Statistical Learning for Reliability Analysis
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Lecture – 01
Introduction to Reliability Engineering

Warm greetings, welcome to the course on statistical learning for reliability analysis. As this is the first course on this topic, first I will introduce you to the world of reliability engineering. However, I will not go to the details of it. Because this is not a course on reliability engineering, I will mainly focus on statistical methods and which I will to explain the different concepts. I will take the examples from the level of engineering however of course I will also consider some example of other application of statistical methods as well.

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So, in this class basically first I introduced reliability engineering, as I already mentioned, then I will discuss why reliability engineering is necessary then I will talk of failures in the parlance of reliability engineering, causes and types of failure. And then I will talk about a concern and objective of a reliability program. So, now reliability it is something which we see in our day to day life, like a human being has reached to such a stage where we are dependent on almost all our activities we are dependent on some of the other machineries.

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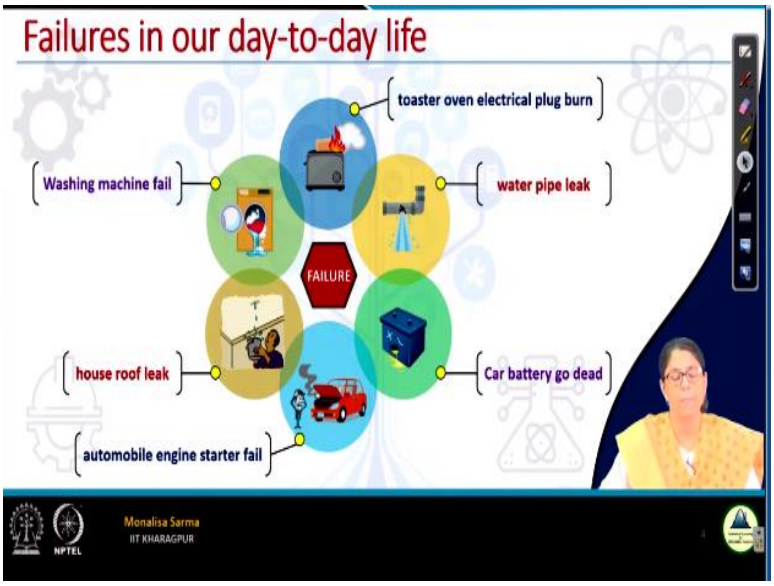

So, if we just look around, we will see many of the things almost failed daily, we will see some of the things which fail one or the other things fail, like if we consider say, washing machine. So, washing machine fail, like washing machine failed, a failure washing machine maybe due to the wear out period like it has done for the normal life and his wear out has crept in that so, maybe there was washing machine and failed. Then the car battery go there that also may be the after walking for the normal life it has gone it has worn out and so it is battery has gone dead.

But again there are something like toaster oven electric plugs burn, this may be the defect in their design, the design of the electric plug, then this house roof leak, house roof leak is maybe due to the faulty construction, then the water heater leakage, water heater leakage is again maybe this may be due to corrosion. The corrosion clips in a video to not proper maintenance which could have easily avoided by doing preventive maintenance. So, these are some simple failures which we experience in our day to day life.

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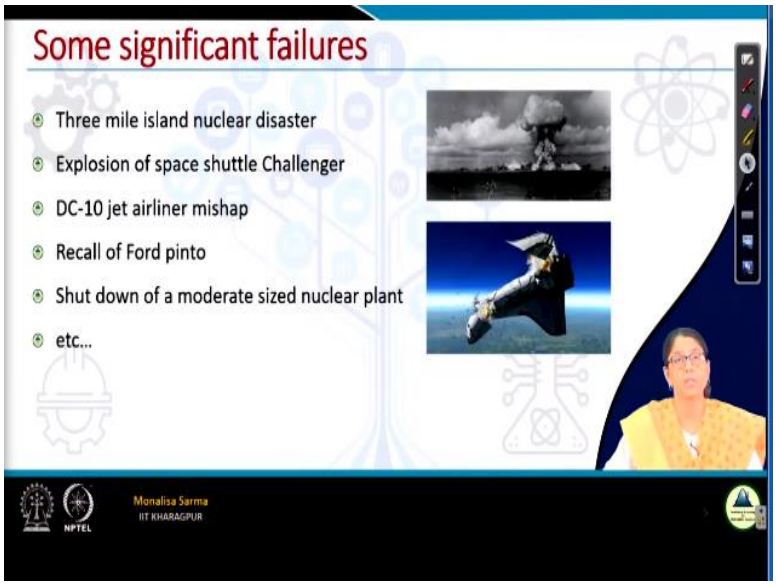

Similarly, there are some failures which are quite significant and whose effects are much more than this, what we have seen are in our last slide like to talk about the significant failure first, let me talk of one failure which has occurred one nuclear failure like which we nuclear disaster is which is happened in Ukraine because I am talking about it because Ukraine is very much in news nowadays. So, in Ukraine there was a wars nuclear disaster is Chernobyl nuclear disaster.

It is most in nuclear disaster in terms of cost in terms of causality that has many billion dollars has been needed to clean up the place. And moreover, the causality during that time is also quite high and the effect was seen for quite a long time affected because of the radiation, we could see many people are suffering from cancer different sort of cancer after many years of disaster as well. Then we are going for back home we can see we can talk about the Bhopal gas tragedy that is one of the worst industrial disaster again in terms of causality.

So, these are some significant failures there are many significant failure like I can talk about the 3 mile Island nuclear disaster which is in US and the explosion of the Challenger Space Shuttle, then we call a Ford Pinto that has happened long back that was in 1970s due to many defects of Ford Pinto like nowadays in news there are so many electric 2 wheelers, there were some electric 2 wheelers we could see it as burning here and there. So, recall of that 2 wheelers is very much in demand now. So, these are some of the significant failure.

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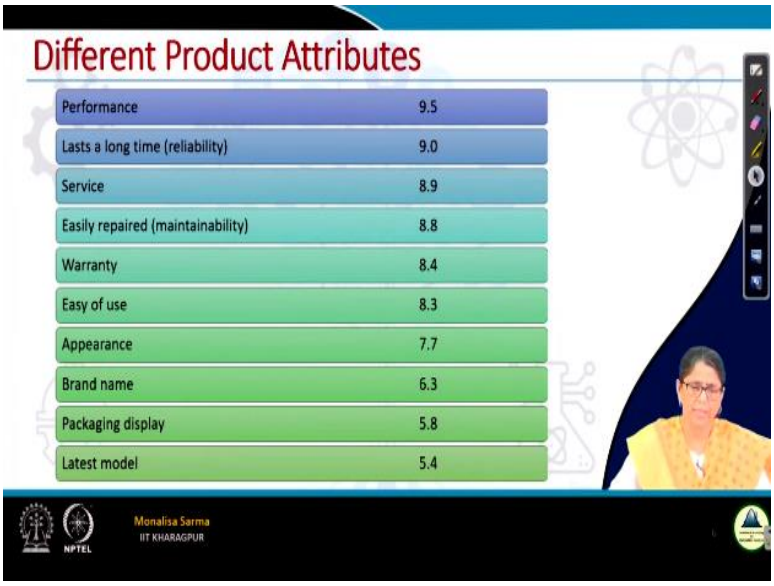

Now from these 2 slides what we can see is that like, because of this failure, that there may be some may be minor irritants or it from starting from minor it may to and it may lead to some catastrophic failures like economy in terms of economic as well as in terms of casualties. So, way back in 1970s, a social science survey was done around they have interviewed around 1000 people that was it was like this survey was mainly done to find out people give what people give importance to which parameters while they are buying a product.

