Introduction to Remote Sensing and GIS

MSTL, NALSAR

III SEM: Laws of Remote Sensing and Geospatial Data

WHAT IS REMOTE SENSING ?

Science of making inferences about objects/targets from measurements made without actual physical contact with them. More commonly remote sensing is associated with identification of earth features by detecting and recording electro-magnetic (EM) radiation reflected or emitted from earth's surface and atmosphere

ACTIVE REMOTE SENSING

PASSIVE REMOTE SENSING

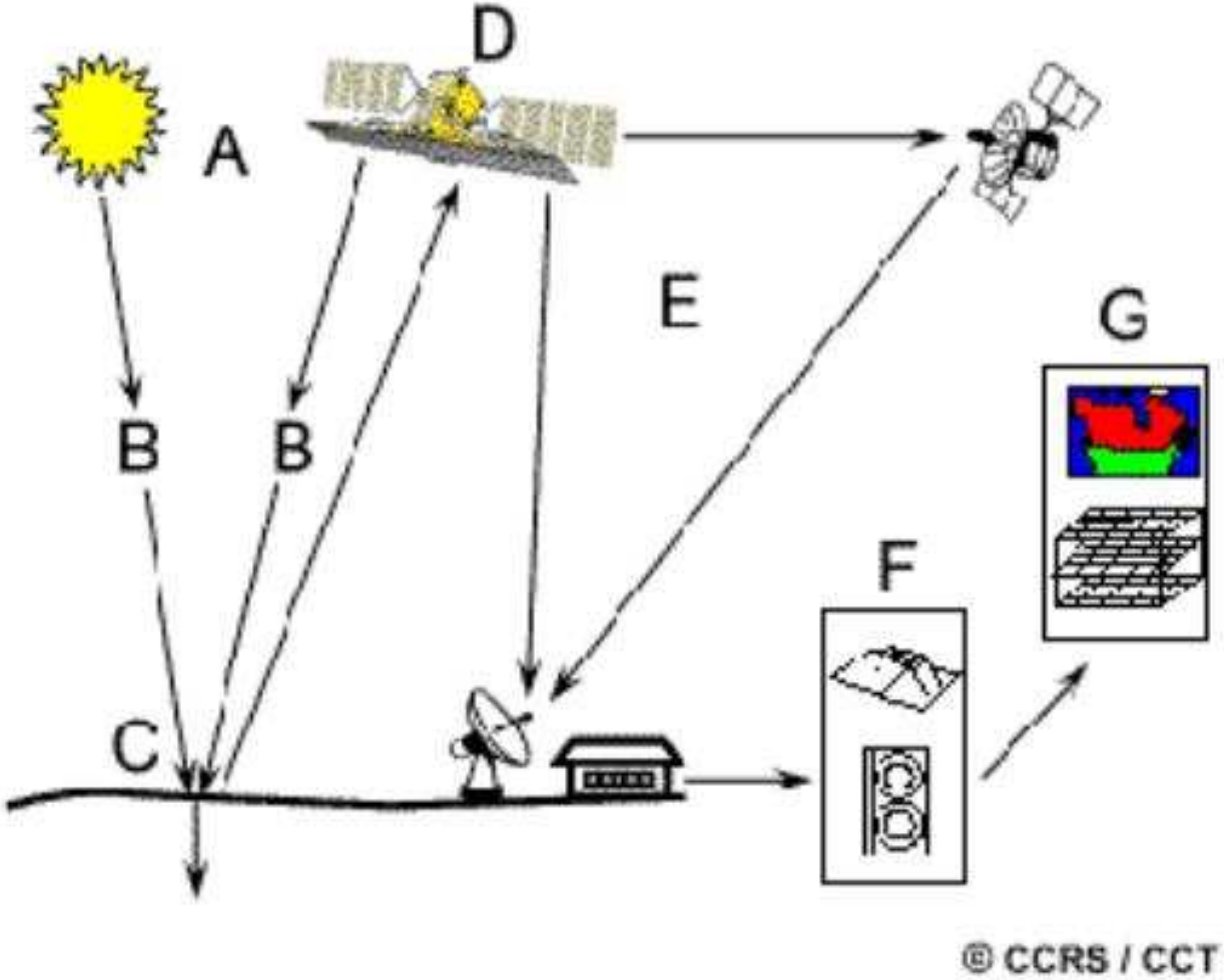
Illustration of the remote sensing concept:

An instrument (i.e., sensor or scanner) mounted on an aircraft or satellite records information about objects and/or areas on the ground.

Typically, these data are spectral in nature, meaning that they document the amount of electro-magnetic energy associated with the targeted objects and/or areas.

The extent, or footprint, of the geographic area captured in a single sensor scene depends on the sensor's design and the altitude of the aircraft or spacecraft on which it is mounted.

