Introduction to Aircraft Design
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Lecture – 14
Key Issues in Design of Airliners

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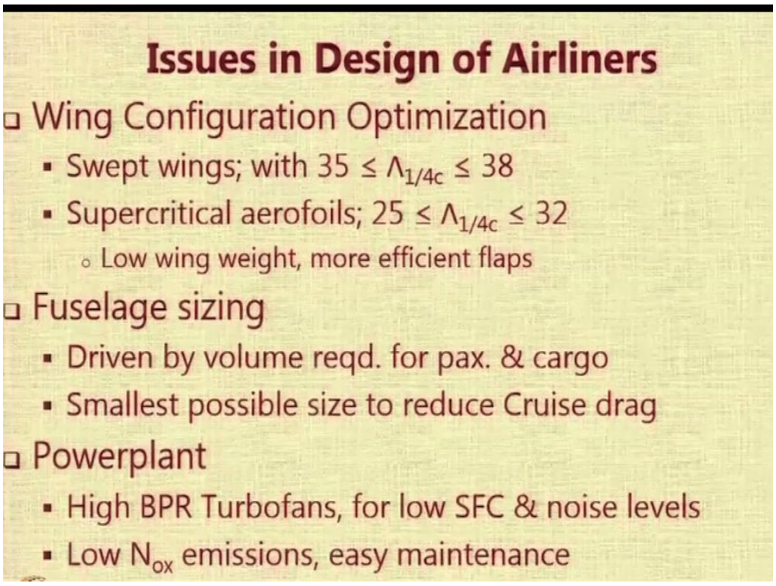

Let us look at some key issues in the design of airliners okay. First of all, the wing of a transport aircraft or an airliner is subject to large amount of optimization okay and why is it so many people wonder, but all airliners whether they are from Boeing or Airbus, they look very much alike because both of them have been subjected to the same amount of optimization, similar requirements and similar objective.

So independently, they have come up with solution which have arrived from various are very similar. There are certain variances of course and it will be interesting for students to actually be given as exercise to identify totally different approaches and totally different solutions to meet the same requirements, but in transport aircraft of this particular type you will find most of them have certain common features. What are these features?

The wings are swept in most of these cases, but the range in which the quarter chords sweep that you will observe will be between 35 and 38 degrees mostly okay. Now some of them might use supercritical aerofoils which allow you to obtain the benefits at a lower sweep angle okay and also when you sweep less you can get more efficient flaps and lower wing weight. So, this is one thing.

So most of the aircraft in this category airliners which fly near transonic speeds, Mach number of around 0.8 they are going to have swept wings with a sweep in a very small band or supercritical aerofoils allowing it a little bit lesser sweep. The sizing of the fuselage is actually not a very difficult task. So fuselage is basically going to be almost like a cylindrical body with some nose and some tail.

The nose is required to put the cockpit and to put some instrumentation and some features in the front and the tail is required essentially to accommodate things like the APU, some amount of baggage maybe and adequate length and conical taper to allow the distancing of the tails okay to provide sufficient moment arms. So the fuselage design is subjected to volume and for passenger and cargo whatever the volume required.

And what we want to do is we want to make it as small as possible to reduce the cruise drag. When we come to the powerplant all of them have generally a high bypass ratio turbofan aircraft because these give you lower SFCs and lower noise levels and also lower emissions, especially the Nox emissions, and easy maintenance okay.

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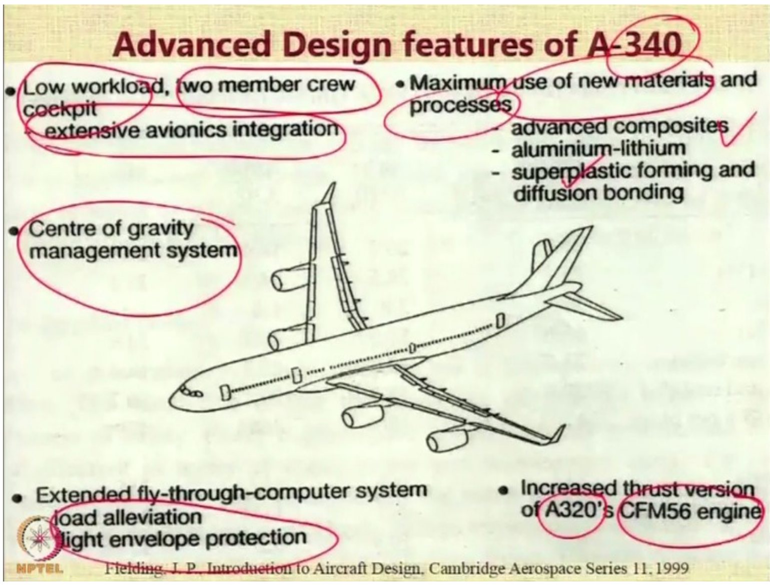

