UNIT 6 MAJOR SPACE PROGRAMMES

Structure

6.1 Introduction
Objectives
6.2 Space Programmes
6.3 Indian Space Programme
Indian Remote Sensing Satellite Series
Radar Imaging Satellite Series
Indian National Satellite Series
6.4 Global Space Programmes
Landsat
SPOT
RADARSAT
European Remote Sensing Satellites
Japanese Earth Resource Satellites
6.5 Commercial Remote Sensing Satellites
QuickBird
IKONOS
OrbView
6.6 Summary
6.7 Unit End Questions
6.8 References
6.9 Further/Suggested Reading
6.10 Answers

6.1 INTRODUCTION

You have studied in Units 4 and 5 that each remote sensing satellite is equipped with a certain type of sensors. From 1957, when the Sputnik satellite was launched by Russia, to the present a number of satellites have been launched by many countries. These satellites, launched under different space programmes, carried with them sensors of different characteristics to gather relevant data about the Earth. The data obtained by satellites have become increasingly important for predicting weather, studying hazards, monitoring global change and managing Earth resources. In this unit, you will be introduced to important space programmes of India and other countries and also the characteristics of the sensors and their utilities.

Objectives

After studying this unit, you should be able to:

- outline the initiatives taken by various countries for space exploration;
- discuss the achievements of Indian space programme; and
- explain the importance of various types of satellites launched by different countries.

6.2 SPACE PROGRAMMES

A space programme commonly includes space missions and their planning. A space mission is the journey of the space by a manned or unmanned vehicle (spacecraft/satellite), aiming to explore solar system and gather scientific data. A space mission programme includes planning, designing and operation of a specific space mission. The planning of a space mission is a complex and multi-disciplinary task which includes various aspects of the mission from its definition to the end of mission's life. According to objectives of the space mission, they can be categorised into the following:

- applications
- technology experiment, and
- science and exploration

The first step into space was taken after World War II, when Russia (USSR) successfully launched first artificial satellite, Sputnik-1, into the space in October, 1957. This marked the beginning of remote sensing era as it provided first view of Earth's surface from the space. Subsequently, in the same year United States of America took leap into space age by launching its first satellite, Explorer-1. On 1st October, 1958, United States of America established National Aeronautics and Space Administration (NASA) for space exploration. But the space age really began with the launch of Vostok-1 on 12th April 1961 by Russia. The space shuttle took Yuri Gagarin (a Russian cosmonaut) into space. Apart from USSR and USA, many other countries of the world including India have taken leap into the space exploration as shown in Table 6.1.

Table 6.1: Space agencies of the world

S.No	Country	Agency	Website
1.	Australia	Australian Space Research Institute (ASRI)	www.asri.org.au
2.	Belgium	Belgian Institute for Space Aeronomy (BISA)	www.aeronomie.be
3.	Brazil	Brazilian Space Agency (AEB)	www.cbers.inpe.br
4.	Canada	Canadian Space Agency (CSA)	www.asc-csa.gc.ca
5.	China	China National Space Administration (CNSA)	www.cnsa.gov.cn
6.	Europe	European Space Agency (ESA)	www.esa.int
7.	France	French Space Agency (CNES)	www.cnes.fr
8.	Germany	German Aerospace Center (DLR)	www.dlr.de
9.	India	Indian Space Research Organisation (ISRO)	www.isro.org
10.	Iran	Iranian Space Agency (ISA)	www.isa.ir
11.	Italy	Italian Space Agency (ASI)	www.asi.it
12.	Japan	Japan Aerospace Exploration Agency (JAXA)	www.jaxa.jp
13.	Netherlands	Netherlands Institute for Space Research (SRON)	www.sron.nl
14.	Russia	Russian Federal Space Agency (RKA)	www.federalspace.ru
15.	South Korea	Korea Aerospace Research Institute (KARI)	www.kari.kr
16.	Spain	Instituto Nacional de Tecnica Aeroespacial (INTA)	www.inta.es
17.	Sweden	Swedish National Space Board (SNSB)	www.snsb.se
18.	Ukraine	National Space Agency of Ukraine (NSAU)	www.nkau.gov.ua
19.	United States	National Aeronautics and Space Administration (NASA)	www.nasa.gov
20.	United Kingdom	UK Space Agency (UKSA)	www.bis.gov.uk

6.3 INDIAN SPACE PROGRAMME

Indian space programme started way back in 1920s, when a scientist, S.K. Mitra conducted a series of experiments to sound the atmosphere using ground based radio techniques in Kolkata. From 1950, Government of India (GOI) started to invest in space science programmes. From 1950 to 1962, Department of Atomic Energy provided funds for research in space sciences. For the development and formulation of Indian space programmes, GOI established the Indian National Committee for Space Research (INCOSPAR) in 1962 under the leadership of visionary Dr. Vikram Sarabhai. Dr. Vikram Sarabhai is considered as father of Indian space programme (Fig. 6.1). In 1963, INCOSPAR took decision to setup Thumba Equatorial Rocket Launching Station (TERLS) at Thumba, Thiruvananthapuram, South India. The setting up of TERLS marked beginning of the Indian space age. Later on, in June 1972, GOI established the Space Commission and Department of Space (DOS) for promoting unified development and application of space science and technology at national level. In the meantime, during 1969, Dr. Vikram Sarabhai re-designated INCOSPAR as the Indian Space Research Organisation (ISRO), Bangalore and it was brought under DOS in September, 1972. ISRO set up as a research and development wing of DOS which is responsible for the execution of India's national space programme.

Fig. 6.1: Dr. Vikram Sarabhai – father of Indian space programme

The space programme of India was pioneered with a vision to use space technology for national development. The programme is application driven with due emphasis on policy of self-reliance. The primary objective of the Indian space programme is to establish operational space services in a self-reliant manner in thrust areas of satellite communication, satellite based resource survey/management and meteorological applications. The indigenous development of satellites, launch vehicles and associated ground segment for providing these services is integral part of these programmes.

Indian Space Research Organisation (ISRO) is the nodal body for space research under the control of GOI. It is one of the leading space research organisations in the world. It was constituted in its modern form in 1969 with an objective to develop space technology and its application to various tasks of the nation. Indian space programmes are executed through ISRO with four grant-in-aid institutions namely - National Remote Sensing Centre (NRSC), Hyderabad; Physical Research Laboratory (PRL), Ahmedabad; National Atmospheric Research Laboratory (NARL), Tirupati and North-Eastern Space Applications Centre (NE-SAC), Umiam, Meghalaya.

Indian space programme has made impressive stride with its inception in the late 1950s. But during the initial stages, India relied heavily on international assistance and co-operation to develop its space programme. Later India entered in the space age with launching of the first Indian scientific low orbit satellite *Aryabhatta* in April 1975 with the help of *Cosmos-3M* launch vehicle of Soviet Union. Aryabhatta was followed by launching of two Indian satellites for remote sensing namely *Bhaskara-1* in 1979 and *Bhaskara-2* in 1981. India's first three-axes stabilised geostationary tele-communications satellite *APPLE* (Ariane Passenger Payload Experiment) was successfully launched in June 1981 by the European *Ariane* launch vehicle. The other major breakthrough in the Indian space programme includes launch of *SITE*

(Satellite Instructional Television Experiment) which was an experimental satellite communications project of India launched jointly by NASA and ISRO in 1975. The project made available Special Instructional and Educational Television Programme directly to rural India. *STEP* (Satellite Telecommunications Experiments Project) was carried out using the Franco-German satellite Symphonie in 1977 for telecommunication experiments.

ISRO's Rohini satellite (RS-1) was launched with its own launch vehicle in 1979. This made India the seventh nation in the globe to achieve the capability to launch a satellite. Indian satellite launch vehicle (SLV-3) was used to launch Rohini Satellites (RS-1) and (RS-D1) in 1979 and 1981, respectively.

