MODULE – 2 LECTURE NOTES – 5

FEATURES OF THE REMOTE SENSING SATELLITES

1. Introduction

This lecture covers the details of some of the important remote sensing satellites that operate in the optical region of the electromagnetic spectrum. This includes ultra-violet (UV), visible, near-infrared (NIR), middle-infrared (MIR), and thermal infrared wavelength ranging approximately 3-14 μm.

There are many characteristics that describe any satellite remote sensing systems. Satellite's orbit (including its altitude, period, inclination and the equatorial crossing time), repeat cycle, spatial resolution, spectral characteristics, radiometric properties are a few of them.

This lecture gives details of the satellites of the Lansat, SPOT and IRS programs, and some of the very high resolution satellites such as IKONOS and QuickBird

Details of some of the important geo-synchronous satellite programs viz., INSAT and GEOS are also covered in this lecture

2. Landsat Satellite Program

Landsat is the longest running program for acquiring satellite imageries of the Earth.

First satellite in the series, Landsat-1 was launched in July 1972. It was a collaborative effort of NASA and the US department of the Interior. The program was earlier called Earth Resources Technology Satellites (ERTSs) and was later on renamed as Landsat in 1975. The mission consists of 8 satellites launched successively. The recent one in the series Landsat-8, which is also called Landsat Data Continuity Mission (LDCM) was launched in February, 2013.

Fig.1 shows the time line of the Landsat satellite program.

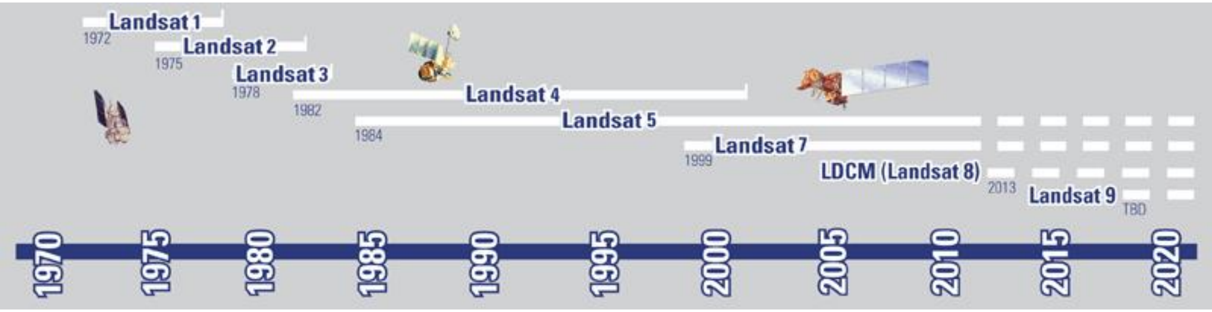

Fig.1. Time line of the Landsat satellite program
(Source: http://landsat.usgs.gov/about_landsat7.php)

Different types of sensors viz., Return Beam Vidicom (RBV), Multispectral Scanner (MSS), Thematic Mapper, Enhanced Thematic Mapper (ETM), and Enhanced Thematic Mapper Plus (ETM+) have been used in various Landsat missions.

Landsat missions use sun-synchronous, near polar orbits at different altitudes for each mission

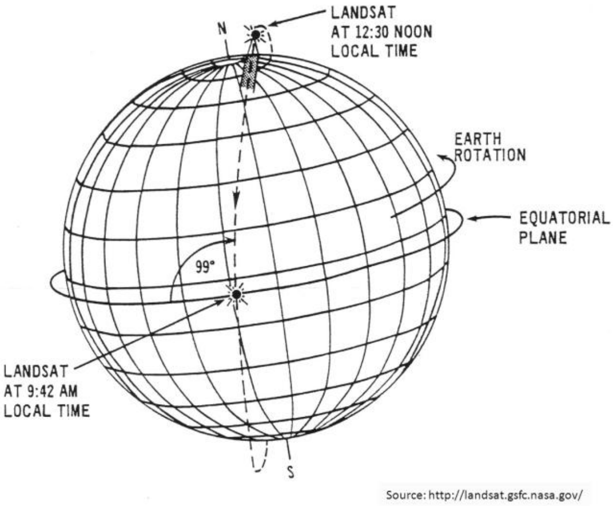

Fig.2. Typical orbit of a satellite in the Landsat program
(Source: http://landsat.usgs.gov/about_landsat7.php)

Table 1 gives the details of different Landsat missions including the type of sensors , spatial, temporal and radiometric resolution.

