The UML Testing Profile

- Tutorial at the ECOOP 2004 -

www.fokus.fraunhofer.de/u2tp

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Agenda

- Motivation
- Basics of Testing
- Overview of the UML Testing Profile
- Example Test Specifications
- The UML Profile and the MOF Model
- The Mappings
- Concluding Remarks

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The Problem

- Software
  - Increases in complexity, concurrency, and dynamics
  - Quality is key
    - Functionality
    - Performance
    - Scalability
    - Reliability
    - Usability
    - Efficiency
    - Maintainability
    - ...
- Testing is
  - Means to obtain objective quality metrics about systems in their target environment
  - Central means to relate requirements and specification to the real system

Testing Today

- Is
  - Important
  - Means to obtain approval
  - Time critical
- But often
  - Rarely practiced
  - Unsystematic
  - Performed by hand
  - Error-prone
  - Considered being destructive
  - *Uncool*

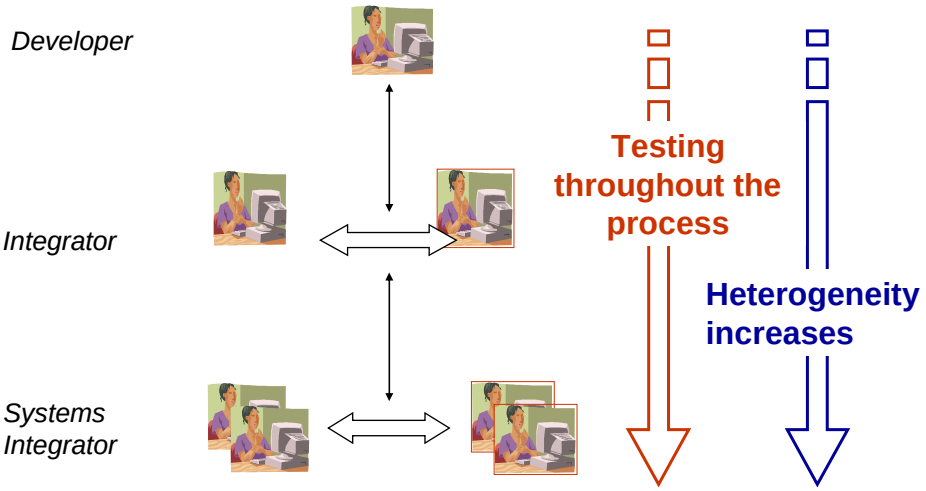
    „If you are a bad programmer you might be a tester“
- Conjecture:

  There is a lack of appropriate test methods and techniques

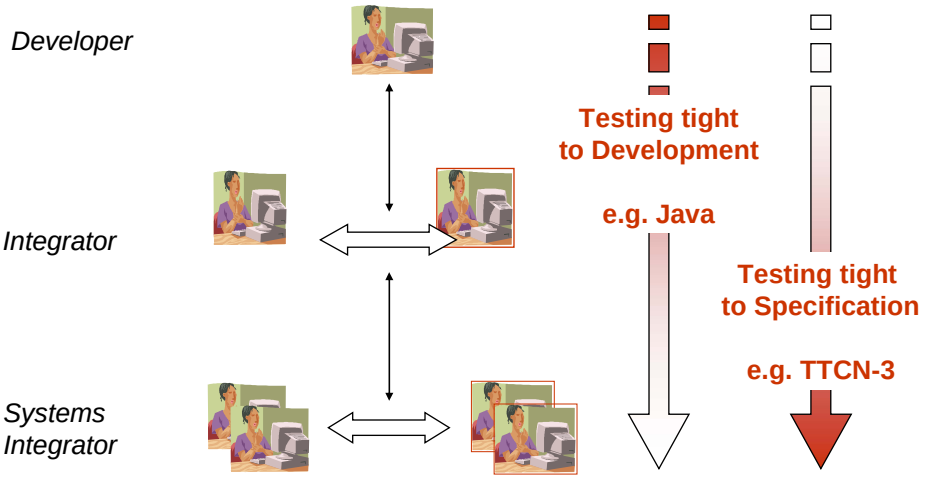
Testing is …

- A technical process
- Performed by experimenting with a system
- In a controlled environment following a specified procedure
- With the intent of observing one or more characteristics of the system
- By demonstrating the deviation of the system’s actual status from the required status/specification.

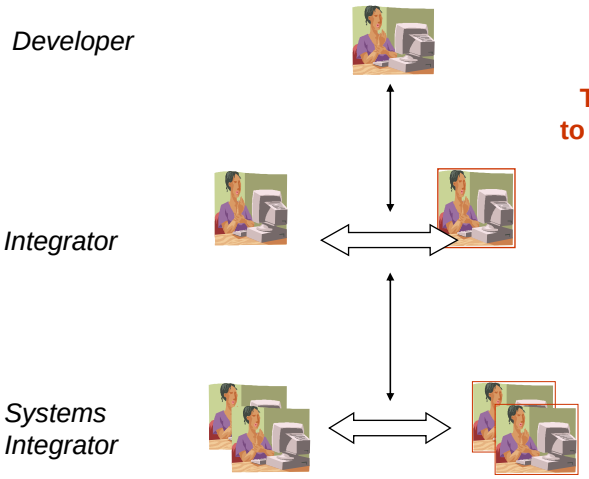
Integrated Development and Testing



Extreme View



Balanced View



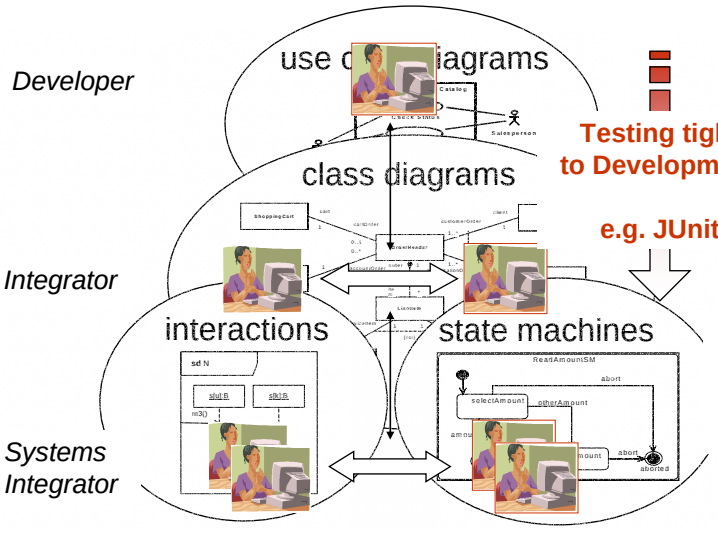
Testing tight to Development

e.g. JUnit

Testing tight to Services

e.g. TTCN-3

An Answer: Model-Based View



Testing tight to Development

e.g. JUnit

Testing tight to Specification

e.g. TTCN-3

UML and Testing

- UML-based test generation, e.g.
  - Integration testing, Siemens, 2000
  - Component test framework (TINA), FOKUS, 2000
  - Component testing (COTE), INRIA, 2001
- UML-based test notation, e.g.
  - Agedis, EC IST project
  - TeLa, COTE project
  - UML Testing Profile, OMG

UML and Testing

- Model Driven Architecture as new OMG strategy
  - One objective of UML 2.0 is executable UML meaning
    - Code generation
    - Simulation
    - Validation
    - Test generation
  - "..., the expanded role of the OMG must be built on rock-solid testing, certification and branding. …"

Goals of the UML Testing Profile

- Definition of a testing profile to capture all information that would be needed by different test processes
  - To allow black-box testing (i.e. at UML interfaces) of computational models in UML
- A testing profile based upon UML 2.0
  - That enables the test definition and test generation based on structural (static) and behavioral (dynamic) aspects of UML models, and
  - That is capable of inter-operation with existing test technologies for black-box testing
- Define
  - Test purposes for computational UML models, which should be related to relevant system interfaces
  - Test components, test configurations and test system interfaces
  - Test cases in an implementation independent manner

U2TP Partners

- A consortium of testers, UML vendors and users dedicated to make UML applicable for software testing

- Submitters
  - Ericsson
  - IBM
  - FOKUS
  - Motorola
  - Rational
  - Softeam
  - Telelogic
  - University of Lübeck
- Supporters
  - iLogix
  - ScapaTechnologies
  - IRISA

