Principles of Engineering System Design

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Lecture - 19
Qualification Planning and Methods

Dear friends, very good day to all of you and welcome back to another session on engineering system design. In the last lecture, we discussed about the integration and qualification methods, the last stage in the design of engineering system where we look at the integration issues as well as the qualification of the system basically we discussed about the various methods of integration that is the bottom up approach or top down approach or the big bang approach normally used by software industries and then we looked at the procedures for component level integration as well as the subsystem level integration what we do in when there is a fault in one of the system. So, what should be the procedure how do we actually look at the impact of these faults and then redesign or change the specification of the system to meet the present status of those components or subsystems.

So, that was about the integration of engineering systems, today we will look at the qualification aspects we briefly explained about qualification what do you mean by qualification and what are the various stages in the qualification like verification validation and acceptance and we discussed about those top level cycle and the bottom level cycle or the higher and lower level cycles of qualification. Today, we will go into the details of this qualification procedure what kind of procedure to be adopted and what are the different kinds of acceptance tests and how do we actually ensure that the customer accepts the system and what are the process by which we can do the testing in order to make sure that the system performs as per the requirements of the customer.

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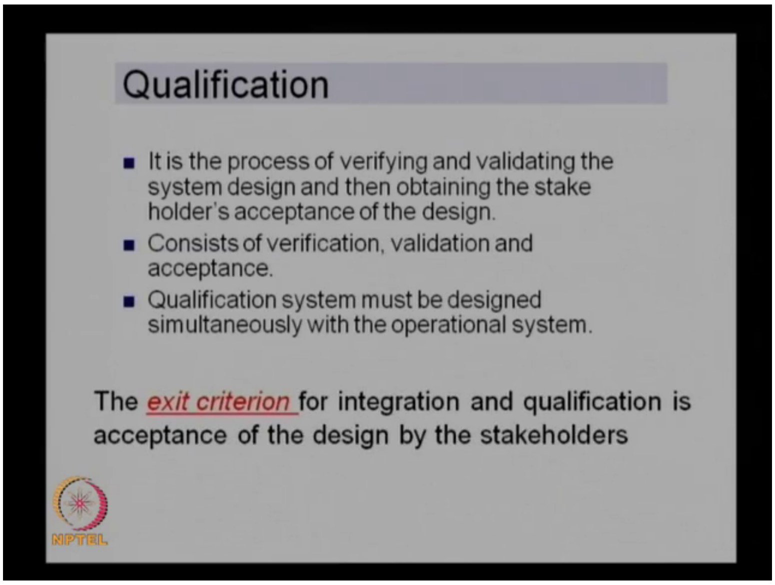

Qualification

- It is the process of verifying and validating the system design and then obtaining the stake holder's acceptance of the design.
- Consists of verification, validation and acceptance.
- Qualification system must be designed simultaneously with the operational system.

The *exit criterion* for integration and qualification is acceptance of the design by the stakeholders

So, first of all let us recap the qualification procedure and what is qualification. So, as we discussed, it is the process of verifying and validating the system design and then obtaining the stakeholders acceptance of the design. So, basically we need to verify and validate the design and to ensure that it actually meets the requirements of the customer and it involves the verification validation and acceptance.

So, as we discussed in the previous class verification is basically to verify the developed system with respect to the specifications we identified at the design stage validation is ensuring that it meets the requirements of the customer in terms of the concepts and validity or the design validity and then acceptance is basically we give the system the complete system to the user and the user conducts acceptance test and then accept the system.

So, these are the 3 stages through which the qualification process goes through and then we need to design the qualification system as we design the engineering system. So, co qualification system need cannot be designed at the end of the process though we discussed as the last step the system need to be designed at the basic level, I mean when we start the design of engineering system the qualification system also need to be parallely developed that is when we design a subsystem, we need to look at what is the requirement for that such system and then how do we test that system and how do we validate that system and then how do we do an acceptance test for that particular system.

So, we need to develop the procedure, we need to identify the resources, we need to identify the schedules.

Then along with the design of the system and then this need to be used when we do the validation or verification or acceptance. So, the design of the qualification system need to be done at the beginning of the design or as we designed the system the qualification system also need to be designed along with that and the exit criterion for integration and qualification is acceptance of the designed by the stakeholders. So, that is the exit criterion. So, we can say that the system design is complete or we can actually come out of that particular design process only when the stakeholder accepts the system.

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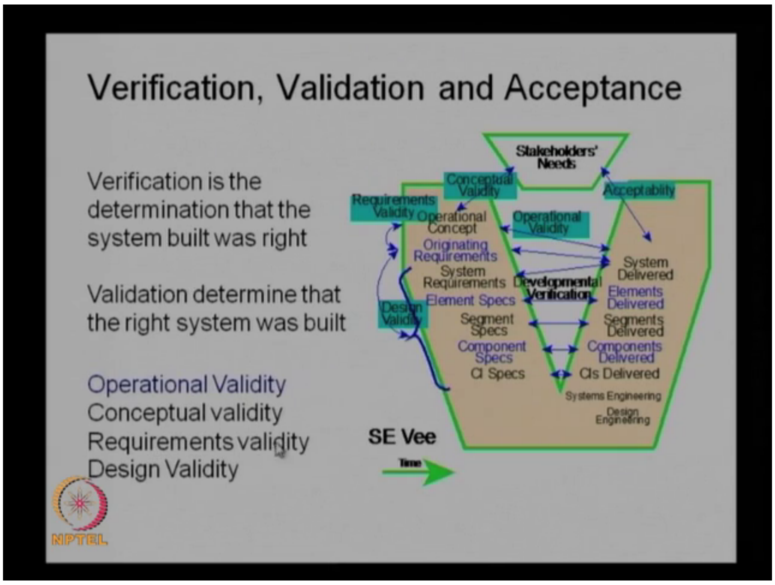

Verification, Validation and Acceptance

Verification is the determination that the system built was right

Validation determine that the right system was built

Operational Validity
Conceptual validity
Requirements validity
Design Validity

And this one will discussed actually and again in the last class that these are the various validation procedures and this is the verification and this is the acceptance test.

So, we do the acceptance test at this stage when the integration is complete and we do the validation test at this stage and parallely we develop the qualification systems in this at this stage itself we develop the qualification system and then verification is basically verifying the elements against the specifications designed and the operation validity conceptual validity and requirements validity and design validity all these need to be validated as we go ahead with the qualification process.

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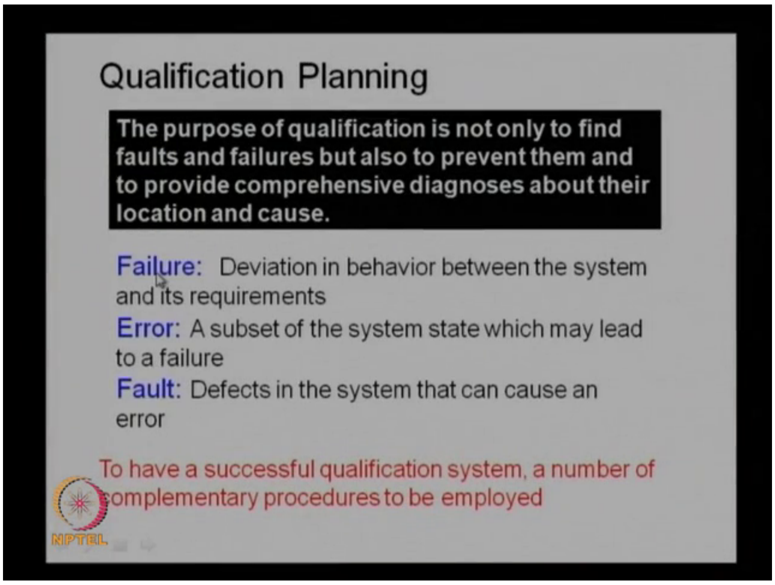

Qualification Planning

The purpose of qualification is not only to find faults and failures but also to prevent them and to provide comprehensive diagnoses about their location and cause.

Failure: Deviation in behavior between the system and its requirements
Error: A subset of the system state which may lead to a failure
Fault: Defects in the system that can cause an error

To have a successful qualification system, a number of complementary procedures to be employed

So, before going to the qualification process we will define few terms which will be interest to the qualification engineers or those who do the qualification test. So, the purpose of qualification is not only to find faults and failures, but also to prevent them and to provide comprehensive diagnosis about their location and cause.

So, it is not only that we just identify the faults and failures we need to ensure that we identify the source of these failures as well as we provide some kind of inputs to the designers to ensure that such faults one occur in the design. So, as we do the testing we ensure that we can identify the faults and failures and we can identify the location of the failures as well we can actually suggest methods to prevent these failures also. So, if you identify the location we can actually see from whether the what is the source of that error and then once we know the source of the error we can do a redesign of the system. So, that the such failures can be eliminated, the qualification engineers or those who are doing the verification or validation. So, they have the responsibility to identify the sources as well as to help the designers.

To prevent such faults, we just recap the term normally we use when we discussed about the failures that is the faults in the system. So, failure is basically a deviation in behaviour between the system and its requirement. So, we have some behaviour requirements in the system and when the system is not providing that behaviour then we call that is a failure error is a subset of the system state which may lead to a failure. So, the a system state whether it is the temperature the pressure or its processing time or the processing capability any of these parameters which is a subset of the system state. So, this may actually cause to a failure. So, that is an error and fault is the defects in the system that can cause an error.

