Basics of Remote Sensing

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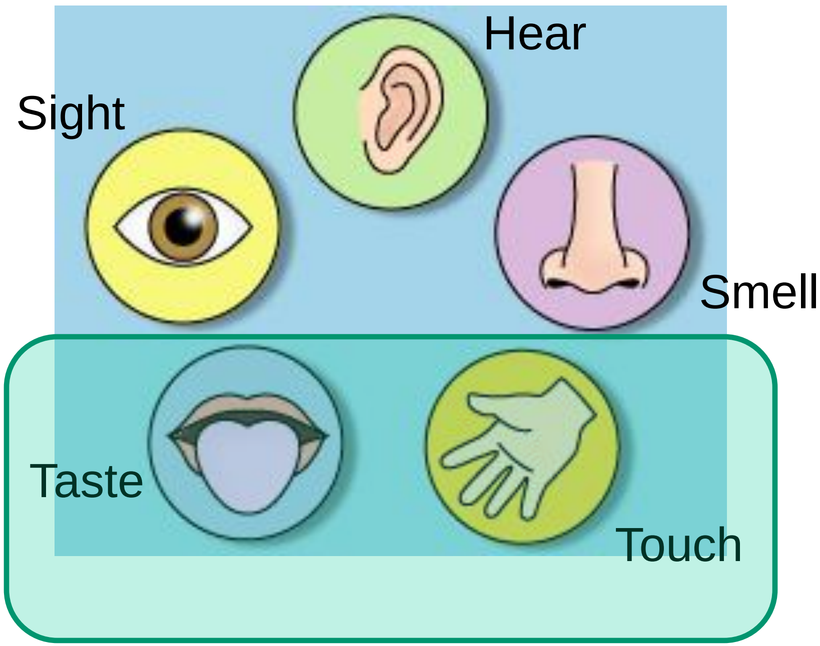
We perceive the surrounding world through our five senses



Contact Sensors

Two senses (Touch & Taste) require direct contact of our sensing organs with the objects.

Touch

Taste

Remote Sensors

Viewing (Sight)

Hearing

Smell

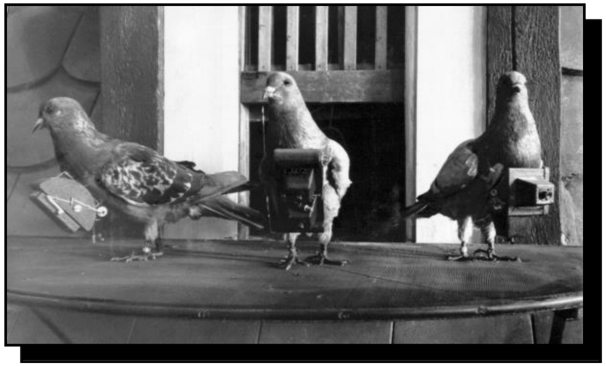
The other three senses (Sight, Hearing, Smell) may be considered forms of "Remote Sensing". That is, we are performing Remote Sensing all the time.

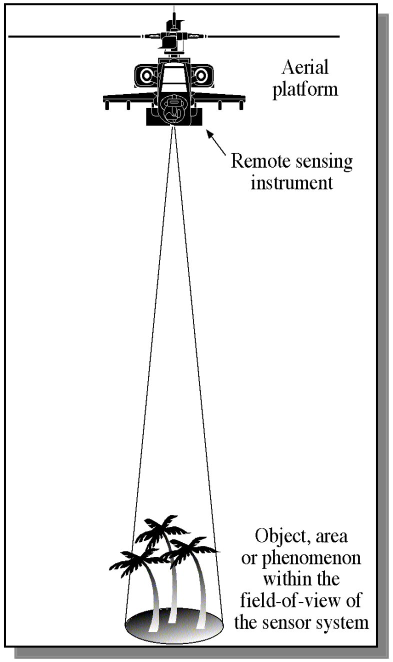
What is Remote Sensing?

Remote Sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation.

History

- 1839 – First ever photographs by Louis Daguerre and Nepce – beginning of Photography
- 1850s- 1900's – Photographs taken by captive balloons,
  pigeons
- World War I – Aerial photography
- World War II – Use of electromagnetic spectrum increases to include infrared and microwave
- "Cold War" – extensive use of reconnaissance techniques – launching of 'spy' satellites
- 1960s –TIROS – meteorological satellite
- July 23, 1972 – Earth Resources Technology Satellite-1 (Landsat 1) – first Earth-orbiting satellite for observation of Earth's land area (Digital image processing development)

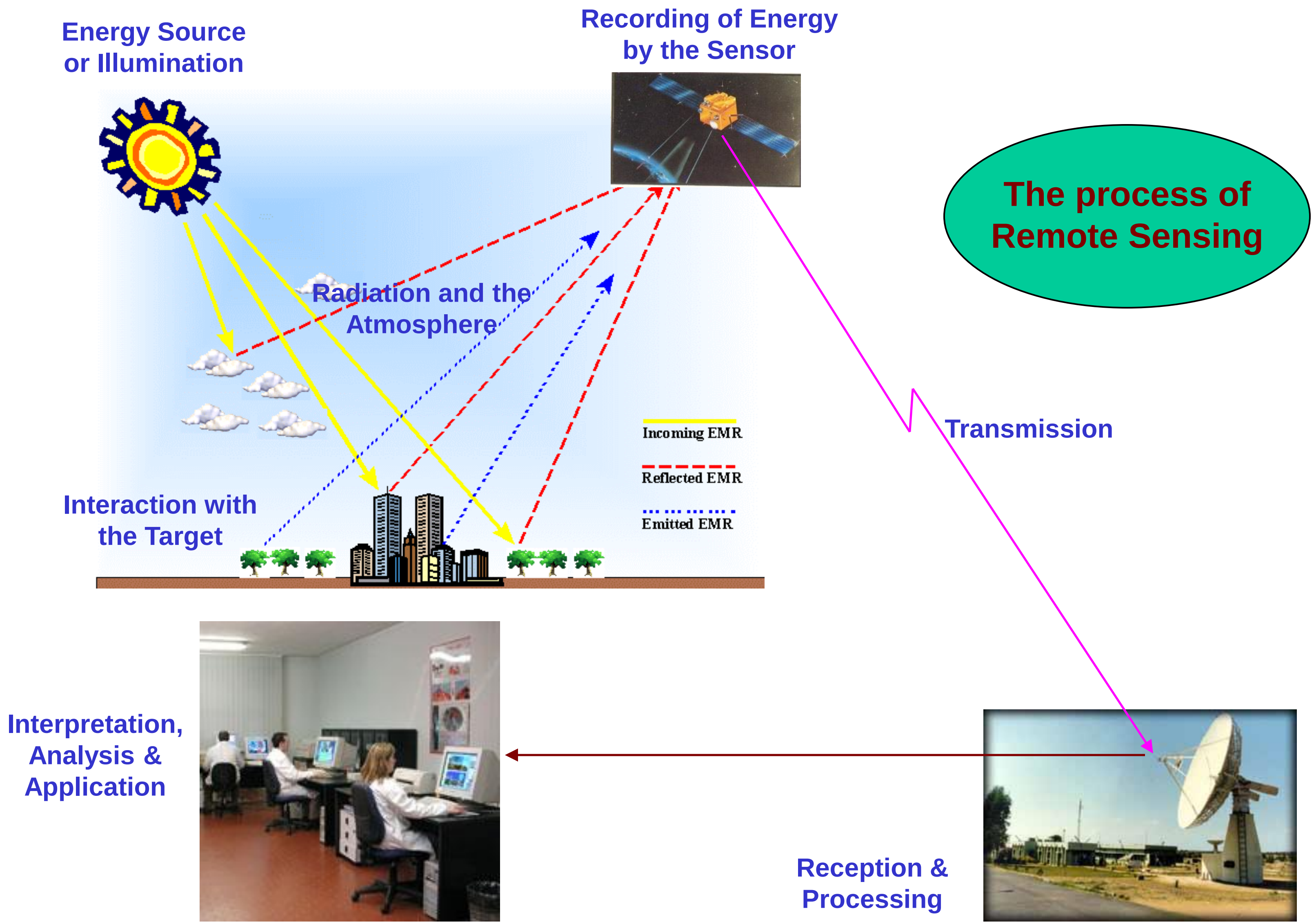




The first known aerial photograph was obtained by Gaspard Felix Tournachon (Nadar) from a tethered balloon 1,700 ft above Paris, France in 1858.

Oblique aerial photograph of downtown Boston obtained by Samuel A. King and J. W. Black from a balloon at an altitude of 1,200 ft. on October 13, 1860.

The process of Remote Sensing



The three mechanisms by which thermal energy is transported are

Conduction

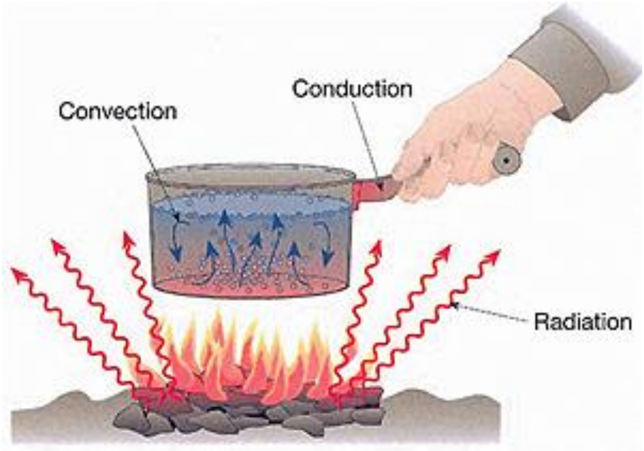
The transfer of energy through matter from one molecule to other (solids)

Convection

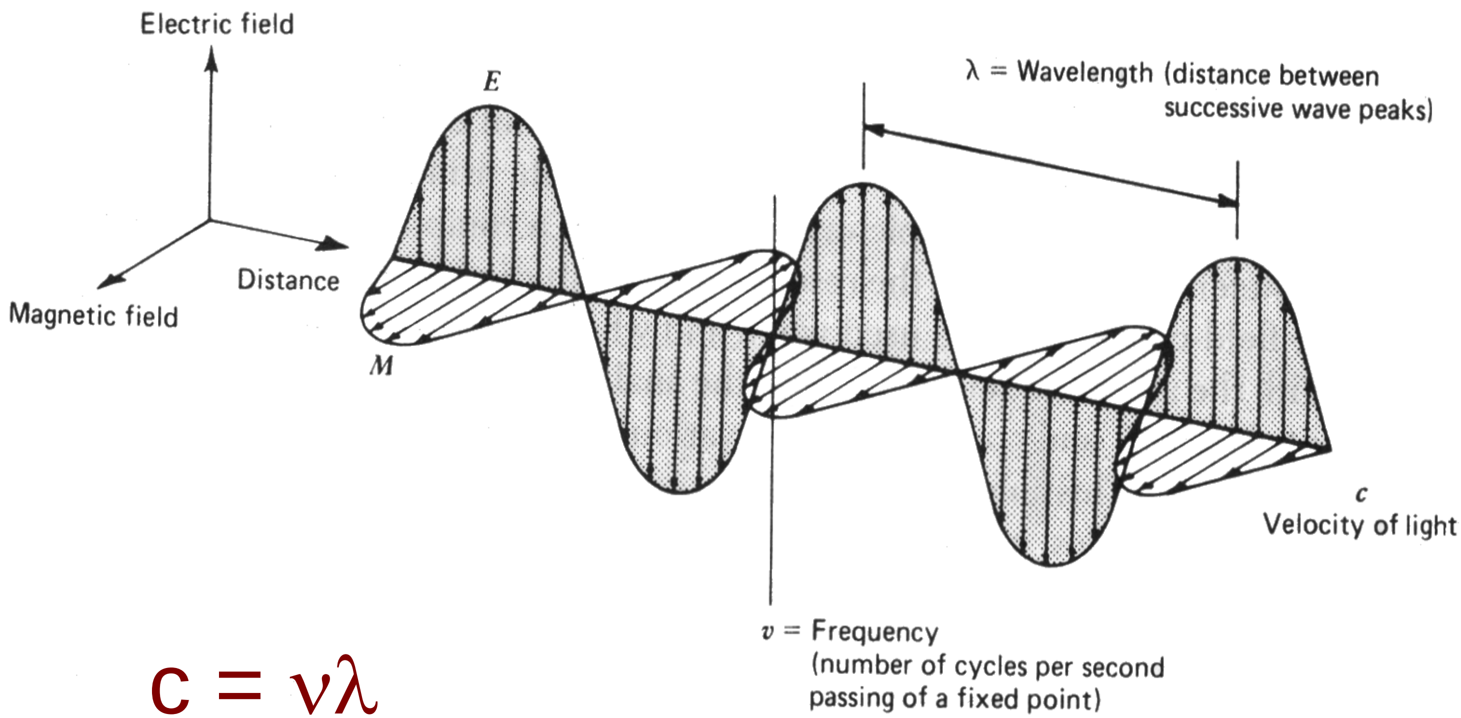
The transfer of heat energy by movement of currents (in a gas or liquid)

Radiation

The direct transport energy by Electromagnetic waves. The energy travels through vacuum.



