**Remote Sensing and GIS**
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# Lecture - 13
# Photogrammetry

This lecture is on Photogrammetry. Today we will see basic concepts as well as the principles of Photogrammetry and their application. So let us start with the definition of Photogrammetry.

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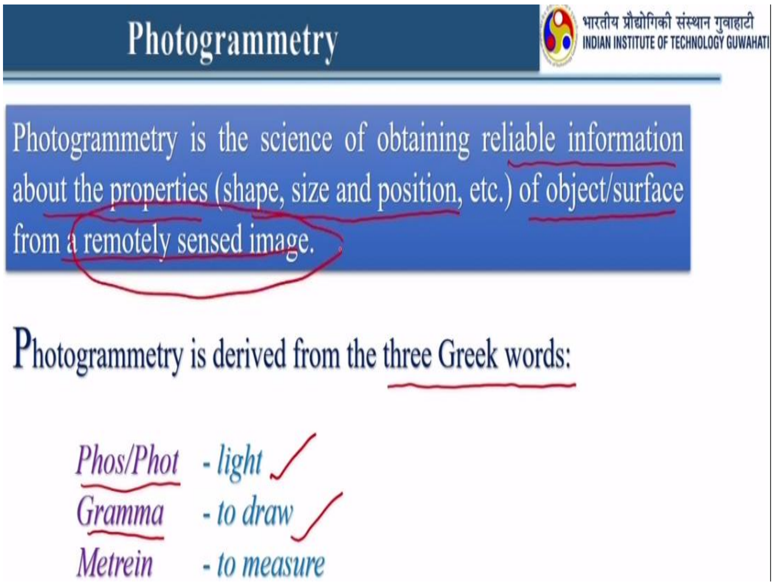


So what do you mean exactly by this photogrammetry term. So photogrammetry is the science of obtaining reliable information about the properties and properties are like shape, size and position of any object or the surface from a remotely sensed image right. So here basically we want to extract the information related to shape, size and position etcetera of an object or the surface which is acquired by the remotely sensed image right.

The photogrammetry term is derived from three Greek words first one is phos or phot that meaning is light. Gramma that means to draw, metrein that means to measure. So basically we want to draw, measure the shape, size and position and other properties of an object or the surface from a remotely sensed image right so that is the meaning of Photogrammetry.

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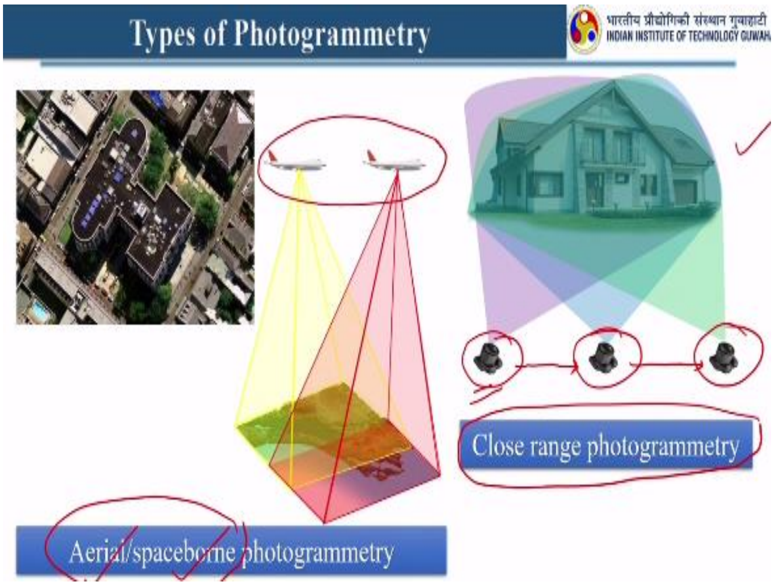


Now there are different types of Photogrammetry so first one is aerial photogrammetry or spaceborne photogrammetry and the next one is your close range photogrammetry. So here you can see different acquisition mode for this different types of Photogrammetry. So let us start with the first one. Here in case of aerial and spaceborne photogrammetry basically we rely on the sensors which are placed in space or in a aircraft right.

And there we are acquiring same area from two different position and that we used to identify the shape, size and other properties of the target. Here in close range photogrammetry let us assume this is my target right and we have sensors with us so first I will pay from this position the image of this house. In the next one I will change the position from here to here and then I will capture the same object and again I can change.

I can move and I can acquire the same target, but the view angle will be different. So tilting will be there for the photograph, but I can capture more information of target if I am changing the position. So this is how we are going to derive this properties of any objects or the target from this photogrammetry.

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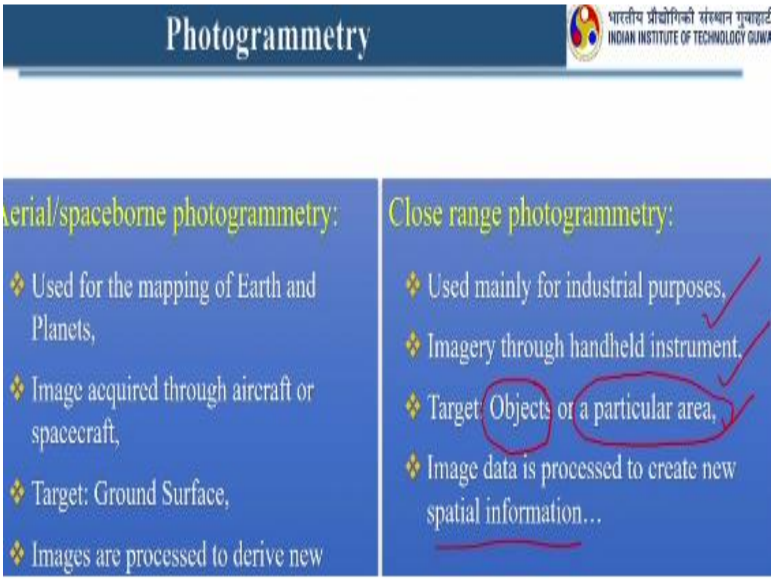


So let us understand what is the difference between spaceborne photogrammetry and close range photogrammetry their strengths and weaknesses. So this aerial spaceborne photogrammetry this is used for the mapping of earth and planets. This is well know image acquired through aircraft or spacecraft. So here the image is which we will be using that will be acquired by any aircraft or maybe from spacecraft right and here the target will be ground surface and the images are processed to derive new spatial information.

So here basically we are talking about the satellite remote sensing, satellite images. In case of close range photogrammetry, we rely with our normal camera or handheld camera or the sensors available to use in the field. So here it is used mainly for industrial purposes where you need more accuracy and then the second one is imagery through handheld instruments. So this is very important this is the major difference between spaceborne and close range photogrammetry and then the target here you can highlight any objects.

Not only ground surface, but you can highlight the object or you can acquire or you can study the objects and you can also focus on a particular area right and here also if you process these images you can derive spatial information about the target very easily.

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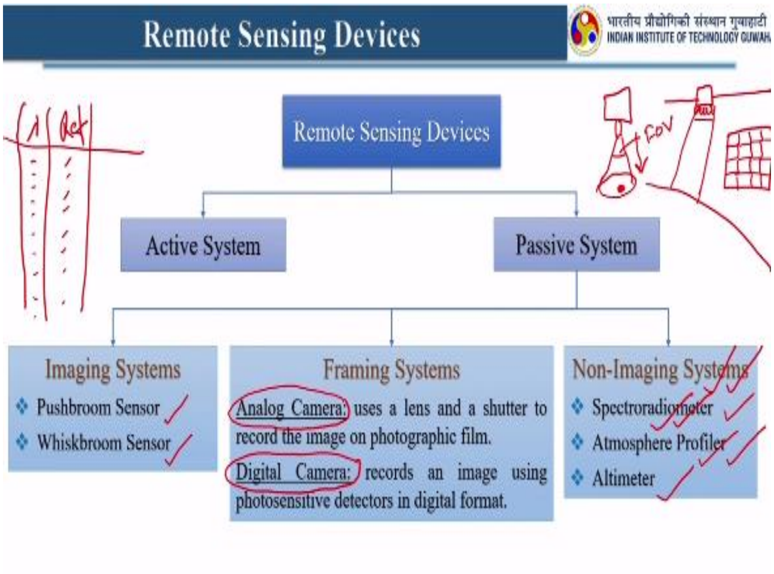


So let us understand what are the different types of devices available in remote sensing. So if you see here we have two different categories. First one is active system and next one is passive system. So I hope you remember this two terms. Active system means you have your own source of light when you are engaged in imaging. In case of passive system, we are using solar energy as source and here if you subdivide this passive system.

So here you have imaging system framing system and non imaging system. So in imaging system basically we have pushbroom and whiskbroom this is known to you right then in framing system analog cameras are used and digital cameras are also used, but in case of non imaging system we have spectroradiometer, atmosphere profiler, altimeter. So what exactly we mean by this non imaging system that I will explain you.

So let us understand the sensors which are launched in the space they are also capable of working on the ground right so in certain environment. So when we have the same instrument for ground measurement then what we do we take them to the field and then we have a fiber-optic cable through which it can sense the energy. So let me redraw this figure and then you will understand it.

So in case of spaceborne satellite we have many detectors attached here right and simultaneously they can see our ground surfaces and the resultant imagery will have pixels right so we can easily generate the image. So this is the imaging system, but in case of non imaging system part of the sensor has been designed to use in the ground. So what happens here you have a sensor and here you can see only one particular area at a time.

So what will be the output you will have values right. So if we are talking about this spectroradiometer so then we can have two columns one will be your wavelength and another will be your reflectance. So in wavelength it is based on the specification of this particular instrument spectroradiometer whether it is designed to capture 100 data in nanometer interval or 20 nanometer interval or 1 nanometer interval depending on that it can measure the reflectance value for the given object.

So here if you see based on the field of view and this is the coverage on the ground. So depending upon the height it will cover your target. So you have to make sure it is seeing your target when you are engaged in acquisition. So in this case you can acquire the response of your target in several wavelength, but that will be only for one particular area so this is called non imaging system right here the output will not be in terms of image here you can generate the spectral profile of your target.

Similarly, atmospheric profiler this is used to see or study the atmospheric constituent using this wavelength. In altimeter also the same principle works so here also we can measure the points right the response of your object in terms of elevation, in terms of atmospheric constituents, in terms of reflectance, in terms of emissivity, in terms of transmittance. So it depends on your application and the instrument you are using you can have several measurement.

So let us understand what are the different advantages or disadvantages of aerial photogrammetry.

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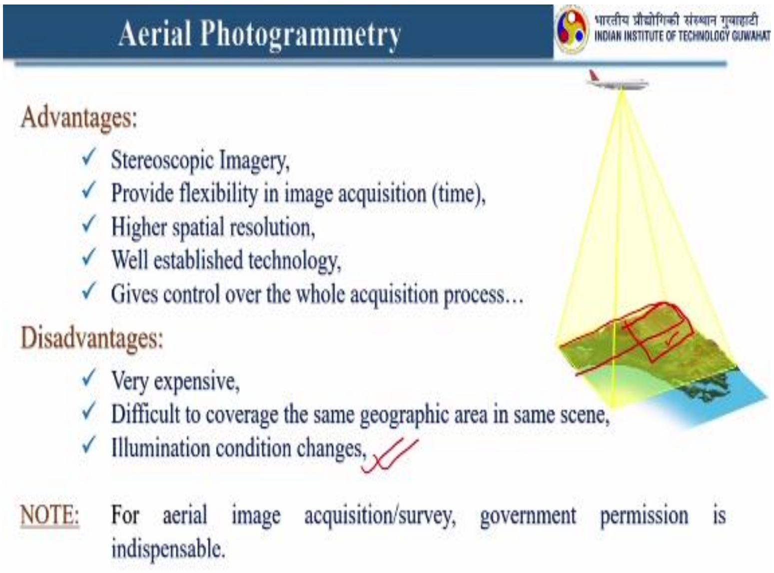


So first advantage of aerial photogrammetry is stereoscopic imagery. So what we mean by stereoscopic imagery that for the same ground suppose this is the target then in the first acquisition you have covered maybe this much area like half of your study area. So this is the first scene. Now in the next scene it should have overlap right. So for the overalap reason you will have extra information captured from different position right then you will have third image and here you will have this rest of the area.

