SPACE DEBRIS – SCIENCE & TECHNOLOGY

NEWS: *A 500-kg metal object, believed to be space debris, crashed in Kenya, highlighting concerns about accountability and regulatory gaps in space governance.*

WHAT'S IN THE NEWS?

Space Debris: Causes, Threats, and Mitigation Efforts

Space debris, also known as **space junk**, consists of non-functional man-made objects in Earth's orbit. These include **defunct satellites, abandoned rocket stages, and smaller fragments from previous space missions**. As the number of space missions increases, the problem of space debris has become a significant concern for global space security and sustainability.

Definition of Space Debris

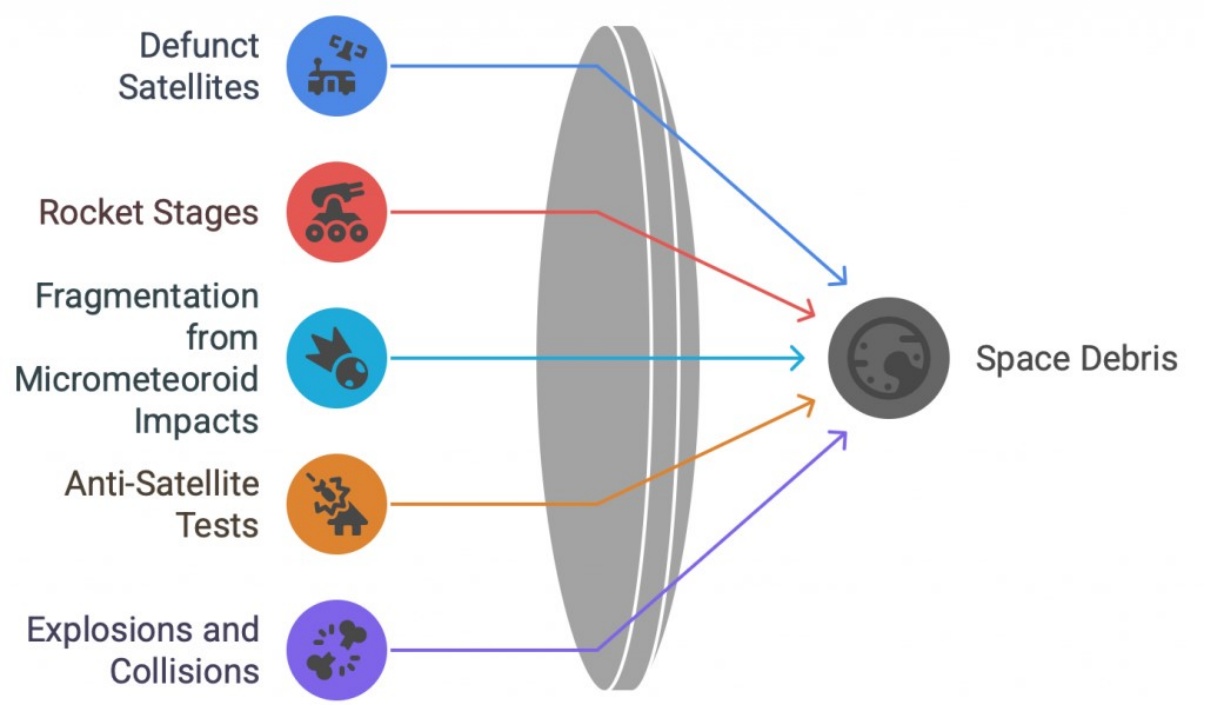
- The **United Nations Committee on the Peaceful Uses of Outer Space (UN-COPUOS)** defines space debris as **all man-made objects in Earth's orbit or re-entering the atmosphere that are no longer functional**.
- According to **NASA**, millions of debris pieces orbit Earth, ranging in size from **tiny paint flecks to large satellite remnants**.
- Even small debris traveling at high speeds poses a serious risk to operational satellites, spacecraft, and space stations.

Factors Causing Space Debris

1. **Defunct Satellites**
    - Many satellites remain in orbit after completing their mission lifespan, turning into space junk.
2. **Abandoned Rocket Stages**
    - Rockets used for launching satellites often leave upper stages in orbit, contributing to space debris.
3. **Satellite Collisions**
    - Accidental collisions between satellites generate thousands of debris fragments. Example:
        - **2009:** The Iridium 33 and Cosmos 2251 satellites collided, producing over **2,000 pieces of debris**.
4. **Anti-Satellite Tests (ASATs)**
    - Some nations conduct **destructive missile tests** on satellites, creating thousands of debris fragments. Example:
        - **2021:** Russia's ASAT test destroyed the Cosmos 1408 satellite, generating **1,500+ trackable fragments**.
5. **Uncontrolled Re-entries**
    - Large rocket parts sometimes **fall back to Earth in an uncontrolled manner**, causing safety concerns.

