Resolutions of Remote Sensing

1. **Spatial** (*what area and how detailed*)

2. Spectral (what colors – bands)

3. Temporal (time of day/season/year)

4. Radiometric (color depth)

Spatial Resolution describes how much detail in a photographic image is visible to the human eye.

The ability to "resolve," or separate, small details is one way of describing what we call spatial resolution.
Spatial Resolution

Planimetric data – roads, buildings, driveways

Spatial Resolution

80 meter MSS w/ planimetric overlay
Spatial Resolution
30 meter TM w/ planimetric overlay

Spatial Resolution
10 meter SPOT w/ planimetric overlay
Spatial Resolution
1 meter DOQ w/ planimetric overlay

Spatial Resolution
Sub-meter data w/ planimetric overlay
## Comparison of Landsat Sensors

<table>
<thead>
<tr>
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<th>Multispectral Scanner (MSS) Landsat 1-5</th>
<th>Thematic Mapper (TM) Landsat 4 &amp; 5</th>
<th>Enhanced Thematic Mapper Plus (ETM+) Landsat 7</th>
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| **Spatial Resolution (meter)** | 79 x 79 | 30 x 30  
120 x 120 (TIR) | 15 x 15 (Pan)  
30 x 30  
60 x 60 (TIR) | 15 x 15 (Pan)  
30 x 30  
100 x 100 (TIRS) |
| **Temporal Resolution (revisit days)** | 18 (Landsat 1,2,3) | 16 | 16 | 16 |

### The best spatial resolution?

- **Panchromatic Orthophotograph**: 2 feet (0.6 m) resolution
- **Advanced Terrestrial Applications Sensor**: 7.5 meter resolution
- **Landsat Enhanced Thematic Mapper Plus**: 30 meter resolution
Resolutions of Remote Sensing

1. Spatial (what area and how detailed)
2. Spectral (what colors – bands)
3. Temporal (time of day/season/year)
4. Radiometric (color depth)

Spectral Response Curve

Energy patterns are recorded by sensors with separated spectral bands.

http://www.cas.sc.edu/geog/hslab/Rssc/mod1/empaths.gif
Electromagnetic Radiation (EMR)

Spectral Response Curve
Spectral reflectance curves, or spectral signatures, of different types of ground targets provide the knowledge base for information extraction.
Spectral Response Curve

Concept of Spectral Bands

Spectral responses from ground targets are recorded in separate spectral bands by sensors.

Spectral Resolution

- Number of spectral bands (red, green, blue, NIR, Mid-IR, thermal, etc.)
- Width of each spectral band
- Certain spectral bands (or combinations) are good for identifying specific ground features

- Panchromatic – 1 spectral band (B&W)
- Color – 3 spectral bands (RGB)
- Multispectral – 4+ discrete spectral bands (e.g. RGBNIR)
Landsat-7 Panchromatic Data (15 m)
Landsat-7 ETM+ Data (30 m), Bands 3, 2, 1 in RGB
Landsat-7 ETM+ Data (30 m), Bands 4, 3, 2 in RGB
Landsat-7 ETM+ Data (30 m), Bands 4, 5, 3 in RGB

Thermal Band (Landsat TM band 6)
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<td>7. 2.08-2.35 (MIR)</td>
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</table>

## Spectral Response Curve

### April and May Spectra for P. australis and S. patens

- **Blue**
- **Green**
- **Red**
- **NIR**

Discrete Spectral Coverage
Spectral Response Curves

April and May Spectra for *P. australis* and *S. patens*

![Spectral Response Curves Diagram](image)

### Spectral Cover of Landsat Sensors

**Band 1: 0.45-0.52μm (blue)**
Provide increased penetration of water bodies, as well as supporting analysis of land use, soil, and vegetation characteristics.

**Band 2: 0.52-0.60μm (green)**
This band spans the region between the blue and red chlorophyll absorption bands and therefore corresponds to the green reflectance of healthy vegetation.

**Band 3: 0.63-0.69μm (red).**
This is the red chlorophyll absorption band of healthy green vegetation and represents one of the most important bands for vegetation discrimination.
Spectral Cover of Landsat Sensors

- Band 4: 0.76-0.90μm (reflective infrared). This band is responsive to the amount of vegetation biomass present in the scene. It is useful for crop identification and emphasizes soil-crop and land-water contrasts.
- Band 5: 1.55-1.75μm (mid-infrared) This band is sensitive to the amount of moisture in plants and therefore useful in crop draught and in plant vigor studies.
- Band 6: 2.08-2.35μm (thermal infrared) This band measures the amount of infrared radiant flux emitted from surface.
- Band 7: 2.08-2.35μm (mid-infrared) This is an important band for the discrimination of geologic rock formation. It is effective in identifying zones of hydrothermal alteration in rocks.

