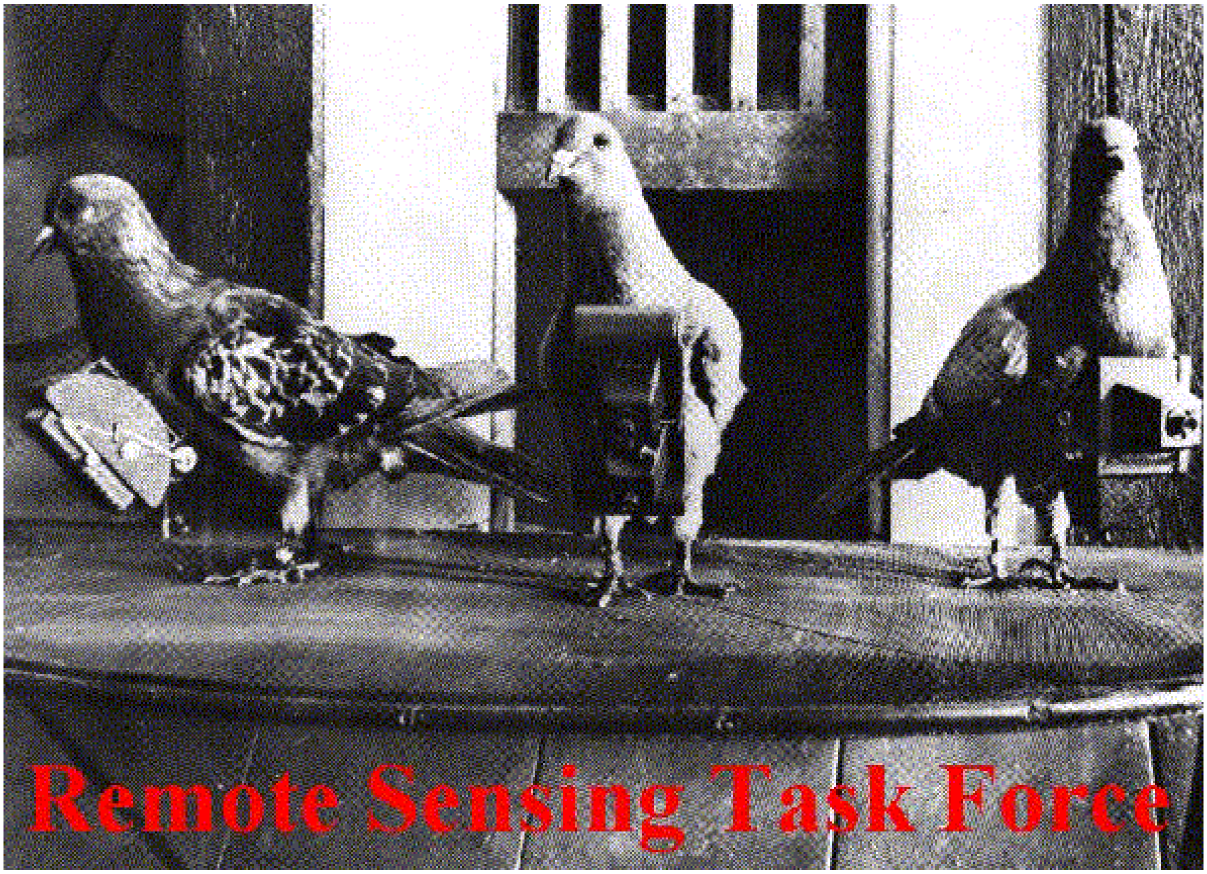
Remote Sensing (Part 1)



Remote Sensing

- The technique of obtaining information about objects through the analysis of data collected by special instruments not in physical contact with objects of investigation
- Figure 3.3 (textbook)
- Detection and recording instruments used include photographic cameras, mechanical scanners, and radar systems.
- The energy measured in remote sensing may be electromagnetic radiation including: visible, infrared, microwave, ultraviolet, or sound energy propagated through water.