Let us now discuss about the two major series of satellite systems established by ISRO.

- **Indian Remote Sensing Satellite (IRS) Series -** this series has been developed for resources monitoring and management.
- **Indian National Satellite (INSAT) Series -** this series provide services for tele-communications, TV broadcasting and meteorology services including disaster warning support.

IRS series of satellites are in the polar orbit whereas satellites of INSAT series are in geostationary orbit. ISRO has developed two satellite launch vehicles, Polar Satellite Launch Vehicle (PSLV) and Geostationary Satellite Launch Vehicle (GSLV) to place IRS and INSAT satellites in the required orbits, respectively. Apart from IRS and INSAT series, ISRO also launched CARTOSATs and radar imaging satellites (RISATs).

6.3.1 Indian Remote Sensing Satellite Series

It is important to note that besides IRS and INSAT series of satellites, India has also made stride toward space exploration by launching Chandrayaan-1 in 2008.

After successful launching of Bhaskara-1 and 2 satellites in space during 1979 and 1981, respectively, ISRO has started developing indigenous Indian remote sensing satellites series. This is named as *Indian Remote Sensing Satellites* (IRS) series. It is a series of Earth observation satellites that have been built, launched and maintained by ISRO. IRS system has the largest constellation of operational remote sensing satellites, which are providing continuity of services both at national and international level from 1988 onwards. IRS system collects data from the Earth's surface in several spectral bands but visible and near infrared are common with a variety of spatial resolutions starting from 360 m to 2.5 m. Data received from IRS series is disseminated to several countries across the globe.

The primary components of IRS mission are:

- to develop a three-axes stabilised polar sun-synchronous satellite with multispectral (pushbroom cameras) sensors for acquiring imagery for Earth resource applications,
- to establish ground based system for reception, recording and processing of multispectral data, and
- to use IRS data along with information obtained from other sources for surveying and managing of resources.

India has successfully launched 18 remote sensing satellites under IRS mission since

India has successfully launched 18 remote sensing satellites under IRS mission since 1988 (Table 6.2). The first Indian remote sensing satellite, IRS-1A was launched into near circular orbit in 1988 (Fig. 6.2) followed by the launching of second identical satellite, IRS-1B, in 1991. Both of them were placed at an altitude of 904 km in a sun-synchronous near polar orbit at an inclination of 99° and were launched from the Soviet Cosmodrome, Baikonure. IRS-1A and IRS-2B had two types of cameras known as *Linear Self Scanning Sensors* (LISS-I and LISS-II) operated in the pushbroom scanning mode using linear charged coupled devices (CCDs) arrays. Both had a repeat cycle (temporal resolution) of 22 days. IRS-1A collected data with a 72 m spatial resolution with a ground swath of 148 km, while IRS-1B system had a 36 m spatial resolution and 74 km ground swath. Both sensors acquired multispectral imagery in blue, green, red, and near infrared spectral regions.

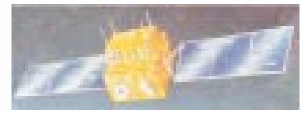


Fig. 6.2: IRS-1A satellite (source: www.isro.org)

Table 6.2: List of remote sensing satellites launched by India (after overview of Indian space sector, 2010)

S.No	Name of satellite	Date of launch	Launch vehicle	Mission status
1	IRS-1A	17th March, 1988	Vostok, USSR	Completed
2.	IRS-1B	29th August, 1991	Vostok, USSR	Completed
3.	IRS-P1	20th September, 1993	PSLV-D1	Crashed, due to launch failure of PSLV
4.	IRS-P2	15th October, 1994	PSLV-D2	Completed
5.	IRS-1C	28th December, 1995	Molniya, Russia	Completed
6.	IRS-P3	21st March, 1996	PSLV-D3	Completed
7.	IRS-1D	29th September, 1997	PSLV-C1	Completed
8.	IRS-P4 (Oceansat-1)	27th May, 1999	PSLV-C2	Completed
9.	Technology Experiment Satellite (TES)	22nd October, 2001	PSLV-C3	In service
10.	IRS-P6 (Resourcesat-1)	17th October, 2003	PSLV-C5	In service
11.	Cartosat-1 (IRS-P5)	5th May, 2005	PSLV-C6	In service
12.	Cartosat-2 (IRS-P7)	10th January, 2007	PSLV-C7	In service
13.	Cartosat-2A	28th April, 2008	PSLV-C9	In service
14.	IMS-1	28th April, 2008	PSLV-C9	In service
15.	RISAT-2	20th April, 2009	PSLV-CA	Completed
16.	Oceansat-2	23rd September, 2009	PSLV-C14	In service
17.	Cartosat-2B	12th July, 2010	PSLV-C15	In service
18.	Resourcesat-2	20th April, 2011	PSLV-C16	In service

The launch of IRS-P1 in 1993 was not successful because of the failure of indigenously developed Polar Satellite Launch Vehicle (PSLV-D1) in the last stage of launching operation; as a result, satellite and rocket plunged into sea. Subsequently, in October 1994, another satellite IRS-P2 was successfully launched by indigenously built PSLV-D2. It was placed in a polar sun-synchronous orbit at an altitude of about 817 km. IRS-P2 had only LISS-II camera, whose specifications were much similar to that of satellite IRS -1A/1B with small modifications in the arrangements of CCDs. IRS-P2 had revisit cycle of 24 days, combined ground swath 131 km with spatial resolution of 32 m across track and 37 m along track. Specifications of IRS sensor system are given in Table 6.3.

Table 6.3: Sensor specifications of IRS

Sensor type	**Band**	**Specifications** Spectral resolution (µm)	**Spatial resolution (m)**
LISS-I	1	0.45-0.52 (blue)	73
	2	0.52-0.59 (green)	73
	3	0.62-0.68 (red)	73
	4	0.77-0.86 NIR (Near-infrared)	73
LISS-II	1	0.45-0.52 (blue)	36
	2	0.52-0.59 (green)	36
	3	0.62-0.68 (red)	36
	4	0.77-0.86 NIR (Near-infrared)	36
LISS-III	1	0.52 - 0.59 (green)	24
	2	0.62 - 0.68 (red)	24
	3	0.77-0.86 NIR (Near-infrared)	24
	4	1.55-1.70 (mid-IR)	24
LISS-IV	1	0.52 - 0.59 (green)	6
	2	0.62 - 0.68 (red)	6
	3	0.77 - 0.86 NIR (Near-infrared)	6
	4	1.55 - 1.70 (mid-IR)	6
	pan	0.62-0.68 (red)	6
WiFS	1	0.62-0.68 (red)	188
	2	0.77-0.86 NIR (Near-infrared)	188
AWiFS	1	0.0.52-0.59 (green)	60
	2	0.62-0.68 (red)	60
	3	0.77-0.86 NIR (Near-infrared)	60
	4	1.55-1.70 (mid-IR)	60

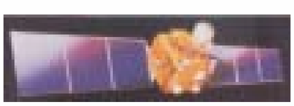


Fig. 6.3: IRS-1C satellite (source: www.isro.org)

The second generation remote sensing satellites IRS-1C (Fig. 6.3) and IRS-1D were successfully launched into polar orbit in December, 1995 and September, 1997, respectively. IRS-1C was launched by a Russian launch vehicle, Molniya and IRS-1D by an indigenous built PSLV-C1. Both satellites are featured by improved spatial resolution, extended spectral bands, stereo viewing, wide swath and fast revisit capability. The satellites contain three sensors namely - Panchromatic Camera (PAN), LISS-III and Wide Field Sensor (WiFS) for collecting panchromatic and multispectral image data at varying resolutions. IRS-1C/1D missions have been continuation of IRS-1A/1B with improved spatial resolution. IRS-1C and 1D have slightly different orbits as a result they do not have the same reference system. IRS-1C operates in a circular, sun-synchronous, near polar orbit with an inclination of 98.69° at an altitude of 817 km. This satellite takes 101.35 minutes to complete one revolution around the Earth and completes about 14 orbits per day. The entire Earth is covered by 341 orbits during a 24 day cycle. IRS-1D launched in September, 1997, entered in a wrong elliptical orbit due to problem associated with launching vehicle (PSLV-C1). But satellite and quality of data produced by it appears to be good.

