Introduction to Remote Sensing
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Lecture 09
Silent characteristics of Landsat, IRS, Cartosat and Resourcesat sensors

Hello everyone, welcome to 9th lecture of this introduction to remote sensing course, in this lecture we are going to discuss in detail the salient characteristics of various satellite and the most popular one the Landsat IRS our own Indian Remote Sensing Satellite also Indian Remote Sensing Satellite (car) Cartosat and Resourcesat and their sensors as well. The focus of this lecture is going to be the on the sensors of this satellites.

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Many of the slides which you might see which you might have already seen in previous lectures but here the emphasis is little different first of all as you know that we have already discussed that there are various types of orbits exist and that is why the whole space near earth is cluttered with the several satellites and but the two main orbits which we would like to focus which are useful from remote sensing point of view, one is the (sola) sunsynchronous or near polar or polar orbiting satellites. Most of earth resources satellite like Landsat IRS Cartosat the Resourcesat, all of them are in these orbits, polar orbiting orbits.

There is another another orbit which is another very popular one is mainly it was for the communication satellites which is geostationary orbit and this this orbit is having many satellites of the world focusing for their own countries, India too is having our own satellites in Sat series of satellites, also one we had a in the name (kal) Kalpana Chawla, the Kalpana satellite, there are some other satellites which the data can also be acquired if they are covering the Indian sub continents like (meteod) Meteosat and others.

Since the purpose of these satellites the geostationary one spatially is for monitoring weather and other things but nowadays advanced sensors are have also been installed on these satellites, so every half an hour of 15 minutes one can grab an image or capture a snapshot and these a many times becomes very very useful.

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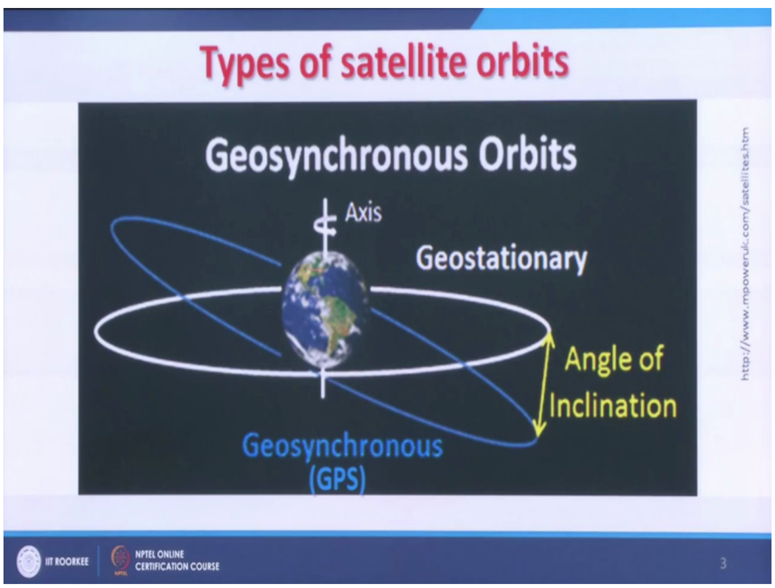

One of the examples form geostationary satellites applications in natural disaster is a now a days like for monitoring some storms or cyclones and you might remember that few years back there were a cyclone Hudhud but because of our better monitoring through geostationary satellite in a more or less continuous fashion we could evacuate lakhs of people from the affected to be affected areas and lives of several thousands of people could be saved.

So remote sensing has played directly, has played a major role for such kind of natural disasters and making life much safer for all of us. So two main orbits, one is a sunsynchronous orbit another one is geostationary orbit and whereas GPS and navigation satellites, many of them are in geosynchronous orbit but now days in case of GPS, several combinations of different types of satellites are the different types of orbits are being used and for example in case of Navic, we do not have totally all satellites are in geosynchronous some are geostationary and so on.

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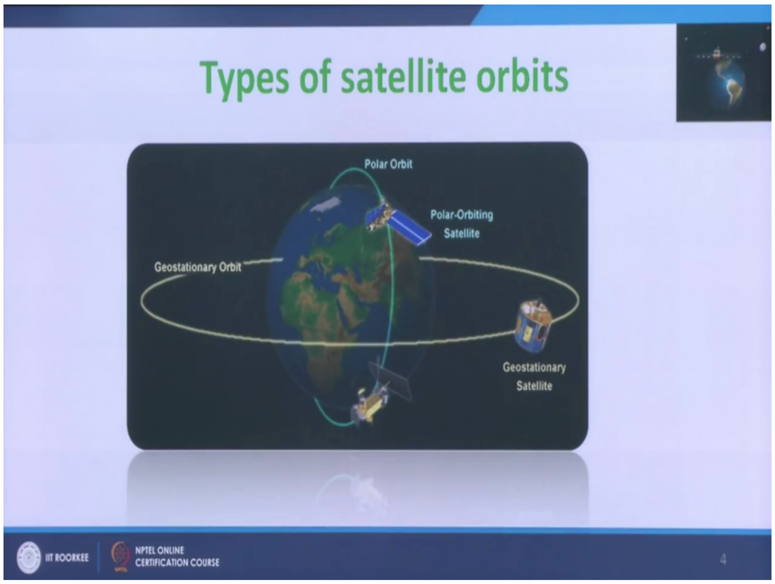

So there are various types or orbits are available, their distances and other things are altogether different, for example polar orbiting satellites are the nearest to the earth, somewhere around 840-50 kilometre away from the earth, with a plus minus 10 kilometre in range, so a complete envelope around the earth which is having hundreds of satellites of various countries including of India are there.

Then the another popular one is the geostationary which is having about 36000 kilometre distance but the purpose of these satellite is to focus on a small part of earth and they since they move along with the the rotation of the earth, they relatively we call them as geostationary satellites.

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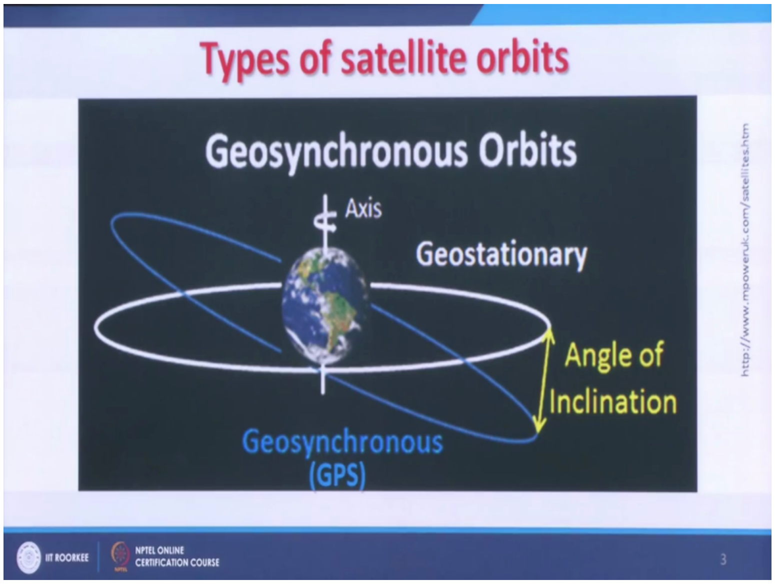

So but if we bring the GPS satellites typical this American Navi Star GPS systems, they are having satellites in different orbit, 6 orbits and all this their distance is about 20,200 kilometre.

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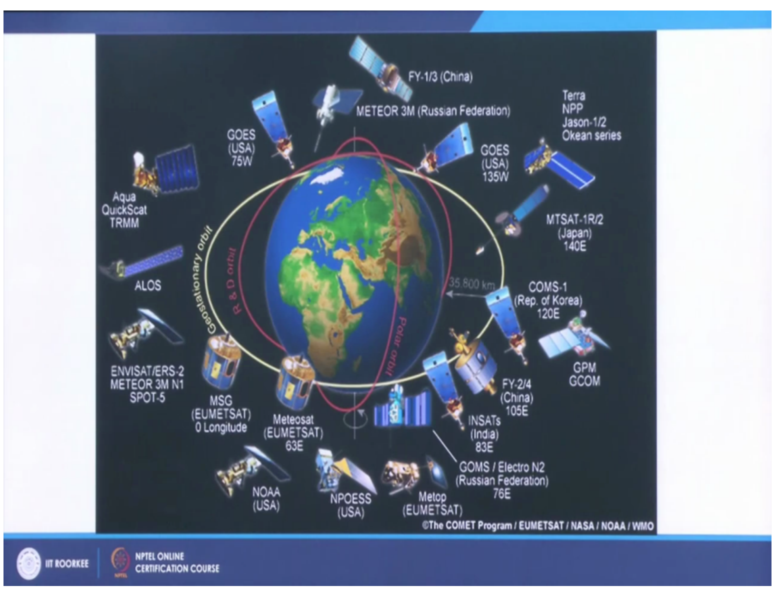

So satellites are various satellites are there, the sky is completely cluttered with satellite or space is full of satellite but at different distances in different orbits, so there are hardly any chance of colliding them.

