Remote Sensing Essentials
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Lecture-10
Significant Characteristics of Landsat, SPOT, Sentinel Sensors

Hello everyone, and today we are going to discuss about some significant characteristics of Landsat, SPOT and Sentinel sensors. And later on we are also going to discuss in detail about the similar significant characteristics of IRS series, Cartosat and Resourcesat. So, let us first start with this characteristics of Landsat, SPOT and Sentinel in much more detail so far we have been just mentioning about this.

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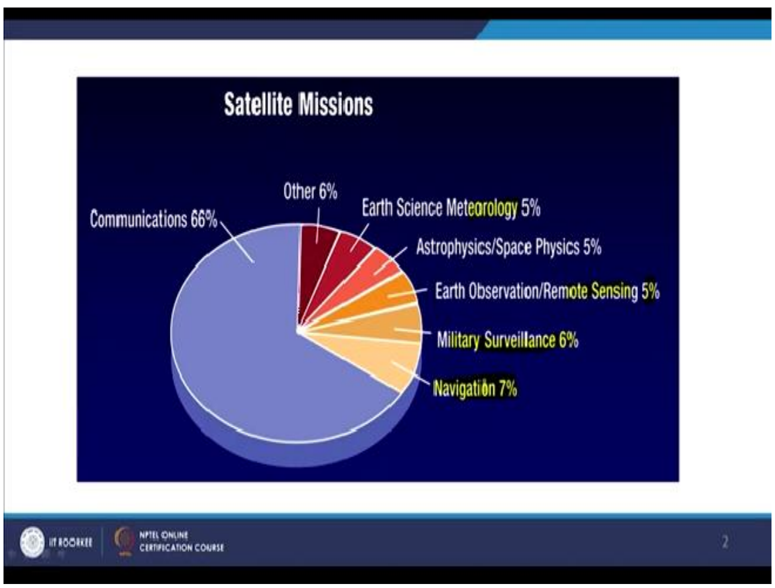

There are as you know, that if I see the overall picture of different satellite missions, and especially I am talking about these are Resourcesat satellites and some communication satellites also. So what we see that if there are 100 satellites, then the 66 satellites are focusing mainly on this communication. And, you know, earth science meteorology, satellite just 5%, astrophysics, or space physics satellite 5%, the remote sensing earth observation satellites, which is what we are discussing, this 5%.

So the major missions are in the communication a word and then of course, the meteorology physics and remote sensing, military surveillance, or I can say spy satellites and of course the navigation satellites, number of navigation satellites are just 7% of total number of satellite missions which we are having currently, this is a rough estimate of distribution of satellite missions in different fields.

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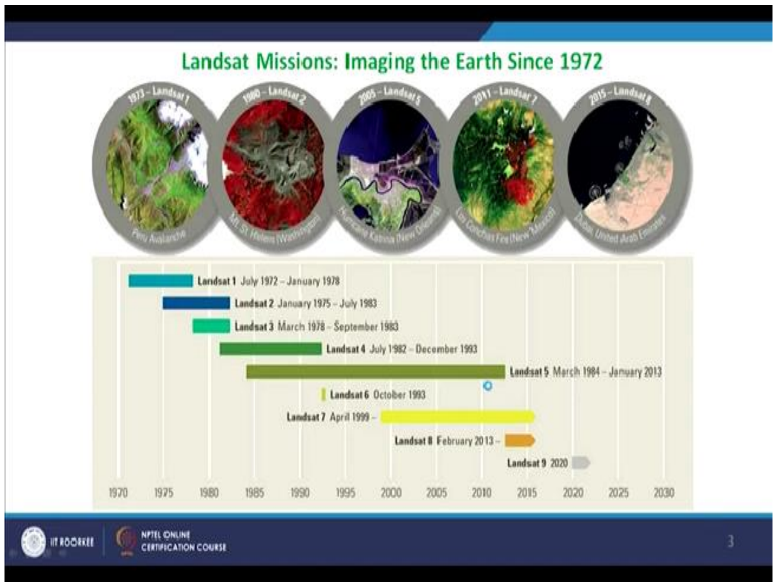

As you know that Landsat mission started in 1972. And this slide we have already discussed in a few earlier lecture, so, I am not going to spend much more time in this.

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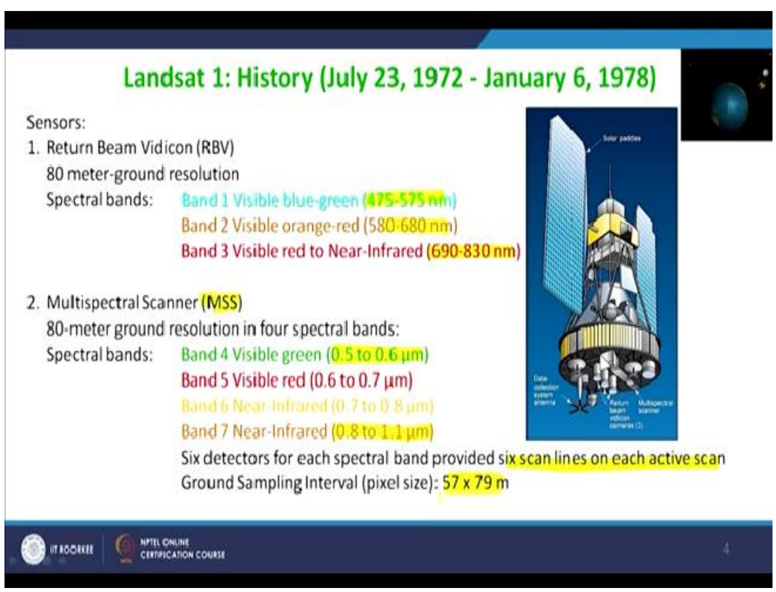

