Systems Engineering

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Lecture - 14
Engineering Development Phase

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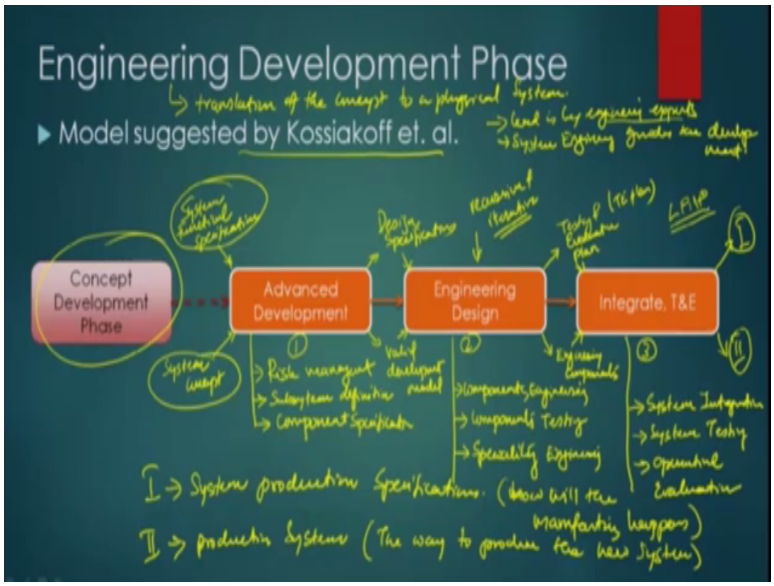

So second aspect of the system development phase is the engineering development phase, again models suggested by Kossiakoff et. al. and this model again as I said the input will be the concept phase whatever is input, output of the concept phase becomes the input of this one. So, if you drive the -- write the inputs, it will be the system functional requirement specifications, that comes as part of the output of the concept development phase and the system concept itself.

That is the that are the two inputs of the first stage of this development, which is actually called as the advanced development and in advanced development of the system, this is where the engineering. So, remember that the engineering is translation of the concept to physical system and here lead is by engineering experts system engineering guides the development. So individual components will be designed by the experts.

But the whole process of this engineering development phase will be guided by the systems engineering. So, the advanced development phase the major aspects of this are, one is the risk management, what are the possible risks that are associated with system and what are the aspects or how, what are the strategies that are available to mitigate that risk, that is one part of this. Second part will be the subsystem definition, because in earlier, one of the presentation we have discussed, how do we go down to each it is an iterative and recursive process.

We talked about the systems engineering approaches an iterative and recursive process, where subsystems are designed and developed are iteratively developed or specified, so that with keeping the functional requirements of the whole system in mind. So, subsystem definitions comes out as part of this and the third part also will be component specifications. So, these three will be the major output of the system from -- not output major activities that happens within the system, I apologize. And output as I also said earlier there will be two outputs of this.

So, the first will be the design specs, specifications and the second will be a valid development model. So, the output of the advanced development phase of the engineering, which is the first phase of the engineering development phase is to take the input from the system concept and the system functional specifications as input and do risk management subsystem definition component specification etc.

To come up with a detailed design specification and as well as a valid development model for the proposed system or the chosen system concept, which becomes input to the second phase of the engineering design, which involves multiple steps and the engineering designed steps are will be the component engineering, it will be engineering the components. The second part will be the component testing, components testing, which is plural, you have multiple components.

We are not talking about single component and we also have something called as specialty engineering. We will discuss what is a specialty engineering, little later but that is an important aspect of this. So, these aspects gets done as the engineering design and you get again two outputs, the first output is the testing and evaluation plan, what is also usually called as a TE plan and other output is called as the engineered, engineering or engineered components.

They are different components of the system, so this is where the, you can think about it as the recursive and iterative applications of the systems engineering happens here. So, these two outputs become input to the third phase varies integrate and test and evaluate, the third phase of this design and the major aspects here includes the system integration. It also involves the system testing -- system testing, it also involves the operational evaluation.

