UAV Design-Part II

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Lecture-22
Subroutine for Takeoff Performance (Powerplant Selection)

Good morning friends, Welcome back. In our previous lecture, we discussed about level flight performance and we have come up with a sub routine, where we identified what should be the thrust required and the power required when you fly at different velocities and what will be the corresponding trim angle of attack and control surface different deflection required? At the same time we also looked at aerodynamic parameters like CL by CD.

And CL power 3 by 2 by CD and its variation with velocity or you can also say the trim angle aperture, right for that what we did is? We considered a trim angle of attack and then we estimated using the Cm and C L equation, we estimated what should be the delta a trim from Cm 0 equation right sorry Cm equation, which talks about statics pitching moment for the longitudinal case for equilibrium you equated the equation to 0 and then figure out what is delta a trim.

From using the delta a trim and the initial considered alpha trim in C L equation like the aerodynamic model I am talking about CL 0 + CL alpha times alpha trim + CL delta e times delta a trim. From there you figured out what should be the corresponding CL trim that you need to maintain? not to maintain that CL trim you have to fly at a particular velocity to generate lift is equals to weight, that is one of our level flight condition right.

So, from there you can figure out what would be the velocity for that particular trim condition? or to maintain CL trim, once you get velocity. Now, you have CL trim we can also figure out the corresponding CD for that CL trim which is CD using drag polar which is CD 0 + K CL square right. So, CL there will be replaced by CL trim, once you have CD and you know what is the velocity?

Now, you can figure out what is the thrust required which is nothing but drag that is equals to half rho V square S CD right. So, you know both the variables V and CD in that particular equation. So, once you know thrust required you can proceed to figure out what is power required which is thrust required times the velocity of flight right. So, for when you start this entire procedure to solve this entire steps so, you are trying to vary the angle of attack right.

So, that is considered as an input for these entire steps. And then we also solve for what should be the CL upon CD for that particular alpha trim and its variation? right. So, we also talked about CL power 3 by 2 by CD, we just want to see how the power required condition depends upon CL power 3 by 2 by CD right and thrust required condition depends upon aerodynamic efficiency CL upon CD.

So, we have solved for all these variables and its variation with velocity. So, let us now proceed with the same example to figure out what will be the power required or yeah power required for takeoff as well as what is power required for climb? right. So, why are we doing this exercise? So, the reason is simple.

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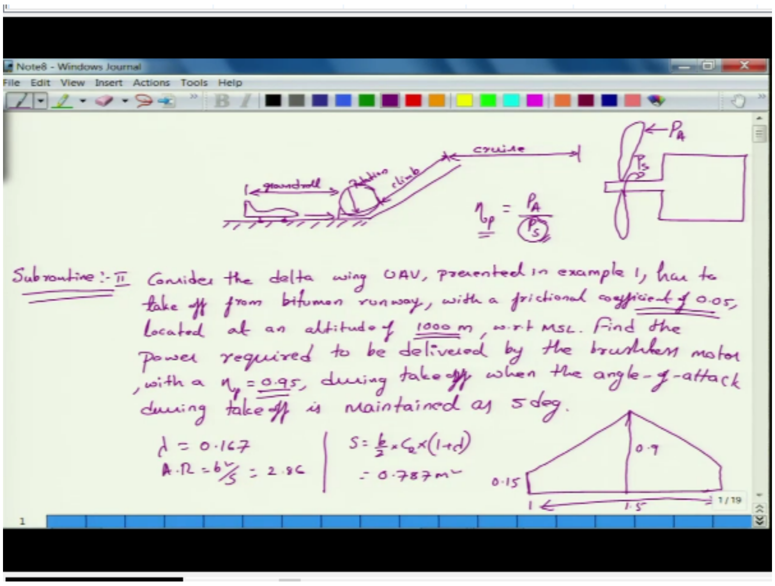

If we consider a typical flight envelope of the UAV right, let us assume it is not a handle on model. So, what you have is a ground roll see the takeoff. So, on ground it will try to run right and then it will try to rotate. So, the time period for which this remains on the ground the aircraft runs on the ground we consider it as ground roll followed by a rotation and then it starts climbing to the desired altitude right.

So, what we call it as climb and then from there, you start performing your mission which is majorly dominated by cruise and then say there can be loiter. So, but why we are doing these exercises, because we try to now figure out what should be the power requirement for by the system at each and every phase, thereby you can select a particular power plant, that satisfies the power requirement or the thrust requirement of all these flight envelops.

So, let us now proceed with the same example what I discussed. So, **so** by doing that we will actually solve again, we are going to again come up with a sub routine that helps us to estimate the power requirement for level**,** takeoff during takeoff condition as well as climb condition. And now we will try to ignore this particular portion the rotation portion power requirement during rotation, which is very minimal for unmanned aerial vehicles, right.

So, let us take up the example problem instead of just doing it in a general manner. We will try to solve it using an example problem, right. So, what we are going to talk about is sub routine to let us assume the first one a sub routine the earlier example that we solved is sub routine I, let us talk about sub routine II okay. So, consider this is the question we will take it as a general question and then we will solve it yeah.

We take it as an example and then we solve it for general purposes. So, consider that delta wing UAV presented in example 1 that our previous example where we talked about level flight performance right. So, it has to take off from a bitumen runway or you can say bitumen runway located at an altitude. So, let us also give the details about this frictional coefficient on the runway with the frictional coefficient of 0.05 to runway located at an altitude of 1000 meters with respect to MSL mean sea level okay.

So, the runway itself the geographic location of this runway itself is 1 kilometre altitude right is at an altitude of 1 kilometre. So, find the power required or say to be delivered by the brushless motor. So, with a propeller efficiency of 0.95 during takeoff when the takeoff angle of attack alpha takeoff let us assume okay, let me write it down for the first time angle of attack during takeoff is maintained has 5 degrees okay.

So, this is our question, we need to figure out what is the power requirement during takeoff for this particular UAV which was presented in example 1. What was that UAV? we talked about a delta wing UAV. So, we talked about top delta wing UAV okay. So, this is the delta wing UAV that we are talking about, which has a root chord of 0.15 meters. So, and then the span of 1.5 meters okay.

So, you can refer to our previous example where we talked about this. So, the lambda for this is 0.167 and aspect ratio, which is b square by S which turned out to be 2.86 and the reference area is b by 2 again, writing it down 1 + lambda. So, it turned out to be 0.787 meter square okay. So, do we need any other details? And we also have the aerodynamic details which you can refer from our previous portion.

So, now the important thing that we need to observe here is so, it has a frictional coefficient the frictional coefficient between the tires of the aircraft and then of the UAV and then the yeah, this bitumen runway is about 0.05 right. So, 0.05 and the details of propeller efficiency is also given right. So, do remember? when the, so you know previous course, we have discussed about what is the output from a reciprocating engine or a brushless motors.

So, the output here you have is shaft power PS right. So, this is a mechanical power that is available from this brushless motor. So, now, you need to attach a propeller to it in order to convert this available mechanical power to useful aerodynamic power or power useful for aircraft to move forward. So, that we will call it as power available. So, the efficiency of the propeller is given as output.

What is the output here? from the system is power available right. So, power available is the output, output upon input, input is shaft power. So, output upon input is the efficiency of this propeller which is power available upon shaft power right. So, what we need to identify is what will be the corresponding shaft power that this particular brushless motor need to deliver? Okay.

For this aircraft to take off from a runway right. So, now, the usual operation of this particular UAV is from an altitude of 1 kilometre right. That means, what is going to affect us? is the density of the air right, that we have to consider at that particular altitude. Now, let us look at what is this takeoff scenario? right. So, let us say it is a wing alone configuration if you remember properly.

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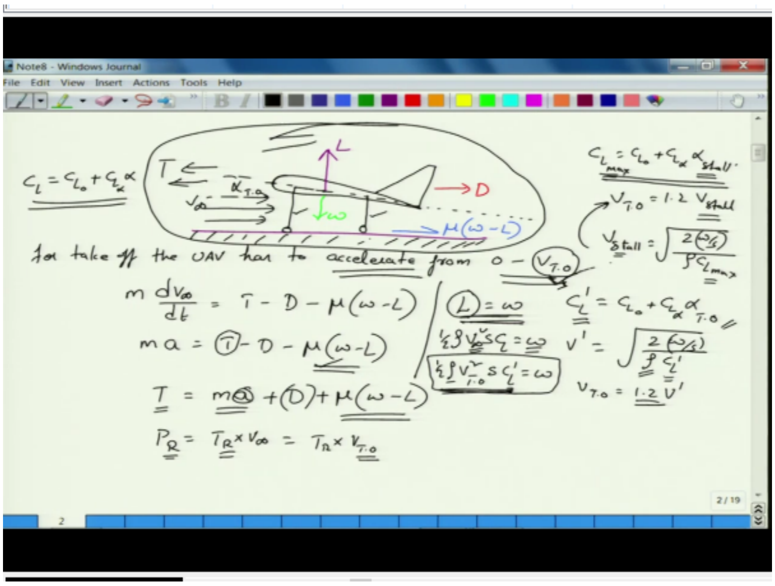

This is my runway. So, let me draw the side view of this aircraft yeah. So, it is all movable vertical tail and then you have the nose full and in the truck yeah, you have this strike right. Now, let us assume a reference axis which is nothing but the chord line for this UAV right, it is a wing alone configuration. So, when the aircraft is on ground roll right, when it is doing a ground roll here that is moving on this runway.

