**NOC: Introduction to Airplane Performance**
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**Lecture - 40**
**Longitudinal Control: Elevator**

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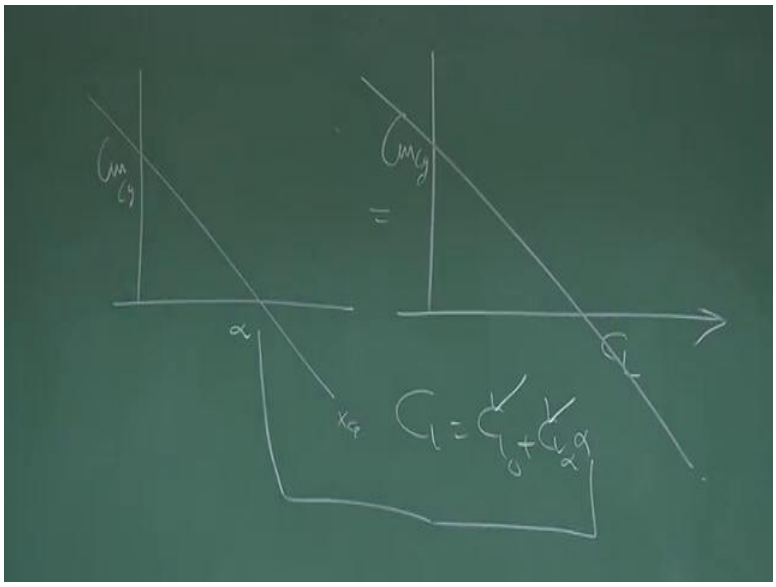

So, far we have been drawing C m C g versus alpha, let say this is the case and you also know this is for a particular C g location. Now, I can easily translate these into an equivalent graph C m C g versus C L, we after all if I know what is the alpha here, I know what is the corresponding C L, because C L is nothing but, C L naught plus C L alpha into alpha, I know C L alpha I know C L naught. So, once I know alpha, I know what is the C L, so I can scale it out and it still the variation of C m and C L will remain like this.

Now, the variation is C m and C L like this, let us see, what is the equilibrium point. Please understand, from C L versus alpha graph, I am now shifting towards C m versus C L graph. And, I understand for each alpha there is a corresponding C L, so I will be replacing alpha by C L, so let say that is the graph which has come.

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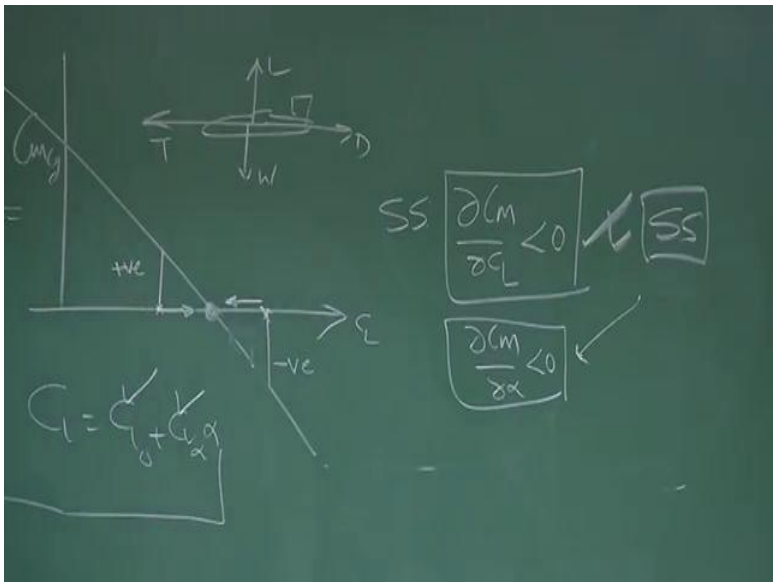


Now, our question is, let us check about the trim point about the equilibrium point, whether this aircraft is statically stable or not. We know it has to be stable, slope is negative, but we know only that C m versus alpha slope is negative. But, because alpha and C L can be related like this, so you know by number the slope has to be negative now, let us add some physics to it. Let us see an airplane was moving like this, a cruse our equilibrium is cruse.

It is because of some disturbance C L has decreased, what is the meaning of that, because of some disturbance C L have increased. It was going, the particular C L is the 0.2 that was corresponding to say set 3 degrees, because of some upward here, the 3 degree has become 5 degree. So, I will say now the C L has changed, the perturbation is on the C L versus C L, this point. From here, let us come to this point, what will happen the airplane initially generate in negative pitching moment, negative means nose down.

