Aircraft Design
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Lecture - 29
Wing Loading: Take off and Landing

Good morning. We are continuing lecture on how to start thinking in terms of wing loading for take off case, right.

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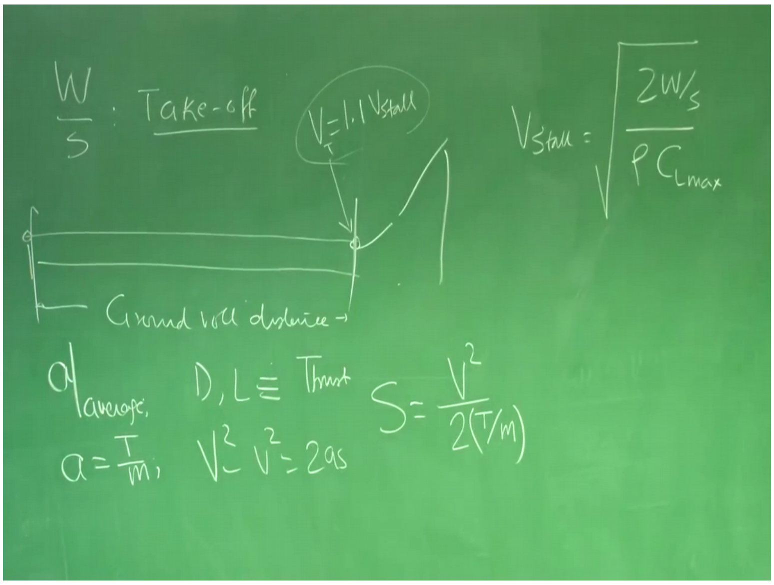

Wing loading for take off at conceptual stage, last two lectures or so, I tried to build how to think to visualize what wing loading is. As far as take off is concerned, we did mention about the forces acting and the approximation and how important it is for their performance. We discussed about high lift devices which can reduce the take off length, we have discussed about thrust to weight ratio which will also reduce take off length. If I increase T by W, but you should also appreciate at a conceptual stage, we do not have all the parameters because we have not configured the whole airplane as it is, but we know one thing about whatever airplane and conceptualizing.

A similar aircraft of that performance will be available in the market and we always select such an aircraft whose mission requirements are closer to what we are going to design and we nomenclature them as baseline aircraft. So, we fix up number from there and try to get some value for W by S. This another popular way is why do not to use statistical data exhaustibly and get the field for wing loading all those parameters because after all the aircraft which you are going to design, we will be part of the family of aircraft existing. Already you are all doing something extraordinarily different, right. So, in that direction I will just use few of the guidance given by Raymour. I thought I will share with you, but before I share, let me also discuss how those charts are prepared, right and you must appreciate the designers insights how much they might have put effort to get those charts in a manner which is based on the model, not just heuristic.

So, if I am talking about let say loosely take off distance, although we know it rolls and climbs and this is the take off, let say we are talking about this much ground, roll ground, roll distance. We understand one thing that if I can somehow manage to approximate as average acceleration, right and neglect drag and lift contribution as compared to thrust which we have done, then I can write a is equal to T by m and I can simply use V square minus u square equal to 2as and s equal to v square by 2 a, where a is T by m. We also know this V which is the final velocity here, it should be 1.1 time V stall as per one of the regulations.

Be careful about it. This sort of numbers are very specific to different types of aircraft, the civil or military and these are guided by the regulatory bodies. So, you have no option to change those.

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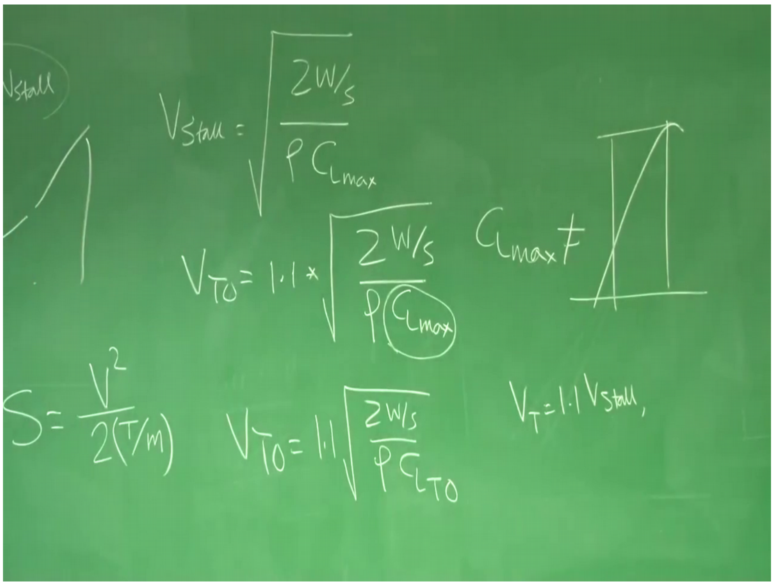

