SPACE TECHNOLOGY

INDEX OF TOPICS

1. Introduction to Space Science and Technology	.1
2. International Space Programs and Collaborations	.7
3. Remote Sensing and Geographic Information Systems (GIS)	.9
4. Space Applications in Communication, Meteorology, Agriculture, and Disaster Management	11
5. Space Debris, Space Law, and Outer Space Governance	.13
6. Astronomy and Astrophysics Basics	14
7. Future Prospects of Indian Space Program	.20

1. Introduction to Space Science and Technology

Basic Concepts of Orbital Mechanics and Trajectories

- Geostationary Satellites (GEO):
  1. Orbit at a fixed/constant height above the Earth.
  2. Altitude is approximately 35,786 km (or ~35,800 km, ~36,000 km) above mean sea level.
  3. Move from West to East.
  4. Period of revolution is 24 hours, matching Earth's rotation period.
  5. A specific type of Geosynchronous Orbit (GSO) with zero inclination.
- Low Earth Orbit (LEO) / Polar Orbits:
  1. Satellites typically move from pole to pole (Polar Earth Orbit).
  2. Altitude range for Polar Earth Orbit: 500 – 2000 km.
  3. Sun Synchronous Orbit (SSO) is a type of LEO, commonly at 700 – 800 km altitude.
  4. Orbital period is approximately 90-120 minutes (e.g., ~99 minutes for some LEOs).
  5. Can view both daytime and nighttime sides of Earth during one half of its orbit.
- Geosynchronous Orbit (GSO):
  1. Altitude is approximately 35,800 km above the Equator.
  2. Period of revolution is 24 hours.
- Parking Orbit:
  1. A temporary orbit where a spacecraft waits before a transfer burn.
  2. As per some contexts (e.g., MCQ 11), it might refer to an altitude of 35,785 km.
- Orbital Mechanics Principles:
  1. Once in orbit, a satellite does not require continuous energy for orbiting; it is maintained by inertia and gravity.
  2. As the height of a satellite above Earth's surface increases, the time taken to complete its orbit increases.

Definition and Scope of Space Science and Technology

- Space Science & Technology broadly covers exploration, understanding, and utilization of space.
- **Dr. Vikram Sarabhai**

  Known as the father of the Indian Space Programme.

Space Technology

- **Dr. Vikram Sarabhai Contributions**
  - Founded Physical Research Laboratory (PRL) in Ahmedabad.
  - Served as Chairman, Atomic Energy Commission of India (AEC).
- **Vikram Sarabhai Space Centre (VSSC)**

  Located in Thiruvananthapuram.
- **ADITYA**
  - India's indigenously developed tokamak.
  - A fusion reactor.
- **LOFAR (Low Frequency Array)**

  World's most powerful radio antenna (radio telescope).
- **"Roc"**

  Refers to the largest aircraft (e.g., Stratolaunch's Roc, designed for air-launch-to-orbit).
- **India's First Nuclear Reactor**

  Apsara.
- **Nuclear Power Plants (Locations)**
  - Kalpakkam: Tamil Nadu
  - Narora: Uttar Pradesh (U.P.)
  - Tarapur: Maharashtra
  - Kakrapara: Gujarat
  - Kudankulam Nuclear Power Station: Has maximum gross power (MWe) in India.
- **Fast Breeder Reactor (FBR)**
  - India's first prototype FBR is situated in Kalpakkam.
  - Uses MOX (mixed oxide) of Plutonium and Uranium as fuel.
- **India's Third Research Station in Antarctica**

  Bharti (following Gangotri & Maitri).
- **India's First Indigenously Developed Remote Sensing Satellite**

  Launched through Baikonur (Soviet Union).
- **Satellites**
  - Aryabhata and Bhaskar are artificial satellites.
  - Moon and Earth are natural celestial bodies, not artificial satellites.
- **Dhruva Space**

  Indian space-tech startup that successfully space-qualified its P30 Satellite platform.
- **Professor V. K. R. Rao**

  Not associated with Space technology.

Fundamental Principles of Rocketry and Space Propulsion

- GSLV-F08 launched GSAT-6A.
- JAXA successfully used steam to propel its EQUULEUS spacecraft.
- **Polar Satellite Launch Vehicle (PSLV)**:
  - Developed to launch low-Earth Orbit (LEO) satellites into polar and sun-synchronous orbits.
  - Has four stages, alternating between solid and liquid fuels.
  - Known as the 'Workhorse of ISRO'.
  - PSLV-C45 launched EMISAT with 28 other satellites.
- **Geosynchronous Satellite Launch Vehicle (GSLV)**:
  - Developed to launch heavier INSAT-class geosynchronous satellites into Geosynchronous Transfer Orbit (GTO).
  - Typical stages: one solid rocket motor (first), one earth-storable liquid (second), and one cryogenic (third) upper stage.
- **GSLV Mark III (LVM3)**:
  - ISRO's largest satellite launch vehicle with the heaviest launch capability payload-wise.
  - A three-stage heavy-lift launch vehicle.
  - Configuration: Two solid strap-ons (S200), a core liquid booster (L110), and a cryogenic upper stage (C25).
  - Capable of launching 4-ton class satellites to GTO and 10-ton class satellites to LEO.
  - HS200: Human-rated version of the S-200 solid rocket booster for LVM3/GSLV MkIII; static tested by ISRO.
- **Small Satellite Launch Vehicle (SSLV)**: A small rocket launching vehicle for small satellites.