History of Remote Sensing

- Early 1800's – Louis Daguerre – beginning of photography
- 1850s- 1900's – Photographs taken by captive balloons, pigeons
- World War I – Aerial photography
- 1920s – Photogrammetry
  - Routine applications for government programs
  - Mapping, surveys, etc.
- World War II – Use of electromagnetic spectrum increases to include infrared and microwave

Santa Monica College
Fall 2000

- "Cold War" – extensive use of reconnaissance techniques – launching of 'spy' satellites
- 1960s –TIROS – meteorological satellite
  - First use of term "remote sensing"

History of Remote Sensing

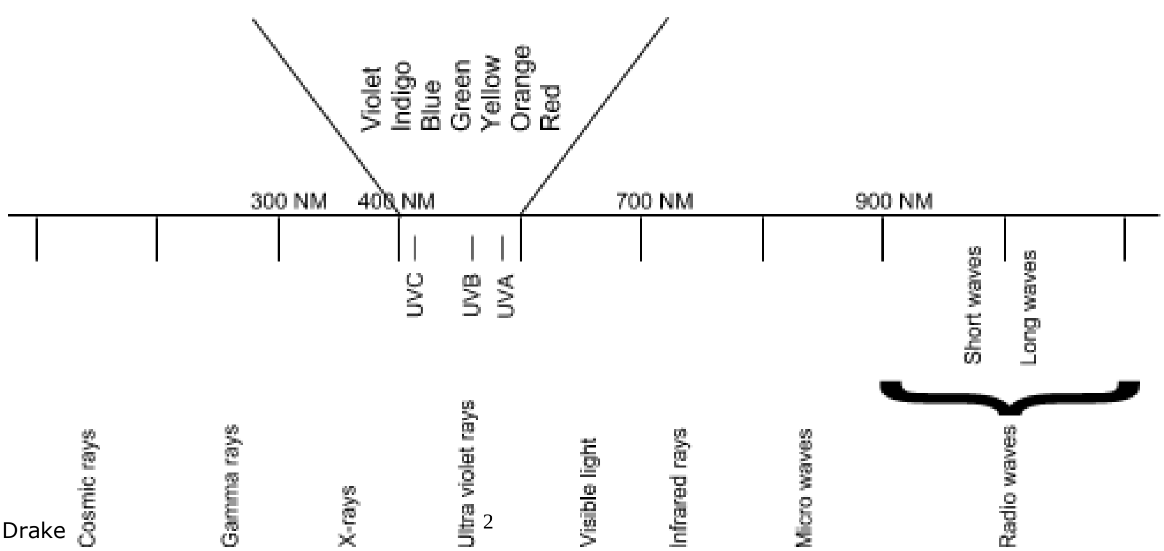
- 1972 – Landsat 1 – first Earth-orbiting satellite for observation of Earth's land area
  - Digital image processing development
- 1975 – Landsat 2 launched
- 1978-1984 – Landsat 3,4, and 5 launched
- 1980s – SPOT satellite launched
- 1990s – hyperspectal systems designed and launched (>100 spectral bands)

Remote Sensing Platforms

- The platform is the vehicle on which the sensor is carried.
- A variety of sensors have been used over time including:
  - Hand held (cameras or other instrument)
  - "Cherry Picker" – a platform similar to ones used by utility workers
  - Balloon – tethered and suspended over a target region.
  - Wildlife –Homing pigeons had time delay cameras strapped to them – used during wars
  - Radio-control models – both fixed and rotary-winged models.
  - Low-altitude aircraft – ultralights can fly up to 5000 feet with light payloads
  - High-altitude aircraft – U2 can fly at altitude of 20 km in upper atmosphere
  - Low- middle- high spacecraft – introduce concept of multilevel remote sensing

Electromagnetic Energy

- A dynamic form of energy created by the acceleration of electrical charge across a 'field'.
- The Sun is the major supplier of EM energy incident on the Earth – providing energy needed for terrestrial life and the natural processes operating in the atmosphere, water and upper layers of solid Earth.



Energy Transfer Methods

- Energy – the ability or capacity to do work on matter
- Energy is transferred from one object to another as a result of work
- Efficiency of energy transfer dependent on proximity of two objects to each other
- Three forms of energy transfer include:
  - Conduction – molecule-to-molecule transfer of energy
  - Convection – energy transfer by currents in a fluid (liquid or gas)
  - Radiation – energy transfer by waves of radiant energy that release energy upon contact with an object

