Introduction to Aircraft Design
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Lecture – 33
Options for Wing Layout

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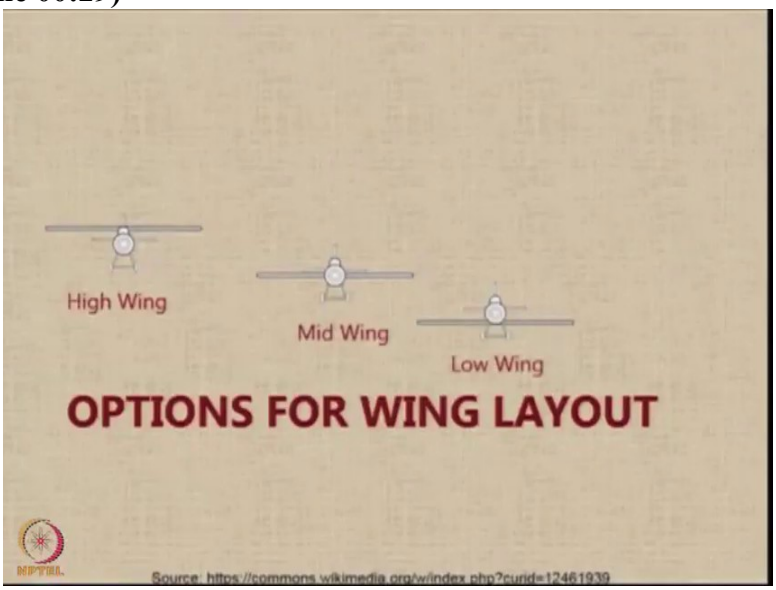

Let us look at the options available for the layout of the wing. Broadly speaking, we have 3 choices; it can be a high wing, a mid wing or a low wing. Each position has its own advantages and disadvantages which we will now look into.

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So, these are the images of some famous aircraft which have these configurations. The high wing configuration shown here is the Dornier 228 dash 212 aircraft which was produced under license by HAL Kanpur.

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Under the low wings, we have a look here at the Airbus A 380 dash 100 aircraft. And for the mid wing the example chosen is that of the RAFALE aircraft which is being procured. Let us first start by looking at the benefits of high wing layout.

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The first and foremost benefit of a high wing layout is to permit ease in loading and unloading of cargo because the wing is mounted above the fuselage; hence the fuselage height tends to be low. This is a very good example of a military cargo aircraft.

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This is the C 5 galaxy aircraft and let us have a look at how it is used to load and unload heavy cargo. In this clip, we see a large number of items being loaded onto the aircraft. We see a helicopter, with its rotor blades, C5 galaxy aircraft can handle 2 large abrams tanks, several of these jeeps and a huge amount of cargo. All of it can be easily loaded because of the ramp configuration given on the rear of the fuselage and you can see when you move in

these heavy items, we tie them down onto the floor of the aircraft with the some anchors which prevent relative motion of these items when the aircraft is operating.

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So, all military aircraft, which are heavy cargo, generally have a high wing configuration and a very low floor of the fuselage.

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One more advantage of a high wing layout is that you can build the whole wing in one piece and then put it literally over the fuselage, attach it with some bolts and you can externally support it by using braces such as the one seen in this aircraft. So, this gives a huge structural advantage and results in a light weight structure.

