Introduction to Flight
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Lecture No 49
Instantaneous and Sustained Turn

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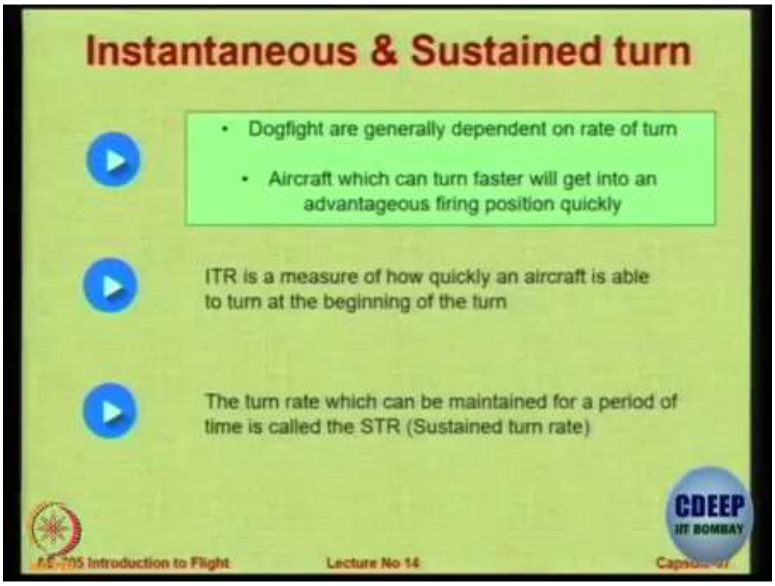

So interestingly during dog fights the rate of turn is not important. What is important now, so let us see. Let us see a small dog fight okay. Let us see a dog fight.

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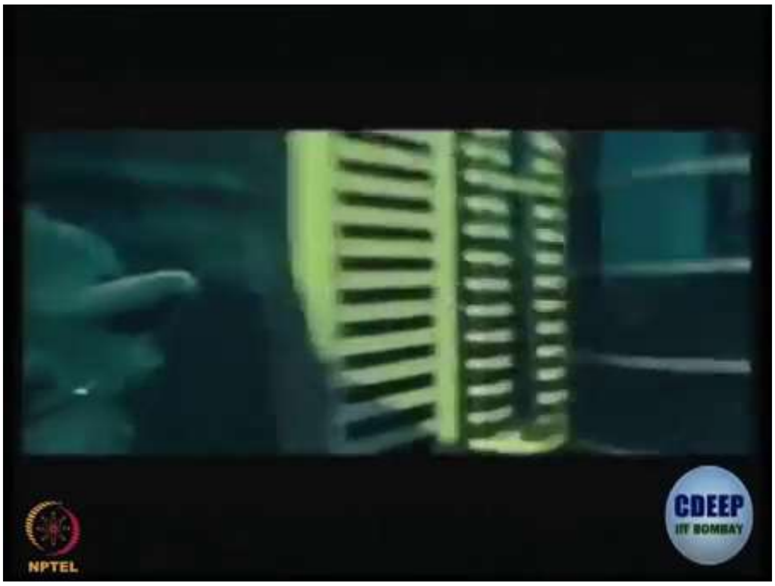

Two aircrafts engaging each other in a turn. You want a tight turn rate here. Instantaneous turn. Because they lost height and speed. So, when you pursue somebody you cannot instantaneous turn. It will not help much, okay. Let us see it once again.

So, we saw that for obstacle avoidance, when you have a building in front of you, then you need an instantaneous turn. But now, I will show you sustain turn, okay.