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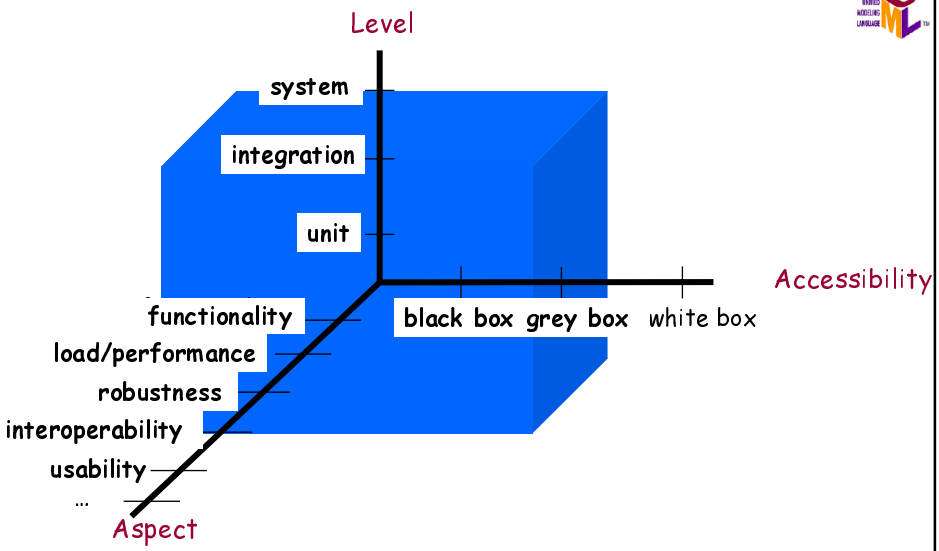
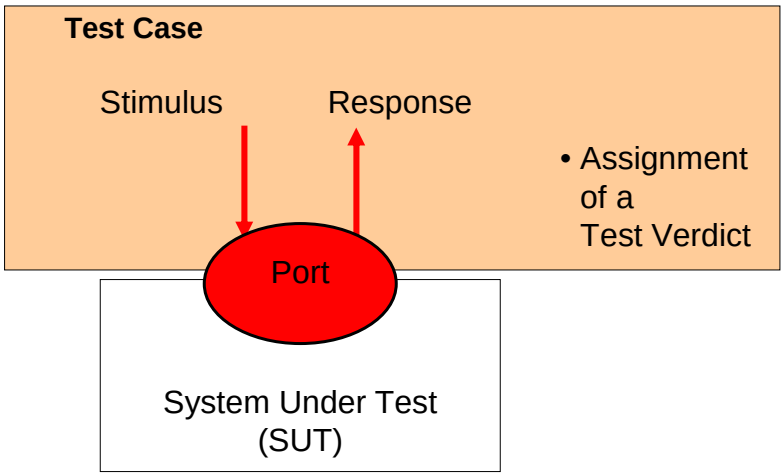
Types of Testing



Test Concepts: Black-Box Testing



Test Concepts: Local behavior

- Stimuli are given to the system under test (SUT) at well-defined interfaces
- Observations are taken and compared to the expected ones – the observations are validated and arbitrated
- The arbitration decides upon the further testing and/or the assignment of test results – the verdicts
- A detailed test procedure consisting of various stimuli and observations is called test case
- Several test cases constitute a test suite
- The relation between test cases and their execution is defined in a test control
- Typically, a test case describes a tree structure: one stimuli – several possible observations
- Alternatives and defaults are used for an efficient description of such trees

Test Concepts: Distributed Behavior

- Typically, distributed SUTs require distributed test setups
- Such test setups are realized via test components which have to be coordinated and synchronized
- All test components have a local verdict, which contributes to the overall verdict
- The initial test configuration defines the test components used initially for a test case – the test configuration can change dynamically
- Test components may use utility parts to use/access information outside the test system

Test Concepts: Data

- Both, stimuli and observation are described as test data
- Test data for stimuli and observations can be unspecific in their properties and values – data pools and data partitions are used
- In addition, test data for observations can be unspecific in certain elements – wildcards are used
- Coding rules describe the encoding/decoding used on interfaces to the SUT

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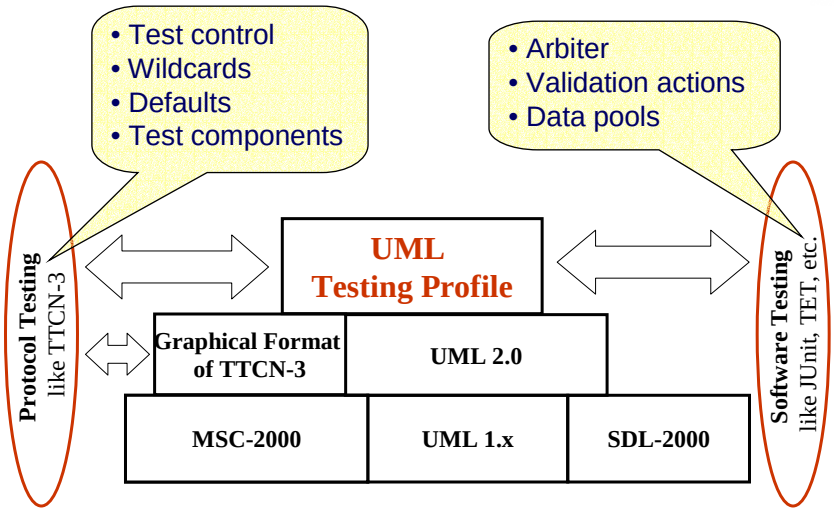
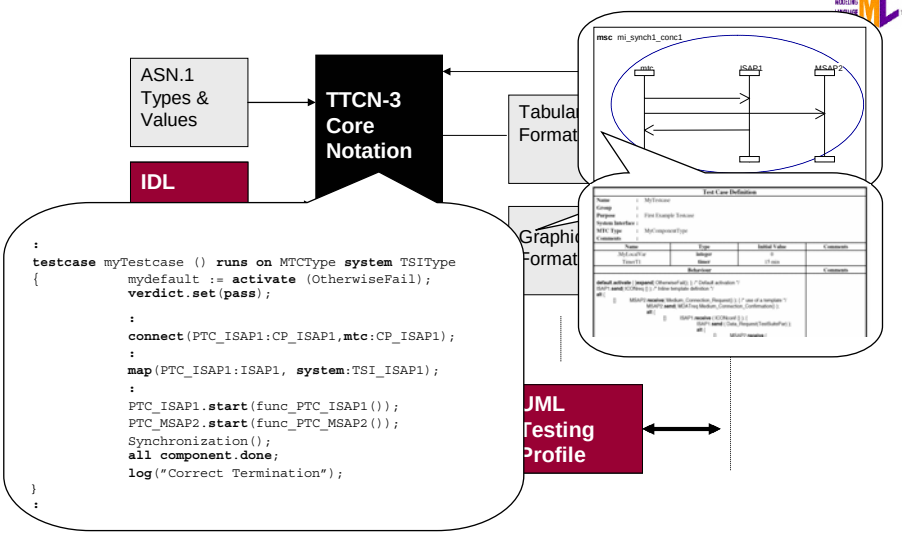
The Testing Profile Roots



1st Root: TTCN-3

- The new standardised test specification and test implementation language
  - Developed from 1999 – 2002 at the European Telecommunications Standards Institute (ETSI)
- Developed based on experiences from previous TTCN editions
  - Removal of OSI specific concepts; Improvement of concepts; Introduction of new concepts
- Applicable for all kinds of black-box testing for reactive and distributed systems, e.g.,
  - Telecom systems (ISDN, ATM, GSM, UMTS); Internet (IP, IP based protocols and applications); Software systems (Java, XML); Middleware platforms and component-based systems (CORBA, .Net, EJB)

TTCN-3



2nd Root: UML 2.0

- Developed by OMG (Object Management Group) 1999-2004, adoption June 2003, available 2004
  - UML 2.0 Infrastructure RFP
    - metamodel restructuring in order for Core to be reusable by other OMG languages
  - UML 2.0 Superstructure RFP
    - new and improvement/extension of UML concepts
  - UML 2.0 OCL RFP
    - defining an OCL metamodel
  - UML 2.0 Diagram Interchange RFP
    - ensuring diagram interchange between different tools

UML 2.0 Improvements

- More unified conceptual base
  - Parts in Internal structure, Collaborations, Use cases and indirectly in Interactions
- More unified semantics
  - Higher precision
- Improved expressiveness
  - Structured Classes, Sequence Diagrams and Statemachines
  - Activities merged with actions
  - Collaborations aligned with structured classes
  - Patterns (templates) and frameworks support

- More powerful and expressive than UML 1.4
- Tighter and more consistent than UML 1.4
- Executable UML becomes possible

