# Principles of Remote Sensing

# Platforms

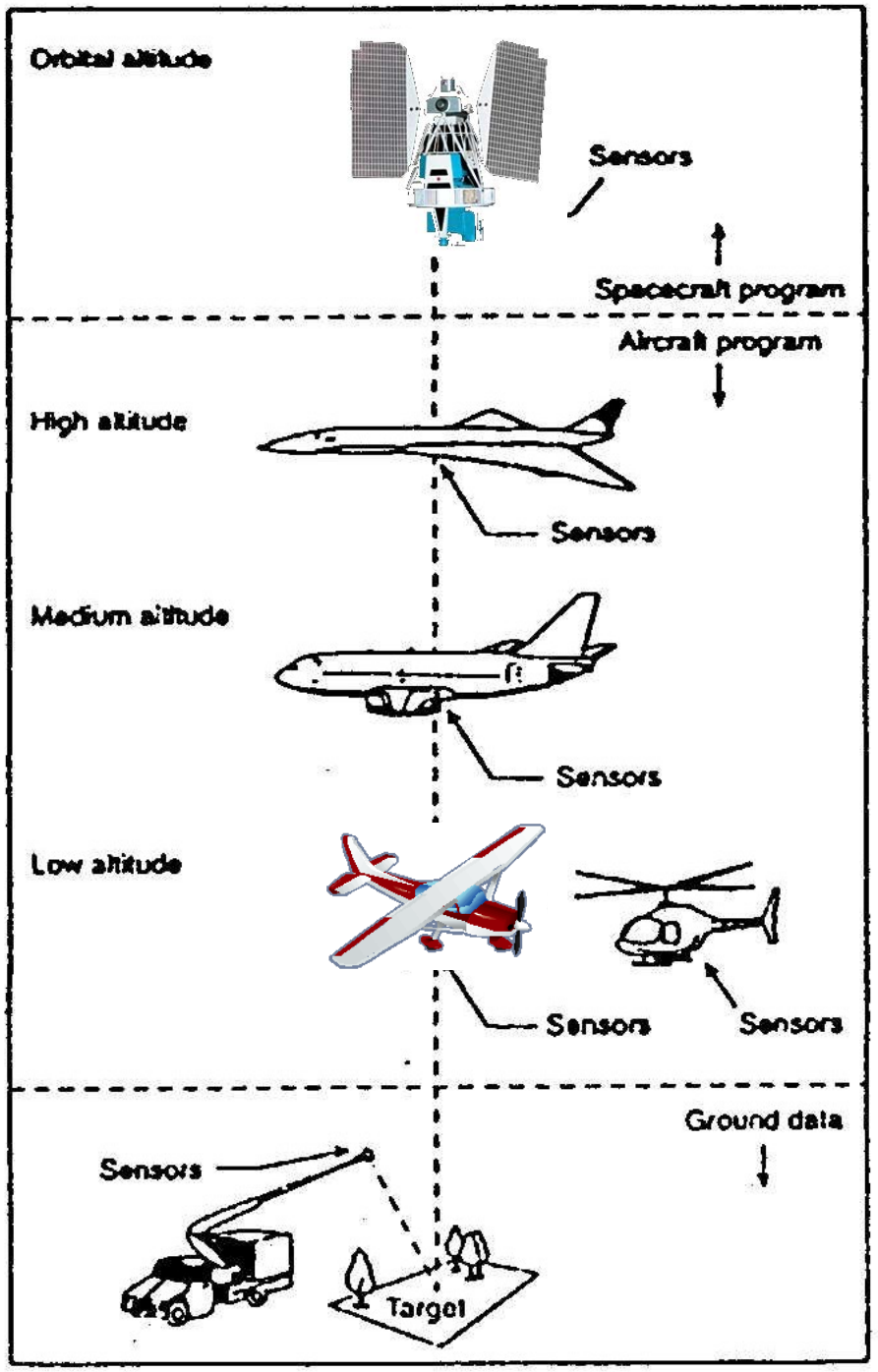
- **Data Collection Platforms.**
- **Balloons.**
- **Helicopters, Aircraft, Space Shuttles.**
- **Satellites:** **LandSat**
  **SPOT**
  **ASTER**
  **MeteoSat**
  **Nimbus**
  **SeaSat**

# Remote Sensing Platforms

- Geostationary — 36,000km
- Polar orbit — 900 km
- manned space — 200-300 km
- High altitude aircraft (U-2) — 90,000 ft
- Jets
- low alt. aircraft — 10-30,000 ft
- Platforms
- In-situ/ground — 500-10,000 ft

10-100 ft

0.5 ft



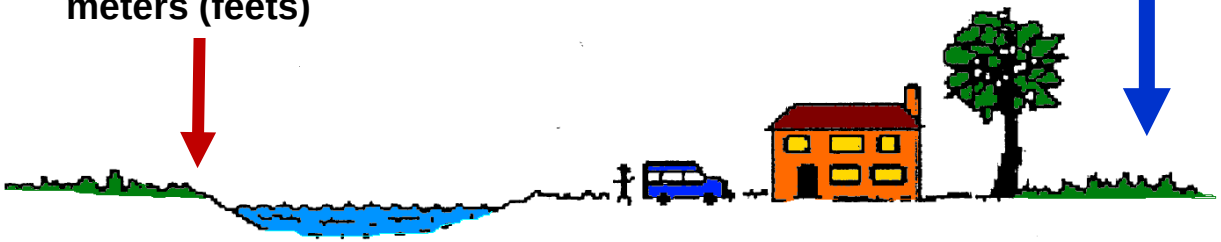
# Aircraft & Satellites

*Satellites*

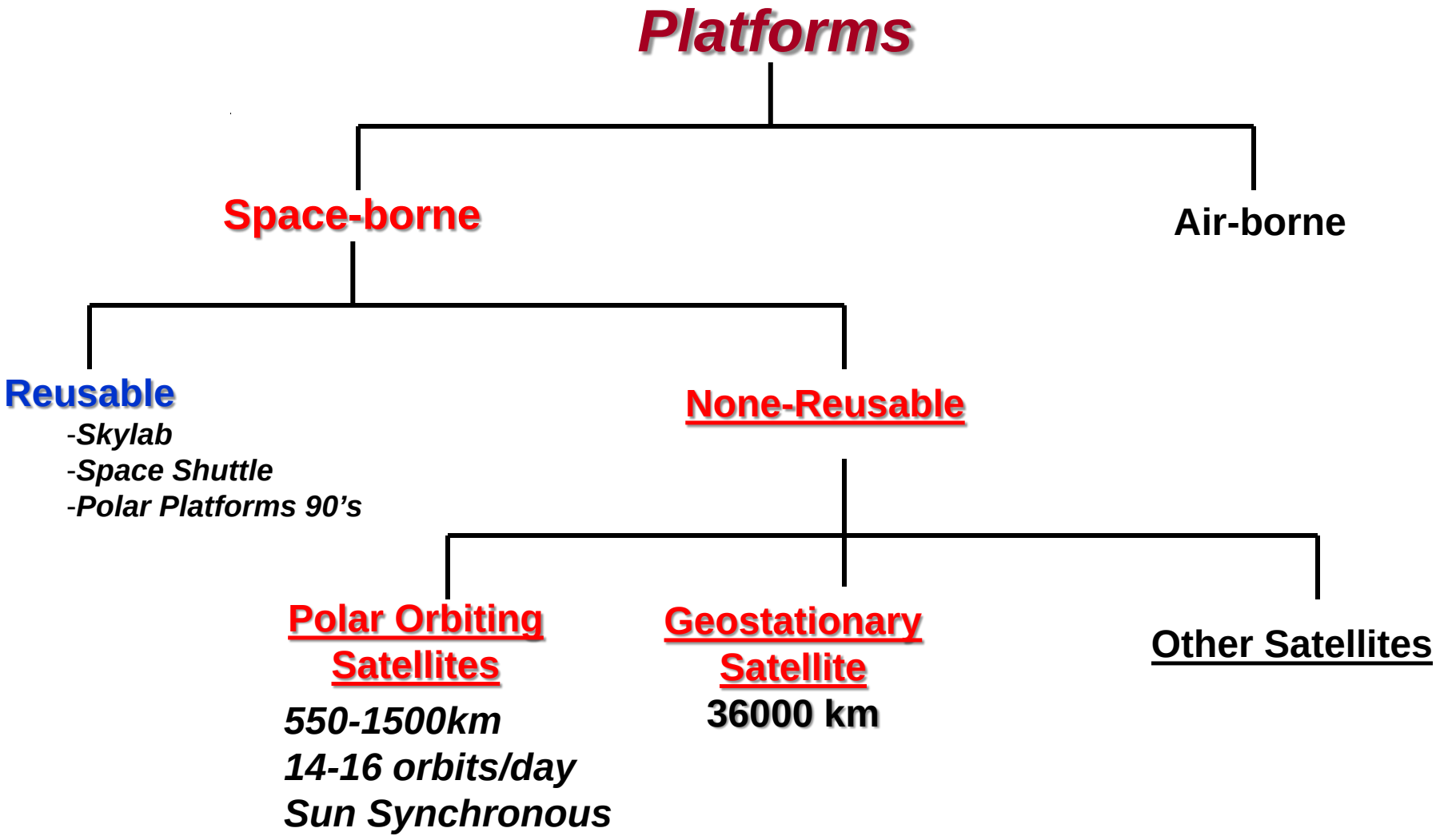
*Aircrafts*

~ hundreds and thousands of Kilometers (miles)

~ thousands of meters (feets)



# Platforms


Platforms
Space-borne
Air-borne
Reusable
-Skylab
-Space Shuttle
-Polar Platforms 90's
None-Reusable
Polar Orbiting Satellites
550-1500km
14-16 orbits/day
Sun Synchronous
Geostationary Satellite
36000 km
Other Satellites

# Satellite Orbits

**The path followed by a satellite is referred to as its *orbit*.**

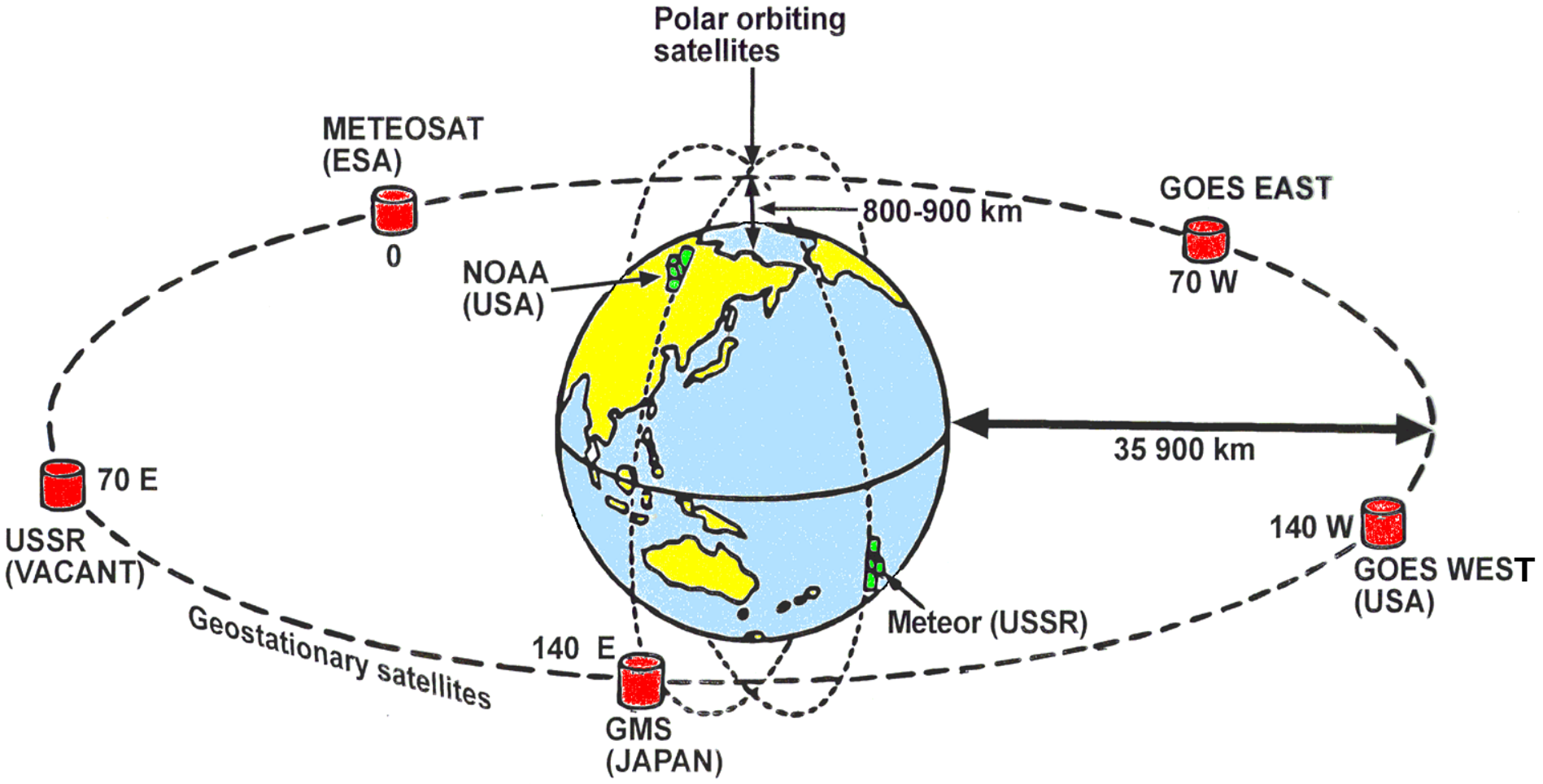
**Satellite orbits are matched** to the **capability** and **objective of the sensors** they carry.

