India’s Space Strategy

This editorial is based on “ISRO’s space launch foray” which was published in The Financial Express on 27/02/2025. The article brings into picture ISRO’s growing role in the global satellite market with the launch of a US-based AST Space Mobile satellite, highlighting its commercial expansion toward self-reliance and profitability in the space economy.

For Prelims: SpaDeX mission, Chandryaan-3, Lagrange Point-1, Reusable Launch Vehicle, Bharatiya Antariksh Station, Gaganyaan, Cyclone Michaung, Chandrayaan-3, NISAR mission, New Space Policy, China’s Chang’e program, IN-SPACe, Anti-satellite (ASAT) capabilities

For Mains: Key Recent Developments Related to India’s Space Sector, Key Issues Associated with India’s Space Sector.

ISRO's upcoming launch of a **US-based AST Space Mobile communication satellite** marks a pivotal moment in India's emergence as a global player in the **satellite launch industry**. Already distinguished by achievements like the **SpaDeX mission**, **Chandryaan-3’s lunar landing**, and **cryogenic engine development,** ISRO is now breaking into the lucrative commercial satellite market. This commercial expansion represents a crucial step toward India becoming **self-reliant and profitable in the international space economy.**

What are the Key Recent Developments Related to India’s Space Sector?

- **Advancing Solar Research:** India’s first solar observatory, **Aditya-L1**, successfully reached its **halo orbit at Lagrange Point-1 (L1)** in January, 2024.
    - The data from Aditya-L1 will enhance **India’s space weather forecasting**, crucial for satellite protection and communication systems.
    - This marks a major step in India’s deep-space research, putting it in league with NASA and ESA.
    - India is now **one of only four countries** to have a dedicated solar mission, alongside the **US, Europe, and China** (ISRO, 2024).
- **Advancements in Reusable Launch Vehicles (RLV):** ISRO conducted two successful **Reusable Launch Vehicle (RLV) Landing Experiments—RLV-LEX-02 (March 2024) and RLV-LEX-03 (June 2024)**.
    - **Reusability can cut launch costs by 80%**, making space more accessible for **commercial and scientific missions** (ISRO, 2024).
    - The **winged prototype ‘Pushpak’** was dropped from a **Chinook helicopter at 4.5 km altitude** before autonomously landing, proving the feasibility of future **reusable rocket technology**.

    - The RLV tests bring ISRO closer to **developing a fully reusable spaceplane, similar to SpaceX's Starship and NASA's Dream Chaser**.
- **India's First Space Docking Experiment (SpaDeX) and Future Space Station Plans:** India achieved a **breakthrough in space docking technology** with the **SpaDeX (Space Docking Experiment) mission in December 2024**.
    - Mastering space docking is critical for **long-duration space missions, in-orbit refueling, and space habitat construction**.
        - This milestone strengthens India's future in **deep-space exploration and interplanetary logistics**.
    - India is now **the fourth country globally** (after the US, Russia, and China) to achieve space docking independently.
        - ISRO plans to **launch the Bharatiya Antariksh Station (BAS-1) by 2035**, starting with an initial **modular space station segment**.
- **Progress in the Gaganyaan Human Spaceflight Mission:** Significant advancements have been made in **India's first crewed spaceflight mission, Gaganyaan**, scheduled for **2025**.
    - This mission aims to send **a three-member crew to low-Earth orbit (LEO) for three days**, marking a historic milestone for India's space program.
    - The **Test Vehicle Abort Demonstration-1 (TV-D1)** successfully tested crew escape systems in case of launch failure.
    - ISRO has trained **four Indian astronauts at Russia's Gagarin Cosmonaut Training Center** and is setting up a **crew training facility in Bengaluru**.
- **Strengthening India's Weather and Disaster Monitoring Capabilities:** The launch of **INSAT-3DS** has significantly improved **weather forecasting, cyclone tracking, and disaster management**.
    - Designed for a **10-year operational lifespan**, the satellite provides **real-time weather data, including temperature, humidity, and atmospheric conditions**.
    - This enhances India's ability to **predict extreme weather events**, mitigating damage from **cyclones, floods, and heatwaves**.
    - INSAT-3DS played a key role in **tracking Cyclone Michaung in December 2023**, enabling early evacuations.
- **India's Growing Role in International Space Collaborations:** ISRO launched **ESA's Proba-3 mission**, strengthening its reputation as a **trusted global launch partner**.
    - This mission, designed to simulate a **total solar eclipse using precision formation flying**, demonstrates India's expertise in **small satellite launches and scientific missions**.
    - India is working with **NASA for the NISAR mission (2024)**, a satellite to monitor **climate change and natural disasters**.
- **Expansion of India's Private Space Sector:** With the introduction of **IN-SPACe and the New Space Policy (2023)**, India's private space sector has seen a rapid rise in **startups, satellite manufacturing, and launch services**.
    - Companies like **Skyroot Aerospace, Agnikul Cosmos, and Pixxel** are developing indigenous launch vehicles and advanced payloads.
    - **Skyroot's Vikram-S (November 2022)** became **India's first private rocket launch**, marking a shift towards commercial space activities.
- **Green Propulsion and Sustainable Space Technologies:** ISRO is actively developing **eco-friendly propulsion systems**, including **liquid methane-LOX engines and solar-electric thrusters** for deep-space missions.
    - The **Vikram-1 rocket (by Skyroot Aerospace) and ISRO's future missions** aim to use **green propellants** to minimize environmental impact.
    - The **Chandrayaan-3 lander used non-toxic propulsion**, aligning with ISRO's commitment to **green space technologies**.
- **Approval of Chandrayaan-4 and India's Upcoming Lunar Ambitions:** Following the **success of Chandrayaan-3**, ISRO has **secured approval for Chandrayaan-4**, a **sample return mission to the Moon**.
    - This mission aims to **leverage India's expertise in precision landing and in-situ lunar studies**, contributing to global lunar science.
    - Chandrayaan-4 will be **India's first robotic mission to return samples from the Moon**, similar to China's **Chang'e-5**.

