IMAGES OF THE EARTH
GEOL 3105

Department of Geology
University of Puerto Rico at Mayaguez

PRINCIPLES OF REMOTE SENSING

GERS

REFERENCE: **Introduction to Remote Sensing**
James B. Campbell and Randolph H. Wynne (2011) Fifth Edition. The Guilford Press.

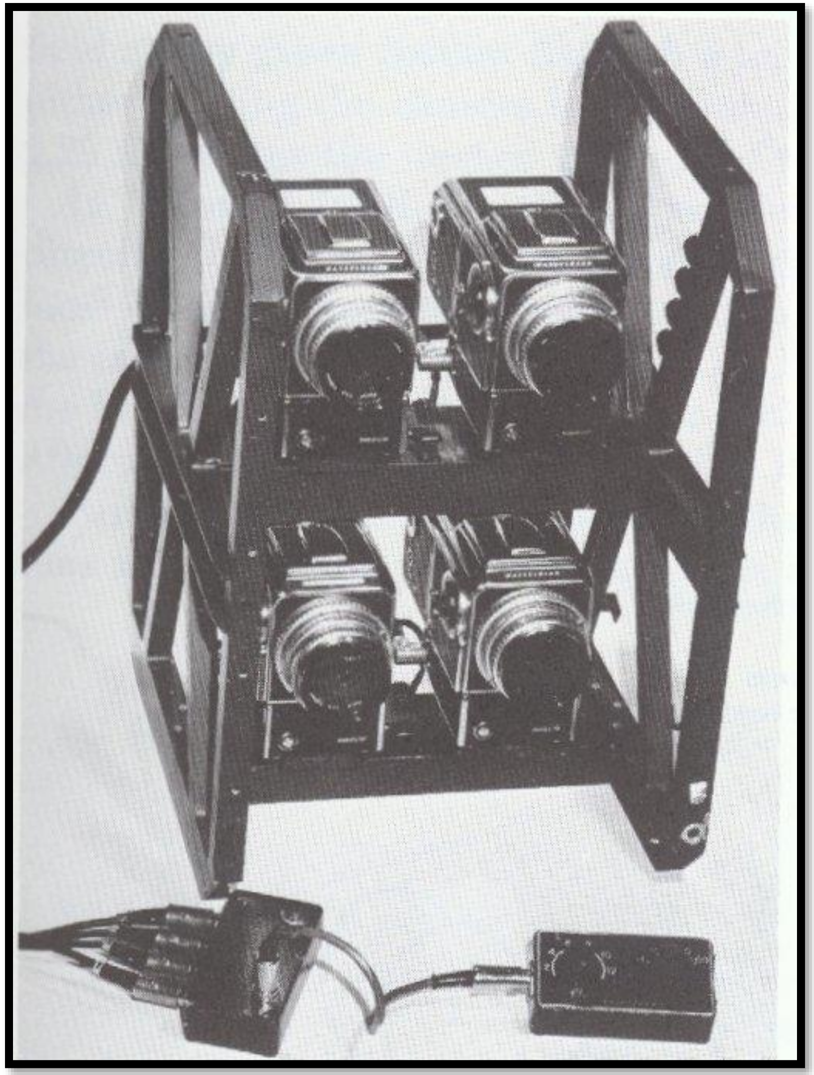
WHAT IS REMOTE SENSING?

"It is the science of deriving information about an object without actually coming in contact with it."

FIRST AERIAL PHOTOS

- Remote sensing as a technology can be said to have started with the appearance of the first photographs.
- The so-called aerial photo - emerged in the 1840s with pictures taken from balloons.
- By the First World War, cameras mounted on airplanes provided aerial views of fairly large surface areas that proved invaluable in military reconnaissance.
- From then until the early 1960s, the aerial photograph remained the single standard tool for depicting the earth surface .

APOLLO PROGRAM

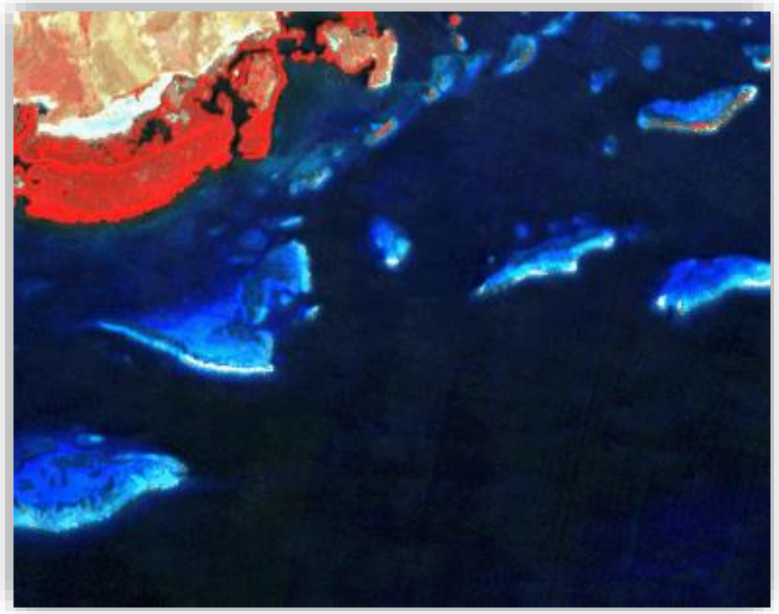


- The mission to the Moon needed maps of the lunar surface, especially of the proposed landing sites. These were prepared using remote sensing techniques.

- The first multispectral photography done from space was on the famous 1968 Apollo 9 manned mission. Four Hasselblad cameras were mounted in a holder such that they all aimed at the same target point when their shutters were triggered simultaneously.

- Images from the Apollo 9 multispectral four-lens camera were digitized and used to develop techniques for processing Landsat data, which, in 1969, was still four years away.

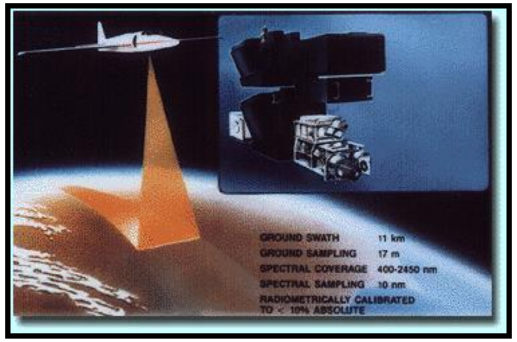
FROM PHOTOGRAPHS TO DIGITAL DATA

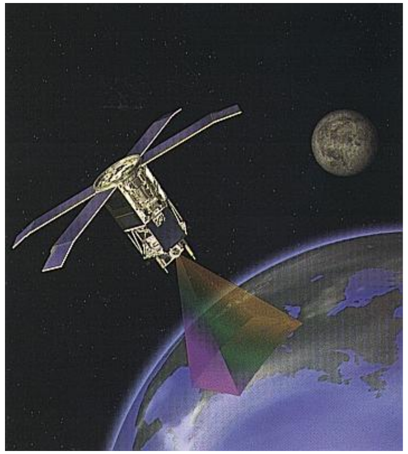


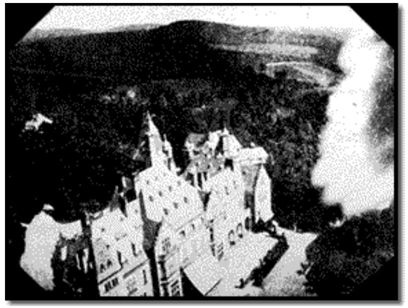
In July 23, 1972 NASA launched the first Earth Resources Technology Satellite (ERTS-1). The multispectral data provided by the on-board sensors led to an improved understanding of crops, minerals, soils, urban growth, and many other Earth features and processes. The name of the satellite, and those that followed, was soon changed to Landsat. Landsat has provided more data about the Earth than can ever be analyzed.

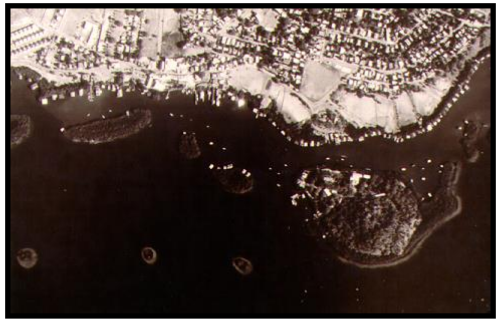
Return Beam Vidicon camera (RBV)	**B,G,R**
Multispectral Scanner (MSS)	**G,R, 2 NIR**
Thematic Mapper (TM)	**B,G,R, NIR, 2 MIR, FIR**
Enhanced Thematic Mapper (ETM)	**B,G,R, NIR, 2 MIR, FIR, PAN**
Operational Land Imager (OLI)	**2B,G,R, NIR, 3MIR, PAN**