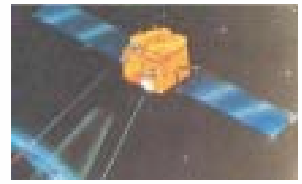


Fig. 6.4: IRS-P3 satellite (source: www.isro.org)

Satellite IRS-P3 was launched successfully in March 1996 from Sriharikota, South India by third indigenously built PSLV-D3 launch vehicle (Fig. 6.4). IRS-P3 was a follow-up project of IRS-P2. In addition to WiFS similar to the IRS-1D, with an additional Short Wave Infrared Band (SWIR); IRS-P3 also had a Modular Opto-electronic Scanner (MOS) and an X-ray astronomy payload. MOS was dedicated for remote sensing of ocean colour and the study of atmosphere. This mission completed in January 2006.

Oceansat

IRS-P4 (Oceansat-1) satellite was launched in May, 1999 from Sriharikota by PSLV-C2 flight. It is placed at an altitude of 720 km with an inclination of 98.28° in a polar sun-synchronous orbit. The satellite has two sensor payloads namely an Ocean Colour Monitor (OCM) and Multi-frequency Scanning Microwave Radiometer (MSMR). Since it represents the first satellite primarily devoted to oceanographic applications, it is commonly known worldwide as *Oceansat-1*. Technical characteristics of OCM are given in Table 6.4.

Table 6.4: Specifications and features of OCM

Parameters	Specifications
IGFOV at nominal altitude (m)	360 x 250
Swath (km)	1420
Spectral bands	8
Spectral bands (nm)	B1: 404-424 B2: 431-451 B3: 476-496 B4: 500-520 B5: 546-566 B6: 610-630 B7: 725-755 B8: 845-885
Quantisation bits	12
Along track steering	± 20º
Data acquisition modes	Local and global area coverage

For providing continuity of operational services of Oceansat-1, ISRO launched Oceansat-2 along with six nano European satellites in September, 2009 by PSLV-C14. The satellite has three payloads such as an OCM, a Ku-band pencil Beam Scatterometer (SCAT) and a Radio Occultation Sounder satellite dedicated to ocean research. It is placed at an altitude of 720 km with an inclination of 98.28°. The main objectives of Oceansat-2 include study of surface winds and ocean surface strata, observation of chlorophyll concentrations, identification of potential fishing zones, monitoring of phytoplankton blooms, study of atmospheric aerosols, suspended sediments in the water and providing inputs for general meteorological observations.

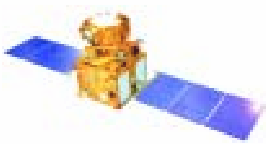


Fig. 6.5: Resourcesat-1 satellite (source: www.isro.org)

Resourcesat

Resourcesat-1 (Fig. 6.5) is the most advanced remote sensing satellite built by ISRO and was launched in October, 2003 by PSLV-C5. It is the tenth satellite of the IRS series and is also known as IRS-P6. It is placed at an altitude of 817 km in a sun-synchronous polar orbit. Resourcesat-1 is designed to provide continuity of the remote sensing data services of IRS-1C/1D in both multispectral and panchromatic imagery. It contains three sensor system viz. LISS-III, LISS-IV, and Advanced Wide Field Sensor (AWiFS) with greatly improved spatial resolutions. Data products obtained from this satellite may be used for advanced applications in vegetation dynamics, disaster management, crop yield estimates, etc. In 2011, ISRO has launched Resourcesat-2, which is a follow on mission to Resourcesat-1. Resourcesat-2 is an improved version of Resourcesat-1. It is placed at an altitude of 822 km in a circular polar sun-synchronous orbit.

National Remote Sensing Centre (NRSC), Hyderabad (A.P.), is continually acquiring and archiving data from IRS series. In addition, data from other contemporary satellites are also being received. Data collected by IRS series can be used for pre-harvest crop acreage and production estimates, monitoring of seasonal drought, flood damage assessment, landuse and landcover mapping, planning of agro-climatic zones, monitoring of forest covers, soil mapping, determination of potential fishing zones and sustainable development of the country.

Cartosat

Since 2005, ISRO has launched four CARTOSATs namely - CARTOSAT-1, CARTOSAT-2, CARTOSAT-2A and CARTOSAT-2B (Fig. 6.6). CARTOSAT-1(also known as IRS-P5) is a stereoscopic Earth observation satellite operating in a sun-synchronous orbit that is primarily deployed for cartographic applications. It was launched in May, 2005 by PSLV-C6 from the newly built second launch pad at Sriharikota. It contains two panchromatic cameras that capture black and white stereoscopic pictures. The imageries have a spatial resolution of 2.5 m and cover a swath of 30 km. CARTOSAT- 2 (also known as IRS-P7) is another Earth observation satellite having a circular polar sun-synchronous orbit and capable of providing scene-specific imageries for cartographic applications. It was launched by PSLV in January, 2007 and was placed at an altitude of 630 km above the Earth with an inclination of 97.91°. Its panchromatic camera provides less than 1m spatial resolution imageries with a ground swath of 10 km.

