Introduction to Flight
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Lecture 53: Number 10.3
Effect of Center of Gravity: A Practical Demonstration

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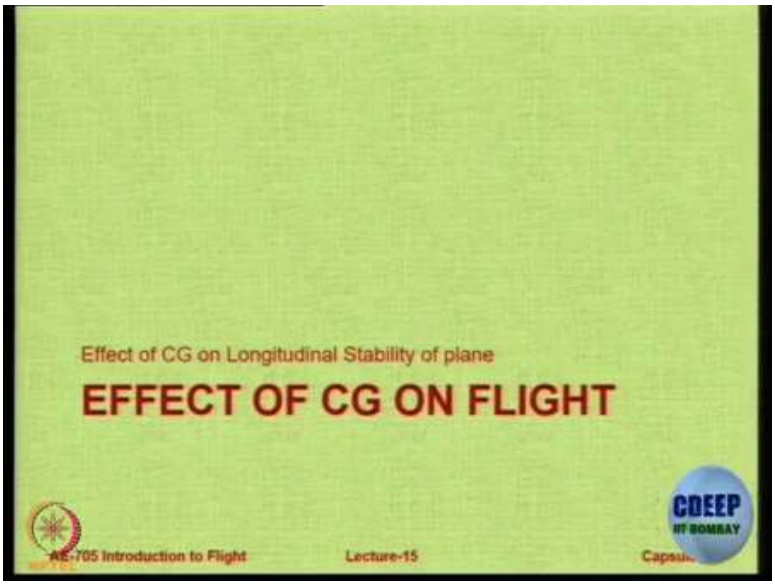

Okay. So, now I want to show you the results of a practical experiment. So, as I mentioned to you, during this summer we had some students who came to do internship. But before them we had two students who came and worked with us on their undergraduate project. These students came from an institute called IIST. One of them is sitting right here Sushil, he did his B.Tech project along with his friend and in their B-tech project, they worked on a very interesting problem. They worked on the design of a glider which I used to go to schools and colleges to demonstrate principal of flight. So, his friend Vishwas Molly and Sushil they worked on these two. The other one was launching by hand is going to bring a lot of variability. Correct. Every time I throw it to be a bit different because my angle is not fixed. So, they designed a launcher and a glider.

The glider that the design was basically a very simple that I will show you now. So, after they left I am sure you are wondering after they left we did some further experiments using their glider and their launcher. So, I want to now present to you the results of those experiments there are two experiments here. One experiment is what is the effect of change in the center of gravity of the aircraft on the flight characteristics of a glider? But this is not a, not a hand launch glider. This is a launcher launch glider, so it will have much better variability. So, the relative changes will be less. The other experiment is effect of angle of attack of launch on flight.

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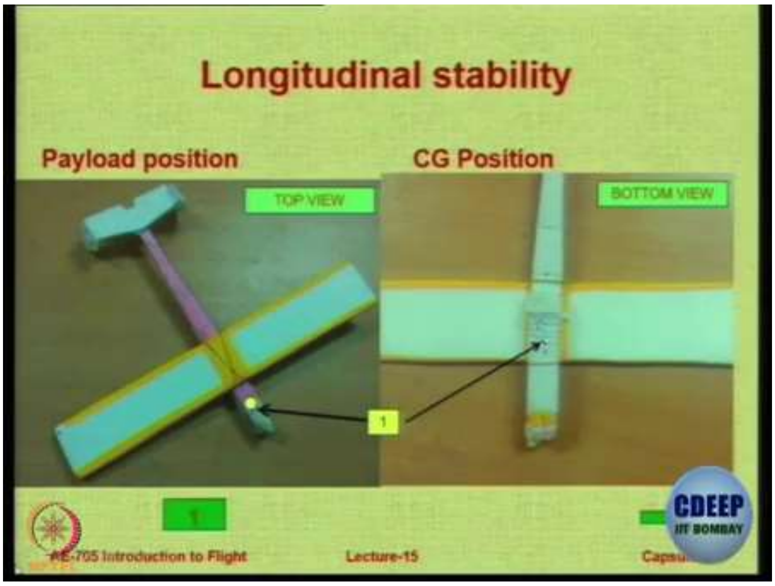