MILESTONE IN THE HISTORY OF REMOTE SENSING PLATFORMS



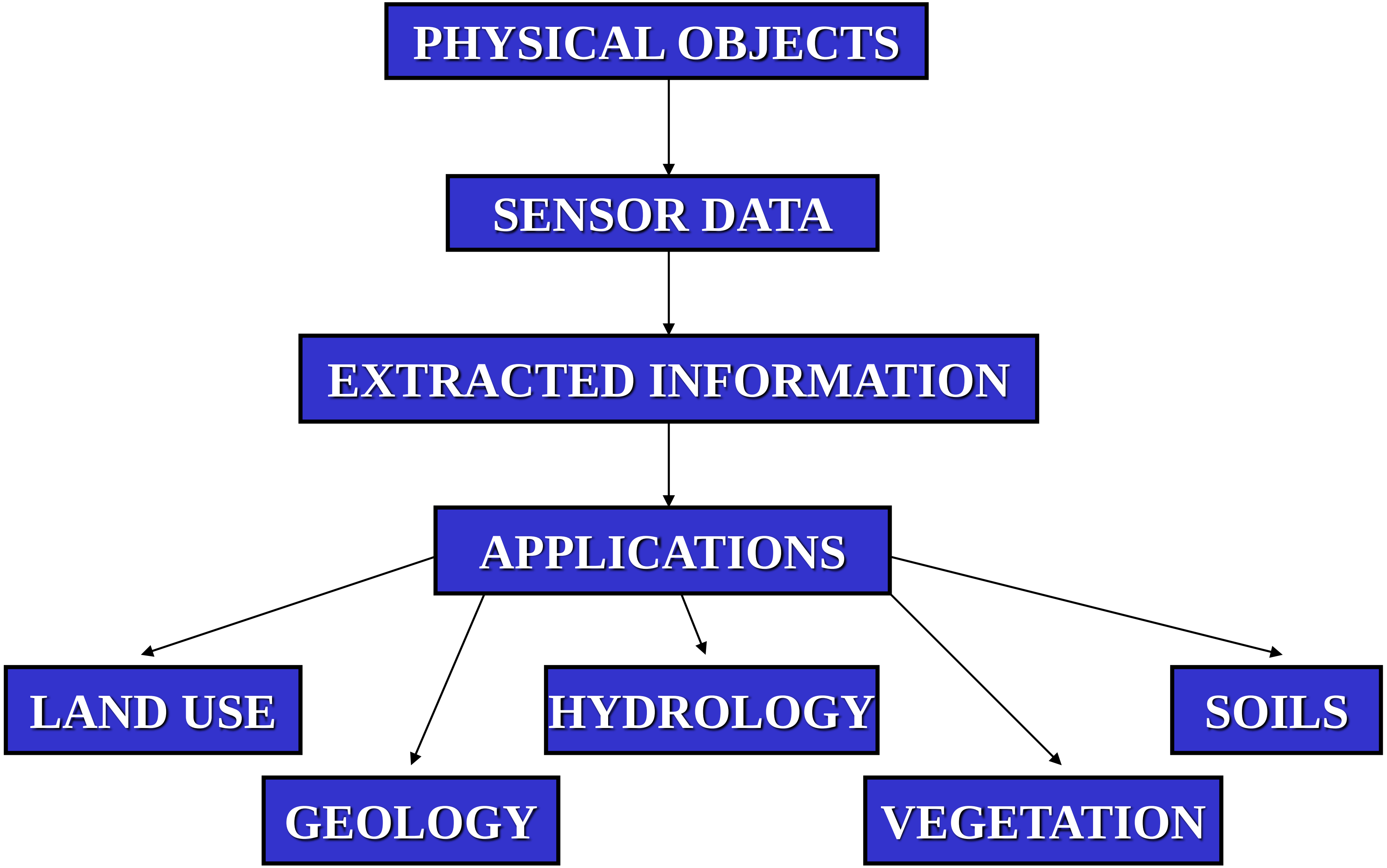






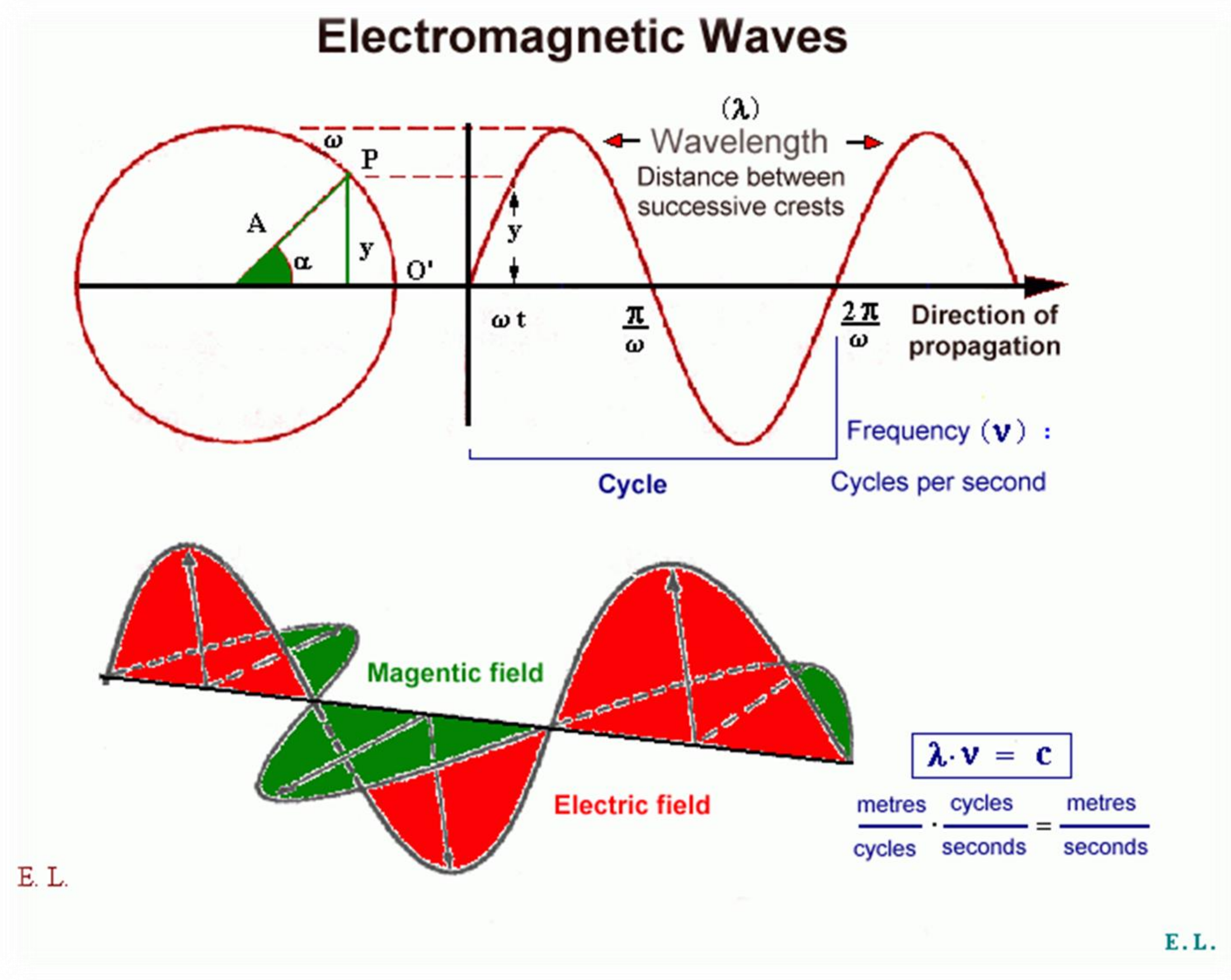
Balloons → **Pigeons** → **Airplanes** → **Satellites** → **Dromes**

OVERVIEW OF REMOTE SENSING PROCESS

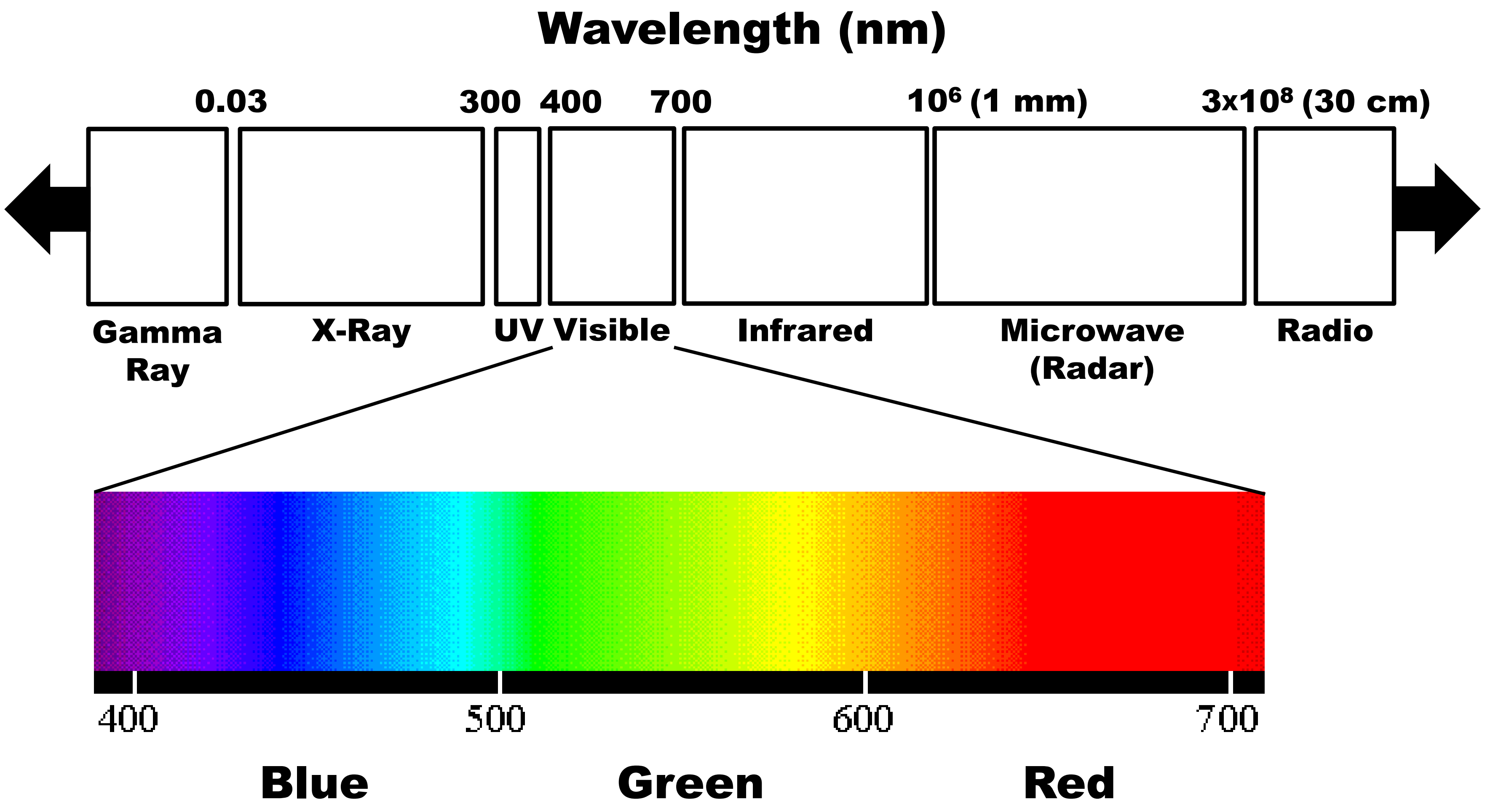


ELECTROMAGNETIC RADIATION

The quantity most frequently measured by current remote sensors is the electromagnetic energy emanating from the object of interest.