- **Reusable Launch Vehicle (RLV)**: ISRO has successfully launched it multiple times.
- **Payload Capacity Order (low to high)**: Satellite Launch Vehicle (SLV-3) < Augmented Satellite Launch Vehicle (ASLV) < Polar Satellite Launch Vehicle (PSLV-XL) < Geosynchronous Satellite Launch Vehicle (GSLV) < GSLV Mark III.
- **Rocket Engine Fuels**:
  - Aluminium powder is used as a solid fuel for rocket engines.
  - Compared to liquid fuel, solid fuel propelled rocket engines generally have lower thrust per amount of fuel burned (specific impulse).
  - "LOx methane" is a space rocket engine fuel (Liquid Oxygen-Methane).
  - Cryogenic engines use super-cooled liquid propellants (e.g., LOx and LH2) and find applications in rocket technology.
  - ISRO successfully conducted the first Pre-Burner Ignition trial for a semi-cryogenic engine (SCE-200).
  - Hindustan Aeronautics Limited (HAL) delivered C32-LH2 (Biggest Ever Cryogenic Propellant Tank) to ISRO.
- Rockets are designed to carry payloads, scientific instruments, and satellites.
- Skyroot Aerospace is the first private Indian company to successfully test-fire a solid propulsion rocket engine named Kalam-5.
- SpaceX designed and manufactured 'Falcon 9', a reusable rocket.
- NASA tested 'Greased Lightning-10 (GL-10)', an electric plane.
- **Radioisotope Thermoelectric Generators (RTGs)**:
  - Used for powering onboard systems of spacecraft.
  - Utilize heat from radioactive decay (not miniature fission reactors).
  - Can use Plutonium-238, a by-product of weapons development.
- "PraVaHa" software, developed by Vikram Sarabhai Space Centre (VSSC) of ISRO, is used for initial aerodynamic design of space vehicles to evaluate large numbers of configurations.
- ISRO uses sounding rocket RH 300 for atmospheric studies.

Future Trends and Prospects in Space Exploration and Utilization

- World Space Week 2022 theme: "Space and Sustainability".

Historical Milestones in Space Exploration

- First artificial satellite: Sputnik-I (USSR, 1957).
- First geostationary satellite: SYNCOM-3 (USA, 1964).
- First man to land on Moon: Neil Armstrong (Apollo 11, USA, 1969).
- Father of Indian Space Programme: Dr. Vikram Sarabhai.
- Indian Space Research Organisation (ISRO) established: August 15, 1969.
- Atomic Energy Commission of India Chairmen (chronological): Homi Bhabha, Vikram Sarabhai, H.N. Sethna, Raja Ramanna.
- First Indian satellite (completely designed & fabricated in India): Aryabhatta.
- Aryabhatta launch: April 19, 1975, from Soviet Cosmodrome (Soviet Union).
- Bhaskara-I launch: June 7, 1979, experimental Earth observation satellite.
- Bhaskara-II launch: 1981.
- SLV-3 (Satellite Launch Vehicle-3): Launched Rohini satellites.
- ASLV (Augmented Satellite Launch Vehicle): Launched SROSS-C satellites.
- INSAT-1B launch: August 30, 1983.
- INSAT-1D launch: 1990.
- IRS-1A (India's first remote-sensing satellite) launch: 1988, from Baikonur.
- PSLV (Polar Satellite Launch Vehicle): Launched Chandrayaan-1.
- GSLV (Geosynchronous Satellite Launch Vehicle): Launched EDUSAT.
- GSAT-10 launch: 2012.
- First Indian born woman astronaut for NASA space voyage: Kalpana Chawla.
- Kalpana Chawla: Born in Karnal, flew on shuttle flight STS-87, performed space-walk to retrieve Spartan Satellite. Trained at Johnson Space Center.

- First Indian to go to outer space: Rakesh Sharma.
- "Missile Man of India": A.P.J. Abdul Kalam.
- "Father of Green Revolution": M.S. Swaminathan.
- NASA's Mars rover landed Aug 6, 2012: Curiosity.
- Other Mars rovers: Sojourner, Opportunity. Apollo was for Moon missions.
- Messenger spacecraft: Mapped and investigated Mercury.
- Voyager 1 and 2 spacecraft: Explored the outer solar system.
- Cassini-Huygens spacecraft: Orbited Saturn (not Venus).
- India's highest number of satellites launched in one mission: 104 (PSLV-C37 mission).
- Chandrayaan-1 lift-off mass was lower than Chandrayaan-2.
- Chandrayaan-2 launch: July 22, 2019, from Satish Dhawan Space Centre (Sriharikota).
- Chandrayaan-2 launch vehicle: GSLV – MK III – M1.
- Chandrayaan-2 lander name: Vikram.
- Chandrayaan-3 touched down on the Moon's South Pole on August 23, 2023.
- NASA's current lunar human exploration program: Artemis (Ares was a proposed rocket system for the earlier Constellation program).
- India's first permanent station in Antarctica: Dakshin Gangotri.
- India's second permanent station in Antarctica: Maitri.
- India's third permanent station in Antarctica (established 2012): Bharati.
- First commercial space station: Axiom Station.

