ENGINEERING GEOLOGY

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LECTURE – 4

Remote Sensing in Engineering Geology

Hello everyone and welcome to session 4 of the theoretical discussion on remote sensing applications in engineering geology. So, in this lesson, we are going to just cover the principles, essential principles of different procedures of remote sensing that are normally used in different applications, particularly geologic mapping that we considered in the last session but before we proceed with the discussions, subject matter of this particular lesson; we are going to discuss the questions that I asked in the previous presentation.

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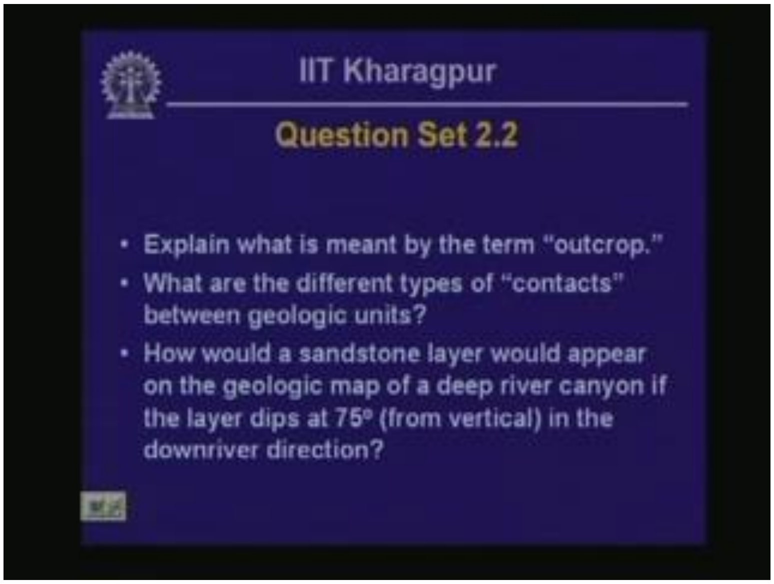

The, first question that I asked was what is meant by the term outcrop? Outcrop is essentially, it essentially is a body of bed rock that is exposed at ground surface. Then the second question that I asked was that what are the different types of contacts between geologic units? We discussed this one in great detail in one of the previous presentations and the types of contacts that we considered at that time were conformal contact, non-conformal contact and one of the types of conformal contacts was considered or we discussed a type of contact called gradational contact. So, these are the 3 different types of contacts we discussed earlier.

Now, contacts can also be classified depending on whether the contact is through the plain of a fault or not. So, the contact could also be classified as a fault contact or depositional contact depending on whether or not the contacts between 2 different geological units is across the plain of a fault or through surface of deposition.

The third question that I asked was how would a sandstone layer appear on a geologic map of a deep river canyon if the layer dips at 75 degree in the down river direction? Now, recall from what we discussed in the previous presentation, previous classroom presentation; it was that when there is dipping layer going across a valley, then the outcrop of that particular layer takes the shape of a V or an U.

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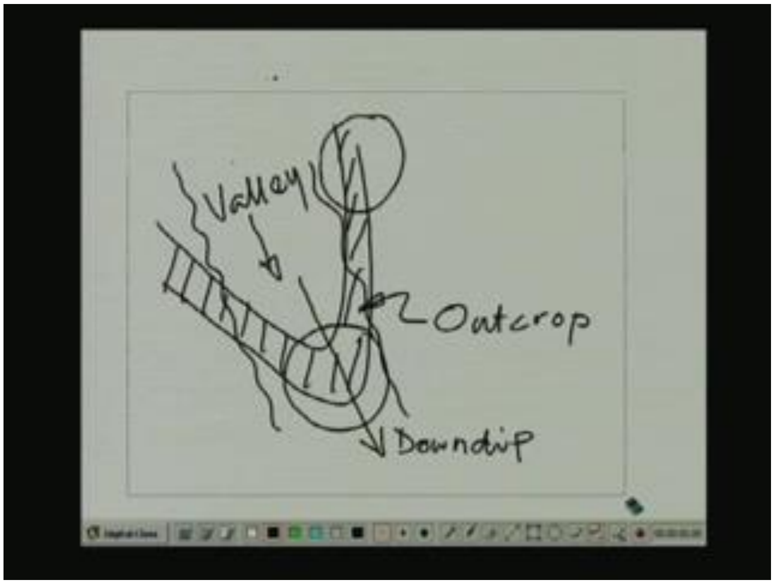

So, this is the outcrop of the layer seen on the plan view that means we are looking at this particular map upside down from an elevation, looking down. Now, this is the outcrop of the geologic unit that we are looking at. Now in this case though; and the reason why the outcrop actually takes a shape of a U or a V inside the valley is because near the valley bottom, at the point where the outcrop is at the lowest level, lowest elevation, that is going to proceed in the down deep direction.

So at this location, the outcrop elevation is the lowest compared to the elevation of the outcrop at the planks of the V shape. That is the reason why the tip of the V always shows or points towards the down deep direction irrespective of the surface topography within the valley. So the valley could be, could either slope in this direction or this is the valley, this could be the valley slope or the valley slope could be the other way around. Irrespective of the direction in which the valley slopes, the down dip is going to point or the down dip direction is going to be pointing towards the sharp corner of the V if we have got a dipping layer crossing a particular valley.

So, in this case though, the dipping, the dip angle is quiet near vertical; so you may not get a pronounced V shape as shown on that particular figure. But what you might get is a shape like this.

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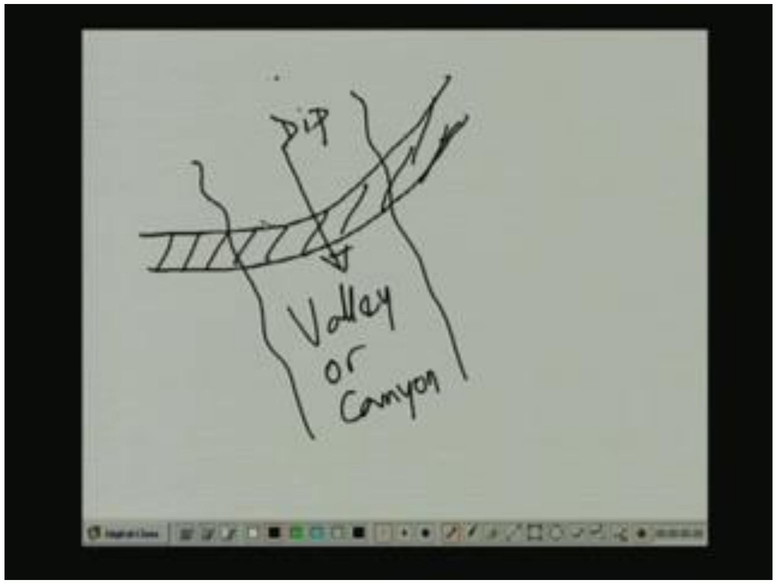

So, this is the valley or canyon that we are considering or canyon and the shape of the outcrop may look somewhat like this and again, this is going to be the direction of dip of that particular layer.

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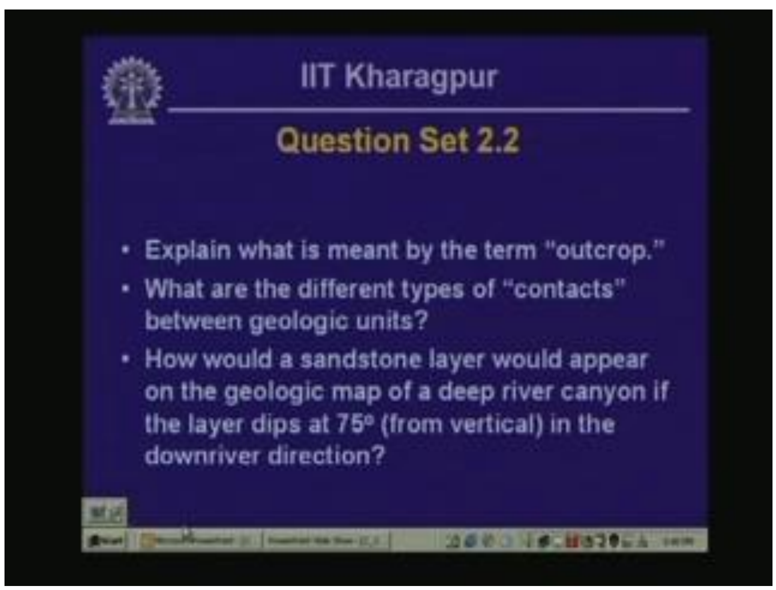

So, that takes care of all the problems that I asked in the previous presentation. So, with that set, I am going to proceed with the subject matter of this lesson. So, what we are going to discuss here? We are going to discuss essential principles of remote sensing applications in engineering geology.

