DEFENSE AND AEROSPACE PROGRAM

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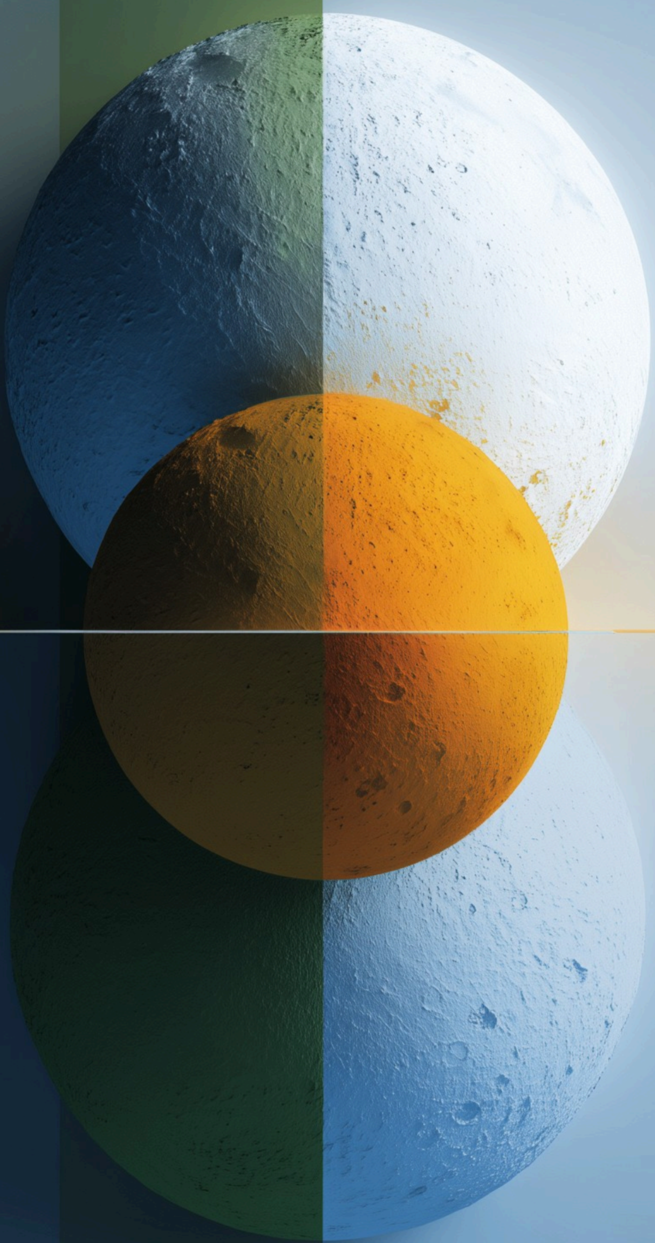
ALIGNED ORBITS

Forging a New Era of Indo-German Space Collaboration



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ABOUT THIS REPORT

This report assesses the Indo-German space partnership, noting that despite historical ties since 1963, the bilateral space relationship has underperformed largely due to ISRO's monopoly and Germany's ESA-centric focus. However, a pivotal opportunity has emerged, driven by concurrent major policy shifts in both countries, including a series of Indian reforms (since 2020) to privatize its space sector and Germany's recently announced $41 billion defense space investment. Technological complementarities are strong across the space value chain, and India can offer reliable, cost-effective launchers (PSLV, SSLV), while Germany leads in advanced payloads, robotics, and synthetic aperture radar. The report identifies Earth Observation, On-Orbit Servicing, space quantum communications, and planetary science as key areas for a high-profile bilateral space project. To realize the full potential of the Indo-German space relationship, B2B collaborations are the way forward, and the report calls for overcoming barriers such as regulatory fragmentation and export controls. Recommendations include establishing an annual high-level Space Dialogue, creating a strategic grants program for startups, initiating a flagship joint mission to foster deeper industrial and strategic interdependence, and fostering talent exchange and codevelopment.

ABOUT CSDR'S DEFENSE AND AEROSPACE PROGRAM

Our Defense and Aerospace Industry Program conducts research, policy analysis and business consulting. We actively collaborate with government entities to present various policy options for achieving defense manufacturing, indigenization, and export goals. In partnership with the Indian Armed Forces, we provide critical insights into the implications of emerging technologies and their impact on warfare and security scenarios through battlespace trend analysis and forecasts. Additionally, our program conducts research to formulate procurement strategies and warfighting doctrines that align with these new technologies and weapon systems.

ABOUT COUNCIL FOR STRATEGIC AND DEFENSE RESEARCH

Founded in January 2020 by Lt. Gen. D.S. Hooda (Retd.) and Dr. Happymon Jacob, CSDR is an innovative think tank and consultancy specializing in foreign policy, geopolitical risk, connectivity, and critical areas of defense and aerospace. With a focus on the Indian subcontinent, Eurasia, and the Indo-Pacific, CSDR is committed to generating strategic insights that drive meaningful change. Read more at www.csdronline.com

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LIST OF ABBREVIATIONS

- AIS: Automatic Identification System
- B2B: Business-to-Business
- BDLI: German Aerospace Industries Association (Bundesverband der Deutschen Luft- und Raumfahrtindustrie)
- CII: Confederation of Indian Industries
- DLR: German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)
- DRDO: Defence Research & Development Organisation
- DST: Department of Space (Note: Referred to as DST in source text, standard abbreviation is DoS)
- EO: Earth Observation
- ESA: European Space Agency
- EU: European Union
- FDI: Foreign Direct Investment
- FTA: Free Trade Agreement
- GSLV: Geosynchronous Satellite Launch Vehicle
- HAL: Hindustan Aeronautics Limited
- IGSTC: Indo-German Science and Technology Centre
- IN-SPACe: Indian National Space Promotion and Authorisation Centre
- INSAT: Indian National Satellite System
- IP: Intellectual Property
- IRS: Indian Remote Sensing
- ISP: Indian Space Policy
- ISpA: Indian Space Association
- ISRO: Indian Space Research Organisation
- ISS: International Space Station
- JWG: Joint Working Group
- LEO: Low Earth Orbit
- MoU: Memorandum of Understanding
- MTCR: Missile Technology Control Regime
- NASA: National Aeronautics and Space Administration
- NavIC: Navigation with Indian Constellation
- NISAR: NASA-ISRO Synthetic Aperture Radar
- NPWI: National Programme for Space and Innovation
- NSS: National Space Strategy
- OOS: On-Orbit Servicing
- PSLV: Polar Satellite Launch Vehicle
- QKD: Quantum Key Distribution
- SAR: Synthetic Aperture Radar
- SCOMET: Special Chemicals, Organism, Material, Equipment and Technologies
- SME: Small and Medium-sized Enterprises
- SSLV: Small Satellite Launch Vehicle
- TERLS: Thumba Equatorial Rocket Launching Station
- TUM: Technical University of Munich
- VC: Venture Capital
- VSSC: Vikram Sarabhai Space Centre

Executive Summary

Indo-German space cooperation stands at a pivotal moment. Concurrent space policy shifts in India and Germany offer a window of opportunity to radically reimagine their bilateral space relations and enhance cooperation in this domain, thereby bolstering their larger strategic partnership.

