Remote Sensing Essential
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Lecture - 49
Remote Sensing of Moon and Mars

Hello everyone and welcome to new discussion of this remote sensing essential course, and today we are going to discuss about remote sensing of Moon and Mars. And you know that nowadays a lot of discussion is happening about Moon surface and especially the South Pole where India was trying to land his own rover and also a Mangalyaan was also launched earlier. So, we will be discussing what is so interesting about Moon and Mars and everything is being done so far, at least by India through remote sensing.

So, they as you know that the Moon has always being very, you know, strange and wonderful celestial body for the humans. And since long people have been trying to get as much as information about Moon and other planets also and though Moon is not planet, Moon is the satellite of the earth.

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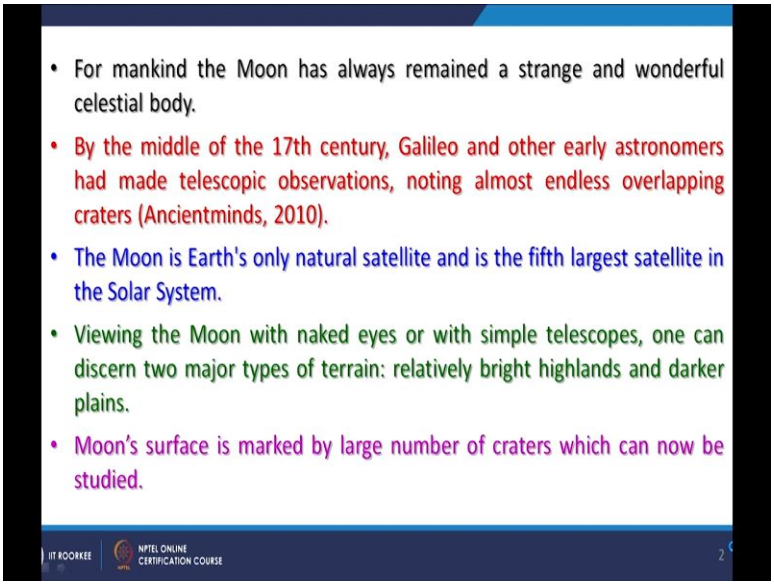

So, in Galileo started in 17th century, and then later on other astronomers have also made telescopic observations and but all the thing continues. Later one, then the satellites were planned and to orbit the Moon and collect as much as data information, especially remote sensing images.

So, that is the as I have already mentioned that the Moon is the earth's only natural satellite and it is the fifth largest satellite in the solar system. And though we can from Earth we can see Moon naked eye or simple telescope and one can discern 2 major types of terrain that is relatively bright highlands and darker planes.

This we have been seeing and Moon surfaces basically marked by large number of craters and which can be studied. Of course, nowadays with the satellite data of which are orbiting the Moon, see like Chandrayaan and others Chandrayaan-2 is also there with his orbiting very successfully. So, closer the view of its surface we could obtain from unmanned spacecraft and which travel near to the Moon and that made be history and knowing the natural satellite, earth's natural satellite and the first program was started by Soviet Union.

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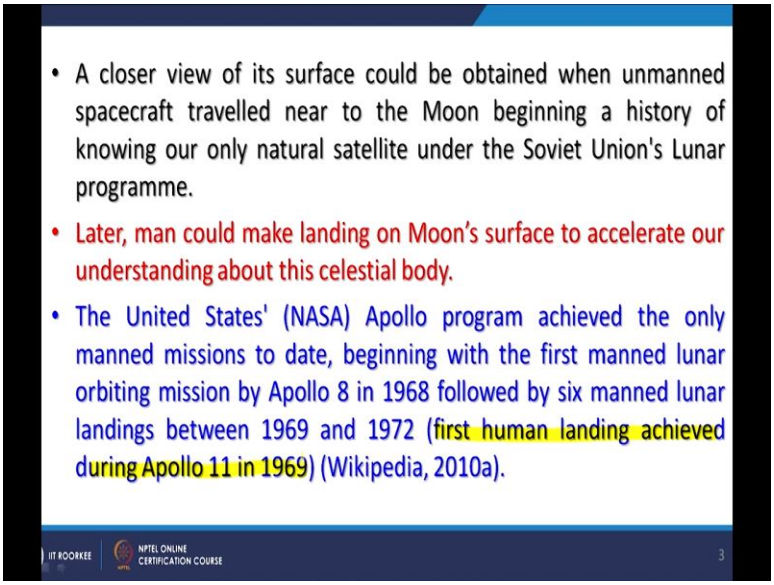

And later other countries also joined and men could also did a landing on Moon surface. And as you know that the first landing was done by Apollo and 2 astronauts Neil Armstrong and the other one which came which we are first human landing achieved during the Apollo 11 and 1969 mission. And of course, before that several missions were there and to get the maximum information about the surface.

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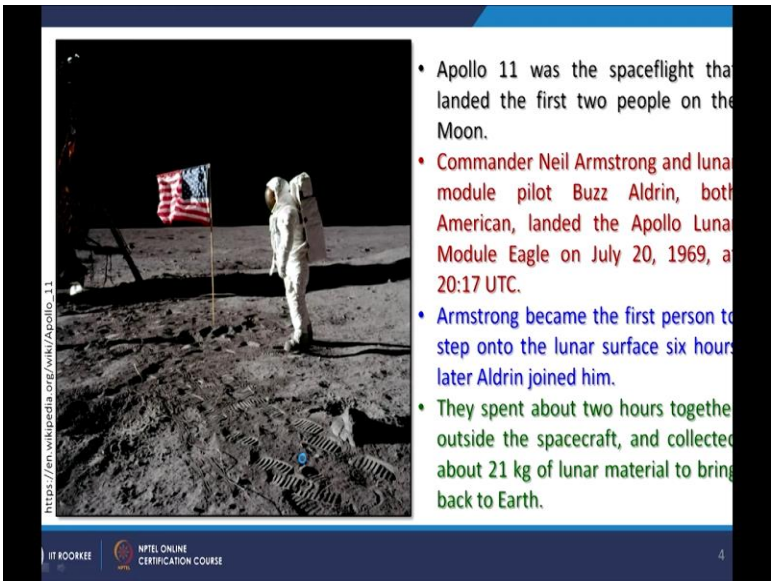

