33

Space Exploration

Man-made satellites orbiting the earth beyond the atmosphere have, now a days, become a part of our everyday life. Daily weather forecast and a picture of clouds taken from a satellite on your TV, a cricket match live on TV which is being played in Australia or any other country, reaches the local TV station through satellite. You talk to your friend far away while electromagnetic waves carry your massage via a satellite. Satellite pictures estimate forest cover and (on finding that it is decreasing fast) you are advised to save paper, and so on, the list is endless.

Space means the vast, limitless and continuous expanse (or region) beyond the earth's atmosphere. Sometimes we call it **outer space** in order to distinguish it from space occupied by atmosphere.

In this lesson you will study how we use space with the help of **space vehicles**. (i.e. satellites orbiting the earth or space probes which leave the earth) for various purposes of importance to mankind, (e.g. for the study of earth's atmosphere or surface or heavenly object like planets, or for communication). This field of knowledge is called **space exploration.**

OBJECTIVES

After completing this lesson, you will be able to:

- explain the meaning of space exploration and state its need and importance;
- recall the efforts made by different countries for space exploration;
- distinguish between natural and artificial satellites;
- give an elementary idea of how a satellite is launched;
- differentiate between the different types of launch vehicles on the basis of their capacity;
- define the nature of path of different types of artificial satellites;
- examine the applications of artificial satellites in the field communication, remote sensing and weather forecasting;
- mention the aim and objective of Indian space programme and identify the Indian achievements in the field of space science.

33.1 KINDS OF SATELLITES AND SATELLITE ORBITS

33.1.1 Natural and artificial satellites

You all are familiar with the Moon. It revolves around Earth. Hence, it is a satellite of Earth. The planet Jupiter has 16 satellites revolving around it. Man has no role in the existence of these satellites. Hence, these are **natural satellites**. Now-a-day we have acquired technology to launch satellites revolving around Earth or any other planet for our own purposes, e.g. scientific data collection. A satellite launched by man around any planet for our own purpose is called an **artificial satellite** or **man-made satellite**. Sputnik-I, Explorer-I, GSAT-I and GSAT-II (recently launched by India) are examples of artificial satellites.

33.1.2 The path of a satellite

The path of a satellite revolving around the Earth is called its **orbit**. It is a circle or an ellipse lying in a plane passing through the center of Earth, shown at O in Figure 33.1. The following three parameters define the orbit of a satellite.

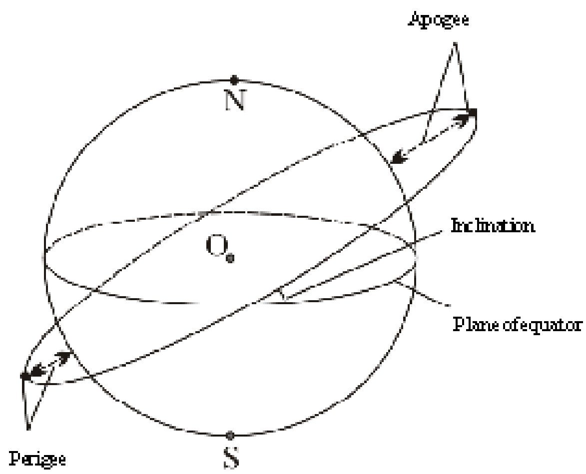

Fig. 33.1 Parameters that define the orbit of a satellite

Apogee: It is a point on the orbit where vertical distance of the satellite from the Earth's surface is maximum. The maximum distance of the satellite from Earth's surface is also called apogee of the orbit of the satellite.

Perigee: It is a point on the orbit where vertical distance of the satellite from the Earth's surface is smallest. The smallest distance of the satellite from the Earth's surface is also called perigee of the orbit of the satellite.

Inclination: The angle between the plane of orbit of the satellite and plane of the equator of Earth is called **inclination** of the orbit.

33.1.3 Types of orbits

If the inclination of the orbit of a satellite is 90^o (Fig. 33.2), then during one revolution around the Earth, the satellite passes once vertically above the north pole of Earth and once above the south pole of the Earth. Such an orbit is called a

polar orbit. The center of Earth, North Pole and South Pole, all lie in the plane of a polar orbit, which is perpendicular to the plane of equator. The satellite moving in a polar orbit is called a **polar satellite**.

Consider a satellite whose orbit is in the plane of equator (Fig.33.3), i.e. its inclination is 0^o. It is at a height of about 36000 km above the equator and keeps this distance constant. Thus, it is a circular orbit. At this height, the satellite makes one revolution around earth in just as much time as the earth itself takes to spin 360^o around its axis. Hence, relative to any location on earth, the position of the satellite is stationary. This orbit is called **geo-stationary orbit**. A satellite revolving in this orbit is called a **geo-stationary satellite**.

The time, which a satellite takes to make one complete revolution in its orbit is called its **time period**. Thus, the time period of a geo-stationary satellite is precisely one day, which is also the time period of rotation of earth.

