Principles of Engineering System Design

Dr. T. Asokan
Department of Engineering Design
Indian Institute of Technology, Madras

Lecture - 01
Introduction to system Design

Dear friends, a very good day to all of you, and welcome to this video lecture on Principles of Engineering System Design. This is the first lecture on this series of lectures on system design and in this lecture I will introduce the topic and discuss about what are the contents we are going to discuss in this lecture.

System design or engineering system design maybe a totally new topic to some of you or to some of you may be wondering what is system engineering and what are the topics we are going to cover in this lecture. And most of you might have use the system or heard about system engineering in various contexts. We talk about various systems, we talk about the democratic system, we talk about education system, we talk about the human body as a system and there are many other system we talk about electrolysis systems and then we talked about even I T as a system.

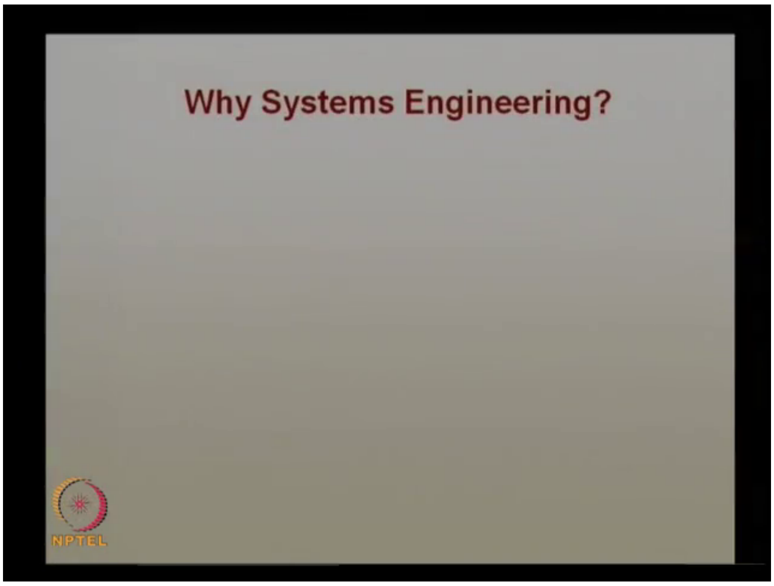
So, what actually we mean by a system and we discuss these various systems which is around all of us. A system basically is a set of entities when put together gives a desired output, engineering system is also something similar to that there are various entities there are human beings in the system, there are machines, there are materials, there are mechanisms, there are computer software's, there are lot of interfaces hardware, there are so many entities in the system and when we put together all these entities and put them in such a way that we get a desired output. So, engineering system is basically a collection of ages and entities when put together gives you a desired output.

So, here also in this course in engineering system design course we are trying to see how do you actually identify the entities needed for a particular output, how do we put them together and how do we actually make sure that this entities put together gives us a desired system.

So, the focus of this course is basically to understand the principles on which the system design is focused or system design is based upon and then how do we actually do a systematic way of designing the engineering systems, in order to make sure that it actually produces the desired output. Most of you must be knowing about the various engineering systems existing in this course we will be focusing on complex engineering systems, where actually the magnitude of the number of components the number of entities or the number of sub system involved is huge therefore, we need to have a very systematic process of designing the system and that is the focus of this course engineering system design.

Sometimes engineering system design they refer it as a systems engineering and this is very common to other fields also it is not only to engineering field again see that a systems engineering is applied in various other social sciences also, we talk about systems engineering and the focus this course is basically to look at the engineering aspects or engineering systems and how do we design the engineering system.

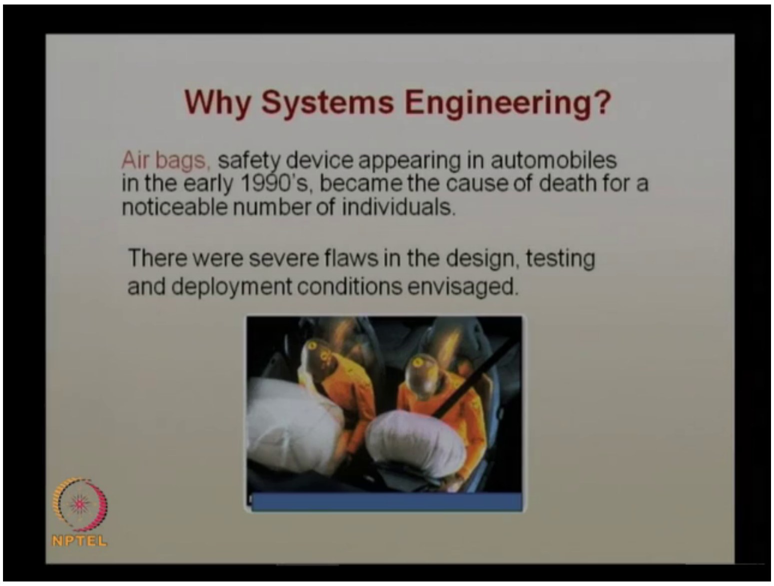
(Refer Slide Time: 03:33)



You just look at what is system engineering or why do we need systems engineering? As we know that most of these engineering systems are there already and we have many natural systems or manmade systems, but then why do we need to have a very focused engineering system design approach. If we look at some of the case studies from the history we can see that there are lots of failures in the engineering systems and this actually led to the development of system engineering as I said discipline.

And therefore, we need to have a systematic approach for designing systems, because a systematic approach will reduce the errors and reduce the failures of the engineering systems and ensure that it actually produces the desired output.

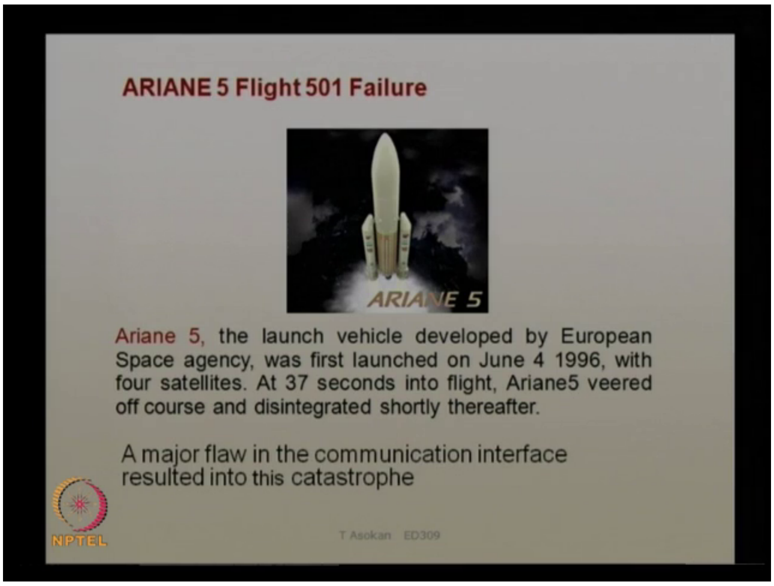
(Refer Slide Time: 04:20)



Look at the picture in this slide you can see this is an airbag system which most of the automobiles are having modern automobile vehicles have this kind of airbags as a protection device for passengers as well as drivers, but when this these devices where introduced in year 1990s this actually the safety device itself became a cause of death for a noticeable number of individuals. Though that was not the intention of airbags the intension of the air bags was to protect the people, but because of some design failures or the system failures this became a cause of death for many individuals because of the mild functioning of the airbag.

If you look at the reason for it we can see that there were many flaws in the design testing and deployment conditions and we set it in the system design. So, the one of the main reasons for the failure was flows in the design testing and deployment conditions. So, that actually tells us that it is necessary to find out the actual requirements of the system. And once we have the actual requirements of the system identified we need to ensure that these requirements are actually implemented, in the system or the functions needed to meet these requirements are implemented and they are tested and verified fully before we really implement the system for the actual application. So, this was the one of the reasons for the failure of this airbag system.

(Refer Slide Time: 05:49)



Like this we can see lot of examples Ariane 5 flight 501 failure again this is a case of system failure you can see this Ariane 5 the launch vehicle developed by European space agency was first launched.

On June 4 1996, with 4 satellites on boards at 37 seconds into flight Ariane 5 veered off course and disintegrated shortly. Thereafter, again this is a failure from the history engineering failure of the system as you know this is a very complex system all the launch vehicles are basically very complex engineering systems and again this had some flows in the interfaces that design interfaces were not proper. So, there were some flows in the conversion of the data and this actually led to the failure of the engineer this particular system.

So, a major flow in the communication interface resulted into this catastrophe. So, again it actually emphasize the importance of having a systematic approach in the design and development of engineering system, because there are many subsystems and there are multiple interfaces and these interfaces are not properly designed in that may result into a tragedy like this.

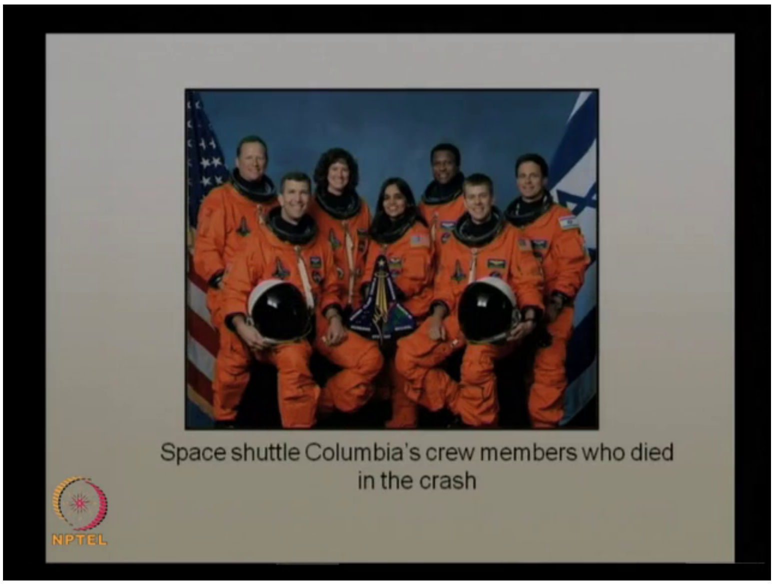
(Refer Slide Time: 07:00)

This is a another example which is very famous and most of you may be aware of it the Columbia disaster again space shuttle Columbia when it was returning back to the earth after it is mission and disintegrated into pieces and all the astronauts were killed in this particular incident.

