UAV Design – Part II
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Lecture No -23
Subroutine for Weight Estimation

Dear friends, welcome back. So let us now proceed to solve weight estimation subroutine where we will take up again an example problem with some data like, we will not get into that how you are going to get the historical data here but we will consider that as an input for this example. And then we will try to develop a subroutine which helps us to figure out what should be the weight of the UAV without not exactly going into the aerodynamic details of the configuration.

So once you have the weight of the UAV then you can think of designing a wing and selecting an aerofoil so that follows this weight estimation. So to start with we need to know how to estimate the weight, so this weight estimation actually requires power requirement; like as an input what should be the power typical power requirement by the system which we have already solved for cruise, takeoff as well as climb performance right.

So that was the reason why we have initially handled those two those three examples or developed those three subroutines. So let us now proceed to solve this weight estimation problem.

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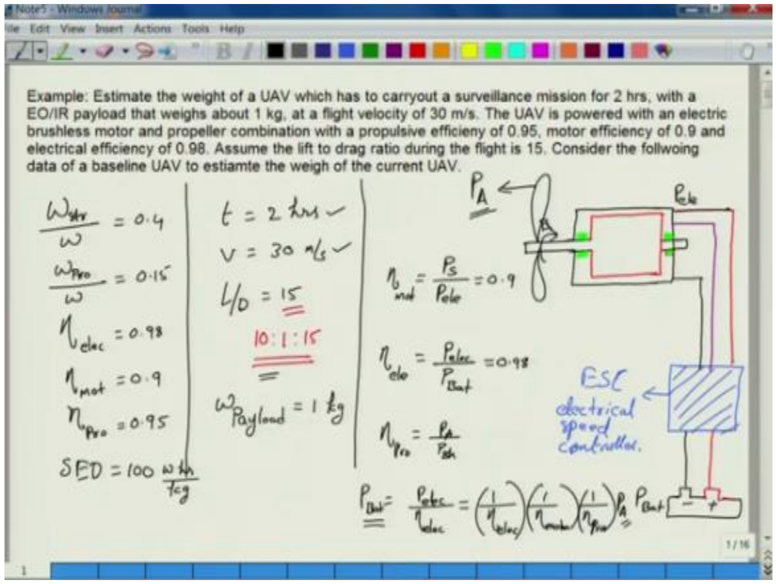

So the example here is, estimate the weight of a UAV which has to carryout the surveillance mission for 2 hours carrying or with a EO IR payload that weighs about 1 kg. So, at a flight velocity of 30 meters per second, the UAV is powered with an electric brushless motor and propeller combination with a propulsive efficiency 0.92, motor efficiency 0.95. Let us change this 0.92 0.95 of propeller efficiency and motor efficiency of 0.9 and electrical efficiency of 0.98.

Assume the lift to drag ratio during the flight is 15. So consider the following data of a baseline UAV to estimate the weight of the current UAV. So given propulsive efficiency, so what we have is structural weight ratio. So this is W. W structure upon total weight of the aircraft is given as 0.4 from the baseline aircraft. So propulsive W of propulsion unit or brushless motor upon weight of the total weight of the UAV was given as 0.15.

And electrical efficiency is 0.98 and motor efficiency 0.9 and then propeller efficiency or propulsive efficiency is 0.95. So what exactly is mean and again let us put down all the data that was given. So we need to carryout a mission requirement, so from the question we need to estimate the weight of a UAV which has to carryout a mission of surveillance mission for 2 hours that means it has to the time of flight has to be minimum of 2 hours.

Let us assume, let us now estimate the weight of the UAV only for this 2 hours plus for takeoff and then returning into the base. So, that we are not accounting here. What we will do is what should be the minimum weight of the UAV in order to carry out this 2 hours mission, 2 hours surveillance mission. So the time required is to see here. And also, the SCD; specific energy density that we have to consider for a battery is 100 watts, whatever per kg.

