https://spaceinafrica.com/2024/12/19/gssti-signs-mou-with-sia-india/.



developments support Africa's Agenda 2063 and Science, Technology, and Innovation Strategy for Africa 2024 (STISA-2024) document that advocates use of advanced technology for economic advancement.[26] The involvement of Indian private firms marks a new inclusive paradigm shift in India's approach to South-South space cooperation.

Latin America

India and Latin America have been using India's advanced and low-cost space technologies to strengthen their cooperation in space. Latin American countries have come to rely on the Indian ISRO as a partner on satellite launches, ground station development, remote sensing applications, and receiving training through capacity-building programs. India has also signed treaties with Brazil, Argentina, Chile, Colombia, and Mexico in which these countries can engage in a multitude of collaborative activities for the peaceful purposes of space.

India and Brazil started cooperating on space projects in 2004 when the two nations signed a formal space cooperation framework agreement.[27] One major aspect of this agreement was Brazilian National Institute for Space Research (INPE) receiving aid from ISRO in setting up satellite tracking and data reception ground stations in Cuiaba and Alcantara.[28] In 2021, ISRO accomplished a significant feat by launching Brazil's first fully self-made satellite, the Amazonia-1, during the PSLV-C51 mission.[29] This was a crucial development in Brazil's space aspirations and reaffirmed India's relationship as a trusted launch service provider. Aside from these, both nations have undertaken remote sensing data sharing projects and India has trained scientists from Brazil in the uses of satellites. The agreement

26 African Union. 2024. "Science, Technology and Innovation Strategy for Africa 2024." 2024. https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf.

27 Ministry of External Affairs. n.d. "Brazil All Set to Boost Ties with India in Space Technologies." 2021. Accessed April 12, 2025. https://indbiz.gov.in/brazil-all-set-to-boost-ties-with-india-in-space-technologies/.

28 Ministry of External Affairs. 2014. "Implementing Arrangement between Government of the Federative Republic of Brazil and Government of the Republic of India Establishing Cooperation in Augmentation of a Brazilian Earth Station for Receiving and Processing Data from IRS Satellites." 2014. https://www.mea.gov.in/outoging-visit-detail.htm?23659/Implementing+arrangement+between+Government+of+the+Federative+Republic+of+Brazil+and+Government+of+the+Republic+of+India+establishing+cooperation+in+augmentation+of+a+Brazilian+earth+station+for+receiving+and+processing+data+from+IRS+satellites.

29 Ibid 27.

is advantageous for both countries as India also utilizes Brazilian ground stations for future space missions.

India and Argentina are advancing space collaboration under the Agreement on Cooperation on Peaceful Uses of Outer Space, signed in 2009. This collaboration has also been strengthened through ISRO - CONAE Joint Committee meetings. At the third meeting, Argentina showcased her increasing interest in India's space training programs. Four Argentine scientists participated in ISRO's sponsored UNNATI program: two in early 2019 and two in late 2022.[30] In June 2024, two CONAE officials also attended a specialized Spacecraft Dynamics and Control Course conducted by IIT Kanpur. This indicates a growing willingness by India towards knowledge-sharing.[31]

Chile and India have been partners in space for a long time, gaining major milestones in 2017 with ISRO launching Chile's advanced SUCHAI-1 satellite. Both partners recognized and further emphasized the cooperation needed in areas like space science, satellite technology, and deeper astrophysics.[32] For Chile, ISRO's help in satellite building, launching, operating, and even research and development as well as the educational uses of space demanded the formation of a Space Executive Committee which is now expected to optimize the pragmatic inter-party cooperation. This is likely to enhance the collaboration and exchange of information in space exploration, along with development of various research programs.

India and Colombia have also fostered space collaboration, with ISRO playing a pivotal role in the launch of Colombia's FACSAT-1 satellite. On November 29, 2018, ISRO placed FACSAT-1, a nanosatellite developed by the Colombian Air Force, into orbit during the PSLV-C43/Hysis mission.[33] This advancement also signifies the nurturing of India-Colombia relations and the rise of India as a competitor in global space missions. Additionally, two Colombian officers took part in

30 Embassy of India to Argentina. n.d. "INDIA-ARGENTINA BILATERAL RELATIONS." https://www.indembarg.gov.in/page/india-and-argentina/.

31 Ibid 30

32 Press Information Bureau. 2025. "India - Chile Joint Statement." 2025. https://pib.gov.in/PressReleasePage.aspx?PRID=2117396.

33 Embassy of India, Colombia. n.d. "India- Colombia Bilateral Relations." http://itj.dgciskol.gov.in/ZCwgGAsFRDLkPgYe0ldlfOssrfTWijVzTyLykIrC.pdf.

> Countries like India which have a rich history in satellite earth observation through RISAT and Cartosat series satellites can assist other nations who want to improve their climate change adaptation strategies.

ISRO's UNNATI training program from October to December 2019 where they learned about the assembly and operation of satellites which enable them to be classified as nanosatellites.[34] These projects underline the increased commitment from India towards the development of space programs in South America.

India and Mexico have further expanded their cooperation in the fields of space technology with a focus on its use in environmental monitoring and disaster management. AEM and ISRO have partnered to create a mobile application for monitoring forest fires using satellites for early warning and response.[35] In August 2024, ISRO carried out a four-day workshop in Mexico where it trained Mexican officials on space-based fire systems for forest fire mitigation. It also pointed out the possible participation of Mexico in the G20 Satellite Mission for Environment and Climate Observation which aims to tackle environmental issues through satellites. There have been some talks regarding potential collaboration between India and Mexico at the industrial level for the development of satellite technologies and applications.[36]

Opportunities and Challenges for India in Global South Space Cooperation

For a long time, India has been identified as having a leader's advantage in space technology due to the low costs ascribed to it. This advantage offers India the opportunity to take a leading position

34 Joshi, Anshu. 2024. "Colombia-India: Bilateral Relations |." Diplomacy & Beyond Plus. 2024. https://diplomacybeyond.com/colombia-india-bilateral-relations/.

35 Singh, Surendra. 2024. "India Offers to Help Mexico Build Its Earth Observation Sats: Isro - Times of India." The Times of India. 2024. https://timesofindia.indiatimes.com/science/india-offers-to-help-mexico-build-its-earth-observation-sats-isro/articleshow/115319145.cms.

36 ISRO. 2024. "Mexican Ambassador Met Chairman, ISRO / Secretary, DOS." 2024. https://www.isro.gov.in/Mexican_Ambassador_met_Chairman_ISRO.html.

> India's leadership in space diplomacy through platforms like the G20, BRICS, IORA and BIMSTEC creates opportunities to control the space-based relations and initiatives of the Global South.

in collaborations throughout the Global South region. ISRO along with a developing private space sector which positions India to enable effective collaborations, especially in climate change and sustainable development monitoring as well as blue economy activities.

One of the most potential opportunities for collaboration is using space technology to solve issues pertaining to climate change. Most of the countries in the Global South are especially susceptible to catastrophic weather changes, sea level rise, and harmful impact on forest cover due to climate change. Countries like India which has a rich history in satellite earth observation through RISAT and Cartosat series satellites can be helpful for other nations who want to improve their climate change adaptation strategies. India can also help in design policy frameworks to reduce climate change impacts by providing useful satellite image analytics on weather, deforestation, and ocean health. In addition, India’s ability to launch small satellites at low cost for environmental monitoring purposes can help several countries in Africa, Latin America, and Southeast Asia to improve the ability to monitor climate changes without incurring large costs of developing indigenous infrastructure.

Further, the technological and surveillance limitations create an underutilization of resources in the Global South’s oceanic regions. Oceansat satellite systems bolster India’s oceanographic observation capabilities and provides information in managing marine resources, fisheries, and oceanic climates. India can help coastal, and island states maximize sustainable value from marine resources through granting data-sharing contracts and technology implementing Maritime Domain Awareness (MDA). Furthermore, Indian satellites and remote sensors can aid the Global South countries in the region battling lawlessness and piracy and hostile maritime activities. India can perpetuate collaborative efforts like the South Asian satellite where real time oceanographic data is provided to partners in the Indo-Pacific and beyond.

Additionally, India's leadership in space diplomacy through platforms like the G20, BRICS, IORA and BIMSTEC creates opportunities to control the space-based relations and initiatives of the Global South. The BRICS countries came together to sign a Memorandum of Understanding (MoU) in 2021 that marked the formal establishment of the BRICS Remote Sensing Satellite Constellation.[37] This serves the purpose of sharing satellite data for the natural calamities, agriculture, and environment upkeep within the BRICS member states. This cooperative effort is beneficial for the space development of the BRICS countries. As per the Memorandum, the BRICS members are backed by the resources of one another in assisting a side with data driven urban planning, disaster management, environmental concern, and many other services. India's satellite capabilities will be crucial in ensuring the success of this cooperations.

Building competencies is another primary area of opportunity for India. Most countries in the Global South lack trained personnel in the field of space. With India's space institutions, like the Indian Institute of Space Science and Technology (IIST) and ISRO's training programs, the country can become a hub for human resource development through established clear policy frameworks. By providing greater access to training for scientists, engineers, and policymakers from the Global South, India can establish strategic partnerships that advance sustainable development in space technology.

India's recent steps in establishing organizations like IN-SPACe indicates a move towards the privatization of its space industry which could benefit the rest of the Global South. The expectations are that with the inclusion of private players the cost of establishing and servicing space satellites will reduce. This will aid the underdeveloped nations that have limited finances, allowing them to use

37 ISRO. n.d. "BRICS Space Agencies Leaders Signed Agreement for Cooperation in Remote Sensing Satellite Data Sharing." 2021. https://www.isro.gov.in/BRICS Space.html.

India’s affordable satellite services or send their own satellites for launch.

Even with its many assets, there are certain challenges India is unable to fully solve as a space collaboration leader in the Global South. One such challenge is the financial and infrastructural issues developing nations face. India has been able to devise space technologies at a very high level, but most countries in the Global South face infrastructural challenges which makes it difficult for them to shift their focus to space. This constraint results in an over dependence on aid from developed countries which heavily impacts their autonomy in space policymaking. While India is a leader in affordable space technology, they do not possess the funds necessary to carry out huge space initiatives in several developing countries simultaneously. To meet the funding challenge, trilateral partnerships (North-South-South) can be explored. There are many developed countries looking to partner with India in third countries for development activities to take advantage of India’s goodwill in these countries.

The other great challenge is the lack of cohesion in the Global South priorities by different countries. The varied political, strategic, and economic goals of these nations, along with different governance structures, weak institutions and economic instability create a challenge for crafting a single space policy. For example, satellite information from coastal countries is highly important for maritime security, fisheries management, as well as for landlocked farming, monitoring, and disaster management. The most notable problem when it comes to formulating a global space policy that serves all is the lack of consensus for the guiding principles. This challenge can be sought to be overcome by forming coalitions of the like-minded to meet shared objectives in the space sector or by partnering with regional organization.

Additionally, gaps in law and policy are a significant barrier. Most countries in the Global South do not have a defined space policy or a strategic vision for space activities within a long-term plan. This lack of framework structure results in irregular and limited participation in space cooperation synergies. Without guiding policies, attempts to strategically collaborate for space cooperation are bound to be haphazard and yield no lasting

> Having been at the receiving end of the world's technology denial regimes for decades, India's approach to technology transfer to other countries of Global South is different and is more tilted in favour of viewing tech as a public good especially in a sector like space which is capital and skill intensive making it out of reach of less developed countries and a sector which is largely meant for development.

benefits. Notably, India's proactive space diplomacy has challenges engaging with countries that lack structured governance frameworks for space. India can however help these countries in writing and crafting a space policy.

New competitive threats from private players in the space industry also adds to the problem. Although the space sector in India has historically been state-centric, the emergence of private sector participation during the last decade, specifically from the U.S and China, has shifted the conversation towards space cooperation. Private enterprises like SpaceX and Blue Origin are gaining prominence for their low cost and rapid pace of innovation cycles, making them more appealing partners for many developing countries. Consequently, there is also an opportunity for private players from India to play a larger role as India already has easy acceptability in these nations.

Global conflict makes working together to solve issues harder. Countries like China and the United States are increasing their military presence for competition in space, causing space activities to be viewed as weapons. Both developmental and peaceful initiatives in space are difficult to accomplish because nations are apprehensive about supporting one side of the geopolitical divide. India's space diplomacy is well-placed to balance these tensions to maintain the image of a neutral and dependable partner for all developing countries.

Lastly, concerns regarding the transfer of technology and sovereignty pose additional challenges. Several countries within the Global South zone are naturally cautious of becoming reliant on external technological assistance due to the potential loss of sovereignty. Although India is perceived as a more reliable collaborator compared to western space agencies, meeting the criteria of equitable technology transfer is problematic. Furthermore, the assumption that the technological gap between India and less advanced nations would create a dependency instead of a truly collaborative ecosystem is troubling. Having been at the receiving end of the world's technology denial regimes for decades, India's approach to technology transfer to other countries of Global South is different and is more tilted in favour of viewing tech as a public good especially in a sector like space which is capital and skill intensive making it out of reach of less developed countries and a sector which is largely meant for development.

Prospects and Recommendations

In recent years, India's space diplomacy has advanced significantly, and so too has its role in the Global South. Considering the issues related to climate change and the emerging significance of the blue economy, the relations in the space sector that India shares with the Global South countries can be enhanced for better sustainable development and economic growth. India may be considered a reliable partner by developing nations because of its advanced space technology, affordable infrastructure, and dedication to capacity building in the space sector.

A few developing economies, particularly Small Island Developing States (SIDS), and coastal nations face severe threats from climate change such as rising sea levels, extreme climate events, and habitat destruction. India, through its Indian National Centre for Ocean Information Services (INCOIS) and sentinel satellites like RISAT and Oceansat, can assist these countries by providing critical information relating to meteorology, oceanography, and natural disasters. To formalize this partnership, India can create a climate monitoring system designed for Global South countries. With these climate monitoring systems, India can give these countries satellite imagery and data sharing treaties for the purpose of evacuation planning. This would enable these countries to better manage their responses to and preparedness for disasters. Moreover, by providing satellite data interpretation and analysis courses, India would enable these scientists and meteorologists to devise climate mitigation and adaptation plans.

The blue economy, which incorporates fisheries, navigation, tourism, as well as both coastal and offshore energy, is equally important for the economic development of the countries in the Global South. On the other hand, these countries face the issues of illegal, unreported and unregulated (IUU) fishing, piracy, and maritime environmental degradation. India's investment in satellite-based maritime domain awareness (MDA) systems could help resolve these problems. India can work with African, Latin American, and Indo-Pacific countries by integrating their satellite surveillance systems with maritime security and resource management to improve security and management of the sea resources. Integration of Automatic Identification Systems (AIS) and Synthetic Aperture Radar (SAR) imagery can facilitate monitoring of fishing and traffic movement in real time. Finally, India can help these countries design regional databases or data warehouses, which allow collaboration and joint coordination in responding to security and environmental challenges.

Numerous countries in the Global South do not have the technical skills or the supporting infrastructure to develop and sustain space-based climate monitoring and blue economy systems. India, for example, can broaden its efforts by providing active training for scientists and engineers from developing countries through the UNNATI (UNispace Nanosatellite Assembly & Training) program. Emphasis may also be placed on the remote sensing and oceanographic data analysis for the satellites so that they can lead to the development of coarse satellites. Moreover, India can promote technology transfer through joint satellite missions with Global South partners. Collaborative projects, such as building small satellites for climate observation and ocean monitoring, can not only boost local capacity but also create a sense of ownership among partner nations. By making its space technology available to everyone, India can foster innovation and encourage countries to use these tools for sustainable development.

