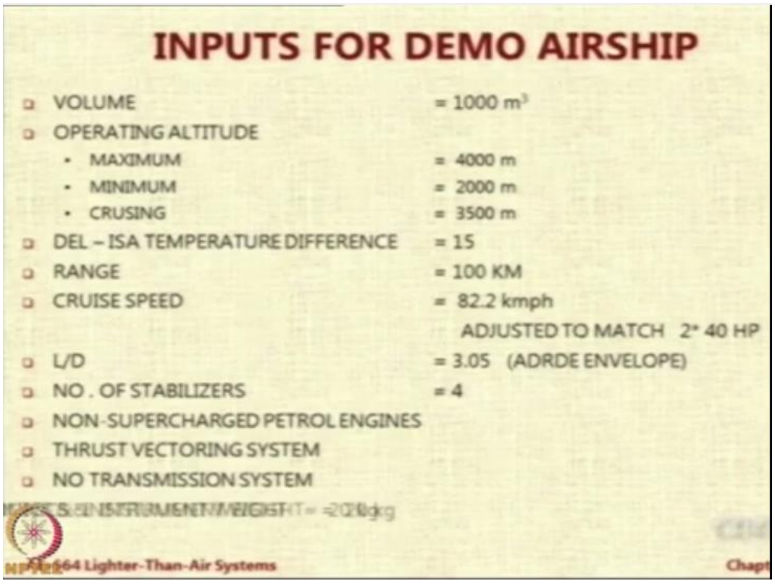
Lighter-Than-Air Systems
Prof. Rajkumar S. Pant
Department of Aerospace Engineering
Indian Institute of Technology - Bombay

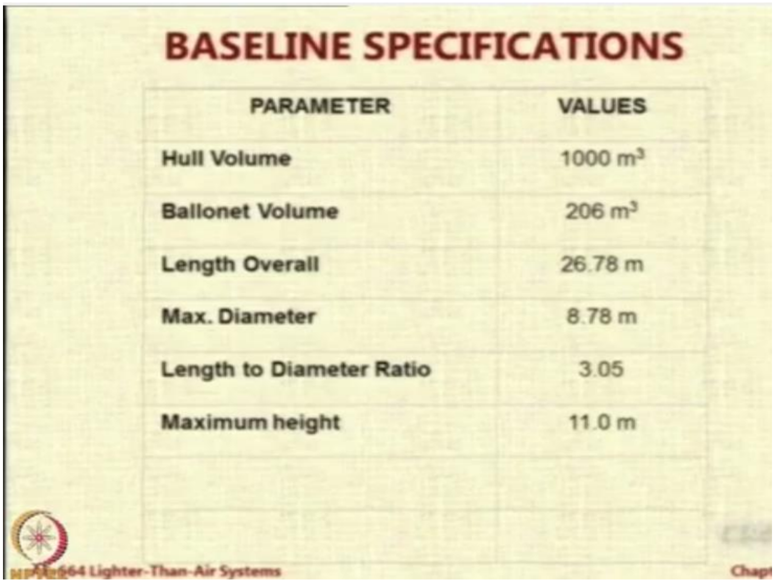
Lecture - 81
Example of Application of Airship Design Methodology

(Refer Slide Time: 00:21)



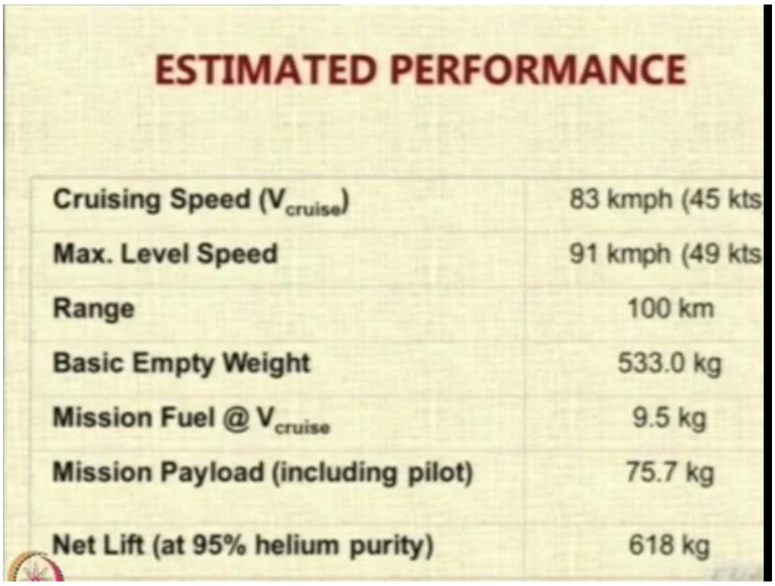
This will come later. Now I just want to very quickly go through some results. What you will see from now on are nothing for you to really learn or acquire, is just to show you how results are presented. So, this is the input data mostly. So, we chose 2 engines of 40 horsepower motor and we said with that you get a speed up at 82.2 kilometers per hour.

(Refer Slide Time: 00:48)



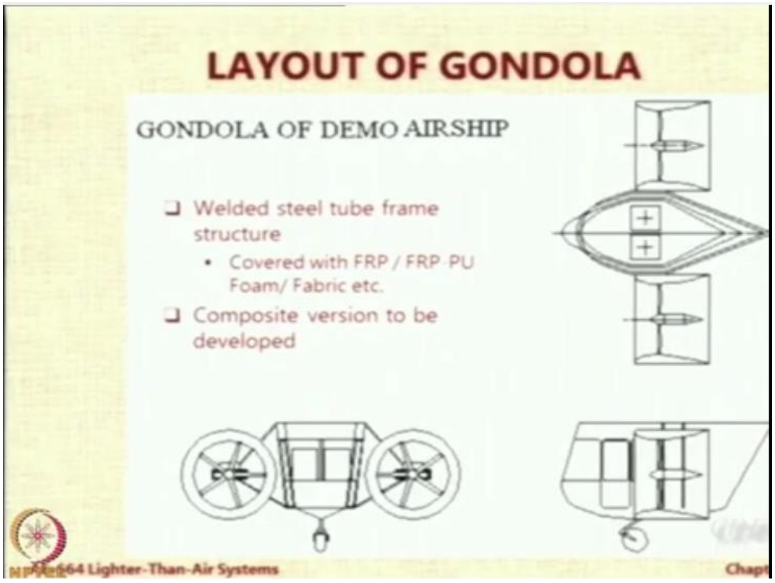
And here are some values. So, the ballonet is around 80%. The inflation fraction is around 80%, 206 meter cube is the ballonet volume upon 1000 meter cube. I have already told you about the height, etc.

(Refer Slide Time: 01:10)



Speed has been met, this also I have already given you.

