UAV Design - Part II
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Lecture - 01
Introduction of Design Algorithm: Flight Dynamics Point of View

Hello all. Welcome back to this course, Design of Fixed Wing UAV. I hope all of you are safe and sound. This is again Dr. Subrahmanyam Saderla from the Department of Aerospace Engineering, IIT Kanpur. So the second part is in fact the continuation of what we have covered during the lecture series 1. So I do not consider this as a new course, and indeed it is not right.

So I do not want to again reintroduce the content that we are going to cover in this course. So and in the first part, we have covered about the performance aspects, starting with some introductory concepts, and then we have covered the performance aspects and how performance aspects help us in weight estimation. And also we started with some aspects of stability to be frank.

Long about we started studying about longitudinal static stability and then we reached up to a point where we can find out neutral point given a wing and tail combination. So that is where we ended the previous course. And yeah, I have got many requests from your friends saying that they were not able to do the first part of this course and then they want to participate in this current course.

So I would like to structure this course in such a way that these newcomers will also find it comfortable. So I will not repeat the concepts that we have covered during the first lecture series. So I may not go into the detail derivations of those, but I will touch base all those yeah, during the first week of this course I will try to cover a little bit about all the concepts that will be helpful even for those who already completed the first part and also for the newcomers, right.

So we will cover those concepts which will be useful in the current course, in the current lecture series. Yeah, so I would like to say this course will cover an algorithm right. So I would like to present a flowchart. So algorithm of design. The main emphasis is it will, this course will try to address some of the subroutines or subroutines of the design process right.

So where we develop our own codes, since we all know design is an iterative process. So instead of depending upon pen and paper repeatedly, let us develop codes parallely during the course, and then use them for solving some design problems right design subroutines.

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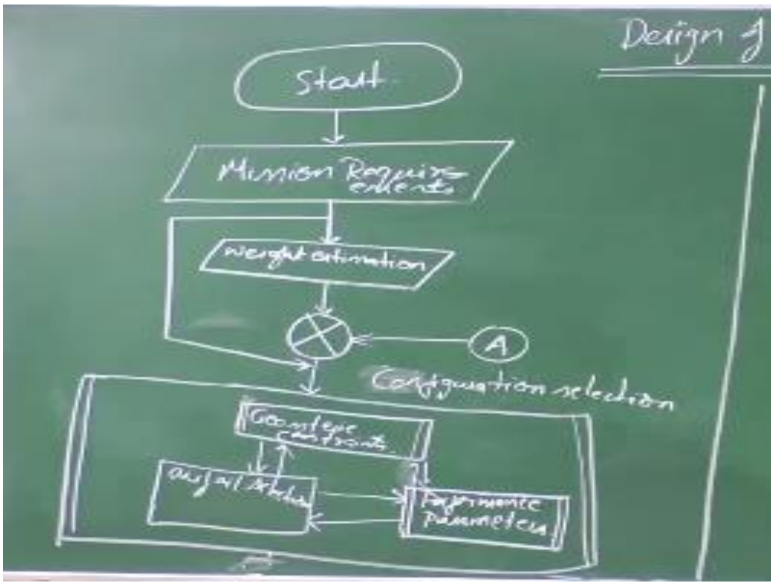

So we are here to discuss about this. So basically part 2, continuation from where we have left last time. So as I mentioned in the first, first one week will be dedicated for revisiting those concepts, which we will be using in this course, and we will again start with stability and briefly derive those expressions which we have arrived during the previous course, maybe even the last week of the previous course, right.

We will revisit that again and solve few example problems, and then proceed with our current design process. So let us consider the following flowchart that is going to talk about a typical design process, right. So we will start with certain mission requirements, which are a set of statements that helps I mean set of statements that you need to achieve right with that particular UAV. So you have mission requirements.

So from this statements, we will be able to figure out, at least figure out what will be the aim of this design right. So in the sense, you will have certain geometric constraints from machine requirement statements, as well as performance constraints. So for example, if you consider a high altitude hill, right high altitude and long endurance UAV.

