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INDIAN SPACE SCIENCE

INTRODUCTION

The Indian Space programme under the Department (DoS) aims to promote the development and application of space science and technology for the socio-economic benefit of the country. It includes two major satellite systems, INSAT for communication, television broadcasting and meteorological services, and Indian Remote Sensing Satellites (IRS) system for resources monitoring and management. It has also developed two satellite launch vehicles, Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV), to place IRS and INSAT class satellites in orbit. Space activities in the country started during early 1960s with the scientific investigation of upper atmosphere and ionosphere over the magnetic equator that passes over Thumba near Thiruvananthapuram using small sounding rockets. Realising the immense potential of space technology for national development, Dr. Vikram Sarabhai, the visionary leader envisioned that this powerful technology could play a meaningful role in national development and solving the problems of common man.

From the beginning, space activities in the country, concentrated on achieving self reliance and developing capability to build and launch communication satellites for television broadcast, telecommunications and meteorological applications; remote sensing satellites for management of natural resources. Space technology has allowed the nation of India to move into the world of high technology, a place previously occupied only by more-developed nations. India has been up there since July 18, 1980, when it became the eighth nation in the world to demonstrate it could send a satellite to orbit above Earth. India launched the satellite Rohini 1 on an Satellite Launch Vehicle (SLV) rocket from the Sriharikota Island launch site. Indian cosmonaut Rakesh Sharma spent eight days in 1984 aboard the USSR's space station Salyut 7. In recent years, India has concentrated much of its space development work on complex applications satellites and more powerful rockets. The nation's two main interests are satellites for remote sensing and communications -- used for weather pictures, disaster warnings and feeds to 552 television and 164 radio stations on the ground.

The Space Commission formulates the policies and oversees the implementation of the Indian space programme to promote the development and application of space science and technology for the socio-economic benefit of the country. DOS implements these programmes through, mainly Indian Space Research Organisation (ISRO), Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern-Space Applications Centre (NE-SAC) and Semi-Conductor Laboratory (SCL). The Antrix Corporation, established in 1992 as a government owned company, markets the space products and services. The objective of ISRO is to develop space technology and its application to various national tasks. ISRO has established two major space systems, INSAT for communication, television broadcasting and meteorological services, and Indian Remote Sensing Satellites (IRS) system for resources monitoring and management. ISRO has developed two satellite launch vehicles, PSLV and GSLV, to place INSAT and IRS satellites in the required orbits.

SATELLITES

An artificial satellite is a manufactured object that continuously orbits the Earth or some other body in space. Most artificial satellites orbit the Earth. People use them to study the universe, help forecast weather, transfer telephone calls over the oceans, assist in the navigation of ships and aircraft, monitor crops and other resources, and support military activities.

Artificial satellites also have orbited the moon, the sun, asteroids, and the planets Venus, Mars, and Jupiter. Such satellites mainly gather information about the bodies they orbit. Piloted spacecraft in orbit, such as space capsules, space shuttle orbiters, and space stations, are also considered artificial satellites. Artificial satellites differ from natural satellites, natural objects that orbit a planet. Earth's moon is a natural satellite. The Soviet Union launched the first artificial satellite, Sputnik 1, in 1957. Since then, the United States and about 40 other countries have developed, launched, and operated satellites. Today, about 3,000 useful satellites and 6,000 pieces of space junk are orbiting Earth.

Types of Satellites

1. **Killer Satellites** are satellites that are armed and designed to take out enemy warheads, satellites and other space assets. They may have particle weapons, energy weapons, kinetic weapons, nuclear and/or conventional missiles and/or a combination of these weapons. Anti-satellite weapons (ASATs) are space weapons designed to incapacitate or destroy satellites for strategic military purposes. Currently, only the USA, the former USSR and the People\'s Republic of China are known to have developed these weapons.
2. **Astronomical satellites** are satellites used for observation of distant planets, galaxies, and other outer space objects.
3. **Biosatellites** are satellites designed to carry living organisms, generally for scientific experimentation.
4. **Communication satellites** are satellites stationed in space for the purpose of telecommunications. Modern communication satellites typically use geosynchronous orbits, Molniya orbits or Low Earth orbits (polar and non-polar Earth orbits). For fixed (point-to-point) services, communication satellites provide a microwave radio relay technology complementary to that of submarine communication cables. They are also used for mobile applications such as communications to ships, vehicles, planes and hand-held terminals, and for TV and radio broadcasting, for which application of other technologies, such as cable, is impractical or impossible.
5. **Miniaturized satellites** are satellites of unusually low weights and small sizes. New classifications are used to categorize these satellites: minisatellite (500–200 kg), microsatellite (below 200 kg), nanosatellite (below 10 kg).
6. **Navigational satellites** are satellites which use radio time signals transmitted to enable mobile receivers on the ground to determine their exact location. The relatively clear line of sight between the satellites and receivers on the ground, combined with ever-improving electronics, allows satellite navigation systems to measure location to accuracies of the order of a few metres in real time.
7. **Reconnaissance satellites** are observation satellites deployed for military or intelligence applications. Little is known about the full power of these satellites, as governments who operate them usually keep information pertaining to their reconnaissance satellites classified.
8. **Earth observation satellites** are satellites intended for non-military uses such as environmental monitoring, meteorology, map making etc.
9. **Space stations** are man-made structures that are designed for human beings to live in outer space. A space station is distinguished from other manned spacecraft by its lack of major propulsion or landing facilities — instead, other vehicles are used as transport to and from the station. Space stations are designed for medium-term living in orbit, for periods of weeks, months, or even years.
10. **Tether satellites** are satellites which are connected to another satellite by a thin cable called a tether.
11. **Weather satellites** are primarily used to monitor Earth\'s weather and climate.

GEOCENTRIC ORBITS OF SATELLITES

ASPECT- I

Classifications on the basis of altitudes

Geostationary Orbit

The most common orbit used for satellite communications is the geostationary orbit (GEO). There is only one main force acting on a satellite when it is in orbit, and that is the gravitational force exerted on the satellite by the Earth. This force is constantly pulling the satellite towards the centre of the Earth. A satellite doesn't fall straight down to the Earth because of its velocity. Throughout a satellites orbit there is a perfect balance between the gravitational force due to the Earth, and the centripetal force necessary to maintain the orbit of the satellite.

The satellites in this orbit remain over the same point of Earth always. It moves around the Earth at the same angular speed that the Earth rotates on its axis. The rotational period is equal to that of the Earth. The orbit has zero inclination so is an equatorial orbit (located directly above the equator). The satellite and the Earth move together so a GEO satellite appears as a fixed point in the sky from the Earth. So the orbital radius required for a geostationary, or geosynchronous orbit is 42,300 km. Since the radius of the Earth is 6378 km the height of the geostationary orbit above the Earth's surface is ~36000 km.

