Chapter-II

Testing throughout the Software Life Cycle

Chapter II –Testing throughout the Software Life Cycle

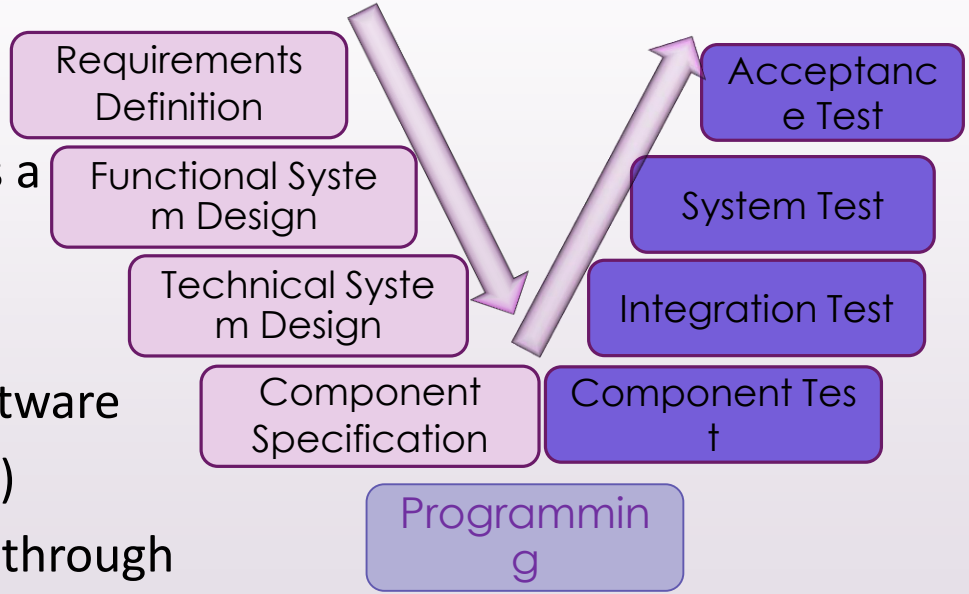
- II/01 Software development models
- II/02 Testing levels of the V-Model
- II/03 Testing types – the targets of testing
- II/04 Maintenance testing

Chapter II –Testing throughout the Software Life Cycle

- **II/01 Software development models**
- II/02 Testing levels of the V-Model
- II/03 Testing types – the targets of testing
- II/04 Maintenance testing

Testing along the general V-Model

- The general V- Model is most commonly used software development model.
- Development and test are two equal branches
- each development level has a corresponding test level.
- Test (right hand side) are designed in parallel with software development (left hand side)
- Testing activities take place through the complete software life cycle



Testing along the general V-model

Software development brace

- Requirements Definition

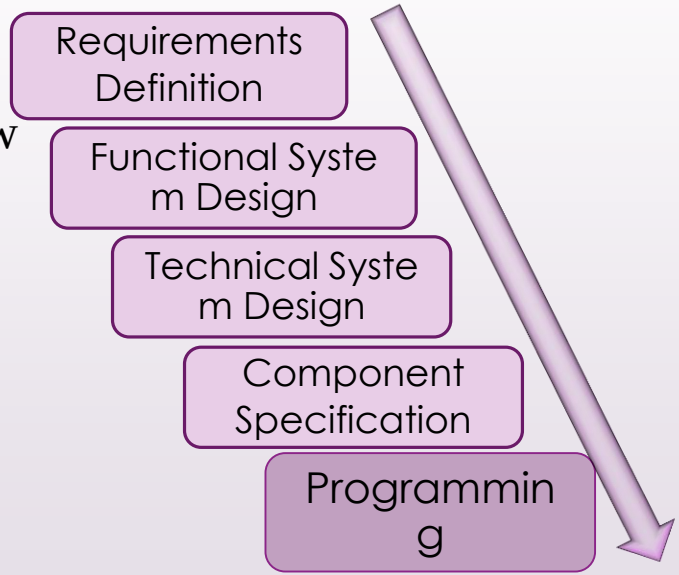
  specification documents
- Functional System Design