Types of Wave Motion – Radiant Energy

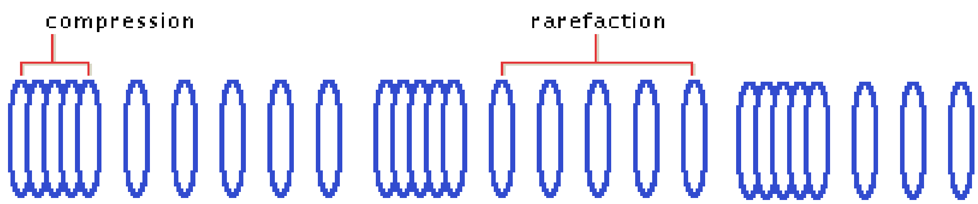


Figure 1: Longitudinal Wave

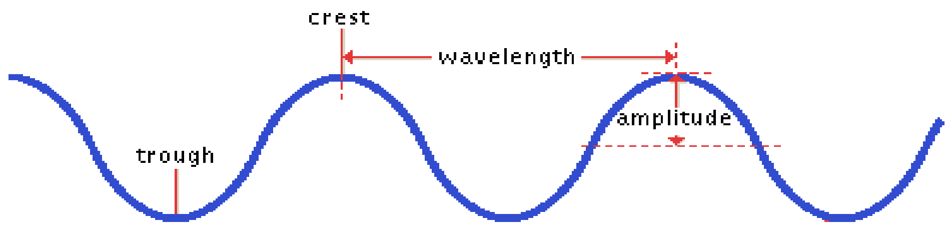
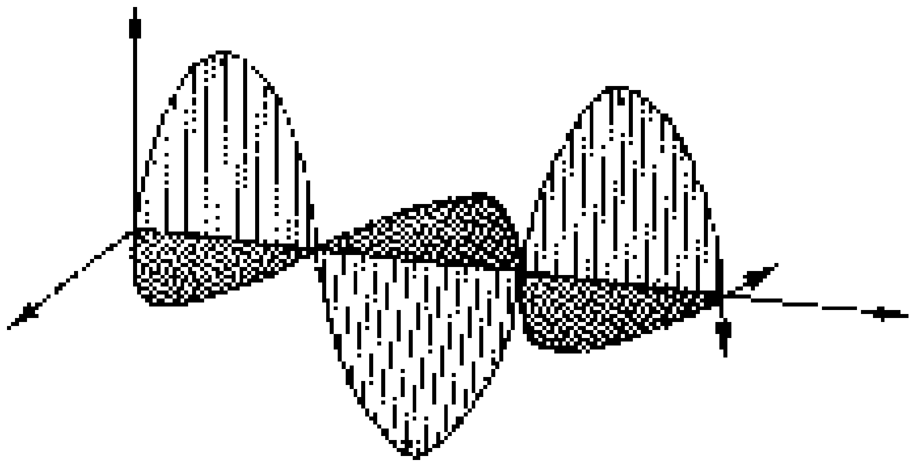


Figure 2: Transverse Wave

Electromagnetic Radiation

- Electromagnetic Radiation (EMR) is EM energy detected when it comes into contact with an object
- EMR travels in a **straight path** at the speed of light – postulated by Albert Einstein in 1905 as ~ 300,000 km/sec or ~186,000 miles/sec
- The Wave Model in the previous slide demonstrates how EMR can be carried by a series of continuous waves equally and repetitively carried in time (harmonic waves).
- The wave pattern is in the form of two fluctuating fields – one electric and the other magnetic