Process in Remote Sensing

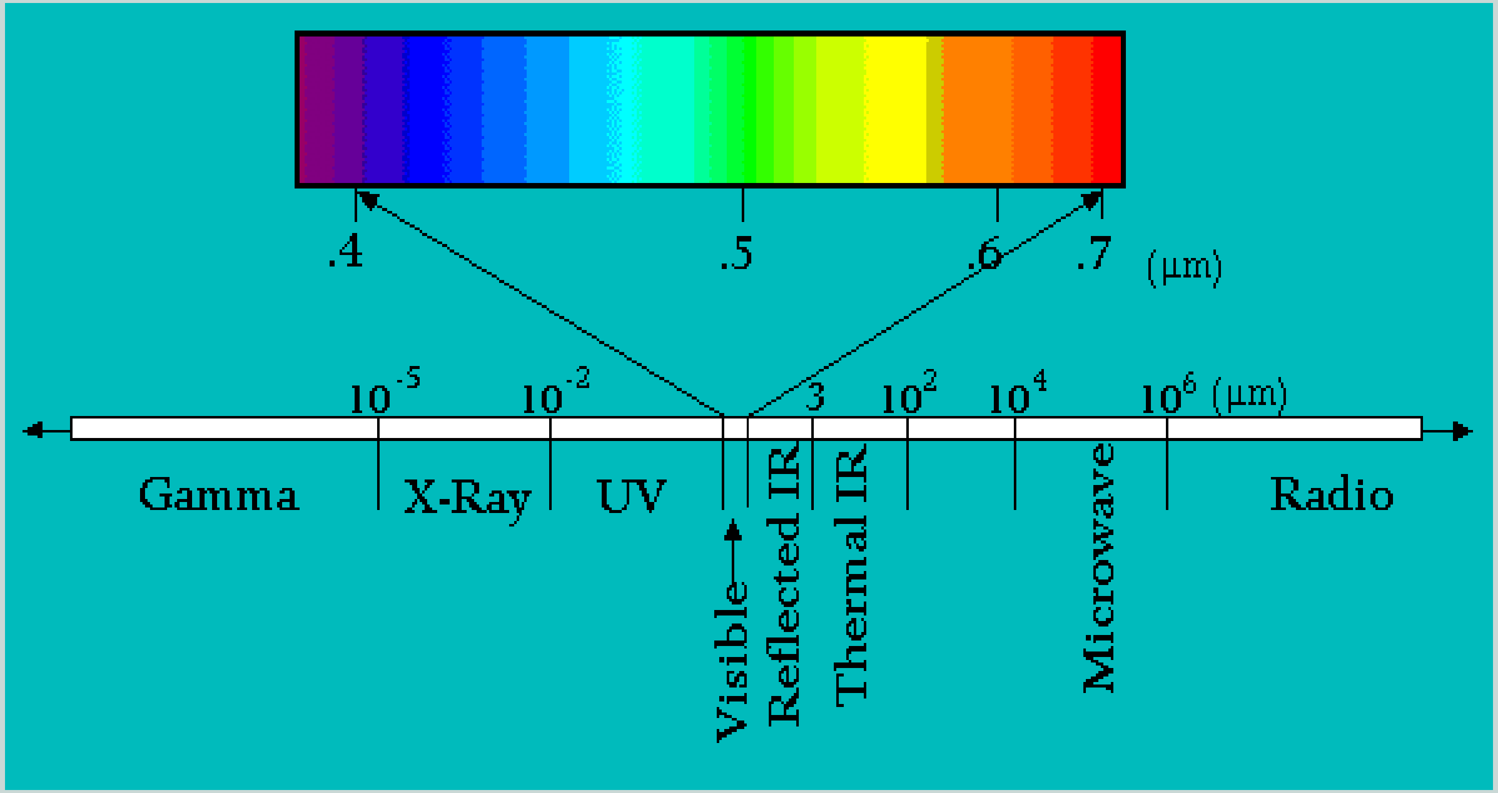


A. Energy Source
B. Radiation & Atmosphere
C. Interaction with Target
D. Recording of Energy by Sensor
E. Transmission, reception &processing
F. Interpretation and analysis
G. Application

REMOTE SENSING ADVANTAGES

- SYNOPTIC COVERAGE
- REPEATED OBSERVATION
- MULTI SPECTRAL IMAGING
- INFORMATION IN SPATIAL DOMAIN
- STEREO COVERAGE
- TIMELY AND ECONOMIC
- GLOBAL TO LOCAL APPLICATIONS

ELECTRO MAGNETIC SPECTRUM



Optical Sensors operate in the visible part of the electromagnetic spectrum, measuring electromagnetic radiation emitted by the sun and reflected by land and ocean surface.

OPTICAL REMOTE SENSING : 0.4 – 3.0 µ meters

MICROWAVE REMOTE SENSING : L, C, X, Ku, Ka bands

THERMAL REMOTE SENSING : 8 – 15 µ meters

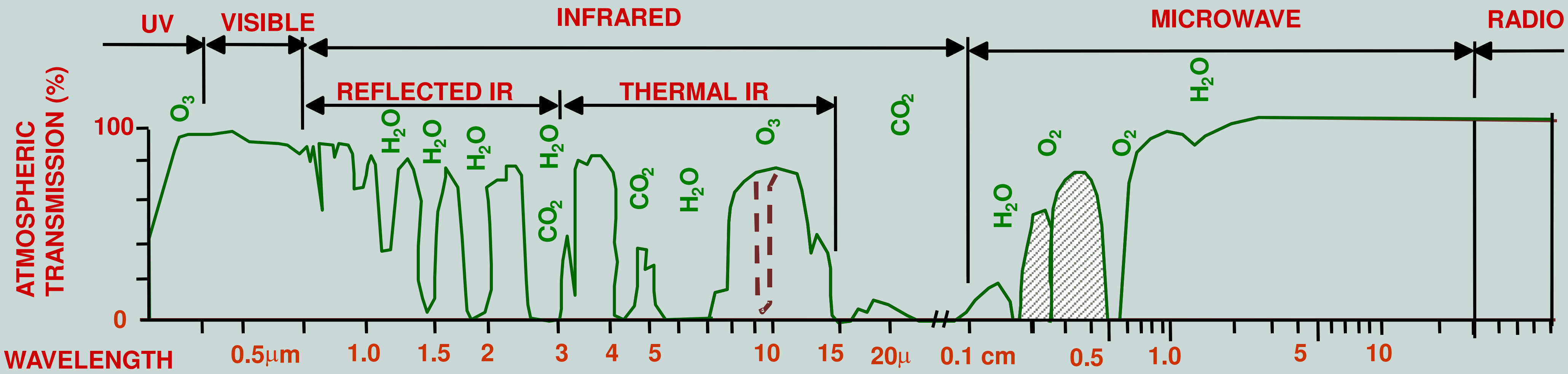
ATMOSPHERIC WINDOWS FOR EARTH OBSERVATIONS

Atmosphere practically transparent in visible EM region, whereas opaque in other regions. Remote sensing utilizes the transparent regions known as windows to avoid the effects of absorption of radiation.

0.38 - 0.78 Microns (visible)

0.72 - 3.00 Microns (middle IR, near IR)

8.00 - 14.00 Microns (thermal IR)



EFFECT OF ATMOSPHERE

The following compounds of the atmosphere change its transmittance:

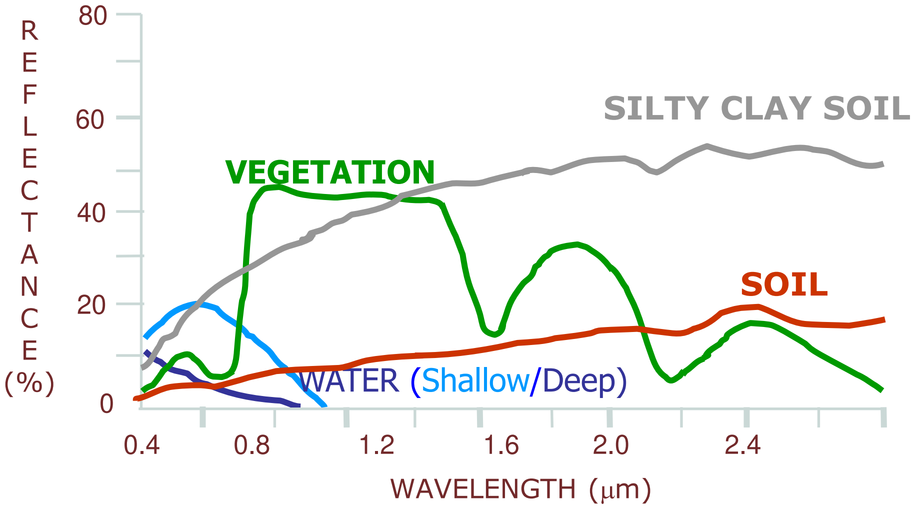
- **Gas molecules themselves**
- **Water vapor**
- **Aerosols**
- **Suspended particles of dust**
- **Water droplets in the form of clouds**

Rayleigh Scattering: when much small particles comparable to wavelength size interact with the light (radiation) in upper regions of atmosphere. Shorter wavelengths scatter more. Ex: Blue sky