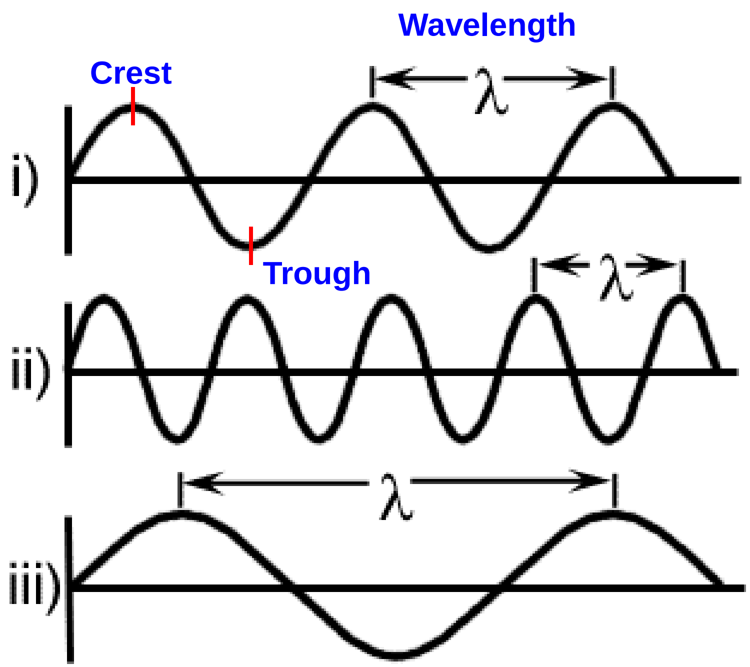
ELECTROMAGNETIC WAVE

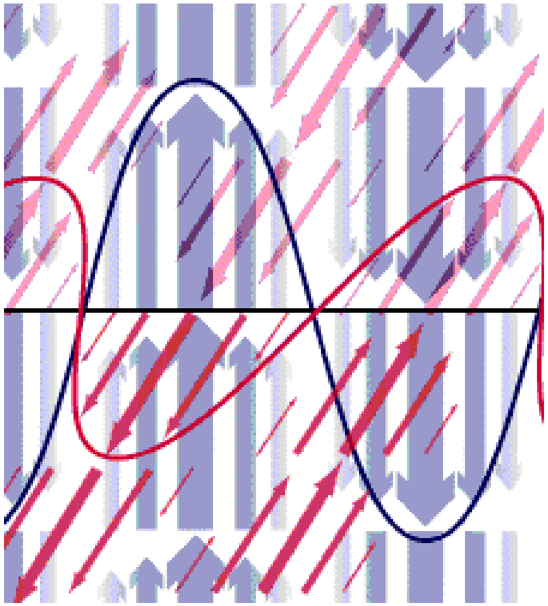


$$c = \nu\lambda$$

where speed (c) = 3 x 10^8 ms^{-1}

in vaccum


Wavelength
Crest
Trough
λ
i)
ii)
iii)



Electromagnetic Radiation

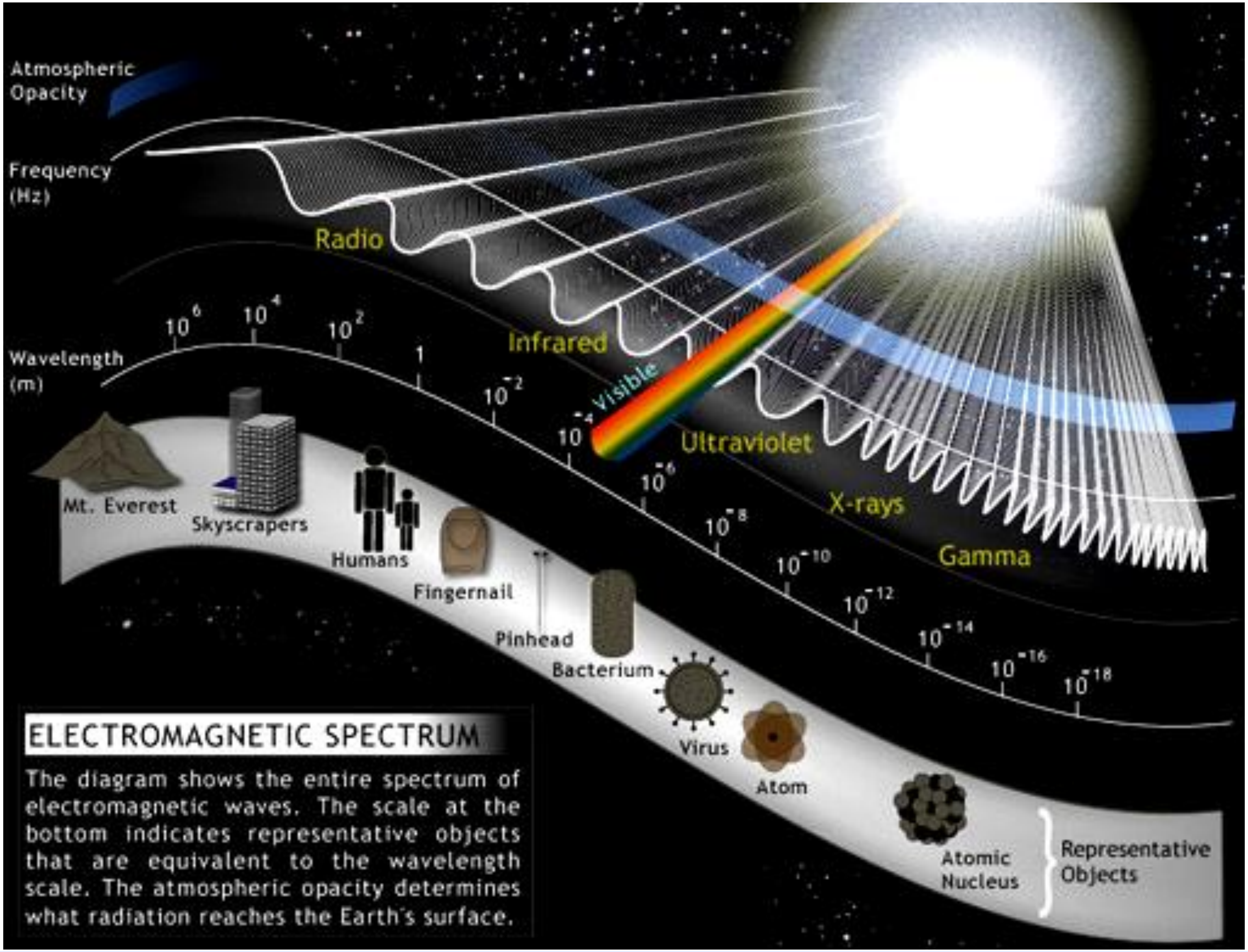
Sun light, Heat, Radio waves, X-rays … are inherently similar in nature and can be conveniently grouped under a single classification called "Electromagnetic Radiation".

Visible light is only one of many forms of electromagnetic spectrum.

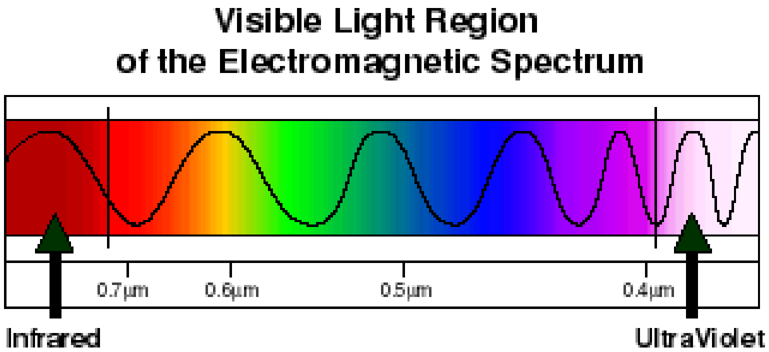
Arrangement of different types of these radiations by wavelength or frequency is called “Electromagnectic Spectrum”.

All radiations in this spectrum

- obey similar laws of reflection, refraction, diffraction and polarization.
- travel with the same speed ($3x10^8$ ms^{-1}).


Atmospheric Opacity
Frequency (Hz)
Wavelength (m)
Radio
Infrared
Visible
Ultraviolet
X-rays
Gamma
10^6
10^4
10^2
1
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
10^-14
10^-16
10^-18
Mt. Everest
Skyscrapers
Humans
Fingernail
Pinhead
Bacterium
Virus
Atom
Atomic Nucleus
Representative Objects
ELECTROMAGNETIC SPECTRUM
The diagram shows the entire spectrum of electromagnetic waves. The scale at the bottom indicates representative objects that are equivalent to the wavelength scale. The atmospheric opacity determines what radiation reaches the Earth's surface.

Visible Light: This narrow band of electromagnetic radiation extends from about 400 nm (violet) to about 700 nm (red). The various colour components of the visible spectrum fall roughly within 7 wavelength regions.



	Wavelength (nm)
Red	610 - 700
Orange	590 - 610
Yellow	570 - 590
Green	500 - 570
Blue	450 - 500
Indigo	430 - 450
Violet	400 - 430

Radiation Principles

Planck's Law

It allows us to calculate total energy radiated in all directions from a blackbody (radiator) for a particular temperature and wavelength.

$$M_\lambda = \frac{2\pi hc^2}{\lambda^5} \frac{1}{(e^{\frac{hc}{\lambda kT}} - 1)}$$

here

λ = wavelength (μm)

T = temperature (°K)

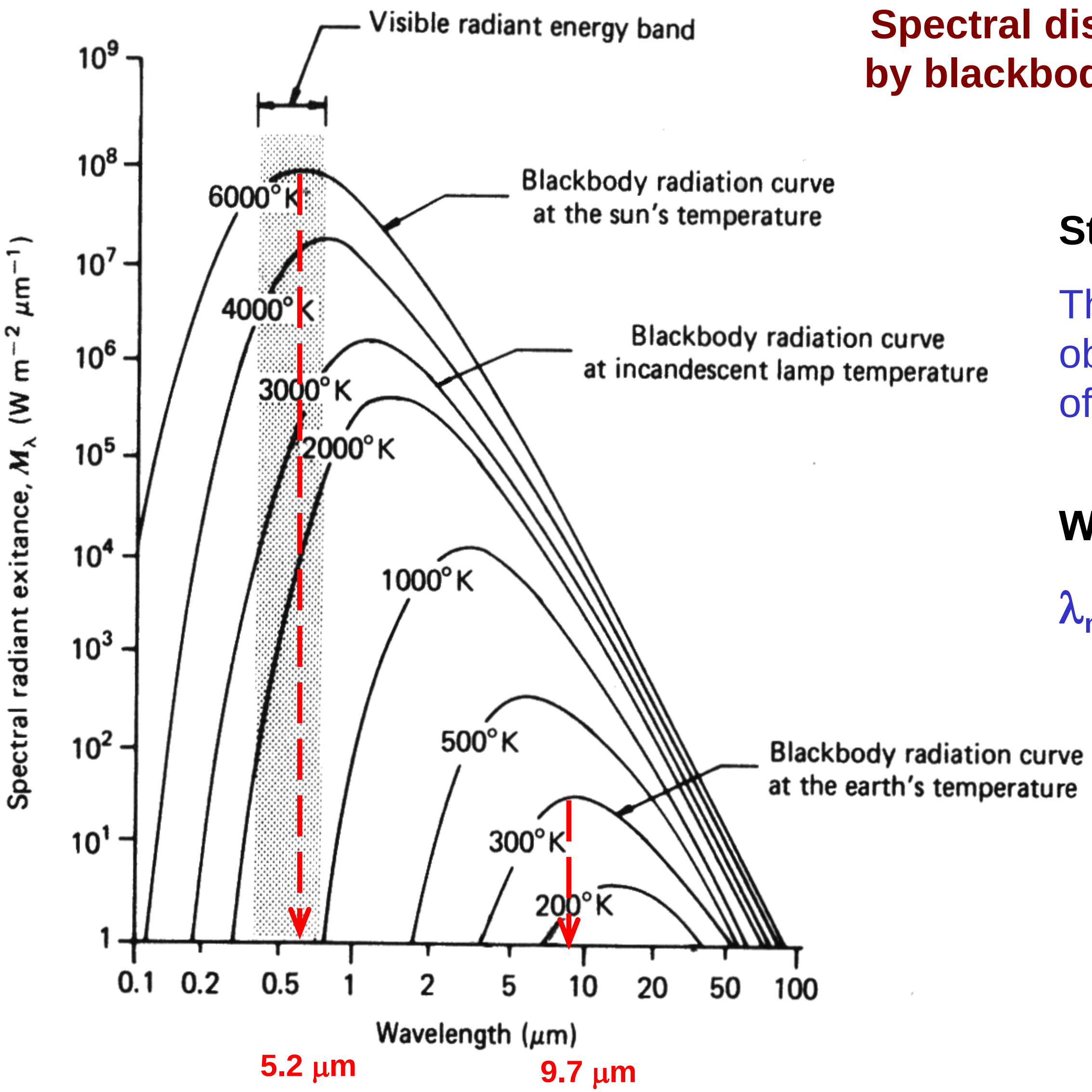
M_λ = spectral exitance (W m^{-2} μm^{-1})

k, Boltzmann constant = 1.38 x 10^{-23} W s K^{-1}

h, Plank's constant = 6.625 x 10^{-34} J s

c, speed of light in vacuum (3 x 10^8 ms^{-1})

Spectral distribution of energy radiated by blackbodies at various temperatures

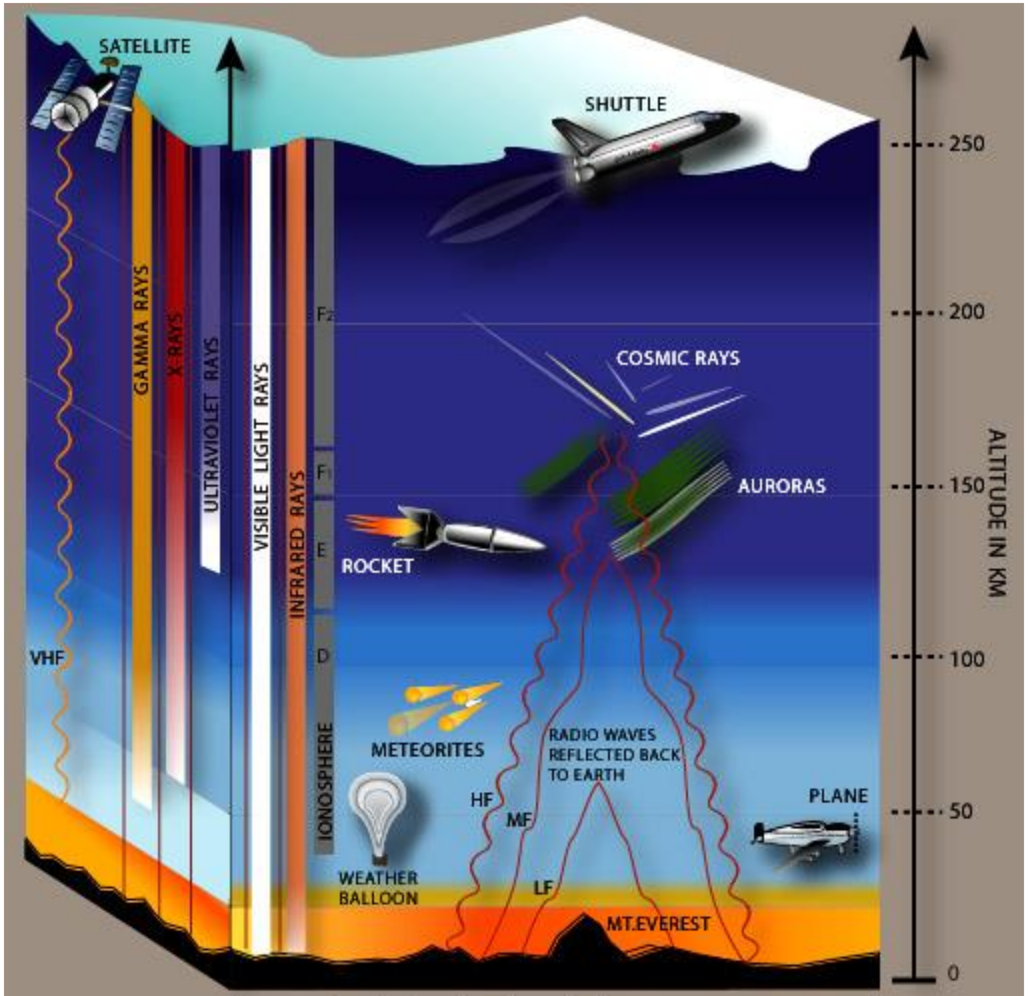


Stefan-Boltzmann Law

The higher the temperature of the object, the greater the total amount of radiation it emits.

