**Introduction to Aircraft Design**
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**Lecture - 18**
**Design Considerations - Cargo Aircraft**

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Let us move on to cargo aircraft. Cargo aircraft basically are also called as freighters because their job is essentially to transport freight. Under the category of cargo aircraft, again we have different aircraft types.

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Mostly these aircraft are converted from existing passenger or military aircraft, usually at the end of their service life as far as the civilian operations is concerned. Essentially, an aircraft may have a lot of residual life remaining when it ends its life for civilian purposes to carry passengers. So, it is very common to extend the usage of such aircraft by converting them into cargo variants of the basic passenger aircraft. Now, this conversion, and the end of life may happen because of noise or environmental regulations.

In most cases, its either the noise limits or the emission limits which create a problem in the old aircraft and hence they become obsolete. The good example is Cessna caravan 208, which was converted into cargomaster and then into a super cargomaster dedicatedly for Fed Ex. Similarly, a Boeing 747 also has a freighter version, and Airbus 380 also has a 380 F, which is a freighter version of the same basic aircraft. There have been some attempts to design aircraft for dedicated cargo and freighters.

Ab-initio one example from the channels of history is that of the spruce goose from the Hughes Aircraft Corporation, and recently, a consortium between Casa of Spain and IPTN of Indonesia took up the design of a dedicated cargo as well as military aircraft called as the CN 235. And there are also attempts to have joint civil military air cargo aircraft.

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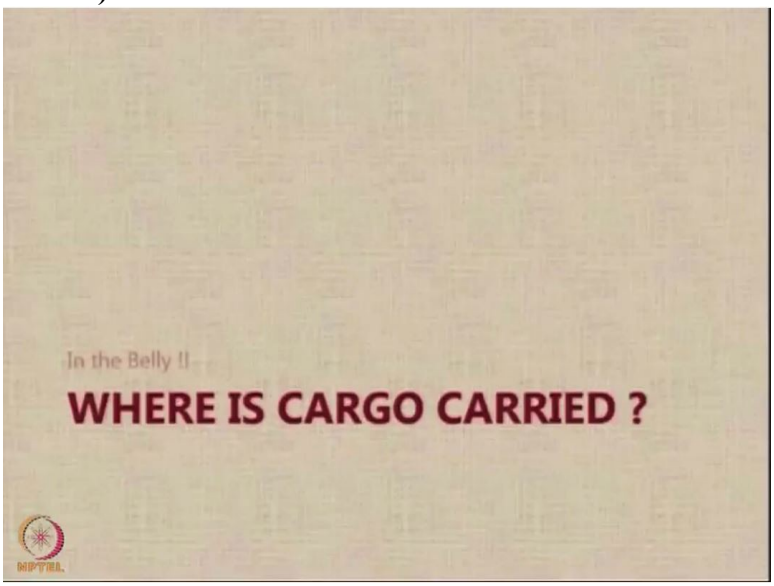


Sometimes people wonder where is the cargo carried in a conventional airliner of course, is carried in the belly. So, let us have a look. This shows the cross section of Airbus A 320.

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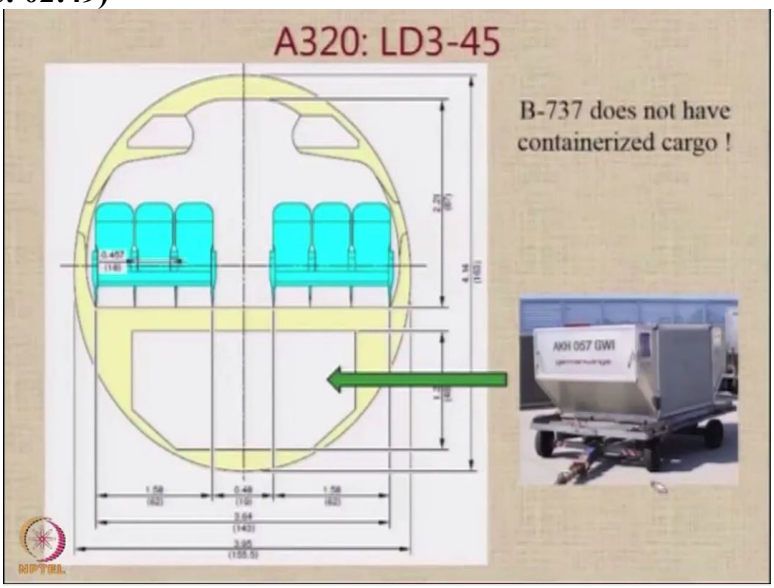


