What is Remote Sensing?

Defining Remote Sensing

Remote sensing :

Data collection about features or phenomena of the earth surface (and near surface) **without being in direct contact**

- Lack of contact with features or phenomena
- Sensors utilize electromagnetic radiation (**EMR**)

Sensing

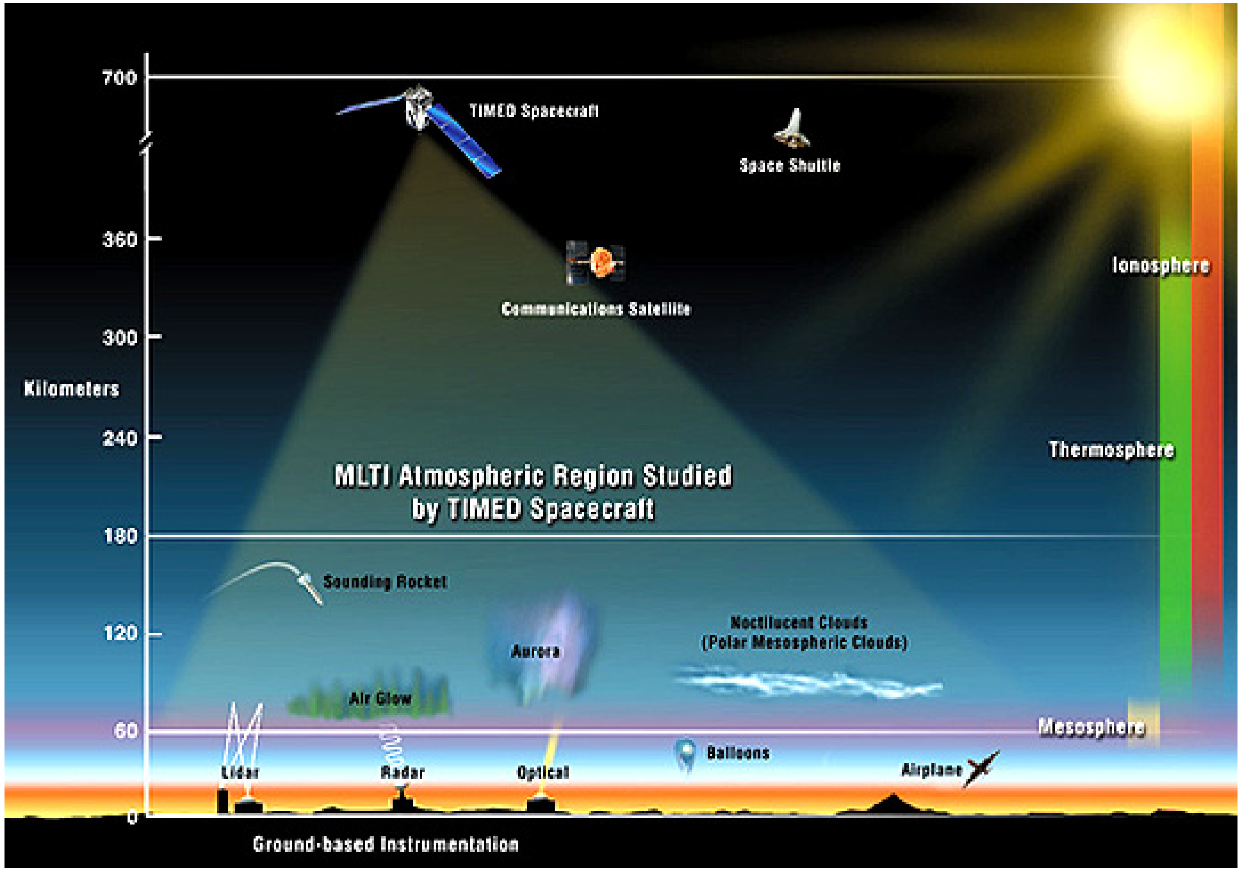
- Data are collected by **sensor**
  - Passive sensor – collection of reflected or emitted electromagnetic radiation
  - Active sensor – Generates signal and collects backscatter from interaction with terrain **(with Flash Lights)**

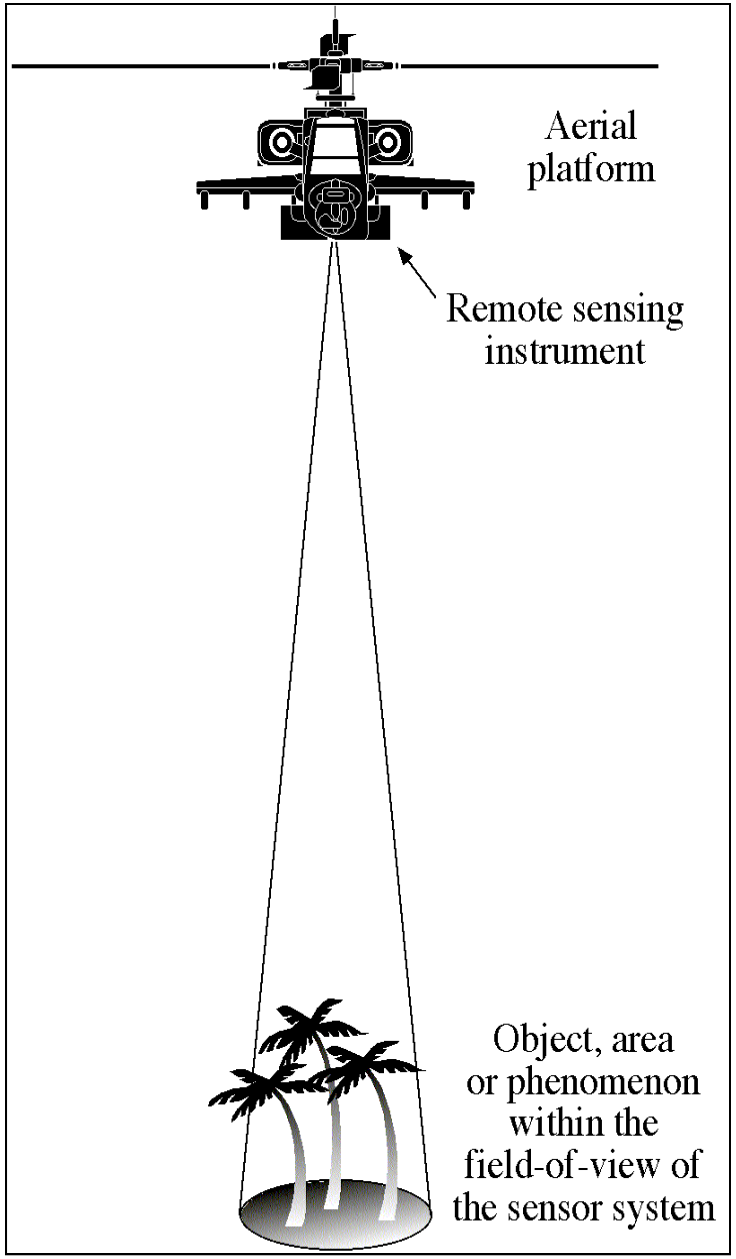
Distance – How remote is remote?

Platforms for sensors operate at multiple levels

- Cranes
- Balloons
- Aircraft
- Satellite

- Permit near-surface to global scale data collection





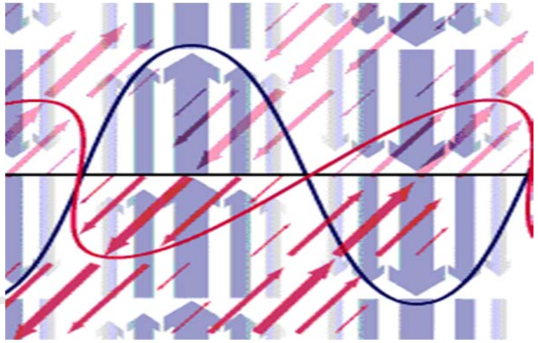
Remote sensing:

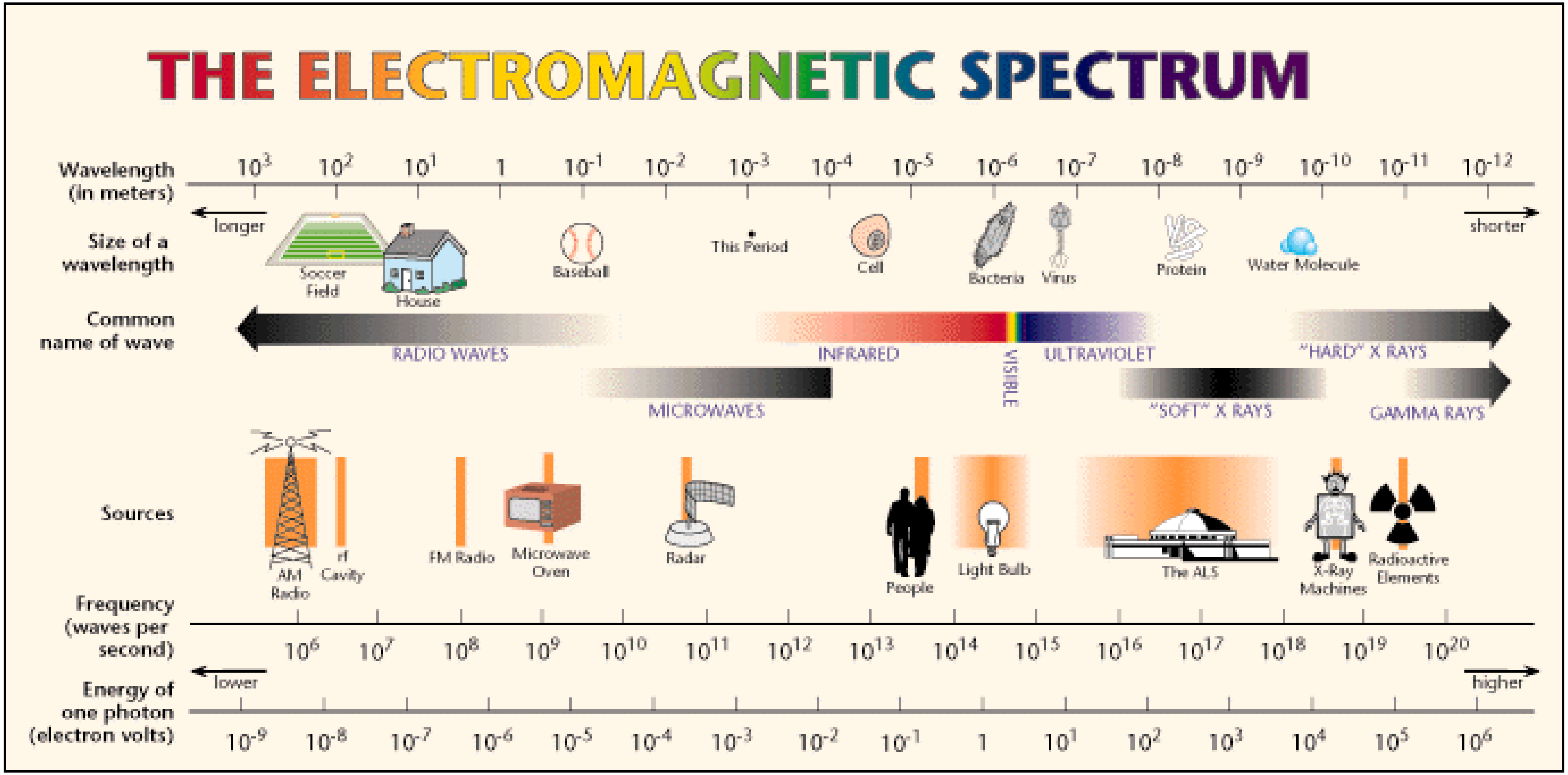
the collection of information
about an object without
being in direct physical
contact with the object.

What is FOV?

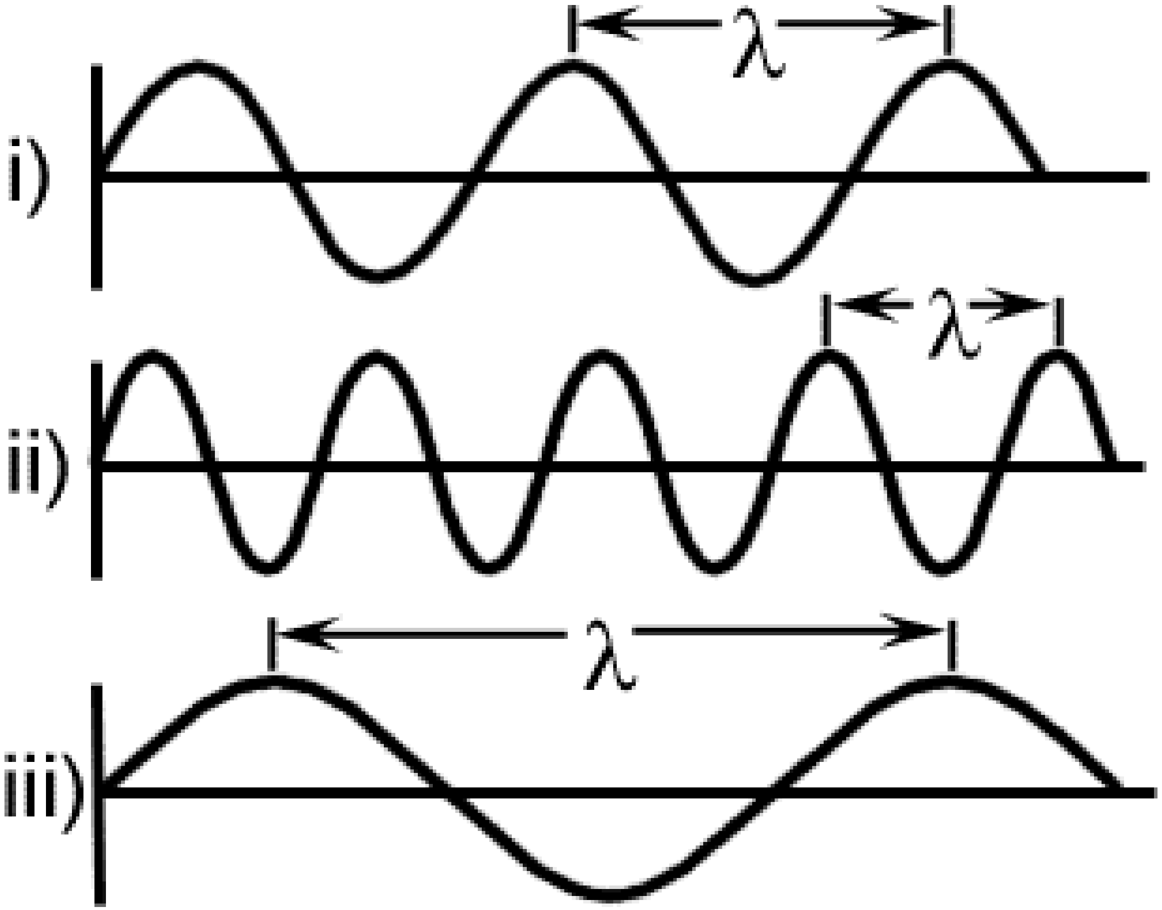
EMR: Electromagnetic Radiation

EMR




THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20
lower
higher
Energy of one photon (electron volts)
10^-9 10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10^1 10^2 10^3 10^4 10^5 10^6

Wavelength & Frequency



Near Infrared

Green

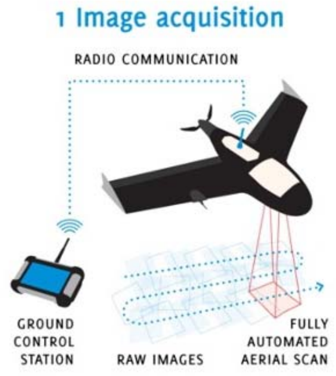
Microwave

Remote Sensing vs. Aerial Photography

- Remote sensing is performed using a variety of sensors and platforms that may operate in multiple parts of the **EMR spectrum**

