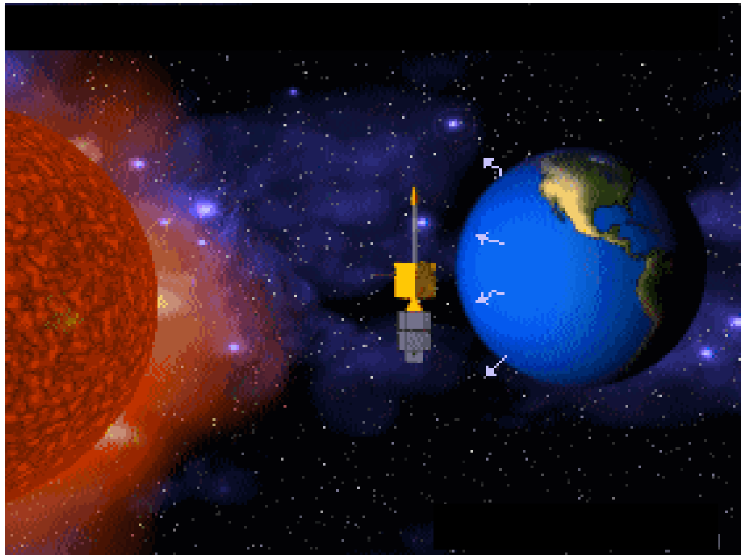
Earth Observation Sensors and Platforms



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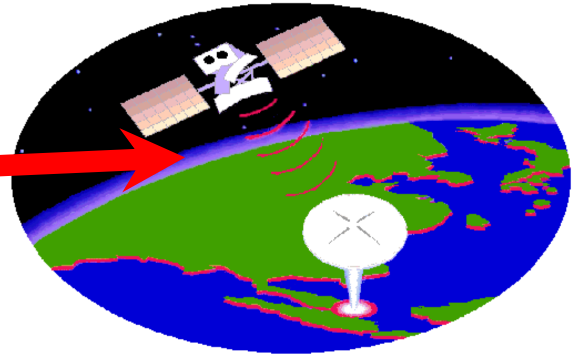
8/21/2019

Remote Sensing

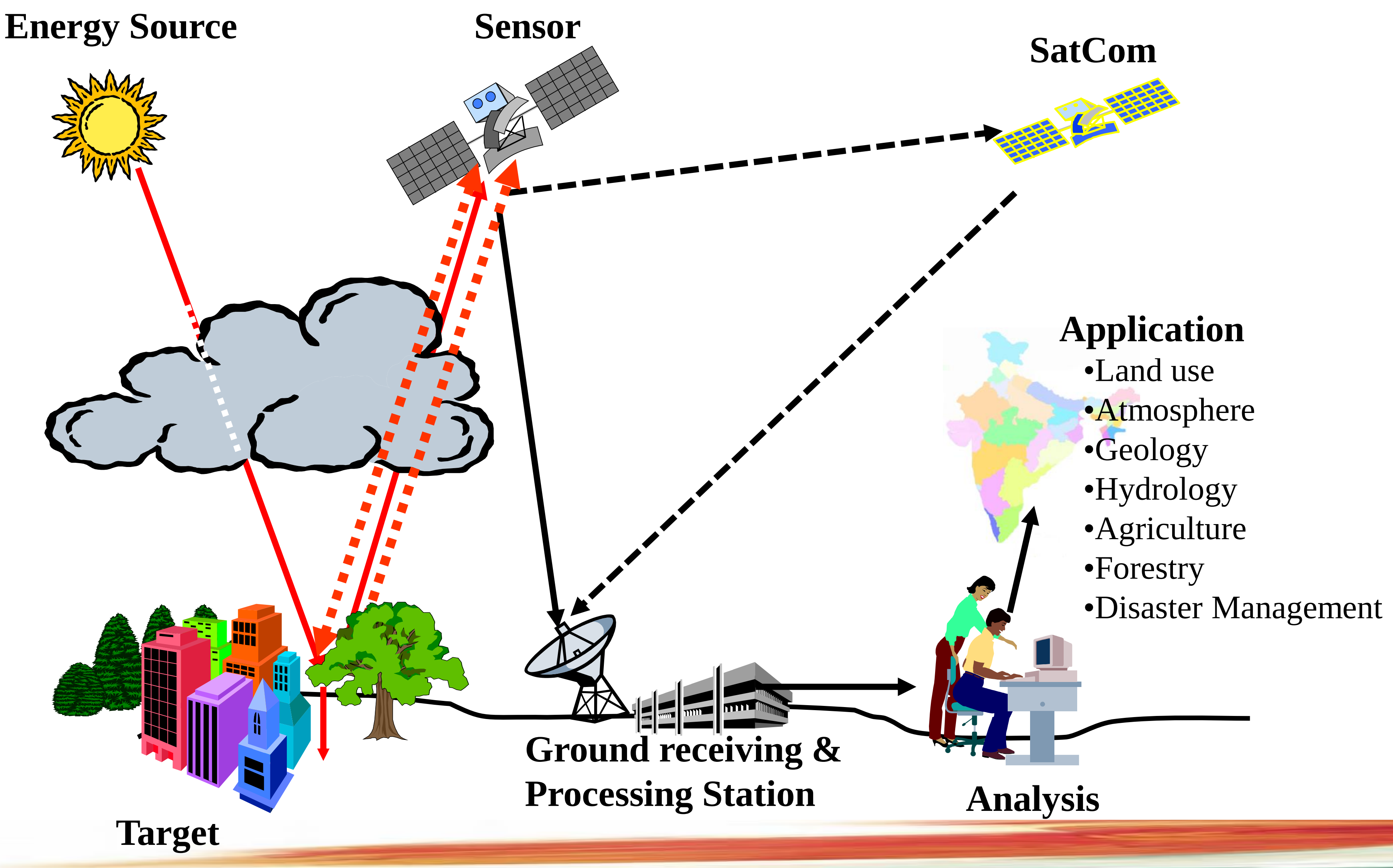
- ***Remote Sensing is the art, science and technology* of observing an object scene or phenomenon by instrument-based techniques.**
  - **Remote: because observation is done at a distance** without physical contact with the object of interest
  - **Sensing: Detection of energy, such as light or another** form of electromagnetic energy

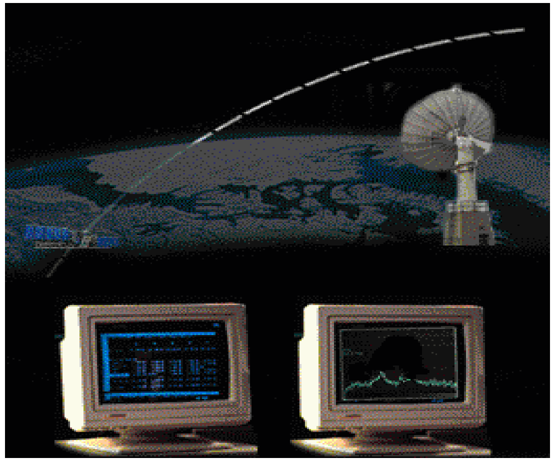
Measurement from a distance



It enables us to observe and study nature in ways that would otherwise be beyond human capability, across great distances and at wavelengths of light invisible to human eyes

Remote Sensing Process

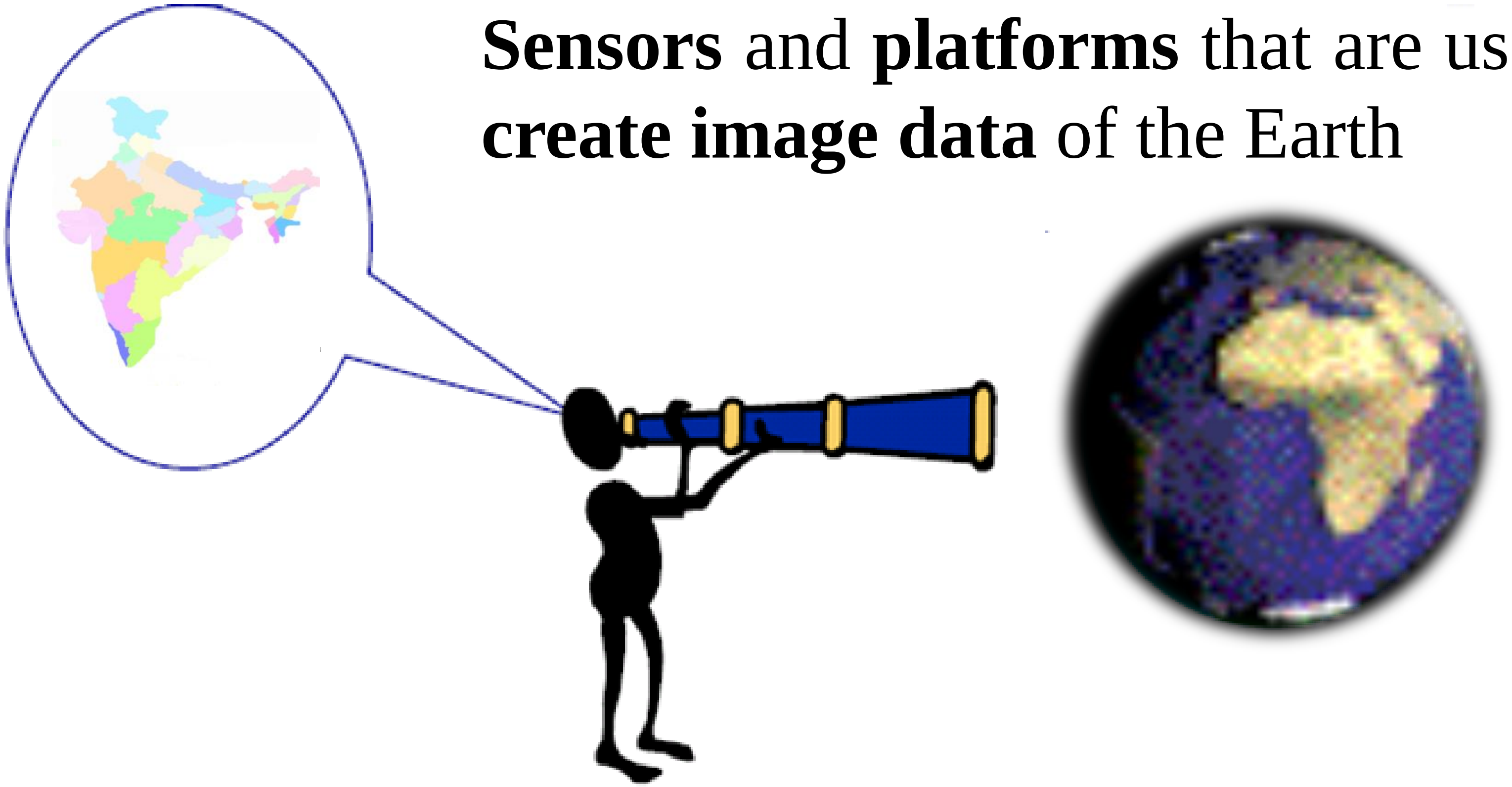




Indian Receiving Station at Shadnagar

Definition

Sensors and **platforms** that are used to **create image data** of the Earth

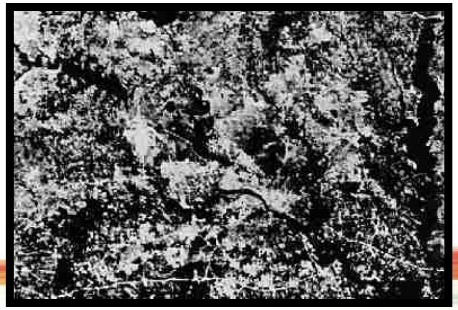


Sensors= a device that **records EM Energy**

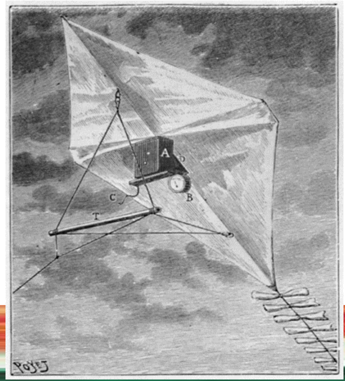
Platforms= carrier bed used **to carry a sensor**

History of remote sensing

- 1827 - first photograph
- 1858 - first aerial photograph from a hot air balloon
- 1861-1865 - Balloon photography used in American Civil War
- 1888 – ‘rocket’ cameras
- 1903 - pigeon-mounted camera patented
- 1906 - photograph from a kite
- 1914-1945 - Plane mounted Cameras WWI, WWII
- 1956 - U2 spy planes
- 1957 - Sputnik-1
- 1960 - 1st meteorological satellite ‘TIROS-1’ launched
- 1967 - NASA ‘Earth Resource Technology Satellite’ programme
- 1972 - ERTS (Landsat) 1 launched...

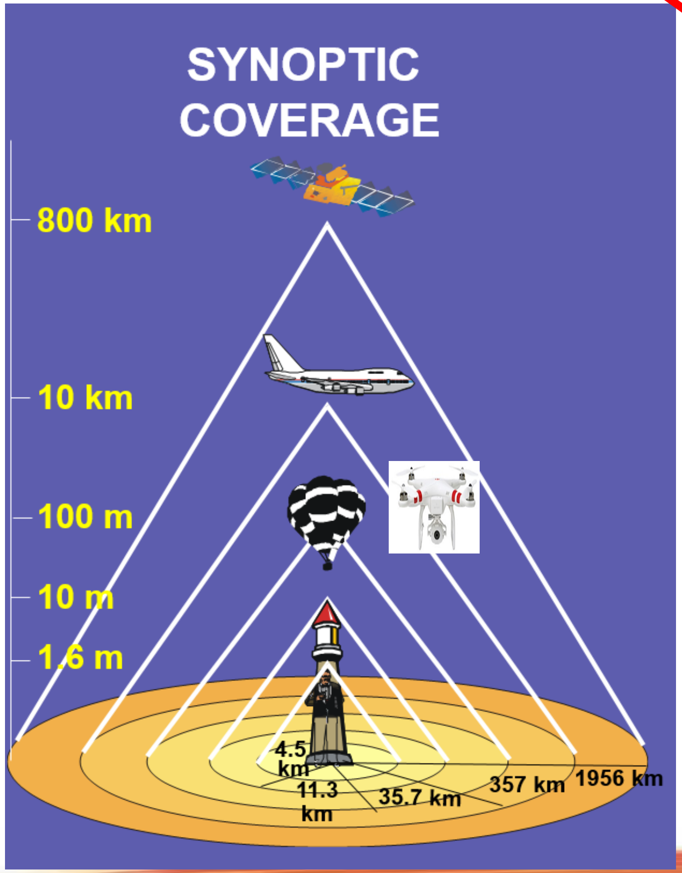


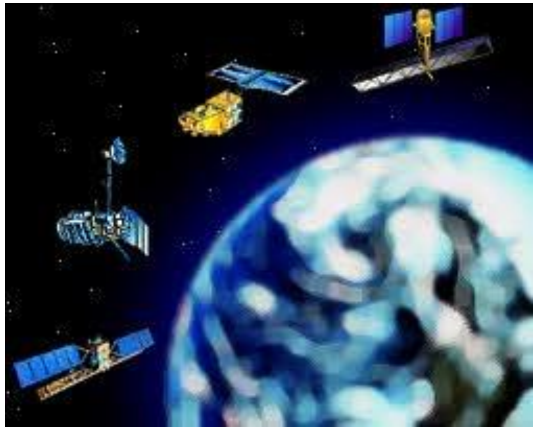
First ERTS-1 image
Dallas, 23 July 1973.



