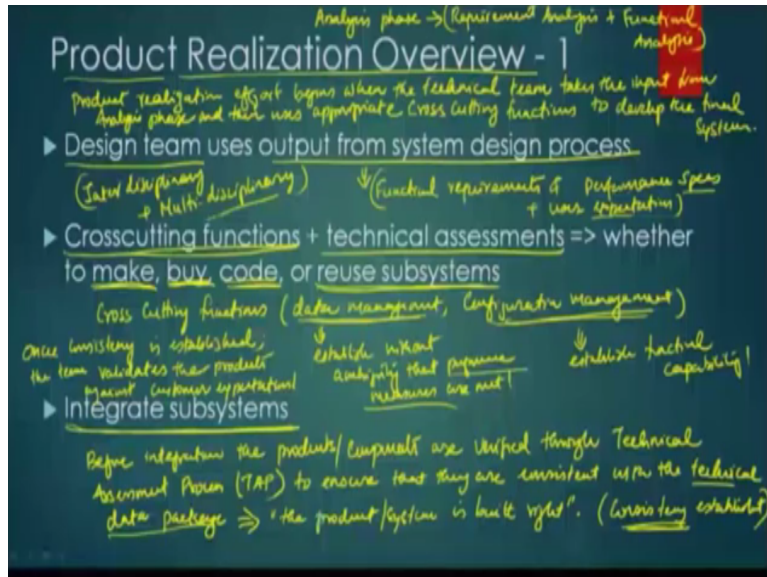


Systems Engineering
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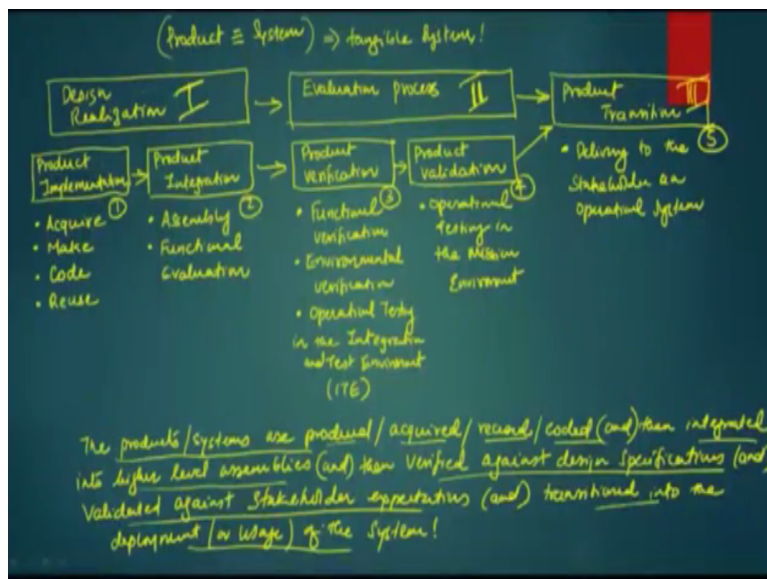
Lecture – 23.1
Design Synthesis (Continued)

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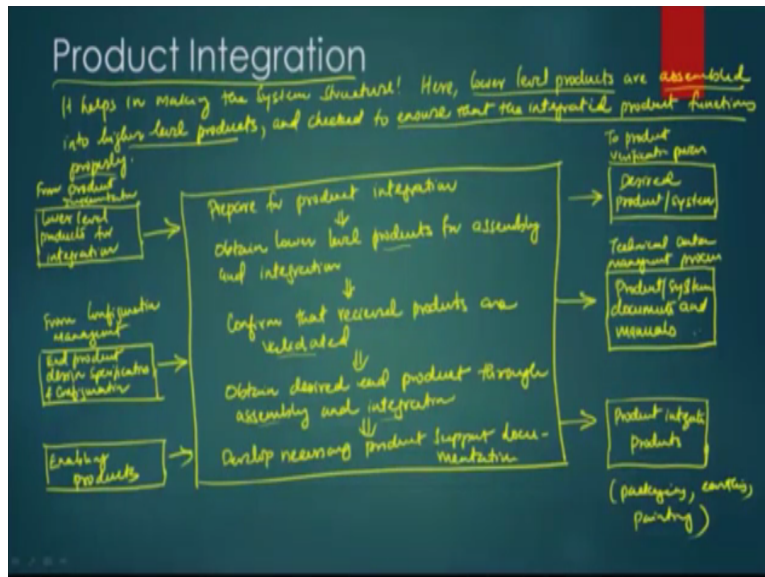
Good afternoon, welcome to the systems engineering course, where we are going to continue the previous lecture and we were talking about the systems.