Examples of Space Debris Incidents

- **2022:** The Chinese **Long March 5B rocket** fell into the Indian Ocean, raising concerns over uncontrolled re-entries.
- **2023:** Parts of a **SpaceX Falcon 9 rocket** were discovered on a sheep farm in Australia.
- **February 2024:** Debris from a **Russian satellite disintegrated over the United States**, alarming residents.



Threats Posed by Space Debris

1. **Collision Risk for Active Satellites**
    - Space debris moves at **extremely high speeds (up to 28,000 km/h)**. Even tiny fragments can **damage or destroy satellites** upon impact.
2. **Threat to Space Stations and Astronauts**
    - The **International Space Station (ISS)** regularly performs **evasive maneuvers** to avoid collisions with space debris.
3. **Risk to Earth from Uncontrolled Re-entries**
    - Large debris re-entering Earth's atmosphere **can cause damage upon impact** if they do not fully burn up.
4. **Impact on Future Space Exploration**
    - Increased debris accumulation can make **certain orbits unsafe**, limiting future space exploration efforts.
5. **Kessler Syndrome (Debris Chain Reaction)**
    - If debris accumulation reaches a tipping point, **collisions could trigger a chain reaction**, making Earth's orbit unusable for decades.

International Laws on Space Debris Responsibility

1. Outer Space Treaty (1967) – UN Office for Outer Space Affairs (UNOOSA)

- Although it does **not explicitly mention space debris**, it states that **nations are responsible for space activities conducted under their jurisdiction, including those by private companies**.
- **Article VI** holds states responsible for any damage caused by their space objects.

2. Liability Convention (1972)

- Introduces the concept of **'absolute liability'** for damage caused by space objects on Earth.
- Under this framework, **launching states are automatically responsible** for harm caused by their debris, without needing to prove negligence.
- However, there are **no penalties for uncontrolled re-entries**, making enforcement difficult.

India's Initiatives in Space Debris Management

1. **Adherence to International Guidelines**
    - **ISRO (Indian Space Research Organisation)** follows the space debris mitigation guidelines set by **UN-COPUOS** and the **Inter-Agency Space Debris Coordination Committee (IADC)**.
2. **ISRO System for Safe and Sustainable Space Operations Management (IS4OM)**
    - Focuses on **spaceflight safety and debris mitigation** strategies.
3. **Network for Space Object Tracking and Analysis (NETRA)**
    - Enhances **India's Space Situational Awareness (SSA) capabilities** by tracking and analyzing space objects.
4. **Debris-Free Space Missions (DFSM) Initiative (2024)**
    - Aims to achieve **debris-free space missions** by all Indian space actors (governmental and non-governmental) by **2030**.
    - Focus areas:
        - **Avoiding Debris Generation**: Designing missions to minimize debris creation.
        - **Collision Avoidance**: Monitoring and maneuvering satellites to prevent crashes.
        - **Post-Mission Disposal**: Ensuring proper deorbiting and end-of-life satellite management.

Challenges in Holding Countries Accountable

1. **Difficulty in Tracing Ownership**
    - Identifying the exact origin of debris is **challenging**, especially for **small, untrackable fragments**.
2. **Bureaucratic and Political Hurdles**
    - **Diplomatic processes for compensation** are often slow and politically sensitive.
3. **Lack of Enforcement Mechanisms**
    - **No legal framework exists to penalize nations** for failing to control debris generation.
4. **No Penalties for Uncontrolled Re-entry**
    - While the **Liability Convention (1972)** holds nations accountable for damage, it does **not impose fines** for **allowing debris to fall uncontrollably**.

Mitigation Strategies and Future Solutions

1. **Strengthening International Cooperation**
    - **Global space agencies and private entities** should work together through organizations like **UN-COPUOS** to establish standardized debris removal procedures.
2. **Mandatory End-of-Life Plans for Satellites**
    - All new space missions should **include clear deorbiting strategies** to prevent accumulation of space junk.
3. **Investing in Debris Removal Technologies**
    - Research and development in **Active Debris Removal (ADR)** is crucial. Example:
        - **ADRAS-J Mission by Astroscale**: Aims to demonstrate **space junk removal using robotic arms and advanced tracking**.
4. **Liability Insurance for Space Debris Damage**
    - Countries and **private companies could be required to have insurance** covering potential damage from space debris.
5. **National Regulations for Space Sustainability**
    - Implementing and enforcing **domestic space policies aligned with international treaties** will ensure responsible space operations.

Conclusion

- **Space debris poses a significant challenge** to the sustainability of space activities.
- While **international laws provide a framework for liability**, **enforcement remains weak**, and **accountability is difficult to establish**.
- **India and other spacefaring nations** are taking steps to minimize debris generation, but **global cooperation and technological innovation** are essential.
- Investing in **debris removal, collision avoidance, and sustainable space practices** will ensure that future generations can continue to explore and utilize space safely.

Source: https://www.thehindu.com/sci-tech/science/space-debris-crash-lack-accountability-liability-convention/article69281563.ece