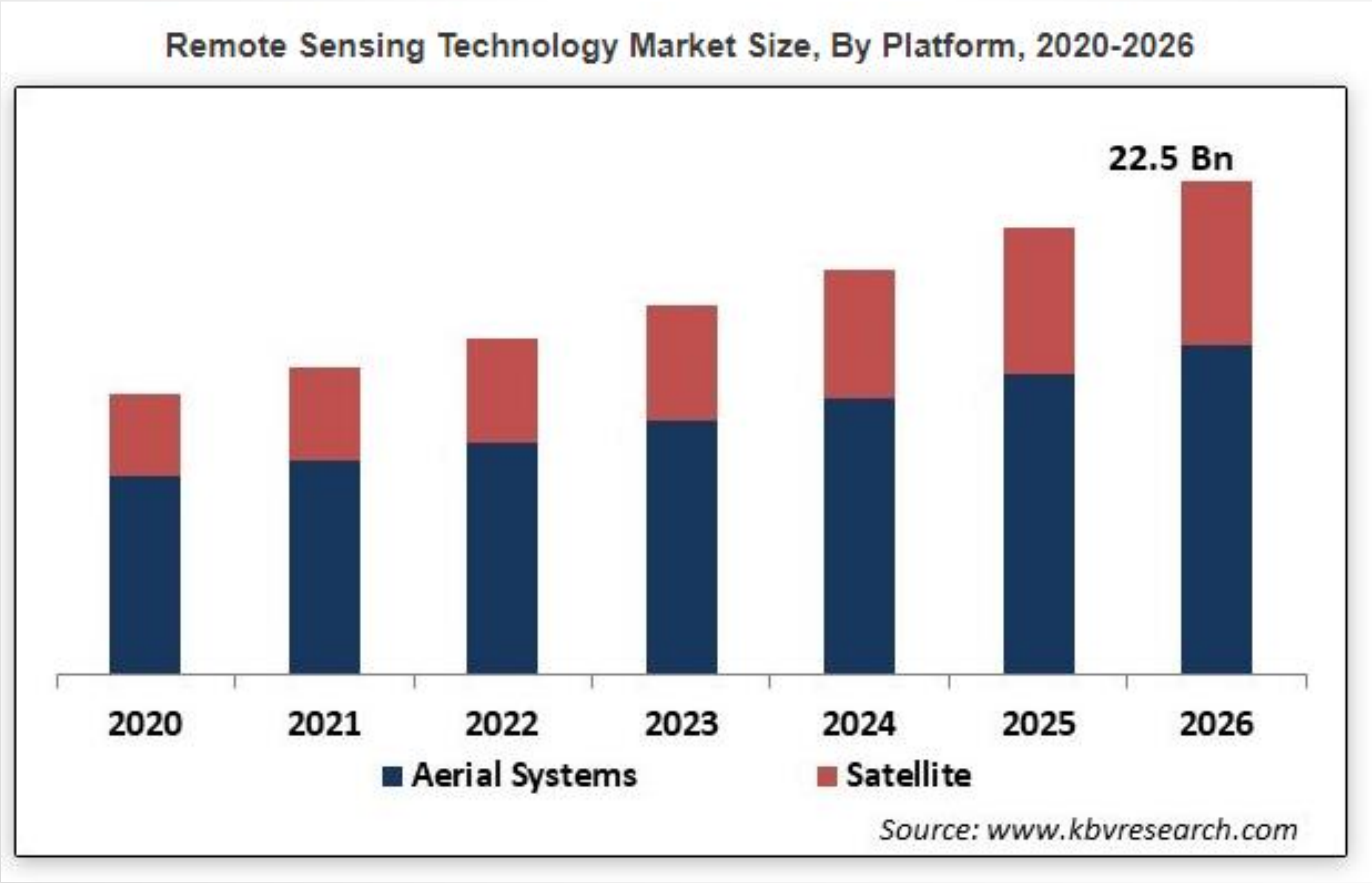
REMOTE SENSING

Introduction

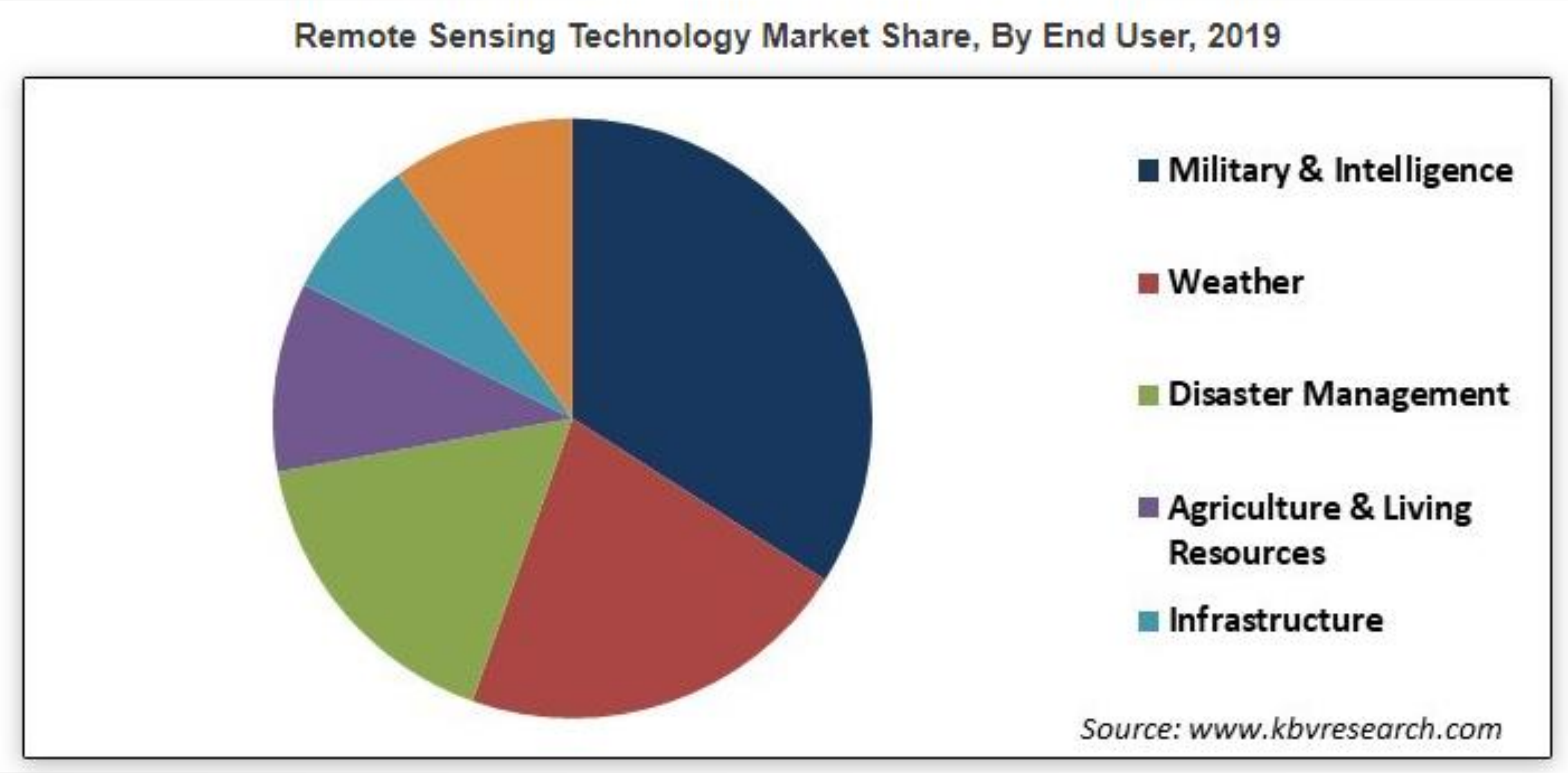
OVERVIEW

- Remote sensing: definition
- Remote sensing versus photogrammetry
- Elements of remote sensing
- Key concepts:
  - Spatial resolution
  - Radiometric resolution
  - Spectral resolution
  - Temporal resolution
- Acquisition platforms:
  - Historical overview
  - Terrestrial, aerial, and space borne platforms
  - Passive versus active remote sensing sensors
- Remote sensing: applications

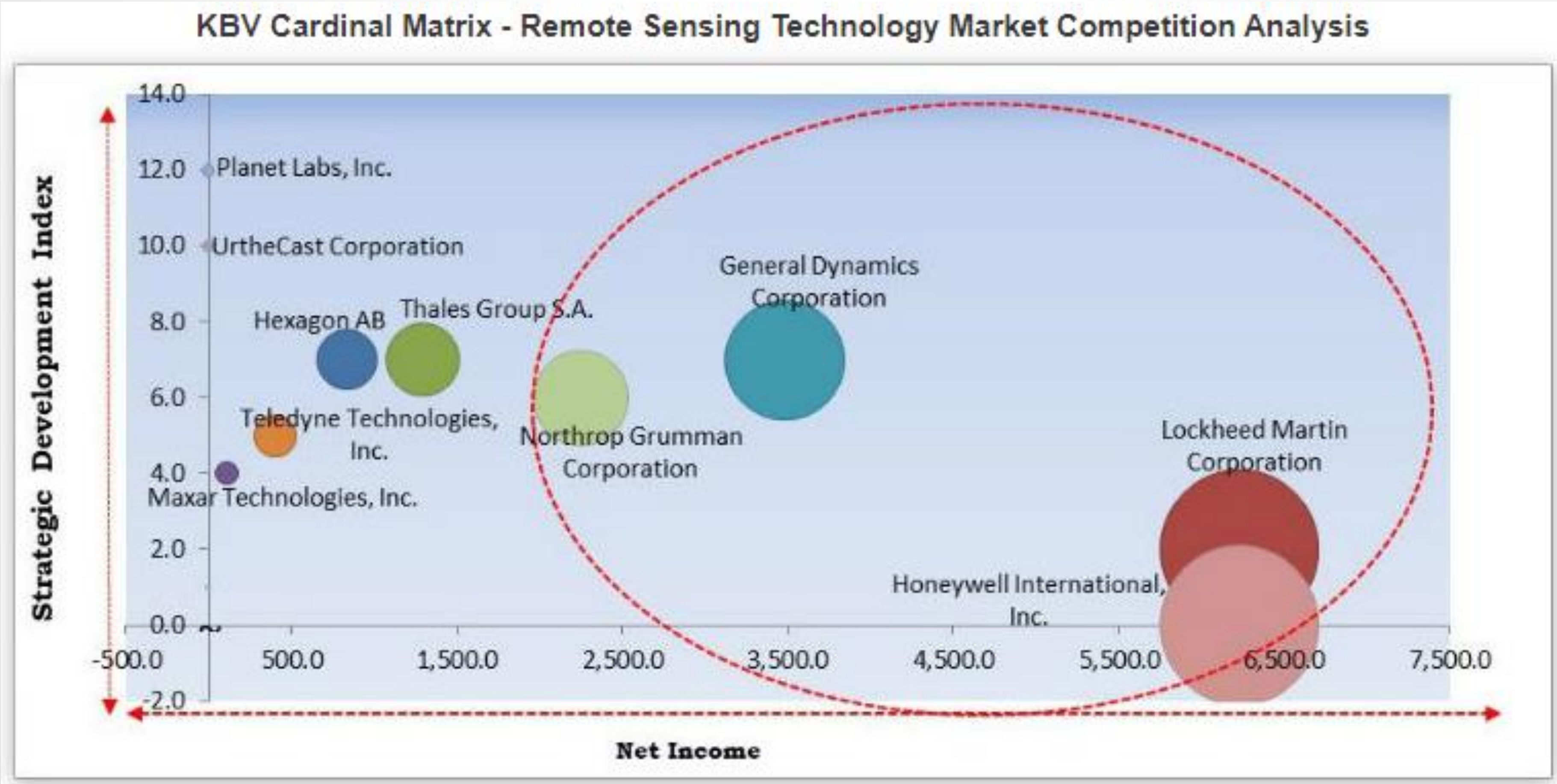
REMOTE SENSING



REMOTE SENSING



REMOTE SENSING



$$\frac{\text{\% of a Brand's Total Sales in a Particular Market}}{\text{\% of Total Population in a Particular Market}} \times 100$$

REMOTE SENSING: DEFINITION

- Remote sensing is the process of obtaining information about an object using a sensor that is physically separated from the object.
- Remote sensing relies on sensors, which detect emitted or reflected energy from objects.
- Human vision is the most popular example of a remote sensing system.

