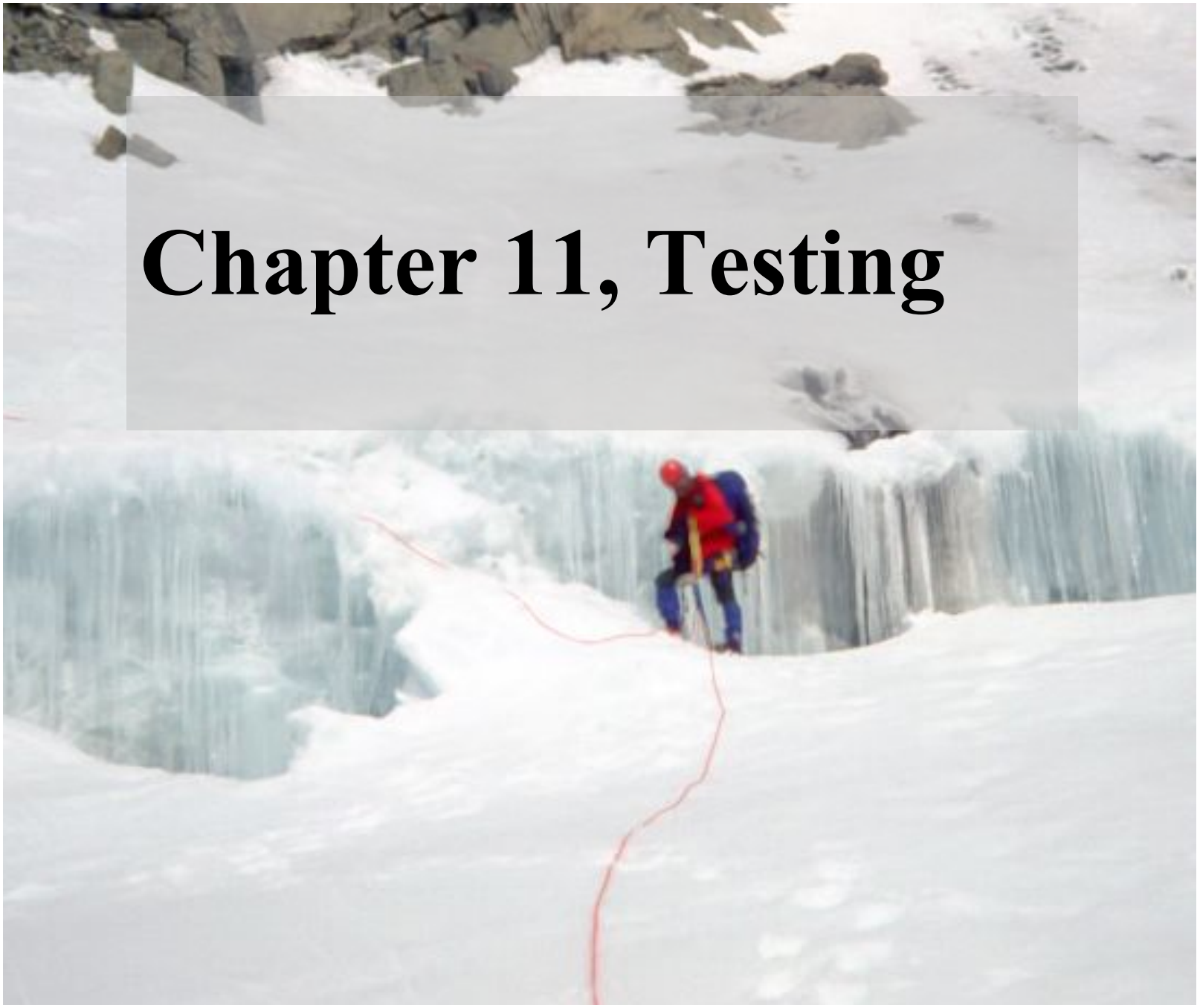
Object-Oriented Software Engineering
Using UML, Patterns, and Java

Chapter 11, Testing



Outline of the 3 Lectures on Testing

This PowerPoint:

- Terminology
- Testing Activities
- Unit testing

Second PowerPoint:

- Integration testing
  - Testing strategy
  - Design patterns & testing
- System testing
  - Function testing
  - Acceptance testing.

Third PowerPoint:

- Model-based Testing
- U2TP Testing Profile

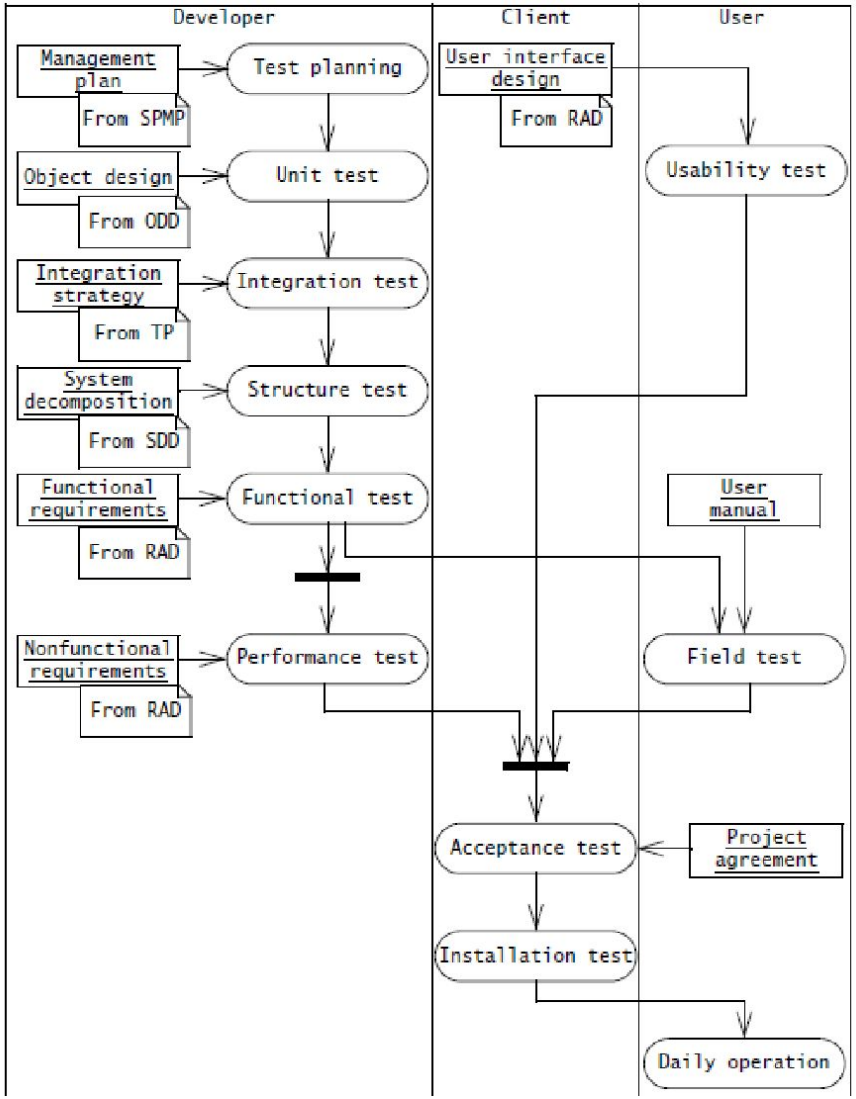
Famous Problems

- F-16 : crossing equator using autopilot
  - Result: plane flipped over
  - Reason?
    - Reuse of autopilot software

- The Therac-25 accidents (1985-1987), quite possibly the most serious non-military computer-related failure ever in terms of human life (at least five died)
  - Reason: Bad event handling in the GUI
- NASA Mars Climate Orbiter destroyed due to incorrect orbit insertion (September 23, 1999)
  - Reason: Unit conversion problem.

An overview of testing

SPMP - Software Project Management Plan
TP - Test Plan
SDD - System Design Document
RAD - Requirements Analysis Document



Terminology

- Test component is a part of the system that can be isolated for testing. A component can be an object, a group of objects, or one or more subsystems.
- Failure: Any deviation of the observed behavior from the specified behavior
- Erroneous state (error): The system is in a state such that further processing by the system can lead to a failure
- Fault: The mechanical or algorithmic cause of an error ("bug")
- Validation: Activity of checking for deviations between the observed behavior of a system and its specification.

Terminology

- Test case is a set of inputs and expected results that exercises a test component with the purpose of causing failures and detecting faults.