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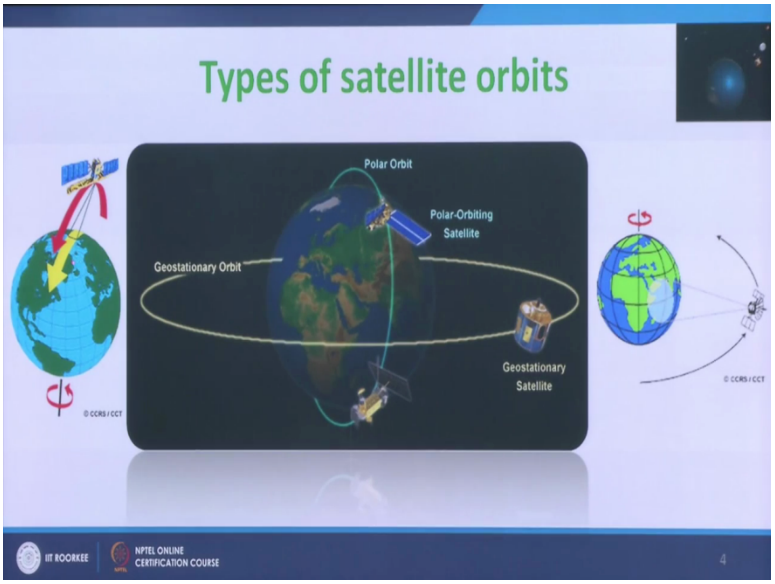

So now we, we come to this mainly we will focusing mainly on the geostationary satellites which covers small part of the earth and not like geostationary satellite this polar orbiting satellites and sun synchronous satellites and this is what we call as the footprint of the satellite, the red one is showing the orbit of these polar orbiting satellites.

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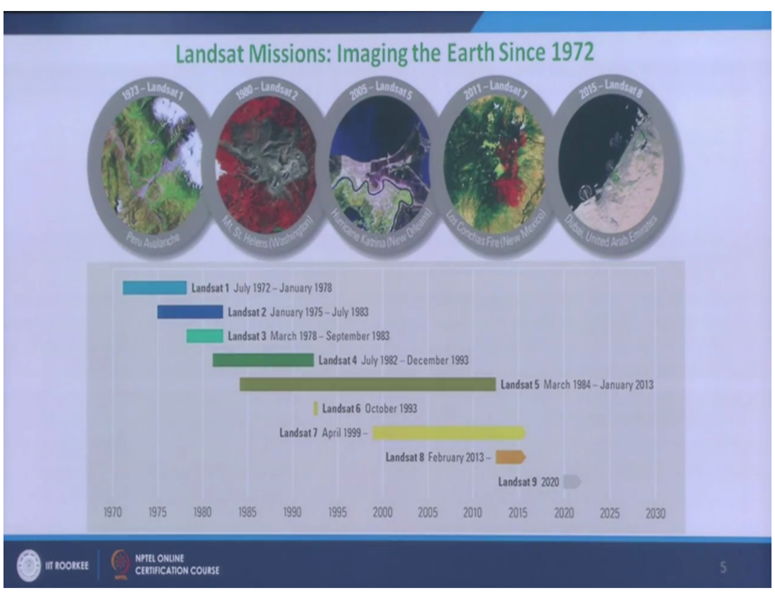

The as I said in earlier lectures that the real beginning of (())(6:03) and remote sensing started with the Landsat, spatially with the Landsat one which earlier we used to call as ERTS1 which was launched in July 1972 and since then continuously we are having series of these Landsat. Currently is the Landsat 8 which is also called OLI series launched in February 13, still it is operational.

This providing enormous amount of data from all parts of the globe and most importantly data is available free of cost for any part of the globe on really near real time, once the data is acquired by the Landsat earth stations which are spread over world over within few minutes you get the data on net and you can download and see what exactly 15 minutes back the situation was in a part of the earth, where the satellite was orbiting, so that is the biggest advantage of having a complete series.

Another point which I want to bring here that since 1972 to 2016 all this data the archives of all such data is also available, so this about 45 years of archive, archive of such data sets, enormous data sets has made possible for us to look for time series data analysis spatially focusing on global climate change or any long term studies whether it is related with natural disaster, lands subsidence or many many you know monitoring of things like whether vegetation is changing or whether the sea surface is changing, whether the snow or snow and ice is disappearing from the high scapes or mountains, all these things, all such type of studies are now possible because of availability of all these archive and data still free of cost.

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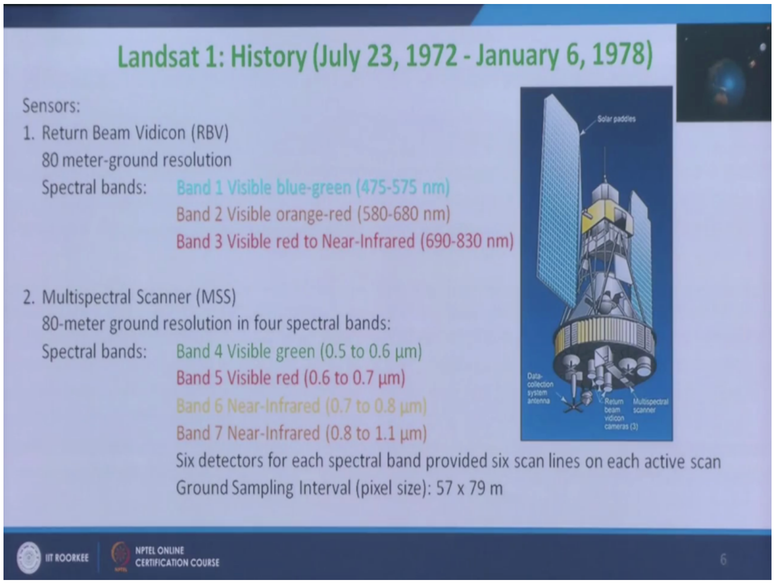

As we have also seen this this slide but I want to, I wanted to bring it again because we are now focusing not much on the satellite but on the sensors, the sensor (charas) characteristics, so this Landsat one is had this one return Videocon RBV sensor which which was there but it has a altogether different technology of acquiring data, so it was not as that popular as Landsat MSS, MSS which is Multi Spectral Scanner the the data was provided roughly at 80 meter resolution but it was not a perfect square.

As you know that a pixel of an image has to have square in shape but initially when we started because of this 57 and 79 meter spatial resolution because of some overlap of the data or the pixel with another we had some problems and that time we used to call as a mixel but these problems were solved in subsequent Landsat missions and this these data sets which was available initially by MSS became very popular and very useful.

So though we write 80 meter spatial resolution or ground resolution but in fact it is 57 by 79 because here we are having a 15 meter roughly 15 meter overlap in this. It has four channels, starting from initially the names of these bands they are four, 1, 2, 3, 4, later on this were named to 4, 5, 6 and 7 starting we don't have any channel in the blue part of EM spectrum as you know that lot of the, lot of this solar radiation is absorbed by the atmosphere of this part of EM spectrum.

Therefore we do not have any channel in that or any band there but we start with visible green channel, visible red channel, visible near infrared and there at, there are 2 channels near infrared channel point 7 to point 8 micro meter, point 8 to point 1 micro meter and these were the sensor became very popular and in fact the modern day remote sensing revolution started with the Landsat MSS.

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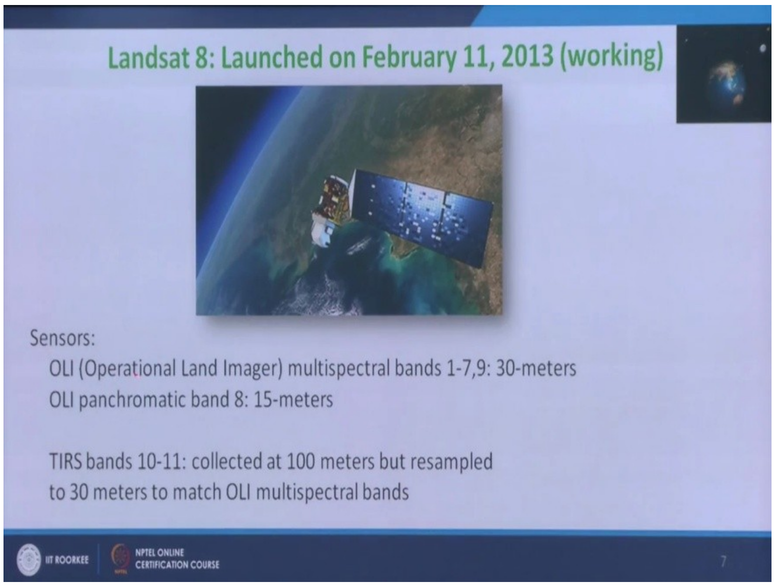

And the latest one and it has gone through the Landsat TM, Landsat ETM, Landsat ETM plus now we are having Landsat 8 which is also called OLI series means Operational Land Imager which is having data at different spatial resolutions and may channels 9 channels data is available. So instead of now four SB has increased MSS, now we are having 9 channel data and the channel 8 is having 15 meters spatial resolution which is specially designed for panchromatic data acquisition, whereas channel 1 to 7 or band 1 to 7 and band 9 are having 30 meters spatial resolution.