Platforms

- Ground based
- Airborne
- Spaceborne





Ground Based Platforms

- Used to **record detailed information** about the surface which is compared with **information collected from aircraft or satellite sensors.**

- In some cases, this can be used to **better characterize the target** which is being imaged by the other sensors, making it possible to **better understand the information in the imagery.**

- Sensors may be **placed on a ladder, scaffolding, tall building, crane**, etc.

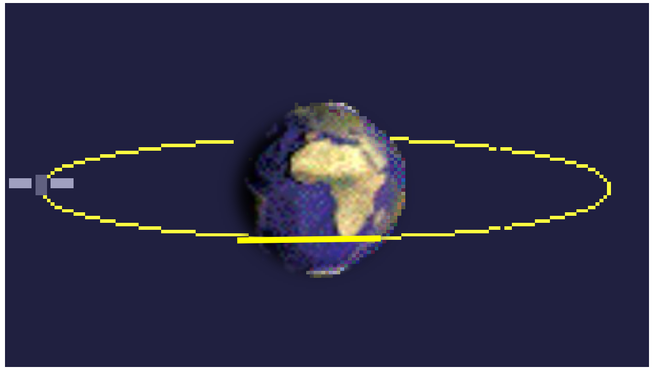
Airborne Platforms

- Are primarily **stable wing aircraft,** although **helicopters** are occasionally used.
- To collect **very detailed images** and facilitate the collection of data over **any portion of the Earth's surface at any time.**

Spaceborne Platforms

- **Space remote sensing** is sometimes conducted from the
  - **Space Shuttle**
  - **Satellites** (more commonly)
- **Satellites** are objects which **revolve around another object** - in this case, the Earth.
- e.g: the **moon is a natural satellite**, whereas **man-made satellites** include those platforms launched **for remote sensing, communication, and telemetry (location and navigation) purposes**.

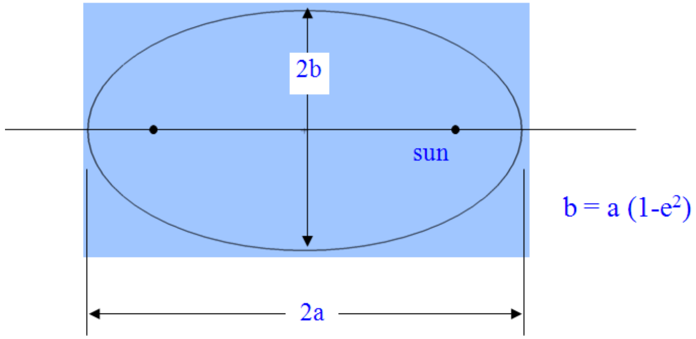
Orbits



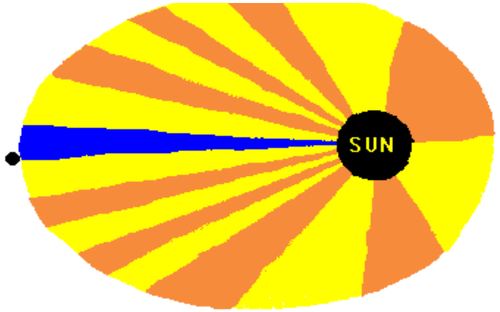
- **The path followed** by the **satellite** is called **orbit**.
- The satellite moves as per **Kepler's law**.

Kepler's Law

- **1st Law:** The **path followed** by each planet **is an ellipse** with **sun at one FOCI**.



- **2nd Law:** The line joining to the planet to sun **sweeps out equal areas in equal times.**

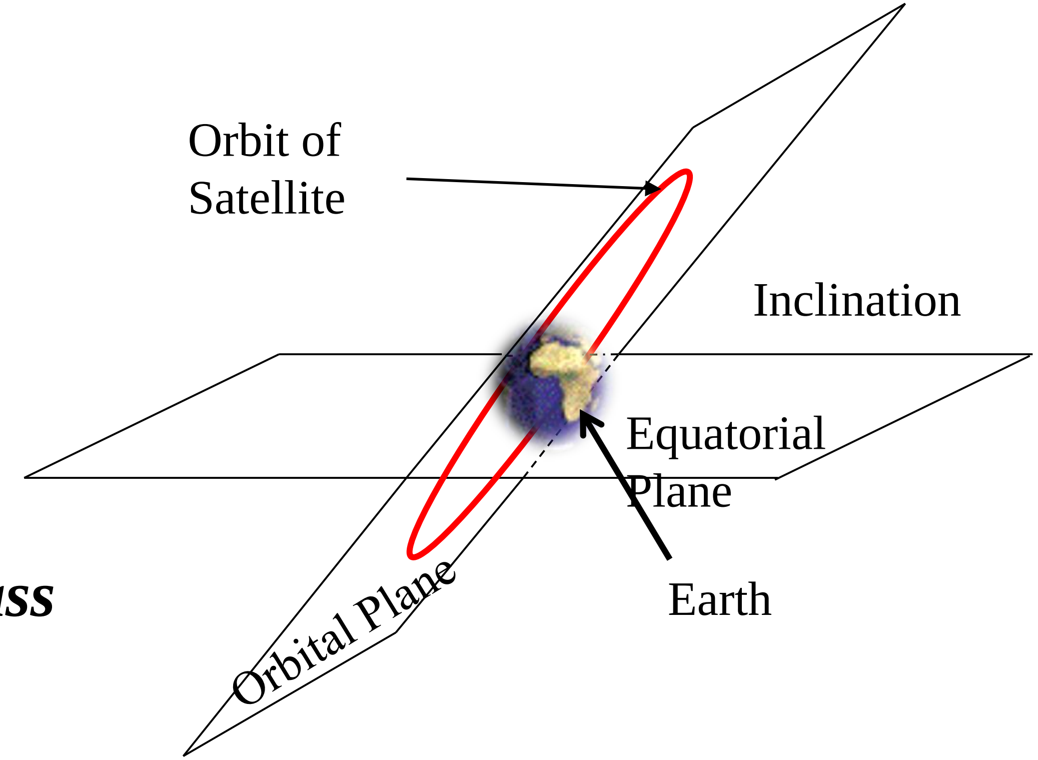


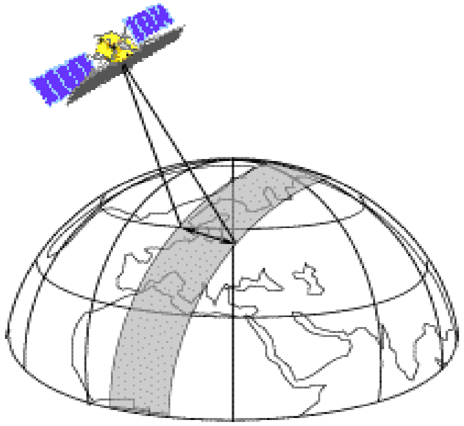
- **3rd Law:** The square of the period of the planet is proportional to the cube of the semi major axis.

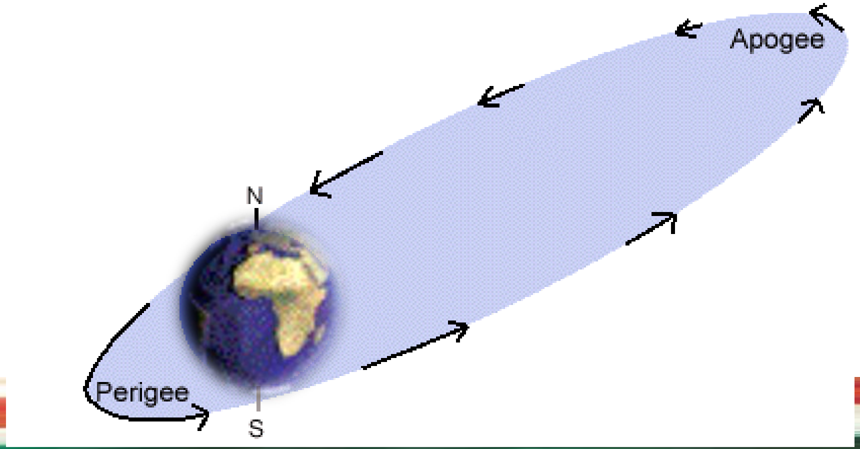
$$T^2 \propto a^3$$

Satellite Orbital Characteristics

- ***Altitude***
- ***Inclination angle***
- ***Period***
- ***Repeat Cycle***
- ***Swath***
- ***Ascending pass & Descending pass***
- ***Perigee & Apogee***

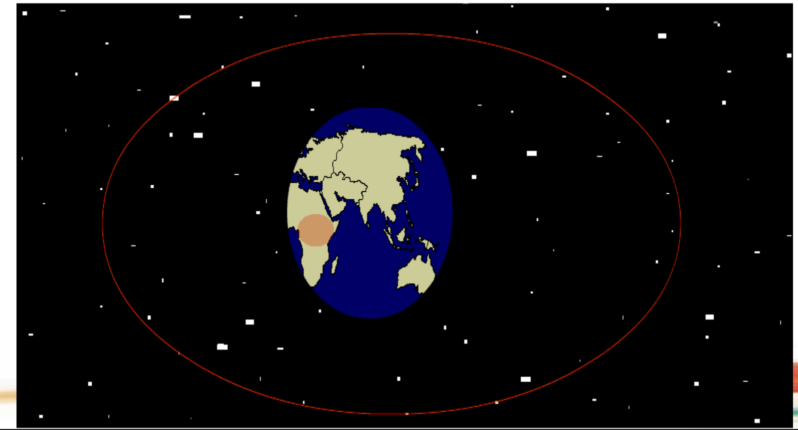






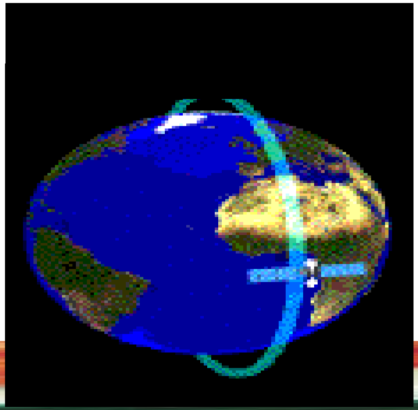
Geostationary Satellite

- Altitude ~ **36,000 km**,
- Orbit inclination ~ **0°**
- Period of orbit = **24 hours**
- **Global coverage requires several geostationary satellite** in orbits at different latitudes
- Good for repetitive observations, **poor for spatially detailed data**
- Large distortions at high latitudes
- **W-E** satellite orbiting Earth
- Mainly used for communication and meteorological applications – **GOES, METEOSAT, INSAT etc.**

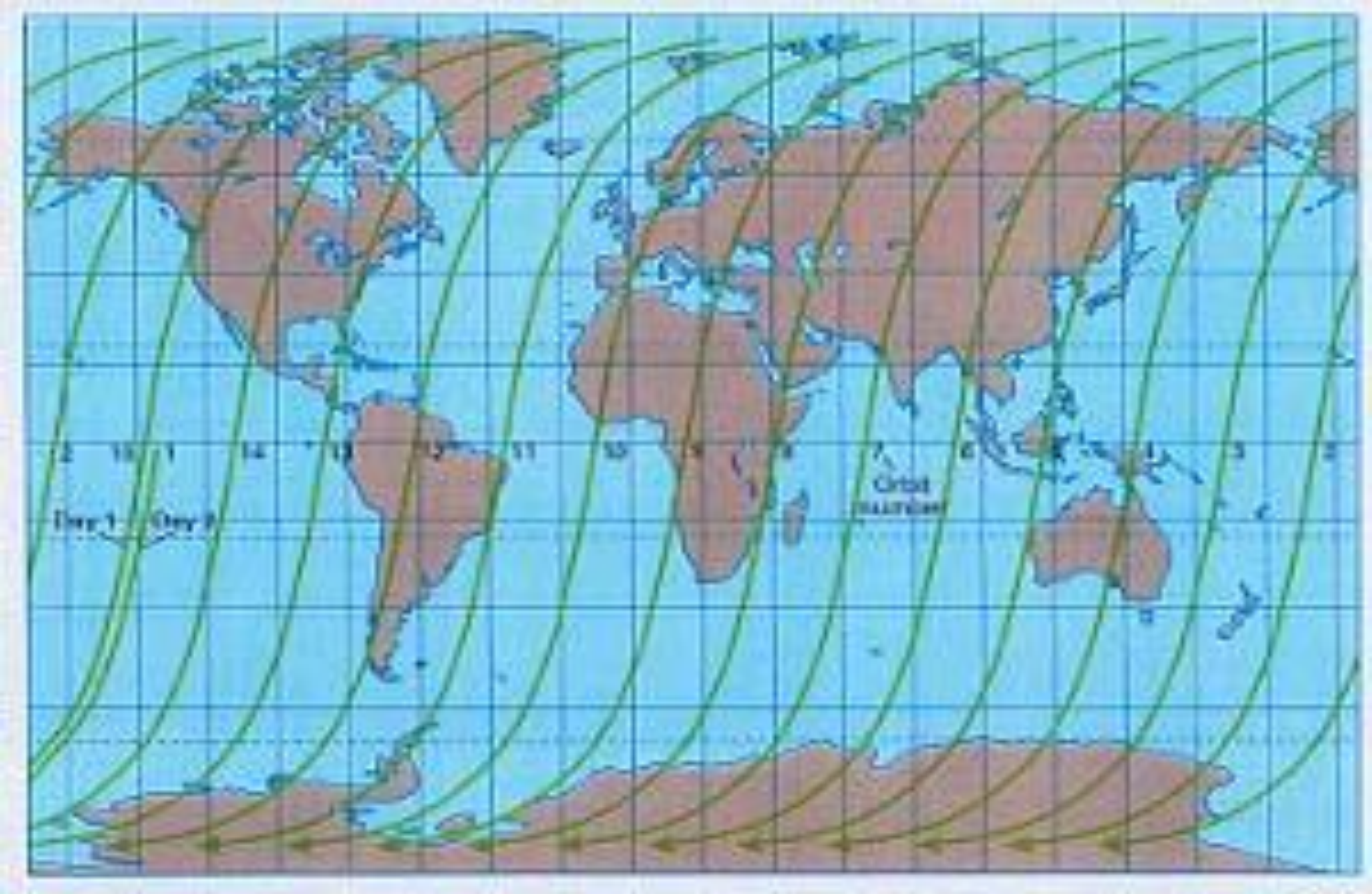


Sun Synchronous Satellite

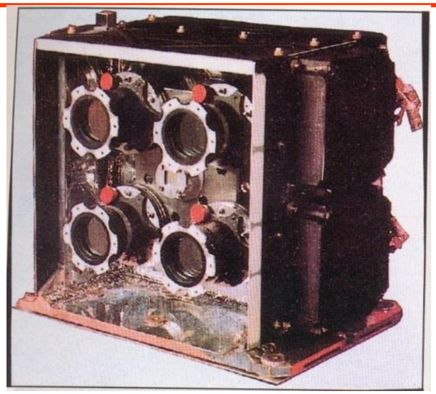
- Altitude ~**700-800 km**
- Orbit inclination ~ **98.7º**
- Orbital period ~**90 minutes**
- Sun-synchronous, near-polar, near-circular
- Satellite orbit is fixed in space (basically **north-south**): Earth rotates beneath it (**west-east**)
- Cross the equator (N-S) at ~**10.30am local time**
- Satellite Orbital plane is near polar and the altitude is such that the satellite passes each place at same local sun-time.
- Cover entire globe – **LANDSAT, SPOT, NOAA, IRS** etc.

