**Lighter-Than-Air Systems**
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**Lecture – 109**
**Hybrid Ultra Heavy Lift Cargo Vehicle Transport**

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Now let us look at a study done by some students whom I supervised. So, I will simply go to their presentation. So this team of students lead by one Carlos they took part in a global competition AIAA student design competition for a hybrid ultra heavy lift cargo vehicle. And they called this as HULC-VT because VT is the Virginia Tech.

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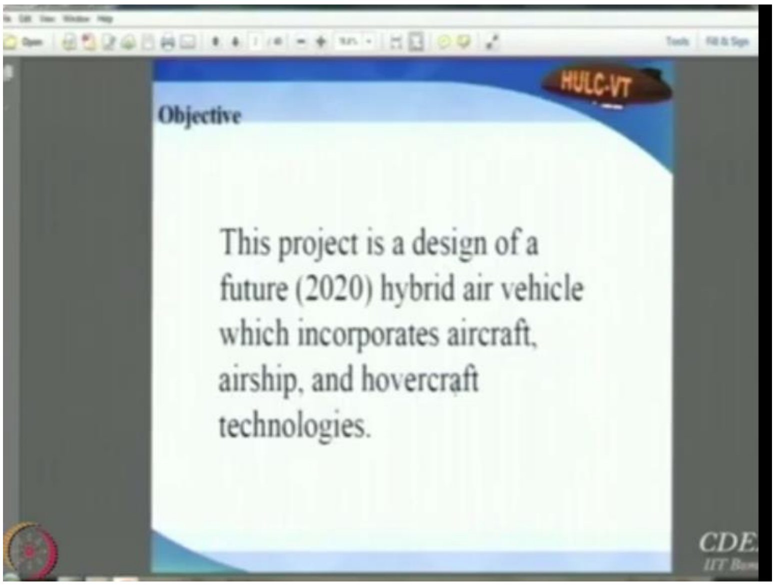

So, you can see the idea is to come up with a vehicle for 2020 which can combine aircraft, airship and hovercraft technologies.

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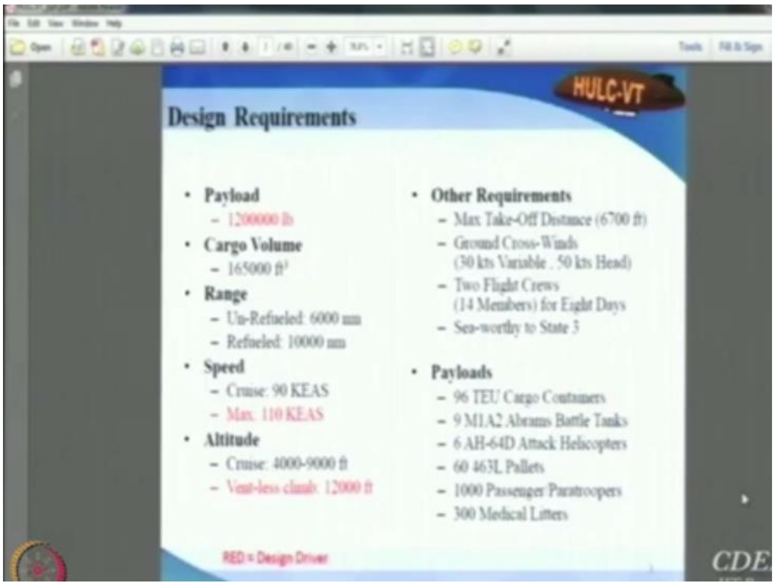


And look at the serious requirements or the large design requirements you have to carry 1.2 million pounds of cargo over a distance of 6000 nautical miles around 12,000 kilometers approximately, nonstop at a speed of 110 knots. So these students carried out a critical study of the design requirements and the ones which are in red color are the 3 design drivers that they established. And you can see that the amount of cargo to be carried is like something like 9 tanks or 6 Apache helicopters. They have to be taken nonstop and delivered.

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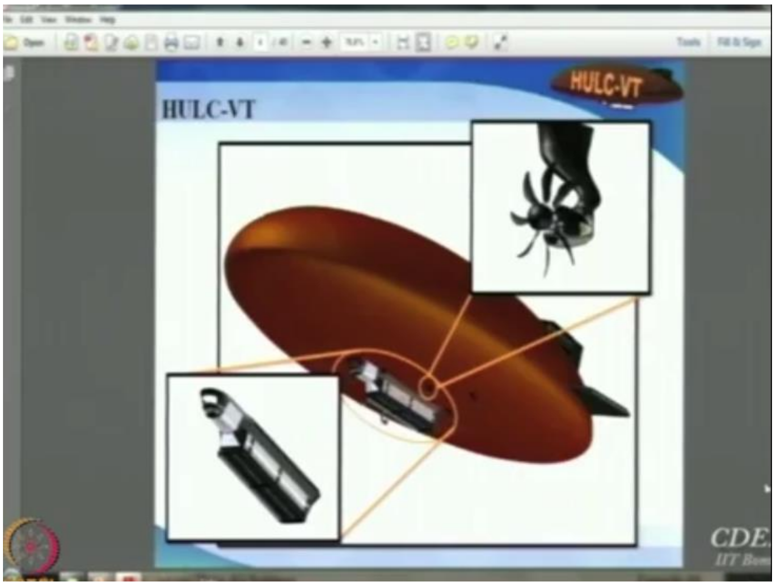


So they came up with this design and I will take you through the work that they did. This is a presentation which was made by them.

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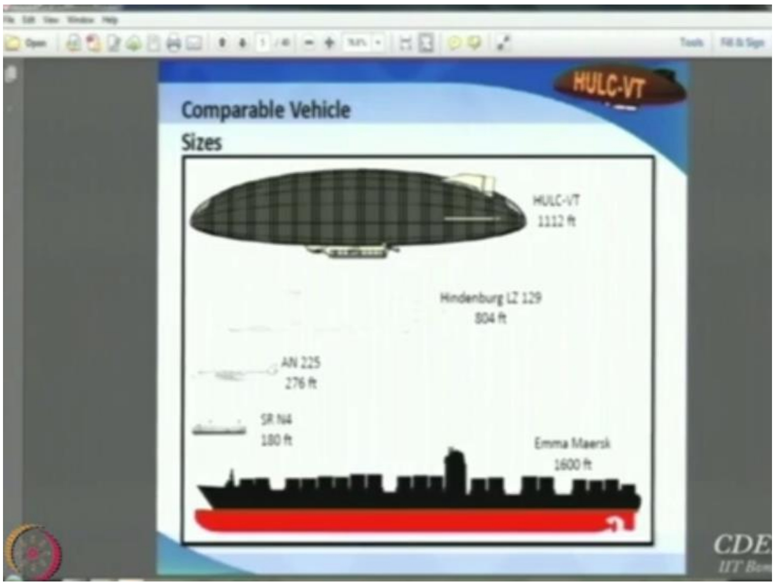


So, here is a picture which looks at the largest ship in the world and it compares the dimensions of the proposed airship with all the big aircraft, Hindenburg and the airship.

