SPACE TECHNOLOGY

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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.

- **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.

- **Meteorological Satellites**

  Specialized for weather forecasting and climate monitoring. E.g., Kalpana-1.

- **Academic Institute Satellites**

  Developed by educational institutions. E.g., SathyabamaSat (SATYABAMASAT).

- **Satellite Navigation Systems (Global/ Regional)**

- **GPS (Global Positioning System)**

  Owned by the United States.

- **GLONASS**

  Owned by Russia.

- **Galileo**

  Owned by the European Union.

- **NavIC (Navigation with Indian Constellation) / IRNSS (Indian Regional Navigation Satellite System)**

  Owned by India; provides PNT services over India and its neighborhood (approx. 1500 km).

- **IRNSS-1B**

  A navigation satellite, part of NavIC; lifted off by PSLV-C24 from Sriharikota; has civil and defence applications.

- **Indian Space Missions & Satellites**

- **Mars Orbiter Mission (MOM) / Mangalyaan**

  India's first interplanetary mission to planet Mars with an orbiter craft.

- MOM was launched by PSLV-C25.
- MOM consists of five payloads: Methane Sensor for Mars (MSM), Mars Color Camera (MCC), Lyman Alpha Photometer (LAP), Thermal Infrared Imaging Spectrometer (TIS), Mars Exospheric Neutral Composition Analyser (MENCA).

- **Chandrayaan-2 Rover 'Pragyan'**

  A six-wheeled robotic vehicle for lunar exploration.

- **ISRO Launch Vehicles**

- **PSLV (Polar Satellite Launch Vehicle)**

  India's reliable workhorse launch vehicle. Primarily used for launching Earth Observation/remote sensing satellites (e.g., IRS, Cartosat) into Polar Sun Synchronous Orbit (SSO) and Low Earth Orbit (LEO).

- PSLV-C15 launched 5 satellites in July 2010.
- PSLV-C37 successfully launched 104 satellites in a single flight in February 2017.

- **GSLV (Geosynchronous Satellite Launch Vehicle)**

  Primarily designed to launch heavier communication satellites (e.g., GSAT series) into Geostationary Transfer Orbit (GTO) for eventual placement in Geostationary Earth Orbit (GEO).

- Satellites launched into GEO by GSLV appear to remain permanently fixed in the same position in the sky as viewed from a particular location on Earth.

- **GSLV Mk III (LVM3)**

  A three-staged launch vehicle (solid boosters, liquid core, cryogenic upper stage) for heavier payloads.

- **Other Key International Missions**

- **'Curiosity' Rover**

  A robotic mission for exploration of Mars launched by NASA. It is powered by a radioisotope thermoelectric generator (RTG), not solar energy.

- **NEOSSat (Near-Earth Object Surveillance Satellite)**

  A Canadian space telescope dedicated to searching for asteroids that might threaten Earth. It was launched by PSLV in February 2013 but was not designed and developed by ISRO.

- **Satellite Orbit & Frequency Fundamentals**

- **Geostationary Satellite**

  Orbits at approximately 36,000 km height above the Earth's surface in the equatorial plane, matching Earth's rotation period.

- **C-band Transponder**

  Downlink frequency is typically around 4 GHz (e.g., 3.7 to 4.2 GHz).

2. International Space Programs and Collaborations

Artemis Accords and other frameworks for lunar exploration and resource utilization.

- Artemis Program: NASA-led (USA) international human spaceflight program.
- Artemis Program Objective: To return humans to the Moon for sustainable exploration, including the first woman and person of color.
- Artemis I: Uncrewed test flight mission launched in November 2022 as part of the Artemis Program, using the Space Launch System (SLS) rocket and Orion spacecraft.
- Artemis Accords: US-led international agreement outlining principles for responsible and peaceful lunar exploration and resource utilization, based on the Outer Space Treaty.

Bilateral and multilateral space agreements: India's collaborations with other nations.

- **Indian-origin Astronauts (Chronological order of space flights)**

  Rakesh Sharma (1984), Kalpana Chawla (1997), Sunita Williams (2006), Sirisha Bandla (2021).

- **Indo-US Joint Radar Satellite Project**

  NASA-ISRO Synthetic Aperture Radar (NISAR) is a collaborative Earth-observing mission.

- **Megha-Tropiques Satellite Project**

  A joint mission between India (ISRO) and France (CNES) launched in 2011 for tropical weather and climate studies.

- **India-Japan Lunar Collaboration**

  ISRO and JAXA (Japan) are collaborating on the Lunar Polar Exploration Mission (LUPEX) to explore the Moon's permanently shadowed regions.

- **PSLV-C45 Mission (April 1, 2019)**

  Successfully launched EMISAT and 28 international satellites from four countries: USA (24), Lithuania (2), Spain (1), and Switzerland (1).

