SPACE SCIENCE & TECHNOLOGY

6.1 Introduction

"Our civilization is no more than the sum of all dreams that earlier ages have brought to fulfillment. And so it must always be, for if men cease to dream, if they tura their backs upon the universe, the story of our race will end."-Arthur C. Clarke.

For centuries, the stars and planets and their interesting patterns and positions have been used for purposes similar to those for which we use modern space systems. Notable and ancient applications include navigation and environmental prediction. As Bruce campbell and Samuel Water Mc Candlers Jr. Writes "after the first few pictures were returned from some of the early sub-orbital test rocket flights, experimenters recognized that one of the greatest advantages of being in space was the expanded perspective looking back toward earth."

The understanding of remote sensing brought a sea change in the knowledge of environment, allowing the observance and prediction of adverse conditions and thereby saving life and property from disaster. Further, the need for advanced global communication capabilities caused many to look toward space as an alternative to earlier methods. In the 1940s, Arthur C. Clarke hypothesized that a platform placed at a particular location in space where it would appear motionless with respect to the ground, could be used as a communications relay station.

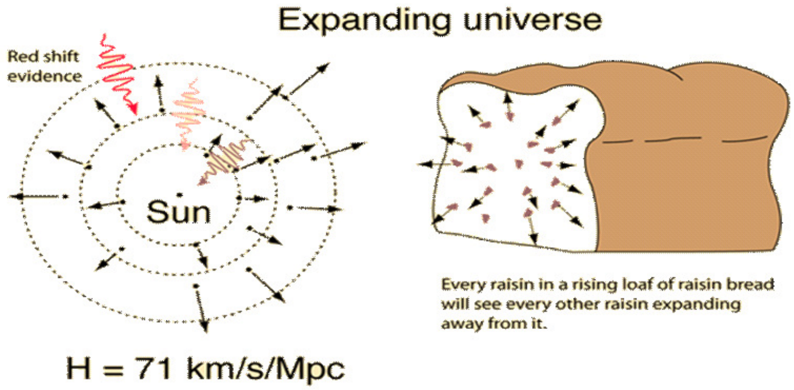
Astronomy and space science have advanced rapidly in recent years, seminally due to the advent of the space age over the past five decades. The united nations office for outer space Affairs recognises that the needs for a new development process because obvious as countries made efforts to benefit from rapid progress in space science and technology. This process required a complete innovation of the driving forces for development where no previous examples were available.

Space & its Regions

Space or 'Outer Space' (the term was coined in 1901 by H.G. Wells) is near vacuum and collectively include earth and all other planets, stars, galaxies etc. According to the world Air sports Federation (Federation Aeronautique International –FAI), the Karman Line separates the earth's atmosphere and outer space. The line named after Theodore Von Karman. This imaginary line is located at about 100km above sea level. The majority of space contains very little matter hence most of it is a vacuum. Items in space are free to move back and forth and up and down, and left and right. These three dimensions are what make 3D space. Space is included in the concept of universe. Typically, the universe includes all regions of space, galaxies, stars, planets and other celestial bodies. In 1925 Edwin Hubble and others proposed a law proposing expansion of the universe.

According to Hubble's law, the fact that we see all other galaxies moving away from us does not imply that we are the centre of the universe.

All galaxies well see all other stars moving away from them in an expanding universe. The action of gravity works against the expansion. Hence, if the density were large enough, the expansion would stop and the universe would collapse. This is called a closed universe. If the density were small enough, the expansion would continue forever which is called an open universe. At a certain precise critical density, the universe would asymptotically approach zero expansion rate, but never collapse. Most of the evidences indicate that the universe is very close to that critical density.



The outer space comprises a number of regions which could be defined by various atmospheres and winds that sominate within them.

1. Geo-space

Geospace is the earth's environment at the edge of space and is largely plasma dominated. This atmosphere is surrounded by earth's magnetic field. It serves as a line of defence against matter and radiation from space.

2. Inter-galactic space

It is a physical space between galaxies. It contains rarefied plasma of hydrogen. A number of observations indicate that much of the atomic matter in the universe might exist in this region.

3. Inter-Stellar Space

It is the physical space within a galaxy not occupied by stars or planetary systems of the galaxy. Most of this space contain hydrogen atoms enriched with helium atoms.

4. Inter-Planetary Space

It is the region of space around the sun and planets of the solar system. It contains the magnetic field generated by the Sun and also by the planets. It also contains ionized atomic nuclei and subatomic particles.

6.2 Law of Space

It was believed that states had boundless sovereignty over their outer space but today this belief has become meaningless with the rapid development and use of space science and technology. The need to regulate the outer space was felt in 1957 when the erstwhile soviet Union launched the first artificial satellite Sputnik-I. The issue was discussed at the UN which set up the committee in 1958 named Committee on the Peaceful Uses of Outer Space (COPUOS) with a view to reviewing the scope of international cooperation in peaceful uses of outer space and also to encouraging continued research and the disseminative of information on outer space matters. The committee has two sub-committees, the scientific and Technical Sub-committee and the Legal sub-committee. The COPUOS has sixty seven members including India which is a founder members under General Assembly Resolution 1348 (XIII) 1958. The Committee is responsible to oversee the implementation of five international treaties and agreements.

1. Outer space Treaty

Originally named the Treaty on Principles Governing the Activities of States in the exploration and use of outer space, including the moon and other celestial Bodies, this treaty was opened for signature. On 27 January, 1967 by the US, USSR and UK. It came into force on 10 October, 1967. Presently, 98 countries are parties to the treaty. Another 27 countries have signed it but have not yet ratified. Dubbed as Outer Space Treaty, it is the basic legal framework of international space law. The main tenets of the treaty include the following:

1. Outer space shall be used and explored for the benefits and interests of all the states and the states shall not be discriminated on the parameters of economic and scientific developments
2. Outer space shall be used and explored only in the interest of mankind.
3. All states shall have the right to use and explore outer space beyond their territorial boundaries
4. No state shall place any nuclear or other weapon in any of the orbits around the Earth.

2. Rescue Agreement

The agreement was created on 19, December, 1967 through a UN General Assembly Resolution [2345 (XXII)] and came into force on 3 December, 1968. It was originally named the Agreement on the Rescue of Astronauts the Retura of Astronauts and the Retura of Objects Launched into Outer Space. According to the Agreement members states shall provide all assistance to rescue the personnel of a spacecraft who have landed within their territory. The agreement presently has 90 members, of which 24 have ratified. Moreover, the European Space Agency (ESA) and the European Organisation for the Exploitation of Metrological Satellites have accepted the provisions of the Agreement.

3. Liability Convention

The Space Liability convention (Convention on International Liability for Damage Caused by Space Objects) was opened for signature in 1972. It entered into force in September 1972. It expands the liability rules provided in the Outer Space Treaty, 1967. 82 states have already ratified the Treaty.

4. Registration Convention

It is also known as the Convention on Registration of Launched Objects into outer space. It was adopted in 1974 and is in force since 1976. The registration is done with the UN Office for Outer Space Affairs (UNOOSA).

5. Moon Treaty

This treaty, through created in 1979, has not been ratified by any nation, hence considered as a failed treaty.

