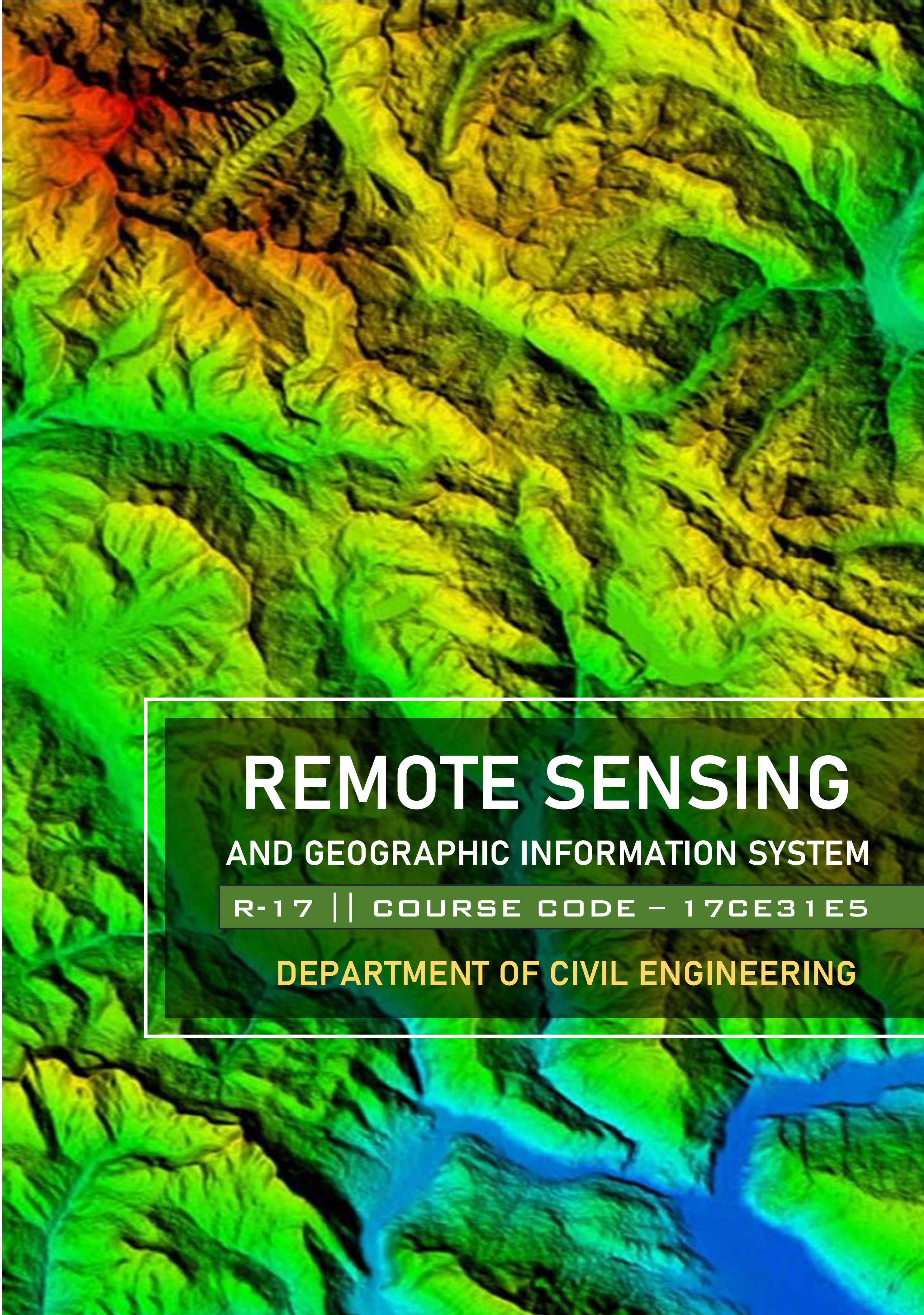


REMOTE SENSING

AND GEOGRAPHIC INFORMATION SYSTEM

R-17 || COURSE CODE – 17CE31E5

DEPARTMENT OF CIVIL ENGINEERING

MODULE – II

REMOTE SENSING SYSTEM & SENSORS

Course objective	To learn about various types of sensors and platforms.
Content	**REMOTE SENSING SYSTEM:** Introduction – Platforms – Types – Satellites – Indian remote sensing satellites. **SENSORS:** Introduction – Types – Characteristics of sensors – IFOV – Indian remote sensing sensors – LISS – WIFS – PAN.
Course outcome	Understand the different technical aspects of a remote sensing network with special emphasis on India remote sensing technology.

SATELLITES AND ORBITS

Remote Sensing Platforms

Based on the elevation from the Earth's surface platforms are classified as

Ground level remote sensing Ex: camera	Aerial remote sensing Ex: balloon, helicopters, aeroplanes	Space borne remote sensing Ex: satellite
o Ground level remote sensors are very close to the ground o They are basically used to develop and calibrate sensors for different features on the Earth's surface.	o Low altitude aerial remote sensing o High altitude aerial remote sensing	o Space shuttles o Polar orbiting satellites o Geo-stationary satellites

From each of these platforms, remote sensing can be done either in passive or active mode.

Airborne and Space-borne Remote Sensing

Airborne remote sensing:

✓ Downward or sideward looking sensors mounted on aircrafts are used to obtain images of the earth's surface.

- ✓ Very high spatial resolution images (20 cm or less) can be obtained through this.
- ✓ However, it is not suitable to map a large area.
- ✓ Less coverage area and high cost per unit area of ground coverage are the major disadvantages of airborne remote sensing. Airborne remote sensing missions are mainly one-time operations.

Ex: Analog aerial photography, videography, thermal imagery and digital photography are commonly used in airborne remote sensing.

Space-borne remote sensing:

- ✓ Sensors mounted on space shuttles or satellites orbiting the Earth are used.
- ✓ There are several remote sensing satellites (Geostationary and Polar orbiting) providing imagery for research and operational applications.
- ✓ While Geostationary or Geosynchronous Satellites are used for communication and meteorological purposes, polar orbiting or sun-synchronous satellites are essentially used for remote sensing.
- ✓ The main advantages of space-borne remote sensing are large area coverage, less cost per unit area of coverage, continuous or frequent coverage of an area of interest, automatic/ semiautomatic computerized processing and analysis.

  "when compared to aerial photography, satellite imagery has a lower resolution "

Introduction

When a satellite is launched into the space, it moves in a well defined path around the Earth, which is called the **orbit** of the satellite. Spatial and temporal coverage of the satellite depends on the orbit.

Characteristics of satellite orbits

- ❖ The path followed by a satellite in the space is called the **orbit** of the satellite. Orbits may be circular (or near circular) or elliptical in shape.
- ❖ **Orbital period:** Time taken by a satellite to complete one revolution in its orbit around the earth is called orbital period.

It varies from around 100 minutes for a near-polar earth observing satellite to 24 hours for a geo-stationary satellite.

- **Altitude:** Altitude of a satellite is its heights with respect to the surface immediately below it. Depending on the designed purpose of the satellite, the orbit may be located at low (160-2000 km), moderate(2000 to 36000) and high (>36000km) altitude.
- **Apogee and perigee:** Apogee is the point in the orbit where the satellite is at maximum distance from the Earth. Perigee is the point in the orbit where the satellite is nearest to the Earth.
- **Inclination:** Inclination of the orbital plane is measured clockwise from the equator. Orbital inclination for a remote sensing satellite is typically 99 degrees. Inclination of any satellite on the equatorial plane is nearly 180 degrees.
- **Nadir, ground track and zenith:** Nadir is the point of interception on the surface of the Earth of the radial line between the centre of the Earth and the satellite. This is the point of shortest distance from the satellite to the earth's surface.