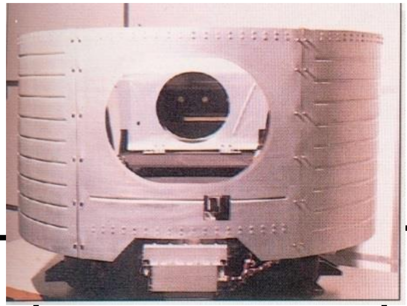


The **satellite's orbit (North –South)** and the **rotation of the Earth (from west to east)** work together to allow **complete coverage of the Earth's surface**, after it has completed **one complete cycle of orbits**

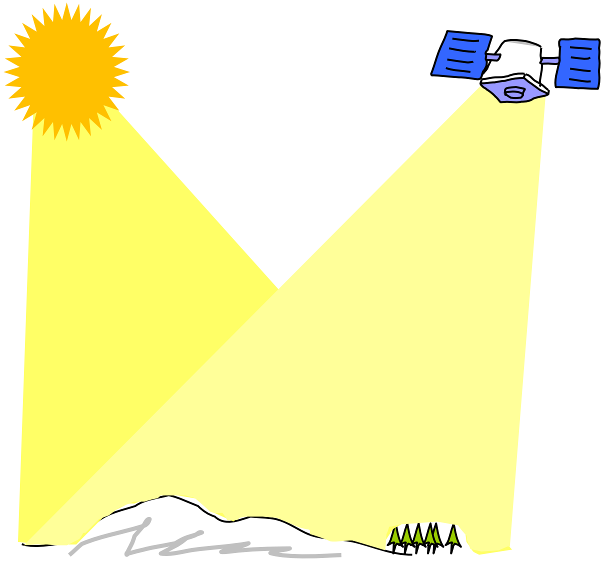


SENSORS



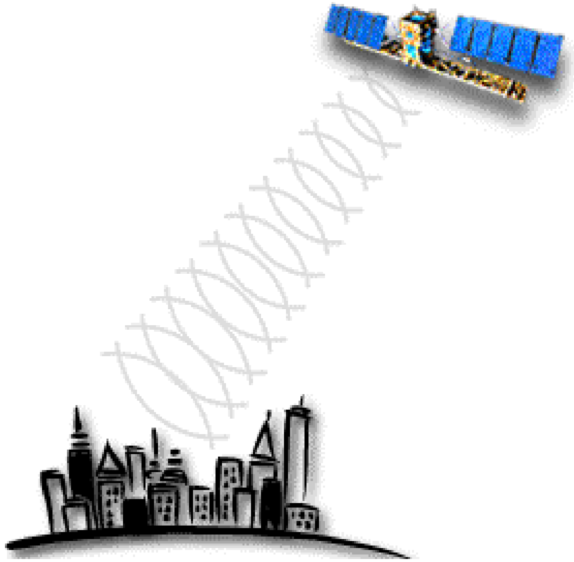


Passive



Optical Remote Sensing

Active



Microwave Remote Sensing

Imaging Sensors

Passive Sensors

- **Photographic Camera**
- **The Optical Scanners**
  - Across Track Scanners
  - Along Track Scanners
- **The Thermal Scanner**

Active Sensors

- **SAR (Synthetic Aperture RADAR)**
- **LiDAR (Light Detection and Ranging)**

Non-imaging Sensors

Passive Sensors

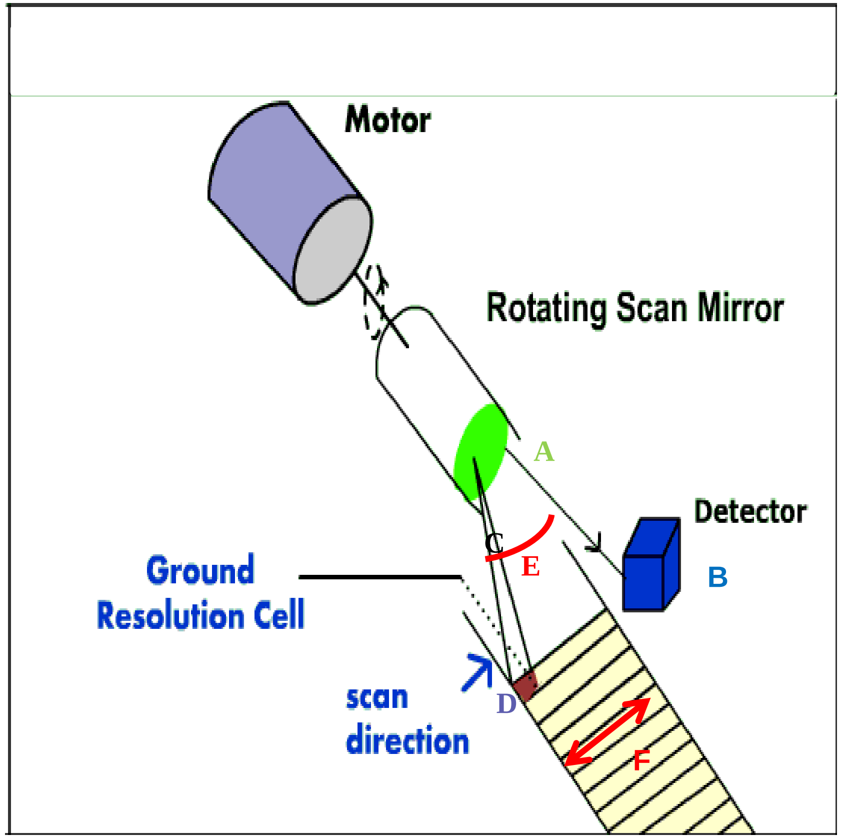
- Spectro-radiometers

Active Sensors

- Laser Distance Meter
- Laser Water Depth Meter
- Microwave Altimeter

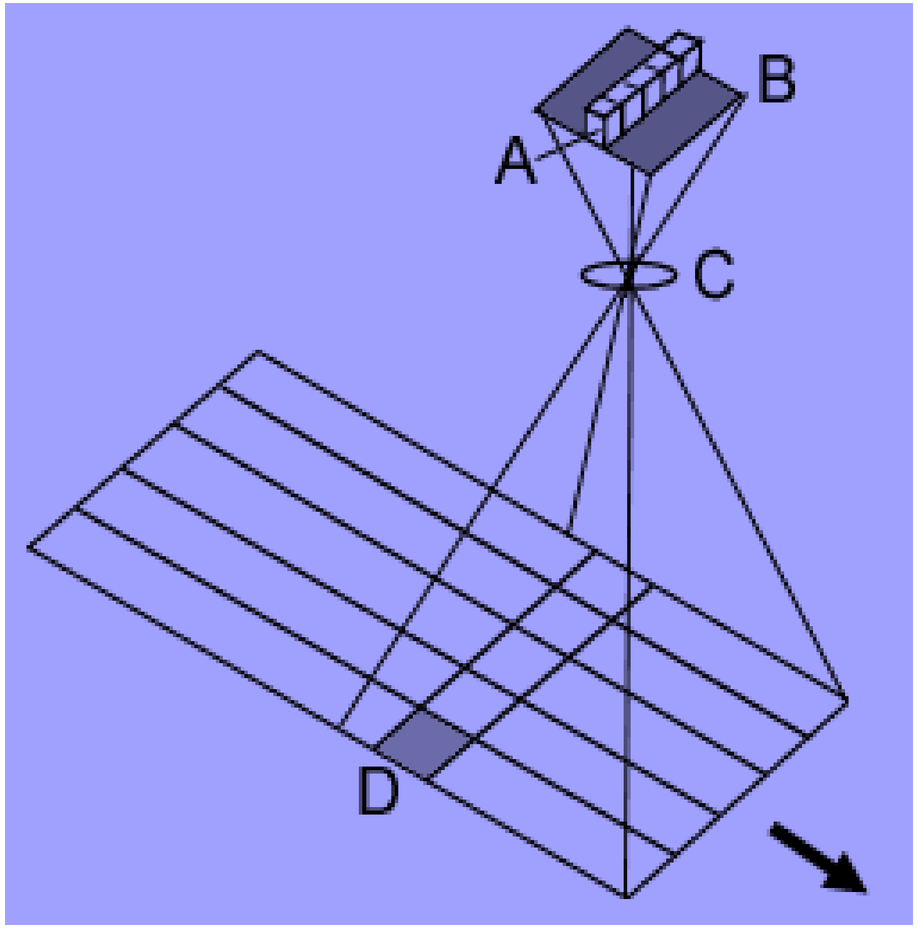
Across Track Multispectral Scanning

- Whisk broom scanning
- Scan the Earth in a series of lines.
- The lines are oriented perpendicular to the direction of motion of the sensor platform (i.e. across the swath).
- Data are collected within an arc below the system typically of some **90º to 120º**
- Multispectral scanner (MSS) and thematic mapper (TM) of LANDSAT, and Advanced Very High Resolution Radiometer (AVHRR) of NOAA are the examples of Whisk Broom scanners

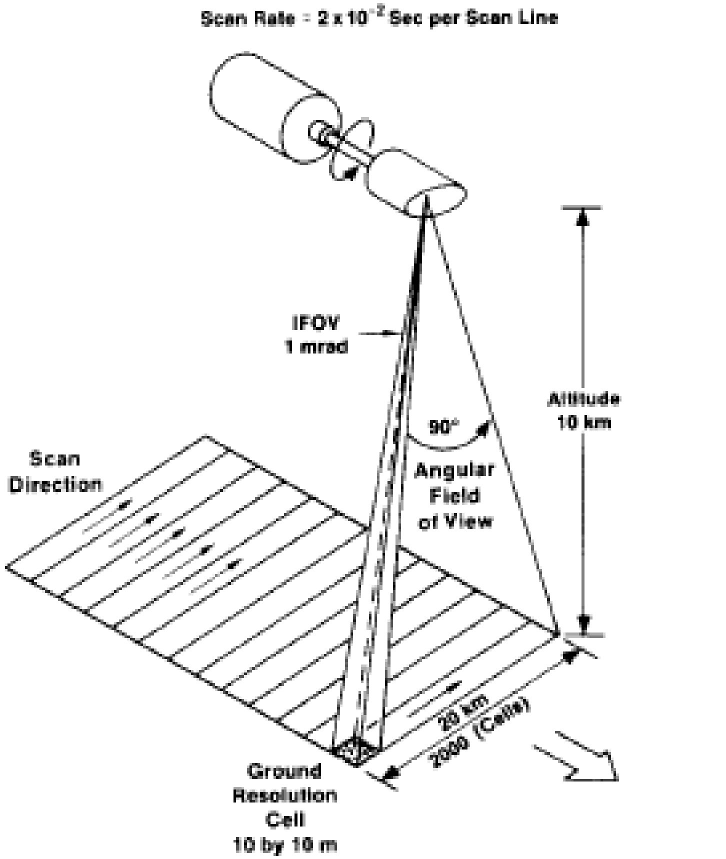


Along Track Multispectral Scanning

- Push broom scanning
- Scan the Earth in a series of lines.
- This 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.
- Linear arrays normally consist of numerous **charge-coupled devices (CCDs)** positioned end to end.
- Linear imaging self scanning (LISS) and Wide Fielf Sensor (WiFS) of IRS Series, and High Resolution Visible (HRV) of SPOT-1 are the examples of Push broom scanners



Across Track Scanners

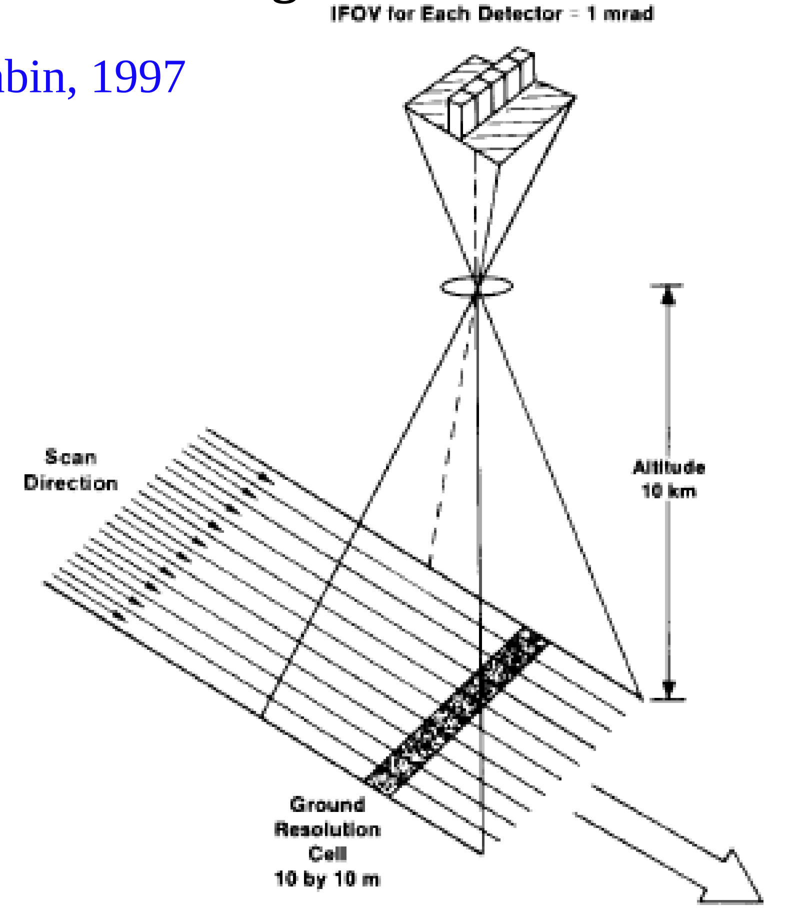


$$\text{Dwell Time} = \frac{\text{Scan Rate per Line}}{\text{Number Cells per Line}} = \frac{2 \times 10^{-2}\ \text{sec}}{2000\ \text{cells}} = 1 \times 10^{-5}\ \text{sec} \cdot \text{cell}^{-1}$$

Whiskbroom

Along Track Scanners

Sabin, 1997



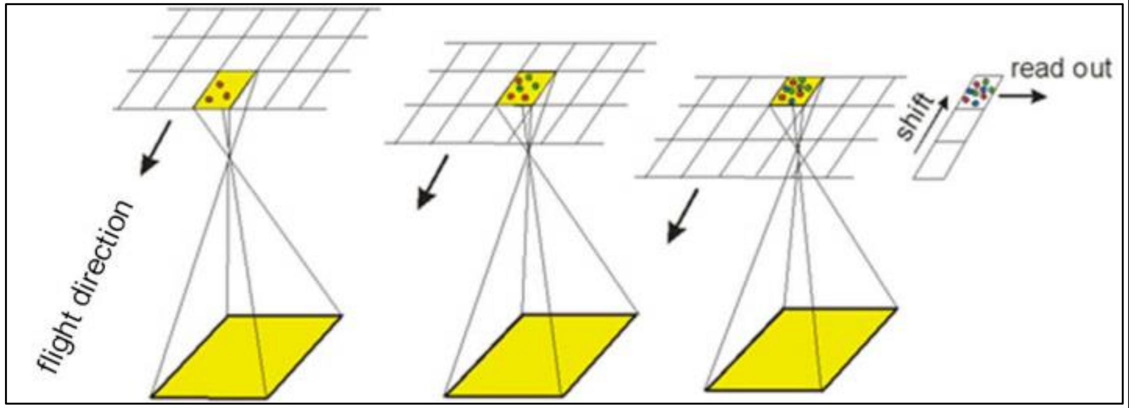
$$\text{Dwell Time} = \frac{\text{Cell Dimension}}{\text{Velocity}} = \frac{10\ \text{m} \cdot \text{cell}^{-1}}{200\ \text{m} \cdot \text{sec}^{-1}} = 5 \times 10^{-2}\ \text{sec} \cdot \text{cell}^{-1}$$

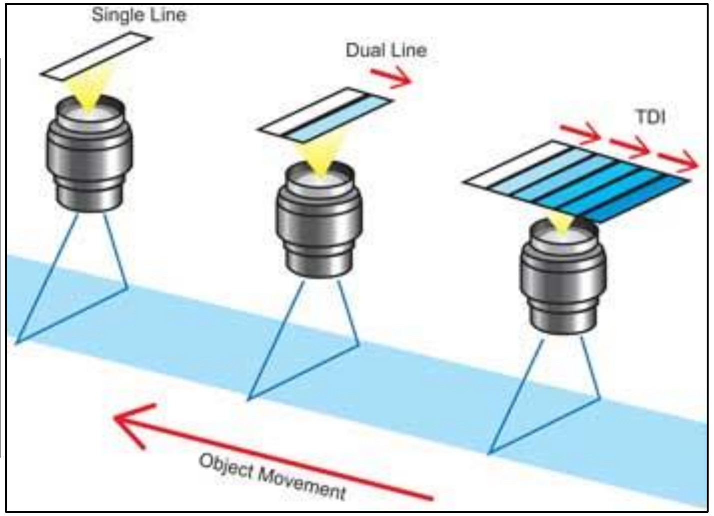
Pushbroom

Field of View (FOV), Instantaneous Field of View (IFOV)
Dwell time is the time required for the detector IFOV to sweep across a ground cell.
The longer dwell time allows more energy to impinge on the detector, which creates a stronger signal.