And this is what the most famous photograph, and that Apollo 11 was first spacecraft that landed on the first 2 people on the Moon. And these people were, of course, Neil Armstrong and Buzz Aldrin, and both were Americans. And landed lunar module eagle on 20th of July 1969 at 20:17 UTC, so that was a great step and in to you know, visit another body especially that the Moon and the Armstrong basically became the first in the history who step into the lunar surface.

And later on also his colleague Buzz Aldrin also after 6 hours and joined with him on the Moon surface. And then together they spend about 2 hours outside the spacecraft and have collected large number of samples of about 21 kg of lunar material that material included rocks and soils, which brought back to the surface and studied

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About their mineralogy and especially looking for the water content also. These are the very famous photograph again, that 10 more astronauts who are shown here have also walked on the Moon surface. So, Neil Armstrong and Buzz Aldrin were the first 2, later and many also join, Aldrin is seen here and also Armstrong is standing behind. So there were a lot of Americans who walked on the surface of the Moon very successfully.

So far now, we are having quite good amount of information about the nature and topography of the Moon's surface through all these missions and of course, continuous coverage by satellites of many countries, including India. And through this chandrayaan-1 and chandrayaan-2 and very good product which was created by Google Earth. So when you install Google Earth on your, a small utility when you install on your computer at the same time you also install Google Moon and Google Mars as well.

And as for the Google Earth, you are having satellite images of the Earth and digital elevation model. So same with the Google Moon and Google Mars.

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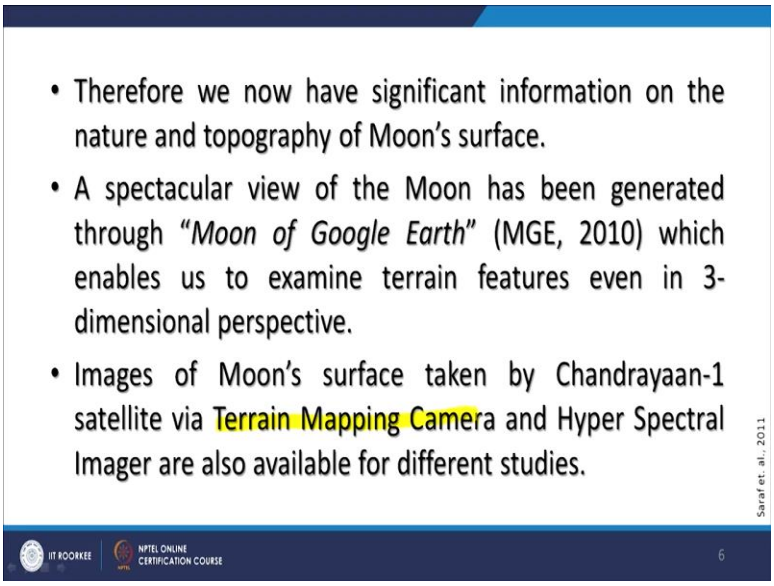

You are having same kind of arrangement their 3d 3 dimensional perspective view of the Moon can be visualized on your screen with very high resolution satellite images. Images of course, taken by our Chandrayaan-1 by a special camera was there which is terrain mapping camera for the mapping of the terrain and especially the you know, the elevation model to prepare elevation model. And also one important scanner was there which is hyper spectrally scanner and to study basically different minerals and if at all there is a water that too is.

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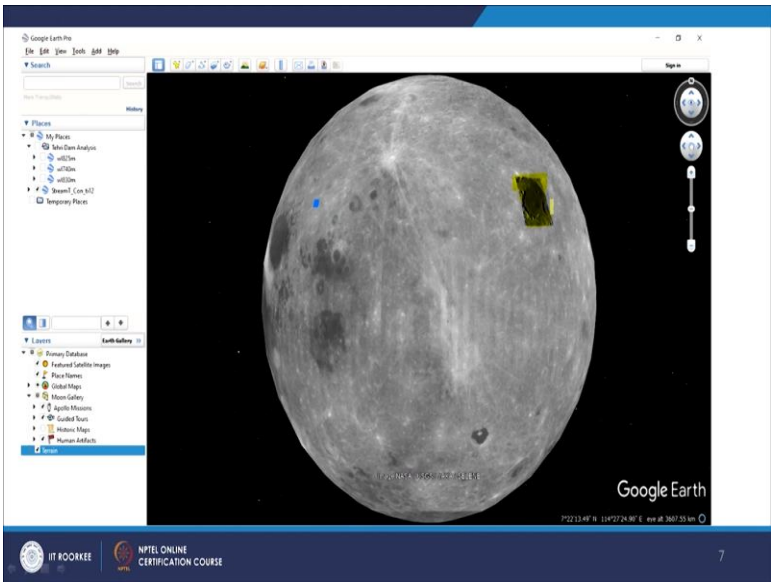

This is the picture of screen and screenshot of Google Moon, large part of Google Moon has already been covered in this of course, this the black part is also covered with the some very spatial resolution images. And the entire Moon surface is you would see when you start zooming

it is basically the dark parts and other parts that the entire surface of the Moon is fitted with these mutualized and it is having craters throughout.

