Principles of Engineering System Design
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Lecture - 03
Modern System Design Processes

Hello friends. Welcome back to this third lecture. I hope you enjoyed the previous lectures and got some understanding of what is system engineering and what are the basic principles we need to know before we actually design the system, and what are the roles of system engineers. And in this lecture we will try to learn about some of these processes which are being used for design of engineering systems.

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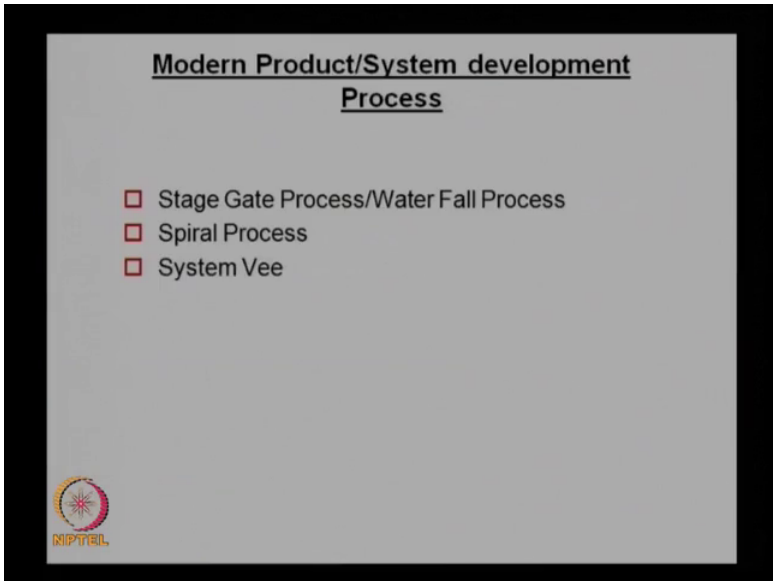

So, we will be discussing about the 3 major processes which are used for product or system development. The first one is known as a stage gate or waterfall process, which is used for mainly for product development. And then the next one is a spiral process, which is again a modification of stage gate process with the multiple stage gates. And then the last one is known as system vee, it is a system design process which is known as system vee.

So, let us go to the first one which is the stage gate process.

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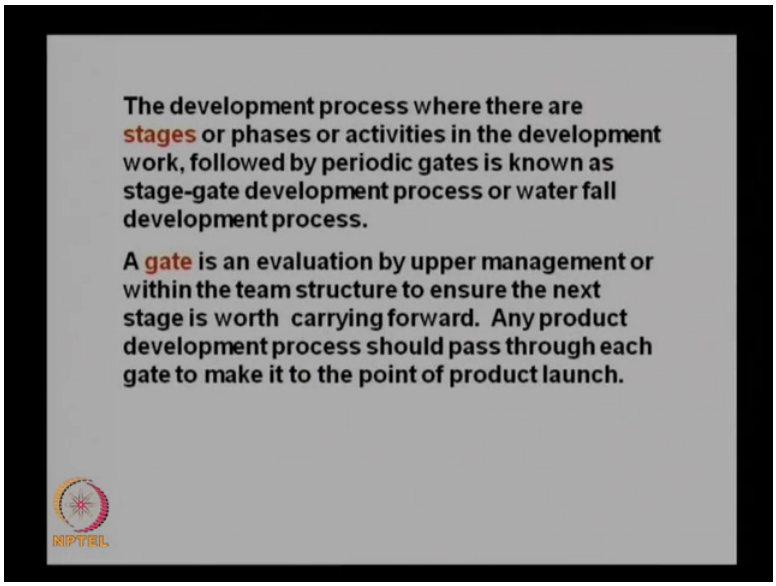

These development processes there are multiple stages in the design of a product or a system. So, every stage of development will be passing through a gate, which actually verify the system the design of that particular stage and then decides whether to go ahead with the design project or not. So, as you can see there are multiple stages or phases or activities in the development work, followed by periodic gates which are known as the stage gate development process. Because of this stages and gate we call it as a stage gate development process. A gate is nothing but an evaluation by upper management or within the team structure, to ensure the next stage is worth carrying forward.

Any product development process should pass through each gate to make it to the point of product launch. So, there are stages and gates. So, every stage will pass through a gate every design that stage will pass through a gate and if the fails at the gate the project will be scrapped or it will be modified to suit that present requirement and that is why this is known as a stage gate development process. Most of the project will be scrapped at the initial stages, but not at the later stages because once we put a lot of effort in developing a product and then coming to a particular stage scrapping that project may not be viable.

So, most of the cases, the scrapping of the project will be done at the early stages and at the later stages modification of the product or adding new functionalities of the product to meet the present requirement will be undertaken. Though the project continues the

product the final product may not be the same as which is anticipated in the beginning of the process. This is the stage gate development process.

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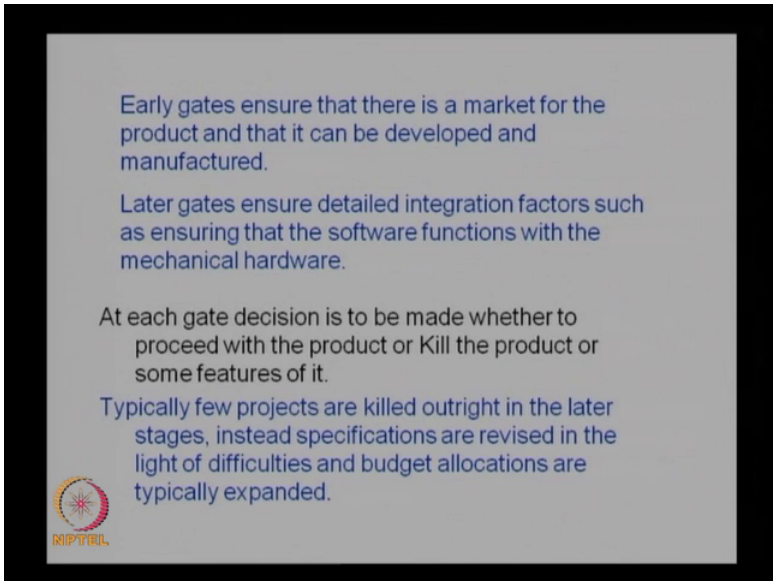

So, the early gates ensure that there is a market for the product, and that it can be developed and manufactured. So, that is the function of the early gates, which actually ensure that there is a market for the product and the product can be developed and manufactured. But later gates ensure detailed integration factors such as ensuring that the software functions and all other integration factors are taken into account that is taken care of in the later gates.

At each gate listen is to made whether to proceed with the product or kill the product or kill the some features of the product. So, depending on the product and the requirement, decision will be taken whether to kill the project or to modify the project or change some of the features of the product. So, as I mentioned only few projects are killed outright in the later stages instead specifications are revised in the light of difficulties and budget allocations and necessary changes are done in the gate analysis.

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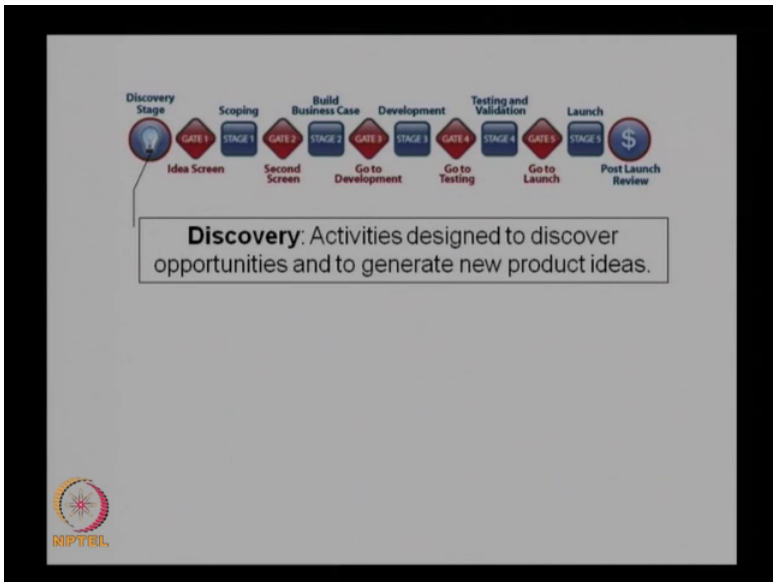

This picture shows how the stage gate process proceeds; as you can see that at every stage every design of a product or system starts with the discovery of a new requirement. So, somebody identifies a need for a particular product or a discovers in opportunity to develop a new product or a system, that is the earliest stage in the development process and it passes through an idea screen, were actually the gate the initial gate somebody analyzes that whether there is a good opportunity to develop the product.

So, if there is an opportunity to develop the product or that opportunity identified by the discovery of the opportunity of that particular product or a process, if it is worth proceeding then go ahead with that in the first gate it will be passed. And it will go to the next level of product scoping, do a market survey, and try to understand what are the customer requirements whether there is a real need for that for a particular product, those things will be analyzed in the next stage. And again you will pass through a gate and that takes it to the stage of build a business case for the particular product.