UML 2.0 Profiles

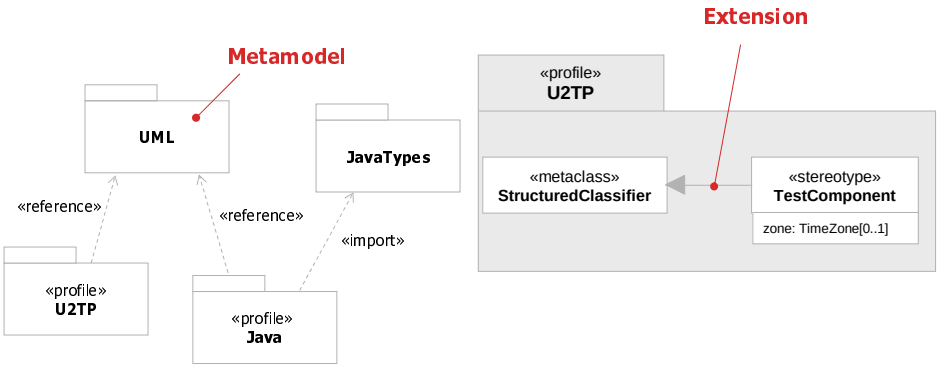
- Use of UML in
  - Analysis
  - Design/implementation
  - Directly executable notation (eg xUML)
  - Architecture description
  - Process engineering, workflow
  - Website structures
  - Data Modeling
- with obviously different (and inconsistent) semantics

- UML has many "semantic-free zones", so called "semantic variation points"
  - E.g. detailed semantics of state machines, ...
- Profiles
  - Specializations of UML by stereotypes, providing special semantics

<<TestContext>>
ATM

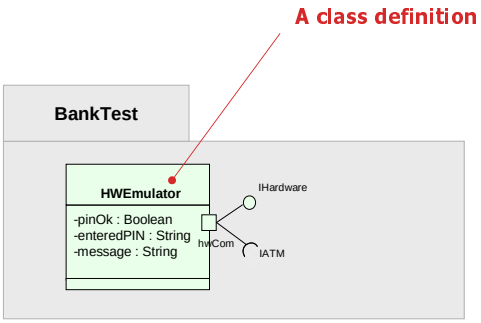
UML 2.0 Profile Walkthrough (1)

- Define profile(s)
  - based on reference metamodel
  - may use other packages for its definition



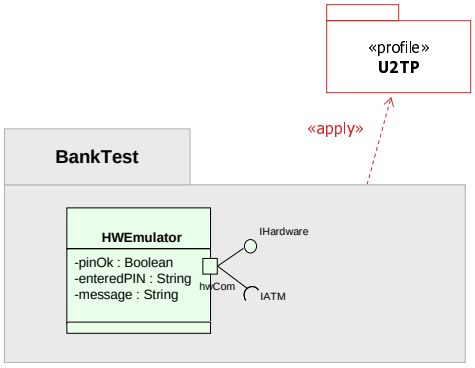
UML 2.0 Profile Walkthrough (2)

- Specify model
  - based on UML metamodel



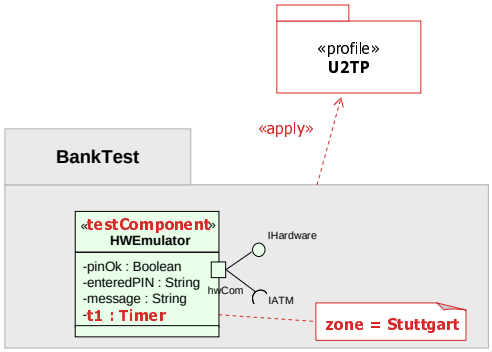
UML 2.0 Profile Walkthrough (3)

- Apply profile(s) to model
  - make it possible to apply stereotypes of the profile to the model elements



UML 2.0 Profile Walkthrough (4)

- Apply stereotypes to model elements as desired



Concepts of the Testing Profile

- Test architecture
  - Test structure, test components and test configuration
- Test data
  - Data and templates used in test procedures
- Test behavior
  - Dynamic aspects of test procedures
- Test time
  - Time quantified definition of test procedures

Test Architecture Realization

- System Under Test (*SUT*)
- *Test components*
- *Test context* with test configuration and test cases
- Test verdict arbitration with *arbiter*
- Test coordination with *scheduler*

Test Data Realization

- Individual *coding rule* definition
- *Wildcards* ***** and ***?***
- Concrete test data with *data pool, data partition and data selector*

Test Behavior Realization

- *Test objectives*
- *Test cases*
- Test *verdicts:* pass, fail, inconclusive
- *Defaults* behaviors on different levels
- *Utility* part

Test Time Realization

- *Clock*
- *Timezone* definition for synchronizing test components
- *Timer* operations

Concepts beyond TTCN-3

- Unification of test cases:
  - Test case as a composition of test cases
  - Test behavior defines the execution of a test case
- Separation of test behavior and verdict handling
  - Arbiter is a special component to evaluate the verdict
  - Validation actions are used to set the verdict
- Abstract test cases that work on data partitions rather than individual data
  - Data partitions to describe value ranges for observations and stimuli
- Test architecture with test deployment support
  - Part of the test specification is the definition of deployment requirements for a test case

Concepts beyond UML

- Defaults within test behavior
  - Concentration on main flow of test behavior
  - Default hierarchy to handle different concerns
- Wildcards within test data
  - Flexible definition of value sets
- Timers and time constraints
  - Time controlled test behavior
- Arbitration and verdicts
  - Assessment of test behavior
- Coding attributes
  - Encoding/decoding for data exchange with the SUT

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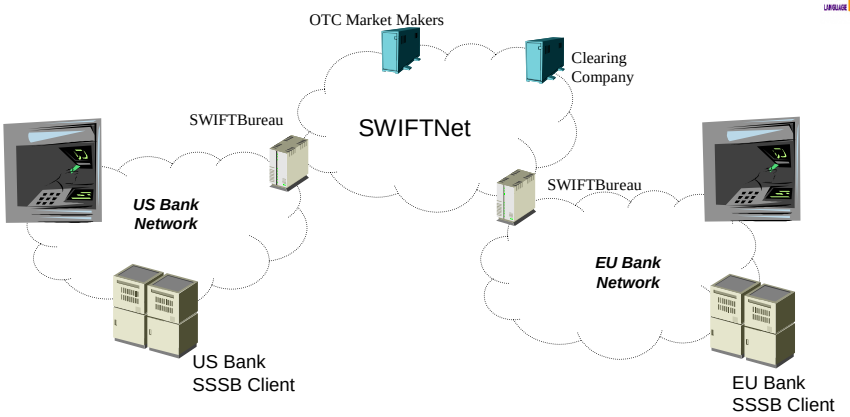
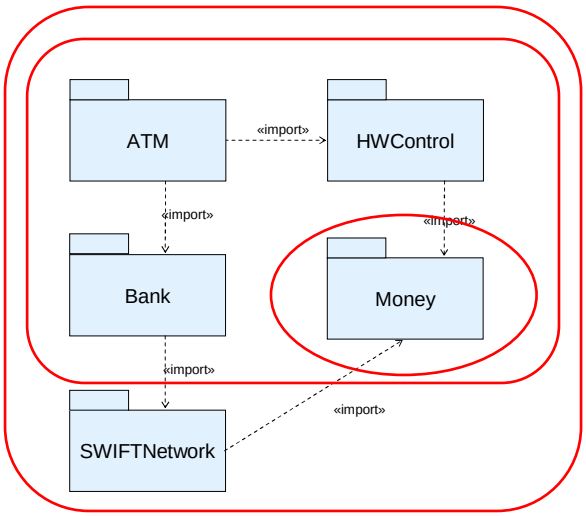
The Example



