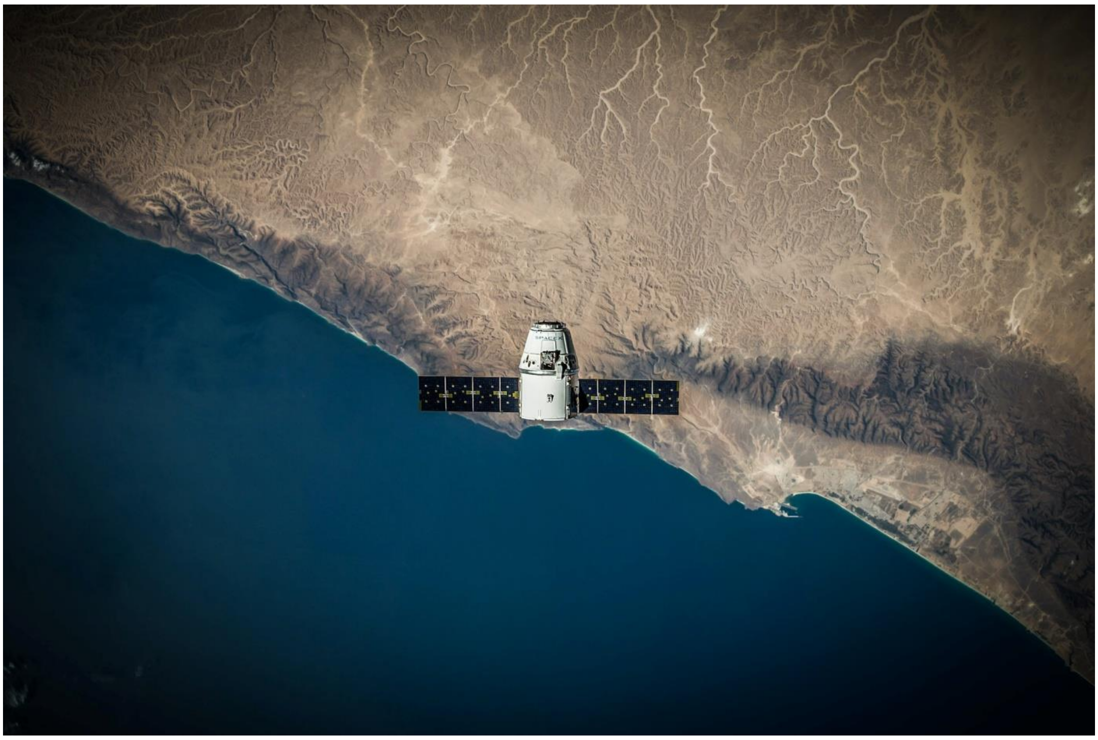
Remote Sensing



Principles of Remote Sensing

Here, we will discuss the basic principles of remote sensing. Let us divide the topic into three main headings for our better understanding. The headings are Definition of Remote Sensing, Concepts of Remote Sensing and GIS Work Flow and Components of remote sensing:

Definition of Remote Sensing:

Remotely Sensed is remote sensing. If we are reading this topic, now you are doing Remote Sensing.

In fact, the process of acquiring any information from the object without touching is Remote Sensing.

Following are some scientific definitions of Remote Sensing.