These are the three aspects of process. This will give rise to two outputs again, as we discussed earlier. So, I am just writing the outputs as one and two here and we will see what these outputs are quickly. So, the outputs one, one will be the system production specification. So, how will you manufacture? Here you are talking about the question is, how will the manufacturing happens? How will you produce the system?

Two will be the production system itself. Okay, the way to produce the system, the new system. So, these are the two outputs of the engineering development phase. So, as I said earlier, the concept development phase gives two, two outputs, which becomes input to the engineering development phase and where systems engineering approaches are get iteratively and recursively applied to design components, engineer the components.

And to test the components, ensure that the components meet the functional requirements of the system and also do specialty engineering. And once after that engineer, the engineer components, engineered components becomes the input along with the testing and evaluation plan where the system gets integrated. So you are recursively moving up and integrating the system and then testing the system and operational evaluation to ensure that the system is done ready, where you have.

So, this is where the, we talked earlier about the limited production LRIP and all those kinds of things happens as part of this, this step.

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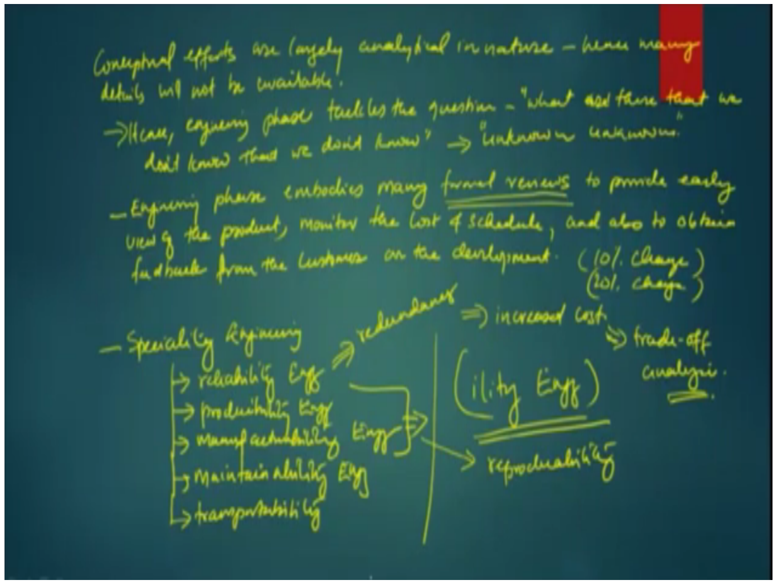

Also when we talk about it, we should also understand the part that the conceptual efforts, okay or the conceptual phase are largely analytical in nature. So, hence many details will not be available. So, that is one of the important aspect of the concept development phase. So, the, hence engineering phase tackles the question what is, what are there that, we do not know, that we do not know. Okay or in a simple way to know it as unknown unknowns.

So, it is a situation where you do not know that you do not know it. If you know that you do not know it then you can actually fix the problem. If you do not know that you do not know it, it is actually, it will escape your attention. So the engineering phase typically talks about understanding what are the things that we do not know that we do not know and how do we fix that. So, this is the one aspect of the engineering design.

The second aspect engineering phase embodies many formal reviews to provide early view of the product, that is one aspect. So, many formal reviews happen as part of the engineering stuff, because this is where the physical translation of the product happens. And also this one gives you something called as the option to monitor the cost and schedule. Okay. Where is the cost going? How is the cost escalating? How is this scheduled? Is it with the timeline within feasible aspects?

That is also as part of the engineering design phase. And also to obtain, obtain feedback from the customer on the development. The customer might change the mind at this phase and say I want to do this instead of this. If the customer gives a specific input, then still, because we are in the engineering phase where you are not really mass producing the system. It is quite possible to accommodate that as long as it is not a huge change or something like that.

There are situations where people even talk about 10 percent change rules, certain people talk about 20 percent change rules also. So, something like if the customer makes a 10 or 20 percent change the design usually can be accommodated if it is provided that the customer is willing to foot the bill for the additional costs and the scheduled delays. So, there are multiple models and methods used here. Okay.

Now one of the things that we did not discuss too much here is the specialty engineering and specialty engineering forms an important part of the engineering phase. So what are the specialty engineering? So, the engineerings that are called the reliability engineering, then we also called as a producibility engineering, some people also call it as the manufacturability engineering, some people call it as the, also as something called as the maintainability engineering.