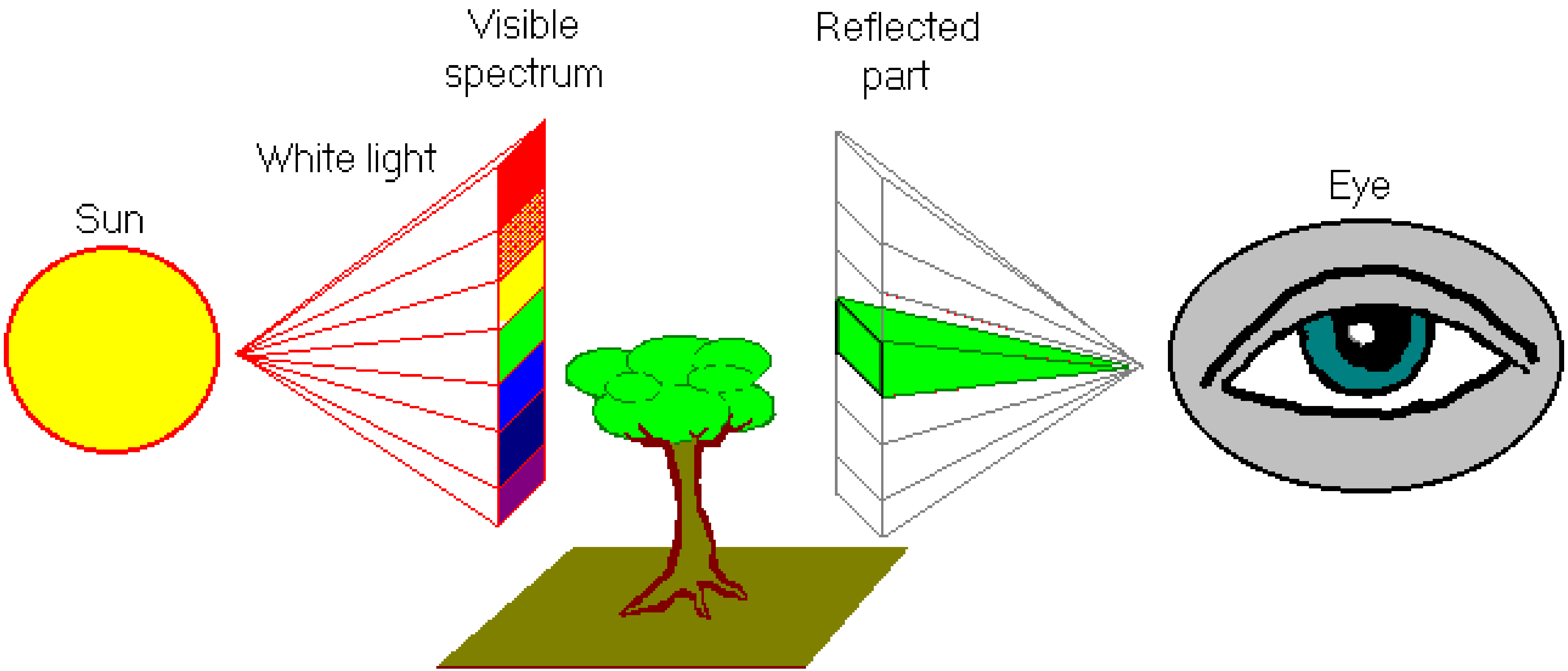


ELECTROMAGNETIC SPECTRUM

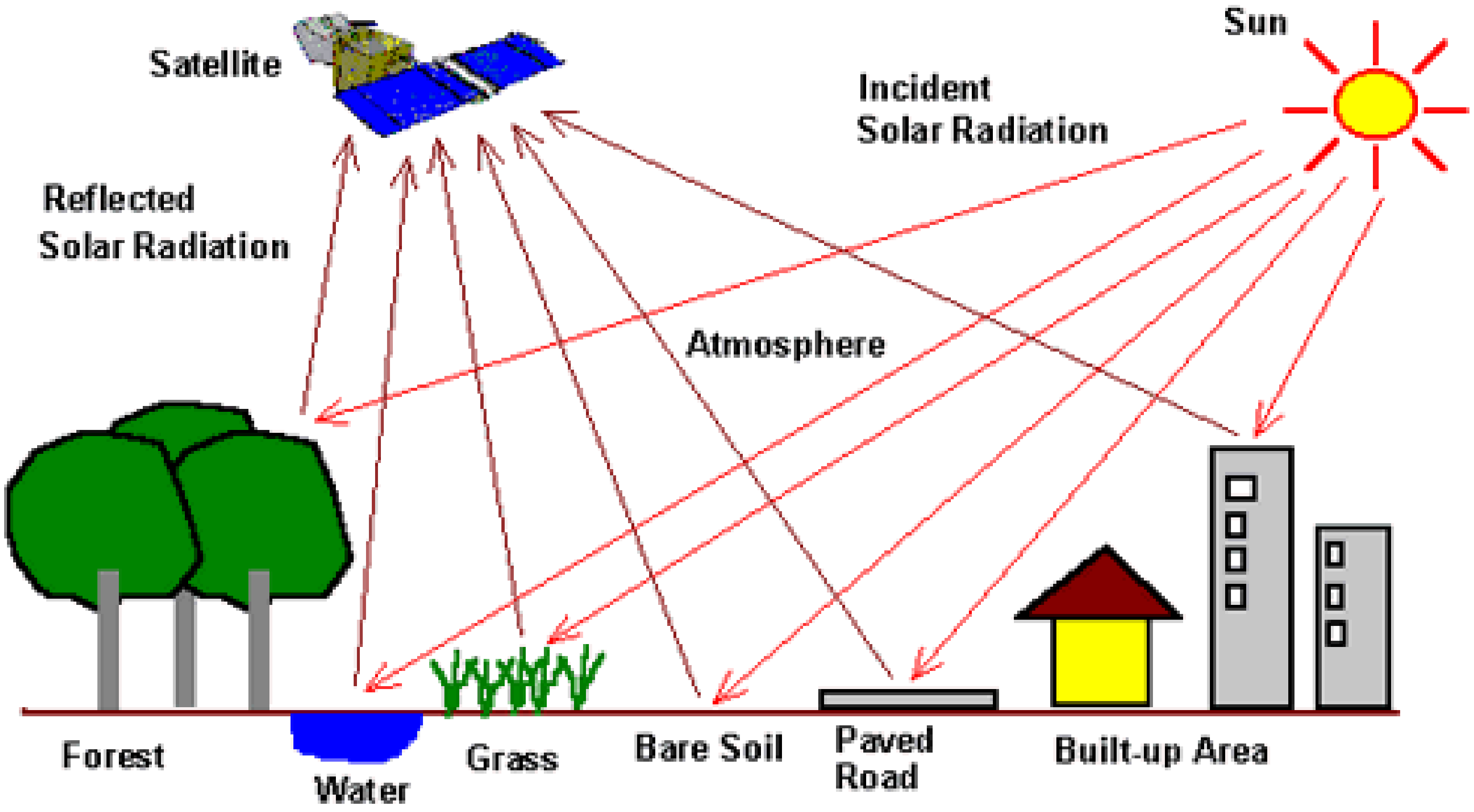


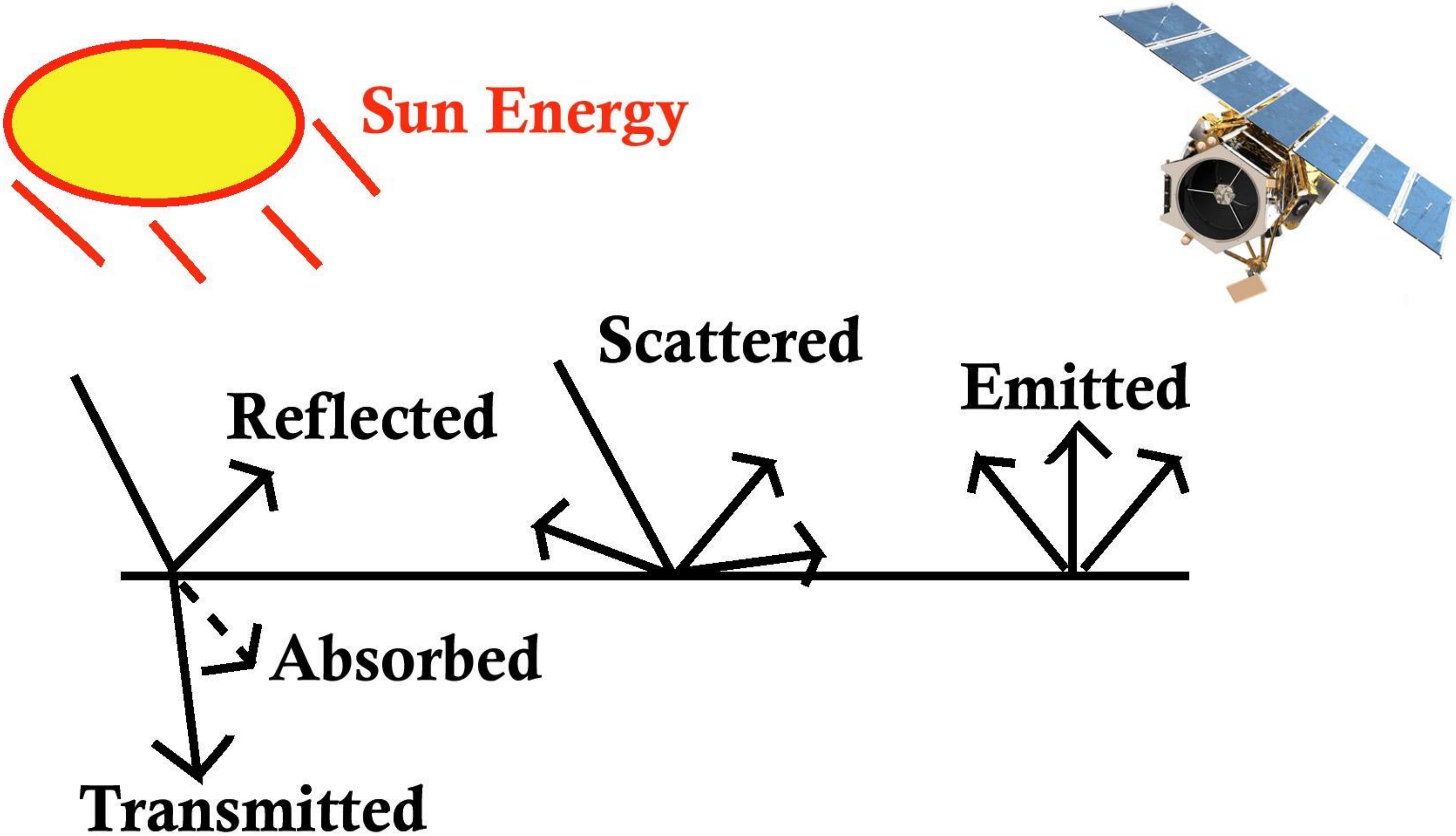
REFLECTION OF COLORS

REFLECTION OF COLORS



DETECTING THE REMOTE SIGNAL



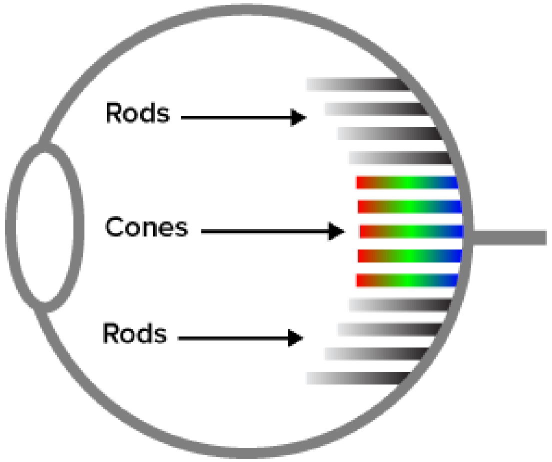

Sun Energy
Scattered
Emitted
Reflected
Absorbed
Transmitted

KEY CONCEPTS OF REMOTE SENSING

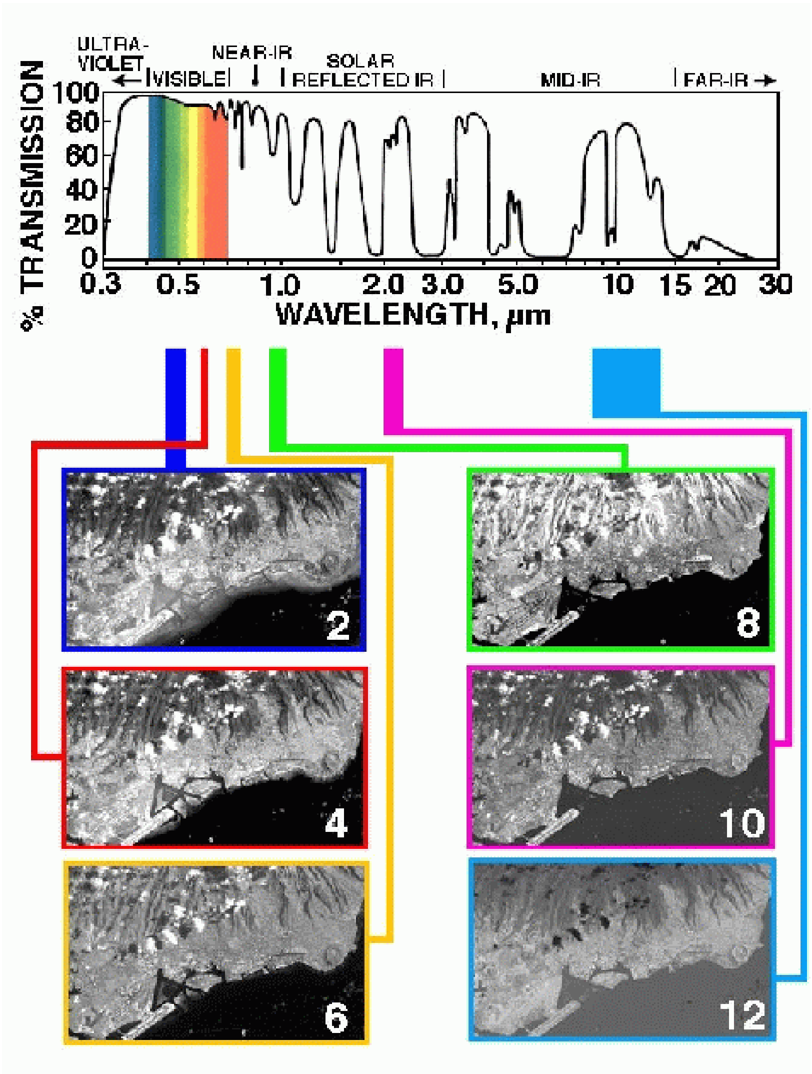
SPECTRAL DIFFERENTIATION - Remote sensing depends upon observed differences in the energy reflected or emitted from features of interest.

