Some Basic Concepts of Remote Sensing

Lecture 2

August 31, 2005

What is remote sensing

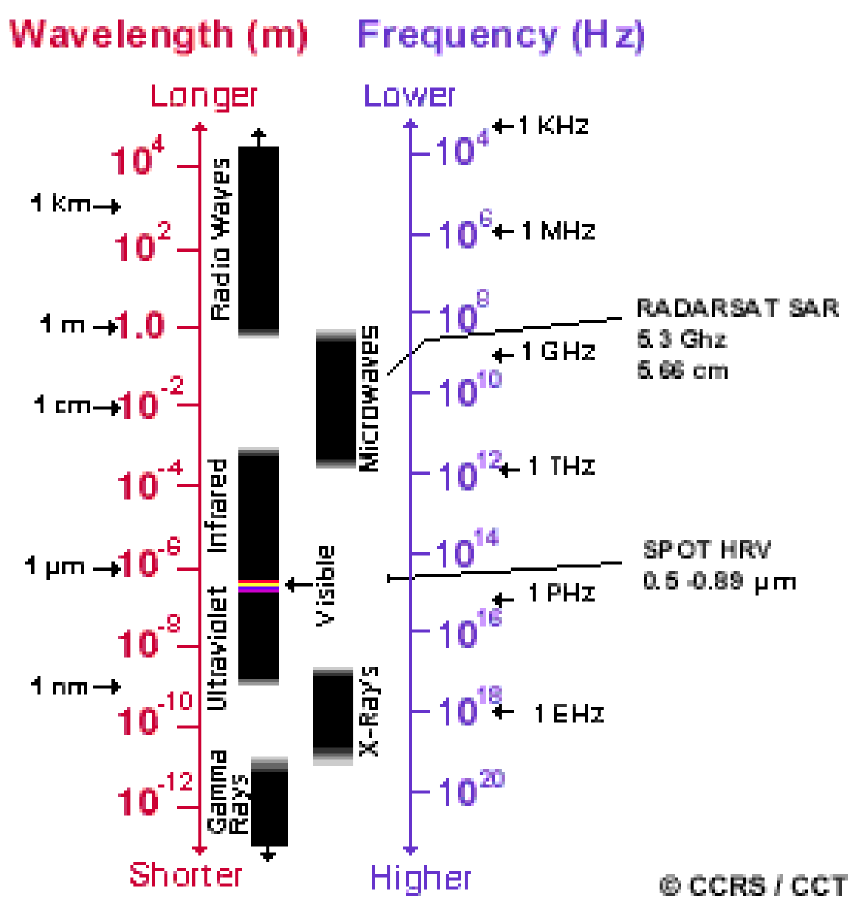
- **Remote Sensing:** remote sensing is science of
  - acquiring,
  - processing, and
  - interpreting

  images and related data that are obtained from ground-based, air-or space-borne instruments that record the interaction between matter (target) and electromagnetic radiation.

- **Remote Sensing:** using electromagnetic spectrum to image the land, ocean, and atmosphere.

- **In this class,** we will mostly focus on the
  - the principles and techniques for data collection and the interaction of electromagnetic energy with the Earth's surface (2/3 of the time)
  - some application examples (1/3 of the time)
  - also you will get familiar with ENVI, an image processing software.

Electromagnetic Spectrum



Source: http://oea.larc.nasa.gov/PAIS/DIAL.html

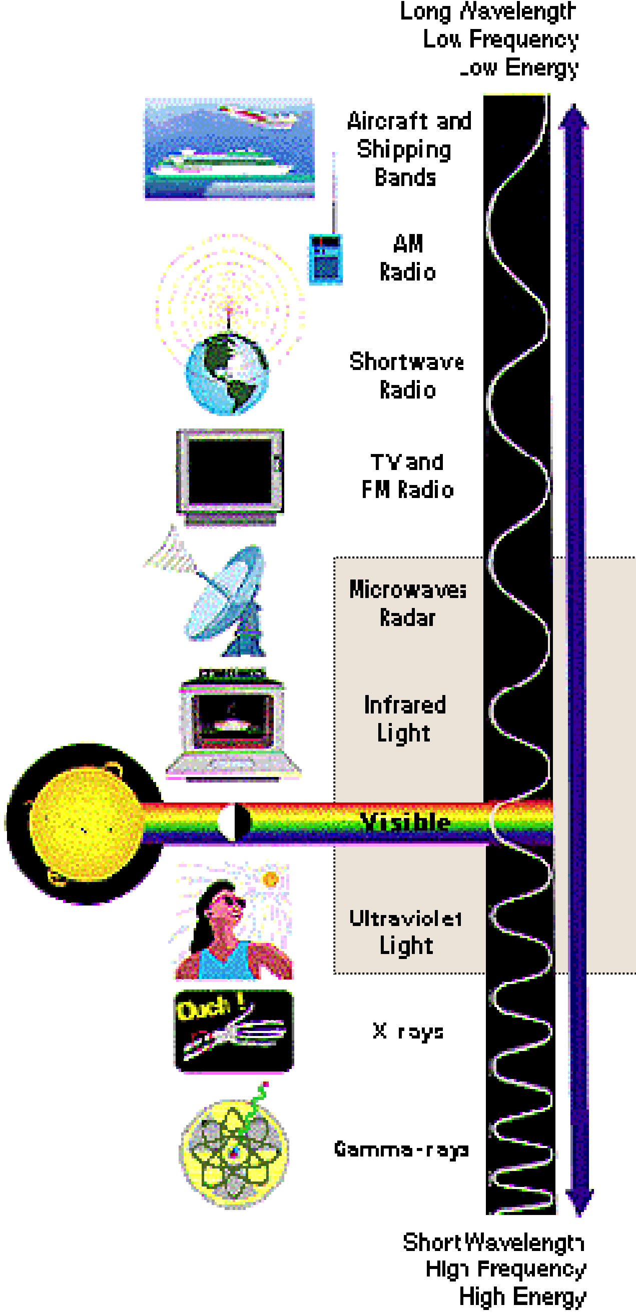
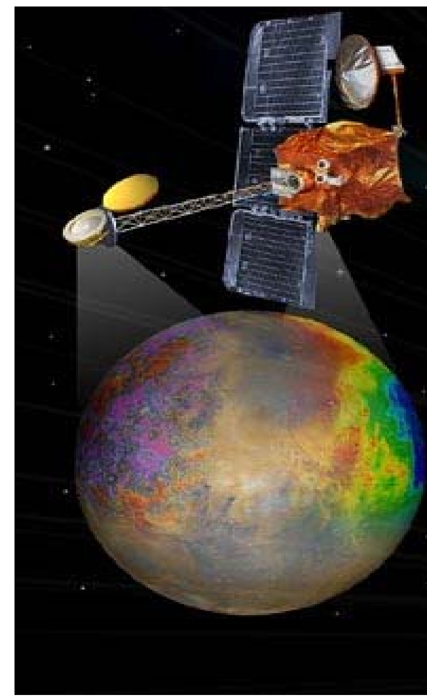


Fig. 1: The electromagnetic spectrum categorizes solar radiation from the longest to the shortest wavelengths.