So, it is a basically a fault in the system causes an error and this error leads a failure of the system. So, to have a successful qualification system a number of complementary procedures to be employed; so, if you use 1 or 2 methods that alone will not that help you to identify all the faults. So, one procedure may identify the are faults in the operational scenarios one another method may identify the faults in the internal systems or the interfaces. So, there is no single test which can actually identify all the faults in the system and therefore, we need to identify different procedures or different testing procedures or verification procedures which are complimentary. So, that most of the faults can be identified. So, that is the requirement here we need to have many tests; so, many procedures which are complementary to each other which can identify most of the faults in the system which can actually prevent the failures of the system.

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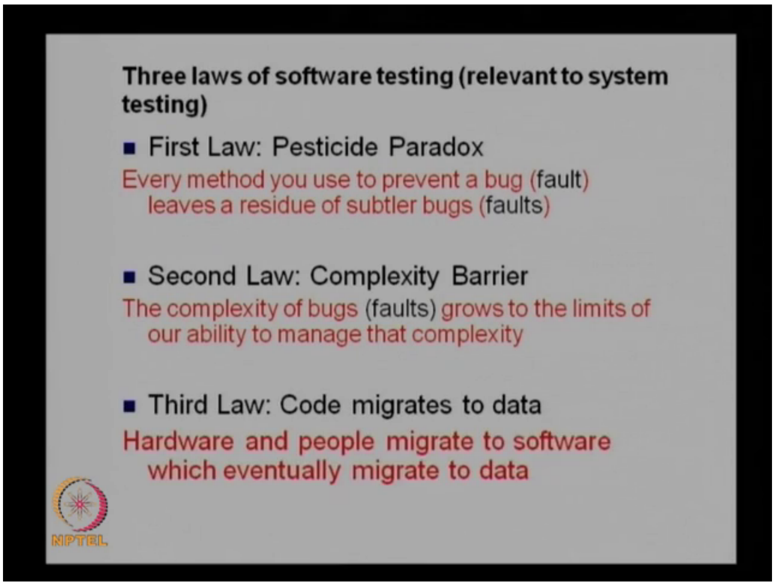

Three laws of software testing (relevant to system testing)

- First Law: Pesticide Paradox

  Every method you use to prevent a bug (fault) leaves a residue of subtler bugs (faults)

- Second Law: Complexity Barrier

  The complexity of bugs (faults) grows to the limits of our ability to manage that complexity

- Third Law: Code migrates to data

  Hardware and people migrate to software which eventually migrate to data

So, in order to do this there are many methods employed by various system engineers and various system development methods, but it is the software community which actually put the more comprehensive procedures and rules for testing of engineering systems software systems, but some of these rules can actually be implemented or can be adopted for the engineering systems also basically there are 3 laws in software testing or software qualification procedures.

If this can actually be used in the engineering system analysis also because the many of the procedures are common to the software engineering as well as the system engineering the first law is known as the pesticide paradox which actually states that every method you use to prevent a bug fault in the case of engineering system. So, every method you use to prevent their fault leaves a residue of subtler faults; that means, whenever you use a particular method to prevent a fault that actually brings in another fault in the system which cannot be identified using the present method. So, whenever you introduce a new method to prevent a fault the faults associated with that new method cannot be identified at that stage. So, this is known as the pesticide paradox. So, you cannot actually ensure that by simply.

By removing one bug you are actually eliminating a all the bugs because this the fault may come because of the new method also that is the first law of the first door software testing which is known as the pesticide paradox the second law is known as the complexity barrier; this actually states that the complexity of bugs or the faults grows to the limits of the our ability to manage that complexity. So, as we are more and more capable of solving a complexity then the complexity of the fault also will keep on increasing. So, that is known as the complexity barrier the third law is that the code migrates to data these actually states that the hardware and people migrate to software which eventually migrate to data.

So, initially if something is done by the hardware or something by the human; this actually will slowly com migrate to the software. So, we will try to replace it with software and then the software will replace it with the actual data. So, that is the code migrates to data. So, whenever it will be planned for the engineering system qualification or testing we need to ensure that these are the facts which actually limits our capability to do the testing. So, whenever we try to employ a new method of avoiding fault that actually can bring another fault which cannot be identified by that method. So, we need to be careful while introducing a method to remove your fault. So, we should look at the importance of that fault it is a frequency of the fault.

Then we decide whether to introduce a another method to prevent that fault because this new method can bring another fault which cannot be identified by that particular method similarly the complexity of the fault also will keep on increasing as we are more capable of solving the problem the complexity also keep on increasing and then there is a migration of hardware software extra to data. So, our algorithms or the methods should be capable of taking this into account when we do the testing of the engineering systems, then again when we do the verification of the system. So, as we know verification is one of the easiest stages in the qualification. So, we have verification validation and acceptance. So, verification is one of the easiest method or easiest part of the qualification procedure. So, here again there are a few barriers.

Because verification is basically we look at the specification of the design and then see whether the actual system or the actual component meets that specification when the problem here is that we can never be sure that the specifications are correct. So, the specification can be wrong. So, the specification whatever we made the specification need not be always correct, but we always we have to go assuming that the verifications are correct and do the specific testing verification test, but they not be correct always.

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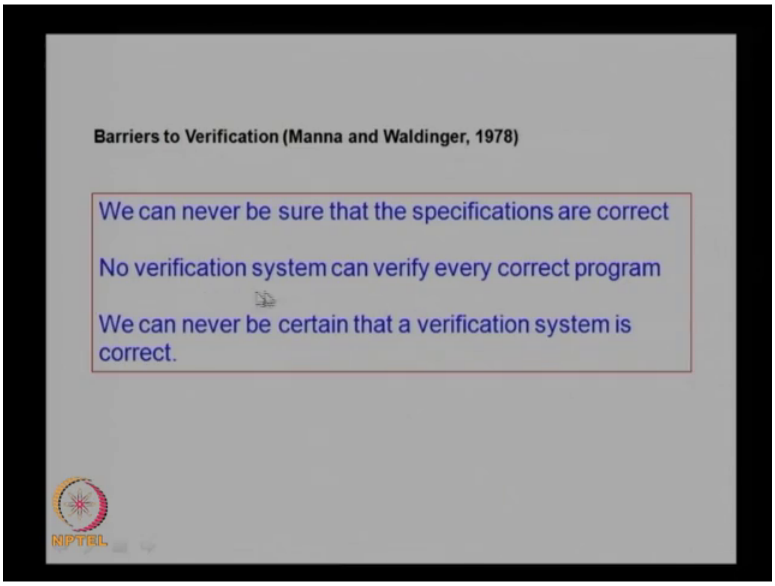

Barriers to Verification (Manna and Waldinger, 1978)

We can never be sure that the specifications are correct

No verification system can verify every correct program

We can never be certain that a verification system is correct.

And now verification system can verify every correct program. So, there is no verification system which can verify every correct program.

You need to have different procedures or different methods to do the verification of a complete program or one method may not ensure that it is completely correct and then we can never be certain that a verification system is correct. So, again there is no guarantee that the verification system is always correct. So, these are the barriers in verification that is never we do a verification we actually have some assumptions and have some limitations. So, within that limitation only we are doing the verification. So, this shows that the confidence level of the verification engineer depending on to what extent we can assure that specifications are correct to the action possible and the system the most of the there are different complementary methods he uses to ensure that all the aspects of the system is tested or verified.

And similarly, whether the verification system how good is the verification system is. So, based on this confidence level only we can say that the verification is complete or the verification is up to the expectations of the design engineers. So, that is the barriers in verification, but then before we discuss about the methods.

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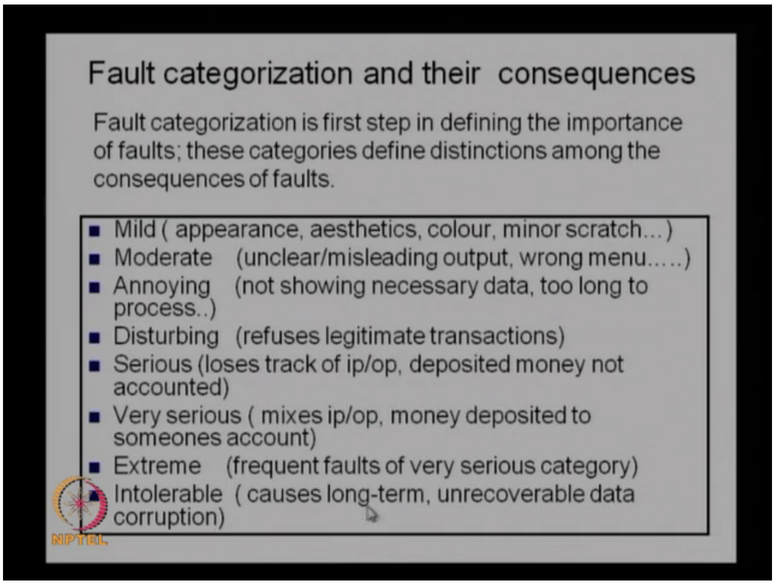

Fault categorization and their consequences

Fault categorization is first step in defining the importance of faults; these categories define distinctions among the consequences of faults.

- Mild (appearance, aesthetics, colour, minor scratch…)
- Moderate (unclear/misleading output, wrong menu…..)
- Annoying (not showing necessary data, too long to process..)
- Disturbing (refuses legitimate transactions)
- Serious (loses track of ip/op, deposited money not accounted)
- Very serious (mixes ip/op, money deposited to someones account)
- Extreme (frequent faults of very serious category)
- Intolerable (causes long-term, unrecoverable data corruption)

We need to define a few terms about the fault categorization also. So, there are different kinds of faults happening in the system. So, some of the faults are very sever some of them are not very sever, but some of them needs attention some of them can be left as such because it may not cause any other problem in the system. So, the fault categorization is the first step in defining the importance of faults. So, if you have if you want to categorize the fault on the in terms of the importance.