So, these two are kind of same, but maintainability engineering is different then you have the transportability, yeah, then so these kind of things. So, usually these are called as ility engineering, the specialty engineering. That is why these would require an extremely specialized person to realize to do the reliability analysis, reliability engineering, what, so reliability engineering sometimes translates to redundancy.

Anyhow redundancy it translates to increased cost. So, ideally you would like to have redundancy throughout the system, but then the cost will increase drastically, so here is where the trade-off analysis also happens. Where do we call it good, so that type of studies are also part of this. So the specialty -- the produce ability or manufacturability engineering is can the product be really manufactured or can the system be manufactured well within the tolerances and the reproducibility.

So here you can talk about the reproducibility being studied. So, all these ilities, the specialties that is also aspect of the engineering studies of the system. So, before, and then we talked about the past deployment phase or what we call as the fielding phase where we have already seen Boeing 787 as an example and we discussed the aspects of it.

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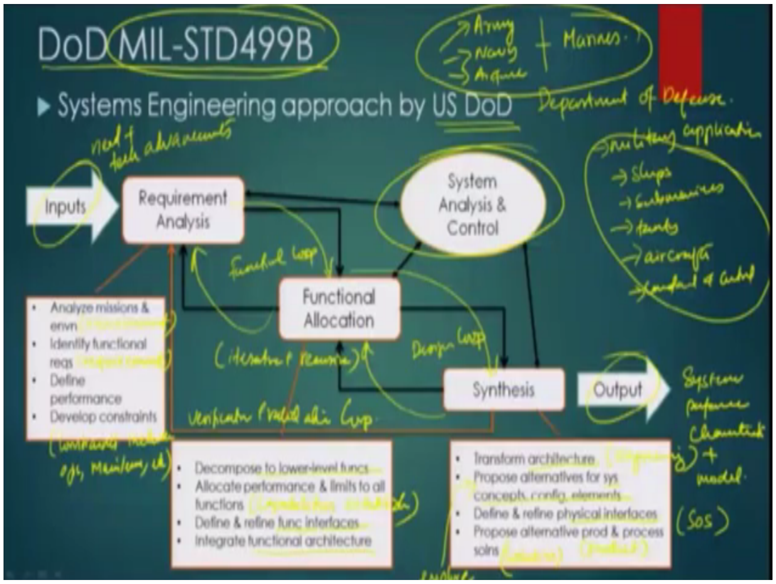

So, before we conclude today's lecture, I would like to run through three different systems approaches that are used in -- used as part of, used and we will be studying different tools that are related to different aspects of it. The first one is the DoD MIL Standard 499B. We studied, we talked about how the US Department of Defense Systems Engineering model earlier in this course.

So, this Systems Engineering Department, this was – this approach was developed with the US Department of Defense, this is the Department of Defense. So, the aim was to actually develop a system that is basically for military applications. So, stuff like ships, submarines, submarine is also one kind of a ship, tanks, airplanes, aircrafts, command control, command and control etc. So these kind of things, which are specific military applications.

The approach to develop these things were outlined by US Department of Defense and if you – in US the entire army or the military might, is divided into four parts. The four parts will be Army, Navy, Air Force and the fourth one will be plus Marines. Each one of them has specific different requirements and but to a large extent the requirements are pretty clear and crystallized. So, hence the model proposed by DoD.

The US Department of Defense is quite significantly applicable to military system design. Or it is, to a large extent is still followed in military systems engineering design. Not that much applied in the other areas. So, the input is where as we talked about the need and the technological advancements, the need plus tech advancements comes, advancements, comes here and from there the requirement analysis happens and the requirement analysis from where the function allocations.

So we talked about this loop as the functional loop earlier, functional analysis loop. Then the functional analysis we will go to the synthesis loop, which we also call as a design loop, and then from the design loop, we have what we call as the verification and validation loop. Okay. So, these different loops we talked about and then we have what we call as the system analysis and control where you are basically controlling the different steps throughout this to realize what we call as a system performance characteristic plus model.