While historical collaboration dates back to the birth of India's space programme in 1963, bilateral space cooperation always remained limited relative to potential—constrained by ISRO's monopoly, Germany's ESA-centricity, and absence of high-level strategic dialogue.

The German Defence Minister's announcement on 25 September 2025 of a $41 billion investment in defence space technologies over the next five years marks a landmark moment. Driven by geopolitical tensions with Russia and China's rapid advances in space, this investment will make Germany the third-largest spender on space, behind the US and China, and can be expected to significantly bolster the country's space-tech capabilities across the value chain. It also signals recognition of the need for sovereign space capabilities and reduced overdependence on external powers, such as the US, for national security.

In parallel, since 2020, India has undertaken a series of reforms to liberalize its own space sector. The Indian Space Policy 2023 opened ISRO facilities to private enterprise and enabled the transfer of legacy technologies to industry. The number of space players in the country has surged from 11 in 2019 to over 400 today, and the vast majority of them are start-ups. Foreign Direct Investment (FDI) restrictions have been considerably relaxed; for instance, up to 100% FDI in satellite components and 74% through automatic approval. As a result, India's space economy is projected to grow from $8.4 billion (2022) to $44 billion by 2033, and expand its global share from 2% to 8%.

Today, technological complementarities exist across a range of space technologies and can be exploited, especially through B2B collaborations. India offers cost-effective, reliable end-to-end systems —proven launchers like PSLV and satellite platforms through the IRS missions. Germany leads in advanced payloads, Synthetic Aperture Radar technology (TerraSAR-X, TanDEM-X), precision subsystems, and sophisticated scientific instruments. India's demonstrated space-docking capability and Germany's robotics expertise (CAESAR robotic arms) also create natural synergy for On-Orbit Servicing and debris management. Indian startups excel in hyperspectral imagery and 3D-printed engines; German startups have pioneered hybrid propulsion and staged combustion cycles.

Yet barriers to joint ventures persist: mutual illiteracy about capabilities and regulations, the absence of consolidated space laws in both nations, which create legal uncertainty in not one but two regulatory landscapes, complex IP protection frameworks, and stringent export controls on dual-use technologies that impede technology transfer.

The window created by simultaneous policy shifts in both nations will not remain open indefinitely, and without deliberate action – such as high-level political dialogue, regulatory harmonization, and concrete joint projects – will not translate into a higher-order bilateral space partnership. However, if capitalized upon, it can help India and Germany to advance technological autonomy and economic competitiveness in an increasingly contested domain.

Introduction

The strategic partnership between India and Germany stands at a pivotal moment today. As consecutive cycles of geopolitical and geoeconomic crises create turbulence in the international system, New Delhi and Berlin, much like many other major powers, find themselves compelled to seek (and create) stability wherever available. This quest overlaps with a stark realization, while uncomfortable and often difficult to admit, that incumbent great powers and their policy decisions (predicated on great-power rivalry) are increasingly the very source of instability on the world stage. In this context, the Indo-German strategic partnership, if reinforced and built upon, can help New Delhi and Berlin counter new and deep challenges introduced by their respective external environments.

This shared imperative is already evident, for instance, in the renewed momentum and political commitment behind an early conclusion of the EU-India FTA. As India's largest trade partner within the EU, with bilateral trade at $36 billion in FY24, Germany has thrown its weight behind the agreement.[1] If and when signed, it would elevate the economic relationship between India and Germany to new heights, creating momentum and a higher-order logic for collaborations across new sectors.

> "A far greater enabler of a strategic relationship between two nations is scientific and technological collaboration, as it allows partners to build and share core capabilities and, in the process, to develop interdependencies (through investments and technology transfers) that both require and foster trust and goodwill.

While bilateral trade ties are of paramount importance, particularly at a time when the liberal economic order appears to be in retreat, they remain a weak guarantor of depth in a strategic partnership. Arguably, a far greater enabler of a strategic relationship between two nations is scientific and technological collaboration, as it allows partners to build and share core capabilities and, in the process, to develop interdependencies (through investments and technology transfers) that both require and foster trust and goodwill.

Take the example of the German-built Rourkela Steel Plant, inaugurated by the first President of India, Dr. Rajendra Prasad, in 1959. It was one of the first large-scale industrial ventures undertaken in independent India, and PM Jawaharlal Nehru went on to describe the plant as a "temple of modern India.[1] It remains a key symbol of the India-Germany relationship and forged the legacy of industrial partnership that has endured for over six decades. As a result, India continues to view Germany as a technological powerhouse and seeks deeper ties to upgrade its own capabilities. As the Indian EAM Jaishankar put it in his speech at the German Council on Foreign Relations (Deutsche Gesellschaft für Auswärtige Politik, or DGAP) in May this year, India has "high expectations" from Germany.[3]

He also noted that New Delhi and Berlin need "to forge new ways to this relationship." As novel technologies emerge at the forefront of geopolitical competition and trade tensions reconfigure global supply chains, India and Germany today have a window of opportunity to radically increase collaboration in key tech sectors. In this context, one area where enormous synergy has been created, due to both technological and geopolitical trends, but bilateral cooperation remains largely unfulfilled relative to its potential, is the domain of space.

Union External Affairs Minister S Jaishankar with German Chancellor Friedrich Merz during a meeting in Berlin, Germany. Source: PTI

A Brief History of Indo-German Space Ties

Bilateral space cooperation between India and Germany dates back to the inception of India's space program. In November 1963, years before the Outer Space Treaty was signed (1967) and ISRO was created (1969), the Nike Apache rocket achieved lift-off from a small launch pad outside Thiruvananthapuram, Kerala. It was India's first spaceport, the Thumba Equatorial Rocket Launching Station (TERLS), and was built with support from the US, the USSR, France, the UK, and West Germany.[4] Notably, India later offered the TERLS to the United Nations as a gesture of goodwill, reflecting the country's commitment to the peaceful use of outer space for the benefit of all humanity. In turn, the UN formally sponsored the station as an international scientific facility open to all its members.[5] The TERLS was later embedded into the Vikram Sarabhai Space Centre (VSSC) in 1972, which today serves as ISRO's lead facility for the design and development of launch-vehicle technology.[6]

Throughout the 1960s, Indian scientists and engineers studied at German universities through DAAD programs, and as a result, personal relationships were later established between ISRO and the DFVLR, the predecessor of the German Aerospace Center (DLR).[7] German scientists have consistently provided technical support to India's space programme.