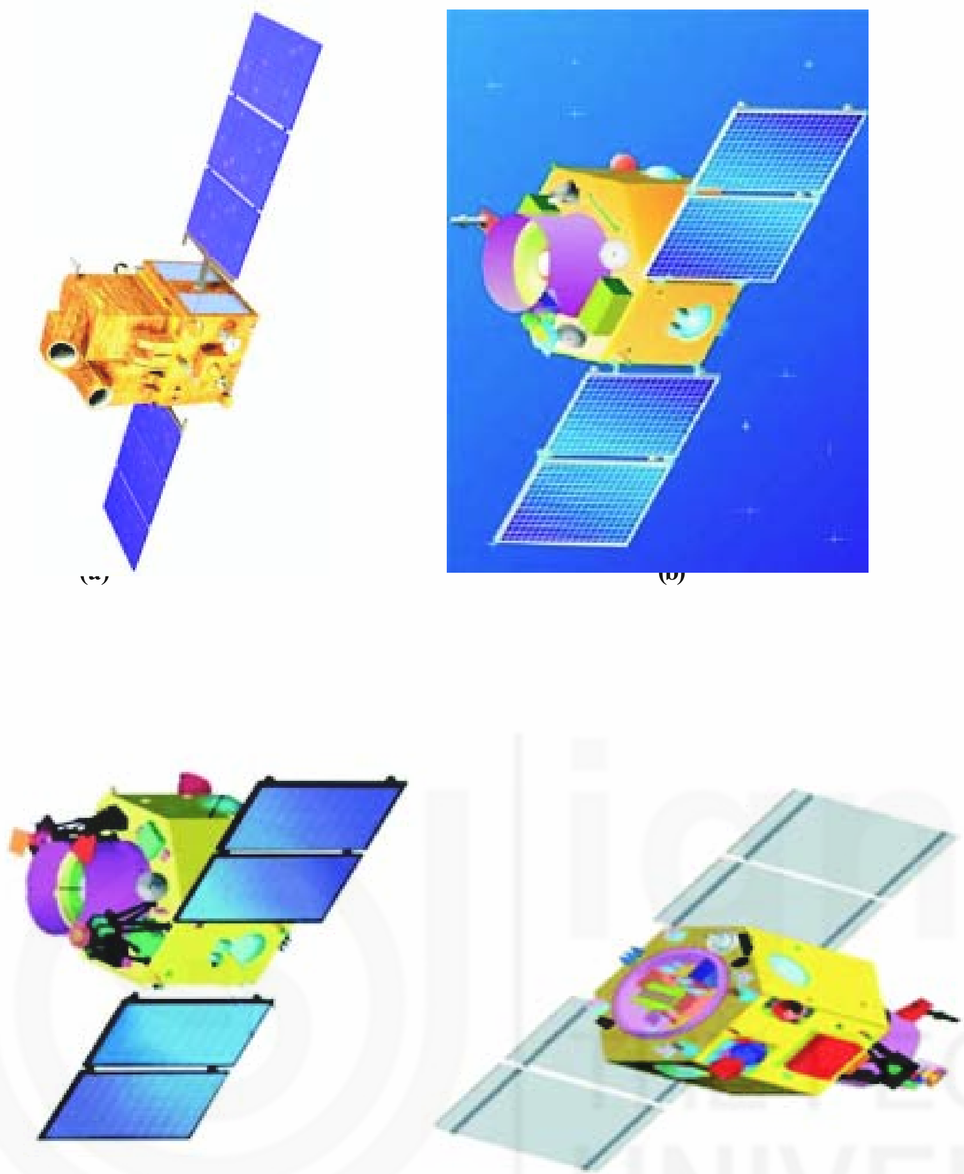


Fig. 6.6: Schematics of (a) CARTOSAT-1, (b) CARTOSAT-2, (c) CARTOSAT-2A and (d) CARTOSAT-2B satellites (source: www.isro.org)

CARTOSAT-2A was launched by PSLV-C9 in April, 2008 along with an Indian mini satellite (IMS-1) and eight other nano research satellites belonging to Canada, Denmark, Germany, Japan and Netherlands. It was placed at an altitude of 635 km with an inclination of 97.94°. It contains a panchromatic camera having a spatial resolution better than 1m and swath of 9.6 km. Data products of the satellites can be used for cartographic applications like mapping, urban and rural infrastructure development and management as well as application in land information and GIS. CARTOSAT-2B is the latest and an advanced Indian remote sensing satellite. It represents seventeenth satellite in the IRS series and was launched in July, 2010 by PSLV-C15 along with Algerian satellite, one nano satellite each from Canada and Switzerland and StudSat, a pico satellite from Sriharikota. It was placed at an altitude of 630 km in a polar sun-synchronous orbit at an inclination of 97.71°.

CARTOSAT-2B carries a panchromatic camera similar to CARTOSAT-2 and 2A. It is capable of imaging a swath of 9.6 km with a resolution of 0.8 m. The scene specific spot panchromatic imagery of CARTOSAT-2B is useful for cartographic and a host of other applications. The satellite has high agility with capability to steer along as well as across the track up to ± 26° to obtain stereoscopic imagery and achieve a four to five day revisit capability.

6.3.2 Radar Imaging Satellite Series

Radar Imaging Satellites (RISAT) are a series of Indian radar (microwave) imaging reconnaissance satellites developed by ISRO. It differs from IRS series by having a multi-mode Synthetic Aperture Radar (SAR) as the sole payload for RISAT. Basically, SAR is an all weather imaging active sensor which is capable of taking images of the Earth in cloudy and snow covered regions and also both during day and night. RISAT provides advantages over the earlier Indian Earth observation satellites of IRS series which rely mainly on optical and spectral sensors which cannot image areas during night as well as covered by snow and clouds. RISAT-2 (Fig. 6.7) is the first satellite of the RISAT series. It was launched successfully by ISRO on 20th April, 2009 by PSLV-C12 along with micro ANUSAT from the Satish Dhawan Space Center, Sriharikota. It has C-band SAR payload operating in a multi-polarisation and multi-resolution mode. It is placed at an altitude of 550 km above the Earth's surface and having an inclination of 41°. RISAT-2 weighed about 300 Kg and was jointly manufactured by ISRO and Israel aerospace industries space division. On the other hand, ANUSAT which is the first experimental communication satellite developed by Anna University, Chennai under the overall guidance of ISRO demonstrates technologies related to message store and forward operations.

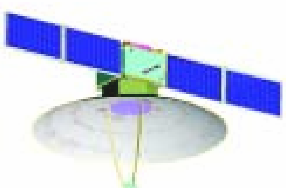


Fig. 6.7: RISAT-2 satellite (source: www.isro.org)

RISAT-2 enhances ISRO's capability in Earth observation with microwave remote sensing. Its basic focus is on agriculture and to provide requisite temporal sampling capability which is important for monitoring *Khariff* crop produced during monsoon season. The C-band frequency operation of RISAT-2 also ensures wide applicability data in the thrust areas like vegetation, forestry, soil moisture, geology, sea ice, coastal processes, man-made object identification, cyclones, landslides and flood mapping in a more effective way. RISAT-2 is also known as *spy satellite* as it helps security agencies of India to keep an eye on the country's borders round the clock.

6.3.3 Indian National Satellite Series

Indian National Satellites (INSAT) series is a series of geostationary communication satellites. It was commissioned with the launch of INSAT-1B in August 1983, shortly after the launch of satellites APPLE and INSAT-1A. It is a series of multi-purpose satellites launched by ISRO to provide indigenous services in telecommunications, broadcasting, meteorology, and search and rescue operations in India. It is developed jointly by the Department of Space (DOS), Department of Telecommunications (DOT), India Meteorological Department (IMD), All India Radio (AIR) and Doordarshan (DD). Now it has been representing one of the largest domestic communication satellites systems in Asian-Pacific region providing about 175 transponders in C, Ku and S frequency bands. INSAT space segment consists of twenty four satellites out of which eleven satellites such as INSAT-2E, INSAT-3B, INSAT-3C, KALPANA-1, INSAT-3A, GSAT-2, INSAT-3E, EDUSAT, INSAT-4A, INSAT-4B, and INSAT-4CR are presently in service (Table 6.5). Satellites of INSAT series are monitored and controlled by master control facilities at Hassan and Bhopal. Satellites of INSAT series are commonly placed at an altitude of about 36,000 km above equator in the geostationary orbit. As a consequence, they remained at a fixed position relative to Earth.

Bhopal. Satellites of INSAT series are commonly placed at an altitude of about 36,000 km above equator in the geostationary orbit. As a consequence, they remained at a fixed position relative to Earth.

Table 6.5: Communication satellites of India (after overview of Indian space sector, 2010).

S. No.	Spacecraft	Launch date	Launch vehicle	Mission Status
1.	APPLE	19th June, 1981	Ariane-1	Completed
2.	INSAT-1A	10th April, 1982	Delta	Failed after 5 months
3.	INSAT-1B	30th August, 1983	Space shuttle	Completed
4.	INSAT-1C	21st July, 1988	Ariane-3	Failed after 2.5 years
5.	INSAT-1D	12th June, 1990	Delta	Completed
6.	INSAT-2A	10th July, 1992	Ariane-4	Completed
7.	INSAT-2B	23rd July, 1993	Ariane-4	Completed
8.	INSAT-2C	7th December, 1995	Ariane-4	Completed
9.	INSAT-2D	4th June, 1997	Ariane-4	Failed after 4 months
10.	INSAT-2E	3rd April, 1999	Ariane-4	In operation
11.	INSAT-3B	22nd March, 2000	Ariane-5	In operation
12.	GSAT-1	18th April, 2001	GSLV-D1	Completed
13.	INSAT-3C	24th January, 2002	Ariane-4	In operation
14.	KALPANA-1	12th September, 2002	PSLV-C4	In operation
15.	INSAT-3A	4th April, 2003	Ariane-5	In operation
16.	GSAT-2	28th September, 2003	GSLV-D2	In operation
17.	INSAT-3E	28th September, 2003	Ariane-5	In operation
18.	EDUSAT	20th September, 2004	GSLV-F1	In operation
19.	HAMSAT	5th May, 2005	PSLV-C6	Completed
20.	INSAT-4A	22nd December, 2005	Ariane-5	In operation
21.	INSAT-4C	10th July, 2006	GSLV-F2	Launch failed
22.	INSAT-4B	12th March, 2007	Ariane-5	In operation
23.	INSAT-4CR	2nd September, 2007	GSLV-F4	In operation
24.	GSAT-4	15th April, 2010	GSLV-D3	Not placed in orbit

Check Your Progress I

Spend 5 mins

1) How many remote sensing satellites have been launched by ISRO?

