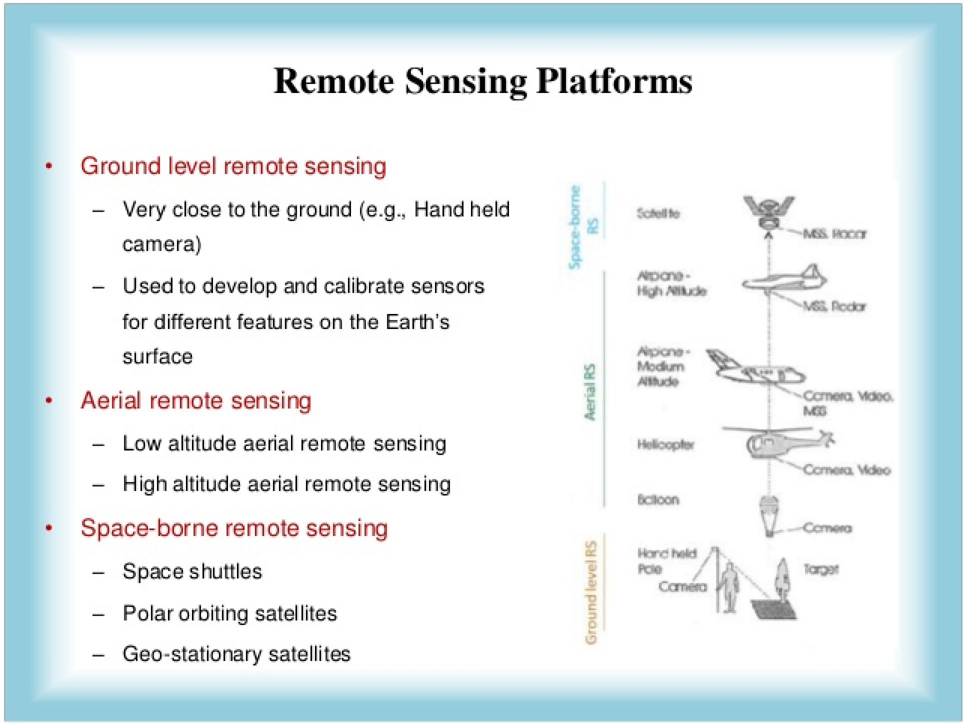
Chapter 2: “Satellites & sensors”

Part 1 out of 6

Introduction:

In order for a sensor to collect & record energy reflected or emitted from a target or surface, it must reside on a stable platform removed from the target or surface being observed.



