Multispectral Technology and Archaeological Applications

Part 1: Technology

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Acknowledgment

- I would like to acknowledge Dr. Gregory Vanderberg and Dr. Bradley Rundquist, University North Dakota, for granting me permission to use some of their slides.

Outline

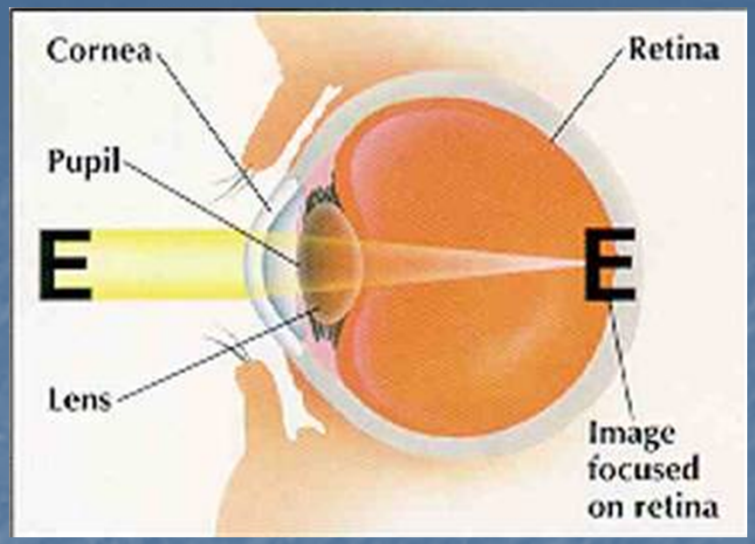
- Remote Sensing Defined
- Resolution
- Electromagnetic Energy (EMR)
- Types
- Interpretation

Remote Sensing Defined

- Remote Sensing is:
  - "The art and science of obtaining information about an object without being in direct contact with the object" (Jensen 2000).
  - There is a medium of transmission involved.

Remote Sensing Defined

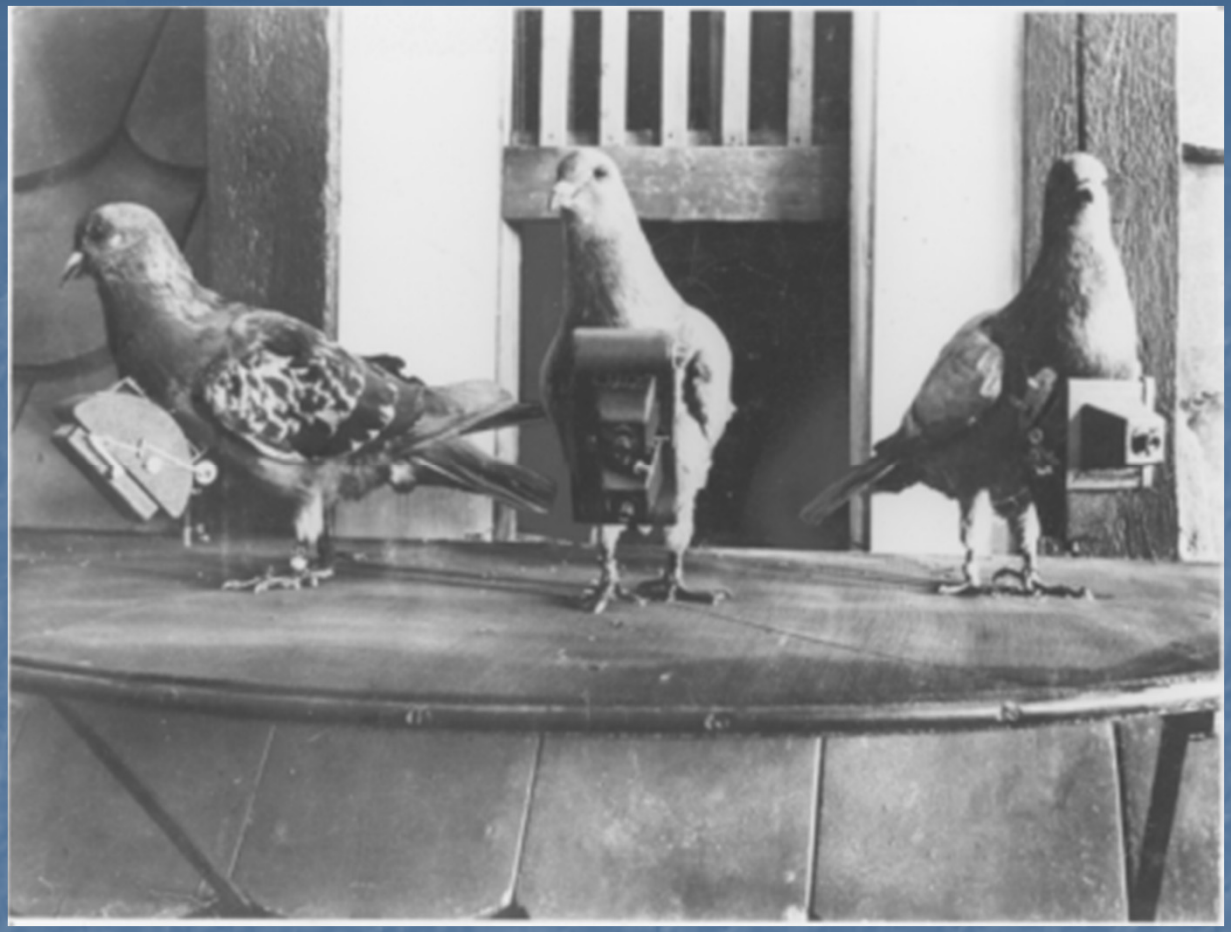
- The not-so-expert says Remote Sensing is:
  - Advanced coloring-in
  - Seeing what can't be seen, then convincing someone that you are right
  - Being as far away from your object of study as possible and getting the computer to handle the numbers
  - Legitimized voyeurism


Cornea
Retina
Pupil
E
E
Lens
Image
focused
on retina


pinna
external ear canal
tympanic membrane
cochlear nerve
malleus
cochlea
incus

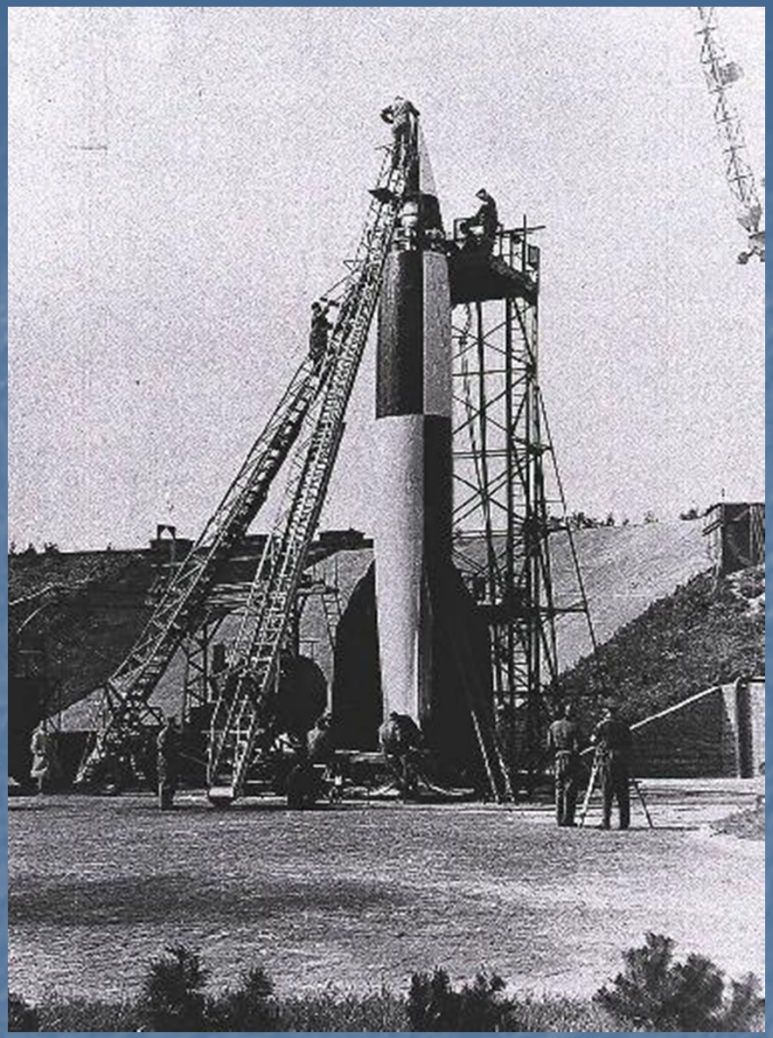

Nikon
N60

- First aerial photo credited to Frenchman Felix Tournachon, Bievre Valley, 1858.
- Boston from balloon (oldest preserved aerial photo), 1860, by James Wallace Black.



The Bavarian Pigeon Fleet took this picture of a Bavarian castle with an automatic camera in 1903

- Kites used to take this panorama of San Francisco, 1906.
- Motivation was to see destruction after 1906 Earthquake
- Up to 9 large kites used to carry camera weighing 23kg.



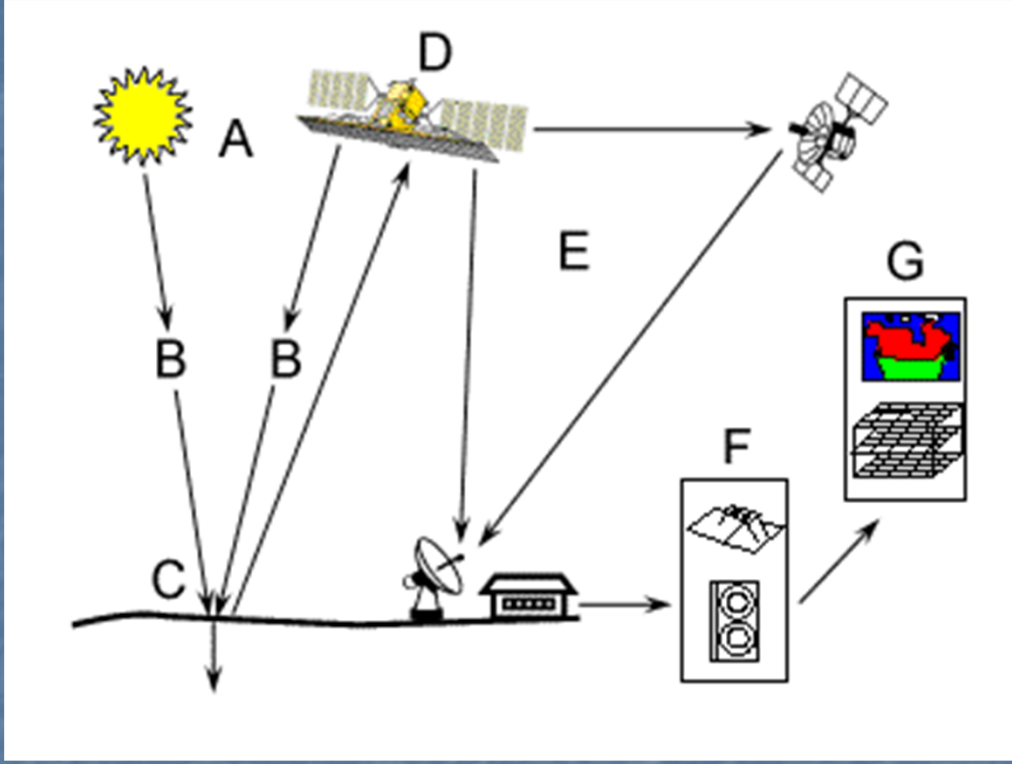
First pictures from "space" taken in 1946 by German V-2 rockets captured during WW2

Caveats!