So, this products, maybe any sort of product, and they were like different parameters when you talk a product attributes the different product attributes to product attributes may be performance, my warranty, ease of use, brand name that is more than many things, many parameters, all functional parameters as well as non functional parameters. And it was noticed that people give me quite a bit of importance to reliability and maintainability.

Of course performance is something which people really definitely they will give importance to it, but along with that, people gives quite a bit of importance to reliability and maintainability other things like latest model brand name, appearance and all those things, they are not very much important while purchasing a product.

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So, from this, we could conclude that engineers responsible for product design much therefore, include both reliability and maintainability as design criteria meaning like, when we developed a product, it is not that we should only focus on the functionality of the product like, if I am developing a washing machine, what is the functionality of the washing machine? Functionality of the washing machine maybe just washes clothes. So, it is not that we should not only focus on the functionality, but at the same time we should also focus on the reliability.

How well this washing machine will perform over a period of time, maintainability if something goes back, is it repairable is it how much time it takes to bring back the machines to its original condition like a working condition. So, this criteria reliability criteria, maintainability criteria this has to be incorporated in the design criteria as well. So, that was the conclusion from the survey, but it was done from the around 1000 customers.

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So, now coming to what is the compulsion for a reliable product? It is only economy compulsion or is it only safety compulsion what we have seen in the last few slides, no it is not only that, there are 3 different types of compulsion for reliable products that is one is economy compulsion, environmental compulsion and performance compulsion. Now, these 3 compulsion are not independent to each other, it is to compulsion are very much inter linked.

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Like if we talk about economy compulsion, first like the old concept of using throw, it is no longer applicable in today's world wide because the cost of harnessing material and energy use while making product it goes very high. So, the product has to be long lasting from the economy consideration provider has to be long lasting, as well as it needs to be recyclable and moreover, for a company to survive in this market.

The one important criteria is that today's market as you know it is a very competitive market for similar type of product, there are many customers, many producers, they are producing similar type of product. So, to survive in this competitive market, a product must provide trouble free service, it must provide better customer satisfaction, along with the functionality of course, functionality is definitely very important, along with the proper functionality.

It should provide trouble free service, better customer satisfaction and all this at the very cheaper price. So, this is the economy compulsion of reliability product, unless the product is reliable you cannot achieve this.

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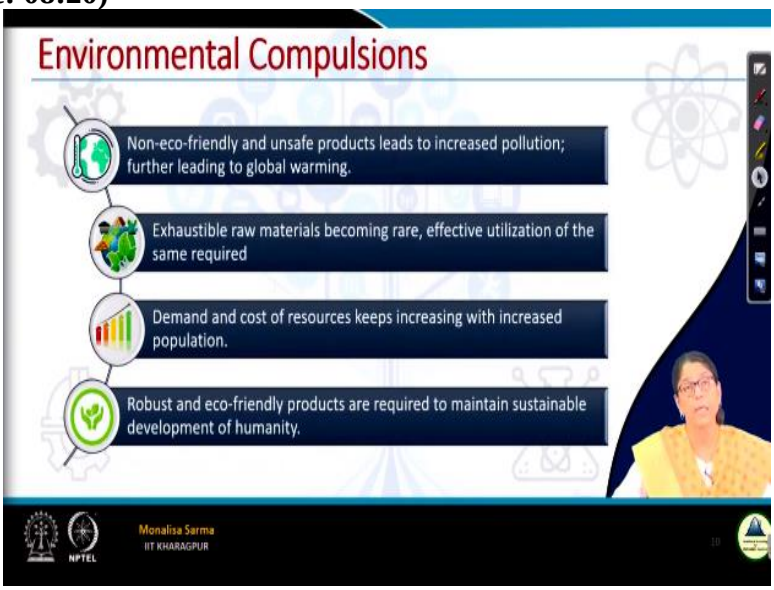

Now, coming to the environmental compulsion, so, environmental compulsion when we talk about the environmental compulsion, we see that if we use non eco friendly or unsafe products, what happened? It leads to increase pollution and increase pollutions what happened? It leads to depletion of ozone layer global warming, these are the consequences basically and the main thing is that now the resource are depleting. So, because of this exhaustible raw material, it is becoming rare, effective utilization of same are very much required.

So, for the sustainability and sustainability it is to be the motto for a company for considering the health of an environmental health of heart. So, these are the different environmental compulsion.

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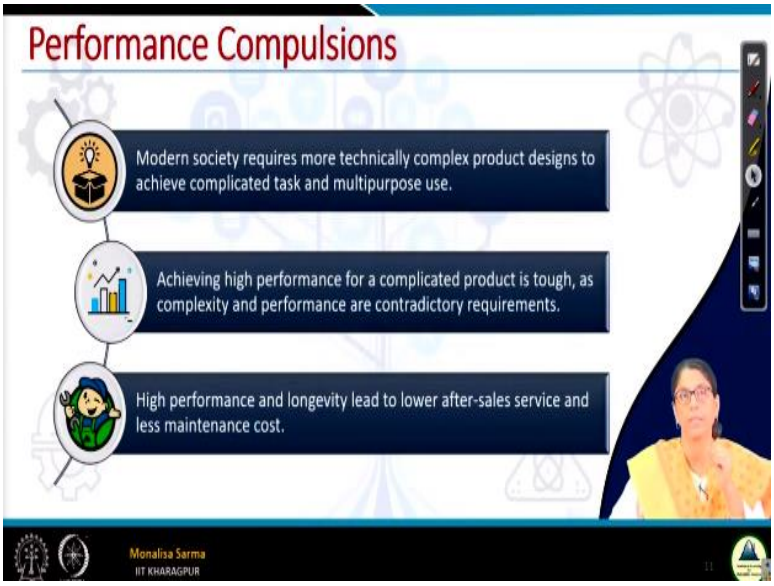

Now coming to the performance compulsions. Now, the main thing is that nowadays the products that we use, it has to be like multipurpose and like it teach to cater to different kinds of needs. Let me talk about a washing machine only, washing machine and wait like around 20 30 years back washing machine, it says wash clothes. Now, we have many requirements, we need different type of functionality for different types of clothes.

So, our demands are more, demands has become more and more complex and the demands has become more and more complex, definitely the design becomes more complex and the design becomes more complex, achieving high performance has in reliability, it becomes a challenge. So that is what high performance and longevity leads to aft er lower after sale service and lower after sale service means it leads to lower maintenance costs. And does it reduce the lifecycle costs?

