Systems Engineering
Prof. Deepu Philip
Department of Industrial & Management Engineering
Indian Institute of Technology- Kanpur

Lecture - 24
Design Synthesis Tools

Welcome to the one more lecture System Engineering on the tools that are used in Design Synthesis. So, the lecture is titled Design Synthesis Tools and just to recap on where we are today.

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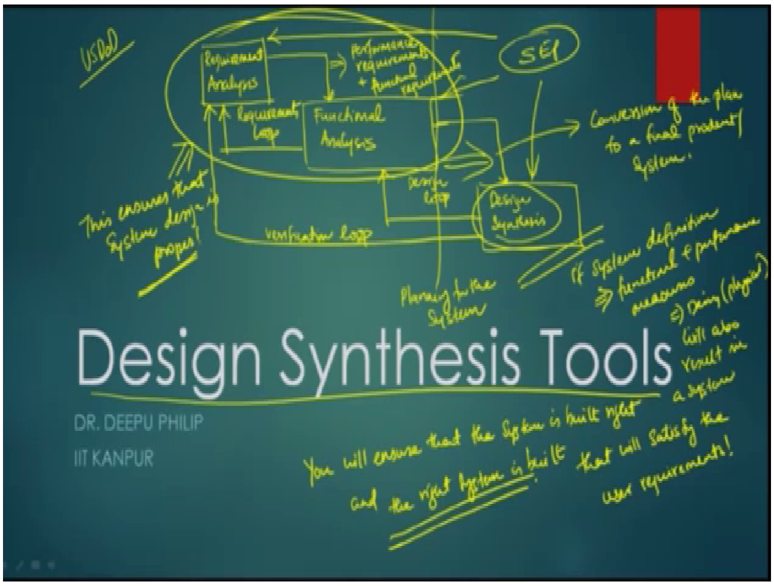

We have in the System Engineering process we have seen which is predominantly the US Department of Defense model US DoD model where the requirement analysis then we had the functional analysis and this was the requirements loop. Then, we talked about from there - we talked about design synthesis and this was the loop between the functional analysis and Design Synthesis is called as the design loop.

And we had a another loop which is called as the verification loop/verification validation loop we can call all those kind of things. And you had the System Engineering process controlling all these, we had seen this model. And we also seen that from the Requirement analysis and Functional analysis put together gives as the performance requirements plus functional requirements.

What are the functions that are necessary and once from up to this point all of these things that we do in System Engineering is the planning for the system and from there to this point the Design Synthesis is there were doing the conversion of plan to a final product or system.

So, now we were seeing the different aspects of the Design Synthesis and today we are going to see certain tools that are used in Design Synthesis, there lot of tools that are used in Design Synthesis but for the purpose in this course you will be looking at few of them.

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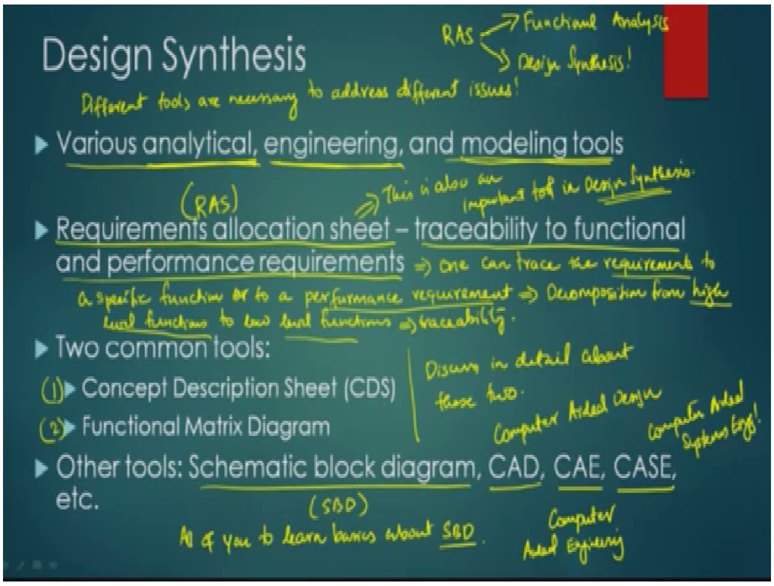

So, Design Synthesis what is it? It involves a lot of tools and various analytical, engineering, and modeling tools that used as part of this, so why we use so many tools as part of this the reason being is instead of various we will use different tools are necessary to address different issues. So you require analytical tools we saw what – why analytical is necessary we saw why engineering tools are necessary and we also require modeling tools okay.