6.3 Dark Matter & Dark Energy

Dark matter is the hypothetical form of matter which does not emit or reflect electro-magnetic (em) radiation, hence called dark. This matter comprises WIMPs (Weakly Interacting Massive Particles) which interact through weak force and gravity. When astronomers began measuring the rotation of spiral galaxies in the 1950s and 60s, they made a puzzling discovery's centre, where the visible matter is more concentrated, move faster than stars at the edge. Instead they saw that stars at the edge of a galaxy had the same rotational velocity as stars near the centre. Astronomers observed this first with the milky way, then in the 1970s Vera Rubin confirmed the Phenomenon when she made detailed quantitative measurements of stars in several other galaxies including Andromeda. They inferred that more likely galaxies and galactic clusters contain an invisible form of matter called dark matter responsible for observed gravitational effects. Astronomers believe that MACHOs (Massive Compact Halo Objects) probably contribute to the mystery of dark matter MACHOs are large objects that reside in the halos of galaxies but elude detection because they have low luminosities. They include brown dwarfs, exceedingly dim white dwarfs etc. However, mostly it is observed that dark matter contains WIMPs Such as neutrinos and a few other such as-

1. Neutrinos or, massive neutrinos
2. Axions which are small neutral particles
3. Photinos which are similar to photons and are charged.

On the other hand, dark energy is a mysterious repulsive force which permeates all the space and tends to increase the rate of expansion of the universe. It is believed that a volume of Space has some intrinsic believed that a volume of called the cosmological constant. Since energy and mass are related by E- mc^2, Einstein's theory of general relativity predicts that this energy will have a gravitational effect. It is sometimes called vacuum energy.

6.4 Large Hadron Collider (LHC)

LHC is the world's largest and most powerful particle accelerator, built by the European Organisation for Nuclear Research (CERN) is located in a tunnel (27 km long) below the Franco-Swiss border near Geneva. In an attempt to understand the universe, including how it works and its actual structure, scientists proposed a theory called the standard model. This theory tries to define and explain the fundamental particles that make the universe what it is. it combines elements from Einstein's theory of relativity with quantum theory. it also deals with three o! the four basic forces of the universe .strong nuclear force, weak nuclear force and electromagnetic force, it does not address the effects of gravity, the fourth fundamental force.

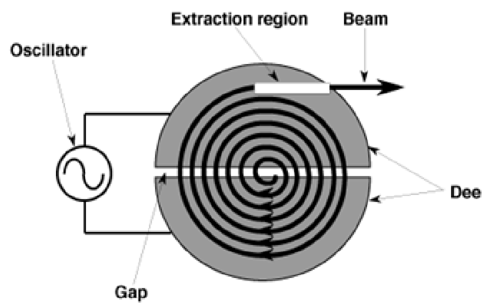
The Standard Model makes several predictions about the universe, many of which seem to be true according to various experiments. But there are other aspects of the model that remain unproven. One of those is a theoretical particle called the Higgs boson particle. The Higgs boson particle may answer questions about mass. Why does matter have mass? Scientists have identified particles that have no mass, such as neutrinos. Why should one kind of particle have mass and another lack it? Scientists have proposed many ideas to explain the existence of mass. The simplest of these is the Higgs mechanism. This theory why some particles have mass. The theoretical particle has never been observed and may evidence for the existence of the Higgs boson particle.

Particle Accelerator

A particle accelerator is a device to produce beams of energetic charged particles and to direct them against various targets. Particle accelerators are of two types-

1. **Linear Accelerator:** In these accelerators particles travel in a vacuum down a long copper tube. The electrons ride waves made by wave generators called Klystrons. Electromagnets keep the particles confined in a narrow beam. When a particle beam strikes a target various detectors record the events- the sub-atomic particles and radiation released.

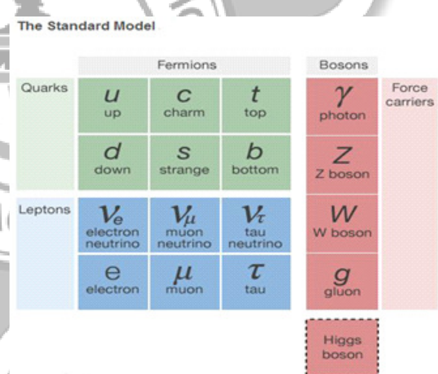
2. **Circular Accelerator:** Unlike linear accelerator, types propel the particles around a circular track many times. At each pass the magnetic field is strengthened so that the particle beam accelerates with each consecutive pass. Circular accelerator is called cyclotron. A descendent of cyclotron is known as synchrotron which works on the principle of synchronization of magnetic and electric fields.



Standard Model

- Simplest set of elementary
  Particles needed to makeup the universe
- **Quarks –** e.g. Protons & Neutron
- **Leptons-** e.g. Electron

Force Carriers: Particles whose movement are observed as forces behind electromagnetism & radioactive decay.



Experiments at LHC

1. **CMS (Compact Muon Solenoid)**
   - A general purpose detector to search for particles that make up dark matters.
2. **ATLAS: (A Torroidal LHC Apparatu S):**
   - Large experiment for detecting various dimension of Higgs Bosons.
3. **ALICE (A Large Ion Collides Experiment)**
   - Experiment of lead (pl) ion collisions
4. **LHCb (Large Hadron Collides beauty):**
   - To study the cause of existence of life in Universe.
5. **TOTEM (Total Elastic & diffractive Cross section Measurement)**
   - To study the result obtained from CMS
6. **LHC (Large Hardron Collider Forward)**

- To simulate cosmic says in lab. Conditions.

According to Dr. Higgs, the Higgs Boson particles, proposed in 1964, enable other particles in the universe to acquire mass. As the universe cooled after the Big Bang, an invisible force known as the Higgs Field as formed. This field permeates the universe and is made up of countless numbers of tiny particles or, Higgs Bosons. As these particles passed through it they picked up mass giving them shape and size and allowing them to form atoms. In July 2012, scientists at CERN claimed the discovery of a new particle. Consistent with Higgs Bosons at LHC Particles discovered had about 125.3 GeV (Giga electron volt) energy and were about 133 times heavier than protons. Since it is believed that Higgs Bosons must have given mass to other particles, they have been dubbed "God Particles". As most of the universe is full of dark matter, this discovery would contribute to throw light on the existence and origin of the universe.

6.4 Satellite

NASA defines a satellite as a moon, or machine that revolves around a planet. Usually, the word 'Satellite' refers to a machine that is launched into space and moves or revolves around Barth. Satellites are very important because they have the ability to collect more data, more quickly than instruments on the ground. Though satellite come in many shape and sizes, most of them have at least two parts-an antenna and a power source. The antenna sends and receives information , after to and from earth. The power source can be a solar panel or battery. Solar panels make power by turning sunlight into electricity. A satellite orbits earth. When its speed is balanced by the earth's gravitational pull. On the basis of their roles, satellites are of various types as discussed briefly below:-

1. **Communication Satellites:** These satellite use mainly an equipment called transponder (Transmitter + Responder) and allow telephone and data conversations to be relayed through them, e.g. INSAT group of satellites.

2. **Weather Satellites:** These satellite are very useful in weather forecast and generally use cameras that can return photos of earth's weathers. For example, Metsat or, Kalpana-I.

3. **Earth Observation Satellites (EOS):** These are essentially remote sensing satellites for resource management, disaster management etc.

4. **Navigational Satellites:** These satellites are very useful in navigation such as GPS satellites, or India's IRNSS (Indian Regional Navigation Satellite System).

In addition to antenna and power sources, satellites also have altitude control system (ACS) that keeps it pointed in the right direction. All of the satellites have a metal or composite frame and body usually know as 'bus'. After a rocket that launches a satellite uses the inertial guidance system to calculate necessary adjustment.