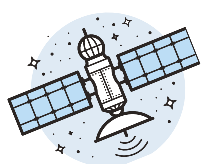
India can strengthen its international collaborations by constructing

Indian cooperation with other regional organizations like the African Union or ASEAN can facilitate the creation of oceanographic, climatological, and sustainable fisheries management research space centres.

space infrastructure systems in partnership with countries in the Global South. These partnerships can establish ground stations, data processing facilities, and satellite navigation technologies. India can also further develop its NavIC system by integrating more geographies in the Global South. This development would greatly improve navigation and climate resource related application. Indian cooperation with other regional organizations like the African Union or ASEAN can facilitate the creation of oceanographic, climatological, and sustainable fisheries management research space centres. Such centres can foster international cooperation by providing advance training sessions and seminars on addressing space-related economic and environmental problems.

As space activities are carried out, it's important to manage the use of space resources. India can lead Global South countries in advocating for sustainable policies that honour developmental priorities of the region. India actively participating in regional and international forums would allow the nation to help establish regulations on space debris mitigation, satellite data governance, and access to space-based infrastructure services. Furthermore, India could endorse new approaches to developing regional space governance policies focusing on the climate and sustainable blue economy. Collaborating with SAARC, the African Space Agency, and the Latin American and Caribbean Space Agency, India can help create policy frameworks for developing countries while promoting the responsible use of space resources and ensuring equity in international space cooperation.

ISRO has successfully partnered with private players to offer more economical solutions for space exploration. Following this model to the Global South, India can foster partnerships between Indian space technology startups and businesses in developing countries



ISRO has successfully partnered with private players to offer more economical solutions for space exploration. Following this model to the Global South, India can foster partnerships between Indian space technology startups and businesses in developing countries to collaboratively create innovative applications for space technology.

to collaboratively create innovative applications for space technology. For instance, Indian satellite ocean monitoring system startups can work with local fisheries cooperatives in Africa and Latin America to supply real-time monitoring of fish stocks and marine biodiversity. Moreover, India's progress in remote sensing technologies can be utilized to devise partner country-specific smart climate resilience measures, including precision agriculture and water management.

Natural risks like cyclones, tsunamis, and floods have a greater impact on countries in the Global South. India, owing to her experiences in using space-based technologies for disaster management, can contribute to improving regional capacity for disaster preparedness and response. India can collaborate with countries in the Global South to develop a coordinated satellite-based disaster monitoring and response system. Such a system would enable the timely provision of satellite images and geospatial information to the relevant authorities and humanitarian agencies to enable efficient and effective planning of relief operations. Furthermore, India can also provide aid in formulating policies at the national level that utilize space technology in real time risk evaluation and emergency communication for effective disaster response management.

India's space capabilities have created a reputation for being extremely low cost compared to many other nations. Indian space entities like ISRO have managed to accomplish high quality missions at a fraction of the cost, compared to competitors. This focus of maintaining a frugal approach should remain dominant in India's narrative while seeking to position the Indian space market as a reliable option. India has built a reputation for being an economically viable option for

> India's strategy on space exploration is unique as it promotes collaboration and not competition. Unlike other countries that pursue competitiveness and nationalistic pride, India makes it clear that it wants to have strong friendly relations with other countries and space agencies.

satellite launches, having catered for over 34 countries, which enhances its position as the most favourable option in the space market. While being cost-effective, India will however be required to be conscious of quality and international standards in its products in this sector.

India's strategy on space exploration is unique as it promotes collaboration and not competition. Unlike other countries that pursue competitiveness and nationalistic pride, India makes it clear that it wants to have strong friendly relations with other countries and space agencies. This spirit of friendship and cooperation should definitely be further developed. India has an opportunity to be the preferred partner for new space faring nations not just for low-cost services but for collaborative joint missions and technological innovations as well. India can create collaborations that transcend contracts by building strong relationships with other countries, fostering a sense of progress for all partners involved in space exploration.

One of India's most notable merits is how easily foreign space companies can work with its space industry. Unlike other major space agencies like SpaceX and Blue Origin, which take a long time and a myriad of steps to initiate any partnerships, and have closely – held confidentiality and Intellectual Property Rights (IPR) clauses, India has a far more cooperative approach. The quick and simple partnership systems offered through Memorandum of Understanding (MOUS) have proven to work wonderfully. Government and private space companies in India should do everything in their power to keep these frameworks as easy and simple as possible. Doing so, India will not only have more international business partners, but also grant them the freedom to work on space projects without any unnecessary delays.

Furthermore, India's private space companies and academic bodies, such as the Indian Institutes of Technology (IITs), have been instrumental in the satellite technology and space research. These institutions have created remarkable innovations in satellites, space research, and launch vehicles. It is evident that greater innovation and expansion of space technological resources within the country will enable India to develop as a premier global partner for international space enterprises.

Conclusion

India's space collaboration with the Global South has emerged as a crucial pillar in advancing sustainable development, particularly in the domains of the blue economy and climate change. India has significantly contributed to developing countries in the maritime and coastal regions of satellites-based monitoring, resource management, and disaster management through international partnerships, technology transfer, and capacity building programs. Space based Fisheries management, oceanographic resource distribution surveys, and climate change adaptation programs serve to demonstrate India's commitment towards equitable development and environmental protection. India's space diplomacy enhances regional and global data sharing, early warning systems, policy making, and deployment and utilization of spaced based assets for development purposes.

Furthermore, the emergence of private Indian space businesses offers new avenues for creative advancements and collaboration. With the improvement in miniature satellite technology, remote sensing, and data analytics, private enterprises can aid in India's government efforts by assisting in the management of marine resources, climate change, and rapid response to international disasters. They can also improve the participation in technology acquisition and increase indigenous capacity in partner countries and commercially sustainable opportunities aligned with the sustainable development goals. Going forward, further strengthening collaboration, utilizing new technologies, and developing partnerships that are holistic from the public and private domains will be crucial in making sure that space-based capabilities and solutions address common problems and foster mutual development in the Global South.

INDIA'S SPACE TECHNOLOGY FOR CLIMATE CHANGE

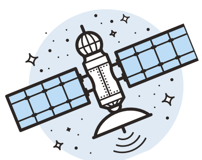
Ajey Lele

Addressing the challenges of climate change involves a range of technologies across various sectors. Much of the focus is on solutions aimed at mitigating or reducing the impact of climate change, such as renewable energy sources, solar and nuclear power, smart grids, energy storage and electric vehicles (EVs). However, there is also a critical need for technologies that help monitor and inform us about the ongoing effects of climate change. For this purpose, weather stations, sensors, ocean monitoring systems, balloons, drones and carbon monitoring technologies are employed to track changes in the atmosphere and the environment. Additionally, numerical weather prediction and climate models (some AI-based) play a crucial role in assessing and forecasting future climate patterns, helping us understand the trajectory of climate change and its potential impacts. Satellites are the foremost platform that helps us to understand the ongoing changes in weather and climate patterns.

Weather observations have been obtained for centuries using ground-based observatories. During the last few decades, satellite technology has become an indispensable tool in the fight against climate change, providing critical insights into environmental shifts on a global scale. By offering a bird's-eye view of the planet, satellites enable real-time monitoring of key climate indicators, such as temperature fluctuations, deforestation, ice melt and rising sea levels. Presently, various operational satellites together are helping us to provide near-global coverage, which helps us to monitor both short-term and long-term changes in climate behaviour. This chapter examines how the Indian state addresses the challenges of climate change using space technologies. It begins by exploring the nature of space technologies used to recognise various changes and the global application of space technologies before focusing on India-specific issues and strategies.

Context

Weather is the state of the atmosphere at a given time and place. Mainly it is about the prevalent conditions of air and atmosphere, while climate is the average weather conditions over a long period. Climate change denotes changes in weather and climate patterns known to happen essentially



owing to long-term changes in temperatures and atmospheric patterns. Such changes could happen due to natural reasons like changes in the sun's activity, changes in the earth's crust like volcanic eruptions, massive earthquakes or other major events like massive tsunamis. However, various assessments indicate that for the last two centuries or so, human actions have been mainly responsible for the changes in climate that we are witnessing today. This is chiefly caused by unregulated and unscientific use of existing energy resources, mainly fossil fuels, like coal, oil and gas.

The terms "global warming" and "climate change" are often used interchangeably, but it is important to understand that global warming is just one aspect of climate change. Global warming refers specifically to the long-term increase in the Earth's average temperature. Extensive evidence shows that global temperatures have been rising since the early 20th century, with a particularly notable increase since the late 1970s. Since 1880, the Earth's average surface temperature has risen by approximately 1°C, relative to the mid-20th-century baseline (1951-1980). This is in addition to roughly 0.15°C of warming that occurred between 1750 and 1880[38].

One of the main reasons for climate change is the emissions from greenhouse gases (GHG). These gases naturally occur in the atmosphere; however, they also get generated from human activities. There are different types of greenhouse gases, and their global warming potential differs. Normally, the gases generated through human activities like carbon dioxide (CO_2), methane (CH_4) and nitrous Oxide (N_2O) are known to impact the climate adversely. GHG works like the glass in a greenhouse. They trap heat from the sun that is reflected off the Earth's surface, keeping it in the atmosphere instead of letting it escape into space. This helps keep the Earth warmer, which is necessary for life. They are known to impact weather patterns, such as shifts in snow and rainfall patterns, higher average

38 https://science.nasa.gov/climate-change/faq/whats-the-difference-between-climate-change-and-global-warming/, accessed on Nov 12, 2024.

temperatures and more extreme events like heat waves and floods.[39]

The Earth's climate system is composed of several interconnected elements:

- **The Atmosphere:** The layer of air that surrounds the Earth's surface.
- **The Hydrosphere:** Comprising Earth's freshwater and saltwater bodies.
- **The Cryosphere:** Is the frozen water on Earth's surface, including ice caps, glaciers and sea ice.
- **The Biosphere:** Encompasses living organisms, including plants and animals.
- **The Lithosphere:** Is the solid land that makes up the Earth's surface.

These elements form a complex ecosystem in which they interact and maintain balance. When any of these elements are disrupted, it can lead to negative consequences that occur with increasing severity and frequency, such as rising sea levels, heat waves, droughts, floods and extreme storms. There is a view that climate change (as a natural process) has been occurring for the past 4.5 billion years. It is true that Earth has experienced cycles of cooling, warming and changes in ocean levels throughout its history. However, what is particularly concerning today is the rapid pace of the current changes. The rate of anthropogenic (human-induced) climate change is the fastest in the past two thousand years, and the concentrations of key greenhouse gases are now higher than they have been in the last 800,000 years[40].

Satellite systems in space act as the "eyes" in the sky, offering vital information about conditions on Earth's surface and in its atmosphere.

Satellite systems in space act as the "eyes" in the sky, offering vital information about conditions on Earth's surface and in its atmosphere.

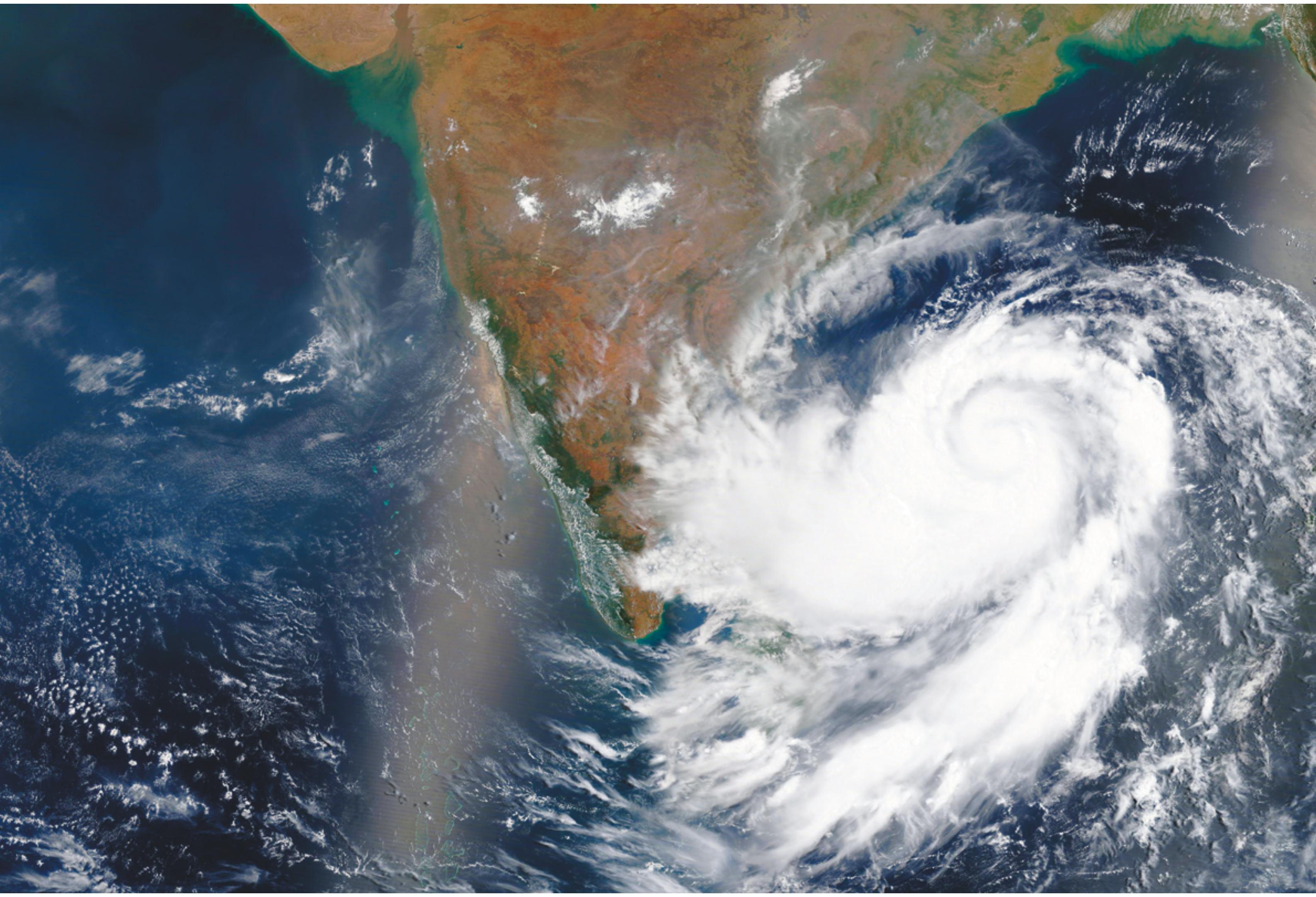
39 https://www.europarl.europa.eu/topics/en/article/20230316STO77629/climate-change-the-greenhouse-gases-causing-global-warming#:~:text=There%20are%20different%20types%20of,and%20nitrous%20Oxide%20(N2O). accessed on Nov 28, 2024.

40 Justyna Więcławska, "How Satellite Data Helps Us Understand Climate Change," April 22, 2022, https://geoawesome.com/eo-hub/how-satellite-data-helps-us-understand-climate-change/, accessed on Dec 1, 2024.

To fully understand climate change, it is crucial to first identify the specific data inputs expected from space-based systems and assess whether existing satellites can provide them. In addition, there is a need to innovate, design and develop new satellite systems — particularly sensors — that can capture the required data. This process begins with a clear understanding of climate, as well as key meteorological and topographical factors that satellites are capable of monitoring. While satellites provide essential data, interpreting this data requires the development of algorithms and forecasting models (such as numerical weather and climate prediction models) to better understand the various critical aspects of climate change.