Electromagnetic Energy Radiation Waves

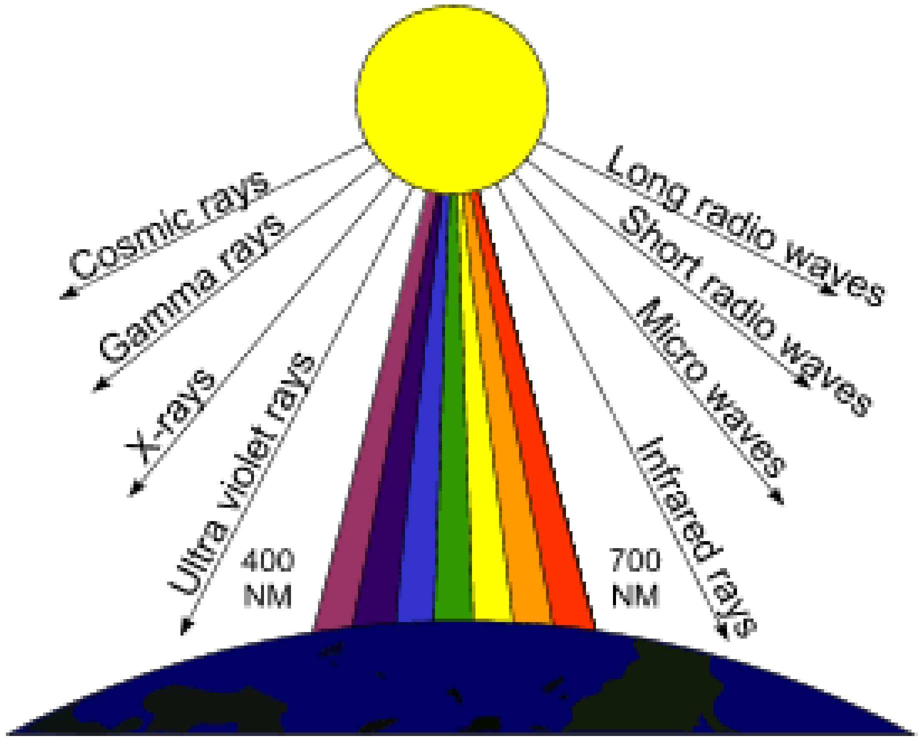


Electromagnetic Spectrum – Spectral Bands

- The entire range of EMR comprises the electromagnetic spectrum subdivided in divisions called **spectral bands**, that share common characteristics
- The boundaries of the visible band are defined by the wavelength of human vision, while boundaries for other bands may be arbitrarily defined.
- Wavelength (frequency) is normally defined in either Angstroms (10^{-10}m), nanometers (10^{-9}m), or micrometers (10^{-6}m)
- The visible portion of the EM Spectrum ranges from 0.4μm to 0.7μm
- For remote sensing applications in the ultraviolet, visible, and infrared spectral regions, *micrometers* is the preferred unit of measurement.

Remote Sensing Spectral Regions

- The most common bands of the EM spectrum used for remote sensing are ultraviolet (UV), visible, infrared (IR) and microwave.
- The visible spectrum is composed of three equal-wavelength segments that represent the additive primary colors (a color that cannot be made from any other).
  - Blue – 0.4 – 0.5 μm
  - Green – 0.5 - 0.6 μm
  - Red – 0.6 – 0.7 μm



Spectral Bands – Infrared and Microwave

- The Infrared (IR) band has wavelengths between the red light of the visible band at 0.7µm and microwaves at 1,000 µm (1 cm).
- The Infrared band is divided into the
  - Near IR – 0.7 µm – 1.5 µm
  - Middle IR – 1.5 µm –5.6 µm
  - Far IR – 5.6 µm – 1,000 µm
- The microwave band falls between the infrared and radio bands and has a wavelength range extending from approximately 0.1 cm to 1.0 m (meters)
  - Microwave radiation can pass through clouds, precipitation, tree canopies and dry superficial deposits, such as sand.

Radiation – Matter Interactions

- When EMR strikes matter **–** it can be **transmitted, reflected, scattered,** or **absorbed**
  - Interaction depends on (1) composition and physical properties of matter (2) wavelength or frequency of radiation (3) angle at which radiation strikes surface
  - **Transmission** – radiation passes through matter without measurable attenuation – it's as if the matter were 'transparent' to the radiation. Refraction or diffraction occurs when EMR passes through matter of different densities creating a change in velocity or wavelength