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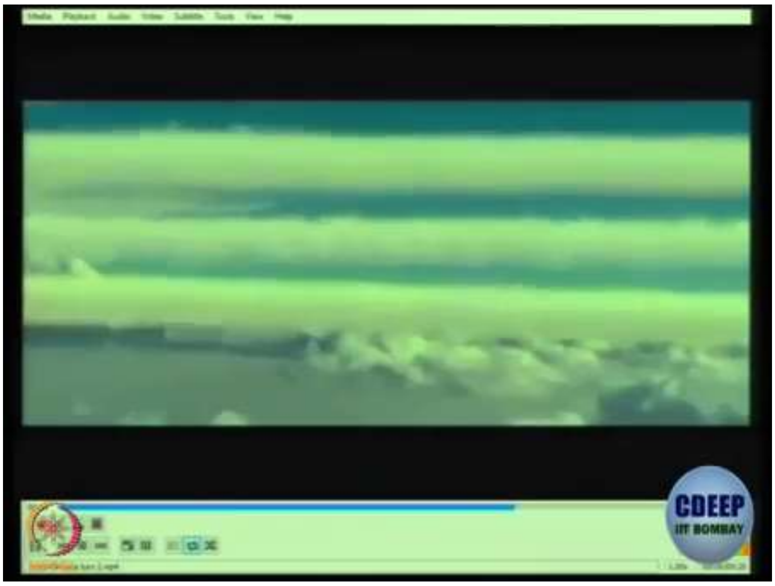

So now you see the difference. So, you see that is why you want to be behind and above. Instantaneous turn to avoid. Sometimes, Hollywood teaches you more aeronautics, than in the classroom.

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So, here for example, I could see that the speed came down. The speed reduced. So during air shows you see a lot of instantaneous turns, when you are trying to impress the audience about the capability. But, it is important for you to be able to maintain it. It is only for show purpose. The real capability is only when you are able to maintain that particular turn rate and height as well as velocity, okay.

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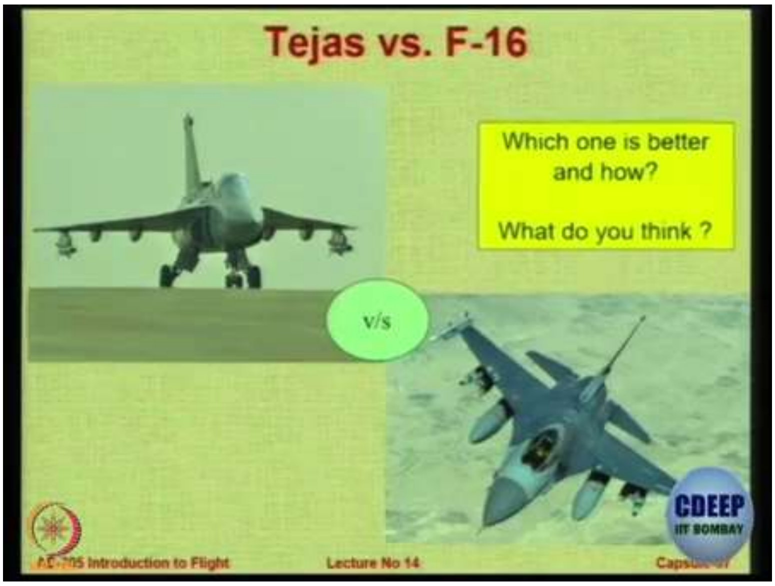