So, now if I use this and we find that V stall is 2 W by S by rho Cl max, then I can easily see from here V take off will be 1.1 time 2 W by S rho Cl max, but we also understand that C is I have taking off at 1.1 times V stall. This V take off is 1.1 time V stall and we need to understand this Cl max is not Cl max here. What we are aware of that is C l max corresponding to be stall because V take off is 1.1 times V stall.

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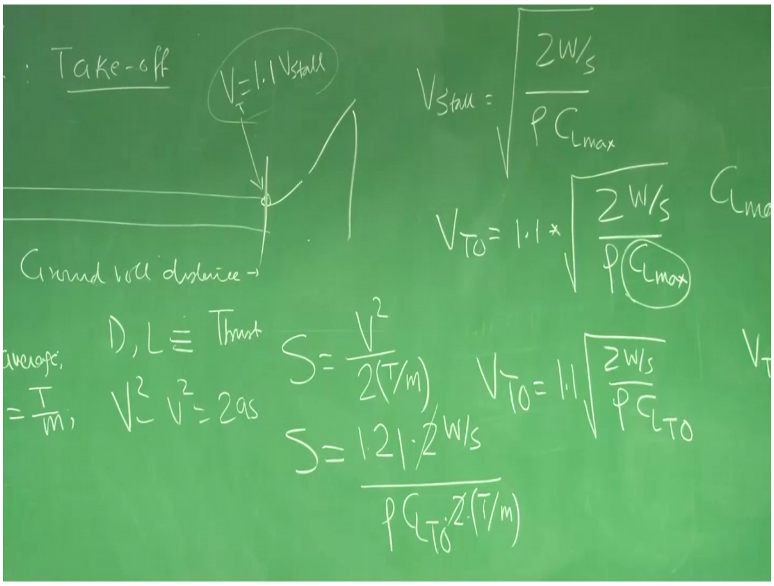

So, let me write V take off as 1.1 under root 2 W by S rho C l take off. If I do this, then I find S equal to 1.21. This becomes we take off 2 W by S, then rho C l take off into 2 into T by m. So, this 2 and this 2 get cancelled.

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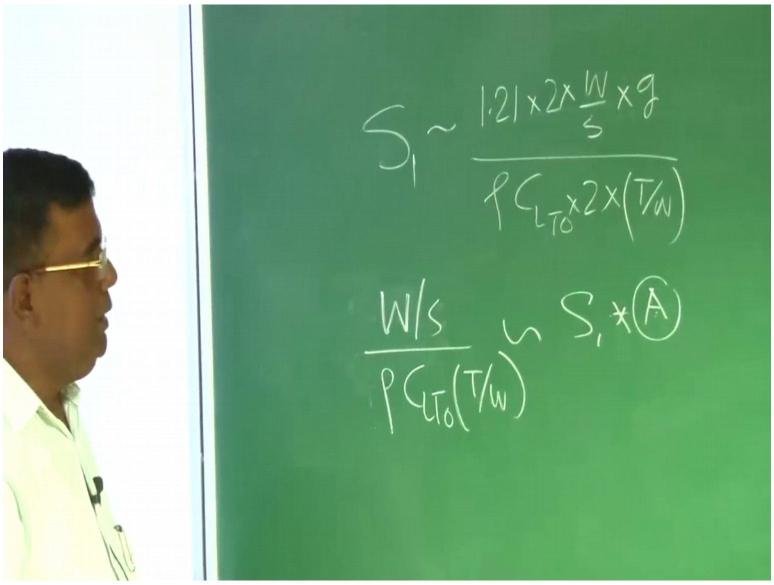

So, I am left with S1 which I am telling this distance S1 going to 1.21 into 2 into W by S into g divided by rho C l take off into 2 into T by W. So, watch out for the parameter W by S by rho C l take off into T by W. This will be proportional to W by S C l take off T by W and rho proportional to S1 into some factor a which say you can find out from here.