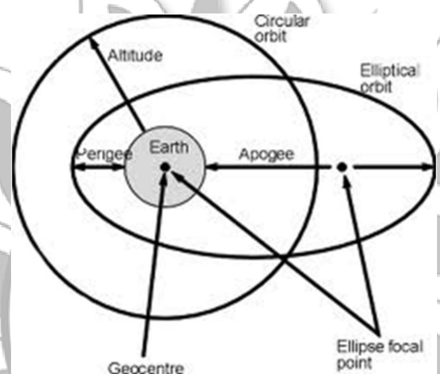
Why a rocket head towards East?

The flight plan of most rockets calls for the rocket to head east because the earth rotates from west to east giving a launch vehicle a free boost. The strength of this boost depends on the rotational velocity of earth at the equator, where the distance around earth is greatest and so rotation is the fastest.

6.5 Orbital Basics

Orbit of a satellite is the path which it revolves around earth. For any given orbit there is a speed for which gravity and centrifugal force balance each other and the satellite remains in a stable orbit, neither gaining height nor losing it. The lower the orbit, the stronger is the gravitational pull which means that the satellite must travel faster to counteract this pull. This is the reasons why a satellite in polar orbit has a velocity of about 17500 miles per hour while in orbits at an altitude of 22000km and above, it travels with a velocity of less than 7000 miles per hour. A satellite orbits the earth in one of the two basic types of orbit-

1. **Circular-** The distance from the earth remains the same at all times
2. **Elliptical-** This orbit changes the distance to the earth.



When the satellite orbits the earth either in circular or elliptical, it forms a plane that passes through the centre of gravity called the geo-centre of the earth. The rotation of the satellite may be either 'posigrade' i.e. when it rotates in the same direction as the rotation of earth. On the other hand, the rotation is retrograde when it rotates in the opposite direction to the rotation of the Earth. In addition, a few more concepts are associated with orbit of a satellite, such as Circular & Elliptical Orbits.

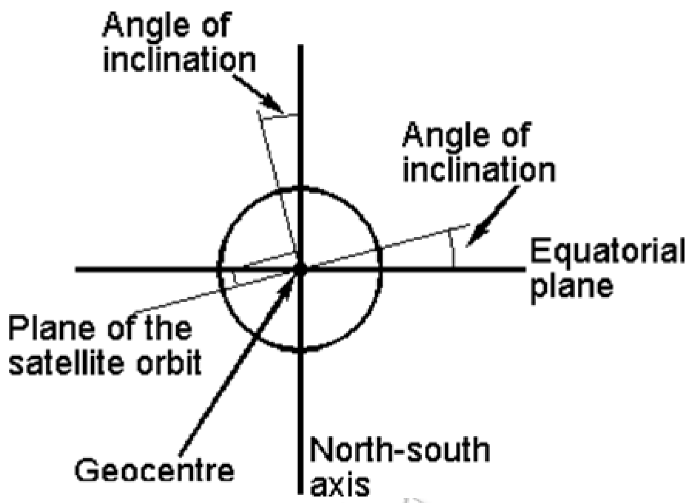
Ground Track: It is the point earth's surface where a satellite is directly overhead. It shifts to west as earth rotates to east.

Nodes: Nodes are the point where ground track passes from one hemisphere to another. If the grow track passes from the southern hemisphere to the northern hemisphere it is called the ascending node and the node is descending if it passes from northern to Southern hemisphere.

Orbital Velocity: For an elliptical orbit the velocity changes and it is maximum in apogee to counter force of gravitation. On the other hand, it remains the same in a circular orbit.

Angle of Inclination: It is the angle between the equatorial plane and the plane of satellite orbit. Hence, it is not found in most low earth orbits.

Other types of orbit: On the basis of altitude satellite orbits may be classified as-



1. **Low earth orbits (LEO)**

It extends from 200km to 200km. The lower altitude means hisher velocities are required to balance the earth's gravitational field. Typically it is 8km/sec. Earth observation satellites (remote sensing satellite) use LEOs as they are able to see the surface of the Earth more clearly. Objects in LEO encounter atmosphere (approximately 80-500km) or exosphere (500km and above), depending on orbit Light. LEO is an orbit around earth between the atmosphere and below the inner Van Allen Radiation Belt. LEOs with usually called Polar Orbit.

2. **Medium Earth Orbit (MEO)**

MEO is located between LEO and HEO (High Earth Orbit) and extends from 2000 to about 35000km. Mostly, navigational satellites are placed in this orbit. In various patterns, these satellites make the trip around earth in anywhere from 2-12 hours.

3. **High Earth Orbit (HEO)**

It is located at an altitude of about 35000km and above. It is geocentric and the orbital period is greater than24 hours, mostly communication satellites are placed in these orbits. HEO is also called geo-stationary orbit.

Van Allen Radiation Belt

It extends from an altitude of about 1000 to 60,000km in which radiations levels vary. Most of the particles forming the belt come from solar wind. The Upper region of the belt contains energetic electrons while protons and electrons are found in the inner region.

1. **Graveyard Orbit**

It is also called super synchronous orbit or disposal or junk orbit. Space craft are placed after their life ends to avoid collision causing Kessler syndrome/effect. Moving a craft to a graveyard orbit requires less effort than de-orbiting it. According to NASA, transferring derelict Spacecraft to a graveyard orbit can be challenging requiring reliable attitude control and the same amount of fuel needed by the satellite for approximately three months station keeping

On the basis of synchronization, orbits may be the following types:

Polar Sun-Synchronous Orbits:

A polar orbit is inclined at 90° to the equatorial plane, so that a satellite is able to pass over both poles of the Earth. With the plane of the orbit lying north-south and almost fixed in space, the spinning Earth results in a polar-orbiting satellite sweeping over different swaths of ground with each orbit, eventually covering the entire globe. The orbit is designed to ensure that the angle between the orbital plane and the Sun remains constant, resulting in consistent lighting conditions. This is achieved by a careful selection of orbital parameters to produce a precession of the orbit equal to the apparent motion of the Sun as seen from Earth orbit, i.e. about one degree eastward each day. The satellite's orbital plane must be inclined away from a true north-south polar orbit. With an inclination of 98.7° to the equatorial plane, the asymmetric gravitational pull of the Earth causes the orbit to precess by the required amount. A key feature is that, in each half of this orbit, the satellite always crosses a particular line of latitude at the same local solar time. The angle of the sunlight (in the daytime half) is consistent, only varying slowly as the seasons change in the course of a year.

The altitude of a satellite in polar orbit is a compromise between different requirements:

- High ground resolution and a short orbital period for frequent coverage — these result from a low orbit.
- A swath of observation that is wide enough so that successive orbital swaths overlap. This ensures complete ground coverage, and is favoured by a higher orbit.

As a result, a typical polar satellite moves in a circular orbit with an altitude of about 850 km and a period of 100 minutes. The satellite scans a swath about 3000 km wide on the Earth's surface, which is also wide enough to cover the poles, despite the north-south orbital inclination of 8.7°. With these parameters, the satellite makes just over 14 orbits in a day, and every point on the Earth is covered at least twice.

