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

Lecture – 99
Methodology for Tether Profile Estimation

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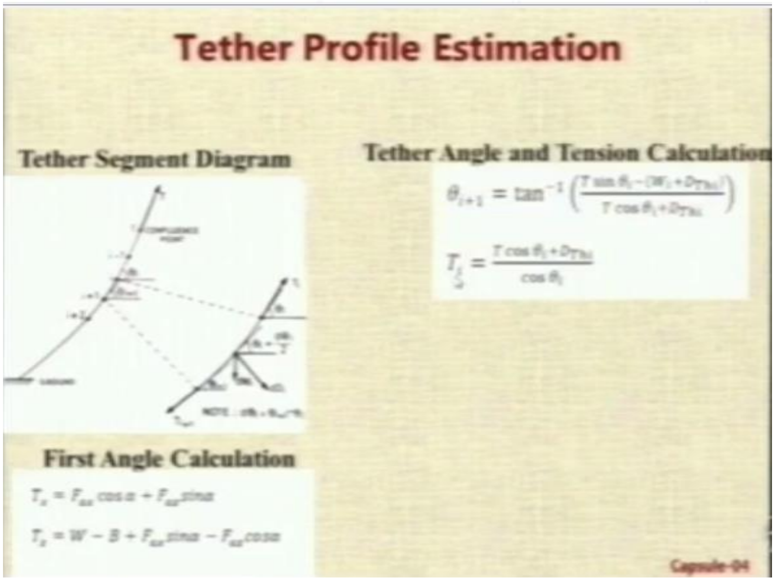

Alright, the next thing is the tether profile estimation. Very briefly we will discuss it although it is there in the paper in more detail. So, what we do is starting from the confluence point till the ground, you assume the tether to be broken into small small components. Let us say 1000 segments okay. So, now let us take at any segment. So this is i – 1, this is i, this is i + 1. So, let us look at this i and i +1. This is one segment of the tether.

What are the forces acting on the tether? One is the self-weight. The other is the aerodynamic load acting on it because it is a cylinder at an angle to flow. So, again there are the 2 components, one will be along the length, one normal to the length. So, for that for cylindrical body at some Reynolds number C_D is available by empirical data or from wind tunnel testing.

So, W_i is the elemental weight acting and there will be drag force acting here and the tension will be more here and less here tension. The tension will keep on elemental, tension will efficiently be conveyed. So, the rope will have the same tension. But what will happen is because of the weight, weight overcomes the tension. Component of the weight is going to overcome the tension.

So, what will happen is after some time the net tension acting on the tether will be 0 that is the place where you can assume that tether will not have any curvature after that. So, this is how to calculate. You take the tension which will be the force acting into $\cos\alpha$ plus $\sin\alpha$ aerodynamic forces acting on the tether and z force will be the weight of the tether minus buouncy minus the two forces acting and you do this incrementally.

Calculate the angle of each element and at the end you will find this tension will become 0 that is the maximum. After that tether will be, so if I leave the aerostat it will occupy some curvature and then it will remain flat on the ground. So, that is what is done and this is one of the results obtained, right.

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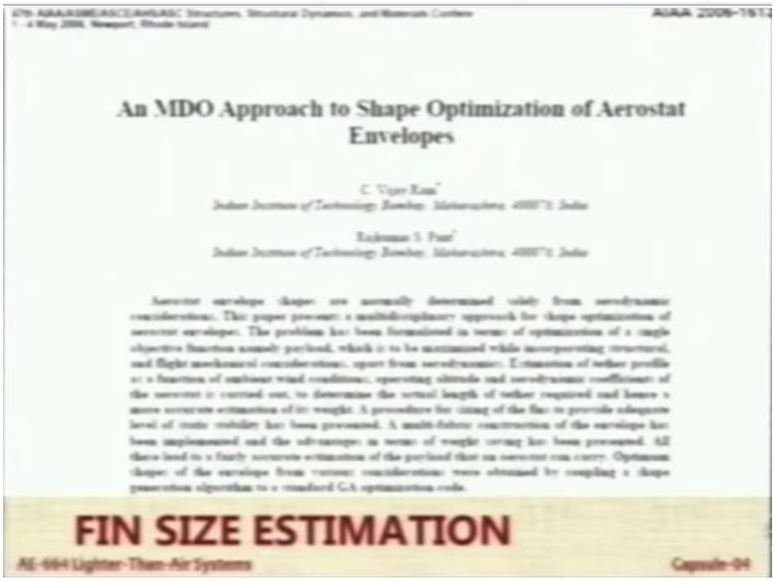

So, now just to show you an example of fin size determination. Again we have an M. Tech student called Vijayaram. He came for the fare recently in the panel discussion also. So, Vijayram based on his M. Tech. He has published a couple of papers. One of them is on aerostat design and in this particular paper, Vijayram has given the some method to calculate the fin area. So, I encourage you to read his report and you can see this is the comparison.

