Higher Surveying
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Module – 06
Photogrammetry
Lecture – 15
Introduction to Photogrammetry

Hello everyone, welcome back on course of Higher Surveying and today we are in the new module called Photogrammetry, which is module 6. So, far we have covered 5 modules. In the last module we talked about a technology called GPS and basically we discussed about the additional information that is somehow not covered in the other courses on survey. So, but today we are going to start a completely new technology photogrammetry and this module has 8 lectures, this is the largest module on this course and it has 8 lectures.

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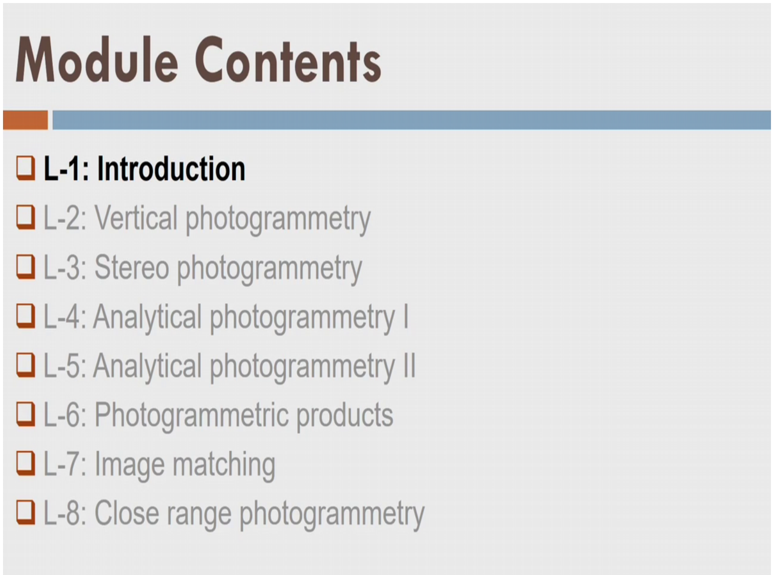

First is the introduction, second one will be vertical photogrammetry, stereo photogrammetry; then we have analytical photogrammetry I and 2; later we will cover photogrammetric products which are developed as a process of photogrammetry.

Then we have 2 lectures on digital photogrammetry which are very special lecture from the perspective of digital photogrammetry; rather they are the additional lectures in the view of digital photogrammetry. And one is image matching and other is close range photogrammetry; yes close range photogrammetry was performed earlier also, but in the digital photogrammetry with the perspective of digital photogrammetry close range becomes more relevant today. So, let us start with the introduction.

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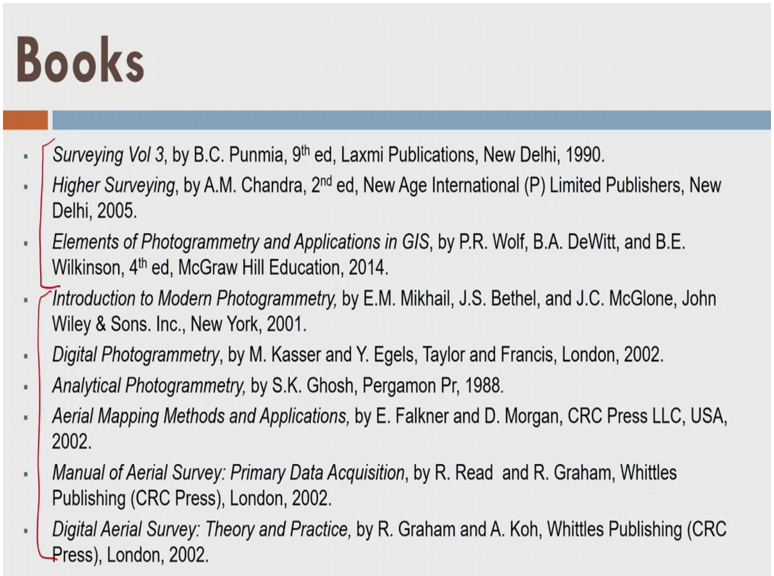

So, these are the books I will recommend you let us see in the first 3 books are easily available in our country, rather they are available with low price edition also. However, remaining books which are listed here in order to refer these books you should go to some library maybe public library or institute library. And, I will say that you should refer these books there only because little expensive they are ok.

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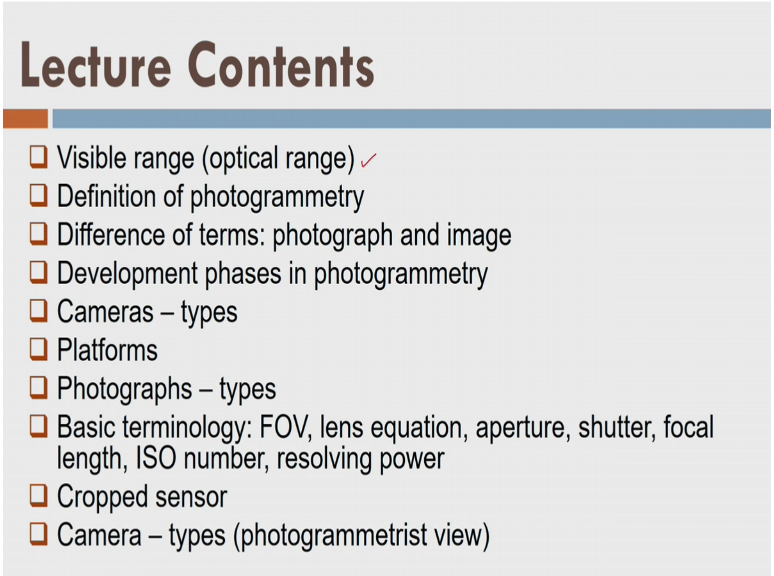

So, this is the first time I am going to give you some contents in the lecture. So, for this lecture we are this is the contents and the reason for giving the contents are this lecture is particularly scattered and having lot of information. And, because of that reason we have to give some kind of categorization that how we are going to cover these information step by step and finally, in the coming lectures we will be keep on connecting these information as and when we need them.

So, let us start the first thing is that we will talk about the visible range or optical range. Then we talk about a definition of the photogrammetry then what is the photograph and what is image. Then we talk about the development of the photogrammetry, then what are the cameras with different different types of cameras.

What are the platforms those carry the camera in order to acquire the image and then we have photographs type of the photographs. Then we will cover the basic terminology of the camera like Field Of View, lens equation, aperture, shutter speed and other things. Finally, in the context of digital photogrammetry we will talk about the cropped sensor and then we will talk what is the photogrammetrist view on the camera. And how a photographer look at the camera, we will look into these aspects today; so, let us start here.

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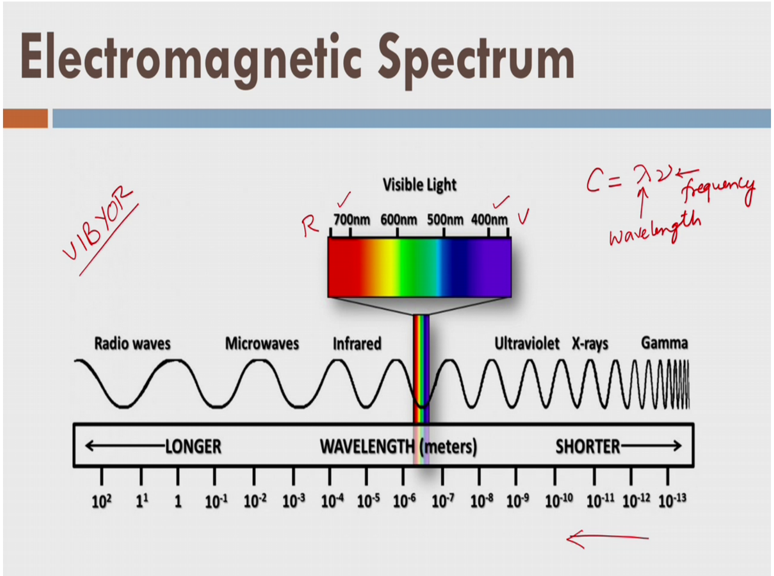

So, first of all if you look into the electromagnetic spectrum that is the spectrum of our light; you will find that this is the wavelength range here shown from left right to left which is in general contrary to our understanding; generally we go from left to right. But there is a issue here if we draw the frequency of these wavelength then I will be going from left to right. And that is the only reason in the books most of the book show the frequency on x axis because wavelength is increasing from right to left if frequency increases from left to right.

And you know the famous relationship of light or into speed of the light is nothing, but lambda into mu, which is lambda is wavelength and mu is frequency of any wave or electromagnetic waves. Now, in this electromagnetic wave if we look at this figure called 400 nanometer and 700 nanometer, you might have come across these, you might have come across some term called VIBGYOR right violet to red colors, these are the 7 colors. So, this is my violet and this is my red or rather I can say that in the electromagnetic spectrum the wavelength of the violet color is 400 nanometer and the red color is 700 nanometer.

And they are basically close to that exact value of red is 720 nanometer the exact wavelength of violet color is 380 nanometer exact. But; however, in general this is a good idea to consider the in the range 400 to 700 nanometer and this is called the optical range or the visible range; why? Because our eyes are sensitive to these wavelength range only.

That means whatever color I am seeing here around me of this room maybe I can say this is the black color, this is the red and white color combination on the shirt or we can say this is the white color on this mobile phone.

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So, all these visible colors are in this range 400 to 700 and that is the reason we say it optical or the word optics has derived from here only. So, remember if anything related to visible light it is called optics optical camera we have a term; that means, the camera that works in the range 400 to 700 nanometer wavelength that called optical camera, well I hope that is clear now.

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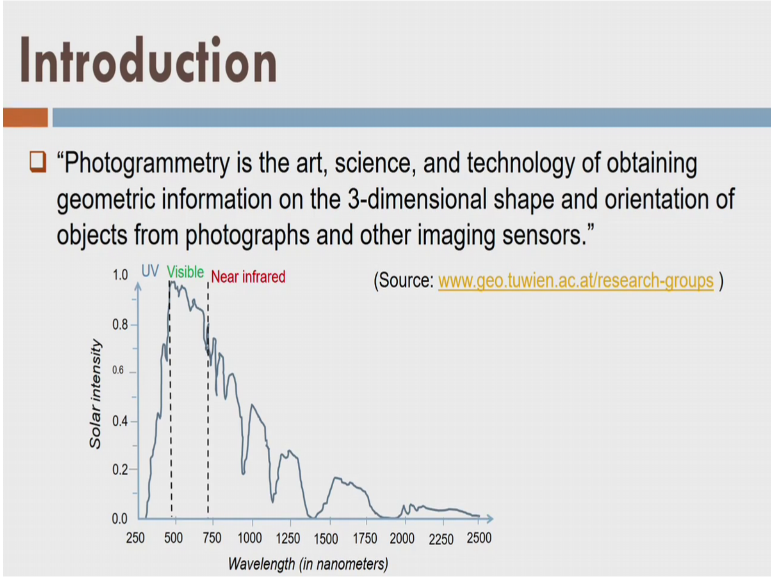

Then let us start with the basic definition of photogrammetry; what is the photogrammetry? If I explain you in Layman’s language photo means photograph that you acquire and then you have metry as a suffix photo system photo the photogrammetry. So, the photograph and photogrammetry the difference is very simple whenever you use a word metry with something; that means, I want to do some kind of 3 dimensional measure using photographs; so, it becomes photogrammetry.

Similarly, we have terms like lidargrammetry, we have terms radargrammetry, we have terms bathymetry, we have terms gravimetry right. So, these terms are using the same suffix metry; that means, 3 D measurement by some means it could be photograph, it could be lidar, it could be radar and so on.

So, the standard definition of photogrammetry which I have taken from some source that is photogrammetry is the art science and technology of obtaining geometric information on the 3 dimensional shape and orientation of objects from photographs and other imaging sensors ok. So, that is a standard definition and again we are showing here the range of visible which is 400 to 700 nanometer or optical range visible range. After that we have near infrared in the wavelength range then before the visible, we have ultraviolet because it is before the violet we call it ultraviolet right.

So, now we are talking about the visible range in the photogrammetry ok. So, what do you mean by photograph and image? We need to first consider these basic terms you might have come across many a times you might be using these terms very intuitively.