So that means you are looking at a higher endurance, typically may not be high speed UAV, right. So you will know certain range of these velocities at which you need to fly, you will get to know. That means, you definitely concentrate on a subsonic, lower subsonic UAV right. So and then you know it flies at certain altitude. So you will try to figure out what kind of propulsion system that I need to use, right.

And also a medium, so you will be asked for example, if you are asked to carry a payload of so many kgs, then you will typically know once you know the kind of payload you will try to figure out what is the power requirement of the payload, right and with that payload for a UAV to lift that payload along with the other accessories you will start with certain geometric parameters, right.

So again mission requirements poses or corners your focus area, right. When you talk about hill you will be concentrating on UAVs which can perform flight at a lower subsonic speeds right. So when you talk about combat UAV then you may be concentrating on higher subsonic or supersonic speeds. So along with them basically constraints the kind of aerodynamic model that you have to consider during the design process.

Apart from that this mission requirements will also give you certain geometric constraints, right. May not be all definitely, but to some extent they will pose certain geometric constraints. So from this mission requirements with a basic estimation of geometry we can do a proper weight estimation right. So from this machine requirements you can perform weight estimation, right?

So and then we can use this weight estimation and of course, this mission requirements here will also be useful again right. So we can use this for initial geometry or initial configuration selection. So again, this is an iterative approach, right. It has multiple steps in achieving this particular configuration, a particular configuration based upon mission requirement. So you start with geometric. So what you have will be constraints.

So you will try to iterate to achieve that no? With those constraints, you will try to achieve certain, doing iterations you will be able to achieve certain geometry. Maybe you can say being planned for. At least for the time being we can understand that way. At the same time, you will also analyze or say you will in fact, this is guided by this performance aspect as well.

So all these subroutines, so we will work hand in hand right in order to figure out a particular configuration, okay. Let us continue this here.

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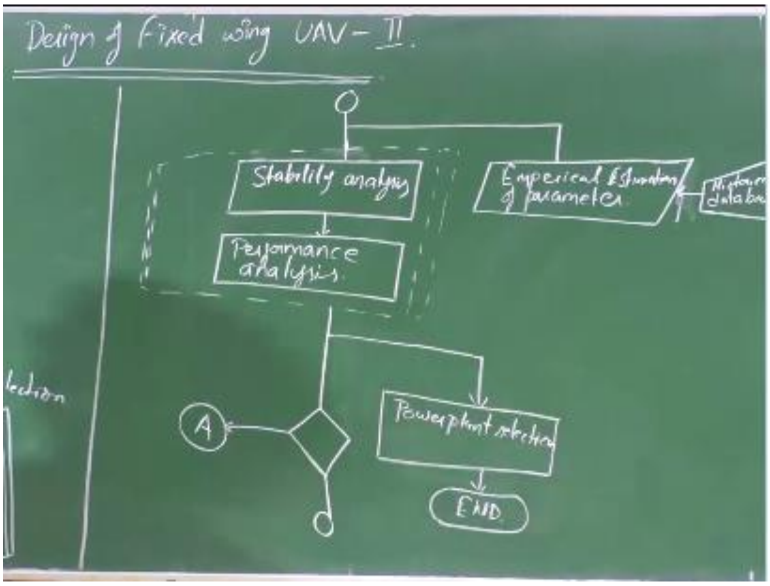

So once you have this geometry, you can independently perform an empirical estimation. So for this what I require is a historical database as an input right. So I have historical database. So this geometry selection will enable me to perform certain stability and performance analysis. So this particular, so this analysis will help me to figure out the propulsion system or power plant selection, right.

So this performance and from this performance analysis once we are satisfied with it, then we will go ahead for simulation. The simulation we will be talking about is as an aircraft flight simulation, right.