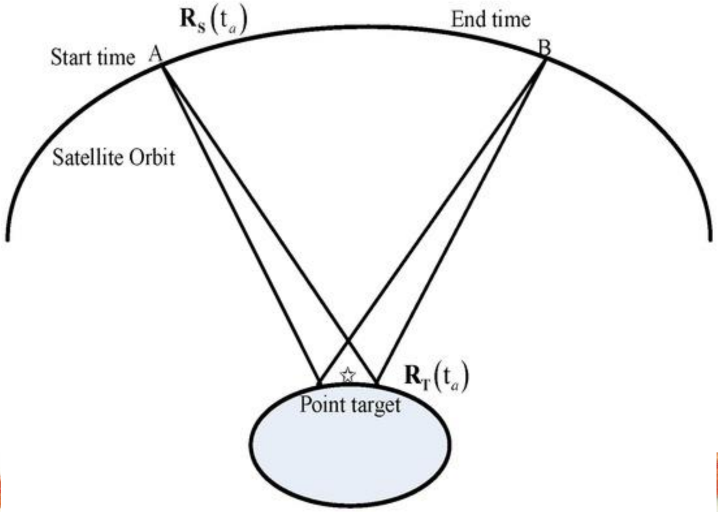
High Resolution Imaging mode

- Time Delay Integration (TDI)



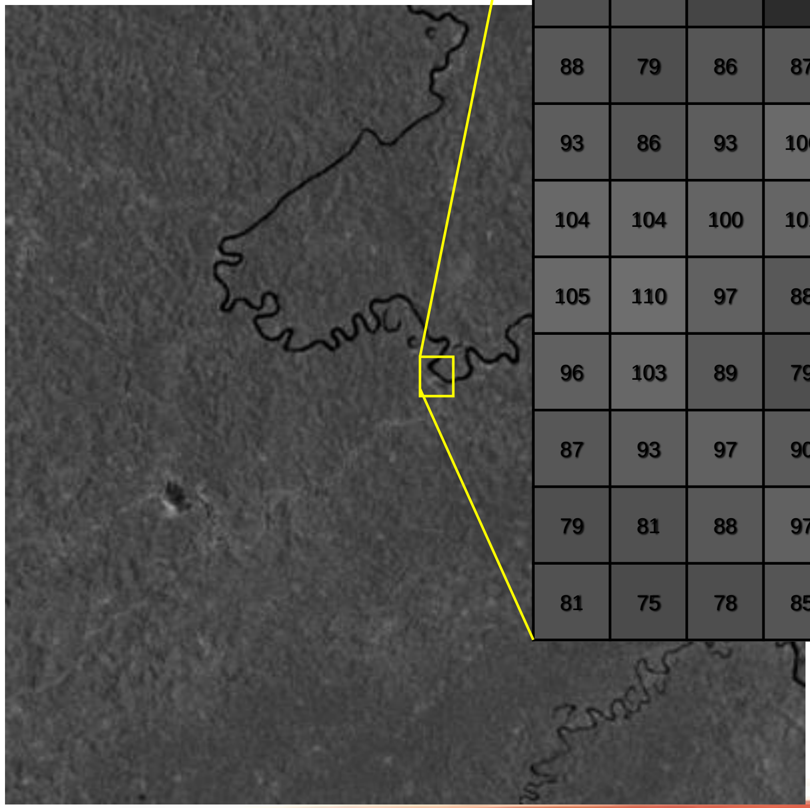


- Step & Stare



What is a digital image?

- Grid cells or pixels
- Each pixel has a digital number (DN) which represents: Spectral Reflectance Value



70	53	41	64	84	85	81	88	91	87
79	77	45	38	59	77	84	86	85	85
80	82	69	44	32	45	72	86	82	78
88	79	86	87	65	40	41	75	79	78
93	86	93	106	106	84	56	43	58	75
104	104	100	101	95	91	83	51	39	56
105	110	97	88	84	85	87	77	59	44
96	103	89	79	79	75	77	79	74	72
87	93	97	90	82	76	70	67	61	71
79	81	88	97	93	85	78	74	70	72
81	75	78	85	94	97	92	84	80	72

What your computer sees…

Resolution

Ability of the system to render the information at the **smallest discretely separable quantity** in terms of distance (spatial), wavelength band of EMR (spectral), time (temporal) and radiation (radiometric).

The Four Resolutions of Remote Sensing

- **Spatial**

A Measure of discernable physical dimension of the surface from the image

- **Spectral**

A measure of the width of the wavelength (bandwidth) which is used to generate the image. *Narrower the bandwidth higher the spectral resolution*

- **Radiometric**

A measure of what is the minimum change in radiance that can be measured

- **Temporal**

Frequency of Observation: Number of days between two consecutive observation for a particular ground target under *similar viewing geometry*

Spatial Resolution

- The physical dimension on earth is recorded
- It refers to the amount of detail that can be detected by a sensor.
- Detailed mapping of land use practices requires a much greater spatial resolution

Instantaneous Field of View (IFOV)

It is defined the solid angle through which a detector is sensitive to radiation.

IFOV = D/F radian

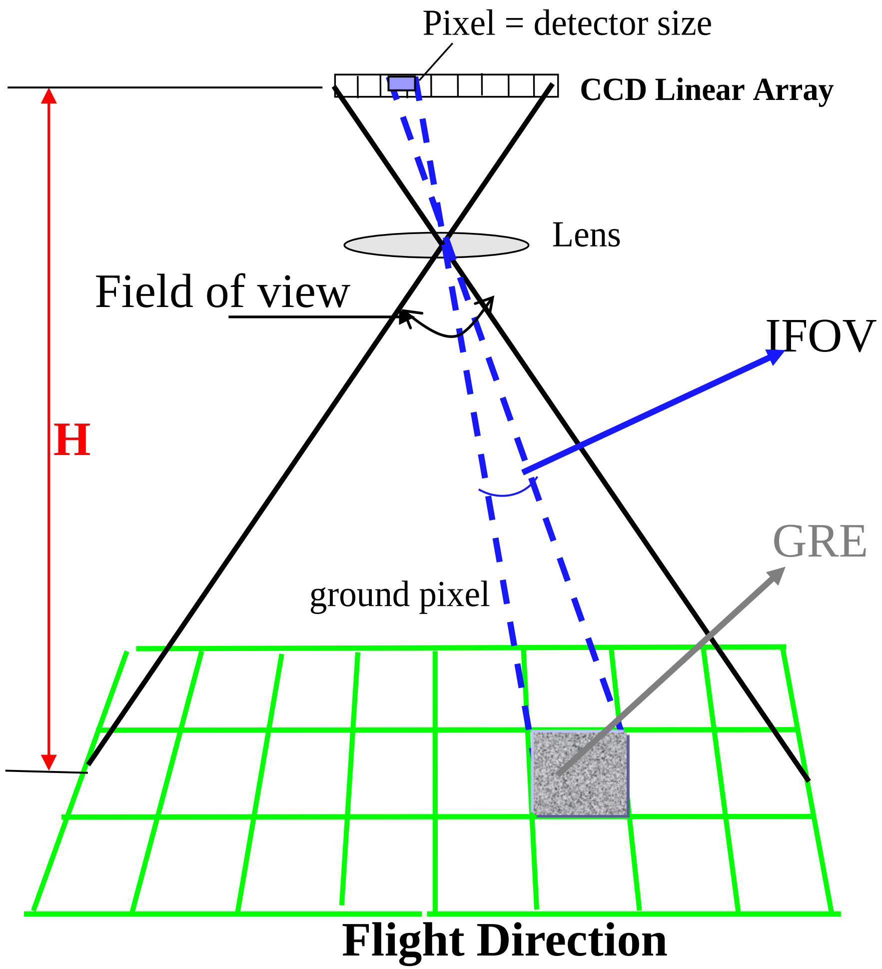
GRE = IFOV x H

where, **GRE=Ground Resolution Element**

D=detector dimension,

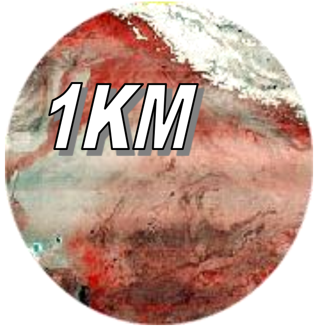
F=focal length, and

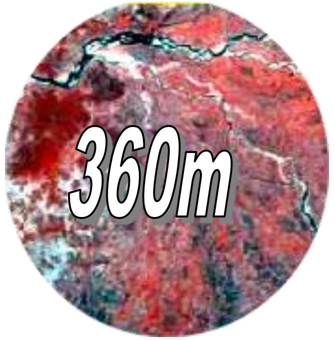
H=flying height

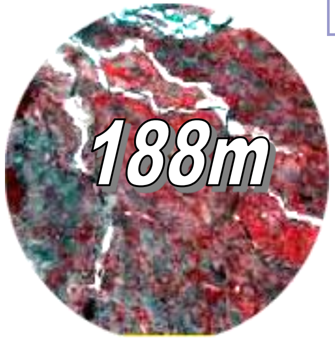


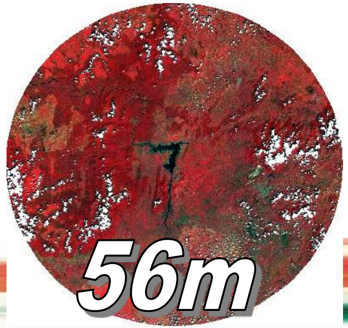
Meteorology	Cloud patterns, movement Water vapor Analysis	1-2 Kms. 8 Kms.
Oceanography	Ocean Color Monitoring (Chlorophyll, Sediment Map, Yellow Substance, Sea Surface Temp. Mapping)	300-1100 m
Land use	Crop monitoring, Forest Mapping, Hydrology etc. Cartography, Urban Planning Military Surveillance	20-30 m 2-6 m $\leq$ 1 m

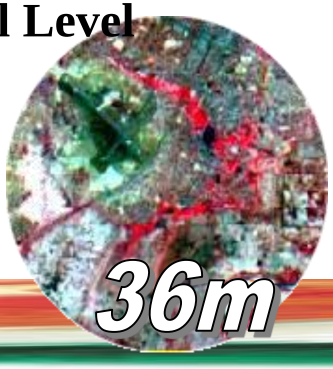
- **1 Km to 1 m spatial Resolution**
- **24 Days to every 30 mts. Repetitivity**
- **1 Million scale to Cadastral Level**

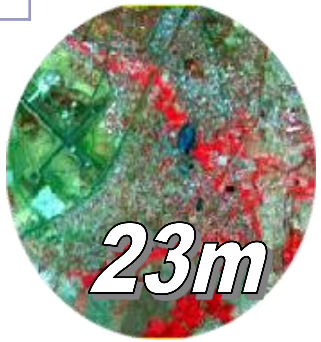


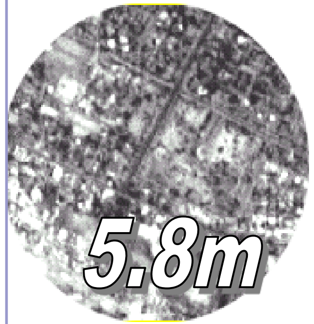


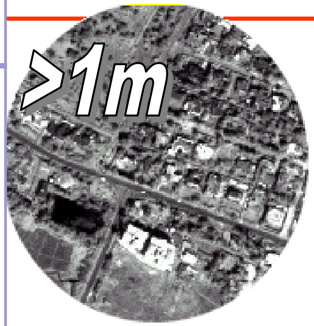




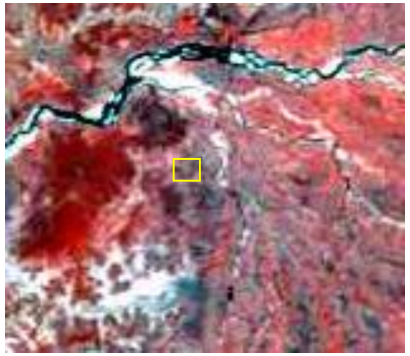






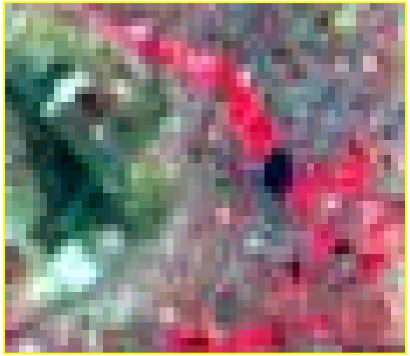


INFORMATION CONTENT VS RESOLUTION

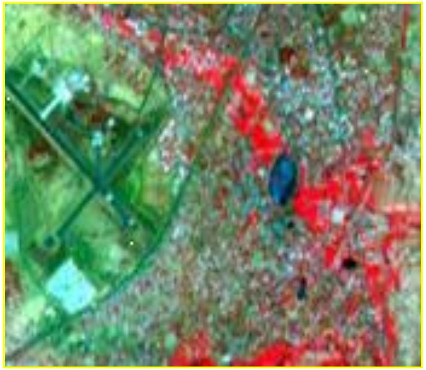

A) OCM (360m)


B) 360m (OCM)


C) 188m (WiFS)


D) 72m (LISS-I)


E) 36m (LISS-II)

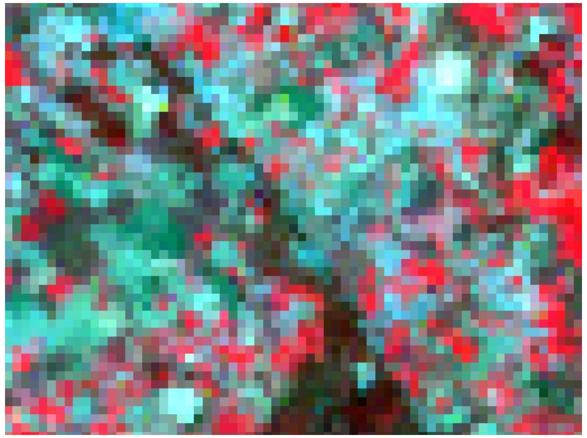

F) 23m (LISS-III)


G) 5.8m (IRS 1C PAN)

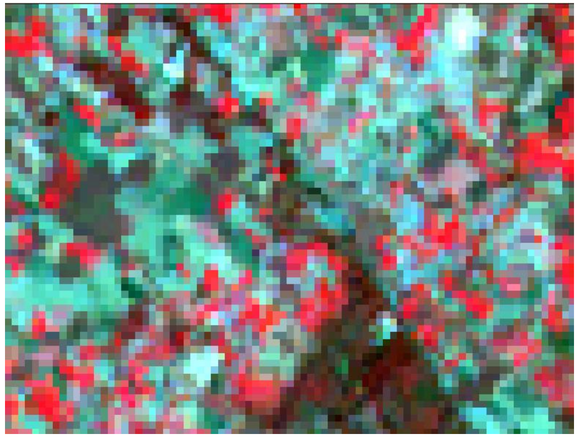
‘A’ is from a scene from IRS Ocean Colour Monitor (OCM). The area in the small square marked (≈ 4km x 4km) is shown in various resolutions from B to G..