Wien's Displacement Law

$\lambda_m = (A/T)$

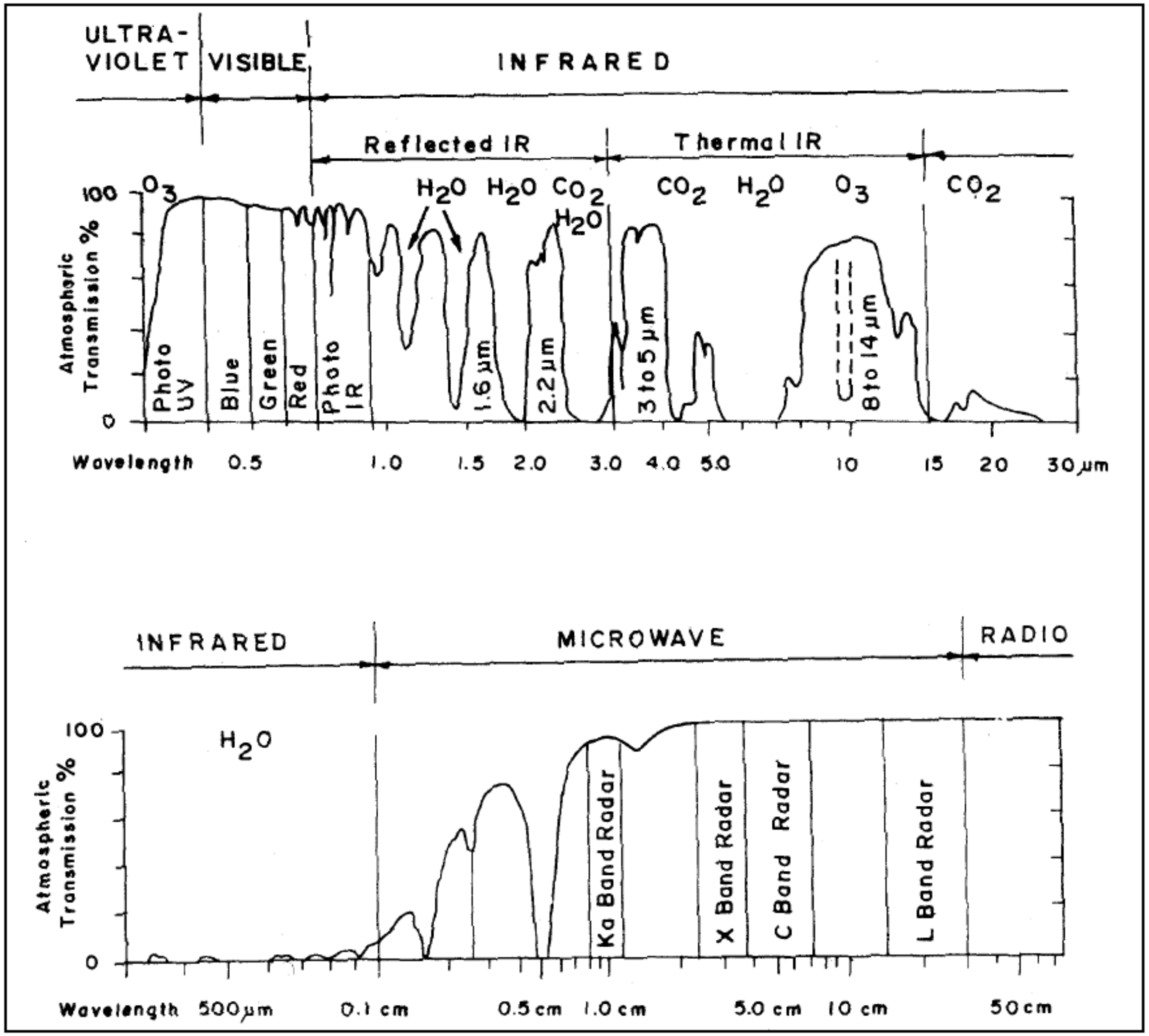


Close-up of a drawing that shows the penetration of different kinds of electromagnetic radiation into the atmosphere. Note also the different layers of the ionosphere (D, E, F).

EMR and the Atmosphere

The characteristics of the atmosphere significantly determine the effective use of EM spectrum for remote sensing.

A T M O S P H E R I C



W I N D O W S

Absorption spectrum of earth's atmosphere *(after Sabins, 1987)*

Interaction of EMR with Earth Surface Features

Conservation of Energy

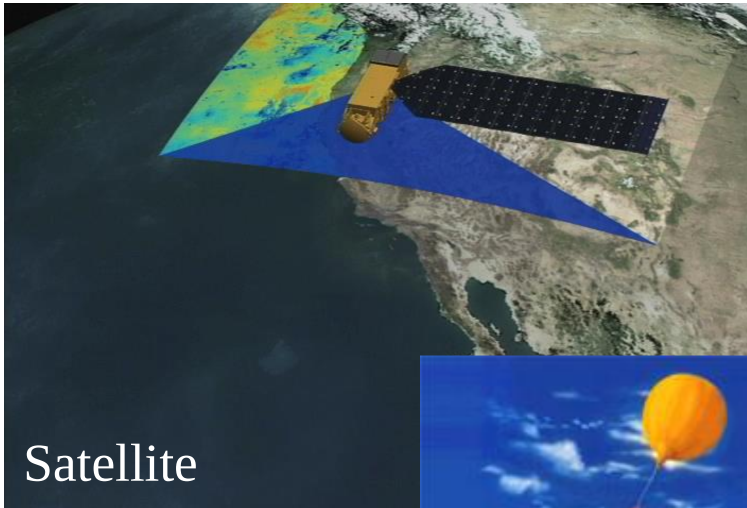
When EM energy is incident on any given earth surface feature, three fundamental energy interactions are possible. A fraction of incident energy is reflected, absorbed and / or transmitted.

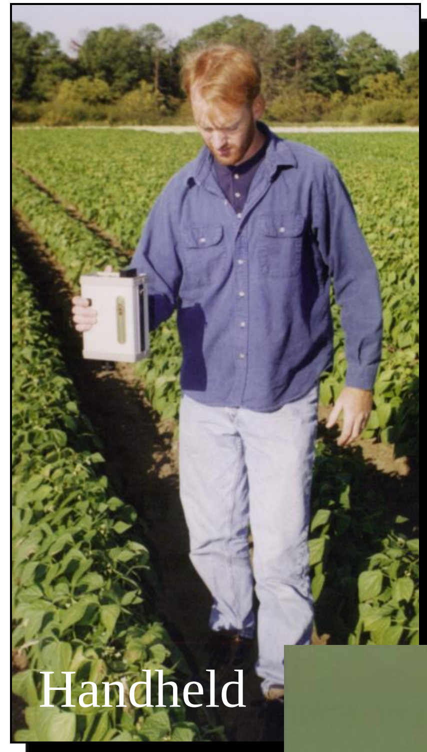
"Energy is neither created nor destroyed".

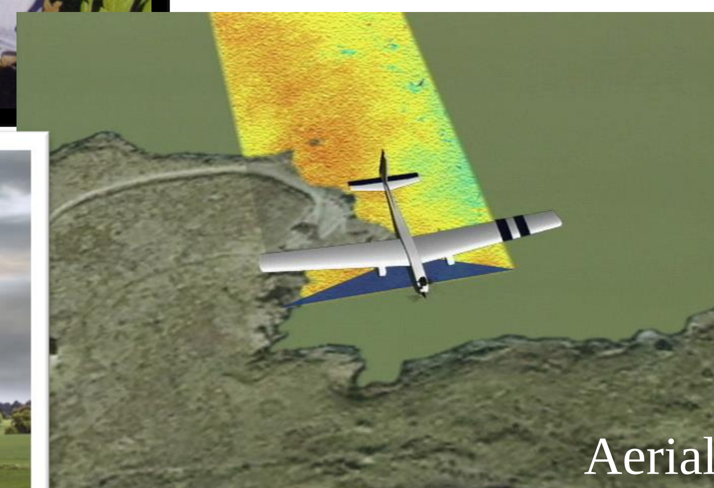
Incident energy = reflected energy + absorbed energy + transmitted energy

Reflectance **(ρ) +** Absorptance **(α) +** Transmittance **(τ) = 1**

Remote Sensing Platforms



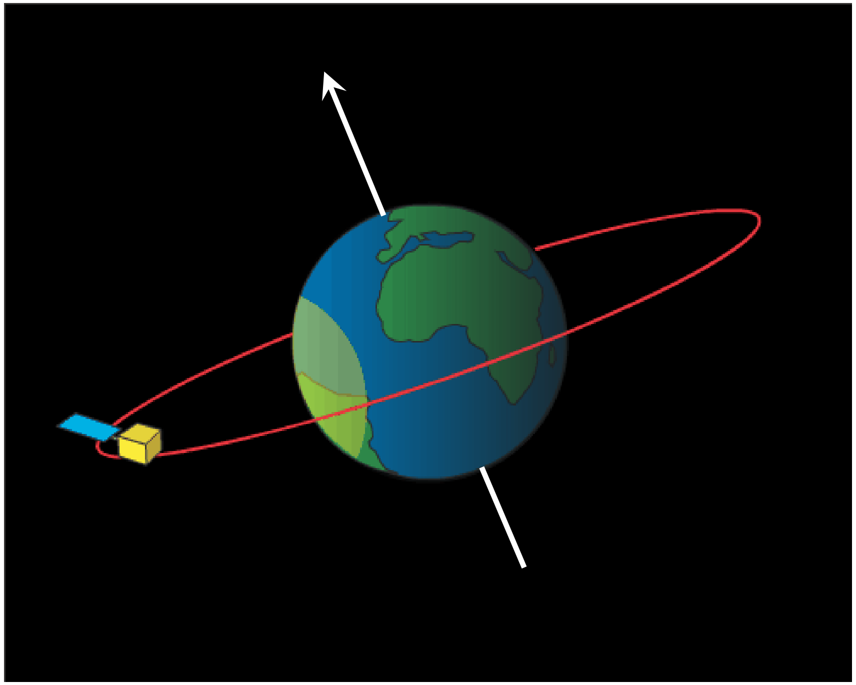




Satellites - The Space Borne Platforms

In space borne remote sensing, sensors are mounted on-board a spacecraft (space shuttle or satellite) orbiting the earth.

G E O S T A T I O N A R Y



Source: http://scijinks.gov/orbit/

Shape: Circular orbit

Altitude: ~ 36,000 km

Period: ~ 24 hours

Inclination: 0°

Communications, Broadcasting and Weather satellites

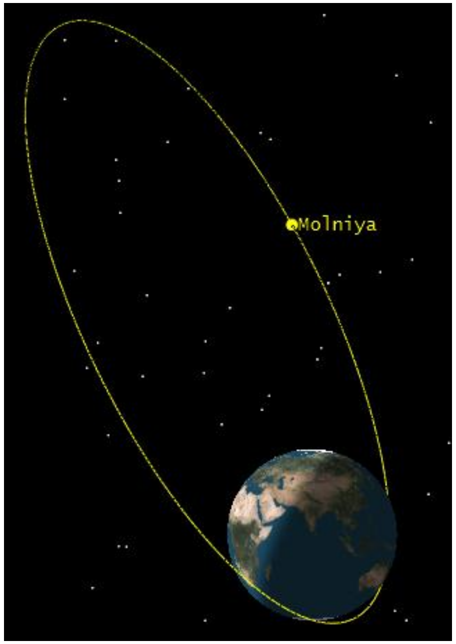
Molyneux / Molniya Satellite

Shape: Highly elliptical orbit

Period: ~12 hours

(2 revolutions per day)

Inclination: 63.4°



Remote Sensing Satellite

Shape: Circular orbit

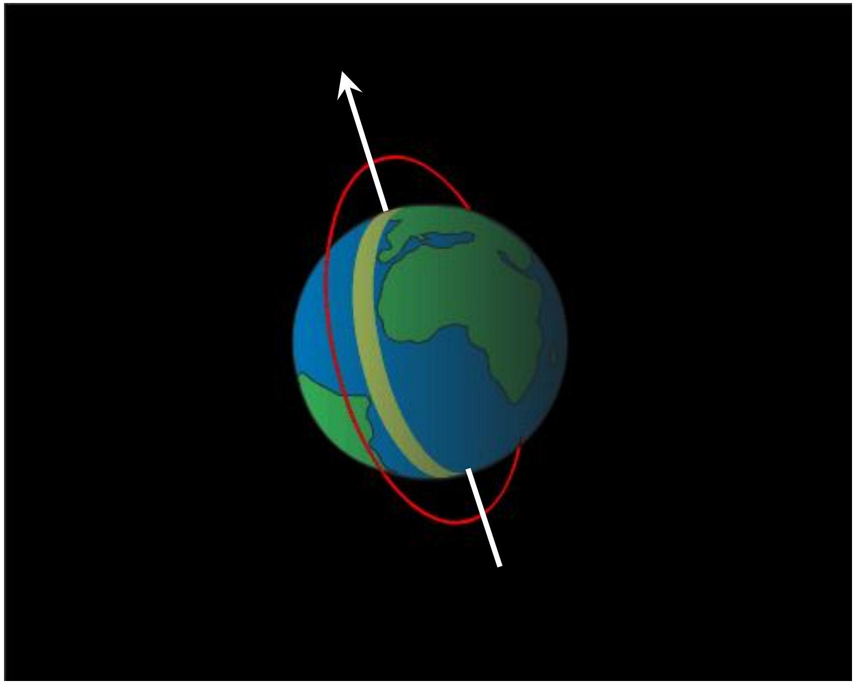
Altitude: 450 – 1000 km

Period: ~ 100 minutes

Inclination: 93° - 99°

Most earth observation satellites revolve in **near-polar orbits** with lower altitudes. These satellite orbits are **"Sun-synchronous"** such that they cover each area of the world at a constant local time of day

At any given latitude, the position of the sun in the sky as the satellite passes overhead will be the same within the same season. This ensures consistent illumination conditions when acquiring images. This is an important factor for monitoring changes between images.