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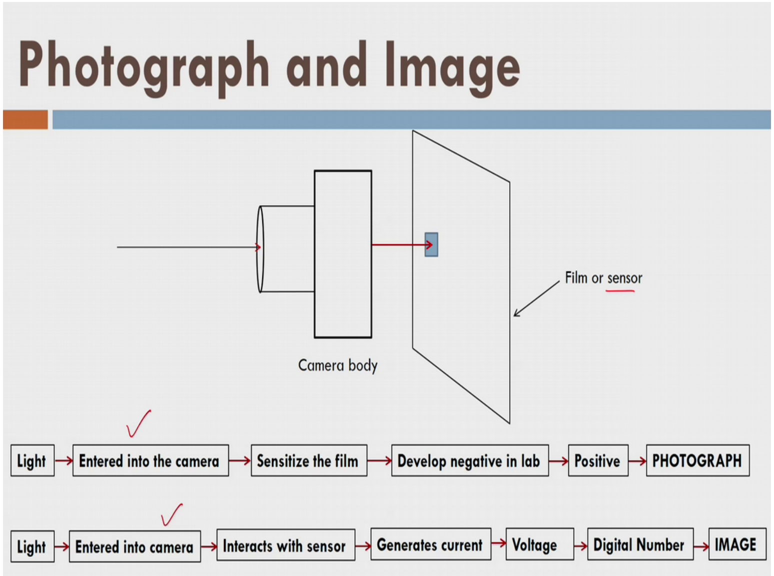

Someone says that this person has a negative image in the brain of others or in the mind of others; does it mean the same image ok? So, let us talk about the technical definition of photograph and image.

So, let us say this is my camera body shown here in the screen; now light enters into the camera and right, light goes to the some film here, it could be film or sensor. Let me tell you, what is the film? Film is kind of polyester acetate based medium; where it once it is sensitized or once it is exposed to the light it cannot be used further for second time it is completely different from the digital sensor or what we call to the digital camera. So, this is the film is not a digital sensor remember right.

Secondly we have sensor these days what we call the digital sensors; so, both are different thing. So, now, in the perspective of two things film and sensor we are defining the terms photograph and image; so, let us see again. So, then this light will sensitize the film. So, right now I am assuming that there is a one film over there is no sensor. So, let us assume that there is a film only ok.

Once the film is sensitized then we develop the negatives by some process chemical process is there in the laboratory like this. And then from these negatives we develop the positives what we call photograph on paper right or these photo positives are called the photographs. So, the idea here is if you follow this process where light enters and sensitize the film and then from the film; we developed negative and then positive and so, called photograph then this process or the process that gives me the output like this it is called photograph the output is called photograph.

Let us consider another process where instead of film I have a digital sensor right. So, let us see there is a digital sensor light has come here ok, then there is a sensor again I am putting both words film and sensor ok. Then the light will interact with the sensor and because of this interaction at certain point electricity will be generated. Because we remember the semiconductor physics or semiconductors has the property, some of the semiconductors that if light interacts with that they will release some photons. And those photons will generate some current and this current will be generating some voltage.

And that voltage now we will measure and convert into some digital number like this. And my so called product that is what we call image will consist of some digital numbers. So, by this process where we have light interacting with sensor generating some photons, photons are generating current; currents are generating the voltage and voltage is convert to some digital number the final product is called image and that is the difference between photograph and image.

Now, you can imagine we have something called photograph in image in optical region for the visible; however, for microwave region in the spectrum we have a term called radar. So, we never have radar photos we always have radar images. Why? Because there is no process like this in the radar; there is only this process available in radar and that is why we say radar images similarly we say lidar images right. So, that is the idea about image and photograph; you should always use proper terms in any of the disciplines.

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Moreover as on date we are using digital sensors and one of the digital sensor are mounted in most of the cameras they are inbuilt now. So, they are basically using the this lower process not the upper process. So, that is why we should use the term image today if you are using a digital sensor or digital camera all right. Let us go ahead ok.

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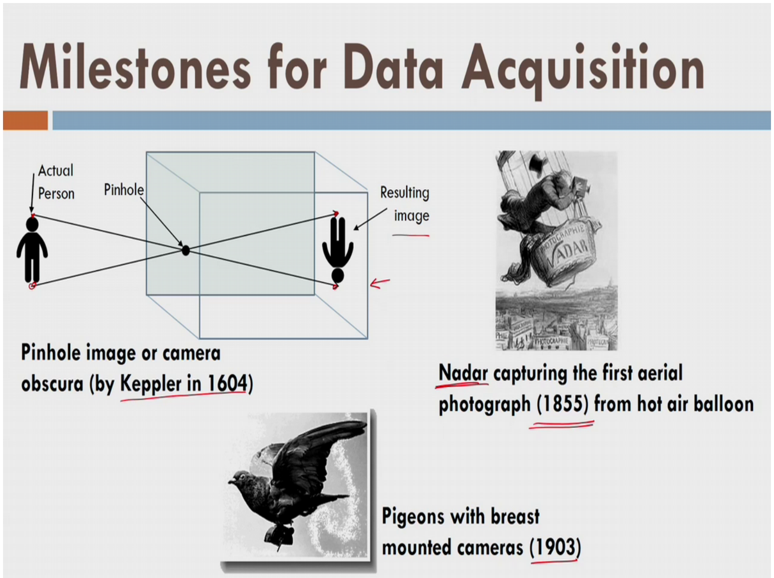

Now, the we are talking about the early stages of photogrammetry. So, Keppler has first conceptualize the idea of camera; that means, there is a person here and if there is a pinhole in the box; so, one can acquire this image right. So, now, you see that person is looking inverted here and that is the idea here. Because a ray which is coming from this point it is going this point and the ray from this point is going to the this point and as a result there is a inverted images formed on this screen.

And what we call here is negative or negative plane or whatever right. Now there is another development in this year the person called Nadar he has first acquired the aerial photograph right using hot air balloon; that means, in the hot air balloon a person was carrying an camera and he first acquired the aerial photograph. We should say aerial photograph because the camera was in those days based on the film; not the digital sensors all right.

Later on around this year some more experiments were done and pigeons were you know mounted or other cameras were mounted on the pigeon and pigeon used to fly with their natural capacity and they used to bring the information. And, the idea was to do spying right, but still it was not a bad idea to acquire the photographic information from a height and that was the concept of doing the aerial photography first came into picture ok.

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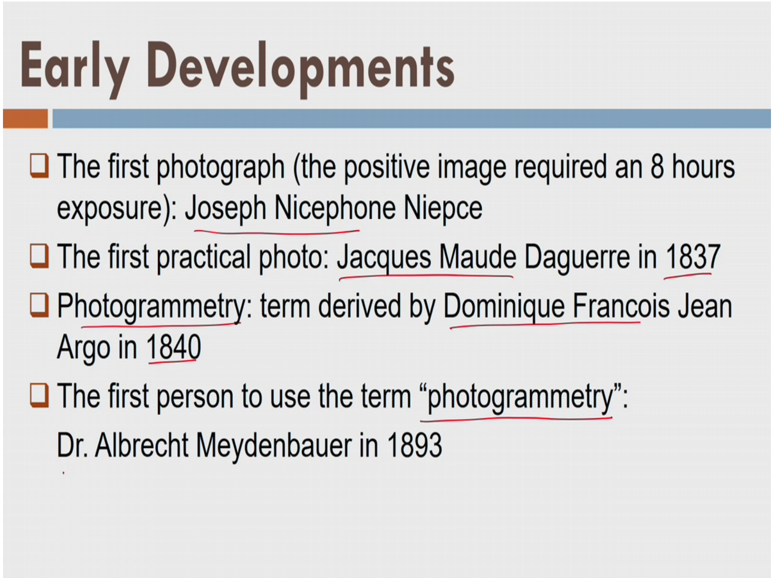

So, in the early development the first photograph that was developed by some scientist called Joseph Nicephone and it took almost 8 hours for him to develop right; this was the early stages of development.

Then first practical photo was delivered by this year by this gentleman Jacques Maude and then later on Dominique Francois used the term in this year the photogrammetry. The first term come where he says that photograph can be used for 3 D measurement that was his idea conception; however, in reality this term was started using by Dr. Albrecht from this year ok.

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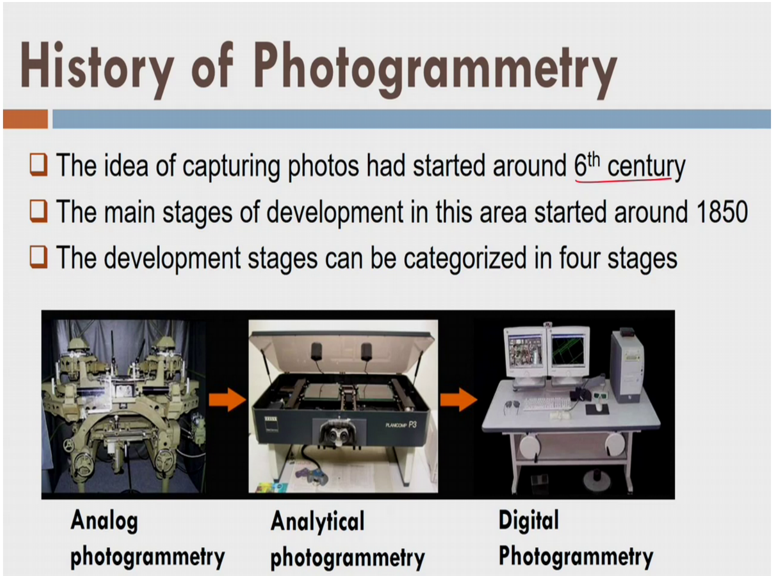

Now, if you look into the history of photogrammetry you will be surprised there are basically 4 stages. First stage we have already discussed where Keppler and all they have you know contributed and that state started from the 6th of the century. However, the real development or the real you know the passion for photogrammetry started much later because of the resources and because of the development and research and so on.

So, the main stages were four, but we have already talked about first stage. The second stage was analog photogrammetry where some kind of mechanical instruments were used to create the 3 D from the photographs. Later on we shifted to analytical photogrammetry where we started with the scanning of the photograph and those scanned photographs in the form of images now, they are supplied to the computer and by using the analog computers because computer started you know under development. So, using those computers and the scanned images we started doing the development and that is why we call them analytical photogrammetry because analytical part has come evident.

Now, the days as time passes from analytical we have started to generate digital computers and with digital computers we started digital photogrammetry. So, these are the basic 4 stages in the photogrammetry development today we are in the era or we are in the phase of digital photogrammetry.

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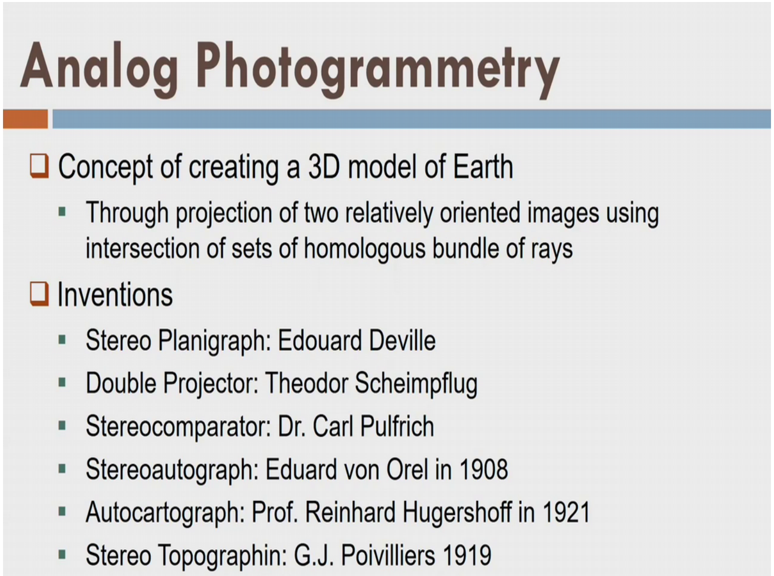

Let us look into what are these basically analog photogrammetry very briefly we will talk about these. So, concept of creating 3 D model was there already; so, by making the projection of two relatively oriented images using intersection of set of homologous bundle of rays. We will talk about in detail in this module, but for time being that 3 D model was started to develop; the what is the idea here? If I have 2 images like this if I place them parallely orient them appropriately. And if I take bundle of rays means one ray from here one ray from here and they are targeting at some point on the ground.