AWIFS (56 m)

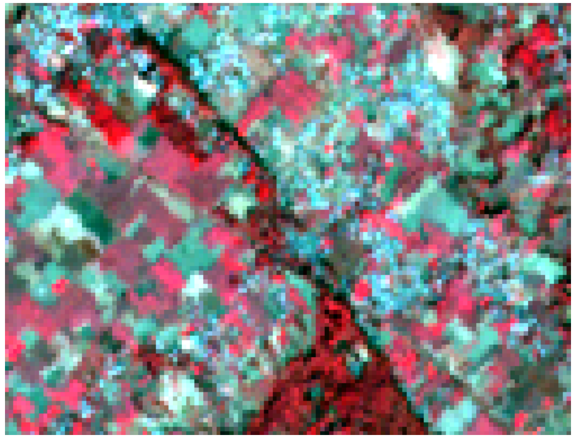
ETM 30m



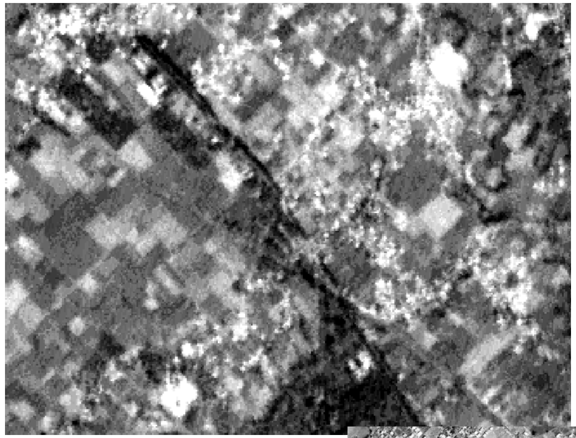
IRS LISS III 23.5 m



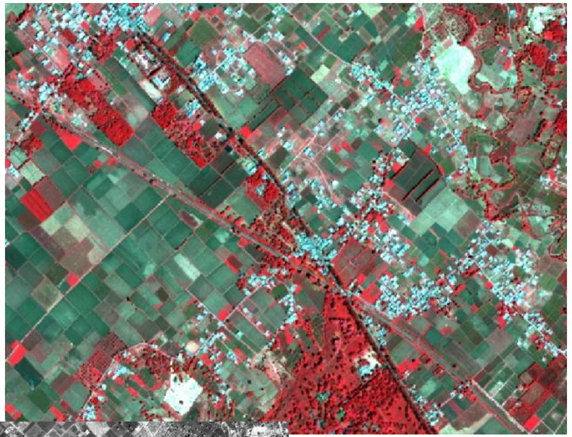
ASTER 15 m



IRS PAN 5.8 m



IKONOS MSS 4 m



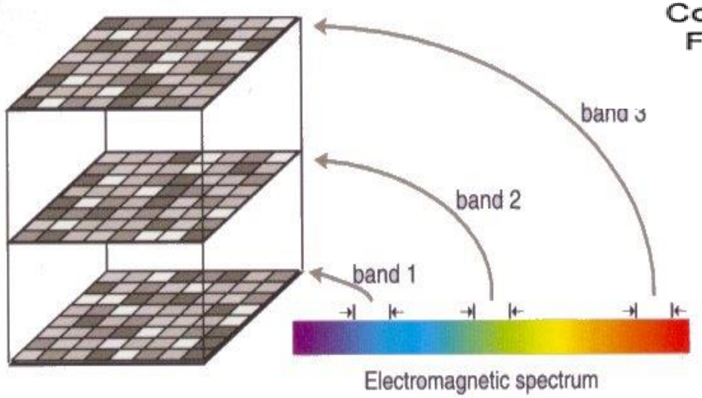
Spatial Resolution

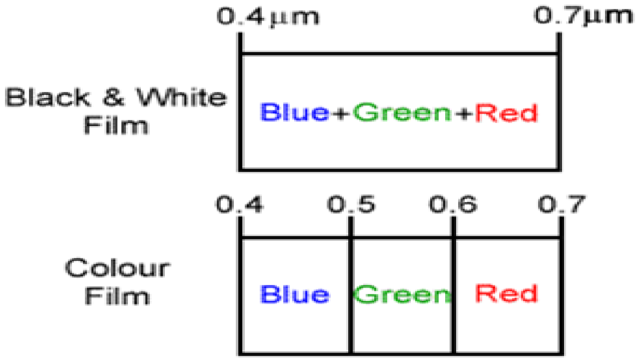
Smallest discernible detail in an image

IKONOS PAN 1m

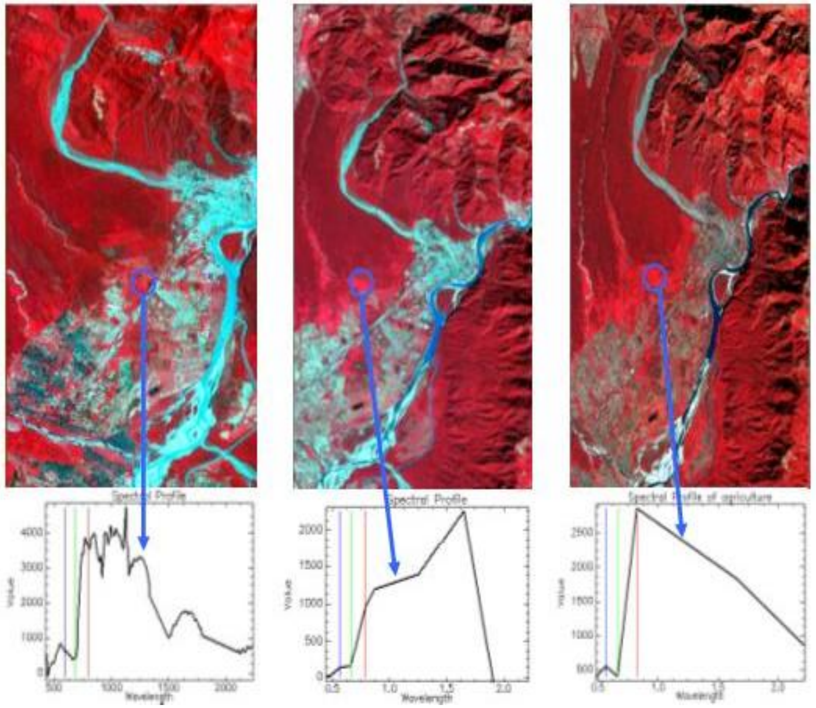
Spectral Resolution

- Spectral resolution describes the ability of a sensor to define fine wavelength intervals.
- This refers to the **number of bands in the spectrum** in which the instrument can take measurements.
- Higher spectral resolution = better ability to exploit **differences in spectral signatures**





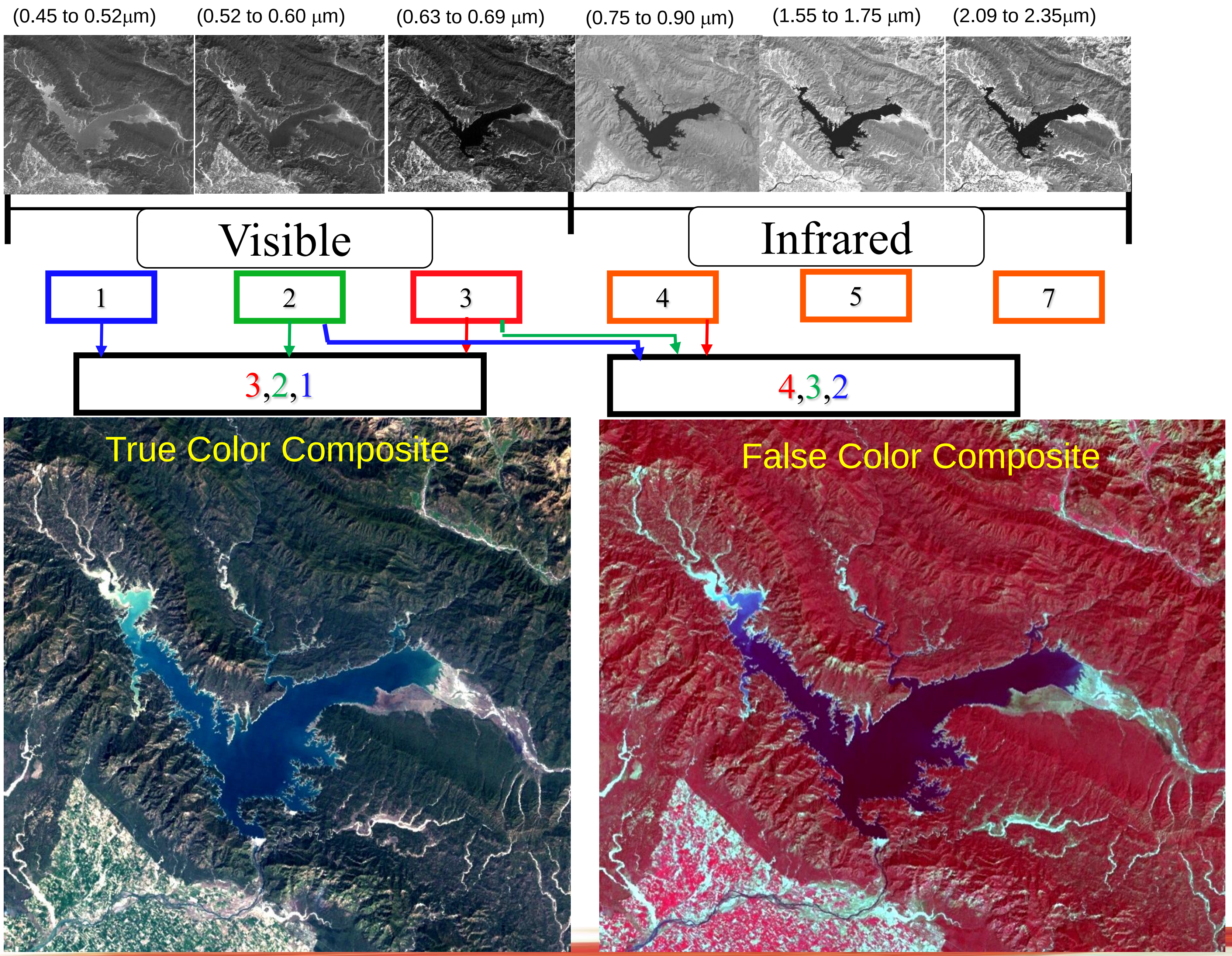
- **panchromatic**
- **multispectral**
- **hyperspectral**

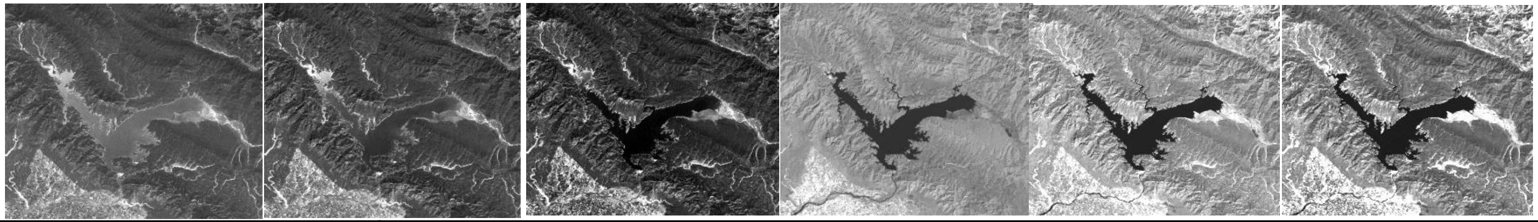


EO-1 Hyperion
Bands-150
(after processing)

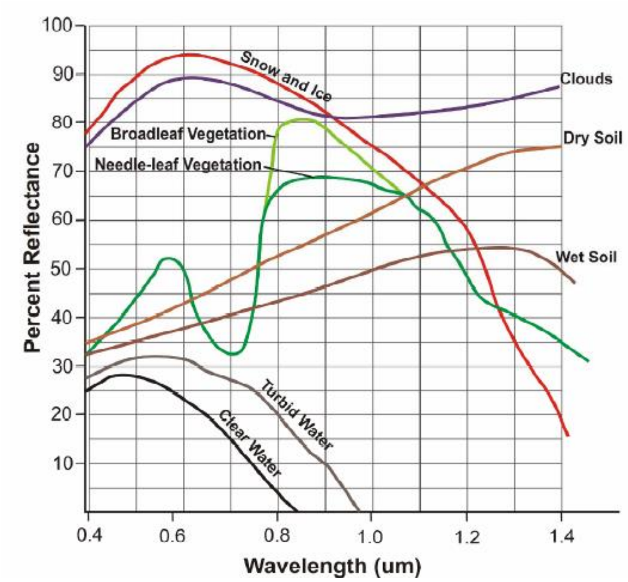
EO-1 ALI
Bands-9

Landsat-7 ETM+
Bands-6

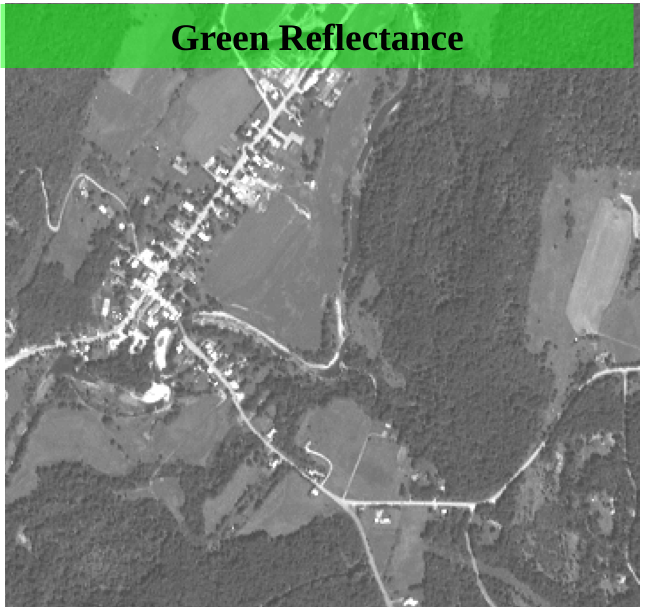

(0.45 to 0.52µm)
(0.52 to 0.60 µm)
(0.63 to 0.69 µm)
(0.75 to 0.90 µm)
(1.55 to 1.75 µm)
(2.09 to 2.35µm)
Visible
Infrared
1
2
3
4
5
7
3,2,1
4,3,2
True Color Composite
False Color Composite