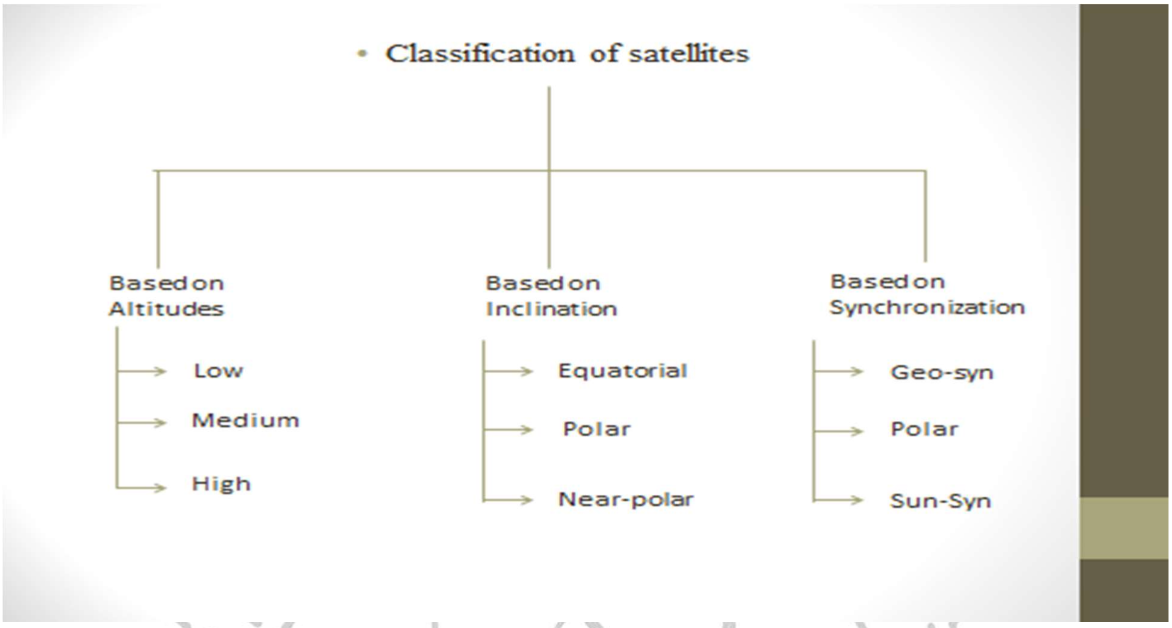
  Any point just opposite to the nadir, above the satellite is called **zenith**.

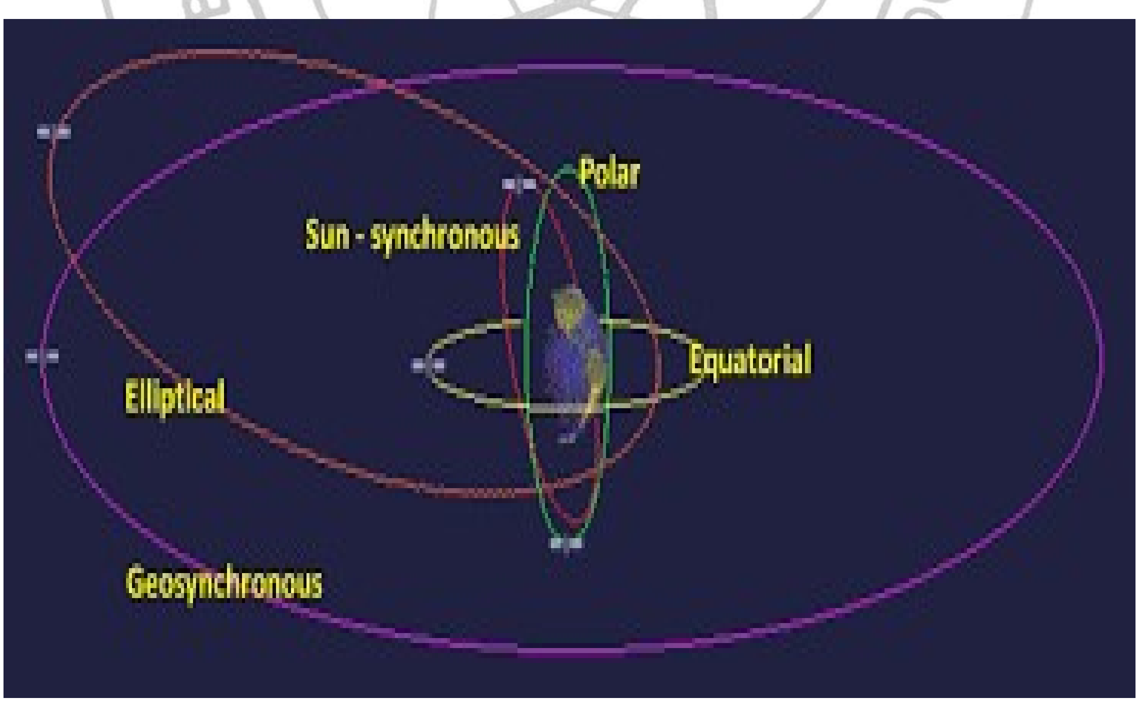
  The circle on the earth's surface described by the nadir point as the satellite revolves is called the **ground track**. In other words, it is the projection of the satellites orbit on the ground surface.
- **Swath:** Swath of a satellite is the width of the area on the surface of the Earth, which is imaged by the sensor during a single pass.

  For example, swath width of the IRS-1C LISS-3sensor is 141 km in the visible bands and 148 km in the shortwave infrared band.
- **Sidelap and Overlap: Overlap** is the common area on consecutive images along the flight direction.

  For example, IRS-1C LISS-3 sensors create 7 km overlap between two successive images.

  Sidelap is the overlapping areas of the images taken in two adjacent flight lines.


• Classification of satellites
Based on Altitudes
Low
Medium
High
Based on Inclination
Equatorial
Polar
Near-polar
Based on Synchronization
Geo-syn
Polar
Sun-Syn


Polar
Sun - synchronous
Equatorial
Elliptical
Geosynchronous

Based on altitudes

Low earth orbit

If altitude of satellite is less than 2000km it is known as low orbit. Most of remote sensing satellites are placed in low earth orbit because they need clear view of the earth surface to produce good quality image.

Medium earth orbit

If altitude of satellite is between 2000km to less than 36000km known as medium earth orbit.

High earth orbit

If altitude of satellite is greater than 36000km known as high earth orbit.

Based on inclination

The angle between orbital plane and earth's equatorial plane is termed as inclination of orbit.

Equatorial orbit

The plane that contains the earth's equator is termed as equatorial plane and the path containing in the equatorial plane is termed as equatorial orbit.

Polar orbit

The inclination of orbit is 90 degrees to the equatorial orbit(0 degrees) , the satellite moves over the poles; centre of the earth, north and south poles lie in the orbital plane is called as polar orbit.

Near polar orbit

If the inclination is close to 90 degrees, it called as near-polar orbit.

Based on synchronous these are three basic types of orbits in use.

- Geo-synchronous orbits
- Polar or near polar orbits
- Sun-synchronous orbits

Satellite orbits are matched to the capability and objective of the sensor(s) they carry. Orbit selection can vary in terms of altitude (their height above the Earth's surface) and their orientation and rotation relative to the Earth.

Geosynchronous orbit

- ✓ Geostationary or geosynchronous orbit is the one in which the time required for the satellite to cover one revolution is the same as that for the Earth to rotate once about its polar axis.
- ✓ In order to achieve this orbit period, geo-synchronous orbits are generally at very high altitude nearly 36,000 km.
- ✓ Geo-synchronous orbits are located in the equatorial plane, i.e with an inclination of 180 degrees. Thus from a point on the equator, the satellite appears to be stationary. The satellites revolve in the same direction as that of the Earth (west to East).
- ✓ This allows satellite to observe and collect information continuously
- ✓ Geostationary or geosynchronous orbits are used for communication and meteorological satellites. Example: INSAT, MeteoSAT, GOES, GMS etc.
- ✓ Satellites in the geo-synchronous orbit are located above any particular longitude to get a constant view of any desired region.

