Contents

Introduction

We all understand that Newton's three laws of motion sum up the basic principles of motion. Before we move ahead, we need to take a look at these laws.

Newton's First law: *Every object* ***continues in its state*** *of rest or of uniform motion in a straight line if no net force acts upon it.*

This is the classic law which we all have studied in our school days and reminds us of "momentum". When a passenger in a fast moving bus falls forward when it stops suddenly, it reminds us of the first law of Newton. Similarly a person getting down from a moving bus has to run a little so that he can 'maintain' the momentum for a while. Here we have to note that "Momentum" is the product of mass and velocity. It is shown as below:

Momentum=mass x velocity

Newton's Second Law: *The rate of change of momentum of a body is proportional to the applied force and takes place in the direction of the force.*

The above law leads to an implication that force is proportional to the product of mass and acceleration. This means that

F=m x a

Where F=Force
M= mass and
a= Acceleration

This means that if same force applies on two products of mass X and 2X, then the acceleration produced in case of X will be twice of that in case of 2X.

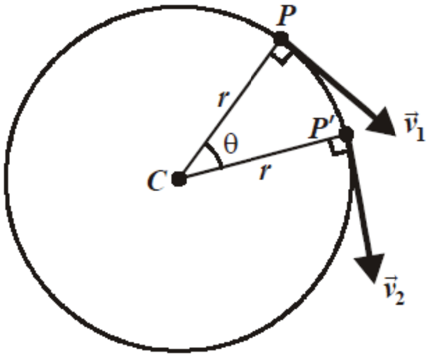
Newton's Third Law: *To every action there is an equal and opposite reaction.*

The above law implies that if a body A exerts a force on body B, then body B exerts an equal and opposite force on A.

The above law is of very interest and rocket science and astronomy. A rocket contains the fuel which burns to produce a high velocity blast of the hot gases. The large force generated by the chemical reaction, propels out the hot gases through the tail nozzle with very high velocity, leading to a reaction in equal and opposite direction that propels the rocket forward.

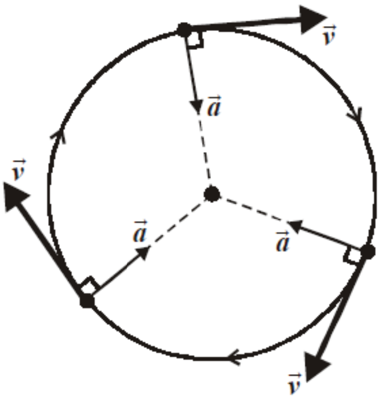
The third law of Newton also applies to the circular motion. When we whirl a stone around by a string, our hand exerts an inner pull to keep it moving around in a curve. It is called Centripetal force. Centripetal Force means "seeking centre" and is the inward force required to keep a particle moving in circular path.

Rather than going to the abstract details of Physics, here we would note that the velocity of the particle is



constant in magnitude but changes in direction as shown in the figure. In this figure, the object moves from P to P'. The velocity at P is v_1 , a vector tangent to the curve at P. The velocity at P' is v_2 , a vector tangent to the curve at P'. Here we note that as the speed of the particle is constant, the vectors v_1 and v_2 are equal in magnitude, but their directions are different.

Now we know that acceleration is the **rate of change of velocity over time**, this means that there is an acceleration in the body. The direction of this acceleration denoted by $\vec{a}$ is instantaneously along a radius inward toward the centre of the circle. This is shown by the following figure:



The above radial acceleration is called the "centripetal acceleration" and its value is shown as the following:

$$\vec{a} = \frac{v^2}{r}$$

Where v is the velocity of the particle or object and r is the radius or length of the string in above case. We here have to note that acceleration resulting from a change in direction of a velocity is just as real and just as much acceleration in every sense as that arising from a change in magnitude of a velocity. The velocity, being a vector, can change in direction as well as magnitude. If a physical quantity is a vector, its directional aspects cannot be ignored, for their effects will prove to be every bit as important and real as those produced by changes in magnitude.

We note that when the object moves from P to P', there is a change in the angle Θ. The rate of change of angle in time is called the angular velocity. Thus angular velcoty is the vector quantity which specifies the angular speed of an object and the axis about which the object is rotating. The SI unit of angular velocity is radians per second, however we can used other units such as degrees per second, revolutions per second, revolutions per minute, degrees per hour, etc. Angular velocity is usually represented by the symbol omega (ω)

The ω is expressed by the following formula:

$$\omega = \frac{v}{r}$$

So, we can write that v=ωr

Thus we arrive at the following formula

$$\vec{a} = \frac{v^2}{r} = \frac{\omega^2 r^2}{r} = \omega^2 r$$

We have studied above that

F=m x a

So,

$$\mathbf{F = m\omega^2 r \text{ or } m\frac{v^2}{r}}$$

The core principle of arriving at above formula is to understand that an object would like to move in a straight line but the above force would be required to keep it departing from the straight motion. The above force is responsible for the circular motion and is known as "centripetal force".

Here we take an example. We suppose that the mass of the object is 5kg and it moves at a constant speed of 6 meters per second in a circular path of radius 2 meters. Then the centripetal force would be:

$$\mathbf{F = m\omega^2 r \text{ or } m\frac{v^2}{r} = 5x\frac{6^2}{2} = 90 \text{ Newton}}$$

Now we take this simple Numerical Question:

We suppose that we have a string which can be broken if we exert a force of 1500 Newton. If we attach an object with mass 8.3 kilogram at one of its end and whirl it horizontal direction in a circle of 80 cm, then what should be the maximum speed it can have, so that the string does not break.

The above equation will be arranged as follows:

$\mathbf{F = m\omega^2 r \text{ or } m\frac{v^2}{r}}$

$\mathbf{1500 = 8.3 \text{ x } \frac{v^2}{0.8}}$

So

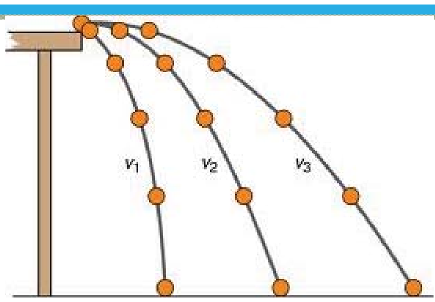
$v^2 = \frac{1500 \ x \ 0.8}{8.3} \approx 144$

v = 12 meter per second.

The above description was taught to us in our school days to explain why a bucket carrying water is, when rotated in a vertical circle does not fall downward when the bucket is at highest point. This is because the necessary "centripetal" force is Provided by the motion.

When moon revolves around the earth, centripetal force is provided by gravitational force of Earth on moon. Similar is with artificial satellites, because as they move around the earth, the force of attraction of earth on the satellite provides necessary centripetal force.

Now, we take another example. When we throw a stone with some speed in the horizontal direction, it will follow a curved path and fall on the ground. When we throw the stone with a greater speed, it will follow a curved path that is even bigger than the previous one. Thus, greater is the speed, greater is the radius of the curved path as shown below:



Now, if we have such a powerful device to throw this stone with such a tremendous speed that radius of the curved path it follows becomes little bigger than the radius of earth, we cannot expect it to return to earth. Rather, it will keep on revolving around the earth. This is how the artificial satellites work. They are projected with such a speed that the "radius" of their curved path is "greater" than the radius of earth.