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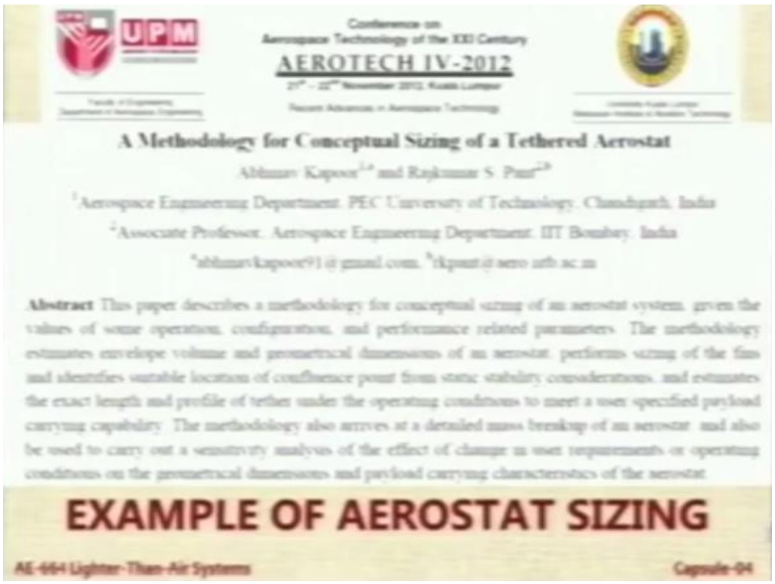

And then recently one intern who came for 6 months. He looked at all these formulas, put them together into one nice spreadsheet and developed a methodology for conceptual sizing of aerostat and he presented or rather I should say I presented his paper in a conference in Kuala Lumpur. So, this particular paper is the one which is being quoted now by people. So, there you will find the same figure which I showed you.

You will find the calculations for the moment and equilibrium, the profile of thether. You will find fin sizing and you will find some results which I will show you very briefly now. So, finally, I will just show you an example.

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Parameter	Value	Units
Payload	420	kg
Operating Altitude	800	m
Deployment Altitude	200	m
Wind Speed	25	m/s
Off Standard Temperature	30	deg
Diurnal Temperature range	25	deg
Duration of deployment	14	days

So, this is one actual scenario for which we did some aerostat design. I cannot name the customer. Those are not important for you. What is important for you is requirements which were actually given. So, payload of 300 kg + 120 kg extra, 800 meter altitude from the ground of 200, wind speed 25, temperatures, temperature range and 14 days deployment.

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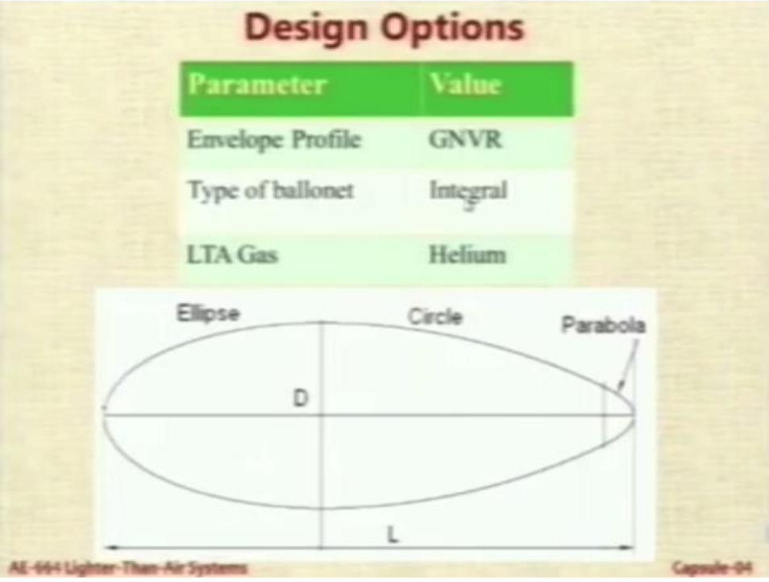

We chose this particular shape for the aerostat. We chose helium gas and we chose an integral ballonet.

