# Introduction to Aircraft Design

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## Lecture - 22
## Aircraft Configuration Design

Hello, let us have a look at aircraft configuration design. This is a very important decision that a designer or a design team has to make regarding the aircraft. And here there are many, many choices available to us. As well as there is a huge room for innovation and change. This particular material, I am indebted to my friend, Professor Bill Mason from Virginia Tech. And I would like to acknowledge his contribution. In fact, most of the material that you are going to see is taken from his notes.

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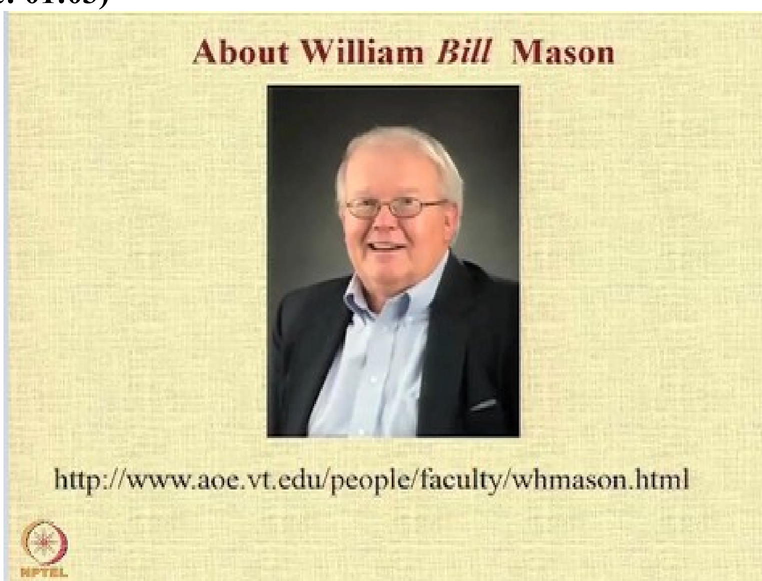


Let us hear about Bill Mason. He teaches aircraft design at Virginia Tech and also is a very established aerodynamicist. Those who want to know about Bill Mason should go to this website. Bill Mason is connected with the collecting and keeping a large amount of data related to aircraft design, several codes, several interesting reports are available on his site. And he was among the first people to make information publicly available on his website.

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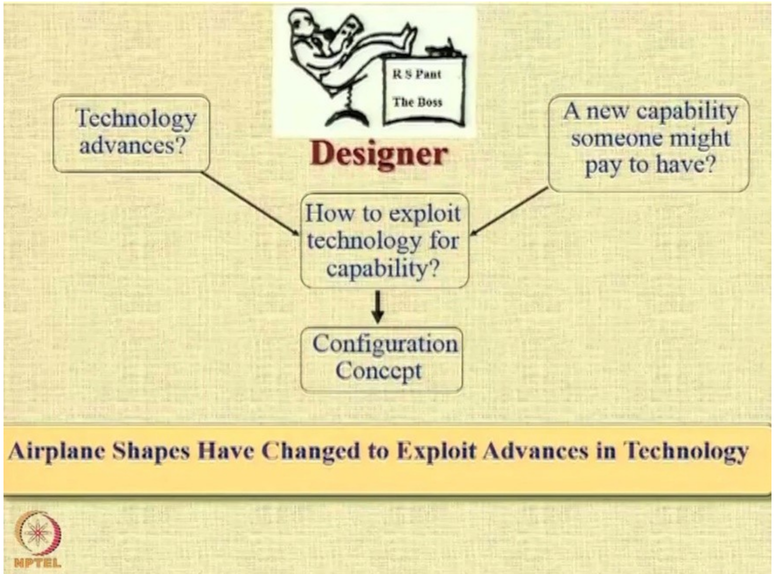


So you have a person who is a designer who is the Chief, he is the boss. And his main area of interest or concern is how do we exploit the technology for generating new capability? Shall we use a new capability that someone might pay to have? Or shall we have a look at the advances in technology and see if we can apply them to meet the customer requirement. So keeping these 2 in mind, the design team I have shown here as an individual but in real life is not an individual in real life, it is actually a team.