**Orbit selection** can **vary** in terms of ***altitude*** (their height above Earth's surface) and their ***orientation*** and ***rotation*** **relative to the Earth**.

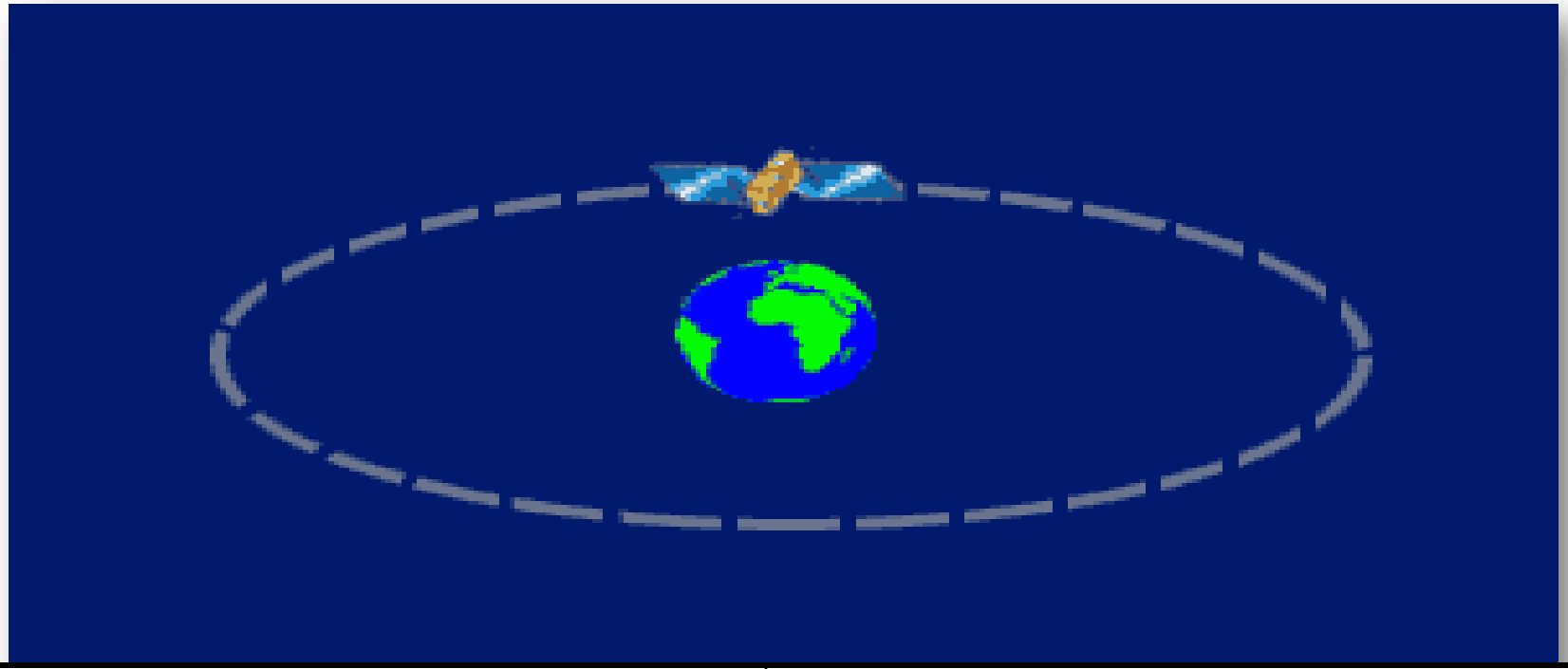
***Orbits critical to remote sensing are***:

1) **Geostationary orbits**
2) **Near polar orbits**

# Satellite Orbits

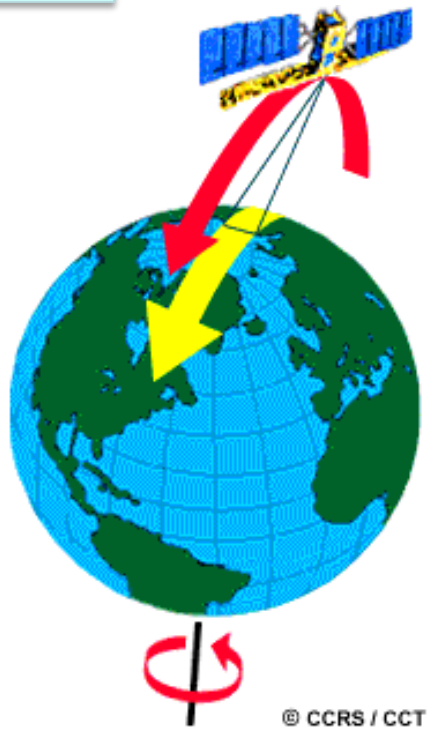


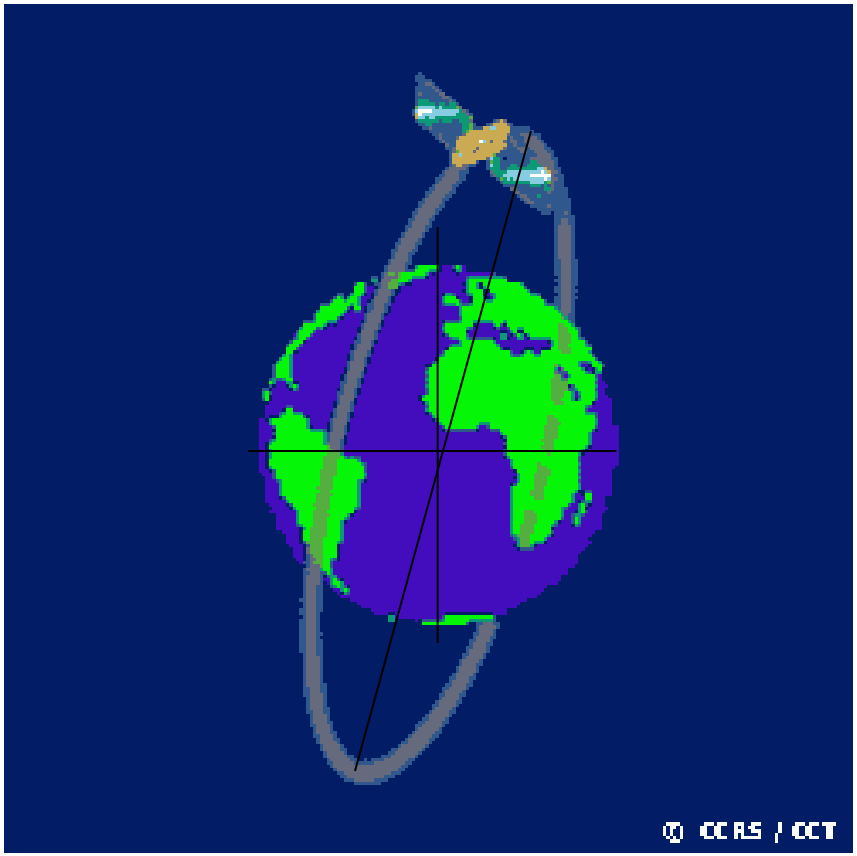
# Geostationary Orbit



| | |
|---|---|
| • These orbit's altitude is about ***36000*** km | • The satellites **move** at the ***same speed of the rotation of the earth*** |
| • The orbit is ***parallel*** to the ***equator and at high angle to the earth's axis*** | • The satellites **move** in the ***same direction of rotation of the earth (anticlockwise)*** |
| • Each satellite always ***faces*** the ***same part of the earth*** all the time | • ***Satellites are placed with about $70^{O}$ away from each other*** |

# Near Polar Orbit

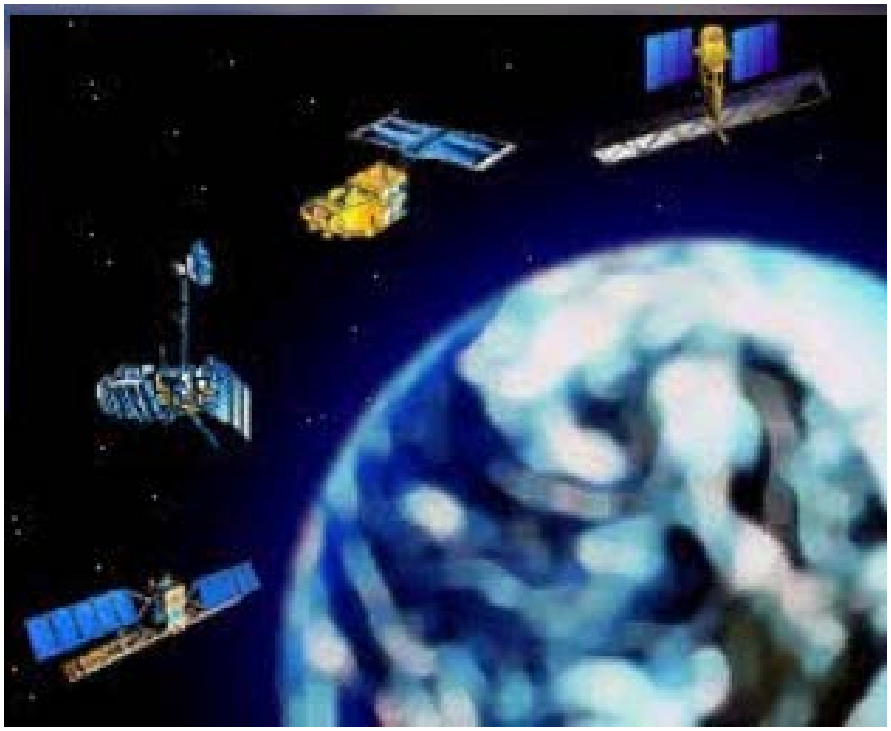



| | |
|---|---|
| • These orbit's altitude is about ***500 - 1500*** km | • The satellites **move** ***faster than the speed of the rotation of the earth*** |
| • The orbit is ***at high angle*** to the ***equator and at about 8-9º to the earth's axis*** | • The satellites **move** in the ***opposite direction of rotation of the earth (clockwise)*** |
| • ***Satellites are Sun Synchronous when ascending*** | • |

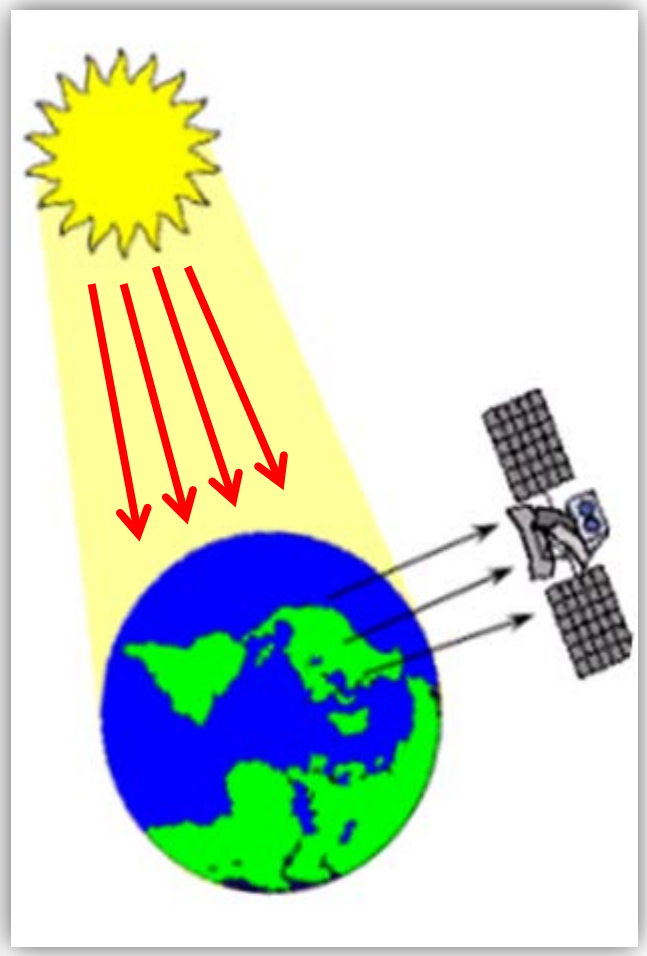
# Sensing Systems

- The ***sun*** provides ***a*** source of energy for remote sensing.
- The **sun's energy** is **either**:
  - ***reflected*** in the **visible** wavelengths, **or**
  - ***absorbed*** **and** then ***re-emitted*** in the **thermal infrared** wavelengths.
- There are artificial sources of energy beside the sun in remote sensing
- Remote sensing systems can be classified into two major categories depending on the source of energy that they sense:
  - **Passive** systems
  - **Active** systems



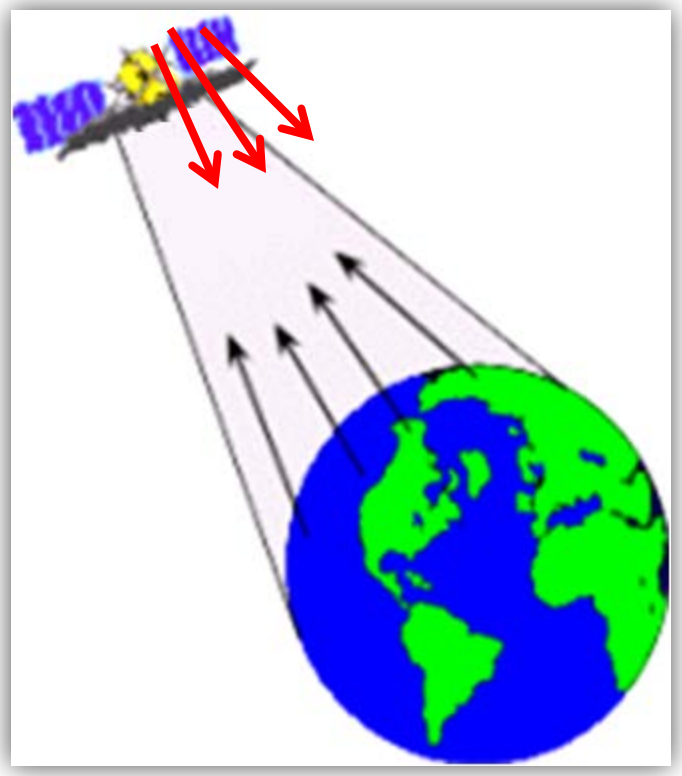
# Passive Sensors

- Remote sensing system which measure energy that is naturally available are called ***passive sensors***.
- For all reflected energy, this can only take place during the time when the **sun *is illuminating the Earth***.
- There is **no reflected energy** available **from the sun at night**.
- Energy that is naturally emitted (such as **thermal infrared**) **can be detected day or night**, as long as the amount of energy is large enough to be recorded.