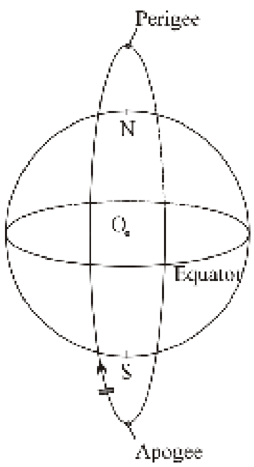

Fig. 33.2 A satellite in a polar orbit

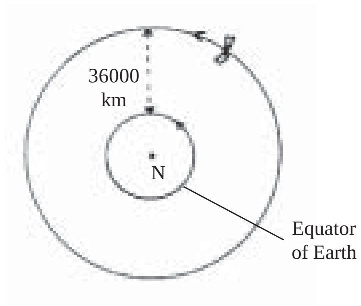

Fig. 33.3 A satellite in the geo-stationary orbit

Referring to Fig. 33.1 or 33.2, consider a satellite whose time period is such that it makes exactly an integral number of revolutions (usually 13, 14 or 15) around earth in 24 hours. After passing over a certain place on Earth, next day it will again pass over the same place at the same time of day. While Earth spins one rotation, relative to sun in 24 hours, the satellite makes an accurately integral number of revolutions. Thus, satellite will be able to look at that place and photograph it on consecutive days in identical illumination, Sun being in the same position relative to that place. Such an orbit is called a **sun-synchronous orbit**. The satellite moving in this orbit is called a **sun-synchronous satellite**.

To be precise, earth spins through an angle a little more than 360^o in 24 hours, say $(360^o + \theta)$ (Fig. 33.4). In the same time it revolves around Sun through angle θ. Thus, the position of Sun relative to any place on Earth is same after 24hours. Thus, the illumination at that place on Earth is the same. But the position of Sun-synchronous satellite is not precisely above that place after 24 hours. It is to the west of that place through angle θ in longitude, though its latitude is same.

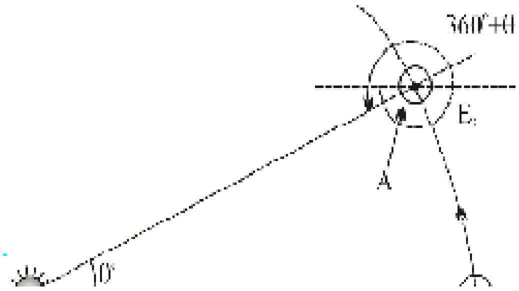

Fig. 33.4 E_1 is the first position of Earth and E_2 the position after 24 hours. It revolves through angle θ around Sun and spins $360^o + \theta$

CHECK YOUR PROGRESS 33.1

1. What is meant by the statement 'apogee of the orbit of a satellite is 900 km'?
2. What is meant by the statement 'perigee of the orbit of a satellite is 450km'?
3. Draw a labelled diagram to show the orbit of a satellite having parameters; apogee 900 km, perigee 300 km and inclination 90^o.
4. Time taken by an artificial satellite for revolving once around Earth is same as the time which earth takes to complete one rotation about its axis. Name the type of this orbit. Give two other features of this orbit.
5. What are the parameters of a polar satellite?
6. State two features of a sun-synchronous orbit? What are its parameters?

33.2 NEED AND IMPORTANCE OF SPACE EXPLORATION

Launching a satellite in orbit and designing and fabricating a satellite, which serves useful purpose, both are extremely expensive tasks. In the beginning of space research, this activity was considered a waste of money, to be done only by some rich countries. With development of technology, cost came down and newer applications were developed. Thus, today it has become an essential part of our everyday life due to its many applications. What are the areas in which it finds application? Some areas of application are given herewith.

33.2.1 Satellite communication

Sending massages to long distances using a geo-stationary satellite is called **satellite communication**. The satellite S (Fig. 33.5) receives signals from an **earth station** A and transmits them to Earth in different directions. Because its direction and distance relative to any ground station A, or B, or C, or D, etc. remains fixed, any ground station can send signals to it or receive signals from it with the help of a dish antenna whose direction is adjusted once for all.

Dish antenna is of parabolic shape. It focuses the **microwaves** coming from the satellite to its focus F. Wavelength of these waves is of the order of a centimeter so that these can travel from satellite to ground unhindered by atmosphere or even by clouds, and can be focused by an antenna of about 3 m diameter, like light rays are focused by a parabolic mirror.

The technique of satellite communication is being used now-a-day for many purposes, e.g. telephonic conversations and conferencing, television broadcast, FAX and computer related network services. A satellite being used for this purpose is called a **communication satellite**. We build high television towers to reach longer distances. A communication satellite is like a 36000 km high television tower, and signals broadcast from it reach almost half the Earth.

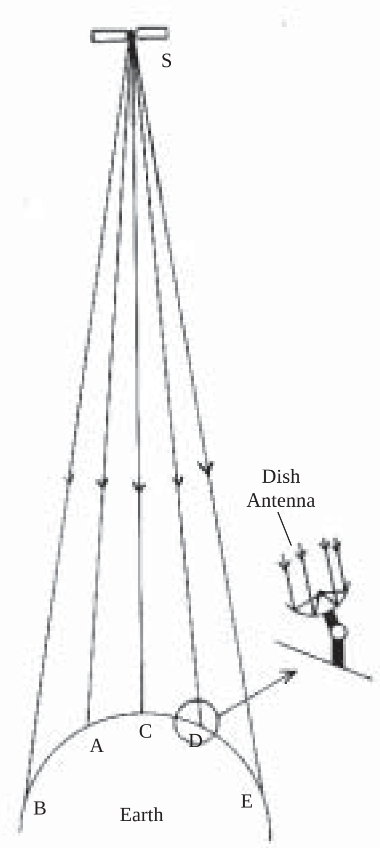

Fig. 33.5 Signal sent by station A to geo-stationary satellite S is retransmitted to TV-stations in almost half the Earth

33.2.2 Weather monitoring and forecasting by satellite

Satellites are very useful in weather monitoring and forecasting. For this purpose a geo-stationary satellite is used. It is equipped with cameras and other sensors by which photographs of cloud formations and many other data about atmosphere in a vast area can be quickly obtained. The satellite being stationary relative to any place on earth, it can monitor the movement of clouds accurately. It is like a fixed observation station at a height of approximately 36000 km (Fig. 33.6).