In October 1971, a bilateral agreement on 'the peaceful uses of atomic energy and space research' was signed between India and the Federal Republic of Germany, which

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kick-started joint research efforts. Throughout the 1970s and 80s, Germany supported India's development of early rocket technology for satellite launch vehicles. ISRO used wind tunnels in Germany for critical SLV tests at (simulated) pressures and altitudes, and in 1976, German interferometers were installed in multiple ISRO rockets to improve their guidance systems.[8] The integration of German research instruments into Indian satellites naturally followed, especially for India's Remote Sensing Satellite Program. For instance, the German MOMS series (Modular Optoelectronic Scanner for Stereoscopic and Multispectral Observation) was integrated into the IRS-1A (1988), the IRS-1B (1991), and the IRS-P3 (1996).[9] In 2008, Chandrayaan-1 carried the SIR-2 instrument, developed by Germany's Max Planck Institute for Solar System Research.[10]

In 1993, Germany provided the Infrared Imaging System for the IRS-1E, which notably marked the first successful launch of India's Polar Satellite Launch Vehicle (PSLV). Six years later, Germany became one of PSLV's first international customers (along with South Korea), with the launch of the DLR-TUBSAT in 1999. Since then, the PSLV has launched several German satellites, including the DLR-developed BIROS in 2016.[11]

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At a broader level, India and Germany's science and technology partnership, under a 1974 intergovernmental agreement, focused on space-related scientific research. An apex Indo-German Committee on Science and Technology (S&T) was established in 1994 to oversee and review joint activities, and the Indo-German Science and Technology Centre (IGSTC) was established in 2010.[12] In 2013, ISRO and DLR organized a technical workshop to explore future areas of space cooperation, identifying components procurement, commercial launch services, and climate change research as key areas of focus.[13] The DLR even helped an Indian power distributor set up a research center in 2016 to develop solar power plants and components, leveraging its own expertise in solar technology.[14]

Vikram Sarabhai, seen with German ambassador Gunter Diehl, signs an agreement on the peaceful use of atomic energy and space research.
Source: The Week

While this history of Indo-German bilateral space cooperation is commendable and has created (to an extent) an institutional memory of partnership with Germany at multiple levels, the unfortunate reality is that the bilateral space partnership never came close to its true potential. In fact, it was largely a result of the globalized nature of space technology development, which transcended borders and geopolitical divides, rather than a concerted high-level strategic push to form linkages between India and Germany's space ecosystems.

Over the decades, bilateral space cooperation plateaued. Today, this is vividly evident in the absence of any major joint space projects between India and Germany, in stark contrast to their other key partners. The limited Indo-German space cooperation that does happen, occurs through the ESA rather than a direct DLR-ISRO pathway. For instance, the Gaganyaan mission – India's first human spaceflight program – will be supported by the ESA's Network Operations Centre at the ESOC Mission Control Centre in Darmstadt, Germany.[15] The ISRO-ESA agreement for Gaganyan also includes a provision for additional antenna systems operated directly by the DLR to be integrated into the support network. At the B2B level, there is a single Indo-German joint venture between Berlin Space Technologies and Azista, which manufactures satellites at a plant in Gujarat, even as complementarity between the Indian and German space sectors extends across a range of space technologies.[16]

Both India and Germany have far deeper space-based collaborations with the USA, France, and Japan than with each other. In fact, before Russia's invasion of Ukraine in 2022, Germany had arguably greater space cooperation with Russia than India. (for example, the Spektr-RG space observatory – a joint project between DLR and Roscosmos, which was terminated immediately after the invasion; the International Space Station is another example).[17] India, for its part, has its own long history of significant space cooperation and joint projects with Russia.

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There are several reasons for this underperformance. To begin with, both India and Germany historically viewed space as a domain for socio-economic development, and were slow to extend strategic focus on the sector.

In India, ISRO monopolized the country's space journey, and the Indian space sector developed largely as a vendor ecosystem for the space agency. India sought space partners but primarily to help build comprehensive national capabilities. Its multi-faceted space cooperation took place with the US, France, and Russia, who (unlike Germany) were inclined to commit to co-development and even co-production of advanced space technologies with India for their own strategic calculations. This created a high entry barrier for other nations. Beyond this, India had extensive regulations in place for the space sector, which historically obstructed the rise of private space companies and start-ups capable of building space assets or services for commercial use, let alone working with international partners. In any case, foreign direct investments in the Indian space sector were largely restricted until 2024.

Germany's approach to space, on the other hand, was largely centred on the European Space Agency (ESA). The ESA's 'geographic return policy' – which ensures that member states receive industrial contracts proportional to their financial contributions to the ESA – not only incentivized the federal government to channel its major space initiatives through the ESA for the sake of a common European agenda but also shaped the development of the German aerospace sector.[18] The 'space primes' such as Airbus and OHB Systems primarily pursued the development of highly specialized and even niche systems (instead of broad national capabilities like India) to secure contracts for ESA missions, which created a horizontal lock-in effect for the German space ecosystem.[19] For this reason, it also made far more sense for the country's space industry to collaborate with other EU-based (or NATO countries') space agencies and companies. In any case, both the EU and Germany's stringent export controls on dual-use technologies (which are highly relevant for any major joint project in the space sector, such as advanced sensors, propulsion systems, and guidance software) made it difficult to collaborate with 'non-aligned' countries like India.

At the same time, New Delhi and Berlin also placed little emphasis on a bilateral space partnership that could bridge the gap between their countries' divergent space trajectories. India and Germany do not hold a formal, high-level strategic space dialogue, unlike India and France and other space powers. Meanwhile, the Indo-German Committee on Science and Technology, the apex intergovernmental body responsible for coordinating science and technology cooperation and, more importantly, approving high-cost and long-term projects, has reportedly not met since May 2017. Germany's historical opposition to the securitization of space was arguably another hurdle. For instance, Germany has long supported a legal ban on anti-satellite weapons, and in 2019, Berlin officially criticized India's anti-satellite (ASAT) missile test (Mission Shakti) at the UN Committee on the Peaceful Use of Outer Space (COPUOS).[20]

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A Window of Opportunity

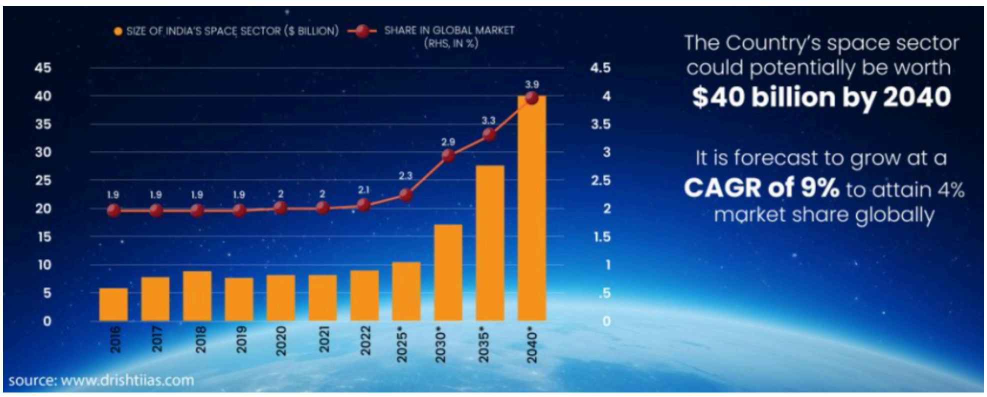
Over recent years, however, major shifts in both their views on and approaches to the space sector have created a window of opportunity for India and Germany to radically reimagine their space partnership.