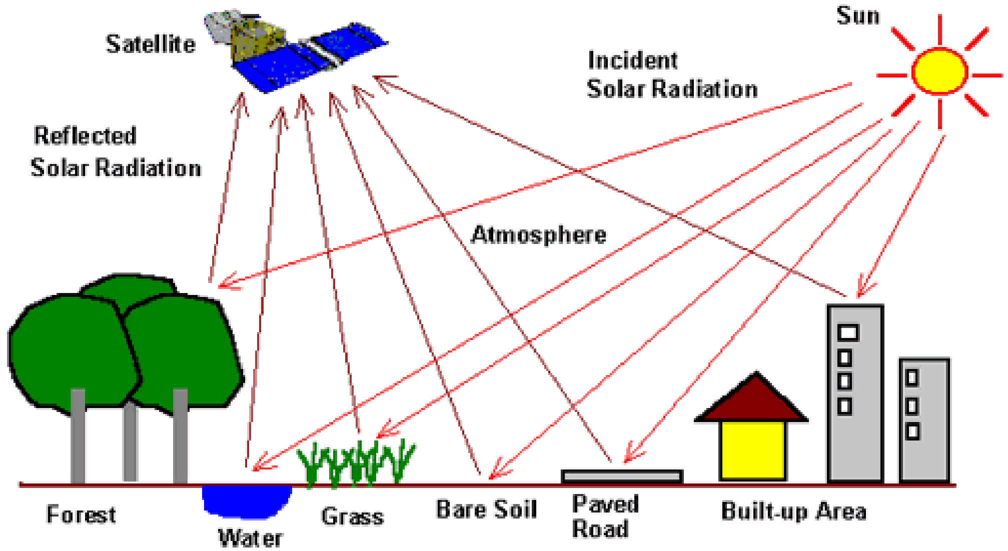
- Aerial photography is performed using cameras (file or digital) that sense only in **Ultraviolet (UV), visible**, and **Near-infrared (NIR)** spectrum and are operated on **aircraft**

- Aerial photography is a subset of remote sensing



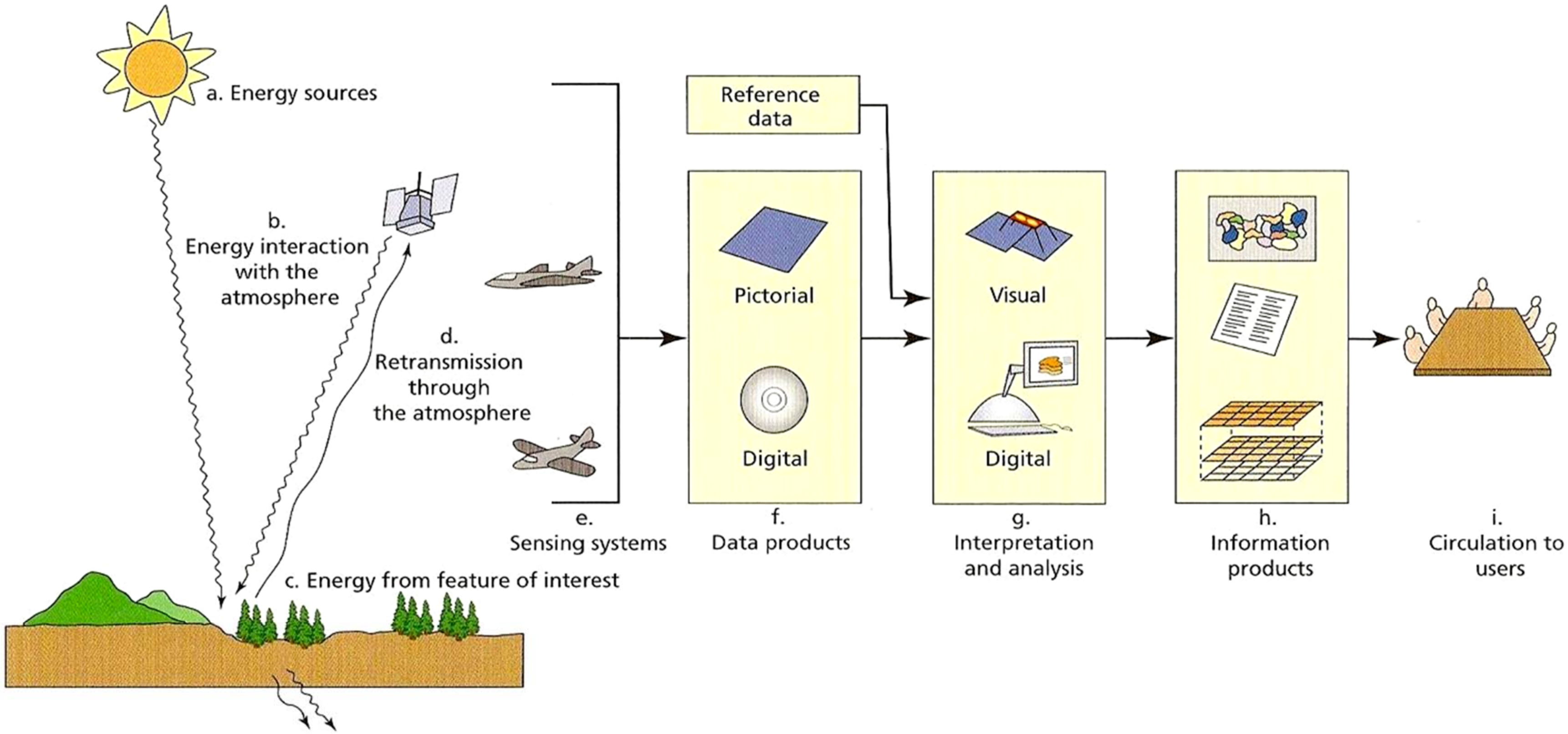
Simplified Information Flow

- Passive systems – detect naturally upwelling radiation
- Flow: Source → Surface → Sensor
- Source, the sun, illuminates surface
- Surface reflects/emits radiation
- Sensor detects reflected radiation within its **field of view (FOV).**
- Interpretation – manual or machine



Complexities of Information Flow (cont.)

- **Sensor**/platform variation
  - Attitude (angular position)
  - Altitude
  - Orbit
  - Film/wavelength sensitivities
  - Calibration or Optics
- **Processing**/interpretation variation
  - Film or digital processing
  - Repeatability of interpretation results



The remote sensing process.

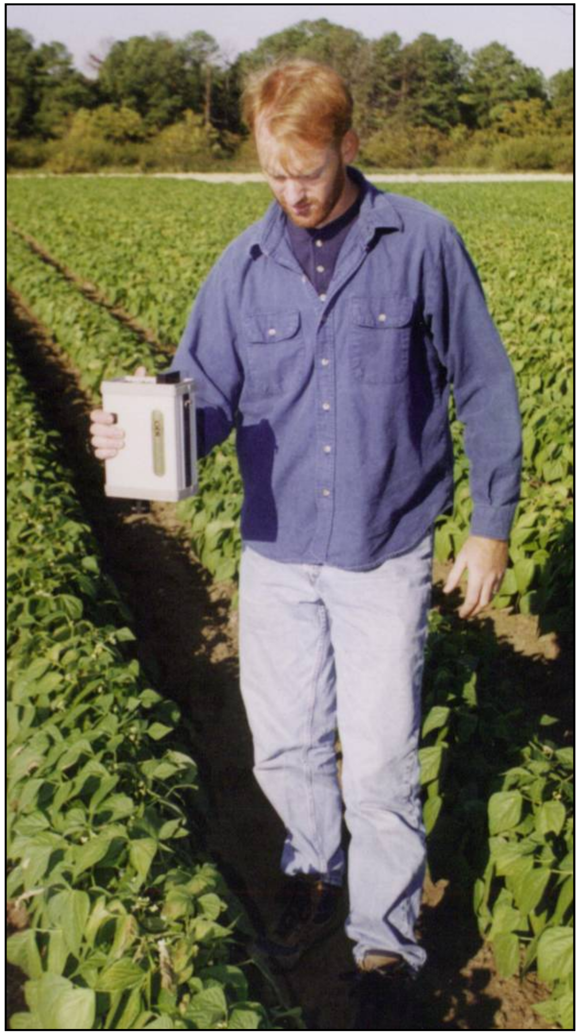
Remote sensing and image interpretation, 2nd. ed. by T. M. Lillesand and R. W. Kiefer.

In situ vs. Remote Sensing

- Both attempt to observe/measure phenomena
- ***In situ*** *(at the field – ground truth)*
  - Physical contact
  - Instruments for direct measure
  - Possible source of **error**
    - Interaction with phenomena (example: measuring CO_2 or temperature).
    - **Sampling method**
    - Ground reference vs. "ground truth"

In situ or remote sensing?

Ground Measurement In Support of Remote Sensing Measurement



Ground spectroradiometer measurement of soybeans

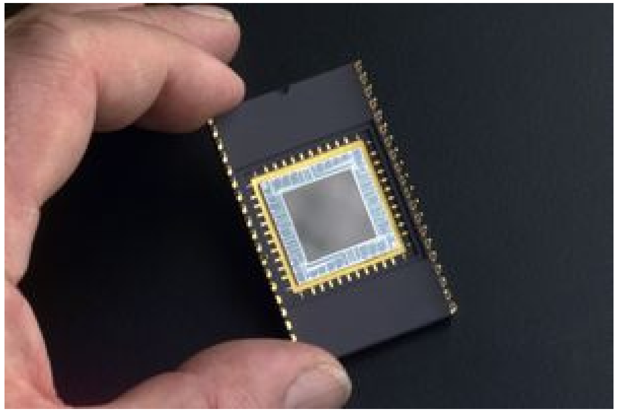
Ground ceptometer leaf-area-index (LAI) measurement

Advantages of Remote Sensing

- Different perspective
- Obtain data for large areas
  - In single acquisition – efficient
  - **Synoptic** (a general view of the whole).
  - Systematic
- Obtain data for inaccessible areas
- No effect/**interaction** with phenomena of interest

Data Collection - Sensors

- **Film Cameras**
- **Video** Systems
- **Imaging Radiometers (digital)**
  - A **charge-coupled device** (**CCD**) is an image sensor
- **Passive Microwave**
- **Radar**



Data Collection - Imagery

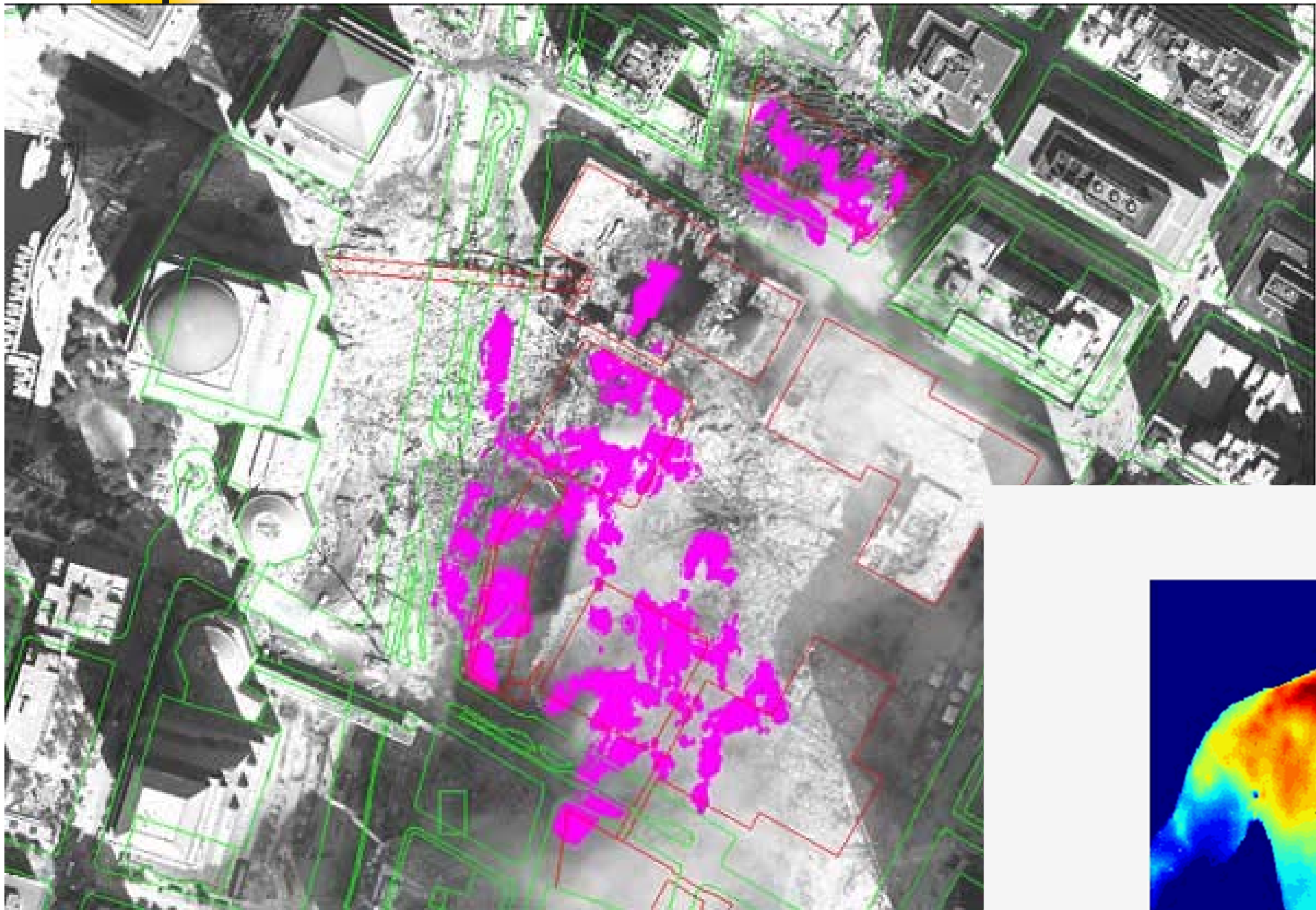
- **Panchromatic** (monochrome or B&W) – sensitive across broad visible wavelengths
- **Color** – may provide added discrimination
  - Color film
  - Color composites
- **Thermal** – in region 3 microns to 1 mm, sensitive to temperature
- **Microwave** – all weather capability

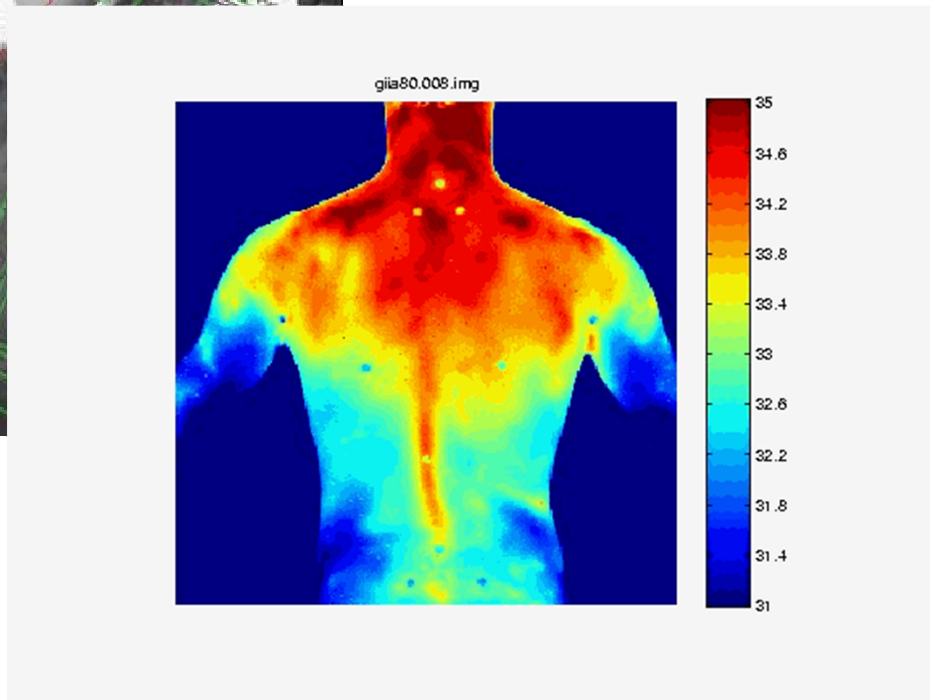
Panchromatic (monochrome or B&W)

