Software Engineering Theory

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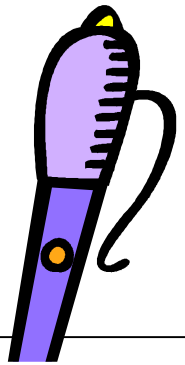
How do you test a ballpoint pen?

- Does the pen write in the right color, with the right line thickness?
- Is the logo on the pen according to company standards?
- Is it safe to chew on the pen?
- Does the click-mechanism still work after 100 000 clicks?
- Does it still write after a car has run over it?

What is expected from this pen?

Intended use!!



Validation vs. Verification

Validation: Are we building the right system?

Verification: Are we building the system right?

Testing software

- Are the functions giving correct output?
- Are the integrated modules giving correct output?
- Is the entire system giving correct output when used?
- Is the correct output given in reasonable time?
- Is the output presented in an understandable way?
- Was this what we really expected?

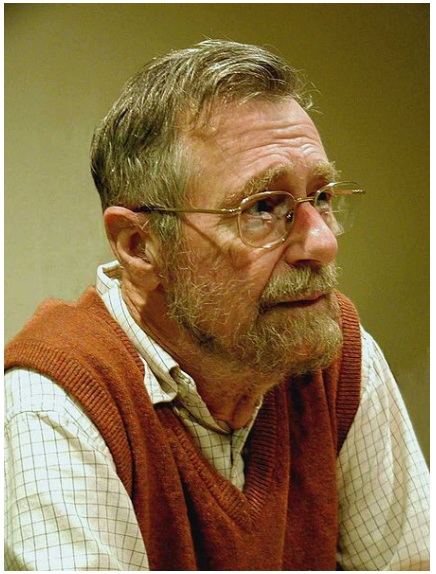
- Software testing is an activity in which a program is **executed** under specified conditions,
the results are **observed**,
and an **evaluation** is made of the program.

Other methods for Validation & Verification

- Formal verification (Z method)
- Model checking
- Prototyping
- Simulation
- Software reviews

”Testing shows the presence, not the absence of bugs“

(Edsger Wybe Dijkstra)



…but you might use experience and statistics to make some kind of assessment.

Basic Definitions – lecture notes

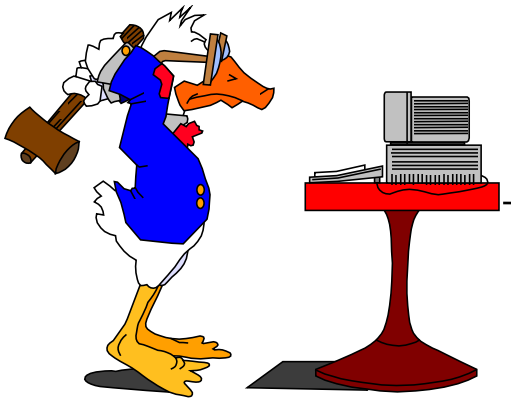
The terminology here is taken from standards developed by the institute of Electronics and Electrical Engineers (IEEE) computer Society.

- **Error**: people make **errors**. A good synonym is **mistake**. When people make mistakes while coding, we call these mistakes **bugs**. Errors tend to propagate; a requirements error may be magnified during design and amplified still more during coding.

- **Fault**: a fault is the result of an error. It is more precise to say that a fault is the representation of an error, where representation is the mode of expression, such as narrative text, data flow diagrams, hierarchy charts, source code, and so on. **Defect** is a good synonym for fault, as is **bug**. Faults can be elusive. When a designer makes an error of omission, the resulting fault is that something is missing that should be present in the representation. We might speak of faults of commission and faults of omission. A **fault of commission** occurs when we enter something into a representation that is incorrect. **Faults of omission** occur when we fail to enter correct information. Of these two types, faults of omission are more difficult to detect and resolve.

- **Failure (anomaly)**: a failure occurs when a **fault executes**. Two subtleties arise here: one is that failures only occur in an executable representation, which is usually taken to be source code, or more precisely, loaded object; the second subtlety is that this definition relates failures only to faults of commission. How can we deal with failures that correspond to faults of omission?

Error, Fault, Failure

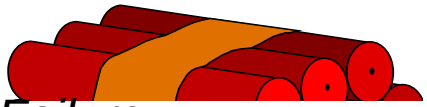


Can lead to

Human error (Mistake, Bug)

Can lead to

Fault (Defect, Bug)



Failure

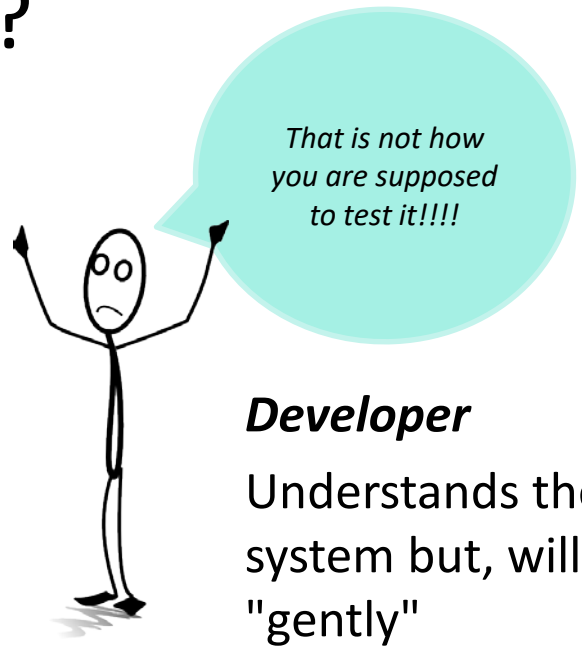
The Ariane 5 fiasco

- 10 years and $7 billion to produce
- < 1 min to explode
- Programmers thought that this particular value would never become large enough to cause trouble
- Removed the test present in Ariane 4 software
- 1 bug = 1 crash

Who does the testing?

Independent Tester

Must learn about the system, but, will attempt to break it and, is driven by quality