- Remote sensing has many problems
  - Can be expensive
  - Technically difficult
  - NOT direct
    - measure surrogate variables
    - e.g. reflectance (%), brightness temperature ($Wm^{-2} \Rightarrow {}^{o}K$), backscatter (dB)
    - RELATE to other, more direct properties.

- Doesn't always go according to plan.....

Remote Sensing Process Components



Source: Canadian Centre for Remote Sensing

Energy Source or Illumination (A)

Radiation and the Atmosphere (B)

Interaction with the Target (C)

Recording of Energy by the Sensor (D)

Transmission, Reception, and Processing (E)

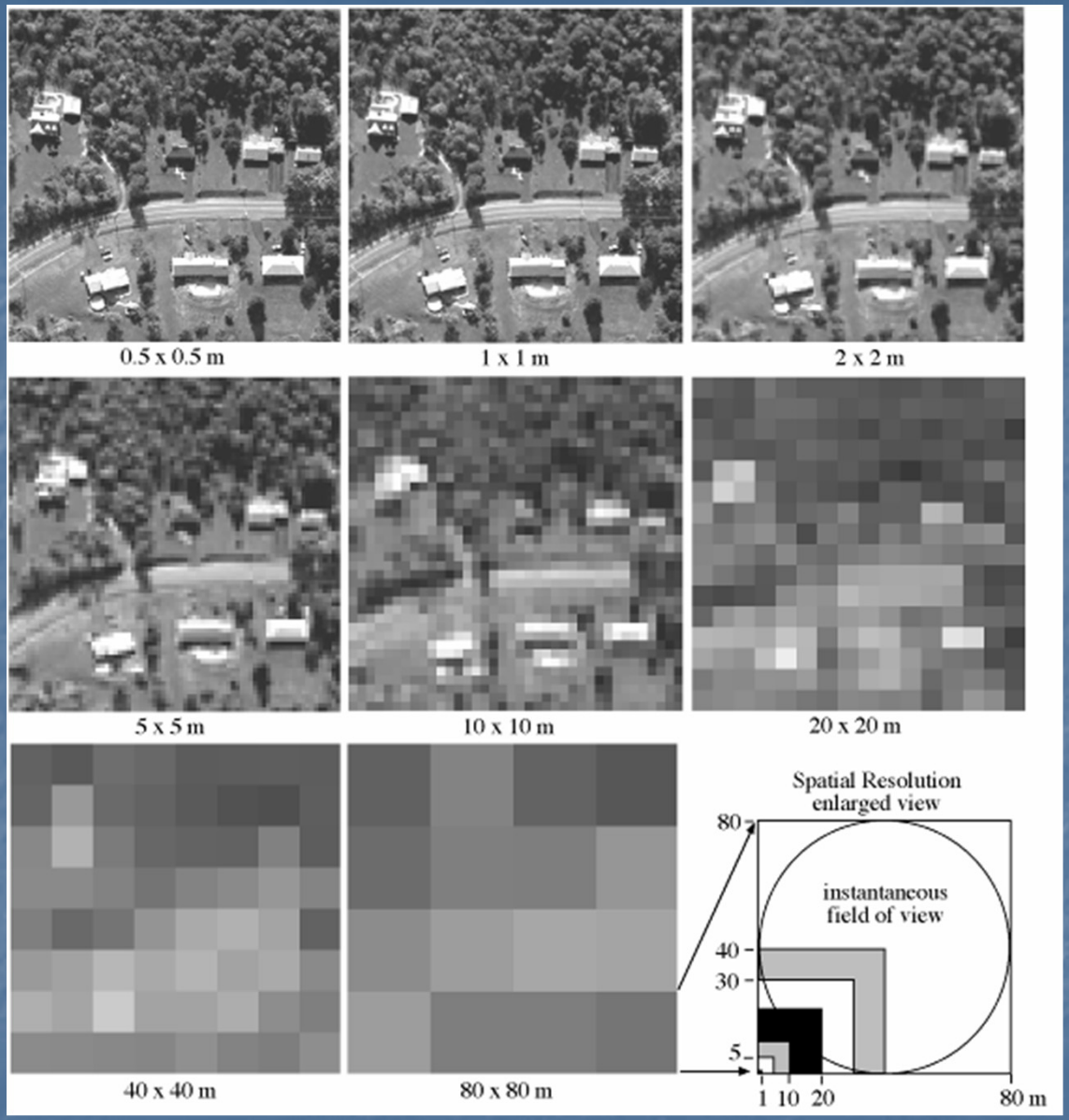
Interpretation and Analysis (F)

Application (G)

Resolution

- All remote sensing systems have four types of resolution:
  - Spatial
  - Spectral
  - Temporal
  - Radiometric

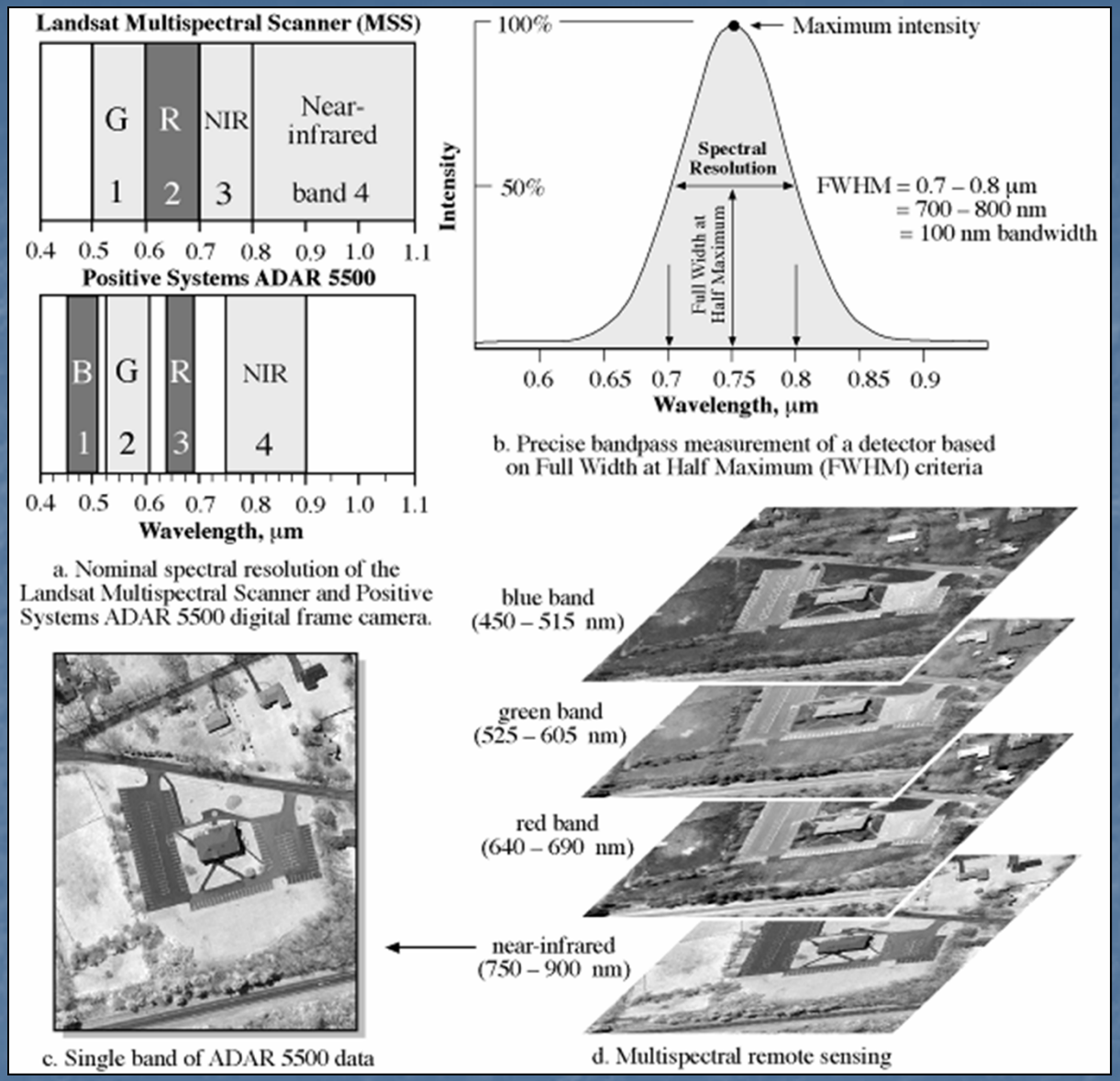
Spatial Resolution



Source: Jensen (2000)

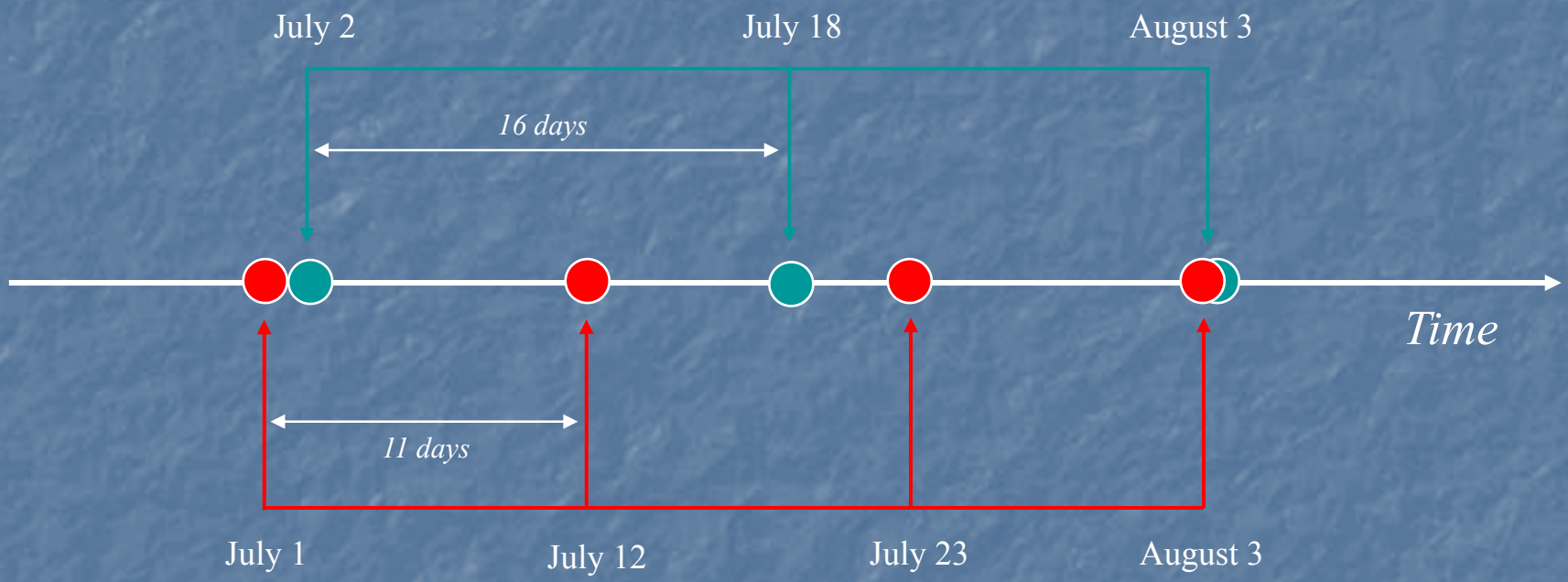
High vs. Low?