Source: http://scijinks.gov/orbit/

Categorisation of Satellites by size

- **Small Satellites (100 – 500 Kg)**
- **Micro Satellites (10 – 100 Kg)**
- **Nano Satellites (1 -10 Kg)**
- **Pico Satellites (0.1 – 1 Kg)**
- **Femto Satellites (< 100 gm)**

EMERGING PLATFORM

Unmanned Aerial Vehicle (UAV)

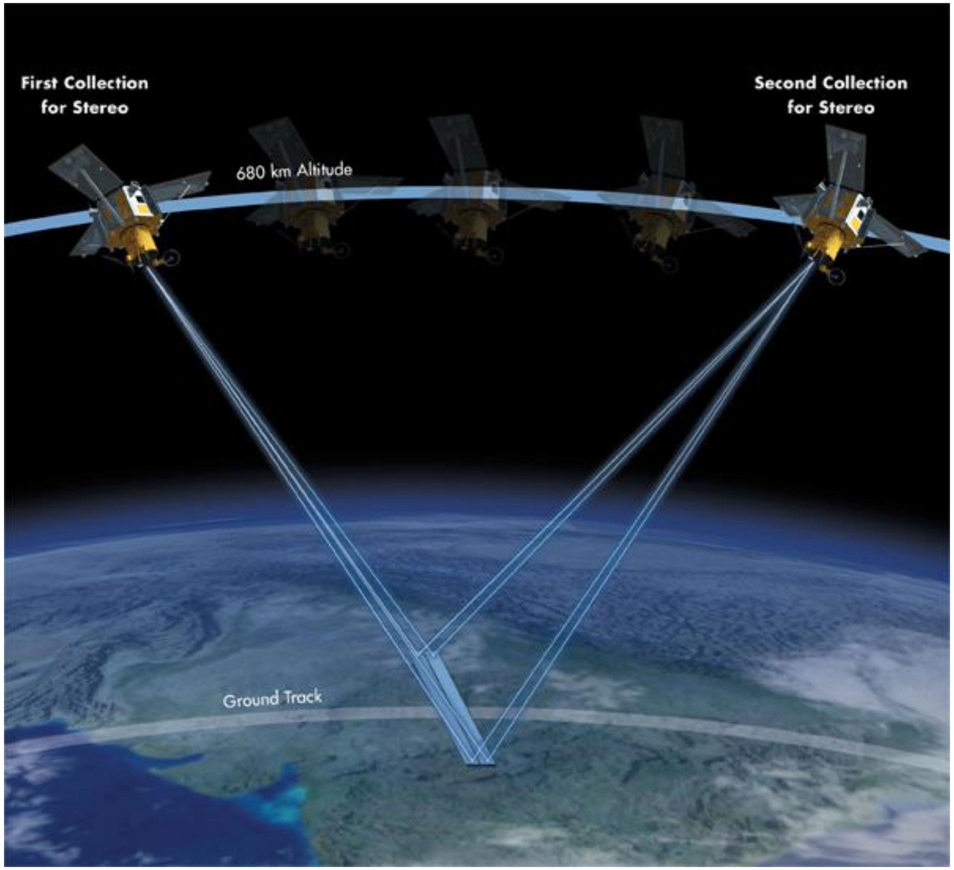
UAV is a remotely piloted miniature aircraft that can carry cameras, sensors, and/or communication equipment.

So far UAVs are in use to gather military intelligence but recently they are in civilian use to collect high-resolution spatial data.

Advantages of Space borne Remote Sensing

- Large area coverage
- Repetitive coverage of an area of interest
- Viewing of physically inaccessible areas
- Computerised processing and analysis of data
- Relatively lower cost per unit area of coverage
- Large archive of historical data

Another advantage!



Getting **THIRD DIMENSION** is possible using remote sensing and photogrammetric principles

Space borne Remote Sensing has the following **disadvantages**:

- **High cost of satellite and launch systems**
- **High cost of data reception infrastructure**
- **Planning, building, testing and launching takes more time**
- **At any point, possibility of failure because of complex subject**

Applications of Space borne Remote Sensing Data

Meteorology - profiling of atmospheric temperature, pressure, water vapor, and wind velocity

Oceanography - measuring sea surface temperature, mapping ocean currents, and wave energy spectra

Glaciology - measuring ice cap volumes, ice stream velocity, and sea ice distribution

Geology - geomorphology, identification of rock type, mapping faults and structure

Geodesy - measuring the figure of the earth and its gravity field

Topography and Cartography - improving digital elevation models

Agriculture, Forestry, and Botany - monitoring the biomass of land vegetation, monitoring the health of crops, mapping soil moisture, forecasting crop yields

Hydrology – monitoring of water resources and forecasting, floodplain management, river basin planning & management

Disaster warning and assessment - monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters

Planning applications – mapping ecological zones, monitoring deforestation, monitoring urban land use

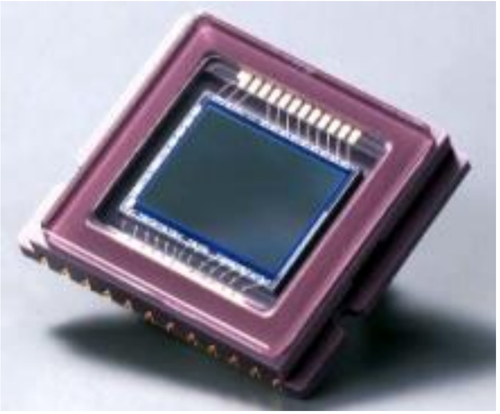
Oil and mineral exploration – locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence

Military – developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements,

etc.

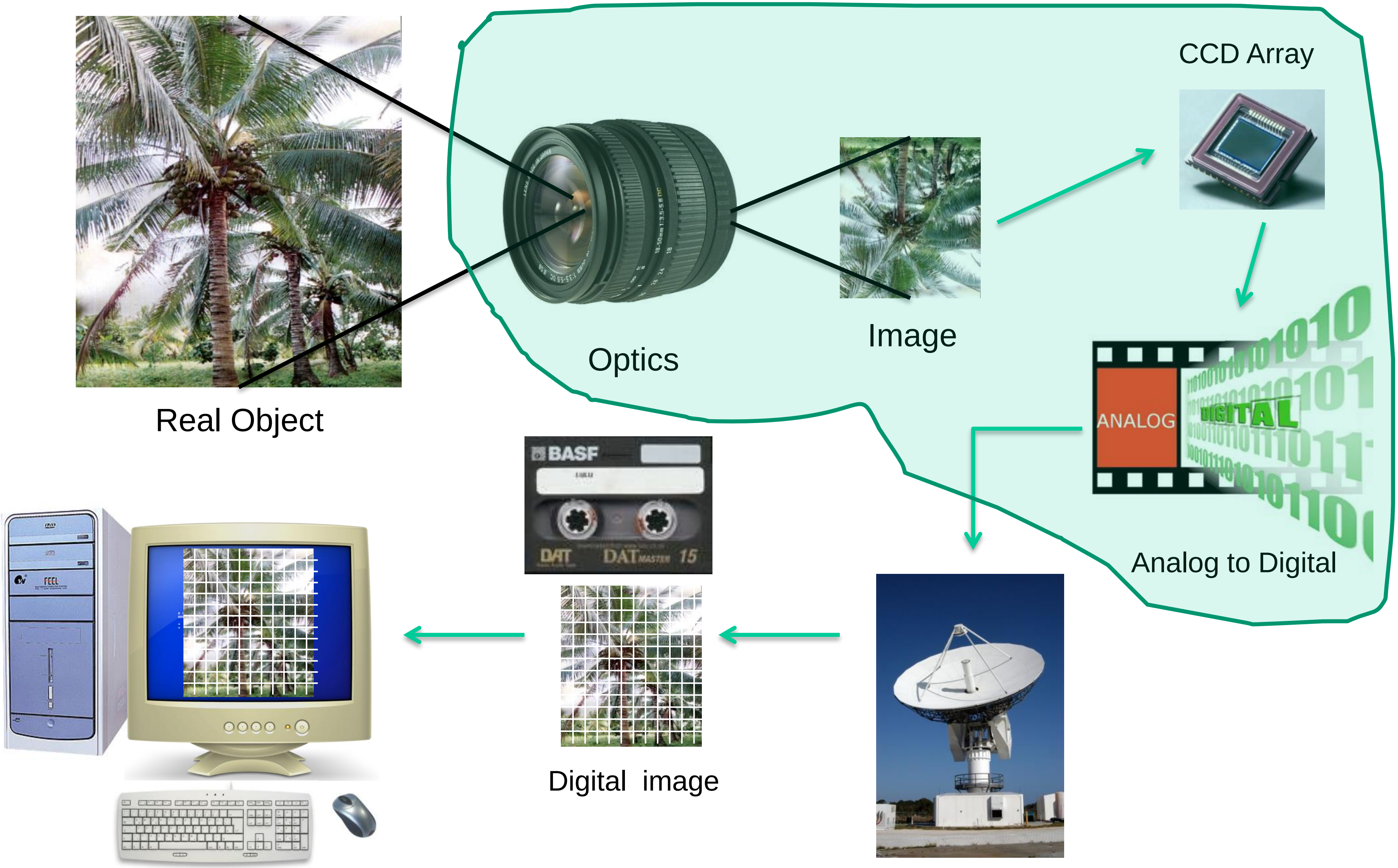
Remote Sensing Sensors

CCD Array



What is a Sensor ?

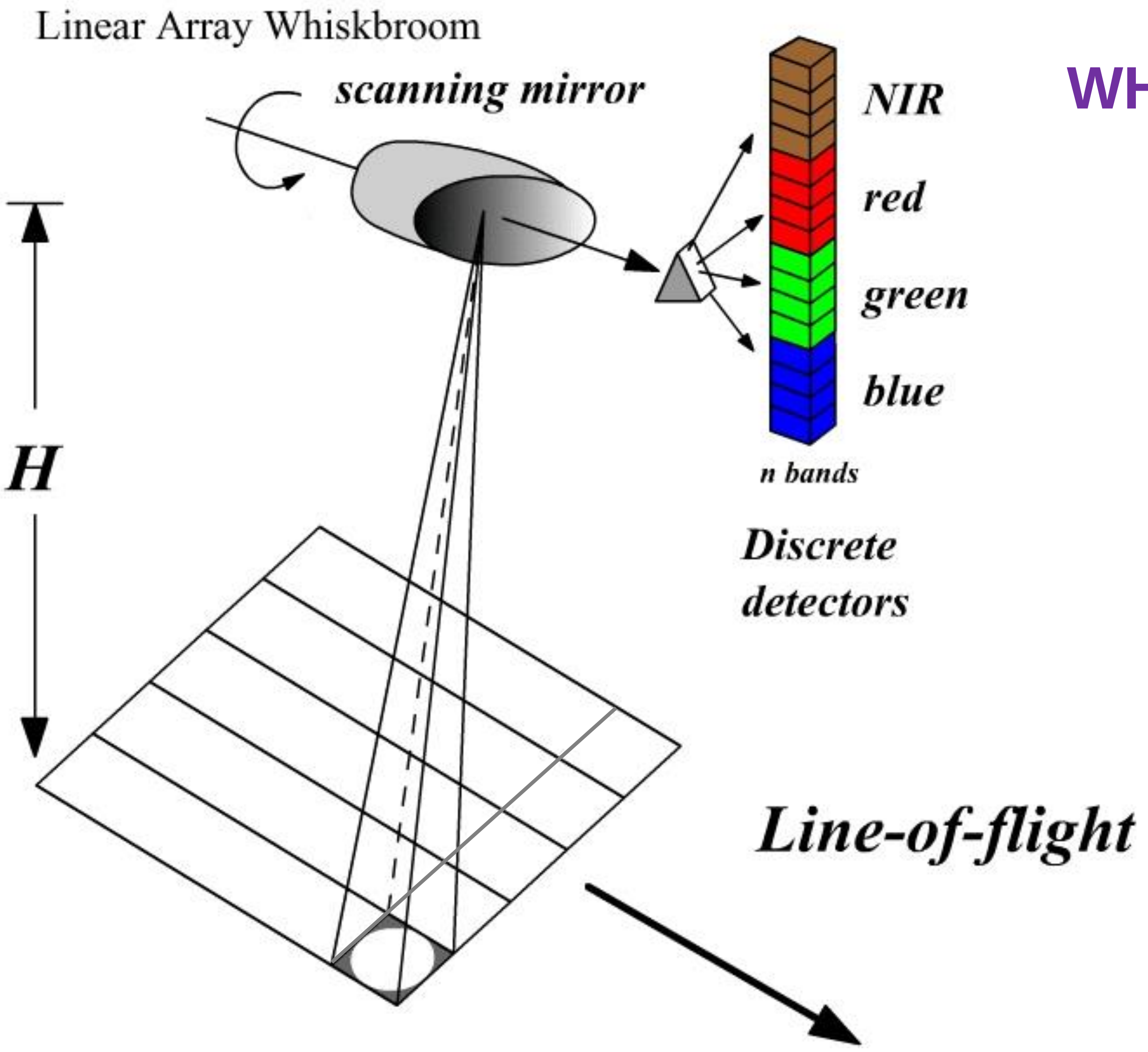
A device that responds to a physical stimulus (heat, light, sound, pressure, motion, flow, and so on), and produces a corresponding electrical signal.