So you are choosing the particular model and establishing its performance characteristics. So that is the output of the system. So the requirement analysis has basically what we call us analyze missions and this is environment, I kind of abbreviated it, I am sorry for that. And also you identify the functional requirements and define the performance and develop constraints. So constraints that are developed.

So, constraints mean, constraints include operational maintenance etc. So, what are the constraints within which what will limit the performance of the system is one aspect of it. The functional allocation on the other hand is where the iterative, so this is where the iterative plus recursive aspect happens, where you decompose it into lower level functions, it keeps going down and then you allocate performance and limit to all functions.

So, capabilities establish, so establishing the capabilities is part of this and you define and refine functional interfaces, how different functions will interface with each other and finally the functional architecture is also being done as part of it. So the different functional aspects, but as I said earlier the -- in defense systems the functional aspects are pretty much limited to the forces within which they are using it. So, hence it is very well crystallized.

So in that regard, so this is why this model works quite well for the defense aspects and the last part is the synthesis where you have the, you have the transform, the architectures, so this is where the engineering aspect comes into picture. You are transforming the architecture into an engineering architecture and you also do the alternative or system concept, configuration and elements.

So, here is the exploration part of it and define and refine physical interfaces, because many a times what happens is military system well have very complex subsystems so, or what we earlier said is something called as a SOS systems of systems is part of this. So hence, how does the interfaces interact and how what are the details of it, that also get specified here and propose alternative products, so this is product and process solutions.

So, this approach, the Department of Defense approach it can be if you go into the standard, which is publicly available Standard 499B, this whole process is outlined for you. And the systems engineering is the aspect, which actually controls this, which ensures that, these none of these loops run for indefinite. So, it ensures that the process moves from this phase to this phase and goes iteratively back.

So, sufficient iterations and recursions happen in such a way that the system design that comes out it, the output is sufficiently crystallized to realize the development of the system.

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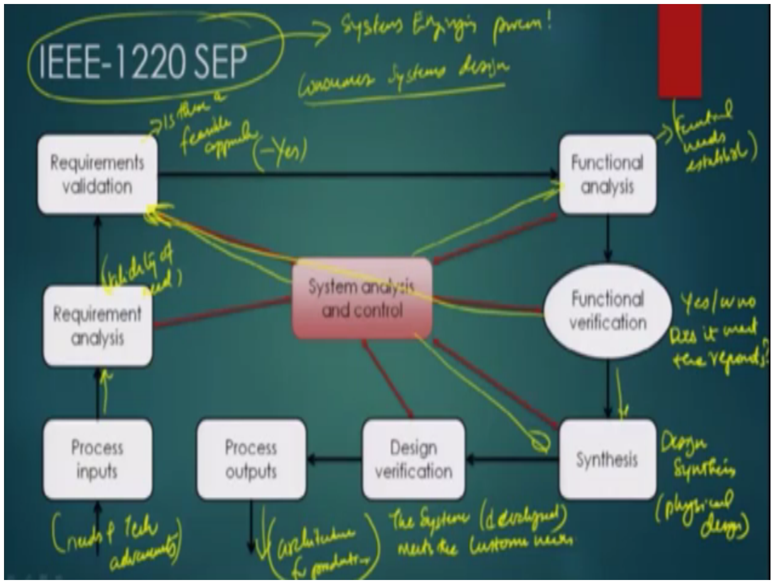

The second model I want to talk about is the IEEE-1220 SEP model and this is different compared to the, you can see this similar building blocks, but it is defined, different compared to the Department of Defense model and to a large extent the IEEE models were designed for the utilization of complex electrical systems to begin with or you can talk about it as consumer systems design. Not just electrical, consumer systems were actually what it was thought through.

So you have process inputs again as I said earlier needs plus tech advancements, will be part of this. Okay. Once you have the needs and the technological advancements then from there the process inputs happens, from there the requirement analysis, so this goes into the requirement analysis, where the requirement, the validity of the need, need and other aspects get established here. From then the requirements get validated. So is there a feasible approach?

Once it is done, if the answer is yes, then you progress to the functional analysis, what are the functions, functional needs establish. You establish the needs of the, what are the different functional needs of the systems. Once it is done, these functions need to be verified, so the verification is with the requirement. So you are checking the requirement, whether the, is the question is yes or no. Does it meet the requirements? That is the question answered here.