So you can see this area has been captured by first, second and third image. So like that if you have the overalap images then they are known as stereoscopic imagery right. Now the next advantage is it can provide flexibility in image acquisition time right then the third one is higher spatial resolution. Since aerial photogrammetry can be done using this Drones or maybe helicopters or maybe aeroplanes.

So obviously your attitude will be lesser than the spaceborne satellite. So in that case what will happen FOV is there and based on this height the coverage will be much smaller. So when you have smaller coverage area then the pixel resolution or the spatial resolution will be very high and it is a well established technology. Next point is it gives control over the whole acquisition process.

So here basically what I mean you will have the full control of this image acquisition in terms of timing whether you want to do it in the morning or in the afternoon or maybe in the evening or maybe in the night. Depending upon in which wavelength you are working and what is your application right. So like that you will have many other flexibilities when you are going for aerial survey or aerial photogrammetry.

Next is disadvantages in disadvantages it is very, very expensive because we have to hire Drone or maybe you have to buy a Drone, you have to hire a helicopter or aeroplane then sensors you have to buy so everything becomes very costly. In the next point it is very difficult to cover the same geographic area in same scene why because suppose if this is your study area this was the first acquisition.

In the next acquisition basically what you did you change the position and from here you have capture. So you have to maintain the position so that in the first it has acquired this. Second I want to acquire this only right not like from here so you require very high precision here. So it will be very difficult it is not a very easy task so that is why it is difficult to cover the same geographic area in the same scene.

And one more thing you may want to capture this particular area in your first scene, but depending upon the attitude and the FOV you are using maybe the first scene may cover only this much area right. So this particular object can be captured in two images not in one so that is again the another limitation of this aerial photogrammetry and illumination condition changes with time.

Because sun is moving if you engaged in passive remote sensing illumination condition always changes with time based on the suns position so you have to correct for the illumination errors. Now the next is it is very important to note that for aerial image acquisition or survey government permission is essential. You cannot go directly and fly aircraft and you can capture this. So you need to have proper permission for this.

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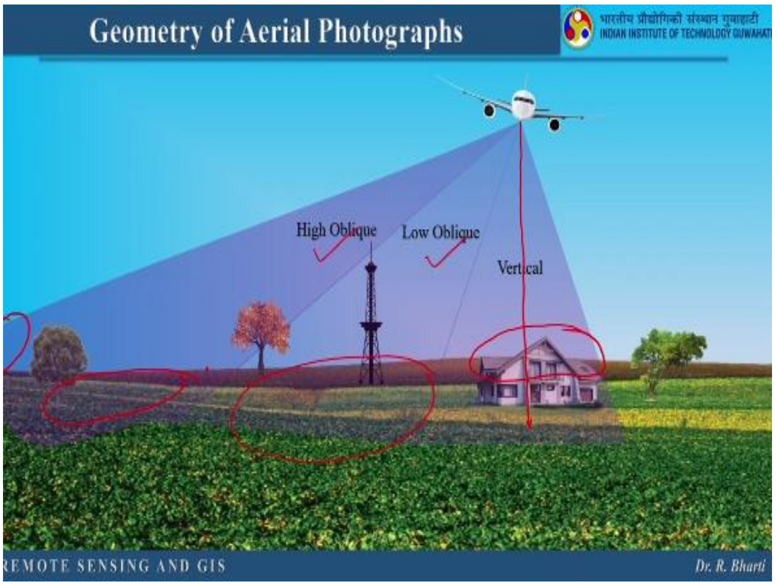


Now let us understand what are the different geometries involved in aerial photographs assuming this is my study area and this is my aerial survey vehicle and here if you capture in this mode where you can see the sky or part of sky along with your features right they are known as high oblique photographs. In low oblique photographs you cannot see sky. This is the basic difference between high oblique and low oblique photograph.

So in high oblique you will have some portion of sky whereas in low oblique you will not capture any of the sky you will have only ground. In case of vertical photograph, you are actually following the Nadir right. So Nadir will be the center of your photograph so if you do that then only the rooftop of this particular house will be visible in your vertical photograph.

Whereas in low oblique and high oblique photograph you can see the base as well as sides of the objects. So this is the basic difference between vertical, low oblique photographs right.

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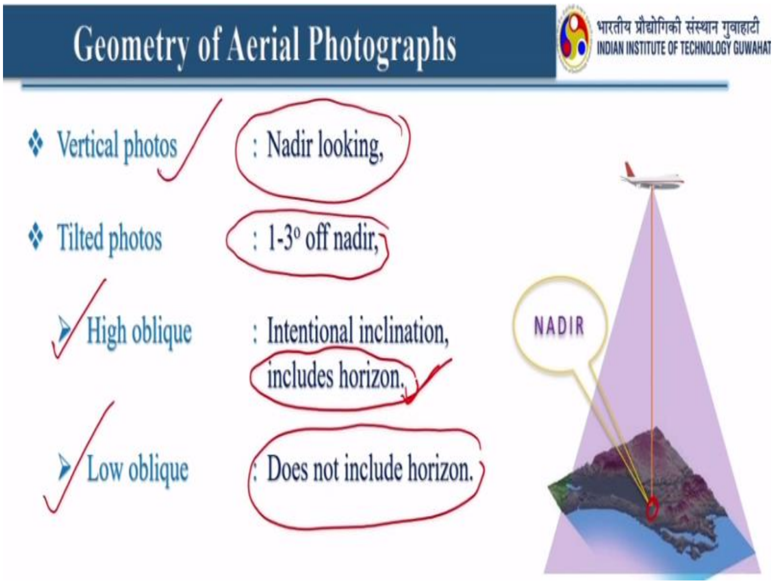


Let us understand in detail these vertical and oblique photographs. So here in vertical photos basically it is Nadir looking this is very important. Then in tilted photograph and which is basically 1 to 3 degree of Nadir that is the minimum requirement then only it qualifies for this titled photographs right and in titled photograph you have to category first one is high oblique and second one is low oblique and here this is the major difference.

So it includes horizon. So in low oblique photograph horizons are not included whereas in high oblique horizons are included. So you can see here this is basically the vertical photograph, but how do we say this is a vertical photograph because we have checked the Nadir position. So if you see the Nadir lies on the center of this photograph then only this will qualify for this vertical photograph right.

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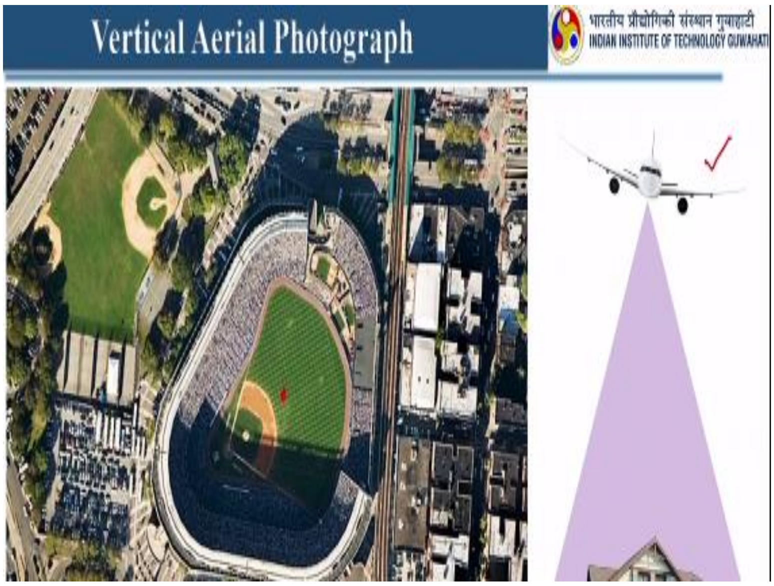

Let us see one by one how this vertical photograph or Nadir looking photographs give you the output. So assuming this is my target and this is my aircraft and through which I am going to capture this house. So let us assume this is the Nadir looking image. So in the Nadir looking image you will see the rooftop of the object right or the buildings which are in the center of the image.

Whereas as you go away from the center you can see some of the sides of the objects. So here you can see this is approximately Nadir position of this photograph.

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But if you see the titled photograph, low oblique photograph you can easily see this sides. So this can give you some perception about the height.

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If you see the next category that is the high oblique aerial photograph. So here you can easily find sky so horizons are included in high oblique aerial photograph so you can try this your own. If you take your normal camera or maybe mobile phone you just pinpoint your target on the table and from that you maintain the 90 degree and capture that. You can see only the top, but as you tilt your camera you can see more objects and slowly if tilt more you can see the horizons in the outdoor right.

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There is a concept called overlapping stereo photography. I have discussed this before also, but I want to explain in detail what exactly we mean by overlapping stereo photography. So let us assume again this is my study area and I have aircraft through which I have started capturing this area. So first image will have this so first image will be something like this output of this first sensing then when we move our aircraft.

Then it will capture from here to here right then again we are moving then it will capture from here to here right then we are capturing from here to here then we are capturing from here to here. So you can see there is always a overlap so these overlap will help you in your study that you will understand slowly, but basically here we are moving in this direction right and always we have some overlap in the next image right.

So it will appear something like this so you will have all the images with some overlap and then you can call it overlapping stereo photographs. So why we need this overlapping stereo photograph this is required for this 3D viewing. So if you want to generate a 3D map of an area or of an object then we need to capture all the sides including top then only you can generate the 3D images or it can also help you to study the parallax and what do you mean by parallax that we will see.

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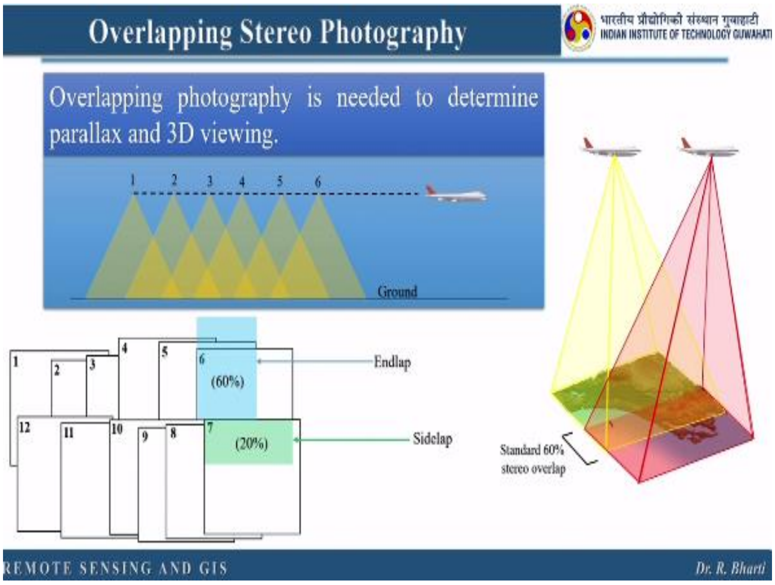


This is sample example I have put here. So here you are having all the images captured like this and then it has moved and it is going like this your aircraft. So here in this particular photography we maintain Endlap 60% so all the next images will have 60% image which is captured in the previous one and once you move to cover this whole area then the sides also they should have some overlap.

So it is something like this when you are capturing this one so this overlap is basically 60% and which is known as Endlap and when you are moving and again you will capture the next portion of this area then this particular portion will be overlap so this should be 20% and they are known as Sidelap. So this is the difference between Sidelap and Endlap and when you are going for a overlapping stereo photography.