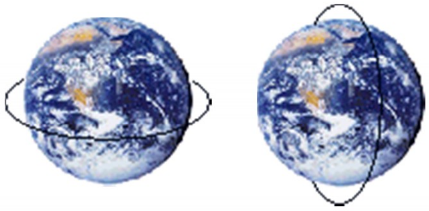
The advantages of Geostationary Orbit are that no tracking is required from the ground station since the satellite appears at a fixed position in the sky. The satellite can also provide continuous operation in the area of visibility of the satellite. Many communications satellites travel in geostationary orbits, including those that relay TV signals into our homes.

However, due to their distance from Earth GEO satellites have a signal delay of around 0.24 seconds for the complete send and receive path. This can be a problem with telephony or data transmission. Also, since they are in an equatorial orbit, the angle of elevation decreases as the latitude or longitude difference increases between the satellite and earth station. Low elevation angles can be a particular problem to mobile communications.

Low Earth Orbit/Medium Earth Orbit

A low earth orbit (LEO) and medium earth orbit (MEO) describes a satellite which circles close to the Earth. Generally, LEOs have altitudes of around 300 – 1000 km with low inclination angles, and MEOs have altitudes of around 10,000 km.

A special type of LEO is the Polar Orbit. This is a LEO with a high inclination angle (close to 90 degrees). This means the satellite travels over the poles.



LEO Orbit Polar Orbit

Satellites that observe our planet such as remote sensing and weather satellites often travel in a highly inclined LEO so they can capture detailed images of the Earth's surface due to their closeness to Earth. A satellite in a Polar orbit will pass over every region of Earth so can provide global coverage. Also a satellite in such an orbit will sometimes appear overhead (unlike a GEO which is only overhead to ground stations on the equator). This can enable communication in urban areas where obstacles such as tall buildings can block the path to a satellite. Lastly, the transmission delay is very small.

Any LEO or MEO system however, for continuous operation, requires a constellation of satellites. The satellites also move relative to the Earth so wide beam or tracking narrow beam antennas are needed.

Elliptical Orbits

A satellite in elliptical orbit follows an oval-shaped path. One part of the orbit is closest to the centre of Earth (perigee) and another part is farthest away (apogee). A satellite in this type of orbit generally has an inclination angle of 64 degrees and takes about 12 hours to circle the planet. This type of orbit covers regions of high latitude for a large fraction of its orbital period.

High Earth orbit

High Earth orbit Geocentric orbits above the altitude of geosynchronous orbit 35,786 km (22,240 miles). The region between low Earth orbit and geosynchronous orbit is very unhealthy to humans as well as electronics due to the van Allen radiation belts. The Van Allen radiation belt is a torus of energetic charged particles (plasma) around Earth, which is held in place by Earth's magnetic field. This field is not uniformly distributed around the Earth. On the sunward side, it is compressed because of the solar wind, while on the other side it is elongated to around three earth radii. To protect the satellites from the adverse impact of these radiation belts, some satellites are placed in High Earth Orbit.

ASPECT- II

Classifications on the basis of inclination

Inclined orbit

An orbit whose inclination in reference to the equatorial plane is not 0.

Polar orbit

An orbit that passes above or nearly above both poles of the planet on each revolution. Therefore it has an inclination of (or very close to) 90 degrees.

Polar sun synchronous orbit (SSO)

A nearly polar orbit that passes the equator at the same local solar time on every pass. Useful for image-taking satellites because shadows will be the same on every pass.

Non-inclined orbit

An orbit whose inclination is equal to zero with respect to some plane of reference.

Ecliptical orbit

A non-inclined orbit with respect to the ecliptic.

Equatorial orbit

A non-inclined orbit with respect to the equator.

Near equatorial orbit

An orbit whose inclination with respect to the equatorial plane is nearly zero. This orbit allows for rapid revisit times (for a single orbiting spacecraft) of near equatorial ground sites.

ASPECT- III

Classifications on the basis of eccentricity

Circular orbit

An orbit that has an eccentricity of 0 and whose path traces a circle.

Elliptic orbit

An orbit with an eccentricity greater than 0 and less than 1 whose orbit traces the path of an ellipse.

Geostationary or Geosynchronous transfer orbit

An elliptic orbit where the perigee is at the altitude of a Low Earth Orbit (LEO) and the apogee at the altitude of a geostationary orbit.

Hohmann transfer orbit

An orbital manoeuvre that moves a spacecraft from one circular orbit to another using two engine impulses. This manoeuvre was named after Walter Hohmann.

Parabolic orbit

An orbit with the eccentricity equal to 1. Such an orbit also has a velocity equal to the escape velocity and therefore will escape the gravitational pull of the planet. If the speed of a parabolic orbit is increased it will become a hyperbolic orbit.

Escape orbit

A parabolic orbit where the object has escape velocity and is moving directly away from the planet.

Capture orbit

A parabolic orbit where the object has escape velocity and is moving directly toward the planet.

Hyperbolic orbit

An orbit with the eccentricity greater than or equal to 1. Such an orbit also has a velocity in excess of the escape velocity and as such, will escape the gravitational pull of the planet and continue to travel infinitely.

Radial orbit

An orbit with zero angular momentum and eccentricity equal to 1. The two objects move directly towards or away from each other in a straight-line.

Radial elliptic orbit

A closed elliptic orbit where the object is moving at less than the escape velocity. This is an elliptic orbit with semi-minor axis = 0 and eccentricity = 1. Although the eccentricity is 1, this is not a parabolic orbit.

Radial parabolic orbit

An open parabolic orbit where the object is moving at the escape velocity.

Radial hyperbolic orbit

An open hyperbolic orbit where the object is moving at greater than the escape velocity. This is a hyperbolic orbit with semi-minor axis = 0 and eccentricity = 1. Although the eccentricity is 1, this is not a parabolic orbit.

ASPECT- IV

Classifications on the basis of synchronisation

Synchronous orbit

An orbit whose period is a rational multiple of the average rotational period of the body being orbited and in the same direction of rotation as that body. This means the track of the satellite, as seen from the central body, will repeat exactly after a fixed number of orbits. In practice, only 1:1 ratio (geosynchronous) and 1:2 ratios (semi-synchronous) are common.

Geosynchronous orbit (GEO)

An orbit around the Earth with a period equal to one sidereal day, which is Earth's average rotational period of 23 hours, 56 minutes, 4.091 seconds. For a nearly circular orbit, this implies an altitude of approximately 35,786 km (22,240 miles). If both the inclination and eccentricity are zero, then the satellite will appear stationary from the ground. If not, then each day the satellite traces out an analemma in the sky, as seen from the ground.

Geostationary orbit (GSO)

A circular geosynchronous orbit with an inclination of zero. To an observer on the ground this satellite appears as a fixed point in the sky.