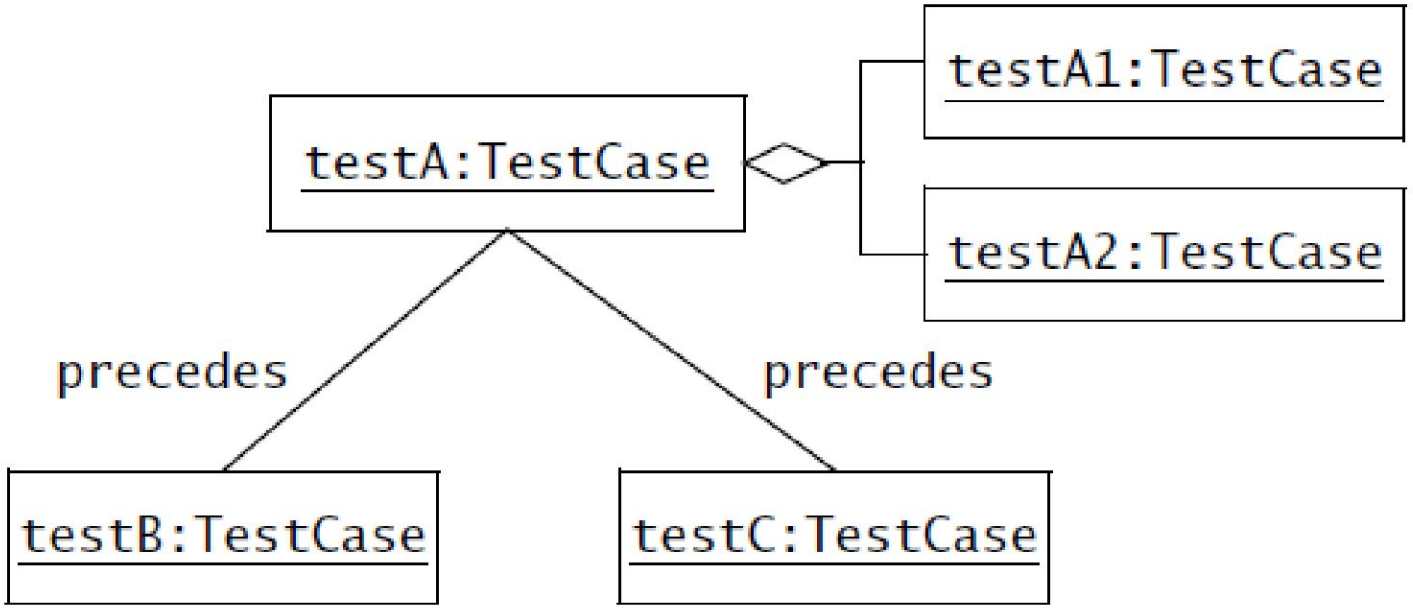
- Test stub is a partial implementation of components on which the tested component depends.
- Test driver is a partial implementation of a component that depends on the test component.

Test stubs and drivers enable components to be isolated from the rest of the system for testing.

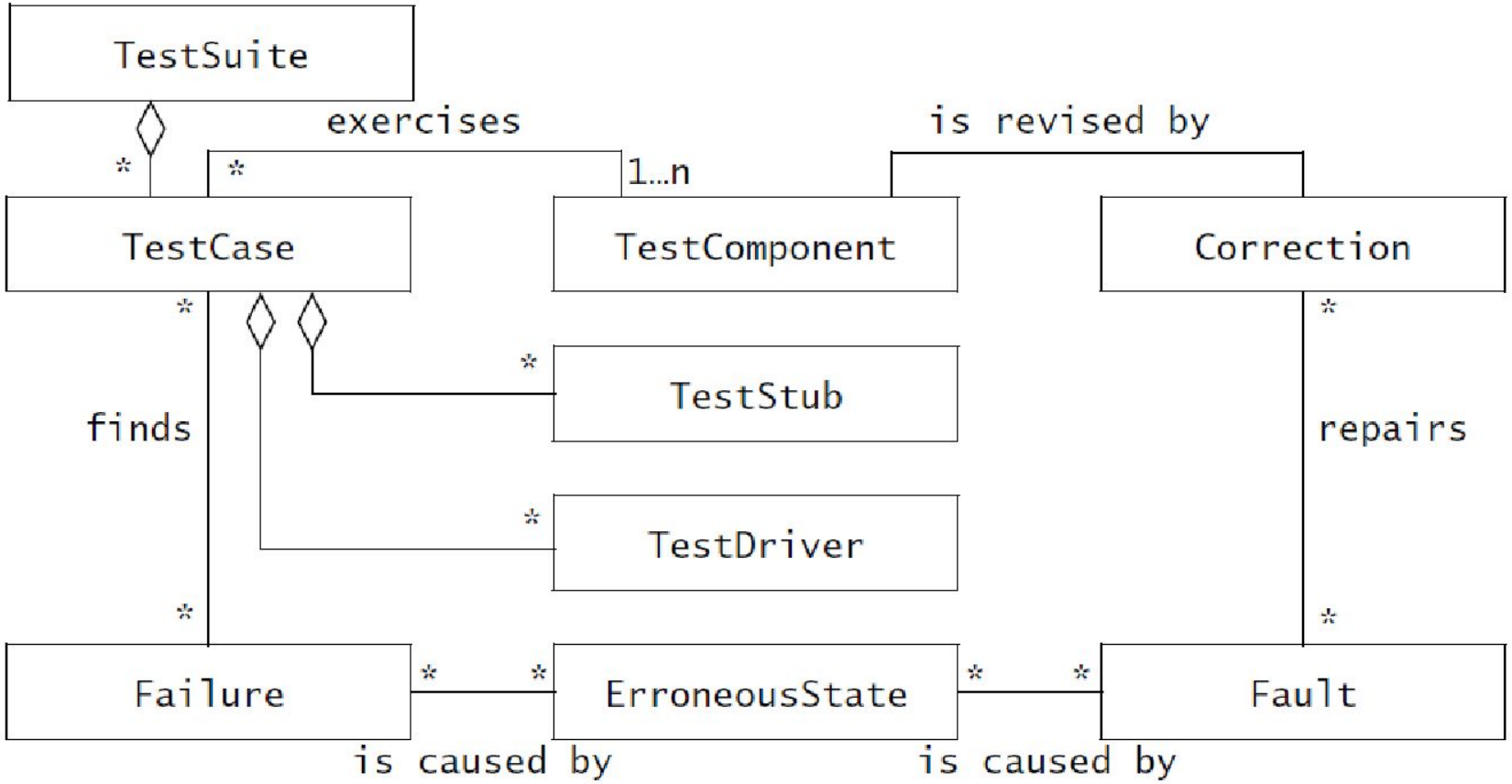
Attributes of the class TestCase

Attributes	Description
`name`	Name of test case
`location`	Full path name of executable
`input`	Input data or commands
`oracle`	Expected test results against which the output of the test is compared
`log`	Output produced by the test

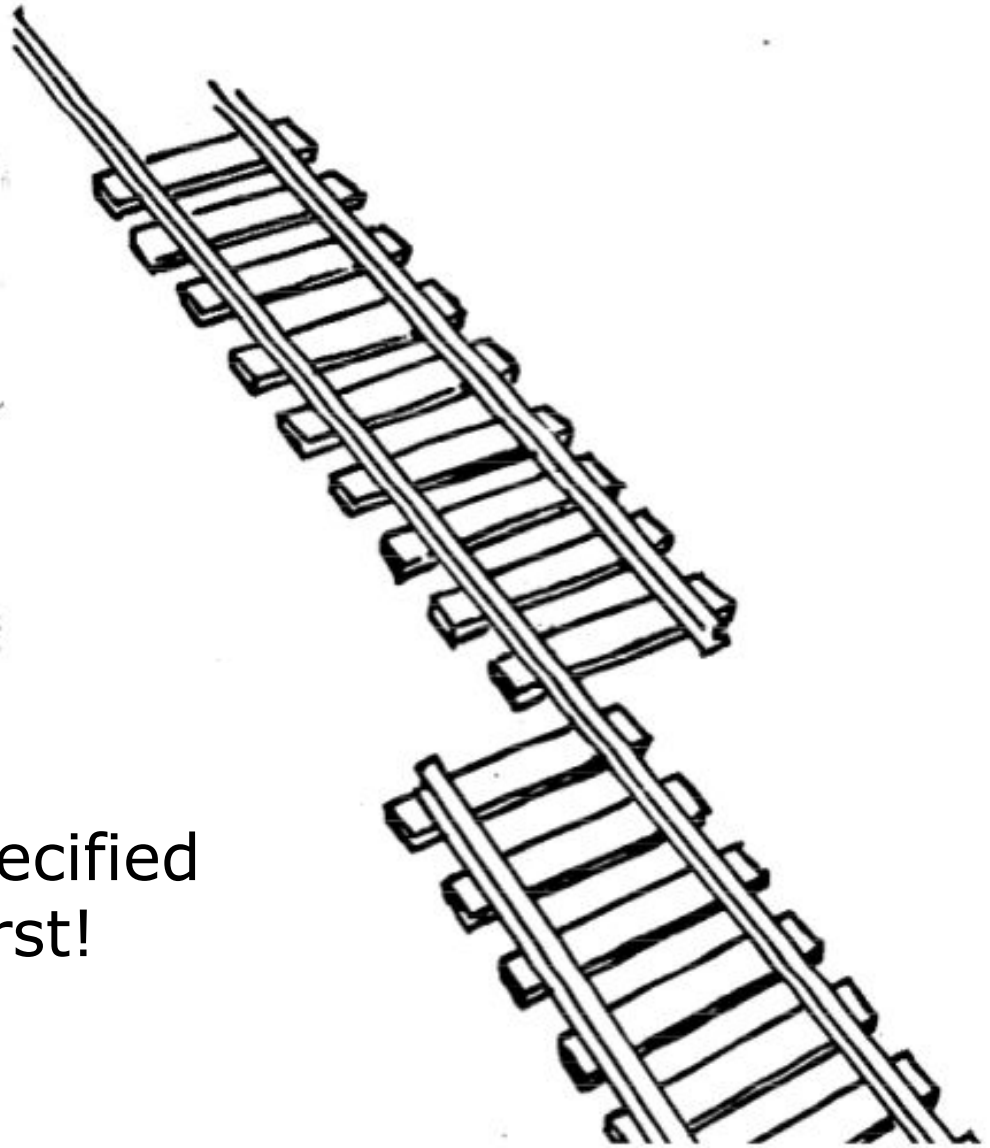
Test model width test cases



Model elements used during testing



What is this?



