



CHAPTER 2/ Section -1

(2-1) Satellites and Sensors

On the Ground, In the Air, In Space:- In **Chapter 1**, we learned some of the fundamental concepts required to understand the process that encompasses remote sensing. We covered the first three components of this process in some detail: the energy source, the interaction of energy with the atmosphere, and the interaction of energy with the surface. We briefly touched on the fourth component - the recording of energy by the sensor - when discussing passive vs. active sensors and the characteristics of images.

In this chapter, we will take a closer look at this component of the remote sensing process by examining in greater detail the characteristics of remote sensing platforms and sensors and the data they collect. We will also touch briefly on how that data is processed once they have been recorded by the sensor.

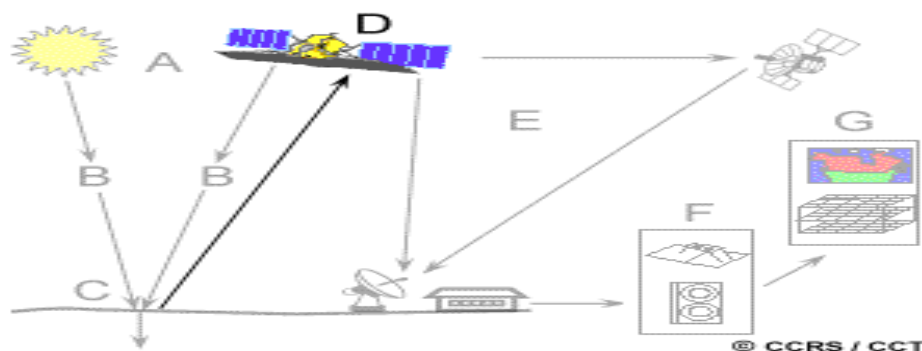


Fig. (2-1-1) Satellites and Sensors



In order for a sensor to collect and 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. 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.



Fig. (2-1-2) Ground platform

(2-1-1) Ground-based sensors are often used to record detailed information about the surface, which is compared with information collected from aircraft or satellite sensors. In some cases, this can be used to better characterize the target that is being imaged by these other sensors, making it possible to better understand the information in the imagery.



Sensors may be placed on a ladder, scaffolding, tall building, cherry-picker, crane, etc. Aerial platforms are primarily stable-wing aircraft, although helicopters are occasionally used. Aircraft are often used to collect very detailed images and facilitate the collection of data over virtually any portion of the Earth's surface at any time.



Fig. (2-1-3) Aerial platform

In space, remote sensing is sometimes conducted from the space shuttle or, more commonly, from satellites. Satellites are objects that revolve around another object, in this case, the Earth. For example, the moon is a natural satellite, whereas man-made satellites include those platforms launched for remote sensing, communication, and telemetry (location and navigation) purposes. Because of their orbits, satellites permit repetitive coverage of the Earth's surface on a continuing basis. Cost is often a significant factor in choosing among the various platform options.

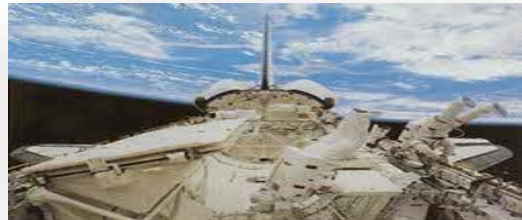


Fig. (2-1-3) Space platform



(2-2-2) Satellite Characteristics: Orbits and Swaths

We learned in the previous section that remote sensing instruments can be placed on a variety of platforms to view and image targets. Although ground-based and aircraft platforms may be used, satellites provide a great deal of the remote sensing imagery commonly used today. Satellites have several unique characteristics that make them particularly useful for remote sensing of the Earth's surface.

The path followed by a satellite is referred to as its orbit. Satellite orbits are matched to the capability and objective of the sensor(s) they carry. Orbit selection can vary in terms of altitude (their height above the Earth's surface) and their orientation and rotation relative to the Earth. Satellites at very high altitudes, which view the same portion of the Earth's surface at all times, have geostationary orbits. These geostationary satellites, at altitudes of approximately 36,000 kilometres, revolve at speeds that match the rotation of the Earth so they seem stationary, relative to the Earth's surface. This allows the satellites to observe and collect information continuously over specific areas.