PHOTOGRAMMETRY: DEFINITION

- The art and science of determining the position and shape of objects from photography.
- The process of reconstructing objects without touching them.
- Non-contact positioning method.
- Question: what is the difference between remote sensing and photogrammetry?
  - Photogrammetry deals with the measurements of geometric properties of objects.
  - Remote Sensing focuses on determining the material and condition of surfaces based on their radiometric properties.

REMOTE SENSING: DEFINITION

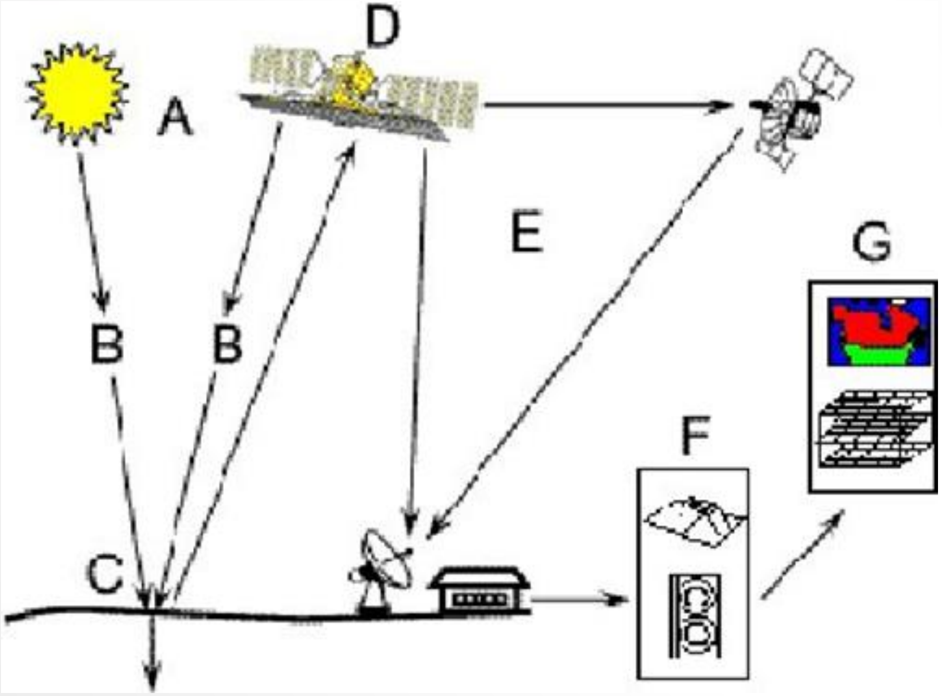
Remote sensing or Earth Observation is defined as the art, science, and technology through which the characteristics of object features/targets either on, above, or even below the earth's surface are identified, measured, and analyzed without direct contact existing between the sensors and the targets or events being observed.

This allows for information about such object features to be obtained by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

Electromagnetic radiation is normally used as the information carrier in remote sensing. Such electromagnetic radiation that is either reflected or emitted from targets normally constitutes remote sensing data.

As an analogy, of the five basic human senses, three of them namely; sight, hearing and smell may be considered forms of "remote sensing"

ELEMENTS OF REMOTE SENSING



Energy Source or Illumination (A):

The energy source that illuminates or provides electromagnetic energy to the target of interest.

Radiation and the Atmosphere (B):

As the energy travels from its source to the target, it will come in contact and interact with the atmosphere. This interaction may take place a second time as the energy travels from the target to the sensor.

ELEMENTS OF REMOTE SENSING

Interaction with the Target (C):

Once the energy makes its way to the target through the atmosphere, it interacts with the target. The interaction outcome depends on the spectral properties of both the target and the radiation.

Recording of Energy by the Sensor (D):

Scattered/emitted energy from the target is recorded by the implemented sensor.

Transmission, Reception, and Processing (E):

Recorded energy is transmitted, often in electronic form, to a receiving and processing station where the data is converted into an image (hardcopy and/or digital).

Interpretation and Analysis (F):

The processed image is interpreted, visually and/or digitally, to extract information about the target which was illuminated.

Application (G):

Apply extracted information about the target in order to:

Gain a better understanding of that object,

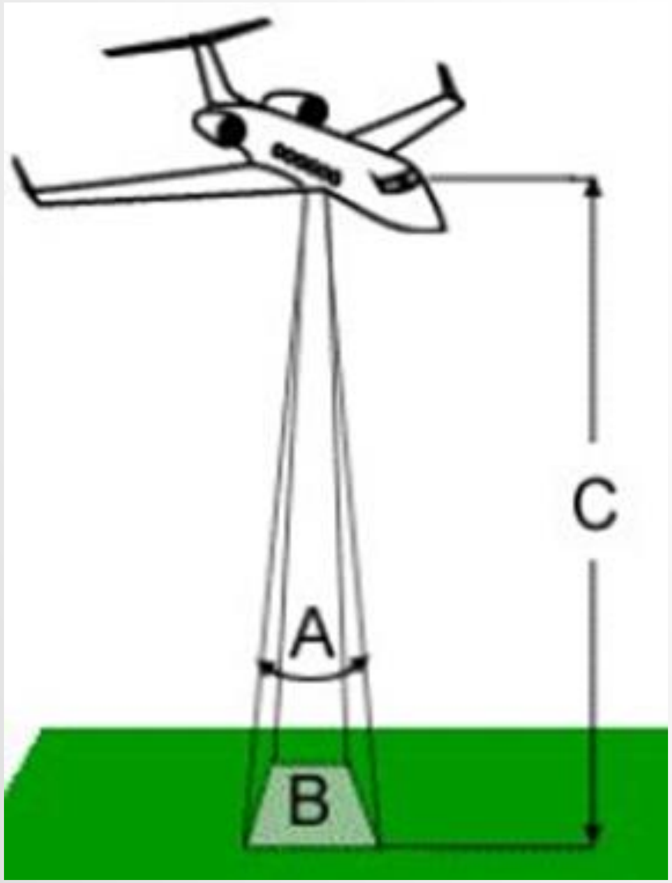
Reveal some new information, or

Assist in solving a particular problem.

RESOLUTIONS

The characteristics of remote sensing systems can be described by the following types of resolutions:
Spatial resolution,
Radiometric resolution,
The spectral resolution, and
Temporal resolution.
These resolutions control our ability to interpret remote sensing data.

SPATIAL RESOLUTION



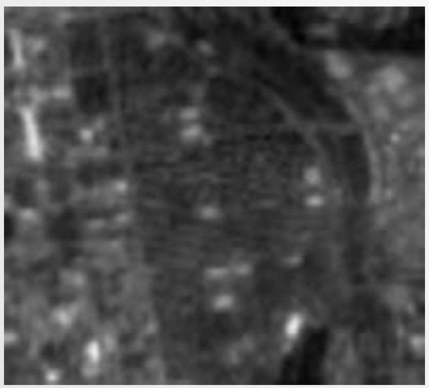
Spatial resolution dictates the number of discernible details in an image:
The size of the smallest possible feature that can be detected.
In general, the spatial resolution depends on the Instantaneous Field of View (IFOV), A, of the implemented sensor.
The IFOV is the angular cone of visibility of the sensor.
The projection of the IFOV into the surface of the earth is known as the resolution cell (B).
The spatial resolution is mainly controlled by the separation between the sensor and the target (C).

SPATIAL RESOLUTION

For a homogeneous feature to be detected, its size has to be equal to or larger than the resolution cell.

– If the feature is smaller than this, it may not be detectable as the average brightness of all features in that resolution cell will be recorded.

However, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing sub-pixel or sub-resolution cell detection.



LANDSAT (30m)

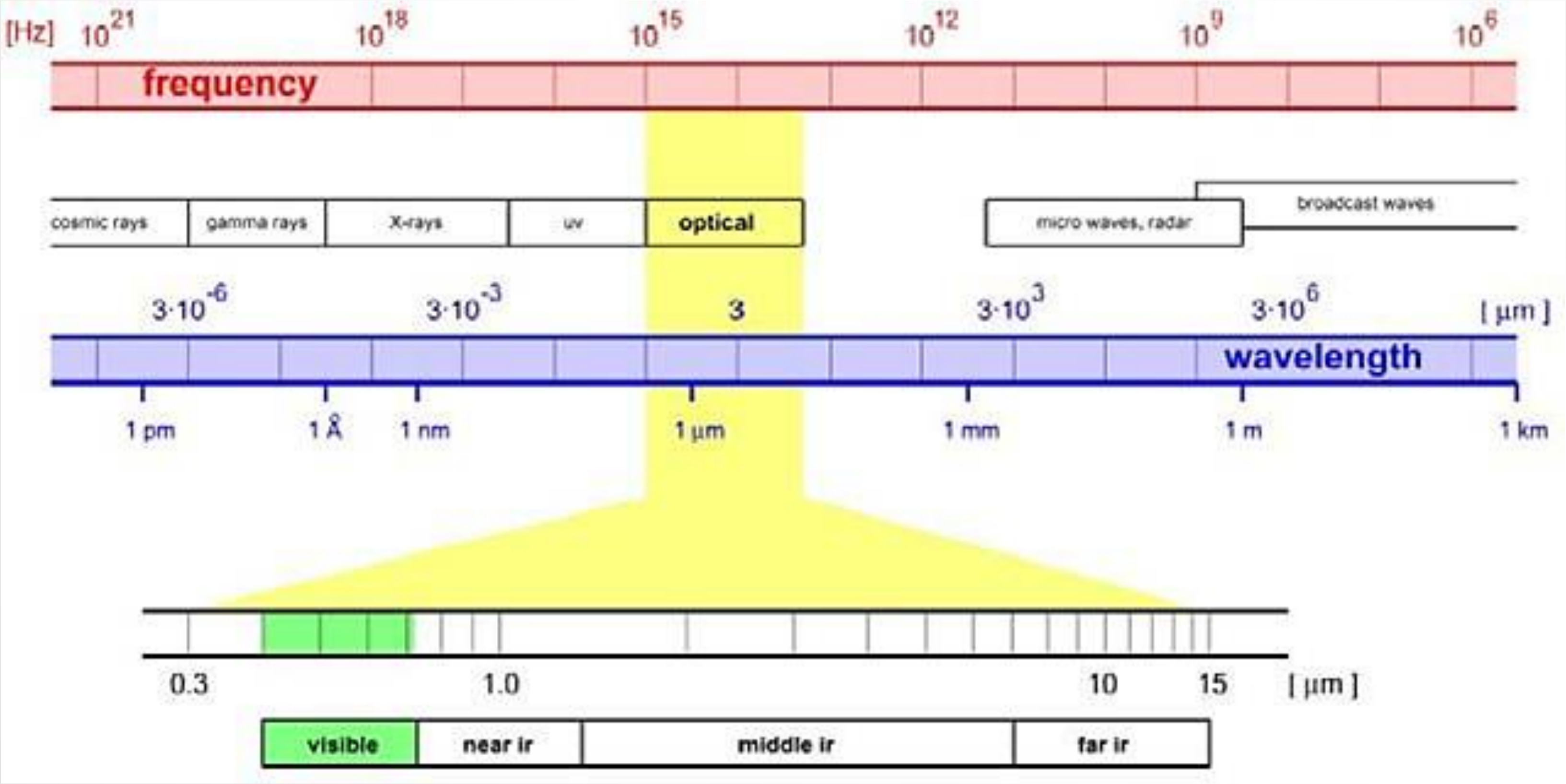
LANDSAT (15m)