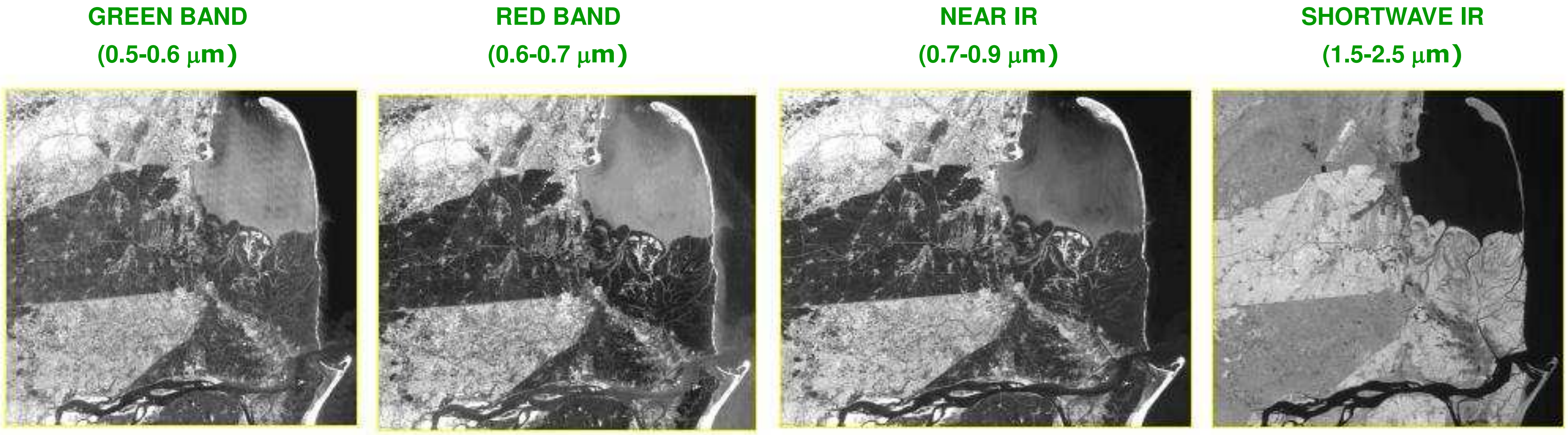
Mie Scattering: when particles are of comparable size to wavelength (dust, pollen, smoke), higher wavelength scatter more. Ex: morning sky's grazing light, reddish sky

Absorption in atmosphere: Carbon dioxide, water vapor, Ozone absorb at specific wavelength ranges. Carbon dioxide absorbs Longwave emissions from earth and warms up (green house effect). Ozone absorbs UV radiation from Sun and protects earth life.

MULTI SPECTRAL REMOTE SENSING



Incident EM energy interacts with the 'Target' and the resultant scattered wave contains the 'Finger print' of the target, in terms of its unique 'signature'. Reflected or emitted electromagnetic energy from earth surface is observed in different wavelengths (bands) of the spectrum to understand the target signature.



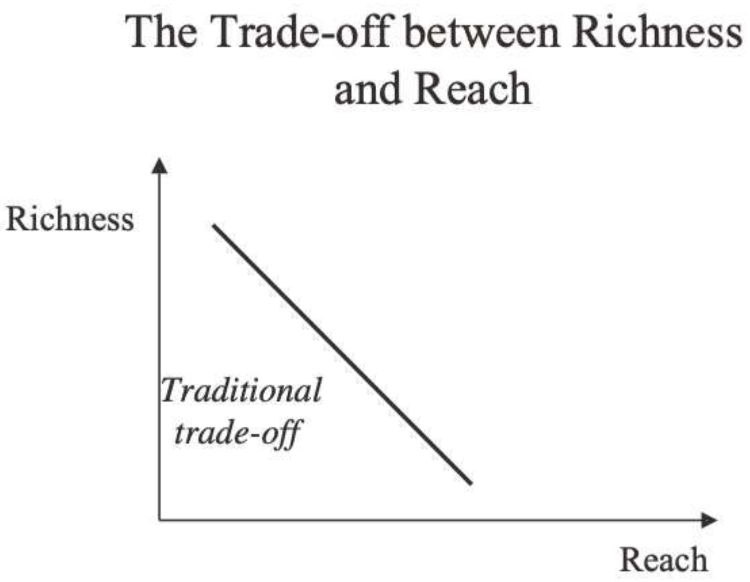
Selection of Spectral Bands

Spectral range (µm)	Major Application
0.45 – 0.52 (B1)	Sensitivity to Chlorophyll ; coastal water mapping soil/vegetation discrimination, forest mapping
0.52 – 0.59 (B2)	Green reflectance from healthy vegetation
0.62 – 0.69 (B3)	Sensitivity to chlorophyll ; water type discrimination ; plant species identification
0.76 – 0.90 (B4)	Water body delineation ; vegetation vigour and biomass determination
1.55 – 1.75 (B5)	Water stress in vegetation, snow / cloud differentiation ; drought monitoring
2.08 – 2.35	Discrimination of minerals and Rock types, identification of hydrothermal alterations in rocks
10.4 – 12.5	Surface temperature mapping incl. SST

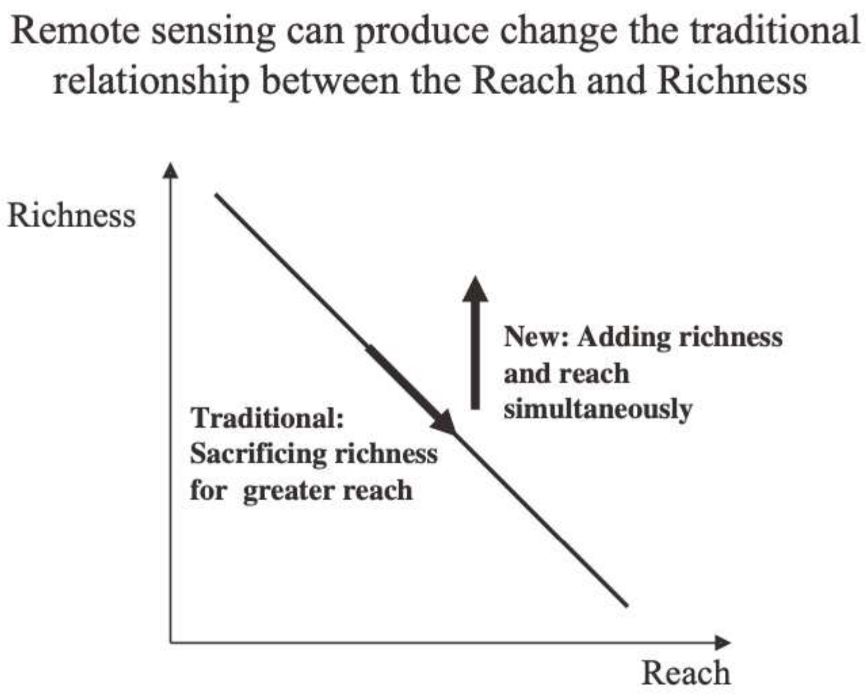
Useful Microwave channels

Frequency (GHz)	Application
1.4	Sea salinity, soil moisture
2.7	- do –
6.7 – 7.1	Ocean surface Temp.
10.6	Rain, snow, Ice
18.7	Water vapour
21	Liquid water content
36.5	Rain, snow, water vapour
50.3	O_2 Temperature profiling
86 – 92	Clouds, oil spills, ice, snow
183	H_2O, moisture profiles, N_2O
200 – 209	H_2O,O_3,N_2O

