Introduction to Flight

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Lecture No 47
Introduction to Turning Flight
Level Turn & Pull-up Maneuver

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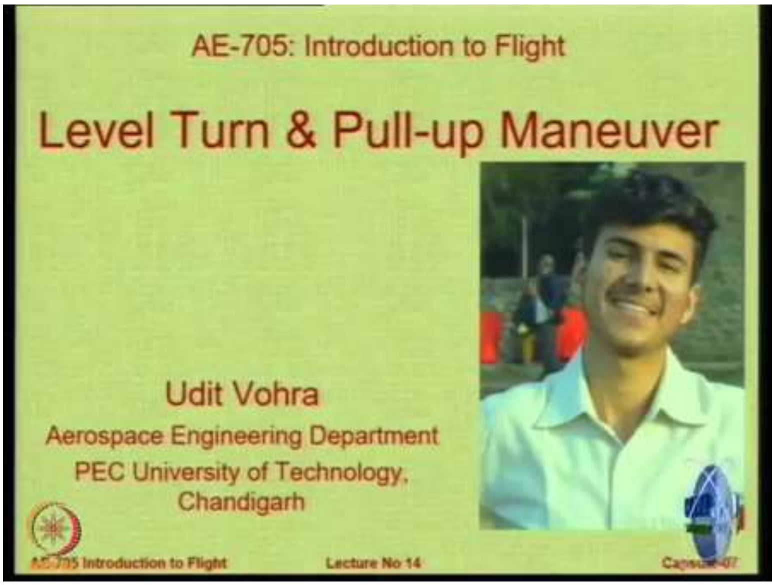

All right. So in about hour time, I am going to talk about level turn and pull up maneuver. Now these 2 maneuvers are more relevant and applicable to military aircrafts. Transport aircraft also indulge in level turn and also do pull up. But the critical conditions are applicable mostly for military aircrafts. So today you will see a lot of videos of military aircraft. I find them very exciting and very interesting.

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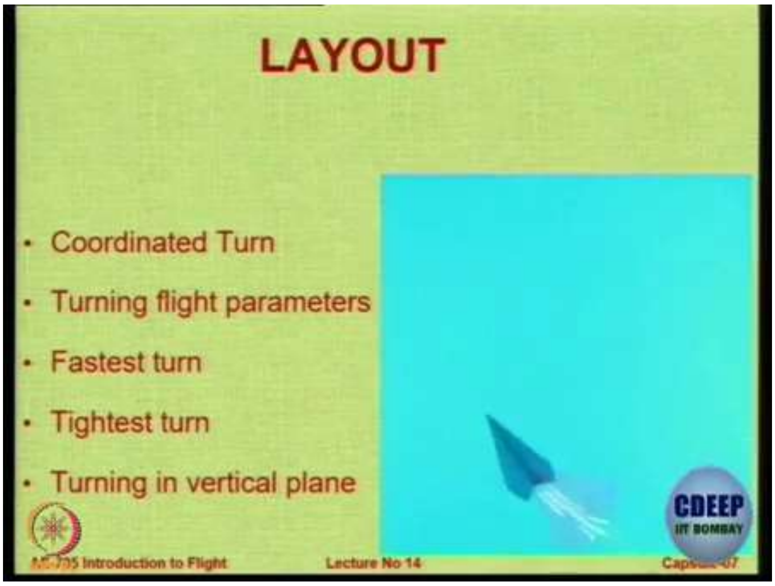

So this is today’s layout. We are going to look at, what is meant by coordinated turn. And after looking at a coordinated turn, we will define what it is and we will show you what it is. Then we look at turning flight parameters, fastest turn, tightest turn and finally turning in a vertical plane. The previous turns are in the horizontal plane, the last one is in the vertical plane. Okay. So I want you to watch a video.

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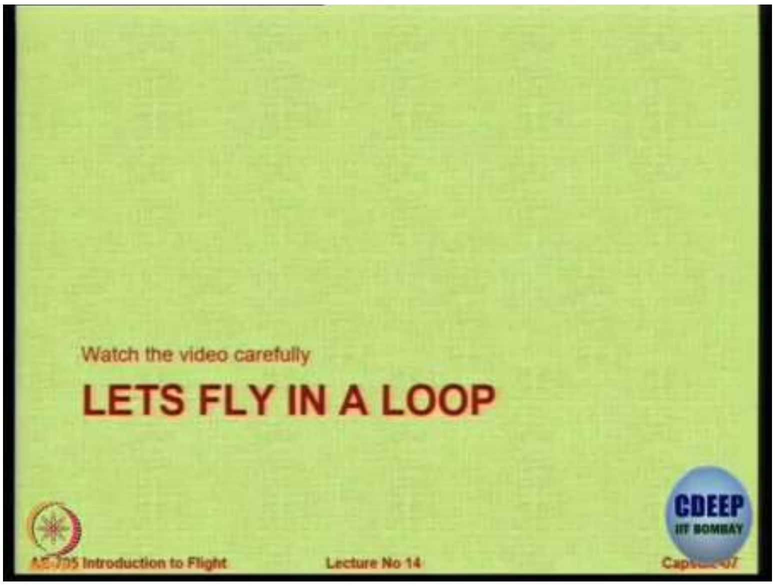


Watch the water level during the tu
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Watch the water level during the tu
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Lecture No 14

Very carefully watch this video. In this video, the pilot is going into what is called a vertical loop, which is actually a, sorry sorry. You can see that by looking at the background. But I want you to focus your attention to the extent possible on the glass that he is holding. The pilot is holding a glass of water. And as the pilot goes into a turn, looking at the background you should be able to make out, whether it is a vertical turn or a horizontal turn.