Color

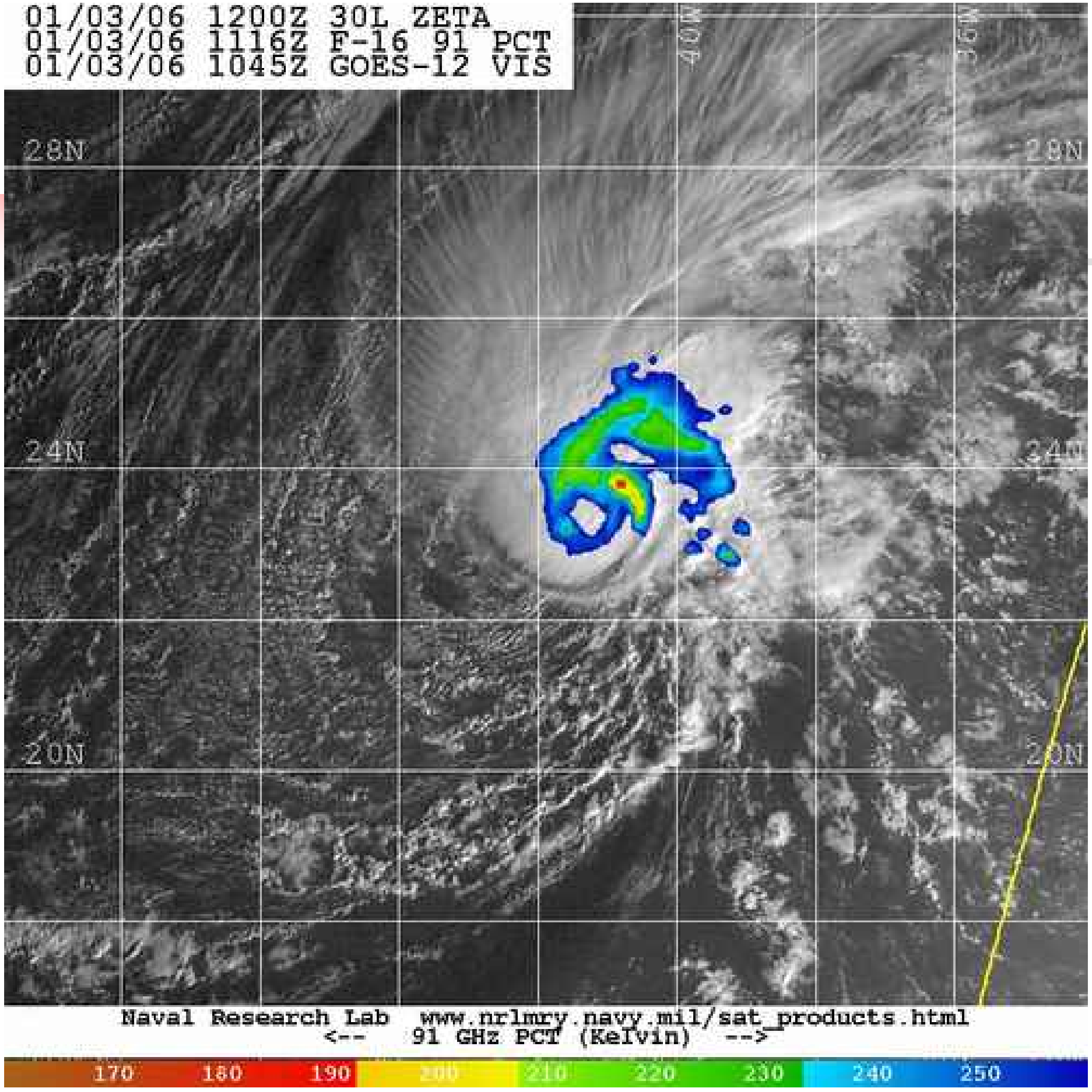

Image © 2008 DigitalGlobe
© 2008 Tele Atlas
Google
Pointer 41°53'24.70" N 12°29'32.65" E elev 106 ft
Streaming |||||||||| 100%
Eye alt 2498 ft

Thermal Imagery (World Trade Center and Human Body)





■ Microwave



http://cimss.ssec.wisc.edu/tropic/real-time/marti/2005_EIGHTEEN/webManager/basicGifDisplay48.html

Art vs. Science

- Image interpretation is not exact science
- Interpretations tend to be **probabilistic** not exact
- Successful interpretation depends on
  - **Training** and **experience**
  - Systematic and disciplined approach using knowledge of remote sensing, application area and location
  - Inherent talents

Image Interpretation - Defined

Act of examining images for the purpose of **identifying** and measuring **objects** and phenomena, and judging their significance

Image Interpretation (II) Tasks

- In order of increasing sophistication…
  - **Detection** (easier tasks)
  - Identification
  - Measurement
  - Problem-Solving (most difficult tasks)

- Not necessarily performed sequentially or in all cases

II Tasks - Detection

- Lowest order
- **Presence**/absence of object or phenomena
- Examples: buildings, water, roads and vegetation

II Tasks - Identification

- More advanced than detection
- **Labeling** or typing of the **object**/phenomena
- Tends to occur simultaneously with detection
- Examples: my houses, Lake Murray, highway I-8.

II Tasks - Measurement

- Quantification of objects / phenomena
- Direct **physical measurement** from the imagery
- Examples
  - Inventories (count) – five lakes in SD county.
  - Length, area and height of objects. Lake Murray: 3.5 acres

II Tasks – Problem Solving

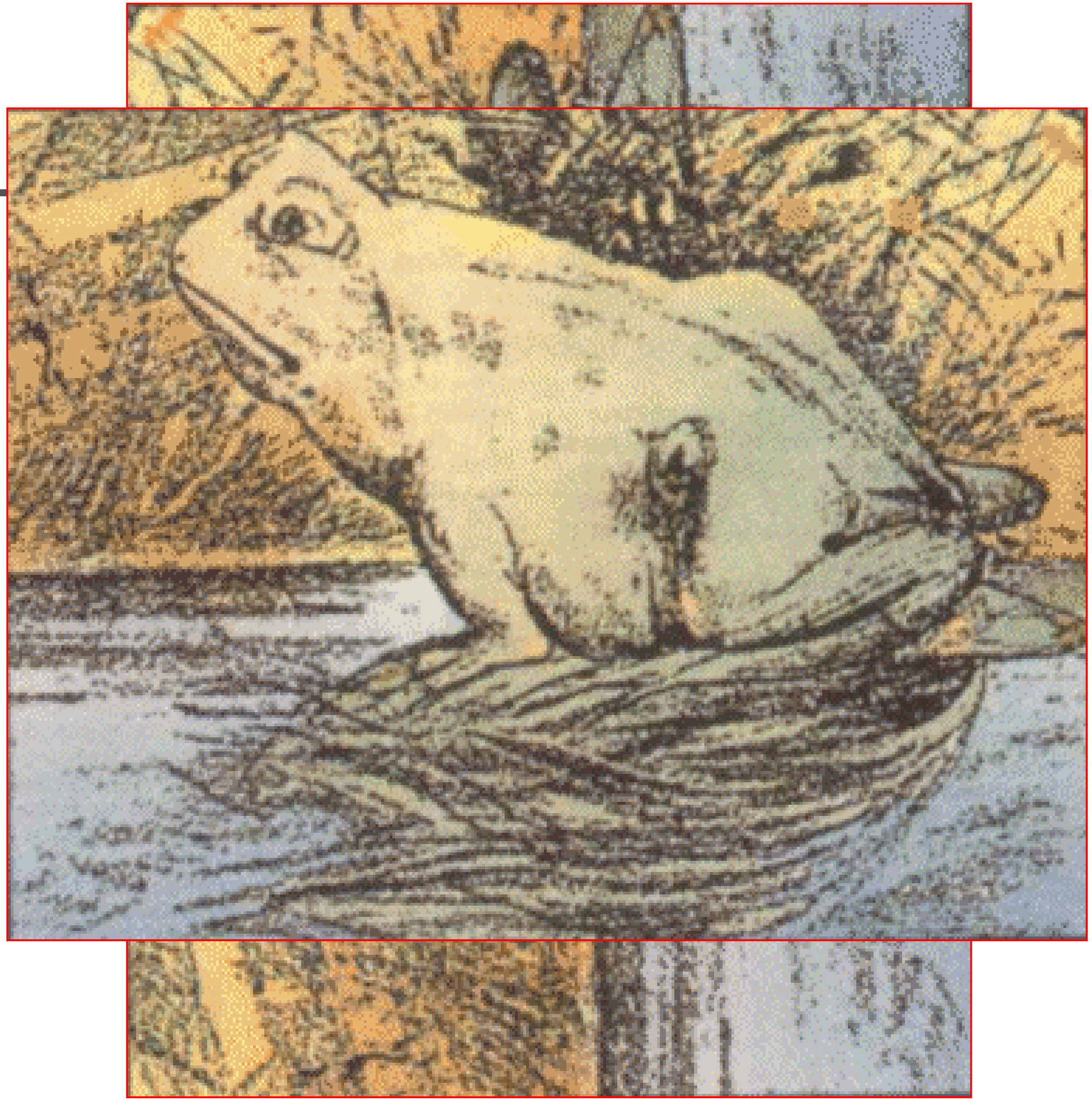
- Most complex task
- Uses information acquired in first three tasks to put objects in assemblages or associations needed for higher-level identification
- With experience, recognition becomes more automatic and tasks become less distinct
- Example:
  residential housing density

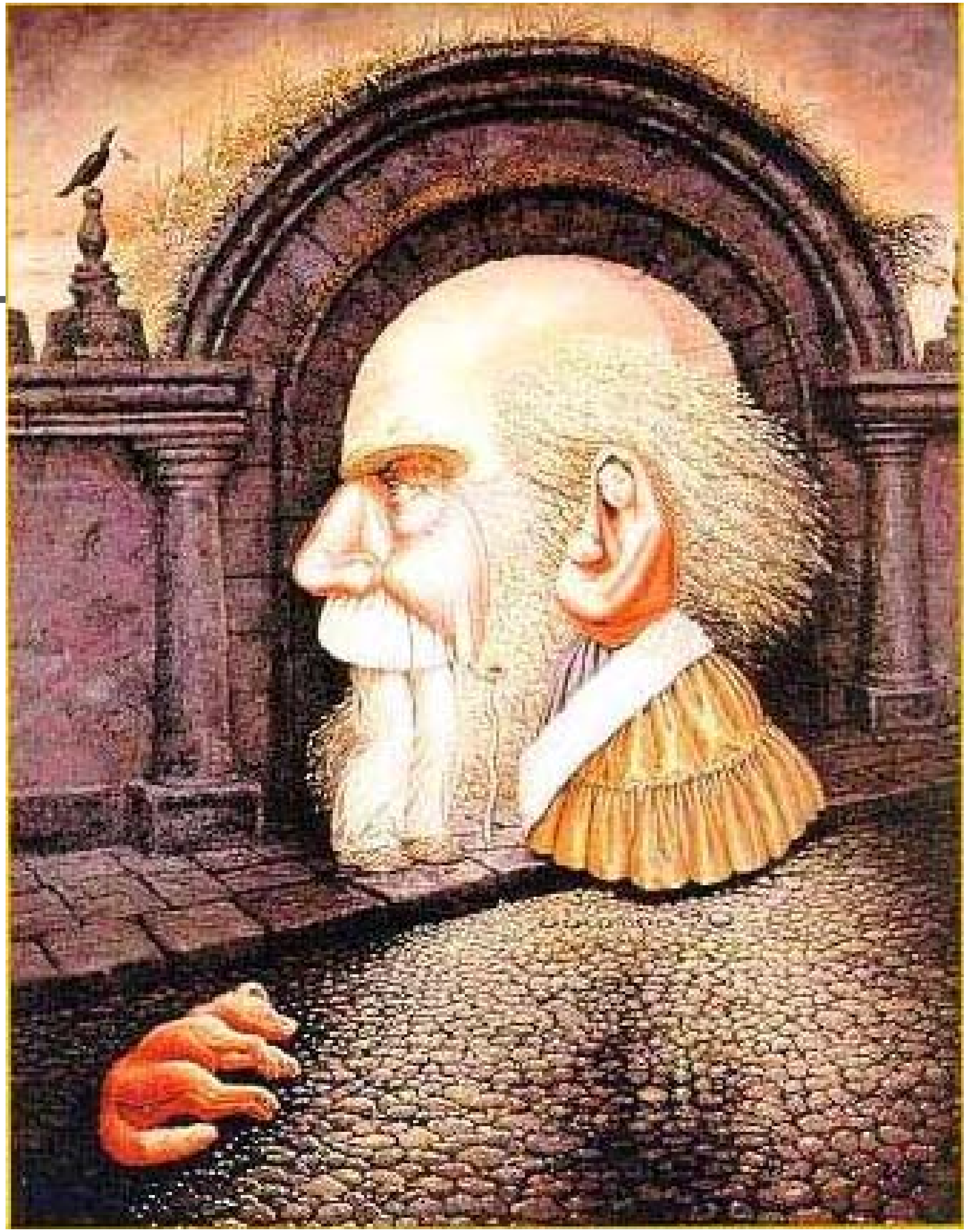
Interpreter Requirements - Cognition

- Concerned with how interpreter derives information from the image data

- **Varies from individual to individual**
  - Reasons for differences/inconsistencies among interpreters

- **Cognitive processes** are concerned with perceptual evaluation of elements of interpretation and how they are used in interpretation process





Imagery Resolution

- Four components of resolution
  - **Spatial**
  - **Spectral**
  - **Radiometric**
  - **Temporal**

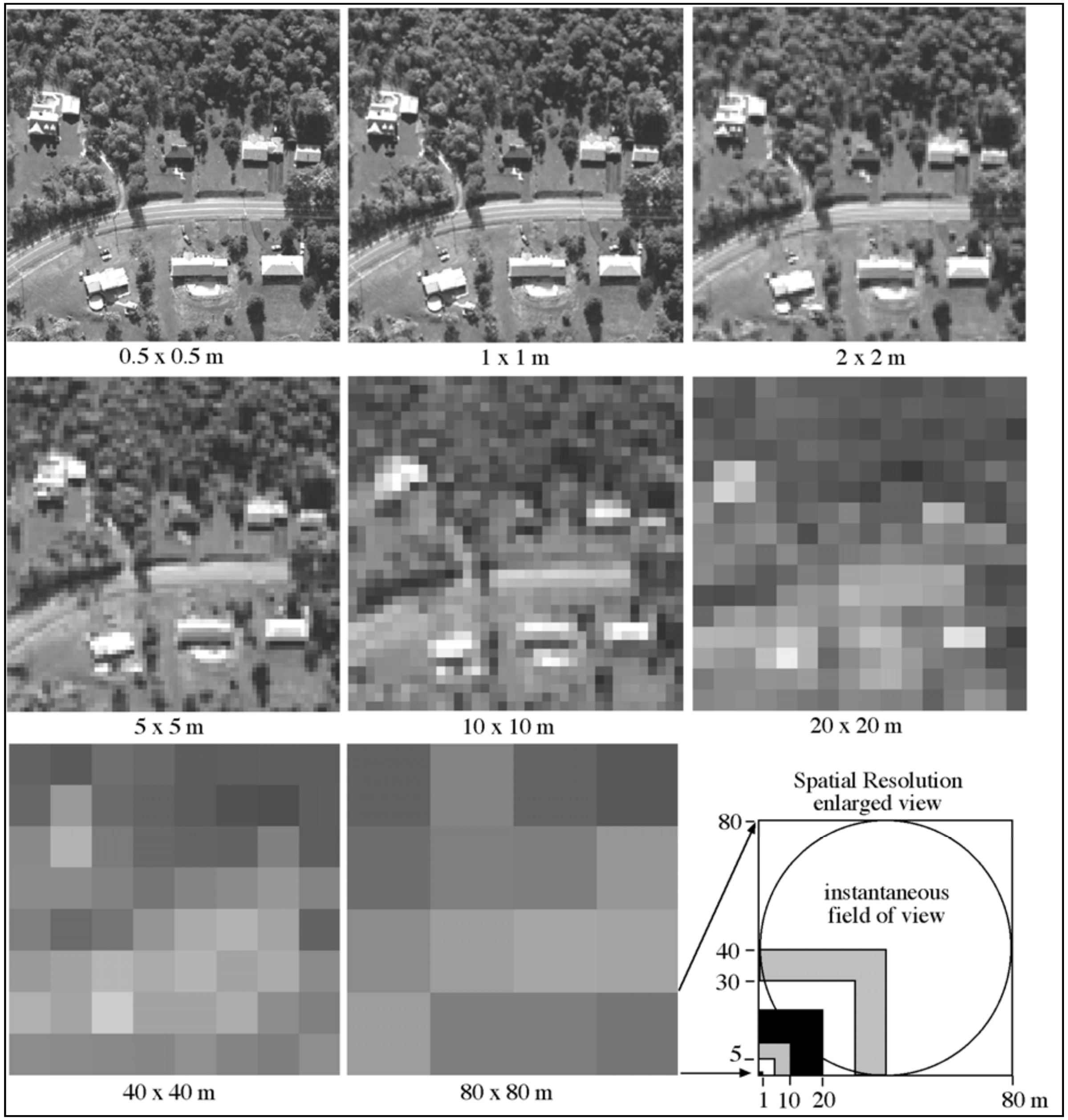
Spatial Resolution

- Indication of how well a sensor records spatial **detail**
- Refers to **the size of the smallest possible feature** that can be detected as distinct from its surroundings
- Aerial Camera: function of platform **altitude** and film and **optical** characteristics
- Non-film sensor: function of platform **altitude** and **instantaneous field of view (IFOV)**