  design functional program flow
- Technical System Design

  design architecture / interfaces
- Component Specification

  structure of component
- Programming

  create executable code



Testing along the general V- Model

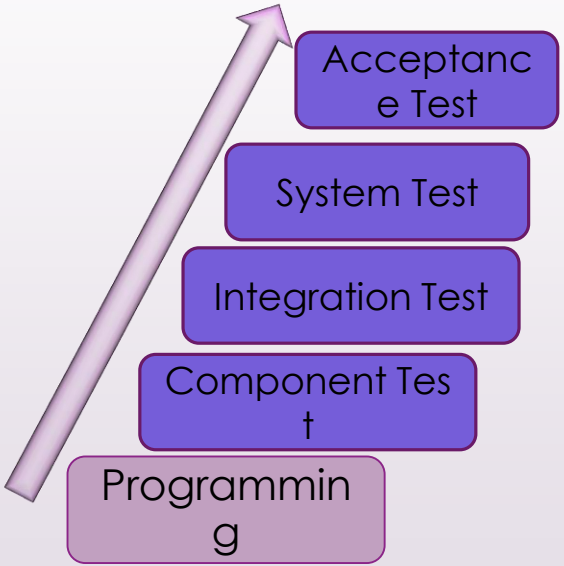
Software test brace

- Acceptance test

  formal test customer requirements
- System test

  integration system, specifications
- Component's functionality

  component's functionality



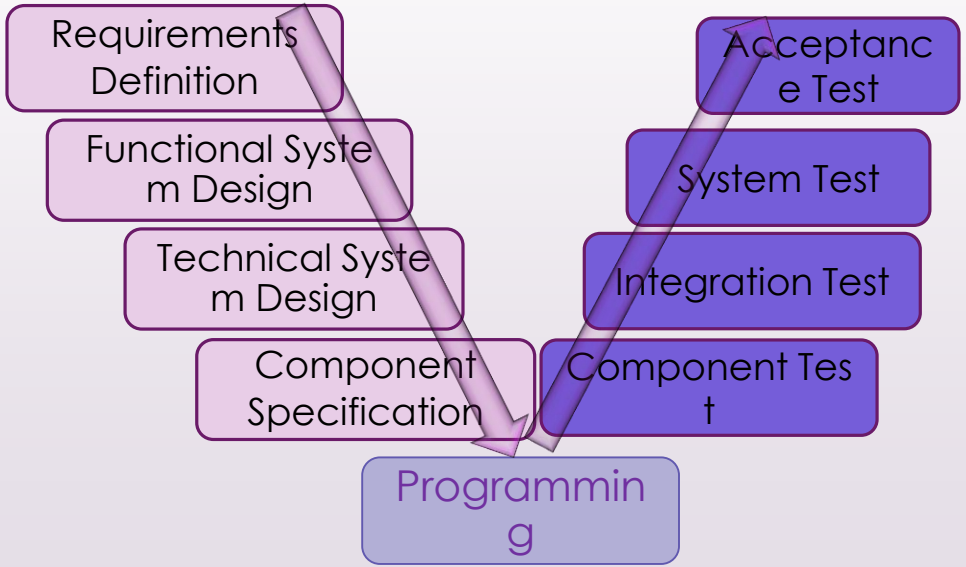
Verification Vs Validation

- Verification
  - Proof of compliance with the stated requirements (Definition after ISO 9000)
  - Main issue: Did we proceed correctly when building the system? Did we add 1 and 1 correctly?

- Validation
  - Proof of fitness for expected use (Definition after ISO 9000)
  - Main issue: Did we build the right software system? was it the matter to add 1 and 1 or should we have subtracted?

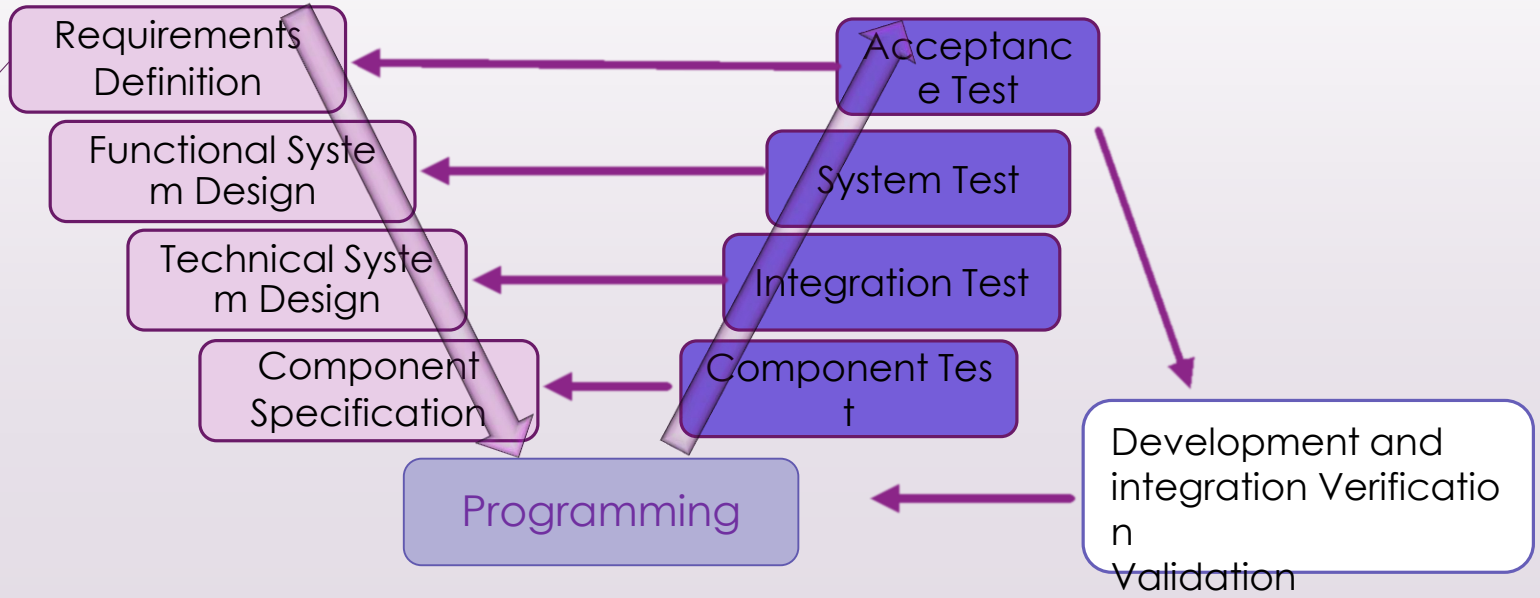
Verification within the general V- Model

- Each development level is verified against the contents of the level above it
  - to verify: to give proof of evidence, to substantiate
- To verify means to check whether the requirements and definitions of the previous level were implemented correctly



