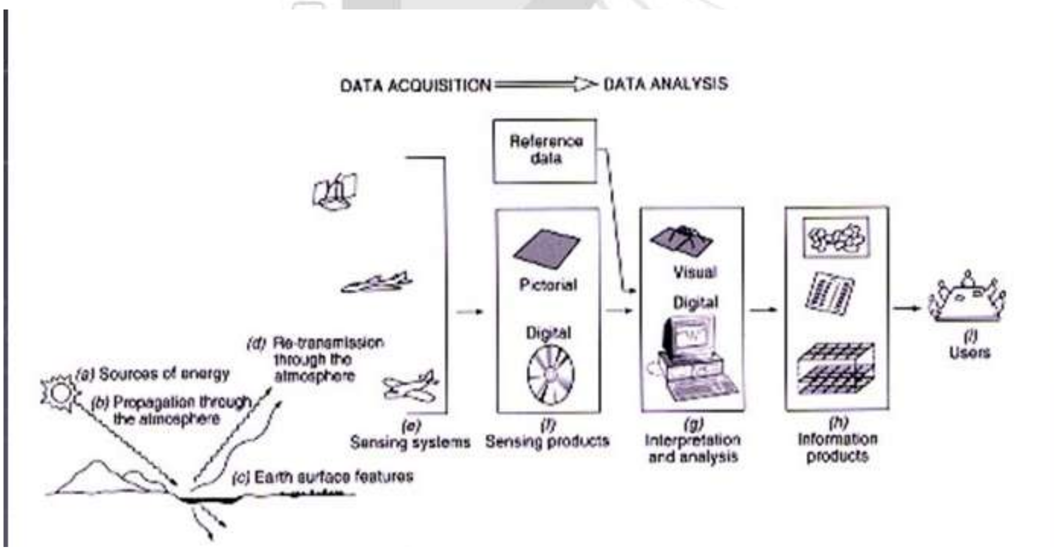
Remote Sensing

The term remote sensing was first used in the early 1960s. Later, it was defined as the total processes used to acquire and measure the information of some property of objects and phenomena by a recording device (sensor) that is not in physical contact with the objects and phenomena in study.

STAGES IN REMOTE SENSING

Illustrates the processes used in remote sensing data acquisition. These basic processes that help in the collection of information about the properties of the objects and phenomena of the earth surface are as follows:

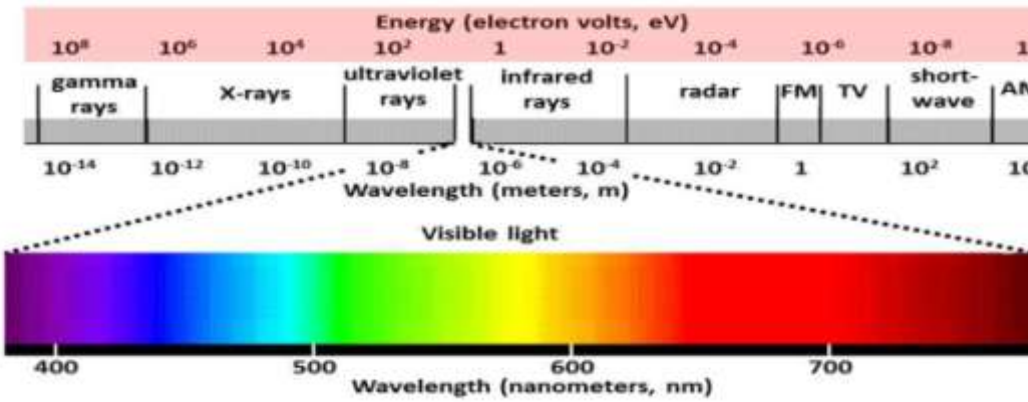
(a) Source of Energy (sun/self-emission);
(b) Transmission of energy from the source to the surface of the earth;
(c) Interaction of energy with the earth's surface;
(d) Propagation of reflected/emitted energy through atmosphere;
(e) Detection of the reflected/emitted energy by the sensor;
(f) Conversion of energy received into photographic/digital form of data;
(g) Extraction of the information contents from the data products; and
(h) Conversion of information into Map/Tabular forms.