Clarke orbit

Another name for a geostationary orbit. Named after the writer Arthur C. Clarke.

Tundra orbit

A synchronous but highly elliptic orbit with inclination of 63.4° and orbital period of one sidereal day (23 hours, 56 minutes for the Earth). Such a satellite spends most of its time over a designated area of the planet. The particular inclination keeps the perigee shift small.

Semi-synchronous orbit

An orbit with an orbital period equal to half of the average rotational period of the body being orbited and in the same direction of rotation as that body. For Earth this means a period of just under 12 hours at an altitude of approximately 20,200 km (12,544.2 miles) if the orbit is circular.

Molniya orbit

A semi-synchronous variation of a Tundra orbit. For Earth this means an orbital period of just under 12 hours. Such a satellite spends most of its time over two designated areas of the planet. An inclination of 63.4° is normally used to keep the perigee shift small.

Supersynchronous orbit

A disposal / storage orbit above GSO/GEO. Satellites will drift west. Also a synonym for Disposal orbit.

Subsynchronous orbit

A drift orbit close to but below GSO/GEO. Satellites will drift east.

Graveyard orbit

An orbit a few hundred kilometres above geosynchronous that satellites are moved into at the end of their operation.

Disposal orbit

A synonym for graveyard orbit.

Junk orbit

A synonym for graveyard orbit.

Areosynchronous orbit

A synchronous orbit around the planet Mars with an orbital period equal in length to Mars' sidereal day, 24.6229 hours.

Areostationary orbit (ASO)

A circular Areosynchronous orbit on the equatorial plane and about 17,000 km (10,557 miles) above the surface of Earth. To an observer on the ground this satellite would appear as a fixed point in the sky.

Heliosynchronous orbit

An heliocentric orbit about the Sun where the satellite's orbital period matches the Sun's period of rotation. These orbits occur at a radius of 24.360 Gm(0.1628 AU) around the Sun, a little less than half of the orbital radius of Mercury.

THE OUTER SPACE TREATY

Two years after Yuri Gagarin became the first human to venture into space, the U.N. General Assembly adopted the 'Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space.' It recognized "the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes." These ideals were enshrined in an international treaty called the Outer Space Treaty that was adopted in December 1966 and which entered into force a year later.

The Outer Space Treaty represents the basic legal framework of international space law and, among its principles, it bars States Parties to the Treaty from placing nuclear weapons or any other weapons of mass destruction in orbit of Earth, installing them on the Moon or any other celestial body, or to otherwise station them in outer space. It exclusively limits the use of the Moon and other celestial bodies to peaceful purposes and expressly prohibits their use for testing weapons of any kind, conducting military manoeuvres, or establishing military bases, installations, and fortifications (Art.IV). Moreover, it explicitly forbids any government from claiming a celestial resource such as the Moon or a planet. Art. II of the Treaty states that "outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."

Nevertheless, the treaty is driven by loopholes. It is not clear, for instance, where air space (over which countries have national sovereignty) ends and space, which is open to all nations, begins. The treaty makes no effort to specify what ought and ought not to be considered "peaceful purposes" in space or define a space weapon.

Human endeavours in space are often intrinsically dual-purpose. Early satellites and the first human space travellers journeyed aboard powerful rockets that were initially developed by the Soviet Union and the U.S. to lob nuclear warheads at one another. High-resolution space imageries of the sort now freely available from Google Earth over the Internet were once only produced by spy satellites. Communication satellites that employ much the same technology as the ones that beam TV programmes, relay large quantities of data and carry telephone conversations are an increasingly important part of the war machinery of many countries.

In the absence of definitions laid down in international law, the use of space for military purposes has ballooned, with possibly dangerous consequences. These days, "peaceful" use of outer space is often taken to denote only a "non-aggressive" purpose and even that conceptual distinction may not long endure.

The use of satellites to support conventional warfare has grown dramatically. The U.S. demonstrated the effectiveness of this strategy in the first Gulf War of 1991 and space has played an important part in U.S. military operations in Afghanistan and Iraq in recent years. It is a lesson that other countries have no doubt taken to heart.

But the resulting dependence on space assets inevitably raises concerns of protecting those vital satellites. It also sets off ideas of trying to blunt an opponent's military capabilities by temporarily or permanently disabling their access to satellites.

The U.S. and the Soviet Union tested a range of anti-satellite (ASAT) weaponry during their Cold War stand-off, including hit-to-kill devices carried by missiles. More recently, China destroyed one of its aging weather satellites with an impactor launched by a missile in January 2007. The U.S. responded by blowing up one of its dying spy satellites in February last year with a modified version of a missile interceptor developed for ballistic missile defence.

Besides, more and more countries are developing space capabilities of one kind or another. Given the dual-use possibilities, such capability can also mean the option to turn space into another theatre of war. Bilateral arms treaties between the U.S. and the Soviet Union at least provided a measure of stability in that they forbade attacking each other's key military satellites. But these treaties do not apply to the new players.

An internationally-binding agreement to strengthen the Outer Space Treaty is therefore both desirable and increasingly a necessity. The obvious forum for that would the U.N.

HISTORY OF SATELLITES

The first artificial satellite, Sputnik 1 was launched by the Soviet Union on 4 October 1957. Sputnik 1 helped to identify the density of high atmospheric layers through measurement of its orbital change and provided data on radio-signal distribution in the ionosphere. The success of Sputnik ignited the so-called Space Race within the Cold War.

Sputnik 2 was launched on November 3, 1957 and carried the first living passenger into orbit, a dog named Laika.

Explorer 1 became the United States' first satellite on January 31, 1958. In June 1961, three-and-a-half years after the launch of Sputnik 1, the Air Force used resources of the United States Space Surveillance Network to catalogue 115 Earth-orbiting satellites. The largest artificial satellite currently orbiting the Earth is the International Space Station.

CHRONOLOGY OF INDIAN SATELLITES

- 1963 The first sounding rocket was launched from TERLS.
- 1965 Space Science & Technology Centre (SSTC) was established in Thumba.
- 1967 Satellite Telecommunication Earth Station was erected at Ahmedabad.
- 1969 Indian Space Research Organisation (ISRO) was created on August 15 in the Department of Atomic Energy. Since then, ISRO has managed India's space research and the uses of space for peaceful purposes.
- 1972 The government established the Space Commission and the Department of Space (DOS) in June. DOS conducts the nation's space activities for ISRO at four space centres across the country. DOS reports directly to the Prime Minister.
- 1972 ISRO placed under DOS on June 1.
- 1975 ISRO made a Government Organisation on April 1.