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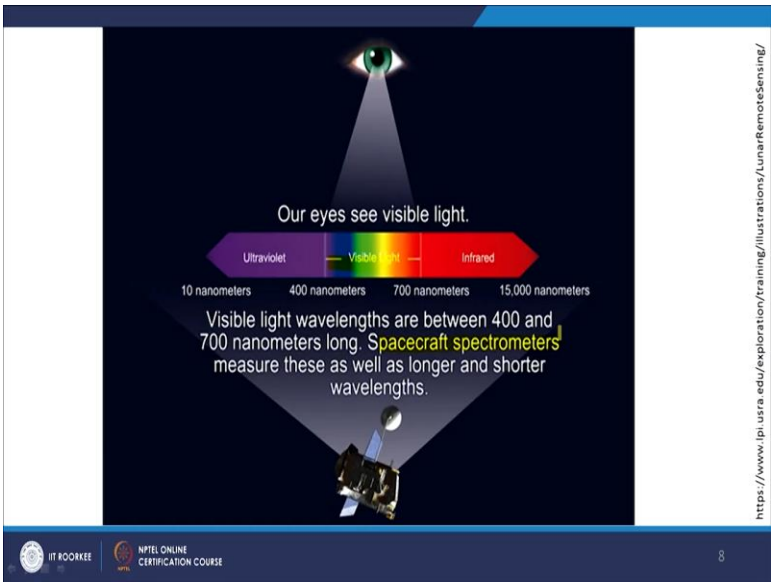

Some parts of that are having and less craters, some are having more craters, but there are craters are there. As we know that you know, our eyes are effective only in the visible part of EM spectrum But there are you know spacecraft sensors which can and do the you know scanning or collect the data in other parts of EM spectrum. So, a spacecraft spectrometer and measure also these longer or sort wavelength apart from visible.

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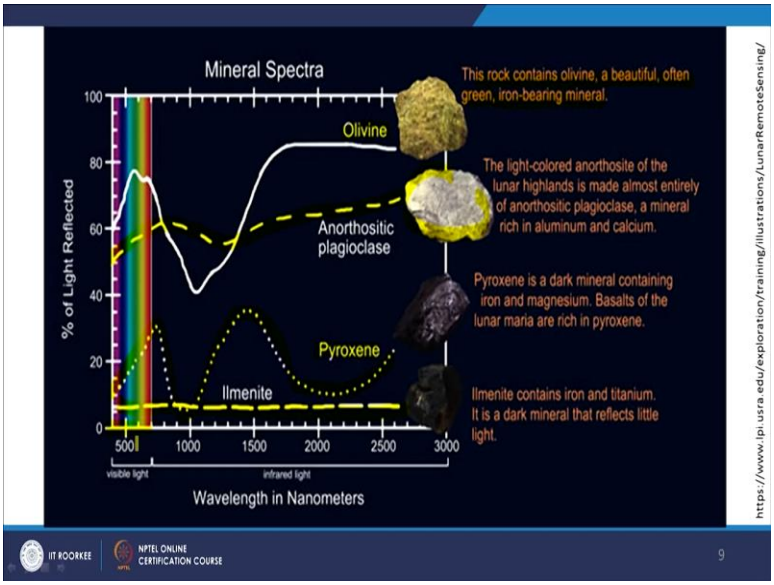

And therefore, it becomes possible to detect different minerals and minerals in some rocks and get more idea about the Moon surface. What are the materials are available? For example here and that rock olivine was seen on was, of course, brought back to the earth. So, this rock contains olivine a beautiful often green iron, bearing mineral and it definitely has got a complete different spectra has compared to an Anorthositic plagioclase which is shown here.

And this is light colored Anorthosite of lunar highlands of from higher grounds and is made of an Anorthositic plagioclase feldspar which is rich in aluminum and calcium and the spectra of this Anorthositic plagioclase is completely different than olivine. Similarly, there is another mineral pyroxene which you can see here. So, the spectral curve of pyroxene is also and different here that the pyroxene is a relatively darker mineral containing iron and magnesium and the results of lunar mana are rich in pyroxene

And that is what we get pyroxene also then ilmenite contains another ilmenite throughout this part of EM spectrum is having similar response, it is a sort of straight line parallel to it x axis or the wavelength which is lignite contains iron and titanium, it is a dark mineral that reflects little light. So, this is of course a visible part is here, which you can see in the first part and later on, you are having other part of EM spectrum this is how you can distinguish different minerals on the surface of the Moon.

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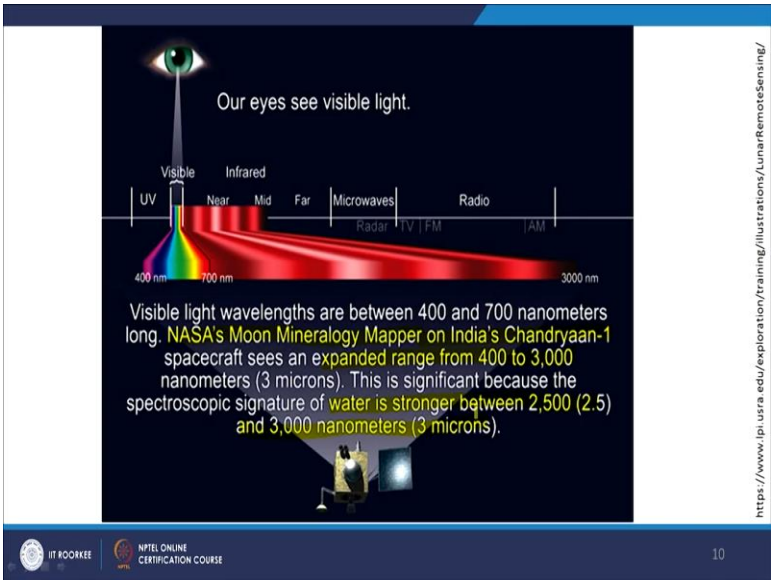

And of course, the rock samples were collected by many astronauts. So, those samples have also been analyzed and whatever is available on the surface of the Moon, that information a lot of that information is now on the Earth and with the scientist who have been working and there so they were special missions like Moon Mineralogy Mapper on which was the went along with the chandryaan spacecraft.