Remote sensing platforms

Ground-based

Airplane-based



Satellite-based

Satellite Based

- **Sun-synchronous polar orbits**
  - Most earth imaging satellites is polar-orbiting, meaning that they circle the planet in a roughly north-south ellipse while the earth revolves beneath them. Therefore, unless the satellite has some sort of "pointing" capability, there are only certain times when a particular place on the ground will be imaged
  - global coverage, fixed crossing, repeat sampling
  - typical altitude 500-1,500 km
  - example: MODIS, Landsat

- **Non-Sun-synchronous orbits**
  - tropics and mid-latitudes coverage, varying sampling
  - typical altitude 200-2,000 km
  - example: TRMM

- **Geostationary orbits**
  - regional coverage, continuous sampling
  - over low-middle latitudes, altitude 35,000 km
  - example: GOES

Types of remote sensing

- **Passive:** source of energy is either the Sun or Earth/atmosphere
  - Sun
    - wavelengths: 0.4-5 µm
  - Earth or its atmosphere
    - wavelengths: 3 µm - 30 cm

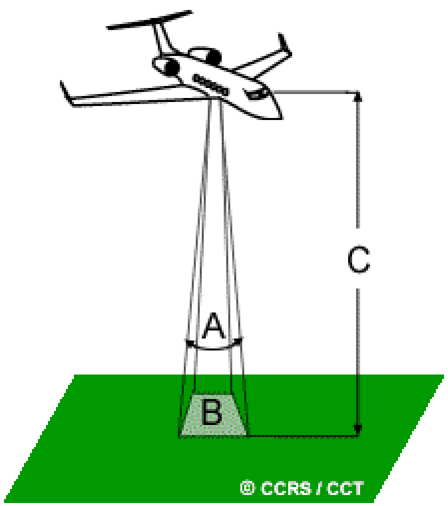
- **Active:** source of energy is part of the remote sensor system
  - Radar
    - wavelengths: mm-m
  - Lidar
    - wavelengths: UV, Visible, and near infrared

Camera takes photo as example, no flash and flash

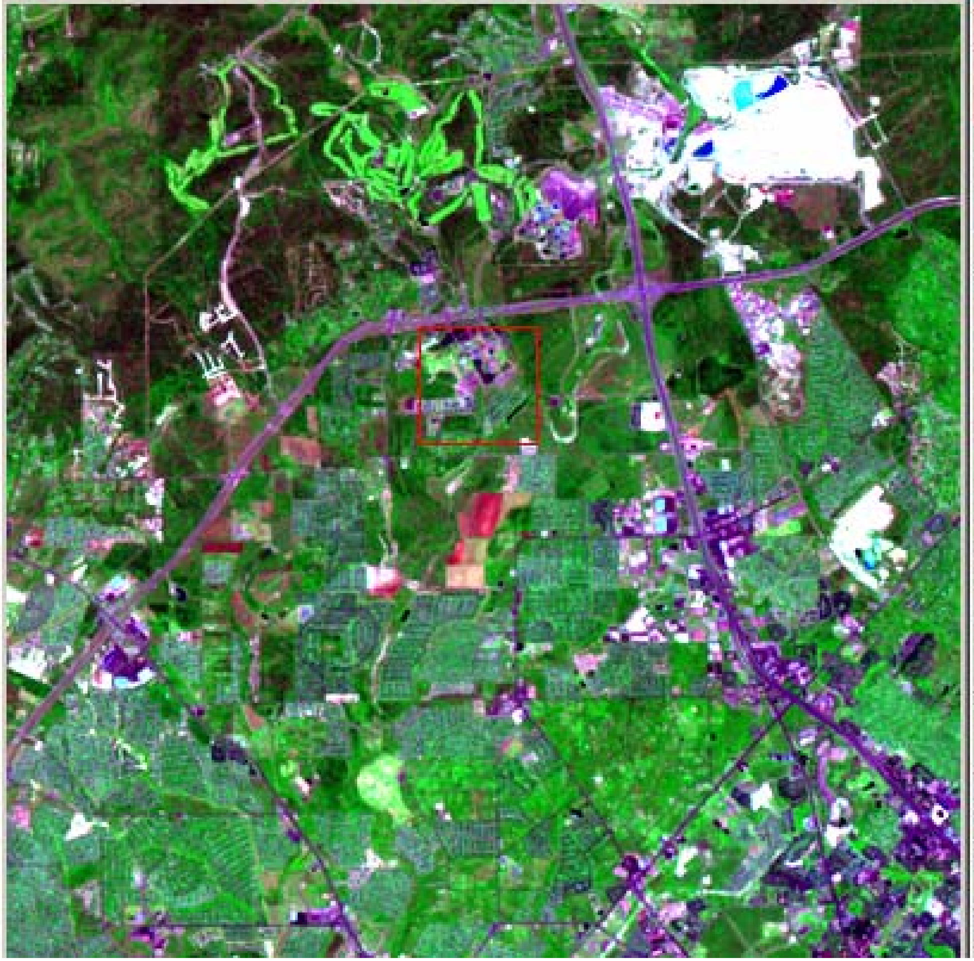
Four types of resolution

- **Spatial resolution**
- **Spectral resolution**
- **Radiometric resolution**
- **Temporal resolution**