Real Object
Optics
Image
CCD Array
ANALOG
DIGITAL
Analog to Digital
BASF
DAT
Digital image

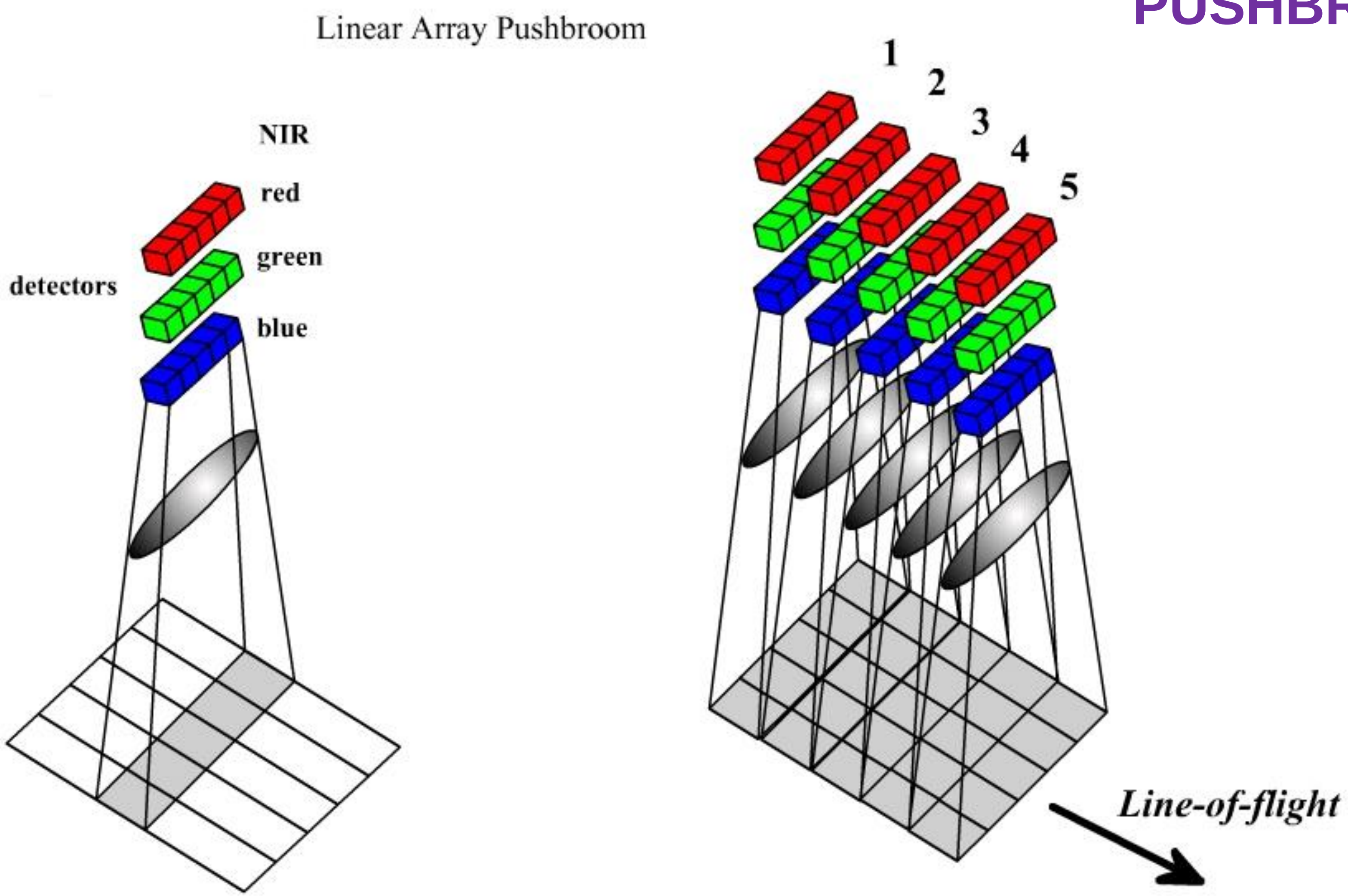
Active Sensor System

Passive Sensor System

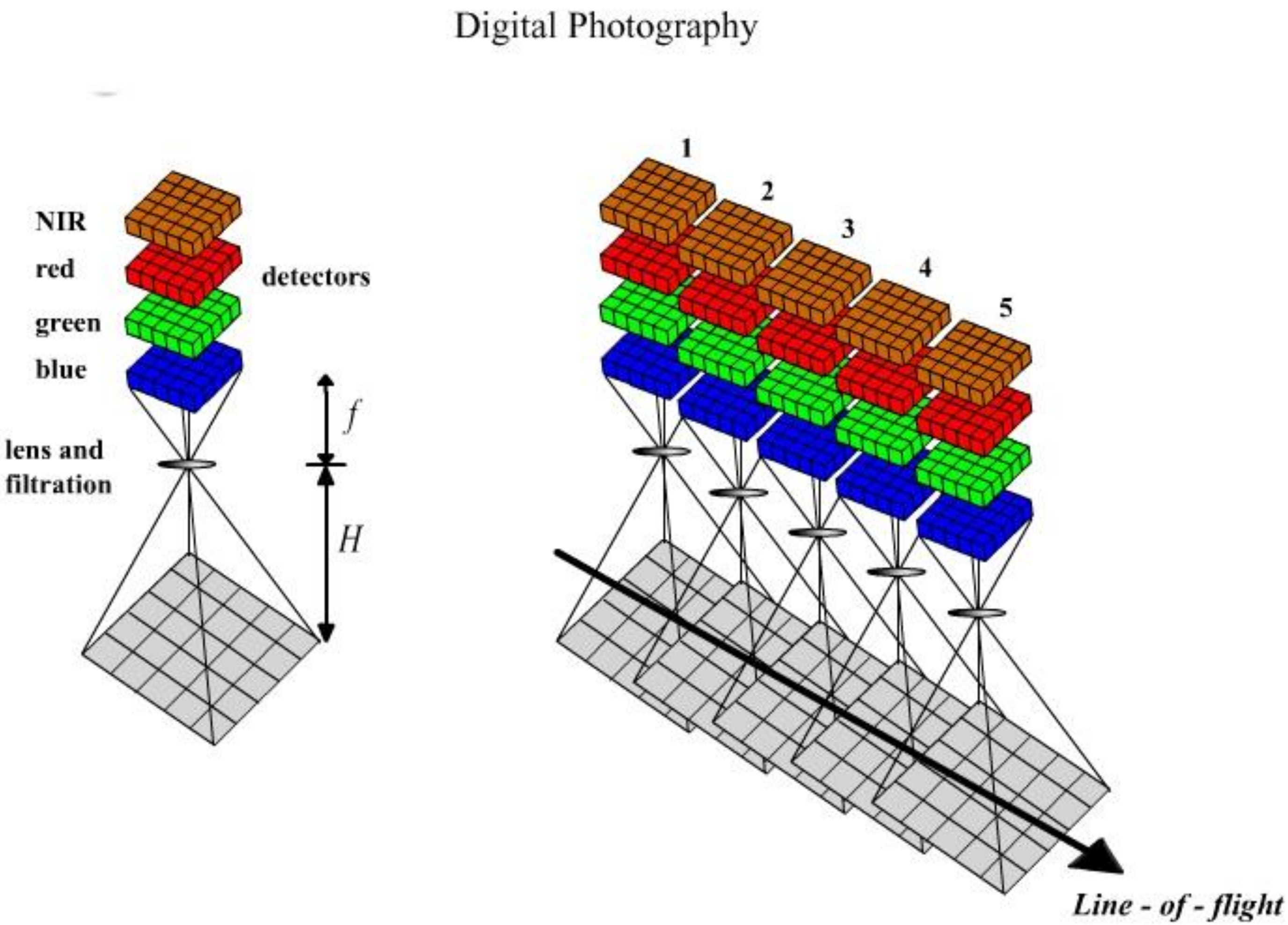
WHISKBROOM


Linear Array Whiskbroom
scanning mirror
NIR
red
green
blue
n bands
Discrete
detectors
H
Line-of-flight

PUSHBROOM


Linear Array Pushbroom
NIR
red
green
detectors
blue
1
2
3
4
5
Line-of-flight

FRAME BY FRAME



Sensor Resolution

There are ***four types*** of resolutions for a given sensor system

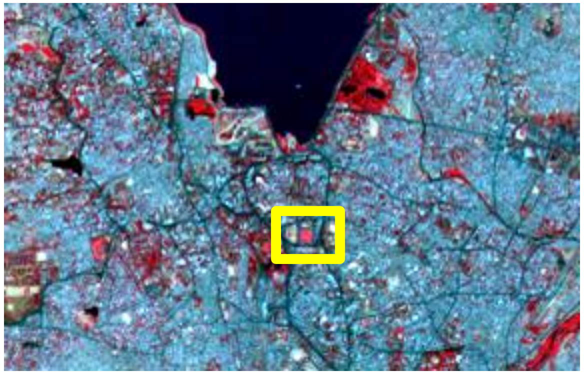
(a) Spatial resolution

(b) Spectral resolution

(c) Radiometric resolution

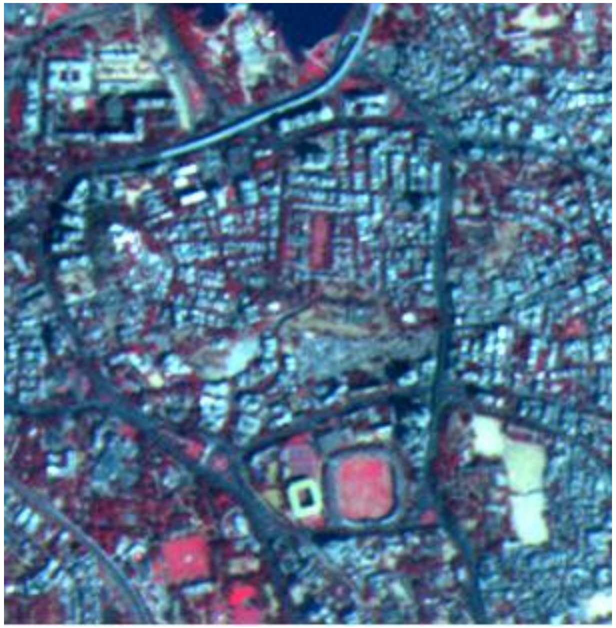
(d) Temporal resolution

Spatial Resolution



LISS III (23.5 m)

IKONOS (1m)

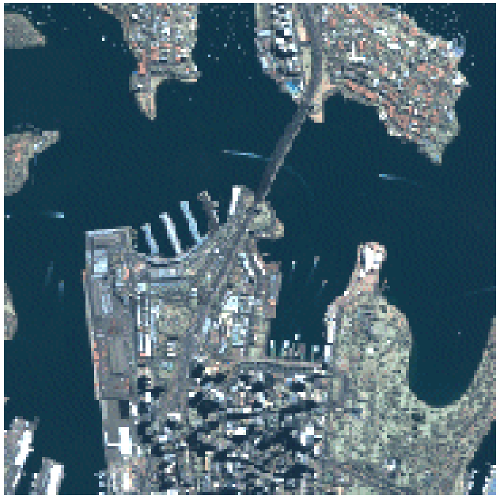


LISS IV (5.8 m)

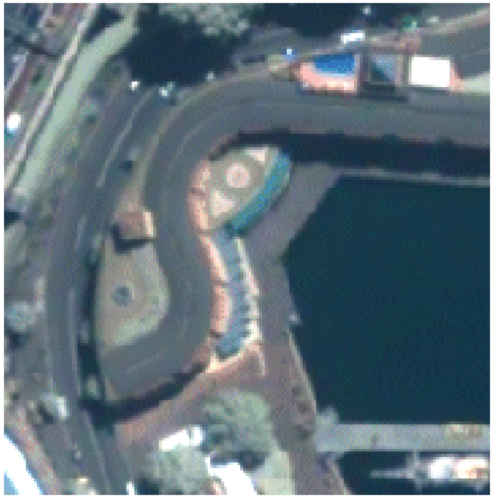
Scale 1:20,000
Cell size: 15 m

Scale 1:20,000
Cell size: 15.24 cm

PIXEL SIZE
vs.
SCALE



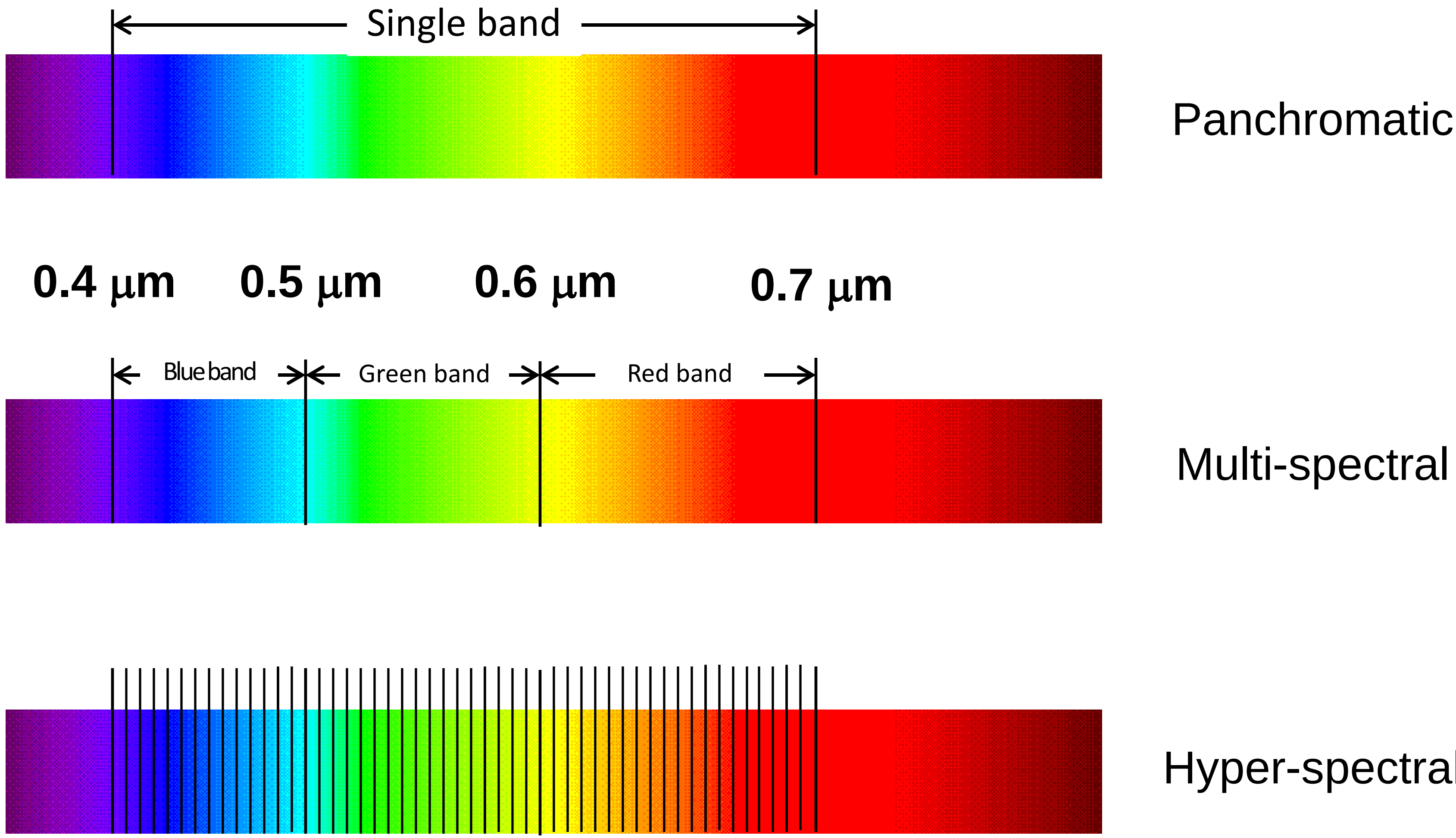
Scale 1:50,000
Cell size: 61 cm



Scale 1:2,500
Cell size: 61 cm

The higher the resolution of a raster, the smaller the cell size and, thus, the greater the detail. This is the opposite of scale. The smaller the scale, the less detail shown.