Lower (coarser) spatial resolution

Higher (finer) spatial resolution

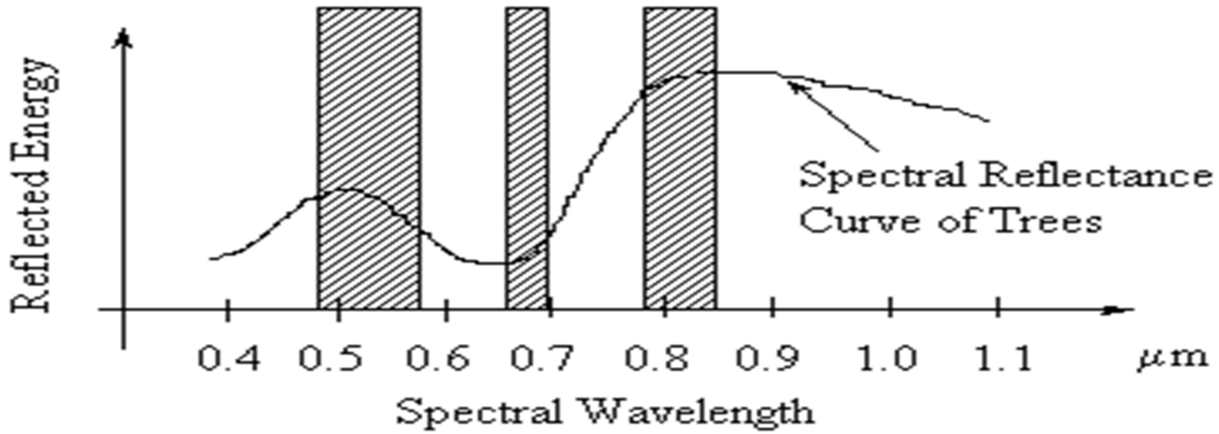
Spatial Resolution



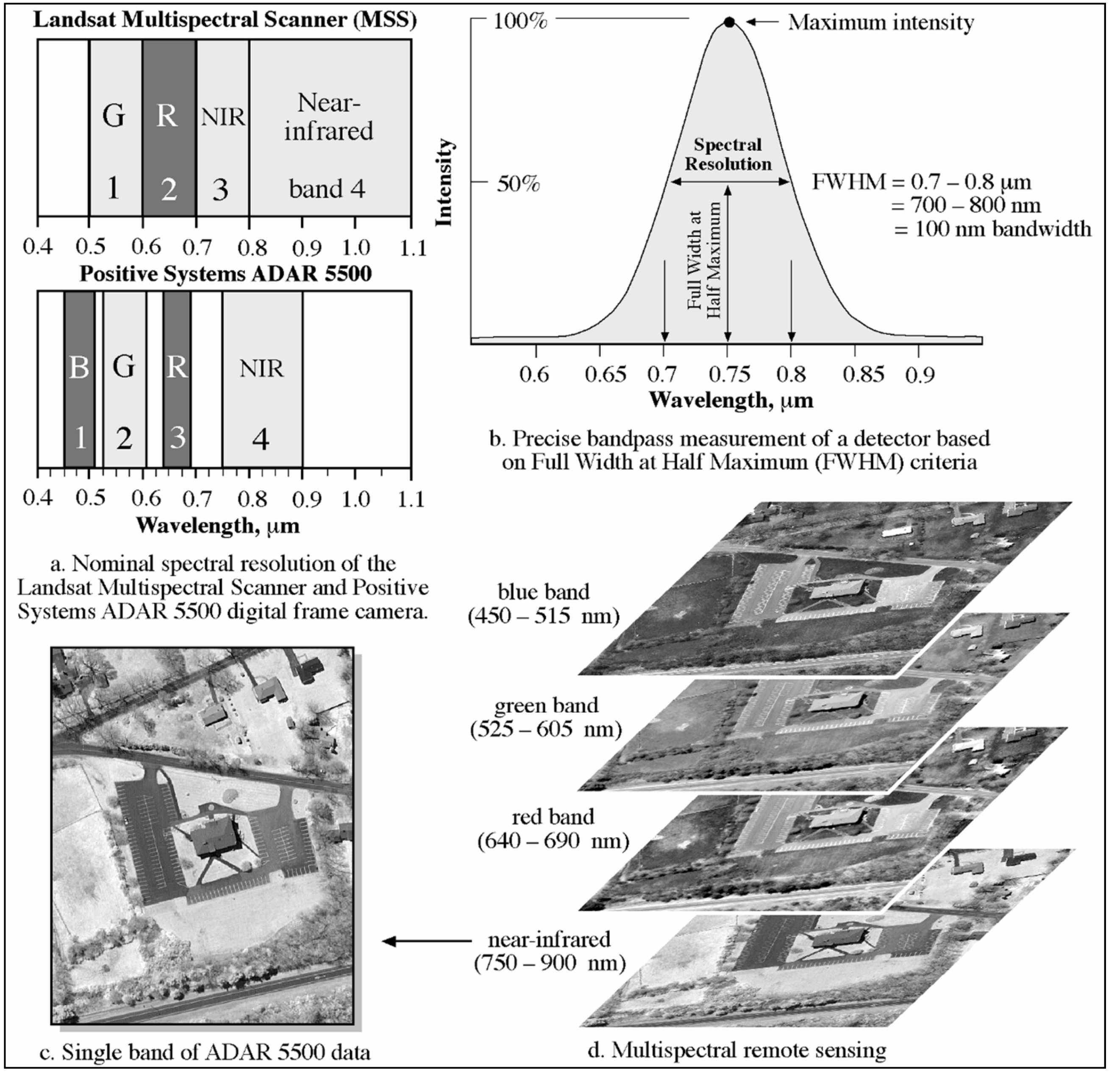
Jensen, 2000

Spectral Resolution

- The width of the specific EMR wavelength band(s) to which sensor is sensitive
- Broadband
  - Few, relatively broad bands
- Hyper-spectral
  - Many, relatively narrow bands



Spectral Resolution



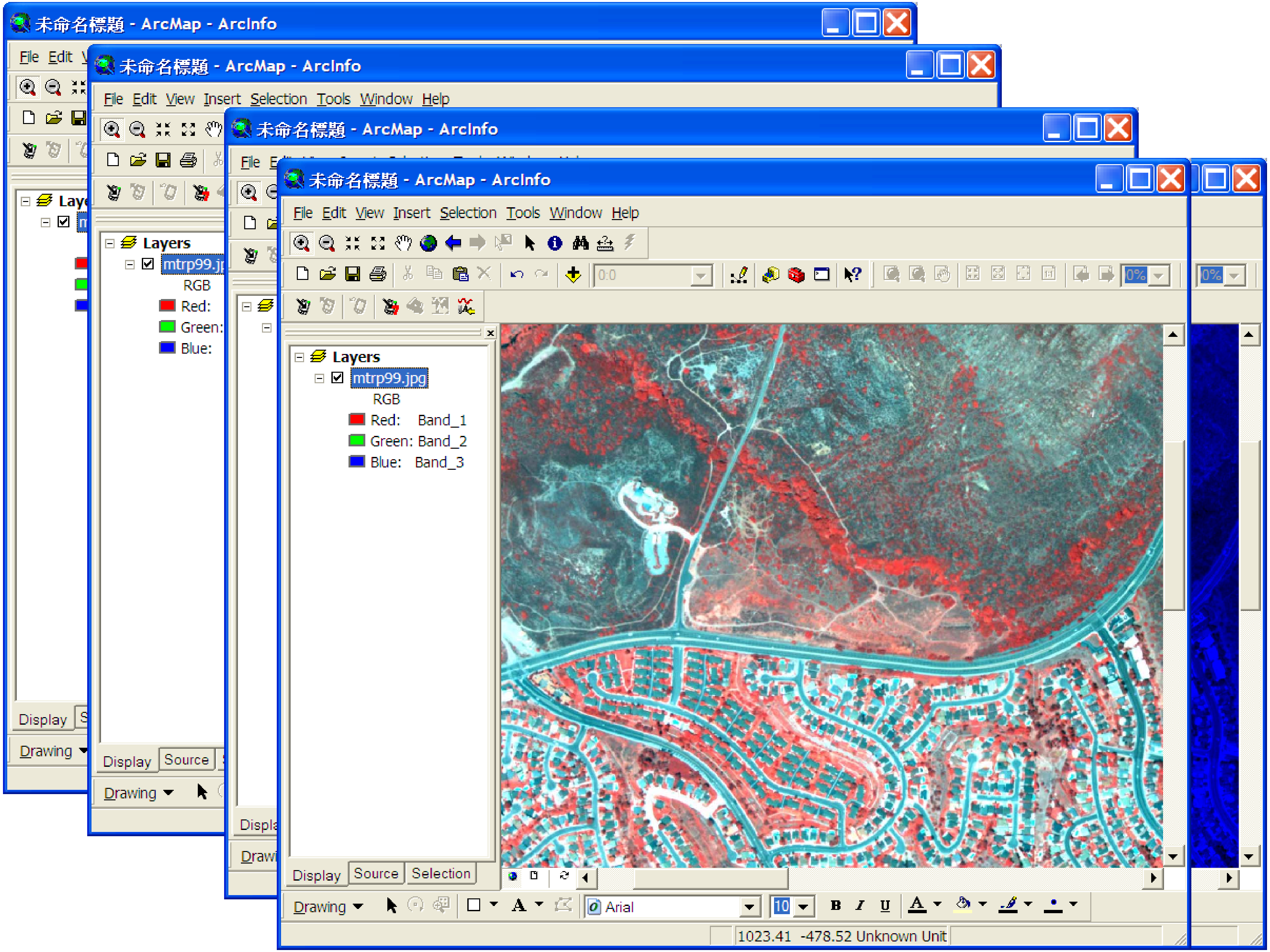
a. Nominal spectral resolution of the Landsat Multispectral Scanner and Positive Systems ADAR 5500 digital frame camera.

b. Precise bandpass measurement of a detector based on Full Width at Half Maximum (FWHM) criteria

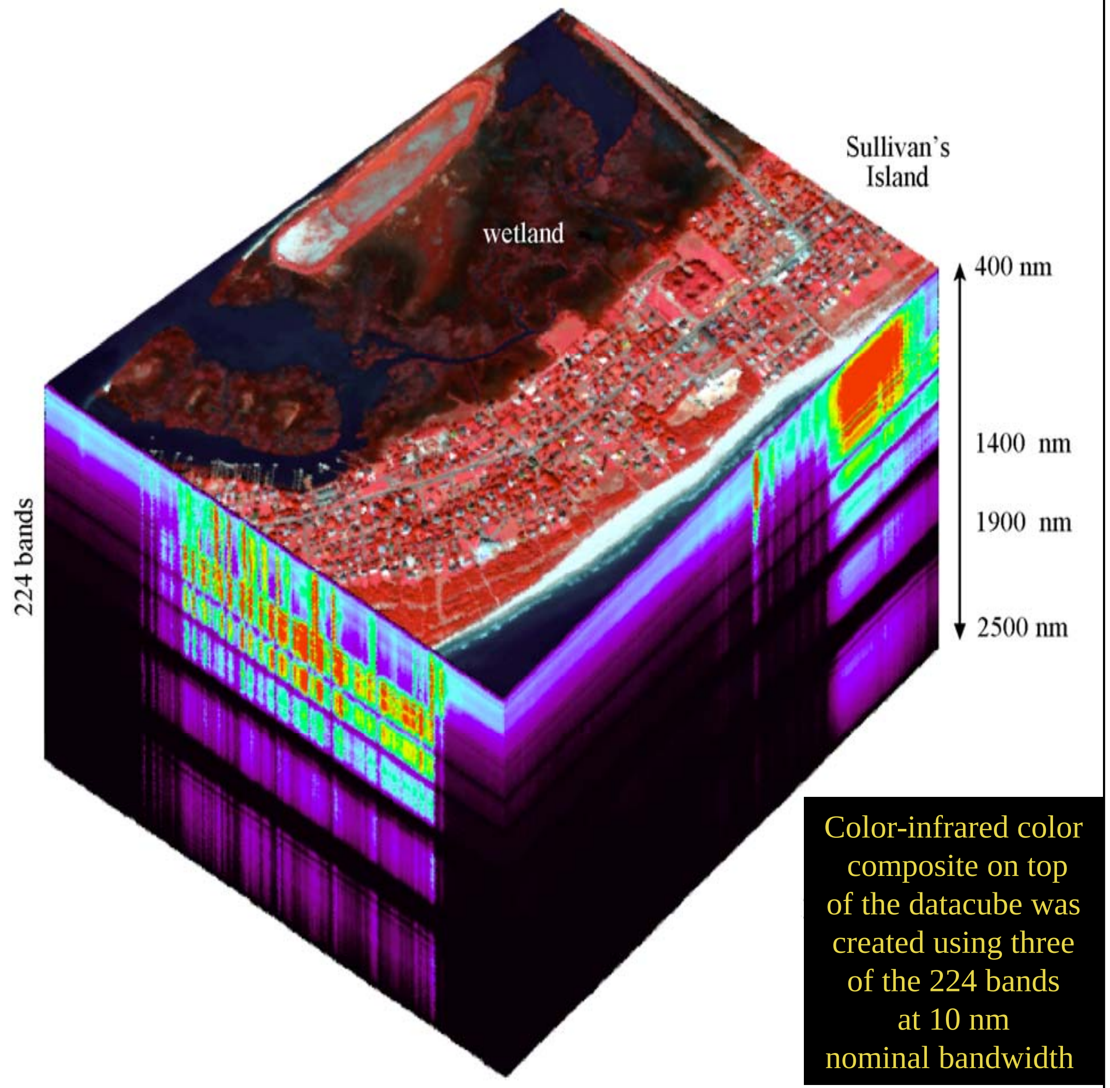
c. Single band of ADAR 5500 data

d. Multispectral remote sensing

Jensen, 2000


未命名標題 - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
Layers
mtrp99.jpg
RGB
Red: Band_1
Green: Band_2
Blue: Band_3
Display Source Selection
Drawing
Arial
10
1023.41 -478.52 Unknown Unit

Airborne Visible Infrared Imaging Spectrometer (AVIRIS) Datacube of Sullivan's Island Obtained on October 26, 1998



Color-infrared color composite on top of the datacube was created using three of the 224 bands at 10 nm nominal bandwidth