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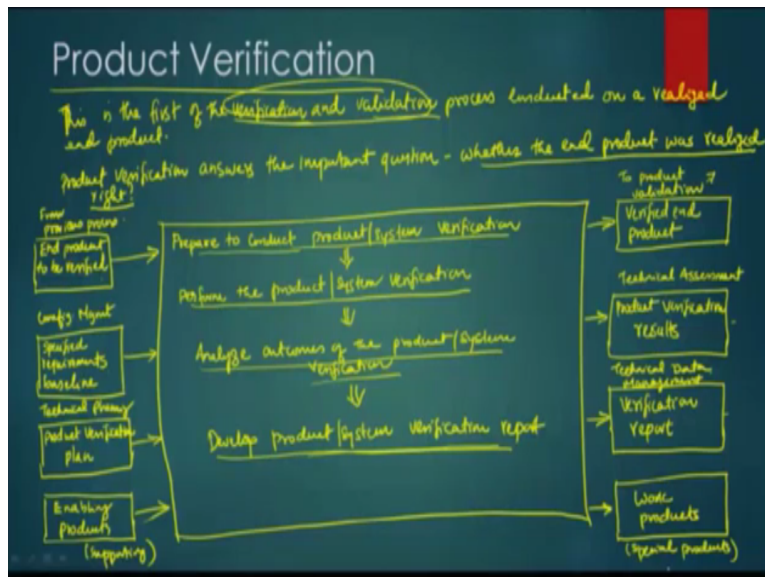
Actually the design synthesis aspect of the systems engineering and we were talking about how do we realize this and we talked about the, if you look at this, we talked about the product implementation, product integration, product verification, validation and product transition.

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And we looked into important aspects of it. We talked about what is product implementation? What is integration? And now we will get into what is called as product verification.

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So the product verification, which is the third step in this, if you think about this in the grand scheme, this is the third step. The product verification, this is the first of the verification and validation process conducted on a realized end product. So we are talking about a realized end

product in which it is the first of the verification and the validation process, verification and validation, verification and validation they both happen together and the first you always you do is the verification process, okay.

So the question is product verification, why do we do product verification? We do product verification because product verification answers the important question. Which is that important question? The question is whether the end product was realized right. This is a very important question. Was the product realized right, okay was the product built right? That is the question. So, we are trying to ensure that it meets all the performance requirements that is the aspect.

So we diagrammatically look at it, then we can see that following the similar lines of what we discussed the earlier. First input will be end product to be verified, okay. Then we have is specified requirements baseline, so the end product this comes from the from previous processes, okay. Then the configuration management, from configuration management, we get specified requirements baseline then we also get the, what we call as the product verification plan.

This comes from the tech planning, technical planning, then comes the enabling products, the last part. So these four inputs goes into the verification system those becomes the input to this, all of them and the first step is prepare to conduct product verification, product system verification, then after that what we do is we perform the product system verification. So once we perform the product system verification what we do is we analyze outcomes of the product system verification, okay.

Once this is done what we do is, we develop product verification report, product system verification report. So the process if you look at it again, first we prepare to conduct the product system verification that is the first part, then we actually perform the system verification. So preparation means you have to come up with certain experimentations you are to use certain machinery. You have to ensure that things are all set up appropriate data capturing mechanisms are available, all those kind of things.

So, once you do the perform system verification, you analyze the outcomes of the product system verification. So, whatever the outcome comes out it, you verify that and then you develop the product system verification report. From here we actually get four outputs and the outputs are, the first one is the verified end product, okay.

This goes into two product validation. Once verification is over you do validation, after validation then we have the product verification results, the second one, this goes to the technical assessment then we get what we call as the verification report and this report actually goes to technical data management, because this verification report needs to be taken out later and retrieved and then worked on it.