And watch the water level when this turn takes place. So right now the pilot is horizontal because the clouds are stationary. Okay. But later on we saw that the horizon went down. That means, we know that the aircraft went up. But what happened to the water level during this? Did it move or did it? Did you see any meniscus formation. Well it was not clear. Let us see once again. So the aircraft is going into a non-uniform maneuver, but the water in the glass does not seem to be affected. So what is the g force acting on the glass? Or what is the force acting on the glass is the same. As when the aircraft is flying in level flight or even when it is stationary. So how can you do this?

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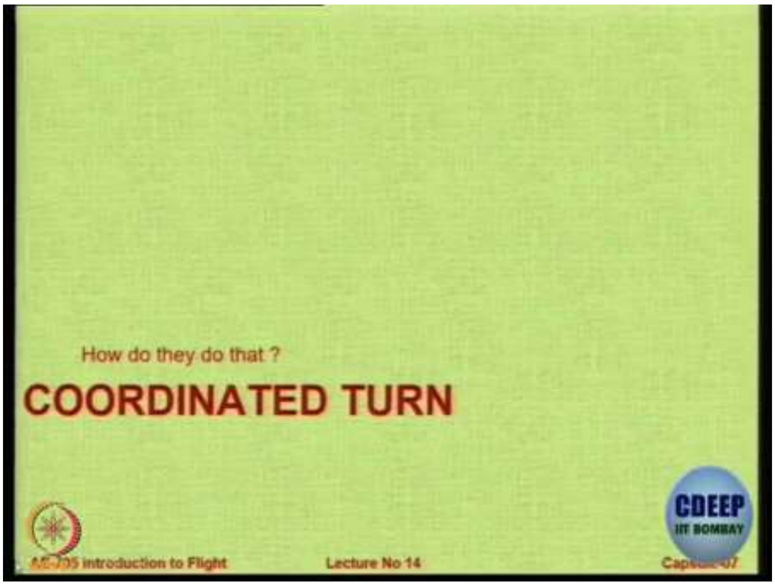

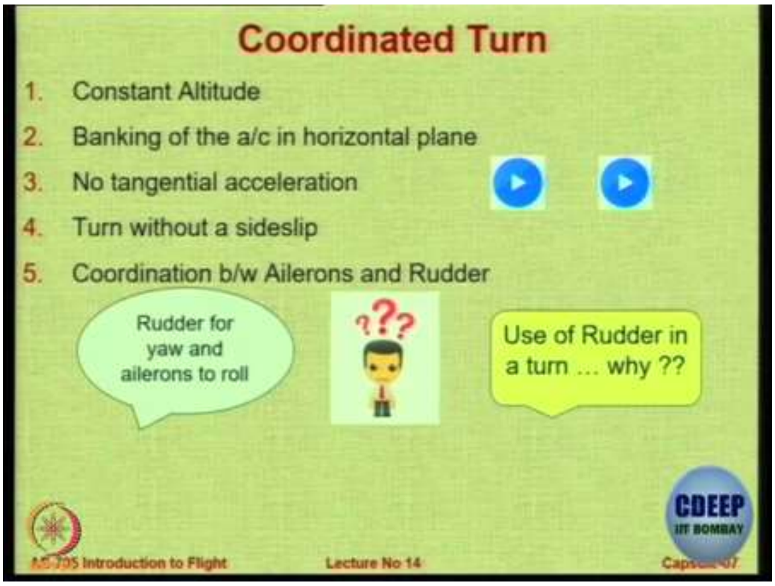

The whole aircraft is moving, but the level of the water is stationary that means there are no net imbalance forces acting on the water. So this is done by what is called as coordinated. Although in the example we have shown a vertical motion, but the same can also be shown on other directions.

So what is a coordinated turn? In a coordinated turn, now this called as, this is basically a level coordinated turn in the horizontal plane. So the altitude remains constant. The aircraft banks at the horizontal plane at some angle and that angle also remains constant during the turn. There is no acceleration either this way or this way to cause what is called a skidding or a drift. So you turn without side slips. So you do not turn like this and then go this way. Some aircrafts' maneuvers are like that, when you turn and then go this way.

That is intentional. When you peel off. So many air shows that you see; that is intentional. But in a coordinated turn, no side slips, it has to be on a circle. And this is achieved by a very nice coordination between the ailerons and the rudder. Ailerons which give you the roll and rudders which give you the yaw. So let us see. We have 2 small videos indicating. Now you must tell me looking at the aircraft, whether you think the turn is a coordinated turn or not.

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The aircraft is in a heavy bank actually. Which aircraft is this? One more! Okay. So you have to be very sure. Do you think they were coordinated? Do they meet all these higher requirements? These requirements only the pilot knows. You cannot comment by seeing. Now even though first four requirements; I do not think only by looking at the video we can be sure. So we are not sure. Let us see. What do we need? We need rudder for yaw and ailerons for rolling. Okay. And some people get confused here, as to why do we need rudder in a turn? So that we will explain very soon.

So to understand coordinated turn, let us first look at a uncoordinated turn. And for the pilot the only visual indication of an uncoordinated turn is a turn and bank indicator which is a small instrument in the cockpit. We will show you the video.

So if the aircraft is in coordinated turn that means it goes exactly along the horizontal circle with the aircraft always tangential to the circle at all points, although in a bank. Then there is no lateral acceleration on any side. There is no vertical acceleration also. And therefore, in this particular experiment, this ball remains in the Centre. one option is you maybe in a slipping turn in which case the aircraft is slipping inside because rudder has not been applied.

That is why we need the rudder. So we are go into a turn, but you do not apply the corrective rudder, you are going to slip inside the turn. You will be turning but you will be slipping. Or you will be skidding. Okay. So, this, as you know this presentation was made by an intern, so I wanted him to explain skidding. This is what he came up with. It is completely unconnected with aviation but it is interesting so I left it here.