So, using these 2 photographs or 2 rays I can find out D coordinate or 3 D coordinate of this point on ground. So, that was the idea of developing and development of the 3 D models and that started with the analog photogrammetry. So, these are the basic inventions if you look at planigraph, double projector, stereocomparator, stereoautograph, autocartograph, stereo topographin and all these are the early development in the analog photogrammetry.

However, today they are more or less obsolete because later the analog photogrammetry was replaced by the analytical photogrammetry after the invention of computers further the analog computers were superseded by the digital computers and the even the analytical photogrammetry was replaced by digital photogrammetry ok

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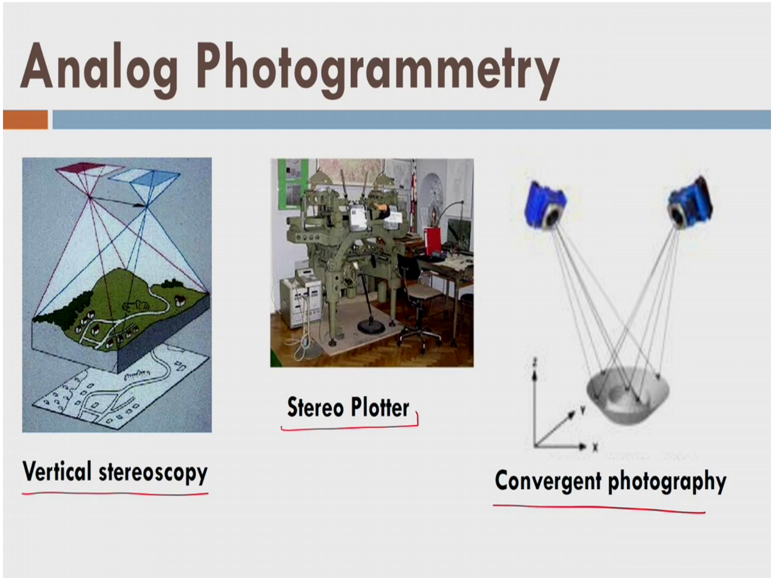

So, in case of analog photogrammetry also; this is the idea of vertical stereoscopy what we call having 2 images simultaneously put together and try to find out the coordinate of a point in 3 dimension. So, there are 2 dimensional image; so, I am putting 2 images together and trying to find out the 3 D coordinate and we will see all these development or we will see all these concepts very carefully in the this module ok. In those days they used to have mechanical machines like stereo plotters and they used to do they used to use this one to create the 3 D using acquired photos from the aerial photographs or maybe terrestrial one ok.

Then if they were not able to acquire the photo by stereo logic which means let us say there was some place on the land surface; which were which could not be acquired with the help of stereo photographs, they used to follow the convergent photogrammetry or convergent photography; where they use to put 2 cameras like this and 2 cameras not like this rather on this view they use to acquire the photo like this and they use to use again stereo plotter to develop the 3 D models.

The idea was to have some overlap between the 2 images; that means, if there are 2 images they are acquiring the same land or rather they have some overlap more than 50 percent. So, with this overlap they use to develop the 3 D models for the only overlapping area not for the non overlap area right. So, let us try to get into this thing.

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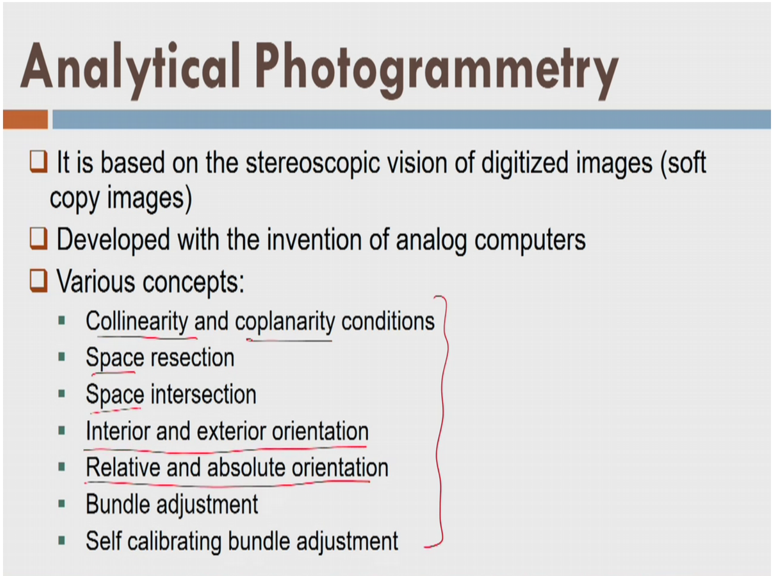

The third phase was analytical photogrammetry; so, it was based on the stereoscopic vision of digitized images which means whatever images or photographs we used to create using negatives; that means, we used to create positives what we call photograph using the negative films. From those photographs, now I started using the scanner and we started using the scanning of those photographs. And those images which are generated by the scanners are used as a soft copy images in the computers.

And then, so the analytical photogrammetry started right if you look at the various developments; then we have lot of development like collinearity and coplanetary conditions space resection, space intersection, interior and exterior orientation, relative and absolute orientation we have bundle adjustment and self calibrating bundle adjustment.

So, these are the basic concepts that came with the analytical photogrammetry and we will talk about all these in detail in this module ok. So, let us go one by one basically we are trying to understand what is the meaning of these concepts? So, we will take only few which are very very important to understand now and anyhow we are going to deal in detail with these concepts in coming lectures.

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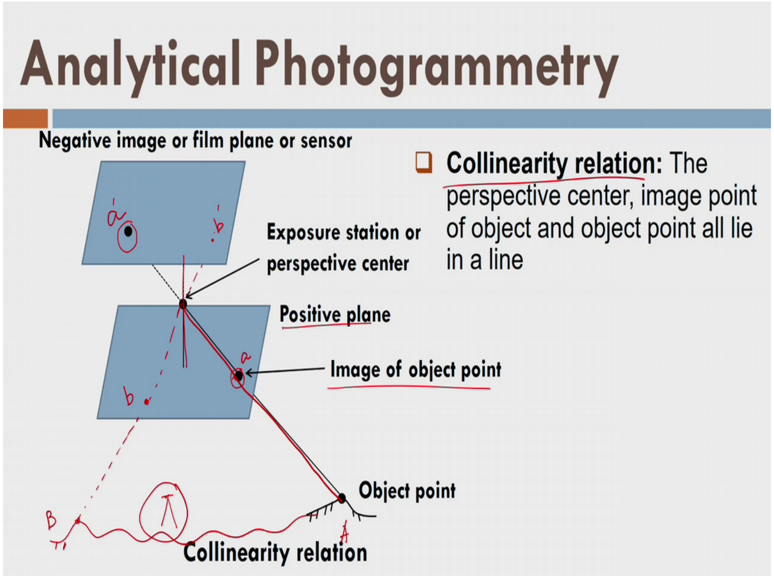

So, let us first look let us say this is my terrain and there is a point; we call it the object point let us see there is a image and positive. So, this is my negative image or film plane or I call today sensor well this is my positive plane here; that means, positive that I developed up from the negative. So, so far in the place in those days only negative was there in the camera. So, this is my camera assembly where there is only negative is there.

So, now let us see that this point has been imaged into the negative and as a result we will say this is my exposure station through which light passes into the camera or light goes into the camera ok. And then it creates this is my image of the point we will talk about that. So, this is my image of the object point we call this point as image and not this point as image remember; this is the impression of this object point into the negative film right.

From the negative film, we develop the positive and the positive where about this point comes we call image of the object point and there is a reason for that let us see, what is the reason? Let us say there is another point on the same terrain like this terrain is like this and there is a point here called B point and this is my A point ok. So, B point if I try to make a image in this one. So, that will be like this it is some here appears here and it will go through the exposure station.

And now it will create some kind of impressions; let us say here this is my small b, this is my small a or let us call a dash and b dash and let us call this point as a small a and this point as small b. If you look at this thing very carefully you will see that we have some kind of experience of looking at the terrain. The idea here is suppose if I am standing here right somewhere here then I will see the point B is on my left hand side and point A is on my right hand side.

But if from the same point of view if I look at the negative I can see here; that the position a dash and b dash are relatively inverted on the other side; that means, now from my position here point a dash on the negative is on the left hand side which is completely contrary to the position of point a in the field. Similarly you can see that b is imaged at b dash which is on the opposite side with respect to this axis here right.

However if you look at the positive they are on the same sides and I have the same experience the way I am looking at the world I will get the same experience in the positive not in the negative. And as a result we always use positive for referring the any point on the image. So, we use the positive image not the negative image. So, negative image lies in the camera that is generally we developed even our sensor; if you look at the sensor also acquires the same fashion they first create the negative and then their software internal software it again develops the back and show us the positive on the screen right. So, you should understand it first.

So, although you are looking at the same thing in the camera what you are looking at the world, but that is developed by the your mobile phone or maybe your camera. So, that has some internal software to that and same the human mechanism the human vision is also like that if our brain always create an inverted images. So, later on brain converted back into the non invited or straight images or the original images the world looks like to us ok.

So, their idea was here that if I look at point a now, so small a here and this exposure station they are all in one line like this; they are falling in a straight line one 3 dimensional line. And this relationship is called the collinearity relation; that means, object point the image point and the exposure station they are in one line, they are collinear and that is why it is called the collinearity relationship I hope it is very clear and very very easy to understand.

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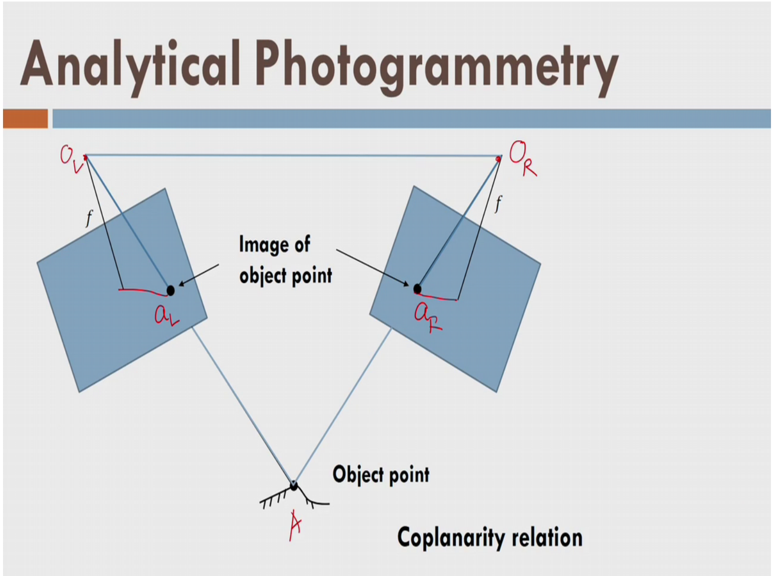

Now, let us look into the another one the coplanetary what is the coplanetary? Let us look into that. So, let us see there is a point object point again here and there is there are 2 images this is there are 2 images here and both images are acquiring the some scene or some kind of information on the ground surface and let us say this object point is acquired in both of the images.

So, like this; so, I have let us say these 2 camera and these 2 images are acquiring the image of this point like this. So, I can call it point a; so let me call it a left maybe this is a right fine; now if you see that if I orient carefully these 2 images such that point a this is my exposure station this and this they may come in one plane. So, these are my image points and now I have drawn this plane say.

So, if I image orient my 2 images very carefully such that this line here and this line here this triangle 2 triangles they come in one place automatically this plane will contain the exposure station let us say O left O right and the object point. So, these 3 points O L O R and object point a will be in one plane and this relationship is called coplanarity they will be in one plane coplanar; so, it is called coplanarity relationship ok.