So, this aircraft will have initial tendency to come back to the equilibrium, negative means start reduce angle of attack, so C L will reduce. Similarly, if there is a reduction in C L, then this aircraft will generate positive pitching moment, we try to again has initial tendency to come back to the equilibrium. So, we see that indeed about the equilibrium as the C L is changing it has initial tendency to come back to the equilibrium.

So, for static stability d C M by d C L should be less than 0 is nothing great, because you know that d C M by d alpha should be less than 0. We have spent lot of time on that and

alpha C L is related by this, the slope has to be less than 0. But, we will be now using this definition for static stability instead of d C M by d alpha, you can use both. But, designers can use some time d C M by d C L is less than 0, sometime d C M by d alpha is less than 0, depending upon what is the requirement.

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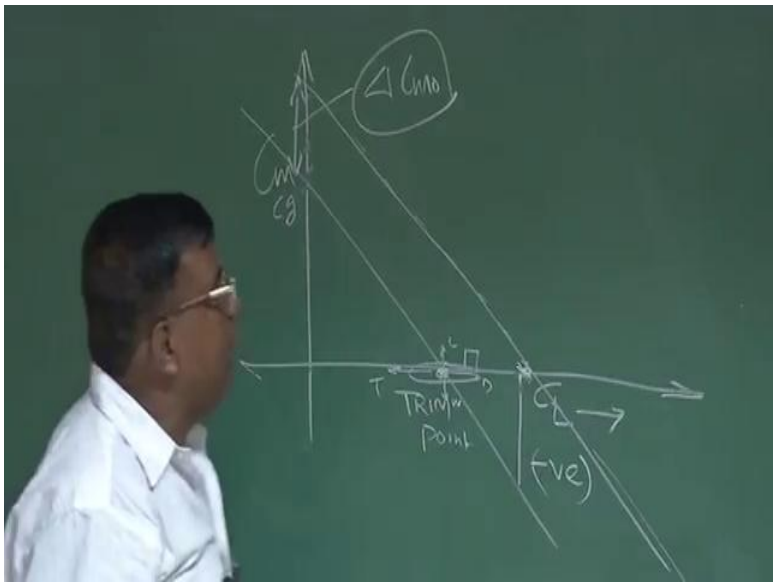


Now, let us also understand C m C G and C L please take a note, now I am using C m C g versus C L graph, which is equivalent which is little bit of numerical scale of upper scale now, C m versus alpha. And for static stability d C M by d C L should less than 0 or which is equivalent to d C M by d alpha less than 0.

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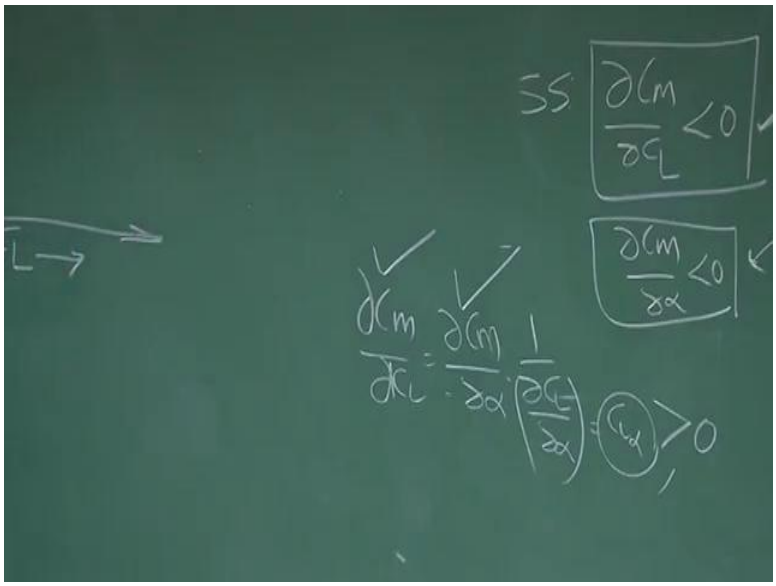


You, can see this d C M by d C L, I can write as d C M by d alpha into 1 by d C L by d alpha in the linear domain, d C L by d alpha is C L alpha, which is always positive. So, whatever sign d C M by d alpha is having, d C M by d C L also will have same sign, so this is the positive number. So, that is why I am telling this is scaling that is all. ((Refer Time: 04:43)) Let us say airplane is flying here and this is the trim point, that is what you know trim point, I add this point thrust equal to drag, lift equal to weight, the airplanes flying like this.