So this is the specific energy density that is considered. So the time of light is 2 hours and the velocity of flight should be 30 meters per second and L by D during flight is given as 15. So instead of just fixing this 15 again, let us try to iterate this from say from 10 with a step of 1 up to 15. So this is what we are going to do or say 17 as well, that is up to you. So we can iterate this we can make this as a variable as well as, so this is from the mission requirement.

So we cannot change this much. So 2 hours of flight is also mission requirement here and another data that we have from here is payload weight. So, W payload is given directory, so it is given as 1 kg. So this is what the data we have from the giving question. Now, let us look at the typical architecture of this brushless motor propulsion. So what we have is similar to that of IC engine we have shaft power as an output from a brushless motor.

Let us assume this is my brushless motor. So the output from this brushless motor is shaft power p s, when I connect a propeller to this shaft. So what I can what I achieve is power available or the useful power for the UAV to help the like this power available will help the UAV to move forward. Let us see what exactly the shaft is connected to. This shaft inside is connected to a armature which is positioned between permanent magnets.

You can say multiple permanent magnets in most of the cases. So say there will be a bearing here. Through which the shaft will be out right and then the end of the shaft again is connected to the other like opposite end of this motor. So say this is another bearing through which this shaft is mounted. So it is like a simply supported setup here. It is grounded to two ends to ends of it and then this armature rotates inside this particular motor which is having what you call coaxial permanent magnets.

So now, so the reason for me to consider this is, like the input for this motor is electric electricity electric, am I correct or not? P electric. So the input for the motor is P electric and the output from this motor is shaft power. So the electrical efficiency or say the motor efficiency motor efficiency here and mot is equals to so output from this motor is P s upon P electrical. So this is the output from this motor.

And then this motor again is connected to a speed controller here what we call it as electric speed controller. So this is ESC, and then. It is again connected to, finally to the power source. So the power source that we carry is a battery here lithium lipo battery. So say this is your lipo battery. So, and from here; so this is the power from the battery, so the power from the battery P B. So the P B is the input for these electrical connections that includes ESE and all other wiring here.

So when there is a power supply through this electrical equipment, there is resistance, of course, we cannot avoid resistance, so there are certain losses here. So that electrical efficiency is given as so the input for this electrical efficiency is power from the battery Bat otherwise you can consider this power from the battery and the output is power electrical to the motor which is input to the motor here.

So P electric upon P battery is the electrical efficiency and it is given as 0.98 and motor efficiency is given as 0.9 and we have like the useful aerodynamic power here or the power that is useful for the UAV to move forward is PA. So that is the output from the shaft power, so from the propeller. So the propulsive efficiency is the output upon input. So output is power available upon shaft power PSH or PS.

So now if I have to talk about what is the overall power available if I have to relate this power available and power battery power what I need to do is to power at the battery that are required is equals to Bat is equals to power electric upon propulsive efficiency eta electric, so this is equals to so what is P electric? Again I can convert this P electric from here. P s upon P motor. So one upon eta electric.

One upon eta motor. So times P s here, so again, I can convert this P s as P A upon one upon eta propulsion times P A power available, so whatever the power available from the system should be equal to the power requirement at that particular flight velocity is not it? That is what this power available should do? If I should set the throttle of the motor in such a way that the combination of this motor with the propeller should deliver the required power by the system to perform the particular mission; which is surveillance mission here.

At a particular velocity and L by D. So if this power, so the power required for that particular fight flight condition when it is satisfied with this power available from the motor then it will be able to fly at the constant velocity of 30 meters per second. So finally if I have to see understand what should be the weight of the battery. I need to first understand what should what should be a power requirement of this entire system or the power that has to be supplied from the battery. So how long they should supply this power? So it is mentioned that 2 hours here, let us say.