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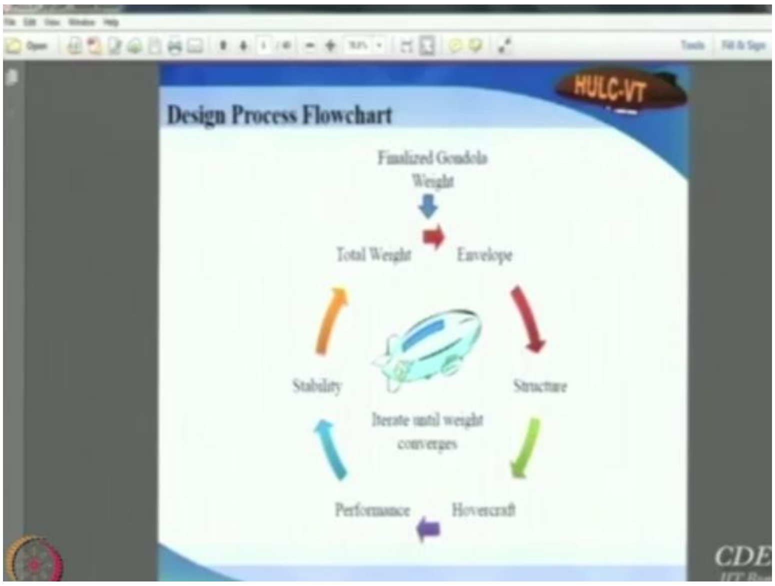


And this is the design cycle that was followed. They started with an envelope, did the structure analysis, did the hovercraft work, performance estimation, stability, total weight and then iterate it till it was converged.

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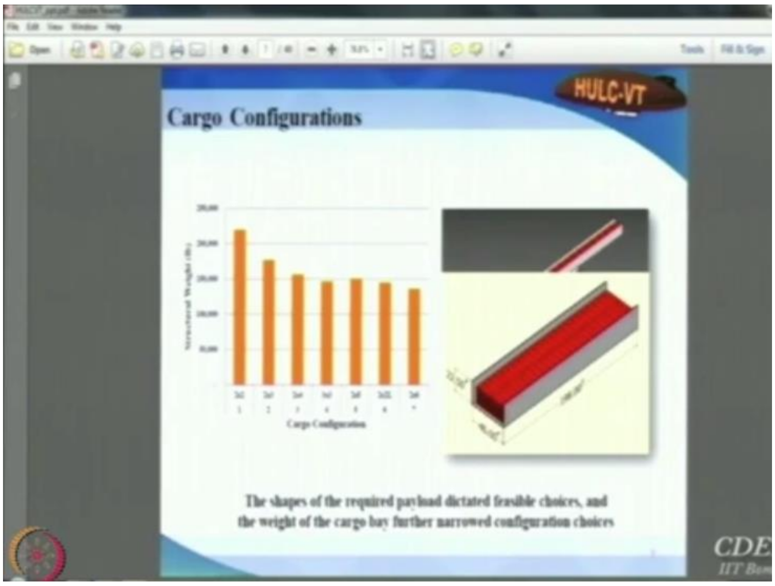


So, there are many types of cargo to be carried, not just one type. It is a big list. So, which combination of the cargo is going to give you the maximum space requirement you do not know in the beginning. So what they did is they did various types of combinations of the cargo to be carried.

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And then they sized the envelope. This is a picture that they came up with for typically how their cargo cabin will look like.

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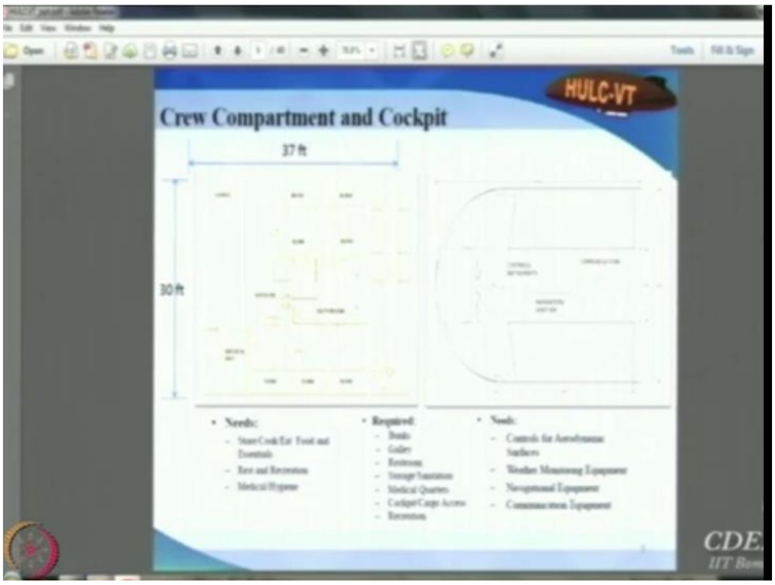


And this is the final configuration of the crew compartment or the place where the crew. This vehicle is going to fly for a very long time nonstop. So you cannot have just pilot and copilot. You have to have people who can be rested and replaced. So look at there are 4 bunk beds. At any given time, there will be eight people operating this particular vehicle. Then they started by defining just a simple oblate spheroid shape with length, width and height.

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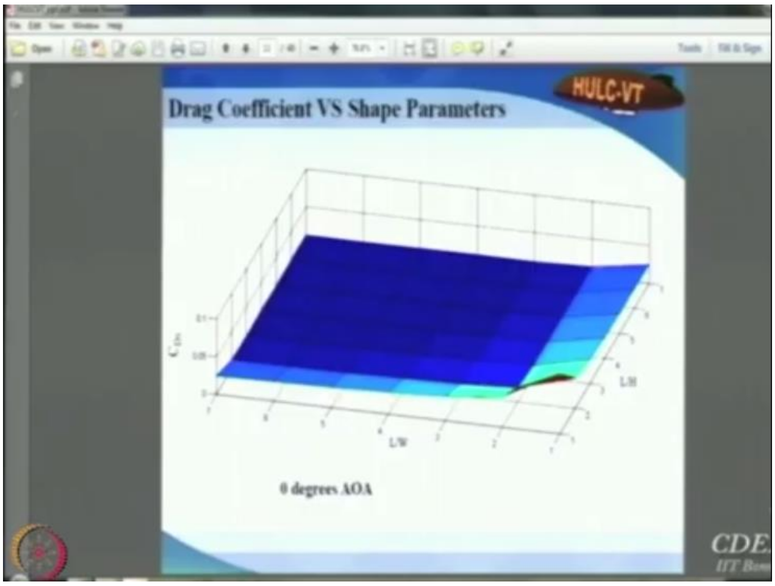


And then they did some kind of parametric study on the effect of the drag coefficient $C_{DV}$ volumetric drag coefficientt with respect to this L/W ratio and L/H ratio. So, they found that as long as you stay within 3 L/W and within something like 4 or 5 L/H the drag does not increased rapidly.