Here we need to note that

- Gravitational pull of earth would provide the necessary centripetal force that is needed to keep it in its particular orbit

Here, we should not that speed of the satellite is carefully chosen so that it provides necessary force to keep it revolving. Here we note that:

F (Gravitational) = **F** (centripetal)

So $m\frac{v^2}{r}$ **= mg**

∴

$v^2 = rg$

$V = \sqrt{rg}$

From the above formula, we don't find **m ,** which means that the speed of an artificial satellite does NOT depend upon its mass. This implies that at a particular distance from earth, all objects would move at same speed of revolution.

But the above formula says that v is dependent upon r. The above formula now we derive again as follows:

F (Gravitational) = **F** (centripetal)

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

In the above formula, G is the universal gravitational constant and M is the mass of earth. We arrive at v as follows:

$$m\frac{v^2}{r} = \frac{GMm}{r^2}$$

$$v = \sqrt{\frac{GM}{r}}$$

Here we come to two conclusions:

- v is dependent upon r because **V=** $\sqrt{rg}$
- **v is inversely proportional to r because** $v = \sqrt{GM/r}$

Here we conclude that higher the orbit is, lower is its speed. When we whirl a small string with an small object tied at one of its and also allow to get it rolled around our finger, we find that the smaller the radius of the circle is, higher is its speed.

- So, when a satellite moved from higher orbit to lower orbit, its speed increases.

Now, most of us know that g= 9.8 square meters per second and radius of earth is 6.4 x 10^6 meters, we conclude that

V = $\sqrt{rg}$ =$\sqrt{6.4 \times 10^6 \times 9.8}$ **= 7.9 x 10^3 meters per second = 7.9 kilometers per second**

Thus, if we throw the satellite of a speed lesser than 7900 meters per second or 28500 kilometers per hour, it will simply fall on earth. But the speed higher than this will produce an elliptical orbit. However if this speed is more than 11.2 kilometers per second , it will escape the earth's gravitation field and will never come back.

This value of 11.2 kilometers per second is known as escape velocity and it explains why we have the gaseous atmosphere which does not go away from earth. On moon the escape velocity is 1.9 kilometers per second and molecules of any gas formed on moon would have velocity more than this value and that is why moon has not gaseous atmosphere.

Launching a satellite needs tremendous forces, because providing it an speed of 28500 kilometers per second is not an easy task.

- Earth is not round and we all know that its radius on poles is smaller than its radius on equators. The away we move from centre of earth, lower is the gravitational force and this is the reason that the gravitational pull is minimum at Equator. So, **Equator or the places near to equator are found suitable for launching the satellites** as it will save efforts.
- We know that Earth rotes from west to east , the satellites are launched in Eastward direction so that the speed of earth's rotation which comes nearly 462 meters per second[1] will provide it additional push.

Understanding Orbits

The core principle of an orbit is that as a satellite or object moved tangentially, it falls toward the earth / other body, but it moved so quickly that earth / body will curve away beneath it. Thus we can understand that gravity pulls this object into a curved path as it attempts to fly off in a straight line. A satellite has enough tangential velocity to miss the orbited object, and will continue falling indefinitely.

In other words, when the satellite is moving in the orbits, it stays in position because the centripetal force on the satellite balances the gravitational attractive force of the earth. This balance depends on the following:

- ✓ Distance from the earth
- ✓ Tangential speed of the satellite
- ✓ Earth's radius
- ✓ Gravitational force of the earth.

But it does not depend upon:

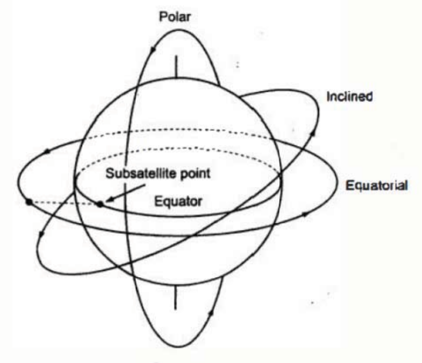
- ✖ Mass of the satellite
- ✖ Size of the Satellite

Please note that we select the satellites on the basis of the following:

- ✓ Its usage (communication or Earth Observation or other uses such as Satellite killers)
- ✓ Transmission path loss
- ✓ Delay time
- ✓ Period for which satellite is visible from a particular point on earth.

There are three major types of orbits viz. Polar, Inclined and Equatorial. The Polar Orbits cover the poles, Equatorial are above the equator and inclined orbits are inclined from the equatorial orbit. They are shown as below:

[1] 40000 x 1000 ÷24÷60÷60=462 (though exact speed is 465.1 meters per second)



Geostationary

If we need a satellite for the purpose which needs this satellites to remain at a particular distance from earth at all the time, then we need **circular orbits so all the points on circular orbit are at equal distance from earth's surface**. The **circular equatorial orbit** is exactly in the plane of equator on the earth. If the satellite is moving in the circular-equatorial orbit and its angular velocity is equal to earth's angular velocity, the satellite is said to be moving along with the earth. This satellite would appear stationary from the earth and this orbit would be called **Geostationary Orbit**. Thus the features of geostationary satellite are as follows:

- ✓ The **orbit is circular**
- ✓ The **orbit is in equatorial plane** i.e. directly above the equator and thus **inclination is zero**.
- ✓ The **angular velocity of the satellite is equal to angular velocity of earth**
- ✓ Period of **revolution is equal to period of rotation** of earth.
- ✓ Finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1 seconds
- ✓ There is **ONLY one** geostationary orbit.

Geosynchronous

But here, we need to understand the difference between the geostationary and geosynchronous orbits. We should note that while other orbits may be many, there is ONLY ONE Equatorial orbit, i.e. the orbit which is directly above the earth's equator. Sometimes we send a satellite in the space which though has a period of revolution is equal to period of rotation of earth, but its orbit is **neither equatorial nor Circular**. So, this satellite will finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1 seconds, yet it does NOT appear stationary from the earth. **It looks oscillating** but NOT stationary and that is why it is called **Geosynchronous.** So, the main features of a geosynchronous satellite are as follows:

- ✓ The orbit is **NOT circular**
- ✓ The orbit is **NOT in equatorial plane** i.e. directly above the equator, it's **in inclined orbit**
- ✓ The **angular velocity of the satellite is equal to angular velocity** of earth
- ✓ **Period of revolution is equal to period of rotation of earth.**
- ✓ Finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1 seconds
- ✓ There are **many geosynchronous orbits**.