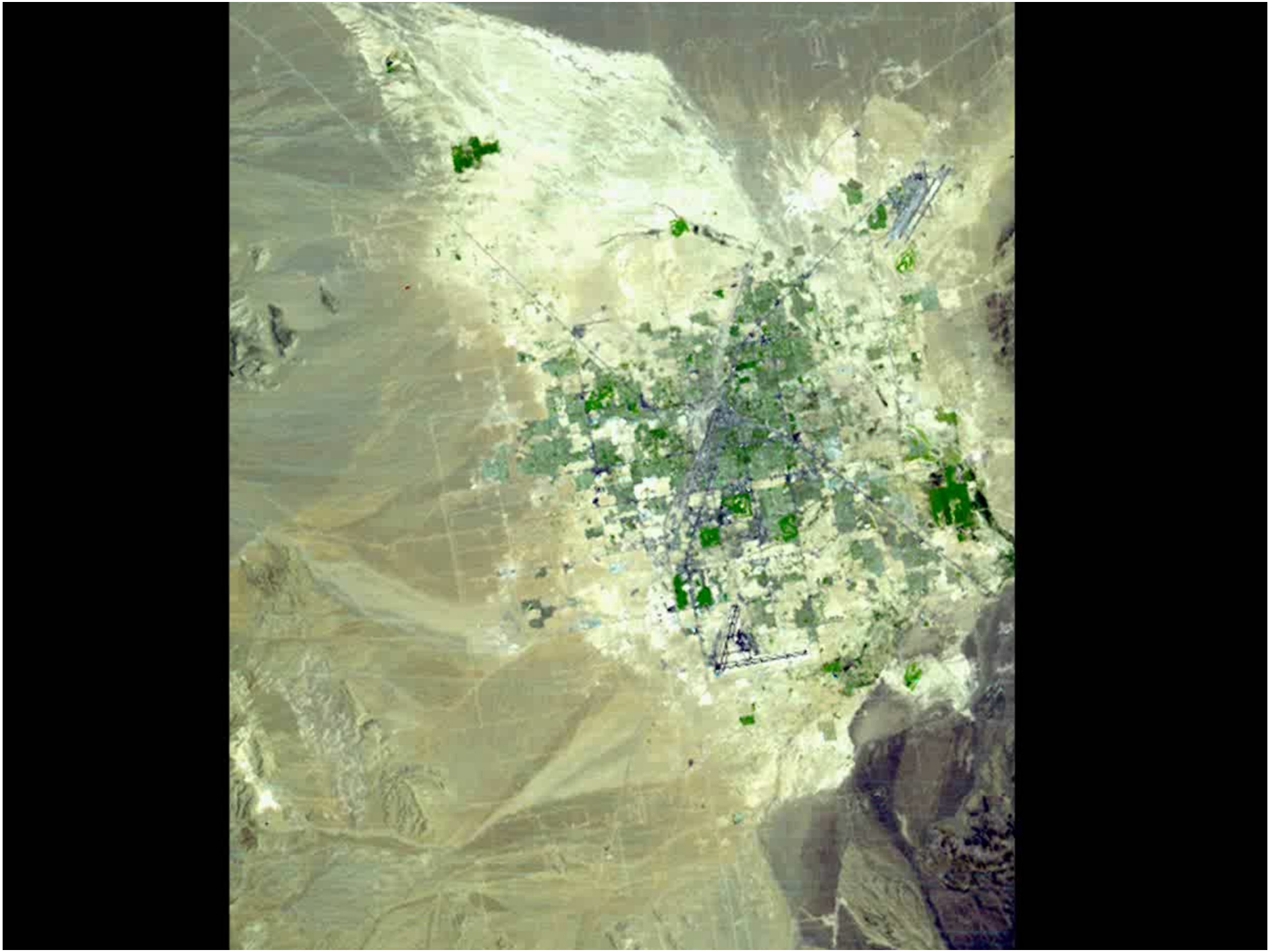
Spectral Resolution



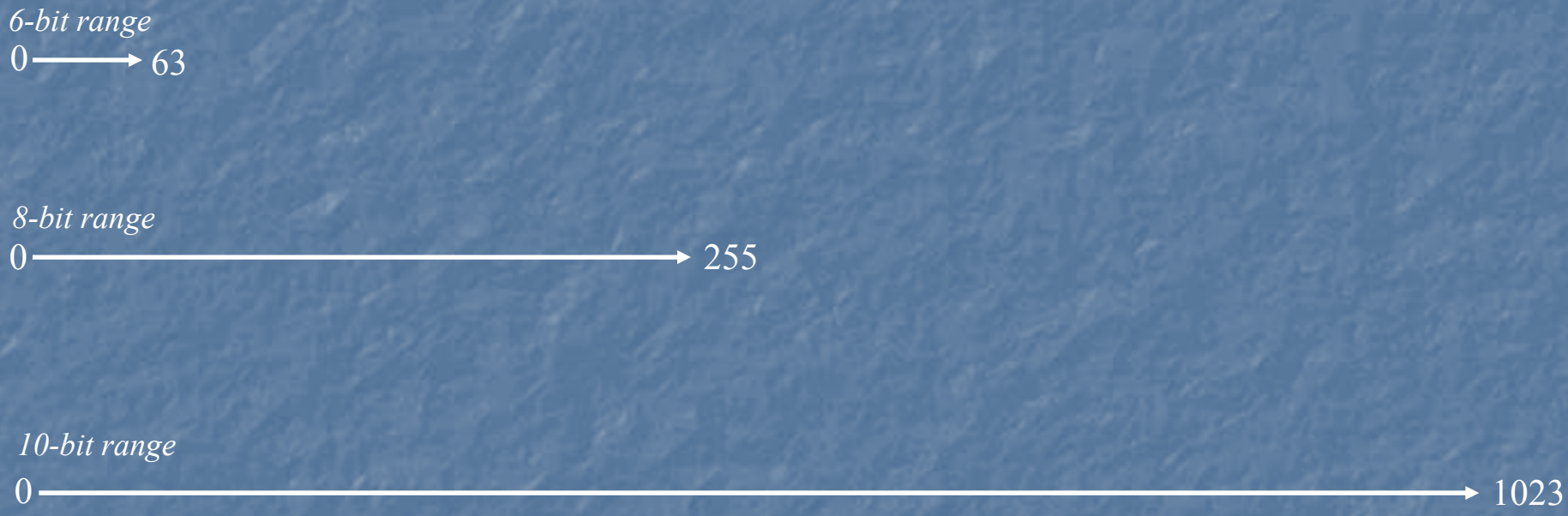
Source: Jensen (2000)

