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

Lecture - 47
Take-off Weight Build up

Let us have a look at the take-off weight built up or how the take-off weight builds up what are the various components of takeoff weight.

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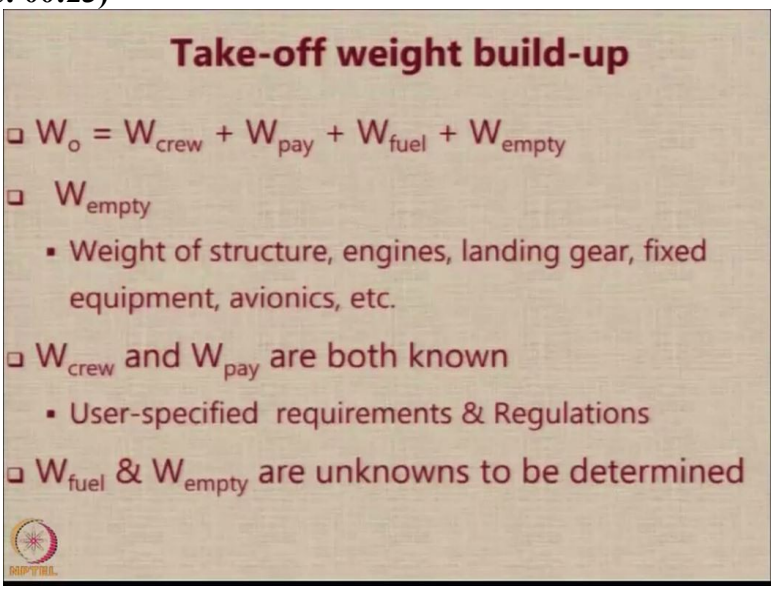

In initial sizing you can actually consider that the aircraft consists of only 4 elements there is a crew which you have or you may not have if you are flying an unmanned aircraft which is there on the aircraft and then you have a payload which you are supposed to carry you have a fuel and everything else is called as the empty weight. So, the empty weight would consist of the weight of the structures, engines landing gear fixed equipment, avionics, everything other than fuel payload and crew is clubbed into empty weight.

Now, W_{crew} and $W_{payload}$ are 2 items that are both known to us, because they will be decided either based on the user specified requirements or we have to take them from the regulatory information or whatever is the normal trend. So, W_{fuel} and W_{empty} are the only 2 unknowns. And these depend on the aircraft type and also on the mission profile. So, the takeoff weight built up

or W_0 gross weight design gross weight that is what we want to calculate. And 2 items in the 4 of these 4 are now going to be available, the remaining 2 are going to be estimated.

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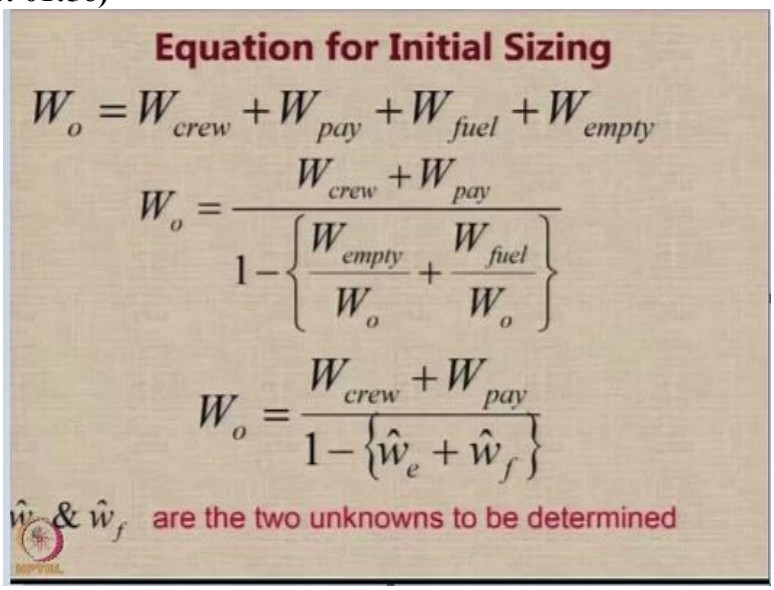

So let us see how we go about doing it. So, what we can do is if 2 of these the crew and the payload are knowns and the other 2 are unknowns, we let the known values remain in the numerator and we try to bring the unknown values in the denominator. To do that, you can see very easily that the equation can be converted into

$$W_0 = \frac{W_{crew} + W_{payload}}{1 - \left\{ \frac{W_{empty}}{W_0} + \frac{W_{fuel}}{W_0} \right\}}$$

We also call them as the empty weight fraction $\acute{w}_e$ and the fuel weight fraction $\acute{w}_f$.