# Active Sensors

- ***Active Sensor***, provide ***their own energy source*** for illumination.
- The sensor **emits radiation** which is directed toward the target to be investigated.
- The **radiation reflected from that target is detected and measured by the sensor**
- Advantages for active sensors include:
- The ability to obtain measurements anytime, regardless of the time of day or season.
- ***Active sensors*** can be used for examining wavelengths that are not sufficiently provided by the sun, such as ***microwaves***.
- However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets.



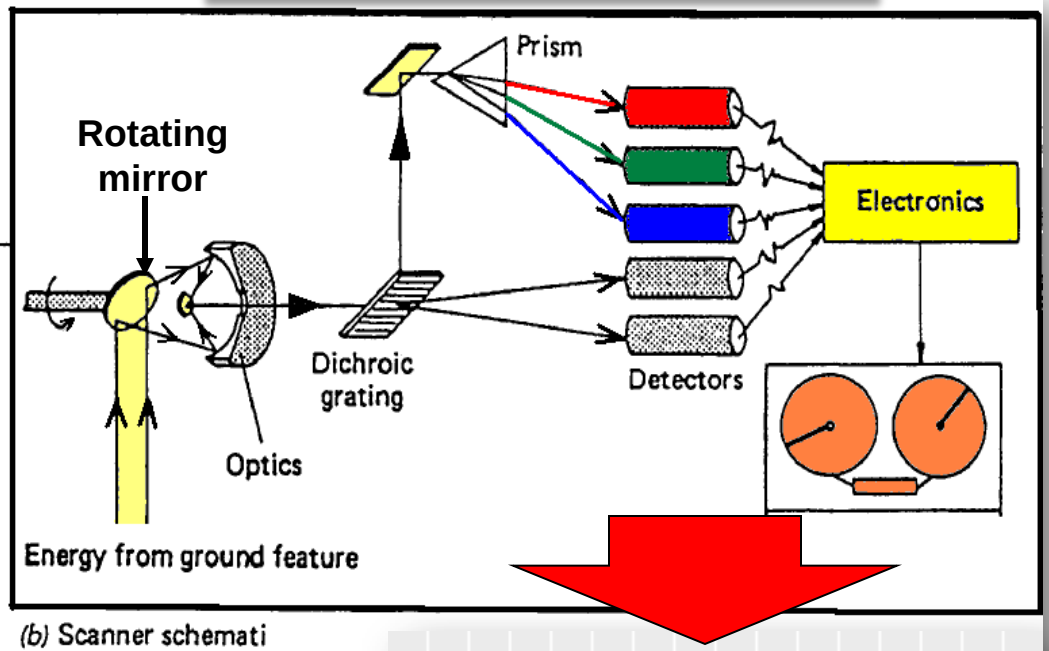
# Sensors

## Sensors

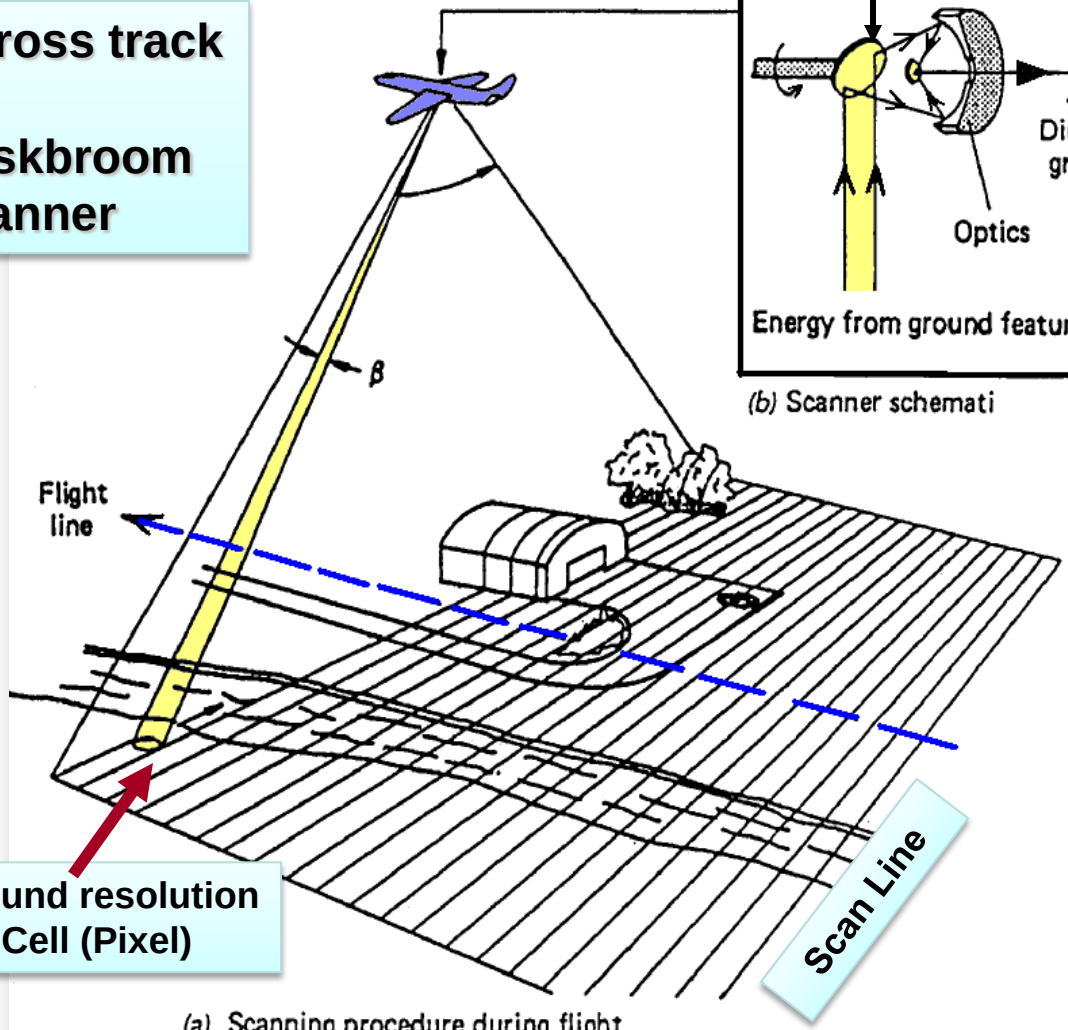
- **Imaging**
  - **Framing**
    - Cameras
      - LFC
      - Metric Camera
    - Vidicons (Image plane Scanner)
      - Return Beam Vidicon (RBV)
  - **Scanning**
    - **Push broom** Sensor
      - SPOT
    - **Wisk broom** Sensor
      - Landsat (MSS& TM)
    - Radar Devices
      - SeaSat,
      - SIR-A, SIR-B,
      - ERS-1
      - Radar Sat
- Non-Imaging
  - Radar Altimeter

# Electro-optical sensor

**Across track or Wiskbroom scanner**




(b) Scanner schemati



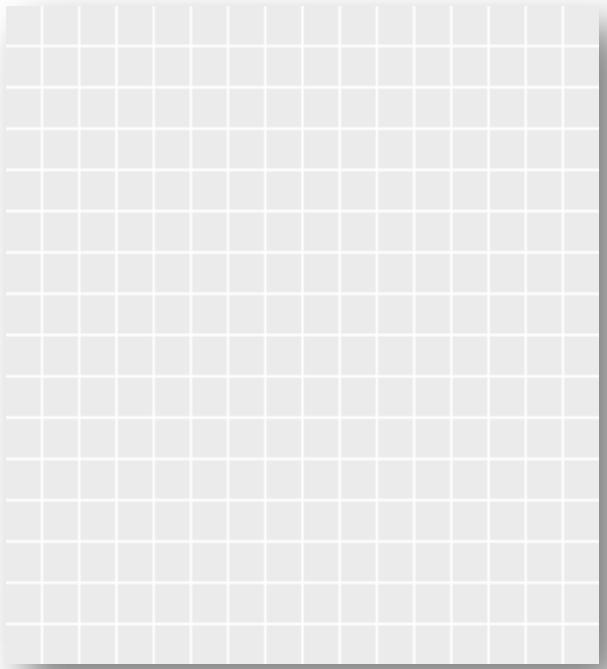

(a) Scanning procedure during flight

**Ground resolution Cell (Pixel)**

**The direction of flight**

# SPOT System Operation

**Along-track**
**or**
**Push broom**
**Scanner**



**Flight Direction**

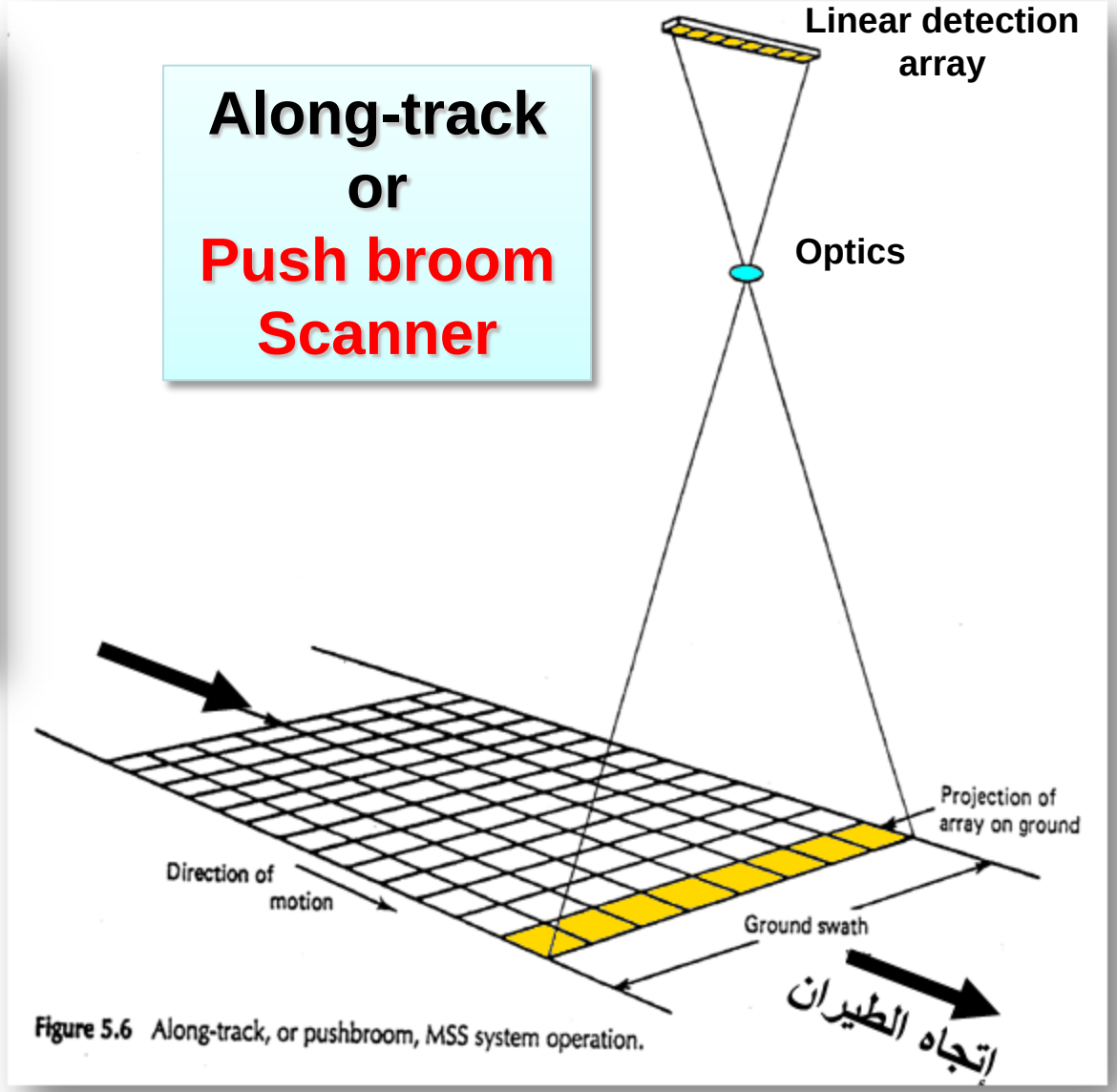



Figure 5.6 Along-track, or pushbroom, MSS system operation.

