Integration testing, system testing, validation testing

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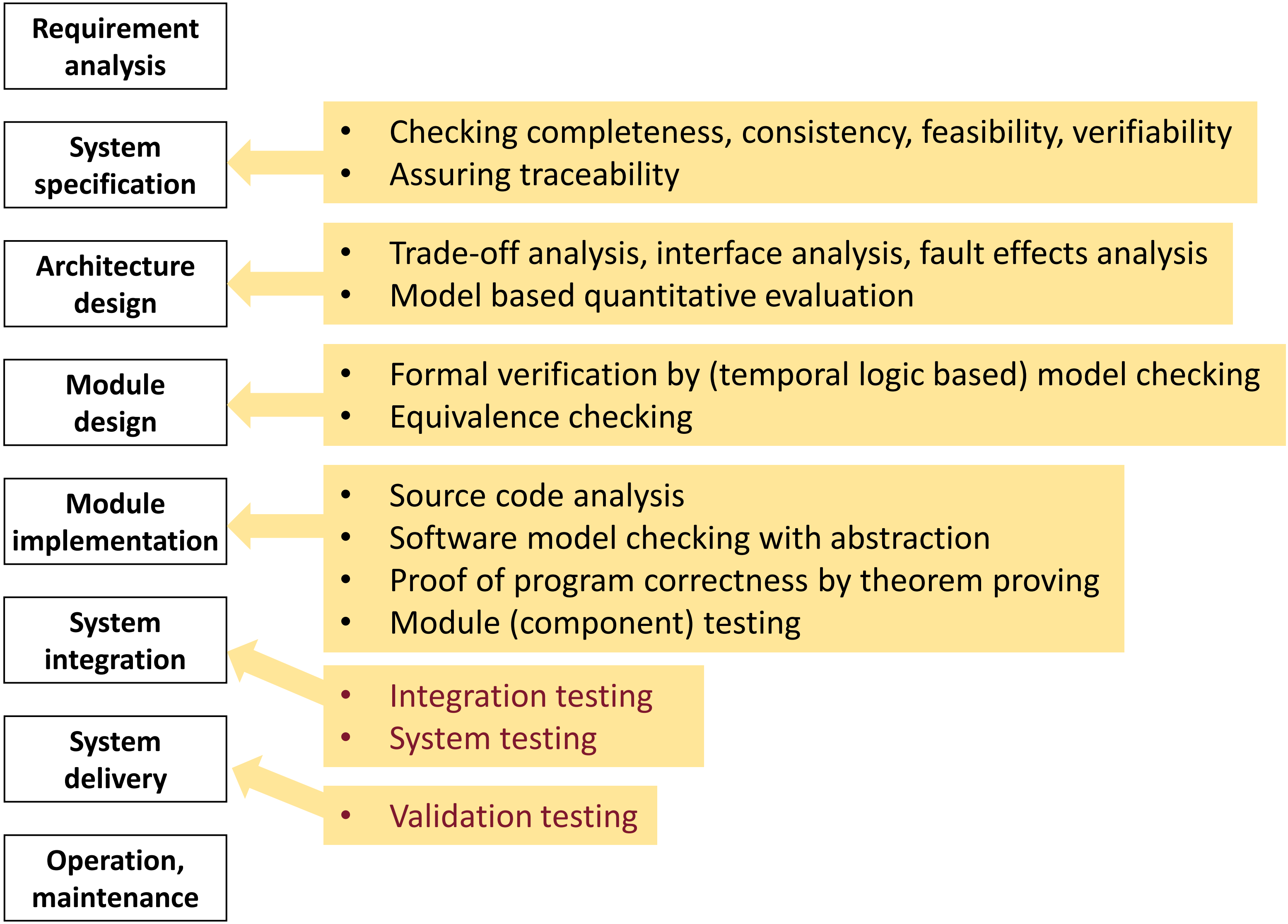
Typical development steps and V&V tasks



Requirement analysis

System specification

- Checking completeness, consistency, feasibility, verifiability
- Assuring traceability

Architecture design

- Trade-off analysis, interface analysis, fault effects analysis
- Model based quantitative evaluation

Module design

- Formal verification by (temporal logic based) model checking
- Equivalence checking

Module implementation

- Source code analysis
- Software model checking with abstraction
- Proof of program correctness by theorem proving
- Module (component) testing