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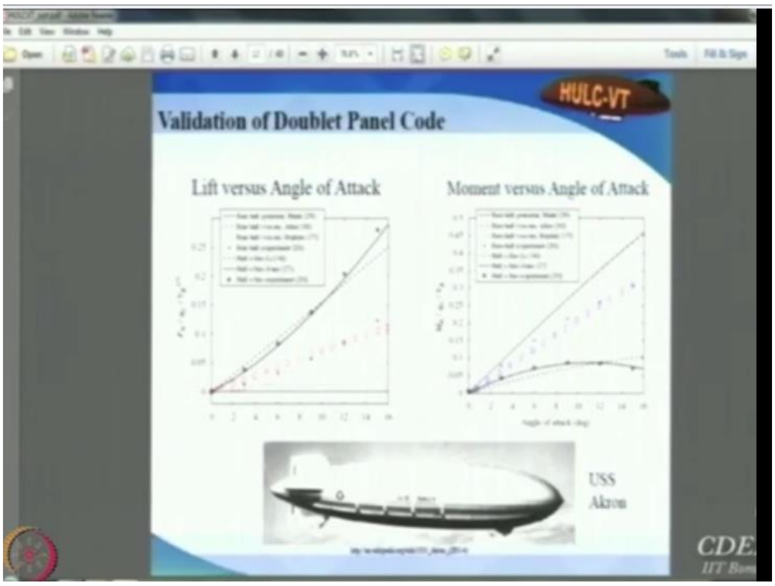


Similarly, they located a panel code which was available in literature for axisymmetric body of revolution and then they did the validation of that particular code. So you can see the dots that you see red and blue dots are the numbers obtained by them against the data which they got from literature.

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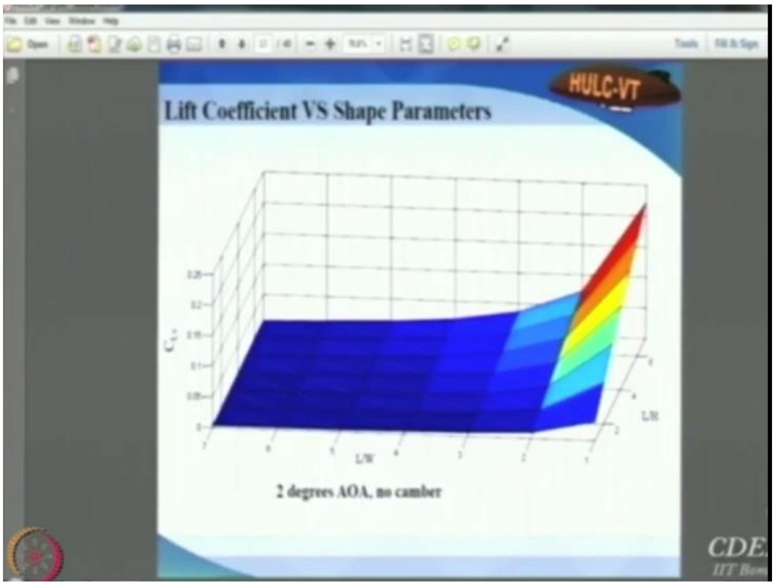


And then again, shape parameters versus the lift coefficient. So, it remains pretty flat as far as the L/W is concerned but L/H length by width, there is a marked effect especially when you go towards the large values.

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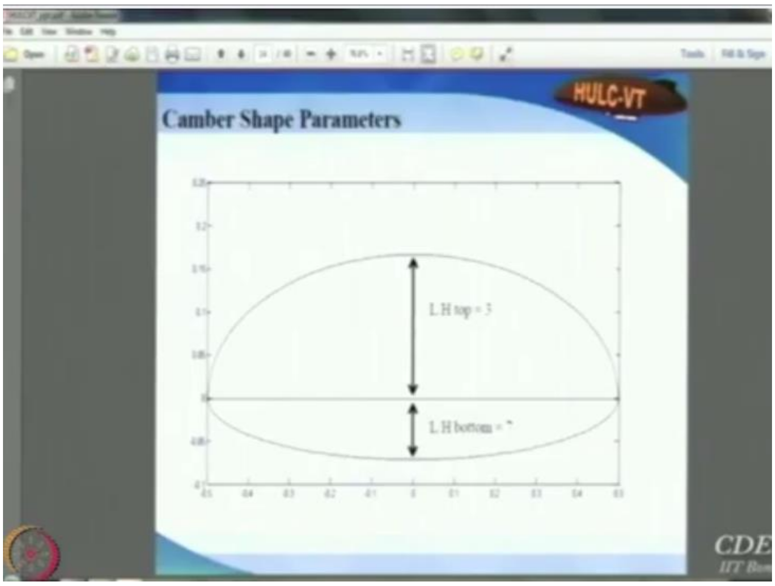


So, with all these studies, this is the final shape that was decided. So, the bottom portion will have some contour and the top will have some contour. This is the cross-sectional shape and then again further studies. They studied for various buoyancy levels, what kind of $C_D$, surface area $C_L$ will be available.

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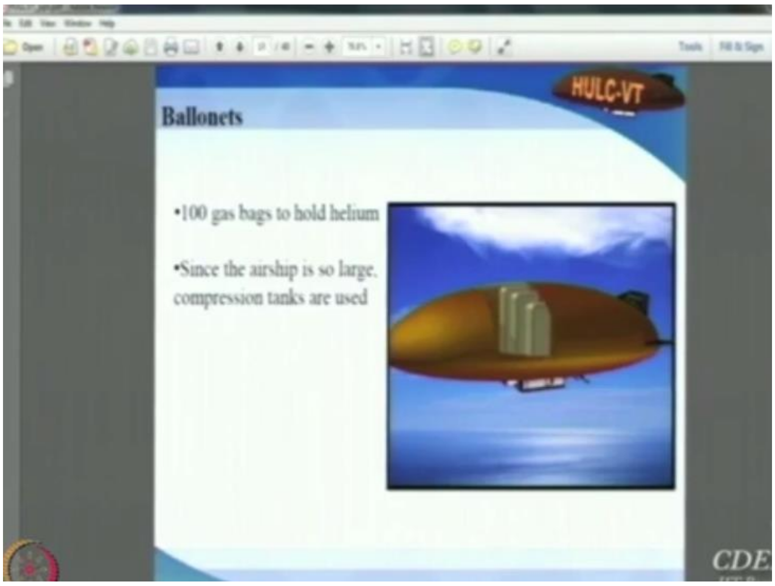


And the same kind of system which we saw compressed gas system a similar system is being proposed here for reducing the volume.

