1. Space Technology

1.1. Meaning

- Space Technology is the **exploration and utilisation of outer space** by the systematic application of engineering and scientific disciplines.
- It includes space vehicles such as spacecraft, satellites, space stations, orbital launch vehicles and a wide variety of other technologies including support infrastructure equipment, and procedures.

1.2. Applications of Space Technology

Agriculture

- Space-based technology is of value to farmers, agronomists, food manufacturers and agricultural policymakers to enhance production and profitability.
- Remote sensing satellites provide key data for **monitoring soil, snow cover, drought and crop development.**
- Rainfall assessments from satellites, for example, help farmers plan the timing and amount of irrigation they will need for their crops.
- Accurate information and analysis can also help **predict a region's agricultural output** well in advance and can be critical in anticipating and mitigating the effects of food shortages and famines.

Global Health

- Information from remote sensing technologies can be applied **to study the epidemiology of infectious diseases.**
- Data can be used to monitor disease patterns, understand environmental triggers for the spread of diseases, predict risk areas and define regions that require disease-control planning.
  - This **tele-epidemiology** is of particular relevance in developing countries like India, where infectious diseases remain among the top causes of death.
- By bringing medical specialists into virtual contact with patients and health practitioners in remote, rural and underserved areas, **tele-health and tele-medicine** can improve access to medical and health-related services.

Environment

- Space-based technologies have enhanced **scientific understanding of water cycles, air quality, forests and other aspects** of the natural environment.
- These surveying and monitoring tools provide valuable information on the state of ecosystems, which offers objective support for positive environmental action, including **conservation and sustainable resource management.**

Sustainable Development

- Earth observation is a vital tool for facilitating the sustainable development of the world's cities.
- Sustainable Goals and their universality can only be attained through **readily available data from affordable sources** such as satellite images and similar commonly available sources.

- Decision makers use this information to understand trends, evaluate needs, and create sustainable development policies and programmes in the best interest of all populations.

Disaster Management

- Space-based technologies can **contribute to all phases of the disaster management** cycle, including prevention, preparedness, early warning, response and reconstruction.
- Before a disaster takes place, remotely sensed data provides information for systems and models which can **predict disasters and provide early warnings.**
- Various kinds of satellites, including meteorology and geophysics satellites provide operational capability for storm warnings and search-and-rescue efforts.

Education

- Technologies like web and videoconferencing and voice over Internet protocol allow educators and students to create virtual classrooms, regardless of physical locations.
- **Tele-education** has become so popular that many institutions worldwide now offer distance education options ranging from the simplest instruction to degree and doctoral programs.

Human Settlements

- Space-based technologies provide unique tools for planning socially and environmentally sustainable human settlements.
- Central government policymakers, city planners, engineers and landscape architects are among those who use remote sensing tools that **measure and monitor existing patterns of land use** and infrastructure development.

Communication

- Space-based technologies, namely communications satellites, enable global telecommunications systems by relaying signals with voice, video and data to and from one or many locations.
- While Earth-based alternatives to space technologies are sometimes possible, space-based technology can often **reduce infrastructure requirements** and offer more **cost effective service delivery options.**
- For instance, instead of constructing a series of transmission and relay towers to broadcast television programmes to far-to-reach places, one satellite dish could be provided to a remote community to pick up broadcast signals sent from a satellite.

Humanitarian Assistance

- Space-based communications technologies often provide valuable assistance with logistical planning, rapid decision-making and resource allocation and can thereby improve the ways in which humanitarian assistance is designed and delivered.

2. Orbits and its types

2.1.What is an orbit?

- An orbit is a **regular, repeating path** that an object in space takes around another one **due to gravity.**
- **An object in an orbit is called a satellite.** A satellite can be natural, like the moon, or human made.