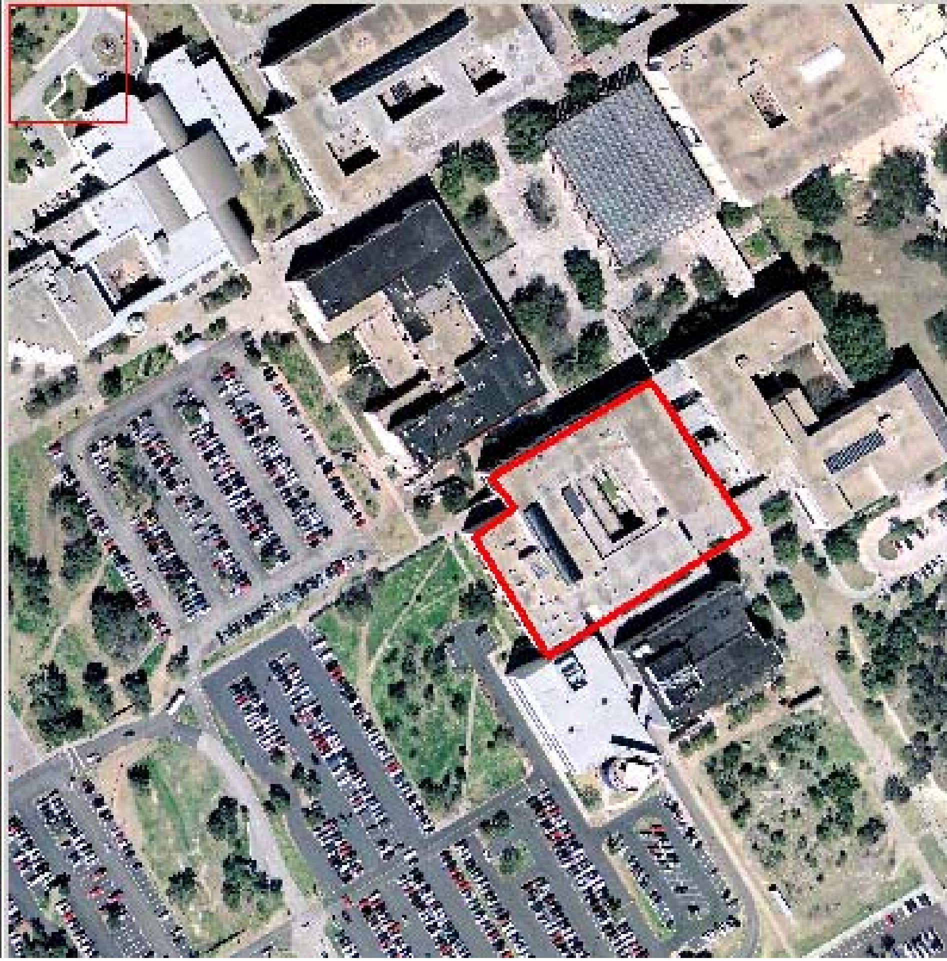
Spatial resolution and coverage



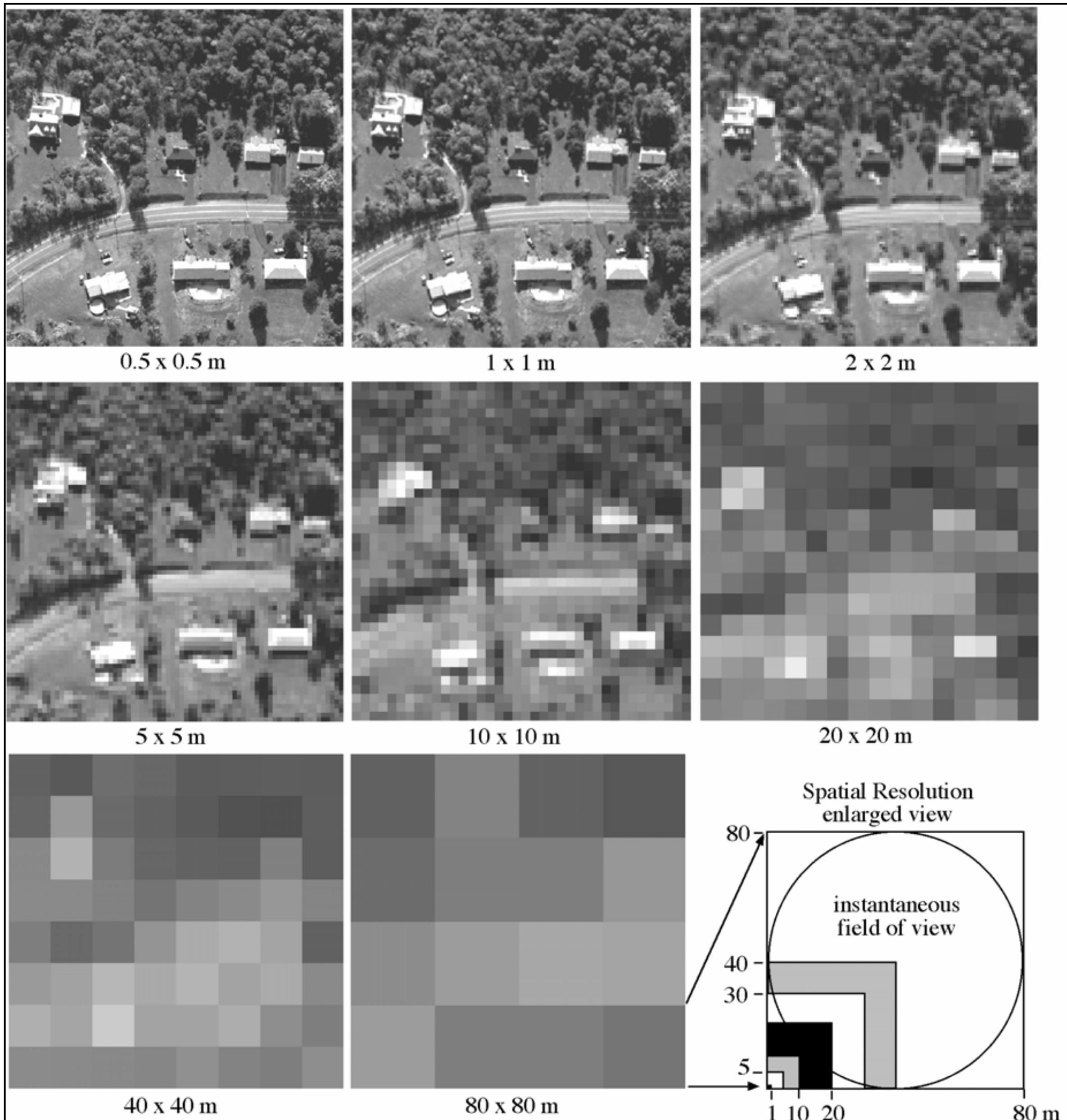
- Spatial resolution
  - Instantaneous field-of-view (IFOV)
  - Pixel: smallest unit of an image
  - Pixel size
- Spatial coverage
  - Field of view (FOV), or
  - Area of coverage, such as MODIS: 2300km or global coverage, weather radar (NEXRAD): a circle with 230 km as radius



30 meter, spatial resolution
Northwest San Antonio



1 meter, spatial resolution
UTSA campus,
red polygon is the Science Building

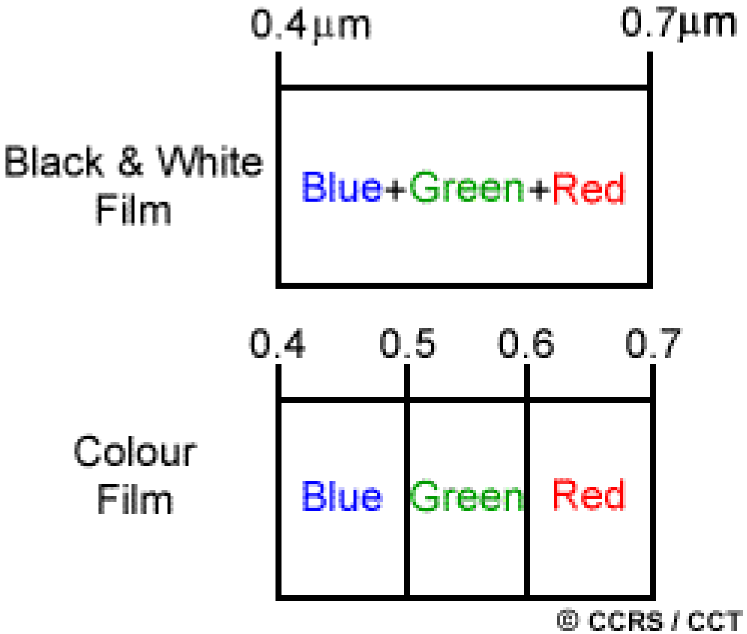


Spatial Resolution

Jensen, 2000

Spectral resolution ($\Delta\lambda$) and coverage (λ_{min} to λ_{max})