Instead, I would go on scanner systems on the Landsat-1. So, it has one scanner which is also used to call it Vidicon along with your MSS scanner. So MSS scanner was also there. So, in what we see that this RBV had 3 channels, visible, blue, green, and visible orange, red and visible red to near infrared and in different micrometer ranges are here they are mentioned in nanometre ranges where there and we used to call band 1, band 2, band 3.

And on the same satellite that is on Landsat-1B also had a scanner Landsat MSS and that has 4 channels. So, because RBV had 1 2 3 RBV 3 channels were assigned 1 2 3 and therefore MSS are assigned 4 5 6 7 and later on because this RBV never worked as per expectations and therefore, these channels were renumbered as 1 2 3 4 in case of MSS but does not matter and distribution within these EM spectrum of visible infrared was very simple that band 4 was 0.5 to 0.6 and visible was 0.6 to 0.7 micrometer near infrared was 0.7 to 0.8 micrometer.

And then another near infrared channel 0.8 to 1.1 micrometer and this was a little wider channel compared to the previous that is band 6. And this they had 6 detectors for each spectral band provided 6 scan lines on each activity scan ground sampling interval and this had this kind of a spatial resolution it is not exactly square shape but 79 57. So, of course, the image has to be by theory, it has to be square.

So, they were actually overlap along the side. So 79 and rest about 12 meter overlay was there on the side. So, that is why the pixel size was not square and shape in rectangular. But when you talk in terms of metrics to demonstrate metrics, of course, it was treated as square, each pixel is square say.

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Now, the latest series which was Landsat-8 also call OLI series, which was launched in February 11 2013 still working giving good quality of data. So, there are more number of channels as compared to Landsat MSS. Of course, in between Landsat TM is okay. So, OLI is having channel number in the multispectral bands 1 to 7, then there is also 9 channel, channel 9 for band 9 and all are having 30 meter space resolution.

Where is there is a panchromatic band which is channel number 8 and having very good resolution which is 15 meter. I also told you earlier that as soon as the data is acquired by these the OLI series that Landsat-8, it is in few minutes time it is put on net and for free download. So anybody want suppose I am interested in some part of India by calculation for you know, we know that when this next orbit will come over India or in my area of interest.

And once that date is shown, then on that particular day and morning hours the scanning will be done and in few minutes time the data is available on net for download. So, that is the another big advantage with new series of Landsat satellites. And there are other bands are there and thermal infrared bands are there TIRS. So, 10 to 11 band which are numbered as 10 and 11 collected 100 meter resolution.

So, these are not only multispectral scanners, but multi resolution scanner. So, you are having 100 meter resolution, you are having 30 meter resolution and you are having 50 meter resolution.

So, in case of these thermal infrared band in 10 and 11 data is originally collected 60 meter, but resembled at 30 meter to match with the other data sets when reband 1 to 7 and band 9. So, in that way, it is there though the data is collected at 100 meters.

So these high as I have been discussing that thermal infrared data is in order to record good quality of data, you require a relatively clearer resolution and say to provide that much of energy to be registered with the sensor. So, therefore, relatively the space of resolution of thermal bands are always less than visible infrared. Now, when we compare a Landsat-1 8, along with Landsat-7.

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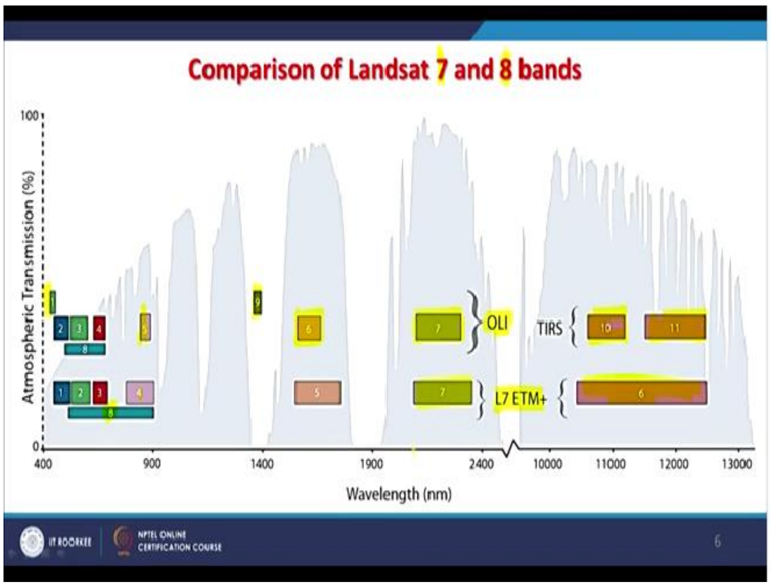

And 7, 8 here. So, this is what we find that different bands are given here for Landsat-7 and 8. So and this is a for Landsat-7 which had the sensor ETM + and OLI series that is Landsat-8. So, if I compare it starting from say right hand. So, in case of ETM + this was a very broad thermal channel was there, thermal infrared channel on Landsat-7, whereas, within that band 2 new channel, 2 individual channels were created.