And which sees the expanded range of 400 to 3000 nanometers or 3 micro meter microns and this significant and because the spectroscopy signatures of water is stronger between 2.5 to 3 microns, and that was basically purpose of and this sensor mapper on Chandryaan - 1 of NASA.

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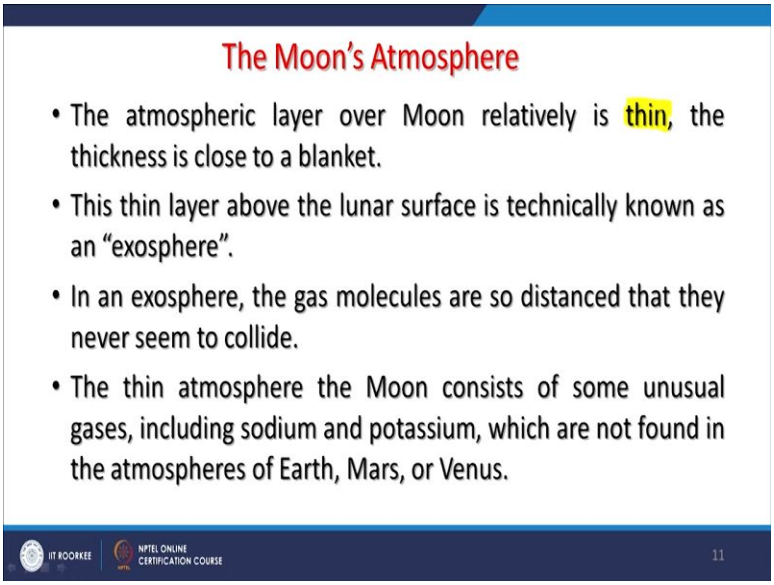

So, this was a sort of collaboration between NASA and ISRO to have a joint mission about this mapper. And one other thing is the atmosphere which is around the earth, it is not as the same is on the Moon. So, it has a relatively very thin atmosphere. And this is a advantages for from remote sensing point of view. If you recall the discussion on atmospheric distortions and remote sensing images of earth, a lot of distortions occurs in the satellite images of the earth.

But when we start taking images of the Moon through different missions, like Chandryaan -1 and 2 or other countries, satellites or sensors, then the atmospheric effects are very less because of that is very thin and the thickness is close to a blanket. And you can imagine that only less than a

centimeter thick atmosphere is there, so it does not affect the same way. And the electromagnetic waves is in case of the earth, which is thick of many kilometers.

So this thin layer of the lunar surface is basically technically known as the exosphere. And this exosphere has the gas molecules are so distance that they never seem to collide. And this say it advantages from remote sensing point of view, but may not be good from, you know, having a life on the surface of the Moon. Because Earth atmosphere though it creates problem for remote sensing, but the same time it is it supports the sustainability of life on their surface.

So, this thin atmosphere of the Moon basically consists of some unusual gases, including sodium potassium, which generally we do not get in the atmosphere of the Earth, Mars or Venus. Mars to is a very thin atmosphere around it. And therefore expectancy of life there is very less, and it is not expected basically. And due to thin atmosphere of the Moon surface or around the Moon, as remote sensing of Moon is relatively easy for better.

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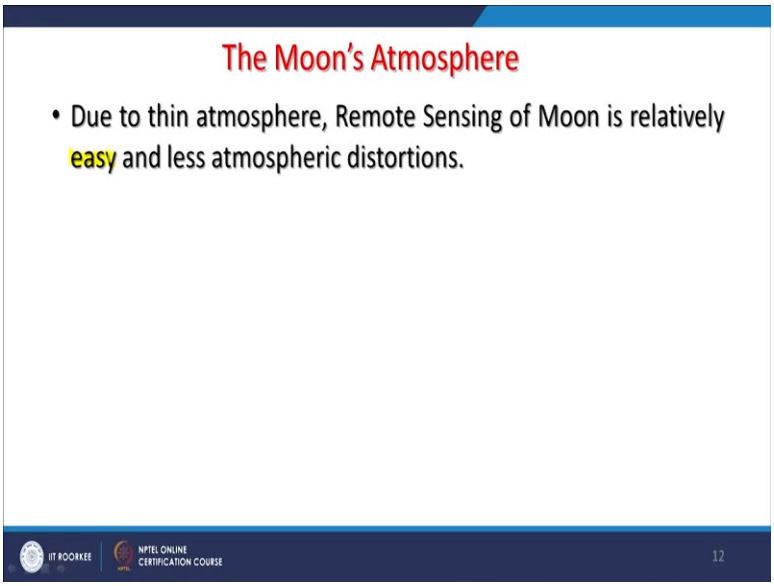