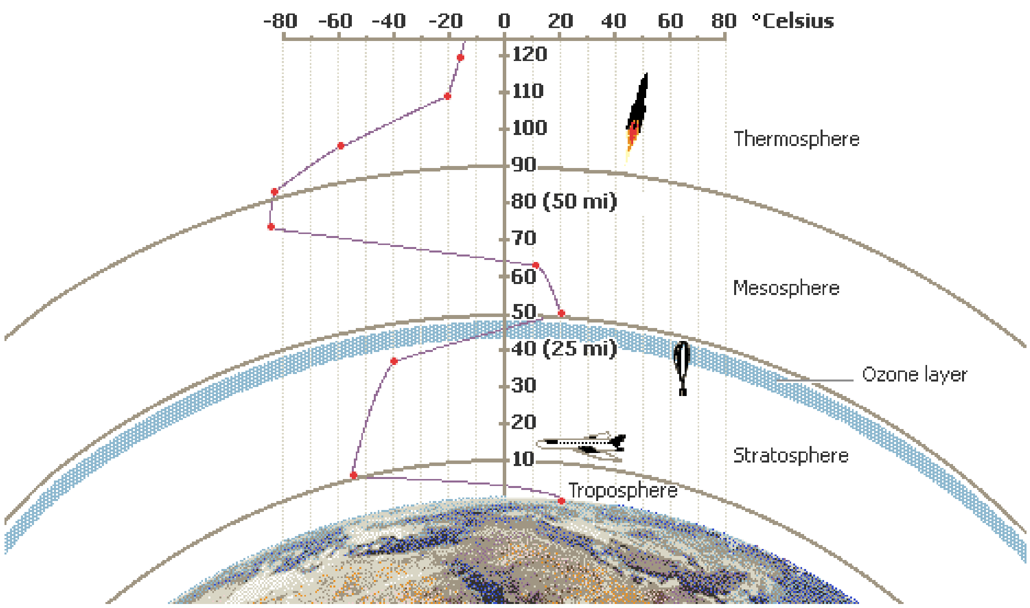
Radiation – Matter Interactions

- **Reflection** – the process of radiation 'bouncing off' a smooth surface (a spectral reflector) with no change to velocity or wavelength. The reflection occurs in a single, predictable direction as the angle of reflection equals the angle of incidence.
- **Scattering** – radiation is dispersed or spread out unpredictably in all directions, including back in the direction of origination. Scattering more common than reflection and occurs with surfaces that are rough relative to the wavelengths of the radiation (surfaces are called diffuse reflectors). Velocity and wavelength are not affected.
- **Absorption** – Radiation taken in by matter that is opaque to radiation. Some of radiation converted to heat energy, which is subsequently emitted at thermal infrared wavelengths.

EMR – Atmosphere Interactions

- EMR travels through empty space without modification, however, at certain wavelengths, travel may be restricted.
- **Transmission bands**, or **"atmospheric windows**" are areas of the spectrum that pass unimpeded through the atmosphere.
- **Absorption bands** of the EMR represent wavelengths that are totally or partially blocked by the atmosphere
- EMR interactions with the atmosphere include
  - Absorption or re-radiation at longer wavelengths (heat energy)
  - Reflection or Scattering
  - Direct transmission in a straight-line path