And they were named in OLI series as 10 and 11. So, earlier if there were some differences, but what happens, this gives a very good advantage, if I am having 2 thermal channels. So, that there are a lot of algorithms, which works on a split window algorithms and for which you require 2 channels, 2 thermal channels like NOAA AVHRR, it has been possible to drive land surface temperature using a standard split window algorithms.

And which requires 2 thermal channels. So, with up to Landsat-7 it was not possible, but now with Landsat-8 or OLI series, because now we are having 2 bends in thermal channel or thermal part of EM spectrum and therefore standard split window algorithms can be applied and directly Landsat land surface temperature or a skin temperature of that can be determined. As you can also see that these in OLI series or Landsat-8 these channels have become further narrow.

So, I should say we have become much sharper as compared to Landsat-7, how why it has been done, how it has been done. The basically as studies as a whenever there is a new design of sensors is done for the new series of satellites, then it is studied that if I am having a broad channel like here in case of 7 and then sometimes we miss a lot of signatures. So, in order because we exactly know there is a atmospheric window at level.

And if we put the sensor or a band a little narrower than previous one, then the detection may be much more sharper, that is why it is becoming finer and finer after having a lot of experience of more than 46 or 47 years of Landsat data. And also whereas if I compare these a few first few channels in like 2 of OLI series is equal to have 1 in of Landsat-7 and again there is as you can see 4 correspond to 3, 3 correspond 2, 5correspond to 4.

But here the band 5 has again become narrow and there is an unfortunate channel one, there is a little shift towards the left edge and it is starting at a much more earlier as compared to Landsat. So, they all end the one more channel as we put especially for certain purposes that is band 9. So, as you can realize that in new series of satellites, if in this case the example is Landsat then channels are becoming narrower number of channels have increased and of course, and then utility of the data becomes much more.

So, these gray states which are shown here are all atmospheric windows where these channels have been designed and put in a space.

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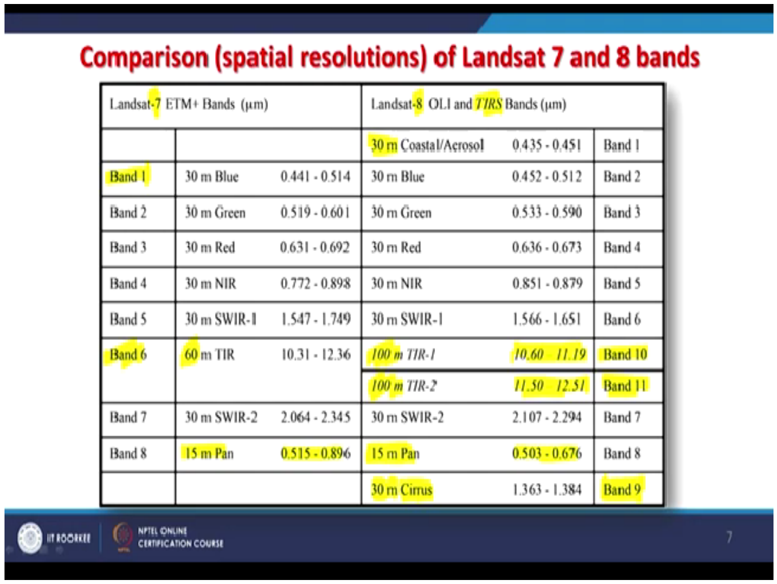

Landsat-7 ETM+ Bands (µm)			Landsat-8 OLI and TIRS Bands (µm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	100 m TIR-1	10.60 11.19	Band 10
			100 m TIR-2	11.50 12.51	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9

Further details if we want to see about and the comparison between Landsat-7 ETM and OLI series and thermal infrared bands and they are corresponding. So many are very close and many like band 6 in ETM. Now, it is called band 10 and 11 and it has been splitted in 2 parts thermal infrared part and especially, I would like to talk about band 1 in ETM +, which was 0.44 to 2.514 and now here much before that 0.43 to 0.5451 and that band 1 is there at 30 meter resolution.

So, if we just focus on resolution and then it was a 60 meter thermal infrared, but here it is 100 meter, but later on it is being resampled so that it can match with other sensors data 30 meter, but originally the data is collected at 100 meter resolution, because it was realized that the responses which are coming at 60 meter resolution are not very good. So, in order to improve the image quality here, there will compromise with the spatial resolution in new series, though the number of bands have increased.

So, what we can say the spatial resolution has become coarser, but a spectral resolution has become finer in that way and rest of the bands are most fit there. And of course, this is important one that the 15 meter panchromatic was also there, here also there, but the position has changed a little bit and then there is a this 30 meter that is should have been band 9. This is serious band some very special purpose to major serious.

And this is band 9 here. So, this is a new band, band 1 is again new bend and 1 thermal band is also new band and spatial resolution in this case ETM + they were just 2, 3 types 60 meter, 30 meter 15 meter here also 3 types 100 meter, 30 meter and 15 meter. So, likewise and development is taking place.