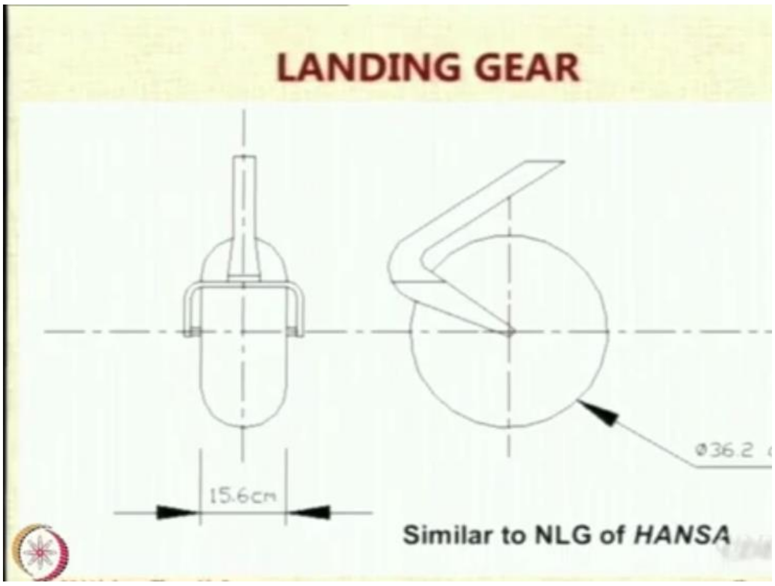
(Refer Slide Time: 01:17)



So, the gondola was, this is a demo airship. It has to be light, it has to be made quickly. So, either welded steel tube framework with FRP-PU Foam, etc., or a composite version. This was a simple gondola that we designed. So you can see there are two ducted motors, one on each side, and just a small gondola. We have given two seats. But actually it can take only one pilot.

The other seat is meant for mounting a camera or payload. If we can reduce the weight somehow by using composites maybe, then you can use the next seat to either carry a passenger or to carry some kind of a payload with the pilot can operate, maybe a camera.

(Refer Slide Time: 02:04)

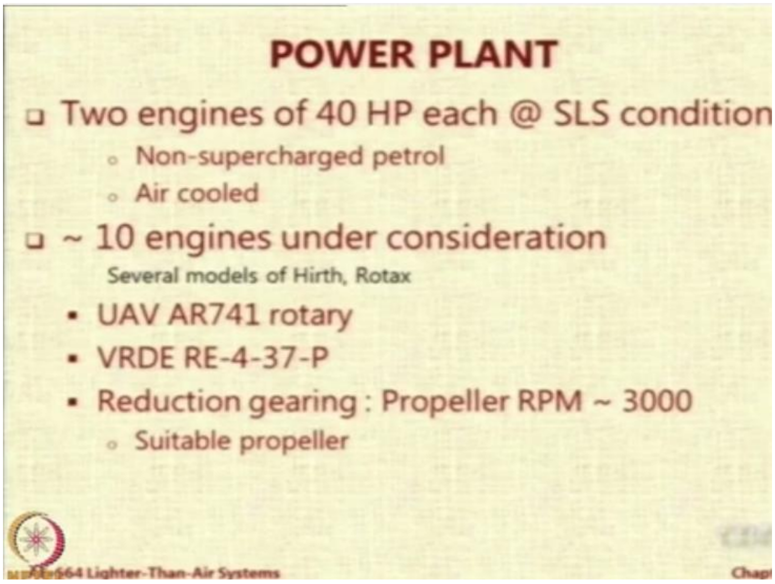


Landing gear. So what we did is we looked at an aircraft called as HANSA available with NAL. Study the landing gear and however yes we can make a landing gear similar to that.

(Refer Slide Time: 02:12)

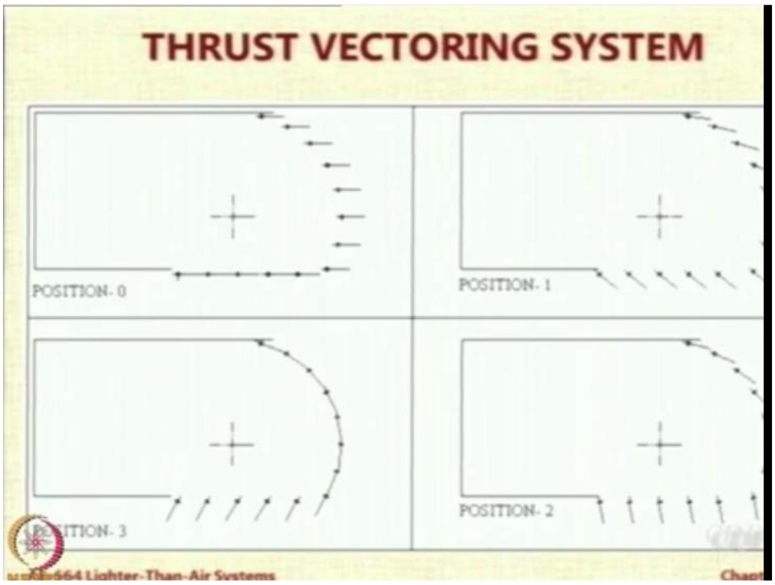
These are the answers of the sizing of the stabilizer, just numbers. I leave the numbers with you.

(Refer Slide Time: 02:22)



Then as I said we went around and searched for engines which are available and cheap. We found that there are around 10 engines and these were the one which are shortlisted. One of them is available within India by vehicles R and D establishment in Ahmednagar, 37 horsepower I think.

(Refer Slide Time: 02:45)



Then we thought let us go for some thrust vectoring system. So our concept was to have a load type system so that you can deflect a series of flat plates, which can deflect the slip stream rather than tilting the engine or tilting the nozzle. We said we will just tilt the slipstream by flat surface. We could never get a chance to build this, but this was one project and this is still available as a project for someone who is interested in developing a thrust vectoring system.

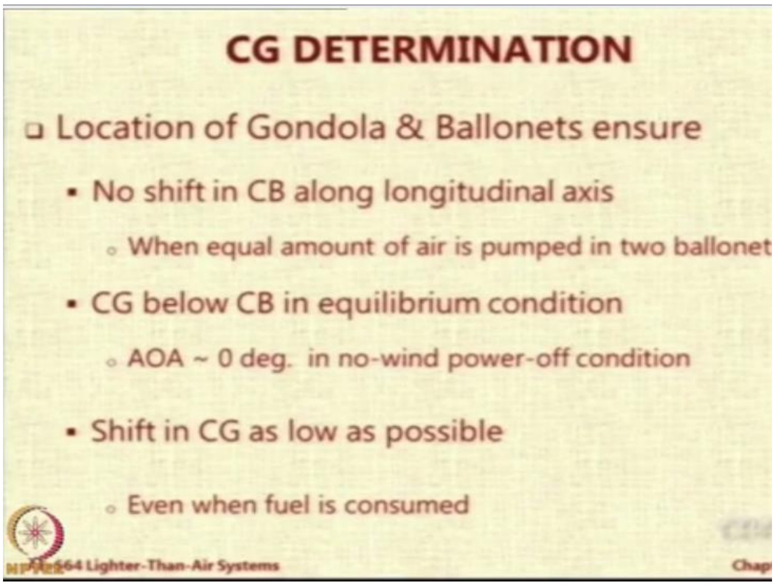
Students have come and worked on thrust vectoring system with me. In fact, there is a team of 3 girls from a college who have made this kind of a duct recently. But still, it is an open problem for a bigger airship. They did it for a remotely controlled airship. Then if you want to make it 4 seater little bit more work. I will just go through how you determine the center of gravity location on an airship.

So our main aim is that we should locate two things, the ballonet and the gondola. They are under our control. Everything else gets fixed by its function and position. You can move the gondola slightly forward backward and you can probably move the ballonet inside. So, what is the aim? The aim is that when equal amount of air is pumped into two ballonet, I should not get a CG shift.

You have seen in the calculations in our class during tutorials that the weight of the air of the ballonet is quite large. I think a 53 kg or so in one problem for a big airship that can change CG drastically. It is like putting 53 kg weight at one particular place. So it is important that as you suck in air you do not go nose down or nose up, you should remain in the same trim.