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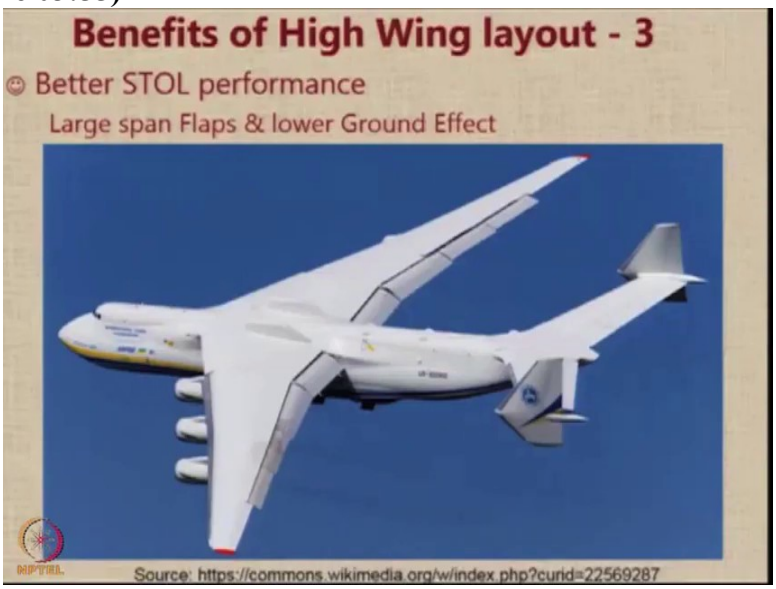

The third benefit of a high wing layout is to allow better short take-off and landing performance, because we have a huge uninterrupted wing mounted over the fuselage, you can have flaps over a much larger span and since you are away from the ground, you will also be

able to have lesser ground effect. Ground effect is useful when you have take-off, but it can be detrimental when you come for land. So, in a high wing, since the wing is far away from the ground, you have a lower ground effect and hence you have a better stall performance.

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There is a fourth benefit of high wing layout which is to give better rough field performance. by rough field performance we mean operating the aircraft from runways and airports which are not paved and properly maintained from grassy lands etc.

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Let us have a look at a video which shows us the versatility of this aircraft called Twin Otter. This aircraft is being operated from a farm from a field in a farm. And as you can see, as the aircraft comes into land, there are a large number of bumps which the landing gear has to encounter. And because of that, a lot of mud and dirt is thrown. A high wing is very useful, because in a high wing configuration, the wing is far away from all this dirt, clouds which are being thrown up.

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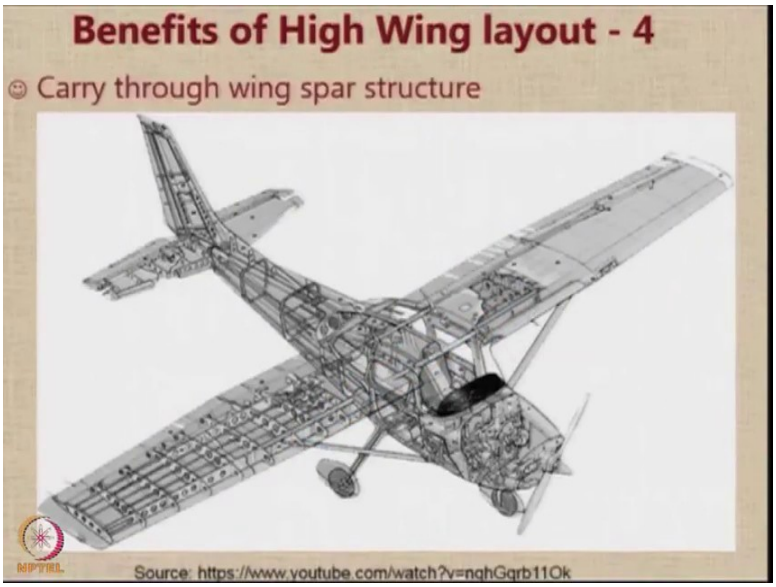

This is an example of the mounting of the high wing, you can see that you can have a through and through spar. As you can see here, the spar can be through the rear spar and this is the front spar. Both can be through and through. And that leads to tremendous structural advantages.

