Introduction to Aircraft Design

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Lecture -70

Aircraft Life Cycle Cost Estimation

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Let us look at aircraft lifecycle cost estimation. Before that we should learn the breakdown of lifecycle cost. As we know the LCC consists of the total cost of the aircraft from the cradle to the grave and it is inclusive of the cost incurred in designing the aircraft or conceiving the aircraft which is this element then producing the aircraft and producing the airframe engines and avionics which is this element. Then we need to provide some ground support equipment and initial spares that is this one.

And then there may be the need to construct some special test facilities to check out the various concepts and then we have a largest component which is the operations and maintenance cost, fuel oil, crew maintenance recurring costs, insurance and finally you have the disposal cost. So these are the elements of LCC which we have to consider. Notice that the LCC will depend upon the maximum takeoff weight of the aircraft.

It will depend upon what is the maximum velocity at the mission altitude how much is the quantity produced in the design testing and evaluation phase and production phases. And how are the costs of these phases amortized. The size of the boxes in the figure shown here in the center is proportional to the magnitude of these costs. Let us look at each of these cost elements now the RDT and E cost transport the research, development, testing and evaluation cost. In somebody we can call it as the cost to conceive and design the aircraft.

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There are many components of RDT and E the first component is the technology research that is studying the technology that has to be incorporated in the aircraft. And then the next component is the design engineering or the effort that goes into the carrying out of the conceptual design. After the design is completed we take a decision and may manufacture a prototype this prototype is used for actual flight testing.

So the ground testing and the flight testing is the next component. After that we have the evaluation of the operational suitability of the aircraft. This can also be done at the customer site or if it is a military aircraft for example you may fly the aircraft at the locations where the aircraft is going to be used and then you have certification or the approval. Now the certification is of 2 types there is a mission compliance certification which is done in conjunction with the user agency or the customer.

And then you also need to obtain the airworthiness certification of the aircraft. And last but not the least is the design documentation. Many people ignore this and this is a huge component and also it is important to document the whole procedure in detail which will help us in understanding what the various decisions were and why were they taken and also it helps in keeping representation of the design knowledge.

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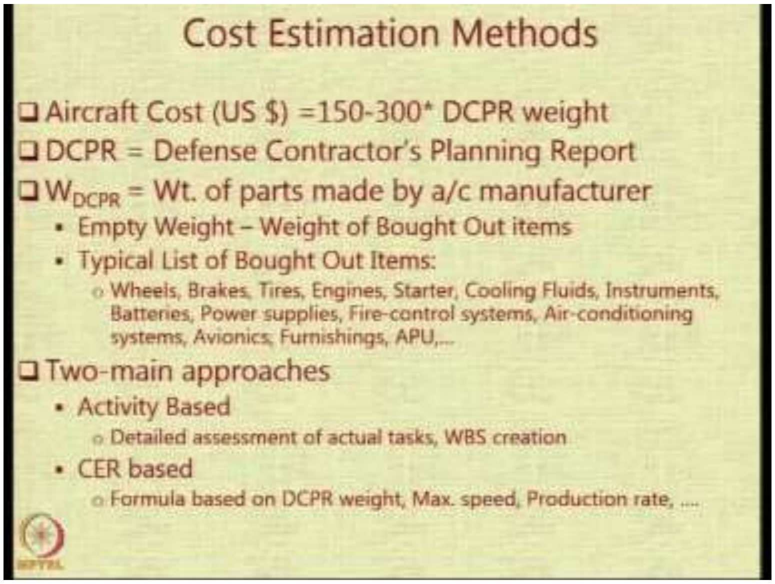

Now the cost estimation methods for the RDT and E phase or you know various levels. One simple way is you can just assume that there is a particular weight per kilogram of the aircraft and there is something called as a defense contractors planning report or DCPR weight this particular weight basically consists of only the parts which are manufactured by the aircraft manufacturing company and all the other parts which are outsourced or procured from other vendors are not included in this particular weight.