Layers of the Atmosphere

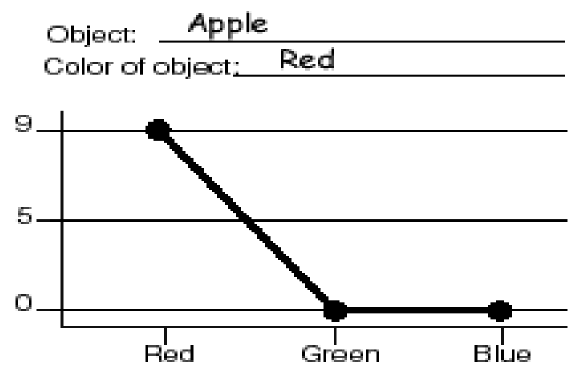


Atmospheric Absorption and Scattering

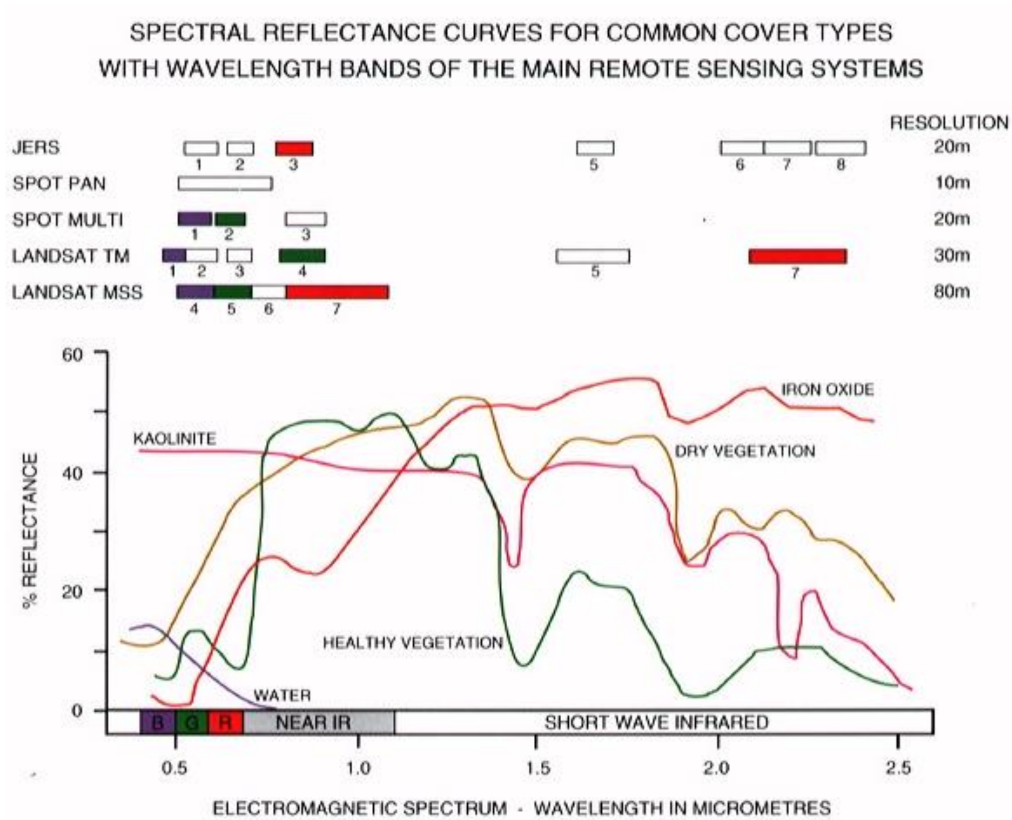
- **Absorption** – Most significant absorbers of EMR include Oxygen, Nitrogen, Ozone, Carbon Dioxide and water vapor absorbing up to 16% of short-wave solar radiation
- **Scattering** – EMR within certain sections of UV, Visible and Reflected IR bands in impeded by scattering.
- Three main types of scattering important to remote sensing:
  - **Rayleigh scattering** – blue wavelengths scattered 5 times as often as red. Creates blue sky
  - **Mia scattering** –smoke, dust, volcanic material and salt crystals scatter longer radiation wavelengths
  - **Nonselective scattering** – suspended aerosols (with diameters at least 10x larger than wavelengths) including all Mia particles and water droplets and ice crystals, scatter longer radiation wavelengths

Spectral Signatures

- All objects (natural or synthetic) reflect and emit electromagnetic radiation over a range of wavelengths characteristic of the object:distinctive reflectance and emittance properties is **spectral signature** of object
- Remote sensing depends upon operation in wavelength regions of spectrum where these **spectral signatures** occur for identification purposes.

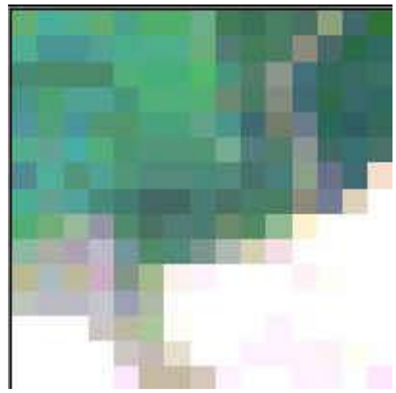


Spectral Signatures



Spectral Signatures

- The characteristic reflectance properties of surface features (for example soil, vegetation) are measured by the sensor and stored as digital numbers.
- Similar objects exhibit similar reflection values, consequently, their appearance when displayed as images and the statistical distribution of pixel values in the different bands, in the *feature space*, is similar.
- This typical pattern of reflection in different wavelength regions yields a distinguishable spectral signature, making different surface types distinguishable.
- Ideally, each object class is characterized by a corresponding *spectral signature*.



Remote Sensor Systems

- Passive Remote – detect only reflected sunlight or thermal IR and microwaves
  - Photograph camera
  - Electro-optical
  - Passive microwave
- Active Remote – beam own artificially produced energy to a target and record reflected component
  - Radar
  - Sonar