SPOT (10m)

IKONOS (1m)

KOMPSAT-1 (6m)

ELECTROMAGNETIC RADIATION



SPECTRAL RESOLUTION

Spectral resolution describes the ability of a sensor to define fine wavelength intervals.

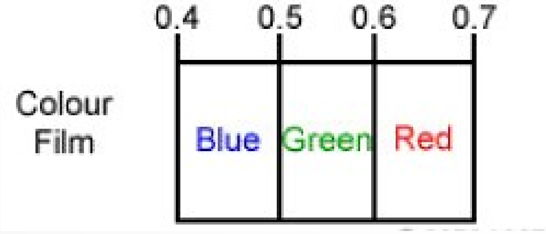
The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

Black and white film records wavelengths extending over much or all of the visible portion of the electromagnetic spectrum.

Color film is individually sensitive to the reflected energy at the blue, green, and red wavelengths of the spectrum.

Color film has a higher spectral resolution when compared to black and white film.

Spectral sensitivity of black and white films



Spectral sensitivity of color film

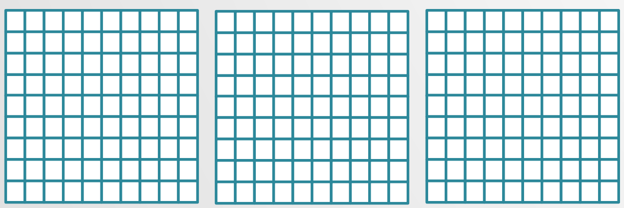
SPECTRAL RESOLUTION

Multi-spectral sensors record energy over several separate wavelength ranges at various spectral resolutions.

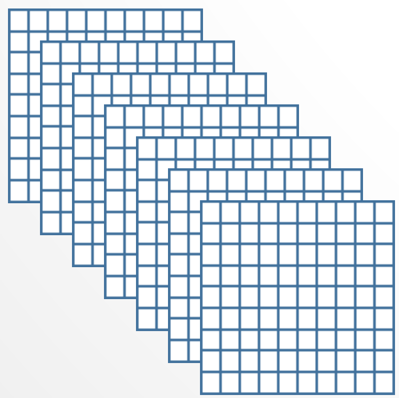
Advanced multi-spectral sensors, called hyper spectral sensors, detect hundreds of very narrow spectral bands throughout the visible, near-infrared, and mid-infrared portions of the electromagnetic spectrum.

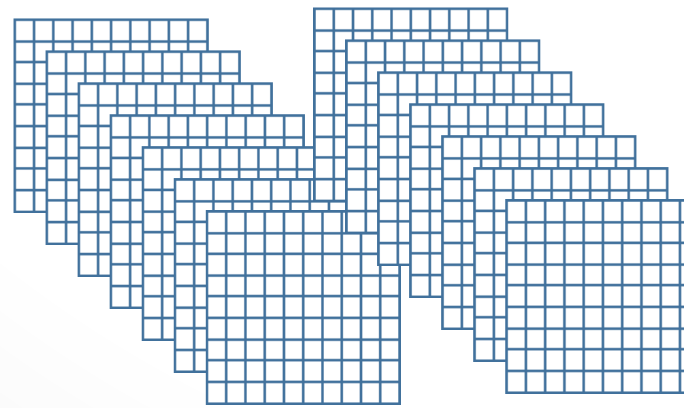
Such sensors facilitate fine discrimination between different targets based on their spectral response in each of the narrow bands.

SPECTRAL RESOLUTION



R G B





3 bands

7 bands

216 bands?

RADIOMETRIC RESOLUTION

Radiometric resolution of an imaging system describes its ability to discriminate very slight differences in the recorded energy.

The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.

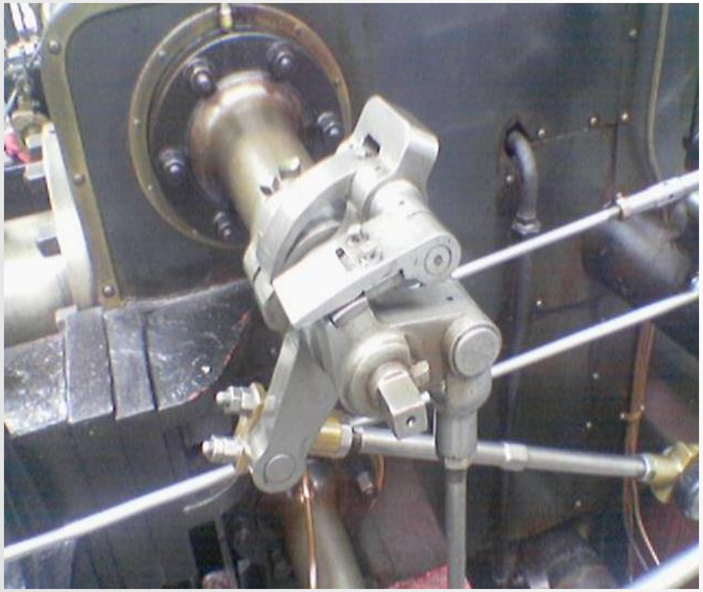
For digital imagery, the radiometric resolution is defined by the number of bits used for coding the recorded grey values.

– By comparing a 2-bit image with an 8-bit image, one can see that there is a large difference in the level of discernible details.

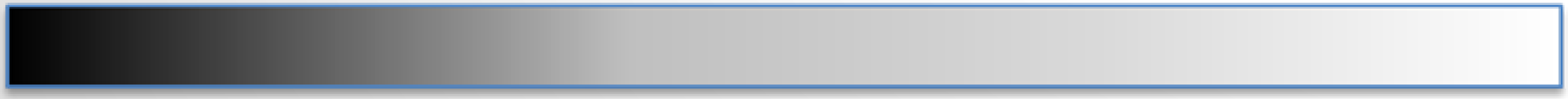
8 bits per pixel

2 bits per pixel

RADIOMETRIC RESOLUTION



50	34	36	45	67	75
23	33	66	45	15	13
32	22	77	86	23	27
43	66	86	35	35	37
54	45	56	32	99	84
65	35	54	16	100	35
86	57	23	24	66	22



0

255=8bit

TEMPORAL RESOLUTION

Temporal resolution of a remote sensing system refers to the frequency with which it images the same area.

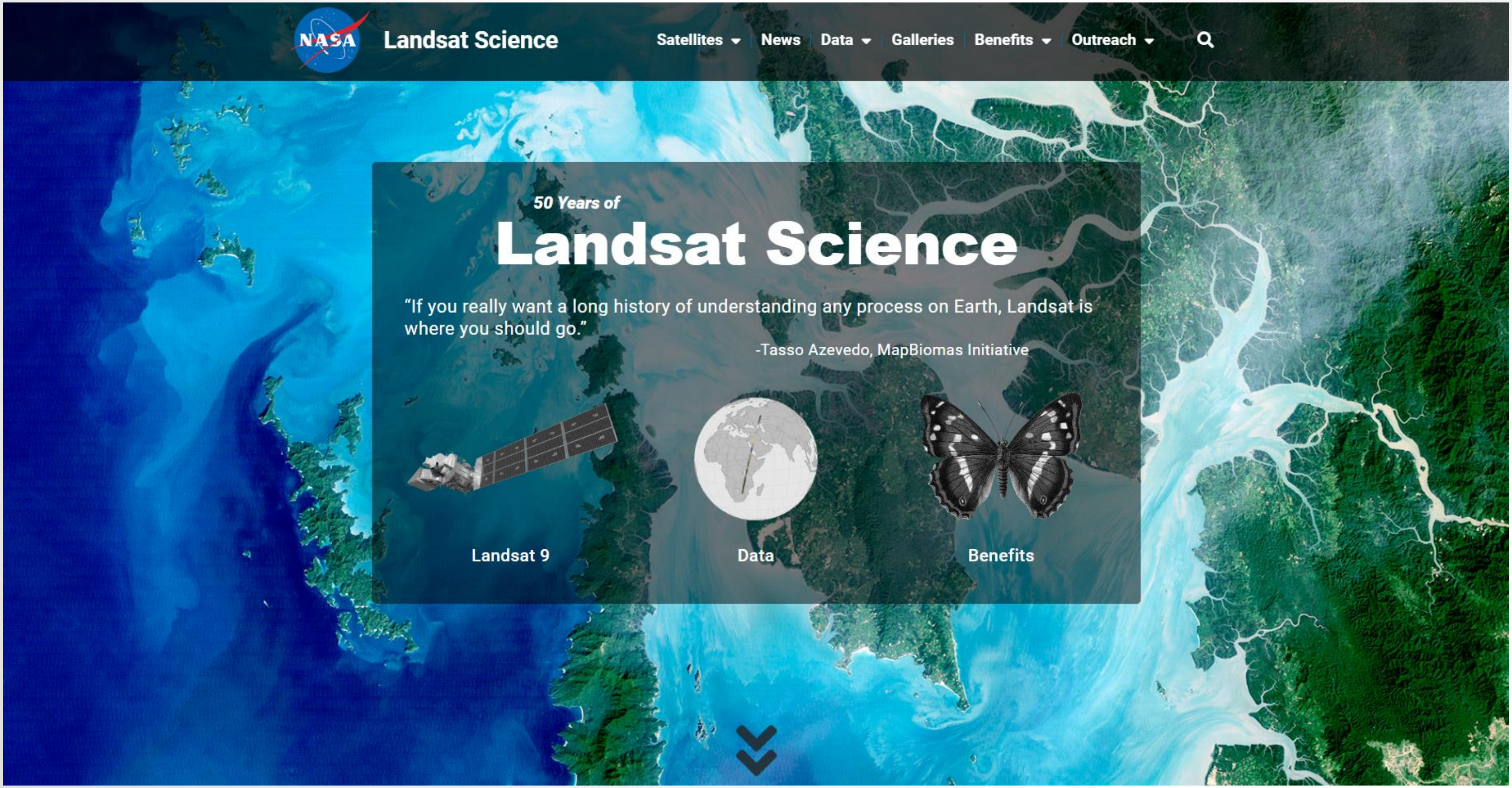
Frequent imaging is important for:

Disaster & environmental management.