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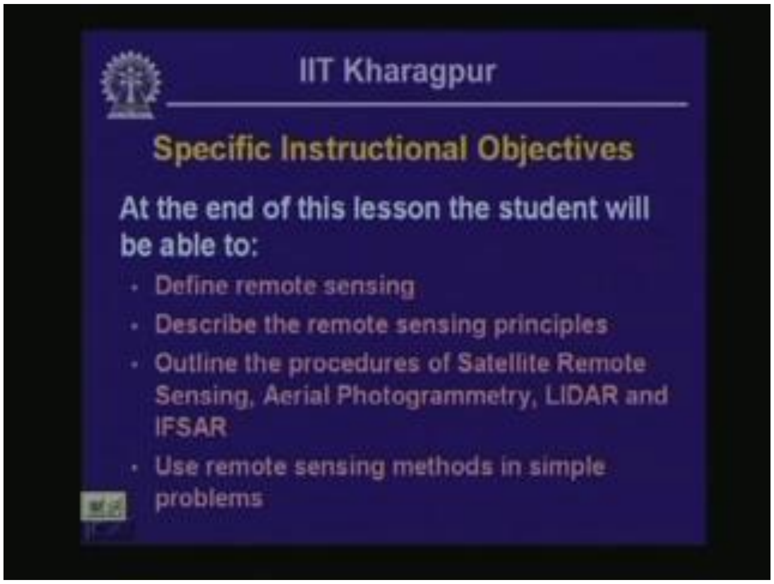

We are going to consider the procedural details, essential details of the procedures of several different types of remote sensing like aerial photogrammetry, LIDAR and IFSAR we are going to discuss in this lesson and we are going to try to develop a notion of how to use these remote sensing procedures in simple problems of geologic mapping.

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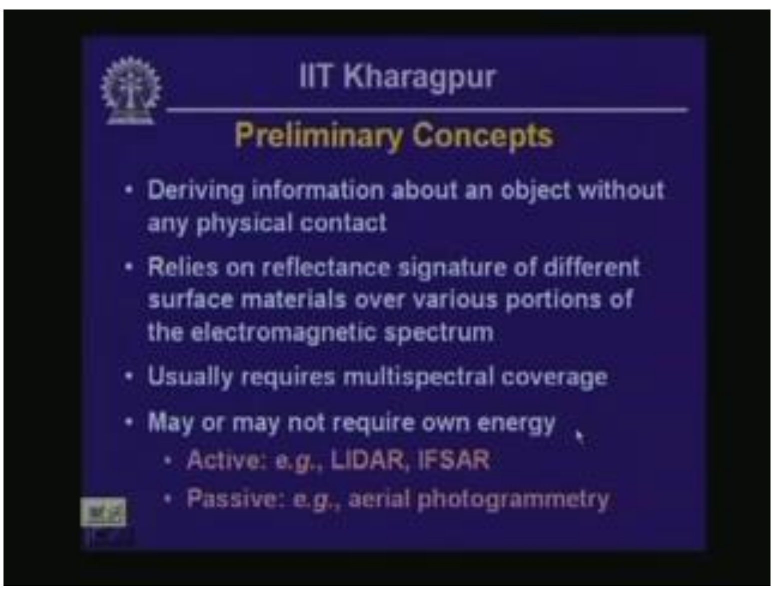

Now, preliminary concepts; we begin with the preliminary concepts of remote sensing application in engineering geology. We first of all need to understand what we mean by remote sensing. Remote sensing essentially means deriving information about the characteristics of a geologic deposit without any physical contact with the deposit.

For example, if we take a photograph of a particular geologic deposit and derive some of the characteristics of the deposit that are of interest from engineering standpoint, then that kind of investigation is going to be known as remote sensing. Then remote sensing, the principle; principally remote sensing relies on the reflectance characteristics of different surface materials over various portions of the electromagnetic spectrum.

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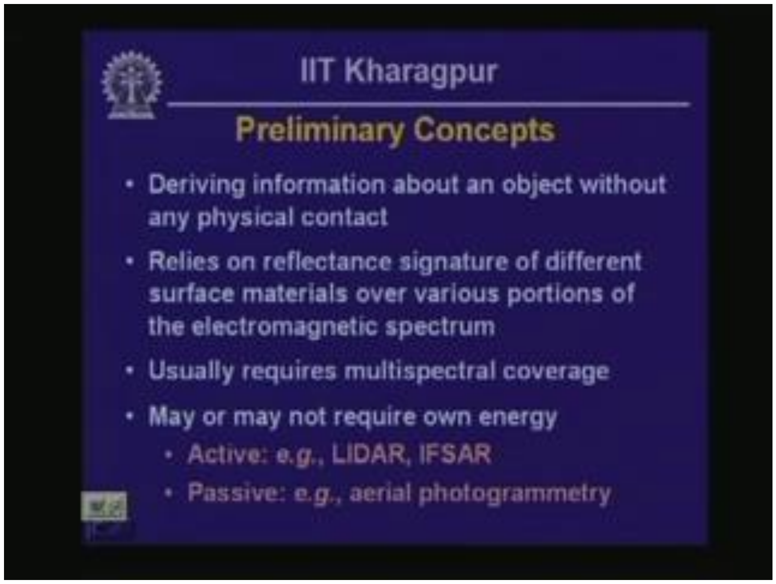

Now typically, not only visible light is considered but infrared near and far infrared are utilized in trying to get the reflectance characteristics of different materials. We are going to see how different materials behave in these different regions of electromagnetic spectrum. Microwave is also used in remote sensing.

Thirdly, we typically require multi spectral coverage to derive useful information about different geologic units. Then remote sensing procedures that we are going to consider in this lesson may or may not use its own energy and depending on whether or not it uses its own energy, the remote sensing procedure is classified as active or passive with the active remote sensing procedures are essentially, they require their own energy source; whereas, passive remote sensing procedures, require no energy source. They purely depend on the reflectance, reflected electromagnetic waves that bounce of those of different geologic units. The origin, those electromagnetic waves might originate from sources other than the source specifically dedicated for the remote sensing investigation.

Now let us understand why we require, why we require multispectral image? In other words, why information derived from a particular wave band is not going be sufficient in the normal investigation procedure.

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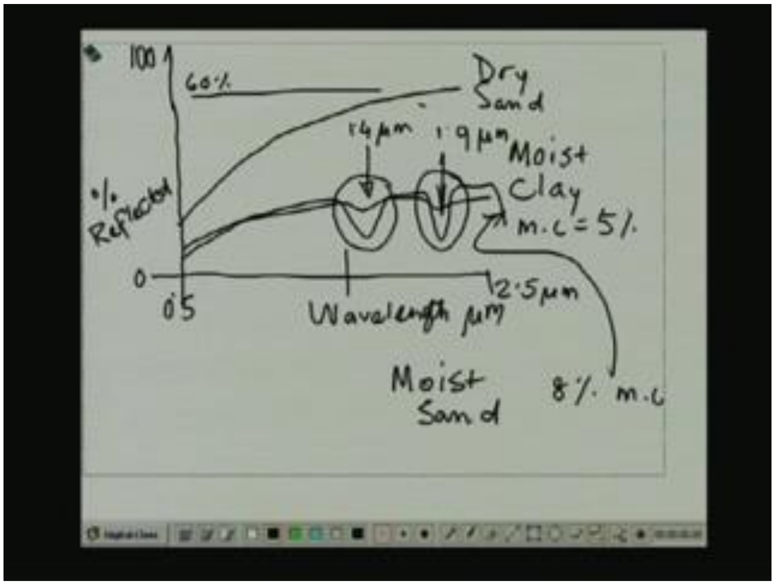

What we are going to consider here is the reflectance characteristics of sand and clay and we are going to consider that there are different moisture contents within these deposits. So, in the vertical scale, we are plotting the percent reflectance, percent reflected and in the horizontal scale, we are plotting the wavelength in micrometer and let us draw the scale as well. So, we are plotting in the vertical scale, we are plotting from 0 to 100% and in the horizontal scale, we are plotting from 0.5 micrometer to say 2.5 micrometer.

Typically, the reflectance characteristics of sand, dry sand is going to take a shape like this; this value where it saturates is approximately 60 to 70%. On the other hand, if you look at clay, clays are much less reflective than sand and typically what you might you get is a shape like that. So, this one is sand and the lower one is clay.