So it is basically the empty weight of the aircraft minus the weight of the various bought out items. And there is a huge list of items which a manufacturer buys from other ancillary suppliers and does not necessarily manufacture themselves. So one estimate is that you just multiply the DCPR rate by a number like 150 or 300 depending on the aircraft type and you will get the basic estimate of the aircraft costs.

We admit that this particular method is a very crude method. Then there are 2 other approaches one approach is called as the activity based approach. In which the actual tasks to be carried out in doing the conceptual design are detailed and work breakdown structure is created and then the cost of each element is going to be added up. That is called activity based costing then you also have got the cost estimation relationship or CER based costing.

These are used essentially when you want to compare various aircrafts and when you want to have an estimate of the likely costs based on the past experience. So there are formulae based on the DCPR weight parameter like maximum speed production rate etc.

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And these formulae's are used to calculate or to estimate the cost of various elements. So when you do a CER based RDT and E estimation one model which is very popular is the DAPCA IV model given by the RAND Corporation. So in the DAPCA IV model this is not the only model but this is a very popular model and it is explained in detail in Raymer's textbook also in the DAPCA IV model given by the RAND Corporation one estimates the hours needed for various aspects of the RDT and E phase and the production of the prototypes.

And these particular activities are divided into the engineering activity, the tooling activity, the manufacturing activity and the quality control activity. We assume here that some n numbers of prototypes of the aircraft are going to be fabricated and hence we have the requirement for tooling and manufacturing of the aircraft. So what we do is based on certain important parameters which affect the values of the hours needed you estimate these hours and then you multiply when by the man hour rates.

And then there are other costs which are not easy to estimate they have to be added as a number by estimating directly for example the cost of providing the developmental support the wind tunnel testing the FEM analysis then the cost of the material that is used for manufacturing the cost of flight testing. And then every design activity is actually an activity that a company incurs and it incurs lots of expenditure those expenditures have to be financed. So there is going to be a financing cost and if a company has to sustain itself in the future it also has to charge a profit for the activity. So additional cost elements of financing and profit also come

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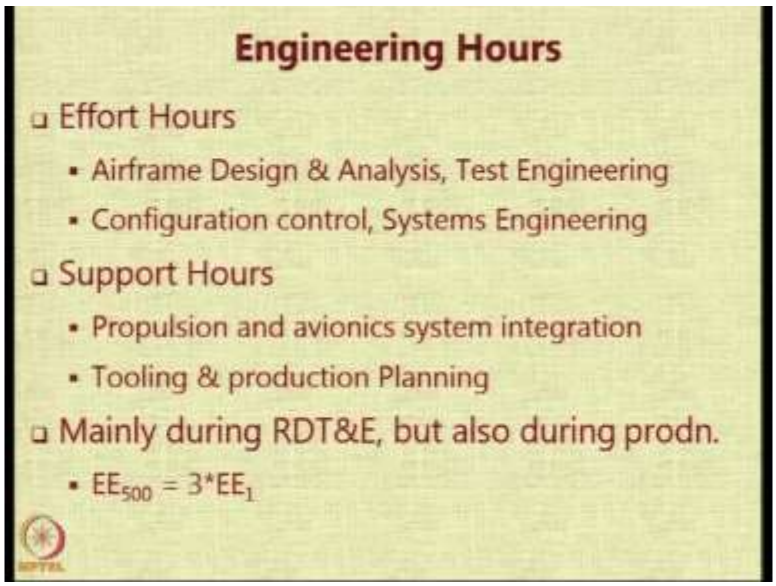

Let us see how engineering hours are estimated for various aspects. So for airframe design analysis and test engineering for configuration control and systems engineering we calculate the amount of hours which are going to be put in by the engineers to carry out this part. Then there are support hours the hours required to be spent by the design teams in integrating the avionics system and integrating the propulsion system on the aircraft.