So, how important that particular fault is we need to categorize them into various categories and these categories defined distinctions among the consequences of faults. So, the categories can actually give the distinction about the consequences of these faults. So, some of the categorization or the taxonomy of the faults here; so, a mild fault is something which can actually be discarded which actually say that we do not really need to look at that particular fault because it is a very mild one like colour is not proper or there is not uniform surface finish or there is a minor scratch on the system. So, these are known as the minor fault which can actually be discarded because they are create any further problem in the system, but then we have a moderate faults which are unclear or misleading output or a wrong menu.

So, once you give a input it is giving a different output which is not related to the input we are giving or the menus are not properly given. So, one menu is not leading to another one or the; whatever recurred functions are not providing in the menu. So, these are known as moderate faults, this is actually may be a problem, but again you do not need to invest too much on this kind of moderate errors moderate faults there are annoying kind of faults which actually give annoy the users basically, he is looking for something some data and he is getting some other data or it is taking too long to process or that menu is not properly a coming or which is not visible properly. So, these are annoying kind of faults which need to be avoided because the users may not like to have that kind of faults.

But again these are not going to create any major problem in the system performance because the system may be performing, but it may not be performing as the convenience of the user or the user may not like to have that kind of faults because that actually annoys him and he is using the system. So, again this; this need to be eliminated as much as possible the next one is known as the disturbing kind of faults. So, this actually we will refuse legitimate transaction. So, if you have a legitimate transaction you have a proper authority to enter to that system and then carry out some transaction then system is not allowing you it is giving some errors. So, this is a kind of a disturbing fault which again is not acceptable.

Next level is serious faults this is actually loses the track of input output. So, it actually does not know what actually transacted in the system. So, what kind of inputs was given and what output was given and that is something like in an ATM, you deposited some money it is not accounted into your account or it does not know where the money has gone. So, that kind of a situation is a serious fault in the system then again the next level is a very serious transaction a very serious fault which actually says that there can be mixing up of inputs and outputs. So, a person deposits money into one account and that the money goes to some other account and the money is withdrawn from his account because of someone else withdraw the money. So, this kind of mismatches of input output and this is a very serious fault.

Which need to be addressed at any cost then again there are extreme faults where actually this very serious faults are happening frequently that is that kind of situation is an extreme condition whether frequent faults of very serious category. So, very serious category faults are happening very frequently, then it is an extreme fault situation, then there are intolerable faults which actually causes long term unrecoverable data corruption. So, this actually intolerable because that actually you can you can cause the whole system on or a period of time the whole data may be corrupted or they lose the track of what actually happened. So, that kind of long term errors should not be there and this intolerable kind of faults.

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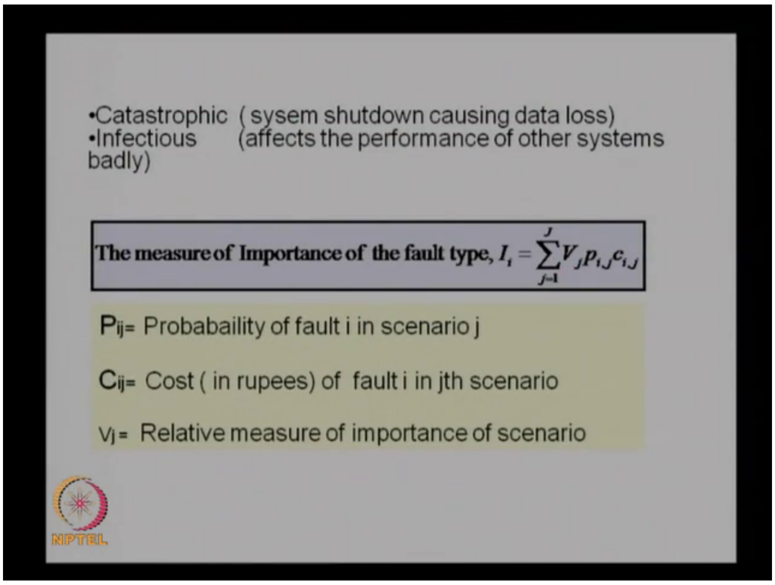

•Catastrophic (sysem shutdown causing data loss)
•Infectious (affects the performance of other systems badly)

The measure of Importance of the fault type, $I_i = \sum_{j=1}^{J} V_j p_{i,j} c_{i,j}$

Pij= Probabaility of fault i in scenario j

Cij= Cost (in rupees) of fault i in jth scenario

Vj = Relative measure of importance of scenario

And again considering the seriousness of the issue there are catastrophic; catastrophic faults which actually the system shutdown causing data loss.

So, it actually causes a data loss to the complete system because it goes to shut down the whole system and then lot of data is lost without any trace of what happened. So, that kind of situation is the; a catastrophic fault and the last one is the infectious fault infectious fault is that it is not only the that system all the system is associated with that system is also getting corrupted. So, this is a very serious situation its known as infectious faults. So, based on the security of these faults we can actually classify them under various categories they starting from mild to catastrophic and infectious situations. So, it is the duty of the qualification engineers to identify these faults and categorize them what kind of a fault it is whether it is a very mild one or it is a an infectious one.

So, accordingly they need to look at the importance of these faults and then identify the required actions to be taken though need to look at the source of these errors and then find out the or suggest to the design engineers the procedures or how to actually a eliminate them. So, if you can develop the methods and procedures to identify all these kinds of faults from mild to the infectious depending on the severity of the fault and then try to eliminate them that is the job of the qualification engineers basically they will qualification engineers will develop the procedures to identify all these faults and categorize them and then report them to the design engineers. So, that the design engineers can actually look at the system and then go for a redesign of the system.

Again for looking at the importance of the faults we can actually find out the measure of importance depending on the frequency of the fault happening as well as the severity of the situation or the environment at which these particular faults are happening. So, a method of a quantity measure of the importance of the fault type is given here, where I is the importance of the fault type and for the I th fault in j th scenario. So, Pij the probability of the fault I to happen in a scenario j and Cij is the cost of fault in fault I in j th scenario in terms of rupees. So, if you can actually convert that cost of that particular fault if it is a mild for the cost will be less, but if it is a very sever fault then the cost will be very high. So, if we can actually convert that into rupees then we can say the Cij is the cost of fault i in j th scenario and Vj is the relative measure of importance of that scenario.

So, if you have multiple scenarios in which the fault is happening. So, we can actually give the relative measure of importance of scenario at some scenarios may be very important some may not be important. So, Vj gives the relative value of this importance. So, the actually importance of the fault type can be obtained as sigma j is equal to 1 to j Vj Pi j Cij. So, Pij is the probability Cij is the cost and Vj is the relative measure. So, if you have one particular fault happening then various scenarios and if you know the cost of that particular fault as well as the probability of the that fault as well as the measure of the importance of that scenario we can find out what is the importance of that fault type and this along with the tax for taxonomy discussed earlier will be able to categorize these fault in terms of whether it is very severe and then we need to look at procedures to eliminate them or we can actually just leave it like that because it is not causing to cause any problem.

So, this is the way how the faults are categorized and then how do we do the analysis of the faults based on the probability of fault as well as the cost of fault and the importance of the scenarios now let us look at the methods and procedures to do the qualification planning.

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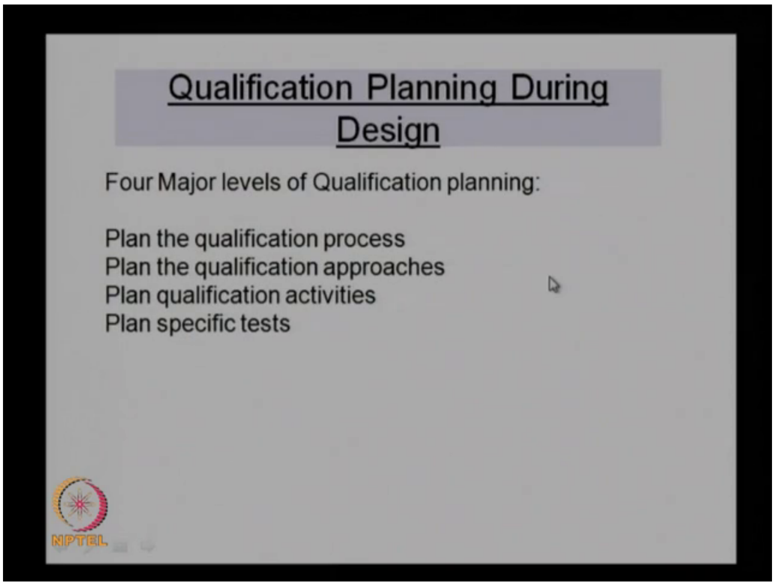

Qualification Planning During Design

Four Major levels of Qualification planning:

Plan the qualification process
Plan the qualification approaches
Plan qualification activities
Plan specific tests

So, as I mentioned the qualification strategy need to be planned during the design stage itself. So, there are 4 major levels of qualification planning one is the qualification process you plan the qualification process plan the qualification approaches and you plan the qualification activities and then plan specific test.

So, these are the 4 activities to be carried out in the qualification planning as you know the first one is the qualification process this is the first level of design of the qualification planning where.