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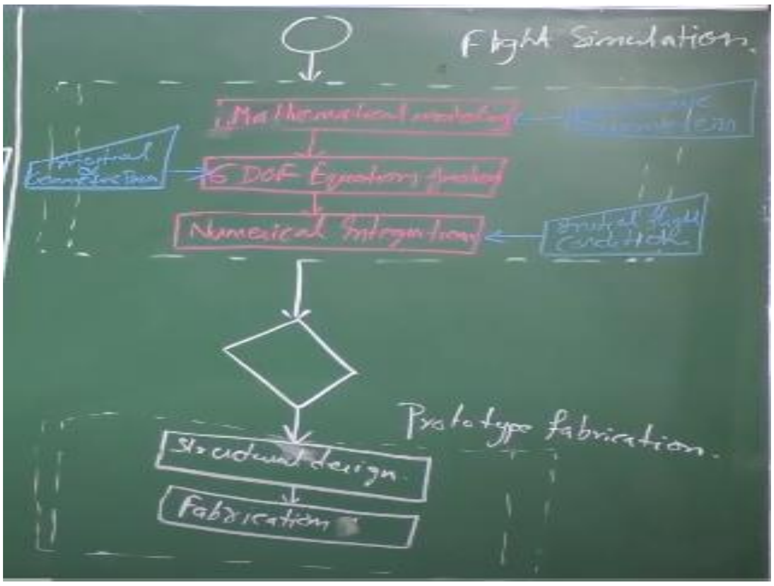

So for this flight simulation subroutine, what we need is, is a numerical model, right? So or say what we have is a 6 DOF equations of motion, right. So we have mathematical modeling which will be used along with 6 DOF 6 degrees of freedom equations of motion. We will use a numerical integration. So this equations of motion in general result in first order differential equations, right may be linear or nonlinear.

So in order to solve them we have to use some numerical algorithm. So we have to solve them simultaneously. So we will use some numerical integration. So for this numerical integration to happen we need to give, so initial flight conditions as an input. And also for this mathematical model you need to give so aerodynamic parameters as an input.

So for this 6 DOF equations of motion, so the input you need to provide is regarding inertial and geometric parameters or details you can say, right. So this will help us to figure out how the system behaves or the current design that you are considering how it behaves under various conditions, right. So if you are happy with this simulation results, then you can proceed to the next part, which is prototype fabrication.

So in this prototype fabrication again you have a structural design. So once you have the structural vision you may now go for a scaled down configuration right? So that will now, that I will include in the structural design itself. And then these are the major steps. I am not going in detail at each and every level. So once you have scaled down the configuration then you may go for fabrication methodology.

Or in between yeah, in the structural design when I say there is analysis as well, once you have come up with the design then you can use any of the existing analysis software, right. That will help you to figure out what are the structural stress as well as loads acting on this, right. And then fabrication of fabrication, right. So this fabrication again includes a scaled down prototyping and manufacturing, okay.

So I require some more space here. What I can do, I will try to reduce this one.

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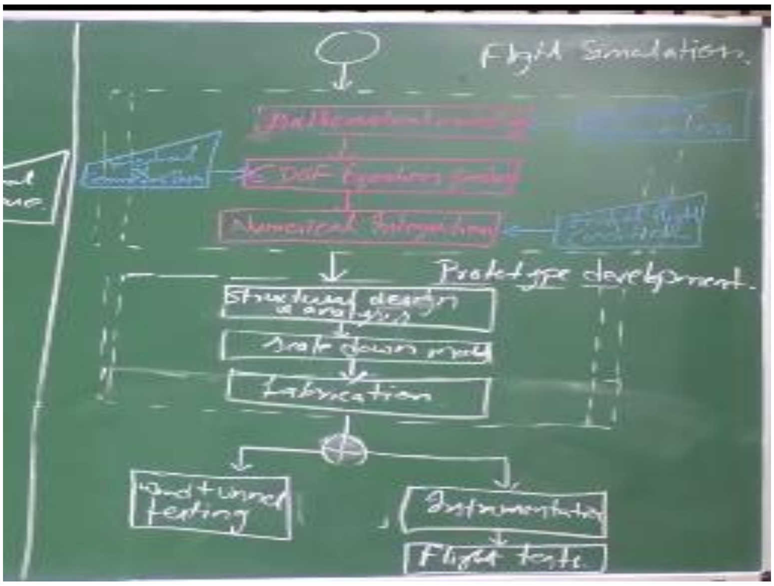

This subroutine we will talk about prototype development right or fabrication. So where you have structural analysis, design and analysis and then scaling down the configuration and then perform or carry out the manufacturing or fabrication process. So this so at each and every level, we have iterative approach apart from say every addition like at each and every stage we should also make a decision right.