Table 1. Details of the orbit and sensors of different Landsat missions

Mission	Landsat-1		Landsat-2		Landsat-3		Landsat-4		Landsat-5		Landsat-6	Landsat-7	Landsat-8(LCDM)	
Mission period	1972-1978		1975-1982		1978-1983		1982-2001		1984-2012		1993, failed	April 1999 -	Feb 2013 -	
Orbit	Sun-synchronous, near-polar													
Altitude	917 km		917 km		917km		705 km		706 km			705km	705 km	
Inclination	99.2 deg		99.2 deg		99.2 deg		98.2 deg		98.2 deg			98.2deg	98.2 deg	
Eq. crossing (+/- 15min)	9:30am		9:30am		9:30am		9:45am		9:45am			10am	10 am	
Period (min)	103.34		103		103		99					98.9	98.9	
No. orbits /day	14		14		14		14		14			14	14	
Repeat cycle	18		18		18		16		16			16	16	
Swath width	185		185		185		185		185			185	185	
Sensors	RBV	MSS	RBV	MSS	RBV	MSS	MSS	TM	MSS	TM	ETM	ETM+	OLI	TIRS
Bands	1-3	4-7	1-3	4-7	1-4	4-8	1-4	1-7	1-4	1-7	1-8	1-8	1-9	1-2
Spatial resolution (m)	80	82	80	82	80	82 B8:240	79	30 B6:120	79	30 B6:120	B1-B5,B7: 30 B6: 120 B8: 15	B1-B5,B7: 30 B6: 60 B8: 15	30 B8:15	100
Radiometric resolution (Bits)	6	B1-B3:7 B4: 6	6	B1-B3:7 B4: 6	6	B1-B3:7 B4: 6	B1-B3:7 B4: 6	8	B1-B3:7 B4: 6	8	8	8	12	12

Landsat satellites typically complete 14 orbits in a day. Figure 3 shows the orbital path of a Landsat satellite.

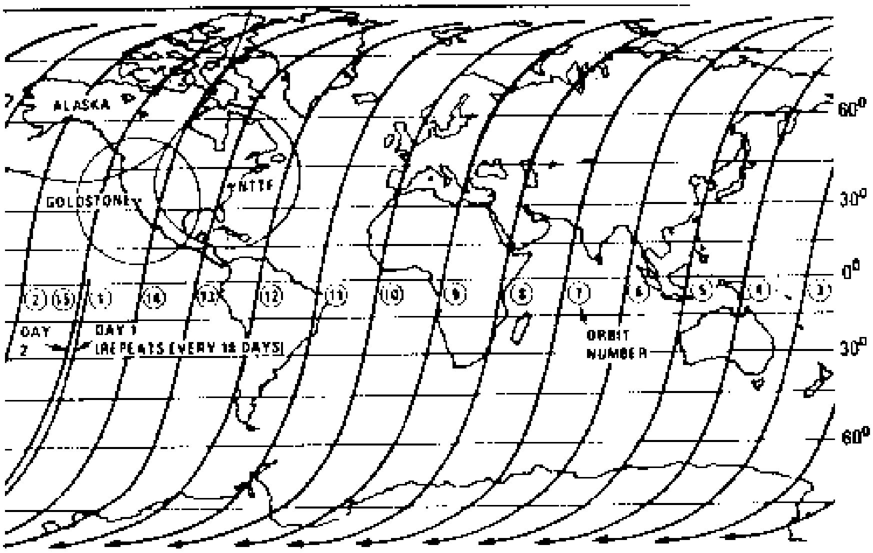

Fig.3. Successive orbits of a typical Landsat satellite
(Source: http://landsat.usgs.gov/about_landsat7.php)

Landsat 4 and 5 maintained 8 days out of phase, so that when both were operational, 8-day repeat coverage could be maintained. MSS used in the Landsat programs employs across line scanning to generate two-dimensional image.

Spectral bands used in various sensors of the Landsat mission are given in Table 2.

Table 2. Characteristic features of the sensors used in the Landsat program

Sensors									
RBV		MSS		TM		ETM		ETM+	
Band	Wavelength (μm)	Band	Wavelength (μm)	Band	Wavelength (μm)	Band	Wavelength (μm)	Band	Wavelength (μm)
1	0.475-0.575	4	0.5-0.6	1	0.45-0.52	TM B1-B7	Same as TM	ETM bands 1-8	Same as ETM
2	0.580-0.680	5	0.6-0.7	2	0.52-0.60				
3	0.690-0.830	6	0.7-0.8	3	0.63-0.69	8	0.5-0.90		
4	0.505-0.750	7	0.8-1.1	4	0.76-0.90				
		8	10.4-12.6	5	1.55-1.75				
				6	10.4-12.5				
				7	2.08-2.35				

Landsat 8 mission is inclusive of two sensors called Operational Land Imager (OLI) and Thermal Infrared Scanner (TIRS). The OLI is operational in 9 bands including 1 panchromatic band. Spectral ranges of these bands are given in Table 3. The TIRS operates in 2 thermal bands. Spectral ranges of the TIRS bands are also given in Table 3.

