Systems Engineering

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Lecture - 12
The System Development Process

Good morning. Welcome to the today's lecture 12 of the systems engineering where we are going to discuss the system development process in detail and this is the first time we will be looking into various models that are used for systems development processes and various systems engineering models that are available. And I am Deepu Philip, and I am from IIT, Kanpur.

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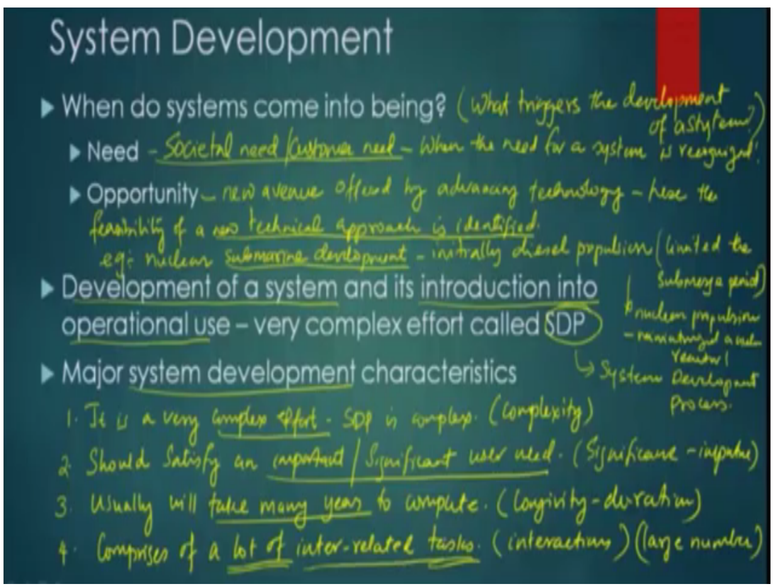

So, the system development, let us talk about this first. We already seen these various aspects of it in different lectures and we also asked this question many times, when do the systems come into being or what causes the development of a system to start? So, if we go through this, there are two aspects that we mentioned earlier, the first aspect being the need. Okay, so, the question usually is that what triggers the development of a system? Okay.

So, the question is what triggers the development of a system and or when does a system comes into be? The first is a need or sometimes people also call this as a societal need or a customer need, okay. Here, what happens here is, what happens is, when the need for a system is recognized, that is a first part. We identify the need for a system or we identified that there is a system that is required at this point.

Second one is the opportunity or this is also something called as a new avenue offered by advancing technology. Here the advancements in the technology has offered this new avenue or a new option and the thing is that here the feasibility of a new technical approach is identified. So, you have been doing some stuff, some similar activities and after some point of time you come across this new technological opportunity that is available to you.

Because the technology advanced from the previous time period and because of it you ended up developing a new system. So, an example of this let us think about an example, the example is the nuclear submarine development. Submarines were developed for a long time and people have been using it, the Germans called it as the U-boats and they use to go under the water, stay incognito and being able to identify the enemy ships and destroy them without the enemy ship noticing it, this was the general idea.

And initially, submarines were initially diesel propulsion. So, the diesel engine used to propel the submarine and the issue with that was that it limited the submerging, submerge period, but people were focusing on using diesel propulsion to submarines and at some point of time, the technology enhanced and what happens is nuclear propulsion, where the technology miniaturized a nuclear reactor.

This enhanced the endurance of the submarine to stay submerged in the water and all other aspects of it. So, the submarine, which was an existing non technology, the propulsion got changed to nuclear submarine within which the entire aspects, the design, the size, the endurance and all other aspects of the submarine really got changed. So, this is an example where a new technological approach has identified the opportunity to develop a system.

A system that is a modification of an existing system that is possible, other case when you societal need of a customer need is necessary, then a new system, need has been recognized and then the system development happened in that particular process. So we think about it, the development of a system, the development of a system and its introduction into the operational use, okay.

When you develop it and you introduce it into an operational use it is a very complex effort and it is called as SDP typically or it is the system development process. So the conception and development of a system and its introduction into an operational use along with retirement everything actually is called as SDP. Well, we don't really call a retirement as part of the SDP, but some people do, because when we see the different models available, models use different aspects.

So, there are major many characteristics of the system development. So, the system development process has many characteristics and it is important that we look into those kind of characteristics. So, what are some of those characteristics? So, the number one characteristics, it is a very complex effort. So, the SDP is complex, that is what it means. So, the effort is quite complex, there are multiple aspects, multiple fields, multiple agencies, multiple organizations all involved in it, so it is a complex effort.