2.2. Shape of the orbit

- All orbits are **elliptical**.
- For the planets, the orbits are almost circular.
- The orbits of comets have a different shape. They are highly **eccentric** or "squashed."
- The **closest point a satellite** comes to Earth is called its **perigee**. The **farthest point** is the **apogee.**
- For planets, the **point in their orbit closest to the sun** is **perihelion.** The **farthest point** is called **aphelion.**

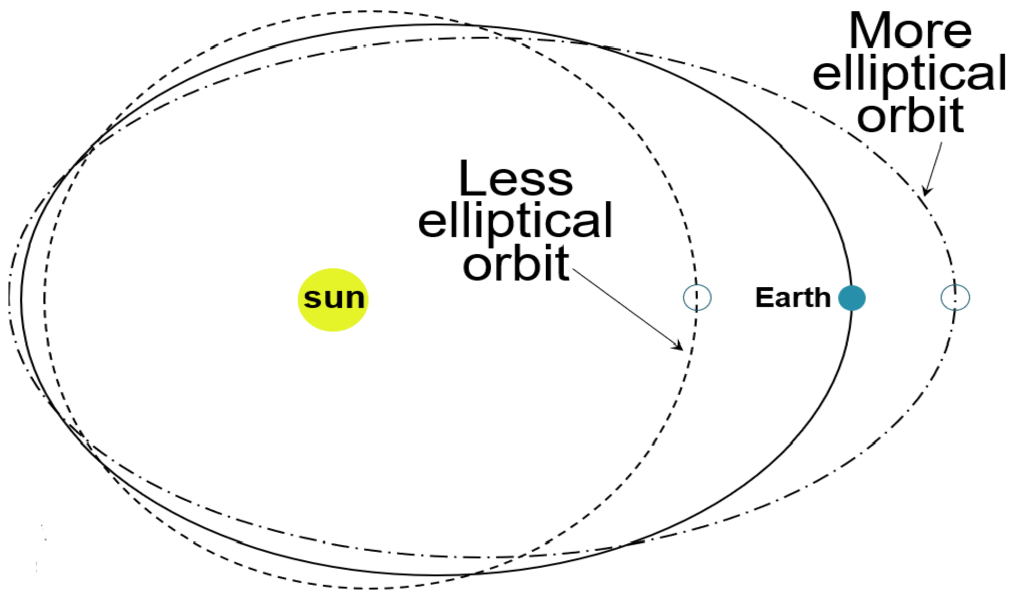

Figure.1. Shape of the Orbit

2.3. Types of Orbits

2.3.1. Low Earth Orbit (LEO)

- A low Earth orbit (LEO) is an orbit that is relatively **close to Earth's surface.**
- It is normally at an altitude of less than 1000 km and could be as low as 160 km above Earth.
- Unlike satellites in GEO that must always orbit along Earth's equator, LEO satellites **do not always have to follow a particular path** around Earth in the same way – their plane can be tilted.
- LEO is the orbit most **commonly used for satellite imaging,** as being near the surface allows it to take images of higher resolution.
- It is also the orbit used for the International Space Station (ISS), as it is easier for astronauts to travel to and from it at a shorter distance.
- Individual LEO satellites are **less useful for tasks such as telecommunication.**
  - They move so fast across the sky and therefore require a lot of effort to track from ground stations.
- Therefore, communications satellites in LEO often work as part of a large combination or constellation of multiple satellites to give constant coverage.

