4. Rocket Re-entry AND Atmospheric Pollution - ENVIRONMENT

A recent study has found that the re-entry of rockets such as the Falcon 9 is altering the chemistry of the upper atmosphere, leading to a tenfold surge in lithium atoms

1.Introduction

1. The rapid expansion of space activities, including satellite launches and rocket missions, has introduced a new dimension of environmental concern in the form of atmospheric pollution from space operations.
2. Re-entry of satellites and rocket components releases metallic particles into upper atmospheric layers, raising concerns about long-term ecological and climatic impacts.
3. This issue links space technology with environmental sustainability and global governance.

2.Nature of Atmospheric Pollution from Space Activity

Material Composition and Emissions

1. Satellites and rockets are composed of materials such as aluminum alloys and lithium-ion batteries.
2. During atmospheric re-entry, these materials burn and vaporize, releasing metals into the mesosphere and lower thermosphere.
3. The injection of artificial metals significantly exceeds natural cosmic dust contributions, especially in terms of lithium content.

Space Debris as a Source of Pollution

1. Space debris includes all non-functional, human-made objects in orbit or re-entering Earth's atmosphere.
2. These objects travel at extremely high velocities, increasing risks of fragmentation and atmospheric contamination.
3. Increasing launch frequency has amplified the accumulation of such debris.

3.Major Environmental and Scientific Concerns

Impact on Atmospheric Chemistry

1. Artificial metallic particles alter the natural composition of upper atmospheric layers.
2. The imbalance between natural and anthropogenic inputs disrupts chemical equilibrium.
3. Long-term accumulation may lead to unknown chemical interactions.

Threat to the Ozone Layer

1. Metal particles released during re-entry can catalyse reactions that degrade ozone molecules.
2. Ozone depletion increases exposure to harmful ultraviolet radiation.
3. This may have cascading impacts on ecosystems and human health.

Climate Implications

1. Changes in atmospheric composition can influence radiative balance and heat retention.
2. Alterations in upper atmospheric layers may indirectly affect lower atmospheric climate systems.
3. Long-term climate feedback mechanisms remain insufficiently studied.

Kessler Syndrome Risk

1. Continuous collisions between space debris can trigger a cascade effect, exponentially increasing debris.
2. This may render certain orbital zones unusable for satellites.
3. It poses a serious threat to future space missions and global communication systems.

4.International Legal and Institutional Framework

Space Liability Convention (1972)

1. Establishes liability of launching states for damage caused by their space objects.
2. Imposes absolute liability for damage on Earth and fault-based liability in space.
3. Provides a legal mechanism for compensation.

Zero Debris Charter

1. Adopted by multiple nations and the European Space Agency.
2. Aims to achieve debris-neutral space operations by 2030.
3. Focuses on sustainable space practices and mitigation strategies.

5.Global and National Initiatives for Debris Removal

Global Missions

1. RemoveDebris mission demonstrates technologies such as nets and harpoons for debris capture.
2. Russia's proposed Space Debris Removal System aims to actively remove debris from low Earth orbit.
3. These initiatives indicate growing global awareness but remain at experimental stages.

India's Efforts

1. Project NETRA enhances space situational awareness by tracking debris and predicting threats.
2. It enables India to independently monitor space hazards affecting its satellites.
3. IS4OM (2022) provides continuous monitoring and risk mitigation for space operations.

6.Strategic and Policy Implications

Need for Sustainable Space Practices

1. Increasing commercialisation of space necessitates responsible design and disposal of satellites.
2. Adoption of reusable launch systems and eco-friendly materials is critical.
3. End-of-life deorbiting mechanisms must be standardised.

Global Governance Challenges

1. Lack of binding international regulations on space debris management.
2. Coordination among nations is essential due to the global nature of space.
3. Balancing technological advancement with environmental sustainability remains a key challenge.

7.Way Forward

Strengthening Monitoring and Research

1. Enhanced scientific studies on atmospheric impacts of space debris are required.
2. Development of global databases and monitoring systems is essential.

Technological Innovations

1. Investment in debris removal technologies and sustainable satellite design should be prioritised.
2. Promotion of green propulsion systems can reduce environmental impact.

International Cooperation

1. Establishment of binding global norms for debris mitigation is necessary.
2. Collaborative frameworks under UN bodies can ensure equitable and sustainable use of space.

Conclusion

Atmospheric pollution from space activity represents an emerging environmental challenge at the intersection of technology and sustainability. As space operations scale up, unmanaged debris and emissions could have irreversible impacts on atmospheric systems.

A proactive, science-based, and globally coordinated approach is essential to ensure that space remains a sustainable frontier for future generations.

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