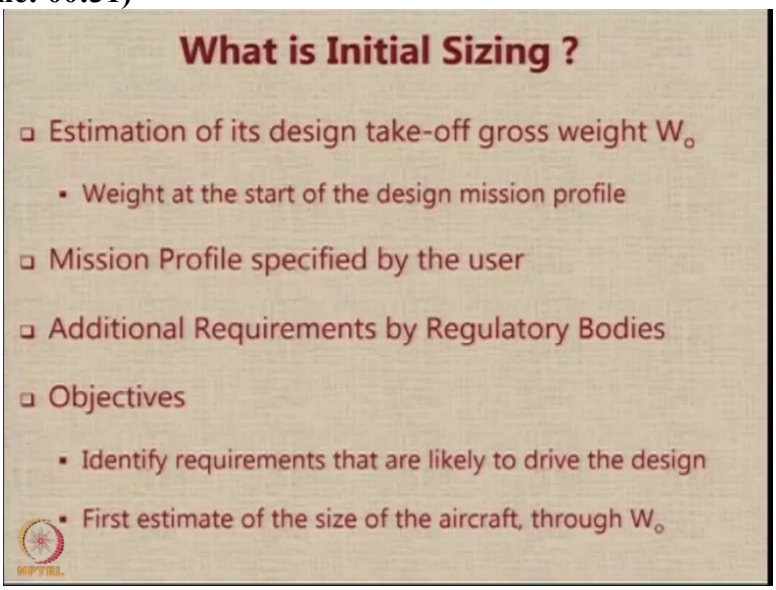
Introduction to Aircraft Design
Prof. Rajkumar S. Pant
Department of Aerospace Engineering
Indian Institute of Technology, Bombay

Lecture – 40
Initial Sizing in Aircraft Design

All right let us look at the concept of initial sizing in aircraft design. This is the first step in design where we start looking at some estimates or some numbers.

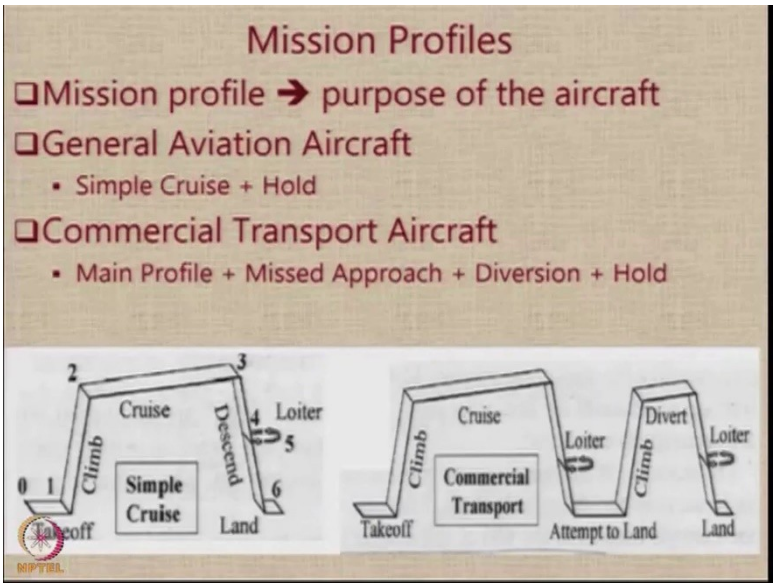
(Refer Slide Time: 00:31)



What is initial sizing the words initial sizing in aircraft design have a very specific meaning and that meaning is estimation of the aircraft design takeoff gross weight. Now, what is design takeoff gross weight, it is the weight of the aircraft at the start of the design mission profile. Every aircraft is designed to meet or to operate its mission using a specific profile. This mission profile is essentially a sketch that indicates what the aircraft is supposed to do.

And this is specified by the user. But apart from the mission profile given by the user, there are some additional requirements which also have to be taken care while carrying out the sizing these requirements as we know are specified by the regulatory bodies. So, the objectives of initial sizing are 2-fold. First is to identify the requirements that are likely to derive the design. And secondly, to get a first estimate of the size of the aircraft, through the estimation of its design gross weight W0.