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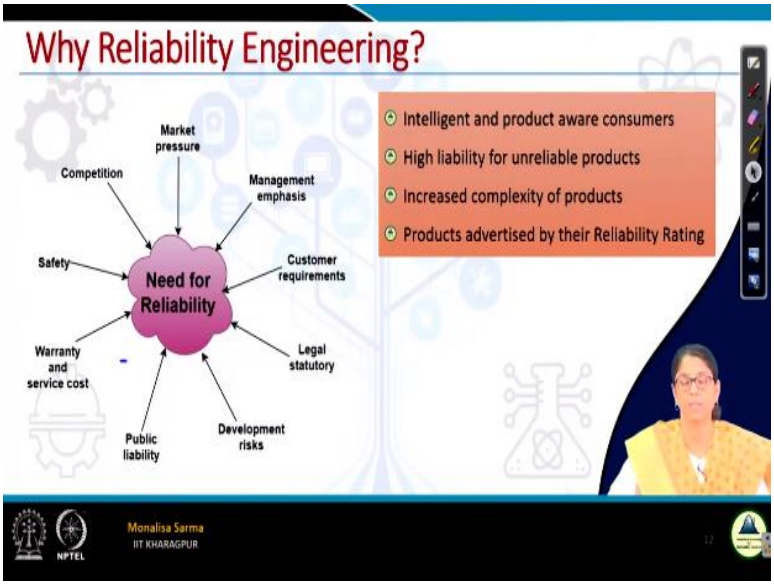

So, now having the knowledge of why the different compulsion of the reliability engineer, now we are in a position to answer why reliability engineering. So, why reliability engineering basically the first point is now, our customers are intelligent, we cannot just fool them, they are very intelligent customers and they are very product our customers. So, when the customers are intelligence and product our customers, you just cannot give any product you have to be very, very careful about all aspects of the product.

And the main thing is that we have to face high liability for an unreliable product high liability maybe in terms of a legal suit, maybe in terms of warranty costs and with the increased cost increased complexity of the product achieving this becomes very big challenge. And moreover, now as I told you for the same type of similar type of product, there are many players in the market. So, now, the products are advertised by the reliability rating.

Now promotion, promotion is very much necessary for the sale of a product. So, until and unless you do not have a proper reliability rating, you cannot advertise your product. So, these are some of the reasons why we need to go for reliability engineering.

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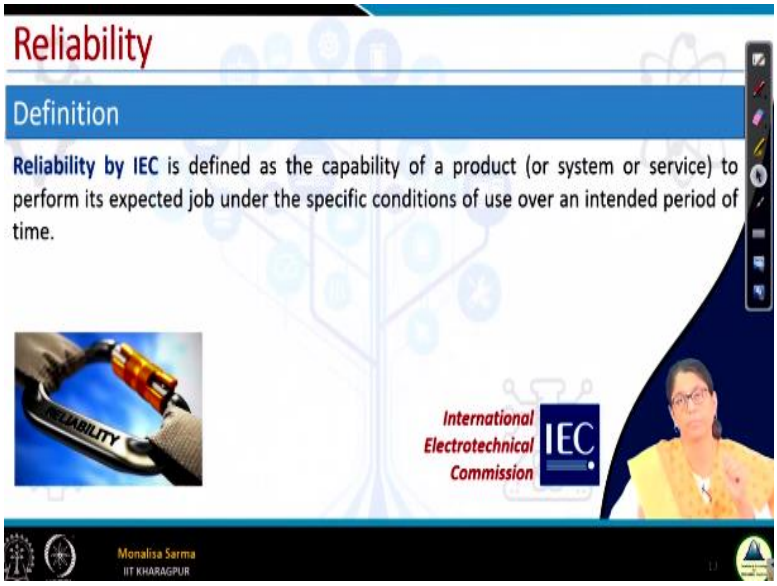

Now, we have talked enough about reliability engineering, we have basically understood what is. Now let us formally, define what is reliability engineering? So, reliability as defined by IEC What does IEC means IEC: International Electrotechnical Commission, it is an industry in international standard organizations that publishes standards for electronic, electrical, electronics and related technologies. So, reliability as defined by IEC as the capability of a product, a system of service to perform its expected job under specific conditions of use over an intended period of time.

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Now, if you see the definitions, there are 3 different elements to it, the first element is the performance expected job. So, what is the expected job like if we talk about a missile, what is the expected job of the missile? Expected job of the missile is to hit a target with very high accuracy

and high speed that is the expected job of the missile. So, that is the expected job after the job is product or unit should function satisfactorily within performance limit. So, now, what it may be the performance limit of the missile? Performance limits of the missile maybe the speed, maybe the accuracy. So, this is one element when we consider reliability that is the expected job.

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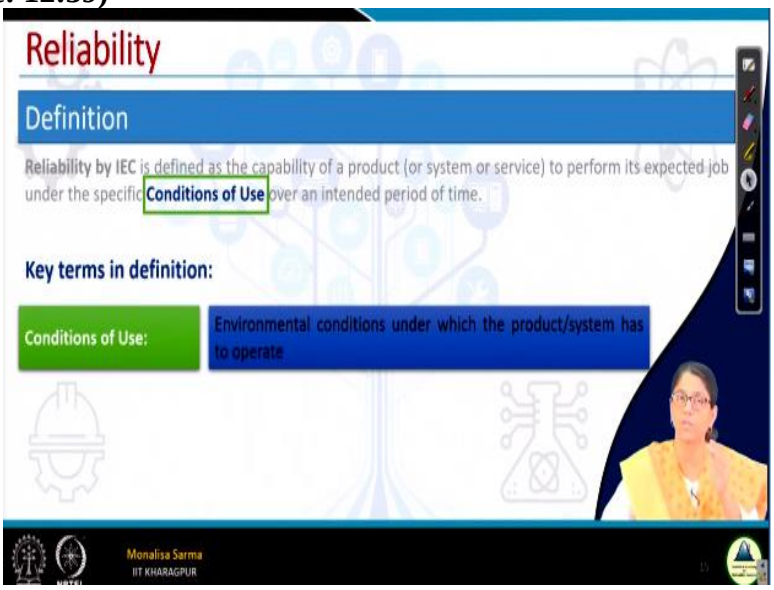

Next element is a condition of use. So, condition of use now, again when we try to find out the reliability of the product of course, the condition of use is also very important, like a product is built to operate in a particular condition of it, let us talk about luxury car, a luxury car is not expected to run in a mountain terrain when so, if you are trying to run a luxury car in a mountain terrain and then if you try to find out the reliability of the luxury car then it is not done basically. So, condition of use is the environmental condition under which the product or system has to operate.