Then you should maintain at least this 60% and 20% then only you will be able to generated this 3D or you can study the parallax and parallax will be used further in estimation of height of any object capture in that particular scene. So here you can see this is another example where this particular repetition in the first and second scene is 60% right. So let us understand what is the difference between vertical and oblique aerial photographs and what we can do with vertical and oblique photographs.

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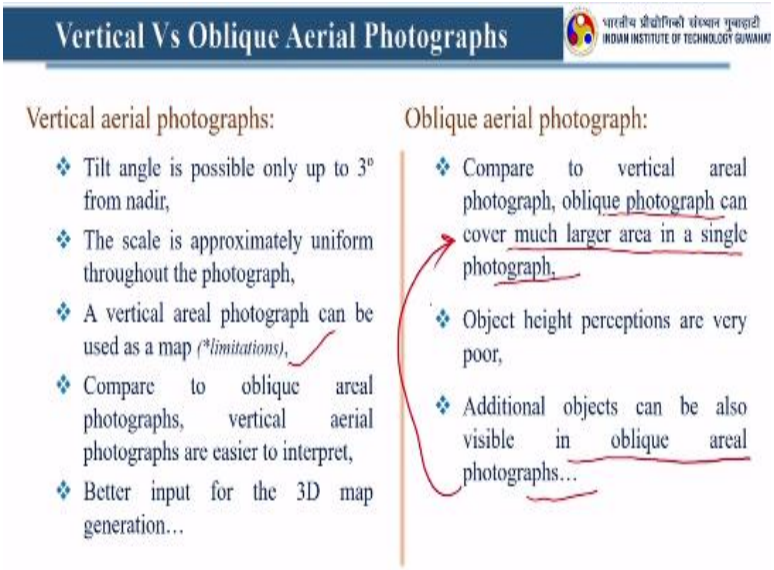


So in vertical aerial photographs tilt angle is possible only up to 3 degree from Nadir. So in vertical photograph up to 3 degree is allowed. In vertical aerial photograph the skills is approximately inform throughout the photograph why because you are going to measure this area from the top and this is basically 90 degree right. So if you see this is your center of the image so you will see the top of your building here.

But as you go away there will be slight change in the position so you can see little bit of the sides of the corner buildings right. So but assuming that this is very less or negligible and it is up to 3 degree only then we say that this is a vertical aerial photograph. A vertical aerial photograph can be used as map because you are saying from the top and there is no distortion involve in this vertical aerial photograph.

Compared to oblique aerial photograph vertical aerial photographs are easier to interpret because you know what is the spatial resolution what is the distortion what was the position of aircraft or spacecraft and what are the different objects you are going to study so it will be relatively easier and better input for 3D map generation and once you know more information about your object or your image the correction will be easier and it gives you better 3D output.

But when you go for this oblique aerial photograph your advantages are different and there will be certain disadvantages, but you have to decide basically what kind of photography you want to do. So compared to vertical aerial photograph oblique photograph can cover much larger area in a single photograph this is the main advantage right then object height perceptions are very poor.

So here when you are tilting your camera you cannot say directly like this is the height of this building right because everything is proportional changed and there will be some error introduced by your tilting and the sensor. So object height perceptions will be very poor. Additional objects can also be visible in oblique aerial photograph because you are going to cover more area right.

So as I told you that this photogrammetry is to derive the properties of your objects or the ground using this stereopairs right or the aerial photography. So here basically we want to identify or we want to estimate the scale if you know the scale everything will be easy. So let us understand what are the different types of scale you can use and what are the different application you have when there are certain known factors or known variables or known values are with you right.

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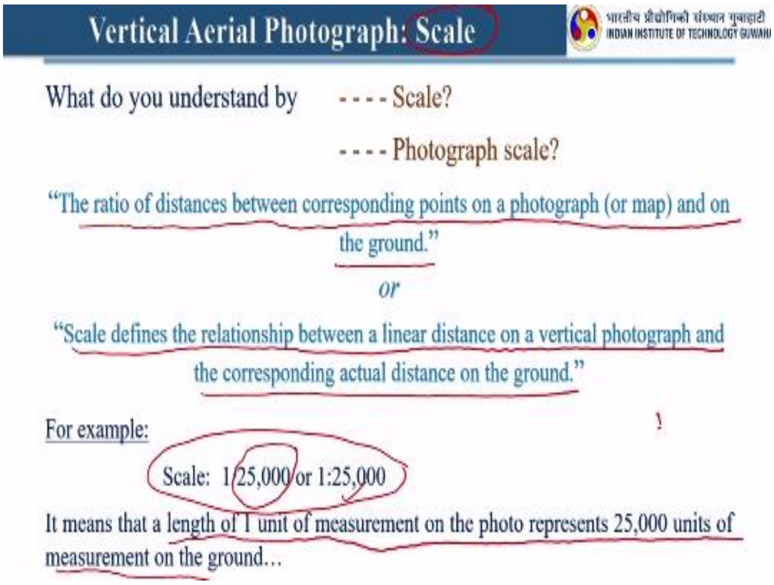


So let us start by what do you understand by scale and that too photograph scale because now we are talking about the photograph. So here this is the ratio of distances between corresponding point on photograph which is basically map and on the ground right so this is the ratio and in other words scales defines the relationship between a linear distances on a vertical photograph and the corresponding actual distance on the ground right.

I hope this is very clear this is very simple statement so you can understand easily. Now let us see some examples like scale you might have come across this particular values like scale people write 1:25,00 or 1/25,000. So what does it mean? It indicates like one unit on the image is basically 25,000 unit on the ground unit is it depends like if you are using meters, centimeter, inches so it is up to the photograph and what scale you are using.

So it means that a length of one unit of measurement on the photo represents 25,000 units of measurement on the ground. So if we are talking about the satellite images or aerial images we know the pixel size you know this spatial resolution so you can easily say that this is the size of one pixel and one pixel or maybe one object which is on the ground maybe one meter, but in image it is coming one inches.

So one inch on the image=1 meter on the ground so that will be your scale and that you can represents as 1:250,000, 25,000, 1:1, 1:2, 1:3 so you can use whatever values you get from your image.

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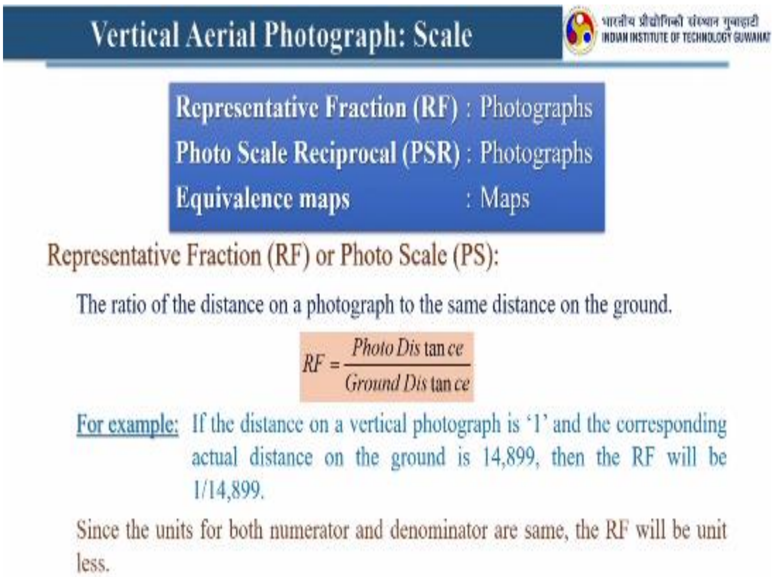


So let us see there are few terms which you need to understand first one is representative fraction RF. So now onwards I will call it RF so that is for the photographs then photo scale reciprocal that is also for a photograph and equivalence map right. So that is for the map now let us see one by one what they exactly mean and how do we calculate them. So first one is representatives fraction or photo scale both are same.

The ratio of the distance on a photograph to the same distance on the ground that is known as RF and here you can simply take the photo distance and ground distance. Again this is your image and there is a house right. So on image you know what is the distance between this to this wall if you have a high resolution data then let us assume this is coming may be 5 pixels. So 5 pixel that means

5 pixel into spatial resolution right. So if that is 5 into 2.5 centimeter spatial resolution so that will be your distance on the image and in the ground you can easily measure this. So maybe let us say this is maybe 30 meter right so this is 30 meter. Now this value represents 30 meter on the ground. So here photo distance will come and here ground distance will come like that you can easily calculate the RF right.

For example, if the distance on a vertical photograph is 1 and the corresponding actual distance on the ground is 14,899 then the RF will be 1/14,899 both values are having same unit so RF will be unit less. When you do not have the information about that object that what is the size or what is the distance of that on the ground then how you can calculate this RF for that we use this formula.

That focal length/flying height so this will give you again the RF right. So for calculation of RF either you should have the photo distance or the ground distance, focal length flying height then you can calculate the RF value right.

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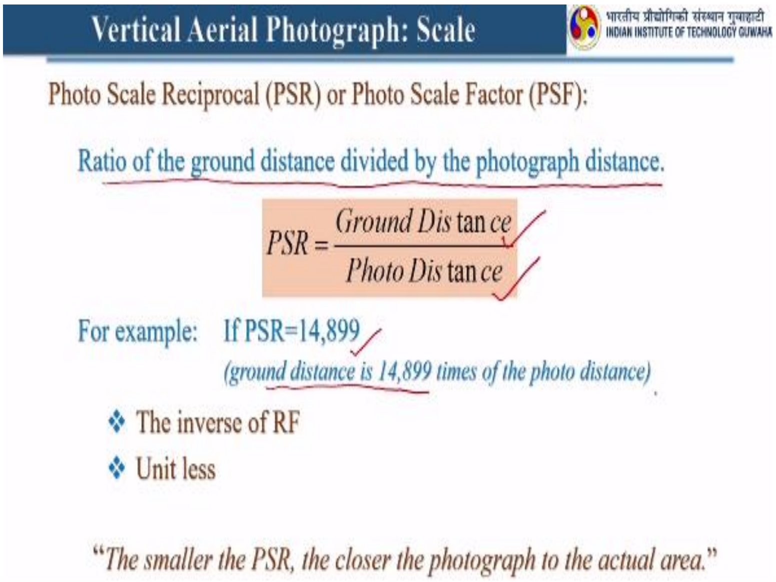


The next scale is photo scale reciprocal that is known as PSR or photo scale factor that is PSF right. So this basically the ratio of the ground distance/ photograph distance. So PSR is ground distance/photo distance and for example PSR is 14,899 that means ground distance is 14,899 times of the photo distance so this is basically the inverse of RF and this is again unit less. The smaller the PSR the closer the photograph to the actual area.

So if the PSR is very less then that means photograph and the real object they are having similar dimensions right.

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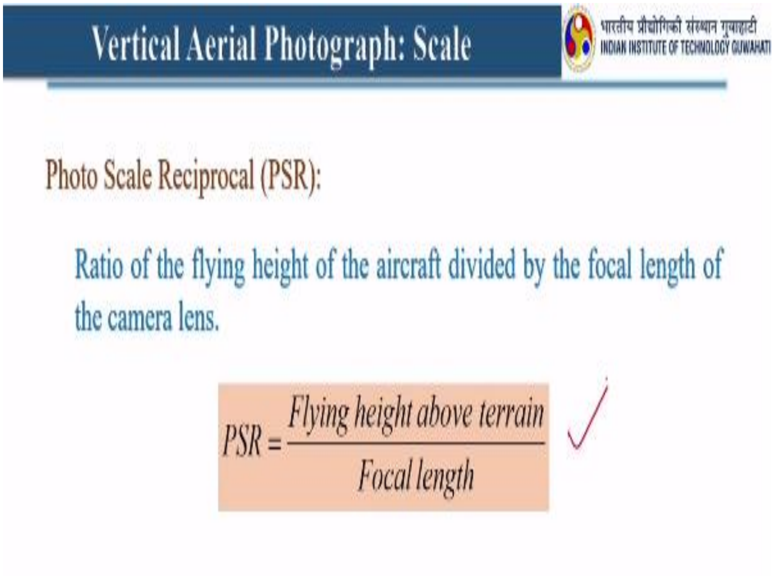


Similarly, PSR can be calculated using this focal length and flying height using this formula right.