So now days because the technology has compared to Landsat and MSS till in 2016 the technology has improved so much that on the same sense on the same satellite we can have sensors which can acquire data for various bands but at different spatial resolution, earlier these things were not possible and especially this TIRS Thermal Infrared Red Bands are channel 10 and 11 and which are collecting data at 100 meters but later on they are resampled to 30 meters so that we can use them along with our multi-spectrum data.

So this kind of data you think that earlier we had only only four channels data now 11 channel data, 2 channels in thermal channel, in case of MSS we did not have any thermal channel. So in a lot of a data is now available thermal channels applications of thermal channels is also very very useful for example like for sea surface temperature mapping extensively thermal channels are being used and also for land surface temperature mapping and then time series data analysis how things changes in thermal resume of the surface of the earth.

This is only possible if we are having thermal channel, so in Landsat we are having thermal channels, in extra satellite we are having thermal channel and of course in NOAA tough the data is available at 1.1 kilometre resolution but having wide swath large coverage but it is also having 2 thermal channels which we will see little later.

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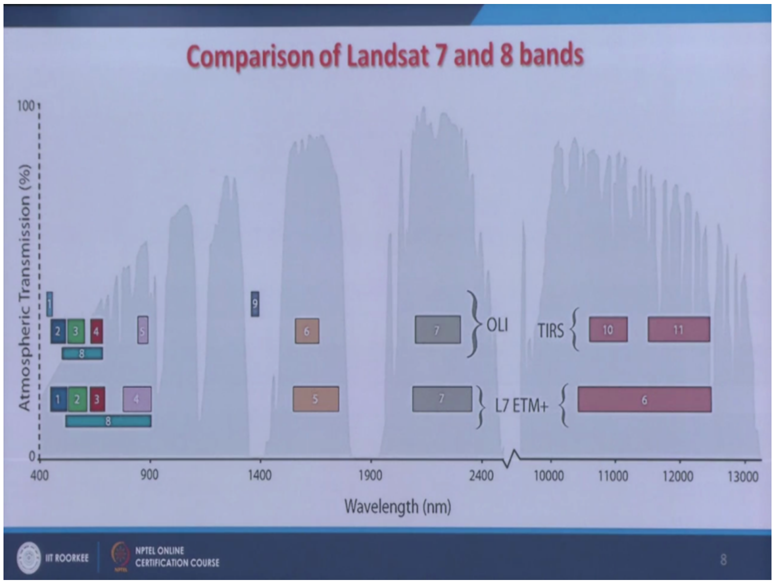

Mostly importantly here that we are comparing the just previous lands 7 and 8 satellites then how things keep changing as new sensors are designed and so on. As you can see that the top one are the OLI that means the Landsat 8 bands which are located and in the background what you are seeing is spectra which is showing the absorptions or atmospheric windows.

So you will see that very carefully these have been designed to place there, so that these shaded one are the atmospheric windows and these are the opec area so that we can acquire data of different ground features in a all this 11 channels in case of OLI data and whereas compared to see the improvements with the lands between Landsat 7 and 8 is the 7 had only the 7 channels whereas 8 is having 11 channels.

Though there were only 1 channel for a thermal data sets but then this in Landsat 8 we are having 2 channels. Now advantage of having two channels in thermal range because many of algorithm which drives the land surface temperature or sea surface temperature, they are based on split window algorithm and that means they require 2 thermal channels to estimate the temperature of the earth.

And for that purpose the OLI series that means Landsat 8 is very very suitable because you are having 2 channels and also if you see very carefully, you will find that all of these channels which were in the in Landsat 7 they, they have further improved and these channels have become further narrow because the advantage of having narrow channels that you can discriminate minute changes in a you know objects which are present on the earth very easily compared to having broad channels.

So like a channel 7 and you are having again you compare with Landsat 7 and Landsat 8 there is a difference that Landsat (6) Landsat 8 is (chan) band 6 and Landsat 7 band 5 again band 5 of Landsat 7 is relatively almost having double width as compared to band 6 of Landsat 8. Similarly as you can see the panchromatic, panchromatic say instead of covering a very large area of visible part of EM spectrum in case of Landsat 7 as you can see Landsat band 8 had a very broad spectrum now in Landsat 8 the band 8 is having almost half width they have.

So what we are seeing through the development of say just in case of Landsat series the channels are number of channels are increasing, spatial resolutions are increasing for almost all channels and the width of these channels are reducing, that means the spatial resolution is improving, our radiometric resolution is improving means the quantisation instead of having just 6 width data or 7 width data now we are having 8 widths or 10 widths data and also the this this channels are also our spectrum resolution that means the width of channel is also reducing and that means the improvement in the spectral resolution.

So on all frames almost except for temporary resolution the spatial resolution is improving, the radiometric resolution improving and your spectral resolution improving, just we compare only Landsat 7 and 8 we can see the changes but if we compare Landsat 1 and 8 there huge changes, number of channels are also increased and multi-spatial resolution data are now days also possible with these sensors, so just in a one Landsat series huge changes, major changes have been observed and maybe in few future Landsat's we will be seeing more better improvements on this front.

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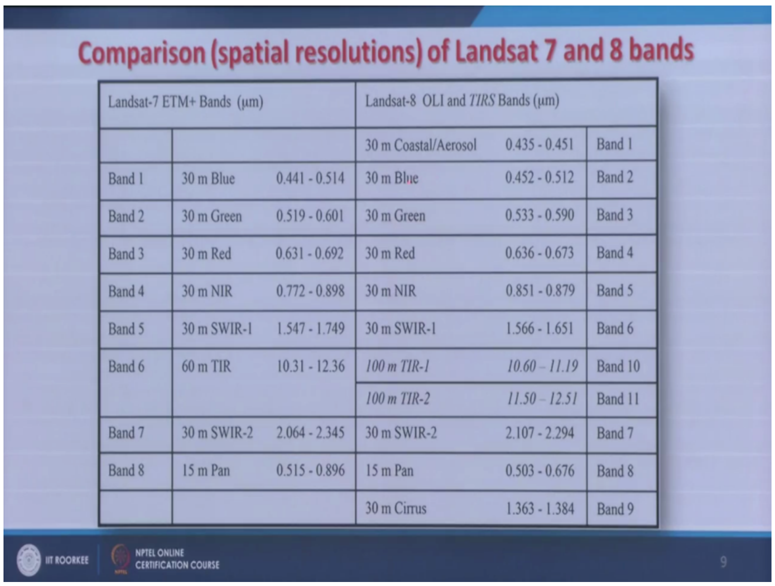

Comparison (spatial resolutions) of Landsat 7 and 8 bands

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

Ok so now we will compare the spatial resolutions one by one for all bands of between Landsat 7 and 8 what we find like a band 1 which we also roughly we say a blue band is having 30 metre spatial resolution in case of Landsat 7 but in landsat8 this remain same but another band, band 1 so there is a change in the numbering of these bands are there but the from between them 1 to 5 not much changes in terms of spatial resolution and neither much change in their position but they definitely as we have seen in the previous slide that these bands in Landsat 8 has become much narrower that means our spectral resolution is improving.

We are putting more bands, more number of bands within the available atmospheric windows and band 6 if you see here that it was providing data 60 meter resolution, now it is providing in a Landsat at 100 meters but these are instead of 1 channel now we are having 2 thermal channels data and in case of band 7 the spatial resolution remains same and though here is a some changes on the spectral band, Landsat 7 band 8 is having 15 meter and that is spatially reserved for panchromatic data whereas Landsat in case of landsat8 band 8 is having almost same thing but of course it has become further narrower. 1 more band has been added here after this band 9 which is having 30 meter and specially it is designed to capture data about the snow or ice.