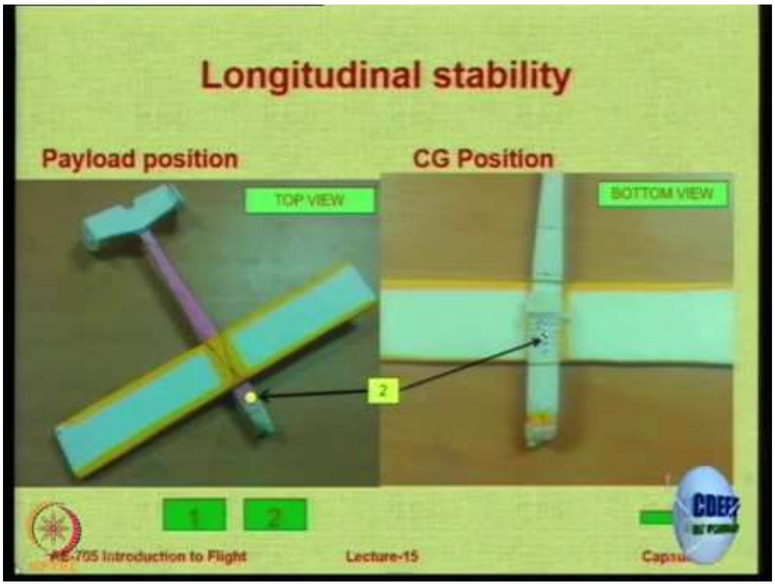

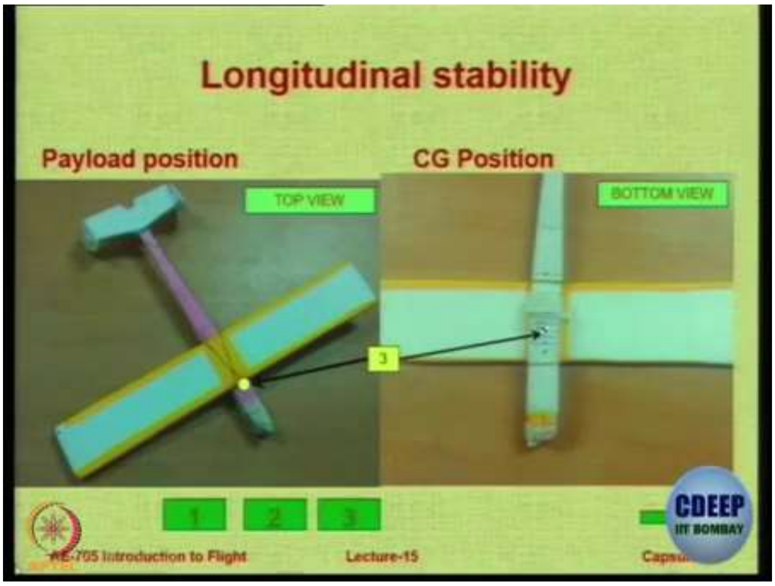

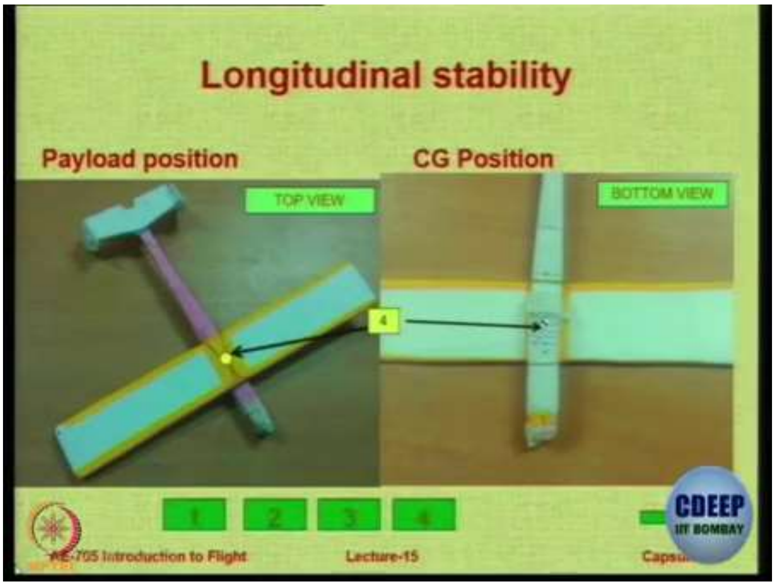

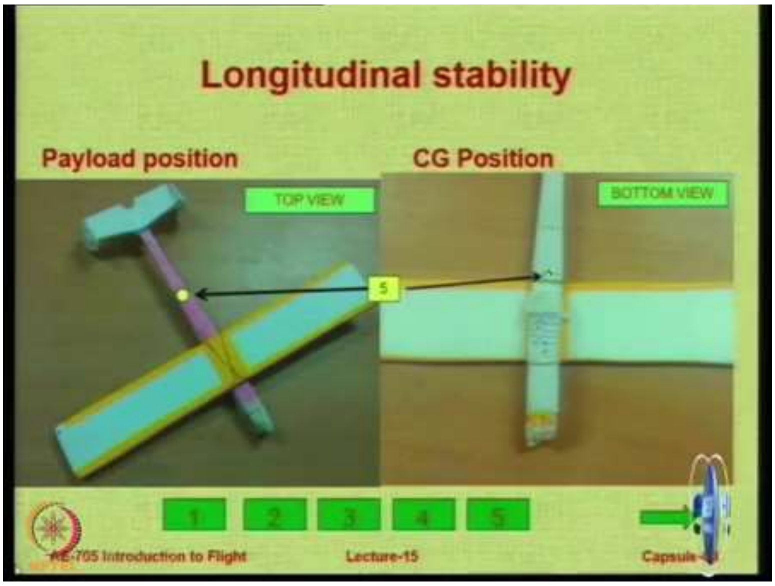

So, let us see. So, this is the glider that was made. You have a top view and a bottom view. In the bottom view we have drawn some lines. These lines are the location of some payload that we have put to adjust the center of gravity. So, this aircraft will have some center of gravity location on it is own because of its geometry. But if you want to play with the CG you have to add weight.

I cannot delete weight because then I will have to destroy my glider. I can only do CG change by adding weight so the screws have been added. So, the first position of center of gravity on the left hand side you will see the position of the payload or the screw. On the right hand side you will see what is the CG location because of that. So, this is position number one which was slightly ahead of that aerodynamic center. So, let us see position number two we move the payload a little bit behind CG has gone slightly ahead of an aerodynamic center. Third position, The CG is at aerodynamic center. Fourth one, CG is behind the aerodynamic center. And the fifth one is horrible, The CG is now behind the neutral point. You can see the CG is behind the wing.

Now I do not know where neutral point is and nor can I find out. I told you I cannot find out neutral point but I can find out the CG. So, by putting the weight at the fuselage on the rear side we ensured that the CG is so much behind that it is behind their wing. I know that normally the neutral point is you know 35 40 percent it is now 100 percent behind the wing. So, I am very sure that the neutral point has been exceeded. So, now I want to show you the effect.

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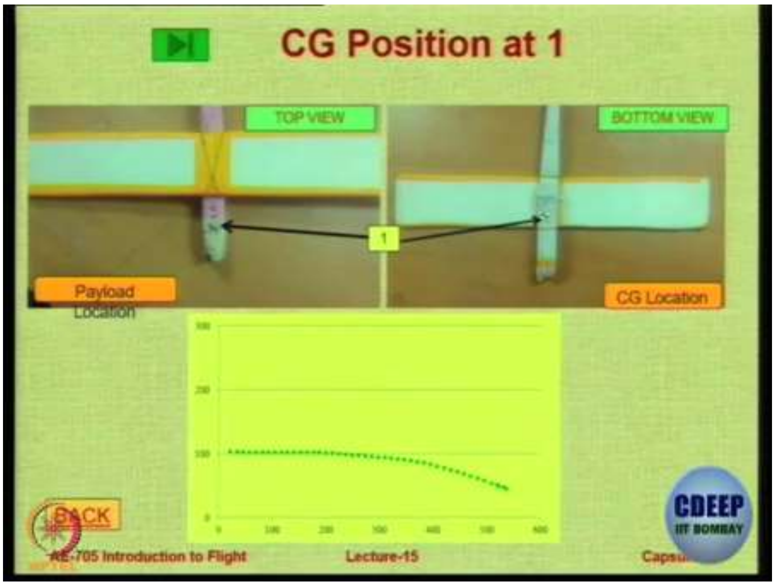

So, this one the payload is here the CG is here and let us see the flight. This is in slow motion. Which in slow motion because it flies very fast. So, if I do not make it slow you will not be able to really see how the aircraft behaves. So, can you comment on the flight? Is it flying straight? Yes or no. No or Yes. You cannot say. I would say flies straight straight straight straight straight. And then here it starts going down. So, initial flight path is fairly straight, is the aircraft flying stably, yes. Where is a disturbance?

Stable unstable is only if you are disturbed it na. Did I disturbed it? I did not disturb it correct. So, if you did not disturb an aircraft you cannot say it is stable. So, right now we cannot comment on stability. We can only comment on whether the flight is good or not. Now good or bad is a relative term.

This is the first video you are seeing so hang on Comment at the end of the Fifth Flight. There is a first flight so what do we observe? The plane leaves the launcher is not visible we have hidden it out of the camera and we have put this black background. For increase we also have a software and open source software. Through which we can track this object. I will show you the result of that little bit ahead. Enough of the flight that first CG location.

This is the tract or recovered trajectory from the software. So, as I said from our location around 20 from the wall which was the starting position. It flies straight up to around 320 sorry up to around 270 or so. This is not meters or inches. This is just some frames and then it starts going down. So, its range will be approximately 600. In this figure, right, Approximately 600 by projecting it. We do not know but approximately 600, Alright. Now let us see what happens if I…

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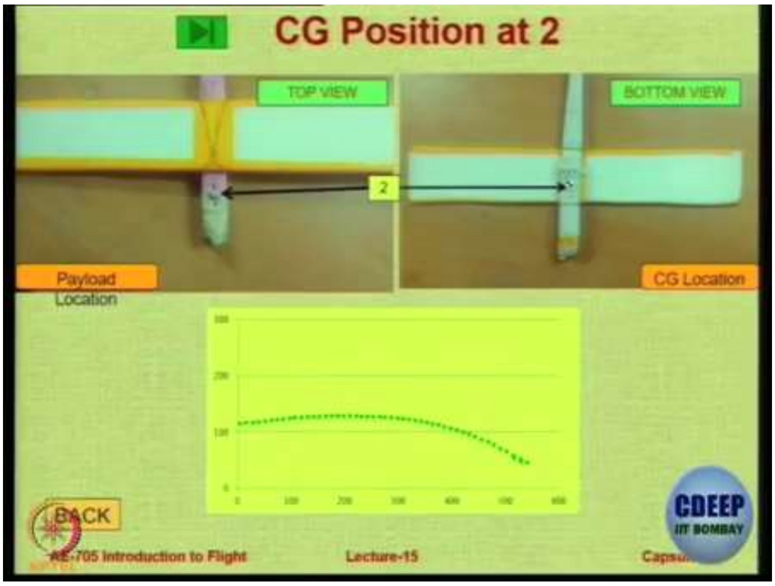