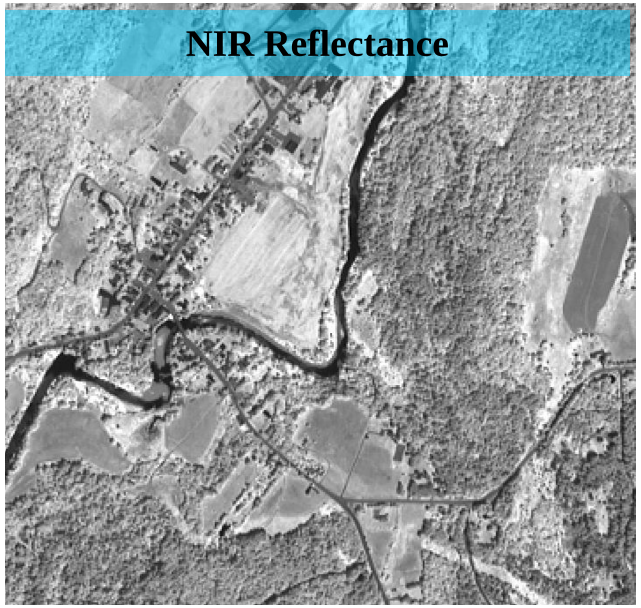


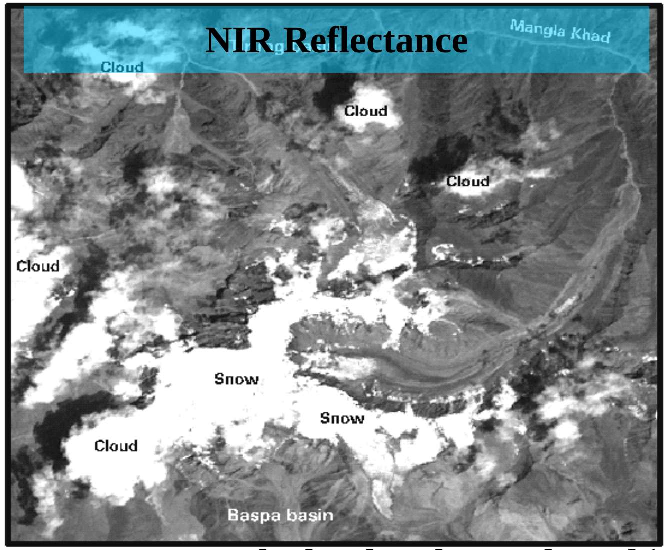
Band	Wavelength (μm)	Principal applications
1	0.45 – 0.52 (blue)	Penetration of clear water: bathymetry; mapping of coastal waters; chlorophyll absorption; distinction between deciduous and coniferous vegetation.
2	0.52 – 0.60 (green)	Records the green reflectance peak of vegetation; assesses plant vigor; reflectance from turbid water.
3	0.63 – 0.69 (red)	This band operates in the chlorophyll absorption region and is best for detecting roads, bare soil.
4	0.75 – 0.90 (NIR)	This band is used to estimate biomass. Although it separates water bodies from vegetation and discriminates soil moisture, it is not as effective as B3 for road identification.
5	1.55 – 1.75 (MIR)	Band 5 is considered to be the best single band overall. It discriminates roads, bare soil, and water. It also provides a good contrast between different types of vegetation and has excellent atmospheric and haze penetration. Discriminates snow from clouds,
7	2.09 – 2.35 (MIR)	This band is useful for discriminating mineral and rock types and for interpreting vegetation cover and moisture.

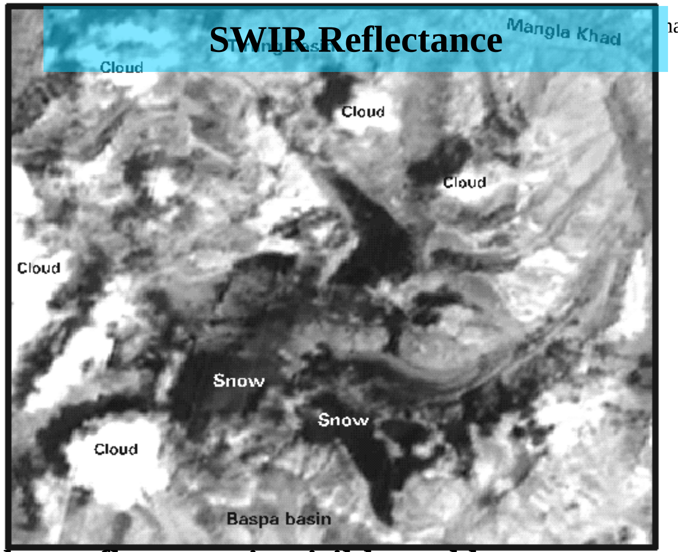


Spectral Signature of different Land cover Features









naging

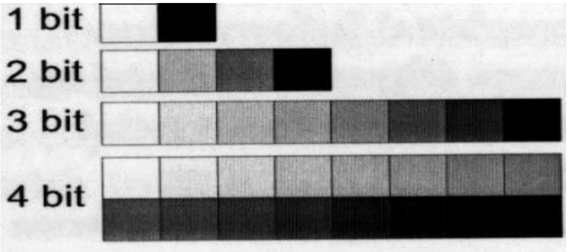
IRS LISS-3 Both cloud and snow have higher reflectance in visible and hence cannot be discriminated (except from shadow). In SWIR, low reflectance of snow can discriminate snow from cloud.

Radiometric Resolution

- It describes the actual information content in an image.
- Sensitivity to the magnitude of the electromagnetic energy determines the **radiometric resolution.**
- **The radiometric resolution of an imaging system** describes its ability to discriminate very slight differences in energy.
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.

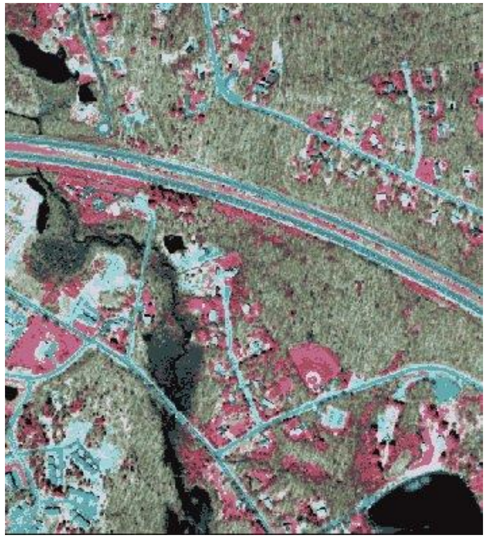
Radiometric Resolution

$2^{\text{(number of bits)}}$ = number of grey levels



1	2	0-1
2	4	0-3
3	8	0-7
4	16	0-15
5	32	0-31
6	64	0-63
7	128	0-127
8	256	0-255
9	512	0-511
10	1024	0-1203

256 colors



16 colors

2 colors

Temporal Resolution

- Represents the frequency with which a satellite can re-visit an area of interest and acquire a new image.
- Depends on the instrument's field of vision and the satellite's orbit

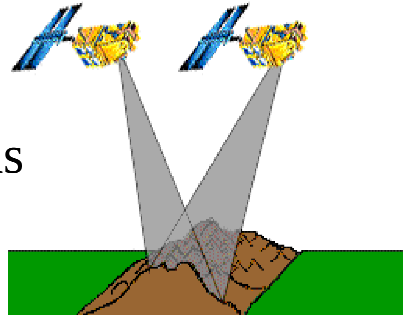
Application demand

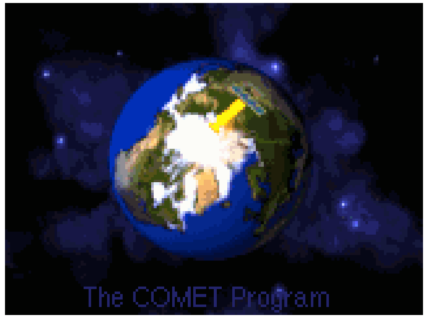
Meteorological → hourly need to monitor clouds

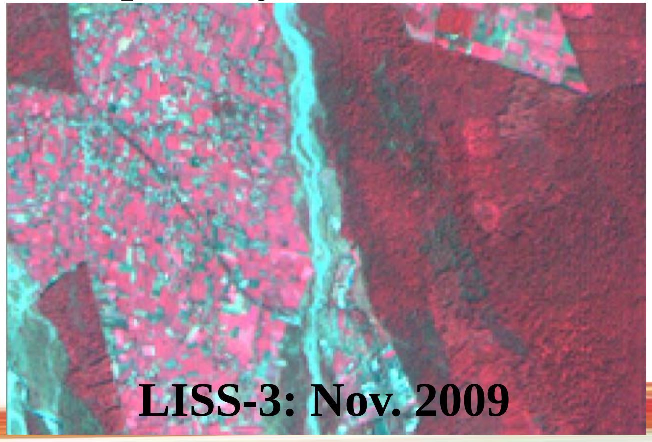
Oceanographic → 2-3 days of repetivity

Stereo viewing → 0-1 days of repetivity

Vegetation monitoring → 5 days of repetivity






LISS-3: Nov. 2009


LISS-3: Feb. 2009

Quiz Time

Q. Which scanner has lesser dwell time ………….

a) Across Track Scanners b) Along Track Scanners c) None of these

Q. **First remote sensing satellite was launched on ………….**

a) 1957 b) 1962 c) 1967 d) 1972

Q. Which scanner has lesser dwell time ………….

a) Across Track Scanners b) Along Track Scanners c) None of these

Q. Snow can be discriminated from cloud in …………. band

a) Red b) NIR c) SWIR d) None

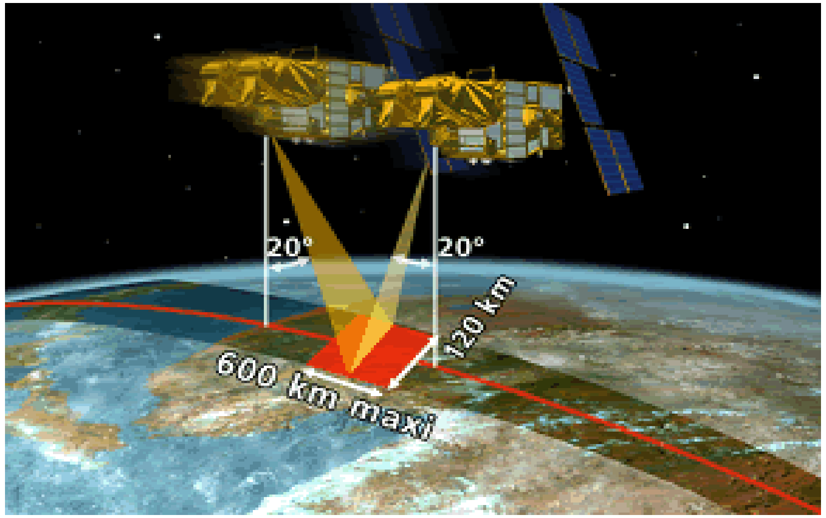
Various Earth Observation Satellites

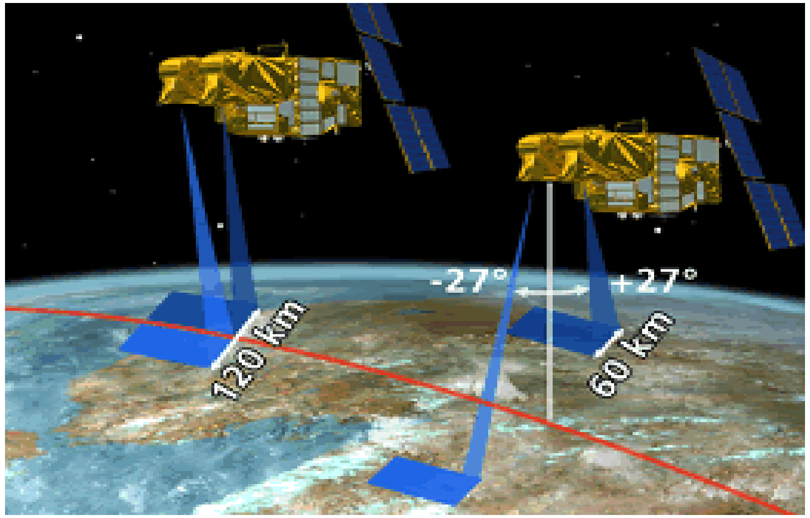
Europe		MIDDLE EAST	North America			Asia	
France	**ESA**	**Israel**	**USA**		**Canada**	**India**	**Japan**
SPOT1-86 10m			LANDSAT5-85 30m				
SPOT2-90 10m	ERS1-92/00 radar		LANDSAT6-93				
SPOT3-93/96	ERS2-95 radar		EARLYBIRD-98	IKONOS1-99 1m	RADARSAT-95	IRS1C-95 6m	
SPOT4-98 10m	ENVISAT-2001 Radar		LANDSAT7-99 15m	IKONOS2-99 1m		IRS1D-97 6m	
		EROS A/1-00 2m	QUICKBIRD-01 0.6m	ORBVIEW-01 1m		IRS P6-2003 5.8m	
SPOT5-02 3m+HRS10		EROS B/1-02 1m		ORBVIEW-02 1m	RADARSAT-03	CARTOSAT1-2.5m	ALOS 2.5m
SPOT6-2012 SPOT7-2014	Sentinel-1A & 1B-2014 & 2016 Sentinel-2A & 2B-2015 & 2017		Landsat8-2013			CARTOSAT2-<1m	
Distribution							
SPOT IMAGING	Miscellaneous Copernicus	Imagesat	SI-EOSAT, Earthwatch, Orbimage, USGS		RADARSAT	NRSC-EOSAT	Jaxa

Landsat Series of Satellites

- First launched in 1972
  - 185Km swath
  - **Multi Spectral Scanner (MSS)**
  - **4 bands (Green, Red, NIR x2)**
  - **80m** ground resolution
  - First Series - Landsat 1,2 and 3
- Landsat 4 Launched 1983
  - **Thematic Mapper (TM)**
  - Seven bands **-Blue, Green, Red, NIR, SWIR x 2, TIR**
  - **30m** ground resolution
- Landsat 6 failed after Launch
- Landsat 7 launched 1999
  - Additional 15m panchromatic
- **Landsat Data Continuity Mission (LDCM) launched on February 2013 with OLI and TIRS**
  - Additional coastal blue, Cirrus bands
  - **Two thermal band of 100 m resolution**