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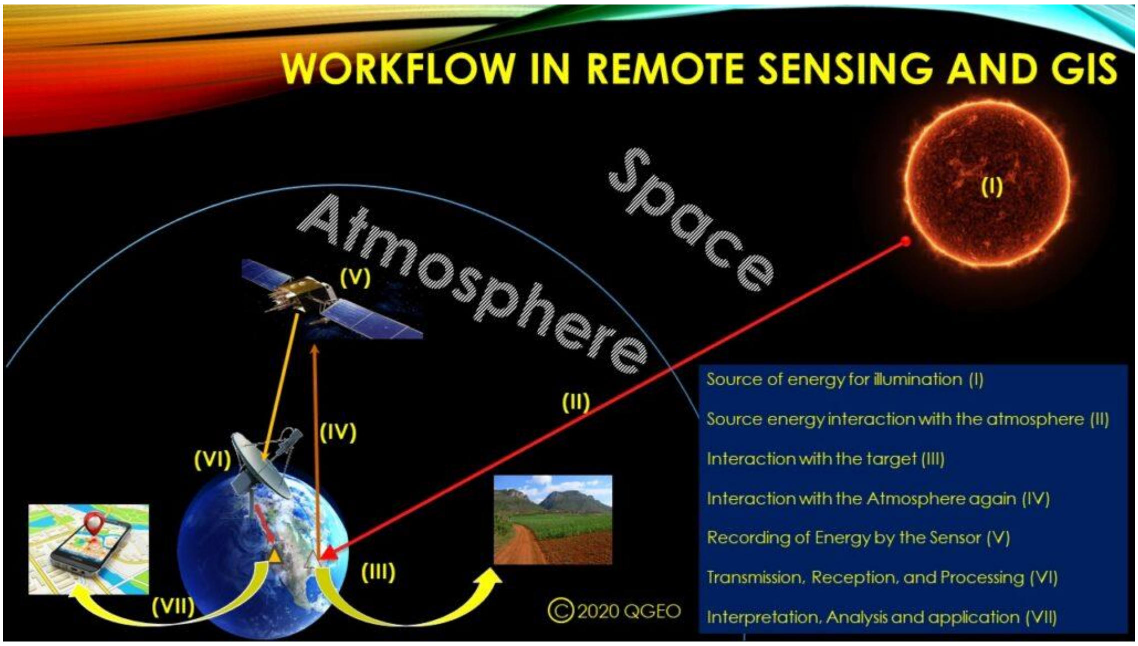
1. *"Remote sensing is the technique of deriving information about objects on the surface of the earth without physically coming into contact with them."* (Source: India's National Remote Sensing Agency, June 1995)
2. *"Remote sensing is the non-contact recording of information from the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum by means of instruments such as cameras, sensors, lasers, linear arrays, and/or area arrays located on platforms such as aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing"* (Source: John R. Jensen, University of South Carolina)

Concepts of Remote Sensing and GIS Work Flow:

There are seven elements on the basis of which remote sensing and GIS technique works. They are categorized as follows;



Work flow in Remote Sensing

A.2.1. Source of energy for illumination (I):

To better understanding the fact we have to acquire the minimum knowledge about the following concepts.

A.2.1.1. Concept of energy:

The ability to do work is energy. It often transfers one place to another and one body to others. The processes of transfer of energy are radiation, conduction, and convection.

The process of energy transfer without any medium is known as radiation. The solar energy passes through the vacuum space to the earth in the process of radiation in the form of Electromagnetic radiation (EMR).

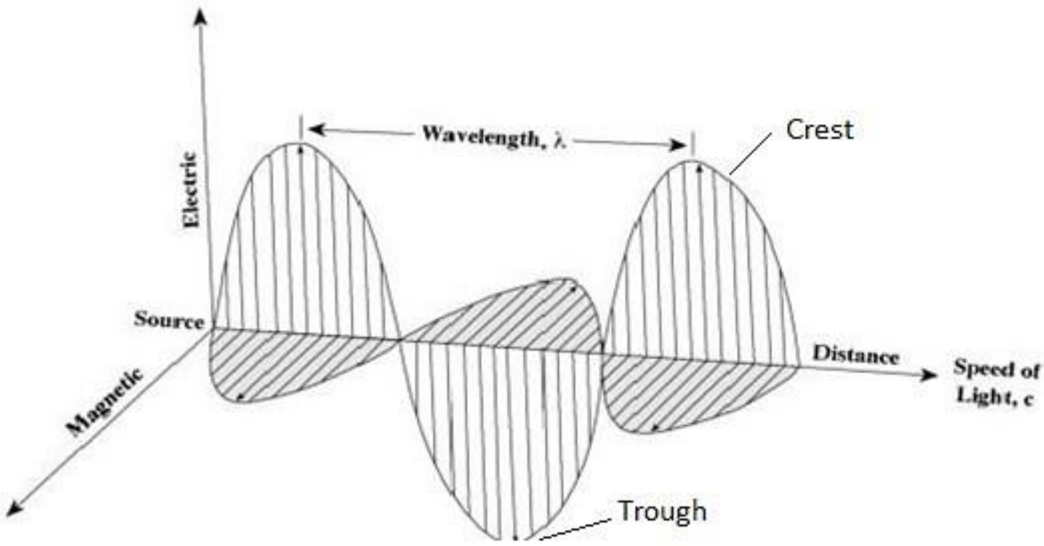
The process of energy transfer from one molecule or atom to another just beside it is known as conduction. A metal body is heated by a hot burner in this process.