What are the Key Issues Associated with India's Space Sector?

- **Limited Budget Allocation:** Despite ISRO's achievements, India's space sector operates on a **relatively small budget compared to global counterparts**, limiting the scale of deep-space missions and technology development.
    - Most funding still comes from the government, restricting private sector-led innovation and commercialization.
    - 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**, without any reductions.
    - India's space economy is **only 2% of the global space market**.
- **Slow Development of Reusable and Cost-Effective Launch Technologies:** While ISRO has made progress with **Reusable Launch Vehicle (RLV) experiments**, it lags behind private companies like **SpaceX (Falcon 9) and Blue Origin (New Shepard)** in operational reusable rockets.
    - **High launch costs** limit India's ability to compete in the **global commercial satellite launch market**, which demands **low-cost, frequent, and reusable launch systems**.
    - Accelerating the development of **fully reusable rockets** is crucial to maintaining global competitiveness.
- **Rising Space Debris and Orbital Congestion:** With increasing satellite launches, **space debris management** has become a critical challenge, posing risks to operational satellites and future missions.
    - India lacks an **independent space traffic management system**, making it reliant on international organizations for debris tracking.
    - With **thousands of satellites planned for Low Earth Orbit (LEO) mega constellations**, **collision risks and orbital congestion will intensify**, requiring urgent regulatory and technological interventions.
    - A total of 3143 objects originating from **212 launches and on-orbit break-up events** were added to the space object population in 2023, highlighting the growing threat of space debris.
- **Delayed Implementation of Space Policy and Regulatory Frameworks:** India's **New Space Policy 2023** was a major step in opening the sector to private players, but **implementation delays and bureaucratic hurdles** have slowed its impact.
    - **IN-SPACe**, meant to regulate and facilitate private sector participation, is still evolving its framework, leading to uncertainty for startups and investors.
    - A **clear legal framework on space activities, satellite licensing, and liability in case of damages** is necessary to attract global investments.
    - India has **over 150 space startups**, but most struggle with **funding, regulatory approvals, and global market access**
- **Cybersecurity Threats and Space Asset Protection:** With growing reliance on satellites for **communication, defense, and navigation**, cyber threats targeting space assets pose **national security risks**.
    - India lacks an **independent Space Cybersecurity Command** to protect against **satellite hacking, GPS spoofing, and space-based espionage**.
    - ISRO currently lacks an autonomous cybersecurity division, making its satellites **potential targets for hostile cyber intrusions**.
- **Climate Change Impact on Space Infrastructure:** Extreme weather events, rising temperatures, and increasing humidity levels are **posing risks to ISRO's launch sites and ground stations**.
    - Coastal launch sites like **Sriharikota (SHAR) and Thumba** are vulnerable to **cyclones and sea-level rise**, potentially affecting **future launch schedules and infrastructure durability**.
    - Climate adaptation strategies, including **hardened launch complexes and alternative inland launch sites**, are needed to mitigate these risks.
- **Growing Competition from Emerging Space Powers:** India faces increasing competition from **China, UAE, and South Korea**, which are advancing in **lunar exploration, deep-space missions, and private sector growth**.
    - **China's Chang'e program is targeting lunar colonization by 2035**, while the UAE's **Mars and Moon missions** are attracting global partnerships.
    - To maintain leadership, India must **accelerate Chandrayaan-4, Venus missions, and**

interplanetary exploration projects.

- **Delays in Strategic Military Space Capabilities:** India has been slow in **developing dedicated military space assets**, lagging behind China's **Space Force and weaponized satellite capabilities**.
    - While India has **anti-satellite (ASAT) capabilities**, it lacks **dedicated space-based missile defense and electronic warfare satellites**.
    - Establishing an **integrated space command and defense satellite constellation** is critical for national security.
    - China has over **300 military satellites,** while **India operates with fewer for defense and surveillance**.

What Strategic Measures can India Adopt to Enhance the Space Sector?

