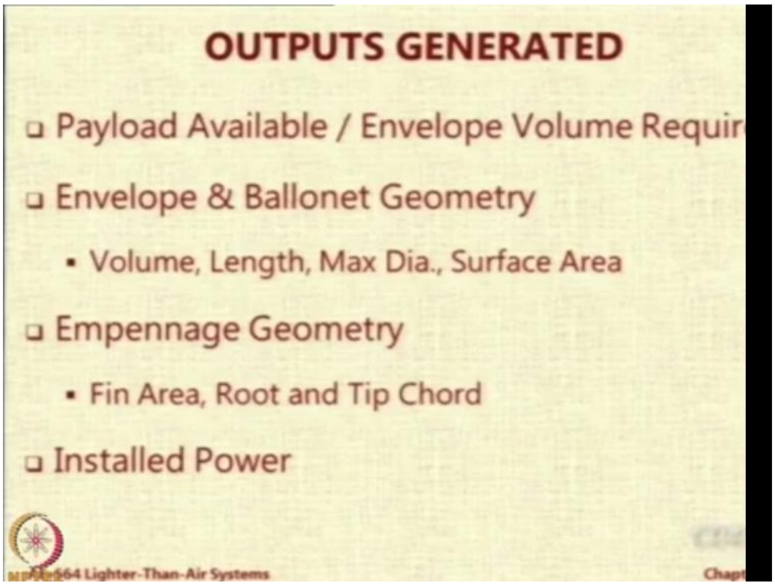
Lighter-Than-Air Systems
Prof. Rajkumar S. Pant
Department of Aerospace Engineering
Indian Institute of Technology - Bombay

Lecture - 77
Outputs from Airship Design Methodology

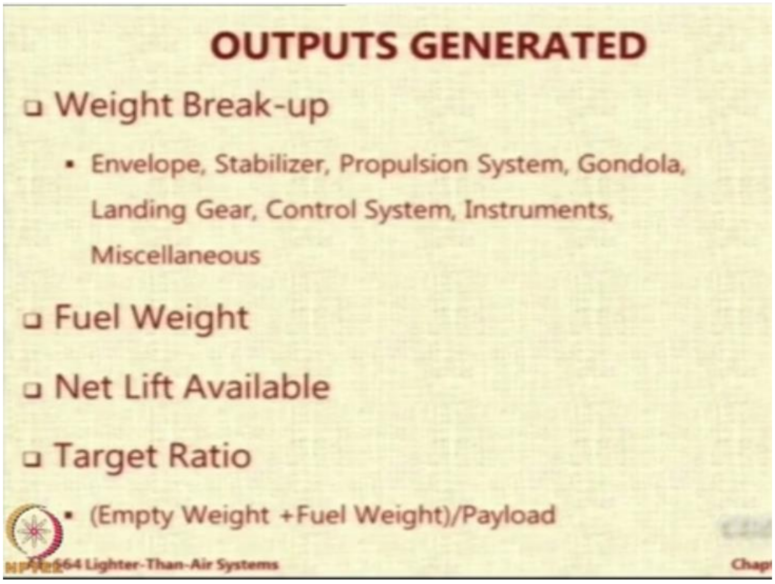
(Refer Slide Time: 00:15)



Let us start now looking at what are the kind of outputs this methodology can give you. First of all if you give it the envelope volume it gives you the payload. If you give it the payload it gives you the envelope volume. Then it also gives you the geometrical information for both the envelope and the ballonet. So, the typical parameters which you need are volume, length, max dia, surface area of the envelope and ballonet.

Then it gives you the empennage geometry or the tail geometry. What is the area of the fins? What are the root and tip chords for a given shape? Shape of the fins is fixed. It also gives you an idea about how much power needs to be installed assuming some uptake for other accessories, remaining is used for providing the maximum speed performance at a given operating condition how much power will you need and it generates lots of data as output.