- **Women in Space Leadership (WiSL) Program**

  Launched by the Department of Space (DoS) in collaboration with the British Council.

Global navigation satellite systems (GNSS) interoperability and international cooperation (GPS, GLONASS, Galileo, BeiDou).

- **GNSS (Global Navigation Satellite System)**

  General term for satellite-based navigation systems providing autonomous geo-spatial positioning.

- **Key GNSS Systems and Operators**
  - **GPS (Global Positioning System)**

    Operated by the United States.
  - **GLONASS (Globalnaya Navigatsionnaya Sputnikovaya Sistema)**

    Operated by Russia.
  - **Galileo**

    Operated by the European Union.
  - **BeiDou Navigation Satellite System (BDS)**

    Operated by China.
- **Interoperability**

  The ability of GNSS receivers to effectively utilize signals from multiple independent GNSS systems simultaneously to improve positioning accuracy, availability, and reliability.
- **International Cooperation**

  Agreements and partnerships among GNSS providers and user communities to ensure compatibility, spectrum sharing, common standards, and mutual benefits from diverse GNSS systems.

International efforts in Earth observation for climate change monitoring and disaster management.

- NISAR (NASA-ISRO Synthetic Aperture Radar) is an Earth-Observation satellite jointly developed by NASA and ISRO.
- The NISAR partnership was envisioned by NASA and ISRO in 2014.

International Space Station (ISS) program and its evolution.

- International Space Station (ISS) orbits Earth in Low Earth Orbit (LEO).
- Orbital altitude: Approximately 400 km (ranging between 278 km and 460 km).
- Primary purpose: Microgravity research laboratory.
- Origin: Synthesis of several projects including American Freedom, Russian Mir-2, European Columbus, and Japanese Kibo.
- First component (Zarya module) launched: 1998.
- First crew (Expedition 1) arrived: November 2000.
- Major module assembly largely completed by 2011.
- Astronaut Christina Koch: Set record for longest single spaceflight by a woman (328 days, during 2019-2020).
- Christina Koch's crewmates during part of her mission included Luca Parmitano and Alexander Skvortsov.
- Example research conducted on ISS: Growing protein crystals for potential treatments for Parkinson's and Alzheimer's diseases.

Major international space agencies and their collaborative frameworks (e.g., NASA, ESA, Roscosmos, JAXA, CNSA).

- **NASA** (National Aeronautics and Space Administration): U.S. government agency responsible for civilian space program, aeronautics, and aerospace research. Major contributor to the International Space Station (ISS) and led missions like Hubble Space Telescope, Mars rovers, and Artemis program for lunar exploration.
- **ESA** (European Space Agency): Intergovernmental organization of 22 member states dedicated to space exploration. Coordinates European space activities, contributes to ISS, develops Ariane launchers, and operates scientific missions like Rosetta, Gaia, and James Webb Space Telescope (in collaboration with NASA).
- **Roscosmos**: State Corporation for Space Activities of the Russian Federation. Manages Russia's space program, including human spaceflight (Soyuz spacecraft), satellite launches, and significant contributions to the ISS. In 2019, Roscosmos sent the humanoid robot **"Fedor"** (Final Experimental Demonstration Object Research) to the ISS aboard a Soyuz MS-14 mission.
- **JAXA** (Japan Aerospace Exploration Agency): Japanese national aerospace agency. Conducts space exploration, satellite deployment, and scientific research. Known for its Kibo module on the ISS, Hayabusa asteroid sample return missions, and lunar probes.
- **CNSA** (China National Space Administration): National space agency of China. Responsible for China's space program, including human spaceflight (Shenzhou program), lunar exploration (Chang'e program), Martian exploration (Tianwen-1), and the construction of its Tiangong space station.
- **Collaborative Frameworks**: The **International Space Station (ISS)** is a flagship example, involving NASA, Roscosmos, ESA, JAXA, and CSA (Canadian Space Agency). Other collaborations exist for specific missions, data sharing, and standards, such as the **Artemis Accords** led by NASA for future lunar exploration.

Multilateral initiatives in planetary exploration (e.g., James Webb Space Telescope, Mars missions).

- **Hope Mars Mission (Emirates Mars Mission - EMM)**

  Launched by the United Arab Emirates (UAE) to Mars.

- **UAE's Achievement**

  Became the fifth entity (after USA, Russia, European Space Agency, and India) and the first Arab nation to successfully place a probe (Hope Probe) into Mars orbit.

Public-private partnerships and commercial international space ventures.

- **Public-Private Partnerships (PPPs) in Space**

  Collaboration between government space agencies (e.g., NASA) and private commercial entities (e.g., SpaceX) to reduce costs, accelerate innovation, and enable new missions.

- **SpaceX (founded by Elon Musk)**

  Private American aerospace manufacturer and space transport services company.