- Spectral resolution describes the ability of a sensor to define fine wavelength intervals
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band



Radiometric resolution and coverage

- Sensor's sensitivity to the magnitude of the electromagnetic energy,
- Sensor's ability to discriminate very slight differences in (reflected or emitted) energy,
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in energy

Comparing a 2-bit image with an 8-bit image

Basics of Bit

- Computer store everything in 0 or 1

Bit no.								
Bit no.	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0
256	1	1	1	1	1	1	1	1

8 bits as an example

bits	Max. num (2^{bits})
1	2
2	4
3	8
6	64
8	256
11	2048
12	4096

Resolution: 12 bits

Coverage: 0 - 4095

a

b

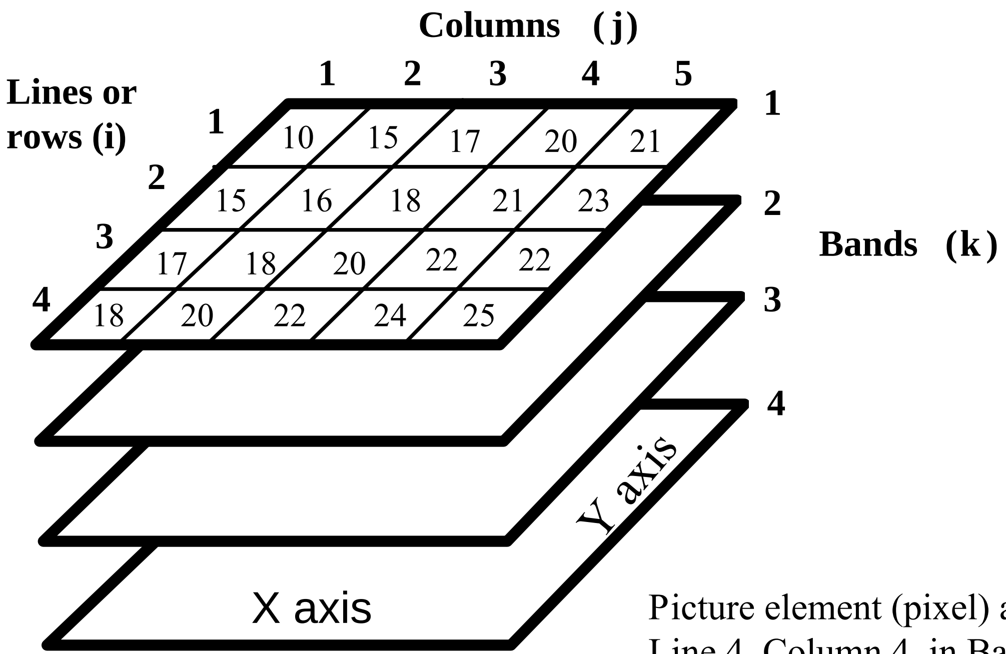
Figure 4.19 IKONOS 11-bit data enables detail to be captured in areas within the cloud shadow. In the 8-bit image (a), there is no detail in the black cloud shadow area. Image (b) shows improved shadow detail after enhancement using the full 11 bits of data.

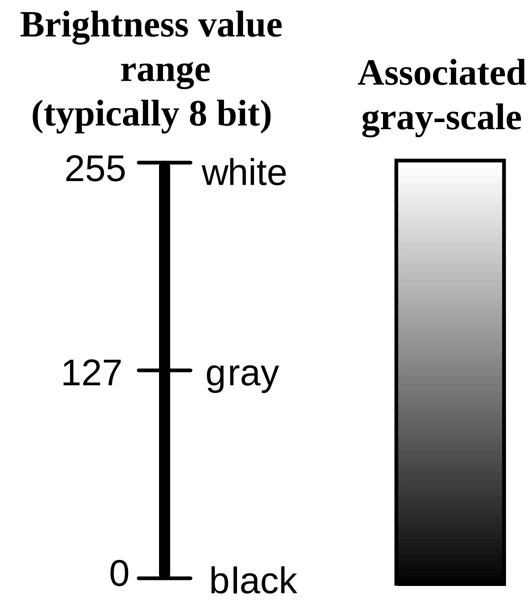
Source: Image courtesy of Space Imaging Corporation.

Temporal resolution and coverage

- Temporal resolution is the revisit period, and is the length of time for a satellite to complete one entire orbit cycle, i.e. start and back to the exact same area at the same viewing angle. For example, Landsat needs 16 days, MODIS needs one day, NEXRAD needs 6 minutes.
- Temporal coverage is the time period of sensor from starting to ending.
  - MODIS/Terra: 2/24/2000 through present
  - Landsat 5: 1/3/1984 through present

Remote Sensing Raster (Matrix) Data Format



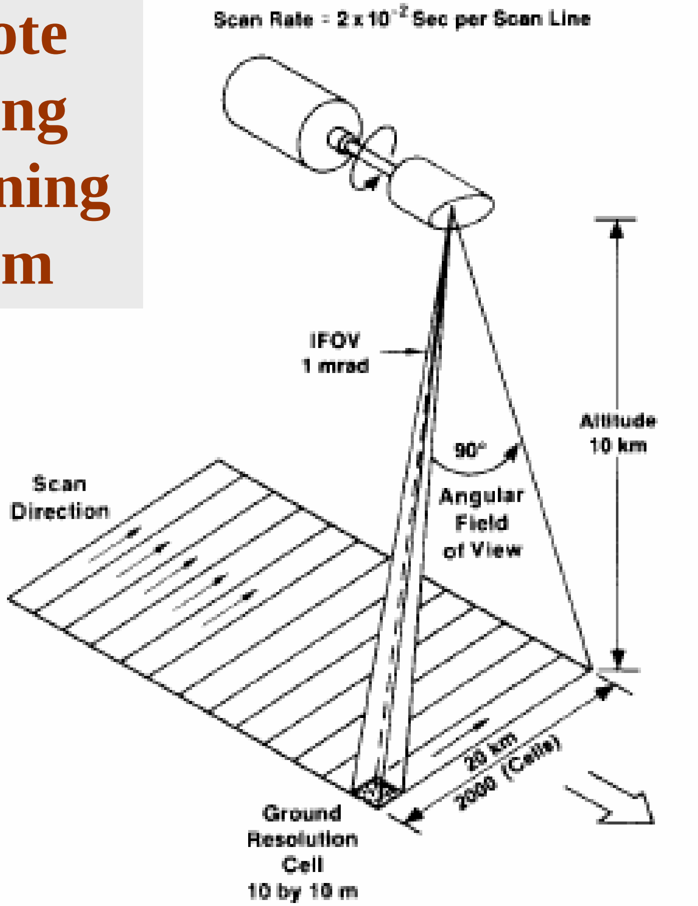


Picture element (pixel) at location Line 4, Column 4, in Band 1 has a Brightness Value of 24, i.e., $\mathbf{BV_{4,4,1} = 24}$.