They come up together with a configuration concept. And there is an interesting note that shapes of the aircraft have changed over the years to exploit the advances in technology. And this statement will be elaborated in detail in the next few slides.

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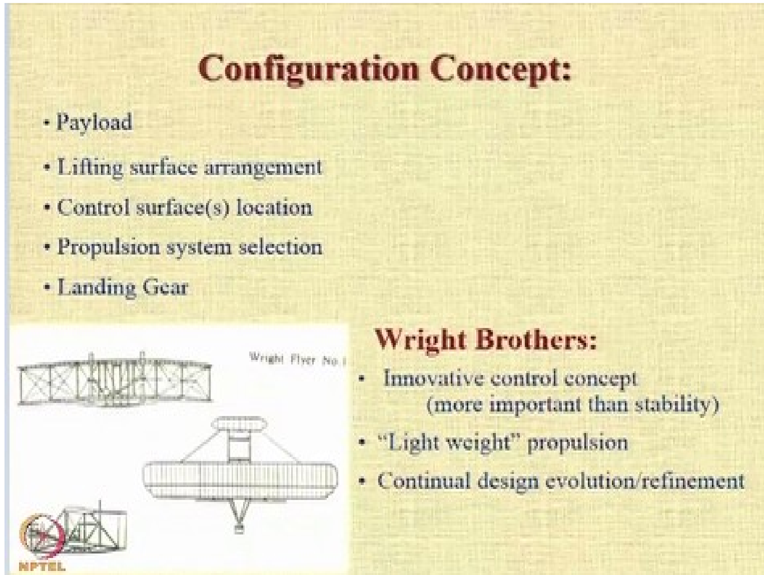


When we talk about the configuration concept, we have to understand that we are looking at how to locate items like the payload. What kind of lifting sources arrangement we need to use? Do we have a control surface or many control surfaces? And what is their location? We have to decide what kind of propulsion system we will use. And we have to also decide if we have a landing gear and what type and roughly what kind of landing gear layout.

Let us start by looking at the first successful aircraft which the Wright brothers had developed. What were the key configurational aspects of this particular aircraft? First is, they went for a very innovative control concept. They were more concerned about control than about stability. So that is why they have used canards. They were very accomplished fliers and they were trying to achieve a milestone and using their piloting skills, they were able to successfully achieve flight.

They were also successful partly because they were able to integrate a very light weight propulsion system onto their aircraft. And their designed was a continual improvement and evolution. It was not overnight.

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Let us look at what are the features of a good transport aircraft and this slide shows one aircraft from the Airbus stable and one from the Boeing stable. They both look quite similar except 1of them is twin engine, the other is four engines. But both of them share some standard good features. First of all, a good transport aircraft has to be aerodynamically efficient. And when I say this I also mean integrating the propulsion system in such a manner that the runway efficiency is not compromised.

And this is achieved by what is called a streamlining. So, a good transport aircraft should be properly streamlined, it must balance near the stability level for minimum drag. If it balances at some other location then the drag is going to be higher because the trim drag which is 1 component of the drag, we will have a look at drag estimation and drag components a little bit later. There I will elaborate this point little bit further. In a good transport aircraft the landing gear must be located relative to the center of gravity.

This should be done in such a manner that the aircraft can easily rotate during the takeoff. Otherwise, the takeoff distance is going to be large or you will need a very large size control surface. Throughout the flight envelope or throughout the height and velocity envelope in which their aircraft has been cleared to operate we must have adequate control authority. So, that there is no chance of the aircraft entering into any area of instability also as we mentioned right in the beginning design is good if it can be built easily and in large numbers.

So, that it becomes affordable and also it should have low maintenance costs. So, that the operating costs are minimized and in modern days and an aircraft has to be a good neighbor. It has to be able to operate in our environment without much disturbance. So, it should be quiet and it should have low emissions. So, these 6 points are the hallmark of a good transport aircraft and the configuration of the aircraft should be chosen to try and achieve a balance in these 6 points.