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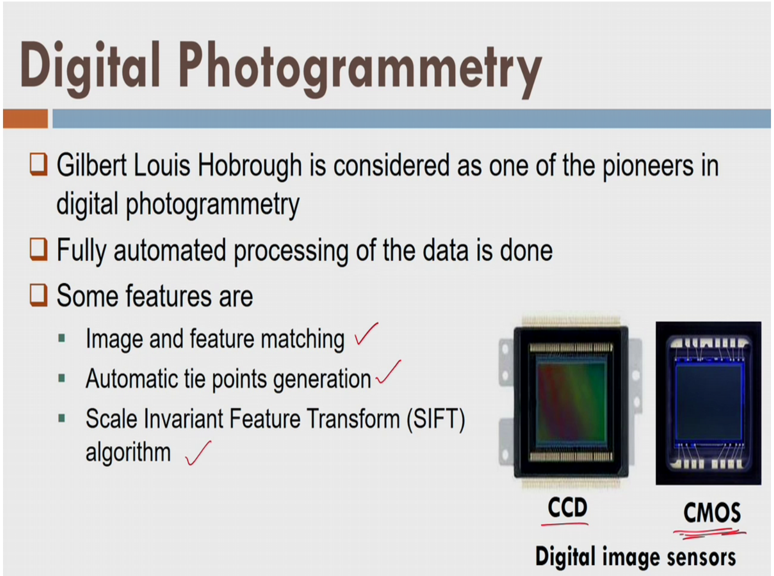

Now, let us divert; divert to the types of photogrammetry or still we are on the development phases of the photogrammetry. So, now, we are talking about digital photogrammetry after the analytical photogrammetry. In digital photogrammetry only sensor has change; that means, earlier we used to have film based cameras, now we have digital computer and digital sensor which is my digital camera.

And generally we have two technology here one is charge coupled device CCD and we have CMOS which has Complementary Material Oxide Semiconductor; they are 2 technologies which are used to develop these sensors; digital sensors. In most of the cameras what we use today CMOS is more popular because it is less expensive ok. In case of digital photogrammetry now there are some distinct advantages because of the use of digital computer as well as digital sensor.

And these advantages has brought many many new development compared to the analytical photogrammetry ok. So, first of all we have fully automated processing of the data it is possible now ok. And as a result they are of very important thing for example, image and feature matching. Suppose there are 2 images and they are having some overlap or they are having information about the area on ground; so, we say that they are overlapping images.

So, now I want to find out which point here is also there; that means, which are the common points in 2 images. So, that is why we say image and feature matching; then we have automatic tie point generation let us try to remember right now and we will talk about this in detail in coming lectures. Then we have important development like scale invariant feature transform sift algorithm and this is very very important in the era of digital photogrammetry ok.

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So, let us go ahead and now after the you know discussion on the various phase or various development of the photogrammetry in for different different like early stages then we have analog, then we have analytical, then we have digital photogrammetry. So, let us talk about the cameras.

So, we have in general 2 type of cameras as we already disclosed it to you few minutes back. Film based cameras and then we have digital cameras yes in case of film based camera, we have a negative film which can be exposed only ones to the light. So, the moment it is placed in the camera the cover of the camera is closed and then the moment I take the photograph light enters into the camera it exposes the film and that film cannot be used anymore.

As a result it has to be shifted and the new piece of film has to be replaced ok. So, once we do we again repeat the same process and again we shift the expose film to the roll, we roll it basically in the camera room itself and then we keep on doing this process. And let us say if there are 36 pieces of the film connected together in one reel. So, once the reel is over camera indicates you reel is over this means all the negatives are exposed. So, then you will replace the whole reel by another reel and then you keep on acquiring; the photographs like that; that means, you are keep on exposing the films it was slightly expensive affair.

Why? Because, I cannot reuse the used film the film which is already exposed now has to be brought to their laboratory thereby some chemical process we used to develop the films and after development we used to call them negatives. From those negatives which are permanent in nature now we used to develop positives. So, what do you mean by permanent in nature? When film is exposed in the camera when it was standing in the camera or what when it was housed in the camera at the time I cannot use it.

So, we need to brought into a dark room where there is no light available in the dark room; there is a standard chemical process through which it film passes and it becomes a permanent in features; that means, whatever features are there which are required in the film they will become permanent on this. So, now, you can use it anywhere it will not be removed the using those negative films, we used to develop the positives or photographs in hard copy and then we use to use those photographs. So, this was the process of film based cameras.

In case of digital camera we do not do anything rather we click it and then we immediately transfer or data to the laptop or computer. So, that is a fundamental difference in the analog camera and digital camera. Well the photographs here are given for the consumer grade cameras although this categorization also true for aerial cameras and satellite cameras; satellite camera now the days are completely digital in nature.

But at times in around 1950 to 1975; they were in the analog mode also; that means, we used to have film based camera in satellite also and famous corona satellite program was having a panoramic camera you can read the details on internet about that. Let us talk about the consumer grade camera which means the being a consumer I am using some camera, it could be SLR camera, it could be point and shoot camera, it could be mobile camera all are called consumer grade camera ok.

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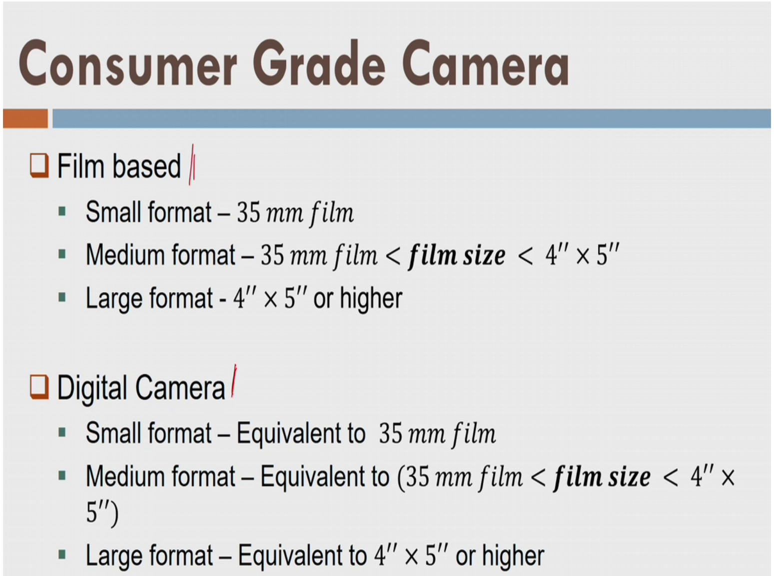

So, now we have again the consumer grade camera film based as well as digital. Most of you and including me today we are using digital cameras, but still there are some passionate photographers they still use film based camera today. Because they have a passion to use those rather they are habitual of using those and they feel there is there are a lot of advantages with analog camera or film based camera, no problem. But now the days most of us have already shifted to digital cameras and it is very easy because it does not it is a less expensive; why? Because unlike negatives it does not have a permanent kind of stuff; that means, once a negative is exposed it cannot be used for taking another photograph.

However, in case of digital camera once you take the photograph, you keep on using the same sensor for acquiring another photograph. Or rather photograph which is acquired by the sensor is transferred to some kind of memory or some kind of hard disk. And that is the reason it vanishes the information whatever it acquires and it is again ready to acquire new information. And that is the advantage of the digital camera and hence this technology has more or less replace the film based technology.

So, now we have small format, medium format and large format and these formats are also equally applicable aerial cameras; while whereas, I would like to say here that these definitions are more or less stable for the consumer grade camera, but in case of aerial cameras this is changing very very rapidly today. So, that is why we are not specifying any limit for the or any criteria for the digital aerial cameras alright.

So, in 2009 or 10 there was some paper in journal photogrammetric engineering and remote sensing PERs where some definition was there I do not know whether that definition is valid today or not, but they have specified some what is the small camera what is a small format camera, what is a medium format camera and what is a large format camera? And if I can recall something like a large format camera has a pixel size of 250 megapixels. But it is about aerial camera not the consumer grade camera here in case of consumer grade camera we have something like 12 megapixel 20 megapixels maximum 50 megapixels right n. So, let us go ahead.

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Then we have consumer grade camera in the digital camera we will see there are frame cameras. So, what do you mean by frame camera ok? Let me show you this camera this is a an mobile camera here; the moment I click it with this camera what happens in a one click or in one moment it acquired some information on the frame what we call frame. And it exposes the whole frame of the sensor or maybe a negative film and such kind of cameras are called frame camera right. So, we have digital frame camera as well as earlier we used to have frame camera there were which were film based cameras no problem.

So, definition of frame camera is very very fixed; then we have stereo camera what does it mean? Rather they have 2 cameras into one box and using stereographic principle they are acquiring the 3 D model directly well we will look into that, but we are just talking today about the what are the digital cameras available in the consumer grade range.

Now, let us talk about the platforms platform means something that carries the camera. So, that camera can acquire the image or the camera can acquire the information on the ground surface. So, the first is satellite.

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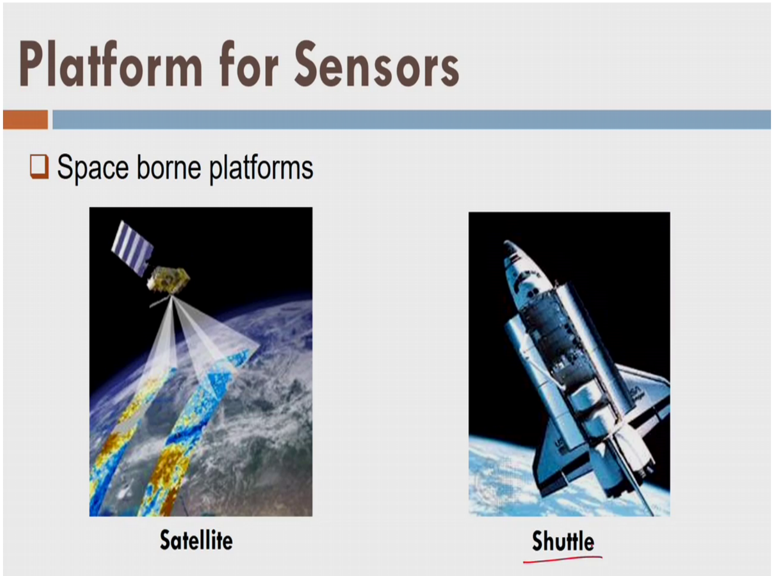

In case of satellite satellites are projected by the rockets in their respective orbits in the orbiting around earth; they also carry the camera which is already mounted there and camera acquires the information. For example now we have many many sensors let us say Landsat even the corona satellite was having some panoramic camera mounted on that there, then we have Quickbird, then we have Iconos and many many such sensors are there.

So, even including let us say pen camera we have panchromatic images or we have spot sensors or rather spot satellite we call, but it has some linear array sensor and those were fitted or those were mounted into the satellite. So, there they were acquiring the satellite based information. Similarly, we have shuttles they can also carry the camera in the space.

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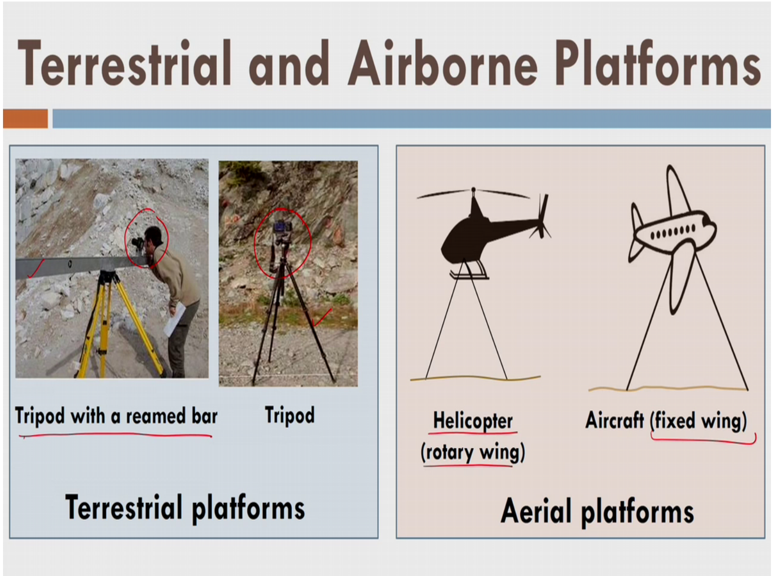

Now, on terrestrial and airborne platforms we can also mount the camera right and as a result if we see that there is a tripod with a reamed bar; that means, on this reamed bar here you can see camera is mounted And this gentleman is trying to acquire some photograph or image or information.