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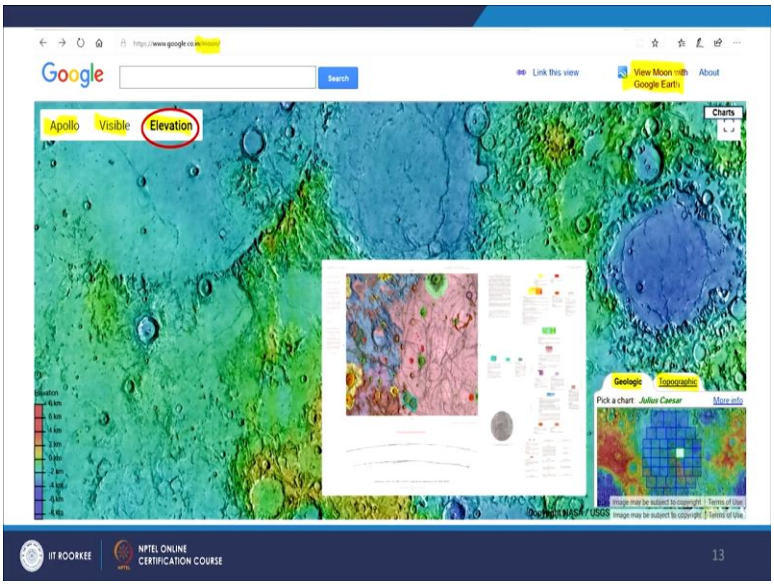

And good and therefore, we have less distortion and then it is possible to create or you to get a very good data of the Moon surface. As you can see here, that if you search a Google and especially this Moon part, you get a not only images of Apollo, you get also the visible images of Apollo, you get a digital elevation model, which is in the background. It is now being soon and also and the geological map have also been prepared for all parts of Moon surface like which one you are seeing here the one of the example is.

So, when you choose this geologic, you get you know that there is a grid which has been marked and I am for any sale of the thing you get a very good geological map prepared of course on the Earth based on the data and samples were collected, remote sensing data and samples were collected of Moon surface. So, that much of detailed information of Moon surface is now available on earth, including of course detail digital high resolution digital elevation model is also available pseudo relief model you are seeing in the background.

Of course, the same datasets you can also see on the Google Earth and one other advantage with Google Moon or Google Mars is having compared to Google Earth is that it also shows the digital elevation model without satellite images. So, you have got the option to choose like Apollo images or visible images or elevation there is on the for the Google Earth indirectly we get the elevation values but directly we cannot see digital elevation model or pseudo relief model of the Google and Google earth. So in that way, it is very good advantages for us.

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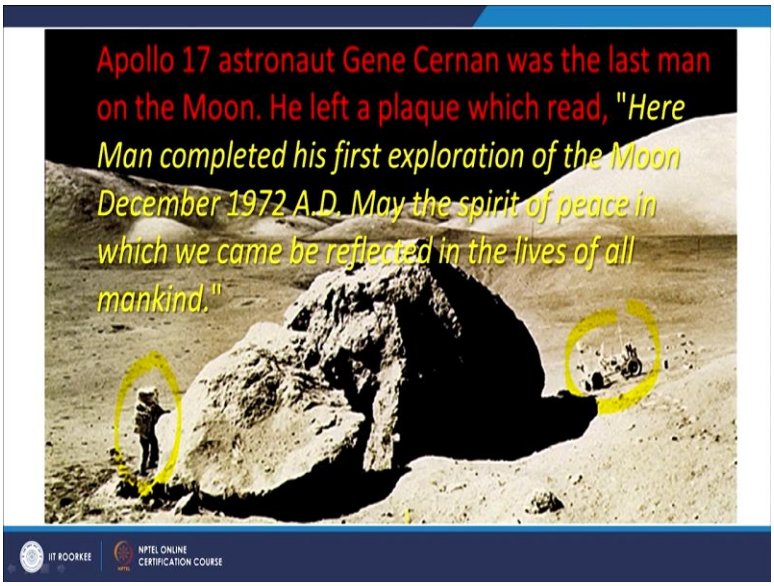

Now, you know, Apollo 17 remember that 11 carried the Neil Armstrong and Aldrin. But then this Apollo 17 astronauts Gean Cernan was the last men on the Moon. And there he left a plaque which read here men completed his first exploration of the Moon on December 1972. And may the spirit of peace in which we came be reflected in the lives of all mankind. And the rover is there, which is shown here, he himself was there and a big rock exposure and can be seen also in this photograph.

So, that kind of detailing has been done and between in 1969 to 1972 through various Apollo missions. And therefore, we have been able to even prepare geological maps in detailed geological maps of the surface of the Moon.

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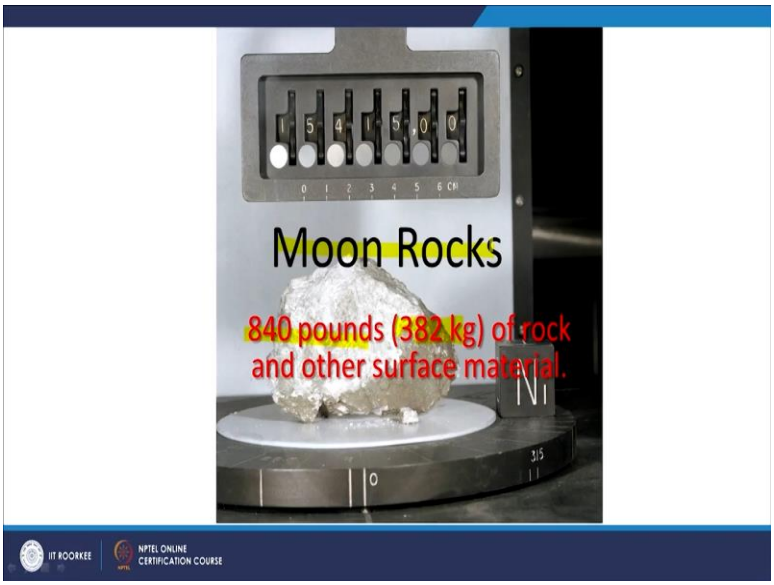

Now, the Moon rocks are, they are on display at various museums, and this is 180 pounds, or 382 kg of rock and other surface materials and which is of course belongs to the Moon. So it is called the Moon rock.