If you are satisfied with this analysis then you will be going to this step or you will be either going to step A here, right where I say this step A right. So once you have this we will go for once you have the scaled down model we will go for wind tunnel testing. So you will do an experiment and analysis right.

So the initial experimental or the like once you have the design, once you are satisfied with the simulation results, and then you can go for the initial experimental analysis using wind tunnel testing. And then you can also perform scaled down flight test right. You have the configuration. So before this so you will do instrumentation as well. When you do the flight test, you will also do instrumentation here, right.

So instrumentation. So this can be like instrumented flight test as well as initial flight test without any instruments, right to see the flying capabilities. So instrumentation. So this entire design approach is from flight dynamic point of view. So and then flight test. So once you are happy with this data, go for the scaled up configuration, the full scale configuration.

And again go for flight test data where if you are not, if you are not able to accommodate a full scale configurations in the wind tunnel, then you can directly go for the flight test, instrumented flight test and perform experiments right, analyze the performance as well as estimate the parameters using existing parameter estimation techniques, right.

And if you find any of this if you need to change any of the parameters say if you need to increase the damping, so you again revisit the stability analysis here either without changing the configuration, can we do it by changing the CG right. So in a way you can shift the loads, rearrange the loads and achieve the different CG location and see the simulated response of it.

And then you can proceed with the structural design, see if there is any change in the stresses that are acting at the joints or the change in CG location is it changing the is it changing the load distribution significantly right. So look at that and then proceed with the flight test and then get the data. So the wind tunnel test is a costly affair again, and of course, the flight test right.

So at each and every level, you have an iterative approach here. So we may not be covering the entire part in this course, right. So the emphasis of this course is to concentrate is to get a inverse solution. So here any of this design algorithms, we will talk about airfoil selection in the first place, right. So I would like to approach this in an inverse way, where I will take the mission requirements, right.

So we will have the mission requirements, and then we will use those mission requirements along with performance and stability analysis, right? We will get airfoil selection, geometry and other all the geometric parameters say root chord, tip chord in the reference area. So all this thing as an output, including what should be the CL alpha of the entire aircraft. What should be the CL naught of the UAV right.

And also what should be the two dimensional CL naught and CL alpha, right. We will get that as an output and we will be concentrating only on lower subsonic speeds. So that particular algorithm will corresponds to lowest subsonic speeds. So what we will be dealing with is yeah coming back to this. In order to get that as an output we need to give certain input, right in terms of non-dimensional geometric parameters, okay.

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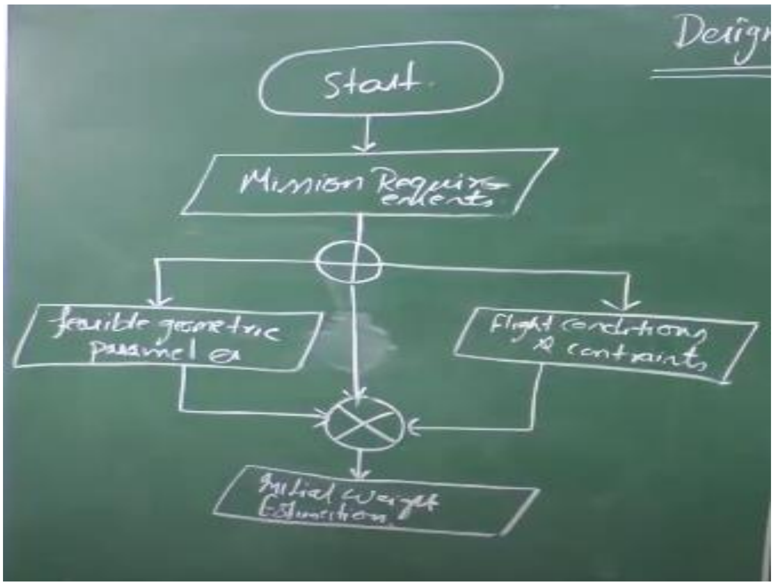

So what we have is a weight estimation and then yeah up to this it is similar. So weight estimation. In fact everything so we will have the same thing. Flight conditions and constraints.