One example I would like to show you. This has been taken again from the booklet of Professor John Fielding, about how some advanced features have been provided in a transport aircraft to address particular requirements. So this aircraft for example is one of the aircraft which has come with two member crew. This is now standard, but when this aircraft appeared in the market, it was one of the first aircraft that came up.

Before this we had aircraft like Boeing 747 older versions which had a pilot, a copilot and a flight test engineer or navigator. So the cost of the crew has come up because the workload is low. So you have a low workload cockpit, so you can manage with 2 people and this was possible by extensive avionics integration. This is an example of how technological developments drive the requirements.

Earlier people were happy to, customers were happy to have the requirement of 3 or 4 people in the cockpit but now it is only 2. This aircraft has got a centre of gravity management systems, it allows it to fly optimally at various conditions and there is a flight envelope protection and load alleviation by automatic deflection of the control surfaces to handle the gust loading and this is possible because of the extended fly-through-computer system.

On the structure side, the designers have gone for use of new materials and processes okay, composites and superplastic forming and diffusion bonding and also aluminium-lithium alloys. On the power plant side, they have been installed with the CFM56 engine which gives you the, so it is an old engine which was on Airbus A320. It has been enhanced to power the A-340. We will come again to this aircraft in the future because there are certain other additional features that I will discuss.

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Now let us look at some trends in the design of airliners, especially let us look at families and commonalities. Now just like we have families in our own personal life, we also have families in aircraft design.

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Now what you do in families is basically you design a baseline aircraft and then you meet the changing market requirements or provide a competition to another existing aircraft by stretching or shrinking the aircraft okay. So what you mean by stretching and shrinking, basically by inserting and removing the fuselage plugs, you could also do it by changing the engine or by increasing the thrust of the same engine to meet a requirement.

There are many, many examples of this in the Airbus and the Boeing stable which we will see very shortly. The aim of this exercise is to ensure that every aircraft which the competition makes available there is an equivalent or similar aircraft in your stable, so you give the airline a choice that if you want to beat that aircraft in the competition, here is our solution to that particular problem.

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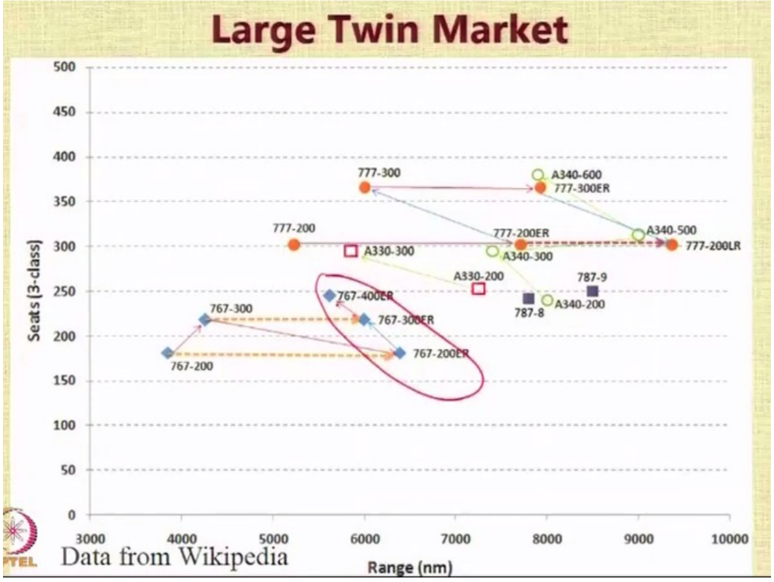

You can see for example if you look at the large twin market okay, twin engine aircraft you can see, for example you have 767-200 which was for this particular range and this particular capacity and it has been stretched and again you know and again. Similarly, you know you have this family.