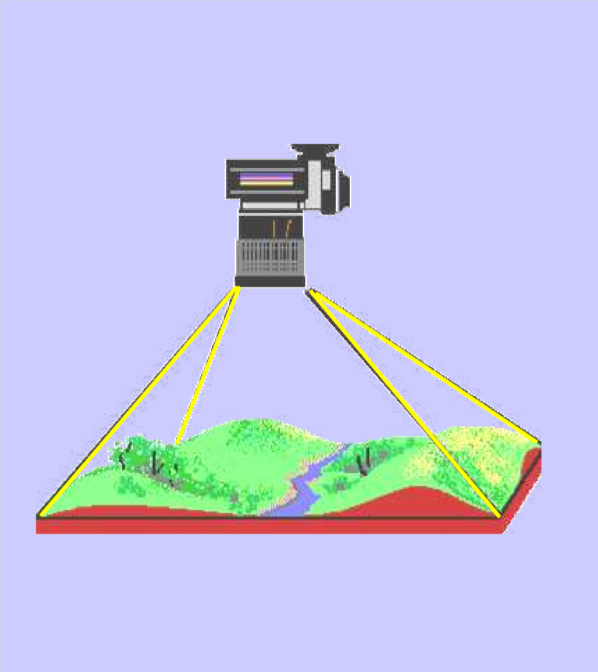
Reach/ Richness trade-off of Remote sensing data



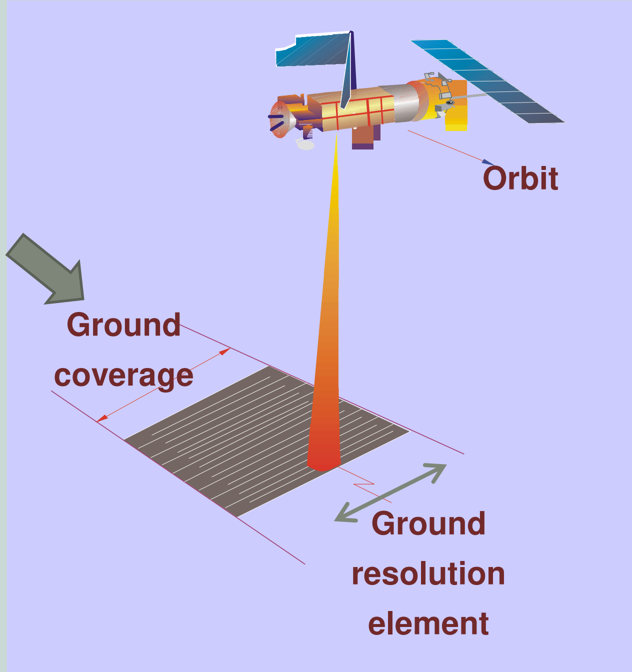
Source: P. B. Evans and T. S. Wurster, "Strategy and the New Economics of Information," Harward Business Review, Sept.-Oct. 1997, p. 74.



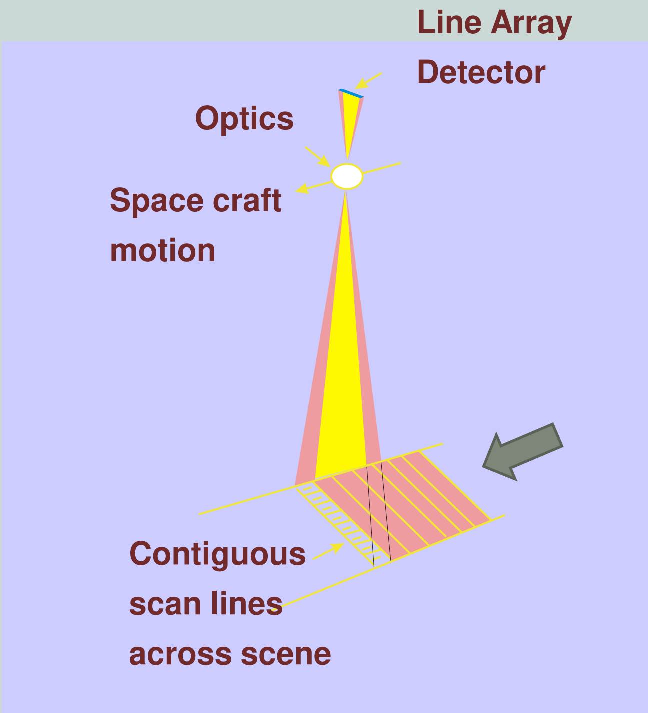
IMAGING SENSORS – TYPES OF SCANNING



AREA ARRAY



WHISK BROOM



PUSH BROOM

Push-broom Scanners using Charge Coupled Devices offer advantages like longer dwelling time (more signal), no moving parts (high reliability) and high geometric fidelity

Trade-offs among optics, altitude and detector size

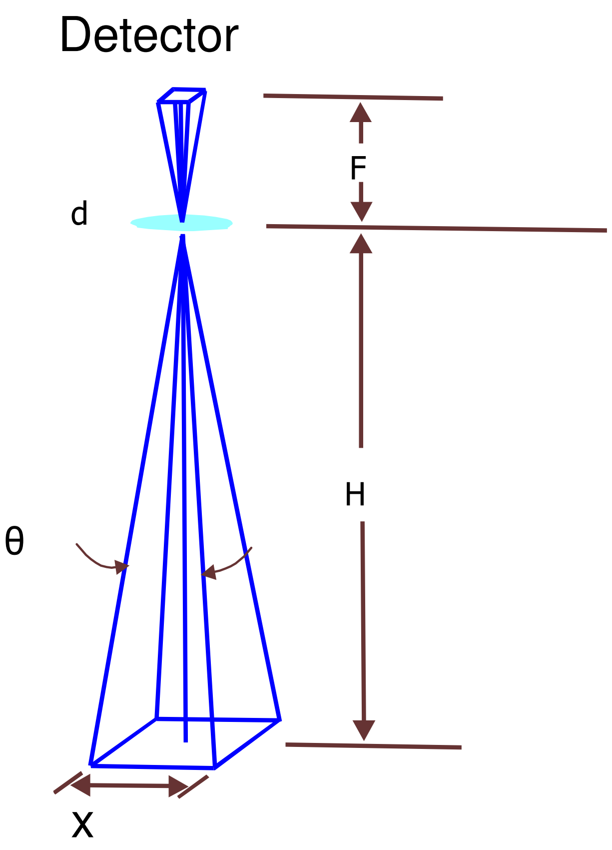
- IGFOV is governed by the relation, $d / F = x / H$

(IGFOV= Instantaneous ground field of view, H= altitude,
x= IGFOV or pixel size, d= aperture of the optics, F= focal length)

- IGFOV (x) = $2 \times \tan\theta/2 \times H$

- f/no = F / Aperture diameter

Smaller the f/no , Higher will be the Signal to Noise Ratio



Irradiance at image plane is inversely proportional to square of f/no.

Larger focal number—slow optics (light gathering capacity is low)

Passive microwave radiometers

Passive microwave radiometers operate at electromagnetic wavelengths 1.5–300 mm (i. e., the frequency 1–200 GHz).

Their advantage is the

• comparatively long wavelength, which is not sensitive to scattering by the atmosphere or aerosols, haze, dust, or small water particles in clouds

• the microwave sensors are all-weather devices.

• This advantage is countered by the fact that thermal emission is very weak at these longer wavelengths.

• To overcome noise levels a large field of view must be received; that results in low spatial resolution (25–150 km).