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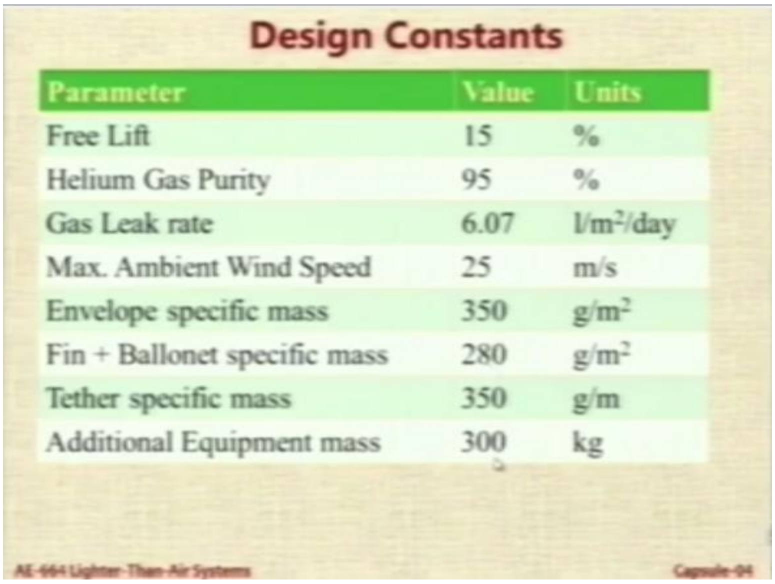
Design Constants

Parameter	Value	Units
Free Lift	15	%
Helium Gas Purity	95	%
Gas Leak rate	6.07	$l/m^2/day$
Max. Ambient Wind Speed	25	m/s
Envelope specific mass	350	g/m^2
Fin + Ballonet specific mass	280	g/m^2
Tether specific mass	350	g/m
Additional Equipment mass	300	kg

AE-664 Lighter-Than-Air Systems Capsule-04

We gave these constant parameters free lift how much, gas purity, gas leak rate, maximum speed, envelope mass, fin mass, tether mass, additional mass.

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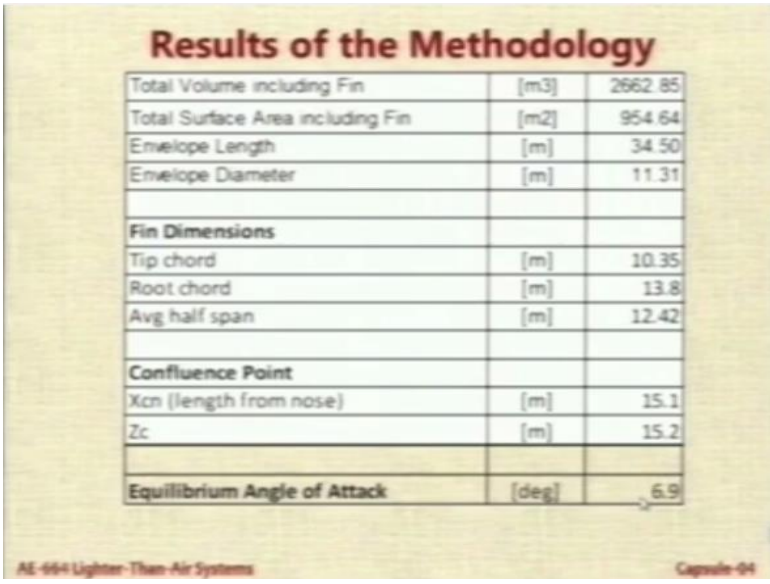

Results of the Methodology

Total Volume including Fin	[m3]	2662.85
Total Surface Area including Fin	[m2]	954.64
Envelope Length	[m]	34.50
Envelope Diameter	[m]	11.31
Fin Dimensions		
Tip chord	[m]	10.35
Root chord	[m]	13.8
Avg half span	[m]	12.42
Confluence Point		
Xcn (length from nose)	[m]	15.1
Zc	[m]	15.2
Equilibrium Angle of Attack	[deg]	6.9

AE-664 Lighter-Than-Air Systems Capsule-04

and we got output. The envelope was 2662 volume meter cube. And the angle at which trim around is 7 degrees. So, at around 7 degrees the aerostat is at automatically trimmed.