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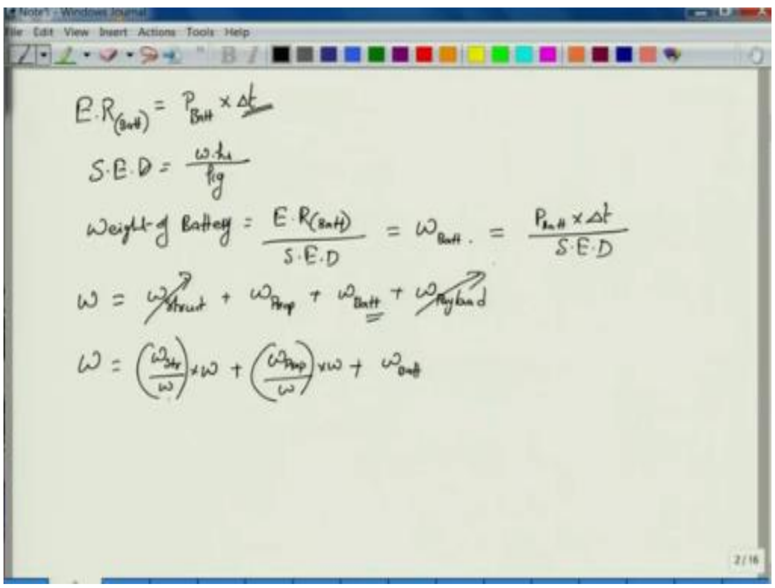

So this power from the battery, so energy at the battery otherwise so we cannot talk in terms of power there right so energy or E, energy required at battery is equals to power required or power at the battery, power that need to be delivered by the battery times the total duration of flight or delta t. So this is what will help us to know what is the energy required by the battery. Now once you know, what is energy required by the battery by using the definition of specific energy density.

So what is specific energy density? Specific energy density is a amount of energy stored in a battery per kg, So that is watt hour per kg. Weight of the battery, why we are calculating this that

that will be the only variable here, is not it? I will show you that so weight of the battery is; specific energy required by the battery or energy required from the battery. Upon to carry out that particular mission upon specific energy density.

So if you have energy in watt hour, then you divide it by watt hour per kg, what you have is a weight of the battery in kg. So, that is what WB this is equals to W battery. So what is the total weight of the aircraft? Weight of the aircraft is, this we have already derived in our previous course please refer to that video the video link will be given below, so please refer to that. So the weight of the aircraft is structural weight plus propulsive weight proper weight of the propulsion system plus weight of the battery plus assuming all other accessories weight of all other accessories.

That is for a particular system is already included in this. So, structure plus propulsion plus battery plus payload for a UAV. So payload weight is given directly in kg so we do not have a structural weight as such so what we need to do is this is given as the ratio W str right W str upon W is given, this structural weight ratio is given times the total weight plus propulsion weight upon total weight is a propulsion weight ratio times the total weight of the aircraft plus weight of the battery is not given which is unknown that we need to find out.

So it varies from mission to mission is not it that is very clear here. If it is delta t changes the battery per weight changes here because battery weight again this battery weight is equals to P Bat times power that is need to be delivered from the battery times delta t upon SCD specific energy density, so this power at the battery depends upon this power available. So it depends upon the flight conditions as well.

So from one mission to the other mission the overall power requirement changes, so if you are flying at different velocity this power available that the power that need to be made available from the power plant to the system changes. So at the same time when you are flying at a different L by D you have different power requirement altogether. So the current approach that we are going to adapt is not a generic approach.

So this is what I generally use and found to be very useful in in designing a UAV, so there can be many other approaches. I am not a generalizing and stating that this is only approach that is available. So the steps that we need to follow here is;