So, we will refer to this from now on as $\acute{w}_e$ and $\acute{w}_f$. So, the exercise of estimating W_0 is now converted into an exercise of estimating only $\acute{w}_e$ and $\acute{w}_f$. These are the 2 unknowns to be determined.

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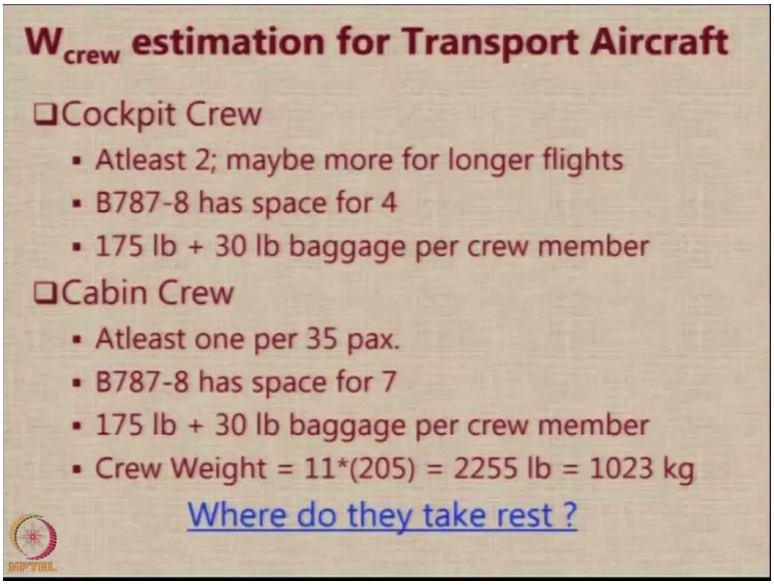

Let us first try to tackle W_{crew}. W_{crew} estimation for transport aircraft is very straightforward process based on the information that is relevant to the operations scenario. The crew of a transport aircraft consists of 2 as 2 different distinct groups of people, there is a cockpit crew. And the cockpit group generally consists of 2 pilot and the copilot or we also call it as a captain on the first officer at least 2 from the regulatory requirements.

Aircraft more than 9 seats which are carrying passengers that pay fare from safety requirements are required to have minimum 2 people in the cockpit. But for longer flights, because there are something there are some limitations called as the flight duty time limitations FDTL flight duty time limitations require that a pilot is not expected to fly for a very long period without a rest. And because of that, if the flight duration exceeds around 10 to 12 hours nonstop flight you need to have more than 2 or more than 1 set of crew members.

Boeing 787 dash 8 aircraft has space for 4 crew members. So we typically assume that each crew member is going to be 175 pounds. Plus it will carry 30 pounds of or they will carry 35 30 pounds of baggage per crew member. In addition to the crew cockpit crew, we also have cabin crew. Now for cabin crew, there is a kind of an understanding that at least 1 crew member will be available to serve and to look after the entrance and safety of 35 passengers so the Boeing 787 dash 8 aircraft has space for 7 crew members.

So, basically, each of these crew members also is assumed to weigh 175 pounds and 130 pounds. So 205 pounds has to be kept aside as the weight of each crew member plus their baggage. And there are 7 + 4= 11 of these in a Boeing 787 aircraft. So, the crew weight is going to be 11 into 205 pounds which is approximately 1023 kg. So, approximately 1 ton of weight is to be kept aside for the crew members to operate a Boeing 787 dash 8 aircraft. Now the question is, there are 11 people, where do they take rest. So let us have a look at the rest areas for the crew members of a Boeing 787.

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So, you can see that there is a staircase which is not visible to the passengers and above that you have rest area for the crew members. So 2 pilots are going to be flying the aircraft and the other 2 pilots are going to be taking rest at any given point of time. And this is the place for the cabin crew members. Again, there is a secret staircase not visible to the passengers where the crew members are taking rest.