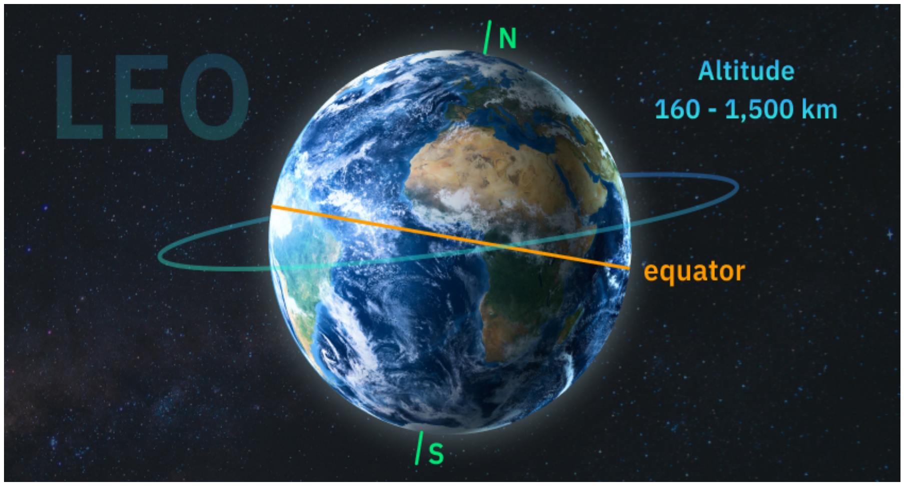

Figure.2. Low Earth Orbit

2.3.2. Medium Earth Orbit (MEO)

- Medium Earth orbit comprises a wide range of orbits anywhere **between low Earth and geostationary orbits.**
- MEO is similar to LEO in that it also does **not need to take specific paths around Earth,** and it is used by a variety of satellites with many different applications.
- Positioning and navigation services, like GPS (Global Positioning System), extensively use MEO type of satellites because MEO satellites are located at a medium altitude, so they have a wider field of view.
- This allows the satellites to pick up a greater number of navigational signals, resulting in a more precise and reliable navigational system.

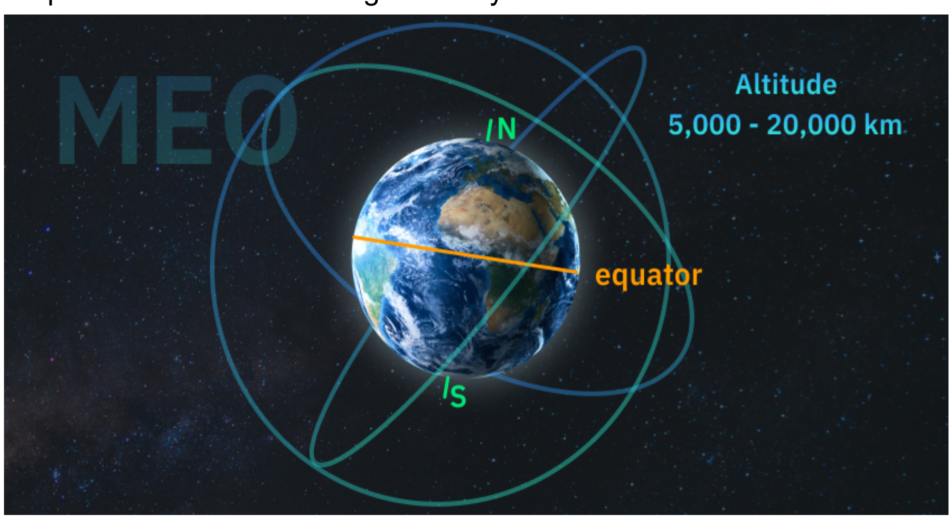

Figure.3. Medium Earth orbit

2.3.3. Geosynchronous Orbit (GSO)

- When a satellite reaches exactly **42,164 kilometres from the centre of the Earth** (about 36,000 kilometres from Earth's surface), it enters a spot in which its orbit matches Earth's rotation. This special, high Earth orbit is called geosynchronous.
- Satellites in GSO **take 24 hours to complete one rotation** around the Earth.

- Most of the communication satellites are placed in the geosynchronous orbit so that they appear stationary at the same point in the sky, making it easier for ground-based satellite antennas to communicate with them.
- A satellite in a circular geosynchronous orbit directly over the equator (eccentricity and inclination at zero) will have a geostationary orbit that does not move at all relative to the ground.