So, your direction is parallel to this ground, right? So, the freestream velocity that you will encounter will also be parallel to this ground and your aircraft orientation is constant is not it? because of the tires right because of this undercarriage, though, the way you designed the undercarriage. So, the orientation of this aircraft remained constant when you are running on this runway during the ground roll.

And the velocity will be parallel to your flight path in general. So, the flight path here is nothing but the direct parallel to runway right. So 0 right. So, this is your freestream velocity and this is your reference axis that means you maintain a particular angle of attack, which is almost constant during the ground run right. So, that means what you need to understand? The alpha that you are maintaining during ground run is constant thereby forcing the CL has to remain constant during this ground run okay.

So, in general, if you will just look at the dynamic equations, and then we will discuss further. So, let us say this is the direction of the thrust, let us say in the direction of V infinity T is the direction. So, let us say T is acting in this direction, what you have is drag due to this right. And then you generate lift perpendicular to flight velocity and the weight of the aircraft acting downward right, is not it? So, the weight of aircraft of the UAV is acting vertically down.

So, again, L is acting perpendicular to V infinity and V infinity is parallel to the ground. So, L and W are along the same axis, but in opposite direction right. And D is in the direction of V infinity during this ground run, right. Apart from this what you have is? friction, which is retarding the motion that is acting in the opposite direction of the motion, which is mu times w - L. So, when the aircraft is completely addressed, there is no drag and lift.

So, what you have is w mu times w right, mu times the reaction. Reaction is nothing but the total weight of the aircraft acting, but in the opposite direction right. So, coming back to this now, we know for takeoff. So, the UAV has to accelerate from 0 to takeoff velocity right is not it? So, that is what a typical acceleration that we look at within over a period of time right. So, now, if we look at the dynamic equation, so, total acceleration is should be equals to T is in the direction. So, the acceleration that we produce will be in the direction of motion right.

That is along the thrust here, T - D - mu times w - L right. So, let us say this is the acceleration that I am looking at. So, should be equal to the total forward force minus the total retarding force which is drag and frictional force here and then the lift has to be balanced by weight. So, at takeoff this is a condition that you can achieve right, when you lift is balanced by the weight you are now no more running on the ground right your airborne okay.

So, until we achieve that particular condition, we have to make our UAV run on the runway. And then once you reach that particular velocity, which enables you to produce a lift which is greater than the weight then you are born and the frictional force disappears at that particular point. So, till that we need to produce power which will satisfy this frictional drag or the friction that we encounter here.

So, now, how do you find out what is the power required during this particular face, is not it? So, let us say this thrust that has to be generated by the engine here, is not it? So, the thrust that I need to generate by this brushless motor is equals to mass times the acceleration that I need to do to this aircraft for takeoff, right for takeoff, I need to produce acceleration. So, that is m times a plus I need to satisfy the drag when I am moving at a particular velocity, I need to satisfy the requirement of the system which is drag here.

And then apart from that there is frictional force right because I am running on the ground right now. So, which is mu times w - L. So, this is the power on the thrust I have to generate if I have to achieve a takeoff velocity with this particular acceleration right. And then so, the power that I need to deliver from this or the power required by the system is equals to which is the thrust required times the velocity as we know very well.

So, the velocity here will consider this thrust required V take off velocity right. So, why we are doing this? it will be higher right, power required will be higher at higher take off velocity, we want to know what is the maximum power required during this takeoff process, is not it? So, that means, we need to look for if the engine can deliver that maximum power it always can satisfy anything lesser than that right by just adjusting total of the engine.

So, now, I will be able to figure out what is the power required given? what is thrust required during the takeoff from this particular runway? which has to satisfy again the acceleration that you required to produce and then the drag as well as the frictional force okay. Let us now proceed further to understand what is this takeoff velocity based? Yeah, what is this takeoff velocity from aerodynamic point of view? right.

What should be the take of velocity? So, now, we have again this C L = C L 0 + C L alpha into alpha. In general if you refer any of the standard textbooks in related to flight dynamics. So, the takeoff velocity is in general given as 1.2 times of V stall velocity, assuming you. So, what is stall velocity? which is given by. So, C L max which we discussed many times right. So, stall velocity corresponds to C L max.

That means, if I make this C L max and what I assume is I am flying at alpha stall, but who is producing that alpha stall? The aircraft orientation is not it? but on ground when you come back to this again this scenario again. So, on ground this alpha is fixed, is not it? That is what we discussed earlier. When it is running on the ground, it is alpha is fixed. But for UAVs I do not think it is feasible.

For most of the UAVs small scale UAVs, I do not think it is feasible to have dedicated flaps to produce that C L max, which is a case for a commercial aircraft, right. So, I do not think that is possible. So, what we have to look at is a practical way of understanding the power requirement during takeoff instead of adapting to this standard procedure of calculating what is the V stall required based upon C L max?

And then the 1.2 times of V stall, what we do is instead of stall angle of attack, what we will say is C L prime during takeoff is equals to C L alpha times alpha during takeoff. So, this is nothing but alpha during takeoff okay. So, because the orientation is fixed when the UAV is running on ground, hence, the angle of attack has to be a constant value here right, this is alpha takeoff.

So, for this particular alpha takeoff, what will be the corresponding C L that I can achieve without flap deflection and elevators are not effective to change the orientation when it is running on the ground right and there is no point of doing that. So, the corresponding V prime during this takeoff procedure is square root of 2 w again it has to satisfy. I need to run or I need to take my aircraft to a velocity where it is able to produce the lift which is equivalent to weight of this aircraft, which can lift the weight of the aircraft right.

So, there should be a force that can lift the weight or we should produce a force which is in the opposite direction of weight. And for that you need to make your aircraft achieve a particular velocity, which is V takeoff velocity, what we will call it is? V takeoff square S times C L prime is equal to w right. So, the C L prime is now defined by this alpha takeoff which depends upon the orientation of your aircraft during the ground roll right.

And then once you have this C L prime you will be able to find out what is V prime square. So, from here 2w by S upon rho C L prime. So, once you have V prime then we will adapt to this V takeoff is equals to 1.2 times of V prime okay. So, that will consider that this is a factor of safety right 1.2 times of V prime. So, that when you substitute in this particular equation, you will be satisfying lift is equals to weight definitely more than weight here, okay.

Because V takeoff is higher than that C L prime square is not it? So, V takeoff condition is higher compared to that of the velocity that you need to maintain for C L prime. So, this will definitely ensure that you are off the ground, you are airborne, this particular condition, okay? That is when you can change your orientation, once you are airborne, then your control surface are effective and then you can change the orientation of this aircraft okay.

So, now we will look at the procedure a bit more in detail. We will write down the steps how to solve this. And moreover, you see this takeoff velocity depends upon density right. And all of our calculations depend upon density because we are talking about aerodynamic forces. And is do not you think, is it not mandatory for us to come up with a sub routine that talks about variation of density with altitude right. So when we are talking that what do we remember? standard atmosphere right?.

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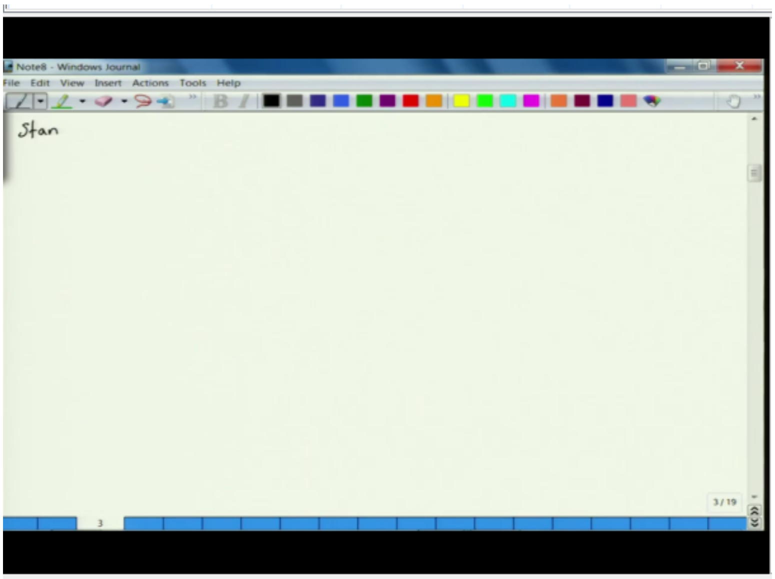

So before solving this particular example problem, I would like to come up with a sub routine that talks about yeah, density, like given an altitude of flight as an input, I will get density pressure and the temperature as an output right.