For example, floods, oil slicks, and the spread of forest disease from one year to the next.

Change detection applications.

LET'S FIND OUT THE RESOLUTIONS OF LANDSAT



https://landsat.gsfc.nasa.gov/

LET'S FIND OUT THE RESOLUTIONS OF MODIS

MODIS
MODERATE RESOLUTION IMAGING SPECTRORADIOMETER

About | Data | Tools | Science Team | Images | News | Related Sites | MODARCH

About

- MODIS Design
- Components
- Specifications
- Outreach Materials

Home >> About >> Specifications

Specifications

Orbit: 705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun-synchronous, near-polar, circular

Scan Rate: 20.3 rpm, cross track

Swath Dimensions: 2330 km (cross track) by 10 km (along track at nadir)

Telescope: 17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop

Size: 1.0 x 1.6 x 1.0 m

Weight: 228.7 kg

Power: 162.5 W (single orbit average)

Data Rate: 10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)

Quantization: 12 bits

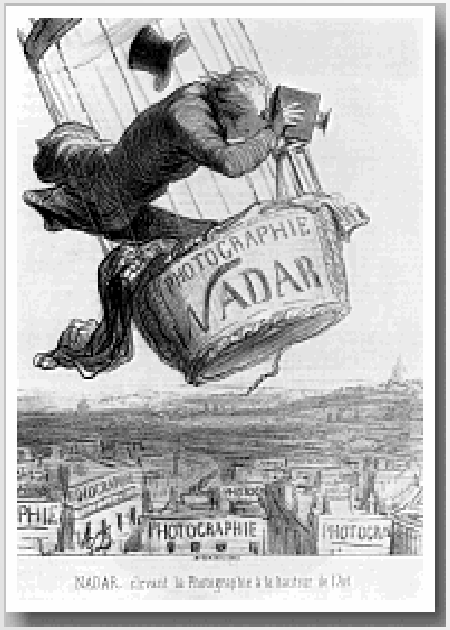
Spatial Resolution: 250 m (bands 1-2), 500 m (bands 3-7), 1000 m (bands 8-36) Design Life: 6 years

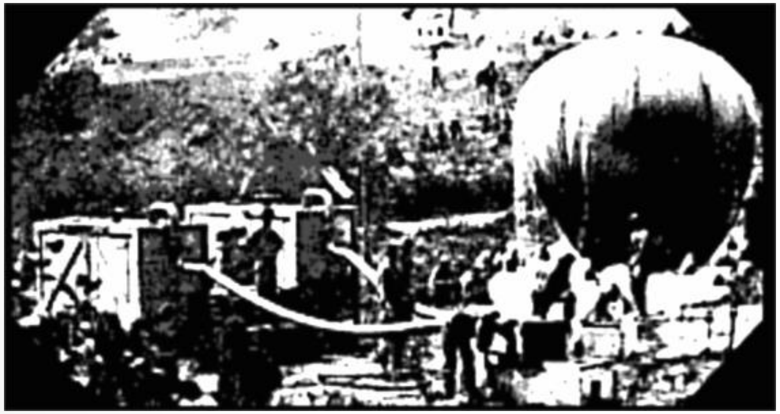
Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required SNR[3]
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29.0	228
	5	1230 - 1250	5.4	74

https://modis.gsfc.nasa.gov/about/specifications.php

DATA ACQUISITION SYSTEM

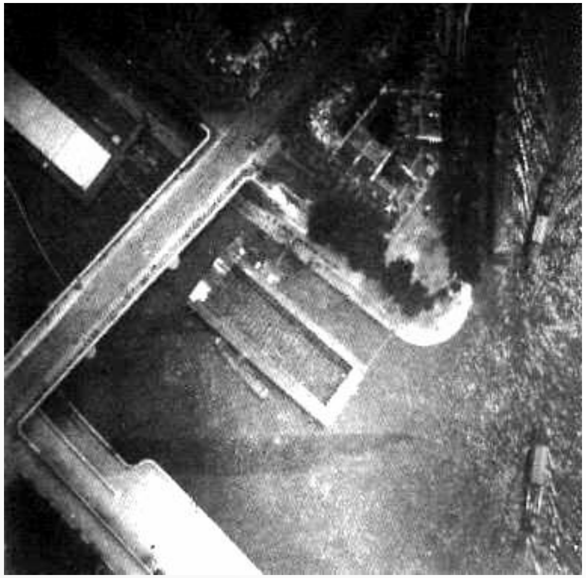
Historical Review: Balloons





First image was captured in 1859

Boston from a Balloon (1860)



St. Luis Island, Paris Captured by Balloon, 1860

DATA ACQUISITION SYSTEM

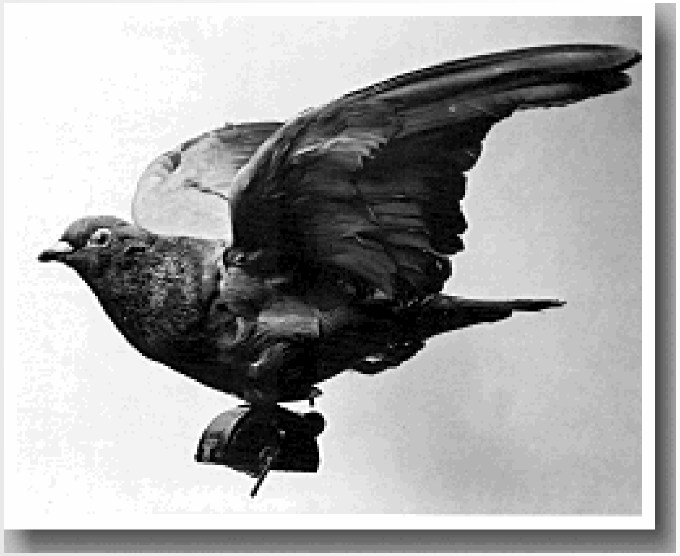
Historical Overview: Kites

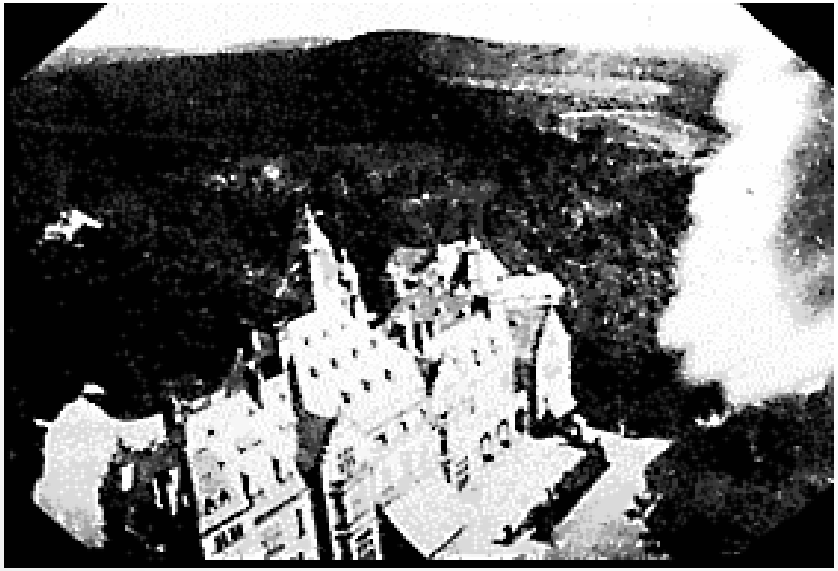
Labrugauere, France from a kite (1889)

kite photos, San Francisco, California right after the infamous 1906 earthquake that, together with fire, destroyed most of the city

DATA ACQUISITION SYSTEM

Historical Overview: Pigeons





DATA ACQUISITION SYSTEM

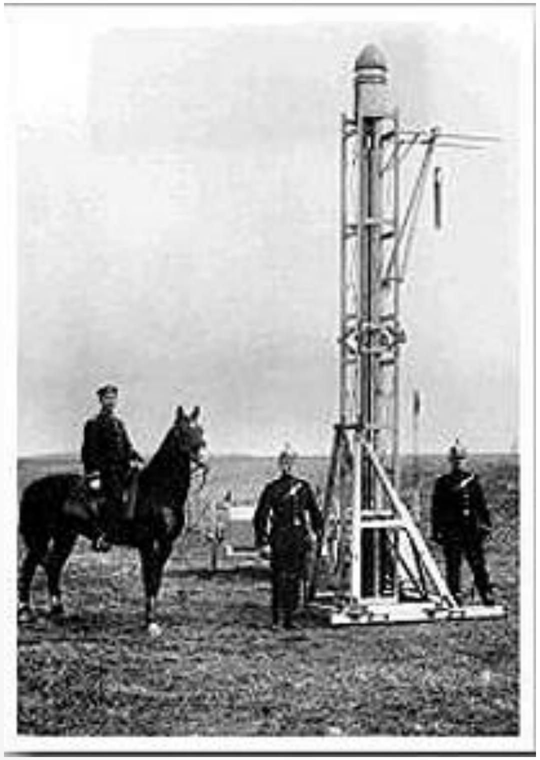
Historical Overview: Planes (1908)

New York

Reims

DATA ACQUISITION SYSTEM

Historical Overview, Rockets

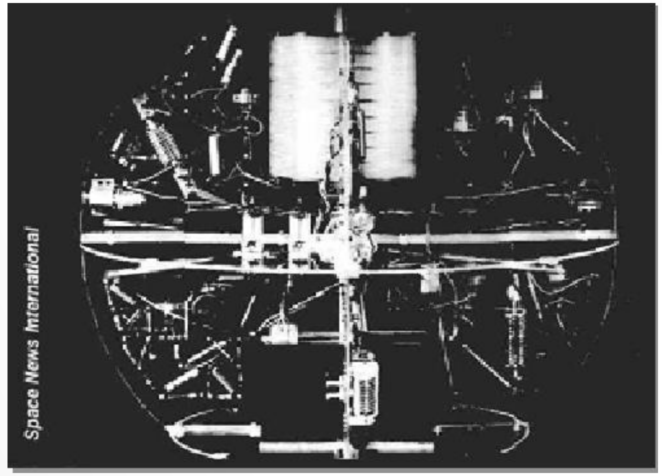


Historically, the first photos taken from a small rocket, from a height of about 100 meters, were imaged from a rocket designed by Alfred Nobel, launched in 1897 over a Swedish landscape

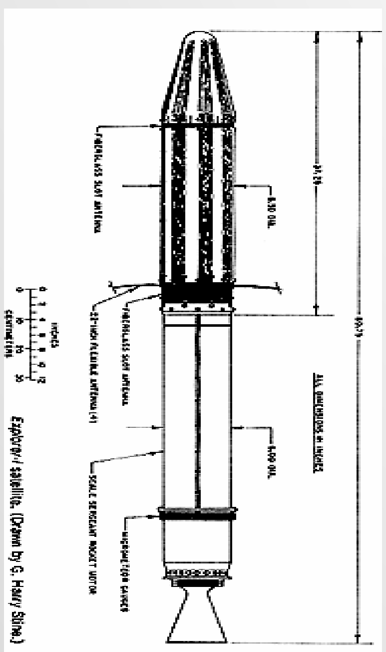
A camera succeeded in photographing the landscape at a height of 600 meters by Alfred Maul's rocket during a 1904 launch.