  For example, the GOES East and GOES West satellites are placed in orbits over North America (normally at 75° W and 135° W, respectively), INSAT 3-A is located at 93.5o E longitude, the Japanese Geostationary Meteorological Satellite (GMS) is located over New Guinea, and Meteosat over Europe.
- ✓ Because of the very high altitude, the foot prints of geostationary satellites are generally very high. They can yield area coverage of 45-50% of the globe.
- ✓ Period of 1436 minutes
- ✓ Good coverage from remote areas
- ✓ Has wide field of view minimum 50 degrees
- ✓ But it has low resolution
- ✓ Provides continuous data 15-30 min.
- ✓ Not very suitable for vertical soundings.

Polar (or Near Polar) orbits

- These orbits have near 90 degree inclination Polar orbits are usually medium or low orbits (approximately 700-800km) compared to the geo-synchronous orbits.
- Consequently the orbit period is less, which typically varies from 90 to 103 minutes. Therefore satellites in the polar orbits make more than one revolution around the earth in a single day.
- The National Oceanic and Atmospheric Administration (NOAA) series of satellites like NOAA 17, NOAA 18 are all examples of polar orbiting satellites.
- Taking advantage of the rotation of the earth on its own axis, each time newer segments of the Earth will be under view of the satellite. The satellite's orbit and the rotation of the Earth work together to allow complete coverage of the Earth's surface, after it has completed one complete cycle of orbits.
- An orbital cycle is completed when the satellite retraces its path, i.e., when the nadir point of the satellite passes over the same point on the Earth’s surface for a second time. Orbital cycle is also known as repeat cycle of the satellite. The orbital cycle need not be the same as the revisit period.
- Revisit period is the time elapsed between two successive views of the same area by a satellite.
- Using steerable sensors, a satellite-borne instrument can view off-nadir areas before and after the orbit passes over a target.
- In view of this off-nadir viewing capability of the satellites, revisit time can be less than the orbital cycle. **The revisit time is important especially when frequent imaging is required.**
- In near-polar orbits, areas at high latitudes will be imaged more frequently than the equatorial zone due to the increasing overlap in adjacent swaths as the orbit paths come closer together near the poles.
- Near polar orbiting
- 800 -900 km above the earth
- Period of 101 minutes
- Excellent coverage at the poles
- Has relatively narrow field of view
- Has high resolution
- Passes vary with latitude

- ❖ Very suitable for vertical soundings

Sun-synchronous orbits

- ✓ It is a special case of polar orbit. Like a polar orbit, the satellite travels from the north to the south poles as the Earth turns below it.
- ✓ In a sun-synchronous orbit, the satellite passes over the same part of the Earth at roughly the same **local sun time** each day. These orbits are between 700 to 800 km altitudes.
- ✓ Sun synchronous satellites cover each area of the world at a constant local time of day called local sun time.
- ✓ These are used for satellites that need a constant amount of sunlight. A typical sun synchronous satellite completes 14 orbits a day, and each successive orbit is shifted over the Earth's surface by around 2875 km at the equator. Also the satellite's path is shifted in longitude by 1.17deg (approximately 130.54 km) everyday towards west, at the equator "from platforms and sensors.
- ✓ Landsat satellites and IRS satellites are typical examples of sun-synchronous, near-polar satellites. The orbits of the Landsat satellites (1, 2 and 3) in each successive pass and on successive days. Repeat cycle of the satellite was 18days and each day 14 orbits were completed. Remote sensing application

Remote sensing applications generally use near polar, sun-synchronous, near circular orbits.

The near polar orientation helps to attain near global coverage, whereas the near circular orbit helps to attain uniform swath for the images. Sun synchronous orbits are preferred for maintaining constant angle between the aspect of incident sun and viewing by the satellite.

Remote sensing satellite orbits maintain nearly 90 degree inclination from the equatorial plane for the difference in the gravitational pull. Also, medium orbit periods are adopted for the remote sensing satellites so as to assure the global coverage in each single day.

History of Indian satellite program.

India has launched 88 satellites upto 2016 December

Past satellites

Aryabhatta

Bhaskara I

Bhaskara II

Rohini series

SROSS Series

IRS 1A

IRS P1

IRS-1B

IRS-P2

IRS-1C

IRS-P3

IRS-1D

IRS-P4, (Oceansat)

IRS-P6, (Resourcesat-1)

IRS-P5, (Cartosat-1)

IRS-P7, (Cartosat-2)

IRS-P6, (Resourcesat-2)

RISAt-1, (RISAt-1)

IRS-Digital Products

Aryabhatta

Launch Date: April 19, 1975
Weight: 360 kg

Orbit: 619 x 562 km inclined at 50.7 deg
Launched by : Soviet Intercosmos rocket.
Objectives: The objectives of this project were to indigenously design and fabricate a space-worthy satellite system and evaluate its performance in orbit.
* To set up ground-based receiving, transmitting and tracking systems and to establish infrastructure for the fabrication of spacecraft systems.
The exercise also provided an opportunity to conduct investigations in the area of space sciences.

Bhaskara I

Launch Date: June 7, 1979
Weight: 444 Kg
Orbit: 619 x 562 km inclined at 50.7 deg
Launched by: Soviet Intercosmos rocket.

Sensor Systems

- Television Cameras operating in visible (0.6 micron) and near-infrared (0.8 micron); to collect data related to hydrology, forestry and geology.
- Satellite microwave radiometer (SAMIR) operating at 19 GHz and 22 GHz for study of ocean-state, water vapour, liquid water content in the atmospher, etc.

Bhaskara II

Launch Date: Nov. 20, 1981
Weight: 444 Kg
Orbit: 619 x 562 km inclined at 50.7 deg
Launched by : Soviet Intercosmos rocket.
Sensor Systems

- Television Cameras operating in visible (0.6 micron) and near-infrared (0.8 micron); to collect data related to hydrology, forestry and geology.
- Satellite microwave radiometer (SAMIR) operating 19.24 GHz, 22.235 GHz and 31.4 GHz for study of ocean-state, water vapour, liquid water content in the atmosphere, etc.

Rohini series

First RS-1A
Launch Date : July 18, 1979
Weight : 35 kg
Orbit : 300 km x 900 km elliptical orbit (97 minutes period)
Launched by : India, SLV-3 rocket
Objectives : The satellite provided data on the fourth stage performance and ranging. Unfortunately it failed due to thrust vectoring of the second stage.

First RS-1B

Launch Date : July 18, 1980
Weight : 35 kg
Orbit : 300 km x 900 km elliptical orbit (97 minutes period)
Launched by : India, SLV-3 rocket
Objectives : The satellite provided data on the fourth stage performance and ranging. Successfully launched.

Second RS-2
Launch Date: May 30, 1981
Weight: 35 kg
Launched by: India, SLV-3 (D-1) rocket
Orbit : 300 km x 900 km elliptical orbit (97 minutes period)
Objectives : Carried a Land Mark sensor payload whose solid state camera performed to specifications. The satellite re-entered the earth's atmosphere nine days after launch on account of the launch vehicle's injecting the satellite into a lower than expected altitude.

Third RS-3

Launch Date: April 17, 1983
Weight : 42 kg
Launched by : India, SLV-3 (D-2)rocket
Orbit : 300 km x 900 km elliptical orbit (97 minutes period)
Objectives : The Smart Sensor Camera was the primary payload on board the satellite. It was operated for over five months and sent more than 5000 pictures frames in both visible and infrared bands for identification of landmarks and altitude and orbit refinement. The camera had on-board processing capability to use the data for classifying ground features like water, vegetation, bare land, clouds and snow.