Table 3. Spectral bands of the OLI and TIPS sensors of the Landsat-8 mission
(Source: landsat.usgs.gov/band_designations_landsat_satellites.php)

Operational Land Imager (OLI)			Thermal Infrared Scanner (TIRS)		
Band	Wavelength (μm)	Remark	Band	Wavelength (μm)	Remark
1	0.43-0.45	Coastal aerosol detection	1	10.60-11.19	Thermal infrared
2	0.45-0.51	Blue	2	11.50-12.51	Thermal infrared
3	0.53-0.59	Green			
4	0.64-0.67	Red			
5	0.85-0.88	Near infrared			
6	1.57-1.65	Short wave infrared			
7	2.11-2.29	Short wave infrared			
8	0.50-0.68	Panchromatic			
9	1.36-1.38	Cirrus cloud detection			

3. SPOT satellite program

SPOT (*Systeme Pour l'Observation de la Terre*) was designed by the Centre National d'Etudes Spatiales (CNES), France as a commercially oriented earth observation program. The first satellite of the mission, SPOT-1 was launched in February, 1986. This was the first earth observation satellite that used a linear array of sensors and the push broom scanning techniques. Also these were the first system to have pointable/steerable optics, enabling side-to-side off-nadir viewing capabilities.

Fig.4 shows the timeline of various missions in the SPOT satellite program.

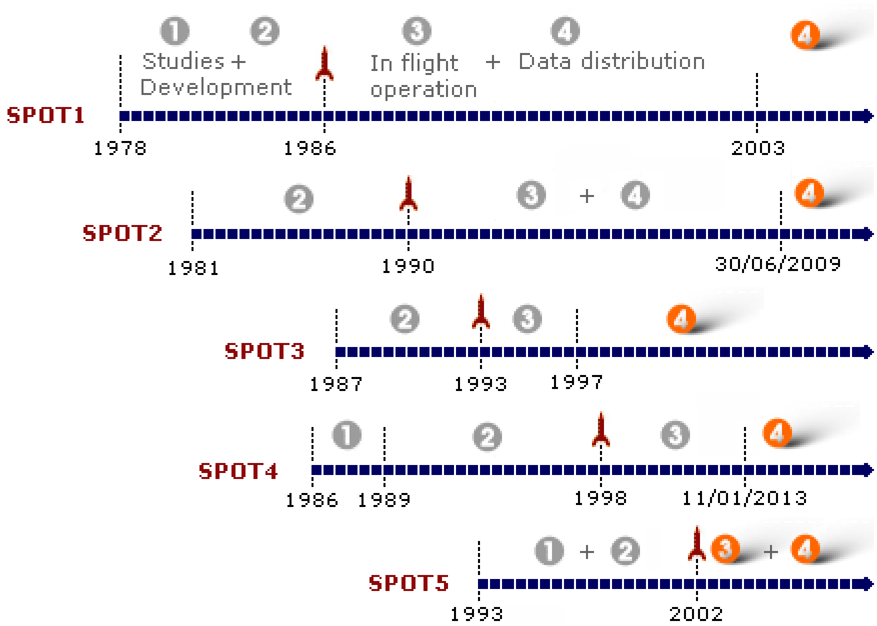

Fig. 4. Time line of various SPOT missions (Source: http://smsc.cnes.fr/SPOT/index.htm)

The recent satellite in the SPOT program, SPOT 6 was launched on September 2012.

SPOT 1, 2 and 3 carried two identical High Resolution Visible (HRV) imaging systems. Each HRVs were capable of operating either in the panchromatic mode or in the MSS mode. HRVs used along-track, push-broom scanning methods. Each HRV contained four CCD sub-arrays. A 6000-element sub-array was used for recording in the panchromatic mode and the remaining 3 arrays, each with 3000 elements, were used for the MSS mode. Due to the off-nadir viewing capability, HRV was also used for stereoscopic imaging. Frequency with which the stereoscopic coverage can be obtained varies with the latitude; more frequent imaging is possible near the polar region compared to the equatorial region.