In 2020, India announced its intention to liberalize the space sector and has since implemented a series of reforms and new policies to unlock its space economy. The Indian National Space Promotion and Authorisation Centre (IN-SPACe) was created the same year to act as a single-window agency that can promote, authorise, and supervise the activities of 'non-governmental' entities.[21] It's important to note that although IN-SPACe has been deemed an 'autonomous' body under the Department of Space (DoS), it's yet to receive statutory powers from the Indian Parliament (A draft Space Activities Bill will reportedly grant the same, as and when adopted). Meanwhile, New Space India Limited was established as ISRO's commercial arm, facilitating the integration of private enterprise into the national space ecosystem.[22] ISRO's facilities (such as test labs and spaceports) have also been opened to the private sector.

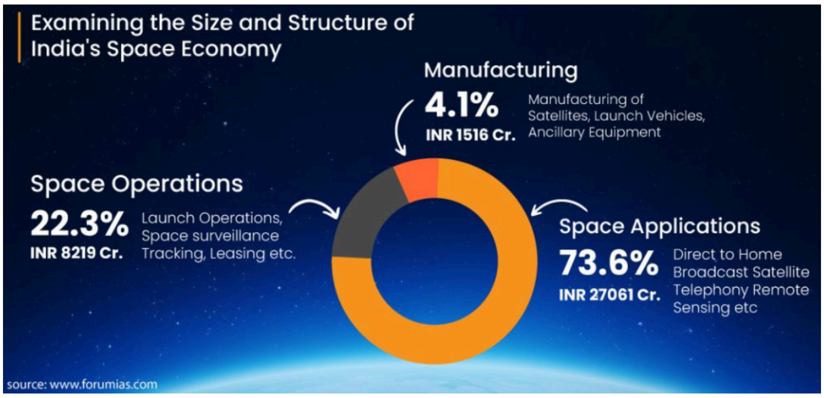
Three years later, New Delhi released a landmark Indian Space Policy to indicate a future direction for the transformation already underway. The document outlined a vision in which ISRO would (eventually) focus entirely on the R&D of advanced space technologies and transition out of both the production and operation of 'legacy space systems', which, in turn, would largely be handed over to the private sector.[23] Indeed, ISRO has since signed 100 technology transfer agreements with the space industry. Recently, on 10 September 2025, ISRO agreed to transfer its Small Satellite Launch Vehicle (SSLV) technology to Hindustan Aeronautics Limited (HAL).[24] The agreement marked the 100th tech transfer milestone, and although HAL is a PSU, it was nevertheless the most serious demonstration yet of ISRO's commitment to the ISP 23 vision.

> In 2024, the Government of India significantly relaxed restrictions on FDI in the space sector. The new rules allow up to 100% FDI in satellite component production, up to 74% through the automatic route, even as FDI is capped at 49% for specific sectors such as launch vehicles, and an approval is required to exceed that cap. Recent reports project that India's space economy could grow from $8.4 billion (in 2022) to $44 billion by 2033, and thereby increase its global share from 2% to 8%.

The results of India's space policy overhaul are already evident. In 2019, the country had merely 11 private space companies. Today, that number is estimated to be over 400 (a large portion of which are space startups), with private players heavily involved in a wide range of space-based services across the value chain from satellite design and fabrication to downstream services in the EO sector.[25]



To support them with risk capital, especially start-ups, the GoI has approved a $110 million venture capital fund to be disbursed to approximately 40 players over a five-year period. Even more importantly, in 2024 the GoI significantly relaxed restrictions on FDI in the space sector. The new rules allow up to 100% FDI in satellite component production, up to 74% through the automatic route (without any approval whatsoever),



even as FDI is capped at 49% for specific sectors such as launch vehicles, and an approval is required to exceed that cap. In a recent report, the Confederation of Indian Industries (CII) and KPMG jointly project that India's space economy could grow from $8.4 billion (in 2022) to $44 billion by 2033, and thereby increase its global share from 2% to 8%.[26]

In parallel, Germany's space policy landscape has undergone significant changes. In 2023, the same year the ISP was released, the German government unveiled a National Space Strategy, a long-overdue successor to the 2010 framework.[27] It signalled a decisive pivot from the country's historically idealistic view of a scientific and cooperative ethos in space to a more pragmatic, dual-track approach. It identified nine key areas for space development, including EO and satellite communications. Importantly, while the strategy reaffirmed Germany's commitment to the European Space Agency, it also recognized new commercial opportunities presented by the "NewSpace era," heightened global economic competition in the space sector, and the rapid securitization of space-based assets amidst geopolitical tensions.[28]

It is committed to supporting new business models that strengthen German space startups and SMEs, which, in turn, ties into Germany's newfound strategic imperative to reduce foreign dependencies in space capabilities. An important example of the latter in play is the DLR's micro-launcher competition, which aims to address a key vulnerability in Germany's space sector – the lack of domestic, dedicated, and commercially operated launch capabilities available to the country's small satellite manufacturers.[29] Under the competition, three key startups have already been funded, and this approach is in line with the NSS 23's vision of the federal government as an 'anchor customer' for smaller players, so that it can act as a reliable first-buyer of commercial space services, help de-risk private investment, and stimulate innovation and development in the process.[30]

The NSS 23 also recognized the importance of a legal framework for the German space sector and announced the federal government's intention to draft a National Space Act. Indeed, the lack of a single, consolidated national space law has long been identified as a significant hurdle for the commercial space sector, creating a patchy, uncertain regulatory landscape, especially for relatively sensitive activities such as launches and in-orbit operations.

> "Germany's space policy landscape has undergone significant changes. In 2023, the same year the ISP was released, the German government unveiled a National Space Strategy, a long-overdue successor to the 2010 framework...signalling a decisive pivot to a dual-track approach.