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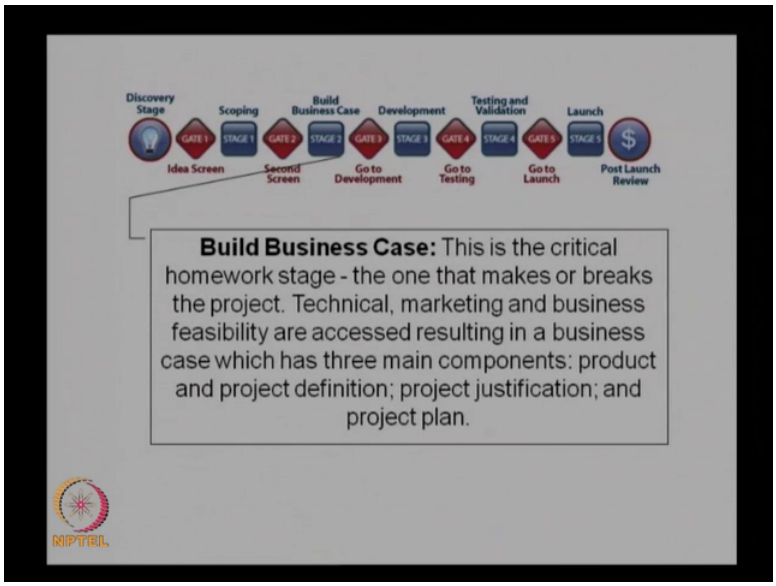

So, building a business case is the critical homework stage, one that makes or breaks the project. The technical marketing and business feasibility are accessed resulting in a business case which has three main components product and project definition, project justification and project plan. So, this is one of the important stages in the development where all the important factors are analyzed business aspect, a technical aspect and the feasibility of the project is accessed and decision is taken whether to go ahead with the project or not.

So, as you can see there are multiple stages product and project definition, and I mean you define the product and the project and then you justify the project and then you plan the project, how do we take this forward from that this to the next level. So, that is the stage 2. And again it goes through a gate where an upper management team will assess the whole project plan.

The project requirements and the feasibility of the project, and once it is satisfied it will go to the next stage for where actually the design and development; stage 3 where the design and development takes place that is the development stage where stage 3 is there where the development plans are translated into concrete deliverables.

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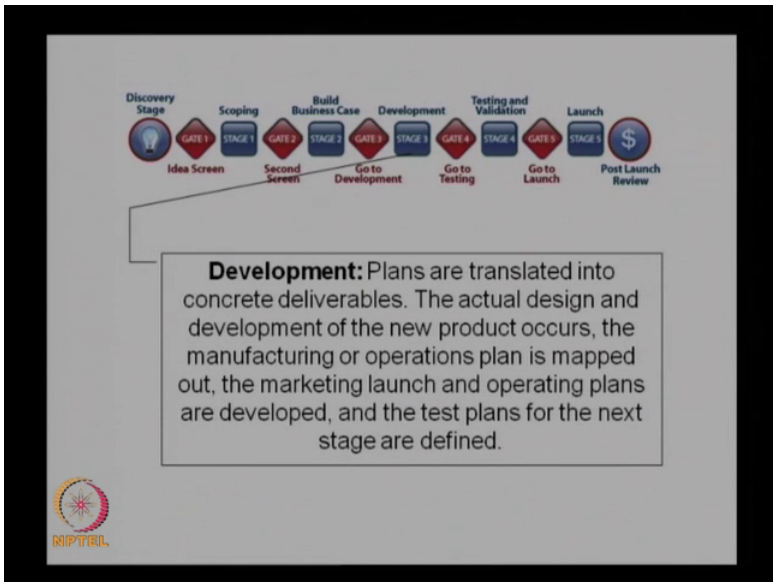

The actual design and development of the new product occurs the manufacturing or operations behind is mapped out, the marketing launch and operation team plans are developed and the test plans for the next stage are defined. So, all these are done in the stage 3 which is the development stage.

So, once it passes gate 3 then the complete design and development takes place all the technical people will be involved in this particular aspect. And they design the product develop the product plan for testing and verification and it goes through the testing stage which is the gate 4 and once it passes through the stage four that is the testing and validation.

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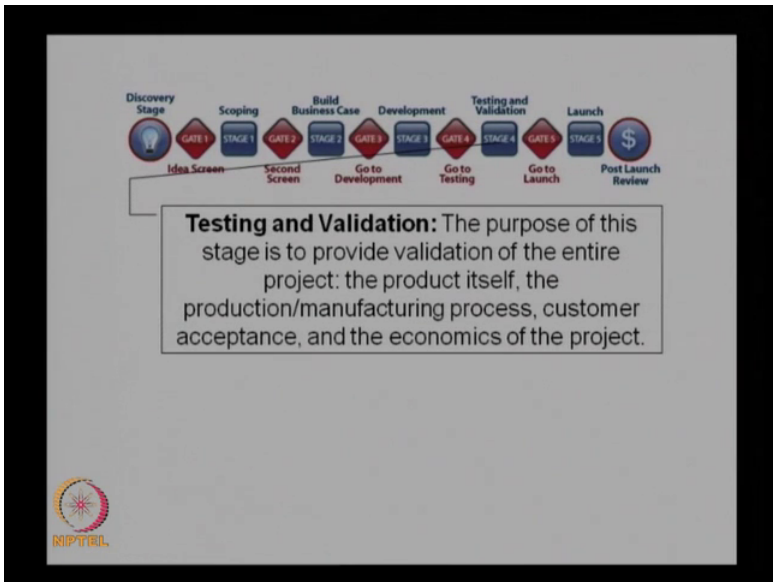

Where the entire project is tested and the product is tested, and validated for the requirement. The product itself the production manufacturing process, customer acceptance and the economics of the project are analyzed in this gauge, which actually decides to on this stage, then once it passes through the gate reaches to the launching stage of the product.

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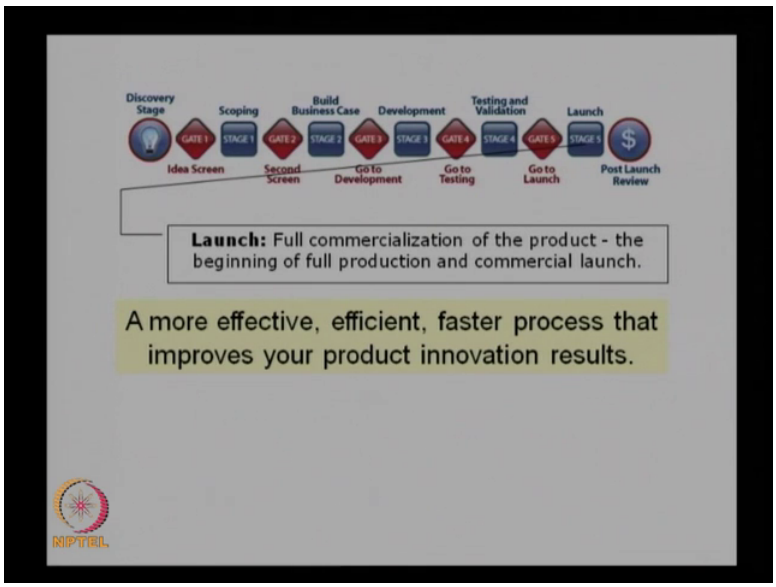

That is once it passes the testing and verification validation are those procedures, it goes to the launching stage and the product is launched into the market and starts getting

earning money from the project. So, it is a very effective efficient and faster process that improves our product innovation results. So, because there are stages and gates actually make sure that, whatever you develop at every stage is meeting the requirement and then only it goes to the next level of design. So, it becomes efficient and a faster process which improves the product innovation results.

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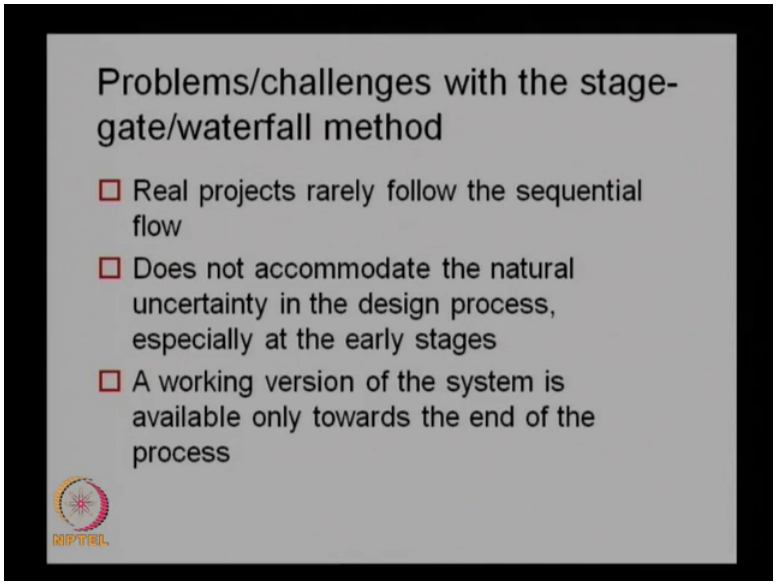

Though there are good things about stage gate development process, there are a few drawbacks also. The main problem is that real projects rarely follow the sequential flow. As we can see the project is following a sequential procedure, where you take do the first part of market analysis then go through a stage gate, then analyze the designed product, then do the fed testing verification etcetera. So, it is going in a sequential way. Most of the times the real projects would not do go take these sequential paths. There will be many parallel activities going on and it is very difficult to capture those activities in the stage gate process.

So, this is one of the drawbacks of stage gate process. Another one is that it does not accommodate the natural uncertainty in the design process especially at the early stages. So, there are many uncertainties in the early stages, which cannot be fully captured in this process because every stage gate once the gate passes the gate and all of the factors which are considered earlier will not be considered again in the next gate. Therefore, many uncertainties are not fully accounted in this particular process; and the working

version of the system is available only towards end of the process, again you do not have any product till we complete the whole project.