## Pushbroom scanner



Flight direction

Flight Line

## Wiskbroom scanner



Flight direction

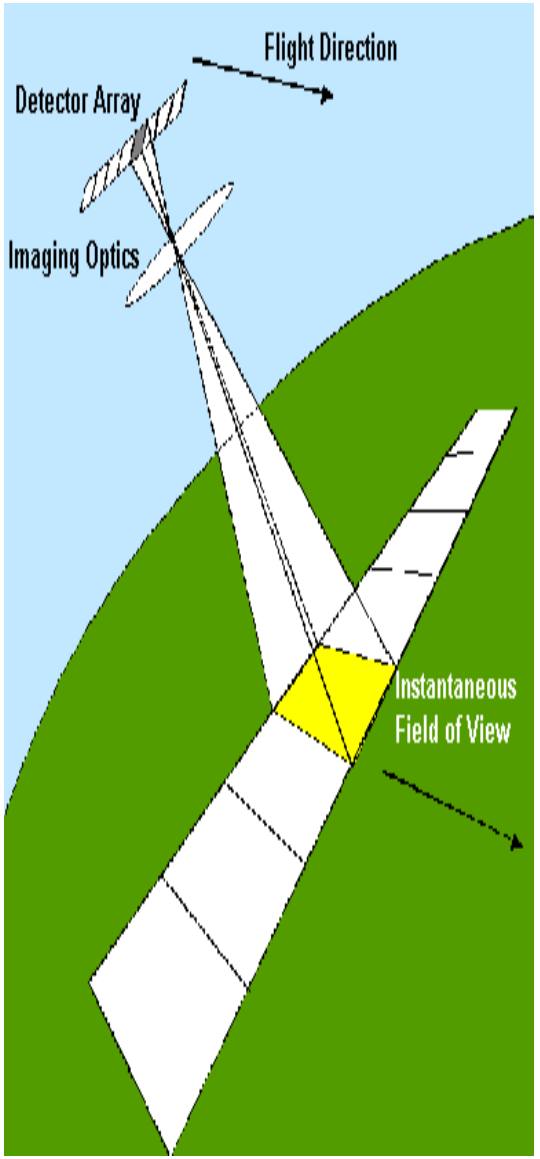
Flight Line

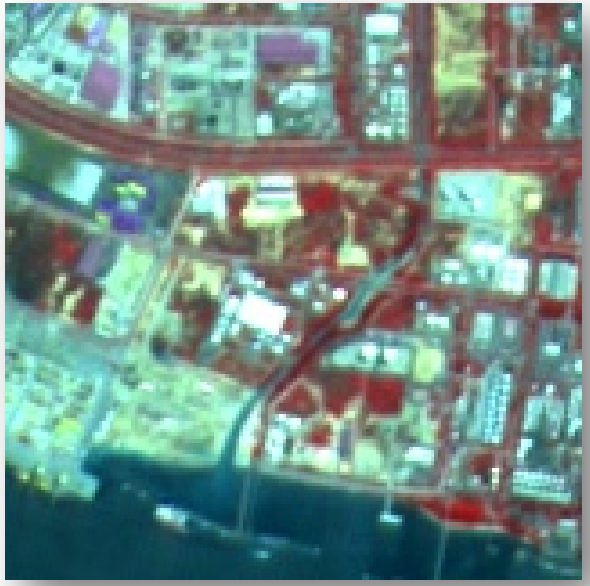
# Resolutions in Remote Sensing

- Spatial
- Spectral
- Temporal
- Radiometric

# Spatial Resolution

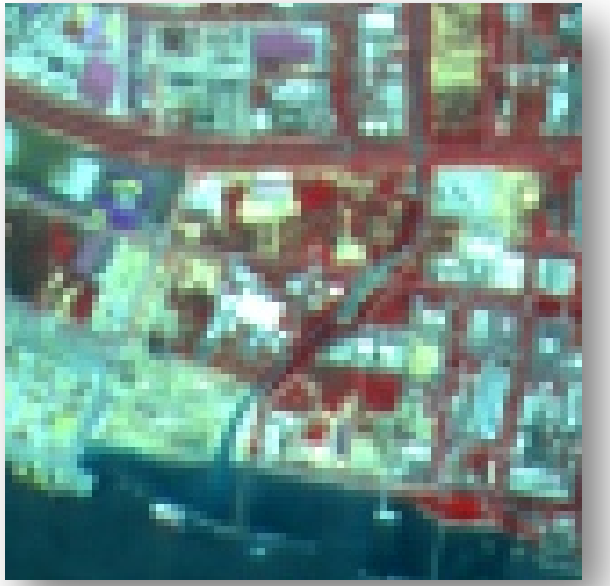
- **Spatial resolution refers to the size of the smallest object that can be resolved on the ground.** In a digital image, the resolution is limited by the **pixel size in meters**, i.e. the **smallest resolvable object *cannot be smaller than*** the **pixel size**. The intrinsic resolution of an imaging system is determined primarily by the **instantaneous field of view (IFOV)** of the sensor, which is a measure of the ground area viewed by a single detector element in a given instant in time.
- A **"*High Resolution*" image** refers to one **with a small resolution size**.
  - **Fine details can be seen in a high resolution image**. On the other hand, a **"*Low Resolution*" image** is one **with a large resolution size**.
  - **Only coarse features can be observed in the image.**