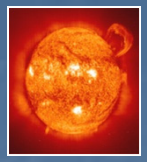
Temporal Resolution



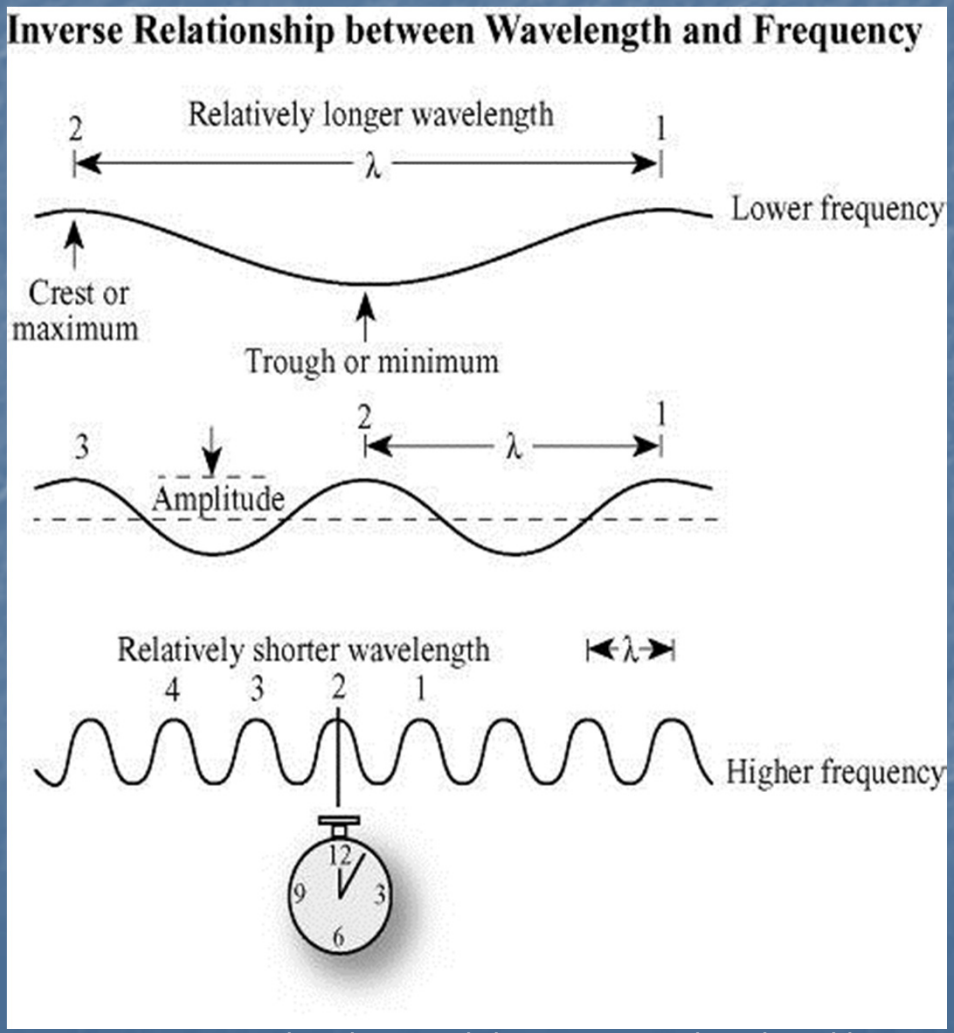


Radiometric Resolution



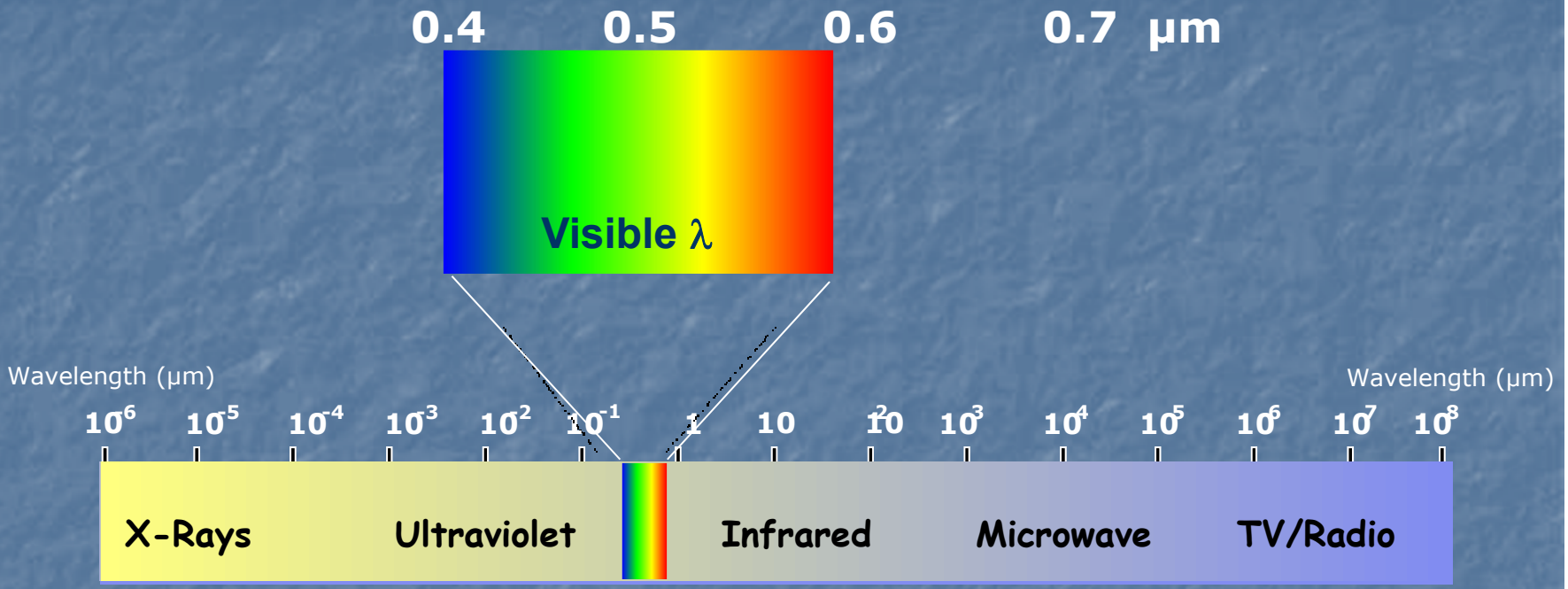


Wave Model of Electromagnetic Energy



This cross-section of an electromagnetic wave illustrates the inverse relationship between *wavelength* and *frequency*. The longer the wavelength the lower the frequency; the shorter the wavelength, the higher the frequency. The amplitude of an electromagnetic wave is the height of the wave crest above the undisturbed position. Successive wave crests are numbered 1, 2, 3, and 4. An observer at the position of the clock records the number of crests that pass by in a second. This frequency is measured in cycles per second, or hertz.

The Electromagnetic Spectrum



- The visible portion of the EM spectrum is very small...
- EM energy is a continuum which we (somewhat arbitrarily) classify according to wavelength. Wavelengths extend from very, very short (cosmic and X rays) to very, very long (thermal, radar, etc...).

Response to EM Energy

- Objects, when struck by EM energy, respond by absorbing, reflecting or transmitting the energy. Different objects, because of their physical properties, respond differently to equivalent inputs of EM energy. This allows us to tell one thing from another...

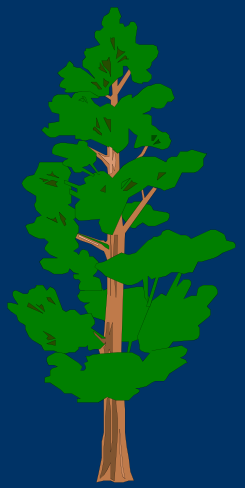
On striking the land or ocean surface the sunlight will be partitioned into three modes of energy-interaction response:

(1) **transmittance** - some radiation will penetrate into certain surface media such as water;
(2) **absorptance** - some radiation will be absorbed through electron or molecular reactions within the medium encountered; a portion of the energy incorporated can then be re-emitted (as emittance), largely at longer wavelengths, so that some of the sun's radiant energy engages in heating the target giving rise then to a thermal response;
(3) **reflectance** - some radiation will, in effect, be reflected (and scattered) away from the target at different angles (depending in part on surface "roughness" as well as on the angle of the sun's direct rays relative to surface inclination).

Most remote sensing systems are designed to monitor reflected radiation.

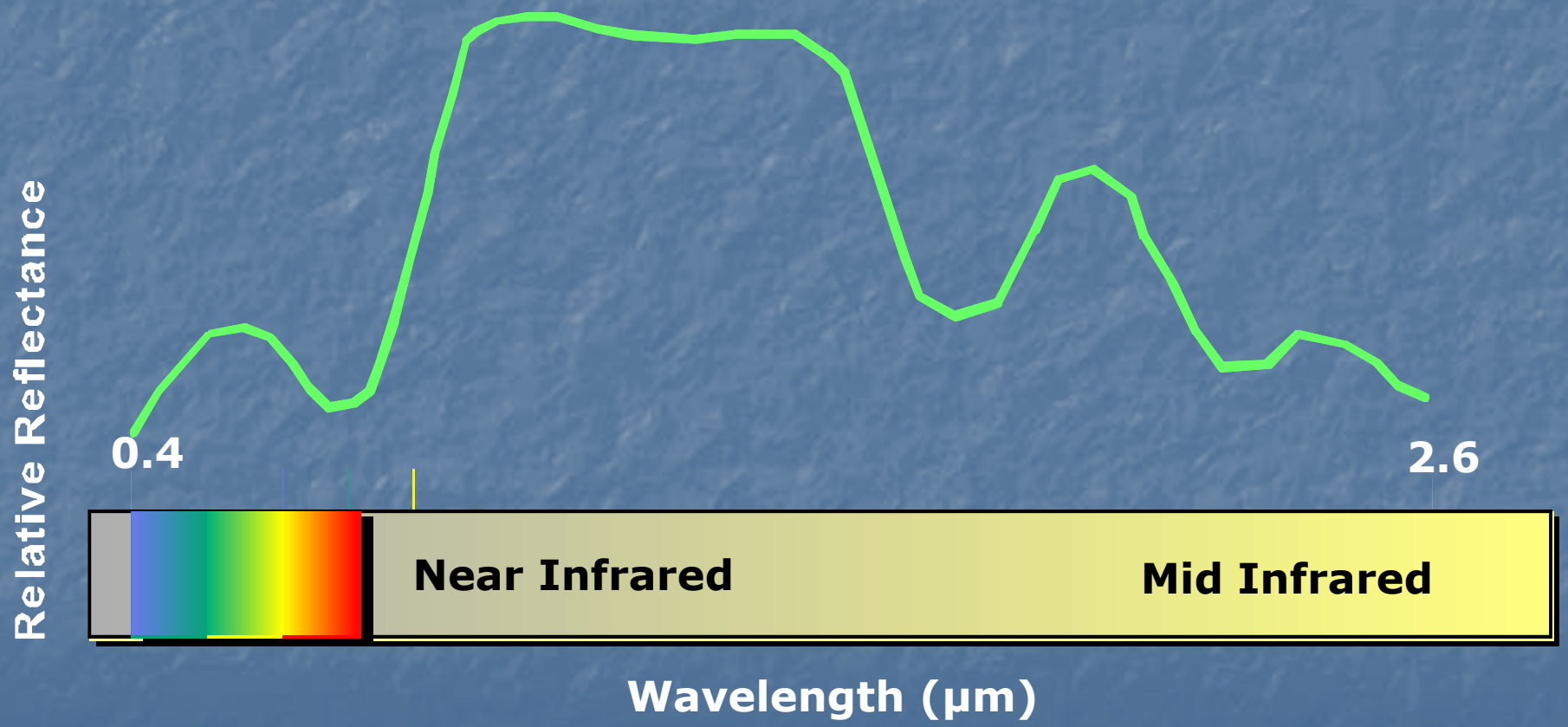
Response to EM Energy

Spectral Response Curves aka Spectral Reflectance Curves, aka Spectral Signatures...



Graphically, the spectral reflectance of green vegetation in the visible wavelengths may be represented as shown...