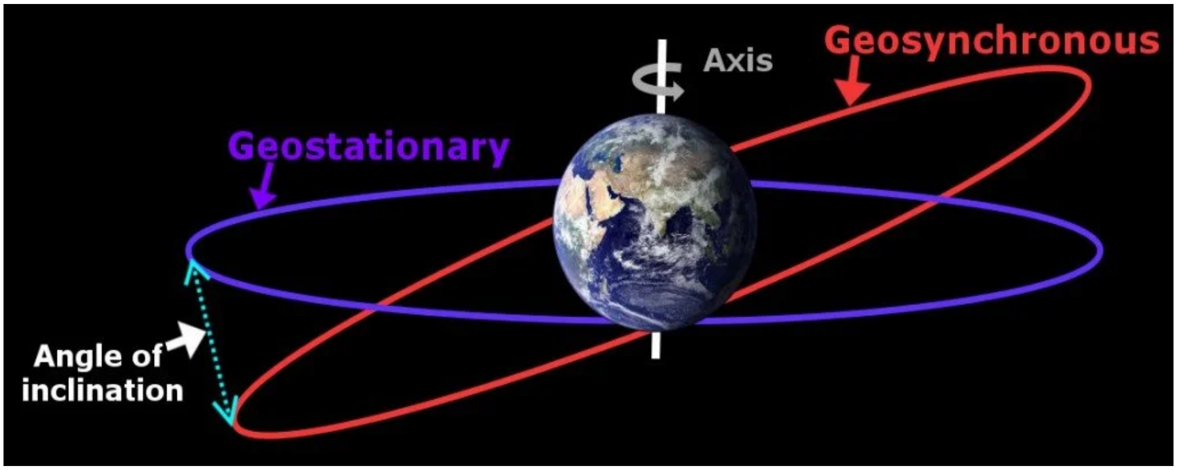

Figure.4. Geosynchronous Orbit

2.3.4. Geostationary Orbit (GEO)

- Satellites in geostationary orbit (GEO) circle Earth above the equator **from west to east following Earth's rotation** and travel at exactly the **same rate as Earth, i.e., 23 hours 56 minutes and 4 seconds.**
    - This makes satellites in GEO appear to be 'stationary' over a fixed position.
- The speed of GEO satellites should be about **3 km per second at an altitude of 35,786 km** to perfectly match the Earth's rotation.
- **Telecommunications satellites** are often placed in a GEO so that earth-based satellite antennas (located on Earth) do not have to rotate to track them but can be pointed permanently at the position in the sky where the satellites are located.
- It can also be used in **meteorology** to keep an eye on the weather in particular regions and track the development of local patterns.
- The downside of GEO type of spacecraft for real-time communication is the **longer signal delay caused** by their great distance from Earth.

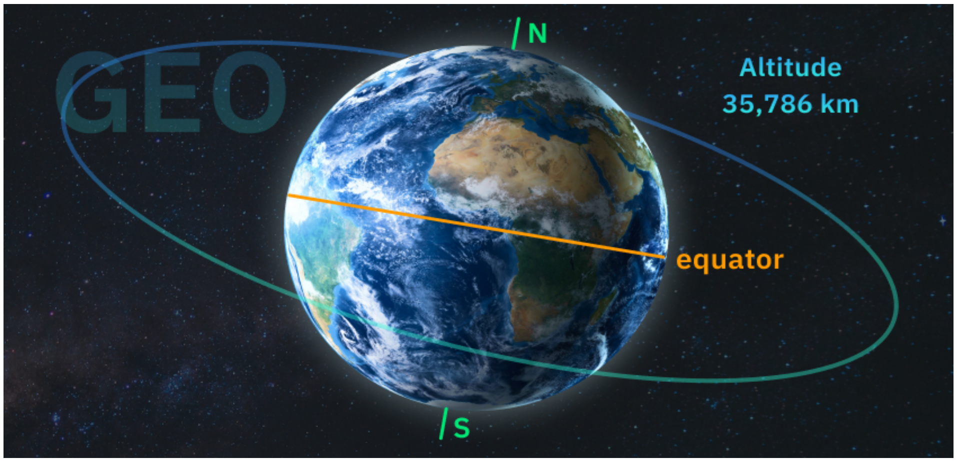

Figure.5. Geostationary Orbit

2.3.5. Sun-Synchronous Orbit (SSO)

- Satellites in Sun-synchronous orbit go from north to south across the polar regions at an altitude of 600 to 800 km above the Earth.
- The orbital inclination and altitude of SSO spacecraft are calibrated so that they **always cross any given location at precisely the same local solar time.**