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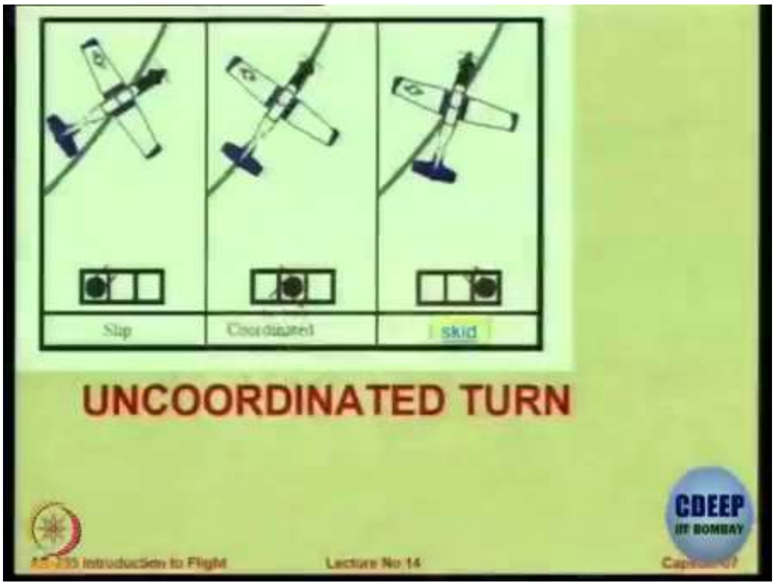
Slip
Coordinated
skid
UNCOORDINATED TURN
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It is skidding. You are going into a turn, you are going into a turn. That is skidding. Now that is skidding on a car, but what happens when you skid in an aircraft?

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So to skid in an aircraft, you need to ensure, or you need to have a situation where you either give excessive yaw or the role is not matching. So let us see, how we use rudder in a turn and this video will also explain to you some more detail about coordinated turn.

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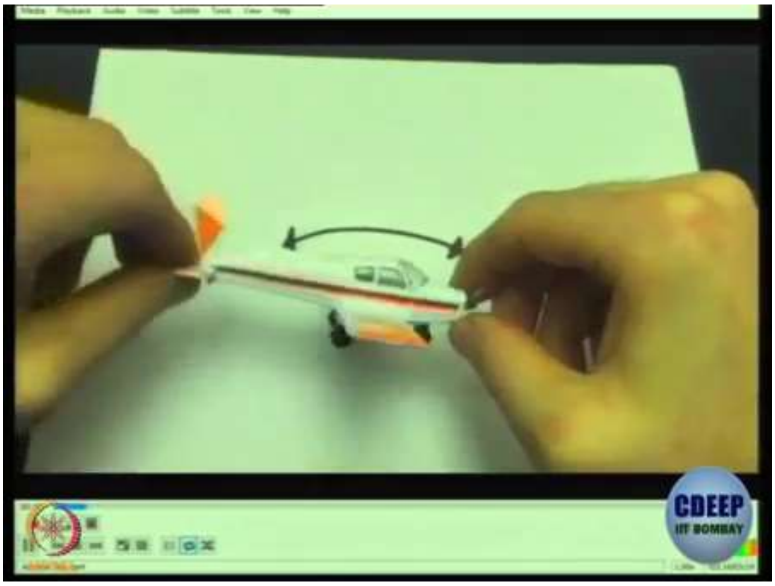