(Refer Slide Time: 07:17)

This actually happened in 2003 February 1, 2003.

(Refer Slide Time: 07:24)



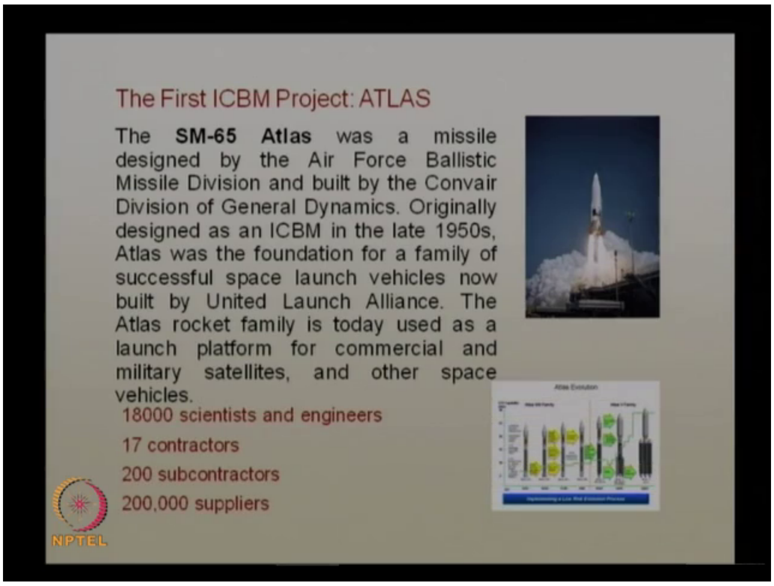
In fact, these are the crew members we actually died during the return of the space shuttle and as you know one of India's daughter is also lost her life in this particular mission. If you look at the details of this particular incident we can see that this particular incident happened because there was a small problem in the space shuttle took off one of the tiles on it is surface developed some cracks and it was a an issue which actually mission managers they identified in the beginning itself when it took off they could see that.

There is a problem with the one of the tiles on the surface, but then it was not possible to bring it back immediately. So, they did lot of analysis they did modelling analysis and lot of simulations to see what are consequences are for this particular damage. And finally, after lot of analysis and a lot of studies and then they took a decision that this may not cause a major problem. So, that they can continue with the mission and then returned the space shuttle back to earth and then do the repair work. So, the here actually it was a decision making under uncertain conditions.

So, it was not sure I mean the team was not very sure whether the system will perform as per the simulation, but they need to take a decision under lot of other uncertain conditions and they took the decision to continue with the flight and then while coming back, while the shuttle was returning back the temperature grows up very high and then it actually to certain to the complete failure of the system. So, whole space shuttle and all the crew were killed in the accident.

So, here you can see that it is not only the engineering aspect, but there are. So, many other aspects like making a particular decision about whether to continue with the system mission or not. So, we need to consider. So, many other aspects of the system and then see then take a decision under lot of uncertainties. So, taking a decision under very uncertain conditions also is part of system engineering. So, here all this incidences basically tells us that engineering complex system is very difficult and there are lot of issues need to be taken into account when we actually design and develop and deployment deploy an engineering system.

(Refer Slide Time: 09:48)



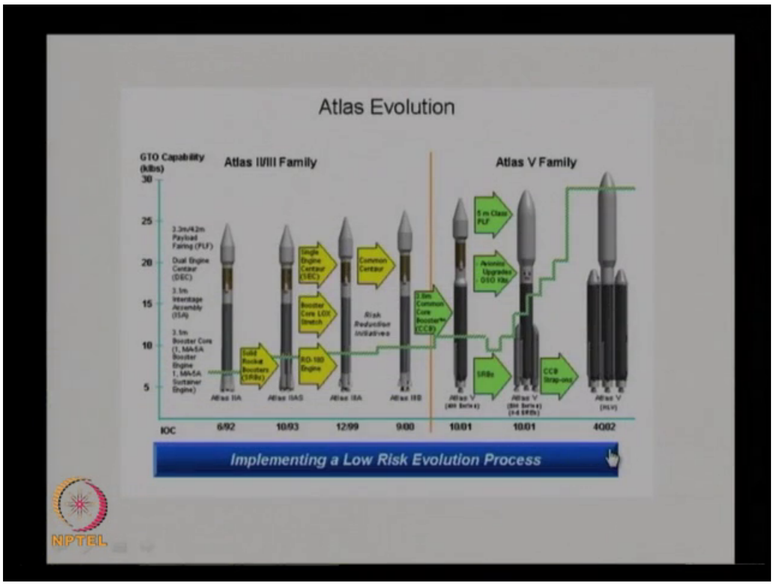
To show the level of complexities you can take this example for ICBM project which is the intercontinental ballistic missile project Atlas, the Atlas had lot of various steps involved in this development of this particular missile shield system.

So, SM-65 was the missile designed by the air force ballistic missile division and built by a conveyer division of general dynamics, this was originally designed as an ICBM in the late 19 fifties and the atlas was the foundation for a family of successful space launch vehicle now build by united launch alliance, the atlas rocket family is today used as a launch platform for commercial and military satellites and the others space vehicles.

So, this actually got a series of a launch vehicles the present one is it was built around 2001 to 1003, but the development started somewhere in 1950es and then actually there were the various versions of this particular program a missile. To see the complexity of this development you can see that there were 1800 scientists and engineers working in this particular project there were 17 contractors there were 200 sub-contractors and 200,000 suppliers involved in this particular project. So, you can actually imagine on the scale of the project with the 18, 000 scientists and 20,000 suppliers and in between lot of contractors and subcontractors working together in order to deliver a particular project.

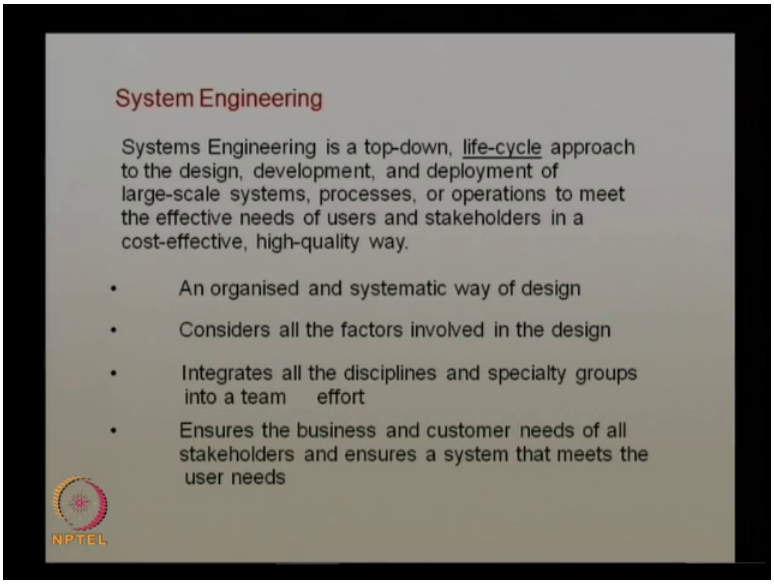
So, the management of the whole man power the subsystems at the interfaces all this becomes too complex for anyone to manage the system.

(Refer Slide Time: 11:18)



This actually shows the evolution of atlas family you can see that started somewhere in 92 it is a first version of this atlas 2 a and then atlas 5 is the latest one it is atlas 5 family consists of this the 3 series, then it was final one was developed in 2002. You can see that as the development progress there will be a lot of additions lot of changes in this system, and every time we somebody has to closely monitored the variations in that system design and closely record it and then maintain a proper strategy for the development also. So, all this makes the system development very complex and requires a very systematic approach in the design development as well as deployment and even the disposal of the system.

(Refer Slide Time: 12:08)



So, let us see the what are the important points we need to discuss or we need to learn when we design this kind of a complex engineering systems, to define the system engineering basically it is a top down lifecycle approach to the design, development, and deployment of large scale systems, processes, or operations to meet the effective needs of users and stakeholders in a cost effective high quality way.

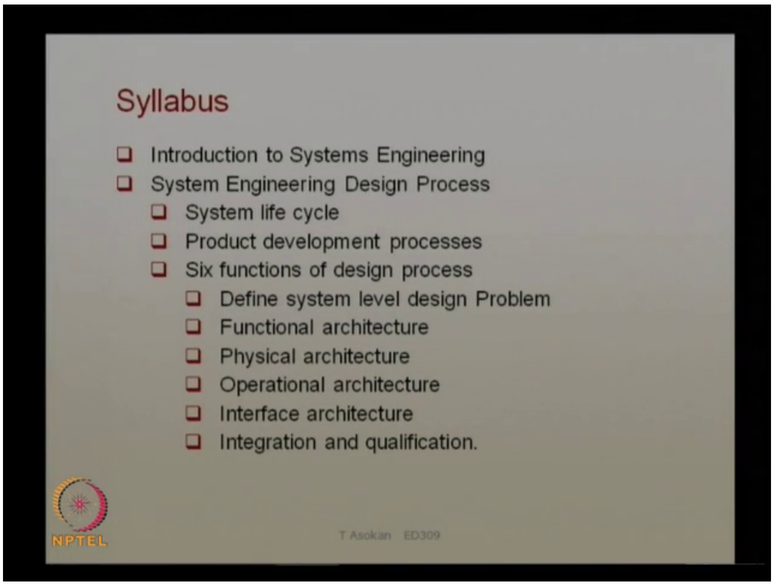
So, as you can see it is a top down life cycle approach. So, it is not only the design which is important. So, we need to look at the whole life cycle of the system, where we look at the design, the development, the deployment, and even the training and maintenance of the system and then how do we actually dispose the whole system. So, it actually a life cycle approaches.