So, because it is a sequential process, you need to wait till the end of the process to get it a prototype of the product or a functional prototype of the product which actually will show you how the product will look like, what are the features and how to improve. And again by modification we may have to go back to the initial stage and again pass through the same stage gate process, to reach to the next prototype. So, this is another drawback of stage gate process and that is why there is another process called spiral model.

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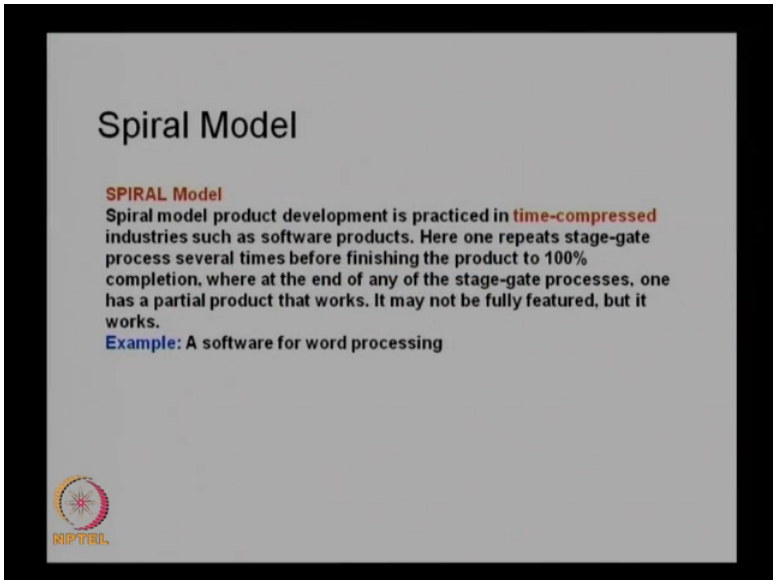

This is an improved stage gate process, where this methodology is implemented especially in industries where there are lots of pressures on time delivery or delivery of the product in time.

So, especially software companies are using this kind of a development model, where the product will pass through multiple stage gate process. So, it actually passed through a loop where one end to the other end you will pass through one stage gate, and you get the product and again it will pass through another stage gate again you would be having a product. So, you will be having different versions of the product that at the end of every stage though it may not be completely functional, it may not be a complete product. So, here one repeats stage gate process several times, before finishing the product to 100 percent.

So, the stage gate process is repeated with several times, to get a 100 percent complete product and at the end of any of the stage gate processes on has a partial product that works that is important. So, you have a partial product that works, at the end of every process it may not be fully featured, but it works. So, that is the thing the product may not be fully featured, but still it works example is for a software for word processing.

If you take the word processing software, you will see that this software will come with multiple versions. So, the first version may not be having are the features, then after that sometime that another person will come with the additional features, and he will keep on changing and at some stage the company will decide to stop that process and then will go to a next product. So, this is typically a spiral process where at one stage gate process, if the software windows need to be released in 2010. So, they cannot wait it to 2011 for all the features.

So, the windows 2010 will be released in 2010 with limited features, and as you progress as the time progressed they will add more and more features and become the next versions will be made available to the consumers. So, this is the way how a spiral model works.

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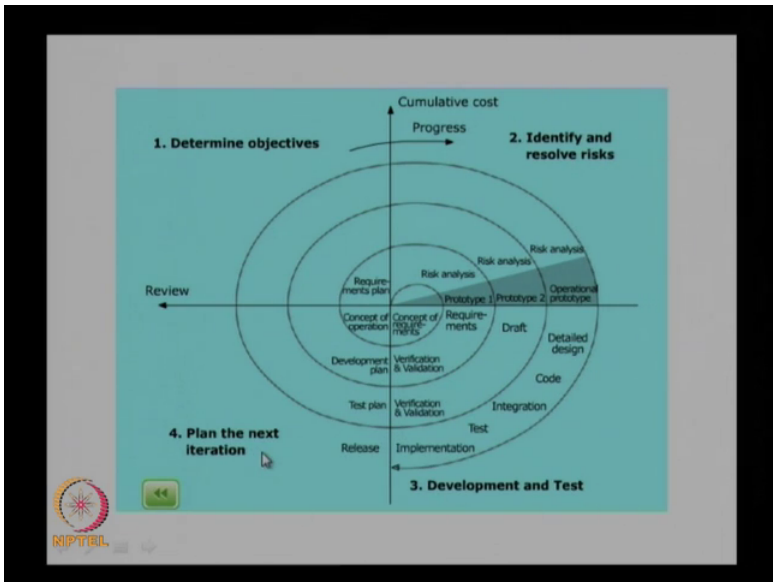

So, this animation shows the way in which the spiral model works. So, as you can see there are four buttons here one is the determinate the objectives of the process of the system, identify and resolve risk development and test and plan for the next iteration.

So, you can see here first it will start from this quadrant, where the objectives are determined. It will start with the identifying the reload risk concept requirements concept of operation requirements, plan risk analysis and prototype one. As we can see a prototype one is available once you complete one stage gate process of course, there are different stages in gates in this. And once we complete this stage gate, you will be getting at the end of this stage gate process you are having prototype one.

Again if the next level it will go once we complete the prototype one, we will not stop there again it starts the process again requirements verification development plan risk analysis and prototype two is available made available, again it will pass through and you will be getting prototype 3 also. So, you can see here at the end of every one stage gate process you have a prototype: prototype 1, prototype 2 operation prototype and depending on the requirement.

This will be keep on increasing once the company is satisfied with the operation prototype then it will go for detailed design code integration test and implementation. So, this is how a spiral gate process works. As I mentioned the advantages here is that you know that you can see a prototype right at the end of the first process, you do not need to wait till the end of this stage, where to the release stage to see a final product. You will be seeing a product and then it is easy to make the changes in the product by looking at this prototype and then you can see the improvement taking place over a period of time.

As you can see in software this typically happens the first version will come, and then again that will go through another design process, the second version will come like that keep on improving on the design. This is good for time compressed industries because they can deliver the product even though it is not fully operational, but partially operation product will be available for the consumer. This kind of process cannot be applied for consumer products mainly because you cannot have a partially working product to the customer. So, mostly if you go for a stage gate process or some other process to ensure that the fully functional product is made available to the customer.

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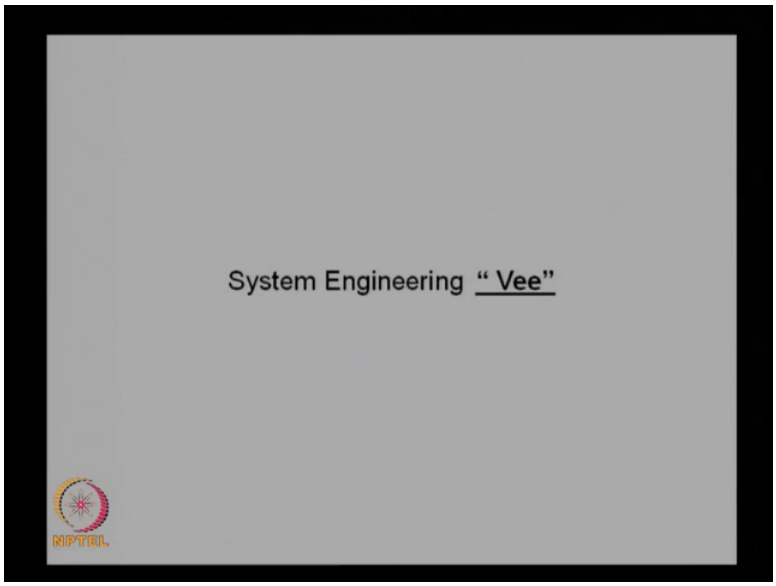

Another process is known as the system engineering Vee. So, we saw that stage gate process and spiral process. So, both this got their own problems and difficulties in implementing for a complex engineering system that is why we go for a another process called a system engineering Vee.

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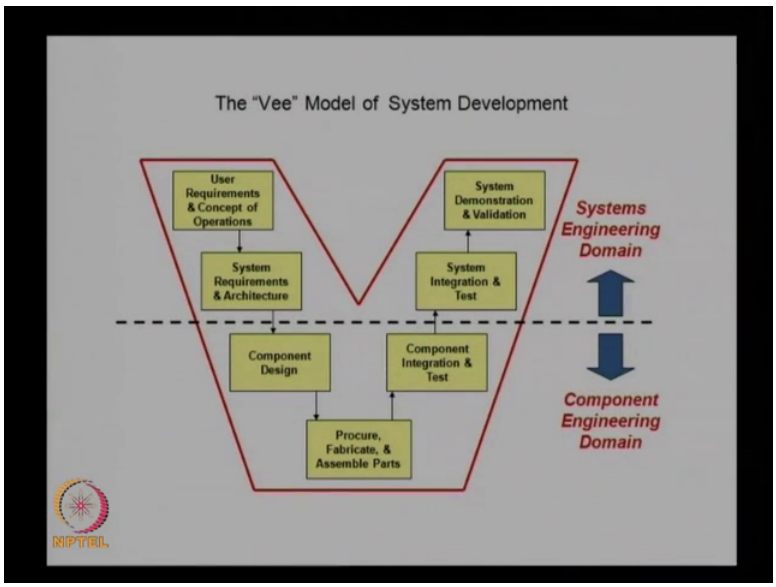

This is coming the name it comes from; the shape of this particular as the process it looks like a Vee where the activities involved in this process development are taking place some of them are a sequence and some of them are parallel. So, you can see many

parallel activities in this a completely sequential, since there are some parallel activities taking place that I why these looks like a v shape and that is why it is known as Vee model of system development.