Sl. No.	Satellite	Launch Date	Launch Vehicle	Type of Satellite
1.	Aryabhata	19.04.1975	C-1 Intercosmos	Experimental / Small Satellite
2.	Bhaskara-I	07.06.1979	C-1 Intercosmos	Earth Observation Satellite
3.	Rohini Technology Payload (RTP)	10.08.1979	SLV-3	Experimental / Small Satellite
4.	Rohini (RS-1)	18.07.1980	SLV-3	Experimental / Small Satellite
5.	Rohini (RS-D1)	31.05.1981	SLV-3	Earth Observation Satellite
6.	Ariane Passenger Payload Experiment (APPLE)	19.06.1981	Ariane-1(V-3)	Geo-Stationary Satellite
7.	Bhaskara-II	20.11.1981	C-1 Intercosmos	Earth Observation Satellite
8.	INSAT-1A	10.04.1982	Delta 3910 PAM-D	Geo-Stationary Satellite
9.	Rohini (RS-D2)	17.04.1983	SLV-3	Earth Observation Satellite
10.	INSAT-1B	30.08.1983	Shuttle [PAM-D]	Geo-Stationary Satellite
11.	Stretched Rohini Satellite Series (SROSS-1)	24.03.1987	ASLV	Space Mission
12.	IRS-1A	17.03.1988	Vostok	Earth Observation Satellite
13.	Stretched Rohini Satellite Series (SROSS-2)	13.07.1988	ASLV	Earth Observation Satellite

14.	INSAT-1C	21.07.1988	Ariane-3	Geo-Stationary Satellite
15.	INSAT-1D	12.06.1990	Delta 4925	Geo-Stationary Satellite
16.	IRS-1B	29.08.1991	Vostok	Earth Observation Satellite
17.	Stretched Rohini Satellite Series (SROSS-C)	20.05.1992	ASLV	Space Mission
18.	INSAT-2A	10.07.1992	Ariane-44L H10	Geo-Stationary Satellite
19.	INSAT-2B	23.07.1993	Ariane-44L H10+	Geo-Stationary Satellite
20.	IRS-1E	20.09.1993	PSLV-D1	Earth Observation Satellite
21.	Stretched Rohini Satellite Series (SROSS-C2)	04.05.1994	ASLV	Space Mission
22.	IRS-P2	15.10.1994	PSLV-D2	Earth Observation Satellite
23.	INSAT-2C	07.12.1995	Ariane-44L H10-3	Geo-Stationary Satellite
24.	IRS-1C	28.12.1995	Molniya	Earth Observation Satellite
25.	IRS-P3	21.03.1996	PSLV-D3	Earth Observation Satellite
26.	INSAT-2D	04.06.1997	Ariane-44L H10-3	Geo-Stationary Satellite
27.	IRS-1D	29.09.1997	PSLV-C1	Earth Observation Satellite
28.	INSAT-2DT	January 1998	Ariane-44L H10	Geo-Stationary Satellite
29.	INSAT-2E	03.04.1999	Ariane-42P H10-3	Geo-Stationary Satellite
30.	Oceansat(IRS-P4)	26.05.1999	PSLV-C2	Earth Observation Satellite
31.	INSAT-3B	22.03.2000	Ariane-5G	Geo-Stationary Satellite
32.	GSAT-1	18.04.2001	GSLV-D1	Geo-Stationary Satellite
33.	Technology Experiment Satellite (TES)	22.10.2001	PSLV-C3	Earth Observation Satellite
34.	INSAT-3C	24.01.2002	Ariane-42L H10-3	Geo-Stationary Satellite
35.	KALPANA-1(METSAT)	12.09.2002	PSLV-C4	Geo-Stationary Satellite
36.	GSAT-2	08.05.2003	GSLV-D2	Geo-Stationary Satellite
37.	INSAT-3E	28.09.2003	Ariane-5G	Geo-Stationary Satellite
38.	INSAT-3A	10.04.2003	Ariane-5G	Geo-Stationary Satellite
39.	Resourcesat-1(IRS-P6)	17.10.2003	PSLV-C5	Earth Observation Satellite
40.	EDUSAT (GSAT-3)	20.09.2004	GSLV-F01	Geo-Stationary Satellite
41.	CARTOSAT-1	05.05.2005	PSLV-C6	Earth Observation Satellite
42.	HAMSAT	05.05.2005	PSLV-C6	Experimental / Small Satellite
43.	INSAT-4A	22.12.2005	Ariane-5GS	Geo-Stationary Satellite
44.	INSAT-4C	10.07.2006	GSLV-F02	Geo-Stationary Satellite
45.	INSAT-4CR	02.09.2007	GSLV-F04	Geo-Stationary Satellite
46.	SRE - 1	10.01.2007	PSLV-C7	Experimental / Small Satellite
47.	CARTOSAT - 2	10.01.2007	PSLV-C7	Earth Observation Satellite
48.	INSAT-4B	12.03.2007	Ariane-5ECA	Geo-Stationary Satellite
49.	IMS-1	28.04.2008	PSLV-C9	Earth Observation Satellite
50.	CARTOSAT - 2A	28.04.2008	PSLV-C9	Earth Observation Satellite
51.	Chandrayaan-1	22.10.2008	PSLV-C11	Space Mission
52.	RISAT-2	20.04.2009	PSLV-C12	Earth Observation Satellite
53.	ANUSAT	20.04.2009	PSLV-C12	Experimental / Small Satellite
54.	Oceansat-2	23.09.2009	PSLV-C14	Earth Observation Satellite
55.	GSAT-4	15.04.2010	GSLV-D3	Geo-Stationary Satellite

56.	CARTOSAT-2B	12.07.2010	PSLV-C15	Earth Observation Satellite
57.	STUDSAT	12.07.2010	PSLV-C15	Experimental Satellite
58.	GSAT-5P	25.12.2010	GSLV-F06	Geo-Stationary Satellite
59.	YOUTHSAT	20.04.2011	PSLV-C16	Experimental / Small Satellite
60.	RESOURCESAT-2	20.04.2011	PSLV-C16	Earth Observation Satellite
61.	GSAT-8	21.05.2011	Ariane-5 VA-202	Geo-Stationary Satellite
62.	GSAT-12	15.07.2011	PSLV-C17	Geo-Stationary Satellite
63.	Megha-Tropiques	12.10.2011	PSLV-C18	Earth Observation Satellite
64.	SRMSat	12.10.2011	PSLV-C18	Experimental / Small Satellite
65.	Jugnu	12.10.2011	PSLV-C18	Experimental / Small Satellite
66.	RISAT-1	26.04.2012	PSLV-C19	Earth Observation Satellite
67.	GSAT-10	29.09.2012	Ariane-5 VA-209	Geo-Stationary Satellite
68.	SARAL	25.02.2013	PSLV-C20	Earth Observation Satellite
69.	IRNSS-1A	01.07.2013	PSLV-C22	Navigation Satellite
70.	INSAT-3D	26.07.2013	Ariane-5 VA-214	Geo-Stationary/Meteorological Satellite
71.	GSAT-7	30.08.2013	Ariane-5 VA-215	Geo-Stationary Satellite
72.	Mars Orbiter Mission Spacecraft	05.11.2013	PSLV-C25	Space Mission
73.	GSAT-14	05.01.2014	GSLV-D5	Geo-Stationary Satellite
74.	IRNSS-1B	04.04.2014	PSLV-C24	Navigation Satellite