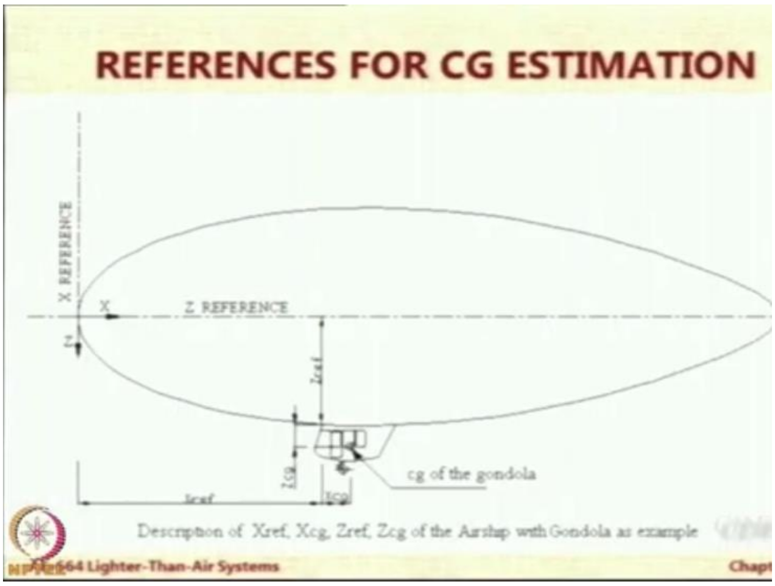
So, we also wanted to have centre of gravity below centre of buoyancy in the equilibrium condition so that if there is no angle of attack and there is no wind, we should not have any moment, the airship should trim.

(Refer Slide Time: 05:04)



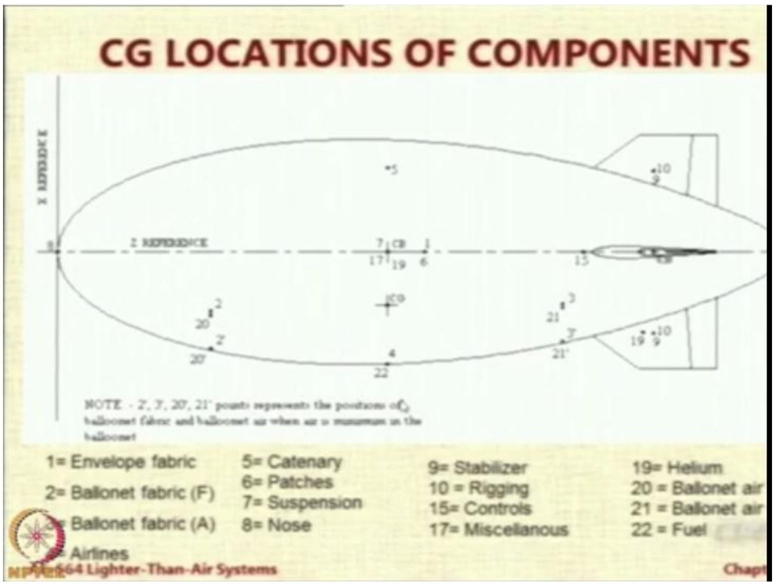
And location of the fuel tank should be such that when even when fuel is consumed, the CG will shift. It will go up because fuel is on the bottom and the fuel is being consumed that should not be too much. All of these are going to affect the trim condition of the airship.

(Refer Slide Time: 05:19)



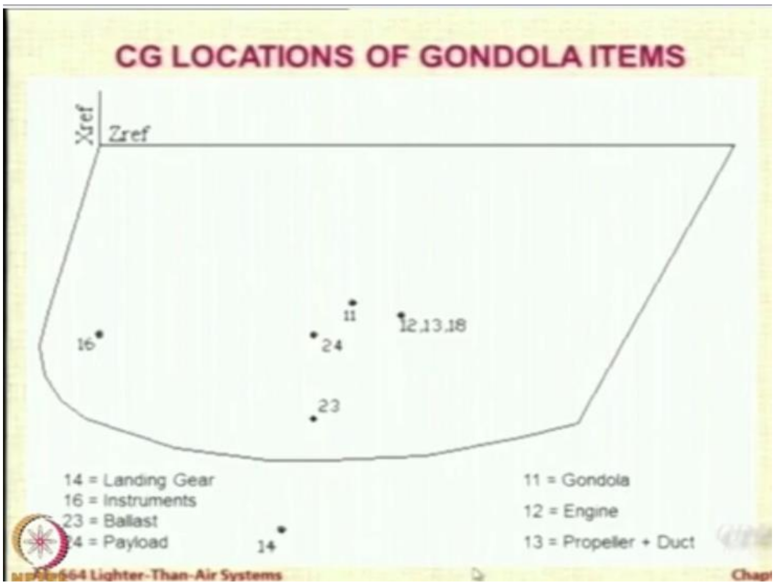
So, there are some references used. For example, there is x, y, z reference at the nose. Then there is a reference for the center of gravity of the gondola, CG, etc.

(Refer Slide Time: 05:29)



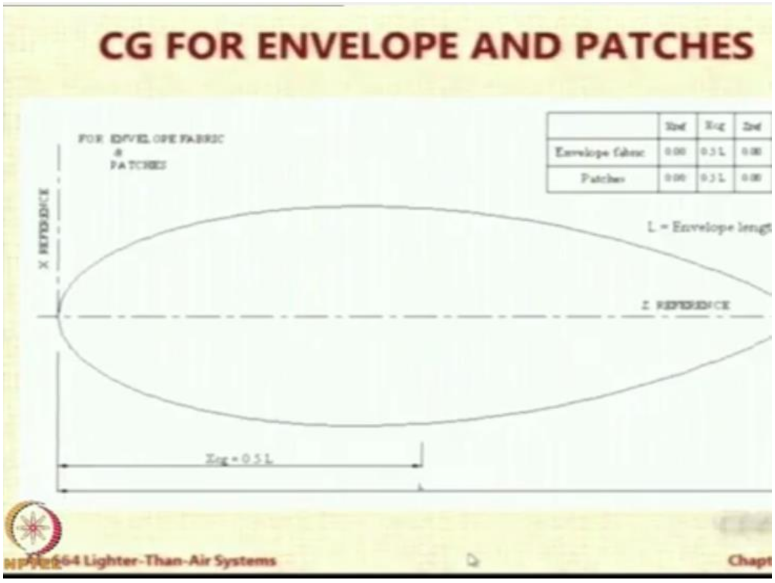
And then for each component with little bit detailed calculations, we made a 3D model and got the lightly CG location. For example, if you see number 5, number 5 is a catenary which are basically ropes that go inside the ship to hold the gondola or transfer the load on the top. Then number 10 is rigging. Number 9 is the stabilizer, 15 is the controls, 4 is the air lines or the cables. So every item we have accurately tried to locate where they will be an add the weight of that.