Spectral Response Curve of Typical Vegetation From 0.4 to 2.6 µm

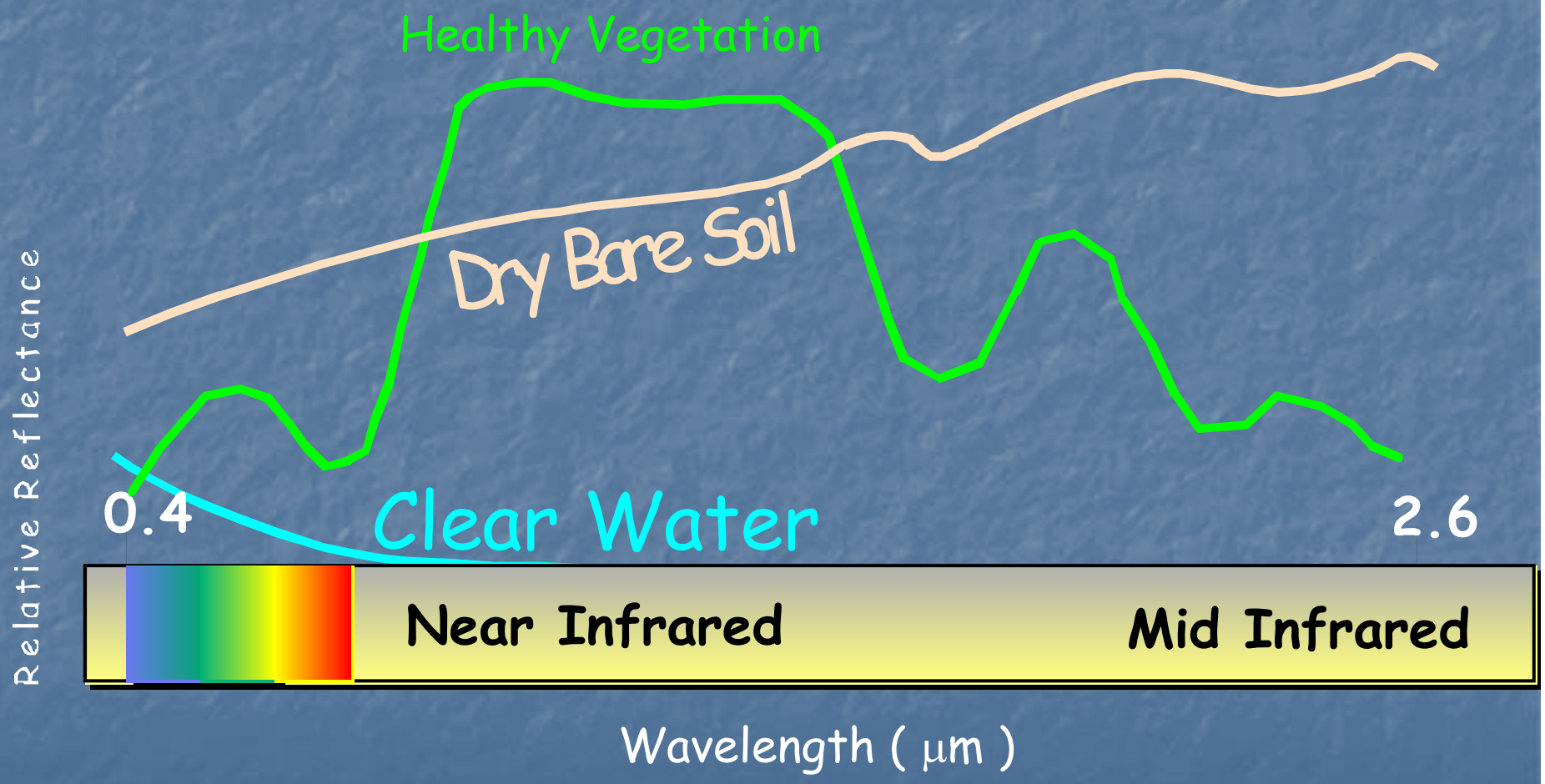


Spectral Response Curves

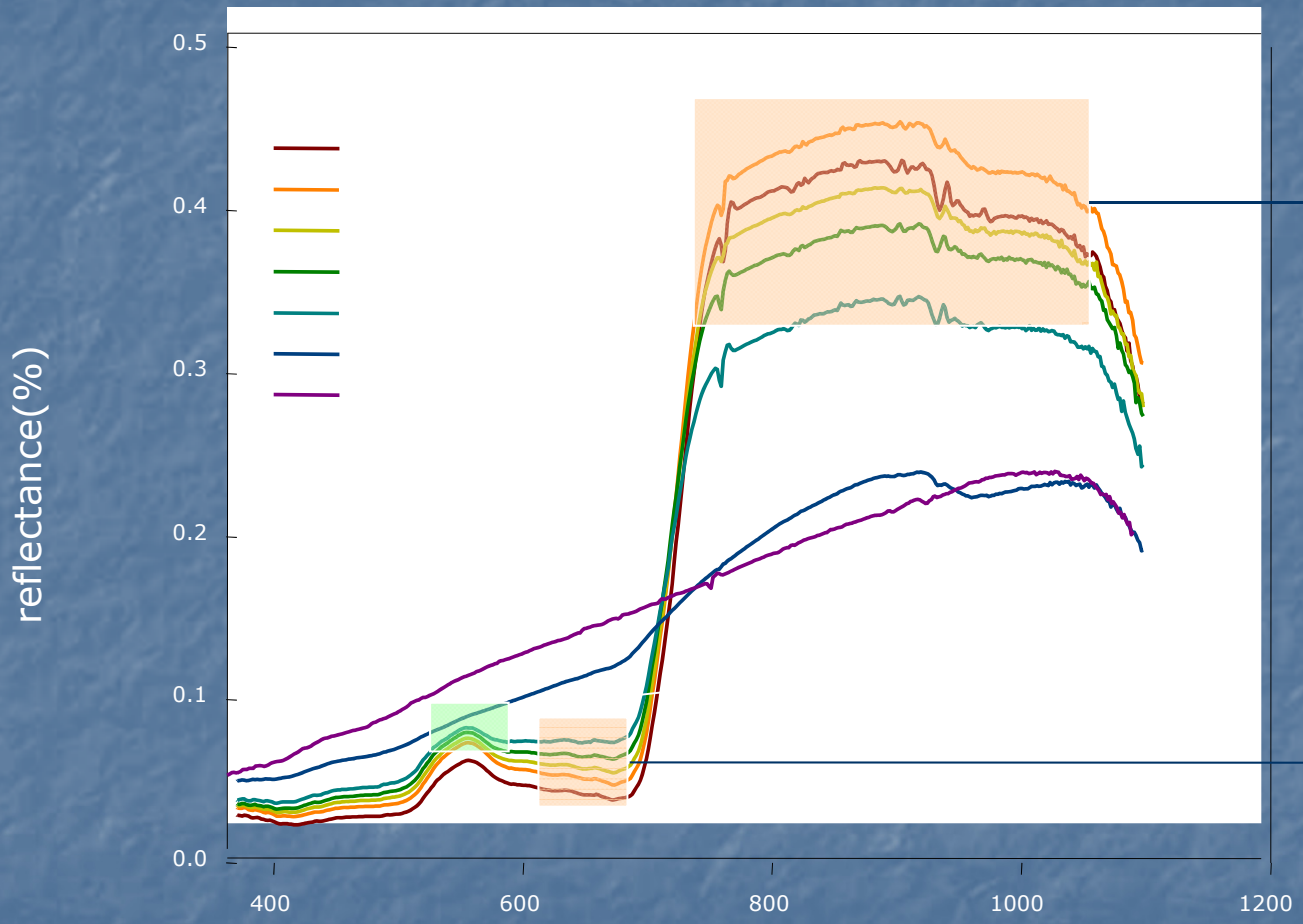
- An object's Spectral Response Curve is a representation of the reflected EM energy of that object across a portion of the EM spectrum, as the object is exposed to (our Sun's) EM radiation.
- For most purposes, Spectral Response Curves, Spectral Reflectance Curves and Spectral Signatures are synonymous.

Typical Spectral Signatures

Typical Spectral Response Curves in the 0.4 to 2.6 µm Region...



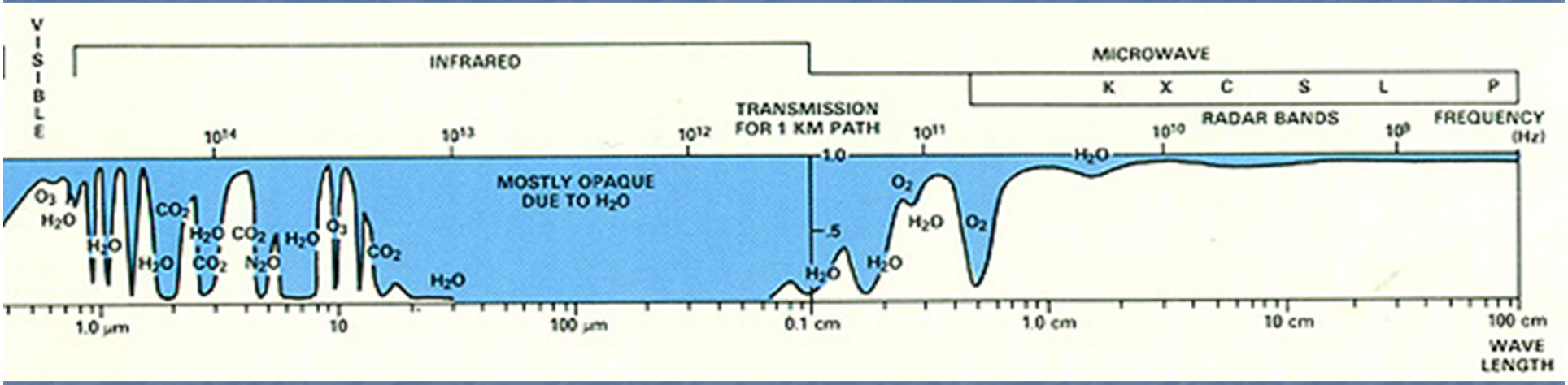
Spectral information: vegetation



NIR, high reflectance

Visible red, low reflectance

On Earth cannot use all spectrum because of the atmosphere.
Here is a generalised diagram showing relative atmospheric transmission of radiation of different



Blue zones mark minimal passage of incoming and/or outgoing radiation whereas white areas denote "atmospheric windows" in which the radiation experiences much reduced interactions with various molecular species and hence can penetrate the air with little or no loss by absorption.

Types of Remote Sensing

- Aerial Photography
- Multispectral
- Active and Passive Microwave and LIDAR

Aerial Photos

- Balloon photography (1858)
- Pigeon cameras (1903)
- Kite photography (1890)
- Aircraft (WWI and WWII)
- Space (1947)

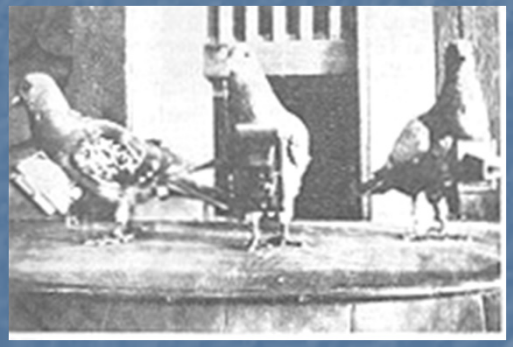


Fig. 2-3. Pigeon photo.