Topography refers to the physical features of the Earth's surface, like hills, mountains, valleys and plains. Topography impacts various features of the Earth's surface, like water resources, weather patterns and climate. The climate is influenced by many factors, including latitude, elevation, proximity to an ocean and/or other water bodies and vegetation cover. Climate is the state of the atmosphere concerning various factors like wind (speed and direction), ground and atmospheric (say at altitudes from ground to troposphere/stratosphere) temperature, sea surface temperature, humidity, atmospheric pressure, sunshine duration, evaporation and precipitation (including old and new snow). Climate is influenced by a region's latitude, altitude and landscape. The main factors are elevation changes, which affect air pressure and temperature. The landscape, or topography, plays a big role in climate. For example, high places are cooler than low ones because there is less atmosphere to hold heat. Higher altitudes are colder than lower ones because they get less sunlight in the winter.

Mountains affect climate in many ways. They act as barriers to cold air and create rain shadow areas. The shape and height of mountains influence wind patterns, changing wind speed and direction as air flows over the land, which affects the weather. Mountains with high elevations (which could have snow-clad peaks to glaciers) can induce some changes in climate. Low-lying areas can lead to extreme weather like floods and hurricanes while higher areas usually have milder



temperatures due to the cooler air at higher elevations. Soil type also affects temperature changes. Dry soil heats up quickly and stays warm longer, while wet soil does not heat up as fast[41].

For a country like India, topography, terrain and weather-related challenges are unique. A variety of mineral deposits are found in the Indian subcontinent. The geology of India is diverse, and different parts of the country contain rocks belonging to different geologic periods, and there are varied geological structures. Remote sensing technologies have relevance for mineral exploration. In addition, India is a geographically unique state. It has a range of geographical features, from mountain ranges, snow-capped mountainous ridges, thick vegetated forests, rain forests and deserts to a long coastline. The Thar Desert (the Great Indian Desert) is in the northwestern part of the Indian subcontinent, including parts of India and Pakistan, and about 85% of this desert is in India. From Thar to Siachen in the Himalayas, within around 1,000 km, the variation in temperature is more than 100 degrees Celsius (–50 degrees C at Siachen to +50 degrees C in the desert region.) By contrast, the northeastern part of India has the most extensive forest cover.

India is in the Northern Hemisphere, approximately 8 degrees north of the equator. The peninsular region of India is primarily affected by tropical weather systems, while the northern part of the country experiences the influence of extratropical weather systems. The peninsular region is bordered by the Bay of Bengal to the east, the Arabian Sea to the west and the Indian Ocean to the south. The Southwest Monsoon plays a major role in precipitation across the country, while some parts of South India receive rainfall during the Northeast Monsoon. Cyclonic storms impact the peninsula during certain months. In northern India, rain and snow are primarily caused by Western Disturbances, especially during the winter months. To accurately monitor these weather patterns, satellite systems must be designed to provide timely and accurate data. This requires not only the proper placement of sensors in space but also an adequate number of satellites, as a limited

41 "How Does Topography Affect Climate?", February 7, 2022, https://www.spatialpost.com/how-does-topography-affect-climate/, accessed on Dec 26, 2024.

number can restrict the frequency of revisits to a particular area.

Climate refers to the average weather conditions over an extended period, while weather can change rapidly from day to day or even hour to hour. Weather exhibits diurnal variations due to daily shifts in meteorological variables, such as temperature, humidity, wind speed and precipitation. Additionally, a location's climate and weather patterns are influenced by its geographical features. Therefore, satellites must be equipped with sensors that can monitor required weather parameters. These satellite systems operate in various orbits, ranging from low Earth orbit (LEO) to geostationary orbits (GEO).

In addition to satellites, numerous weather stations are deployed on the ground, in mountainous regions, and at sea. Weather buoys, which collect data about weather and ocean conditions, are deployed in the oceans. These data sources share their findings with satellite systems, ensuring the timely distribution of weather information. Ultimately, satellite systems play a critical role not only in gathering data but also in collecting and disseminating meteorological data acquired from other sources to different stakeholders.

These highlight the importance of identifying climate indicators from the perspectives of climate change and global warming. Once these indicators are determined, the next step is to select appropriate satellite systems capable of providing the necessary data. As mentioned earlier, satellite data offers valuable insights into climate systems, weather patterns, upper atmospheric winds and temperatures, sea-surface temperatures, sea levels, ocean pollution, greenhouse gas concentrations and the melting of glaciers and polar ice. Additionally, satellites can track changes in wildlife migratory patterns, which can indirectly reveal information about climate-related displacements.

Climate Change and Space Technologies

The Earth has been observed from space for nearly eight decades. The first image of Earth was captured in 1946 by a modified V-2 rocket (V-2, No. 13, which reached an altitude of 105 km), and in 1957, the Soviet Union launched Sputnik, the first artificial satellite. Since then, space science and

Satellites contribute to climate change research in two major ways. First, weather satellites provide real-time data on weather patterns, essential for analysing climate change. Second, specific satellite systems are designed to monitor greenhouse gas (GHG) emissions.

technology have evolved significantly. For many years, satellites have been monitoring Earth's atmosphere, surface, subsurface, glaciers and water bodies. Additionally, humans have had a continuous presence in space aboard the International Space Station (ISS) since 2000. This ongoing presence of humans in space along with technological advancement plays a crucial role in our understanding of climate change. Satellites contribute to climate change research in two major ways. First, weather satellites provide real-time data on weather patterns, essential for analysing climate change. Second, specific satellite systems are designed to monitor greenhouse gas (GHG) emissions. While many countries have developed various satellite systems to study weather and GHG emissions, this section does not aim to list all of them. Instead, it provides a general overview of some key satellite systems and constellations involved in climate change research.

Satellites to Know GHG Emissions

The assessment of greenhouse gas (GHG) concentrations is crucial for understanding and mitigating climate change. The term GHG was perhaps first used in 1907. These gases, responsible for the warming effect, are present in the atmosphere at very low concentrations. For example, carbon dioxide is about 0.04%, methane is around 0.017%, and the concentration of water vapour varies widely but averages about 1%. Despite their low concentrations, these gases are essential for creating the conditions necessary for life on Earth. Over the past two centuries, the burning of coal, oil and gas to meet human energy needs has released significant amounts of greenhouse gases into the atmosphere, thereby affecting Earth's temperature profile substantially. The knowledge about the carbon dioxide concentrations, from the distant past, is based on the analyses of carbon dioxide levels by studying tiny air bubbles trapped in polar ice. Presently, a variety of scientific techniques like experimentation, mathematical modelling and careful observation are helping to expand the understanding of GHG behaviour[42]. Today, satellites play a vital role in providing real-time data and furthering our knowledge of greenhouse gases.

Satellite technology has several advantages that make it important for measuring GHG emissions. First, it offers a way to detect and measure GHG emissions worldwide without being intrusive. Second, it provides near real-time data, warranting timely measurements. Third, it aids in improving transparency in measuring emissions and can be used to validate estimations or clarify differences between conflicting data[43]. Exploration of satellite technology for measuring GHG emissions has technical and policy advantages. Satellites, apart from their sensors, also help collect observations from ground-based sensors (for example, there is the Total Column Carbon Observing Network called TCCON, which is a network of ground-based Fourier Transform Spectrometers that provide accurate measurements of column CO_2, CH_4 and other gases) and aerial sensors. Finally, the data gets shared globally.

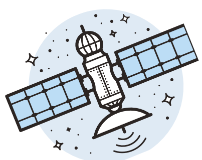
The Global Carbon Project (GCP)[44] was established in 2001 through a partnership between the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP) and Future Earth. Its goal is to create a shared, reliable knowledge base to support policy discussions and actions aimed at slowing and ultimately halting the increase of greenhouse gases in the atmosphere. The GCP utilises data from Earth-observing satellites to study greenhouse gas emissions.

Satellites measure gases in the atmosphere by detecting how gases absorb electromagnetic radiation at specific wavelengths. These satellites

42 "Hot topic: Discovering the greenhouse effect," March 11, 2021, https://www.sciencemuseum.org.uk/objects-and-stories/our-environment/hot-topic-discovering-greenhouse-effect, accessed on Dec 24, 2024.

43 Anwar Gasim, Walid Matar and Abdelrahman Muhsen, "Using Satellite Technology to Measure Greenhouse Gas Emissions in Saudi Arabia," Nov 2023, https://www.researchgate.net/publication/376271323_Using_Satellite_Technology_to_Measure_Greenhouse_Gas_Emissions_in_Saudi_Arabia_Discussion_Paper, accessed Jan 03 2025.

44 https://www.globalcarbonproject.org/ and https://www.globalcarbonproject.org/global/pdf/gcpframeworkfinal.pdf, accessed on Jan 23, 2025.



Globally, there are various satellite systems that monitor GHG concentrations and emissions. There are also commercial satellite constellations available to detect methane and carbon dioxide emissions in high resolution.

largely use sunlight reflected off the Earth's surface; nonetheless, some can also detect radiation emitted by the Earth or from lasers on the satellite itself. Instruments that measure radiation at specific wavelengths are called spectrometers. Satellite spectrometers use different wavelengths to measure gases like CO2 and CH4 based on how they absorb light. Satellites that look at shorter near-infrared wavelengths can detect CO2 concentrations near the Earth's surface, which is helpful for studying surface emissions. Other satellites, using longer thermal infrared wavelengths, can measure CO2 concentrations in the middle of the atmosphere, about 6 to 11 km above the surface[45]. If the area under observation is under cloud cover, then the quality of data collected is poor.

Globally, there are various satellite systems that monitor GHG concentrations and emissions. There are also commercial satellite constellations available to detect methane and carbon dioxide emissions in high resolution[46]. There is a Greenhouse Gas Satellite Missions Portal[47] that provides an up-to-date list of current and planned satellite missions that can measure greenhouse gases. This includes missions run by public and private organisations, as well as NGOs. These satellites track the emissions and removal of greenhouse gases from natural sources and human activities, covering areas from large cities to entire countries. However, these satellites typically cannot measure emissions from individual facilities. For that, there are special plume monitors used by the fossil fuel industry to track emissions from

45 Stephen Hardwick and Heather Graven, "Satellite observations to support monitoring of greenhouse gas emissions" Grantham Institute Briefing Paper No 16, March 2016, www.imperial.ac.uk/grantham/publications, accessed on Nov 30, 2024.

46 GHGSAT Greenhouse Gas Emissions Monitoring Satellites, https://www.ghgsat.com/en/technology/constellation/, accessed on Jan 14, 2025.

47 "Greenhouse Gas Satellite Missions Portal," https://database.eohandbook.com/ghg/, accessed on Jan 14, 2025.

their operations. Furthermore, there are operational sounders that help with weather forecasting, and these can measure methane (CH_4) and/or carbon dioxide (CO_2) in the upper atmosphere. These measurements are important for studying how greenhouse gases are transported into the atmosphere and their effect on the climate.

The US space agency National Aeronautics and Space Administration (NASA) has two dedicated GHG satellites for making carbon dioxide (CO_2) measurements, the Orbiting Carbon Observatory-2 (OCO-2) and the Orbiting Carbon Observatory-3 (OCO-3), and a methane (CH_4) and CO_2 plume mapper (the Earth Surface Mineral Dust Source Investigation mission or EMIT). OCO-2 is a polar-orbiting satellite with a 16-day revisit, and OCO-3 and EMIT are instruments hosted on the International Space Station (ISS). Combined, OCO-2, OCO-3 and EMIT help scientists understand natural carbon sources and sinks and anthropogenic sources of methane from oil, gas, coal and agricultural activities. The Scanning Imaging Absorption Monitoring Spectrometer for Atmospheric Chartography (SCIAMACHY) was a European Space Agency's (ESA) satellite that operated from 2002 to 2012 and provided the earliest record of total column CO_2 and CH_4 measurements. The Greenhouse Gases Observing Satellite (GOSAT) is operated by the Japanese Aerospace Exploration Agency (JAXA) and was launched in January 2009[48]. GOSAT was the first satellite dedicated to the monitoring of greenhouse gases in the atmosphere. Japan launched GOSAT-2 in October 2018. Other important missions include the Methane Remote Sensing Lidar Mission (MERLIN), a joint mission by the French and German space agencies, which was launched in 2019. In 2020, a mission called MicroCarb was launched by the French space agency to observe column CO_2 concentrations. In addition, there are a few more missions launched, like in China, to study GHG emissions.

With new advancements in technology, particularly in sensor technology, satellites now have gas-specific sensors that can detect the concentrations of individual gases. ESA's Copernicus Sentinel-

48 https://svs.gsfc.nasa.gov/5332/#:~:text=NASA%27s%20has%20two%20dedicated%20greenhouse,Source%20Investigation%20mission%20(EMIT) and https://global.jaxa.jp/projects/sat/gosat/, accessed on Jan 23, 2025.

5P satellite, launched on 13 October 2017, is dedicated to monitoring Earth's atmosphere. It carries the advanced Tropomi instrument, which maps various trace gases. Such satellites play an important role in tracking and reducing greenhouse gas emissions. The Tropomi instrument is the only instrument that can map global methane levels every day. Methane, the second most significant greenhouse gas after carbon dioxide, is closely monitored to identify large sources worldwide. The satellite also provides valuable data on ozone levels and gases like sulphur dioxide, formaldehyde, nitrogen oxides and UV-absorbing aerosols.[49] Another important satellite project is Sentinel-3, which was launched during 2016–2018 (Sentinel-3A and Sentinel-3B). Two more such satellites are expected to be launched between 2025 and 2028. One of the important instruments on board these satellites is the Sea and Land Surface Temperature Radiometer (SLSTR).

Additionally, the use of NOAA's Geostationary Operational Environmental Satellites (GOES) provides scientists with a quicker, more accurate way to detect large methane emissions. The Advanced Baseline Imager (ABI), on satellites like GOES-16 (2016), GOES-18 (2022) and GOES-19 (2024), can spot methane leaks or releases as quickly as every seven seconds. This technology is expected to provide faster, more detailed data on methane emissions and support better responses to accidental leaks.[50]

To help combat climate change by addressing methane emissions, the UN launched a new satellite-based system on 11 November 2022 to detect methane and enable governments and businesses to act. This system, called the Methane Alert and Response System (MARS), was introduced at the 27th United Nations Climate Change Conference. MARS is a data-driven platform, part of the UNEP International Methane Emissions Observatory (IMEO), designed to provide policy-relevant data to the right stakeholders for emissions reduction efforts. The goal of MARS is to accelerate global efforts to identify and respond to major methane sources transparently, supporting the implementation of the Global

49 https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P, accessed on Jan 30, 2024.

50 https://science.nasa.gov/mission/goes/, accessed on Jan 30, 2025.

Methane Pledge (GMP). Launched in November 2021 by the US and the EU, the GMP aims to reduce methane emissions. By January 2025, it had gained the support of 159 countries. Methane is a major focus because human activities are responsible for about 25% of anthropogenic climate change. Through MARS, governments, companies and operators will be alerted to large methane sources, enabling quick action to mitigate this potent greenhouse gas.[51]

The latest addition to monitor methane is an American-New Zealand space mission called MethaneSAT. This satellite was launched on 4 March 2024. This Earth observation satellite is designed to monitor and study global methane emissions using a high-performance spectrometer methane sensing system. It takes high-resolution measurements of methane emissions from around 50 major regions worldwide, identifying leaks from oil and gas operations.[52] The data collected will help governments develop new methane regulations for the oil and gas industry.