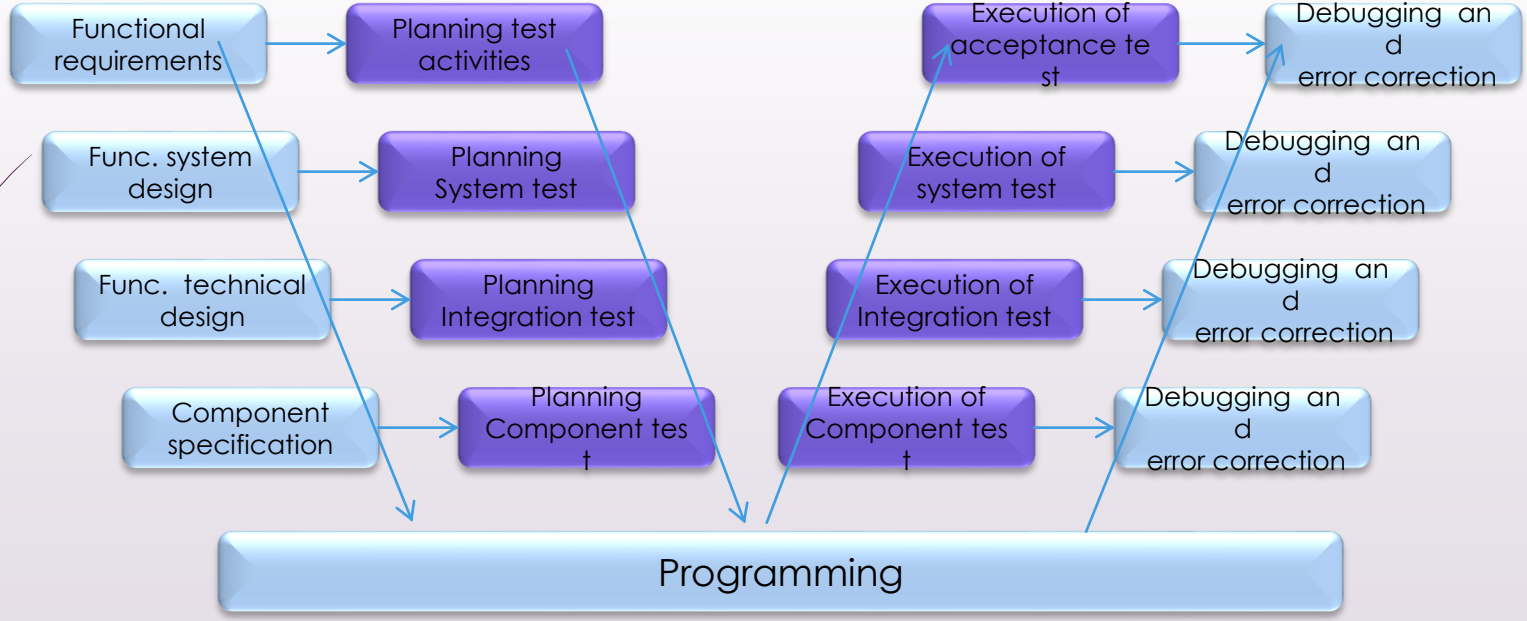
Validation within the general V- Model

- Validation refers to the correctness of each development level
  - ∗ to validate refers to the correctness of each development level
  - ∗ to validate: to give proof of having value
- To validate means to check the appropriateness of the results of one development level



Testing within the W-model

- The W-model can be seen as an extension to the general V model.
- The W-model states, that certain quality assurance activities shall be performed in parallel with the development process.



Iteration models: types of iteration models

Iteration software development

- The activities: requirement definition, design, development, testing are divided into small steps and run continuously
- in order to redirect the progress if necessary, a consent must be reached with the customer after each iteration

Iteration models are for example

- **prototyping**: building quickly usable representation of the system, followed by successive modification until the system is ready.
- **Rapid Application Development** (RAD): the user interface is implemented using out of-the box functionality faking the functionality which will be later developed.
- **Rational Unified Process** (RUP): object oriented model and a product of the company Rational/IBM. It mainly provides the modeling language UML and support for the Unified Process.
- **Extreme Programming** (XP): development and testing take place without formalized requirements specification

Iteration models: characteristics

Characteristics of iteration model:

- ✓ Each iteration contributes with an **additional characteristic** of the system under development
- ✓ Each iteration can be tested separately
- ✓ **Regression tests** and **test automation** are of high relevance
- ✓ at each iteration, verification(relation to preceding level)

And validation (correctness of the product within the current level) can be performed separately

Iteration models: Test driven development (TDD)

- Based on: test cycles
- Prepare **test cycles**
- **Automated** testing using test tools
- Development accounting to test cases
- Prepare early versions of the **component** for **testing**
- **Automatic execution** of tests
- **Correct defects** on further version
- **Repeat** test suite until no errors are found

First the tests are designed, then the software is programmed

Principles of all models

Each development **activity** must be **tested**

- No piece of software may be left untested, whenever it was developed “in one procedure” or iteratively

Each test level should be tested specifically

- each **test level** has its own test objectives
- the test performed at each level reflect these objectives

Testing begins long **before test execution**

- as soon as development begins, the preparation of the corresponding tests cab start
- this is also the case for document reviews starting with concepts, specification and overall design