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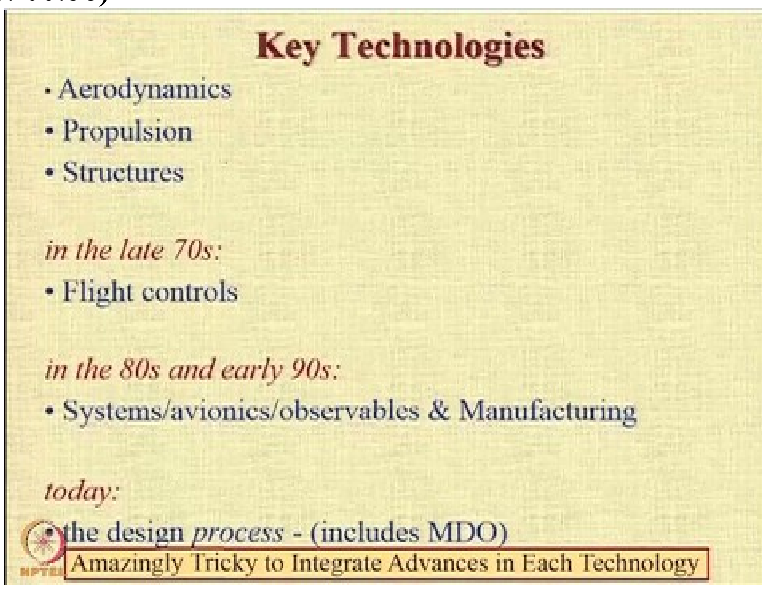


Let us look at the key technologies that are used in designing an aircraft aerodynamics propulsion and structures. These are very well known technologies about these we study. In the late 70s flight controls as technology began emerging as a huge role player. In the 80s and early 90s, we started looking at systems, avionics and observables and manufacturing technology, manufacturing techniques became very important.

And today, the design process itself is a key technology. We have today a technology called as multidisciplinary design optimization which is used to conceive and design the aircraft keeping in mind the interaction between various disciplines and trying to achieve excellence and efficiency right from the beginning. And to do this, the various interactions between disciplines have to be captured.

And hence we have to look at a concurrent approach and that is very well amendable to analysis using the MDO techniques. So, today, aircraft design is mostly driven by the MDO technology available. Now, it is not very easy to integrate advances in each technology into this multidisciplinary environment. And sometimes individual technological developments can cause a lot of problems or issues when they have to be integrated.

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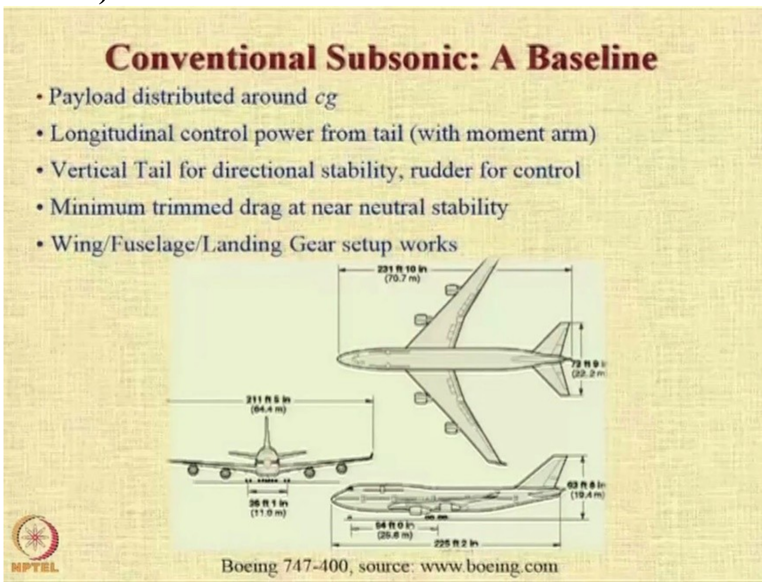


Let us look at what is meant by a baseline aircraft because any innovation or any new configuration will be considered with respect to this particular baseline. So, for a subsonic transport aircraft, you have a baseline which was first suggested by the Boeing Company in the form of Boeing 747. So, what are the features we distribute the payload around the center of gravity. So some part of the payload is ahead of the center of gravity, some part is behind and we try to maintain the CG.