Now, this one is dry sand by the way; this one is dry sand and this one is clay with little moisture content. So, it is moist clay with moisture content of say 5%. Moisture content is typically defined as the volume of water to the volume of dry soil. It is the ratio of volume of water within a soil matrix the volume of dry soil.

Now, let us see what happens when we try to saturate the sand that was originally derived. So, when we saturate the sand; then what happens? The sand may actually come down to have a reflectance characteristics sort of looks like this. Now, you see these valleys; these valleys are expected to occur at 1.4 micrometer and 2.7 micrometer, actually 1.9 micrometer sorry 1.9 micrometer, we are not plotting 2.7. So, this one is 1.9 micrometer. So, these valleys are indicative of presence of water. They are actually absorption, they are absorption bands of water and they confirm the presence of water within the soil.

Now, look at the similarity of the moist clay and saturated sand with a moisture content of say about

8% moisture content, this one is moist sand; so what I want you to look at is the remarkable similarity of the moist sand and moist clay over in this region of bandwidth from about 0.5 micrometer to about say 1.2 micrometer. So, they are largely similar.

Now, if we do not consider the reflectance characteristics beyond 1.2 micrometer, greater than 1.2 micrometer, we would not able to distinguish whether we are looking at moist clay or moist sand in most cases. Now, you can realize the importance then of covering a large range of wave bands of wavelengths in the remote sensing technique in order to distinguish between different types of geologic materials.

Getting back; next we are going to talk about, we are going talk about the reflectance. Let us explore what are the factors that the reflectance generally is influenced by. So, you understand that reflectance depends on the geologic characteristics of the material that we are trying to identify, then it also depends on other things like what are the other constituents that might exists within that particular geologic body, geologic material.

For instance, the example that we just considered, in that, we had water as the other constituent that was present within the body of sand and the body of clay. Now, you could also imagine that there could be other types of chemicals present in a geologic material. For instance, there could be iron oxide that might be present within a surface soil layer and depending on whether or not iron oxide is present, the reflectance signature is going to be quiet different and you can expect that many of you might know that the colour of iron oxide is red, so the reflectance characteristics of a material of a geologic material containing iron oxide is going to be much richer in the red wave bands compared to another material of very similar characteristics but without iron oxide.

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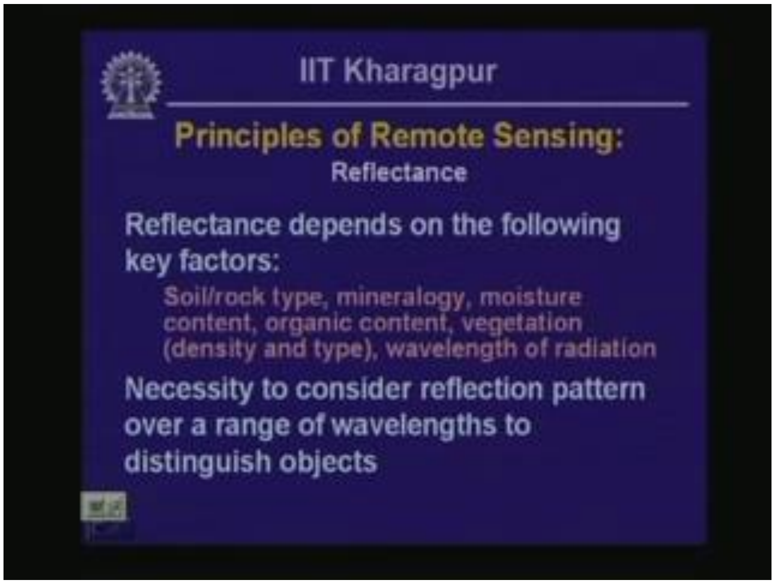

Then the reflectance characteristic also is going to be affected by the organic content, the density of vegetation and type of vegetation that might grow on that particular geologic unit, what is the wave length of radiation which is considered in the reflected signature and again we want to state as I stated, as I explained in the previous sketch that I was drawing that we need to consider a wide range of wavelengths in order to distinguish different geologic materials because of the non-uniqueness that is that are going to crop up because of different combinations of chemical constituents that might be present in a parent geologic body.

Now, let us consider the type of I mean, type of or the range of wave lengths that are normally exploited in existing platforms of remote sensing satellites. This slide here actually shows the entire wave band of electromagnetic spectrum ranging from 10 to the power 12, 10 to the power minus 12 meter to 10 to the power 4 meter.

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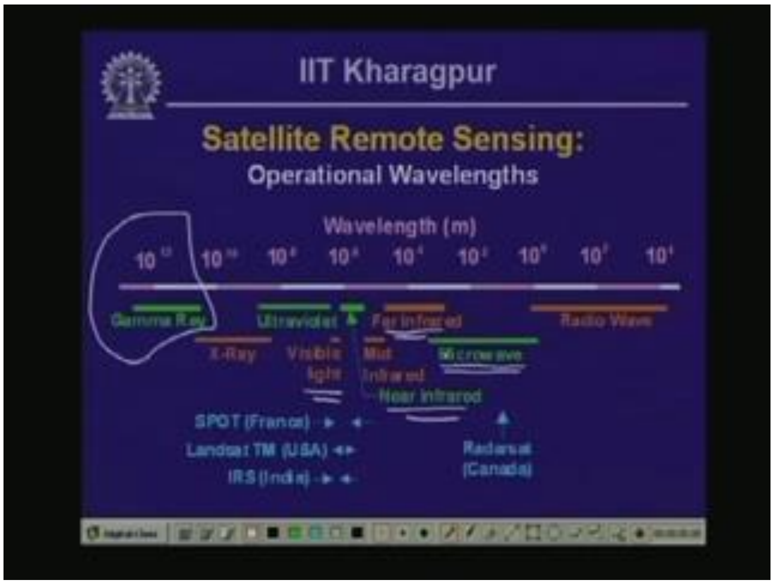

Here, what we got, we actually as you all know that we begin from gamma radiation at the shortest range of the wavelength, then we gradually transition from X rays to ultraviolet rays to the visible spectrum, then infrared microwave and eventually into radio waves. So, the spectrum that is normally exploited in remote sensing are the visible spectrum, the visible light near infrared and some of the remote sensing platform, they also utilize the far infrared and there are quite a few satellites that exploit the microwave wave bands of the electromagnetic spectrum.

Now, you know from visible light, we can distinguish different objects like; we can see whatever we can see out of a photograph, we can also distinguish when we take a photograph from a satellite platform in the visible wave band. Now, near infrared, actually they are actually characteristics of different constituents of within the geologic unit. Like for example, depending on what is the density of vegetation and whether there is any water body present; depending on those things the reflectance characteristics in the near infrared are going to be different. We are going to discuss these things in greater detail in the next little bit.

Now, far infrared is essentially, that essentially indicates what is the amount of heat that is coming out of a particular geologic body and this information is also useful in some remote sensing techniques but most of the satellites that we normally use, they cover the visible light and the near infrared signals and out of these satellites, common or Indian remote sensing satellites, then land sat and the spot satellites of the European space agency. In the microwave band also there are useful informations about geologic characteristics of materials and there is a satellite operated by Canadian space agency it is called RADAR sat and that generates useful information in the microwave wave band in the RADAR, those are essentially RADAR imaginary.

Now, these platforms are essentially satellite platforms, they actually go around in space and circle around the earth every so often, we are going to look at the characteristics of the satellites later on. You could also think about similar multispectral imaginary covering a large range of wave bands based on airborne systems other than satellites. Like for example, you could try these remote sensing tools on aircrafts or even blimps, they are also used in remote sensing techniques.

Now, airborne imaginary is going to get, going to give you a very high resolution pictures within these wave bands in comparison with the RADAR imaginary but the x bands that is involved in carrying out a project specific airborne survey would be quiet large and may not thus be possible to be undertaken in projects that are of comparatively smaller size. But in this project, satellite images could be purchased from the remote sensing agencies that I indicated in the previous slide and these satellite photographs also generate quiet useful informations but in a much larger scale.

Now, this slide actually summarizes the characteristics of different airborne or different satellites that are used for getting remote sensing images.