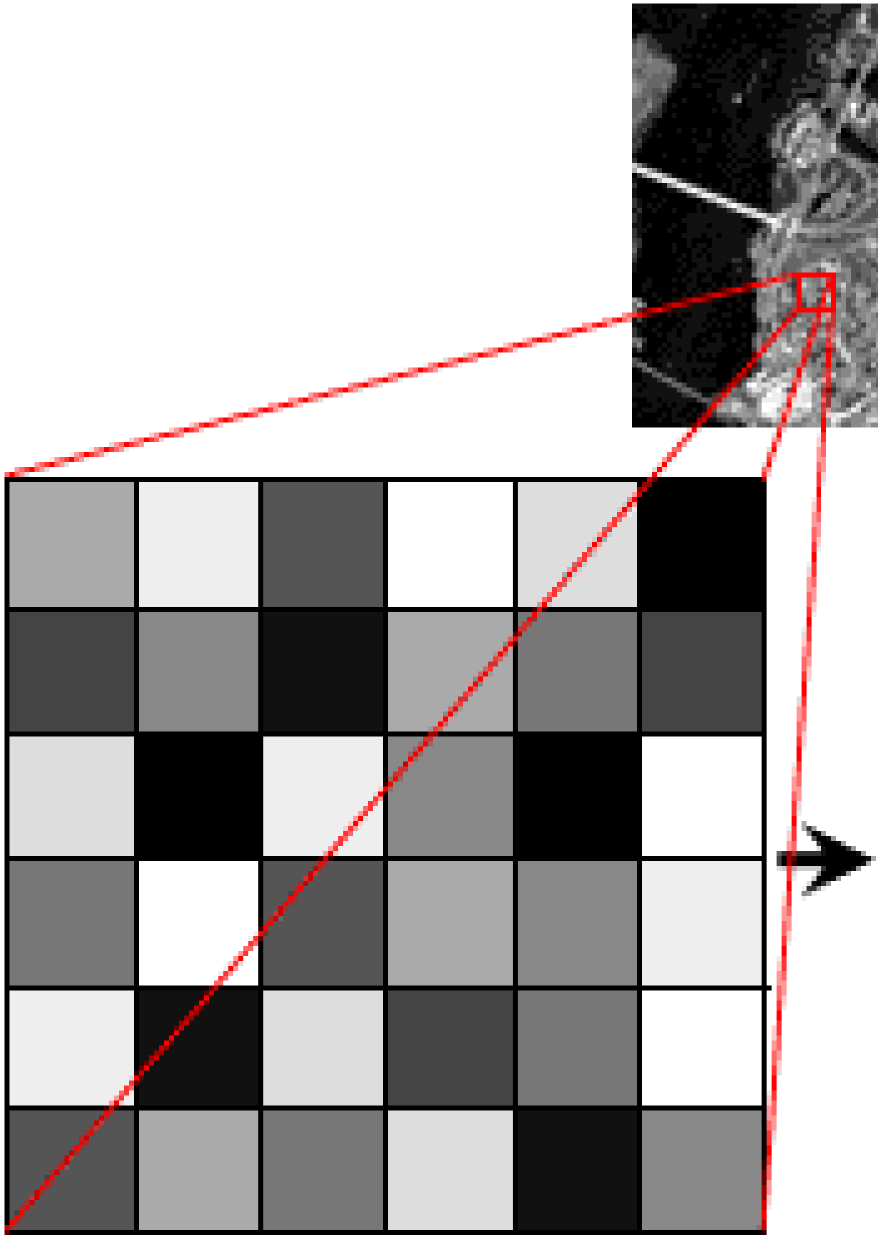
Jensen, 2000

Radiometric Resolution (sensitivity)

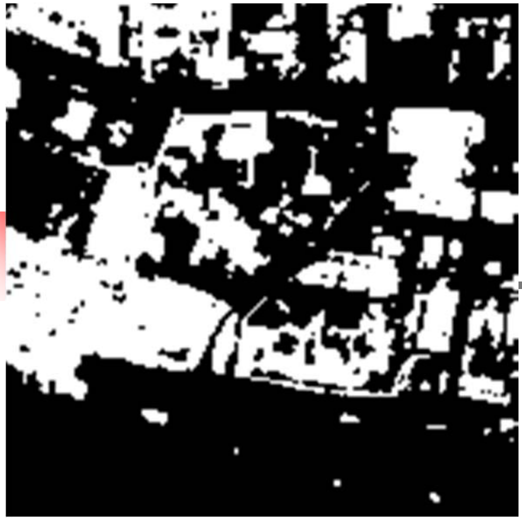
- Ability of a sensor to distinguish between objects of similar reflectance

- Measured in terms of the number of energy levels discriminated
  - 2^n, where n = number of ‘bits’ (precision level)
  - Example: 8 bit data = 2^8 = 256 levels of grey
  - 256 levels = 0-255 range
  - 0 = black, 255 = white

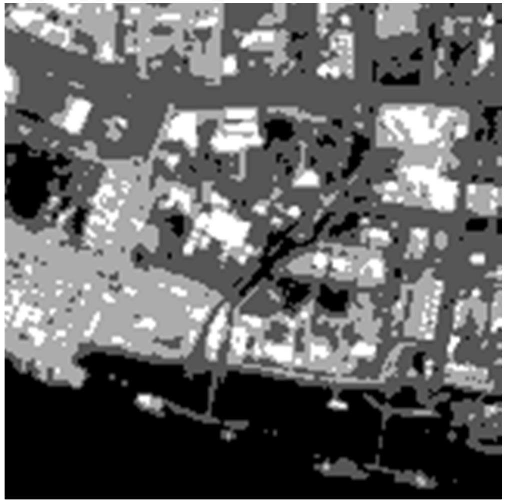
- Affects ability to measure surface properties



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136



1 - bit



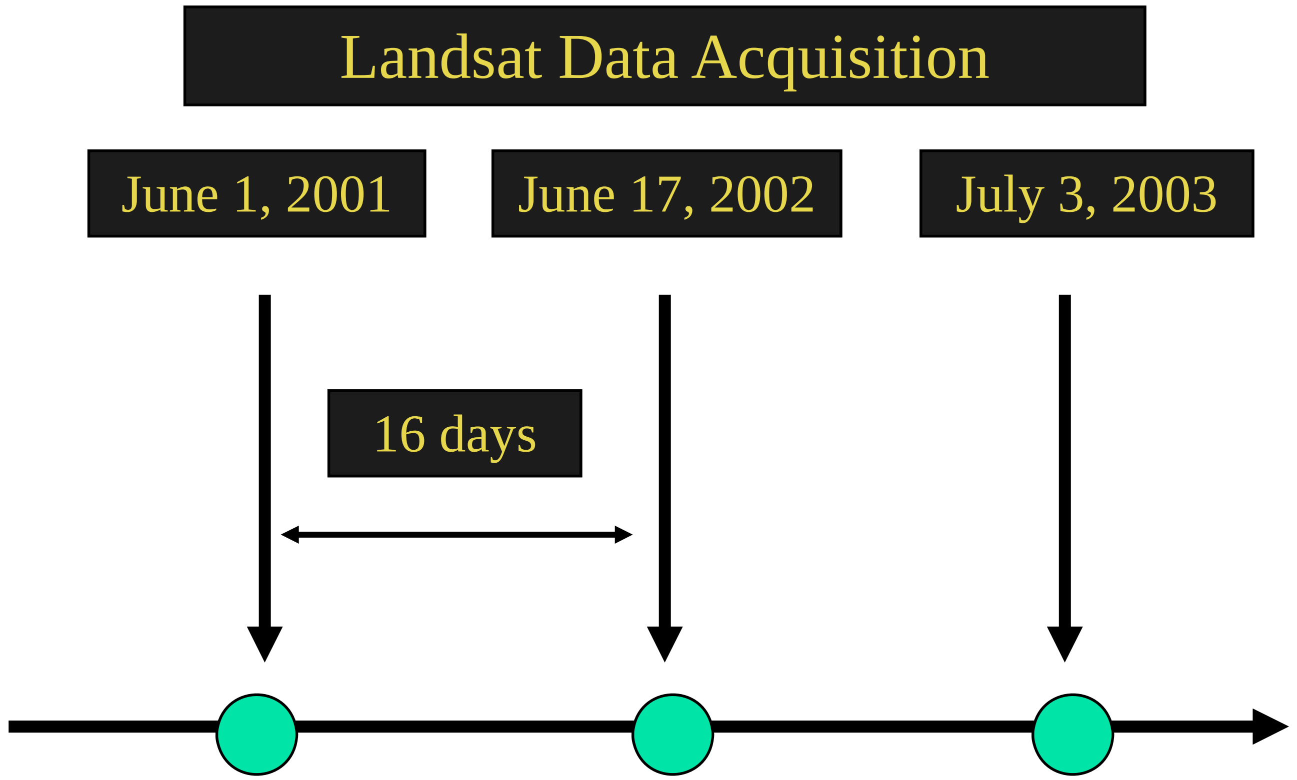
2 - bit

8 - bit

Temporal Resolution

- The ability to obtain repeat coverage for an area
- Timing is critical for some applications
  - Crop cycles (planting, maximum greenness, harvest)
  - Catastrophic events
- Aircraft
  - Potentially high
  - Actually (in practice) lower than satellites
- Satellite
  - Fixed orbit
  - Systematic collection
  - Pointable sensors

Temporal Resolution

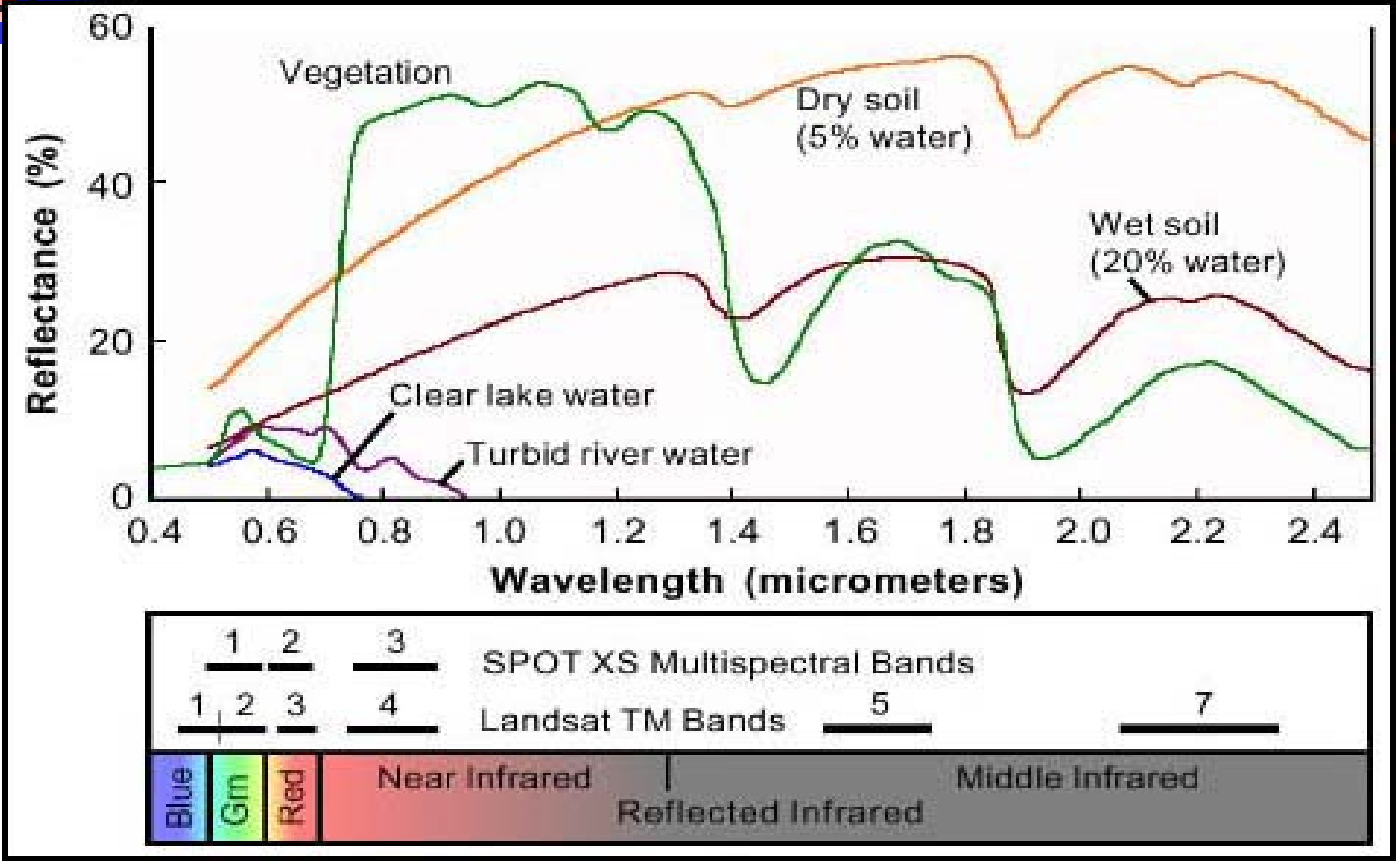


Jensen, 2000

Spectral Signature Concept

- Describes spectral **reflectance** of a target at different wavelengths of EMR
- **Spectral reflectance curve** - graphs reflectance response as a function of wavelength
- Key to separating and **identifying** objects
- Selection of optimum wavelength bands

