1. Orbit-based Classification:

- ✓ **Low Earth Orbit (LEO) Satellites:**

  Altitude: 180 to 2,000 kilometers.

  Examples: Landsat series, Sentinel-2.

- ✓ **Medium Earth Orbit (MEO) Satellites:**

  Altitude: 2,000 to 35,786 kilometers.

  Examples: Navigation satellites like GPS.

- ✓ **Geostationary Earth Orbit (GEO) Satellites:**

  Altitude: 35,786 kilometers.

  Examples: Weather satellites like GOES.

2. Sensor-based Classification:

- ✓ **Optical Satellites:**

  Capture images in the visible, infrared, and ultraviolet spectra.

  Examples: Landsat, Sentinel-2.

- ✓ **Radar Satellites:**

  Use radar waves to observe Earth's surface.

  Examples: RADARSAT, Sentinel-1.

- ✓ **Multispectral Satellites:**

  Combine data from multiple spectral bands for detailed analysis.

  Examples: Landsat, MODIS.

- ✓ **Hyperspectral Satellites:**

  Capture data in many narrow, contiguous spectral bands.

  Examples: Hyperion on EO-1.

3. Purpose-based Classification:

- ✓ **Earth Observation Satellites:**

  Monitor Earth's surface for environmental, agricultural, and urban planning.

  Examples: Landsat, Sentinel series.

- ✓ **Weather Satellites:**

  Monitor atmospheric conditions.

Examples: GOES, Meteosat.

- ✓ **Communication Satellites:**

  Facilitate communication services.

  Examples: Intelsat, Iridium.

- ✓ **Navigation Satellites:**

  Provide global positioning and navigation services.

  Examples: GPS, Galileo.

4. Resolution-based Classification:

- ✓ **High-Resolution Satellites:**

  Capture detailed images with high spatial resolution.

  Examples: WorldView-3, Pleiades.

- ✓ **Medium-Resolution Satellites:**

  Provide moderate details.

  Examples: Landsat, Sentinel-2.

- ✓ **Low-Resolution Satellites:**

  Capture images with lower spatial detail but cover larger areas.

  Examples: MODIS.

5. Temporal Resolution-based Classification:

- ✓ **High Temporal Resolution Satellites:**

  Capture frequent images of the same area.

  Examples: MODIS, Landsat (for some applications).

- ✓ **Low Temporal Resolution Satellites:**

  Capture images less frequently.

  Examples: Some scientific satellites.

6. Government vs. Commercial Classification:

- ✓ **Government Satellites:**

  Often operated by government agencies for various purposes.

  Examples: Landsat (NASA/USGS), Sentinel series (European Space Agency).

- ✓ **Commercial Satellites:**

  Owned and operated by private companies for commercial purposes.

Examples: World View series (Maxar), Planet Scope.

7. Specialized Satellites:

- ✓ **Scientific Satellites:**

  Designed for specific scientific research purposes.

  Examples: Hubble Space Telescope.

- ✓ **Military Satellites:**

  Used for defence and intelligence purposes.

  Examples: KH-11 Kennen (USA), SAR-Lupe (Germany).

4.1 GEOSYNCHRONOUS SATELLITES:

- A geosynchronous satellite is a type of satellite that orbits the Earth at the same rate as the Earth's rotation, allowing it to remain stationary relative to a fixed point on the Earth's surface.
- These satellites are typically placed in a circular orbit directly above the equator at an altitude of approximately 35,786 kilometres (22,236 miles).
- At this specific altitude, the satellite's orbital period matches the Earth's rotational period, which is about 24 hours.
- The term geosynchronous refers to the satellite's orbital period which enables it to be matched, with the rotation of the Earth ("geo-").
- Along with this orbital period requirement, to be geostationary as well, the satellite must be placed in an orbit that puts it in the vicinity over the equator.
- These two requirements make the satellite appear in an unchanging area of visibility when viewed from the Earth's surface, enabling continuous operation from one point on the ground.

➢ **Key characteristics of geosynchronous satellites include:**

- ✓ **Fixed Position:** A geosynchronous satellite appears to hover over a fixed point on the Earth's surface. This is beneficial for applications that require constant communication with a specific location, such as weather monitoring, communication, and broadcasting.

- ✓ **Communication:** Geosynchronous satellites are commonly used for communication purposes, including television broadcasting, satellite radio, and telecommunications. Since they remain in a fixed position relative to the Earth, ground-based antennas can point to the satellite consistently, simplifying communication infrastructure.

- ✓ **Weather Observation:** Geosynchronous satellites are often equipped with sensors to monitor weather patterns. By remaining stationary over a specific region, they can provide continuous and real-time data on weather conditions, which is crucial for meteorological forecasting and monitoring.

- ✓ **Navigation:** While low Earth orbit (LEO) satellites are commonly used for global navigation systems like GPS, geosynchronous satellites can play a role in regional navigation and surveillance applications.

- ✓ **Earth Observation:** Some geosynchronous satellites are equipped with sensors for Earth observation, allowing them to monitor environmental changes, natural disasters, and other phenomena over a specific region.