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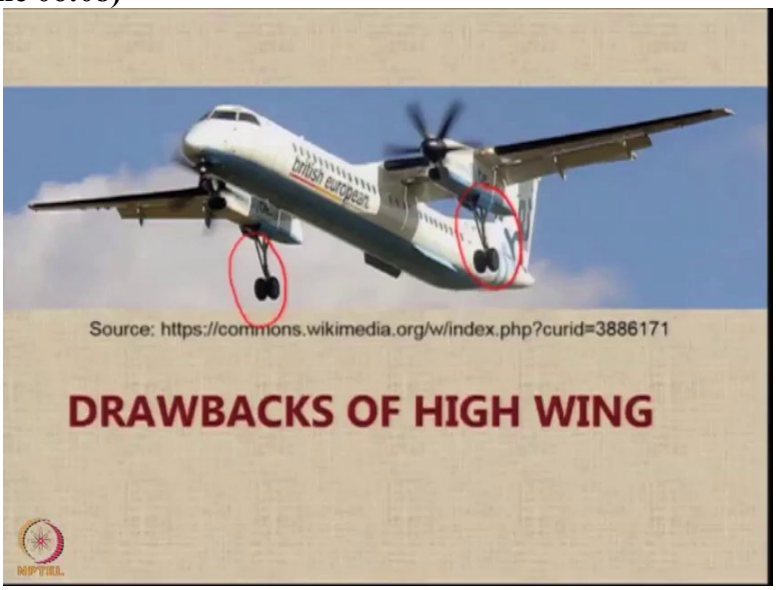

Now high wing also has some drawbacks. One drawback is visible in this aircraft, you can see the landing gear of the aircraft is mounted below the wing mounted engine Nacelle, but you can see the landing gear is very slender. In most high wing aircraft, you do not have the option of mounting landing gear like this; we will have to mount them on the side of the fuselage, which leads to its own problems.

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One serious issue of concern for a high wing is poor visibility of the pilots especially when they go into turning and climbing flight. As you can see here, the port side view of this pilot is obstructed to a large extent by the presence of this particular wing structure. Now, special features have to be provided in the aircraft. For example, you can see in this aircraft, they have actually created a cut in the wing at the root and on the top of the fuselage canopy.

That is actually a perspex covering and this perspex covering is enabling good view. So, it is claimed that in this particular aircraft called Zenith 701 there is a very good forward and downward visibility available to the pilot and also a little bit of sideward visibility because the wing is having a special kind of a configuration. But what it shows us that certain special features have to be provided in the aircraft to increase its visibility during turning and climbing flight if it is a high wing layout.

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Another drawback of the high wing layout, which I discussed a few minutes ago is also due to the landing gear being heavy, the landing gear is heavy because the landing gear cannot be mounted always on the wing, you can see the landing gear is mounted here along the side of the fuselage, you need to have a sufficient amount of wheel track for stability in the ground motion.

And therefore, you need to take the main landing gear wheels little bit out and that leads to the need for providing this particular blister in the landing gear. So, these blisters are the ones that you know create a lot of drag. So, while they are on the ground, you can see that the landing gear is visible.

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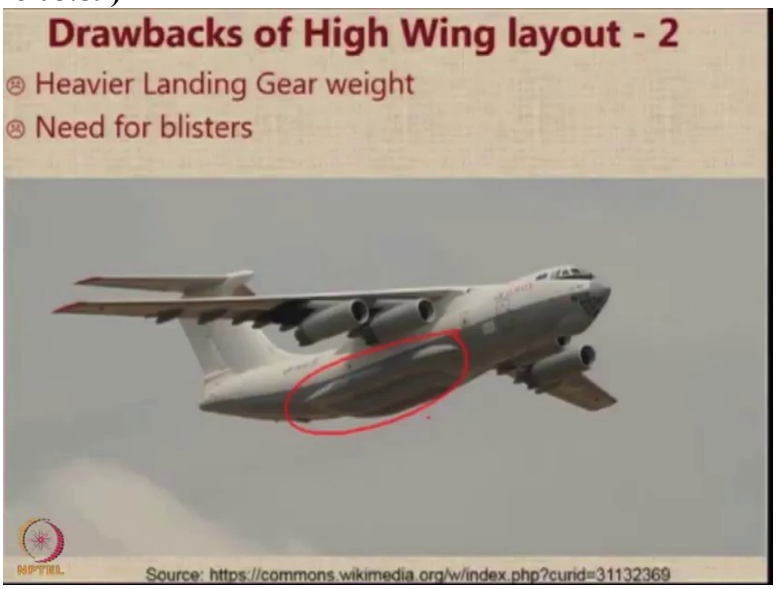

And when the aircraft takes off and the landing gear is retracted, there is a requirement for these large blisters on the fuselage and these blisters create additional drag and also additional weight.

