

# SUSTAINABLE MINING AND GEOINFORMATION

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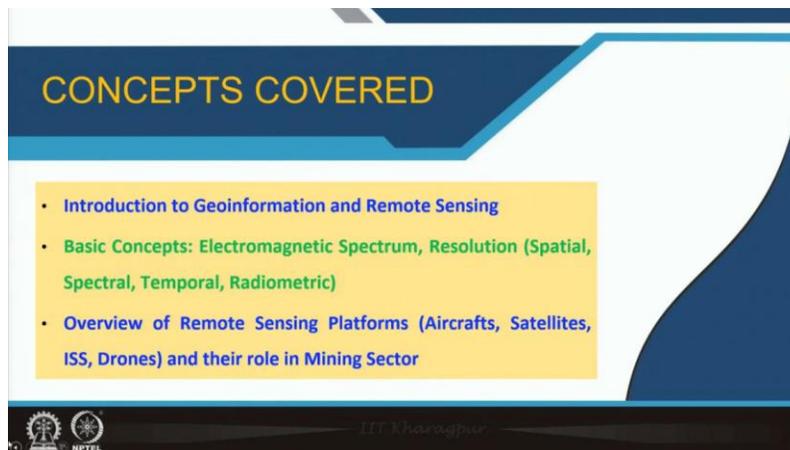
**Indian Institute of Technology Kharagpur**

**Week – 01**

## **Lecture 01: Fundamental of geoinformation**

Welcome to the first lecture on sustainable mining and geoinformation. I am Dr. Mukunda Dev Behera, an associate professor at the Centre for Oceans, Rivers, Atmosphere and Land Sciences at IIT, Kharagpur. The first lecture is on fundamentals of geo information and remote sensing. So, with this we will try to understand the broad aspect of geo information and its applications to mining sector particularly in achieving sustainable mining.

Thank you for joining this particular course. The concepts ah will be covered in this particular lecture is this 3. We will have an introduction to geo-informations and remote sensing. So, in this we will try to understand what we can understand by the term geo-information and remote sensing though they are now very well known. And then we will go on to understand the basic concepts in terms of electromagnetic spectrum EMS.



The resolution with respect to these 4 resolutions that is spatial, spectral, temporal and radiometric. And then we will discuss an overview of remote sensing platforms, the various platforms which are offered from aircrafts, different space born satellites, even if the ISS International Space Station and the drones. Let us also discuss their role in mining sector

how the geo information plays an important role and contributes in understanding different aspects of mining industry. Friends, as far as the term geo information is concerned it is we say a science or a technology that involves gathering, storing, processing, and delivering spatially referenced information. The moment we talk about gathering it is a collection of information or the data having collected the data we need to understand how to store it so we need to follow an appropriate protocol of storing then once it is stored it has to be retrieved for processing as per our need and then once it is processed we need to understand what are the results has been achieved.

The slide features a yellow header with the title 'What is Geoinformation?'. Below it, an orange box contains the definition: 'Geoinformation is the Science and Technology of Gathering, Storing, Processing and Delivering Spatially referenced information. It integrates Data and Technology to support Spatial Analysis, Mapping and Decision-Making Processes.' To the right is a stylized atomic symbol. A blue box labeled 'Key Components' points to three items: 'REMOTE SENSING', 'GIS (Geographic Information System)', and 'GNSS (Global Navigation Satellite Systems)'. The slide also includes logos for IIT Kharagpur and NPTEL at the bottom left, and a small inset photo of a man in a suit at the bottom right.

And then, perhaps we have to deliver the spatially referenced information. The moment we talk about spatially referenced information, it indicates that it has a reference to the earth coordinates—the X, Y, and also Z coordinates. It integrates data and technology to support spatial analysis and mapping. And this activity is particularly a spatial support system, and spatial analysis and mapping lead to a kind of decision-making process. The managers and the planners take some decisions and actions based on the information provided on the spatial platform. So, the three key components of geo-information are remote sensing, GIS (which is expanded as Geographic Information System, also called Geographical Information System, as it is very often used). Then, GNSS—the Global Navigation Satellite Systems—gives us X, Y, and Z coordinates. Together, all these three—remote sensing, GIS, and GNSS—form the basic three pillars of geo-information.

