***Minireview Article***

**Indian Space Research Organisation (ISRO) and its Key Milestones: A Review of last Five decades**

**Abstract**

In this mini review article, it has been discussed on progressive development of Indian Space Research Organisation (ISRO) as a premier space agency in international space arena for executing tasks related to space-based applications, [space exploration](https://en.wikipedia.org/wiki/Space_exploration) and the expansion of related technologies. Since its inception in the late 1960s, ISRO has played a pivotal role in advancing India’s space capabilities, transforming the nation into a major player in the global space community. This review article examines the historical evolution of ISRO, from its early beginnings to modern-day technological feats. Special emphasis is placed on landmark missions such as the Aryabhata satellite, Chandrayaan, Mangalyaan (Mars Orbiter Mission), and the upcoming Gaganyaan project. The discussion also underscores ISRO’s unique approach to low-cost innovation and examines how its space program has contributed to societal development through telecommunications, earth observation, disaster management, and more. Additionally, the article provides insights into international collaborations and partnerships, highlighting ISRO’s role in fostering global cooperation. The review concludes by exploring the future prospects of the Indian space program, emphasizing emerging challenges and potential opportunities.

*Keywords: ISRO, Indian space program, Chandrayaan, Mangalyaan, Gaganyaan, PSLV, GSLV, satellite technology, low-cost innovation, international collaborations*

**Introduction**

In the present era everyone recognizes the impact of space activities in a major portion of our everyday life and mostly welfare of our humanity. Despite the high cost of these space activities, there is a tremendous return to the society in terms of space exploration, scientific knowledge of stars, planets and our planet Earth, communication systems, international cooperation and economy. India’s space endeavours have undergone a remarkable transformation over the past several decades, evolving from modest experimental rocket launches to sophisticated interplanetary missions. The driving force behind this progress is the Indian Space Research Organisation (ISRO), which has consistently demonstrated that ambitious goals in space exploration and satellite technology can be achieved within modest budgets. Founded in 1969, ISRO has emerged as one of the most efficient and cost-effective space agencies in the world, contributing to India’s global image as an emerging technological powerhouse (Kaul, 2023), (Murthi and Gopalakrishnan, 2024).

ISRO’s journey has been characterized by several landmarks that have redefined the scale and scope of India’s space ambitions. Early missions like the Aryabhata satellite in 1975 laid the groundwork, while subsequent achievements such as the Chandrayaan lunar explorations and the Mars Orbiter Mission (Mangalyaan) propelled India into an elite group of nations capable of undertaking complex interplanetary missions (Thomas, et al., 2024), (Rajagopalan and Stroikos 2024). Beyond scientific exploration, ISRO’s diverse satellite fleet has facilitated multiple socioeconomic applications, including telecommunication, television broadcasting, weather forecasting, and disaster management (Khosla et al., 2024). Major scientific databases like SCOPUS, Web of Science, Google Scholar, DOAJ were searched by using the following keywords “ISRO, Indian space program, Chandrayaan, Mangalyaan, Gaganyaan” to collect the relevant articles used for this review paper.

In addition to reviewing historical milestones, this article delves into ISRO’s underlying ethos of cost-effectiveness and multi-stakeholder collaboration. The objective is to provide a comprehensive overview of ISRO’s past achievements, analyse the societal impact of its satellite applications, and evaluate prospects for the future. The article is organized into sections covering historical background, major space missions, contributions to national development, international collaborations, challenges, and future outlooks. By offering a holistic examination, this review highlights the multi-dimensional significance of ISRO in shaping both national and global space discourse.

**2. Historical Background**

**2.1 Pre-ISRO Era**

India’s scientific interest in space can be traced back to the 1920s when Indian scientists like C.V. Raman and Meghnad Saha made fundamental contributions to astrophysics (Aliberti, M, 2018), (Roca et al., 2020). However, structured efforts to develop indigenous space technology began in the post-independence period. The establishment of the Indian National Committee for Space Research (INCOSPAR) in 1962 marked a turning point. Led by Vikram Sarabhai, INCOSPAR focused on scientific research in atmospheric and space sciences, leveraging the Thumba Equatorial Rocket Launching Station (TERLS) in Kerala to conduct initial sounding rocket experiments (Umarani, 2024) (Narayana Murty and Sharma, 2022).