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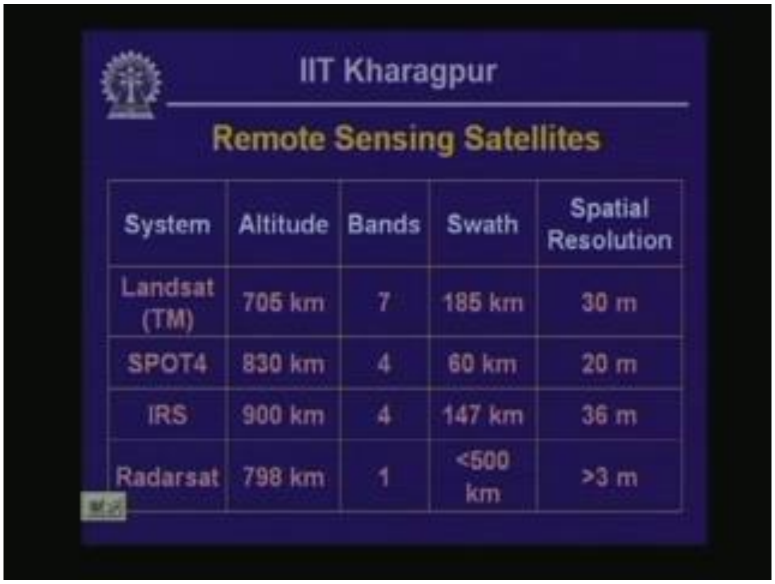

System	Altitude	Bands	Swath	Spatial Resolution
Landsat (TM)	705 km	7	185 km	30 m
SPOT4	830 km	4	60 km	20 m
IRS	900 km	4	147 km	36 m
Radarsat	798 km	1	<500 km	>3 m

At the top is the Landsat thematic mapper. You can see that the altitude of this particular satellite is about 705 kilometer, then the bands that are obtained in a different or the bands that are obtained; number of bands that are obtained from this platform is 7. The swath width of this satellite is 185 kilometers and the special resolution of the satellite is 30 meters. In other words, in one coverage, this particular satellite is going to cover a width of 185 kilometer on the surface of the earth and you could distinguish 2 objects only if they are separated from each other by about 30 meters.

If you want to actually get a better resolution, then this particular satellite images obtained from this particular satellite may not be useful. But you look at spot 4 satellite of the European space agency - Landsat is a satellite is operated by NASA of the US - so spot 4 satellites on the other hand, it has got an altitude of 830 kilometers but it gives only, photographs in only 4 wavebands. It has got a smaller swath radius of 60 kilometer and it has got a much better special resolution which allows you to distinguish two objects that are separated from each other only by 20 kilometers.

You look at RADAR sat; actually Indian remote sensing satellites, it has got a larger altitude, it operates at 900 kilometer above the earth surface and it also covers 4 wave bands but it has got a larger swath band than spot 4 satellite. This one has got a swath width of 147 kilometers and it has got a special resolution that is slightly poorer than the Landsat thematic mapper imagery.

RADAR sat on the other hand, it has got or actually, you might remember that RADAR sat obtains photograph in the microwave band, it has got a much better resolution and you could distinguish two objects even if they are as close as 3 meter from each other. This one has got a swath width of less than 500 kilometer. Let me explain actually what I mean by the swath width; this is the different terminology that I used when I was talking about the satellites.

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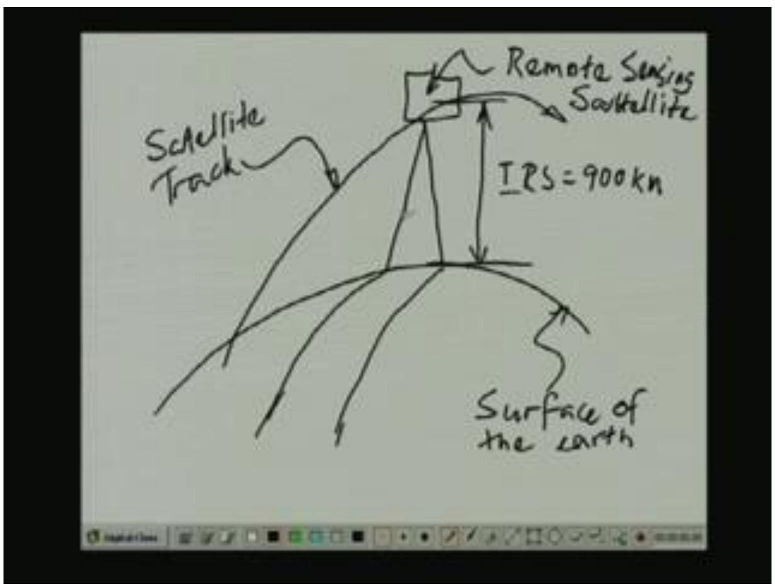

Now, consider a satellite, consider a satellite that is operating at some elevation above the earth and this elevation depends on the platform that you are thinking of; for example, in case of IRS, this elevation is about 900 kilometers. So, this is the surface of the earth, this one is the surface of the earth and by swath width what I mean is that the remote sensing camera is going to look at a width I mean, it is going to cover a track on the surface of the earth as the satellite is actually rotating above the earth. So, this one is the satellite track, this one here is the remote sensing satellite and this one here, this one, it is the field view of the sensor, of the remote sensor; of the sensor or sensor array in general. So, this width is called the swath width. So, that explains the terminology that we are using, that we used in the last slide.

So now, let us look at the kind of mapping capabilities that will be available on these different remote sensing platforms that we considered, that we listed in the previous slide.

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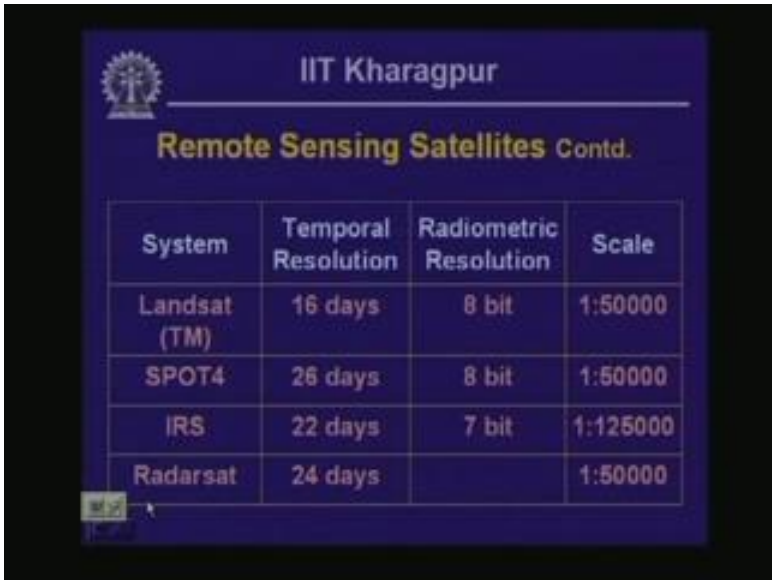

System	Temporal Resolution	Radiometric Resolution	Scale
Landsat (TM)	16 days	8 bit	1:50000
SPOT4	26 days	8 bit	1:50000
IRS	22 days	7 bit	1:125000
Radarsat	24 days		1:50000

Now, Landsat thematic mapper has got a temporal resolution of 16 days. What it means is that it covers the same portion on the surface of the earth once in every 16 days; so if you take 2 images covering the same location on the surface of the earth, it is going to be apart from each other temporally in terms of time by 16 days. It has got a radiometric resolution of 8 bit. What it means is that it has got a scale of reflectance that ranges from 0 to 2 to the power 8 minus 1 and the scale of images from Landsat thematic mapper are typically one in 50,000. So, you cannot get a better resolution than one in 50,000.

For instance, if you have got a large project in which you are going to be requiring a remote sensing image of one in 10,000 or one in 5,000; then the thematic mapper images will not be enough, will not provide enough resolution that will be suitable in your project. So in that situation, what you have to do? You have to develop your own; you have to actually develop your own remote sensing program in order to cover your area of interest.

Now, let us look at what are the corresponding temporal and radiometric resolutions for a spot 4 satellite. Temporal resolution for a sport 4 satellite is 26 days, it has also got a radiometric resolution of 8 bit and the scale of the images is again one in 50,000. IRS satellites on the other hand; it has got a temporal resolution of 22 days, actually it covers the same location on the surface of the earth once in every 22 days. It has got a 7 width radiometric resolution that means the brightest part on an IRS image is going to have a reflectance of 2 to the power of 7 minus 1 whereas, the darkest part on the image is going to have a value of 0. It has got a much poorer scale actually and the best scale that you can get out of an IRS image is one in 125,000.

RADAR sat again is going to give you photograph, going to give you remote sensed images of one in 50,000 scales and it has got a temporal resolution of 24 days.