Please note **that it is practically NOT possible to achieve an absolute geostationary orbit. So, the terms geostationary and geosynchronous are used alternatively.**

Inclined

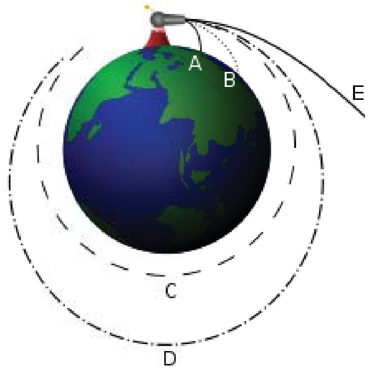
An inclined orbit is used to cover the Polar Regions. It's not a very popular orbit and used not very frequently. The height of the inclined orbit is kept such that it covers the required area of the region of interest. The time for which the satellite is visible to the point on the earth is also controlled. Satellite cannot remain in continuous contact with the point on the earth if rotating in inclined orbit. Sometimes the inclined orbit is also called elliptical inclined orbit.

Polar Orbit

The Polar Orbit is not much suitable for communication purposes because it moved in a different direction than that of direction of earth's rotation. So, the use of Polar satellites depends upon their arrival at a particular point on earth at a particular point. The Polar orbits are used for special applications like navigational satellites.

Circular and Elliptical Orbits

The concept of Circular and Elliptical Orbits was explained by Newton and is known as **Newton's cannonball**. According to this explanation, if a gravitational force acts on the cannon ball, it will follow a different path depending on its initial velocity.

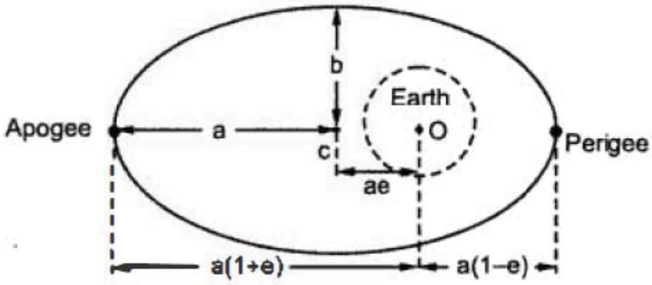


1. If the speed is low, it will simply fall back on Earth. (A and B)
2. If the speed is the orbital velocity at that altitude it will go on circling around the Earth along a fixed circular orbit just like the moon. (C)
3. If the speed is higher than the orbital velocity, but not high enough to leave Earth altogether (lower than the escape velocity) it will continue revolving around Earth along an elliptical orbit. (D)
4. If the speed is very high, it will indeed leave Earth. (E)

The above four positions have been depicted in this image (source: Wikimedia commons)

Elliptic orbit is also known as **Kepler Orbit.** We have three concepts of orbits viz. **Pure circular, elliptic and parabola**. The parabola is no longer a closed circuit. The difference between these three is of **Orbital eccentricity**. Orbital eccentricity refers to the ratio by which its orbit deviates from a perfect circle. Orbital eccentricity is **0 for perfectly circular, and 1.0 is a parabola**.

When the Orbital eccentricity is between 0 and 1, it is an elliptical orbit. When a satellite revolves around earth in an elliptical orbit, its nearest and farthest points from earth are known as Perigee and Apogee respectively as shown in the following figure:



In the above figure, the lengths a and b are known as **semi major** and **semi minor** axis.

To understand the orbital mechanics, we need to go thru the Kepler's laws. Johannes Kepler was a German mathematician and astronomer. He is best known for his eponymous laws of planetary motion, codified by later astronomers, based on his works *Astronomia nova*, *Harmonices Mundi*, and *Epitome of Copernican Astronomy*. He predated Newton and provided one of the foundations for Isaac Newton's theory of universal gravitation.

Kepler's Laws

The three laws of Kepler are discussed briefly here:

Kepler's First Law

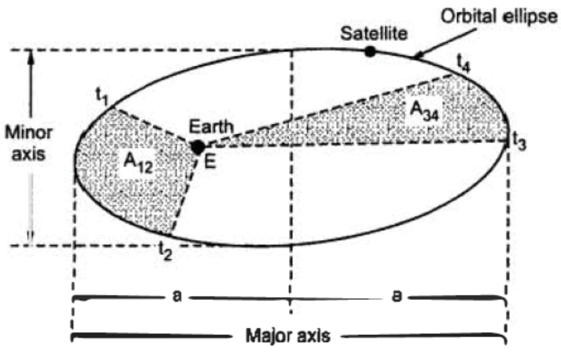
- ✓ When small body rotates around large body, it follows elliptical path. One of the foci of this elliptical path is at the center of mass of large body. Kepler postulated it as follows:

  "The orbit of every planet is an ellipse with the Sun at one of the two foci."

  We are not going into the mathematical details as they are out of ambit of GS.

Kepler's Second Law

Kepler's second law states that "*A line joining a planet and the Sun sweeps out equal areas during equal intervals of time.*"



We can understand this law with the adjoining diagram. In this diagram, we see that the planet moves faster near the Planet so the same area is swept out in a given time as at larger distances, where the planet moves more slowly. In this diagram, the satellite sweeps area A_{34} in time t_3 to t_4 and sweeps an area of A_{12} from time t_1 to t_2. As per Kepler's second law if

$$t_1 - t_2 = t_3 - t_4,$$

Then $A_{12} = A_{34}$

The core principle behind above law is that the satellite has to move faster when it is closer to the planet so that it sweeps an equal area. The law is known as **Law of Equal areas**. Please note that area means the two lines as well as the arc.

Kepler's Third Law

Kepler's Third Law states that *"The Square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.".*

The above law is applicable to the motion of all planetary bodies such as moon around earth, earth around Sun, Mars around Sun etc.

In the above figure, semi-major axis has been shown by **a**. So, we can write this law as follows:

$$T^2 \propto a^3$$

$$T^2 = k\, a^3$$

Where: **T** is the orbital period of the Planet (or satellite in case of earth / planets) and **a** is the semi major axis.

But in the above equation what should be the value of k, it was not possible to calculate at that time.

Newton used the third law as one of the pieces of evidence used to build the conceptual and mathematical framework supporting his law of gravity. So, when we consider Newton's laws of motion, and consider a hypothetical planet that happens to be in a perfectly circular orbit of radius r, and then we have:

$$F = m\frac{v^2}{r}$$

For Sun's force on the planet.

We have also derived above that for circular motion of a planet:

F (Gravitational) = **F** (centripetal)

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

V is the speed. Now, we know that the speed v of the planet in its orbit is equal to the circumference of the orbit divided by the time required for one revolution T. so v=2πr/T. So, the above formula becomes as follows:

$$\frac{GMm}{r^2} = m\frac{\left(\frac{2\pi r}{T}\right)^2}{r}$$

From the above formula, we can derive the value of **T^2** as follows

$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$$

The above mathematical derivation is suitable for circular as well as elliptical orbits. Now we know that geostationary satellite follows a **circular, equatorial, geostationary** orbit, without any inclination, so we can apply the Kepler's third law to determine the geostationary orbit. Since, the path is circle, its semi-major axis will be equal to the radius of the orbit.

Now, it has already been calculated that Earth completes one rotation on its polar axis in 23 hr 56 min and 4.09 sec, which comes out to be 86164.09 seconds. So, the period of rotation of the Geostationary satellite should be 86164.09 seconds.