The data collected by the satellite is sent by it to a ground station. The data is analyzed and weather forecast is done. It is now possible to get prior information about an emerging cyclone or flood or possible draught condition. This enables the government to take appropriate measures to minimize loss of lives and property. Satellite used for this purpose is called a **weather satellite** (or **meteorological satellite**).

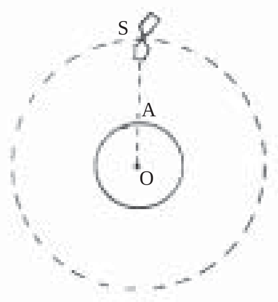

Fig. 33.6 A geostationary satellite is like a fixed observation station

33.2.3 Study of world resources (remote sensing)

For this purpose we use a satellite in sun-synchronous orbit. It is equipped with cameras and other sensors, by which data about Earth's resources can be obtained. These equipments observe and photograph Earth's surface illuminated by sunlight, using

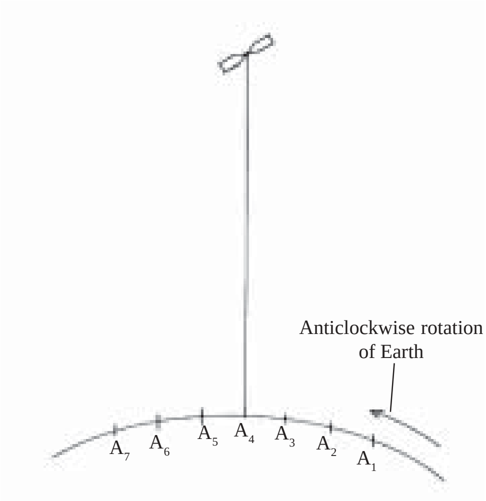

Fig. 33.7 Satellite in a polar orbit

selected wavelengths in ultra-violet, visible and infrared electromagnetic spectrum. Atmosphere is transparent for these wavelengths. This technique is called **remote sensing**, because the data is observed from a large distance (almost a thousand kilometres). A satellite used for this purpose is called **remote-sensing satellite**. It photographs a particular location on Earth each day (Fig. 33.7).

Remote sensing satellites have served many practical purposes like, forestry and estimation of forest cover, preparing waste land maps, ground water surveys, draught assessment, estimation of yield of various crops, detection of crop diseases, detection of potential fishing zones in the ocean, and survey for exploration of minerals. This list keeps on expending with time.

The most significant feature of this technology is that it offers some special advantages:

i) A remote-sensing satellite can provide information about the areas/objects, which are very difficult to be reached physically, (i.e., which are inaccessible) like dense forests.

ii) A remote-sending satellite can survey a vast area in a very short time.

iii) A remote-sending satellite can survey any region repetitively at regular intervals. Repetitive surveys of the same regions make a comparative study possible.

33.2.4 Scientific experiments and collecting information about heavenly bodies

This is done by sending unmanned spacecrafts (called space probes) to target destinations, e.g. Mars, Venus, and other planets. These are equipped with cameras and other sensors suitable for the objective of the project. Another method is by launching a satellite in a suitable orbit above the Earth's atmosphere equipped by a telescope and suitable sensors. The first noteworthy attempt of the second method was the launching of Cos-B, a gamma ray observatory in 1975 jointly by five European countries. Then came the launching of Hubble Space Telescope by the US in 1990. This telescope observes the visible, ultra-violet and infrared waves coming from heavenly bodies and sends the data back to Earth. It was soon followed by launching of Einstein X-ray Telescope and Chandra X-ray Telescope in space by the U.S.A., to study X-rays coming from heavenly bodies. The era after 1970s is thus called the Golden Era of Astronomy and Astrophysics.

Atmosphere creates many problems for the earth-based telescopes. It absorbs most of the wavelengths of electromagnetic spectrum. Thus, earth-based telescope cannot study heavenly bodies by those wavelengths. Again, atmosphere is like a wavy windowpane through which we cannot see things clearly. A telescope in orbit above the atmosphere overcomes these problems.

33.2.5 Satellite launch vehicles

For a satellite to stay in an orbit close to earth (just above the atmosphere in the plane of equator, Fig. 33.8), it has to be given a horizontal speed of about 8 km per second. At this speed attraction of Earth is precisely equal to the force required to keep the satellite on the circular orbit, instead of going in a straight line. The satellite makes a revolution in about 90 minutes, i.e. it makes about 16 revolutions in a day. If it moves in the same direction as rotation of Earth (anti-clockwise as seen from north pole), then it has a relative speed of about 15 revolutions per day, or about 7½ km/second with respect to Earth's surface. If it moves opposite to direction of rotation of Earth, then it has a greater relative speed (8½ km/second) with respect to Earth's surface. Hence, it is easier to launch a satellite in the same direction as rotation of Earth.

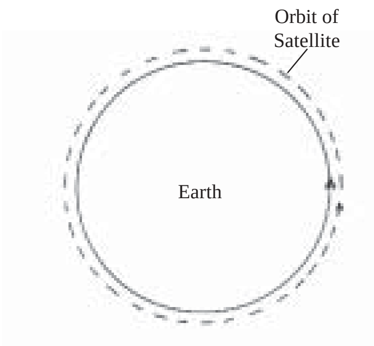

Fig. 33.8 Satellite in low orbit

A rocket used for launching the satellite is called a **satellite launch vehicle**. Its operation is based on Newton's III law of motion. Burning of fuel in the vehicle produces gases at high temperature and pressure. These are ejected backwards through a jet. Then due to reaction applied by the gases, the vehicle is pushed forward (Fig. 33.9). There exists no fuel which gives so much energy per kg of its weight on burning which it can impart a speed of 7½ km /second. Hence, satellite-launching vehicle usually has 3 or more stages, which function one after the other.