The energy of a body transfer from one place to another by moving the body itself is known as convection. The process of heating air in the atmosphere through rising of warmer air from the ground and falling of cool air to the ground is an example of it.

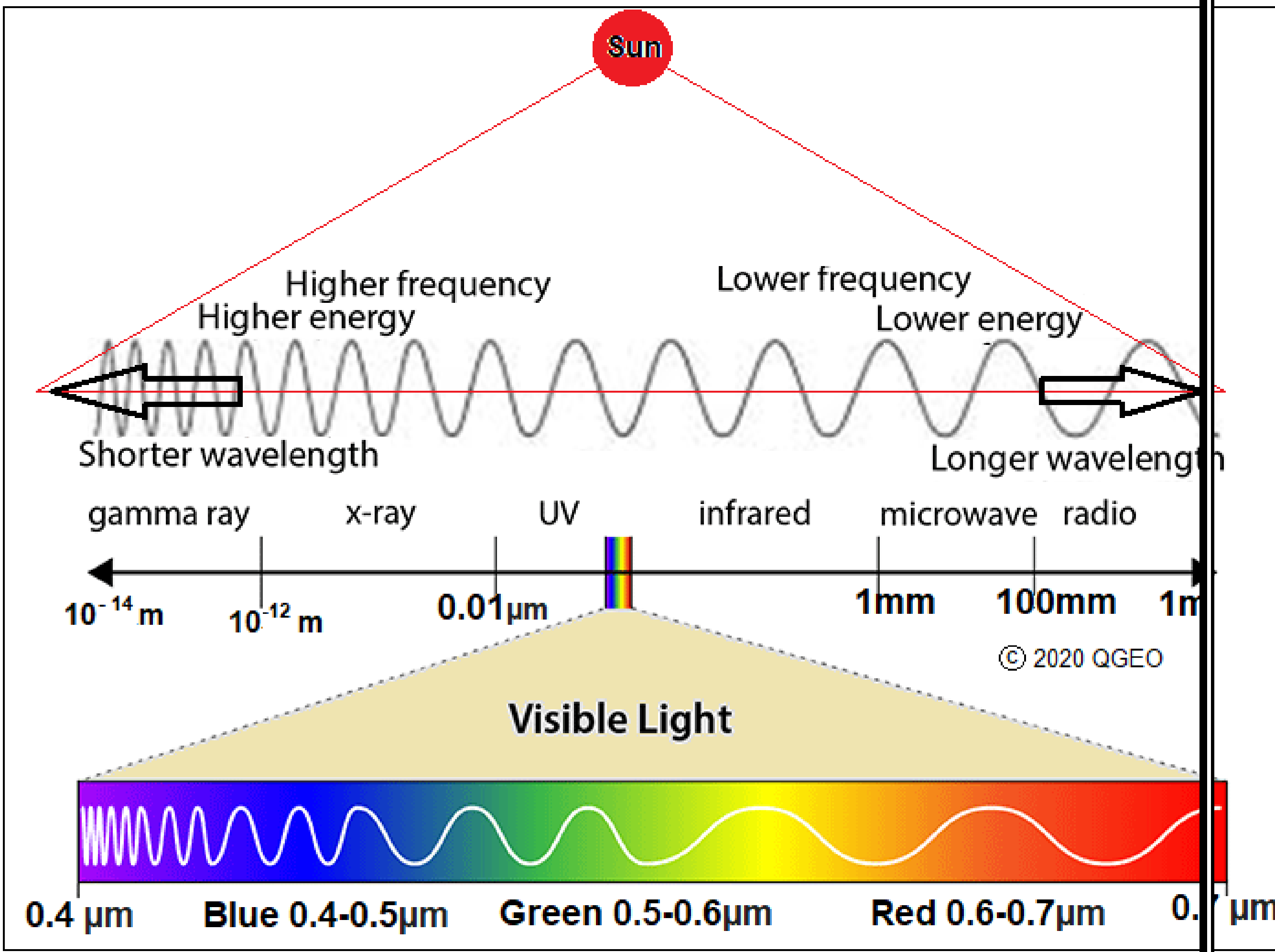
From the three processes, the first is most important for the remote sensing process.