This means that

T=86164.09 seconds

Now we use this formula

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$r^3 = \frac{GM}{4\pi^2}$$

$$r^3 = \frac{6.67x10^{-11}x5.983x10^{24}x86164.09}{4\pi^2}$$

$$r^3 = 7.546\text{x}10^{22}$$

$$r = 4.23\, x10^7 \text{ meters}$$

$$r = 42300\ kilometers$$

The above derivation gives the height of the Geostationary orbit. Now, please note that the above height includes radius of Earth which is 6,384 km. When we deduct it from the calculated height we get 35916 Kilometers. The precise height is altitude of 35,786 km (22,236 mi) above ground.

Orbital speed (how fast the satellite is moving through space) is calculated by multiplying the angular speed by the orbital radius:

$$v = \omega r \approx 3.0746 \text{ km/s} \approx 11068 \text{ km/h} \approx 6877.8 \text{ mph}.$$

Orbiting at the height of 22,282 miles above the equator (35,786 km), the satellite travels in the same direction and at the same speed as the Earth's rotation on its axis, taking 24 hours to complete a full trip

around the globe. Thus, as long as a satellite is positioned over the equator in an assigned orbital location, it will appear to be "stationary" with respect to a specific location on the Earth.
Please note that a single geostationary satellite can view approximately **one third of the Earth's surface**. If three satellites are placed at the proper longitude, the height of this orbit allows almost all of the Earth's surface to be covered by the satellites.

What is the minimum number of artificial satellites required for communication throughout the globe?

It was first of all conceptualized by world famous science fiction writer Arthur C. Clarke who lived at his permanent residence in Colombo and died in 2008. Any of you, who read about this excellent author, would have easily ticked the correct option - 3 satellites.

Arthur C. Clarke described the concept of geostationary satellites in his work: "Extra Terrestrial Relays -Can Rocket stations give worldwide coverage? " This work was published in 1945. He said that *"A single station could only provide coverage to half of the globe and for a world service 3 would be required, though more could be easily utilized".*

The arrangement which was suggested by Clarke is shown in the following figure:

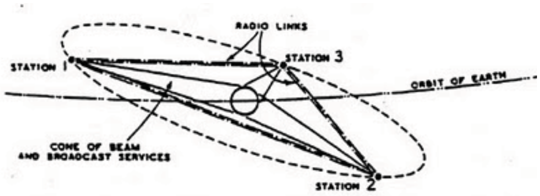


Fig. 3. Three satellite stations would ensure complete coverage of the globe.

The stations would be arranged approximately equidistantly around the earth and the following longitudes appear suitable:

- **30°E - Africa & Europe**
- **150°E - China & Oceania**
- **90° W- The Americas**

The station chain would be linked by radio or optical beams and thus any broadcast service could be provided. The geostationary orbit is now sometimes referred as the Clarke Orbit or the Clarke Belt in his honor.

Before we move ahead to low earth orbits, kindly note the following terms

- ✓ **Supersynchronous orbit** is a disposal / storage orbit above GSO. From earth , they would seem drifting in westerly direction.
- ✓ **Sub synchronous** orbit is a orbit close to but below GSO and is used for satellites undergoing station, changes in an eastern direction.
- ✓ **Graveyard orbit** is a Supersynchronous orbit where spacecraft are intentionally placed at the end of their operational life.

GEO Systems: Advantages & disadvantages

Advantages

- Most communications satellites in use today for commercial purposes are placed in the geostationary orbit, because one satellite can cover almost 1/3 of Earth's surface, offering a reach far more extensive than what any terrestrial network can achieve.
- The geosynchronous satellites remain stationary over the same orbital location, users can point their satellite dishes in the right direction, without costly tracking activities, making communications reliable and secure
- GEO satellites are proven, reliable and secure - with a lifespan of 10-15 years.

- GEO systems have significantly greater available bandwidth than the LEO and MEO systems. This permits them to provide two-way data, voice and broadband services that may be unpractical for other types of systems.
- Because of their capacity and configuration, GEOs are often more cost-effective for carrying high-volume traffic, especially over long-term contract arrangements. For example, excess capacity on GEO systems often is reserved in the form of leased circuits for use as a backup to other communications methods.

Disadvantages

- GEO systems, like all other satellite systems, require line-of-sight communication paths between terrestrial antennae and the satellites. But, because GEO systems have fewer satellites and these are in a fixed location over the Earth, the opportunities for line of sight communication are fewer than for systems in which the satellites "travel" across the sky. This is a significant disadvantage of GEO systems as compared to LEO and MEO systems, especially for mobile applications and in urban areas where tall buildings and other structures may block line-of-sight communication for hand-held mobile terminals.
- There are concerns with the transmission delays associated with GEO systems, particularly for high-speed data. However, sophisticated echo cancellation and other technologies have permitted GEOs to be used successfully for both voice and high-speed data applications.

Low Earth Orbits

In the above description we have read that orbital speed of a satellite is 11068 km/ hour, when it is in a geostationary orbit. A satellite can also be placed in orbits below the Geostationary orbit. We now know that to place an orbit below the Geostationary orbit, it will require higher orbital velocity. For example, a satellite which is a satellite which is placed in an orbit at altitude of 200 kilometers will need an orbital velocity of approximately 29000 kilometer per hour. Similarly, a satellite placed in an orbit at around 1730 kilometers will need a speed of 25,400 kilometers per hour.

LEO systems fly about 1,000 kilometers above the Earth (between 400 miles and 1,600 miles) and, unlike GEOs, travel across the sky. A typical LEO satellite takes 1 and half hours to orbit the Earth, which means that a single satellite is "in view" of ground equipment for a only a few minutes. As a consequence, if a transmission takes more than the few minutes that any one satellite is in view, a LEO system must "hand off" between satellites in order to complete the transmission. In general, this can be accomplished by constantly relaying signals between the satellite and various ground stations, or by communicating between the satellites themselves using "inter-satellite links."

LEO systems are designed to have more than one satellite in view from any spot on Earth at any given time, minimizing the possibility that the network will lose the transmission. Because of the fast-flying satellites, LEO systems must incorporate sophisticated tracking and switching equipment to maintain consistent service coverage. The need for complex tracking schemes is minimized, but not obviated, in LEO systems designed to handle only short-burst transmissions.

The advantage of the LEO system is that the satellites' proximity to the ground enables them to transmit signals with no or very little delay, unlike GEO systems. LEO satellites rotate the earth and currently deliver significant voice quality over the Geosynchronous (GEO) satellite systems. Now days, LEO Satellites are used in constellations such as Globalstar and Iridium constellations. In addition, because the signals to and from the satellites need to travel a relatively short distance, LEOs can operate with much smaller user equipment (e.g., antennae) than can systems using a higher orbit. In addition, a system of LEO satellites is designed to maximize the ability of ground equipment to "see" a satellite at any time, which can overcome the difficulties caused by obstructions such as trees and buildings.

LEO systems Pros and Cons

- It requires less energy to place a satellite into a LEO and the LEO satellite needs less powerful amplifiers for successful transmission, LEO is still used for many communication applications.
- However, since these LEO orbits are not geostationary, a network (or "constellation") of satellites is required to provide continuous coverage.
- The transmission delay associated with LEO systems is the lowest of all of the systems.
- Because of the relatively small size of the satellites deployed and the smaller size of the ground equipment required, the LEO systems are expected to cost less to implement than the other satellite systems.