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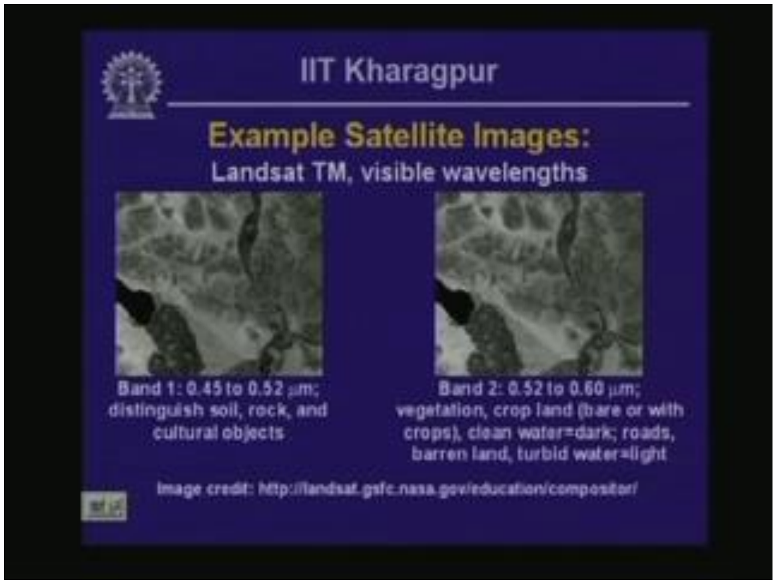

Now, let us consider a few examples of Landsat thematic, few examples of multispectral remote sensing images. Now, we consider Landsat thematic mapper images, they are available from NASA and we give the example images covering the same area in each different wavebands. You recall Landsat images are available, Landsat images are available on 7 different wavelengths, a range of wavelengths and they are going to be shown one after another.

Let us consider band 1; band 1 covers wavelength of 0.45 to 0.52 micro meter and you can imagine, you understand that band one is in the visible spectrum and these images, the reflectance in band 1 distinguish different types of soil and rock and also it distinguish cultural objects. By cultural objects we mean man made objects. Like for example; a large dam can be visible, it can be identified on band 1 of Landsat thematic mapper image.

Then, band 2 shown on the right of slide there, you realize that it covers the same location on the surface of the earth. Band 2 covers wavelengths from 0.52 micrometer to 0.6 micro meter and at this waveband, actually vegetation, crop land, crop land and clean water they appear as dark objects. So for instance, in the image to the right, this one, this object is a water body and as indicated, as indicated here, as indicated here, it actually appears as a dark object in this particular image.

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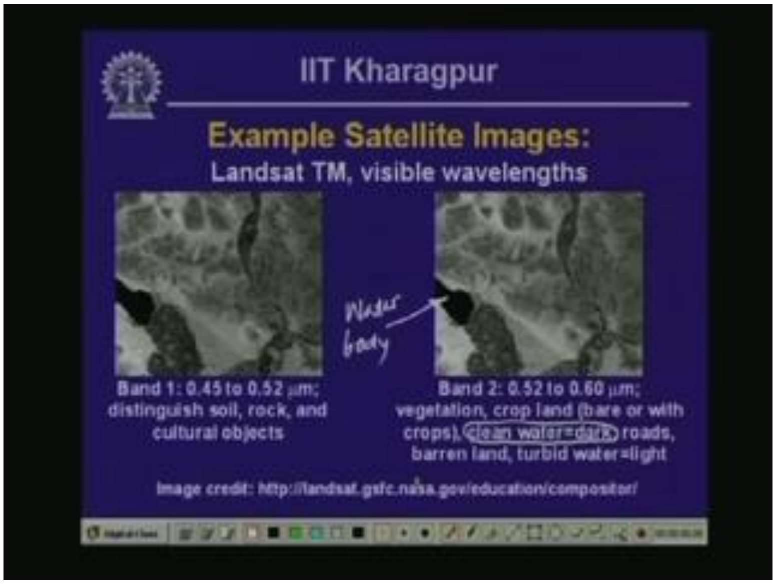

Now, if the water becomes turbid; the water, the colour of that particular water body becomes lighter. So obviously, the water body that is shown at the middle of the left edge of the particular image is comprised of reasonably clean water. Let us move on to band 3.

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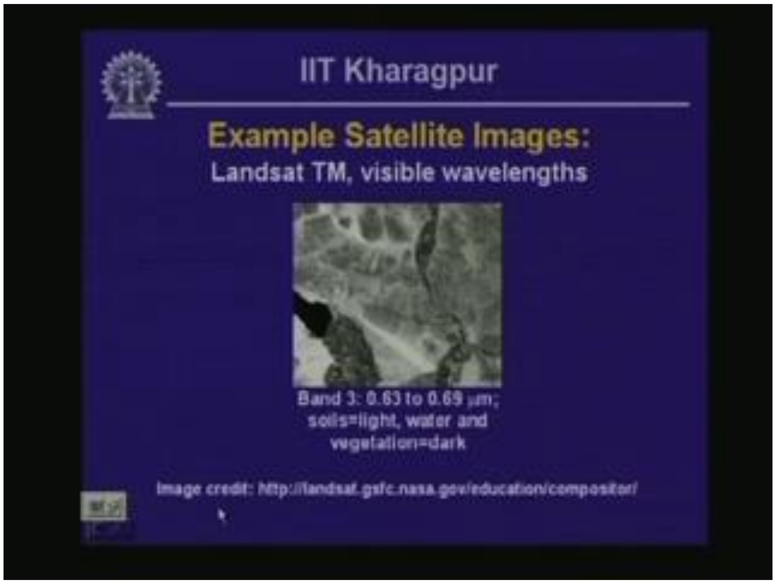

Now, band 3 actually covers waveband between wavelengths 0.63 micrometer to 0.69 micro meters. So, you can see that gradually, we are actually changing from the red end of the visible spectrum, actually from blue end of the visible spectrum to the red end of the visible spectrum. Band 3 is again in the visible spectrum but it is towards the red end of the visible spectrum. Again, you can you can see that the water body that we considered, we saw in the previous image, that appears as a dark object here.

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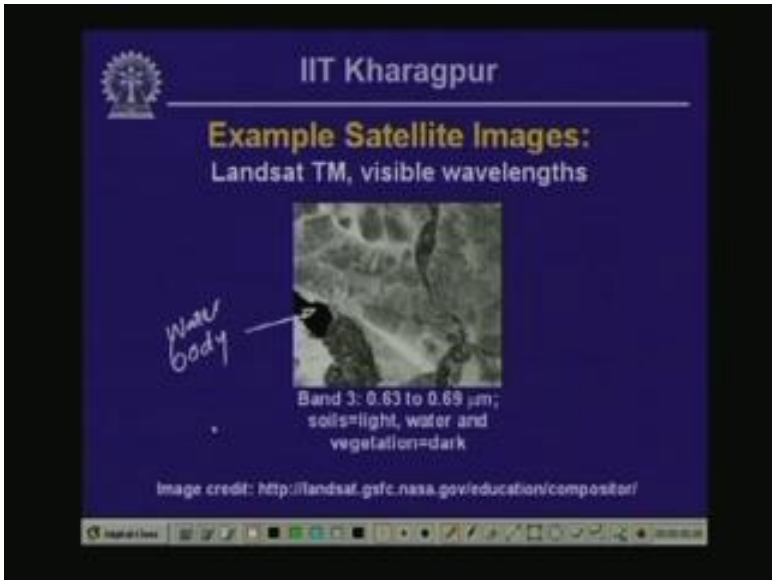

So, this was shown in the previous image as well and here again water and vegetation appears as dark objects and different types of soils, they appear as light coloured objects.

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So, this one here, this feature here actually is a vegetated area around a stream that actually flows across this particular area. So, this one here is the stream and the vegetated area that I is showed up there, actually are forested land on the valley of the stream, of this stream, water stream; this one is another vegetated area.

So, that kind of tells you about what are the different types of characteristics, reflectance characteristics in this particular wavelength waveband that you might expect for these images. Let us move on to the other bands. These bands are not in the visible spectrum and you can see the characteristics, you can see the change in characteristics. This portion here, this portion here you recall, was the vegetated area that we considered that we saw as dark object in band 3.