Similarly, now there is a tripod here shown in the figure in the image where a camera is mounted over the tripod. You might have seen this kind of arrangement of tripod and camera assembly or camera mounted on a tripod; even we have the still cameras or the photographic camera they also are mounted on the tripod to acquire the image information. What about the helicopters and aircrafts? Yes we also do that.

So, helicopter sometimes you find out a term called rotary wing is used for aircraft; you will find out some term called fixed wing aerial vehicle this term used. So, I am writing this also. Yes helicopter and well as well as aircraft both can also carry the camera for aerial photography; so now we have a kind of 2 terminology here. If I use the camera on platform which is used on the terrestrial way or on the ground surface; it is called terrestrial platform like this.

Similarly, if I use or mount the camera in the aircraft or helicopter and they go up to certain height which is quite a high then we call it aerial platforms. So, helicopter and aircraft are aerial platform while tripod and let us say tripod with a reamed bar they are terrestrial platforms right. What if you carry yourself a camera and try to do the photography without tripod. Well, it will be call terrestrial photography or terrestrial photogrammetry right because you yourself is acquiring the photo on the surface of ground and you are carrying yourself. And your height is more or less very limited on the surface of earth; now recently there is some more development happened in platforms.

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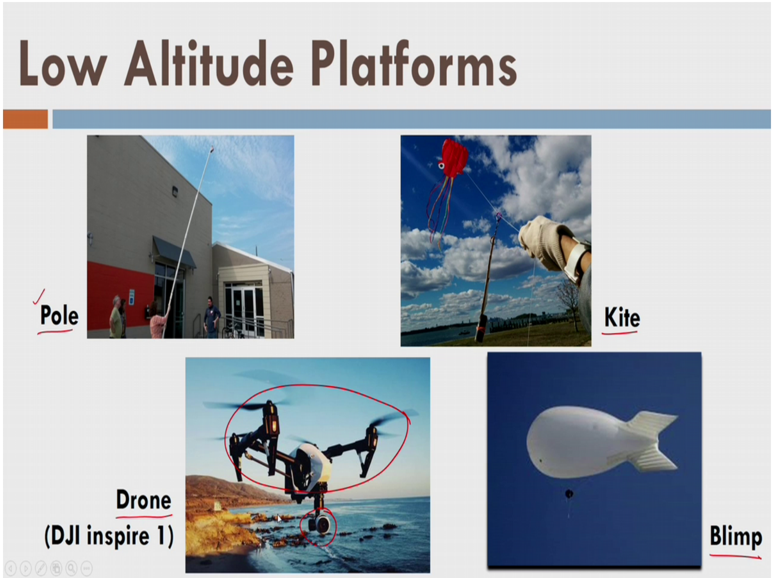

So, recently scientists and relay practitioners of the photogrammetry have introduced a new term called low altitude platforms; that means, they are not terrestrial platforms like tripod unlikely they are also not aerial platform like helicopter or aircraft they are in between the 2 right.

So, first is the pole means we have almost 20 to 30 feet high pole and the top of the pole we make some arrangement to hang a camera and buy some automatic arrangement on the ground; we try to control it and camera acquires the images from that height of 30 feet or maybe 20 feet. So, that is the arrangement called pole and that is comes into the low altitude platforms well.

Then second is kite; kite it has some special material and like the regular kite that we and you know we fly in the air for our entertainment. Same way this kite is sent into the flow of air and that thread which is connecting the human and the kite it has some arrangement to suspend a camera in the air. And after certain height when kite reaches to its peak height at that time a suspension arrangement which is suspending the camera is using the camera to acquire the information; so, that is the arrangement of the kite

Similarly, we have a blimp; blimp has helium gas filled into that or even we have balloon blimp and balloon are the kind of same kind of arrangement; where they have helium gas which is quite a light gas and then that balloon is again the carrying the camera on its thread and thread is connecting the human and the balloon. So, that is suspension arrangement is also there and using that suspension arrangement camera is suspended in the air and after at certain height, we try to acquire some information using that automatic triggering mechanism; so, that is the idea here.

Further we have drone which can go to around good heights 150 meter 200 meter and so on. So, they are also classified in the low altitude platforms; remember the drone carries the camera drone is a platform and there is a camera. So, here you can see this there is a DJI; DJI inspire platform here and there is a camera here ok.

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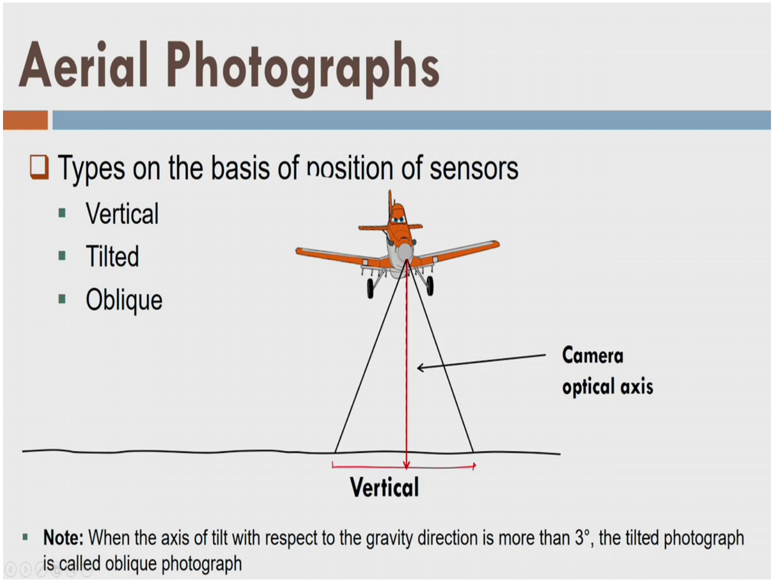

Now, let us talk about the type of aerial photographs as I told these the information in these lecture are quite scattered. So, we will go one by one and you may feel that there is no connection between the two, but yes these are the basic terms that we should understand before you know getting involved into the photogrammetry ok. So, based on the position of the sensor we have vertical photographs, tilted photographs and oblique photographs ok.

So, let us look into one by one. So, let us see if I acquire the image and that is a kind of field of view of the vertical photographs; what is the meaning here? If I draw the optical axis or the camera axis of the camera which is completely matching with the northern direction here like this; the northern or the gravity direction of the aircraft then we call it vertical photograph.

Right now it is very simple definition to understand we will again try to modify it, try to look into these deeply in the coming lectures where we find out there are more criteria's to define a vertical photograph. But right now understand that if the optical axis or the camera axis of a camera is matching or it is in the direction of gravity; then it is called vertical photograph and this is the coverage of the vertical photograph from here to here, what next?

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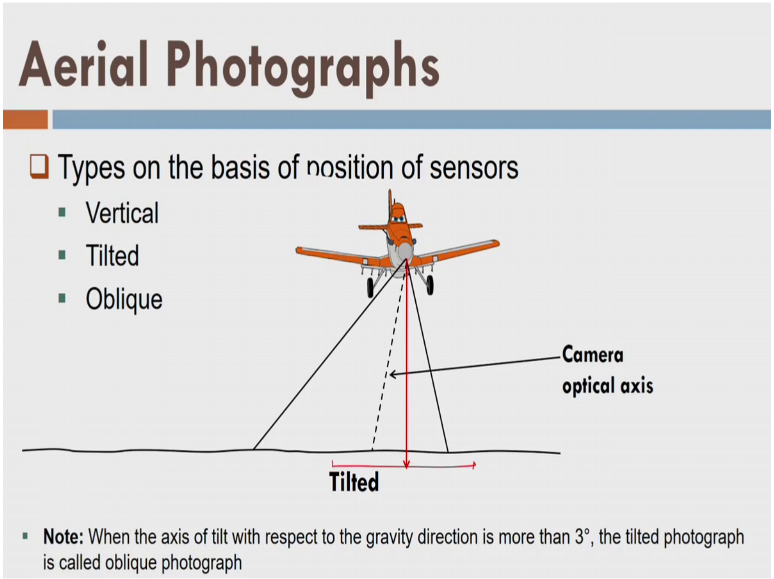

Then we have tilted photographs; that means, this is the gravity direction.

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But the axis of camera is somehow tilted; that means, my that camera was there this was a gravity direction; now this axis of camera optical axis of camera is tilted like this. And as a result we have this as my camera optical axis and this coverage is called that tilted photograph; that means, we are acquiring a tilted photograph. Naturally we should accept some distortion into tilted photograph what are the distortions? Distortions is something away from the expected one.

So, in vertical photograph we have some kind of expectations that it will covers this much of area, but tilted photograph because it is tilted. So, instead of covering this much area it will cover some kind of shifted area; we will see all these things further; if I further tilt the axis quite oblique way like this; deliberately.

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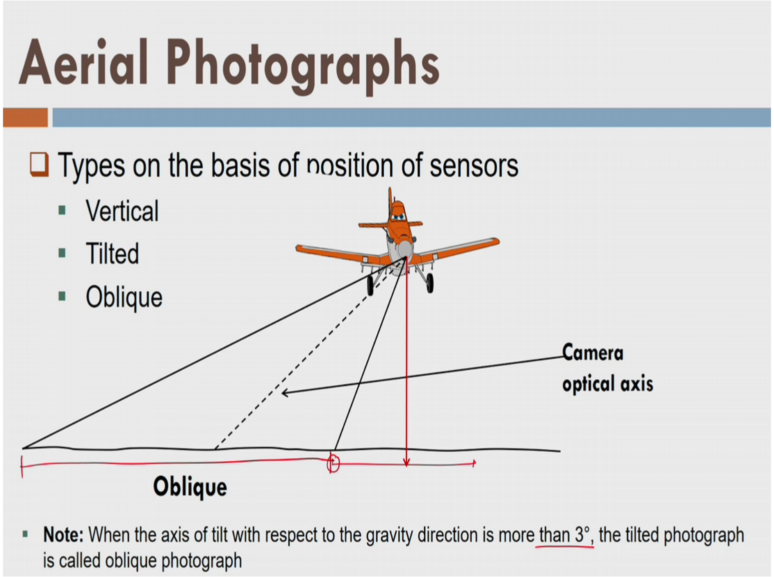

Then this is my optical axis and this arrangement or the photograph acquired by this kind of system is called oblique photograph. You will be surprised to see here, but there is a limit if I have this gravity direction; if the axis is within 3 degree the optical axis it is called tilted photograph. Vertical photograph there is no deviation of camera axis as well as gravity direction that is called vertical photograph; that means, there could be some random error, but knowingly we do not commit any error there, but in case of tilted photograph the deviation is there up to 3 degree then it is called tilted photograph.

More than 3 degrees it is called oblique photograph; that means, the deviation of camera axis from the gravity direction is more than 3 degree it is oblique photograph if it is up to 3 degrees it is called tilted photograph; if it is 0 degree it is called vertical photograph right.

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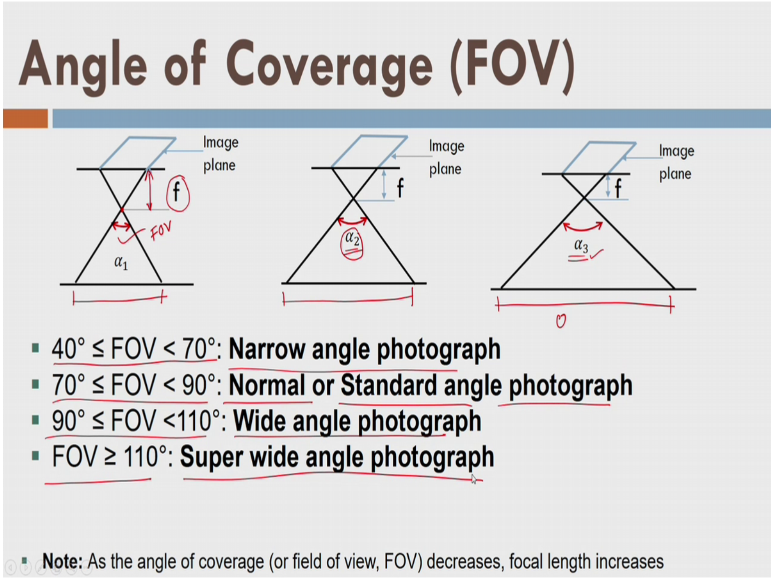

Now what about the angle of coverage or field of view? In the last photograph I have shown you 2 lines like this here this point and this point that is coverage of the photograph a this much length or this much area a photo a camera is going to cover on ground surface. So, now, if I have this angle called alpha 1 it is called field of view right and I am representing here the focal length f and this is my image plane or what we call negative plane or we can call it negative image plane.

