Introduction to Remote Sensing
Use of Remote Sensing

- The unique perspective from above (space or airborne platforms) is ideal for understanding the changes to the environment in space and time.
- Information can be gathered without disturbing the site.
- Cultural resources can be monitored and protected.
- Natural resources can be explored and managed.
- Non-destructive Remote Sensing (RS) investigations range from site-specific to regional analysis (site detection; natural/cultural resources management).
- RS enables interdisciplinary research (geography, botany, forestry, soil sciences, hydrology, geology etc.). All contribute to a more complete understanding of the Earth, climate shifts, and how people make use of the environment and its resources.
Remote Sensing Systems

An orbiting platform containing imaging equipment gathers data from a specified section of the Earth and transmits the data to an earth-bound receiving station.

**Remote Sensing Process:** (A) energy source/illumination; (B) radiation and atmosphere; (C) interaction with target; (D) recording energy; (E) transmission, reception and processing; (F) interpretation and analysis; (G) application.
Remote Sensing

Definition:

Remote Sensing means obtaining information about an object without touching the object itself. It has two aspects:

- The technology of acquiring data through a device which is located at a distance from the object, and
- Analysis of the data for interpreting the physical attributes of the object.

Both aspects are intimately linked with each other. Measurement of phenomena or objects can be obtained with devices that are sensitive to force/energy components.
Advantages of RS Technology

Major advantages of satellite borne RS techniques over other methods of ground investigations are:

1. **Synoptic overview**: Remote sensing permits the study of various spatial features in relation to each other, as well as delineation of regional features/trends/phenomena.

2. **Feasibility aspect**: as some areas may not be accessible to ground survey, the only feasible way is from remote-sensing platforms.

3. **Time saving**: the technique saves time and manpower.

4. **Multidisciplinary applications**: the same remote sensing data can be used by researchers/workers in different disciplines, like archaeology, geology, forestry, land use etc. => overall benefit to cost ratio is better.
Earth Observing Satellites

NASA
NOAA
USGS
Brazilian Space Agency (INPE)
Canadian Space Agency
Centre National d'Etudes spatiales (CNES, France)
Chinese National Space Admin.
European Space Agency (ESA)
Japan Aerospace Exploration Agency (JAXA)
Indian Remote Sensing Agency
Commercial satellites and many others
Sensor Characteristics

Optical and Infrared Sensors
ASTER
SPOT
LANDSAT
ALOS AVNIR-2
Quickbird
IKONOS

Microwave Sensors
ENVISAT-1 ASAR
ALOS PALSAR
RADARSAT
Shuttle Imaging Radar

Hyperspectral Sensors
DAIS 7915
HYMAP
Hyperion
Proba-1 CHRIS
Solar irradiance at the top of the atmosphere (solid line) and at sea level (dotted line). Differences are due to the atmospheric effects.
**Solar Spectrum**

<table>
<thead>
<tr>
<th>Wavelength (μm)</th>
<th>Spectral Region</th>
<th>Sensors</th>
<th>Photomultipliers</th>
<th>Cameras</th>
<th>Infrared Radiometers</th>
<th>Microwaves</th>
<th>Thermal Infrared</th>
<th>TV/Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10^{-1}</td>
<td>Ultraviolet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.4</td>
<td>Visible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.7</td>
<td>Near &amp; Mid Infrared</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10.0</td>
<td>Thermal Infrared</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10^{-2}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10^{-3}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10^{-4}</td>
<td>Microwave</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10^{-5}</td>
<td>Microwave Radiometers and Radar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10^{-6}</td>
<td>TV/Radio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**What wavelengths say about the past.**

- **Blue:** Information on soil and plant types, forest types, buildings, roads, coasts, and water.
- **Green:** Borders between types of vegetation and tracts of buildings and roads.
- **Red:** Chlorophyll absorption for plant identification and man-made features like buildings and roads.
- **Near-Infrared:** The amount of biomass, vegetation types, water body identification, and degrees of soil moisture.
- **Mid-Infrared:** The amount of moisture in vegetation and soils. Distinguishable differences among types of rocks.
- **Thermal Infrared:** Vegetation stress differences, soil moisture and relative amounts of heat.
- **Microwave:** Buried artifacts in arid regions (water absorbs microwaves). Man-made objects tend to reflect microwaves.
Imaging System

Analog - Digital Conversion

$L_{\text{surface},i,j,k}$
Landsat 1 was the first Earth-observing satellite launched (in 1972) to space for civilian use. It carried the multispectral MSS sensor.
Sensor Bands & Spectral Curves

Sensor Bands

Reflectance

Wavelength, um

Simulated Landsat TM Spectrum

Kaolinite Laboratory Spectrum
Figure 2.2 Angular instantaneous field of view (IFOV), \( \alpha \), showing the projection XY on the ground. Note XY is the diameter of a circle.

Figure 2.3 Instantaneous field of view based on the amplitude of the point spread function (PSF).
IFOV (instantaneous field of view) is defined as the area on the ground that is visible by the instrument from a given altitude at a given instant of time.

IFOV is influenced by:
1. Changes in orbit altitude (pixel size of a given sensor varies);
2. The point spread function PSF (the way a sensor sees a reflective point source; recorded intensity distribution of the signal).