SPOT 4 carried the High Resolution Visible and Infrared (HRVIR) sensor and the vegetation instrument (VI). HRVIR also includes two identical sensors, both together capable of giving 120km swath width at nadir.

SPOT-5 carries two high resolution geometric (HRG) instruments, a single high resolution stereoscopic (HRS) instrument, and a vegetation instrument (VI). Details of the sensors used in various SPOT 4 and 5 missions are summarized in Table 4.

Table 4. Details of the sensors used in SPOT 4 and SPOT 5 missions

SPOT-4				SPOT-5			
HRVIR		VI		HRG		HRS and VI	
Bands	Wavelength (μm)	Bands	Wavelength (μm)	Bands	Wavelength (μm)	Bands	Wavelength (μm)
1	0.53-0.59	1	0.43-0.47	PAN	0.48-0.71	PAN	0.49-0.69
2	0.61-0.68	2	0.61-0.68	1	0.50-0.59	1	0.45-0.52
3	0.79-0.89	3	0.79-0.89	2	0.61-0.68	2	0.61-0.58
4	1.58-1.75	4	1.58-1.75	3	0.78-0.89	3	0.78-0.89
				4	1.58-1.75	4	1.58-1.75

SPOT-6 mission employs two New AstroSat Optical Modular Instruments (NAOMI). The instrument operates in 5 spectral bands, including one panchromatic band. Details of these bands are given in Table 5.

Table 5. Spectral bands of the NAOMI used in SPOT-6 mission

Band	Wavelength (μm)	Remark
PAN	0.45-0.745	Panchromatic
1	0.450-0.525	Blue
2	0.530-0.590	Green
3	0.625-0.695	Red
4	0.760-0.890	Near infrared

Table 6 gives the details of various SPOT missions. Mission period, orbit characteristics, sensors employed, and the resolution details are given in the table.

Table 6. Details of the SPOT satellite missions

Mission	SPOT-1	SPOT-2	SPOT-3	SPOT-4		SPOT-5			SPOT-6
Mission period	1986-2003	1990-2009	1993-1997	1998-2013		2002-			2012-
Orbit	Sun-synchronous, near-polar, circular								
Altitude	822			822		822			694
Inclination	98.7			98.7		98.7			98.2
Eq. crossing	10:30 AM			10:30 AM		10:30 AM			10:30 AM
Period	101.4			101.4		101.4			98.79
Repeat cycle	26 days (More frequent revisit is achieved due to the off-nadir viewing capability)								
Sensors	HRV			HRVIR	VI	HRG	HRS	VI	NAOMI
Bands	PAN and B1-B3			B1-B4	B0 B2-B4	PAN B1-B4	PAN	B0 B2-B4	PAN B1-B4
Spatial resolution	PAN:10m , MSS:20m			B1-PAN: 10m B1-B4 MSS: 20m	1000	PAN:2.5-5m MSS: 10m B4: 20m	10m	1000	PAN: 2m MSS: 8m
Radiometric resolution	8bit			8bit	10 bit	8 bit		10 bit	12 bit

Pointable optics used in the program enables off-nadir viewing. This increases the frequency of viewing viz., 7 additional viewings at equator and 11 additional viewings at 45deg latitude. Due to the off-nadir viewing capabilities, stereo imaging is also possible. Stereo pairs, used for relief perception and elevation plotting (Digital Elevation Modelling), are formed from two SPOT images.

5. IRS satellite program

Indian Remote Sensing (IRS) satellite system is one of the largest civilian remote sensing satellite constellations in the world used for earth observation. Objective of the program is to provide a long-term space-borne operational capability for the observation and management of the natural resources. IRS satellite data have been widely used in studies related to agriculture, hydrology, geology, drought and flood monitoring, marine studies and land use analyses.

The first satellite of the mission IRS-1A was launched in 1988. IRS satellites orbit the Earth in sun-synchronous, near-polar orbits at low altitude. Various missions in the IRS satellite program employ various sensors viz., LISS-1, LISS-2, LISS-3, WiFS, AWiFS etc.

Spectral bands used in various sensors of the IRS satellite program are given in Table 7.

Table 7. Spectral bands used in various sensors of the IRS satellites

Sensor	LISS-1 and 2	LISS-3	LISS-4	WiFS	AWiFS
Wavelength bands (μm)	0.45-0.52 0.52-0.59 0.62-0.68 0.77-0.86	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	0.52-0.59 0.62-0.68 0.77-0.86	0.62-0.68 0.77-0.86	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70

Details of various satellite missions of the IRS program, including the mission period, orbit characteristics, sensors and resolutions are given in Table 8.