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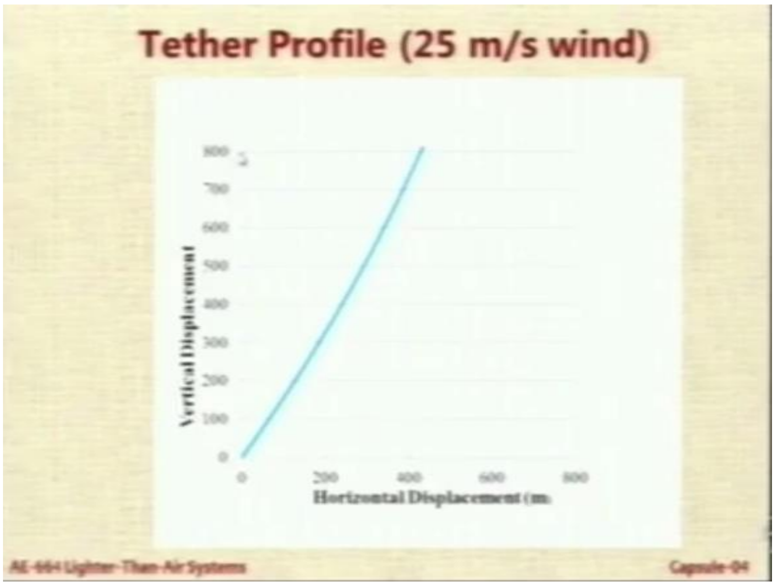

This is the tether profile. So, notice that the aerostat is to be deployed at the height of 800 meters from the ground, but because of this heavy wind of 25 meter per second it is having a blowby of so much. So, it is actually going much behind, but that you cannot avoid.

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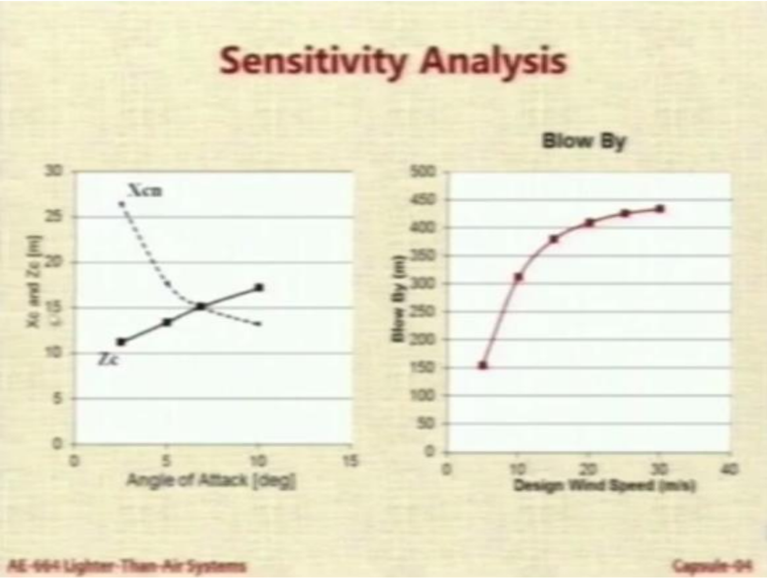

Then we did some analysis as to how the angle of attack. So, you notice that when the diameter of the, what is the diameter of the aerostat? Diameter was 11.31 meters. So, it so happens that at 15 degree 15 meters location X_c and Z_c the angle of attack is around 7 degrees, 6 point something degrees and that is the location. If the α changes, the optimum confleuence point changes, but at least they both meet here.

And this is how the blowby changes with the wind speed. So, you will notice that at 5 meter per second that blowby only 150 meters, but as the wind increased to 25 meters it becomes around 400 to 420 meters and as wind become more and more blowby is reducing, but there is a substantial blowby. For a height of 800 meters, I have 400 meters of blowby which is quite large.