**2.2 Formation of ISRO**

In 1969, INCOSPAR was reorganized into the Indian Space Research Organisation, with the mandate to harness space technology for national development (Rajagopalan and Stroikos,2024). Vikram Sarabhai, widely regarded as the “Father of the Indian Space Program,” laid out a vision emphasizing the application of space science and technology in addressing India’s developmental imperatives, from weather forecasting to educational broadcasting. During the early 1970s, ISRO’s focus remained on building the requisite infrastructure and workforce capable of conducting satellite-based research and technology demonstrations.

**3. Key Milestones in the Indian Space Program**

ISRO has achieved several milestones that have propelled India’s space program onto the global stage. These milestones reflect ISRO’s evolving technological capabilities and its commitment to cost-effective and application-driven space missions. This section outlines some of the most significant achievements, ranging from the first indigenous satellite launches to interplanetary explorations and emerging ventures in human spaceflight.

**3.1 Early Satellite Launch Missions**

One of the earliest successes in India’s space journey was the launch of Aryabhata in 1975. Developed and assembled by ISRO, it was launched using a Soviet rocket. Although Aryabhata’s primary mission was technological experimentation, it served as a watershed moment, proving that India could design and fabricate satellites of its own. (Kasturirangan, 2021), (Kumar et al., 2021), (Murthy, et al., 2022). The success of Aryabhata laid the groundwork for subsequent experimental satellites such as Bhaskara-I (1979) and Bhaskara-II (1981), which carried remote sensing instruments and contributed valuable Earth observation data.

Another key development in this early phase was the creation of India’s first indigenous rocket, the Satellite Launch Vehicle-3 (SLV-3). Under the guidance of Dr. A.P.J. Abdul Kalam, SLV-3 successfully placed Rohini (RS-1) into orbit in 1980, demonstrating that India had gained the capability to design, build, and launch satellites independently. This achievement significantly boosted national confidence and paved the way for more advanced launch vehicles. (Cottom, 2022).

Following these foundational successes, ISRO moved to application-oriented satellites. The INSAT (Indian National Satellite) series, starting in the early 1980s, played a major role in revolutionizing India’s telecommunications, broadcasting, and meteorological services. By providing television signals to distant rural areas, INSAT directly impacted millions of people who previously had limited access to information and educational content. Parallel to INSAT, ISRO developed the Indian Remote Sensing (IRS) satellite program to harness Earth observation data for resource management. Launched in 1988, IRS-1A marked the beginning of India’s robust remote sensing capabilities. Subsequent satellites in this series — including IRS-1B, IRS-1C, and IRS-1D — provided increasingly sophisticated imagery for agriculture, forestry, urban planning, and disaster management. These developments were critical for a country like India, where regional disparities in resources and infrastructure demanded data-driven solutions.

**3.2 Chandrayaan Missions**

India’s ambitions for lunar exploration took shape with the **Chandrayaan** program, initiated in the early 2000s. The first mission, **Chandrayaan-1**, launched in 2008, made significant discoveries, including finding evidence of water molecules on the Moon’s surface (Sahu et al., 2025). The spacecraft included scientific instruments developed in collaboration with international partners like NASA and ESA. Chandrayaan-1’s success bolstered ISRO’s reputation and brought India into the global spotlight for planetary exploration.

Building on this momentum, **Chandrayaan-2** launched in July 2019. It comprised an orbiter, a lander (Vikram), and a rover (Pragyan). While the lander-rover combination faced challenges during the soft-landing phase, the orbiter continues to function, conducting extensive scientific research on lunar topography, mineralogy, and exosphere (Kanu, et al., 2024). Chandrayaan-2 marked a significant leap in India’s technological prowess, showcasing advanced navigation, guidance, and control systems for orbital and descent operations (Sharma, 2023).

India’s lunar exploration program witnessed a significant milestone with Chandrayaan-3, which successfully landed on the Moon on August 23, 2023. This achievement made India the first country to land near the lunar south pole and the fourth country globally to achieve a soft landing on the Moon after the Soviet Union, the United States, and China (Sharma, 2023). Chandrayaan-3 confirmed the presence of sulfur and oxygen in the lunar regolith, supporting theories about ancient volcanic activity in the Moon’s south pole. These findings are crucial for potential lunar colonization and in-situ resource utilization (ISRU), aiding future Artemis program missions by NASA and other global space agencies. Moreover, Chandrayaan-3’s cost-effective approach (around $75 million) reaffirmed India’s reputation as a leader in affordable and efficient space exploration. The success of Chandrayaan-3 has bolstered ISRO’s plans for Chandrayaan-4, which aims to return lunar samples to Earth, and LUPEX (Lunar Polar Exploration), a joint mission with JAXA (Japan Aerospace Exploration Agency) targeting permanent lunar bases. These advancements place ISRO at the forefront of global lunar exploration (Rajasekhar et al., 2024) (Vijayan et al., 2025) (Kanu et al., 2024) .