This actually starts with the system user requirements and concepts of operation then system requirements and architecture component design, then fabrication assembled integration and test and system demonstration validation. So, the horizontal line here actually shows the difference or the domains of system engineers and the component engineering domain. It will go a little bit more into this process by taking another case.

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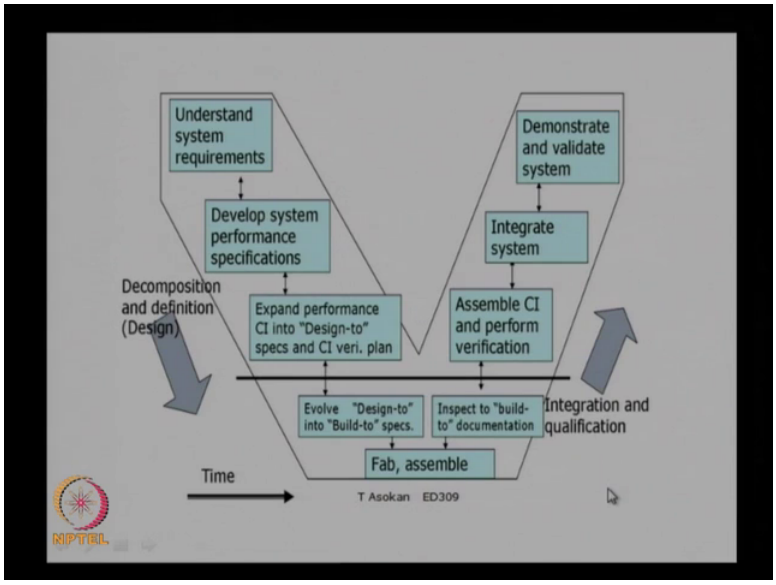

So, here you can see all the processes involved in the system vee engineering process; the left hand of the v actually represents the decomposition and definition stage of system design, which actually it starts with the customer need. So, you identify the customer need at the top and then go through the different stages of identifying the system performance specification and expand the performance into components and design specs to see a verification plans and then gives this to the domain experts, who actually define the system and then assemble and integrate and then again pass it to right hand side of the V which is the integration and qualification plan.

So, here you can see it is a decomposition and here it is an integration. So, we are decomposing a problem into sub tasks and then going ahead with the design, and once the design is completed we start making the system and then integration. So, this stage is

a decomposition stage and this is a integration stage. As you can see here, we start with the customer need then understand the system requirement from the customer perspective and develop the performance specifications, then go to the performance configuration items into design to specs and configuration item verification plan. So, we identify the performance specification and identify the systems and components needed for this particular performance, and then parallely develop the verification plan also and then pass it to the technology domain experts to design the actual components and subsystems.

So, the horizontal line again represents the division of job between the system engineers and domain experts here. So, once this is completed, this design performance configuration items and design to specs are identified, then the design engineers will develop the components and integrate them fabricate assemble and integrate and inspect to build to documentation.

There will be a documentation which actually specify what are the requirements or the specifications the component should satisfy for the build to system. And then we will go to the integration stage, where the configuration items are assembled and the performance is verified then again the system is integrated with all the sub components and sub assemblies, and then you demonstrate and validate the system to the customer and then once the customer accept it goes to the customer. So, this is how the system design process takes place in an engineering system.

As you can see here this is the timeline you can see there are many activities taking place parallel. Here you can see there as the process of understanding the customer requirements going on, you start the developing the system performance specifications also and it keeps on modifying as we progress with the time. And once it is finalized I mean as the system performance specification being developed performance here into design two specs and see a verification plan that is configuration item verification plan also will be developed. So, many parallel activities take place along with the sequential activities also, that is why we have a v shape for this particular system design.

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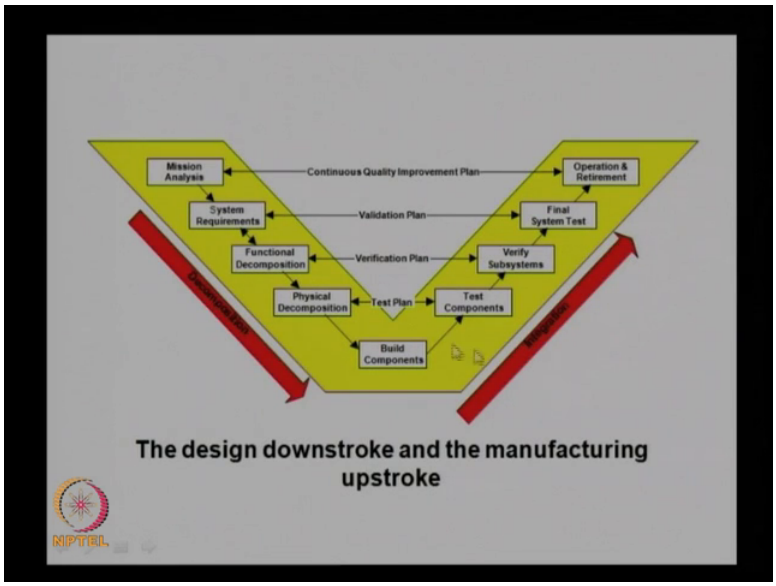

And these are the interactions between different stages in V as I told you the decomposition stage and integration stage, here we can see that at the mission analysis or the identification of requirement stage or the need stage, there will be a continuous quality improvement plan depending on the operation and requirement.

So, as we final system test is done and then the operation of the system is going on, based on the feedback the requirement will be modified. So, that the next level of development will be incorporating the requirements identified from the operation. Then there will be a final test the validation plan will be checked if the system requirements. So, as we develop the system requirement a validation plan also will be developed and the system will be tested against this validation plan or validated against the plan already worked out. Similarly there is a verification plan for the components and subsystems and the system so that will be the verification plan will be coming from this stage and it will be going, and it will be the system will be verified against this plan.

Similarly the component decomposition the physical decomposition and the test plan will be developed at this stage, which will be tested again the components which are being developed by the design engineers. So, there will be lot of interaction between this the two arms of the V and that actually helps to continually improve the design process.

So, this is the design down stroke and the manufacturing and assembly upstroke is this one.

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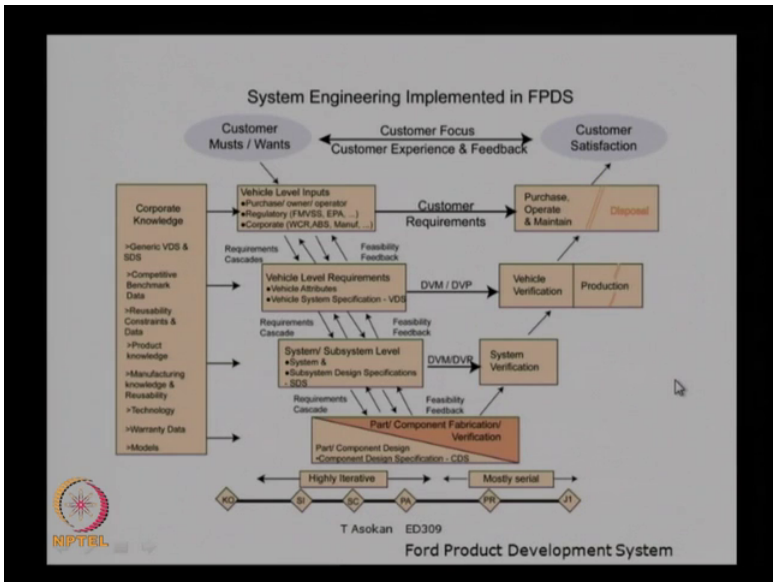

This shows the afford product development system. So, Ford Company uses this kind of a development system for their products. So, it starts with the customer must send once as you know that what are the requirements of the customer for a particular car or a particular vehicle from a Ford motor company. So, they look at these customer requirements, and then take this input and develop the purchase and owner operator requirements regulatory requirements and corporate requirements of the system. So, all these requirements are identified at this stage, and for this input the corporate knowledge what is the knowledge base what they have will be used to improve on this one. Already the company will be having a lot of data base from different correct customers and different products that will be used to define these customer requirements and that customer requirement will be the final checkpoint where when you have the system.

Then once the requirements are identified, then it will go to the vehicle level requirements that is more like this is customer requirement and then it go to the vehicle level requirements, identify the vehicle attributes, vehicle system specifications and all other requirements related to the vehicle. And once it is identified it will go to the next level of system and subsystem level system specification.

So, the company will develop specifications, based on the requirements are to be identified from the customer as well as from the vehicle requirements. Once that is identified it will go to the fabrication part design and fabrication plan and this will be

done by the domain experts. So, this will be the job of system engineer and again once it the part design is completed and fabrication is completed, it will go to the verification plan and once it is will be verified against the requirements or the specifications identified at this stage, and again it will go to the vehicle verification.

Verified against the vehicle level requirements and goes to the purchase or commercial aspect or the go to the customer, and that will be verified against the customer requirements and once that satisfied, we will go to the customer where the customer will be satisfied with the system. So, this is the flow of process in a system vee model of engineering system development which is widely practiced in industry.