System integration

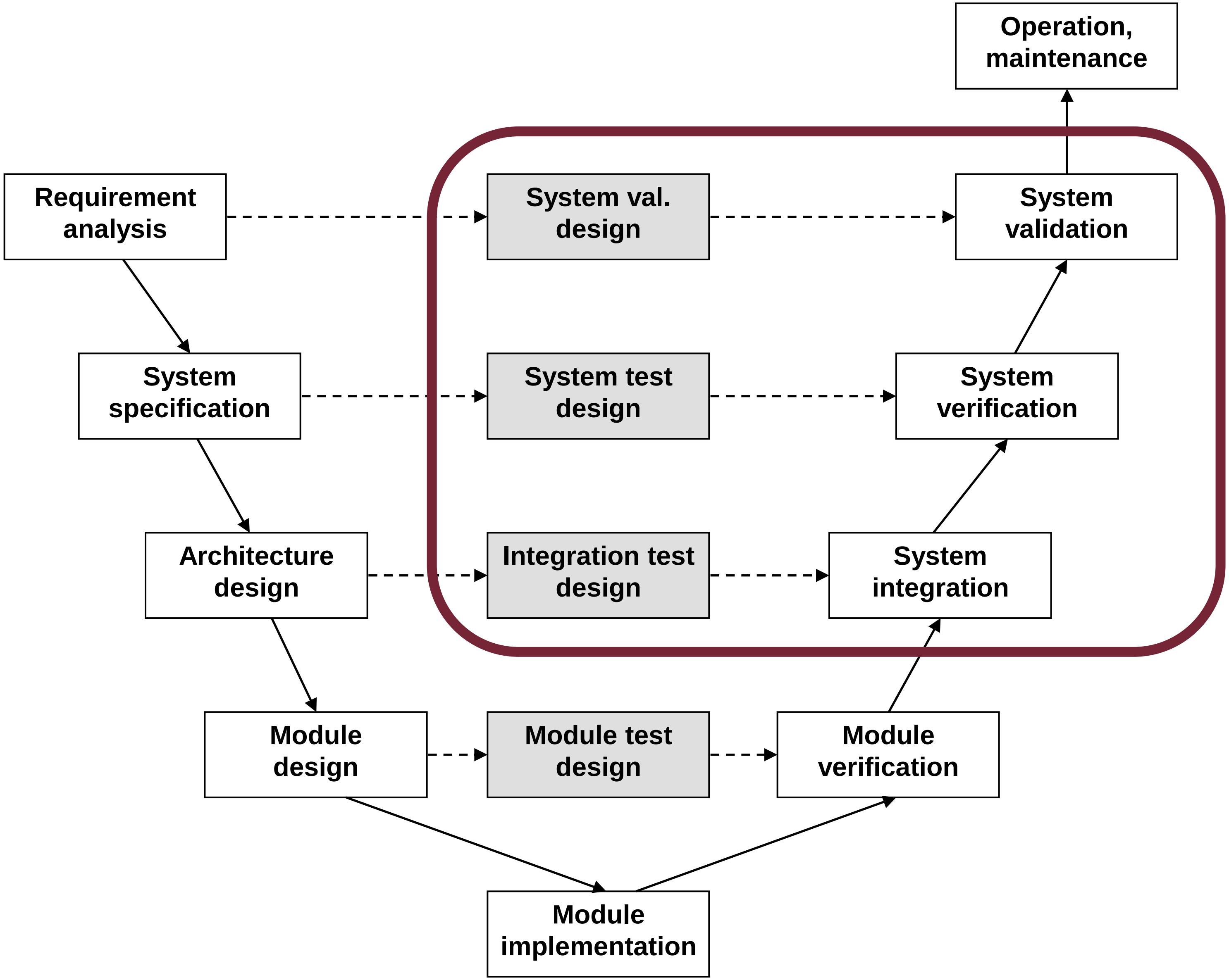
- Integration testing
- System testing

System delivery

- Validation testing

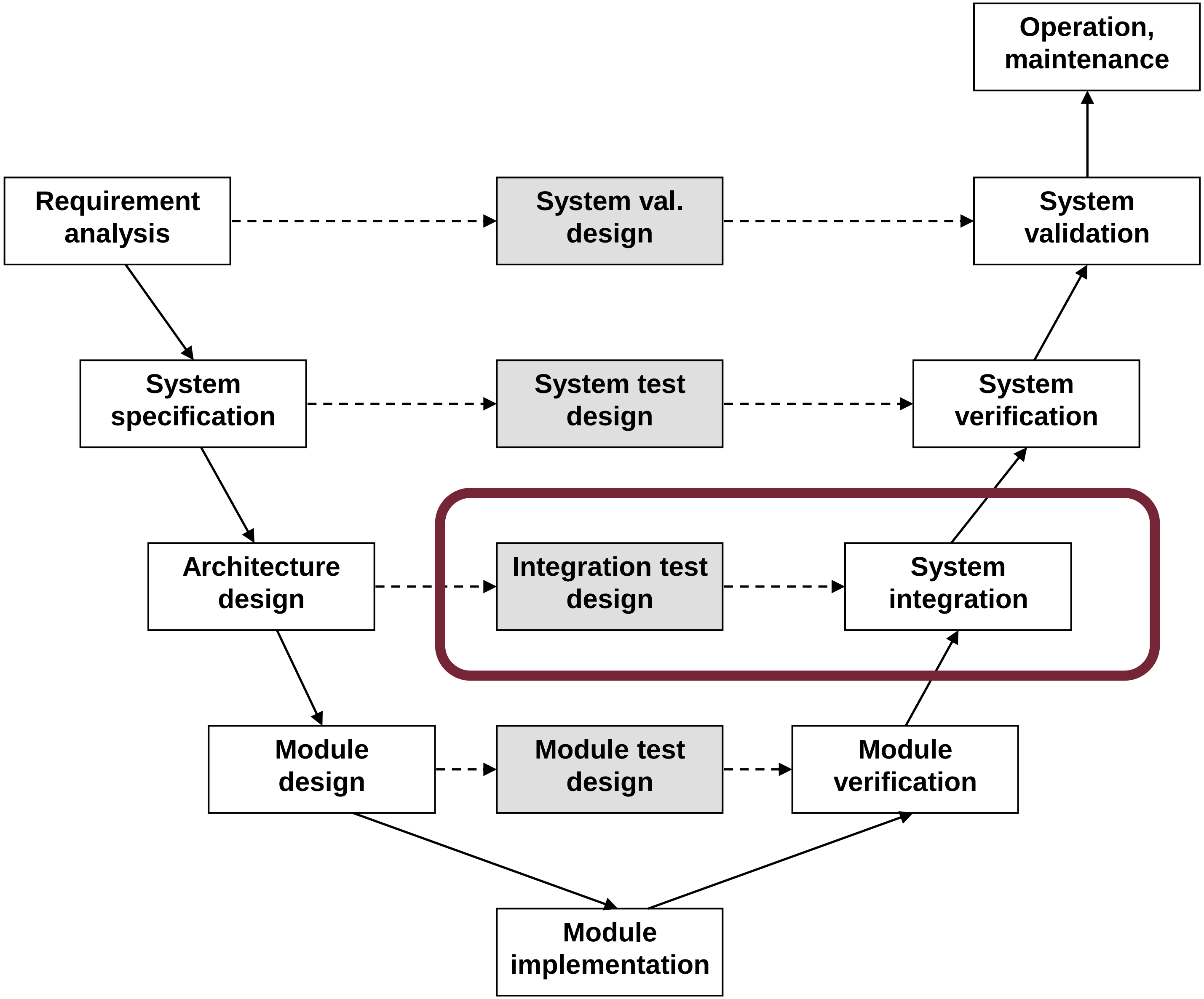
Operation, maintenance

Testing and test design in the V-model

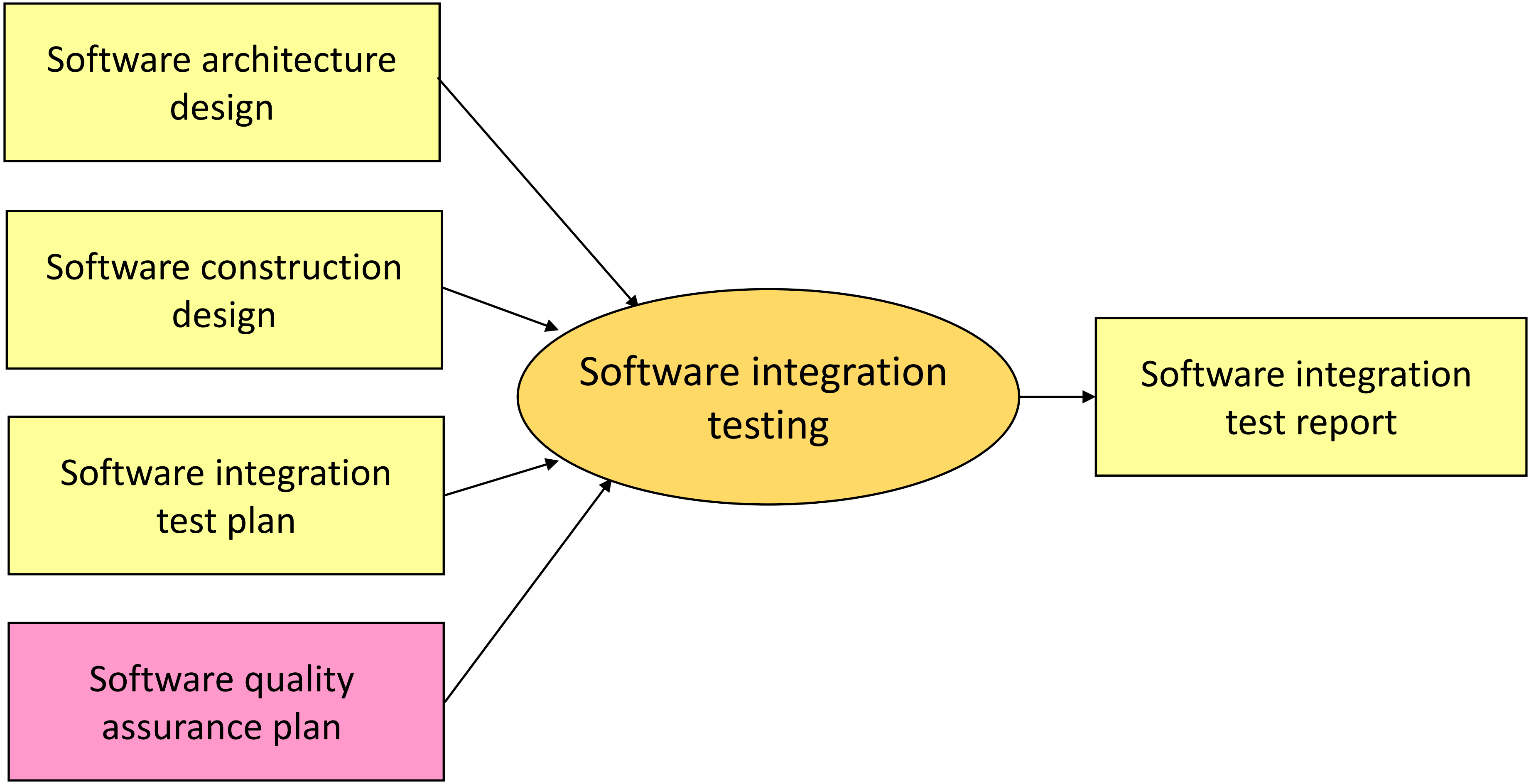


Integration testing

Testing and test design in the V-model



Software integration testing



Software architecture design

Software construction design

Software integration test plan

Software quality assurance plan

Software integration testing

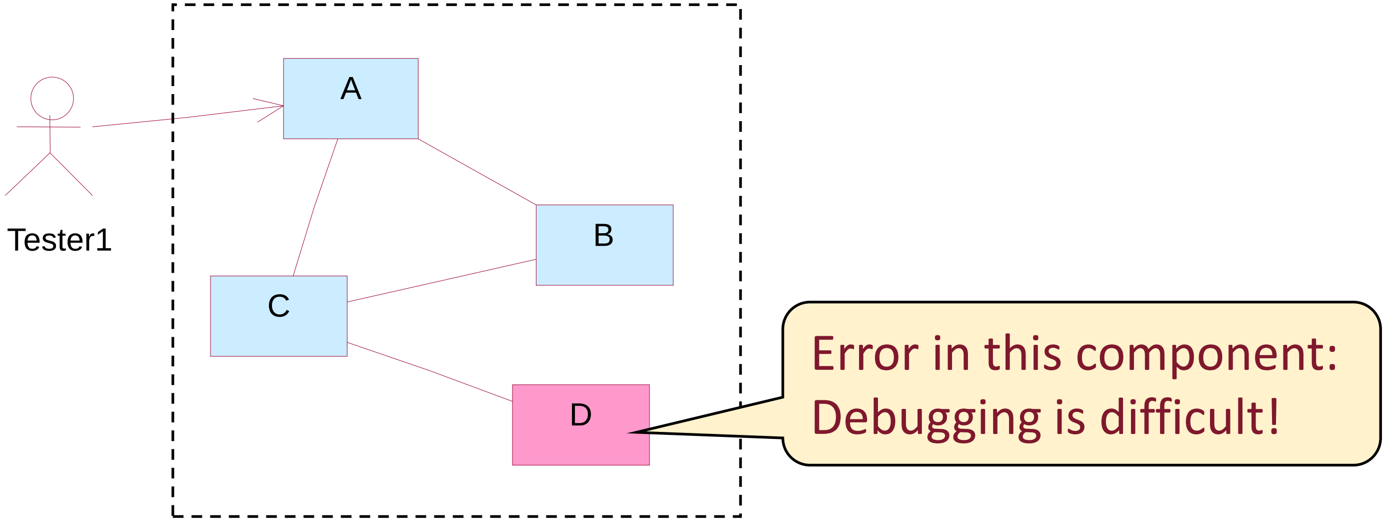
Software integration test report

Goals, methods and approaches

- Goal and motivation:
  - Testing the interactions of modules
  - The system-level interaction of modules may be incorrect despite the fact that all modules are correct
- Methods: Testing interaction scenarios
  - Sometimes the scenarios are part of the specification
  - Systematic testing: Covering all / representative scenarios
  - The concept of equivalence partitions and boundary values applied for interactions (scenario / input data level)
- Approaches
  - “Big bang” testing: integration of all modules before testing
  - Incremental testing: stepwise integration + testing

"Big bang" testing

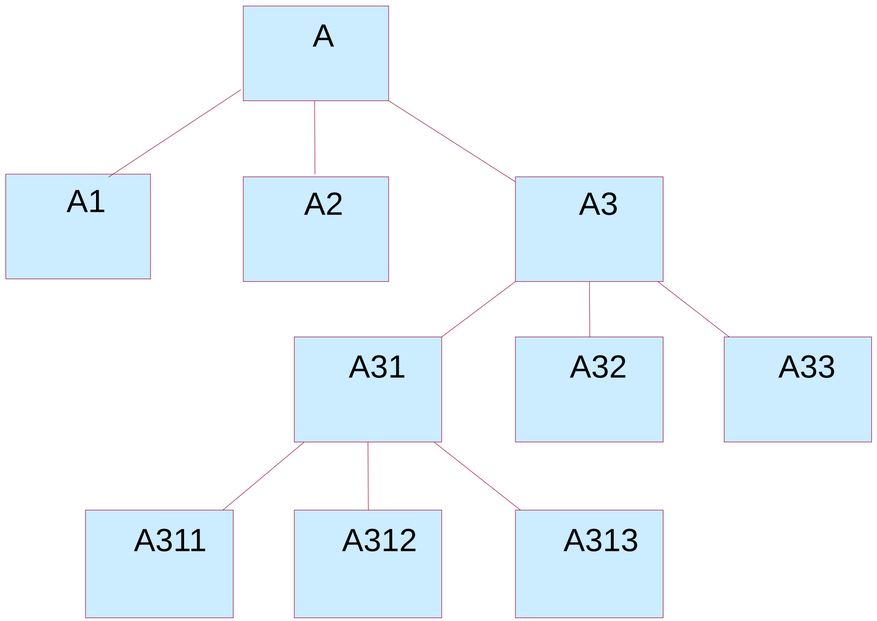
- Integration of all modules then testing using the external interfaces of the integrated system
- External test driver
- Based of the functional specification of the system
- To be applied only in case of small systems

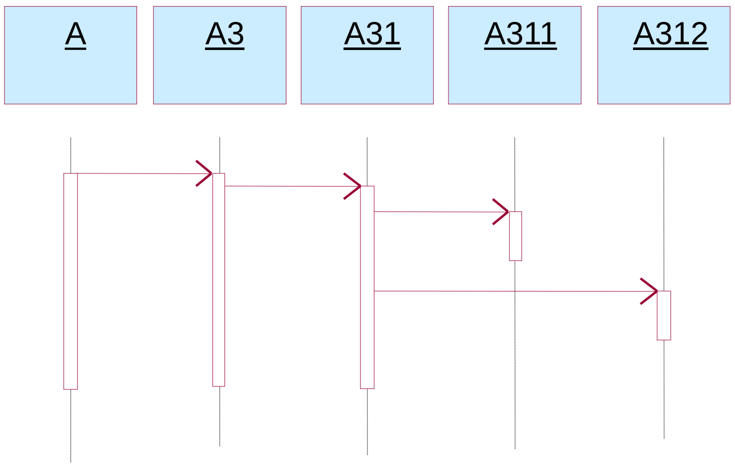


Error in this component: Debugging is difficult!