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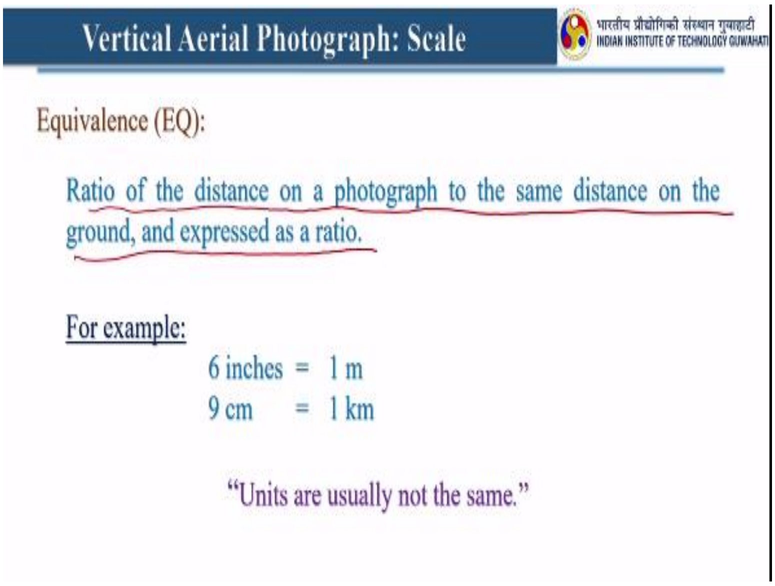


Now let us understand equivalence. So ratio of the distance on a photograph to the same distance on the ground and expressed as a ratio. So here basically ratio of the distance on a photograph to the same distance on the ground and expressed as a ratio right. So for example 6 inches=1 meter or 9 centimeter=1 kilometer and usually these units are not same in equivalence.

So you have seen the scale different scales we use in photogrammetry, but what is their variation how they vary with respect to ground.

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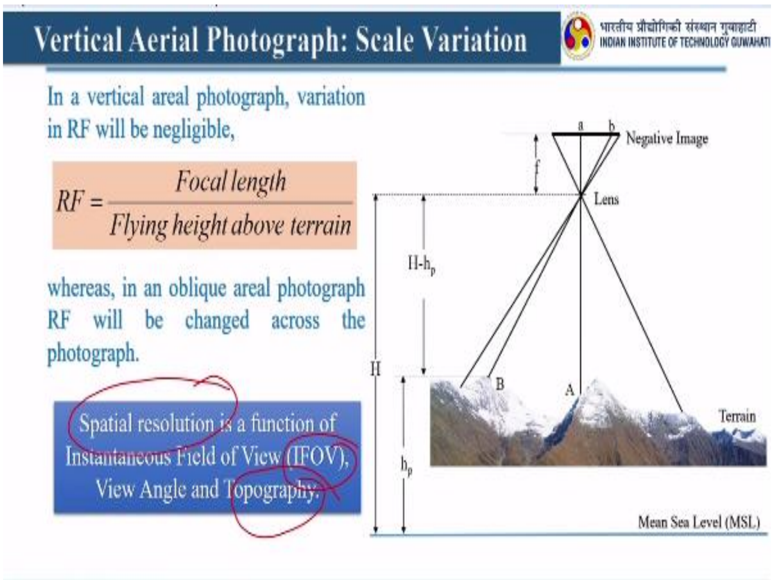


So apart from this scale there is very important to understand this variation because scale we identify for a particular object or for a particular scene but on ground we have this elevation different. So do this scale is consistent throughout the scene or they can vary place to place so that you need to understand. So in a vertical aerial photograph variation in RF will be negligible right because in vertical aerial photograph we assume distortion is very less and we are seeing from the top.

So we assume that RF variation is negligible so you can use this focal length and flying height above the terrain right whereas in oblique aerial photograph RF will be changed across the photograph because you have tilted the camera and then you have acquired the target. So here if you see even in the vertical photograph you can see the effect of topography. Since this is snow you cannot see this.

So here if you calculate scale here if you calculate the scale here if you scale here, if you calculate scale here, if you calculate here that will be different why because you have to take care of the topography right. So in that case you need to calculate scales at different places even in a single image. So spatial resolution is a function of IFOV view angle and topography.

So this gives you a hint like how it can help you to estimate the scale because every time you are going to calculate the photo distance so it depends what was the elevation of the ground at that particular position and what is the spatial resolution acquired by your sensor at that particular location because that is going to change the scale right because as you see the topography on the spatial resolution it is basically IFOV and this elevation.

So it is very important to understand what is the effect of spatial resolution and IFOV and topography and then elevation right.

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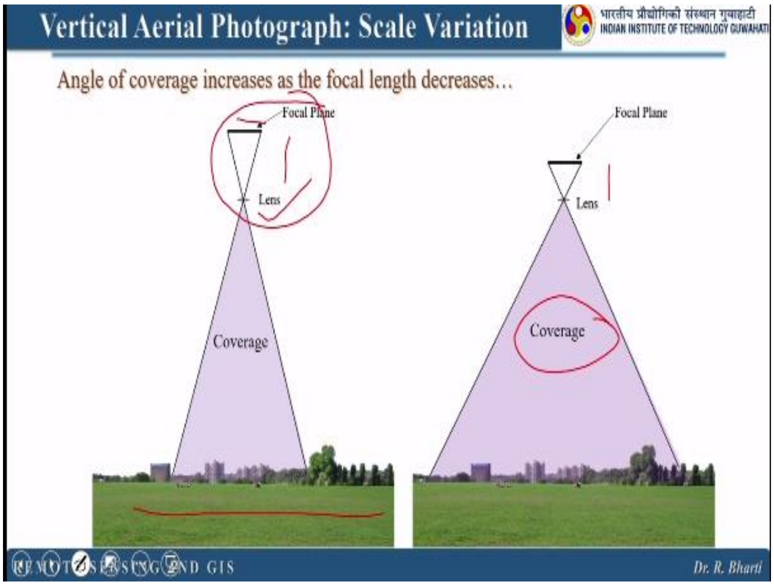


So this is one example I have put to understand what is the effect of focal length on the acquired image. So if you see here we have this is the focal plane, this is the lens and this is the area which we want to capture. So here you can see this is different and this is different. So if you see the coverage of this particular setup or this particular instrument is basically less.

But whereas if you see this is the coverage for the same area when we have changed the FOV and this is the effect when we have changed the focal length right. So angle of coverage increases as the focal length decreases. So I hope you must have understood this.

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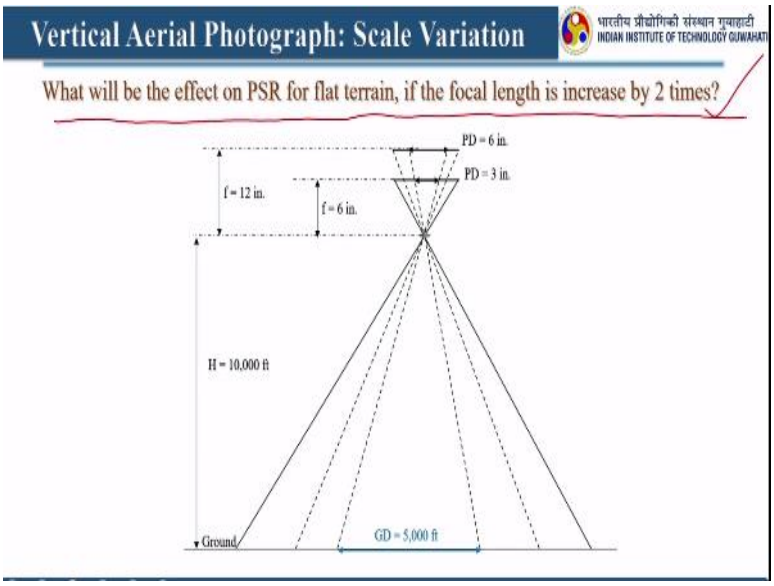


Now let us see some examples so this is one question for you that you can answer you can try and the answer is already given in the next slide, but before going to next slide you please try this one yourself and then see the answer. So here the question is what will be effect on PSR for flat terrain if the focal length is increased by 2 times.

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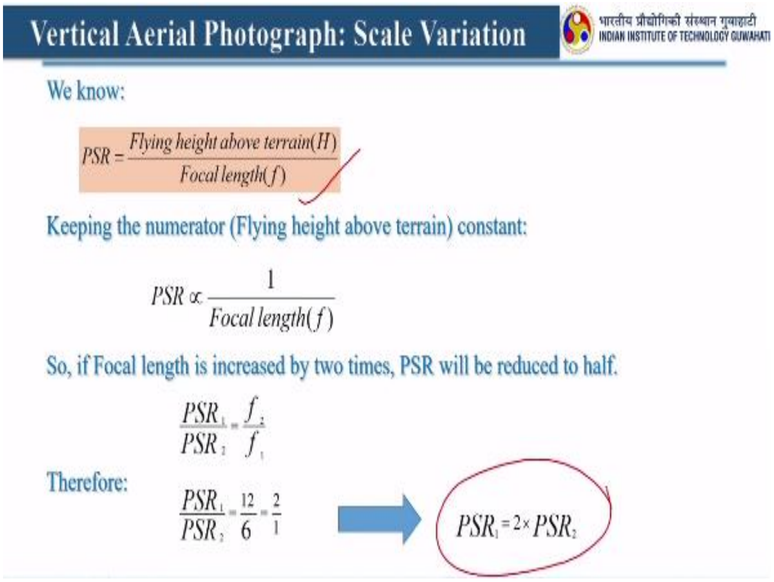


So here we know PSR= flying height above terrain/focal length and keeping the numerator flying height above terrain constant PSR is directly proportional to 1/focal length. So if focal length is increased by 2 times PSR will be reduced to half. So therefore there will be change in the PSR with this right.

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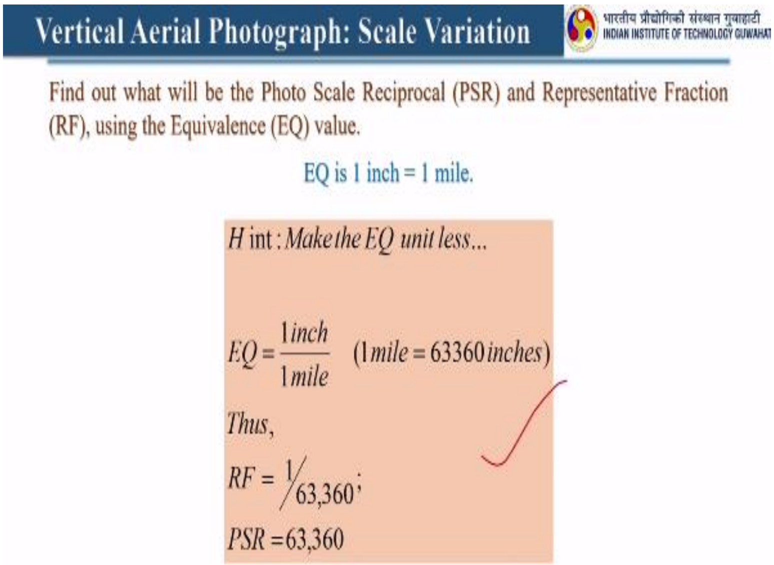


Now the next question is find out what will be the photo scale reciprocal and representative fraction that is RF using the equivalence value right an equivalence is 1 inch= 1 mile. So here this is the solution you can go through it, you can calculate it because this is very simple you just have to correlate your basic understand with the problem. So you have seen the different scale.

And you have also seen what is the effect of height, topography and change in the focal length on the image and how do we analyze them.