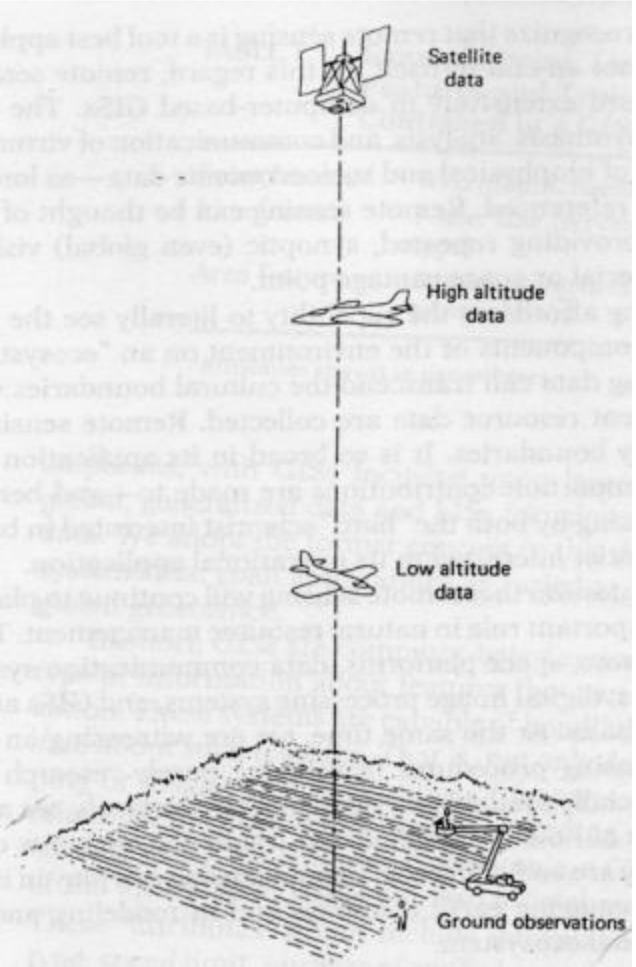
Remote Sensing Platforms

- Ground level remote sensing
  - Very close to the ground (e.g., Hand held camera)
  - Used to develop and calibrate sensors for different features on the Earth's surface
- Aerial remote sensing
  - Low altitude aerial remote sensing
  - High altitude aerial remote sensing
- Space-borne remote sensing
  - Space shuttles
  - Polar orbiting satellites
  - Geo-stationary satellites

Chapter 2: “Satellites & sensors”

Introduction: (continue)

Platforms for remote sensors may be situated on the ground, on an aircraft or balloon (or some other platform within the Earth's atmosphere), or on a spacecraft or satellite outside of the Earth's atmosphere.



Chapter 2: “Satellites & sensors”

Introduction: (continue)

Ground-based sensors are often used to record detailed information about the surface which is compared with information collected from aircraft or satellite sensors.

Aerial platforms are primarily stable wing aircraft, although helicopters & UAV are occasionally used. Aircraft are often used to collect very detailed images & facilitate the collection of data over virtually any portion of the Earth's surface at any time.

In space, remote sensing is sometimes conducted from the space shuttle or, more commonly, from satellites. Satellites are objects which revolve around another object.

Chapter 2: "Satellites & sensors"

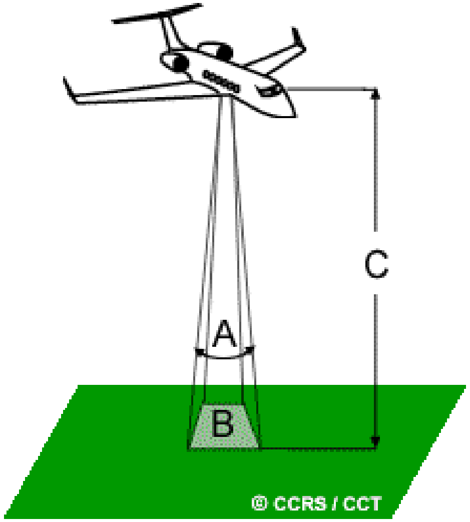
Spatial Resolution, Pixel Size, & Scale:

The distance between the target being imaged & the platform, plays a large role in determining the detail of information obtained & the total area imaged by the sensor.

Sensors onboard platforms far away from their targets, typically view a larger area, but cannot provide great detail.

Chapter 2: “Satellites & sensors”

Spatial Resolution, Pixel Size, & Scale: *(continue)*



The detail discernible in an image is dependent on the spatial resolution of the sensor & refers to the size of the smallest possible feature that can be detected.

Spatial resolution of passive sensors depends primarily on their Instantaneous Field of View (IFOV).

The IFOV is the angular cone of visibility of the sensor (A) & determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time (B).

Chapter 2: “Satellites & sensors”

Spatial Resolution, Pixel Size, & Scale: *(continue)*

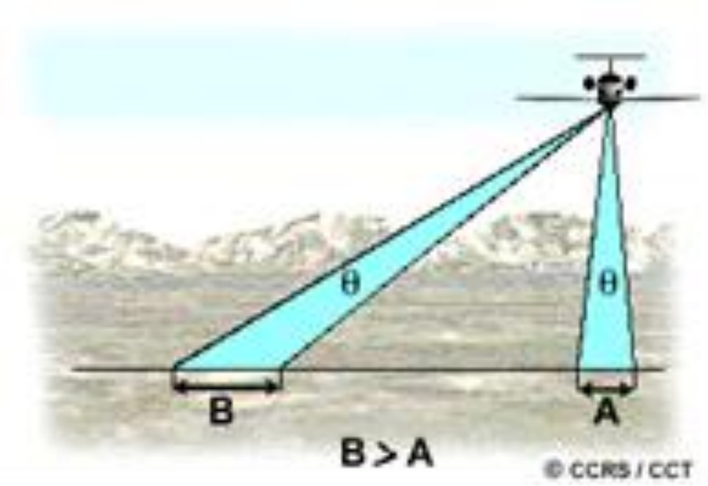
The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor (C).