SROSS Series

Lunched by India's Augmented Satellite Launch Vehicle, ASLV,

SROSS-A launched on 1987 by ASLV-D1. It was lost in failure

SROSS-B launched on 1988 by ASLV-D2. It was lost in failure.

SROSS-C launched on May 20, 1992 by ASLV-D3, at stage four of third ASLV spun 80rpm instead of 180rpm, yields low perigee and short life.

SROSS-C2 launched on May 4, 1994 respectively. Carried a Retarding Potential Analyser and a Gamma Ray Burst (GRB) detector. SROSS-C2 has provided valuable scientific data.

IRS 1A

Orbit Details

Launch date : March 17, 1988 (Soviet Launcher VOSTAK used)
Altitude : 904 Kms.
Inclination : 99.5 degrees
Period : 103.19266 minutes
Temporal resolution : 22 days
Equatorial crossing time : 10.25 AM descending
Imaging Sensor Characteristics (LISS-I and LISS-II Cameras)

This is first indigenously built sun-synchronous polar orbiting satellite.

* LISS -Linear Imaging Self-Scanning Sensor, CCD charge coupled devices.
* LISS-II contains two separate identical sensors **LISS-A** and LISS-B with a spatial resolution of 36.25 each.
* The 4 bands are:

B1 - 0.42-0.52 (blue)
B2 - 0.52-0.59 (green)
B3 - 0.62-0.68 (red)
B4 - 0.77-0.86 (near IR)
The bands are similar to the LANDSAT 1, 2, 3 and 4 bands.

Parameters	LISS-I	LISS-II

Instantaneous field of view(IFOV) Microrad,	80	40
Detectors (CCDs)	2048 elements CCD	2048 elements CCD
Ground Resolution (m)	72.5m	36.25m
Spectral range (micro meter)	0.45 - 0.86	0.45 - 0.86
Number of Bands	4	4
Swath (Kms.)	148km	74x2 (LISS-A and LISS-B)
Radiometric Resolution (grey levels)	128	128
Data rate (Mbps)	5.2	10.4x2
Weight (Kgs)	38.5	80.8x2
Power (Watts)	34	34x2

IRS-1B

This is similar to IRS-1A satellite in all aspects.

Orbit Details
Launch date : August 29, 1991 (Soviet Launcher VOSTAK used)
Altitude : 904 Kms.
Inclination : 99.049 degrees
Period : 103.19266 minutes
Temporal resolution : 22 days
Equatorial crossing time : 10.25 AM descending
Imaging Sensor Characteristics (LISS-I and LISS-II Cameras)

* LISS -Linear Imaging Self-Scanning Sensor, CCD charge coupled devices.
* LISS-II contains two separate sensors LISS-A and LISS-B with a spatial

resolution of 36.25 each.
* The 4 bands are:
B1 - 0.42-0.52 (blue)
B2 - 0.52-0.59 (green)
B3 - 0.62-0.68 (red)
B4 - 0.77-0.86 (near IR)
The bands are similar to the LANDSAT 1, 2, 3 and 4 bands.

Parameters	**LISS-I**	**LISS-II**
Instantaneous field of view(IFOV) Microrad,	80	40
Detectors (CCDs)	2048 elements	2048 elements
Ground Resolution (m)	72.5	36.25
Spectral range (micro meter)	0.45 - 0.86	0.45 - 0.86
Number of Bands	4	4
Swath (Kms.)	148	73x2 (LISS-A and LISS-B)
Radiometric Resolution (grey levels)	128	128
Weight (Kgs)	38.5	80.8x2
Power (Watts)	34	34x2

IRS-1C

This is one of the best satellites having highest spatial resolution of 5.8 m in Panchromatic and 23.5 m in multispectral.

Parameters	**Specifications (PAN)**

Band (microns)	0.50 - 0.75
Resolution (m)	5.8
Effective focal length	980 mm
Radiometric resolution	6 bits (64 grey levels)
Data rate (MBPS)	84.903
Swath (km.) 1. Nadir 1. Off-nadir	70 91
Off-nadir viewing (deg)	+/-26 for obtaining stereoscopic data and 5 day revisit
Steering step size (deg)	0.09

Orbit Details

Launch date : Dec. 28, 1995 (Soviet Launcher Molniya used)
Altitude : 817 Kms.
Inclination : 99.049 degrees
Period : 101.35 minutes
Temporal resolution: 24 days (5 days - revisit)
Equatorial crossing time : 10.30 AM descending
No. of Sensors : Three; 1) PAN, 2) LISS-III and 3) WiFS
Panchromatic Camera (PAN)

The data in the panchromatic region is useful in geological studies for mapping geological and geomorphological features. Higher spatial resolution will be useful for urban planning studies, detecting urban fringe growth, updating the urban transportation infrastructure etc. It is having off-nadir viewing capability and the view angle can be varied between +/- 26 deg. The advantages of off-nadir viewing are increased **Temporal resolution** coverage and stereoscopy. Stereoscopic image pair obtainable by PAN can be used for topographic studies and generation of digital terrain models.

Imaging Sensor Characteristics (LISS-III Sensor)

Parameters	B2 B3 B4	B5
Spectral bands	0.52-0.59(green) 0.62-0.68(red) 0.77-0.86(NIR)	1.55-1.70 (SWIR)
Resolution (m)	23 (for bands B2,B3,B4)	70 (for b5)
CCD devices	6000 elements	2100
Swath (Kms)	141	148
Equi focal length (mm)	347.5	301.2
Number of grey levels	128 (7 bits)	128

Swir- shortwave infrared

The bands are similar to the IRS-1A, IRS-1B and IRS-P2 except blue band which is not included in IRS-1C.

Band 2 is centered around the first peak of the vegetation reflectance curve (refer to reflectance curves in standard books) and is useful for discrimination of vegetation. This band along with red and near IR regions forms the core data useful for discrimination of vegetation.

Band 3 is centered around the chlorophyll absorption region of vegetation. Strong correlation exists between spectral reflectance in this region and chlorophyll content. A reduction in the amount of chlorophyll can occur when the plant is stressed. This results in less chlorophyll absorption and an increase in red reflectance. This band along with the near IR band is used widely for deriving spectral indices like ratio and Normalised Difference Vegetation index (NDVI) which have been found to be very good indicators of crop vigour and biomass.

Band 4: The high reflectance plateau region of the vegetation reflectance is in this band. Plant reflectance in this region is highly governed by the internal structure of plant leaves. This band shows high reflectance for healthy vegetation and is useful for green biomass estimation and crop vigor.

Band 5: the middle infra-red region from 1.3-2.5 microns is sensitive to leaf water content. It has been shown that 1.55 - 1.70 is best suited in 0.7-2.5 region for monitoring plant canopy water status. Major applications of this band include discrimination of crop types, canopy water status, forest type separation and damage assessment. Crop classification accuracies can be improved by 1-15% when this band is included with other bands. Also useful snow-cloud discrimination. In geology, it will be useful for rock type discrimination.

Wide Field Sensor (WiFS)

This sensor is most useful for vegetation studies. With larger swath (770 Km), high repetivity (5 days) and operation in two vegetation specific bands, the sensor provide vegetation index at regional level, thus helping in assessment of crop condition and drought monitoring.

Parameters	**Values**
Spectral bands (microns)	B3 - 0.62-0.68 (red) B4 - 0.77-0.86 (near IR)
Resolution (m)	188m
CCD devices	2048 elements
Swath (Kms)	810 (5 days repetivity)
Equivalent focal length (mm)	56.4
No. of grey levels	128 (7 bits)
SNR	>128

IRS-1D

Satellite entered in elliptical orbits instead of circular after it was separated from rocket. Due to this problem, there is change in swath, resolution according to orbit distance from the earth centre.