Then one of the most important one that we talked about is as Requirement allocation sheet or what we called as RAS we already seen that okay, the – the need of the RAS is to incorporate traceability to functional and performance requirements so this means one can trace the requirements to a specific function or to – or to – or to a – a performance requirement.

One can trace it and also decomposition from high level functions to low level functions traceability. So what does this means is when you decompose requirement and performance measures from high level to low level functions then you need to ensure that the requirement is decomposed appropriately and allocated to the appropriate lower level functions, so that type of process is done with the help of RAS (Requirement Allocation Sheet).

And hence this is also an important tool in Design Synthesis though we said that this a important tool that is an important in case of functional analysis it is also a tool in the case of Design Synthesis, so RAS (Requirement Allocation Sheet) is applicable to both Functional analysis and Design Synthesis In addition to this we seen already seen this tool.

We will look at two common tools as part of this one is called as a Concept Description sheet (CDS) which is normally called as a DS and then the Functional Matrix Diagram are normally some people called as FM okay, so these tools we will see what these are all about and why they are and what they are – and what they are used for this kind of aspects so we will discuss in detail about these two.

There are other tools as well as what we call as Schematic block diagram okay some people actually call this as SBD, I would recommend that you would – guys would read about this tool. Another one is CAD which is Computer Aided Design, CAE you can talk about it as Computer Aided Engineering, here CASE which is Computer Aided Systems Engineering Etc.

So there are many other tools mostly depend upon the advent of the PC or high power computing these kind of tools are quite common as part of System Engineering now and also SBD is also one other common simple tool so I request all of you guys to – all of you to learn basics about SBD it is quite simple do not need to discuss that in a class I think all of you are qualified enough to read through that.

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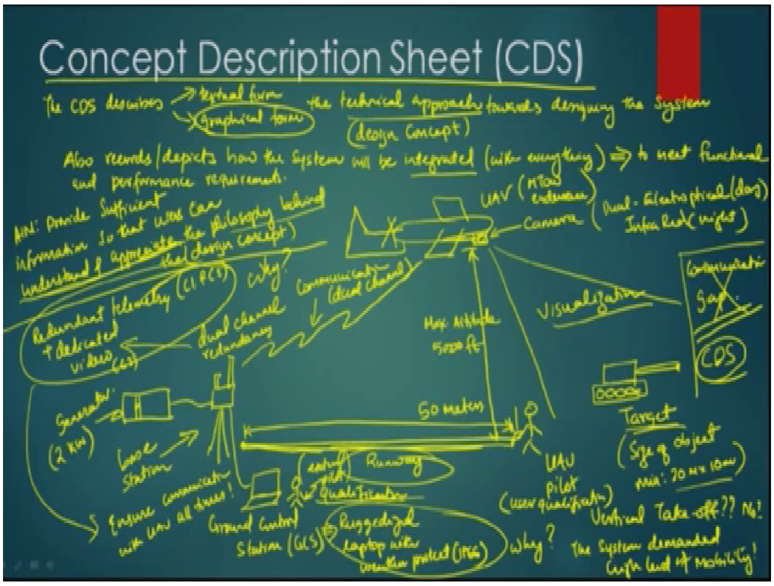

So the CDS let's look at these tools as the first and foremost tool that we need to talk about this okay. The CDS - the CDS it describes okay - it describes - it can describe in two ways it can describe in textual form or graphical form, so it describes either in textual form or graphical form. The technical approach in or towards designing the system okay, some people also called this as technical approach it is also called as the design concept.