The hours of effort needed in carrying out the activity of producing the drawings for tooling and the drawings for production planning or the production planning activity. This particular cost is mainly incurred during the RDT and E but also during the production phase. So basically there is a rough idea a rough estimate that if you are producing a 500 hour if you are producing 500 aircraft then the total engineering effort that is needed to put in to support the design.

And fabrication and production of 500 aircraft is only 3 times the effort of just producing one airframe because the entire effort for the design and for the conservation control extra and also the support will be there whether you make 1 aircraft or you make 500 aircraft but the tooling production planning and manufacturing those costs are going to be higher if you can if you have a higher quantity.

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Now tooling basically is the preparation for production that is called as tooling you need to create tools and fixtures you need to create molds than dies you need to program the NC machines and you have to design and fabricate the test operators all of these requires tooling and the tooling for production aircraft is different from tooling for the prototype aircraft. And then during the production also you have to provide some tooling support. So this is an important activity in the lifecycle of an aircraft production.

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The next is manufacturing and quality control labor. Manufacturing involves forming machining fastening. It involves more making the sub-assemblies and assembling them it involves routing of the hydraulics pneumatics electronics it involves installation of the items which have been purchased like the engine the avionics subsystems. And there are many airframe subcontractors who are also going to work with the power with the engineers of the manufacturing organization all of them together constitute the manufacturing.

Then quality control is an important aspect because you would like to get things right at the first time and you would not like to have many defects in the production because that affects the life of the aircraft. So inspection at the receiving when the material arrives or the BO items arrive production assembly.

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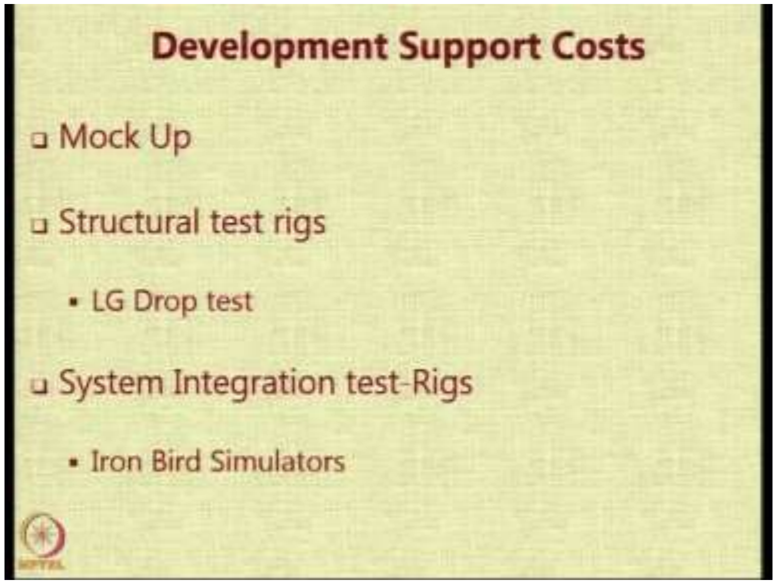

And all these items they have to be costed then there are some development support costs these are costs created for making the mock up where you try out the various configurational details then there are some structural test risks. For example landing gear testing is to be carried out by dropping it at some height with some weight then you have to do iron bird simulators where the whole system is integrated all the actuators bought out items accessories are put together. And on the ground you test the functioning of the aircraft under various loads and various operating conditions.