For a homogeneous feature to be detected, its size generally has to be equal to or larger than the resolution cell; however, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing sub-pixel or resolution cell detection.

Chapter 2: “Satellites & sensors”

Spatial Resolution, Pixel Size, & Scale: *(continue)*

The ground area represented by pixels at the nadir will have a larger scale then those pixels which are off-nadir. This means that spatial resolution will vary from the image center to the swath edge.



Most remote sensing images are composed of a matrix of pixels, which are the smallest units of an image. Image pixels are normally square & represent a certain area on an image.

Chapter 2: "Satellites & sensors"

Spatial Resolution, Pixel Size, & Scale: *(continue)*

It is important to distinguish between pixel size & spatial resolution - they are not interchangeable.

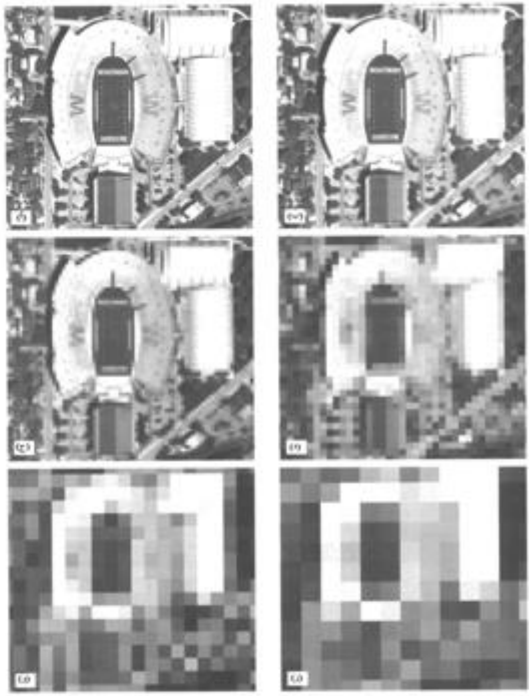
If a sensor has a spatial resolution of 20 meters & an image from that sensor is displayed at full resolution, each pixel represents an area of 20m x 20m on the ground. In this case the pixel size & resolution are the same; however, it is possible to display an image with a pixel size different than the resolution.

Chapter 2: "Satellites & sensors"

Spatial Resolution, Pixel Size, & Scale: *(continue)*

Many posters of satellite images of the Earth have their pixels averaged to represent larger areas, although the original spatial resolution of the sensor that collected the imagery remains the same.

Various spatial resolution starting from *1* meter resolution at upper left to 30 meter resolution at lower right.

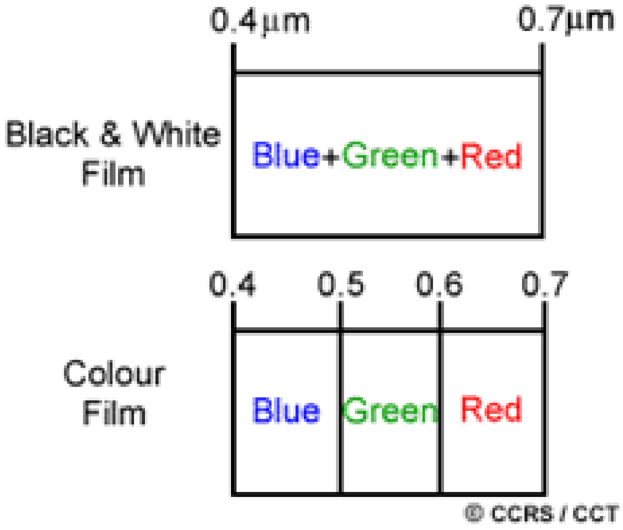


Chapter 2: "Satellites & sensors"

Spectral Resolution:

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

Black & white film records wavelengths extending over much, or all of the visible portion of the electromagnetic spectrum. Its spectral resolution is fairly coarse.