UML Model of the System Level Archicture

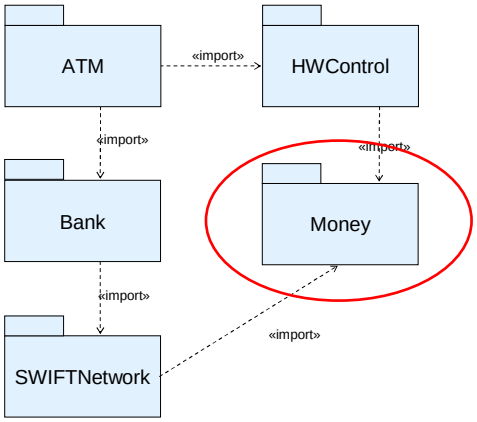


System Integration Test

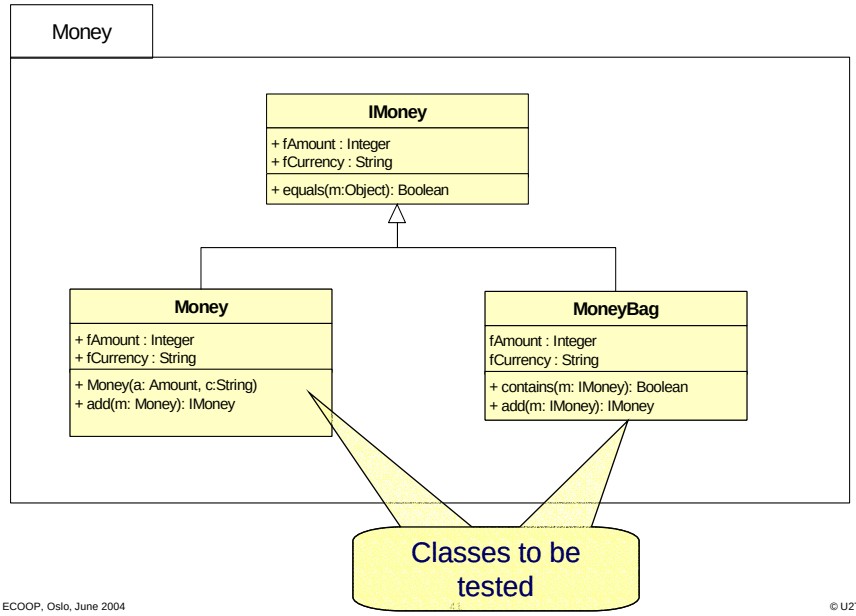
System Test

Unit Test

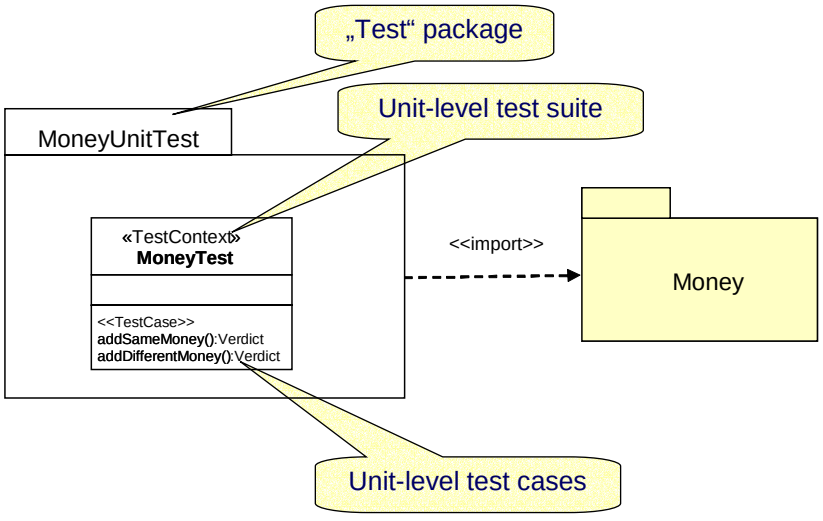
Unit-Level Test



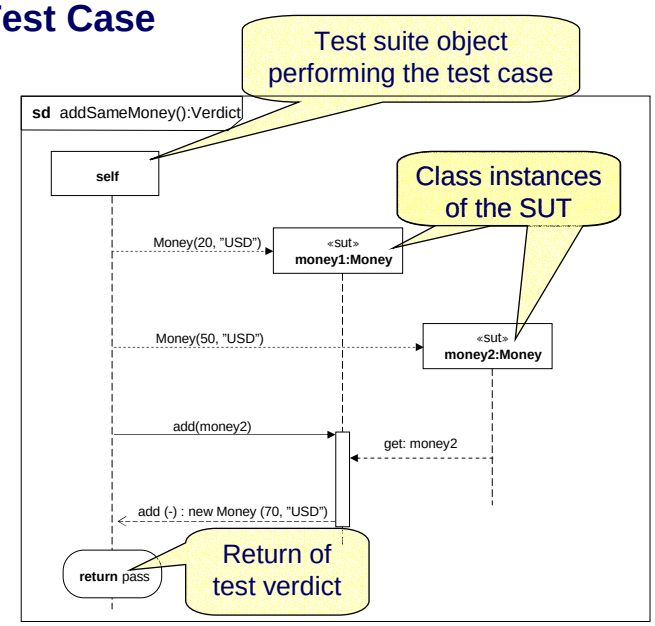
Unit-Level Test



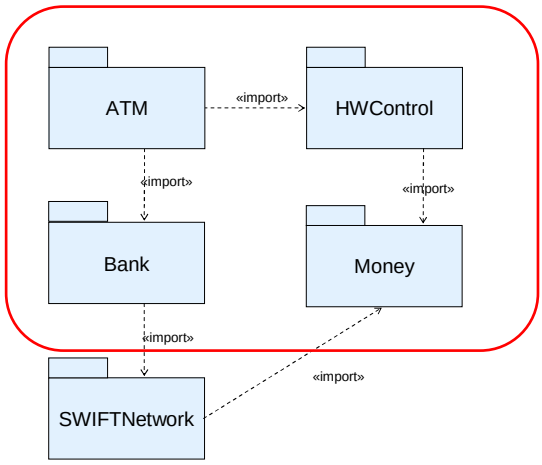
A Unit-Level Test Suite



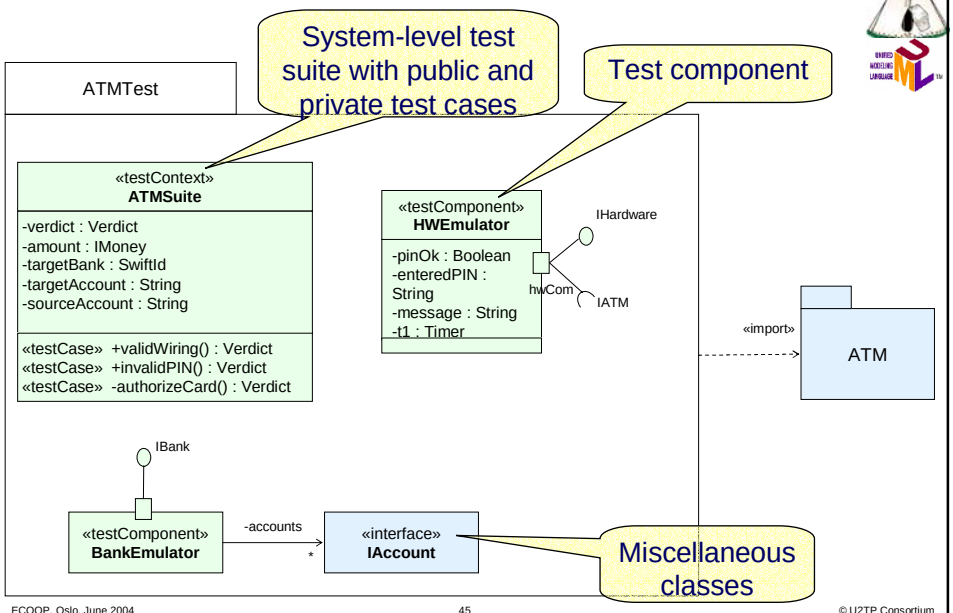
A Test Case