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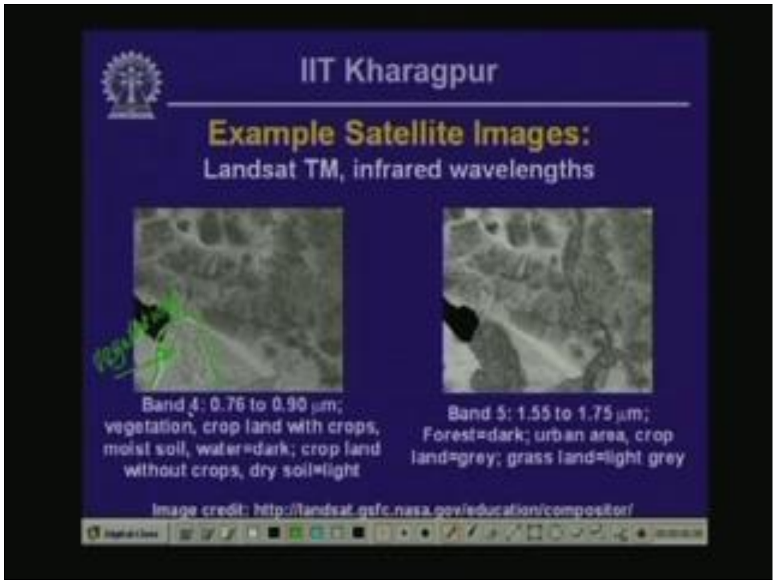

So, this is actually vegetation, whereas this was, this appeared as a dark area, dark patch in band 3; whereas now, this area is starting to appear as a bright image. But the water body is still uh showing up us a dark patch. So, here what we get? Vegetation, crop land with crops, moist soil and water, they appear as dark objects. Now, crop land without crops and dry soil, they appeared as relatively light objects.

Then we move on to band 5; band 5 covers wavelengths between 1.55 to 1.75 micro meters. Here again, forests appear as dark and urban area crop land, they appear has grey areas. Moving on to band 6 and band 7; you remember Landsat thematic mapper images, they actually have got 7 band multi spectral coverage. So, band 6 is shown on the left there and band 6 covers wavelength between 1.04 and 1.25 micro meter and these are actually thermal infrared images. So, they show the heat reflected of the different types of geologic units and band 7 shown on the right that covers wavelengths between 2.08 to 2.37 micro meters. In this wave band, actually water and forest, they appear as dark objects whereas urban area, crop land, bare as well as without crop and highways, they appear as light coloured objects.

So you can see, the reflectance characteristics of different objects, they actually tend to differ from each other when you consider different ranges of wavelengths in a multispectral image. For instance, crop land on band 7, let us move back a little bit; crop land in band 7 bare or with crop, they will appear as light coloured images in band 7. Now, if we go back to band 5, then all crop lands, they will be appearing as grey objects. So, by comparing band 5 and band 7, you could then say whether a particular crop land is actually vegetated at the time when the photographs were taken or not.

So, this kind of illustrates the use of multispectral remote sense imagery in trying to distinguish different geologic objects.

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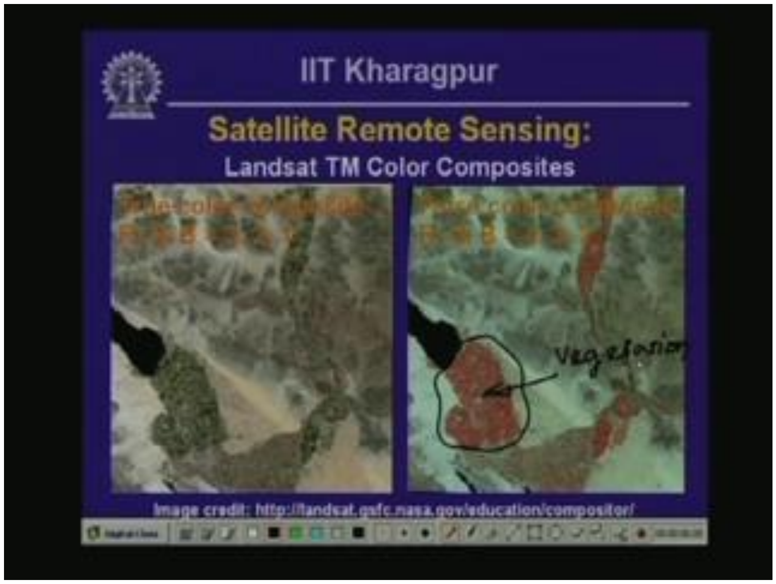

Now, these individual bands of photographs can be combined to give true colour composite images or false colour composite images. The one that is shown on the left of this particular slide shows the true colour composite image of the same area that we saw in the earlier bunch of remote sensed images. Here, what we have are channels – 3, 2 and 1 and they are combined together in true colours; you remember, channel 3 was of red colour, channel 2 was green and channel one was blue.

On the right is a fault colour false coloured composite image and a false coloured composite image actually combines different objects by assigning different colours that are not exactly the same, that do not exactly match the waveband in which the particular image was obtained.

For example, in the false colour composite that is shown on the right, in that channel 4 was taken as red, channel 3 was taken as green and channel 2 was taken as blue image and in this particular way of combining different images, show vegetated land as red as it is apparent from this patch here. So this one, if you recall, shows a vegetated area, vegetation and that shows as a red colour image on this particular, this type of false colour composite.

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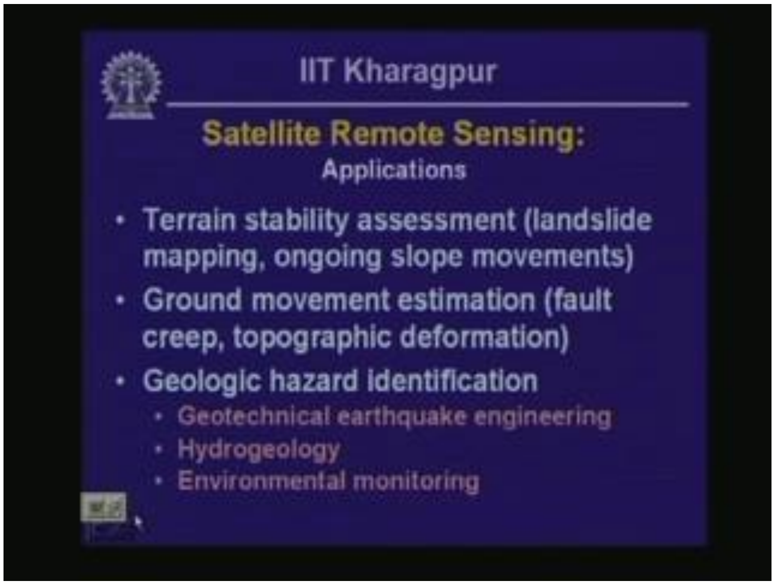

Now, what are the applications of satellite remote sensing? Satellite remote sensing is, the major application of satellite remote sensing is in trying to assess terrain stability whether there is any land, whether there is any signature of existing landslide features on the surface of the earth or whether there are any indications of ongoing slope movement?

Now, ground movement estimations are also another application of satellite remote sensing. For example, there are visible false scarps; if there are visible false scarps on the surface of the earth whether the blocks on both sides of the fall is actually moving or not, that can also be also be detected if we are looking at a very high resolution satellite remote sense photograph.

Then we can look at geologic hazard identification, all these things can be combined in geologic hazard identification, we can assess whether landslide hazard is present in a particular area or there are earthquake hazards available, earthquake hazard exist in a particular area from satellite remote sensing.

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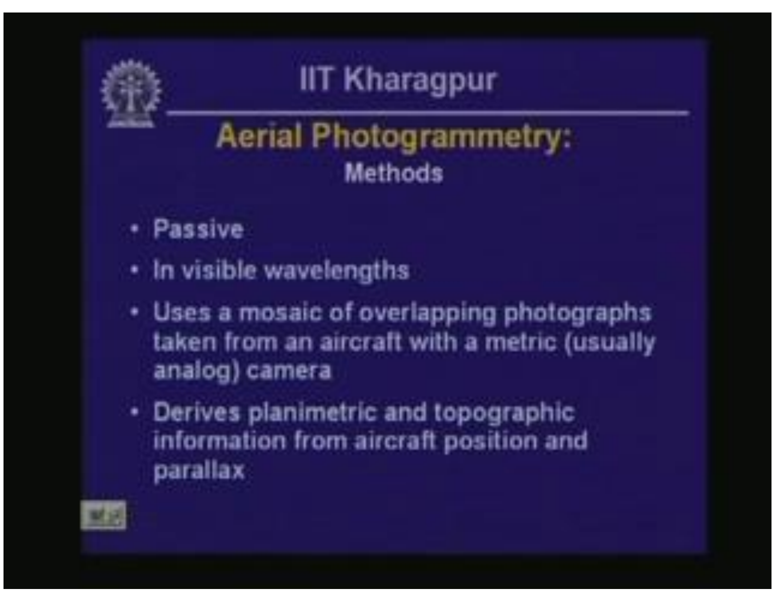

The second procedure for remote sensing is actually aerial photogrammetry. In aerial photogrammetry, it is essentially a passive procedure in which we look at what is the reflect ant signature of the reflected electromagnetic waves that bounce off from a source of light, for example the sun and we take a photograph using those reflections of this these objects.