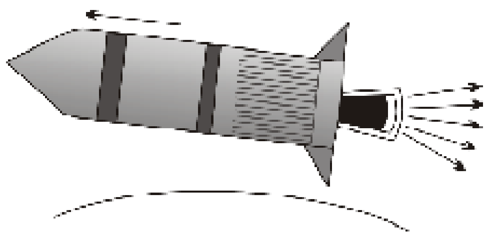

Fig. 33.9 SLV is accelrated forward by the force of reaction applied by hot gases

In order to launch a polar satellite, it has to be given a speed of 8 km/second relative to ground. The (Fig. 33.9) SLV is accelerated forward by the force of reaction applied by hot gases. Thus the vehicle must give more kinetic energy to the polar satellite than to the satellite in an orbit of low inclination, in the ratio $(16/15)^2$. Therefore, a vehicle, which launches a polar satellite, must have more powerful rocket motors, than the one for launching a satellite with small angle of inclination.

In order to launch a geo-stationary satellite, it has to be lifted to a great height also (about 36000 km). Hence, a geo-stationary satellite launch vehicle has to give far more energy to the satellite than a PSLV gives. **A cryogenic engine** (or **cryogenic rocket motor**) is an essential last stage of a vehicle for launching geo-stationary satellite. It uses hydrogen as its fuel, which is the fuel having highest energy output per kilogram of its weight.

The process of launching of satellite is quite simple in principle. The first stage rocket motor lifts the satellite out of the atmosphere along the shortest path (i.e. vertically upwards) so that the least amount of energy is spent against friction of air. The second and subsequent stages provide it speed in horizontal direction and simultaneously bring it into the orbit at desired height.

CHECK YOUR PROGRESS 33.2

1. The orbit of a satellite is perpendicular to equator and it takes exactly 1.6 hours to complete one revolution around the earth. State two purposes for which it can be used.
2. What is a remote-sensing satellite? Why is it placed in a sun-synchronous orbit?
3. What band of electromagnetic waves is used to carry audio-signals of telephone conversation in satellite communication? What is the order of their wavelength? State one reason to select this band for the purpose.
4. Name the orbit of a meteorological satellite. How is it able to monitor accurately the movement of clouds?
5. What are the four areas in which space technology finds application? State the kind of orbit in which satellite is placed for each.

33.3 HISTORICAL PERSPECTIVE

33.3.1. Efforts of different countries in space exploration

The first step into space was taken on 4th October 1957 when USSR (it has now been split up into several countries, biggest among them being Soviet Russia) successfully launched **Sputnik-I** weighing 84 kg. Due to friction with air, it soon came down. **Sputnik–II** a month later carried a dog whose health in space was closely monitored. Data about the health of the dog in space helped to better plan the journey of first man in space.

Space age really began on 12 April 1961 when Yuri Gagarin of USSR made a journey into space in **Vostok-I**. He made a single revolution around Earth. The whole journey took 108 minutes. Soon after, on 5 May 1961, the first American astronaut made a journey into space. On 20th February 1969, the first human being, Neil Armstrong of USA set foot on the moon, traveling in Apollo-XI. Some landmarks in the history of development of space technology are given in table 33.1

Table 33.1 Some landmarks in the field of technology

S.No.	Date of launching	Name of space flight or space mission	Achievement
1.	04-10-1957	Sputnik-I*	Fist ever man-made satellite launched in space by USSR.
2.	03-11-1957	Sputnik –II*	First satellite to carry a living animal (dog) into space (USSR).
3.	31-01-1958	Explorer –I*	First spacecraft by USA, first scientific discovery by a spacecraft (Van Allen Radiation Belt in upper atmosphere).
4.	12-04-1961	Vostok-I*	The first space flight by a man (USSR).
5.	04-12-1963	Vostok –III	The first space flight by a woman (USSR).
6.	21-10-1968	Luna –IX	First successful soft landing by a space-probe on the Moon's surface (USSR).
7.	16-07-1969	Apollo –XI*	Neil Armstrong of USA becomes the first human being to set foot on the moon on 20-07-1969.
8.	19-05-1971	Mars – II	First landing of a space probe on the planet Mars (USSR)
9.	02-03-1972	Pioneer – X	First space probe to (a) explore the asteroid belt between Mars and Jupiter and to (b) take photographs of Jupiter from a close distance (USA).
10.	July 1972	Landsat-I	First satellite dedicated to remote- sensing (USA).
11.	05-09-1977 20-08-1979	Voyager-I Voyager-II	First journey to all the outer planets of the solar system and photographing them from close distance. After 10 years of flight, Voyager-II flew past Neptune precisely on the planned path and time (USA).
12.	09-08-1975	Cos-B	First gamma-ray observatory in space, operational till 1982 (five European countries).
13.	12-04-1981	First space shuttle 'Columbia'*	First space craft to carry astronauts from earth to an orbiting satellite and back – spacecraft usable several times (USA) (Fig. 33.10)
14.	03-04-1984	-	The first space flight by an Indian, Sqn. Leader Rakesh Sharma.
15.	1986	Space station 'Mir'	More than a year (366 days) of stay in orbit by two-person crew (Soviet Russia).
16.	25-04-1990	'Hubble space telescope'*	First telescope in orbit to study heavenly bodies by infrared, visible and ultra-violet light. (USA) (Fig. 33.11).