Incremental integration and testing

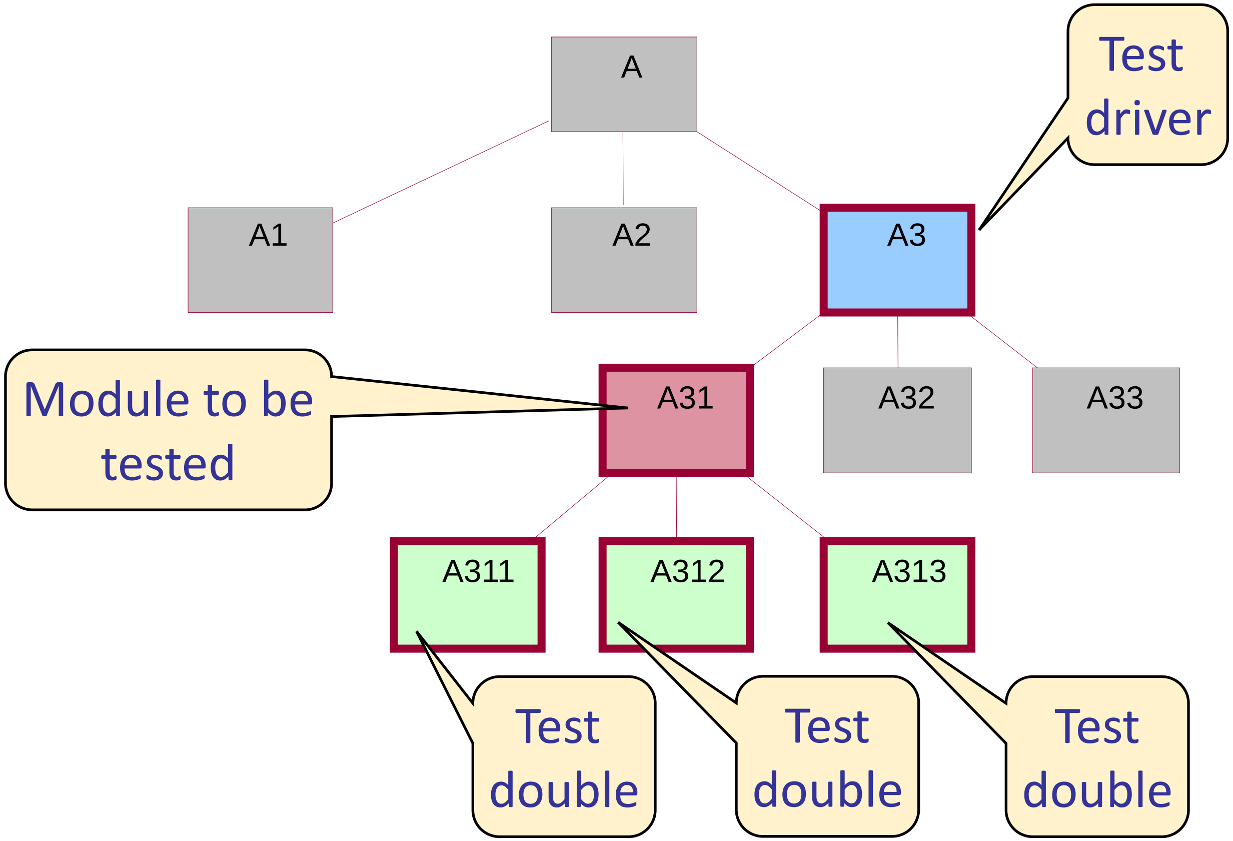
- Applied in case of complex systems
- Adapted to module hierarchy (calling levels)





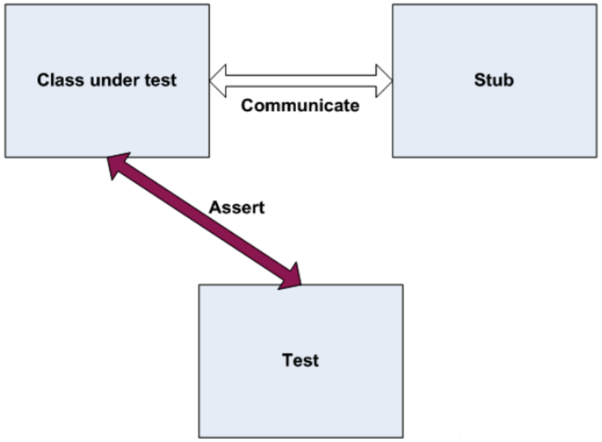
Module testing: Isolation of modules

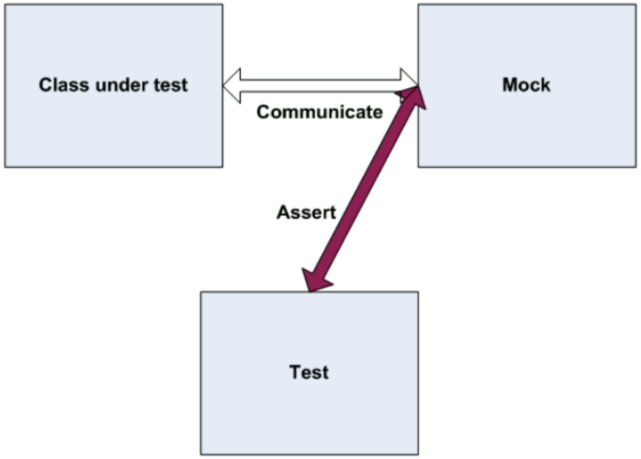
- Modules are tested in isolation
- Test drivers and test doubles (used for substitution w.r.t dependencies)
- Dependency: Anything collaborating with the SUT (does not belong to it)



General problem: Handling dependencies

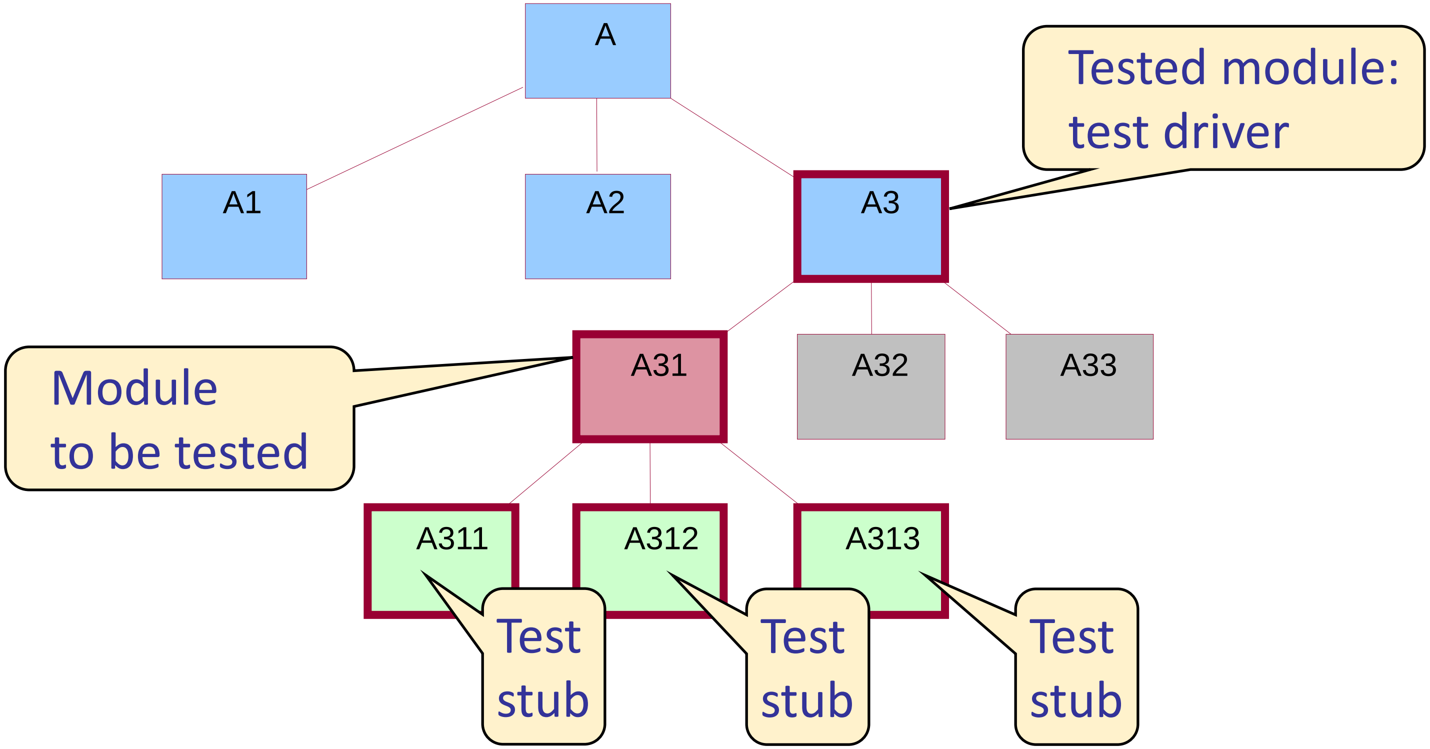
- Several approaches for substituting dependencies
  - Isolation frameworks (e.g., Mockito, JMock, …)
  - Test double: Generic name of substitute
- Stub
  - Predefined replies to calls
  - Checking the state of the SUT
- Mock
  - Expected and checked behavior
  - Checking the interactions of the SUT (number of calls, with parameters …)
- Dummy
  - Not used component (just "filler")
- Fake
  - Working component, but not the real one





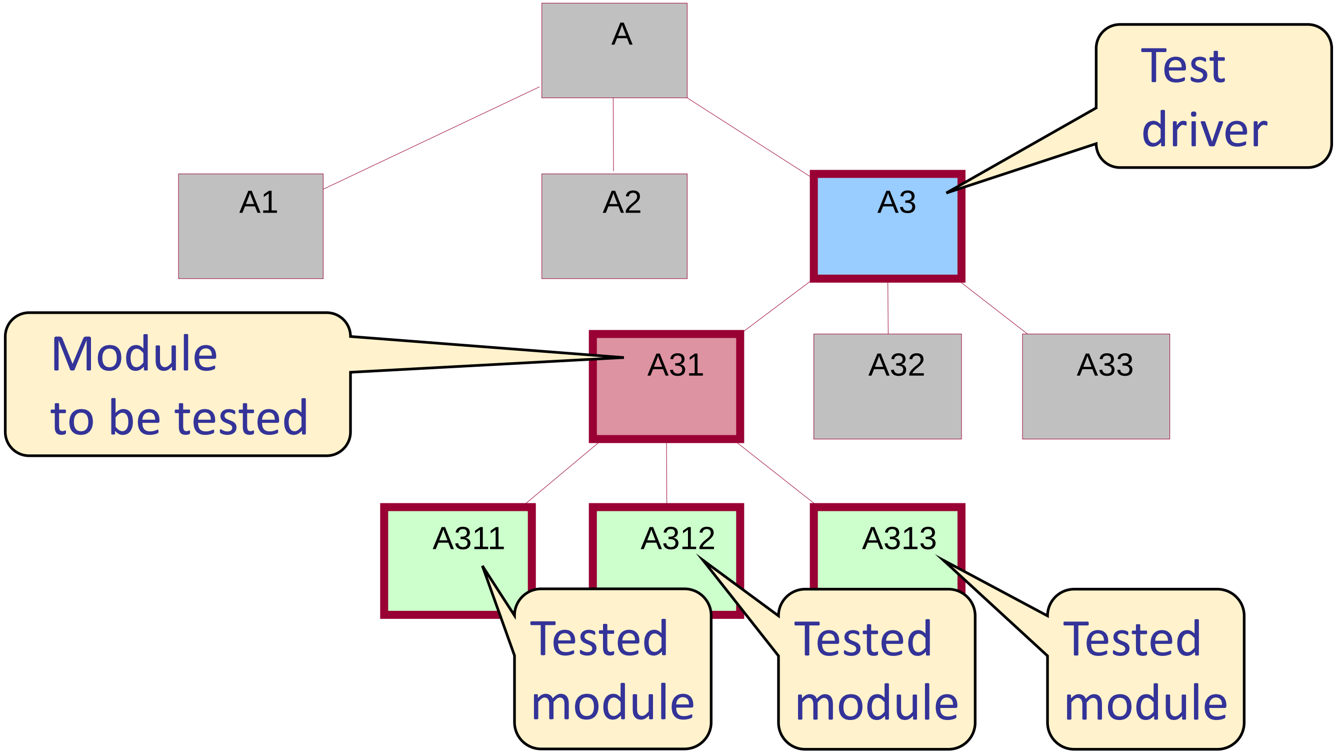
Top-down integration testing

- Modules are tested from the caller modules
- Stubs replace the lower-level modules that are called
- Requirement-oriented testing
- Module modification: modifies the testing of lower levels



