

Supply Chain Challenges in India's Space Sector

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INTRODUCTION

Over the decades, space has been recognised as critical infrastructure. The evolution of the space industry forms an integral part of India's growth sector as it influences everything from communication and navigation to new scientific exploration. In India, the government has a strong influence over the space sector. It is overseen by the Department of Space (DoS) and Department of Telecommunications (DoT). Here, the Indian Space Research Organisation (ISRO) acts as the primary service provider.

The space industry segments are broadly divided into upstream segments¹ comprising satellite manufacturing and launch services and downstream segments comprising ground segments, including ground stations, control services, and satellite services. The stages for the development of these space services

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1. Jayant D Patil, Lieutenant General Anil Kumar Bhatt, and Prashant Singhal, "Developing the Space Ecosystem in India: Focusing on Inclusive Growth," September 2022, https://ispa.space/assets/pdf/EY-ISpA-report_Developing.pdf.

include research and development, manufacturing of high-tech systems and components, production, and rigorous testing that must meet strict safety and quality standards. It requires a high level of expertise in engineering, material sciences, and other technical disciplines, along with cooperation between countries in terms of a sustainable supply of the components related to this critical infrastructure.

This entire system of producing and delivering products forms a supply chain.² A supply chain includes interconnected parts that result in finished products purchased by customers. The Indian space sector's supply chain ecosystem is a complex web of processes encompassing procurement, manufacturing, distribution, and logistics, as it is interdependent, with many different stakeholders involved. These include government agencies, private companies, research institutions, and instructors. The supply chain in India's space sector faces significant challenges due to the need for extreme precision and reliability. Space missions require flawless components, as any minor defect can result in substantial financial losses and risks to human life. Since hardware cannot be repaired once in orbit, rigorous quality control and testing processes are essential, making them more time-consuming than in other industries.

The space sector in India faces a lot of setbacks due to its limited domestic manufacturing and the technical gaps, leading to dependence on raw materials from other nations. India relies on imports for some of the high-tech components necessary for sophisticated space missions like Rare Earth Elements (REEs), space-grade integrated circuits, strength carbon fibres, cryogenic fibres, etc. They are imported from multiple sources such as

2. McKinsey & Company. "What Is Supply Chain?," August 17, 2022, <https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-supply-chain>.

China, the USA, Europe, Taiwan, Korea, and Singapore, creating geopolitical challenges to a sustainable supply chain.

Geopolitics of Supply Chains

The evolving geopolitical landscape, particularly the India-China tensions, the US-China trade war, the Taiwan Strait crisis, and the Russia- Ukraine conflict, has created significant challenges for India's space sector supply chain. India's tense relations with China hinder access to REEs, which are essential for satellite and rocket manufacture, as China controls most of the worldwide supplies of REEs. It gives China power over a major global supply chain, giving the perception that the rest of the world must search for alternatives. According to the United Nations Commodity Trade Statistics Database (COMTRADE)³ on international trade, India imported electronic equipment worth 44.15 billion from China in 2023,⁴ making it highly dependent on the Chinese market for its basic electric components requirements.

The US-China trade conflict, which began in 2017⁵ when the Trump Administration imposed tariffs on Chinese exports, prompted retaliatory measures by China and created chaos in the global supply chain. Most recently, the issue reemerged with military aid supplied to Taiwan by the US, actions that China saw as going against the "One China" policy in December 2024. The small island claimed by China forms a vital link in the supply chain of semiconductors for the global economy. Any crisis in the Taiwan Strait could severely affect the supply chain of semiconductors. This could lead to a further disruption of the supply chain for semiconductors that are vital to multiple

3. "UN Comtrade," n.d., <https://comtradeplus.un.org/>.