So, let us understand: what is remote sensing? Friends, remote sensing—as the term indicates—is the art and science of acquiring information about an object or an area without coming into direct physical contact with it. So, what does it mean? It means the object is at a distance from the source, the person, or from where we need to collect the data or information. So, the objects are at a distance.

**What is Remote Sensing?**

**Remote sensing is the Science of acquiring information about an Objects or areas from a Distance, typically from Aircraft or Satellites**  
**It enables the collection of data on the Earth's Surface without Physical Contact**

**Remote Sensing Processes**

A  
Radiation by energy source  
B  
Interaction with the earth's atmosphere  
C  
Interaction with the target  
D  
Recording of energy by the sensor  
E  
Transmission, reception, and processing  
F  
Interpretation and analysis  
G  
Application

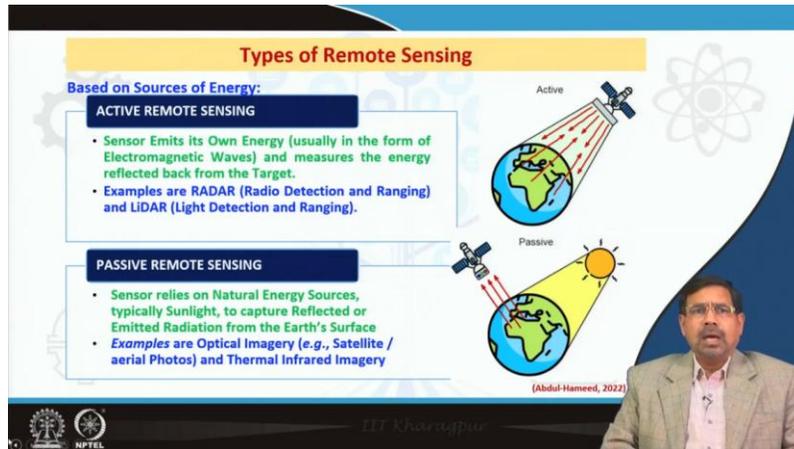
Earth's atmosphere  
Vacuum  
(Bhatta, 2020)

The collection of data on the earth's surface has to be done without direct physical contact—that is the main point as far as the definition of remote sensing is concerned. And we can understand it across seven different steps—the broad process of remote sensing, which has been termed as: first, radiation by an energy source; second, interaction with Earth's atmosphere; third, interaction with the target. Then, recording of energy by the sensor; transmission, reception, and processing; interpretation and analysis; and finally, applications. So, let us take them one by one. As far as the first one is concerned: radiation by energy sources. That talks about two different sources of energy—you have to have either passive or active.

So, if active, then in the case of passive, the source of energy is always the sun, where we always receive the radiant energy. So, that means if it is sun-based, solar-based, or optical-based remote sensing, then it has to be done particularly during the daytime. Then we also have the active, which means we need to generate a source of energy, so that comes under the active sources of energy. Then, coming to the second one, the interaction with Earth's atmosphere. Once the energy is released or this energy has to fall upon the Earth's surface, and it has to travel through the Earth's atmosphere. So, while traveling, it also comes across many phenomena, which are explained by scattering. Then, once it falls on the surface, we have other things like reflection, reflectance, transmittance, and all such things.

Then, coming to the interaction with the target, once the energy falls on the target, there has to be an interaction, which is the interaction between the radiant energy and the target. So, it depends on the target's behavior, the kind of material, and the constituents the target has. Then, coming to the recording of energy by the sensor, once it falls on the target, the energy is recorded by the sensor and is either transmitted or received, and then goes for processing. Once it has been received for processing, it is interpreted by the interpreter and

goes for several analyses, including analysis in the mining industry sector, and that includes a lot of applications as far as different sectors are concerned. Coming to the types of remote sensing, broadly, we can divide remote sensing into two types based on the sources of energy: active and passive.



So, in the case of active remote sensing, the sensor emits its own energy. So, what does it mean? Usually, in the form of electromagnetic waves, the sensor emits its own energy that measures the energy reflected back from the target. For example, radar (radio detection and ranging) and lidar (light detection and ranging). So, these two types of remote sensing fall under the active remote sensing category. Then, coming to passive remote sensing, the sensors rely on natural energy sources, typically sunlight.

