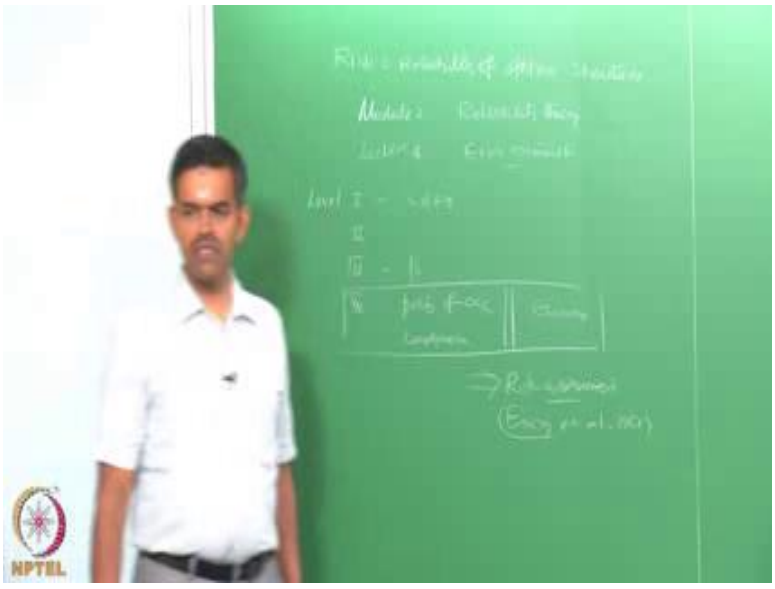
Risk and Reliability of Offshore Structures
Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 02
Reliability theory and Structural Reliability
Lecture - 04
Error Estimation

Welcome friends to the fourth lecture on module 2 on the course on risk and reliability of offshore structures.

(Refer Slide Time: 00:21)



We are talking about lectures on module 2, we have already completed module 1. Module 2 is focusing on reliability theory in general and structural reliability (Refer Time: 00:48) offshore structures in particular and now this is the lecture 4, where we are going to talk about error estimation. We already saw that reliability or done analysis are done in 4 levels; level one, which is a classical example of l r f d method load risk and factor design method and level 2 takes about one variable circumscribe the reliability study with respect to that variable, level 3 of course, does the analysis of the complete problem it involves integration of multidimensional joint probability density function, of the random variable is extended over the safety domain in this particular level reliability

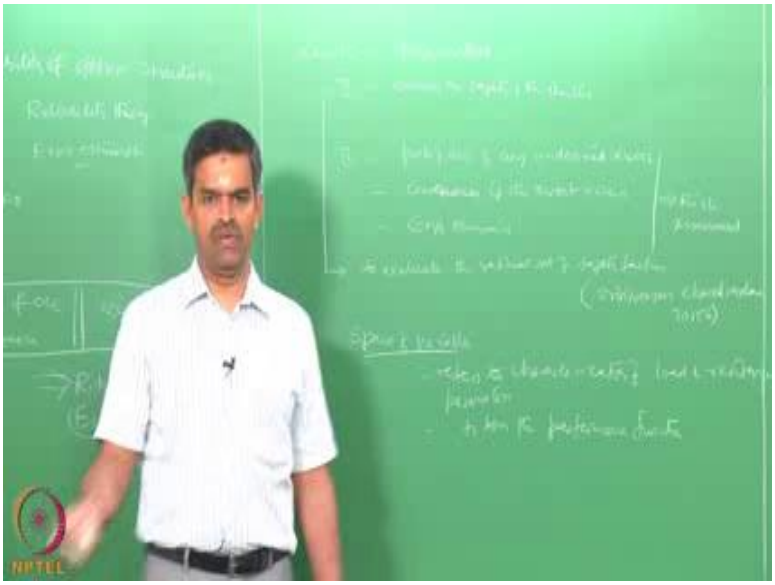
is expressed as in terms of reliability index, which also gives me the failure of probabilities.

Level 4 of course, includes the engineering economics into the whole analysis under the uncertainty, it considers cost and benefit of construction, it considers maintenance applicable for repair and other studies, and it of course, extends the study to understand details of consequences of failure. Now, level 4 talks about, the probability of occurrence of an event, which is undesirable, as well as the consequences and it also address interestingly the economic perceptive of this therefore, in level 4 actually the reliability analysis is converged towards risk assessment.