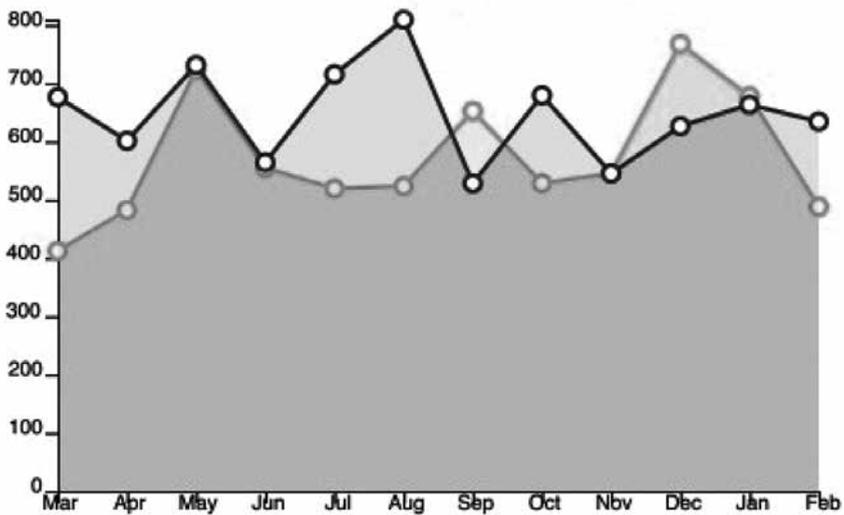
4. Axel Firer, "Top 8 Chinese Products Imported to India in 2025," *Statrys*, January 8, 2025, <https://statrys.com/blog/chinese-india-imports>.

5. "The US-China Trade War: A Timeline," *China Briefing News*, November 20, 2024, <https://www.china-briefing.com/news/the-us-china-trade-war-a-timeline/>.

industries, including space technology. In addition, for India, which depends overwhelmingly on China for the import of electronic components, this could raise costs and delay obtaining space-grade microelectronics, ultimately resulting in delaying the development and deployment of Indian space technologies.

Meanwhile, the ongoing war between Russia and Ukraine disrupts India's dependency on Russia for aerospace-grade materials, propulsion systems, and cryogenic engines.

Fig 1: Integrated Chip (ICs) Import Shipment



Between February 2023 and January 2024, India has imported 7,771 consignments of IC chips, which were sourced by 634 foreign suppliers to 311 Indian importers, denoting a growth of 13 per cent every year. Imports in February 2024 totalled 634 shipments, up by 30 per cent from February 2023 but 4 per cent below January 2024.⁶

6. "IC Chip Imports in India", Volza, July 3, 2025, <https://www.volza.com/p/ic-chip/import/import-in-india/>.

CASE STUDY: CRYOGENIC ENGINE TECHNOLOGY AND SUPPLY CHAIN BOTTLENECKS⁷

In the late 1980s, India embarked on an ambitious journey to develop the Geosynchronous Satellite Launch Vehicle (GSLV), aiming to enhance its capabilities in launching heavy payloads into geostationary orbit. A critical component of this endeavour was the acquisition of cryogenic engine technology⁸, essential for such missions. This case study delves into the challenges India faced due to supply chain bottlenecks, the strategic responses formulated, and the eventual triumph in achieving indigenous cryogenic propulsion technology.

In view of the strategic significance of cryogenic technology for future space missions, the Indian Space Research Organisation (ISRO) wished attain this capability to substitute foreign reliance on suppliers. In 1991, ISRO signed an agreement with Russia's Glavkosmos to purchase cryogenic engines, which had a provision for technology transfer. This agreement was crucial for India's desire to develop the GSLV and become independent in satellite launch capability.

Supply Chain Challenges

India's space sector faced critical challenges due to its reliance on foreign cryogenic engines, exposing vulnerabilities to geopolitical pressures. Early dependence on imported technology led to setbacks, such as U.S. sanctions pressuring Russia to withhold engine blueprints under the Missile Technology Control Regime (MTCR), stalling India's tech assimilation. Developing indigenous

7. Generator, Metatags, "View of Delayed Technology Transfer to Developing Countries in Strategic Sectors," n.d., <https://journalspoliticalscience.com/index.php/i/article/view/653/116>.

8. Team, Bs Web, "Chandrayaan-3: Here Is the Story Behind India's Cryogenic Engine," [www.business-standard.com](https://www.business-standard.com/india-news/chandrayaan-3-here-is-the-story-behind-india-s-cryogenic-engine-123071400797_1.html), July 14, 2023, https://www.business-standard.com/india-news/chandrayaan-3-here-is-the-story-behind-india-s-cryogenic-engine-123071400797_1.html.

alternatives demanded steep Research and Development (R&D) investments and extended timelines, taking two decades due to restricted knowledge transfer. Early GSLV missions using Russian engines also suffered failures, highlighting the risks of foreign dependency. These hurdles underscored the need for self-reliance, driving India to master cryogenic technology independently.

To counter these challenges, India launched several strategic programmes, including investment in indigenous development (ISRO), and made concerted efforts to develop indigenous cryogenic technology⁹, the culmination of which was the successful development and testing of gas generators, sub-scale cryogenic engines, and thrust chambers. This effort brought India into the elite club of countries with indigenous cryogenic propulsion capabilities.