DATA ACQUISITION SYSTEM

Historical Overview: Satellites

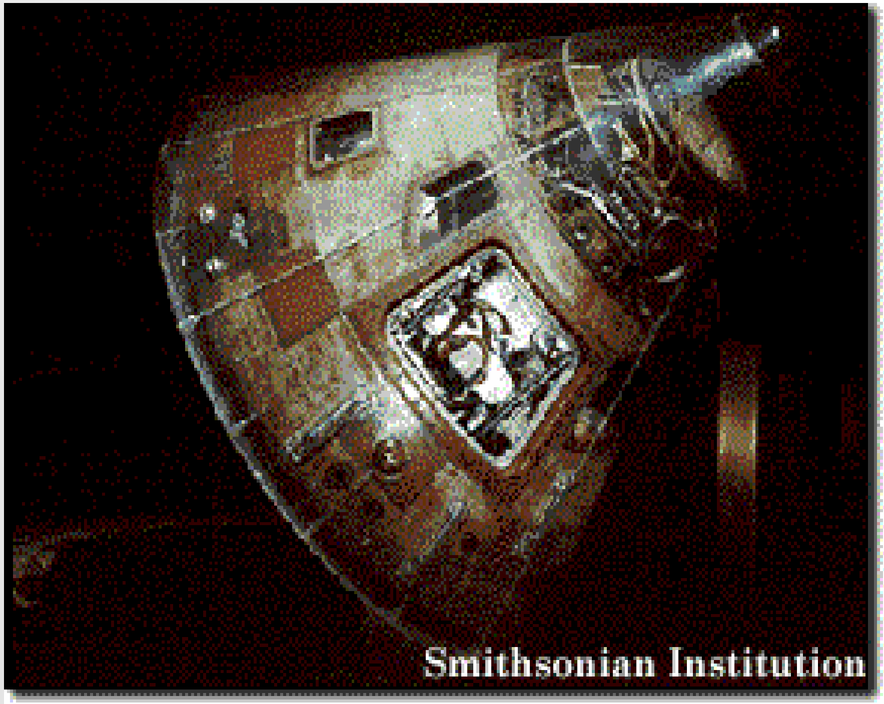


Sputnik-1, 1957



First US satellite Explorer-1, 1958

DATA ACQUISITION SYSTEM



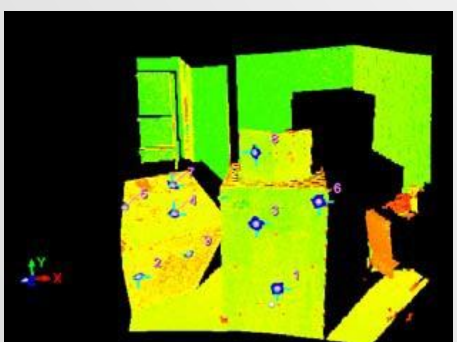
Apollo-8, First photo of Earth from space, 1968

Africa, July 1972
Apollo 17

DATA ACQUISITION SYSTEM

Ground Based Sensors

- **Ground-based sensors** are often used to record detailed information about the surface.



Laser System

Digital Camera

DATA ACQUISITION SYSTEM

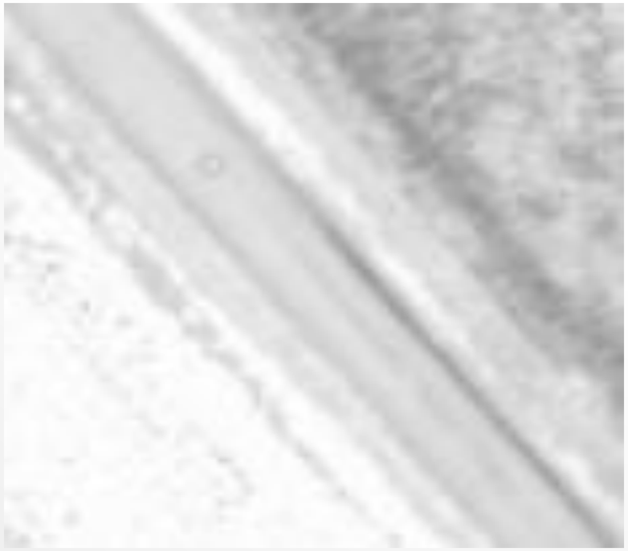
Aerial Platforms

Aerial platforms are primarily stable wing aircraft, although helicopters are occasionally used.

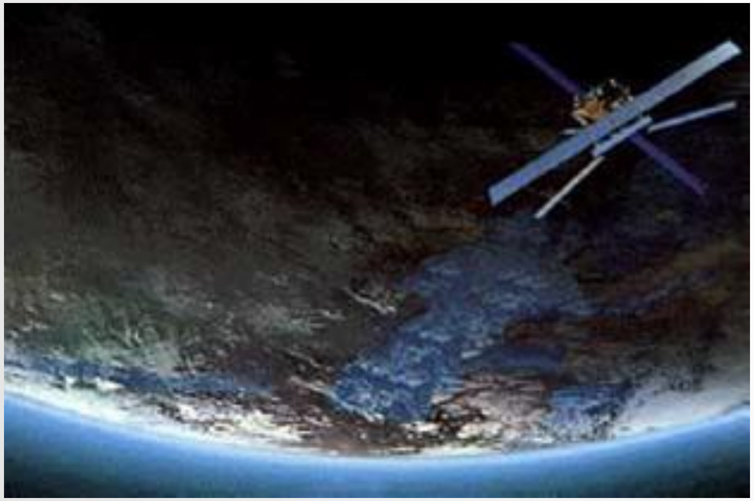
Aircrafts are often used to collect very detailed imagery.

They facilitate the collection of data over virtually any portion of the Earth's surface at any time.

Terrestrial versus Aerial Platforms



DATA ACQUISITION SYSTEM

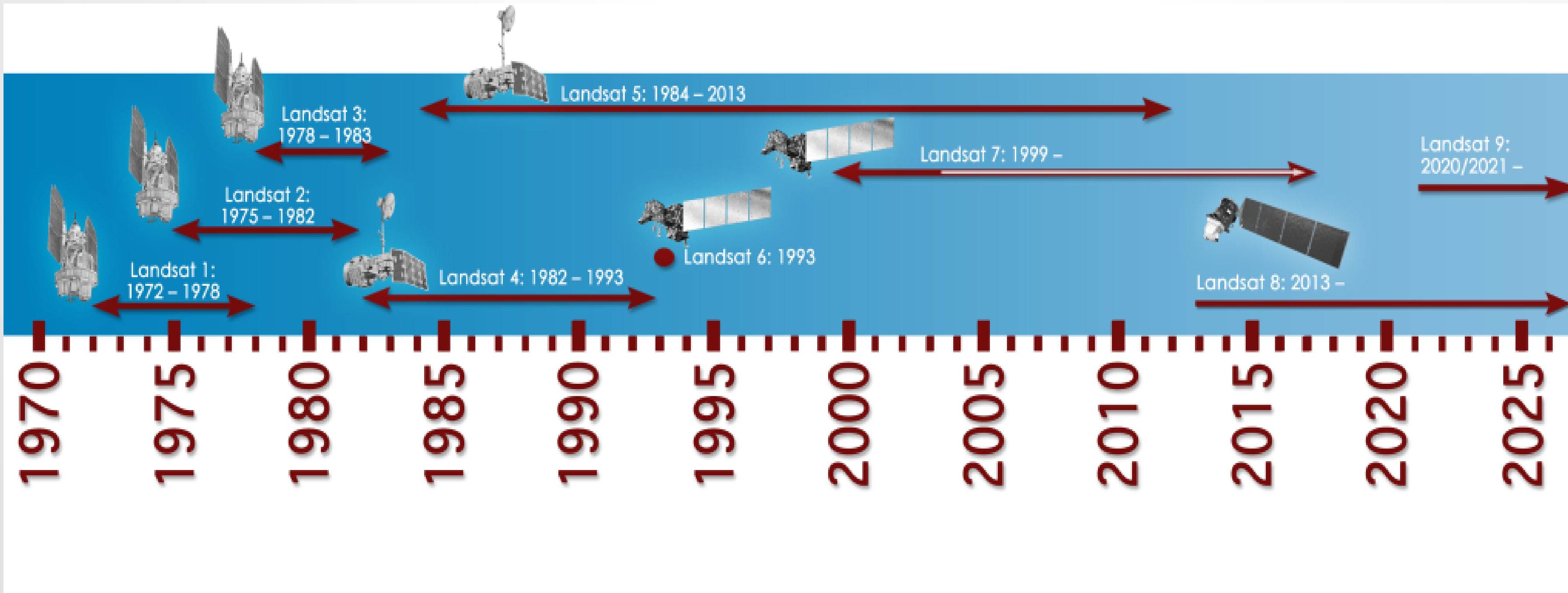


Space Borne Platforms

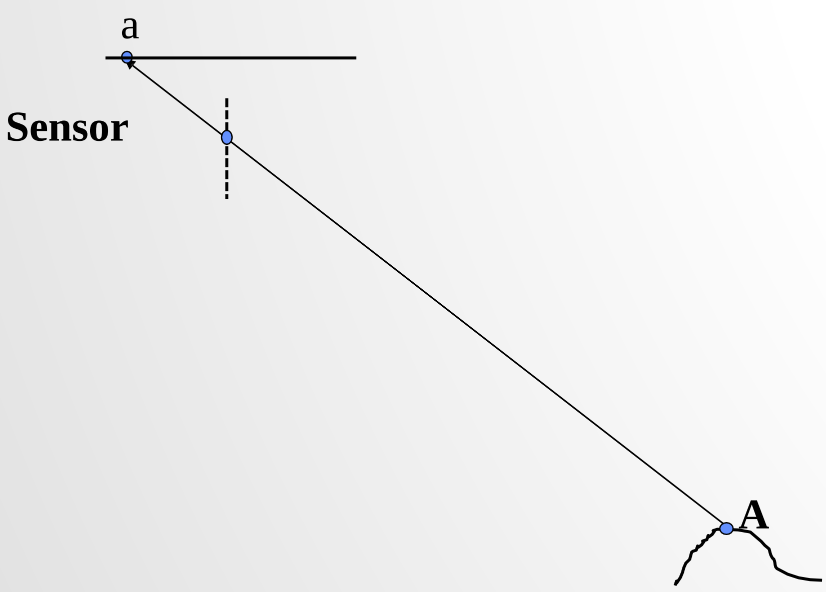
Remote sensing data can be captured by satellites.
Because of their orbits, satellites permit repetitive coverage of the Earth's surface on a continuing basis.

The choice of the remote sensing platform depends on:
The application is under consideration.
Accessibility of the area under consideration.
Amount of required details.
The cost.