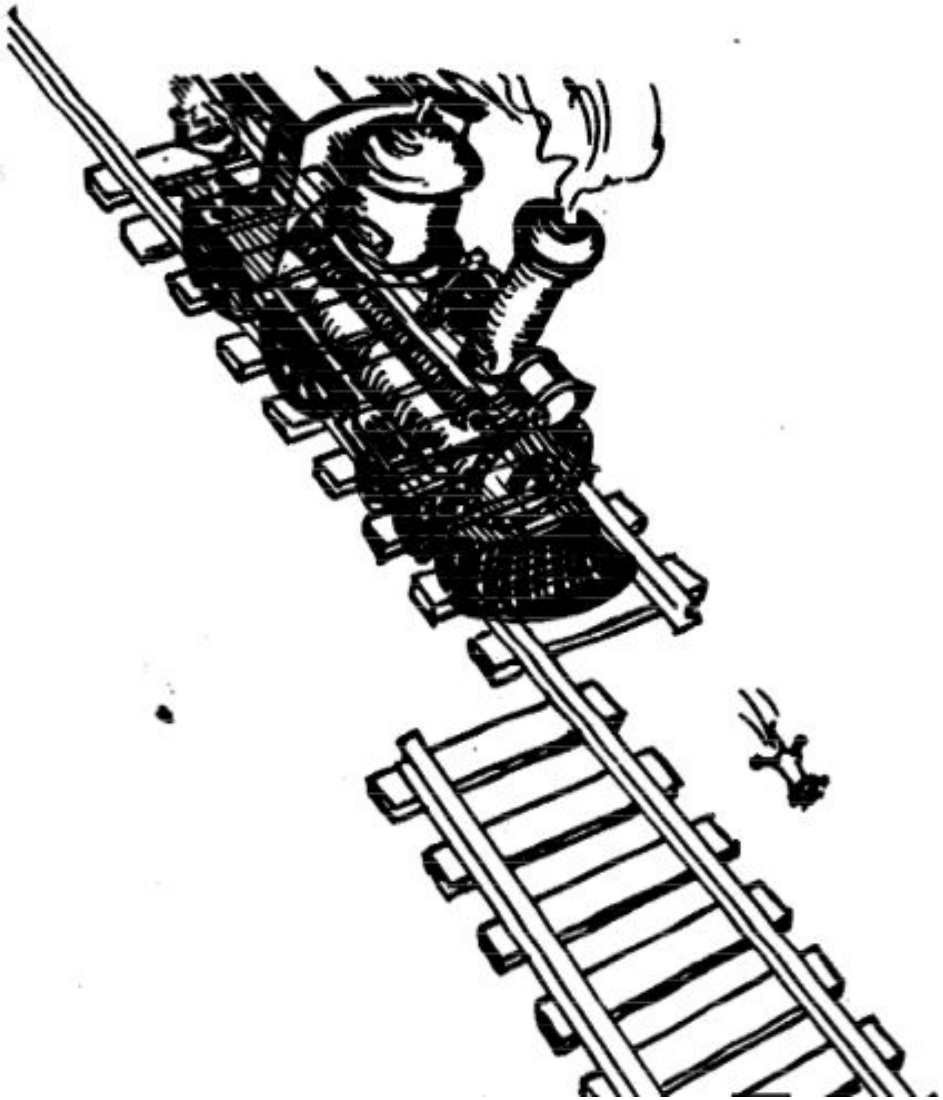
A failure?

An error?

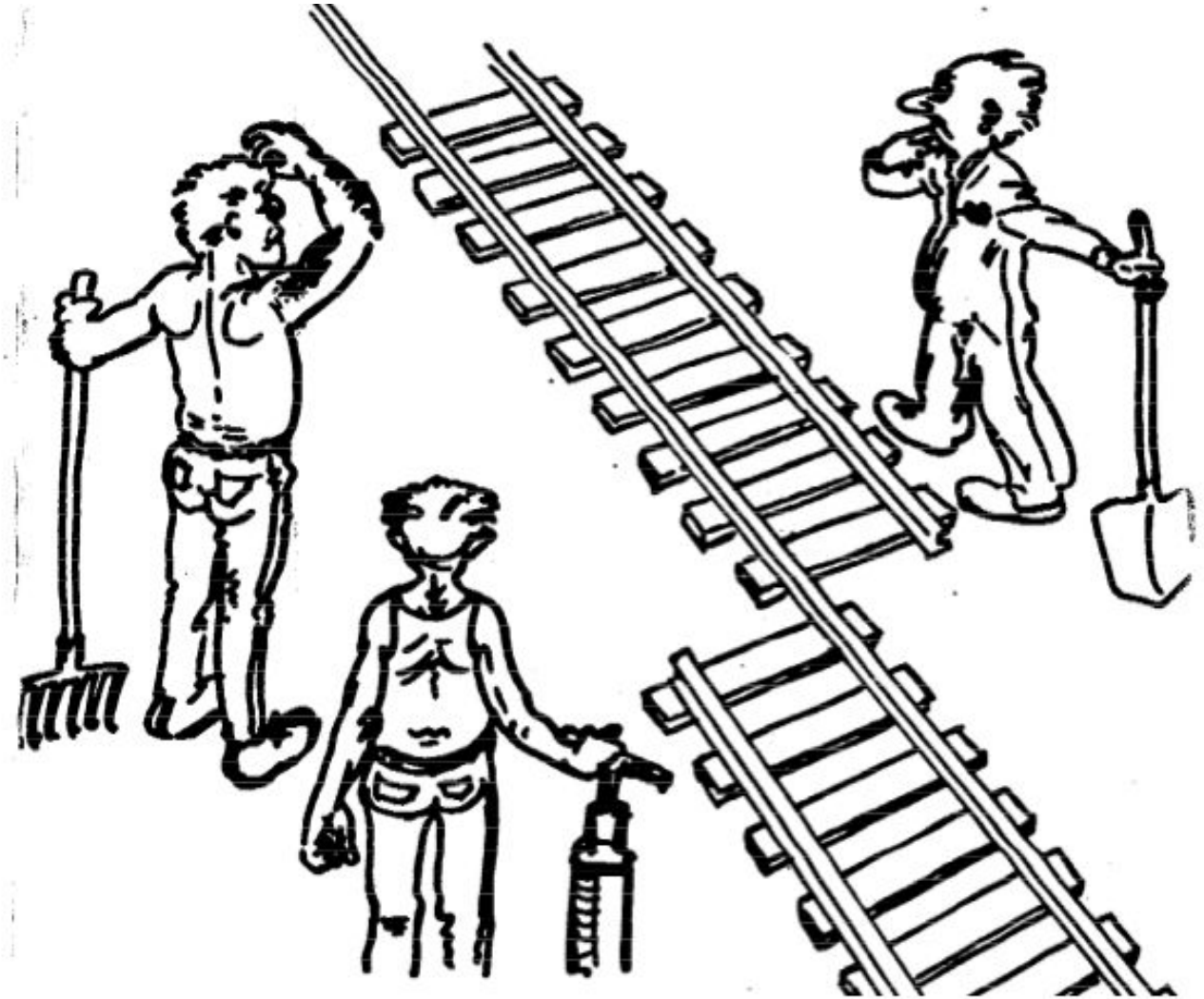
A fault?

We need to describe specified and desired behavior first!

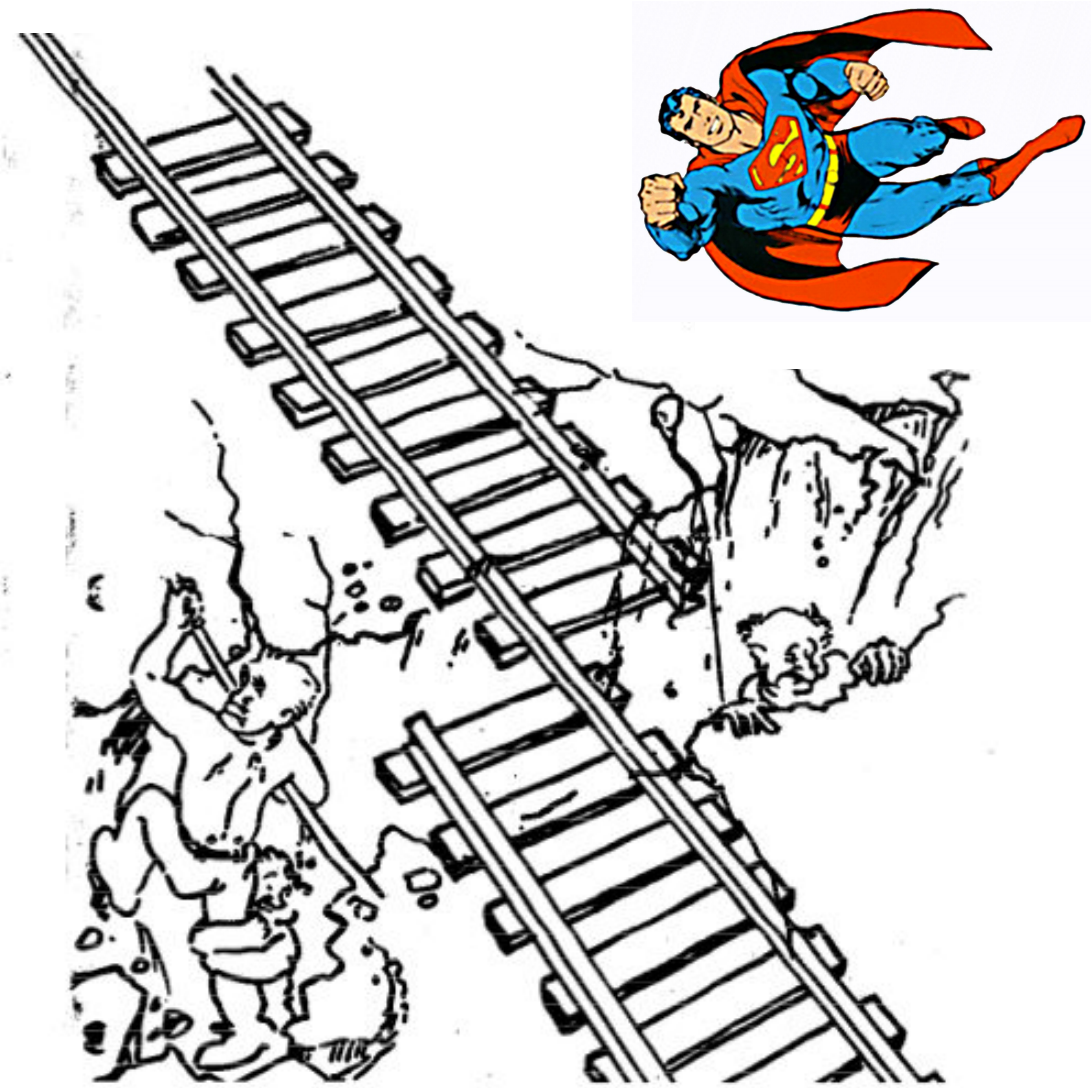
Erroneous State ("Error")