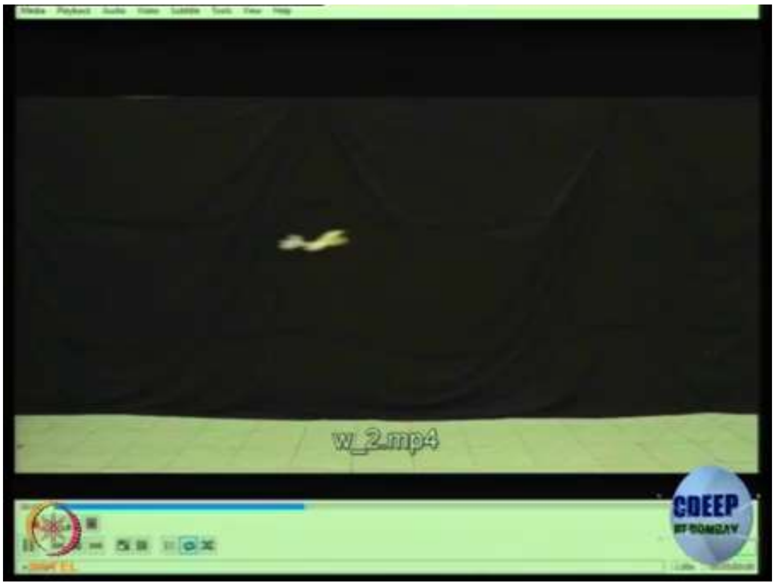

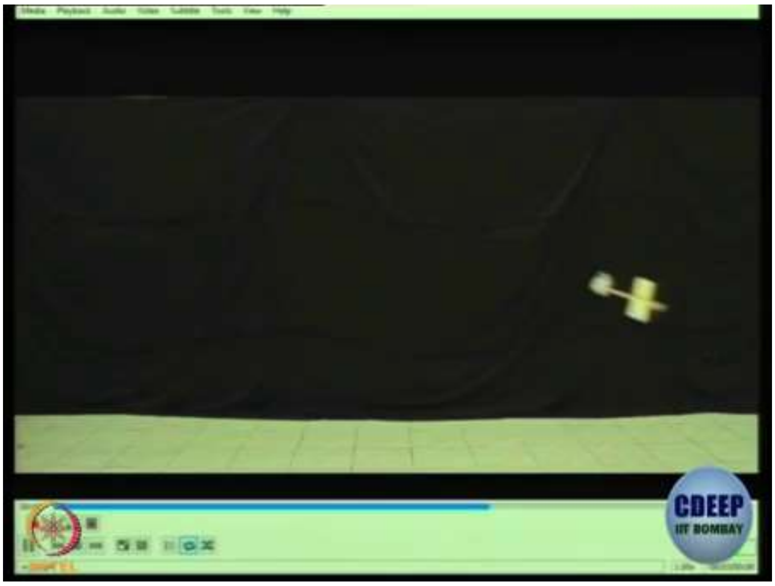

In number two I have moved this slightly behind? It is little bit ahead of that aerodynamic center. I am telling you because I have passed by this is post facto information you do not know right now but we just moved CG behind. Is it better or is it worse than the previous one? There is a slight amount of roll introduced. Do not worry about it. This class is not about lateral stability or rolling stability. This class is about longitudinal stability. So, is this flight better or worse. We have moved the CG slightly behind but still ahead of aerodynamics center.

Student: Worse.

Professor: worse, why do you say it is worse?

Professor: I think it is better. What is the measurement of better or worse? Range not how it flies. We are competing for maximum… did I say if your aircraft go like this and hits the pillar. There is no mark did I say that no your aim is to travel maximum distance and hit the pillar. So, I think it is better. How do you know it is better? Not by looking at the video but by trajectory. So, now what we see is it was earlier flying almost straight. And then down. It will go down it is a glider. It cannot go up unless some gust comes it. There is no gust here. So, this particular flight is actually slightly better. Let us not argue. You may say it is worse. I accept it. If you say better I accept it but I found it better simply because we got little bit with more range in this. Because see it is going up slightly. So, whatever goes up will also come down and go longer. So, you got slightly more range.

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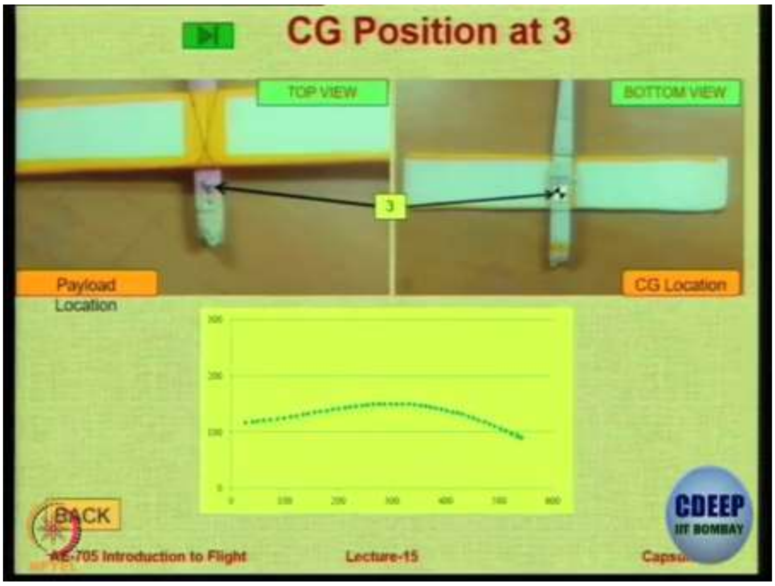
CG Position at 3
TOP VIEW
BOTTOM VIEW
3
Payload Location
CG Location
BACK
CDEEP
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AE-705 Introduction to Flight
Lecture-15


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Now let us go to location number three in location number three the CG is now at aerodynamic center. What do you say now? Better. So if you are designing your glider and competing for maximum range what will you do. One or two or three, three Yes. You can see by the trajectory also that the aircraft. It now climbs further up goes down, the range we got was more. In this case.

You can see surely more than 600 although I wish I would have captured it. See what happens is when you captured with the camera there is the software so it capture that to some point and then if there are some table or something else it loses. So, we lose it. So these are the data these actual data of our capture trajectory. Let us see what happens if we move the CG further behind.

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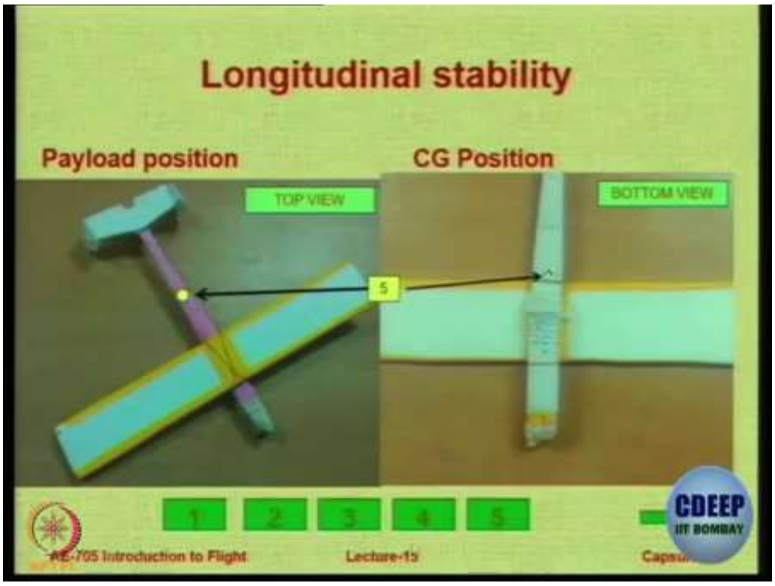

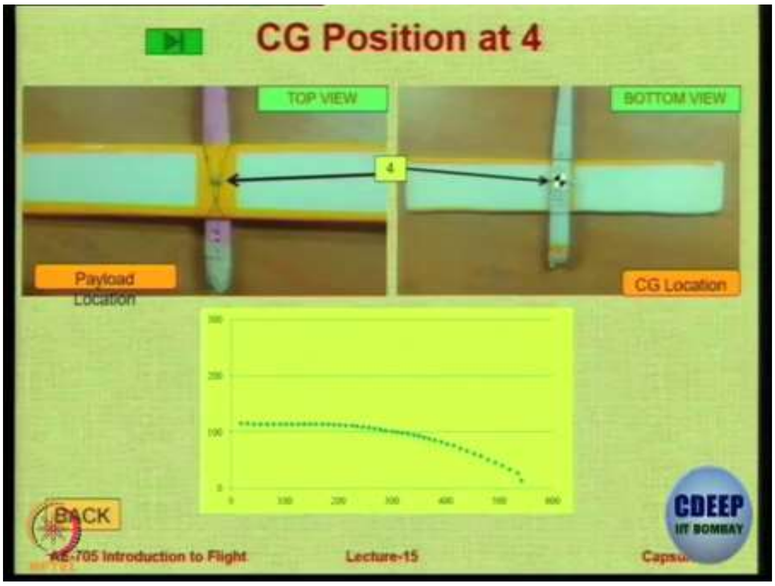
CG Position at 4
TOP VIEW
BOTTOM VIEW
4
Payload Location
CG Location
300
200
100
0
100
200
300
400
500
600
BACK
AE-705 Introduction to Flight
Lecture-15
CDEEP
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Position number 4, behind the center behind the quarter chord. This is not good. The range was not larger in this case. You can see less than 600.