Where you can see that the fuselage is neatly compartmentalize into 2 separate segments. The upper segment which is shown here, in which we have a 6 abreast seating layout and passenger floor and below the floor in the belly, we have this area where the cargo is carried and we call this as a belly area. In the case of Airbus A 320 cargo in the belly is carried in a containerized form as shown here, there are dedicated containers which are designed and the cargo that you carry is first filled in the containers and then the containers are pushed inside the aircraft.

This is very helpful in saving time on loading and unloading of aircraft as well as in ensuring that no cargo moves as the aircraft is flying. Plus there are also some safety issues regarding any cargo which is which can create a problem maybe there is a small explosion that can be contained by the container. However, Boeing 737 which is competing in the same market, it goes for palletized cargo system, it does not have a containerized cargo.

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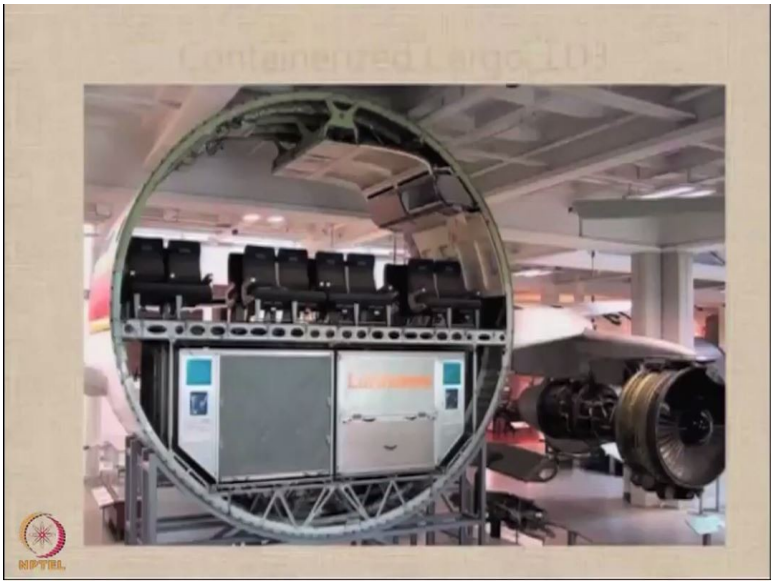

Here is a cross section of a larger Airbus aircraft, where you can see the top cabin has a seating of 8 abreast and on the bottom we have these containers they are called as the LD3 containers, containers to be carried on the aircraft come in various sizes and there are there is a dedicated series LD3 LD4 etc. So, there are these dedicated containers which are designed keeping in mind their transportability below the belly or in the belly of transport aircraft.

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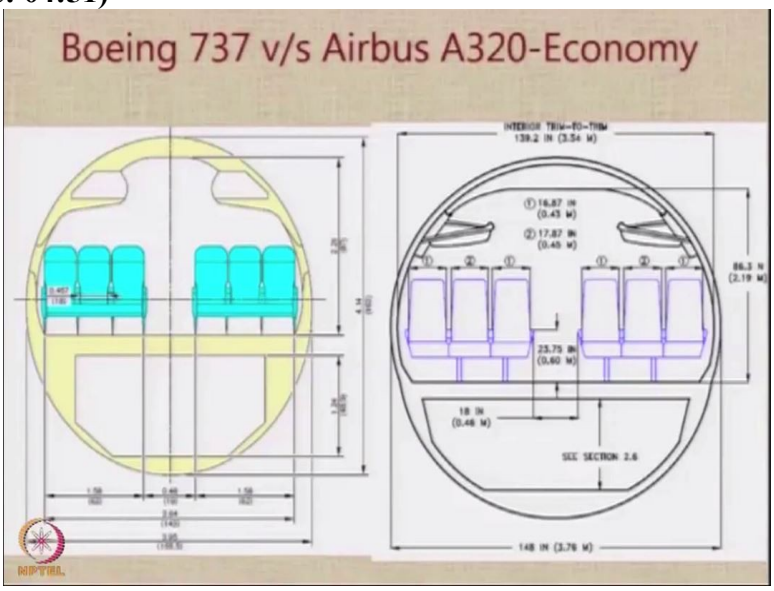


Here is a comparison of the cross section of Boeing 737 versus Airbus A320 we noticed that the both the aircraft have a 6 abreast seat layout and a clearly compartmentalized fuselage and the dimensions are also quite similar.