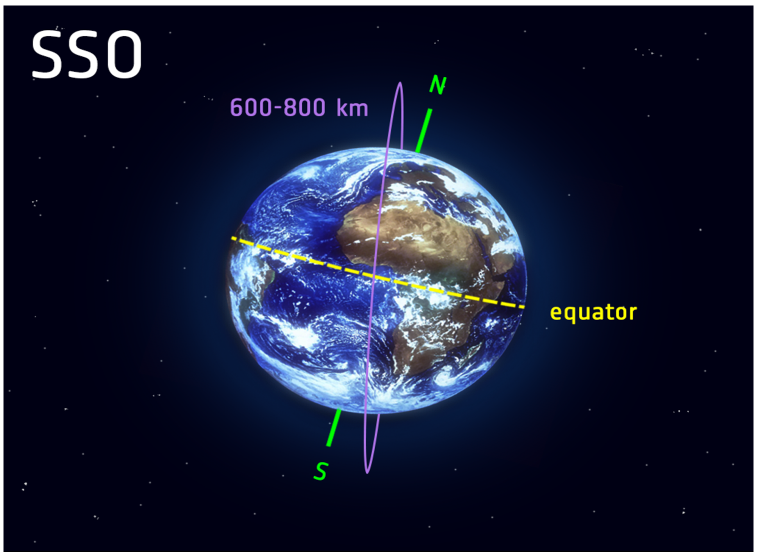

Figure.6. Sun-Synchronous Orbit

- Thus, the lighting conditions are consistent for imaging, making this type of satellite **ideal for earth observation and environmental monitoring.**
- Scientists use these image sequences to learn about the development of weather patterns, forecast cyclones, prevent wildfires and floods, and gather information on issues like deforestation and coastline changes.

2.3.6. Geostationary Transfer Orbit (GTO)

- Often, the satellites are placed on a transfer orbit; an orbit where, by using relatively little energy from built-in motors, the satellite or spacecraft can move from one orbit to another.
- This **allows a satellite to reach a high-altitude orbit** like GEO **without actually needing the launch vehicle** to go all the way to this altitude.

- Reaching GEO in this way is an example of one of the most common transfer orbits, called the geostationary transfer orbit (GTO).
- When the payload reaches the apogee at the GEO altitude of 35,786 km, it fires its engines in such a way that it enters onto the circular GEO orbit and stays there.

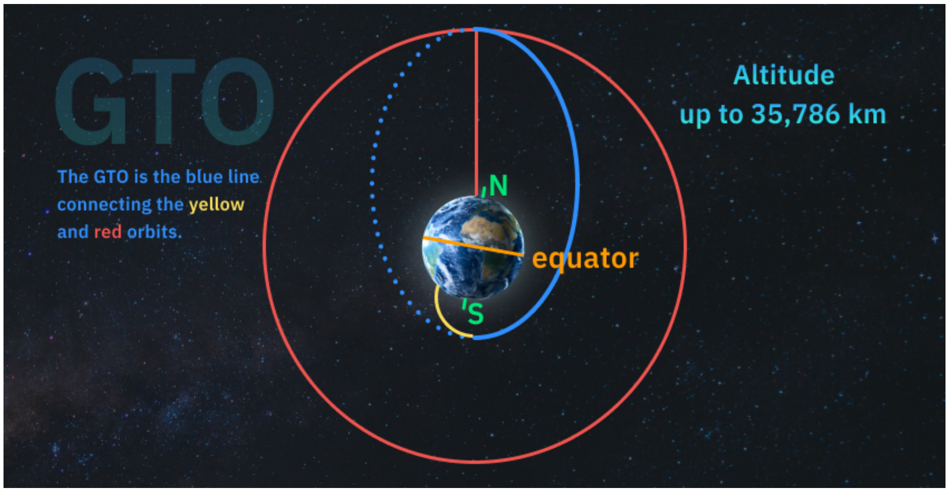

Figure.7. Geostationary Transfer Orbit

3. Lagrange Points

3.1.What is a Lagrange Point?