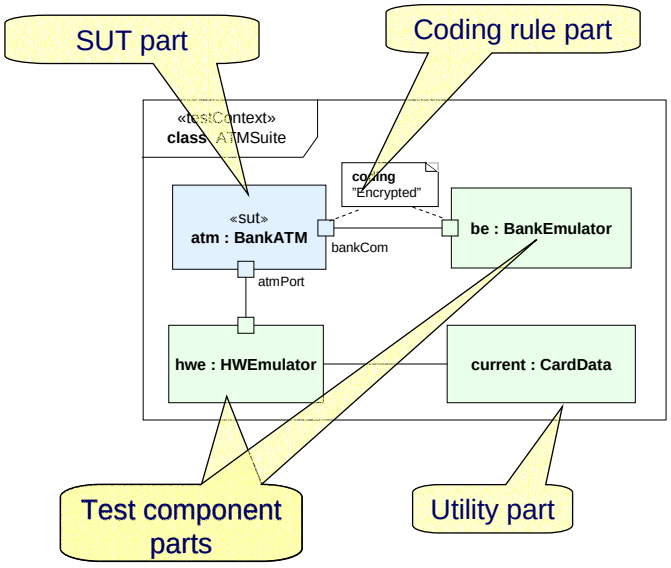
System-Level Test



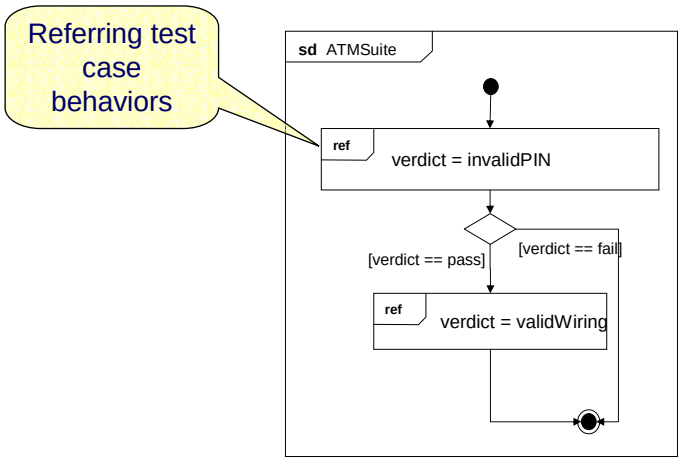
System Level Test



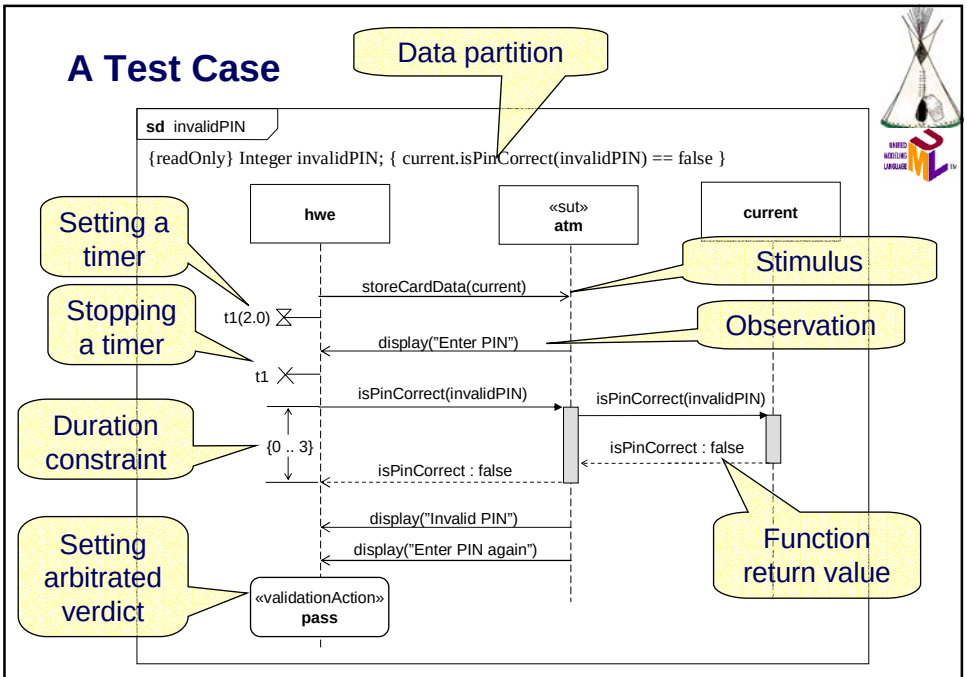
Test Configuration



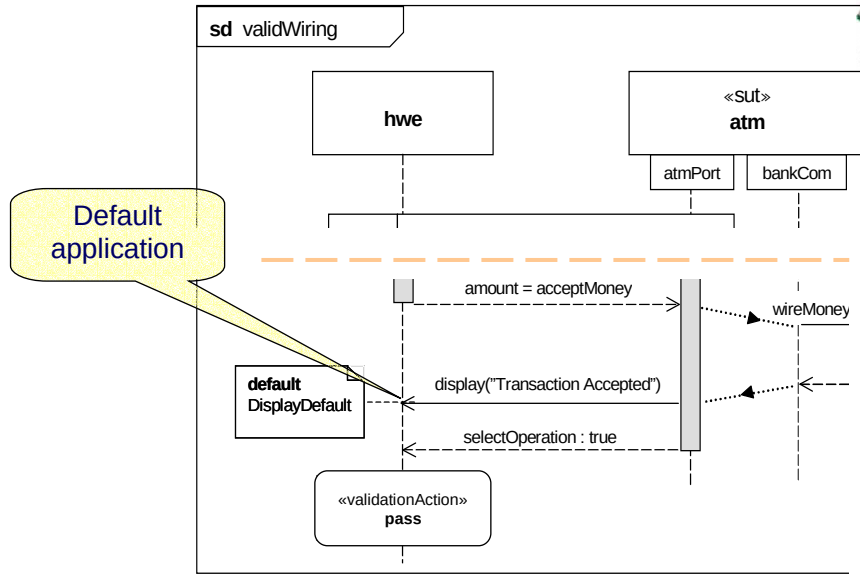
Test Control (execution of test suite)



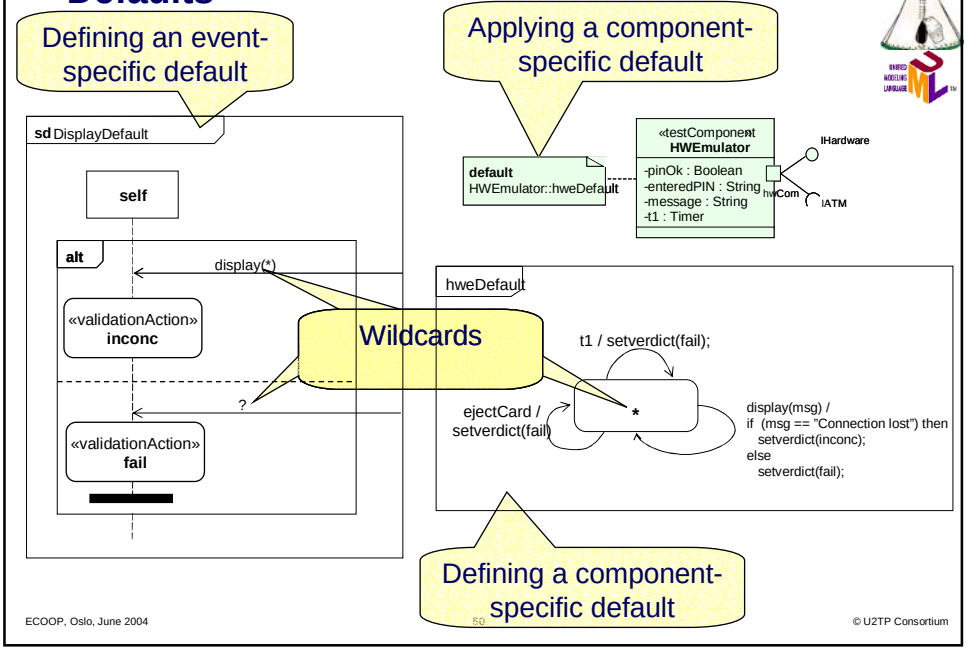
A Test Case



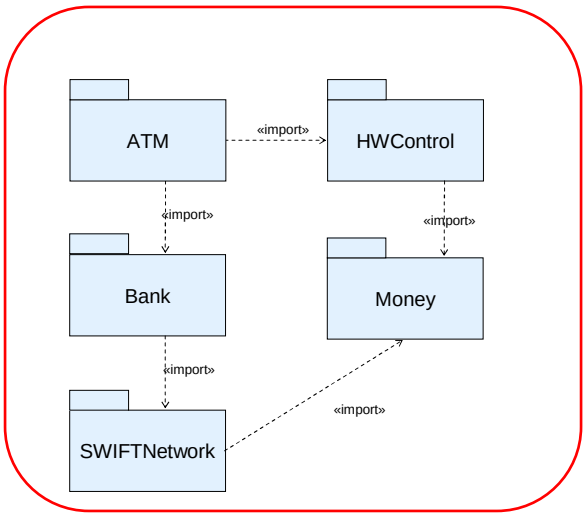
A Test Case with Default (extracts)