So, there this is my exposure station you see this cross. So, this is my focal length from here to here f and then this is called field of view of camera and it is this camera is going to acquire this much of length or I can say in 2 dimension; this much of the area if I consider the 2 dimensions of the camera then let us say this is length that is being acquired by the camera. So, this angle is called a FOV which is alpha 1 here right

Now, if I increase the angle FOV it becomes let us say alpha 2 which is more than alpha 1 and again it is alpha 3 here. You will see here for the same arrangement of camera as we increase the field of view alpha, focal length will has to be reduced and that is also true for the consumer grade camera or terrestrial camera right you can see here and you can feel it here.

Similarly, if I further increase my alpha that is field of view my focal length has further reduced. So, idea is there if I have higher coverage I will cover more length on the ground, but at the same time you can see that focal length will reduce. And we will see in the next lecture if focal length is less I will have less resolution of the image we will talk about this thing, but for time being you can just collect this information.

Similarly, focal length is higher here. So, I will have less area to cover compared to this area. So, I will have higher resolution you can just imagine suppose you have a 12 megapixel camera and if you are acquiring some information. Because of that you acquire some area and now if you divide that length or area into 20 megapixels. So, each pixel will have certain value on the ground surface or on the wall or wherever you acquire on the object space and that is called the resolution for time being just understand that right.

So, we can see that the resolution is somehow a kind of represented by the pixel although it is not very correct definition right now, but for right now you can assume it to be correct we will correct it modify it later in this lecture only. So, as you see that if you have some kind of wide angle camera; you will acquire with the same 12 megapixel more coverage or more length on the ground surface or on the object surface or each pixel of the 12 megapixels will represent higher length of the ground. Or I can say less information compared to the earlier arrangement what we talked.

So, that is kind of idea why we have higher focal length if coverage is less and as a result we will get high resolution right. Anyhow, so we call if the FOV is between this range the Field Of View; it is called narrow angle photographs. Then we have this range for normal or standard angle photograph then we have more than 90 degree to 110 degrees we have wide angle photographs and more than 110 degree FOV is called super wide angle photograph or rather I should say is it camera or is this photograph no because camera can have varying focal length and as a result my field of view can also vary.

And so we say that whatever arrangement I make at the time of acquiring the photograph it will characterize my photograph not the camera because has lot of facility right. So, we do not attach these values to the camera or rather we attach these values of FOV with the photograph.

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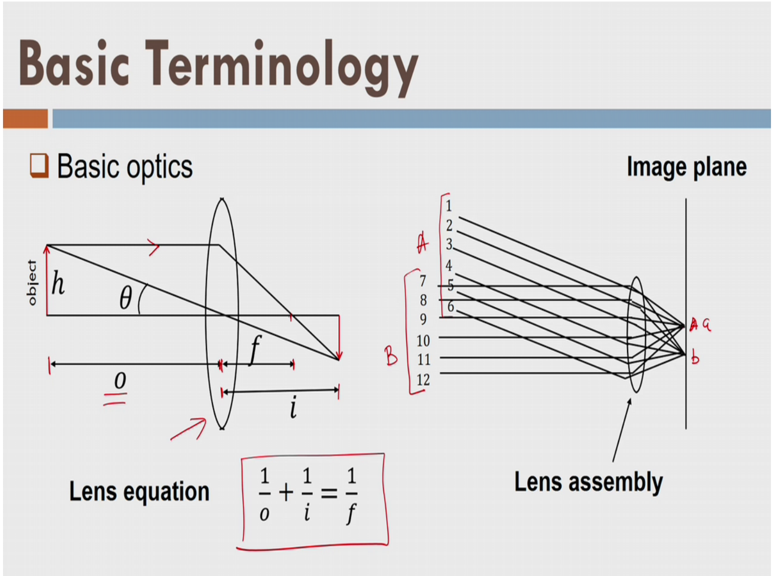

Now, let us look into the basic terminology of the camera first thing is that the basic optics we have here ok. So, the first thing let us say that there is object and which is imaged here. So, there is a lens assembly there and then it is imaged invertedly here. So, the distance between this focal point this lens where rays are converging from this point and rays are converging here. So, this distance from the center of lens to this distance is called focal length and from this point if I go towards object, this is called distance o here and if I go towards the image from this point it is called i and then I can write this famous lens equation like this.

So, now it is shown here that all this rays they are basically converging on this point let us say A. And all this rays they are basically converging at point B here; let us say small a small b; so that is the idea here. So, we are showing only one ray here multiple rays we are showing.

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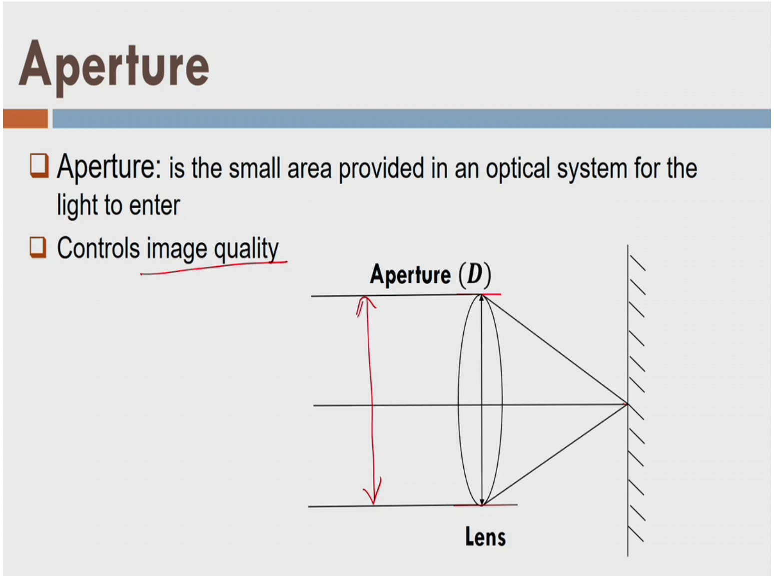

Now, coming to the aperture what is aperture? If you see in your camera like this somewhere here you will feel there is small hole in any camera. Now if you look at the camera carefully then there should be hole that allows the light to get into the camera system and that hole is called aperture right.

If more light is going; that means, the larger the aperture; more light will go into that camera and it will create bright images. If there is aperture is completely close no light will go if aperture is open slightly minimum light will go and so, it controls the image quality the rather illumination on the image fine. It is shown here that if there is a aperture here of size this much which is equal to the height of the lens here then it is creating a focus here and it is along the light. So, basically the function of aperture is to control the amount of light to pass in or to go into the camera.

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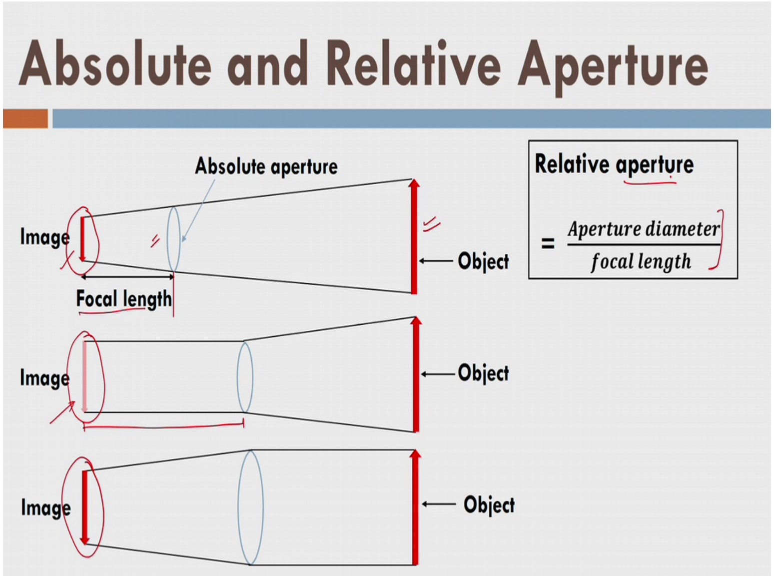

Now, let us look into this thing as we know that we can vary the focal length; similarly we can vary the size of the aperture. So, what is the effect here? As you know that there is a focal length like this and as a result this is the object here on the right hand side and there image has created of this object inverted image as you know. Now let us think that you have increased the focal length from here to here by bringing your lens backward towards the or bringing your lens towards the object.

That means, if you remember if you open your lens telescopic tube it will more in the length and as a result you are increasing the focal length. And because of that what will happen this object image will be increased the size of the image will be increased with it. But you can see here because of the length increase of or the increase in the focal length; the amount of light that was coming earlier is still same because aperture is same the opening is same. And as a result you will get dull image or little less illuminated image compared to this image all right.

On the other hand, what if I want to have the same illumination, but at the same time I want to increase the focal length; that means, I want to have higher details clear image better image. So, what can I do here? I need to increase both focal length as well as aperture size that we are showing here. And now you are getting larger image or image with higher details as well as you are getting same illumination.

What do you get here in this case. So, now, we understood that there is some relationship between the focal length and aperture size. And now we can say because focal length is controlling by details and aperture is controlling the light amount or amount of light or the illumination or the quality of visibility or radiometric quality and focal length is controlling my special quality the details right. So, let us have the relationship between the two. So, aperture diameter and focal length ratio is called relative aperture.

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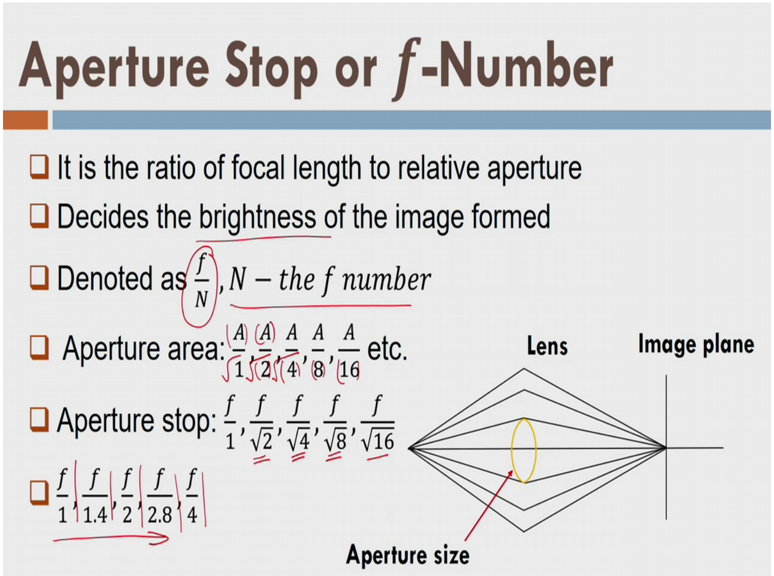

Now, we can say that the ratio of focal and to relative aperture and it is also called the f number or sometimes aperture stop and it decides the brightness of the image. Secondly, now it is the moment we take the ratio it is independent of the focal length now right it is indicated by f by N, where N is the f number what is meaning here? So, let us say I have aperture area A and if I reduce it by 2; that means, I am reducing my light the amount of light by 2 or I can reduce it by 4 times 8 times and so on.

What will happen? I need to reduce the diameter of the aperture by under root of this let us say under root of 1, under root of 2 under root of 4 and so on. So, accordingly as we told in the last slide aperture diameter to the focal length ratio; so, my diameter is reduced by root 2 root 4 root 8 and so on. So, you will find out these are the f numbers f 1.4, f 2, f 2.8 and so on. So, they are representing the diameter of the aperture not the area if you make it a square of this 1.4 square it is 2 right. So or 2 square it is 4; so it is indicating that we are reducing the area by a factor of 2 right and as a result we are reducing the diameter of aperture by a factor of under root of that factor.