(Refer Slide Time: 06:04)



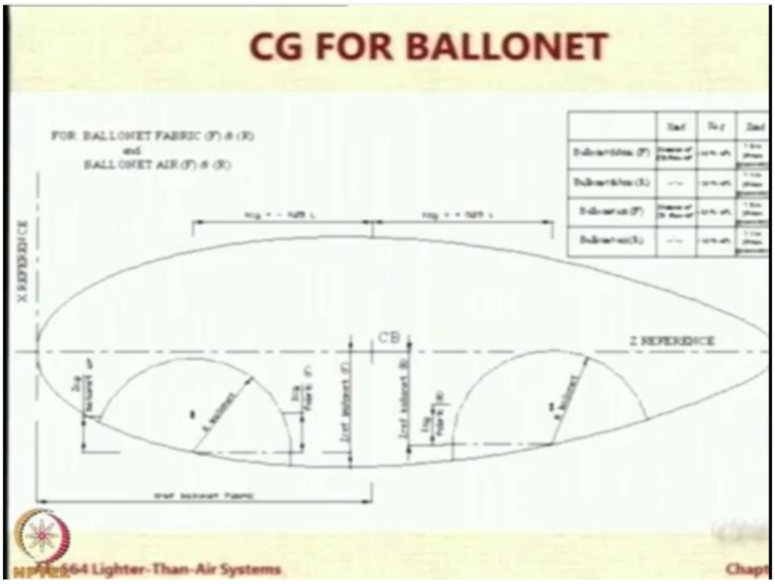
Gondola has got so many items. Instruments, landing gear, ballast, payload; all of them where they will be and then find the center of gravity.

(Refer Slide Time: 06:12)



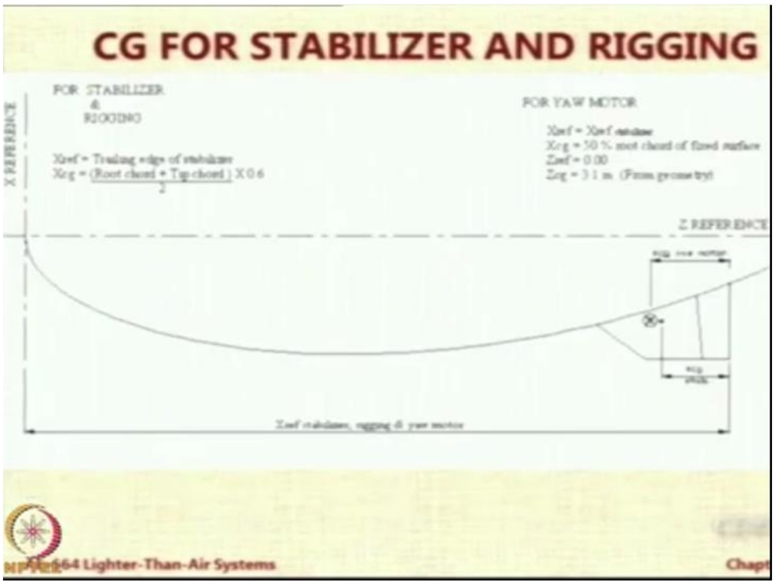
Envelope and patches.

(Refer Slide Time: 06:16)



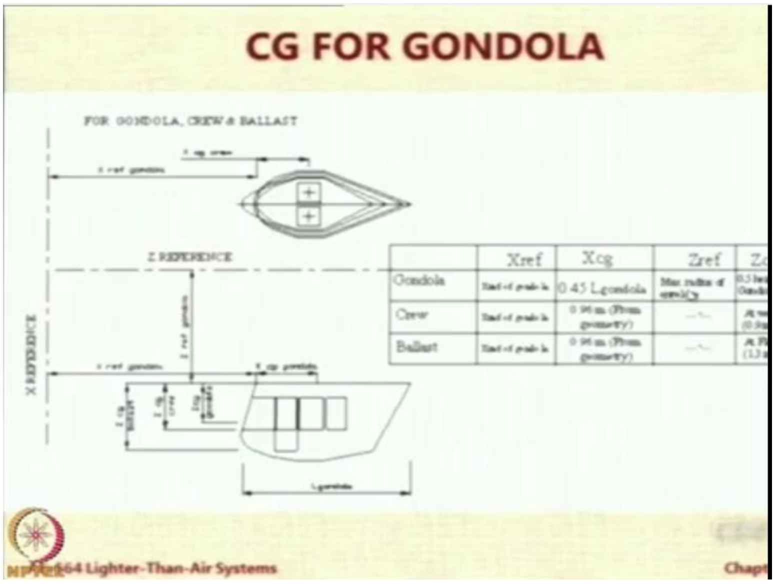
Then the two ballonet, their geometrical sizing. They would not be exactly hemispherical because they will be having a contour of the envelope. So we have to match with that and do exact calculations.

(Refer Slide Time: 06:28)



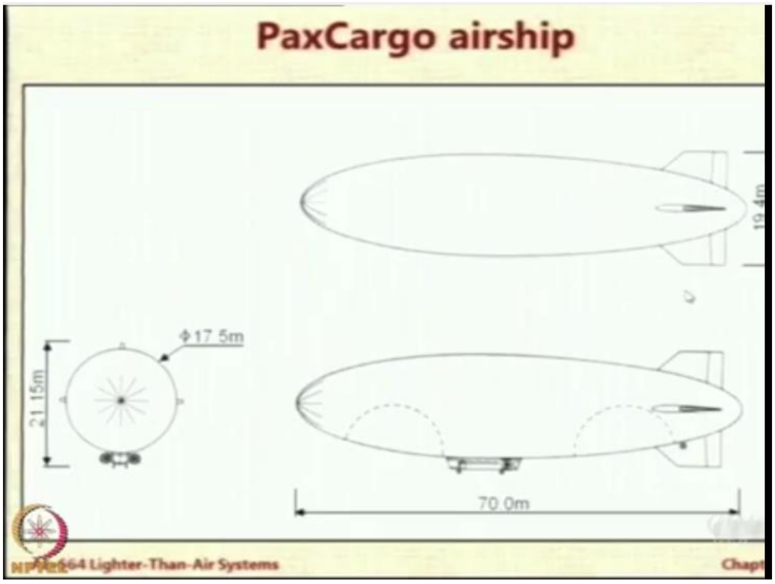
Similarly for stabilizer and rigging.

(Refer Slide TImeL 06:31)



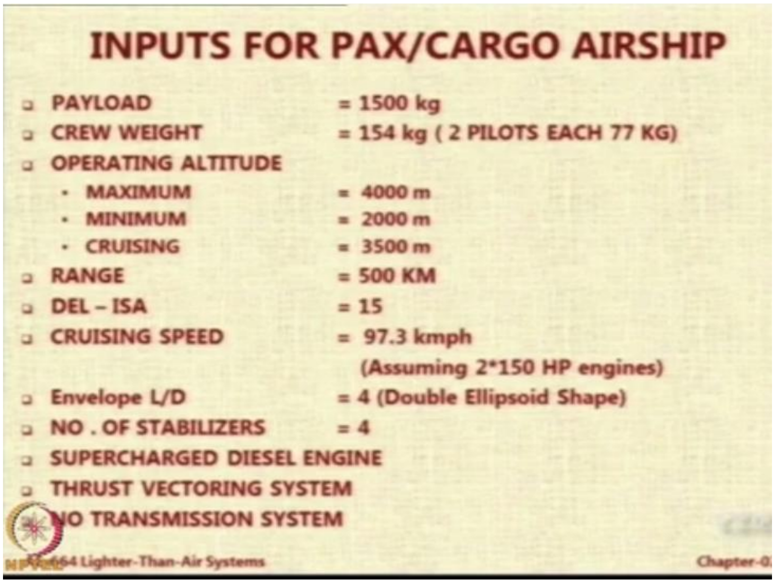
Gondola.