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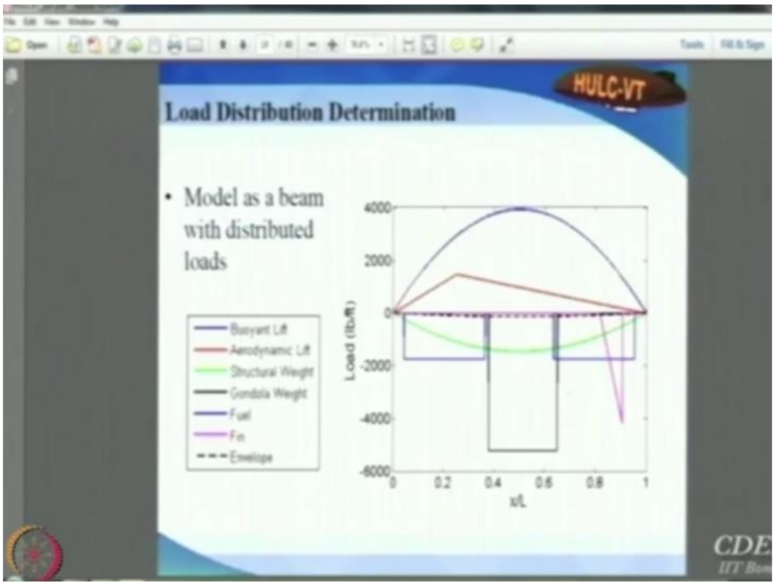


It is impossible for you to use a conventional ballonet in this particular system because a ballonet will occupy such a large part of the envelope that it will be hardly any space available. This is some work on the basic structural dynamic modeling of the configuration. So, you can see there are these the blue line for example is a buoyant lift. Along the length from 0 to 1, the blue line gives you the buoyant load distribution.

And that will clearly vary by the cross section because it is purely a function of density. The red one is the aerodynamic lift which will be more at the quarter chord, so you will have a similar kind of a peak. Then the structural weight will also be distributed clearly as per the cross sectional area, except when you come to the central area where you have the payload. But the structure of the vehicle itself will generally vary as per the cross sectional area.

This is the gondola weight which suddenly increases when your fuel weight, fuel is kept inside the tanks, fuel is only at the rear and then the envelope weight variation.

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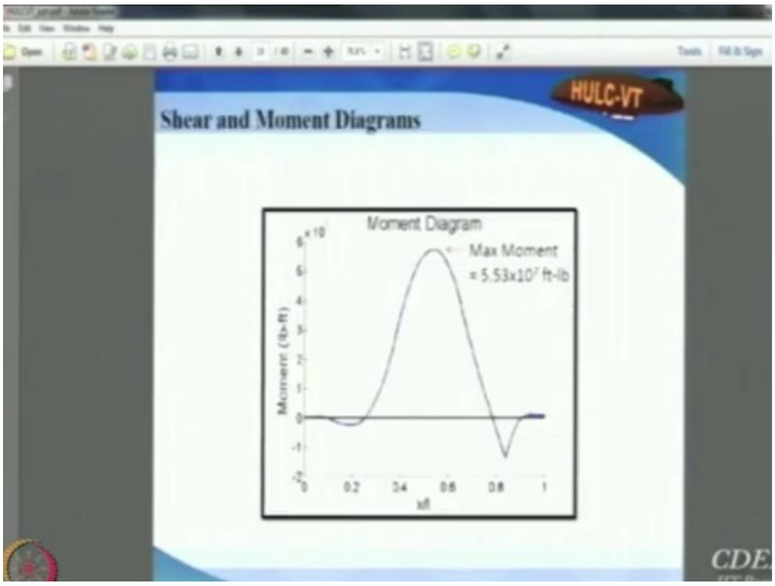


Then they got the bending moment diagram and the shear force diagrams.

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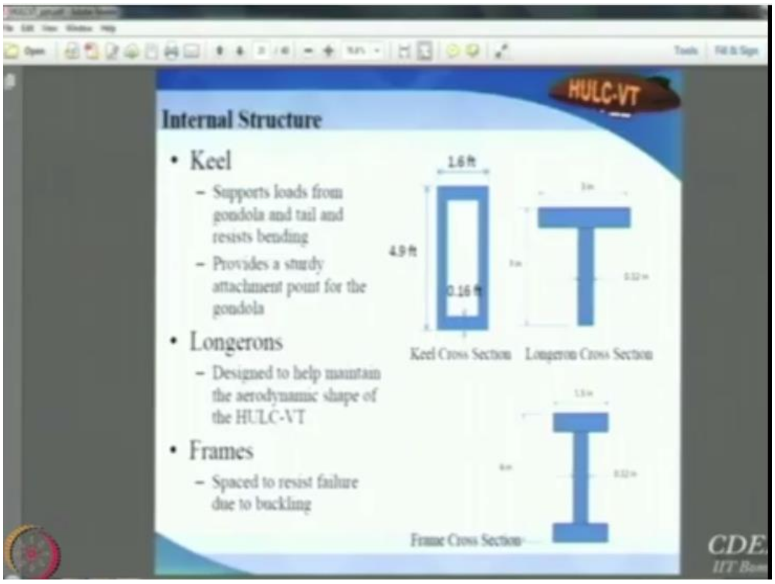


They did structural analysis of the basic framework. So, look at the amount of work is involved in doing all these calculations.

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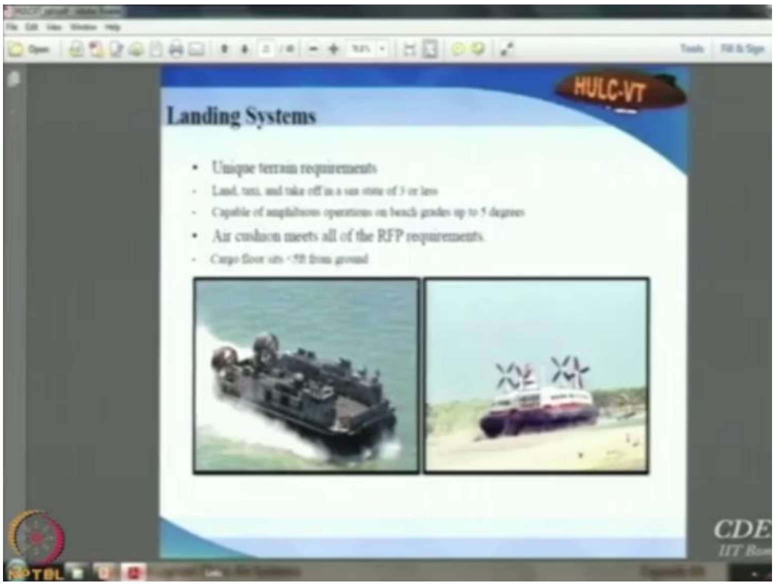


And finally, one student I remember was focusing only on the air cushion vehicle system. So, he studied what kind of vehicles systems can be considered and he zeroed into the air cushion system.