So, let us see here what is this is my lens; so rays are going like this focusing here right. So, aperture size is highest now aperture size I am reducing. So, here and then here again I am reducing the aperture size. So, basically this arrangement is going on like this and generally we have in this ratio only f 1.4, f 2, f 2.8 and f their fixed discrete values available with cameras; so, here I am showing all this together ok.

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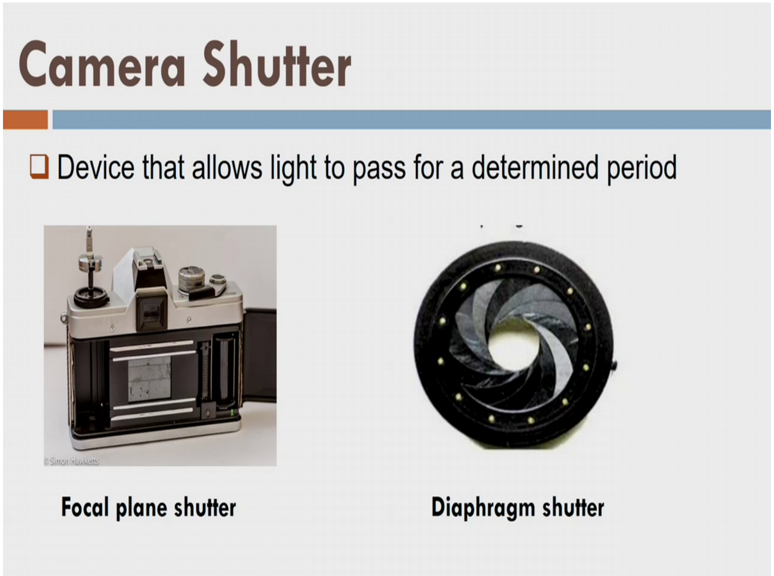

So, what is the shutter? Shutter is kind of you know; it controls the timing of opening. So, aperture is opening and if I control the shutter; that means, I allow the light for certain duration and that is called the operation of shutter. So, shutter is kind of shutter of the your shop; so, you open the shutter light will come and if you close the shutter light will not come or rather if you open it shut it will come for that duration. So, that is the shutter the operation of shutter is.

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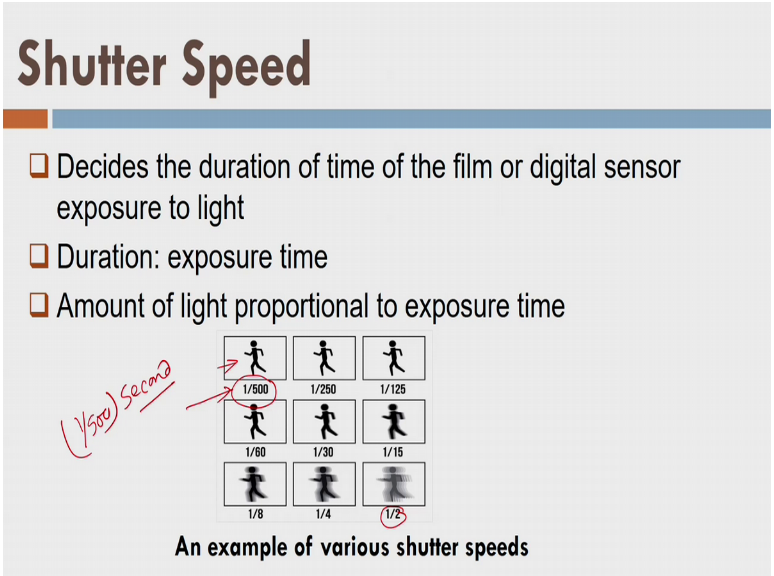

Now, shutter speed if you imagine that sometimes you get blurred images; we try to you know you have a pet dog with your home and you try to you know he is making some kind of entertainment or some kind of you know natural movements or you want to capture it if it runs very fast and if you use a camera you come some across some blurred images.

Why? Because if the shutter is open for large time during that time that movement has happened and that movement has captured and as a result you get blurred image what is the solution here open the shutter for very less time. So, during that time even that movement happens it is so, less movement that it will appear as a static object right. So, that is the operation of the shutter.

So, you can see here different different shutter speeds. So, if we have high time for exposure compared to this time I have very clear image because shutter speed very very less 1 upon 500 second that much of speed that much of time if you open the shutter and close it and as a result I get very crisp image.

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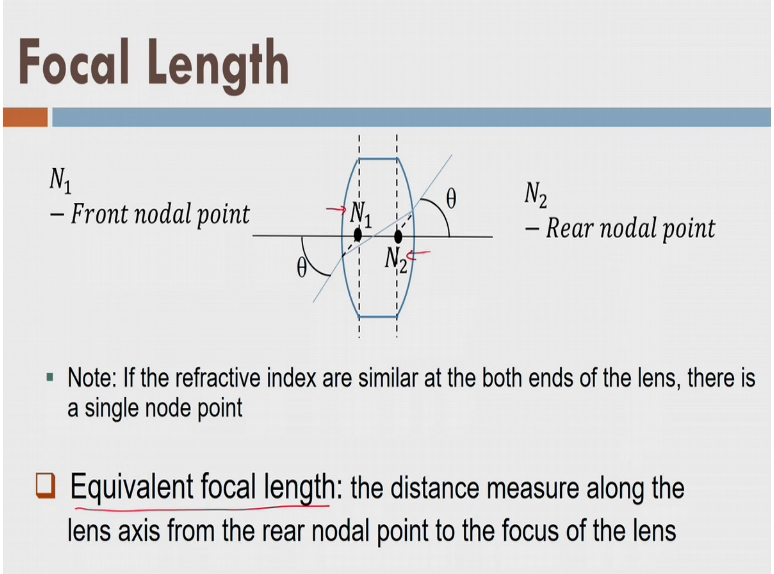

Now, focal length if no focal length many times; it is a basically if there is a lens assembly and it is called front nodal point N 1 and there is a real nodal point N 2. So, the distance between the real nodal point and the image or the image plane it is called the focal length right. So, now in the digital camera we have equivalent focal length concept that we will look into this now ok.

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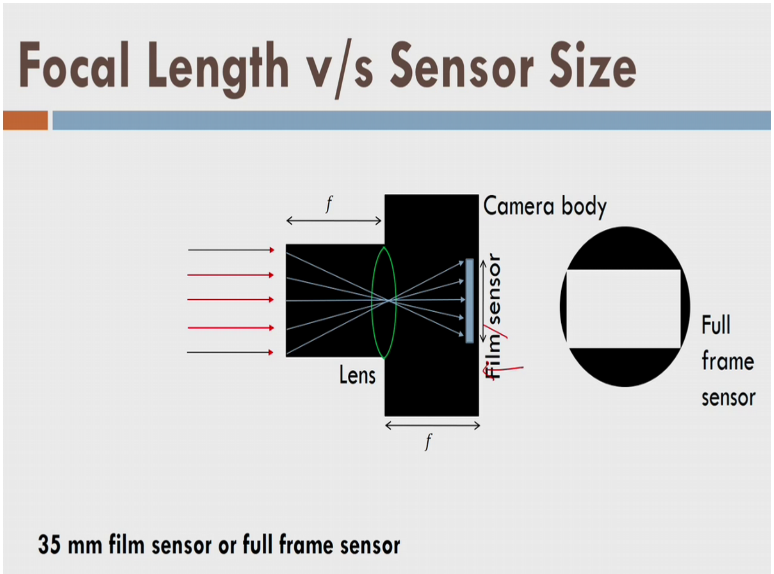

Focal length versus sensor size important concept let us say this is my camera and this is the lens here. So, this is the focal length because image is placed here or the lens sensor is placed here. Let us see this is my sensor what you call film sensor or call it a film or oblique sensor. Now rays are coming from infinity, so they are parallel they will be imaged like that with the help of lens ok. So, this is my called full frame sensor which has complete size like this. Now, today if you see our mobile cameras have a sensor. So, what do you do there? We reduce the size of the sensor and that is called a cropped sensor let us look into that.

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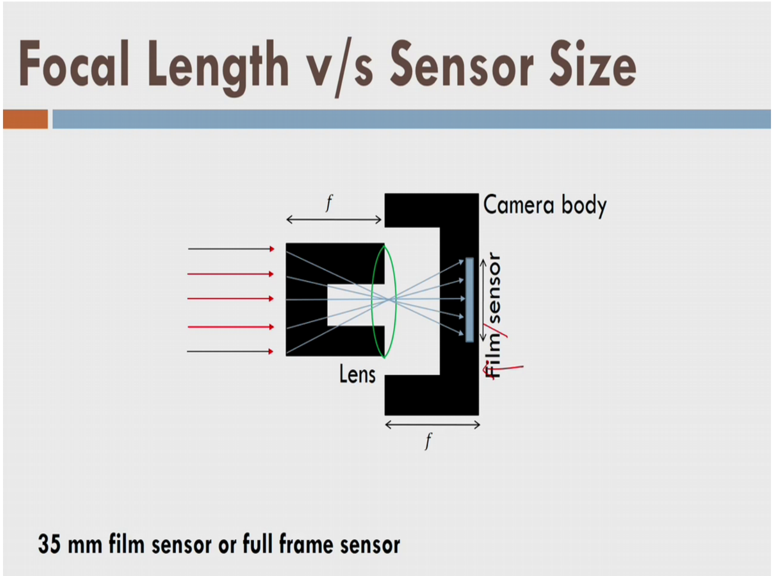

Let us make the camera small and this is my lens fine.

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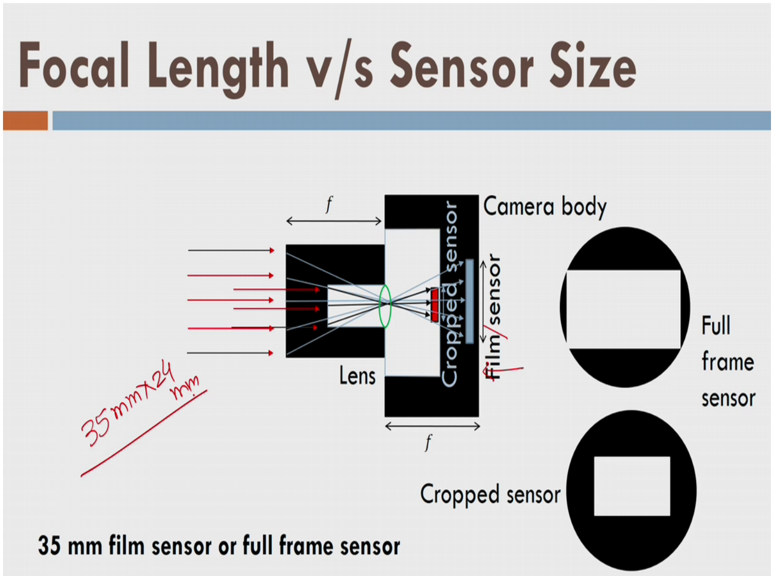

I have reduce the size of lens also because I want to bring my miniature camera small small cameras. So, now light is entering like that it is being focused at some point like this. So, the size of the sensor has also reduced now you see compared to the earlier sensor. So, this is called the cropped sensor and as a result of that now you can see we have small small cameras and cameras are so small that we are fitting into our mobile phones and that is the reason they are all cropped sensors and it is because of the technology only.

. So, this is my cropped sensor compared to the full frame sensor right. So, all these mobile cameras are using cropped sensor not the full frame sensor and full frame sensor is called 35 mm full frame sensor and the definition of full frame is 35 mm or sometime 36 mm into 24 mm or 26 mm just checker yeah 24 mm.