(Refer Slide Time: 01:55)



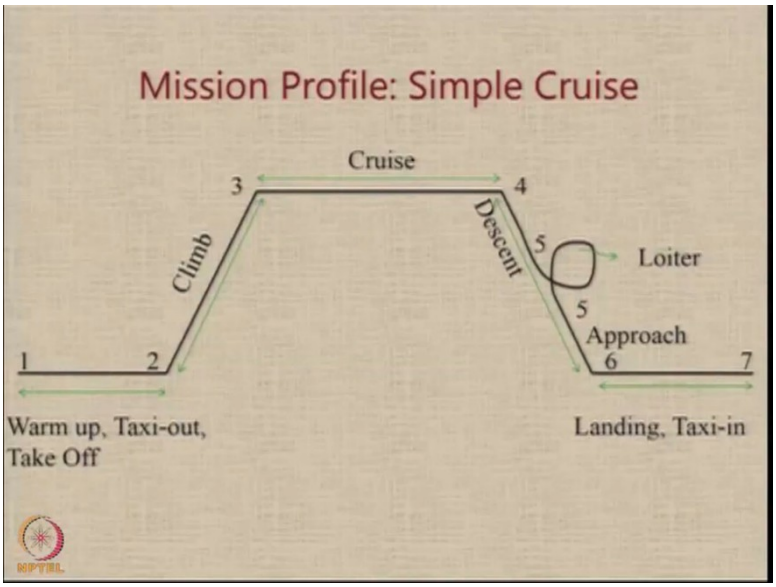
Mission profile is something that varies with the purpose of the aircraft. So, let us have a look at some standard mission profiles. Now, if you have a simple general aviation aircraft, then the mission profile is very straightforward. You just take off climb to the height, cruise descent, when you descend, you may be forced to loiter for some time, because the runway is not available to you.

This requirement or loiter is normally specified by the airworthiness agencies, we call it as a hold and then once you are cleared to land, you would be then proceeding with the descent and landing. When you have a commercial transport aircraft, the mission profile is slightly more complicated. Apart from the initial profile, which is similar to the general aviation aircraft, you have to also keep a provision for one attempt to land which is unsuccessful.

And this could be because of a various of reasons it could be because when you are attempting to land there is some obstruction on the runway or when you are attempting to land because of weather or any other reason you are forced to abort the landing and divert to a nearby airport. So, you should have enough fuel to be able to climb after an attempted landing which is aborted divert to a nearby location.

Approach and again have some fuel for lighter because even at that airport, you may have to hold for some time and then land. So, these requirements for lighter and diversion and the second lighter are the requirements which are given by the airworthiness agencies essentially to ensure our safety.

(Refer Slide Time: 03:53)



Let us have a look at simple cruise. The mission profile of a simple cruise can be broken down into various sub segments. So, for instance, you have the first leg, which is the warm up taxi-out and take off every aircraft spends some time in a pilot needs some time to check all the systems just before the takeoff is commenced typically the pilot would put the aircraft would start the aircraft and go for a checklist and during that time the engine is on and hence fuel is being consumed.

After that, once you are given the clearance to proceed, you have to taxi-out that is to proceed from the place where you are parked of the terminal or the gate to the start of the runway and then from there you have to execute the takeoff. So, during this phase when you are still on the ground, in many ways, you are going to consume some amount of fuel therefore, this is the first leg the second segment would involve climb to the cruising altitude.

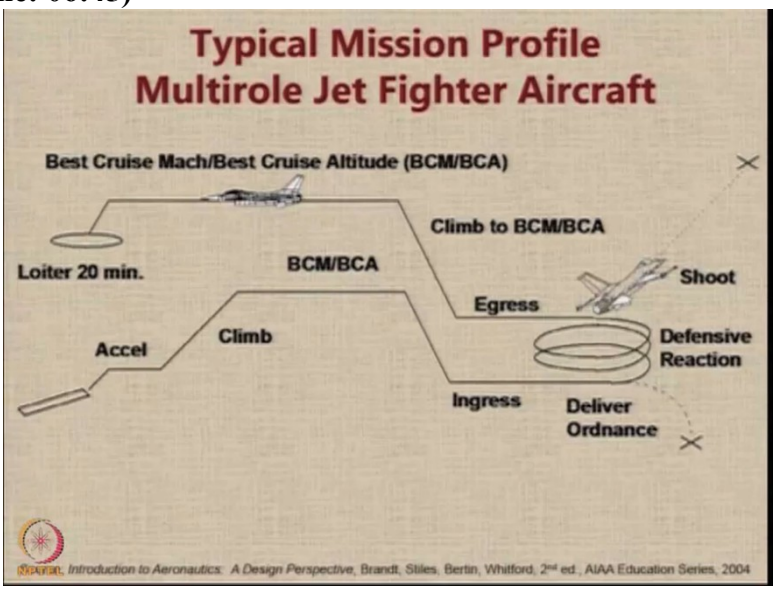
The next would involve cruise to the desired destination this cruise could be a constant altitude cruise as shown here or it could be a cruise climb in which the altitude is constantly increasing because of consumption of fuel that is a matter of detail. So, there is not shown here. And then you have a descent phase when you are now approaching when you are wanting to now land.