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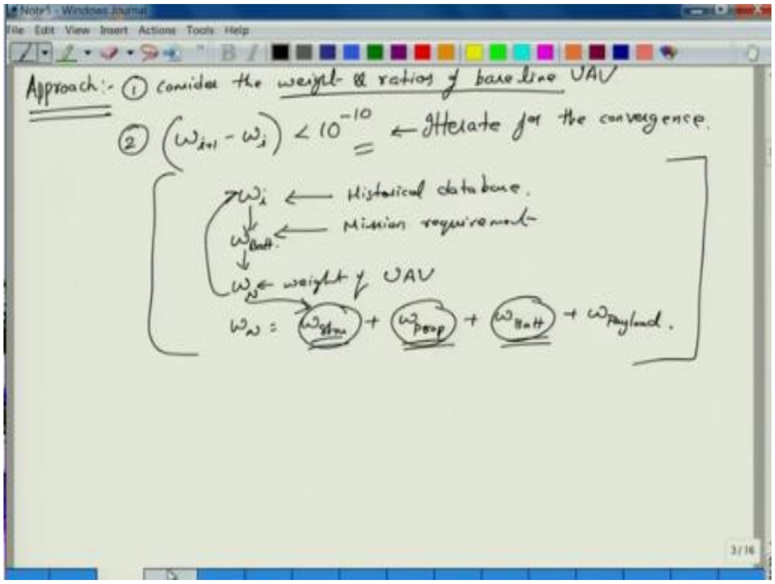

Approach: what will be doing? So, consider the weight and ratios of baseline UAV. Now, so what are we doing here? So this battery weight, so payload weight is fixed payload this is fixed. So this is what is changing is not it? That the battery weight has to change and it depends upon the initial weight as well initial weight of the aircraft as well. So with the initial weight; for a different region requirement.

So the initial weight was given from the baseline aircraft right, is not it? Here it is from the baseline aircraft. So considering that weight and estimating it for a different altogether different mission will also affect the initial weight itself at the end of this mission because the battery weight may not be same as the battery weight of the previous UAV, which was considered as 4 kgs, right?

That was the baseline UAV that we considered that may not be the battery weight that this particular mission may not stay within that limit So in that 4 kg maybe say about 1.5 kg is the battery weight for to carry out a mission that was like that UAV was designed for. But the current UAV has to perform a different mission altogether which is a 2 hours surveillance. So for the case that 1.5 kg of battery, which you have considered earlier;

For that case, the 1.5 kg battery that was assumed for the total weight of the aircraft which is about 4 kg may not be suitable for this particular mission requirement, that is a reason why we are trying to estimate with that initial weight assuming that is the initial weight what is the overall weight of the battery that we need to carry here? Now with that battery we will try to update it this W.

So that iteration continues until we achieve convergence between two consecutive iterations. So let us say so i+1 - wi. So the error between them is if it is less than 10 power say some value. So then we will say that okay what we have achieved is a kind of convergence. So weight estimation is more or less a decent value. It gives us a decentral value here. So further, what we have to do is, so first wise consider the initial weights and then try to iterate for the convergence.

Because the battery weight changes that means the overall weight changes. So, with that over all weight figures out what is the power requirement. So initial guess weight so or say initial historic, from initial weight from historical database. So this is from historical database. So with this initial weight and for that particular mission requirement right for mission requirement estimate what should be the battery weight, thereby estimate what should be the weight of UAV.

So let us say WN is the new weight of the W, i is a initial weight that is considered so if this initial new weight in the initial weight if they are same one and the same that means whatever you guessed as the initial weight earlier or whatever you have considered the initial weight will also is good enough to satisfy this particular mission requirement which means this new weight again is a structural weight right of the new UAV times the propulsive weight of the new UAV.

And then the battery weight of the new UAV plus the payload. So here these weights are updated based upon this new weight here. So if this new weight and the previous weight if they turn out to be same in the previous iteration, if they, let us say if there is an error then this iteration continues like the power requirement for this with the updated weight, so the new weight will become the what you call input of this iteration.

Let us say if I iterate within this loop then the new weight will now become the initial weight and then, we will try to estimate what is the power requirement with this new weight right to carry out that particular mission thereby estimating the battery weight and then from the battery weight again will find out what is the total weight of the UAV. So within the loop we will not update this structural weight and propulsion weight.