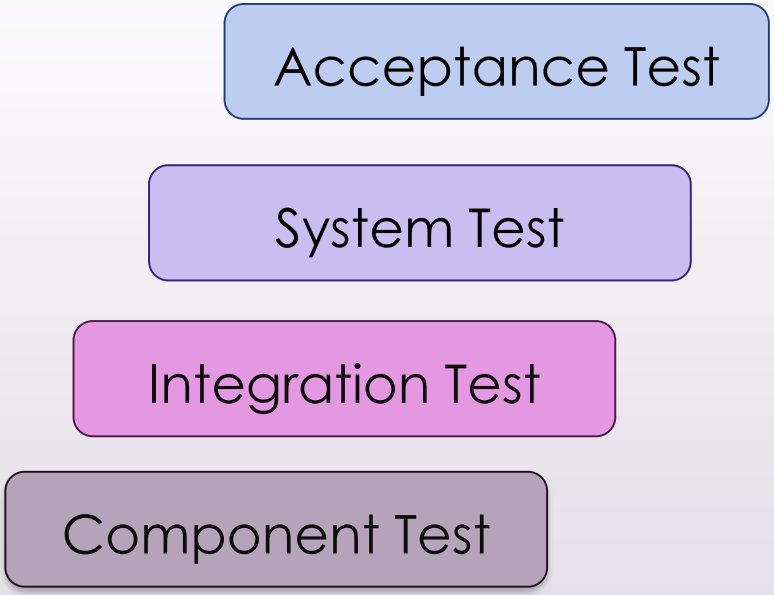
Summary

- Software development models are used for **software development** including test activities
- The best known model is the **V-model**, which describes development levels and test levels as two related branches
- The most relevant **iterative modes** are RUP, XP and SCRUM
- **Test activities** are recommended at all development levels

Chapter II –Testing throughout the Software Life Cycle

- II/01 Software development models
- **II/02 Testing levels of the V-Model**
- II/03 Testing types – the targets of testing
- II/04 Maintenance testing

Testing levels of the V-Model



Component Test

Component Testing

Definition

- **Component testing**

  test of each software component after its realization

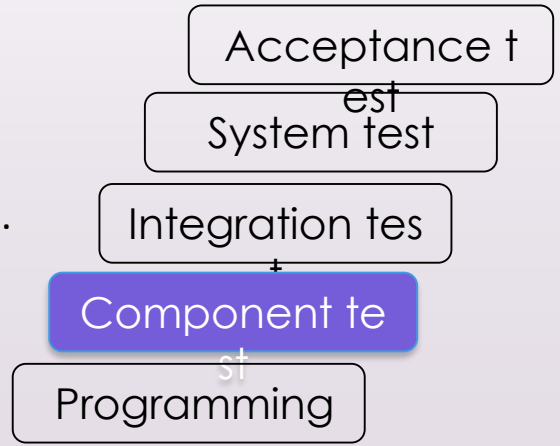
- Because of the naming of components in different programming languages, the component test may be referred to as:

  -module test (e.g. in C)

  - class test (e.g. in java or C++)

  - unit test (e.g. in Pascal)

- The components are referred to as modules, classes or units.
- Because of the possible involvement of developers in the test execution, they are called **developer's test**



Component testing: Scope

- Only **single components** are tested
  - components may consists of several smaller units
  - test objects often cannot be tested stand alone
- **Every** component is tested **on its own**
  - finding failures caused by internal defects
  - cross effects between components are not within the scope of this test
- **Test cases** may be **derived** from
  - component specifications
  - software design
  - data model

Component testing: Functional / non functional testing

-Testing Functionality

- **Every function** must be **tested** with at least one test case
    - are the functions working **correctly**, are all specifications met?
- **Defect** found commonly are:
    - defects in **processing data**, often near **boundary values**
    - **missing functions**

- **Testing robustness** (resistance to invalid input data)
    - Test case representing invalid inputs are called **negative test**
    - A robust system provides an appropriate handling of **wrong inputs**
        - wrong inputs accepted in the system may produce failure in further processing (wrong output, system crash)
- Other **non functional** attributes may be tested
    - e.g. performance and stress testing, reliability

Component testing: Test harness

Test execution of components often requires drivers and stubs

- Drivers handle the interface to the component
  - **drivers** simulate inputs, record outputs and provide a test harness
  - drivers use programming tools
- **Stubs** replace or simulate components not yet available or not part of the test object

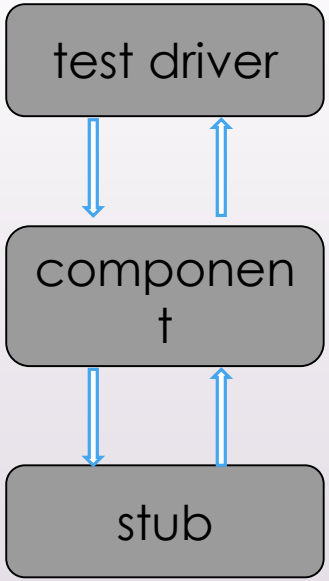
- To **program drivers and/or stubs** you
  - must have **programming skills**
  - must to have the source code available
  - may need special tools

Component testing: Test harness

Test execution of components often requires drivers and stubs

- Drivers handle the interface to the component
  - **drivers** simulate inputs, record outputs and provide a test harness
  - drivers use programming tools
- **Stubs** replace or simulate components not yet available or not part of the test object

- To **program drivers and/or stubs** you
  - must have **programming skills**
  - must to have the source code available
  - may need special tools



Component testing: Methods

- The program code is available to the tester
  - in case “tested = **developer**”:
    testing take place with a strong **development focus**
  - knowledge about **functionality**, **component structure** and **variable** may
    be applied to **design test case**
  - often functional testing will apply
    additionally, the use of **debuggers** and other development tools (e.g. unit test frameworks) will allow to **directly access** program **variables**
- Source code knowledge allows to use white box methods for component test

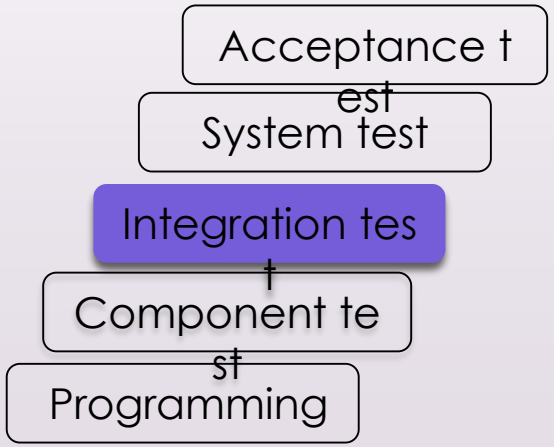
Summary: Component testing

- A **component** is the smallest system unit specified.
- **Module**, **unit**, **class** and **developer's test** are used as synonyms.
- **Drivers** will execute the component functions and adjacent functions that are replaced by **stubs.**
- Component test may check **functional** and **non functional** system properties.