The efforts of people like V. Narayanan propelled the development initiative. To design and build the C25 cryogenic propulsion system for the GSLV Mk-III launch vehicle and enable the successful first launch of the GSLV Mk-III, Narayanan played a crucial role as the project director of the C25 Cryogenic Project.

Cryogenic technology served as the foundation for the development of ISRO's Next-Generation Launch Vehicle (NGLV), which is known as "Soorya."

India had a difficult time developing its cryogenic engine technology. The challenges that needed to be addressed were supply chain bottlenecks, geopolitical pressures, and technological complexities. To counter the geopolitical flux restricting India's growth, several steps were taken, such as initiating *Atmanirbhar*

9. Hari Pulakkat, "How ISRO Developed the Indigenous Cryogenic Engine," *The Economic Times*, January 9, 2014, <https://m.economictimes.com/news/politics-and-nation/how-isro-developed-the-indigenous-cryogenic-engine/articleshow/28575364.cms>.

*Bharat*¹⁰, strengthening defence capabilities, targeting Japan and, France for partnerships, privatising business innovations, and, most importantly, becoming self-sufficient and trying to optimise these opportunities. Apart from these centres of crisis, India imports¹¹ most of its space specialist's Integrated Circuits (ICs), which are uniquely manufactured for efficiently operating in the rough environments of space, including high radiation, low temperature, and mechanical shocks from launches, and which are imported from friendly nations like the USA, Europe, and Japan.

Domestic Challenges

Several actions were taken to strengthen India's space supply chain, making it less reliant and more robust, including the *Atmanirbhar Bharat*, which included liberalisation for the private sector to carry out end-to-end space activities. The lack of financial incentives for small firms to tap into more efficient ways to borrow credit from the banking sector is considered a significant obstacle to production. Because of these financing challenges, small firms are subjected to problems with cash flow that impede their capacity to buy raw materials, maintain production schedules, or invest in technology upgrades. Consequently, this creates a ripple effect, impacting the entire supply chain's efficiency. India's manufacturing infrastructure faces several challenges. Inadequate physical infrastructure hampers growth. Roads and railways require significant upgrades. Ports in India struggle with congestion and inefficiency. These issues delay the movement of goods and increase costs. Power outages and inconsistent supply affect manufacturing operations. Regulatory procedures in India

10. Rajesh Trichur Venkiteswaran, "India: Potential in Space Economics," *Global Finance Magazine*, October 26, 2023, <https://gfmag.com/emerging-frontier-markets/india-potential-in-space-economics/>.

11. n. 6.

are complex, with businesses having to navigate through multiple layers of the bureaucracy.

Despite the recent reforms and the launch of India's space policy in 2023¹², which aims to create a robust ecosystem for effective implementation of space applications while promoting R&D, public-private partnerships, indigisation, and a regulatory framework, India's space sector still faces regulatory complexities. The lack of a comprehensive Space Act causes uncertainty for the private players, leading to ambiguities in the regulatory framework. The lack of clear policies puts India at a disadvantage in the emerging space markets. As the Indian private space sector is at a nascent stage, it lacks awareness about the dynamics and demands of the global space industry.

The downstream segment¹³ of India's space sector includes the ground segment, comprising satellite ground equipment, which forms the largest part of the space economy. This segment includes critical network equipment required for communication and data transfer. The space industry of India's economy has many challenges because of inadequate facilities. There is only one major satellite launching centre located in Sriharikota, due to which there is low frequency and poor scheduling of satellite launching services. This situation constitutes a blockade in the supply chain of satellites because there is high dependence on foreign satellite launching services, and this also causes delays in satellite deployment. Another deficit in the satellite launching services is caused by the lack of several launching sites which, when owned by a country, enable it to fulfill the changing geopolitical or commercially determined requirements at a faster pace.

12. Government of India, "Indian Space Policy - 2023," n.d. https://www.isro.gov.in/media_isro/pdf/IndianSpacePolicy2023.pdf.

13. Patil, et. al., n. 1.

CASE STUDY: SUPPLY CHAIN CHALLENGES IN INDIA'S GAGANYAAN MISSION

The Gaganyaan Mission is India's first human spaceflight programme, led by ISRO.¹⁴ Initially planned for a 2022 launch, the mission has faced multiple delays, with the first crewed flight now rescheduled for 2026.¹⁵ Among the critical challenges affecting the timeline, supply chain disruptions have played a significant role.