Satellites to Know Weather and Climate Changes

Weather satellites are launched to collect weather data from space. These satellites are equipped with instruments to study, observe and measure key weather parameters, such as air temperature, precipitation and wind. They also provide data on snow and ice cover, large-scale fires, volcanic eruptions and space weather phenomena like geomagnetic storms. Weather satellites not only track weather changes, but they also help compile and transmit data from various ground- and sea-based weather observatories.

There are two main types of weather satellites: geostationary and polar-orbiting. Geostationary weather satellites orbit the Earth at an altitude of approximately 36,000 km above the equator. They remain stationary relative to the Earth's rotation, which allows them to continuously record data and transmit images using visible, infrared and water vapour sensors. These images typically show cloud cover and are available every 30

51 https://www.unep.org/news-and-stories/press-release/un-announces-high-tech-satellite-based-global-methane-detection and https://www.globalmethanepledge.org/, accessed on Jan 23, 2025.

52 Andrea Willige, "6 ways satellites are helping to monitor our changing planet from space," https://www.weforum.org/stories/2024/05/earth-observation-satellites-climate-change-research/, May 16, 2024, accessed on Dec 23, 2024.

Weather satellites are launched to collect weather data from space. These satellites are equipped with instruments to study, observe and measure key weather parameters, such as air temperature, precipitation and wind. They also provide data on snow and ice cover, large-scale fires, volcanic eruptions and space weather phenomena like geomagnetic storms.

minutes, though this interval can be shortened depending on the needs. Polar-orbiting weather satellites orbit the Earth at a much lower altitude of around 850 km in a north-south direction, passing over the North and South Poles. These satellites provide coverage of each location on Earth twice a day — both during the day and at night. While they cannot continuously observe any given location, their revisit time varies. Since these satellites are much closer to the Earth, they provide images with higher resolution and more clarity. These satellites gather valued information that helps in short-term/medium-term weather forecasting and long-term climate and environmental data archives.

Per the World Meteorological Organisation (WMO), currently, there are 322 in-orbit Earth observation satellites. About 23 are in geostationary orbit, and 223 are polar-orbiting satellites. These belong to various agencies. There are only two satellites on highly elliptical orbits (Molniya orbits).[53] Exact details about the orbits of the remaining satellites are unavailable. All these satellite systems help measure various weather elements, including wind, air pressure, temperature, precipitation, visibility, humidity and cloud cover.

One of the most important elements, wind, can be measured (speed and direction) from a satellite with a scatterometer or radar scatterometer. This instrument is fitted to a satellite that, in low orbit, operates over a wide swath, typically around 500 km. Resolution is between 25 and 50 km. Wind speed can be estimated with an accuracy of 2 m/s and direction with 20° accuracy[54]. Also, based on the available imagery, cloud track wind observations are obtained by using different techniques for assessments. Atmospheric motion vectors (AMVs) are obtained by tracking cloud or moisture patterns in satellite images. Additionally, sea roughness can help determine wind conditions over oceans using active radar scatterometers (e.g., ASCAT) or passive microwave radiometers (e.g., WindSat).[55]

Meteorological satellites do not measure temperature directly. For

53 https://wmo.int/topics/earth-observation-satellites, accessed on Feb 01, 20225.

54 https://www.sciencedirect.com/topics/engineering/scatterometer, accessed on Jan 25, 2025.

55 https://resources.eumetrain.org/data/4/438/navmenu.php?tab=1&page=1.0.0, accessed on Jan 12, 2025.

weather forecasting and climate assessment, surface (land and sea) and upper-air temperatures at various altitudes (up to the stratosphere) need to be assessed. Satellites also measure other weather elements using specific sensors onboard. In some cases, data from other platforms, such as ocean buoys, radiosondes and radars, are incorporated to help improve satellite assessments. The ideal input received from satellites for weather and climate assessment is cloud imagery, which helps greatly in weather assessment.

An important instrument for indirect measurement of temperature is a radiometer. It measures electromagnetic radiation, such as visible light, infrared or microwaves, reflected by the Earth's surface and atmosphere. They help monitor sea surface and air temperatures, cloud cover and storms. An example is the Advanced Very High-Resolution Radiometer (AVHRR) used by NOAA. Sounders are also used for temperature measurements, using infrared radiation to assess temperature and humidity in the atmosphere. They provide data on the vertical distribution of temperature, water vapour and gases. Other satellite instruments include Radar Altimeters, which send radar pulses to measure the distance to the Earth's surface and provide sea surface height data. The Geostationary Lightning Mapper (GLM) tracks lightning activity, helping forecasters detect severe storms and issue warnings.[56]

Environmental (weather) satellites are designed to observe different aspects of the Earth's atmosphere, land and oceans. Scientists use these satellites to study a variety of features, including ocean depth, sea surface temperature, ocean colour, coral reefs and ice cover. While meteorologists have used satellites for years to monitor the atmosphere, using satellite data to study the ocean is a more recent development. With advances in technology, scientists can now use satellites to make detailed observations about the ocean. These include tracking ocean waves, studying currents and eddies, monitoring sea level changes and measuring ocean carbon levels. Satellites also help monitor the health of coral reefs, sea ice changes, and even the migration of whales. By observing

56 Aleks Buczkowski, "A look at the ways in which satellites are used to monitor and forecast weather," 07 September 2023, https://geoawesome.com/eo-hub/a-look-at-the-ways-in-which-satellites-are-used-to-monitor-and-forecast-weather/, accessed on Dec 24, 2024.

Rising ocean temperatures account for 91% of global warming, and Arctic sea ice melt is a key indicator of climate change. Satellites have become essential for monitoring these conditions, offering frequent, precise data on sea ice since 1979.

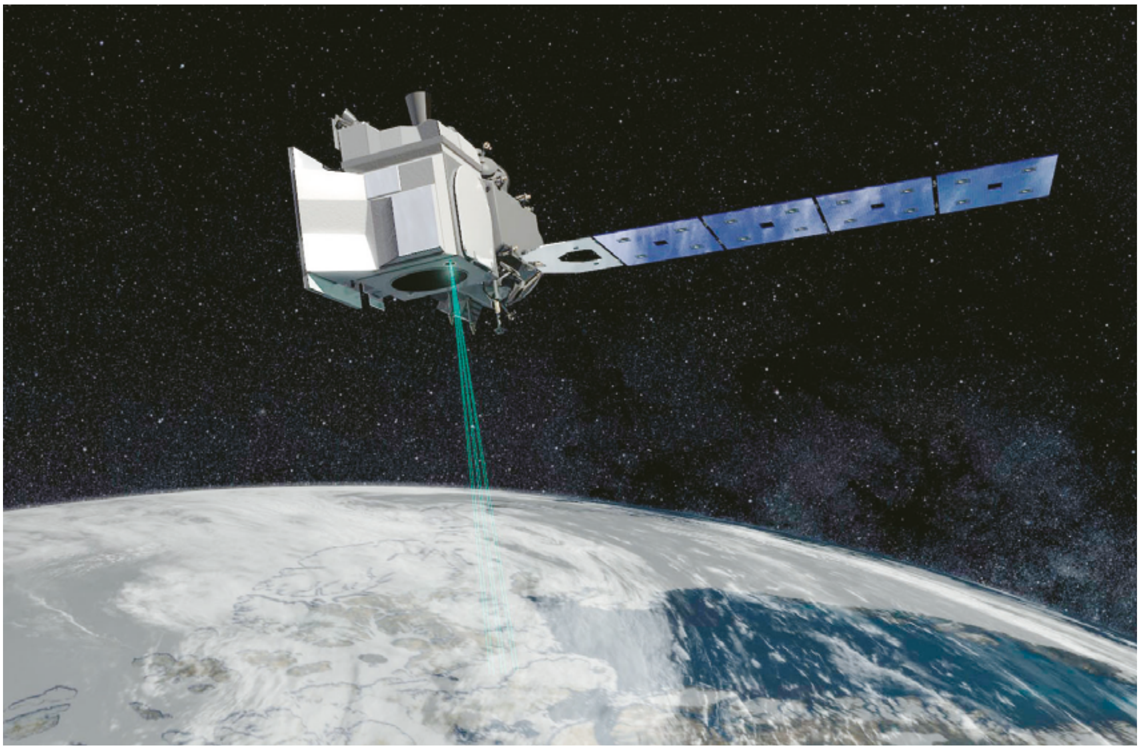
sea surface temperatures and biological activity like phytoplankton production, satellites provide a wealth of information about our oceans[57]. All this helps in a big way to undertake climate studies.

Rising ocean temperatures account for 91% of global warming, and Arctic sea ice melt is a key indicator of climate change. Satellites have become essential for monitoring these conditions, offering frequent, precise data on sea ice since 1979. Satellites monitor sea ice through thermal microwave radiation, as different surfaces emit different wavelengths. Equipped with microwave radiometers, satellites create digital maps that distinguish land, water and ice. This method is reliable even in harsh polar conditions, accounting for snow, rain and fog.

A greater challenge is measuring ice thickness, a key factor in sea level rise due to warming ocean waters thinning ice. Since 1992, satellites with altimetry instruments have used radio pulses or lasers to measure ice thickness by calculating the time it takes for the signal to return. Radar altimetry can observe large ice areas frequently, while laser altimetry provides more precise data for smaller, more complex areas. Together, they

A greater challenge is measuring ice thickness, a key factor in sea level rise due to warming ocean waters thinning ice. Since 1992, satellites with altimetry instruments have used radio pulses or lasers to measure ice thickness by calculating the time it takes for the signal to return.

57 https://oceanexplorer.noaa.gov/technology/satellites/satellites.html#:~:text=Satellites%20that%20detect%20and%20observe,%2C%20ice%20cover%2C%20and%20more, accessed on Jan 31, 2025.



NASA's ICESat-2 (short for Ice, Cloud and land Elevation Satellite)

offer a more accurate picture of sea ice melt.[58] The important satellites in use for measuring polar sea ice thickness, ice sheet elevation and sea ice thickness and monitoring changes in ice sheets, ice flows, snowmelt and flooding, are the European Space Agency's CryoSat-2 (radar), launched on 8 April 2010, and NASA's ICESat-2 (laser) satellite, launched on 15 September 2018.

On 25 May 2024, NASA launched Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE), a mission to study climate change. This mission features two small, shoebox-sized CubeSats designed to measure heat emissions from Earth's poles. The data collected would provide critical understandings to improve climate change predictions, specifically in relation to ice, sea levels and weather patterns in polar regions. PREFIRE's focus is on the polar regions, where heat loss plays a key role in understanding climate change. The CubeSats are equipped with advanced infrared sensors to measure the heat radiated from the poles. This information collected is expected to provide a detailed picture of the polar

58 Kathryn Urban, "How Do Satellites Help Us Track Climate Change?" November 22, 2022, https://www.american.edu/sis/centers/security-technology/how-satellites-track-climate-change.cfm, assessed on Dec 24, 2024.

heat balance, which in turn will help scientists refine climate models.[59]

In addition to PREFIRE, some other satellites are also used in climate change research. The GRACE (Gravity Recovery and Climate Experiment) was a unit of twin satellites that orbited Earth from 2002 to 2017. These satellites have made detailed measurements of Earth's gravity field and added to the knowledge about Earth's water reservoirs, over land, ice and oceans.[60] Another important mission is the EarthCARE (Cloud, Aerosol and Radiation Explorer) mission, launched on 28 May 2024. It is the largest and most complex Earth Explorer to date and is a joint venture of the space agencies from Europe and Japan. It will advance our understanding of the role that clouds and aerosols play in reflecting incident solar radiation into space and trapping infrared radiation emitted from Earth's surface.[61]

India's Space Tech: Tackling Climate Change

India recognises the challenges of climate change and is among the top 10 countries most affected by it. At the same time, India is one of the largest contributors to global greenhouse gas emissions, with coal being the main source. With a population making up nearly 18% of the world's total and ranking first globally, India faces huge demands. However, the country is committed to reducing carbon emissions and is working to decrease its reliance on coal. To address climate change, India introduced the National Action Plan on Climate Change (NAPCC) in 2008, outlining several key goals for the country's response to climate challenges.

For over 20 years, India has been taking steps to tackle climate change. Its climate and environmental policies include protecting glaciers, greening the railway system, reducing single-use plastics and promoting

> In its fight against climate change, India is leveraging space technologies.

59 https://prefire.ssec.wisc.edu/, accessed on Dec 15, 2024.

60 https://sealevel.nasa.gov/missions/grace, accessed on Dec 14, 2024.

61 https://earth.esa.int/eogateway/missions/earthcare, accessed on Dec 14, 2024.

India's approach to addressing climate change is not just about using any one satellite system, but about how it uses its entire space technology architecture to tackle climate-related challenges.

clean cooking fuel. The 2022 IPCC report highlights India's low per capita emissions compared to other major economies. India has set enhanced targets under its Nationally Determined Contributions (NDCs) to achieve net zero by 2070, aligning with goals set by other industrialised nations. Given its low historical contribution to greenhouse gas emissions, India's net-zero goal is considered ambitious.[62] In its fight against climate change, India is leveraging space technologies. Despite being part of the Global South, India has a well-established space programme and a strong industrial base. The country is home to various scientific institutions focused on high-tech research, development and innovation. Additionally, India boasts globally recognised educational and academic institutions that contribute to cutting-edge research. This combination enables India to effectively use space and related technologies to tackle climate change.

India is using space technology to track and reduce the impacts of climate change. It has one of the largest remote-sensing satellite programs in the world. The Indian Space Research Organisation (ISRO) plays an important role in using space technology to monitor climate change. India's approach to addressing climate change is not just about using any one satellite system, but about how it uses its entire space technology architecture to tackle climate-related challenges. Currently, India's satellite network provides important data on factors like temperature, sea level rise, air quality and deforestation. This data helps track how fast and how much climate change is happening.

The India Meteorological Department (IMD) celebrated its 150th anniversary on 15 January 2025. For many decades, IMD has been a leader

62 https://www.lse.ac.uk/granthaminstitute/explainers/how-is-india-tackling-climate-change/, accessed on Jan 14, 2025.

> India became a spacefaring state in 1980, but only in September 2002 did it launch its first dedicated meteorological satellite called Kalpana-1

in meteorological observations, providing weather information to various sectors, from aviation to agriculture. IMD also issues short-, medium- and long-term weather forecasts that are crucial for industries, such as aviation, agriculture, travel, tourism, shipping, irrigation, mining and energy. Satellite technology plays a key role in IMD's observation, data storage and forecasting and prognosis practices.

ISRO and Meteorological Satellites[63]

The Indian establishment realised during the early phases of its space programme in the 1970s that the field of meteorology would greatly benefit from satellite technologies. India's agriculture sector was losing much during those days owing to the country's inadequacies in weather forecasting and providing timely weather inputs to the farmers. Some studies indicate that as many as 117 cyclones hit India in 50 years from 1970 through 2019, claiming more than 40,000 lives. Most of these deaths were caused by weather conditions during the 20th century. Today, thanks to the availability of satellite imagery, adequate early warning of the approach of cyclonic storms and hurricanes is given by weather forecasters and disaster management agencies, which ensures timely evacuation from the coastal areas.