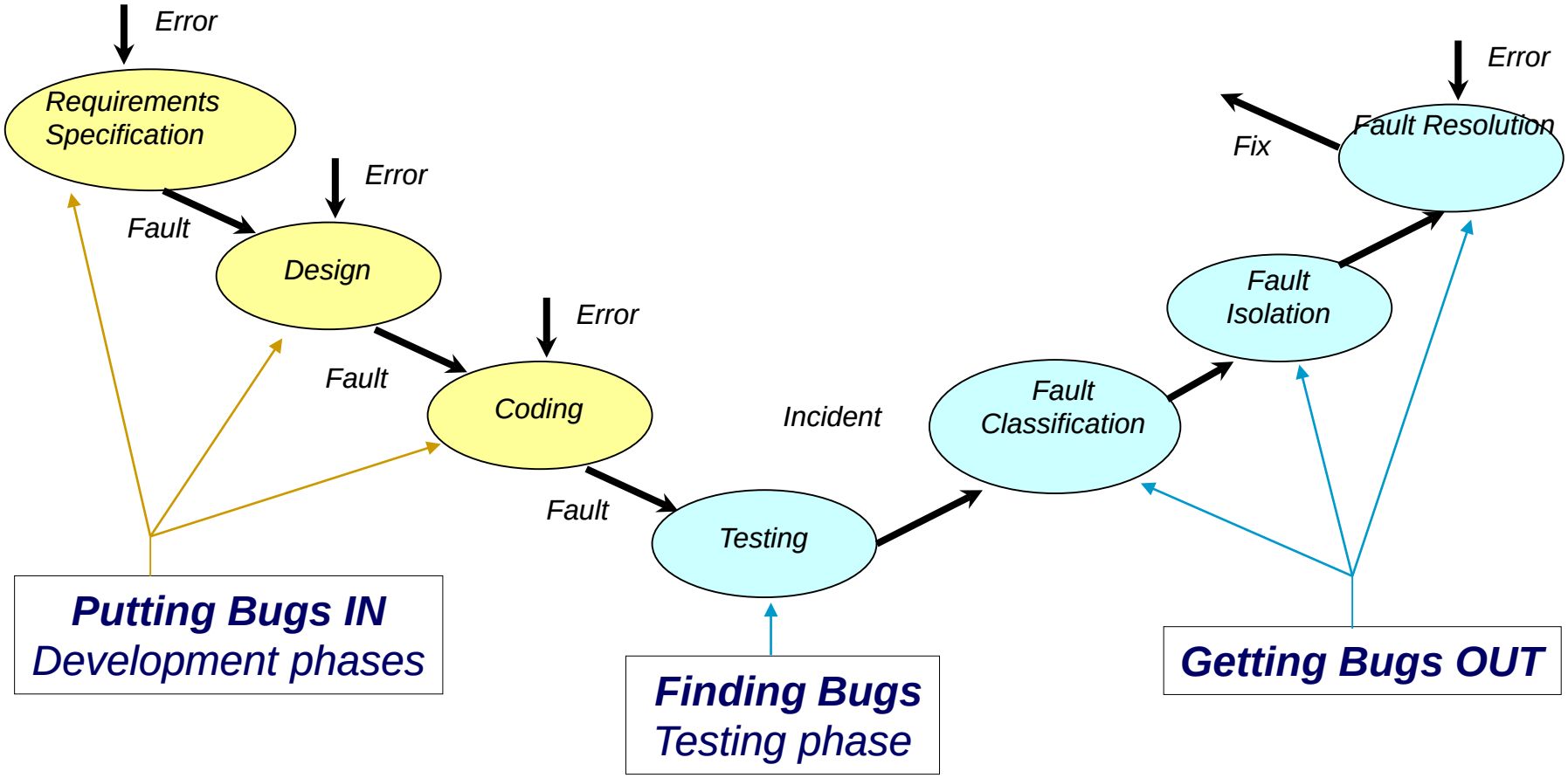


Developer

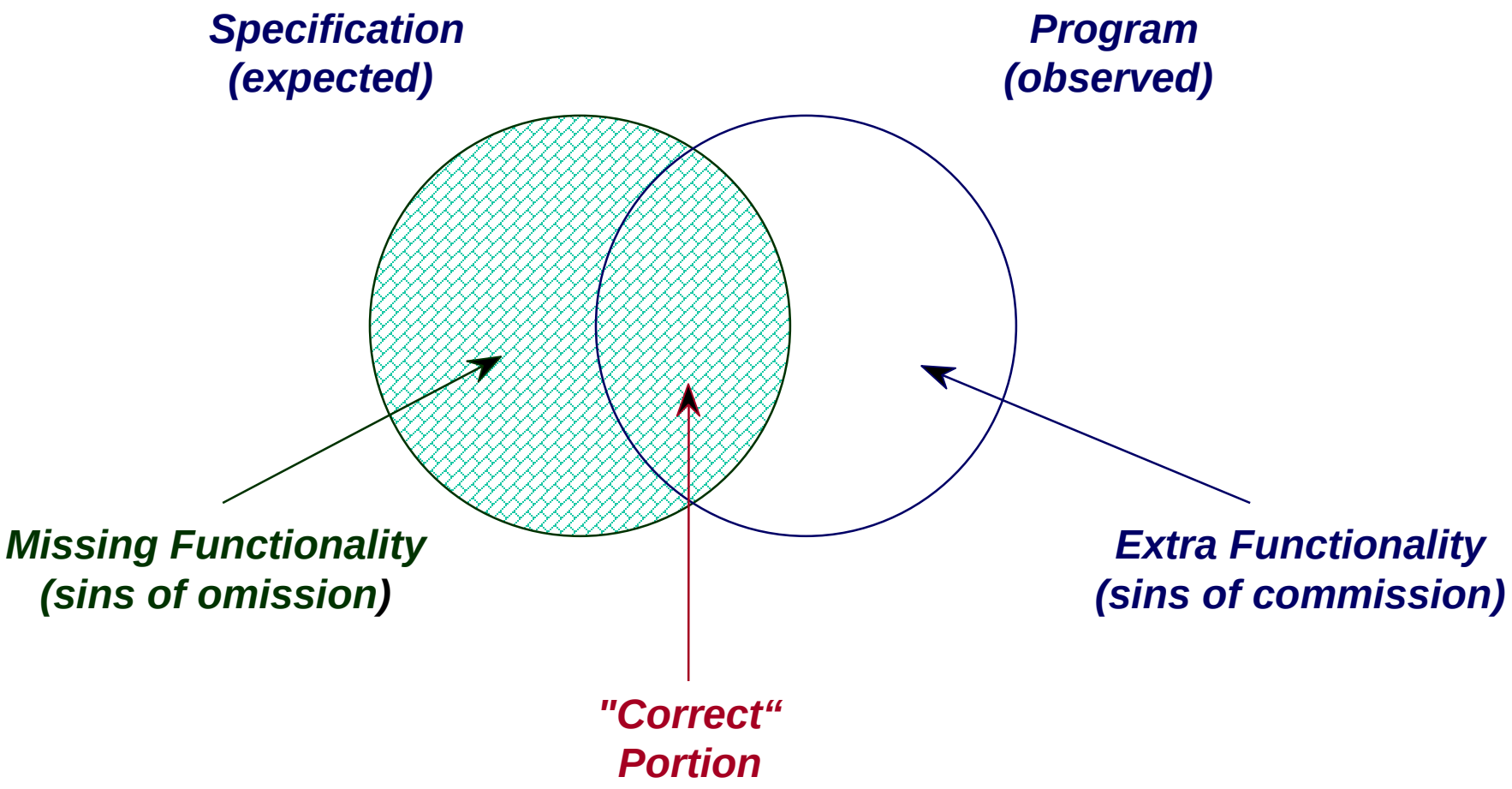
Understands the system but, will test "gently"
and, is driven by "delivery”

- Development team needs to work with Test team
- “Egoless Programming”

The V-model from the tester perspective



Program Behaviors



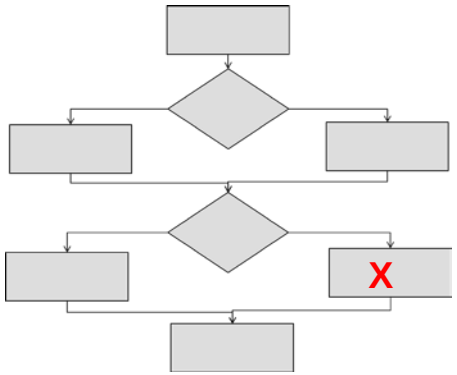
Basic Approaches

Specification

R1: Given **input**, the software shall provide **output**.

Functional (Black Box) establishes confidence

Program



Find **input** and **output** so that **X** is executed.

Structural (White Box) seeks faults

Types of Faults

(dep. on org. IBM, HP)

- Algorithmic: division by zero
- Computation & Precision: order of op
- Documentation: doc - code
- Stress/Overload: data-structure size (dimensions of tables, size of buffers)
- Capacity/Boundary: x devices, y parallel tasks, z interrupts
- Timing/Coordination: real-time systems
- Throughout/Performance: speed in req.
- Recovery: power failure
- Hardware & System Software: modem
- Standards & Procedure: organizational standard; difficult for programmers to follow each other.

Faults classified by severity

(Beizer, 1984)

1.	**Mild**	Misspelled word
2.	**Moderate**	Misleading or redundant information
3.	**Annoying**	Truncated names, bill for $0.00
4.	**Disturbing**	Some transaction(s) not processed
5.	**Serious**	Lose a transaction
6.	**Very serious**	Incorrect transaction execution
7.	**Extreme**	Frequent ”very serious” errors
8.	**Intolerable**	Database corruption
9.	**Catastrophic**	System shutdown
10.	**Infectious**	Shutdown that spreads to others

Course standard

Contents of a Test Case

"Boilerplate": author, date, purpose, ***test case ID***

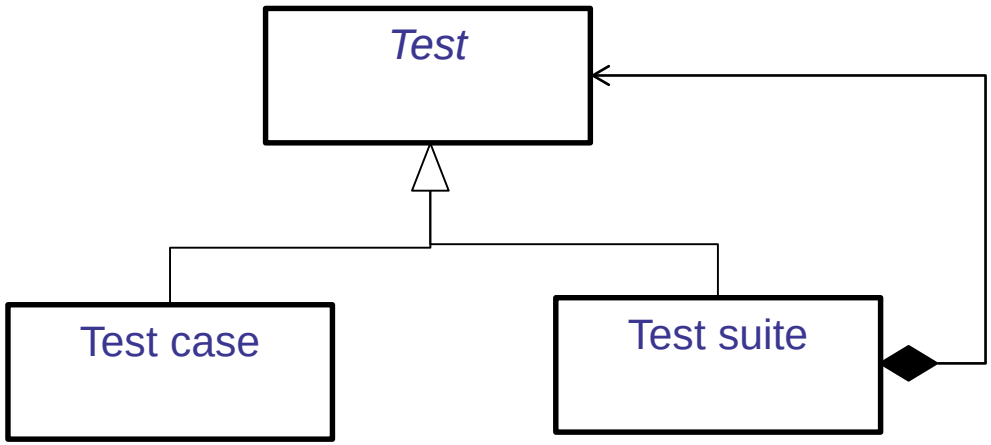
Pre-conditions (including environment)