So the complexity is one part of the system development characteristic. The second part of it is, it should satisfy an important / significant user need. Here we are talking about the significance or the importance. The user do need or what is the, how much the user need it? What is the importance of the need of the user that is the second aspect of this? So, it should actually satisfy an important or a significant user need.

The third point is usually will take many years to complete. So the systems development process, so the first part was the complexity, second part was the significance and the third one is what we talk about the longevity or the duration what we talked about. So, this is a long process, it will take many years to complete and hence it requires a lot of planning lot of resources and other things being committed into this.

So the longevity is the third aspect, if we talk about the fourth aspect, it comprises, the system development process comprises of a lot of inter-related tasks. So what we are saying here is that we have a lot of inter-related tasks or what we can call this as interactions, so there are so many interactions or so many interrelations that happens in between different tasks that are associated with the system development.

So the task are lot of, there are lot of tasks, lot means there are many, quite a large number, so large number of inter-related tasks is what we talk about here. So, we will look at the four aspects once again then we will go to the next one, it is a complex effort, so the complexity of the development process is one part, it should satisfy an important or a significant user needs, so significance is an important aspect.

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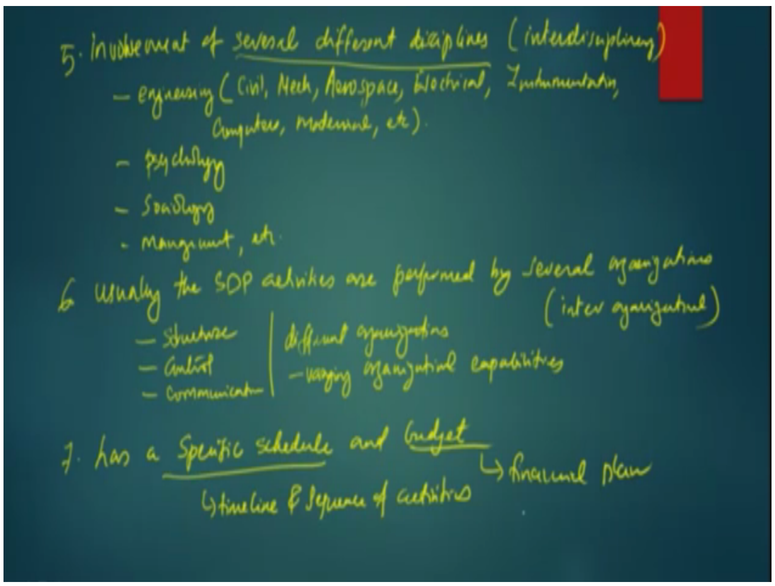

It will take many years or longevity, the duration is an aspect and inter-related task, lot of inter-related tasks is also one of the important characteristics. So, the fifth characteristic that we talk about here today is the involvement of several different disciplines, different disciplines. So disciplines for a matter involves engineering, we can think about it does the involvement of civil engineering, mechanical engineering, we can think about of aerospace, then there is electrical, there is instrumentation, computer science, material sciences, metallurgy, etc.

So wide different disciplines of engineering gets a part of being a part of this system development or they get involved in the development of the system, then other fields in called psychology, sociology, management, etc. So different disciplines, multiple, so this is what we call as the interdisciplinary aspect of systems engineering and sixth point that we need to talk about today is the usually the SDP activities are performed by various or several organizations, okay.

So, many different organizations will perform several aspects. so I can - an example will be that the structure might be developed by somebody, the control system might be developed by somebody else, then the communication will be by someone else, etc. So different aspects, different organizations because the capabilities vary across organizations because of varying organizational capabilities.

So, this is an inter organizational approach as well, it is an inter organizational favor to it, okay. The last point, seventh point that we need to talk about it is the SDP it has a specific schedule and budget. The development process has a specific schedule or a timeline and sequence of activities and there is a budget, budget means the financial plan is also as part of the development process.