Algorithmic Fault



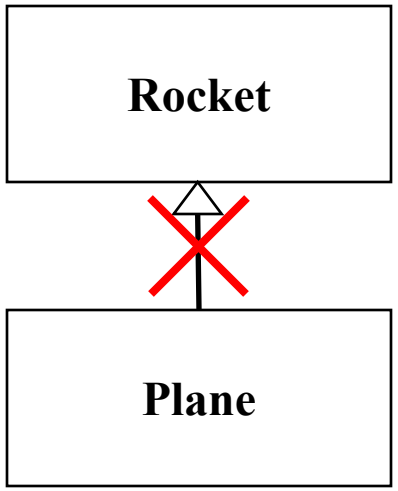
Mechanical Fault



F-16 Bug



- What is the failure?
- What is the error?
- What is the fault?
  - Bad use of implementation inheritance
  - A Plane is **not** a rocket.



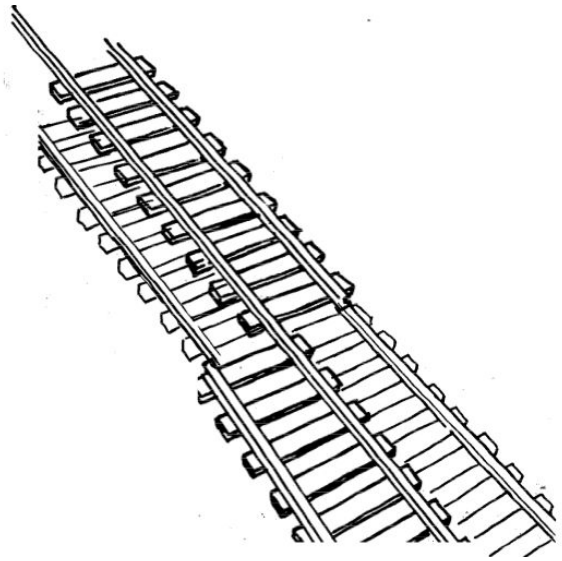
Examples of Faults and Errors

- Faults in the Interface specification
  - Mismatch between what the client needs and what the server offers
  - Mismatch between requirements and implementation
- Algorithmic Faults
  - Missing initialization
  - Incorrect branching condition
  - Missing test for null

- Mechanical Faults (very hard to find)
  - Operating temperature outside of equipment specification
- Errors
  - Null reference errors
  - Concurrency errors
  - Exceptions.

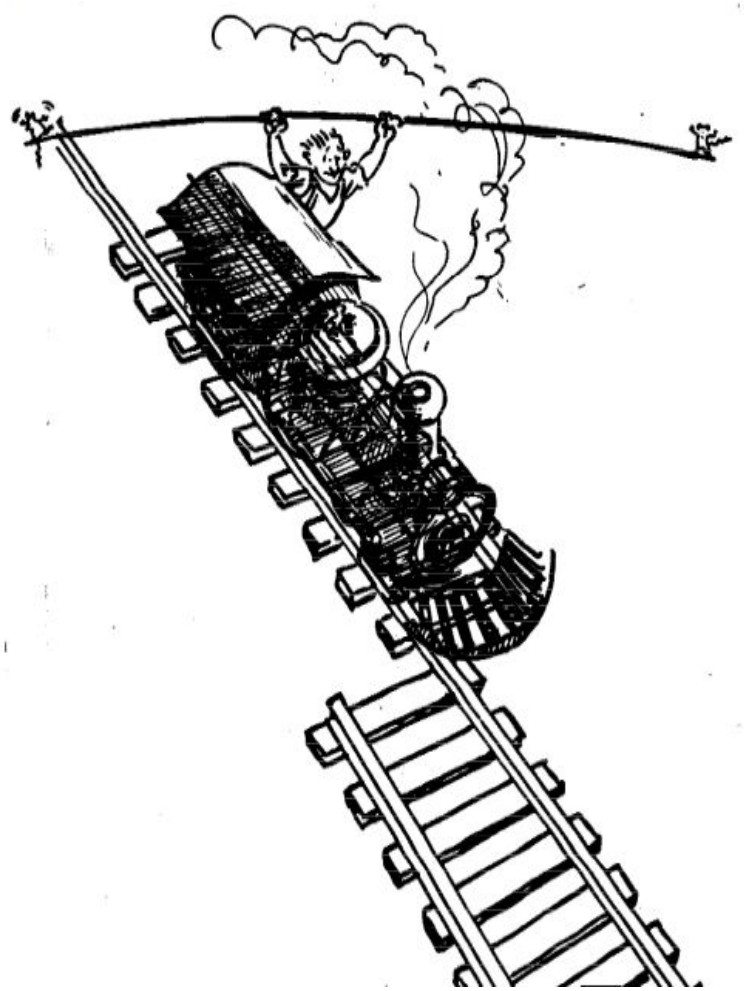
How do we deal with Errors, Failures and Faults?

Modular Redundancy



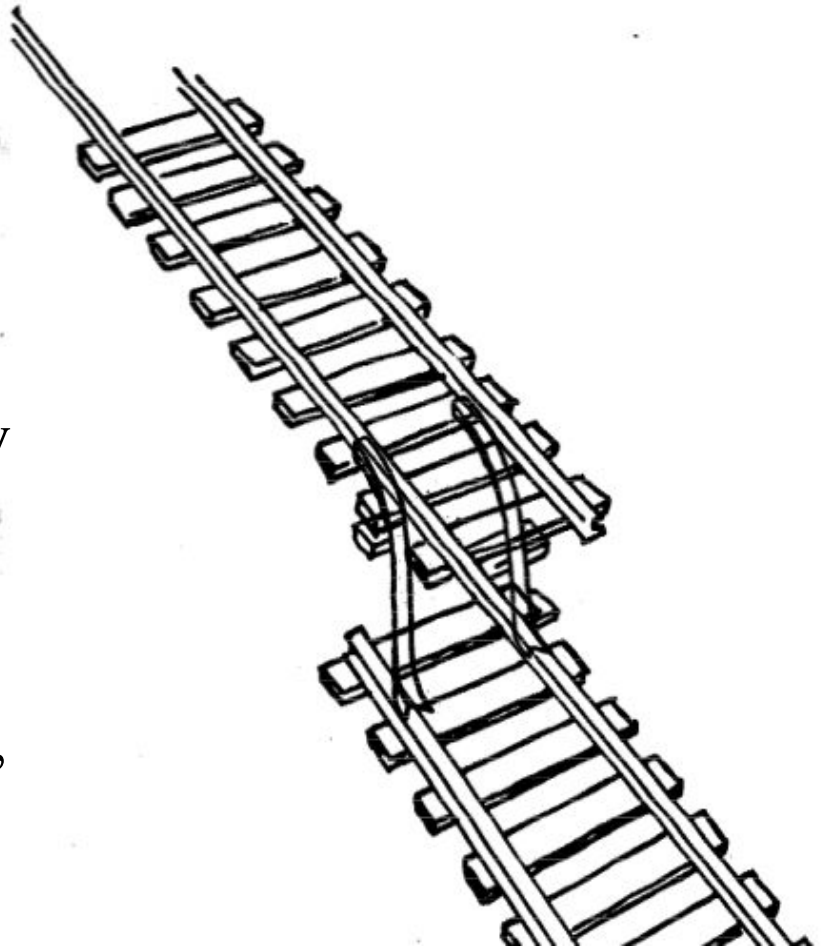
The Saturn rocket that launched the Apollo spacecraft used triple modular redundancy for the guidance system; that is, each of the components in the computer was tripled. The failure of a single component was detected when it produced a different output than the other two.