Once answer is yes then you do the synthesis, synthesis means you are basically doing the design synthesis. So the physical design happens here. So once the design synthesis is completed then the design gets verified, so the verified again is with the, you verified with the functional aspects, you verify with the requirements, you verify with the synthesis all those kind of things. The verification happens all across to ensure that the system, which is the developed system, developed system meets the customer needs.

Okay. So the design meets the customer needs that is being tested here and the output of this as usual we said earlier is that you get the, the architecture of the system. Architecture for production comes out as part of the system. You are -- you are again encouraged to study the standard and see what the systems engineering process involved in this. The SEP as we said earlier stands for Systems Engineering Process.

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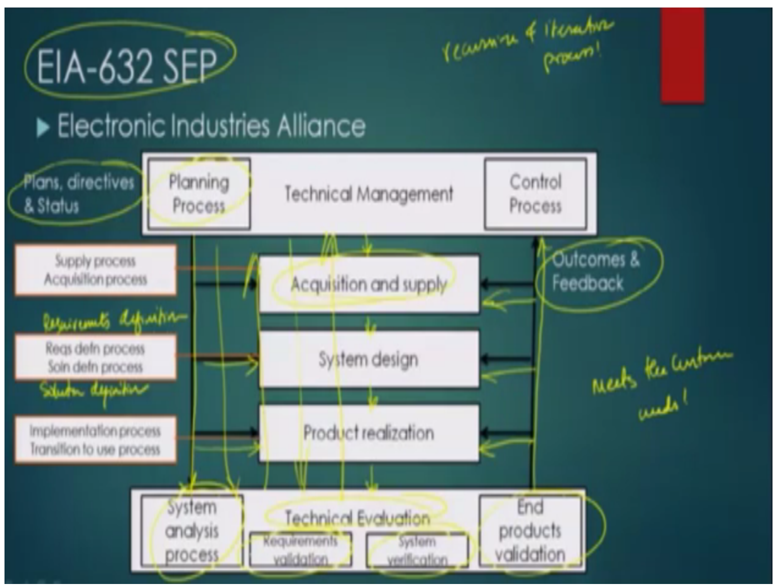

And then the third one I want to talk about EIA, the Electronic Industries Alliance Standard 632 Systems Engineering Process standards that is being also part of this. And here the, there is as I said earlier is that, it is a or many of the times, you have seen it is a recursive and iterative process. So it can be, it is quite evident here.

So the initial part is the technical management process, where the planning is starts with the planning, where the plans, directives and status, the need and the technological advancements comes into this picture from where, you know, you follow this line down where you have the acquisition and supply, where its supply process and acquisition processes gets these part of this. From there you follow down to what we call as the systems design.

So technical management goes like this through each level, but the follow up is that the first time you actually go from the planning to the system analysis process, where is the technical evaluation happens. So, the systems design is the, this is the requirements definition and as well as the solution definition. So you would – you define the solution and define the requirements as part of the system design while going down.

And then you talk about the realizing the product, the beta prototype is being realized, implementation process and transition to use process. So, then you get into what you call as a technical evaluation process, where the system analysis happens then the requirements are validated, the system is verified and then the end products is validated. And then you go back, which is the, where the outcomes and the feedbacks?

Where the process is controlled in this aspect? where the product realization? the feedback goes into the product realization, it also goes back to the system design and acquisition and supply. So we go through this process like, you know come down then go up, come down, go up like this. So you might do multiple iterations to realize what is the -- to realize the system that meets the customer needs.

So specific documents require -- related to all these three models will be provided as additional reading materials in the class and hopefully you can read that and understand. Covering this entire approach is part of the, the course is not feasible, so the people will be expected to do this as self-study. With that we will come to the conclusion of today's lecture on systems engineering, especially the lifecycle phases and as well as some of the brief overview or some of the lifecycle models.

With this we will now be drilling further deeper into different tools and techniques that we already have briefly mentioned certain tools. So, now some of the tools and techniques we will see what can be used and where it can be used and how it can be used and we will continue this discussion later. Thank you.