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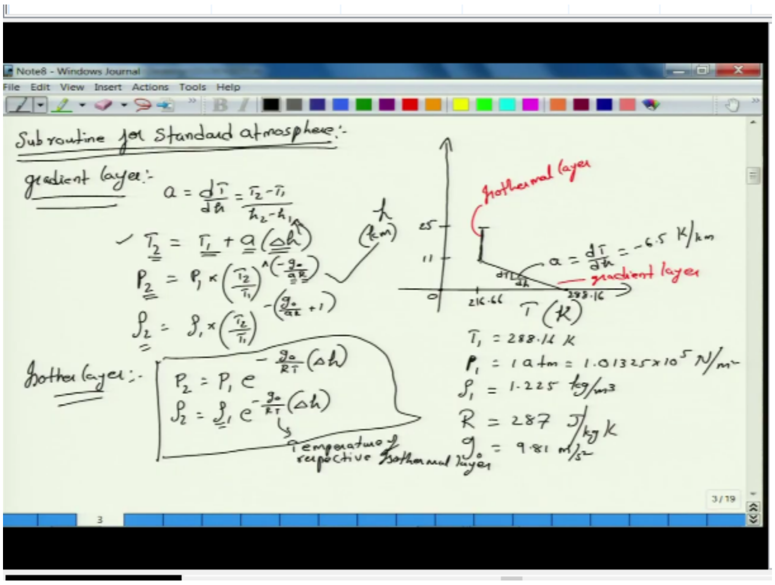

So, what we are going to talk about sub routine for standard atmosphere. So, most of our flights are limited to say about 13 kilometres right. So let us try to like come up with the sub routine for the first 2 layers of standard atmosphere, we know this is the altitude and this is in kilometres right this is an x axis, we have temperature like or say the when the altitude is varied what is the change in temperature?

That is what the standard atmosphere talks about. So, we have temperature in Kelvin, right on the vertical access we have altitude in kilometre. So, at sea level say at 0 kilometres to 11 kilometres we know it is governed by gradient layer equations where there is a slope here right which is called dT upon dH right, it is given by dT upon dH 0 dH upon dT, kilometers please make a note of it, just for the visualization purpose and to make like plotting the altitude on the vertical axis make more sense right is not it?

So, altitude on vertical axis make more sense the only reason why this is plotted in this manner, but in general this data is acquired by means of varying the altitude and measuring the corresponding temperature density and yeah sorry temperature and pressure at those altitudes okay. So, the lapse rate here is given us dT upon dH which is Kelvin upon Kelvin per kilometre - 6.5 for the first gradient layer which is Kelvin per kilometre okay.

And then from 11 kilometres to 25 kilometres what we have is isothermal layer. So, the first layer is this is gradient layer and what we have is a thermal layer. So, up to 25 kilometres okay. So, the constant temperature resume. So, T 0 altitude is 288.16 Kelvin right at this particular altitude of 11 kilometres is 216.66 Kelvin okay right. So, let us now come up with the sub routine.

So, before this we will just recollect what our gradient layer equations? So, the gradient layer which is characterised by the slope lapse rate what we call is dT upon dH which is T 2 - T 1 upon h 2 - h 1 right. So, where h is and then so T at a particular altitude T 2 given T 1 is T 1 + a times delta h okay. So, this is one equation that gives me the information about temperature at an altitude right.

And then what I have is radiant layer equations which is P is equals to or P 2 is equals to P 1 times T 2 upon T 1 raise to the power of - g 0 by a R okay and then rho 2 is equals to rho 1 at rho at sea level let us say for the first gradient layer P 1 and r 1 is rho at mean sea level right. So, that is T 1 = 288.16 Kelvin at P 1 = 1 atmosphere which is 1.01325 times 10 to the power of 5 Pascal or Newton per meter square.

And density at this rho 1 is 1.225 kg upon meter cube okay. So, the density for density variation again is a function of T 2 upon T 1 which we had derived using standard atmosphere which is - of g 0 by a R + 1 right. So, I can find out for the gradient layer right given the altitude let us say in our case which is 2 kilometers given the altitude what I can find?

I can definitely find out what is delta h which is S 2 - h 1 and then multiplying it with the lapse rate what I get is yeah with by plugging in the information of T 1 and I will be knowing what is the corresponding temperature at that particular altitude using the T 2 and T 1 and we know what is the lapse rate and r is a universal gas constant for a root is 287 joule per kg Kelvin right.

So, by and g 0 of course, we know is 9.81 meter per second square. So, plugging in this values what I will be able to find out what is P 2? and what is rho 2? Okay. So, similarly for so, isothermal is constant temperature regime right, for constant temperature regimes P 2 = P 1 times e raise to the power of - g 0 by RT times delta h right e raise to the power of - g 0 by RT times delta h.

Similarly, rho 2 = rho 1 times e raise to the power of - g 0 by RT times delta h. So, once I know what is T is nothing, but the temperature of respect to isothermal layer okay. And then I do not think there are any other new variables that we need to discuss. So, using these equations, let us now write a subroutine. So, for that I will take help of MATLAB.

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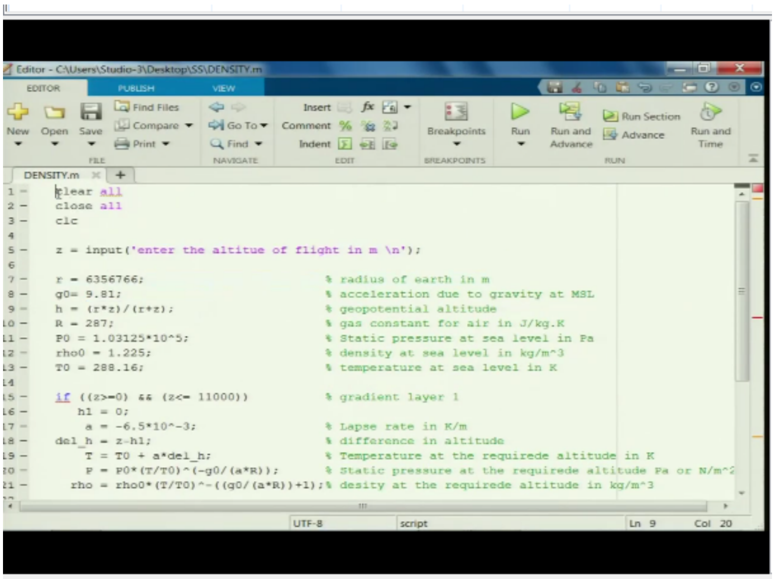

So, I will try to first clear all the data from the memory. So, I am closing any other windows that are open and I am clearing the screen what am CLC helps you let us say there is something here right, some let us assume there is something some details here. **(Video Starts: 31:05)** And then first I would like to save this**.** This was our example 1 which we have solved in our previous lecture, I named it as performance underscore level flight.

I wish you should also do that and then the second example is for this one we are talking about density right. So, this is density okay. Now, I have to make it as a function that will finally convert know, firstly, let us try to write it as a normal dot m file normal program. So, this will help clear all close all will try to remove everything from its memory which is the workspace here you can see it removes everything from the memory.

And it will clear the editor page here, clear the command window here right. **(Video Ends: 31:53)** So, from then you start writing the code okay. So, first thing I would like to do is consider the input of z right, what is the altitude here? let us say z is my altitude which is equals to let us say h that you are considering, whereas h, h is my or z is my altitude that is considered right.

So, input I will consider this as an input into the altitude of flight in meters right. So, this will be an input for this program okay. So, now, once I get the height then I should be knowing what is the corresponding g acting at that altitude right which is g is equals to or say r the radius of earth which is why we need is? we will try to convert this geometric altitude to geopotential altitude by means of h is equals to right h is equals to r times h d right, r is radius of earth small r times h g

Or say the h is nothing but z input here upon r times hd upon r + hd, you can refer our discussion regarding standard atmosphere, we have discussed a bit during the introductory lectures of this course as well as during our previous course, right. In the previous course we have derived in detail. So, r + z right okay. So, z is nothing but the geometric altitude that you consider.

Rz times r z upon r + z here which is and then we need the input of this radius of earth which is 6400 kilometres approximately that to be precise with 66356766 is a radius of earth in meters. So, for a given geometric altitude you know converted it to geopotential altitude right. So, for example, first we need to see whether the input altitude whether it falls in isothermal layer or gradient layer.

Let us say if at all the z is greater than or equal to 0 right and is z is less than 11 kilometres right, this is 11,000 meters is not it? So, less than or equal to 11,000 meters let us assume okay. So, then this false in gradient layer right. In that case what I have is P 2 or P = P 0 which is at sea level, let us say P 0 is at sea level. So, P 0 times T 2 upon T 1 okay, T upon T 0 again yeah.

T is the temperature at this particular altitude T times T 0 raise to the power of we just discussed it is not it? So, this particular equations T 2 by T 1 raise to the power of - g 0 by a R. So, we are talking about this particular equation T 2 by T 1 where T 1 raise to the power of - g 0 upon a times R okay. So, for this particular gradient layer. So, what we are talking if this falls into this category then what we are talking about is? the gradient layer 1 okay.

For this what is the value of a = - 6.5 times 10 raise to the power of - 3, but we need to talk in terms of meters we have to make sure that the units are consistent. So, lapse rate I would like to comment this as lapse rate in right Kelvin per meter. So, before okay and then this is static pressure at the required altitude okay. So, what you get here is in Pascal pa or Newton upon meter square.

So, that is output from this particular what you called equation okay. So, the scripted line number 12 gives you the output of static pressure that the particular altitude and then say I need to find out density. So, den let us assume den is at the corresponding density at that particular altitude which is equals to den 0 right that is the density at sea level. Otherwise, instead of den you can say rho density is equal to rho 0 rho 0 right times T 2 upon T 1 I am just copying this. So, T 2 upon T 1 raise to the power of - g 0 by a R.

So, -1 right or if you take minus common it will become plus inside. So, let me I will just try to take this inside. So, this is like g 0 by a R + 1. So, whole raise to the power of minus, this will also work, may not this extra apparent what you call brackets may not be required. So, what do you get is a density at the required altitude in kg upon meter cube right. So, what you get is a density at that particular altitude. Now, yeah this is done.