APPLICATIONS OF SATELLITES

Space has become the mainstay of national infrastructure providing vital services. INSAT with more than 210 transponders, is providing tele-communications, television broadcasting, weather forecasting and societal application services such as tele-medicine and tele-education. IRS System with Nine satellites in operation is providing data for a variety of application programmes such as Groundwater Prospects Mapping, Crop Acreage and Production Estimation, Potential Fishing Zone Forecast, Biodiversity Characterisation etc. In order to take space-based services directly to the rural population, nearly 500 Village Resource Centres (VRCs) have been set up in association with NGOs, Institutes and Government Agencies.

INSAT Applications

The telephone circuit devices through INSAT connect remote inaccessible areas to major cities in India. The launch of INSAT-4A during December 2005, INSAT-4B and INSAT- 4CR in 2007 have ushered in Direct To Home (DTH) television services in the country. Television reaches 85 percent of India's population via INSAT. Over 200 AIR stations are linked via INSAT network. In the recent years, Very Small Aperture Terminals (VSAT) have revolutionised our telecommunications sector. INSAT supports over 20,000 VSATs for e-commerce and e-governance. National Stock Exchange and Bombay Stock Exchange use VSAT technology across the country for instantaneous transactions. Today exclusive channels are provided for interactive training and Developmental communication including distance learning.

India has an exclusive meteorological satellite Kalpana - 1. The imaging instruments (VHRR) & (CCD) collect meteorological data and provide timely warnings on impending cyclones. The data relay transponder in the INSAT system is used for collect real time hydro meteorological data for river monitoring flow forces.

The launch of EDUSAT on September 20, 2004 heralded new era in the field of distance education and today, about 35,000 class rooms are in the EDUSAT network providing services at primary, secondary and university levels.

The satellite based telemedicine network has expanded its network connecting 375 hospitals (305 remote and rural hospitals including those in Jammu & Kashmir, North Eastern region and Andaman and Nicobar Islands, 13 mobile units and 57 super specialty hospitals in major cities).

IRS Applications

Imagery taken by Indian Remote Sensing (IRS) Satellite System has found application in diverse fields ranging from agriculture to urban planning. Crop health monitoring, crop yield estimation and drought assessment are the significant areas of application in the agriculture and the allied fields. Soil mapping at different scales with relative ease has become a reality.

IRS data has also been used for Ground Water potential zone mapping and mineral targeting tasks. The ocean applications of IRS data include potential fishing zone identification and coastal zone mapping.

Forest cover mapping, biodiversity characterisation and monitoring of forest fire is now carried out using IRS imagery. IRS spacecraft provide timely inputs to Flood and earthquake damage assessment thereby providing the necessary supportive strength to disaster management. Even in the field of Archaeological survey, the utility of IRS imagery has been well established.

The judicious combination of information derived from space based imagery with the ground based socio economic data is leading to a holistic approach for resource monitoring and its management.

Village Resource Centre (VRC)

Combining the services offered by INSAT and IRS satellites, a new concept namely Village Resource Centre (VRC) to provide information on natural resources, land and water resources management, tele-medicine, tele-education, adult education, vocational training, health and family welfare programmes has been established. Nearly 500 such VRCs have been established in the country.

OTHER APPLICATIONS

Satellite Communication (Satcom)

Satellite Communication (Satcom) technology offers the unique capability of simultaneously reaching out to very large numbers spread over large distances even in the most remote corners of the country. The hallmark of Indian Space Programme has been the application oriented efforts and the benefits that have accrued to the country. In the past two and a half decades Indian National Satellite (INSAT) system have revolutionized the country's telecommunications, TV broadcasting, DTH services, business communications, rural area connectivity, Tele-education, Tele-medicine, Village Resource Centres, Search and Rescue operations and Emergency Communications.

INSAT system is a joint venture of the Department of Space, Department of Telecommunications, India Meteorological Department, All India Radio and Doordarshan. Established in 1983, INSAT system is one of the largest domestic communication satellite systems in the Asia Pacific Region with eleven satellites in operation. These satellites carry more than 200 transponders in the C, Extended C and Ku-bands, besides meteorological instruments.

INSAT is used for a variety of societal applications in the area of Tele-education, Tele-medicine and support to the Disaster Management System (DMS). Meteorological data from INSAT is used for weather forecasting and specially designed disaster warning receivers have been installed in vulnerable coastal areas for direct transmission of warnings against impending disaster like cyclones.

GRAMSAT Programme

The Gramsat Programme (GP) is an initiative to provide communication networks at the state level connecting the state capital to districts and blocks. The networks provide Computer Connectivity, Data Broadcasting and TV Broadcasting facilities having applications like e-Governance, National Resource Information System (NRIS), Development Information, Tele-conferencing, Disaster Management, Tele-medicine and Distance Education.

The Gramsat networks are operational in Orissa, Andaman & Nicobar Islands, Rajasthan and West Bengal. Now, the plans are to provide the integrated services through a single hub for the state networks - i.e. a grid for diverse developmental services, with integration of Satcom networks with existing communication infrastructure for seamless information through hybrid systems.

Telemedicine

Telemedicine Programme is an innovative process of synergising benefits of Satellite communication technology and information technology with Biomedical Engineering and Medical Sciences to deliver the health care services to the remote, distant and underserved regions of the country.

Providing healthcare to India's over one billion population of which about 75 percent live in villages, is a formidable task. About 75 percent of the doctors practice in urban areas and 23 percent in semi-urban areas. This leaves just 2 percent of the qualified doctors, who are attached to about 23,000 primary health and 3000 community health centers, to attend to 70 percent of the population living in villages.

ISRO's telemedicine pilot project was started in the year 2001 with the aim of introducing the telemedicine facility to the grass root level population as a part of proof of concept technology demonstration. The telemedicine facility connects the remote District Hospitals/Health Centres with Super Specialty Hospitals in cities, through the INSAT Satellites for providing expert consultation to the needy and underserved population.

Telemedicine initiatives at ISRO have been broadly divided into the following areas:

(a) Providing Telemedicine Technology & connectivity between remote/rural hospital and Super Speciality Hospital for Teleconsultation, Treatment & Training of doctors & paramedics.