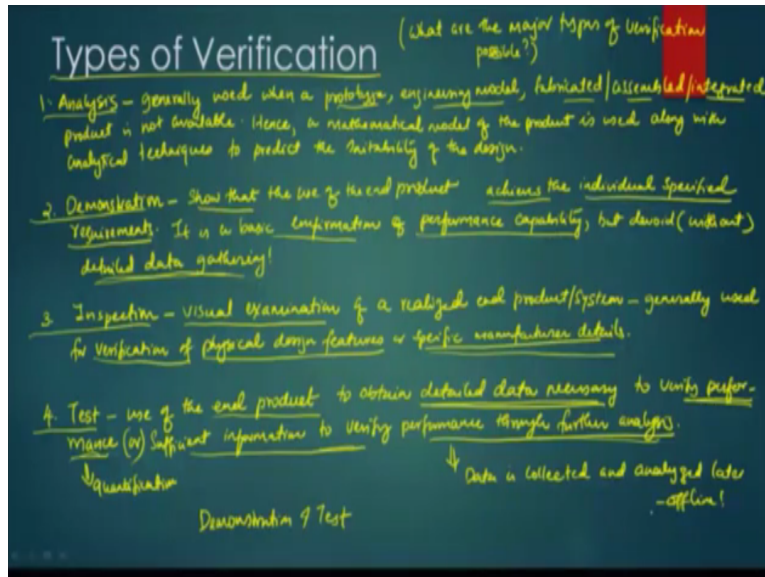
And then we have work products of the last one or whatever the special setups and other things that are necessary to realize the verification will be the part of the work products, so these will be the four outputs of the system. So, just looking at again, we take the end product to be verified. It actually comes from the previous processes. It could be the product implementation or assembly whatever it is then also the configuration management gives us a specified requirements baseline.

Then the technical planning from there the product verification plan comes out and then also the enabling products these are the supporting products or supporting items that are necessary to conduct successful validation of the verification of the system then the verification process is a four step thing.

First, we prepare to conduct the verification, then we perform the verification, then after that is done we analyze the outcomes of the verification and then we develop the system verification report, okay. And the output comes out is the verified end product which moves towards the validation stuff and the technical assessment part will get the verification results.

The verification report will go to the data management part of it and the work products, which are the end products that were used for conducting the verification will be also a part of that. So these are like you can think about the special products, okay, like special data acquisition systems, sensors, etc, will be part of that, okay.

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Now, what we will do is, we will talk about types of verification. Everybody talks about verification, verification, so what are the major types of verification possible, okay. It is a simple question, but there are actually four major things that are possible, the first one that is possible is called analysis. Analysis is a type of verification and what is analysis.

It is a verification that is generally used, it is generally used when a prototype, okay or an engineering model or a fabricated or assembled or integrated or manufactured product is not available. So when you really don't have a product available with you, neither a prototype nor an engineering model nor a fabricated, assembled, integrated product is not available that is when the analysis is used.

Hence, since the model is not available what you do? A mathematical model of the product is used along with analytical techniques to predict the suitability of the design. So a classical example of this is if you want to study what would be, the develop a model for safety evacuation of a big city in case of a nuclear attack. So you cannot really create a model of that because you can't take a nuclear bomb and put it in the big city where people are living.

So then what happens is model of the city, a mathematical model of the city is being built with appropriate buildings and all those kind of things and dropping off a bomb be simulated and then

the propagation of the shock wave through the different structures of the city is kind of simulated by the computer and it shows, okay.

If a bomb gets dropped this these are the areas that will be damaged significantly, so the evacuation plan should go for this and difference (()) (12:15) such a way that finally you have a solution, though that solution is not validated on a or verified on a real model, the computer systems are good enough at that point to give a very good ballpark figure of what to be done, good.

Then the second one that we talked about it is called as demonstration. So, demonstration is it show that the use of an end product achieves the individual specified requirements. So, here what you are doing is, you are showing that by using the end product or by using the system, we achieve the individual specified requirements, whatever the individual specified requirements they can be achieved.