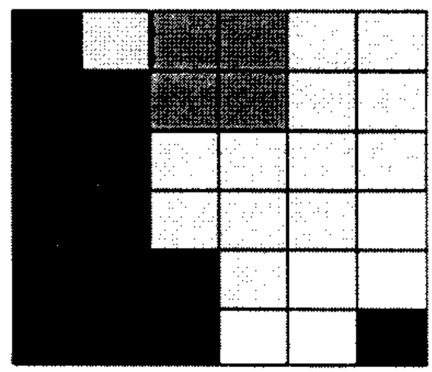
Digital Image

- A digital image comprises a series of numbers that represent the amount of EMR emanating from a small region on the surface.
- A series of these small regions is "pieced" together in a grid pattern to form an image.
- The values recorded for each pixel are termed *brightness values* (BV) or *digital numbers* (DN)

Digital Image

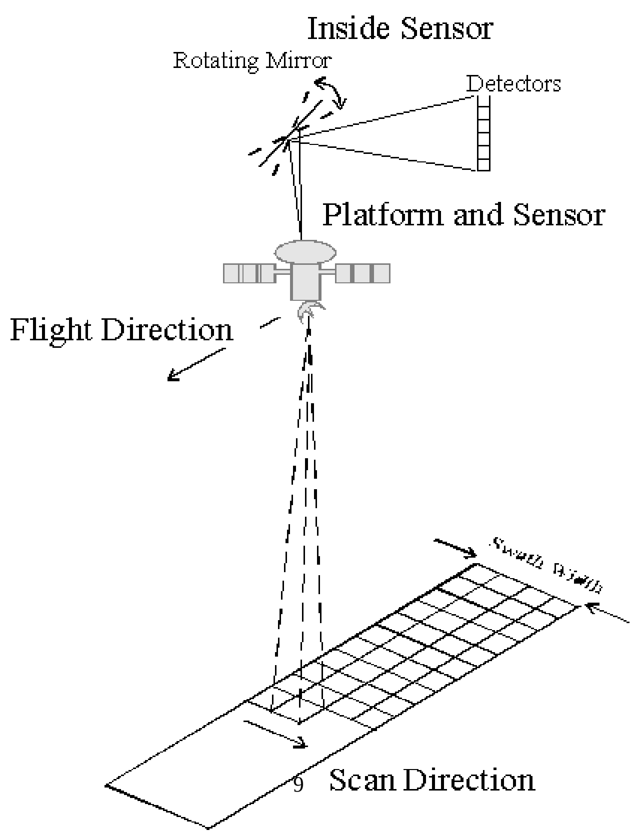
- The pixel size determine the *spatial resolution* of the system – smaller pixel equals finer resolution

32	62	45	45	54	54
32	32	45	45	54	54
32	32	54	54	54	54
32	12	54	54	54	99
12	12	12	54	99	99
12	12	12	99	99	0



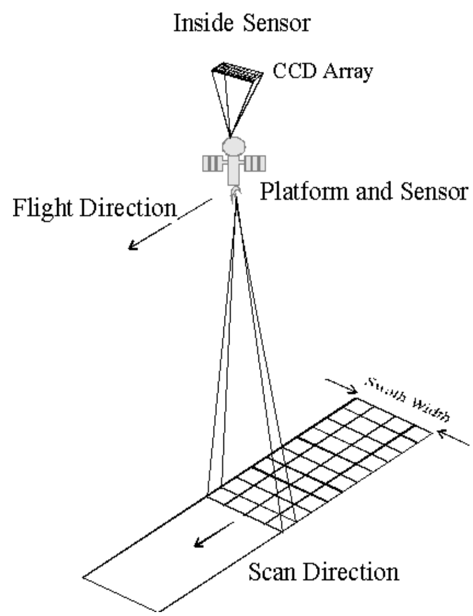
Imaging Systems

- Most imaging systems today use either a *whisk broom scanner, a push broom scanner,* or *a 2D CCD array.*
- A whisk broom scanner utilizes a mirror that sweeps in a direction perpendicular to the flight path.
  - As the mirror sweeps across the path, EMR is directed via the optics into a series of mirrors and prisms.
  - The EMR is split into its various wavelengths and focused onto detectors.
  - Detectors measure EMR from point on ground, storing the value as as digital number.
  - Image is built of multiple rows of discrete ground segments called "pixels"
  - Landsat System uses this approach



Imaging Systems

- A push broom scanner uses a one-dimensional array of charged couple devices aligned in a direction perpendicular to the flight direction.
- Each CCD is aimed at a specific point on the ground with the neighboring CCD viewing the neighboring piece of ground.
- The entire line of image data (line of pixels) is acquired at one time.
- The SPOT system uses this approach



Imaging Systems

- 2D CCD arrays use a chip onto which is set a number of rows and columns of individual CCDs.
- These systems take a snapshot of a region at a one in a process similar to a camera (digital cameras are an example of this type of sensor).