Some people say what's a design concept towards designing the system this is designing the system okay. Also it - also demonstrate - also records/depicts how the system will be integrated (with everything) why do we need to integrate them to meet functional and performance requirements okay. So it is quite I usually use this in a graphical format so my preference in this scheme of CDS is a graphical form.

So I will show a simple example of how the graphical format display of the unmanned aerial system what we talk about we have been describe in this and so we can say what the System Design concept in this - in this regard so we can say that so here is I will draw I will try to be like do a good drawing exercise and I am not very good at this.

So this is a we will say Runway, at one end of the runway we will have what we call as a you would say base antenna and we would have like cable running and we would have like a laptop computer which will be Ground Control Station which we call as a GCS and we would have a operator associated with it and then there would be like a UAV we will draw this way will have the propeller in the back it is flying it is also has a tail bone like this okay and here is a UAV okay and it - it will fly.

There is somewhere here you have a here is a target okay and we can say a camera okay visualization and then this is the communication okay and so we can say that okay also we can put like a something like a - like a say generator something like this okay, so what we can say is that when you say this diagram like this you can kind of see that it is a like a gives a scenery of the whole system.

So then I can put specifications here so I can say that the ground control station. I can put specs as ruggedized laptop with weather protection or something like this protect I can mention certain things also (IP666) some things like that, so here we will say runway I can specify things like 50 meters okay, target then I can always say size of object minimum - minimum let's say 20 meters/10 meters something like this right.

Then we can also write some stuff like that a max altitude 5000ft right, camera you can always put a Dual Electro Optical for day Infrared for night vision. Then you can say the base station or we call this as the a bas - instead of base antenna it is we can called as base station actually speaking it is called as BS.

And you can say Dual channel okay so Dual channel redundancy okay now we need to specify what's redundancy so I can always say this okay a redundant telemetry + dedicated video channel 2 then we can say channel 1 and channel 2 dedicated video channel 2 then we can specify what is channel 1 and channel 2 someplace okay. Generator then I can say this is a 2kw generator something like this.

Then we can other say user we can specify what's the name of what's the user and we can also have like a another person here which is the UAV pilot who will also have a base box in his hand who will communicate with the UAV if he wants to the communication will run from here to this base box and will be updated and visualization what type of visualization we are looking at then the UAV against puts details like you know maximum takeoff weight, endurance these kind of stuff.

So when you look at this diagram you can slowly see that you can keep on adding things, but it also gives you a really good input on how the – the actual concept of the system is described so the if you do not put runway then you will sometime the people think that will the UAV will takeoff vertically or so now with the runway you know that it is not going to do VTOL so something like if somebody says vertical takeoff at this point the question most of the time the answer is no.

Because you already depicted a runway or you would have probably said okay if there is no runway somebody could have say okay fine it could have been a vertical takeoff that kind of confusion, and here we said target the size of the target is specified so that kind of gives an idea that this UAV designed to identify a target of this size as the minimum size I just giving examples in this regard.

And you can say the UAV pilot you can put what are the - this is the user qualification you can add, so what the person should know how many hours of flying time here is the person you can also say the qualification which is the we can call it as the external pilot actually or internal pilot I would say, qualifications other details can be specified.

So when you take a look at it either Concept Description Sheet gives you sufficient information to so the aim is that is what we will be writing here. Aim provide sufficient information so that users can understand and appreciate the philosophy behind the design concept, because this is quiet important the user should understand and appreciate the philosophy behind the design concept or why that particular approach was used in designing that system.

So somebody would say why did you guys use the ground control stations as the ruggedized laptop? The obvious question asked here is why? The answer to the problem is why? The answer is the system demanded high level of portability it need to be moved from one place to another or mobility instead of portability let's say – let's call it as mobility as the right phrase so we will say mobility so you need to be moved from place to place as quickly as possible.

So then you have to build systems around in such a way that it can be quickly packed and moved to a loc - from one location to another okay, then the second questions says somebody cannot obviously say is that why did use two channels for communication why do you not so - so we can says dual channel why did you use dual channel for communication well the customer wanted so the question here is dual channel this question is why?