....

....

....

2) Write about the uses of IRS and INSAT series.

....

....

....

6.4 GLOBAL SPACE PROGRAMMES

A number of remote sensing satellites have been launched by various space organisations of the world to collect remote sensing data. USA, European Union, Russia, Japan, China and Canada are leading countries in Earth observation satellite programmes. Let us now discuss about the important international remote sensing satellite programmes.

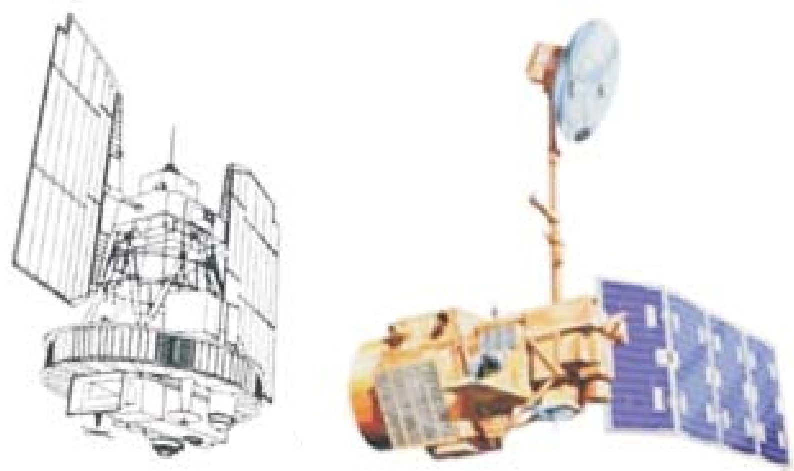
6.4.1 Landsat

Landsat satellite system is a joint venture of NASA and U.S. Geological Survey (USGS) to gather Earth resource data using a series of satellites. It is an unmanned system that was originally called ERTS (Earth Resources Technology Satellite) and later its name was changed to Landsat in 1974. Up to now seven Landsat satellites have been launched (Table 6.6). NASA operated Landsat system through early 1980s, but in January 1983 responsibility for operating the system was transferred to commercial division of the National Oceanic and Atmospheric Administration (NOAA). In October, 1985, Earth Observation Satellite Company (EOSAT) took responsibility of operating Landsat-4 and 5. According to the Land Remote Sensing Policy Act of 1992, Landsat programme returned to the Government under joint management of U.S. Department of Defence and NASA. Landsat programme management structure changed repeatedly from 1992 through 1998. As a result, USGS assumed operational responsibility for Landsat programme in 1999 and NASA continued flight operations for Landsat-7.

Table 6.6: List of Landsat series of satellites launched by USA

Satellite	Launched	De-commissioned	Sensors
Landsat-1	23rd July, 1972	January 6, 1978	MSS and RBV
Landsat-2	22nd January, 1975	February 25, 1982	MSS and RBV
Landsat-3	5th March, 1978	March 31, 1983	MSS and RBV
Landsat-4	16th July, 1982	June 30, 2001	MSS and TM
Landsat-5	1st March , 1984	(Operational)	MSS and TM
Landsat-6	5th October, 1993	(Did not achieve orbit)	ETM
Landsat-7	15th April, 1999	(Operational)	ETM+

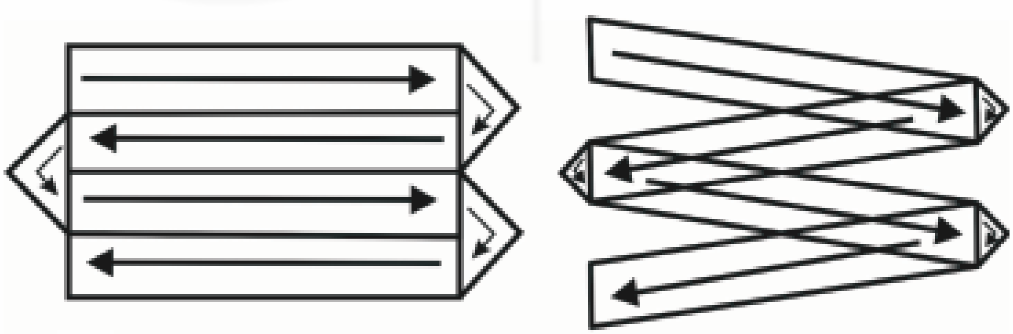
All Landsat satellites have flown in a sun-synchronous orbit. Out of seven Landsats, the first three (Fig. 6.8a) Landsat-1, 2 and 3 launched in 1972, 1975 and 1978, respectively, are known as first generation Landsats. They are placed at an altitude of 919 km with an inclination of 99°. Platform of these Landsats was a modified version of pre-existing Nimbus meteorological satellite. Multispectral Scanner (MSS) and Return-Beam Vidicon (RBV) were the imaging systems for these Landsats. Landsats orbited the Earth every 103 minutes, completing 14 orbits per day. It took 18 days and 251 overlapping orbits to provide almost complete coverage of the Earth's surface with 185 km image swaths. On the other hand Landsat-4 and 5 (Fig. 6.8b) belong to the second generation Landsats and consist of two Landsats launched in 1982 and 1984. MSS and a new improved Thematic Mapper (TM) were the main sensors in these Landsats. Landsat-4 and 5 placed at lower altitude about 705 km than Landsat-1 to 3. As a result, only 233 orbits and 16 days are required for Landsat-4 and 5 to cover the Earth. These satellites collected data over a 185 km swath.



(a) (b)

Fig. 6.8: (a) Schematics of Landsats-1 to 3 and (b) Landsat-5 (source: http://landsat.usgs.gov)

Launch of Landsat-6 failed because satellite did not achieve required orbital position. It was equipped with the first version of the Enhanced Thematic Mapper (ETM) sensor which had new capability of imaging in a 15x15 m panchromatic band as well as in other 7 spectral bands. Landsat-7 was successfully launched in 1999. It is placed at an altitude of 705 km above the Earth. The payload of Landsat-7 is a single nadir pointing instrument which is called Enhanced Thematic Mapper Plus (ETM+). ETM+, the successor of TM, records data in scan line corrector (SLC) mode (Fig. 6.9a). Unfortunately, SLC mode of ETM+ failed in 2003 and subsequent efforts to recover SLC were not successful. Without an operating SLC, ETM+ line of sight now traces a zig-zag pattern along the satellite ground track (Fig. 6.9b). As a result, imaged area is duplicated with width that increases toward the scene edge and about 22% of any given scene is lost because of this failure.



(a) (b)

Fig. 6.9: (a) Scan line corrector mode of Landsat-7 and (b) failure of SLC (source: www.landsat.usgs.gov)

Data gathered by Landsats have extensively been used by government, commercial, industrial and educational institutions over the globe. The changes in agricultural areas, deforestation, natural disasters, desertification, urbanisation and degradation of water resources can be monitored with the Landsats data. Characteristics of Landsat sensor system are given in Table 6.7.