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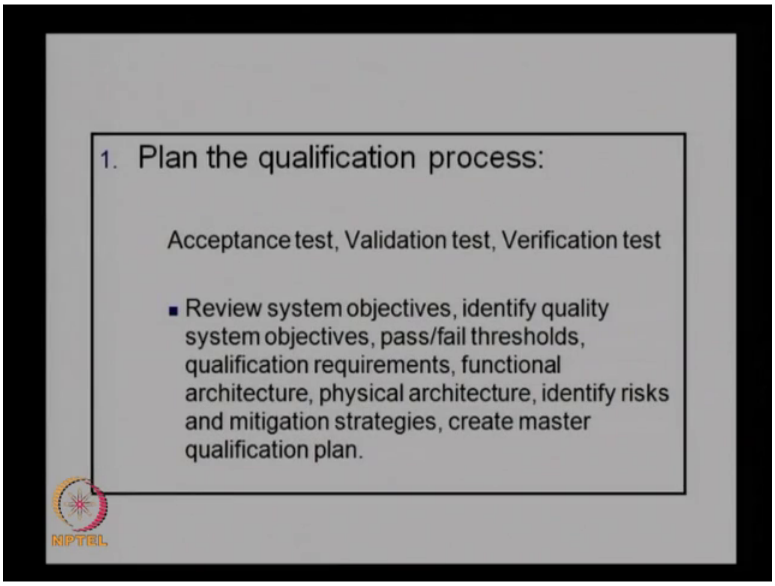

1. Plan the qualification process:

Acceptance test, Validation test, Verification test

- Review system objectives, identify quality system objectives, pass/fail thresholds, qualification requirements, functional architecture, physical architecture, identify risks and mitigation strategies, create master qualification plan.

We look at the various aspects of the qualification basically we need to do the acceptance test validation testing and verification test and all these 4 stages we look at the these 3 tests to be carried out in the qualification and we plan for these 3 tests in all the 4 stages what we discussed. So, this is the planning the qualification process in planning the qualification process, we look at the system objectives we identify what are the requirement identified in the system objectives that is one of the earlier lectures we discussed how do we identify the system objectives and then use these objectives to define the system requirements as well we look at the hierarchy of the objectives.

So, in the qualification planning also we need to start with the system objectives. So, what actually the system supposed to achieve and based on that only we will look at the objectives to be a needed and then these objectives become again a base line for the qualification process also. So, we look at the system objectives and then we identify the qualification system objective system objectives more like a performance objective. So, based on the performance objective we look at the qualification system objective.

So, they will be directly related because the qualification system should actually ensure that the performance objectives are met and therefore the qualification objectives need to be developed from the system objectives, then we need to look at the pass fail threshold for each test because we need to conduct many tests like acceptance test validation test and verification test and we need to look at what are the pass fail threshold for these tests. So, we cannot have a very low value for the threshold. So, if you put a very low value for the thresholds then that test becomes not really useful, but if you put a very high threshold then what happens is that you may find that most of the tests the system will not be able to pass the test also.

So, one of the main requirement here is to look at the objectives the system objectives and the qualification objectives and then decide about a value for this threshold the pass fail threshold for each and every test to be connected and then based on that we go for the qualification requirements that is like any other system design process we look at the requirements of the qualification and then the functional architecture for the qualification what are the functions need to be provided what are the top level functions and what subdural functions are needed then we go for the physical architecture development and then identify risks and mitigation strategies . So, what are the risks involved in these processes and how do we actually overcome these risks and then create a master qualification plan.

So, at the end of the qualification planning process we will be getting a qualification plan which can actually be employed for the throughout the design. So, initially by looking at the system objectives we will develop the qualification objectives and then based on the qualification objectives.

We decide about the threshold values for different test and then we identify the qualification requirements and from there we look at the functional and physical architecture and finally, we will be getting the qualification plan that is a master qualification plan document and this document will be the master document for all kinds of qualification activities. So, that is the first function in the qualification planning plan the qualification process.

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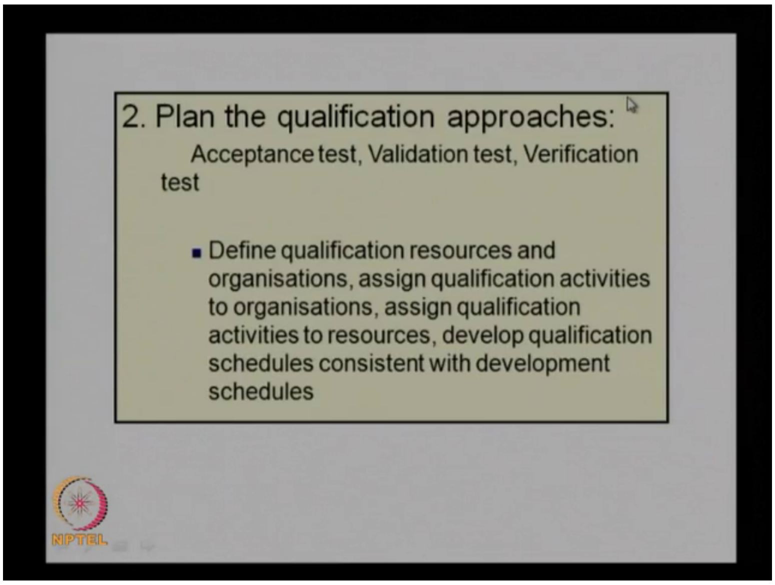

2. Plan the qualification approaches:

Acceptance test, Validation test, Verification test

- Define qualification resources and organisations, assign qualification activities to organisations, assign qualification activities to resources, develop qualification schedules consistent with development schedules

The next one is planning the qualification approaches and again this has been done for all the 3 kinds of a test acceptance validation and verification. So, here in that approach we will try to identify the resources and organizations.

Then the assign the qualification activities to organizations assign qualification activities to resources and develop qualification schedules consistent with the development schedules. So, this is the planning the qualification approach. So, here we try to identify all the resources needed for qualification. So, we need to carry out various tests and for this various tests we need to have various resources and need to identify the infrastructure available and the people who are capable of doing these tests if the test can be done in house we can actually identify if some equipment to be procured that be planned or there are some standard testing facilities available whether the test can be carried out. So, that also need to be planned.

So, that is the first stage you identify the organizations and activities and assign these activities to various resources and then develop the schedules consistent with the development schedule. So, here will be having various schedule for the design activity as we a planned for the design we have the component level design and then some system level design and. So, along with that in consistent with those schedules we need to have the qualification schedule also; for example, if you want to verify the components. So, when a particular component is made available as per the schedule then the qualification schedule also should match with that component similarly when that component is going for an integration the verification of that integrated subsystem need to be carried out and the subsystem is ready.

So, the schedule whatever we developed for qualification should inconsistent with the design activities and this is to be ensured in the qualification approach developments or planning the qualification approach. So, these are the various activities carried out in the qualification approach.

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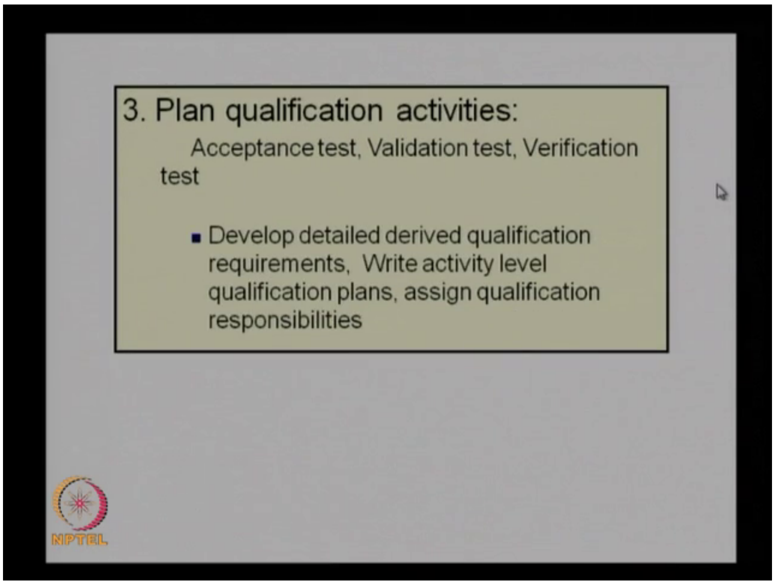

3. Plan qualification activities:

Acceptance test, Validation test, Verification test

- Develop detailed derived qualification requirements, Write activity level qualification plans, assign qualification responsibilities

The next one is planning the activities actually. So, how do we actually do carry out these activities. So, develop detailed and derived qualification requirements write actively level qualification plans and assign qualification responsibilities. So, these are actually planning the real activities. So, we find out the detailed and derived qualification requirements. So, there are maybe different requirements from the main requirement there may be some derived requirements.

So, we go into the details. So, in the third level we go into the details if we look at the individual items configuration items and components and then identify the detailed plans for each component. So, if you have a particular component identified in the design you have to look at what is that particular component and what kind of requirements are there for this component whether we need to have any specific or specialized fixtures to assemble it and then do the testing or any specialized features are needed or specialized facilities are needed for that particular component. So, that kind of detailed planning will be done in the third function which is the qualification activities. So, for each component and subsystem, we look for the details.