(Refer Slide Time: 06:33)



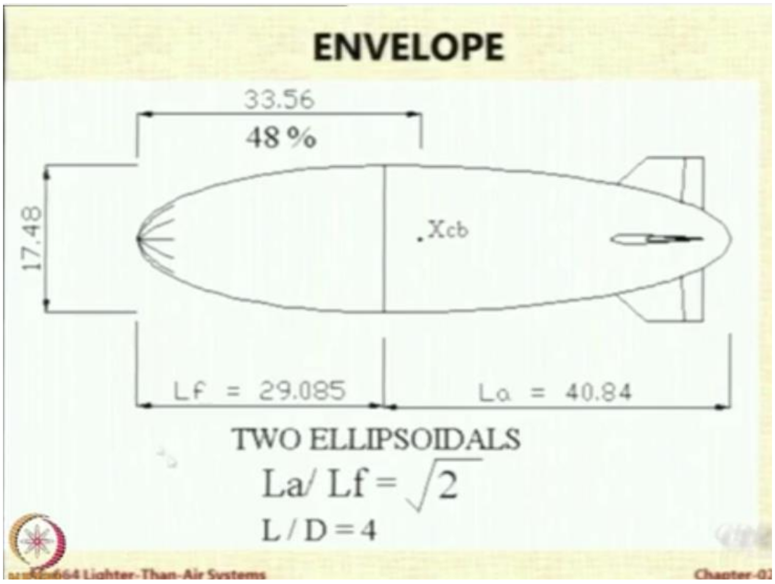
Let us go to the next one PaxCargo airship. This becomes 70 metres in length, quite large and the envelope dia is 17.5 meters. So it is a big structure.

(Refer Slide Time: 06:51)



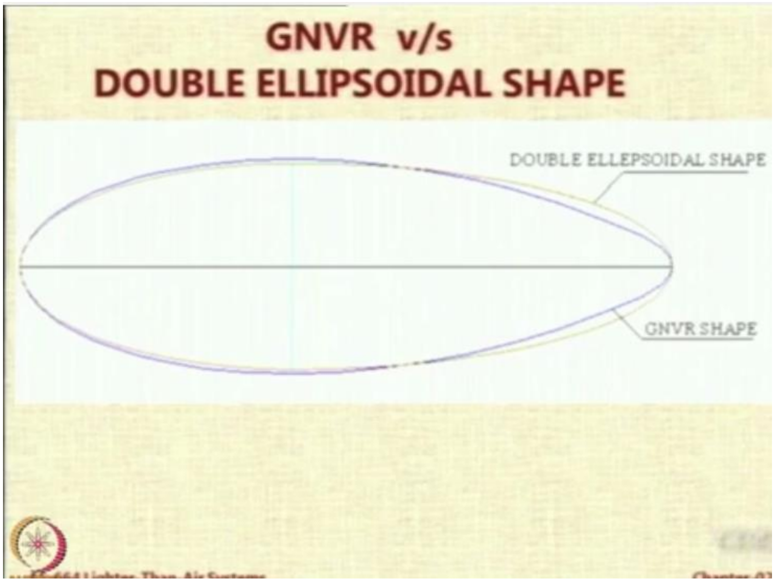
So what are the inputs for it. The inputs were same as that for the demo airship but for the payload and the envelope shape. So for this, we did not want to go for l/d of 3 GNVR shape. We went for what is called as a double ellipsoid shape, 2 ellipsoids.

(Refer Slide Time: 07:14)



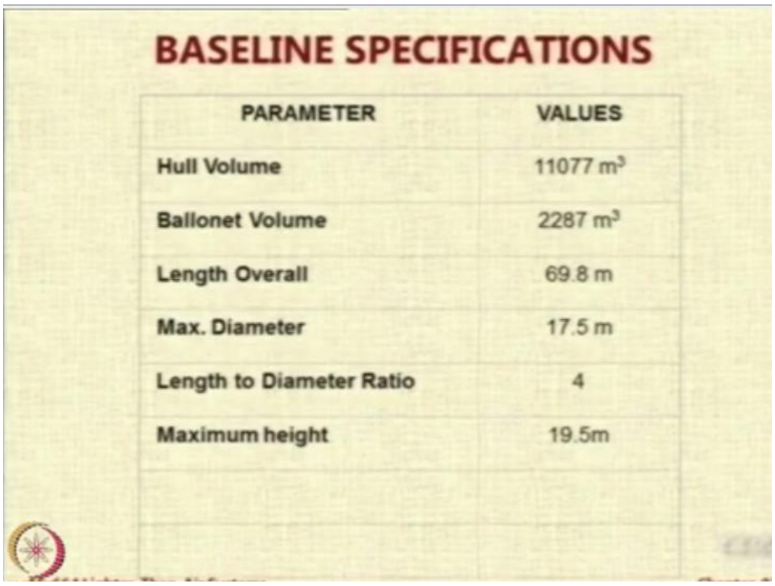
One behind the other. And the ratio of the major axis is root 2. So this distance from the center this distance is going to be root 2 times this distance 1.7 times this distance. This is one shape which has been recommended in literature. This is called as a NPL shape. NPL stands for National Physical laboratory. It is a laboratory in UK which came up with this shape and they said this is a good shape for airships because l/d equals to 4 and it is slender. So for airships it is a very good shape. So we took it as the candidate.

(Refer Slide Time: 07:57)



It is not too much different from GNVR. But this is a very funny thing because GNVR shape has l/d of 3. So, I have to check this and get back to you.

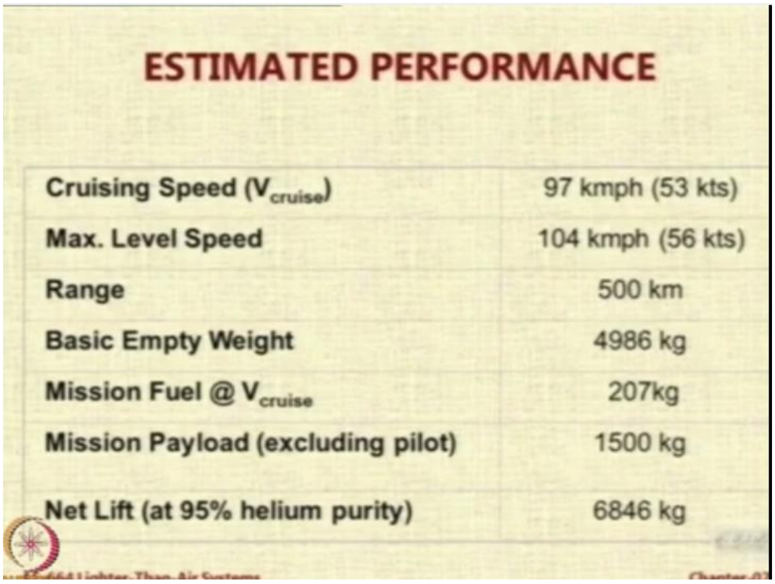
(Refer Slide Time: 08:15)


BASELINE SPECIFICATIONS

PARAMETER	VALUES
Hull Volume	11077 m^3
Ballonet Volume	2287 m^3
Length Overall	69.8 m
Max. Diameter	17.5 m
Length to Diameter Ratio	4
Maximum height	19.5m

This number I have already given you.