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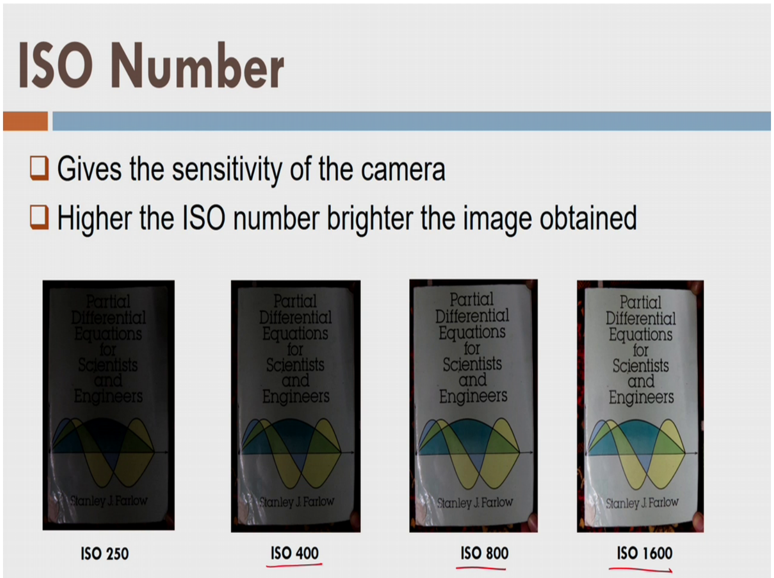

Now ISO number; ISO number is controlling the quality or the radiometric quality or the brightness of the images. You see if I put in to dark time this ISO 250 and I am increasing the ISO now; and I am getting brighter images right. So, that is a kind of operation of the camera. So, camera when provides higher ISO number even in the time of dark it can acquire good images right. So, it is a basically the sensitivity of the camera to the brightness of the scene.

Now resolving power ok; what is the resolving power? In general, we can say if there are 2 objects like this you know side by side; let us say one is my hand one is my mobile camera and if I take the photograph in the photograph if these 2 objects are looking separately.

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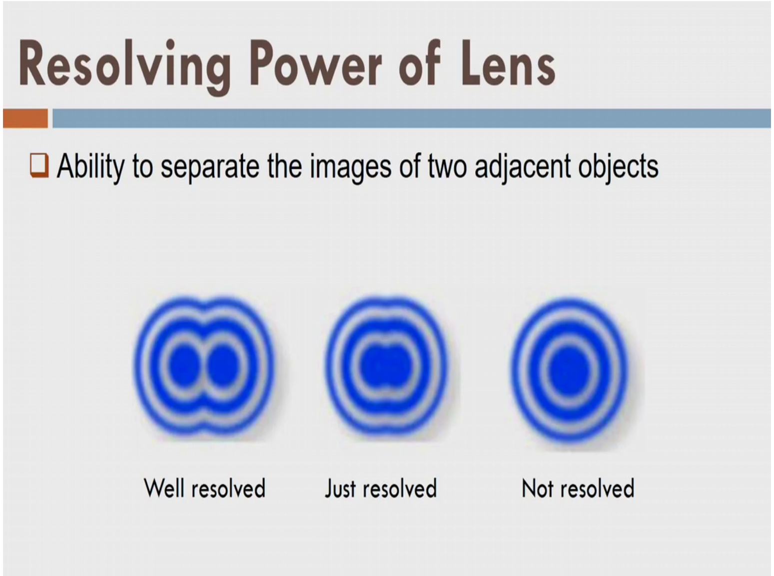

That means they are appearing distinct objects or 2 objects; I will say that the camera is able to resolve the distance between the object and this object; so, this is the distance here right. So, let us say this is the distance shown by my finger between the two; so this is the distance here. So, that is these distance are resolved by the camera.

Now we have 3 terms here the well resolved; that means, I can see 2 objects as a distinct objects just resolved; that means, they are appearing very close to each other, but still they are distinct. And finally, not resolved they are appearing as now we have just talked about the resolving power of lens or the resolution of camera ok. So, let us look into the relationship between the resolution, Field Of View and focal length.

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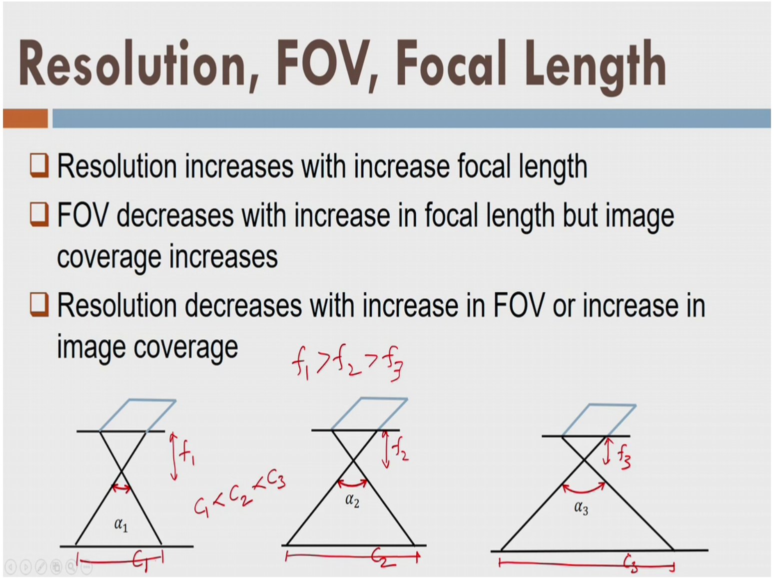

Because we have been arbitrating again and again; that if I increase the focal length my resolution will improve and as I told that field of views decreasing, well look into these things now. That is a very clear term that if I increase the focal length my resolution improves no doubt and you can understand it by simple logic if I increase the focal length, the field of view will be less and as a result now this length which is on the ground surface is less acquired by the camera. Now I have 12 megapixel camera; so, 12 megapixels are acquiring this much of space let us see this tablet for example, ok.

Now, I increase the focal length I can see that the space on this tablet maybe from this to this completely or the less space on this tablet will be acquired again my megapixels are 12 megapixels; so, number of pixels are fixed. And as a result each pixel is acquiring less space and I can see that if there are small objects; they will be clearly demarcated or they will be I can distinguish them very easily.

If pixel size on the ground is small which means if I have high resolution; that means, my pixel size is small; that means, I have higher focal length compared to the lower focal length local I have high resolution. Similarly it has direct relationship with the FOV because higher the focal length higher the resolution higher the focal length less the field of view. So, automatically field of view is inversely proportional to the resolution or focal length here right.

So, that is a relationship here. So, I can say this photo with the same camera I meant it is focal length is high f one let us say it is f 2 and it is f 3. So, I have f 1 more than f 2 more than f 3 right. So, I can see here this is my field of view which is I can say the coverage call me let us call c 1 is less than c 2 is less than c 3 and this is my c 2 this is my c 1 and this coverage is my let us say c 3 the higher the coverage less the resolution simple.

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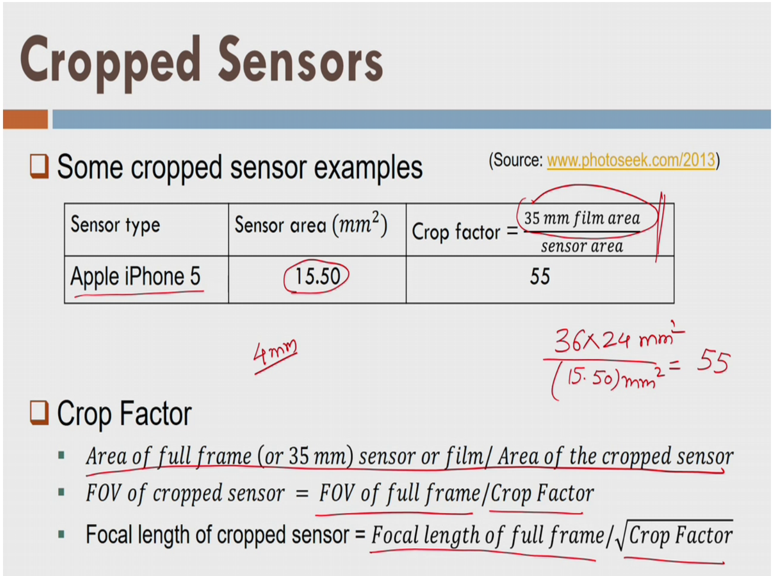

Ultimately we talked about the cropped sensor now we have something called crop factor; what is the crop factor? If I take the standard film camera of 35 mm film and if I calculate the area that will be equal to let us say they calculate like that mm square. Now, if I take the ratio of this divided by the my cropped sensor area which is a let us say this mobile phone; this is so, if has this mm square area.

Then if I divided by this mm square I will get this crop factor of 55; try it yourself for other cameras you can get this data from net right. So, this is called the crop factor; so I know that the area of full frame divided by the area of cropped sensor it is called crop factor this is definition of crop factor here which is also written here.

Then what is the FOV of cropped sensor it is FOV of the full frame divided by crop factor direct relationship what about the focal length of cropped sensor? Focal length of the full frame divided by crop under root of crop factor; so, you will get the focal length also of the cropped sensor. That means, you find out what is the focal length of this apple iPhone 5; it should be around 4 mm try it yourself why use the crop factor logic.

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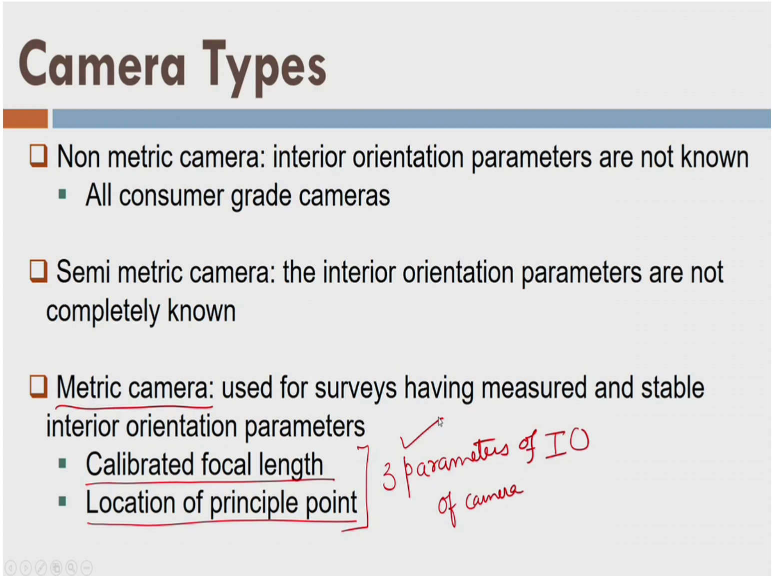

Now we have learned all the things about camera a platforms and other terminology ok; being a photogrammetrist what photogrammetrist say ultimately about the camera; they say 3 things camera is non metric camera, camera is semi metric camera or camera is metric camera. Non metric means the interior orientation parameters are not known in general all the consumer grade cameras are non metric camera. I am telling you one thing that focal length itself is a interior parameter of a camera; we will look into this what are the interior parameters or interior orientation parameters of a camera.

So, there are 3 interior orientation parameters focal length is one of them. So, if focal length is not known or the 3 interior parameters are not known; then it is called non metric camera from the photogrammetry perspective. If out of 3 parameters let us say focal length is known we will call it semi metric camera or even the other 2 parameters are known and focal length is not know; we will say semi metric camera. And if all the 3 parameters of interior orientation are known we will call it the metric camera. So, that is a definition from the photogrammetric perspective.

Well, now you might be thinking let us say you have a some high end camera of Canon or maybe Nikon or whatever which is a DSLR camera. And it has some range of focal length 18 mm to 55 mm; you hide the you know lens you can fix some eighteen mm then some other lens and. So, on then the length of the focal length is known to you think like that. In fact, when we go for the photogrammetry this length is not perfectly known in a sense; it could be 18 mm, it could be 19 mm; it could be 18.5 mm.

For the photogrammetry for the 3 D measurement focal length plays a very vital role and we should know its exact value. And that is why we go for the calibration process where we determine the exact calibrated focal length right and the location of the principle point. We will look into this what are this, but these are my 3 parameters of interior orientation of camera; so, a metric camera always know these 3 parameters.

Right, so in the next lecture we will start with the vertical photogrammetry and there whatever we discussed today in this lecture; they are the preliminary knowledge about the photogrammetry field, but they are important information without which we cannot proceed further and that is why this lecture is designed like that only.

So, let us meet in the next lecture on vertical photogrammetry.

Thank you.