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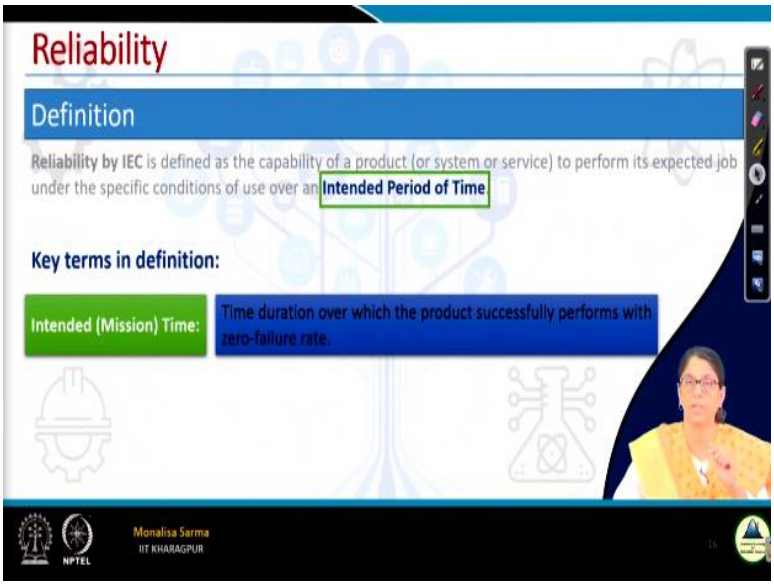

That the third element is the mission time and then that order mission time, mission time is the time as a time which we do not want any failure for the system to occur. Like for the missile, missile the mission time is a time when we deployed a missile till it hits the target that is the mission time. So, we do not want any failure in this mission time. So, what we defined time duration over which the product successfully performed with 0 failures. So now, when we talk about reliability? We should talk about these 3 terms that is the expected job, condition of use, as well as the intended period of time.

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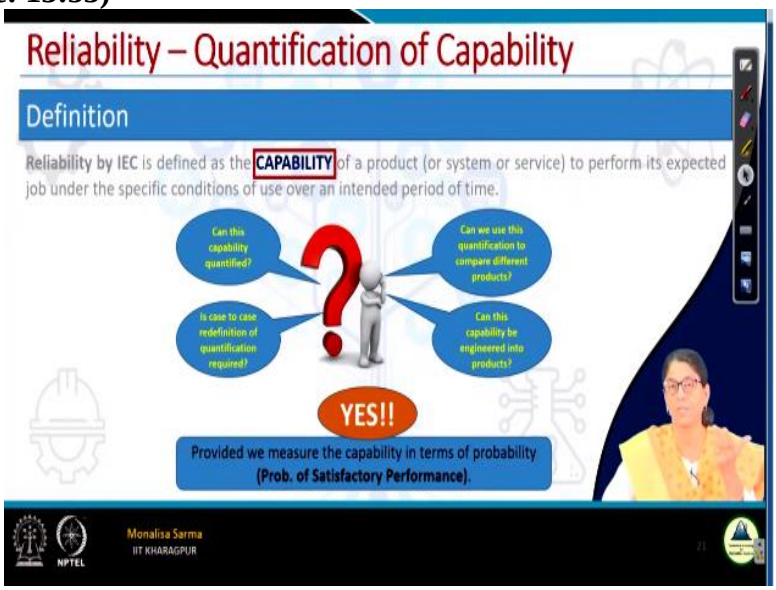

Now, there is something else also that is the capability it is defined as the capability of a product. Now what is this capability? Can this capability be quantified that is the first question. Second question, this capability do we have to resort to re-definition from case to case like for different

products? This capability we will have to define it separately as it like that or is the same definition is applicable for all types of product.

Next, can we use the quantification to compare different products? Now; similar kinds of products produced by different players using maybe different technologies. So, can we use this quantification to compare these different products? And also, can this capability be engineered into the products? So yes, the answer to all this question is a big YES. But provided we measured a capability in terms of probability that is the probability of satisfactory performance. So, when this probability is the science of basically uncertainty, right?

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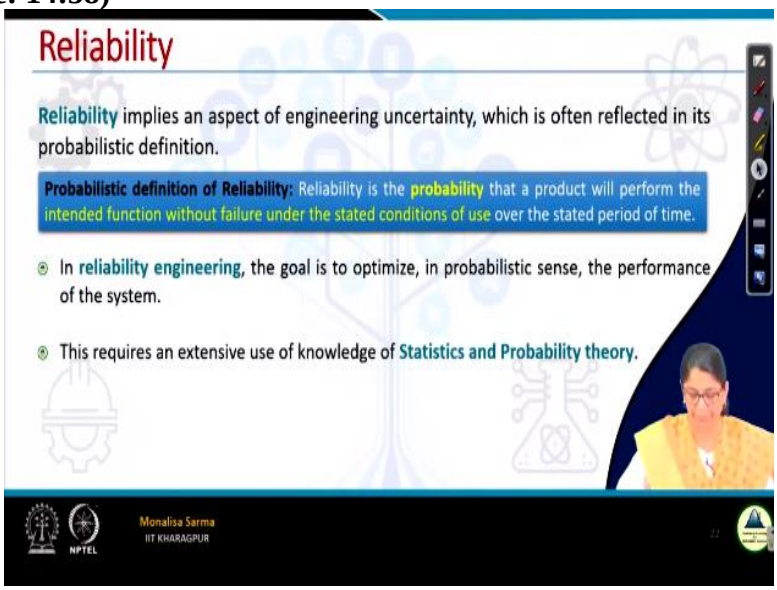

So, reliability that means it implies an aspect of engineering uncertainty. So, hence, we will come to a probabilistic definition of reliability. So, what is that? Reliability is the probability that a product will perform the intended function without failure under the stated condition of use over the stated period of time, everything remains same just instead of capability we have changed it to the Reliability that is the probability that a product will perform, the intended function without failure under a stated condition of use over a stated period of time.

So, in reliability engineering, the main goal is to basically to optimize in probabilistic sense the performance of the system. So, now to do this, it requires an extensive use of the knowledge of statistics and probability theory. So, this is basically the goal of this course. So, we will be learning the statistics and probability theory. Again, I am mentioning here which I have already

mentioned in my introductory class, that the statistics and probability theory do I will be focusing mainly from the reliability analysis application, but this is statistical as you know, it is applicable to many other fields as well.

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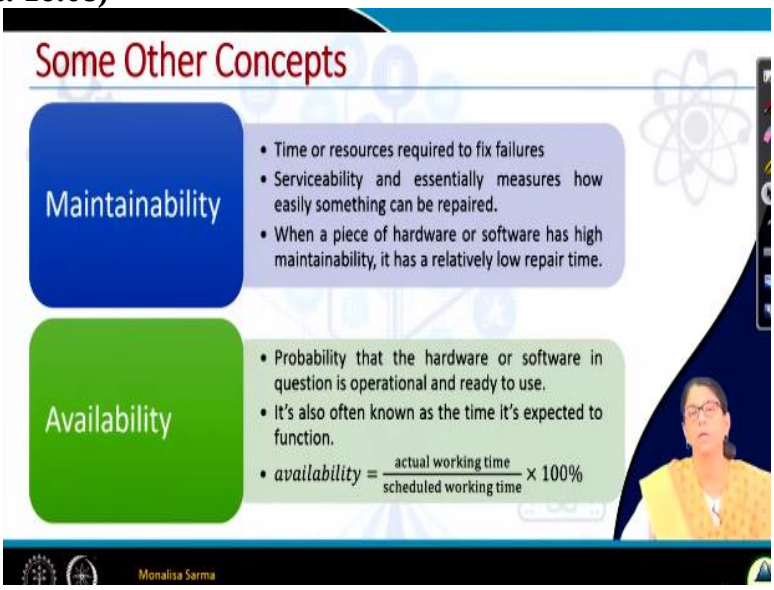

So, there are some other related concepts of reliability which you need to know first is the maintainability. Maintainability it is the extent of time or resource required to fix failure. It is also known as serviceability and essentially it measures how easily something can be repaired. Now, what is availability? Availability is the probability that the hardware or software or any product in question is operational and ready to you. How you define mathematically availability is actually working time and schedule working time in to 100%.