Declaring the Bug as a Feature

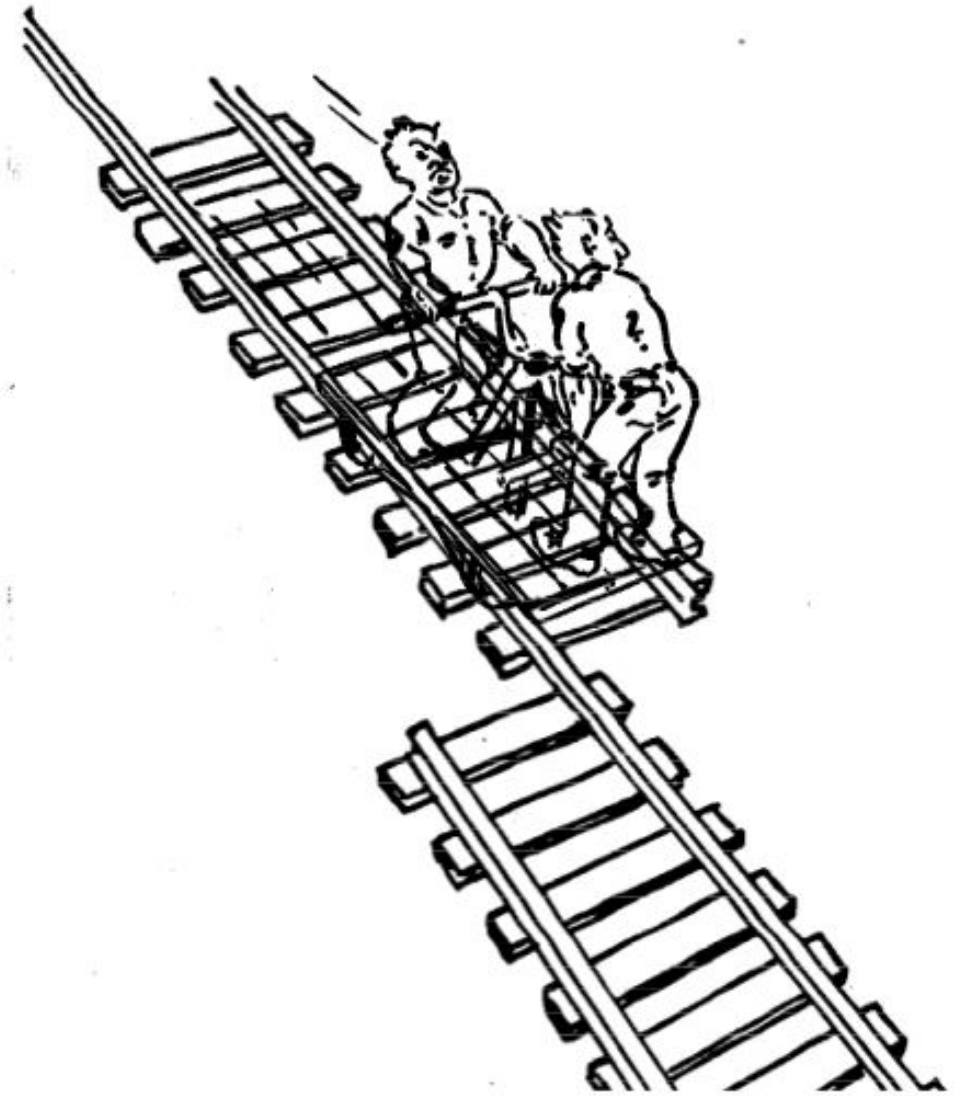


Patching

A **patch** is a set of changes to a **computer** program or its supporting data designed to update, fix, or improve it. This includes fixing security vulnerabilities and other bugs, with such **patches** usually being called bugfixes or bug fixes, and improving the usability or performance.



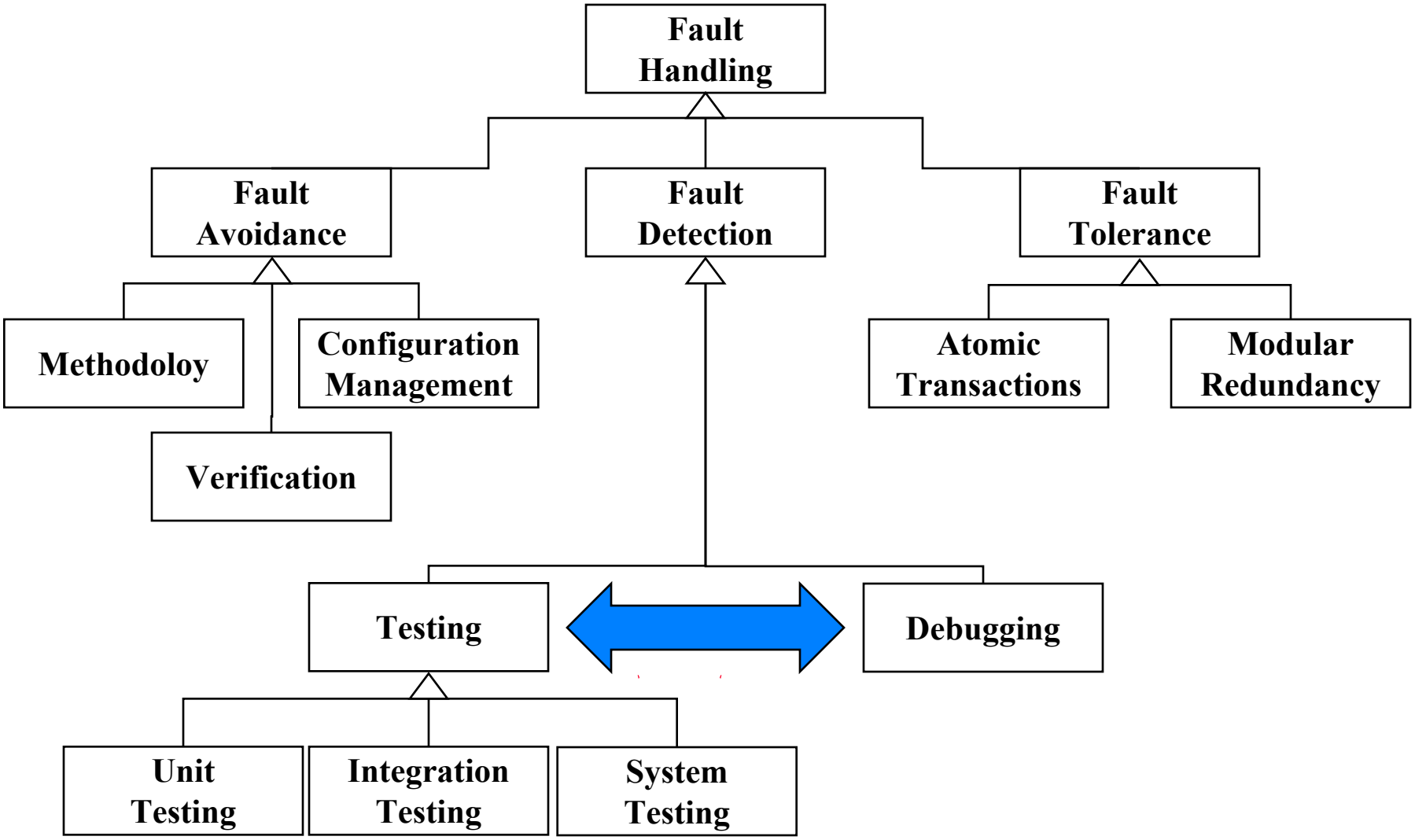
Testing



Another View on How to Deal with Faults

- Fault avoidance (before the system release)
  - Use methodology to reduce complexity
  - Use configuration management to prevent inconsistency
  - Apply verification to prevent algorithmic faults
  - Use Reviews
- Fault detection (while system is running)
  - Testing: Activity to provoke failures in a planned way
  - Debugging: Find and remove the cause (Faults) of an observed failure
  - Monitoring: Deliver information about state => Used during debugging
- Fault tolerance (recover from failure after release)
  - Exception handling
  - Modular redundancy.

Taxonomy for Fault Handling Techniques



Observations

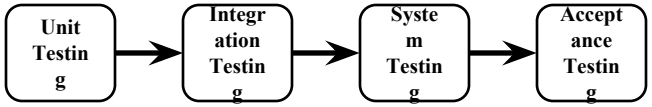
- It is impossible to completely test any nontrivial module or system
  - Practical limitations: Complete testing is prohibitive in time and cost
  - Theoretical limitations: e.g. Halting problem
- "Testing can only show the presence of bugs, not their absence" (Dijkstra).
- Testing is not for free