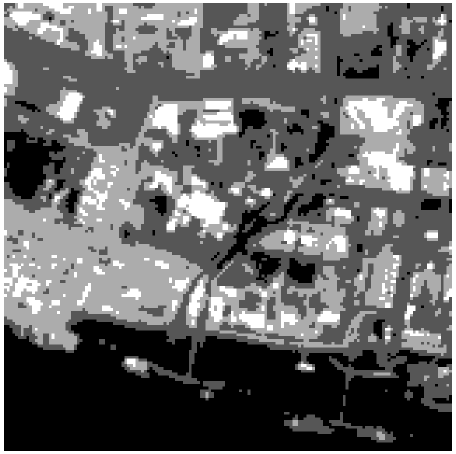
Spectral Resolution



Radiometric Resolution

8-bit quantization (256 levels)

Available grey levels with ‘n’ bits are 2^n

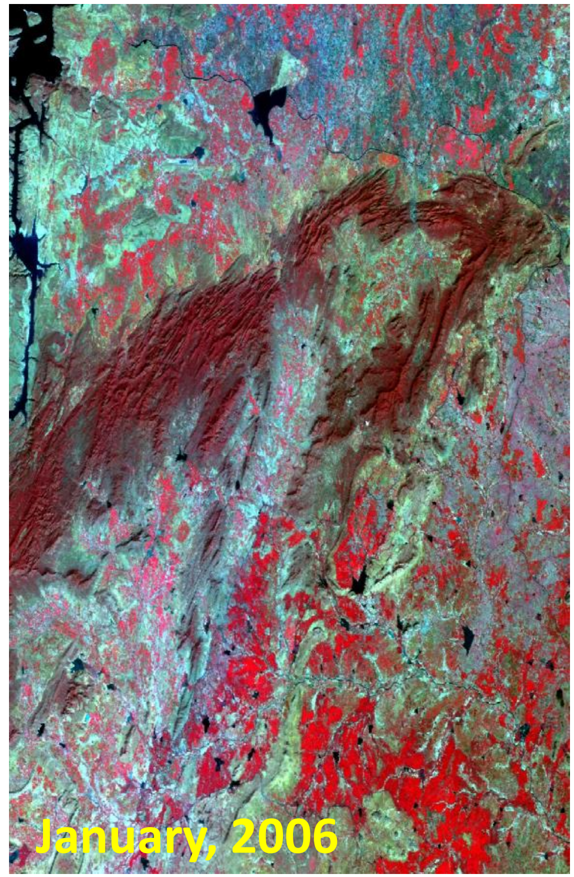


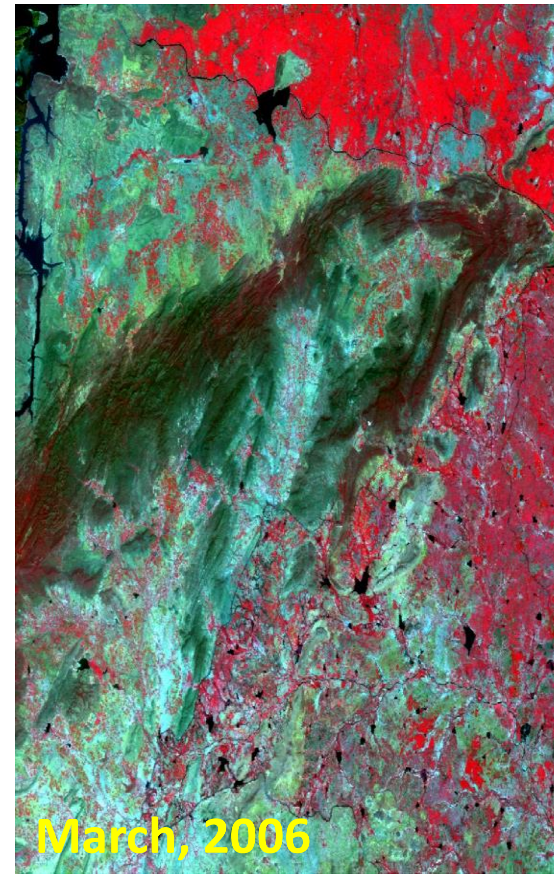
2-bit quantization (4 levels)

4-bit quantization (16 levels)

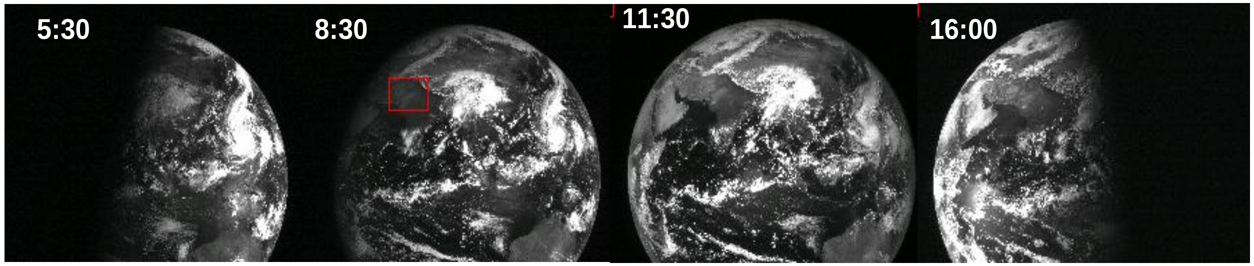
Temporal Resolution

Refers to the ability of the satellite to frequently image a given area either by vertical imaging or oblique.

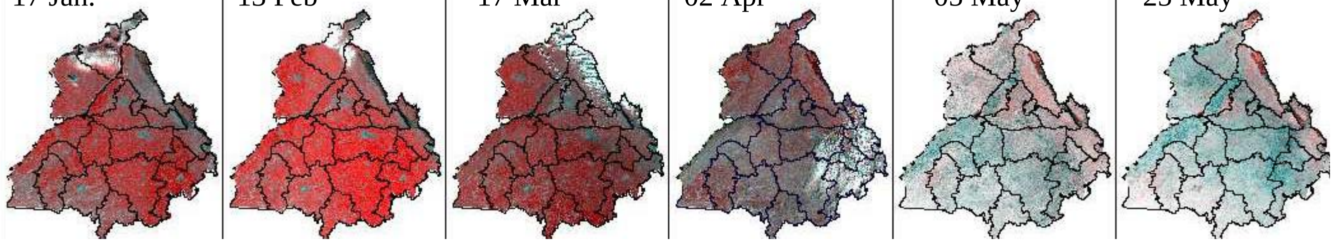




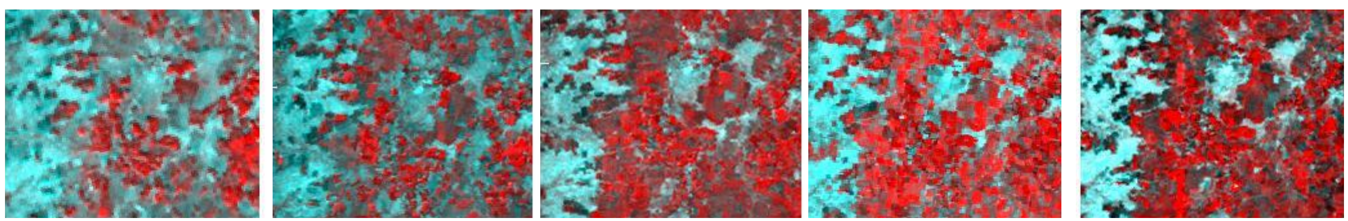
Diurnal



Seasonal

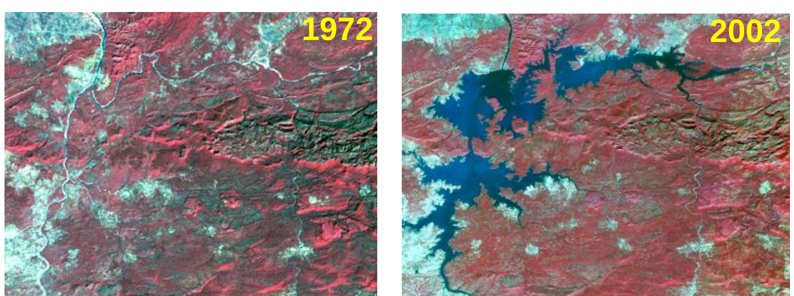


Annual



1995 | 1996 | 1997 | 1998 | 1999

Long term



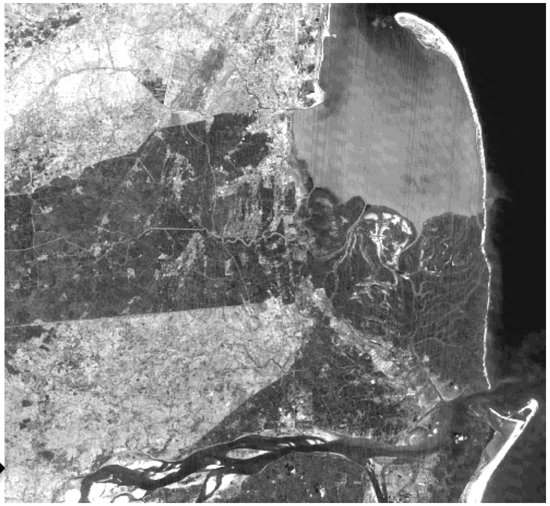
Multi Temporal Observation

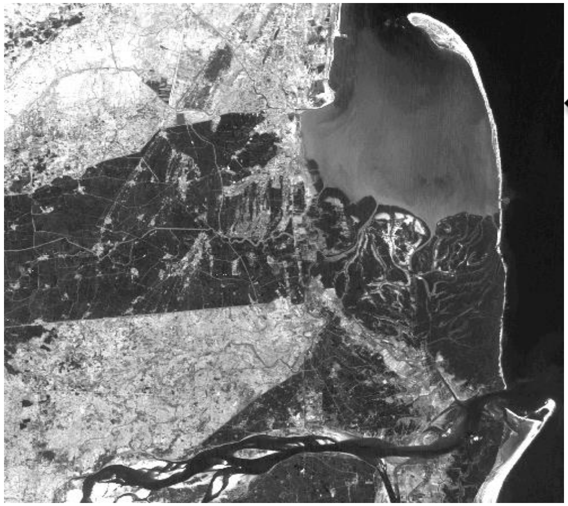
IRS LISS II

Kakinada (AP)

Band 1 (Blue)

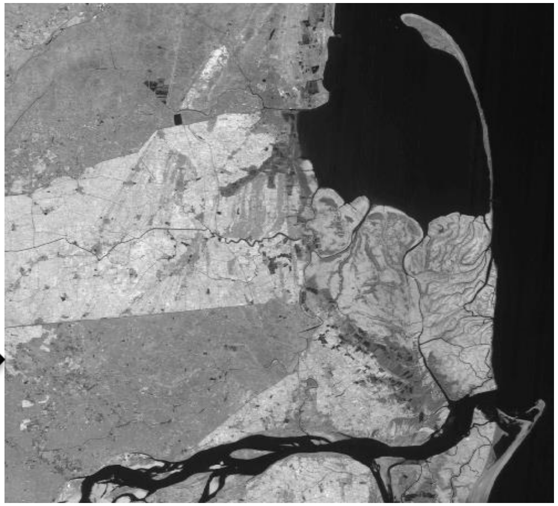
Band 2 (Green)





Band 3 (Red)

Band 4 (NIR)

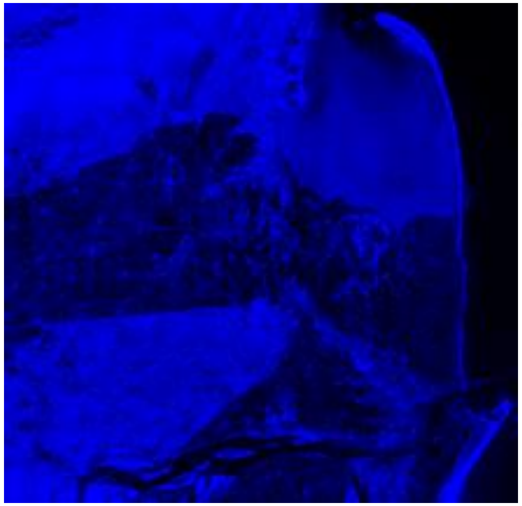


Suitability of TM single bands to different themes

Theme	B1 (0.45-0.52)	B2 (0.52-0.60)	B3 (0.63-0.69)	B4 (0.76-0.90)	B5 (1.55-1.75)	B7 (2.08-2.35)
Water bodies	P	P	M	G	G	G
Water characteristics	G	G	P	N	N	N
Drainage patterns	P	P	M	G	G	M
Soil boundaries	P	M	G	M	G	M
Forest areas	M	M	M	G	G	M
Agricultural areas	P	M	M	G	G	M / G
Urban / Residential areas	M / G	G	G	P	P	P / M
Quaries	P	P	P	G	M	M

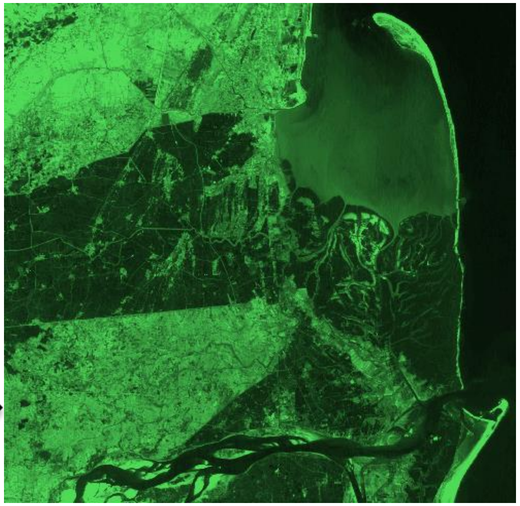
Good, **M**edium, **P**oor, **N**ot Usable