ISRO's Indian National Satellite System (INSAT) programme officially began in 1976. This has been a unique project in the world where a satellite system was developed to undertake both telecommunications and meteorological tasks. In those days, owing to budgetary limitations, ISRO was developing multipurpose satellite systems. There were different stakeholders for the INSAT programme like the Department of Telecommunications

63 Ajey Lele, "The evolution of India's weather satellite programs," Feb 19, 2024, https://www.thespacereview.com/article/4743/1, accessed on Jan 17, 2025.

and TV and radio agencies. Another important stakeholder was the Indian Meteorological Department (IMD). The initial missions of INSAT during the early 1980s had a meteorological payload called Very High-Resolution Radiometer (VHRR).

During the early 1980s, ISRO faced problems with the INSAT-1 program. The INSAT-1A satellite had a meteorology package consisting of a scanning very-high-resolution, two-channel radiometer to provide full-frame, full-Earth coverage every 30 minutes. This satellite was launched on April 10, 1982, but started facing problems within a few months. INSAT-1B also had some issues. However, INSAT-1C and -1D were successful missions and provided IMD with imagery for many years. INSAT-2A, -2B and -2E were multipurpose satellites with meteorological payloads, and the same is the case with INSAT-3A and -3C.

India became a spacefaring state in 1980, but only in September 2002 did it launch its first dedicated meteorological satellite called Kalpana-1, which was deactivated in September 2017. INSAT-3D (July 2013) and INSAT-3DR (August 2016) satellites were launched mainly for meteorological purposes in the INSAT series. They have data relay and satellite-aided search-and-rescue systems as well. In September 2016, ScatSat-1 (Scatterometer Satellite-1) was launched by ISRO to provide additional weather forecasting, cyclone prediction and tracking services. This satellite lasted for around five years.

In October 2011, ISRO launched a 1,000-kilogram Indo-French weather observation satellite called Megha-Tropiques. This was India's first major joint space project with France in meteorology. The satellite was deactivated in April 2022. Another such joint mission is a satellite called SARAL with altimetric measurements designed to study ocean circulation and sea surface. This system entered in service in June 2013 and is still active.

ISRO has a series called Oceansat for the purposes of oceanography and atmospheric studies. So far, three Oceansat Earth observation satellites have been launched, starting with Oceansat-1 in May 1999. At present, Oceansat-2 and Oceansat-3 are operational.

On 17 February 2024, ISRO successfully launched the GSLV-F14 mission. This launch placed

India's INSAT-3DS satellite into a geosynchronous transfer orbit. INSAT-3DS is a 2274-kilogram satellite launched for meteorological purposes. It has an additional element of data relay and satellite-aided search-and-rescue service. According to ISRO, there are four main payloads in INSAT-3DS. The Imager Payload is for generating images of the Earth and its environment in six wavelength bands. The Sounder payload has one visible channel and 18 narrow spectral channels. It would provide information on the vertical profiles of the atmosphere, like temperature and humidity. The third payload is a Data Relay Transponder (DRT) for receiving global meteorological, hydrological and oceanographic data from automatic data collection platforms and Automatic Weather Stations (AWS) and would relay the information back to the user terminal. The only non-meteorological payload is a satellite-aided search-and-rescue (SA&SR) transponder meant for relaying a distress signal for search-and-rescue purposes with global receive coverage in the UHF band.

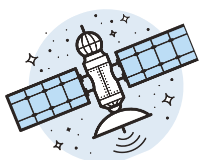
These weather satellites play a crucial role in addressing climate change. The data they provide helps various users, forecasting units and scientific groups. Additionally, this data enhances transparency and supports the Indian government in showcasing its efforts to tackle the challenges of climate change in the world.

ISRO and Climate Change Studies

As mentioned earlier, ISRO has different types of weather satellites that help analyse climate change. Earth observation satellites play an important role in sustainability and governance, and India uses these systems to address climate change concerns[64]. These satellites, including INSAT, Cartosat and Oceansat, are essential for monitoring the climate. They capture detailed images of land use, forests, water resources

Earth observation satellites play an important role in sustainability and governance, and India uses these systems to address climate change concerns.

64 The Hindu, August 08, 2024.



Space technology plays a crucial role in identifying ideal sites for renewable energy production. ISRO's satellites, primarily the INSAT and Oceansat series, gather data on solar radiation. This is helping agencies identify regions with high solar energy potential.

and urban growth. This data helps policymakers develop better climate strategies. Satellites like RISAT provide all-weather surveillance, which is important for agriculture, water management and coastal areas. Collecting information over time helps improve the understanding of climate change.

The INSAT system and other meteorological satellites discussed above collect data on atmospheric conditions. This data helps scientists understand global warming, predict extreme weather and assess climate impacts. Real-time data allows authorities to issue early warnings, reducing risks and damage during disasters like floods and cyclones.

India faces frequent natural disasters, such as floods, cyclones and heat waves, exacerbated by climate change. Today, investments made by ISRO over the years are helping India in disaster response and management. Over the Indian continent, the rapid increase in the intensity of disasters is defiantly attributable to climate change.

ISRO is using satellite data in a constructive way for climate change mitigation. To reduce greenhouse gas emissions, India is investing in renewable energy sources like solar, wind and biomass. Space technology plays a crucial role in identifying ideal sites for renewable energy production. ISRO's satellites, primarily the INSAT and Oceansat series,

India's involvement in global agreements like the Paris Agreement is backed by its space-based ability to track emissions and assess climate impacts. India's satellites contribute to global climate monitoring via its participation in programmes like the United Nations Framework Convention on Climate Change (UNFCCC).

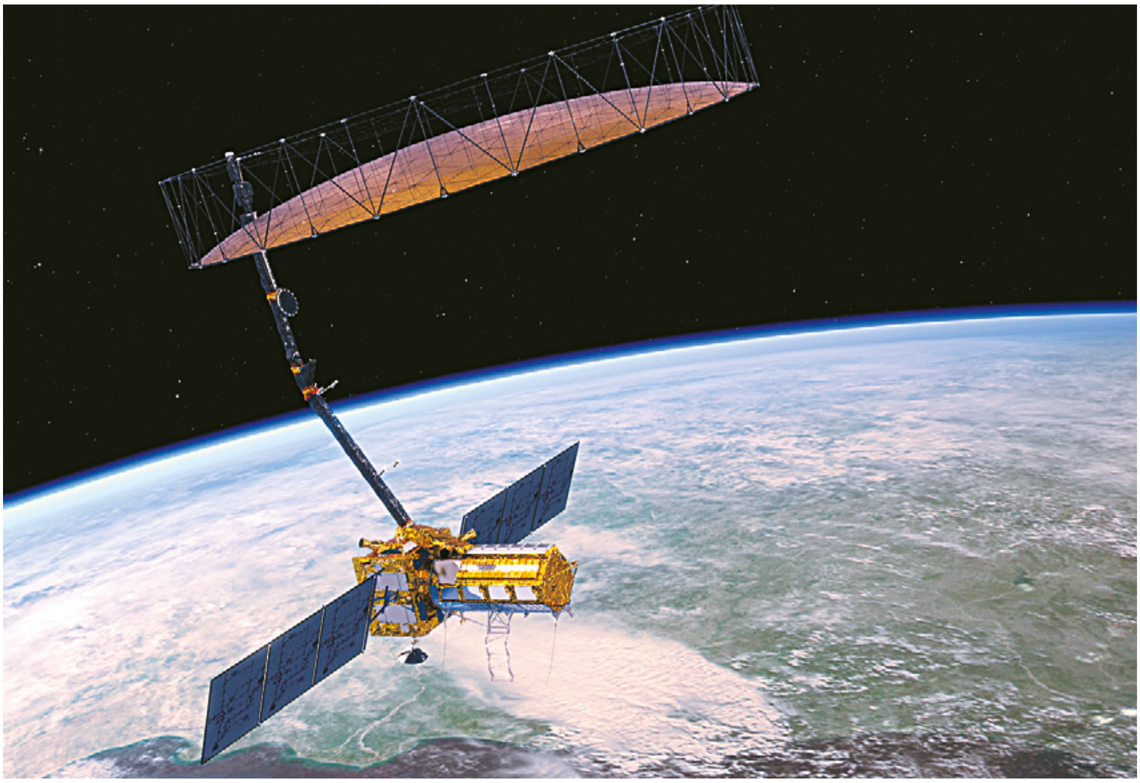
In 2025, ISRO is set to launch an important satellite mission called NASA-ISRO Synthetic Aperture Radar (NISAR). This joint project between NASA and ISRO will provide high-resolution radar images of Earth's surface. It will allow precise monitoring of ice sheet changes, glaciers and other land features impacted by climate change. There is significant global interest in this mission.

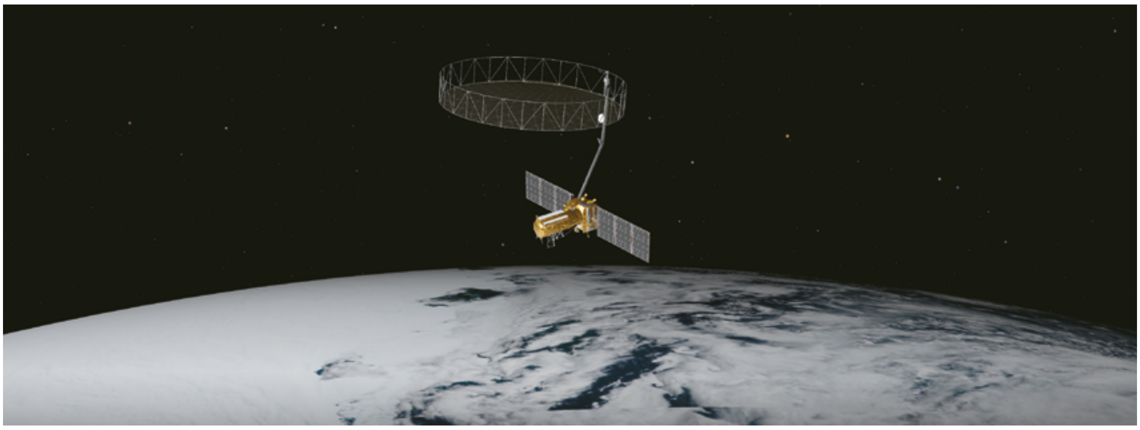
gather data on solar radiation. This is helping agencies identify regions with high solar energy potential. This permits further efficient solar energy deployment across the country. Similarly, satellites help in assessing wind energy potential by monitoring wind patterns and speeds. These aids determine the most suitable locations for wind farms, improving energy production. ISRO also contributes data globally in support of global climate initiatives and international climate research and policymaking. India's involvement in global agreements like the Paris Agreement is backed by its space-based ability to track emissions and assess climate impacts. India's satellites contribute to global climate monitoring via its participation in programmes like the United Nations Framework Convention on Climate Change (UNFCCC).

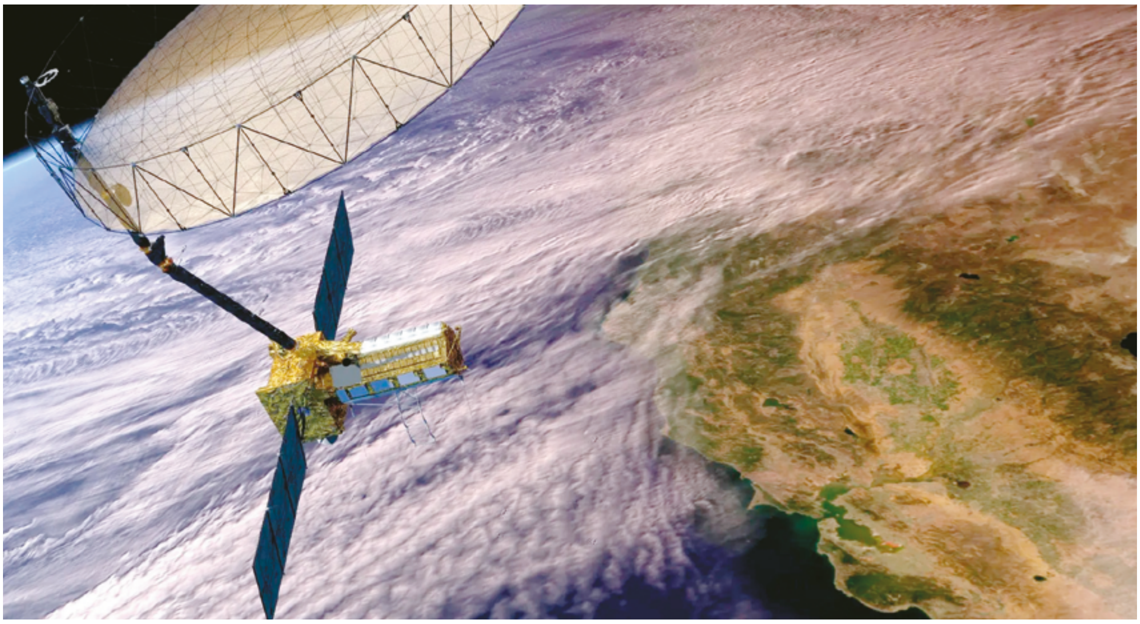
India is planning to expand its use of space technology for climate change. ISRO is working on advanced satellites to improve climate modelling, disaster response and sustainability efforts. ISRO scientists[65] are also undertaking research work to understand climate change by analysing globally available data sets. There are published research works dealing with analyses of methane emissions over multiple Indian locations using satellite data.

In 2025, ISRO is set to launch an important satellite mission called NASA-ISRO Synthetic Aperture Radar (NISAR). This joint project between NASA and ISRO will provide high-resolution radar images of Earth's surface. It will allow precise monitoring of ice sheet changes, glaciers and other land features impacted by climate change. There

65 Asfa Siddiqui et al, "Detecting Methane Emissions from Space in India: analysis using EMIT and Sentinel-5P TROPOMI", https://assets-eu.researchsquare.com/files/rs-3855832/v1_covered_1e51afbb-4682-41c7-96b9-914a6332b6a1.pdf?c=1705418458, accessed on Feb 2, 2025.





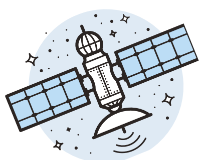


NASA-ISRO Synthetic Aperture Radar (NISAR). https://nisar.jpl.nasa.gov/

is significant global interest in this mission, as it is expected to make a substantial contribution to understanding and monitoring climate change.

Conclusion

Over the years, space technologies have become crucial for monitoring weather and climate. Today, the world relies heavily on these technologies to address various challenges posed by global warming and climate change. Several major space projects are currently underway, studying climate change and providing valuable data to help create solutions for its mitigation. With rapid developments taking place in the field of artificial intelligence (AI), some new projects are also being developed. India's use of space technology to tackle climate change is a great example of how innovation can help solve environmental problems. By using satellites for monitoring, promoting renewable energy and improving disaster management, India is not only enhancing its ability to handle climate impacts but also contributing to global efforts to fight climate change. As the world faces more severe effects of climate change, India's space technologies will be key in building a more sustainable and resilient future for everyone.