So, important thing is if I plot the ground role distance and this parameter, they will form a straight line, right.

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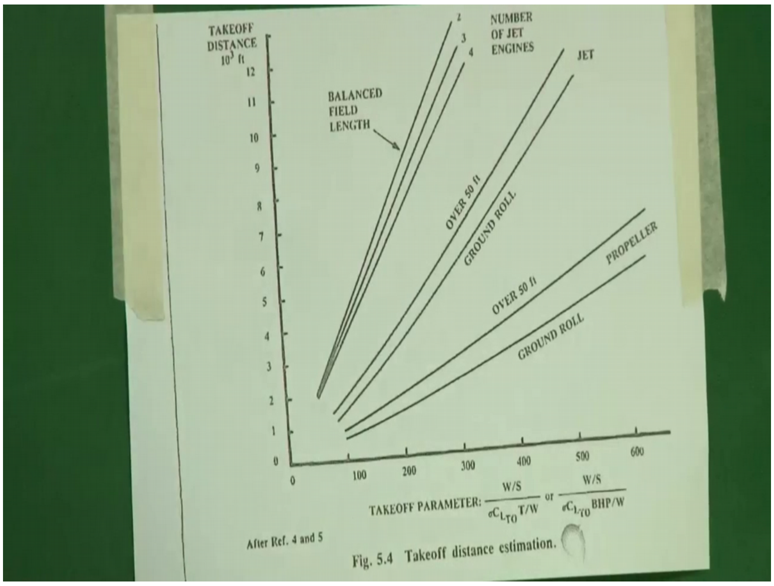

I can do different experiments or I can take the data from different aircraft and feed the data using this model, right and that is exactly has been done if you see here.

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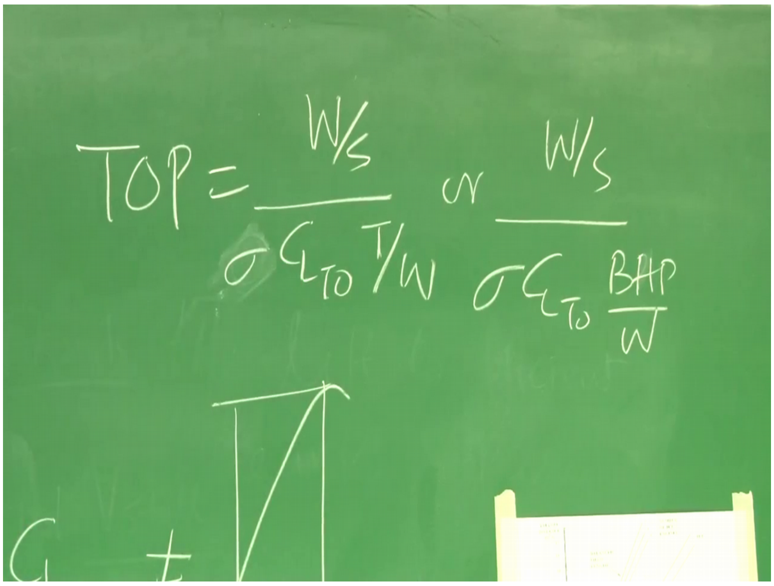

I am referring to Raymore’s book. If you see this x axis is take off parameter, where the take off parameter TOP is defined as W by S wise sigma C l take off into T by W or it is W by S by sigma C l take off into BHP by W. It is the similar form. Only in this we have seen there is a rho. Rho has been replaced by sigma to take the density effect because sigma is nothing, but density ratio whereas, rho by rho naught.

So, they have given lot of correlation between this parameter which called take off parameter and the take off distance which essentially what we are referring and thus for example, if you want to find out what wing loading is, I should have for 7000 feet take off length and for a jet aircraft. So, I will go like this and jet here I come down. It will be around 340 or 350 around. That value will be take off parameter. We will be around 350 which we will be equated to W by S sigma C l take off into T by W. This is clear depending upon work sort of a landing. Land role distance is 1 say 7000. So, pick 7000 here. What about engineer using jet engine. You found this point come down and get what is the take off parameter number, right.