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Chapter 2: "Satellites & sensors"

Spectral Resolution: *(continue)*

Color film is also sensitive to the reflected energy over the visible portion of the spectrum, but has higher spectral resolution, as it is individually sensitive to the reflected energy at the blue, green, & red wavelengths of the spectrum.

Thus, it can represent features of various colors based on their reflectance in each of these distinct wavelength ranges.

Many remote sensing systems record energy over several separate wavelength ranges at various spectral resolutions. These are referred to as multi-spectral sensors.

Chapter 2: "Satellites & sensors"

Radiometric Resolution:

Radiometric resolution describes the actual information content in an image. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy.

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

Imagery data are represented by positive digital numbers which vary from 0 to (one less than) a selected power of 2. This range corresponds to the number of bits used for coding numbers in binary format.

Chapter 2: “Satellites & sensors”

Radiometric Resolution*: (continue)*

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 28=256 digital values available, ranging from 0 to 255.

Image data are generally displayed in a range of grey tones.

Chapter 2: “Satellites & sensors”

Temporal Resolution:

Temporal resolution refers to the length of time it takes for a satellite to complete one entire orbit cycle.

The ability to collect imagery of the same area of the Earth's surface at different periods of time is one of the most important elements for applying remote sensing data.

Spectral characteristics of features may change over time. These changes can be detected by collecting & comparing multi-temporal imagery.

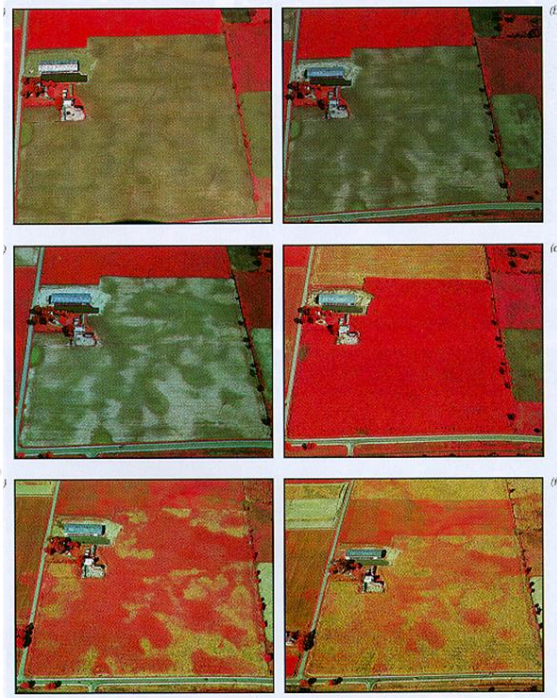


Plate 8 Oblique color IR aerial photographs illustrating the effects of date of photography: (*a*) June 30; (*b*) July 1; (*c*) July 2; (*d*) August 11; (*e*) September 17; (*f*) October 8. Dane County, WI. Approximate horizontal scale at photo center is 1 : 7600. (For major discussion, see Section 4.5.)

Chapter 2: "Satellites & sensors"

Temporal Resolution: *(continue)*

The time factor in imaging is important when:

- *persistent clouds offer limited clear views of the Earth's surface (often in the tropics),*
- *short-lived phenomena (floods, oil slicks, etc.) need to be imaged,*
- *multi-temporal comparisons are required (e.g. the spread of a forest disease from one year to the next),*
- *the changing appearance of a feature over time can be used to distinguish it from near-similar features (wheat / maize)*

Chapter 2: "Satellites & sensors"

Part 2 out of 6

Cameras & Aerial Photography:

Cameras & their use for aerial photography are the simplest & oldest of sensors used for remote sensing of the Earth's surface.

Photographic films are sensitive to light from 0.3 µm to 0.9 µm in wavelength covering the (UV), visible, & (NIR).

Panchromatic films are sensitive to the NIR & the visible portions of the spectrum. Panchromatic film produces black & white images & is the most common type of film used for aerial photography.

Chapter 2: “Satellites & sensors”

Cameras & Aerial Photography: (continue)

UV photography also uses panchromatic film.

UV photography is not widely used, because of the atmospheric scattering & absorption that occurs in this region of the spectrum.