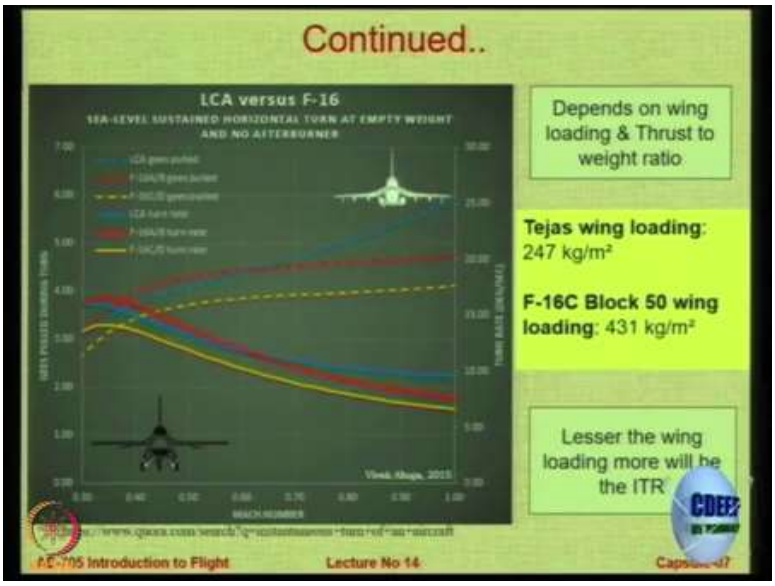

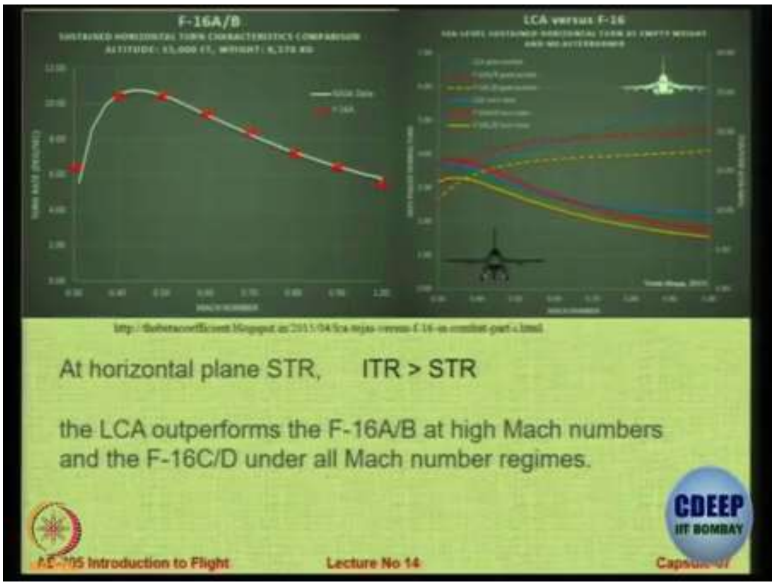

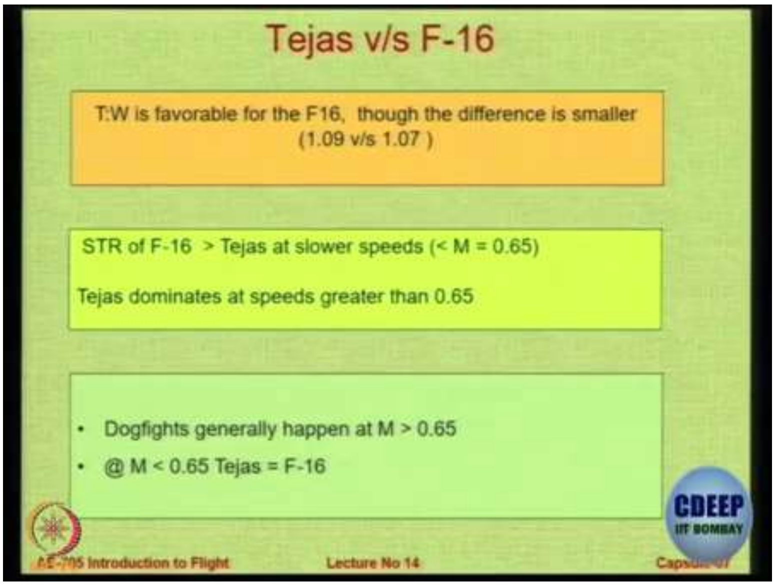

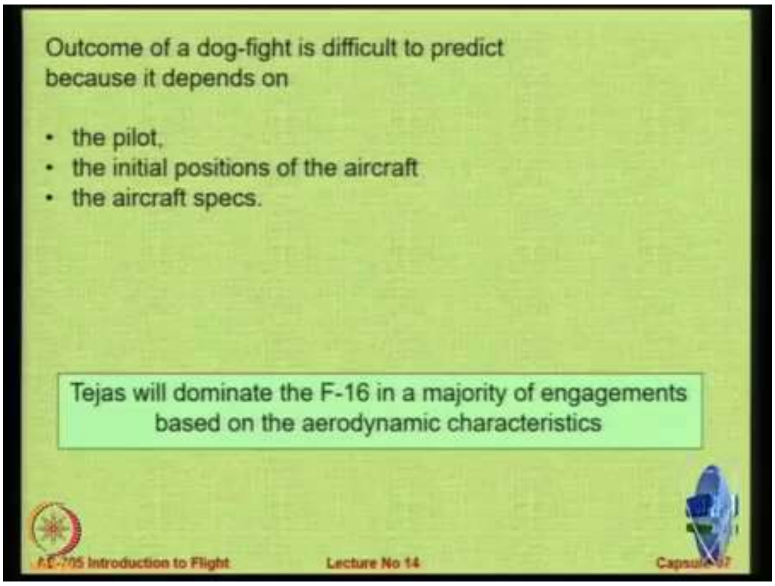

So, some students have sent me a message saying can we compare some aircraft which we have along with the ones that our enemies have. So, this is a good example. We will look at the turning performance of these two aircrafts. What do you think? Often what do you think? As far as turning moment is concerned do you think our aircraft Tejas is better than F16.

Let us see the numbers, okay. We cannot just go by the emotions, okay. Just because it is made in India, you cannot say it should be better. Let us see the numbers. So, here are the two aircrafts, okay. Let us see. So, here is the graph. Now, the source of this graph is not a very authentic source. So, therefore I do not want to say that it is perfectly correct. I am not confirmed these numbers. I do not have the data with me. But if you look at the graph there are two types of F-16 aircraft. There is the F-16 AB which is the previous generation of F-16 and then there is F-16 C and D which are the modified versions.

So, obviously the one which are modified are slightly better. They are more capable. So, the orange, the orange or the yellow line that you see. The dark line is for the F-16 CD turn rate. So, this is the modified F-16. The blue line that you see is for the LCA and the red line is for the previous version of F-16 that is F-16 AB. Now, what do we notice? We notice that if you look at Mach numbers up to approximately 0.65, 0.65 Mach number. The blue line is above the red line. That means the blue line is having a higher values of turn rate. Or, high values of g compared to the red one. Below 0.6 the F-16 AB seems to be better, having an advantage. But compared to F-16 C and D we are consistently better at all mach numbers right from 0.3 to 1. F-16 is inferior compared to Tejas.