S.No.	Date of launching	Name of space flight or space mission	Achievement
17.	April, 1991	Compton gamma-ray observatory	Second gamma-ray observatory in space (USA).
18.	April, 1992	By using a space shuttle, American astronauts repaired a satellite in space itself and put it back into its original orbit.	
19.	Prior to 1994	Einstein X-ray observatory	First true X-ray telescope in space. X-rays do not reflect or refract in usual experiments (USA).
20.	1999	Chandra X-ray observatory*	Second X-ray telescope in space achieved are – second resolution, named after Professor S. Chandrashekhar (USA).

* The more significant space flights.

It should not be inferred from this table that US and USSR (now Soviet Russia) are the only countries doing significant work in this field till now, though most of the 'firsts' go to their credit. Several other countries, including India, are noteworthy partners. On April 3, 1984 Sqn. Ldr. Rakesh Sharma became the first Indian to journey into space, with the co-operation of USSR. He stayed there until April 11, 1984.

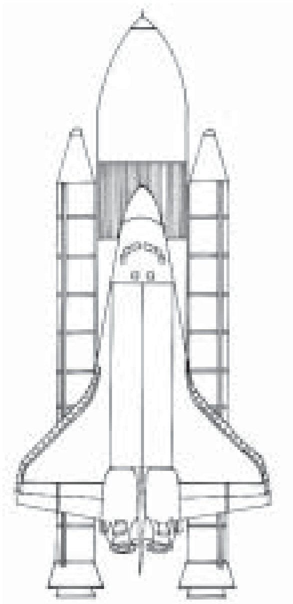

Fig. 33.10 Space shuttle Columbia to carry astronauts from Earth to satellite and back

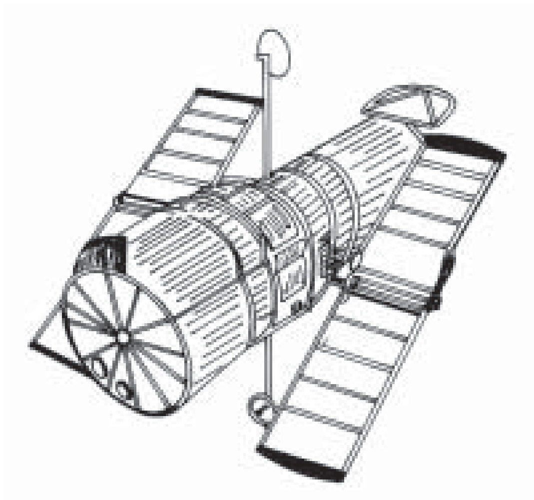

Fig. 33.11 Hubble space telescope

33.3.2. Space science in India

The foundation of modern space research in India was laid in 1961, when Department of Atomic Energy was asked to develop a programme for space research. Following objectives for space research in India were set then. Even today these are the most important objectives.

i) Rapid development of mass communication and education, particularly in widely dispersed rural communities, and

ii) Timely survey and management of the country's natural resources.

India entered the space age on 19th March 1975 when the first Indian satellite Aryabhata (Fig. 33.12) was launched. It was designed and fabricated by Indian scientists but was launched with the help of USSR. It enabled our scientist to:

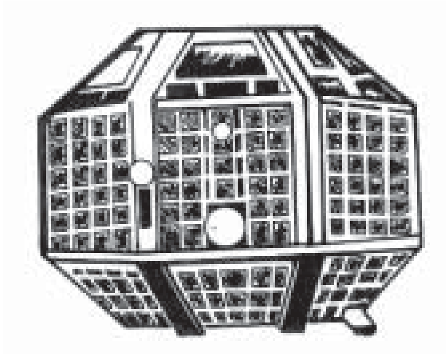

Fig. 33.12 Aryabhata – The first Indian satellite

i) Develope the skills of staff members and physical facilities for designing and fabricating satellite and monitoring their performance during journey.

ii) Establish ground facilities for communicating with satellite, tracking it, and to command it for carrying out various tasks.

iii) Conduct some experiments in the fields of X-ray astronomy, solar physics and meteorology.

Today, India is one of the six nations in the world, which has the technical know-how for putting a satellite in any orbit around the earth.

The Indian space programme has been simultaneously pursuing two objectives. The programme aims at developing

i) expertise in planning, designing and fabricating space satellites for various purposes, and

ii) the necessary technologies, facilities and skills for the development of suitable launch vehicles to place satellites in predetermined orbits around the earth.

However, less progress in one area is not allowed to delay the other. For example, if satellite fabrication is achieved, its launching is carried out in collaboration with one of the advanced nations without waiting for the availability of an Indian launch vehicle, if it is not available at that point of time.

33.3.3 Indian satellite launch vehicles

India started working in this area with the launch of a 75mm diameter meteorological rocket in 1963 for investigation of ionosphere over the geomagnetic equator at Thumba near Thiruvananthapuram.

The first success in the launching of an Indian satellite by an indigenously developed launch vehicle was achieved on 18th July 1980. The launch vehicle for carrying the satellite was a four-stage rocket SLV-3. It carried a 35 kg satellite named 'Rohini' into an orbit with an apogee of 900 km and perigee of 300 km.

The main objective of this launch was to test the performance of the fourth stage of the launch vehicle.

The second generation of India launch vehicles was called Augmented Satellite Launch Vehicle (ASLV). The historic event of launching of a more than 100 kg Indian satellite on an India vehicle took place on 20-05-1992 by ASLV-D3. It was 23 m tall having five stages and used solid fuel. It launched 106 kg satellite named SROSS-C into an orbit 450 km above earth.

The first successful Indian polar satellite launch vehicle was PSLV-D2. On 15-10-1994 this 44 m tall, four-stage rocket launched the 804 kg remote sensing satellite IRS-P2 in polar sun-synchronous orbit.