Similarly, you have another family of the Boeing 767 family where you are just reducing the range by or I would say the other way you are increasing the capacity by putting you know, sorry you are changing the market requirements. Let us look at this in more details as you go ahead.

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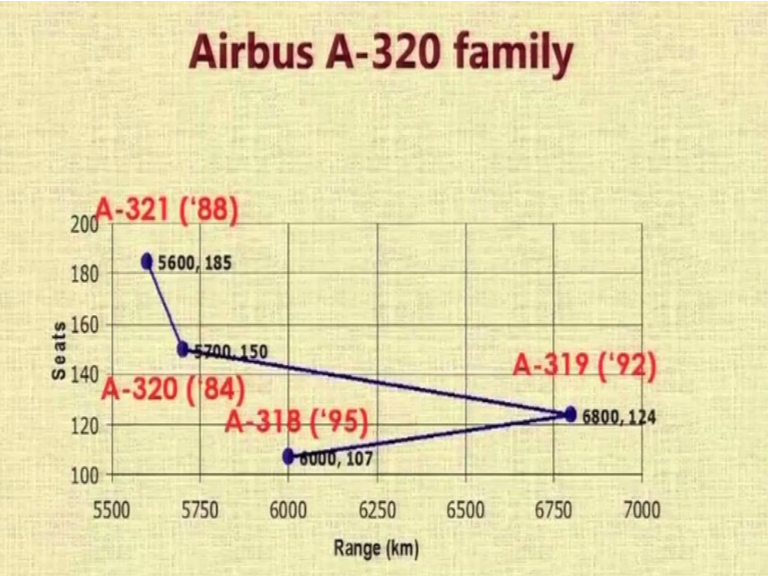

Let us look at the Airbus A-320 family. This is a very popular family worldwide. It started with Airbus A-320 the base aircraft which came in 1984 okay, right. It had 5700 kilometers range and it has a capacity of around 150 passengers. Then in 1988, 4 years later the A-321 was made available with a larger capacity but a 100 nautical miles smaller range. After that we had the A-319 which was a best version as far as the range is concerned.

But a shrunk version as far as the capacity is concerned, 6800 kilometers and 124 passengers. This is one way of fighting the long range regional aircraft and then here is another example of A-318 which came in 1995, here the range was reduced to 6000 kilometers and the capacity was brought down to 107 kilometers. So the same basic aircraft is serving 4 different markets by using the family concept.

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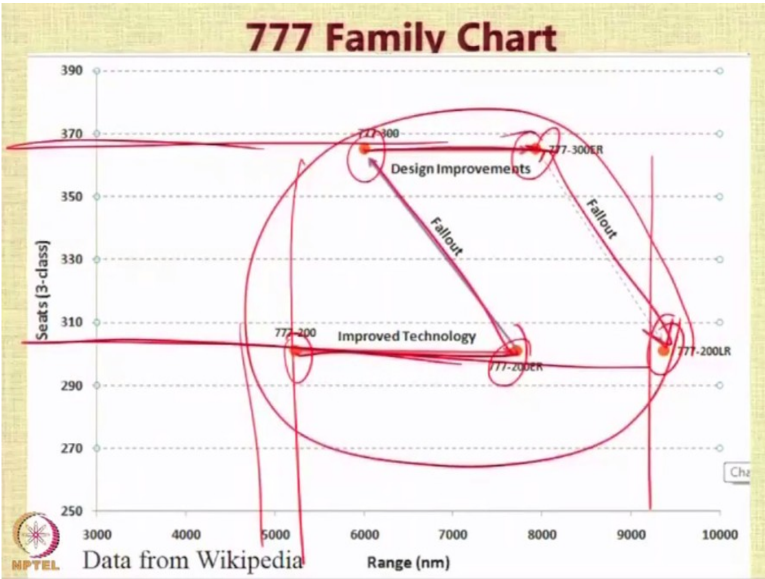

Similarly, you have the triple 7 family chart where you go from you know one aircraft to the other and then this one to the other and then there is a kind of fallout and there is also a fallout aircraft. So you can see 4 different markets, I would say 5 different markets are being addressed. So one aircraft is actually able to handle such a large range of capacity and range by stretching and shrinking.