Inputs

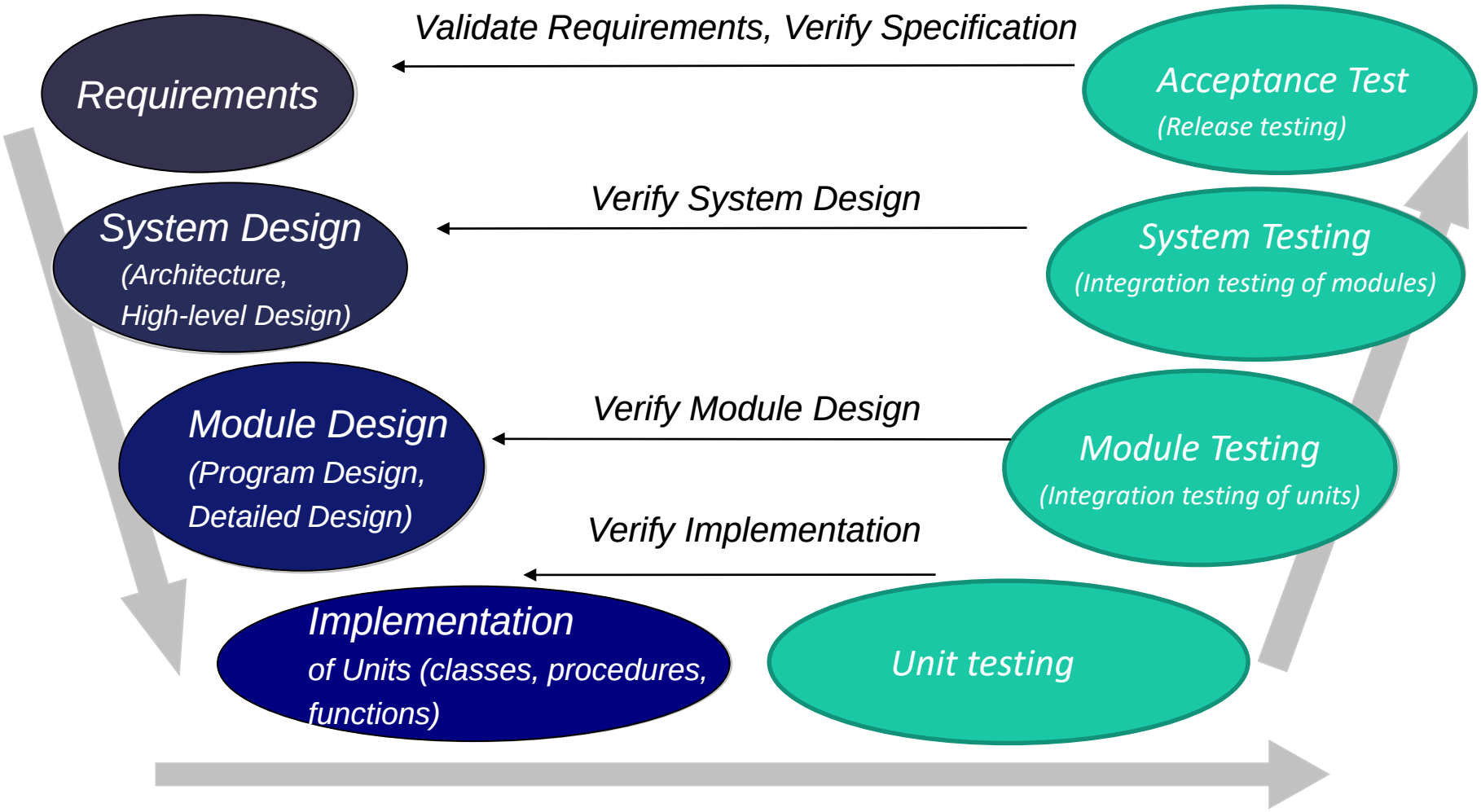
Expected Outputs

Observed Outputs

Pass/Fail



Testing levels



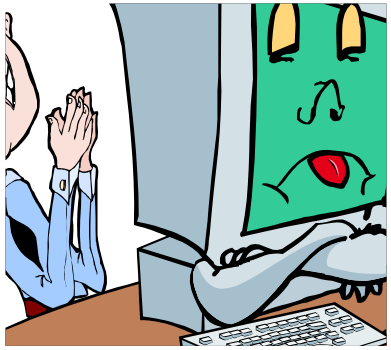
Test table

Id	Advanced course credits in Computer Science	Advanced course credits in total	Masters thesis in subject	Total number of credits	M.Sc., Computer Science
1	20	120	Computer sc.	120	**No**
2	30	90	Computer sc.	120	**Yes**
3	30	90	Physics	120	**No**
…	…	…	…	…	…

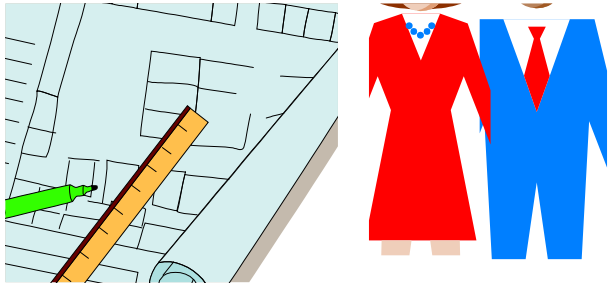
Can be written from specification

Unit-Testing

Objective: to ensure that code implemented the design properly.