Bottom-up integration testing

- Modules use already tested modules
- Test executor is needed
- Testing is performed in parallel with integration
- Module modification: modifies the testing of upper levels



Top down vs. bottom up testing

- Top down

  + Requirement oriented

  + Working “skeleton” is available and tested early

  - Harder to create stubs than drivers

- Bottom up

  + Integration oriented, more constructive

  + Easier to control and observe the subsystems

  - System is assembled only at the end

Functional integration

- Motivation:
  - There are several system-level functions
  - Priorities among these regarding criticality
    → prioritizing testing
- Basic idea:
  - Integration on the basis of system functions
  - Each function is integrated and tested in a top-down way

→ Specific case of top-down integration testing

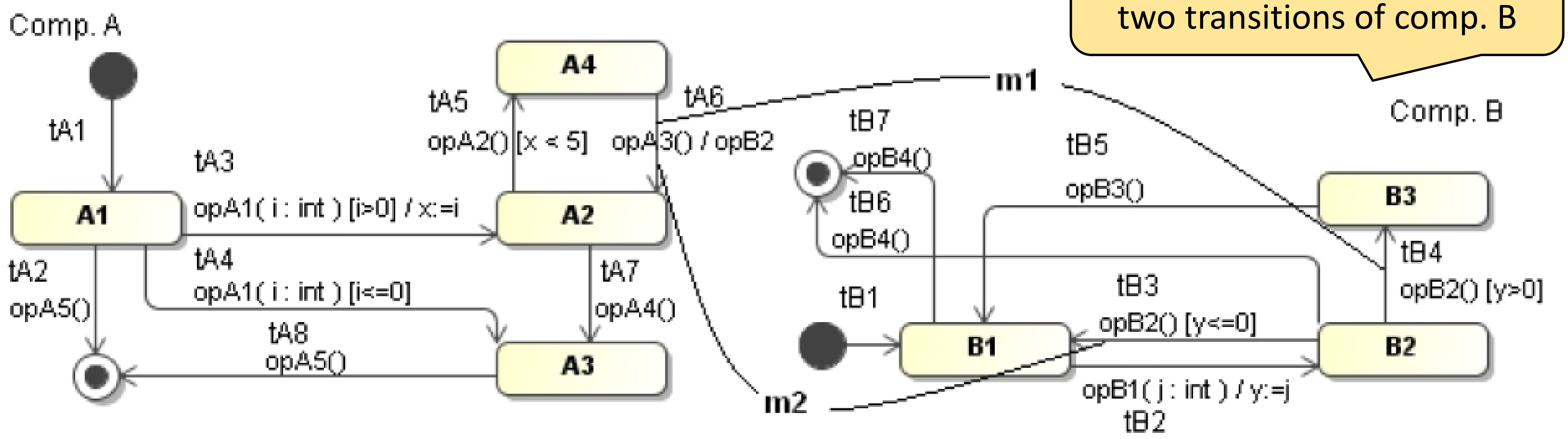
- Requirement oriented (w.r.t. the given function)
- Test doubles (stubs) are needed
- Top level is tested with more and more functions
- Module modification: modifies the testing of lower levels

Integration with the runtime environment

- Motivation:
  - It is hard to construct stubs for the runtime environment
  - See e.g., platform services, RT-OS, task scheduler, …
- Strategy:
  1. Top-down integration of the application modules down to the level of the runtime environment
  2. Bottom-up testing of the runtime environment
     - Isolation testing of functions (if necessary)
     - Testing with the lowest level of the application module hierarchy
  3. Integration of the application with the runtime environment, finishing top-down integration

Coverage metrics: State based approach

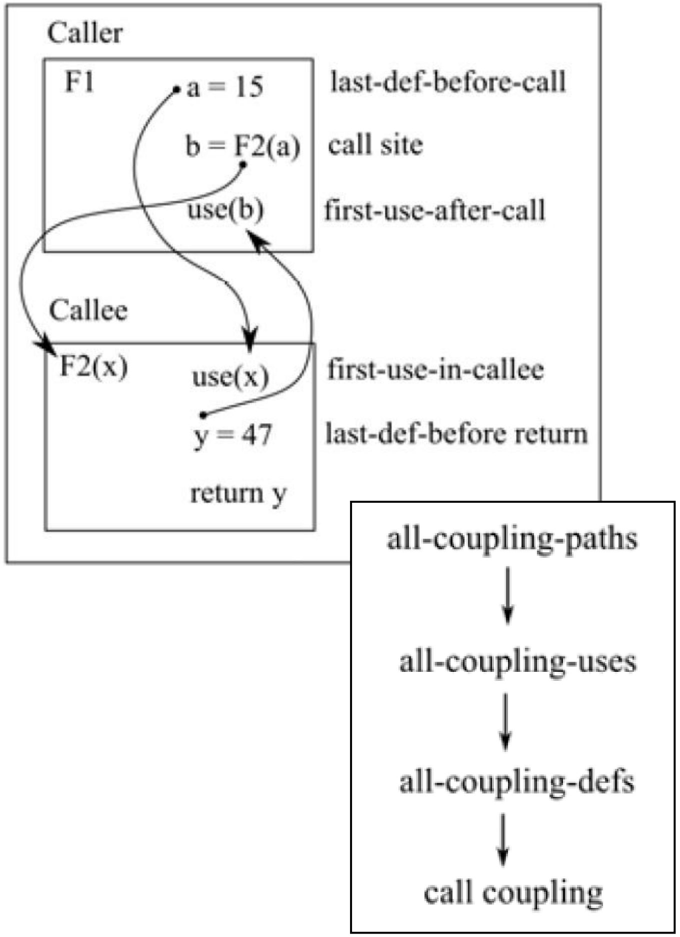
- Goal: Coverage of interactions among modules
  - Basic case: Coverage of interface functions (by calls)
- State based coverage metrics:
  - Coverage of interface functions for all relevant states (or transitions) of the caller and the called module
  - Extension: With all triggers and conditions for the call



opB2() call can be served by two transitions of comp. B

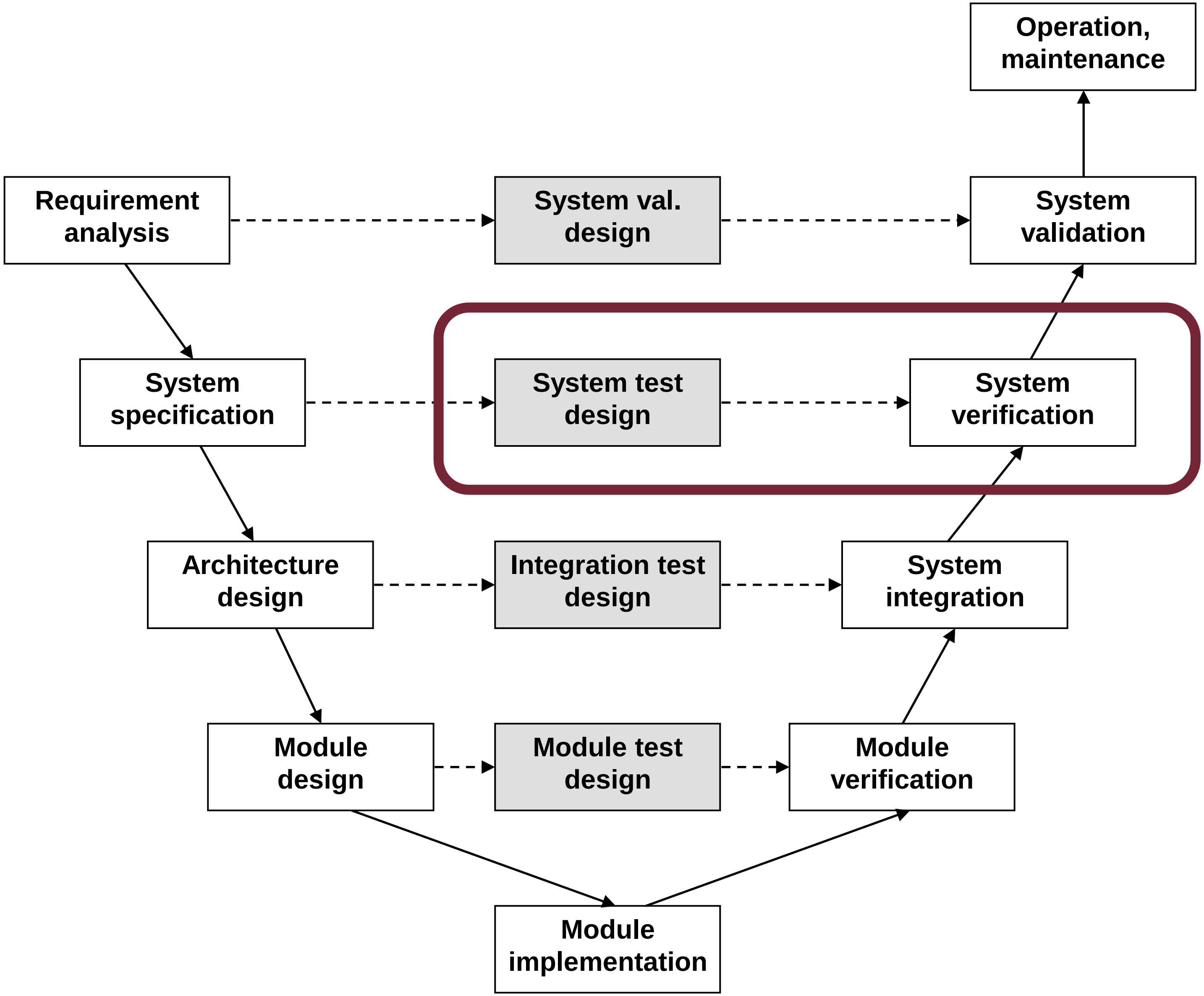
Coverage metrics: Data flow based approach

- Data flow based metrics:
  - Coverage extended for coupling paths (among function calls and returns)
    - Applying def-use labels
  - Coverage metrics:
    - All-coupling-defs
    - all-coupling-uses
    - all-coupling-paths
- Testing robustness of interfaces
  - Extreme and boundary values of call parameters
  - Mutating call scenarios (omission, duplication, change of ordering, extreme parameters etc.)