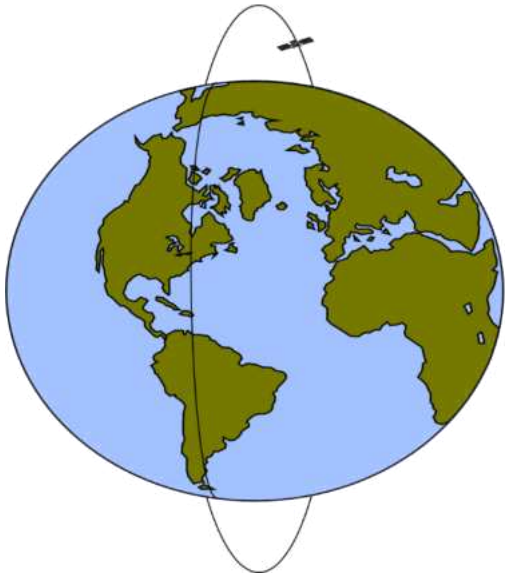
The emissivity of the sea at microwave frequencies varies with the dielectric properties of sea water (including salinity) and the surface roughness.

DATA RECEPTION AND PRE-PROCESSING

- Geometric Corrections
  - Earth rotation
  - Earth curvature
  - Platform attitude
  - Sensor alignments
- Radiometric Corrections
  - Sensor detector response variation
  - Non-uniform illumination

ORBITS

- Orbit height, swath width, resolution and life time trade-offs
- Repetition of path/ revisit consideration



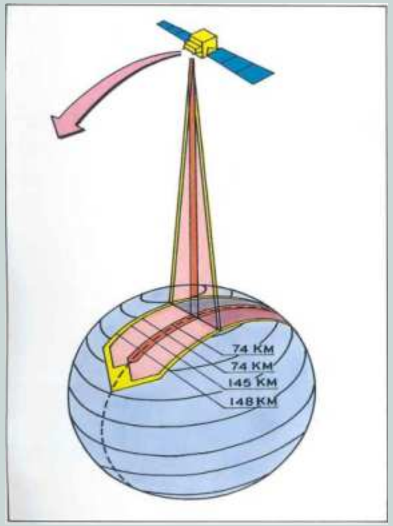
- SUN SYNCRONOUS POLAR ORBITS
  - Sub-recurrent orbit
  - Combined repeat cycle

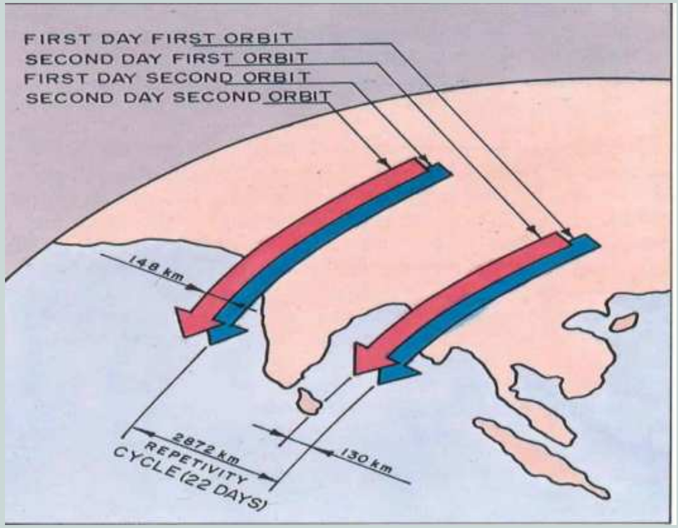
  Landsat 7 & 8 together….8 day repeat cycle
  Sentinel 2A and 2B together … 5 day revisit

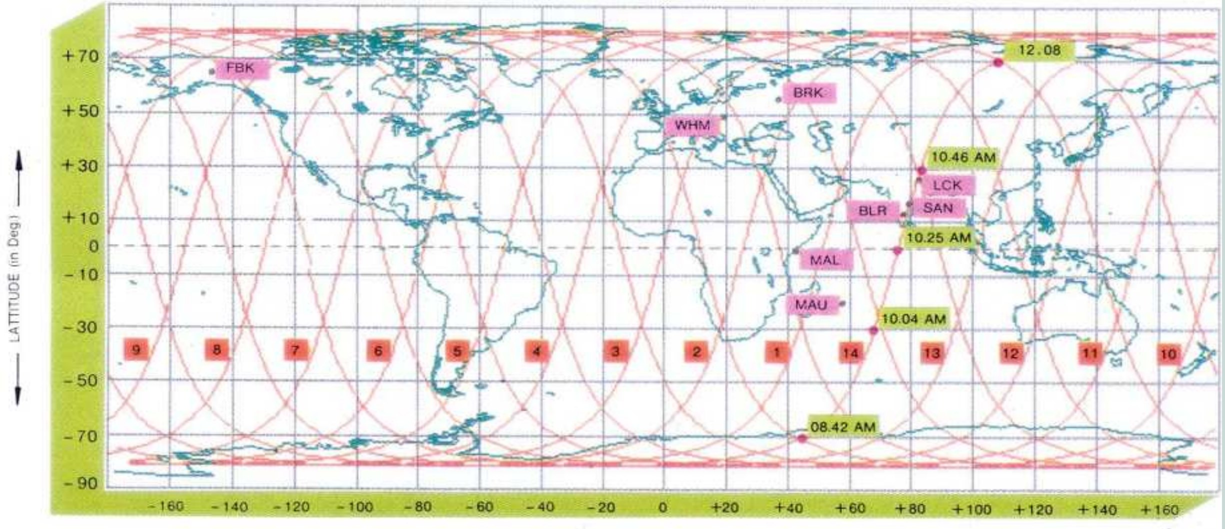
- GEOSTATIONARY EARTH ORBIT
  - Altitude 35, 786 km