DATA ACQUISITION SYSTEM



PASSIVE VERSUS ACTIVE SENSORS



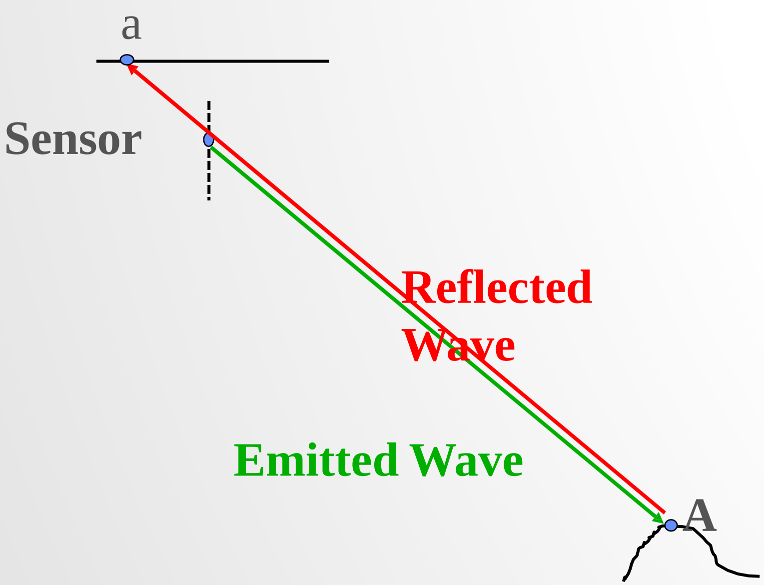
Passive Sensors

Remote sensing systems which measure the energy that is naturally available are called passive sensors. Passive sensors can only be used to detect energy that is naturally available.

– Optical imagery can be only captured during the time when the sun is illuminating the Earth.

Thermal and infrared imagery can be detected day or night, as long as the amount of energy is large enough to be recorded.

PASSIVE VERSUS ACTIVE SENSORS



Active Sensors

Active sensors provide their own energy source for illumination.

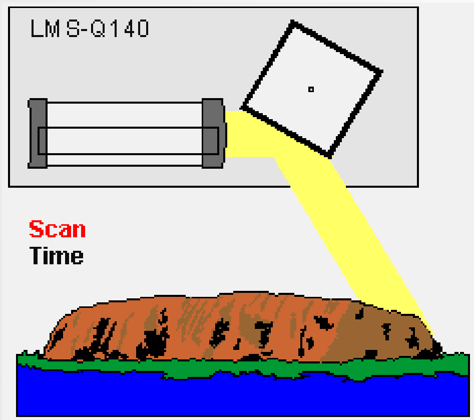
The sensor emits radiation which is directed toward the target to be investigated.

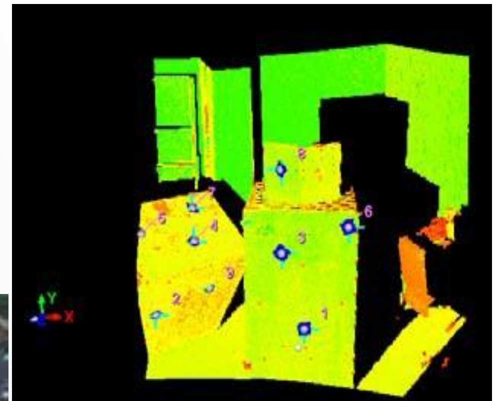
The radiation reflected from that target is detected and measured by the sensor.

The advantages of active sensors include the ability to obtain measurements anytime, regardless of the time of day or season.

Problems: More power is needed.

PASSIVE VERSUS ACTIVE SENSORS





Active Sensor

Passive Sensor

APPLICATIONS

QUESTION: WHAT TYPE OF INFORMATION ARE YOU EXTRACTING?

APPLICATIONS

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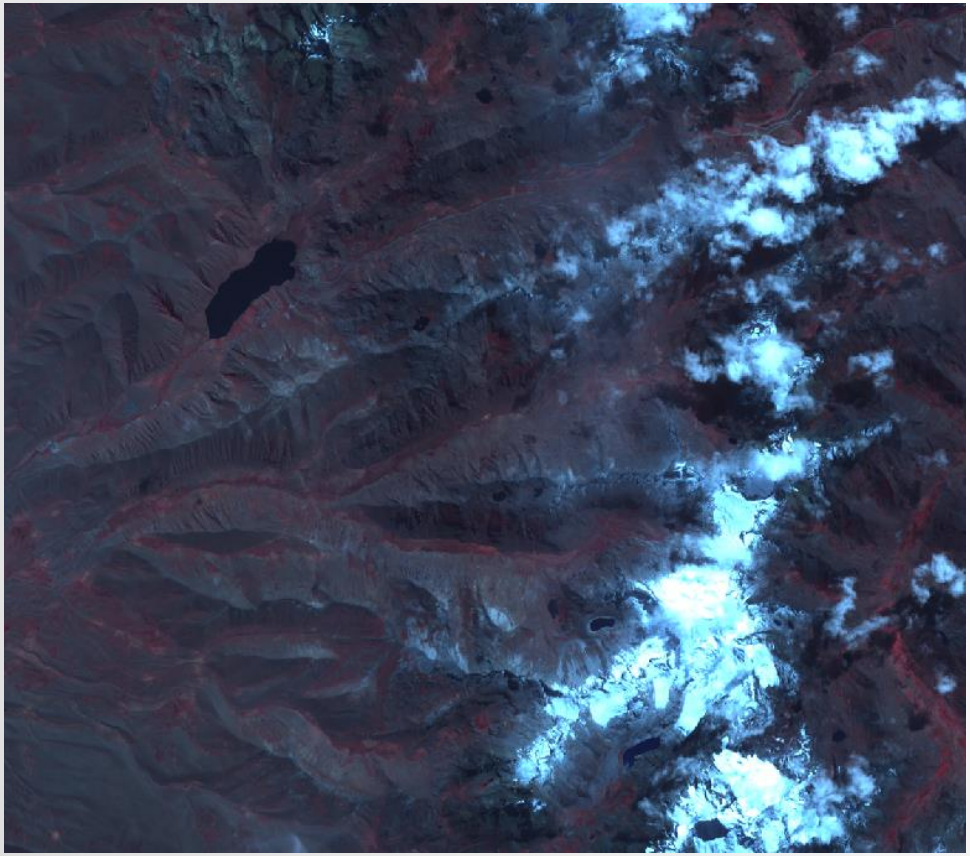
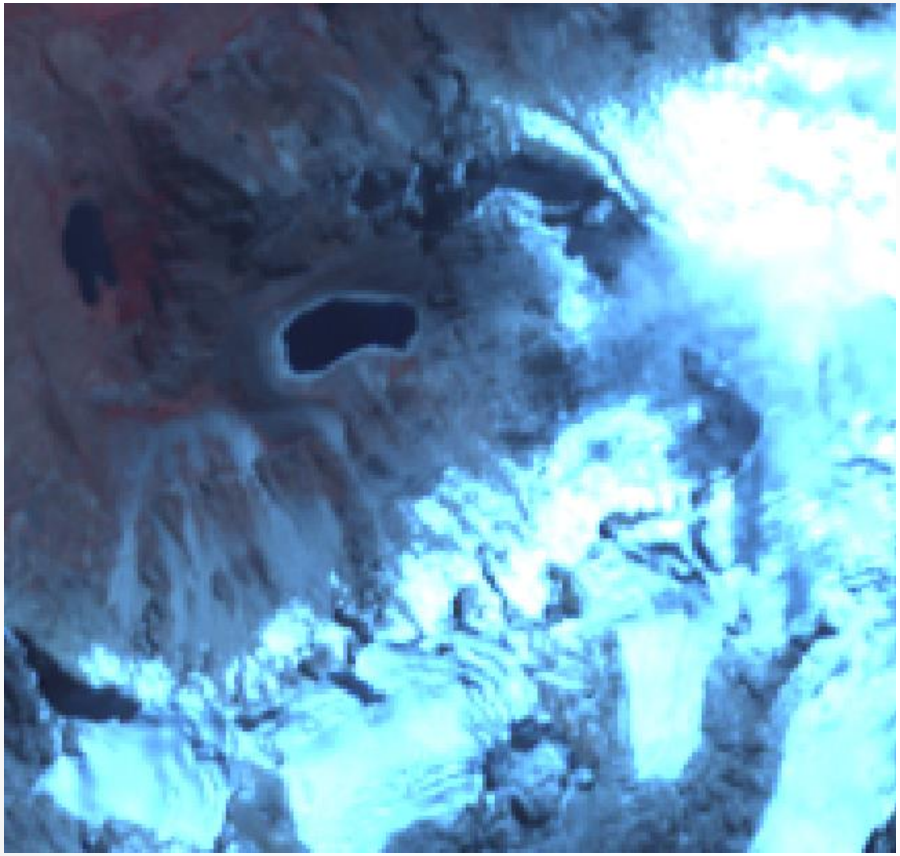
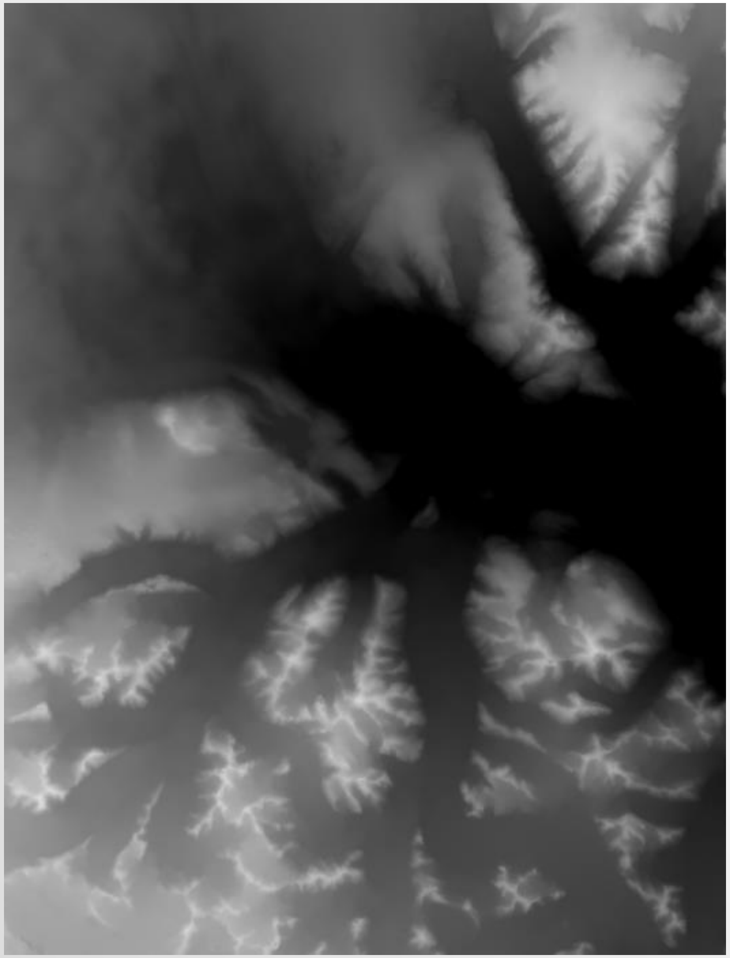