So, this is what we require right, is not it? but how can this equation be? let us say the line at line number 12 how can this script be executed? Because we have quite a good number of unknowns here is not it? So, here P 0 is unknown, P is unknown for this gradient layer at that particular altitude. A is given for this particular layer a is known R is unknown. So, let us initialize the input variables here say R is 287 joule per kg Kelvin right specific.

So, this is universal gas constant for air which is in joule per kg Kelvin and then what do you require here is P 0 at S t p P 0 is sorry at mean sea level P 0 is 1.01325 multiplied by 10 raise to the power of - 10 raise to power of 5 right. This is in Pascal right. So, one atmosphere at most static pressure or atmospheric pressure at sea level in Pascal. And den rho 0 that is density at sea level which is 1.225 kg upon meter cube right density right sea level in kg upon meter cube okay and we also know what is temperature at sea level is 288.16 Kelvin temperature at sea level in Kelvin.

So, we have inputs now. So, the required inputs but T 0 is known P 0 is known in order to solve this equation I need to know what are the variables on the right hand right? P 0 is known as an input P 0 is known at sea level g 0 is known g 0 is also g 0 is not given here. So, what we can do is g 0 = 9.81 meters per second square. So, acceleration due to gravity at MSL okay.

So, g 0 is known and then what we need is? r is known yes, so, the only unknown is T. So, we know from the definition of a lapse rate right. So, we can now find out what is a T at that particular altitude is equal to T 0 + which we just discussed a times delta h right, that is del h delta h. So, what is delta h, this is like temperature at the required altitude in Kelvin. So, del h is nothing but delta h is delta h delta underscore h.

So, let it del underscore h. So, in order to execute this script at line 17 we need to know a is input right T 0 is input again, what is del h? So, del underscore h that we considered is equals to z - z is the input altitude right is in it? z - 0, nothing but from sea level, right, is not it? So this is well okay, so instead of 0 what I will say is z - h 1 here, okay, where for the first layer the h1 is 0, is not it? Do you accept that?

So, for this first layer, so, for this first isothermal gradient layer h1 is 0 here. So, h1 let us say that will be the difference there. So, then h1 = 0 here gradient layer 1 that means. So, this h1 h1 = 0, okay. So, this will get fetch me the data if not else, if this particular z. Let us say if we want to find out at 13 kilometres altitude right.

Density and other parameters are 13 kilometres, if the flight is at 13 kilometers, so, 13 kilometers talks about isothermal layer which is yeah this it falls somewhere here. So, 13 kilometers, so, we need to talk about equations that corresponds to this particular isothermal layer right. So, which means, we need to talk about these equations. So, instead of those which we have used for gradient layer, we will just replace them by these 2 equations. So, that we will complete the details or modeling of isothermal layer here.

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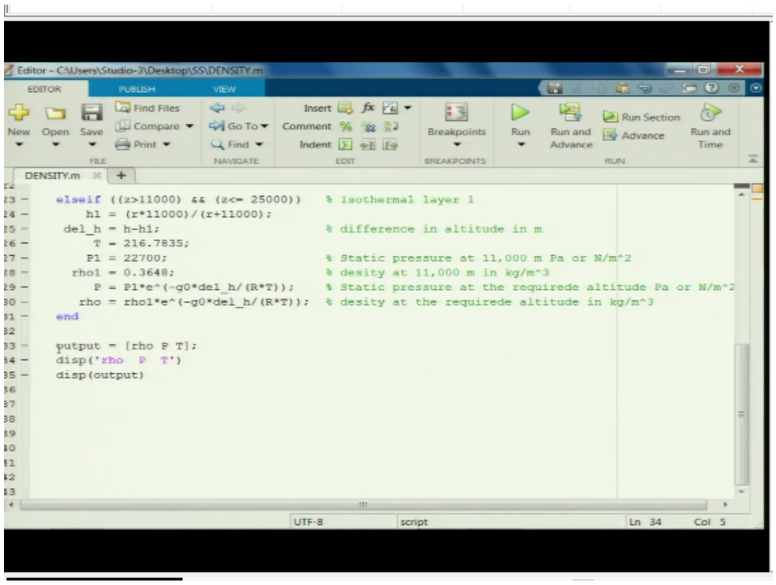

So, if z is less than or if z is greater than 11 kilometers right. So, z is greater than 11 kilometers and less than or equal to 25 kilometers right. So, we know for this particular isothermal layer we have constant temperature right, there characteristic constant temperature. So, what I will say is this is isothermal layer 1 okay and then what is h1? h1 for this is 11 kilometers right because it starts at 11 kilometers.

So, this is the starting of that h1 talks about starting of that particular layer right. So, and then T of this at this particular condition is the input temperature for this isothermal layer. For example, for this isothermal layer P 1 corresponds to this particular point at 11 kilometres P 1 corresponds to 11 kilometers and P 2 corresponds to any other point within this isothermal layer.

Similarly, rho 1 here corresponds to density at 11 kilometers for this isothermal layer and similarly, yeah T 1 corresponds to and T 1 = T 2 and it is equals to this particular value to 16.66 right. So, the T 1 there are the T there = 2166 Kelvin okay. So, what is P 1. So, what you can identify from here from the above program if you plug in let us say if you plug in what is at 11 kilometres?

You can use those values and find out what is P 1 which I already did it. So, what I will do is. So, P 1 at this particular altitude is equals to 22700 this is an again Pascal I am not giving the details I say otherwise, this is static pressure at 11 kilometers at 11,000 meters okay and then density 1 okay is equals to what is the density at 11 kilometers which is 0.36480 0.3648 density at 11 kilometers 11000 meters.

So, I have the initial conditions for this particular yeah. So, for this particular isothermally right and then I will be able to find out what is the corresponding pressure P. So, pressure P = P 1 because we are talking about isothermal layer the initial conditions of isothermal layer we considered as P 1 here right is not it? So, for this is the P 1 for this particular isothermal layer and whereas, P 1 for the gradient layer is nothing but P 0 right.

When you talk about next isothermal layer then P 0 may be different you know next gradient layer let us say. So, for example, if you consider next gradient layer here then P 1 should correspond to the pressure at 25 kilometers altitude static pressure and density at 25 kilometers altitude right, that you need to take them as an input okay. So, P is equals to at that particular altitude in isothermal layer which is P 1 which is at 11 kilometers altitude times e raise to the power of - g 0 by a R - sorry RT g - r g 0 by RT times delta h

So, g 0. So, I will write g 0 times delta h in the numerator multiplied by del underscore h So, delta h I will copy this for this particular isothermal layer what is the corresponding delta h difference in altitude? So, there is a small correction here we have considered h1 as 11000 meters right. So, this is in geometric altitude, we need to convert because z is in geopotential h1 should also be in geopotential altitude.

So, we need to convert this h1 the initial height of this isothermal layer to geopotential altitude either know, we can use this particular equation again and replacing z with that h1 here like otherwise. **(Video Starts: 52:29)** So, let us see you can either do this as an input, for example, r into z. So, here h1 is 11,000 where I need to first queue the details of r r is raise let us say I execute this program till this no okay.

So, I will enter the value of r here. So, this is like calculator. So, r times 11,000 upon r + 11000. So, you can directly use this as h1 there, if not what you can do? **(Video Ends: 53:31)** you simply consider this like r is anyways given as an input to this program. So, r times h 11,000 upon r + h + that is initial altitude of this isothermal layer which is 11,000 meters okay. So, it is now converted to geopotential altitude.

So, z - h 1 **z -** will give you the delta h for this particular isothermal layer and the corresponding pressure and this particular altitude static pressure at this required altitude, this is what this particular equation returns then. So, yeah g 0 times delta h I am sorry there is something more here g 0 times del h upon d 0 times delta h upon a RT right capital R times what is the corresponding temperature of this isothermal layer which is T 216.66 Kelvin okay.

So in the corresponding density and this rho, since this is del 1 or rho 1 otherwise I can say R h by rho 1 this is rho 1 times yeah e raise to the power of - g 0 times delta h upon RT. So, this is the density at that required altitude in kg per meter okay, that is it, we are more or less done with the required outputs and end right. So, so, this ends the if loop here if the entered input value is in this range like gradient layer range.

So, this particular block of the code will be executed and else if it falls in this isothermal range. So, this particular code will be executed. So, after that we will end this program. So, what I need as an output is? Let us say P pressure okay, let us say output, output = P T or say let us say den density and then pressure P and then T as an temperature. **(Video Starts: 57:28)** So, let us run this program.

So, enter the altitude of flight in meters let us say I wanted sea level, let us see what will what it is going to return, so what I have is okay so if it is so the first one is greater than or equal to 0 rho 0 times yeah, so there is a small correction here, earlier here delta h should not be z - it should be h - h1. So, there is a small mistake. So, please correct it and then the pressure at sea level is 1.01325.

Earlier I entered it as 1.0325 right 3125 something, so I miss this one, so please do this corrections. So, 1.01325 multiplied by 10 raise to the power of 5 is your static pressure in Pascal at sea level. So, and then so the delta h should the altitude input altitude or the query altitude in geopotential altitude and then h 1 should be for the first gradient layer it should be 0 and for the second gradient layer again h1 should be in geopotential altitude right.

So, which is 11 corrections, so 1.01325 multiplied by 10, to the power of five is your static pressure in Pascal at sea level. So, and then. So the Delta hedge should be the altitude input altitude, or the query altitude in geopotential altitude and then h1 should be the first gradient layer it should be zero. And for the second render again h1 should be in geopotential altitude, right. So, which is 11 kilometers.