Gaganyaan¹⁶ aims to demonstrate the potential of human spaceflight by sending a three-person crew into a 400 km orbit for three days and safely returning to the Earth by landing in Indian sea waters. The mission is a significant achievement for India, positioning the country in an elite group of countries—the United States, Russia, and China—that are theoretically capable of human spaceflight. The project includes multiple notable components: a Human-certified Launch Vehicle (HLVM-3), an orbital module with life support systems, and an escape system for emergency protection of astronauts in the event of launch failure.

Supply Chain Challenges and Their Impact

The mission has encountered several supply chain-related challenges, which have been directly responsible for its delays. The COVID-19 pandemic hit worldwide supply chains hard, leading to factory closures, logistical jams, and procurement problems.

Several of ISRO's suppliers, including private companies and public-sector entities like the Defence Research and Development

14. "Gaganyaan," n.d., <https://www.isro.gov.in/Gaganyaan.html>.

15. Sharmila Kuthunur, "India Delays Its 1st-ever Gaganyaan Astronaut Launch to 2026," Space.Com, November 4, 2024, <https://www.space.com/space-exploration/human-spaceflight/india-delays-its-1st-ever-gaganyaan-astronaut-launch-to-2026>.

16. "Discussion on ISRO's Test Crew Escape System: First Human Space Flight Mission Gaganyaan", *Singrauli News, Singrauli Mirror*, n.d., <https://singraulimirror.in/article/discussion-on-isro-s-test-crew-escape-system-first-human-space-flight-mission-gaganyaan>.

Organisation (DRDO), Hindustan Aeronautics Limited (HAL), and Bharat Electronics Limited (BEL), encountered manufacturing and procurement disruptions, decelerating the production and delivery of vital components. Also, even as India's space capabilities have continued to expand, the mission is still dependent on foreign avionics, sensors, and life support systems being imported from the United States, Russia, and France. Export controls, shipping delays, and worldwide semiconductor shortages further complicated procurement. The stringent safety and testing requirements for human spaceflight further complicate the issue. The hold-up in procuring vital components resulted in delayed testing and certification stages, hence, impacting the general readiness of principal sub-systems. In addition, geopolitical issues like the Russia-Ukraine conflict created further interruptions, resulting in increased prices and timing delays in providing technical knowhow and critical materials.

ISRO'S RESPONSE TO SUPPLY CHAIN DISRUPTIONS

To offset these supply chain interruptions, ISRO has adopted strategic steps to boost domestic capabilities and reduce delays. As part of the *Atmanirbhar Bharat* (Self-Reliant India) programme, ISRO has increasingly collaborated with private companies such as Skyroot Aerospace and Agnikul Cosmos to create indigenous substitutes for imported parts.

The agency also updated its mission schedule, adding more uncrewed test flights to guarantee system reliability. The TV-D1¹⁷ test vehicle mission was carried out successfully in October 2023, and another uncrewed flight (TV-D2) was planned for 2024 before the ultimate crewed mission in 2026. The Indian government also

17. "Gaganyaan TV-D1 Mission," n.d., https://www.isro.gov.in/Gaganyaan_TV-D1_Mission.html.

raised¹⁸ the mission's budget to \$2.32 billion to enable alternative sourcing and hasten development activities.

The supply chain constraints of the Gaganyaan mission highlight the necessity of a more robust and self-reliant space ecosystem in India. Minimising reliance on international suppliers through local manufacturing and research partnerships will be critical for subsequent space missions. The delays also identify the need for adaptable project planning that provides for unexpected worldwide crises. Building stronger public-private partnerships for the space industry will further boost innovation, efficacy, and supply chain resilience.

The Gaganyaan mission delays due to supply chain disruptions are an indicator of the complexities involved in executing high-technology space missions. However, ISRO's adaptable actions, increased government backing, and enhanced domestic collaborations indicate India's resilience to overcome such obstacles. The learnings from this case study will be crucial for India's future space missions, including lunar, planetary, and deep-space missions, to strengthen its space industry and make it more independent.

Moreover, the issue related to the lack of a deep space network affects the capability of the country to execute multifaceted interplanetary missions. This problem, in the long run, also damages the supply chain system of India as it fails to carry out and fully plan and actualise more advanced space missions that require elaborate methods of ground support, communication architecture, and satellites. Apart from that, without a committed network, India is not able to follow and manage its deep space assets. This, in a way, affects the space operations within the country.