It is very interesting for us to realize and understand that we will be heading because in the later module we will talk about risk assessment alone on offshore structures there we will also talk about how risk assessment is bridged with reliability therefore, they want to give you an introduction to you here that, when reliability analysis or any analysis talking about probability of failure is focusing on the occurrence of that failure event, and parallely the consequences if the failure occurs with respect to the engineering economics in terms of economic perceptive then, we actually call the whole analysis or analogy as risk assessment.

So, reliability is converging ahead in an advanced risk assessment because it will also talk about the interest on capital etcetera as told by Essery, et al 1967; sensitive projects like offshore structures nuclear power projects transmission towers highway bridges all fall under this category of level 4. Now, interestingly although level one is still used in the structural design methodologies level two methods are useful in evaluating the safety of structure.

(Refer Slide Time: 03:55)



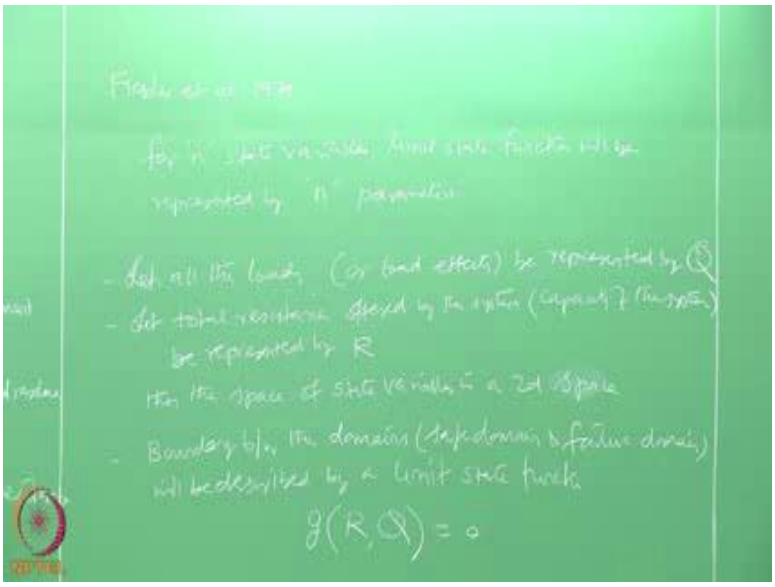
Once can quickly say level one is used as a design method level 2 is used for assessing the safety of the structure of course, level 4 is going to include the consequences and economics. So, probability of occurrence of any undesired event, in our case undesired event is a non-fulfillment of the functional requirement of the structure or its intended function on demand, we are not talking about the structural failure at all in this case, probability of occurrence have been undesired event, consequences if the event occurs; the moment we talk about consequences you must know whether it is going to talk about the human loss or it is going to talk about the asset management. So, it is very interesting that we include engineering economics into this. So, it is converging towards as we just now said the path of risk assessment.

Of course, level 2 is interestingly useful for this assessing the safety and structure now interestingly this can also be used as a tool to determine the rational set of safety factors that is very important. Now, level 2 can be also used to evaluate the rational set of safety factors, as we all know that the whole process is going to be under the circumstances of probability theory.

We now discuss about random variables let us say space of variables let us talk about this; space of variables actually refers to the characterization of the basic load and

distance parameters, which actually refers to characterization of load and resistance. There are only two events parameters, because these are the 2 events which are generally used to form the performance function, we already said in the last lecture what we mean by performance function? and how do you assess this function to say whether the function is failing or safe?

(Refer Slide Time: 07:05)



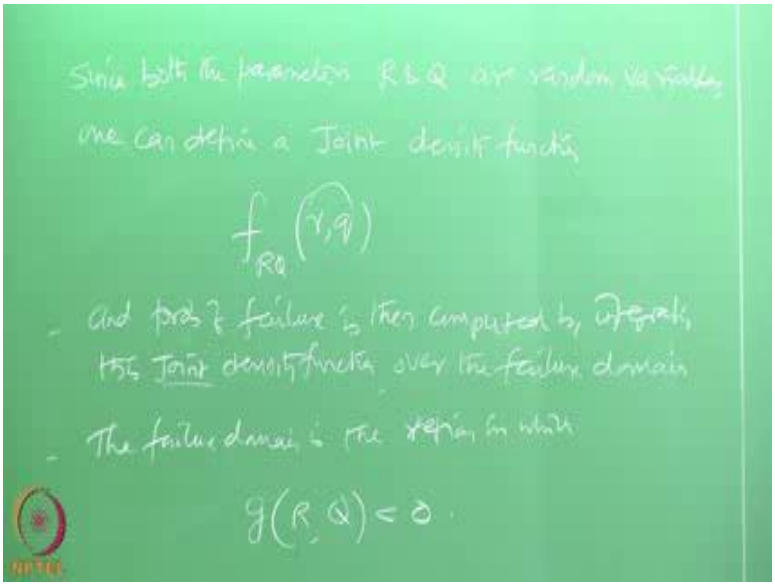
In simple terms, as said by Essery et 1979, for n state variables, limit state function will represented by, n parameters. If all the loads or load effects let us say, if all the loads are to be very specific the effects caused by the loads or load effects be represented by; let us say q (Refer Time: 08:11) let us say let all the loads or load effects we represented by q ,let the total resistance offered by the system, what we call capacity of the system be represented by r, then the space of straight variables is at two dimensional space, we will try to plot it, as I will draw the figure later; now the boundary between the domains what is the what are the two domains failure domain and safe domain.