Images: Jensen (2000)

Multispectral

- NOAA-AVHRR (1100 m)
- GOES (700 m)
- MODIS (250, 500, 1000 m)
- Landsat TM and ETM (30 – 60 m)
- SPOT (10 – 20 m)
- IKONOS (4, 1 m)
- Quickbird (0.6 m)

Color Composites: multi-spectral images

'Real Color' composite

Red band on red

Green band on green

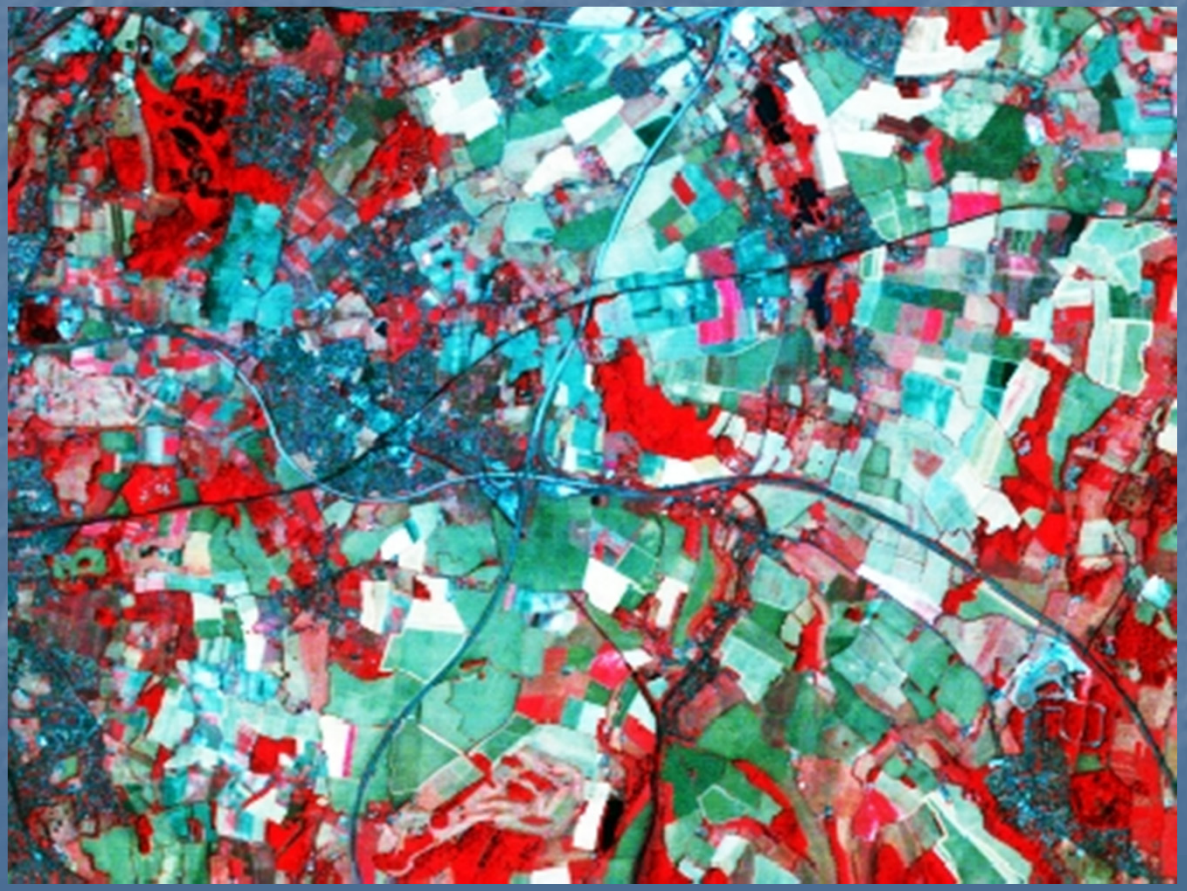
Blue band on blue

Approximates "real" color (RGB color composite)

Landsat TM image of Swanley, 1988

'False Color' composite

NIR band on red
red band on green
green band on blue



SPOT (2.5 m)

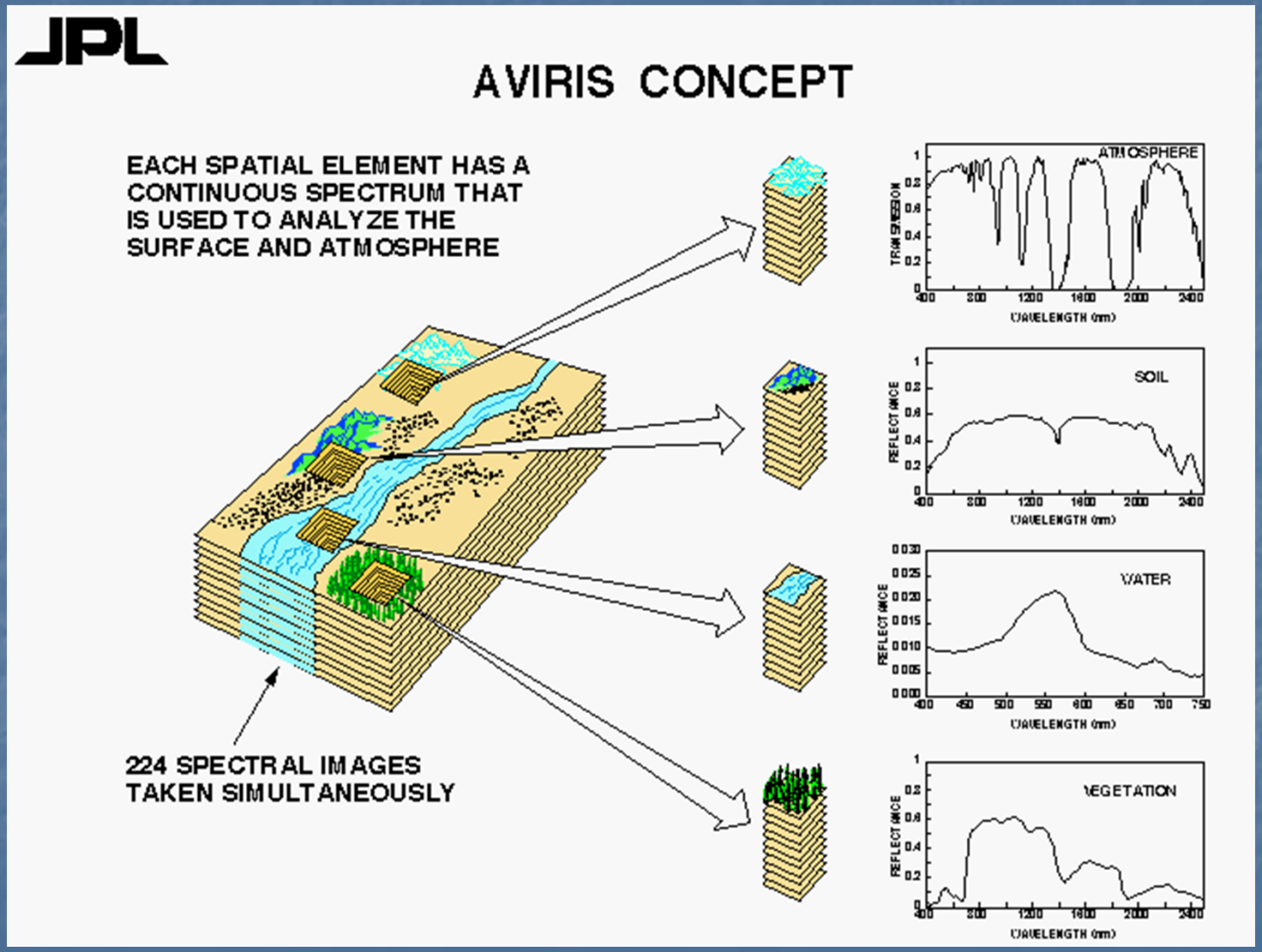

SPOT 5 - 2.5m - Washington - USA - November 2002
© Cnes 2002 - Distribution Spot Image - All rights reserved
SPOT IMAGE

QUICKBIRD (0.6 m)

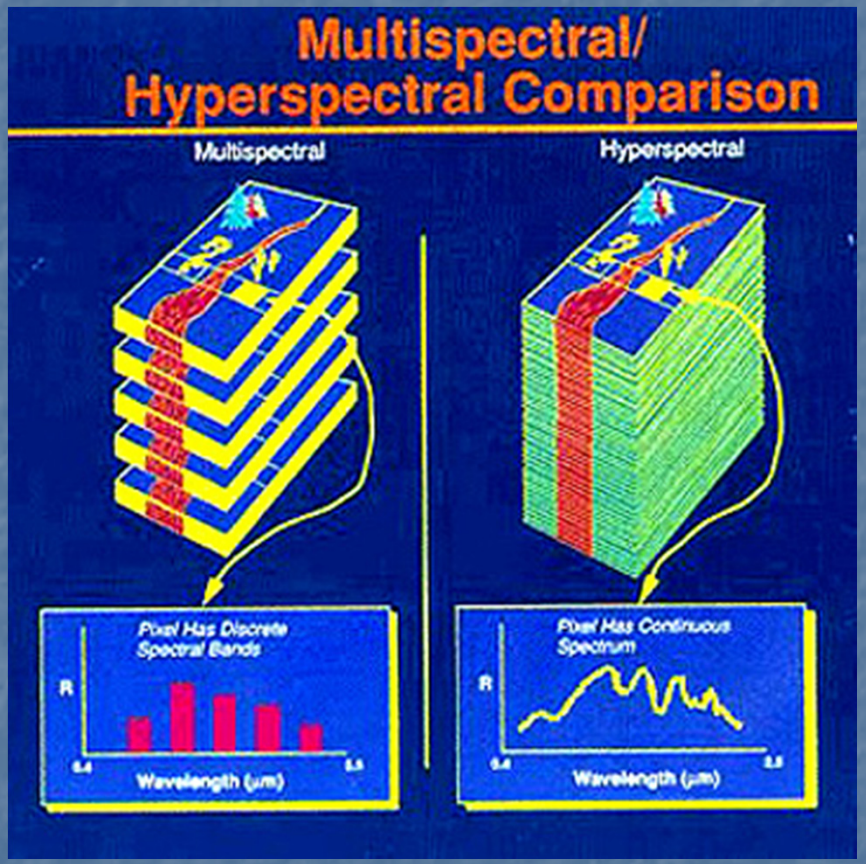
IKONOS (1 m Panchromatic)

IKONOS (4 m Multispectral)