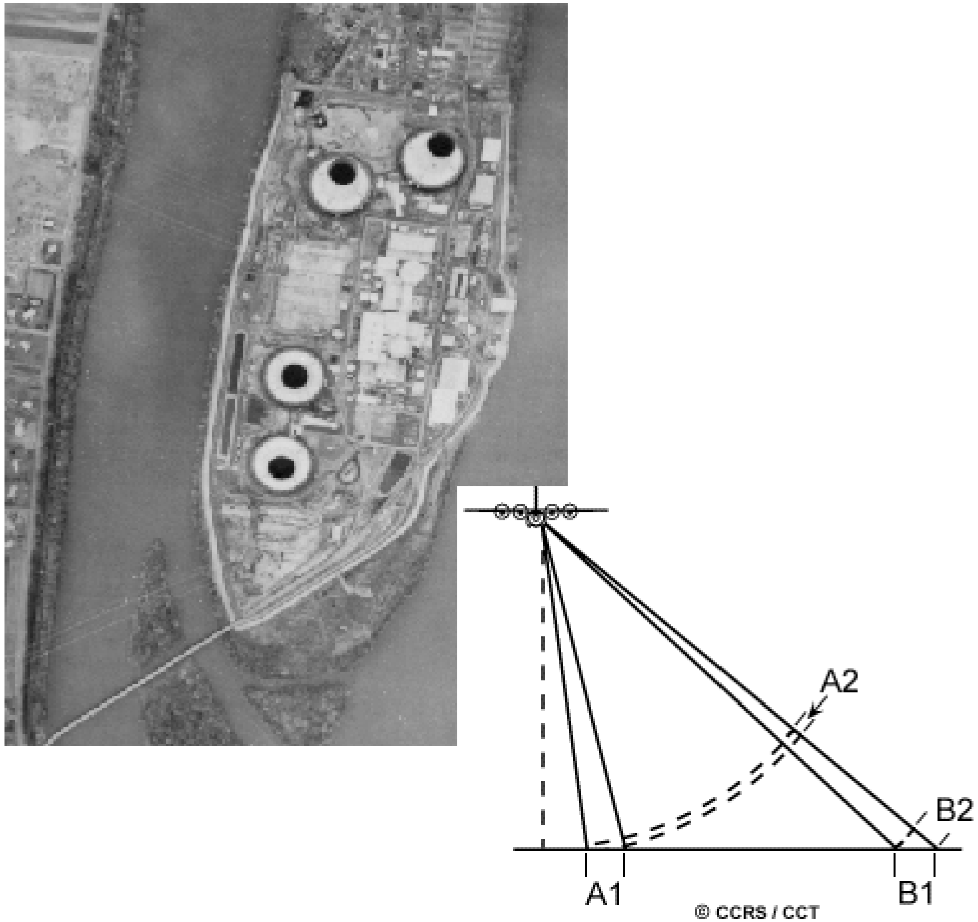
More Spectral Reflectance Curves

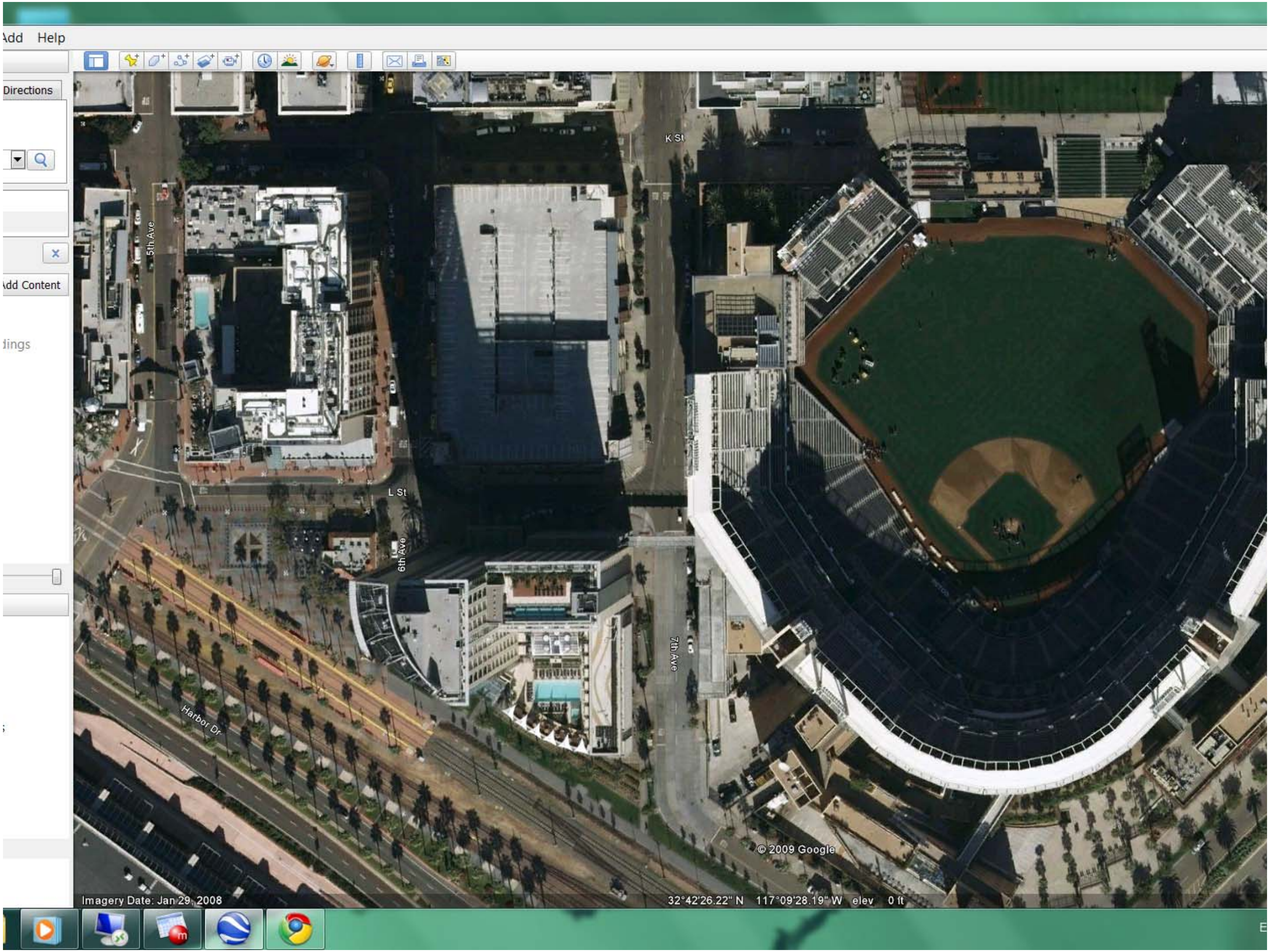


Relief Displacement - Definition

Relief Displacement

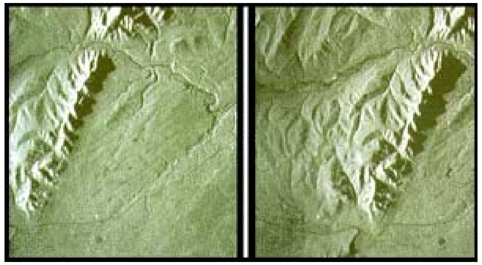
- jects will tend to lean
  ward, i.e. be radially
  placed.
- e greater the object is
  from the principal point,
  the greater the radial
  displacement.
- Example: cooling towers
  towards the edge of photo
  show greater radial
  displacement.




Help
Directions
K St
5th Ave
L St
6th Ave
7th Ave
Harbor Dr
© 2009 Google
Imagery Date: Jan 29, 2008
32°42'26.22" N 117°09'28.19" W elev 0 ft

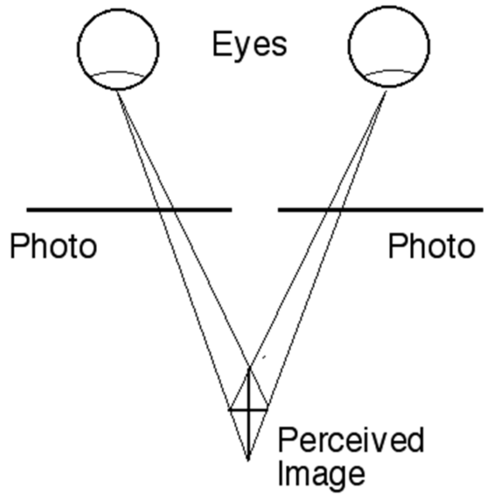
Stereoscopic Viewing

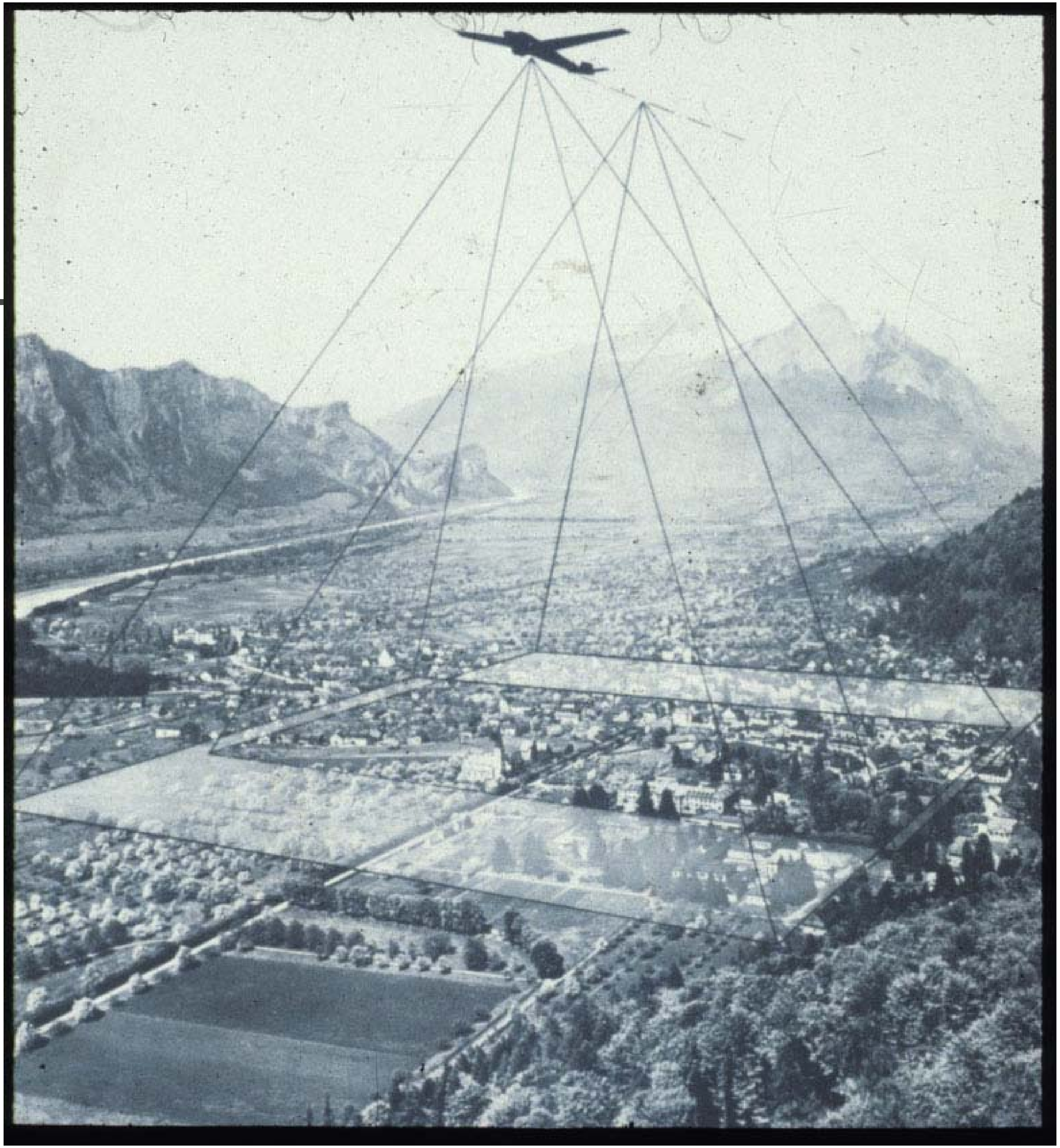
- Provides 3rd dimension to air photo interpretation
  - Identify 3-D form of an object (volcano, building, etc.)

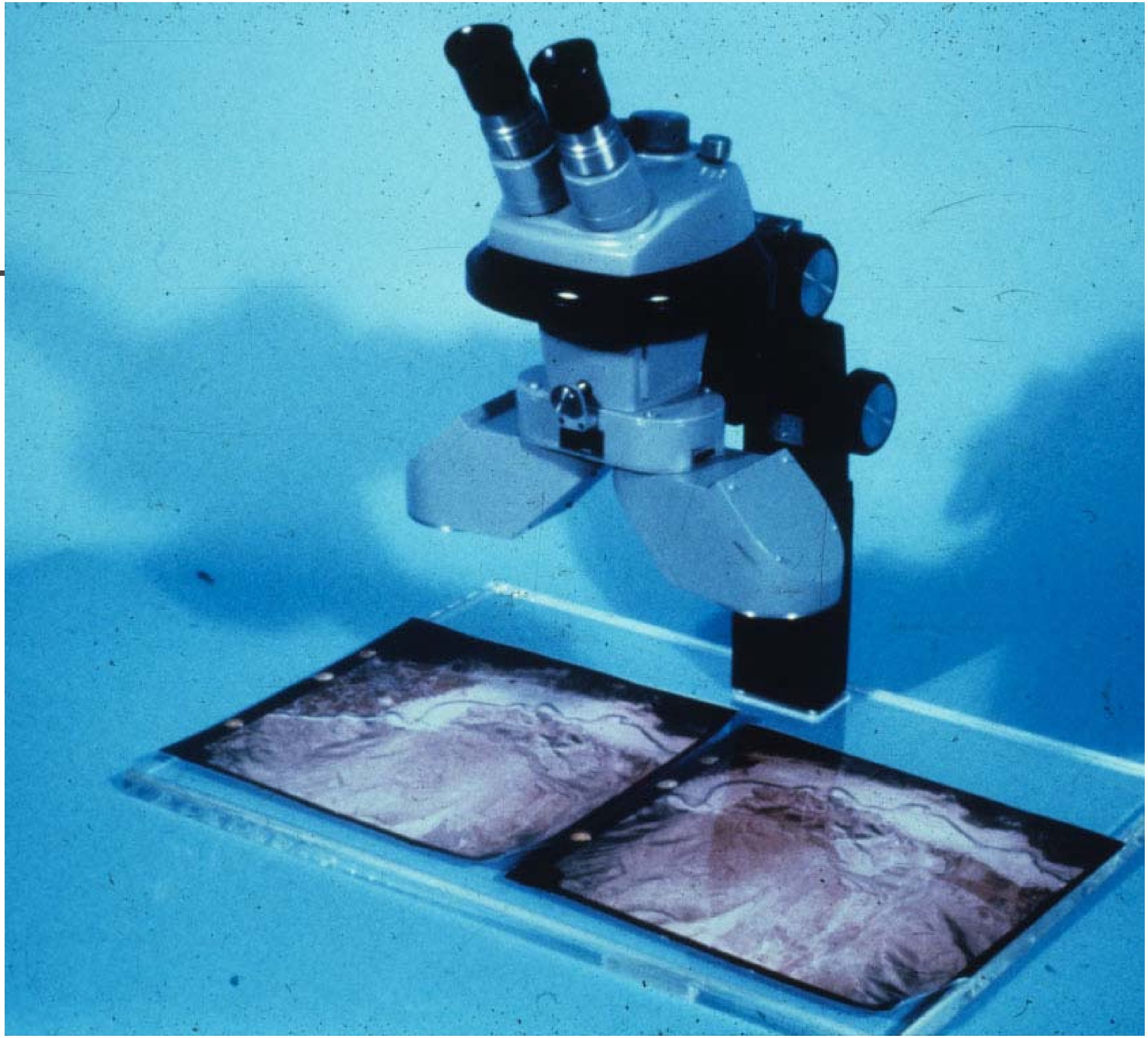


- Stereopairs
  - Overlapping vertical photographs

- Stereoscopes
  - Used to create synthetic visual response by forcing each eye to look at different views of same terrain
  - Gives perception of depth (3-D)







StereoPlotters

- Various types
- Three main components
  - 1. Projection system that creates the terrain model
  - 2. Viewing system so operator can see model stereoscopically
  - 3. Measuring and tracing system to record elevation and trace features onto a map sheet

StereoPlotter

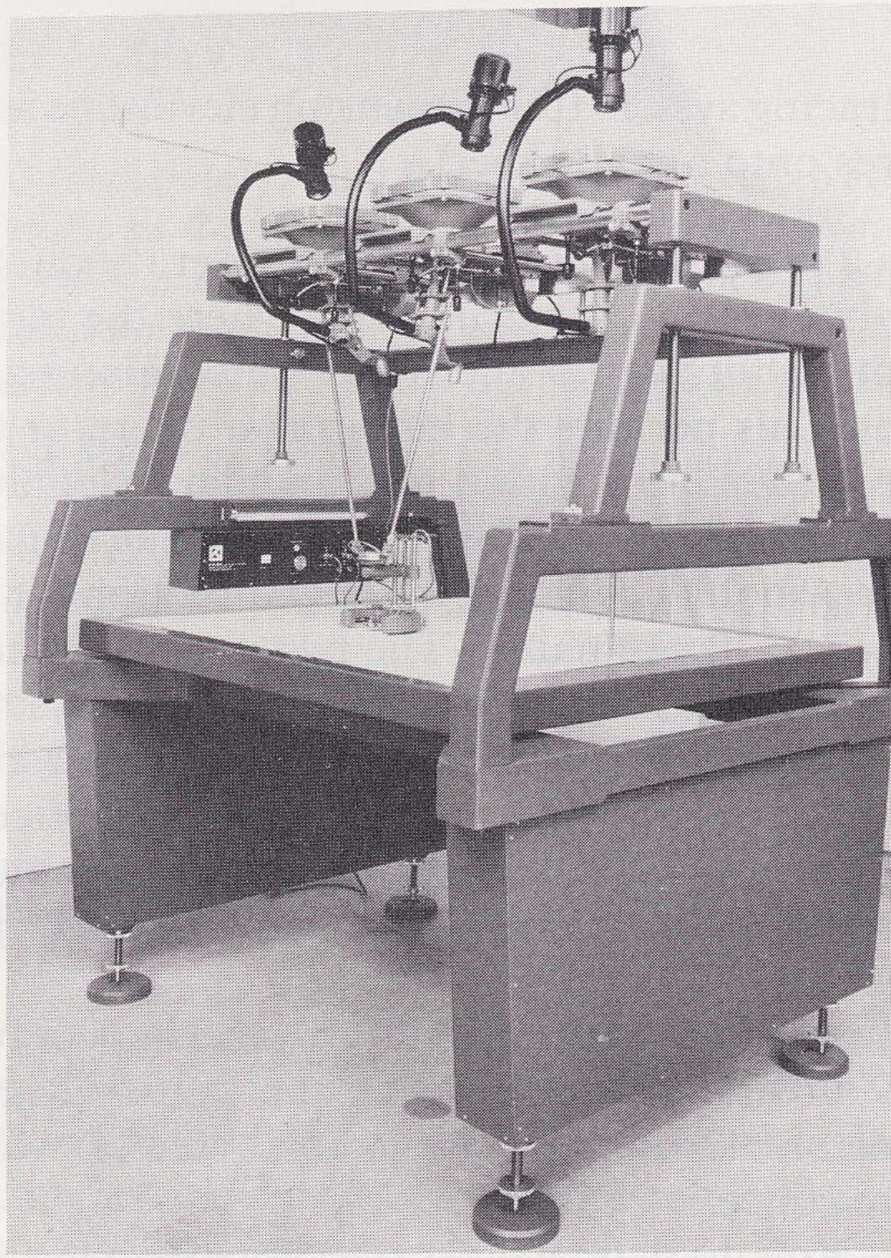


Figure 4.19 Kelsh Model KPP-3B stereoplotter instrument. (Courtesy Kelsh Instrument Division, Danko Arlington, Inc.)