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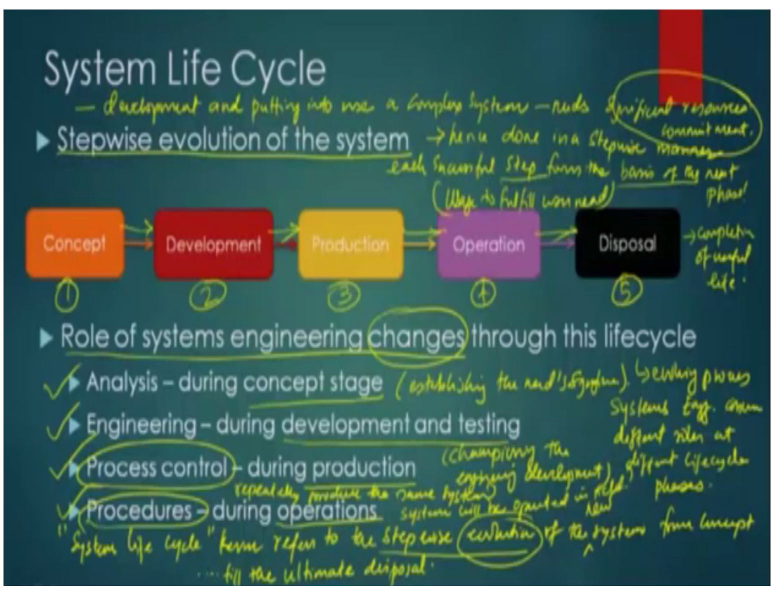

So, all these aspects, these seven aspects that we talked about are the important aspects of the different characteristics that make the system development process complex and unique. So, one of the things that we discussed earlier in the presentations is the system life cycle and we have seen it in the definitions in different flavors and all other aspects and in the simplest way to talk about it is a stepwise evolution of the system or how does the evolution system evolves from one step to another.

So, in a elongated way we can say something like this, it is development and putting into use a complex system, so developing and putting into use a complex system and it takes many steps and it evolves through different steps, okay. But, the major requirement of this, if you want to develop on putting into use a complex system, it needs significant resources commitment, requires time, it requires money, it requires man, it requires materials, it requires methods.

So many resource commitments are required as part of a complex system development phase. So, this is the reason why the system development stuff is done in, so hence done in a stepwise manner. Why do we do it in a stepwise manner because each successful step forms the basis of the next phase? So you do one step or one phase at a time and from there the successful completion of that phase forms the basis, it is the basics for the next phase of the development.

So, in a system life cycle, we talk about the five phases, the phase one is usually the concept phase where the concept of the system is done, phase two is the development phase where you are actually developing the system where you are doing a limited prototype and small-scale development where you are actually testing the feasibility of system development, and the third phase is the production where you are actually mass producing it or manufacturing the system.

Again as we remember the earlier side, we are talking about manufacturable systems in this case, we are not talking about services that much and the fourth one is the operation or the deployment of the system in its full use and is used for -- so here is the usage to fulfill user need, so that is the part of this and finally the fifth phase is the disposal where once the system is completed, so here is after completion of useful life, the system gets disposed.

So these five phases are the broad wise steps within which the system evolves. So, the system life cycle another example refers so, so in a way the “system life cycle”, this term in within quotes. It is this term refers to the stepwise evolution of the system or we can talk about as a new system, of the new system from concept through development, production, etcetera operations till the ultimate disposal.

So this is the one way to think about the system life cycle, so this term refers to the stepwise evolution of a new system from the concept, so it evolves from concept to development, to production, to operation, to the ultimate disposal where the system completes its useful time, so that this is some life cycle within the broader sense when we expand this. There are all of systems.

So since it is a stepwise evolution this term, the most important term here is the evolution. Then the role of the systems engineering also changes so through the life cycle, because life cycle is an evolving process. So, the systems engineering role also changes, it assumes different roles, so the systems engineering assumes different roles at different life cycles phases. So what are some of the roles?

During the concert stage, it assumes a role of an analysis, the need analysis, identifying whether the system is actually needed. Here you are establishing the significance of the need, needs significance. Is the user need significant? Is it worth the commitment of significant resources, this is what is being analyzed, so at that part you are taking the aspect of an analysis. The second is the engineering, during the development and testing phase.

It is basically championing the engineering process, championing the engineering development that is what is in the or managing the engineering development is what happens during the development and the testing phases. During the production or the manufacturing process control is the major aspect. So how does the manufacturing process? Here is where what we call as the repeatability, how do we repeatedly produce the same system?