Dawn to dusk orbit

It is a special kind of sun-synchronous orbit in which the satellite trails the Earths shadow. When the sun shines on one side of the earth it cats a shadow in the apposite side of the earth. As the satellite never moves into this shadow, the sun's light is always on it. Since the satellite is close to the shadow, the part of the earth the satellite is directly above is always at subset or sunrise, hence it is called dawn to dusk orbit.

Geo-Synchronous Orbits:

A geosynchronous orbit has an orbital period matching the rotation rate of the Earth.

This is a sidereal day, which is 23h 56m 4s in length, and represents the time taken for the Earth to rotate once about its polar axis relative to a distant fixed point. This is about four minutes shorter than the civil day length, which is relative to the Sun.

A geostationary orbit is a special case of a geosynchronous orbit. The distance of a satellite in geosynchronous orbit is calculated from Kepler's third law, which states that the average orbit radius squared, divided by the orbital period cubed, is constant.

As a consequence, the orbital period increases with distance, but has a fixed value for a given distance. In the case of the Moon, for example, R = about 383,000 km and T = about 27.3 days.

For a geosynchronous satellite whose period T equals one sidereal day, the equation produces a value R = 42,155 km. Subtracting the Earth's radius yields the average orbit height above the Earth's surface as 35,786 km.

If the orbit is not a circle, the satellite does not move at constant velocity, it appears to oscillate east-and-west at a rate of two cycles per sidereal day.

Further, if the orbit does not lie in the equatorial plane, the satellite does not remain at a fixed point in the sky, it appears to oscillate north-and-south at a rate of one cycle per sidereal day.

6.4 Launch Vehicle

A launch vehicle is a kind of rocket which carries a payload from the earth surface to space. Usually, the payload is artificial satellite to be placed in orbit. The origin of launch vehicles could be traced to ballistic missiles developed during 1950s and early 60,ir was Robert Goddard who built for the first time an experimental liquid-fueled rocket in 1926. However, Sergei Korolev of Russia pioneered in developing an Inter-continental Ballistic Missile (ICBM) to deliver heavy nuclear warheads to targets. It was named R-7 or Semyorka (Number 7) and was first successfully tested on 21 August 1957. This was used as a launch vehicle to launch the first artificial satellite Sputnik 1 in October 1957.

A number of countries including India have since then been able to successfully develop different types of launch vehicles. Every launch vehicle has to go through the developmental stages before making it ready for commercial uses. These stages are represented by the letters 'D' and 'C' respectively.

Kessler Syndrome/ effect

Proposed by Donald Kessler (NASA) in 1978, according to which collisions between object could cause a cascade, i.e. each collision generates space debris which increases the likelihood of further collisions.

Sounding Rocket

It is a type of launch vehicle used for a sub-orbital flight. The term sounding rocket comes from the nautical term 'to sound' meaning to take measurements. It is a research rocket which carries instruments to take measurements and perform scientific experiments during its sub-orbital flight. It uses solid propellant.

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Expendable Launch Vehicle (ELV)

These launch Vehicles are designed to be used only once. Hence, their components are not recovered for re-use after launch. Such vehicles have more than one stages and use solid or liquid propellants. Most of the satellites are launched using ELVs. For example, India's PSLV, GSLV etc.

Reusable Launch Vehicles(RLV)

RLVs are to be used more than once. It is believed that such vehicles would be cost effective and more reliable. In true sense, no orbital RLV is in use currently, however, the closest example has been the space shuttle. A company Space X has partially reusable vehicles.

RLVs may be of two types:

1. **Single-Stage-to-Orbit (SSTO):** This type of RLV is a small and light vehicle carrying a single stage however, it has a high mass ratio (mass of fully fueled vehicle divided by the mass of the vehicle when empty).

2. **Two-Stage-to Orbit or, Dual -Stage-to-Orbit:** These RLVs may have two or more stage. The first stage need to be returned to the launch site for reuse.

Launch Vehicles of India

India began its launch vehicle development programme in 1960s. However, initially India decided to launch sub-orbital sounding rockets. India became successful in developing its first sounding rocket Nike-Apache on 21 November 1963 which was launched from Thumba Equatorial Sounding Rocket Launching Station (TERLS), near Thiruananthapuram in Kerala.

Satellite Launch Vehicle (SLV)

The SLV programme was borne out of the need for developing indigenous satellite launch capability for communications, remote sensing and meteorology. SLV was India's first experimental satellite launch vehicle which was successfully launched on 18th July, 1980, from SHAR Centre Sriharikota. It placed Rohini Satellite (RS-1) in the orbit. It was capable of placing 40kg class payloads in low earth orbits. Technically, it employed the open loop guidance to steer the vehicle in flight along pre-determined trajectory. It was a four stage rocket which used solid propellant (PBAN: Polybutadyne Acrylo Nitrate) in all the four stages.

Augmented Satellite Launch Vehicle (ASLV)

It was created by adding two additional boosters modified from the SLV-3's first stage and by making other improvements. It was a five-stage vehicle which had the payload capacity of 150kg to an orbit of 400km. The first launch of ASLV on 24th March, 1987 failed, however, finally it succeeded on 20 May, 1992 when it placed the SROSS-3 (Stretched Rohini Satellite Series) in LEO.

Polar Satellite Launch Vehicle (PSLV)

PSLV is the first operational launch Vehicle of Indian Space Research Organisation (ISRO). There had been 26 continuously successful flights of PSLV till June 2014. Until the launch of PSLV-D3 in 1996 it used solid propellants in all the four stages however, in PSLV-D3 the indigenously developed Vikas Engine using liquid propellant

(UDMH- Unsymmetrical dimethyl hydrazine as fuel and Nitrogen tetra oxide as Oxidizer) was used in the second and fourth stages. However, the first and third stages continued to use solid propellant HTPB (Hydroxyl Terminated Poly butadyne).

PSLV has a number of variants such as Standard, Core Alone (CA) i.e. without strap-on motors, and PSLV-XL which carries more solid fuel. Another variant PSLV-HP (High Performance) is under development. ISRO has also planned to develop a three-stage version PSLV-3S which will be capable of placing 500kg payload to LEO. PSLV has repeatedly proved its reliability by launching 70 satellites (30 Indian and 40 foreign) into a variety of orbits so far. It can place satellites (about 1600kg) in sun synchronous polar orbits and satellites weighing about 1050kg in geo-stationary transfer orbit. It has already been commercialized and has launched a number of foreign satellites. For instance, PSLV-C23, on 30 June 2014 from Satish Dhawan Space Centre, Sriharikota carried five satellites, SPOT 7 of France, AISAT of Germany, CAN-XY and CAN-X5 of Canada and VELOX-1 of Singapore.

Geo-Stationary (Geosynchronous) Satellite Launch Vehicle (GSLV)

GSLV is a three-stage vehicle. Of these, the first stage comprises solid booster with four liquid strap on motors. The second stage is a liquid engine and the third stage is a cryogenic stage. It is capable of placing INSAT class of satellites into Geosynchronous Transfer Orbit (GTO).

The first experimental flight (GSLV Mk-III X/CARE) of India's next generation launch vehicle GSLV Mk-III was successfully conducted on December 18, 2014 from Satish Dhawan Space Centre SHAR, Sriharikota. It is also known as LVM3-X/CARE. This suborbital experimental mission was intended to test the vehicle performance during the critical atmospheric phase of its flight and thus carried a passive (non-functional) cryogenic upper stage.