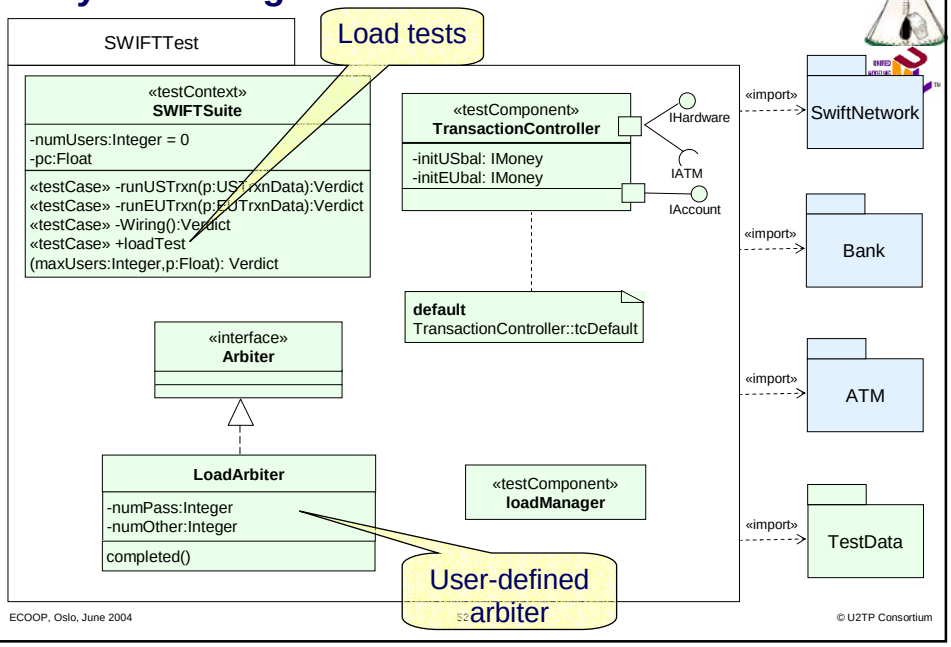
Defaults



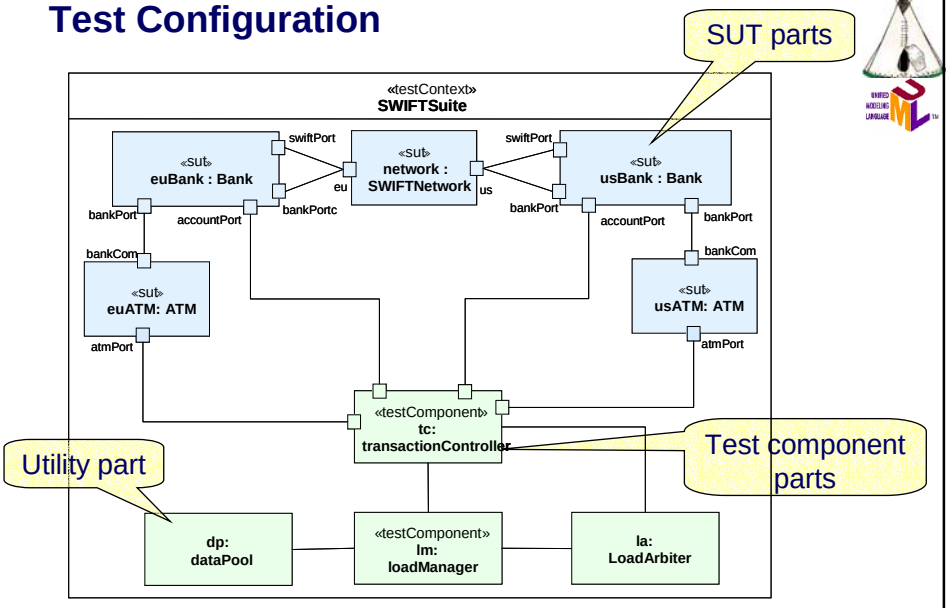
System-Integration-Level Test



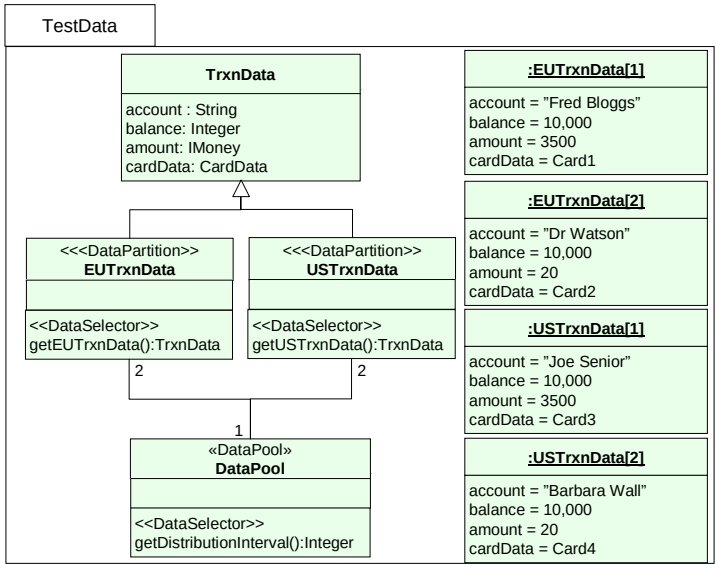
System-Integration-Level Tests



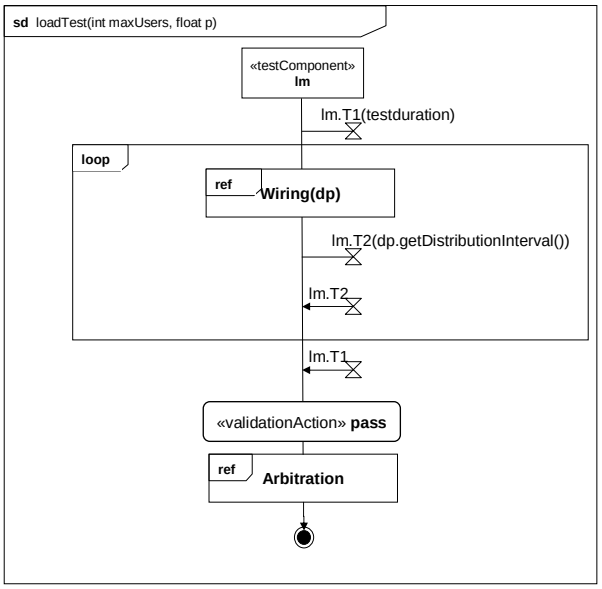
Test Configuration



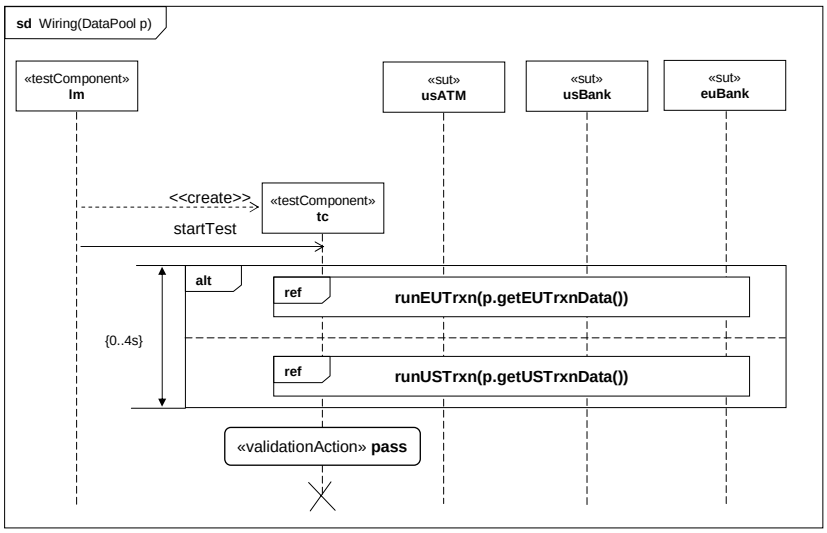
Test Data



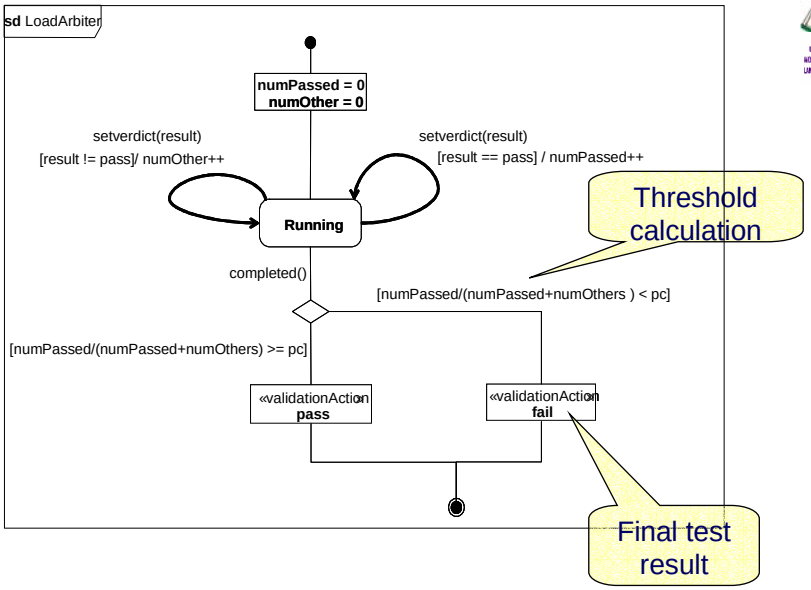
Load Test



Load Test Contd.