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There are also some commonalities in airliner design and this is very interesting. Interestingly, you will notice that in the Boeing stable the Boeing 707 fuselage cross section continues to be used for further aircraft with minimal change. In the case of Airbus, we use the same wing for the two aircraft, the twin engine Airbus A-330 and four engine Airbus 340, they both have almost the same identical wing.

This leads to lower manufacturing cost and commonality in service okay and in operation there are commonalities possible using what is called as a cross crew qualification in the Airbus aircraft okay.

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You can see for example here that you know there is a aircraft called A340 all varieties within a day, the pilot can convert to flying A330 and from 330 to A340 it takes just 3 days.

These are large aircraft. Now if you have a pilot qualified for 340 and 330 and you want that pilot to operate smaller aircraft, it is a matter of just 11 or 15 days you can convert them okay and then 380s they are same, will also have a similar operational advantage.

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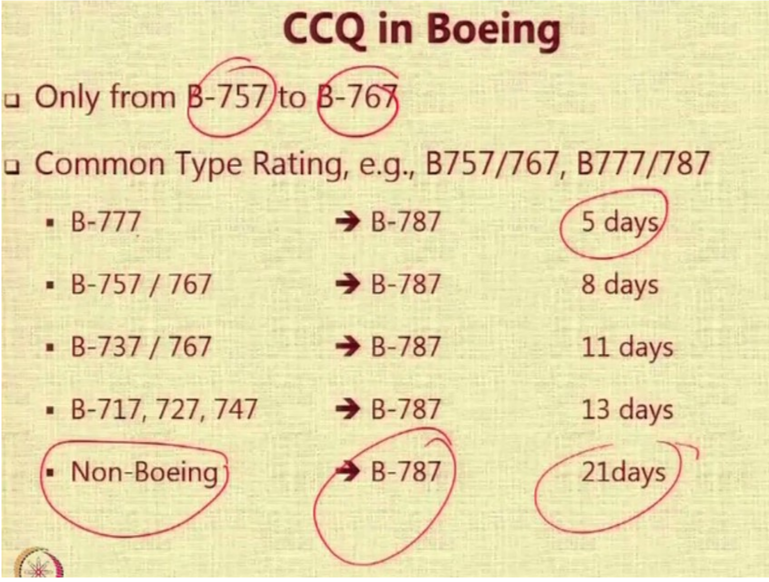

Boeing also allows okay. Now commonality is available only between Boeing 757 and 767 seven five seven and seven six seven. So from 777 to 787 you can go in 5 days, but notice here from a non-Boeing aircraft, basically it means an Airbus aircraft to 787 you require 21 days of training. So commonality is also there in both the companies.

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Here is a cockpit or the flight deck of Boeing 787 okay, a very modern cockpit and a similar configuration you will see now in the future Boeing aircraft.

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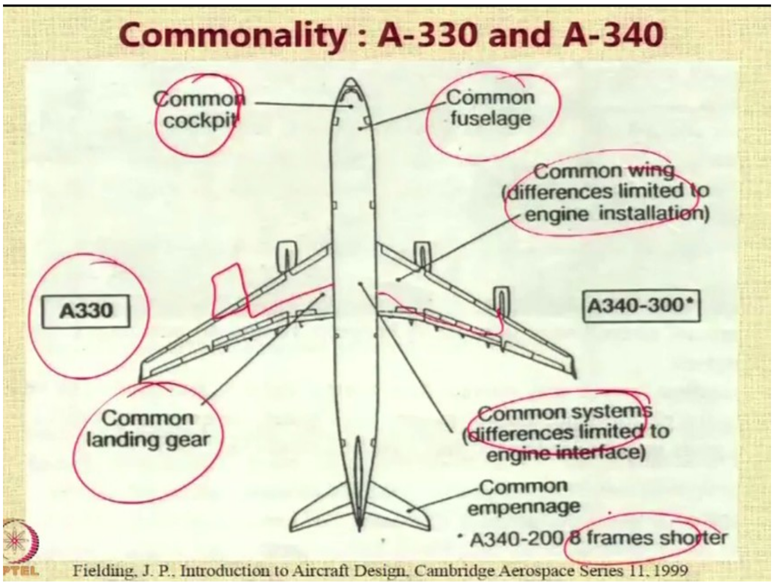

And here is an example of commonality. In fact if I draw a line here, on the left hand side you have A330, on the right hand side you have A340 one of the versions. Both of them are having a common wing platform okay and one side you see a single engine because it is twin engine, on here you see two engines because it is four engine, but they have a common cockpit. They have a common cockpit, common fuselage, common landing gear, common empennage or tail, common systems and common wing.