We provide longitudinal control using a conventional tail mounted behind and using a moment arm we provide the required control power. We provide a vertical tail for giving a directional stability and rudder for control. And we try to fly the aircraft such that the trim drag is minimum near the location or near the stability level at which we want it to fly. Trim drag is caused because of the drag due to the control surfaces which are deflected in order to trim the aircraft.

Or in order to create a situation where the net movement acting on the aircraft is 0 about the center of gravity and larger the deflection of control surface is needed, larger will be the drag because of them. And that will continue throughout the flight and hence, it is going to contribute a large amount to the drag and hence, it is important that the aircraft should be able to trim at little or no deflection of the control surfaces and the standard setup that works for a conventional subsonic aircraft is the wing fuselage landing gear combination as shown in this figure.

So, any departure from this configuration for a subsonic transport aircraft can be considered as a deviation or a variation. And there should be a pretty solid reason to do that. We are not saying that all transport aircraft look like this and should look like this we are just saying that there has to be a solid reason to depart from this particular look. Because over the years, the experience of designers have resulted in this kind of a configuration as the base. But having said that, there are several options available to the designer for the layout.

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Layout stands for the relative location of the various major assemblies like the wing, fuselage, tail etc. So, where do you put the wings? Do you put the wings ahead in the fuselage or behind? Do you put them above the fuselage or below or do you put it through the fuselage? Where do you put the engines? In fact, what kind of engines do you use? And where do you put them, you put them below the wing, above the wing, on the front of the fuselage, on the rear of the fuselage, on the vertical tail. All these choices are available.

Where do you put the control surfaces and what options are available for the control surfaces and we have to be very careful that we should have sufficient room for landing gear because landing gear is a necessary requirement for any large transport aircraft. And can we look at possible innovative designs to get improvements or to meet some of the requirements which may not be possible to be addressed using the conventional baseline?

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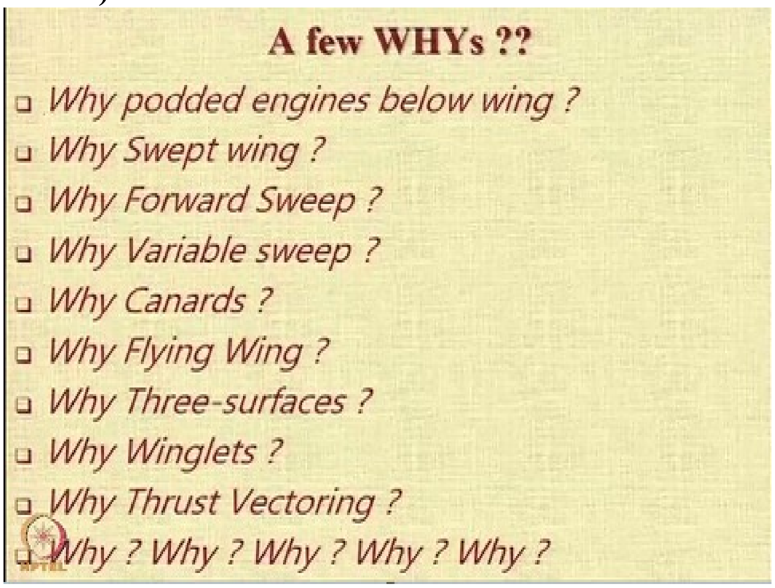


At this point, we start looking at questions that arise in the minds of a student about why we have a particular kind of feature. Why do we have podded engines below the wings? Why do we have a swept wing? Why forward sweep? Why variables sweep? Why canards? Why flying wing? Why winglets? Why 3 surfaces? There are so many questions. And there is a reason and logic for each of these choices that the designer or our design team makes in the layout. Thanks for your attention. We will now move to the next section.