(Refer Slide Time: 01:23)

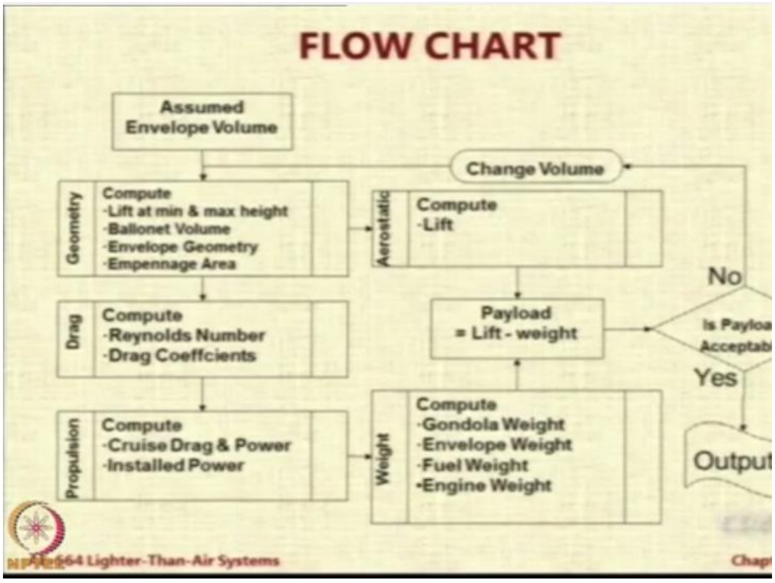


It gives you a weight breakdown which is what is very useful for the designer. What is the weight of all these items and sub assemblies. It gives you the amount of fuel that you need to carry. It gives you the net lift available and hence you can use it to decide whether your static heaviness or lightness is sufficient or not. And there is a parameter called a target ratio which we at that point of time thought to be something like the objective function.

So, empty weight plus fuel weight we would like to minimize and payload weight we would like to maximize. If the payload weight is fixed such as in design loop of the methodology, then for a given payload it will be nice to have lesser empty weight and lesser fuel weight to meet the mission requirements. Less fuel weight will come from better drag characteristics and lesser empty weight will come from the size of the envelope.

So, this target ratio we would always like to make it low and low and low. So, if somebody wants to catch the problem in optimization framework for a minimization of objective function, one could use target ratio as the objective function that was the original purpose of giving up this particular parameter.

(Refer Slide Time: 02:53)



I would like you to look at this flow chart as I explained to you the various elements little bit briefly. So, as you can understand this particular flow chart showcases the methodology in the analysis framework where the envelope volume is to be assumed. In fact in the design methdology because the payload weight is fixed. So, what you do is you assume some envelope volume. How do you assume envelope volume?

What is the starting point? What would you do? Does not matter, you can take anything you feel like. You can take 1 meter cube. In the iteration loop you will have to increase or decrease if it does not meet the requirement. So, any non zero entry is acceptable as an assumption for the volume. So volume is assumed, let us say 100 meter cube just to start with. First thing you do is you compute that geometrical data.

So, first thing that you do is you have to understand what would be the lift available with a given volume of a given shape. Now shape is not being touched here. So, we assume that you do this analysis for a given shape which is already decided. So let us say the shape is spherical for very simple analysis. So lift at minimum and maximum operating altitude or height this you can calculate using the standard buoyancy formulation.

If you really want to be very particular you can use the effect of humidity, effect of superpressure, effect of superheat, effect of purity, etc. All that is incorporated in my methodology. But in a simplistic analysis just like you did for your hot air balloon, you can probably ignore those effects and consider ISA conditions. No superheat, no superpressure, full purity and you can get very simple explanations.

Then with that you will be able to calculate the ballonet volume because the inflation fraction needed for maintaining a particular pressure altitude from operating altitude can be easily obtained using the formulae that we have discussed. It is actually nothing but density ratio. Envelope geometry; once the volume is known, once the shape is known one can workout the length, diameter, etc.

And we have a simple correlation between the envelope area and the area of the tail surfaces required. This is one small contribution that we have done, I will explain to you later on. So, with this you get the geometrical information about the airship. Now, you have to calculate now how much power is needed. So, for that you need to first calculate the drag coefficient. Now in the initial stages of design which is where we are.