The only difference is in the fuel piping, you know the piping that will go the fuel to the engine here, but for that it is all common. And from Airbus A340-300 to Airbus A 340-200 you have 8 frames shorter and you get when you workup to meet the market okay.

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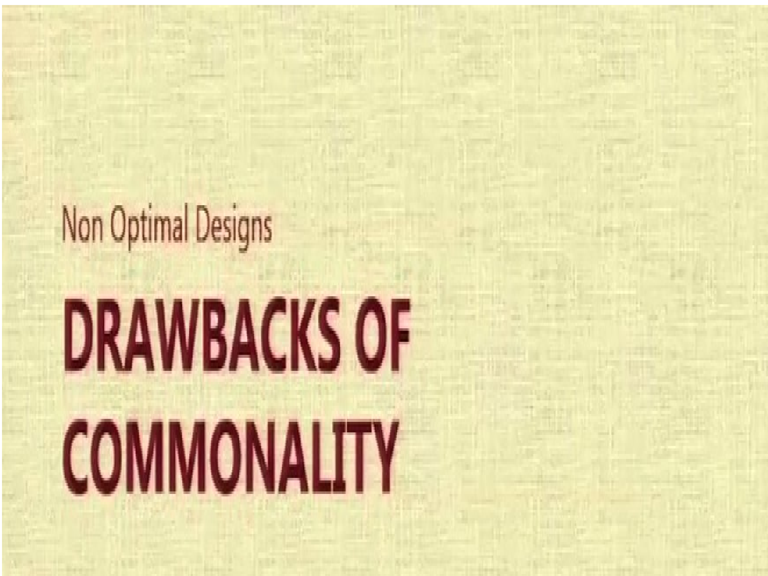

This commonality does not come without a cost. It is good to have commonality, but here is one assessment by Professor Scott Eberhardt about the drawbacks of commonality, the result is non-optimal design.

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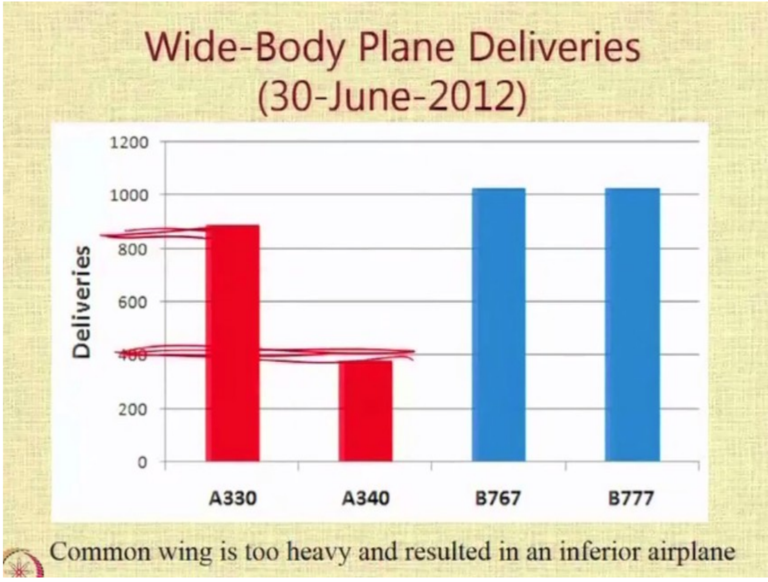

For example, if you look at the deliveries of Airbus A330 and 340 as compared to 767 and 777 you notice that 330 sold quite well. Any aircraft that sells around 400 units typically just is able to recover its market. This is for a new aircraft of course, 330 and 340 are not new aircrafts, but you notice that 767 and 777 have around as on to 2012, they had around 1000 aircrafts being sold compared to only around 850 and 400 for 330. So common wing is good but too heavy and it resulted in an inferior airplane okay.

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Look at the loss in sales. What you saw earlier was loss in numbers, this is the loss in sales. So compared to 767 and 777, 340 have around ten 100 billion dollars loss in the sales and consequently we noticed that there is no new order. So commonality is good, but commonality can lead to serious financial considerations also. Thanks a lot.