Were we need to look at all aspects of the life cycle of the system and then every life cycle need to be analyzed and we need to make proper design for this life cycles and we design a system we need to look at how do we actually. Finally, dispose the system is it going to affect the other existing systems or natural systems or we can be use it for some other system or can upgrade the system further. So, on these aspects need to be taken into account when we actually go for the design of this type of a complex engineering system.

So, system engineering basically an organized and systematic way of design and then it considers all the factors involved in the design. So, it is not only a particular aspect of the system. So, a we need to look at the all the aspects of the design. So, looking from the customer requirements to the disposal of the system everything need to be designed that is all the factors need to be considered and then it integrates all the disciplines and specialty groups into a team effort.

So, here actually you will have multiple disciplines. So, it is not only a particular discipline engineering that would be multiple specialty groups and this actually tries to integrate them into a team effort. And it ensures the business and customer needs or all stakeholders and ensures as systems that needs the user needs. So, here actually the business needs as well as the customer needs of all stakeholders there are multiple stakeholders in the system development. So, we need to ensure that we take care of the other stakeholder's interest and meet their needs of these stakeholders.

(Refer Slide Time: 14:36)



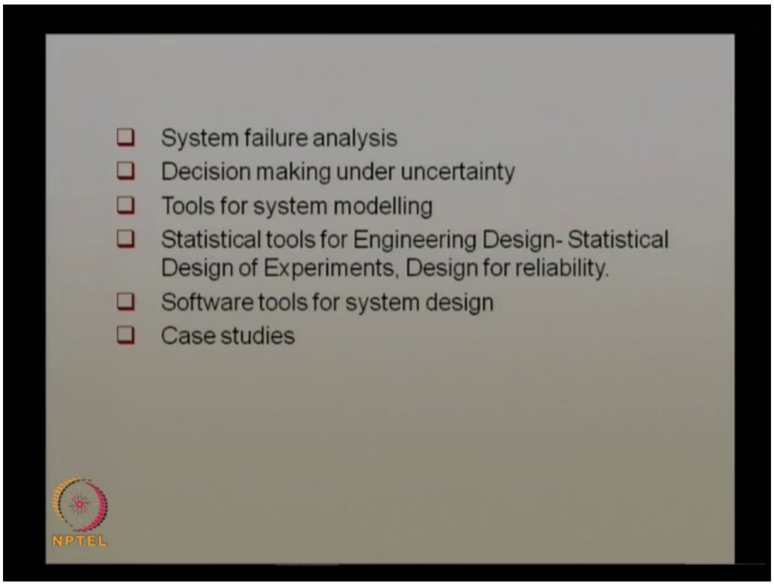
So, what are the things what we are going to discuss in this particular lecture. So, we will see the topics to be covered in this particular course we have around 30 to 40 lectures on systems engineering or principles of engineering system design. So, the main topics to be covered in these lectures are first basically the introduction to system engineering and then we discuss about the system engineering design process.

So, what are the different life cycles in a system and what are the different product development processes we can employee and then we go through the 6 functions of design process, basically we will define the system level design problem then functional architecture of the system, then physical architecture, basically the functional architecture. We will look at the functions needed in the system, in order to satisfy the customer requirements which are identified in the system level design problem and then we go to the physical architecture, where the physical architecture will try to convert the functions into physical building blocks. And then we develop that an operation architecture, which actually integrates all the physical architecture, then we develop the interface architecture basically to look at the subsystems and the interfaces needed for these subsystem. And finally, we will do the integration and qualification. So, that is the last function in the design process.

Whatever we design we to do an integration of or the sub systems and then ensure that the systems or the subsystem meet the requirement of the stakeholder so that is the qualification process, where we do the testing and analysis of the whole system and ensure that it actually meets the customer requirements and ones which is verified then only it will be used for customer application or for the further development of the system.

So, this are the 6 functions of the design process our main focus will be on these 6 functions we will try to understand how do we actually carry out these functions in the design process across the life cycle and then we go to the other topics such as.

(Refer Slide Time: 16:42)

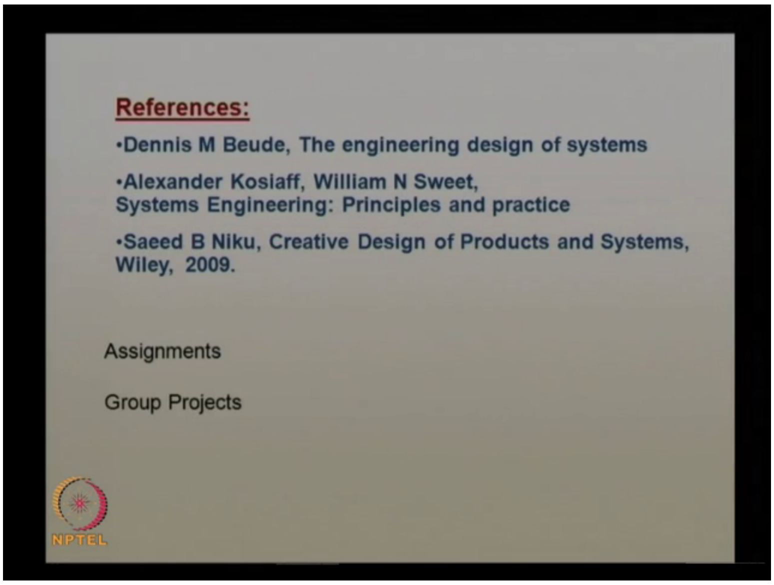


A system failure analysis so we will look at the failure analysis of the system and then see how do we actually design a system in order to make sure that the possibility of area is very minimal, we discuss about the decision making under uncertainty where we look at the various options available or various techniques available in order to take a decision based on the available information at that time.

So, there is a risk involved in decision making. So, we will see how we actually reduce the risk involved in the decision making process and then we will discuss about few system modeling tools because we have to do lot of analysis I will be design the engineering system. So, will discuss about few tools available for modeling of the system and similarly we will look at the statistical tools for engineering design basically the design of experiments and design for reliability etcetera. There are few software tools available for system design.

So, I will briefly explain about these tools and how do we use these softwares for effective design of engineering systems and of course, we will take few case studies and examples to show how to use these tools as well as these methods in the design of system, as well as the implementation of the system. And then to see how the principles of a systematic process actually helps us to design complex systems and ensure that it actually meet the customer requirements. So, this are the main topics which will be covered during this lectures may be 30 to 40 lectures will be there which actually will cover all these topics and few case studies also.

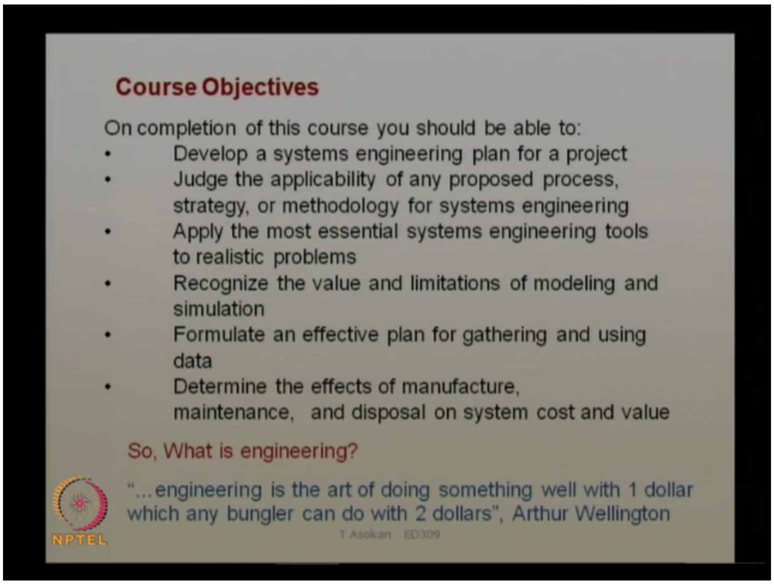
(Refer Slide Time: 18:28)



Some of the references for this lecture the text book is Dennis Beude the engineering design of systems, then another book by Alexander Kosiaff and William N Sweet, Systems Engineering: Principles and practice, then Saeed Niku Creative Design on Products and Systems, Wiley 2009 edition. Apart from these I will giving you few assignments and group projects the assignments will be uploaded to the web and you can actually try it yourself some of the answers for this assignments is also will be given in the web itself, you can actually refer to that and then see whether you are actually going it properly or you are actually understanding the principles and then how to apply these principles for the design of complex systems.

There will be few group projects also of course, this group projects you can actually if you are in a group or 3 or 4 students together you can work out these projects and then try to see how to implement or how to use the principles in a real life scenario or real case studies; so that has. So, you can try as part of the course. So, the main course objectives what we actually can see from after at the end of this course we have some objectives in providing these course materials to you.

(Refer Slide Time: 19:48)



So, the end of this course you should be able to develop a systems engineering plan for a project and judge the applicability of any propose process strategy for methodology for systems engineering. So, you should be able to plan a project in terms of systems engineering and then judge the applicability of any propose process for this particular project and apply the most essential systems engineering tools to realistic problems.

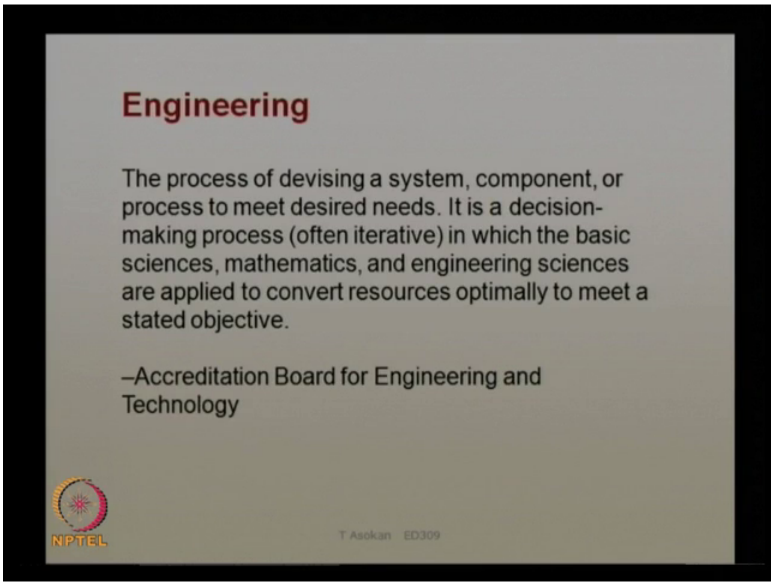
So, if you have a realistic problem how do we actually apply the most essential systems. So, that also you should be able to understand by the end of this course and then recognize the value and limitations of modeling and simulation. We have will be discussing about many simulation and modeling techniques. So, you will be able to recognize the value and limitations of these models and formulate an effective plan for gathering and using data and how do we actually gather data and use them in the design. And then determine the effects of manufacture maintenance and disposal on system course and value. So, you should be able to determine the effects of cost on various aspect like manufacture maintenance and disposal on system. So, they are all different various cost involved in this.