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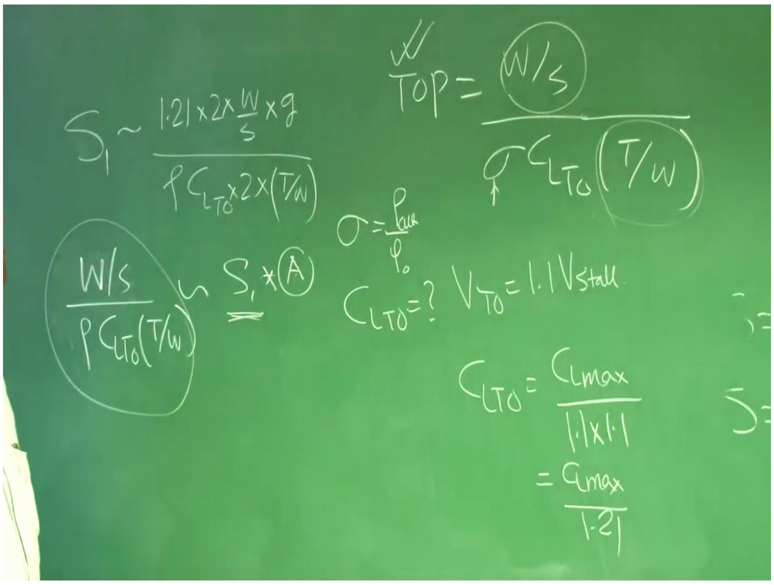

Once you get that number, you get this W by S sigma C l take off into T by W. So, take off parameter equal to W by S sigma C l take off into T by W, this I have seen and I have picked from historical data. My aim is to find out what W by S is for take off sigma. It is in my control because depending upon what altitude I am taking off. So, I know density at that amplitude and I know density a C level. So, this in my hand. Here is a question comes. What is C l take off and we will now answer this since we know V take off is equal to 1.1 time V stall, ok.

So, Cl take off automatically becomes Cl max by 1.1 into 1.1. So, this is equal to C l max by 1.21. So, C l take off is also known the question comes what is T by W values. All of us designer another question comes. What is the combination of W by S and T by W to meet this take off requirement? So, that is where a designer perception is very important. So, he will be looking for a similar baseline aircraft which belongs to the same closer mission requirement.

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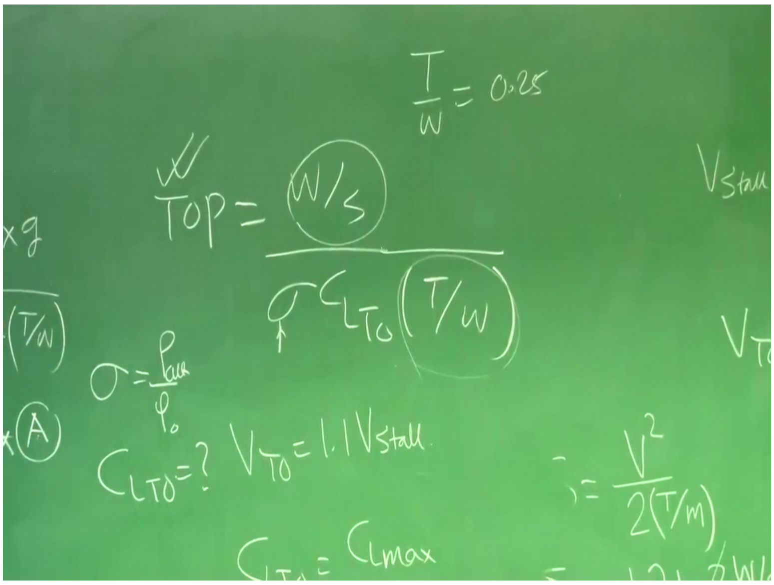

So, he may initially peak T by W. I will take around 0.25 likes for historical data. Also you know T by W 0.25 means what if T by W is 0.25.

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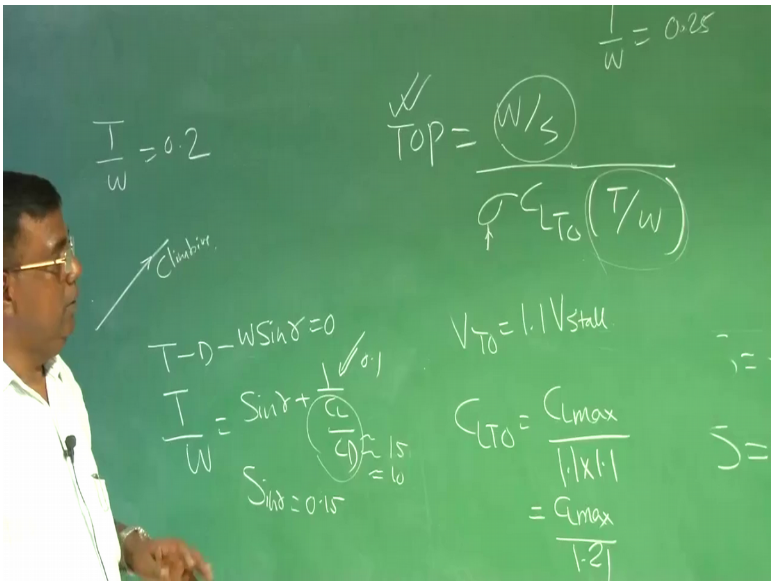