**3.3 Mangalyaan (Mars Orbiter Mission)**

Arguably one of ISRO’s most iconic achievements, **Mangalyaan** or the Mars Orbiter Mission (MOM), made headlines worldwide when India successfully inserted the MOM spacecraft into Martian orbit on September 24, 2014 (Sudhakar., 2018), (Nagendra and Basu, 2016). Not only did ISRO become the fourth space agency to reach Mars, but it also did so in its first attempt, an achievement unmatched at the time. Moreover, the mission cost was notably low compared to similar international missions, demonstrating ISRO’s emphasis on affordability and efficiency (Deshpande, et al., 2024), (Kasturirangan and Shaijumon, 2021).

Mangalyaan’s scientific objectives included studying the Martian surface and atmosphere. Equipped with instruments like the Mars Colour Camera (MCC) and the Methane Sensor for Mars (MSM), the orbiter provided valuable data about dust storms, surface features, and methane concentrations in the Martian atmosphere (Thomas, et al., 2024), (Rajagopalan and Stroikos 2024). The mission’s triumph not only instilled national pride but also underscored India’s capability in interplanetary exploration.

**3.4 Gaganyaan**

With the successes of Chandrayaan and Mangalyaan, India is now venturing into **human spaceflight** with the **Gaganyaan** program. Announced in 2018, Gaganyaan aims to send Indian astronauts into low Earth orbit using an indigenous spacecraft (Somanath et al., 2023), (Singh et al., 2024), (PM et al., 2024). The spacecraft is designed to carry a crew of three and remain in orbit for up to seven days. In preparation, ISRO conducted the **Pad Abort Test** and multiple demonstrations of critical technologies like crew module design, escape systems, and Environmental Control and Life Support Systems (ECLSS).

Beyond national prestige, Gaganyaan is expected to create opportunities for extensive research in microgravity science, including material science, fundamental physics, and life sciences. Technologically, the mission will necessitate advancements in propulsion, life support, and re-entry capabilities, effectively catapulting ISRO into a new domain of manned spaceflight.

**3.5 PSLV, GSLV, and RLV**

ISRO’s primary launch vehicles include the **Polar Satellite Launch Vehicle (PSLV)** and the **Geosynchronous Satellite Launch Vehicle (GSLV)**. PSLV is renowned for its reliability and cost-effectiveness, having launched numerous Indian and foreign satellites into low Earth and Sun-synchronous orbits. A major breakthrough in India’s launch vehicle technology came with the Polar Satellite Launch Vehicle (PSLV) program. First launched in 1993, PSLV emerged as a reliable workhorse for ISRO, placing a variety of satellites into polar and Sun-synchronous orbits. Over the years, PSLV gained international recognition for its cost-effectiveness and reliability, leading various international clients to use it for commercial launches. Notable missions launched by PSLV include Chandrayaan-1 (India’s first lunar mission), the Mars Orbiter Mission (Mangalyaan), and multiple satellites for Earth observation and weather monitoring. PSLV’s ability to deploy multiple satellites in a single launch — demonstrated spectacularly in 2017 when it placed 104 satellites into orbit — highlights ISRO’s ingenuity in rideshare and cost-sharing strategies (Cottom, 2022) (Suresh, 2008). To place heavier payloads into geostationary orbit, ISRO developed the Geosynchronous Satellite Launch Vehicle (GSLV). Early versions of GSLV faced setbacks related to its cryogenic upper stage, a technology that India had to develop indigenously after facing international technology denials. Eventually, the improved GSLV Mk II and the more powerful GSLV Mk III (also known as LVM3) demonstrated consistent success. GSLV Mk III, in particular, represents a leap in capability, as it can launch satellites weighing up to 4 tons into Geostationary Transfer Orbit (GTO). Notably, GSLV Mk III was chosen for the Chandrayaan-2 mission and is slated to be the launch vehicle for India’s upcoming human spaceflight program, Gaganyaan (Cottom, 2022) (Suresh, 2008) (Liu et al., 2021).