Table 8. Details of the various satellites of the IRS satellite program

Satellite	IRS-1A	IRS-1B	IRS-1C	IRS-1D	IRS-P2	Cartosat-2	Resourcesat-2
Period	1988-1996	1991-2003	1995-2007	1997-2010	2003-	2007-	2011-
Orbit	Sun-synchronous, Polar						
Eq. crossing	10:30am						
Altitude	904		817		817	630	822
Inclination	99.08		98.6		98.7	97.91	98.73
Repeat cycle (days)	22		24		24 LISS-4 and AWiFS : 5	310 Revisit: 4	24
Sensors	LISS-1, LISS-2A and 2B		PAN, LISS-3, WiFS		LISS-3 and 4, AWiFS	PAN camera	LISS-3 and 4, AWiFS
Bands	B1-B4		PAN, LISS-3 B1-B4 WiFS B1-B2		LISS-3 B1-B4 LISS-4 B1-B3 AwiFS B1-B4	PAN (0.5-0.85μm)	LISS-3 B1-B4 LISS-4 B1-B3 AwiFS B1-B4
Spatial resolution	72.5m	36.25m	PAN:5.8m LISS-3: 23m (B4:70m)		LISS-3:23.5 LISS-4: 5.8 AWiFS: 56m	0.81m	LISS-3:23.5 LISS-4: 5.8 AWiFS: 56m
Radiometric resolution (Bits)	7	7	7	7	LISS-3 and 4: 7 AwiFS: 10	10	LISS-3 and 4: 10 AwiFS: 12

Fig. 5. IRS-P6 LISS-IV multispectral mode image shows the centre of Marseille, France, in natural colours

Fig. 6. Parts of Paris as viewed by Cartosat-2 in 2011

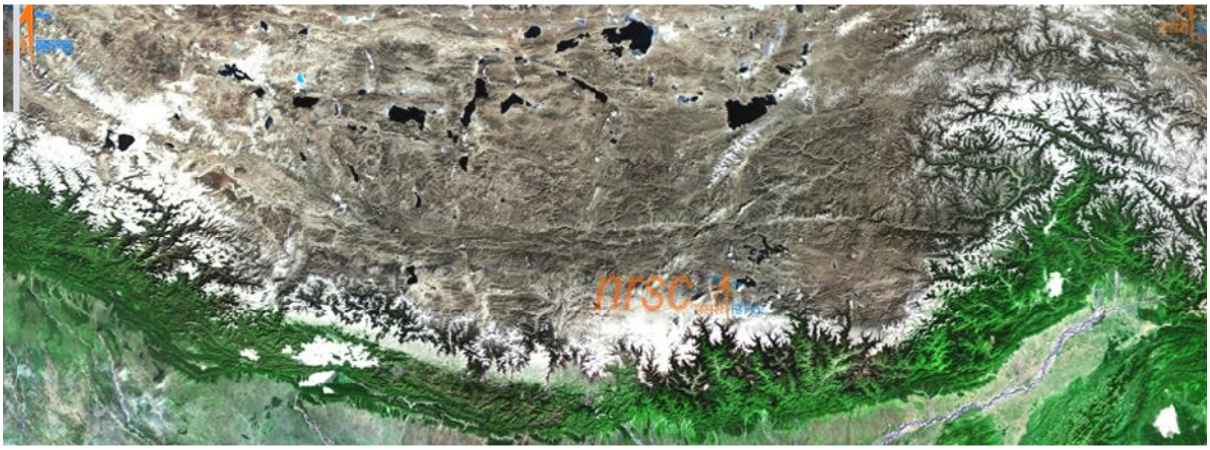

Fig. 7. Parts of Himalayas as viewed by the AWiFS sensor

6. Very high resolution systems

IKONOS

IKONOS is a commercial high resolution system operated by GeoEye. The satellite was launched in September 1999.

IKONOS employs linear array technology and collects data in four multispectral bands and one panchromatic band. The panchromatic images give less than 1 m spatial resolution, whereas the MSS give nearly 4m spatial resolution. IKONOS was the first successful commercial satellite to collect sub-meter resolution images.

Imagery from the panchromatic and multispectral sensors can be merged to create 0.82-meter color imagery (pan-sharpened).