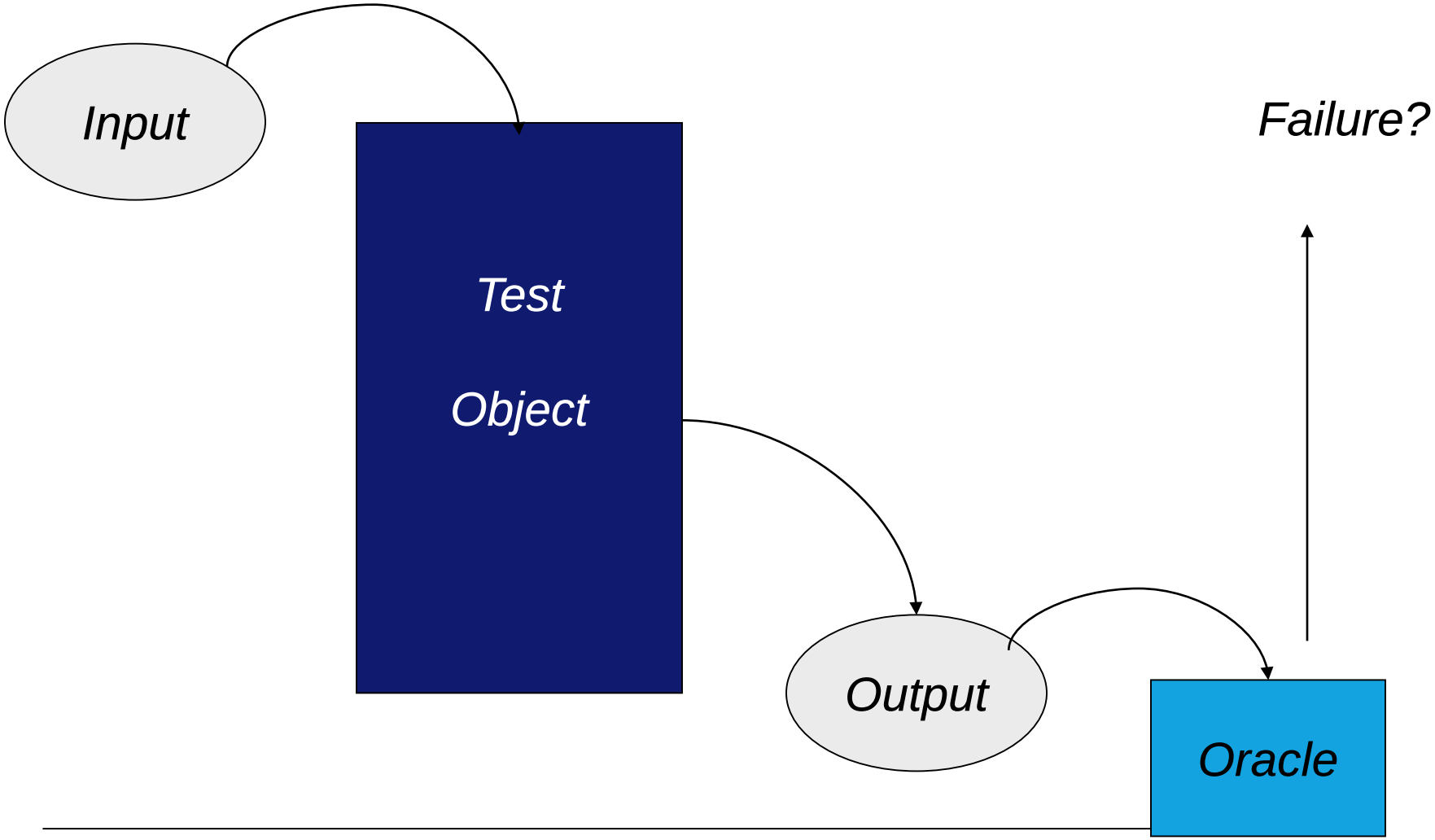
Code = System



Design Specification

Often done by the programmers themselves.

The oracle problem



Two Types of Oracles

- **Human**: an expert that can examine an input and its associated output and determine whether the program delivered the correct output for this particular input.

- **Automated**: a system capable of performing the above task.

R2: “The answer is 42.”

42

42.0

XLII

41.99999

Black-box/ closed box testing

Testing based only on specification:

1. Exhaustive testing
2. Equivalence class testing (Equivalence Partitioning)
3. Boundary value analysis

1. Exhaustive testing

Definition: testing with every member of the input value space.

Input value space: the set of all possible input values to the program.

- Sum of two 16 bit integers: 2^{32} combinations
- One test per ms takes about 50 days.

2. Equivalence Class Testing

- Equivalence Class (EC) testing is a technique used to reduce the number of test cases to a manageable level while still maintaining reasonable test coverage.

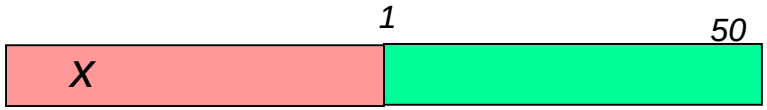
- Each EC consists of a set of data that is treated the same by the module or that should produce the same result. Any data value within a class is ***equivalent***, in terms of testing, to any other value.

Identifying the Equivalence Classes

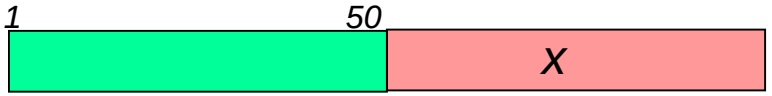
Taking each input condition (usually a sentence or phrase in the specification) and partitioning it into two or more groups:

- Input condition
  - range of values x: 1-50
- Valid equivalence class
  - 1 <= x <= 50

- Invalid equivalence classes
  - x < 1



  - x > 50



Two-variable example

Validate loan application forms against the rule:

- If you are 18 years and older, you can borrow maximally 100.000, but not less than 10.000.
- Variable: **age**
  - EC1: age < 18
  - EC2: age >= 18
- Variable: **sum**
  - EC3: sum < 10.000
  - EC4: 10.000 <= sum <= 100.000
  - EC5: sum > 100.000

Two-variable example, test-cases

Test-case id	Age	Sum	Valid form
1	32	55.300	Yes
2	13	72.650	No
3	44	9.875	No
4	50	60.000	Yes
5	87	103.800	No

Arbitrary, valid sums

Arbitrary, valid ages

Guidelines

1. If an input condition specifies a *range* of values; identify one valid EC and two invalid EC.

2. If an input condition specifies the *number* (e.g., one through 6 owners can be listed for the automobile); identify one valid EC and two invalid EC (- no owners; - more than 6 owners).

3. If an input condition specifies a set of input values and there is reason to believe that each is handled differently by the program; identify a valid EC for each and one invalid EC.

4. If an input condition specifies a “must be” situation (e.g., first character of the identifier must be a letter); identify one valid EC (it is a letter) and one invalid EC (it is not a letter)

5. If there is any reason to believe that elements in an EC are not handled in an identical manner by the program, split the equivalence class into smaller equivalence classes.

Identifying the Test Cases

1. Assign a unique number to each EC.

2. Until all valid ECs have been covered by test cases, write a new test case covering as many of the uncovered valid ECs as possible.

3. Until all invalid ECs have been covered by test cases, write a test case that cover one, and only one, of the uncovered invalid ECs.

Applicability and Limitations

- Most suited to systems in which much of the input data takes on values within ranges or within sets.

- It makes the assumption that data in the same EC is, in fact, processed in the same way by the system. The simplest way to validate this assumption is to ask the programmer about their implementation.

- EC testing is equally applicable at the unit, integration, system, and acceptance test levels. All it requires are inputs or outputs that can be partitioned based on the system's requirements.

3. Boundary Value Testing

Boundary value testing focuses on the boundaries simply because that is where so many defects hide. The defects can be in the requirements or in the code.

Technique

1. Identify the ECs.

Course standard

2. Identify the boundaries of each EC.

3. Create test cases for each boundary value by choosing one point on the boundary, one point just below the boundary, and one point just above the boundary.

Specification: the program accepts four to eight inputs which are 5 digit integers greater than or equal to 10000.

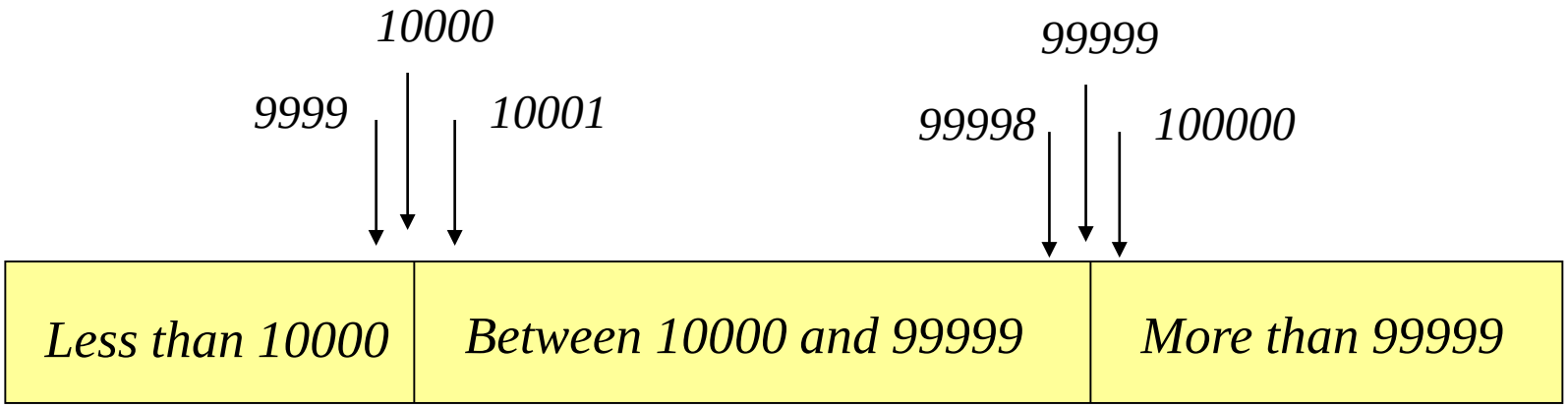
Input values

Less than 10000	*Between 10000 and 99999*	*More than 99999*

Number of input values

Less than 4	*Between 4 and 8*	*More than 8*

Boundary value analysis



Applicability and Limitations

Boundary value testing is equally applicable at the unit, integration, system, and acceptance test levels. All it requires are inputs that can be partitioned and boundaries that can be identified based on the system's requirements.