But when you are descending, you might have to actually go for some amount of loiter or hold at the destination airport. And then once you are clear to land, you will have an approach segment and then you will have the landing segment. After landing you are going to taxi-in to

the terminal or the gate once again. So, each leg of the mission profile is assumed to start and end from numbers. For example, the warm up, taxi-out and take off is from 1 to 2.

So the leg is 1 to 2, 2 to 3, 3 to 4, 4 to 5 5 to 6 6 to 7. Now, if it is a transport aircraft as you know after this there will be a requirement for a between approach there will be and land there will be a requirement for diversion, which will involve another climb and other small cruise another descent another lighter and then final landing.

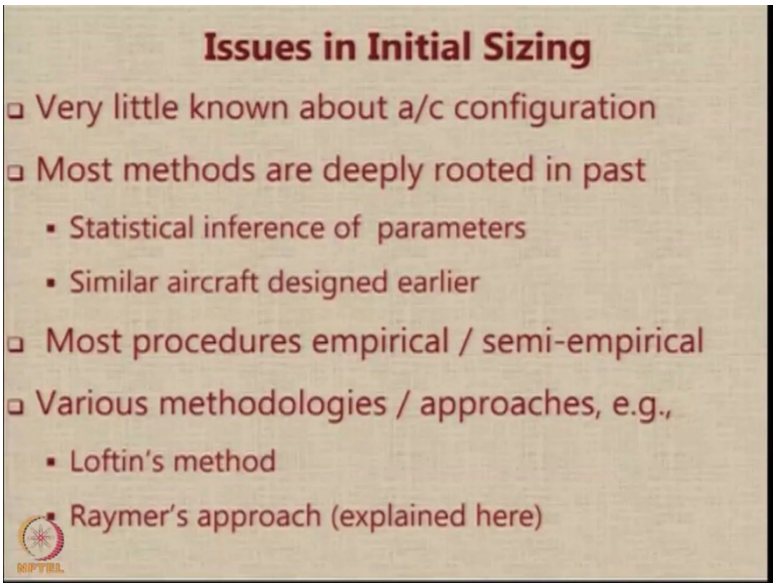
(Refer Slide Time: 06:45)



This is a typical mission profile for a multi-role jet fighter aircraft. Here you take off, accelerate, climb, and then you fly out at the best cruise mark number and the best cruise altitude notice the requirement is not specific here you are allowed to choose and then when you are going to reach the area of operation you are going to come down to the low altitude, there will be ingress at the combat region there will be delivery of some ordnance.

And then you have to avoid you will have to have some defensive reaction. After that once your job is over, you are going to egress back, again you will climb to a best cruise altitude at the best cruise mark number and then you continue your flight back to the origin. And when you come back, you may have to loiter for some time. So, this is a typical mission profile for a multilevel jet fighter aircraft like that there are many mission profiles which have to be considered.

(Refer Slide Time: 07:43)



In our explanation, we are going to focus only on our civil transport aircraft. Now right in the beginning, it is important for us to realize that there are some fundamental issues that are going to play with us when we do initial sizing. The first problem is that you would like to estimate the gross weight of the aircraft, but you have very little information about the aircraft configuration.

You have not yet designed the aircraft you have not even arrived at what kind of shape or configuration you will use. All you know probably is that this will be a turbofan engine aircraft which will have in the typically this kind of, you know, configuration, you do not have the specific configuration yet. You only have a very vague idea, but with very little information, you are supposed to do estimates.

So therefore, most of the methods that you will see in initial sizing are very deeply rooted in the past. Most of the formulae and procedures are going to be basically extrapolations of interpolations within the database available for the existing aircraft. The estimates are going to be arrived by statistical inference of the parameters and it will be based on the data that you have collected for civil aircraft which are designed earlier.

And this is why most aircraft designers, they have with them a large database of information regarding the existing and the past aircraft because you are going to now make an estimate without great information about your aircraft without much information about your aircraft. So, therefore, you have to go for empirical and semi empirical procedures. Now, in literature, there are many many methods available for carrying out initial sizing.

One of the methods which was quite popular earlier was given by Lawrence scale Loftin or called as a Loftin's method. But, these days, most of a the textbooks and the procedures that you normally see being followed is the one that is given by a Daniel Raymer in his very popular textbook, and that is a one we are going to look at in this particular presentation also. So, most of the textbooks that you see today actually, talk about the method given by Raymer which is also what we will see here. Thanks for your attention we will now move to the next section.