Recognizing the importance of lowering the cost of access to space, ISRO has been researching Reusable Launch Vehicle (RLV) technology. In May 2016, the RLV-TD (Reusable Launch Vehicle – Technology Demonstrator) successfully demonstrated a critical re-entry maneuver. Although still in the experimental phase, the RLV initiative signals ISRO’s forward-looking approach. The goal is to develop a fully reusable, two-stage-to-orbit vehicle that can radically reduce launch costs, making space activities more accessible to both public and private stakeholders. . (Narayana Murty and Sharma, 2022)

**3.6 Commercial Launches and International Collaborations**

India’s reputation for cost-effective launches has attracted multiple international clients, with the PSLV deploying hundreds of foreign satellites from over 30 different countries. The commercial spin-off is managed through NewSpace India Limited (NSIL), and it enables ISRO to further monetize its launch capabilities. Additionally, ISRO collaborates with agencies like NASA, ESA, and CNES (France) for joint scientific missions, data sharing, and technology partnerships. These commercial and international collaborations bolster India’s position in the global space market and foster a spirit of cooperation in space research.

**4. ISRO’s Contribution to Societal Development**

**4.1 Telecommunication and Broadcasting**

ISRO’s **INSAT (Indian National Satellite) series** revolutionized telecommunication and broadcasting services in India. Launched in the early 1980s, INSAT satellites facilitated the expansion of television broadcasting, reaching remote areas of the country (Narayana Murty and Sharma, 2022). These satellites also provided critical infrastructure for telephone and data communication, effectively bridging the digital divide (Kaul, 2023), (Murthi and Gopalakrishnan, 2024). Subsequent series like **GSAT** continued this legacy, offering enhanced capabilities for direct-to-home (DTH) broadcasting and high-speed internet connectivity.

**4.2 Remote Sensing and Earth Observation**

India boasts one of the world’s most extensive **remote sensing** satellite constellations. ISRO’s **IRS (Indian Remote Sensing)** series and **Cartosat** satellites provide high-resolution imagery for urban planning, agriculture, forestry, and natural resource management (Rajagopalan and Stroikos,2024). For instance, data from **Cartosat** satellites enable precision agriculture by guiding farmers on crop rotation, soil health, and efficient water usage (Kasturirangan, 2021), (Kumar et al., 2021), (Murthy, et al., 2022). Moreover, satellites like **Oceansat** and **RISAT** support maritime surveillance, fisheries management, and disaster forecasting by mapping ocean parameters and cloud-penetrating radar imaging (Deshpande, et al., 2024), (Kasturirangan and Shaijumon, 2021).

**4.3 Disaster Management Support**

ISRO’s remote sensing capabilities also play a crucial role in disaster management, particularly for a country like India, which is prone to cyclones, floods, and earthquakes (Liu et al., 2021). Satellites like **INSAT** and **METSAT (now Kalpana-1)** provide real-time weather data, enabling early warning systems and efficient disaster response planning (Narayana Murty and Sharma, 2022). GIS-based tools integrated with satellite data are used by various government agencies to assess damage, coordinate rescue operations, and plan rehabilitation efforts.

**5. International Collaborations and Partnerships**

Despite focusing on national self-reliance, ISRO has maintained a collaborative outlook in its space ventures. The organization works closely with international agencies such as **NASA, ESA, JAXA**, and **Roscosmos** in areas like payload development, deep space network support, and planetary science research (Sahu et al., 2025). The **Chandrayaan-1** mission carried instruments from NASA and ESA, facilitating shared scientific data that benefitted the global research community (Kanu, et al., 2024). Similarly, the **Indo-French** collaboration with CNES (Centre National d’Études Spatiales) led to missions like **Megha-Tropiques** for climate research (Aliberti, M, 2018), (Roca et al., 2020).

ISRO’s launch capabilities have also attracted commercial clients. The **PSLV** has placed numerous foreign satellites into orbit, making India an affordable and reliable launch service provider (Sudhakar., 2018), (Nagendra and Basu, 2016). Such collaborations emphasize the cost advantage that ISRO offers and has resulted in growing commercial opportunities for India in the international satellite launch market (Murthi, 2022).