The mission began with the launch of GSLV Mk-III and about five and a half minutes later, carried its payload - the 3775 kg Crew Module Atmospheric Re-entry Experiment (CARE) - to the intended height of 126 km. Following this, CARE separated from the upper stage of GSLV Mk-III and re-entered the atmosphere and safely landed over Bay of Bengal with the help of its parachutes.

Two massive S-200 solid strap-on boosters, each carrying 207 tons of solid propellants, ignited at vehicle lift-off and after functioning normally, they got separated. L-110 liquid stage ignited 120 seconds after lift-off, while S200s were still functioning, and carried forward for the next 204.6 seconds.

CARE separated from the passive C25 cryogenic upper stage of GSLV Mk-III after lift-off and began its guided descent for atmospheric re-entry.

After the successful re-entry phase, CARE module's parachutes opened, following which it gently landed over Andaman Sea about 1600 km from Sriharikota, thereby successfully concluding the GSLV Mk-III X/CARE mission.

With this success the vehicle has moved a step closer to its first developmental flight with the functional C25 cryogenic upper stage.

6.8 Space Based Communication in India

Space communication has revolutionized the modern era seminally because of its omnipotence. The rapidly changing global scenarios in terms of technological, social, economic and environmental developments requires immediacy and a wider reach of communication. Realizing the importance of satellite communication, India took sincere steps during 1970s itself. However, the country had to depend on foreign Satellites. With the launch of Satellite Instructional Television Experiment (SITE) in 1975, India ushered in into a new era of space-based communication (*for details see box*). This programme was considered to be the largest sociological experiment ever initiated in the world. It widened the reach of communication in rural India through a large number of television programmes relating to education, health etc. A similar kind of programme Satellite Telecommunication Experimental Project (STEP) was started in 1977-79 (*for details see box*). The success of these programmes strengthened the space-based communication system. In June 1981 India became able to launch its own experimental communication satellite APPLE (Ariane Passenger Payload Experiment). However, the milestone was the commissioning of the INSAT System in 1983 which started a new era of futuristic and farsighted development in space communication.

The fundamental aim of the policy Frame-work for Satellite Communications in India is to develop a healthy and thriving communications satellite and ground equipment industry as well as satellite communications service industry in India. Also, use and further development of the capabilities built in India in the area of satellites, launch vehicles and ground equipment design and sustaining these capabilities is an equally important aim. Making available the infrastructure built through INSAT to a larger segment of the economy and population is another corner stone of the Policy. Encouraging the private sector investment in the space industry in India and attracting foreign investments in this area are other specific goals. The norms, guidelines and procedures have been evolved so as to help reach these aims and goals.

Satellite Communication Policy 1997

1. Authorize INSAT capacity to be leased to non-government (Indian and foreign) parties following certain well defined norms.

2. Allow Indian parties to provide services including TV uplinking through Indian Satellites, subject to certain terms and conditions which are to be spelt out.

3. Authorize Indian Administration in consultation with Department of Space and other regulatory authorities to inform, notify, co-ordinate and register satellite systems and networks by and for Indian private parties following certain well defined and transparent norms. The satellite systems of all Government agencies to be established by Department of Space.

4.

(a) Operation from Indian soil with foreign satellites may be allowed only in special cases to be notified. These may be in the case of overseas services using international inter-governmental systems, systems owned and operated by Indian Parties but registered in other countries before rules for registrations have been formulated in India, international private systems where there is a substantial Indian participation by way of equity or in kind contribution and where considered necessary reciprocal arrangements could be worked out with the country/countries of registration or ownership.

(b) While operations from Indian soil may be allowed with both Indian and foreign Satellites, proposals envisaging use of the Indian satellites will be accorded preferential treatment.

(c) Satellite broadcasting including Direct to Home (DTH) TV broadcasting, may be licensed by the Licensing Authority constituted under the relevant statute, on Indian Satellite Systems or any other satellite system, excepting those prohibited for the purpose by the competent authority, notified by the Central Government in this regard, on technical or security considerations. In cases where operations of services with foreign satellites are licensed, the Licensing Authority at the time of renewal or re-issue of licenses for these services, will require the licensee to opt for the Indian Satellite System subject to availability of capacity which meets the requirement of the service.

(d) Department of Space should ensure that the various provisions of the Policy would conform to the proposed Broadcasting Law.

Suitably take into account the above policy in the regulations and the laws that may be evolved in the telecommunications and broadcasting sectors.

Satellite Communication (Satcom) Policy, 2000

The government of India launched a Satcom Policy in 2000 covering, *inter alia*, the following:

1. Opening the door for private firms to own and operate communication Satellite systems.
2. Private Companies with foreign investment up to 74 percent will be allocated transponder on board the INSAT satellites.
3. INSAT Coordination Committee (ICC) shall serve as an interface agency.

Satellite Instructional Television Experiment (SITE)

The one year long SITE communed on 1 August, 1975 and concluded on 31 July 1976. Its educational Programme also aimed at making children sensitive to, and learn, community living and improve their basic concepts and skills in the areas of numeracy, language and science. The programmes were directed at creating a positive attitude to formal education and making education interesting, creative, purposive and stimulating. The satellite for this experiment, ATS-6 was provided by NASA and the ground segment was prepared by ISRO working in collaboration with All India Radio/Doordarshan. SITE covered 2330 villages spanning in 20 district of six states.**Satellite Telecommunications Experiments Project (STEP)** STEP was carried out using the Franco-German Satellite Symphonic, the basic aims of the project were to use transportable terminals digital communication with multiple access, network integration etc.

In April 2014 in response to the Supreme Court's decision that natural resources cannot be allotted on a first come first serve basis, the government decided to overhaul India's Satcom Policy. It is likely to tweak foreign direct investment (FDI) rules. The decision to revise India's Satcom Policy also comes in the aftermath of Bharat Sanchar Nigam Ltd's. demand to buy satellite bandwidth from foreign players on grounds that ISRO was unable to give additional capacity on transponders of its choice. The new look policy will also tighten security rules and encourage establishment of surveillance systems to track satellite communication traffic.

Challenges and Prospects in Indian Satcom Market

A recent report released by Euro Consult titled "India Satcom Market, 2014" reveals that there is an average growth of 8 percent per year in commercial bandwidth demand driven by DTH satellite pay TV platforms, cable television, VSAT (Very Small Aperture Terminal) and communications network to meet growing commercial demand, ISRO has engaged in foreign subleases in the past ten years though it considers those subleases as gap-fillers until sufficient domestic capacity becomes available. However, it is likely that ISRO's dependence on foreign operators will continue. Also, ISRO has to reserve capacity for government users such as the Department of Telecommunications, Prasar Bharti and the Military that account for more than one third of its current bandwidth supply, therefore limiting the capacity available for commercial users. It is also estimated that the demand for regular C and Ku band capacity should grow at about 6 percent per year over the decade in addition to new demands for satcom services. During the 12^{th} Plan period (2012-17) India would strive for achieving self-reliance in the design and development of INSAT and GSAT services satellites and also of more capable versions of GSLV, such as MK-II and MK-III.