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Now we take the worst case which is when the neutral point has been crossed. So, the aircraft should actually be unstable in this case but here stability and unstability is not going to really matter. What will matter is what angle the aircraft takes or what angle the aircraft trims into when you launch it. So, although you get very high initial climb but the range is not highest. So, this is what happens. You can imagine now it is like the tail is heavy so when you throw the aircraft angle is increasing and angle increases drag is more. When drag is more you with the same energy you are not able to travel a much longer distance so you go like this and then you fall down. So the range in fact was the least in this case 500.

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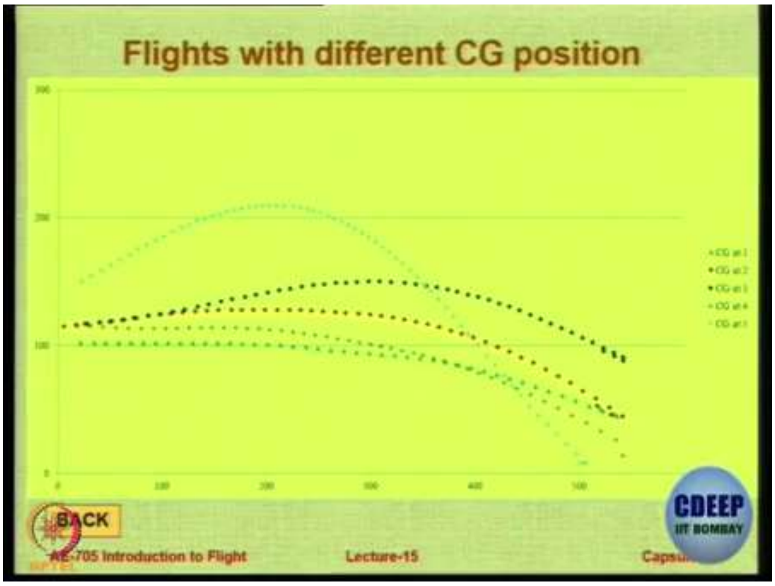

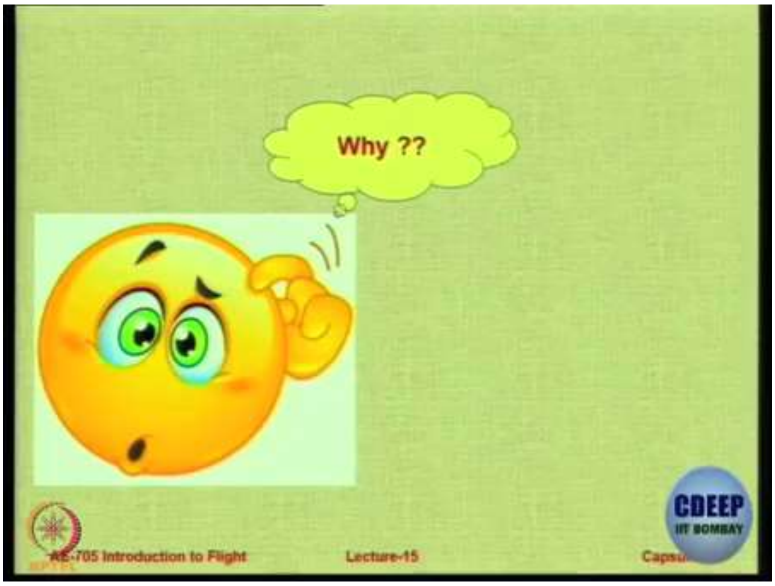

So, in short here is a comparison of all the ranges with the various CG positions. So you can see that these black dots which represent CG at 3 which was we know at aerodynamics center and gave us the maximum range. So, this is a experimental proof of what we learned through a toy aeroplane from Scott Eberhardt's book. And this is my friends a hint to you to get now the different thing now all of you will put the CG at quarter chord. So, now who will win the one which has got on aerodynamics? The one which has got better repeatability so that you do not disturb. Remember we will take average of two throws. So after one throw if it brakes gone. So, you have to I will not take the actually I will not take the best of two throws. No, I want they are designed to be robust. So, if your plane breaks after first throw. Then you have only one reading.

If your plane performs bad after second throw it is actually a bad design. Somebody will say we will break the plane after first throw because why did you get negative marks. It is up to you, you take a call. All right this is our conclusion. Now why did this happen. There is no stability in this calculation because there is no disturbance. So, it is not to do with stability. What is it to do with? If you listen carefully and if you have listened carefully to what I have shown you today then you should be able to answer. So, why is it so? That at position number three CG at number 3 position we had the maximum range. Let me help you by saying apart from the centre of gravity location. What was the difference in the flights of each aircraft? Remember one minute, remember we have attach the aircraft to the launcher and release it. Now tell me, yes. What is your comment?

Okay. He says that the angle of attack of the aircraft during the flights was different. How many of you are agree? There are three people here, Three Mosquitos, Only two there? So others are thinking angle of attack is same. In all Flights. Why is it same? Because the weight is same and the launch angle is the same so the angle of attack is same. Is it different or is it same? Is different. So, you say it is different. How many of you say that that angle of attack of the aircraft in the flight is the same. The logic is very simple the angle of attack will because lift is equal to weight in all of them. Assuming the launch speeds are the same which I expect because it is a very good launcher. So, and the angle is same.

The angle at which the launcher has been launched we have not touched it we have locked it. So they are all going in the same angle from the launcher they are all same weight because the same weight is move backward and forward CG has moved but the W is same. Why should the angle be changing. L is equal to half rho v square S CL. Why should the angle change So, why is the angle of attack changing?

Professor: Behind neutral point.

Professor: Okay correct. So, basically the aircraft is the same. But the angle at which it trims itself when left in flight is automatic. Because moments have to balance. So, the moments will balance at a higher angle of attack when the CG is far behind. So, therefore the alpha at which they are flying is not the same. So is the V same. The V is also not same because V will have to adjust automatically to keep lift equal to weight because the angle is changing. So, although this video recording has been shown you in slow motion the speeds are not the same. They are slightly different. So, now at which angle of attach do you get the best range. The angle of attack at which L by D is maximum. So, that is what is happening.

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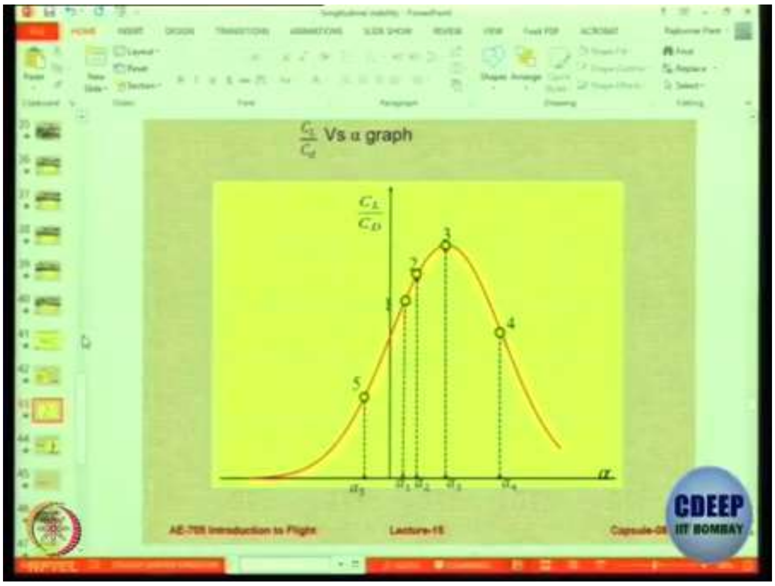