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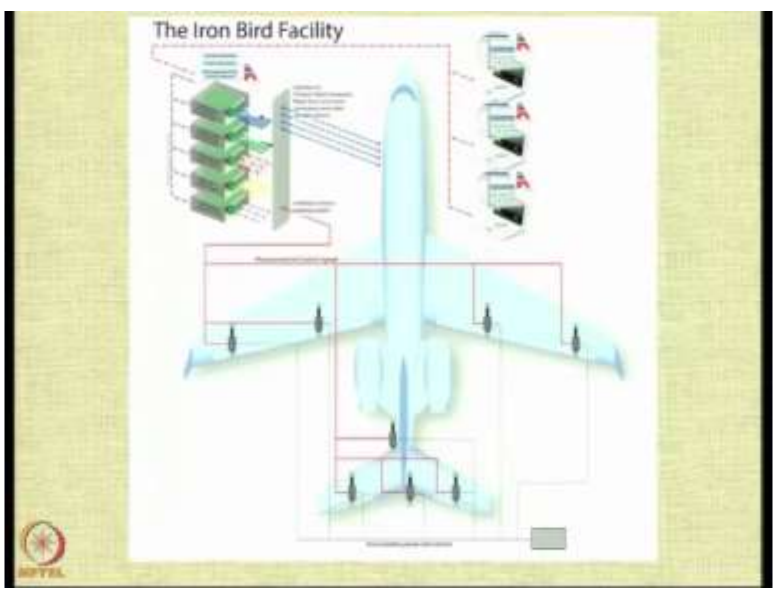

This is an example of an iron bird facility where data regarding the performance of the various actuators and various systems is recorded on the ground.

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There may not be an actual aircraft there but it may be just a facility of the ground which is going to simulate the working of the aircraft. So Boeing has developed an integrated test vehicle ITV for 787-8 and we will share information regarding this particular iron bird simulator in our material for reading.

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F22 v/s F35

Cost Item	F22	F35
Total Production Run	195	2443
RDT&E Cost	47.285	114.821
Production Cost	26.715	268.730
Operation & Maintenance Cost (Over 40 years of service)	59.000	762.216
Disposal Cost	1.000	
Life Cycle Cost	134.000	1145.767
Unit Aircraft Cost	0.137	0.110
Unit Acquisition Cost	0.380	0.157
Life Cycle Cost / Aircraft	**0.687**	**0.469**

Note: All cost terms are in Billion USD

Source: https://www.wired.com/2011/12/f-22-real-cost/

We can notice here that this is a comparison of the lifecycle cost of F 22 and F 35 2 aircraft notice that the column for disposal cost of F 35 is right now blank because there is no clue and the disposal cost of you know a billion USD is an estimate. So there are 195 aircraft to be produced and a billion dollars will be spent in their disposal at the end of their cycle, for F 35 the original planning was to produce 2443 aircraft. And we have no idea what will be spent in their disposal. But if disposal cost is ignored right now the lifecycle of the aircraft comes to around 0.7 billion USD as against point 0.46 billion USD for an F 35.

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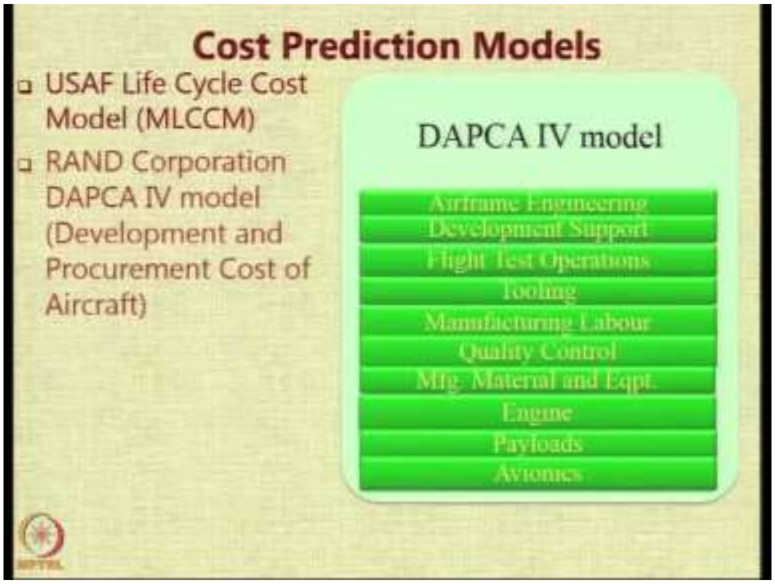

The cost prediction models you know I mentioned about RAND DAPCA IV model this is a standard model there are other models also for example there is a US Air Force has a lifecycle cost model called as MLCCM. We have seen about the RAND DAPCA IV model.