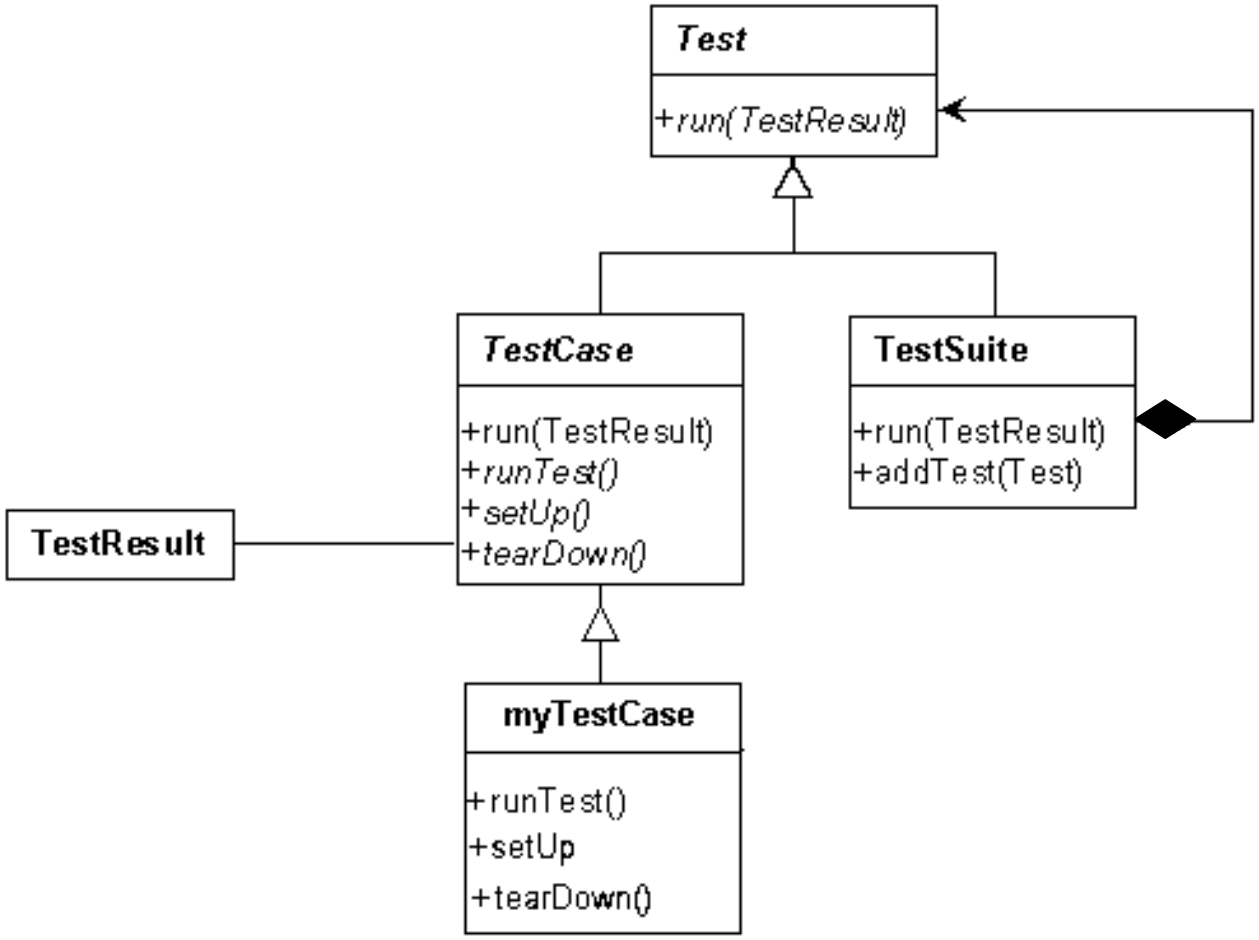
xUnit

- xUnit is a set of tools for regression testing
- x denotes a programming language
- Junit, for Java is one of the earliest and most popular
- TDDC88 has a lab – do that

- Recommended primer:

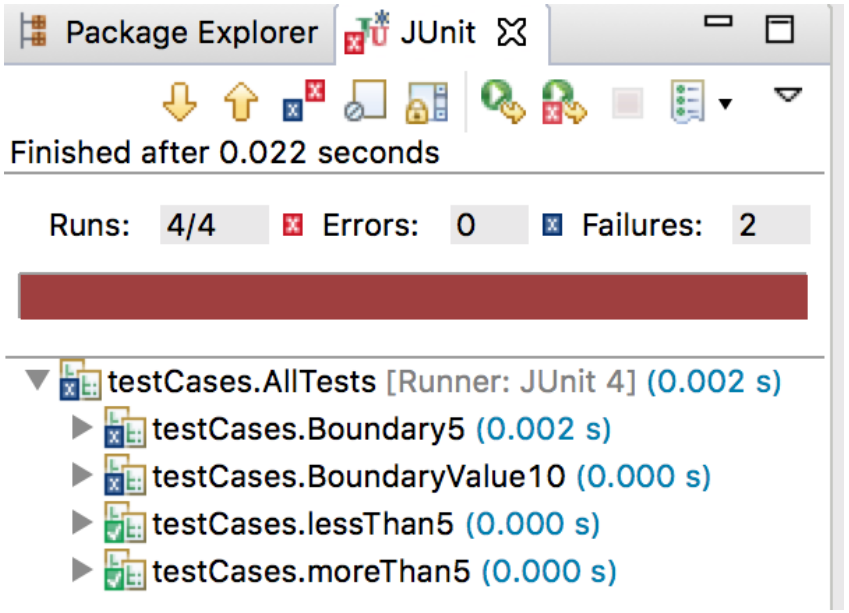
http://www.it-c.dk/~lthorup/JUnitPrimer.html

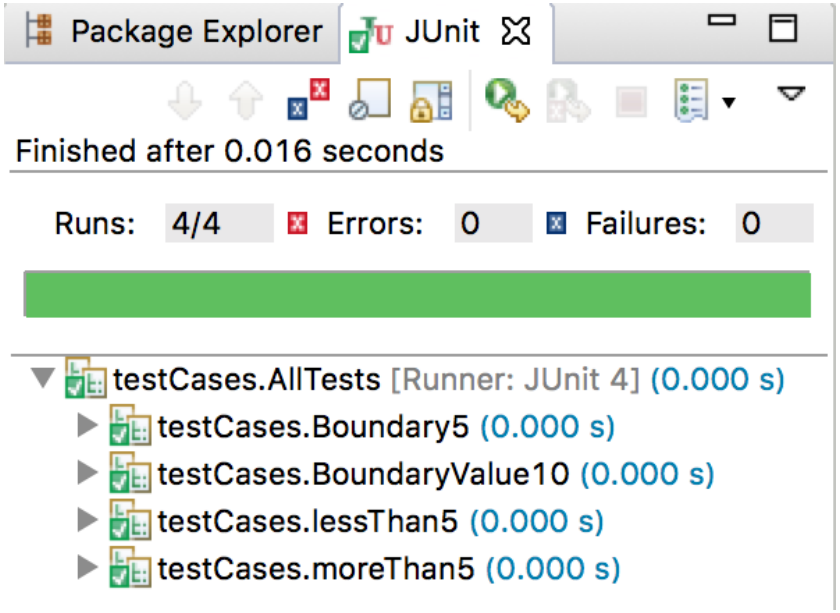
JUnit framework



Object Oriented Framework Development
by Marcus Eduardo Markiewicz and Carlos J.P. Lucena

JUnit interface





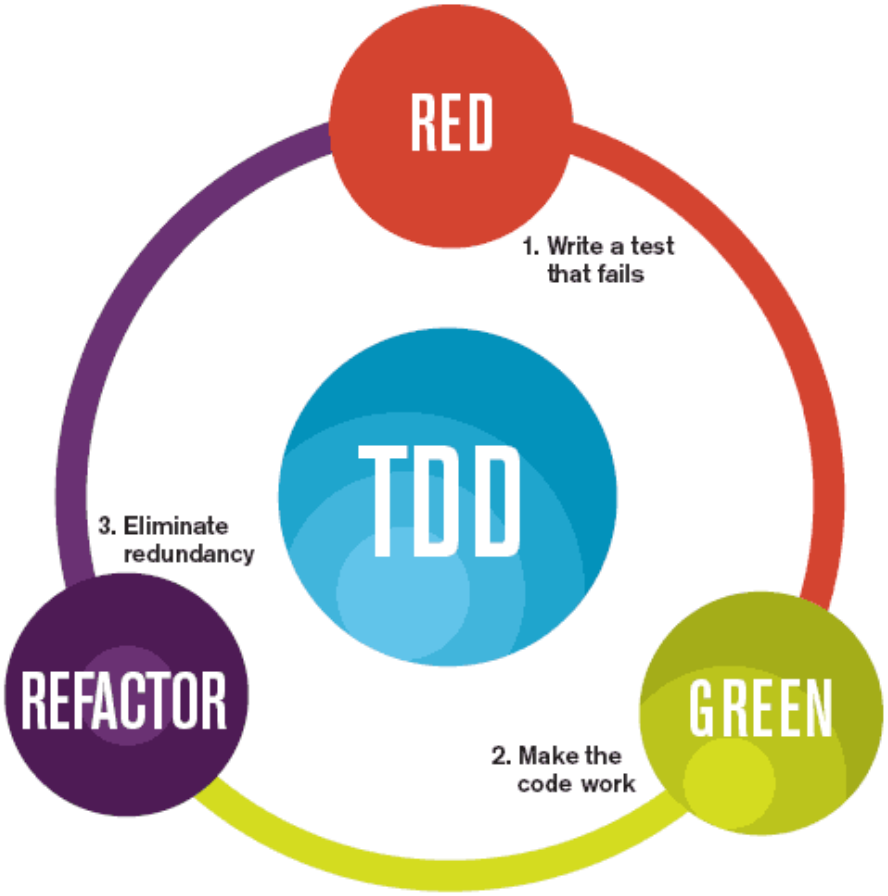
*assertEquals("Checks the boundary value 5", **true, tester.isBetween5and10(5));***