Now, there is a requirement that the aircraft should fly at a higher C L, still maintain lift equal to weight; that means, you have to fly at a lower speed. So, to balance the lift equal to, to satisfy the lift equal to weight condition, if he is flying at a lower speed, he has to fly at a higher C L or higher angle of attack, so this is the case here. The moment you try to come to this point, what happens, this man will generate an negative pitching moment, because high statically stable, you cannot help it, it will always have initial tendency to oppose, but you want to fly here.

Graphically you want something like this, your graph C m versus C L should like this. Now, this point is trim point, but what is happening, the moment I try to go there it generates a negative moment, you have to counter the negative moment, so that it stays here. Graphically I have to shift this graph from here to here, so what is required, required you have to give additional delta C m naught. If, I can generate this additional

delta C m naught, then this will become trim point or indirectly what I am telling, whatever negative pitching moment this aircraft is giving, I need to produce a positive pitching moment to counter it and that is this. How do I do that? How do I generate this additional moment? Let see.

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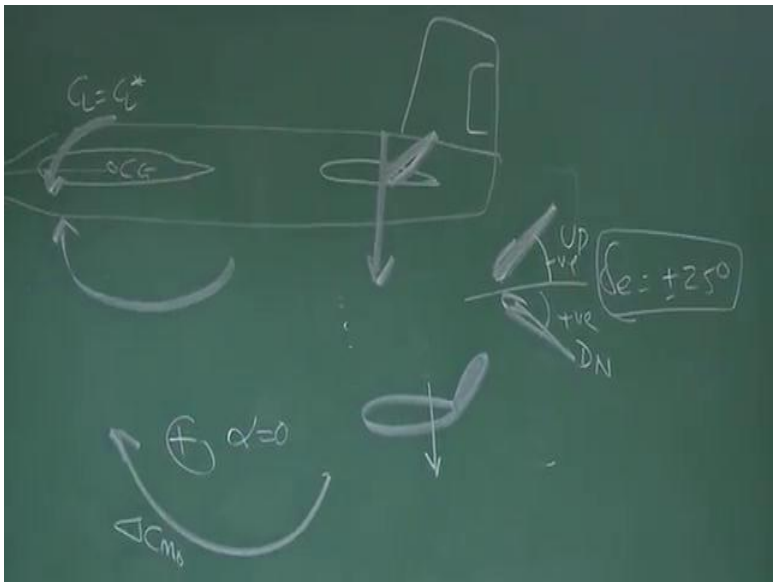


This is your airplane, this is your tail, let us this a few large elevator, let see you are flying at C L equal to C L star. I call this initial as C L star, you want to go to C L double star. The moment you want to go to C L double star, you find there is a negative moment generated it by the airplane about C g, which were negative that is nose down. So, I have to counter this, so what I have to do, I have to give positive moment, so I will take the elevator up. As the elevator goes up, force acts a downward and this is the moment, which counters this negative moment, balance the negative moment.

And, if I try to interpret delta C m naught, what is happening now. See, the moment I am putting the elevator up like this and at alpha equal to 0, this is giving moment about C g and this is, what is delta C m naught, this is here. Is it clear? If, I want to go from here to here, the aircraft will generate the negative moment; that means, I have to generate a positive moment equivalent to this, so that this is counted. I give an elevator deflection up, that counters it and that is how this graph gets shifted from here to here.

Please note that, by giving elevator deflection the stability has not change, the slope remain same. By giving the positive, giving the elevator up deflection, purely understand

elevator up is the negative deflection. So, we will be saying elevator up and this is elevator down, so we will be giving that very bit again, if we are flying at C L star, if you want to fly at C L double star, which is more than C L star.

This aircraft, all aircraft will generate a negative pitching moment, but I want to fly here means, at this point the net moment should be 0, net pitching moment should be 0. So, I will be using the elevator in up configuration to generate a positive moment, so that this moment is counted and I am flying at a higher C L.