Stages in remote sensing data acquisition

a. Source of Energy: Sun is the most important source of energy used in remote sensing. The energy may also be artificially generated and used to collect information about the objects and phenomena such as flashguns or energy beams used in radar (radio detection and ranging).

b. Transmission of Energy from the Source to the Surface of the Earth: The energy that emanates from a source propagates between the source and the object surface in the form of the waves of energy at a speed of light (300,000 km per second). Such energy propagation is called the Electromagnetic Radiation (EMR). The energy waves vary in size and frequency. The plotting of such variations is known as the Electromagnetic Spectrum. On the basis of the size of the waves and frequency, the energy waves are grouped into Gamma, X– rays, Ultraviolet rays, visible rays, Infrared rays, Microwaves and Radio waves. Each one of these broad regions of spectrum is used in different applications. **However, the visible, infrared and microwave regions of energy are used in remote sensing.**



Electromagnetic Spectrum

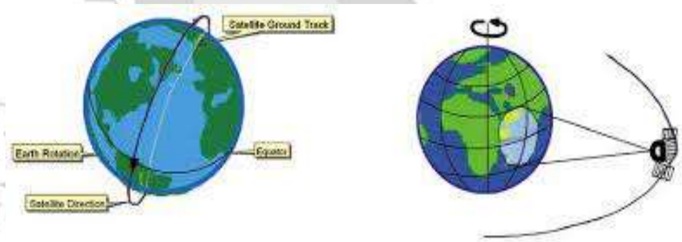
C. Interaction of Energy with the Earth's Surface: The propagating energy finally interacts with the objects of the surface of the earth. This leads to absorption, transmission, reflection or emission of energy from the objects. All objects vary in their composition, appearance forms and other properties. Hence, the objects' responses to the energy they receive are also not uniform. Besides, one particular object also responds differently to the energy it receives in different regions of the spectrum. For example, a fresh water body absorbs more energy in the red and infrared regions of the spectrum and appears dark/black in a satellite image whereas turbid water body reflects more in blue and green regions of spectrum and appears in light tone.

IRS 1 C Band 1 Green (left) and Band 4 IR Images of Sambhar Lake, Rajasthan

d. Propagation of Reflected/Emitted Energy through Atmosphere: When energy is reflected from objects of the earth's surface, it re–enters into the atmosphere. You may be aware of the fact that atmosphere comprises of gases, water molecules and dust particles. The energy reflected from the objects comes in contact with the atmospheric constituents and the properties of the original energy get modified. Whereas the Carbon dioxide (CO_2), the Hydrogen (H), and the water molecules absorb energy in the middle infrared region, the dust particles scatter the blue energy. Hence, the energy that is either absorbed or scattered by the atmospheric constituents never reaches to sensor placed onboard a satellite and the properties of the objects carried by such energy waves are left unrecorded.

e. Detection of Reflected/Emitted Energy by the Sensor: The sensors recording the energy that they receive are placed in a near– polar sun synchronous orbit at an altitude of 700 – 900 km. These satellites are known as remote sensing satellites (e.g. Indian Remote Sensing Series). As against these satellites, the weather monitoring and telecommunication satellites are placed in a Geostationary position (the satellite is always positioned over its orbit that synchronizes with the direction of the rotation of the earth) and revolves around the earth (coinciding with the direction of the movement of the earth over its axis) at an altitude of nearly 36,000 km (e.g. INSAT series of satellites).