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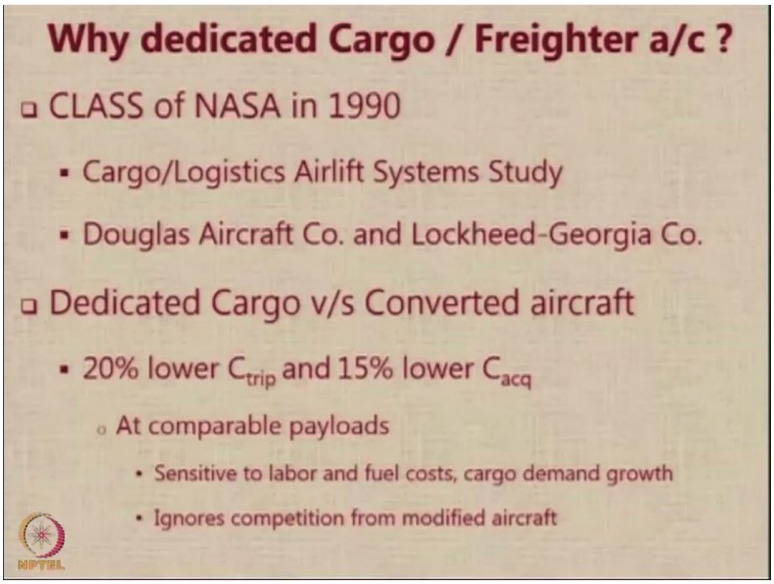


Question arises is what is the need to have a dedicated cargo freighter aircraft, why can we not continue with the current practice of converting a passenger aircraft into a cargo aircraft as and when needed. A study called as class was commissioned by NASA in 1990 class stands for cargo logistics airlift system study, and this study was done by the Douglas Aircraft Company and Lockheed Georgia Company. And it came up with very interesting conclusions.

In the comparison between the dedicated cargos aircraft versus the converted aircraft is first found that a dedicated cargo aircraft would have 20% saving in the trip cost and 15% saving in the acquisition cost. So, one fifth of the cost is reduced in operating costs and a bit less than that, around 1 / 6 is reduced in the acquisition. This study ensures that the comparison is at a comparable payload level. The numbers that you see here are sensitive to labor and fuel costs and the cargo demand growth and it ignores the competition from modified aircraft. So, there is definitely a case for developing dedicated cargo aircraft.

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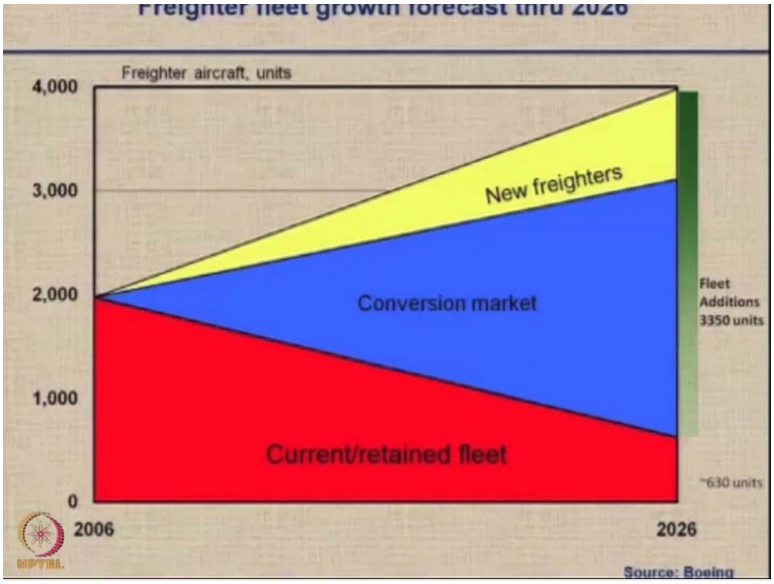


This graphic which has come from the Boeing Airplane Company shows how the freighter fleet will grow as projected by their estimates up to 2026. So, we notice that the current of the returned fleet is going to slowly come down linearly, whereas, there will be a conversion market, but there will be also a huge amount. So, the current fleet will reduce from 2000 to around 630 units, they will be reduced to less than 1 / 3. But there will be an addition of 3350 aircraft of which the bulk will be from the converted ones.