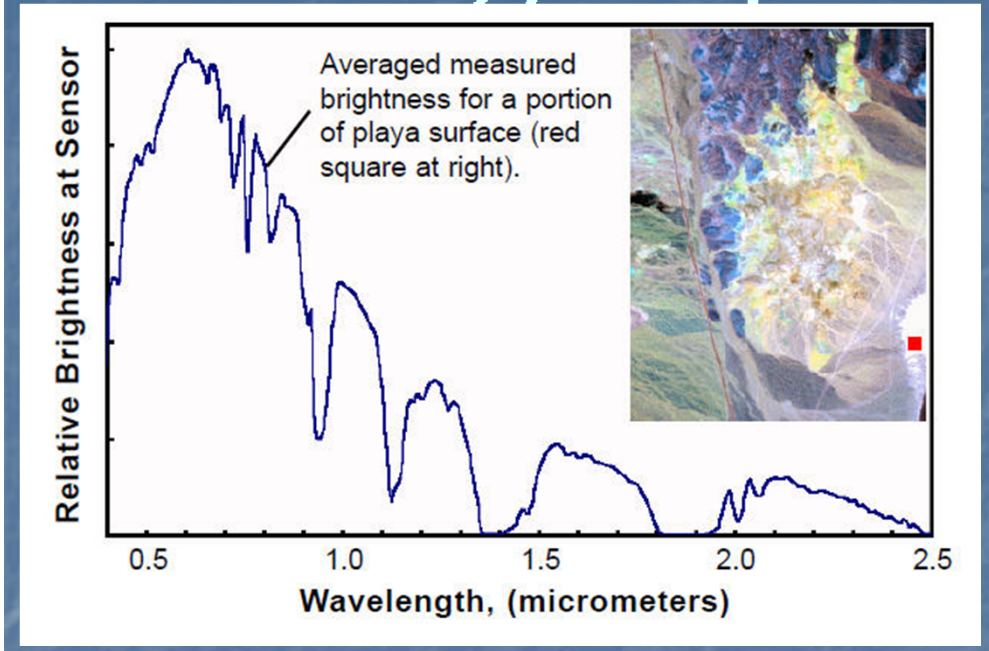
Hyperspectral Concept

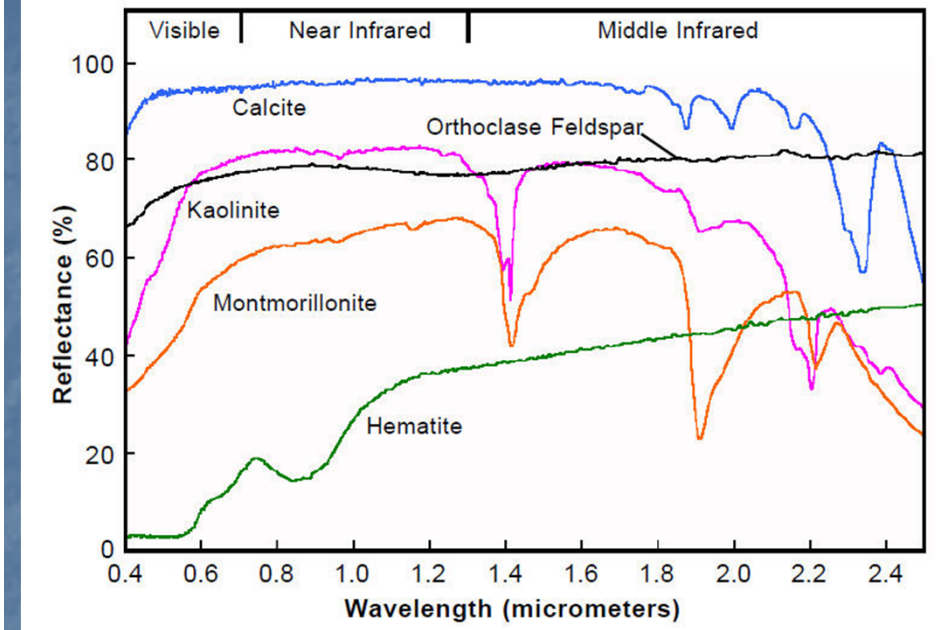


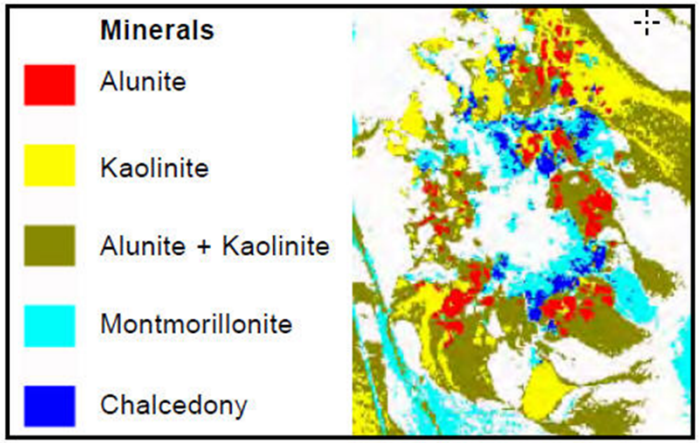
Hyperspectral Concept



Hyperspectral Concept







erence library.

Mineral map for part of the Cuprite AVIRIS scene, created by matching image spectra to mineral spectra in the USGS Spectral Library. White areas did not produce a sufficient match to any of the selected reflectance spectra, and so are left unassigned.

Hyperspectral Concept

Specim ENHANCE YOUR PERCEPTION

Teknologiantie 18 A
FIN–90571 Oulu, Finland

Email info@specim.fi
www.specim.fi

FARM MAPPING

Courtesy of SPECTRUM MAPPING, LLC

- AISA hyperspectral imagery
- 26 spectral channel configuration
- 2,5 meter spatial resolution

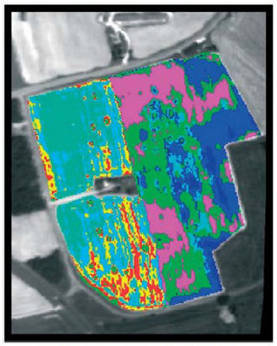


Figure 1. Unsupervised classification

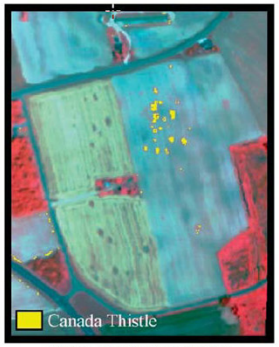


Figure 2. Supervised classification

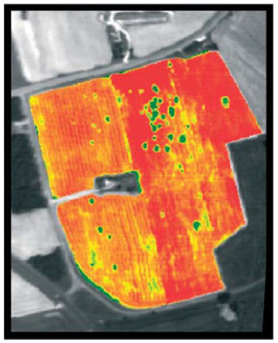


Figure 3. Relative biomass

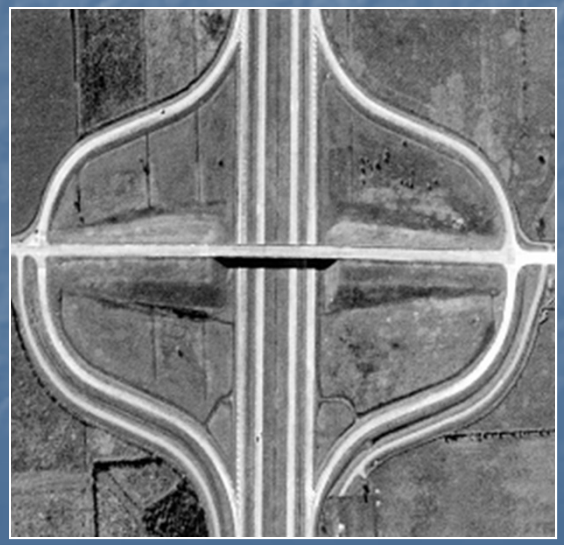
Hyperspectral Scanners

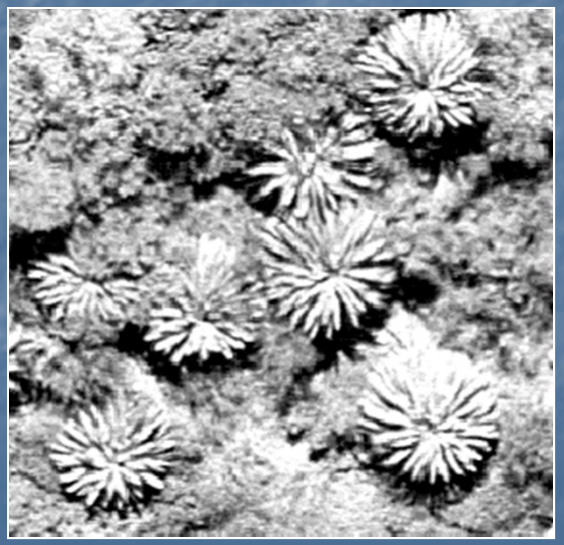
- EO1-Hyperion (US-flying) (30 m)
- AVIRIS (4-50 m)
- CASI (30 – 60 m)
- HyVista, HYDICE, HyMap, AISA (3-10 m)
- HISUI (Japan-future) (30 m)
- EnMap (Germany-future) (30 m)

Elements of Image Interpretation

- Shape:
  - Many natural and human-made features have unique shapes.
  - Often used are adjectives like linear, curvilinear, circular, elliptical, radial, square, rectangular, triangular, hexagonal, star, elongated, and amorphous.

Shape



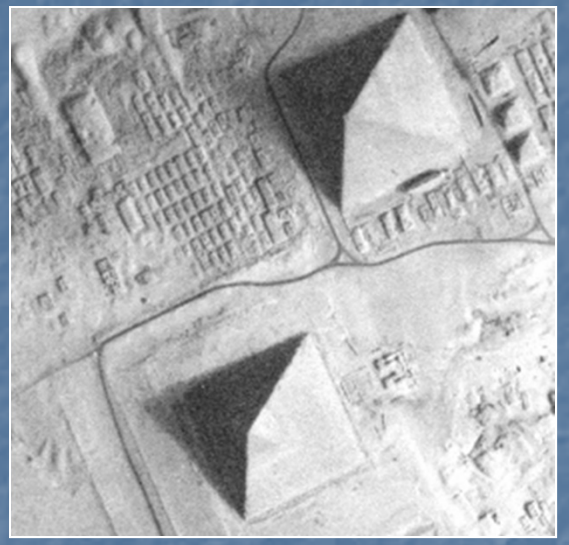


Jensen (2000)

Elements of Image Interpretation

- Shadow:
  - Shadow reduction is of concern in remote sensing because shadows tend to obscure objects that might otherwise be detected.
  - However, the shadow cast by an object may be the only real clue to its identity.
  - Shadows can also provide information on the height of an object either qualitatively or quantitatively.