In September 2025, Germany announced plans to invest $41 billion in its defence space sector over the next five years to build sovereign space infrastructure and defence capabilities.[31] This has already been hailed as a "watershed moment," and for context, Germany's annual space budget in 2024 was just over $1.6 billion. German analysts also suggest that the focus on developing sovereign space assets – a major shift away from ESA centrality in Germany's traditional approach to space development – indicates a certain degree of frustration over the coordination of projects at the European level, which tend to have slow or cumbersome delivery timelines, coupled with strategic pressure.[32] For instance, the European IRIS satellite constellation, approved in 2022, is expected to start launches in 2029 and has come under heavy criticism for delivering "too little, too late."

The investment is primarily meant for defence-related space programs (satcom constellations, space situational awareness radars, launchers, guardian satellites, etc.) and came amidst an uptick in geopolitical tensions with Russia, as well as protracted concerns over China's rapid progress in the space sector. Yet experts argue that the sheer amount of capital indicates that a significant portion will have to flow into the private space industry, particularly NewSpace startups, to be absorbed.[33] Consequently, it is widely expected to bolster Germany's space capabilities across the board, and in any case, much of space technology is inherently dual-use.

India's Space Ecosystem

India's space sector has largely developed as an ISRO-centric ecosystem across the entire space value chain. India's core domestic capabilities encompass satellite production for earth observation and communication, space transportation systems, and interplanetary missions, with a consistent emphasis on self-reliance and cost efficiency.

To begin with, ISRO has multiple operational satellite systems in orbit, which includes the Indian National Satellite System (INSAT) (started in1983), and the Indian Remote Sensing (IRS) Satellite System (started in 1988) which continue to collectively provide crucial space-based services to the country: from earth observation data for resource management, disaster response, environmental studies, and so on; to satellite communications, meteorology, and search-and-rescue services.[34] After the Kargil War, India also conceived the Navigation with Indian Constellation (NavIC) system, which could provide PNT services to both its military and civilian sectors. However, 25 years later, the NavIC system continues to struggle and reportedly has only 4 of its 11 satellites operational at present.[35]

In parallel to satellite systems, the Indian space agency developed indigenous launch capabilities, such as the SLV-3 in 1980. The PSLV is widely hailed as ISRO's "workhorse," a medium-lift launch vehicle renowned for its reliability and cost-effectiveness.[36] It evolved into a rideshare service for small satellites and has launched over 300 satellites for 36 countries.[37] Meanwhile, the Geosynchronous Satellite Launch Vehicle (GSLV) has the capability to launch heavy payloads, communication and navigation satellites, into geostationary transfer orbit (GTO). Its

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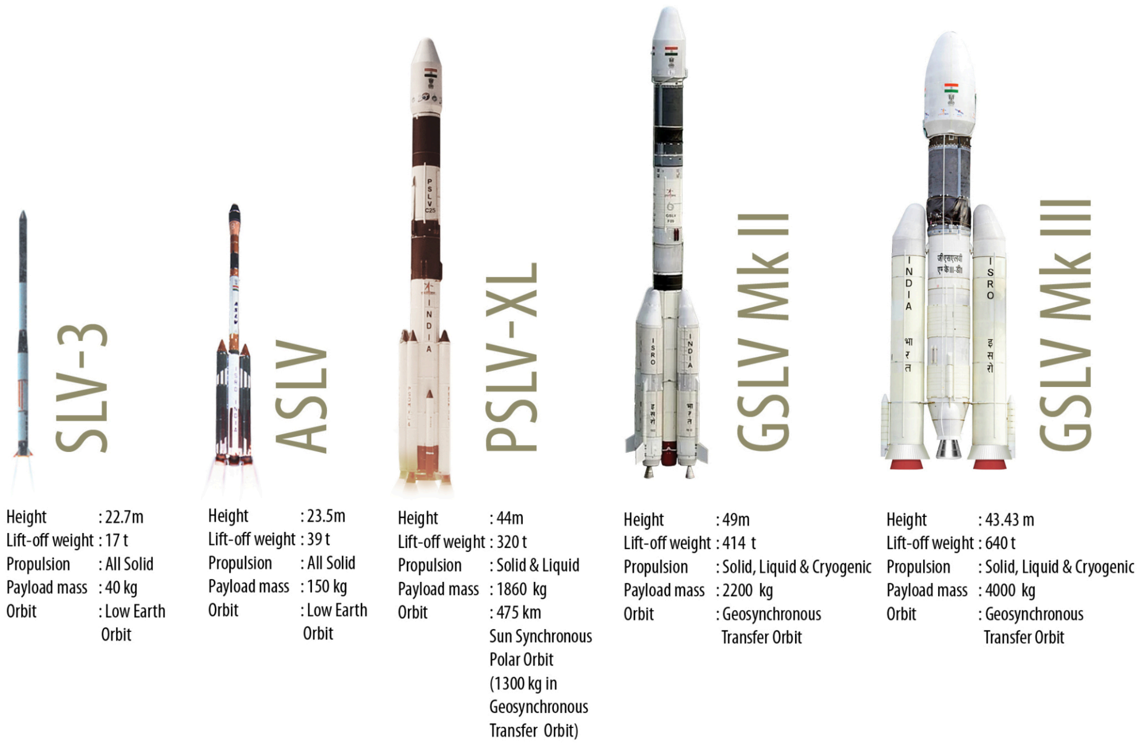
development required mastery of the complexities of cryogenic propulsion, a capability held by only a handful of nations. The successful operationalization of the indigenous CE-7.5 cryogenic upper stage on the GSLV Mk II variant was a landmark achievement for the country.[38] Finally, ISRO's Small Satellite Launch Vehicle (SSLV) caters to the now-massive global market for small satellites. As a low-cost, launch-on-demand service, it can put payloads of up to 500 kg into low Earth orbit (LEO), and, as mentioned above, its commercialization is expected to allow HAL to ramp up mass production and operate the vehicle.