So they are defined outside the loop itself, so within the loop we are not doing that. So once we achieve this, then we will try to structural weight and propulsion weight and then again repeat because when you update them again, the total weight changes and the repeat this exercise so that we are more or less close to this particular weight estimation of a new UAV. So it will be easy as we start writing the code, let us start the new subroutine.

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As usual I am clearing the database, clearing the memory and closing all the windows say if they are open say I would like to consider the velocity of flight as an input here so input, enter the flight velocity. So, velocity in meters per second, so at the same time I would also like to have total time of flight as an input. So enter the total time of flight in hours. So after considering these two as a inputs.

So, from the given data, so the baseline aircraft. So the weight of the baseline aircraft is also given here, so which I forgot to mention which given as 4 kg. This was the weight of the baseline aircraft. So this 4 kg includes everything that was an earlier aircraft we were asked to consider to start like estimating the weight of the current UAV. This may not be for 2 hours mission requirement, like surveillance.

And L by D is 15 and then velocity at 30 meters per second, so that may not be exactly same. So but we will consider that those details here, so the whatever it was given is so baseline aircraft we it is given as 4kg. So and structural weight ratio the value Wst underscores W, that is a structural weight ratio, which is given as 0.4. This is structural weight ratio which is Wst underscore W power set, W structural upon total weight of the aircraft.

So and then the propulsion weight ratio is given W underscore. So W pro underscore W is 0.15. So propulsion weight ratio and then so the L by D of flight we are going to vary. So for what are we doing? L underscore D. Let us say that as L by D of flight is varying from say 10 with an increment of 1 till 15 or say 16 otherwise. So you can control this with limits of this for loop. So while varying this what we need to do is, so for each and every time you need to start with 4 whether it is L by D 11 or L by D 12 or L by D 13 or L by D 15.

So the baseline aircraft details are same one and the same right is not it? So further what I will try to do here is the structural weight ratio before entering into the slope. I would like to give them as an input here. So that is structural weight ratio.W underscore STR is a structural weight itself, which is W STR underscore W that is structural weight ratio times W here. So this is in kg, so we are dealing in kg right now.

So and then W underscore propulsion weight ratio PRO capital letters so this is weight of the propulsion system weight of the structural weight of the UAV, so the propulsion weight is total weight is equal to propulsion weight ratio pro underscore W times the total weight. So this gives me what is the structural rate and the propulsion weight here. So that is outside the iterations and then so I would like to use some variables for this iterate iteration again just to know as well as save the data. So I is equals to 0.

Let us say Id is equals to 0 here, k is equals to +1 so this will talk about L by D. So k corresponds to the variable of iterations in for L by D here. I just want to save this L by D or say let us write this variations a small ld here I am storing it as capital LD of k, 1. It stores in a vector column vector is equals to l underscore d, l by d. I say capital L by D. So now the initial weight of the UAV I would like to assign this wi the initial weight for this iterations as the weight of the base line aircraft w, so that is the weight of the UAV and then I would like to have another variable which is w.

So w, which is 0; I am just assigning it just to start like as I told you I want to compare this. Let us say ww is the final weight after the iteration each iteration, so wi – ww, I would like to compare this should be less than or otherwise a should be greater than 10 power – 10. If it is greater than 10 power - 10 this loop runs, so the error so this loop will break as soon as the error with the initial weight of the iteration in the final weight after that iteration if it is if the error is less than then power - 10 so it will break otherwise it will keep running.

So what I am trying to do here, so wi is considered as w every time inside the even inside the iteration, so wi is equals to w because I need to upgrade this wi is not it, so the initial weight I am considering is a base line aircraft but inside that loop every after each and every loop this wi has to be upgraded here. So this you will understand once we complete this program. So i is again, so wi is not related with this i do not get confused.

So I am i + 1 talks about the iterations progress here and then the wi is w and what I have to calculate is power required right so that was the whole area there. If you look at here I need to calculate the power required and I need to make sure that is available power available here, is not it. So apart from this, there are efficiency probe so an input data related to proposal efficiency, motor efficiency and electrical efficiency.