18. Bhattacharjee, "India Raises Budget for Gaganyaan Human Spaceflight Mission to \$2.32 Billion," Reuters, February 13, 2025.

Supply Chain Diplomacy

India's supply chain diplomacy is also about seeking international partnerships and securing advanced technologies and materials. This approach assists in creating a robust supply chain that can withstand geopolitical shocks. Integrating domestic reforms and international relations, India seeks to address the supply chain gaps in the Indian space sector for long-term sustainability and continued reform.

The present conflicts with China make it critical for India to make efforts to minimise reliance on Chinese imports for critical components of space materials.¹⁹ Strengthening trade with other developed countries will act as a substitute for the nation. India's Free Trade Agreements (FTAs) with nations like Japan²⁰, South Korea, and Sri Lanka, along with the Association of Southeast Asian Nations (ASEAN) and, more recently, Australia, the European Free Trade Association (EFTA), Mauritius, and the United Arab Emirates (UAE) will reduce the dependency of India on any one country.

The development of strong local capacity for production, and fostering and encouraging private sector investment²¹ can improve the capability of local industries to produce space-grade materials and components. The strides made recently which, by the likes of Pixxel, set up the first private satellite network in India, are instances of what private companies can do to develop the space sector.

19. "Challenges for Electronic Circuits in Space Applications, Analog Devices," n.d., <https://www.analog.com/en/signals/thought-leadership/challenges-for-electronic-circuits-in-space-applications.html>.

20. "How Is India's Trade Landscape Shaping up for the Future?", Economics Observatory, May 7, 2024, <https://staging.economicsobservatory.com/how-is-indias-trade-landscape-shaping-up-for-the-future>.

21. Express Defence, "The Impact of 'Make in India' on Domestic Manufacturing and Budget Allocation," *Financial Express*, July 5, 2024, <https://www.financialexpress.com/business/defence-the-impact-of-make-in-india-on-domestic-manufacturing-and-budget-allocation-3544331/>.

Building new infrastructure facilities and upgrading existing ones are equally important in facilitating rapid prototyping and testing for new technologies in space. A high level of research facilities, testing centres, and even factories for the production of what is invented is bound to aid in the growth of the space programme.

Implementing policies that incentivise research and development, ease regulatory processes, and provide financial support can stimulate growth in the space sector. The catalytic reforms²² introduced in May 2020 have already set the stage for such advancements, aiming to develop India's space-industrial ecosystem. While diversifying import sources, and fostering collaborations with countries like the United States, Japan, South Korea and the European nations can facilitate technology transfer²³, joint ventures, and shared expertise, thereby strengthening India's space capabilities.

CONCLUSION

India's space industry has made impressive leaps in recent times, but it still faces complex supply chain issues that hamper its potential. The reliance on overseas suppliers for key components, the splintered domestic manufacturing ecosystems, logistical inefficiencies, and regulatory complexities are all indicators of the need for systemic changes. Despite such challenges, the industry has shown an abidance towards self-reliance with initiatives such as the Space Policy 2023 and the formation of the Indian National Space Promotion and Authorisation Centre (IN-SPACe) to promote private investment and ISRO's trail-blazing efforts in affordable space missions. Nonetheless, the same must be strengthened by a more resilient and nimble framework to overcome enduring

22. "Parliament Question: Promotion of Private Sector in Space Sector," n.d., <https://pib.gov.in/PressReleasePage.aspx?PRID=2085590>.

23. "Industry," n.d., <https://www.isro.gov.in/Industry.html>.

weaknesses. Strengthening supply chain resilience requires India to focus policy actions on simplifying clearances, encouraging indigenous R&D, and bringing about public-private-academic collaboration.

Wider adoption of advanced technologies such as Artificial Intelligence (AI)-based demand forecasting, blockchain-based transparency, and automation in production can bring inefficiencies under control. Strategic investments in localised high-precision component manufacturing and building indigenous skill sets are also essential. Public-private partnerships need to be boosted, with a support system provided by schemes such as the Production-Linked Incentive (PLI) in the space industry. Adherence to international norms, coupled with the pursuit of ethical sourcing and sustainability will boost India's profile in the international space community too. The way ahead requires a holistic response: building innovation ecosystems, minimising bureaucratic drag, and combining supply chain digitisation. By meeting these imperatives, India can turn its supply chain issues into growth drivers, assuring its place as a competitive and self-sufficient actor in the global space economy. Through strategic vision and cooperative effort, the country can translate its stellar ambitions into real accomplishments.