Shadow

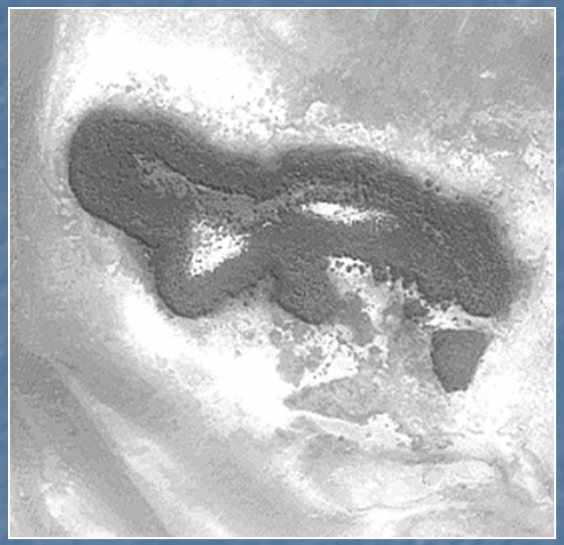


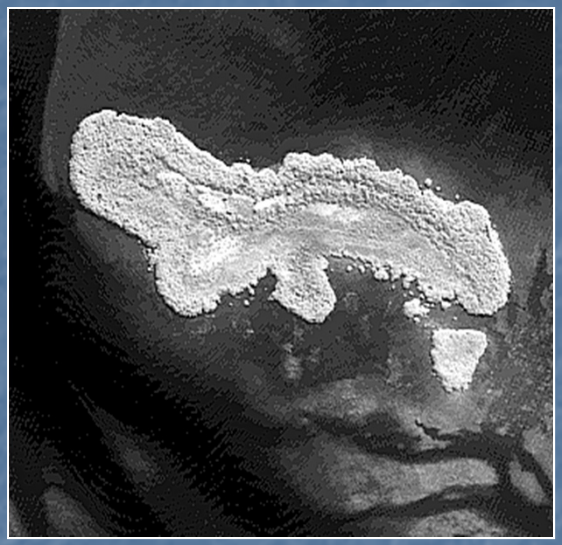
Jensen (2000)

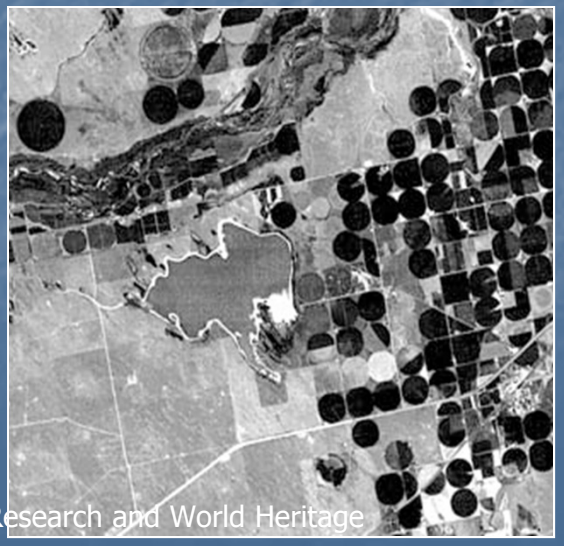
Elements of Image Interpretation

- Tone and Color:
  - A *band* of EMR recorded by a remote sensing instrument can be displayed on an image in shades of gray ranging from black to white.
  - These shades are called "tones", and can be qualitatively referred to as dark, light, or intermediate (humans can see 40-50 tones).
  - Tone is related to the amount of light reflected from the scene in a specific wavelength interval (band).

Tone and Color





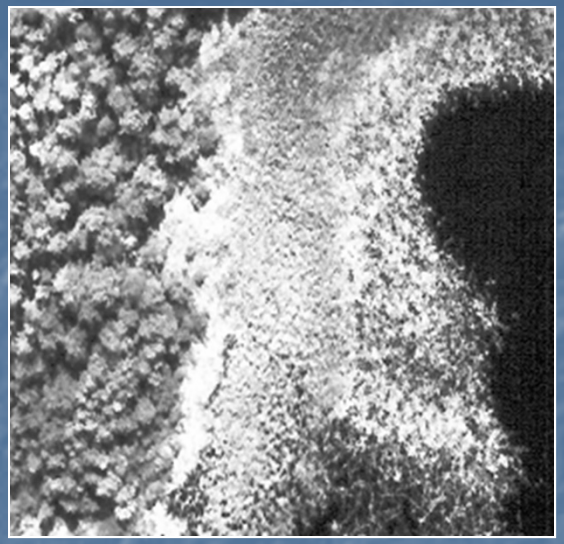
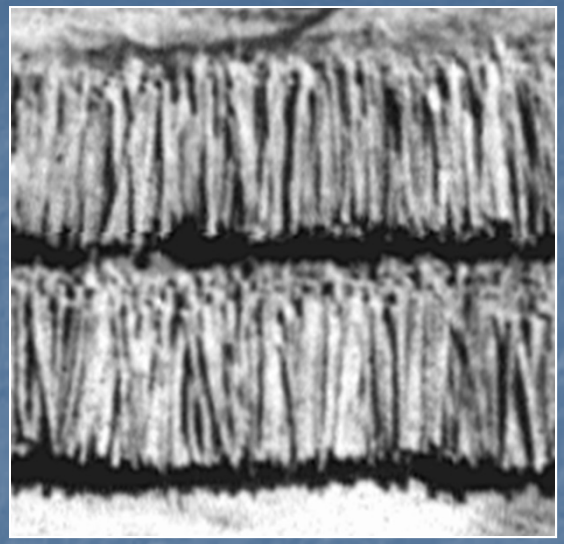
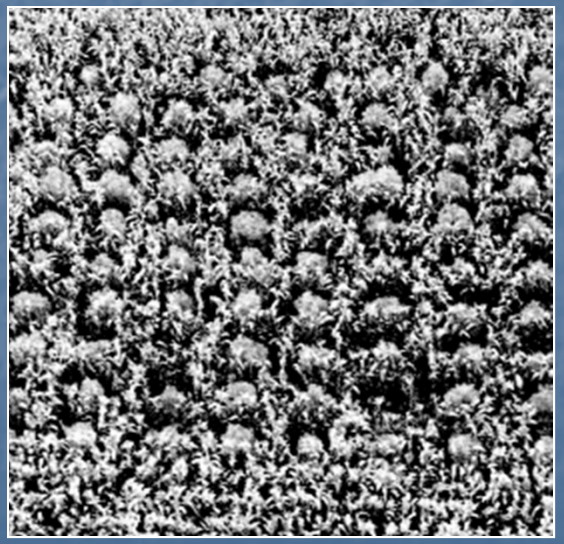
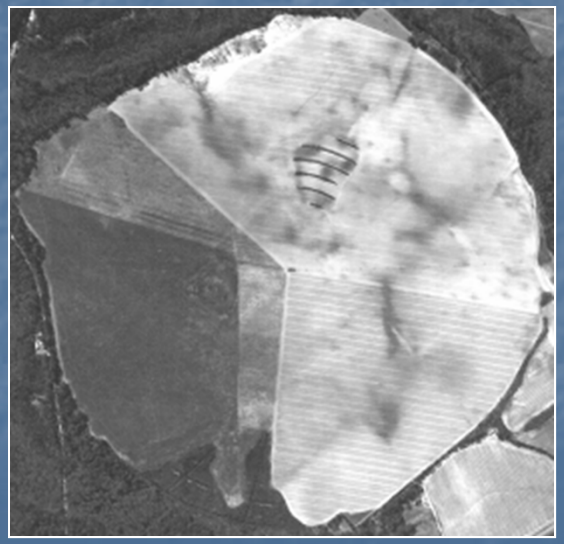
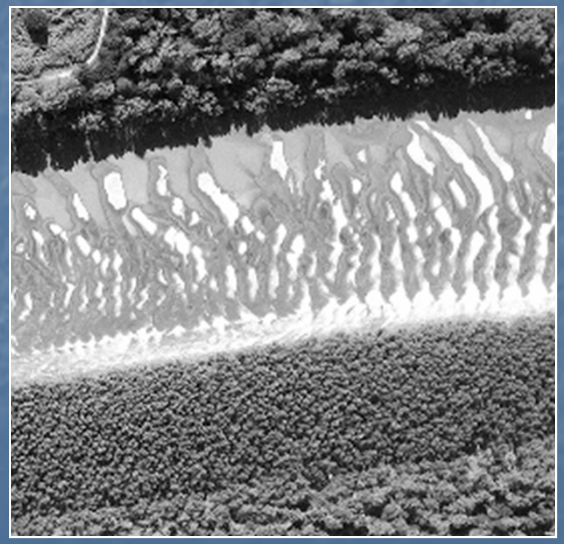


Jensen (2000)

Elements of Image Interpretation

- Texture:
  - Texture refers to the arrangement of tone or color in an image.
  - Useful because Earth features that exhibit similar tones often exhibit different textures.
  - Adjectives include smooth (uniform, homogeneous), intermediate, and rough (coarse, heterogeneous).

Texture

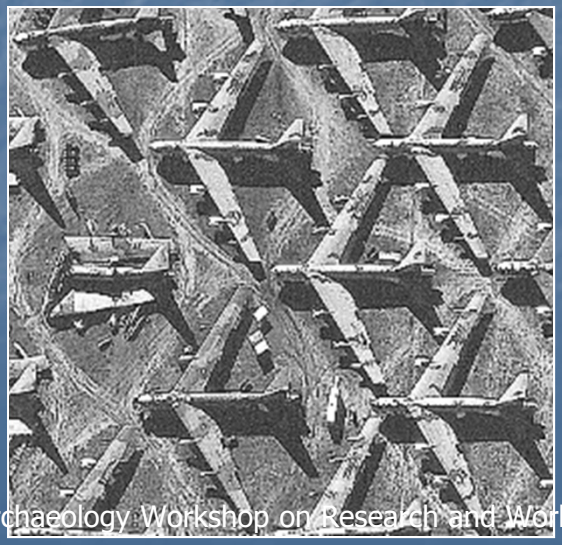







Jen

Elements of Image Interpretation

- Pattern:
  - Pattern is the spatial arrangement of objects on the landscape.
  - General descriptions include random and systematic; natural and human-made.
  - More specific descriptions include circular, oval, curvilinear, linear, radiating, rectangular, etc.

Pattern



Jensen (2000)

Elements of Image Interpretation

- Height and Depth:
  - As discussed, shadows can often offer clues to the height of objects.
  - In turn, relative heights can be used to interpret objects.
  - In a similar fashion, relative depths can often be interpreted.
  - Descriptions include tall, intermediate, and short; deep, intermediate, and shallow.

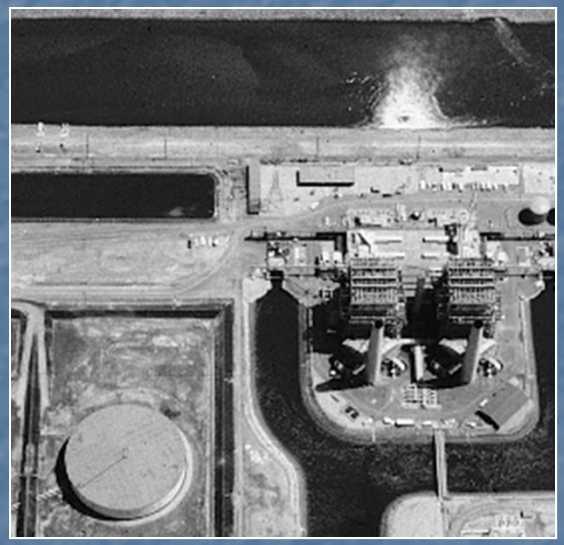
Height and Depth

Elements of Image Interpretation

- Association:
  - This is very important when trying to interpret an object or activity.

    Association refers to the fact that certain features and activities are almost always related to the presence of certain other features and activities.

Association



Jensen (2000)