So efficiency underscore pro, pr prople efficiency is equals to 0.95, so efficiency underscore battery is equal to efficiency underscore propulsion battery, and then what you have electrical ele electrical efficiency let us say this is also pro. And I am sorry this should be motor efficiency, mot motor efficiency redness motor efficiency, which is 0.9 and electrical efficiency 0.98. So the whole idea is since we have this as an input here once I know what is the power that I need to deliver from the battery for this particular mission requirement?

And it is very clear that if I know that battery power required I will know what is the battery weight? So I can update this battery weight and get the new weight here is not it that is what I am trying to do here. So because efficiencies are given as an input here. So what I need to know is power available, which should be power required to perform that particular mission. So that is what I am trying to do power required by the system, which is nothing but the power available in our case.

So power required each and every time is equals to weight of the aircraft wi times, see this is in kg. I am just converting it to Newton. So L upon what is the power required here for a level flight condition? So this is like surveillance machine at a L by D constant L by D right? So that means more or less a level flight here. So l is equal to w right and t is equals to d are the governing equation.

So the power required for us from these two equations is like rest required times velocity of light, is not it? So that is nothing but drag times V infinity or say if you divide these 2 equations. If you divide otherwise power required is thrust required times velocity of light. So divide these two equations what you have is thrust required upon the W, T by W is equal to D by L or say thrust required is W upon L by D.

So we are not exactly going into the details aerodynamic details of this. Instead, we are considering this L by D is available. So for if you want to have this much of weight for your UAV then you need to make sure that you fly at that particular L by D. So you have to design your wing to deliver the particular L by D. So L by D from here will be used as an input for your wing design.

So L by D, W times V infinity is from the mission requirements upon L by D is your power required here. So I am not explicitly calculating each and every variable here take thrust required and then power required the way we performed earlier instead, I will just use this. So this is like w times. G which is like in weight in Newton and then what I have is velocity of light, which is input from here. So, that is V upon L by D right? So L by D is what this is my L by D.

So now I got power required. So, can I calculate what is the battery weight? Or power required at the battery. So power required at the battery is 1 upon electrical, 1 upon motor efficiency, 1 upon propulsion efficiency times this power required here. So let us say P bat is this is k capital P underscore bat battery power that will deliver the battery is equal to; so what is this? This is equals to power require 1 upon I can say 1 upon efficiency E of if efficiency of propeller multiplied by efficiency of motor multiplied by electrical efficiency.

Multiplied by so power required Pr. So you now got to know power at the battery power required at the battery. So, can I say what is battery weight? WB W underscore battery weight. So, W underscore battery capital. So inside the iterations let us W underscore battery is equals to power underscore battery times the time of light, very stem of light t. t is the time of light in our straight. So divided by specific energy density.

So we need to give SED also as an input in whatever per kg say control C SED specific energy density enter the total into the specific energy of the battery in watt hour per kg. So now you got weight of the battery. So with this weight so we it without actually using this no we consider them the structural weight and propulsion weight as a constant inside otherwise we will not be able to achieve a closed form solution here.

So the W of the total aircraft now the new weight of the aircraft is now W assuming the structure still remains same structural weight plus W underscore propulsion system weight because of that propulsion system can deliver a variety of power it is not, considered only for single power so assuming this power requirement is still satisfied by this and the structural changes because of just increase in the battery weight is not much.

So and then what we have is the new battery weight that is bat here, this is the new battery weight. So now actually W is getting updated with this new battery weight plus payload is already given so they or pay lower was not considered here, but it was given as an input so let us write W payload so W underscore PL, let us say is a payload weight, which is equals to 1 kg right so W payload is so load of EO slash IR sensor in kg, directly the payload was given.

So PL talks about payload, so what you are going to achieve is W is in kgs just because everything else is kgs here, so for calculating power we need to convert that weight from kgs to Newton's because we are expecting power in Newton's velocities in meter per second and so we need to convert that again. So for calculating power required we need to convert this weight to newton's instead of kgs because we are expecting power required in watts.