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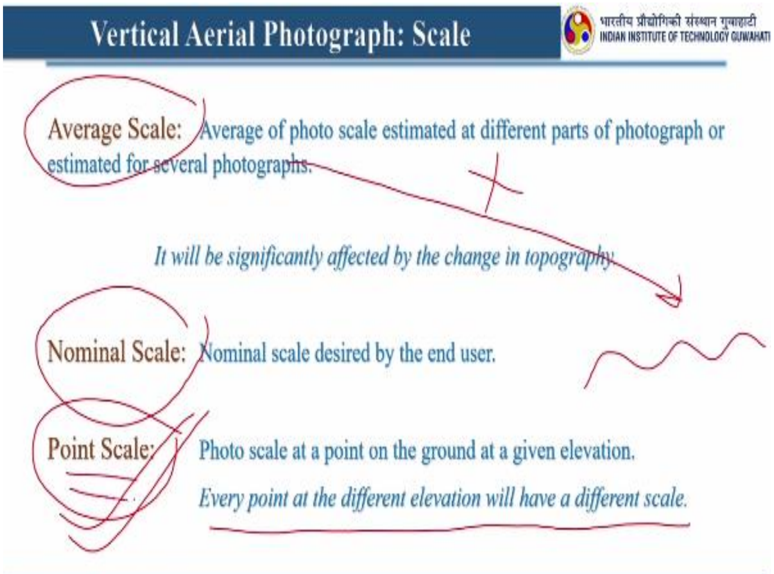


So let us understand different types of scale which are available. So average scale is for the whole image right because sometimes you have to report what is the average scale or the scale of this photography, but sometimes you have use nominal scale. Sometimes you have to use point scale when your surface is very undulating you cannot use this average scale here that will be wrong. So in that case it is better to go for the point scale right.

So in point scale every point at different elevation will have different scale that advantage you will have when you are using this point scale.

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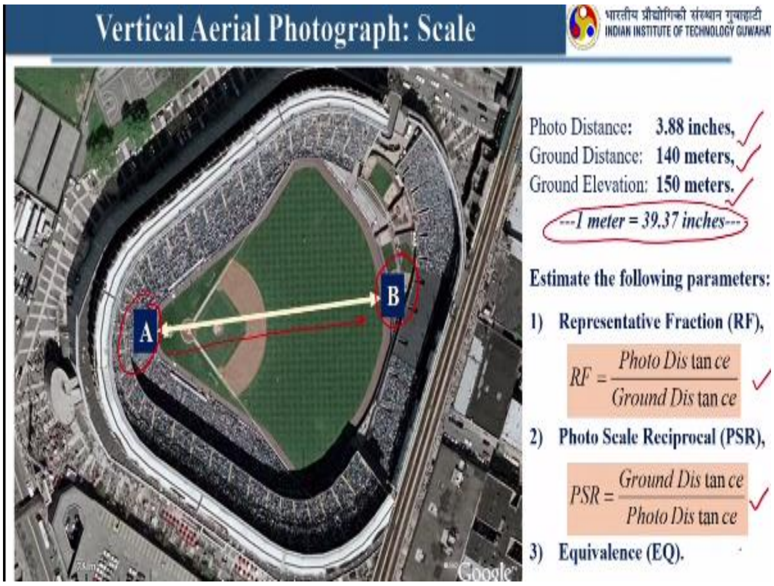


So for a vertical photograph I have taken this A and B location and their distance right. So you can easily measure the distance between these two points on the photograph based on the spatial resolution and assuming we have the ground distance we have visited that particular place and you have calculated the distance between these two or you have measured that. So here we have few known like what is the photo distance, what is the ground distance then ground elevation.

And here basically this is the hint right. So here what you have to calculate you have to calculate representative fraction then photo scale reciprocal and then equivalence how do you calculate using these formulas.

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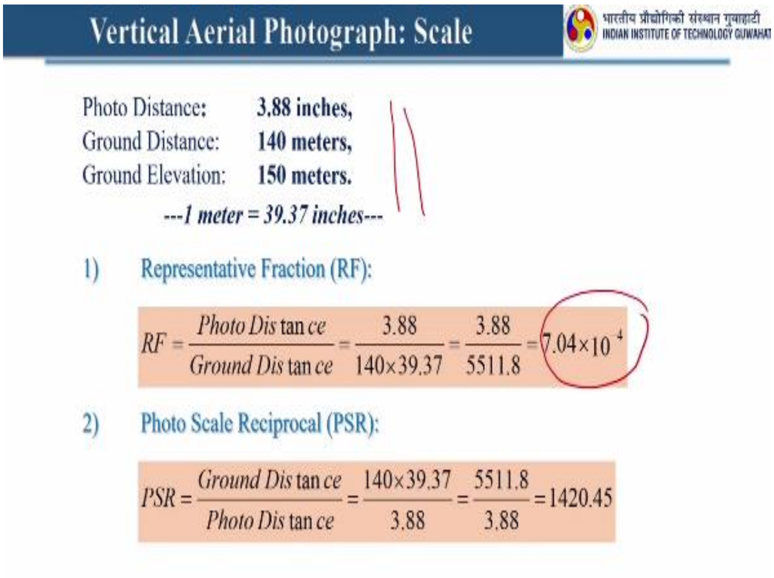


Now let us see we have all this known right and for representative fraction for RF you can use this formula and the values will be like this right for photo scale reciprocal this is the value. So all these problems you can try yourself before seeing the answer and then you match your answer whether it is correct or not then you will learn more.

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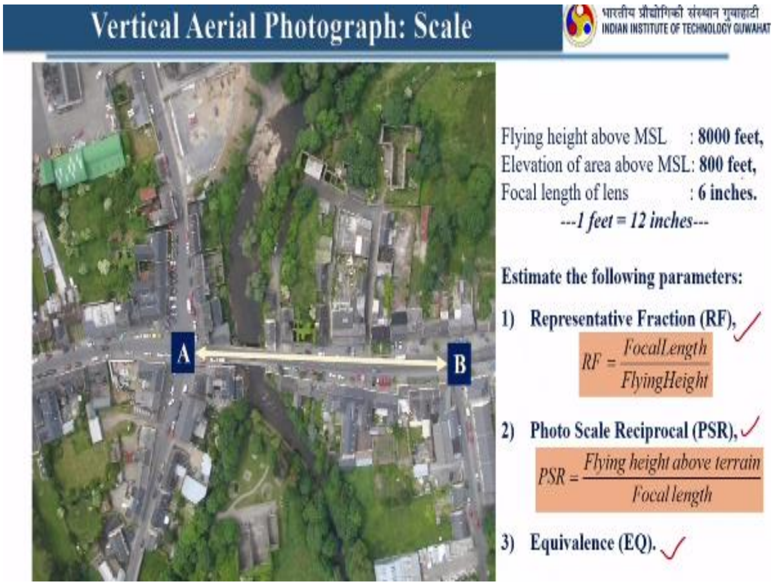


In this particular case I have kept this A and B here and they are separated with some distance and here we have flying height above MSL that is 8,000 feet. Elevation of area above MSL that is 800 feet, focal length of lens that is 6 inches and here you have to calculate RF, PSR and EQ and you just see the next slide after you have done with the calculation.

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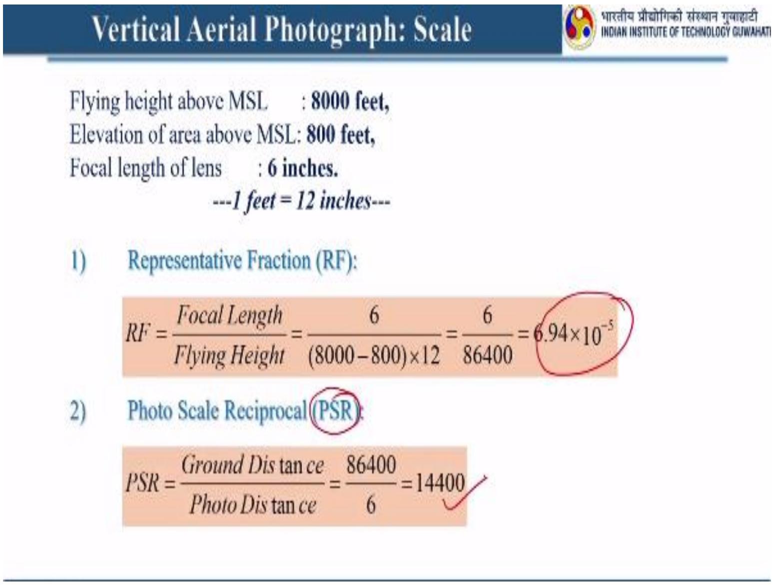


So here you can calculation RF using this formula this will be the value and for PSR this will be the value right. So just calculate and check your answers.

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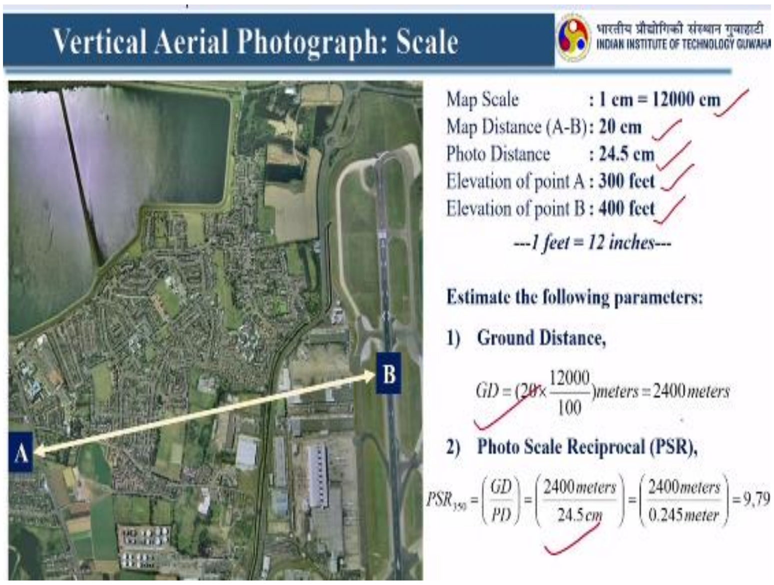


Here this is another example where AB are separated with this line and here you have map scale, map distance, photo distance, elevation of point A that is 300 feet and elevation of point B that is 400 feet. Now how do you calculate ground distance, photo scale reciprocal that is PSR right so you can calculate using this and PSR you can calculate using this.

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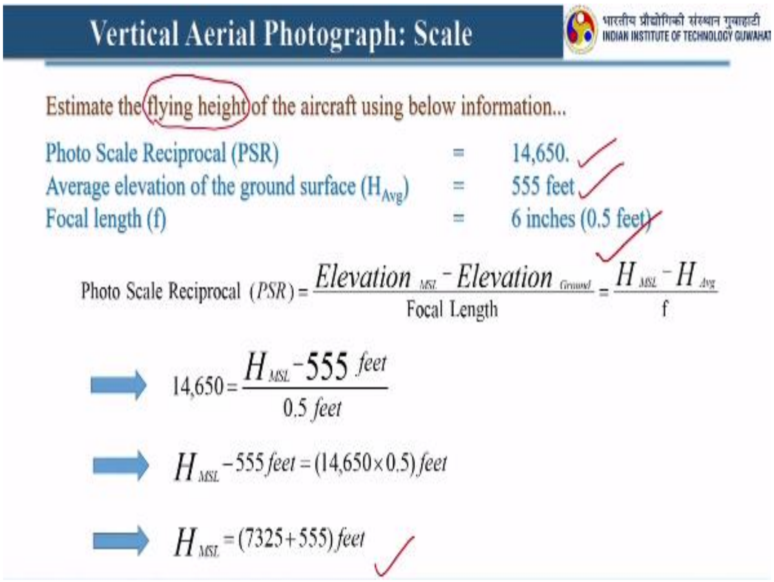


This is another problem where you have to estimate the flying height of the aircraft using following information. So here you have photo scale reciprocal average elevation of the ground surface and then focal length right. So how do you calculate the flying height now this is the reverse problem. Now you can always use the same equation by changing it and then you can calculate what is the flying height of your craft.