That is the question that gets answered or that is what the role of the systems engineering is to ensure that the production and the results in the development of the repeated, the development of the systems, which are exactly same to each other. And in the operations, we talk about the procedures or how does the system will be operated in field, this part gets answered in this. So as the system is going through different life cycle, the role of the systems engineering also changes because at different phases of life cycle the system is evolving.

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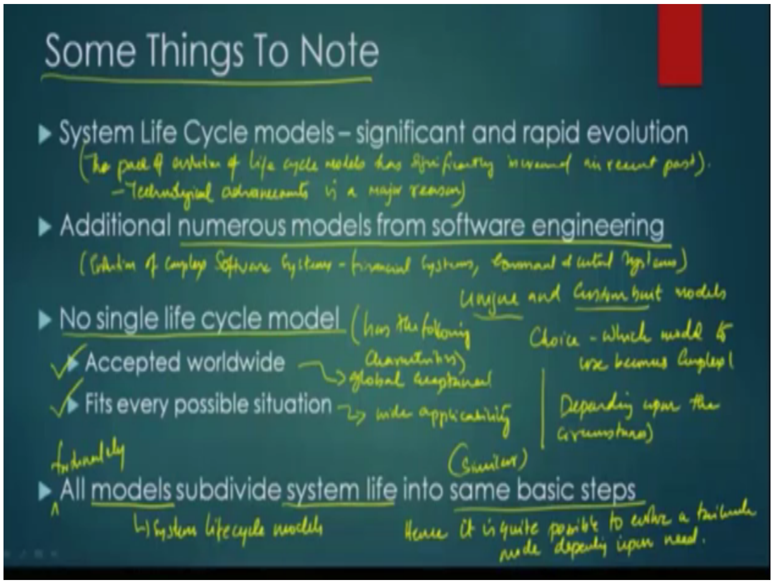

So, and some of the things that we need to note as part of this because it all sounds easy, but it is not that because the reason is of these things are quite important to note purely because of some specific aspects. The System Life Cycle models have seen rapid, significant and rapid evolutions. See this is the pace of evolution of life cycle models has significantly increased in recent past that is one aspect.

The pace at which, the speed at which, the new system models are evolving is quite fast now. One of the major reasons, the prime reason is technological advancement, technological advancements is a major reason. The next major reason is the numerous models from the software engineering or evolution of complex software systems, some of them are financial systems, command and control systems, etc.

So such complex systems, software systems have resulted in proposing numerous models and these models also have been added into the systems engineering. So the systems engineering life cycle models have seen a drastic set of change in the previous decades due to technological advancements and as well as the evolution of complex software systems. So, hence due to this what has happened there are a lot of unique and custom built models.

The lot of unique and custom built system life cycle models now available and when you have lot of models, obviously the choice of which model to use becomes complex. So before deciding which model to use everybody should be able to keep these two things in mind. There is no single life cycle model that has the following characteristics, has the following characteristics. First one is worldwide acceptance.

So there is no single lifecycle model that is accepted worldwide or what we call us a global acceptance. Second part is, there is no single life cycle model that fits every possible situation, so it is called wide applicability. So these two things are important to note, so there is no model that has a global acceptance and no model that has a wide applicability across different situations. So, hence the choice is usually depending upon the circumstance or circumstances.

So, but now the question becomes complex, you have large set of model, so how do you select from which model or which model to use, which life cycle model will fit the situation, it becomes a complex task. But fortunately, the important point to note is fortunately, all these wide variety of models, all these system life cycle models subdivide the system life. The system life is subdivided into same or similar basic steps, so luckily for the systems engineer.

Almost all these models subdivide the system life into the same basic steps. Hence, it is quite possible to evolve a tailor-made model depending upon the situation, depending upon need or situation. So depending upon the need of the systems engineer, you can develop your own custom-built model or tailor-made model.