Then, you know that when I am climbing T minus D minus W sin gamma equal to 0 if I am doing study claim, so T by W I know equal to sin gamma plus 1 by C l by C d roughly and C l by C d let us say you own 15 or 10. If it is 10, then these value is 0.1. So, sin gamma will be equal to 0.15. If you have taken by W equal to 0.25 and that we will cross point to a particular climb angle, so you have to see generally for normal aircraft we will prefer initial climb by 7 to 8 degrees. So, all those things goes into your mind and if you find doing this, this type of T by W I have selected, I am not able to really get a realistic number for 1000 feet or 6000 feet land role distance, then you can increase this.

So, this sort of a matching adjustment goes on, but this is how you can use the data given in Raymour which is fairly useful, right. I thought I must complete that also. So, that brings down the conclusion of W by A is take off for conceptual design. Now, we will also discuss about landing distance.

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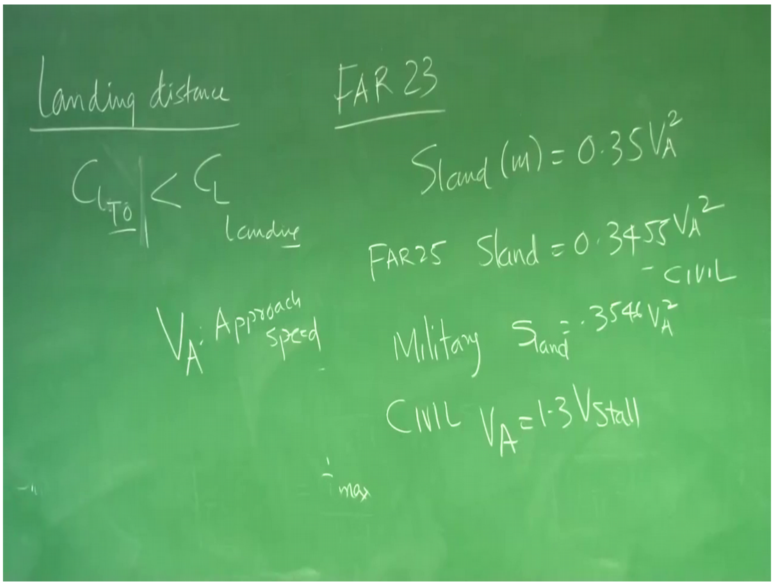

First of all, let us visualize when I am taking off, I will be giving let say 50 percent of the maximum flap deflections, middle conservative in giving flap deflection more because more drag we will be required. So, more thrust weight we will be required for take off right, but while landing we will find almost full flap deflections are given, reason being there will be increment in C l max, but more importantly there will be increment in the drag because you want to break it, right. Anyway for the wing there will be air breaks, we will come out.

So, C l max anyway that we will be destroyed through his boilers, right. So, one thing you understand that C l max required or C l take off during is always less than C l landing and that is more. So, because you want while landing, your touch down velocity should be as low as possible. You land like this. You come for an approach, then start coming down likes slope of around 3 degrees, touch go like this at a conceptual stage. Whatever take off distance you get, you add 15 percent more or even 50 percent more and your landing distance will be safe, but you need to know how the regulation dictate for safety point of view FAR23. I am giving very old far requirement. It says S land in meter should be 0.35 VA square.

This also I have I mean following NPTEL lecture by professor Tular Tulapurkara from IIT Madras, right. You can always read that and FAR to see FAR25. This thing goes on modifications because of more and more experience they get and they 455 VA square and this is for civil of course, and for military S land, these around 0.3546 VA square. What is this VA that is important. VA is approach speed. When you want to land, you come to the point near and that way to airport and you said a glide slope of 3 degrees, right. We talked to ATC. ATC is ok and now start.