Jensen, 2000

Remote Sensing Scanning System

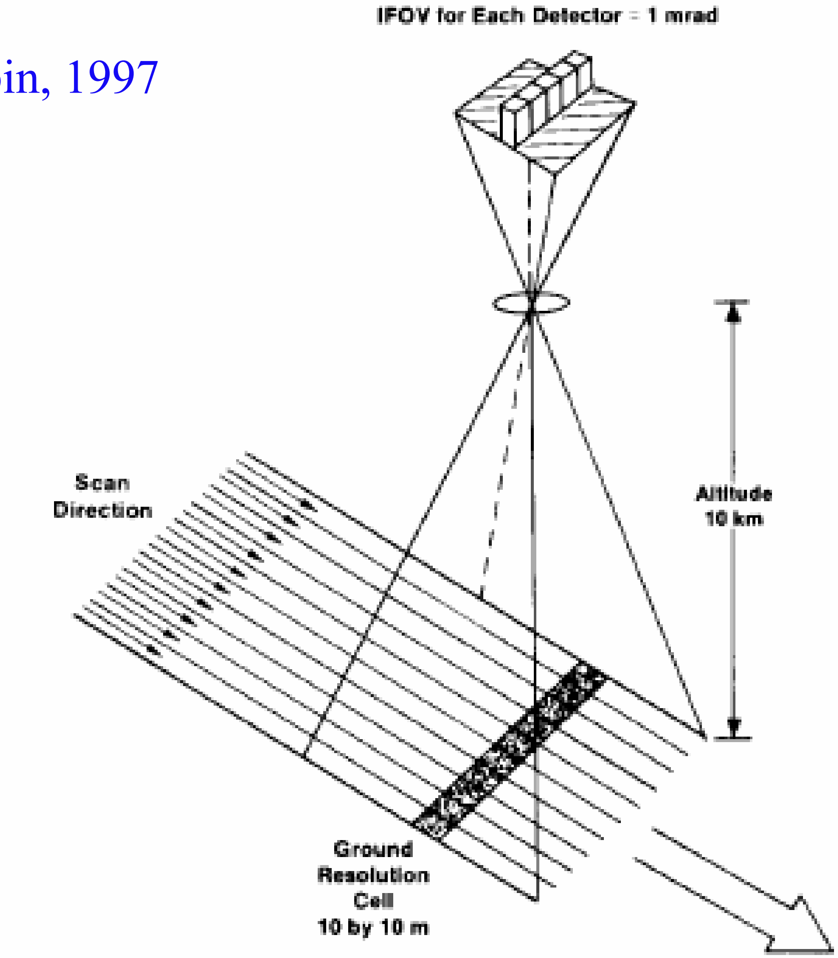
Sabin, 1997



$$\text{Dwell Time} = \frac{\text{Scan Rate per Line}}{\text{Number Cells per Line}} = \frac{2 \times 10^{-2}\ \text{sec}}{2000\ \text{cells}} = 1 \times 10^{-5}\ \text{sec} \cdot \text{cell}^{-1}$$

A. Cross-track scanner.

Wiskbroom



$$\text{Dwell Time} = \frac{\text{Cell Dimension}}{\text{Velocity}} = \frac{10\ \text{m} \cdot \text{cell}^{-1}}{200\ \text{m} \cdot \text{sec}^{-1}} = 5 \times 10^{-2}\ \text{sec} \cdot \text{cell}^{-1}$$

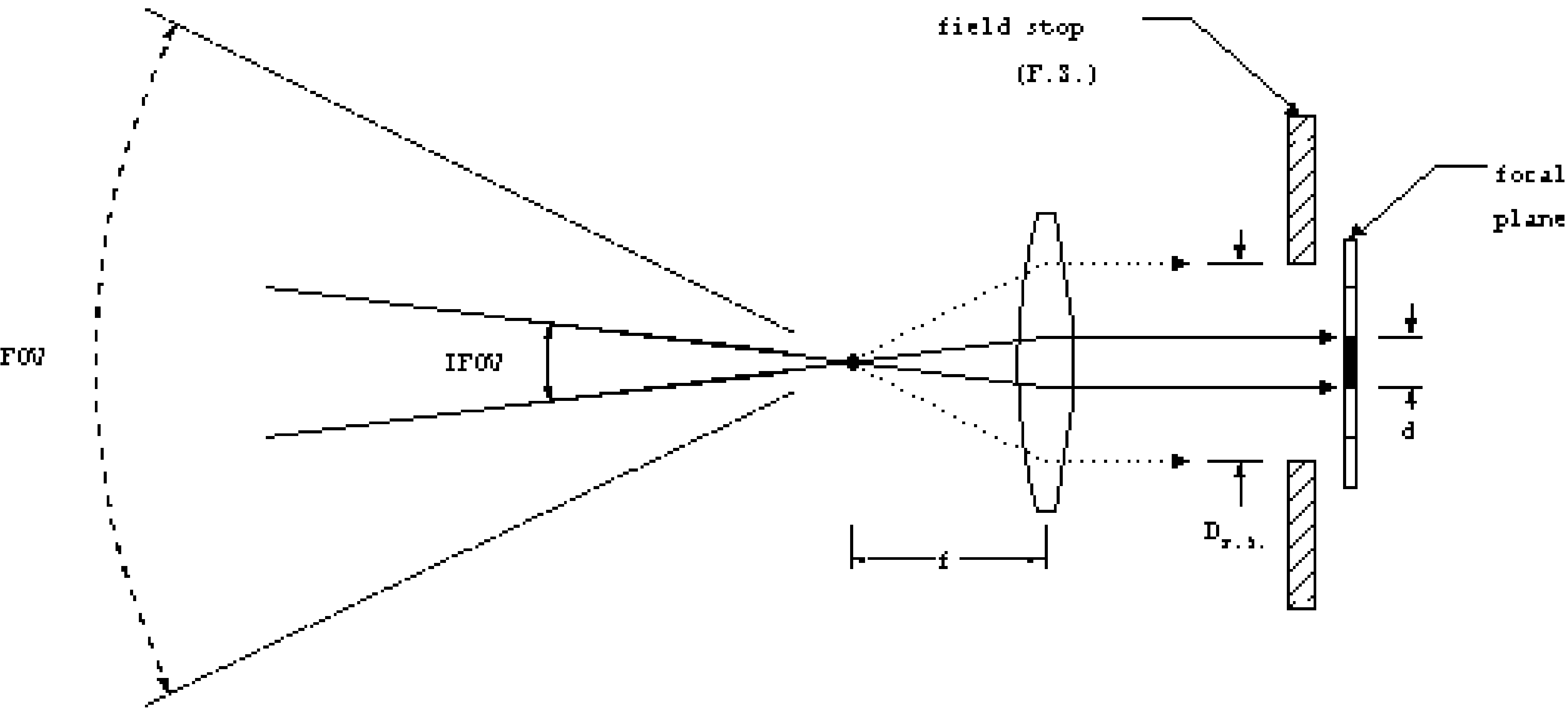
B. Along-track scanner.