Integration test

Integration testing (also: interface testing)

- Examine the **interaction** of software elements (components) after system integration.
- Integration is the activity of combining individual software components into a **larger subsystems**.
- **Further** integration of **subsystems** is also part of the system integration process.
- Each component has already been tested for its **internal functionality** (component test). Integration test examine the **external functions**.
- May be performed by **developers**, **testers** both



Integration testing: Scope /1

- Integration tests assume that the components have **already been tested**.
- Integration tests examine the **interaction** of software components (subsystems) with each other:
  - interfaces with the other **components**
  - interfaces among **GUIs** / **MMIs**
- Integration tests examine the interfaces with the **system environment**.
  - In most cases, the interaction testes is that of the component and **simulated environment** behavior.
  - Under **real conditions**, additional environmental factors may **influence** the components behavior
- **Test case** may be derived from**, interface specifications**, architectural design or data models.

Integration testing: Scope/2

- **A (Sub-) system**, composed of individual components, will be tested.

  -Each component has as interface either external and / or interacting with another component within the (sub-) system.

- **Test drivers** (which provide the process environment of the system or sub-system) are required

  -to allow for or to produce input and output of the (sub-) system

  -to log data

- Test drivers of the components tests may be re-used here.

Integration testing: Scope/3

- **Monitoring tools** logging data and controlling test van support testing activities
- **Stubs** replace missing components

  -data or functionality of a component that have not yet been integrated will be replaced by programmed stubs

  -stubs take over the elementary of the missing components

Integration testing: Approach

- Integration tests aim at finding defects in the interface. They check the correct interaction of components

  -among other reason, in order to check performance and security aspects

- Replacing test drivers and stubs with **real components** may produce new defects, such as
  - **Losing data,** wrong handling of data or wrong inputs
  - The components involved interpret the input data in a different manner
  - The **point in time** where data is handed over is not correct: too early, too late, at a wrong frequency

Integration testing: Strategies /1

- There are different strategies for integration testing
  - Common to most strategies is the **incremental** approach (exception for example “Big Bang” strategy)
  - **Bottom-up** and **top-down** are the most commonly used strategies
- Choosing a **strategy** must also consider aspects of the test efficiency

  - The integration strategy determines the amount of test effort needed (e.g. using tools, programming test drivers and stubs etc)

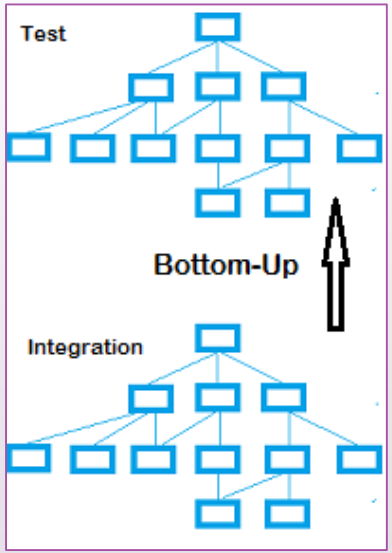
  - Component **completion** determines for all types of integration strategies, at what time frame the component is available. Therefore **development strategy** influences the integration strategy.
- For each individual project, the trade-off between reducing time and reducing test effort must be considered:

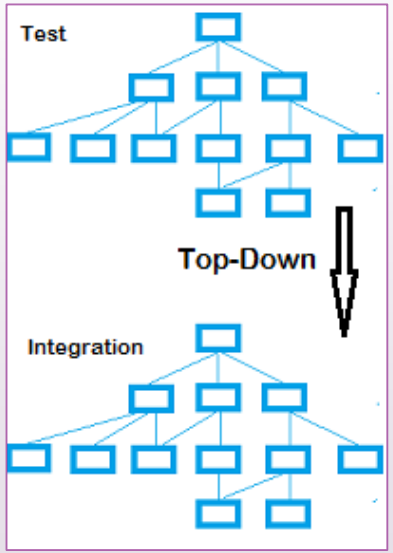
  -testing what is ready: more costs for testing but less idle time

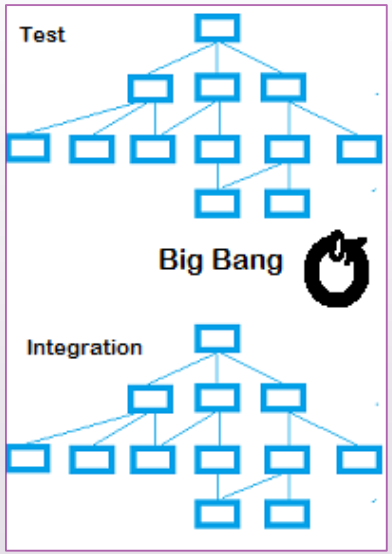
  -follow a strict integration test plan: lower cost but more idle time

Integration testing: strategies

Terminology







Integration testing: strategies /5

Ad-hoc integration

- components will be tested, if possible, direct after programming and component test have been completed

Characteristics of ad-hoc integration

-early start of testing activities, possibly allowing for a shorter software development process as a whole

-depending on the type of component completed, stubs as well as test drivers will be needed

Use of ad-hoc integration

-It is a strategy that can be followed at any stage in the project

-It is often used combined with other test strategies.