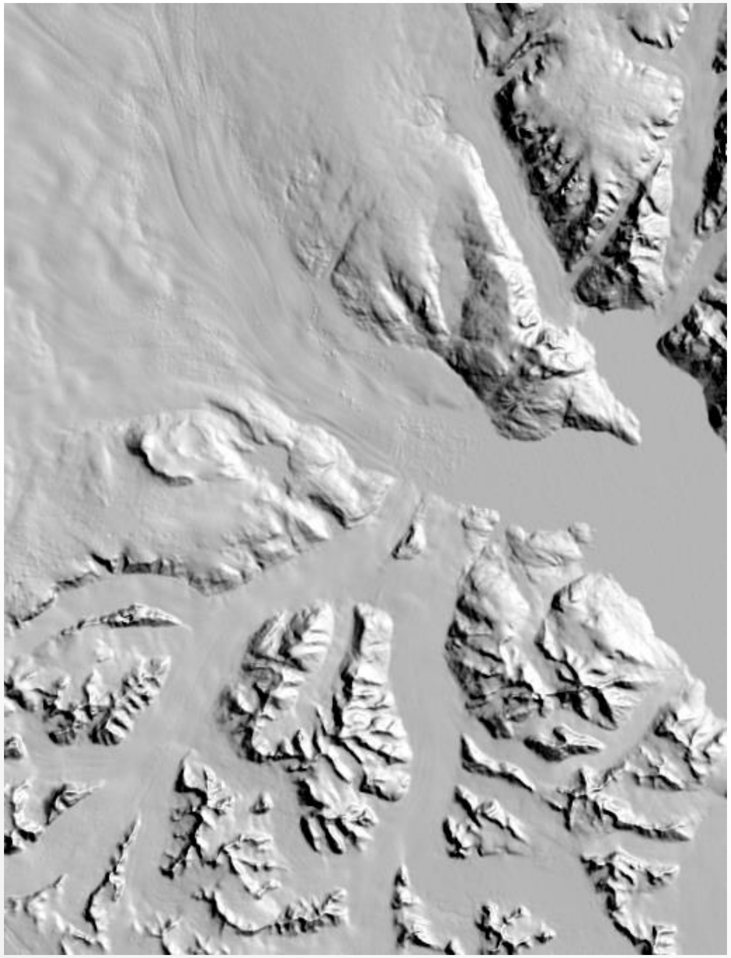


APPLICATIONS

QUESTION: WHAT TYPE OF INFORMATION ARE YOU EXTRACTING?

What do you call this?





APPLICATIONS

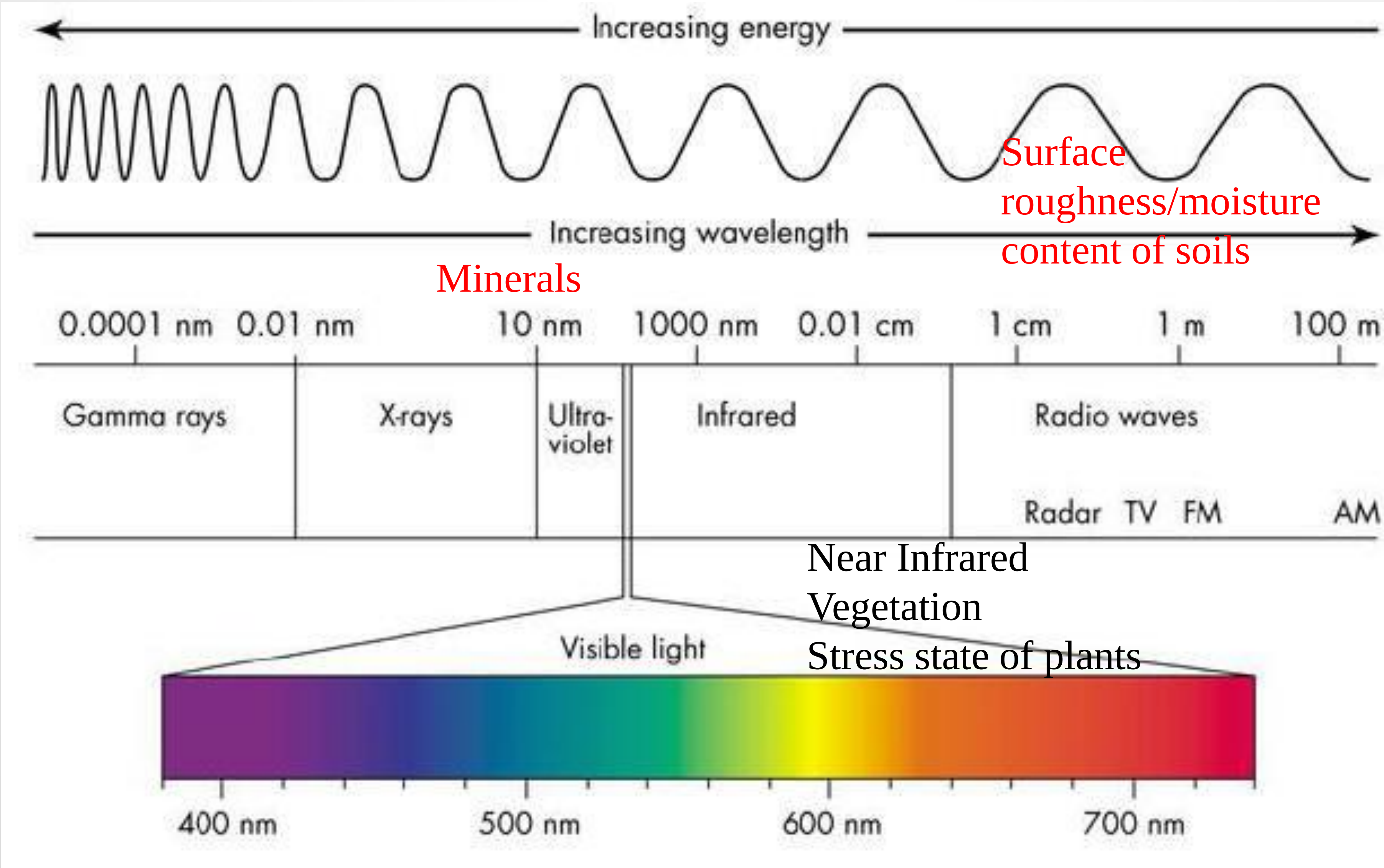
SO, WHAT CAN WE DO WITH THESE DATA?

- Extraction of Roads, Buildings, Trees?
- Snow coverage?
- The size of lakes (water)
- Slopes, contours, aspect

What is time series analysis?

- Elevation
- Pigments
- Canopy structure and height
- Leaf area index
- Moisture
- Mineral composition
- Surface roughness
- Atmosphere
- Water
- Snow and Ice
- Temperature
- Land cover

APPLICATIONS



Minerals

Surface roughness/moisture content of soils

Near Infrared
Vegetation
Stress state of plants

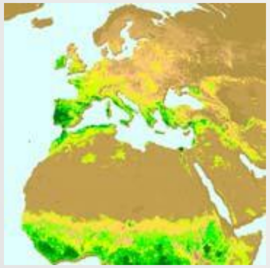
APPLICATIONS

Remote Sensing Applications

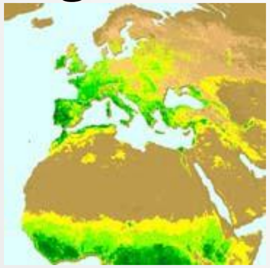
Meteorology.
Agriculture.
Forestry.
Environmental.
Oceanography.
Cartography.

Weather Monitoring

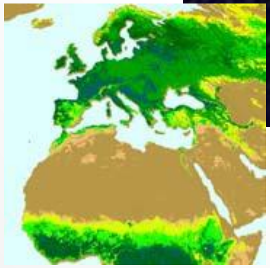
Agriculture



Feb., 86

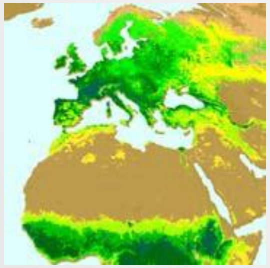


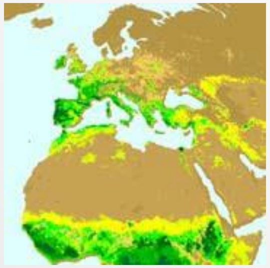
Apr., 86



Jun., 86

Aug., 86



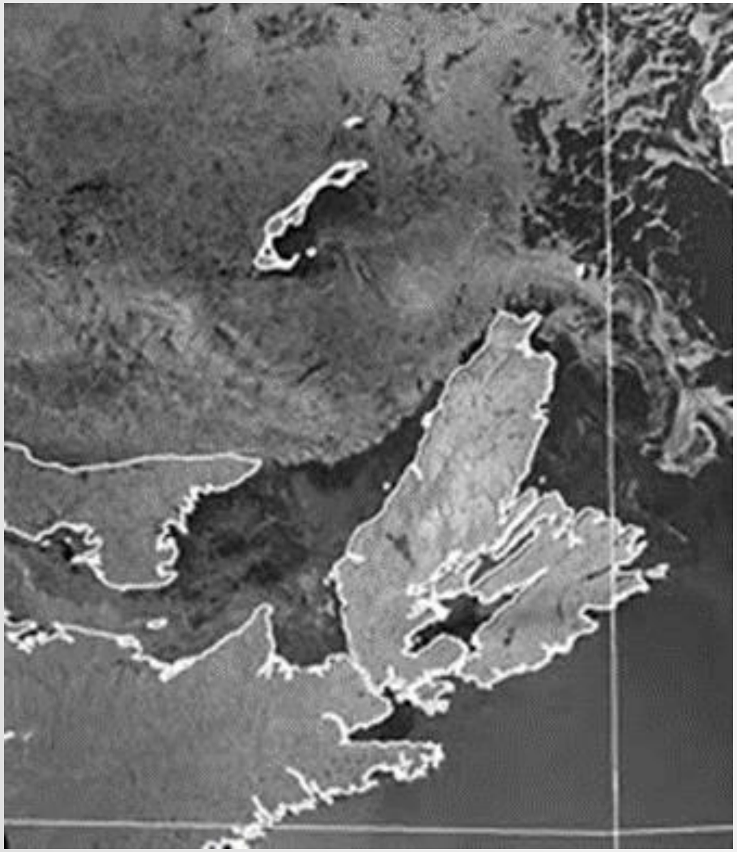


Dec., 86

APPLICATIONS

Ocean & Costal Monitoring

Ice Detection and Mapping



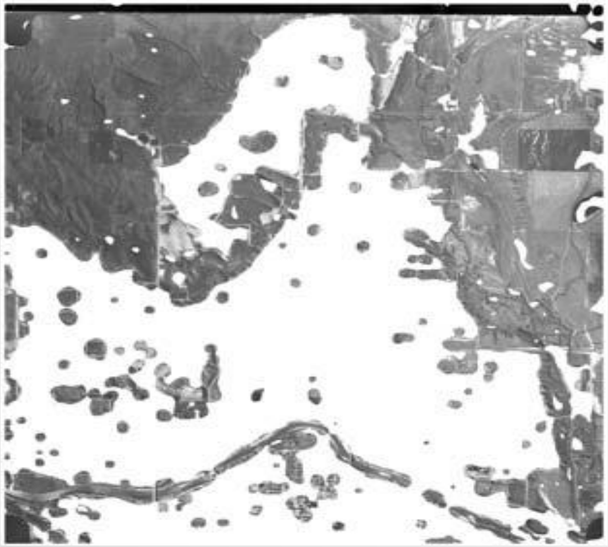
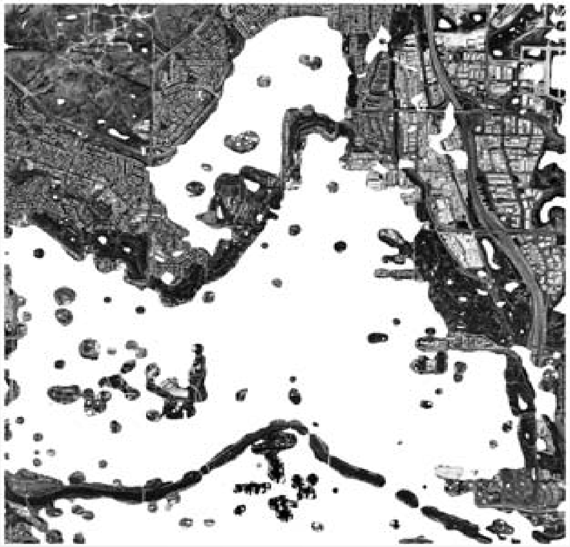
Ocean waves