But there also will be substantial around 1000 aircraft, which would be dedicated freighter aircraft. So, there is indeed a huge market for dedicated fighter aircraft also. And nearly 3 / 4 of these will be the converted aircraft and the remaining 25% would be either the existing or the new ones. Let us have a look at some small cargo aircraft which have been converted from packs variants passenger variants. The first aircraft that comes to mind is the Cessna 208 actually there is a Cessna 208 family.

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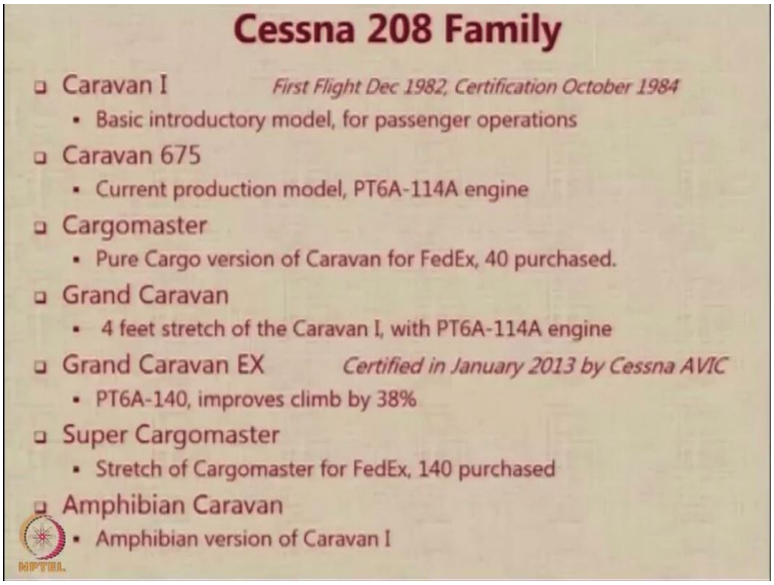


Cessna began this particular family with Cessna caravan 1 which was flown for the first time in 82 and certified in nearly a year later in 1984. It was a basic introductory model essentially for passenger operations, but this was converted into caravan 675 with modified with a change in the engine. And then there was a cargomaster, which was a pure cargo version of the Cessna caravan for FedEx, of which 40 were purchased from the cargo master.

The design was modified into Grand Caravan, which is basically a 4 feet stretch of caravan 1 with the same engine, so you carry more passengers but you keep the same engine. So with a small loss in the performance and the ability, you are able to carry more people that is a Grand Caravan and then we had a Grand Caravan Ex or the extended version which was certified in 2013. This one has a higher version of the engine PT6A-140 which improves its climb performance by more than 1 /3.

We then got a super cargomaster which was a stretched version of cargomaster again it was dedicated for FedEx and 140 aircraft were purchased. And also there is an amphibian version of the caravan. Caravan 1 which is called as an amphibian caravan which operates from seas and lakes.

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So this is the Cessna caravan the basic aircraft caravan 1. You can see that it has these passenger windows and high wing layout with the based wing. On the bottom we have a fuselage shape to carry certain items in the belly, the super cargo master is the one in which the windows are completely removed everything else remains and you actually fill up the whole aircraft with cargo and from super cargomaster, again a reverse version of a passenger aircraft was created called as the Grand Caravan.

So, we went from a passenger aircraft to a cargo variant and the cargo variant was again converted back to a passenger aircraft in the name of Grand Caravan. So, this conversion takes place in both directions, if needed.

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Just to give you an idea here is the cargo cabin of a super cargomaster, there is a partition which protects the crew from the movement of the cargo and you will notice that the fuselage has got this very high strength floorboards and the seat rails and these seat rails are having notches at every approximately 1 inch location. So, you can actually adjust the equipment at any particular point along the length of the fuselage.