Summary: Integration testing

- **Integration** means building up groups of component
- **Integration tests** examine component interactions against the specification of interfaces
- Integration takes place either **bottom-up**. **top-down**, or in a **big bang**
- **Integration Sub-systems** (they consists of integrated components) is also a form of integration
- A further integration strategy is **ad-hoc** integration

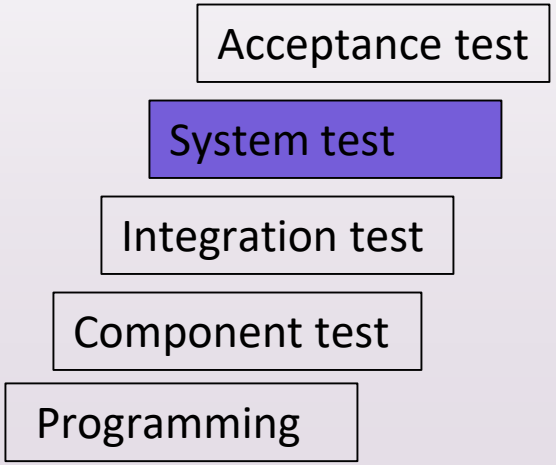
System test

System test

- Testing the integrated software system to prove compliance with the specified requirements
  - -Software quality is looked at form the user's point of view
- System tests refer to (as per ISO 9126):
  - -**functional** and **non functional** requirements (functionality, reliability)

-**Test cases** may be derived from

- Functional specifications
- Use cases
- Business processes
- Risk assessments



System test: Scope

- Test of the integrated system from the user's point of view
  - Complete and correct implementation of requirements
  - Development in the real system environment with real life data
- The **test environment** should match the **true environment**
  - No test drivers or stubs are needed
  - All external interfaces are tested under true conditions
  - Close representation of the later true environment

-No test in the real life environment

- Induced defects could damage the real life environment
- Software under development is constantly changing. Most tests will not be reproducible

System test: functional requirements /1

- Goal: to prove that the implemented functionality exposes the required characteristics
- Characteristics to be tested include (as per ISO 9126):
  - **Suitability**
    - Are the implemented functions suitable for their expected use
  - **Accuracy**
    - Do the functions produce correct (agreed upon) result?
  - **Interoperability**
    - Does interaction with the system environment show any problem?
  - **Compliance**
    - Does the system comply with applicable norms access or less?

System test: functional requirements /2

- Three approaches for testing functional requirements:

-Business process based test

- each business process service as basis for driving tests
- the ranking order of the business process can be applied for prioritizing test cases

-Use case based test :

-Test cares are derived from sequences of expected or reasonable use

- sequence used more frequently receive a higher priority

-Requirements based test (building blocks)

- Test cases are derived from the requirement specification

-The number of the cases will vary accounting to the type/depth of specification

Requirements based test

System test: Non-functional requirements

- **Compliance** with non functional requirements is **difficult to achieve:**
  - -Their definition is often very vague (e.g. easy to operate, well structured user interface, etc.)
  - - They are not stated explicitly. They are an implicit part of system description, still they are expected to be fulfilled
  - - **Quantifying** them **is difficult,** often non-objective metrics must be used, e.g. looks pretty, quite safe, easy to learn.
- Example: Testing / inspiriting documentation
  - - Is documentation of programs in live with the actual system, is it concise, complete and easy to understand?
- Example: Testing maintainability
  - - Have all programmers complied with the respective Coding-Standards?
  - - Is the system designed in a structured, modular fashion?

Summary: System test

- System testing is performed using functional and non-functional test cases
- Functional system testing confirms that the requirements for a specific intended use have been fulfilled (validation)
- Non functional system testing verifies non functional quality attributes, e.g. usability, efficiency, portability etc.
- Non functional quality attributes are often as implicit part of the requirements, this makes it difficult to validate them

Acceptance test

Acceptance testing

Acceptance testing is a formal test performed in order to verify compliance of the system with user requirements. The goal is to establish confidence in the system, so it can be accepted by the customer (see: IEEE 610).

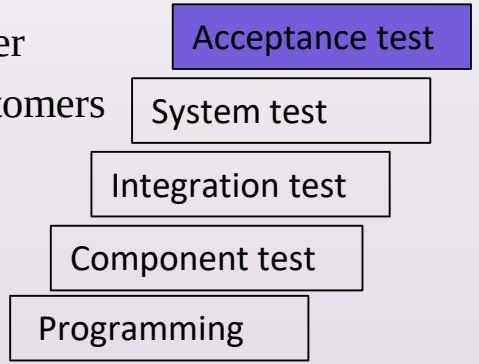
-It is often the first test where the customer is involved (it is advisable, to involve the customer already during software development, e.g. for prototyping purposes)

- The customers involvements may very depending on the type of program (individual software or COTS software)

  -**Individual** software is often tested directly by the customer

  - COTS software may be tested by a selected group of customers

*COTS= commercial off the shelf



Acceptance testing: contractual acceptance

- Does the software fulfill all the **contractual** requirements?
- With formal acceptance legal milestone are reached: begin of **warranty, payment** milestones, **maintenance** agreements, etc.
- **Verifiable acceptance criteria** should be defined when the contract is agreed, this serves is an insurance for both parties
- Governmental, legal, industrial and other regulations have to be taken into account for acceptance testing (e.g. safety regulation FMVSS 208: Federal Motor Vehicle Safety Standard)
- Often **customer** select **test case** for acceptance testing
  - Possible misinterpretations of the requirements come to light and can be discussed, “The customer knows best”
- Testing is done using the **customer environment**
  - Customer environment may cause new failures

Acceptance testing: operational acceptance testing

- Requirements that software is fit for use in a productive environment
  - Integration of software into the customer IT-infrastructure (Backup-/Restore-Systems, restart-, install and de-install-ability, disaster recovery, etc.)
  - User management, interfacing to file and directory structures in use
  - Compatibility with other systems (other computers, data base servers, etc.)