INDIA'S SPACE TECHNOLOGY IN ADVANCING THE BLUE ECONOMY

Namrata Goswami

India is a major power in Asia. The United Nations report titled World Economic Situation and Prospects (WESP) states that India's economy is set to grow at 6.6 percent in 2025, thereby maintaining India's position as a driver of global economic growth. However, the report highlights some challenges that could affect global economic activity. These challenges include "geopolitical conflict, trade tensions, high borrowing costs, inflation thereby affecting the United Nations Sustainable Development Goals (SDGs)". [66] Despite this, in the overall economic development of the global economy, space technology plays a critical role. By 2035, the space economy is set to reach $1.8 trillion, from $596 billion in 2024. That is an exponential rise. A decrease in the cost of rocket launch, and the growth of commercial mega-constellation in Low Earth Orbit (LEO) will affect the way we think about space from an economic perspective. With the drop in cost of launches and satellite manufacturing and maintenance, the cost of data that drives connectivity, has also decreased. Added to this are new space technologies and activities like space tourism, in orbit refueling and manufacturing, space mining, and lunar habitation, that will add new aspects to the global space economy. For instance, the space tourism market, is forecasted to reach $4-6 billion by 2035. Space technologies will have spillover effects on information technology, agriculture, supply chain mechanisms, satellite internet, construction, insurance, and the environment. As per World Economic Forum Executive Committee member, Sebastian Buckup, "space

By 2035, the space economy is set to reach $1.8 trillion, from $596 billion in 2024. That is an exponential rise. A decrease in the cost of rocket launch, and the growth of commercial mega-constellation in Low Earth Orbit (LEO) will affect the way we think about space from an economic perspective.

66 *Namrata Goswami, Ph.D. is Professor of Space Security, West Space Scholars Program, School of Advanced International Studies, Johns Hopkins University. Disclaimer: All views expressed in this article are solely that of the author. United Nations, "World Economic Situation and Prospects (WESP) Report", January 09, 2025, https://www.un.org/development/desa/dpad/document_gem/global-economic-monitoring-unit/world-economic-situation-and-prospects-wesp-report/

> The London School of Economics and Political Science defines the term blue economy as "a sustainable ocean economy- the economic activities associated with the ocean, seas and coastal regions-that allows resources use while preserving the health of the ocean ecosystem. However, there is no universally agreed definition."

technologies are delivering greater value to a more diverse set of stakeholders than ever before...as costs reduce and accessibility rises, these technologies could reshape whole industries, and have as much impact on business and society as smartphones or cloud computing".[67]

It is in this context of growth in the global space economy that this article analyses India's space program and its contribution to the blue economy. According to the World Bank, the concept of blue economy means it is the "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the ecosystem".[68] By extension, we could define a blue economy in, from and to space, as "the sustainable use of space resources for economic growth, improved livelihoods, and jobs while preserving the ecosystem". The London School of Economics and Political Science defines the term blue economy as "a sustainable ocean economy-the economic activities associated with the ocean, seas and coastal regions-that allows resources use while preserving the health of the ocean ecosystem. However, there is no universally agreed definition".[69]

India's space program has been historically focused on developing space technologies for benefitting India's population. Space research in India was developed in the 1960s, specifically propelled by Dr. Vikram Sarabhai, who ardently believed that space technologies could benefit the real problems of society. To institutionally develop

67 World Economic Forum, "Space: The $1.8 Trillion Opportunity for Global Economic Growth", April 08, 2024, https://www.weforum.org/publications/space-the-1-8-trillion-opportunity-for-global-economic-growth/

68 United Nations, "Blue Economy Definitions", n.d., https://www.un.org/regularprocess/sites/www.un.org.regularprocess/files/rok_part_2.pdf

69 The London School of Economics and Political Science, "What is the Blue Economy?", December 11, 2024, https://www.lse.ac.uk/granthaminstitute/explainers/what-is-the-blue-economy/

space capabilities, in 1962, the Indian National Committee for Space Research (INCOSPAR) was set up under the Department of Atomic Energy, subsequently followed by the establishment of the Indian Space Research Organisation (ISRO) in August 1969. In 1972, India established the Department of Space (DoS) under the Prime Minister's Office and constituted the Space Commission and ISRO was brought under the DoS. This structure continues till date but with some major changes to include the development of new institutions to regulate and enable the commercial space sector in India. There were several reasons why India invested in developing space capabilities so early, and Dr. Vikram Sarabhai, specified why he believed India should be investing in space. According to Sarabhai, space played a critical role in a nation's national development and led to scientific progress, something India could not but invest in for its overall national development. Sarabhai stated:

> There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the Moon or the planets or manned spaceflight. 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.[70]

Sarabhai was supported in his advocacy for space by Homi Bhabha, the father of India's nuclear program. The first rocket launch center was established at Thumba near Thiruvananthapuram on the coast of the Arabian sea, based on its proximity to the equator. In 1975, India launched its first satellite, the Aryabhatta, on a Soviet rocket. In 1980, India successfully launched its first rocket Space Launch Vehicle (SLV)-3, with a capacity to place 40 kgs, into LEO. The SLV-3 program made a critical

70 "Meet Dr. Vikram Sarabhai, the Pioneer Who Taught Rocket Science to India", India Today, December 30, 2022, https://www.indiatoday.in/science/story/dr-vikram-sarabhai-death-anniversary-isro-indian-space-program-founder-prl-iim-2315400-2022-12-30

contribution in further development of India's launch vehicle capacity.[71]

India's space program historically has been focused on three important elements of space technology. These includes satellites for communication and remote sensing, a space logistics and transportation system, and finally, the vital necessity to apply space technology to real life problems. The Vikram Sarabhai Space Centre (VSSC) has put out a vision for 2025 in regard to space capabilities. This includes:

- To develop satellite-based communication and navigation systems for rural connectivity, security needs, and mobile services.
- To e nhance imaging capability for the management of natural resources, weather and assist in climate change studies.

- To further develop 'space science' missions to enhance understanding of the solar system and the universe.
- To develop a heavy lift launcher capability.
- To develop Reusable Launch Vehicles.
- To develop a human flight program.[72]

It is important to analyze how these vision statements have translated into practice to enable India to take

Since 2019, there has been some major shifts in India's strategic thinking regarding how space technology is developed with an acknowledgement on the growing role of the commercial space sector. This has brought about reform in how India is institutionalizing itself to take advantage of space technologies across the civil, military and commercial space.

71 Indian Space Research Organisation, Department of Space, "Genesis", n.d., https://www.isro.gov.in/genesis.html

72 Manish Purohit, "India's Space Ambitions to Soar in 2025, IRSO Eyes Big-Ticket Missions", India Today, January 3, 2025, https://www.indiatoday.in/science/story/indias-space-ambitions-to-soar-in-2025-as-isro-eyes-big-ticket-missions-2658761-2025-01-03

advantage of the blue economy to include some important shifts in strategic thinking in regard to space since the 2025 Vision was put out by VSSC around 2017.

India's Space Institutions, Capacities and Future Missions; Major Shifts in Thinking

Since 2019, there has been some major shifts in India's strategic thinking regarding how space technology is developed with an acknowledgement on the growing role of the commercial space sector. This has brought about reform in how India is institutionalizing itself to take advantage of space technologies across the civil, military and commercial space.

Civil Space

In the civil space sector, India has developed capacities to support a grand vision in space known as Space Vision 2047, to coincide with the 100-year celebration of India's independence from British colonial rule in 1947. As per the Space Vision 2047, human spaceflight is a key component of India's space missions. Under its Gaganyaan 1 mission, India is planning to launch an uncrewed test flight mission, utilizing an advanced Human rated Launch Vehicle Mark 3 (LV3). This uncrewed mission will carry a humanoid Vyomitra in a depressurized crew chamber, followed by Gaganyaan 2 and Gaganyaan 3, before the launched a crewed H1. The ambition is to scale this up, in order to be able to have an Indian launch mission to the International Space Station (ISS)-Gaganyaan 4, and the first module of India's own space station, the Bharatiya Antariksha Station (BAS) by 2035. As part of the 2047 space vision are the development of medium heavy lift rocket, as well as a human landing on the Moon by 2040. To develop a robust communication system, India is launching the Data Relay Satellite System (IDRSS-1) by 2025 on a

In his speech on the occasion of India's 78th anniversary of independence on August 15, Indian Prime Minister Narendra Modi mentioned India's aspiration to develop its space station.

Geosynchronous Launch Vehicle Mark II-GSLV-MK II.[73]

As part of the 2047 Space Vision, four projects have been prioritized. First, the development of India's human space flight capacities and its own space station by 2028; the development of a Next Generation Satellite Launch Vehicle (NGLV) to include reusable launch capabilities by 2032, a Chandrayaan-4 mission to develop lunar landing and return to Earth capacities (lunar sample return) by 2027, and a Venus Orbiter Mission by 2028.[74] According to the chairman of ISRO, S. Somanath, "We have a roadmap for what we have planned till 2047... We can build a space station, we can send human beings to the moon, and we can create moon-based economic activity in space".[75] In his speech on the occasion of India's 78th anniversary of independence on August 15 Indian Prime Minister Narendra Modi mentioned India's aspiration to develop its space station.[76]

In the civilian space sector, India has the attributes of a major space power with its independent launch systems, satellites, spaceport, and international partnerships. India has launched 130 Indian satellites and spacecrafts including its Chandrayaan Lunar missions, and Mars Mission,[77] and 424 foreign satellites since 1975 earning India about $174 million from the launch of foreign satellites.[78] Amongst its launch capacities, India has done well in the launch area with several systems: the four-stage Polar Satellite Launch Vehicle (PSLV) with a launch capacity of 1.5 tons to geostationary transfer orbit (GTO), and 2 tons to Sun-synchronous orbit;[79] the three-stage Geosynchronous Launch Vehicle (GSLV)-Mk-II with a payload launch

73 Andrew Jones, "India's First Launch of 2025 Sends NVS-02 Navigation Satellite into Orbit", SpaceNews, January 29, 2025, https://spacenews.com/indias-first-launch-of-2025-sends-nvs-02-navigation-satellite-into-orbit/

74 Department of Space, "Parliament Question: Efforts to Make India a Developed Nation by 2047 in Space Sector", Press Trust of India, December 12, 2024, https://pib.gov.in/PressReleasePage.aspx?PRID=2083766

75 "Bharatiya Antariksha Station by 2030, Presence on Moon by 2040: Somnath Reveals ISRO Goals at Gujarat Space Conference", Mint, January 11, 2024, ww.livemint.com/science/news/bharatiya-antariksha-station-by-2030-presence-on-moon-by-2040-somnath-reveals-isro-goals-at-gujarat-space-conference-11704982649194.html

76 "Independence Day 2024: PM Modi Addresses Nation on 78th Independence Day from Red Fort", August 15, 2024, https://www.youtube.com/watch?v=-q4z7zpG9XA

77 Indian Space Research Organisation, Department of Space, "Spacecraft Missions", n.d., https://www.isro.gov.in/SpacecraftMissions.html

78 "Of 424 Foreign Satellites Launched by India, 389 in Last 9 Years: Jitendra Singh", ET Government, June 6, 2023, ttps://government.economictimes.indiatimes.com/news/technology/of-424-foreign-satellites-launched-by-india-389-launched-in-last-9-years-jitendra-singh/100779485

79 Indian Space Research Organisation, Department of Space, "PSLV", https://www.isro.gov.in/PSLV_CON.html

capacity of 2 tons to GTO and 6 tons to LEO;[80] and the three-stage LVM-3, which has a payload launch capacity of 4 tons to GTO and 10 tons to LEO.[81] The Small Satellite Launch Vehicle (SSLV), which successfully launched for the first time in 2023, can put about half a ton into orbit.[82] In 2024, the Union Cabinet chaired by the Prime Minister of India, Narendra Modi, approved the development of the Next Generation Launch Vehicle (NGLV), with a maximum payload capacity of 30 tons to LEO, with a reusable first stage. The NGLV [tentatively named Soorya] will be utilized for the launch of India's space station, and its crewed landing on the Moon.[83] While India became the first Asian country to enter Mars orbit in 2014, with its Mangalyaan 1 mission, in 2024, India revealed its aspirations for its Mangalyaan-2 mission. India's second Mars Mission aspires to land a rover, and a helicopter on Mars. ISRO is also developing a supersonic parachute to navigate the rather fiery descent into the atmosphere of Mars. The helicopter will be equipped with scientific instruments, to include the Martian Boundary Layer Explorer (MarBLE) that will conduct in depth studies of the Martian atmosphere. ISRO is launching a relay satellite to help continuous communication between the rover and helicopter, serving as the vital link between Earth and Mars for the flow of data and help ensure smooth ground control. For India, developing a Mars logistics capability adds to its space power status.[84] If India succeeds in developing the Mars helicopter, it would beat China to that race, the United States being the only nation to fly a helicopter on Mars with its Ingenuity helicopter.[85]

The Importance of Commercial Space

For long, India's space program has been a state funded and state led enterprise with ISRO in the lead in not only Research and Development (R&D) but also manufacturing of

80 Indian Space Research Organisation, Department of Space, "Geosynchronous Satellite Launch Vehicle Mark II", https://www.isro.gov.in/GSLV_CON.html

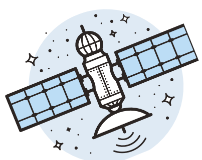
81 New Space India Ltd., "Launch Services (SSLV, PSLV, GSLV-Mk-II and LVM-3)", https://www.nsilindia.co.in/launch-services

82 Ibid.

83 Ibid.

84 Srijan Pal Singh, "Mangalyaan-2: Why India Needs to go to Mars", India Today,

85 Ibid.



space systems. This institutional structure has changed with India's 2023 space policy where the focus is on commercialization of space, ensuring that it is the private sector that takes the lead in building end-to-end space systems. As part of India's 2047 space vision, the 2023 space policy indicates that "to augment space capabilities; enable, encourage and develop a flourishing commercial presence in space [emphasis added]; use space as a driver of technology development and derived benefits in allied areas; pursue international relations, and create an ecosystem for effective implementation of space applications among all stakeholders".[86] Subsequently, the space vision is connected to India's space goals of utilizing space for economic development and advancing its private sector to take advantage of the global commercial space market. As per Jitendra Singh, Union Minister of State (Independent Charge) for Science & Technology, Minister of State (Independent Charge) for Earth Sciences, MoS PMO, Department of Atomic Energy, Department of Space, Personnel, Public Grievances and Pensions, "there has been around 200 times increase in Space StartUps in just about two years [2022-2024]", with an increase from one space start up in 2022 to nearly 200 space startups in 2024. He indicated that the share of India in the global space market was two percent in 2021, which should rise to 8 percent by 2030 and 15 per cent by 2047. More importantly, Singh has directed the transfer of technology from ISRO to the private sector, and there has been 403 such transfers, and an additional 50 such transfers by New Space India Ltd (NSIL), and the Indian National Space Promotion & Authorisation Centre (IN-SPACe) by 2024.[87]

Some of Indian space startups that are developing key technologies like manufacturing satellites, building propulsion system, developing launch platforms include Dhruva Space, Bellatrix, Skyroot Aerospace, etc.[88] Bengaluru based Pixxel specializes

86 Indian Space Research Organisation, "Indian Space Policy-2023", https://www.isro.gov.in/media_isro/pdf/IndianSpacePolicy2023.pdf

87 Department of Space, "200 Times Increase in Space StartUps in Just Two Years", Says Union Minister Dr. Jitendra Singh", June 20, 2024, https://pib.gov.in/PressReleasePage.aspx?PRID=2027137