- The small coverage area of a LEO satellite means that a LEO system must coordinate the flight paths and communications hand-offs a large number of satellites at once, making the LEOs dependent on highly complex and sophisticated control and switching systems.
- LEO satellites have a shorter life span than other systems mentioned here. There are two reasons for this: first, the lower LEO orbit is more subject to the gravitational pull of the Earth and second, the frequent transmission rates necessary in LEO systems mean that LEO satellites generally have a shorter battery life than others.

Examples of LEO

The International Space Station is in a LEO that varies from 320 km (199 mi) to 400 km (249 mi) above the Earth's surface

Medium Earth Orbit (MEO)

- ✓ MEO systems operate at about 8,000-20,000 km above the Earth, which is lower than the GEO orbit and higher than most LEO orbits.
- ✓ The MEO orbit is a compromise between the LEO and GEO orbits. Compared to LEOs, the more distant orbit requires fewer satellites to provide coverage than LEOs because each satellite may be in view of any particular location for several hours. Compared to GEOs, MEOs can operate effectively with smaller, mobile equipment and with less latency (signal delay).
- ✓ These orbits are primarily reserved for communications satellites that cover the North and South Pole
- ✓ Although MEO satellites are in view longer than LEOs, they may not always be at an optimal elevation.
- ✓ To combat this difficulty, MEO systems often feature significant coverage overlap from satellite to satellite, which in turn requires more sophisticated tracking and switching schemes than GEOs.
- ✓ Typically, MEO constellations have 10 to 17 satellites distributed over two or three orbital planes.
- ✓ Most planned MEO systems will offer phone services similar to the Big LEOs. In fact, before the MEO designation came into wide use, MEO systems were considered Big LEOs. Examples of MEO systems include ICO Global Communications and the proposed Orblink from Orbital Sciences

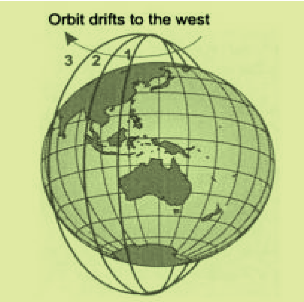
Unlike the circular orbit of the geostationary satellites, MEO's are placed in an elliptical (oval-shaped) orbit

Examples of MEO

The most common use for satellites in this region is for navigation, such as the GPS (with an altitude of 20,200 kilometers (12,552 mi)), Glonass (with an altitude of 19,100 kilometers (11,868 mi)) and Galileo (with an altitude of 23,222 kilometers (14,429 mi)) constellations. Communications satellites that cover the North and South Pole are also put in MEO. (wiki)

Polar Orbits

In a polar orbit, the satellite passes above or nearly above both poles of the earth being orbited on each revolution. So, we can say that the inclination of such orbit is almost 90 degrees to the equator. The Polar orbits are used for earth-mapping, earth observation, and reconnaissance satellites, as well as for some weather satellites. However, Iridium satellite constellation also uses a polar orbit to provide telecommunications services.



Why Polar orbits are used for earth-mapping?

As shown in the diagram, the Polar orbits are in a plane that is almost perpendicular to the plane of the equator and so passes over the poles of the Earth and then also, Earth rotates from East to West under the satellite. For instance, if the period of satellite is 6 hours then in one polar revolution, earth will rotate around 90° westwards. Thus, in a couple of days the whole earth can be mapped.

Some important notes about Polar orbits:

- ✓ Except for polar geosynchronous orbit, a satellite in a polar orbit will pass over the equator at a different longitude on each of its orbits.
- ✓ No one spot on the Earth's surface can be sensed continuously from a satellite in a polar orbit, this is its biggest drawback.
- ✓ The polar orbit can be manipulated also. If we want a satellite in polar orbit to remain hovering over a certain area for larger time, it can be placed in an highly elliptical orbit with its apogee over that area.

What is Orbital decay?

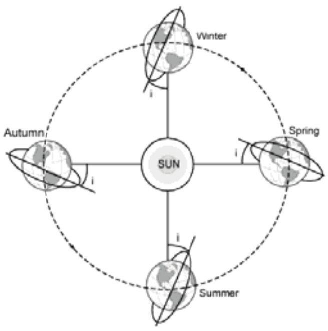
The satellites particularly in the LEO are subject to a drag produced by an atmosphere due to frequent collisions between the satellite and surrounding air molecules. The amount of this drag keeps increasing or decreasing depending upon several factors including the solar activity. The more activity heats of the upper atmosphere and can increase the drag. This drag in a long duration causes a reduction in the altitude of a satellite's orbit, which is called orbital decay.

So, the major cause of the orbital decay is Earth's atmosphere. The result of the drag is increased heat and possible reentry of satellite in atmosphere causing it to burn. Lower its altitude drops, and the lower the altitude, the faster the decay. Apart from Atmosphere, the Tides can also cause orbital decay, when the orbiting body is large enough to raise a significant tidal bulge on the body it is orbiting and is either in a retrograde orbit or is below the synchronous orbit. Mars' moon Phobos is one of the best examples of this.

Sun-synchronous orbit

Sun-synchronous orbit or a heliosynchronous orbit very important because of its particular importance to **satellites intended for remote sensing and military applications**. A sun-synchronous orbit is one that lies in a plane that maintains a fixed angle with respect to the Earth-sun direction. In other words, it combines altitude and inclination in such a way that an object on that orbit ascends or descends over any given point of the Earth's surface at the same local mean solar time.

We can say that the orbital plane in such a case has a fixed orientation with respect to the Earth-sun direction and the angle between the orbital plane and the Earth-sun line remains constant throughout the year. It is shown by the following diagram:



The features of Sun-synchronous satellites are:

- ✓ The satellite passes over a given location on Earth every time at the **same local solar time.**
- ✓ Thus, it **guarantees the same illumination condition**, which varies only with seasons.
- ✓ The orbit is Quasi-polar in nature and so **ensures coverage of the whole surface** of the Earth
- ✓ Every time a sun-synchronous satellite completes one revolution around earth, it traverses a thin strip on the surface of the Earth. During the next revolution it traverses another strip as shown in the diagram.

Frozen Orbits

We all know that Earth is not perfectly round. This means the gravitation is not exactly same at all the places. Apart from that there is gravitational pull from Sun and Moon too, followed by the solar radiation pressure, air drag and so many other forces. In other words, most satellites experience noticeable variations in orbital eccentricity.

But, fortunately, the distorting impacts of these issues can be induced to cancel each other by expert satellite planners. They choose optimum Orbital altitude, inclination, eccentricity and argument of perigee. The satellites whose orbital parameters are controlled by such techniques is said to be in Frozen Orbits.