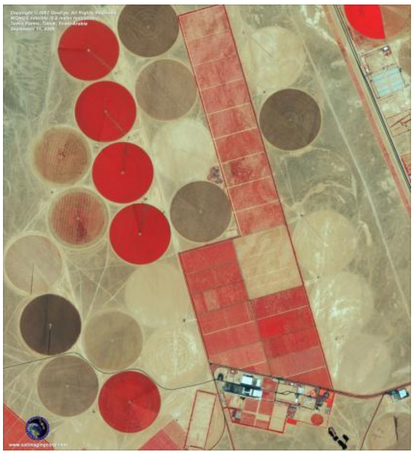

Fig. 8. IKONOS (0.8m) image of the Tadco Farms, Saudi Arabia

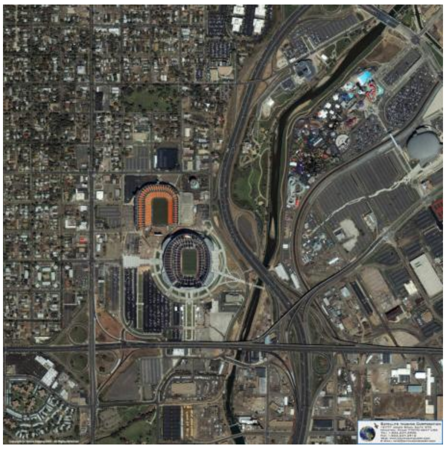

Fig. 9 IKONOS image of the Denver Broncos Stadium, Denver, Colorado, USA

Details of the satellite orbit and the sensors of the IKONOS program are given in Table 9.

Table 9. Details of the satellite orbit and the sensors of the IKONOS program

Satellite	**IKONOS**
Launch date	Sep, 2009
Orbit	Sun-synchronous
Eq. crossing	10:30am
Altitude	682 km
Inclination	98.1 deg
Repeat cycle	11 days (more frequent imaging due to the off-nadir viewing capabilities up to 45 deg)
Sensor	PAN and MSS
Wavelength bands (μm)	PAN 0.45-0.90 MSS: 0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90
Spatial resolution	PAN : 0.81m MSS: 4m
Radiometric resolution	11 bits

QuickBird

QuickBird is another commercial high resolution remote sensing system. It is operated by Digital Globe, Inc. The satellite was launched in October 2001. QuickBird uses a relatively low orbit, at an altitude 450 km.

Payloads over the QuickBird include a panchromatic camera and a four-band multispectral scanner. QuickBird sensors are composed of linear arrays detectors to achieve a spatial resolution as fine as 0.61 m in the panchromatic mode and 2.4 m in the multispectral mode.

Details of the QuickBird orbit and the sensors are given in the Table 10

Table 10. Details of the satellite orbit and the sensors of the QuickBird satellite

Satellite	**QuickBird**
Launch date	Oct, 2011
Orbit	Sun-synchronous
Eq. crossing	10:00 am
Altitude	450 km
Inclination	98 deg
Revisit period	Average revisit time is 1-3.5days depending upon the latitude and the image collection angle
Sensor	PAN and MSS
Wavelength bands (μm)	PAN 0.405-1.053 MSS: 0.43-0.545 0.466-0.620 0.590-0.710 0.715-0.918
Spatial resolution	PAN : 0.61 m MSS: 2.4 m
Radiometric resolution	11 bits

Fig. 10. QuickBird (61cm) true colour image for a small region in Nigeria

(Source: www.satimagingcorp.com)

7. Geo-stationary satellites

INSAT Program

The Indian National Satellite (INSAT) system is one of the largest domestic communication systems in the Asia-Pacific region. Communication satellites of the INSAT program are placed in Geo-stationary orbits at approximately 36,000 km altitude. The program was established with the commissioning of INSAT-1B in 1983. INSAT space segment consists of 24 satellites out of which 9 are in service (INSAT-3A, INSAT-4B, INSAT-3C, INSAT-3E, KALPANA-1, INSAT-4A, INSAT-4CR, GSAT-8, GSAT-12 and GSAT-10).

GSAT-10

The recent one in the INSAT program, GSAT-10 was launched in September 2012. The satellite orbits in the geo-stationary orbit located at 83^{o}E longitude. The mission is intended for communication and navigation purposes.

Fig. 11 shows the coverage of the GAGAN payload onboard GSAT-10.