So, the boundary between the domains that is safe domain and failure domain, there are only two domains here. Now, I may ask you a question why there are only two domains here? As far as reliability analysis of offshore structures are concerned it takes a binary value yes or no 1 or 0 is it going to fail or is it safe there is no third proportion except

these two I think this we have said in the last lecture.

Therefore, boundary between the domains may be safe domain and the failure domain only two domains here, will be described by a limit state function because this function as g of the function has got two space of variables one is the resistance offered by the system or the capacity of the system the total resistance offered by the system other is the total load or the load effects of the resistance system and we said that. Now, since both the parameters r and q are random variables.

(Refer Slide Time: 11:13)

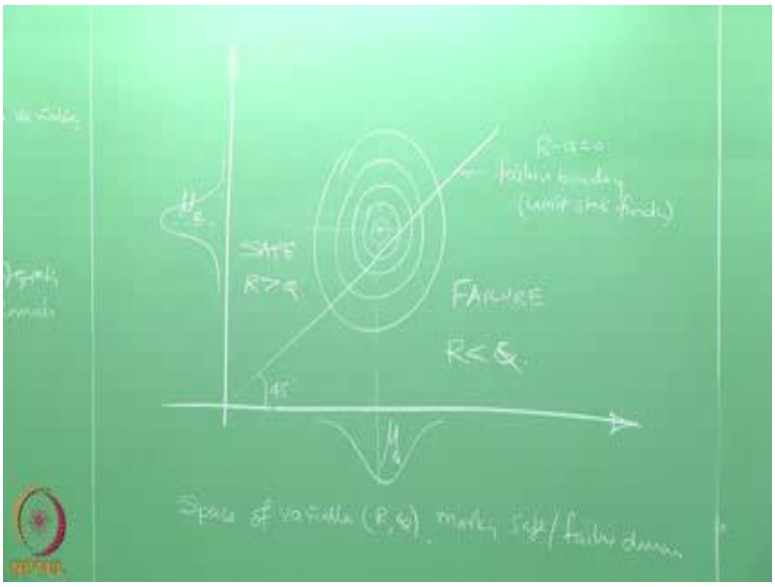


We already said what is a random variable in the first module what how do you qualify a variable to be a random variable, one can therefore, define what we call a joint density function which we can say as f r 2 the variables are r q because r can take any values form 0 to capital r similar q can take any value form 0 to capital q and probability of failure because we are interested in reliability about this is converse of this is then calculated by integrating the joint density function.

Why it is called joint intensity function? Because it joins two parameters which are independent exclusive and exhaustive it connects it bridges. So, joint density function over the failure domain. What is a failure domain? The failure domain is the region in

which my function is less than 0 takes a negative value. Let us mark or draw the space of variables marking a safe and failure domain for two variables r and q, r is the total resistance and q is the total flow I am marking the space of variables.

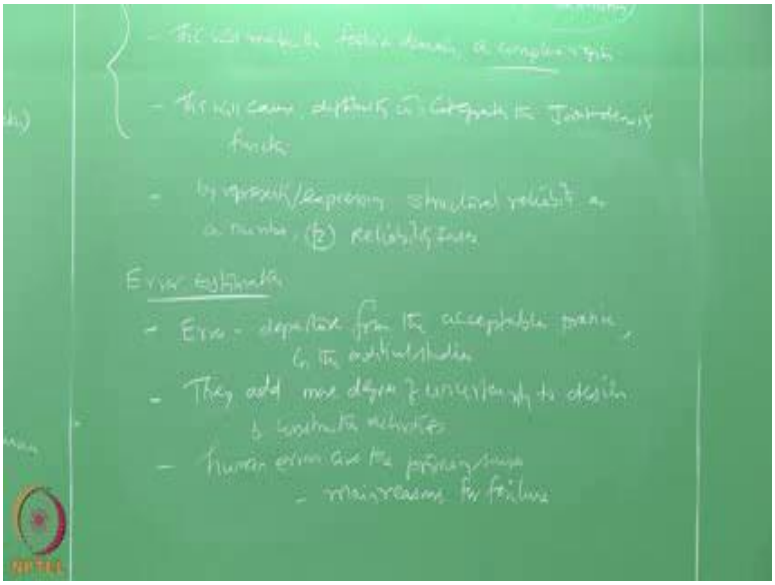
(Refer Slide Time: 13:51)