To capture reflected or emitted radiation from the Earth's surface. Examples are all of our optical imageries or images, for example, satellites, which come from aerial photographs or even from thermal infrared imagery. The two figures on the right-hand side depict the active and the passive. In the case of passive, the source of energy has been shown as the solar or the sun. In the case of active, it is always from an energy source. So, these are the two broad types of remote sensing as far as the sources of energy are concerned.

Now, let us understand the types of remote sensing based on the range of the electromagnetic spectrum. So, as all of us understand, the electromagnetic spectrum is divided into cosmic rays, gamma rays, X-rays, then UV, visible, infrared, microwave, and radio waves, in order of increasing wavelength. So, on this basis, we can broadly divide remote sensing into three categories. One is optical, the second is thermal, and the third one is microwave remote sensing. The first one, optical remote sensing, uses visible, infrared, and shortwave infrared, sometimes abbreviated as SWIR.

**Types of Remote Sensing**

Based on Range of Electromagnetic Spectrum

**OPTICAL REMOTE SENSING**

- Uses Visible, Near-Infrared, and Shortwave Infrared Light to capture Images
- Applications: Mineral Exploration and Mapping, Detecting Surface Changes in Mining Areas

**THERMAL REMOTE SENSING**

- Measures Emitted Infrared Radiation to Detect Heat
- Applications: Identifying Geothermal Anomalies related to Mineral Deposits, Monitoring Heat from Mining Machinery or Processing Plants

**MICROWAVE REMOTE SENSING**

- Uses Longer Wavelengths (Microwaves) and can Penetrate Clouds, Fog, and Rain
- Types: Passive (e.g., radiometers) and Active (e.g., RADAR).
- Applications: Monitoring Ground Deformation and Subsidence around Mining Sites using InSAR (Interferometric Synthetic Aperture Radar) Detecting hidden Geological Structures for Mineral Prospecting

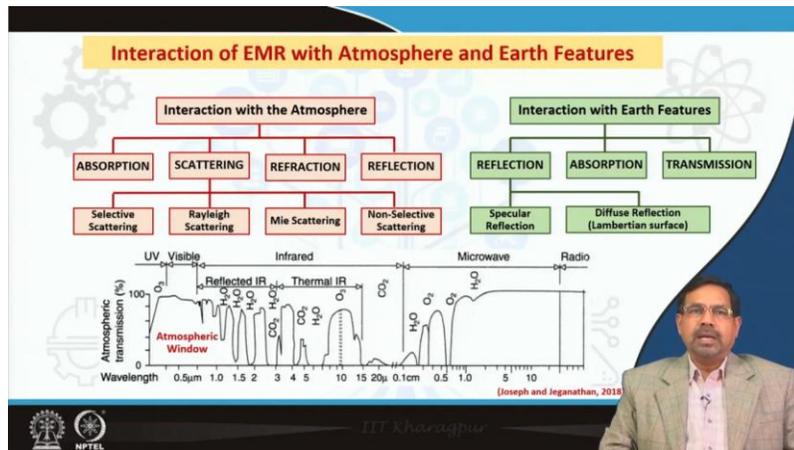
So, visible is abbreviated as VIS, NIR is the abbreviation for near-infrared, and SWIR is the abbreviation for shortwave infrared. These lights capture the images. So, what are the applications? The applications of optical remote sensing in the mining sector could be mineral exploration, mapping, and detection of surface changes in the mining areas. The second one is thermal remote sensing. As the term 'thermal' indicates, it refers to temperature variation.

So, in thermal remote sensing, it measures emitted infrared radiation to detect the heat. So, whatever variation due to heat or temperature can be captured and analyzed using thermal remote sensing. So, the applications in the mining sector are identifying geothermal anomalies related to mineral deposits and monitoring heat from mining machinery or processing plants. So, that has a variation. Even in land surface temperature, we see variations in different land surfaces in terms of their temperature. These are also analyzed using thermal remote sensing.