You can answer that easily saying that okay the people can appreciate that at no matter what the aim is to ensure communication with UAV all times so having a redundant communication in two different frequencies and two different channels ensures you that the UAV is communicating consistently with the base - base station, where us even if the video link we already given one channel because either channel has some problem the only thing that will happen is you will not get to see the video that's it.

The most important thing at that point or the importance that was given as part of that design concept or the technical approach was that the UAV should be recoverable. It should not be a situation where you sacrifice the UAV for the video you would rather sacrifice the video for saving the UAV because you can go back and do the mission again so that where's the design philosophy behind it.

So once the people understand and appreciate the philosophy behind the design then the user will also make amendments to it is easy to convince the user why a certain approach was used and lot of the time the issues that happens in system design is what sometimes we call as communication gap, so the CDS Concept Description Sheet is a good tool that will avoid the communication gap it will ensure that the communication gap between the user and the designer of the system is minimized.

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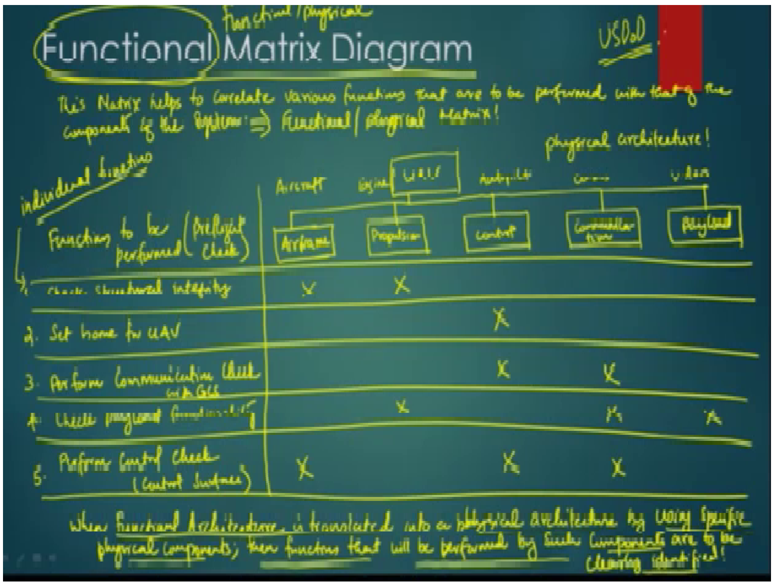

Then we now talk about the second aspect which is called as the Functional Matrix Diagram ok this also another important tool that is used by the systems engineers especially in the

Design Synthesis and let me explain to you why the Functional Matrix Diagram is the – this matrix or a diagram okay whatever you want to call it okay.

It helps this matrix helps to correlate - correlate various functions that are to be performed - to be performed with that of the components of the system hence it is also called as functional physical Matrix the right usage for this is called Functional/Physical Matrix the right usage for this is called Functional/Physical Matrix where the relationship between various functions and the various physical components of the system are described clearly in this.

So let’s take an example of the UAV again where we mentioned about this and let's see whether we can actually draw the system so the first part is we draw about the - we draw the UAV and as I mentioned we have 5 components in the UAV number one is the airframe, and number two we have propulsion, number three we have control, then communication, the last one is payload so these are the five components of the UAV that we mentioned.

Now this is the physical architecture of the system okay here is the physical architecture okay, the physical architecture then you have to have the functions to be performed, what are the functions to be performed so let's talk about their functions to be performed when? Let’s as preflight check okay.

So then you have different rows in this the sheet looks something like this and then we have wherever across we need to do this so that let's say the first thing that we knew do is check structural integrity okay so what first you are doing is you are doing the checking the structural integrity so you will say airframe and propulsion those two things okay.

Then you will say set home for UAV so the home is a feature in which if the communication channel goes away there is no communication between the UAV and the ground control station it will wait for few minutes or few seconds actually speaking it will wait for 30 seconds.

And if it finds that the communication was not resumed between the ground GCS and itself then the UAV will assume that okay the communication is gone and what if it will do is it will immediately turn back around the autopilot will decide ok let’s back to home and home is a hard coded point in the memory of the autopilot which is the place which is somewhere near the which is typically the runway same runway coordinates from which they are craft take off.