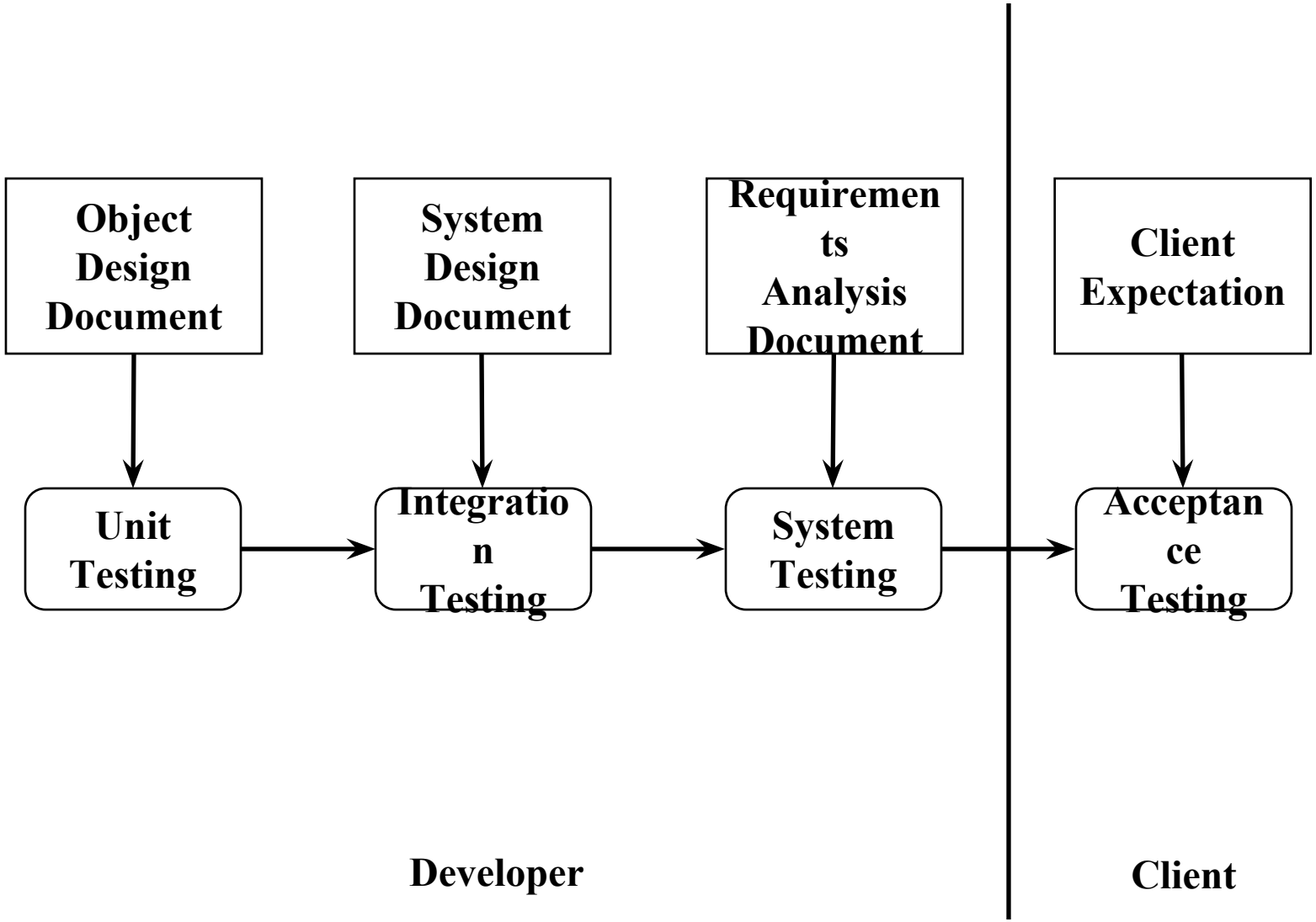
=> Define your goals and priorities

Testing takes creativity

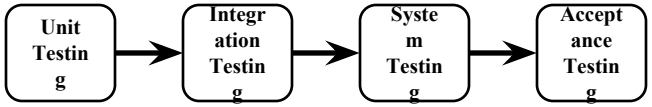
- To develop an effective test, one must have:
  - Detailed understanding of the system
  - Application and solution domain knowledge
  - Knowledge of the testing techniques
  - Skill to apply these techniques
- Testing is done best by independent testers
  - We often develop a certain mental attitude that the program should in a certain way when in fact it does not
  - Programmers often stick to the data set that makes the program work
  - A program often does not work when tried by somebody else.

Testing Activities



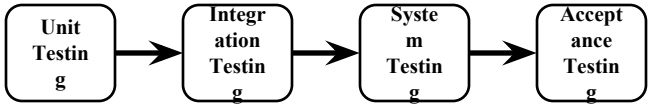


Types of Testing



- Unit Testing
  - Individual component (class or subsystem)
  - Carried out by developers
  - Goal: Confirm that the component or subsystem is correctly coded and carries out the intended functionality
- Integration Testing
  - Groups of subsystems (collection of subsystems) and eventually the entire system
  - Carried out by developers
  - Goal: Test the interfaces among the subsystems.

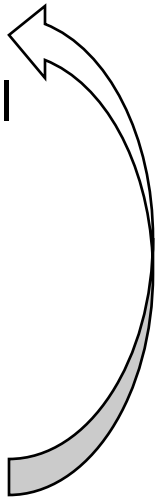
Types of Testing continued...



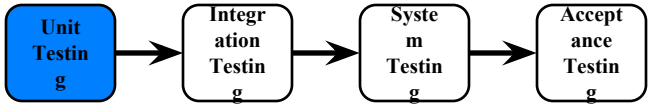
- System Testing
  - The entire system
  - Carried out by developers
  - Goal: Determine if the system meets the requirements (functional and nonfunctional)
- Acceptance Testing
  - Evaluates the system delivered by developers
  - Carried out by the client. May involve executing typical transactions on site on a trial basis
  - Goal: Demonstrate that the system meets the requirements and is ready to use.

When should you write a test?

- Traditionally after the source code is written
- In XP before the source code written
  - Test-Driven Development Cycle
    - Add a test
    - Run the automated tests
      => see the new one fail
    - Write some code
    - Run the automated tests
      => see them succeed
    - Refactor code.

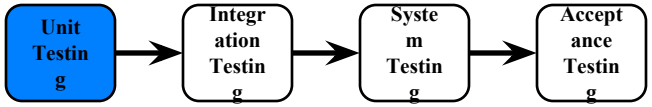


Unit Testing

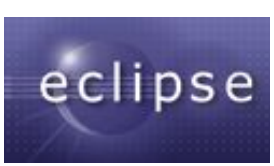


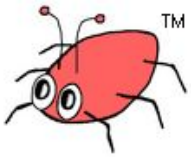
- Static Testing (at compile time)
  - Static Analysis
  - Review
    - Walk-through (informal)
    - Code inspection (formal)
- Dynamic Testing (at run time)
  - Black-box testing
  - White-box testing.

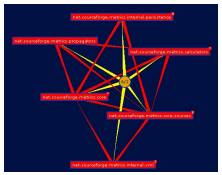
Static Analysis with Eclipse



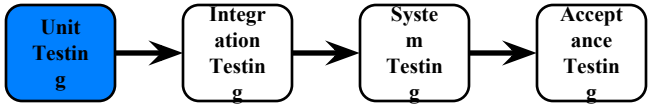
- Compiler Warnings and Errors
  - *Possibly uninitialized Variable*
  - *Undocumented empty block*
  - *Assignment has no effect*
- Checkstyle
  - Check for code guideline violations
  - http://checkstyle.sourceforge.net
- FindBugs
  - Check for code anomalies
  - http://findbugs.sourceforge.net
- Metrics
  - Check for structural anomalies
  - http://metrics.sourceforge.net







Black-box testing



- Focus: I/O behavior
  - If for any given input, we can predict the output, then the component passes the test
  - Requires test oracle
- Goal: Reduce number of test cases by equivalence partitioning:
  - Divide input conditions into equivalence classes
  - Choose test cases for each equivalence class.

Black-box testing: Test case selection

a) Input is valid across range of values
- Developer selects test cases from 3 equivalence classes:
  - Below the range
  - Within the range
  - Above the range

b) Input is only valid, if it is a member of a discrete set
- Developer selects test cases from 2 equivalence classes:
  - Valid discrete values
  - Invalid discrete values

- No rules, only guidelines.

Black box testing: An example

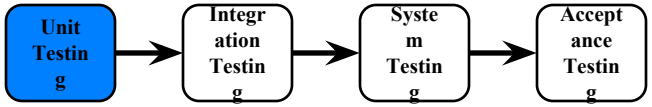
```
public class MyCalendar {

      public int getNumDaysInMonth(int month, int year)
            throws InvalidMonthException
      { … }
}
```

Representation for month:
1: January, 2: February, …., 12: December

Representation for year:
1904, … 1999, 2000,…, 2006, …

How many test cases do we need for the black box testing of getNumDaysInMonth()?

White-box testing overview



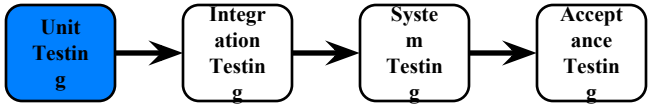
- Code coverage
- Branch coverage
- Condition coverage
- Path coverage

