AI-Powered Autonomous Satellites

For Prelims: Artificial Intelligence, Geostationary Equatorial Orbit, Chandrayaan-3, Kessler Syndrome, Outer Space Treaty

For Mains: Challenges and opportunities of emerging space technologies, Technological advancements in satellite systems

Source:TH

Why in News?

The rise of **Artificial Intelligence (AI)-powered autonomous satellites** has exposed significant gaps in global space governance**.** As satellites gain the **ability to think and act independently,** questions around legal liability, ethical governance, and geopolitical risks have taken centre stage.

What is an AI-Autonomous Satellite?

- **About:** AI-autonomous satellites refer to spacecraft that leverage AI to operate **with minimal or no human intervention.**
  - These satellites use advanced algorithms, often based on **machine learning and deep learning techniques** to analyze data, make decisions, and execute tasks independently in real time.
- **Key Features:**
  - **Data Processing Onboard:** AI enables satellites to analyze data in space, filter out irrelevant details, and send only key insights to Earth, saving bandwidth and reducing delays.
    - Space-based data centers could **harness solar power** and release heat directly into space, reducing energy consumption. This approach could dramatically **cut carbon emissions compared to terrestrial data centers.**
  - **Swarm Intelligence:** In constellations or clusters, satellites can share data and learn collectively (also called **"hive learning"**). This allows for collaborative behavior and improved performance across the network.
  - **Automated operations:** They continuously monitor their own condition, identify faults, and perform repairs independently.
  - **Strategic Defence**: The next-gen AI satellite fleet will create a multi-layered surveillance system across **GEO (Geostationary Equatorial Orbit), and LEO (Low Earth Orbit).**
    - e.g., a GEO satellite detecting something can task a LEO satellite for closer inspection, enabling real-time monitoring and coordinated responses vital for science and defense.
  - **Self-diagnosis:** Detect internal malfunctions and **attempt in-orbit fixes.**
  - **Collision Avoidance:** With increasing space traffic and debris, autonomous satellites can use AI to predict potential collisions and perform evasive maneuvers without awaiting instructions from ground control.

    - **Combat Support:** Satellites provide real-time threat detection with autonomous target tracking and engagement. They can adapt operations based on situational needs, such as retargeting sensors after disasters or adjusting orbit due to environmental conditions.
- **Advancements of AI in Space Exploration:** India will launch **50 AI-powered satellites over the next five years.** These satellites will boost space exploration and national security, marking a major step in integrating AI into space technology.
    - **Indian Space Research Organisation (ISRO)** landmark use of AI was seen in **Chandrayaan-3,** the **Pragyaan Rover,** without an orbiter, used AI to communicate with the **Vikram Lander,** aiding in safe landing, navigation, and resource detection.
    - China launched **12 satellites** as part of building its **Three-Body Computing Constellation**, which aims to create the **world's first space-based supercomputer.** Equipped with AI, these satellites process data in orbit and test advanced technologies.

Note: TakeMe2Space, a Hyderabad-based space technology firm, will launch **My Orbital Infrastructure - Technology Demonstrator (MOI-TD), India's first AI lab in space**. The mission will demonstrate real-time data processing in orbit, making space research more affordable and accessible.

What are the Emerging Risks of AI-Autonomous Satellites?

- **Fault Attribution and Legal Ambiguity:** If an autonomous satellite miscalculates and causes a near-collision or actual damage, it's unclear who is legally liable the **AI developer**, **launching state**, **operating entity**, or **owner nation**.
    - This creates **multi-jurisdictional entanglements** where no single entity is clearly accountable for AI decisions.
- **AI Hallucinations and Misjudgments:** AI systems can misclassify threats, such as mistaking a commercial satellite for a **hostile object or identifying a harmless item as a collision hazard,** which could lead to unintended confrontations in space.
    - This can lead to **unintended manoeuvres** or **defensive actions** that escalate into **diplomatic or military conflicts**.
- **Dual-Use and Weaponisation Risks**: AI technologies carry dual-use risks, as autonomous satellites designed for civilian purposes could be repurposed for **real-time surveillance, targeting, or even offensive operations in space**, aiding military operations and potentially escalating an arms race in orbit.
- **Collision Risk and Orbital Debris** Thousands of autonomous satellites are expected in LEO by 2030. Without coordinated **collision-avoidance protocols**, **autonomous decisions** by multiple satellites could lead to **space traffic congestion**, accidents, or a **cascade of debris** (**Kessler Syndrome**).
- **Lack of Human Oversight:** Current treaties demand "**authorization and continuing supervision**" of space activities by states.
    - True autonomy, however, limits the scope for **meaningful human control**, raising concerns about **automated decision-making without accountability**.
- **Gaps in Certification and Standards:** Unlike aviation or maritime sectors, space lacks **global certification frameworks** for testing and verifying the safety and reliability of AI in satellites.
    - There are no current **international standards for AI performance in hostile or anomalous space conditions**.
- **Ethical Dilemmas:** AI satellites could support **lethal autonomous weapons systems (LAWS)**. This raises ethical concerns over the **delegation of life-and-death decisions to machines**, especially if deployed in or from space, which remains legally and morally contentious.
    - Autonomous AI warfare systems lack a **moral compass and make decisions without considering long-term diplomatic consequences.** When violations of international laws or human rights occur, assigning responsibility becomes complex.
- **Legal Gaps:** Current space laws such as the **Outer Space Treaty (1967)** and the **Liability Convention (1972)** assume **human control and state responsibility** but lack **clear provisions for AI-driven autonomous satellites.**
    - **Article VI of the OST** holds states responsible for national space activities but **does not**

clearly address responsibility for autonomous actions.

Outer Space Treaty and Liability Convention

- **Outer Space Treaty (1967)**: It is based on the **1963 UN Declaration,** and is the foundation of space law. It bans **nuclear and weapons of mass destruction in space** and ensures space is used for peaceful purposes by all nations. **India has ratified the Outer Space Treaty.**
- **Liability Convention (1972):** Building on Article 7 of the OST, Liability Convention makes **launching states absolutely liable for damage their space objects** cause on Earth and liable for fault-based damage in space. **India has ratified the Liability Convention.**

What Should be the Roadmap for Governing AI-Powered Satellites?

- **AI Certification and Testing:** Global standards, inspired by aviation and autonomous vehicles, should certify AI autonomy in satellites.
    - Organizations like the **International Standards Organization (ISO)** and the **United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)** can lead rigorous testing for sensor errors and mandate real-time decision logging to help prevent **AI "hallucinations" and unintended actions.**
- **Liability and Insurance Frameworks:** AI satellite failures can cause multi-party harm across borders, complicating fault attribution and compensation.
    - Inspired by maritime conventions on **hazardous cargo liability (1996 HNS Convention)** and international air carriage rules **(1999 Montreal Protocol),** space governance should adopt pooled insurance schemes.
    - This would ensure streamlined compensation while preventing protracted legal battles.
- **Updating International Space Law:** Foundational treaties assume human oversight, but AI autonomy blurs liability lines. Defining AI satellites and clarifying liability will require amendments or new protocols under **COPUOS.**

Conclusion

Space is **no longer just a physical frontier** but a **digitally governed domain**, autonomous satellites demand modern legal frameworks. Without proactive governance, autonomy in space could introduce instability, rather than innovation.

Drishti Mains Question:

Examine the risks associated with autonomous AI satellites. What governance mechanisms can be adopted to mitigate these risks?

UPSC Civil Services Examination, Previous Year Question (PYQ)

Mains

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