ISRO's launch vehicles. Source ISRO

Since the mid-2000s, India has also focused on interplanetary missions of national prestige, such as Chandrayaan 1 in 2008, which confirmed the presence of H2O molecules on the Moon.[39] India's Mars Orbiter Mission (Mangalyaan), launched in 2013, made India the first nation to reach Mars on its maiden attempt and garnered international headlines for its cost efficiency. At approximately $75 million, Mangalyaan's budget was lower than that of several Hollywood films (some even about space, such as Gravity, which cost $100 million) at the time.[40] Chandrayaan 3 made India the fourth nation to achieve a soft landing on the Moon, and the only nation to do so near the south pole (which is difficult terrain). [41]

ISRO has also demonstrated an ability to integrate sophisticated foreign payloads into its own systems and coordinate highly complex and expensive international missions. For instance, the NASA-ISRO Synthetic Aperture Radar (NISAR) mission recently launched the most expensive EO satellites ever built (which took nearly a decade to develop at a cost of $1.5 billion) and integrated NASA's L-band radar with ISRO's S-band radar and satellite bus.[42]

Meanwhile, India's private sector has made rapid progress in recent years, and despite its 'starved for capital' reputation, Indian startups have pushed technological frontiers. For instance, Skyroot Aerospace and Agnikul Cosmos (both founded by former ISRO scientists and engineers) have emerged as pioneers in advanced rocket production. Skyrrot launched the Vikram-S, India's first private rocket (albeit sub-orbital), in

2022, and Agnikul has developed the world's first single-piece, 3D-printed semi-cryogenic rocket engine.[43] Meanwhile,Pixxel's Firefly constellation – India's first private satellite constellation in orbit – has quickly emerged as a leader in hyperspectral imagery, attracting significant international attention and investment.[44]

Germany's Space Ecosystem

The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e. V., or DLR) is the central institution in Germany's space ecosystem, and possesses a unique and powerful dual mandate.

First, the DLR serves as Germany's national space agency. It manages the national space budget and represents German interests within ESA and other international forums. The DLR manages the National Programme for Space and Innovation (NPWI) – a key instrument for funding companies, universities, and research institutions that develop space technologies and help maintain core competencies in strategic areas.[45] For instance, the aforementioned Microlauncher Competition, which awarded close to $30 million to three startups, was organized under the NPWI. It also facilitates technology transfer between the space sector and other industries.

Second, the DLR serves as one of Europe's largest research and development organizations. It not only operates a national research center for aeronautics and space, but also conducts scientific and technological research projects across various sectors, including energy, transport, and national security, and helps cultivate the expertise and talent that fuels much of Germany's tech-industrial base.[46]

Germany's primary space industrial base comprises a small number of large, highly capable, and globally competitive prime contractors, notably Airbus Defence and Space, OHB SE, and ArianeGroup. They're the primary beneficiaries of Germany's substantial institutional investments in ESA and EU programs and possess deep expertise in systems integration, advanced production of space assets, and the management of complex, multinational projects.

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Airbus is a leader in human spaceflight and space robotics, a role cultivated through its involvement in the International Space Station (ISS) and its current pivotal position in lunar exploration.[47] Airbus is invested in the next generation of in-space infrastructure, and plans (along with the US-based Voyager technologies) to develop, build, and operate Starlab, a commercial space station intended to succeed the ISS in low Earth orbit.[48]

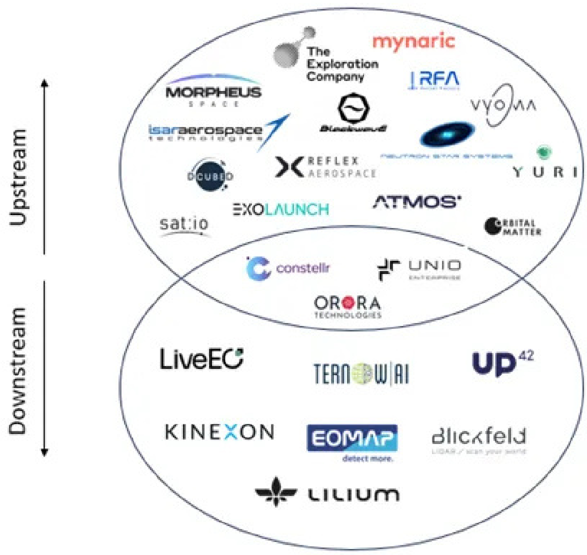
Airbus is also a leader in the design and manufacture of complex satellite systems. It served as a key player in the Copernicus program and has specialties in multispectral imagery, oceanographic altimetry, and advanced radar instruments. For instance, Airbus, in partnership with the DLR, built the TerraSAR-X and TanDEM-X national radar satellites, which provide high-resolution, all-weather EO services globally.[49] It is also a center of competence for critical subsystems, such as solar arrays for spacecraft power and highly advanced optical instruments, such as the Near Infrared Spectrograph (NIRSpec) – one of the four main scientific instruments on the James Webb Space Telescope.[50]

Meanwhile, OHB SE, Europe's third-largest space systems company, is a leader in the development of small and medium-sized satellites. It has secured major institutional contracts, for instance, it built the first-generation Galileo navigation satellites, and has simultaneously built a strong portfolio in Earth observation.[51] It developed Germany's EnMAP hyperspectral environmental satellite, as well as the SAR-Lupe and its successor, SARah, radar satellite systems for the German military.[52] OHB also manufactures subsystems and structural components, such as tanks for the Ariane launcher program. Additionally, it is active in the downstream segment, developing and operating ground systems for satellite operations, and providing market services including maritime surveillance (AIS) and secure communications through its subsidiary, OHB Digital Connect.[53]

ArianeGroup is another major player in Germany, although it's a Franco-German enterprise – a 50/50 joint venture between Airbus and Safran (French). It serves as the design authority and prime contractor for the Ariane family of launchers. Ariane 6, planned a decade ago, was successfully launched in 2024 and is the only significant launch vehicle in Europe, but it is not reusable.[54]

These prime contractors are supported by other large technologically sophisticated companies (such as MTU Aeroengines) that manufacture critical sub-systems and the German 'Mittelstand' – a robust network of highly specialized SMEs – that delivers components, materials, and services, from precision electronics and mechanical parts to specialized software and test services which feed into the complex projects led by the primes.

More recently, Germany has fostered one of Europe's most dynamic and well-funded (privately, often through VCs) "NewSpace" start-up scenes in Europe. Over 125 startups are currently driving significant innovation and technology diversification across key areas, from small-satellite production to launch-vehicle development to downstream applications.[55] They are well-positioned to drive a myriad of technological and economic advances in Germany in the near future, especially if they absorb a significant portion of the $41 billion investment announced in September (for context, German space startups raised over $700 million through 2022).[56]



German SpaceTech companies in the value chain – exemplary selection (graphic slightly adapted from Dealroom)

For instance, the aforementioned DLR micro launcher competition has placed Germany at the cusp of commercial (and sovereign) launch capabilities through three startups:

- Isar Aerospace has raised $330 million in private capital, making it the best-funded independent NewSpace company in Europe. Its flagship launch vehicle, "Spectrum," is a two-stage liquid-fuelled rocket designed to deliver payloads of up to 1,000 kg to low Earth orbit (LEO). Isar has a diverse group of backers, which includes traditional venture capital firms like Lakestar, as well as notable investors such as Porsche SE and the strategically significant NATO Innovation Fund.[57]