Pushbroom

Field of View (FOV), Instantaneous Field of View (IFOV)

Dwell time is the time required for the detector IFOV to sweep across a ground cell. The longer dwell time allows more energy to impinge on the detector, which creates a stronger signal.

IFOV and FOV



FOV= 2 tag^{-1} (D / 2f) (degree)

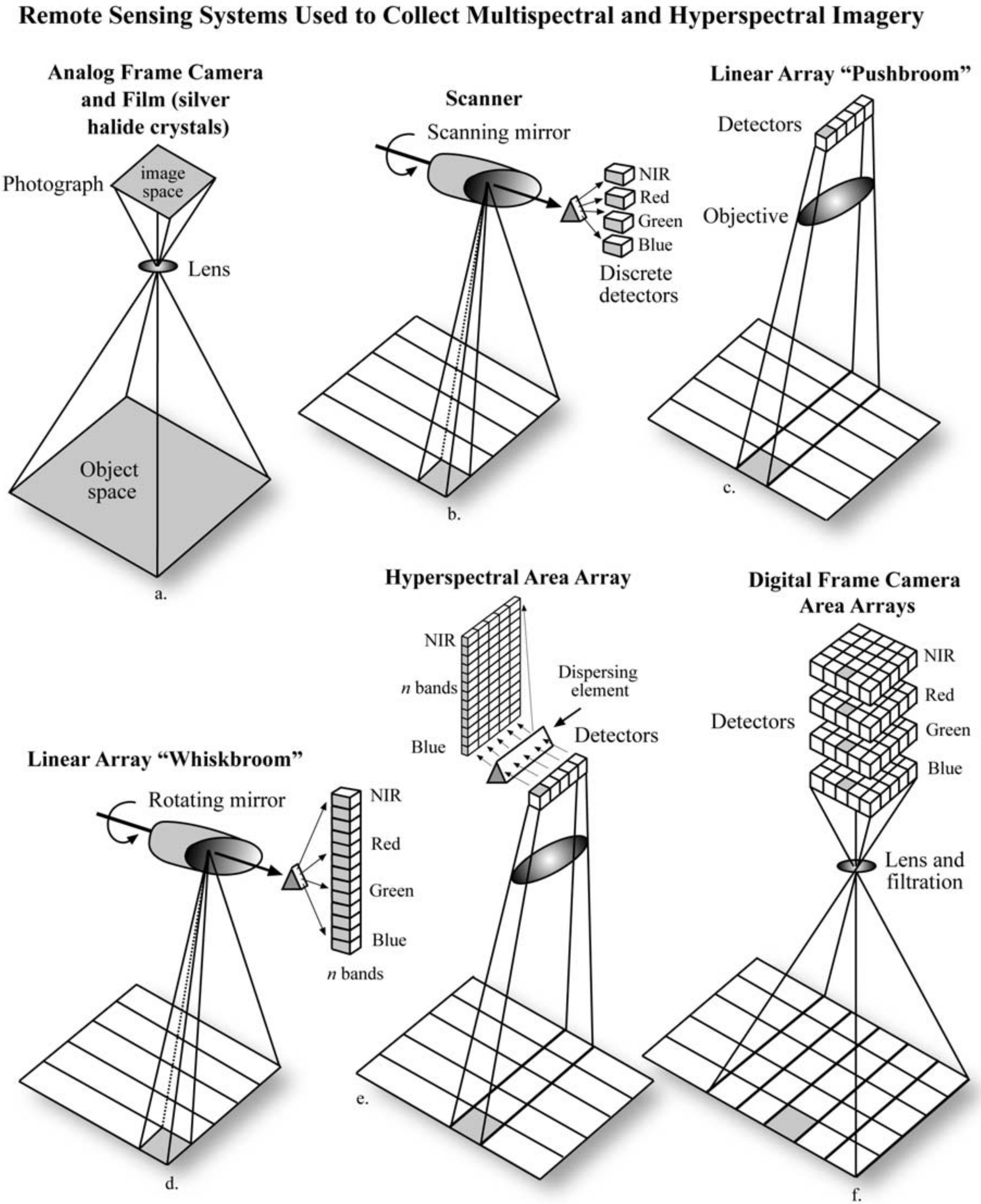
IFOV= 2 tag^{-1} (d / 2f) ≈ d / f (radians). (d is the detector size, f is the focal length). The general unit of IFOV is milliradians (10^{-3} radians).

$1^{o} = (2\pi/360) = 0.01745$ radians = 17.45 milliradians

1 milliradian = $0.057\ ^{o}$

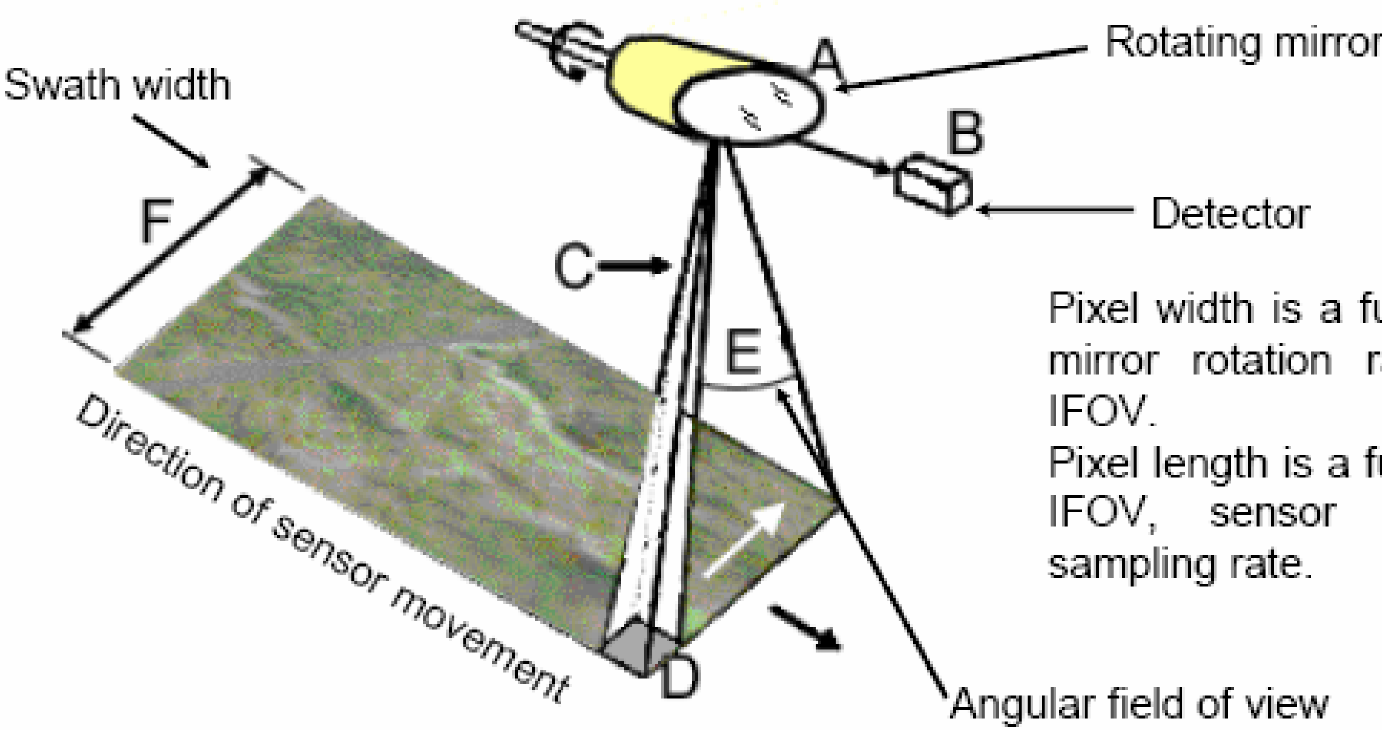
Detector configurations: breaking up the spectrum