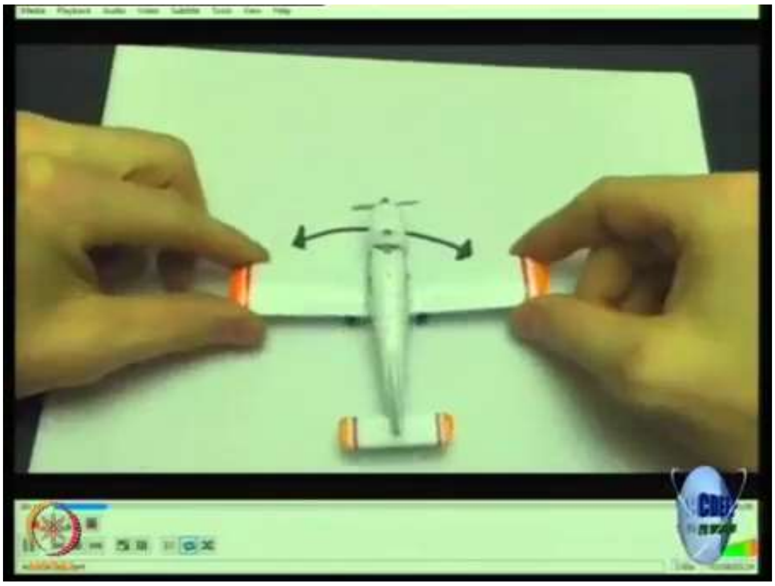


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Aerodynamics: Airfoil Camber, Flaps, Slots-Slats & Drag:
"Smoke Lifts" circa 1938 NACA Langley
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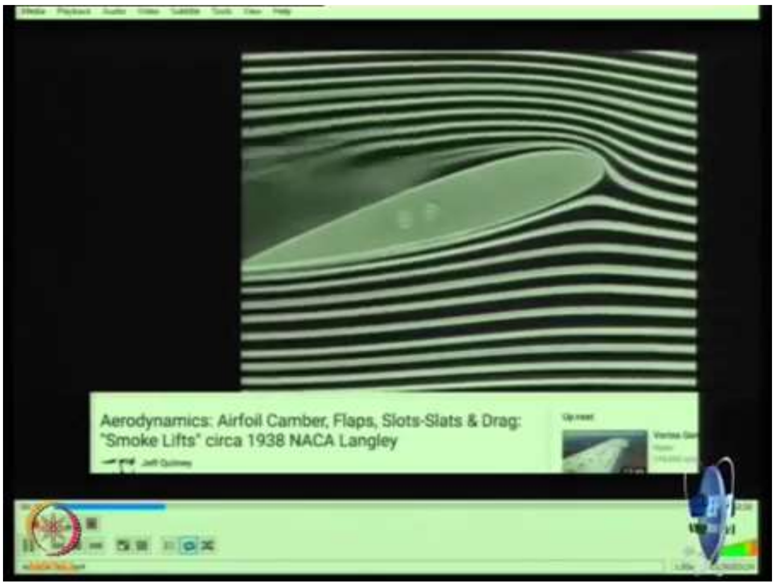
Aerodynamics: Airfoil Camber, Flaps, Slots-Slats & Drag:
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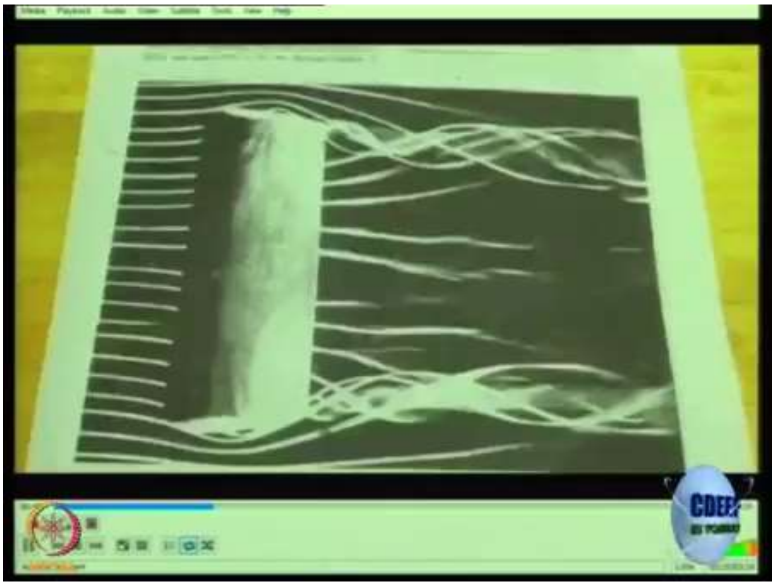

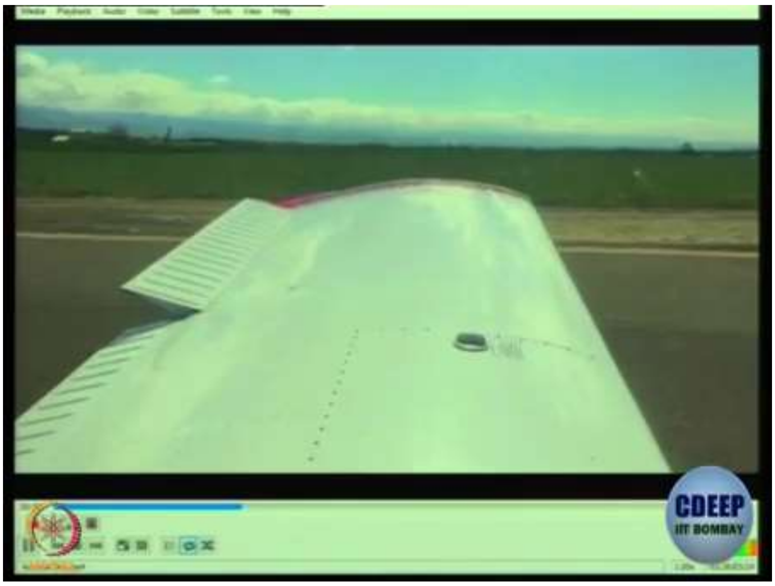

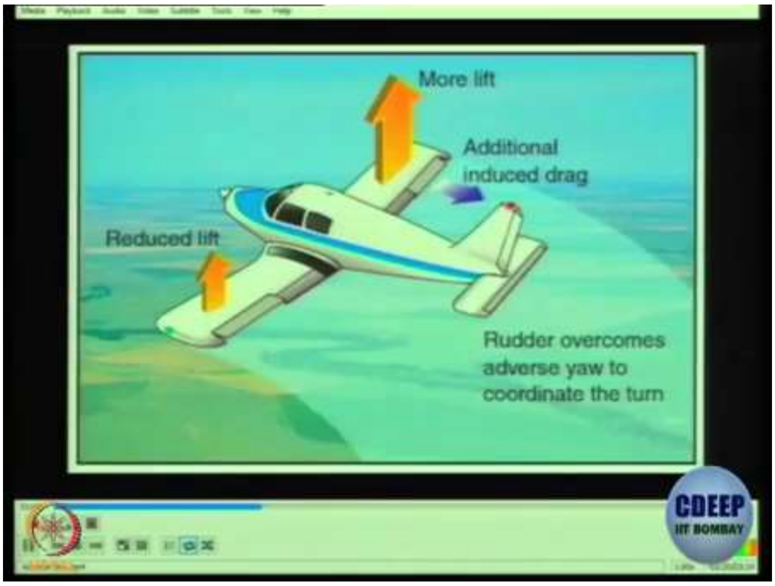
More lift
Additional induced drag
Reduced lift
Rudder overcomes adverse yaw to coordinate the turn
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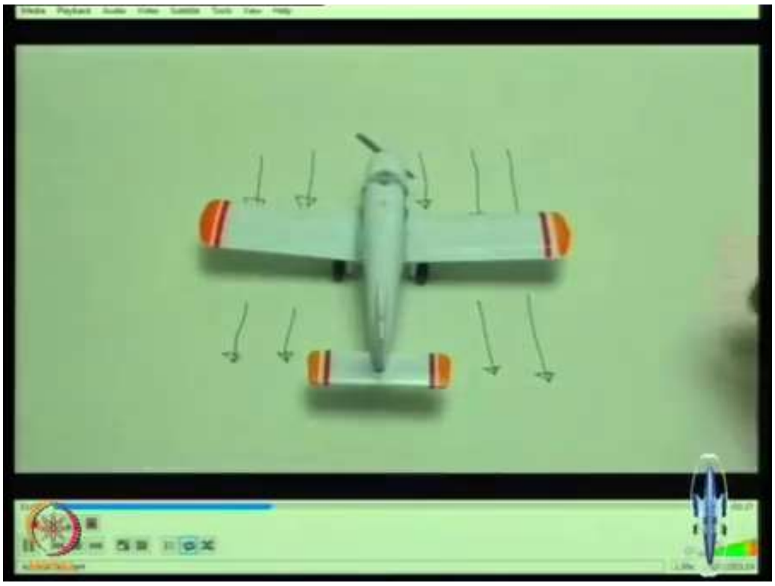