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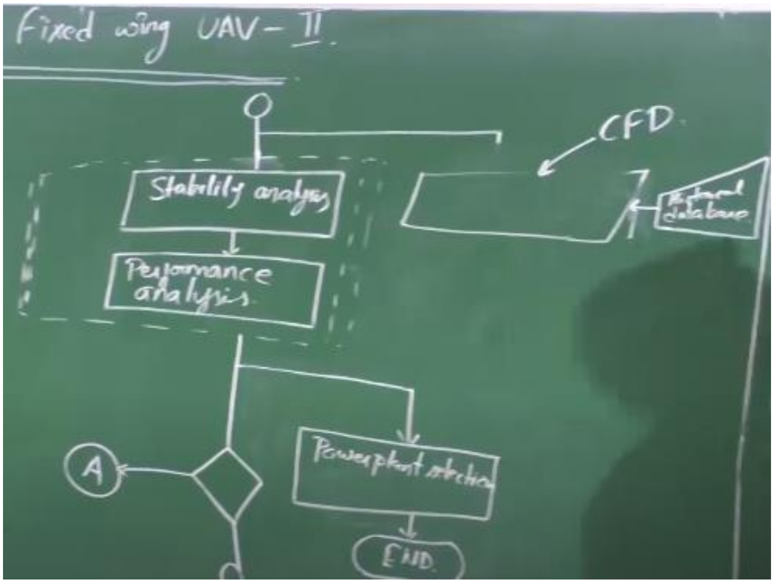

And so here in our previous discussion like you know previous algorithm, so this empirical relation can be replaced by CFD simulations.

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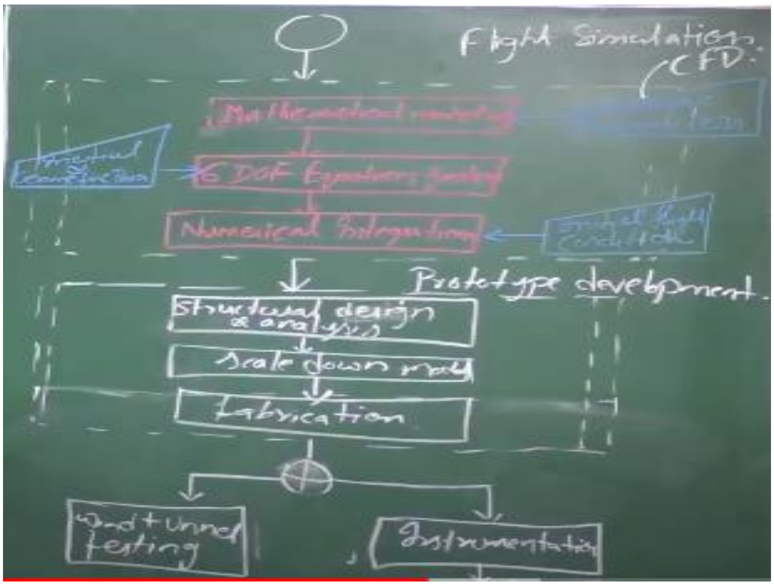

Similarly, the aerodynamic parameters here. Instead of using them we can use this CFD simulations as an input, okay.