(b) Providing the Technology & connectivity for Continuing Medical Education (CME) between Medical Colleges & Post Graduate Medical Institutions/Hospitals.

(c) Providing Technology & connectivity for Mobile Telemedicine units for rural health camps especially in the areas of ophthalmology and community health.

(d) Providing technology and connectivity for Disaster Management Support and Relief.

Presently, ISRO's Telemedicine Network has enabled 382 Hospitals with the Telemedicine facility. 306 Remote/Rural/District Hospital/Health Centres and 16 Mobile Telemedicine units are connected to 51 Super Speciality Hospitals located in the major cities. The mobile vans are extensively used for tele-ophthalmology, diabetic screening, mammography, childcare and community health. The Mobile Teleopthalmology facilities provide services to the rural population in ophthalmology care including village level eye camps, vision screening for Cataract /Glaucoma / Diabetic Retinopathy.

The telemedicine facilities are established at many remote rural district hospitals in many states and union territories of the country including Jammu & Kashmir, Andaman & Nicobar Islands, Lakshadweep Islands, North Eastern States etc. State level telemedicine networks are established in Karnataka, Kerala, Rajasthan, Maharashtra, Orissa and Chhattisgarh. Many interior districts in Orissa, Madhya Pradesh, Andhra Pradesh, Punjab, West Bengal and Gujarat have the telemedicine facility. About 1.5 Lakh patients are getting the benefits of Telemedicine every year.

Television

INSAT has been a major catalyst for the expansion of television coverage in India. Satellite television now covers 100% area and 100% population. The terrestrial coverage is over 65 percent of the Indian land mass and over 90 percent of the population. At present 40 Doordarshan TV channels including news uplinks are operating through C-band transponders of INSAT-3A, INSAT-4B, INSAT-3C and INSAT-2E (Additionally IS-10 & IS-906 INTELSAT leased). All of the Satellite TV channels are digitalized.

INSAT provides bandwidth for DTH broadcasting service over Indian region. At present DTH service is operational through INSAT- 4 series. INSAT-4 series has high power transponders to support DTH service with 60/90 cm dish of TVRO at receive side, all over India.

In all, around 16.2 millions of TVROs are distributed and operational all over India by various service providers.

Satellite News Gathering and Dissemination

Satellite News Gathering using INSAT system enables on the spot real-time news coverage and important events at different locations for transmission to a Central Station at Delhi or to State Capitals for rebroadcast over respective DD channels. Prasar Bharati has 12 C-band and 16 Ku-band Digital Outdoor-Broadcast DSNG terminals operating through INSAT, IS-10 and IS-906 network. 2 in Ku-band and 6 in C-band DSNG terminals are in the process of induction. 16 more DSNGs in C-Band are proposed to be introduced in the network during 11th plan.

Press Trust of India (PTI) is implementing a system to provide its news and information services at higher speed and increased volume and variety directly to a wider range of media and other users by utilising the broadcast facilities of INSAT-3C. The project utilises a Radio Networking (RN) type of channel on one of the broadcast (CxS) transponders of the satellite. PTI satellite news and facsimile dissemination project is working with 15 terminals (14 from PTI and one shared with AIR).

Eight transportable uplink terminals (DSNG) are being utilized by AIR for coverage of events taking place at remote locations and for relay of programmes directly from the spot via INSAT. In addition to this three more DSNG terminals are in the process of induction at different AIR stations. These terminals are capable of uplinking CD quality music channel from any remote location.

Radio Networking

Radio Networking (RN) through INSAT provides a reliable high-fidelity programme channels for national as well as regional networking. At present, 235 All India Radio (AIR) stations have been equipped with S-band receive terminals out of which around 200 AIR stations have been equipped to receive C-band Analogue and Digital RN carriers also and rest of the stations are going to be equipped with analogue and digital C-band RN Terminals by the end of XIth Plan.

A total of 104 RN channels are being up-linked at present. Out of these, 43 are operating in CxS and 61 in CxC bands. For this AIR is utilising two Nos S-band transponders (partial) and one C-band transponder of INSAT-3C. A total of 90 carriers in CxC band are being envisaged for up-linking by utilising full one transponder of INSAT-3C.

In AIR network, a total of 32 earth stations are present with facility to uplink in both CxS and CxC band frequency. The Central earth station at Broadcasting House, New Delhi, has been augmented to up-link 22 RN carriers in CxS and CxC band.

Telecommunications

A total of 620 telecommunication terminals of various sizes and capabilities (excluding NICNET, and VSAT micro terminals) are operating in INSAT telecommunications network providing 8177 two-way speech circuits. These include 95 BSNL, 170 for government users and 204 Closed User Group(CUG)/VSAT operators earth stations and 355 Closed User Group (CUG)/VSAT Operators Earth Stations. 80 Multi Channel per Carrier(MCPC) VSATs,10 RABMN VSATs and 3100 Ku Bnad VSATs under HVNET are working with BSNL. Total of 1,02,421 CUG VSATs are operating through INSAT.

Captive satellite-based networks for National Thermal Power Corporation, Gas Authority of India Ltd, Nuclear Power Corporation, Indian Telephone Industries, Oil and Natural Gas Commission, National Fertilizers Limited and Coal India Limited, DPNET, ERNET, IDRBT, Karnataka Power Transmission Corporation Limited, ITI, GNFC, West Bengal State Electricity Distribution Co. Ltd, IOCL, Khazane Net, BPCL, Jai Prakash Industries Ltd., Indian Railway Project Management Unit are operational. The National Stock Exchange VSAT network & BSE Network in extended C-band are operational. A number of captive government networks are also working with INSAT. More organizations are in the process of implementing their own captive networks using INSAT.

Mobile Satellite Services

An S-band Mobile Satellite Service (MSS) was added to INSAT system with the launch of INSAT-3C in 2002 and GSAT-2 in 2003. The following two classes of services were identified for MSS:

A small portable satellite terminal that works with INSAT for voice/data communication has been developed with the participation of Indian industries. The terminal is useful for voice communication especially during disasters when other means of communication break down. It can be used from any location in India for emergency communication. Transmit and receive frequencies of the terminal are in S-Band.

The portable terminal is connected to the EPABX at central hub station through satellite channel and hence could be considered as an extension of EPABX and call could be made between any satellite terminals and local phones on EPABX. Central hub station is located at SAC, Ahmedabad.

Meteorology

The meteorological data of INSAT system is processed and disseminated by INSAT Meteorological Data Processing System (IMDPS) of India Meteorological Department (IMD). Upper winds, sea surface temperature and precipitation index data are regularly obtained. The products derived from the image data include: cloud motion vectors, sea surface temperature, outgoing long-wave radiation and quantitative precipitation index. The products are used for weather forecasting, both synoptic and numerical weather prediction.