- Operational acceptance testing is often done by the customer’s system administrator

Acceptance testing: alpha- and beta (or filed) testing

- A stable preliminary version of the software is needed
- Mostly done for market software (also called COTS* software)
- Customers use the software to process their daily business process at the suppliers location **(beta testing)**
- Feed back is given on problem found, usability, etc.
- Advantages of alpha and beta tests
- Reduce the cost of acceptance testing
- Use different user environments ,
- Involve a high number of users

*COTS= Commercial Off The Shelf

Summary: Acceptance testing

- Acceptance testing is the **customer's** system test
- Acceptance testing is **contractual** activity, the software will then be verified to comply with customers requirements
- **Alpha**- and **beta** tests are tests performed by potential or existing customer either at the developer's site (alpha) or at the customers site (beta).

Chapter II –Testing throughout the Software Life Cycle

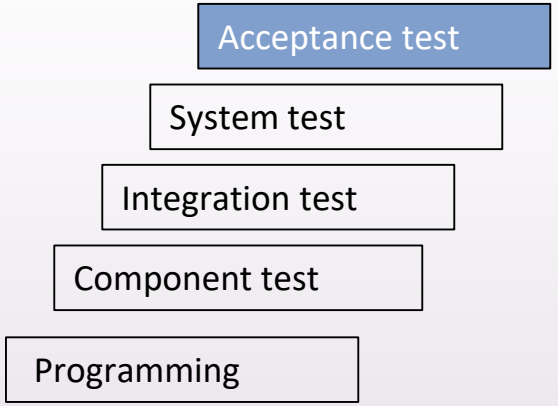
- II/01 Software development models
- II/02 Testing levels of the V-Model
- **II/03 Testing types – the targets of testing**
- II/04 Maintenance testing

Test types and test levels

- Test levels

-The previous section explained the various testing levels, i.e. component test, integration test etc.

- At every test level the test objectives have a different focus!
- Therefore different test types are applied during different test levels



- Test types

- Functional testing (Goal: Testing of function)
- Non-functional testing (Goal: Testing product characteristics)
- Structural Testing (Goal" Testing of SW structure/architecture)
- Confirmation/regression testing (Goal: Testing after changes)

Types of Testing

- **Goal: the function of the test object**
  - Functionality can be linked to **input and output data** of the test object
  - **Black box methods** are applied to design the relevant test cases
  - Testing is to be verify **functional requirements** (as stated in specifications, concepts, case studies, business rules or relevant documents)

- **Area of use**
  - Functional testing may be performed at all test levels

- **Execution**
  - The test object is executed using test data derived from test cases
  - The result of the test execution are compared to the expected results
  - **Security testing**
  - Type of functional testing delaying with external threads
  - Malicious attacks could damage program or data

Types of Testing

Non Functional Testing

- Goal: software product characteristics

- **How well** does the software perform its functions?
- The non-functional quality characteristics (ISO 9126: reliability, usability, efficiency, maintainability, portability) are often vague, incomplete or missing all together, making testing difficult

-Area of use

- Non-Functional testing may be performed at all test levels
- Typical non-functional testing:
  - Load testing/ performance testing/ volume testing/ stress testing
  - Testing of safety features
  - Reliability and robustness testing / compatibility testing
  - Usability testing / configuration testing

- Execution

- Compliance with the non-functional requirements is measured using selected functional requirements

Types of Testing

Non Functional Testing (system test)

- **Load test**
  - System under load (minimum load, more user/tractions)
- **Performance test**
  - How fast does the system performed a certain function
- **Volume test**
  - Processing huge volumes of data / files
- **Stress test**
  - Reaction to overload / recovery after return to normal
- **Reliability test**
  - Performance while in “continuous operation mode”
- **Test of robustness**
  - Reaction to input of wrong or unspecified data
  - Reaction to hardware failures / disaster recovery

Types of Testing

Non Functional Testing (system test)

- **Compliance testing**
  - Meeting rules and regulations (internal / external)
- **Test usability**
  - Structured, understandable, easy to learn for user
- **Other non-functional quality aspects:**
  - -portability: replace ability, install-ability
    conformance/compliance, adaptability
  - maintainability: verifiability, stability, analyzability, changeability
  - reliability: maturity, robustness, recoverability

Types of Testing

Structural testing

- Goal: Coverage

- Analyses the structure of the test object (**while box** approach)

- Testing aims at measuring how well the structure of the test object is covered by the test cases

- Area of use

- Structural testing possible on all test levels, **code coverage** testing using tools mainly done during **component** and integration testing

- Structural test design is finalized after functional tests have been designed, aiming at producing a high degree of coverage

- Execution

-Will test the internal structure of a test object (e.g. control flow within components, flow through a menu structure)