Launch date : Sept. 29, 1997 (indigenous PSLV-D4 rocket was used)
Equatorial Crossing time: 10.40 A.M
Altitude : 737 Km(Perigee)/821 Km. (Apogee)
Temporal resolution : 24 days; (3 days revisit) **No. of Sensors :** Three; 1) PAN, 2) LISS-III and 3) WiFS

Payloads
The payloads are similar to IRS-1C (PAN, LISS-III and WiFS). The satellite is a follow on to IRS-1C
Resolution: PAN Sensor : 5.2 m (Perigee)/5.8 m (Apogee)

IRS P1

IRS-P series are being launched 1993 by indigenously developed polar launch vehicle (PSLV). Due to failure in last stage of rocket, satellite and rocket were plunged into sea.

IRS-P2

Orbit Details
Launch date : Oct. 15, 1994
Altitude : 817 Kms.
Temporal resolution : 24 days
Imaging Sensor Characteristics (LISS-II Camera)

The Satellite is having only LISS-II Camera and its parameters are similar to that **IRS-1A/1B** with small modifications in arrangement of CCDs.

B1-0.42-0.52(blue)
B2-0.52-0.59(green)
B3-0.62-0.68(red)

B4-0.77-0.86(nearIR)
The bands are similar to the LANDSAT 1, 2, 3 and 4 bands

Parameters	**LISS-II**
Instantaneous field of view(IFOV),	40
Ground Resolution (m)	32.00m (across track) 37 m (along track)
Spectral range (micro meter)	0.45 - 0.86
Number of Bands	4
Swath (Kms.)	130 km (Liss A + B)
Radiometric Resolution (grey levels)	128
Weight (Kgs)	80.8x2
Power (Watts)	34x2

IRS-P3

Orbit Details
Launch date : March 21, 1996 (Indigenous PSLV-D3 rocket is used)
Altitude : 817 km.
Inclination : 99.049 degrees
Period : minutes
Temporal resolution : days
Equatorial crossing time : 10.30 AM descending
Weight : Kg.
No. of Sensors : Two 1) WiFs, 2) MOS

Wide Field Sensor (WiFS)

IRS-P3 WiFS is slightly different from IRS-1C WiFS. In IRS-P3 WiFS, another band (B5) in the middle infrared region is added for monitoring plant canopy water content.

Parameters	Specifications)
Spectral Bands (microns)	B3 0.62 - 0.68 B4 0.77 - 0.86 B5 1.55 - 1.69
Resolution (m)	B3 and B4 188x188 B5 188x246
Quantisation bits	7 (128 grey levels
Swath	810 Km.
No. of detectors	2048 x 2 for B3 2048 x 2 for B4 2100 x 2 for B5
S/N ratio	>127

Modular Optoelectronic Scanner (MOS)

The sensor system is primarily meant for ocean related studies. It operates in narrow spectral bands in visible, near infrared and short wave infra-red regions (SWIR) of the electromagnetc spectrum and consists of three optical modules namely MOS-A, MOS-B and MOS-C. Further the sensor should be able to detect small changes in spectral signature. This is achieved by having 16 bits of quantisation as against 7 or 8 bits in the sensors used for land applications.

Parameters	MOS-A	MOS-B	MOS-C
Spectral range	0.755 - 0.768	0.408 - 1.010	1.50 - 1.70
No. of Bands	4	13(*)	1
Resolution (m)	1569 x 1395	523 x 523	523 x 644

No. of detectors	140	384	299
Quantisation bits	16	16	16
Swath (kms.)	195	200	192
S/N ratio	>100	>100	>100

(*) Each band with 0.001 micrometers band-width.

IRS-P4, (Oceansat)

Launch Date : May 26, 1999 by indigenous PSLV rocket

Payloads

- OCM (Ocean Colour Monitor) with 8 spectral bands for the measurements of physical and biological oceanographic parameters.
- MSMR (Multi-frequency Scanning Microwave Radiometers) Operating at 6.6, 10.65, 18.0 and 21 GHz frequencies with H and V polarizations and at spatial resolution of 150 km, 75 km, 50 km and 50 km respectively.

IRS-P6, (Resourcesat-1)

Launch Date : Launched on April 20, 2011, PSLV-C16

Payloads

It will be the state-of-art satellite, mainly for agriculture applications and will have 3 band multispectral LISS-IV camera with a spatial resolution better than 5.86 m and a swath of around 25 km with across track steerability for selected area monitoring. An improved version LISS-III with 4 bands (red, green, near IR and SWIR), all at 23 m resolution and 140 km swath will provide the much essential continuity to LISS-III.

The sensors on board the satellite will provide data which is useful for vegetation related applications and will allow multiple crop discrimination and species level discrimination. Together with an advanced Wide Field Sensor (WiFS), with 80 m resolution and 1400 km swath, the payloads will greatly aid crop/vegetation and integrated land and water resources related applications.

IRS-P5, (Cartosat-1)

Launch Date : May 5, 2005 by indigenous PSLV rocket

Payloads

It has carried two state-of-the-art Panchromatic (PAN) cameras with 2.5 m resolution with fore-aft stereo capability. The swath covered by these high resolution PAN cameras is 30 km. This mission will cater the needs of cartographers and terrain modelling applications. The satellite will provide cadastral level information upto 1:5000 scale and will be useful for making 2-5 m contour maps. The Cartosat-1 also carried a solid state recorder with a capacity of 120 Gigz Bits to store the images taken by its cameras.

IRS-P7, (Cartosat-2)

Launch Date : Jan 10, 2007 by indigenous PSLV-C7 rocket

Payloads

It carried a single Panchromatic (PAN) camera with 1 m resolution capable of providing scene specific spot imageries for cartographic applications at cadastral level. The swath covered by the high resolution PAN camera is 9.6 km. This mission will cater the needs of cartographers and terrain modelling applications. The satellite will have high agility with capability to steer along and across the track up to 45 degrees. It was placed in a sun-synchronous polar orbit at an altitude of 635 km. It has a revisit period of 4 days, which can be improved to one day with suitable orbit maneuvers.

IRS-P6, (Resourcesat-2)

Launch Date : Launched on April 20, 2011 PSLV-C16Payloads

It will be the state-of-art satellite, mainly for agriculture applications and will have 3 band multispectral LISS-IV camera with a spatial resolution better than 5.86 m and a swath of around 70 km (improved 25 km to 70 km) with across track steerability for selected area monitoring. An improved version LISS-III with 4 bands (red, green, near IR and SWIR), all at 23 m resolution and 140 km swath will provide the much essential continuity to LISS-III. Radiometric resolution is improved 7 bits to 10 bits for LISS-III and 10 bits 12 bits for LISS-IV.

The sensors on board the satellite will provide data which is useful for vegetation related applications and will allow multiple crop discrimination and species level discrimination. Together with an advanced Wide Field Sensor (WiFS), with 80 m resolution and 1400 km swath, the payloads will greatly aid crop/vegetation and integrated land and water resources related applications.

RISAt-1, (RISAt-1)

Launch Date : Launched on April 20, 2011 PSLV-C16

Payloads

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Characteristics of sensor

- Objects closer than the resolution appear as a single object in the image.
- However, in remote sensing the term resolution is used to represent the resolving power, which includes not only the capability to identify the presence of two objects, but also their properties.
- In qualitative terms resolution is the amount of details that can be observed in an image.
- Thus an image that shows finer details is said to be of finer resolution compared to the image that shows coarser details.