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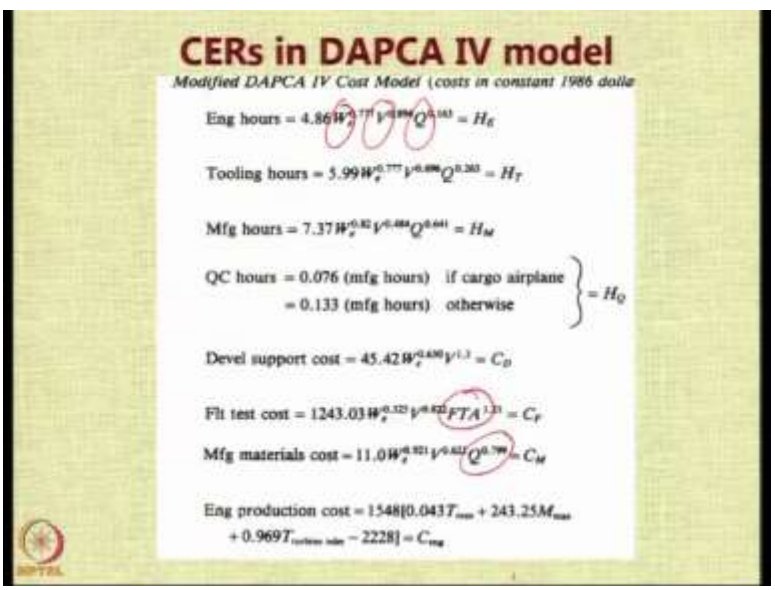

These are the equations which are available for the DAPCA IV model these numbers are applicable for 1986 dollars and they have to be scaled up using the inflation factor all these equations are available either online or in this case they are available in the standard textbooks like the textbook by Raymer. So what you just have to understand is that some of the important parameters like the empty weight of the aircraft or the DCPR weight the maximum velocity and the quantity to be produced.

These are the 3 main factors number of flight test aircraft what is the maximum velocity and you know what is the maximum thrust? All that is going to play a role the quantity of the aircraft to be produced also comes into play when you look at the manufacturing material cost.

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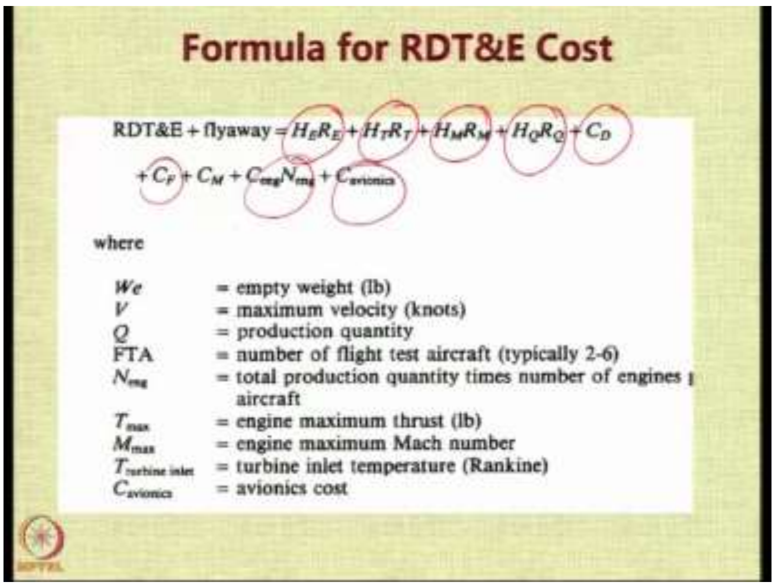

So if you if you look at the combination of all the parameters you have the engineering tooling manufacturing quality control and then equipment which are allowed flight testing. So number of engines into the cost per engine avionics all of these when you add you get the RDT and E and the fly away cost. Thanks for your attention. We will now move to the next section.