This is kind of show that the use of the end product achieves the individual specified requirements. So, it is a basic confirmation of performance capability, but devoid or without detailed data gathering. So, demonstration in a way it is, it is we are basically confirming of the performance capability of the system, but you are not really looking into detailed data gathering.

A classical example of this is when I was talking about the UAV case that we, when we built the UAV, we are to sometime demonstrate the endurance capability of the UAV. So, we might not instrument it to the whole extent to figure out what is the rate at which the propeller is rotating? How much is the fuel is being consumed and all those kind of things. You probably just take off fly and see that whether the UAV can stay in the air for a specified time period thereby proving the endurance.

So you are basically confirming that, okay, fine, we can fly for six hours continuously and if it can actually fly for six hours continuously then you are basically demonstrating the capability of the UAV. So the demonstration, there is no serious detail to get data gathering. Usually detailed

data gathering does not happen because collecting data is an expensive process and costs involved in it.

Now, we talk about the third one, which is the inspection. Inspection is another form of verification, an inspection is typically a visual examination, it is a visual examination of a realized end product or system. So, it is generally used for verification of physical design features or specific manufacturer details. So, the idea is that it's a visual examination, inspection is mostly a visual examination of a realized end product system.

Most of the time you are looking at the physical design features, you are verifying the physical design features, sometimes you also conduct visualization to ensure that a specific manufacturer is there. So like for example, if you say that okay, I want to buy the UAV, we used the sensors made by Honeywell. So, when the Honeywell sensor comes in you would actually check okay, it is a same sensor, it has a same like same size, same weight, those kind of things.

But we also use to check and ensure that this is also made by Honeywell, not by somebody else. So that is where we were ensuring that the specific manufacturer has built that system. Then the fourth one is what we call us test and test is the use of the end product to obtain detailed data necessary to verify performance or sufficient information or you are gathering sufficient information to verify performance through further analysis.

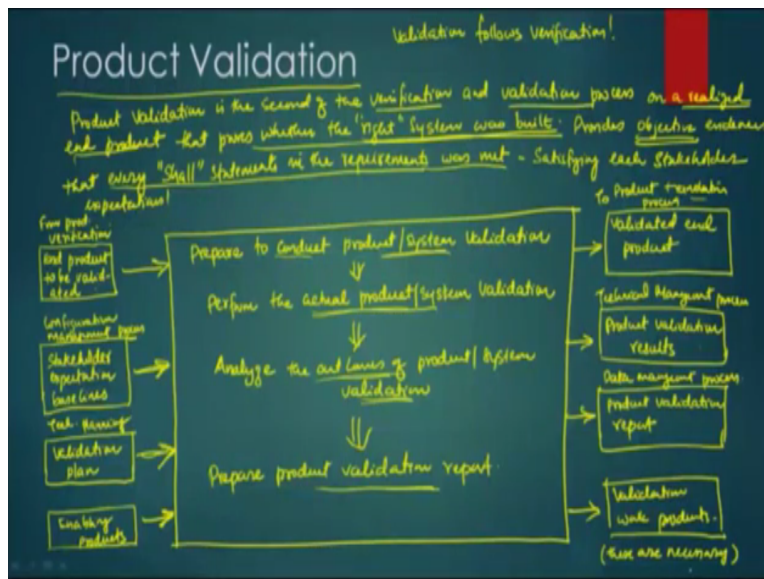
So this or clause is important because it is where the use of the end product. You are using the end product to obtain detailed data, so the difference between demonstration and tests that here you actually collect detailed data to verify the performance. You are quantifying the performance. You are basically doing quantification and for that you require well collected data, and otherwise you collect sufficient information such a way that the performance can be verified through further analysis.

So in this case what happens is data is collected and analyzed later or analyzed offline, this is also one part of the testing. So the verification, the types of verification analysis, demonstration, inspection, and test and we seen that the difference between demonstration and test. So,

demonstration is just demonstration that the individual specified requirement can be met, it can be achieved that is all demonstration talks about whereas test is where you are having sufficient information to verify the performance or sufficient information to do further analysis offline.

So now after seeing how the verification and the types of verification, we will now move towards what we call as validation.

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So the product validation, this is an interesting thing because product validation is the second of the verification and validation process. So it the second of the verification and the validation process, okay. So validation happens after verification, so it is validation follows verification, okay, validation verification process on a realized end product. So you have a realized end product here that proves whether the right system was built, "right".