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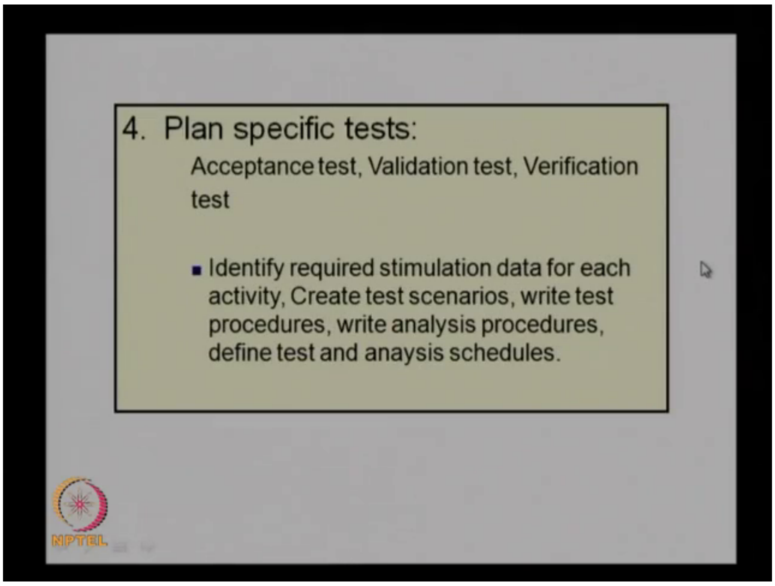

4. Plan specific tests:

Acceptance test, Validation test, Verification test

- Identify required stimulation data for each activity, Create test scenarios, write test procedures, write analysis procedures, define test and anaysis schedules.

And then develop the qualification activities and the fourth one is basically the specific test. So, if you have any requirement of any specific tests like simulation data suppose some tests may require some simulation data which cannot be where the subsystem is available you want to test it for a particular function then we may; may not be having the complete system at that stage. So, we may have to get some simulated data and feed this data to the system and find its output. So, this kind of specific tests need to be planned in the initial stage itself. So, not in every cases, but there are many special cases where you need to have simulated models or simulated data to do the complete testing so that also need to be carried out in the initial planning stage itself.

So, you here we identify the required simulation data for each activity create test scenarios write test procedures write analysis procedures and different test analysis schedules and again going into the final details of a particular test will do in the specific test activities planning. So, these are the 4 activities to be carried out in the qualification planning that is your plan for the qualification process and then plan the qualification approach then plan the qualification activities and then plan in the specific test. So, these are the 4 activities to be planned in the qualification planning.

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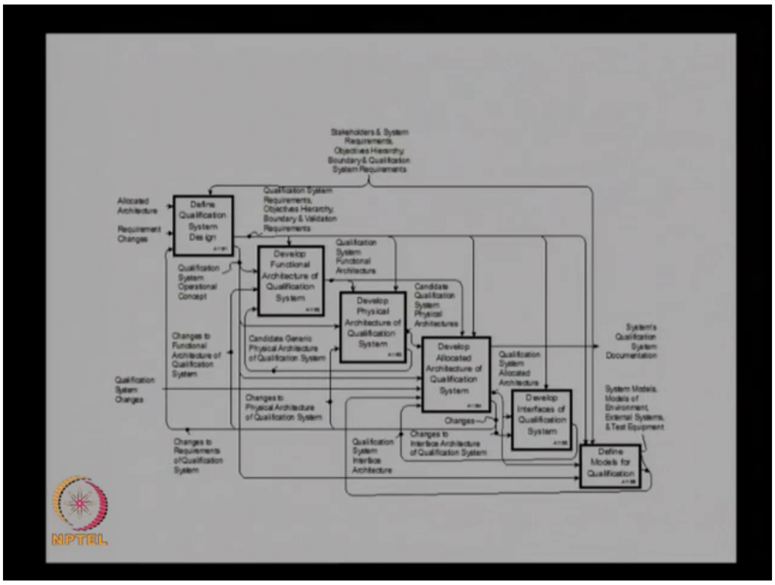

Stakeholders & System Requirements, Objectives Hierarchy Boundary & Qualification System Requirements
Allocated Architecture
Requirement Changes
Define Qualification System Design
Qualification System Requirements, Objectives Hierarchy, Boundary & Validation Requirements
Develop Functional Architecture of Qualification System
Qualification System Functional Architecture
Qualification System Operational Concept
Develop Physical Architecture of Qualification System
Candidate Qualification System Physical Architectures
Changes to Functional Architecture of Qualification System
Candidate Generic Physical Architecture of Qualification System
Develop Allocated Architecture of Qualification System
System's Qualification System Documentation
Qualification System Allocated Architecture
Qualification System Changes
Changes to Physical Architecture of Qualification System
Develop Interfaces of Qualification System
System Models, Models of Environment, External Systems, & Test Equipment
Changes
Changes to Requirements of Qualification System
Qualification System Interface Architecture
Changes to Interface Architecture of Qualification System
Define Models for Qualification
NPTEL

So, if you look at the IDEF 0 diagram for the same process you can see that these are the inputs going to the system that allocate the architecture requirement changes then we have or their inputs and there is functions we have 1, 2, 3, 4, 5, 6 functions in the qualification system design and finally you will be getting the system qualification documentation I will show you a better picture over here. So, you can see here.

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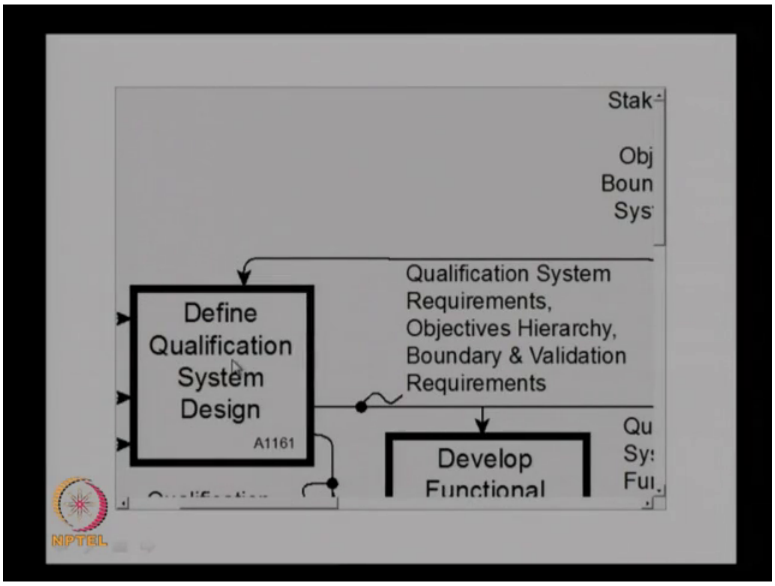

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Qualification System Requirements, Objectives Hierarchy, Boundary & Validation Requirements
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So, this is the first function that we define the qualification system design and then we develop the functional architecture of qualification system and then we go for the physical architecture development and then go for the allocated architecture of qualification system and then the interfaces of qualification system and then we go for the define models for qualification.

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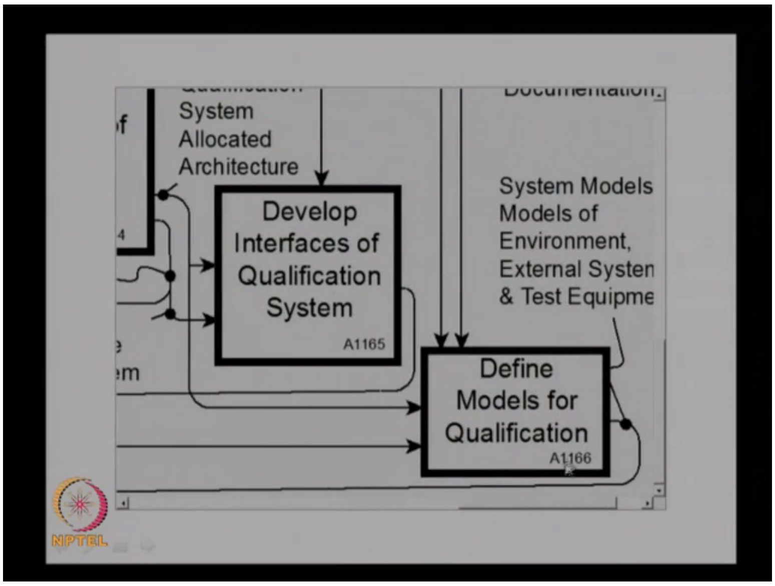

So, in this case this is the additional function we provide these are the common to the any system design, but here we have some system models for qualification. So, we need to develop some models which actually represent different situations like environmental situation or the operating situation.

So, that kind of models also will be developed for qualification. So, finally, the outcome will be the design document the system qualification documentation.

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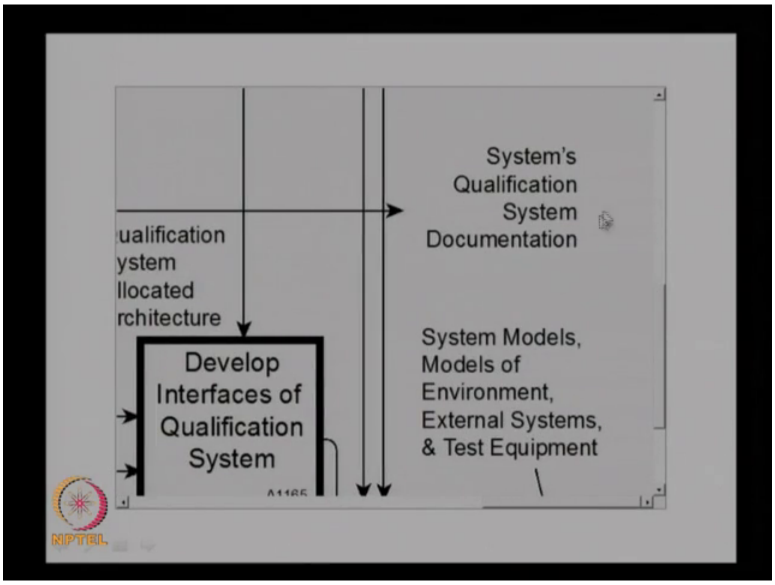

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rchitecture

Develop Interfaces of Qualification System

System's
Qualification
System
Documentation

System Models,
Models of
Environment,
External Systems,
& Test Equipment

So, this is the output from this design process and then the system models; models of environment external systems and test equipment. So, this is also will be an output of the process of developing the qualification system. So, these are the various functions involved in developing the qualification system.