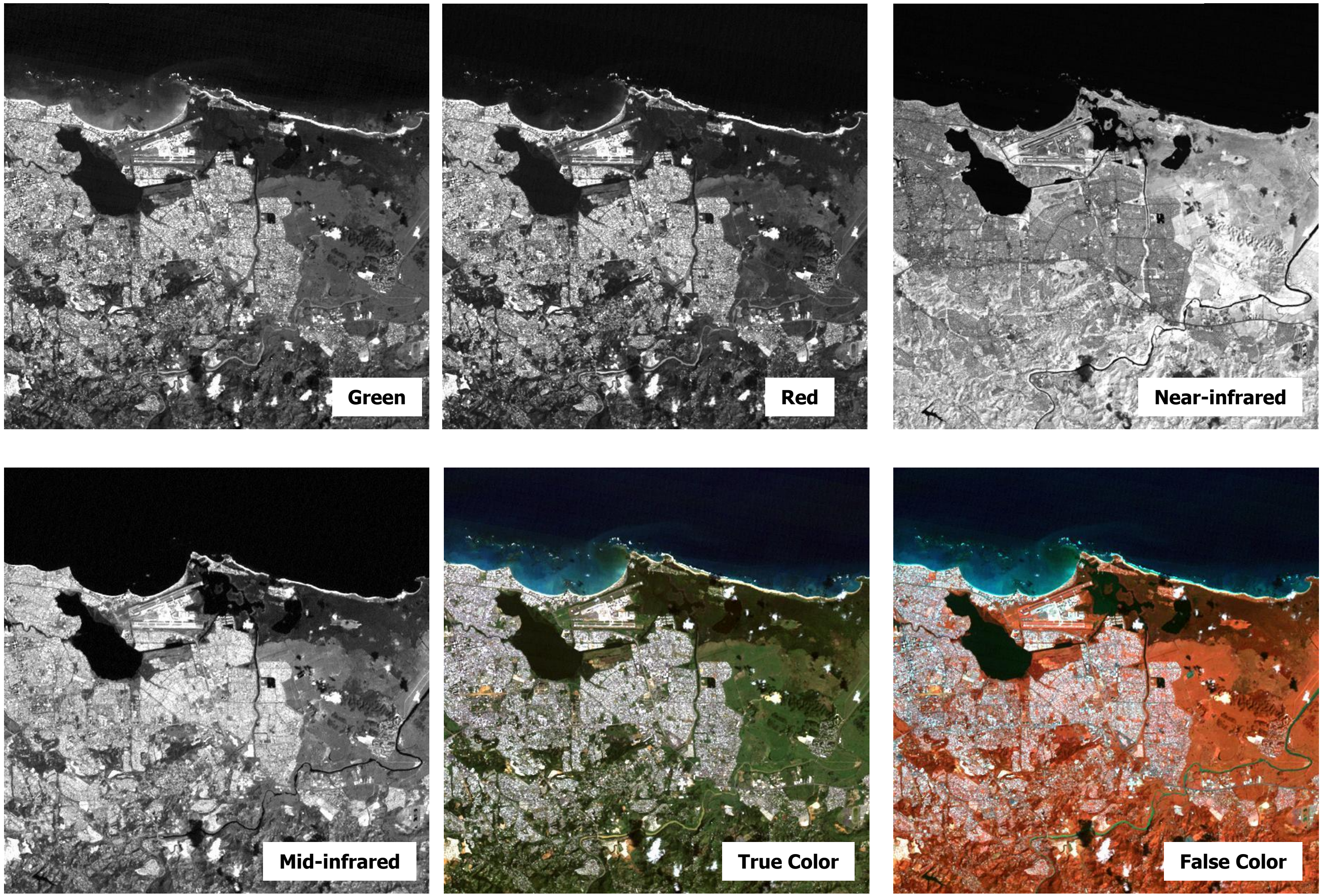
Spectral Resolution: This refers to the number of bands in the spectrum in which the instrument can take measurements.

- **Human Eye = 3 channels (RGB) + 1 Pan**
- **Landsat TM = 7 channels**
- **SeaWiFS = 8 channels**
- **AVIRIS = 224 channels**



SPECTRAL DIFFERENTIATION



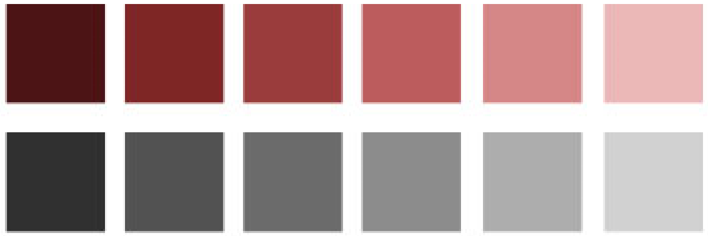


KEY CONCEPTS OF REMOTE SENSING

RADIOMETRIC DIFFERENTIATION - **Examination of any image acquired by remote sensing ultimately depends upon detection of differences in the brightness of objects and the features.**

Radiometric Resolution: This is the sensitivity to small differences in the radiation of an observed object.

- **Landsat TM = 8 bit**
- **MODIS = 12 bit**
- **ERS SAR = 16 bit**

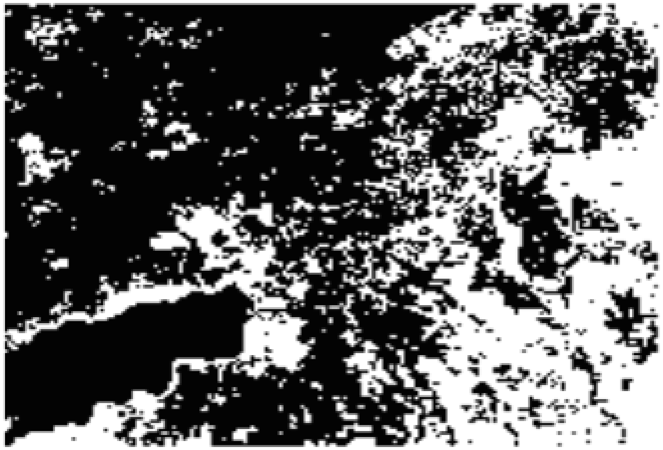


Relative Brightness Comparison

16 Values (4 bit)

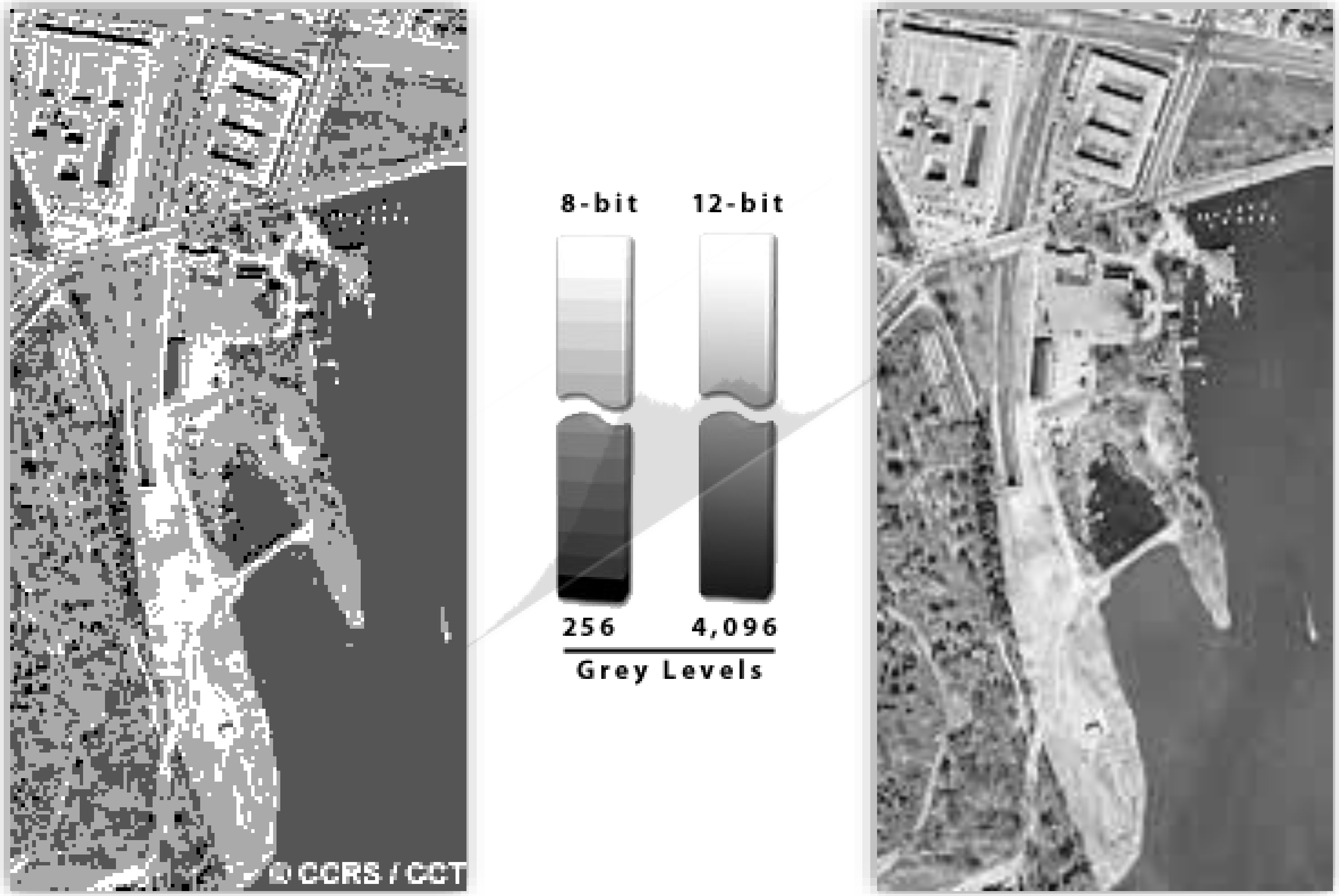
8 Values (3 bit)