- **Discrete Detectors and scanning mirrors**
  - MSS, TM, ETM+, GOES, AVHRR, SeaWiFS, AMS, ATLAS
- **Linear Arrays**
  - SPOT, IRS, IKONOS, ORBIMAGE, Quickbird, ASTER, MISR
- **Liner and area arrays**
  - AVIRIS, CASI, MODIS, ALI, Hyperion, LAC



Types of Sensors

Scanning mirror and single discrete detectors (whiskbroom) and filters: 1 detector per spectral band. Rotating mirror changes the angle of the incident light (and therefore what portion of the ground is being detected). The length of time a detector measures a ground target is the **dwell time**. There are **filters** to restrict the wavelengths.

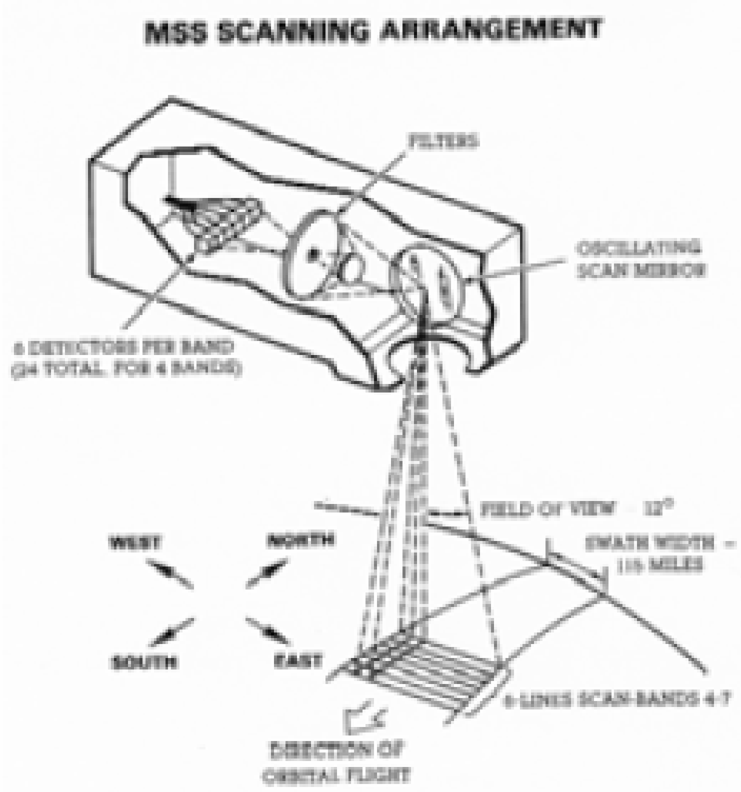


Pixel width is a function of the mirror rotation rate and the IFOV.
Pixel length is a function of the IFOV, sensor speed, and sampling rate.

Ustin, 2003

Types of Sensors

Scanning mirror and multiple discrete detectors (whiskbroom) and filters: uses a linear array of detectors for each spectral band. The mirror angles the light across these multiple detectors instead of just one. Uses **filters** to restrict the wavelengths for each band.

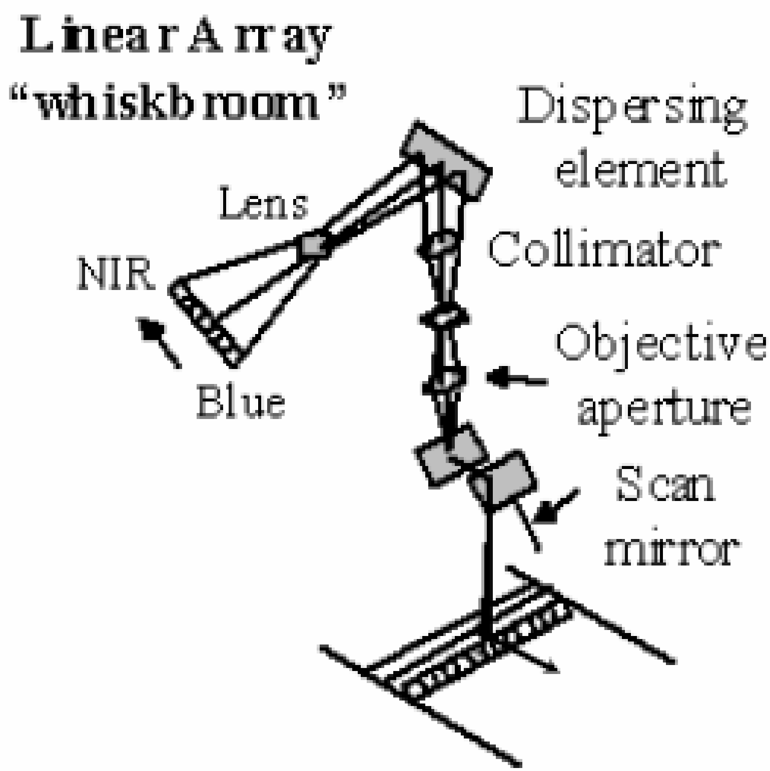


A pushbroom sensor may have thousands of detectors per spectral band, scanning mirror sensors usually only have a few. If there are 6 detectors per array, every 6th pixel in the image is from a given detector.

Ustin, 2003

Types of Sensors

Scanning mirror and multiple discrete detectors (whiskbroom) and dispersing element: instead of wide band filters, a **dispersing element** (a prism) breaks the incoming light into component wavelengths. Light is dispersed across a linear array of detectors. A rotating mirror and forward movement create the spatial arrangement of pixels.