Stereo Model

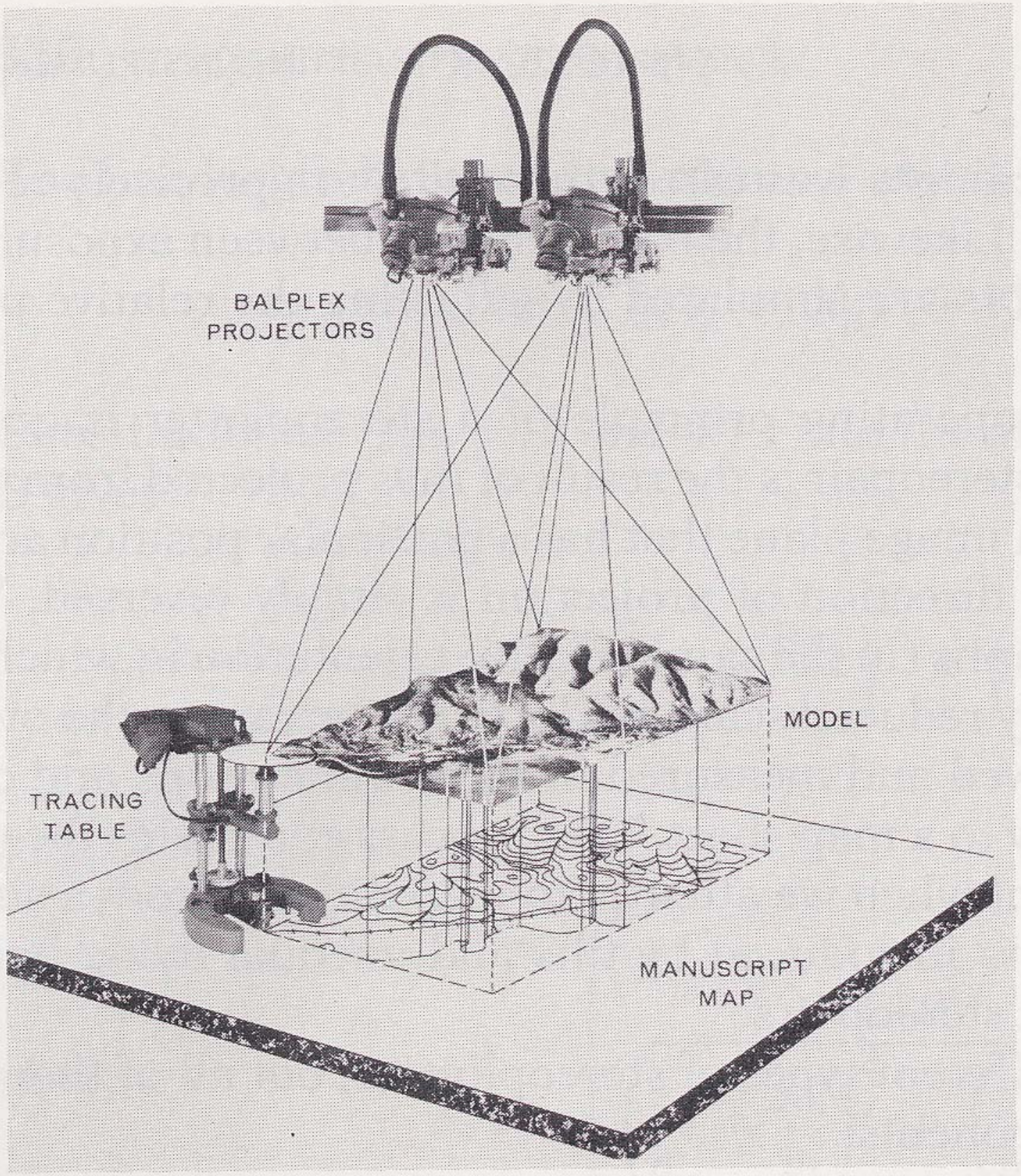


Figure 4.18 Stereomodel projected in a Balplex stereo-plotter. (Courtesy TBR Associates, Inc.)

Orthophotography

- Images corrected for **tilt** and **relief** displacement
- Base of features will be shown in their **true planimetric** position
- Feature distortion is not eliminated
  - e.g., tall buildings will still appear to "lean"
- Perspective of the image is changed from point to parallel rays orthogonal to the surface
- Useful as base map

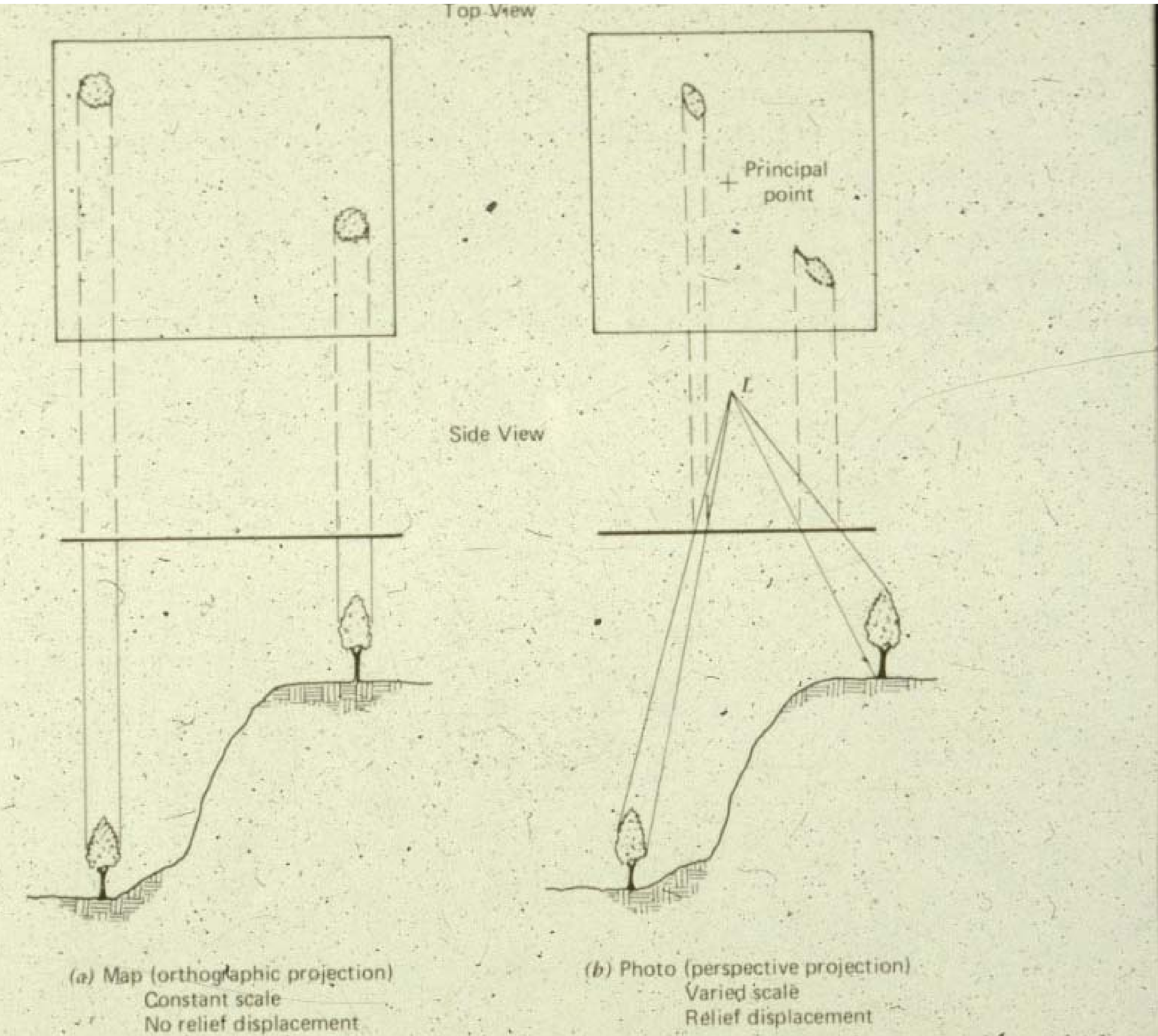


Figure 2.36 Comparative projective geometry of a map (*a*) and a vertical aerial photograph (*b*). Note differences in size, shape, and location of the two trees.

Digital Elevation Models

- Regular **array** of terrain elevations
- Normally stored as a grid of hexagonal pattern
- Created using
  - Ground survey data
  - Cartographic digitization of contour data
  - Photogrammetric measurements
- Other remote sensing approaches
  - Scanning LIDAR

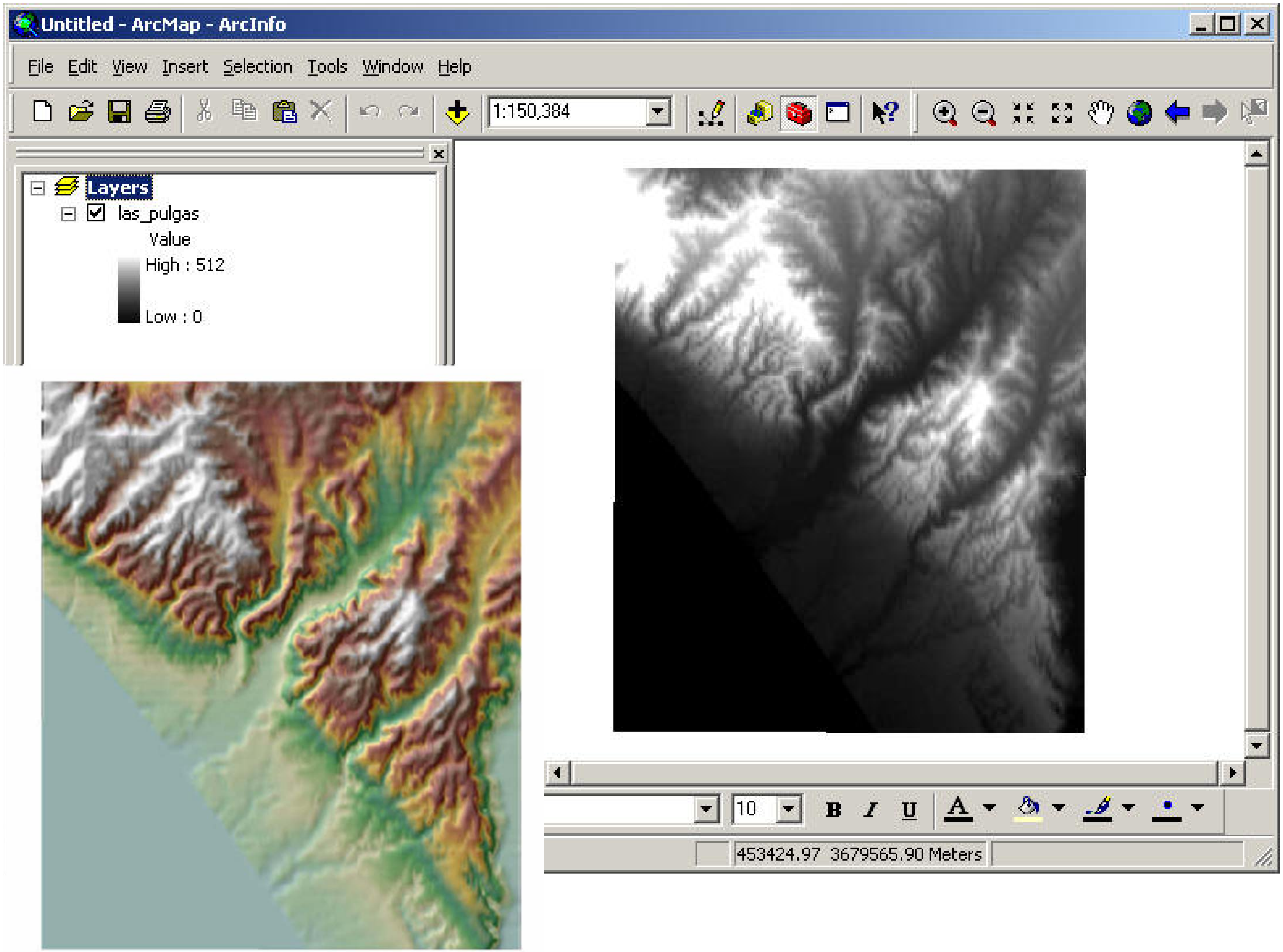
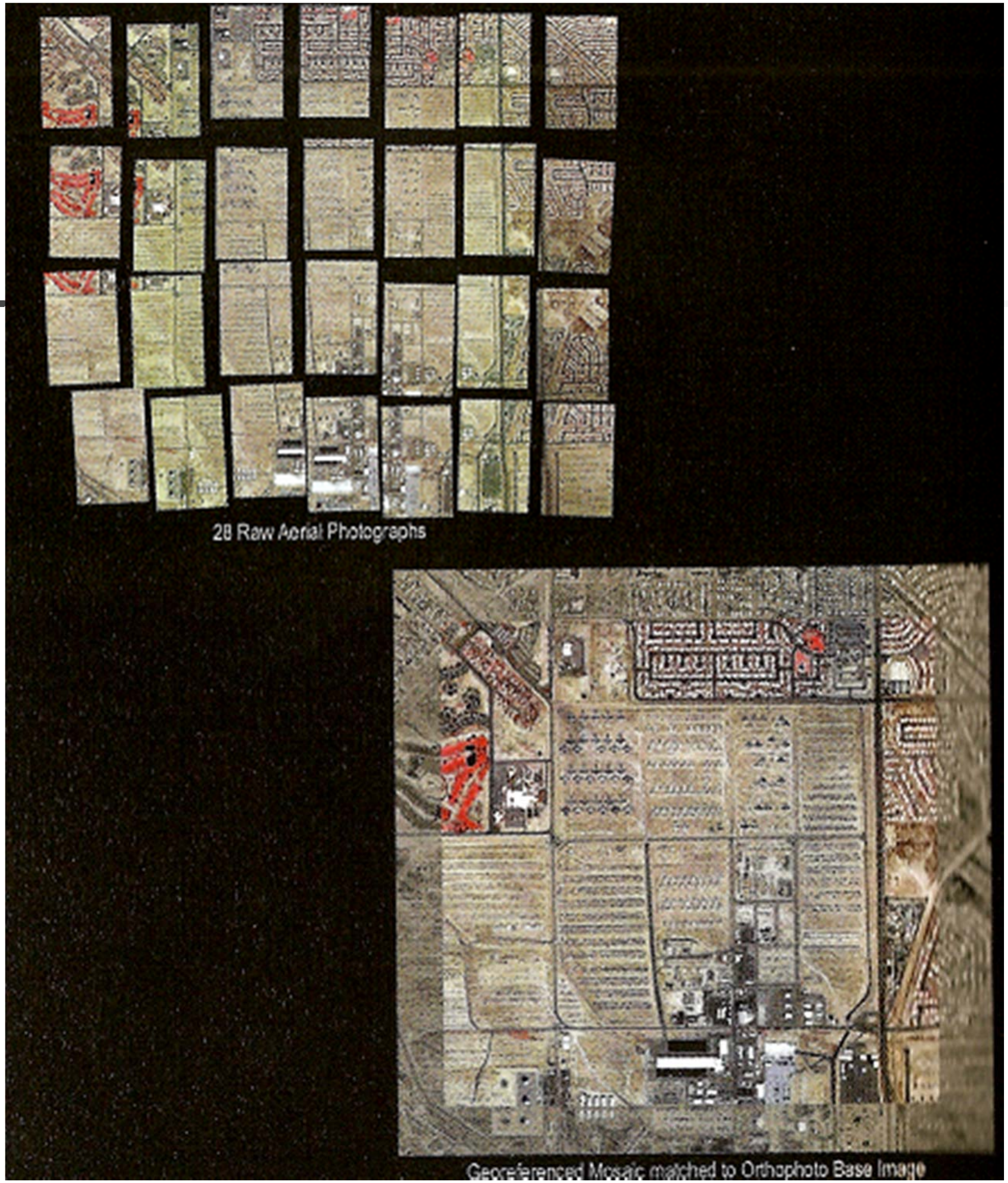

Untitled - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:150,384
Layers
las_pulgas
Value
High : 512
Low : 0
10
B I U
453424.97 3679565.90 Meters