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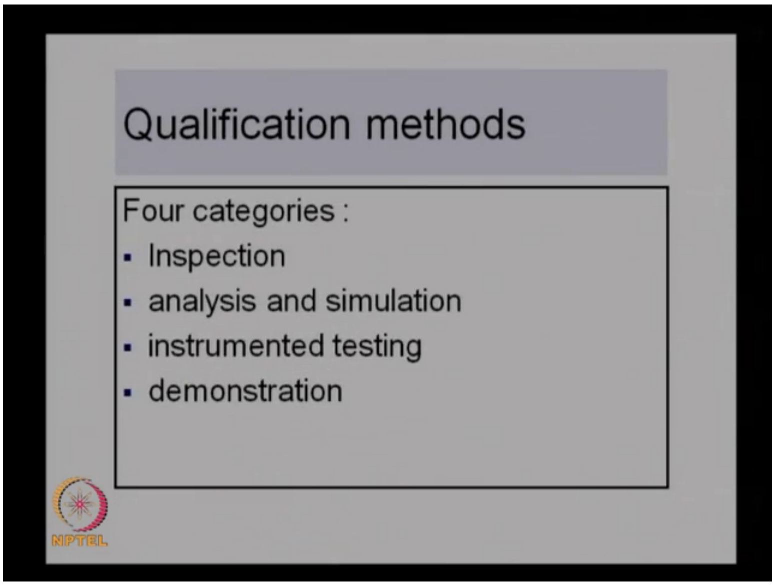

Qualification methods

Four categories :

- Inspection
- analysis and simulation
- instrumented testing
- demonstration

Let us look at some of the methods for qualification there are various methods we can employ that is various tests it say verification test or a acceptance test or validation test we can actually go for these methods of qualification methods.

So, basically we can say there are 4 methods one is the inspection and the other one is analysis and the simulation then instrumented testing and then demonstration. So, we have 4 methods of testing or for qualification methods and the first one inspection is basically used for physical human verification of a specific process or requirement. So, that is a very simple and straightforward qualification method which is the inspection.

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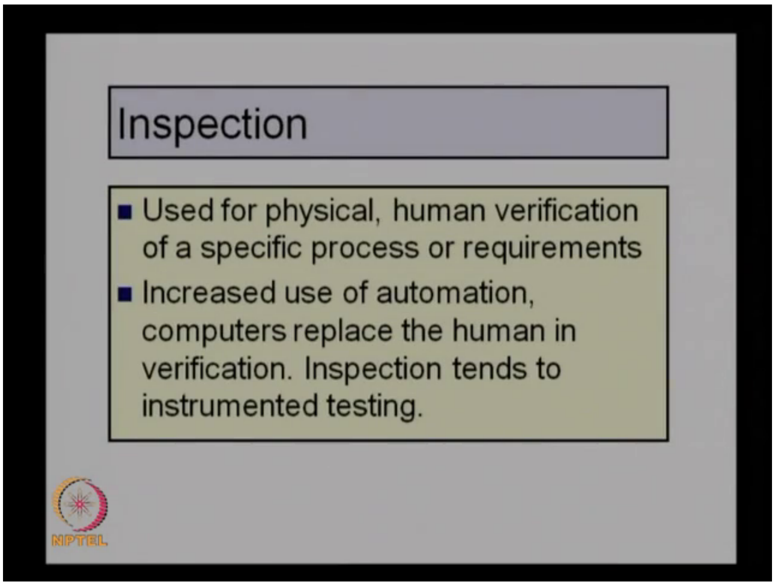

Inspection

- Used for physical, human verification of a specific process or requirements
- Increased use of automation, computers replace the human in verification. Inspection tends to instrumented testing.

It is normally a physical or human verification. So, we will look at the object or we do some kind of manual testing to find out whether there is any fault that is the first method and because of the increased use of automation now some most of these tests are becoming instrumented test or automated tests.

So, the human intervention is becoming decreasing almost to the stage where we do not really need to have any human testing because most of the tests can be automated. So, that is the inspection scenario at present. So, the inspection is basically looking at for the faults which can be easily identified either by observation or through some automated procedures like a visual testing or using camera trying to identify the errors or looking doing some simple tests using instrumented test facilities statement of methods are the inspection method which is for the simplest of the qualification method.

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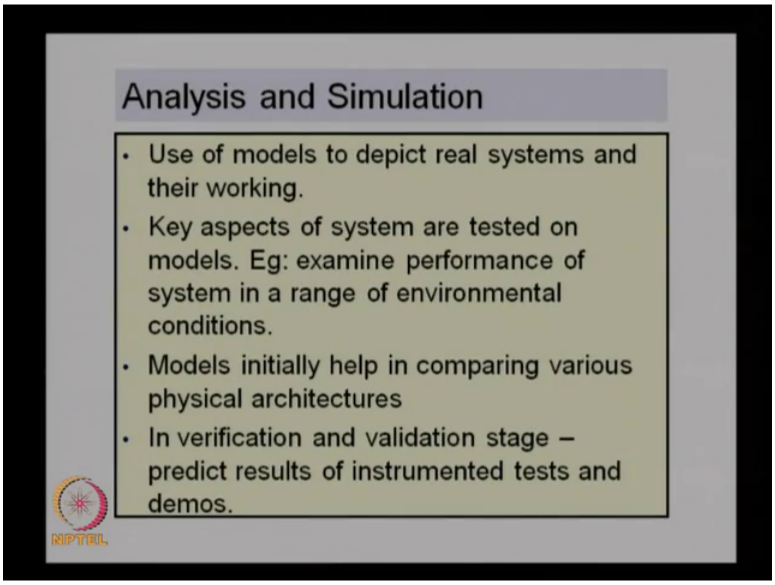

Analysis and Simulation

- Use of models to depict real systems and their working.
- Key aspects of system are tested on models. Eg: examine performance of system in a range of environmental conditions.
- Models initially help in comparing various physical architectures
- In verification and validation stage – predict results of instrumented tests and demos.

The next one is analysis and simulation. So, in this kind of method we normally go for models to depict the real systems and their working.

So, when the system is not available. So, we will try to do it in the beginning at the initial stages we try to make a mathematical model or a physical model and then do the testing to ensure that actually it will perform as per the requirement there is the analysis and simulation way of qualification the key aspects of system are tested on models that is examine the performance of a system in a range of environmental conditions. So, this is difficult to do the actual testing and other various scenarios like high temperature or high pressure or other situations like the presence of water or presence of humidity a humid air. So, these situations cannot be a tested always in many situations.

So, you can develop the models and then predict the performance of the system using these models that is the modelling and simulation methods and then this models initially help in comparing various physical architecture. So, when you have various physical architectures basically these models will help us to compare their performance even before they built and in verification validation stage they predict the results of instrumented test and demos. So, they cannot be used for predicting that test output also. So, if you have a model we can actually predict the what will be the output of an instrumented test because we know the procedure for instrumented test and what we are trying to test in the during the instrumented test. So, we can use the model and then predict the output of the model using this that is the advantages of using a analysis and simulation methods and here the the cost involved is very limited.

Because we will not be going for always most of the time we will be going for the soft models and only in rare cases we go for the real physical prototypes to do the testing, but otherwise it will be more like modelling and then simulation of the system and then trying to find out the faults of the system.

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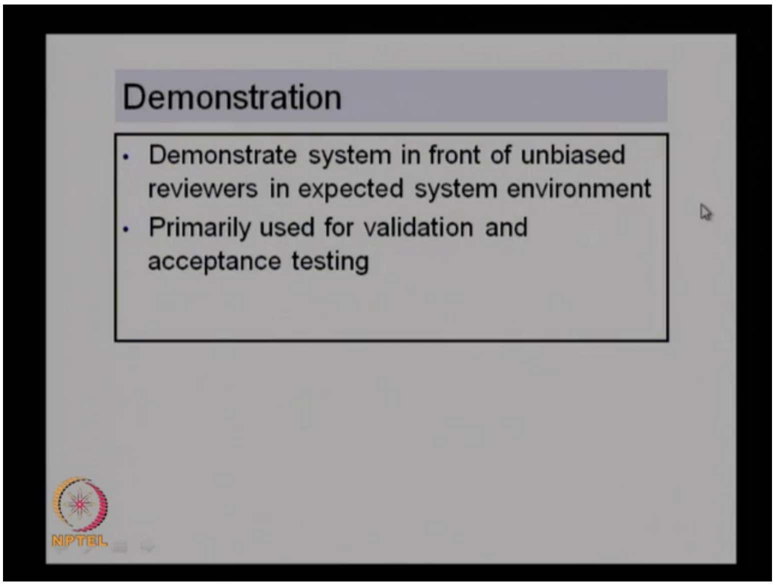

Demonstration

- Demonstrate system in front of unbiased reviewers in expected system environment
- Primarily used for validation and acceptance testing

The third one is demonstration. So, demonstrate the system in front of unbiased reviewers in expected system environment that is the method qualification method demonstration where we do the demonstration of the actual system in front of unbiased reviewers. So, we will not be having the real users what we will do we will take some reviewers who are not to biased to a particular system.