You might be comfortable in using simple empirical formula for drag estimation as a function of the shape and the dimension rather than very complicated CFD analysis. So, somebody might say does not matter, I can couple some kind of a CFD solver here for a given shape. With the operating conditions and the geometry properly known I can run a CFD analysis and get you the correct drag value.

We chose to use a simplistic empirical formula for estimation of drag that formula gives you drag coefficient in terms of two parameters the Reynold's number and the length over diameter ratio. But literature also tells us that this formula can have errors of as high as 25 to 30%. This is very typical in conceptual design. But if you want to compare three shapes, you can assume that the error will be almost the same in all of them.

So therefore the effect of L/D and Reynold's number can be captured through the formula. Let us say we have that drag coefficient either by a slightly more accurate method. So I am looking for someone to help me in creating a better design methodology perhaps as part of a dual degree project or as part of an M. Tech project. So, this methodology is open to enhancement and improvement.

As always in research, we have published a paper based on this methodology, I will show that to you. You can help me enhance it and get a much better publication. Let us say we have drag coefficient. After that, you calculate the power required that would be simply drag into velocity cube and with that you will get how much power needs to be generated. Let us say 100 horsepower.

Then you add to that percentage needed by the onboard systems and you will get an idea about what is the engine that you have to incorporate in this particular airship. So most engines for airships are going to be either piston prop or turboprop depending on the power required. If the power required is more than around 500-600 horsepower, we normally recommend that we should go for turboprops because turboprops below 500 horsepower tend to be very heavy.

But then it is a choice. It is a choice based on your experience, availability and you use your propulsion design knowledge, propulsion engineering knowledge to decide the engine. Whatever you choose, you can get the installed power. Looking at the data available for typical value of engine weight as a function of installed power, you can estimate the engine weight because there will be a matching propeller with every engine suitable and suitably coupled to it it will have a weight.

Engine will have some weight and therefore you can say okay, I need so much horsepower or so many kilowatts of power, so the engine will be roughly so many kilograms. Now, since the geometry is known and since we have all aerostatic formulae we can calculate the bouyant lift available or the gross lift. Since the geometry is known, envelope material has to be assumed, some additional faction to be assumed for other systems you can calculate.

And the gondola is going to be very heavy. So as I mentioned last time, the gondola can be considered to be a typical unpressurized fuselage. So using data available in literature for unpressurized aircraft fuselages, you can estimate the weight of the gondola. So fin weight is known because fin size is known and some estimate for fin weight per area can be obtained. Gondola it is known.

Envelope it is known because area is known with some factors for patches, hooks, other things which go on the envelope, joining allowance, etc. So, what is remaining now? The only thing remaining is the payload. Engine weight also is known from the power requirements. So, with all these calculations you can get the empty weight or the self weight, subtract that from the buoyant lift you get payload.

So, you have some net lift, keep some margin for static lightness or heaviness you have the payload. Now, is this payload matching with what you are supposed to carry? If it is more that means this is the old design go back and reduce the volume. Even if it is less increase the volume and repeat the calculation, very simple methodology. Interesting thing is that each of these boxes can be as detailed as you want them to be or as you can afford them to be.

For example someone gets a no, I will do a sizing of an engine to meet this requirement inside the propulsion box. Somebody might say I will calculate the aerostatic lift with all factors that we are considered, you are free to do that. The more accuracy you bring in better will be your estimate, but it is generally recommended that in the conceptual design stage let us not be so particular and so much in detail.

Because you have to do it many times unless you are able to automate it in a reasonable amount of time. Any questions? I think it is very straightforward. Suppose you want to convert this into the other type that means volume is known find the payload that can can be carried, you can simply tweak the methodology. Assume some payload and then check if the volume available matches.

If not, reuse the payload and increase the payload. So, this is an open problem in which academical, mathematical rigor in each of the boxes that you see could be incorporated to make it more and more accurate, more and more relevant, more and more appropriate so that it is more and more believable. So what I will showcase to you is the kinds of numbers that we established as part of our study.

Remember this is not a student project. This was an actual design project carried out for an industry. I should not say as a consultant but as sponsored R&D work. So I just want you to get a flavor of what kind of mathematical rigor is acceptable and what kind of statistical, empirical, semiempirical data is used by designers.