Black & white IR photography uses film sensitive to the entire 0.5 to 0.9 μm wavelength range & is useful for detecting differences in vegetation cover, due to its sensitivity to IR reflectance.

Chapter 2: "Satellites & sensors"

Cameras & Aerial Photography: (continue)

Color & color-IR photography involves the use of a three layer film with each layer sensitive to different ranges of light.

For a normal color photograph, the layers are sensitive to blue, green, & red light - the same as our eyes.

These photos appear to us the same way that our eyes see the environment, as the colors resemble those which would appear to us as "normal".

Chapter 2: "Satellites & sensors"

Cameras & Aerial Photography: *(continue)*

In color IR photography, the three emulsion layers are sensitive to green, red, & the photographic portion of NIR radiation, which are processed to appear as blue, green, & red, respectively.

Targets with high NIR reflectance appear red, those with a high red reflectance appear green, & those with a high green reflectance appear blue, thus giving us a "false" presentation of the targets relative to the color we normally perceive.

Chapter 2: "Satellites & sensors"

Cameras & Aerial Photography: *(continue)*

Very detailed photographs taken from aircraft are useful for many applications where identification of detail or small targets is required.

Vertical photographs is the most common use of aerial photography for remote sensing & mapping purposes.

These cameras are specifically built for capturing a rapid sequence of photographs while limiting geometric distortion. They are often linked with navigation systems onboard the aircraft platform, to allow for accurate geographic coordinates to be instantly assigned to each photograph.

Chapter 2: "Satellites & sensors"

Cameras & Aerial Photography: *(continue)*

Aerial photographs are most useful when fine spatial detail is more critical than spectral information, as their spectral resolution is generally coarse when compared to data captured with electronic sensing devices.

The geometry of vertical photographs is well understood & it is possible to make very accurate measurements from them, for a variety of different applications.

Chapter 2: “Satellites & sensors”

Cameras & Aerial Photography*: (continue)*

Digital cameras, which record electromagnetic radiation electronically, differ significantly from their counterparts which use film. Instead of using film, digital cameras use a gridded array of silicon coated CCDs (charge-coupled devices) that individually respond to electromagnetic radiation.

Digital cameras also provide quicker turn-around for acquisition & retrieval of data & allow greater control of the spectral resolution.

Chapter 2: "Satellites & sensors"

Part 3 out of 6

Other forms of Imaging:

Multispectral Scanning:

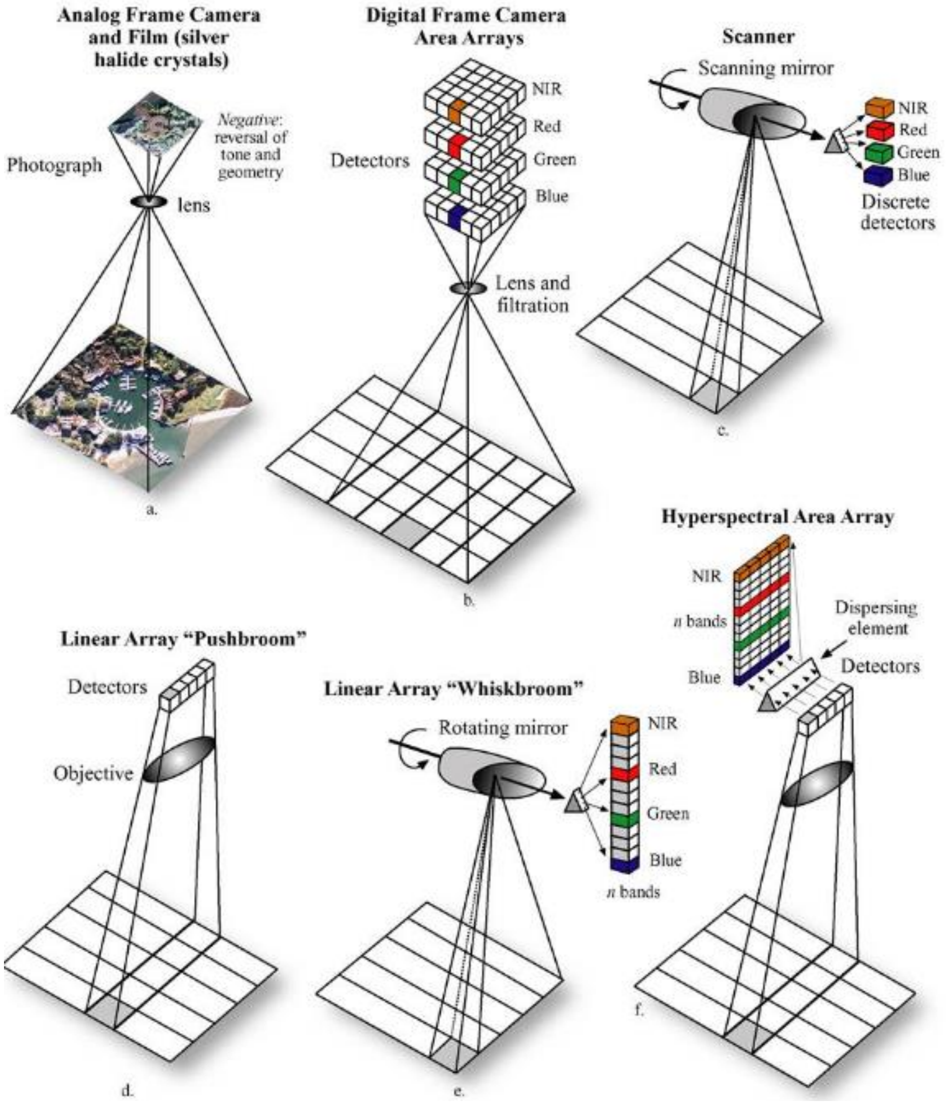
Multispectral Scanning Systems, (MSS), employ sensors with narrow field of view (i.e. IFOV) that sweeps over the terrain to build up & produce a two-dimensional image of the surface.

Scanning systems can be used on both aircraft & satellite platforms & have essentially the same operating principles.

Two main modes or methods of scanning employed to acquire multispectral image data - across-track scanning, & along-track scanning.

Chapter 2: “Satellites & sensors”

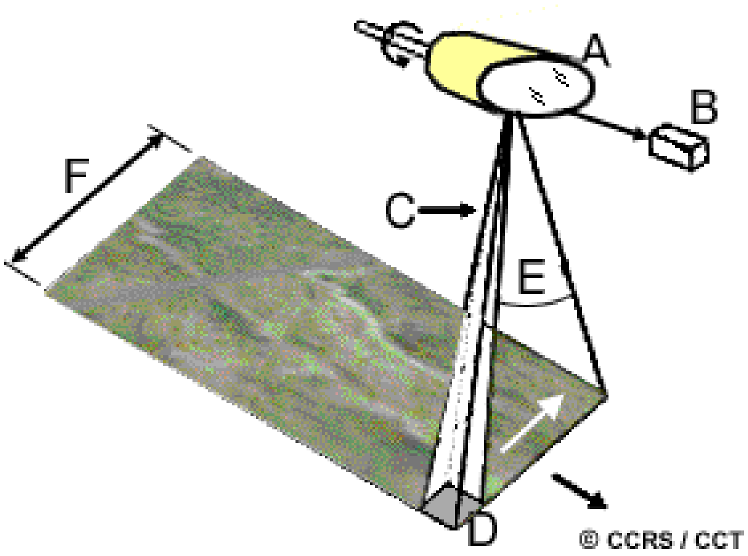
Other forms of Imaging: *(continue)*



Chapter 2: “Satellites & sensors”

Other forms of Imaging: *(continue)*

Across-track scanners scan the Earth in a series of lines. The lines are oriented perpendicular to the direction of motion of the sensor platform.