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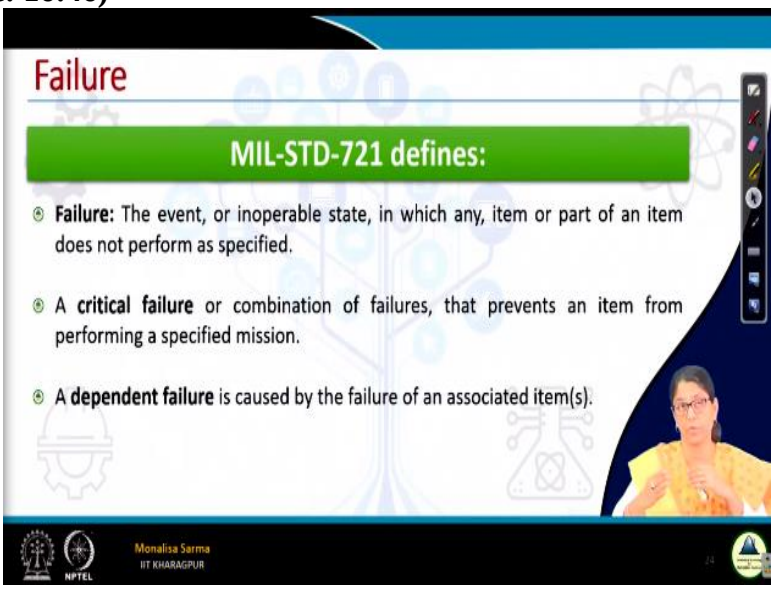

So, now, having talked of reliability say, in the reliability definition we have encountered what different failure now, we will define failure in the parlance of reliability engineering. So, what is a failure in the parlance of reliability engineering? Failure is the event or inoperable state in which any item or part of an item does not perform as specified. Again, there is some order definition, order type of failures which we call is a critical failure, critical failure is that prevents an item from performing a specified mission.

First is a failure which may not stop you from performing a specified mission, but if it is a critical failure when submission will be aborted it will not perform, then there is something called a dependent failure, dependent failure is caused by the failure of an associated item one failure may lead to another failure that is dependent failure.

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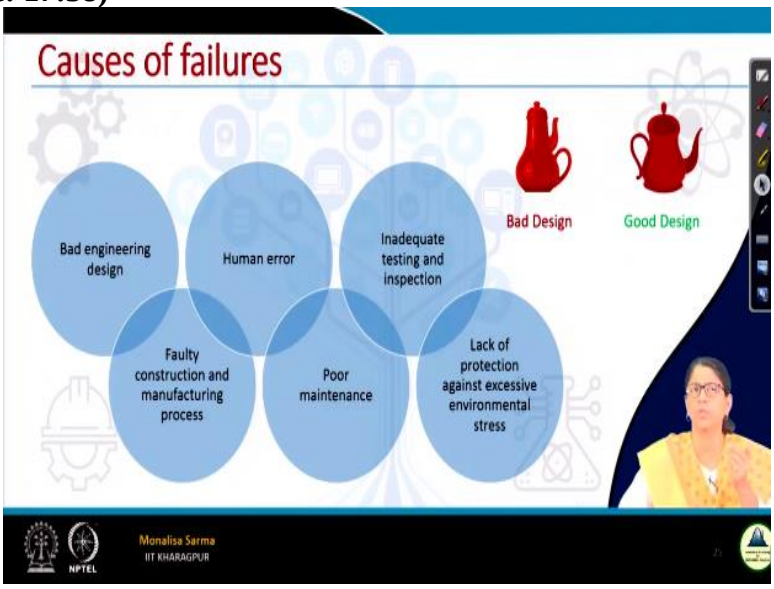

So, on different causes of failure like see, you can see the figure the first I can say different causes of failure maybe a bad design you can see in the figure the 2 designs of teapots take at least one we can see very easily we can find out why this first one is called a bad design and the second picture why we call it a good design. Now, all of you can easily see that. So, the different causes failure means maybe the bad engineering design human error, human error was one of the main reasons for failure.

Then the inadequate testing and inspections maybe faulty construction like what we have seen the house roof failure, in the first light house roof failure may be due to a faulty construction,

then again oven plug and burning that may be the faulty construction of the plug, then poor maintenance, poor maintenance what we have seen that water heater leakage is due to the corrosion has crept in why corrosion could creep in because of poor maintenance, then the lack of protection against excessive environmental stress. So, these are may be the different causes of failures there may be n number of causes for failure.

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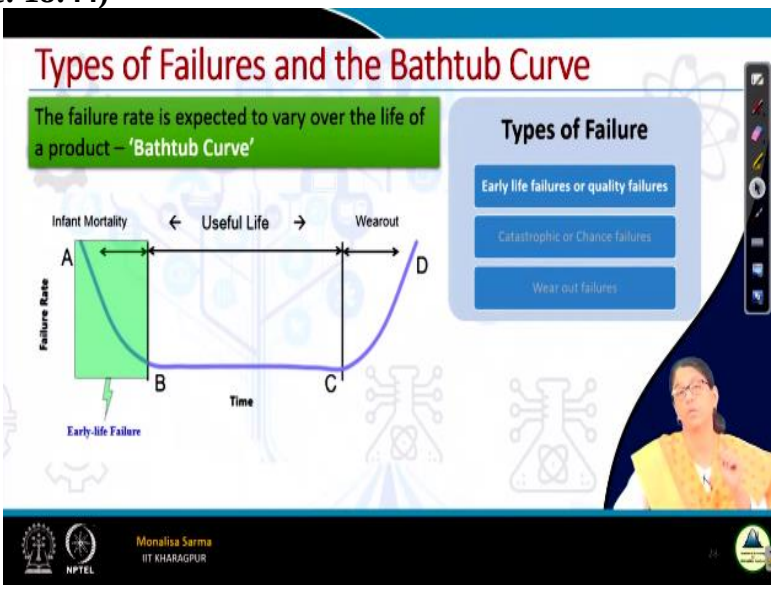

Now, what are the types of failures? Talking about the types of failures, there are basically 3 types of failures that we can see in the lifetime of a product. So, the 3 different the lifetime of a product if we consider, this we call it as a, it basically follows a curve which is very similar to a bathtub. So, it is also called a Bathtub Curve. So, the 3 different failures, the first is the early failures or which you call it a quality failures, It happens in the early life that is also called infant mortality.

This early life this failure happens, why the failure happens in early life? The reasons maybe quality, then the design is defective, maybe the proper quality was not used, quality of material and maybe the design process was not proper. These are the many issues because of which we get failure in the initial period, it is also called the teaching problem. So, that is called the early life failure or the quality failure.