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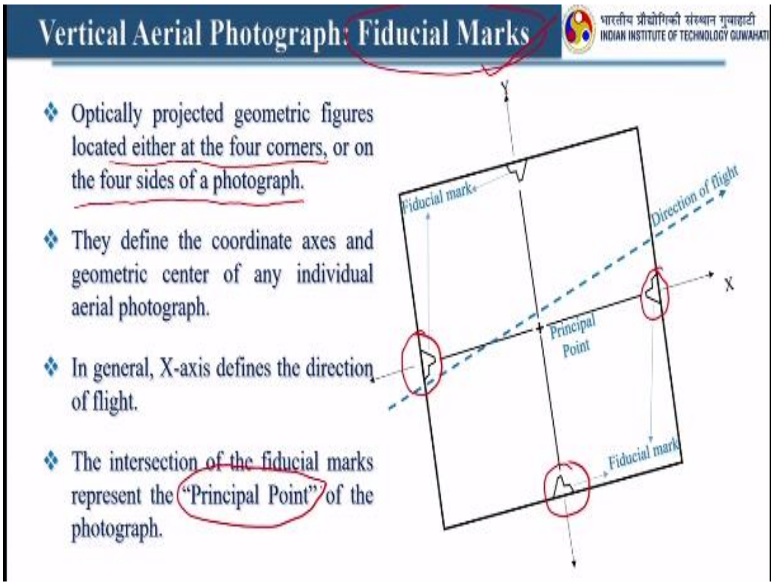


So when remote sensing started we started with the normal camera if you find old vertical aerial photographs you will find there are several marks printed on the photographs. This I am talking with respect to printed aerial photographs right and here we are talking about Fiducial mark. So optically projected geometric figures located either at the four corners or on the four sides of the photograph and they are known as Fiducial marks.

The define the coordinate axis and geometric centers of any individual aerial photograph. In general x axis defines the direction of the flight. The intersection of the fiducial mark represents the principle point of the photograph right. So that is the center of your image by joining these fiducial marks.

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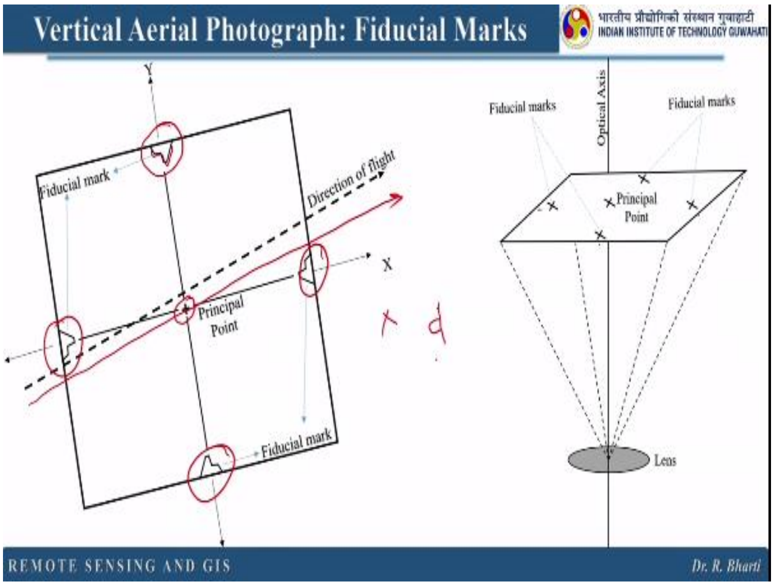


So if you join them these are fiducial marks. Now if you join them you will find your principle point lying somewhere in the center of the image right and in general this defines the direction of the flight which is mentioned here and this has been captured like this. If you see this is your lens, this is the principal points and these are the fiducial marks. So sometimes you may find this kind of shape sometimes you will find some cross sometimes it will be like this right.

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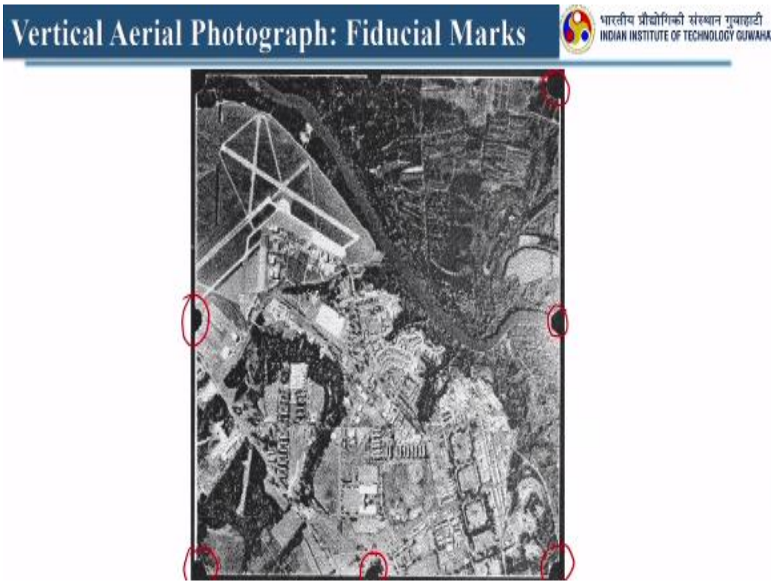

If you see this photograph these are basically fiducial marks and it is very easy to locate on the image and if you join them, you will find the principal point.

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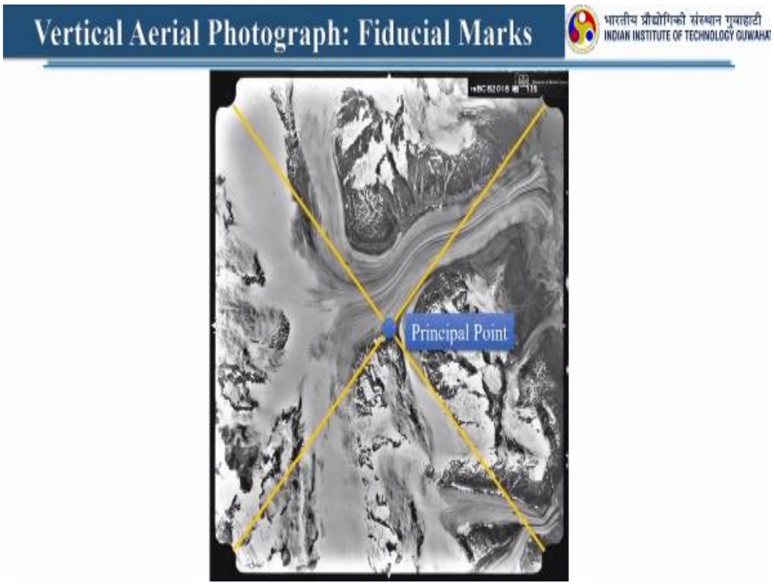


Here this is another examples these are again fiducial marks this is another example and when we join them we find principal point right. So it is very important to note that when you are joining the opposite corner fiducial mark and the center where they are crossing each other that point is known as principal points.

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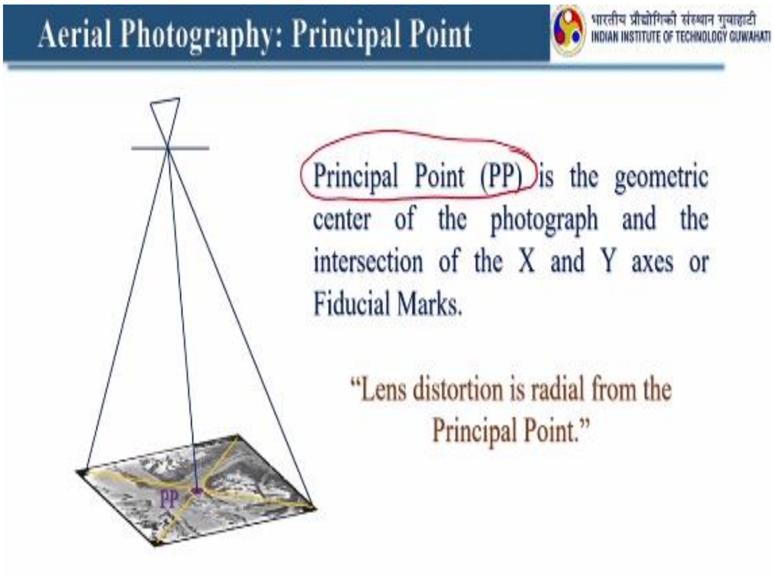


So in image basically it will look like this right so principal point is the geometric center of the photograph and the intersection of X Y axes or fiducial marks. So it is very important that you should able to identify principal point PP in your photograph. Lens distortion is radial from the principal point. So lens distortion will be minimum at principal point. So as you go away your lens distortion will be more.

Let us see whether this principal point and Nadir whether they are same or different. So in a oblique photograph your principal point will be somewhere else in a vertical photograph your principal point will be somewhere else for the same area. So it is definitely the different points on your image.

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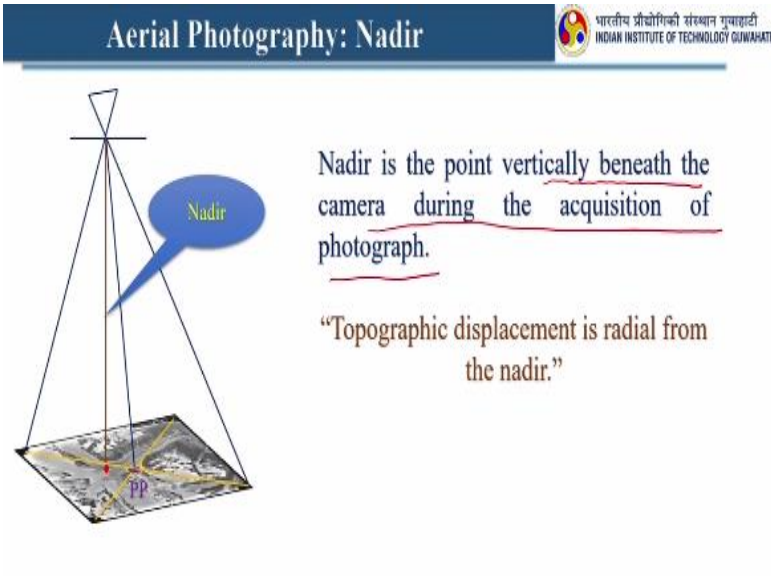


So Nadir is the point vertically beneath the camera during the acquisition of photographs right and here if you see this is the Nadir point so they are definitely different from each other right and topographic displacement is radial from the Nadir. So topographic displacement will be very less at Nadir as you go away of Nadir you will find more topographic displacement.

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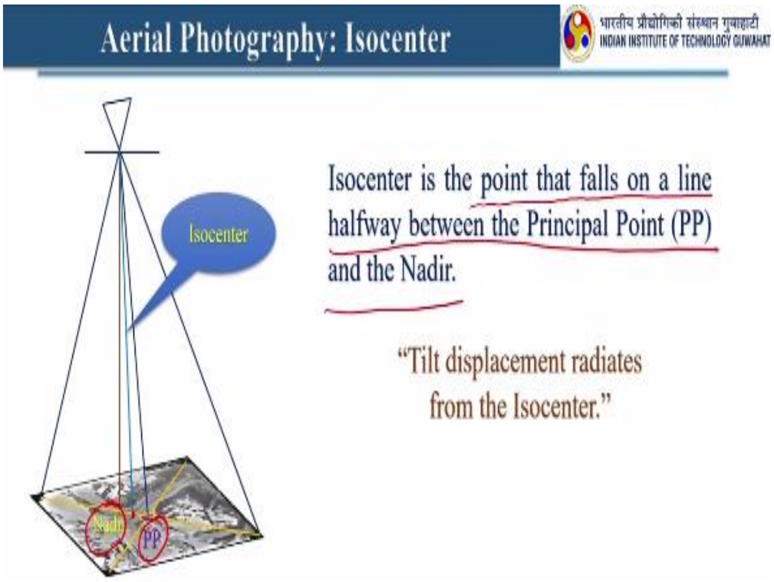


And there is a new term called Isocenter here. So you have already seen this principal point and Nadir right. Now we have another point which is called Isocenter. So Isocenter is the point that falls on a line half way between the principal point and the Nadir right so where here. So this is your Isocenter. The tilt displacement radiates from the Isocenter. So now the tilt displacement will be minimum at Isocenter.