So, you should be able to understand the impact of this on system design. So, these are the course objectives. So, what we mentioned. So, far is the introduction and then what are the topics to be covered in this course and what are course objectives. And now will go to discuss more about the systems engineering and we will try to define the systems engineering from the design point of view from the over from the engineering perspective we will design what is system, what is engineering, and what is system engineering and what are the roles of system engineers in developing this kind of complex systems.

So, let us look at what is the definition for engineering because systems engineering is basically I can say that there is a system and there is engineering. So, we will discuss what is engineering and what is system and then what is this system engineering, there are lot of definitions for engineering, but basically if you look at engineering is a process of doing things in a effective way.

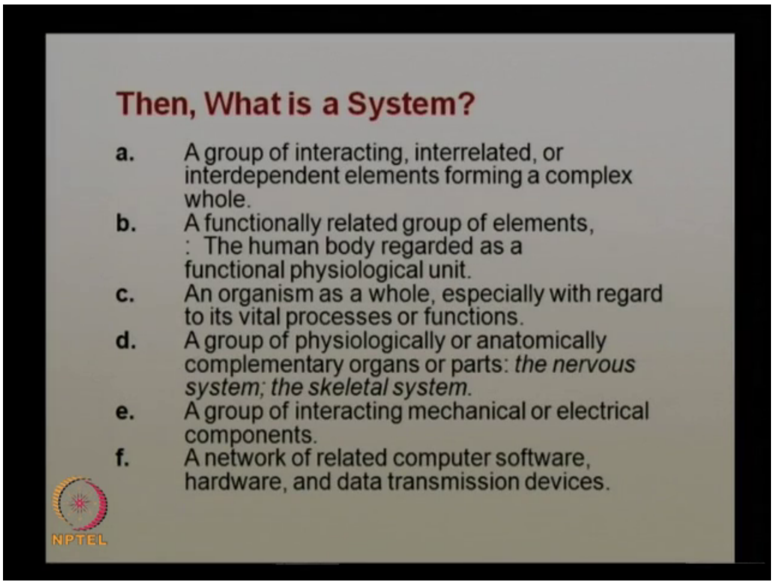
Even without engineering or without a proper definition for engineering engineering projects were taking place people were doing it because whenever you try to do something in a cost effective and efficient manner then we call it as a engineering, as Arthur Wellington said once engineering is art of doing something well with one dollar which anyone can do with 2 dollars. So, basically we are trying to do how do we do it in an efficient way with using the non-principles and practices how do we a complete a project in a cost effective and in a efficient way that is basically the engineering.

(Refer Slide Time: 22:39)



But there are different definitions. So, as far the accreditation board for engineering and technology engineering is the process of device in a system component or process to meet decide needs. So, basically it is a process of devising a system component or process to meet the decide need it is a decision making process of nitrite you in which the basic sciences mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. So, here an optimal utilization of the resources to meet a stated objective is defined as engineering.

(Refer Slide Time: 23:14)

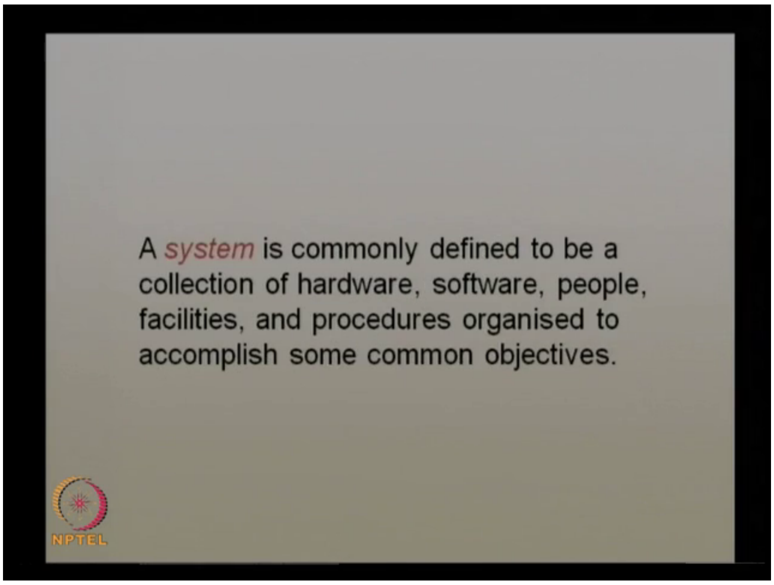


Then what is a system. So, we discussed about system or we briefly mentioned about system basically there are various systems doing in the nature there are manmade systems artificial systems are there. So, how do we actually define a system there are various definition for system a system is defined as a group of interacting inter related or inter depended elements forming a complex hole.

So, that is one of the definitions the other one is a functionally related group of elements like the human body regarded as the functional physiological units or an organism as a whole especially with regard to it is wider processes or with functions, the other definition is a group of physiologically or anatomically complementary organs or parts like the nervous system or the skeletal system. So, this are actually a physiologically or anatomically complementary systems a group of interacting mechanical or electrical components or a network of related computer software hardware and data transmission devices.

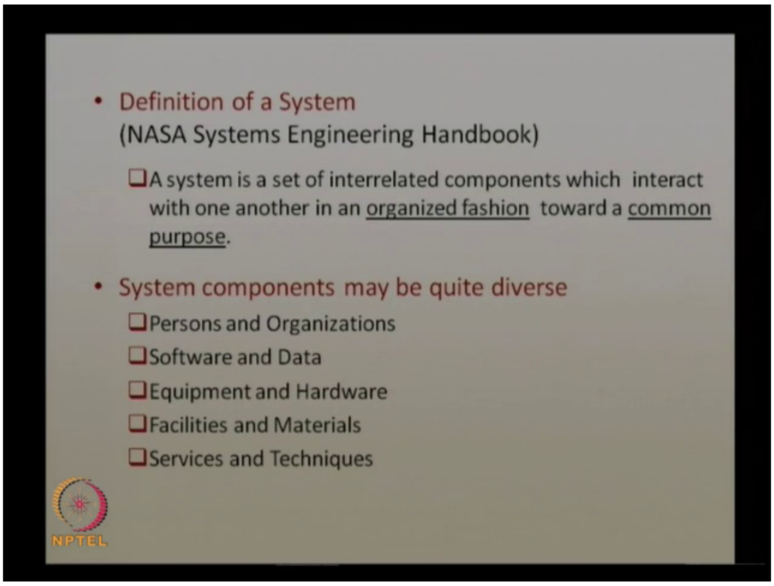
So, if you took an internet as a system again it is a network of related computer software hardware and data transmission devices.

(Refer Slide Time: 24:24)



So, like this there are multiple definitions, standard definition is basically a system is commonly defined to be a collection of hardware, software, people, facilities, and procedure organized to accomplish some common objectives. So, that is a common definition for engineering system which is a collection of hardware software people and other facilities in order to get to accomplish common objectives.

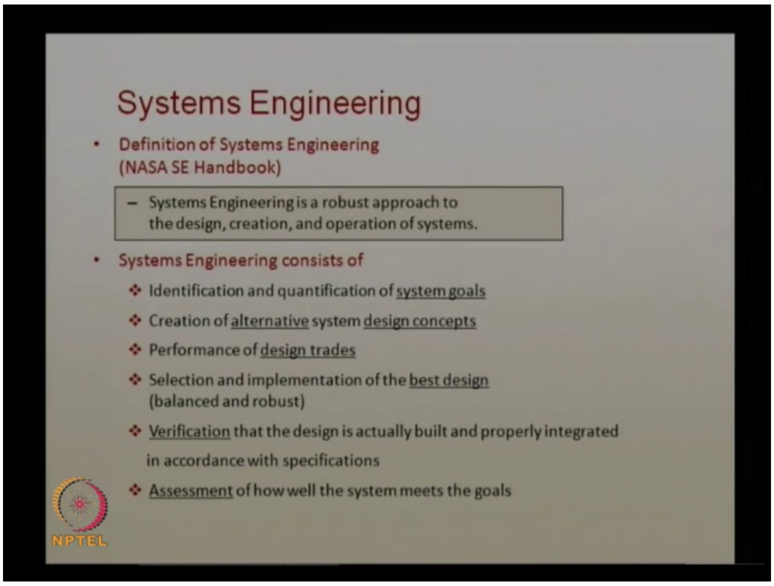
(Refer Slide Time: 24:45)



NASA System Engineering Handbook the definition for a system is given as a set of inter related components which interact with one another in an organized fashion to add a common purpose. So, that was a definition given by the NASA systems engineering handbook.

For an engineering system and it actually contains many components. So, there can be very diverse components in the engineering system can be persons or organization, there can be software data that can be equipment and hardware facilities and materials and services and techniques. So, you can see they are quite diverse persons and organizations software data equipment or hardware in facilities and material services and techniques. So, this can be any system can have any of these components some of the maybe have all these company. So, some of them having a few of these components but any system will be having very diverse components in order to meet the requirements.