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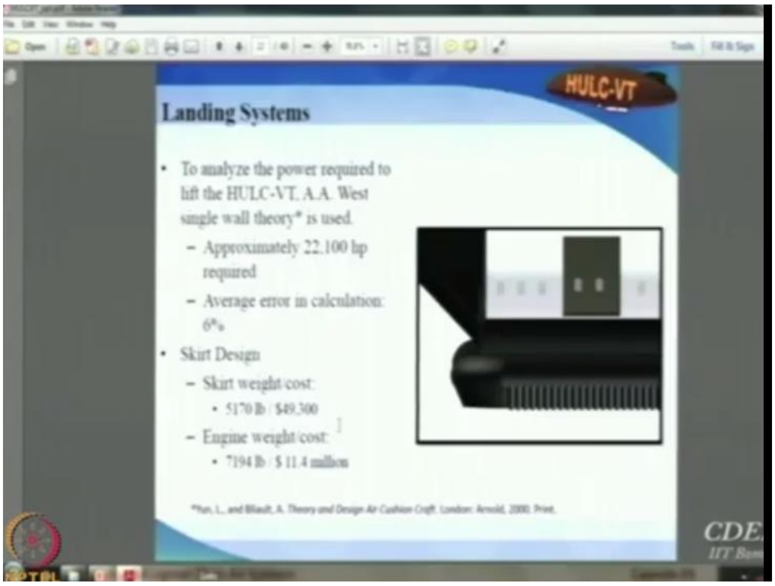


So, then he started looking at the theory and design of air cushion craft and then he designed a system which would be able to take care of the loads and he did the cost estimation also, what it will cost to make it.

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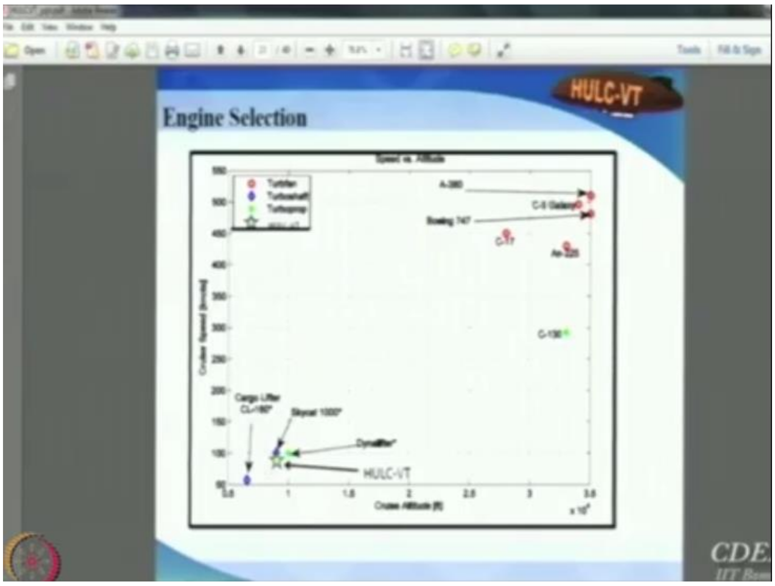


The engine selection was based on the data available for existing engines for large aircraft. So, this particular graph shows the cruising altitude on the x axis versus the cruising speed and he has plotted various aircraft which are large cargo carriers. And this is the point for HULC-VT which is near the SkyCat and the Cargolifter. Of course, as you are going towards the airships you will come to lower altitude and lower speeds.

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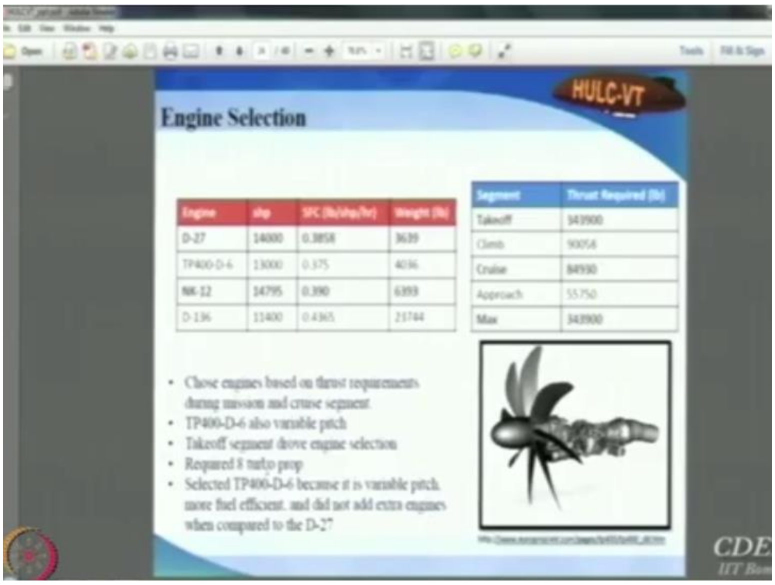


Then from the data available on the internet and from the manufacturer, there were four possible engines which were shortlisted. They were studied in detail and then finally one of the engines was chosen.

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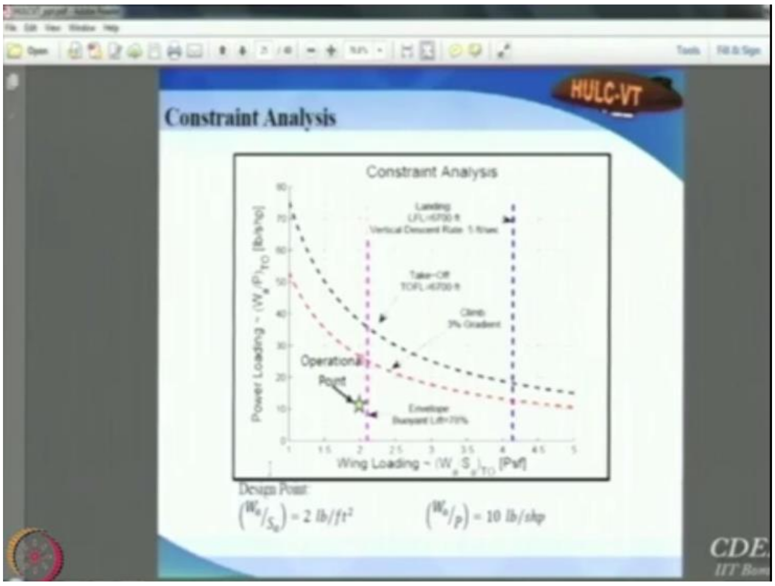


And then in aircraft design we do what is called as constraint analysis where each of the design requirements are to be analyzed on a graph having wing loading on the X axis and power loading or thrust loading on the Y axis and these lines indicate the constraints. So, the area below these lines is infeasible and the area on the right of the line is infeasible. So with that you find out the operational point.