message if fail

expected

actual

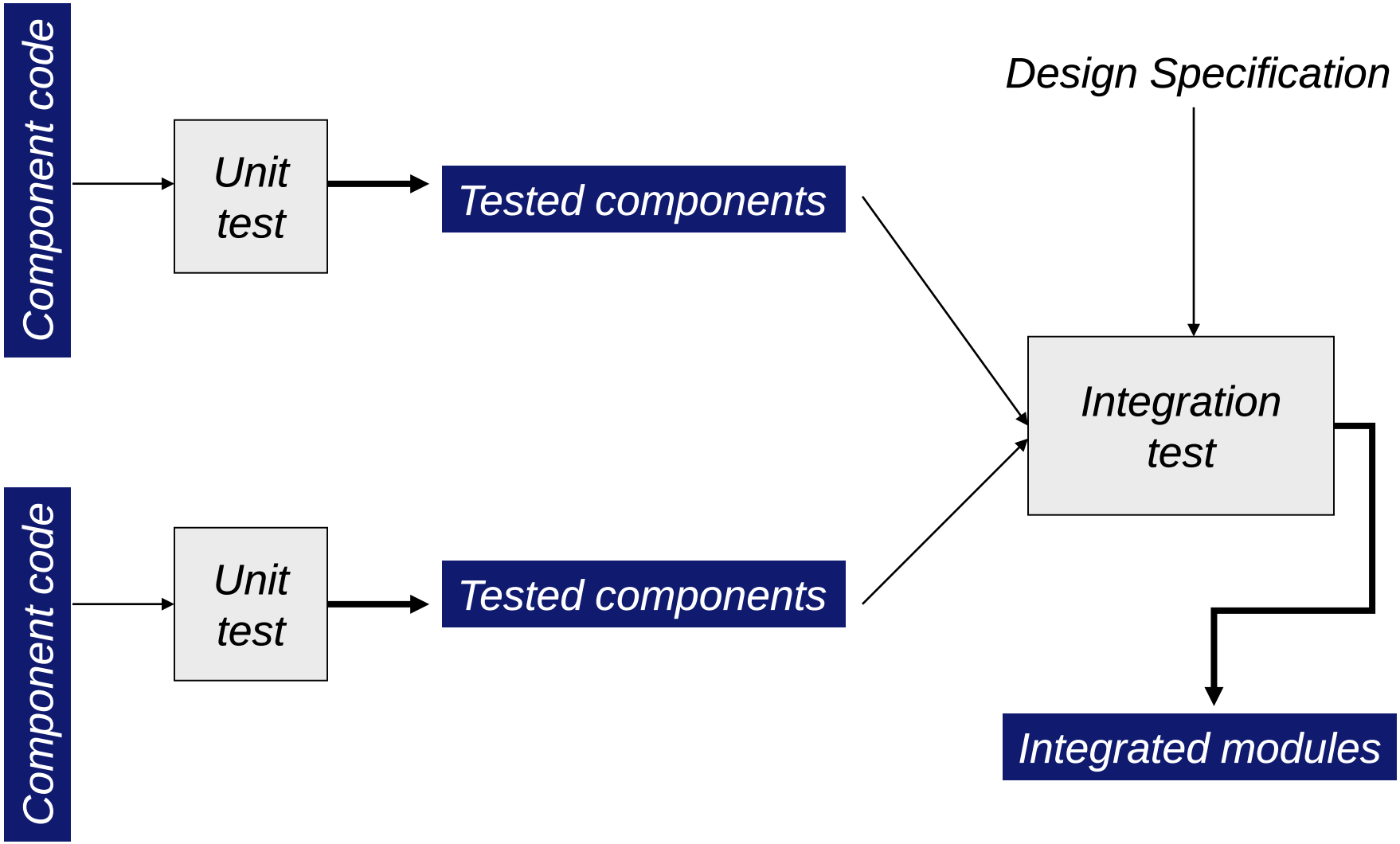
Test-Driven Development (TDD)



The mantra of Test-Driven Development (TDD) is "red, green, refactor."

source: Redmond Developer

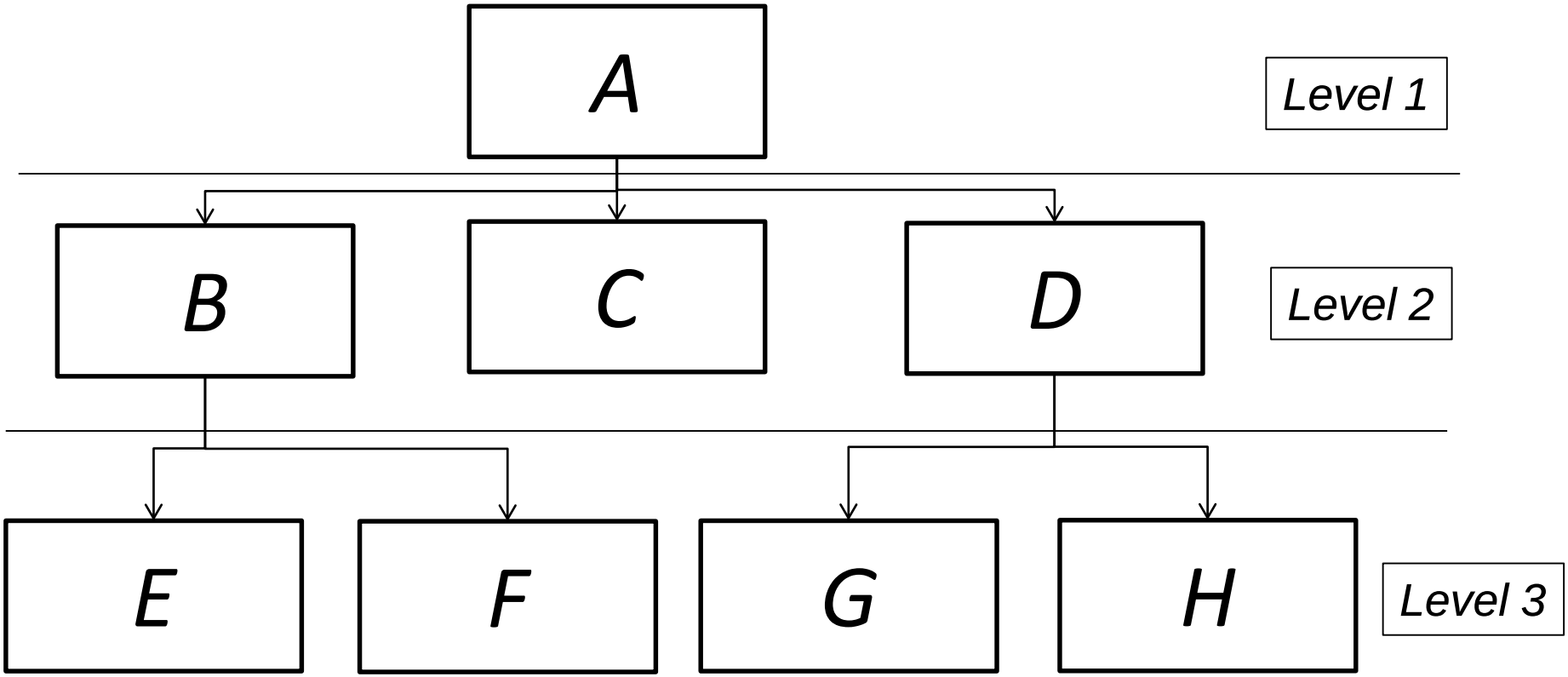
Integration testing

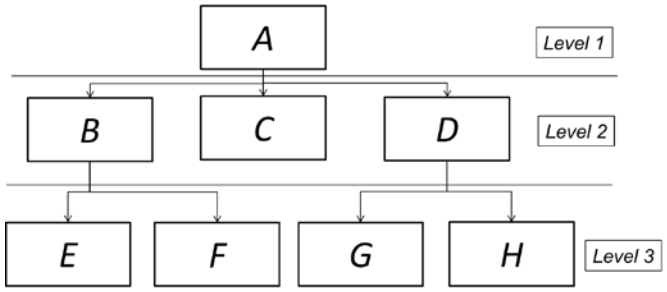

Component code
Unit test
Tested components
Design Specification
Integration test
Component code
Unit test
Tested components
Integrated modules