(Refer Slide Time: 25:42)

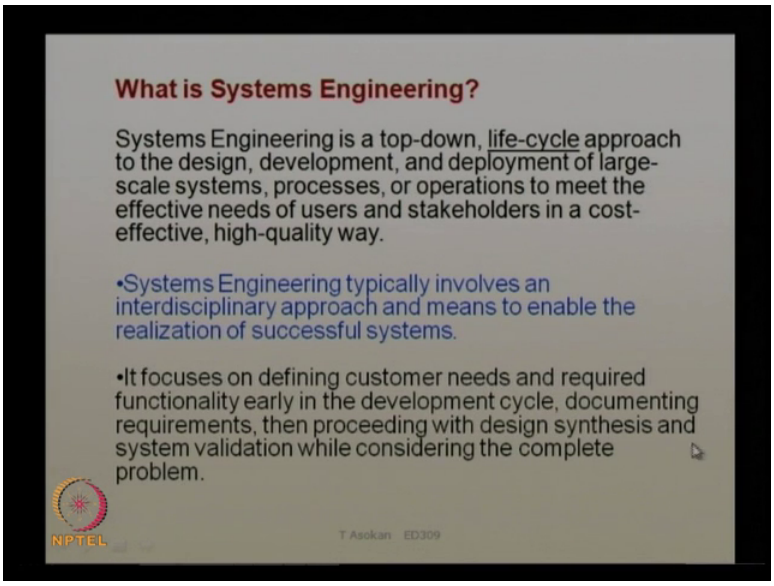


As per the NASA system engineering handbook, system engineering is a robust approach to the design creation and operation of system. So, it is not only the a design activity it is basically an approach to the design creation and operation of systems and it consists of identification and quantification of system goals. So, this are the approach for the system design we need to look into this aspect like the identification on and quantification of system goals, creation of alternative system design concepts, performance of design trades that is there may be many design trade off in the system, because when we design a system we will be looking at the aspects of trade offs were we need to reduce the cost sometimes or increase the performance or when you try to increase the performance the cost may go up.

So, we need to have some kind of a tradeoff and that kind of trade off studies are also part of the system engineering. So, that is the design trades then we have the selection and implementation of the best design that is the balance and robust design then we have verification that the design is actually built and properly integrated in accordance with the specifications then assessment of how well the system meets the goals. So, this are the important steps involved in the system engineering or design of engineering systems.

So, we look at the system goals then the design concepts then trade off then the verification strategies and then assessment of how well the system performed as per the earth to meet the stakeholder needs, these are the things important in the design of systems.

(Refer Slide Time: 27:15)



So, that is about the system and then we discussed about engineering also then what is systems engineering? So, we have the system which is a collection of entities which actually provides you a particular output and then and systems engineering which again we briefly saw this in the earlier slides, system engineering is a top down life cycle approach to the design development and deployment of large scale systems processes or operations to meet the effective needs of users and stakeholders in a cost effective high quality way.

So, it actually involves an interdisciplinary approach and means to enable the realization of successful systems. So, again there are multiple displays involved in this that is why it is an interdisciplinary approach and the means to enable the realization of successful system. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements then proceeding with design synthesis and system validation while considering the complete problem. That is the most important aspect of system design it focus on a defining customer needs and very early stage.

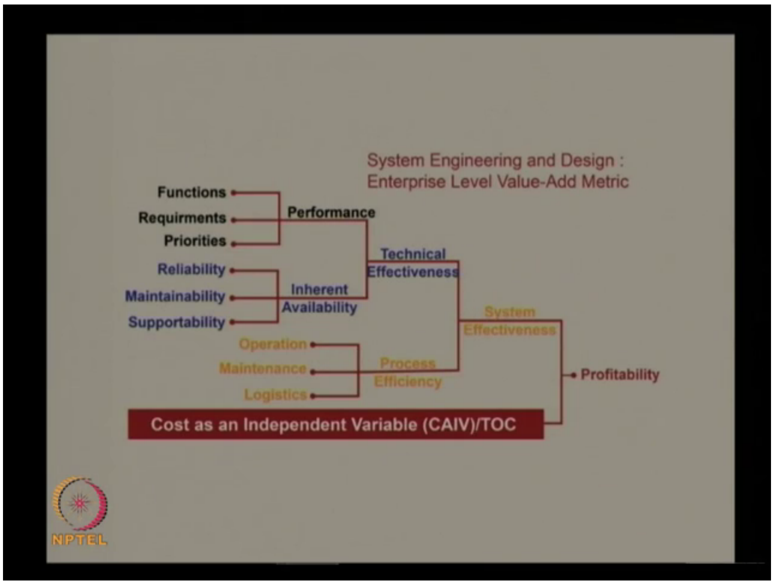
So, even before we really start the design process we look we looks at the customer requirements in the very early stage and then document these requirements and try to identify the origin of these requirements look at the grass root level requirement and then try to design for the problem and documents is requirement in a proper way a systematic way of documenting the requirements and then designing the system to meet these requirements in terms of the functions and the physical architectures. And then, doing the synthesis to see whether we can improve the system design how do we optimize the system design, how do we actually have a proper trade of the design.

And then finally, verifying the system to see whether it actually meets the customer requirement. And that the every time we will be actually having the whole system as a focus and every stage will be focusing on that particular aspect and keeping the whole system as a and the focus. So, that we ensure that once we have the whole system design or when we have this system designed it actually meets the intended goals of the stakeholders.

So, that is the main focus in the engineering system design. So, here we actually considered the complete problem as the in the initial stage itself and then start designing from the fundamental from the basic customer requirement and then proceed with the system synthesis at design synthesis and then deliver the product to meet the customer requirement that is basically the systems engineering. So, we have engineer the system to meet the customer requirement.

Then for that we need to have follow a particular procedure or we need to have a systematic procedure and this procedure basically which actually ensures that the system deliveries the required functionalities that is the system engineering approach.

(Refer Slide Time: 30:18)



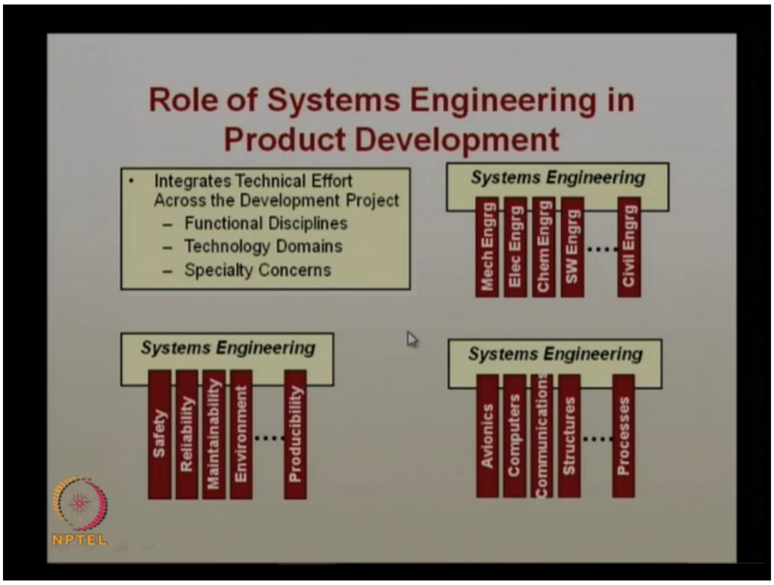
You can see how this actually system engineering basically adds value into the enterprises, you know that the profitability of engineering from or a enterprise actually depends on 2 things one is the system effectiveness, how effective the system is delivering the output and it is cost as an independent variable. So, the cost as in independent variable will come along with the effectiveness that actually ensures the profitability of a system. This is the part where the system engineers or engineering systems designers are focusing on how do we have an effective system or how do we ensure that effectiveness of system, which we develop. So, here there are 2 things one is the technical effectiveness the other one is the process efficiency.

Again technical effectiveness is the focus of the system engineers and operations maintenance and logistics also part of the design process while we design the system we will ensure that the operation maintenance and logistics also taken into account because that is again a large cycle of the system, that also taken into account when we design the system.

And in the technical effectiveness there are 2 things one is the performance, that is the functional performance, the requirements in the priorities, how do we actually define the function or design the functions and identify the requirements, and then get the priorities of the customer. So, based on the priorities we identify the requirements and then provide the functions in the system in order to provide the performance. And other factors are inherent availability of the system like reliability maintainability and support ability of the system.

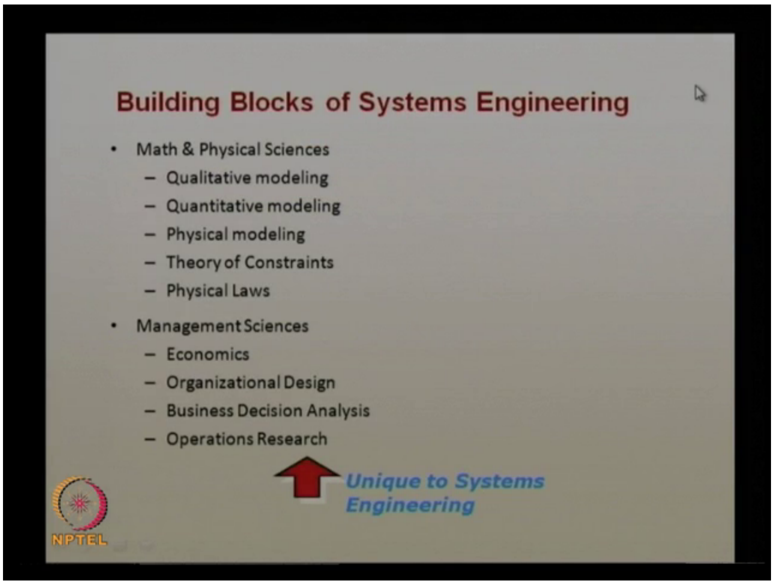
So, while we design the system we ensure that the reliability and maintainability as well as the supportabilities is also built into the system. So, that actually ensures the inherent availability of the system and the components this inherent availability and performance, provide you the technical effectiveness and effectiveness and the technical effectiveness along with the process efficiency and choose the system effectiveness. So, the role of system engineers are basically to ensure that the system is effective and did actually adds value to the enterprises and that actually leads to the profitability of the whole system.