Pixel Size = 10 m

Image Width = 160 pixels, Height = 160 pixels

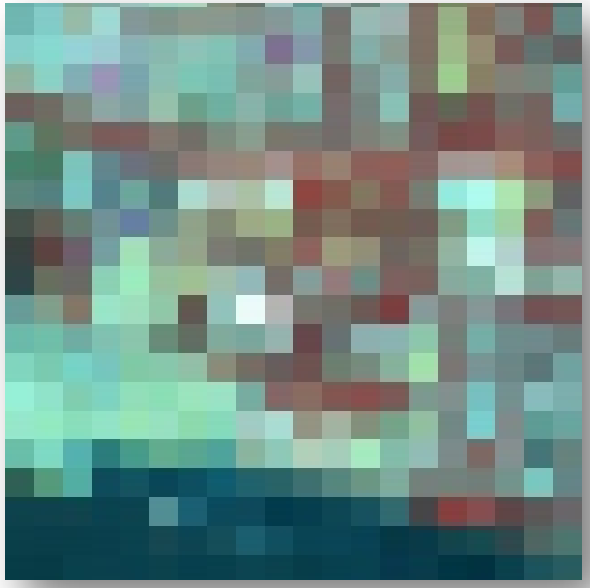


Pixel Size = 20 m

Image Width = 80 pixels, Height = 80 pixels

Pixel Size = 40 m

Image Width = 40 pixels, Height = 40 pixels

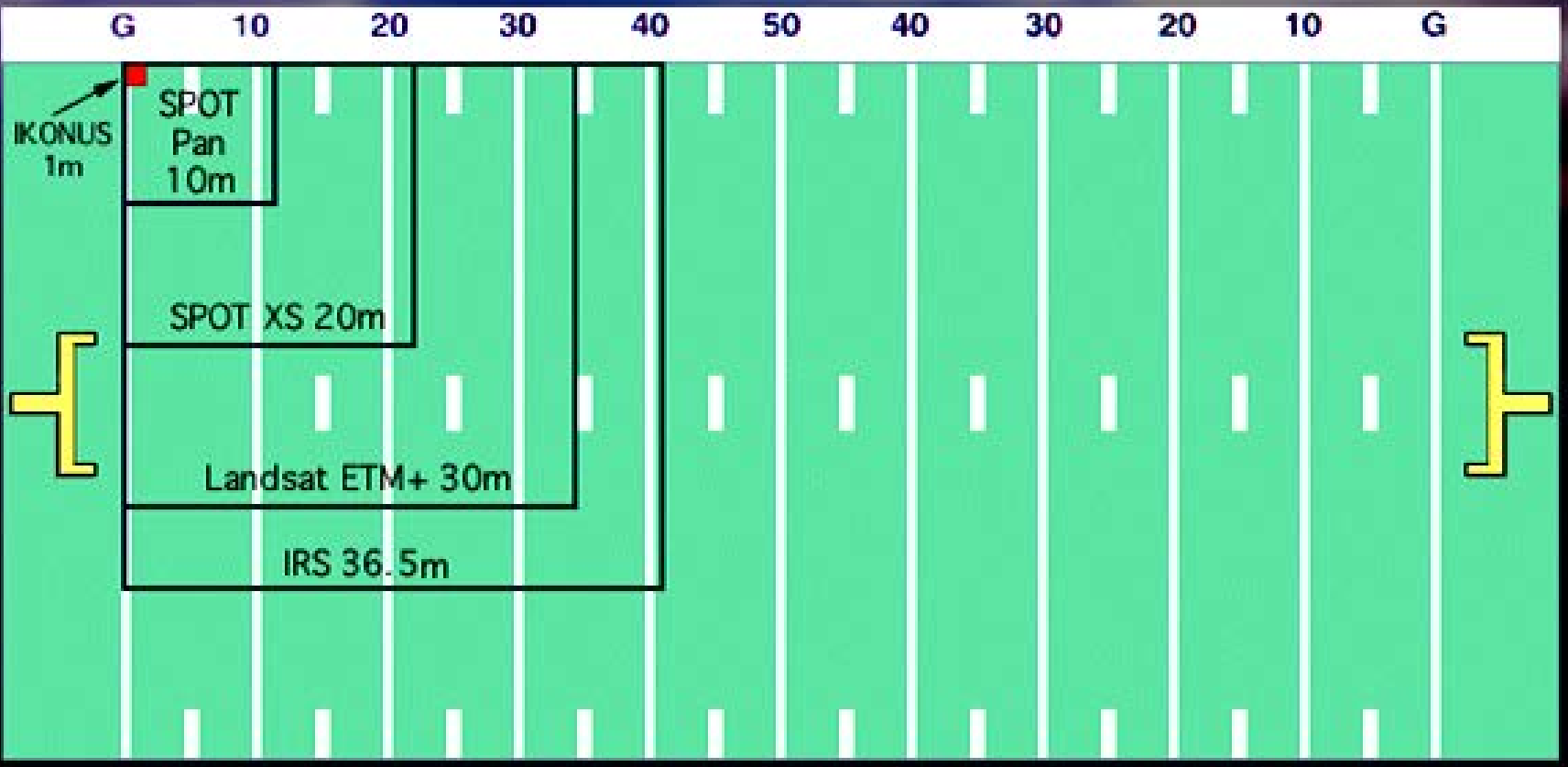


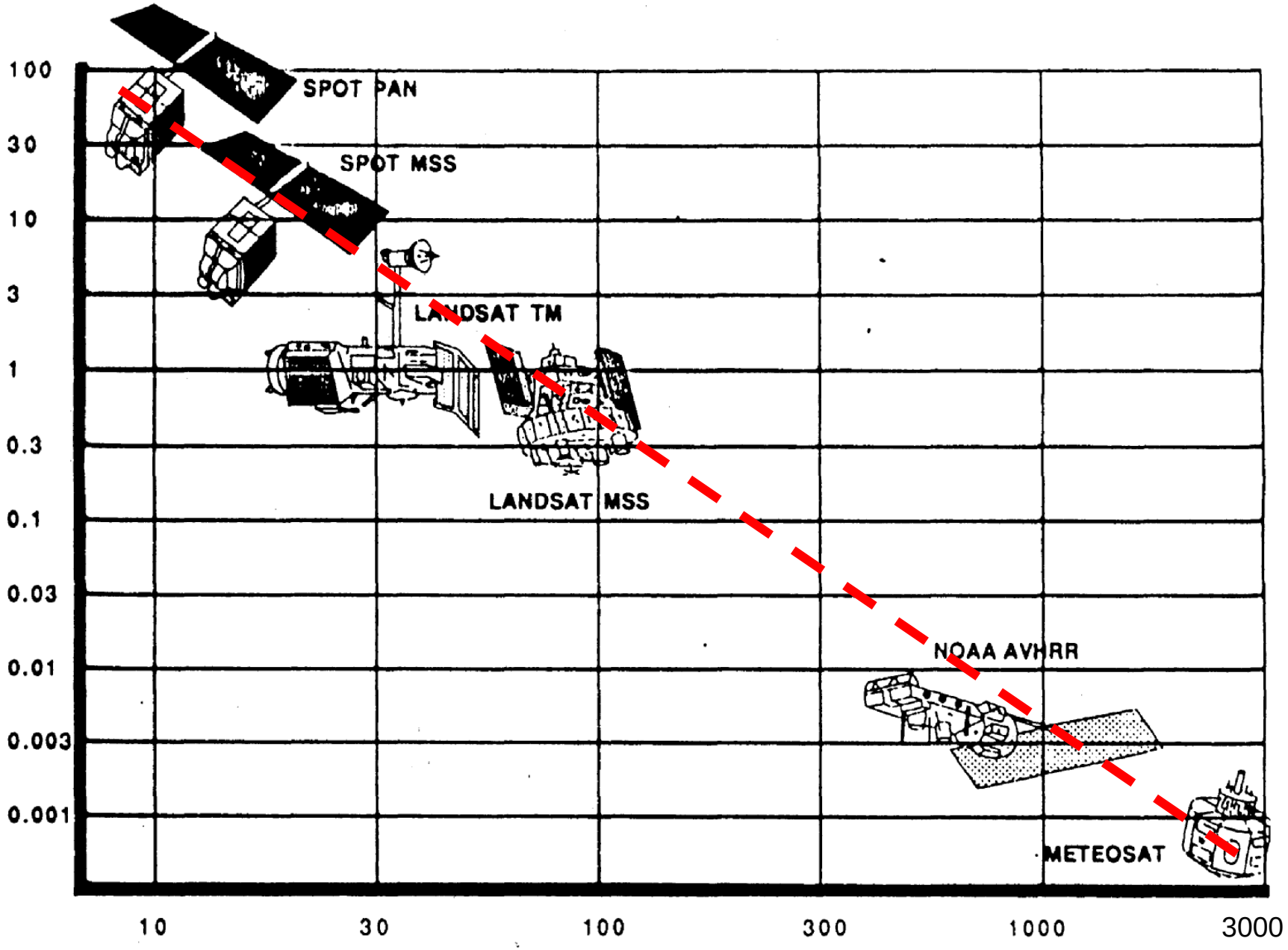
Pixel Size = 80 m

Image Width = 20 pixels, Height = 20 pixels

- Part of a very high resolution image acquired by the **IKONOS** satellite.
- This true-colour image was obtained by merging a 4-m multispectral image with a 1-m panchromatic image of the same area acquired simultaneously.
- The effective resolution of the image is 1 m.
- At this resolution, individual trees, vehicles, details of buildings, shadows and roads can be seen.
- The image shown here covers an area of about 400 m by 400 m.
- A very high spatial resolution image usually has a smaller area of coverage.
- A full scene of an IKONOS image has a coverage area of about 10 km by 10 km.

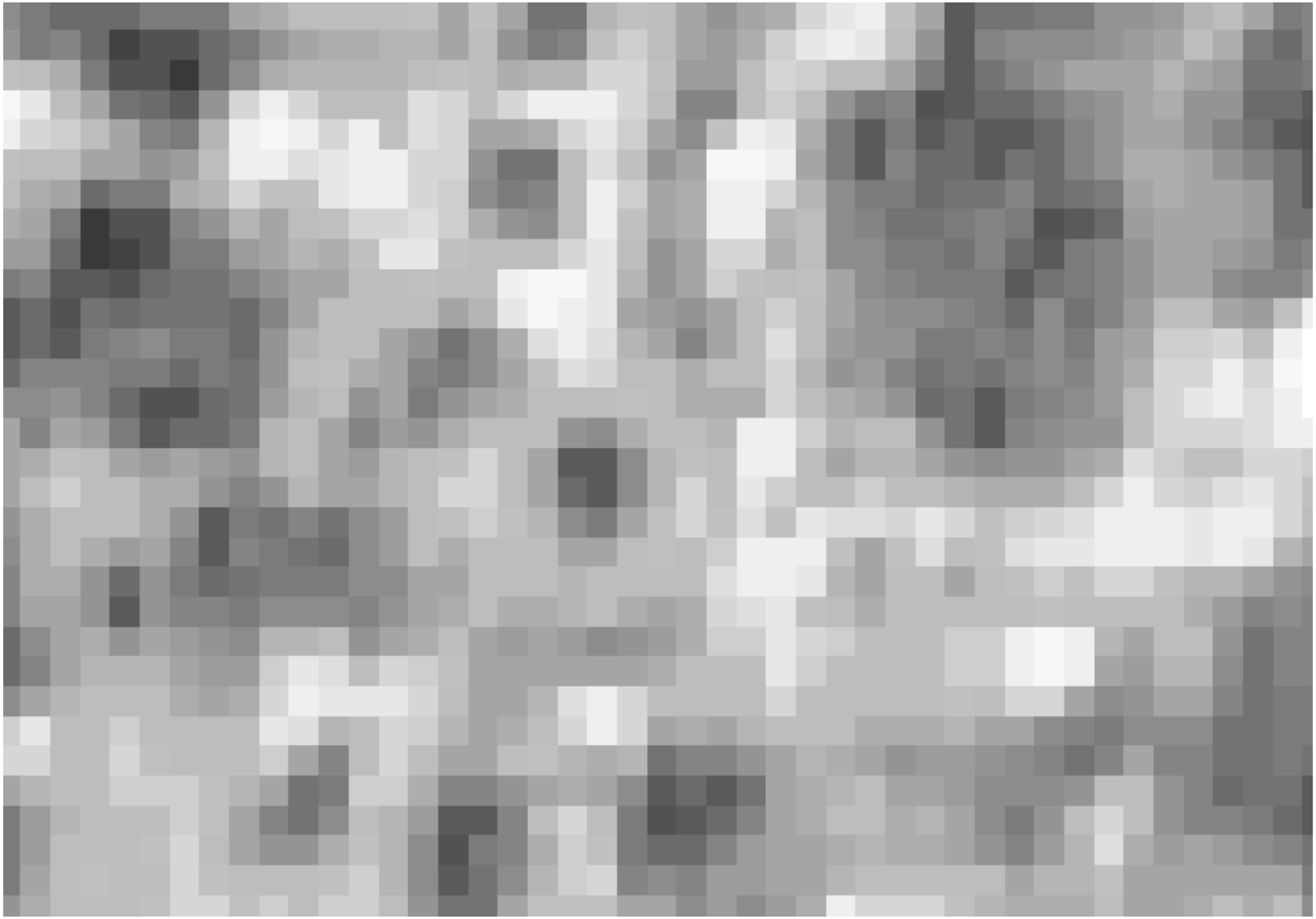
# Resolution – Image (Spatial)






# Spatial Resolution - Meters

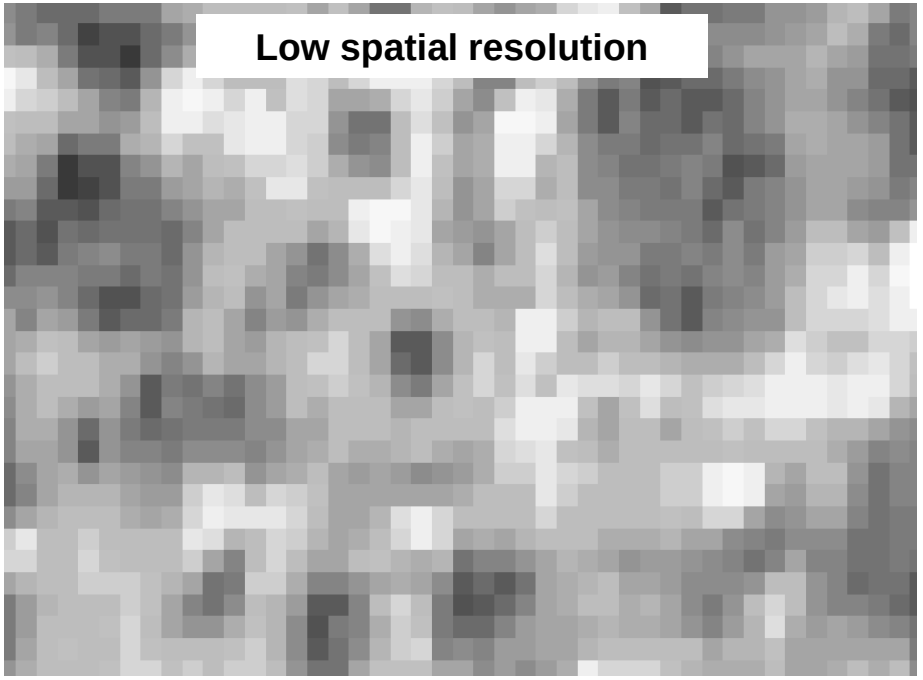
# Image Resolution



# Image Resolution

# Image Resolution

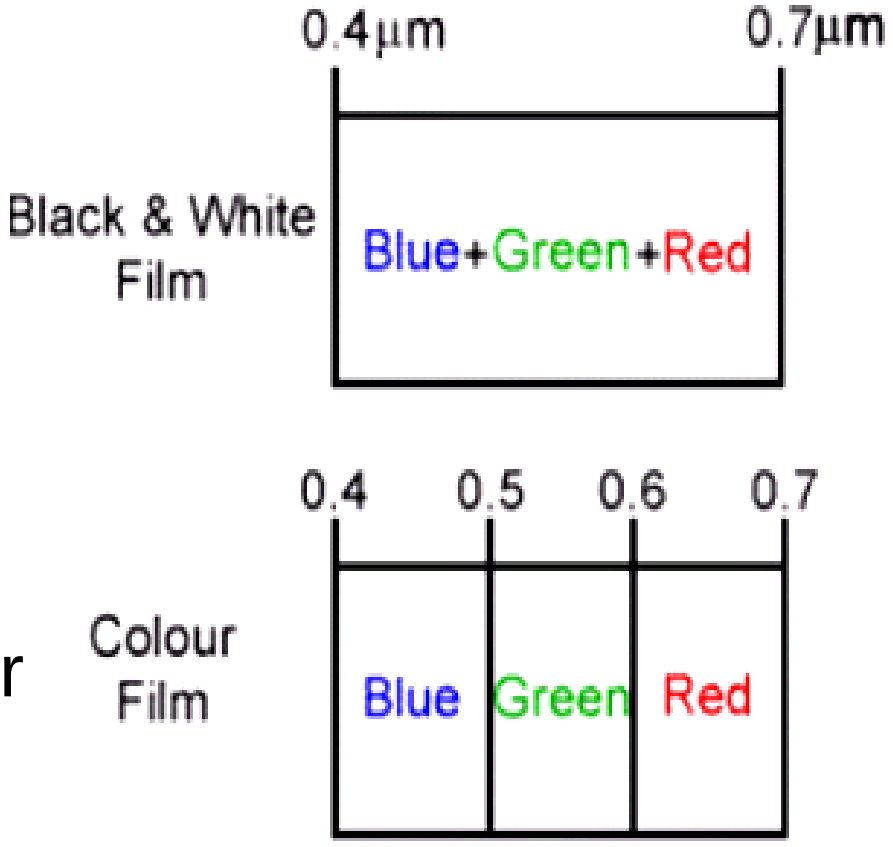
# Image Resolution


Low spatial resolution


High spatial resolution

# Spectral Resolution

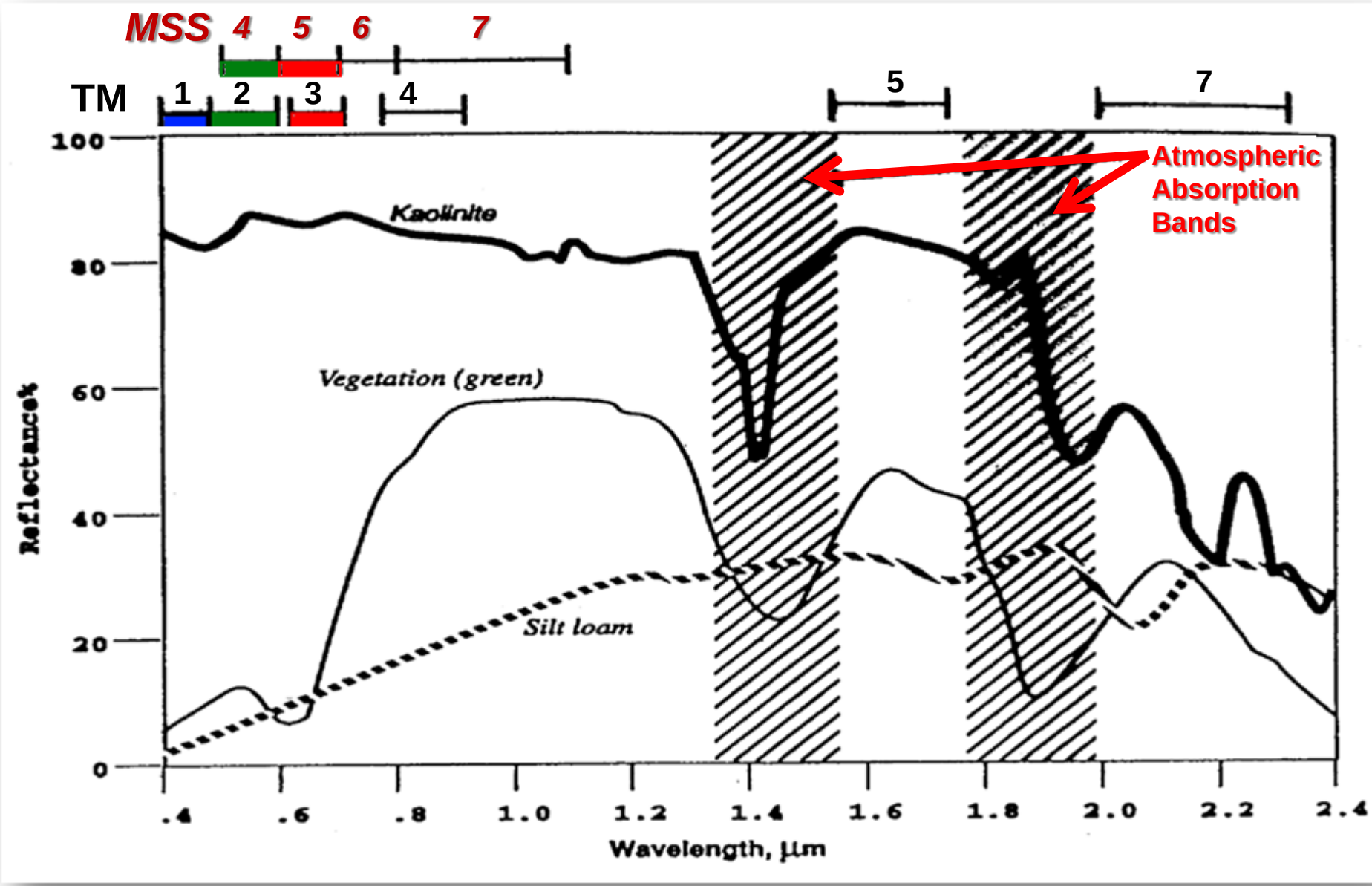
- **Spectral resolution** describes the ability of a sensor to define **fine wavelength intervals**.
- **The finer** the spectral resolution, **the narrower the wavelength range** for a particular channel or band.