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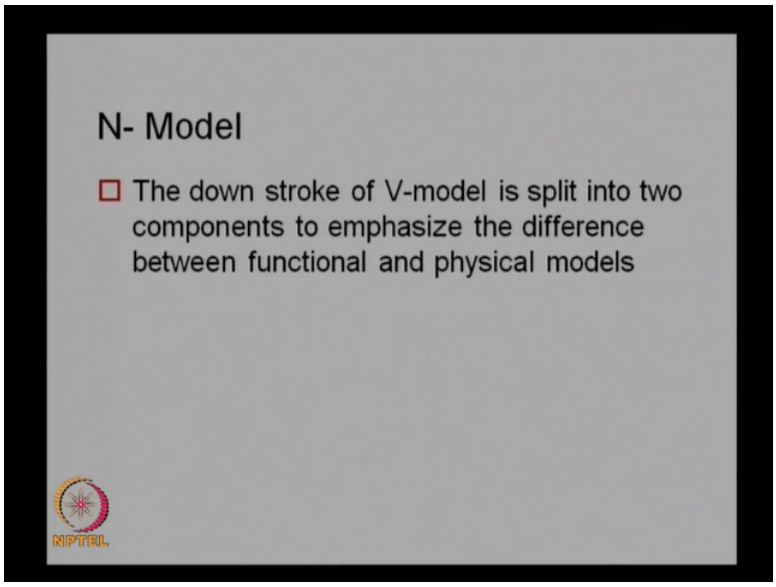

That was about the V-model; and there is another model which is not so, popular, but still for your information again I just mentioned it here it is known as N model. So, the down stroke of V-model in the previous case which is this will be split into two components to emphasize the difference between functional and physical models because in the previous V we have a requirement identification, development of the functional concepts, and then developing the design and then manufacturing of this. So, everything is in the left arm of the V.

So, in this case in n model, I try to change or try to split this into two components which actually will be one will be for the functional model another one will be the physical

model, that is only difference here; which is not very popular N model is not very popular, but the most of the companies still use the V-model only.

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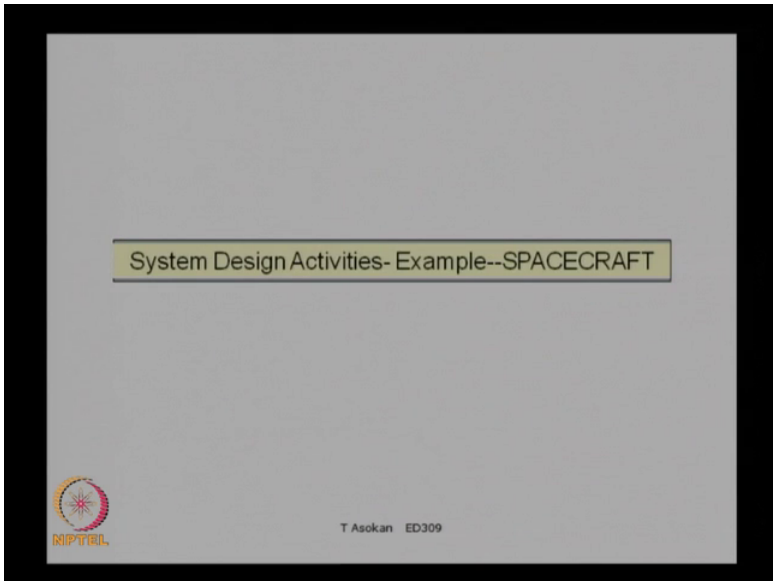

So those were the system design methods, used for development of complex engineering systems.

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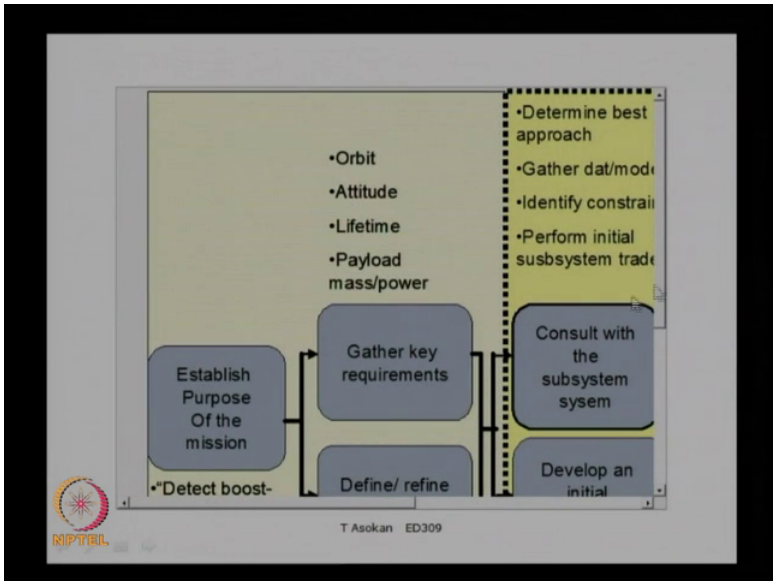

So, let us discuss about how actually a system design process takes place, in a real engineering world. So, this again from an up level view, I will be giving a top level view of how this is done, so because we will be going into the details at a later stage, but some

of the basic activities taking place in the design of an engineering system. So, this actually shows the process involved in the designing of a satellite system.

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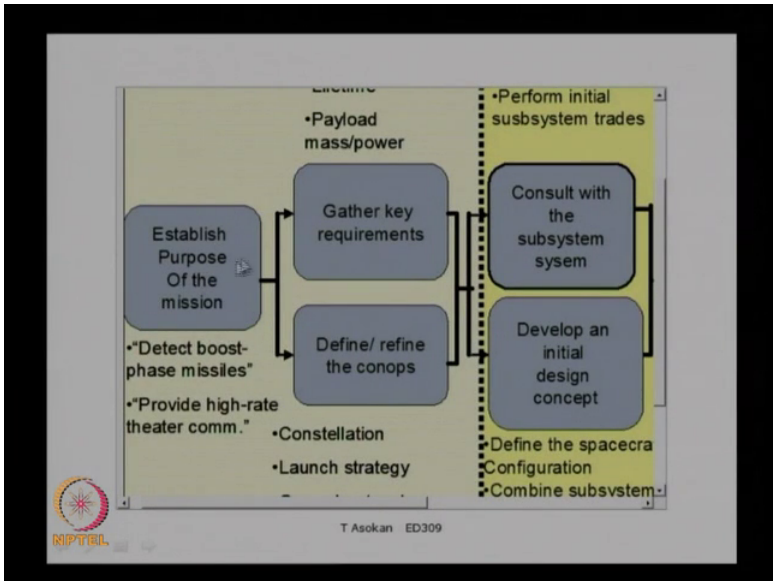

So, as you can see the say first stage we will develop the establish the purpose of the mission here, and then we try to find out what are the boost phase missiles required and provided right theater communication requirement, all those things will be established in the mission. Then we go to the next level, where the decade orbit, attitude, lifetime, payload, mass for etcetera are gathered. So, the key requirements like this are gathered in this stage and then define a concept of operation that is defined the conops. Conops is concept of operation.

So, based on these two purpose of the mission and the key requirements identified for this project, a concept of operation will be defined. W here actually how many what will be the constellation of this particular system, what is the launch strategy what are the ground networks needed for this one, what are the availability of different system and what is the method of data return or what is a data rate needed for this. So, these are the things done in the initial stage. Then, we will go to the next level where the subsystem development will take place.

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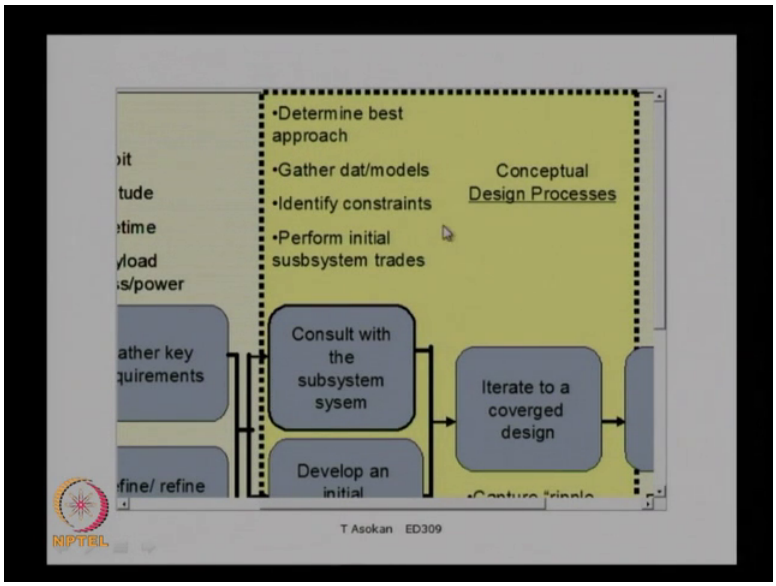

So, consult the subsystem develop an initial design concept. So, have different concept for this and term. Once you identify the best approach identify the data models identify the constraints and performing initial subsystem trades, develop an initial design concept for the whole system.