Basically, there are only two variables r and q, marking the safe and failure domain, that is what I am trying to do here. Let us say I plot, the distribution and find the mean which is call as nu of q similarly, I try to plot a distribution and find the mean and say u upon wherever they intersect the domain will start from there. Now, let us say it can have any values in this region.

Interestingly the failure domain is the failure boundary, which is the limit state function, which is r minus q is 0. So obviously, this is my failure region, because in this region r is less than q take any value q is greater than r it means the load is much more than the capacity and this is my safe domain because in this domain r is greater than q and that is the division. So, that is the space of variables marking the safe and failure domain for two space and variables r and q which represents respectively the capacity of the structure and the load effects on the structures, both are random variables. Now, due to the complex shape of the failure domain, that arises from the uncertainties of the variables.

(Refer Slide Time: 16:49)



Now, these two set of variables r and q, have lot of uncertainties from time a variety of uncertainties, we already saw them in detail. Now, one can ask me a question; what will be the consequence of the presence of uncertainty in estimating r and q this will make the failure domain complex. Now, one can further ask me a question if the failure domain is made complex, what is the difficulties there? This will cause difficulty in integrating the joint density function, that is the overall issue, that is a mathematical crux in the whole problem; you will not be able to easily evaluate the integration of the joint density function over the failure domain because that is a requirement I must be able to integrate the joint density function over the failure domain.

The failure domain will become complex. Why it becomes complex; because the variables first of all they are random no problem, but they are lot of uncertainties. Now, the question is how this issue will be solved? Therefore, this issue is solved by representing or expressing structural reliability as a number, which we call reliability index that is how it is compromised.

Now; obviously, if you are going to estimate the reliability, which is the qualitative issue because uncertainties cannot be defined with high degrees of precision quantitatively. So, it becomes more or less a qualitative issue; whereas, when we move from reliability to

risk assessment it becomes a quantification issue. So, as on that level let us say reliability is more or less a relative comparable qualitative assessment.

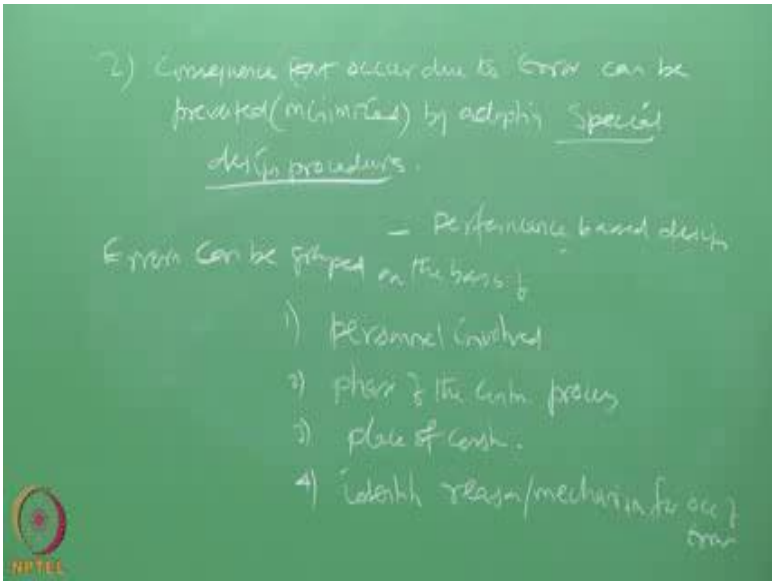
When you are trying to compare two variables qualitatively, which are random in nature are arised from a random process and they have lot of uncertainties inherently present which cannot be ascertained accurately this will result in an error. Now, let us talk about error estimation; error actually is a departure from the acceptable practice with that of the results obtained from analytical studies just an error risk. Error is nothing, but a departure from the acceptable practice, which is present in the analytical studies.