# Spectral Resolution

- **Spectral Resolution** refers to:
  1. The **size of the interval or band** and
  2. ***Number of specific wavelength intervals (spectral bands)*** in the electromagnetic spectrum **to which a sensor is sensitive**.
- The **size of the interval or band** may be:
  - **Large (*coarse*)** as the panchromatic band of LandSat (***0.50 – 0.90*** µm), or
  - **Small (*fine*).** as with band 3 of the LandSat (***0.63-0.69*** µm).

# Landsat MSS & TM Bands

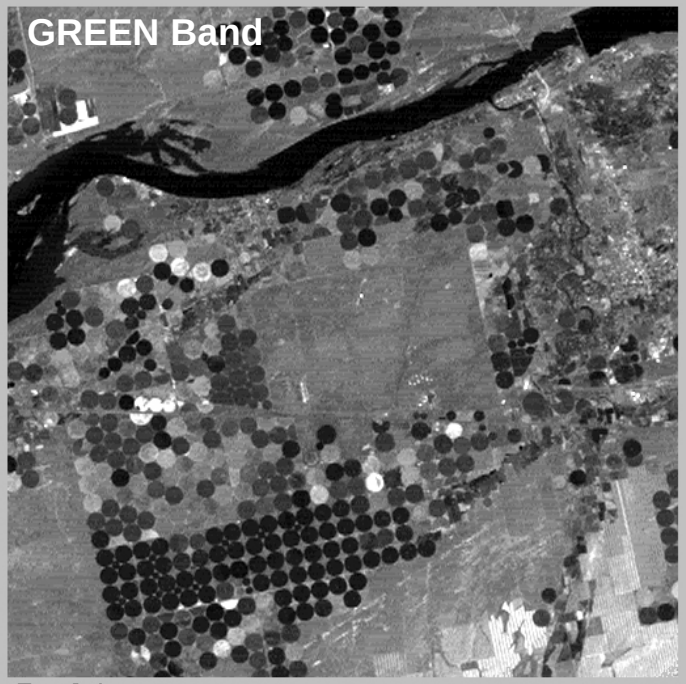


# Landsat

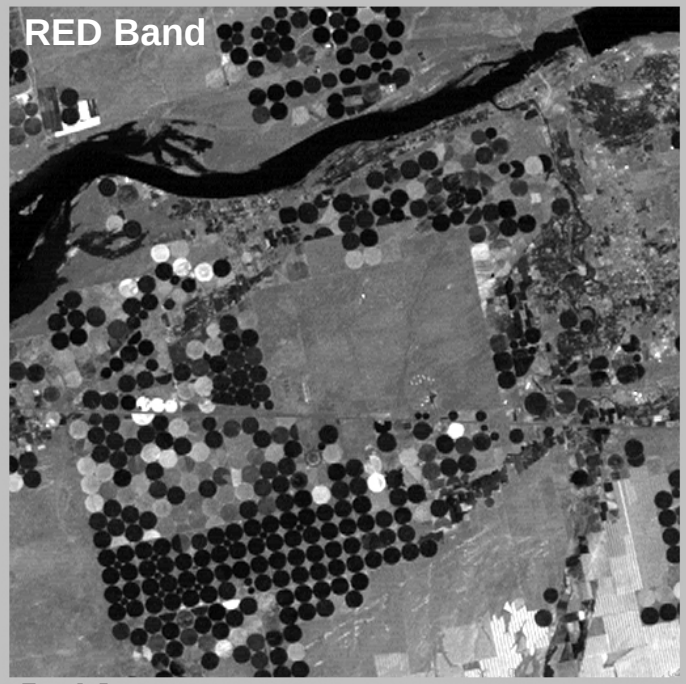
## MultiSpectral

## Scanner (*MSS*)

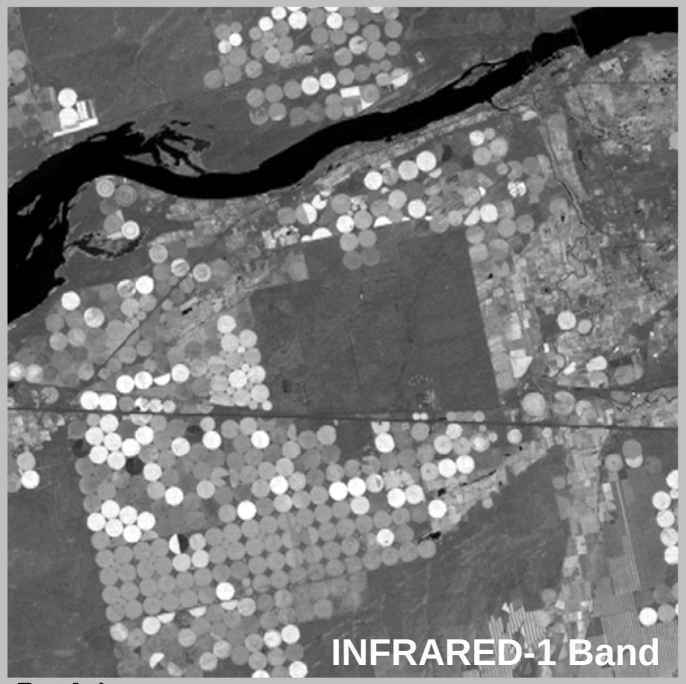
## 4 Spectral Bands



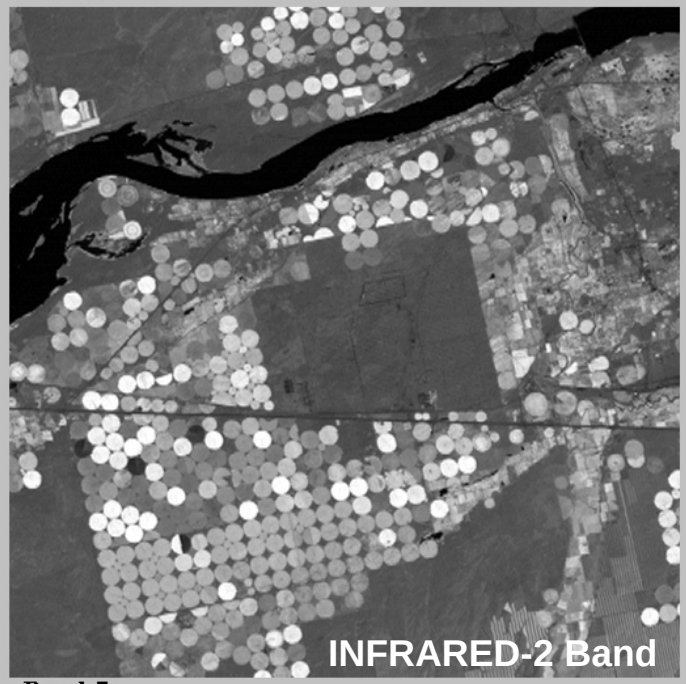

Band 4




Band 5




Band 6

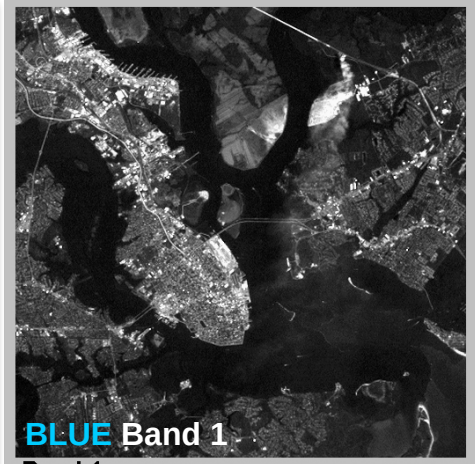



Band 7

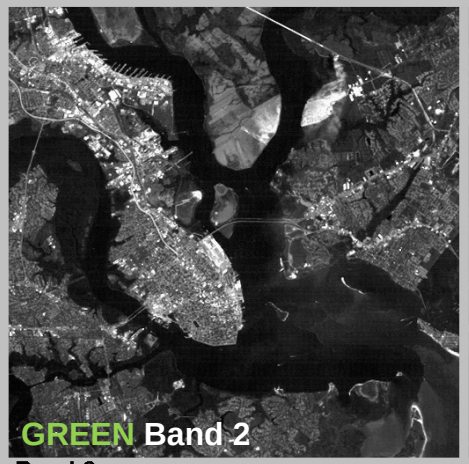
# Landsat

# Thematic Mapper (TM) Scanner

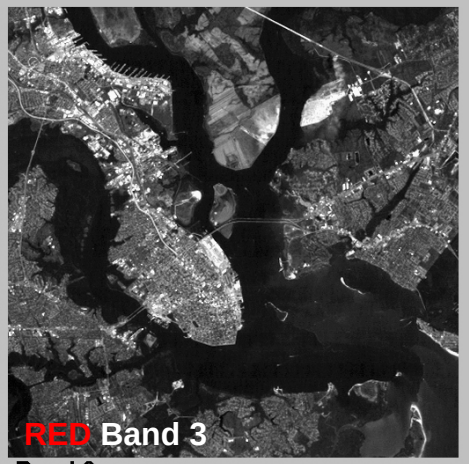
# 7 Spectral Bands



Band 1



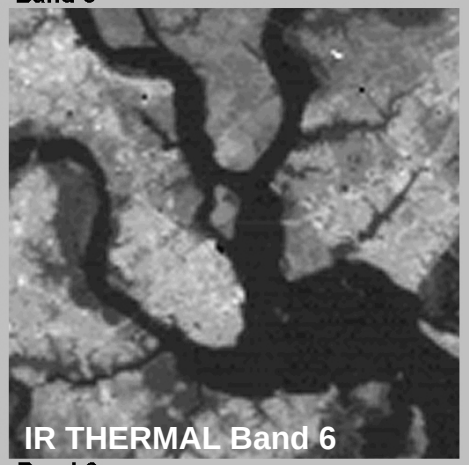
Band 2



Band 3

Band 4

Band 5

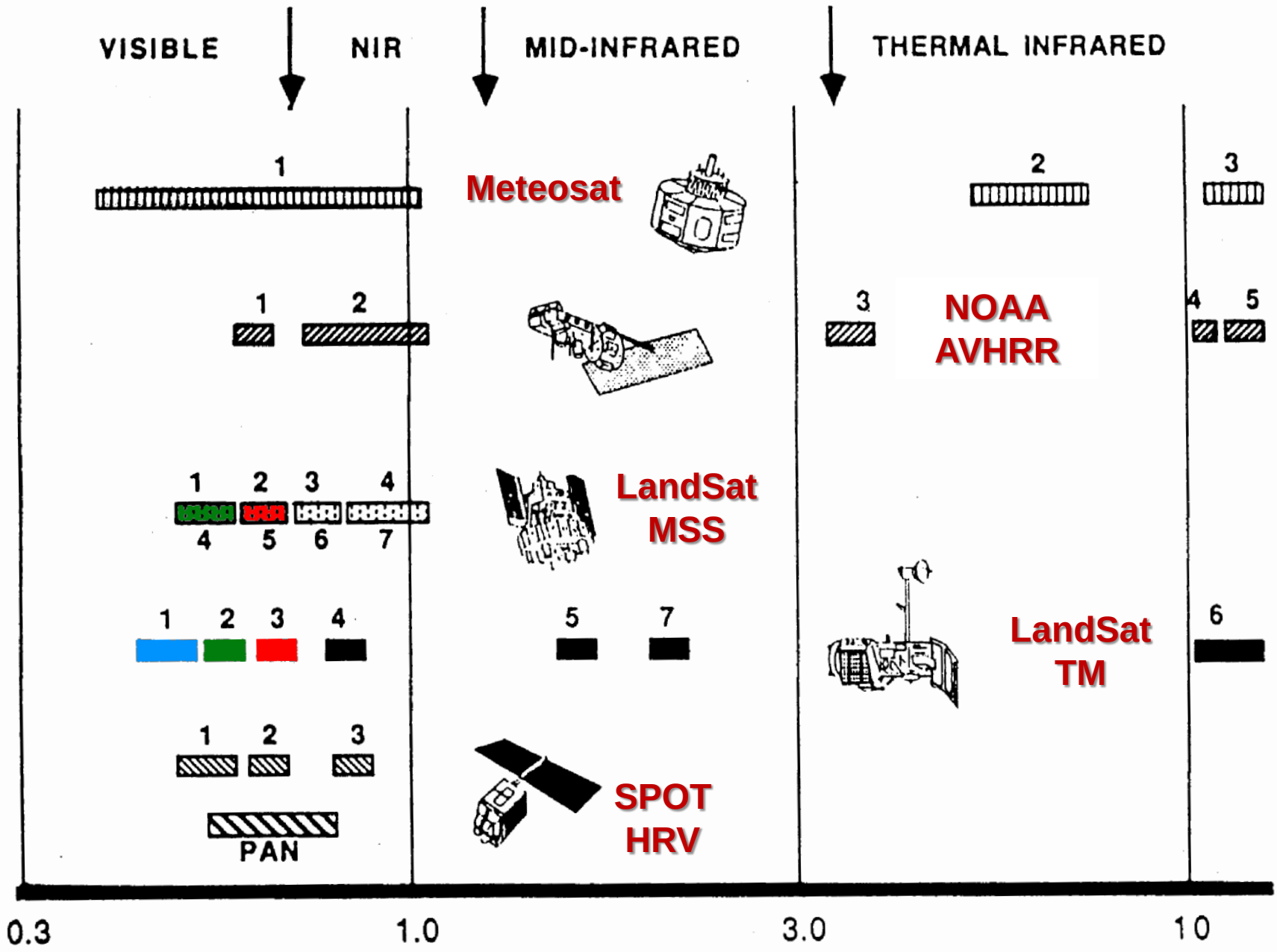


Band 6

Band 7

True Color Composite 321

False Color Composite 432

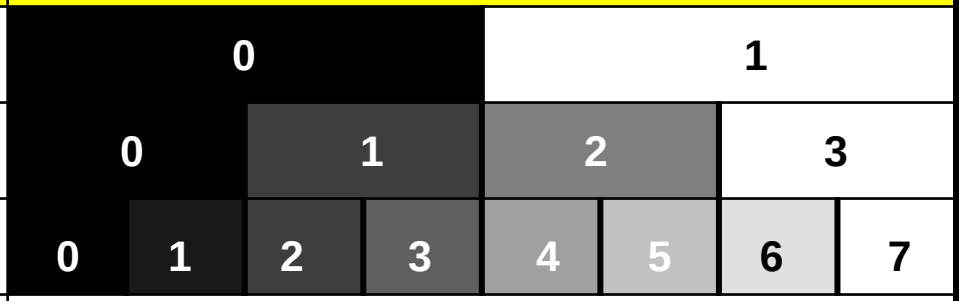

VISIBLE
NIR
MID-INFRARED
THERMAL INFRARED
1
Meteosat
2
3
1
2
3
4
5
NOAA
AVHRR
1
2
3
4
4
5
6
7
LandSat
MSS
1
2
3
4
5
7
6
LandSat
TM
1
2
3
PAN
SPOT
HRV
0.3
1.0
3.0
10
Wavelength - Microns

# Radiometric Resolution

- **Radiometric Resolution or sensitivity** to the **number of digital levels** used to express the data collected by the sensor.
- In general, **the greater the number of levels** the **greater the detail in the information**.
- At one extreme one could be consider a digital image composed of only **two levels** in which level **0** is known **as black** and level **1 as white**.