The isothermal air starts at 11 kilometers, so we need to convert that to geopotential altitude. Again delta h remains in h - h1 which is a query altitude and h1 corresponds for this particular look h1 is yeah from this equation from the above equation. And this is like using geopotential altitude you get 216.7835 right. So, if you run this program for 11 kilometers, you will get this as an input right for this particular.

Yeah, else if condition. And then, yeah, we are more or less ready. So, what I will try to display instead of output here I will say, I will imply display rho P pressure, temperature, right. So, let us run this program, I need to enter the altitude, say at at 0 kilometers or 0 meters in meters right I need to enter it in meters. So, 0 meters, that is at sea level it is 1.225, pressure is 1.01325 10 raise to the power of 5 Pascal, and temperature is 2808.16, Kelvin right.

So, let us now run this for at say, 5 kilometers altitude, which is 5000 meters. So, these are the corresponding value. So, now, you will get this value so this is in gradient layer, you can run this program for, say, 13 kilometers. So, there is some small error and this isothermal layer equation, multiplied by the variable e. So, this should be exponential right, exp, this exp. again the same thing, exp exponential exp.

Okay, let us run this again. So, let us enter the query point query altitude, which is an isothermal layer at 13,000 meters. So, now you get the corresponding density rho, pressure and temperature. So, yeah with this we can say this thing, this program works. So, I would like to make this as a function as I told you, which means.

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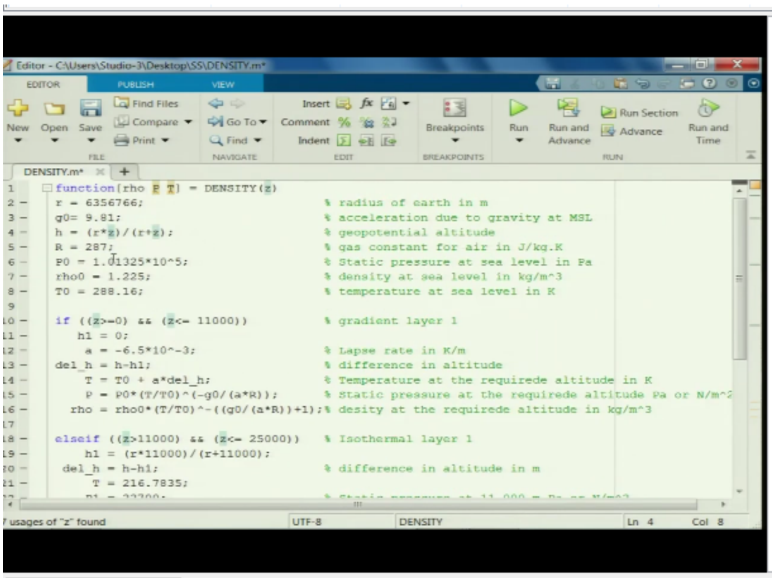

So, the output that I expecting is first function is the syntax for this. So, function of. So, the output that I would like to see from this function is the rho, and pressure right. So, let us say rho and pressure is equals to, or similarly, whatever you can also take out the temperature. So, you will get output as these 3 variables. So, I can use any one of the variable wherever I require. So, rho P and T, and then given the name of the function should be same as name of your file that you are going to save, right.

So, that is density, and then. So, what should be the input value? it should be z right. So, z is the input from here which we initially took as an input directly right. So, I am not displaying this. What I will do is return this function, after this okay. That is okay, you can leave it like this. So, I have saved this as a function right. So, now I will close this function okay. So, now you can see this has become a function.

So, this is m code and that is so I can group them by type, so you can see this so this has become a function. For example, if I simply say, so density okay, density at what altitude, say at 1 kilometre okay. So, answer is 1, you will get only the first variable as an output here. Okay, let me open this function. Okay, let us save this. Then run this program again. In the command window when you do not assign any particular value right to this function, any variable to this function.

So, it will directly give the first variable as an output here right. So, which is the density is the first output from this function. So, instead, let us assume a = density. So, let us just check whether this function is working or not. So, what the function is going to return, it is going to return you density pressure and temperature. That means you have to find out these 3 variables right.

So, this is the way we need to call this function, whatever the variable that you want to call, so let us say if you want the 3 variables as an output then you have to mention these 3 variables here while calling this function. By default, if you just call this density function, let us say, at this function density at say 1 kilometre. So, it returns only the first variable which is density here, this is the first variable right, first output from this function.

So, if you want all the 3, then you need to mention density, pressure, temperature. So, what you get is density, pressure and temperature at this query point right. So, this function is working fine okay. So, now I have saved this as a function. I will be using this function inside whenever I would like to figure out what is the density at a given altitude okay.

So, that is the reason why I explicitly mentioned it as density, and if I do not inquire about this P and T, it will just written density as an output here right, I you should also complete this exercise okay. **(Video Ends: 1:05:22)** Now, let us get back to our initial problem, where**.** So we need to find out what is the power required right that was the initial question consider the delta wing UAV presented in example 1.

And find out the power required when the takeoff angle of attack is maintained as 5 degrees here okay. So, let us now create a new script.

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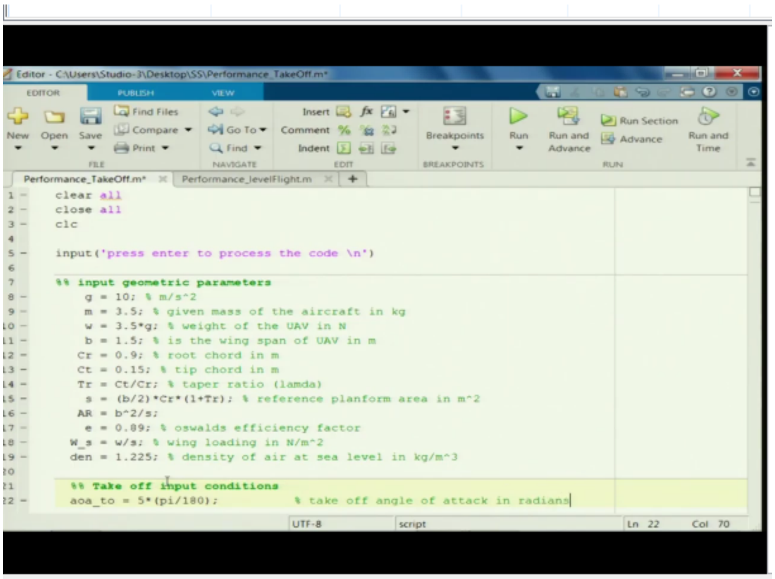

So, let us say clear all, close all, clc, so just before that we will look at the steps that you are going to follow, ok.

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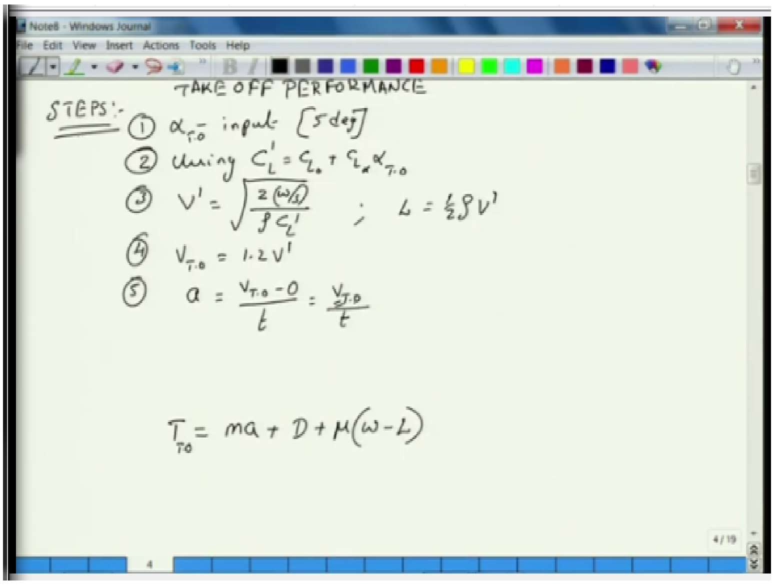

So, this is steps we need to follow is first of all steps for power estimation, right during takeoff, ok. So, first step is now what are we can constrain the input, right, alpha takeoff maintained is input here. So, you can in fact vary this and see if you vary different angles of attack what is the corresponding variation in takeoff distance, takeoff time? right and then what is a power required and the thrust required?

So, once you have this using C L alright is equals to C L 0 + C L alpha times alpha takeoff, find C L prime? right. So, now once you have C L prime you need to find out V prime assuming this particular C L prime when you make the aircraft to move at V prime you will be able to generate lift equal to weight of the aircraft, so that you can climb that your airborne, right. So, C L prime and consider V takeoff with a factor of safety which is 1.2 times of V prime here, ok.

So, this C L prime depends upon alpha takeoff, if you are able to produce alpha stall here then this will become C L max, right, the corresponding C L prime becomes C L maximum. But right now for this particular UAV the takeoff angle of attack is given as 5 degrees, so this will not be alpha stall anymore then it will not be C L max, right and V stall. So, we are making it a more general case, right and the fifth that you have to look at is what should yeah but what is the corresponding takeoff velocity for this configuration?