- Rocket Factory Augsburg is a corporate spin-off of the established space company OHB, partnered with another OHB subsidiary, MT Aerospace. The group has developed the "RFA ONE" launcher, with a payload capacity of up to 1.3 tonnes to LEO, and RFA's key technological advantage is its "Helix" engine, which utilizes a highly efficient staged combustion cycle—a complex technology that RFA has pioneered in Europe.[58] Its corporate model leverages the industrial heritage and supply chain of its parent companies to mitigate development risk. RFA is also developing the Redshift orbital transfer vehicle (OTV), 'a space tug' that will offer customers last-mile delivery services to enable precise orbital placement for satellite constellations.[59]

- HyImpulse Technologies (Neuenstadt am Kocher) has also followed a distinct technological path, utilizing a hybrid propulsion system that combines non-explosive, low-cost paraffin (a wax-based solid fuel) with liquid oxygen. This innovative approach aims to significantly reduce the complexity and cost of production and launch operations. The company's orbital rocket, the SL1, is designed to carry payloads of up to 400 kg into space.[60]

The parallel development of these three companies also indicates a deliberate government strategy of technological diversification through support for distinctly different propulsion technologies (liquid, staged combustion, and hybrid) and business models (VC-backed startup vs. corporate spin-off).

Beyond the high-profile launcher startups, Germany's NewSpace ecosystem has a strong presence in both the upstream (production) and downstream data application segments. A number of agile SMEs are now capable of producing complete small satellites and critical subsystems (for instance, ISPTech has developed an in-space propulsion system).[61] German startups have also leveraged vast amounts of data—often provided free of charge by public programs like Copernicus—to create innovative, value-added services for a wide range of terrestrial industries. For instance, the startup LiveEO has developed an AI-powered platform for satellite imagery analysis and recently analysed the entire US electricity grid for vegetation encroachment.[62]

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Finally, a core German strength in the space sector is its multidimensional and highly advanced research landscape, which extends beyond the DLR. A large number of German universities and technical institutions have made substantial advances in space research and technology development worldwide. The Technical University of Munich (TUM) is a powerhouse in aerospace research.[63] The University of Stuttgart's Institute of Space Systems (IRS) conducts research in aero-thermodynamics for atmospheric re-entry, electric and chemical space propulsion, small satellite design and operation, and airborne astronomy.[64] It houses extensive facilities, such as plasma wind tunnels and a satellite control center. The University of Bremen maintains deep, collaborative ties with Bremen's local concentration of space industry and research institutes. It is home to the world-renowned Center for Applied Space Technology and Microgravity (ZARM), which has pioneered work in microgravity, fluid dynamics, and space exploration technologies.[65] Max Planck Institutes are renowned for their research across astrophysics, cosmology, and planetary science, and contribute to the essential scientific knowledge that underpins present and future space exploration missions.

These are just a few examples among dozens of academic institutions that generate fundamental knowledge and train a large pool of experts who work worldwide. Large research associations, such as Helmholtz and Fraunhofer, along with the DLR, also serve as crucial bridges, helping translate basic research into applied technologies and de-risk them for industrial adoption.[66] They are a key part of the innovative ecosystem that underpins the success of both the prime contractors and new startups, as they provide access to both technology and talent. In fact, a significant number of successful NewSpace companies in Germany have originated from the aforementioned academic institutions.

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Potential Areas of Synergy and the need for an Indo-Germany Space Project

The distinct evolutionary paths of the Indian and German space programs have cultivated ecosystems that are distinct, yet there is a strong case for greater cooperation between India and Germany across the space value chain. To begin with, India's focus on cost-effective, reliable end-to-end systems has led to the development of launchers and satellite buses that create a value proposition for joint missions with Germany, which has built technological excellence in advanced payloads and subsystems. At a broad level, technological synergy exists in key areas, which can be further focused and elevated through high-profile joint projects between ISRO and the DLR, especially if space companies involved can be incentivized to partner with each other. Inter alia, such projects can be conceived in areas such as:

- ***Earth Observation and Climate Science***

Germany is a global leader in space-based Synthetic Aperture Radar (SAR) technology, as demonstrated by the aforementioned TerraSAR-X and TanDEM-X missions, which provide high-resolution, all-weather EO capabilities. This is further complemented by the NewSpace start-ups' focus on advanced sensors, such as hyperspectral imagers, and some have emerged as leaders in the thermal intelligence segment. Similarly, both ISRO and Indian startups have also developed EO capabilities, but more importantly, India has decades of experience in the development of robust satellite platforms (through the IRS/EOS mission, for instance) that can integrate advanced systems and subsystems, as well as deploy the same in a cost-effective manner at scale. Both nations have also developed mature and extensive downstream data application ecosystems that can provide services to various industrial sectors in India, Germany, and other markets.

- ***On-Orbit Servicing (OOS), Space Debris Management, and Space Situational Awareness***

The long-term sustainability of space activities today is threatened by hundreds of thousands of pieces of space debris, particularly in LEO, where the environment is increasingly crowded. In this context, not only have both India and Germany committed to 'zero-debris' missions, but they are also actively involved in the development of debris-removal and OOS technologies such as satellite life extension. The DLR is a world leader in this field and is heavily invested in advanced robotic arms (such as CAESAR), laser-based debris trackers, sophisticated threat-perception algorithms, and rendezvous and capture mechanisms. Meanwhile, India has reliable and cost-effective access to orbit via its PSLV and SSLV launchers and has recently become the fourth country in the world to demonstrate space docking capabilities. Both nations are also highly dependent on the USA for vital SSA data needed to safeguard their own sovereign assets and launch any future space debris management initiatives. Consequently, they could benefit from collaborating to upgrade their SSA capabilities and share data securely.

- ***Space Quantum Communications***

The possible creation of a sufficiently advanced quantum computer has emerged as a novel threat that could render traditional encryption standards (such as RSA) that underpin global cybersecurity obsolete. At the same time, the cost of quantum communications (Quantum Key Distribution or QKD-based) via fibre-optic cables, for instance, increases exponentially as the sender and receiver are separated by a certain distance (a few hundred km, at present). In this context, both India (through the National Quantum Mission) and Germany (through its QuNET initiative) have launched concerted efforts to develop the technological capabilities needed for quantum communications via satellites.[67] Germany has already launched an experimental quantum satellite, QUBE 1, in 2024, and India plans to do so in the next few years.[68] Given that India and Germany are among a handful of nations that have developed nascent strengths in space quantum communications, they stand to reap long-term dividends if they pool their resources and expertise and work together.

- ***Planetary Exploration and Space Science***

ISRO's highly successful and remarkably cost-effective interplanetary missions also position India well to partner with Germany in space science, given its leadership in high-precision and advanced scientific instruments. Germany's advanced scientific payloads can also be integrated with rovers developed in India, potentially leading to a scale-up of joint scientific inquiry that is prohibitively expensive for either nation to pursue independently. Germany's advanced expertise in astrophysics and experience in deep-space mission operations can further support such joint endeavors.