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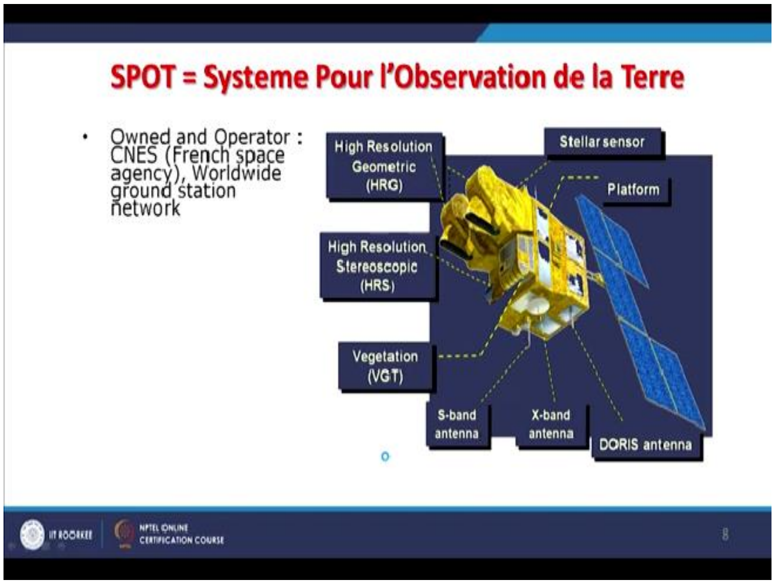

Now we go for a French satellite series, which was very popular, still very popular and which is a sport that systematic pour lay observation de la Terre is difficult to pronounce in French but anyway, I have tried and of course.

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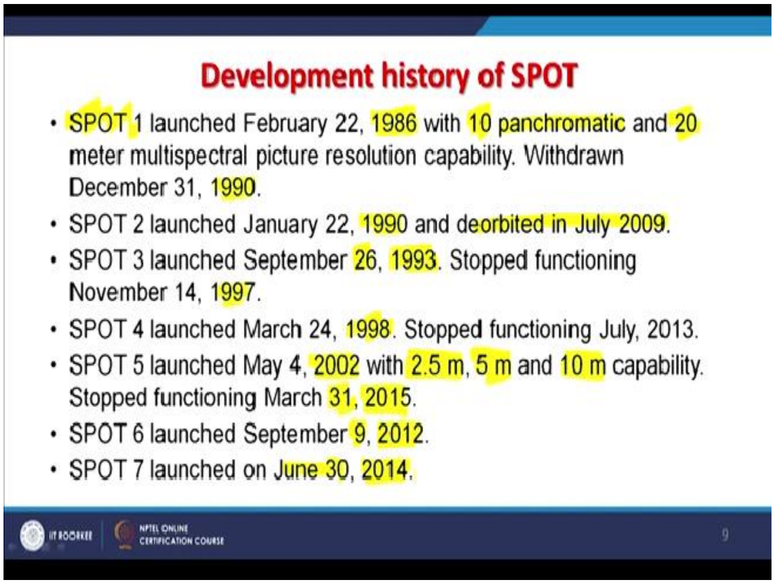

It has development is started in 1986 when we have this French space agency launched this part one and they were the first who could improve this spatial resolution is based in panchromatic band up to 10 meter and multispectral 20 meters. So, at that time when Landsat had 30 meter spatial resolution, SPOT brought our improved that resolution to 10 meter and 20 meter in a multispectral resolution.

And though later on after 4 years this satellite SPOT 1 was withdrawn, then came SPOT 2 it was launched and so there was some overlap between SPOT 1 and the SPOT 2, but deorbited vary after about 9 years of service, and in July 2009, then came SPOT 3 launched in September 26 1993, stopped functioning in 1997. So, it lasted only about less than 3 and a half about 3 and half years.

And then SPOT 4 came in March 24 1998 and stopped functioning on July 2013. So, it worked for very long time, it provided high resolution both multispectral and panchromatic data. Later on then there were lot of overlap between 4 and 5. So 5 was launched on 2002. And again further there is improvement 2.5 meter resolution, 5 meter resolution and 10 meter resolution capabilities which was stopped functioning in 2015.

And then SPOT 6 launched in September 9, which has almost similar scanning or sensor systems as in case of Landsat SPOT 5 and SPOT 7 launched in June 30 2014. So, there is a series of SPOT satellites and things improved after the first launch in 1986.

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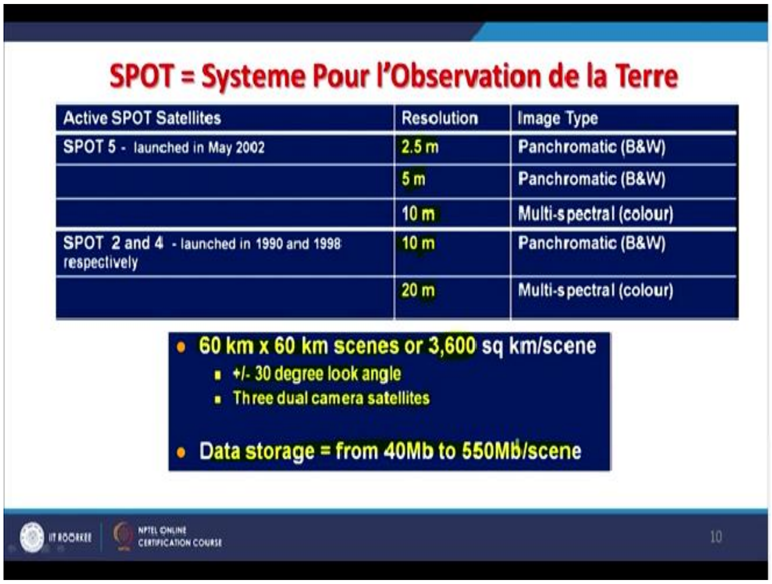

As you can see that SPOT 5 2.5 resolution 5 meter and panchromatic. So, there were 2 bands then 10 meter resolution is part 2 and 4 had 10 meter and 20 meter in early time. And of course, this was the area of swath which used to cover only 3600 square kilometre as we have discussed few times that higher the spatial resolution the width of the swath will reduce and it had 3 dual cameras and it was capable of looking plus minus 30 degree look angle.