Four types of resolutions are defined for the remote sensing systems

- Spatial resolution
- Spectral resolution
- Temporal resolution
- Radiometric resolution

Spatial resolution

- ✓ *For some remote sensing instruments, the distance between the target being imaged and the platform plays a major role in determining the detail of information obtained and the total area imaged by the sensor.*
- ✓ *A digital image consists of an array of pixels. Each pixel contains information about a small area on the land surface, which is considered as a single object.*
- ✓ Spatial resolution is a measure of the area or size of the smallest dimension on the Earth's surface over which an independent measurement can be made by the sensor.
- ✓ A measure of size of pixel is given by the Instantaneous Field of View (IFOV). The IFOV is the angular cone of visibility of the sensor, or the area on the Earth's surface that is seen at one particular moment of time.

IFOV is dependent on the altitude of the sensor above the ground level and the viewing angle of the sensor

- *A narrow viewing angle produces a smaller IFOV. It can be seen that viewing angle β being greater than the viewing angle α, IFOVβ is greater than IFOVα.*
- *IFOV also increases with altitude of the sensor. IFOVβ and IFOVα of the sensor at smaller altitude are less compared to those of the higher altitude sensor.*

- ✓ *The size of the area viewed on the ground can be obtained by multiplying the IFOV (in radians) by the distance from the ground to the sensor. This area on the ground is called the* ***ground resolution or ground resolution cell****. It is also referred as the spatial resolution of the remote sensing system.*
- ✓ For a homogeneous feature to be detected, its size generally has to be equal to or larger than the resolution cell.
- ✓ If more than one feature is present within the IFOV or ground resolution cell, the signal response recorded includes a mixture of the signals from all the features.
- ✓ When the average brightness of all features in that resolution cell is recorded, any one particular feature among them may not be detectable. However, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing sub-pixel or resolution cell detection.

Based on the spatial resolution, satellite systems can be classified as follows.

- Low resolution systems
- Medium resolution systems
- High resolution systems
- Very high resolution systems

- *Remote sensing systems with spatial resolution more than 1km are generally considered as low resolution systems. MODIS and AVHRR are some of the very low resolution sensors used in the satellite remote sensing.*
- *When the spatial resolution is 100m – 1km, such systems are considered as moderate resolution systems. IRS WiFS (188m), band 6 i.e., thermal infrared band, of the Landsat TM (120m), and bands 1-7 of MODIS having resolution 250-500m come under this class.*
- *Remote sensing systems with spatial resolution approximately in the range 5-100m are classified as high resolution systems. Landsat ETM+ (30m), IRS*

LISSIII (23m MSS and 6m Panchromatic) and AWiFS (56-70m), SPOT 5(2.5-5m Panchromatic) are some of the high resolution sensors

- *Very high resolution systems are those which provide less than 5m spatial resolution. GeoEye (0.45m for Panchromatic and 1.65m for MSS), IKONOS (0.8-1m Panchromatic), and Quickbird (2.4-2.8 m) are examples of very high resolution systems.*

If we have a map with a scale of 1:100,000, an object of 1cm length on the map would actually be an object 100,000cm (1km) long on the ground. Maps or images with small "mapto-ground ratios" are referred to as small scale (e.g. 1:100,000), and those with larger ratios (e.g. 1:5,000) are called large scale. Thus, large scale maps/images provide finer spatial resolution compared to small scale maps/images

Spectral resolution

- Spectral resolution represents the spectral band width of the filter and the sensitiveness of the detector.
- *The spectral resolution may be defined as the ability of a sensor to define fine wavelength intervals or the ability of a sensor to resolve the energy received in a spectral bandwidth to characterize different constituents of earth surface.*
- The finer the spectral resolution, the narrower the wavelength ranges for a particular channel or band.

Many remote sensing systems are multi-spectral, that record energy over separate wavelength ranges at various spectral resolutions.

For example IRS LISS-III uses 4 bands: 0.52-0.59 (green), 0.62-0.68 (red), 0.77-0.86 (near IR) and 1.55-1.70 (mid-IR).

The Aqua/Terra MODIS instruments use 36 spectral bands, including three in the visible spectrum.

Recent development is the hyper-spectral sensors, which detect hundreds of very narrow spectral bands.

- The first representation shows the DN values obtained over 9 pixels using imagery captured in a single band. Similarly, the second and third representations depict the DN values obtained in 3 and 6 bands using the respective sensors. If the area imaged is say A km2, the same area is being viewed using 1, 3 and 6 number of bands.

- Generally surface features can be better distinguished from multiple narrow bands, than from a single wide band.
- Using the broad wavelength band 1, the features A and B cannot be differentiated. However, the spectral reflectance values of the two features are different in the narrow bands 2 and 3. Thus, a multi-spectral image involving bands 2 and 3 can be used to differentiate the features A and B.
- *In remote sensing, different features are identified from the image by comparing their responses over different distinct spectral bands. Broad classes, such as water and vegetation, can be easily separated using very broad wavelength ranges like visible and near-infrared.*
- However, for more specific classes viz., vegetation type, rock classification etc, much finer wavelength ranges and hence finer spectral resolution are required.
- Clearly indicate how different bands and their combinations help to extract different information.

Radiometric resolution

- ✓ *Radiometric resolution of a sensor is a measure of how many grey levels are measured between pure black (no reflectance) to pure white.*
- ✓ In other words, radiometric resolution represents the sensitivity of the sensor to the magnitude of the electromagnetic energy. The finer the radiometric resolution of a sensor the more sensitive it is to detecting small differences in reflected or emitted energy or in other words the system can measure more number of grey levels.

Radiometric resolution is measured in bits.

- ✓ Each bit records an exponent of power 2 (e.g. 1 bit = 21 = 2). The maximum number of brightness levels available depends on the number of bits used in representing the recorded energy.
- ✓ For example, Table 1 shows the radiometric resolution and the corresponding brightness levels available.

Radiometric resolution	Number of levels Example	example
✓ 1 bit	✓ 2^1 – 2 levels	✓
✓ 7 bit	✓ 2^7 – 128 levels	✓ IRS 1A & 1B
✓ 8 bit	✓ 2^8 – 256 levels	✓ Landsat TM
✓ 11 bit	✓ 2^{11} – 2048 levels	✓ NOAA-AVHRR

- ✓ Thus, if a sensor used 11 bits to record the data, there would be 2^{11}=2048 digital values available, ranging from 0 to 2047. However, if only 8 bits were used, then only 28=256 values ranging from 0 to 255 would be available. Thus, the radiometric resolution would be much less.
- ✓ Image data are generally displayed in a range of grey tones, with black representing a digital number of 0 and white representing the maximum value (for example, 255 in 8-bit data).
- ✓ *By comparing a 2-bit image with an 8-bit image, we can see that there is a large difference in the level of detail discernible depending on their radiometric resolutions.*
- ✓ In an 8 bit system, black is measured as 0 and white is measured as 255. The variation between black to white is scaled into 256 classes ranging from 0 to 255. Similarly, 2048 levels are used in an 11 bit system.
- ✓ Finer the radiometric resolution, more the number of grey levels that the system can record and hence more details can be captured in the image.
- ✓ As radiometric resolution increases, the degree of details and precision available will also increase.
- ✓ However, increased radiometric resolution may increase the data storage requirements.
- ✓ In an image, the energy received is recoded and represented using Digital Number (DN). The DN in an image may vary from 0 to a maximum value, depending up on the number of gray levels that the system can identify i.e., the radiometric resolution.
- ✓ Thus, in addition to the energy received, the DN for any pixel varies with the radiometric resolution. For the same amount of energy received, in a coarse resolution image (that can record less number of energy level) a lower value is assigned to the pixel compared to a fine resolution image (that can record more number of energy level). This is explained with the help of an example below.

Therefore when two images are to be compared, they must be of same radiometric resolution.