User-Defined Arbiter



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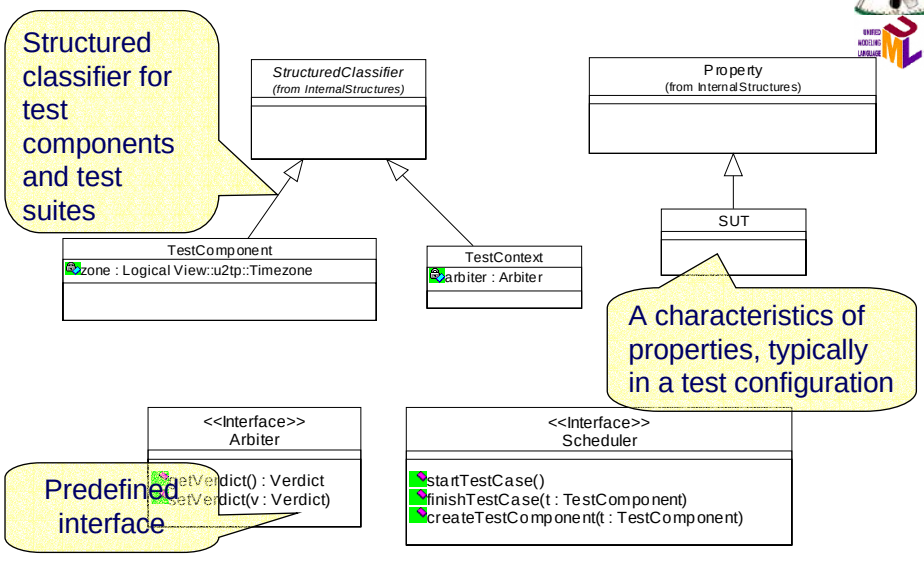
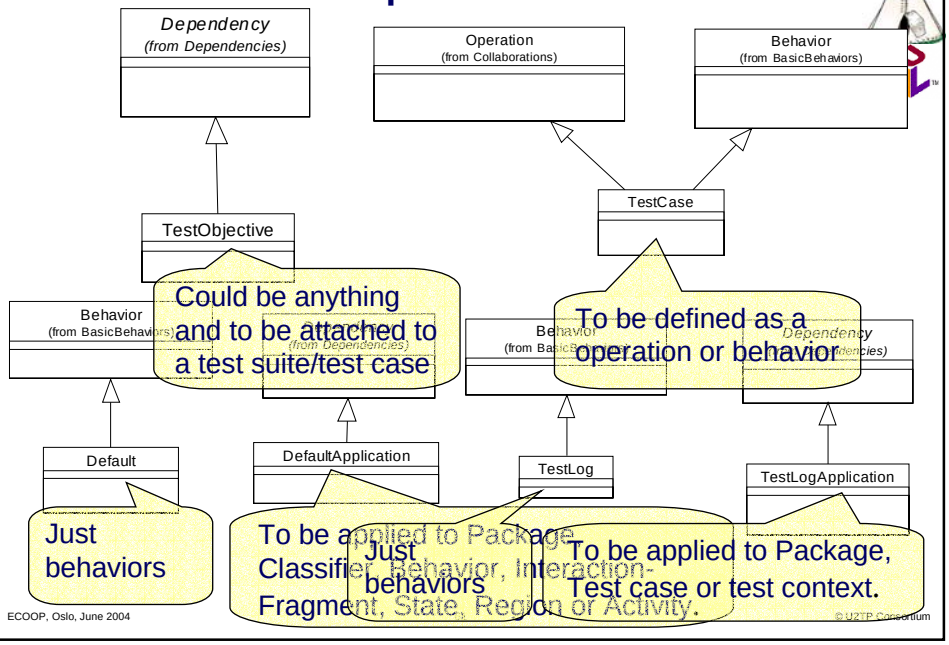
The U2TP Profile and Standalone Metamodel

- Organization of concepts
  - Test Architecture
  - Test Behavior
  - Test Data
  - Time
- The UML-based profile
  - Used by UML tools to provide test specification via profiled UML elements.
- The MOF-based standalone metamodel
  - Used by MOF-based tools and repositories to manage and manipulate artifacts created using the profile.

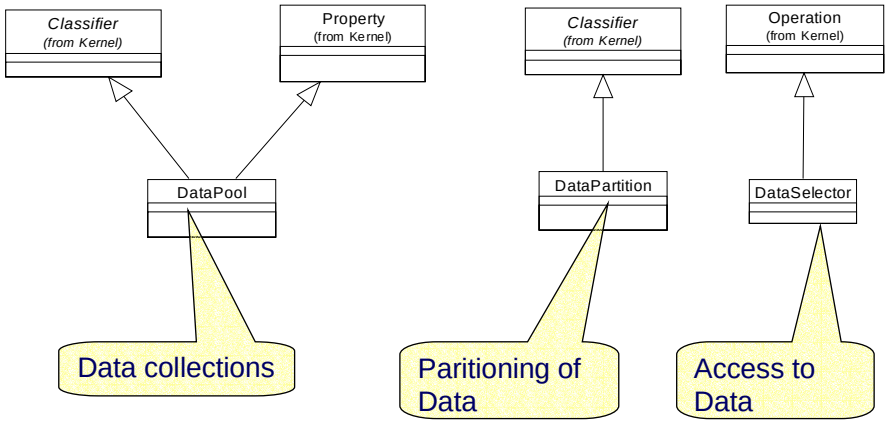
The Profile – Excerpt of Test Architecture



The Profile – Excerpt of Test Behaviour



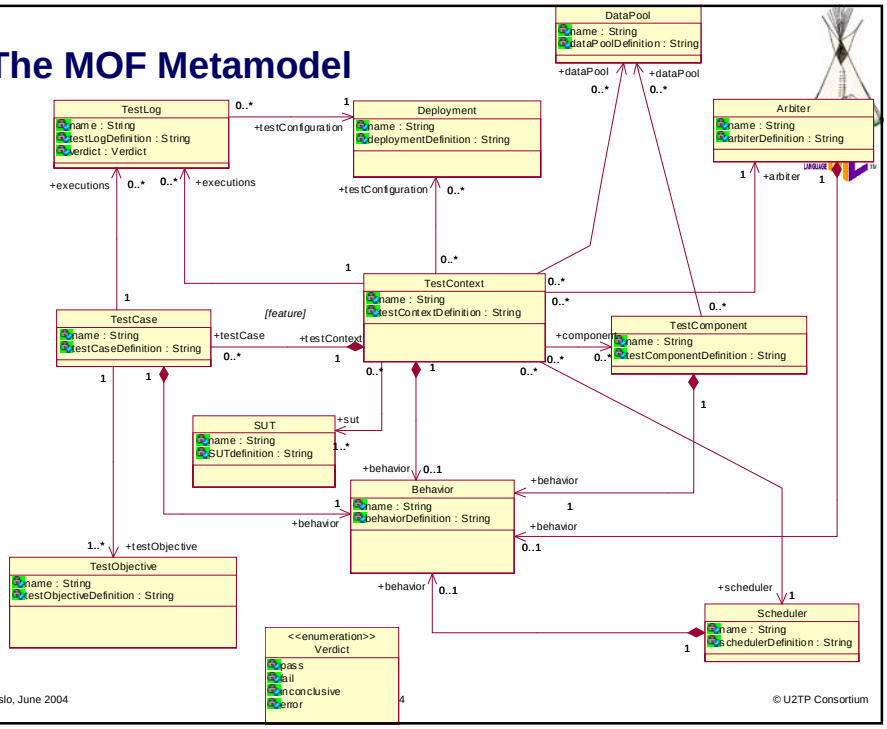
The Profile – Excerpt of Test Data



MOF Walkthrough

- Meta Object Facility
- Foundation for the OMG metadata architecture
  - Design and implement metamodels and models
    - Use UML classes for specification
    - Discover and manipulate metadata
    - Find and manage metadata repositories
  - Provides reflective meta-object interfaces for introspection and update of distributed metadata
  - Provides a MOF-to-IDL mapping to automate generation of concrete object interfaces for specific metamodels
  - Provdes a MOF-to-XML mapping to automate generation of XML schema and documents