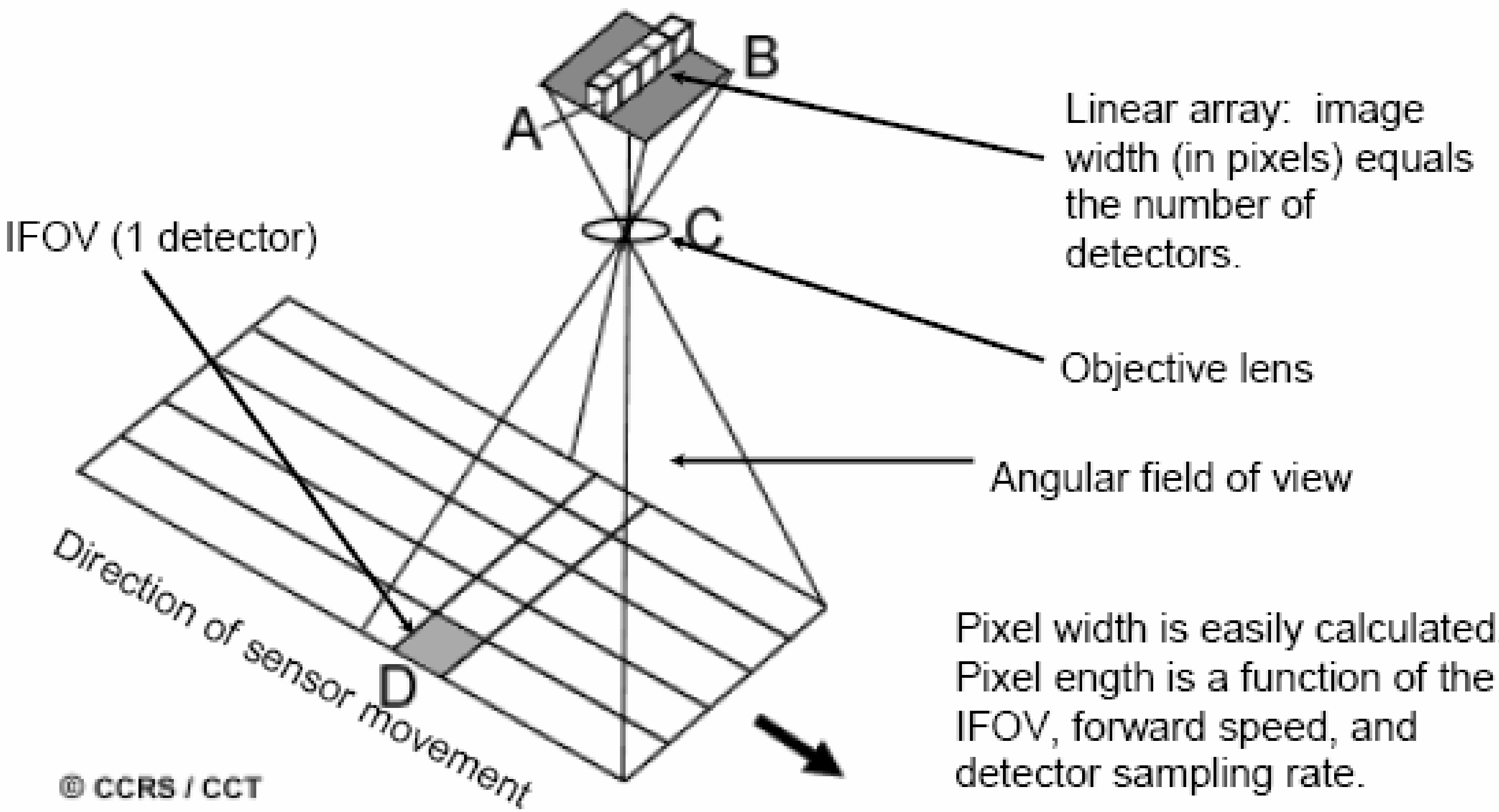


The advantage of a dispersing element vs. filters is that narrow bands can be detected in a small instrument

Ustin, 2003

Types of Sensors

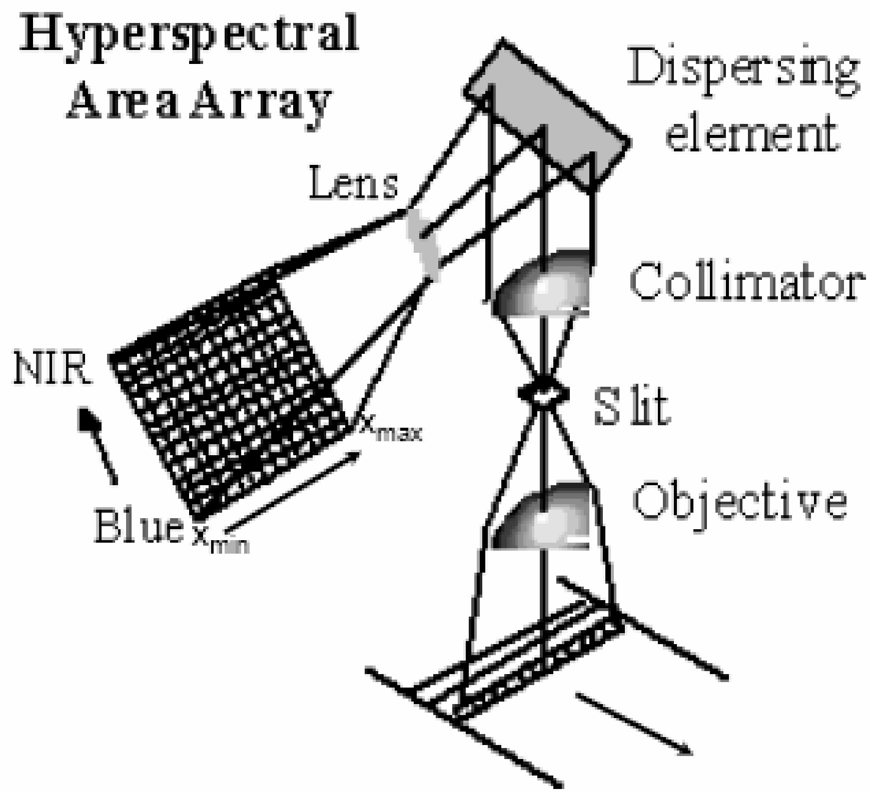
Linear array ("pushbroom"): has 1 row of detectors with one array per band (uses filters to restrict bandpass); The array moves forward with plane/satellite, and radiance is measured at regular intervals.



Ustin, 2003

Types of Sensors

Hyperspectral area array: Combines a pushbroom linear array with a dispersing element.



Ustin, 2003

Comparing Sensor Types

Sensor Type	Advantages	Disadvantages
Digital Frame Camera Area Array	Well defined geometry; long integration time	Many detectors required
Linear Array (Pushbroom)	Uniform detector response in along-track direction; no mechanical scanner; somewhat long integration time	Many detectors per line required; complex optics
Whiskbroom: Scanning mirror and single discrete detector (filters)	Uniformity of detector response over the scene; simple optics	Short dwell time per pixel; high band width and time response of detector
Whiskbroom: Scanning mirror and multiple discrete detectors (filters)	Uniformity of detector response over swath; simple optics	High band width and time response of detector
Whiskbroom: Scanning mirror and discrete detectors (dispersing element)	Uniformity of detector response over the scene or swath; simple optics; more and narrower bands possible	Many detectors per line required; complex optics; high time response of detector
Hyperspectral Area Array	Uniform detector response in along-track direction; no mechanical scanner; somewhat long integration time; more and narrower bands possible	Many detectors per line required; complex optics

Ustin, 2003