# India’s Space Power Revolution

***This editorial is based on “Express View on ISRO’s SpaDeX mission: A tryst in space” which was published in The Indian Express on 01/01/2025. The article brings into picture the SpaDeX mission, marking India’s entry into the elite space-docking club, and highlights ISRO’s evolution into a global leader following Chandrayaan-3 and Aditya-1 successes.***

**For Prelims: India's space program, SpaDeX, Chandrayaan-3, Aditya-1, ISRO’s NavIC, Small Satellite Launch Vehicle, Small Satellite Launch Vehicle, Vikram-S, India’s Anti-Satellite (ASAT) test , 2023 Indian Space Policy.**

**For Mains:** Key Issues Related to India's Space Sector,  Ways in which India is Strengthening its Space-Based Capabilities

**India's space program** has entered a new era of sophistication with **ISRO's latest SpaDeX mission** - a pioneering attempt a**t space docking that could place India alongside the US, Russia, and China** in an elite group of nations. This milestone comes after the successful **Chandrayaan-3 lunar landing and Aditya-1 solar mission in 2023,** showcasing ISRO's rapid evolution from a satellite-launching agency to a leader in planetary exploration. ISRO's growing expertise across all aspects of space exploration signals its **readiness to emerge as a global space power,** capable of contributing significantly to humanity's understanding of the cosmos.

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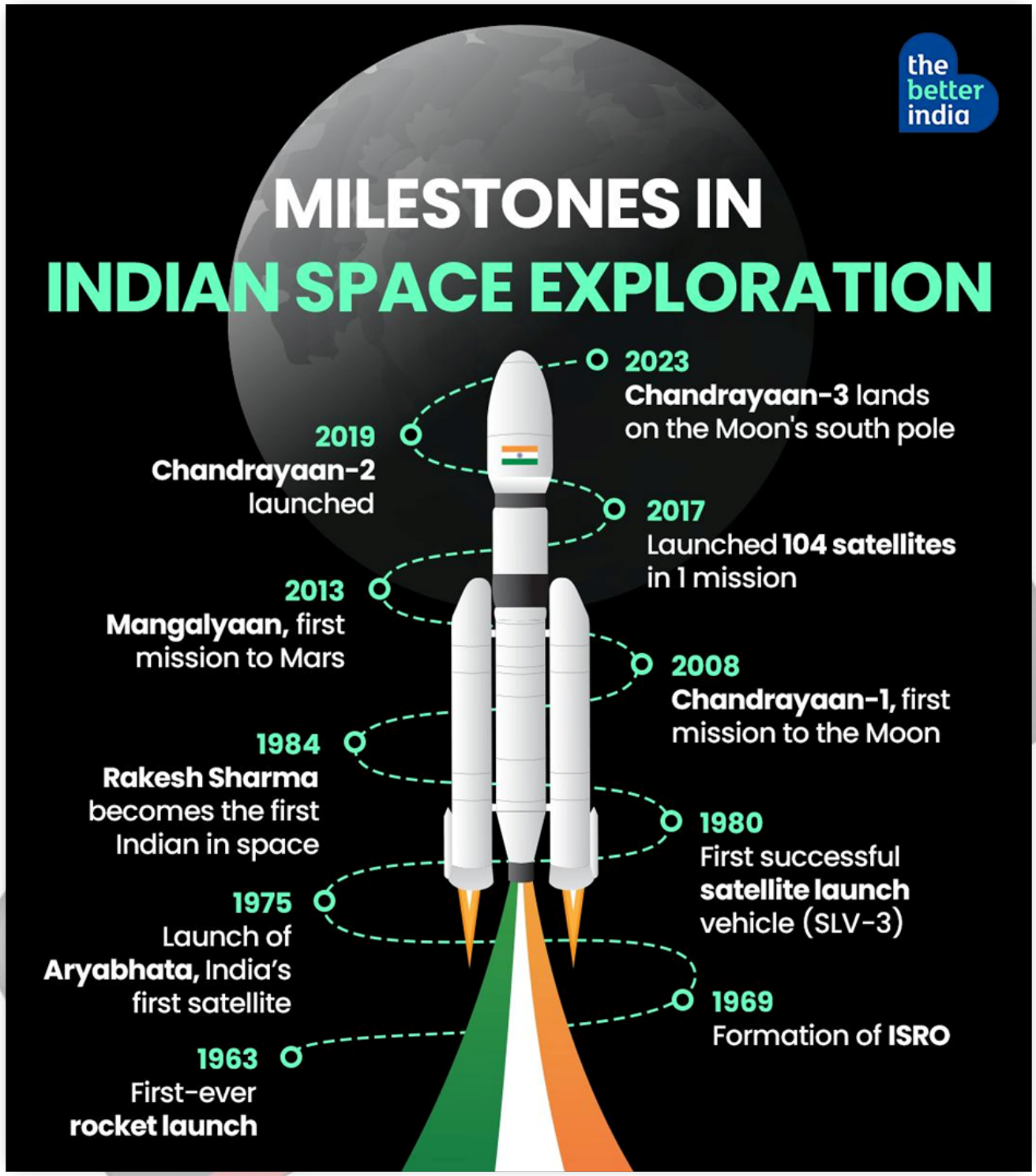