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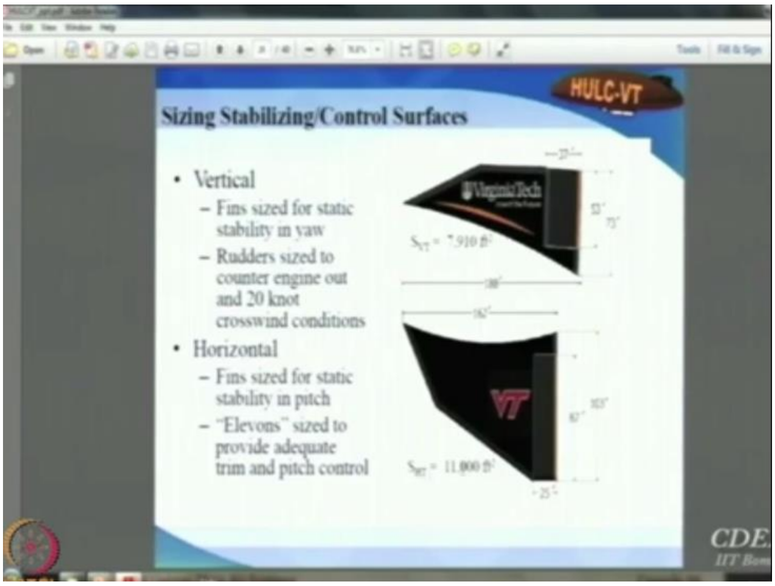


Similarly, the one group of students were focusing on the sizing of the fins and they actually did calculations for stability, calculations for the moment coming when there is a one engine run out and then came up with the exact dimensional requirements. The fins are not small, you can see the horizontal tail is 11,000 square feet.

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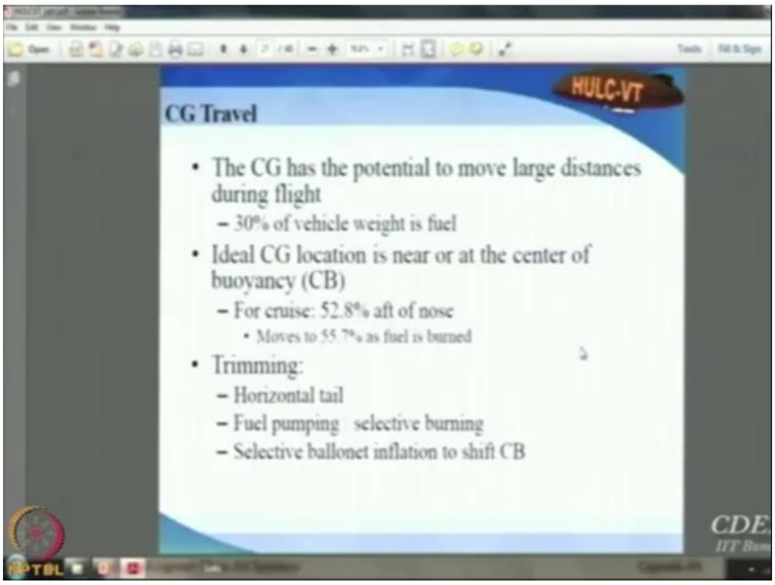


Then one group was focusing on basically the cetre of gravity control so that the moments are not beyond what their aircraft can handle.

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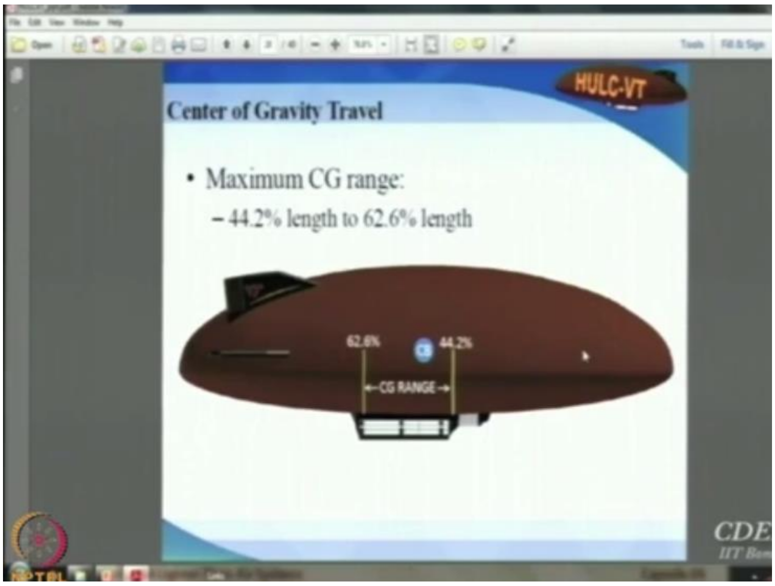


And with that he got the centre of gravity range for the aircraft.

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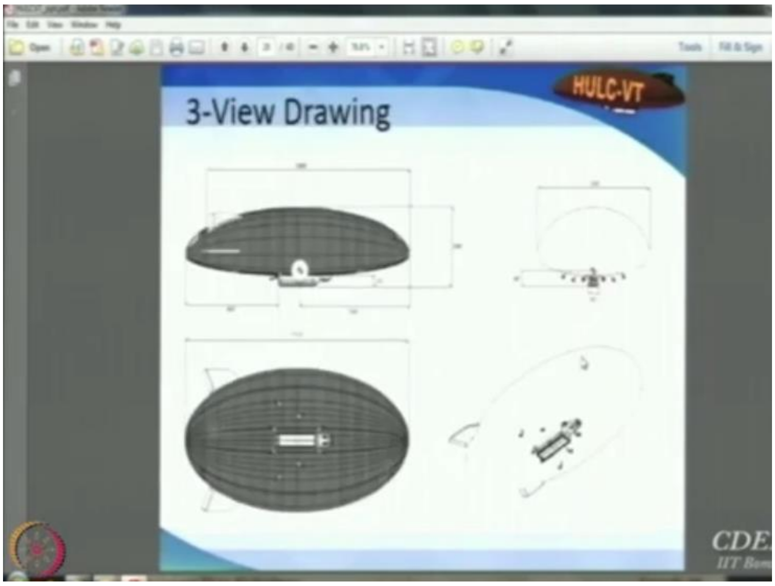


And then finally we had 3-view drawing of the aircraft.