(2-2-3) Weather and communications satellites commonly have these types of orbits. Due to their high altitude, some geostationary weather satellites can monitor weather and cloud patterns covering an entire hemisphere of the Earth.

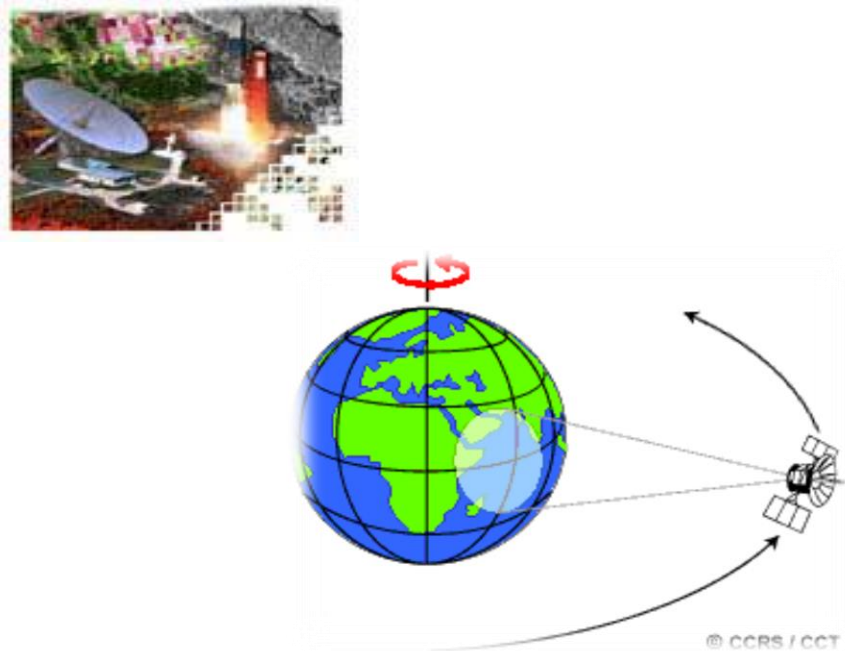


Fig. (2-1-4) Geostationary orbit

Many remote sensing platforms are designed to follow an orbit (basically north-south) which, in conjunction with the Earth's rotation (west-east), allows them to cover most of the Earth's surface over a certain period of time. These are near polar orbits, so named for the inclination of the orbit relative to a line running between the North and South poles. Many of these satellite orbits are also sun synchronous, such that they cover each area of the world at a constant local time of day called local sun time. At any given latitude, the position of the sun in the sky as the satellite passes overhead will be the same within the same season. This ensures consistent illumination conditions when acquiring images in a specific season over successive years, or over a particular area over a series of days. This is an important factor for monitoring changes between images or for mosaicking adjacent images together, as they do not have to be corrected for different illumination conditions.

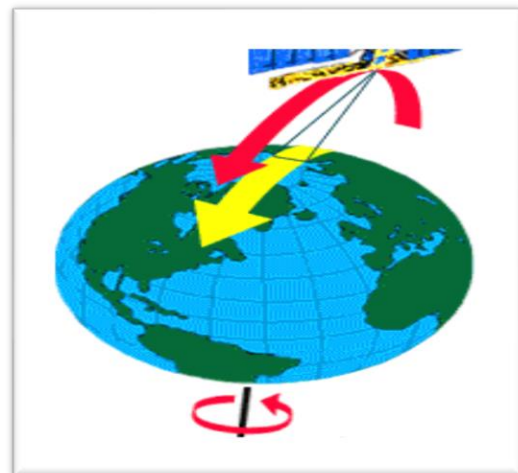
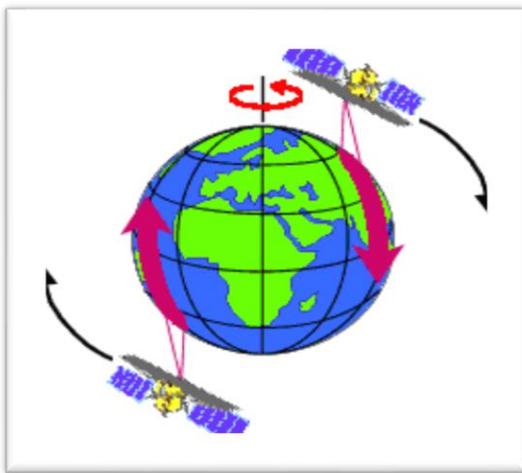