(Refer Slide Time: 32:31)



So, what are the roles of system engineering in product development? So, it actually integrates the technical effort across the development project as you can see there are different functional disciplines, there are different technological domains and there are specialty concerns. We look at the functional disciplines we can see there are mechanical engineering, electrical engineering, chemical engineering. And all kinds of are the domains we need because we need to integrate or we need to expertise for the different disciplines and then different domain in safety reliability maintainability environment and reducibility. And we have the specialty concerns like avionics computers communications structures and process. So, it is it integrates all this technical efforts to provide the effective development of the system.

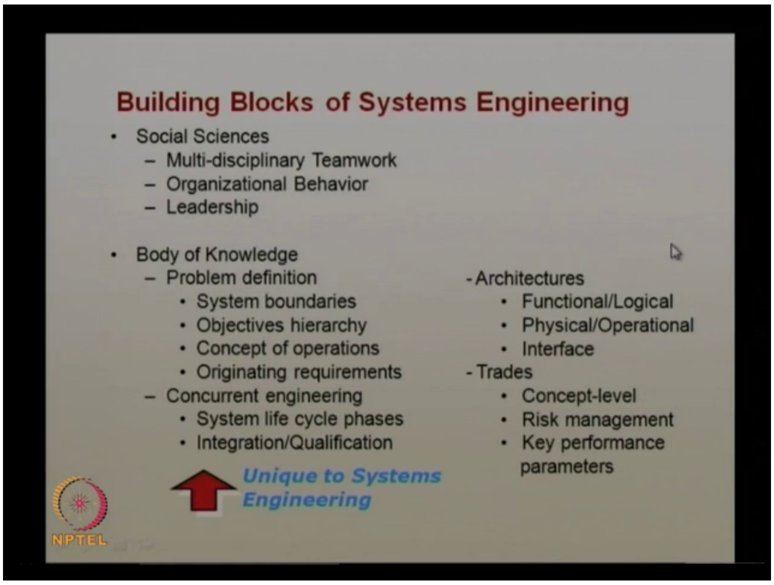
(Refer Slide Time: 33:22)



The basic building blocks of the system engineering as you know that the Mathematics and Physical Sciences that is the one of the basic building block were we do the qualitative modeling, quantitative modeling, physical modeling, theory of constraint, physical loss. So, this are the based on the physical mathematical and physical sciences one of the building blocks of system engineering, but apart from that we have this Management Sciences where the economics, organizational design, business decision analysis and operation research are also part of the building block and this is actually you need to system engineering.

In order to other engineering disciplines or the design aspects the management sciences are you need to this systems engineering.

(Refer Slide Time: 34:09)

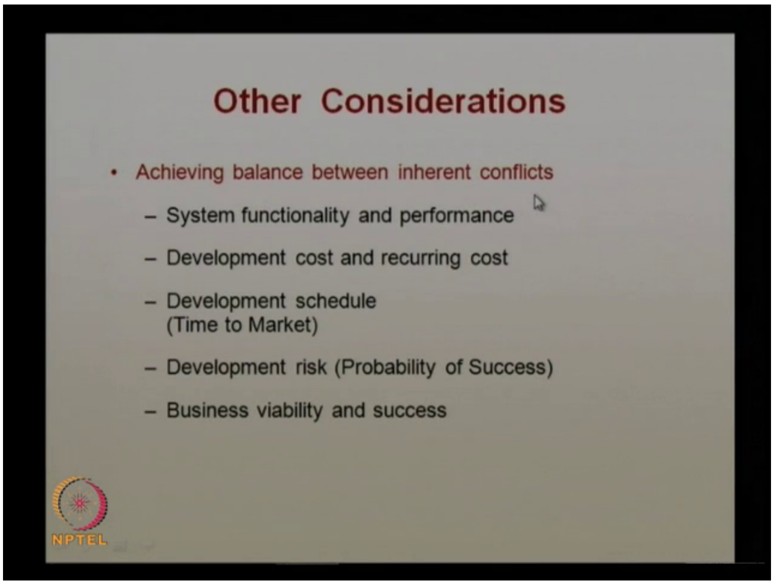


Similarly, you have other building blocks also like social sciences where we have the multi-disciplinary teamwork, organizational behavior, and leadership. Because the systems engineering involves multiple specialties and multiple groups teamwork is very important and organization behavior is very important. So, we actually try to incorporate this aspect also in the system engineering.

Similarly other building blocks are body of knowledge like problem definition system boundaries, objectives concept of operations originating requirements, then concurring engineering system life cycle phases integration qualification again this is very unique to system engineering, because definition of system boundaries objectives hierarchy concept of operations are all very unique to systems engineering approach architectures like functional and logical architecture physical and operational architecture enterprises. These are again building blocks of system engineering as well trade of like concept of level of trade of a risk management key performance parameter trade off these are also again building blocks for a systems engineering.

So, you can see that there are multiple building blocks as I mentioned in the previous slide there are mathematical and physical sciences, there are organizational behaviors, there are many trade off there any many design principles like problem definition the boundary the system, boundary definition and functional architecture development and trade of. So, all these are very essential for the system engineering and some of these are very unique to system engineering also it cannot be seen in many engineering fields, but in system engineering you may be using many of these as very unique in the development and they are actually very crucial to the success of a successful system design.

(Refer Slide Time: 35:53)

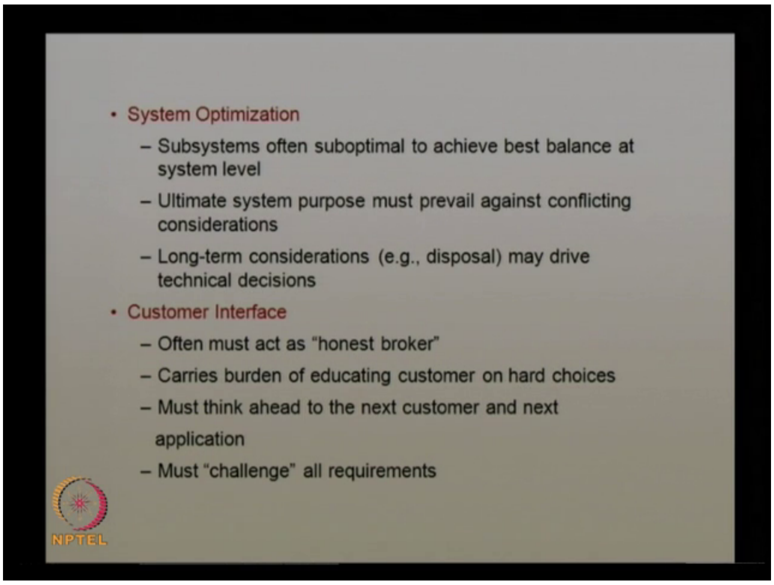


And some other considerations are basically achieving the balance between the inherent conflicts. So, there may be many conflicts in the engineering system design like system functionality and performance development cost and recurring cost as I told you about the tradeoff. So, again it is a balance between the conflict there is a conflict of cost and development cost recurring cost.

So, we need to decide which one need to have a tradeoff then the development schedule that is time to market again you want to do it as early as possible, but then there are inherent risk involved in that one them immediately the development is like a probability of success of the whole system is it the technological risk will be there market risk will be there and similarly the business viability and success.

So, these are the considerations we need to have when we design the system. So, it is not only that technology, but there are many other aspects to be considered when we go for the design of a system.

(Refer Slide Time: 36:49)



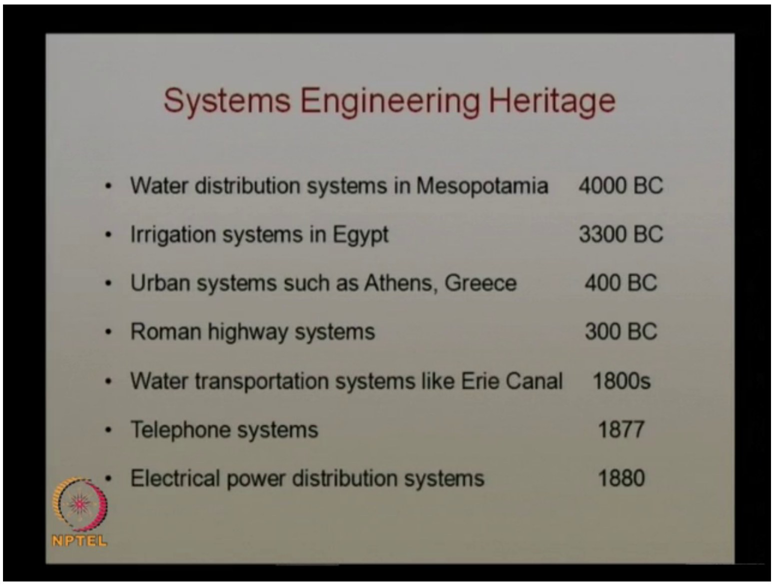
And then we have the system optimization subsystems often to achieve best balanced system level. So, since we have are here heavily having design of subsystems they may not be very optimal at that stage. So, we need to ensure that when the sub systems are assembled or integrated they actually provides you good optimization and then ultimate systems purpose must prevail against conflict in conservations.

So, whatever may be the your conflicting consideration the ultimate system performance what is intended at the initial stage should be always prevail and long time concentrations made that technical decisions. So, like disposal when we have a long time consideration for disposal we need to the technological decisions it actually focus on this also the long term considerations of the system. Similarly the customer interface often acts as honest broker.

So, basically this is one of the important part because that is the area where the customer directly interacts with the system that also need to be considered when we design the system and then carry is burden of educating customer on hard choices. So, sometimes we may have to the system design is in order to educate the customer on harder choices sometime customer may look for another option, but we need to educate them why we this particular choice is needed for the system and then must think ahead to the next customer and to the next application.