- The **number of levels** is commonly expressed in terms of **the number of binary digits** (**bits**) needed to store the value of the maximum level.
- For example,
  - **The MSS of Landsat** records the reflected radiant flux in ***7 bits*** (values ranging from ***0 to 127***). The spatial ground resolution is 80 x 80 m in 4 bands.
  - **The TM of Landsat** Radiant flux in ***8 bits*** (values from ***0 to 255***) at 30 x 30m spatial resolution in six of **7 bands**. Thus, the system has improved radiometric and spatial resolution.

# Radiometric Resolution

| Number of Bits | Number of radiation levels | lowest Highest |
|---|---|---|
| 1 | $2^1$ = 2 *levels* | |
| 2 | $2^2$ = 4 *levels* | |
| 3 | $2^3$ = 8 *levels* | |
| 4 | $2^4$ = 16 *levels* | |
| 5 | $2^5$ = 32 *levels* | |
| 6 | $2^6$ = 64 *levels* | |
| 7 | $2^7$ = 128 *levels* | |
| 8 | $2^8$ = 256 *levels* | |
| 9 | $2^9$ = 512 *levels* | |
| 10 | $2^{10}$ = 1024 *levels* | |

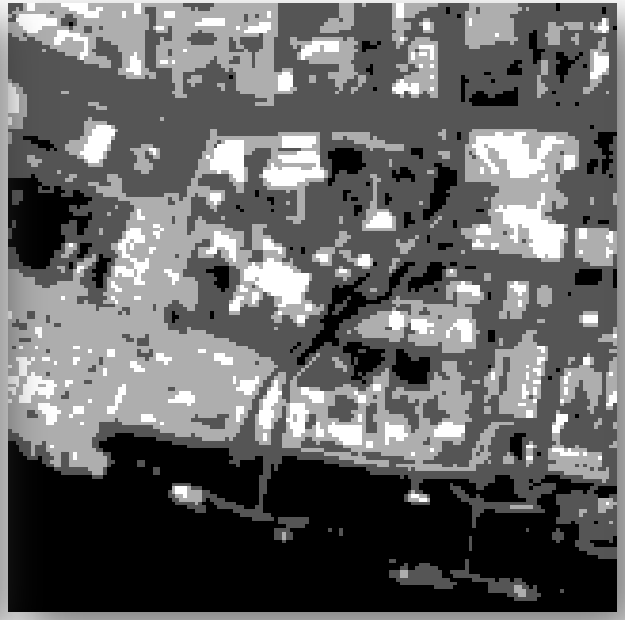


8-bit quantization (256 levels)

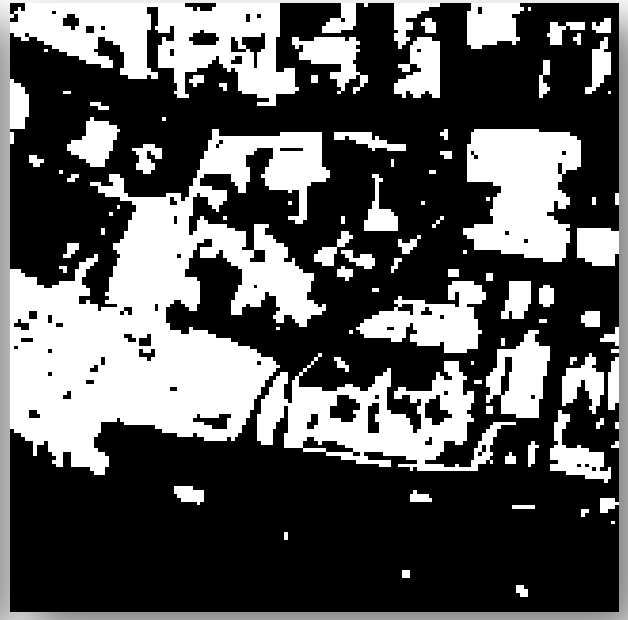
6-bit quantization (64 levels)

4-bit quantization (16 levels)

3-bit quantization (8 levels)



2-bit quantization (4 levels)



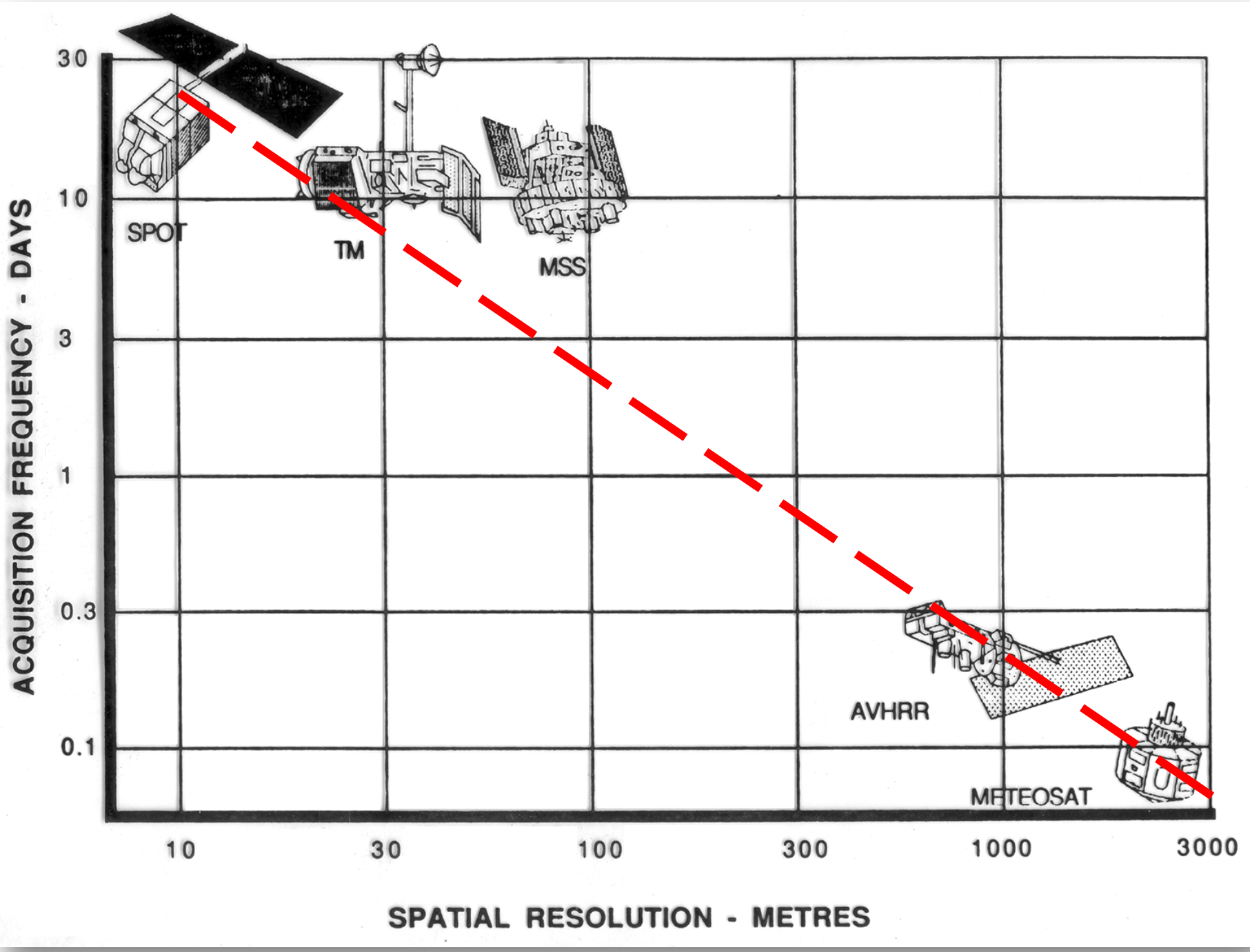
1-bit quantization (2 levels)

# Bit scales for Landsat and SPOT sensor

| Satellite | Sensor / Band | Bits/Pixel (CCT's) | Gray levels |
|---|---|---|---|
| Landsat 1, 2, 3 | **MSS 4, 5, 6** | 7 | ***128*** |
| | **MSS 7** | 6 | ***64*** |
| Landsat 3 | **RBV panchromatic** | 7 | ***128*** |
| Landsat 4, 5 | **MSS 1-4** | 8 | ***256*** |
| | **TM 1-7** | 8 | ***256*** |
| **SPOT** | **HRV -1-3** | 8 | ***256*** |
| | **HRV panchromatic** | 8 | ***256*** |
| **Computer screen (True Color)** | **RED** | 8 | ***256*** |
| | **GREEN** | 8 | ***256*** |
| | **BLUE** | 8 | ***256*** |