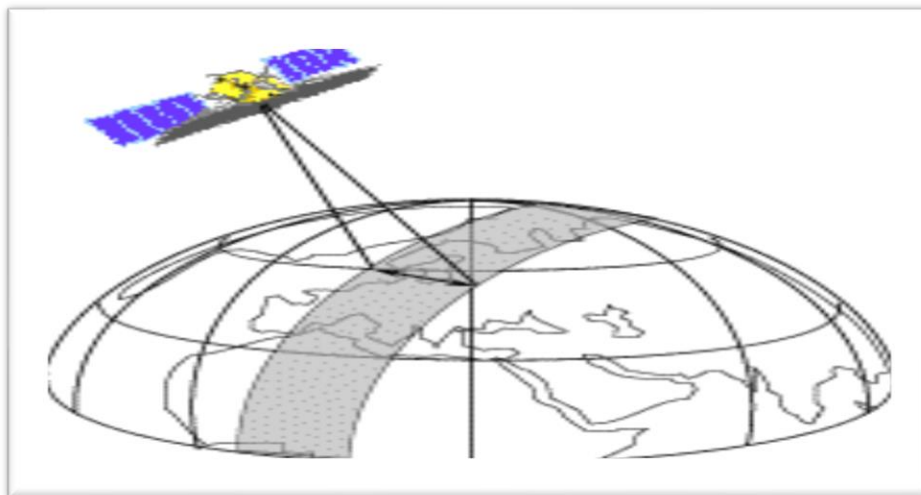
Fig. (2-1-5) near-polar orbit

Most of the remote sensing satellite platforms today are in near-polar orbits, which means that the satellite travels northwards on one side of the Earth and then toward the southern pole on the second half of its orbit. These are called ascending and descending passes, respectively. If the orbit is also sun synchronous, the ascending pass is most likely on the shadowed side of the Earth while the descending pass is on the sunlit side. Sensors recording reflected solar energy only image the surface on a descending pass, when solar illumination is available. Active sensors, which provide their own illumination, or passive sensors that record emitted (e.g., thermal) radiation, can also image the surface on ascending passes.



As a satellite revolves around the Earth, the sensor "sees" a certain portion of the Earth's surface. The area imaged on the surface is referred to as the swath. Imaging swaths for space-borne sensors generally vary between tens and hundreds of kilometres wide. As the satellite orbits the Earth from pole to pole, its east-west position wouldn't change if the Earth didn't rotate.

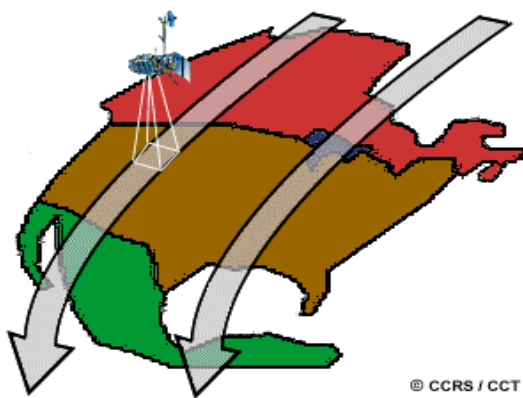
However, as seen from the Earth, it seems that the satellite is shifting westward because the Earth is rotating (from west to east) beneath it. This apparent movement allows the satellite swath to cover a new area with each consecutive pass. The satellite's orbit and the rotation of the Earth work together to allow complete coverage of the Earth's surface after it has completed one complete cycle of orbits.