(Wavelengths in micro meters)

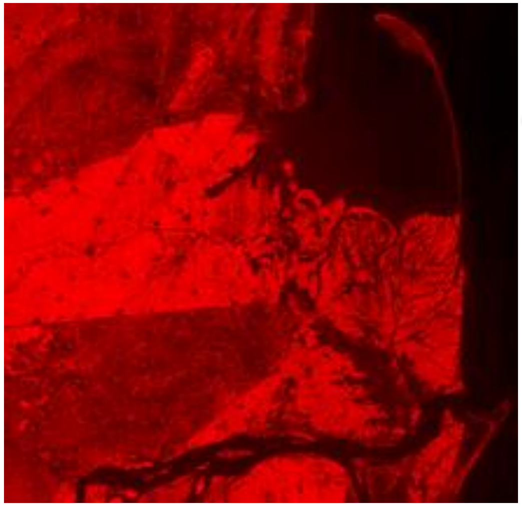


Band 2

Band 3



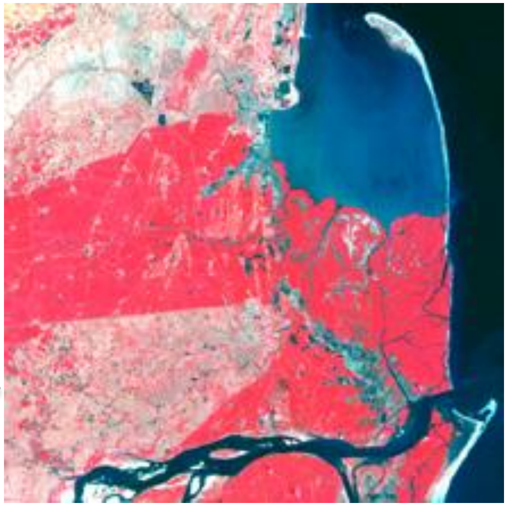
False Colour Composite (FCC)



Band 4

FCC

(432)



TCC (321)

FCC (432)

Some Existing Indian Optical Sensor Systems

Satellite	Sensor(s)	Spatial (m)	Spectral (µm)	Radiometric (bits)	Revisit (days)	Swath (Km)
Cartosat - 2E (Jun 23, 2017) 2X300 Gbit SSR	PAN (45° al & 26° ac track) MX	0.65 Better than 2.0	0.45 - 0.9 B1, B2, B3, B4	11 11	5 (93 days for repetivity)	9.6 9.6
Resourcesat -2A (Dec 17, 2016)	Follow on mission to Resourcesat-2 and intended to provide data continuity to the users.					
Cartosat - 2C (June 22, 2016) 2X300 GB SSR **Cartosat 2 Series (C2S-1)**	PAN HR MX 10° aft & 26° fore Field of Regard of 400 Km cross track	0.65 < 2.0	0.50-0.85 B1 B2 B3 B4	11	5 (93 days for repetivity)	10.2 Continuous strip Spot scene Paint brush
Resourcesat - 2 (Apr 20, 2011) 200 GB	AWiFS LISS III LISS IV (Steerable)	56m nadir 23.5 m 5.8 m	B 2345 B 2345 B 234	12 10 10	5 24 5	737 (2x370) 141 70

ISRO Standard Optical Bands

Band	EM Spectrum	Wavelength (µm)
1	Blue	0.45 - 0.52
2	Green	0.52 - 0.59
3	Red	0.62 - 0.68
4	IR	0.77 - 0.86
5	SWIR	1.55 - 1.70

Not applicable to Oceansat & HySI

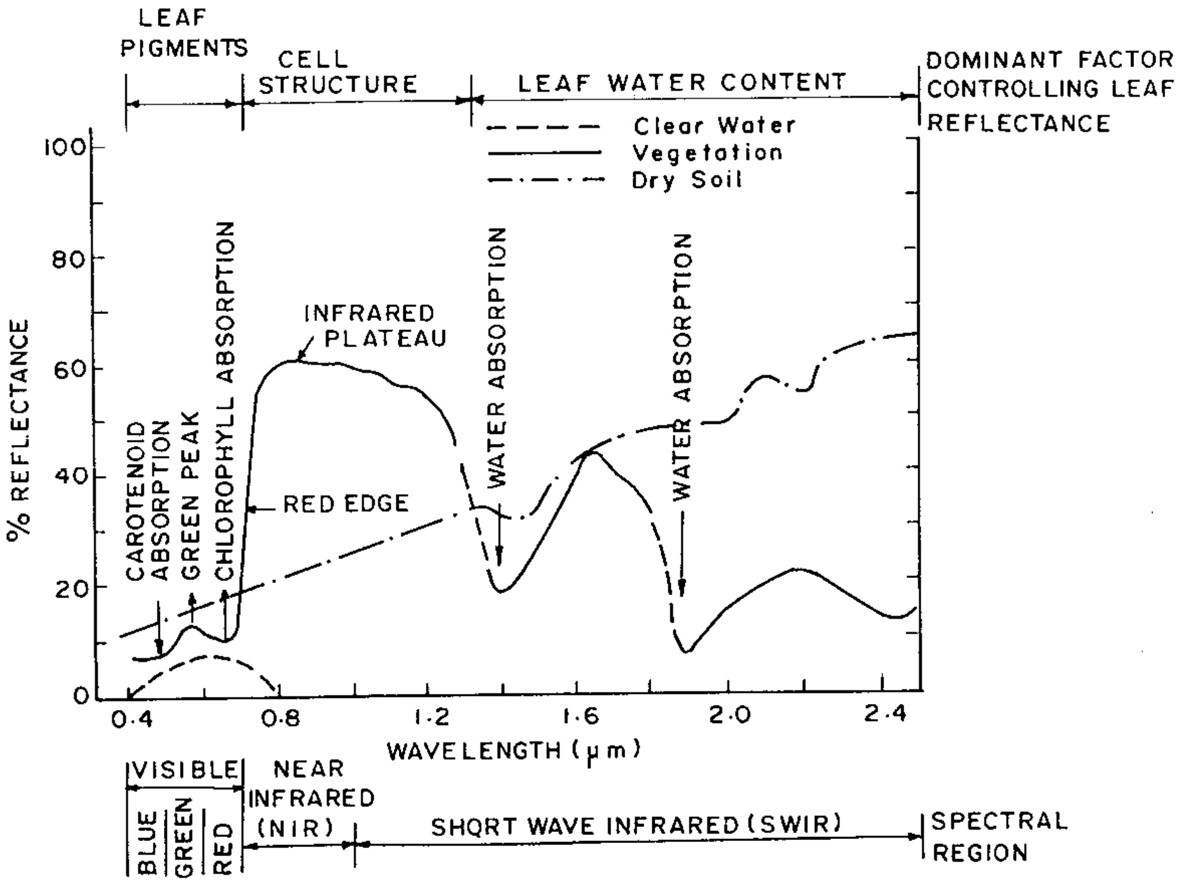
Indian Microwave Remote Sensing Satellite

Radar Imaging Satellite-1 (RISAT-1)

Mode	Look	Resolution	Swath	Polarisation
Coarse Resolution mode	2-4	50	240	Single or Dual
Meduim Resolution mode (MRS)	1-2	25	120	Single or Dual
Fine Resolution Striping Single mode (FRS-2)	9-12	9	25	Quad
Fine Resolution Strip map (FRS-1)	Single	3-6	25	Single or Dual
High Resolution Spot light Mode (HRS)	Single	1-2	10x10	Single or Dual

Single Polarisation	VV / HH / HV / VH
Dual Polarisation	HH & VV / VV & VH
Polarimetric	HH & VV & HV & VH

Spectral Signature



A typical reflectance curve of green vegetation in the visible, near infrared and mid infrared region (after Goetz et al, 1983)