4 Values (2 bit)



2 Values (1 bit)

SAME SCENE WITH TWO DIFFERENT RADIOMETRIC RESOLUTIONS

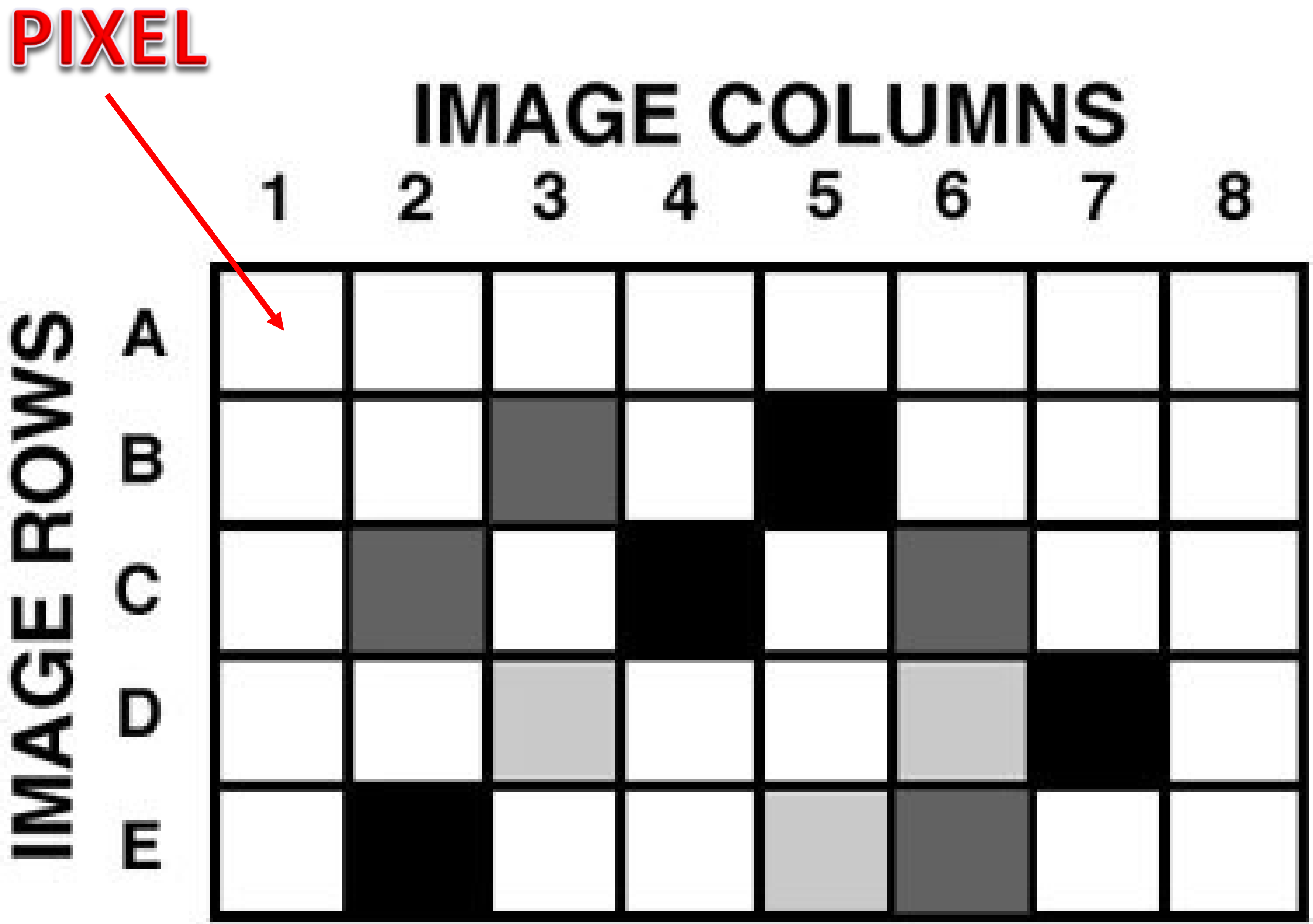


KEY CONCEPTS OF REMOTE SENSING

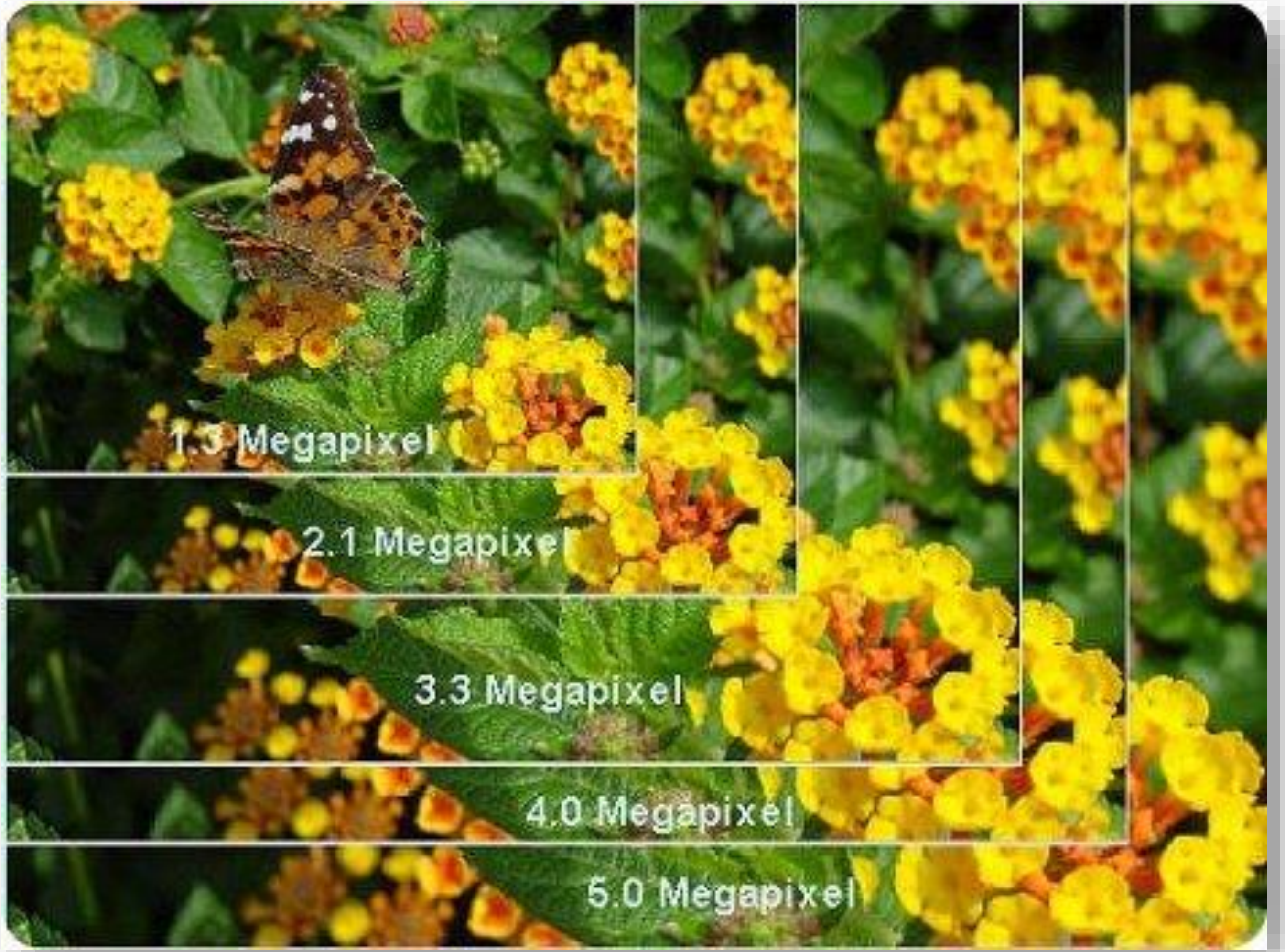
<u>SPATIAL DIFFERENTIATION</u> - Every sensor is limited in respect to the size of the smallest area that can be separately recorded as an entity on an image.

<u>Spatial Resolution</u>: This represents the ability of the sensor to detect and distinguish small objects and fine detail in larger objects. Depends on the instrument's sensitivity and distance from the object, and defines the pixel size of a digital image.

- **IKONOS = 1 m**
- **Landsat TM = 30 m**
- **AVHRR = 1 Km**
- **Meteosat = 7 Km**


PIXEL
IMAGE COLUMNS
1
2
3
4
5
6
7
8
IMAGE ROWS
A
B
C
D
E

DIGITAL CAMERAS AND MEGAPIXELS (10^6=MILLION OF PIXELS)

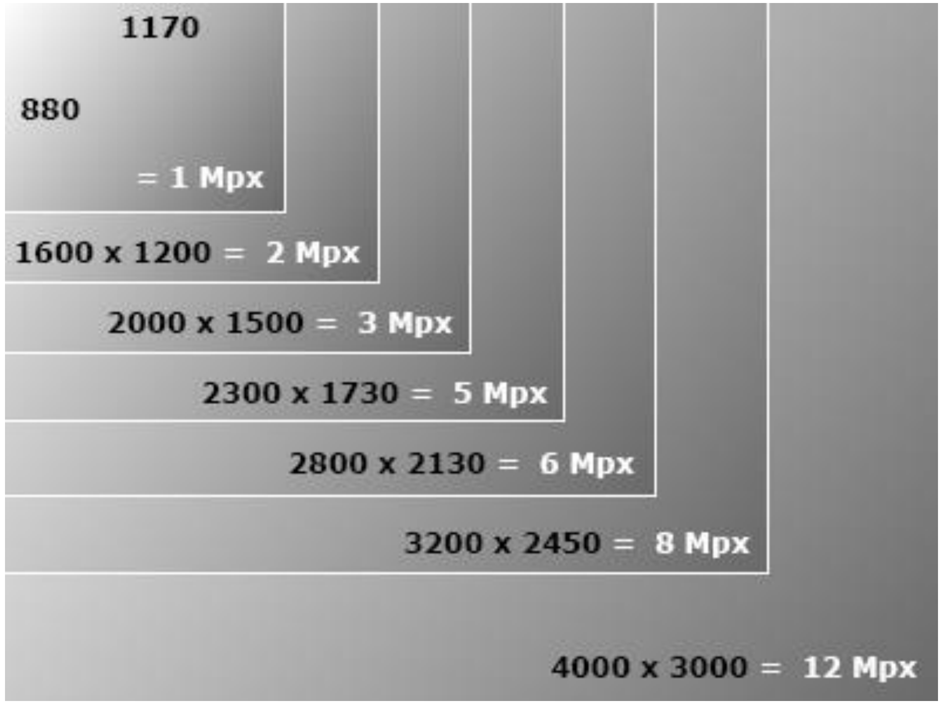


DIGITAL CAMERAS AND MEGAPIXELS

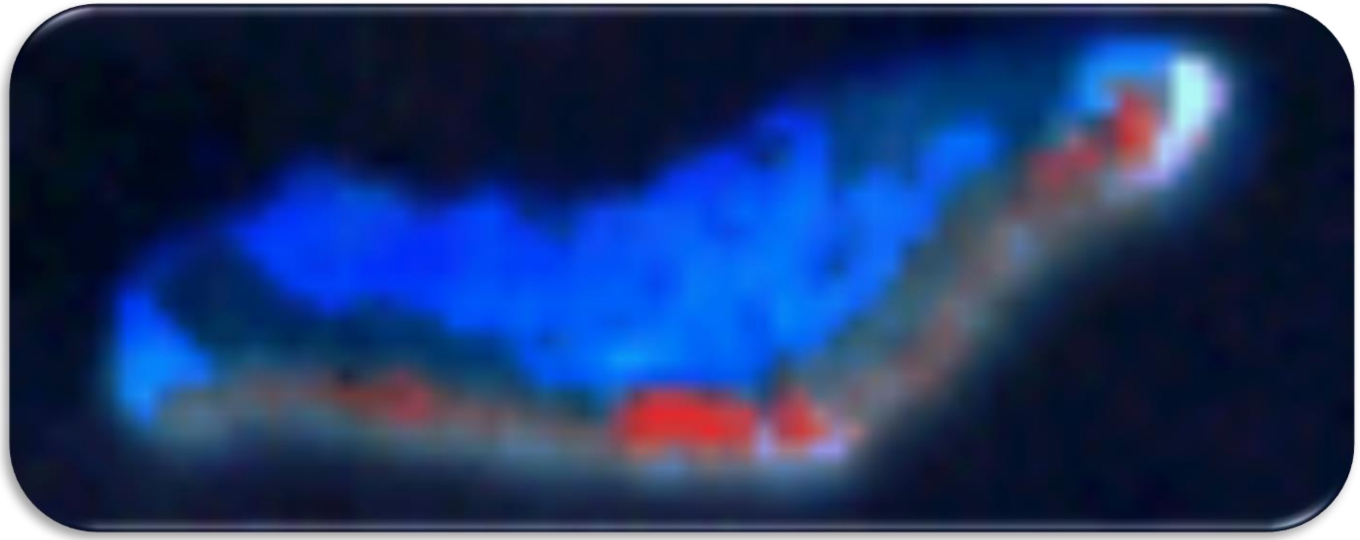
MEGAPIXELS	RESOLUCIÓN	TAMAÑO IMPRESO
2 MP	1600x1200px	20x15 cm.
3.1 MP	2048x1536px	26x19 cm.
4.1 MP	2272x1704px	28x21 cm.
5 MP	2592x1944px	32x24 cm.
6.3 MP	3072x2048px	39x26 cm.
7.1 MP	3072x2304px	39x29 cm.
8.2 MP	3264x2248px	41x28 cm.
9.1 MP	3456x2592px	43x32 cm.
10.1 MP	3648x2736px	46x34 cm.
11.1 MP	4080x2720px	51x34 cm.
12.1 MP	4000x3000px	50x38 cm.

• Resolución 200ppi - apto para impresión de fotografías.

•• Para impresiones profesionales para imprenta (tipografía, serigrafía). se necesitan 300 ppp.