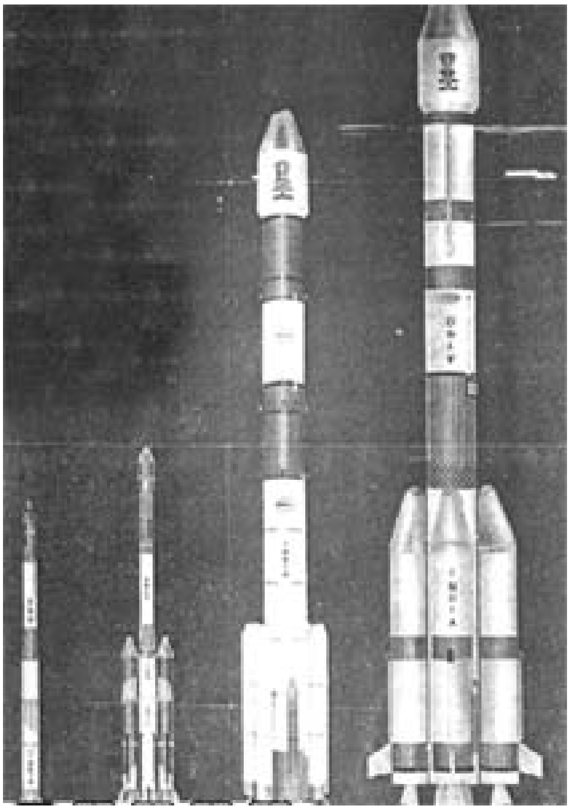

Fig. 33.13 Indian satellite launch vehicles

The first successful Indian geo-stationary satellite launch vehicle was GSLV-D1. In April 2001 this 49 m tall, three-stage rocket launched the experimental satellite GSAT-1 of 1540 kg into a geo-synchronous orbit. It is planned to develop this GSLV further to carry a satellite of 2500 kg.

33.3.4 Indian satellite programme

India has been launching satellites for all the four purposes discussed earlier, viz. telecommunication, study of weather, exploration of earth resources and scientific experiments. It has following series of satellites

i) Indian National Satellite System (INSAT)

These are geo-stationary satellites used for telecommunication and study of weather. This programme was established in 1984 when INSAT-1B was commissioned for being used for these two purposes. It lead to the expansion of TV and telecommunication network to remote areas. It also helped in better whether forecasting. Above all the success of INSAT-1B provided the needed boost to efforts in developing space research further.

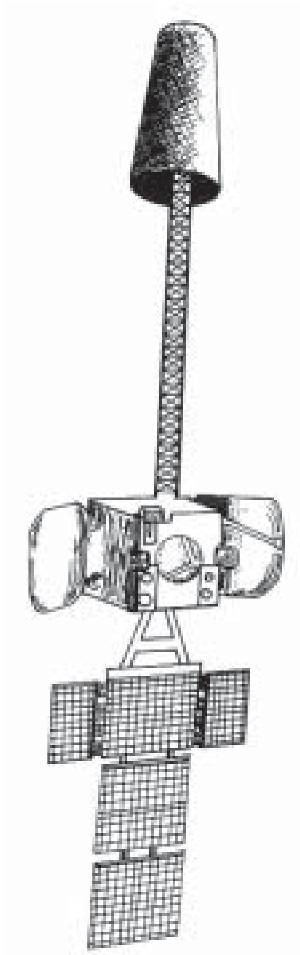

Fig. 33.14 INSAT –2A, first fully Indian built successful satellite for communication and study of weather

The second generation of satellites in this series started with the launch of INSAT-2A (fig. 33.13) on July 10, 1992 and of INSAT-2B on July 23, 1993. The third generation of satellites started with the launch of INSAT-3B in March 2000.

India's INSAT is one of the largest communication satellite system in the world with five active satellites in orbit till March 2002: INSAT-2C, INSAT-2DT, INSAT-2E, INSAT-3B and INSAT-3C. These are being used for telecommunication, television broadcasting, weather monitoring and weather forecasting. An exclusive meteorological satellite METSAT has also since been launched.

These are sun-synchronous satellites, which are being used for the study of earth resources. This programme started with the launch of IRS-1A in 1988 and IRS –1B in 1991 (Fig. 33.15).

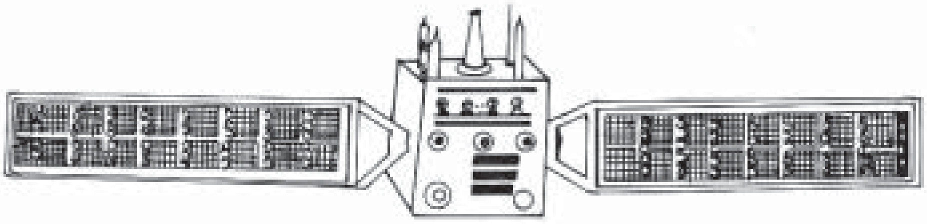

Fig. 33.15 India's remote sensing satellite, IRS-1B

The Indian remote sensing satellite system, IRS, has the biggest constellation of satellites with five operational satellites: IRS –1C, IRS-1D, IRS-P3, IRS-P4 (OCEANSAT dedicated exclusively for the study of oceans) and TES (Technology Experiment Satellite). The TES can take photographs with a resolution of 1 m on the ground (i.e. about 0.3 arc second in terms of angle). These are being used for all the eight applications discussed earlier.

iii) Stretched Rohini Satellite Series (SROSS)

These are launched for purpose of scientific experiments carried out above earth's atmosphere. Their contribution in the study of gamma ray burst events is noteworthy.

At present Indian satellites of INSAT and IRS series are quite advanced and at par with those of any other advanced country. Data collected by these is commercially used by many countries of the world. Significant events of Indian space research programme are summarized in table 33.2.