This is for the sea level sustained horizontal turn that empty weight and know after maneuvers. Now, on the right hand side you have a scale that shows you the turn rate. So read that axis where you are looking at the dark line. The dotted line shown is for the g's pulled. That you should see on the left hand side. So, you can notice that the place where V becomes superior the g is pulled up much higher. We are able to pull up approximately 6g as Mach number 1 as compared to only 4.8 or 5.

Alright so the parameter will be aircraft that make a big difference are wing loading. So we have a lower wing loading, 247 kg per meter square as compared to 431 for F-16C. So, lesser the wing loading higher is the instantaneous turn rate. So, as far as ITR is concerned which gives you the initial advantage of getting into a dog fight. We are far superior. In fact our wing loading is almost double almost half, okay. Let us look at now the sustained horizontal turn rate. This is more important, right? Sustained turn rate.

So, a sustained turn rate, we have some data F-16A we have some data. In that data we are seeing the turn rate versus the Mach number. And the same data which we saw last time we just superimpose there. So the LCA outperforms F-16AB at high Mach numbers, beyond 0.65 and all Mach numbers for F-16C and D. So, thrust to weight ratio is better for F-16. Slightly better but that is not the whole story. So, the sustained turn rate for F-16 is more than they just at lower Mach numbers. But beyond 0.65 Mach numbers our aircraft dominate. And interestingly, most dog fights take place only at Mach numbers beyond 0.65. Approximately at transonic Mach numbers normally.