- A Lagrange point is a location in space where the **combined gravitational forces of two large bodies,** such as Earth and the Sun or Earth and the Moon, **equal the centrifugal force felt by a much smaller third body.**
- The interaction of the forces creates a point of equilibrium where a spacecraft may be "parked" to make observations.
- These points are named after **Joseph-Louis Lagrange,** an 18th-century mathematician who wrote about them in a 1772 paper concerning what he called the **"three-body problem."** They are also called **Lagrangian points and libration points.**

3.2. Different Points

- There are **five special points** where a small mass can orbit in a constant pattern with two larger masses. Of the five Lagrange points, **three are unstable and two are stable.**
- The unstable Lagrange points – labelled L1, L2, and L3 – lie along the line connecting the two large masses.
- The stable Lagrange points – labelled L4 and L5 – form the apex of two equilateral triangles that have the large masses at their vertices.

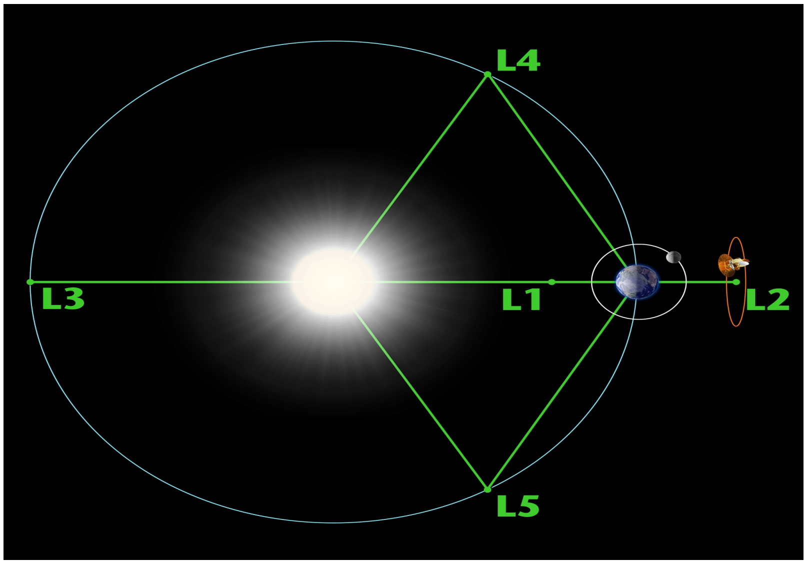

Figure.8. Lagrange Points

- **L1 point** of the Earth-Sun system affords an **uninterrupted view of the Sun,** and is currently home to the **Solar and Heliospheric Observatory Satellite** (SOHO). **Aditya-L1** of ISRO is positioned at the L1 point.
- **L2 point is ideal for astronomy** because a spacecraft is close enough to readily communicate with Earth, can keep Sun, Earth and Moon behind the spacecraft for solar power and provides a clear view of deep space for telescopes.
- **L3 lies behind the sun,** opposite Earth's orbit. For now, science has not found a use for this spot.
- **L4 and L5 points** are home to stable orbits so long as the **mass ratio between the two large masses exceeds 24.96.**
    - This condition is satisfied for both the Earth-Sun and Earth-Moon systems, and for many other pairs of bodies in the solar system.

4. Satellite Launch Vehicles

4.1. What are Launch Vehicles?

- Launch vehicles or launch systems, as the names imply, are **used to carry spacecraft from the surface of the Earth into space.**
- Most launch vehicles operate from a launch pad, supported by a launch control center and systems such as vehicle assembly and fueling.
- They are classified by their orbital payload capacity, ranging from small-, medium-, heavy- to super-heavy lift.