## How is India Strengthening its Space-Based Capabilities?

- **Mastery in In-Orbit Docking and Space Station Development:** India's **SPADEX mission** (Space Docking Experiment), launched by ISRO recently, exemplifies its move towards advanced space technologies.
    - The experiment involves two satellites, **Chaser and Target**, autonomously performing docking maneuvers, crucial for future missions like on-orbit satellite servicing and assembling a potential Indian space station.
    - This complements ISRO's **Gaganyaan program**, aiming for human space exploration by 2025.

        - Such initiatives place India among the select few nations mastering autonomous docking technologies, with broader implications for interplanetary missions.
- **Strengthening Indigenous Satellite Constellations:** India has prioritized building **home-grown satellite constellations** to reduce dependency on foreign data.
    - **30 Indian companies** are collaborating to build and operate Earth observation satellite constellations for defense, infrastructure management, and mapping
    - **ISRO's NavIC upgrade** aims to enhance India's navigation system to compete with global counterparts like GPS.
    - This initiative boosts **data sovereignty and aligns with India's vision for self-reliance in critical infrastructure,** fostering public-private collaboration.
- **Expanding Small Satellite Capabilities and Global Launch Services:** India's **Small Satellite Launch Vehicle (SSLV),** caters to the booming demand for launching nanosatellites.
    - By tapping into the $14 billion small satellite market expected by 2031, India has emerged as a cost-effective global player.
    - The **PSLV-C56 mission** in 2023 successfully deployed commercial payloads, reflecting India's reliability in the space launch sector.
    - Additionally, **SSLVs are enabling universities and startups to deploy experimental satellites**, accelerating technological innovation.
- **Boosting Space Startup Ecosystem and Private Sector Involvement:** The **10 billion rupee fund** for space startups, approved in 2024, has catalyzed innovation in the private sector.
    - Companies like **Pixxel** and **Skyroot Aerospace** are revolutionizing Earth imaging and rocket technologies, with **Pixxel launching hyperspectral satellites** and Skyroot's **Vikram-S** marking India's first private rocket launch.
    - This strategy fosters entrepreneurial participation, with over **40 startups** contributing to India's space economy and creating employment opportunities across sectors.
- **Advancements in Defense and Dual-Use Technologies:** The launch of defense-oriented satellites, such as **GSAT-7**, strengthens India's strategic surveillance and communication capabilities.
    - **India's Anti-Satellite (ASAT) test in 2019** demonstrated its readiness for space warfare, complemented by a dedicated **Defense Space Agency (DSA)** operational from 2020.
    - This ensures India's preparedness in addressing emerging security challenges, especially in the context of militarization of space by global powers.
- **Strategic International Partnerships and Outreach:** India is forging strategic partnerships to enhance its global space standing.
    - **Axiom Space**, U.S.-based startup, plans to utilize Indian rockets for space station missions, showcasing India's cost-efficient launch capabilities.
    - Collaboration with **NASA and ESA** under climate and planetary science missions, like the **NISAR satellite**, also boosts India's role in addressing global challenges.
        - Such partnerships align India's space ambitions with geopolitical objectives, fostering soft power.
- **Enhancing Space Sustainability and Global Contribution:** India is advocating sustainable space practices, as demonstrated by missions like **Aditya-L1** for solar observation, aimed at mitigating space weather impacts on satellites.
    - Additionally, India is contributing to **global debris management through ISRO's NETRA program** for space situational awareness.
    - By balancing growth with sustainability, India aligns with international norms like the **Artemis Accords**, fostering responsible behavior in outer space.
- **Pursuit of Lunar and Interplanetary Exploration:** India's **Chandrayaan-3** success in 2023 marked its entry into the lunar south pole exploration, a feat accomplished by very few nations.
    - **ISRO's plans for Shukrayaan-1, Venus exploration,** signify its ambitions to lead interplanetary research.
    - These missions provide critical insights into planetary sciences, boosting India's academic and research credentials globally.
- **Utilization of Space for Socio-Economic Benefits:** Space-based services are transforming sectors like agriculture, disaster management, and urban planning.
    - For instance, **ISRO's Bhuvan Geoportal** assists in real-time disaster monitoring, while satellite data supports crop monitoring under the **PM Kisan Scheme**.
    - India's space initiatives align with SDG goals, enhancing resilience and inclusivity in