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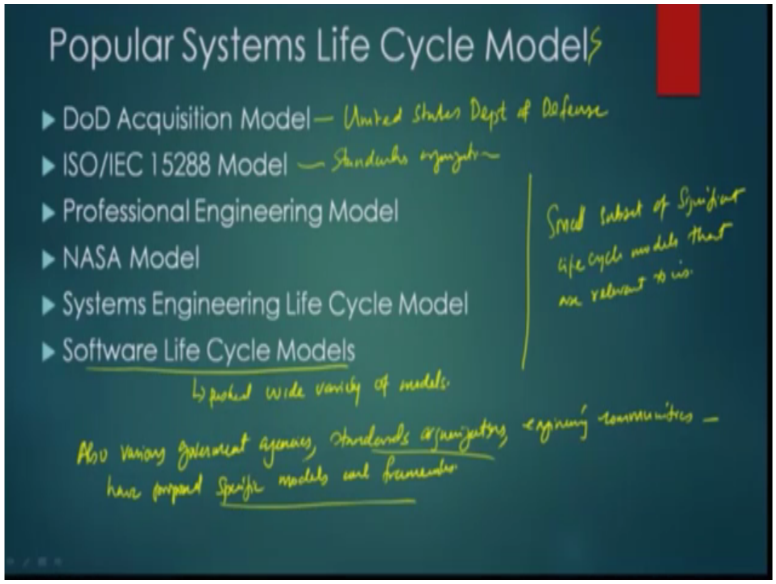

So the popular system life cycle model, so let us talk about which are some popular system life models actually I forgot the s in models. So the first and foremost that we need to talk about is the Department of Defense Acquisition Model, DoD is the, this is the United States Department of Defense Model. We will discuss this model slightly in detail in the following slides because this is usually considered as the precursor.

The starting, the first model that actually evolved and is still continue through evolve. It also limit applicability to large scale systems, but it is on military systems specifically, but it is a pretty good model and of the people uses model different flavors and different aspects or different parts of the model also get used. And then is the ISO/IEC15288 model, we will also discuss this later this is by the Standards Organizations.

Then the Professional Engineering Model is available, then the NASA model, the Space Agency, North American Space Agency's Model, then the system engineering life cycle proposed by Kossiakoff et al that is also is used here, then the Software Life Cycle Model specifically that is also coming from the different aspects of the software. So, here there are this is pushed wide variety of models that is one part.

Second is that the also is that also various government agencies under organizations standards organizations engineering communities, all of them have proposed specific models and frameworks. So the aspect here is all these things are (()) (27:57) this is just a small subset of significant life cycle models that are relevant to us. There are so many other models available, which we are not discussing any of them in detail here.

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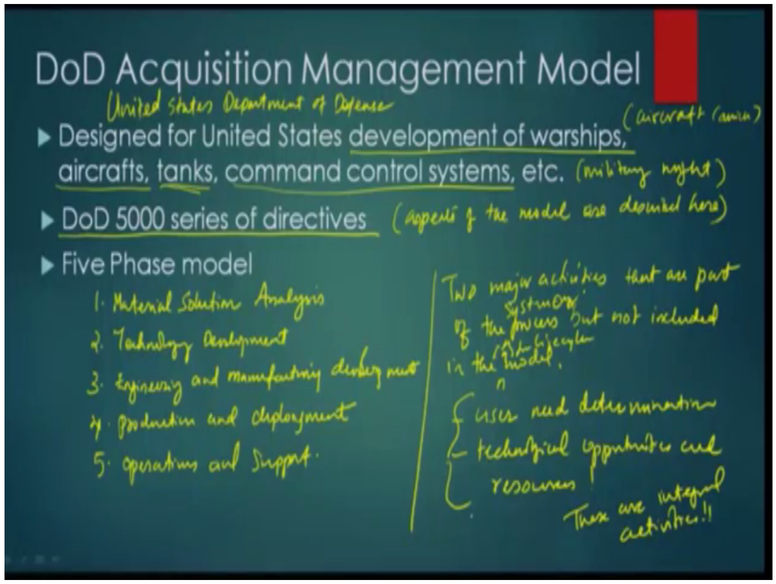

So, let us talk about few of these models in little bit detail. So, the first one we were going to talk about is a DoD Acquisition Management Model, okay. So the Department of Defense, so it is the as I said earlier this is the United States Department of Defense Acquisition Management Model.

So, it is designed for the United States, because United States have been involved in the development of big complex systems like warships or the warships in this case is we can think about aircraft carriers or super carriers that they call it, aircrafts, complex aircrafts, tanks like M1A1 Abrams, command and control systems, all these aspects United States have been in the forefront of the military might.

So this military might, the need to develop new complex systems for military requirement has translated into the acquisition management model by Department of Defense, which comes under the DoD 5000 Series of Directives. So aspects of the model are described here, so if we look at the DoD 5000 Series of Directives, the Acquisition Management Model is explained in detail.