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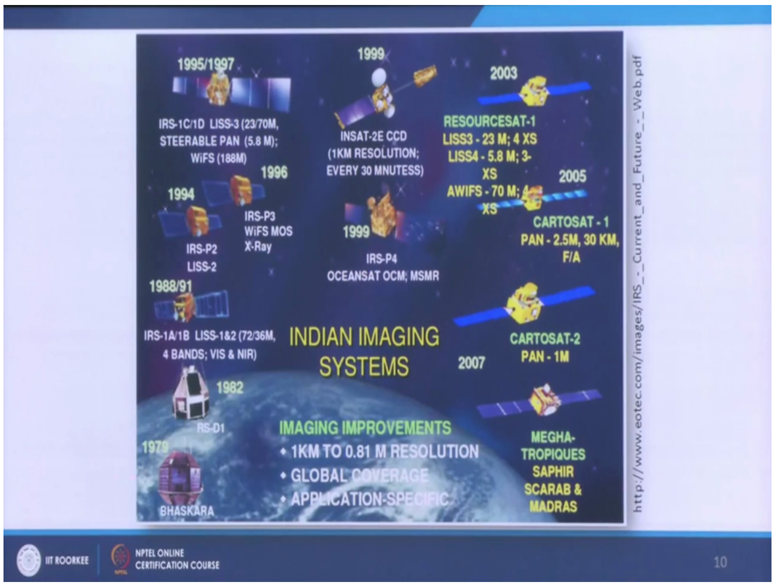

So after seeing the (comparal) comparison between landsat 7 and 8 now I would like to focus mainly on Indian remote sensing satellites as you can see there are many and we started with the Arya Bhatt Bhaskar and now this this is continuing and only in recently that satellite is not added here and that we are having now in only in June 2016 we had another satellite which is out Resourcesat 2.

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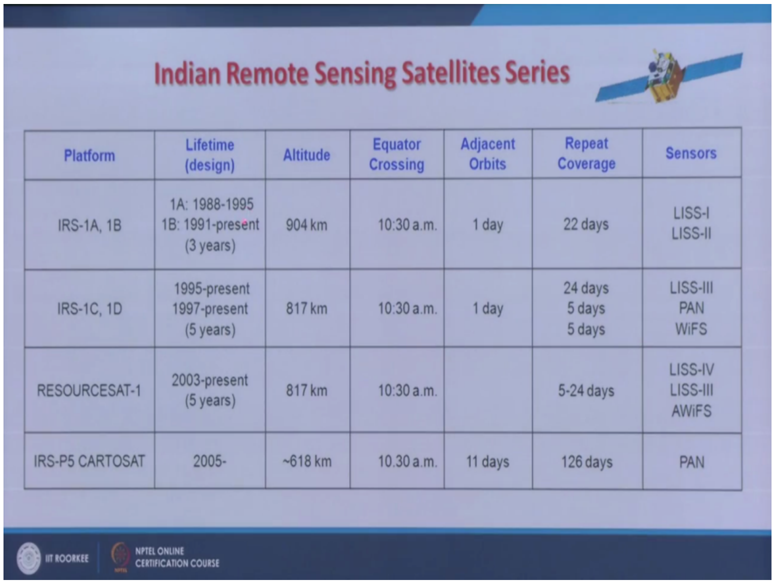

But before that I would like to again bring our focus mainly on the sensors characteristics of the satellite but the same time we will also try to compare the other characteristics of this all these satellites. Because this is not a that now these satellites are not working and therefore like after 95 IRS stopped working but the important part here for every satellite if that for whatever the period they have worked the data is now available and almost free of cost on through net even our IRS 1A, 1C, 1D all kinds of data is also available, so because of availability of these archives we need know.

We need to know details of all these satellites because there are improvements as you can see here in the IRS 1A, 1B it lasted only for between 1988 to 95 and then 1V only after 91, so we had some overlap and in tandem the spatial resolution was improved quite lot and the altitude of this satellite was little higher instead of 840 or 50 kilometre we we had at 904 kilometre and generally like twitter crossing is 1030 but local over pass time might be around 930 or so and it keep moving the the temporal resolution was 22 days when you had the only one single satellite but when you are having tandems in tandem then this was reduced for some time between this about overlapping time for 11 days.

These 2 satellites IRS 1A and 1B had 2 sensors LISS 1 and LISS 2 and these linear sensors we will see much more details about these, then in the next in the series IRS 1C and 1D again there were some overlap between 1C and 1D this is these are not only for 3 years they worked and then the the orbits were little closer as compared to IRS 1A, 1B and other things remain same, the repeativity because once you are in an tandem the temporal resolution improve to about 12 days and it has a 1 more extra sensor, so LISS 3 we had instead of having LISS 1 we had panchromatic sensor and wide field of view sensor that is the WIF.

So it the land instead of Landsat LISS 1, LISS 2 we had LISS 3 and WIF then we started a another P series or the satellite IRS P also called as cartosat and in between also Resoursesat, Rsourcesat one lasted for 5 years, it was again almost the same altitude, same crossing time and repeativity on this temporal resolution was also same. Now in this LISS 3 sensors continue because LISS 3 sensors was one of the best sensors of IRS series of satellites therefore it got continued in the Resourcesat, we introduced one more LISS 4 which has better spatial resolution and other characteristic and instead of WiFS we have AWiFS and in Cartosat because the purpose of this IRS P Cartosat was altogether different.

Therefore orbits was much lower, it was mainly for to acquire the stereo data so that a digital elevation model using the stereo pairs acquired by the Cartosat can be developed and which have been developed for for all parts of India and those data that means digital elevation model are also available free of cost for all parts of India at a very high resolution, so this advantage, so here we need not to focus too much on the 126 days of temporal resolution because the purpose of this satellite was altogether different.

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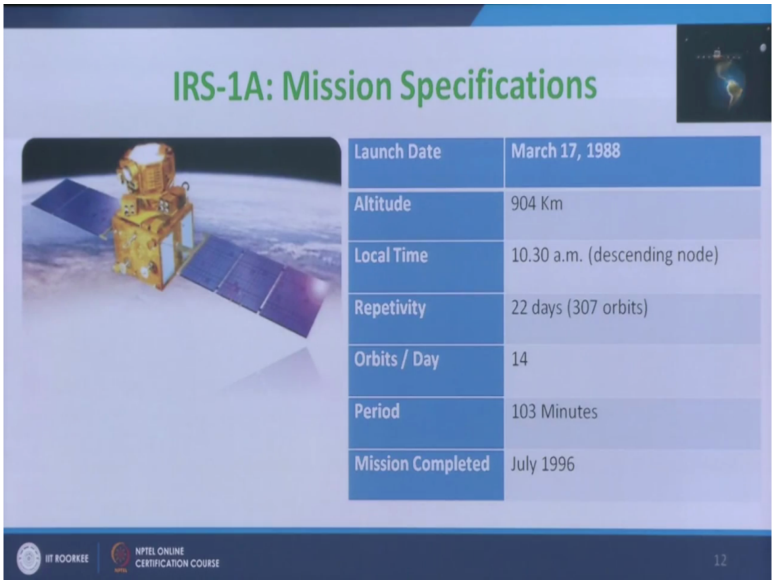

IRS 1A most of this details we have seen so I am going to escape this satellite, 1 important point I want to bring about this descending word and ascending word and generally the in the morning hours the P are having the south bound satellites and they acquire the data so that is why when it is coming from north to south we call as descending mode when it goes in afternoon from south to north we call it as ascending mode. So that is the only thing, one another important thing is the time it takes to complete 1 orbit, so roughly about 2 hours it takes to complete most of the sun synchronous satellites are having that much of timing is there.

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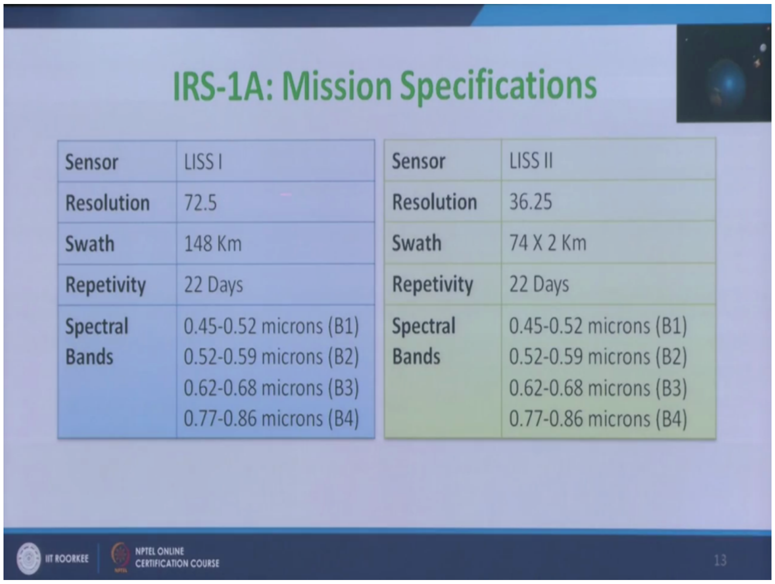

And when we compare the sensors LISS 1 and LISS 2 as you can realise that there is a huge difference between a spatial resolution of LISS 1 and LISS 2, so almost double in that sense the though as you know that a smaller the digital value or number higher the spatial resolution and the swath that they got reduced again it got half because closer the spatial resolution of any sensor larger is going to be the swath bit.