governance.

- **Space Policy and Vision for the Future:** The **2023 Indian Space Policy** emphasizes **democratizing space by enhancing private sector participation** and integrating space assets into national security and economic frameworks.
    - With **plans for a national space station by 2035**, India is charting a robust roadmap for space dominance.

## What are the Key Issues Related to India's Space Sector?

- **Limited Budget Allocation and Financial Constraints:** India's space ambitions are restricted by a **relatively modest budget,** impacting large-scale projects and technological advancements.
    - While India is achieving **high returns on its investments,** its space budget pales compared to global counterparts, limiting exploration programs, infrastructure, and R&D.
    - India only spends **0.04% of its GDP on space,** whereas the United States spends 0.28% of its economy on space.
        - ISRO's budget for 2024-25 is **Rs 13,042.75 crore (about $1.95 billion)**. In contrast, NASA operates with a much larger budget of around **$25 billion**
- **Technological Dependence on Foreign Players:** Despite progress, India relies heavily on **foreign suppliers for critical components like advanced sensors**, propulsion systems, and semiconductors.
    - Indigenous technology development lags behind global standards, limiting India's ability to achieve self-reliance in areas like deep-space exploration and satellite manufacturing.
    - India largely depends on space-tech dependence along with imports. India's solar sector imports reached $7 billion in FY 2024. The **cryogenic CE-20 engine** for GSLV Mk III took a long time to develop, highlighting delays in indigenous innovation.
- **Regulatory and Policy Gaps:** India lacks a robust legal framework governing its space activities, deterring private sector participation and international partnerships.
    - While the **Indian Space Policy 2023** was a positive step, it does not adequately **address liability, intellectual property rights, or dispute resolution mechanisms.**
    - The **Outer Space Treaty (1967)** mandates liability for damages caused by space objects, but **India has no dedicated Space Act to codify such provisions**.
    - Delays in launching private satellites stem from the absence of clear licensing mechanisms, affecting startups like **Pixxel** and **Agnikul Cosmos**.
- **Space Debris and Sustainability Concerns:** India's increasing satellite launches and defunct satellites contribute to growing space debris, posing risks to operational assets.
    - **ISRO's growing footprint in orbit is accompanied by environmental concerns,** with limited mitigation strategies and debris removal mechanisms.
    - By 2022, India had **103 active or defunct spacecraft and 114 objects categorised as 'space debris' in orbit**
- **Limited Defense and Security Preparedness:** India's space capabilities for defense remain underdeveloped compared to global powers, despite growing threats of space militarization.
    - The **absence of robust anti-satellite systems,** space-based early warning systems, and a cohesive military-space policy leaves India vulnerable.
    - India conducted its first **ASAT test in 2019**, while the **U.S. and China maintain dual-use satellites** capable of offensive operations.
    - India's **GSAT-7** is designed for Navy communications but lacks integration with ground-based and space-based surveillance systems.
- **Brain Drain and Human Capital Deficit:** The migration of skilled professionals to global space giants undermines India's domestic innovation capabilities.
    - With better funding, infrastructure, and career opportunities abroad, India faces a talent gap in advanced space research.
    - 70% of Indian students studying abroad opt for STEM fields reducing retention rate for top scientists in India.
    - Indian-origin scientists contribute to major **NASA and SpaceX projects**, including **Mars Perseverance** and **Starship development**.
- **Inadequate Global Market Share:** India's contribution to the global space economy is disproportionately small, considering its cost-effective capabilities.
    - India's share of the global space economy is **2-3%**. Missions like **PSLV-C56** have attracted