The third one is microwave remote sensing, which uses longer wavelengths, that is, microwaves, okay? So, this is beyond the near-infrared. So, microwaves are used because of their higher penetration power. So, the longer wavelength microwaves penetrate clouds, fog, and rain, thereby providing some information that otherwise would not be possible through optical remote sensing. So, in essence, microwave remote sensing serves as one of the means to overcome one of the limitations of optical remote sensing.

In terms of types, we also have passive and active microwave remote sensing. The active one is always referred to as radar, and the passive one is referred to as the radiometer. So, there are many radiometers where we use the sun or other passive sources as an energy source. The applications could include monitoring ground deformation and subsidence around mining sites using InSAR, the interferometric synthetic aperture radar.

This is another technology where we also measure undulation, deformation, and the subsidence. So, it is one of the very important areas as far as mining sites are concerned. And also, we can detect the hidden geological structures that are required or have mineral prospects or prospecting. So, these are the three broad types of remote sensing based on their electromagnetic spectrum ranges or behavior. Let us understand the interaction of electromagnetic radiation with the atmosphere and the earth's features.

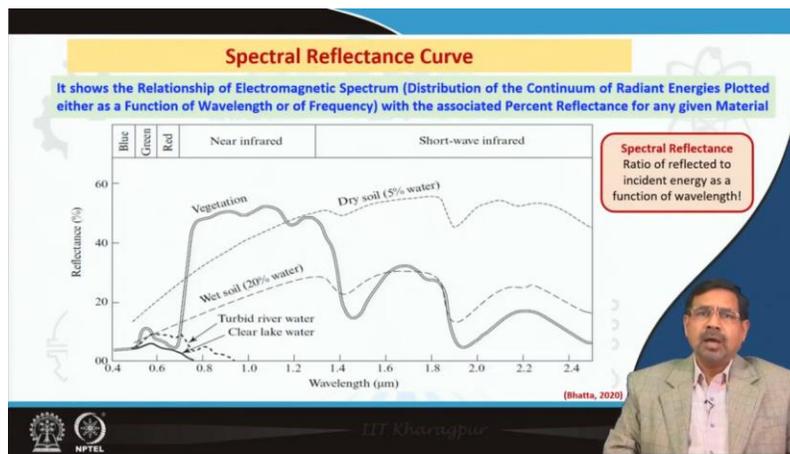


Friends, on the left-hand side, you can see the red boxes, and on the right-hand side, the green-colored boxes, and down below, we have shown an atmospheric transmission profile based on the different gases. What happens is the atmosphere is not that transmittent for all the gases. So, you can see at different parts of the electromagnetic spectrum, it is dominantly having the transmission, and it has the absorption as far as different parts of the electromagnetic spectrum are concerned with respect to different gases. So, interaction with the atmosphere and interaction with earth features—as far as the interaction with the atmosphere is concerned—it can be divided into four phenomena: absorption, scattering, refraction, and reflection. Our interest is mostly in terms of optics, which is the reflection, and then let us see in terms of the scattering, which can again be divided into four: first is selective and the non-selective type of scattering based on different absorption spectroscopy.

And then, the Rayleigh and the Mie scattering, which depend on the particle size. In the case of Rayleigh scattering, the particle size is smaller than the wavelength, whereas, in the case of Mie, it is slightly larger than the wavelength. So, we have these variations of these types as far as the different scattering mechanisms are concerned. Now, let us discuss the interaction with earth features. So, the interaction with earth features can be divided into three broad phenomena: reflection, absorption, and transmission. As far as reflection is

concerned, it can again be split into two: one is specular, and the second one is diffuse, or we say the Lambertian surface.

If it is reflected from a Lambertian surface not a specular surface then it is put under the diffuse reflection. So, this is about the interaction of electromagnetic radiation with atmosphere and the earth features on earth surface. Now friends having got the data in terms of the optical remote sensing let us understand this based on the spectral reflectance curve. So, friends what do we understand by spectral reflectance curve it is a very fundamental as far as the interpretation of any feature is concerned.



It shows the relationship of electromagnetic spectrum which is in bracket I have put distribution of continuum of radiant energies plotted either as a function of wavelength or frequency. with the associated percent reflectance for any given material. So, that means, in short spectral reflectance is a ratio of reflected to incident energy as a function of wavelength. Now, if we see the y-axis, the reflectance is shown in percentage. On x-axis, it is the wavelength or the electromagnetic radiation range is shown in micron meter.