You will put this in double right system was built. So, the first question in verification is did we built the system right, here did the right system got built. So in other way this provides objective evidences, remember we mentioned the importance of objectiveness, objective evidences that every - I will put this in inverted commas, every "shall" statements in the requirements was met or we ended up satisfying simply put each stakeholder expectations.

So, the important aspect in this case is that the validation happens on a realized end product and proves whether the right system was built or we are trying to find out whether the system that was built is capable of satisfying the requirements, set by the customer requirements or the expectations of the customer said at the time of the beginning when the system was conceived. So the every shall statement in the requirements was met, this is an important statement.

So, here you are actually comparing, the validation you are comparing against the wishes of the customer, so this is why it is called the right system was built, okay. The system that the customer wanted, did that system got built, that is what we are looking in this case. So, if you diagrammatically represent this case, we have the following system, again we follow the same pattern as does. So, here it is end product to be validated.

So this will come from the product verification that is one of the input then we have the second input, which is stakeholders, you can think about stakeholder as, stakeholder expectation baselines, okay. Then third one is coming from the validation plan and the fourth one is the enabling products, okay. So, these are the inputs of the system. So the end product to be validated comes from the product verification.

The stakeholder expectation comes from the configuration management process then the validation comes from the technical planning, so all of these get as the input to the model or the validation process, so we have the four inputs. We also have the enabling products because these are the products that are necessary to conduct validations, okay. So the enabling products all these four come in.

And the first thing that we do is we prepare to conduct product / system validations. So, first thing is you prepare yourself to conduct product or the system validation. Once that it is done, the next thing you do is you perform the actual product system validation. Once this is done then you do the third one, what do you do you analyze, you analyze what? Analyze the outcomes of product system validation.

Once you are done with the analysis what you do, you prepare a report, prepare product validation report. So, the four-step process, first you prepare yourself to conduct the product service validation, then you do the actual validation, you conduct the perform validation, then you analyze the outcomes of the validation process and then prepare the validation report, which gives you then four outcomes as well, okay.

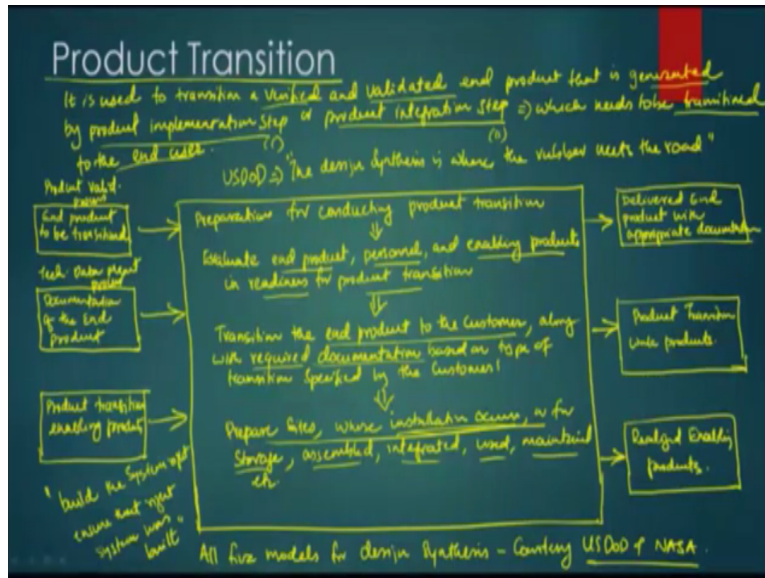
The first outcome is a validated end product, so the validated end product is the first part, which is also called as the product, which is called, this goes into the product translation process, this goes to, the output goes there, then it also the results, product validation results, this goes as part of the technical management process. Then we also have what we call as the product validation report, okay, and this also is the data management process, okay.

And finally we have the enabling products or what you call as validation work products, to do validation what are the special products that are necessary. So, these four outputs comes out of this step, okay. So there are four inputs, the end product we validated, which comes from the product verification from there we go into what, along with that the input goes is a stakeholder expectation, what the customer was wanting, and what is the validation plan that was done at the time of the technical planning, and the enabling products.