Table 6.7: Landsat sensor system characteristics

S. No.	Sensor type	Band	Spectral resolution (µm)	Spatial resolution (m)
1.	**Multispectral Scanner (MSS)**	1	0.5-0.6 (green)	80
		2	0.6-0.7 (red)	80
		3	0.7-0.8 (red - NIR)	80
		4	0.8-1.0 (NIR)	80
2.	**Thematic Mapper (TM)**	1	0.45-0.52 (blue)	30
		2	0.52-0.60 (green)	30
		3	0.63-0.69 (red)	30
		4	0.76-0.90 (NIR)	30
		5	1.55-1.75 (mid-IR)	30
		6	10.4-12.5 (thermal-IR)	120
		7	2.08-2.35 (mid-IR)	30
3.	**Enhanced Thematic Mapper (ETM+)**	1	0.450-0.515 (blue)	30
		2	0.525-0.605 (green)	30
		3	0.630-0.690 (red)	30
		4	0.750-0.900 (NIR)	30
		5	1.55-1.75 (mid-IR)	30
		6	10.4-12.5 (thermal-IR)	60
		7	2.08-2.35 (mid-IR)	30
		PAN	0.52-0.90 (visible-IR)	15

6.4.2 SPOT

SPOT (Satellite Pour l'Observation de la Terre) programme consists of a series of high-resolution optical remote sensing satellites. This series is being developed and operated by the French Space Agency, Centre National d'Etudes Spatiales (CNES). The primary mission of this programme is to obtain Earth imagery for landuse, agriculture, forestry, geology, cartography, regional planning, water resources and GIS applications. Five SPOT satellites have been launched since 1986, which are providing medium to high resolution images of the Earth's surface. The SPOT satellites are in a sun-synchronous orbit at an altitude of about 810 km. SPOT-1 satellite was launched on 21st February, 1986. It had a spatial resolution of 10 × 10 m in panchromatic and 20 × 20 m in multispectral mode. SPOT-2 and 3 having same payloads as that of SPOT-1, were launched on 22nd January, 1990 and 25th September, 1998, respectively. SPOT-1, 2, and 3 are all identical and consist of a multipurpose platform known as SPOT bus, two identical High Resolution Visible (HRV) sensors and a package of data recorders and transmitter. HRV sensors operate in both panchromatic and multispectral modes. Thus, spectral resolution of SPOT-1 to 3 is not as good as that of the Landsat TM. SPOT-3 mission failed in November, 1996, but 1 and 2 are still operational.

SPOT-4 successfully launched in March 1998 and has similar features to that of the previous satellites. But it has additional spectral Short Wave Infrared (SWIR) band equivalent to TM band 5 of Landsat dedicated for vegetation and soil moisture applications. It is equipped with two High Resolution Visible Infrared (HRVIR) push-broom imaging sensors. Each HRVIR had a swath width of 60 km. HRVIR was derived from HRV sensors of SPOT-1 to 3. SPOT-4 provided 10 m spatial resolution in the panchromatic band and 20 m resolution in the multispectral bands. SPOT-5 was launched in May, 2002 and is the most innovative satellite of the series. It is equipped with High Resolution Stereoscopic (HRS), High Resolution Geometry (HRG) and Vegetation sensors. The new HRS and HRG instruments derived from the HRVIR instrument of SPOT-4 which offers high resolution in across-track direction with 2.5 m resolution in panchromatic mode and 10 m in the visible and NIR ranges. Different characteristics of SPOT sensor system are given in Table 6.8.

Table 6.8: SPOT sensor system characteristics

S.No.	Sensor type	Band	Spectral resolution (µm)	Spatial resolution (m)
1.	High-resolution visible (HRV) for SPOT-2 and -3	1	0.50-0.59 (green)	20
		2	0.61-0.68 (red)	20
		3	0.79-0.89 (NIR)	20
		PAN	0.51-0.73 (visible-IR)	10
2.	High-resolution visible-infrared (HRVIR) for SPOT-4	1	0.50-0.59 (green)	20
		2	0.61-0.68 (red)	20
		3	0.78-0.89 (NIR)	20
		4	1.58-1.75 (mid-IR)	20
		PAN	0.61-0.68 (red)	10
3.	HRVIR for SPOT-5	1	0.50-0.59 (green)	10
		2	0.61-0.68 (red)	10
		3	0.78-0.89 (NIR)	10
		4	1.58-1.75 (mid-IR)	20
		PAN	0.51-0.73 (visible-IR)	5
4.	Vegetation for SPOT-4 and 5	1	0.43-0.47 (blue)	1000
		2	0.61-0.68 (red)	1000
		3	0.78-0.89 (NIR)	1000
		4	1.58-1.75 (mid-IR)	1000

6.4.3 RADARSAT

RADARSAT is the first sophisticated Earth observation satellite of Canada. It was built under the management of Canadian Space Agency in co-operation with provincial governments and private sector. Until now two RADARSATs have been launched. RADARSAT-1 was launched in 1995 by NASA on a Delta II rocket. It was placed into a near polar sun-synchronous orbit at an altitude of 798 km above the Earth at an inclination of 98.6°. It orbits the Earth 14 times per day in which each orbit takes 100.7 minutes to complete.

RADARSAT-1 has dawn-dusk orbit which enable it to cross the equator at dawn and dusk, i.e. 6.00 a.m. and 6.00 p.m. of local time. Further, this orbit keeps solar cell arrays of the satellite in almost continuous sunlight and ensures satellite to rely on solar energy rather than battery power. It is equipped with an advanced single C-band radar sensor SAR. RADARSAT SAR is a powerful microwave instrument which transmits a microwave energy pulse in C-band having 5.3 GHz frequency to the Earth. SAR measures the amount of energy that is reflected back to the satellite from the Earth's surface. It has a wide variety of beam widths which can capture swaths from 45 to 500 km with resolution from 8 to 100 m and at incidence angles from 10° to 60°.

RADARSAT-1 is horizontally polarised in which microwaves travel horizontal to the Earth's surface (Fig. 6.10a). It has seven images sizes namely fine, standard, wide, scanSAR narrow, scanSAR wide, extended low and extended high which are collectively termed as beam modes (Fig. 6.11). As a consequence, it provides a range of spatial resolution and geographic coverage.

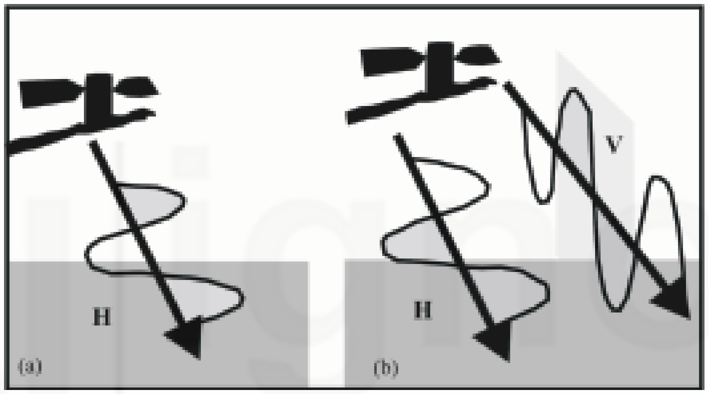


Fig. 6.10: (a) Horizontal polarisation in RADASAT-1 and (b) both horizontal and vertical polarisation in RADARSAT-2. H – horizontal and V – vertical (source: www.asc-csa.gc.ca)