- **Increasing Budget Allocation and Sustainable Funding Models:** India must **increase public investment in space technology** while promoting **private and foreign investments** through **Public-Private Partnerships (PPP)**.
    - Establishing a **dedicated Space Development Fund (SDF)** can ensure continuous financing for **deep-space missions, satellite manufacturing, and human spaceflight programs**.
    - Expanding **ISRO's commercial wing, NSIL (NewSpace India Limited)**, can drive revenue generation through global satellite launches.
- **Accelerating Reusable Launch Vehicle (RLV) and Cost-Effective Launch Technologies:** India must **prioritize RLV development** to reduce **launch costs, increase frequency, and compete with private players like SpaceX**.
    - Strengthening **Pushpak RLV technology**, integrating **AI-driven autonomous landing systems**, and developing **Methane-LOX propulsion systems** can improve reusability.
    - Enhancing **hypersonic flight research and scramjet engine testing** will enable cost-effective space travel. A **dedicated RLV test center** should be established for **high-speed aerodynamic research**.
- **Expanding Private Sector and Startup Participation in Space Economy:** India must **fully implement the New Space Policy 2023** to enable **private players to develop launch vehicles, satellites, and deep-space technologies**.
    - Strengthening **IN-SPACe (Indian National Space Promotion and Authorization Center)** will streamline approvals and reduce bureaucratic delays.
    - Tax incentives, regulatory ease, and venture capital support can encourage more startups to enter the **space manufacturing, propulsion systems, and AI-driven satellite services** sectors.
    - Fast-tracking licensing processes for private satellite launches will boost India's competitiveness.
- **Strengthening Space Traffic Management and Space Debris Mitigation:** India should establish an independent Space Traffic Management (STM) system to monitor, track, and mitigate space debris following the **Convention on International Liability for Damage Caused by Space Objects**.
    - Deploying **active debris removal (ADR) satellites**, using laser ablation and robotic arms, can help clear defunct satellites from orbit.
    - **AI-powered collision avoidance systems** should be integrated into India's growing satellite fleet.
    - Strengthening international cooperation under **UNOOSA and IADC (Inter-Agency Space Debris Coordination Committee)** will enhance India's role in **global space sustainability**.
- **Fast-Tracking Space Infrastructure for Human Spaceflight Missions:** To sustain **long-term human spaceflight programs**, India must develop space habitats, advanced crew modules, and deep-space life support systems.
    - Establishing a **dedicated Human Spaceflight Research Center (HSRC)** will drive innovations in **space medicine, astronaut training, and microgravity research**.
    - The **Bhartiya Antriksh Station (BAS-1) roadmap should be fast-tracked** for operational readiness by **2035**.

- **Enhancing Cybersecurity and Space Asset Protection:** India must create a **dedicated Space Cybersecurity Command** under **ISRO and DRDO** to **protect satellites, GPS systems, and defense space assets from cyber threats**.
    - Strengthening **quantum encryption, AI-driven anomaly detection, and satellite firewalls** will safeguard critical infrastructure.
    - Implementing **real-time threat monitoring systems** for space-based assets will reduce vulnerabilities to **hacking, GPS spoofing, and electromagnetic attacks**.
- **Strengthening Deep-Space and Interplanetary Exploration Capability:** India must **expedite missions to the Moon, Mars, and Venus**, enhancing its global space leadership.
    - **Chandrayaan-4 (Lunar Sample Return Mission) and Mangalyaan-2 (Mars Orbiter Mission-2)** should be prioritized with **advanced robotic rovers, AI-driven navigation, and in-situ resource utilization (ISRU) experiments**.
    - Establishing an **Interplanetary Research Center (IRC)** will boost scientific collaboration and innovation.
- **Expanding India's Satellite-Based Applications and Digital Connectivity:** India must expand its satellite fleet for earth observation, navigation, and broadband internet to strengthen **disaster management, agriculture, and national security**.
    - Deploying **next-generation NavIC satellites** will enhance **independent satellite navigation and geospatial intelligence**.
    - Strengthening **satellite-based quantum communication** will enhance **secure data transmission and defense applications**.
- **Climate-Resilient Space Infrastructure and Alternate Launch Sites:** To mitigate risks from **climate change, sea-level rise, and extreme weather**, India must develop **inland launch sites** beyond Sriharikota.
    - Establishing a **second launch complex in central India** will provide operational redundancy during adverse weather conditions.
    - Strengthening **ISRO's weather monitoring satellites** with advanced **hyperspectral imaging and AI-driven climate modeling** will improve India's disaster response.
    - Implementing **eco-friendly, non-toxic green propulsion technologies** will align India's space program with **global sustainability goals**.

Conclusion:

India's space sector is at a **transformative juncture,** with **ISRO making significant strides in commercial satellite launches, reusable launch vehicles, deep-space exploration,** and human spaceflight. With sustained efforts, ISRO can drive **technological innovation, boost economic opportunities, and contribute to global space exploration**, ensuring India's long-term leadership in the space economy.

Drishti Mains Question:

India's space sector has witnessed remarkable advancements in recent years, from deep-space exploration to reusable launch vehicle technology. Discuss how these developments enhance India's strategic and economic position in the global space economy.

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)