Integration Testing strategies

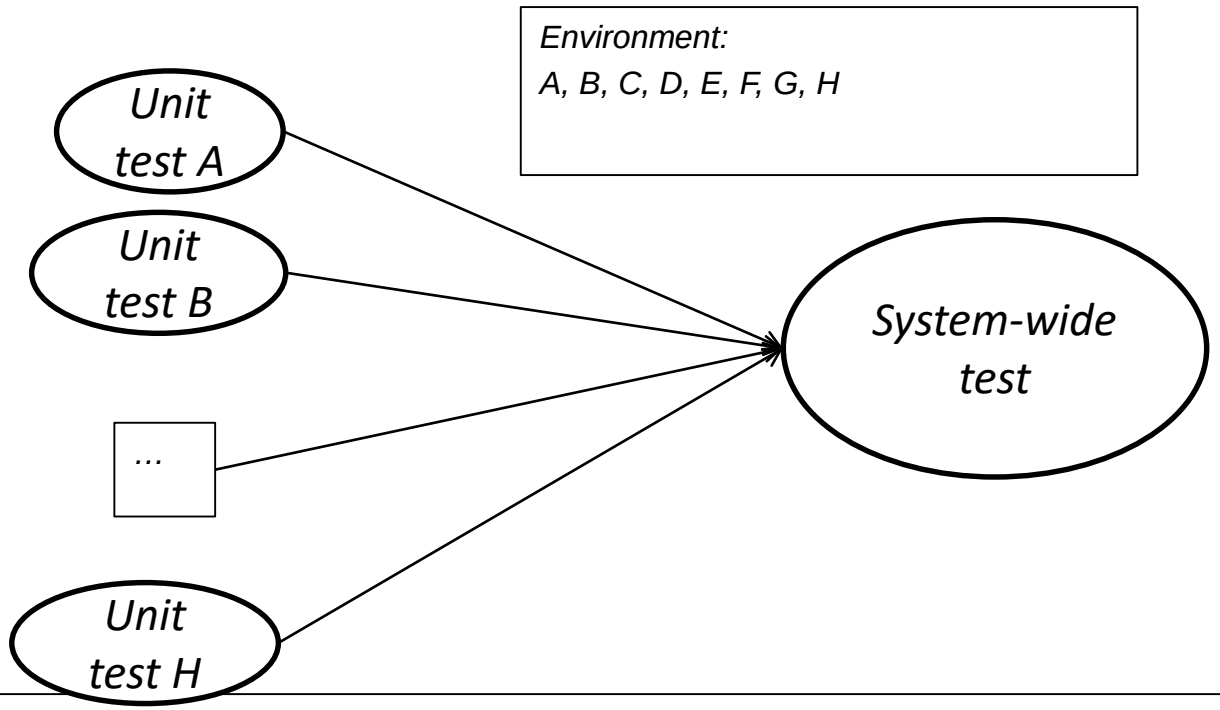
1. Big-bang
2. Bottom-up
3. Top-down
4. Sandwich

Three level functional decomposition tree



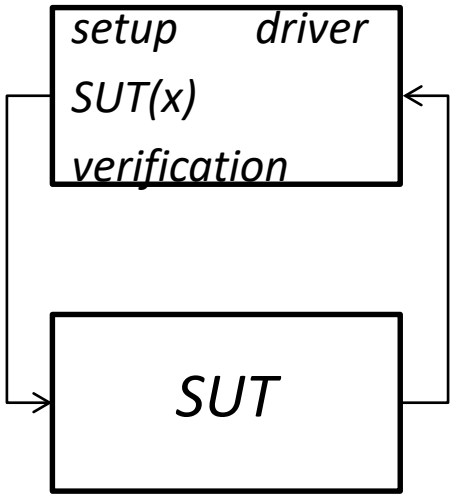


Big-Bang testing

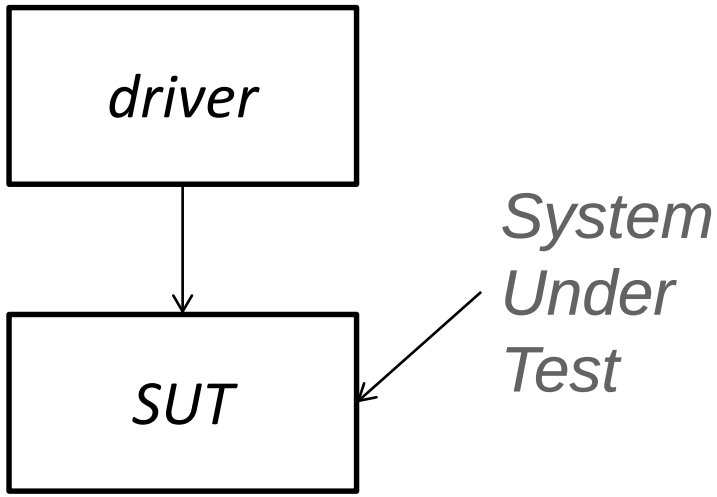


Driver

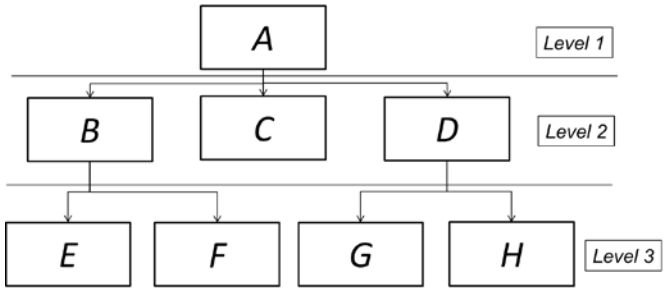
A pretend module that requires a sub-system and passes a test case to it

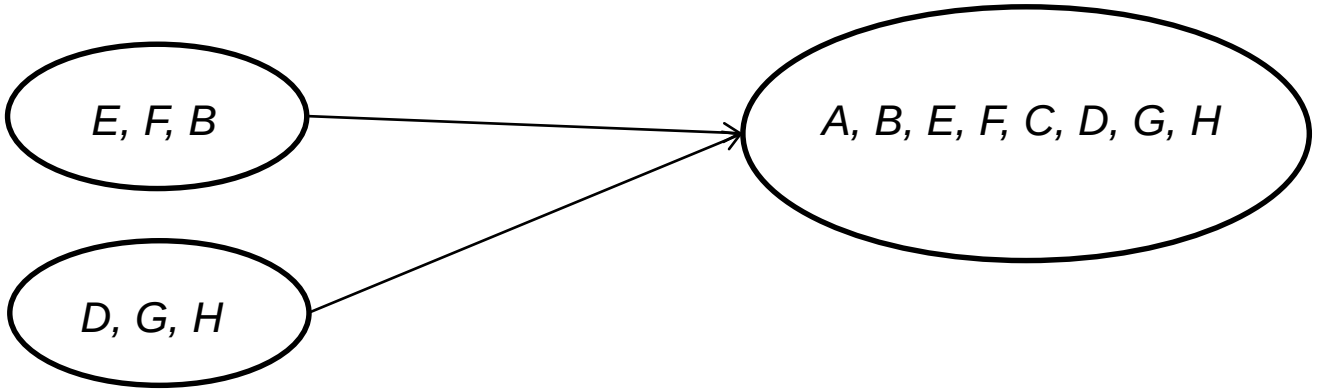


Black-box view



Bottom-up testing





Is bottom-up smart?