- **Crew Dragon**

  Spacecraft developed by SpaceX, used to transport astronauts to the International Space Station (ISS) for NASA.

- **Starlink**

  Satellite internet constellation developed by SpaceX, providing internet access.

- **Blue Origin (founded by Jeff Bezos)**

  American private aerospace manufacturer and spaceflight services company.

- **Moon Express**

  World's first private company to receive U.S. government approval for a commercial lunar mission (flight plan to the moon).

3. Remote Sensing and Geographic Information Systems (GIS)

Applications of Remote Sensing and GIS in various sectors (e.g., Urban Planning, Agriculture, Disaster Management, Environmental Monitoring)

- Bhoonidhi Vista: A data visualization service of Bhoonidhi, providing full resolution mosaicked data visualization via Web Map Service (WMS).
- Bhoonidhi Vista: Enabled for ResourceSat-2/2A, Sentinel 1, and Sentinel 2 satellites.
- Earth Observation Satellites / Remote Sensing applications: Urban planning, Mineral prospecting, Ocean resources management, Disaster management, Assessment of crop productivity, Locating groundwater resources, Traffic studies.
- Department of Space (DoS) / ISRO signed an MoU with geospatial technology company CE Info Systems Pvt. Ltd. (MapmyIndia).
- The DoS-MapmyIndia collaboration aims to build holistic geospatial solutions by utilizing Earth Observation datasets, NavIC, Web Services, and APIs from MapmyIndia, integrating with ISRO's existing geospatial platforms like Bhuvan, VEDAS, and MOSDAC. (Note: Bhuvan, VEDAS, MOSDAC are existing ISRO portals).
- Indian Institute of Remote Sensing (IIRS) is situated at Dehradun.
- Indian Remote Sensing (IRS) satellites are used for: Assessment of crop productivity, Locating groundwater resources, Mineral exploration, Traffic studies. (IRS satellites are generally not used for Telecommunications).
- GAIL (India) Limited launched the "Bhuvan-GAIL Portal" in November 2015.
- Bhuvan-GAIL Portal purpose: Monitoring pipeline Right of Use (ROU) through Space Technology.
- Bhuvan: An ISRO geoportal with 3D imaging capabilities of India.

Global Navigation Satellite Systems (GNSS) and their integration with RS & GIS

- **Global Navigation Satellite Systems (GNSS)**

  Satellite-based systems providing autonomous geospatial positioning with global/regional coverage.

- **Major GNSS Systems**
  - **GPS (Global Positioning System)**
    USA, global.
  - **GLONASS (Globalnaya Navigatsionnaya Sputnikovaya Sistema)**
    Russia, global.
  - **Galileo**
    European Union, global.
  - **BeiDou Navigation Satellite System (BDS)**
    China, global.
  - **NavIC (Navigation with Indian Constellation) / IRNSS (Indian Regional Navigation Satellite System)**
    India, regional.
  - **QZSS (Quasi-Zenith Satellite System)**
    Japan, regional.
- **GPS Fundamentals (USA)**
  - **Satellite Network**
    Operates via a constellation of Earth-orbiting satellites transmitting radio signals.
  - **Positioning Principle**
    Based on
    trilateration/ranging, measuring distances from a receiver to multiple satellites to calculate position. Requires minimum four satellites for 3D position and time.
  - Output GPS receivers provide precise location in terms of
    latitude, longitude, and altitude (3D coordinates) and accurate time.
  - Applications
    Dual-use system – originally developed for military operations, but now extensively used for diverse civilian purposes (e.g., navigation, surveying, mapping, disaster management, timing), thus not exclusively for military operations.
  - Segments Comprises Space Segment (satellites), Control Segment (ground stations), and User Segment (receivers).
- **Integration with Remote Sensing (RS) & Geographic Information Systems (GIS)**
  - **Remote Sensing**
    Provides accurate ground control points (GCPs) for georeferencing satellite imagery and aerial photographs, improving their spatial accuracy.
  - **GIS**
    Acts as a primary data source for collecting new spatial data (points, lines, polygons) in the field, updating existing GIS databases, and enabling real-time location tracking and asset management within GIS environments.

Principles and Fundamentals of Remote Sensing

- Indian Institute of Remote Sensing (IIRS) is a constituent unit of ISRO.
- National Remote Sensing Centre (NRSC), formerly NRSA, is located in Hyderabad.
- Remote sensing employs various sensors/technologies, including: Electromagnetic sensors, Multi-Spectral Scanners, Radar, and Microwave Sensors.

Remote Sensing Data Acquisition, Pre-processing, and Image Interpretation

- LANDSAT satellites are in Sun-synchronous orbits, allowing data acquisition at the same local time.
- For LANDSAT, data for an adjacent area to its west (non-overlapping swath) becomes available after a certain number of days (its