INSAT-VHRR imageries are used by Doordarshan during news coverage and by newspapers as part of weather reporting. At present, repetitive and synoptic weather system observations over Indian Ocean from geostationary orbit are available only from INSAT system. INSAT VHRR data is available in near real-time at 90 Meteorological Data Dissemination Centres (MDDC) in various parts of the country. With the commissioning of direct satellite service for processed VHRR data, MDDC type of data can be provided at any location in the country.

IMD has installed 100 meteorological Data Collection Platforms (DCPs) and other agencies have installed about 200 DCPs all over the country. One DCP is also installed at Schiramacher, the Indian base station in Antarctica.

DCP services are provided using the Data Relay Transponders of Kalpana-1 and INSAT-3A. A rainfall monitoring system which operates at 300 bits/second has been developed. ISRO has taken up indigenous development of low cost automatic weather station for deployment in the country in large numbers. The data collection is proposed to be carried out in TDMA mode instead of the present random access mode.

For quick dissemination of warnings against impending disaster from approaching cyclones, specially designed receivers have been installed at the vulnerable coastal areas in Andhra Pradesh, Tamil Nadu, Orissa, West Bengal and Gujarat for direct transmission of warnings to the officials and public in general using broadcast capability of INSAT. IMD's Area Cyclone Warning Centres generate special warning bulletins and transmit them every hour in local languages to the affected areas. Three hundred and fifty such receiver stations have been installed by IMD. Out of these 100 are Digital CWDS (DCWDS) based on advanced technology. The DCWDS has been deployed with acknowledgement transmitters to get confirmation at transmitting station.

A cooperative agreement has been signed with EUMETSAT for using meteorological data from Meteosat-5 at 63 degree East in exchange for weather pictures collected by INSAT.

Satellite Aided Search and Rescue

406 MHz Cospas-Sarsat Distress beacon developed by VSSC

India is a member of the international COSPAS-SARSAT programme for providing distress alert and position location service through LEOSAR (Low Earth Orbit Search And Rescue) satellite system. Under this programme, India has established two Local User Terminals (LUTs), one at Lucknow and the other at Bangalore. The Indian Mission Control Centre (INMCC), is located at ISTRAC, Bangalore.

INSAT-3A located at 93.5 deg East is equipped with 406 MHz Search and Rescue payload that picks up and relays alert signals originating from the distress beacons of maritime, aviation and land users. INSAT and GOES systems have become an integral part of the COSPAS-SARSAT system and they complement the LEOSAR system.

Indian LUTs provide coverage to a large part of Indian Ocean region rendering distress alert services to Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania. The operations of INMCC/LUT are funded by the participating agencies, namely, Coast Guard, Airports Authority of India (AAI) and Director General of Shipping and Services.

INSAT GEOSAR Local User Terminal (GEO LUT) is established at ISTRAC, Bangalore and integrated with INMCC. The distress alert messages concerning the Indian service area, detected at INMCC are passed on to Indian Coast Guard and Rescue Coordination Centres at Mumbai, Kolkata, Delhi and Chennai. The search and rescue activities are carried out by Coast Guard, Navy and Air Force. INMCC is linked to the RCCs and other International MCCs through Aeronautical Fixed Telecommunication Network (AFTN). The

Indian LUTs and MCC provide service round the clock and maintain the database of all 406 MHz registered beacons equipped on Indian ships and aircraft.

Development of indigenous search and rescue beacons has been completed, and is now in qualification phase. Shortly it will be released to the Indian fishermen community.

Till date, there are about 400 registered user agencies (Maritime & Aviation) in India with more than 5200 radio beacons in use.

Migration from LEOSAR & GEOSAR to MEOSAR system has been under taken. Design of upcoming MEOSAR system is ready and will be implemented in 2 years.

Satellite Navigation

GAGAN

The Ministry of Civil Aviation has decided to implement an indigenous Satellite-Based Regional GPS Augmentation System also known as Space-Based Augmentation System (SBAS) as part of the Satellite-Based Communications, Navigation and Surveillance (CNS)/Air Traffic Management (ATM) plan for civil aviation. The Indian SBAS system has been given an acronym GAGAN - GPS Aided GEO Augmented Navigation. A national plan for satellite navigation including implementation of Technology Demonstration System (TDS) over the Indian air space as a proof of concept has been prepared jointly by Airports Authority of India (AAI) and ISRO. TDS was successfully completed during 2007 by installing eight Indian Reference Stations (INRESs) at eight Indian airports and linked to the Master Control Center (MCC) located near Bangalore.

The first GAGAN navigation payload has been fabricated and it was proposed to be flown on GSAT-4 during Apr 2010. However, GSAT-4 was not placed in orbit as GSLV-D3 could not complete the mission. Two more GAGAN payloads will be subsequently flown, one each on two geostationary satellites, GSAT-8 and GSAT-10.

The Disaster Management Support (DMS) Programme of ISRO, provides timely support and services from aero-space systems, both imaging and communications, towards efficient management of disasters in the country. The DMS programme addresses disasters such as flood, cyclone, drought, forest fire, landslide and Earthquake. These include creation of digital data base for facilitating hazard zonation, damage assessment, etc., monitoring of major natural disasters using satellite and aerial data; development of appropriate techniques and tools for decision support, establishing satellite based reliable communication network, deployment of emergency communication equipments and R&D towards early warning of disasters.

To support the total cycle of disaster/ emergency management for the country, in near real time, the database creation is addressed through National Database for Emergency Management (NDEM), a GIS based repository of data. NDEM is envisaged to have core data, hazard-specific data, and dynamic data in spatial as well as aspatial form.

Airborne ALTM-DC data acquisition is being carried out for the flood prone basins in the country. The development of flight model of C band DMSAR is nearing completion. SAR data was acquired over selected basins using Development model of DMSAR. Towards providing emergency communication for disaster management activities, and at the behest of Ministry of Home Affairs (MHA), ISRO has set up a satellite based Virtual Private Network (VPN) linking the National Control Room at MHA with DMS-DSC at NRSC, important national agencies, key Government Offices in Delhi and the Control Rooms of 22 multi-hazard-prone States. Further ISRO has developed and deployed INSAT Type-D terminals (portable satellite phones), INSAT based Distress Alert Transmitter (DAT) for fishermen, Cyclone Warning Dissemination System (CWCS) and DTH based Digital Disaster Warning System (DDWS) in disaster prone areas.

As part of R&D support to DMS for remote sensing applications, work on Tropical Cyclone Track intensity and landfall prediction, Earthquake Precursor studies, Coastal Vulnerability mapping and Early Warning of Landslides are being carried out.