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Key components;

- *Rotating mirror (A)*
- *Detectors (B),*
- *IFOV (C),*
- *Ground resolution cell viewed (D),*
- *Angular field of view (E),*
- *Swath (F).*

Chapter 2: “Satellites & sensors”

Other forms of Imaging*: (continue)*

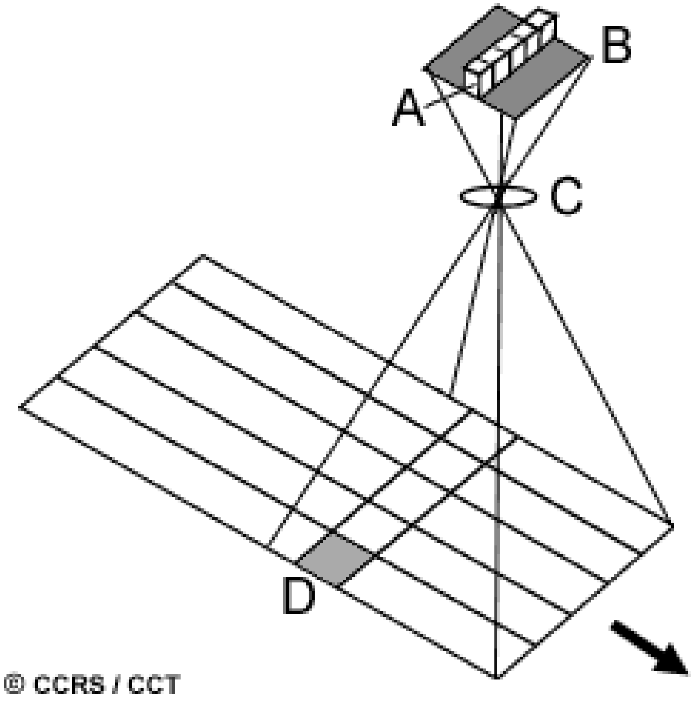
Each line is scanned from one side of the sensor to the other, using a rotating mirror (A). As the platform moves forward over the Earth, successive scans build up a two-dimensional image of the Earth’s surface.

The length of time the IFOV "sees" a ground resolution cell as the rotating mirror scans, called the dwell time, is generally quite short & influences the design of the spatial, spectral, & radiometric resolution of the sensor.

Chapter 2: "Satellites & sensors"

Other forms of Imaging: *(continue)*

Along-track scanners also use the forward motion of the platform to record successive scan lines & build up a two-dimensional image, perpendicular to the flight direction.



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Key components;

- *A linear array of detectors (A)*
- *Focal plane of the image (B),*
- *Lens systems (C),*
- *Ground resolution cell viewed (D).*

Chapter 2: "Satellites & sensors"

Other forms of Imaging*: (continue)*

Instead of a scanning mirror, they use a linear array of detectors (A) located at the focal plane of the image (B) formed by lens systems (C), which are "pushed" along in the flight track direction (i.e. along track).

These systems are also referred to as push-broom scanners.

Each individual detector measures the energy for a single ground resolution cell (D) & thus the size & IFOV of the detectors determines the spatial resolution of the system.

Chapter 2: “Satellites & sensors”

Other forms of Imaging: *(continue)*

A separate linear array is required to measure each spectral band or channel. For each scan line, the energy detected by each detector of each linear array is sampled electronically & digitally recorded.

Along-track scanners with linear arrays have several advantages over across-track mirror scanners.

The array of detectors combined with the push-broom motion allows each detector to "see" & measure the energy from each ground resolution cell for a longer period of time (i.e. longer dwell time). This allows more energy to be detected & improves the radiometric resolution.

Chapter 2: "Satellites & sensors"

Other forms of Imaging: *(continue)*

The increased dwell time also facilitates smaller IFOVs & narrower bandwidths for each detector. Thus, finer spatial & spectral resolution can be achieved without impacting radiometric resolution.

Because detectors are usually solid-state microelectronic devices, they are generally smaller, lighter, require less power, & are more reliable & last longer because they have no moving parts.

On the other hand, cross-calibrating thousands of detectors to achieve uniform sensitivity across the array is necessary & complicated.

Chapter 2: "Satellites & sensors"

Other forms of Imaging: *(continue)*

MSS using either of these two types, has several advantages over photographic systems;

The spectral range of photographic systems is restricted to the UV, visible & near-IR regions while MSS systems can extend this range into the thermal IR. They are also capable of much higher spectral resolution than photographic systems.

Photographic systems record the energy detected by means of a photochemical process which is difficult to measure & to make consistent. It is easier to determine the specific amount of energy measured, in MSS because data are recorded electronically.