6.9 INSAT System

The Indian National Satellite (INSAT) system is one of the largest domestic communication satellite systems in the Asia-Pacific region. It was commissioned in 1983 with the successful launch if INSAT-1B on 20 August 1983. The system is developed as a joint Venture of the Department of Telecommunications, Indian Meteorological Department, All India Radio and Doordarshan. Insat Satellites provide transponders in various bands (C, S, Extended-C and Ku) to serve the communications and television needs of India. As a multipurpose satellite system development of INSAT contributes to India's socio-economic development and provide timely warning on impending cyclones. The launch of Edusat on 24 September, 2004 heralded a new era in the field of distance education and according to ISRO, presently about 35000 class rooms are in its network providing services at primary, secondary and university Gavels, economic development. The system is being utilized for-

<u>Space Vision India, 2025</u>

- Satellite-based communication and navigation systems for rural connectivity, security heeds and mobile services.
- Enhanced imaging capabilities for natural resources management, weather and climate change.
- Space science mission for better understanding of solar system and universe.
- Development of heavy lift launcher.
- Development of Reusable Launch Vehicle.
- Human Space flight.

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VSATs (Very small Aperture Terminals)

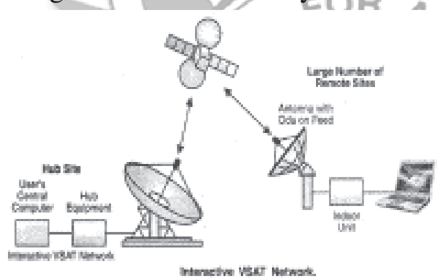
VSAT is an earthbound station which is used in satellite communications of data, voice and video signals excluding broadcast television. A VSAT consists of a transceiver that is placed indoors to interface the transceiver with the end user's communications device, such as computer.

VHRR (Very High Resolution Radiometer)

VHRR is a broad band scanner sensing in the visible, near infrared and thermal infrared portions of the electromagnetic spectrum. It measures thermal emission of the Earth. Hence it is very useful in the study of climate change.

CCD (Charged Couple Device)

It is an integrated circuit etched on to a silicon surface forming light sensitive elements called pixels. Photons incident on the surface generate charge that can be read by electronics and turned into a digital copy of the light patterns falling on the device.



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- Telecommunications
- Television
- Search & Rescue
- Meteorology
- Radio networking
- Tele-education and Tele-medicine

The telephone circuit devices through INSAT connect remote inaccessible areas to major cities in India. Television reaches 85 percent of India's population via INSAT. According to ISRO, over 200 AIR Stations are linked via INSAT network. In recent years VSATs (*see box*) have revolutionized our telecommunication sector. INSAT supports over 20,000 VSATs for e-commerce and e-governance. Moreover, BSE and NSE use VSAT technology across the country for instantaneous transaction. India has an exclusive meteorological satellite Kalpana-I. The imaging instruments VHRR and CCD (*for details see box*) collect meteorological data.

Transponder and Frequency Band

Transponder: It is an electronic device used to wirelessly receive and transmit electrical signals. It is a short term for "Transmitter- Responder".

Frequency Band

Band is a range of frequencies or, wavelength used in radio transmission and radars.

(a) **L-Band (1-2 GHZ):** Being a relatively low frequency, L-Band is easier to process, requiring less sophisticated and less expensive RF equipment. It is used in GPS carriers and also in satellite mobile phones.

(b) **S-Band (2-4 GHZ)**: S- band frequency is used in weather radars, surface ship radars and some communication satellites.

(c) **C-band (4-8 GHZ):** Primarily used for satellite communication and for full time satellite TV.

(d) **Extended C-band (5-6GHZ):** Also called Linear Extended Transponder and is used in mobile communication.

(e) **X-band (8-12GHZ):** Primarily used in radar applications and also in weather monitoring, air traffic control etc.

(f) **Ku-Band (12-18GHZ):** Mostly used in satellite TV and VSAT systems.

Ka-Band (26-40GHZ): Mostly used in HD satellite TV because of its high frequency.

INSAT-3D

INSAT 3D is the advanced meteorological satellite which was launched by Ariane-S rocket from kourou (French Guiana) on 26 July, 2013. It will remain operational till 2020. It has been specially designed to make a crucial difference to the disaster warning systems as well as weather forecasting of India. It will also provide monitoring of the ocean as well as land areas apart from providing meteorological observation.

6.10 Tele education

EDUSAT, India's first thematic satellite dedicated exclusively for educational services, was used extensively to cater to a wide range of interactive educational delivery modes like one-way TV broadcast, video conferencing, computer conferencing, web-based instructions, etc. EDUSAT had manifold objectives - to supplement the curriculum-based teaching, imparting effective teacher training, providing access to quality resource persons and new technologies, thus finally resulting in taking education to every nook and corner of India. EDUSAT provided connectivity to schools, colleges and higher levels of education and also supported non-formal education including development communication.

EDUSAT Programme was implemented in three phases: pilot, semi-operational and operational phases. Pilot projects were conducted during 2004 in Karnataka, Maharashtra and Madhya Pradesh with 300 terminals. The experiences of pilot projects were adopted in semi-operational and operational phases. During semi-operational phase, almost all the states and major national agencies were covered under EDUSAT programme. The networks were expanded under operational phase with funding by respective state governments/user agencies.

The networks implemented under EDUSAT programme comprise two types of terminals, namely, Satellite Interactive Terminals (SITs) and Receive Only Terminals (ROTs). As on December 2012, a total of 83 networks have been implemented connecting to about 56,164 schools and colleges (4,943 SITs and 51,221 ROTs) covering 26 States and 3 Union Territories of the country. Efforts are on to implement Tele-education network in Uttar Pradesh. About 15 million students are getting benefited through EDUSAT programme every year.

The tele-education networks established by ISRO include the networks set up for users with special requirements like:

- Blind People's Association (BPA) of Gujarat – for Visually challenged
- Rehabilitation Council of India (RCI)
- Central Institute of Mentally Retarded (CIMR) in Kerala
- C-DAC for Mentally challenged in Kerala

The EDUSAT (GSAT-3) satellite provided its services till September-2010, supporting Tele-education, Telemedicine and Village Resource Centres (VRC) projects of ISRO. After its de-commissioning, the traffic of Tele-education networks was migrated to other ISRO satellites. Most of the tele-education networks operating in Ku-band were migrated from GSAT-3 to INSAT-4CR and those in Ext. C-band networks were migrated to INSAT-3A, INSAT-3C and GSAT-12. Migration of remaining few networks is in the pipeline.

The Technical Support and Training Centre (TSTC) is established at Guwahati, Assam to provide technical support on continuous basis to all the Remote Sites, Hubs and Teaching-Ends of various state networks in the North East Region. The efforts are being initiated to setup similar TSTCs for Northern parts of the country, namely, Uttarakhand and Jammu & Kashmir.

The 'Network Monitoring Facility' established at Ahmedabad is used to obtain the feedback on the utilisation and assess the quality of programmes transmitted on Ku and Ext C Band EDUSAT networks.

As a special impetus to providing support to tele-education networks installed in North-East (NE) States, support for annual maintenance and hub operations is extended by ISRO.

6.11 Tele-Medicine

Telemedicine is one of the unique applications of Space Technology for societal benefit. ISRO Telemedicine programme started in 2001 has been connecting remote/rural/medical college hospitals and Mobile Units through the Indian satellites to major specialty hospitals in cities and towns. ISRO Telemedicine network covers various states/ regions including Jammu & Kashmir, Ladakh, Andaman & Nicobar Islands, Lakshadweep Islands, North Eastern States and other mainland states. Many tribal districts of Kerala, Karnataka, Chhattisgarh, Punjab, West Bengal, Orissa, Andhra Pradesh, Maharashtra, Jharkhand and Rajasthan are covered under Telemedicine Programme

Extension of healthcare through telemedicine mobile van during Koshi river floods in Bihar. Source : ISRO

Presently, the Telemedicine network of ISRO covers about 384 hospitals with 60 specialty hospitals connected to 306 remote/rural/district/medical college hospitals and 18 Mobile Telemedicine units. The Mobile Telemedicine units cover diverse areas of Ophthalmology, Cardiology, Radiology, Diabetology, Mammography, General medicine, Women and Child healthcare.