The MOF Metamodel



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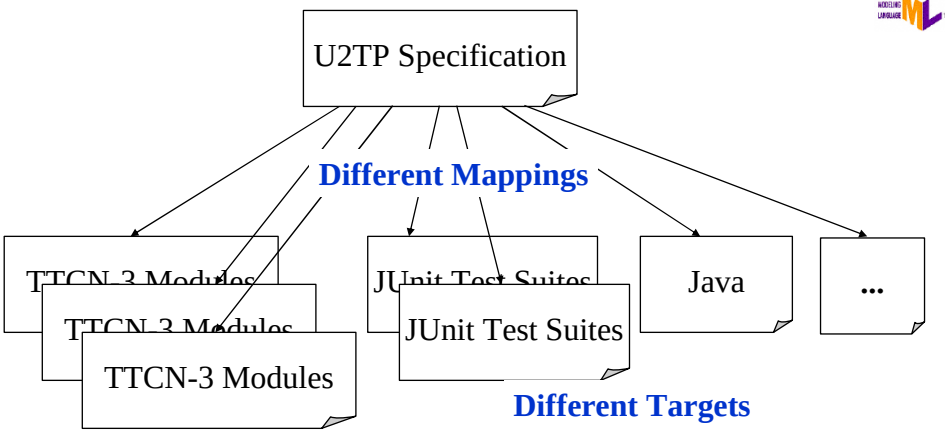
Mappings

- To enable the direct execution of U2TP specifications
- To reuse existing test infrastructures

- Mappings to
  - The JUnit test framework
    - An open source test technology for Java
    - Black-box tests on unit level
  - The Testing and Test Control Notation, TTCN-3
    - A generic test technology by ETSI/ITU-T
    - Black-box/grey-box tests on unit, component, integration and system level

Mappings



- The mappings define possible, but not the only mappings

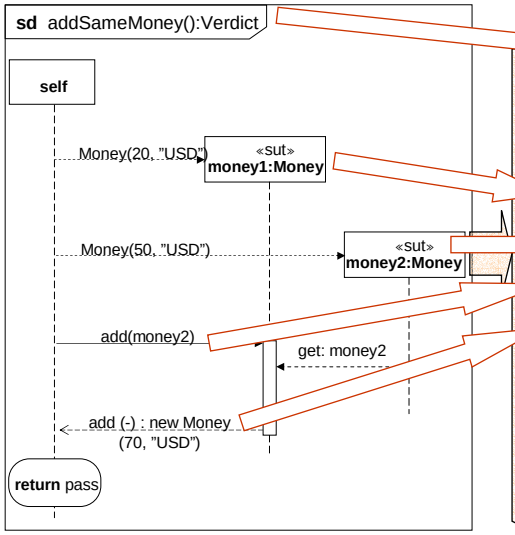
Principles of Mapping to JUnit

Direct mapping	
Test control	`overload runTest`
Test case	`test methods in a test suite`
Test objective	`setName for test case, test suite`
Verdict	`the same except of inconclusive`
Arbiter	`built-in, can be redefined`
Validation action	`assert operations`
Data pool	`(static) data variables, ...`

Principles of Mapping to JUnit

Implicit mapping	
Stimulus, observation, coordination	`as part of the test methods`
SUT and utility part	`any accessible Java class`
Not supported	
Test configuration and test components	
Wildcards and matching	
Defaults	
Test trace and log	
Time concepts	
Coding rules	

Example for Mapping to JUnit




```
public class MoneyTest
extends TestCase {
 public void
 addSameMoney() {
  Money money1 =
  new Money(20,  ´USD´));
  Money money2 =
  new Money(50, ´USD´));
  money1.add(money2);
  assertTrue(money1.equals
   (new Money(70,´USD´)));
 }
...
protected void runTest
throws Throwable() {
  addSameMoney();
  ...
}
```


Principles of Mapping to TTCN-3

Direct mapping	
Test control	`control of a test module`
Test case	`testcase`
Stimulus, observation, coordination	`communication to SUT and to test components`
Defaults	`altsteps and activate/deactivate operations`
Wildcards and matching	`template and pattern mechanisms`
Test components	`component types and instances`
Test configuration	`create, connect, map ... operations`

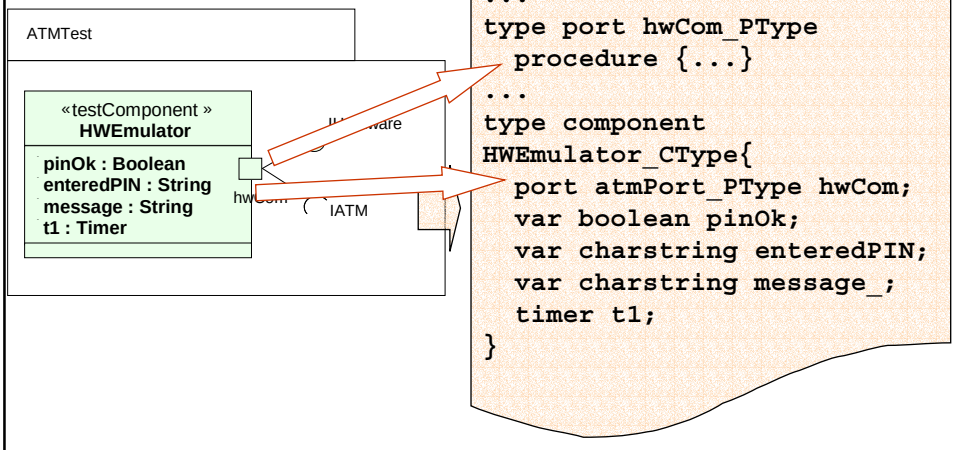
Principles of Mapping to TTCN-3

Direct mapping	
Arbiter	`user defined verdict handling (and user defined verdict type)`
Validation action	`(external) data function`
Utility part and data pool	`(external) constants or module parameters`
Coding rule	`encoding attribute`
Timer	`timer`
Logging	`log operation`

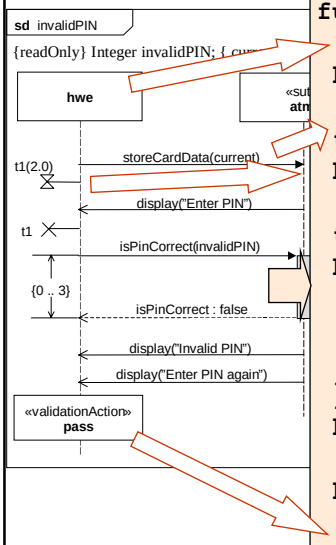
Principles of Mapping to TTCN-3

Implicit mapping	
Test objective	`comment for a test case in a special attribute`
SUT	`characterized via the test system interface only`
Not supported	
Timezone	
Test trace	

Example for Mapping to TTCN-3



Example for Mapping to TTCN-3




```
function invalidPIN_hwe ... {
...
hwCom.call(
  storeCardData:{current},nowait);
t1.start(2.0);
hwCom.getreply(
  display_:{"Enter PIN"});
t1.stop;
hwCom.call(
  isPinCorrect:{invalidPIN},3.0) {
[] hwCom.getreply(
     isPinCorrect:{?} value false) {}
}
hwCom.getreply(
  display_:{"Invalid PIN"});
hwCom.getreply(
  display_:{"Enter PIN again"});
setverdict(pass); }
```


Agenda

- Motivation
- Basics of Testing
- Overview of the UML Testing Profile
- Example Test Specifications
- The UML Profile and the MOF Model
- The Mappings
- Concluding Remarks

Implementations under Development

- Eclipse Project Hyades on an Open Source Trace and Test Framework
  - The test part is based on the U2TP standalone metamodel
- Telelogic Tau G2
  - The test part is based on the U2TP profile
- Microsoft Visual Studio
- ITEA Project on Advanced Test Methods and Tools TTmedal

Compliance Points

1. **UML Profile for Testing**: a compliant implementation supports the UML profiling mechanism, the UML entities extended by the Testing Profile, and the stereotyped entities of the UML Testing Profile.
2. **MOF-based Metamodel for Testing**: the compliant implementation supports all of the entities in the MOF-based metamodel.
3. **Notation**: If graphical notation is used, the compliant implementation recognizably supports the notation defined by the Testing Profile specification.
4. **XMI/DTD**: An XMI compliant implementation of the Testing Profile and/or MOF metamodel provides the UML XMI exchange mechanism.
5. **Static Requirements**: The compliant implementation checks the specified constraints automatically.

➢ **Compliance requires meeting 1 and/or 2.**
Points 3-5 are optional and can be claimed in any combination.

At the End: a Standardized Testing Profile

- One test notation for many testing applications
- Universally understood syntax and operational semantics
- Off-the-shelf tools
- Cheaper education and training costs
- Exchange and reuse of test suites
- Easier maintenance of test suites

- Transparency for the test process, increase of the objectiveness of tests and comparability of test results
- Direct support for test design
- Integration in the system development process

Summary

- UML Testing Profile provides specification means for test artifacts of systems from various domains
- Enhances UML with concepts like test configuration, test components, SUT, verdict and default
- Seamlessly integrates into UML: being based on UML metamodel, using UML syntax

- Adopted at OMG Technical Meeting, Paris, June 2003

http://www.fokus.fraunhofer.de/u2tp/

Thank you for your attention !

Any further questions ?