So, if you have to achieve this takeoff velocity what will be the acceleration? a acceleration that you need to produce is V takeoff minus initial velocity, velocity initial velocity is 0 upon time, right. So, assuming a uniform acceleration to achieve this takeoff velocity what we have is? V T O upon t, ok where initial velocity is 0 meter per second. So, if you have to achieve this acceleration, why because? why we have calculating this?

We need to find out what is the ultimate? let us say at a latest stage we will come up with T is equals to this particular equation. So, the T is equals to m times a, so we need input a here, so how do we find out a there. So, this is like m times a + D + mu times W - L this is what we require, is not it? So, D is a unknown, a is unknown, so a we are finding out from here, so we will see how do we find a?

So, if I want to find T I need to know what is a, D and L, right. So, mu is given as an input, this is an input, mu is an input and yeah we do not what is L here, right. So, but figured out what is L prime, right, so and this implies L is equals to yeah, ok. So, C L prime, right, so you know what is V prime and similarly you can find out what is L, L prime? Which is or L during the for that particular flight condition which is half rho V square. So, we are talking about, so thrust required during takeoff, right final. So, you need to figure out this velocity.

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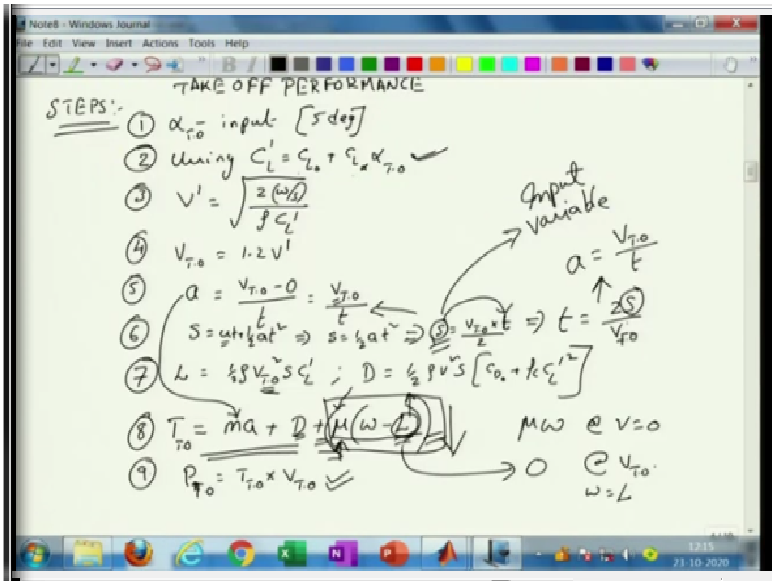

Let us make this as an explicit step here, so let us say there is another step which talks about L is equals to half rho V takeoff square S times C L prime. So, C L prime is what you are going to get maximum because you are not you will not able to change the angle of attack when it is during the ground run rate, it is already fixed because of the way it was designed the undercarriage was designed, right.

And so and the based upon the what you call? wing incidence angle. So, but we do not have a wing incidence angle here, it is a wing alone configuration. So, what the maximum the C L that you can get at the takeoff velocity is half rho V takeoff square times S times C L prime, right. So, this will be definitely you know width of the configuration, ok. So, if it achieves this particular condition.

So for a given velocity, ok or to be frank you can even neglect this lift, so that you will get to know what is the maximum thrust required during takeoff. If you can neglect this particular quantity assuming the lift is not so high, right, so you can get at so similar to the tough condition when you just started the ground run, lift is 0. So, mu times W is a drag the resistance due to friction, right, so at takeoff you have lift, right almost during the entire procedure which is W - L, ok.

So, now this will be another step where you will find out what is C L prime and then similarly you find out what is drag which is half rho V square S times C D 0 + k C L prime square, ok. So, this is a step before this let me say this as step 7 you have steps of 8 here and step 6 should be like how do you decide this? We know S is equals to ut + half at square, right, is not it, so from here since the initial velocity during this ground run is 0 assuming a constant acceleration.

So, what you have is? S is equals to half at square, so this implies once you substitute this the acceleration will be S is equals to V takeoff multiplied by t upon 2, right, ok. So, now what you need to decide is what is the length of the runway, correct, depending upon the length of the runway you will be able to what is the corresponding time required to achieve this particular velocity, right.

Assuming a uniform acceleration and once you know what is the V takeoff and V and the time you know V takeoff and once you figure out what is the time taken for this takeoff. So, you will be able to find out the required acceleration, so this acceleration can further be used in this equation to find out what is the takeoff thrust required. And then so there are many methods like this is the one that I generally adopt.

And the power required to takeoff is equals to takeoff thrust required for takeoff times the velocity. So, this will gives the maximum power, right, so I am not doing it for the entire process, right. So, what is the power requirement variation from 0 to the maximum or the point where you achieved V takeoff. I am just talking about the final number V takeoff what is the power required at V takeoff?

So, that will be the maximum anyways, so I would like to see that you know what is the value and it is variation with takeoff distance, how it is varying with takeoff distance? So, the input variable here is takeoff distance, it is a variable input variable, so I keep varying the takeoff distance I make it as a variable of this subroutine from there I will be able to figure out what is the time taken to achieve that V takeoff velocity, alright.

So, what is it? Time taken to achieve V takeoff, ok, so once I know this particular time I will be able to find out acceleration which is step 5, acceleration for takeoff is required is V takeoff upon time. So, that means the length of the runway matters here, how much length of the runway it is available for you. So, from there find out what is lift what are this factors? right.

So, mu is given as an input is a you can have acceleration as a input for equation 8, right or step 8. And drag from step 7 and as well as this mu which is W - L from, so at takeoff to be frank this particular value is 0 takeoff. So, see this value keep decreasing as the velocity increasing because the lift keep increasing, is not it. So, at 0 velocity you have the maximum which is mu times W.

And at V = 0 and this is 0 at V takeoff assuming so V takeoff is equals to 0 at V takeoff this is 0 why because? W = L or in fact L is greater than W, so this becomes negative. So, let us keep it as it is for the time being so for the initial program, so we are going to write another subroutine. **(Video Starts: 1:17:02)** So, **so** now the aim is input, ok, so no need of ok input this one if I just want to see the screen command window we can, ok press enter to process the code.

So, now alpha T takeoff so we are using the same aircraft, right, is in the same UAV. So, performance instead of level flight I will say takeoff, ok, . In fact not exactly the performance we are talking about power requirement, ok. So, and we were told that we can use the data from the previous aircraft, so let me put plug in all this variables directly from this previous program. So, for takeoff performance these are the input geometry parameters because since the UAV is same.

So, all these parameters remains same and then alpha takeoff, right. So, this is like the second block, so takeoff input conditions, so what are the takeoff input conditions? alpha right let me see it is as aoa angle of attack underscore to takeoff, right. That is which is fixed which is constrained due to the design of undercarriage which we discussed here, is not it. So, it is constrained because of the design of the undercarriage, so alpha takeoff is fixed due to during takeoff.

Say when you cannot deploy flaps for that particular UAV, you cannot change or alter the C L value during the takeoff, right for this particular configuration. So, angle of attack during takeoff is 5 degrees that is what it was mentioned, so 5 times pi by 180 I am converting it to radians, so this is in radian. So, takeoff angle of attack in radians, ok. So, also we require aerodynamic parameters as an input, right.

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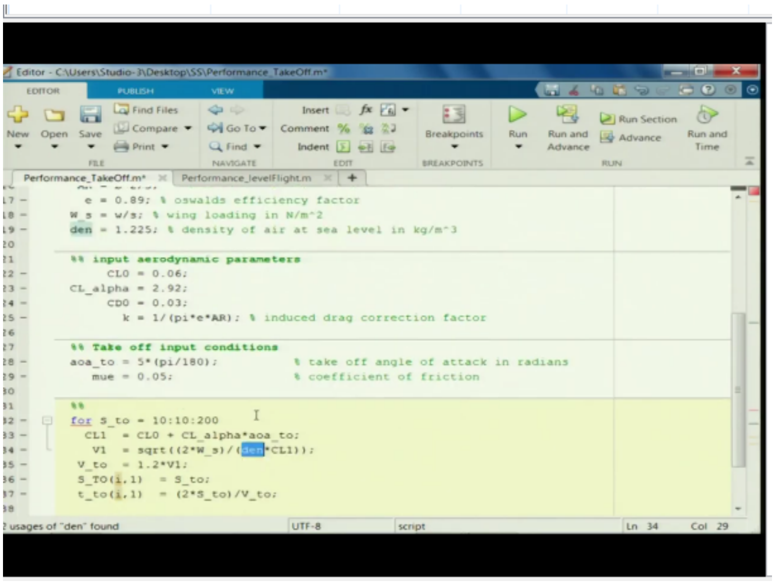

So we will just copy paste this values here and then C m alpha is also given, ok and k. We may not be requiring all these parameters but still I will try to copy them and then delete it whatever the that and all required? So, C D 0 is 0.03, C m 0 is 0.01, C m 0 is not required, C m alpha C m delta E is not required and then C L delta is not required for our current program, ok. So, these are the few aerodynamic parameters that we need to give as an input apart from this takeoff conditions what we have is mu, right, mu or coefficient of friction say which is 0.05, right coefficient of friction, ok. So, and then what you are require as an input nothing else I guess.