Visual interpretation elements for remote sensing data

Tone, Texture

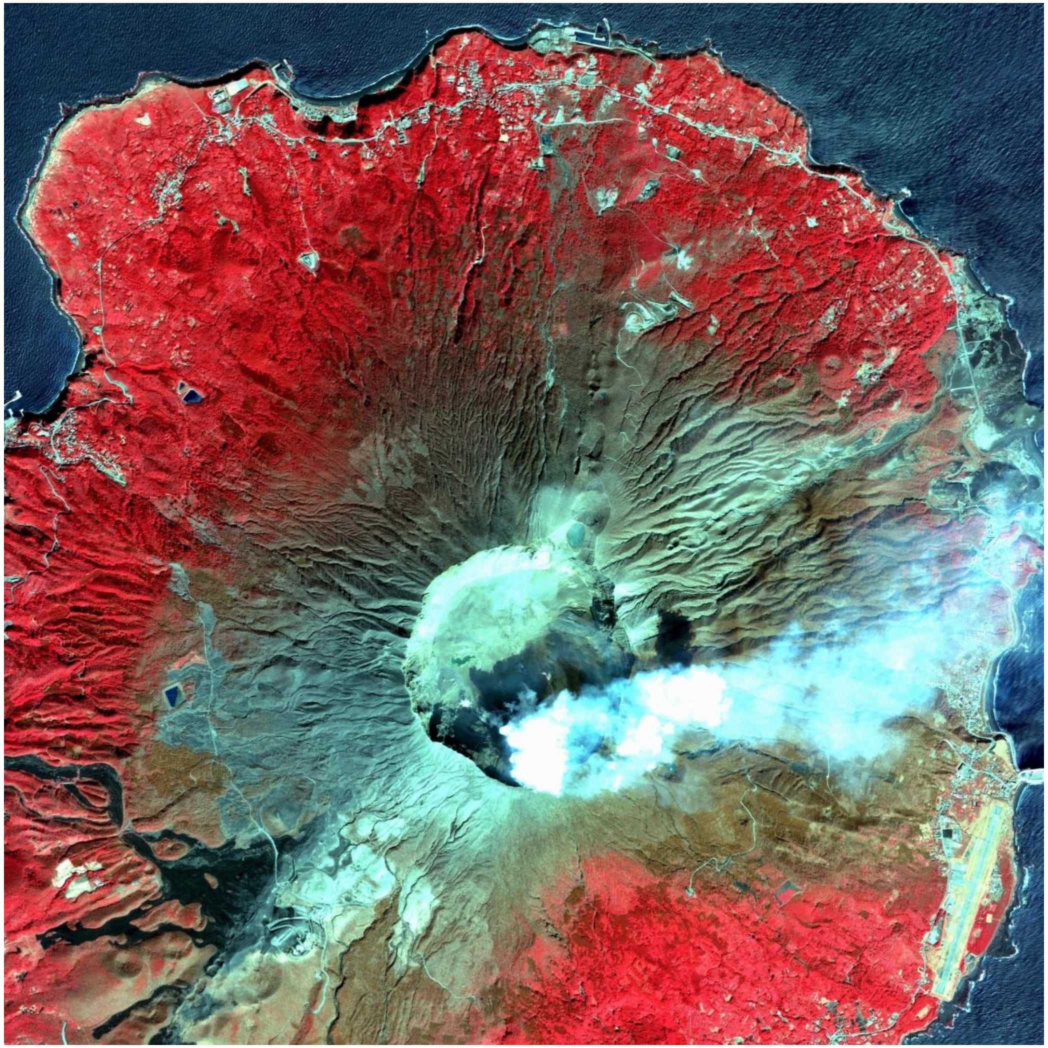
Size, Shape

Pattern, Shadow

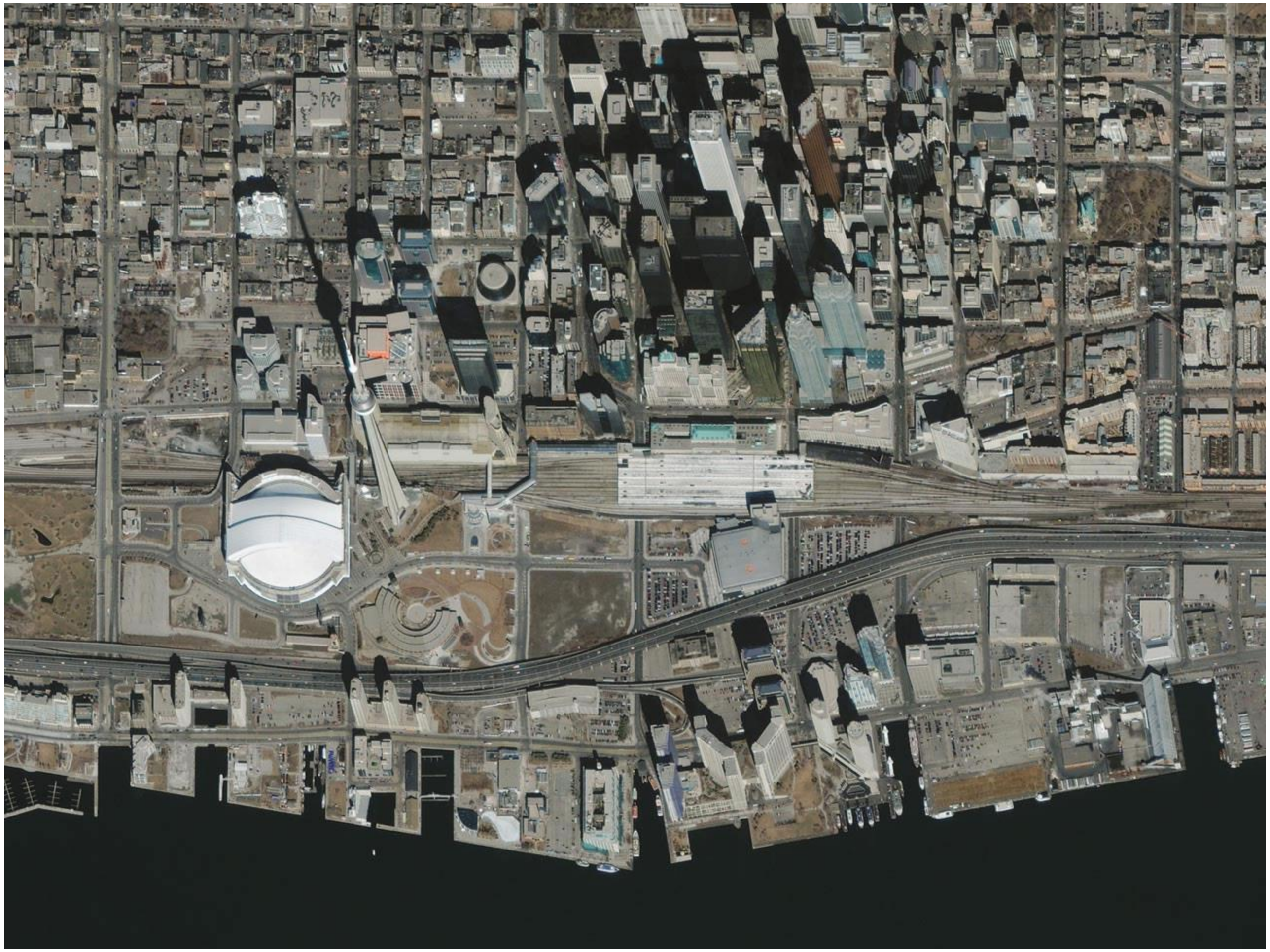
&

Association, Location

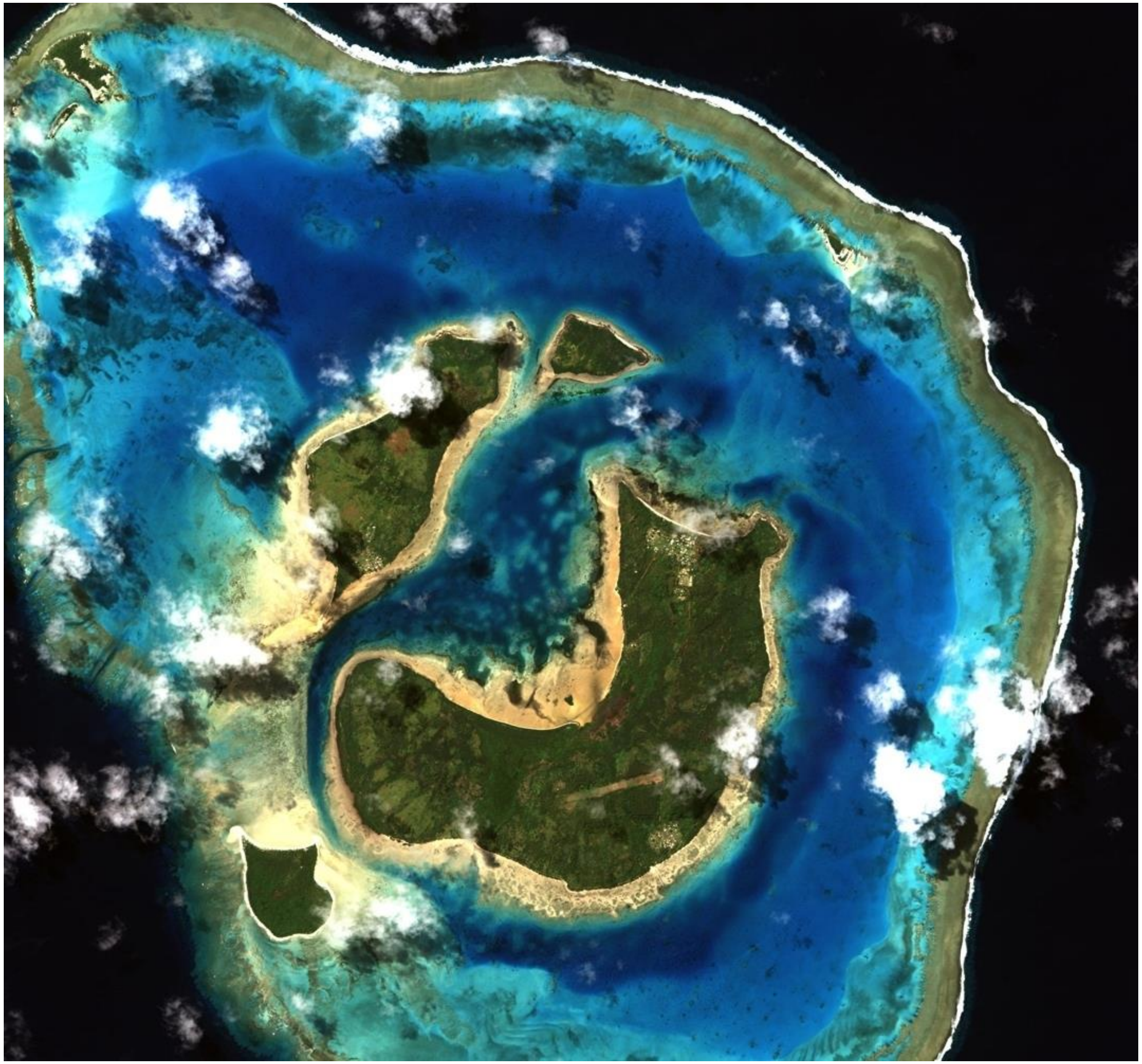
TONE
&
TEXTURURE



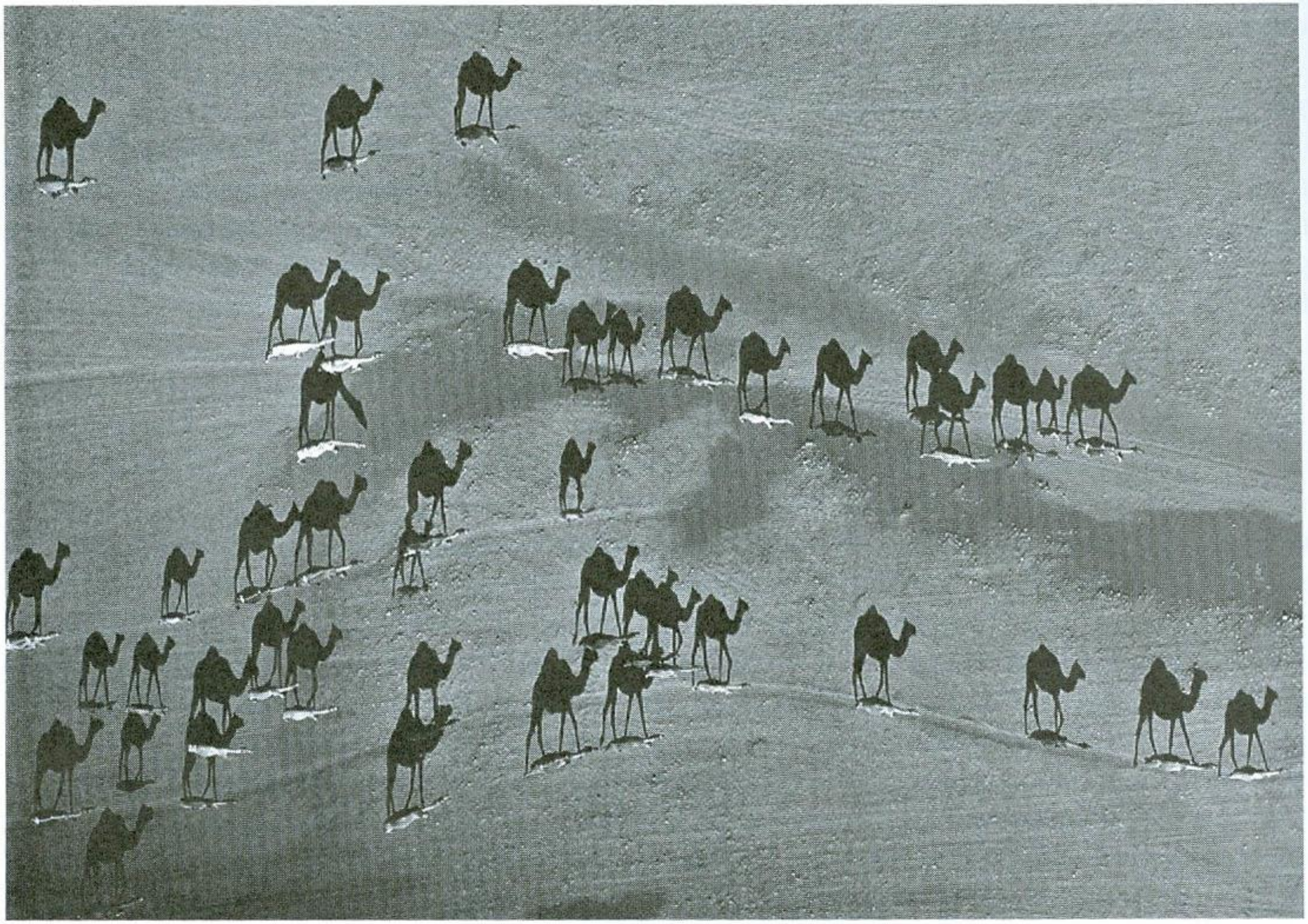
SIZE, SHAPE & SHADOW



SHADOW

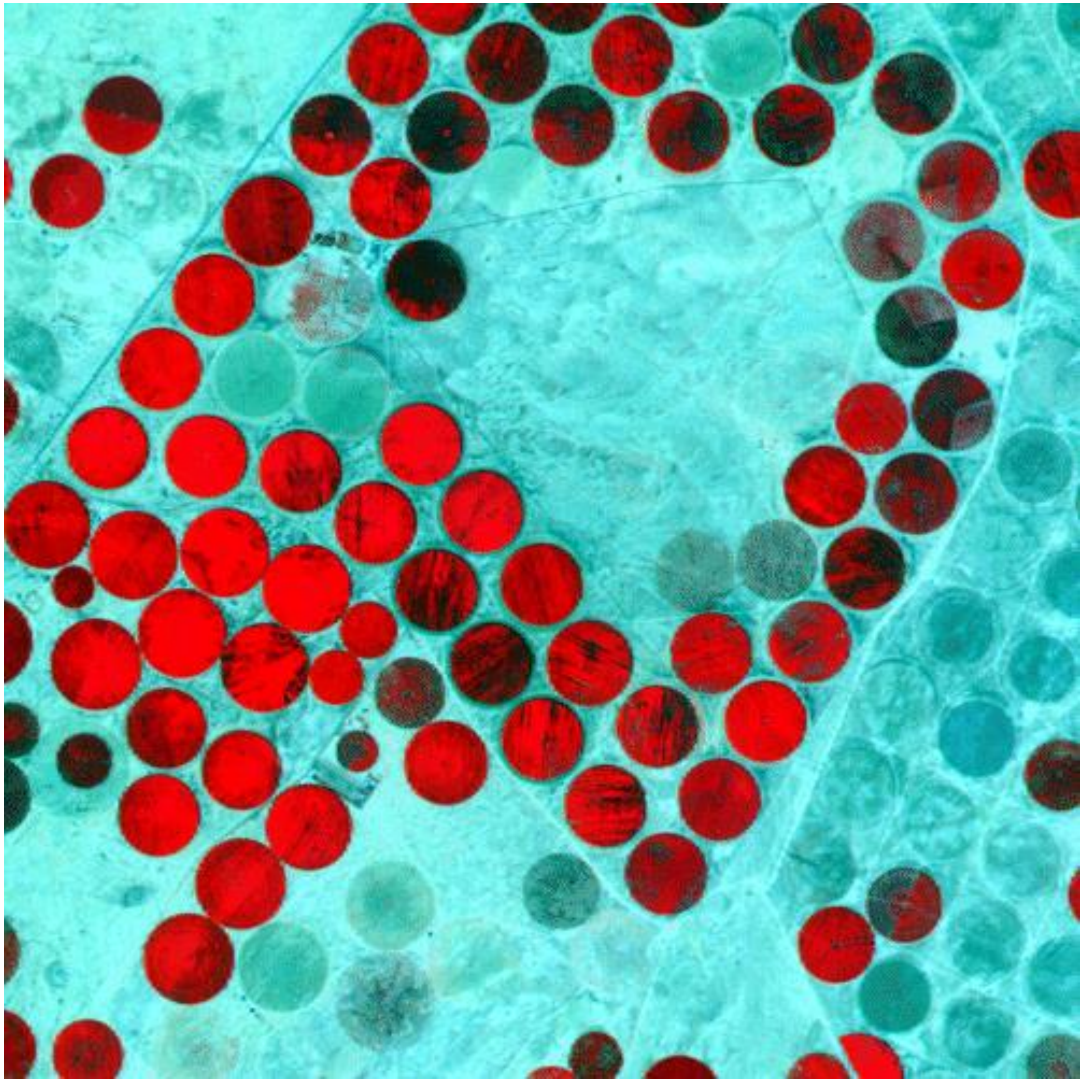


Ono-i-Lau, Fiji collected by ORBIMAGE's OrbView-3 satellite on Thursday, May 13, 2004



Vertical aerial photograph showing camels that cast long shadows under late afternoon sun in Oman. (Photo by George Steinmetz – taken from Remote Sensing and Image Interpretation by Lillesand, Kiefer and Chipman, 6th edition, John Wiley & Sons, 2008)

PATTERN



A S S O C I A T I O N

SITE / LOCATION

Mt. Everest at 4 m by Ikonos

References

WEBSITES

http://isro.gov.in
http://nrsc.gov.in/Earth_Observation_Missions
https://www.itc.nl/Pub/sensordb/AllSensors.aspx
https://earthdata.nasa.gov/learn/remote-sensing
https://www.nrcan.gc.ca/maps-tools-publications/satellite-imagery-air-photos/remote-sensing-tutorials/fundamentals-remote-sensing-introduction/9363
http://www.esa.int/SPECIALS/Eduspace_EN/SEMF9R3Z2OF_0.html
https://crisp.nus.edu.sg/~research/tutorial/intro.htm
https://gisgeography.com/remote-sensing-earth-observation-guide/
https://directory.eoportal.org/web/eoportal/satellite-missions
http://space.skyrocket.de/index.html (Gunter's Space Page)
http://www.satimagingcorp.com/satellite-sensors/
https://sentinel.esa.int/web/sentinel/missions/

References

BOOKS

Remote Sensing and Image Interpretation by Lillesand and Kiefer, Wiley Publication
Fundamentals of Remote Sensing, George Joseph, Orient Blackswan
Introduction to Remote Sensing, James B Campbell, The Guilford Press
Introduction to the Physics and Techniques of Remote Sensing, Charles Elachi, Wiley Publication

FREE DATA SITES

http://gisgeography.com/free-satellite-imagery-data-list/
http://bhuvan.nrsc.gov.in/data/download/index.php (Indian data)
https://scihub.copernicus.eu/ (The Copernicus Open Access Hub)
https://sentinel.esa.int/web/sentinel/sentinel-data-access
https://apps.sentinel-hub.com/eo-browser/?lat=40.305&lng=23.346&zoom=7
https://earthexplorer.usgs.gov/
https://earthdata.nasa.gov/earth-observation-data/near-real-time/download-nrt-data/modis-nrt

Thank You