Comparison between Sun-Synchronous and Geostationary Satellites		
Orbital Characteristics	**Sun Synchronous Satellites**	**Geostationary Satellites**
Altitude	700 – 900 km	@ 36,000 km
Coverage	81° N to 81° S	1/3rd of the Globe
Orbital period	@ 14 orbits per day	24 hours
Resolution	Fine (182 metre to 1 metre)	Coarse (1 km x 1 km)
Uses	Earth Resources Applications	Telecommunication and Weather monitoring



Orbit of Sun Synchronous (Left) and geostationary (Right) satellites

Remote sensing satellites are deployed with sensors which are capable of collecting the EMR reflected by the objects.

The sensors used in remote sensing satellites possess a mechanism that is different from photographic camera in collecting and recording the information. **The images so acquired by space-borne sensors are in digital format as against the photographic format obtained through a camera-based system.**

f. Conversion of Energy Received into Photographic/ Digital Form of Data: The radiations received by the sensor are electronically converted into a digital image. It comprises digital numbers that are arranged in rows and columns. These numbers may also be converted into an analogue (picture) form of data product. The sensor onboard an earth-orbiting satellite electronically transmits the collected image data to an Earth Receiving Station located in different parts of the world. In India, one such station is located at Shadnagar near Hyderabad.

g. Extraction of Information Contents from Data Products: After the image data is received at the earth station, it is processed for elimination of errors caused during image data collection. Once the image is corrected, information extraction is carried out from digital images using digital image processing techniques and from analogue form of data products by applying visual interpretation methods.

h. Conversion of Information into Map/Tabular Forms: The interpreted information is finally delineated and converted into different layers of thematic maps. Besides, quantitative measures are also taken to generate a tabular data.

SENSORS

A sensor is a device that gathers electromagnetic radiations, converts it into a signal and presents it in a form suitable for obtaining information about the objects under investigation. Based upon the form of the data output, the sensors are classified into photographic (analogue) and non– photographic (digital) sensors.

A Photographic sensor (camera) records the images of the objects at an instance of exposure. **A non–photographic sensor obtains the images of the objects in bit-by-bit form. These sensors are known as scanners.**

Non–photographic sensors that are used in satellite remote sensing.

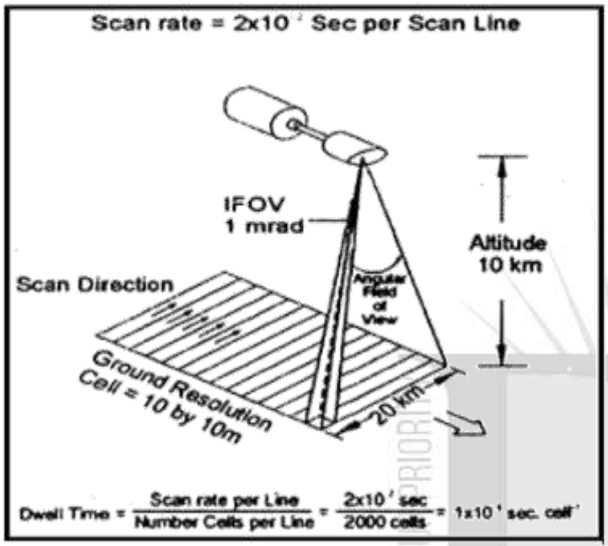
Types of Aerial Photographs

Multispectral Scanners: In satellite remote sensing, the Multi Spectral Scanners (MSS) are used as sensors. These sensors are designed to obtain images of the objects while sweeping across the field of view. A scanner is usually made up of a reception system consisting of a mirror and detectors. A scanning sensor constructs the scene by recording a series of scan lines. While doing so, the motor device oscillates the scanning mirror through the angular field of view of the sensor, which determines the length of scan lines and is called swath. It is because of such reasons that the mode of collection of images by scanners is referred bit–by–bit. Each scene is composed of cells that determine the spatial resolution of an image. The oscillation of the scanning mirror across the scene directs the received energy to the detectors, where it is converted into electrical signals. These signals are further converted into numerical values called Digital Number (DN Values) for recording on a magnetic tape.