Temporal Resolution

- *Temporal resolution describes the number of times an object is sampled or how often data are obtained for the same area*
- The absolute temporal resolution of a remote sensing system to image the same area at the same viewing angle a second time is equal to the repeat cycle of a satellite.
- *The repeat cycle of a near polar orbiting satellite is usually several days,* eg., for IRS-1C and Resourcesat-2 it is 24 days, and for Landsat it is 18 days.
- *However due to the off-nadir viewing capabilities of the sensors and the sidelap of the satellite swaths in the adjacent orbits the actual revisit period is in general less than the repeat cycle.*
- *The actual temporal resolution of a sensor therefore depends on a variety of factors, including the satellite/sensor capabilities, the swath overlap, and latitude.*
- Because of some degree of overlap in the imaging swaths of the adjacent orbits, more frequent imaging of some of the areas is possible.
- *It can be seen that the sidelap increases with latitude.* Towards the polar region, satellite orbits come closer to each other compared to the equatorial regions. Therefore for the polar region the sidelap is more. Therefore more frequent images are available for the polar region.
- *In addition to the sidelap, more frequent imaging of any particular area of interest is achieved in some of the satellites by pointing their sensors to image the area of interest between different satellite passes. This is referred as the off-nadir viewing capability.*
- Images of the same area of the Earth's surface at different periods of time show the variation in the spectral characteristics of different features or areas over time.

Such multi-temporal data is essential for the following studies.

• Land use/ land cover classification

• Temporal variation in land use / land cover

• Monitoring of a dynamic event like – Cyclone – Flood – Volcano – Earthquake

- **Flood studies:** Satellite images before and after the flood event help to identify the aerial extent of the flood during the progress and recession of a flood event. The Great Flood of 1993 or otherwise known as the Great Mississippi and Missouri Rivers Flood of 1993, occurred from April and October 1993 along the Mississippi and Missouri rivers and their tributaries. Comparison of the two images helps to identify the inundated areas during the flood.
- **Land use/ land cover classification:** Temporal variation in the spectral signature is valuable in land use/ land cover classification. Comparing multi-temporal images, the presence of features over time can be identified, and this is widely adopted for classifying various types of crops / vegetation. For example, during the growing season, the vegetation characteristics change continuously. Using multi-temporal images it is possible to monitor such changes and thus the crop duration and crop growth stage can be identified, which can be used to classify the crop types viz., perennial crops, long or short duration crops.

Sensor selection for remote sensing

While selecting a sensor the following factors should be considered:

i. The spectral sensitivity of the available sensors
ii. The available atmospheric windows in the spectral range(s) considered. The spectral range of the sensor is selected by considering the energy interactions with the features under investigation.
iii. The source, magnitude, and spectral composition of the energy available in the particular range.
iv. Multi Spectral Sensors sense simultaneously through multiple, narrow wavelength vegetation type, rock classification etc,

Much finer wavelength ranges and hence finer spectral resolution are required. Ranges that can be located at various points in visible through the thermal spectral regions

Introduction

i. Multi-band imaging employs the selective sensing of the energy reflected in multiple wavelength bands in the range 0.3 to 0.9 µm. Generally broad bands are used in multi-band imaging. Multi-spectral scanners operate using the same principle, however using more number of narrower bands in a wider range varying from 0.3 to approximately 14 µm. Thus multi-spectral scanners operate in visible, near infrared (NIR), mid-infrared (MIR) and thermal infrared regions of the electro-magnetic radiation (EMR) spectrum.

ii. Thermal scanners are special types of multi-spectral scanners that operate only in the thermal portion of the EMR spectrum.

iii. Hyperspectral sensing is the recent development in the multispectral scanning, where hundreds of very narrow, contiguous spectral bands of the visible, NIR, MIR portions of the EMR spectrum are employed.

iv. This lecture gives a brief description of the multispectral remote sensing. Different types of multispectral scanners and their operation principles are covered in this lecture. The lecture also gives brief overview of the thermal and hyperspectral remote sensing.

Classification of sensors based on number of bands used

Panchromatic sensor

- Collection of reflected, emitted, or backscattered energy from an object or area of interest in a single band of the electromagnetic spectrum.
- Generally mages are collected in visible region (0.4-0.7micro meter). Sometimes wider region also used
- But if sensor captures images in a single band in microwave region it cannot be a panchromatic sensor.
- Panchromatic sensors collect data either photographically or digitally.
- If it include wavelength outside photographic region

Multispectral scanners

- A Multispectral scanner (MSS) simultaneously acquires images in multiple bands of the EMR spectrum.
- It is the most commonly used scanning system in remote sensing.

For example the MSS onboard the first five Landsat missions were operational in 4 bands: 0.5-0.6, 0.6-0.7, 0.7-0.8, 0.8-1.1 µm. Similarly, IRS LISS-III sensors operate in four bands (0.52-0.59, 0.62-0.68, 0.77-0.86, 1.55-1.70 µm) three in the visible and NIR regions and one in the MIR region of the EMR spectrum.

- Spectral reflectance of the features differs in different wavelength bands. Features are identified from the image by comparing their responses over different distinct spectral bands.
- Broad classes, such as water and vegetation, can be easily separated using very broad wavelength ranges like visible and near-infrared. However, for more specific classes viz., vegetation type, rock classification etc, much finer wavelength ranges and hence finer spectral resolution are required vegetation type, rock classification etc, much finer wavelength ranges and hence finer spectral resolution are required.
- Sensors and imaging techniques are different for different regions.

Hyperspectral Sensors

- Hyperspectral sensors (also known as imaging spectrometers) are instruments that acquire images in several, narrow, contiguous spectral bands in the visible, NIR, MIR, and thermal infrared regions of the EMR spectrum. Hyperspectral sensors may be along-track or across track.
- A typical hyperspectral scanner records more than 100 bands and thus enables the construction of a continuous reflectance spectrum for each pixel.

For example, the Hyperion sensor onboard NASA's EO-1 satellite images the earth's surface in 220 contiguous spectral bands, covering the region from 0.4 µm to 2.5 µm, at a ground resolution of 30 m.

- From the data acquired in multiple, contiguous bands, the spectral curve for any pixel can be calculated that may correspond to an extended ground feature. Depending on whether the pixel is a pure feature class or the composition of more than one feature class, the resulting plot will be either a definitive curve of a "pure" feature or a composite curve containing contributions from the several features present.

- Spectral curves of the pixels are compared with the existing spectral library to identify the targets. All pixels whose spectra match the target spectrum to a specified level of confidence are marked as potential targets. Spectral curves generated from the image are used to identify the vegetation or crop type in the circular fields and are verified with the ground data. Hyperspectral imaging has wide ranging applications in mining, geology, forestry, agriculture, and environmental management.

Based on energy

Passive

- Sensors which can only be used to used to detect naturally occurring energy.
- Passive sensors collect data in optical region only during the sun is illuminating because sun is natural source of energy.
- But in thermal region energy can be detected by sensor in day time as well as night time.

Passive sensors senses data 2 types

- ✓ Scanning
- ✓ Non-scanning

Active

- Sensor emits energy towards target and data collected which is reflected from the target this type of sensors which generated radiation and collects the reflected data are called active sensors.
- This sensors have ability to get a data at anytime.

Active sensors senses data 2 types

- ✓ Scanning
- ✓ Non-scanning

Scanning:

- This can be done along the track or across the track.

Across-track scanning

- Across-track scanner is also known as whisk-broom scanner. In across track scanner, rotating or oscillating mirrors are used to scan the terrain in a series of lines, called scan lines, which are at right angles to the flight line.
- As the aircraft or the platform moves forward, successive lines are scanned giving a series of contiguous narrow strips. Schematic representation of the operational principle of a whisk-broom scanner the scanner thus continuously measures the energy from one side to the other side of the platform and thus a two-dimensional image is generated.