So there is a if this value is larger that means spatial resolution number is larger than swath is also going to be the larger but the term which we will use is relatively closer and here is the white swath, here is the better spatial resolution but narrow swath is there because as you go higher and higher in spatial resolution the swath bit reduces the scape which is going to cover of the part of the earth becomes narrower and narrower. So the repeativity, the same repativity can also get affected but here because it remained almost same and the chain number of bands it has the same identical bands between Landsat 1 and 2.

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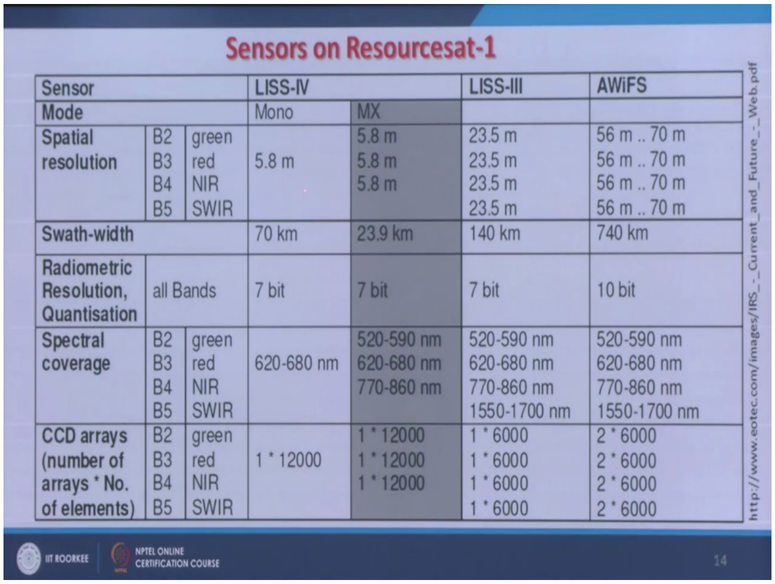

Sensor			LISS-IV		LISS-III	AWiFS
Mode			Mono	MX		
Spatial resolution	B2	green		5.8 m	23.5 m	56 m .. 70 m
	B3	red	5.8 m	5.8 m	23.5 m	56 m .. 70 m
	B4	NIR		5.8 m	23.5 m	56 m .. 70 m
	B5	SWIR			23.5 m	56 m .. 70 m
Swath-width			70 km	23.9 km	140 km	740 km
Radiometric Resolution, Quantisation	all Bands		7 bit	7 bit	7 bit	10 bit
Spectral coverage	B2	green		520-590 nm	520-590 nm	520-590 nm
	B3	red	620-680 nm	620-680 nm	620-680 nm	620-680 nm
	B4	NIR		770-860 nm	770-860 nm	770-860 nm
	B5	SWIR			1550-1700 nm	1550-1700 nm
CCD arrays (number of arrays * No. of elements)	B2	green		1 * 12000	1 * 6000	2 * 6000
	B3	red	1 * 12000	1 * 12000	1 * 6000	2 * 6000
	B4	NIR		1 * 12000	1 * 6000	2 * 6000
	B5	SWIR			1 * 6000	2 * 6000

Now we compare Landsat 3 and 4 and A waves what we find that because Landsat this LISS 4 was panchromatic and it provided data at 5.8 meter resolution at that time that was the one of the best data available from Indian remote sensing satellite at 5.8 meter resolution and at panchromatic bands but at the same time the same satellites like IRS 1C, 1D had a LISS 3 sensors and the at the higher spatial resolution compared to LISS 2 and that was 23.5 and all sat has 4 bands band 2, 3, 4, 5 and then AWiFS has a resolution relatively relatively poor as compared to LISS 3.

But the purpose was here to cover a large area more swath as you can see the swath width in case of a Landsat in case of LISS 4 panchromatic it was 5.8 whereas the swath that was 70 kilometre in case of LISS 3 where the spatial resolution was 23.5 meter swath that was 140 kilometre and in case of the waves the swath waves 740 kilometre.

As I was mentioning the higher spatial resolution less the swath width you will observe this is what it is demonstrated here 5.8 so 70 kilometre swath width, 23.5 meter spatial resolution, 140 kilometre swath width and 56 to 70 meter spatial resolution swath width has improved that is 740 kilometre. Another important thing is a 1 is radiometric resolution or quantisation term which we use, so one is spatial resolution, another one is radiometric resolution, so radiometric resolution is say how number of bits for each pixel the data is being acquired.

If it is say 7 widths that means a the value between 1 to 127 any value can be a sign with pixel, if it would have been a width band like in earlier versions the panchromatic we had only the 6 bit data and therefore it was values were ranging only between 0 to 63 so in case of LISS 3 it remained 7 but in case of air waves it has poor spatial relatively spatial resolution but the quantisation or radiometric resolution was better than other sensors or previous sensors and spatial coverage was also spectral coverage was also here.

We had 4 channels but of course panchromatic will have only 1 and that are almost identical in case of LISS 3 and AWiFS and this also the number of arrays in a this linear sensors were also different depending on the resolutions, if resolutions is more the number of CCD's are going to be much more whereas if resolution is closer this CCD's will be relatively less.

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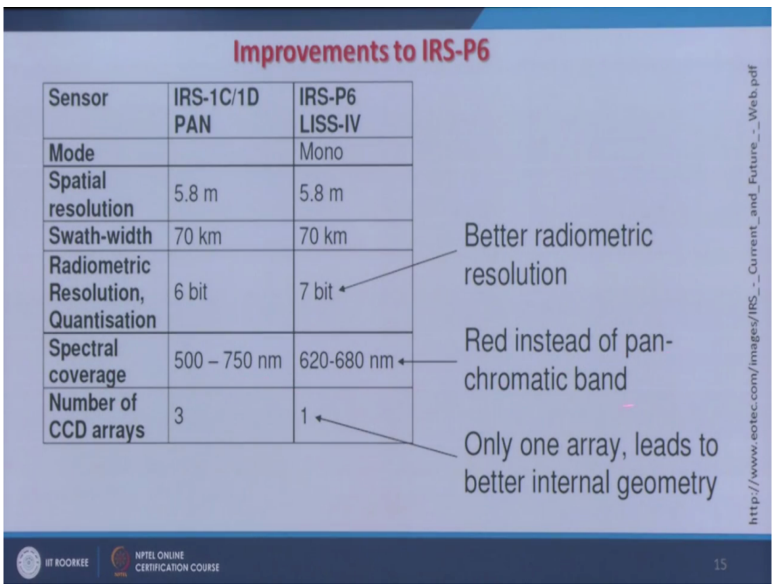

Sensor	IRS-1C/1D PAN	IRS-P6 LISS-IV
Mode		Mono
Spatial resolution	5.8 m	5.8 m
Swath-width	70 km	70 km
Radiometric Resolution, Quantisation	6 bit	7 bit
Spectral coverage	500 – 750 nm	620-680 nm
Number of CCD arrays	3	1

So this how things gets affected with the spatial resolution, the swath bits the radiometric resolution and also temporal resolution we see. Here the IRS 1C, 1D had a panchromatic camera, IRS P6 has the LISS 4 which was also mono or panchromatic many things are completely comparable but the major difference became between like I mentioned earlier that in case of IRS 1C 1D we had only the 6 bit data that means pixel value could vary only between 0 to 63 total number 64 whereas in case of LISS 4 we had the 7 bit so the this radiometric resolution was better in case of LISS 4 which was on board IRS P6 and a spectral coverage was positioned at different location and number of CCD's in case of an we had 3 arrays is whereas in case of only single array data because by that time people realised that it is single array would be more than sufficient.