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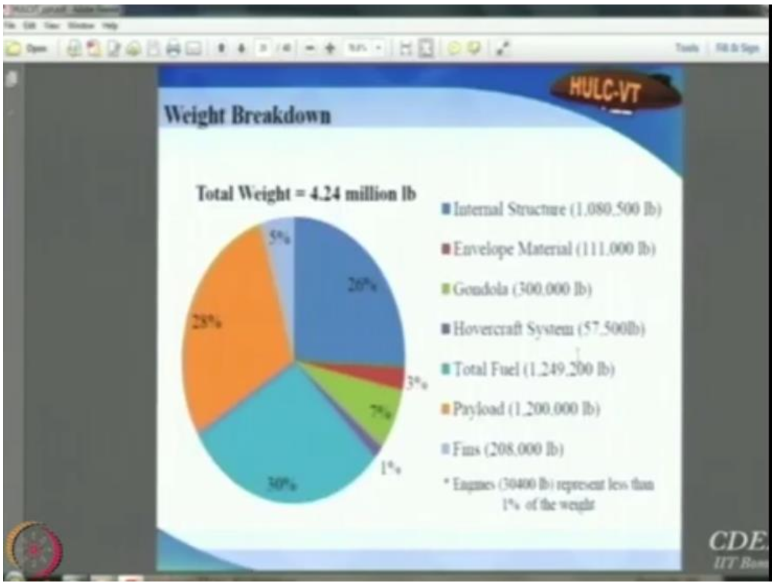


Weight breakdown; so you can see that around 30% of the weight is basically for the internal structure. This is 26%. Fuel weight is around 30% and payload is 28%. So, the amount of fuel you need to carry roughly matching with the amount of payload that you are supposed to carry in this particular example. And other things are very small in size. Gondola is only 7%. Material of the envelope is just 3%.

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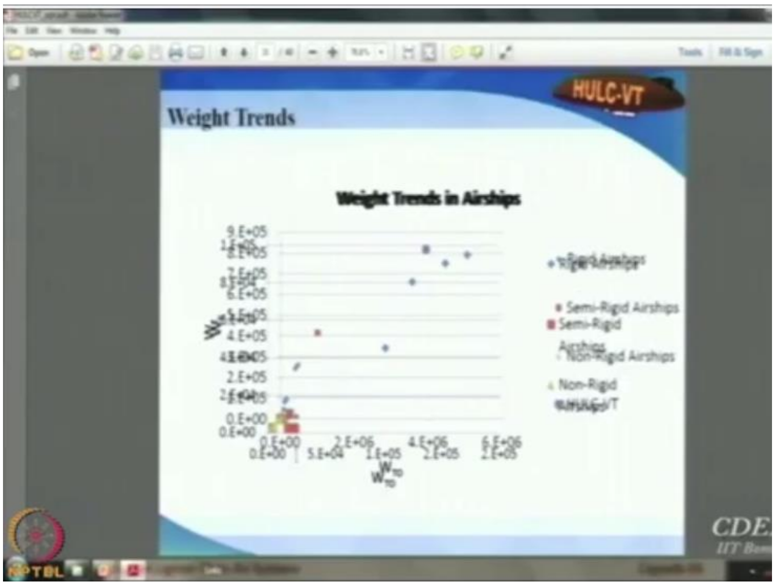


Then these are other airships which they they plotted.

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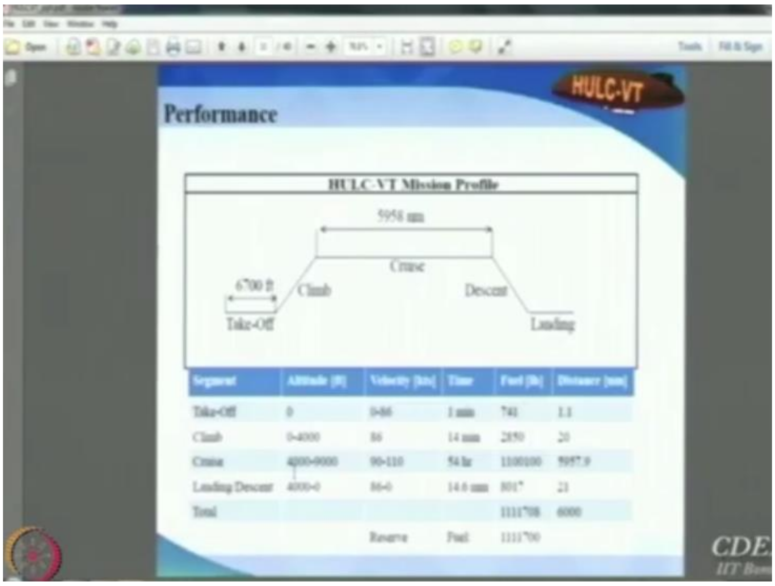


Mission analysis, how it will perform, you can notice it is 6000 nautical miles.

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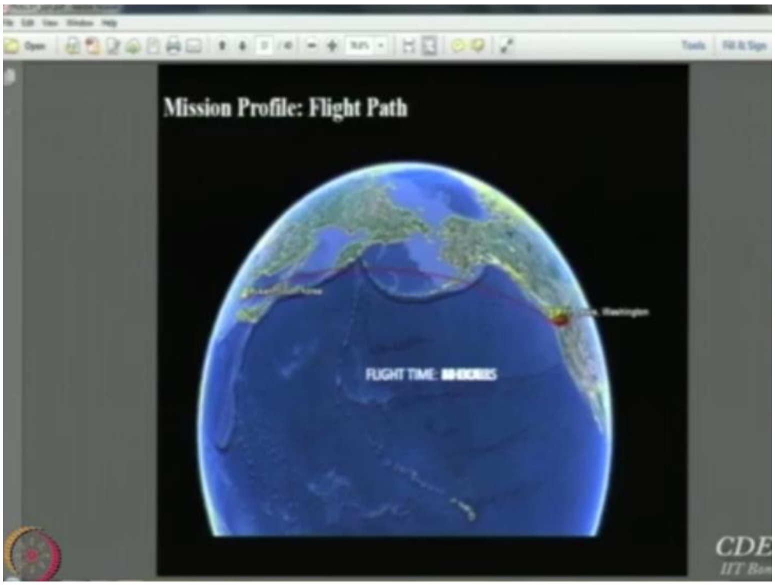


And then they did very nice animation which I do not have a video from the place where it is supposed to take off that is Footloose in Washington, what route will it take to fly to Busan in Korea, which is supposed to be the place where we will be delivering it.