**6. ISRO’s Low-Cost Approach in Space Exploration**

One of the most defining characteristics of the Indian Space Research Organisation (ISRO) is its ability to achieve major space exploration milestones at a significantly lower cost compared to other space agencies like NASA, ESA, Roscosmos, and CNSA. The organization has developed a reputation for cost-effectiveness, making it a global leader in affordable space missions. ISRO’s ability to minimize costs without compromising mission success is attributed to several factors like, Innovative engineering, Efficient Workforce Management, Modular and Scalable Design, In-House Production and Indigenous Components, Smaller and Lighter Spacecraft, Minimal Dependence on Costly International Collaborations, etc.

**Cost Comparisons with Other Space Agencies**

| Mission | Space Agency | Cost (USD) | Remarks |
| --- | --- | --- | --- |
| Chandrayaan-3 (2023) | ISRO | $75 million | Most affordable lunar lander mission (Bhattacharjee, 2023) |
| Mangalyaan (Mars Orbiter Mission) (2013) | ISRO | $74 million | 10x cheaper than NASA’s MAVEN (Anonymous, 20213) |
| MAVEN (2013) | NASA | $582 million | High-end Mars mission (Anonymous, 2013) |
| Chandrayaan-2 (2019) | ISRO | $140 million | Lunar orbiter and lander mission (Anonymous, 2019) |
| Lunar Reconnaissance Orbiter (2009) | NASA | $504 million | Lunar mapping mission (Anonymous, 2009) |

**7. Future Prospects and Challenges**

While ISRO’s track record is commendable, it faces multiple challenges and opportunities in the evolving space landscape.

1. **Human Spaceflight and Beyond:** With the Gaganyaan project, ISRO is venturing into complex territory requiring advancements in human-rated launch vehicles, life support, and crew safety systems (Somanath et al., 2023), (Singh et al., 2024), (PM et al., 2024). These developments will demand robust funding, skilled workforce, and international partnerships.
2. **Deep Space Exploration:** Future missions include **Chandrayaan-3** (focusing on a soft lunar landing) and possible follow-up Mars missions or even a Venus exploration mission (Rajagopalan and Stroikos,2024). These missions aim to fortify India’s position in planetary science and expand scientific collaborations globally.
3. **Reusable Launch Technologies:** Achieving fully reusable systems could significantly reduce launch costs. However, the development of RLV technology requires extensive research and testing, along with robust infrastructure (Narayana Murty and Sharma, 2022).
4. **Space Science and Research:** Beyond Earth observation and communication satellites, ISRO is increasingly investing in scientific missions like **Aditya-L1** to study the Sun (Thomas, et al., 2024), (Rajagopalan and Stroikos 2024). Strengthening domestic research institutions to utilize the data from these missions will be critical for maximizing scientific return (Mayank et al., 2022).
5. **Commercialization and Competition:** The global small satellite and launch services market is becoming increasingly competitive, with private players like **SpaceX** and **Blue Origin** revolutionizing launch costs through reusable rockets. ISRO’s commercial arm, **NewSpace India Limited (NSIL)**, will play a pivotal role in leveraging international partnerships and scaling commercial launches (Sudhakar., 2018), (Nagendra and Basu, 2016).
6. **Space Debris and Sustainability:** As India’s satellite fleet expands, considerations around **orbital debris** and long-term sustainability of space operations become more pressing. India is part of international forums focused on space situational awareness (SSA) and is exploring active debris management strategies (Narayana Murty and Sharma, 2022).
7. **Policy and Governance:** With the formation of **IN-SPACe** (Indian National Space Promotion and Authorization Centre) and a revised space policy framework, India aims to encourage private sector participation in space activities. Balancing national security interests, commercial aspirations, and international treaties will require coherent policymaking and regulatory oversight (Deshpande, et al., 2024), (Kasturirangan and Shaijumon, 2021).

**8. Conclusion**

From the first experimental rocket launches in Thumba to the intricate operations of the Mars Orbiter Mission, ISRO’s evolution reflects a blend of ambition, innovation, and societal focus. Its successful track record in delivering high-impact missions at relatively low cost has not only advanced India’s global standing but also democratized space technology through international collaborations. By aligning satellite technology with developmental needs such as communication, resource management, and disaster mitigation, ISRO has become an integral part of India’s socio-economic fabric.

Looking ahead, the challenges of human spaceflight, reusable launch vehicles, and deep space exploration are significant but not insurmountable. ISRO’s proven ability to adapt and innovate suggests that it will continue to be a critical stakeholder in shaping the future of space exploration and technology. As India moves forward in this “space age,” ISRO’s journey stands as a testament to the potential of indigenous innovation and international cooperation in pushing the boundaries of human knowledge and capability.

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Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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