commercial payloads but **fall short of maximizing international contracts compared to SpaceX.**

- **Lagging Human Spaceflight Capabilities:** India lags behind global leaders in human space exploration, with no operational capacity for sustained manned missions.
    - While the **Gaganyaan mission** is promising, delays in development and reliance on foreign life-support systems highlight gaps in India's capabilities.
    - India's first manned mission is planned for **2025**, nearly **20 years behind China** and **55 years after the U.S. Apollo mission**.
- **Rising Geopolitical and Strategic Challenges:** The global competition for space dominance creates geopolitical challenges for India, **especially with China's rapid advancements.**
    - India's focus on civilian applications leaves it lagging in space diplomacy and dual-use technologies compared to aggressive competitors.
    - China's **Tiangong Space Station** became operational in 2022. India's regional navigation system, **NavIC**, has limited international adoption compared to **China's BeiDou.**

## What Measures Can India Adopt to Ensure Sustained Space Exploration and Strengthen Its Space-Based Capabilities?

- **Enhance Budgetary Allocation and Diversify Financing Mechanisms:** Increase the space sector's share of GDP to support high-priority projects like human spaceflight and deep-space exploration.
    - Introduce **sovereign space bonds** and **public-private co-financing models** to attract long-term investments.
    - Establish an **Indian Space Fund** under IN-SPACe to support R&D, startups, and disruptive innovation.
- **Promote Public-Private Collaboration:** Operationalize seamless **public-private partnerships (PPPs)** by granting private players access to ISRO's infrastructure, such as launchpads and testing facilities.
    - Develop **joint venture models** for satellite constellations, reusable launch vehicles, and lunar missions.
    - Simplify the regulatory ecosystem with **single-window clearances for private space missions** under IN-SPACe.
- **Prioritize Indigenous Technology Development:** Accelerate the establishment of **dedicated Space Technology Innovation Hubs** focusing on propulsion systems, AI in satellite operations, and space-grade semiconductors.
    - Collaborate with academic institutions and startups to create **disruptive tech solutions**, including reusable rockets and in-orbit docking systems.
    - Implement **import substitution policies** for critical components to achieve strategic autonomy.
- **Focus on Talent Retention and Workforce Development:** Launch **specialized space education programs** in universities, integrating disciplines like robotics, astrophysics, and aerospace engineering.
    - Establish **national-level space training academies** to groom a skilled workforce for advanced missions like **Gaganyaan** and **Shukrayaan-1**.
    - Incentivize research fellowships and retain talent through lucrative career pathways and international collaborations.
- **Develop Modular Space Station and Advanced Space Infrastructure:** Commit to building a **modular space station** to support long-term human presence in space.
    - Expand launch capacity by upgrading **Satish Dhawan Space Centre** and establishing new launch sites with cutting-edge technology for **hypersonic and reusable vehicles**.
    - Develop in-orbit servicing and assembly systems for satellite maintenance and expansion of mission capabilities.
- **Strengthen Satellite Constellation Development:** Accelerate deployment of indigenous **Earth observation, navigation, and communication constellations** like NavIC and RISAT to enhance data sovereignty.
    - Integrate **dual-use satellites** that serve civilian and defense needs for applications such as disaster management and military surveillance.
    - Encourage **private participation** in satellite manufacturing through policy incentives.
- **Foster Space Sustainability and Debris Mitigation:** Adopt **space situational awareness**