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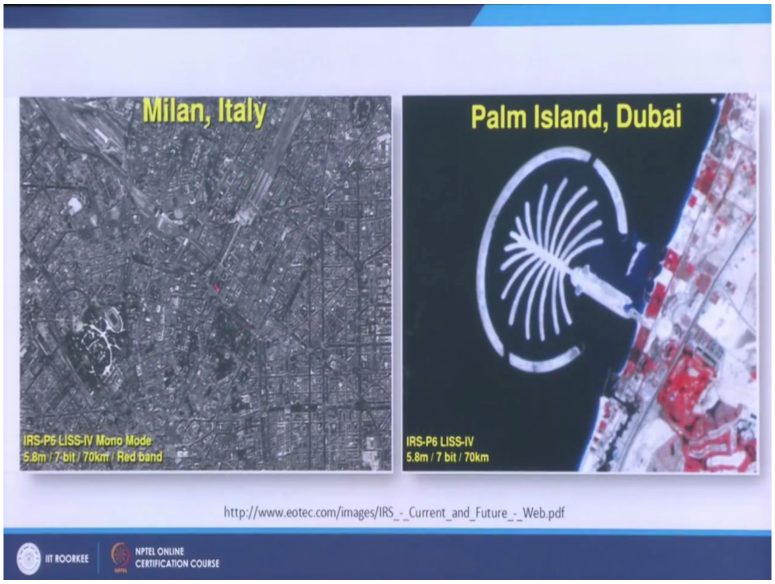

As you once the spatial resolution improves then the clarity of an image also gets improved and this is what the example is that if you are looking a city you can see all individual roads and and if you zoom it to a certain extent then you will be able to see individual buildings of course form the top, so this is a example of the Milan City of Italy you are having our own IRS LISS 4 data 5.8 meter resolution 7.

But radiometric resolution and the coverage here it is having about 70 kilometre and the channel which is being used red band whereas this is false cover composite and this is IRS LISS 4 IRS P6 LISS 4 sensor and the resolution again here is 5.8 meters resolution because they merged the same 7 bit and 70 kilometre. So you can see that see the clarity in this image relatively because this is the merge image of Palm Island of Dubai which is a completely man made structure in the sea.

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Also as a spectral resolution improves and if a swath is much more you can cover large areas one example of Mansarovar lake is a given here and also part of Myanmar costal is also, so this is AWiFS data and this is LISS 3. LISS 3 sensors as mentioned earlier was very became very popular because the spatial resolution 23.5 metre was quite good at that time even still it is quite good because it provides relatively wider swath which becomes very useful for several kinds of studies.

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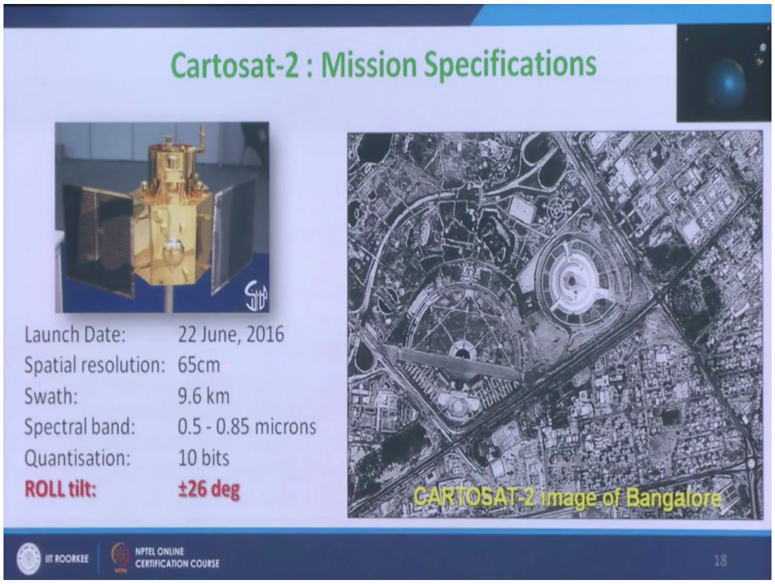

And now the new in the series is the Cartosat which was only launched on June 2016 this year, the spatial resolution has improve very significantly, it is now only 0.65 meter that means 65 centimetre and as I have been mentioning that higher the spatial resolution lesser the swath bit, so swath bit has reduced to about now 10 kilometre.

So only very tiny strip, a very narrow strip of the part of the earth is being covered and the of course the band also has become narrow but the sea the quantisation instead of now having 6 or 7 in panchromatic now we are having 10 bits data and is a huge improvements in case of a spatial resolution, in case of radiometric resolution and it is having the role capabilities of about 26 degree, so it can acquire the stereo data and the stereo data can be used to prepare very high spatial resolution roughly 65 centimetre spatial resolution digital resolution model of any part of the globe that is going to be a great boost in the Indian remote sensing missions and for world as a whole.

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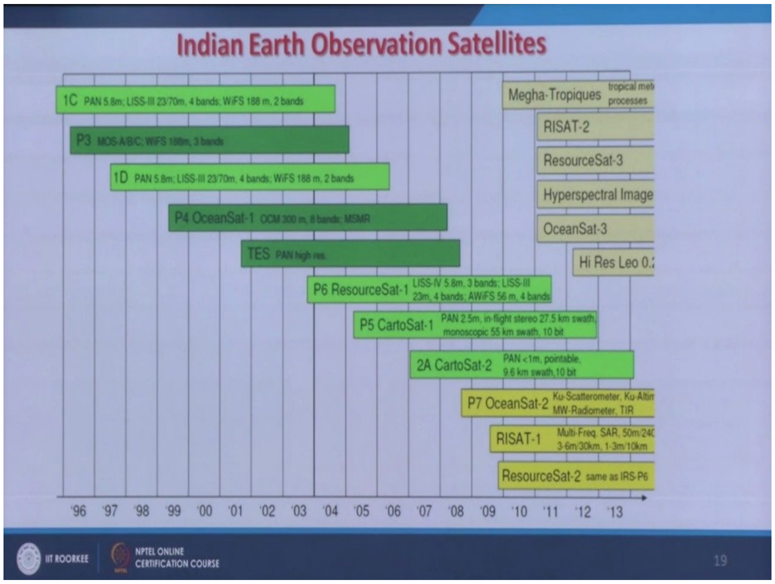

As a India has got long plans and it is working on that on this chart only few examples are seen the latest one as I have just mentioned is Resourcesat is there it will continue to provide the data then of course our radar remote sensing satellite RISAT is also there it is providing the data then there are Oceansat which was again radar sat but mainly focus for oceanoraphy related applications and Cartosat 2 which which worked up to 2013 and it provided data at less than 1 meter resolution and 9.6 meter swath and 10 bits quantisation and so on so forth.

So as you must have realised that if we compare just like on case of Landsat 1 and Landsat 8 same way if we compare IRS 1A and our now Resourcesat 2 a lot of improvements have happened in Indian remote sensing satellite missions and which are still continuing, things are improving instead of having just multi-spectral channels or panchromatic channels now we are changing and also we are having a radar satellite as well as satellite specifically for preparing digital elevation model or providing stereo data plus our normal multi-spectral data.

Future is also there is for the hyper spectral that is will be in future that means the more number of channels within the same atmospheric windows we will have so narrow channels but number of channels are going to be more many more so the spectral resolution is going to improve significantly.

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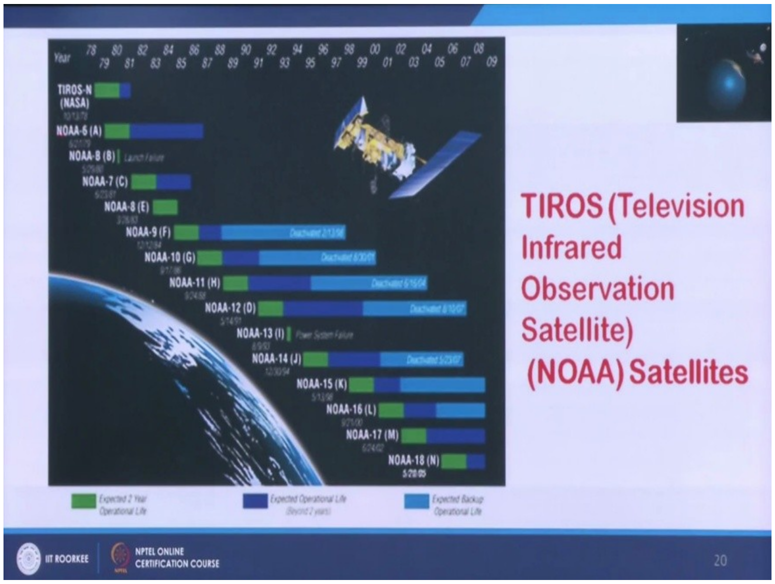

Now this is another very popular series of satellite still operation still providing data so we started with this Tiros and series that later on it was renamed as NOAA and NOAA 6 and NOAA 18 even 19 are operational 18 and 19 is still providing the data and which covers though relatively spatial resolution that sensor is advanced very high radiometer this AVHRR. That means advance very high resolution radiometer, this AVHRR sensor is still very popular though it provides data at 1.1 kilometre spatial resolution but the swath or the the footprint of this sensor is very wide about 2800 kilometre, so it covers a very large area in one go.