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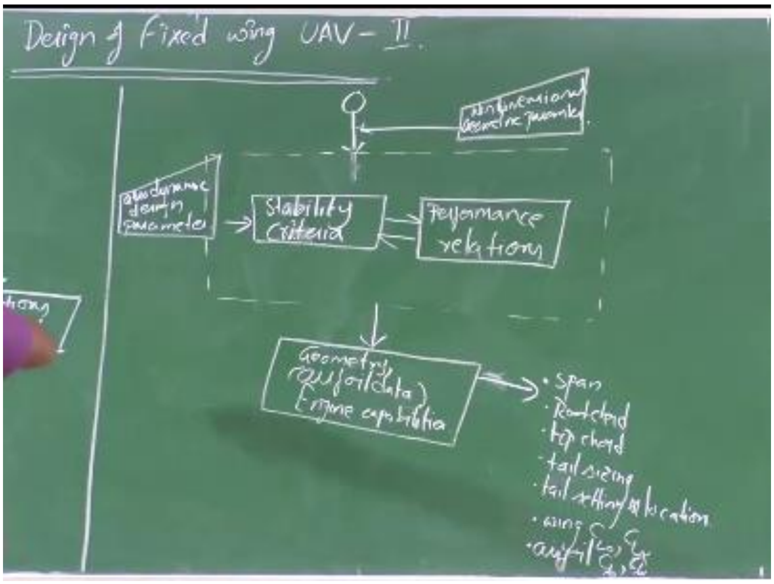

So what we have, what we will be doing is we will consider the issues of stability and also performance. So we will use this together, right? So for this stability criteria in order to figure out this we need, so we need some inputs in terms of aerodynamic design parameters. And we also require, so here we will also require some non-dimensional geometric parameters as an input.

So the output from this particular subroutine will be geometry airfoil data and also engine capabilities. See, again design is not we will not be able to achieve a straightforward, is a closed form solution for the design process, right. So but here with this particular algorithm we will try to achieve right with of course with all these inputs in terms of aerodynamic design parameters as well as non-dimensional geometric parameters.

We will try to achieve these as a closed form solution from this algorithm, okay. So basically what you are going to have is the details that you will get is about the span about the root chord and tip chord. So and tail sizing, tail setting and location. So wing characteristics in terms of CL naught, CL alpha, right. And airfoil characteristics in terms of two dimensional yeah properties CL naught and CL alpha.

So this will be the aim of the current lecture series, right. So we will develop various subroutines in order to achieve this particular parameters. So this particular analysis can be used as a initial or a preliminary during the preliminary design analysis. When you add optimization techniques to this that can be used for detailed design analysis, right.

So and again, I would like to clear certain misconceptions, general misconceptions about this course. So this course is not aimed at aeromodelling, right. We are not going to do any aeromodelling stuff in this particular course. And moreover, we are not going to talk about the structural and I am not an expert in that definitely.

Yeah we are not going to talk about this structural design and analysis as well as aerodynamic design and optimization, right. And neither we are employing any of these optimization techniques here in order to come up with an optimal design. So this can be used, as I mentioned this particular algorithm that we are going to develop can be used for preliminary design analysis, right.

So and once you have hands on experience with this then of course, optimization techniques and all this are mathematical tricks, which you can learn very easily, right and apply those mathematical tricks or optimization techniques for this particular yeah algorithm, so that you will get optimized values of this parameters. So we have two TAs in our course this time.

So fortunately Prabhajit is on campus. So meet Mr. Prabhajit. Yeah you can take off your mask. So you can introduce yourself. Yeah, hello all myself Prabhajit Singh. So I am one of the TAs of this course, training assistant and the other one is Kasi. Yeah, that is our second TA is Kasi Salauddin who was TA for the first part of this course. And both the times when it was offered.

So he was the TA, main TA for that course. So both of them will be helping us. And yes, we are talking about an iterative approach here. So we need to use some of the, anyone of the programming language. And I would prefer MATLAB as yeah, I would prefer MATLAB here to program them. And I wish you should start learning MATLAB.

So for those who are not comfortable with that Prabhajit and Kasi will help you with some of the tutorials, right in MATLAB, okay. Sounds good. Yeah. So in the coming lectures, we will try to revisit some of the important concepts that we have already covered during our previous lecture series and will be useful for the current design process that we are going to take up. Right. Okay then. See you soon.