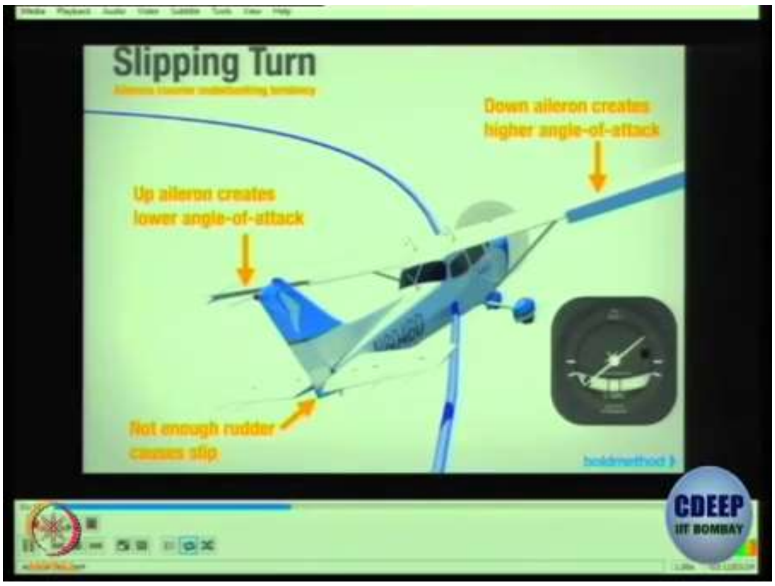
Slipping Turn
Down aileron creates higher angle-of-attack
Up aileron creates lower angle-of-attack
Not enough rudder causes slip
boldmethod
CDEEP IIT BOMBAY


Adverse Yaw Is Counteracted By Rudder In Coordinated Turn
Horizontal Lift From Rudder
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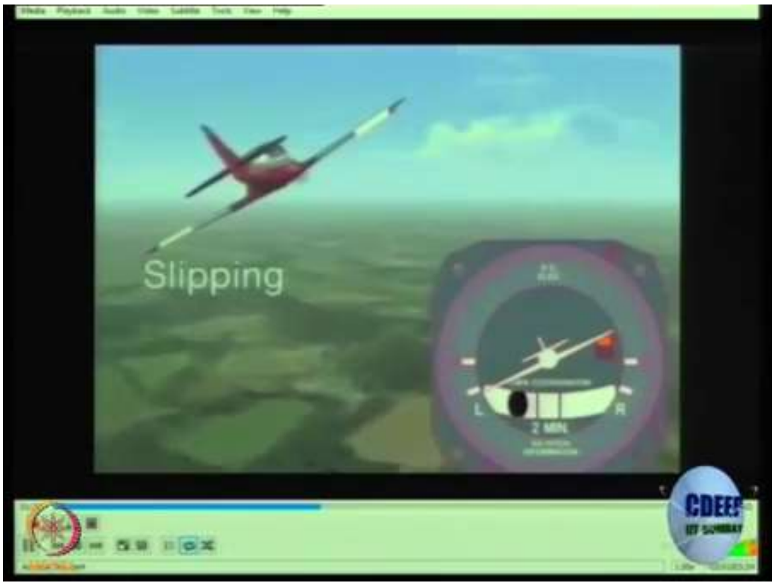
Slipping
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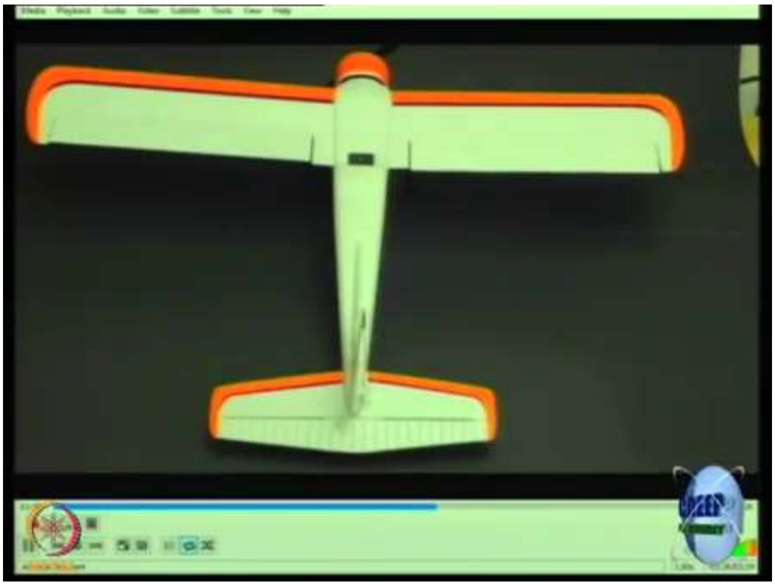