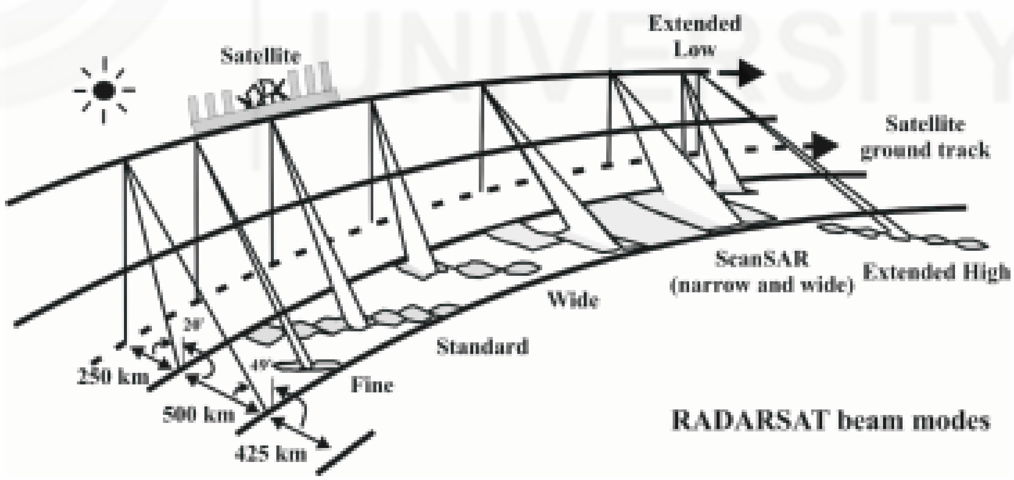


Fig. 6.11: RADARSAT-1 imaging modes (source: www.asc-csa.gc.ca)

Fig. 6.12: RADASAT- 2 satellite (source: www.asc-csa.gc.ca)

The world's most advanced commercial C-band SAR satellite RADARSAT-2 was launched in 2007 (Fig. 6.12). It retains many specifications of RADARSAT-1 (e.g., imaging modes and orbital parameters). But some significant modification of RADASAT-2 made it a premier Earth observation radar remote sensing system. These modifications include 3 m high resolution imaging, both horizontal and vertical polarisation imaging modes (Fig. 6.10b), left and right looking imaging options, superior data storage and onboard GPS receivers for monitoring satellite position.

RADARSAT supply data to monitor environmental changes and natural resources of Earth at national as well as global level. It also provides important information in the fields of agriculture, hydrology, cartography, forestry, oceanography and coastal monitoring for both scientific and commercial users.

6.4.4 European Remote Sensing Satellites

European Remote Sensing satellite (ERS) is a European programme for Earth observation sponsored by the European Space Agency. Under this programme two satellites ERS-1 and ERS-2 (Fig. 6.13) have been designed and developed to observe oceans and its circulation, sea ice distribution, sea surface wind and land areas with high resolution radar. ERS-1 was launched in July, 1991. It is placed in sun-synchronous polar orbit at an altitude of about 785 km at an inclination of 98.5°. It has a ground swath width of 100 km. It is equipped with a comprehensive payload including an imaging C-band SAR, radar altimeter, wind scatterometer, along-track scanning radiometer, micro-wave sounder and other powerful instruments to measure ocean surface temperature and winds at sea. During 1995, ERS-2 was launched which represents a follow-on mission of ERS-1. ERS-2 is identical to ERS-1 but it is provided with an additional sensor to monitor atmospheric ozone levels. There is about 30 minutes time lag between ERS-1 and ERS-2, in the same orbital plane as a consequence a one day interval between ERS- 1 and ERS-2 is observed on the same ground swath. Both ERS-1 and ERS-2 were operated in tandem from August, 1995 to May, 1996 to provide image pairs for SAR interferometry research. In March, 2000, ERS-1 satellite finally ended its operations but ERS-2 is expected to continue operating for several more years.

(a) **(b)**

Fig. 6.13: (a) ERS-1 and (b) ERS-2 (source: www.esa.int)

6.4.5 Japanese Earth Resource Satellites

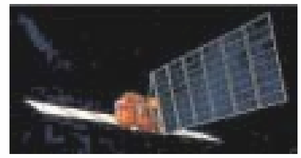


Fig. 6.14: JERS-1 satellite (source: www.jaxa.jp)

National Space Development Agency (NASDA) of Japan launched the Japanese Earth Resource Satellite, JERS-1 in 1992 (Fig. 6.14). JERS-1 (*FUYO-1in Japanese*) is an advanced Earth observation satellite which is jointly developed by NASDA and the Ministry of International Trade and Industry (MITI), Japan. NASDA developed satellite bus, while MITI built

JERS-1 gathered data on global land masses which have great applications in the fields of land surveys, agriculture, forestry, fisheries, environmental management, disaster prevention, coastal surveillance and for locating natural resources.

Check Your Progress II

1) SPOT-1 satellite had a spatial resolution of .... in panchromatic and .... in multispectral mode.

2) JERS-1 had a spatial resolution .... in cross-track and .... in along-track direction.

6.5 COMMERCIAL REMOTE SENSING SATELLITES

Recently, some high resolution Earth observation satellites have been launched by commercial operators such as DigitalGlobe, GeoEye, ImageSat International and Leica Geosystems. Let us now discuss about some of the successful commercial satellites.

Spend 5 mins

6.5.1 QuickBird

QuickBird (Fig. 6.15) is a remote sensing satellite of DigitalGlobe which is a commercial imagery provider company with headquarters located at Longmont, Colorado, USA. Up-to-date DigitalGlobe launched four commercial satellites namely - EarlyBird-1, QuickBird, WorldView-1 and WorldView-2 in December, 1997, October, 2001, September, 2007, and October, 2009, respectively. DigitalGlobe lost communication with EarlyBird-1 after four days of its launching. But other satellites are functioning successfully.

QuickBird represents first satellite in a constellation of sub-meter spacecraft that developed by DigitalGlobe. It offers a unique highly accurate and commercial high resolution imagery of Earth. It was launched on 18th October, 2001 by Boeing Delta II launch vehicle into a 600 km orbit. It has a swath width of 20 to 40 km. It offers images with 0.61 × 0.61 m panchromatic and 2.44 × 2.44 m multispectral spatial resolution. Its revisit time ranges from 1 to 5 days. It is the fourth satellite which obtains highest resolution commercial imagery of Earth after WorldView-1, WorldView-2 and GeoEye-1. It has a greatest capacity of on-board storage of data than any other satellites. It is capable of acquiring more than 75 million km^2 of imagery data yearly and also allowing DigitalGlobe to update its image library at rapid speed. The high quality satellite imagery of QuickBird is commonly used for map creation, change detection and image analysis.

Fig. 6.15: Quickbird satellite (source: www.digitalglobe.com)

6.5.2 IKONOS

IKONOS is a satellite of GeoEye Inc. (formerly known as ORBIMAGE or Orbital Imaging Corporation) which is a commercial imagery provider company located in Herndon, Virginia, USA. GeoEye Inc. has launched IKONOS, OrbView-2 (SeaStar), OrbView-3 and GeoEye-1 satellites in 1999, 1997, 2003 and 2008, respectively. The first IKONOS was launched on 27th April, 1999 but unfortunately, it never achieved its orbit. Subsequently, a second IKONOS was launched successfully on 24th September, 1999.

The IKONOS is in a sun-synchronous 681 km orbit with an inclination 98.1°. The orbit provides daily access to regions within 45° of nadir, 3 day revisit within 26° of nadir and 141 day revisit within 1° of nadir. The satellite provides imagery with spatial resolution of 1 × 1 m in panchromatic band and 44 m in multispectral bands. One meter colour imagery can be created by merging IKONOS's panchromatic and multispectral imageries. In addition, the satellite has both cross-track and along-track sensors which allow it to acquire data flexibly having frequent revisit capability. Satellite collects data at a rate of over 2,000 km^2/m. As a result, it has collected over 250 million km^2 of imagery of Earth surface digitally. High spatial resolution imagery collected by IKONOS is being largely used for national security, military mapping, Earth resources management, air and marine transportation, and city and urban planning.