This model is a five phased model and the five phases of the model, we can think about the phase one is the material solution analysis, is the first phase, the second phase is the technology development, the third phase is the engineering and manufacturing development, the fourth one is the production and deployment and the fifth phase is the operations and support. Okay, so these are the five phases of the model.

Then also you should understand that there are two major activities that are part of the process, of the systems engineering process, but not included in the model. So this is the part of the systems engineering process, but they are not included in the system life cycle model. What are those? Number one is the user need determination or determination of user needs, this is not included as part of the model. Second one is the identification of technological opportunities and resources.

These two aspects are not part of the model in fact they are considered outside the model, but they are, these are integral steps, these are integral activities. So just never get confused with the fact that the DoD Model does not include these two. They don't in the model, but that is considered as a precursor to this, so it's part of the systems engineering process.

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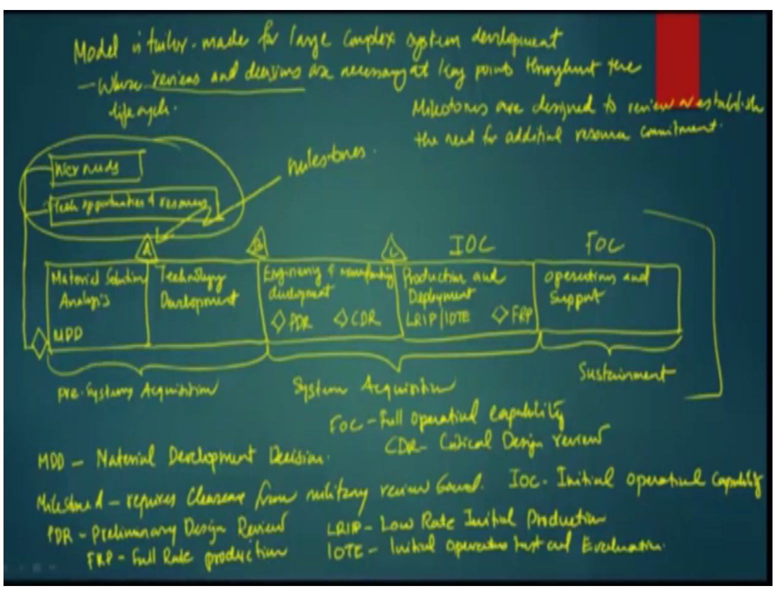

So, if we diagrammatically represent the, you know, systems engineering model or the DoD Systems Engineering Model, the model will look like this, but before we do this model is tailor-made for large complex system development. So we are looking at, it is a tailor-made model for large complex system development, so then what happens where reviews and decisions are necessary at key points throughout the life cycle.

So the DoD focuses on reviews and decisions at key points throughout the lifecycle of the system or the development of the system. So if you diagrammatically represent this model, the first two things that we need to talk about, which is not part of the model is the, let us talk about that as the user needs and the next one is the let us talk about it has the technology -- tech opportunities and resources.

So these two are the first part, but that is not part of the model. The model starts with the first step as we said earlier as the material solution analysis and the first key decision point is right here, the starting point, the decision point, this is called as the MDD. This decision point is called as the MDD, MDD stands for Material Development Decision, so the first part of the process is that the decision for deciding whether the material to be developed or not is taken as part of this.

Then the second part of the development goes into what we call as a technology development and here there is milestone, so these things are called as, these are the milestones. So for example milestone, A, okay milestone A is it requires clearance from, this is an example okay, from military review board. So, here you are saying that okay we presented, we developed the material for this material solution analysis has been done. Here is a user need.

Here is a technology opportunity and we worked on the material development, we have the material now, now we want to develop the technology. So, this is where the milestone a does a review and in the review if it agrees, okay this seems like a plan then it goes ahead and the technology development phase started. These two things put together is what we call as a pre-systems acquisition.

Pre-systems acquisition is the first two phases put together, then comes the third phase of the model, which we call it as the engineering and manufacturing development. Here is two major what we call as reviews or critical reviews the first one is what we call us PDR and second one is what we call as CDR. The PDR stands for Preliminary Design Review and CDR stands for obviously Critical Design Review.

So the two reviews here, which is the PDR and CDR and as well as there is an engineering and manufacturing development and there is another milestone here which is called as milestone B. It is similarly like the milestone A, it requires another review board to take a look into it and decide whether to continue to the next phase of engineering and manufacturing development. So, the aim of the milestones is milestones are designed to review or establish the need for additional resource commitment.