88 Namrata Goswami, "Indian Space Program and its Drivers Possible Implications for the Global Space Market", The French Institute of International Relations January 2022, https://www.ifri.org/sites/default/files/migrated_files/documents/atoms/files/goswami_indian_space_program_2022_3.pdf

in satellites with hyperspectral imaging satellites, building a small constellation of 24 satellites called Firefly that will build an image of Earth with hundreds of wavelengths, using its analytic platform, Aurora. Backed by Google, Pixxell has already launched three of its six hyperspectral imaging satellites onboard a SpaceX's Transporter share rideshare mission, a first batch of the company's 24 satellites to be launched by 2026-2027. Pixxel co-founder and CEO Awais Ahmed stated that "it is the world's highest-resolution hyperspectral satellite constellation and India's first-ever private commercial constellation".[89] Hyperspectral imagery can offer deep insights into ocean pollution, oil spills, deforestation and the quality of water. Pixell's Firefly satellites can provide hyperspectral imagery at a five-meter resolution, covering a 25-mile (40 kms) radius covering data over 150 spectral bands. This can unearth hidden patterns in atmospheric conditions, vegetation health, and guide agriculture and crop yield and patterns. Those funding Pixell include Google, Accenture Ventures, Radical Ventures, etc.[90] Skyroot Aersopace aims to build 'cabs' that can get to space. These are small rockets, build to bring payloads to very specific orbits. Skyroot's Vikram-S rocket is India's first privately launched rocket that achieved 88.8 kms peak altitude to space in November 2022.[91] The next step is to launch the Vikram I with a launch capacity of 500 kilograms toLEO. Interestingly, Space X Falcon 9 charges $6, 000 per kilogram to LEO; Skyroot says it will charge $20, 000 per kilogram to LEO. While that is a major competitive cost difference with Falcon 9 ahead of the curve, rideshares are not always available and what Skyroot is aiming for is to fill that gap faster, and bring about a drop in its payload cost. Skyroot is also aspiring to develop the customized launch capacity, aimed at specific orbits that a Space X rideshare may not target. Skyroot has received funding from Singapore Sovereign

89 Jagmeet Singh, "Google-backed Pixxel Launches India's First Private Satellite Constellation", Techcrunch, January 14, 2025, https://techcrunch.com/2025/01/14/google-backed-pixxel-launches-indias-first-private-satellite-constellation/

90 Ibid.

91 Skyroot, "Vikram-S Stats", https://skyroot.in/vks.html

Wealth Fund GIC.[92] In March 2024, Skyroot Aerospace tested the Stage-2 of its Vikram-1 rocket, that lasted 85 seconds, and demonstrated the rocket's capacity to generate substantial power "measuring around 186 kilonewtons (kN) at sea level, with an expected increase to approximately 235 kN in the vacuum of space".[93] Another space startup, Agnikul is developing a small rocket, AgniBaan, a 3D printed rocket that will be customized to the need of particular launch requirements. In May 2024, Agnikul successfully tested the Mission 01 of Agnibaan SOrTeD from India's private launchpad ALP-01 at Sriharikota. This was also India's first Semi-Cryogenic Engines developed by Indian Institute of Technology (IIT) Madras. Agnikul is located at the National Centre for Combustion Research and Development at IIT Madras and supported by the Department of Science and Technology. "Agnibaan SOrTeD (Agnibaan Sub-Orbital Technology Demonstrator) is a single-stage vehicle propelled by a single semi-cryogenic pressure-fed engine which has been used for Agnibaan".[94] Dhruva Space, another space startup aims to develop modular small satellite platforms, satellite deployment and supporting ground stations.[95] Bellatrix Aerospace is aimed at building satellite propulsion, from water to electric propulsion systems. Some of the technologies it has tested include hall effect thrusters, an electric propulsion system, and test of a green alternative to hydrazine, which is seen as a toxic chemical for satellite fuel. Bellatrix is developing a microwave plasma thruster powered by water, for nano satellites.[96] All this is geared towards building a $44 billion space industry by 2033 to include developing the institutional and regulatory environment to

92 Amy Gunia, "Cabs to get into space: How this Indian Startup wants to revolutionize satellite space travel", CNN, April 24, 2024, https://www.cnn.com/2024/04/23/business/india-space-startups-skyroot-aerospace-hnk-intl/index.html

93 "Skyroot Aerospace Achieves Milestone: Successful Test-Fire of Vikram-1 Stage-2 Propulsion System", Financial Express, March 28, 2024, https://www.financialexpress.com/business/defence-skyroot-aerospace-achieves-milestone-successful-test-fire-of-vikram-1-stage-2-propulsion-system-3439403/

94 Press Information Bureau, Ministry of Science & Technology, "Combustion Research at Department of Science and Technology Supported Centre Provides Base for Space Tech Startup Fuelling India's March towards Low-Cost Space Missions", July 08, 2024, https://pib.gov.in/PressReleseDetailm.aspx?PRID=2031582&reg=3&lang=1

95 Dhruva Space, "Diverse Payloads Distinct Space Missions", https://www.dhruvaspace.com/

96 Bellatric. Aero, "Transforming In-Space Mobility", https://bellatrix.aero/

The 2023 Indian space policy created the path to open up FDI in the commercial space sector. What India aspires for, in this regard, is to attract investments in India's space sector, that boosts a highly skilled young workforce, and competitive workforce employment and retention capabilities, in the global market, for major space companies like SpaceX and Blue Origin.

support the Indian commercial space sector.[97] In February 2024, the Union Cabinet chaired by Narendra Modi approved an amendment in Foreign Direct Investment (FDI) in the space sector, that specified the three important updates.

- **Upto 74% under Automatic route:** Satellites-Manufacturing & Operation, Satellite Data Products and Ground Segment & User Segment. Beyond 74% these activities are under government route.
- **Upto 49% under Automatic route:** Launch Vehicles and associated systems or subsystems, Creation of Spaceports for launching and receiving Spacecraft. Beyond 49% these activities are under government route.
- **Upto 100% under Automatic route:** Manufacturing of components and systems/ sub-systems for satellites, ground segment and user segment.[98]

This is a part of the 2023 Indian space policy that created the path to open up FDI in the commercial space sector. What India aspires for, in this regard, is to attract investments in India's space sector, that boosts a highly skilled young workforce, and competitive workforce employment and retention capabilities, in the global market, for major space companies like SpaceX and Blue Origin. The 100 per cent automatic approval for manufacturing components for satellite systems, is aimed at the global space market, dominated by satellite-based services. More importantly, foreign companies that invest up to 74 per cent for

97 Julia Seibert, "5 Best Space Startups in India [2024], https://spaceinsider.tech/2024/09/04/5-best-space-startups-in-india-2024-edition/

98 Ministry of Commerce & Industry, "Cabinet Approves Amendment in the Foreign Direct Investment (FDI) policy on the Space Sector", February 21, 2024, https://pib.gov.in/PressReleasePage.aspx?PRID=2007876

satellite manufacturing and data sharing, will get automatic approval as well. This change in FDI policy demonstrates long-term thinking as India aspires to become an integral and important part of the global space market between 2032-2047. In 2023, investments in India's space startups reached $124.7 million, and all signs indicate that this will grow. The Indian space economy was valued at $8.4 billion, in 2024, constituting two per cent of the global space market. The Indian government wants to scale that up to $44 in 2033, "including US $11 billion in exports amounting to 7-8% of the global share".[99]

Significant Policy Shifts

As per the 2023 Indian space policy, ISRO will concentrate itself on Research &Development (R & D) in developing new technologies, and missions to understand outer space better. Access to remote sensing data will be made widely available by ISRO, and ISRO will concentrate on developing human spaceflight technologies as well as support sustained human presence in space. What is new is that the 2023 space policy directs ISRO to "undertake studies and missions on in-situ resource utilization, celestial prospecting and other aspects of extra-terrestrial habitability."[100] ISRO will move out of manufacturing of space systems, and instead focus only on the R& D side. Manufacturing and operations will be turned over to the private space sector, a rather big and bold change in space policy and the institutional process for India, who has historically been partial to developing space technologies through state funded institutions like ISRO. The New Space India Ltd (NSIL), established in 2019 under the Department of Space (DoS) is responsible for the commercialization of ISRO's space products, and tasked with building launch vehicles by utilizing

> IN-SPACe has been tasked to proactively promote private industry in order to "establish India as a preferred service provider for global requirements of products/services in the space sector."

99 Department of Space, "Empowering India's Space Economy: Rs. 1, 000 Crore Venture Capital Fund Initiative for Innovation and Growth", October 25, 2024, https://pib.gov.in/PressReleasePage.aspx?PRID=2068155#:~:text=At%20present%2C%20the%20Indian%20space,8%25%20of%20the%20global%20share.

100 Indian Space Research Organisation, "Indian Space Policy-2023", n.8.

India's commercial space industry, dovetailed to the requirement of the customer, space based services related to Earth Observation and Communication Satellites, supporting technology transfers to the Indian space industries, and develop the entire value chain of space products through the commercial sector, that includes user ground equipment, satellite manufacturing, launch services, with a focus on value added services.[101] The Indian National Space Promotion & Authorisation Centre (IN-SPACe) functions as the single window independent authorization center within the Department of Space, for both public and private sector space activities.[102] The activities IN-SPACe authorizes includes launch, operation, in orbit slots, re-entry of space objects, and the dissemination of Earth observation data. IN-SPACe has been tasked to proactively promote private industry in order to "establish India as a preferred service provider for global requirements of products/services in the space sector."[103] IN-SPACe enables the Indian private companies file International Telecommunication Union (ITU) filings for orbital slots, and maintain a balance between government and Non-Governmental Entities (NGE) for ITU filings for orbital slots. In-SPACe also authorizes launch manifests, issues safety and security guidelines, maintains registration and ascertains liability in regard to the private sector as per India's international treaty obligations. The key thrust of this organization is to make every aspect of India's space sector private, with private companies now encouraged to build, manufacture, operationalize and maintain space infrastructure.[104] The Indian government now views its role as an enabler to the commercial space industry, and they in turn will build the platforms and the capabilities.[105] The 2023 space policy makes it clear that the strategy adopted by the Government of India to develop India into a space power is via commercialization of space.[106] Non-Governmental Entities

101 "Role of NSIL-Space Sector Reforms and Indian Space Policy-2023", https://www.nrsc.gov.in/sites/default/files/pdf/ebooks/UIM-2024/4_UIM_2024.pdf

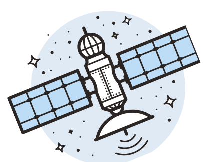
102 Indian Space Research Organisation, Department of Space, "Indian National Space Promotion and Authorization Center (IN-SPACe)", https://www.isro.gov.in/IN-SPACe.html#:~:text=Indian%20National%20Space%20Promotion%20and%20Authorisation%20Centre%20(IN%2DSPACe),the%20participation%20of%20private%20players.

103 Indian Space Research Organisation, "Indian Space Policy-2023", n.8.

104 "Indian National Space Promotion and Authorization Center (IN-SPACe)", https://www.isro.gov.in/IN-SPACe.html

105 Namrata Goswami, "Indian Space Program and its Drivers: Possible Implications for the Global Space Market", January 28, 2022, https://www.ifri.org/en/papers/indian-space-program-and-its-drivers-possible-implications-global-space-market

106 Indian Space Research Organisation, "Enhancing the Private Participation in Space Activities", March 2023, https://static.pib.gov.in/WriteReadData/specificdocs/documents/2023/apr/doc2023410179001.pdf



The 2023 space policy makes it clear that the strategy adopted by the Government of India to develop India into a space power is via commercialization of space. Non-Governmental Entities (NGEs) or the private sector will be encouraged and facilitated through funding, institutions and regulations to participate and develop capabilities in the entire "value chain" of the space economy.

(NGEs) or the private sector will be encouraged and facilitated through funding, institutions and regulations to participate and develop capabilities in the entire "value chain" of the space economy.

In regard to the blue economy, there has been a growing policy and organizational conversation around the issue of space resources. Space resources are defined as "the mineral or energy resources extant (and available for exploitation) in outer space, including mineral substances from planetary bodies such as the Moon and asteroids, as well as energy resources present both on planetary bodies (such as Helium 3) or in free space (such as space-based solar power)".[107] As per John S. Lewis, in his seminal book, Mining The Sky: Untold Riches from the Asteroids, Comets, and Planets, if we take a singly asteroid like 3554 Amun, there are $20 trillion worth of resources on it, to include valuable metals like iron, nickel, cobalt and other platinum group metals.[108] The Moon has resources like water-ice that can be utilized for both sustaining life on the Moon by creating oxygen

Space resources are defined as "the mineral or energy resources extant (and available for exploitation) in outer space, including mineral substances from planetary bodies such as the Moon and asteroids, as well as energy resources present both on planetary bodies (such as Helium 3) or in free space (such as space-based solar power)".

107 Namrata Goswami and Peter Garretson, Scramble for the Skies: The Great Power Competition to Control the Resources of Outer Space (Lanham: Lexington Books, 2020), p. 6.

108 John Lewis, Mining the Sky: Untold Riches From the Asteroids, Comets, and Planets (New York: Basic Books, 1997).

> The major game changer in the 2023 Indian space policy document is India's stand on space resources [asteroid resources or resources on the Moon].

but also rocket fuel. Helium-3 is known to be in high quantities on the Lunar surface as well as platinum group metals. That is one of the core reason why Chinese Lunar scientists like Wu Weiren has have advocated for China to invest in its Lunar program called Chang'e. Another very influential Chinese scientists, Quyung Ziyuan specifies that "there are large amounts of resources on the Moon. For example, there is a large amount of titanium on the Moon. Also, the lunar soil is rich in Helium 3, which can be used as raw material for the fusion reaction, theoretically sufficient to meet the energy demand of all mankind for 10 000 years".[109] Another resource that one can extract from Earth orbit is Space Based Solar Power (SBSP), that offers the ability to extract sunlight from space 24 hours, beamed back to rectennas on Earth, through microwave or laser power beaming, something that India's former President and father of India's nuclear program, Abdul Kalam advocated for.[110]

The major game changer in the 2023 Indian space policy document is India's stand on space resources [asteroid resources or resources on the Moon]. Until now, India has been officially reticent to discuss this issue of space resources, neither has it been committed to creating a space program that develops space resources like space solar power, asteroid mining, and/or lunar mining. The 2023 space policy provides India's position on the extraction of space resources. On pages 6 and 7 of the 2023 space policy documents, India stakes its position, to include clarifying ownership issues.

"Non-Governmental Entities (NGEs) will be encouraged to engage in the commercial recovery of an asteroid resource or a space resource. Any NGE engaged in such process shall be

109 Weijie Zhao and Chi Wang, "China's Lunar and Deep Space Exploration: Touching the Moon and Exploring the Universe", National Science Review, 6/6 (November 2019), pp. 1274-1278, Mayhttps://academic.oup.com/nsr/article/6/6/1274/5550235

110 "Space-based Solar Power: A Future Source of Energy?", Geospatial World, May 22, 2023, https://geospatialworld.net/prime/special-features/space-based-solar-power-future-energy/

India's Defense Research and Development Organization (DRDO) chief, Samir V. Kamat specified that India needs to develop greater space situational awareness, resilient space systems, and better ISR capabilities.

entitled to possess, own, transport, use, and sell any such asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of India."[111]

This Indian policy position on space resources is similar to the U.S. position on space resources as per the U.S. Commercial Space Launch Competitiveness Act (2015);[112] Luxembourg Space Resources Mining legislation (2017),[113] the 2021 Japan space resources act,[114] and the 2023 United Arab Emirates (UAE) position on space resources.[115] India now joins the team in encouraging its private sector to engage in the extraction of space resources by creating the enabling policy and regulatory structures for it, the second country in Asia to do so.