(Refer Slide Time: 08:19)

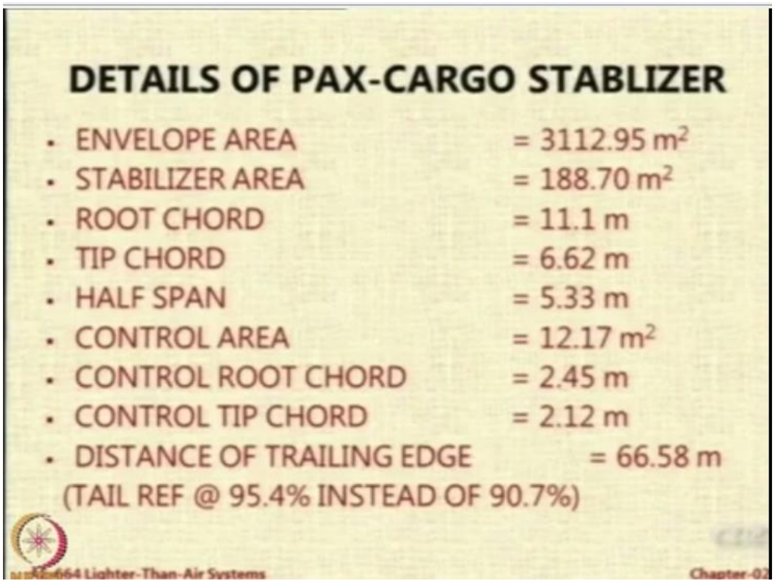


ESTIMATED PERFORMANCE

Cruising Speed (V_{cruise})	97 kmph (53 kts)
Max. Level Speed	104 kmph (56 kts)
Range	500 km
Basic Empty Weight	4986 kg
Mission Fuel @ V_{cruise}	207kg
Mission Payload (excluding pilot)	1500 kg
Net Lift (at 95% helium purity)	6846 kg

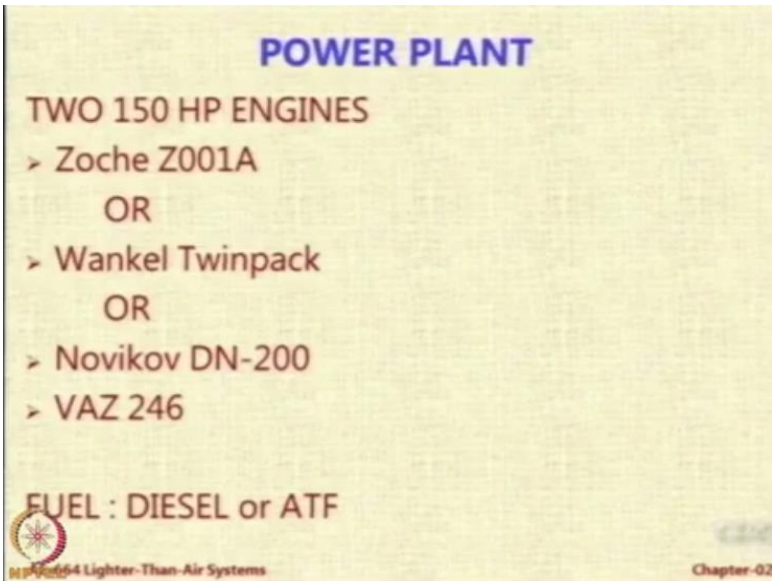
This is the estimated performance for a range of 500 kilometers, this is the number we got.

(Refer Slide Time: 08:26)



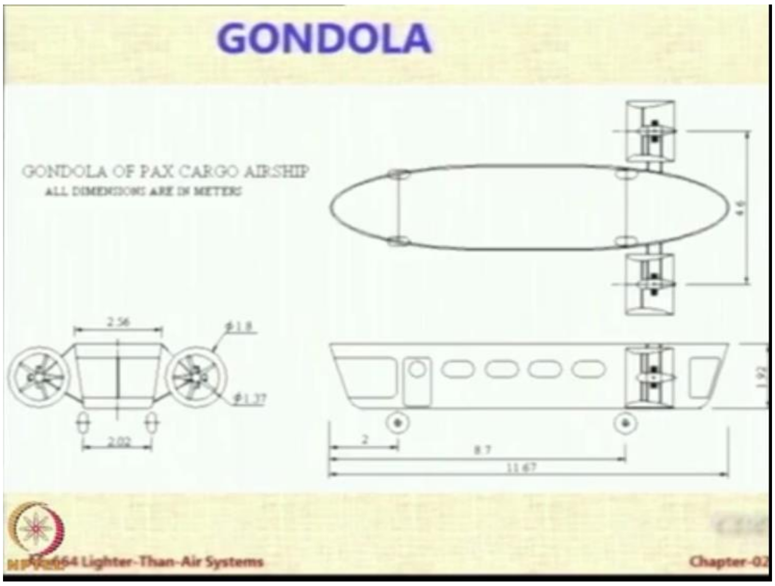
Again, these are numbers for the stabilizer.

(Refer Slide Time: 08:28)



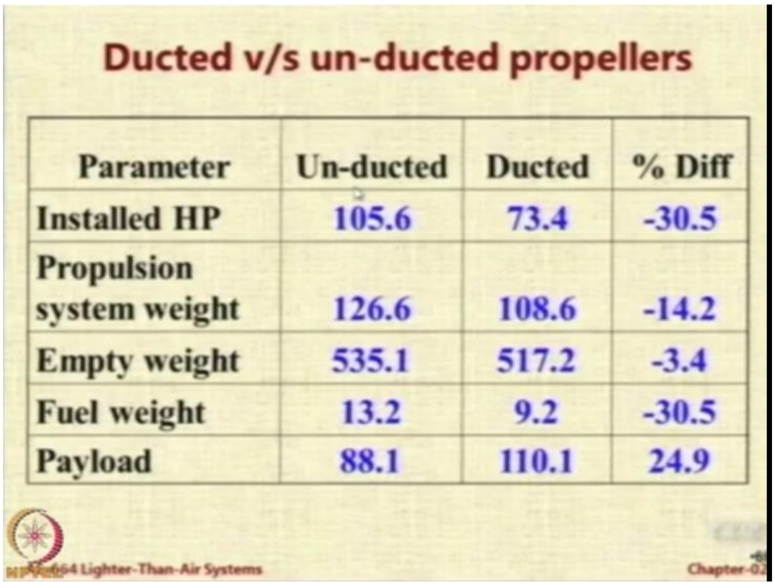
For this we had some power plants in mind. So, we looked at 3 or 4 engines commercially available.

(Refer Slide Time: 08:35)



We did the complete layout and sizing of the gondola.

(Refer Slide Time: 08:41)



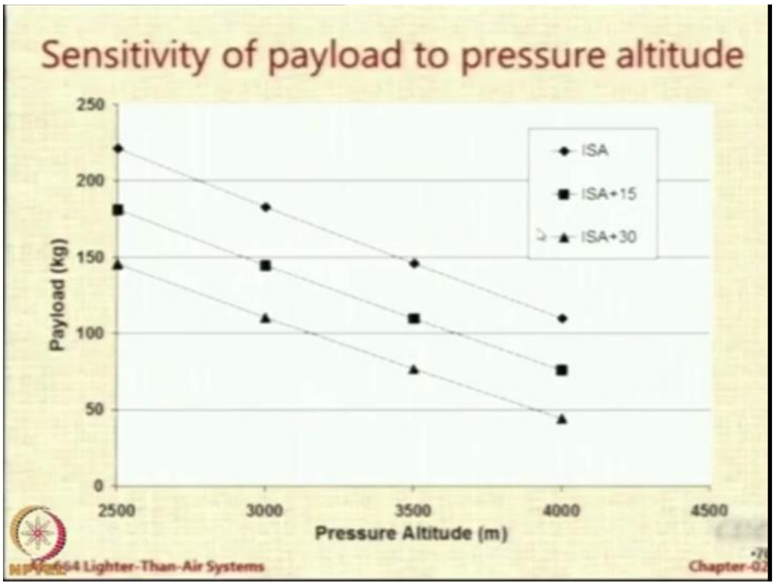
Ducted v/s un-ducted propellers

Parameter	Un-ducted	Ducted	% Diff
Installed HP	105.6	73.4	-30.5
Propulsion system weight	126.6	108.6	-14.2
Empty weight	535.1	517.2	-3.4
Fuel weight	13.2	9.2	-30.5
Payload	88.1	110.1	24.9

And then the most important thing is the sensitivity analysis. When you change some parameter, how much does it affect the weight, size, capacity, etc. So, look at now between unducted fan and ducted fan. So, the ducted fan requires 30% lower horsepower. You can imagine the savings in the weight just by that too it becomes 30% lower horsepower. But the propulsion system weight, now this weight comes down although there is a duct.