What do they do actually; I mean what would be the consequence difficulty because of presence of error? They add more degree of uncertainty to the design and construction presence of error adds more degree of uncertainty to design and construction activities. So, it is good that we must minimize this error. Now, let us see can we mathematically minimize them, the basic reason of difficulty arising from this level is these errors what we are talking about which are departure from the acceptable practice are essentially human errors or the primary source which are found to be one of the main reasons for failure. We have seen popular case studies also one of the main reasons for failure has been seen from the human error. So, therefore, if structural reliability should be focused towards error control, it should deal with minimization of human errors now errors are generally categorized according to the causes and consequences.

(Refer Slide Time: 22:59)

There are two approaches to control errors, we have already said in reliability analysis. We already have uncertainties in r and q, which are inherently present, we cannot eliminate it. We do not want to add further uncertainty, which generally arise from error, which is essentially or majority coming from human error. So, therefore, reliability should focus towards controlling these errors. Now, there are two approaches by which you can control the error; one the reduced error frequency, alternatively, you can minimize the consequences, which arise due to these errors. Now, let us classify the errors we already said errors are classified based on the cause and consequences.

(Refer Slide Time: 25:13)



Errors can be classified or categorized on the basis of causes and consequences which may be useful in selection of efficient control measures. Analysis of causes, are actually useful in identifying the occurrence mechanisms therefore, one can plan to reduce the frequency further, which is actually the first way to control the error. Consequences of the error can be prevented or I should say minimize, you can prevent it because it will be always existing by adopting special design proceeds.

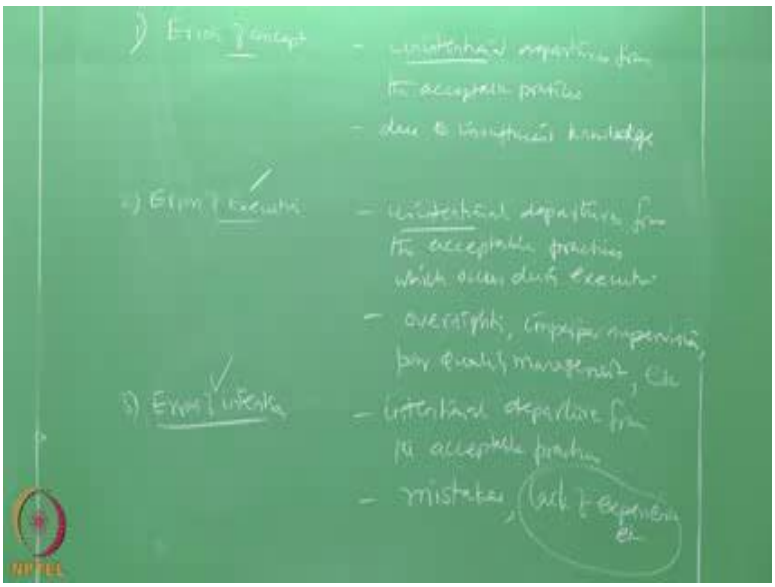
We can name one very quickly one could be performance based design, can be one design approach which first highlights or emphasis or prestates what is the performance level required is it immediate occupancy like safety prevention etcetera; what is that level required and to that level what should be the material characteristic required to be used in the construction? What should be the preferable structural form? What should be the order of determining in deterministic in the given system etcetera?

So, one can always first prefix the performance desired by the or fixed by the designer then based on that one can always try to reduce or minimize the consequences, from the errors which are inevitably present, because these errors cannot be eliminated please understand because they are originated from the uncertainties present in the variables r and q and these uncertainties which are present in the variables resistance and load are

inherintanly and implicitly present they cannot be eliminated at all; what they can do is, they can exit control the error by minimizing the consequences or they can control it by reducing the frequency of occurrence of these errors in the density therefore, errors can be considered with regard to the person involved.

There can be many phases by which you can categorize and let us say highlight or separate a group the errors. So, the errors can be grouped based on or on the basis of; one the personnel involved, two phase of the construction process, three place of construction, four identifying the reason and the mechanism for occurrence of error based on that also you can group it. So, there are actually three fundamental types of errors.