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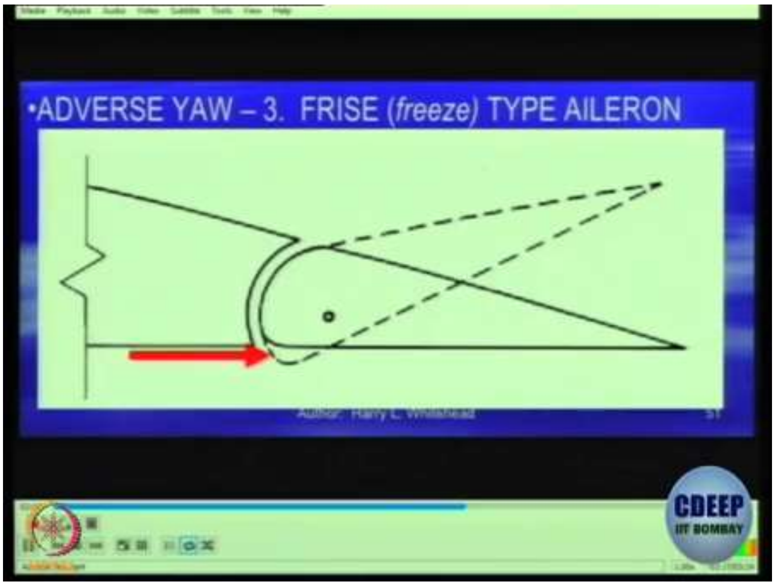
•ADVERSE YAW – 3. FRISE (freeze) TYPE AILERON
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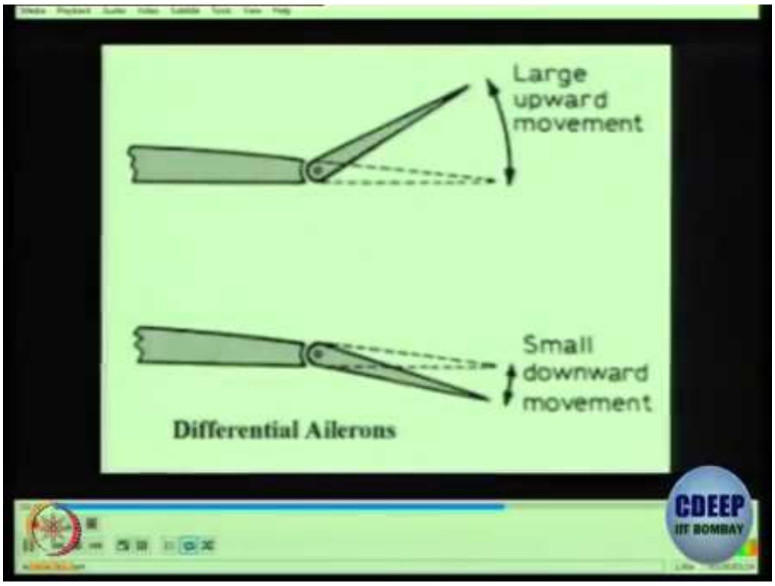
Large
upward
movement
Small
downward
movement
Differential Ailerons
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Adverse Yaw Is Counteracted By Rudder
In Coordinated Turn
Horizontal Lift
From Rudder
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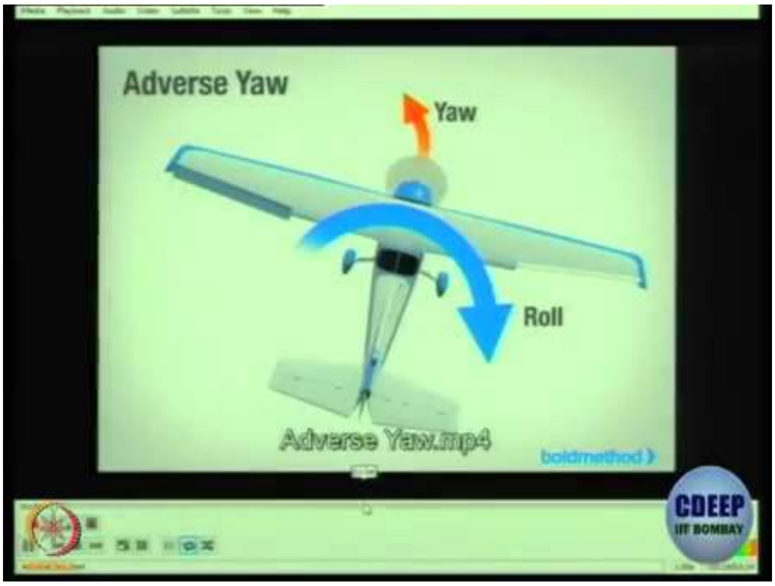
Adverse Yaw
Yaw
Roll
Adverse Yaw.mp4
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Slipping
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The opposite direction that it rolls. Okay. video done. Okay, now it starts. Just kidding. So first let us look at the 3 directions at which an airplane can rotate. This is pitch. When we move the nose of the aircraft up and down. This is roll, when we move the wings up and down. And this is yaw, when we move side to side. A wing is like the fins on this air vent directing wind at different directions.

As we increase the angle, the wing is moving the air, it start to change and manipulate the air travelling around it. This not only produces difference in pressure between the top and the bottom but we also get a net downwash of air. Anyway when the wing is producing a lift, it is a system doing work on the air. And no system that does work on another is 100 percent efficient. The byproducts of producing lift is induced drag, which is a drag that is induced by the production of lift.

And usually the amount of lift that each half of the lift creates is equal. However, when we use our ailerons to roll left to right, one ailerons deflects up causing the wing to produce less lift and the other aileron goes down causing the wing to create more lift. By changing the amount of lift that each wing makes, we can roll the aircraft. But since the byproduct of producing lift is drag, the wing that is producing more lift is also producing more drag.