- There is a specific subtype of geosynchronous orbit called geostationary orbit.
- In a geostationary orbit, the satellite not only remains above the equator but also stays directly above a fixed point on the equator.
- Geostationary satellites are a subset of geosynchronous satellites, and the terms are sometimes used interchangeably.

➢ **Advantages of geo-stationary satellites:**

- Get high temporal resolution data.
- Tracking of the satellite by its earth stations is simplified.
- Satellite always in same position.

➢ **Disadvantage of geostationary satellites:**

- Incomplete geographical coverage, since ground stations at higher than roughly 60 degrees latitude have difficulty reliably receiving signals at low elevations.

➢ **Some of the most common types of geosynchronous satellites include:**

- **Communication satellites:** These satellites are used to relay communication signals between different points on the Earth's surface.
- **Direct broadcast satellites (DBS):** These satellites are used to broadcast television and radio signals directly to homes and businesses.
- **Geostationary operational environmental satellites (GOES):** These satellites are used to monitor weather patterns and environmental conditions over the Americas.
- **Global navigation satellite system (GNSS) satellites:** These satellites are used to provide positioning, navigation, and timing services around the world.

4.2 SUN SYNCHRONOUS SATELLITES:

- A Sun-synchronous satellite, also known as a Helio synchronous satellite, is a specific type of Earth observation satellite that has an orbit designed to synchronize with the Sun.
- Unlike geosynchronous satellites, which stay fixed over a specific point on the Earth's surface, Sun-synchronous satellites are in a polar orbit, meaning they orbit the Earth from pole to pole.

➢ **Key characteristics of Sun-synchronous satellites include:**

- ✓ **Orbit Inclination:** Sun-synchronous satellites have an inclination that is usually near polar (close to 90 degrees). This means their orbit takes them over the Earth's poles.

- ✓ **Orbit Precession:** The orbit of a Sun-synchronous satellite is designed to process (rotate) at such a rate that it maintains a consistent angle with respect to the Sun. This allows the satellite to pass over any point on the Earth's surface at the same local solar time during each orbit.

- ✓ **Constant Sunlight Angle:** The primary benefit of this specific orbit is that the satellite's orbital plane rotates in such a way that it intersects each latitude at the same local solar time. This results in consistent lighting conditions during each pass over a given location, making it easier to compare and analyse data collected at different times.

- ✓ **Earth Observation:** Sun-synchronous satellites are commonly used for Earth observation and remote sensing applications. They are particularly useful for monitoring changes in the Earth's surface, such as vegetation growth, land use changes, and environmental conditions.

- ✓ **Scientific Research:** These satellites are also employed in scientific research, including studies related to climate change, atmospheric conditions, and natural disasters.

- ✓ **Repeatable Ground Track:** The orbit of Sun-synchronous satellites is carefully designed to create a repeatable ground track, which means that the satellite passes over the same geographic locations at the same local solar time during each orbit.

- The synchronized timing with the Sun allows these satellites to capture images and data under consistent lighting conditions, which is crucial for various applications, especially in Earth observation and environmental monitoring.

- ➢ **Sun-synchronous satellites are used for a variety of purposes, including:**

  - ✓ **Earth observation:** Sun-synchronous satellites are ideal for Earth observation because they provide consistent lighting conditions at the same time each day. This makes it easier to compare images taken at different times and to track changes over time.
  - ✓ **Weather monitoring:** Sun-synchronous satellites are also used for weather monitoring, providing global coverage of cloud cover, precipitation, and other weather patterns.
  - ✓ **Resource management:** Sun-synchronous satellites are used to monitor natural resources, such as forests, oceans, and agriculture.
  - ✓ **Mapping:** Sun-synchronous satellites are used to create detailed maps of the Earth's surface.

- ➢ **Some of the most common examples of sun-synchronous satellites include:**

- ✓ **NASA's Landsat program:** The Landsat program has been providing high-resolution images of the Earth's surface since 1972. Landsat satellites are in sun-synchronous orbits so that they can provide consistent lighting conditions for image comparison.
- ✓ **NOAA's POES program:** The POES program provides weather data and images from a constellation of sun-synchronous satellites. These data are used by meteorologists to forecast weather patterns and to issue warnings for severe weather events.
- ✓ **ESA's Sentinel program:** The Sentinel program is a series of satellites that are being deployed to monitor the Earth's environment. The Sentinel satellites are in sun-synchronous orbits so that they can provide consistent data for monitoring changes over time.

- Sun-synchronous satellites are an important tool for Earth observation and environmental monitoring. They provide us with a unique perspective on our planet and allow us to track changes over time.

5. ORBITAL PERTURBATIONS AND MANEUVERS

- Orbital perturbations and maneuvers are critical aspects of satellite and spacecraft operations in space.
- Perturbations refer to small forces or influences that can affect the motion of an object in orbit, causing deviations from its ideal path.
- Maneuvers, on the other hand, involve intentional changes in a spacecraft's trajectory or orientation to achieve specific mission objectives or to counteract the effects of perturbations.
- Orbital perturbations are small deviations from the two-body orbit motion. The two-body orbit motion can be expressed by the conic solutions (ellipse, hyperbola, and parabola) in closed form.