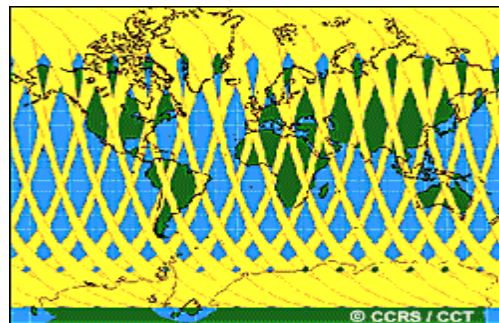


If we start with any randomly selected pass in a satellite's orbit, an orbit cycle will be completed when the satellite retraces its path, passing over the same point on the Earth's surface directly below the satellite (called the **nadir** point) for a second time.

The exact length of the orbital cycle will vary with each satellite. The interval of time required for the satellite to complete its orbit cycle is not the same as the "**revisit period**". Using steerable sensors, a satellite-borne instrument can view an area (off-nadir) before and after the orbit passes over a target, thus making the 'revisit' time less than the orbit cycle time. The revisit period is an important consideration for a number of monitoring applications, especially when frequent imaging is required (for example, to monitor the spread of an oil spill, or the extent of flooding). In near-polar orbits, areas at high latitudes will be imaged more frequently than the equatorial zone due to the increasing **overlap in adjacent swaths** as the orbit paths come closer together near the poles.



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Section-3

(2-3) Spatial Resolution, Pixel Size, and Scale: -

For some remote sensing instruments, the distance between the target being imaged and the platform plays a large role in determining the detail of information obtained and 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. Compare what an astronaut onboard the space shuttle sees of the Earth to what you can see from an airplane. The astronaut might see your whole province or country in one glance, but couldn't distinguish individual houses. Flying over a city or town, you would be able to see individual buildings and cars, but you would be viewing a much smaller area than the astronaut. There is a similar difference between satellite images and aerial photos.

The detail discernible in an image is dependent on the spatial resolution of the sensor and refers to the size of the smallest possible feature that can be detected. Spatial resolution of passive sensors (we will look at the special case of active microwave sensors later) depends primarily on their Instantaneous Field of View (IFOV). The IFOV is the angular cone of visibility of the sensor (A) and determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time (B). The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor (C). This area on the ground is called the resolution cell and determines a sensor's maximum spatial resolution.



For a homogeneous feature to be detected, its size generally has to be equal to or larger than the resolution cell. If the feature is smaller than this, it may not be detectable, as the average brightness of all features in that resolution cell will be recorded. However, smaller features may sometimes be detectable if their reflectance dominates within an articular resolution cell, allowing sub-pixel or resolution cell detection.

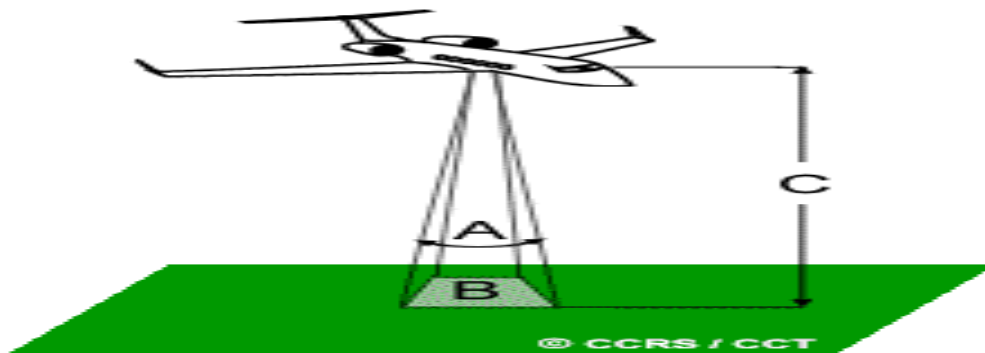


Fig. (2-3-1) Instantaneous Field of View (IFOV)

As we mentioned in **Chapter 1**, most remote sensing images are composed of a matrix of picture elements, or pixels, which are the smallest units of an image. Image pixels are normally square and represent a certain area on an image. It is important to distinguish between pixel size and spatial resolution - they are not interchangeable. If a sensor has a spatial resolution of 20 metres and 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 and resolution are the same. However, it is possible to display an image with a pixel size different than the resolution. 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.