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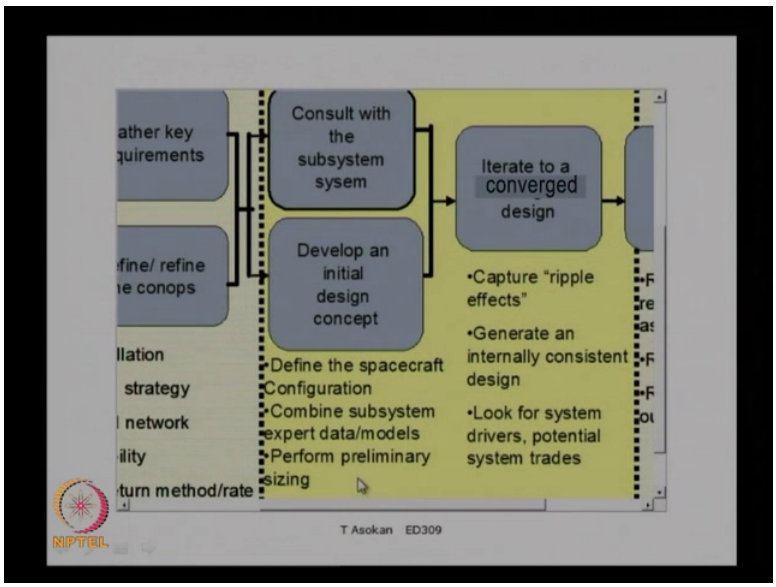

So, here you define the spacecraft configuration, the combined subsystem expert data models perform preliminary sizing of the system. And once you do the preliminary concept will go to the next level of Conceptual design process.

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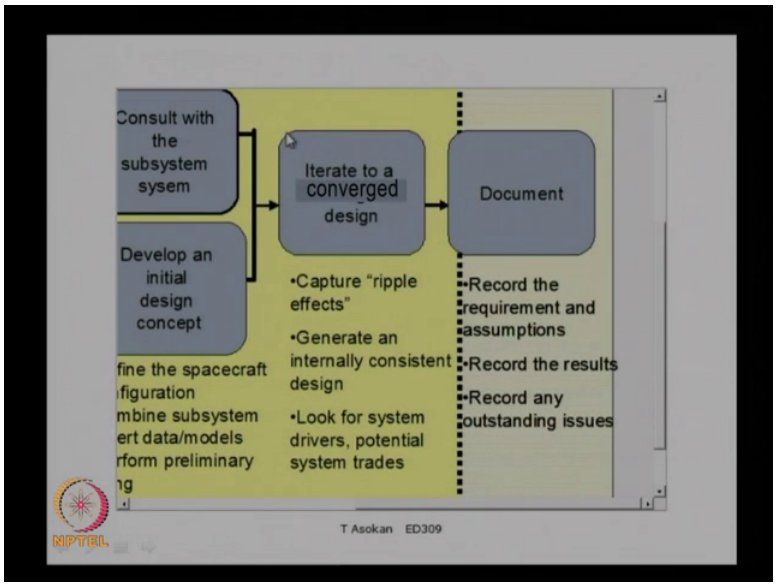

So, we have a converged design after many iterations of concepts, where we capture the ripple effects of having multiple iterations has generated an internally consistent design and look for system drivers potential system trade off.

So, what are the drivers for this particular system design and what are the potential trade off, you need to have to define this system. And once you have this design process is completed, we will document the system the whole design process where the requirements and assumptions are documented. The results of the design concept developments are recorded and then record any other outstanding issues. So, this is the first level of design process, where we develop at document for recording all the requirements design concepts.

And whatever the information we gathered from the process through this process of developing a particular system, where we follow a process were identify the purpose of the mission, then identify the requirements and then develop the concept of operations, initial concepts, refine the concepts, and finalize a particular concept to launch the system; that is how a typical top level process works.

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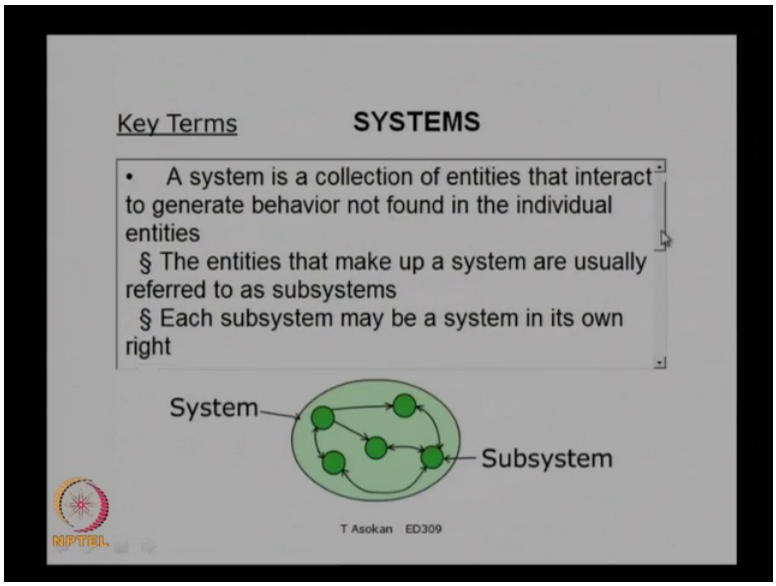

So, let us design some of the important key terms, which we may be using frequently in the design of the system. Definition of the system we already saw, which is a collection of entities that interact to generate behavior not found in the individual entities, and there are the entities make up a system are usually referred to as subsystems. And each subsystem may be a system in its own right and a system takes inputs and generates corresponding outputs.

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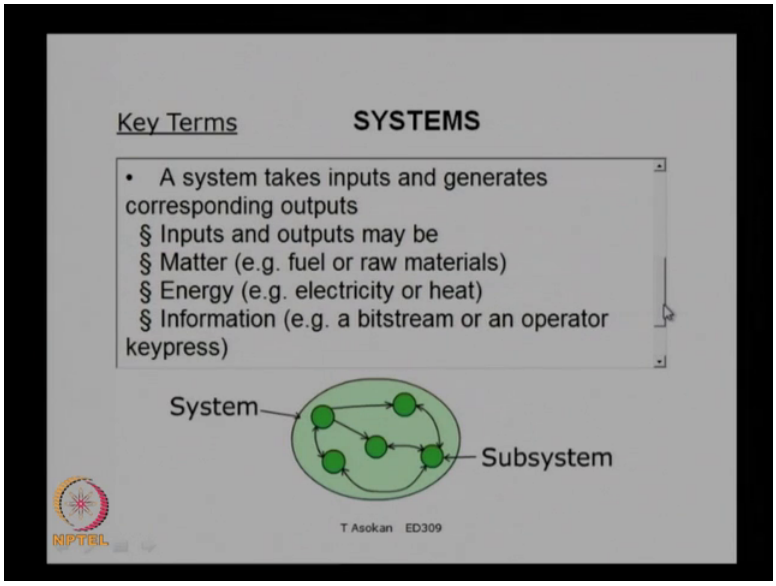

So, every system takes some input and generates outputs and this inputs and outputs may be matter energy into or all information. So, any of this can be the input.

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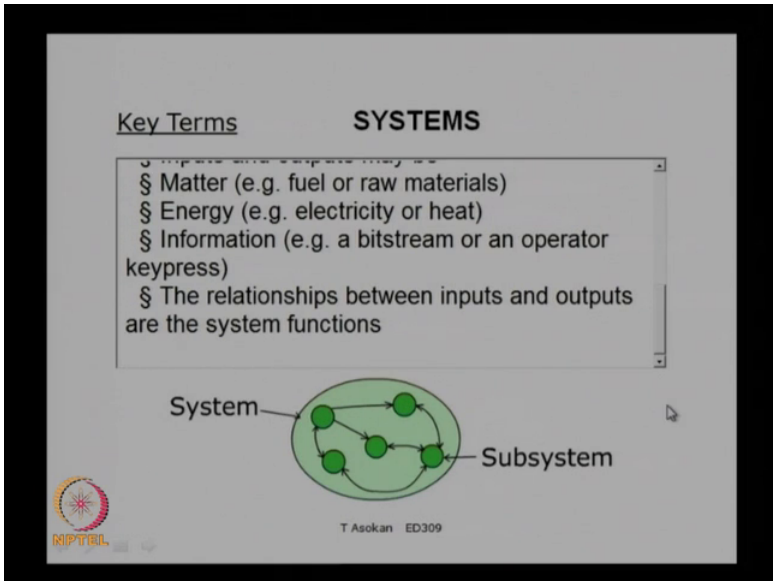

The relationship between inputs and outputs are the system functions. So, as we can see there will be the system, will be having many subsystem inside and there will be a boundary for the system.

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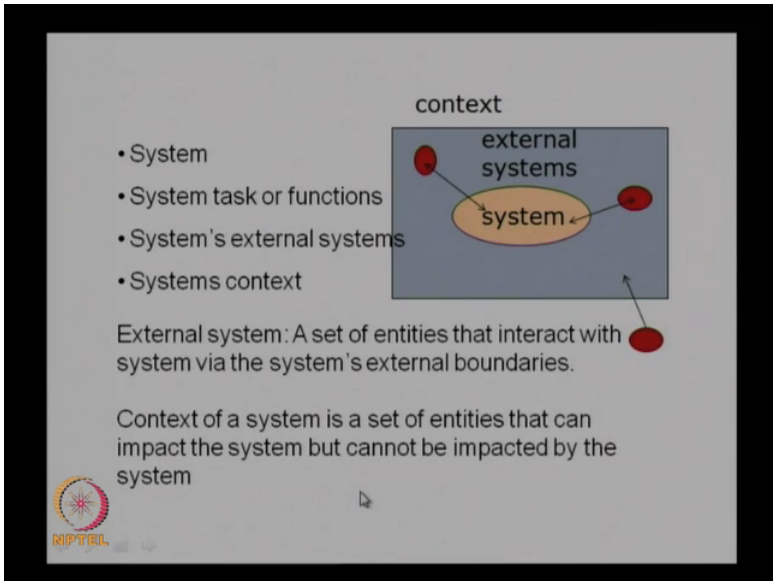

So, this is the system and the systems boundary. So, we define a system and its boundary and we define some other terms like external system. So, we have many system which are external to the main system.