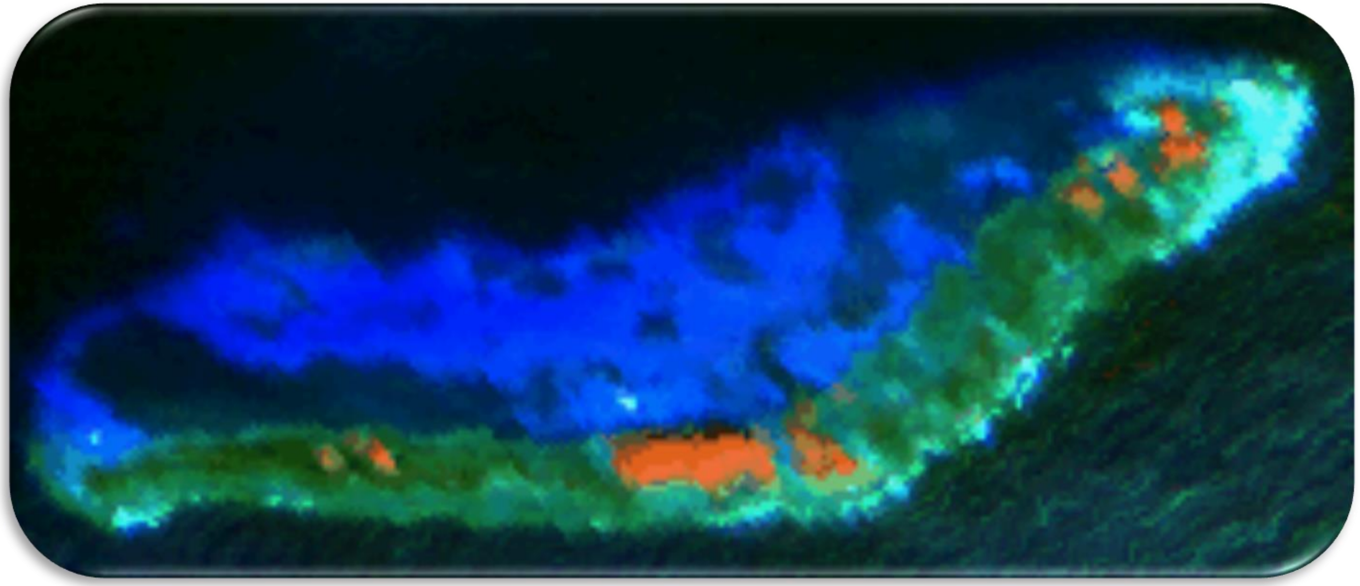
SAME SCENE-DIFFERENT PIXEL SIZE



Satellite
Pour l'Observation
de la Terre

SPOT

20 m

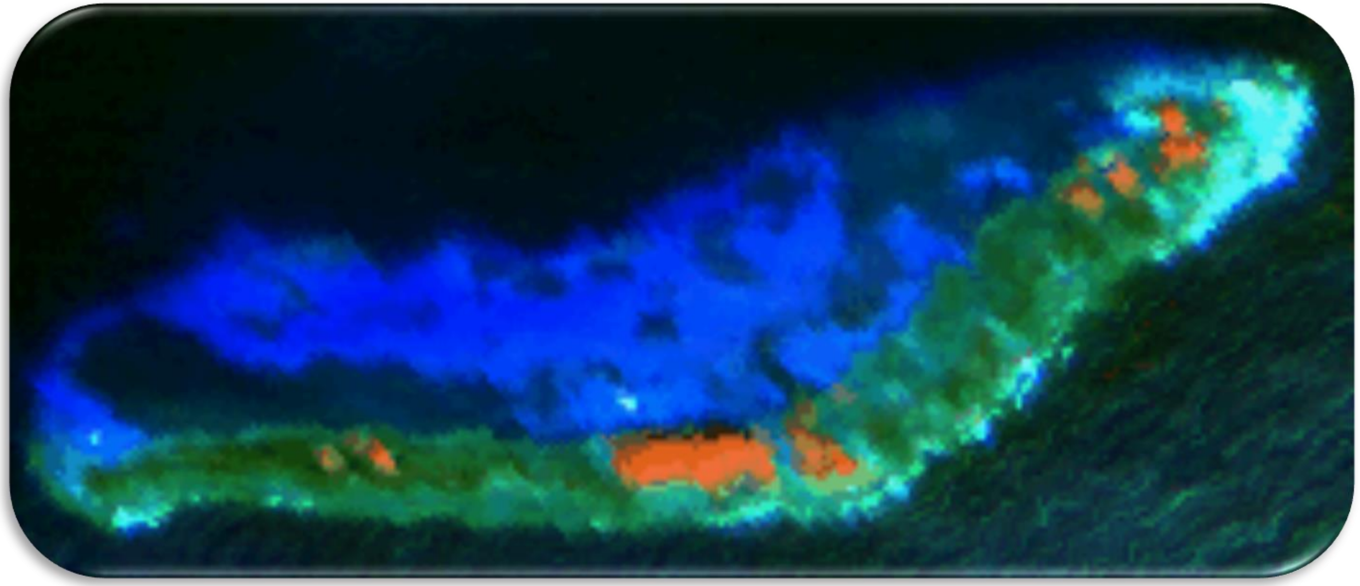


Compact
Airborne
Spectrographic
Imager

CASI

5 m

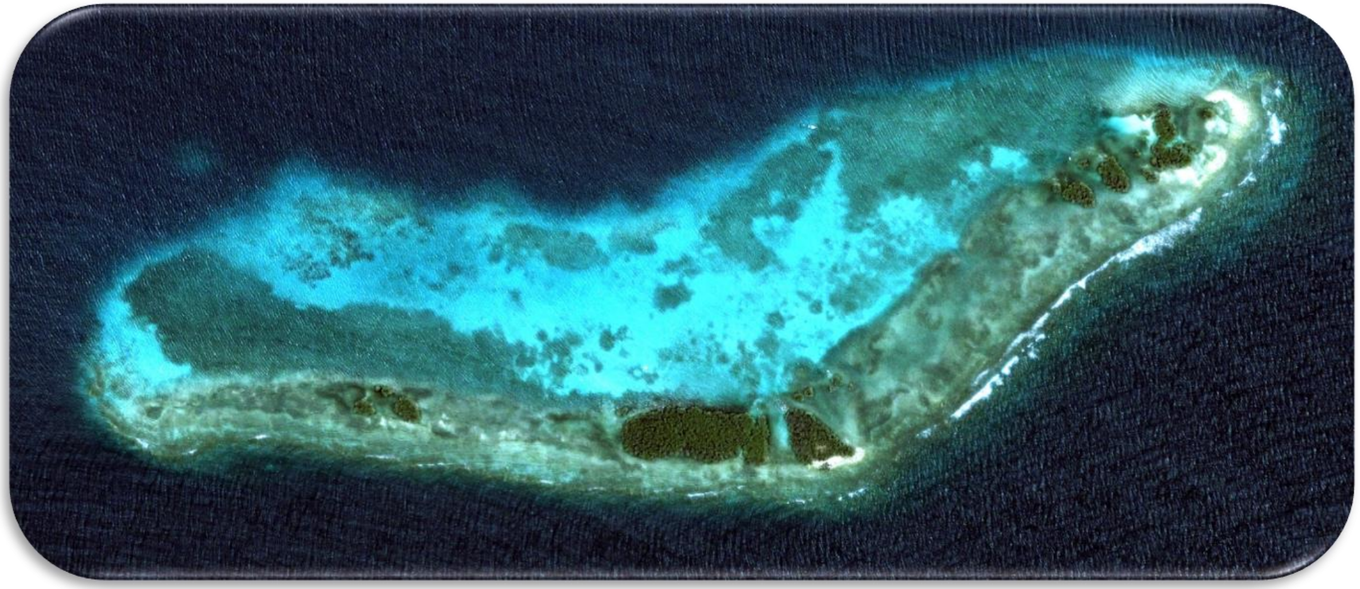
SAME SCENE-DIFFERENT PIXEL SIZE



Compact
Airborne
Spectrographic
Imager

CASI

5 m



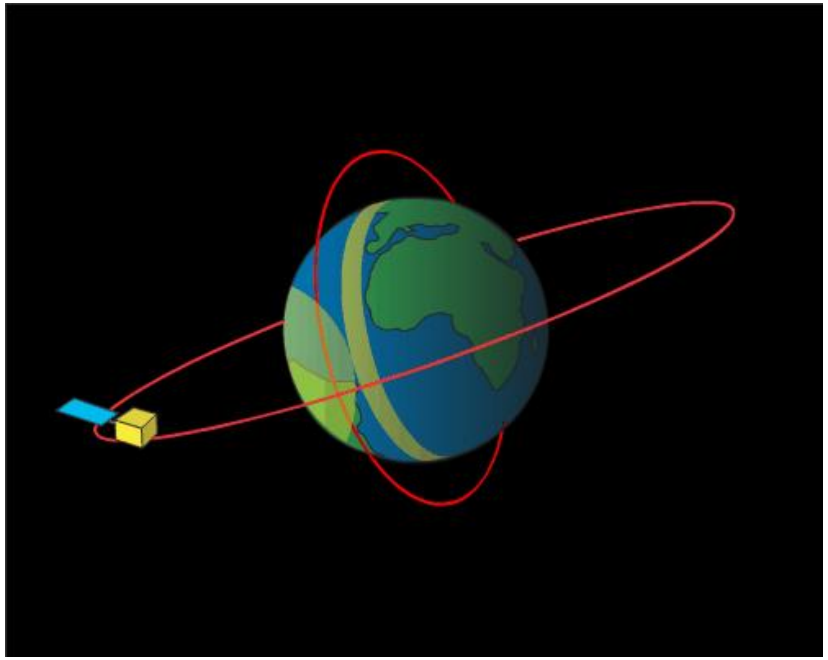
IKONOS

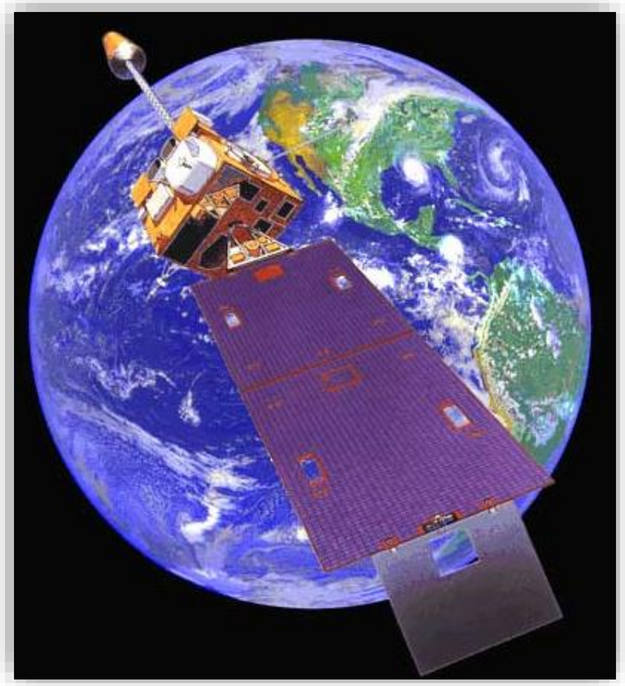
1 m

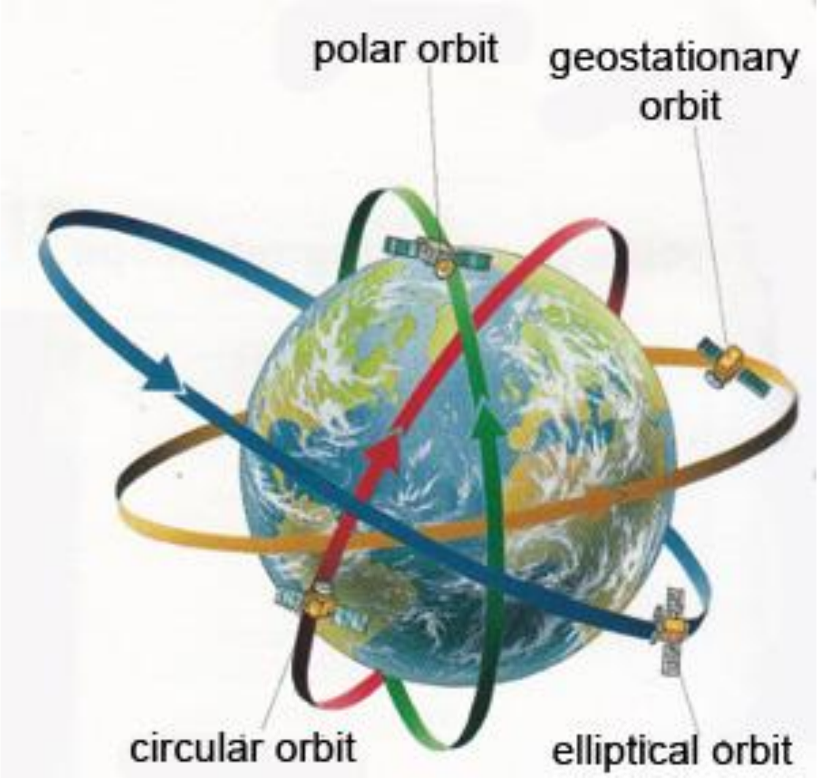
KEY CONCEPTS OF REMOTE SENSING

TEMPORAL RESOLUTION (TR) – it refers to the precision of a measurement with respect to time. Represents the frequency with which a sensor can re-visit an area of interest and acquire a new image. Depends on the instrument's field of vision, and the platform (ex. Satellite) movement.