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Let us move on to the mid wing layout. The mid wing layout is a layout in which as we can see in this Piper PA-60-600 aerostar the wing is mounted in the center of the fuselage.

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Now, the most important advantage of a mid wing layout is the aerodynamic advantage. A mid wing aircraft has the least interference drag and also it has neutral stability. These parameters make it the configuration of choice for all aerobatic aircraft in most fighters and aerobatic aircraft, we observed that we go for a mid wing layout.

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However, a mid wing layout leads to a restriction on the design of the carry through structure and the spar because in normal circumstances in a mid wing aircraft, the spar carried through structure will go through the fuselage and that will create a lot of trouble or the disturbance in the passenger cabin. One solution for such a problem is to have a configuration in which the entire passenger cabin is ahead of the wing such as the one in this Hansa jet aircraft.

In this aircraft as we can notice, the mounting of the fuselage and the wings structure is behind the passenger cabin. This is a 10 seat business jet aircraft. So the passengers are seating ahead of the wing.

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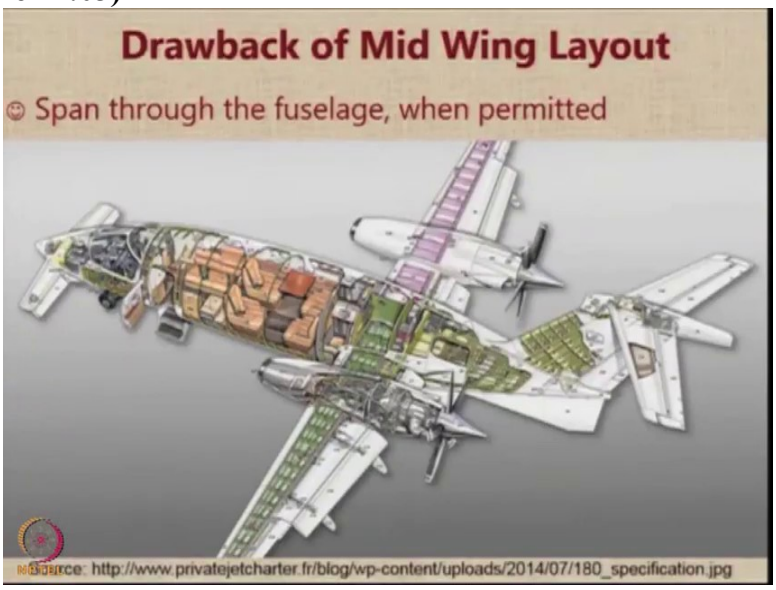

Another example of this configuration is the Piaggio P 180 avanti aircraft, where you can see clearly that the passengers are sitting in front of the wing and you have a carry through structure of the wing giving it sufficient structural rigidity. So, when you can go for such kind

of carry through structure, then mid wing is possible. But apart from these 2 examples, there are very few aircraft which actually have a mid-wing configuration for a passenger aircraft.

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Finally, we come to the low wing configuration such as the one in this spit fire aircraft. The first benefit of a low wing layout is that it leads to lower structural mass and this becomes extremely important and relevant, when we look at large transport aircraft such as the airbus A 380 or the Boeing 787. In these aircraft, it has been shown that lowing configuration leads to the least possible structural weight.

Here is a photograph of the attachment area of the wing onto the fuselage for an airliner you can notice that there is this huge structure and a low wing configuration actually allows you to have an uninterrupted passenger cabin located above the wing.

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This is another photograph of the same aircraft which shows the 2 wings being brought in for assembly at the location.