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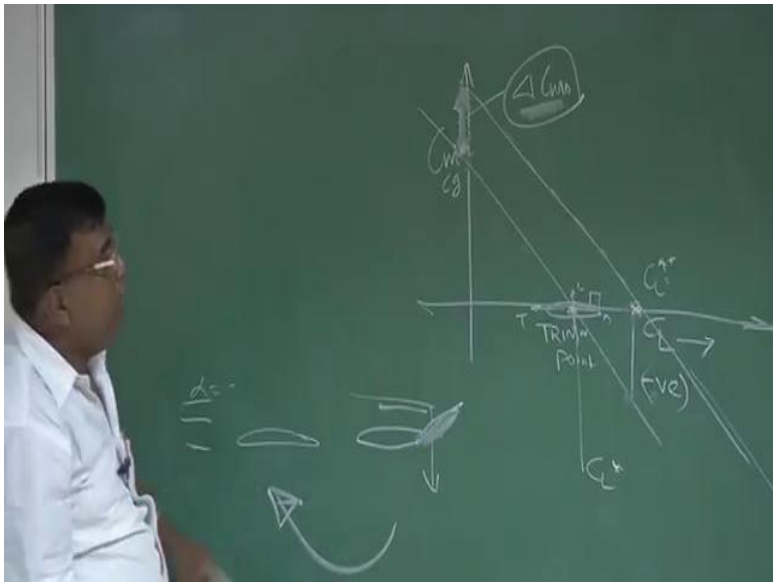


If, I try to explain through this graph, if I want to fly at this C L, which is C L double star I have to add additional delta C m naught and since elevator deflection does not change, the stability slope remain same. To add this delta C m naught, I have to put the elevator up and definition of C m naught is C m at alpha equal to 0 with the wing, that alpha equal to 0 with the force downward, which gives the positive moment that is in our case delta C m naught.

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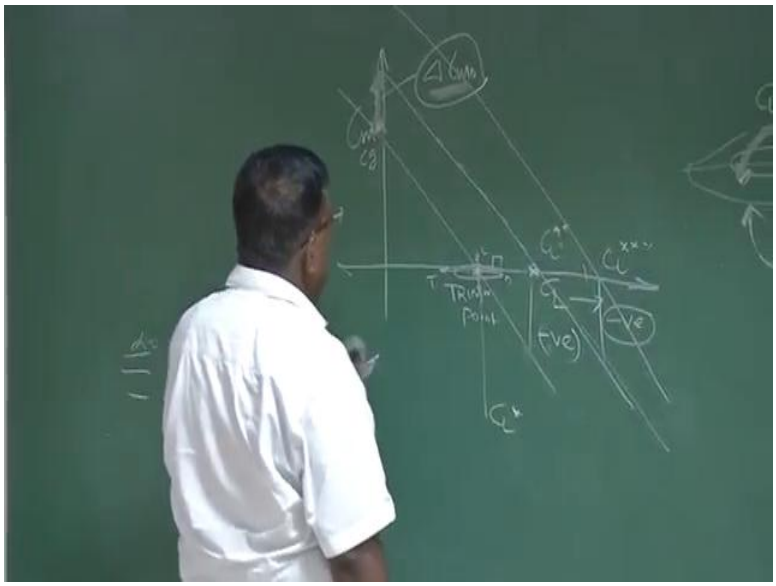


If you want to fly at another C L star or triple star, again you have to see how much additional moment it will generate with respect to this equilibrium. So, this negative moment after here compensate, so I have to further put the elevator up, but you know you cannot go on putting the elevator up or down, because beyond a certain deflection the flow will separate, elevator will become effective, so there is a restriction.

In general, 25 degree plus minus is good enough, 25 degree plus minus means delta e plus minus 25 degree means, plus is down and negative is up, this is negative and this is plus positive. So, total plus minus 25 degree is a good assumption that flowing air separately. I hope, if you have understood this, what I am doing, I have, I mean trim points 1, 2, 3. I was flying at C L here, I want to fly at another C L, when I am flying here I check that I am statically stable, because the slope is negative.

So, I want to go from this C L to this C L, because this is statically stable at this equilibrium, it will generate opposing moment. To fly at here, which C m 0 have to generate positive moment, so I give elevator up.

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See that something here ((Refer Time: 11:47)), so from one and equilibrium to other equilibrium to other equilibrium, this process is called control of airplane, one of these aspects of control of airplane in the pitch plane or you called longitudinal control. This flying at different equilibrium the different C L here, here, here these problem we called control problem and stable depart you know here. So, if de gives your connection between stability and control.