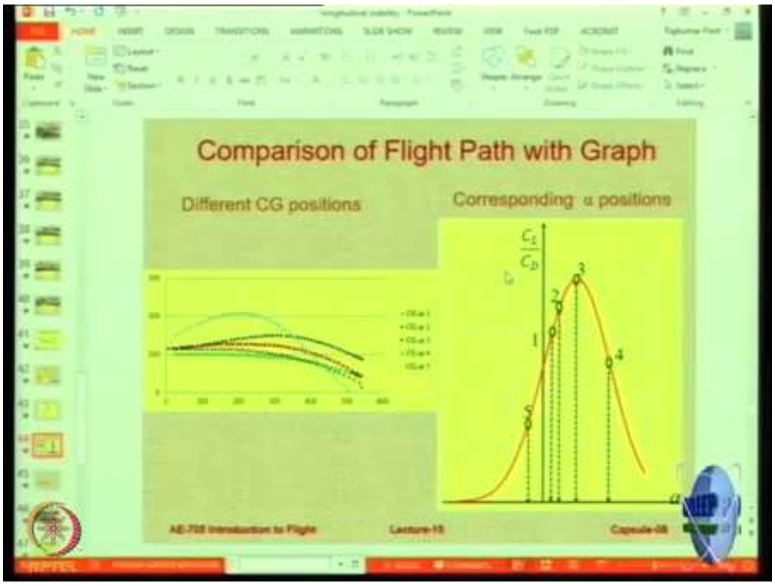

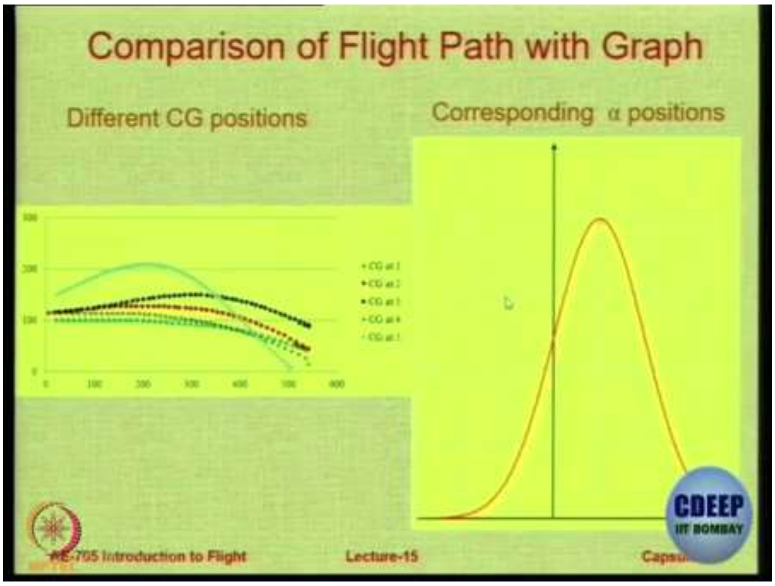

So this is a graph of the L by D verses alpha. So, at alpha one we had some angle of some L by D. At alpha two we had some L by D. at alpha three we had the best L by D at Alpha Four we had less, Alpha five was the worst. So that is why at three I get the maximum range. So, on the left hand side we have the flight flight profiles on the right side we have the corresponding Alpha positions, Yes.

Professor: No no no, it is on the launch angle the launch angle is same for all.

Professor: The line that you are seeing on the line for CL by CD max for various alpha. The red line the figure is, the value CL by CD for this aircraft for various Alphas. So,

Professor: Because the aircraft will automatically because of center of gravity orient with the flight path at an angle at which the moments are canceled or balanced. So, it will fly at this condition throughout. Now you cannot see the flight you cannot see the arrows of flight direction and the angle of attack so that is why you cannot see but the angle between them is the constant in the entire flight once the aircraft leaves the launcher look at the flight number five what happened when you launch it, it became like this. Now it went like this only correct so if you draw a line which is the trajectory and if you draw tangent to the flight path you will find the angle is a same. So, what is happening is the aircraft is flying at different angle of attacks at which L by Ds are different. So the same aircraft is having a different range.

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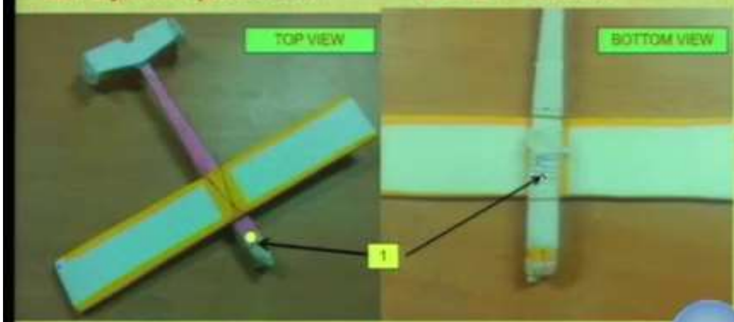
Longitudinal stability concept explanation

NEUTRAL POINT

Longitudinal stability

- Payload position
- CG Position



1

Comparison of flights (CG at 1)

without Vertical Gust

with Vertical Gust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h_1.mp4


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IIT BOMBAY

So, now let us look at the neutral point. So, Now I want to show you the effect of the effect of stability. So, far is not stability. So, first position.

Now I introduce vertical gust. Which is a disturbance. Now you will see the response of the aircraft after the gust and then decide which is more stable. So, the same flight the first one. And now what we have done is we have put a small disturbance we have put a small fan. So, you can see behind the fan the aircraft responds.

In fact here that response is happening even before the flights slightly because this fan is not giving me just a clear vertical gust. This is not giving me a steps gust. The fan is actually going to give me a fan of air. So, the effect will be highest just above the fan at this point. So, the aircraft responds beyond that. Remember this is this slow motion recording. So, once the aircraft crosses the fan now look at that response again. This is when the CG is that number one position.

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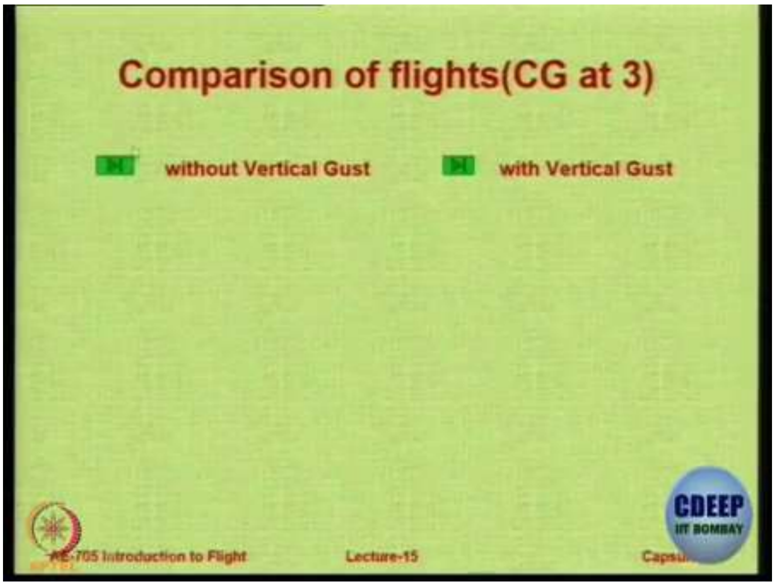


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Let us see, CG now I skip two I am just trying to save some time. So at number three without gust. With gust you can now see the difference in the stability. So it responded but responded little bit less see now the air hits it.

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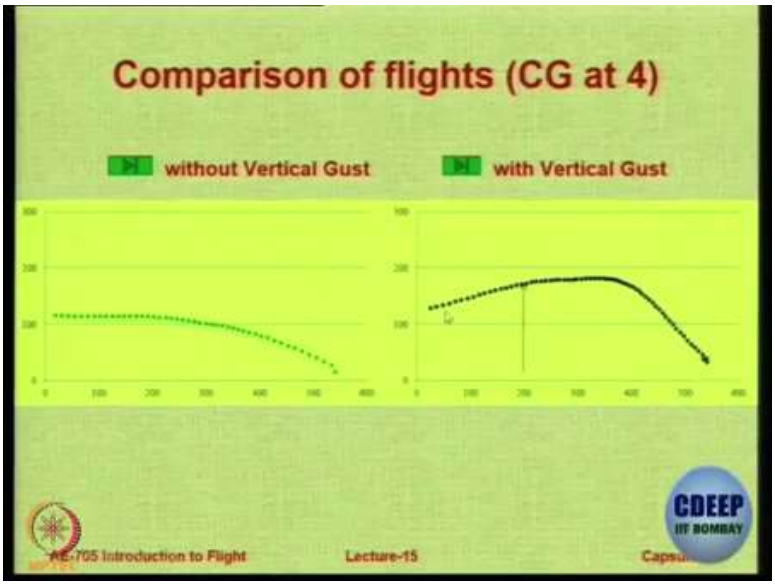