System testing

Testing and test design in the V-model

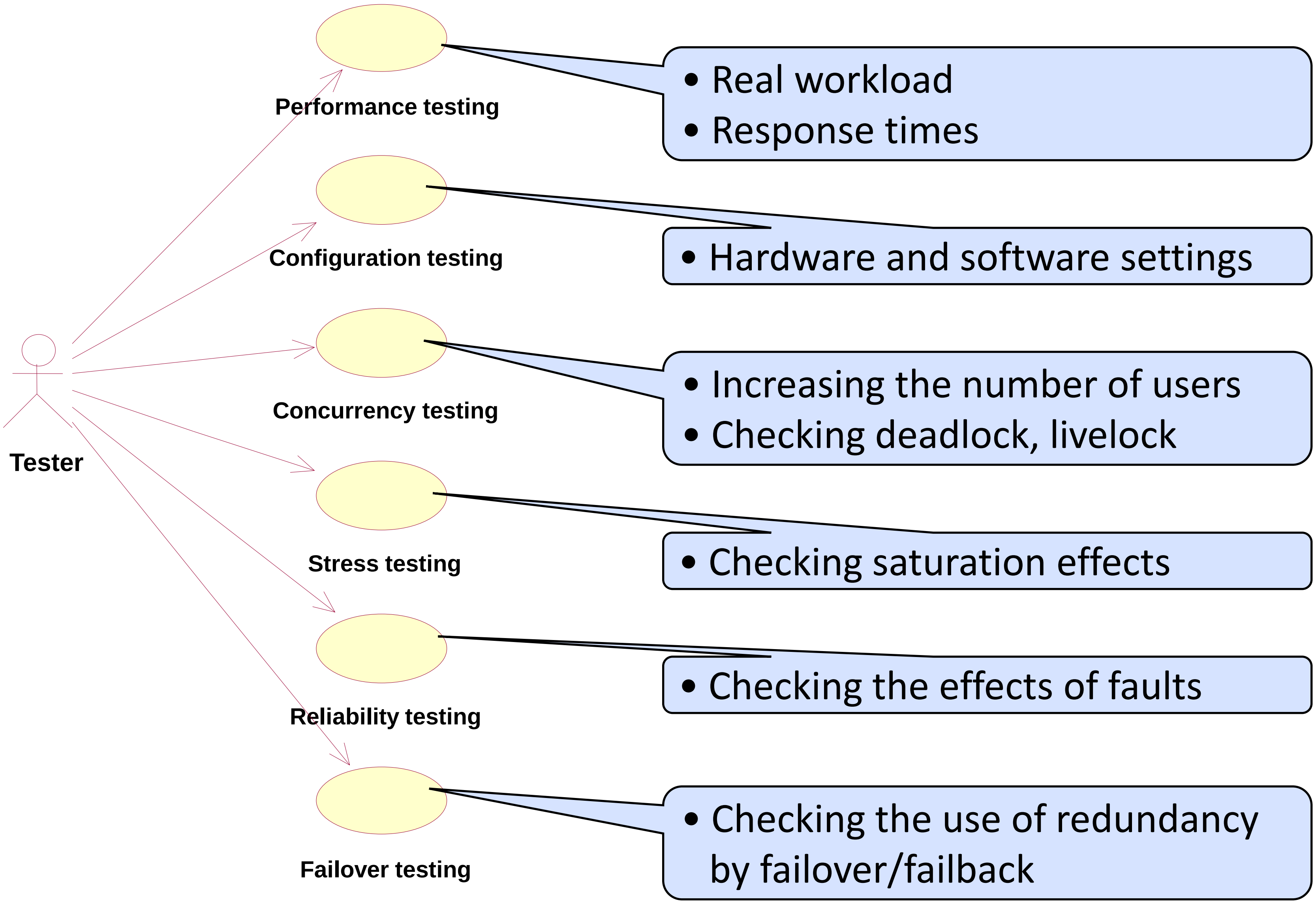


System testing

Testing on the basis of the system specification

- Characteristics:
  - Performed after hardware-software integration
  - Testing functional specification + testing extra-functional properties
- Testing aspects:
  - User workload (according to user profile)
  - Checking application conditions of the system (resource usage, saturation)
  - Testing fault handling
  - Data integrity
  - … (depending on the system specification)

Types of system tests (examples)



Tester

Performance testing
- Real workload
- Response times

Configuration testing
- Hardware and software settings

Concurrency testing
- Increasing the number of users
- Checking deadlock, livelock

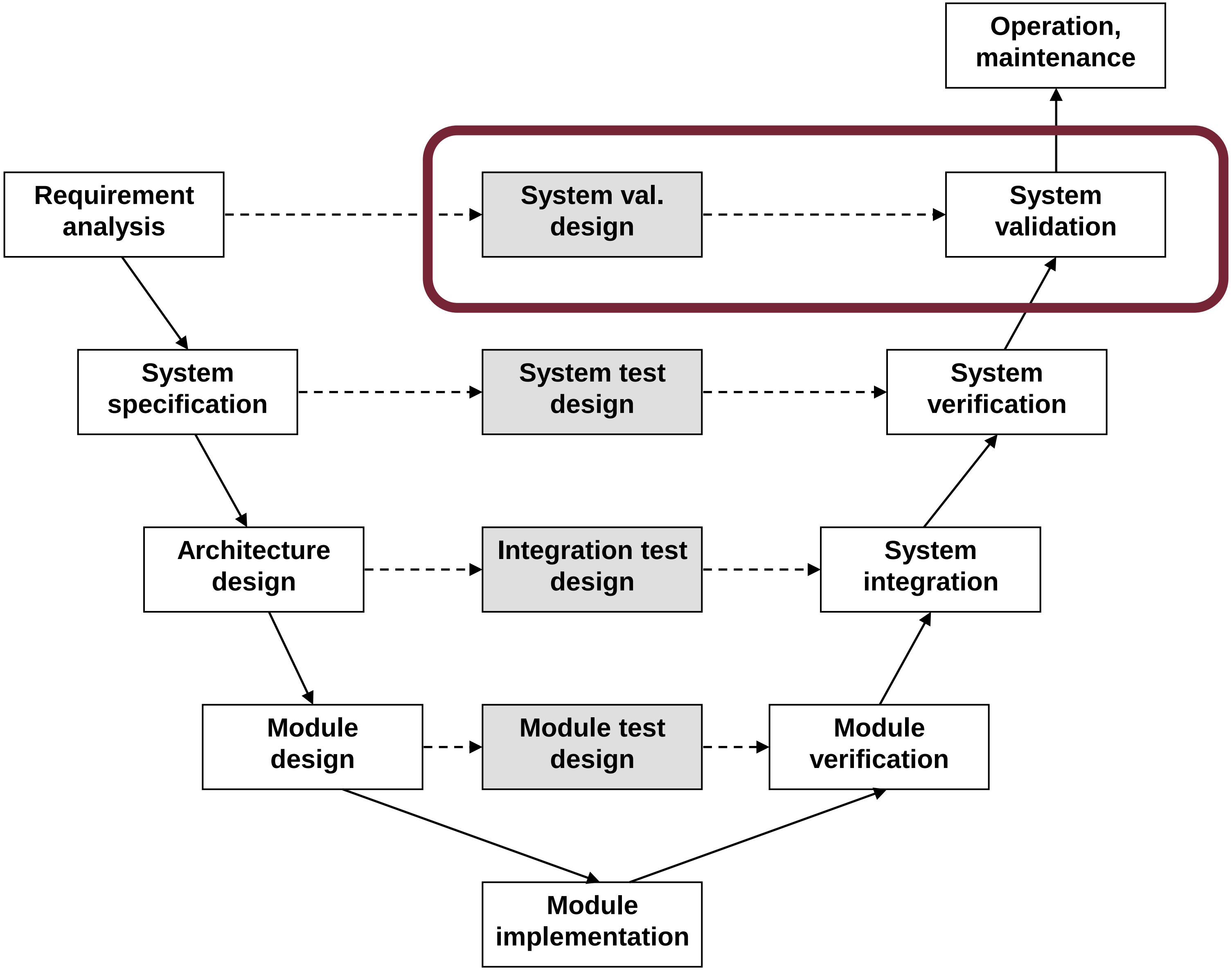
Stress testing
- Checking saturation effects

Reliability testing
- Checking the effects of faults

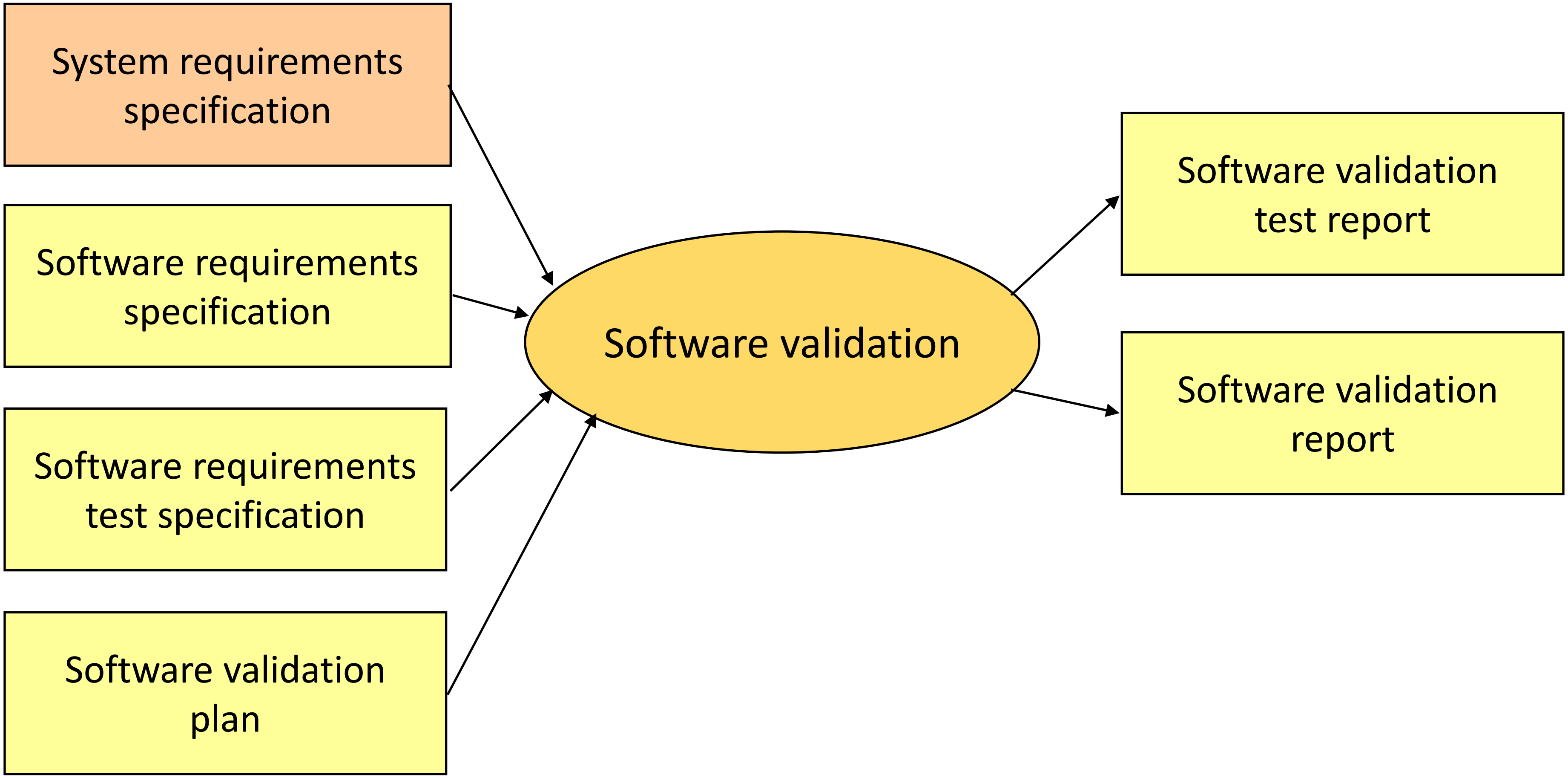
Failover testing
- Checking the use of redundancy by failover/failback

Validation testing

Testing and test design in the V-model



Software validation


System requirements specification
Software requirements specification
Software requirements test specification
Software validation plan
Software validation
Software validation test report
Software validation report

Validation testing

- Goal: Testing in real environment
  - User requirements and expectations are taken into account
  - Non-specified expectations may come up
  - Reaction to unexpected inputs/conditions is checked
  - Events of low probability may appear
- Timing aspects
  - Constraints and conditions of the real environment
  - Real-time testing and monitoring is needed
- Environment simulation
  - If given situations cannot be tested in a real environment (e.g., protection systems)
  - Simulators shall be validated somehow

Summary: Testing levels

1. Module (unit) testing
   - Isolation testing
2. Integration testing
   - (”Big bang” testing)
   - Top-down testing
   - Bottom-up testing
   - Functional integration
   - Integration with the runtime environment
3. System testing
   - Testing the integrated system
4. Validation testing
   - Testing user expectations in the real environment
   - Environment simulation