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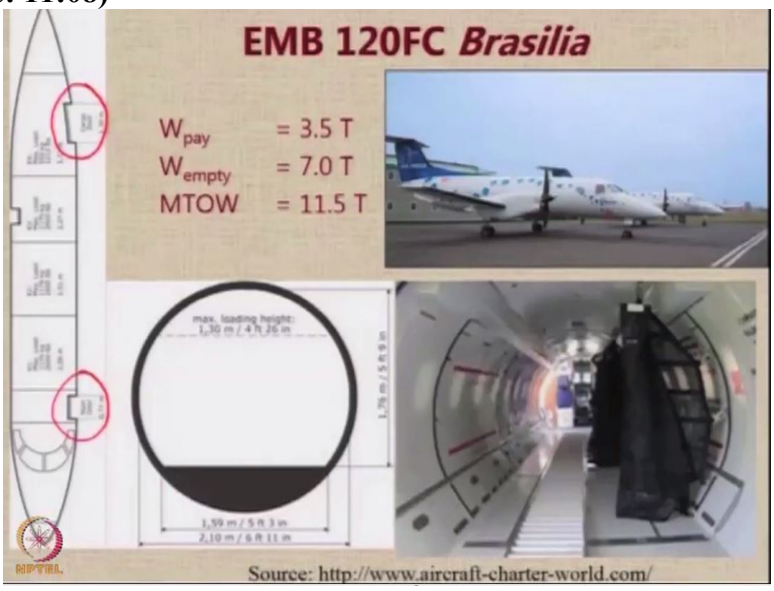


Another example of a popular aircraft which is a passenger variant into a cargo is the EMB 120 FC Brasilia, this aircraft has a payload of 3.5 tons on an empty weight of 7 tons and the max takeoff weight is 11.5 tons. So, you can see in this aircraft, the whole of the fuselage is meant for only carrying the cargo and in the center of the fuselage there is a floor with mounted with these

roller bearings which allow you to slide the cargo to a location that you need and then there are these curtains which are used to separate or isolate various cargo pallets.

There are 4 separate cargo compartments in this aircraft as we see along the length and there are 2 doors, there is a door on the back for cargo and there is a main door here. The cargo door of course is wider, so we can see that the whole aircraft is compartmentalize into 4 cabins and these cabins you can carry different types of cargo.

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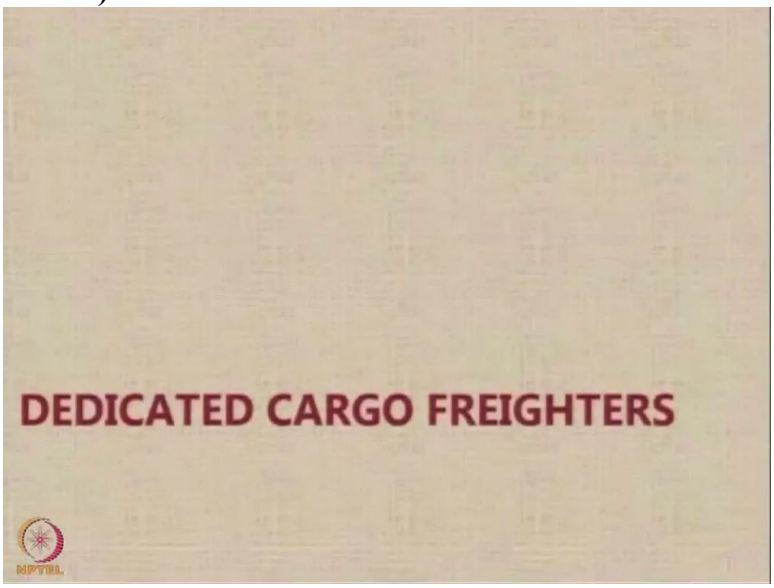


Let us have a look now at some dedicated cargo freighters.