Thus we can say that:

- ✓ Frozen orbit is a Sun-synchronous orbit in which the precession of the orbital plane around the polar axis of the Earth caused by the oblateness of the Earth is utilized to the benefit of the mission by choosing correct orbital parameters.
- ✓ The Earth observation satellites ERS-1, ERS-2 and Envisat are all operated in Sun-synchronous "frozen" orbits

Indian Space programme

- ✓ During the formative decade of 1960s, space research was conducted by India mainly with the help of sounding rockets.
- ✓ The Indian Space Research Organization (ISRO) was formed in 1969. Space research activities were provided additional fillip with the formation of the Space Commission and the Department of Space by the government of India in 1972. And, ISRO was brought under the Department of Space in the same year.
- ✓ In the history of the Indian space programme, 70s were the era of Experimentation during which experimental satellite programmes like **Aryabhatta, Bhaskara, Rohini and Apple** were conducted.
- ✓ The success of those programme, led to era of Operationalisation in80s during which operational satellite programmes like **INSAT and IRS** came into being.
- ✓ Today, INSAT and IRS are the major programmes of ISRO.
- ✓ For launching its spacecraft indigenously, India is having a robust launch vehicle programme, which has matured to the state of offering launch services to the outside world.
- ✓ Antrix, the commercial arm of the Department of Space, is marketing India's space services globally.
- ✓ Fruitful co-operation with other space faring nations, international bodies and the developing world is one of the main characteristics of India's space programme.

Indian National Satellite System (INSAT)

- ✓ The Indian National Satellite (INSAT) system is one of the largest domestic communication satellite systems in the Asia-Pacific region.
- ✓ In the 1980s, it initiated a major revolution in India's communications sector and sustained the same later.
- ✓ The satellites of INSAT system, which are in service today, are INSAT-2E, INSAT-3A,INSAT-3B, INSAT-3C, INSAT-3E, KALPANA-1, GSAT-2, EDUSAT and INSAT-4A, that was launched recently.
- ✓ The system provides a total of about 175 transponders in the, **Extended C and Ku-bands.** Being a multipurpose satellite system, INSAT provides services to telecommunications, television broadcasting, weather forecasting, disaster warning and Search and Rescue fields.
- ✓ At present, IMD is receiving and processing meteorological data from two Indian satellites, namely **Kalpana-1 at 74°E and INSAT-3A at 93.5°E.** At present, about 48 satellite images are taken daily from Kalpana-1 which is the main operational satellite and 9 images are taken from INSAT-3A. Imaging from CCD is done five times during daytime only. All the received data from the satellite is processed and archived in National Satellite Data Centre (NSDC), New Delhi.
- ✓ The INSAT system serves many important sectors of the Indian economy. Foremost amongst them is Telecommunications sector wherein INSAT is providing Mobile Satellite Service besides providing VSAT services.
- ✓ Today, more than 25,000Very Small Aperture Terminals (VSATs) are in operation. Similarly, Television broadcasting and redistribution have been immensely benefited by INSAT.
- ✓ Due to INSAT, more than 900 million people in India have access to TV through about 1400 terrestrial rebroadcast transmitters.
- ✓ Social development through exclusive channels for training and developmental education has become possible through INSAT.
- ✓ A Telemedicine network to take super specially medical services to the remote and rural population has become a reality.
- ✓ The launch of EDUSAT, India's first thematic satellite dedicated exclusively for educational services, has provided further fillip to the educational services offered by the INSAT system. INSAT system is also providing meteorological services through Very High Resolution Radiometer and CCD cameras on some of its spacecraft.
- ✓ This apart, cyclone monitoring through meteorological imaging and issue of warnings on impending cyclones through disaster warning receivers have been operationalize. For this, 350 receivers have been installed along the east and west coasts of India.

Indian Remote Sensing Satellite System (IRS)

- ✓ India's first **low orbit Earth Observation Satellites** were Bhaskara-I and II built by ISRO.
- ✓ They collected data on telemetry, oceanography and hydrology.
- ✓ With these satellites, India entered into the era of Remote Sensing.
- ✓ India established the National Natural Resources Management System (NNRMS) for which the Department of Space (DOS) is the nodal agency, providing operational remote sensing data services.
- ✓ The **First true Remote sensing satellite of India was IRS -1,** launched on 17 March 1988.

After that the following satellites have been launched: (Satellites in Dark Background are in service at present)

No.	Satellite	Date of Launch
1	IRS 1A	17-Mar-88
2	IRS 1B	29-Aug-91
3	IRS P1 (also IE)	20-Sep-93
4	IRS P2	15-Oct-94
5	IRS 1C	28-Dec-95
6	IRS P3	21-Mar-96
7	IRS 1D	29-Sep-97
8	IRS P4 (Oceansat-1)	27-May-99

9	Technology Experiment Satellite (TES)	22-Oct-01
10	IRS P6 (Resourcesat-1)	17-Oct-03
11	IRS P5 (Cartosat 1)	05-May-05
12	Cartosat 2 (IRS P7)	10-Jan-07
13	Cartosat 2A	28-Apr-08
14	IMS 1	28-Apr-08
15	Oceansat-2	23-Sep-09
16	Cartosat-2B	12-Jul-10
17	Resourcesat-2	20-Apr-11

- ✓ When India had launched its IRS-1C in 1995, the satellite's panchromatic camera, with a resolution of 5.8 metres, gave the highest resolution images available from any civilian satellite in the world.
- ✓ At that time this satellite took large blocks of imagery and some of them were considered sensitive and not released.
- ✓ In 1999, United States launched its Ikonos satellite that was capable of taking images with a resolution of one metre.
- ✓ Following this, in 2001, India launched its own **one-metre-resolution remote sensing satellite**. This satellite was called the **Technology Experiment Satellite** and it was mainly intended for the security services.
- ✓ Today India has **one of the largest constellation of Remote Sensing Satellites**, which are providing services both at the national and global levels.
- ✓ From the Indian Remote Sensing (IRS)Satellites, data is available in a variety of spatial resolutions starting from 360 meters and highest resolution being 1 meter.
- ✓ Besides, the state-of-the-art cameras of IRS spacecraft take the pictures of the Earth in several spectral bands.

Launch Vehicles

- ✓ India successfully tested the first indigenous launch vehicle **SLV-3 in 1980**.
- ✓ After that, ISRO built the next generation **Augmented Satellite Launch Vehicle** (ASLV).
- ✓ ISRO's Launch Vehicle Programme had a giant leap with the successful launch of **IRS-P2** spacecraft onboard the **Polar Satellite Launch Vehicle (PSLV) in October 1994**.
- ✓ On 18 April 2001,India successfully launched its Geosynchronous Satellite Launch Vehicle (GSLV).

Polar Satellite Launch Vehicle

- ✓ The four stage PSLV is capable of launching upto 1,600 kg satellites into a 620 km polar orbit. It has provision to launch payloads from 100 kg micro-satellites ormini or small satellites in different combinations. It can also launch one-ton class payloads into Geosynchronous Transfer Orbit (GTO). So far, it has performed nine missions with eight consecutive successes. The latest launch of PSLV (PSLV-C6) was on 5 May 2005 during which the vehicle precisely placed the 1560 kg CARTOSAT-1and the 42 kg HAMSAT into a 620 km high polar SSO.
- ✓ PSLV was developed to allow India to launch its Indian Remote Sensing (IRS) satellites into sun synchronous orbits.
- ✓ Before that India got this service commercially from Russia.
- ✓ Please note that PSLV is used to launch the satellites in sun synchronous/ Polar orbits but it can also launch small size satellites into geostationary transfer orbit (GTO).
- ✓ The PSLV has launched 41 satellites (19 Indian and 22 from other countries) into a variety of orbits to date.