Please understand, if I am trying to fly from one equilibrium to another equilibrium because they are statically stable, they are generate negative opposing moment to discourage that change and you have to give moment form outside for a Longitudinal control it is a elevator. See that whatever opposing moment is coming is they can scale equivalently saying you increase the C m not by delta C m not both are same steps.

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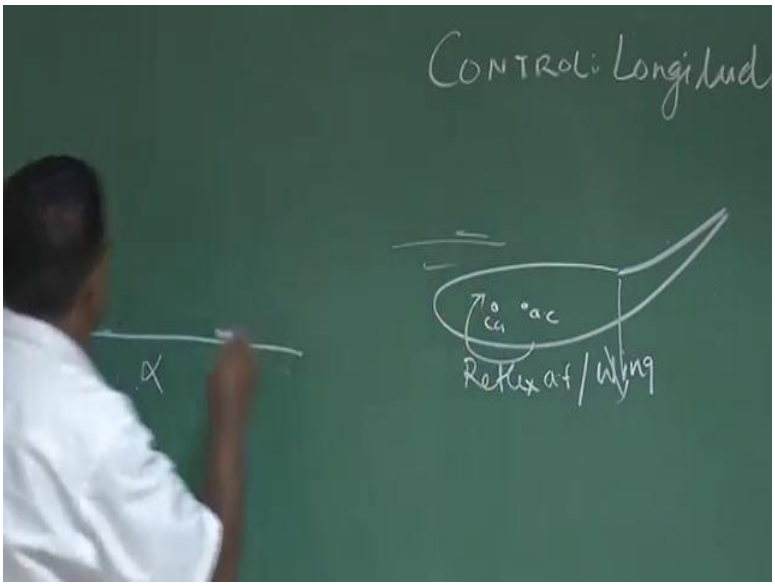


So, you are saying one aspect of control which is Longitudinal is in elevator, now again I come back to configuration which is flying wing. Let us say, this is a flying wing by now, we know it has to be reflects airfoil and this, the C g and this is the ac. So, if I draw this is reflex airfoil, which is at reflex airfoil of course, what you mean by that is wing flying wing having a reflex airfoil take a cross section is having reflex aerofoil.

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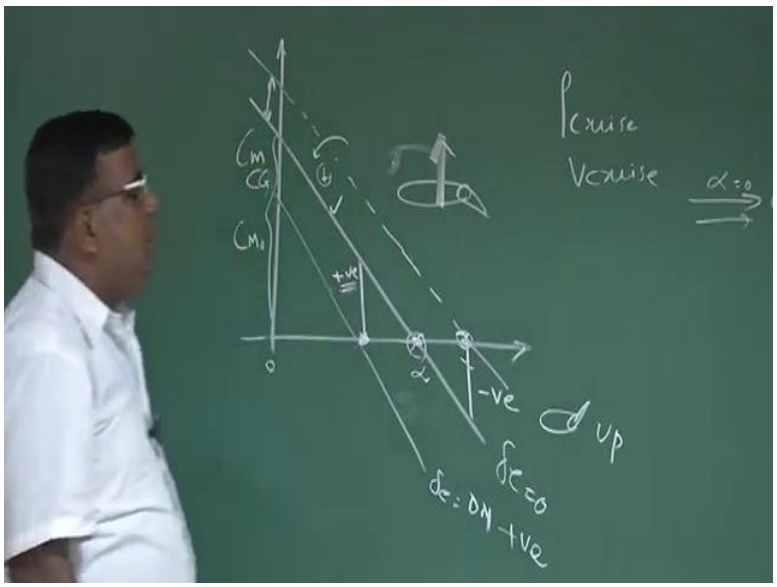


If, I plot C m C g versus alpha for this configuration you know that alpha equal to 0, they will be C m naught alpha equal to 0. Then, they are force downwards which will give

you positive moment, so this graph something come like this I am statically stable this is beyond C g no problem you are expert in this down. You know by now, that if I am flying a flying wing and I want that flying wing should trim at a positive alpha that enough the lift is there if I given velocity to balance with, then not only the aircraft should be statically stable or that is the adorable center of the wing.

So, would behind C g, but also it should be able to by itself generate C m at alpha equal to 0, which I call C m naught, we have one I am talking about flying wing, flying wing does not mean it does not have an elevator. So, there is a clarity you must have generally whenever you design and airplane are a flying wing for that matter you design for a particular mission. So, it of course, it will have a takeout you have claim it will you are a cruise you have a many words, but you are designing always for a one of the most important aspect it could be cruise.