Military Shifts

The 2023 space policy document offers no in-depth details on India's national security space architecture. In the Defense Space Symposium organized by the Indian Space Association on April 11, 2023, India's Chief of Defense Staff (CDS) General Anil Chauhan stated that "the very nature of warfare is on the cusp of major transformation and what is being witnessed is militarisation of space and steady progress towards weaponisation... the aim for all of us should be towards developing dual-use platforms with special focus towards incorporating cutting-edge technology and we must

111 Indian Space Research Organisation, "Indian Space Policy-2023", n.8.

112 U.S. Congress, "H.R.2262-U.S. Commercial Space Launch Competitiveness Act", November 25, 2015, https://www.congress.gov/bill/114th-congress/house-bill/2262/text

113 Luxembourg Space Agency, "Law of July 20th 2017 on the Exploration and Use of Space Resources", https://space-agency.public.lu/en/agency/legal-framework/law_space_resources_english_translation.html

114 Library of Congress, "Japan: Space Resources Act Enacted", https://www.loc.gov/item/global-legal-monitor/2021-09-15/japan-space-resources-act-enacted/

115 United Arab Emirates, "Space Resources Regulation", 2023, https://space.gov.ae/assets/download/2de177/SpaceResources-EN.pdf.aspx

expand our NAVIC constellation, provide agile space-based Intelligence, Surveillance and Reconnaissance (ISR) and ensure secure satellite-assisted communications."[116] India's Defense Research and Development Organization (DRDO) chief, Samir V. Kamat specified that India needs to develop greater space situational awareness, resilient space systems, and better ISR capabilities. For this, he called upon collaborations with India's private space sector and academia. In October 2022, Indian Prime Minister Narendra Modi launched Mission DefSpace that called for private sector space companies to apply for 75 defense space challenges for indigenous development.[117] This included the development of "Launch System, Satellite System, Communication & Payload System, Ground System, and Software System".[118] Insights from the CDS's speech as well as strategic policy conversations within India indicate that there is a general assessment that Anti-Satellite (ASAT) capability that India tested in 2019 is not enough of a deterrence against an adversary that has enhanced capabilities to destroy India's space-based assets through non-kinetic capabilities like high powered laser, high powered microwaves, electro-magnetic pulse, jamming and spoofing.[119] The role of commercial space in augmenting space warfare capabilities was specified by the CDS Gen Chauhan when he stated that "as seen during the Russia-Ukraine conflict by SpaceX and Maxar, had unfolded a new area in the war on convergence...This combined with the intense race towards militarisation of space has resulted in the battlespace becoming expanded and the very nature of warfare is at a major cusp of transformation".[120] India does have a Joint Doctrine issued by the

116 Dinakar Peri, "We are seeing Militarisation of Space, Steady Progress Towards Weaponisation: Chief of Defence Staff", The Hindu, April 12, 2023, https://www.thehindu.com/news/national/we-are-witnessing-militarisation-of-space-and-steady-progress-towards-weaponisation-cds/article66725336.ece

117 India CSR, "Mission DefSpace: India Launches 75 Defence Space Challenge for Indigenous Development", 2023, https://indiacsr.in/mission-defspace-india-launches-75-defence-space-challenges-for-indigenous-development/

118 Ibid.

119 Mark Stokes, et.al., "China's Space and Counterspace Capabilities and Activities", The U.S.-China Economic and Security Review Commission, March 30, 2020, https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf

120 Press Trust of India, "War in Space a Possibility, Relevant Developments Needed: CDS Chauhan", Business Standard, April 11, 2023, https://www.business-standard.com/india-news/war-in-space-a-possibility-relevant-developments-needed-cds-chauhan-123041100542_1.html

India does have a Joint Doctrine issued by the Integrated Headquarters of the Integrated Defense Staff (HQ IDS) in 2017, that views space as a multi-domain enabler.

Integrated Headquarters of the Integrated Defense Staff (HQ IDS) in 2017, that views space as a multi-domain enabler. In Chapter VI of the joint doctrine, titled "Concepts of Military Power Application", there is a section on space power that specifies that "space is a medium like land, sea, air and cyber through which various activities are likely to expand in the future. Emergence of space power is analogous to conventional land, sea or air power that will mark it out as a 'Revolution in Military Affairs'. Space bestows immense force multiplication capability on the Armed Forces, and the dependence on space assets for military operation is rapidly increasing..."[121]

India's military space capacities have undergone significant changes with the establishment of two new institutions, the Defense Space Agency (DSA) and the Defense Space Research Organization. The DSA is a tri-service (Army, Navy, Air Force) agency and was created alongside India's Defense Cyber Agency (DCA) in 2019. In collaboration with the Defense Research and Development Organisation (DRDO), DSA aspires to build India's defense space capacities, specifically focused on showcasing space power. This includes antisatellite capabilities (kinetic and non-kinetic), signal intelligence (SIGINT), communication intelligence (COMINT), and electronic intelligence (ELINT). In a Request for Information (RFI), the DSA pointed out that

India's military space capacities have undergone significant changes with the establishment of two new institutions, the Defense Space Agency (DSA) and the Defense Space Research Organization.

121 Headquarters Integrated Defence Staff Ministry of Defence, "Joint Doctrine Indian Armed Forces", April 2017, https://bharatshakti.in/wp-content/uploads/2015/09/Joint_Doctrine_Indian_Armed_Forces.pdf

building a Mobile Launch System capable of launching about 0.71 tons, supported by an Integrated Launch Control Center, was of vital necessity. As it explained:

> Static launch sites are vulnerable to hostile actions and could be prime targets in case of hostilities. This necessitates development of transportable launchers which can be moved and deployed for launch as per convenience. It is proposed to develop Transportable/Mobile Launch Systems that can operate from ground/ aerial/ sea-based platforms to provide launch capabilities with flexibility of launch windows for different kind of payloads. The launch system should be all weather capable and be able to deploy satellites weighing upto 650 Kgs to altitudes up to 700 Kms. The system should be able to change from transportable position to 'Launch ready position" in not more than 60 minutes.

The DSA also called for an RFI regarding a Mobile Multi-Object Tracking Radar with a detection range of 250 kilometers and an ability to track about 15 objects, a modular small satellite bus that can integrate different payloads, and a GEO data relay satellite with an optical inter-satellite link capable of communicating with satellites in LEO. DSA highlighted the importance of developing a "GEO-AI-based Multi-Sensor Optical/Radar Equipua nment Siting Simulator" that will help deploy sensors faster. From an analysis of DSA's RFI, we could infer that India wants to develop both a mobile launch capability and a diversified launch system consisting of solid- and liquid-propelled rockets. This, as mentioned above, is vital to replace defunct or damaged satellites that the Indian military depends on. There are calls for the Indian Air Force to be renamed the Indian Air and Space Forces.[122] This move reflects the growing significance of space in India's military culture. In February 2025, India's first military grade intelligence satellite was manufactured by Tata Advanced

122 Gp. Capt (Dr) Swaim Prakash Singh, "Mission 2032: Transforming the Indian Air Force into the Indian and (sic) Air Space Force", Center for Air Power Studies, November 29, 2023, https://capsindia.org/mission-2032-transforming-the-indian-air-force-into-the-indian-and-air-space-force/; Smruti Deshpande, "India's 'Air and Space Force': Spaceplane to 'Desi GPS': How IAF Renaming will Widen its Ambit", The Print, December 11, 2023, https://theprint.in/defence/indias-air-and-space-force-spaceplane-to-desi-gps-how-iaf-renaming-will-widen-its-ambit/1880160/

India wants to develop both a mobile launch capability and a diversified launch system consisting of solid- and liquid-propelled rockets. This, as mentioned above, is vital to replace defunct or damaged satellites that the Indian military depends on. There are calls for the Indian Air Force to be renamed the Indian Air and Space Forces. This move reflects the growing significance of space in India's military culture.

Systems (TASL) in collaboration with Satellogic, a company from Uruguay, and launched on a SpaceX Falcon 9 rocket, specifically for the Indian Army. The satellite is equipped with a high-resolution camera that can capture images within a spatial resolution of 0.5 meters, and discern objects as small as 50 centimeters. The plan is to manufacture about 25 such satellites and launch them to LEO.[123]

Certain Limitations and Challenges for India's Space Program

While India's efforts at institutional reform is a welcome step specifically its thrust on the commercialization of space development, the 2023 space policy document reads more like a internal reform document for India's space institutions, and not really a space policy document. Space policy documents usually identify a nation's top priorities in terms of space missions. The policy document does not give a clear idea of what those grand Indian space missions are. Commercialization is a means to get to a particular end. So, what are those ends for India in regard to its space goals? Is the goal to send humans to Low Earth Orbit (LEO); is it focused on developing India's capabilities for a lunar and Mars missions, and if so, what are these missions. Is there an asteroid mission that India is focused on? What about India's position on space based solar power? We do know now that India aims to recognize the private ownership of space resources. If so, is there an Indian mission afoot that aims to do exactly that, like the one we are witnessing with Japan's i-space mission to the Moon to carry

123 Manu Pubby, "India's First Spy Satellite Made by Local Private Player Set for SpaceX Liftoff", The Economic Times, February 19, 2024, https://economictimes.indiatimes.com/news/defence/first-spy-satellite-made-by-local-pvt-player-set-for-spacex-liftoff/articleshow/107802192.cms?from=mdr

Its time India comes up with an in-depth space policy that clearly tells the world what its focus in space is, from civil, commercial to military.

out the first commercial activity on the Moon. The Indian space policy reads more like a roadmap to ‘What are the mechanisms required to develop its private space sector”, without really clarifying what for. Why are these space technologies being developed? Subsequently, we have witnessed speeches that point to the 2047 space vision. Its time India comes up with an in-depth space policy that clearly tells the world what its focus in space is, from civil, commercial to military.

India would also need to catch up with the U.S. and China in regard to mega-constellation of satellites in LEO, as well as a super heavy lift reusable rocket, similar to SpaceX’s Starship and China’s Long March 9, with the capacity to launch 150 metric tons to LEO respectively. The lack of a military space doctrine identifying the mission focus of India’s militaries diminishes India’s power projection capabilities as well. Clarity in matters of national security is a requirement given India is poised to emerge as a prominent international player, with a robust economy and a demographic dividend. It might also have to take over leadership roles in the Indo-Pacific and the Quadrilateral Security Dialogue, or Quad. While India is poised to take advantage of the blue economy, it requires focused development of reusable rockets, LEO based constellations, and military space capacities that can cumulatively advance India’s space advantages.

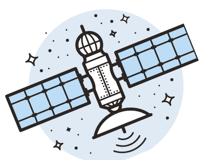
While India is poised to take advantage of the blue economy, it requires focused development of reusable rockets, LEO based constellations, and military space capacities that can cumulatively advance India’s space advantages.

Disclaimer: The views expressed are those of the author and do not reflect the official guidance or position of the United States Government, the Department of Defense, the United States Air Force, or the United States Space Force.

BIO-PROFILES

Dr. Dhrubajyoti Bhattacharjee

Dr. Dhrubajyoti Bhattacharjee is a Research Fellow at the Indian Council of World Affairs (ICWA), Sapru House, New Delhi. He received his M. Phil and Ph.D. from Jawaharlal Nehru University working extensively on Pakistan's foreign policy decision making under civilian and military leaderships. He has taught as an Assistant Professor in the Department of Political Science, Siliguri College for ten years, after which he has been involved in research with ICWA. His interest also includes India and Vietnam, ASEAN, India and Israel, terrorism, Foreign Policy Decision Making, India and Myanmar, Bangladesh, South Asian politics and political and strategic development in Pakistan and Afghanistan. He has published books on Pakistan Foreign Policy Decision Making, Indian Foreign Policy, India's Development Administration and on Gandhi in World Politics along with many research papers contributing chapters in edited books and has edited multiple special editions of Council publications. He has also been part of many international conferences and lectures abroad.



Keshav Verma

Keshav Verma is a Research Associate at the Indian Council of World Affairs, New Delhi. He is pursuing Doctor of Philosophy in International Relations from the Department of International Studies, Political Science and History, CHRIST (Deemed to be University), Bengaluru. His PhD focuses on the Governance of the Global Commons (Antarctica, Atmosphere, High Seas, and Outer Space). His research areas are Global Commons, Indo-Pacific, Non-Traditional Security, India's Foreign Policy, etc. He did his master's in political science from S.S. Jain Subodh PG Autonomous College, and his master's dissertation focuses on Opportunities and Challenges for India in BIMSTEC. Previously, he was a Senior Research Affiliate at the Centre for East Asian Studies, CHRIST University and a Project Assistant in collaboration with George Washington University, Washington D.C., funded by the U.S. Department of State. He has published several research articles, book chapter and op-eds on various platforms such as SCOPUS, Springer, UGC CARE 1, Peer-Reviewed Journals and Think Tanks. He has also presented several papers at National and International Conferences on Global Commons, Maritime Security, and other Non-Traditional Security threats.

Dr. Ajey Lele

Dr. Ajey Lele is the Deputy Director General, of the Manohar Parrikar Institute for Defence Studies and Analyses (MP-IDSA). His specific areas of research include issues related to Weapons of Mass Destruction (WMD), Space Security and Strategic Technologies. He has contributed articles to various national and international journals, websites and newspapers.

Dr. Namrata Goswami

Dr. Namrata Goswami is an author and educator specializing in space policy, international relations, and ethnic identity. Currently, Dr. Goswami teaches at the Schriever and West Space Scholar Programs, the School of Advanced International Studies, Johns Hopkins University, Thunderbird School of Global Management, Arizona State University, and at the Joint Special Forces University. She is a guest lecturer at Emory University for seminars on Technology, Society & Governance, and India today. She worked as a Research Fellow at MP-Institute for Defence Studies and Analyses, New Delhi; a Visiting Fellow at Peace Research Institute, Oslo, Norway; La Trobe University, Melbourne, Australia; University of Heidelberg, Germany; Jennings-Randolph Senior Fellow, United States Institute of Peace; and was a Fulbright Senior Fellowship Awardee. She was awarded the Minerva grant by the Office of the U.S. Secretary of Defense to study great power competition in outer space. In April 2019, Dr. Goswami testified before the U.S-China Economic and Security Review Commission on China's space program. Her co-authored book, Scramble for the Skies: The Great Power Competition to Control the Resources of Outer Space was published in 2020 by Lexington Press; Rowman, and Littlefield. Her book on The Naga Ethnic Movement for a Separate Homeland was published in 2020 by Oxford University Press. She has published widely including in The Diplomat, the Economic Times, The Washington Post, Ad Astra, Asia Policy, Live Encounters Magazine, Cairo Review. She was invited in November 2019 to share about her life and her work at a Tedx event held at the Rosa Parks Museum, in Montgomery, Alabama.

About ICWA

The Indian Council of World Affairs (ICWA) was established in 1943 by a group of eminent intellectuals led by Sir Tej Bahadur Sapru and Dr. H. N. Kunzru. Its principal objective was to create an Indian perspective on international relations and act as a repository of knowledge and thinking on foreign policy issues.

The Council today conducts policy research through an in-house faculty as well as through external experts. It regularly organizes an array of intellectual activities including conference, seminars, roundtable discussions, lectures and brings out a range of publications. It has a well stocked library, publishes the journal 'India Quarterly', and is active on social media.

ICWA has over 100 MoUs with leading international and national think tanks, research and academic institutions to promote better understanding on international issues and develop areas of mutual cooperation. The Council's international partnerships are focused on dialogue and joint activities like research publications, while its national outreach is focused on creating awareness of and scholarship on issues pertaining to foreign policy and international relations.

Indian Council
of World Affairs

Sapru House, New Delhi

₹ 0/-

Available online at
www.icwa.in

9 789383 445899