The DMS programme is also supporting the many international initiatives by sharing data and information. Through International Charter "Space and Major Disasters" and Sentinel Asia (SA) initiative for supporting disaster management activities in the Asia-Pacific region, ISRO is providing IRS datasets and other information for use during major calamities

To provide the space technology enabled services directly to the rural population, ISRO launched the Village Resource Centres (VRCs) programme in association with reputed NGOs/ Trusts and state/ central agencies.

473 VRCs have been set up in 22 States/Union Territories, namely Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Nagaland, Orissa, Puducherry, Rajasthan, Sikkim. Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal and A & N islands.

The VRCs are connected to Knowledge/Expert Centres like Agricultural Universities, Skill Development Institutes and Hospitals. Over 6500 programmes have been conducted by the VRCs in the areas of, Agriculture/horticulture, Fisheries, Live stock, Water resources, Tele health care, Awareness programmes, Women empowerment, Supplementary education, Computer literacy, Micro credit, Micro finance, Skill development / vocational training for livelihood support etc. So far, over five Lakh people have availed VRC services.

LAUNCH FACILITIES IN INDIA

India has established a strong infrastructure for executing its space programme. They include facilities for the development of satellites and launch vehicles and their testing; launch infrastructure for sounding rockets and satellite launch vehicles; telemetry, tracking and command network; data reception and processing systems for remote sensing.

A number of academic and research institutions as well as industries participate in the Indian Space Programme. Several Indian industries have the expertise to undertake sophisticated jobs required for space systems.

SDSC SHAR has the necessary infrastructure for launching satellite into low earth orbit, polar orbit and geostationary transfer orbit. The launch complexes provide complete support for vehicle assembly, fuelling, checkout and launch operations. Apart form these, it has facilities for launching sounding rockets meant for studying the earth's atmosphere.

FIRST LAUNCH PAD

The individual stages of PSLV or GSLV, their subsystems and the spacecraft are prepared and checked out in separate facilities before they are sent to launch pad for integration. A-76-meter tall mobile service tower (MST) facilitates the vertical integration of the vehicle. The foldable working platforms of MST provide access to the vehicle at various elevations. A massive launch pedestal, made up of steel plates, acts as the base on which the vehicle is integrated.

The spacecraft is integrated to the vehicle in a clean room, set up inside the MST. However, in the case of GSLV, the spacecraft is interfaced with the payload adopter and then encapsulated in the heat shield in the preparation facility itself. The encapsulated assembly is moved to the launch pad for integrating with the 3rd stage of GSLV. The umbilical tower houses the feed lines for liquid propellants and high-pressure gases, checkout cables, and chilled air duct for supplying cool air to the satellite and equipment bay.

SECOND LAUNCH PAD

In order to provide redundant facilities for launching the operational PSLVs and GSLVs and also to have quick turnaround time for launch, an additional launch pad with associated facilities was constructed. It was designed to accommodate, both the present PSLVs and GSLVs, and also the future launch vehicle configurations such as GSLV-MkIII.

As per the integrate, transfer and launch (ITL) concept, based on which the new launch pad and the associated facilities are designed, the entire vehicle is assembled and checked-out on a mobile pedestal in the Vehicle Assembly Building (VAB) and then moved in vertical position to the launch pad on a roll track.

Other facilities include, Solid Stage Assembly Building (SSAB) connected to the Vehicle Assembly Building (VAB) by a rail track, Technical Complex-2 (TC2), Spacecraft Preparation Facility, Range Instrumentation facilities comprising tracking, telemetry and tele-command systems.

LAUNCH VEHICLES OF INDIA

Launch Vehicles are used to transport and put satellites or spacecrafts into space. In India, the launch vehicles development programme began in the early 1970s. The first experimental Satellite Launch Vehicle (SLV-3) was developed in 1980. The first experimental flight of SLV-3, in August 1979, was only partially successful. SLV-3, India's first experimental satellite launch vehicle was successfully launched on July 18, 1980 from SHAR Centre Sriharikota, when Rohini satellite, RS-1, was placed in orbit. SLV-3 was a 22 m long, all solid, four stage vehicle weighing 17 tonnes capable of placing 40 kg class payloads in low earth orbit. Apart from the July 1980 launch, there were two more launches held in May 1981 and April 1983, orbiting Rohini satellites carrying remote sensing sensors.

An Augmented version of this, ASLV, was launched successfully in 1992. India has made tremendous strides in launch vehicle technology to achieve self-reliance in satellite launch vehicle programme with the operationalisation of Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV).

PSLV represents ISRO's first attempt to design and develop an operational vehicle that can be used to orbit application satellites. While SLV-3 secured for India a place in the community of space-faring nations, the ASLV provided the rites of passage into launch vehicle technology for ISRO. And with PSLV, a new world-class vehicle has arrived. PSLV has repeatedly proved its reliability and versatility by launching 44 satellites/spacecrafts (19 Indian and 25 for international customers) into a variety of orbits so far.

ISRO also makes the Rohini series of sounding rockets used by the Indian and international scientific community to launch payloads to various altitudes for atmospheric research and other scientific investigations. These rockets are also used to qualify some of the critical systems used for advanced launch vehicles.

It employed an open loop guidance (with stored pitch programme) to steer the vehicle in flight along pre-determined trajectory.

Augmented Satellite Launch Vehicle (ASLV) was developed to act as a low cost intermediate vehicle to demonstrate and validate critical technologies. With a lift off weight of 40 tonnes, the 23.8 m tall ASLV was configured as a five stage, all-solid propellant vehicle, with a mission of orbiting 150 kg class satellites into 400 km circular orbits. The strap-on stage consisted of two identical 1m diameter solid propellant motors, Under the ASLV programme four developmental flights were conducted. The first developmental flight took place on March 24, 1987 and the second on July 13, 1988.

The Polar Satellite Launch Vehicle (PSLV)

The Polar Satellite Launch Vehicle, usually known by its abbreviation PSLV is the first operational launch vehicle of ISRO. PSLV is capable of launching 1600 kg satellites in 620 km sun-synchronous polar orbit and 1050 kg satellite in geo-synchronous transfer orbit. In the standard configuration, it measures 44.4 m tall, with a lift off weight of 295 tonnes. PSLV has four stages using solid and liquid propulsion systems alternately. The first stage is one of the largest solid propellant boosters in the world and carries 139 tonnes of propellant. A cluster of six strap-ons attached to the first stage motor, four of which are ignited on the ground and two are air-lit.

The reliability rate of PSLV has been superb. There had been 16 continuously successful flights of PSLV, till July 2010. With its variant configurations, PSLV has proved its multi-payload, multi-mission capability in a single launch and its geosynchronous launch capability. In the recent Chandrayaan-mission, another variant of PSLV with an extended version of strap-on motors, PSOM-XL, the payload haul was enhanced to 1750 kg in 620 km SSPO. PSLV has rightfully earned the status of workhorse launch vehicle of ISRO.