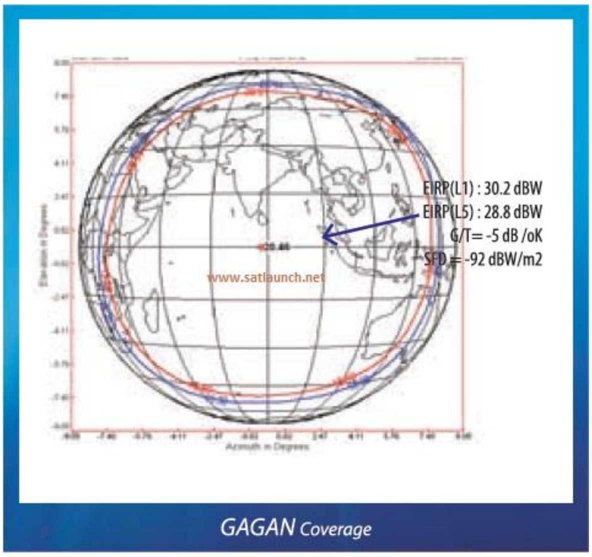

Fig. 11 Coverage of the GAGAN payload onboard GSAT-10
(Source: http://www.isro.org/satellites/geostationary.aspx)

KALPANA-1

Another satellite in the INSAT program, KALPANA-1, launched in September 2002, is the first satellite launched by ISRO, exclusively for the meteorological purposes. The satellite orbits in geostationary orbit located at an altitude ~35,786 km and above 74^{o} E longitude. It carries two pay loads: Very High Resolution Radiometer (VHRR) and Data Relay Transponder (DRT). The satellite was originally named Metsat, and was renamed in 2003 in the memory of astronaut Kalpana Chawla.

The VHRR onboard the KALPANA satellite operates in 3 bands: visible, thermal infrared and water vapour infrared. The instrument gives images in every half an hour. Fig.12-14 show the KALPANA images obtained in the three bands of the VHRR.