These imagery are typically in the visible wavelengths and we can use a mosaic of overlapping photographs taken from an aircraft with a metric camera, we can we can overlap these photographs to form the topography, we can develop the topographic map of a particular area by using mosaic of overlapping photographs by using the principle of parallax.

We can also derive planimetric information from these images that means we can find what is the physical distance between an object a that appears on A particular photograph from object B because we know exactly what is the photo scale because we know very precisely what are the features, what are the dimensions of a metric camera and from what height the photograph was taken.

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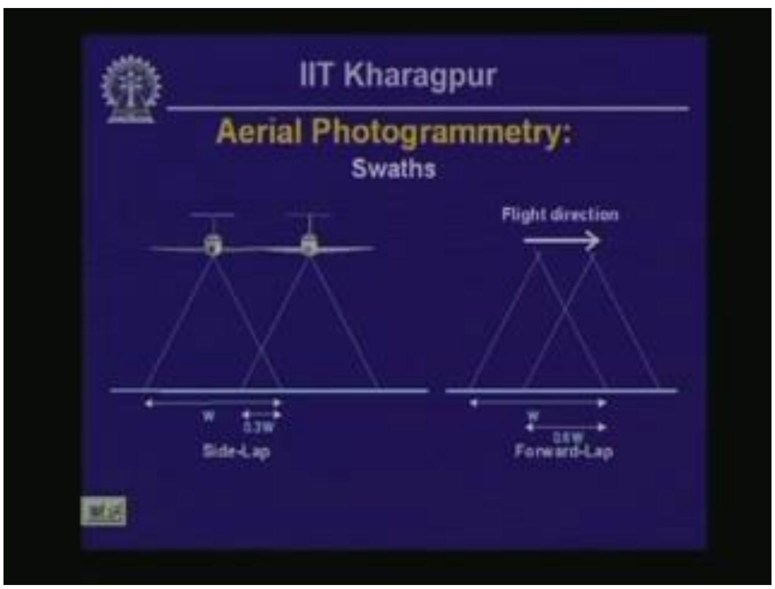

The principle of aerial photogrammetry is illustrated on this slide. The overlapping pictures are obtained by having flights running parallel to each other as shown on the left sketch so that the field views of these photographs overlap with each other. Usually, this is called the side lap and side lap, usual side lap is typically is 0.3 times the width of swath. The overlap in the direction of the flight is called forward lap. In this case, the over lap between two consecutive images is 0.6 times the swath width.

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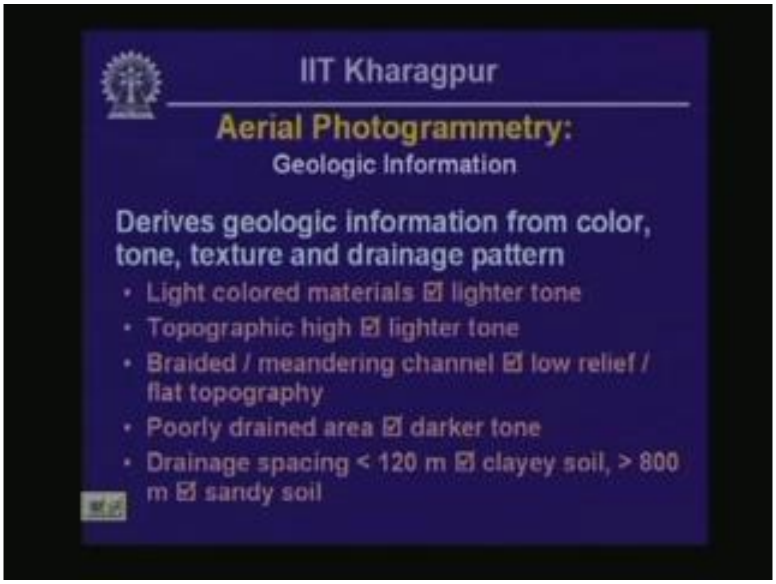

Aerial photogrammetry also can be used to develop geologic information from colour tone and texture of drainage pattern. Light coloured materials actually appear as lighter objects, topographic highs of appear as a lighter tone, braided and meandering channels are low relief areas and they actually appear as darker coloured objects, poorly drained areas also appear as dark coloured objects.

Drainage spacing, another way actually you can interpret aerial photographic images is by looking at the physical spacing between drainage bodies. If the drainage bodies are closer to each other than 120 meter, then that indicates that one is in a clay terrain; if the distance on the other hand exceeds 800 meter, then one is actually in a sandy area.

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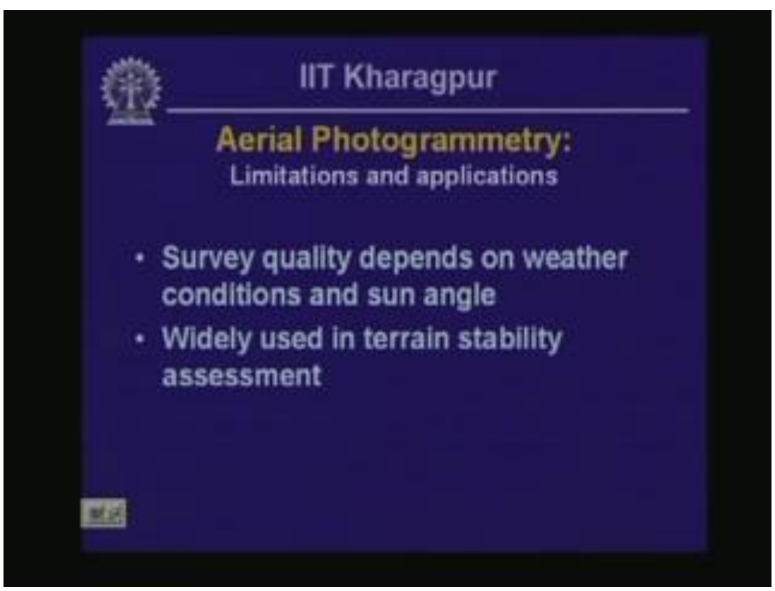

Now, aerial photogrammetry has got a surveying quality that means we can distinguish different objects as close as less than one meter from each other and this is widely used in terrain stability mapping.

Now, there are two other techniques commonly utilized in aerial in remote sensing; they are called LIDAR - Light Detection and Ranging in which what is done is from an aircraft, pulses of lasers, laser pulses are bounced off of different geologic images.

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And, from the two way return time of the signal, one could develop the topography of a particular area as well as the nature; whether there is any vegetation cover or not from these two way return time of the LASER pulses.

Another procedure commonly used is called the IFSAR. IFSAR is an imaginary in the RADAR band, like the RADAR sat image.

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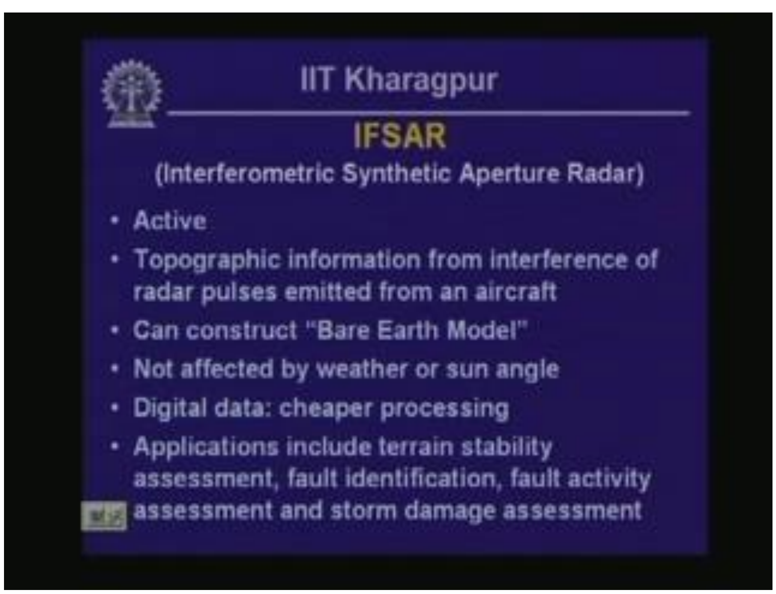

This is also another active remote sensing procedure and here, what is done is we use the interferometric principle to develop the topographic details of a particular area and again, both LIDAR and IFSAR, they can be used to construct a bare earth model that means if there is a vegetation cover, we can formulate a topographic information of the surface of the earth that is underneath the vegetation cover.