So, at Mach numbers less than 0.65 both are equal, roughly equal. Above that our aircraft is far superior. But remember one thing, you cannot take this and say therefore, it will always win. Because winning in a war or winning in a combat is a function of pilot skill. It is a function of the initial positions. And also on the actual aircraft specs. So, if you look purely from the aircraft point of view. If you remove the pilot from the equation, and if you remove some advantages which may be there because of the initial engagement, then our aircraft is superior. See it all depends now, if our pilots are also superior then they have a superior aircraft with better skills, they will always win, okay.

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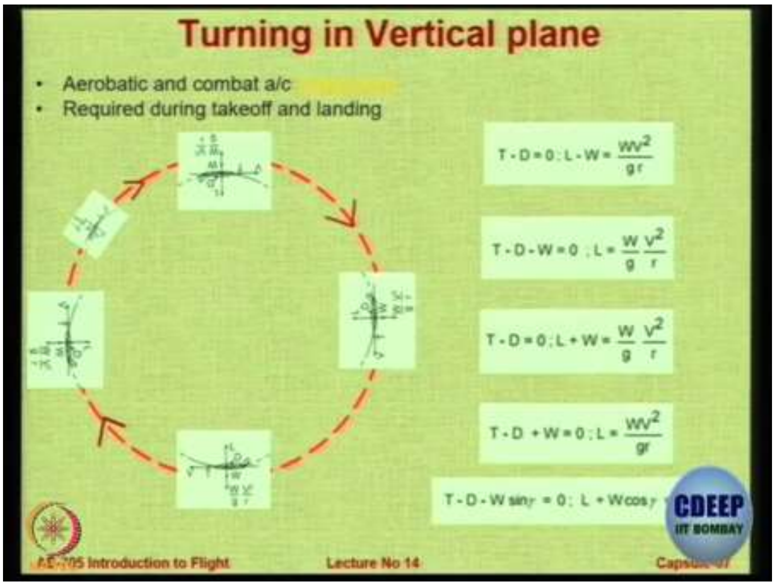

The last thing that we discussed about turning flight is turning in a vertical plane. Now, In the vertical plane, basically it is only for, not for transports. okay. It is meant only for aerobatic and commuter aircraft. And also, they also only when they indulge in some maneuvers. So let us see some maneuvers.

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Professor: This is a vertical climb. Now almost vertical. Perfectly vertical. In fact now inverted. So it is only for these kind of situations that we are now going to look at vertical flight. And obviously during takeoff and landing you need to do this. Every aircraft does it, although not so dramatically. But you need to actually go into a vertical plane turn when you go for a take-off. So, there are many positions in which aircraft can be. Let us say the bottom of the turn, you will have thrust in the forward direction. Weight below, lift up. So in this 'T' will be equal to 'D' because you are horizontal but lift will be equal to weight, okay.

Lift minus 'W' sorry. So, the excess lift L minus 'W' will be equal to the force required to go into a vertical path. That is $\frac{WV^2}{gR}$. When you move to this condition, now, your nose is pointing vertically upwards. So, now thrust will be equal to weight. If you want to go vertically up, but you are into a turn. So there is a lift force which is trying to make you go inside the circle, correct. So here $T - D = W$ and $L = \frac{WV^2}{gR}$. Here now you are inverted. So, again horizontal. So T equal to D. So, T minus D equal to zero. But L plus W both will give you the acceleration and therefore, you come inside. So, now if this is the case what happens at the final position or in the what you called as a 3 o'clock position.

So, here the T minus D plus W is zero. Which means T plus W, thrust and weight equal to drag and lift will be equal to centrifugal force. So you can see the lift keeps on changing, the thrust keeps on changing. So to fly in this particular condition continuously at a constant speed is not very easy. You need a co-ordination between the throttle and also the control surfaces, okay. So, in general if there is an angle you can use this formula for angle cos gamma will go from zero to 360, okay.