While the Department of Space and ISRO provides Telemedicine systems software, hardware and communication equipment as well as satellite bandwidth, state governments and the speciality hospitals have to allocate funds for their part of infrastructure, manpower and facility support. In this regard, technology development, standards and cost effective systems have been evolved in association with various state governments, NGOs, specialty hospitals and industry.

The recent activities under Telemedicine Programme involved migration and operationalisation of the nodes which were affected due to non-availability of EDUSAT (GSAT-3). Most of 190 nodes operating on EDUSAT were migrated to operational GSAT-12 satellite. Around 139 nodes are now operational on INSAT-3A and the remaining nodes on INSAT-3C and INSAT-4A satellites. ISRO is in the process of bringing in annual maintenance support for the Telemedicine systems to ensure continuity of service.

6.12 Space Science Missions

A. The Moon Mission

India's first lunar probe Chandrayaan-I was launched by PSLV–C11 in October 2008. On 8 November, 2008, the Vehicle was successfully inserted into the lunar orbit. On 14 November, 2008, the Moon Impact Probe (MIP) separated from the Chandrayaan Orbiter and struck the south pole in a controlled manner making India the fourth country to place its flag on the Moon. The MIP impacted near Shackleton Crater (named after Ernest Shackleton) to find out the presence of water ice. The mission was designed to prepare a 3-dimensional atlas and for chemical and mineralogical mapping. Unfortunately Chandrayaan stopped sending radio signals and ISRO declared that the mission was over on 29 August 2009.

The Indian Space Research Organisation (ISRO) is planning second moon mission Chandrayaan-2 Moon Rover by 2016 or early 2017 with the assistance of Russia. The rover would move on wheels on the lunar surface, pick up samples of soil or rocks, do a chemical analysis and send the data to the spacecraft orbiting above.

B. Technology Demonstration

India gave a new direction to its national space programme 10 January, 2007 when the Space Capsule Recovery Experiment (SRE-1) was launched by PSLV-C7. It was recovered on 22 January, 2007. SRE-I was placed in a polar orbit of an attitude of 637km. The capsule was monitored by the Bengaluru-based ISRO Telemetry, Tracking and command Network (ISTRAC) and was supported by the centers at Luckonw, Sriharikota, Mauritius, Biak in Indonesia, Saskatoon in Canada and Svalbard in Norway.

SRE-I was designed to demonstrate the capability to recover an orbiting capsule and also the technology of an orbiting platform for performing experiments in microgravity. During its space life of twelve days, SRE-I conducted mainly two experiments:-

1. Studies on melting of metals and crystallization in microgravity.
2. Research on making nano-particles in microgravity.

Considering the success of SRE-I, the Indian Space Research Organization has approved the SRE-2 mission to test some of the critical technologies for the Indian human space flight mission. SRE-2 will carry these experiments devoted to biological science and an improved isothermal furnace with 1000^0C temperature to carry out materials science experiment.

C. Solar Exploration

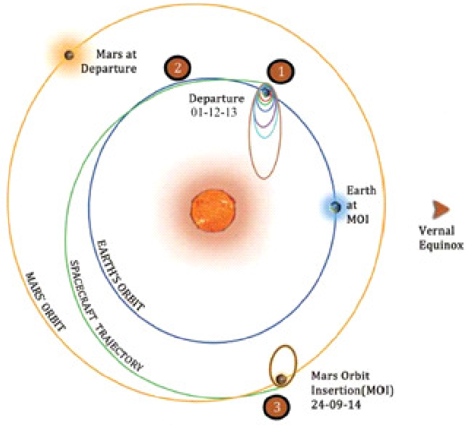
ISRO had initially planned to carry out an unmanned mission to sun by 2014, however, the current plan is to launch it between 2017-2020. Budgeted at Rs. 49 crore, Aditya-I will be the first satellite specifically designed to study the Sun's corona. Originally conceptualized by the Advisory Committee for Space Research, Aditya-I will have two main objectives:

1. To study the Coronal Mass Ejection (CME), i.e. massive burst of solar wind and plasma into the space.
2. To study the physical parameters for space.

D. Human Spaceflight Mission

India plans to build a crew vehicle that can accommodate 2 or 3 astronauts and human rate its GLSV Mk-III launcher Initially, a manned space flight was proposed before 2017, at a budget of Rs 12.4 billion ($242 million), using a fully autonomous orbital vehicle carrying two or three crew members

to 400-km (250 miles) low Earth orbit for up to 7 days and back. The planning commission approved the mission and the government sanctioned Rs 95 crore to study all aspects of the manned space mission. A 100 acre astronaut training is being constructed on the outskirts of Bengaluru by ISRO in collaboration with IAM Bengaluru at a cost of Rs 10 billion. The centre will feature a centrifuge to simulate the conditions encountered during launch and re-enter and a swimming pool like facility to train astronauts under water wearing zero buoyancy suites to simulate the weightlessness of space. A new launch pad is being built for use with the Human Rated Launcher. Later, the new launch pad will be also used with the Reusable Launch Vehicle (RLV). The facilities at the spaceport at Sriharikota and ISRO Telemetry, Tracking and Command Centre (ISTRAC), Bengaluru, are being upgraded to serve as the Mission Control Centers.



Trajectory Design

1. **Geo Centric Phase**

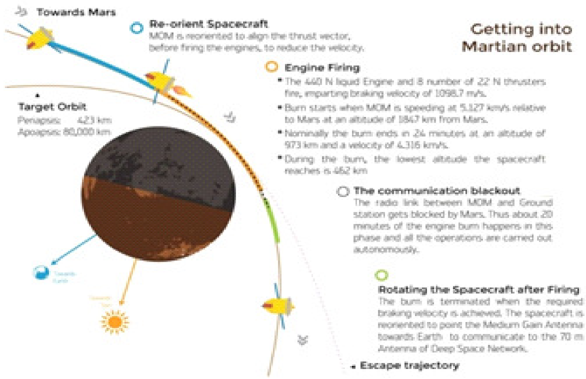
The spacecraft is injected into an Elliptic Parking Orbit by the launcher. With six main engine burns, the spacecraft is gradually maneuvered into a departure hyperbolic trajectory with which it escapes from the Earth's Sphere of Influence (SOI) with Earth's orbital velocity + V boost. The SOI of earth ends at 918347 km from the surface of the earth beyond which the perturbing force on the orbiter is mainly due to the Sun. One primary concern is how to get the spacecraft to Mars, on the least amount of fuel. ISRO uses a method of travel called a Hohmann Transfer Orbit – or a Minimum Energy Transfer Orbit – to send a spacecraft from Earth to Mars with the least amount of fuel possible.

2. **Helio Centric Phase**

The spacecraft leaves Earth in a direction tangential to Earth's orbit and encounters Mars tangentially to its orbit. The flight path is roughly one half of an ellipse around sun. Eventually it will intersect the orbit of Mars at the exact moment when Mars is there too. This trajectory becomes possible with certain allowances when the relative position of Earth, Mars and Sun form an angle of approximately 44o. Such an arrangement recur periodically at intervals of about 780 days. Minimum energy opportunities for Earth-Mars occur in November 2013, January 2016, May2018 etc.