Design and documentation of testing

Standard test documentation (IEEE 829:1998)

Standard for Software Test Documentation

Test planning:

- Test Plan: What is tested, by whom, how, in what time frame, to what quality
  SPACEDIRT: Scope, People, Approach, Criteria, Environment, Deliverables, Incidentals, Risks, Tasks

Test specification:

- Test Design Specifications: Test conditions, expected outcome, what is a successful test
- Test Case Specifications: The specific test data (test suites)
- Test Procedure Specifications: What kind of physical set-up is required, how the tester runs the test, what steps need to be followed

Test reporting

- Test Item Transmittal Report: When specific tested items are passed from one stage of testing to another
- Test Log: What tests cases were run, by whom, in what order, and whether individual tests were passed or failed
- Test Incident Report: Details of test failure (when, why)
- Test Summary Report: Assessment about the quality of the system

Standard test documentation (IEEE 829:2008)

Standard for Software and System Test Documentation

Test planning:

- Master Test Plan (MTP): Overall test planning for multiple levels
- Level Test Plans (LTP): Scope, approach, resources, and schedule of the testing

Test design:

- Level Test Design (LTD): Test cases, the expected results, the test pass criteria
- Level Test Case (LTC): Specifying the test data for use in running the test cases
- Level Test Procedure (LTPr): How to run each test (preconditions and the steps)

Test reporting:

- Level Test Log (LTL): Record of relevant details about the execution
- Anomaly Report (AR): Events that occur during testing and require investigation
- Level Interim Test Status Report (LITSR): Summarize/evaluate interim results
- Level Test Report (LTR): Summarize/evaluate the results after test execution has finished for the specific test level
- Master Test Report (MTR): Summarize/evaluate the results of the levels

U2TP: UML 2 Testing Profile (OMG, 2004)

- Able to capture all needed information for functional black-box testing (specification of test artifacts)
  - With mapping rules to TTCN-3, JUnit
- Language (notation) and not a method (how to test)

Packages (concept groups):

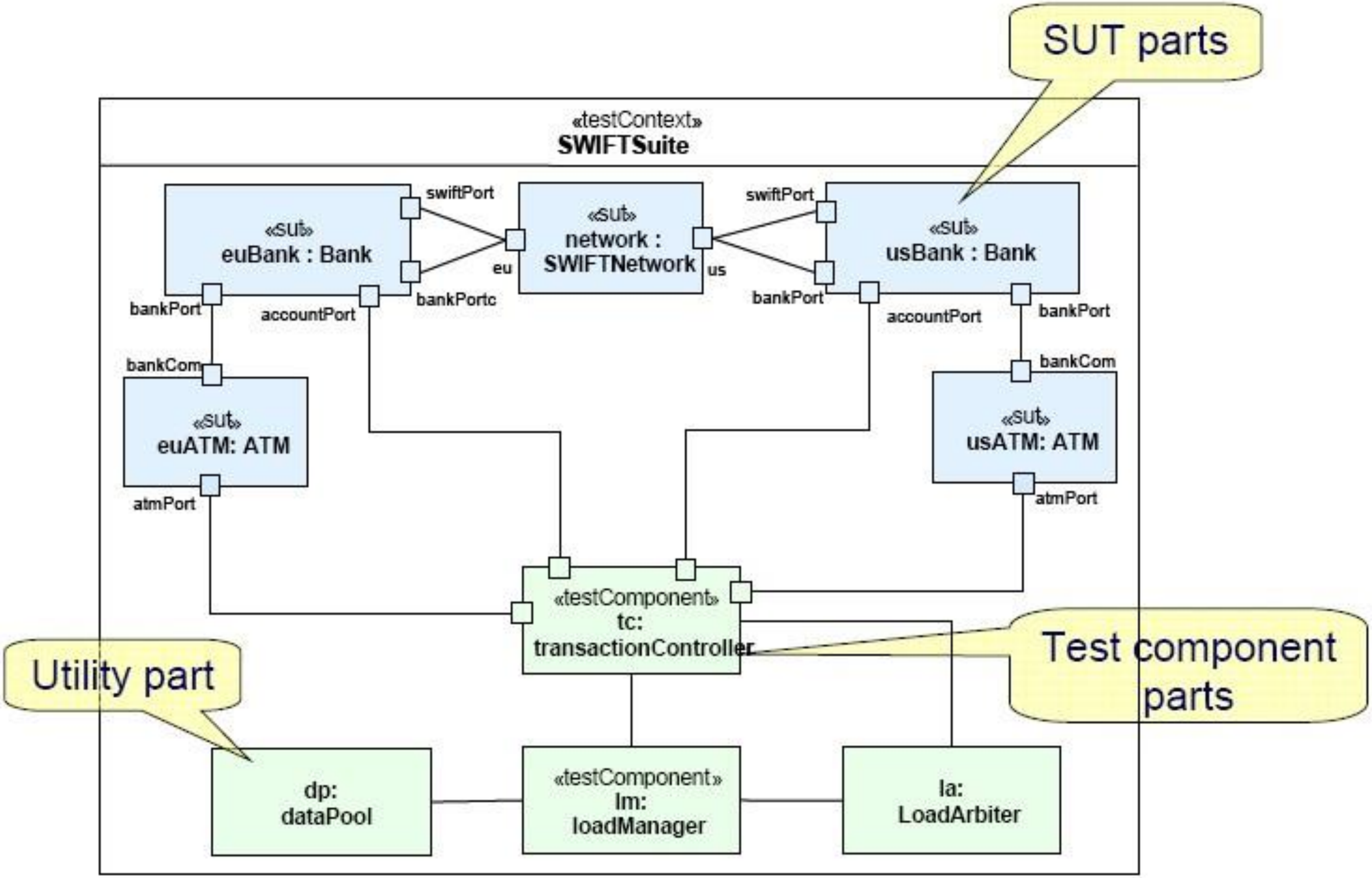
- Test Architecture
  - Components and relationship involved in test
  - Importing the UML design model of the SUT
- Test Data
  - Data structures and values to be processed in a test
- Test Behavior
  - Activities and observations during testing
- Time Concepts
  - Timer (start, stop, read, timeout), TimeZone (synchronized)

U2TP Test Architecture package

Identification of main components:

- SUT: System Under Test
  - Characterized by interfaces to control and observation
  - Can be: System, subsystem, component, object
- Test Component: Part of the test system (e.g., a simulator)
  - Realizes the behavior of a test case
    (Test Stimulus, Test Observation, Validation Action, Log Action)
- Test Context: Collaboration of test architecture elements
  - Initial test configuration (test components)
  - Test control (decision on execution, e.g., if a test fails)
- Scheduler: Controls the execution of test components
  - Creation and destruction of test components
- Arbiter: Calculation of final test results
  - E.g., threshold on the basis of test component verdicts

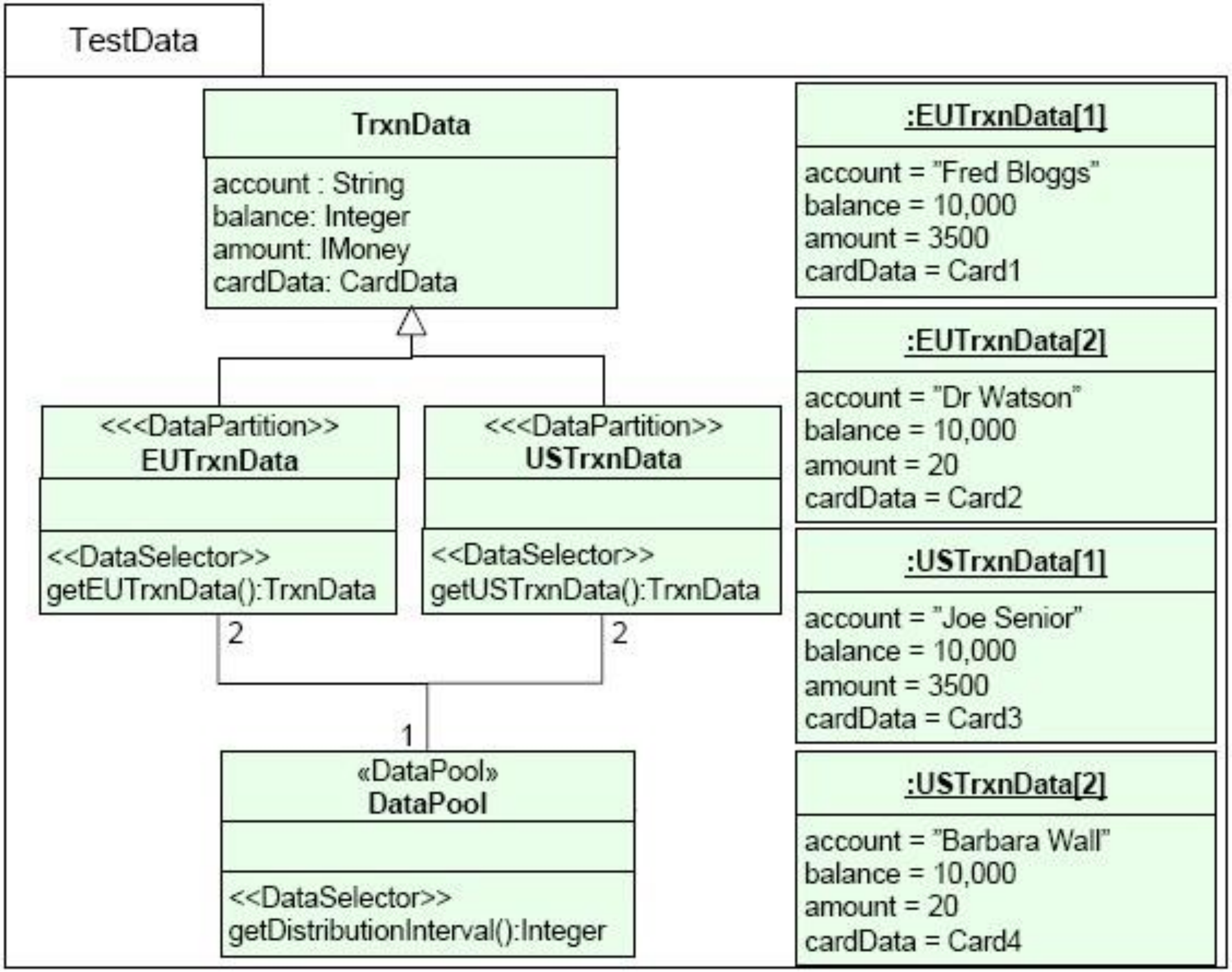
U2TP Test Architecture example



U2TP Test Data package

- Identification of types and values for test (e.g., sent and received data)
  - Wildcards (* or ?) can be used
  - Test Parameter
    - Stimulus and observation
  - Argument
    - Concrete physical value
  - Data Partition: Equivalence class for a given type
    - Class of physical values, e.g., valid names
  - Data Selector: Retrieving data out of a data pool
    - Operating on contained values or value sets
  - Templates