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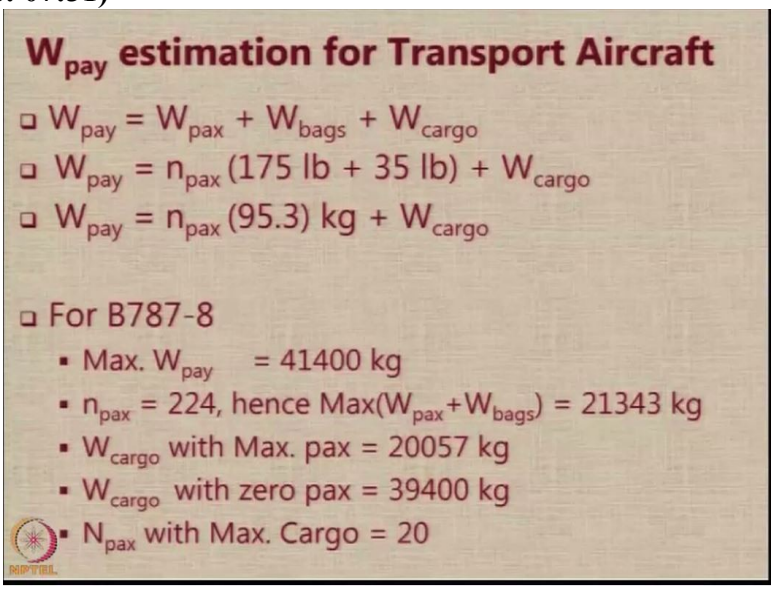

Let us look at the estimation of payload for transport aircraft. The payload is basically the weight of the passengers the weight of the baggage that they carry and the weight of the cargo that is carried in the aircraft. So, for every passenger again, we can assume the weight to be 175 pounds plus 35 pounds for their standard baggage. So if you multiply that with number of passengers, you will get the weight of passengers and baggage and W_{cargo} is a number that depends on how much cargo the airline is carrying.

So, for Boeing 787 the maximum payload weight is 41,400 kg this is the maximum payload capacity. So since it carries 224 passengers, therefore the maximum value of the pax and baggage will be 21343 kilograms. Therefore, the cargo that you can carry with all the passengers would be around 20 tons 220057 kg and if you do not carry any passengers and if you carry only cargo, then it will be 39 tons approximately.

And if you carry maximum cargo, then the margin available is to carry only 20 passengers. So, between 20 and 224 passengers, the amount of passengers that can be carried in the aircraft will vary depending on how much cargo is being carried by the airline.

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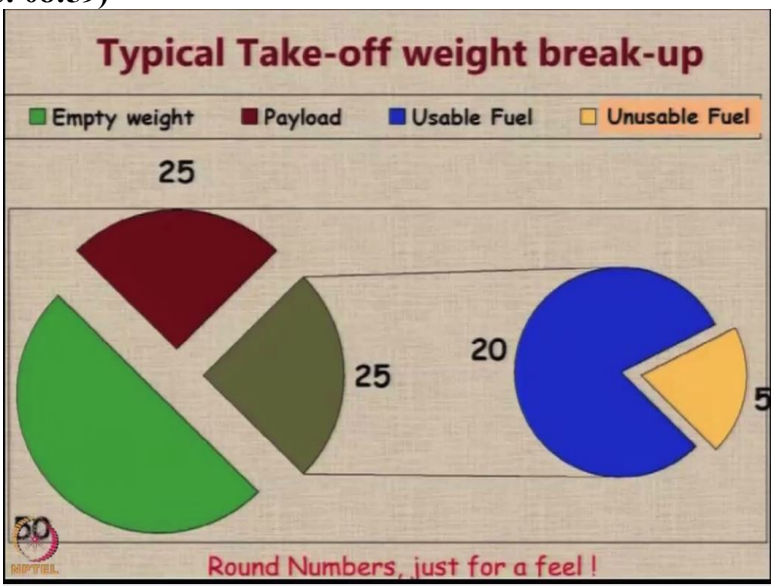

So, the typical take-off weight built up is as shown here. This particular breakup, it may be noted is just for a feel when you do calculations of the typical values of the fractions. If you get numbers which are totally different from the number shown here, it should ring a small alarm bell in your mind. But if you are aware that the numbers are going to come very awkward because you are looking at a designer for totally new aircraft, then you know this is just a warning. So how do we remember?

We remember in the following fashion, roughly half the aircraft is going to be just the empty weight of the remaining half. The half of that or 1 / 4 of the aircraft might be the payload and the remaining 1 / 4 of the aircraft might be the fuel. Now this ratio can change it in some aircraft, the

empty weight maybe 60% in which case you have only 40% remaining in some aircraft the fuel maybe 20%. So, the numbers can vary slightly.

Now, if the fuel is around 25% of the total weight, then 20% of that or 20% of the total fuel weight is going to be usable fuel and 5% of the total weight of the aircraft may consist of unusable fuel. Now, what is unusable fuel this is fuel, which you cannot use. Thanks for your attention. We will now move to the next section.