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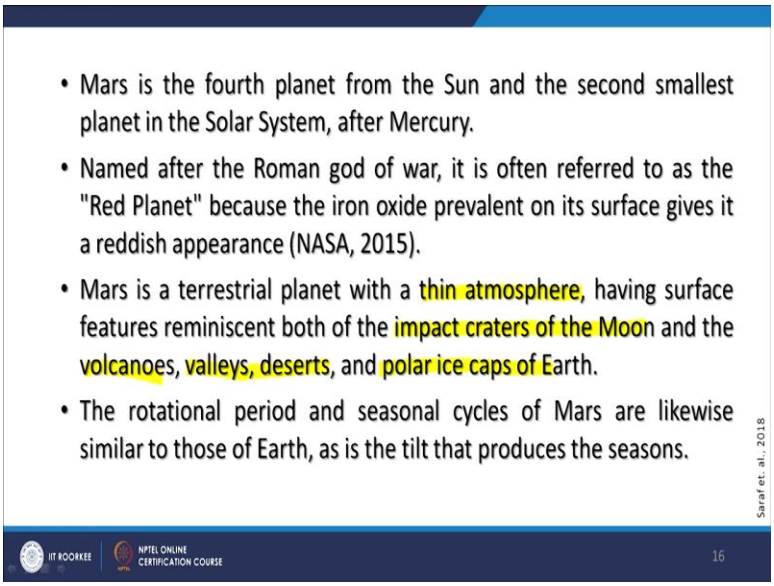

Rather than identifying different minerals, or space and rocks. So and now when we go for the mars, and then Mars is the fourth planet as we know from the sun, and the second smallest planet in the solar system after mercury. But Mars has also been very interesting for human and a lot of missions are going on around the Mars as well to know about the surface and interior and even to know whether there is a presents of life or not especially looking for the water.

So this is Mars is named as one Roman god of war, and which is often referred as red planet, because this is full of iron oxide on the surface, and that gives the reddest appearance in the satellite images is basically the visible images and Mars is a, of course, is a terrestrial planet with thin atmosphere. The atmosphere which we get around the Earth is nowhere. At least so far this is what we know, especially I am talking about Moon and Mars.

So, Mars 2 is having very thin atmosphere. And therefore, it is again wonderful for remote sensing. And this surface of Mars is a having a lot of again impact craters like of Moon and also it is having volcano, valleys desert, polar ice caps of the earth surface, like you are having on the Earth also. But the interesting part here, like on the earth, we are having plates and therefore we are having plate tectonics, seismic activities and tectonically landforms.

But on the surface of Moon or Mars, we do not have plates like Earth and therefore, there is no plate tectonics. There are no seismic activities and therefore there are no tectonic landforms either. So, the landforms which we see on the surface of Moon, and Mars, are due to the impact craters and some volcano activities. And then we are having a valleys maybe some fluid must have been flowing, so, fluvial landforms can be seen.

We are also see the yuvleen landforms that occurs in the desert conditions and also polar ice caps like on Earth. So, because of course, As the Earth rotates Moon rotates is but this rotational period in seasonal cycles of Mars are quite similar to the earth. And as it also tilted that produces the seasons as on the earth. So Mars is quite similar in many ways except from a point of view atmosphere. And again it is because of very thin atmosphere for remote sensing is a wonderful.

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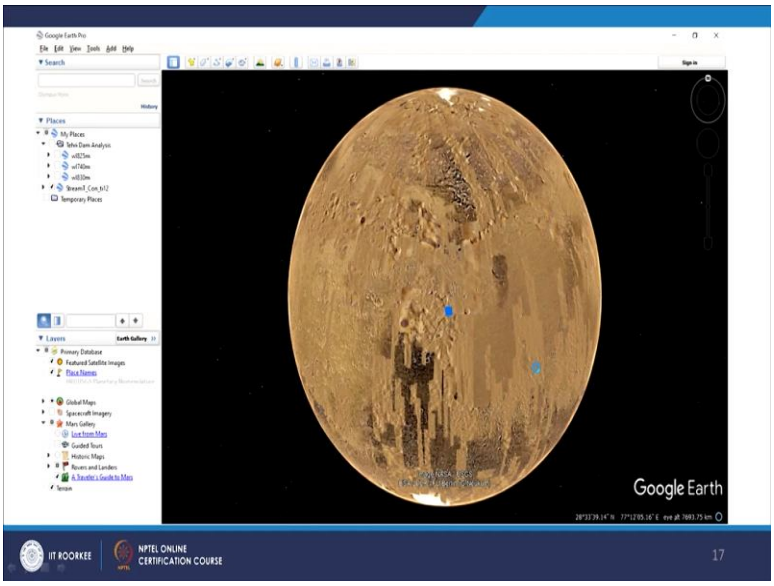

And this is the example of Google Mars, again, like in Google Moon, and all those things have been organized here that you are having digital elevation model, high spatial resolution, satellite images, everything is dropped, and in the 3D perspective view of any part of the Mars can be seen.

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Now, in recent years, the planet Mars has been explored extensively even India is also having his Mangalyaan mission. And through these manmade satellites, which were of course launch from the earth, and the first mission to the Mars, or the satellite, which was launched as Mars-2 which was successful in 1971 by USSR, and then USSR, and after that many countries like USA,

Russia, India have sent, including China have sent various orbiting satellites, a total number of 13 missions so far around the Mars.