3. Martian Phase

The spacecraft arrives at the Mars Sphere of Influence (around 573473 km from the surface of Mars) in a hyperbolic trajectory. At the time the spacecraft reaches the closest approach to Mars (Periapsis), it is captured into planned orbit around mars by imparting "V retro which is called the Mars Orbit Insertion (MOI) manoeuvre. The Earth-Mars trajectory is shown in the above figure. ISRO plans to launch the Mars Orbiter Mission during the November 2013 window utilizing minimum energy transfer opportunity.



1. Lyman Alpha Photometer (LAP) :

A photometer measures light intensity or optical properties of solutions or surfaces. The **Lyman series** is a Hydrogen spectral **series** of transitions and resulting ultraviolet emission lines of the hydrogen atom as an electron goes from n e” 2 to n = 1 (where n is the principal quantum number) the lowest energy level of the electron. When electron in a hydrogen atom makes transition from n=2 energy level to n=1 energy level, a photon is released and this type of emission of photon is known as Lyman Alpha emission. Photometer is an instrument for measuring intensity of light. Lyman Alpha Photometer is an absorption cell photometer. An absorption photometer for measuring the absorption by conducting the light to a thin flow cell in which a liquid sample flows, wherein the sample light for measuring the absorption peak is superimposed on the reference light selected from the transparent (window) range of the liquid and the absorbance is detected by separating the sample light and reference light after transmission of the flow cell. changes in the light path conditions can be mentioned accurately, and therefore high accuracy measurement immune to noises is made possible even using an elongated flow cell.

It will measure relative abundance of deuterium and hydrogen from Martian exosphere and exobase (the lowest altitude of esosphere). Measurement of Deuterium/Hydrogen ratio will help understand the loss process of water from Mars.

2. Methane Sensor for Mars (MSM) :

It is to be used to collect data for presence of methane in the Martian atmosphere. The Sensor will be passive, i.e. will work using reflected radiation. Observations over the last decade suggest that methane clouds form briefly over Mars during the summer months. Release of methane has been observed to occur from discrete surface locations on Mars, although the exact location and mechanism of release is still unknown.

3. Mars Exospheric Neutral Composition Analyzer (MENCA) :

Martian Exospheric Neutral Composition Analyzer, MENCA payload weighing 3.56 kg, is a quadrupole mass spectrometer based scientific payload on MOM, capable of measuring relative abundances of neutral constituents, in the mass range of 1-300 amu .The core objective of MENCA is to study the exospheric neutral density and composition at altitudes as low as 372 kilometers above the Martian surface. The instrument examines radial, diurnal, and seasonal variations in the Martian exosphere. With Mangalyaan in its operational orbit, MENCA is to estimate the upper limits of the neutral density distribution and composition around mars. Studying Martian exosphere will provide valuable data on the present conditions.

4. Mars Color Camera (MCC) :

Mangalyaan carries a camera payload that acquires color images of planet Mars. MCC covers a spectral range of 400 to 700 nanometers – the visible spectrum. This tri-color Mars color camera gives images & information about the surface features and composition of Martian surface. They are useful to monitor the dynamic events and weather of Mars. MCC will also be used for probing the two satellites of Mars-Phobos & Deimos. It also provides the context information for other science payloads.

5. Thermal Infrared Imaging Spectrometer (TIS) :

The TIS instrument measures thermal emissions from the Martian surface to deduce surface composition and mineralogy.

Science goals of TIS are:

- To estimate ground temperature of Mars surface.
- To map surface composition and mineralogy of Mars.
- To detect and study the variability of aerosol/dust in Martian atmosphere.
- To detect hot spots,which indicate underground hydrothermal systems.

TIS will be useful in mapping mineral compositions and surface temperature during perigee imaging(The perigee is the point in a satellite's elliptical path around the earth at which it is closest to the center of the earth)and it will be used for assessment of global temperature distribution and aerosol turbidity in Martian atmosphere during apogee viewing(apogee is the point in the orbit of an artificial satellite most distant from the center of the earth).

The objectives of Mars Orbiter Mission may be categorized into two categories :

1. Scientific : Exploration of Mars surface features and mineralogy.
2. Technological : To develop technologies for designing, planning, management and operation of inter-planetary mission and also deep space mission.

So far as its rationality is concerned, it would contribute to developing scientific temper and bring in scientific excellence. It may also contribute to an improved bilateral relations with a number of countries. For instance, China has already proposed that it might work together with India in space denying the notion of aerospace competition. Moreover, it also signifies India's commitment to the peaceful use of space.

6.12 Satellite Navigation System

Satellite navigation system are group of electronic equipments or devices by which the latitudinal, longitudinal, relief and other related data of an object or place are collected. In other words, a satellite navigation system provides geo-spatial data. These systems primarily use radio signals which are transmitted by the satellites to the ground stations where they are precisely analyzed. These systems use long wavelength radio waves. Global coverage for each system is achieved by a satellite constellation of 20-30 Medium Earth Orbit (MEO) satellites spread between several orbital planes.

The basic principle underpinning satellite positioning is the use of distance measurements at a precise moment in time between a receiver and several navigation satellites whose exact positions in space are known. The satellites emit electro-magnetic waves which are propagated through space at the speed of light. It is then possible to calculate the distance separating the satellite from the receiver by determining the time a wave takes to travel from satellite to receiver using a mathematical formula-

$d = c \times t$ where d is the distance, c the speed of light and t the time it takes for the wave to travel from satellite to receivers.

Until 1960, the ground based radio navigation systems such as DECCA, LORAN & OMEGA were using terrestrial long wave radio transmitters instead of satellites. However, the first satellite navigation system TRANSIT (also known as NAVSAT) was developed by the US in 1960s. The system was based on Doppler effect (*see Box*).

The Satellites named OSCAR and NOVA were used in this system which were placed in the polar orbits. These satellites used to broadcast their signals on a well known frequency. Satellite navigation systems are useful for both military and civilian operations. For military purposes, the system allows precision in the delivery of weapons to targets. It also allows forces to be directed and to locate themselves.

Other Applications:

- In aircrafts it is used to display a moving map for an en-route navigation.
- Boats and ships use it to locate themselves and navigate in right direction.
- Heavy equipments can use this system in construction, mining and precision agriculture.
- Surveying buildings and road construction.
- Mapping of an area with the help of GIS (Geographic Information System).
- Mobile satellite communication.
- Emergency and location based services.

Global Positioning System (GPS)

GPS is a satellite based navigation system comprising at least 24 satellites. Presently there are 31 operational satellites, plus 3-4 decommissioned ones (residuals) that can be reactivated, if needed.

The satellites in GPS constellation are arranged in 6 orbital planes and fly in Medium Earth Orbit (MEO) at an altitude of approximately 20,200 km. Each satellite circles the Earth twice a day while originally a military project, GPS is considered a dual-use technology, meaning it has significant military and civilian applications.

HOW GPS Works?

The working of GPS is based on the process of 'trilateration'. It is a method of determining the relative position of objects using the geometry of triangles. This is the reason why 'trilateration is sometimes understood as 'triangulation'. A GPS receiver measures distance using the travel time of radio signals. Each transmits data that indicates its location and the current time. All GPS satellites synchronize operation so that these repeating signals are transmitted. The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times. The distance to the GPS