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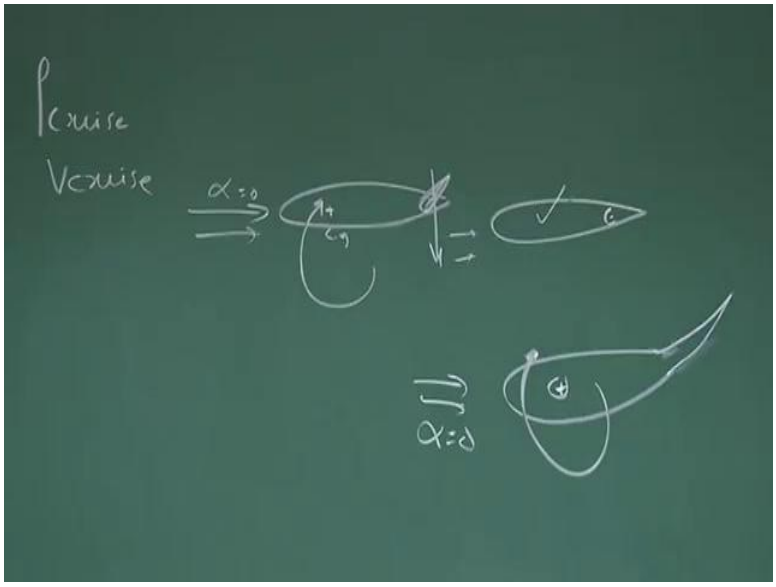


So, if it is for a cruise, then you will like that at cruise altitude, which is pre decided at cruise altitude at a cruise speed V cruise, which is again pre decided to the deciding stage itself. You, try that the airplane wing tail should be late out you such a way, let automatically, you should able to generate this C m naught at alpha equal to 0 without deflecting the elevator. Please understand, if I am deflecting the elevator of a flying wing and it suppose by deflecting the elevator, you can generate C m naught you know, you

know very well, if this alpha equal to 0, this which generate first downwards about C g it will also give C m not.

So, if you design is in ferial, then we have one auction at that attitude you deflect the elevator by exquisite amount. So, that it generates this much of C m naught, but do thing as a good design definitely not, because most of the time will you flying like this and because of this deflection there will be track and unnecessarily you are giving a penalty. So, what you would like we should look for it design, so that this flying wing we fly and by itself it should generate C m naught positive even when delta is not deflected.

And by now you know, how it can be done, how can be done you know it cannot be done for a symmetric configuration, but it could be done for a reflex airfoil. I can design and select the deflect airfoil and manufacture wing flying wing using reflex airfoil configuration. And, this you know this will generate C L naught V naught alpha equal to 0, the message is very clear that.

If, I want to make an airplane design an airplane, which is statically stable and you should be able to trim without any elevator deflection at the altitude at a cruise condition you are flying most of the time. Then C m not should be generated by weaving and tail other component not by the elevator, now suppose you are flying this condition here, now this is delta e is 0. Now, for some time you want to fly at the different alpha different alpha mean differential there, what does it mean it means it will generate negative moment.

So, you have to know use the elevator in it up condition, so that it gives the positive moment about cg and this give nullified and you are C m versus C L graph with of this. So, now, again it is a trim point and effectively could see, but deflecting the elevator I have increase C m naught value this is the control problem. So, this is called the control aspect of the airplane and there is the limit to which you can deflect the elevator typically for normal configuration plus for 25 degrees there are mechanisms to increase that also for physics should be C L, here the mechanics should be clear.

If, I would fly here, if I want to fly here, you going to fly here as should the basic graph is concerned this is generate a positive moment, so we have to counter it, so I should give elevator now down. Because, if I am from this point if I want to fly here it will generate positive moment, so I have to ensure that elevator is deflected down. So, that it gives

nose down moment about center of gravity somewhere here, because either put it down, we have be lift increment in the upward direction, which will give about C g a nose down moment.

So, that will counter this positive moment and I can say that this language shifted here this become the trim point. So, this delta 0 to delta negative delta down delta down is positive delta negative means delta up this of the conversion use and if you C H R, you find frequently this set of a graph or variation displayed for a pilot you know, if I going to fly at this speed, what are the elevator required and he gets the feel for the airplane.

Thank you.