=> Details in the exercise session about testing

Unit Testing Heuristics

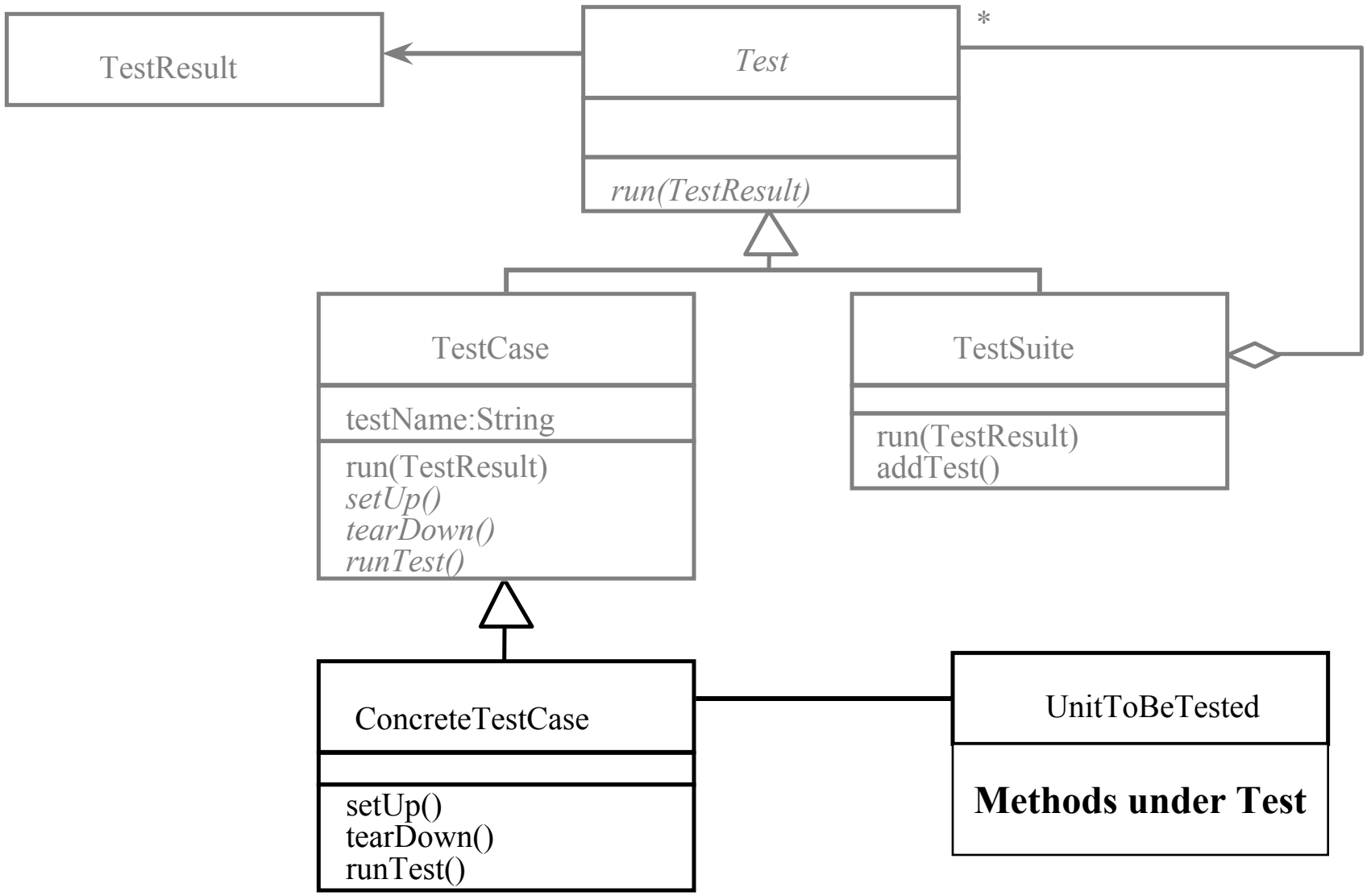
1. Create unit tests when object design is completed
   - Black-box test: Test the functional model
   - White-box test: Test the dynamic model
2. Develop the test cases
   - Goal: Find effective number of test cases
3. Cross-check the test cases to eliminate duplicates
   - Don't waste your time!
4. Double check your source code
   - Sometimes reduces testing time
5. Create a test harness
   - Test drivers and test stubs are needed for integration testing
6. Describe the test oracle
   - Often the result of the first successfully executed test
7. Execute the test cases
   - Re-execute test whenever a change is made ("regression testing")
8. Compare the results of the test with the test oracle
   - Automate this if possible.

JUnit: Overview



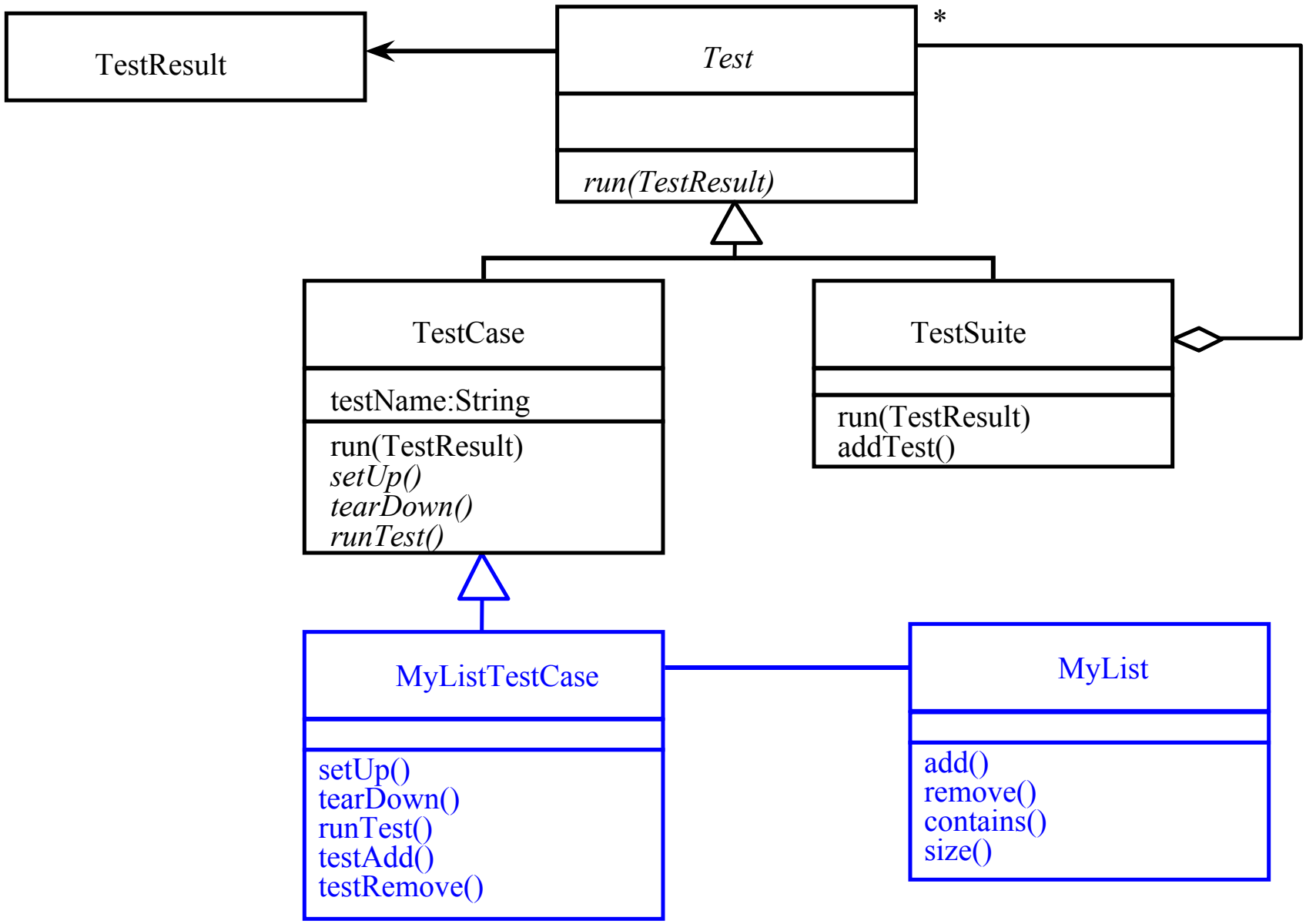
- A Java framework for writing and running unit tests
  - Test cases and fixtures
  - Test suites
  - Test runner
- Written by Kent Beck and Erich Gamma
- Written with "test first" and pattern-based development in mind
  - Tests written before code
  - Allows for regression testing
  - Facilitates refactoring
- JUnit is Open Source
  - https://junit.org/junit5/
  - JUnit Version 5, was released on OCT 24, 2017

JUnit Classes



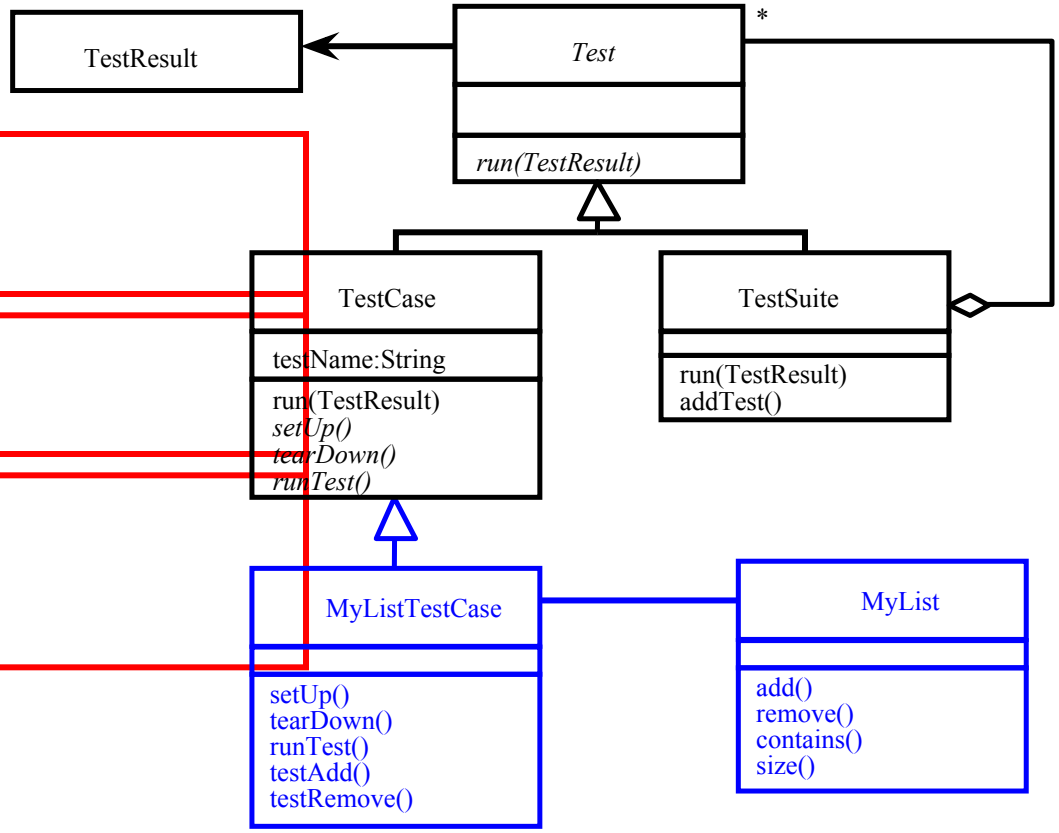
An example: Testing MyList

- Unit to be tested
  - MyList
- Methods under test
  - add()
  - remove()
  - contains()
  - size()
- Concrete Test case
  - MyListTestCase