So now we got the weight W, now what I want to do is so this W – Wi, Wi is the initial weight that I have considered, so what I am trying to do is I am assigning this Ww as w, after the otherwise you can say Wf you can consider this as Wf for this loop Wf and then say Wa. Wa is the final I read that is estimated after this particular iteration each and every iteration which is equals to W here, that is a final weight.

Now difference of this initial weight that I have considered in the final weight let us say, if there are if it is very, very less if it is 10 power minus 10 let us say so then this will this loop will break saying that whatever the battery weight that you have estimated for this particular endurance is already satisfied for that 4 kg, otherwise this will keep iterating this is one converging convergence approach that we have used.

So this will end this first while loop and now since the weight is the structure weight as well as propulsion weight need to be upgraded a little these structural weight and propulsion weight since the battery weight is increased the total weight also increased. So but these two at line 22 and 23, the structural weight and propulsion weight we considered is from the weight of the baseline UAV, not the current upgraded UAV.

So once this iteration completes then we will try to upgrade this and then all again repeat the same procedure to find out what is the total increase of the change in the weight of the battery thereby finding out the overall weight of the UAV. So now again, let us say this has to be for the same L by D. So what I will do is I will just copy paste these things here again same including the entire you can either make it as a function that will make more sense but just want to copy paste this again.

So the second iteration here is the structural weight is now the same structural weight ratio we still have the same structural ratio, but the new W so the new W is this one after this initial iterations. So initially in this particular loop what we have graded is just the battery weight, So that means the total weight of the aircraft is upgraded from in terms of battery. Now what we are doing is with that battery weight we are upgrading structural weight and propulsion weight system.

So; that these are the two weights that we are upgrading for the new UAV for the new mission requirements. And once we complete this task then again the when there is an increase in structural weight and propulsion weight there should be an increase in the power requirement to perform that that means again the battery weight has to be changed. So that means again in the second iteration so this battery weight will be changed.

So while considering this upgradation you can take a factor of safety so that this particular battery weight no will be satisfied within the limit. The increase in the weight will not affect the propulsion weight increment as well as structural weight increment. So we end this after two iterations here. In general, what I observed is like after this two iterations, the weights are more or less within the estimates, you know limits of the estimates.

So I will end this program finally the weight that I am going to get here is a end up this particular so for each loop each for loop for each L by D it ends after this 2 while loops. So that means the final weight of the battery or the final weight of the UAV, W of otherwise what should say V underscore final for the particular L by D, that means I which is k, 1. So which is k, 1 here is equals to W that I am going to get here.

Now WF whatever it is, that is stored in them weight of the batteries also stored. Weight of the Bat battery after this 2 while loops is k, 1 is also stored for each and every L by D this keeps varying. So this weight of the battery is here W underscore Bat you want to get here and then weight of the battery propulsion system. What will be the weight of the propulsion system? So once you know power requirement for each and every flight envelope you can select a power plant and you can get the precise power requirement.

So this is an initial estimate to start the design process. So once you have precise weights, once you select the power plant based upon the power requirement, you will get to know you can again come back to this loop and then iterate this and finalize the battery because in that case more or less you have another fixed variable here, is not it? So the same motor which can deliver 23 k say jet engine or a small brushless motor which can generate 10 kgs of thrust can also generate 5 kgs of thrust right the same motor.

So, with that understanding we are now we are not upgrading these structural weight propulsion weight inside the loop itself. So this is the battery weight that we are solving and then the propulsion weight is for W PRO. So propulsion weight battery weight and then payload is given. So the total weight is also given, apart from this; what do we require? We do not require anything. So with L by D how this proper W finally changing as well as battery is changing propulsion. So if we want to plot you can plot a figure. So figure 1, I can have subplot PLOT L by D, L underscore D.