Table 33.2: Significant events in the Indian space research programme

S.No.	Sateliite	Date	Launching country/ Launching vehicle
1.	ARYABHATA*	March 19, 1975	USSR, India's first satellite
2.	BHASKAR-1	June 7, 1970	USSR
3.	ROHINI*	July 18, 1980	India (SLV-3), India's first success to launch a satellite
4.	APPLE	June 19, 1981	French Guyana (ARIANE)
5.	BHASKAR-2	Nov. 20, 1981	USSR
6.	ROHINI	April 17, 1983	India (SLV-3)
7.	IRS-1A*	March 17, 1988	USSR
8.	IRS-1B*	Aug. 29, 1991	USSR
9.	SROSS-3	May 19, 1992	India (ASLV)

S.No.	Sateliite	Date	Launching country/ Launching vehicle
10.	IRS-P2	Oct. 15, 1994	India (PSLV-D2)
11.	IRS-1C	Dec. 18, 1995	USSR
12.	IRS-1D	Sept. 29, 1997	India (PSLV-C1)
13.	INSAT-1B*	Aug. 30, 1982	USA, First major expansion of communication network in India by satellite in 1984
14.	INSAT-1D* SCROSS-C*	June 12, 1990 May 20, 1992	USA India (ASLV-D3). India’s succes to launch a more than 100 kg satellite
15.	INSAT-2A*	July 10, 1992	French Guyana (ARIAN E)
16.	INSAT-2B IRS-P2*	July 23, 1993 Oct. 15, 1994	Frech Guyana (ARIANE) India (PSLV-D2). India’s success to launch a 1000kg class satellite in polar orbit
17.	INSAT-2C	Dec. 7, 1995	French Guyana (ARIANE)
18.	INSAT-2DT	Oct., 1997	Purchased from ARABSAT after a snag in INSAT-2D so that services are not disrupted
19.	INSAT-2E	April 3, 1999	International Telecommunications Satellite Organization (INTELSAT)
20.	INSAT-3B	March 22, 2000	French Guyana (ARIANE)
21.	INSAT-3C	Jan. 24, 2002	French Guyana (ARIANE)
22.	Technology experiment satellite (TES)	Oct. 22, 2001	India (PSLV-C3), launched three satellite inlcuding Belgian PROBA and German BIRD
23.	GSAT-1 Experiemental Satellite*	April, 2001	India (GSLV-D1), India’s success to launch a geo-stationary satellite
24.	METSAT	Sept. 12, 2002	India (PSLV-C4), exclusively dedicated to study weather, launching a geostationary satellite by a vehicle of PSLV class is a technological feat

* The more significant launches by India.

CHECK YOUR PROGRESS 33.3

1. Explain how are TV programmes transmitted to remote areas through INSAT satellite?
2. Explain how does IRS-1D (launched in 1997) estimates the forest cover of India and detect its decrease.
3. Why was a dog first sent into space before sending a man?
4. Name the first Indian who went into space. How long did he stay in space? Did he go into space by India's own launch vehicle?

LET US REVISE

- Now-a-days man has the technology to launch artificial satellites revolving around Earth or any other planet for scientific purposes.
- Orbit of a satellite is defined by its apogee, perigee and inclination.
- Satellite may be launched to revolve around Earth in different types of orbit for different purposes:

i) Geo-stationary orbit: inclination 0^{O}, apogee = perigee = 36000 km (approx.)

ii) Polar orbit: inclination 90^{o}, apogee and perigee of any value depending on the objective of the project.

iii) Sun-synchronous orbit: apogee and perigee so selected that it makes precisely an integral number of revolutions in 24 hours, and inclination of any value depending on objective of the project.

- Artificial satellites revolving around Earth and space-probes find application for several areas of human activities:

i) Communication over long distances: telephonic conversation and conferencing, television broadcast, FAX and computer related network service.

ii) Weather monitoring and forecasting.

iii) Exploration of resources, which mother Earth, provides.

iv) Scientific purposes like experiments in zero gravity and/or in near perfect vacuum; observation of other planets and stars (including the Sun) etc.

- Low inclination satellites are launched revolving in the same direction as rotation of Earth, so that less kinetic energy per unit mass of satellite need be given to them. More kinetic energy needs to be given to a satellite for launching it in polar orbit.
- Highest amount of energy per unit mass of satellite needs be given to launch a satellite in geo-stationary orbit.
- For launching a satellite, it is first lifted vertically out of the atmosphere, so that least amount energy is spent against friction of air. Thereafter the task of providing it speed in horizontal direction and placing it into desired orbit is carried out.
- Now days, Man can look down on Earth from space, using ultra violet, visible and infrared rays. Similarly Man can study heavenly bodies from above the atmosphere, using gamma rays, X-Rays, ultra-violet rays, visible light and infrared rays, eliminating all the disadvantages that atmosphere creates in

such studies. Thus, the era after 1970s is called the golden era of Astronomy and Astrophysics.

- India entered the space age with launching of Aryabhata in 1975. Since then India has been developing space science with two objectives:
  - i) Designing and fabricating satellites for various purposes along with ground satellite to utilize the data provide by these satellites.
  - ii) Developing suitable launched vehicles to place satellites in desired orbits around the earth.