Major Global Space Agencies and International Collaboration

- **Indian Space Research Organisation (ISRO)**
  - Full Name: Indian Space Research Organisation.
  - Established: 1969.
  - Parent Body: Department of Space (DoS), headquartered in Bengaluru, Karnataka.
  - Primary Role: India's agency for space science and technology development.
  - Developed "Vyommitra," an Indian humanoid robot.
  - Operates the 'NICES Programme'.
  - Designated Gujarat Council on Science and Technology as the nodal centre for the 'Space Science and Technology Awareness Training (START)' program.
- **Key ISRO Centres & Facilities**
  - **Headquarters (DoS/ISRO)**
    Bengaluru, Karnataka.
  - **Vikram Sarabhai Space Centre (VSSC)**
    Trivandrum, Kerala (Launch vehicle development).
  - **U R Rao Satellite Centre (URSC)**
    Bengaluru, Karnataka (Satellite design & development).
  - **Satish Dhawan Space Centre (SDSC) SHAR**
    Sriharikota, Andhra Pradesh (India's primary spaceport).
  - **National Remote Sensing Centre (NRSC)**
    Hyderabad, Telangana (Satellite data acquisition & processing).
  - **Indian Institute of Remote Sensing (IIRS)**
    Dehradun, Uttarakhand (Training in remote sensing & GIS).
  - **Space Applications Centre (SAC)**
    Ahmedabad, Gujarat (Space-borne instruments, communication, navigation, remote sensing, meteorology).
  - **Indian Institute of Space Science and Technology (IIST)**
    Thiruvananthapuram, Kerala.
  - **North Eastern-Space Applications Centre (NESAC)**
    Shillong, Meghalaya.

- **International Collaborations & Missions**
  - **NISAR**

    NASA-ISRO Synthetic Aperture Radar (joint Earth observation mission).
  - **Mars Orbiter Mission (MOM/ Mangalyaan)**

    Launched from Sriharikota.
- **Recent ISRO Missions (Specific Mentions)**
  - **PSLV-C54 Mission (Nov 26, 2022)**

    Launched EOS-06 (Oceansat-3) and 8 nano-satellites into two different Sun-Synchronous Polar Orbits (SSPOs) from SDSC SHAR.
  - **LVM3 Mission (Oct 2022)**

    Launched 36 satellites (OneWeb India-1 mission).

Overview of Spacecraft Systems and Subsystems

- **Space Shuttle**

  A re-usable spacecraft designed for crew and cargo transport to space and return to Earth.
- Often described as an aeroplane-shaped re-usable rocket, capable of atmospheric flight and runway landing.

The Space Environment: Characteristics and Challenges

- Space Environment Characteristics: Vacuum, extreme temperatures (hot/cold), microgravity, high radiation (cosmic rays, solar flares, trapped radiation belts), space debris.
- Key Challenges: Equipment degradation, power system issues, navigation/communication interference, human health risks, debris collision risk.
- Radiation Belts (Van Allen Belts): Regions of energetic charged particles (protons, electrons) trapped by Earth's magnetic field.
- Hazards of Radiation Belts:
  - Deterioration of electronic circuits (single event upsets, total dose effects).
  - Damage to solar cells of spacecraft (reduced power generation, degradation).
  - Adverse effects on living organisms (e.g., astronauts), including DNA damage, increased cancer risk, and acute radiation sickness.
- Other Radiation Sources: Galactic Cosmic Rays (GCRs) and Solar Particle Events (SPEs).
- Space Debris: Non-functional human-made objects in orbit, posing collision risk to active spacecraft.

Types and Applications of Satellites (Communication, Earth Observation, Navigation)

- **Satellite Types & Applications**
- **Communication Satellites**

  Used for telecommunication, broadcasting, internet services. E.g., India's GSAT series.
- **GSAT-7 (Rukmini)**

  India's first dedicated military communication satellite.
- **Earth Observation/Remote Sensing Satellites**

  Monitor Earth's surface, environment, weather, resources, disaster management. E.g., India's IRS & Cartosat series.
- **TanSat**

  China's satellite to monitor global carbon emissions.
- **Navigation Satellites**

  Provide precise positioning, navigation, and timing (PNT) services. E.g., GPS, GLONASS, Galileo, NavIC.
- **Scientific Satellites**

  Conduct scientific research, astronomy, space exploration. E.g., India's Astrosat, Mars Orbiter Mission (MOM).
- **Astrosat**

  India's first dedicated multi-wavelength space observatory; categorized as a Scientific satellite.