A.2.1.2. Electromagnetic radiation:

The solar energy produces the Electromagnetic radiation (EMR) EMR refers to the waves of the electromagnetic field, generated from the sun, propagating through space, carrying electromagnetic radiant energy. It includes radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.



Different energy model explains the process of propagation of EMR through space and interacts with other matter. The Wave model and Particle model are remarkable in this context.



Electromagnetic Spectrum

A.2.1.2.1. Wave Model of Energy:

James Clerk Maxwell in the 1860s, introduces the concept of wave model. As per the model electromagnetic waves travel in a vacuum at the speed of light (3 X10^8m/s or 1,86,000 miles/s).

Electromagnetic radiation consists of electromagnetic waves in two fluctuating fields, which are electric and magnetic fields. These two fields are right angle (900) to each other and both are perpendicular to their propagation direction. Both have the same amplitude at the same time. It can be transmitted through the vacuum. Electromagnetic radiation is generated whenever the electrical charge is accelerated. The wavelength and frequency are the two important characteristics of this electromagnetic radiation. We have to understand clearly these two properties in this context.

Weave length is the length or distance of a complete wave cycle. It can be measured by the linear distance between two successive wave peaks. It depends upon the length of time that the charged particle is accelerated. Greek letter lambda (λ) is used to represent the wavelength. The unit of wavelength is metres (m) or factors of metres such as Millimetres (mm, 10^{-3} m), Micrometres (μm, 10^{-6} m), nanometres (nm, 10^{-9} m) and Angstrom (Å, 10^{-10} m).

The number of cycles of a wave passing in a fixed point per unit time is called the frequency of a wave. The Greek letter nu (v) is used to represent it. The unit of frequency is Hertz (Hz). It is equivalent to one cycle per second. The multiplication values of hertz are Kilohertz (kHz, 103 Hz), Megahertz (MHz, 106 Hz), and Gigahertz (GHz, 10^9 Hz).

The relationship between Weave *length and Frequency of* Electromagnetic radiation is inversely proportional. Thus we can conclude that longer wavelength is related to the shorter frequency and vice versa. It is derived from the formula:

$c= \lambda v$

So, $\lambda= c/v$

Where:

c= velocity of light

λ= Wave length

v= Frequency

A.2.1.2.1. Particle Model of Energy:

From this model, Electromagnetic energy may also be described in terms of Jules (J) and electron volts (eV). The rate of transfer of energy from one place to another is termed as the flux of energy which is measured by watts (W). The amount of energy generalized by Planck's general equation as:

Q= hv .....(i)

Where:

Q= Energy of a quantum measured by Joules (J)

h= Planck's constant (6.6260 x 10^{-34} J)

v= Frequency of the radiation

The relationship among the energy (Q), weave length (λ) and frequency (v) from the two models:

From weave model: λ= c/v .....(ii)