6.5.3 OrbView

OrbView is another group of satellites belonging to GeoEye. Four OrbView satellites have been launched by GeoEye. OrbView-1 was launched in April, 1995. It is an atmosphere monitoring satellite that provided weather data to NASA. Following this, GeoEye launched OrbView-2 in August, 1997. It provides images of oceans which are useful for the study of global warming, commercial fishing, environmental and coastal monitoring. In June 2003, the third satellite of the series, OrbView-3 was launched successfully. OrbView-4 was launched in September, 2001 but this satellite failed to reach required orbit.

OrbView-3 was designed to provide high resolution imagery of the Earth (Fig. 6.16). It was successfully launched on 26th June, 2003. This satellite is equipped with a camera to take images with 1 × 1 m in panchromatic and 4×4 m in multispectral spatial resolution at a swath width of 8 km. It is in a 470 km sun-synchronous orbit with an equatorial crossing time of 10.30 a.m. The sensor revisits locations on Earth in less than three days. OrbView-3 is the first commercial satellite to supply high resolution imagery from space. Therefore, the imageries collected by it can be used for environmental monitoring, construction planning, precise mapping and intelligence gathering.

6.6 SUMMARY

In this unit, you have studied about:

- Remote sensing satellites which are being operated by various countries. Notably among them are IRS series, CARTOSATs and RISAT of ISRO, India; Landsat of NASA and USGS, USA; SPOT of FSA, France; RADARSAT of CSA, Canada; ERS of ESA, Europe; JERS-1 of NASDA, Japan and commercial satellites such as QuickBird of DigitalGlobe, and IKONOS and OrbView-3 of GeoEye.

- Remote sensing satellites equipped with improved sensor systems are placed in a sun-synchronous orbit with difference in altitude above the Earth (average altitude is 900 km). They record imagery of the Earth at different spatial, temporal and spectral resolutions.

- Under IRS series of ISRO, India has launched 18 remote sensing satellites. Data gathered from IRS series is received, processed and disseminated from NRSC, Hyderabad. It is extensively used for monitoring of crops health, drought conditions, forest covers, natural resources; land use and land cover mapping; disaster management and sustainable development of the country. CARTOSAT data is mostly used for cartography and a host of other applications.

- India has made tremendous progress in the field of communication by launching 24 satellites under the INSAT series of ISRO. Out of 24, eleven are active and giving continuous service. Satellites of INSAT series are providing indigenous services in telecommunications, broadcasting, meteorology, and search and rescue operations in India.

- Quickbird has highest resolution which is followed by IKONOS and OrbView-3. But Landsat and SPOT are the more popular groups of satellites than others because these satellites are extensively used as they also provide wide spectral range.

- A group of advanced Earth observation satellites such as RISAT, RADARSAT, ERS-1 and 2, and JERS-1 operating in C and L-band frequency of microwaves have been launched. These satellites equipped with active sensors, record 24 hours data of the Earth during day and night and they also include regions covered by clouds, snow and ice.

6.7 UNIT END QUESTIONS

1) Discuss Earth resource remote sensing satellites.
2) Differeniate between IRS and INSAT series of satellites.
3) Discuss RADARSAT.

6.8 REFERENCES

Spend 30 mins

- http://landsat.usgs.gov.
- www.asc-csa.gc.ca.
- www.digitalglobe.com.
- www.esa.int.
- www.geoeye.com.
- www.isro.org.
- www.jaxa.jp.

All the above websites were retrieved between 15 May, 2011 and 30 June, 2011.

6.9 FURTHER/SUGGESTED READING

- Gupta, R. P., (2003), *Remote Sensing Geology,* 2nd Ed., Springer-Verlag, Berlin.

- Jensen, J. R., (2009), *Remote Sensing of the Environment – An Earth Resource Perspective*, 2nd Ed., Dorling Kinderslay India Pvt. Ltd, New

Delhi.

- Joseph, G. (2005), Fundamentals of Remote Sensing, University Press (India) Pvt. Ltd, hyderabad.

6.10 ANSWERS

Check Your Progress I

1) 18

2) IRS is being used to record earth's resources data. INSAT is being used for communication, television broadcasting, weather monitoring and weather forecasting.

Check Your Progress II

1) 1010 m in panchromatic and 2020 m multispectral.

2) 18.3 m in cross-track and 24.2 m in along-track.

Unit End Questions

1) It includes all man-made staellites which are used to study the Earth's surface to explore its natural resources and other phenomena useful to humans. These are placed in sun-synchronous orbit so that they can take repeated images of a location.

2) Refer to subsections 6.3.1 and 6.3.3.

3) Refer to section 6.4.3.

GLOSSARY

Band: A wavelength interval in the electromagnetic spectrum. For example, in Landsat by non-photographic methods.

C-band: The region of radar wavelength from 4 - 8 cm.

Contrast: The ratio between the energy emitted or reflected by an object and its immediate surroundings.

Detectability: The ability of a remote sensing system to record the presence or absence of a feature on the landscape

GPS: The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defence.

Ground resolution cell: Area on the terrain that is covered by the IFOV of a detector.

Ground swath: The width of the strip of terrain that is scanned by a sensor system.

Image: Pictorial representation of a scene recorded by a remote sensing system. Although image is a general term, it is commonly restricted to representations acquired images the bands designate specific wavelength intervals at which images are acquired.

Instantaneous field of view (IFOV): Solid angle through which a detector is sensitive to radiation. In a scanning system, the solid angle subtended by the detector when the scanning motion is stopped.

Laser altimeter: Laser altimeter is an instrument that measures the height or elevation of the terrain from an aircraft or a satellite.

L-band: The region of radar wavelength from 15 to 30 cm.

MSS: The multispectral scanner of Landsat that acquires images at four wavelength bands in the visible and reflected infrared regions.

Noise: Random or repetitive events that obscure or interfere with the desired information.

Orbital period: The orbital period is the time taken for a given object to make one complete orbit about another object.

Passive remote sensing: Uses natural energy, either reflected sunlight or emitted thermal or microwave radiation

Radar: Radar is an object-detection system which uses electromagnetic waves specifically radio waves to determine the range, altitude, direction, or speed.

Recognisability: The ability of the human interpreter to identify a feature detected by the sensor but may not be recognisable (e.g., narrow straight lines in an image may be roads, railways, or canals).

Resolution cell: The cell defined by the resolutions in the range and azimuth directions (does not mean the same thing as pixel). Pixel sizes need not be the same thing. This is important since (i) the independent elements in the scene are resolutions cells, (ii) neighbouring pixels may exhibit some correlation.

Resolution: Ability to separate closely spaced objects on an image or photograph. Resolution is commonly expressed as the most closely spaced line-pairs per unit distance that can be distinguished.

Round Trip Time (RTT): In a satellite network, Round Trip Time (RTT) is the time required for a signal to travel from a terrestrial system up to the satellite and back, or for a signal to travel from a satellite down to a terrestrial system and back up to the satellite again.

Satellite: An object revolving around earth or any planet. Man-made satellites are called artificial satellites e.g. IRS-1A. Other satellites are called natural satellites e.g. Moon.

Scatterometer: A calibrated radar that measures the scattering properties of a surface and it is designed for back scatter measurements

Spectral reflectance: Reflectance of electromagnetic energy at specified wavelength intervals.

Stratosphere: The stratosphere is the second major layer of Earth's atmosphere.

Swath: It is the area imaged on the surface by the sensor.

TM: A cross-track scanner of Landsat that records seven bands of data from visible to the thermal infrared regions.