Chapter 2: "Satellites & sensors"

Other forms of Imaging*: (continue)*

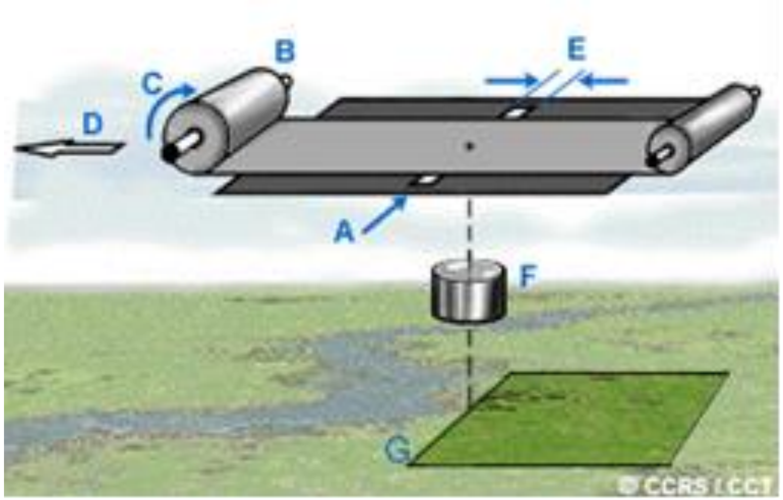
Photographic systems require a continuous supply of film & processing on the ground after the photos have been taken.

The digital recording in MSS systems facilitates transmission of data to receiving stations on the ground & immediate processing of data in a computer environment.

Chapter 2: "Satellites & sensors"

Other forms of Imaging: *(continue)*

There is a photographic parallel to the push-broom scanner. It is based on the "slit camera". This camera does not have a shutter per se, but a slit (A) running in the across-track direction, which exposes film (B) which is being moved continuously (C) past the slit.

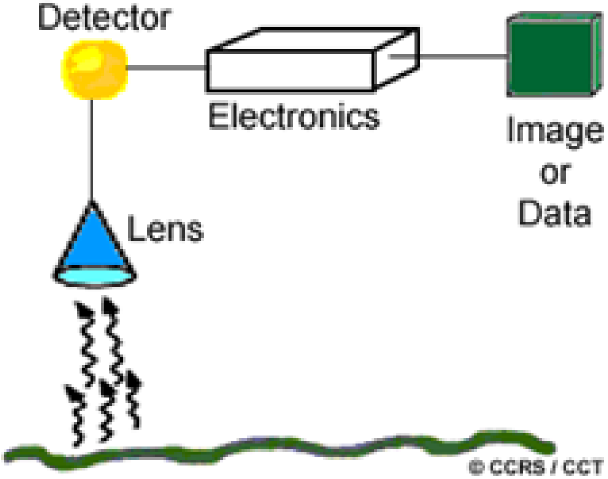


Chapter 2: "Satellites & sensors"

Other forms of Imaging: *(continue)*

Thermal Imaging:

Remote sensing of energy emitted from the Earth's surface in the thermal IR (3 µm to 15 µm) is different than the sensing of reflected energy.



Thermal sensors use photo detectors sensitive to the direct contact of photons on their surface, to detect emitted thermal radiation. Thermal sensors essentially measure the surface temperature & thermal properties of targets.

Chapter 2: “Satellites & sensors”

Other forms of Imaging: *(continue)*

Because of the relatively long wavelength of thermal radiation atmospheric scattering is minimal. However, absorption by atmospheric gases normally restricts thermal sensing to two specific regions - 3 to 5 µm & 8 to 14 µm.

Because energy decreases as the wavelength increases, thermal sensors generally have large IFOVs to ensure that enough energy reaches the detector in order to make a reliable measurement.

Chapter 2: "Satellites & sensors"

Other forms of Imaging: *(continue)*

Therefore the spatial resolution of thermal sensors is usually fairly coarse, relative to the spatial resolution possible in the visible & reflected IR.

Thermal imagery can be acquired during the day or night (because the radiation is emitted not reflected) & is used for a variety of applications such as military reconnaissance, disaster management (forest fire mapping), & heat loss monitoring..