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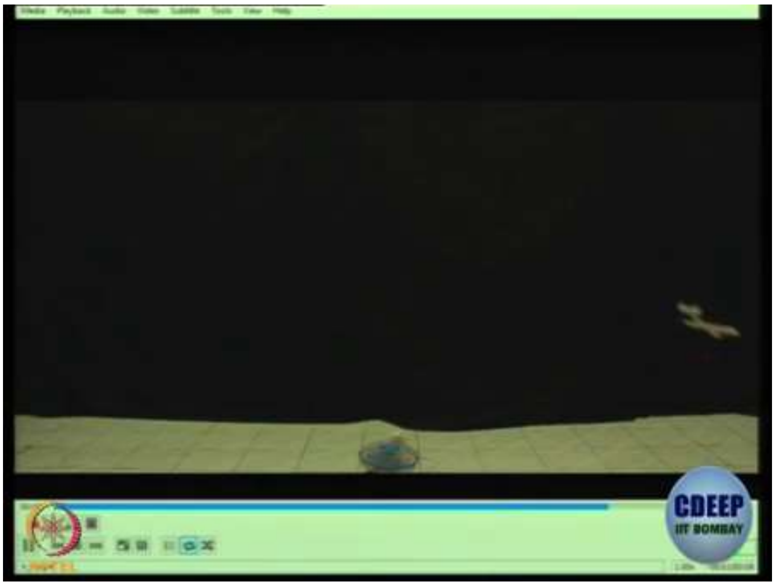

Let us see so there is a difference in the flight. This arrow vertical arrow shows the place where the fan is placed. It shows you that behind that there is a slight dip and increase in the flight. Let us look now at position number four, first without the gust, now with the gust. The Gust act now. The aircraft responds slowly. So, now what is happening is unfortunately these experiments we have to do them little bit with more care. Because you are actually going so much above the fan that its effect is getting effect depleted. But still you see the reaction.

There is a continuous increase even here because this fan is not going to give you only a straight line like this is going to you a band of air. So, I think if you see the response of the aircraft it starts falling here. So, I would assume that this area is being affected by the fan. And let us see now the response when you are behind.

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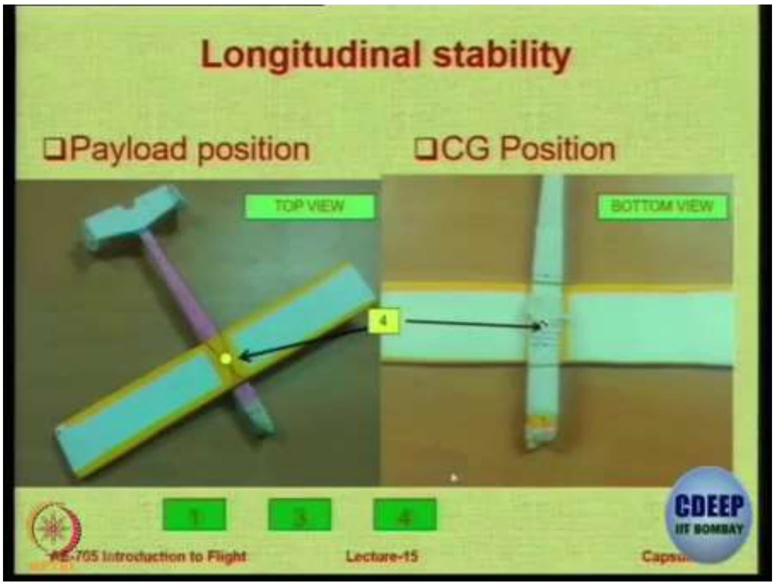


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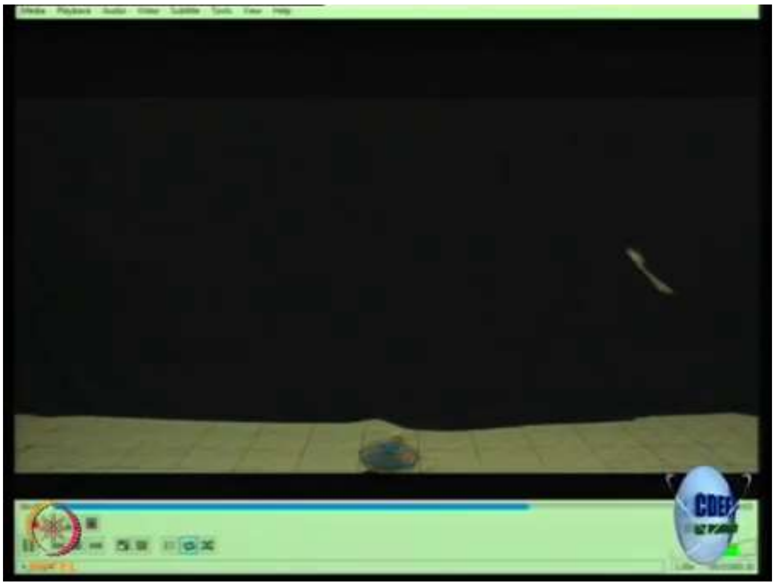

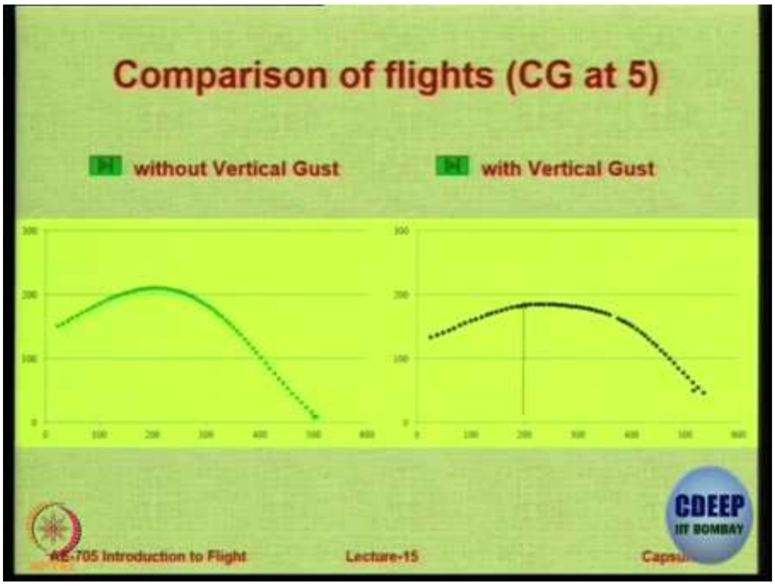

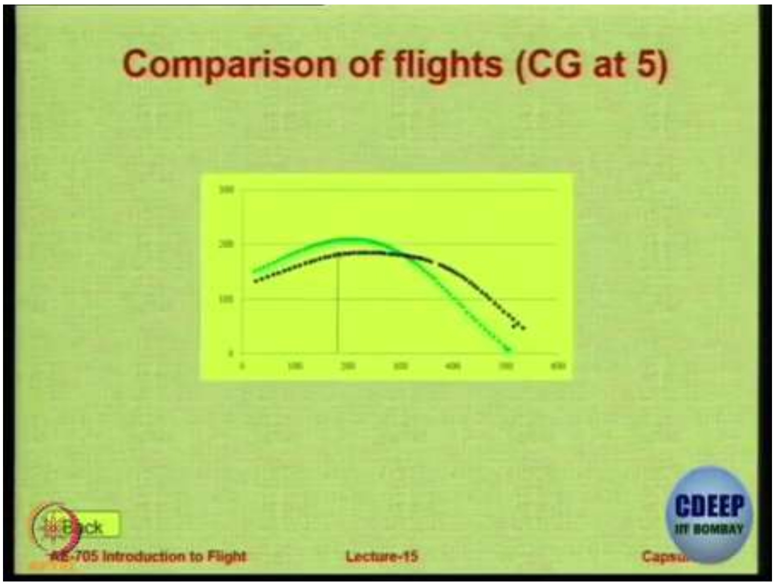

So, now this aircraft is unstable because it is, there you go. The moment you throw angle of attack becomes very large and then it immediately starts descending but when you put the vertical Gust let us see what happens. I would say not much effect because it is not able to reach. But if you see the data that we captured. So, instead of coming down it is actually going little bit the angle at which falling is reducing slightly.