Photo Mosaics

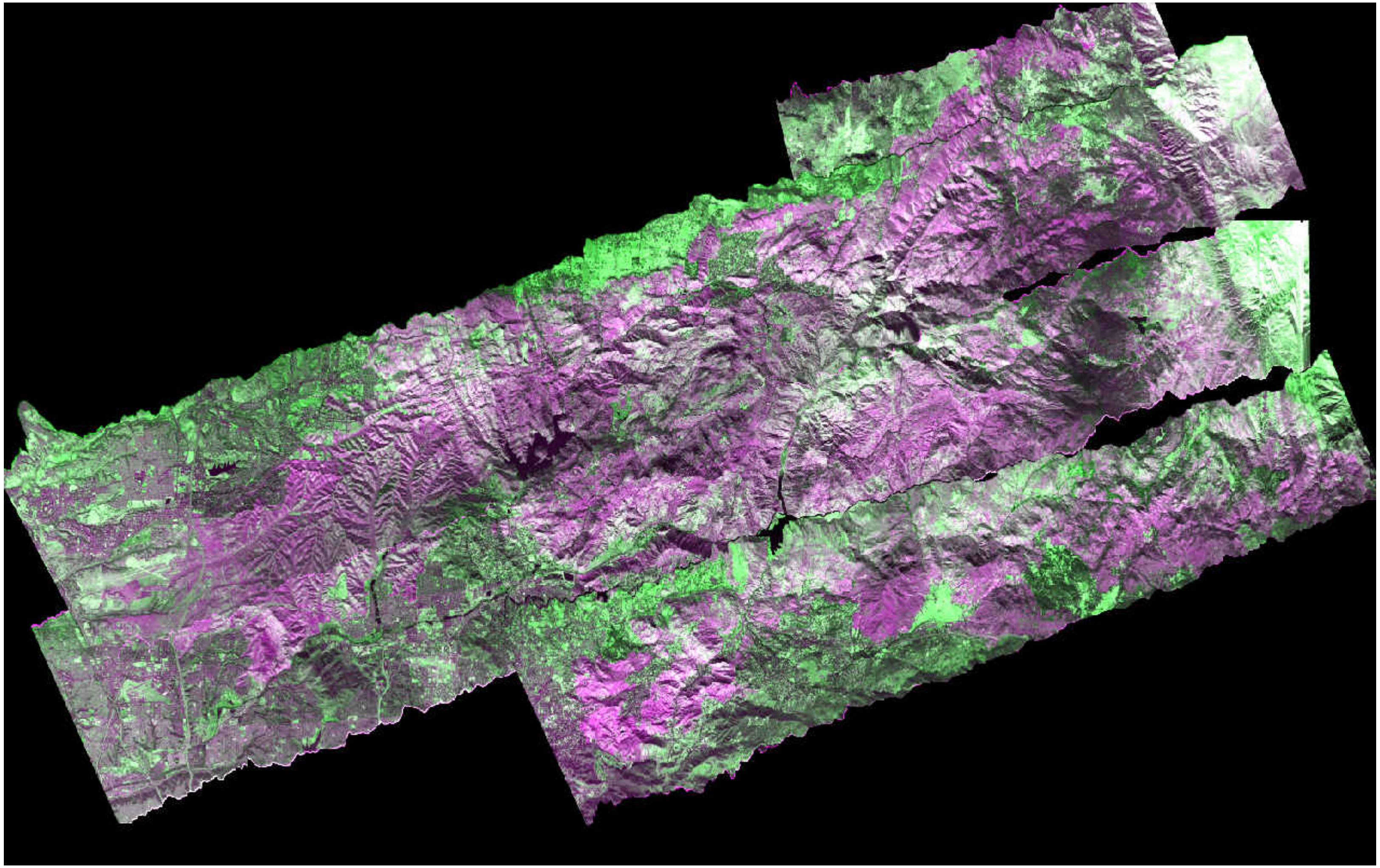
- Stitching together series of aerial photographs to cover large areal extents

- Uncontrolled
  - Photos are matched visually without ground control
  - Generally limited to center of images
  - Scale may not be constant
  - Unequal brightness between photos may make interpretation difficult

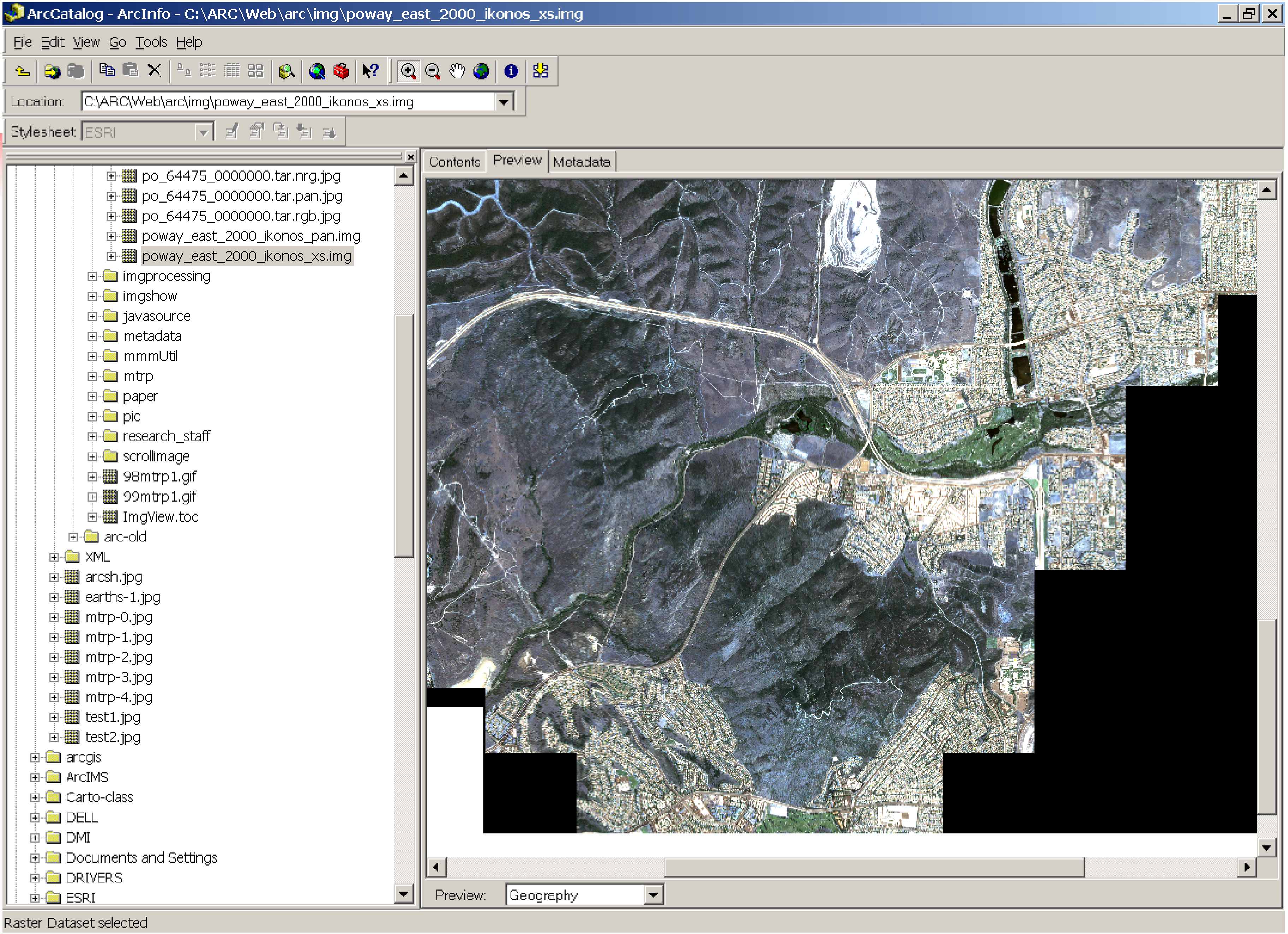

28 Raw Aerial Photographs
Georeferenced Mosaic matched to Orthophoto Base Image

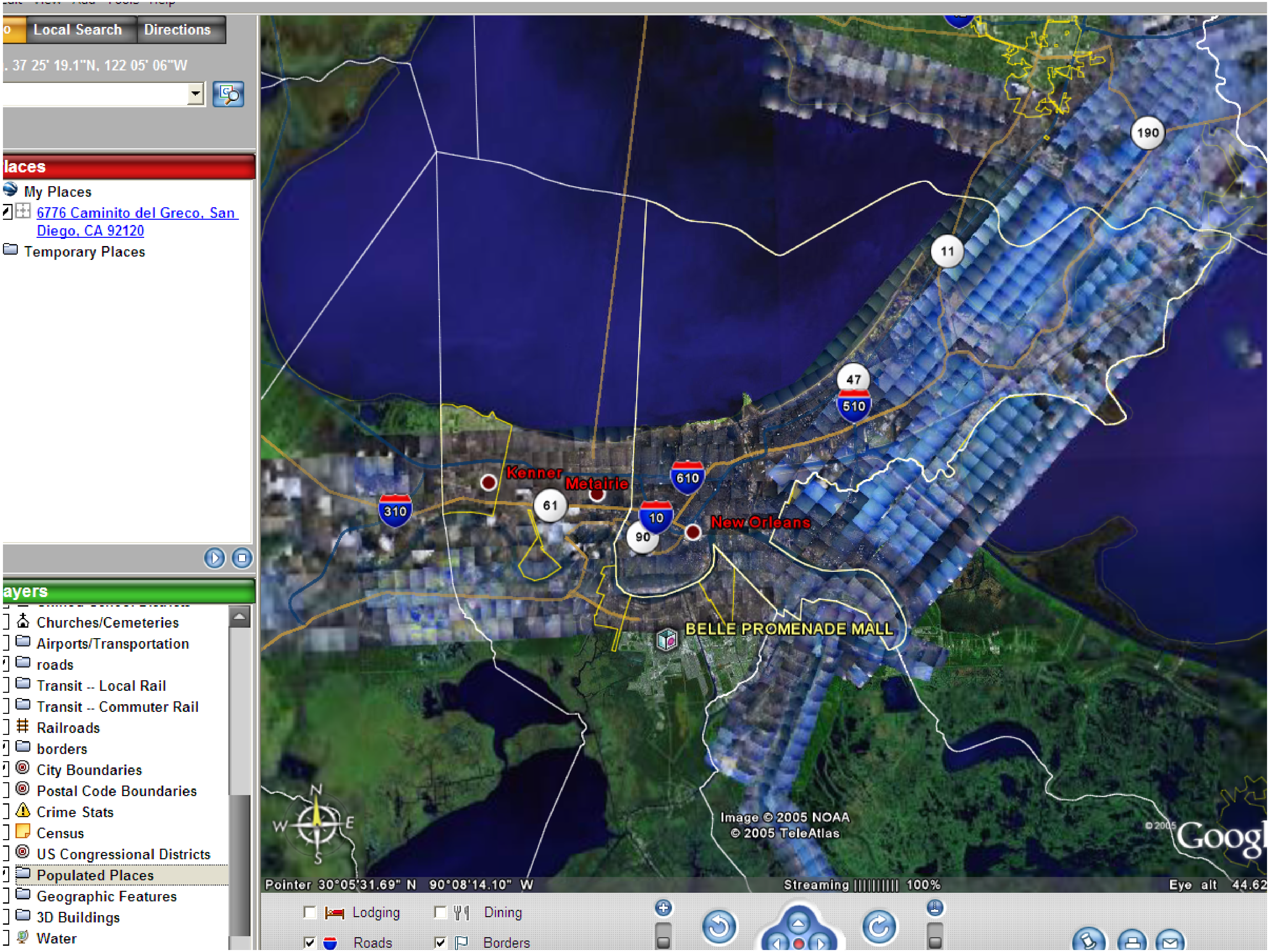
AIRDAS: (NASA Ames; airborne, Cessna 208)

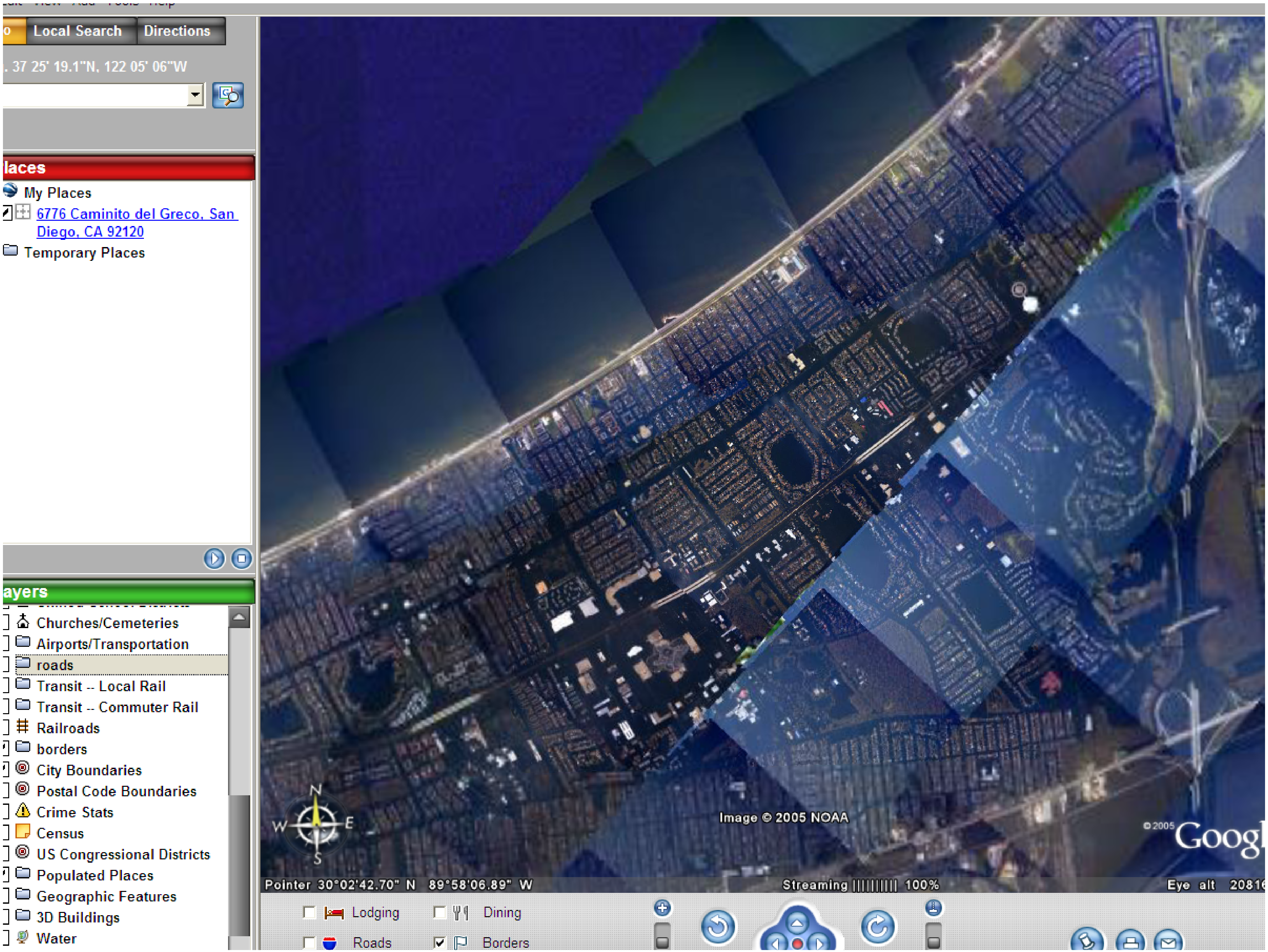
12 meter resolution; multispectral



•IKONOS 4-meter multipsectral (color infrared– 4 bands)




Local Search
Directions
. 37 25' 19.1"N, 122 05' 06"W
laces
My Places
6776 Caminito del Greco, San Diego, CA 92120
Temporary Places
ayers
Churches/Cemeteries
Airports/Transportation
roads
Transit -- Local Rail
Transit -- Commuter Rail
Railroads
borders
City Boundaries
Postal Code Boundaries
Crime Stats
Census
US Congressional Districts
Populated Places
Geographic Features
3D Buildings
Water
190
11
47
510
610
310
61
10
90
Kenner
Metairie
New Orleans
BELLE PROMENADE MALL
Image © 2005 NOAA
© 2005 TeleAtlas
Pointer 30°05'31.69" N 90°08'14.10" W
Streaming |||||||||| 100%
Eye alt 44.62
Lodging
Dining
Roads
Borders



Local Search
Directions
. 37 25' 19.1"N, 122 05' 06"W
laces
My Places
6776 Caminito del Greco, San Diego, CA 92120
Temporary Places
ayers
Churches/Cemeteries
Airports/Transportation
roads
Transit -- Local Rail
Transit -- Commuter Rail
Railroads
borders
City Boundaries
Postal Code Boundaries
Crime Stats
Census
US Congressional Districts
Populated Places
Geographic Features
3D Buildings
Water
Image © 2005 NOAA
© 2005
Googl
Pointer 30°02'42.70" N 89°58'06.89" W
Streaming 100%
Eye alt
N
W
E
S
Lodging
Dining
Roads
Borders