SPOT (Système pour l'observation de la Terre) **Series of Satellite**



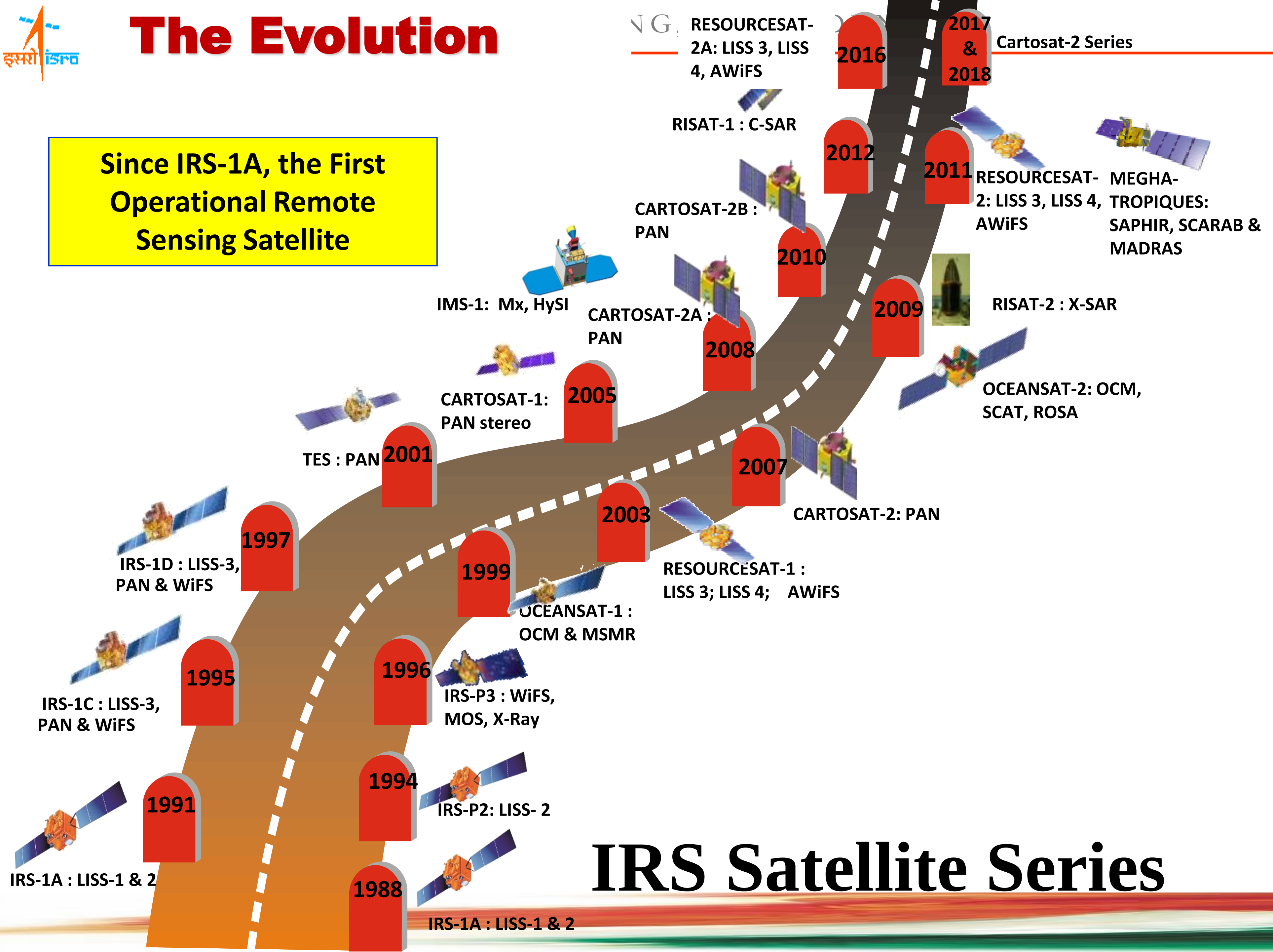


- French satellite SPOT-1 was launched in 1986
- Two modes of operation
- Off nadir look capability
- Stereo capability

***SPOT-6 (2012) & SPOT-7 (2014) form a constellation of Earth-imaging satellites designed to provide continuity of high-resolution, wide-swath data up to 2024**