TestResult
Test
*
run(TestResult)
TestCase
testName:String
run(TestResult)
setUp()
tearDown()
runTest()
TestSuite
run(TestResult)
addTest()
MyListTestCase
setUp()
tearDown()
runTest()
testAdd()
testRemove()
MyList
add()
remove()
contains()
size()

Writing TestCases in JUnit

```
public class MyListTestCase extends TestCase {

public MyListTestCase(String name) {
        super(name);
}
public void testAdd() {
    // Set up the test
        List aList = new MyList();
        String anElement = "a string";

    // Perform the test
        aList.add(anElement);

    // Check if test succeeded
        assertTrue(aList.size() == 1);
        assertTrue(aList.contains(anElement));
}
protected void runTest() {
        testAdd();
}
}
```



Writing Fixtures and Test Cases

```
public class MyListTestCase extends TestCase {
// …
private MyList aList;
private String anElement;
public void setUp() {
        aList = new MyList();
        anElement = “a string”;
}

public void testAdd() {
        aList.add(anElement);
        assertTrue(aList.size() == 1);
        assertTrue(aList.contains(anElement));
}

public void testRemove() {
        aList.add(anElement);
        aList.remove(anElement);
        assertTrue(aList.size() == 0);
        assertFalse(aList.contains(anElement));
}
```

Test Fixture

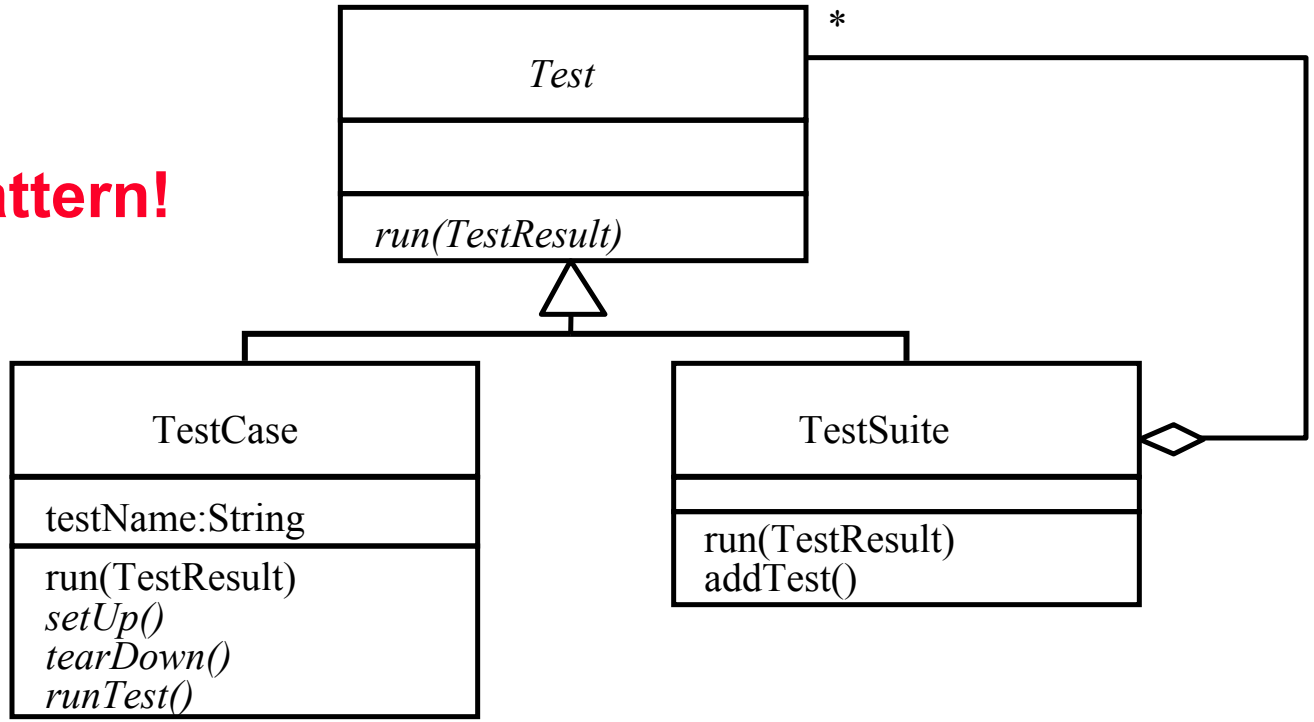
Test Case

Test Case

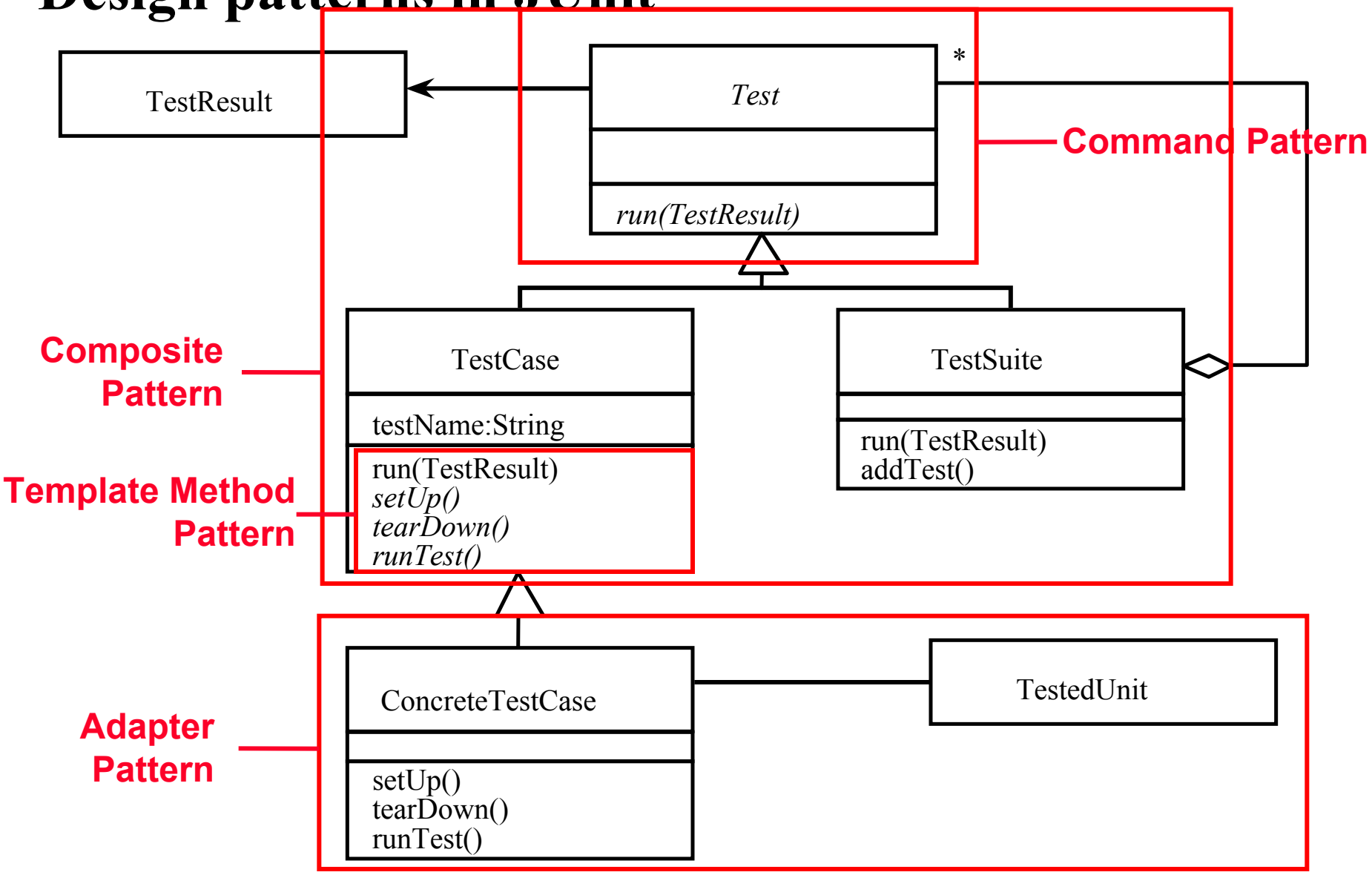
Collecting TestCases into TestSuites

```
public static Test suite() {
        TestSuite suite = new TestSuite();
        suite.addTest(new MyListTest("testAdd"));
        suite.addTest(new MyListTest("testRemove"));
        return suite;
}
```

Composite Pattern!



Design patterns in JUnit



Other JUnit features

- Textual and GUI interface
  - Displays status of tests
  - Displays stack trace when tests fail
- Integrated with Maven and Continuous Integration
  - http://maven.apache.org
    - Build and Release Management Tool
  - All tests are run before release (regression tests)
  - Test results are advertised as a project report
- Many specialized variants
  - Unit testing of web applications
  - J2EE applications

Additional Readings

- JUnit Website junit.org/junit5