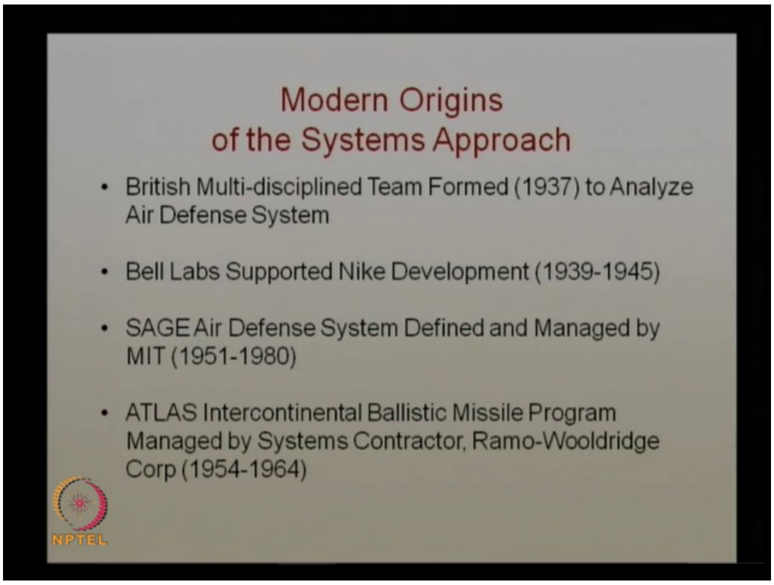
So, it is not only for that system or that customer we need to look at the changes happening in the market or in the technology and the design should always focus on the next application or the next customer and always must challenge the all the requirements or do not take all the requirements as granted. So, we need to challenge the requirements and then ensure that these requirements are genuine. And then we have the this requirements origin of these requirements are really understood and then only we go for go ahead with the design of the system, always we need to challenge this requirements and ensure that you understand that particular requirement, and the reason behind that requirement that logic of having that requirement in the system should be completely understood.

(Refer Slide Time: 38:54)



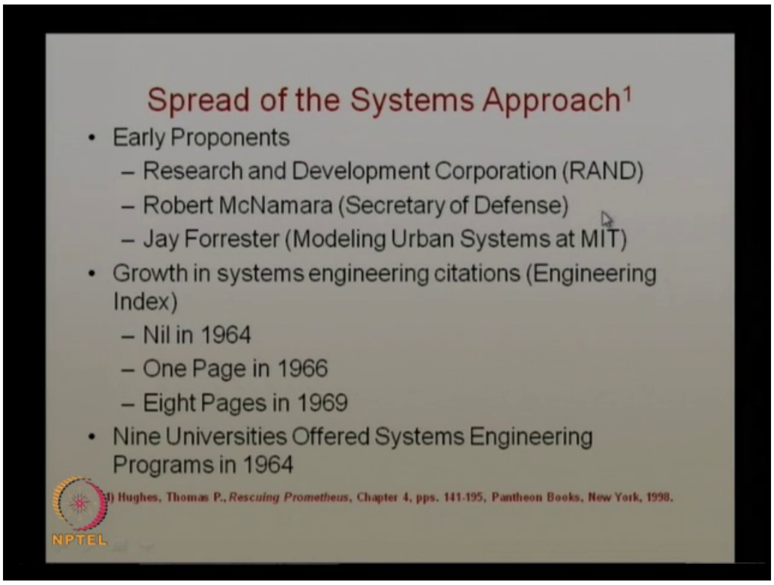
We will briefly go through the system engineering heritage and how actually the system engineering developed as a particular stream though the system engineering is only 100 years. So, old are the traces of engineering systems can be seen even in the 4000 BC, the water distribution system in Mesopotamia it was in 4000 BC in exampled for a system engineering. And similarly the irrigation system in Egypt the urban systems such as Athens and Greece, Roman highway systems, Water transportation systems, Telephone systems in 1877 and Electrical Power distributions in 1880. So, these are example for the latest or the recent ones, but we can see in BC itself in 4000 BC itself there were systems which actually could qualifiers engineering systems.

(Refer Slide Time: 39:45)



The modern origins of the systems can be found in the British multi-disciplined team formed in 1937 to analyze air defense system probably that was one of the first organized system engineering approach in the signing of some complex engineering systems. So, it is in 1937 British team multidiscipline team was formed to analyze air defense system, then bell lab supported Nike development in 1939 to 1945 and sage air defense system defined in managed by MIT in 1931 to 1980. I will see little bit about the sage air defense system what are the subsystems involved in this system at a later stage and then as I mentioned that atlas ICBM project which was managed by a systems contractor Remo Woodbridge corporation in 1950 between 1954 and 1964.

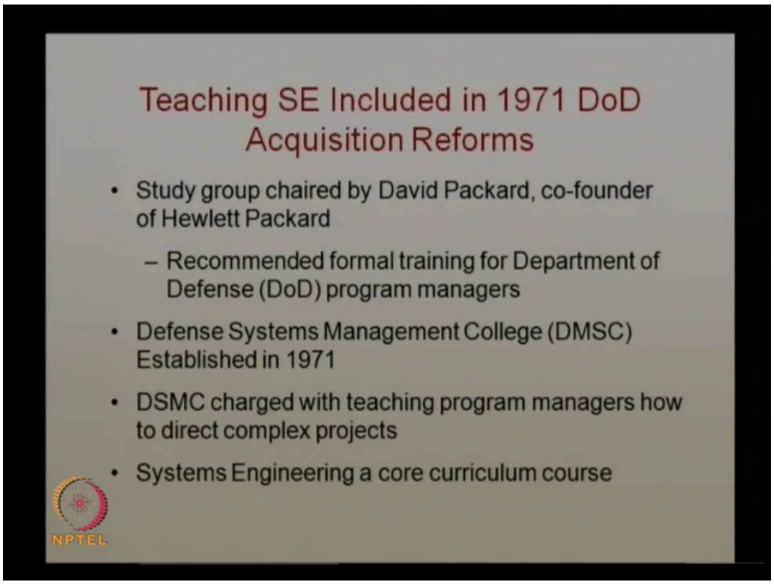
(Refer Slide Time: 40:44)



After these there was a spread of systems approach in various applications the early proponents where the research and development corporation which was actually responsible for the development of SEBM and then Robert McNamara the Secretary of Defense who actually introduced this systems engineering.

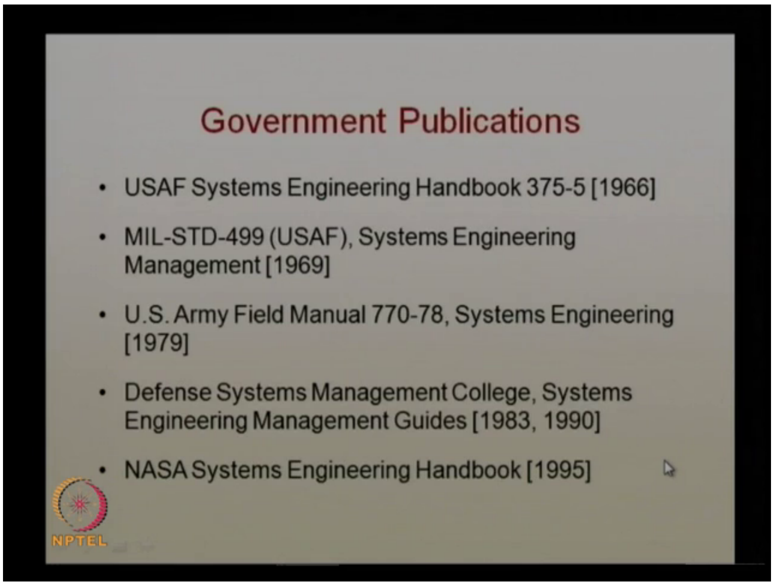
Principles in defense systems similarly there were growth in engineering citations also on 1964 the that is not nil citations, but in 1966 there was one page citation and then and 69 it increase to 8 pages 1964 there were 9 universities offering systems engineering program, but now there again it is increasing there are lot of people actually adopting systems engineering principles for their applications.

(Refer Slide Time: 41:27)



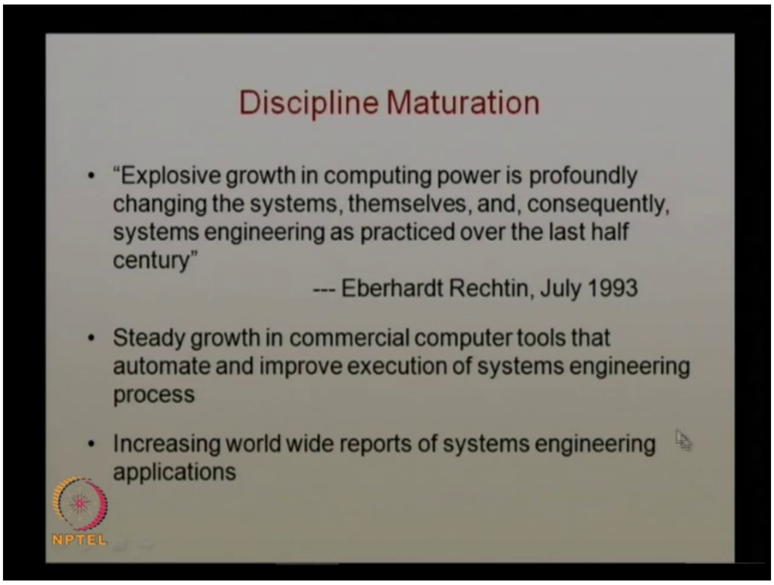
So, the teaching of system engineering was included in 1971 DOD Acquisitions Reforms that is reforms department of defense acquisition reforms a study group chat by David Packard co-founder of HP was form to study this. And then they are recommended formal training for department of defense program managers. And then defense system management college was established in 1971 and DSMC charged with teaching program managers how to direct complex projects, system engineering became a core curriculum course in most of this course.