Fig. (2-3-2) The spatial resolution

Images where only large features are visible are said to have coarse or low resolution. In fine or high-resolution images, small objects can be detected. Military sensors, for example, are designed to view as much detail as possible, and therefore have very fine resolution.

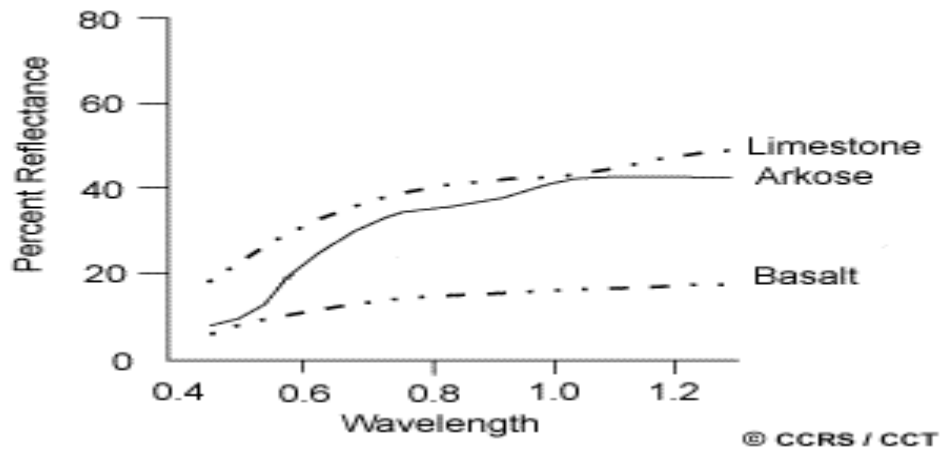
Commercial satellites provide imagery with resolutions varying from a few meters to several kilometres. Generally speaking, the finer the resolution, the less total ground area can be seen.

The ratio of distance on an image or map to actual ground distance is referred to as scale. If you had a map with a scale of 1:100,000, an object of 1cm length on the map would actually be an object 100,000cm (1km) long on the ground. Maps or images with small "map-to-ground ratios" are referred to as small scale (e.g., 1:100,000), and those with larger ratios (e.g., 1:5,000) are called large scale



SECTION -4

(2-4) SPECTRAL RESOLUTION



In **Chapter 1**, we learned about spectral response and spectral emissivity curves, which characterize the reflectance and/or emittance of a feature or target over a variety of wavelengths. Different classes of features and details in an image can often be distinguished by comparing their responses over distinct wavelength ranges. Broad classes, such as water and vegetation, can usually be separated using very broad wavelength ranges - the visible and near infrared. Other, more specific classes, such as different rock types, may not be easily distinguishable using either of these broad wavelength ranges and would require comparison at much finer wavelength ranges to separate them. Thus, we would require a sensor with higher spectral resolution. 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.



Black and white film records wavelengths extending over much or all of the visible portion of the electromagnetic spectrum. Its spectral resolution is fairly coarse, as the various wavelengths of the visible spectrum are not individually distinguished, and the overall reflectance in the entire visible portion is recorded. 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, and red wavelengths of the spectrum. Thus, it can represent features of various colors based on their reflectance in each of these distinct wavelength ranges.

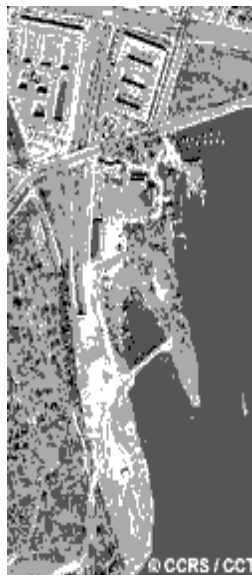
Many remote sensing systems record energy over several separate wavelength ranges at various spectral resolutions. These are referred to as multi-spectral sensors and will be described in some detail in the following sections. Advanced multi-spectral sensors called hyperspectral sensors detect hundreds of very narrow spectral bands throughout the visible, near-infrared, and mid-infrared portions of the electromagnetic spectrum. Their very high spectral resolution facilitates fine discrimination between different targets based on their spectral response in each of the narrow bands.