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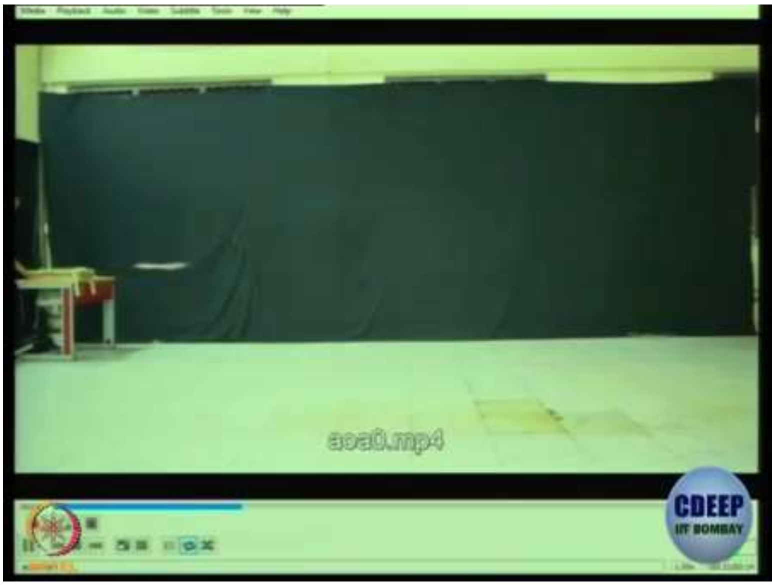
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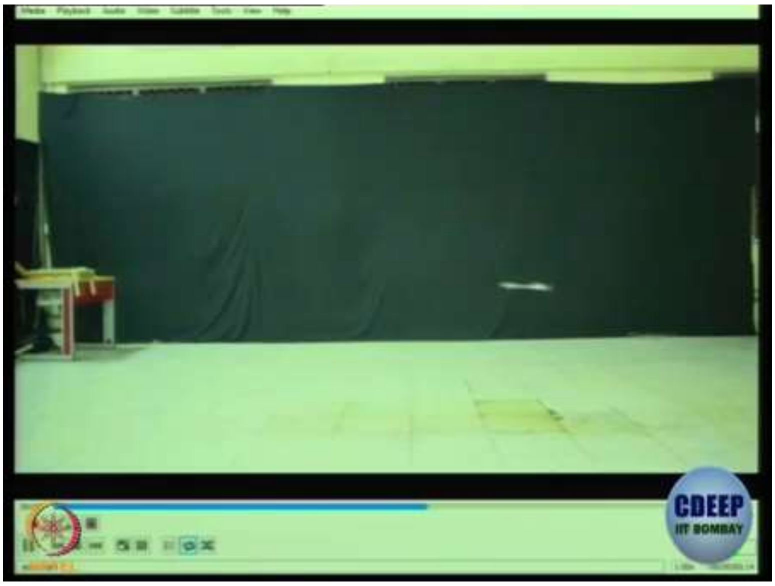
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So, these are experiments we tried, Then we have flights at different angle of attacks. So I will show you quickly. Now here we have given the alpha, yes.

Professor: Yes most stable position, Yeah.

Professor: No, least it will be the least so.

Professor: Response should increase, yes, the effect the effect of the gust should be more. Unfortunately it is flying so much above. That by the time you reach there they the numerical value of the gust is not the same. I want to show you also the effect of angle of attack Very briefly. Now you can see the launcher also. This is zero angle of attack. So, therefore you throw it went exactly straight in the beginning.

These are results taken by you right. These are the recording by by him and his friend. You will see them also.

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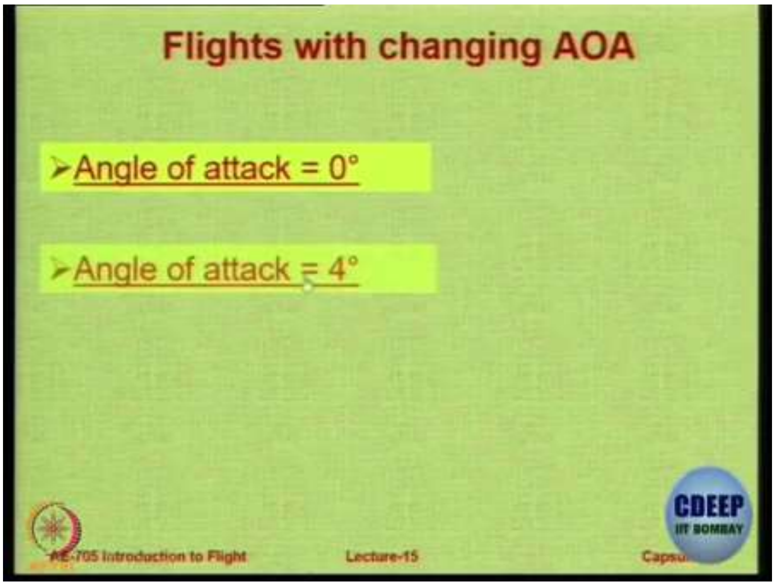

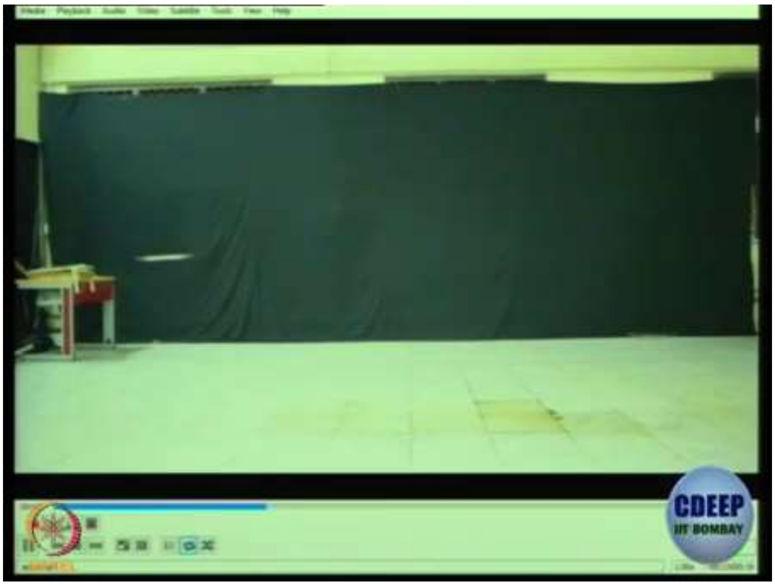

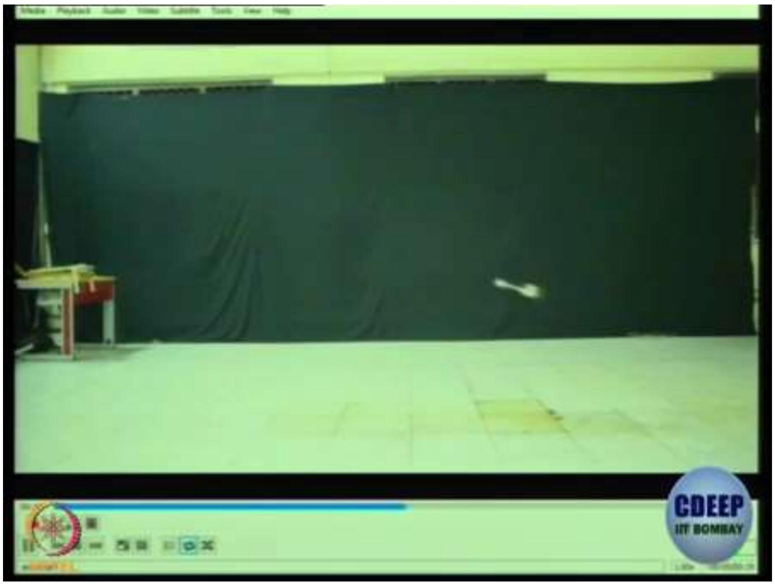

Now alpha at four degrees,

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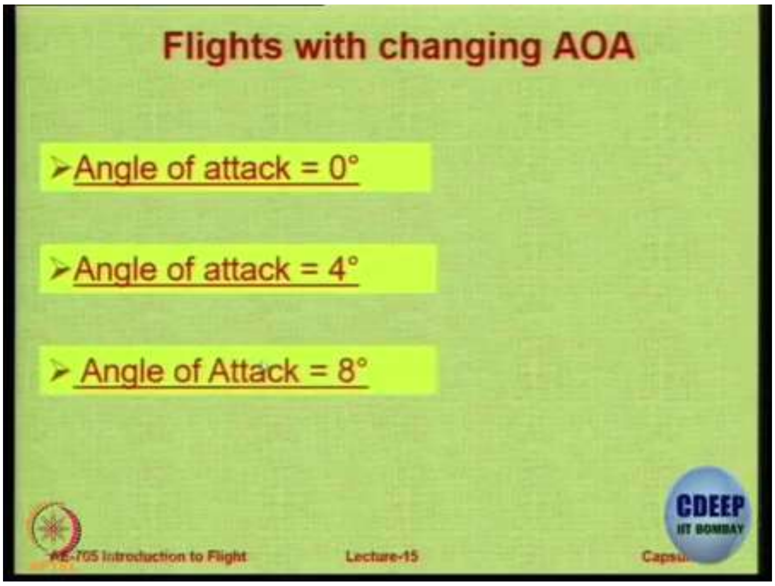