So in both directions it was possible to look and the SPOT was providing also stereo images and using those stereo images it was possible to create digital elevation models using programmatic techniques. And of course, the data storage was 40 Mb to 550 Mb per scene, depending on which resolution or whichever channel data if you are going for a multispectral you require again because there will be 4 channels. And if you are going for panchromatic depending on the resolution, the requirements are there.

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Just one comparison of images that when you are having 10 meter resolution, this is how the terrain looks, but when we focus on this part here and 5 meter, these details are available, which was not possible to see in 10 meter. And when you go for much higher resolution 2.5 by itself is a very good spatial resolution for multispectral images, then you get a very much is available. So, one in the same area has been scanned at 3 different resolutions. Of course, the timing might be a little different, but anyway.

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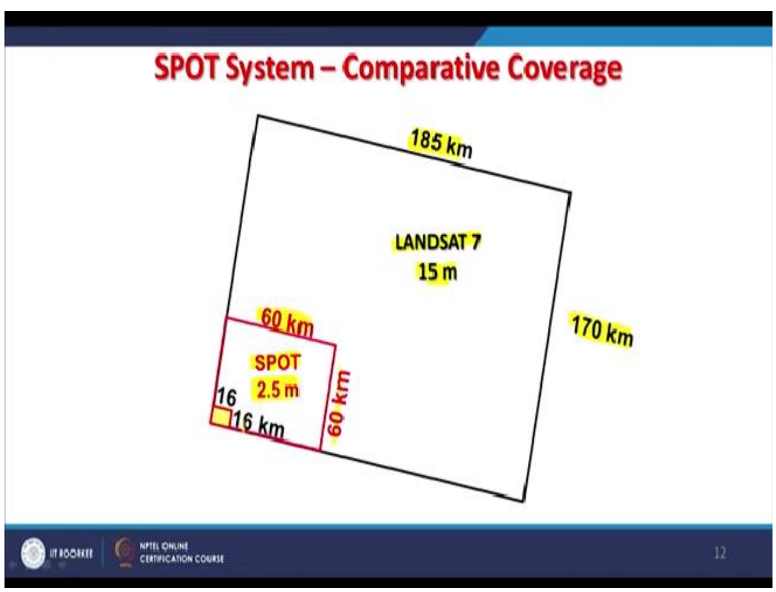

If we compare with the Landsat, the coverage, how much you know competitive coverage versus Landsat versus a SPOT, then this is what the scenario is that Landsat-7 is having 185 by 170 coverage or 1 scene will cover this much of area at 15 meters resolution, but when we go for 2.5

meter resolution in case of SPOT that will cover only 60 kilometer by 60 kilometer area and if we go further in resolution, then this will reduce to 16 kilometer by 16 kilometer. So, as I have been saying that higher the space and resolution the coverage reduces the size of the area, the scene is representing would become smaller, but in much more detail.

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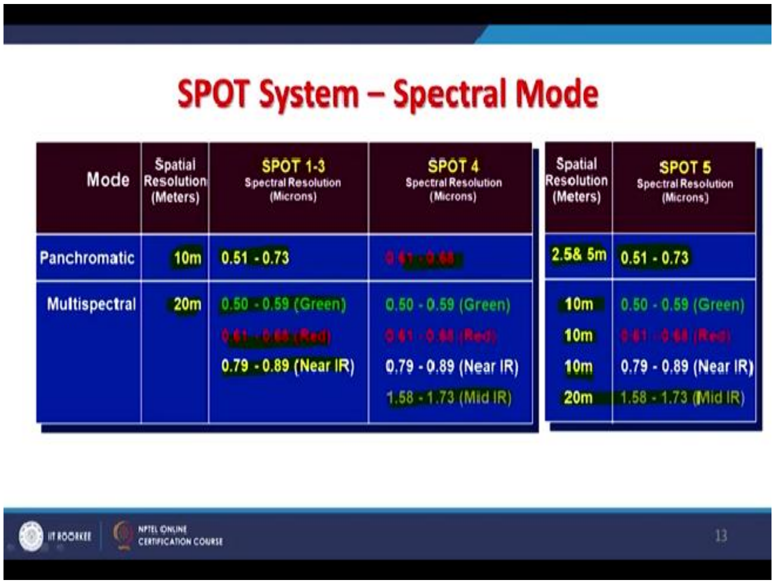

In a quick, sense we can compare the spectral you know, comparison of a SPOT system starting from SPOT 1 2 3, then 4 and then 5 is also there and the later on they are the same like 5 6 7. So, when we compare the panchromatic the position in a SPOT 4 was change instead of 051 to 0.73, it was located at 0.61 to 68 and then in a SPOT 5 when we had multi spatial resolution, panchromatic sensors.