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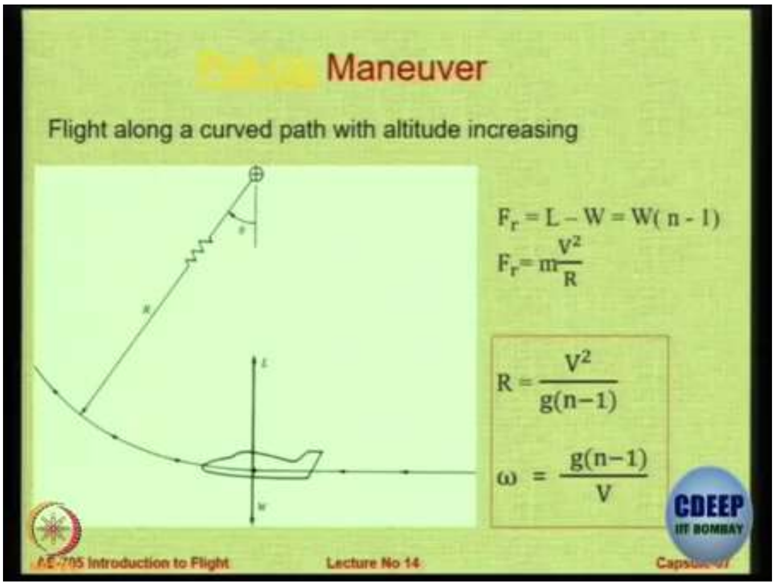


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So, what is a pull up maneuver? Pull up maneuver basically is a maneuver in which you pull yourself up from a horizontal flight.

Professor: So this is a dive pull up. You go into a dive and then pull up. This is a dive pull up.

Ok. So you are in a curved path and your altitude is continuously increasing from the horizontal you are going towards that side, okay. So, the forces can be balanced. The force acting would be lift minus weight. And that will be equal to $\frac{mV^2}{R}$. It is like the turning flight. So the same formulae only thing is plane has now changed from horizontal to vertical. The formulae are the same. If you replace that aircraft with a point mass, whether you draw a circle like this or you draw a circle like this it is the same, okay.

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Let us see one more short video about a dive pull out.

Professor: This is a dive, and this is a pull out. Although this is inclined, so it is not a normal pull out. It is a inclined pull out.

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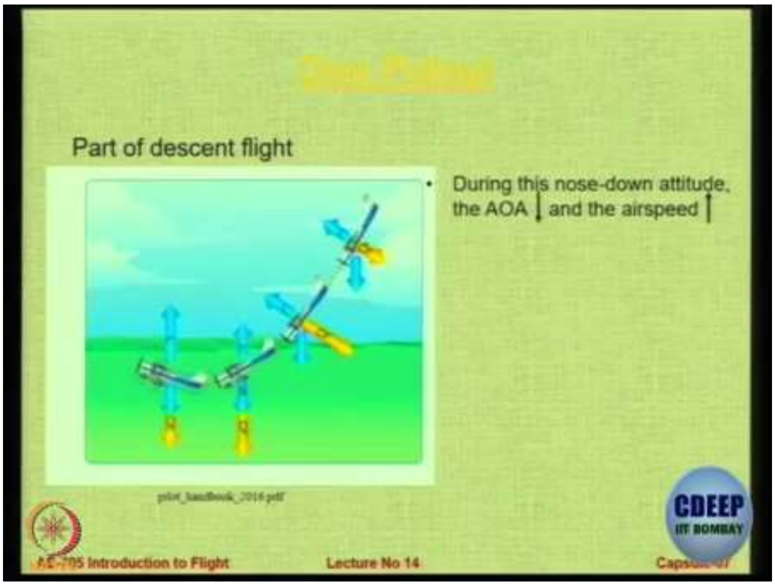

So dive pullout is about a descending flight. So the angle of attack is going to decrease and the speed is going to increase because they are related you know.