So, we demonstrate this system and then try to find out their response in terms of acceptance or in terms of the validity of that system. So, that is the third method of demonstration and this is primarily used for validation and acceptance testing only. So, verification stage you cannot really have it because verification has to be done by the designers, but validation and acceptance test we can use the real system and then demonstrate it to the biased reviewers and get their feedback about the system performance as well as we can find out the faults with the system from the customer point of view. So, these are the 4 methods of testing.

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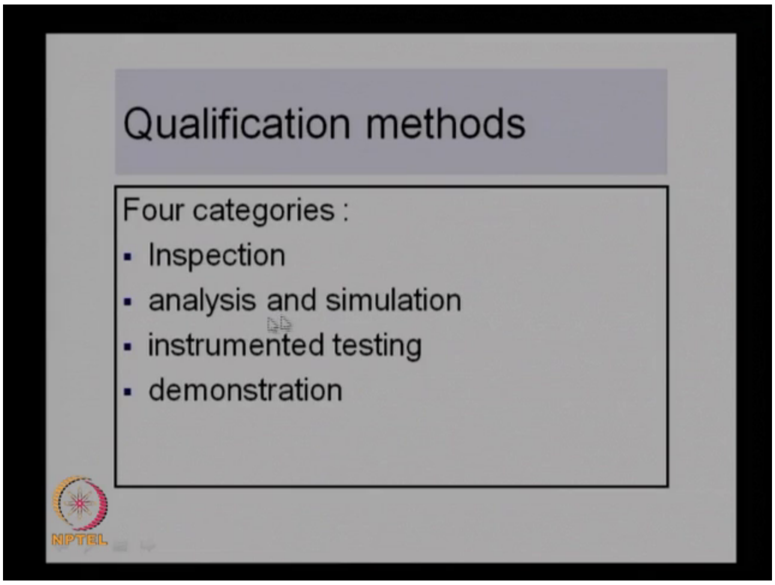

Qualification methods

Four categories :

- Inspection
- analysis and simulation
- instrumented testing
- demonstration

That is inspection analysis and simulation instrumented testing and demonstration. So, we have the inspection which is inspection by a human operator, then we can have analysis and simulation.

Then we have instrumented testing where we do testing using instrument instrumentation or standard test as per the standards and then we go for the demonstration of the real product. So, these are the 4 methods of qualification these are actually explained here with more details.

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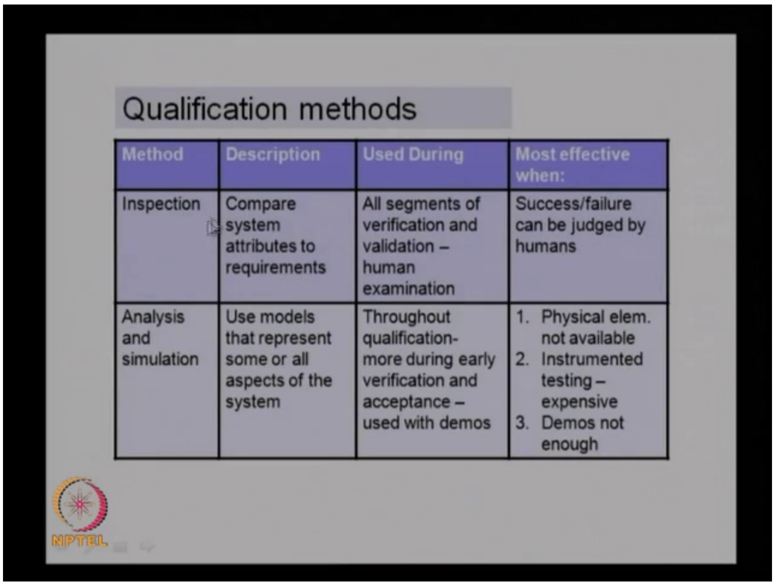

Qualification methods

Method	Description	Used During	Most effective when:
Inspection	Compare system attributes to requirements	All segments of verification and validation – human examination	Success/failure can be judged by humans
Analysis and simulation	Use models that represent some or all aspects of the system	Throughout qualification- more during early verification and acceptance – used with demos	1. Physical elem. not available 2. Instrumented testing – expensive 3. Demos not enough

So, here the inspection which will compare the system attributes to requirements and here these all segments of verification validation can be done using this method of inspection basically for human examination and here the success and failure can be judged by the humans that is the inspection method and analysis and simulation here we use the models that represent some or all aspects of the system and then throughout the qualification we can use this method not during early verification and acceptance used with demonstrations.

So, that is the application it is used for the early stages and the here the physical elements are not available because what we are having is more of a model and then the instrumented testing is expensive under that situation, we can always go for an analysis and simulation and then demos not enough when the demos are not enough they can go for analysis and simulation. So, they are most effective and review situations where physical elements are not available or instrumented testing is very expensive and demos are not enough. So, we can go for the analysis and simulation method under this situation.

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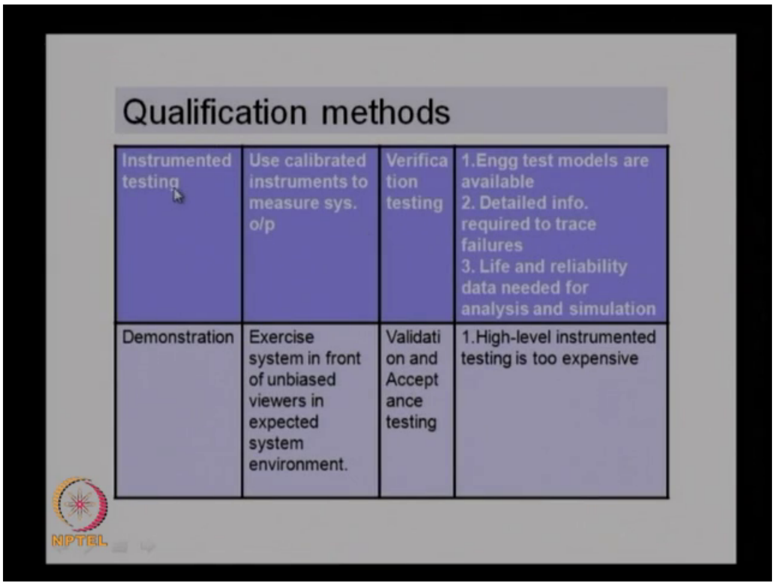

Qualification methods

Instrumented testing	Use calibrated instruments to measure sys. o/p	Verification testing	1.Engg test models are available 2. Detailed info. required to trace failures 3. Life and reliability data needed for analysis and simulation
Demonstration	Exercise system in front of unbiased viewers in expected system environment.	Validation and Acceptance testing	1.High-level instrumented testing is too expensive

And instrumented testing is used with the calibrated instruments we use calibrated instruments for doing the instrumented testing and they can be used for verification testing and it is most effective when the engineering test models are available when you have the actual models available we can use the instrumented testing and when detailed info required to trace failures. Now if you want to trace the failures and we want detailed information then we can go for the instrumented testing and then life and reliability data needed for analysis and simulation. So, when you have want this reliability data that not so, you can go for this, then the last one is a demonstration. So, which as basically demonstrating the product in front of the viewers and this is most effective when we have the final product and it can be used for validation and as well as acceptance procedures. So, these are the 4 methods which are normally used for qualification of systems.

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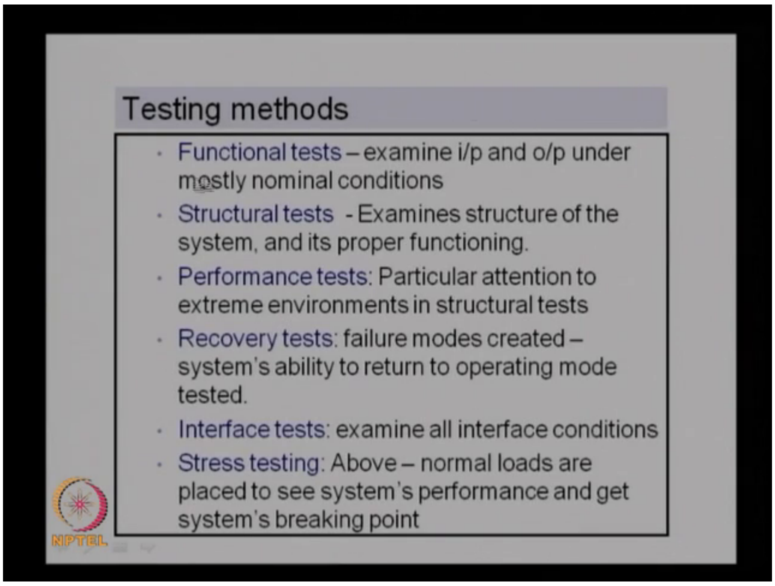

Testing methods

- Functional tests – examine i/p and o/p under mostly nominal conditions
- Structural tests - Examines structure of the system, and its proper functioning.
- Performance tests: Particular attention to extreme environments in structural tests
- Recovery tests: failure modes created – system's ability to return to operating mode tested.
- Interface tests: examine all interface conditions
- Stress testing: Above – normal loads are placed to see system's performance and get system's breaking point

Now, let this look at what are the testing methods. So, we mentioned that testing is one of the most important qualification method. So, there are different types of tests to be carried out on a system because the system has to be as to perform under various situations you need to have various test requirements. So, the system need to satisfy these requirements and therefore, we need to do various tests; it is not a single test which will a give you all the output. So, we need to do the test under various situations under various tests need to be carried out some of these tests are actually functional tests basically the functional tests are to examine the input and output under mostly nominal conditions. So, here what we try to do is to give you the non inputs to the system and try to find out.