So, then they after having experience of SPOT 4, they realized that it is better to go back 2.5 2.7 window and in those panchromatic or visible channel window that was there. Generally panchromatic channels are quite wide compared to unlike Landsat-8 OLI series. So, they cover a quite broad part of the spectrum relative sense. Whereas multispectral we had a 20 meter resolution and the locations green, red and in near infrared we are like this in case of SPOT 1 2 3.

Then of course in a SPOT 4 we had 4 channels here, so, there were one additional channel mid infrared channel, in case of is SPOT 5 again 4 channels 10 meter resolution, 10 meter resolution 10 and this mid infrared band 4 30 meter resolution up to 4 it was multispectral had the 20 meter resolution. So, if I just compare with this SPOT 1, 3, up to 1, 3 and 5 what I find that resolution definitely spatial resolution has definitely improved instead of 10 meter.

And now in new series of SPOT, we are having this resolution of 2.5 and 5 meter and in multispectral again it has doubled from 20 meter to 10 meter except for mid infrared channel. But the problem with the SPOT data it is not free and therefore, I hardly see much utilization or SPOT data in India, because it is very expensive relatively and when now, when we are having free data sets from various satellites including our own Indian satellites that I will be discussing.

And we will discuss in detail our Indian satellite system and therefore, much utilization is not seen in India but in Europe definitely extensively SPOT data has been used to since when the SPOT 1 was launched since then 1986 continuously the data has been used there.

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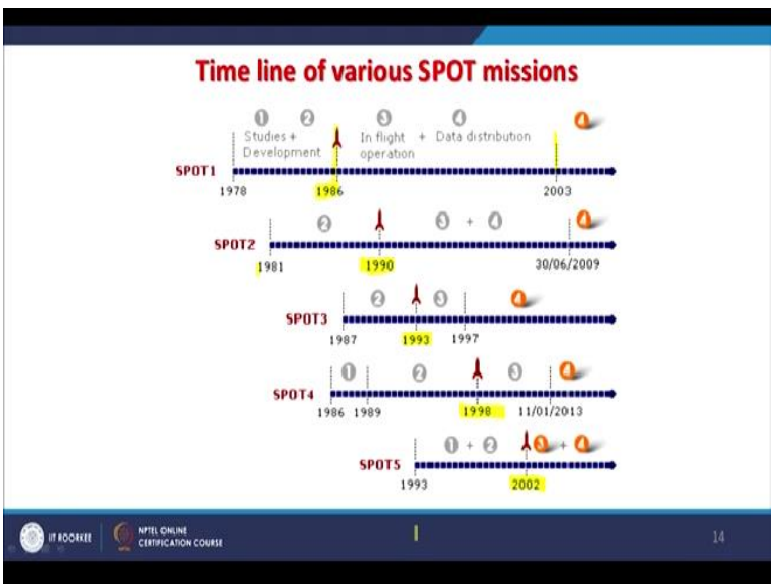

And these are the timelines which we have already discussed that is SPOT 1 was in 1986 was launched and then how much time it remained there in the flight operation SPOT 2 it was launched in 90 and 93 98 2002 one few more would have been here and which we are up to 2013 they were launched. So, likewise, and these are the timelines.

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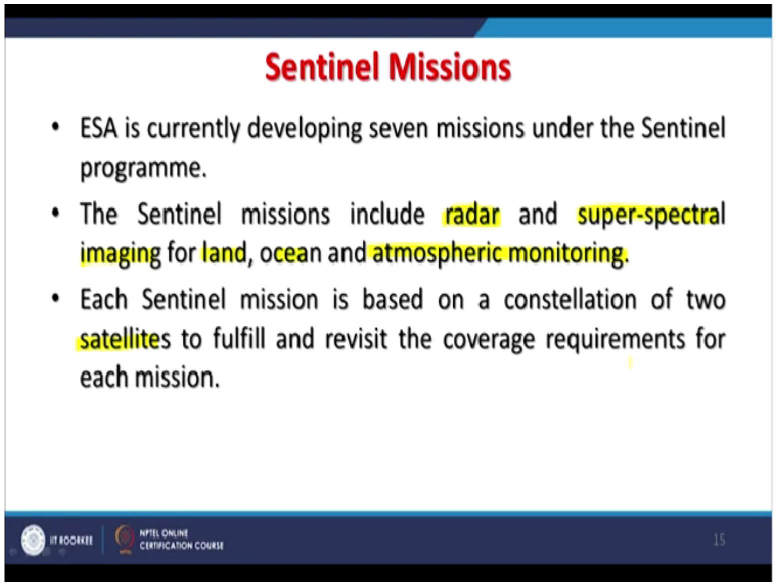

Now, we also cover one more very important mission which is Sentinel missions, there are now the Sentinel 1 and 2. So, these are very important data set and not only they provide the normal means these multispectral is cannot but they are also capable of providing interferometric radar data. So Sentinel missions include radar and super spectral imaging for land, ocean and atmospheric monitoring.

So that is the bigger do not try in that way Sentinel series is very unique to other satellites, the Landsat or a SPOT or IRS and each Sentinel mission is based on a constellation of 2 satellites. This is very interesting combination to fulfil and revisit the coverage requirements for each mission. So they are in tandem 2 satellites in 1.