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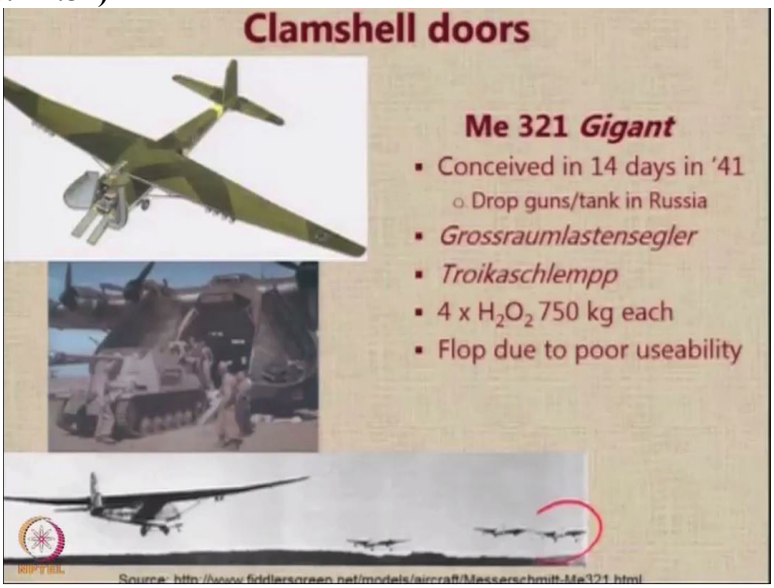

Going back to history, we look at one aircraft called as the Messerschmitt Me 321 gigant which basically means giant. This aircraft was conceived in a period of only 14 days over 2 weeks in 1941 during the Second World War, and the aim was to design an aircraft which can quickly be used to drop guns and tanks in Russia when the German forces were fighting the Russians. So, this is basically a grossraumlastensegler which in German means a large sized long range glider.

And the mechanism used to launch this aircraft also very unique, a bit dangerous but very unique is called as Troikaschlempp that means toeing by 3. So, as you can see in the bottom, the aircraft was a glider so it had no engine of its own, it used to be towed by these 3 other aircraft and these aircraft were powered by hydrogen peroxide. So, they gave a huge thrust. And, you know, they would pull the aircraft and they would just launch it once it launches, the aircraft would just glide to the location land and release the cargo.

But this particular aircraft was a huge flop, because it was very difficult to have a 3 aircraft available always to launch it. And it was very cumbersome. There were many accidents. So therefore it was a failure.

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Spruce goose is a very famous aircraft, which was actually a flying boat, a dedicated huge flying boat. And a movie called aviator was launched in 2004, in which among many things, there is a story of how this aircraft was designed and how it had its maiden flight, after which it was never used commercially.

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As I mentioned, the Spanish company CASA and IPTN Indonesia, they join hands together to come up with this dedicated freighter come military transport called as the CN 235. It was purchased by many other countries. Now the largest operator of this aircraft happens to be Turkey, and many other countries like Morocco, Pakistan, they have purchased this aircraft and they are using it. Of course, Indonesia also uses the aircraft for its military applications.

There have been very interesting attempts to provide features on a cargo aircraft, which improve its usability. One of the main requirements for a cargo aircraft is the ease to load and unload huge cargo.

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So, here is Canadair CL 44D4 which looks very conventional in the first look, but pay attention to this particular portion on the fuselage, where there are 2 huge hinges and when the hinges are permitted to be open, the whole fuselage actually swings across those hinges, and then you have an empty tube from the rear, in which you can load or unload cargo as shown in this particular picture. So this is a very interesting way of providing a feature of quick loading and unloading into a cargo aircraft.

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Here is the world's largest aircraft, is AN225 MRIYA which is a dedicated heavy lifter. This is the world's largest aircraft, it weighs 640 tons the max takeoff weight and it can carry a payload of 254 tons on an empty weight of 285 tons and it carries 300 tons of fuel because there are 6 engines. So there has been a world record of a single payload of around 189 190 tons. It can carry 80 large cars, 3 or 4 battle tanks. Each of the engines produces a thrust of 230 kilo Newtons.

The main landing gear of this aircraft has 32 wheels it has 32 wheels. And interestingly, only one aircraft was built. The second one was also planned, but then the plans to build it were abandoned. So, there is only one aircraft of this type available in the world today.