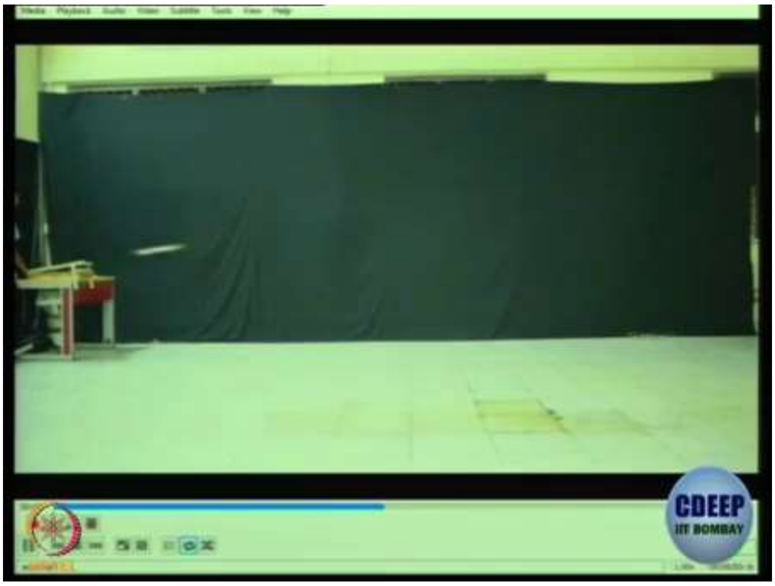

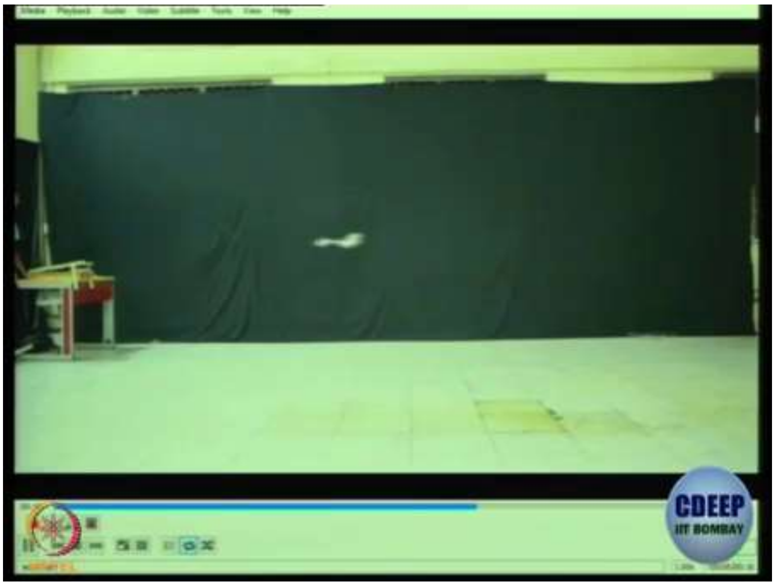

Eight degrees, Range is lower.

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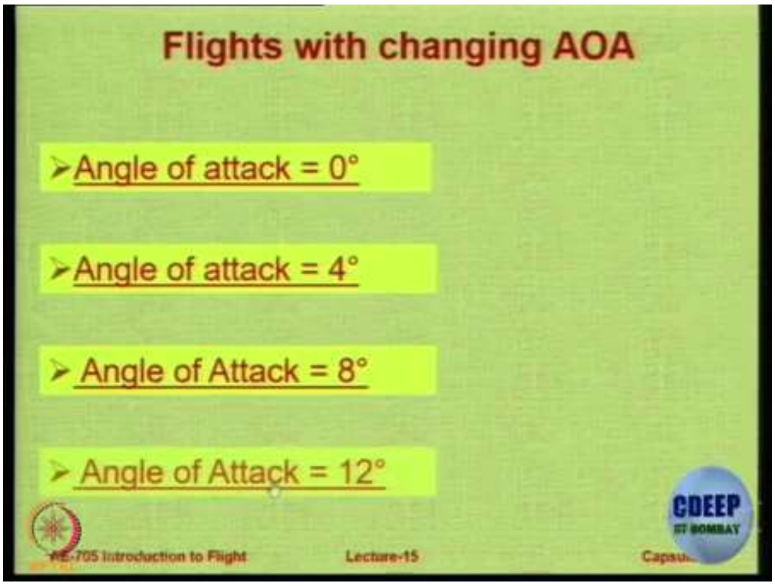

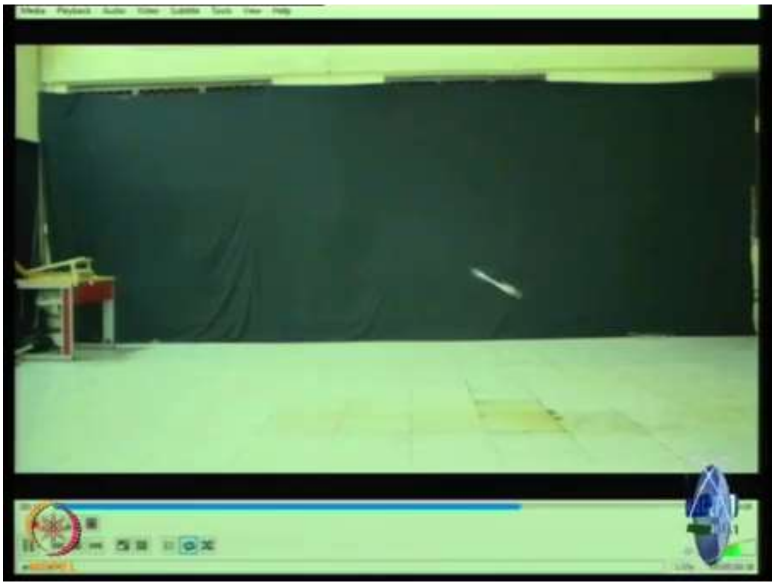

Twelve degrees.

Range is lower. L by D is going to maximum at one particular angle. That is not eight degree or twelve degree but at a lower degree. Approximately 3 to 4 degrees. So that is where you will get the maximum range. So, if you compare the flight.

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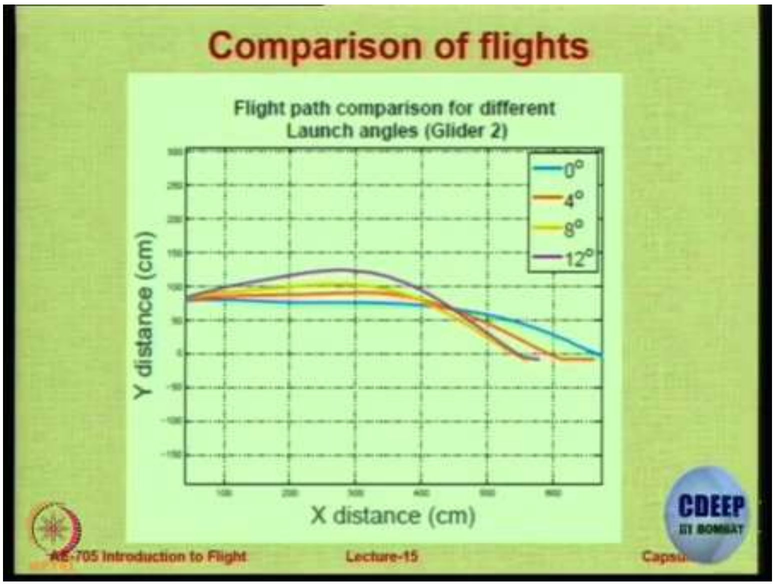

This is from their paper. If you compare the flights you find that in this case the maximum range came for actually zero degrees. But the next angle we had was only four degrees. So, maybe at three degrees or something like that maybe you could have got a good one and you see a horizontal line on the ground. That is because of this sliding on the ground of the glider, after falling it slides. So, that gets recorded. Alright. So, that is all I had for stability and control.