Where you will see that these external systems are interacting with the main system, and there is another term called systems context, which is the context in which the system is operating. So, an external system is a set of entities that interact with system via the systems external boundaries. The context of a system is a set of entities that can impact the system, but cannot be impacted by the system. So, this external system can be impacted by the system or it can impact the system, but in a context of a system which cannot be impacted by the system, but always the context will be having an impact on the system.

So, that is the difference here external system directly interact with the main system, but the context is not interacting directly or it cannot be impacted by the system, but there will a lot of influence of external system sorry the context on the system performance. Therefore, and we design a system we need to look at what is the external systems and what is the context in which the system is being used. So, that we know the system may get affected by the context. Therefore, we need to prepare or make the system in such a way that the impact of the context on the system is very minimal.

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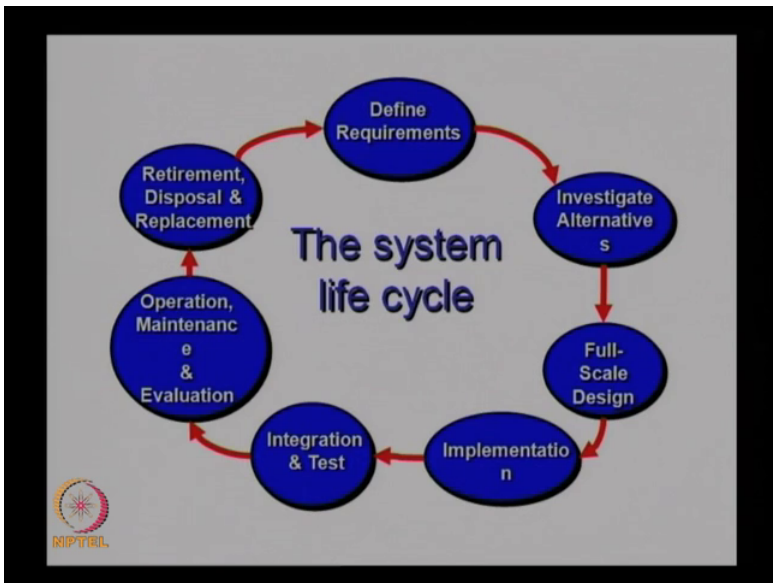

Another important term in system design is the system lifecycle. So, as I mentioned in the earlier lecture about process of engineering system design, where we look at the design development manufacturing implementation maintenance as well as disposal of the system. So, here you can see that the system engineering basically looks into the whole lifecycle of the system, overcome the beginning of identifying the customer requirements to the disposal of the system is taken care of by the system engineering.

So, we need to look at what are the life cycles of a system, whenever we try to develop it. So, basically as we can see here we have the requirements definition then alternatives identification or the concept development, then the full scale design then implementation of the design, then integration and testing operation maintenance and evaluation retirement disposal and replacement. So, all these are involved in the in a particular system that is why this is known as a system lifecycle. So, whenever we design a system we look at the life cycle of the system and then design it in such a way that, they actually passes through all this life cycles what actually happens to the system even at the dispersal stage.

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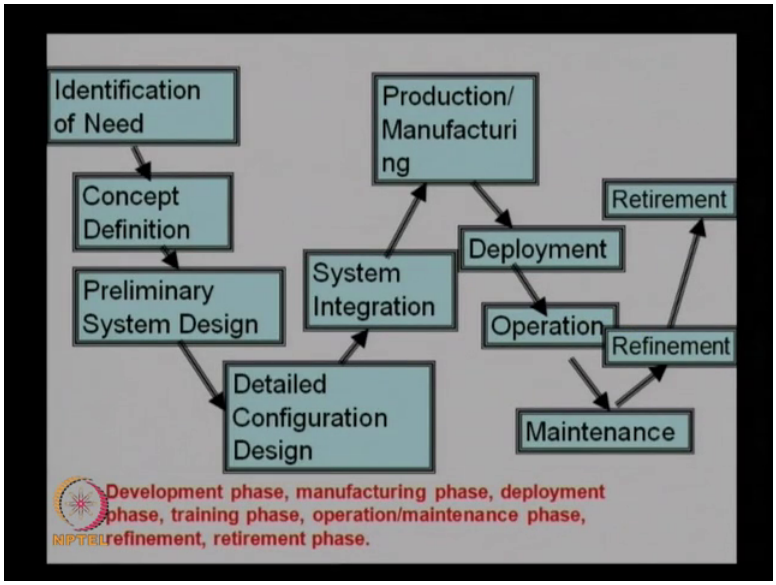

This actually gives a little bit more explanation about the initial stages of development in the life cycle. So, we can actually divide this life cycle into development phase, manufacturing phase, deployment phase, training phase, operation maintenance phase, refinement and retirement phase. So, these are the life cycles phases of a system. In the

development phase what we do is to identify the needs for the system and then define a concept.

And then do a preliminary system design and then detailed configuration design and once configuration design is done we will do an integration of the system design at the development stagem and then go for production and manufacturing. So, the development phase tree consists of identification of new concept definition preliminary system, design detailed configuration design, and system integration. In manufacturing phase as you know it involves the production and manufacturing and then deployment phase where the system is deployed to carry out the desired tasks. And there will be an operation continuous operation of the system because deployment itself could be a major task depending on the complexity of the system you may require a lot of planning, the and resources to deploy a particular system. And then operation of the system you may require a lot of manpower and other support systems to operate the system and maintenance of the system, it may be a separate process and then refinement of the system and retirement.

So, you can see here the operation maintenance phase, refinement and retirement phase this are the last three stages in the development of a system. So, we look into all these phases of the system design, and try to find out how system development is carried out in each of these phases, to ensure that we look into all aspects of the system design. It is not only developing and design and development it actually takes care of even the retirement of the system.

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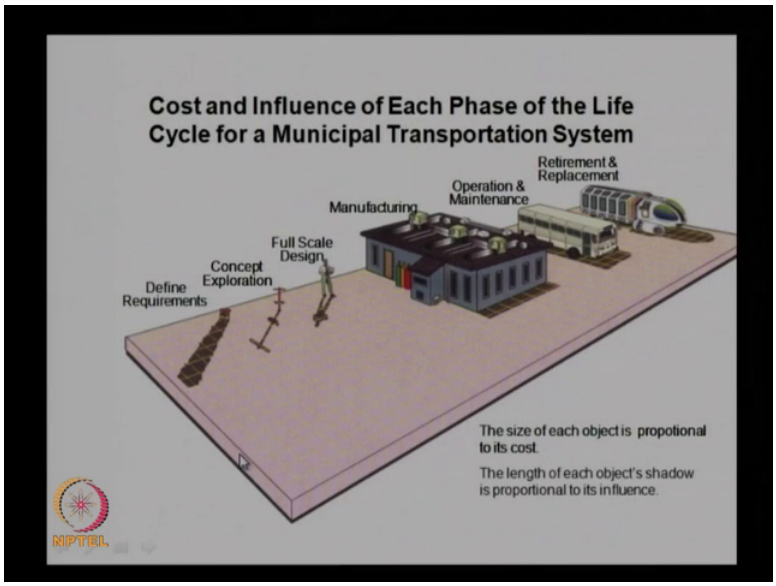

This actually gives a comparison of the cost and influence of each phase of the lifecycle for a particular system. For any engineering system, the cost will be varying in this scale. So, you can see here the size of each object is proportional to its cost and the length of each objects shadow is proportional to its influence. So, the influence of the requirement definition is you can see the size of the shadow is very large. So, you can see that the influence of this is much more higher than the influence of the retirement or replacement or the manufacturing cost.

The cost of manufacturing may be very high, but its influence on the system or the cost influence on the system is very limited. Therefore, you can see that all these are having very large influence on the cost of the project like the defined definition, concept acceleration, full scale design all these are having large influence on the system performance, but the cost involved is very less. But if you go to the next level of manufacturing maintenance and refinement the cost of manufacturing or maintenance is very high, but its influence on the total cost of the system is very limited.

So, it is clearly shows that these are very important stages in the system design because it influences the total cost of the system at a later stage that is why though the cost involved in doing this phase carrying out this phase is very limited it has got large influence. And therefore, we need to ensure that we pay lot of attention to this stage so that the total cost

of the system remains comparatively less in case you do not put that much of effort in this phases.