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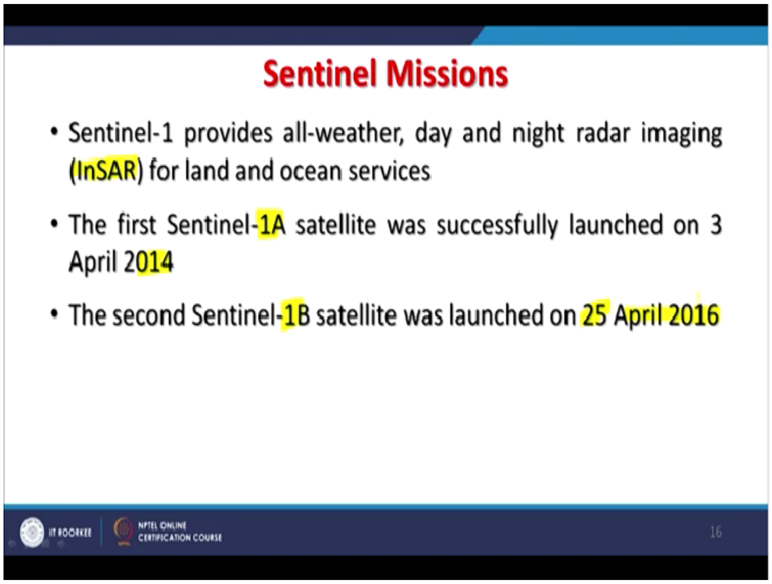

And basically Sentinel-1 provides all weather day and night radar imaging because this is active remote sensing satellite, and also InSAR interferometry data, which can be used for land and ocean services. In past I will be showing one example how extensively it has been used in case of earthquake related ground deformations and the first Landsat-1 A was satellite which was successfully launched on April 2014. And then the second Sentinel-1A was launched on 25th of April 2016. So, just after roughly 2 years the Sentinel-1 B was also launched.

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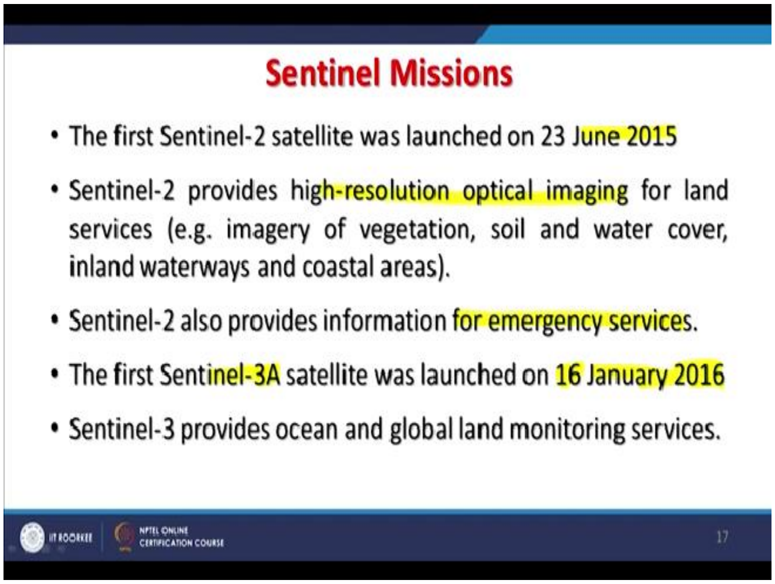

Now the first Sentinel-2 satellite a new series in Sentinel that is Sentinel-2 satellite was launched in June 2015 and then Sentinel-2 provides a high resolution optical imaging which is again variable in all data is free and which can be used for studying vegetation, soil, water cover, inland waterways coastal area, all kinds of applications. And Sentinel-2 also provides information for emergency services whatever.

Now the first Sentinel-3 satellite was launched in January 16 2016 and Sentinel-3 again provides the ocean and global land monitoring services. So, these are the missions of Sentinel.

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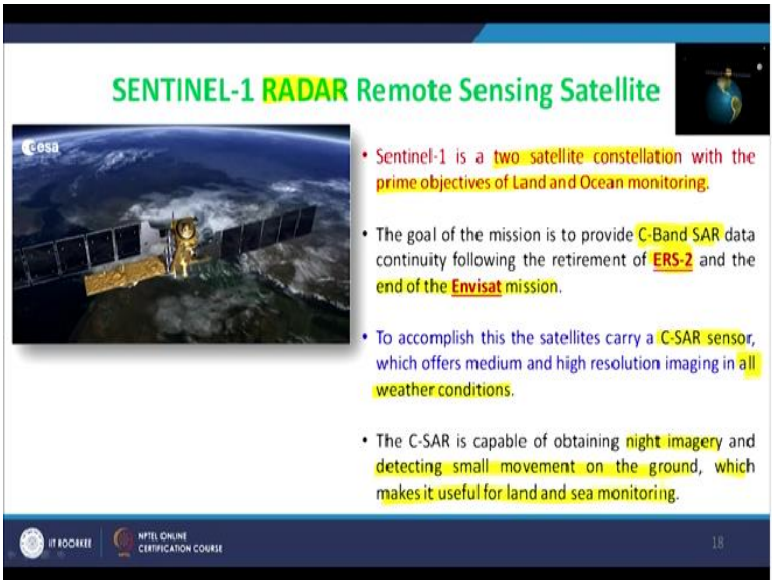

I will just focus more on the radar data because radar data used to be very expensive, but after the launch of Envisat and later on this radar sat or a Sentinel and this data has become free and very, very useful data for various kinds of studies. So, Sentinel-1 which is a 2 satellites constellation, Sentinel-1 A and 1 V with prime objective of land and ocean monitoring and the goal of the mission is to provide C band.