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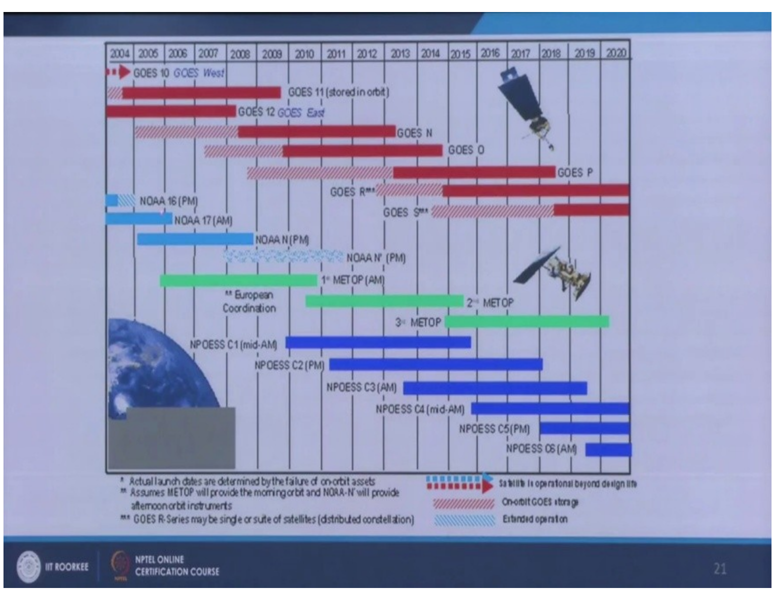

Now if we look the future of specifically for NOAA and now NOAA after this 18 and 19 they are going to shift from that and maybe now this going to be first Metop satellite has been launched in Metop 2, Metop 3 these have been also planned so this NOAA series is going to be replaced by these Metop satellites some other changes are also happening in case of goes and other satellite but this slide was mainly to tell about the future of NOAA because there were few years back there were one survey of applications of remote sensing data that means the which satellite date has been used maximum and this survey was done of 25 years of publications of international journal of award sensing and they found that NOAA AVHRR data has been used maximum in their publications. So because of free availability of data covering a wide swath, availability of thermal channels this data became very popular to cover any large part of the earth.

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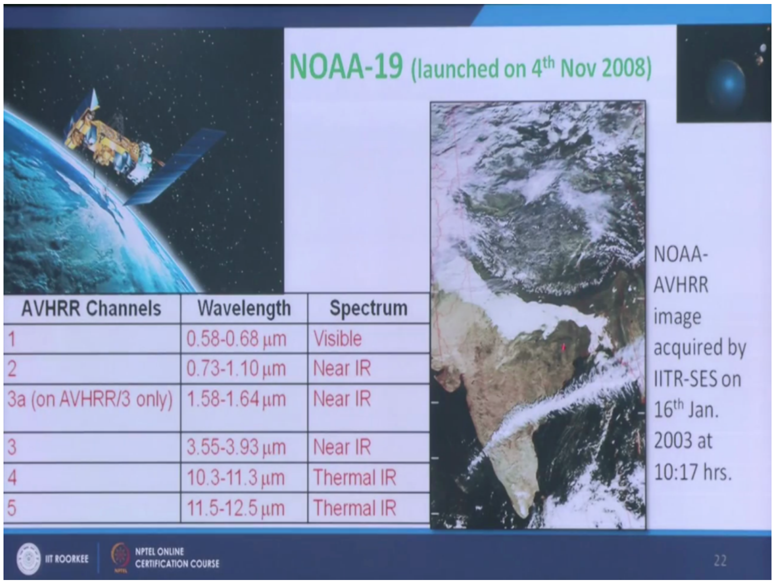

Lower data is still being acquired as I mentioned it is having 5 channels and you know that there are visible channels, near infrared channel and thermal infrared channels are there all are having spatial resolution of 1.1 kilometre at the centre of the sea because it the swath is very wide it is 2800 kilometre. So on the edges the resolution further deteriorate but the because of large swath and because of availability of thermal channels and daily bases or multiple times in a day the new types of applications have been developed based on this just on NOAA AVHRR data.

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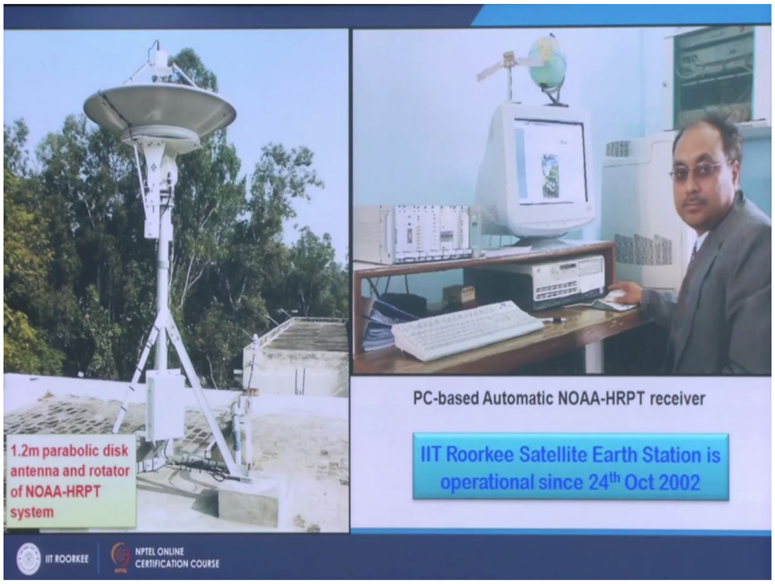

And this is the station which I have already shown in previous lectures and we have been operation this earth station since October 24th 2002, still it is operational it has acquired thousands of NOAA images which we have archived and can be used for long term applications.

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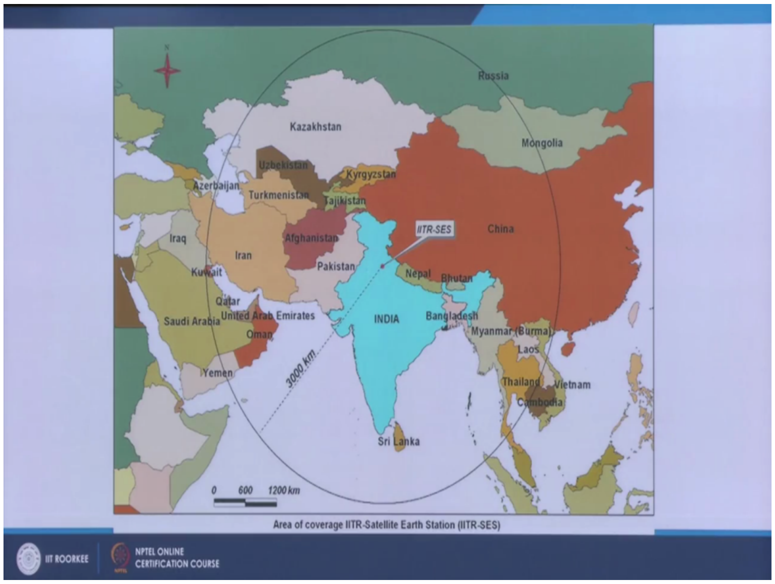

One more thing which I want to bring here about several times I have mentioned about ground station, so we also call satellite translation that means that we we need to have a antenna system that is the tracking antenna and or rotating antenna and it covers a very large area that means anywhere the satellite when it is over passing spatially the example here is the NOAA then within this circle which is about 3000 kilometre radius then we can acquire the data or this earth station can acquire data almost fully automatically.

So this is because it is computer based system there is a prediction program about the over passes so once the data is supposed or once the satellite is supposed to fly over within this circle the this antenna will go in that direction and will acquire the data because remote sensing not only involves the analysis interpretation application of satellite based remote sensing data but also how data is acquired, so for that purpose I wanted to discuss this point here also.