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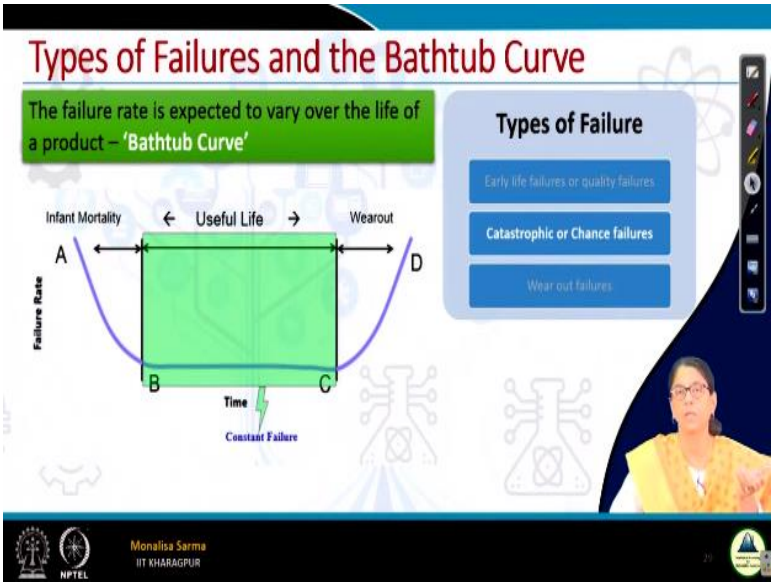

After that, then comes the normal life once this after the system has become stabilized then the normal life of the product starts. In the normal life the failure rate is more or less constant here we are do not encounter any of the quality failures here mainly the failures are chance failure, maybe due to natural environment natural causes like maybe due to earthquake, maybe due to tsunami. So, like when the stress accumulation of the products becomes more and the strength of the product than the failure occurs in the useful life time. So, that is called a catastrophic or chance failure, the failure rate at this time is constant.

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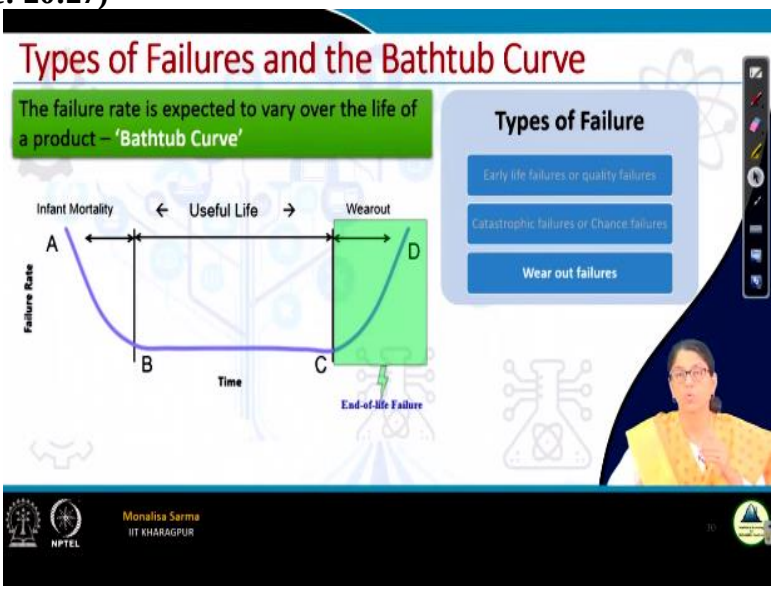

Then the last is that is wearout failures when the component or the system ages. So, it is the end of the life failure. So, aging happens, so corrosion creeps in, wearout happens, so, because of this again our failure rate increases. So this is the wearout failure.

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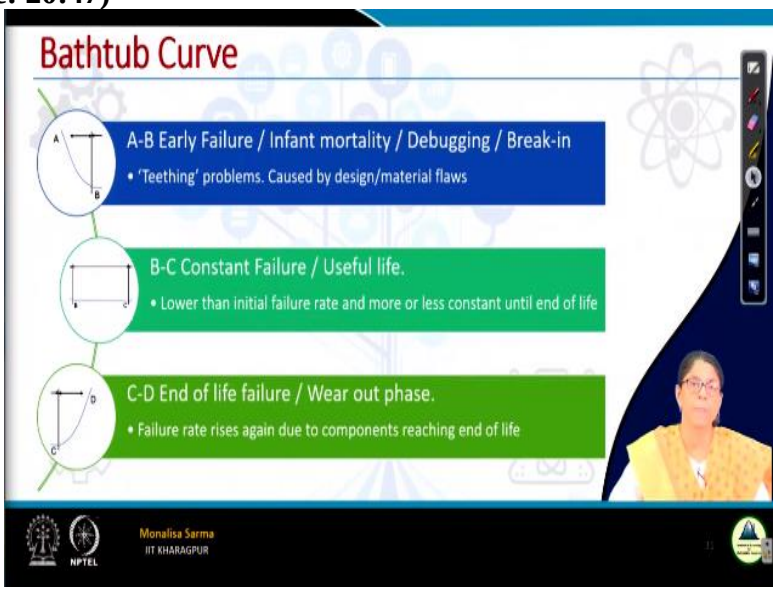

So, here we see the first initial the early failure, early failure what happens, gradually our failure rate decreases. So, you see the first figure top figure, top failure rate visually decreases, then it is the constant failure or that is the useful life and the useful life or failure rate remains more or less constant than the wearout life wearout again failure it increases. So, these are the 3 different types of failure that we encounter usually in a component.

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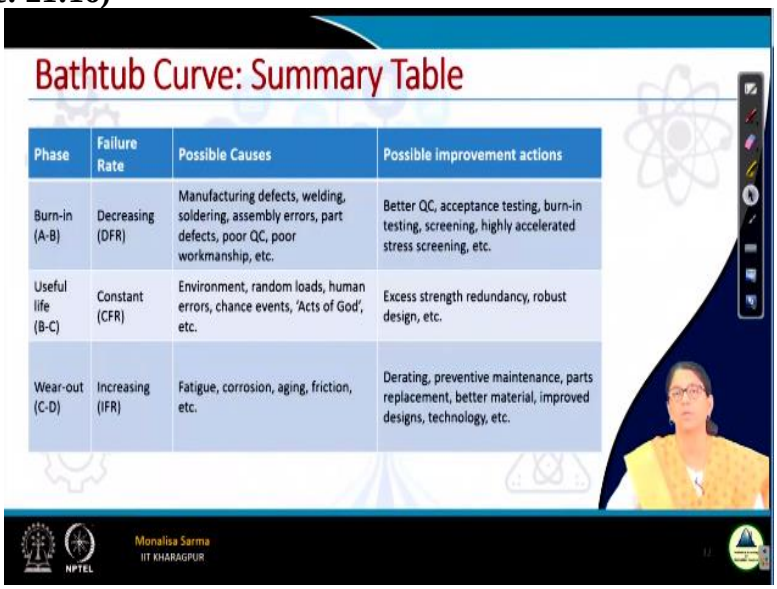

So, now, again so this is a basically summary table what may be the possible causes, why this failure has happened in 3 different phases and what are possible improvement action which I will not be explaining and it was can just go through it as scattered as a summary table here.