So at each stage as we progress from one stage to another or one phase to another, resources need to be committed and this resource commitment is actually established as part of this. Then comes the fourth phase, which we will draw here as the next box, which is called as the production and deployment. Here is another milestone between these two, which is called as a milestone C, and this step is also called as IOC or abbreviated usually in DoD terms as IOC, and what IOC stands for the Initial Operational Capability. Okay.

And here there is again what we do here is LRIP and IOTE, that is one part, which is not a review and then there is a review happens here, which is an FRP, so what are those, we will talk about this. So the LRIP stands for, LRIP stands for Low Rate Initial Production. So, the Low Rate Initial Production happens here, and IOTE stands for Initial Operations Test and Evaluation, this IOTE.

So, as the production and deployment phase the LRIP and IOTE is done where the Low Rate Initial Production and Initial Operations Test and Evaluation is done and then we do is the once that is done then there is a major decision that need to be made, which is called as the FRP and FRP stands for Full Rate Production. So deciding to go into a Full Rate Production is a decision point, a key decision point here.

These two steps put together Department of Defense calls this as the Systems Acquisition Step, system acquisition. So, step three and four together gives you the systems acquisition step and then the last step that we talk about is the Operations and Support and in the Operations and Support, it is called also called as the FOC and FOC stands for Full Operational Capability, and this fifth step is actually called as the Sustainment Step in the model.

So, I hope that you guys have understood how the Department of Defense model in a broad overview. You can read the DoD 5000 directives to understand the model much detail, but you can see that these two, the user needs and the technology development, when though they are not part of the model, the model is this aspect, but they are necessary before the first review, MDD review is basically taken care where the materiel development decisions whether we should go ahead and develop the material necessary for the processes done part of the here.

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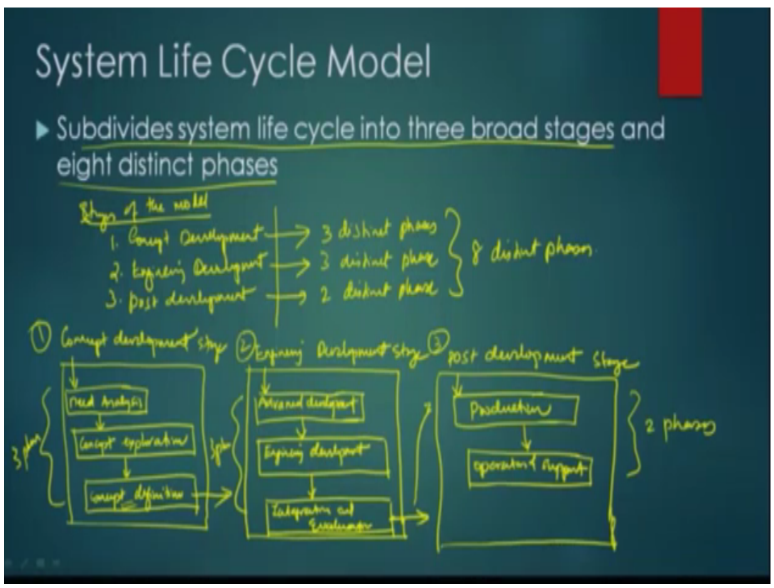

Now we will talk about the second model, the system life cycle model, we are not going to talk about all models, we can (()) (42:17) take different textbooks or the different documents and read and understand these models in detail, but I am mostly talking about the models that we will be discussing further down the course or aspects of different models, which we will be discussing further down the course is what we will be discussing here.

Other aspects you can read and find similarities among the models and understand it by yourself. So, the second model that we talked about is a system life cycle model and this is proposed by Kossiakoff et al and many variants of these models are available also. What it does is this model subdivides the system into three broad stages and eight distinct phases. So the three broad stages of this model are the stages are, the stages of the model.

There are three major stages as I said, stage one is concept development, stage two is engineering development and stage three is post development. So it develops the entire life cycle of the model into three different stages and each stage has multiple distinct phases. So the concept development has three distinct phases, engineering development has another three distinct phases and this has two distinct phases, so altogether eight distinct phases.