(Refer Slide Time: 42:02)



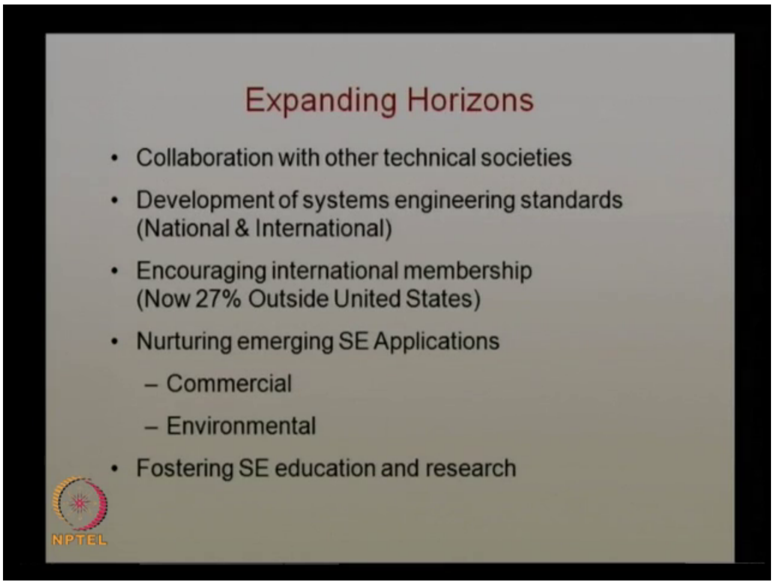
There are lot of publications existing available for engineering system that us air force systems engineering handbook then mill standards, then you have us army field manual then Defense System Management College, System Engineering Management Guide and NASA Systems Engineering Handbook 1995.

(Refer Slide Time: 42:21)



The discipline is actually measuring the system engineering discipline is maturing slowly. The explosive growth in computer power is changing the systems themselves and consequently systems engineering as practiced over the last half century. This was comment by a Rechtin in July 1993 and then study growth in commercial computer tools that automate and improve execution of systems engineering process and increasing worldwide reports of system engineering applications. So, we can see a increase in the world wide reports of system engineering application which I actually shows that system engineering is actually maturing as a separate discipline.

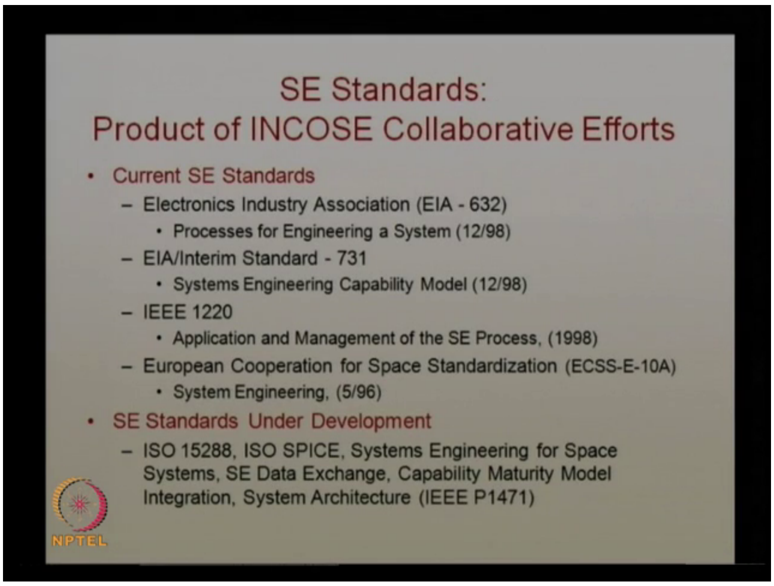
(Refer Slide Time: 42:58)



Expanding Horizons collaboration with other technical societies taking place there are many standards being developed for system engineering, there is an encouraging international membership for this systems engineering society and then nurturing emerging systems engineering applications.

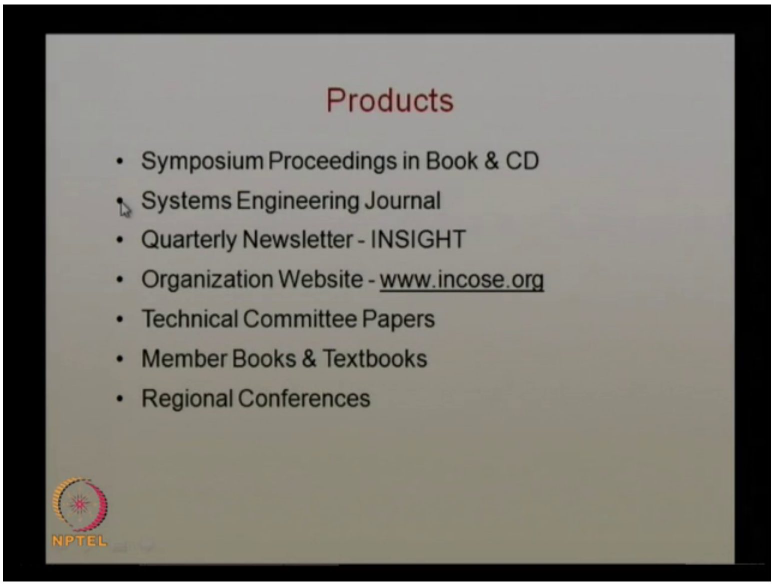
There are many applications coming up its commercial and environmental areas and then fostering the system engineering education and research is also happening. So, these are all actually promising for the system engineering to mature as a separate discipline.

(Refer Slide Time: 43:28)



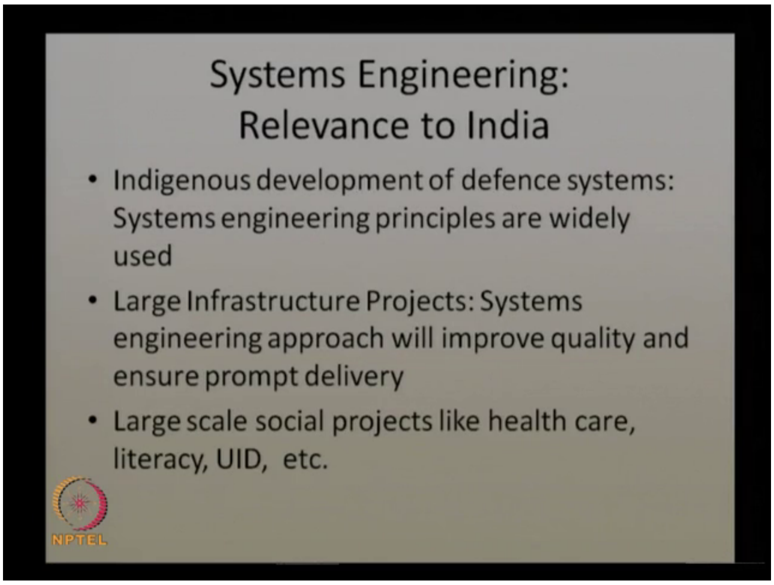
There are many standards existing in in course that is international constitute for system engineering. So, there are current system engineering standard by electronics industry association, then I triple E standards are there then we have the systems engineering standards under development ISO standards ISO spice and system engineering for space systems and I triple E P 1471 . So, these are the standards being developed for systems engineering.

(Refer Slide Time: 43:54)



There are many products available in the market. So, if you are interested to know more about this system engineering and the what are the developments taking place you can actually refer to the most these proceedings or genres or the organization website www dot incose dot org other technical committee papers m bar books and text books and regional conference are available, you can actually refer to these proceedings to know more about the system engineering.

(Refer Slide Time: 44:18)

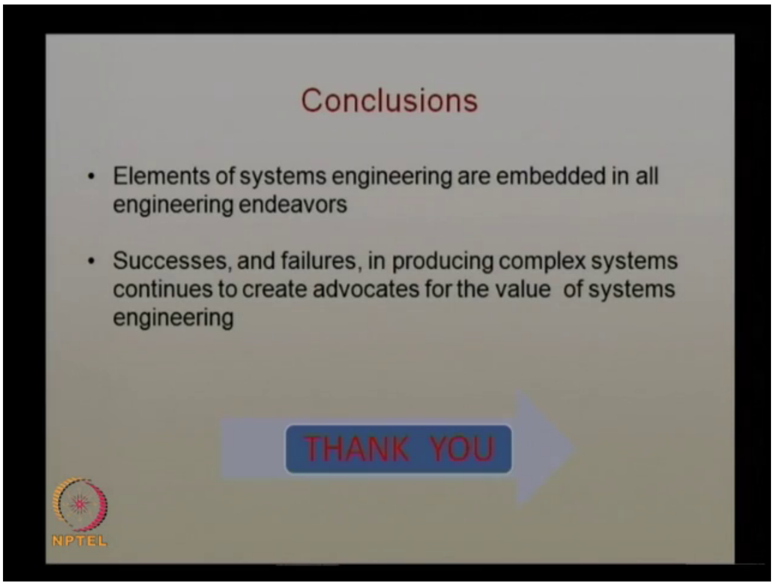


Why is it relevance to India or why do we need to have to learn the systems engineering because lot of engineers development of defense systems are taking place in India and this developments really need to follow the system engineering approach because they are very complex engineering system they are actually requires multiple discipline and their actually multiple teams working on it.

So, unless we have systems engineering approach for this projects it is very difficult for success of the project and therefore, we need to impress the system engineering in a big way to for the success of these projects. Similarly there are large infrastructure projects coming up in India especially in the construction sector Highways and Expressways and there are a lot of other construction activities we have multiple infrastructure projects in terms of power plants and other areas.

So, these are all very complex engineering systems and therefore, we need to follow the systems approach in order to ensure that actually it delivers on time as well as it meets the customer requirement or the stakeholders requirement, apart from these there are many other social projects also coming up like the healthcare projects, education projects, then we have this a unique identification project. So, these are all projects with lot of complexity some of them having the engineering complexity some of the maybe having some other complexities, but most of them have multi-disciplinary teams working not to provide the desired output. So, for the success of this project we need to ensure that we follow the principles of engineering system design and implement these principles to ensure that it projects are successful and meets the requirements.

(Refer Slide Time: 46:01)



So, to conclude this lecture we discussed about the basics of systems engineering the importance of system engineering and why do we need to have a system engineering as a separate discipline and what are the benefits of these using the principles of engineering system in complex system design. And then we discussed about the some of the success and failures of the systems and how do we actually learnt from this failures to ensure that we when we have a systematic approach in the design of system, we can ensure that the failures are minimized and always there be a success in the system design. And we mentioned about some of the developments took place in system engineering and some of the projects under going as well as some of the standards existing.

In the next lecture we will look at the classification of various systems then the role of system engineers and how does a system engineers play a vital role in the design of system and then further to that we will look at the requirement analysis and then the 6 functions of design process; so till we meet in the next lecture, very good bye to all of you.

Thank you.