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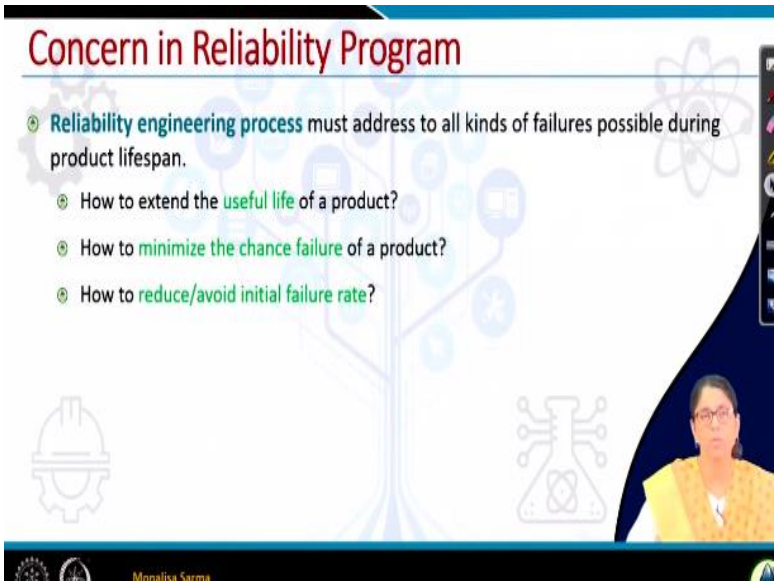

Now, we have seen the bathtub curve of a system so we know at what stage what type of failures occur? Now with this knowledge now we know what exactly to do in a reliability program. So, what are the main concerns in a reliability program? So, the main concern in a reliability program is basically, first thing is the how to extend the useful life of the product? We need our whole life to be more and more before the aging creeps in.

So, how we can extend the useful life of the product? This may be one of the concerns, second concern may how to minimize the chance failure of a product and or use chance failure that is not a catastrophic failure that against happens in normal life failure. So, how to minimize this? And then thirdly, then again how to reduce or avoid the initial failure rate , Initial failure Rate that is the teaching problem, how we can reduce the failure rate?

Then again, there may be some other concern as well how to what to say in reduce the failure rate and wearout period how to reduce the what to say reduce the increase the normal lifetime, so, that wearout happens, wearout does not happen quite fast, how we can do that? So, maybe these are the some of the concerns of the reliability program.

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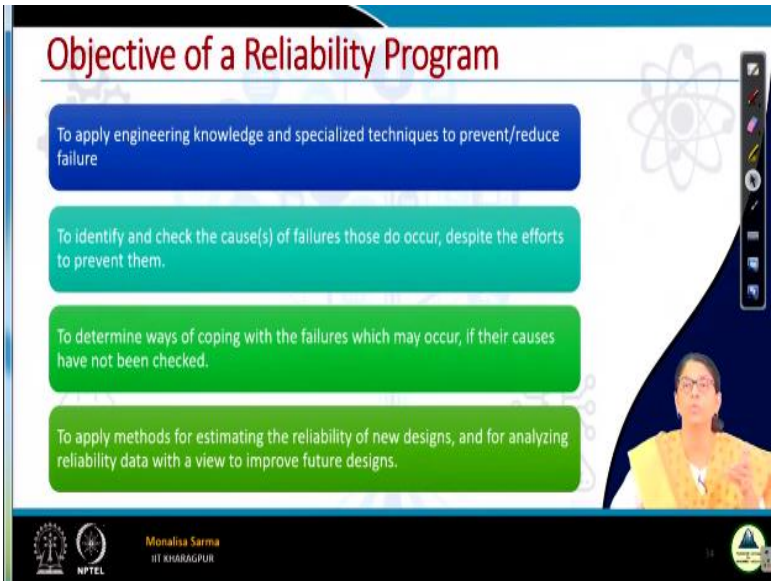

Now, we know what is reliability engineering? Why reliability is necessary? What are the different concerns of the reliability? With this now, we can basically stay down our objective of reliability program. So, what are the objectives of reliability program, there may be other objective as well as just noted down here to 4 objectives. So, first one maybe to apply engineering knowledge and specialized technique to prevent or reduce failure reduce failure needs, in all of the stages, in the initial state, the normal life and the wearout stage.

So, next to identify and check the causes of failures those 2 occur despite the effort to prevent them, how we can check the causes of the failure? We have taken steps to prevent them, but still those failures are happening, how we can check those failure? Then next to determine ways of coping with a failure which may occur if their causes have not been checked, some causes which goes, we just overlook it, then if such type of failure occurs, how we can cope with it?

This is also another objective or reliability program. Again, we can apply methods for estimating the reliability of a new design with our gain knowledge, how we can estimate the reliability of a new design? And then we can analyze the reliability data with a view to improve future designs, this may be the some of the objective of a reliability program.

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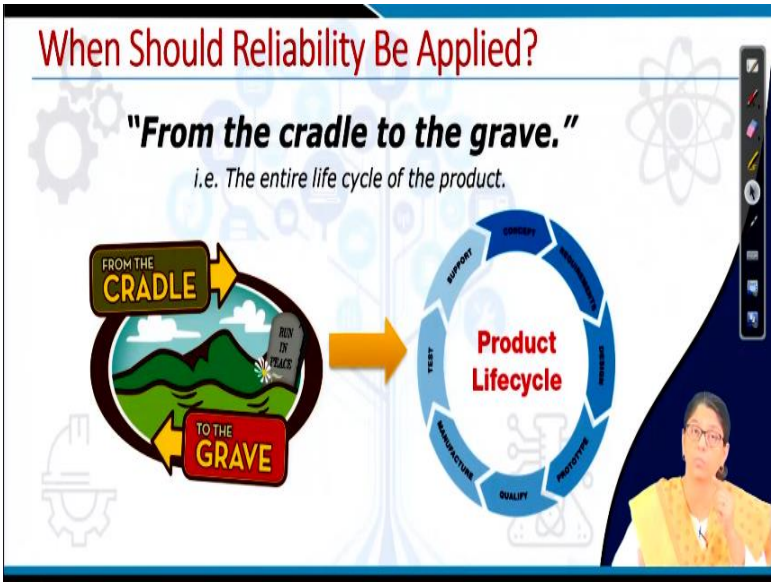

Now, when should be apply reliability? There is not a fixed timing when we should apply reliability in the whole lifetime of the product. It is basically the answer is if simple answer from the cradle to the grave. That means when I tell is from the cradle to the grave that means it is the entire lifecycle of the product. Lifecycle of the product starts from the concept when we are developing a new product, we are first we conceptualize the product, once we conceptualize the product, then we think of the different requirements of the product.

Then we design the product, we develop the prototype, qualify a prototype, then we manufacture and once we manufacture, after we manufacture we again test the product, then they are just sent to the market, and then our support. So, these are the different stages of the product, in the different stages the product goes product lifecycle, reliability should be incorporated in all these stage that is why it is called from the cradle to the grave.