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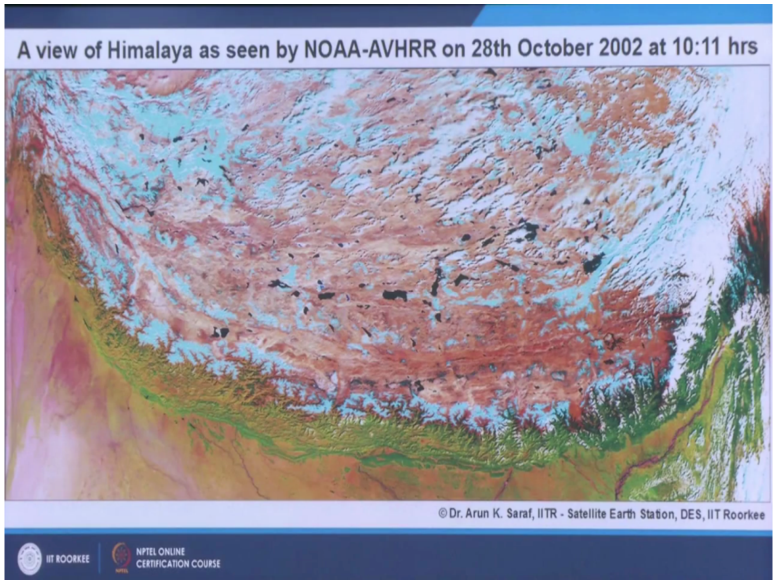

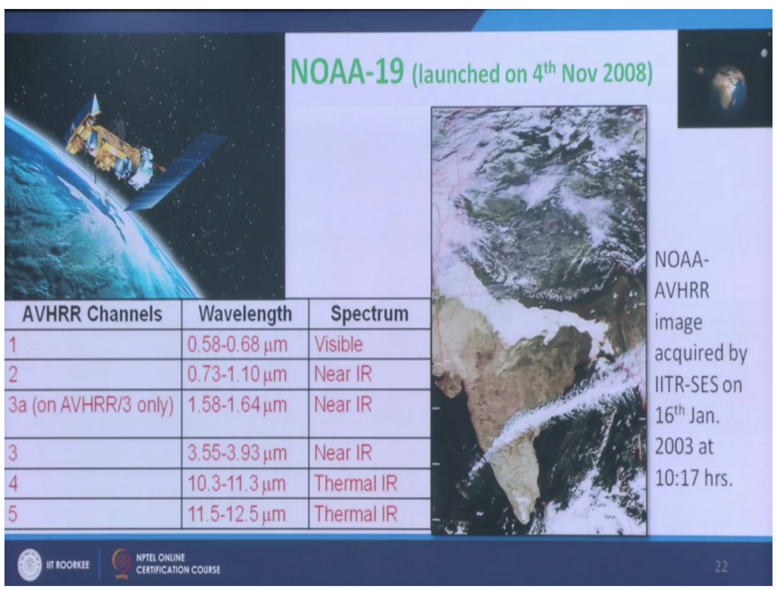

AVHRR Channels	Wavelength	Spectrum
1	0.58-0.68 μm	Visible
2	0.73-1.10 μm	Near IR
3a (on AVHRR/3 only)	1.58-1.64 μm	Near IR
3	3.55-3.93 μm	Near IR
4	10.3-11.3 μm	Thermal IR
5	11.5-12.5 μm	Thermal IR

Once you are having a large swath bit instead of having just 9.6 kilometre swath based in case of Cartosat 2, here the swath width is 2800 kilometre and the advantages is in one go you can see the cloud conditions in a of entire Himalaya there is a fog belt or something then entire thing can be seen like here the one fog belt, if the swath width have been very narrow than you would know that particular phenomena only for a narrow part of the earth but if swath width is larger you know a complete extent of sometimes of a phenomena like a here the fog is been seen in the clouds and these a the relatively closer spatial resolution data are very useful to cover a large area and to monitor things for a large part of the earth.

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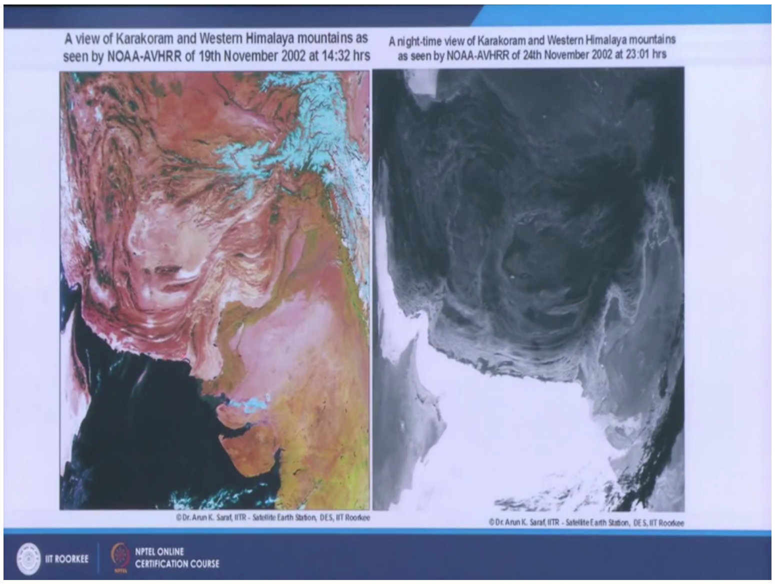

And this is a again this is these are the visible channels, so if falls composite here which I have already discussed, this is a thermal channel which is something like X-rays of and it shows the emissivity. These are all passive data but the the details are altogether different though in case of NOAA AVHRR the spatial resolutions are same but in case of Landsat 8 the spatial resolution between visible channels and thermal channels are different.

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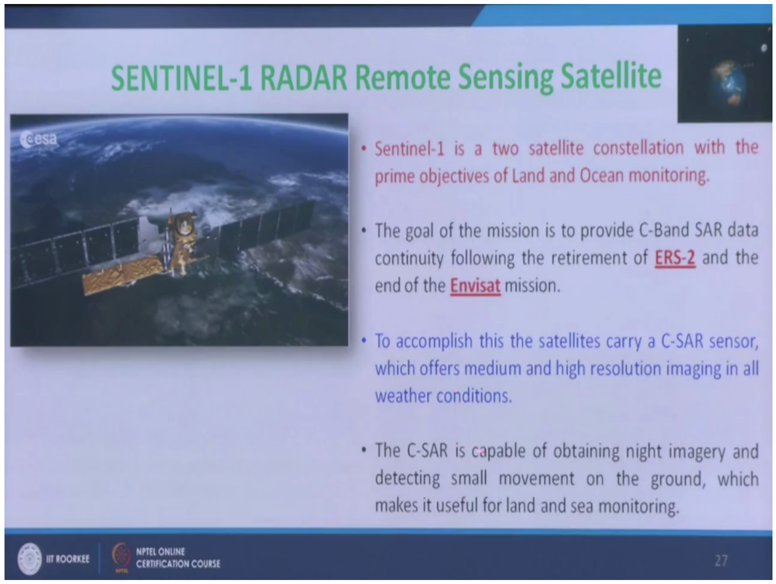

One last point in this one is the sentinel, which is has become very popular radar remote sensing satellite which is active remote sensing and sentinel 1 is a 2 satellite constellation with the prime objective is to cover the land and ocean monitoring or part and a specially because it is providing data for interferometry the operates in the sea band and synthetic aperture radar is a continuously providing the data and basically it is a continuation of ERS series of satellites and Envisat.

So now ERS and Envisat are no more in operation but sentinel one has replaced them is better satellite better having better sensors and providing regular data including for this interferometry. So C band is a having obtaining night visionary because this is radar data so it can acquire data anytime of the day.

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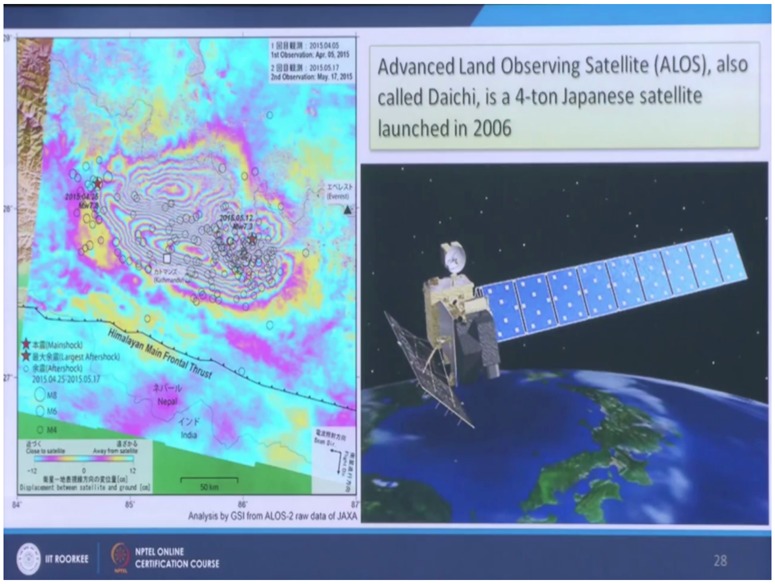

And with the best example recently we have observed about from the sentinel is about using this Sar interferometry capability or in short we say In-Sar in case of ground deformation studies induced by an earthquake which has been seen in case of Nepal. This example is from another radar remote sense satellite of Japan which is Alos the sensor was Palsar and this ground deformation map which is the fringes different colored fringes which you are seeing can so that the ground information induce by those 2 earthquakes of Nepal occurred in 2015 could be estimated very easily very accurately in case of such natural disaster. So this brings to the end of this presentation, thank you very much.