So if you represent this model diagrammatically or graphically the model will look something like this the first will be called as the concept development and to the concept development, the first aspect as we usually say is need analysis, unlike the DoD model, the need analysis is part of the model here, the system life cycle model here. Then from there we get the next one which is called as concept exploration.

Here we are exploring various concepts and once the various concepts have been explored and alternatives have been evaluated then we do concept definition. Once the concept is defined it becomes the precursor to the next phase of the model, the second phase of the model, which we call as the engineering development. So the definition, the concept definition becomes part of the model and from the previous step it comes forward and here what happens is the first phase is the advanced development.

What is the advanced development, it is the advanced development of this particular defined concept that gets here and the concept further gets advanced then from there we have what we call as the fifth phase, which is called as the engineering development and once the engineering development happens then what we have the third phase, third distinct phase of it what we call as integration and evaluation, integration and evaluation.

So the model gets integrated and evaluated, the engineering development different aspects of the model gets engineered out and then they are integrated and evaluated, then comes the third phase of the model, which has only, third stage of the model, which has only two distinct phases. The third stage is what we call as the post development phase, not phase sorry stage. So this is the concept development stage, this is another stage, this is the third stage.

And here are the three phases, here is also the three phases and here we have two phases. So, the first phase is production. So you have integrated and evaluated the model and this becomes the precursor here, okay. Once the production is done then comes in is the operations and support and support, okay. So the three distinct phases, not phases, stage, I am sorry, three distinct stages, and eight different phases.

So three in the first stage, three in the second stage and two in the third stage gives what we call as the system life cycle model, its completeness.

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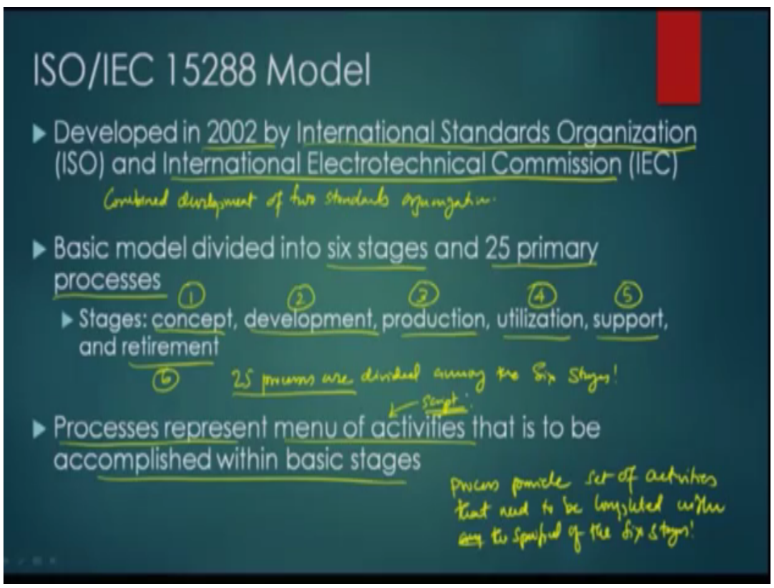

We will also discuss the last model today is the ISO/IEC 15288 Model, you can read this further this was developed in 2002 by the International Standards Organization, so ISO stands for International Standards Organization and IEC stands for International Electro-technical Commission. So it was a combined development of two standards organizations, so combined development of two standards organization, ISO and IEC.

And the basic model is divided into six stages, there are six stages and 25 primary processes, okay and the stages are, the concept stage, the development stage, production stage, utilization stage, supports stage and retirement stage. So, the first stage is concept, the second stage is development, third stage is production, fourth is utilization, fifth is support and sixth is retirement stage.

And there are 25 primary processes, these processes, the 25 processes are divided among the six stages. I am not going to get into the details of this model, this is slightly more complex, but you can read the details of this, it is freely available in the ISO website and other documents that documents are also available (()) (49:22). So what these processes, these 25 primary processes what are they?

These processes represent a many of activities that need to be complete within the basic stages. So the processes provide set of activities that need to be completed within, any within the specified of the six stages. So you can think about the processes, a set of activities, many of activities or we can think about this as a script that will ensure that you develop the system improperly.

So, what we will do in the next presentation would be we will discuss the system life cycle model in much more detail and we will look at various aspects of the model and we will try to study the salient features of, saline features and tools associated with these models so that depending upon the problem, the people who are attending this course will gain the insight to use appropriate tools and techniques for successful development of the system. Thank you.