SECTION-5

(2-5) Radiometric Resolution: -

While the arrangement of pixels describes the spatial structure of an image, the radiometric characteristics describe the actual information content in an image. Every time an image is acquired on film or by a sensor, its sensitivity to the magnitude of the electromagnetic energy determines the radiometric resolution. 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.





Imagery data are represented by positive digital numbers that 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. Each bit records an exponent of power 2 (e.g., 1 bit= $2^1=2$). 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. However, if only 4 bits were used, then only $2^4=16$ values ranging from 0 to 15 would be available. Thus, the radiometric resolution would be much less. Image data are generally displayed in a range of grey tones, with black

representing a digital number of 0 and white representing the maximum value (for example, 255 in 8-bit data). By comparing a 2-bit image with an 8-bit image, we can see that there is a large difference in the level of detail discernible depending on their radiometric resolutions.



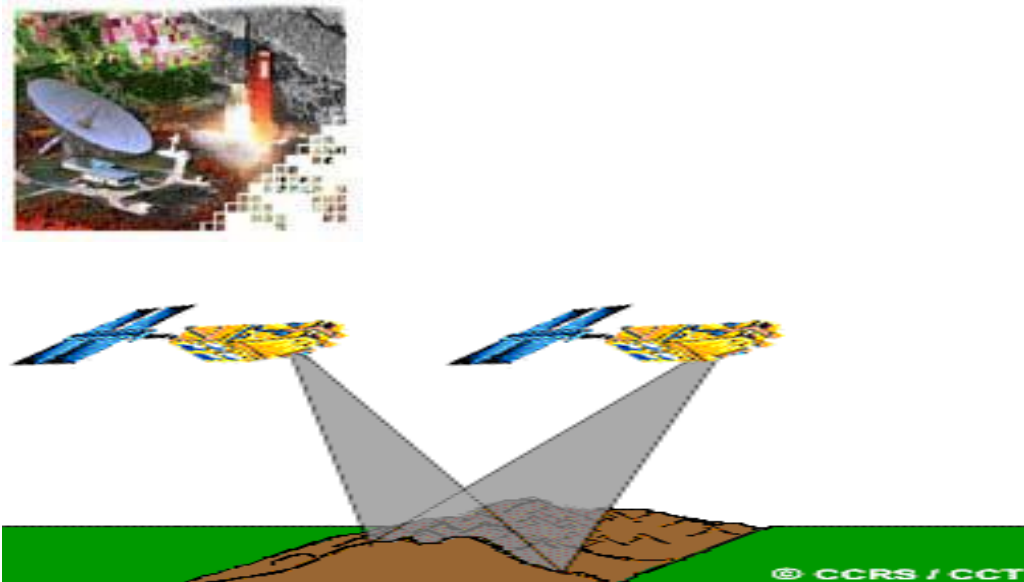
SECTION-6

(2-6) Temporal Resolution: -

In addition to spatial, spectral, and radiometric resolution, the concept of temporal resolution is also important to consider in a remote sensing system.

we discussed the concept of revisit period, which refers to the length of time it takes for a satellite to complete one entire orbit cycle. The revisit period of a satellite sensor is usually several days. Therefore, the absolute temporal resolution of a remote sensing system to image the same area at the same viewing angle a second time is equal to this period.

However, because of some degree of overlap in the imaging swaths of adjacent orbits for most satellites and the increase in this overlap with increasing latitude, some areas of the Earth tend to be re-imaged more frequently. Also, some satellite systems are able to point their sensors to image the same area between different satellite passes separated by periods from one to five days. Thus, the actual temporal resolution of a sensor depends on a variety of factors, including the satellite/sensor capabilities, the swath overlap, and latitude.



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, and these changes can be detected by collecting and comparing multi-temporal imagery. For example, during the growing season, most species of vegetation are in a continual state of change, and our ability to monitor those subtle changes using remote sensing is dependent on when and how frequently we collect imagery. By imaging on a continuing basis at different times, we are able to monitor the changes that take place on the Earth's surface, whether they are naturally occurring (such as changes in natural vegetation cover or flooding) or induced by humans (such as urban development or deforestation). 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)