Science and Technology Post-cursor

SCT06 - Space Technology

Space Technology refers to the application of engineering and scientific principles to explore, utilize, and operate in outer space. It is a dual-use technology, having both civilian (e.g., communication, weather forecasting) and military (e.g., surveillance, reconnaissance) applications.

Key Components

- **Satellites/Spacecraft:** Artificial objects placed in orbit for specific functions (communication, Earth observation, navigation).
- **Launch Vehicles (Rockets):** The systems that provide the necessary thrust to carry satellites/payloads beyond Earth's atmosphere and inject them into a desired orbit.
- **Ground Segment:** The infrastructure (tracking stations, control centres) on Earth that commands and receives data from space objects.

Major Applications

- **Communication:** DTH TV, mobile telephony, internet services (e.g., India's INSAT/GSAT series).
- **Navigation:** Providing accurate positioning, velocity, and time information (NavIC - India's own GPS)
- **Earth Observation/Remote Sensing:** Weather forecasting, disaster management, resource mapping, agricultural monitoring (e.g., IRS series).
- **Scientific Exploration:** Missions to study the Moon (Chandrayaan), Mars (Mangalyaan), Sun (Aditya-L1), and deep space.

Contemporary Issues in Space

1. Space Debris

- **What it is:** Space debris refers to any human-made objects in orbit around Earth that are no longer functional, including old satellites, rocket stages, and fragments from collisions or explosions. This "space junk" poses a significant threat to active satellites, spacecraft, and future missions by increasing the risk of high-speed collisions. The problem is growing, especially in low Earth orbit, and solutions are needed to track, mitigate, and remove this debris.

1. **The Problem:**

- **Kessler Syndrome:** A theoretical scenario in which the density of debris in LEO becomes so high that a single collision generates enough fragments to trigger a cascade of further collisions, rendering certain orbits unusable for generations.
- **Collision Risk:** Even small fragments, travelling at high orbital velocities (thousands of km/h), can critically damage active satellites and the International Space Station (ISS).

2. **Mitigation Measures:**

- **25-Year Rule (International Guideline):** Satellites should be de-orbited within 25 years of completing their mission.
- **Passivation:** Draining residual energy (fuel, batteries) from spent rocket stages to prevent accidental explosions.
- **Active Debris Removal (ADR):** Developing technologies (like nets, harpoons, or robotic arms) to actively capture and de-orbit large pieces of debris.
- **ISRO's Initiatives:** Project NETRA and IS4OM for tracking space objects and ensuring the safety of Indian space assets.

2. Space Commerce (NewSpace)

- **What it is:** The growing commercialisation of space activities, driven by private-sector players (e.g., SpaceX, Blue Origin). This shifts the focus from purely government-funded exploration to market-driven activities.

1. **Key Trends:**

- **Mega-Constellations:** Deploying thousands of small satellites in LEO for global internet access (e.g., Starlink, OneWeb), which adds to orbital congestion.
- **Launch Services:** Private companies offering cheaper and more frequent launch options using Reusable Launch Vehicles (RLVs).
- **Space Tourism, Mining, and Manufacturing:** Emerging business areas for the future.

2. **India's Response:** The establishment of IN-SPACe (Indian National Space Promotion and Authorisation Centre) and NSIL (NewSpace India Limited) to facilitate and regulate private sector participation.

Launch Vehicles and Orbits

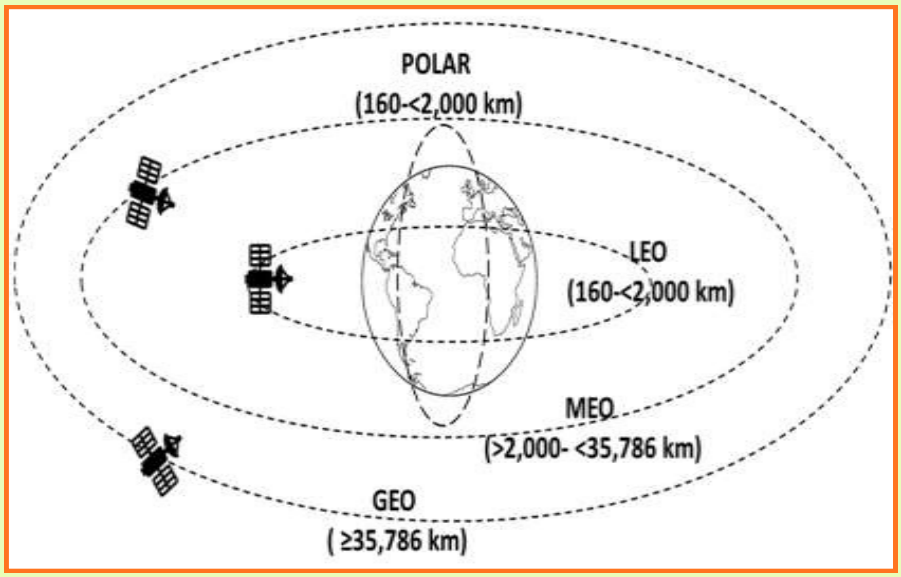
1. Launch Vehicles (Rockets)

A launch vehicle is a rocket that uses the principle of Newton's Third Law of Motion (Every action has an equal and opposite reaction.) to achieve thrust by expelling mass (hot gas) at high velocity.

- They are typically multi-staged, reducing weight progressively as they ascend.
- Propellants can be Solid (simple, high thrust, non-stoppable), Liquid (complex, lower thrust, storable/stoppable), or Cryogenic (highly efficient, use liquefied gases like Liquid Hydrogen/Oxygen at extremely low temperatures, used in upper stages for heavy payloads).

2. Orbits

An Orbit is the curved path an object takes around a celestial body due to the perfect balance between the object's forward velocity and the celestial body's gravitational pull.



Orbit Type Comparison

Characteristic	Low Earth Orbit (LEO)	Medium Earth Orbit (MEO)	Geostationary Earth Orbit (GEO)	Sun-Synchronous Orbit (SSO)
Acronym	LEO	MEO	GEO	SSO
Altitude (Approx.)	200 km to 2000 km	2000 km to 35,786 km	approx 35,786 km	600 km to 900 km (a type of LEO)
Key Features & Applications	High speed, short orbital period. Used for Remote Sensing/Earth Observation and Space Stations (e.g., ISS, Starlink).	Used primarily for Navigation systems (e.g., NavIC, GPS).	The satellite appears stationary relative to a point on Earth's equator. Perfect for Communication and Weather satellites as a single satellite can cover a large area continuously.	Satellites pass over any given point of Earth's surface at the same local mean solar time every day, ensuring consistent lighting conditions for imaging. Ideal for Remote Sensing satellites.