- IKONOS = 3-5 days
- Landsat TM = 16 days
- AVHRR = ~6 hours
- GOES = ~15 minutes



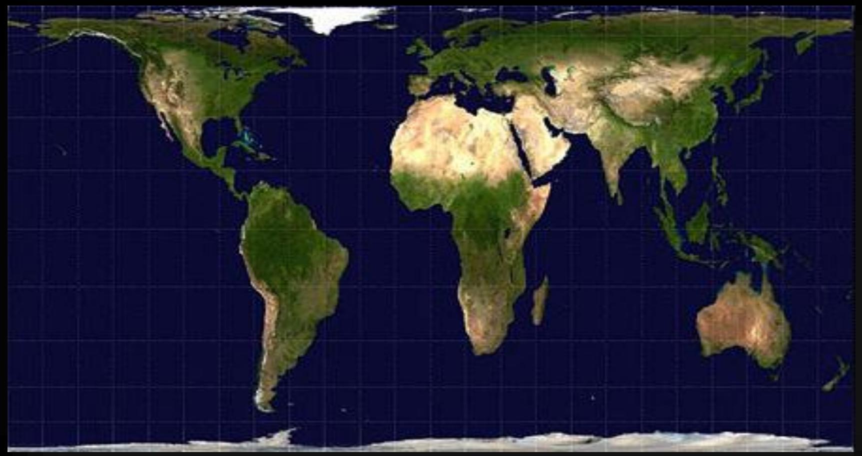



polar orbit
geostationary
orbit
circular orbit
elliptical orbit

KEY CONCEPTS OF REMOTE SENSING

GEOMETRIC TRANSFORMATION - Every remotely sensed image represents a landscape in a specific geometric relationship determined by the design of the remote sensing instrument, specific operating conditions, terrain relief, and other factors.

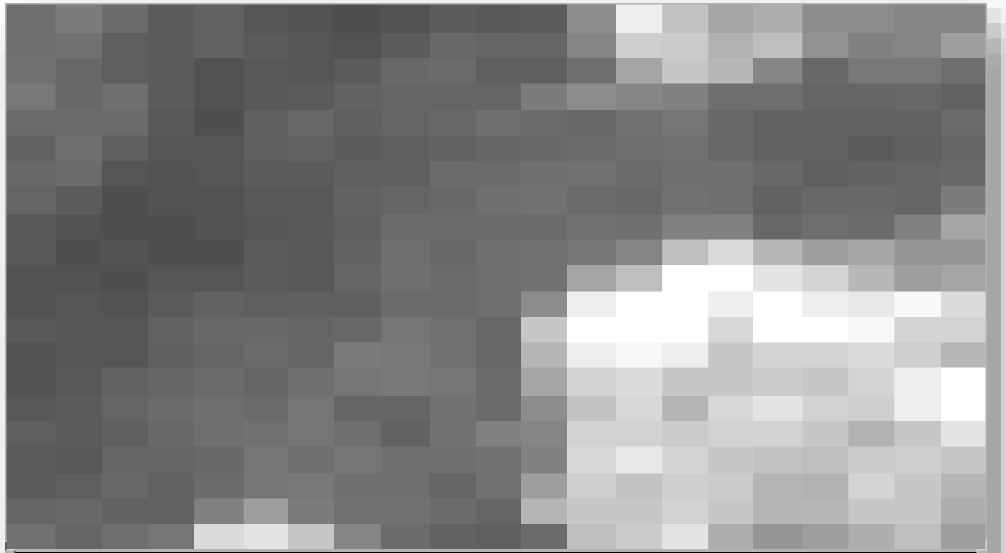
Each image includes positional errors caused by the perspective of the sensor optics, the motion of scanning optics, terrain relief, and Earth curvature.



KEY CONCEPTS OF REMOTE SENSING

INTERCHANGEABILITY OF PICTORIAL AND DIGITAL FORMATS - Most remote sensing systems generate photograph-like images of the Earth's surface. Any such image can be represented in digital form by systematically subdividing the image into tiny areas of equal size and shape, then representing the brightness of these areas by discrete values.

DIGITAL IMAGING



111	124	107	91	98	85	82	79	82	91	88	91	142	238	194	168	171	142	142	136	136
111	113	95	91	98	91	85	82	91	104	101	101	136	206	203	178	187	145	127	136	161
113	104	95	91	82	88	85	91	104	107	95	95	111	165	199	183	133	104	120	120	111
120	104	111	91	82	88	91	98	101	101	101	124	140	136	129	111	111	101	101	104	98
107	107	107	88	79	95	104	95	101	104	111	107	104	113	117	104	98	98	98	98	107
98	111	95	85	85	95	98	91	95	98	101	104	107	111	113	104	98	98	91	95	101
104	107	85	82	85	91	91	95	95	107	107	111	113	107	111	111	104	95	98	101	104
101	91	79	82	82	88	88	98	101	104	111	113	107	104	113	111	98	104	104	101	124
88	82	79	79	82	85	88	95	107	107	107	107	113	111	127	127	104	111	107	129	165
88	79	82	79	79	91	88	98	111	104	111	113	117	133	187	219	183	161	165	152	149
82	82	79	85	85	91	88	101	111	107	111	113	168	190	255	255	228	212	183	161	168
82	85	82	91	98	95	95	95	107	107	111	142	241	255	255	235	255	238	232	248	219
88	85	85	98	104	104	101	104	117	113	104	197	255	255	255	215	255	255	251	212	212
82	85	85	95	101	107	101	124	120	113	104	181	241	251	235	199	212	212	219	206	183
82	88	98	101	107	101	111	117	120	117	107	165	210	219	199	199	203	199	212	241	255
88	91	101	107	111	107	117	101	101	113	107	140	194	215	181	215	226	210	206	241	255
95	91	95	104	111	113	117	111	98	113	129	133	210	210	203	210	210	199	178	199	228
91	88	101	101	104	117	111	117	111	111	113	127	215	232	212	199	194	187	203	206	199
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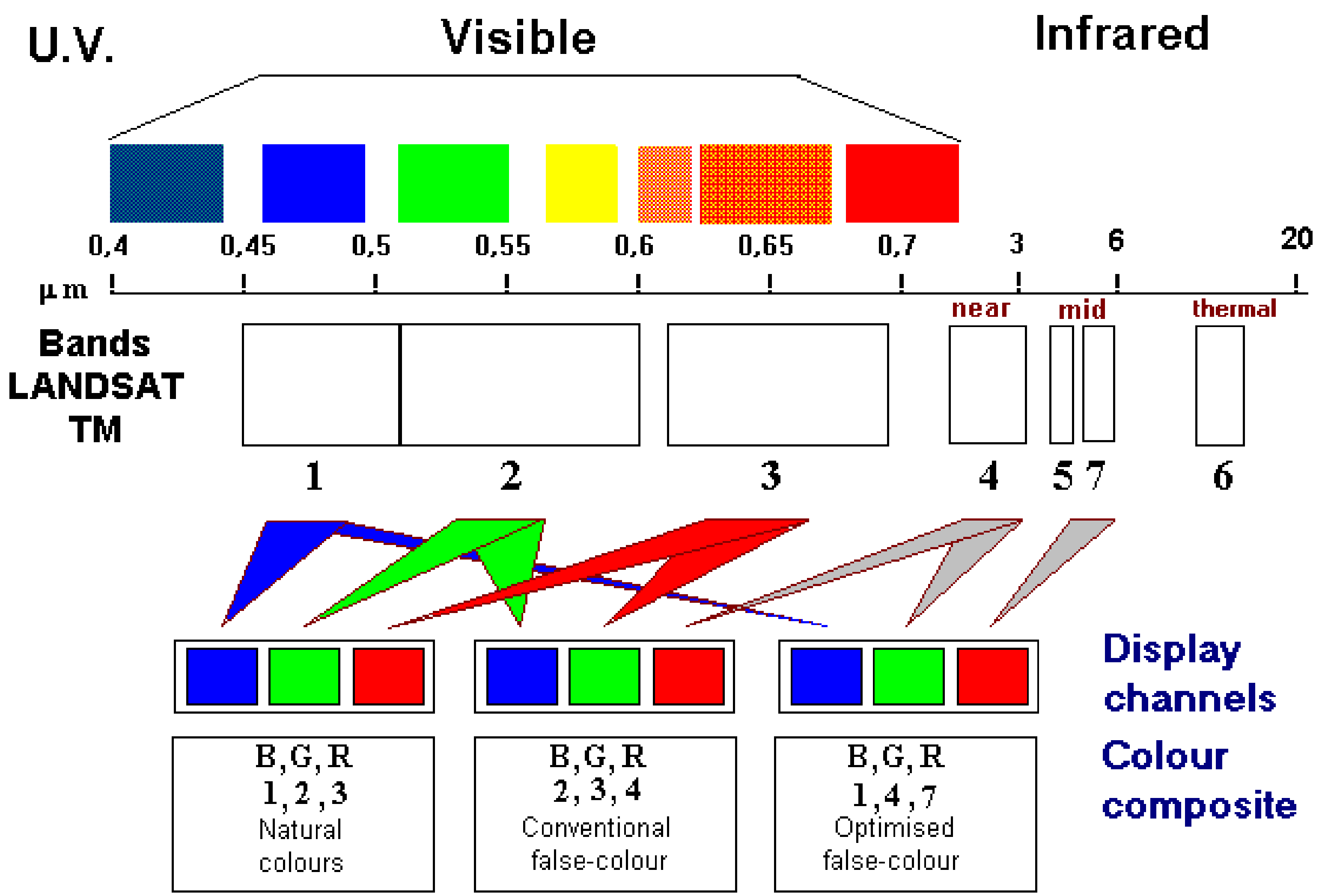
101	104	98	98	129	161	124	113	113	107	101	181	199	197	210	199	181	183	199	199	174
113	101	111	117	219	228	197	133	107	98	95	107	187	203	228	171	149	161	174	190	161