- Constellations
- Formation flights

DATA COLLECTION – COVERAGE PATTERN





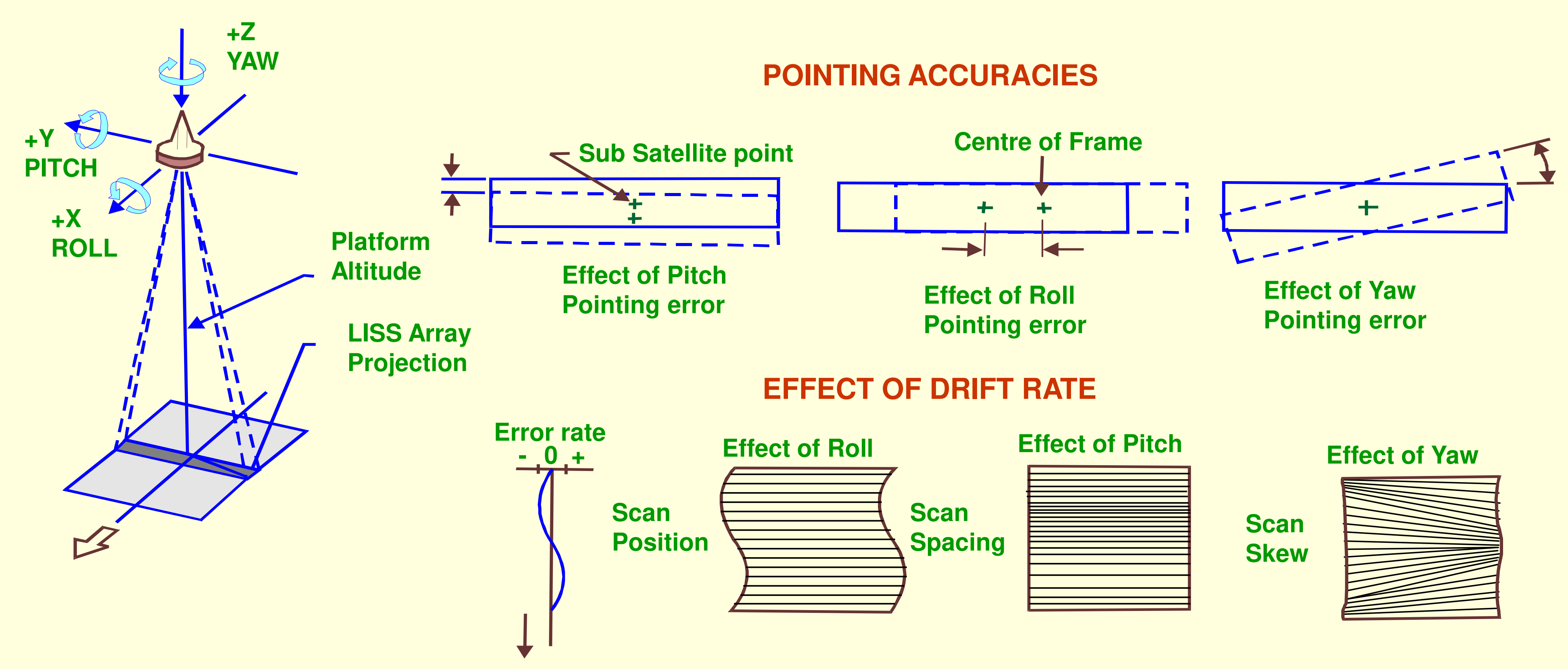


GROUND TRACE FOR IRS SATELLITES

- **Multi-spectral imaging**
  - to identify / discriminate targets
- **Multi-date imaging**
  - to monitor temporal changes
- **Multi-directional imaging**
  - to obtain bidirectional/ polarisation signatures
- **Multi-station imaging**
  - global coverage

SPACECRAFT ATTITUDE EFFECT ON IMAGERY

- Pointing accuracy affects location accuracy
- Angular velocities (drift rates) distorts image and affects pixel registration
- Jitter affects the resolution



Johnson's criteria of interpretation

- Detection - an object is present: 2 +1/-0.5 pixels
- Orientation - symmetrical, asymmetric, horizontal or vertical: 2.8 +0.8/-0.4 pixels
- Recognition - the type object can be discerned, a person vs. a car: 8 +1.6/-0.4 pixels
- Identification - a specific object can be discerned, a woman vs. a man, the specific car: 12.8 +3.2/-2.8 pixels

These measurements give a 50% probability of an observer discriminating an object to the specified level.

CONCEPT OF RESOLUTION

Quality of information derived from RS images strongly influenced by spatial, spectral, radiometric & temporal resolutions as well as by angular & polarimetric signatures

- **Spatial Resolution**

  instrument resolving power needed to spatially discriminate the smallest object
- **Spectral Resolution**

  encompasses the width of bands used from the wavelengths of the EM spectrum.
- **Radiometric Resolution**

  quantify No. of discernible signal levels in a band, {sensor's ability to discriminate radiance differences (NE$\Delta\rho$)}
- **Temporal Resolution**

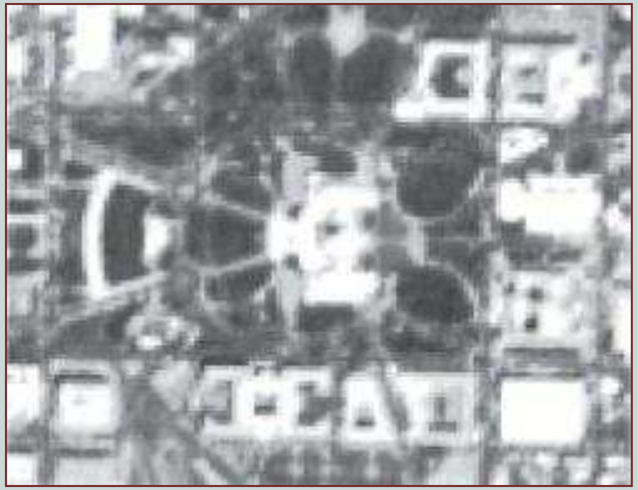
  time interval between imaging collections over the same geographic location