So, each and every time let us say this is w b is the baseline w underscore b so this will become w underscore be otherwise it will be an issue. So from here, once you get w. So that will automatically be changed here. So let us assume for the initial iteration it will be always for different L by D, you have to start with the same baseline aircraft. So let it be W underscore b otherwise it will be upgraded now with the new weight every time L by D.

And, There is the L by D here it is a column vector L by D how this w underscore final weight is changing y label syntax. It is W, let me just put w underscore total weight. So, maybe it is worth mentioning kg okay total weight in kg, L by D varying with w or the battery weight is varying. Ba, just copy this b a t battery weight, t o t total let us not write the entire total. So we are also plotting the propulsion wheat variation with battery weight.

So, x label is upon D, so let us see this work. So we have not saved this set. So weight estimation, so we are estimating the weight of the UAV only for say that particular mission only for the cruise we are not estimating for say if there is any extra or with a factor of safety as well as we are not considering the take off and climbing flight as well as landing flight. So here in the first value so since we have updated this as w base is b weight w underscore b instead of w.

If there is no for loop then it will not be an issue but since we are iterating for L by D here. So for different l by d how this weight of the changing? So what I did is I used a if loop here. So if I i is 1 like this variable of this loop is 1 then, that is at the initial iterations. So this w i is nothing but w b. So else if or any other thing so this w i will take w weight of the new weight that we have estimated right.

So and then it will find out what is the error between them and if the if the error is less than that it will break and it will continue with the next iterations next while loop here with the upgraded structural weighted propulsion weight. So here it will not be a problem because what we want is the new estimated weight should be the input to this particular while loop, which is happening here.

So the only difference that makes this if loop with that too because we have a for loop here. We are iterating it for L by D. So another a upgrade is that I would also like to plot this structured weight how it is varying with L by D. And then I have made it as a subplot of 4 by 1. So therefore rows would talk about this 4 sub plots with final weight, battery weight, propulsion weight and structure weight varying with L by D here.

So let us figure out. So the flight velocity is 30 meters per second and then duration of flight is 2 hours from the data and the structural SCD says specific energy density of the battery or energy density of the battery. It should be specific energy density, I missed it. Please I will make a correction. So if this is okay, so we have a plot here. So see the structural weight in kg is so has to be 13 when L by D is 11 and then it can be as low as 2 point 2.3 when you have L by D 16 here.

So, see the propulsion weight ratio is almost close to 850 grams you have so with that propulsion and the battery weight is close to. Say 3.2 kg when you have L by D 16 for the same flight conditions when L by D is varying overall weight turns out to be 7.3 kg. So when it is when the L by D is say 11. See the structure weight increases to 3.5 kg and then the propulsion weight you need to will be carrying is about 1.3 kg.

So the battery weight and is as high as 10 kg no, you need to carry a battery which weighs about 10 kg here just to perform that mission and then the overall take total weight of the aircraft turns out to be about 16 kgs here. So this this helps us to like help us to understand the significance of L by D in the flight. So as a performance increases with the L by D you require less battery weight, less structural weight and overall weight will also turn out to be compared to the less here.

So this is just a an attempt to start with the weight estimation you can say preliminary weight estimation that you can start with this code and then once you have the detail weights you can further complicate this algorithm. I wish you should extend this program for even take off and based upon the mission requirement, whether it is a hand launch UAV or say it has a typical take off and landing capability.

So then based upon that you need to and then the climb, so what is the climb that you are expecting, what is the altitude of cruise? So, based upon those parameters. I wish you should upgrade this chord to estimate the overall weight of the battery as well as the UAV depending upon a baseline aircraft. So this baseline aircraft we do not have much time to discuss. So that is from the historical database.

I leave it to you to figure out to study, at least study various textbooks and figure out what are the baseline like how do how do we extract this historical database from the previous UAVs.

(Video End Time: 58:23)

So in the next lecture we will talk about wing sizing based upon this weight estimation and the l by D that we have considered what should be various combinations of like say or what should be the wing plan for geometries as well as the cross sectional profile geometries or say parameters. Okay then, see you thank you.