<table>
<thead>
<tr>
<th>Spatial Resolution</th>
<th>Spectral Resolution</th>
<th>SNR (Signal-to-Noise Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiometric Resolution</td>
<td>←→</td>
<td>IFOV (Instant. Field of View)</td>
</tr>
</tbody>
</table>

High spatial resolution (small pixel size) → smaller IFOV (lower SNR)
High spectral resolution (many narrow bands) → lower SNR (more noise)
High radiometric resolution (bytes per pixel) → larger IFOV (lower spatial res.)
## Digital Image

### Gray Levels

<table>
<thead>
<tr>
<th>Row</th>
<th>193</th>
<th>194</th>
<th>195</th>
<th>196</th>
<th>197</th>
<th>198</th>
</tr>
</thead>
<tbody>
<tr>
<td>244</td>
<td>2139</td>
<td>2108</td>
<td>2108</td>
<td>2122</td>
<td>2108</td>
<td>2108</td>
</tr>
<tr>
<td>245</td>
<td>2145</td>
<td>2124</td>
<td>2124</td>
<td>2133</td>
<td>2120</td>
<td>2120</td>
</tr>
<tr>
<td>246</td>
<td>2145</td>
<td>2124</td>
<td>2124</td>
<td>2133</td>
<td>2120</td>
<td>2120</td>
</tr>
<tr>
<td>247</td>
<td>2126</td>
<td>2106</td>
<td>2106</td>
<td>2100</td>
<td>2113</td>
<td>2113</td>
</tr>
<tr>
<td>248</td>
<td>2074</td>
<td>2068</td>
<td>2068</td>
<td>2091</td>
<td>2097</td>
<td>2097</td>
</tr>
<tr>
<td>249</td>
<td>2074</td>
<td>2068</td>
<td>2049</td>
<td>2078</td>
<td>2084</td>
<td>2084</td>
</tr>
<tr>
<td>250</td>
<td>2057</td>
<td>2049</td>
<td>2049</td>
<td>2078</td>
<td>2084</td>
<td>2084</td>
</tr>
<tr>
<td>251</td>
<td>2077</td>
<td>2057</td>
<td>2057</td>
<td>2083</td>
<td>2069</td>
<td>2069</td>
</tr>
<tr>
<td>252</td>
<td>2126</td>
<td>2088</td>
<td>2102</td>
<td>2102</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>253</td>
<td>2126</td>
<td>2107</td>
<td>2119</td>
<td>2119</td>
<td>2136</td>
<td>2136</td>
</tr>
<tr>
<td>254</td>
<td>2135</td>
<td>2107</td>
<td>2119</td>
<td>2119</td>
<td>2136</td>
<td>2136</td>
</tr>
</tbody>
</table>

### Digital Numbers

Pixel Values
Image Structure
**Spectral Reflectance Curve:** describes the type or condition of the surface material, also called spectral signature of a specific material; it may change over time. Many earth surface features can be identified, mapped, and studied on the basis of their spectral characteristics.
Spectral reflectance curves for two types of green vegetation, light and dark soils, and clear and turbid water.

Typical reflectance and absorption characteristics of green vegetation.
MULTI/HYPERSPECTRAL IMAGING SYSTEM
Digital image processing techniques can be divided into four categories:

- **Image restoration**: involves processes to remove systematic errors in data such as noise or geometric distortion. Procedures include restoring periodic line dropouts, filtering random noise, and correcting for atmospheric scattering. They are also called *preprocessing* methods.

- **Image enhancement**: includes any alteration of the data that improves the interpretability of the image information. Procedures include contrast stretching, edge enhancement, false color composites and image transformations.

- **Image extraction**: involves spectral data analysis and the application of statistically based decision rules for determining feature identification. Procedures include density slicing, principal component separation and pattern recognition (classification).

- **Image merging**: aids interpretation by manipulating and merging several data sets together (multi-source and multi-temporal data).
Remote sensing analysis involves identification of various targets (environmental and/or artificial features). Recognizing targets is the key to interpretation and information extraction.

Visual elements used to differentiate between targets and their background:

- **Tone**: relative brightness or color of objects
- **Shape**: general form, structure or outline of individual objects
- **Size**: is a function of scale and affects level of extractable information
- **Pattern**: spatial arrangement of visibly discernible objects
- **Texture**: arrangement and frequency of tonal variation (rough texture → gray levels change abruptly in a small area; smooth texture → little tonal variation)
- **Shadow**: provides an idea of the profile and relative height of targets
- **Association**: relationship between recognizable objects in proximity to target
Shapes
ETM MULTI – 30m

ETM PAN – 15m

KVR-1000 2 m
Texture (Urban Area)
Shadows

Washington, D.C., IRS

Alcalá, KVR-1000

\[ h = \frac{ls}{\tan \theta} \]
Association
**Visual image interpretation:** relies on a series of interactions involving shapes, patterns, assemblages of tones and colors, texture, scale and context.

Four steps:

1. Detection (perception that something of interest exists)
2. Localization (defining the position of this ‘thing’)
3. Recognition (that it is a particular category of ‘thing’)
4. Identification (of its unique attributes/features)