EO-1: Hyperion – Hyperspectral sensor

An imaging spectrometer having a 30 meter ground sample distance over a 7.5 kilometer swath and providing 10nm (sampling interval) contiguous bands of the solar reflected spectrum from 400-2500nm.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>MULTISPECTRAL</th>
<th>HYPERSONAL</th>
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<tr>
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<td>Landsat 7 ETM+</td>
<td>EO-1 ALI</td>
<td>EO-1 HYPERION</td>
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<tr>
<td>Spectral Range</td>
<td>0.4 - 2.4 μm</td>
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<td>Spatial Resolution</td>
<td>30 m</td>
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<td>Swath Width</td>
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<td>37 Km</td>
<td>7.5 Km</td>
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<td>10 m</td>
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<tr>
<td>Number of Bands</td>
<td>7</td>
<td>10</td>
<td>220</td>
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*excluding thermal band
Hyperspectral Data

Example:

Hyperion hyperspectral sensor is capable of resolving over 220 continuous spectral bands at 10 nm interval (from 0.4 to 2.5 μm) with a 30 meter spatial resolution.
Resolutions of Remote Sensing

1. Spatial (what area and how detailed)
2. Spectral (what colors – bands)
3. Temporal (revisiting time interval)
4. Radiometric (color depth)

Temporal Resolutions

*Time of day/season image acquisition*

- Leaf on/leaf off
- Tidal stage
- Seasonal differences
- Shadows
- Phenological differences
- Relationship to field sampling
Seasonal Considerations

**Spring**
Landsat TM bands 4,5,3 in RGB

Seasonal Considerations

**Summer**
Landsat TM bands 4,5,3 in RGB
How much has changed?  
How severe was the damage?  
What would be the ecosystem responses?  

......

Repeat Coverage

- Revisit period for satellites – how often can you make a measurement for the same area
  - Landsat – 16 days (continuous collection)
  - Quickbird – varies (point-and-shoot)
  - MODIS – daily (continuous collection)

- Airborne images – collected as needed
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### Resolutions of Remote Sensing

1. **Spatial** (what area and how detailed)
2. **Spectral** (what colors – bands)
3. **Temporal** (time of day/season/year)
4. **Radiometric** (color depth)
Radiometric Resolution

Every time an image is acquired by a sensor, its sensitivity to the magnitude of the electromagnetic energy determines the **radiometric resolution**.

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

Imagery data are represented by positive digital numbers which vary from 0 to a selected power of 2. This range corresponds to the number of bits used for coding numbers in binary format. Each bit records an exponent of power 2.

The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded. Thus, if a sensor used 8 bits to record the data, there would be $2^8=256$ digital values available, ranging from 0 to 255.

12-bit data translate into 4096 potential grey levels, compared with only 256 grey levels in previous 8-bit instruments.
Digital Data Acquisition

Spatial Resolution (Pixel size)

Spectral Resolution (Bands)

Multispectral Digital Image

 rows (i) 1 2 3 4 5
 columns (j) 1 10 15 17 20 21 22 23 24 25

Brightness value range (often 8-bit) 255
Associated grayscale
white
gray
black

Picture element (pixel) at location row 4, column 4, band 1 has a brightness value of 24, i.e., \( BV_{4,4,1} = 24 \)
Energy patterns from a landscape are recorded by sensors with a spatial resolution and spectral/color combination and presentation.

To paraphrase a Zen Koan

In the beginning, before studying Remote Sensing,
Mountains were Mountains,
Rivers and Oceans were Rivers and Oceans, and
Forests were Trees.

After beginning my study of Remote Sensing,
I began to see that Mountains were no longer mountains, they were pyramid clusters of data points,
Rivers and Oceans were no longer Rivers and Oceans, they were unclassified regions, and
Forests were no longer Trees, they were percentages of various spectrograph reflections.

After attaining some small level of competence in remote sensing,
Mountains were once again Mountains,
Rivers and Oceans were once again Rivers and Oceans, and
Forests were once again Trees.

Mike Coppa, December 2015