Multiplying h/h with c/v without changing its value

λ=h c/h v

λ= h c/Q

Q = h c/ λ

Thus, we can say from the equation the energy of a quantum is inversely proportional to its wavelength. As the wavelength is inversely proportional to frequency so, energy is proportionate to frequency (Q = 1/ λ = v)

A.2.1.3. Electromagnetic Spectrum:

The electromagnetic spectrum is the wide range distribution of frequencies of electromagnetic radiation and their respective wavelengths and photon energies. In the entire electromagnetic spectrum, from the lowest to the highest frequency or longest to shortest wavelength includes all radio waves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. Nearly all frequencies and wavelengths of electromagnetic radiation can be used for spectroscopy. In remote sensing visible and infrared used as optical remote sensing or passive remote sensing and microwave used for active remote sensing purposes.

A.2.2. Source energy interaction with the atmosphere (II):

The energy propagates from its source through the atmosphere to the target. It interacts with the atmosphere. The solar energy in the form of EMR (Electro-Magnetic Radiation) first propagates through a vacuum of space almost in the speed of light. After that, it penetrates the earth's atmosphere. The speed, wavelength intensity, and spectral distribution of EMR affected by the process of absorption, scattering, and refraction in the atmosphere.

A.2.2.1. Absorption:

The process by which the radiant energy absorbed and converted to other forms of energy is called absorption. The process may take place in the atmosphere and also at the target or surface of the earth. In the atmosphere ozone, Carbon dioxide and water vapor are the most absorbing elements. The atmospheric elements absorb a very specific region of the electromagnetic spectrum. The regions of the electromagnetic spectrum which are not mostly influenced by atmospheric absorption are known as atmospheric windows. The atmospheric windows are very useful to the remote sensing process. The regions of visible light, mid-infrared, far-infrared, and all the higher weave length region of EMS are almost opaque to EMR. The absorption and interaction mostly occur at the part of a shorter wavelength region where harmful cosmic rays and ultraviolet rays almost destroy. We, the all habitat of the earth are fortunate for it.

A.2.2.2. Scattering:

It is the phenomenon in which radiation energy gets deviated from its straight path on striking the atmospheric particles. The wavelength of radiation and the diameter of the particles.

The processes are subdivided by two. One is Selective and another is non-selective. The selective scattering is three types. They are Rayleigh scattering, Mie scattering, and Raman Scattering.

Rayleigh scattering takes place when the effective diameter of the particles is much time smaller than the wavelength of radiation. In the upper atmosphere (>4.5 Km) effective diameter of nitrogen and oxygen molecules is very smaller (<0.1 times) than the wavelength of incident radiation. The shorter wavelength light scatters more than a larger wavelength. That is why due to the blue light scattering we see the same color of the upper atmosphere.

Below the height of 4.5 km in the atmosphere, the effective diameter of the particles is almost equal to the wavelength of radiation. Here Mie Scattering takes place.

Where the effective diameter of atmospheric particles is less, equal, or greater than the length of incident radiation Raman scattering takes place. The process depends upon the elastic collision of the particles.

In non-speculative scattering, the effective diameter of atmospheric particles is very larger (>10times) than the wavelength of incident radiation. In the cloud-forming particles such as water droplets and ice crystal, all the regions of visible light in EMS scattered and produce the white light.

A.2.2.3. Refraction:

The slight change of direction of light when it passes from one medium to another is known as Refraction. It depends upon the densities of different mediums and speed of light. The optical density of a substance is measured by the **refraction index** (n). We know the speed of light in a vacuum ($c = 3 \times 10^8$ m/s). If we know the speed of light in a medium (c_n) then we calculate the refraction index of that medium by the formula:

$$n = c / c_n$$

As the speed of light is maximum in a vacuum so the value of refraction index (n) always be greater than one. The refraction error in the image can be removed by Snell's law. It is:

$$n_1 \sin\phi_1 = n_2 \sin\phi_2$$

Where:

n_1 = Refraction index in medium-1

n_2 = Refraction index in medium-2

$\sin\phi_1$ = Angle between the ray and line of normal in medium-1

$\sin\phi_2$ = Angle between the ray and line of normal in medium-2

A.2.2.4. Reflection:

It is the process of sending back or bounces off the light rays from the top of the surface of an object. In the atmosphere cloud is the most important reflector. Ice, water bodies, soil, and vegetation also are important reflectors on the surface of the earth. It is very useful in remote sensing rather than scattering as the direction of reflection is predictable. From the smooth surface, the reflection is specular, and in the rough surface, it is defused in type.