Recall our discussion on part of EM spectrum where we have discussed in previous lectures about where the active remote sensing takes place. So, there are different band x band s band c band. So, this your Sentinel-1 was in the very common band is the C band also X band or S bands are used, and this synthetic aperture radar data, which you continue to be following the retirement of ERS which we are again, European series satellite ERS 2 and the end of Envisat.

So a radar data by ESA started being provided through ERS-1 A 12, ERS-2 later on Envisat and then when these missions were over, then the new series started which is Sentinel-1, especially I am talking about radar data 2 accomplish this satellites carry a C-SAR sensor, C band scanner which offers medium and high resolution imaging in all weather conditions. So when we say all weather condition, it means is a active remote sensing or radar data we are talking.

And C-SAR is capable of obtaining night imagery because you do not require any energy source external energy source, the sensor itself will provide the energy signals send or pulses will be sent towards the earth and then back scattering is collected. So, it is possible to acquire images in night time detecting a small moment on the ground. So, ground information is studies can be done and which makes it useful for land and sea monitoring.

So, for the sea part also, ocean part also the Sentinel-1 data can be as mentioned that I will be show you one example of very good utilization of this radar data in this case this example is coming from Japanese satellite which is a ALOS a sensor is pulsar.

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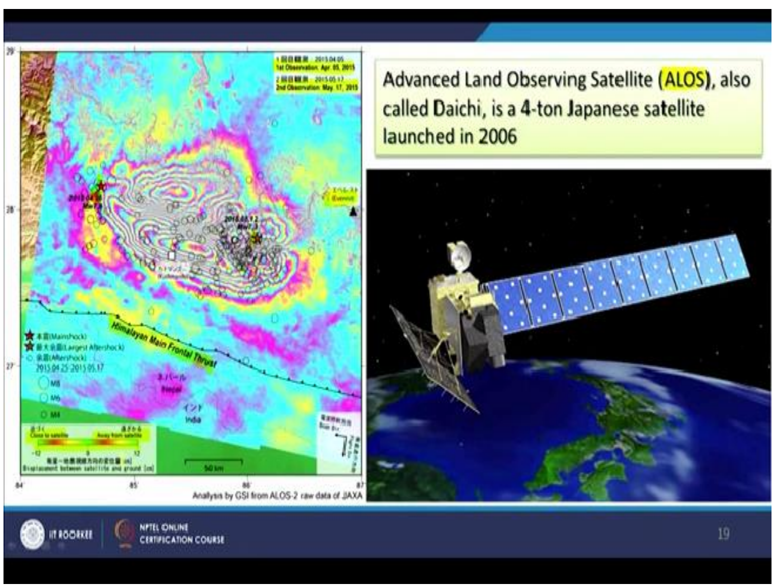

And similarly in the Sentinel SAR interferometry data has also been used. So, what here we are seeing on the left side is interferogram and interferogram which is showing of earthquakes, which has occurred in Nepal in 2015, which is on 25th April here on the left side and on the right side 12th May 7.3 magnitude. So, first one was 7.8 magnitude of 25th April and then 12 May it was 7.32.

That is the series of earthquakes are there just for your reference Everest is located here. And this is basically the Kathmandu Valley Himalayan frontal thrust is there and here the MCT was basically became active during that time. Now, in order to have interferometry or these fringes, we require 2 sets of data or 2 images if I say in simple terms, then the first observation was done on 5th April 2015.

Nobody knew at that time when data was being acquired by ALOS, that there will be an earthquake on 25th April. And then second observation was done on 17th May, by the same satellite, same sensor post these 2 earthquakes and in between 2 earthquakes have occurred and whatever the deformation have taken place ground deformations taking place due to these 2 big earthquakes or major earthquakes not greater earthquakes.

And then these could be mapped and one fringe represents a particular you know, like in C band it is about 2.8 millimeter difference is there. And this is what if you count the total number of fringes multiply by 2.8 and then you get a complete the deformation which has taken place by looking the pattern color patterns from inside out, you can also find out that which part of this deformed earth has subsided or uplifted.

So, that is also possible because as you see these in the Legion, but it says that close to satellite away from satellite. So, when we get these color fringes in the away from satellites that the land has subsided and when land has moved towards the satellite, close to satellite that means land has uplifted. So, like this seeing these color patterns in sequence, we can identify very easily or can create one more product which is called ground deformation map in which we will be exactly seeing which part of this affected region of Kathmandu valley in Nepal area has gone up and which part has gone down.

That is the and this is all weather day and night functioning. So, even there are clouds or any other thing in the atmosphere and will not be a problem. So, that is another big advantages and the crazy part as you can realize of millimeter we are talking. So, this provides a millimeter accuracy of estimating the ground deformation. And that too is very accurately. So, this brings to the end of this discussion about different sensors of the European Space Agency. And thank you very much.