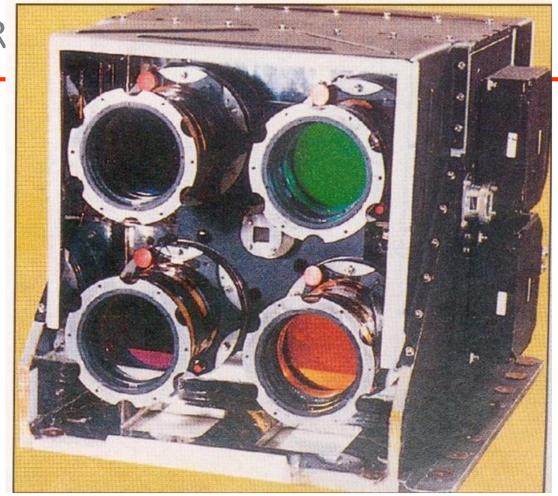
The Evolution

Since IRS-1A, the First Operational Remote Sensing Satellite

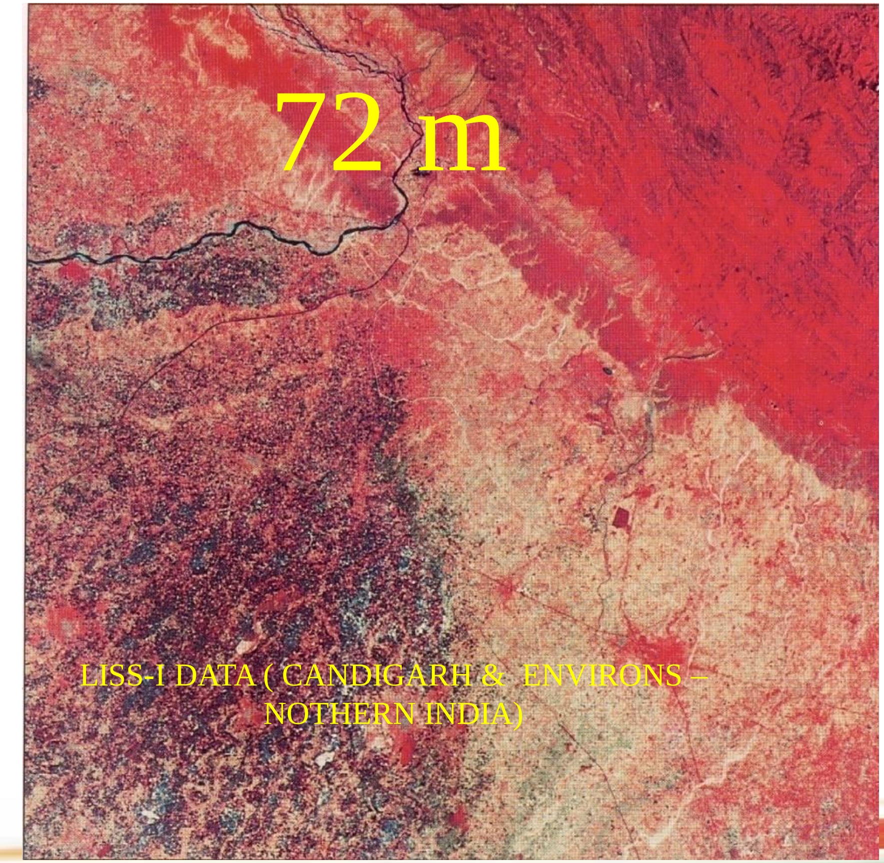


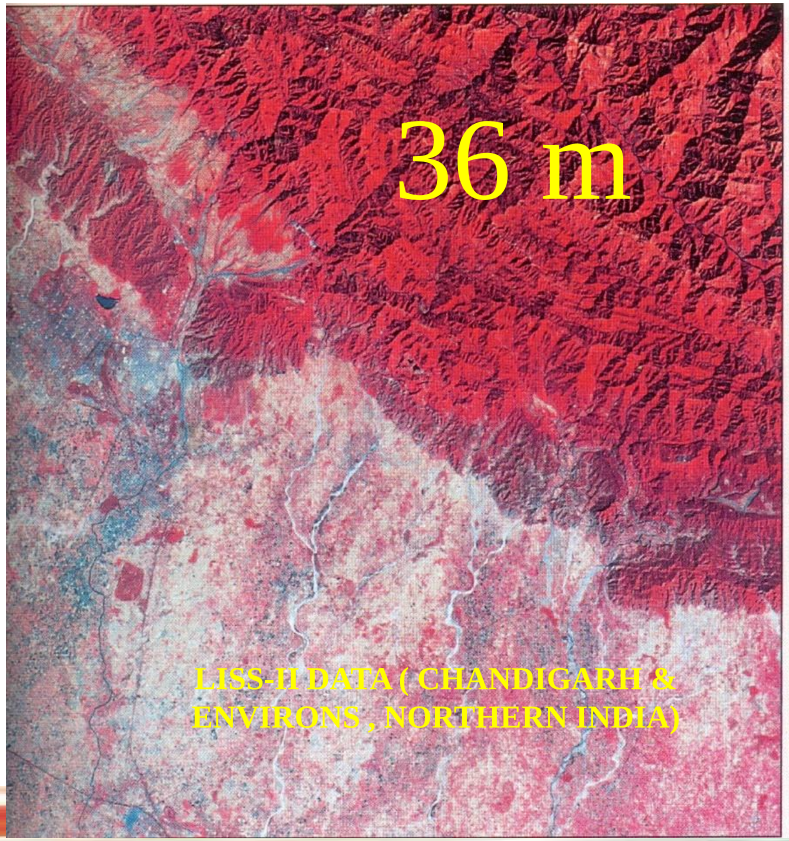
IRS Satellite Series

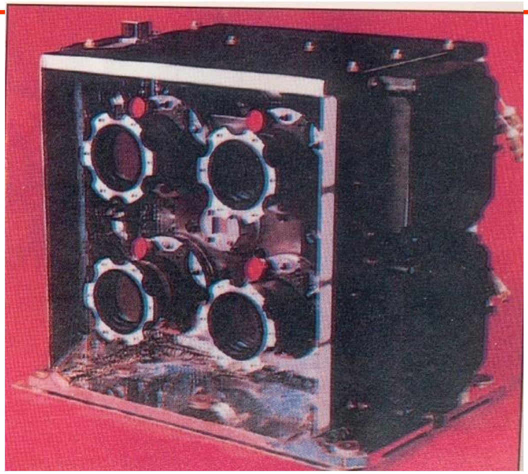
IRS : LISS-I CAMERA



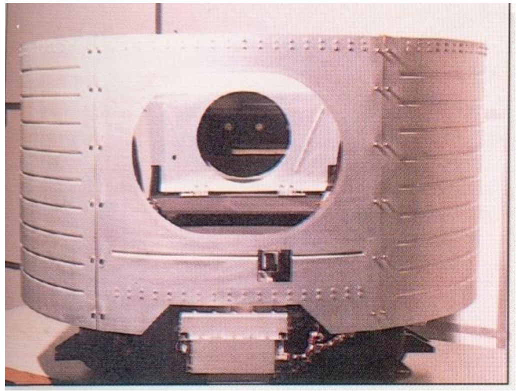
IRS : LISS-II CAMERA



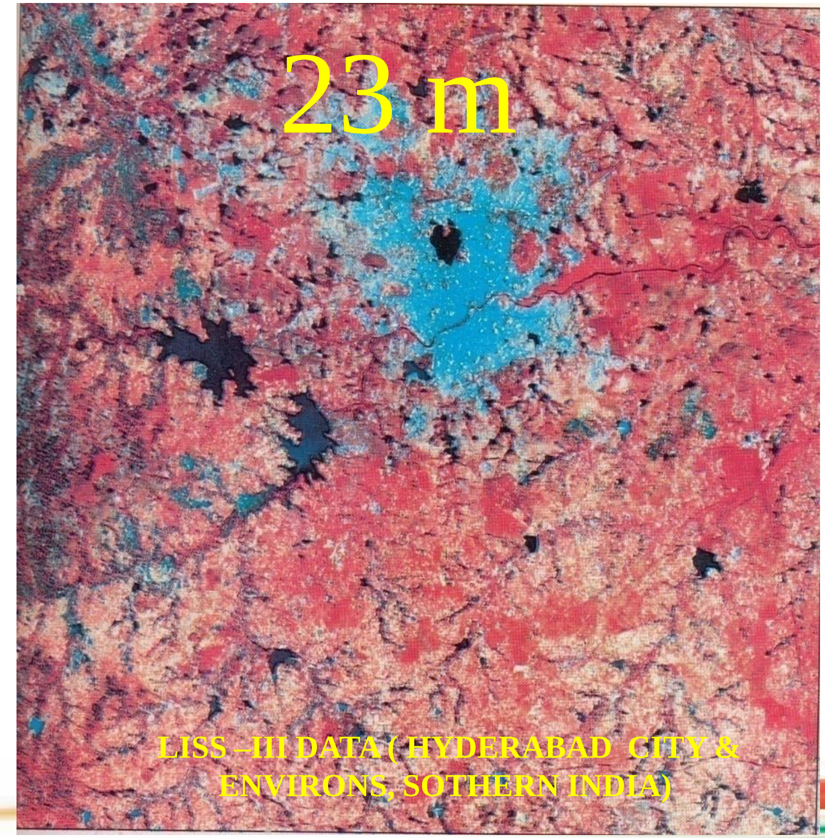




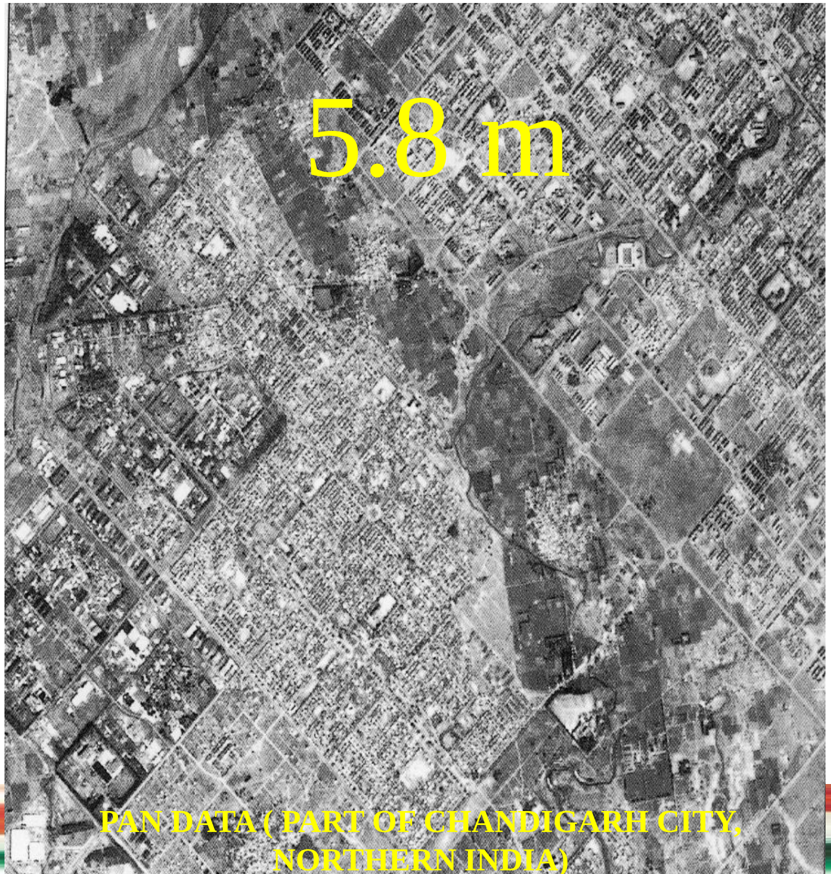
IRS : LISS-III CAMERA



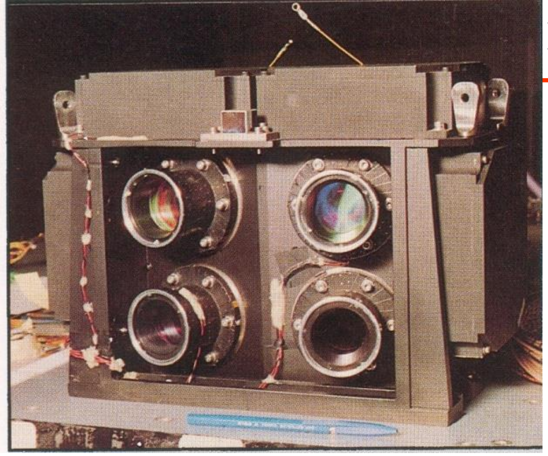
IRS : PAN CAMERA



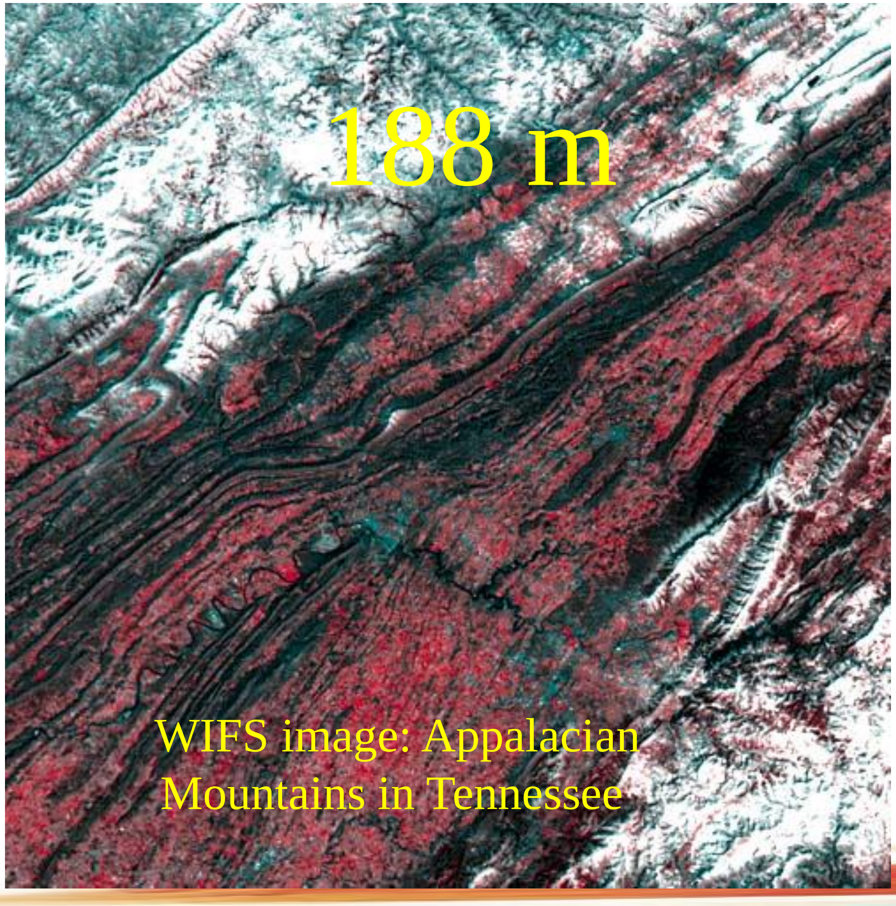
LISS –III DATA (HYDERABAD CITY & ENVIRONS, SOTHERN INDIA)

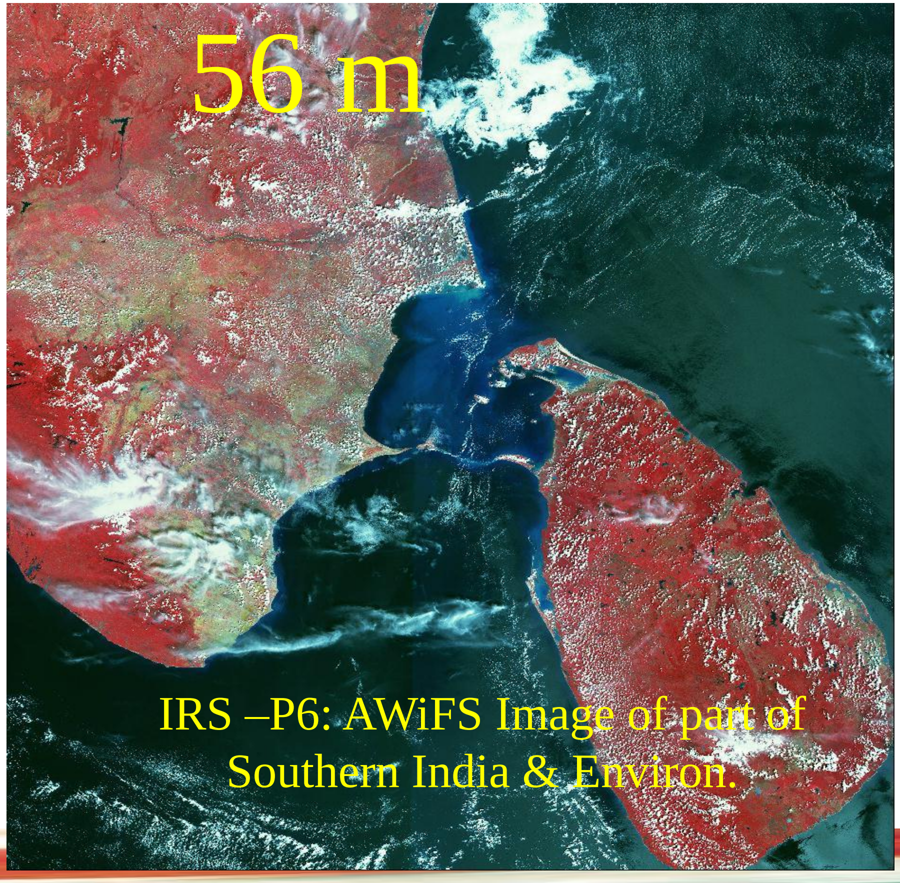


PAN DATA (PART OF CHANDIGARH CITY, NORTHERN INDIA)

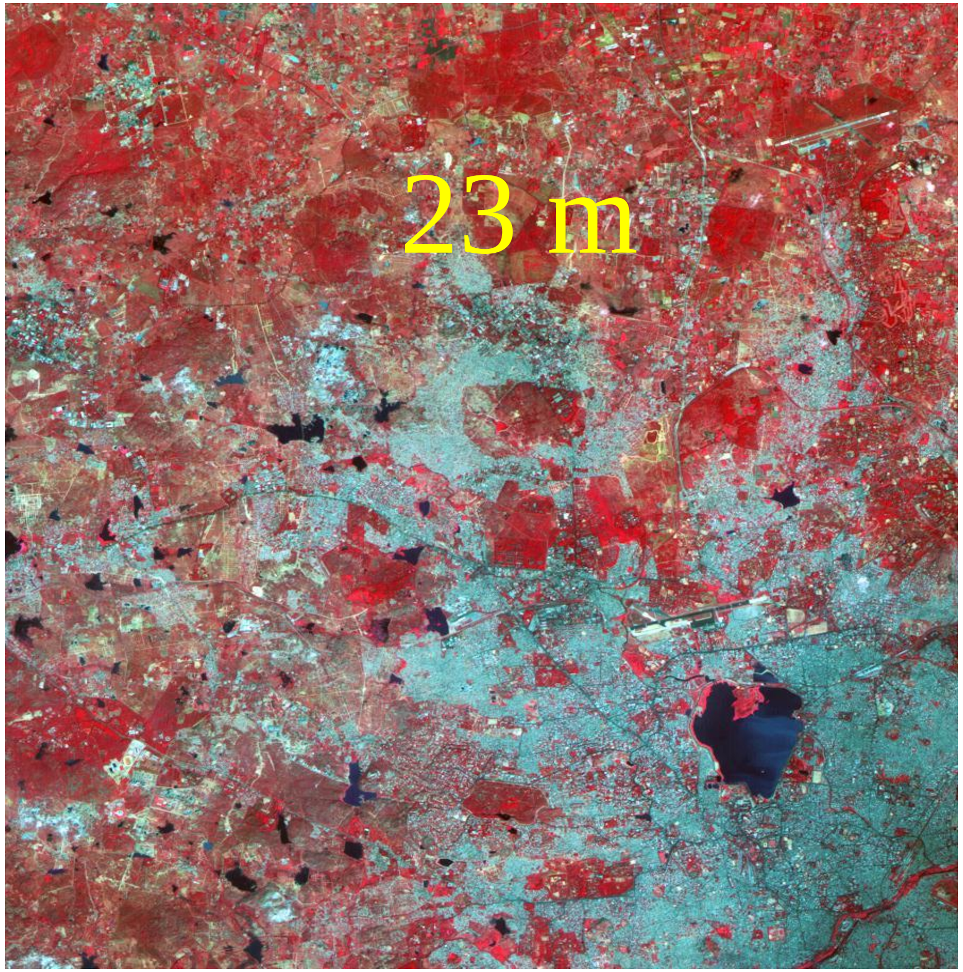


IRS : WiFS CAMERA

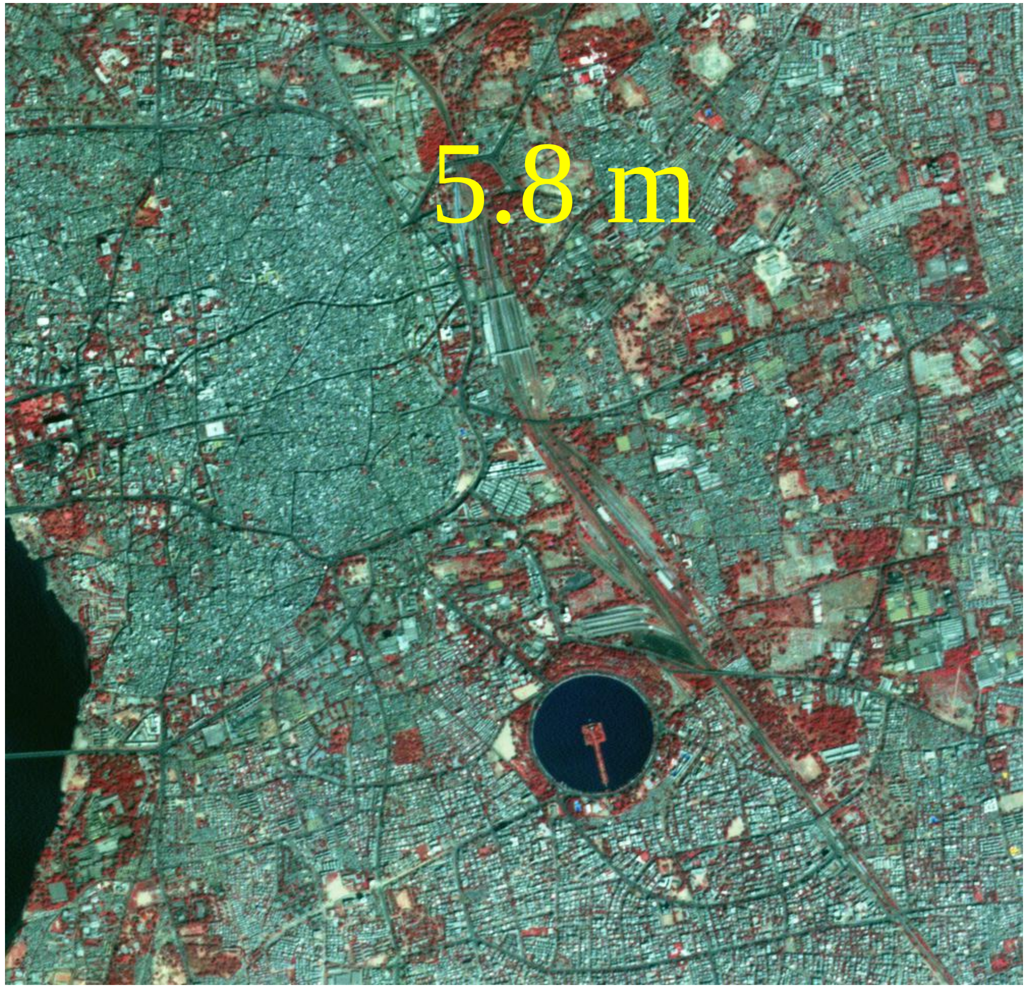




IRS –P6: LISS –III
Image of part of Hyderabad City



IRS –P6: LISS –IV
Image of part of Ahmedabad City



Cartosat-Images

Cartosat-2Series Image Part of Kishangarh city

Cartosat-2Series Image Part of Indore city

Indian EO Missions in the near future

- Cartosat 3 : Pan; 0.25 m, 16 km ; Mx; 1m, 16 km
- Resourcesat 3 & 3A : ALISS 3; 10m, 925 km, Atmcorr
- Oceansat 3 & 3 A: OCM of 13 bands, Ku band scat
- RS Sampler 3S & 3SA: 1.25m stereo imaging
- GISAT 1 : HR Mx VNIR; 50m, SWIR; 1.5 km, HYSI

High Spatial Resolution satellites

- IKONOS

It is first commercial satellite to deliver near photographic quality imagery of anywhere in the world from space.

- QUICK BIRD
- WORLDVIEW 1, 2, 3 & 4
- GEOEYE
- PLEIADES-1A & 1B
- SKYSAT-1 & 2
- KOMPSAT-1, 2, 3 & 3A

IKONOS Image of IIRS

Fukushima Daiichi Nuclear Power Plant

GeoEye-1 Image,
Nov. 15, 2009

IKONOS Image
March 17, 2011


KOMPSAT 3


WORLD VIEW-3


KOMPSAT 3A


WORLD VIEW-4

Meteorological Satellites

- Designed specifically for **weather prediction and monitoring**
- Advantages of **global coverage** at very high temporal resolution.
- Various types of meteosats are as follows:

  e.g. →**NOAA series** (operated by U.S. named after the National Oceanic and Atmospheric Administration). These have near-polar, sun-synchronous orbits.

  →**GOES, GSAT & INSAT** series satellites are in geo-stationary orbits.

- India has launched **GSAT & INSAT series** satellites, which are telecommunication, and meteorological satellites.

Where to find this information?

- 100's of websites of vendors, distributors, value adders, NGO's Or http://www.itc.nl/research/products/sensordb/searchsat.aspx

- Real time satellite tracking
  http://www.satview.org/

Data Browsing Websites

- http://earthexplorer.usgs.gov/
- http://www.nrsc.gov.in/
- http://www.spaceimaging.com
- http://www.digitalglobe.com
- http://edcimswww.cr.usgs.gov/pub/imswelcome/
- http://www.spotimage.fr/home
- http://bhuvan-noeda.nrsc.gov.in/download/download/download.php
- https://scihub.copernicus.eu/dhus/#/home
- http://glcf.umiacs.umd.edu/data/
- http://www.usgs.gov/pubprod/
- https://cross.restec.or.jp/cross-ex/topControl.action?language=en-US

Thank You

Email: vinaykumar@iirs.gov.in

The material for the presentation has been compiled from various sources- books, tutorials, IRS satellite-datasets and several resources on the internet