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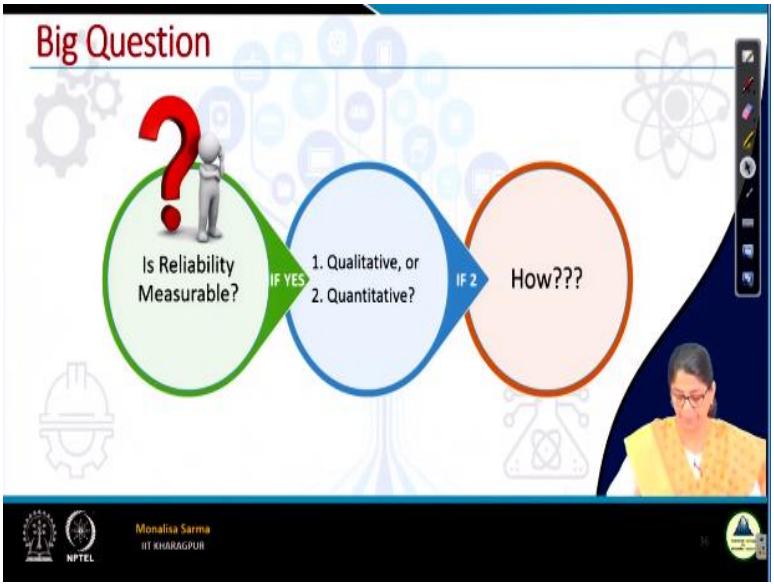

So, now the big question, is reliability measurable? If yes, then it is qualitative or quantitative? Already we have seen that reliability is measurable; already we have seen it is the capability is measurable. Therefore, I think around 6 or 7 slides we have talked about that. So, now, it is definitely it is quantitative, it is measurable, it is quantitative and how we will measure it, there are different ways how we can measure reliability. One of the ways of measuring reliability, one of the most used methods of measurability is by using statistical method which is basically the genesis of this course.

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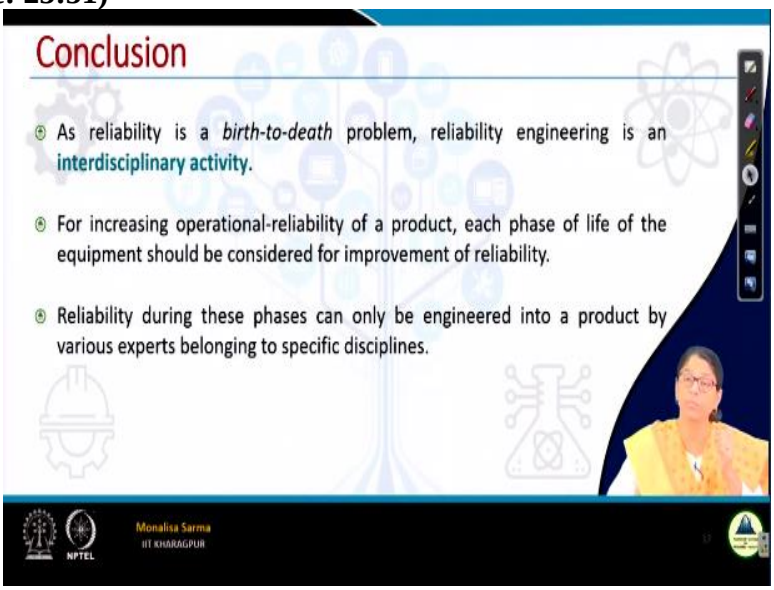

So, now, to conclude this lecture for I would like to bring in front of you this reliability when we talk with a birth to death problem, it is this reliability when starting from birth to death, it is very much an interdisciplinary activity, it is not that a simple when you are developing a mechanical

product is not a mechanical engineer is involved in so, many types of different people are involved in the development of a product. So, in the different phases, so, people from different disciplines are involved.

So, when we talk about reliability during this phase, it can be engineered into a product by various experts belonging to different disciplines.

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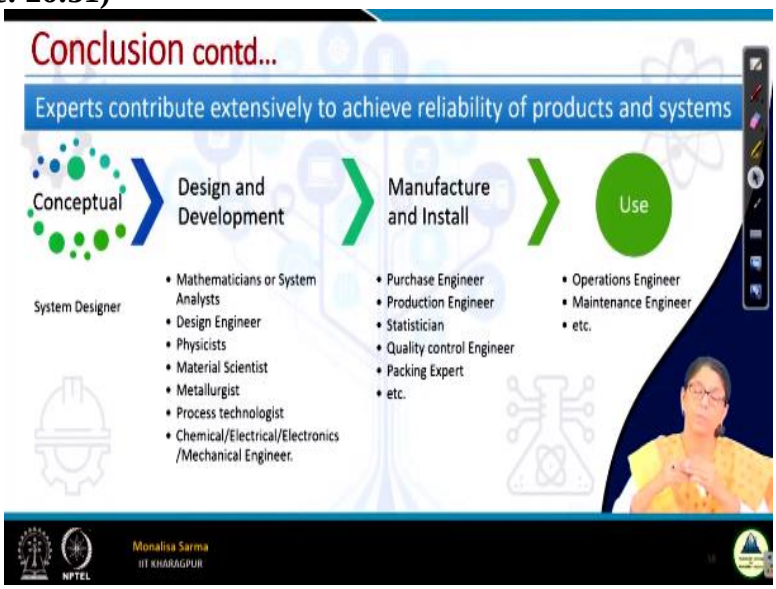

Like we can say and when we talks about the conceptualizing a product conceptualizing maybe a system designer, then the design and development and mathematician maybe there and the design engineer, physicist, physicists maybe there metrologists, process technologists, chemical engineer, electrical engineer, mechanical engineer, design and development, many different types of engineering disciplines from there.

And then again in manufacture and install them a purchase engineer, production engineer, then packing expert, then in use, use means during maintenance time for the support there can be operation engineer, maintenance engineer. So, we see different, it is a totally an interdisciplinary activity, people from different fields of disciplines are involved and incorporating reliability from the life to death process.

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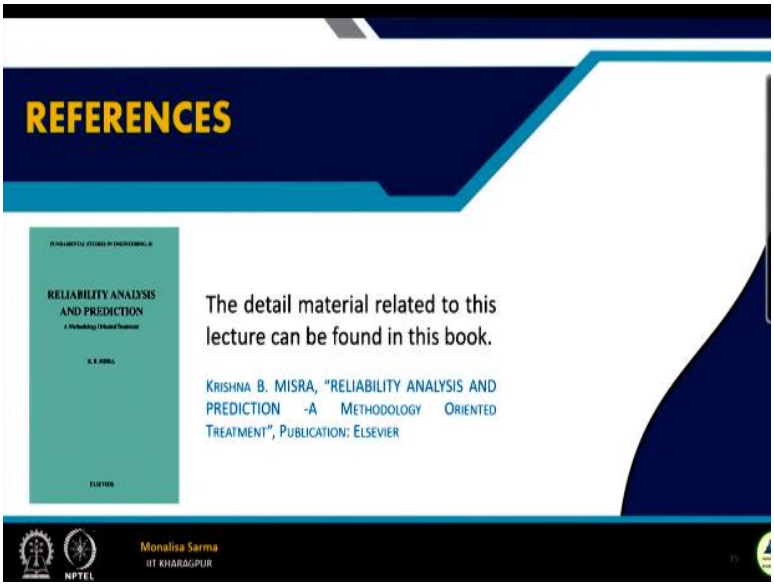

With this, I end this presentation this lecture and the detail material which I have covered in this lecture it will be found in this book, reliability analysis and prediction by Professor Krishna B Misra and thank you.