So, coming back to this, so alpha takeoff is an input from here and then yeah, so C L 0 is input, C L alpha is input which you already copied, the aerodynamic parameters are copied. Now let us find out what is C L prime here? So, C L prime, so let us start programming, so that means this entire steps , so what I need to find out is C L prime, right C L 1 let it be is equals to C L 0 which is as an input here C L 0 + C L alpha I just copy this.

So, that I will not make any mistake here, C L alpha times alpha, this alpha is nothing but aoa underscore takeoff, ok. So, C L alpha is in per radian and then alpha is also in radians, ok, so this with this C L 1 I will be able to find out what is V 1, V 1 is equals to square root of 2 times W underscore S wing loading, right, upon density times we will see what is the density? Density times C L 1, ok.

So, this is your V 1, so V takeoff V underscore to, to is stands for takeoff, so V takeoff is equals to 1.2 times of V 1, let us assume that, ok. And then what I need to find? so the acceleration, so S is a variable here. So, depending upon the value of S I will be able to find out what is the corresponding time taken per takeoff. So, t for takeoff is 2 S upon V takeoff, right, 2 times S underscore to takeoff, right, ok upon V underscore takeoff, ok.

So, now S is a variable here, right, is not it, so I will do is for S underscore takeoff ok, so S underscore takeoff is varying from what? Say let us start with 10 meters or say let us start yes 10 meters when increase it by 10 meters every increment and it should be up to 200 meters let us say, ok. So, if say this is my takeoff distance then every time aoa is constant, C L 1 is constant, so that is not a variable here.

So, V 1 is also not a variable, so V takeoff is not a variable here, so what is the variable is? time to takeoff. Because it depends upon S takeoff, right, so S takeoff is a variable, so automatically t to takeoff will also change. So, let us say this is i, 1 depends upon S takeoff there, right. So, I will try to store this S takeoff also as a new variable, S underscore takeoff, right, capital takeoff is for storage purpose.

So, as I storing this as what i, 1 is equals to S underscore takeoff, ok, distance per takeoff in meters. So, V takeoff anyways is not a variable, so it depend can you see that like can you appreciate this a takeoff is constant and hence C L 1 is constant and V 1 constant. Because we are not changing the aircraft, right, and then at a given altitude this is constant. So, here density should be an input, right, is not it.

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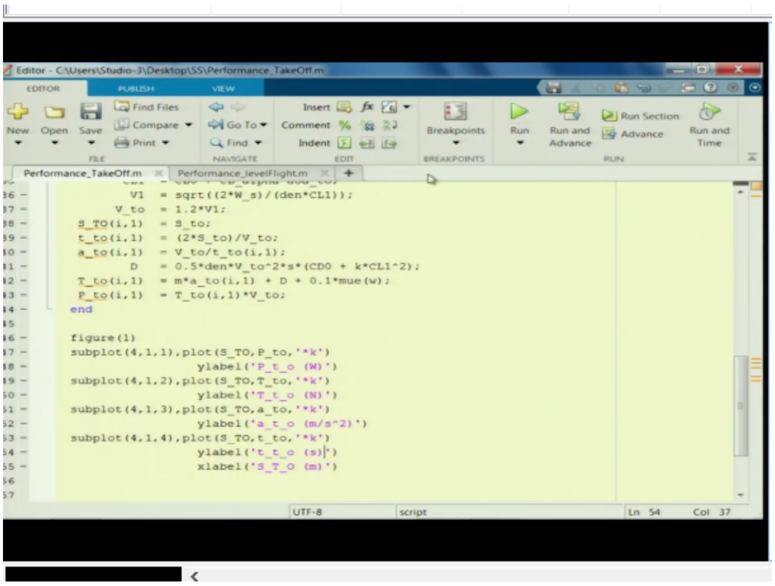

So, what I can do is press enter process the code instead of this the input that I would like to take is Z, correct. Let us say Z is equals to have you use Z anywhere here, no, so Z is equals to is an input let us enter the altitude of flight. So, since I am asking for only one output, so it will automatically returns density, right. So, means let me do that as well. So, density is equals to so den, let us say den is equals to density of Z, right.

So, I require only one variable here, right which is density for this particular program. So, I am calling only one output here which is den right, so den is equals to density of set returns only first output which is density of, so it was considered here, ok, that I am trying to delete this part. So, this now like user’s choice you can enter the density of altitude of flight, enter the altitude of flight in meters, right.

So, now that comes in as an input here accordingly, ok, so S takeoff is clear which is from here. And then using the same S takeoff I will be able to find out what is time to takeoff. So, for this program we require some inputs to follow which is i, i is starting 0, right, so for storage purpose, so i = i + 1, ok, right.

And then, so we need to find out what is the acceleration required which is V takeoff times t upon t, ok. So, this is an approximation acceleration for takeoff again it is a function of distance, right, that is available. So, takeoff distance that is available, so which is again V takeoff, so V takeoff is constant upon t to takeoff, right which is a variable, i, 1. So, whatever the acceleration for takeoff depends upon that particular t takeoff, right.

So, for that particular and which in fact depends upon that S takeoff which is a variable of this program, right, and then input variable in fact there. So, a takeoff is done, now I can find out what is C L, so mu is also required, so mu is given, so what I required further is what is D and what is L, right. Let us assume there is no L acting here, ok, so let us also neglect this, so that we have adequate drag you know adequate what you call? Friction still at the takeoff time, right.

So, which is mu times W, fine ok. Or you can say this prime is equals to when you run at this particular velocity this will automatically disappear, is not it. If you plug in that this will automatically disappear, so you can do that but in like what I will try to do is I will take some at least, so at takeoff this is lift is definitely equal to weight, so this becomes 0. But still I would like to have it just before takeoff I want to I have say about say 50% or say 10% of this you know 10% of this particular mu times W, right.

That I would like to consider still as a significant number during takeoff, right. So, let me use that 90%, so 10% of that mu times W instead of W - L I would like to use thrust during takeoff is equals to, so this is again a variable, right, is not it. So, thrust during takeoff times i, 1 is equals to mass times mass of the aircraft times acceleration to takeoff i, 1, ok plus the drag that you need to overcome.

And then plus the frictional force mu times W - L, right. So, but I would like to omit this L, ok, I would like to omit this yeah omit this L and then take 10% of this, right 0.1 times 10 % of this mu, this is at the takeoff condition, right. I am trying to take the frictional force as 10% at static force, right during the static condition, ok. So, mu times W, mu is as an input W is the weight of the aircraft which we have, so small w is at a this one is small w.

So, let us change this small w, so this will automatically become an input from this geometric parameters and mass of course is considered as an input. So, mass times the acceleration +

drag times mu, right, so this is what the total thrust required. So, but for this equation to solve we need to know what is drag here, right, is not it. So, drag again is a function, right, is not it, so drag of i, 1 will it be so drag is half den half rho V square, V is nothing but here V takeoff, right.

So, it will not be a variable anyway, V takeoff square half rho V square times a reference area times C D 0 + k times C L square, ok. So, C L is lift coefficient C L 1 square here, just C L 1 square which is constant, so this is not a variable here of this program. So, this is simply drag you are figuring out based upon V takeoff square times reference area C D 0 + k C L 1 square, ok.

This will get you the details of drag, so I think we are more or less done, so the power required for takeoff is i, 1 is equals to power required is thrust required during takeoff i, 1 times velocity during takeoff, ok. So, let us end this program here, so you know the output here will be, so based upon the takeoff distance, so the variable here is takeoff distance. And you will find out what is the time for the takeoff to happen.

And then acceleration that is required and then the thrust as well as the power required. So, once you know what is the thrust and power required you will be able to understand the requirement from your power plant, right. So, this has to be delivered by your power plant to this particular UAV, ok. So, let us have a pictorial or say let us have a plot of this variables with takeoff distance, right.

So, figure 1 subplot, so how many variables I can say 1, 2, 3, 4 right, 4 variables here. So, the 4 variables here are so let us have 4, 1, 1 is a subplot and we have plotting what takeoff with respect to takeoff distance how this is varying, right. So, S underscore takeoff on the x axis and then first thing that I would like know is what is the ok, so power variation during takeoff, y label.

So, I can simply copy this, ok, y label is power to takeoff, ok, power underscore t underscore o, power takeoff in watts, ok. I am not mentioning the unit but that is in watts, ok. So, this is in Newtons and this is in watts, so subplot this is done I will try to paste. I will paste this and then say, subplot 4 by 1 of 2, 3 and 4, the second one I would like to see what is the thrust required for takeoff.

And then the third one I will talk about acceleration during this takeoff and it is variation with takeoff distance and the time taken with the takeoff to have. And the time yeah required for takeoff, so this is like thrust for required and then acceleration meter per second square time in seconds, ok. So, this x label is takeoff S underscore t underscore o, right, it is takeoff distance in meters.

So, I am not giving the units here, let us say you can still have watts, right, in the brackets V mentioned units as watt. And then thrust for takeoff is Newtons and then this is in meter per second square and which is in seconds, ok. So, just let us run this code, so from the question yeah if you look at the question. So, we need to find this takeoff performance from a runway which is at 1000 meters, right.

So, with a propeller efficiency of 0.95 yeah we forget to mention about this, so this is like power required, right. So, power required during takeoff PR during takeoff let us say this is power required during takeoff by the aircraft. And now the engine has to deliver a shaft power, right, so ultimately, so the engine or the brushless motor here has to deliver the shaft power.