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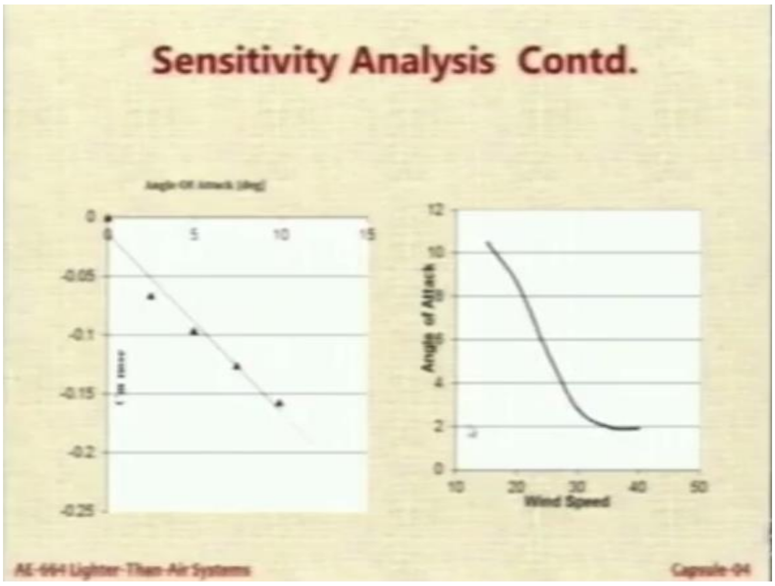

And then some study we did about, you can see the same methodology which I showed you, similar results. We are triming it at around 2 degree angle of attack. This is the wind speed versus angle of attack.

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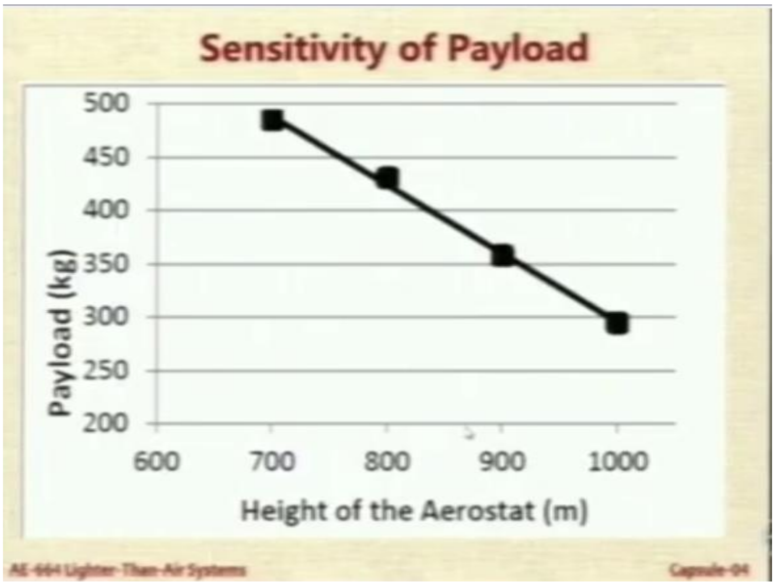

And this is how the payload changes. It changes linearly. In the question I asked you about payload drop and I asked you justify our methodology. Some of you said that as shown in the class, the payload reduces linearly that is what I want you to understand. The data in the question paper may be linear but that is not your reasoning. The reasoning is that payload drops linearly with altitude. It is something which is known to us. So, even here also at the height of 700 meters payload is around 480, 1000 meters it is at 300 kg payload.

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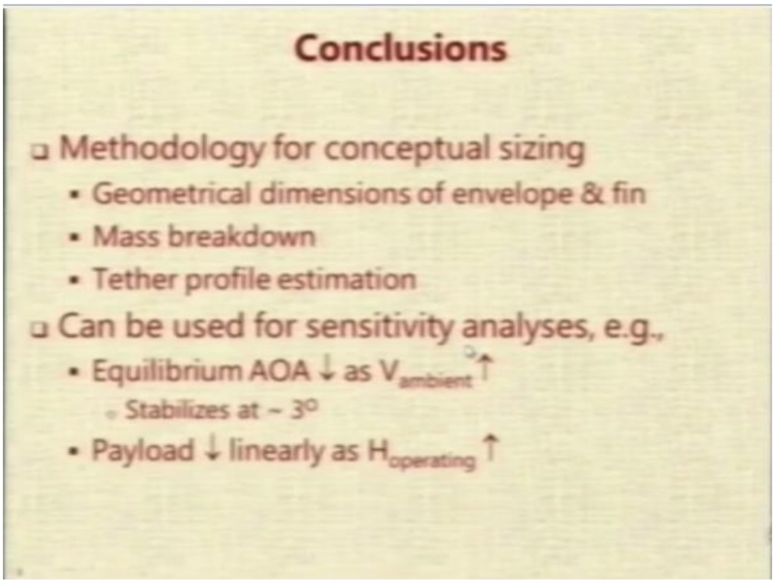

So, in conclusion we have methodology for sizing of the aerostat. It can be used for carrying out this analysis of sensitivity okay.