This causes the airplane to kind of slip through the side ways. The vertical stabilizers will help keep the airplane from yawing too far. But to stay coordinated, we have to use little bit of rudder. When the airplane slips sideways through the air, the wing hitting the side of the fuselage creates extra drag. And we feel this as a sideways force. This instrument here, is called a turn coordinator.

And the little level looking thing at the bottom is called inclinometer. It is just a marble and a curve glass tube and so when the airplane slips sideways, the ball gets funneled outwards on the outlet tube from the sideways on the fuselage. The person in the coordinated airplane will only ever experience downward g forces. Much like a motorcycle and unlike a car. If you feel a sideways force pushing you into a side the airplane then your plane is uncoordinated.

There are couple of different things that aircraft designers can use to try and reduce the effects of adverse yaw. Some airplanes actually mix in a little bit of rudder with the aileron usage and some aircrafts like this Beachcraft touches use this frise type aileron. This is where when 1 aileron goes up, the leading edge of the aileron touches down into the air flow to cause extra drag. This is to countering the induced drag on the other side.

Some airplanes like this piperaerope use differential aileron. This is where the upgoing aileron travels farther than downward one. And some of the bigger and complicated airplanes use roll spoilers. But even with all this, pilots still need to apply rudder pressure with aileron in order to stay coordinated. So I am going to take this piper aerope and see if I can try and demonstrate some adverse yaw even though it has differential ailerons.

First I am going to just drag the wings forth and back without touching the rudder pedals. Notice how the nose of the airplane that swings back and forth when I bank on the ailerons. Now I am going to try and do the same thing. Except this time I am going to apply rudder pressure simultaneously with my aileron inputs. Notice how I am able to keep the nose of the airplane locked on as the same position on the mountains.

It is kind of hard but I am like twisting the fuselage in the air. Thanks for watching. I hope you liked it. And let me know what you thought.

Professor: Okay so I want to just reinforce 3 or 4 concepts here… slips sideways, the ball gets funneled outwards on the outlet tube from the sideways on the fuselage.

So one interesting thing that this author has explained is the fact that when we use ailerons, we use them differentially. So one of them was goes down, the other one goes up. The one that goes down produces more lift compared to the one that goes up. And hence we start rolling in the direction where the one that goes down or opposite to one that goes down. But he mentioned that along with increase in lift there is also going to be increase in drag because the moment you have more lift, you have more induced drag. So there will be a tendency of the aircraft to yaw in the direction opposite to the intended.

So like he showed, here is an aircraft. He rolled it this way but because of differential drag, it will also yaw this way. This is the opposite direction to the one intended. You would be happy if it rolls this way and yaws this way. That is the way you wanted but what will happen is adverse. So you roll it like this, it will yaw this way. So to cancel this tendency, there are 3 or 4 technique. one technique is to have what is called as a freeze aileron.

In a freeze aileron, what you want is the side that is producing less lift should also produce more drag, to counter the drag that is produced on the other side. So the side that produces less lift is the one that the aileron goes tail up. So what they do is, they project the nose down below the wing so that there is a drag created. So the aileron which his going down generates more lift, hence more drag.

The aileron which goes up, the nose produced in the airstream that also produces more drag. So these two drags are kind of cancelling each other. So this yaw tendency is cancelled. This is one way but this is a bad way because you are fighting drag with drag. Ultimately, the engine has to suffer. The engine has to produce more thrust or your speed will come down. The other way of doing it is differential aileron deflection. So the amount by which the ailerons go up by more than the aileron go down as you saw in the video also. You can see in again because that will help you remember it.

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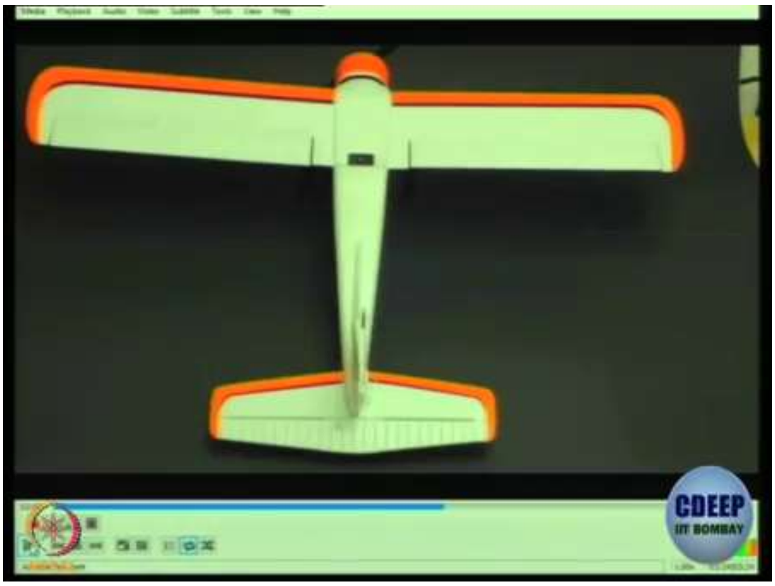
CDEEP
IIT BOMBAY

The person in the coordinated airplane will only ever experience downward g forces. Much like a motorcycle and unlike a car. If you feel a sideways force pushing you into a side the airplane then your plane is uncoordinated. There are couple of different things that aircraft designers can use to try and reduce the effects of adverse yaw. Some airplanes actually mix in a little bit of rudder…

So one way is that the moment you deflect the rudder, the ailerons, there will be some automatic rudder deflection. Notice how it is happening. The rudder and ailerons are coupled. With the aileron; so this aileron is going up, this aileron is going down. So this side will have more lift, so the tendency will be to yaw towards that side. Look at the rudder. It is trying to bring it to the opposite side. This is automatic. This is just linkages. So the pilot does not do anything. The pilot applies the ailerons, the rudders move automatically by some amount.