But as you go away you will find more tilt displacement. So I hope you have understood the principal point. Now here basically we find principal point for two different images they are basically stereopairs. So stereopairs are like 60% overlap will be there. So in the first image you see this particular feature is coming here, but in the next photograph it is coming here right.

In the previous photograph this feature was here in the next photography it is coming somewhere else right. So what we will do we will start marking the principal point on the first image.

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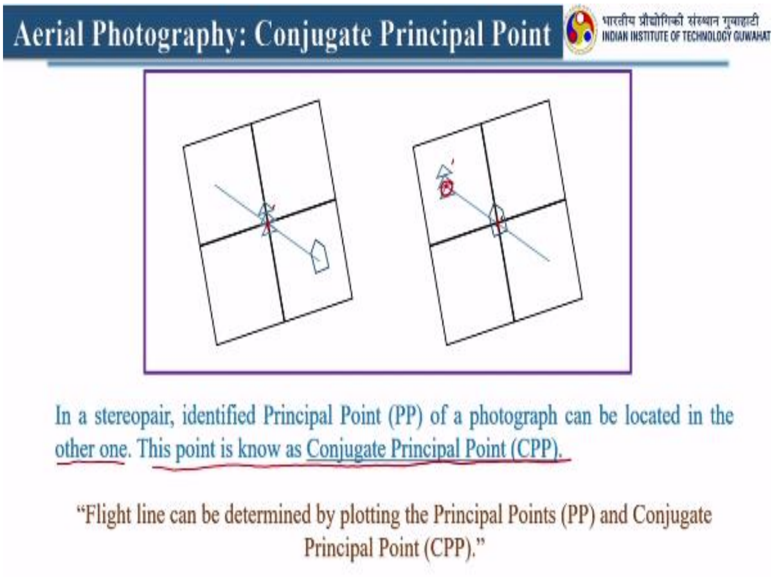


So here if you are marking this as a principal point by joining the fiducial marks then in the next image also you will find this principal point. Now where this principal point is coming in the next image that you need to find. So suppose we have marked this so this will be here right. So here this point will become conjugate principal point right. So in a stereopair identified principal point of a photograph can be located in another image right this point is known as conjugate principal point.

I hope this is very clear to you. So flight line can be determine by plotting the principal point and conjugate principal point in a line. So if you plot this then this is the direction of flight.

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The shift in position of a landscape feature on a photograph that alters the perspective characteristic of the image. So film and print shrinkage that is negligible. Atmospheric refraction of light rays that is also negligible motion of the landscape feature that also we consider it is negligible because we are maintaining that speed. Now the next is lens distortion so lens distortion we cannot ignore.

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So how they appear in the image so you can see this particular area right. So you will find this curve effect that is one example of this lens distortion. So here if you want to do some kind of study or if you want to find out the pixel size they are different across this image right. So you cannot really use this lens distortion image. So let us understand in terms of principal point, Isocenter, Nadir how this lens distortion occur right.

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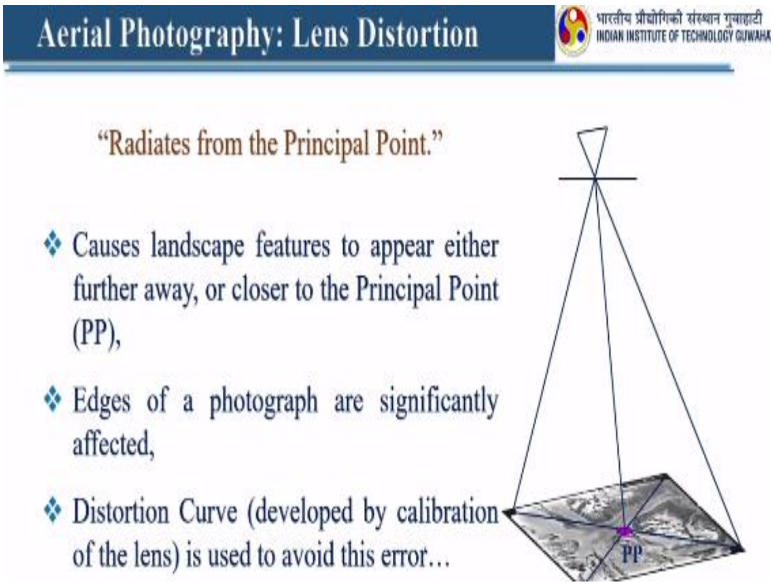


So this lens distortion radiates from principal that you are familiar with this PP right and it causes landscape feature to appear either further away or closer to the principal point. Edges of the photograph are significantly affected you remember last slide and distortion curve developed by calibration of the lenses is used to avoid this particular error.

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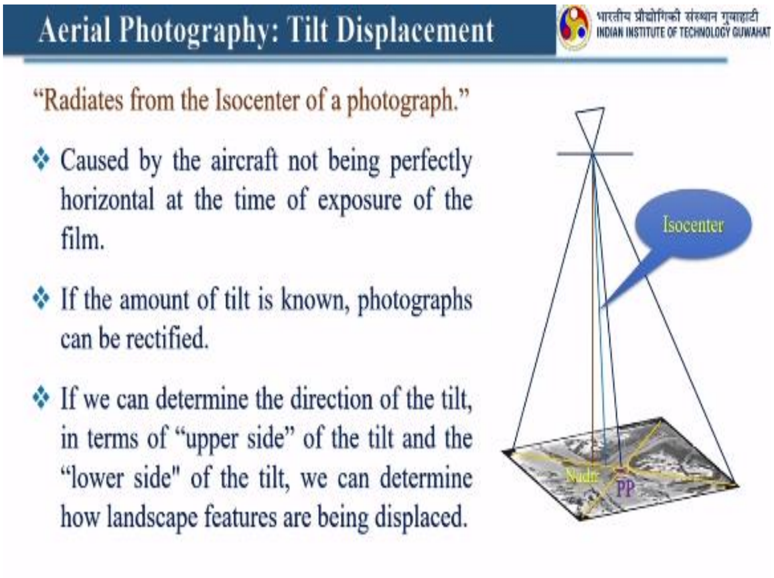


Then the displacement is the shift in the position of the landscape features that does not alter the perspective characteristic image. So here again curvature of the earth is negligible, tilt and topographic relief. So tilt displacement it radiates from the Isocenter of a photograph so here this is the Isocenter it is caused by the aircraft not being perfectly horizontal at the time of exposure of the film right.

If the amount of tilt is known photographs can be rectified if we can determine the direction of the tilt in terms of upper side of the tilt and the lower side of the tilt, we can determine how landscape feature are being displaced.

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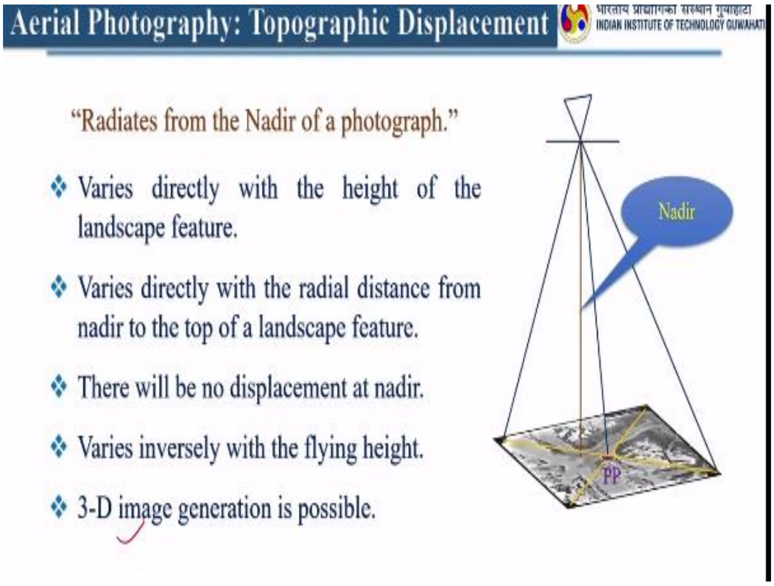


The topographic displacement they radiates from the Nadir of the photograph. So here we have Nadir varies directly with the height of the landscape features and varies directly with the radial distance from Nadir to the top of the landscape feature. There will be no displacement at Nadir because you are looking above that varies inversely with the flying height and when you have this you can always generate 3D images.

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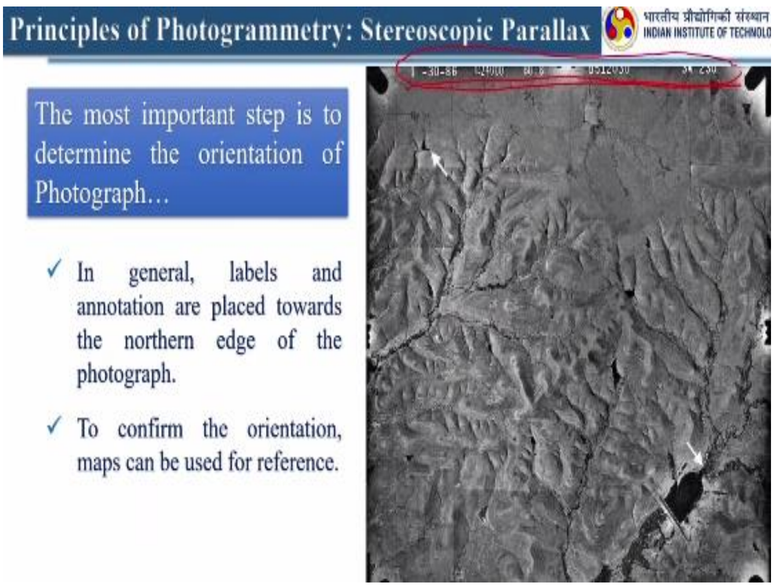


So now let us start with parallax. So what do we mean by stereoscopic parallax. So here the most important step is to determine the orientation of photograph. In general labels an annotations are placed towards the northern edge of the photograph. So if you see this is the northern edge of this photograph. To confirm the orientation map can be used for reference. You can use some previous images or the maps to reorient this if by mistake this has been wrongly put.

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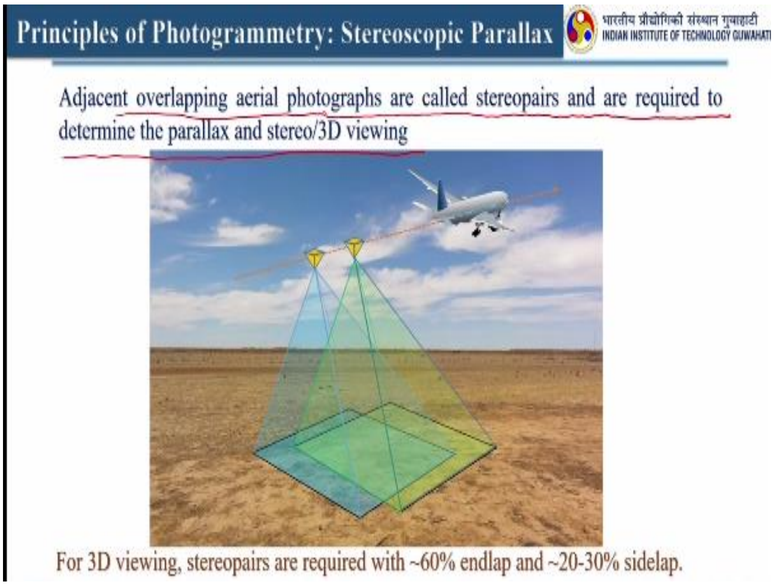


So here what exactly we are doing we are going to do the overlapped aerial photography. So adjacent overlapping aerial photographs are called stereopairs and are required to determine the parallax and 3D viewing. So here this is the ground and here for the first position I have capture this particular area. Now I have changed the position and then I have captured with some overlap and then we can have the stereopairs.