The products that will allow you to do the validation from there you do validation, which is a four-step process where you first conduct the, prepare yourself to conduct the validation, then you conduct the actual validation, then analyze the outcomes of the validation, and then the product validation report you prepare.

And the output is, the validated end product, which will go to the product translation process, the product validation results will go to the technical management process. The data management process will take the report and the validation work products are also an output because if you want to do further validation then these are necessary, okay, fine.

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So, then we move into the last step what is called as the product transition, okay. This is the fifth step. The product transition, it is used, when it is used? It is used to transition a verified and validated end product that is generated by the generated by product implementation step or product integration step, which needs to be transitioned to the end user. So what we are thinking here is that the product, which is very verified and validated end product, okay.

That is generated either by the product implementation step or the product integration step. This is step one and this is step two one of those, which got validated and verified and now it needs to be transitioned to the end user or the system needs to be taken and given to the end user for actually applying it in the field. So, if you actually look at it how the system is designed, the diagram looks something like this, similar to the previous diagrams we are drawing.

So, the first box will be end product to be transitioned, okay. This comes from the product validation process, okay. Then the second input is, documentation of the end product, okay. This from the tech data management process, then comes the third one, product transition enabling products, okay. So, these three becomes the input to our system, okay. The first one is you do the preparations for conducting product transition.

So, first you prepare the system to do product transition, then the second is you evaluate the end product, so you evaluate end product, the personal and enabling products in readiness for product

transition. So, this is where you are ensuring whether the product is ready for transition, being transitioned. So you just look at the end product, you also look at the personal, the people who are going to use it, and you are going to also see the enabling products and see whether they are ready to undergo the product transition.

Once that it is done, then what you do is, you transition, the answer is yes, then you transition the end product to the customer. How do you translate, transit, just do not just transit along with required documents, required documentation based on type of transition, transition specified by the customer. The customer has specified some transition and you provide the, you transition the end product to the customer along with the required documentation, so that the customer can use it.

Then what you do is, prepare sites where the product is going to be installed, sites then where installation will begin, where installation occurs or for storage, the product in to be stored or need to be assembly, assembled, integrated, used, maintained, etc, all these things, where you are talking about the storage, assembly, integration, usage, maintenance, okay. So you prepare the sites where the final system installation will happen, okay.

And this is where actually, Prof. Ian Angell also talked about systems engineering to a large extent currently being translated to what we call as installation, okay. So, when people talk about systems, instead of that people talk about installations. So, I think everybody is to focus on the last step and in the whole process forget the steps in between and then there are three outputs also like this earlier, sorry, outputs are first one is, delivered end product with appropriate documentation, okay, that is one part.

So then, we also will have what we call as the product transition work products and then the third one is the realized enabling products, okay. So, the three inputs into the process translate into three outputs, okay. So all these five models that we talked about, okay, all five models for design synthesis, okay, courtesy US Department of Defense and NASA, okay. So these are the two agencies, who have actually worked on developing this extensive framework on design synthesis.

How do the design has been once these specifications that are developed at the time of requirement analysis and the specifications that are further refined at the time of functional analysis along with the performance requirements, how does it runs, how can you come up with a step-by-step process in which these documentation, these drawings, these requirements, these functions everything can be translated into a tangible product.

So, this is where actually the US DoD kind of mentions this is these, the design synthesis is where the rubber meets the road. This is very true of a statement, okay. This is where the actual realization of the system happens. All that effort that you put into planning, all that effort that you put into doing other things everything is being part of is realized here at this point in such a way that you actually get a system that you deserve, not you deserve the customer deserves.

So, the important thing is build the right system and ensure that right system was built. So build the, build the system right, and ensure that right system was built. This is the nutshell of the design synthesis process. You are building it, but also building it not just for the sake of building it, you are building it that you are building it right and the right system actually got built, both of them are important.

Because when you are saying that when you are building the system right that means it is meeting all the performance requirements and the right system got built means you are actually building the system what the customer wants. So with this we actually come to the end of this long design synthesis process and in the following lecture what we will do is, we will learn about some of the tools and tricks that are used in the design synthesis process. Thank you for your patient listening.