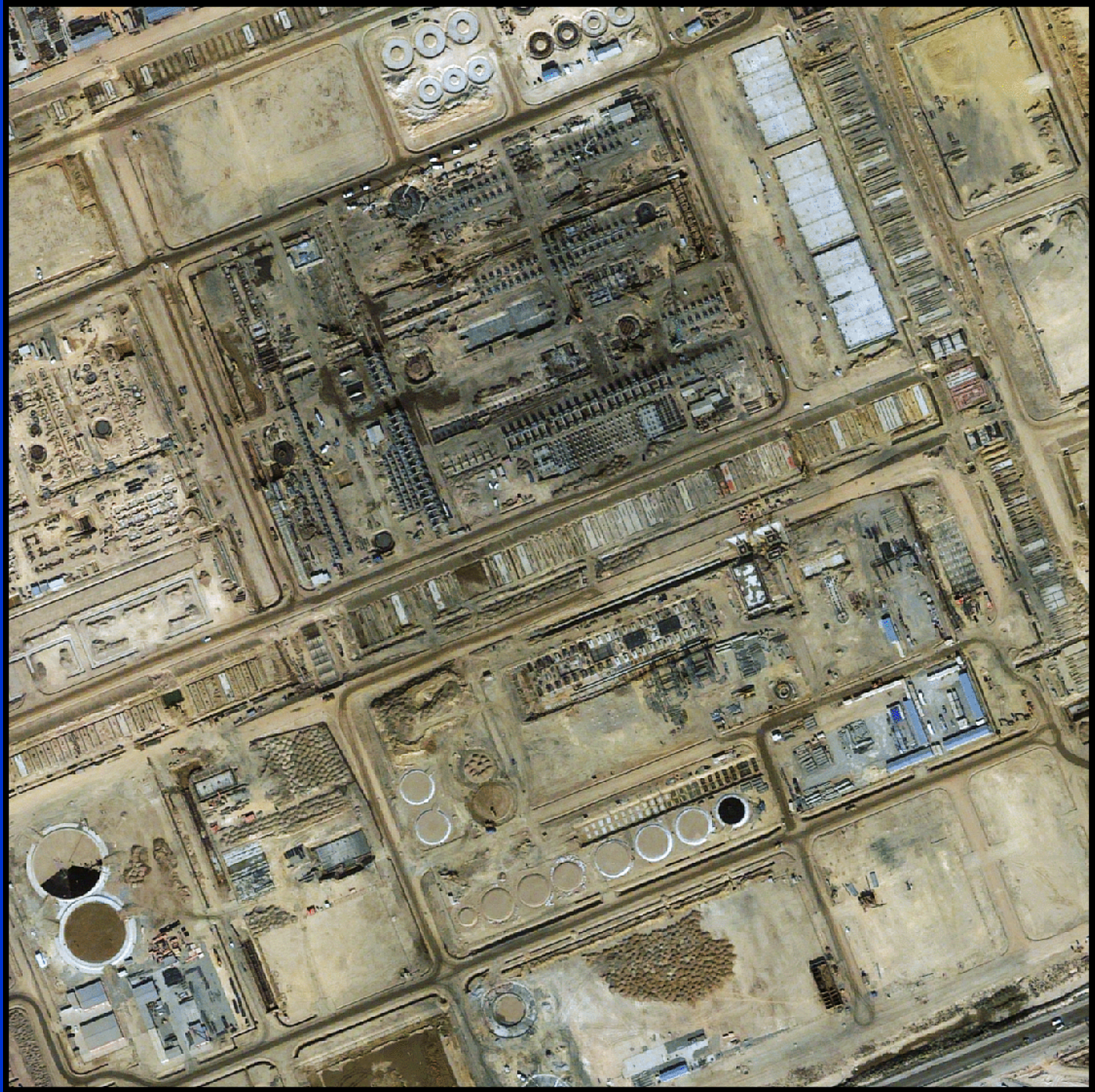
# ***Temporal Resolution***

- **Temporal Resolution** of a sensor system refers to:
  - ***How often*** a given sensor obtains imagery of a particular area. (***revisit period***). Also
  - ***How many days***, it takes the sensor to cover the whole earth with pictures.


ACQUISITION FREQUENCY - DAYS
30
10
3
1
0.3
0.1
SPOT
TM
MSS
AVHRR
METEOSAT
10
30
100
300
1000
3000
SPATIAL RESOLUTION - METRES

# Time lapse Animation of Construction in China.

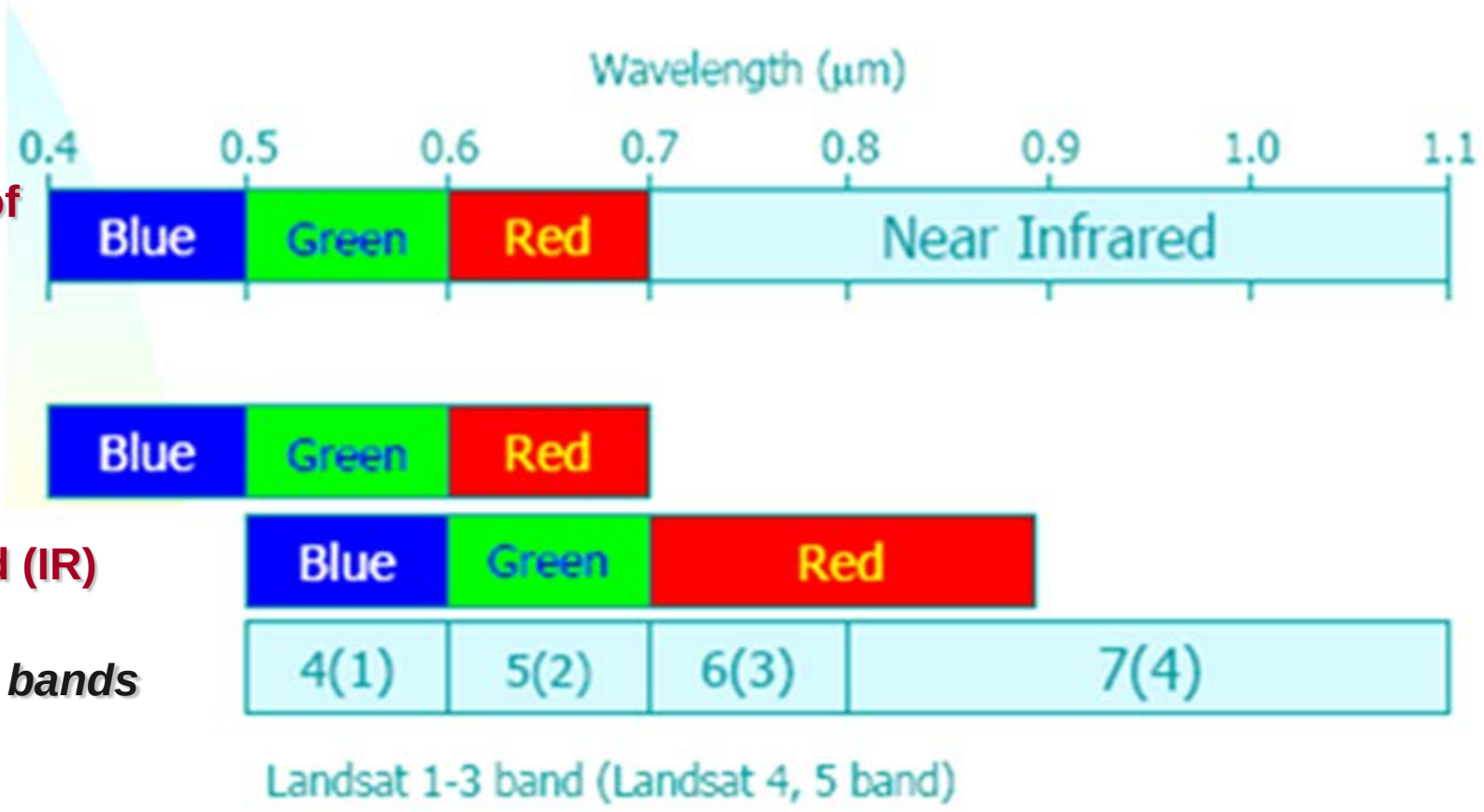
(QuickBird Satellite Image - DigitalGlobe - © 2010 All rights reserved)



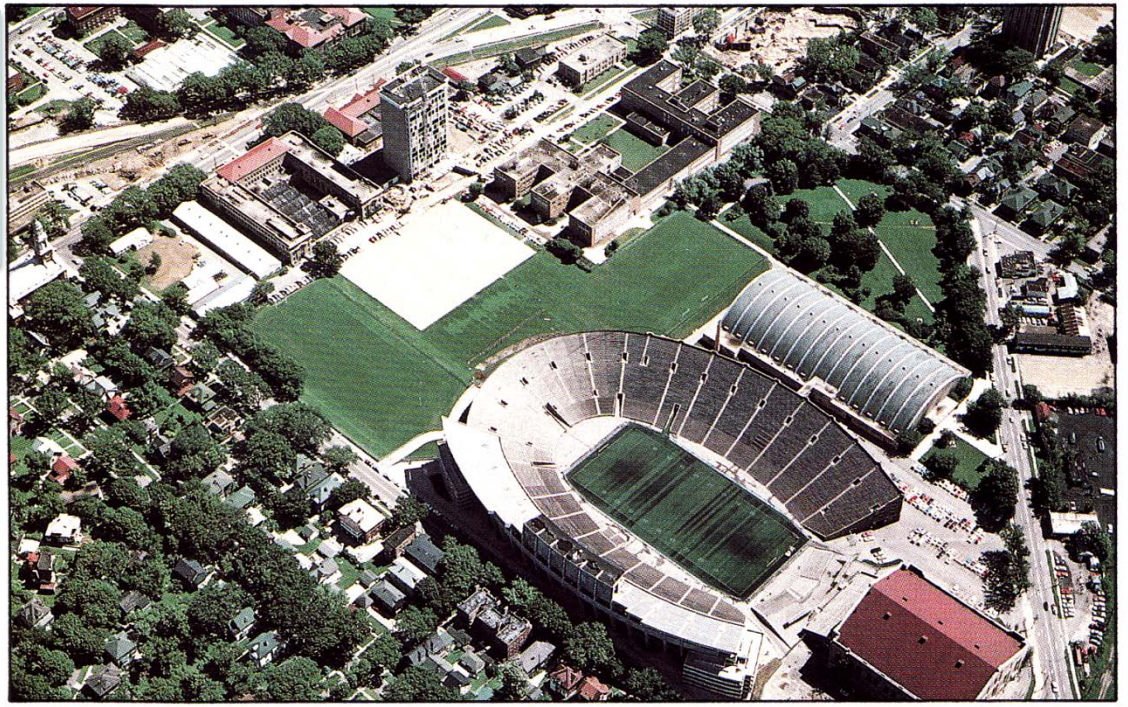
# Sensors

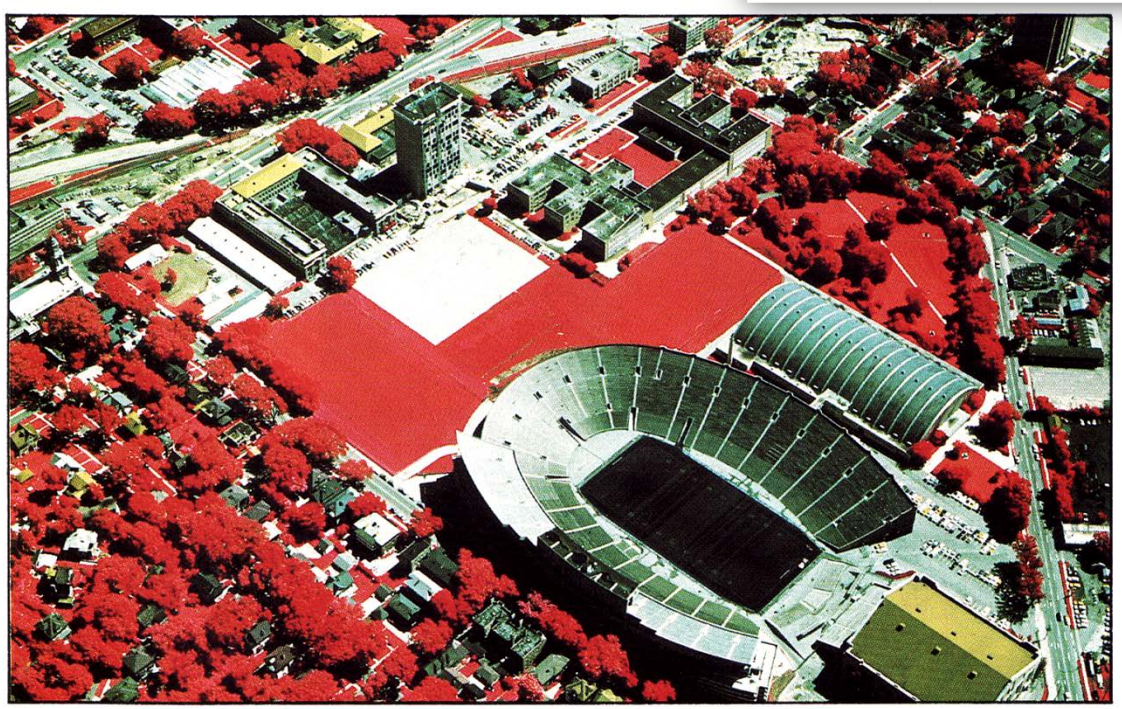
- **Cameras**,
  - **conventional color film,**
  - **color-infrared film.**
- **Landsat** (**RBV** – **MSS** – **TM** – **ETM+**).
- **Spot** (**HRV**).
- **ASTER**
- **Radar**, SLAR, Laser Systems (LIDAR)

# Spectral sensitivity of MSS Bands



Oblique **normal color aerial photograph,** the football field has artificial turf with medium reflectance in the **green** band





Oblique **color infrared aerial photograph,** the football field has artificial turf with ***low*** **infrared** reflectance

- Oblique **normal color (a)** and **color infrared (b)** aerial photographs showing flowing lava on the face of Kilauea Volcano, Hawaii.
- The **orange** tones on the **color infrared photograph** represent infrared energy ***emitted*** from the **flowing lava**.
- The **pink** tones represent ***sunlight reflected*** from the living vegetation.