(Refer Slide Time: 30:25)



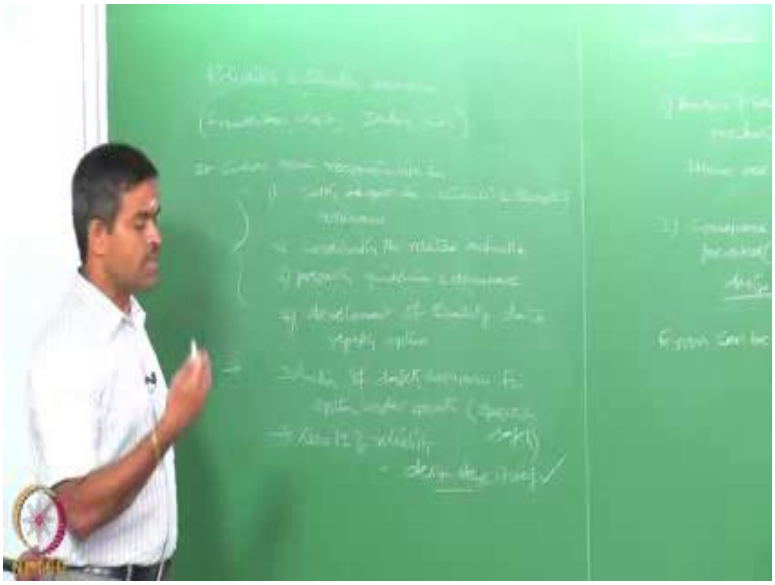
One can be errors of concept; they are unintentional departures from the acceptability practices. Why do they occur? They occur due to insufficient knowledge. The second error could be; errors of execution; they are unintentional departures again from the acceptable practices, which occur during execution just because execution errors. This may be due to over sighting, improper supervision, poor, quality management, etc. There may be many factors. The third could be; errors of intention, their intentional departure from the acceptable practice; Why do they occur? They occur because of mistakes.

In fact, I should also say lack of experience etcetera. So, we are talking about error control which can achieve or which can able us to achieve the desired level of reliability or in or the other hand to be very specific and simple they required level of safety because reliability is actually converse of probability of failure and safety is also more or less talking about reliability, there is a very good difference between safety and reliability which we discussed I think you will be able to recollect them. So, to ensure reliability or level of reliability desired by the reliability engineer or the user, one should be able to control the errors, either we can minimize the consequences or you can minimize the frequency of occurrence of these errors.

These errors can be a free order two of them are unintentional by mistake they happen, you can try to avoid them by imparting proper sufficient training, sufficient knowledge, capacity building etcetera whereas, the one which is intentional should be avoided completely by using or employing experienced personnel at all stages of construction of the structures; starting from planning, guidelines, layout, feed level, material selection, detailing or at all stages including commissioning and exploring oil till that level at all stages people should have dedicated set of experienced professional, who already have thorough level of understanding of the whole scheme and process, and all facets of the offshore structure project.

Not only a construction engineer does not know about the design, engineer does not know about the material choice nothing, like that he should know he should be thorough and through with all facets of this project, then only one can minimize the consequences or avoid the occurrence of frequency. These errors in the whole system which ensures the desired level of reliability or desired level of safety in the given project, we already said in the last lectures, that the reliability is also closely associated with what we call quality assurance. Let us revisit back the same statement in a more elaborate manner.

(Refer Slide Time: 35:52)



Interestingly, the solution of reliability problems can be applied at different operational levels. So, there are various responsibilities which are fulfilled through reliability as a tool and quality assurance. Let us see what are they; it involves various responsibilities like setting targets for reliability and quality assurance. Two, coordinating related activities. Three, preparing guidelines and documents for that; four, development and operation of quality data reporting system that is very important, development of quality data reporting system. If these are all done, it can lead to solutions of safety assurance for systems under operation, what we call operable safety or operational safety as discussed by (Refer Time: 38:39) 1947 and Dowling, 1972.

Usually, major part of the performance assurance is done at the first stage of design itself therefore, this is generally assured in level one of reliability itself; why? Because most of these questions will be answered in the design stage itself; however, even the design stage there are different levels of uncertainties, which are inherently present in the design, how to handle them; because uncertainties will improve or increase complexity in the whole process if you are not able to address in the design stage itself they will propagate further and they will cause a permanent damage which can be seen as a consequence of those errors, which arise essentially from the uncertainties present in the design stage itself.

In the next lecture we will talk about what are those uncertainties which are inherently present in the design? How they can be handled or how are they handled suggested by various researchers and what are those different tools or methods or theories by which this can be focused. So, that the whole goal is to minimize error, which essentially arise in an intentionally or unintentionally, from the uncertainties which are present in the variables which are r and q where r the resistance of the system and q refers to the load effects or the load acting on the system.

Thank you very much.