Introduction to Aircraft Design
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Lecture - 31
Choices in Aircraft Layout

Let us have a look at what are the various choices available to a designer while deciding the aircraft layout. Remember that the word aircraft layout in aircraft design basically means the relative location of various components as well as the nature of these or the shape and size of these components. So, what is the objective of aircraft layout assuming that the aircraft that we are designing has major components like the fuselage, the wings, the tail planes, the engines, the landing gear etc.,

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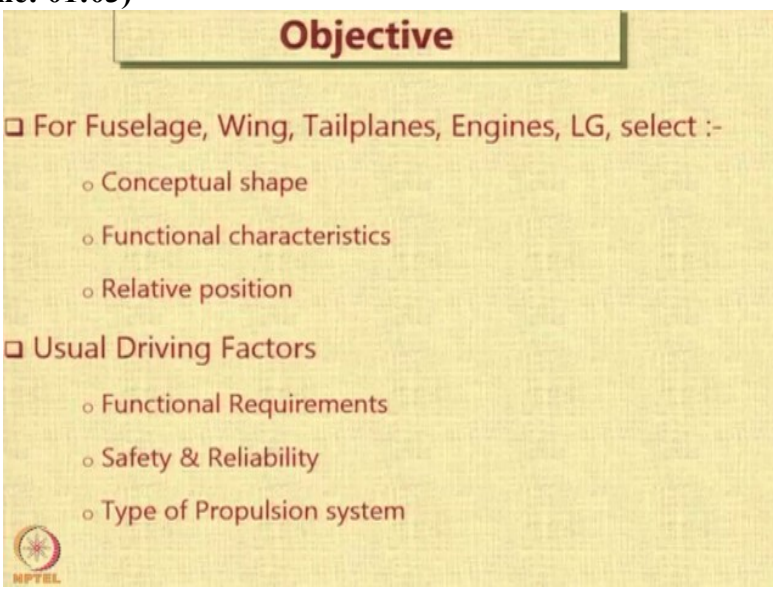

The main task of the designer, while deciding the layout is to look at the conceptual shape of these components. Look at the functional characteristics which they have to possess and also the relative position with respect to each other. Now, there are a few driving factors which generally affect the choice of layout of an aircraft. There are also some special driving factors which we will see separately.

So usually the functional requirements decide the layout. This is the most important thing after that, one can always attribute selection of a particular layout due to safety and reliability considerations. And sometimes, the layout is a function of the type of the propulsion system which is used by the designer. So these are the 3 principal driving factors, which decide the layout.

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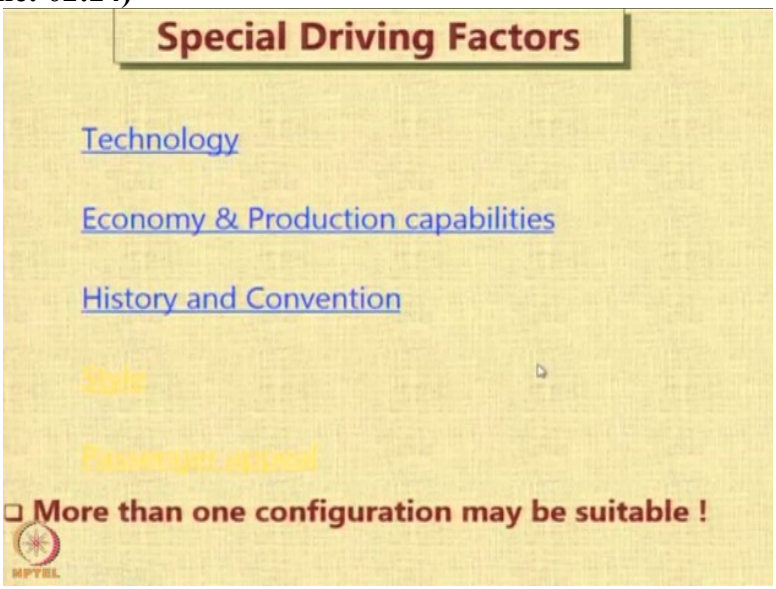

But there are many examples where there are certain special driving factors, which have decided or affected the choice of the layout. Let us look at a few of them. But sometimes there are certain special driving factors which are not very much obvious. So, let us have a look at a few of them. Availability of technology is one such factor. For example, let us have a look at this very challenging aircraft.