A.2.3. Interaction with the target (III)

After passing through the atmosphere the energy interacts with the target. The energy interacts depending on the characteristics of both the target and energy radiant flux.

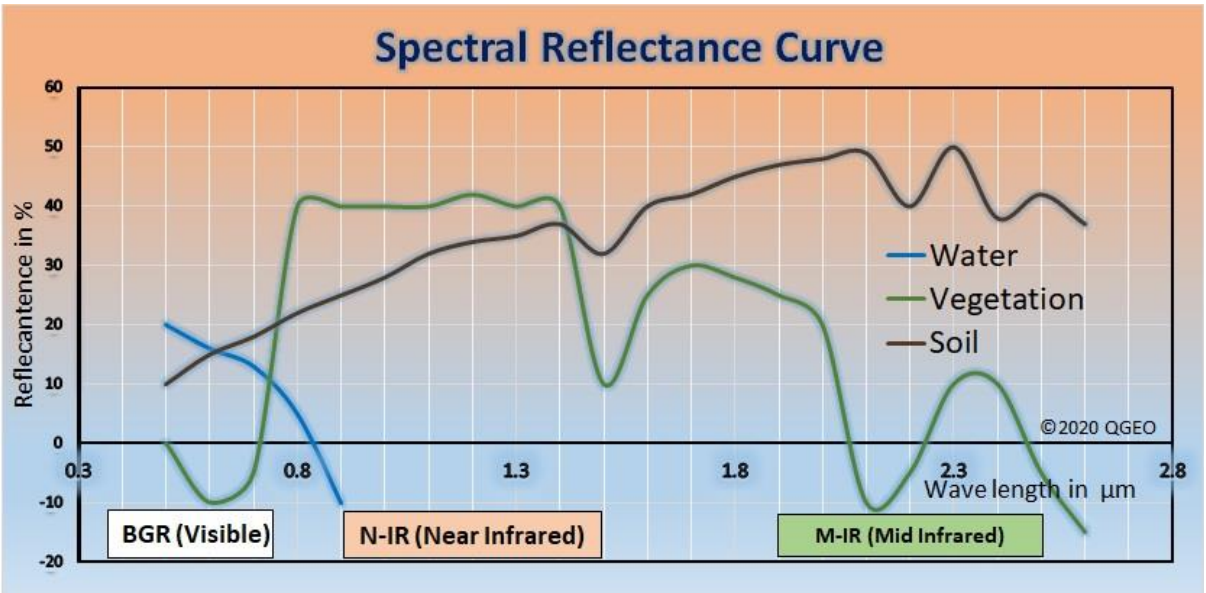
"The amount of radiant energy onto, off of, or through a surface per unit time is called radiant flux (ø) and is measured in watts (W)." (Source: B. Bhatta, Remote Sensing, and GIS)

In radiation budget equation the total amount of radiant flux in specific wavelengths (λ) incident to the target ($\O_{t\lambda}$) is equal to the amount of energy reflected from the surface (R_λ), the amount of energy absorbed by the surface (A_λ) and the amount of energy transmitted through the surface (T_λ)

$\O t\lambda =+ R\lambda + A\lambda + T_\lambda$

How much (%) energy an object reflects at a specific wavelength is measured by Spectral Reflectance.

Spectral Reflectance Curve is the graphical representation of the relationship in the electromagnetic spectrum with reflectance amount in percent for any object on the ground.