But the weight becomes less because the engine is lighter. Empty weight is also a little bit less. Fuel weight is 30% less and therefore the payload is straight away around 30% more or 25 kg more. So, by using ducted propellers, you can carry 25 kg more payload.

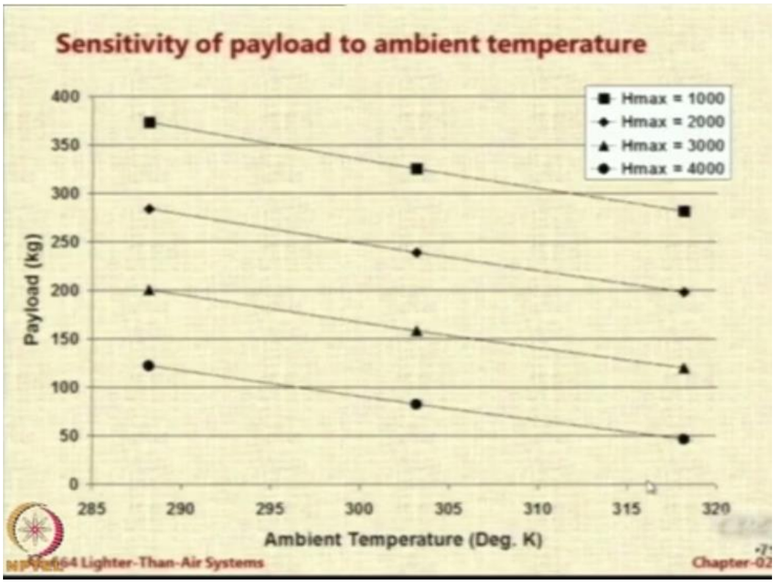
(Refer Slide Time: 09:50)



Then this is information that you should keep in mind mentally because this information is very much applicable to almost all kinds of airships. So, there are two informations here. One is if you have a payload and if you increase the pressure altitude say from 2 and a half to 4 kilometers for the same operating temperature ISA the payload reduces linearly. So, what can carry 50 kg at 4000 can carry 150 kg at 2 and a half thousand.

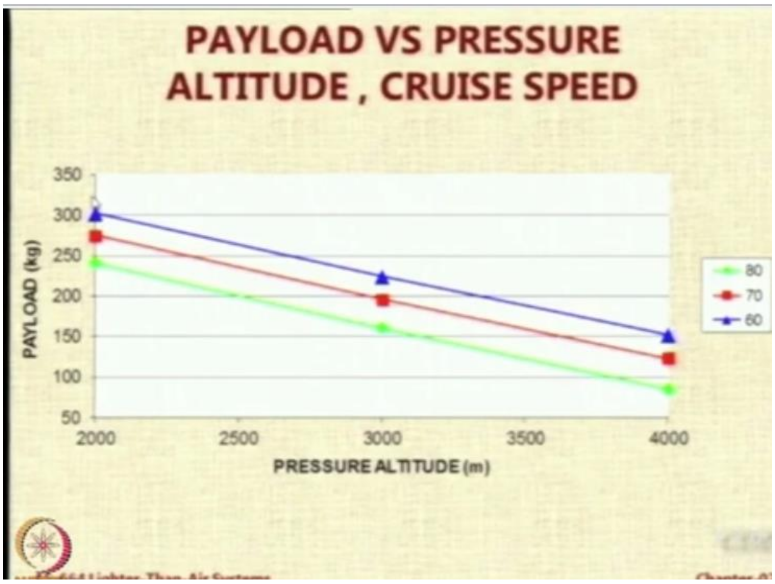
And if you take it further to 0 altitude you will find more. As I said to you the airship that carries only the pilot can carry 4 passengers and pilot at sea level. So, it is a straightaway linear relationship. So, what we learn from here is in airships there is a drastic change in the payload capacity either when the operate ambient temperature increases because of the superpressure and the super heating effects or as the pressure altitude increases. Both of them are going to hit the payload carrying capacity.

(Refer Slide Time: 11:15)



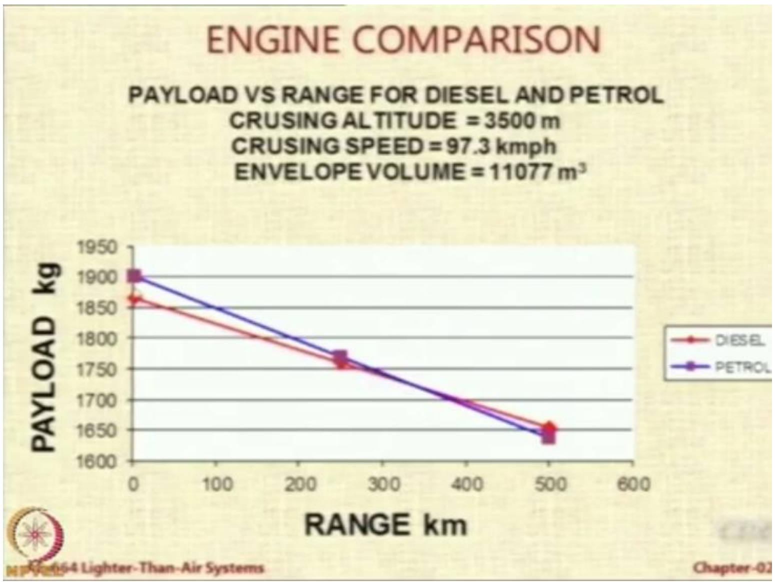
This information I have already given you in the previous graph. Now, I am just plotting it reverse. I am plotting the same data for various maximum altitudes. So, all of them decrease linearly. So 50 kg payload becomes 120 kg payload if the temperature is reduced. That means if you operate in a cold environment, you can carry more payload.

(Refer Slide Time: 11:38)



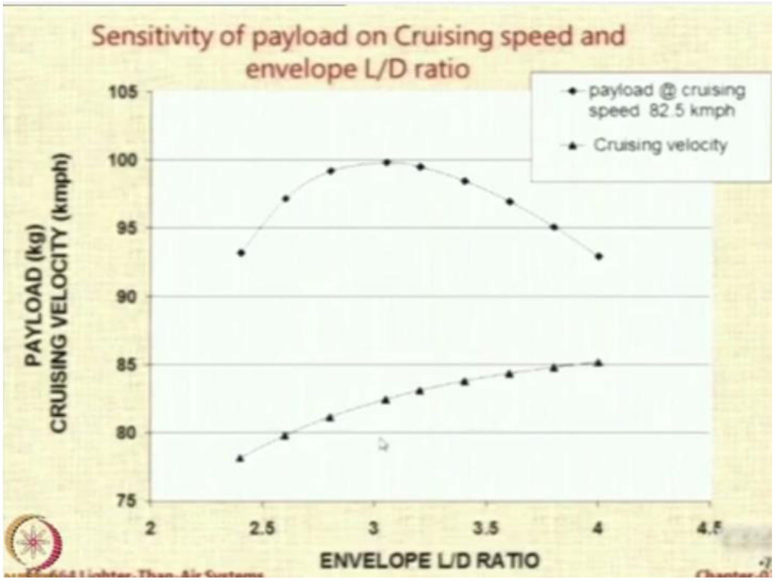
Similarly, effect of speed. So speeds of 80, 70, 60 for a given pressure altitude, you have to go vertically on the lines. So, you see there is a small change. There is a change, but a small change. So, 250 kg payload is available with 80 kilometres per hour, maybe 275 with 70, maybe 300 with 60, So, 25 kg more for 10 kilometers per hour difference, but the loss in the pressure because of pressure altitude is much larger.