- Goal: all identified structural elements should be covered by test cases

Confirmation /Regression testing /1

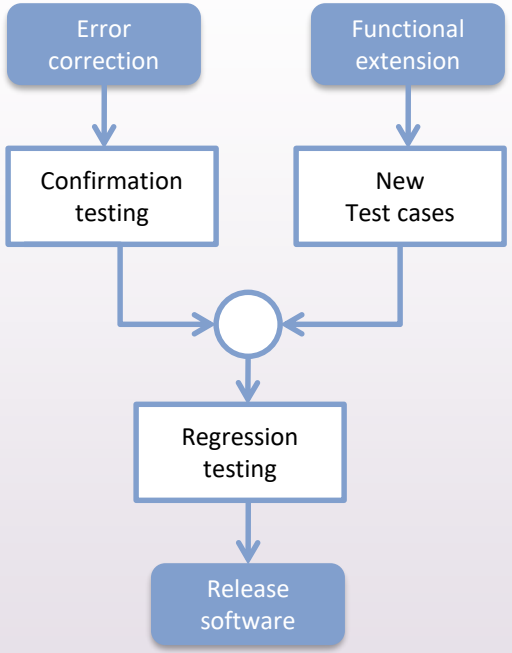
- Goal: test object after changes

-After a test object or its system Environment has been **changed**, results Related to the change have become Invalid: **test** have to be repeated

-Two main reasons for changing Software

- Error correction
- functional extension

- Because of undesired side effects of extended or **new functionality**, it is necessary to also retest adjacent areas!



Confirmation /Regression testing /1

- Area of use

- Replacing a test of functionality that has already been verified is called a **regression test.**
- The scope of the regression test depends on the risk, that the newly implemented functionality (extension or error fix) imposes to the system.
- Analyzing this risk can be done with an impact6 analysis
- Confirmation / Regression testing may be performed at all test levels.
- Typical test after changes are:
- Confirmation testing , retest (= Testing after correction of errors)
- Regression testing (= Testing to uncover newly introduced defects)

Confirmation /Regression testing /2

- Execution

- Basically, execution takes place as in previously executed test iterations
- In most cases, a complete regression test is not feasible, because it is too expensive and takes too much time
- A high degree of modularity in the software allows for more appropriate **reduced** regression tests
- Criteria for the selection of the regression test cases:
  - -Test case with high priority
  - Only test standard functionality, skip special cases and variations
  - Only test configuration that is used most often
  - Only test subsystem / selected areas of the test object
- If during early project phases, it becomes obvious that certain tests are suitable for regression testing, test automation should be considered

Summary

- On different **test levels** different **types of tests** are used
- Test types are: **functional, non-functional**, **structural** and **change related testing**
- **Functional testing** examines the input / output **behavior** of a test object
- **Non- functional** testing checks **product characteristics**
- **Non- functional testing** include, but is not limited to, **load testing**, stress testing, performance testing, robustness testing
- Common **structural tests** are tests that check data and control flow within the test object, measuring the degree of coverage
- Important test after changes are: **confirmation tests(re-tests)** and **regression tests**

Chapter II –Testing throughout the Software Life Cycle

- II/01 Software development models
- II/02 Testing levels of the V-Model
- II/03 Testing types – the targets of testing
- **II/04 Maintenance testing**

Testing after Product Acceptance /1

- **Customer** has **approved** the product and sets it into production

  - The initial development cycle, including its related **tests**, has been **completed**

- The **software** itself is at the beginning of its life cycle:

  - it will be used for many years to come, it will be **extended**

  - it most likely still have errors, hence it will be further modified and **corrected**

  - it need to adapt to new conditions and to be integrated into new environments

  - it will one day be retired, put out of operation

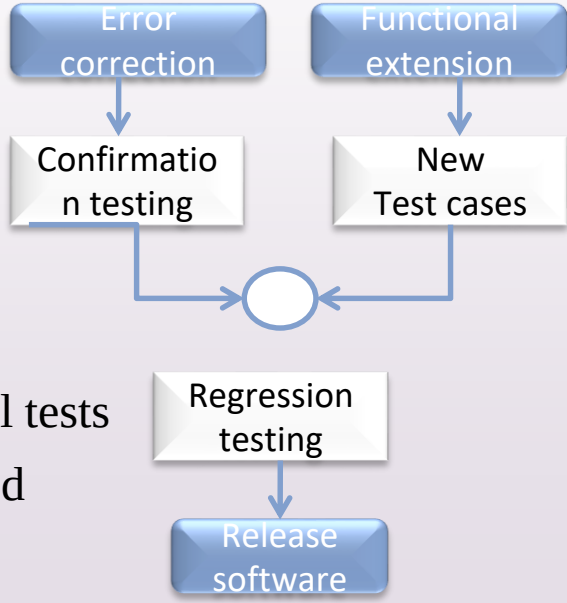
- **Any new version of the product, any new update and any other change in the software requires additional testing!**

Testing after Product Acceptance /2

- Software maintenance covers two different fields:

  -**maintenance** as such: correction of error, that already were part of the initial version of the software

  -**software extension**: adaptations as a result of a changed environment or new customer requirements



- **Test scope** of maintenance testing
  - Error correction requires retests
  - Extended functionality requires new test case
  - Migration to another platform requires operational tests
  - In **addition**, intensive **regression testing** is needed

Testing after Product Acceptance /2

- **Scope of testing** is affected by the impact of the change
  - **Impact analysis** is used to determine the affected areas
  - Problems might occur if **documentation** of the old software is **missing** or **incomplete**

- Software **retirement**
  - Test after software retirement may include
    - Data migration test
    - Verifying archiving data and programs
    - parallel testing of old and new systems

Summary

- Ready developed software needs to be **adapted** to new conditions, errors have to be **corrected**
- An **impact analysis** can help to judge the changes related risks
- Maintenance tests make sure , that
  - New function are implemented correctly **(new test cases)**
  - Error have been fixed successfully **(old test cases)**
  - Functionality, that has already been verified, i9s not affected **(regression test)**
- If software gets **retired**, migration tests or parallel tests may be necessary

Thank You