TERMINAL EXERCISES

1. What is meant by space (outer space)?
2. What is a satellite?
3. What is meant by orbit of a satellite?
4. What is the height of a geo-stationary satellite above Earth's surface?
5. What do you understand by space exploration?
6. What are two types of satellites? Give one example of each.
7. Name the parameters that define the orbit of a satellite around Earth.
8. Time period of revolution of a satellite around earth is 24 hours with reference to Sun. In which type of orbit is it? State its parameters.
9. What is a communication satellite?
10. Name any three areas of application of space science and one characteristic feature of the satellite used in each case?
11. State four purposes for which remote-sensing satellite is used?
12. What bands of electromagnetic waves are used to study world resources by a satellite in outer space? What is the special advantage of using those bands?
13. When was the first step into space taken and by which country? Name the first Man who went into space?
14. When was the first step taken on the Moon, by whom and in which spacecraft?
15. What does IRS-1A refer to? Mention any two uses of it.
16. "Successful launching of INSAT-1B has brought revolution in the field of communication in India". Give two reasons in support of this statement.
17. What is a geo-stationary satellite? State its two applications. State for one of the applications why a geo-stationary orbit is used. Name India's geo-stationary satellite, which has been launched by India's own launch vehicle, and name that vehicle too.
18. Write the full forms of following abbreviations:
    IRS, INSAT, SROSS, ASLV, PSLV, GSLV

ANSWERS TO CHECK YOUR PROGRESS

33.1

1. At the point where the satellite is farthest from Earth, its height above Earth is 900 km.

2. At the point where the satellite is closest to Earth, its height above Earth is 450km.
3. Please refer fig. 33.16.
4. Geo-stationary orbit. Features: (i) Apogee = 36000 km (Approx.), perigee = 36000 km (Approx.) (or circular orbit), and (ii) inclination = 0^o (or in the plane of equator).
5. Inclination = 90^o, apogee = any value, perigee= any value.
6. i) It makes precisely an integral number of revolutions of Earth in 24 hours.
   ii) It looks at (or photographs) any location on Earth on consecutive days in identical illumination.

   Inclination = any value, apogee and perigee are so chosen as to satisfy the first feature.

33.2

1. Number of revolutions in 24 hours = 15 precisely.

   It is a sun-synchronous orbit. The satellite is usable for remote sensing (for purposes refer to 33.2.3).
2. Remote sensing satellite is one by which we study the surface of Earth to explore its resources and other phenomena useful to mankind. It is placed in sun-synchronous orbit so that it can take repeated photographs of a location on consecutive days in identical illumination and very meaningful comparison of photographs can be done.
3. Microwaves are used for satellite communication. Their wavelength is of the order of a centimeter. These are not hindered by atmosphere and not even by clouds.
4. A meteorological satellite is placed in a geo-stationary orbit. Its position with respect to any location on ground is fixed. Thus it is like a fixed observation station 36000 km high. It can see almost half of Earth. Being in a fixed position relative to Earth's surface, it can accurately observe movements and formations of clouds.
5. The areas are:
   i) Communication to far-off places: Geo-stationary orbit.
   ii) Monitoring and forecasting weather: Geo-stationary orbit.
   iii) Study of world resources: Sun-synchronous orbit.
   iv) Scientific experiment and collecting data about heavenly bodies: Orbit depends upon the objectives of experiment. For study of heavenly bodies a satellite may be placed in a suitable orbit or a space probe may be sent to the target heavenly body.

33.3

1. INSAT is 36000km above equator in a fixed position relative to Earth, in the geo-synchronous orbit. A beam of microwaves from the transmitting station carries the signal to the satellite. The satellite re-broadcasts it. This re-broadcast signal can be received by any one in almost half the world (refer Fig. 33.5).

2. IRS-ID is a remote sensing satellite in sun-synchronous orbit. Photographs of various areas of India illuminated by sunlight are taken by it. Entire country is quickly covered by the satellite (in three weeks). The photographs clearly show-up forest areas. Their total area is measured, which gives the forest cover of India at that point if time. Year after year values of forest cover clearly tell the yearly decrease of the forest cover.
3. The health of dog in space was closely monitored. This data about a living dog helped very much to better plan the journey of first man in the space.
4. First Indian to go into space was Sqn. Ldr. Rakesh Sharma. He stayed in space for eight day. He did not go into space by India's own vehicle. It was the launch vehicle of USSR.

GLOSSARY

Apogee: The highest point of the orbit or height of that point above earth's surface.

Artificial satellite: A man-made satellite.

Communication satellite: A geo-stationary satellite, which is used for purpose of telecommunication between distant locations on earth.

Geo-stationary orbit: The circular orbit in the plane of equator in which a satellite remains stationary with respect of any location on earth.

Inclination: Angle between the planes of equator and of the orbit.

Meteorological satellite: A geo-stationary satellite being used for observing weather related data and sending it to ground stations.

Orbit of a satellite: The path along which the satellite revolves around a planet.

Perigee: The lowest point of the orbit or height of that point above earth's surface.

Polar orbit: An orbit passing over north and south poles of earth.

Remote sensing: Study of world resources by cameras and other sensors placed in a satellite in outer space.

Remote sensing satellite: A satellite in sun-synchronous orbit being used for study for world resources by cameras and other sensors placed in it.

Satellite: A natural or man-made object revolving around earth or any planet.

Satellite communication: The entire activity of telecommunication between various distant locations on earth with the help of geo-stationery satellites.

Satellite launch vehicle: Rocket of 3 or more stages that lifts a satellite and places it in a desired orbit.

Space/outer space: Vast limitless and continuous region beyond earth's atmosphere.

Space exploration: Study of earth's atmosphere or surface or of heavenly bodies by man-made space vehicles.

Space-laboratory: A laboratory set up in a satellite orbiting the earth for experiments in zero gravity, or for observation of rays or particles coming towards earth.

Space telescope: A telescope placed in a satellite orbiting the earth above atmosphere in order to overcome the disadvantages to observing process caused by the atmosphere.

Sun-synchronous orbit: An orbit in which satellite makes accurately an integral number of revolution in 24 hours.

Time period of orbit: The time in which a satellite in the orbit makes one complete revolution.