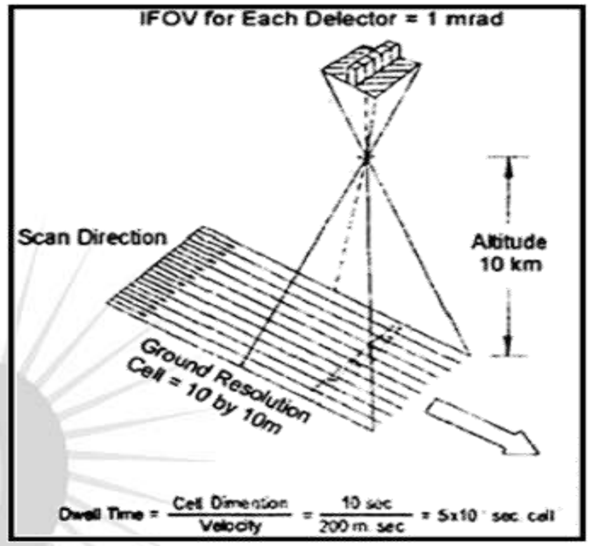
The Multi-Spectral Scanners are divided into the following types:

i. Whiskbroom Scanners
ii. Pushbroom Scanners

(i) Whiskbroom Scanners: The whiskbroom scanners are made up of a rotating mirror and a single detector. The mirror is so oriented that when it completes a rotation, the detector sweeps across the field of view between 90° and 120° to obtain images in a large number of narrow spectral bands ranging from visible to middle infrared regions of the spectrum. The total extent of the oscillating sensor is known as the Total Field of View (TFOV) of the scanner. While scanning the entire field, the sensor's optical head is always placed at a particular dimension called the Instantaneous Field of View (IFOV).



Whiskbroom Scanners



Pushbroom Scanners

(ii) Pushbroom Scanners: The pushbroom scanners consist of a number of detectors which are equivalent to the number obtained by dividing the swath of the sensor by the size of the spatial resolution. For example, the swath of High Resolution Visible Radiometer – 1 (HRVR – 1) of the French remote sensing satellite SPOT is 60 km and the spatial resolution is 20 meters. If we divide 60 km x 1000 metres/20 metres, we get a number of 3000 detectors that are deployed in SPOT HRV – 1 sensor. In pushbroom scanner, all detectors are linearly arrayed and each detector collects the energy reflected by the ground cell (pixel) dimensions of 20 meters at a nadir's view.

SENSOR RESOLUTIONS

Remote sensors are characterized by spatial, spectral, radiometric and temporal resolutions that enable the extraction of useful information pertaining to different terrain conditions.

(i) Spatial Resolution:-

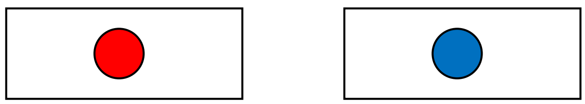
In remote sensing, the spatial resolution of the sensors refers to the capability of the sensor to distinguish two closed spaced object surfaces as two different object surfaces. As a rule, with an increasing resolution the identification of even smaller object surfaces become possible.

(ii) Spectral Resolution: It refers to the sensing and recording power of the sensor in different bands of EMR (Electromagnetic radiation). Multispectral images are acquired by using a device that disperses the radiation received by the sensor and recording it by deploying detectors sensitive to specific spectral ranges.

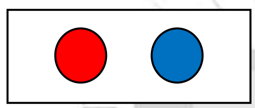
(iii) Radiometric Resolution: It is the capability of the sensor to discriminate between two targets. Higher the radiometric resolution, smaller the radiance differences that can be detected between two targets.

(iv) Temporal Resolution: Capability of the sensor to discriminate two objects moving in a fraction of time.

Eg:-



Needed low temporal resolution.



Frequent simultaneous appearance – Needed High temporal resolution.