Business-to-Business Ties: Potential, Challenges, and Recommendations

There are numerous technological and commercial complementarities between the German and Indian space industries, with significant potential for collaboration across the entire space value chain. As India's space sector liberalizes, it can benefit from German investments and technological expertise, particularly through joint ventures. Meanwhile, German space companies and startups can offshore and scale up the production of their own space technologies in India, which offers a large and skilled talent pool and cost efficiency. Indo-German joint ventures in the space sector would also be uniquely positioned to compete in key third-party markets, where customers seek a balance between advanced technology and cost-effectiveness—a niche that is often poorly served by higher-cost US and European solutions or Chinese alternatives that are often technologically unproven and may come with detrimental national security implications.

An example that illustrates this logic already exists in the form of a joint venture between BST and Azista Industries, which jointly established a satellite factory (Asia's first) in Ahmedabad, India, and launched their first satellite in 2023.[69] They mass-manufacture small satellites in the 50-150 kg class. While BST is a key technology provider and minority stakeholder, the production plant is operated by Azista and boasts a capacity to manufacture up to 250 satellites per year.

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There are multiple challenges, however, that hinder deeper and wider collaborations between India's and Germany's space sectors.

- To begin with, due to the lack of interlinkages between the Indian and German space sectors, stakeholders in each sector have very little knowledge of the other's capabilities, markets, and regulatory systems. This literacy gap hinders collaboration at both the conceptual and implementation levels.

- Both countries lack a single, consolidated space law. While India has released ISP 23, and IN-SPACe has released a document on Norms, Guidelines, and Procedures (NGP) for the implementation of ISP, these instruments fall short and lack the full statutory authority of a law passed by Parliament.[70] Meanwhile, in Germany, a complex patchwork of laws governs space regulations, including the Air Traffic Act, the Satellite Data Security Act, and the Foreign Trade and Payments Act, among others.[72] This parallel legal void creates a dual-jeopardy problem, in the sense that investors and joint ventures must navigate not one but two incomplete and ambiguous regulatory systems simultaneously. This leads to significant legal and operational uncertainty on critical issues, such as liability for launch or in-orbit failures, mandatory insurance requirements, dual licensing procedures, and mechanisms for dispute resolution.

- Relatedly, the lack of space laws in both countries creates uncertainty about the protection of intellectual property. In Germany, general German and EU IP laws apply, and India does not have a specific legal framework for protecting IP generated by space activities.[73] A significant legal question arises: if outer space is considered a domain beyond national appropriation under the Outer Space Treaty, who has jurisdiction over the extraterritorial application and enforcement of national IP rights? For joint R&D projects, this legal ambiguity on both sides necessitates highly complex, lengthy contractual agreements that define IP ownership, usage rights, and enforcement mechanisms – already a significant barrier to collaborations between agile, innovative startups in India and Germany. Even with complex contracts, enforceability remains uncertain in the absence of statutory authorities, posing a risk for collaborations through technology-intensive joint ventures.

- Both India and Germany maintain independent and stringent export control regimes, particularly for dual-use technologies prevalent in the space sector. This creates significant friction in the transfer of technology and data. Any project that involves sensitive German technology would be subject to Germany's Foreign Trade and Payments Act, the Foreign Trade and Payments Ordinance, the EU's Dual-Use Regulation, the Satellite Data Security Act (SatDSiG), and various other embargo regulations. This mandates government permission for foreign investments in space companies abroad and often involves a government review process, for instance, in the distribution of high-resolution satellite data. In India, the GoI maintains its own list of controlled items, the Special Chemicals, Organism, Material, Equipment and Technologies (SCOMET) list, and any application to export an item on this list, which would include technology co-developed in a joint venture, is reviewed by an Inter-Ministerial Working Group that includes representatives from the Department of Space, the Defence Research & Development Organisation (DRDO), and the Ministry of External Affairs.[73] This collective bureaucratic scrutiny can lead to delays and create bottlenecks that block the seamless flow of hardware, software, and technical data essential to an integrated collaborative project.

Policy Recommendations

- India and Germany should undertake a major joint project in EO, OOS, or Space Science, led by ISRO and DLR, and incorporating a range of technologies developed by private companies and start-ups in both countries. This will help kickstart space cooperation, foster interoperability, and create opportunities for co-production and co-development between the two countries.

- Establish a high-level annual Indo-German Space Dialogue to identify and create opportunities to expand bilateral space cooperation, remove key regulatory bottlenecks, and review progress. The same will also help signal and channel political will for space technology collaborations.

- The Indo-German Space Dialogue can incorporate a number of joint working groups – composed of current and former ISRO and DLR officials, as well as independent experts and space leaders – to identify potential areas of future collaboration and develop dedicated, detailed implementation roadmaps for each area.

- Launch an Indo-German Strategic Grants Programme for NewSpace to fund startups that wish to undertake joint research and development of next-generation space-tech capabilities that are of strategic significance to both India and Germany.

- Establish a separate JWG to study the resilience of India and Germany's respective space supply chains, identify future risks, and develop a plan to 'friendshore' supply chains, if and where needed.

- Consider a bilateral agreement at the G2G level to eliminate additional, stringent export controls on dual-use items and technologies between India and Germany that curtail collaborations in the space sector. In particular, any requirements beyond those already enforced by existing multilateral arrangements, such as the Wassenaar and MTCR regimes, to which both nations are party and adhere, can be removed by such an agreement.

- Launching an annual Indo-German Space Industry Roundtable, which includes NewSpace startups, can go a long way toward addressing the literacy gap between the Indian and German space ecosystems, help develop relationships between the two, and identify and capitalize on opportunities already present. An MoU can be facilitated between India's and Germany's respective space industry (aerospace industry, in Germany's case) associations, namely ISpA and BDLI, towards this end.

- Foster talent development and exchange at multiple levels through the participation of space research institutions, and private space companies, in addition to universities in both India and Germany, to help create a future-ready and specialized workforce for their space ecosystems. Such a process, over time, would also build crucial relationships between their space industries, which, in turn, would further increase the likelihood of future collaborative joint ventures. Such a process can involve, inter alia:

    - MoUs for academic exchange between India's eminent technical institutions and German universities that lead in space research and technology development.

    - MoUs between Indian or German universities and private space companies in both countries that are engaged in innovative, advanced R&D.

    - Creation of an Indo-German Young Space Leaders Fellowship that can fund the work of excellent early-career researchers in the space sector and provide them with access to research facilities in the DLR or ISRO (or other institutions in India or Germany, as needed) and other requisite resources.

    - A year-long internship exchange program between ISRO and the DLR, where interns from both countries work six months in India and six months in Germany.

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