Structural basics of PSLV

- ✓ PSLV has been designed and developed at Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram, Kerala.
- ✓ The PSLV has four stages using solid and liquid propulsion systems alternately.
- ✓ The first stage is one of the largest solid-fuel rocket boosters in the world and carries 138 tonnes of Hydroxyl-terminated polybutadiene (HTPB) bound propellant with a diameter of 2.8 m.
- ✓ The second stage employs the Vikas engine and carries 41.5 tonnes (40 tonnes till C-5 mission) of liquid propellant – Unsymmetrical Di-Methyl Hydrazine (UDMH) as fuel and Nitrogen tetroxide (N2O4) as oxidizer.
- ✓ The third stage uses 7 tones of HTPB-based solid propellant.
- ✓ The fourth and the terminal stage of PSLV has a twin engine configuration using liquid propellants that is 2 tonnes of Mono-Methyl Hydrazine as fuel + Mixed Oxides of Nitrogen as oxidizer.
- ✓ Each launch of PSLV costs $17 million

Variants of PSLV

1. The first variant of PSLV is PSLV (Operational) with four stages using solid and liquid propulsion systems alternately and six strap-on boosters. It can launch 1,678 kg to 622 km into sun synchronous orbit.
2. Second PSL variant is PSLV-CA (Operational), where CA stands for "Core Alone". It does not include the six strap-on boosters used by the PSLV standard variant. It can launch 1,100 kg to 622 km sun synchronous orbit.
3. Third variant of PSLV is PSLV-XL which has more powerful, stretched strap-on boosters. It weighs 320 tons at lift-off and uses larger strap-on motors (PSOM-XL) to achieve higher payload capability. PSOM-XL uses larger 13.5m, 12 tons of solid propellants instead of 9 tones used in the earlier configuration of PSLV. The first version of PSLV-XL was the launch of Chandrayaan-1 by PSLV-C11. It can launch 1800 kilogram.
4. The fourth variant of PSLV is PSLV-HP which is at proposed state. HP stands for higher performance with payload capacity of 2000 kg.

Brief Launch History: Some important launches

- ✓ The first flight of PSLV took place on 20 September 1993, when IRS 1E was sent to space unsuccessfully. The launch failed because of software failure and the satellite fell in Bay of Bengal.
- ✓ The first successful flight of PSLV took place on 15 October 1994 from Sriharikota by which IRS P2 was successfully sent in a sun synchronous orbit.
- ✓ PSLV's first successful commercial launch took place on 26 May 1999 when it sent Oceansat 1 and along with it two foreign satellites viz. **DLL-Tubsat** of Germany and **KitSat-3** of South Korea,
- ✓ On October 22, 2001, India launched Technology Experiment Satellite which was speculated as a Spy Satellite. It was TES that made India the second country in the world after the United States that can commercially offer images with one meter resolution.
- ✓ ISRO's first launch in the Geostationary Transfer orbit via PSLV was METSAT-1 which was known as Kalpana-1 in September 2002.
- ✓ The C7 flight of PSLV in 2007 used the "Dual Launch Adapter" for the first time, which made it capable of launching 4 satellites in one flight. Two Indian Satellites viz. Cartostat-2 and SRE or SCRE (Space Capsule Recovery Experiment) were launched.
- ✓ The above C-7 flight of PSLV made Indonesia enter into the field of Remote sensing by launching its first satellite named LAPAN-TUBSat.

- ✓ The first flight of PSLV's Core Alone version took place in 2007. This C-8 flight was ISRO's first "exclusively commercial launch".
- ✓ In April 2008, ISO made a world record of launching 10 satellites in one attempt via its C9 flight.
- ✓ The maiden flight of PSLV-XL took India's First mission to Moon via Chandrayaan-1 in the C-11 flight on 22 October 2008.
- ✓ The C-12 flight in 2009 sent India's first all weather observation spy satellite RISAT-1 in space. With this flight only, ANUSAT was sent in space, which was India;s First satellite built by a University (Anna University).
- ✓ On 20 April 2011, ISRO sent Resourcesat-2 via C-16.
- ✓ On 15 July 2011, India sent GSAT-12. This was the first Flight in which India's home developed flight computer Vikram was used for the first time.

Resourcesat-2

- ✓ The seventeenth consecutive successful flight of the Polar Satellite Launch Vehicle PSLV C-16 placed India's latest remote sensing satellite Resourcesat-2, in a **Polar Sun Synchronous orbit**.
- ✓ This was the eighteenth mission of the Polar Satellite Launch Vehicle and the eleventh flight that employs standard configuration.
- ✓ The Resourcesat -2,is India's latest remote sensing satellite weighs 1206kg at lift-off. It has three cameras for high, medium and low resolution.
- ✓ The high resolution Linear Imaging Self Scanner, LISS-4 has a spatial resolution of 5.8 m and an enhanced swath of 70km.
- ✓ The medium resolution LISS-3 has a spatial resolution of 23.5m while the coarse resolution Advanced Wide Field Sensor has a spatial resolution of 56 m.

GSAT-12

On July 15, 2011, India has successfully launched its latest communication satellite GSAT-12 via India's home-grown Polar Satellite Launch Vehicle, PSLV-C17, from the spaceport in Sriharikota. The successful mission was PSVL-C17 GSAT12. The launch vehicle injected the satellite very precisely into the intended orbit.

Weight:

- ✓ GSAT-12 weighs about 1410 kg at lift-off.

Cost:

- ✓ Rs. 200 Crore Including PSLV

Life:

- ✓ Life of GSAT 12 is approximately 8 years.

Objective:

- ✓ Aimed at augmenting the capacity in the INSAT system for various communication services like tele-education, tele-medicine and Village Resource Centres and 'more importantly' provide support for disaster management.

Orbit:

- ✓ GSAT-12 was injected into an elliptical Transfer Orbit of 284 km perigee (closest point to Earth) and 21,000 km apogee (farthest point to Earth) with an inclination of 17.9° with respect to equatorial plane. Subsequently, the onboard Liquid Apogee Motor would be used to place the satellite in a circular orbit.

Transponders:

- ✓ GSAT-12 is configured to carry 12 Extended C-band transponders to meet the country's growing demand for transponders in a short turn-around-time. The 12 Extended C-band transponders of GSAT-12 will augment the capacity in the INSAT system for various communication services like Tele-education, Telemedicine and for Village Resource Centres (VRC).

Why this PSLV Flight was special?

- ✓ This was the second time in its 19 flights that the PSLV has been used for launching a communication satellite after Kalpana-1 in 2002. This flight was also special due to the fact that it used the most powerful XL configuration with six extended solid strap-on motors carrying 12 tonnes of solid propellant as against nine tonnes for the standard PSLV. This kind of configuration was used for Chandrayan-1 mission in 2008.