Spatial, Spectral and Radiometric Resolution of Landsat, IRS and SPOT Sensors			
Satellite/Sensor	Spatial Resolution (in metres)	Number of Bands	Radiometric Range (Number of Grey Level Variations)
Landsat MSS (USA) IRS	80.0 x 80.0	4	0 - 64
LISS – I (India)	72.5 x 72.5	4	0 - 127
IRS LISS – II (India)	36.25 x 36.25	4	0 - 127
Landsat TM (USA)	30.00 x 30.00	4	0 - 255
IRS LISS III (India)	23.00 x 23.00	4	0 - 127
SPOT HRV - I (France)	20.00 x 20.00	3	0 – 255
SPOT HRV – II (France)	10.00 x 10.00	1	0 - 255
IRS PAN (India)	5.80 x 5.80	1	0 - 127

DATA PRODUCTS

The photographic process uses light sensitive film to detect and record energy variations. A scanning device obtains images in digital mode. An image refers to pictorial representation, regardless of what regions of energy have been used to detect and record it. A photograph refers specifically to images that have been recorded on photographic film. Hence, it can be said that all photographs are images, but all images are not photographs.

The remotely sensed data products may be broadly classified into two types :

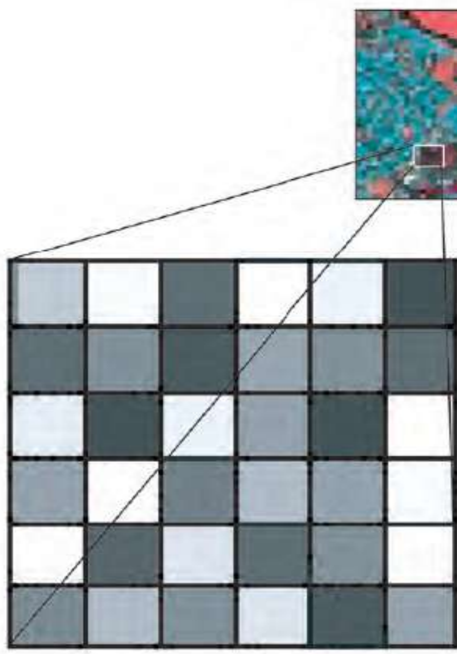
(a) Photographic Images
(b) Digital Images

Photographic Images: Photographs are acquired in the optical regions of electromagnetic spectrum, i.e. 0.3 – 0.9 µm.

Digital Images: A digital image consists of discrete picture elements called pixels. Each one of the pixels in an image has an intensity value and an address in two-dimensional image space. A digital number (DN) represents the average intensity value of a pixel. It is dependent upon the electromagnetic energy received by the sensor and the intensity levels used to describe its range.

The details pertaining to the images of the objects are affected by the size of the pixel. A smaller size pixel is generally useful in the preservation of the scene details and digital representation.

All photographs are digital images but all digital images are not photographs.



170	230	85	255	221	0
68	136	17	170	119	68
221	0	238	138	0	255
119	255	85	170	136	238
238	17	221	68	19	255
85	170	119	221	17	136

Digital image (top) and part of it zoomed showing pixel's brightness (left) and the associated Digital Numbers (right)

INTERPRETATION OF SATELLITE IMAGERIES

1. **Tone or Colour**
2. **Texture**
3. **Size =** Relative to one other
4. **Shape =** depends on the object outline
5. **Shadow =** helps to determine height
6. **Pattern**
7. **Association =** features that are normally found near object.

Colour Signatures on Standard False Colour Composite of Earth Surface Features		
S. No.	**Earth Surface Feature**	**Colour (In Standard FCC)**
1.	**Healthy Vegetation and Cultivated Areas** Evergreen Deciduous Scrubs Cropped land Fallow land	 Red to magenta Brown to red Light brown with red patches Bright red Light blue to white
2.	**Waterbody** Clear water Turbid waterbody	 Dark blue to black Light blue
3.	**Built – up area** High density Low density	 Dark blue to bluish green Light blue
4.	**Waste lands/Rock outcrops** Rock outcrops Sandy deserts/River sand/ Salt affected Deep ravines Shallow ravines Water logged/Wet lands	 Light brown Light blue to white Dark green Light green Motelled black