Now, we have actually more or less covered in a nut shell, what are the different types of remote sensing techniques used in engineering geology and how the information that are obtained from these different techniques are used in remote sensing in different fields of engineering geology.

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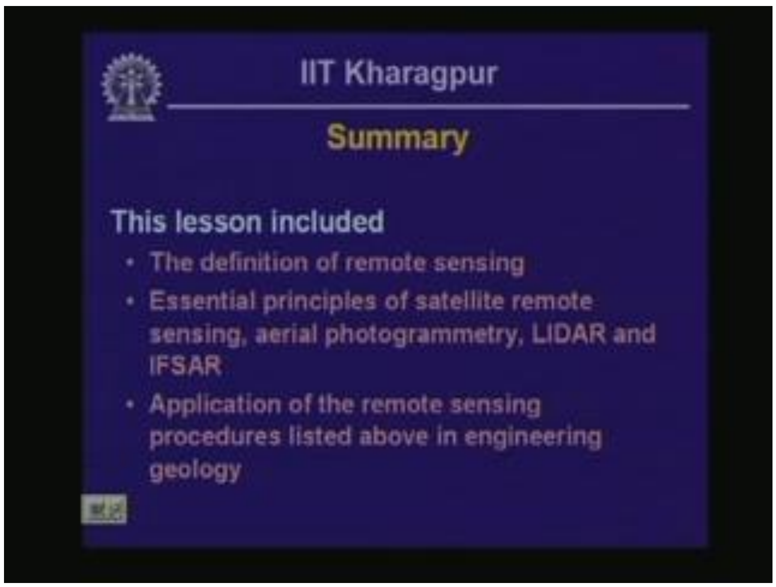

We explained how satellite images are obtained? How the satellite images are interpreted? Aerial photographic, the principles of aerial photogrammetry - LIDAR and IFSAR, what are the uses of these procedures and we looked at the application, very simple applications of these techniques in remote sensing, these techniques of remote sensing in engineering geology.

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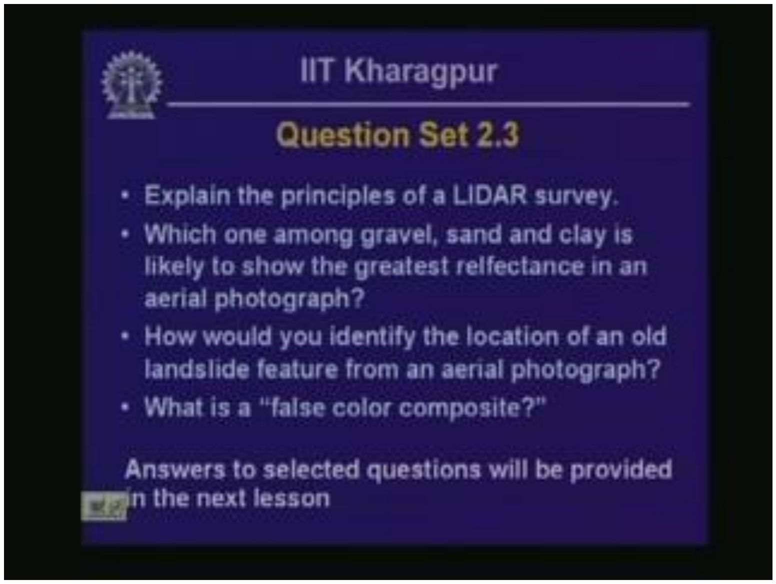

We finally end this section with a question set that is shown on the slide there. I asked you to explain; what are the principles of a LIDAR survey? Which one amongst gravel, sand and clay is likely to show the greatest reflectance in an aerial photograph? Then the third question is how do you identify the location of an old landslide feature from an aerial photograph and finally, what is a false colour composite in connection with satellite remote sensing multispectral image? These answers will be provided when we meet again in the next session. So, until then, you try to answer these questions and I will see you again when we meet with the next session of this course.

Thank you very much.

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Hello every one and welcome back to the class room session number 5 for the video course on engineering geology. Today we are going to learn different aspects of physical properties of minerals and we will try to identify different minerals based on their different types of physical properties. We will try to list them and we will try to see how they differ from mineral to mineral. But as is the practice; we are going to answer, we are going to prepare the answers for the problems given in the previous presentation.

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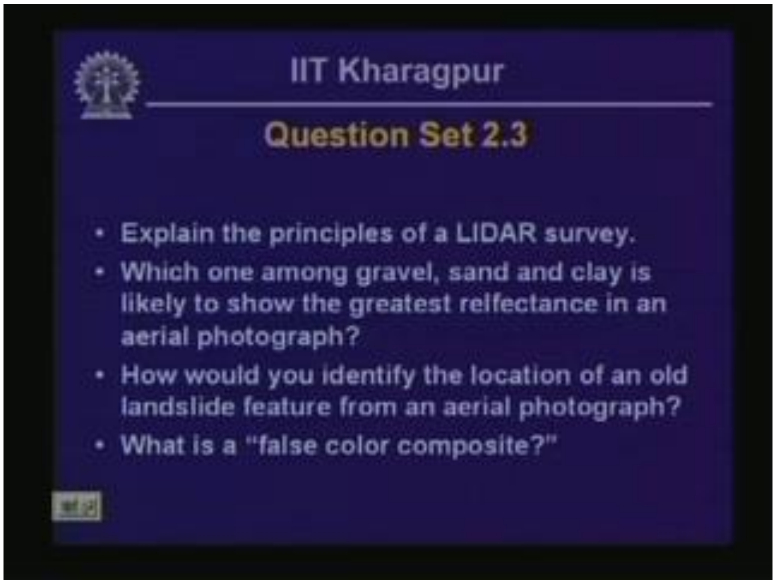

So, the question set in the last presentation went like this; explain the physical principle, explain the principles of LIDAR survey. Let me explain with a sketch.

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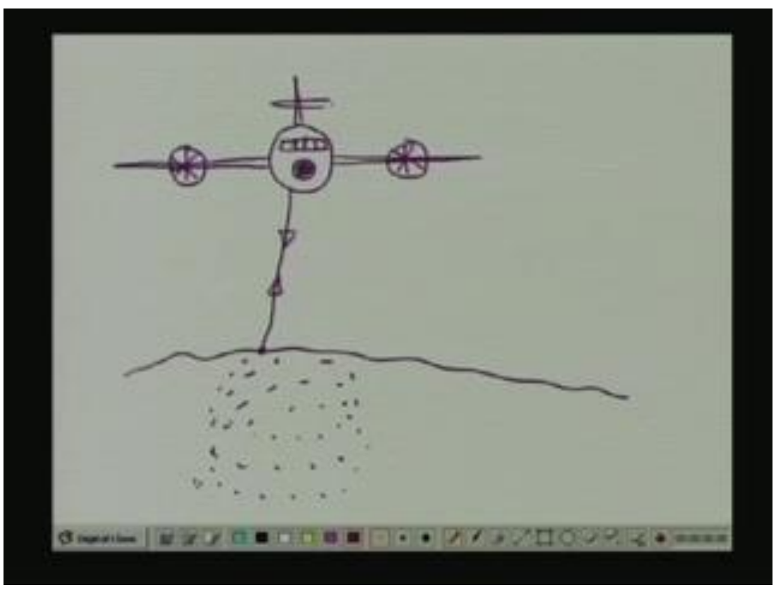

So, what is done essentially is from an aircraft, we emit RADAR actually LIDAR LASER pulses and those pulses are made to bounce of on the topographic features. So, this is our aircraft and there is a laser source onboard the aircraft and that emits pulses of laser signals and there is an onboard instrumentation system that actually picks up, calculates the two way travel time of the laser pulse and also it keeps track of the position attributes of the aircraft from those informations. It actually computes the X Y and Z coordinate, all the two horizontal and the vertical coordinate of the point of which the laser pulse was reflected.

Now, as the aircraft progresses forward what is done is to emit a series of laser pulses in this pattern of an elliptic spiral and using information from each one of those pulses together with all the other information, all the other two way travel times for other pulses from the same area… ((59:14))