➢ Orbital Perturbations:

- **Gravitational Perturbations:**
  - ✓ **Solar Gravitational Effects:** The gravitational pull from the Sun can perturb an object's orbit, leading to changes over time.
  - ✓ **Lunar Gravitational Effects:** The Moon's gravitational influence can cause perturbations, especially in low Earth orbit.
  - ✓ **Atmospheric Drag:** In low Earth orbit (LEO), the presence of a tenuous atmosphere can exert drag on a spacecraft, causing it to lose altitude and orbital energy.
  - ✓ **Earth's Oblateness (J2Effect):**
  - ✓ Earth is not a perfect sphere, and its equatorial bulge introduces perturbations, known as the J2 effect, affecting the shape of orbits.
  - ✓ **Radiation Pressure:** Solar radiation can exert pressure on a spacecraft, causing small changes in its orbit.

- **Third Body Perturbations:**
  - ✓ The gravitational influence of other celestial bodies, such as planets, can induce perturbations.

➢ **Orbital Maneuvers:**

- **Station - Keeping:** Satellites in geostationary orbit require periodic maneuvers to counteract gravitational and other perturbations to maintain their orbital positions.
- **Rendezvous and Docking:** Spacecraft may perform maneuvers to rendezvous and dock with another object, such as a space station or another satellite.
- **Orbit Insertion:** Maneuvers are conducted during launch or in space to insert a satellite into its designated orbit.
- **Plane Change:** Changing the inclination of an orbit requires a significant amount of energy. This maneuver is often performed during the launch phase.
- **Deorbit and Reentry:** Controlled maneuvers are conducted to bring a satellite or spacecraft out of orbit for controlled reentry into Earth's atmosphere.
- **Collision Avoidance:** Satellites may perform maneuvers to avoid collisions with other objects in space, especially in crowded orbits.
- **Trajectory Correction Maneuvers (TCM):** Small maneuvers are executed to correct the trajectory of a spacecraft during its journey.
- **Escape Maneuvers:** Spacecraft leaving Earth's orbit for deep space may execute escape maneuvers to achieve the required velocity.

➢ **Strategies to Counteract Perturbations:**

- **Active Orbit Control:** Using thrusters or reaction wheels to actively control and adjust the spacecraft's orbit.
- **Gravity Assist Maneuvers:** Utilizing the gravitational pull of a celestial body to alter a spacecraft's trajectory.
- **Solar Sail Technology:** Employing large, lightweight sails that use pressure from solar radiation for propulsion.

6. LAGRANGE ORBITS:

- Lagrange points are specific positions in space where the gravitational forces of two large bodies, such as Earth and the Moon or Earth and the Sun, balance the centrifugal force felt by a smaller object, like a satellite or spacecraft.
- There are five Lagrange points in any two-body system.
- In the Earth-Sun system, for example, they are denoted as L1, L2, L3, L4, and L5.
- However, L1, L2, and L3 are often considered more practically significant for space missions.

➢ **Lagrange Points:**

- **L1 (Lagrange Point 1):**
  - ✓ Located along the line defined by the two large bodies, beyond the smaller of the two.
  - ✓ In the Earth-Sun system, an object at L1 remains in line with the Earth and the Sun and is often used for solar observatories.

- **L2 (Lagrange Point 2):**
  - ✓ Also, along the line defined by the two large bodies but on the opposite side of the smaller object.
  - ✓ L2 is often used for space telescopes as it allows an uninterrupted view of the night sky.
- **L3 (Lagrange Point 3):**
  - ✓ Opposite to L1, it's along the line but farther away from the larger of the two bodies.
  - ✓ L3 is not as commonly used in practice due to stability concerns.
- **L4 and L5 (Lagrange Point 4 and Point 5):**
  - ✓ Form an equilateral triangle with the two large bodies.
  - ✓ These points are stable and are sometimes used for the placement of satellites in celestial orbits.

- Objects placed at Lagrange points tend to stay in relatively constant positions with respect to the two large masses, making them valuable locations for certain types of space missions.
- They provide a stable environment for spacecraft to remain in fixed relative positions, which is beneficial for various applications such as space telescopes and interplanetary probes.

➢ **Orbits Around Lagrange Orbits:**

- While not commonly termed as "Lagrange orbits," spacecraft can be placed in orbits around Lagrange points.
- These orbits can be stable or unstable, depending on the specific Lagrange point.
- The stability of these orbits allows for long-duration missions without significant fuel consumption.
- **Halo Orbits:** Orbits around L1, L2, and L3 (particularly L1 and L2) are often referred to as halo orbits. These are three-dimensional, periodic orbits that allow a spacecraft to "hover" near the Lagrange point.
- **Lissajous Orbits:** Orbits around L4 and L5 are often called Lissajous orbits. These are also three-dimensional orbits but have a more complex shape compared to halo orbits.
- The use of orbits around Lagrange points is common in space missions, especially for observatories and satellites where a stable and predictable position relative to Earth and the Sun is advantageous.