Oil spill detection

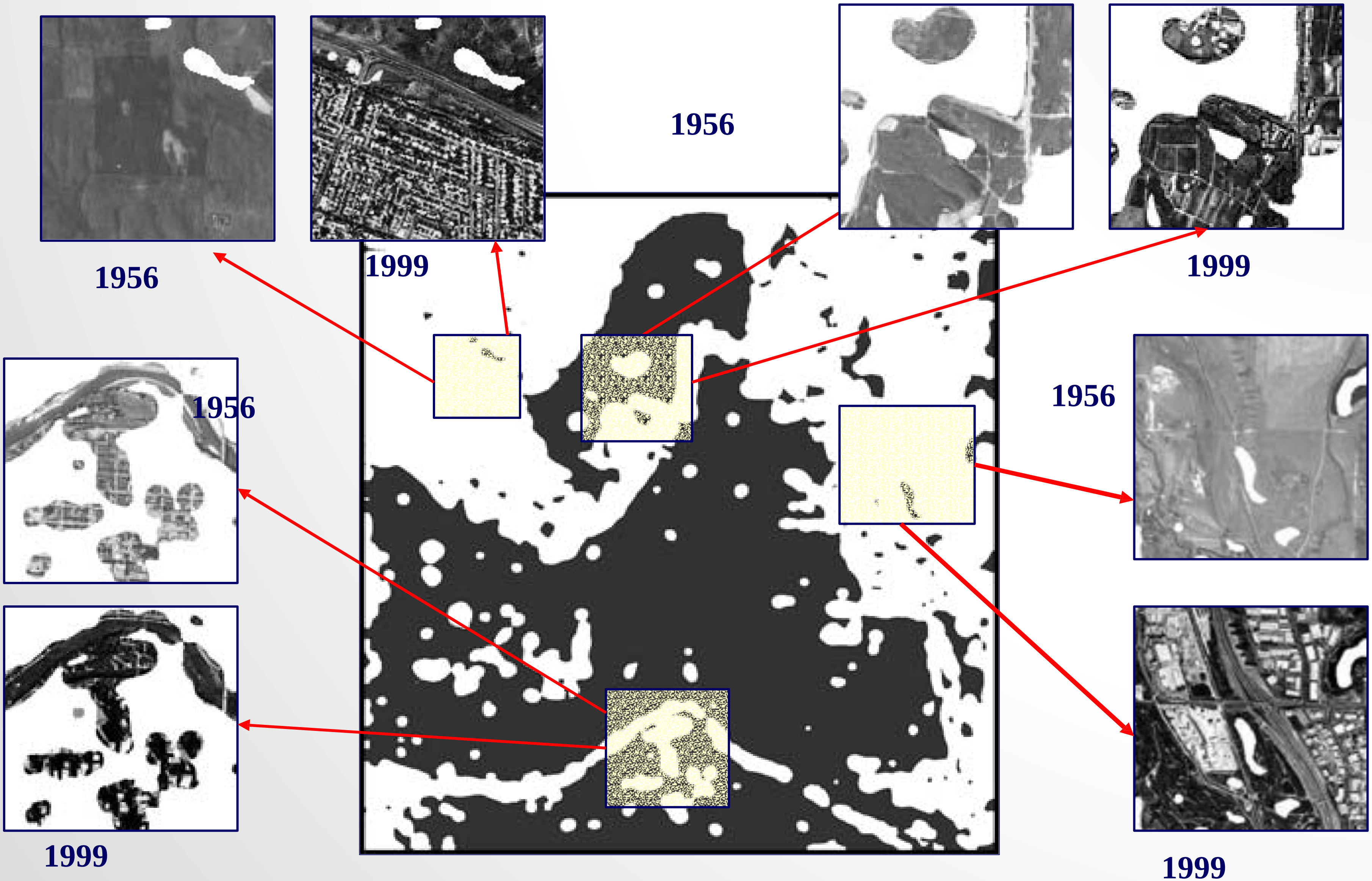
APPLICATIONS

Change Detection


Change Detection Analysis

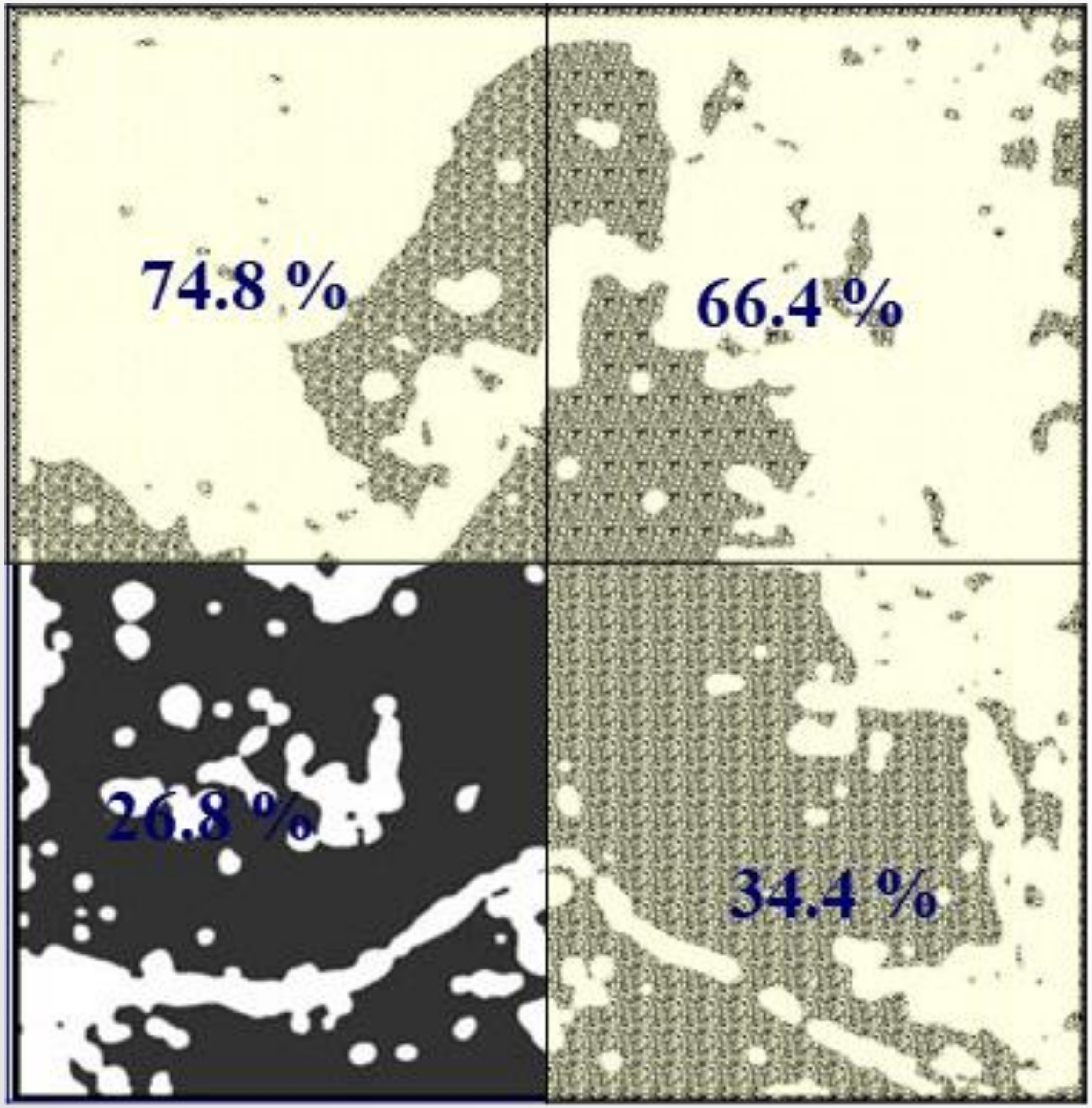



APPLICATIONS



APPLICATIONS

Change Detection: (Quantitative Measurements)



APPLICATIONS

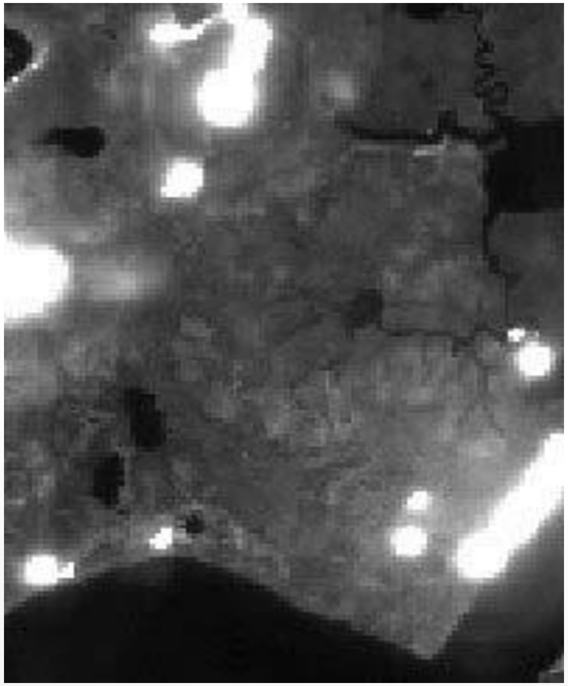
Disaster Assessment

Devastation created by tornado

Forest Fire Monitoring

True Color Image

Thermal Image



FINAL REMARKS

For remote sensing, we need to:

Understand the characteristics of the energy, which will be recorded, and how it is interacting with the atmosphere and the target.

Understand the characteristics of the remote sensing system.

Understand the processing mechanism of the acquired remote sensing data.

Radiometric processing.

Geometric processing.