The output and to see whether the; it is functioning normally. So, the functional tests are basically we look at the input and output and it will not look into the details of how the output is coming if the output is not coming it will not tell you from why it is not coming. So, functional test is basically to look at the functioning of the system whether the input a particular input is giving an output the required output.

So, the planner the test planner need to identify what are the inputs to be given to test the functioning. So, various inputs will give you a various output and under various situation you will be giving various inputs. So, the planner need to identify all the inputs required to test that particular function and then get the output from this. So, this kind of test is sometimes is known as black box testing also because in black box testing we do not look at the details of in what is inside we will give an input and get an output. So, that is the functional tests a structural tests basically examines the structure of the system and its proper functioning. So, basically looking at the physical structure of the system whether it is reliable whether it can take the load whether it an can be withstand the temperature.

So, these kind of features are tested in the structural tests then we have the performance tests particular to attention to extreme environments in structural tests. So, this structural tests actually we have these 4 tests which are basically part of the structural tests and we do a structural tests we look at the performance tests we look at the recovery tests we look at the interface tests and we look at the stress testing also these 4 tests are part of the a structural testing. So, we look at the performance under various environments we look at the failure modes created and systems ability to return to operating mode that also tested in the recovery tests, then we do the interface testing we examine all interface conditions and you do the stress testing where above normal loads are placed to see systems performance and get systems breaking point.

So, these are the 4 tests which are conducted under the structural testing. So, the basic tests are functional tests and they are structural tests and in structural tests we go for the performance evaluation the failure recovery analysis interfaces and stress testing to see whether it can actually take the load or above normal loads which can whether the system can withstand such loads. So, these are the 4 methods coming under structural tests and the functional and structural tests are the 2 testing methods normally employed.

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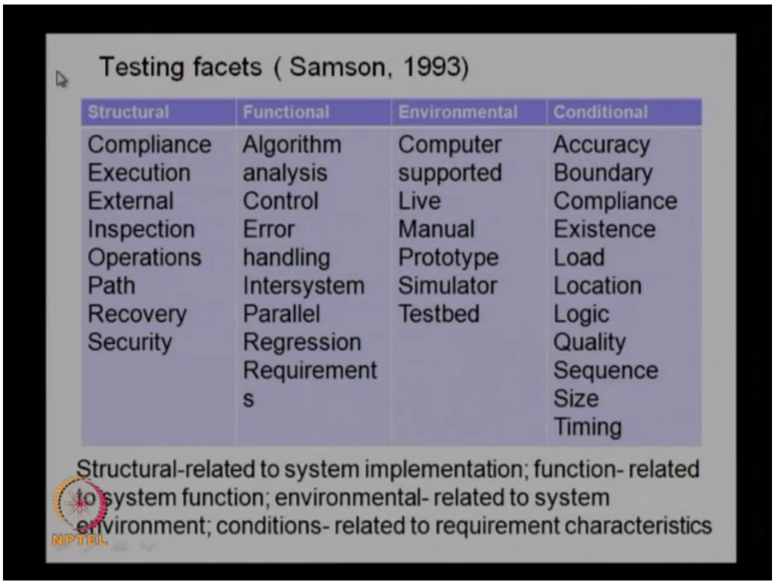

Testing facets (Samson, 1993)

Structural	Functional	Environmental	Conditional
Compliance Execution External Inspection Operations Path Recovery Security	Algorithm analysis Control Error handling Intersystem Parallel Regression Requirements	Computer supported Live Manual Prototype Simulator Testbed	Accuracy Boundary Compliance Existence Load Location Logic Quality Sequence Size Timing

Structural-related to system implementation; function- related to system function; environmental- related to system environment; conditions- related to requirement characteristics

Apart from this tests 2 tests basically structural and functional Samson as defined testing facets that is the; you need to have different facets of testing its not only that you do a structural or functional tests we need to look at the various facets of tests to be carried out and then he classified them as a structural functional then environmental and conditional. So, what it says that system implementation is looked at the structural definition and then functional related is connected to the system function environment is basically the environment and conditions related to requirement characteristics.

So, these are these 2 are actually to be tested the environmental and conditional need to be tested under the both the conditions when you do this structural tests you need to look at the environmentally aspects as well as conditional aspects for all these tests when you do a compliance tests for in the under structural tests or an external testing or the operations tests you need to look at the environment what kind of an environment this particular operation is carried out where it is a computer controlled or it is a manual one or it is a prototype we are doing or it is a simulator.

So, what is the environment under with this particular structural tests is carried out to be looked at similarly the conditional also what kind of accuracy is needed for that particular test what kind of load is there what kind of logic size timing. So, these environmental and conditional facets are to be added to all these tests under structural and functional that is the testing facets to be identified when we do the testing of the system.

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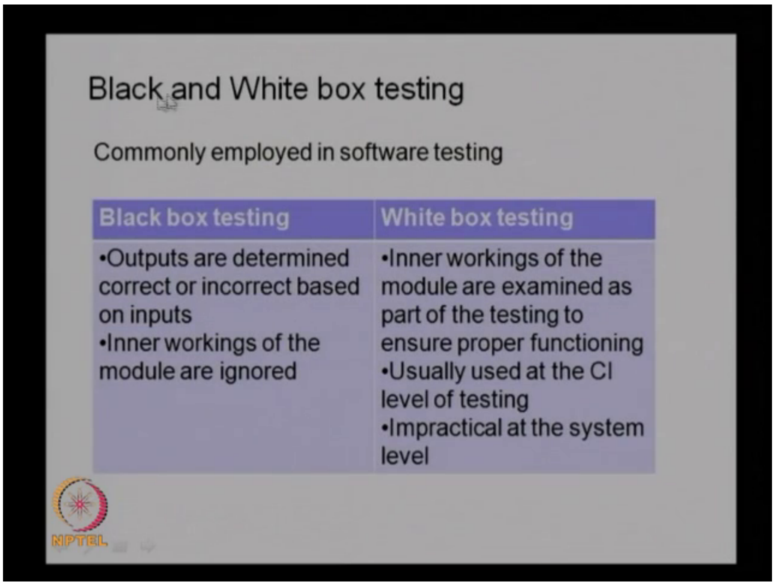

Black and White box testing

Commonly employed in software testing

Black box testing	White box testing
•Outputs are determined correct or incorrect based on inputs •Inner workings of the module are ignored	•Inner workings of the module are examined as part of the testing to ensure proper functioning •Usually used at the CI level of testing •Impractical at the system level

And these are the black box white box testing I mentioned about the black box testing recent that the outputs are determined correct or incorrect based on inputs and inner workings of the module are ignored. So, this black box testing, we do not really look at the inner modules we look at only the input and output and in white box testing.

We look at the inner workings of the module and look at the; what is actually the problem. So, usually used at the configuration items level of testing and it is impractical at the system level. So, this black box testing is used more at the system level and white box testing is used at the component level or the configuration item level because the inner workings of the module can be examined in the white box testing which is difficult in the black box testing. So, whenever we are testing we need to see whether we have to do a black box testing or a white box testing and accordingly, we will plan for the particular tests.

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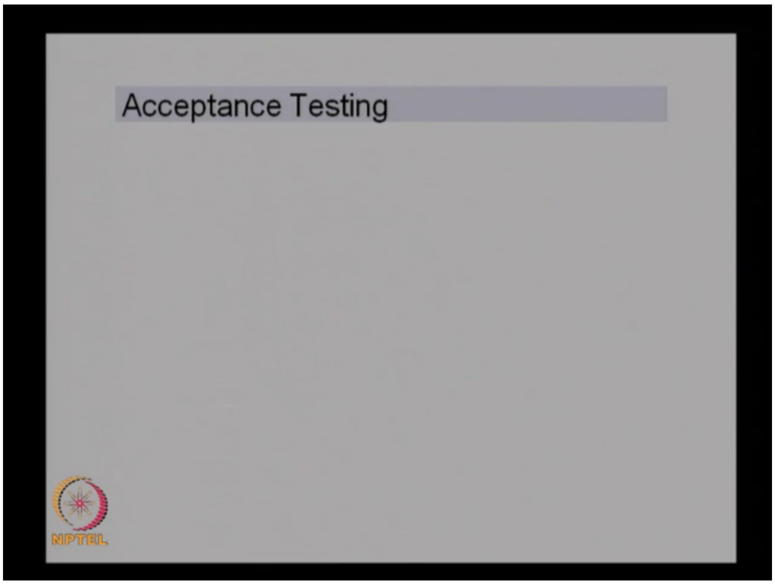

Acceptance Testing

The next one is the acceptance testing probably we will discuss about this acceptance testing in the next lecture.

So, whatever we discussed today is basically looking at the qualification methods and what kind of planning we need to do what are the procedures to do the qualification testing and how do we identify the various tests to be conducted and what other our qualification methods to be employed and qualification methods to be employed for testing the system. So, basically we were looking at the verification and validation of the system and then we need to go for the acceptance of the system. So, verification and validation there are various tests to be conducted and these tests can be classified under various categories and depending on the fault also we can identify the fault category and then decide about the testing procedures that is all what we discussed today and in the next class, we look at the acceptance procedures how do we ensure that the acceptance tests are sufficient to made the customer requirements that we will be discussing in the next class.

So, till then goodbye.