So, with 3 degree glide slope, you start approaching the air sweep, then you do flare and land whatever it is and if you see the regulations for civil VA is 0.3 times V stall. Please note that whatever VA conditions are giving as per FAR23 and 25, they are old. Now, they have been modified, but it will be how we are around 1.2 and 1.3. So, you understand what is required. That is more important.

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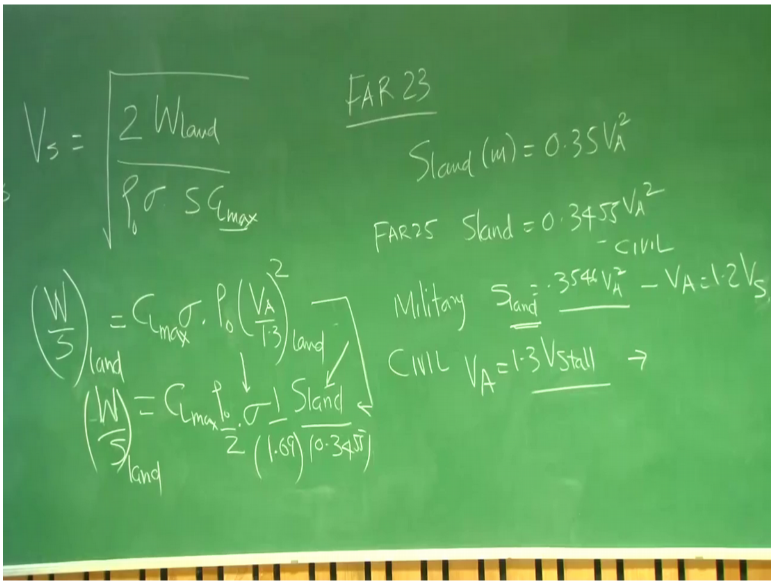

For military when you say this here VA is 1.2 time V stall and for civil, it is 1.3 times V stall. So, you understand then if pilot is not maintaining this sort of conditions during landing, it can lead to an accident. If it is lower than this speed, then the moment you flat of it will go to install because it start sinking. If it is higher, then it will be lot of impact to landing here. So, how important is these numbers, right and it will be cleared when we actually solve an example. Please note down this thing. These are important thing for us.

Yes, what we are looking for you are looking for wing loading. So, I write down D land by rho naught into sigma into S Cl max. Please see the difference here W land is W landing. So, whatever weight with which you are taking off when you come for landing at, least fuel is burnt. So, the weight reduces. So, W by S during landing is less than W by U will take off, right. Now, here instead of sigma re sigma rho naught into row by row naught, it is written both are same and C l max you know what C l max is. If this is agreeable, then I can write V or W by S land landing and this is square. It will be C l max into sigma into rho naught into VA by 1.3 square landing, right because you know VA equal to 1.3 times VS. So, VS will be VA by 1.3 ans that is being done here. So, if I further simplify, it will become C l max into rho naught by 2 into sigma 1.69 and then, S land by 0.3455. So, this will be W by S landing. I hope you have understood how we have come from here to here. If VA by 1.3 is clear and also, we know that S land equal to 0.346 into VA square, so that has been VA is S land by 0.3455. That is exactly has been put here.

So, now life is simple. If I want W by S for landing, I need to know what is the land role distance, I need to know what is the sigma density ratio, I need to know what is C l max of the April, I have designing. That is all. So, this becomes very simple.

Now, W by S landing, we will have W by S cruise, we have W by S climb, you have W by S loiter and W by S for acceleration. You will find to meet all this requirement, you will have different wind loading. The challenge would be which one should I pick because if I pick any one of them, it may satisfy that condition, it may satisfy other condition.

So, that is where the design optimization becomes important and once we solve an example, then only we will be able to tell you or demonstrate a designer how he apply his mind because whatever aircraft you are designing, you have to find out what the main purpose of the airplane is. If it is a transport, the airplane for carrying passenger from point A to point B, then naturally you will give more weightage to W by S cruise, right.

If it is a fighter doc fighter applying, you will give more weightage to W by S acceleration. So, all such things or if it is surveillance airplane, you may give more weightage to W by S loiter, right because to just move around and for more endurance. So, all these things we have to see depending upon mission requirement and select the W by S.

My next lecture we will be on monthly bath that you know where I will be summarizing whatever you have done. So, we are now ready for designing an aircraft, early conceptual level up to the wind loading and thrust loading.

Thank you very much.