Image formation

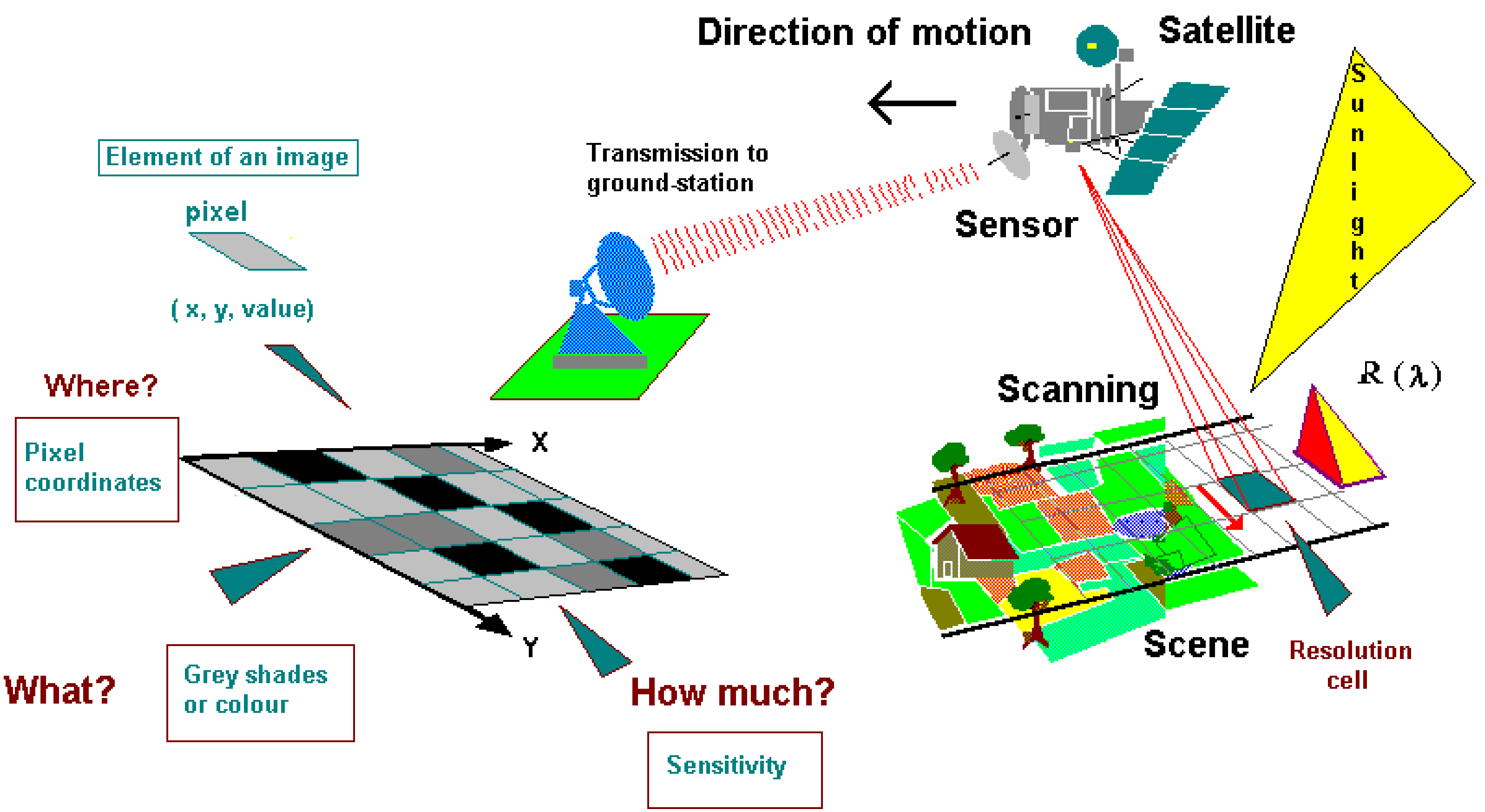


E.L.

KEY CONCEPTS OF REMOTE SENSING

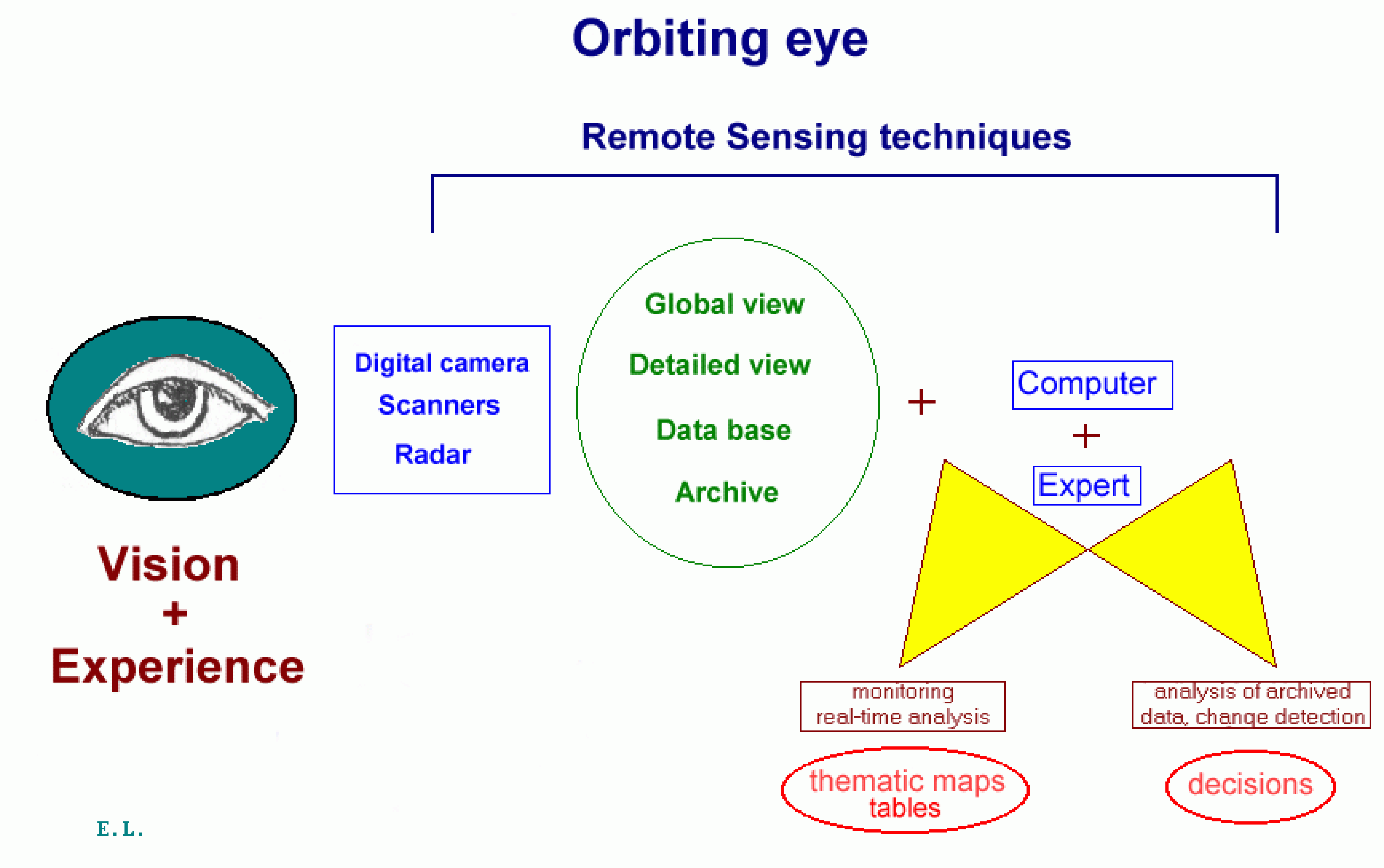
REMOTE SENSING INSTRUMENTATION ACTS AS A SYSTEM - The image analyst must always be conscious of the fact that the many components of the remote sensing process cannot be isolated from one another. This means that the interpreter must know the remote sensing system and the subject of the interpretation.

Acquisition and reproduction of remotely sensed images



E.L.

IMAGE INTERPRETATION

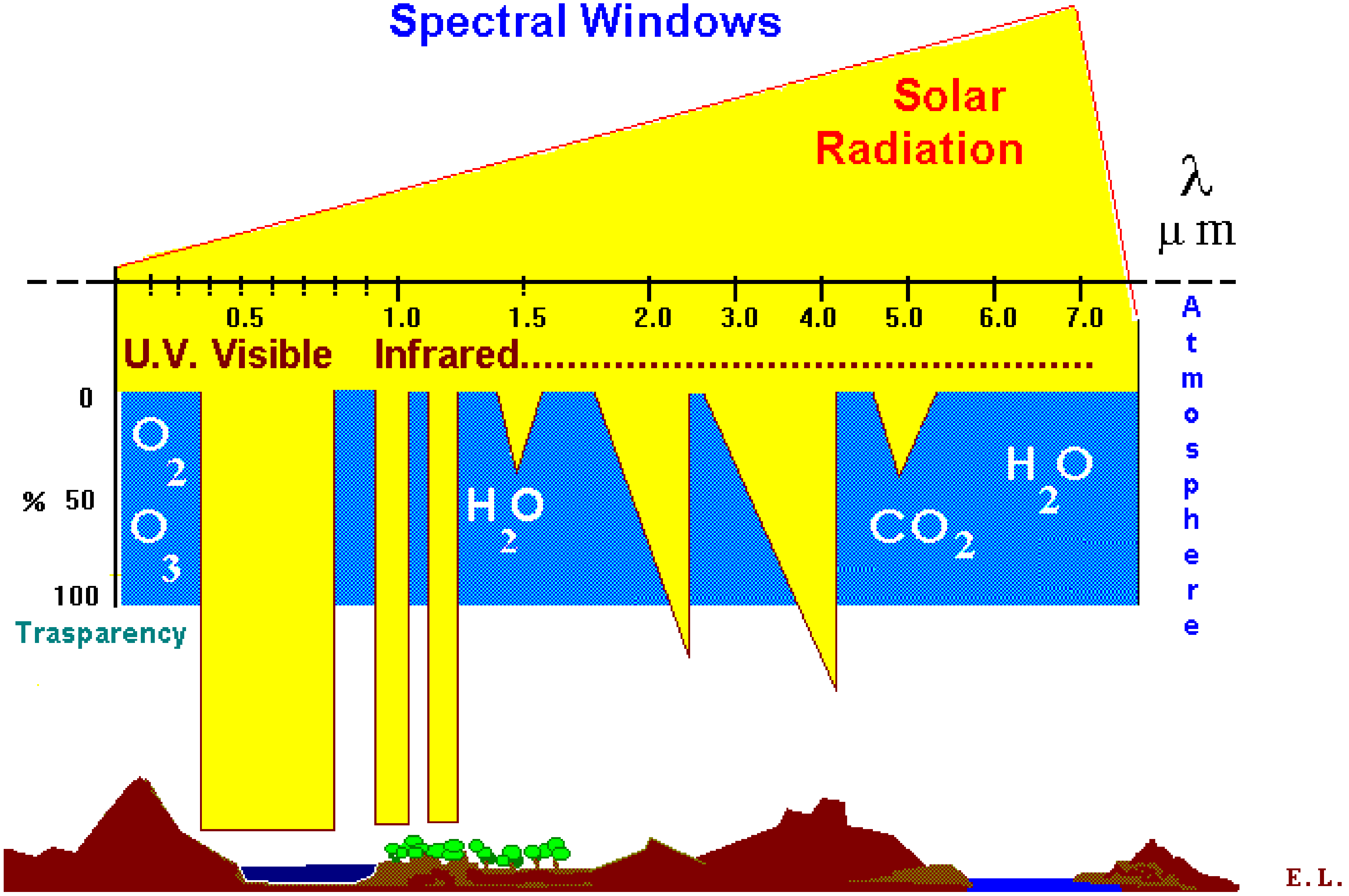


KEY CONCEPTS OF REMOTE SENSING

ROLE OF THE ATMOSPHERE - All energy reaching the remote sensing instrument must pass through a portion of the Earth's atmosphere. The Sun's energy is altered in intensity and wavelength by particles and gases in the Earth's atmosphere. These changes appear on the image in ways that degrade image quality or influence the accuracy of interpretation.

90 % of the signal in a satellite image is coming from the atmosphere.

Spectral Windows



IN SUMMARY…
THE KEY CONCEPTS OF REMOTE SENSING ARE:

1. Spectral Differentiation
2. Radiometric Differentiation
3. Spatial Differentiation
4. Geometric Transformation
5. Interchangeability of Pictorial to Digital Formats
6. Remote Sensing Instrumentation Acts as a System
7. Role of the Atmosphere

CHARACTERISTICS OF THE SENSORS

1. SPECTRAL RESOLUTION: This refers to the number of bands in the spectrum in which the instrument can take measurements.

Landsat TM = 7 channels

2. RADIOMETRIC RESOLUTION: This is the sensitivity to small differences in the radiation of an observed object.

Landsat TM = 8 bit

3. SPATIAL RESOLUTION: This represents the ability of the sensor to detect and distinguish small objects and fine detail in larger objects. Depends on the instrument's sensitivity and distance from the object, and defines the pixel size of a digital image.

Landsat TM = 30m

4. TEMPORAL RESOLUTION: Represents the frequency with which a sensor can re-visit an area of interest and acquire a new image. Depends on the instrument's field of vision, and the platform (ex. Satellite) movement.

Landsat TM 16 days