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This is the F-22 Raptor the design that we are bringing to this computer systems is vector capabilities of some 20 degrees up and down from straight back hour and that was 1 maneuver deck and sure do it. There is not expecting to just go you know what G force a G is we stand right here in the ground with 1 G, you have ever been in an elevator and that made that second start?

Well, you are wanting probably the subject of about 1 and a half G's make it kind of bend your knees a little bit well imagine what 5 to 6, 7, 8, 9 G's speed of light this router coming around out to actually squeeze you out of the air.

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So, we had a look at F-22 raptor, several technologies which were developed in this particular project are now fairly standard and because they are available, you know, there can be driving factors, the economy and the production capabilities available are also a driving factor in choosing the layout there we see the whole process of assembling the aircraft is along a production line. Sometimes the layout is decided purely by history and convention.

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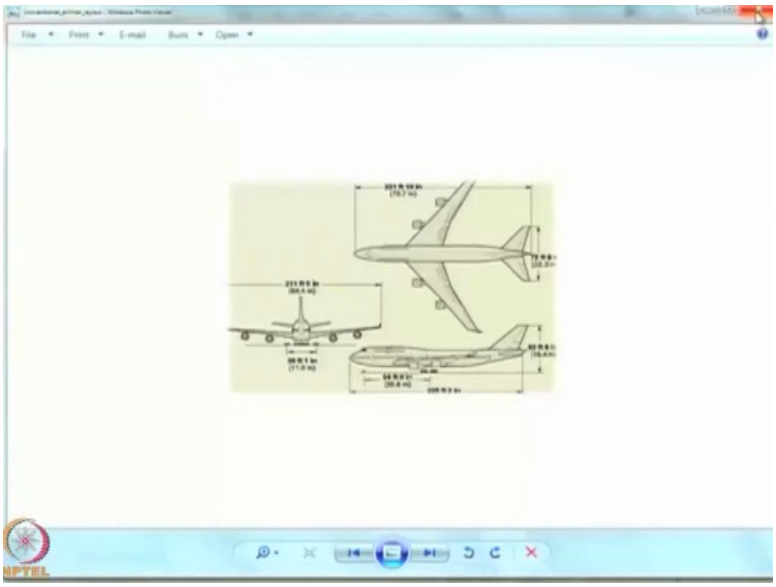

For example, for instance, this is a typical configuration which has become fairly standard as far as airliner is concerned. This is the conventional layout of an airliner which was perfected by the Boeing aircraft company. And then, firstly, in the Boeing 707, but then it is now fairly standard and almost every airliner that you see has a similar configuration. It has wing mounted engines, a conventional tail configuration on the back and the wings are mounted on the lower side. Sometimes the layout is decided purely by stylish considerations or by style.

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For example, let us have a look at this very stylish aircraft called as the Mooney acclaim. This aircraft is meant for private use. So you can look at the interiors. It is an acclaimed model type S. But there are certain features in this aircraft which are outstanding. For example, I just have a look at the design of the vertical tail. You will notice that the leading edge of the vertical tail is straight and the trailing edge is actually in a way swept forward.

Now this is a style statement from Mooney Aircraft Corporation. There may not be any scientific reason for that this is very clear in this particular figure. As you can see, the tail has a very distinctive feature. And this distinctive feature of the tail is basically a style statement from this company, which wants to distinguish itself in the market of general aviation aircraft, they want to stand out and they are making a style statement. So, this is an example of how style can dominate aircraft design.

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Then there are sometimes design considerations which are driven by passenger appeal.

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Here is an example of a very interesting aircraft, which is completely different from the other aircraft of its category. This is the beech starship the looks of the aircraft are completely unconventional. This is also a general aviation aircraft. So first thing that strikes is the canard in the front then you see that the wings are mounted behind in a striped fashion with twin vertical tails on the back. Now, interestingly, this aircraft appears to be a high speed aircraft by the shape, but it is actually driven by you know 2 turboprop engines.

So it is a turboprop engine aircraft, but the looks and the feel are that of a high speed aircraft. So, this is driven by passenger appeal. Here the attempt by the designer is to provide a shape that stands out makes a style statement and looks completely different from anything else. Now, unfortunately, this aircraft was a technical success, but the commercial failure it did not sell very well. But it all was it was considered to be a very appealing aircraft to the eyes and always drew attention.