SPATIAL RESOLUTION - DISCRIMINABILTY

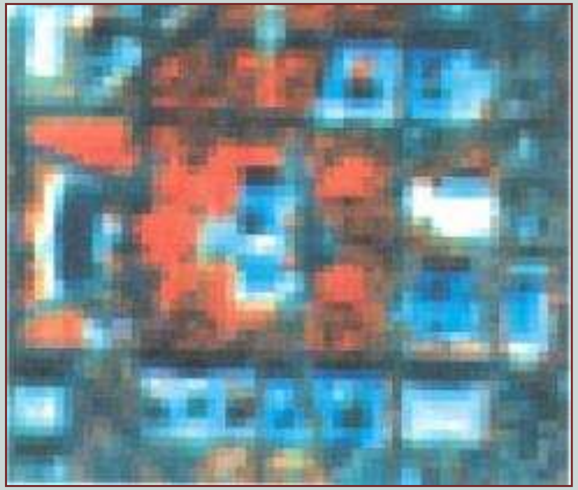
Ikonos Pan - 1 m GSD

Ikonos Colour - 4 m GSD

IRS-1C Pan – 5.8 m GSD



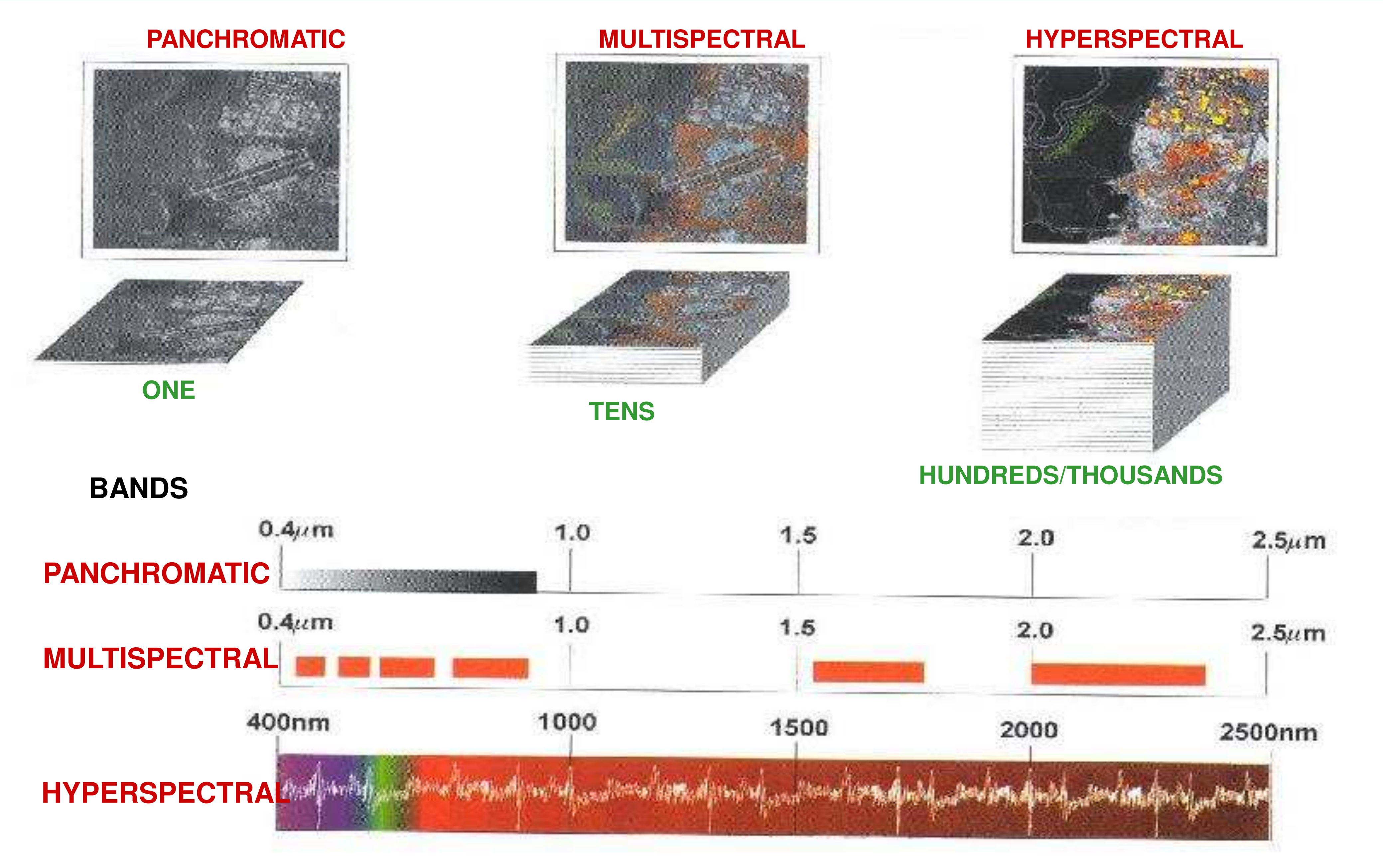
SPOT Pan - 10 m GSD



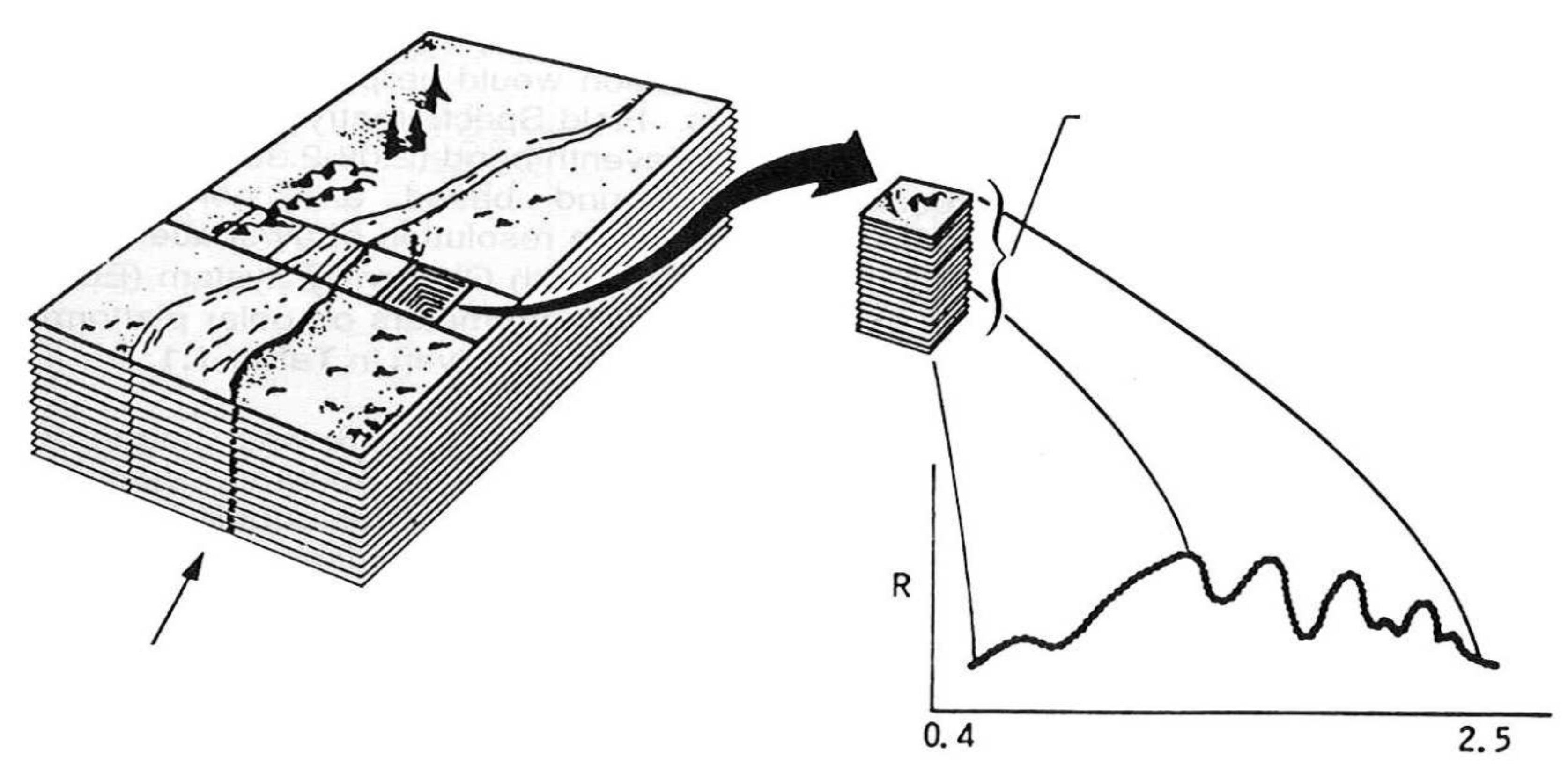
SPOT XS - 20 m GSD

LANDSAT TM - 30 m GSD

SPECTRAL RESOLUTION CONCEPTS



HYPERSPECTRAL IMAGING –
'CAT SCANNING' FROM SPACE



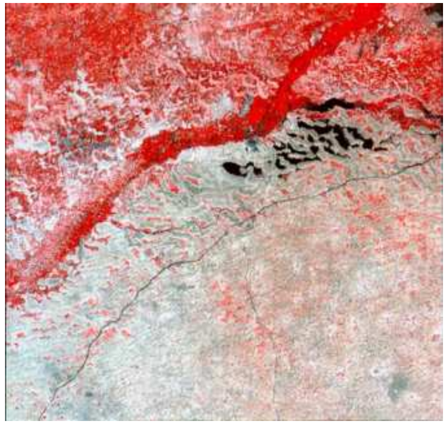
Each pixel has an associated, continuous spectrum that can be used to diagnose the subtle features – specific identity to a target

Images taken simultaneously in 100-200 narrow spectral bands, inherently registered