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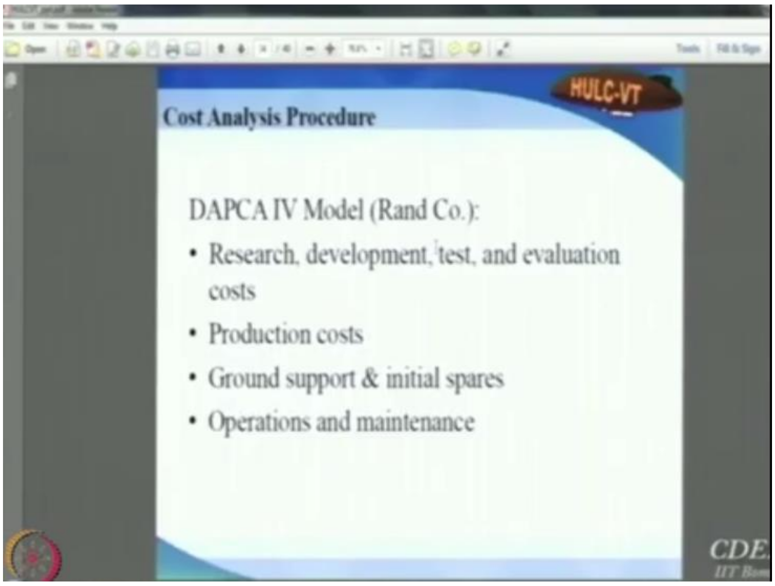


Then cost analysis is very important because the whole exercise was to be judged against what is the cost that you will incur per kilometer per kg for transporting cargo as compared to other means. So, for that they looked at what is called as a DAPCA IV model from Rand Corporation.

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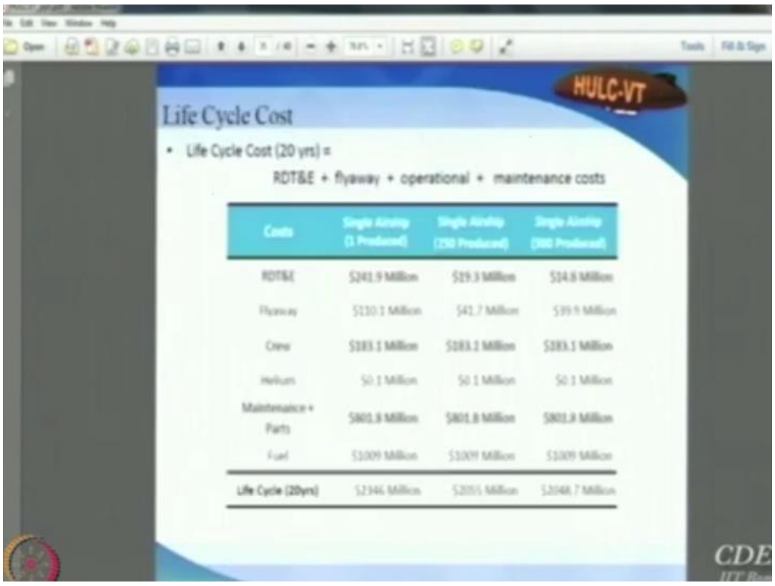


And then I will not go into the details, but there are large amount of terms explaining various costs.

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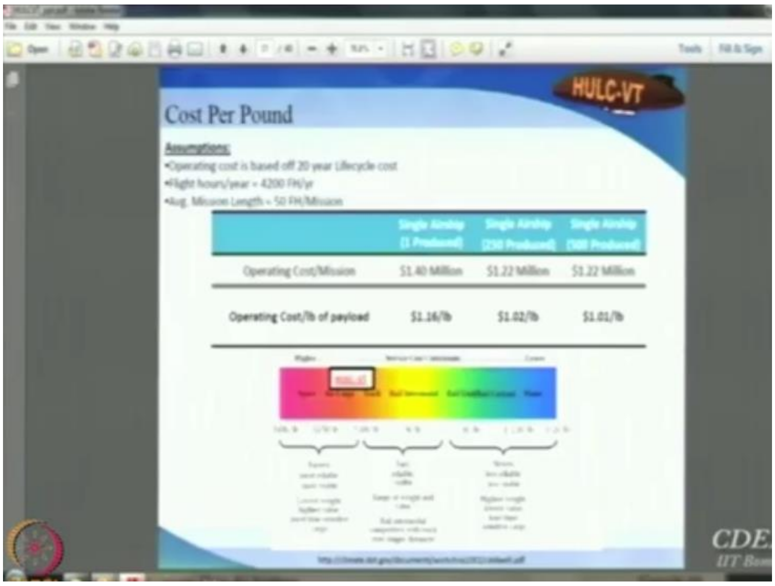


The important point is that if you produce one airship, just one airship is produced then the entire R&D cost is going to be put on one airship. But if you produce more of them, then some part of the cost can be offset on to the airship sold. So you can notice here that the operating costs can come down from 1.16 dollars per pound to 1 dollar per pound. This represents around 17% improvement by making a larger quantity. And they compared the location of HULC-VT with respect to water based transport, rail, truck, air and space so it is somewhat matching with air cargo.

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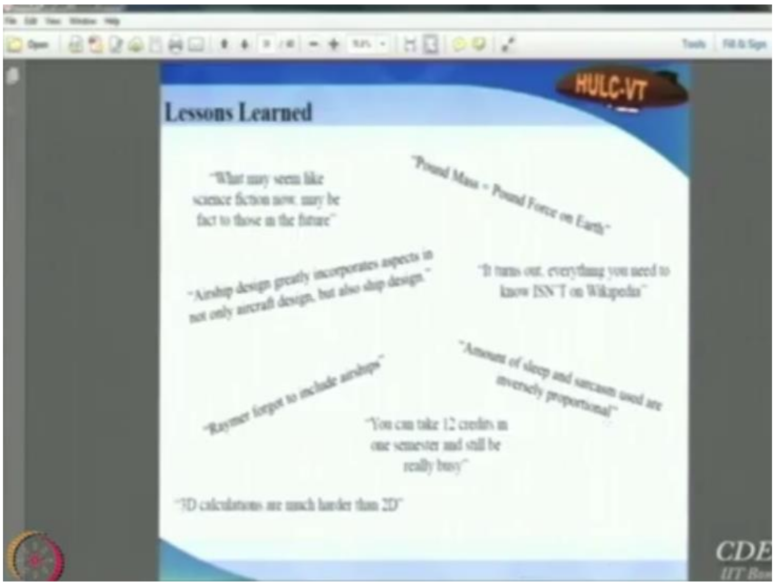


And then this is just some comments students made at the end of the presentation about what they learned from this exercise because they all were with me on this for about a year along with their course on aircraft design. And this was submitted to the competition.