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So, like that, some configurations are driven by appeal. Another interesting point that we should keep a note when we do aircraft design is that for the same requirements more than 1 configuration may be suitable. So in aircraft design, there are no fixed answers, there is no unique answer. There could be multiple solutions to address the same requirements. And one could argue that each of them has its own distinct features.

And those features make it suitable or desirable. So whenever students are given an aircraft design problem, it is quite possible that different teams will come out with totally different looking designs. Let us also look at what happens in real life. For example, here are 3 strategic bombers, almost, which appeared at almost the same time.

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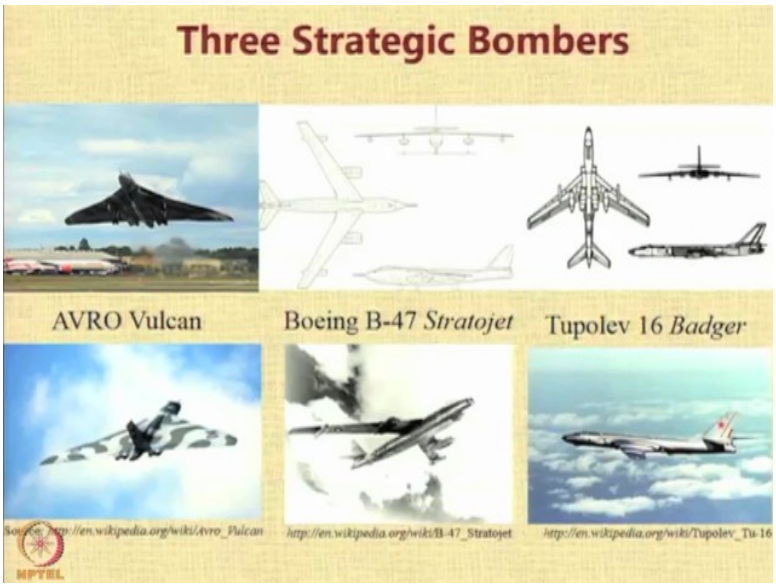

On the extreme left is the flying wing configuration of AVRO Vulcan bomber. In the middle, is the Boeing B-47 stratojet, which is a conventional configuration with a highly swept wing. This is from the American designs table. On the right, is the Tupolev 16 Badger, which is a solution to the same problem by the Russians. So we noticed that to meet the same requirement or almost similar requirements of a strategic bomber.

We have the Britishers coming up with a flying wing Vulcan. The Americans coming up with highly swept Boeing B-47. And similar but a little bit different looking configuration with the engines mounted on the root of the Tupolev 16 badger.

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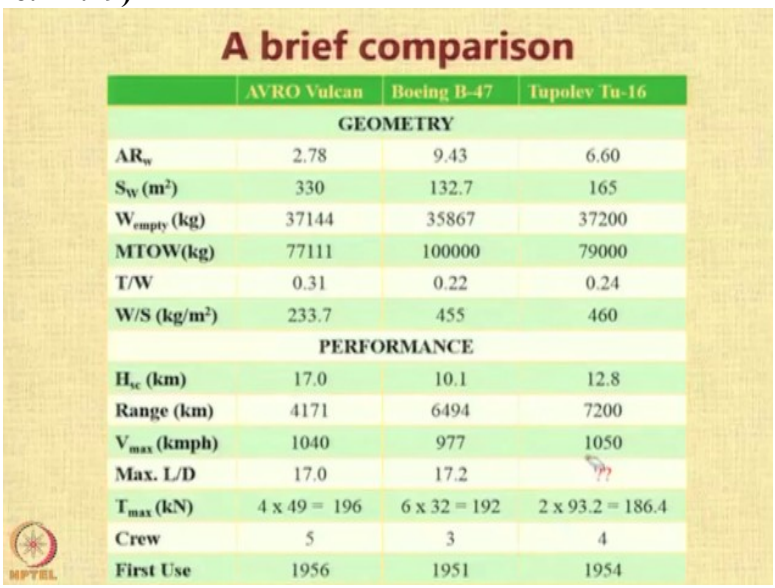