Now for 3D viewing stereopairs are required with approximately 60% Endlap and 20% to 30% Sidelap. If you have this, then only you can generate the 3D image of that particular area.

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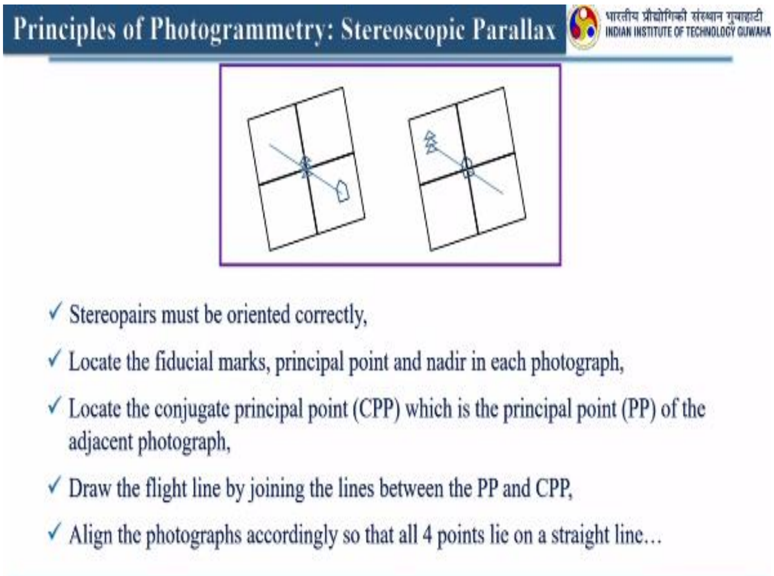


Now for stereoscopic parallax calculation what we have to do first we have to identify the principal point conjugate principal point and then we have to find out the flight direction and then we can calculate the stereoscopic parallax. So let us go step by step what we have to do. So stereopairs must be oriented correctly then locate the fiducial mark, principal point and Nadir in each photograph.

Locate the conjugate principal point and principal point in both the images. Draw the flight line by joining the lines between PP and CPP. So PP is your principal point CPP is your conjugate principal points. Align the photograph accordingly so that all the 4 points lies on the straight line. If you have this, then if you have a stereoscope you can easily see the 3D of that area using this stereopairs right.

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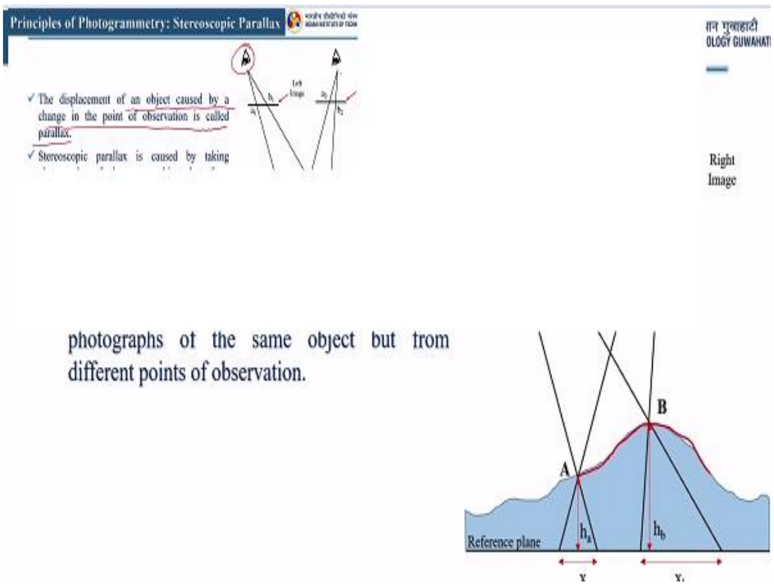


So the displacement of an object caused by a change in the position of observation is called parallax. When we are seeing from here we will see some feature of this particular object, but when we see from here we will see another side or next information above the same target and if we are changing the position and when we have displacement of an object caused by a change in the position of observation is called parallax.

Stereoscopic parallax is caused by taking photograph of the same object, but from different point of observation.

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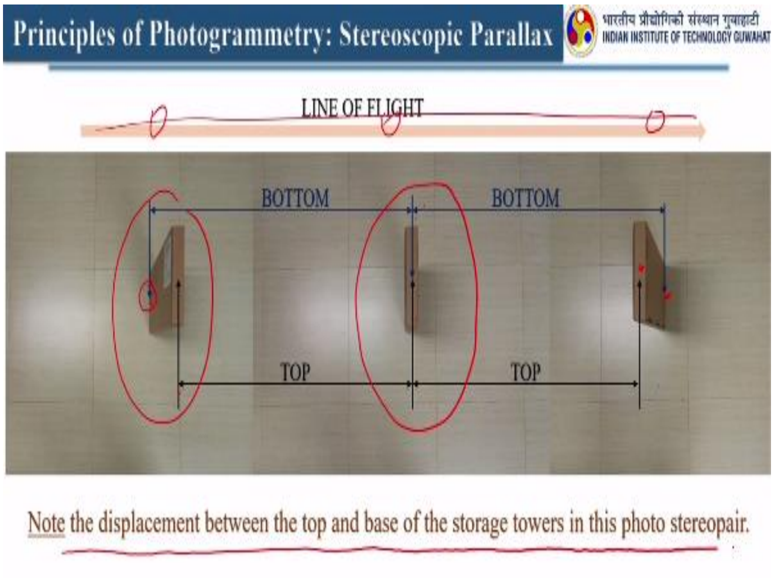


So if this is the line of flight if you see this is one object and how they appear when you are changing the location right location of the observation. So they will appear differently and here in this image you can see only top here you can see this side and in this image you can see this side right. So if you have this complete observation assuming from here, here and here you can fully cover this area right and you can estimate the distances these top and distance between bottom.

So here in this case you can see this bottom so you can easily pinpoint it and you can take this distance, but here in this case top and bottom both will be same whereas in this one also top will be different bottom will be different. So if you are having such information you can always calculate top and bottom distance from a stereopairs. Note the displacement between top and base of this storage towers in this photo stereopairs.

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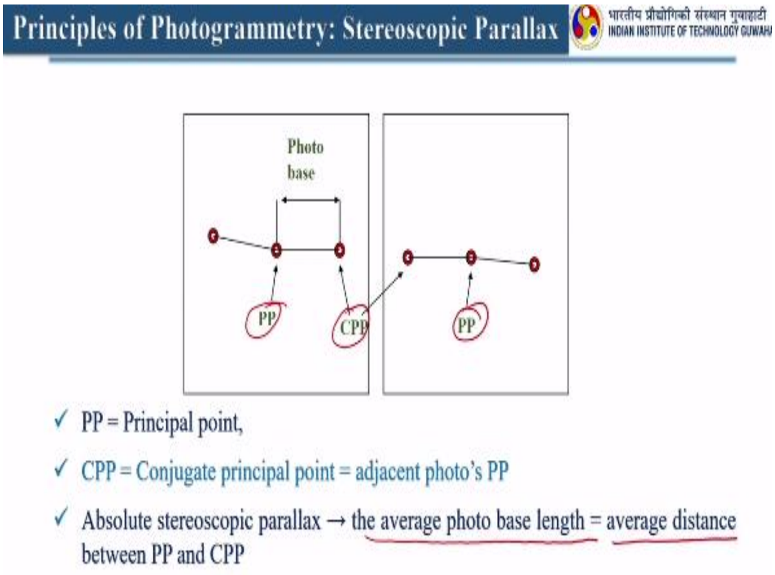


Now here we have PP, CPP and this is another CPP and PP right. Once you have that then you can easily calculate the absolute stereoscopic parallax which is the average photo base length which is average distance between PP and CPP

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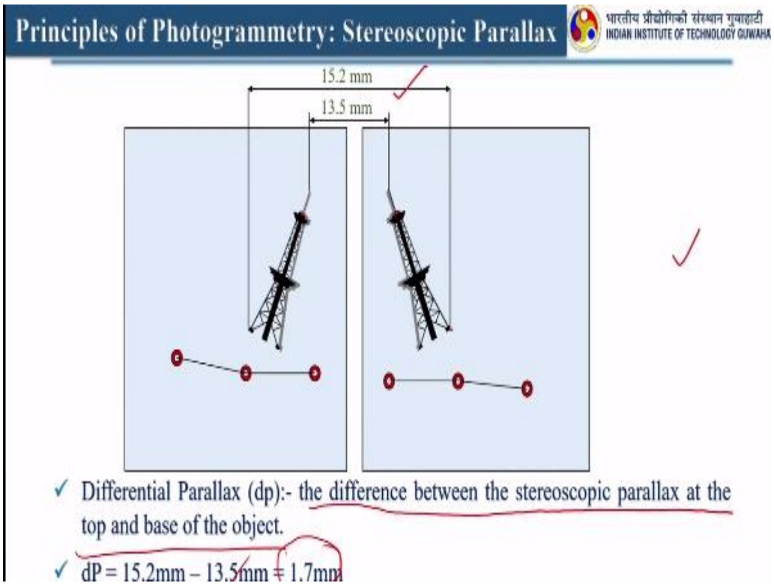


Here this is another example where this base distance is different, top distance is difference because in both the images none of them were vertical photographs right. When you have such images with you, you can always calculate the distance between these two right and you can always calculate the distance between bottom and differential parallax you can calculate using the difference between the stereoscopic parallax at the top and base of the object.

So here the differential parallax= distance of bottom- distance of top. So this is the differential parallax of your image of that particular object.

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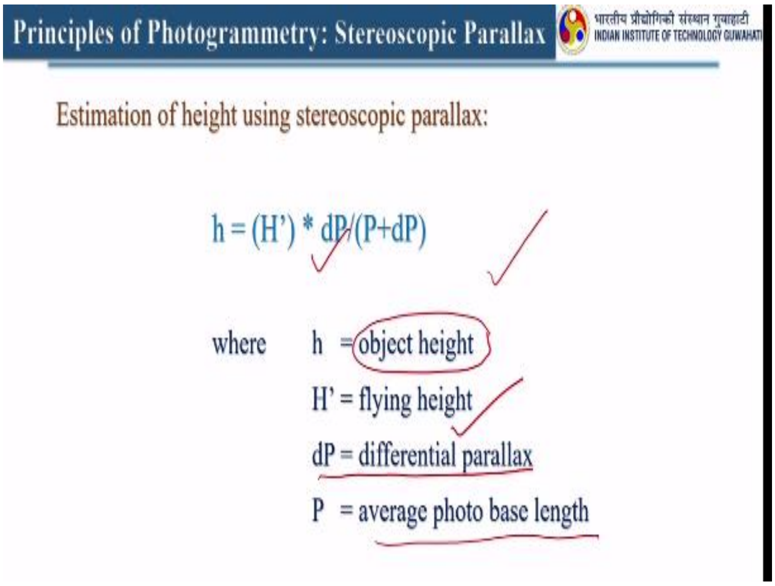


So how do we use this stereoscopic parallax in height estimation. So once you have all this information with you, you can always calculate what is the height of the object. So here in this equation h is basically object height which we want to calculate H dash if flying height that is known then differential parallax you can calculate using the previous method and P is the average photo base length right. So this equation can be used to estimate the object height when you are having stereoscopic parallax. Thank you.