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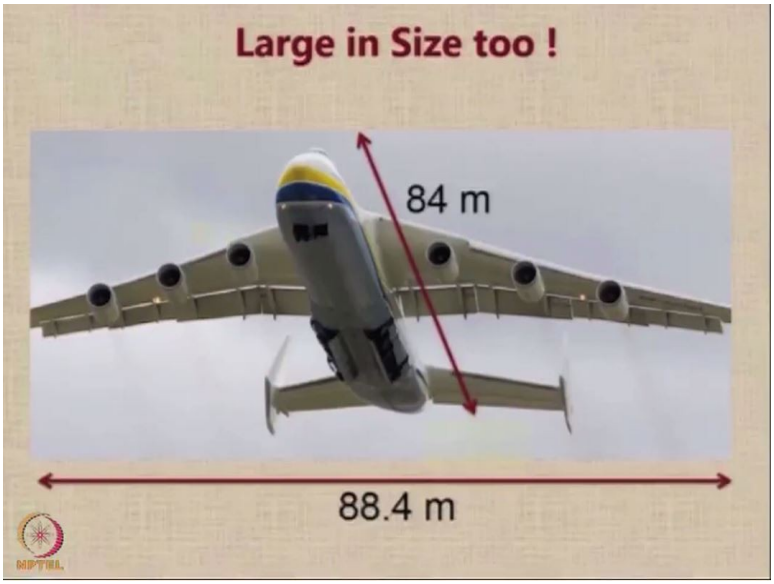


This record is really large in size to get an idea about its dimensions, the length of the aircraft is 84 meters.

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And the wingspan of the aircraft is 88.4 meters. And if you look at the cargo cabin, you have a height of 4.4 meters or width of 6.4 meters and a gross length of around 43.4 meters available for you to carry the cargo. So, this is a real heavy lift aircraft.

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And the main design requirement for this aircraft was to carry the Russian Space Shuttle called Buran. So you can see in this picture, the space shuttle from Russia mounted on top of the aircraft being transported. As I mentioned, there are many world records in the name of AN225 Mriya as far as payload is concerned. So you can see some numbers around 190 tons of payload. Single item 250 odd tons total airlifted payload 247 tons is the max payload that can actually be mounted.

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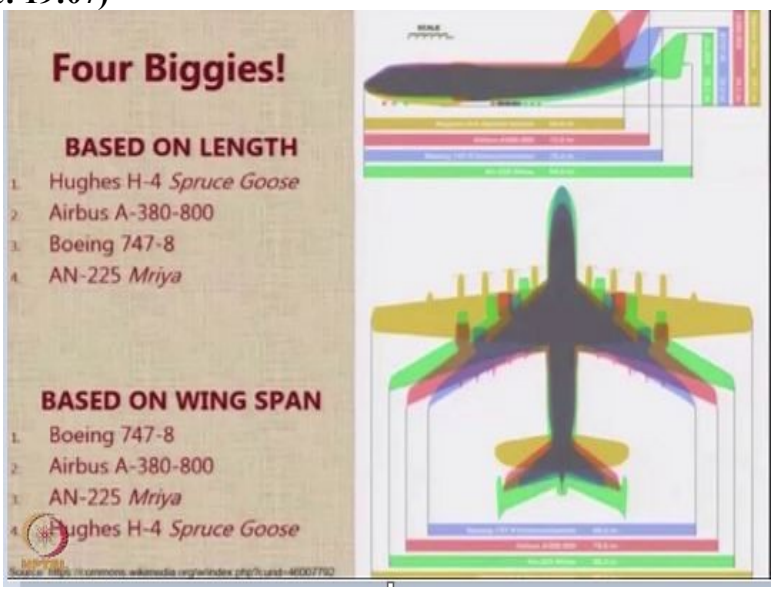


Let us have a quick comparison between the 4 biggies based on length, if you go in the increasing order of length, you have the spruce goose followed by Airbus A 380 dash 800 followed by Boeing 747 dash 8 followed by the AN 225 Mriya. So based on length the longest

among the 4 biggies is Mriya and the shortest is spruce goose. But if you base the comparison on wingspan then Boeing 747 dash 8 is the smallest.

The Airbus A 380 800 is the second largest, the Mriya comes third, but the aircraft with the largest wingspan is the huge edge for spruce goose. So these 4 aircraft are called as the 4 biggies because they are the largest aircraft which have ever been built.