So, the shaft power that engine needs to deliver should be power available upon or power available which is equals to power required by the system here, right. So, this is power required by the system upon shaft power, so the shaft power that the engine has to deliver is power required by the system upon efficiency of the propeller.

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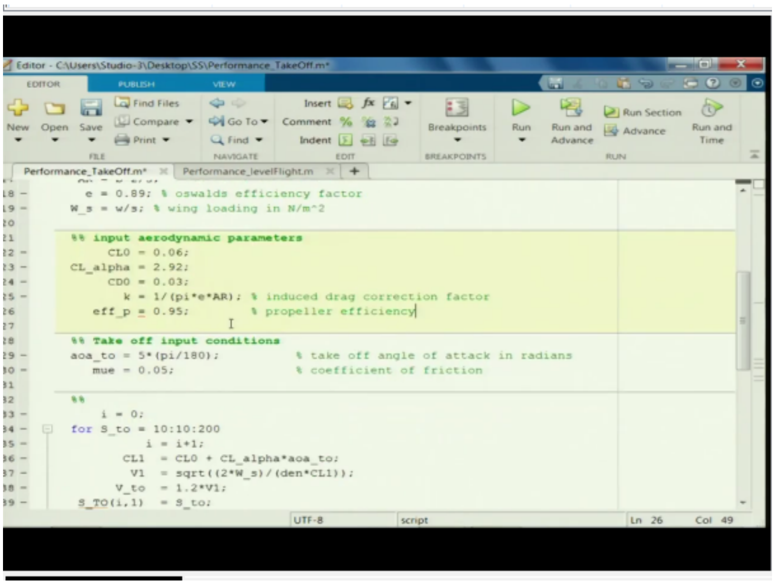

So, let us say efficiency of the propeller here is input aerodynamic characteristics let us say efficiency underscore p, propeller efficiency, right. Otherwise eta p is equals to efficiency of the propeller is 0.95 is given from the data. So, the power that need to be delivered or PS is shaft power let us say. So, PS is shaft power during takeoff is depends upon the power required by the system upon efficiency of the propeller, ok, eff underscore P, fine. So, let me add one more plot here apart from the power required, so it is say let us have 5 subplots here.

So, this is 5 by 5 of 2, 5 of 3 and 5 of 4, so 5 of let us say this is third one, this is fourth one, this is fifth one, ok, this is second one. I want to add one more this is power required it becomes PR and PR underscore takeoff, right. So, let us say this is power shaft power that need to be delivered by the engine, so, ok. So, this is becomes the first plot here again this is in watts, ok.

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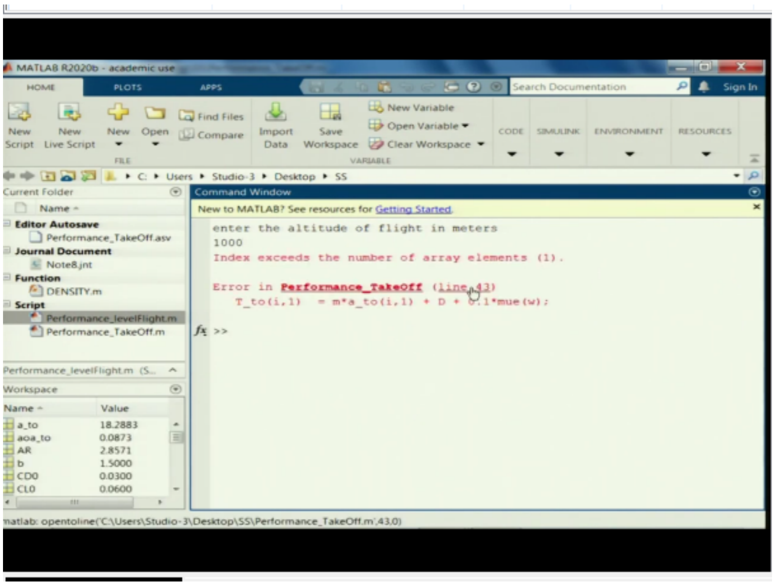

So, we will run this code. I think the earlier code is already, ok, I have break this code. Now I will run this again. So, now it like it will ask us to given input enter the altitude of flight in meter, so that is 1000 meters, right. So, ok there is some error here, we will just see, so this is mu times W, right, so here mu times W it is where is, ok. So, we have corrected this and then again yeah.

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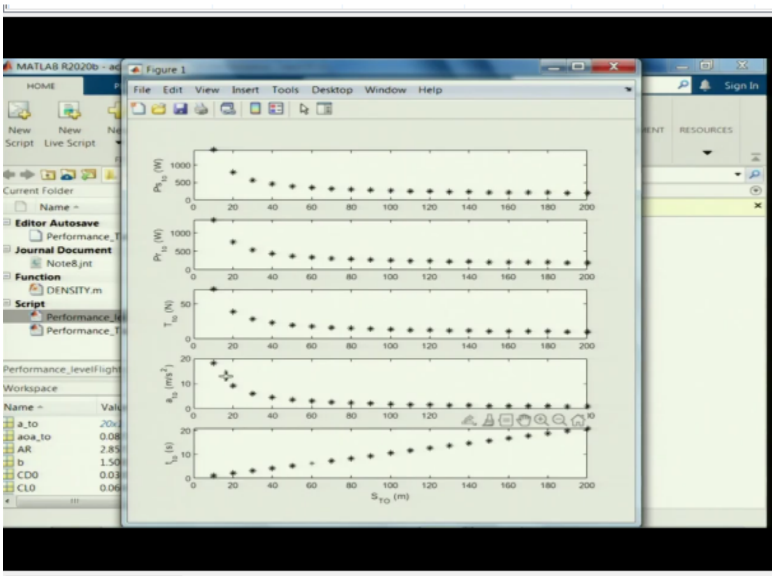

So, this is the takeoff distance in meters, right. So, this particular yeah you can see here at the x axis is takeoff distance in meters. And time to take so the acceleration is like, so at shorter distances as we know that you know you need higher acceleration. So, if you have a runway which is 100 meters, so you hardly require an acceleration of 2 meters per second, right and yeah you can see that the corresponding thrust required is about 14 Newtons which is 1.4 kgs of thrust required in this case.

And then the power required for this is about 269 for takeoff is about 269, if you want to make it takeoff within 90 meters distance, right. So, and then shaft power that we need to deliver is, so this is about 269 watts 270 watts and shaft power that you need is bit more than that 283 watts, ok. So, this for a brushless motor this power need to be given from your battery, is not it, it is a electric motor you need to supply this power from the battery.

So, you have the voltage, right, you know number of cells in the voltage of the battery times the amount. So, this is from here you can figure out what should be the current drawn from the battery is not it, so you know what is power required here, shaft power. So, once you know what is shaft power required. **(Video Ends: 1:42:19)**

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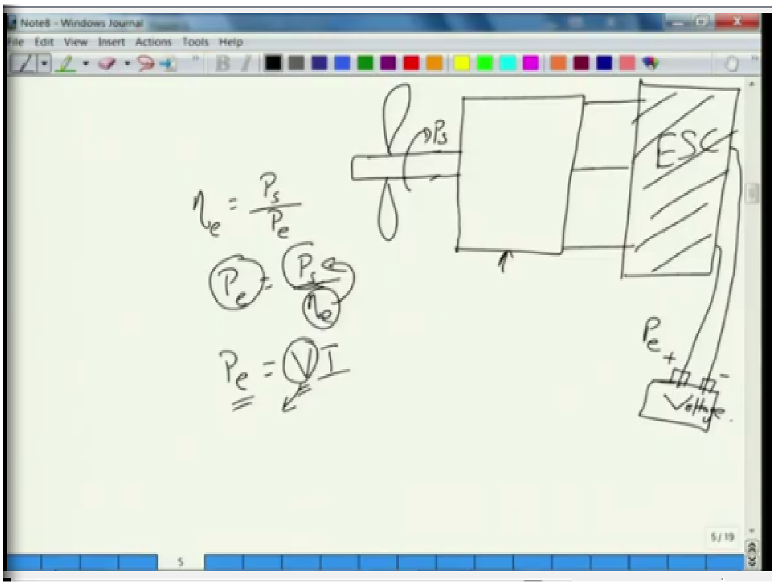

So, I need to connect this say this brushless motor to a speed controller and a battery let us ok. So, I need to connect this brushless motor to a speed controller unit let us say there is a speed controller. So, this speed controller again now I need to give power supply to this speed controller, right. So, this happens from right, so, ok, so that means this battery is having certain voltage, right.

So, and there is a speed controller electronic controller ESC and you have your propeller attached to this. So, what you are delivering is Ps here, so there is the Ps is output from the motor, right, and the input is electrical power, right. Let us say P electrical, so the efficiency electrical efficiency e, eta e is output P shaft power upon P electrical, right, so the P e is Ps upon eta e.

Now once you have this electrical efficiency say about 90% then you know what is P electrical power that you need to give. So, this P electrical is equals to voltage times current, right, so now you can decide which cell which kind of based upon the like. So, in general this brushless motor operate or wide range of potential difference. So, depending upon the requirement of this motor you can now have an option to select the respective voltage.

So, and then if you want to have low power low current drawing system then you need to choose for a high voltage yeah supply yeah high voltage supply, yeah. So, that means you need to go for high cell LIPO batteries or lithium polymer or any other that you like to power it up you know. That you like to use to power up the system, so that is our electrical power required by the system, right. So, this is how you can decide what is the power required during takeoff for this particular UAV, thank you.