So you have to set the home for the UAV then you basically deal with that in the controls - the control system which is the so the colloquial names for this is the airframe is the airframe or some people also called this as the aircraft, the propulsion the colloquial name for this is engine, control the colloquial name for this is the autopilot okay, communication this - this is typically called as comms, and payload is usually the video most of the time people called video as the payload ok.

So said home for the UAV this pretty much part of the you know autopilot, then perform communication check with GCS so the comms will be used for checking that and then we also some check on the control also so that we both part of that. Then fourth we will do is check payload functionality, so you are checking whether the payload is working then obviously the communication and the payload both needs to be worked and then you also need to ensure that the propulsion is ready because you require power to do this so all these three things need to be done.

And then let's say do one more thing what we call as Perform Control Checks - control check - control check is the control surfaces there are three control surfaces in this - this is the ailerons, elevators and rudders so they need to be checked so you need to check the airframe you also need to check the control and you also need to check the communications.

So this type of matrix system where when you doing at each functionality so these are individual functions okay individual functions that are to be performed so these individual functions are to be performed at some point in time and once these functions are to be performed what we do is we take that and then which are the aspects the physical architecture the physical aspects of the system whatever is relevant to this we put cross mark on it so that means there are the parts that are to be used to realize that particular function.

So the - the important thing is that this kind of a tool is necessary because the main thing is that the when Functional Architecture - Architecture is transformed or is translated into a physical architecture - architecture by using specific physical components then functions that will be performed - will be performed by such components are to be clearly identified.

So when we say that the func we - when we translate the functional architecture into a physical architecture where we use specific physical components then when the specific - specific physical components are used than these functions will be performed we have to decide which - which of these functions will be performed by such components and then they are to be clearly identified accordingly okay.

So if we - when we talk about this one of the major thing that we need to be very clear about in this regard is how the - how the different components are how the different physical components that are chosen to build the product will accomplish different functionalities so the functional so it the right name for this would be as Department Defense would call it the Functional Physical Matrix though different books called it a different name but the most right name for this functional physical matrix.

It is extensively used by again US DoD, I would say this tool was to a large extent developed by the people of the US Department Defense and is also a very good tool in actually identifying which functions are allocated with the which aspect of the which - which physical component of the system okay.

Now before we conclude this I also want to do a quick recap on something that we discussed earlier, so now as I said you know when you are synthesizing the design okay as part of this when you are doing Design Synthesis you are translating your requirements the whatever is the performance so remember that this is where your performance + functions - functions are translated to a physical product okay.

So when you are doing a product development when we are actually doing the development of a system than the if there is any error that happens in this it will actually cycle down to the physical product, so that's one of the other reasons why there is a lot of effort that goes into the ensuring that the performance requirements and the functional requirements the documents that are part of the loop that we mentioned earlier okay.

Or as we go back this emphasis lot of emphasis actually goes into this particular loop of the system so this ensures that system design is proper that is the most important aspect of it and if this is proper then the Design Synthesis okay if system definition which is in terms of functional + performance - performance measures, if these are popular then design or physical design is also or instead of ‘is’ will also result in a system that will satisfy the user requirements okay.

So by following the Systems Engineering process you will ensure that the system is built right and the right system is built, this is the most important take away from the Systems Engineering especially the design synthesis aspect of it. It is an expensive proposition as we said the Systems Engineering process is expensive and there are a lot of other (()) (34:27) associated with it.

But it also is imperative for all of us to understand why it is so and what are the other aspects of it so we gone through various aspects of few tools that are related to it. And thank you for your patience listening and hope that you will actually learn some - something out of this course and in that process you also I hope that you guys will apply some of the knowledge that you learnt at some places and you will soon find out that there are so many more tools that you need to learn

And then hopefully you will try to take your career into the higher levels of system engineering you will probably get an advanced degree in Systems Engineering and hopefully that this course will act as a precursor in that regard. Thank you very much.