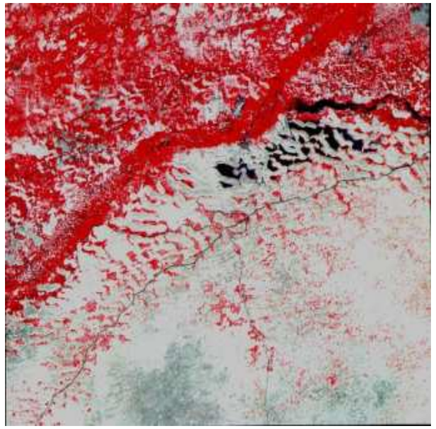
Wavelength, μm

MULTI –TEMPORAL COVERAGE

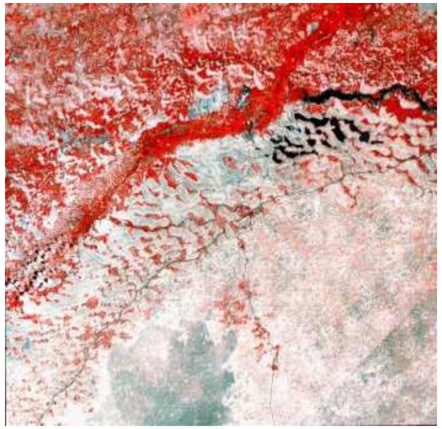
1975



1985

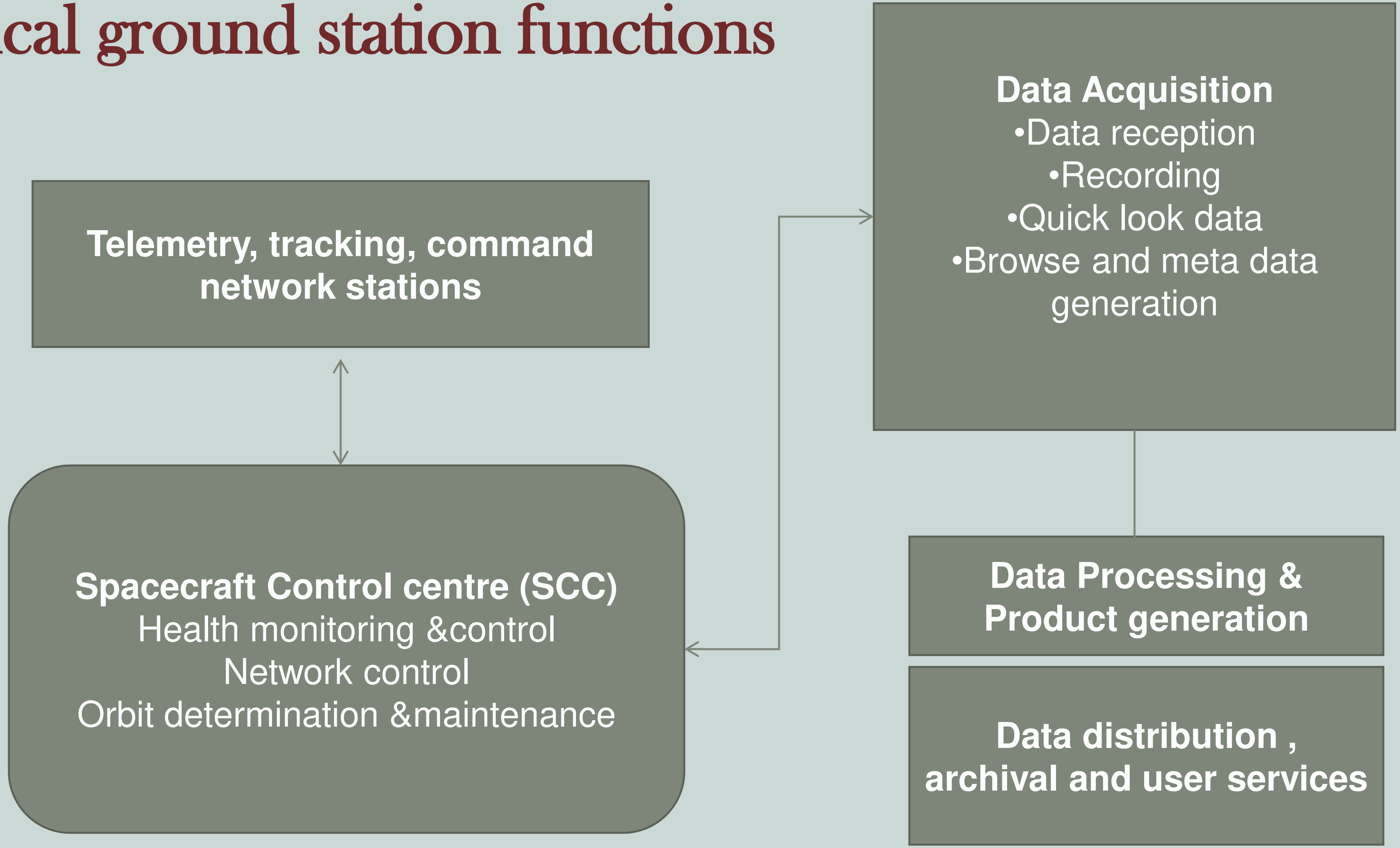


1990



1995

Typical ground station functions



• Radiometric errors - causes

Radiometric errors are introduced due to sensor characteristics, intervening atmosphere, noise introduced during signal generation, transmission/reception

• Geometric errors

Earth rotation, earth shape, sensor focal plane detector geometry, mis-registration of bands, off axis viewing distortions, altitude/ velocity variations causing scale changes, attitude variation induced distortions, measurement errors etc

Data Products

Photo products and digital products

1. **Standard**
2. **Special (example merged products)**

Level 0 Uncorrected (raw data)
Level 1 Radiometrically corrected and geometrically corrected only for earth rotation (browse product)
Level 2 Both Radiometrically and geometrically corrected
Level 3 Special processing like precision processing using GCPs, merging, enhancement, ortho image using DEM (digital elevation model) etc after level 2 corrections

Geo coded products are corrected products and oriented to north so that they can be overlaid on topographic survey maps. Resolution of data product will be suitable for map scale

Data Format

Data arrangement

Band Sequential (BSQ) : Band 1 data file, Band 2 data file , … etc
(within each band line by line and each line contains pixels in order)

Band interleaved by line (BIL) : All bands in single file and sequence of Line 1 (Band1) Line1 (Band2) Line 1 (Band3) , then line 2 (B1, B2, B3) etc

Band interleaved Pixel (single file)
Line1 (First Pixels of all bands, second pixels of all bands.. Etc)
Then sequence of Line 2 pixels in the same way …. etc

Super structure file format: Volume directory file, Leader file, Image file, Trailer file, Null volume directory file

Special processing

1.Contrast enhancement .. Linear and non linear stretching
In the image for each band, each pixel has unique reflectance (Digital Number DN)
Example DN values in an image ranging 25 to 150 is stretched to 0 to 250
Value 25 becomes 0
Value 150 becomes 250
Value 75 becomes (75-25)x 250/125

2**. Colour coded enhancement** Ranges of gray level values in black & white image are assigned colour codes

3. Spatial Filtering- Process of modifying the gray value of a pixel on the basis of gray values of neighboring pixels. Filtering can be done for high frequency or low frequency spatial content. High frequency is rapid change in DN values in relatively smaller number of pixels. Low pass filter smoothes high frequencies. High pass filter highlights contrasts

Image transforms

From images of two or three bands or two or three different time periods, create a new transformed image, whose pixels represent the ratio of the differences in pixel radiances of original images. Ratios of multiple bands can eliminate gain or bias errors. They can bring out features not discernible in original images

Principal Component transforms

Multi spectral images often exhibit high correlation between spectral bands. When two data sets are perfectly correlated, then same information content in one set is available in the other set and hence second data set is redundant. Thus if there are n correlated spectral bands, PC transformation tries to reduce such redundancy in multi spectral data sets