**(SSA) technologies** to track and manage space debris and prevent collisions.
    - Invest in **de-orbiting technologies** and adherence to international standards on debris mitigation.
    - Introduce a **National Space Sustainability Plan** to ensure India's compliance with global norms and promote leadership in sustainable space exploration.
- **Strengthen Strategic Space-Based Defense Capabilities:** Expand the role of the **Defense Space Agency (DSA)** to develop counter-space technologies, including satellite jammers and anti-satellite (ASAT) weapons.
    - Focus on developing **dual-use platforms** that **enhance India's strategic advantage in communication, reconnaissance, and navigation.**
    - Collaborate with DRDO to integrate space technologies into national defense frameworks.
- **Advance International Collaborations for Technology Sharing:** Deepen cooperation with global agencies like **NASA, ESA, and Roscosmos** to gain access to advanced technology and shared resources.
    - Leverage bilateral agreements to participate in international missions like **Artemis and planetary defense initiatives.**
    - Strengthen ties with emerging space nations in Africa and Southeast Asia for **space diplomacy** and capacity-building.
- **Establish a Comprehensive Space Act:** Draft a **dedicated Space Act** to provide a robust legal framework governing space activities, ensuring clarity on licensing, intellectual property rights, and dispute resolution.
    - Codify India's liability under international treaties like the **Outer Space Treaty** and promote ease of doing business in space ventures. Include provisions for **private sector indemnification** to attract foreign investments.
- **Expand Socioeconomic Applications of Space Technology:** Leverage satellite-based geospatial data for **precision agriculture**, water resource management, and urban planning.
    - Expand the scope of programs like **Bhuvan Geoportal** to include telemedicine and e-education for rural areas.
    - Integrate space assets into national missions like **PM-Kisan**, **Digital India**, and **Smart Cities** for transformative impact.
- **Build Reusable and Hypersonic Launch Systems:** Accelerate the development of **Reusable Launch Vehicles (RLVs)** to reduce launch costs and enhance mission frequency.
    - Invest in **hypersonic propulsion systems** to support rapid deployment of satellites and exploration payloads.
    - Collaborate with private firms to operationalize technologies like **scramjets** and **spaceplanes** for next-generation launch capabilities.
- **Promote Space-Based Entrepreneurship:** Create a **National Space Innovation Framework** to encourage startups and MSMEs in areas like satellite manufacturing, data analytics, and payload development.
    - Offer incubation support through ISRO's facilities and mentorship programs for entrepreneurs.
    - Launch **hackathons and space innovation challenges** to tap into youth-driven ideas and solutions

## Conclusion

India's space program is at a transformative juncture, marked by significant advancements in **technology, strategic collaborations, and a growing ecosystem of public-private synergy.** While challenges persist in terms of funding, regulatory frameworks, and indigenous capability development, India's cost-effective innovations and ambitious missions position it as a rising global space power.

***Drisht Mains Question:***

India's advancements in space technology have the potential to redefine its role in global geopolitics and socio-economic development. Discuss the challenges and opportunities for India in achieving self-reliance in space technology.

## UPSC Civil Services Examination, Previous Year Question (PYQ)

**Q.1** What is India’s plan to have its own space station and how will it benefit our space programme? (2019)

**Q.2** Discuss India’s achievements in the field of Space Science and Technology. How the application of this technology helped India in its socio-economic development? (2016)

**Q.3** What is the main task of India’s third mood mission which could not be achieved in its earlier mission? List the countries that have achieved this task. Introduce the subsystems in the spacecraft launched and explain the role of the ‘Virtual Launch Control Centre’ at the Vikram Sarabhai Space Centre which contributed to the successful launch from Sriharikota. (2023)

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