Why NOT GSLV?

- ✓ Because PSLV has proved itself reliable. ISRO had seen failures of two previous GSLV flights in April and December 2010, which were meant to place GSAT-5 and GSAT-5P into orbit causing transponder shortage.

Some more notes

- ✓ This is the nineteenth mission of the Polar Satellite Launch Vehicle and the second flight that employs PSLV-XL configuration . It has 4 stages using solid and liquid propulsion systems alternately.
- ✓ For the first time, use of indigenously designed and developed On-Board computer (OBC) with Vikram 1601 processor in both primary and redundant chains of the vehicle. The OBC performs the functions of Navigation, Guidance and Control processing for the vehicle.
- ✓ Use of extended solid strap-on configuration
- ✓ Satellite injection in elliptical transfer orbit sub-Geosynchronous Transfer Orbit (GTO)
- ✓ Five burn strategy (2 perigee burn and 3 apogee burn) for placing the GSAT-12 satellite from its sub-GTO to Geostationary Orbit.

Geosynchronous Satellite Launch Vehicle

- ✓ **Geosynchronous Satellite Launch Vehicle** was developed to enable India to launch its Communication satellites into geostationary orbit and to make India less dependent on foreign rockets.
- ✓ Development took place in 1990s and until then, India depended on the former Soviet Union for the launch of heavy satellites.
- ✓ GSLV improved on the performance of the PSLV with the a**ddition of liquid strap-on boosters and a cryogenic upper stage**.
- ✓ It is a **three-stage launch vehicle** with the first stage being solid-propelled, the second liquid-propelled and the final stage being liquid propelled as well with cryogenic fuels.
- ✓ The solid first and liquid second stages are carried over from the PSLV.
- ✓ Early GSLV launches used cryogenic upper stages supplied by Russia. India originally tried to buy the technology to build a cryogenic upper stage from Russia, but under pressure from the United States, that technology was not provided. Therefore, ISRO developed the cryogenic engine used in the GSLV indigenously. (wiki)

Capacity

- ✓ The GSLV can place approximately 5000 kg into an easterly Low Earth orbit. Using the Russian 12KRB upper stage, with KVD-1 cryogenic rocket engine, GSLV can place 2200 kg (4,850 lbm) into an 18 degree geostationary transfer orbit.

Variants

- ✓ There are 3 variants of GSLV viz. GSLV Mk.I, GSLV Mk.II and GSLV Mk.III. GSLV Mk.I was capable of launching 1500 kg into geostationary transfer orbit, GSLV Mk.II can launch 1900 kg into geostationary transfer orbit and GSLV Mk.III is the technological successor to the GSLV, however is not derived from its predecessor. It is intended to be able to launch 10,000 kg to low-earth-orbit.

Launch History:

- ✓ The first developmental flight of GSLV took place on 18 April 2001 which resulted in success. Via this flight GSAT-1 was to be placed in geosynchronous orbit but this 1.54-tonne satellite was orbiting with a period of 23 hours two minutes, instead of the planned 24-hour geosynchronous orbit.
- ✓ The second developmental flight of GSLV took place on May 8, 2003 and GSAT-2 was placed in GEO.
- ✓ The Third developmental flight of GSLV took place on 20 September 2004 and it placed GSAT-3 or EDUSAT, the first Indian satellite built exclusively to serve the educational sector.
- ✓ The Fourth flight of GSLV took INSAT 4C in space and failed.
- ✓ The Fifth flight of GSLV resulted in partial failure as apogee was lower and inclination was higher than expected.
- ✓ The 6th and 7th Flights resulted in failures. Latest flight GSLV-F06 powered by a Russian cryogenic stage, with GSAT-5P communication satellite on board, failed in its mission following a technical problem soon after the lift-off from the Sriharikota spaceport in Andhra Pradesh in December 2010.

Compendium

How many artificial satellites revolve around the Earth right now? Which country has the most?

The total number of artificial satellites orbiting the Earth today is around 6,300. Of these, about 3,000 are not operational having lived out their useful life and are part of the **space debris.** The remaining include satellites used for communication, weather tracking, navigation, research, remote sensing and reconnaissance. Since the Soviet Union launched the world's first satellite Sputnik 1 on October 4, 1957, nine countries and a few international consortia have acquired the capability to launch satellites. Of these, the US owns the maximum number of satellites in orbit today.

Some other estimates say that approximately 23,000 items of space junk objects that were inadvertently placed in orbit or have outlived their usefulness are floating above the Earth. The actual number varies depending on which agency is counting. Payloads that go into the wrong orbit, satellites with rundown batteries, and leftover rocket boosters all contribute to the count. This count is almost 26,000.

How simulation of Zero Gravity takes place?

Simulation of zero gravity while still within the pull of the earth's gravity is achieved in a similar manner to that of a man-made satellite. When a body moves in a circular path, it experiences centrifugal force acting on it. This force points radially outwards and depends on both the speed and the radius of trajectory. Given this factor, if a plane flies in a **circular arc trajectory, then passengers experience a centrifugal force**

pointing away from the earth. **At a certain velocity, this force exactly counterbalances gravity,** and passengers experience weightlessness or zero gravity.

What is captured rotation?

When a satellite, natural or artificial, is orbiting its parent planet (or primary) under some conditions, the satellite revolves around itself (or spins) quite fast relative to its period of rotation around the primary, and under some other conditions, both the periods coincide. The latter phenomenon leads to the satellite facing the primary always with the same side and it is called captured rotation or synchronous rotation. It occurs especially when the satellite is much smaller than the primary, and the two are separated by a relatively short distance. In the solar system, the moon and some inner moons of Jupiter experience captured rotation.

Which was the First Biosatellite?

A biosatellite is a satellite designed to carry life in space. First biosatellite with animal (dog) was Soviet Sputnik 2 at November 3, 1957. On August 20, 1960 Soviet Sputnik 5 first time recovered animals (dogs) from orbit to Earth.

What is the principle behind sending satellites in highly elliptical orbits (HEO)?

As we have studied above, that polar orbit can be manipulated also. If we want a satellite in polar orbit to remain hovering over a certain area for larger time, it can be placed in an highly elliptical orbit with its apogee over that area. The main feature of highly elliptical orbit (HEO) is an elliptic orbit with a low-altitude perigee and a high-altitude (over 35,786 kilometres apogee. These orbits are extremely elongated orbits and have the advantage of long dwell times at a point in the sky during the approach to, and descent from, apogee. Visibility near apogee can exceed twelve hours of dwell at apogee with a much shorter and faster-moving perigee phase. This makes these elliptical orbits useful for communications satellites.

What are Tether satellites?

Tether satellites are satellites which are connected to another satellite by a thin cable called a tether.

What is a Horseshoe orbit?

A horseshoe orbit is a type of co-orbital motion of a small orbiting body relative to a larger orbiting body so that orbital period of the smaller body is very nearly the same as for the larger body, and its path appears to have a horseshoe shape in a rotating reference frame as viewed from the larger object.