Now let us see a few curves, one double lined curve is shown which is representing a typical reflectance coming from vegetation. The dotted line a small dotted line which crosses the vegetation in the near infrared range that is the that is showing the dry soil with 5 percent water content and another down below showing the wet soil having 20 percent water content. And then down below also we have two more curves that show the clear lake water and the turbid lake water. Clear lake water is shown by a dark ah black color curve whereas, the turbid river water is slightly above that we are showing in a dotted black color curve.

So, what is the difference let us first understand the vegetation reflectance curve it has it has a typical nature in the visible range 0.39 to 0.76 micron meter it shows very less reflectance that means lot of absorption because photosynthesis happens in this green range we say the green PAR photosynthetic active radiation range. And then suddenly there is an increase in the trend and the vegetation reflectance goes from about 8 to 9 percent to about 45 to 50 percent in the edge the near infrared part of the electromagnetic spectrum. where we say that vegetation reflectance is very high and then in the middle infrared the shortwave infrared region, we can see the vegetation reflectance is coming down with a dip again going little up the dip is at 1.39 then at 1.96 micron meter. And this is the typical nature of vegetation and this is explained by some physical mechanism. The reflectance behavior in case of as I mentioned in case of visible region it is dominantly because of the absorption by the pigments the dominant pigment is the green pigment chlorophyll. And, in the high reflectance in the near infrared region is because of the inter cellular space ok.

The reflectance coming is directly which is a function of the inter cellular space as far as the vegetation material is concerned. And then in the short-wave infrared there has been little absorption it depends on the absorption, or the percentage of moisture present there. So, this is how the three regions are broadly explained as far as the vegetation reflectance is concerned. Now let us take a look at the other two curves, one is the dry cell with 5 percent and 20 percent water content and the another one is about the water one is clean the other one is the turbid water. So, friends the dry soil has a typical signature which starts from about 15 percent and goes up to 50 and 55 percent and having higher kind of reflectance.

So, in the short wave infrared whereas the same soil having 20 percent moisture content has a lower reflectance value. So, this variation based on the moisture content helps us in differentiating between dry to wet soil or based on their moisture quantity or moisture content. And similarly with respect to water based on the turbidity behavior the two curves are having a different signature as the the turbid water having higher reflectance than that of the clear water. So, this spectral reflectance curve is very fundamental in terms of understanding the reflectance behavior of different earth surface features and three broad features have been shown just to understand how the spectral reflectance curves for three different broad earth surface features behave. Now let us understand the resolutions friends we talk about the resolution that means how it is resolved.

So, what are the different resolutions we have ah 4 different resolutions spatial, spectral, temporal and radiometric. As far as the spatial resolution is concerned, on the left hand side you can see the smallest ground area a sensor can distinguish or measure between two objects. So, that means, what has to be the minimum size. So, that the area on the ground can be distinguished or can be measured as two different objects. So, friends based on our requirement we have also 1 kilometer resolution spatial resolution data we also have 60 centimeter data based on different applications.

So, this is essential for high detail mapping of mine sites and identifying small scale surface features. We need to understand the object size which has a direct linkage with the spatial resolution. And based on that we decide which data at what spatial resolution should be utilized to identify or to get information about that object or surface feature which is of interest to the mining sector. Now let us go to the spectral resolution the ability to distinguish between wavelengths in EMS. Friends in the previous slide discussed the spectral reflectance curve there we found that the same object the same surface feature let us say vegetation behave differently across the electromagnetic spectrum.

That means if it has 12 percent reflectance in the green part of the electromagnetic spectrum. The same vegetation has 8 percent reflectance in the red part of the electromagnetic spectrum, whereas the same vegetation shows 52 percent reflectance in the near infrared part of the electromagnetic spectrum. So, this leads to the conclusion that the same surface feature has different reflectance behavior across the electromagnetic spectrum. So, to capture that we need to understand, and we need to also use different channels we call it different channels of the bands to capture the reflectance property of the feature on ground.