Data Acquisition Concepts

- Success of remote sensing studies improved by *multi-concept* of data acquisition and analysis
- Components include:
  - **Multistage** - data acquired from different platforms
  - **Multilevel** –data acquired at different altitudes
  - **Multiscale -** data depicted at different degrees of detail
  - **Multistations** – collection of data in successive, overlapping photographs (3-D imagery)
  - **Multispectral** –data collected in different areas of spectrum
  - **Multisensor** – data collected by different sensors
  - **Multitemporal** – data collected at different times
  - **Multisource** – data combined with additional ancillary data (maps, in-situ data collection, instrument data, etc.)

Data Acquisition and the EMR

- Remote sensing instruments cannot sample the entire EM spectrum.
- Instead – they sample particular regions of the spectrum over a range of wavelengths
- For example:
  - Landsat MSS
    - 0.5 – 0.6 (visible green)
    - 0.6-0.7 (visible red)
    - 0.8-1.1 (Near Infrared)

Display of Digital Images

- For satellite images – there are choices of "bands" to be displayed
- Bands can be displayed as single channel using *grey scale* or *pseudo-color*.
- Displaying three bands at once (using standard CRT) and variations of red, green and blue, can produce *color composite* representation.
- Assigning "true colors" to the Landsat TM bands may produce a true color representation.
- More commonly, false color images will result (I.e., infrared images)

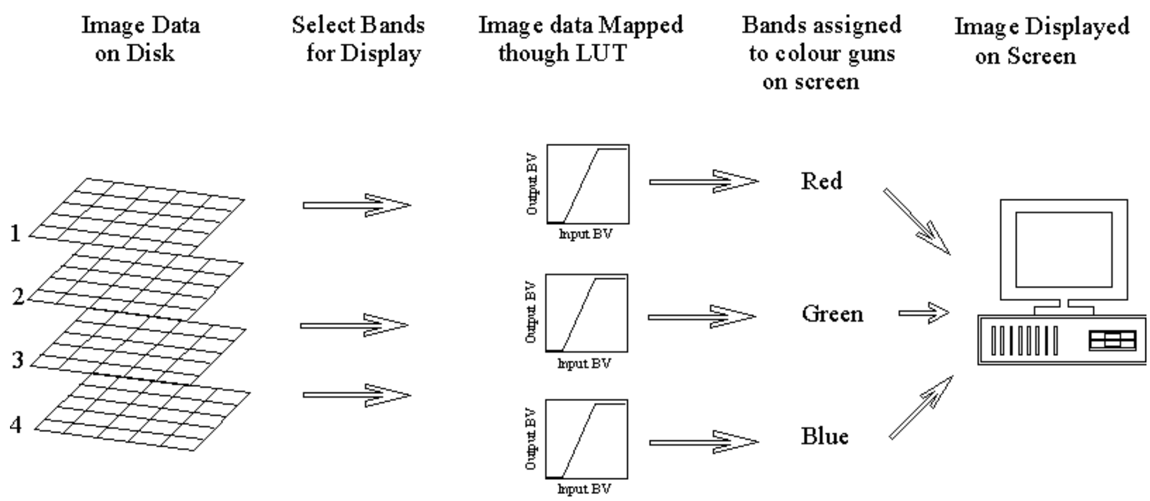


Image display using 24 bit colour board.

Satellite and Sensor	Band details (microns)	Spatial Resolution
Landsat MSS	1. 0.5 - 0.6 Green 2. 0.6 - 0.7 Red 3. 0.7 - 0.8 NIR 4. 0.8 - 1.1 NIR	80 m
Landsat TM	1. 0.45 - 0.52 Blue/green 2. 0.52 - 0.60 Green 3. 0.63 - 0.69 Red 4. 0.76 - 0.90 NIR 5. 1.55 - 1.75 MIR 6. 10.40 - 12.50 TIR 7. 2.08 - 2.35 MIR	30m except band 6 (thermal) which is 120m
SPOT XS	1. 0.53 - 0.6 Green 2. 0.6 - 0.7 Red 3. 0.7 - 1.0 NIR	20 m
SPOT PAN	1. 0.53 - 0.68 Visible	10 m (panchromatic)