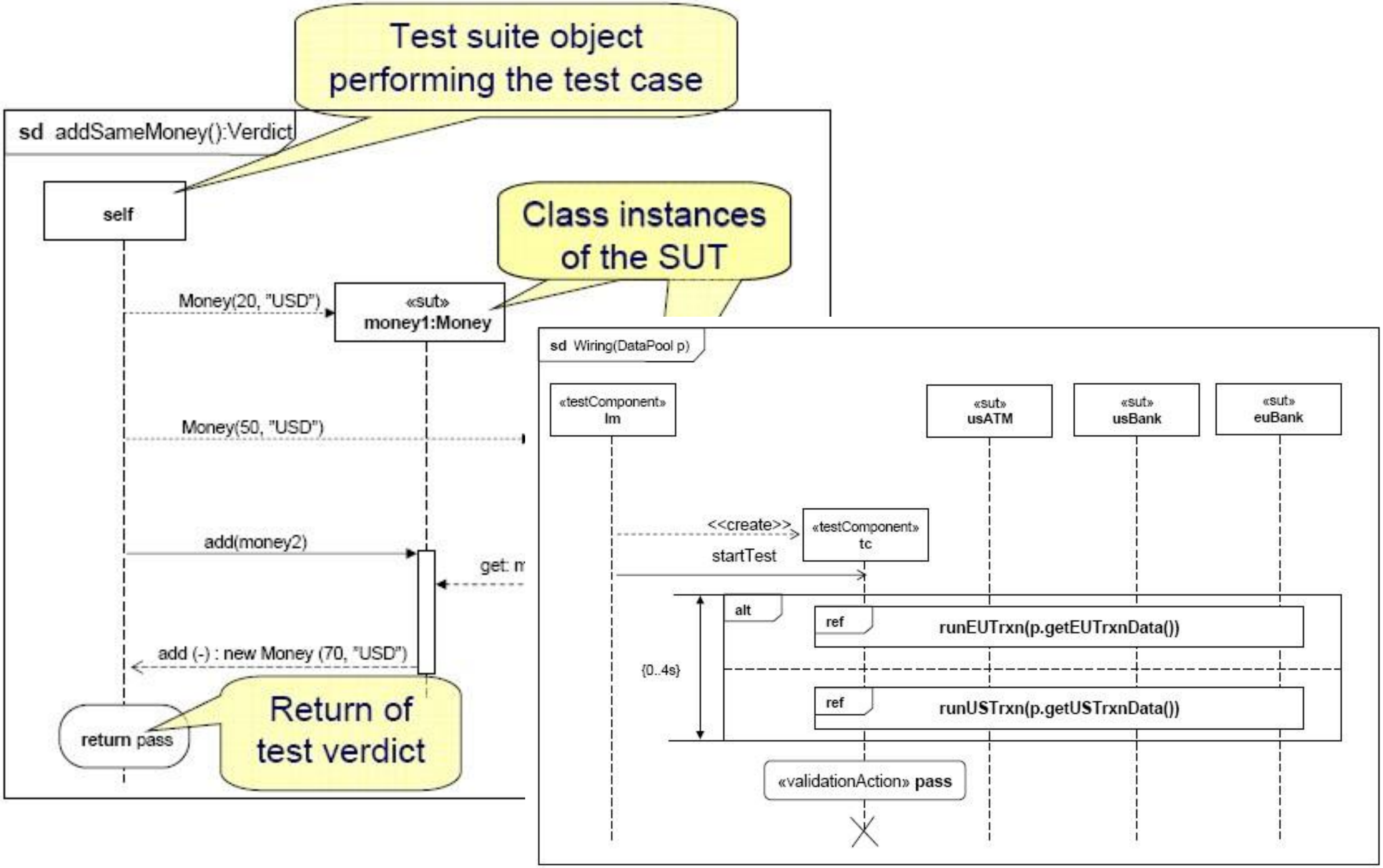
U2TP Test Data example



U2TP Test Behavior package

- Specification of default/expected behavior
- Identification of behavioral elements:
  - Test Stimulus: Test data sent to SUT
  - Test Observation: Reactions from the SUT
  - Verdict: Pass, fail, error, or inconclusive
  - Actions: Validation Action (inform Arbiter), Log Action
- Test Case: Specifies one case to test the SUT
  - Test Objective: Named element
  - Test Trace: Result of test execution
    - Messages exchanged
  - Verdict

U2TP Test Behavior example



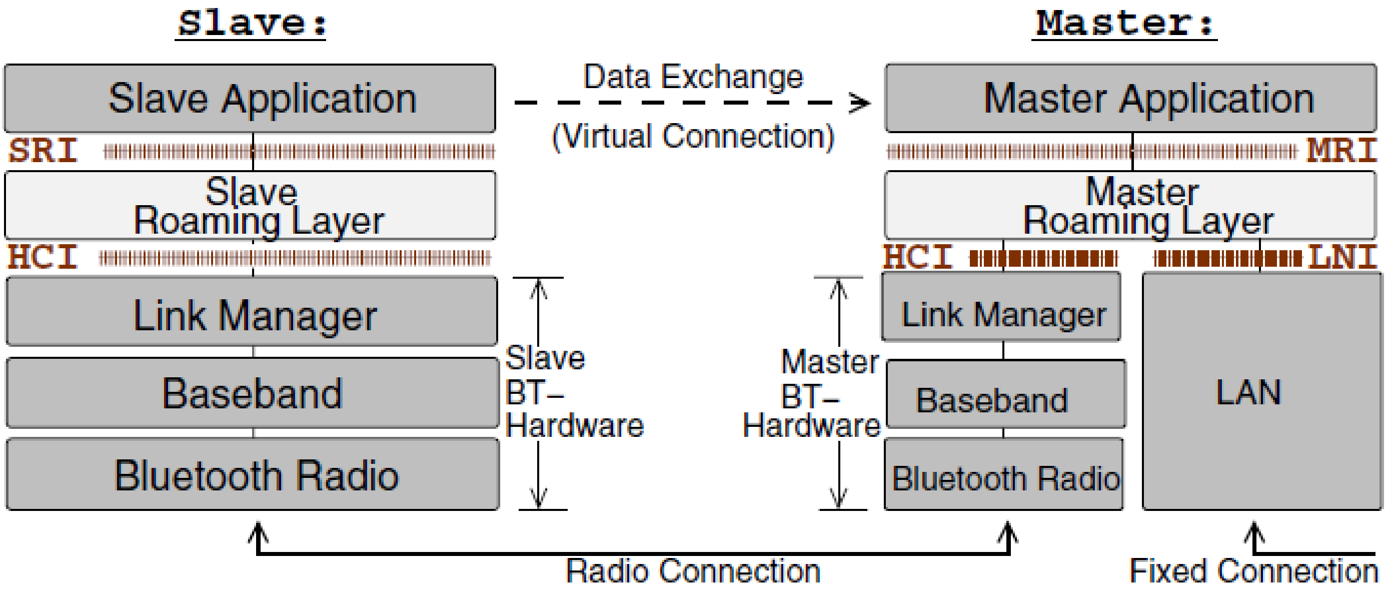
Test suite object performing the test case

Class instances of the SUT

Return of test verdict

Example: BlueTooth roaming

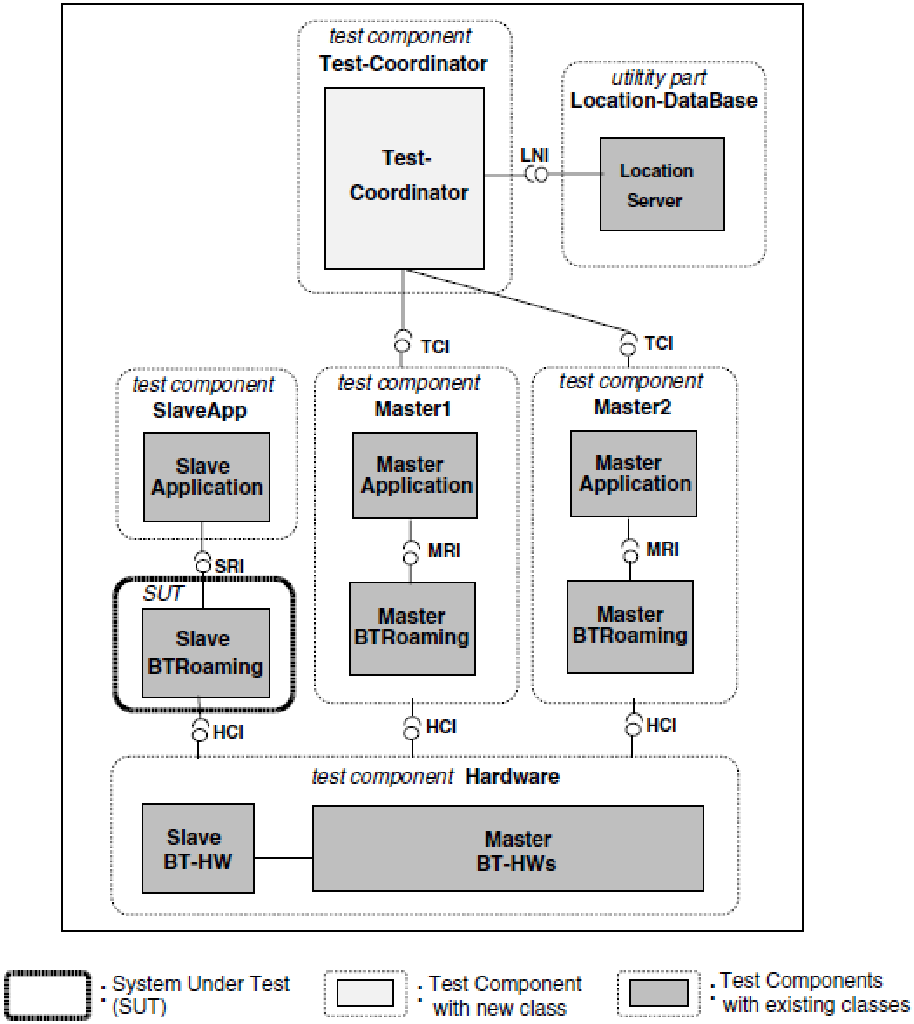
System under test:



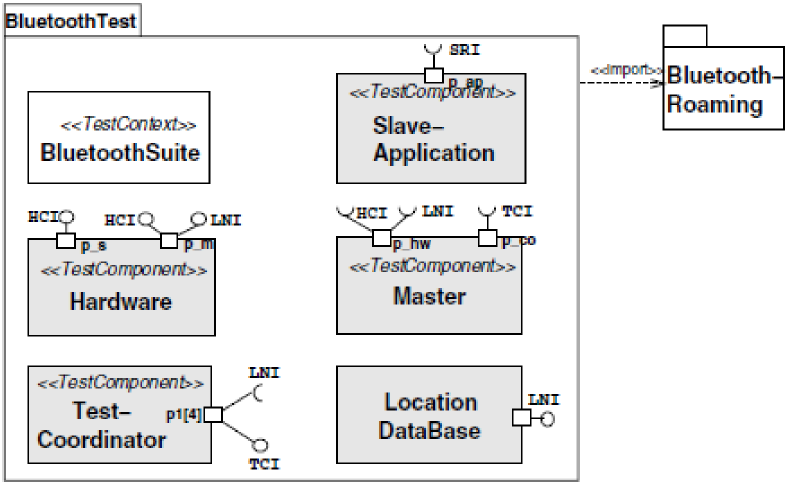
Test objective:

- Slave Roaming Layer functionality
  - Monitoring link quality
  - Connecting to a different master