Many of these missions are still operational, like Mangalyaan and the sending lot of remote sensing data and towards the earth, so the latest in this series have been of course the mission Mangalyaan-1. And this was launched on 5th November 19 of 2013 and the USA Mars Atmosphere and Volatile Evolution (MAVEN) and which was launched by USA on the 18th of November 2013.

So, just after 13 days of Mangalyaan, this mission of USA was also launched, because sometimes the window which is available time window which is available is in that period. So, both countries have done that kind of launching. Now, this martian surface that is the face of the Mars.

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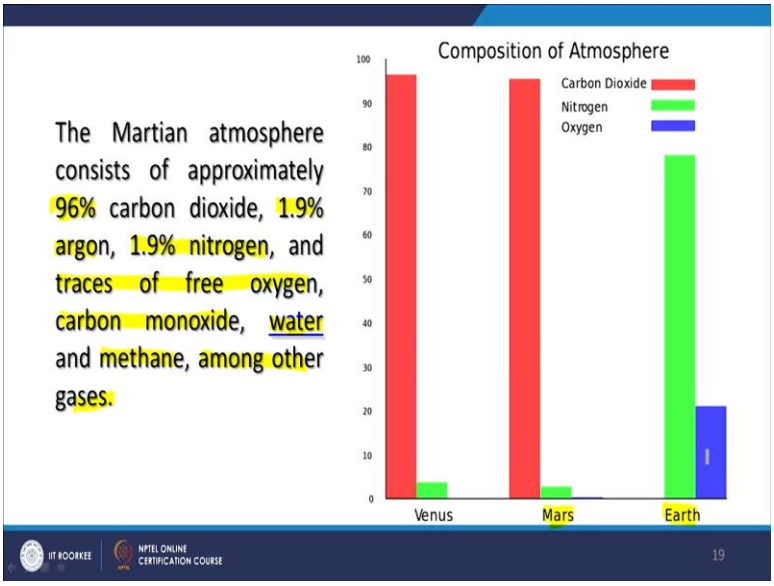

And this atmosphere consist approximately 96% of carbon dioxide and if you see here, the and it has got traces of free oxygen. So, lack of oxygen would make very difficult for human to sustain their and contrary to this you are having 96% of carbon dioxide and the remaining is like 1.9% is argon 1.9% is nitrogen and just little bit traces of free oxygen is available of course the carbon monoxide.

And water on the caps is also there apart from these gases then methane is also there and some other gases in trace forms are also there the major part as you can see is the carbon dioxide which is 96% and rest are very little. If you compare the Earth with the mars, see the nitrogen which we are having on the Earth is you know is about 76, 78% and whereas on the Mars you are having about 2% and of course, oxygen is also available about more than 20%.

But on in on the surface of the Mars hardly there. So, that makes a lot of difference in the atmospheric conditions of Mars and Earth. atmosphere is thin, it is prevalent with only and this carbon dioxide and that creates life difficult there. Also it is important to note about that atmosphere and which of the Mars is quite dusty because the Mars surface is having a lot of loose soil there. And as I have said that is iron rich soil and because of impact craters and other activities.

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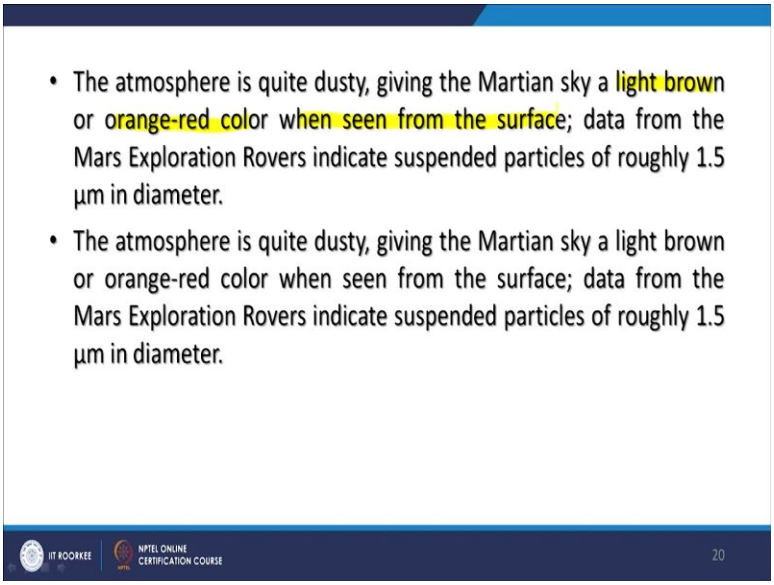

And this say the sky is light brown or orange red color. when seen from the surface and the remote sensing data which we are gathered from Mars Exploration Rovers and indicate the suspended particles of roughly 1.5 micro meter in diameter. So, it is having dust in it atmosphere, though that atmosphere is very thin. Nonetheless, these things are important to know from remote sensing point of view, because the images which we get will have effects of these things.

So, if we go for any quantitative analysis of implying remote sensing of Mars surface, then these things will play very important role. Now, as you know that atmosphere of Mars is very dusty, and giving martian sky a light brown or orange red color when seen from the surface and busy this, this is very interesting about Mars as well.