	AVRO Vulcan	Boeing B-47	Tupolev Tu-16
GEOMETRY			
AR_w	2.78	9.43	6.60
S_W (m^2)	330	132.7	165
W_{empty} (kg)	37144	35867	37200
MTOW(kg)	77111	100000	79000
T/W	0.31	0.22	0.24
W/S (kg/m^2)	233.7	455	460
PERFORMANCE			
H_{tc} (km)	17.0	10.1	12.8
Range (km)	4171	6494	7200
V_{max} (kmph)	1040	977	1050
Max. L/D	17.0	17.2	??
T_{max} (kN)	4 x 49 = 196	6 x 32 = 192	2 x 93.2 = 186.4
Crew	5	3	4
First Use	1956	1951	1954

Let us have a look at a comparison of the geometry and the performance of these 3 aircraft. So we notice that the numerical values of various design parameters are quite different. But interestingly, the lift over drag ratio or the L over D ratio is the almost the same for a B-47 as

well as for the AVRO Vulcan, for the Tupolev Tu-16 we do not have a value so we do not know you can see they were all designed almost at the same time 1956, 1951, 1954. But they look so different and that is because different designers came up with different solutions.

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Similarly, that is 1 example in the recent history of an advanced tactical fighter, which was essentially an air superiority fighter, a replacement for the various versions of the F-15 aircraft. The requirements specified were to use advanced alloys in the construction along with composites to provide a feature of fly by wire and stealth. This competition was launched in 1986 by the US Department of Defence and 2 consortia locked into a battle.

There was 1 consortium; consortium consists of Lockheed, Martin Boeing and general dynamics. Their design was called as the YF-22. And on the other side, there was a partnership between Northrop and McDonnell Douglas and they had a configuration called as YF-23. After about 5 years of rigorous design review, the winner was declared in 1991. The first aircraft was delivered 9 years later in 2000, but within 7 years, 100 aircraft were delivered and this is some information regarding the cost of the aircraft. Now, the question is who was the competition from the Russians table for this aircraft?

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The competition was the Sukhoi 27 aircraft.

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And to compete with this aircraft, the 2 competing designs for the advanced tactical fighter of the US Air Force on our left is the YF-22 and on the right is YF-23. So, you can notice that the 2 designs are quite distinct there are some common features also. The YF-23 for example, has a diamond shaped wing whereas the YF-22 which ultimately won the competition and through that we have got the Raptor F-22 was more of a delta configuration platform.

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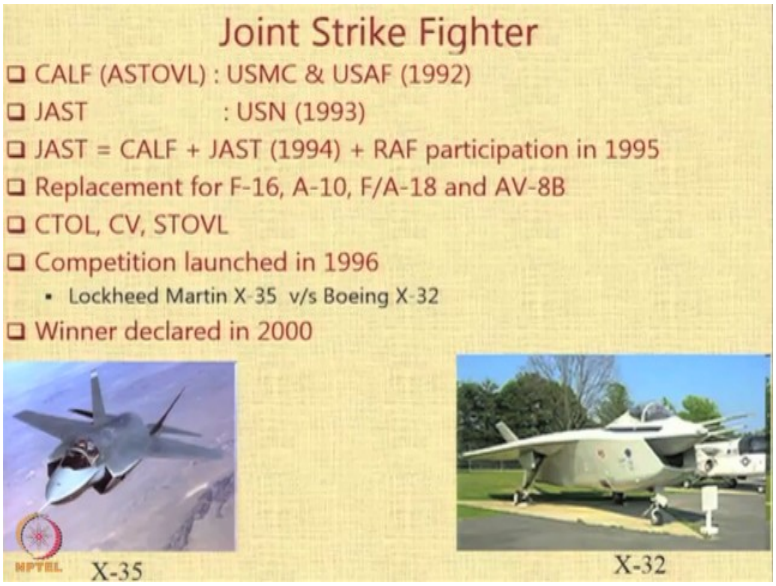

Similarly, there was a competition recently on a Joint Strike Fighter Aircraft. So this particular aircraft was it has undergone many, many variations. US Marine command and US Air Force gave a requirement for an ASTOVL in 1992. Then there was a US Navy joined hands next year. And their craft was called as JAST. In 1995 The Royal Air Force of UK also said that we are interested in the same aircraft. So then it became a multi country project, it is supposed to replace 4 different aircraft. That is why it is a multi role aircraft.