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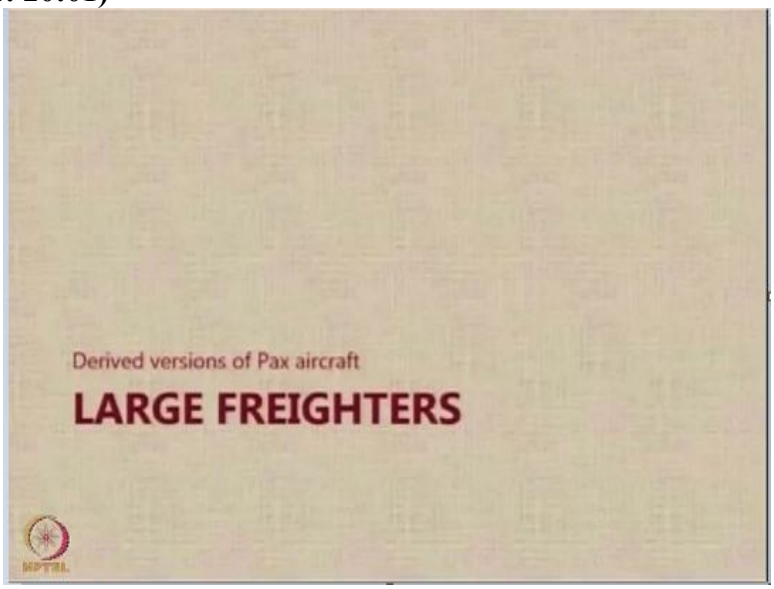


Let us have a look at large freighters which are derivations of passenger aircraft.

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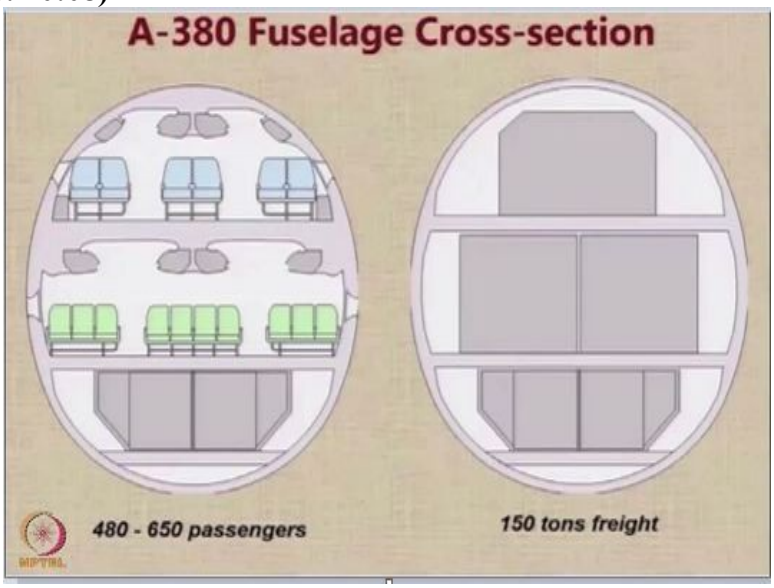


Here is a cross section of Airbus A 380 when it carries passengers, as we know the Airbus A 380 is an aircraft that has twin passenger cabin along its entire length. It is a double decker aircraft

for passengers. But actually it has got 3 decks, the bottom one for the containerized cargo and it can carry 480 650 passengers. But when we use it as a pure freighter, then the Airbus A 380 f uses all the 3 passenger cabins, the 2 passenger cabins and the bottom for carrying a total of 150 tons of cargo.

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Here is the big daddy the Airbus Beluga, which was designed essentially to carry large sub-assemblies fuselage of the Airbus aircraft for final assembly at Toulouse.

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And recently, the Beluga XL was launched and tested by the Airbus.

And let us have a short video describing the first test flight of Beluga XL. These are the crew members who are a part of the flight testing team. So notice it needs 5 crew members. This is a towed tractor, which is pushing it back to take it to the runway for takeoff. This is the flight control center where all the key parameters of the aircraft as it flies are being monitored.

Thanks for your attention. We will now move to the next section.