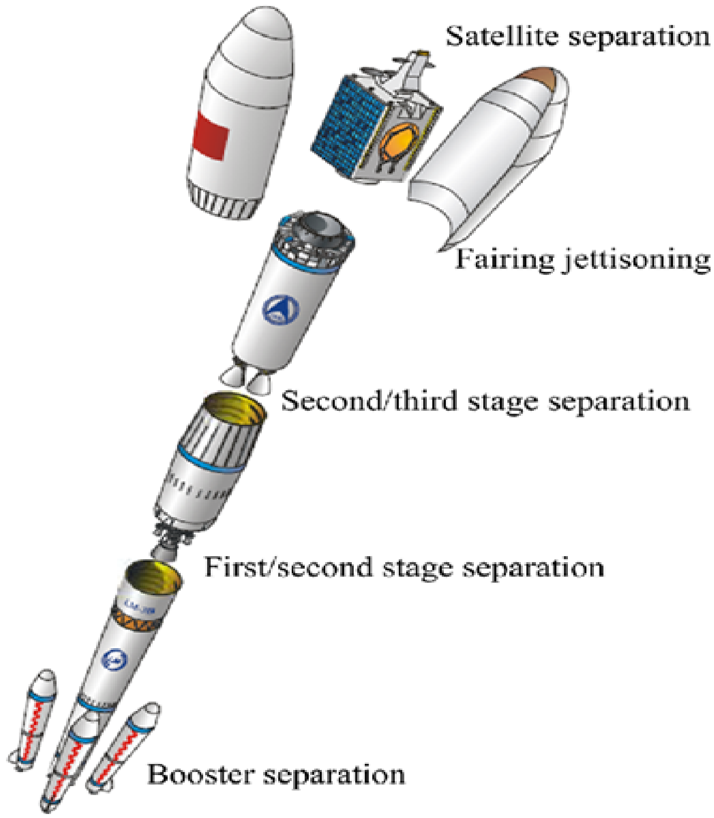

Figure.9. Structure of Launch Vehicle

4.2. Launching of Satellite

- The process of placing the satellite in a proper orbit is known as the launching process.
- A launch vehicle is a good illustration of **Newton's third law of motion,** i.e., "for every action, there is an equal and opposite reaction."
- In the case of a launch vehicle,
  - "Action" is the flow out the rear of the vehicle of exhaust gases produced by the combustion of the vehicle's fuel in its rocket engine, and
  - "Reaction" is the pressure, called thrust, applied to the internal structure of the launch vehicle that pushes it in the direction opposite to the exhaust flow.
- The launch of a spacecraft comprises a period of powered flight during which the vehicle rises above Earth's atmosphere and accelerates at least to orbital velocity.
- Powered flight ends when the rocket's last stage burns out, and the spacecraft separates and continues in freefall.

4.3. Types of Satellite Launch Vehicle

The launch vehicles are basically multi-stage rockets and thus are mainly classified as:

Expendable Launch Vehicles (ELV)

- An expendable launch vehicle is a **single-use launch vehicle** usually used to launch a payload into space. Most satellites are launched into orbit using expendable launchers.
- Expendable launch vehicles typically consist of stages which are discarded one by one, in order not to have to carry and accelerate parts that are no longer needed.
- The ELV contains three stages. First and second stages of ELV raise the satellite to about 50 miles and 100 miles. Third stage of ELV places the satellite in transfer orbit.

- Once the satellite reaches the transfer orbit then the task of the launch vehicle will get completed and the various parts will get destroyed by themselves generally by falling to the earth.

Reusable Launch Vehicles (RLV)

- This category of launch vehicles **offers reusability** and so can be used various times for launching satellites in space.
- Generally, this type of launch vehicle will return back to earth after leaving the satellite in space. Sometimes it is given the name, space shuttle.
- Functions of RLV are similar to the functions of first and second stages of ELV.
- However, in the third stage, the satellite is inserted with a cargo bay and the satellite gets ejected from the cargo bay when the RLV attains an elevation of around 150 to 200 miles.
- Once this height is achieved then the shuttle will be fired thereby placing the satellite in the transfer orbit. After this, the space shuttle will return back to earth for reuse.

4.4. Advantages and Limitations of Satellite Launch Vehicles

Launch Vehicles	Advantages	Limitations
Expendable Launch Vehicles	● Simpler in design than reusable launch systems. ● Lower Development Costs. ● Low risk of mission failure. ● Short time to launch. ● Offer greater payloads.	● Usable only once. ● Have a significantly higher per-launch cost than modern reusable vehicles.
Reusable Launch Vehicles	● Lower Cost per Launch. ● Improved Environmental Footprint. ● Reduced material cost due to reusability. ● Increased Launch Flexibility.	● Landing and recovery requires a high degree of precision and accuracy. ● High Development Costs. ● Technical Complexity.