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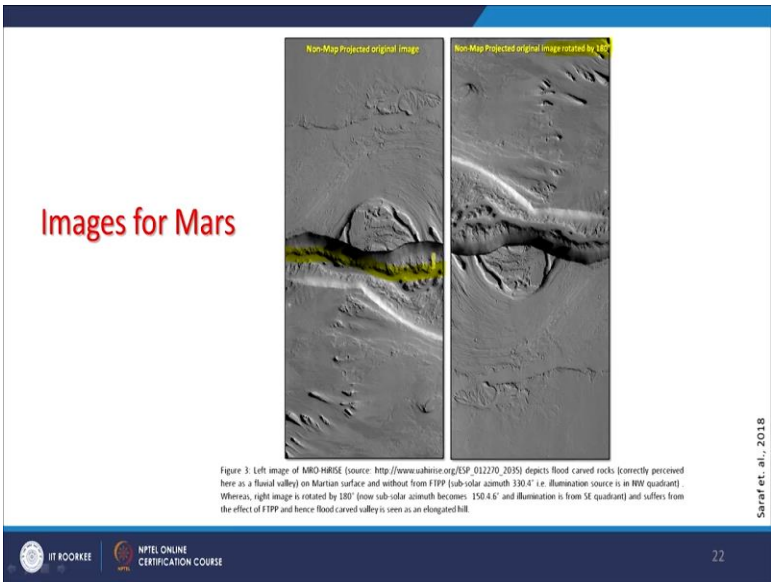

If you recall the discussion which we had about the first topographic perception phenomena, earlier examples were shown on the earth. Later one also examples were shown for the Moon surface and Mars surface in of the satellite images. But on the surface of the Mars but you are having these impact craters. So, aim these impact craters and if you see there and then what do you find that these impact craters.

Sometimes they are seen like this in the images, and if you do not get a correct perception about the depth, but when you wrote it by 180 degree, then you get the correct perception about these impact craters. So, that means that FTB the false topographic perception phenomena. And it can also be seen in remote sensing images of Mars as well, including Moon and earth. So, this is what and for that purpose one is 180 degree rotated.

Another one is an non rotated and that is what you see the difference in the perception as basically the depth perception of Mars images. Similarly, here also that this map rotated the original image on the left side and on the right side you see here it is a image rotated 180 degree

and then you see a completely different perception. So, while interpreting the satellite images of Mars like Mangalyaan, one has to be very careful that in which side is the north, which one is a giving you the correct perception, depth perception, then interpretation.

And so distorted, I mentioned that there are some fluvial landforms. And this is what it depicts here, the fluvial landforms very clearly, I am not saying that these landforms have been made by water and. But there must have been some fluid, which has created the fluvial landforms quite similar to what we see on the surface of the earth. So, having that kind of understanding about the landforms which are created by the water movement of water on surface of the Earth if you see the similar kind of characteristics, then we can say that these are fluvial landforms.

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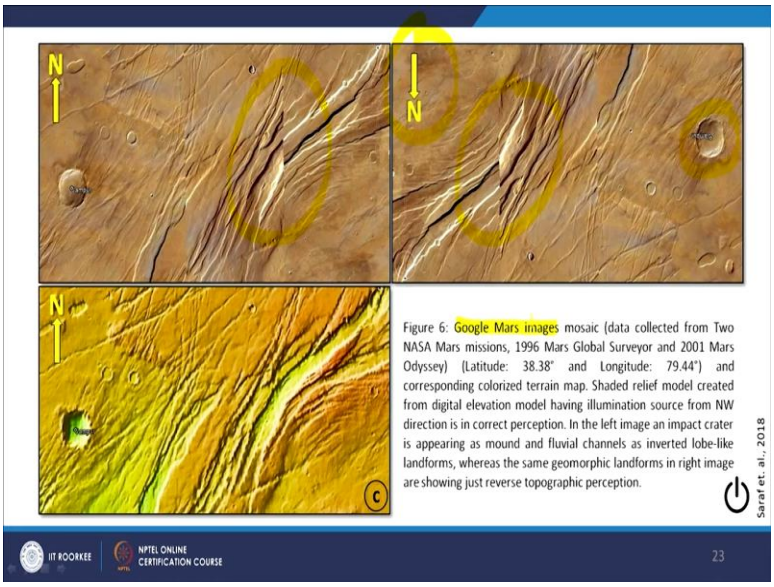

And there are few more examples here, like a, this is the top left image is suffering from FTPP and as you can see, all these craters are and not giving you good, correct depth perception when it is rotated by 180 degree. Now, these craters and other parts are giving you correct depth perception, but the purpose of showing this image was and if you see this part which is having the scene or joining of 2 scenes.

And one scene is having you know suffering from FTPP and another one is not there and therefore, you see the scene very distinctly and you see that there is a sharp cut in the landforms which are naturally it cannot occur. That means it is the FTPP exists on the surface of the mars,

as well of remote sensing images that clearly a clear indication of existence of FTPP on the remote sensing images of Mars similarly, many is such a things which can be seen.

And these images we have grabbed from, of course, Google Mars images, mosaic, are available on the Google Mars. And that gives us a lot of information about the surface of the Mars. So, as I have said about Moon and Mars, that both are having very thin atmosphere, and from remote sensing perspective, these are wonderful bodies. One is of course, the satellite of the earth, another one is a separate planet.

But because of thin atmosphere they provide a very good opportunities to study these planets are these bodies through remote sensing data, which is, of course being done and though the surface of the Mars or the atmosphere is having some dust, but being a very thin and that does not affect much of course on the surface of Moon or mars, you do not have any vegetation you do not have any other distortions apart from only FTTP first topographic perception.

And distortion or phenomenon definitely exists on the surface of the Moon as well as on Mars otherwise, and these are wonderful for remote sensing point of view and a lot of nowadays discussion is going on, after India is having his own missions to Moon and Mars and orbiting satellites, both Chandrayaan - 2 and Mangalyaan -1 are it is still working images are available and therefore a lot of things can be studied especially about landforms and presence of mineral deposits.

And maybe, you know, some study of atmosphere whatever the thin is, and major focus of these studies have been to look for the water. So this bring to this brings us to the end of this brief discussion on remote sensing of Moon and Mars. Thank you very much.