(Refer Slide Time: 12:13)



Similarly, a comparison of two engines. Somebody was wondering why we are looking at petrol engine and diesel engines because the availability of diesel is always going to be better than petrol. But interestingly as the range increases, there is a crossover point. Beyond this range, it is the petrol engine which gets lower payload than a diesel engine. So, even payload wise you are better off. So, for longer range airships use diesel engines. For shorter range airships use a petrol engine.

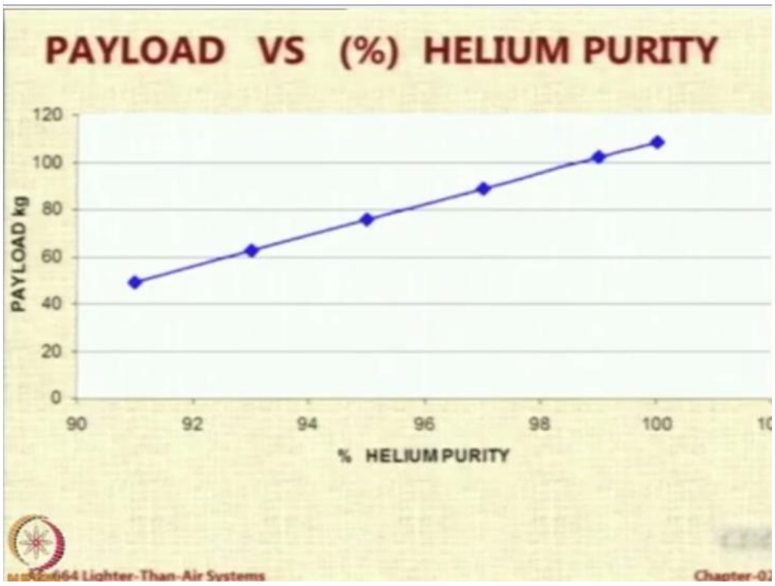
(Refer Slide Time: 12:47)



Similarly, we plotted out the l/d ratio. How does l/d ratio because as you know l/d ratio is going to affect the aerodynamics. So, there is a peak. It is a very interesting result. It tells you that this l/d ratio of around 3 or 3.05 is actually the peak. This is the GNVR shape. So, you make it less than this and the payload decreases. You make it more than this, the payload decreases.

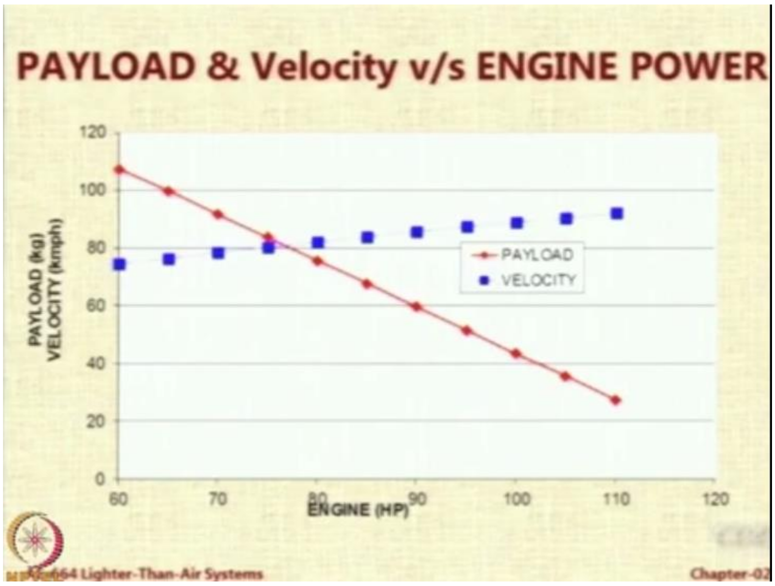
In one case the drag increases and hence there is a larger heavier engine. In one case the weight increases because of the larger surface area. In both the cases, the payload is lower than what you can get. But for you know if you look at changing the cruising velocity, you find that 4 is the best. The highest payload is available with l/d = 4 for various speeds. So, the y axis is payload in this graph and speed in this graph. This is just like putting two graphs in one.

(Refer Slide Time: 13:57)



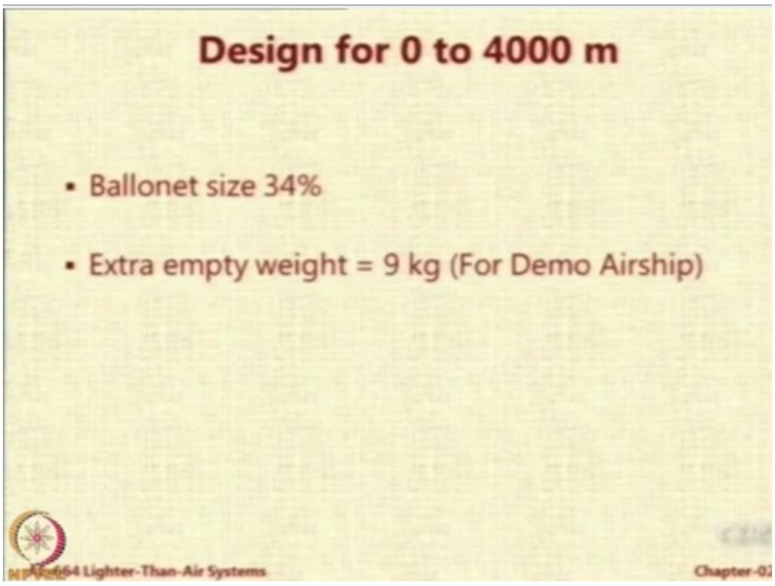
What happens with helium purity? Notice that when the purity of helium is 100% if the payload is 115 kg, it shoots down to only 50 kg if the purity of 91%. So, there is a linearly reducing effect of helium purity. This is because the buoyant lift becomes less straightaway. The impurity which will be air will not only reduce the buoyancy, but also increase the weight.

(Refer Slide Time: 14:32)



Then payload and velocity versus engine power. So, on the y axis you have either payload in kg which is the red line or velocity in kmph which is the blue line. On the bottom on the x axis, you have the engine. So, you notice that as the payload decreases, the engine horsepower follow suit and as the cruise as the engine power increases you can get slightly more cruise speed also, blue line goes up.

(Refer Slide Time: 15:34)



Then we wanted to know suppose we make an airship which goes from 0 to 4000 delta H, so we found that instead of 20% it is 34% ballonet size. So, the inflation fraction will reduce from around 80 to 66. And because of that you have 9 kg more weight. So, that means the payload capacity which was 77 kg will become further less if you have a larger ballonet.