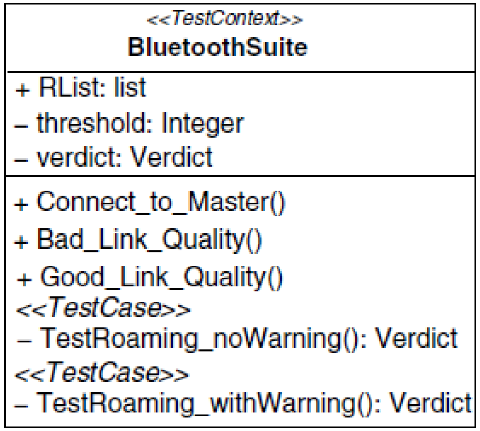
Example: Components



Overview



Test package



<<TestContext>>

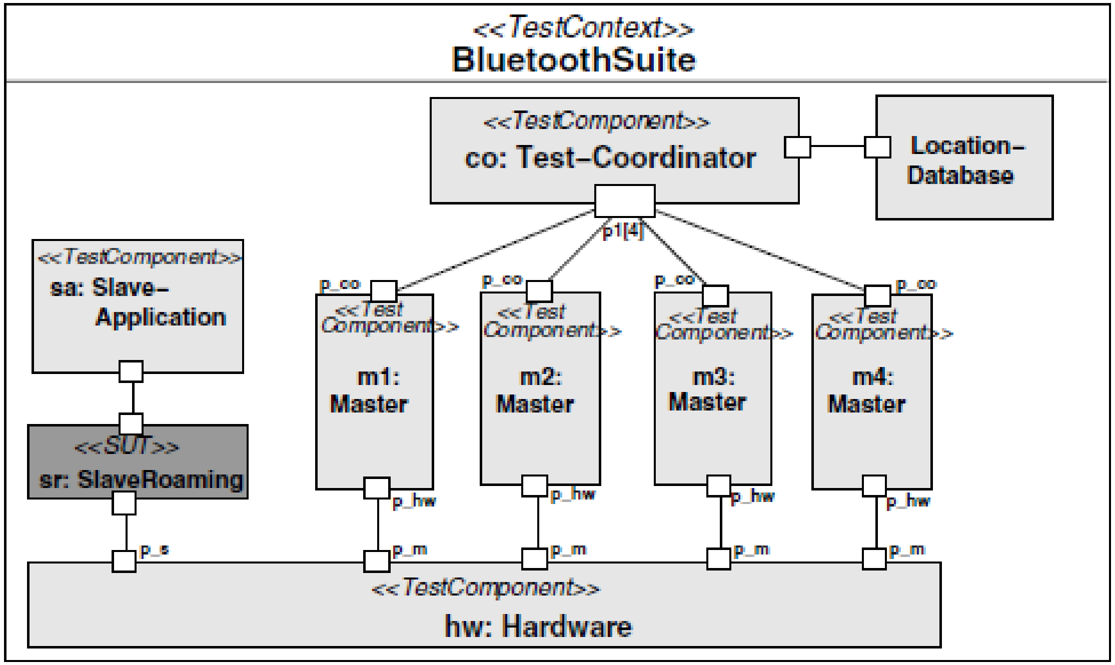
BluetoothSuite

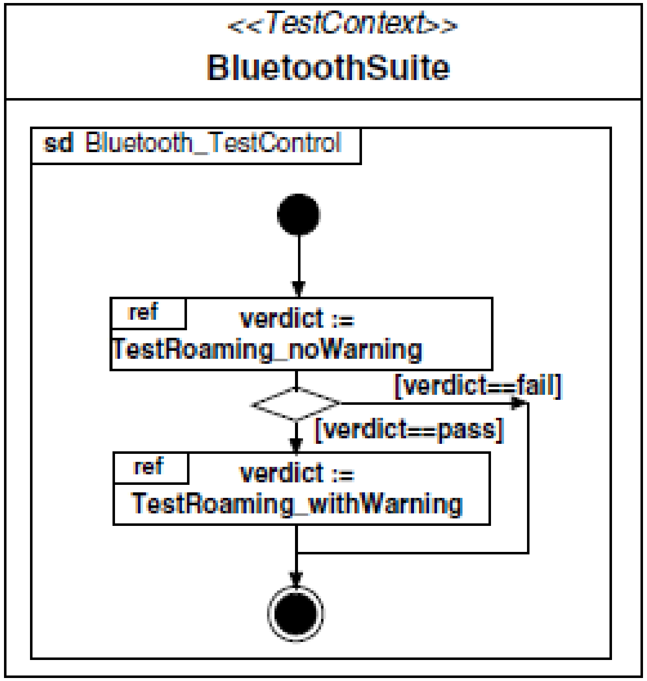
+ RList: list
– threshold: Integer
– verdict: Verdict

+ Connect_to_Master()
+ Bad_Link_Quality()
+ Good_Link_Quality()
<<TestCase>>
– TestRoaming_noWarning(): Verdict
<<TestCase>>
– TestRoaming_withWarning(): Verdict

Test context

Example: Test configuration and control





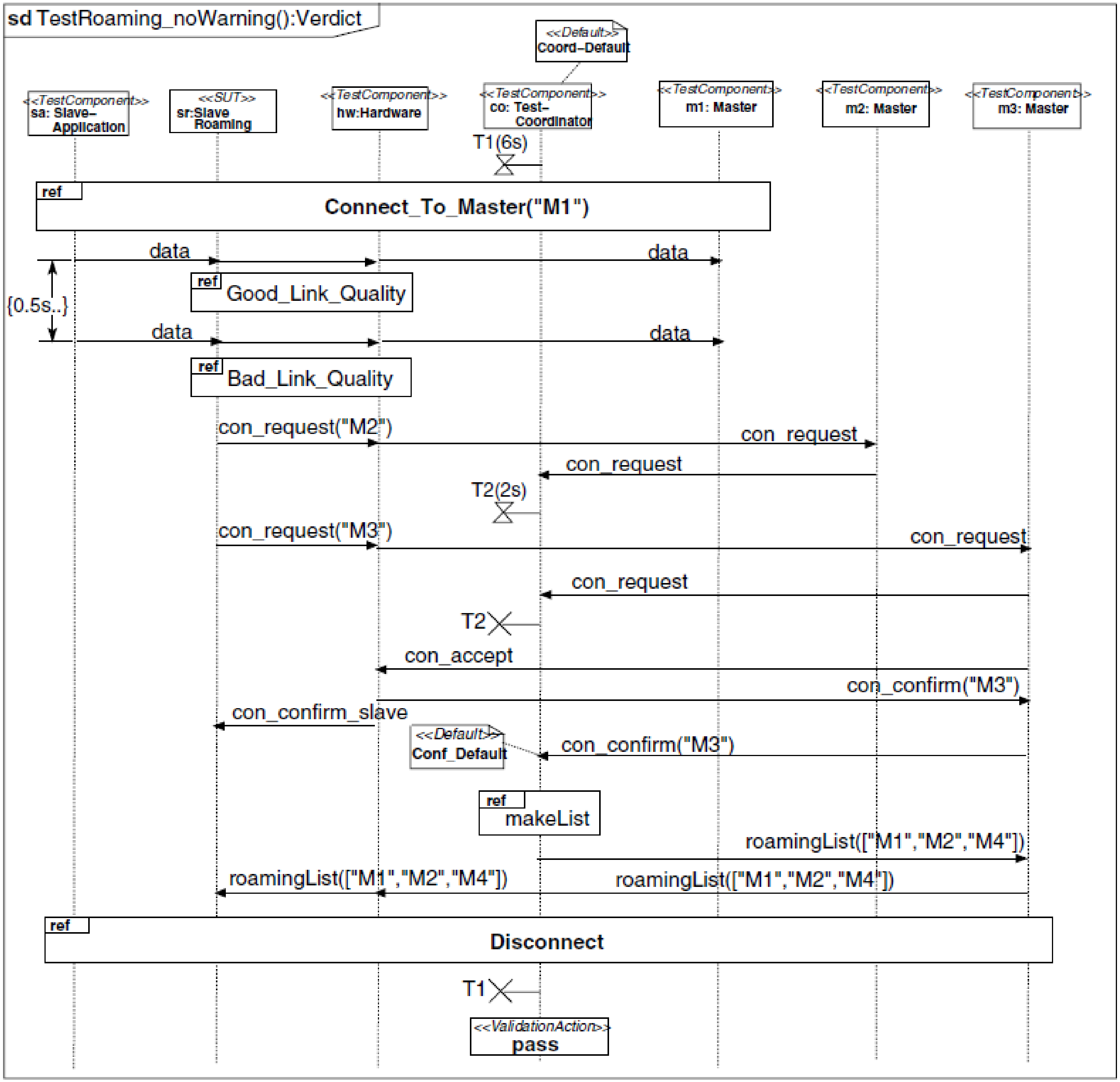
Test configuration

Test control

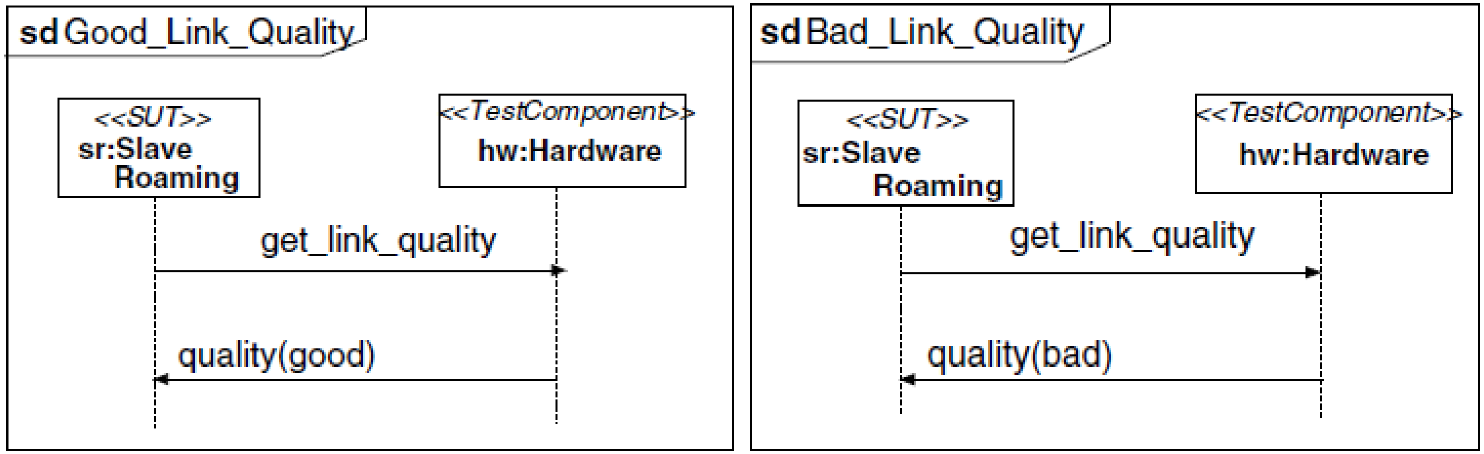
Example: Test scenario

Test case implementation (see BlueToothSuite)

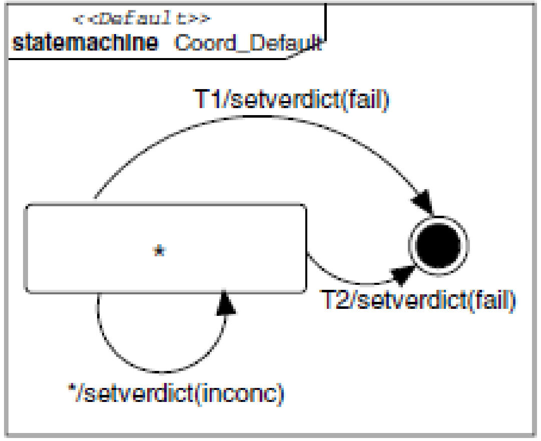
- References
- Timers
- Defaults



Test scenarios (details)



Sequence diagrams



Default behaviors specified to catch the observations that lead to verdicts

- Here: Processing timer events