So, this is what essentially talks about the spectral resolution—the ability to distinguish between different wavelengths in the EMS. So, this spectral resolution—understanding of spectral resolution—is useful for differentiating between mineral types based on techniques and the unique properties of their spectral signatures. Then, let us understand the temporal and radiometric resolution. The temporal resolution talks about the frequency or repetitiveness of data collection. So, we define it as the frequency at which data of the same location is captured, indicating how often the area is revisited.

So, as the depiction shows: June 1, then June 17, then July 3. So, that means you have a 16-day repetitiveness as far as the data take is concerned—it does not matter which platform you take it, whether it is from satellite data, a satellite sensor, or any other platform. So, it allows for regular monitoring of changes, such as tracking site development and environmental impact. The fourth one is the radiometric resolution, which talks about purity in terms of representation. So, the ability to differentiate slight variations in intensity or brightness is represented by bit depth.

So, accordingly, we say 7-bit, which means 2 to the power of 7—it actually varies from 0 to 127, or if we start at 1, then it goes up to 128 (2 to the power of 7). So, if it is 8-bit data, it is 0 to 255 or 1 to 256, and so on. So, this is useful for detecting subtle changes in heat, moisture, or reflectance, aiding in the assessment of surface conditions and identifying anomalies. So, particularly, radiometric detection helps in terms of the intensity or brightness represented by the bit depths. So, now coming to different platforms: we have ground-based, air-borne, and space-borne. You can place it on any close-range data or from an ideal tripod, any tower, or vehicle—that falls under the ground-based category.

### Remote Sensing Platforms

GROUND-BASED

- Positioned directly on the Earth's surface, these platforms provide highly detailed, close-range data. Close-range, high-detail, ideal for validation.
- Examples are tripods and towers, vehicles etc.

AIRBORNE

- The ability to distinguish between different wavelengths in the electromagnetic spectrum. High-resolution, flexible, ideal for targeted surveys.
- Examples are Manned Aircraft and Unmanned Aerial Vehicles (UAVs) like drones.

SPACEBORNE

- Satellites in Earth's orbit capturing data over large areas with diverse sensor types.
- Large coverage, periodic monitoring for broader environmental impact analysis.

Dr. Kharsappan

And, if you mount the sensor over an aircraft and collect the data, it is regarded as airborne or aircraft-mounted, or a UAV (unmanned aerial vehicle) also falls under this category. Then, spaceborne—yes, we launch several satellites into orbit and mount the cameras or sensors on them, which falls under the space category. These days, we have also started putting sensors on ISS (International Space Station) platforms and collecting data, which is at an altitude of 300 kilometers from Earth's surface. So, depending on the sources or the platforms, the remote sensing types or categories can also vary. Then, coming to the examples in terms of mining. So, we can have different applications in terms of mineral exploration, operational monitoring, environmental impact assessment, rehabilitation and reclamation, geological mapping, and hydrothermal alteration.

### Satellite Remote Sensing in Mining

- Mineral Exploration
- Operational Monitoring
- Environmental Impact Assessment
- Rehabilitation and Reclamation
- Geological Mapping
- Hydrothermal Alteration Zones

EXAMPLE OF SATELLITES USED

- Landsat (Multispectral imaging for surface mapping)
- Sentinel-2 (High-resolution imagery for land cover and mineral detection)
- ASTER (Thermal infrared for mineral mapping)
- WorldView-3 (Very high-resolution for precise geological mapping)
- SAR Satellites (e.g., Sentinel-1 for ground deformation monitoring)

ADVANTAGES OF SPACEBORNE PLATFORMS

- Global coverage for Remote or Inaccessible Mining Sites
- Long-Term Data for Monitoring Environmental Impacts
- Cost-Effective compared to Ground Surveys

Machine Learning Algorithms are applied to large Satellite Datasets to Automatically Detect patterns related to Mineral Deposits and assess Environmental impacts, providing quick and cost-effective solutions!

Dr. Kharsappan

We will be discussing all this in our next classes. The examples in terms of satellites used could be Landsat, ASTER, WorldView, SAR data, and the advantages of spaceborne platforms are many because they come from a different platform. So, these are the references and thank you very much.