A.2.4. Interaction with the Atmosphere again (IV):

Reflected or emitted radiant flux from the target object on the earth's surface once again enters into the atmosphere. It interacts with atmospheric gasses, vapor, and aerosols or SPM (Suspended Particulates Matter). Hence here also absorption, reflection, and refraction influence the radiant flux before the energy is recorded by the sensor of the remote sensing platform.

A.2.5. Recording of Energy by the Sensor (V):

The sensor on the remote sensing platform records the retreating electromagnetic radiation. The radiant flux which scattered or emitted from the target influenced by the interaction with the atmosphere. The amount of energy received by the sensor depends upon the location and operational system of that particular sensor. The sensor receives additional energy due to the atmospheric interaction of returned energy from target and path radiance. In other words, the path radiance introduces unwanted radiometric noise in the sensor. Path radiance occurs due to the defused sky irradiance and reflectance from the neighboring area of the target object.

We can formulate it as follows.

Pr = Sr + Nr

Where:

Pr = Path radiance

Sr = Diffuse sky irradiance

Nr = Reflectance from the neighboring area of the target

Tλ = Tr + Pr

Where:

Tλ = Total Energy received by the sensor

Tr = Energy received from the target area.

Pr = Energy received from the path radiance.

A.2.6. Transmission, Reception, and Processing (VI)

The sensor transmitted the received energy, to the receiving and processing station in the form of electronic energy. After receiving the data the Ground Receiving Station (GRS) processes the electronic energy into an image as in hardcopy and/or in digital form.

The data can be directly transmitted to the GRS if it is in the line of sight (L) of the Satellite. In the other case, data can be recorded onboard satellite (S) for transmission to a GRS after a suitable time through the (T) Tracking and Data Relay Satellite System (TDRSS). The TDRSS consists of a series of communication Satellite in geosynchronous orbit.

Indian Space Research Organization (ISRO) operates the Ground Receiving Station (GRS) at Shadnagar near Hyderabad in Andhra Pradesh. It covers all of India and about nine neighboring countries.

A.2.7. Interpretation, Analysis and End users application (VII)

The processed image is interpreted, visually (Analog) or digitally (DIP), to extract information about the target.

The most important elements of visual image interpretation are size, shape, shadow, tone or color, texture, pattern, parallax, site, and association, etc. The outcome of the processes influenced by human skill and error as it is a mixture of art and science.

Digital image processing (DIP) follows the most scientific algorithm to interpret and analysis of the image. The accuracy of the result influenced by the spatial resolution of the image. IRS PAN Data (5.8m X 5.8m) is often used for interpretation in different projects. IKONOS, Quick Bird are also the higher resolution image presently used for DIP.

The user segments use the remote sensing process in a different manner. The researchers, administrators, and planners use the information extracted from the imagery in solving a particular problem. General civilians and defense units also use this information in their specific fields.

3.Components of remote sensing:

a) Platform: It is the vehicle that carries a sensor, such as satellite, aircraft, balloon, etc.

b) Sensors: It is the device that receives electromagnetic radiation and converts it into a signal that can be recorded and displayed as either numerical data or an image.

Remember that, one platform can carry one or more than one sensor.

For the example of a platform with one sensor are:

1. The platform Landsat TM carries Thematic Mapper (Passive: Optical sensor).
2. In the same way, the platform Landsat ETM carries Enhanced Thematic Mapper (Passive: Optical sensor)

For the example of a platform with more than one sensor is:

The platform ALOS carries three different sensors. They are:

1. PRISM (Passive: Optical sensor)

2. AVNIR-2 (Passive: Optical sensor) 3. PALSAR (Active: Microwave sensor)

The most important and primary requirement for any remote sensing process is to have an energy source. The Source of energy which illuminates or provides electromagnetic energy to the target of interest. In most of the cases, the Source of energy is the Sun. This remote sensing method is known as Passive Remote sensing. In some cases, remote sensing methods provide their own source of electromagnetic radiation to illuminate the target. The process is known as Active Remote sensing. Radar is the one example of active remote sensing.