Along-track scanning

- Along-track scanner is also known as push-broom scanner.
- Along-track scanners also use the forward motion of the platform to record successive scan lines and build up a two-dimensional image, perpendicular to the flight direction.
- However, along-track scanner does not use any scanning mirrors, instead a linear array of detectors is used to simultaneously record the energy received from multiple ground resolution cells along the scan line.
- This linear array typically consists of numerous charged coupled devices (CCDs). A single array may contain more than 10,000 individual detectors. Each detector element is dedicated to record the energy in a single column.
- Also, for each spectral band, a separate linear array of detectors is used. The arrays of detectors are arranged in the focal plane of the scanner in such a way that the each scan line is viewed simultaneously by all the arrays. The array of detectors are pushed along the flight direction to scan the successive scan lines, and hence the name push-broom scanner. A two dimensional image is created by recording successive scan lines as the aircraft moves forward.

Based on spectra used

Thermal scanner

- Thermal scanner is a special kind of across track multispectral scanner which senses the energy in the thermal wavelength range of the EMR spectrum.
- Thermal infrared radiation refers to electromagnetic waves with wavelength 3-14 µm. The atmosphere absorbs much of the energy in the wavelength ranging from 5-8 µm.
- Due to the atmospheric effects, thermal scanners are generally restricted to 3-5 µm and 8-14 µm wavelength ranges.
- The target appears in light tone if the thermal emission from the target is more in the day time.

  The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard Terra, TIMS developed jointly by NASA JPL and the Daedalus Corporation are some of the examples. ASTER data is used to create detailed maps of land surface temperature, reflectance, and elevation. TIMS is used as an airborne geologic remote sensing tool to acquire mineral signatures to discriminate minerals like silicate and carbonate.
- It uses 6 wavelength channels since the energy received at the sensor decreases as the wavelength increases, larger IFOVs are generally used in thermal sensors to ensure that enough energy reaches the detector for a reliable measurement. Therefore the spatial resolution of thermal sensors is usually fairly coarse, relative to the spatial resolution possible in the visible and reflected infrared.
- However, due to the relatively long wavelength, atmospheric scattering is minimal in thermal scanning. Also since the reflected solar radiation is not measured in thermal scanning, it can be operated in both day and night times.

Microwave sensors

- Microwave sensor employs microwave radiation using wavelengths that range from about 1mm to 1m.
- It enables observation in all weather conditions without any restriction by cloud or rain.
- Microwaves have longer wave lengths compare to visible and infrared, they can penetrate through cloud cover, haze, dust because longer wavelengths are not susceptible to atmospheric scattering.
- So data can be collected at any time.
- Sensors can be active or passive. Passive microwaves sensors generally performed from satellite.
- Data collected in digital format because digital image is the only choice if the sensors uses wavelengths that are out of visible region.

Photographic sensors

- Photographic sensors performed within the photographic region i.e. 0.4-0.9micro meters.
- Photographic systems records the energy detected by means of a photographic process.

Optical sensors

- Optical sensors performed within the optical region i.e. 0.4-0.7 micro meters.

Indian remote sensing sensors

1. Panchromatic Sensor (PAN) sensor to collect data in single band.
2. Linear Imaging Self Scanning sensor (LISS) for multi spectral data collection. LISS sensors had four generations- LISS-I, LISS-II, LISS-III, LISS-IV
3. Wide Field Sensor (WiFS) to collect data in wide swath with 2 bands.

4. Advanced Wide Field Sensor (AWiFS) to collect data in wide swath with 4 bands.
5. Multi frequency optoelectronic scanning sensor (MOS)
6. Ocean colour monitor (OCM) sensor operating in eight narrow spectral bands, for oceanographic application.
7. Multi spectral optoelectronic sensor (MSMR)in 3 and 19 spectral bands, for oceanographic application.
8. Synthetic aperture radar(SAR) for active microwave remote sensing.

Panchromatinc Sensor (PAN)

Parameters	**Specifications (PAN)** **Used in 1C and 1D**	**Specifications (PAN)** **Used in cartosat-1**	**Specifications (PAN)** **Used in cartosat-2**
Band (microns)	0.50 - 0.75	0.50 - 0.75	0.5-0.75
Resolution (m)	5.8	2.5	1
Radiometric resolution	6 bits (64 grey levels)	10bit	10bit
Swath (km.) 1. Nadir 1. Off-nadir	70 91	30	9.6
Temporal resolution	24 day revisit	5 days revisit	4days

Linear Imaging Self Scanning sensor

LISS-I and II launched using satellite IRS 1A and 1B in 1988, 1991 respective years and LISS-III used in IRS 1C and 1D satellite, were launched in 1995 and 2997. LISS-IV has launched using ITS P6 in 2011.

Parameters	LISS-I	LISS-II	LISS-III		LISS-IV
			B2 B3 B4	B5	
Instantaneous field of view(IFOV)	80	40	40	40	40
Detectors (CCDs)	2048 elements	2048 elements	6000 elements	6000	210
Ground Resolution (m)	72.5	36.25	23	70 (for b5)	5.8
Spectral range (micro meter)	0.45 - 0.86	0.45 - 0.86	0.52-0.59(green) 0.62-0.68(red) 0.77-0.86(NIR)	1.55-1.70 (SWIR)	0.52-0.59(green) 0.62-0.68(red) 0.77-0.86(NIR)
Number of Bands	4	4	B2 B3 B4	B5	B2 B3 B4
Swath (Kms.)	148	73x2 (LISS-A and LISS-B)	141	148	25
Radiometric Resolution (grey levels)	128	128	128 (7 bits)	128	10 bit

* LISS-II contains two separate sensors LISS-A and LISS-B with a spatial resolution of 36.25 each.
* The 4 bands are:
B1 - 0.42-0.52 (blue)
B2 - 0.52-0.59 (green)
B3 - 0.62-0.68 (red)
B4 - 0.77-0.86 (near IR)

Wide Field Sensor (WiFS) and Advanced Wide Field Sensor (AWiFS)

Satellite IRS 1C and 1D launched WiFS sensor in 1995 and 1997 respective years. AWiFS was launched by satellite IRS-P6 in 2011

Parameters	**Values**	AWiFS
Spectral bands (microns)	B3 - 0.62-0.68 (red) B4 - 0.77-0.86 (near IR)	B2:0.52-0.59 B3:0.62-0.68 B4:0.77-0.86 B5:1.55-1.7
Resolution (m)	188m	56m
CCD devices	2048 elements	6000
Swath (Kms)	810	370
Temporal resolution	5 days repetivity	5days

Modular Optoelectronic Scanner (MOS)

The sensor system is primarily meant for ocean related studies. It operates in narrow spectral bands in visible, near infrared and short wave infra-red regions

(SWIR) of the electromagnetic spectrum and consists of three optical modules namely MOS-A, MOS-B and MOS-C. Further the sensor should be able to detect small changes in spectral signature. This is achieved by having 16 bits of quantisation as against 7 or 8 bits in the sensors used for land applications.

Parameters	MOS-A	MOS-B	MOS-C
Spectral range	0.755 - 0.768	0.408 - 1.010	1.50 - 1.70
No. of Bands	4	14	1
Resolution (m)	1569 x 1395	523 x 523	523 x 644
No. of detectors	140	384	299
Quantisation bits	16	16	16
Swath (kms.)	195	200	192
S/N ratio	>100	>100	>100

OCM (Ocean Colour Monitor)

Ocm with 8 spectral bands from 0.4-0.8micron meter for the measurements of physical and biological oceanographic parameters. Swath width of 1420km and 2days temporal resolution. Orbit altitude of 720km. used to collect data chlorophyll concentration, detect and monitor phytoplankton blooms, and obtain data atmosphere and suspended sediments in water. This launched by IRS P4 satellite.