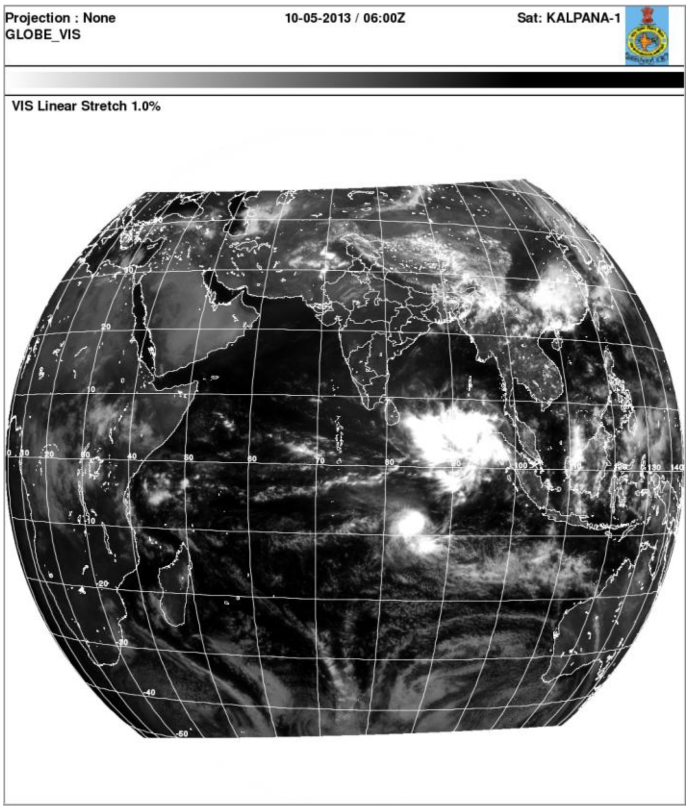

Fig. 12. Images from the KALPANA satellite in the Visible spectral band

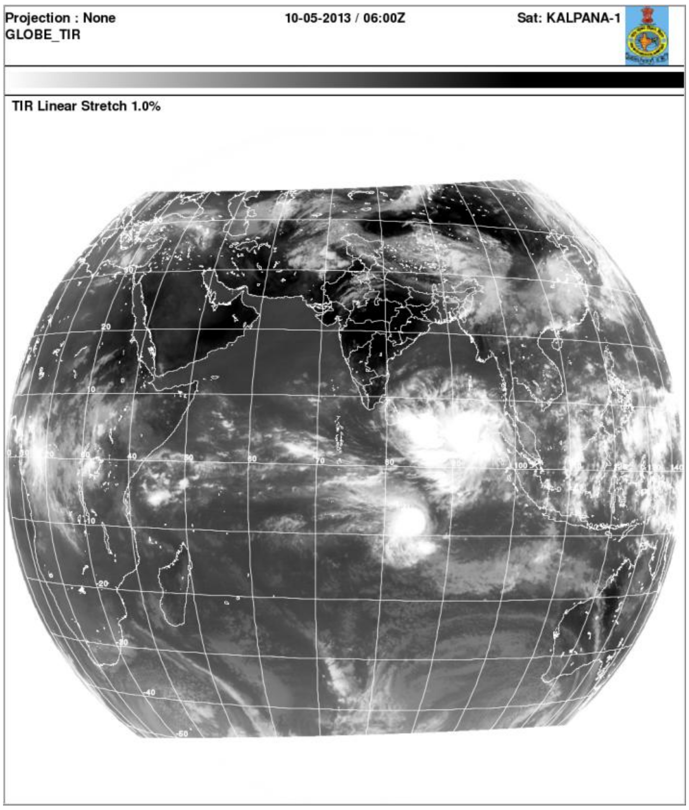

Fig. 13. Images from the KALPANA satellite in the Thermal infrared band

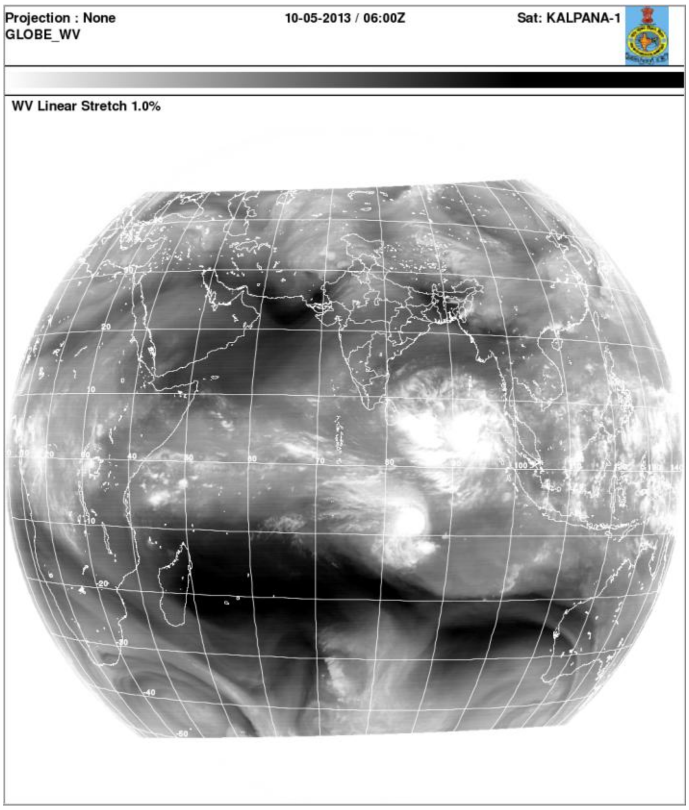

Fig. 14. Images from the KALPANA satellite in the Water vapor band

8. CARTOSAT

Cartosat series of satellites are examples of earth observation satellites built by India. To date, 4 Cartosat satellites have been built by Indian Space Research Organization (ISRO). Cartosat -1 or IRS-P5 is a stereoscopic earth observation satellite. Maintained by the Indian Space Research Organization (ISRO), this satellite carries two panchromatic (PAN) cameras that take imageries of the earth in the visible region of the electromagnetic spectrum. The imaging capabilities of Cartosat-1 include 2.5 m spatial resolution, 5 day temporal resolution and a 10-bit radiometric resolution.

The second among the series is Cartosat-2 which also images earth using a PAN camera in the visible region of the electromagnetic spectrum. The data obtained has high potential for detailed mapping and other applications at cadastral level. The imaging capabilities of Cartosat-2 are upto 100cm in spatial resolution. The third among the series of satellites was named as Cartosat-2A. This satellite is dedicated for the Indian armed forces. This satellite can be steered upto 45 degrees along as well as across the direction of movement for the purpose of imaging more frequently. Cartosat 2B is the fourth of the Cartosat series of satellites, launched in July 2010. Apart from the imaging capabilities, Cartosat-2B can be steered upto 26 degrees along as well as across the direction of its movement to facilitate frequent imaging of an area. Cartosat-3 is the fifth satellite.

9. RADARSAT

RADARSAT is a constellation of Canadian Remote Sensing satellites that relies on the operational use of Synthetic Aperture Radar (SAR). The main applications for which RADARSAT was designed include:

- Maritime surveillance (such as monitoring of ice, wind, oil pollution etc)
- Disaster management (which includes mitigation, warning, response and recovery)
- Monitoring of ecosystem (such as forestry, agriculture, wetlands etc)

In addition to these applications, RADARSAT offers a wide range of applications involving climate change, land use evolution, coastal change, urban subsidence etc. More details regarding the instrument characteristics and project status can be obtained in the following link www.asc-csa.gc.ca/eng/satellites/radarsat

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