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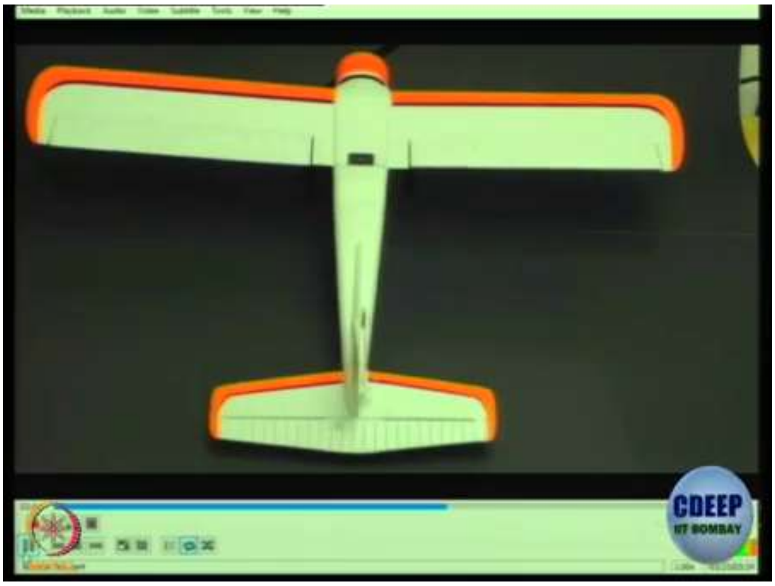

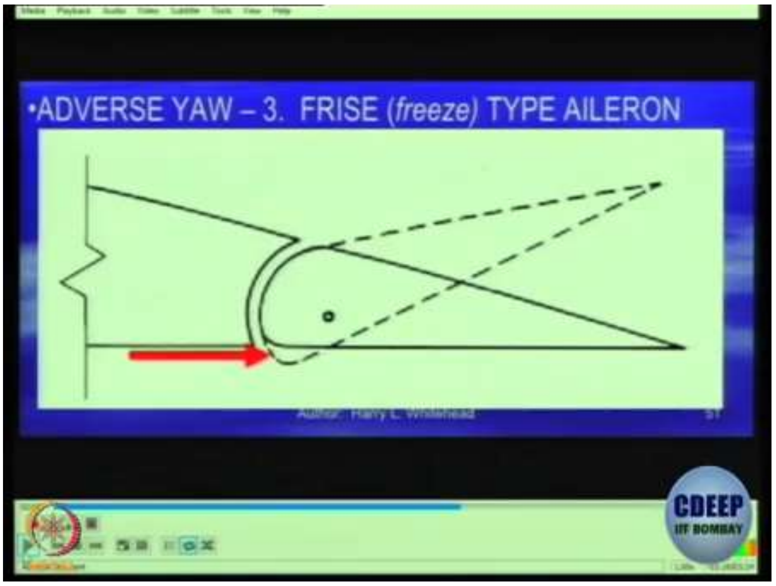

Usage and some aircrafts like this beachcraft touches use this freeze type aileron. So you can notice, the aileron, when it is not deflected, it is beautifully matching with the contour of the wind. But when it is going nose down, tail up, at that time you want more drag because other side is creating more drag. So we project it below. This is where when one aileron goes up, the leading edge of the aileron dips down into the air flow to cause extra drag.

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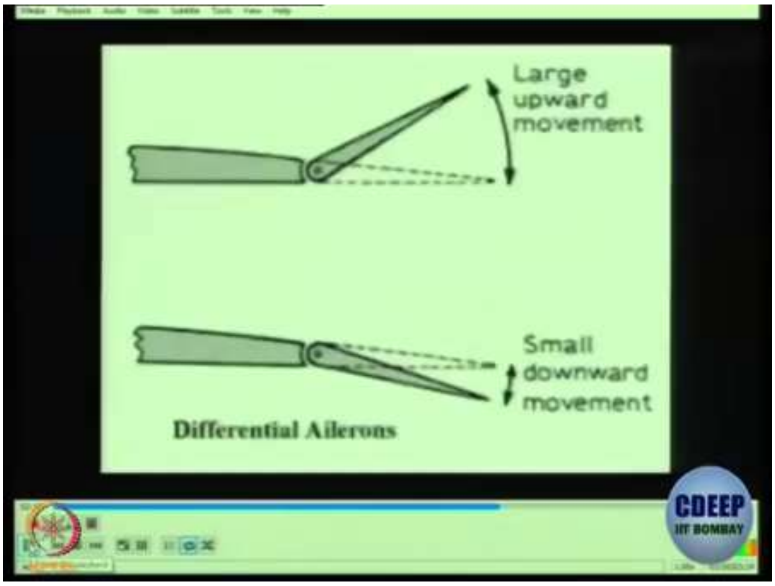

See, the air from the front is going to cause extra drag; countering the induced drag on the other side. Some airplanes like this paperaerope use differential aileron. This is where the upgoing; so upper aileron has larger movement lower aileron has downward, has smaller movement. So this is also a way of combating. aileron travels farther than downward one.

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Adverse Yaw Is Counteracted By Rudder
In Coordinated Turn
Horizontal Lift
From Rudder
boldmethod

So when you deflect the aileron down, you create lift but you are creating more drag on the other side. So that additional drag is going to cancel the drag created because of induced. So you can see, up is more than down. And some of the more bigger and more complicated; now this is more complicated, using spoiler again not recommended. So here what we are doing is, we are creating addition drag by deflecting the spoilers whenever we are going into a roll. This is again not a good way but it is an automatic way of doing things. So you put roll spoilers; Use roll spoilers. But even with all this, pilots still need to: Yeah but still with all that also, there might be a need. Okay, so now once we have seen, how it is, what is to be done and what is not to be done.