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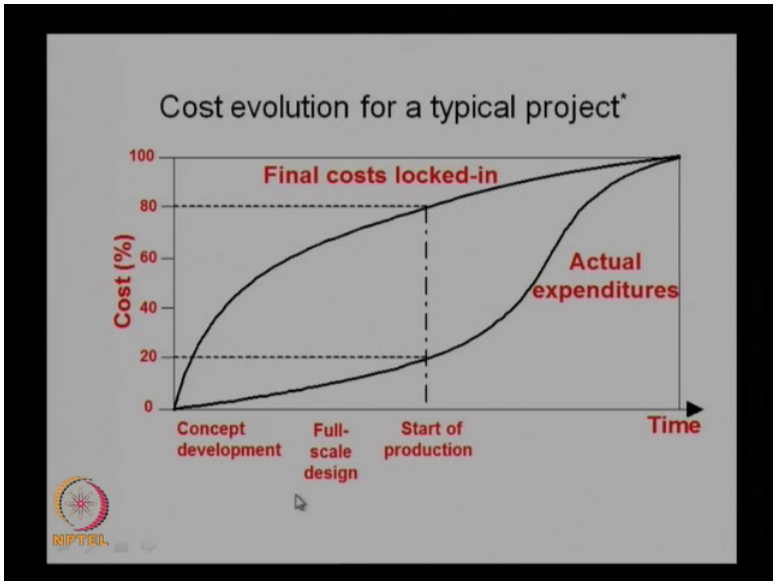

This shows more a clear picture of the same thing, because the cost evaluation of a typical project. So, you can see here this concept development full scale design and start of production. Till start of production 80 percent of the cost of the project is logged in already. Because you are concept and the design actually determines the cost of the product.

So, by the time you start the production 80 percent of the total cost of the project is locked in, and you cannot make any changes or if you make any changes at this stage your total cost will be going much higher or you will be making a lot of losses in cost and the actual cost for doing these 3 phases it is only 20 percent. So, you can see that 80 percent of the cost is locked in simply by 20 percent of the expenditure and actual expenditures are going up in the next stages, where the cost locked in will be only 20 percent this shows that the cost of 80 percent.

Of the cost is determined by these 3 stages and therefore, we need to take a lot of care and lot of time and effort to make sure that this stage is taken care of well and we do a very good job in first 3 phases, and then go to the next phase of production and operation maintenance etcetera.

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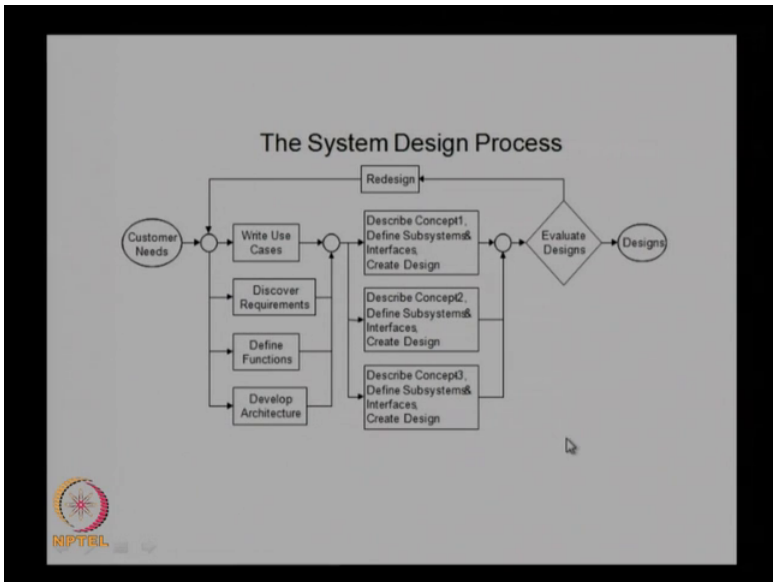

So, this was the flowchart for the design process. So, where you identify the customer needs and then parallely do the use cases discover requirements, define functions and develop architecture. We will be going through all these stages at later stage details of how do we identify the use cases, how do we discover the requirements how do we define functions and how do we develop architecture all these things will be discussed in detail. So, one from the customer needs we do all this and then we go for a concept development, multiple concept development and then evaluate these concepts and then take a final design and if the designs are not to the required specification or not meeting the requirement then we go for a redesign and again go through all these stages and.

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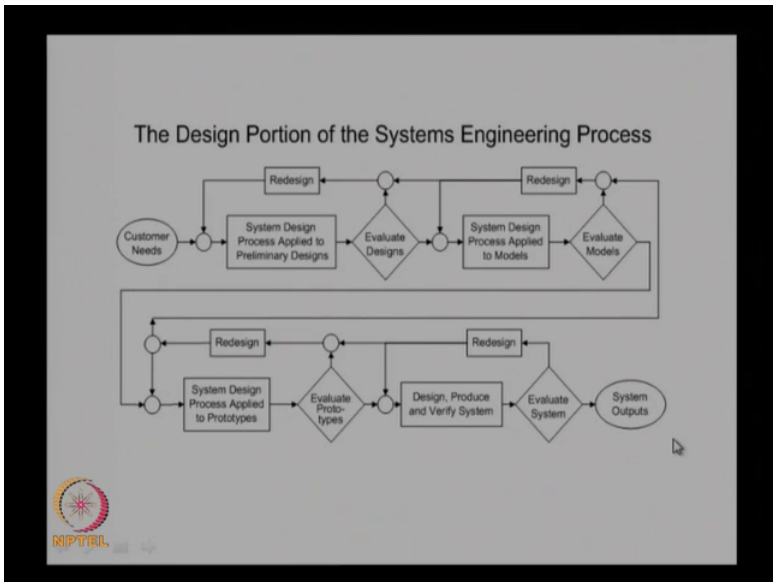

Again this is from the system design point of view, because from the customer needs the system design process applied to preliminary designs will be applied and you get anyway design and it will be evaluated and again system design process applied to models and you evaluate the models, and this models will be given to the process applied to prototypes. So, we have the design principles for all these stages like design stage, modeling stage and then prototype stage and then for verification stage produce and verification stage.

So, every stage we apply the system design principles, and then go for go back for redesign if it is not satisfying the requirements and finally, we end up with the final system outputs which actually comes through the design produced and verifying of the system, which is evaluated and given out as the proper complete system.

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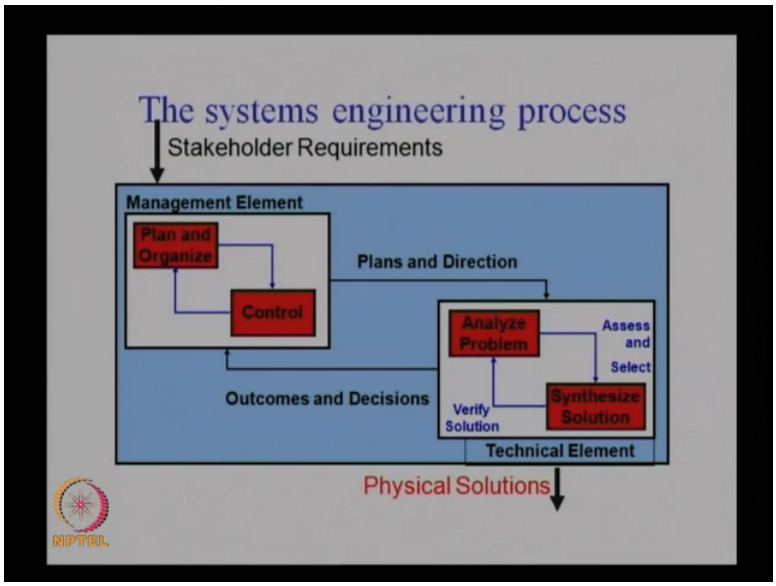

So, again this shows that the management element in the system, where we plan and organize to the previous flow charts were showing only the engineering part of it. So, this actually shows the managerial part of the system engineering development, where we have the planning and organizing of the whole process and controlling the flow of the activities in the system. So, it goes to the technical element and here we unless the problem synthesize the solution and then. So, the outcomes of these stages can be given back to the management element, and this management element gives output in what direction the project should move.

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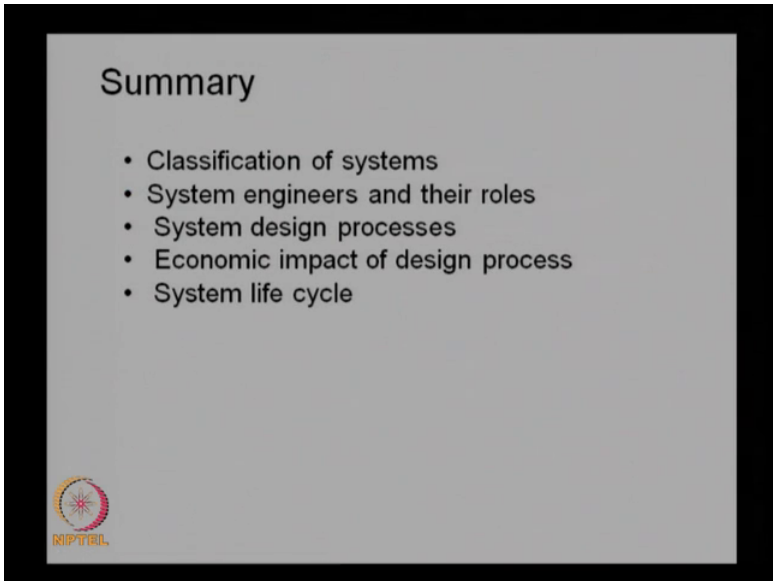

So, summarize the whole whatever we discussed in this class. So, whatever we discussed was the classification of the system, how do I discuss and then we what are the roles of system engineers, and then we discussed about the system design processes, basically the stage gate process spiral process and the system vee process we discussed and then we looked at the economic impact of design process.

So, what other different phases in the life cycle, and which are the phases which really affect the economics of the project or as we saw that 80 percent of the cost is locked in by the first 3 phase in the life cycle and only 20 percent of the cost is actually accounted on in the remaining phases and so, we saw the life cycle impact of the system and how the system engineering process takes place in an industry to ensure timely delivery and the quality delivery of the outputs. So, with this I conclude this lecture.

Thank you very much. We will see you in the next lecture bye.