It is supposed to replace F-16, A-10, FA-18 and AV-8B harrier. So if it wanted to have a conventional takeoff and landing facility, and also a short takeoff and landing ability. This competition was launched in 1996. And Lockheed Martin came up with X-35. And Boeing came up with X-32. After 4 years, we had another we had a declaration of the winner. And that winner was X-35, which is now in production.

But you can see a totally different looking aircraft with a huge intake mounted below the fuselage was the configuration suggested by the Boeing aircraft corporation. So Boeing and Lockheed Martin competed for the same requirements and came up with totally different configurations. This particular competition has been very nicely filmed in a documentary called as the Battle of X Planes, and I recommend that this documentary should be shown in the class as part of the course because many interesting features about this 2 aircraft and their designs have been explained very nicely in this documentary.

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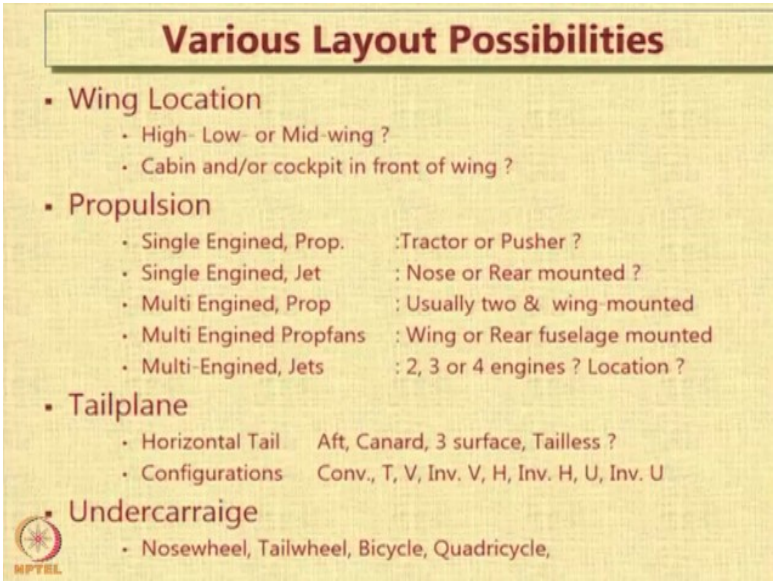

So when you look at the layout of the aircraft, you have various possibilities. First, let us look at the possibilities for the layout of the wings should we go for a high wing that means the wing mounted over the fuselage, should we go for a low wing, the wing mounted below the fuselage or should we go for a mid wing should the passenger cabin and or the cockpit be located ahead of the wing in the middle of the wing or behind the wing.

So, when we come to propulsion, we have a large amount of choice depending on which power plant type we use, and how many units of power plant or how many engines do we provide. If we choose a single engine propeller driven aircraft, we have a choice between a tractor or a pusher configuration. A tractor is a configuration in which the engines are mounted ahead of the aircraft. And pusher is the configuration in which the engine is mounted behind the aircraft.

For example, the beech starship, which we saw a few minutes ago, is a pusher configuration because the engines are mounted behind in that case, we have 2 turboprop engines. Whereas the Mooney acclaim that we saw recently, whereas the Mooney acclaim that we saw a few minutes ago was a tractor because there was a single engine and that was mounted right in the front. If you have a single jet engine, you have a choice of whether you mounted in the nose or you mounted in the rear.

If we have multiple engines on a propeller driven aircraft, usually we go for 2 engines and mount them on the wing. But there are examples of 3 engines and you know other configurations also, if you are using multi engine propfans, generally we go for either wing

mounted or rear fuselage mounted in the pusher configuration. If you have multiple engine jet aircraft, then we have a choice of either, 2 engines, 3 engines, 4 engines, maybe more.

The record is for 8 engines and location, wing mounted, fuselage mounted, tail mounted or at multiple places for the tail plane, we have again a choice for the horizontal tail, it could be an aft tail or it could be a canard or you can have 3 surface or you can have tailless then in the configurations we have various types which we will see very shortly. You can have conventional tail, T tail, V tail, inverted V, H tail, inverted H, U, inverted U etc.

As far as landing gear is concerned, you could have nosewheel type, tail wheel type, bicycle type and quadricycle type and there are several other types also which are possible. Thanks for your attention. We will now move to the next section.