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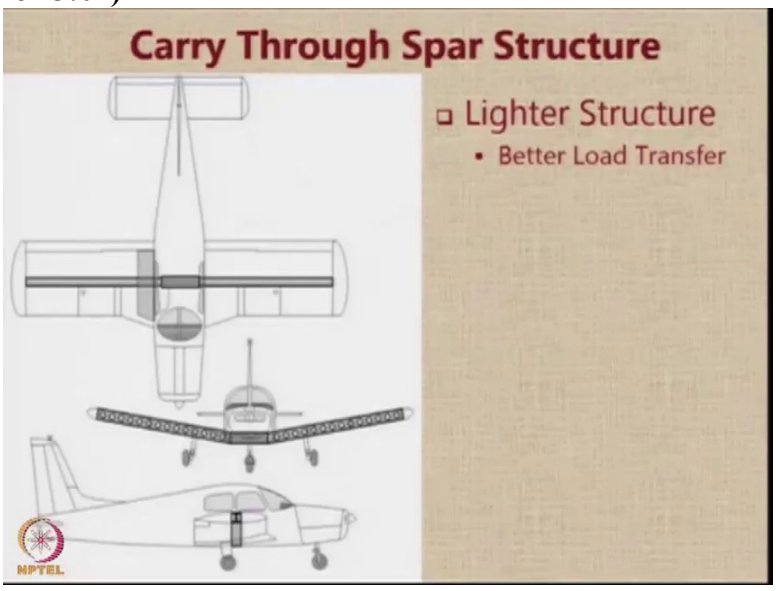

In case of a loading structure as I mentioned, you are able to provide a carry through structure and through a carry through structure for the spar, you have a better load transfer and you have a lighter structure. As you can see in this figure, the whole spar actually passes through the wing and the fuselage joint uninterrupted.

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One more benefit of the low wing layout is it gives you additional safety during accidents. In case there is a bad landing, in which let us say the landing gear is crumpled or there is a tyre burst. Or as in this case, when you see for a JetBlue aircraft there was in a locked nosewheel and it was actually turned sideways. And when the aircraft came in to land, the nosewheel tyre actually was so hot that the nosewheel caught fire.

Now, if we were looking at a high wing configuration for similar accident, the fire would have immediately reached the passenger cabin and caused grievous harm and injury to the passengers. We see in this figure, how the wing of the aircraft is actually coming as a protective layer in between the disturbed and the damaged portion below and the passengers in the cabin. So, from passenger safety point of view, low wing is something that comes in between you and the mother earth in case of an accident during landing.

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A low wing configuration also allows mounting of engines in the proximity of the ground, and hence for the maintenance crew. It is very easy for them to look after the engines or to do the inspection and the maintenance activities such as the case in this photograph of a Boeing 737 dash 100 aircraft.

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But then, when you go for changes in the fuselage length, when you go for upgrades of the aircraft, the same low wing location which gave an advantage of engines nearby become a problem because as in this case, this is an example of the same Boeing 737 aircraft, but now this is dash 600 version the 600 version had more the CFM 36 engines, which were more efficient than the GTA DS which are used earlier in dash 100 and dash 200 engines, but these engines were larger in size.

Now, we cannot change the location of the engine mount so easily because that would require major structural reworking and redesign. So, to ensure that the structural modifications are minimal, the location where the engine is mounted is undisturbed. And hence, if you have to put a larger diameter engine, the only option that you have is to create a non-circular entry you will have to create a flattish bottom so that the minimum distance between the bottom of the nacelle and the ground which is typically

18 inches by requirement can be maintained. So, in a low wing configuration, the benefit of having engines near the ground for servicing can soon become a disadvantage, if you are looking at the higher growth versions of the same aircraft, in which you have to provide such special features and shapes to the engine nacelle to accommodate at the same location.

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Let us look at some other drawback of low wing layout. Since the wing is nearer to the ground, there is a much larger chance of the foreign object being ingested by the engines on the wing and also creating a problem?

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Here is a video of Vampire aircraft which is taking off from a runway and you see very soon when the aircraft engine is Wrapped up to the highest RPM they are you see the exhaust of the jet is actually creating damage to the runway. Now, in the low wing aircraft, this debris from the runway or from any foreign object can create a lot of problem with the ingestion of the debris by the engines or damage.

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So, in the low wing configuration, this is a problem high wing is better you are expecting such kind of disturbances from the ground. Thanks for your attention; we will now move to the next section.