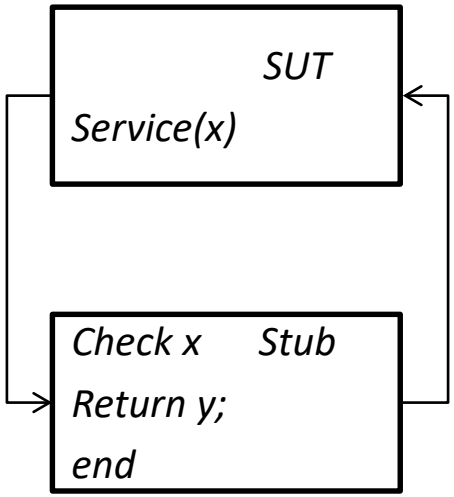
- If the basic functions are complicated, error-prone or has development risks
- If bottom-up development strategy is used
- If there are strict performance or real-time requirements

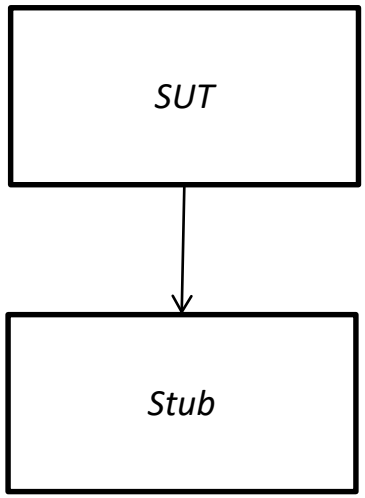
Problems:

- Lower level functions are often off-the shelf or trivial
- Complicated User Interface testing is postponed
- End-user feed-back postponed
- Effort to write drivers.

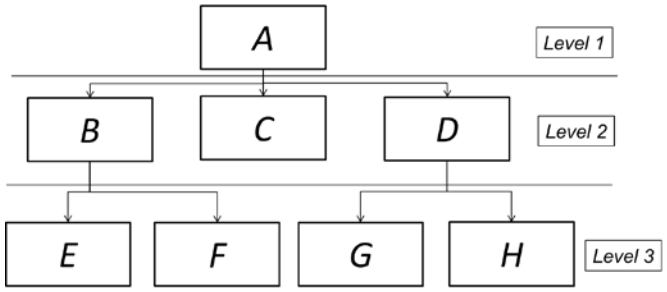
Stub

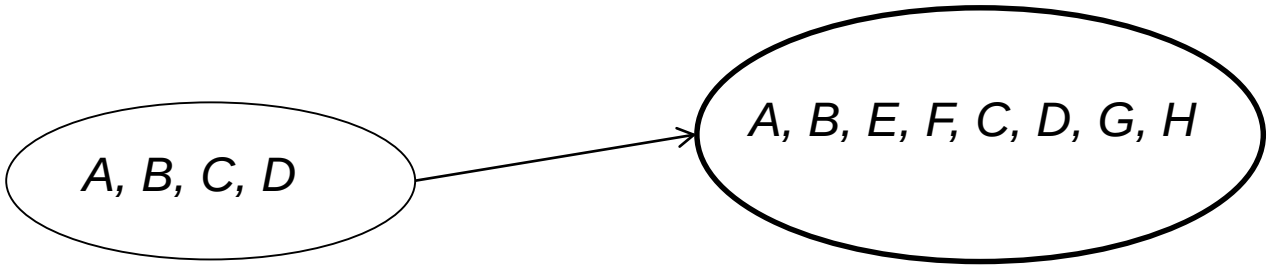
- A program or a method that **simulates the input-output functionality** of a missing sub-system by answering to the decomposition sequence of the calling sub-system and returning back simulated or ”canned” data.





Top-down testing





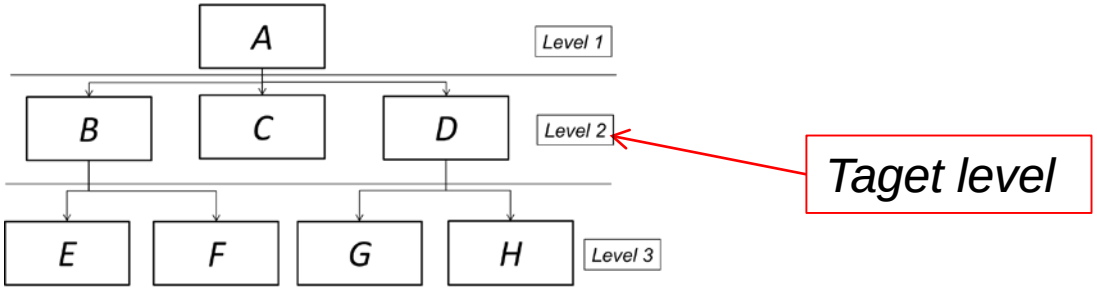
Is top-down smart?

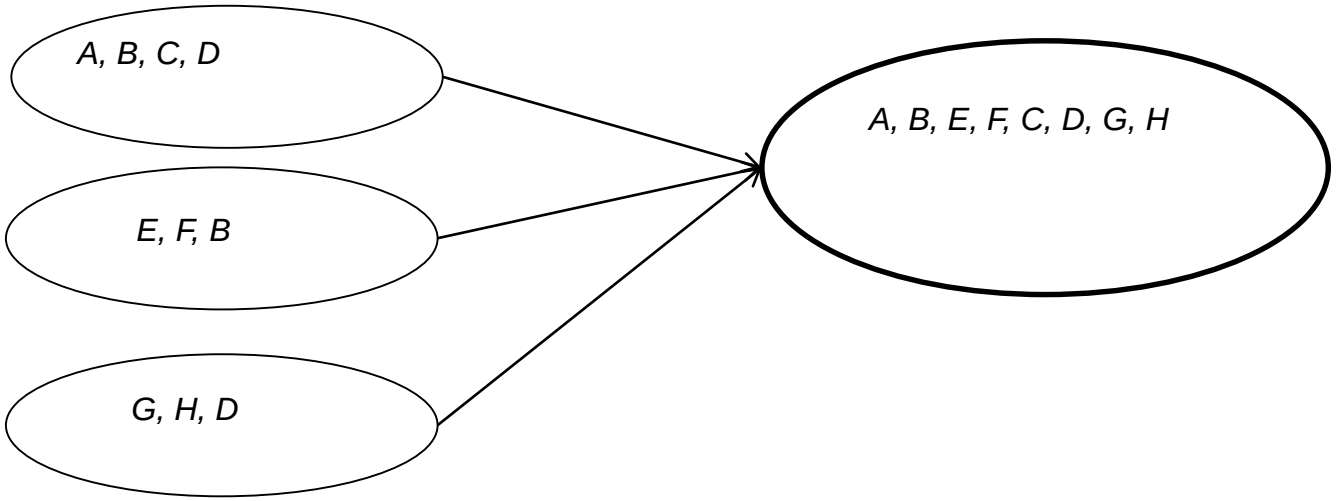
- Test cases are defined for functional requirements of the system
- Defects in general design can be found early
- Works well with many incremental development methods
- No need for drivers

Problems:

- Technical details postponed, potential show-stoppers
- Many stubs are required
- Stubs with many conditions are hard to write

Sandwich testing

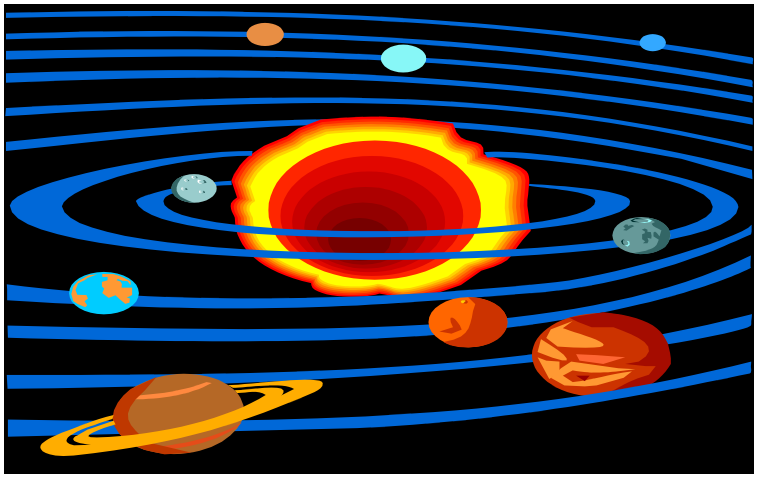


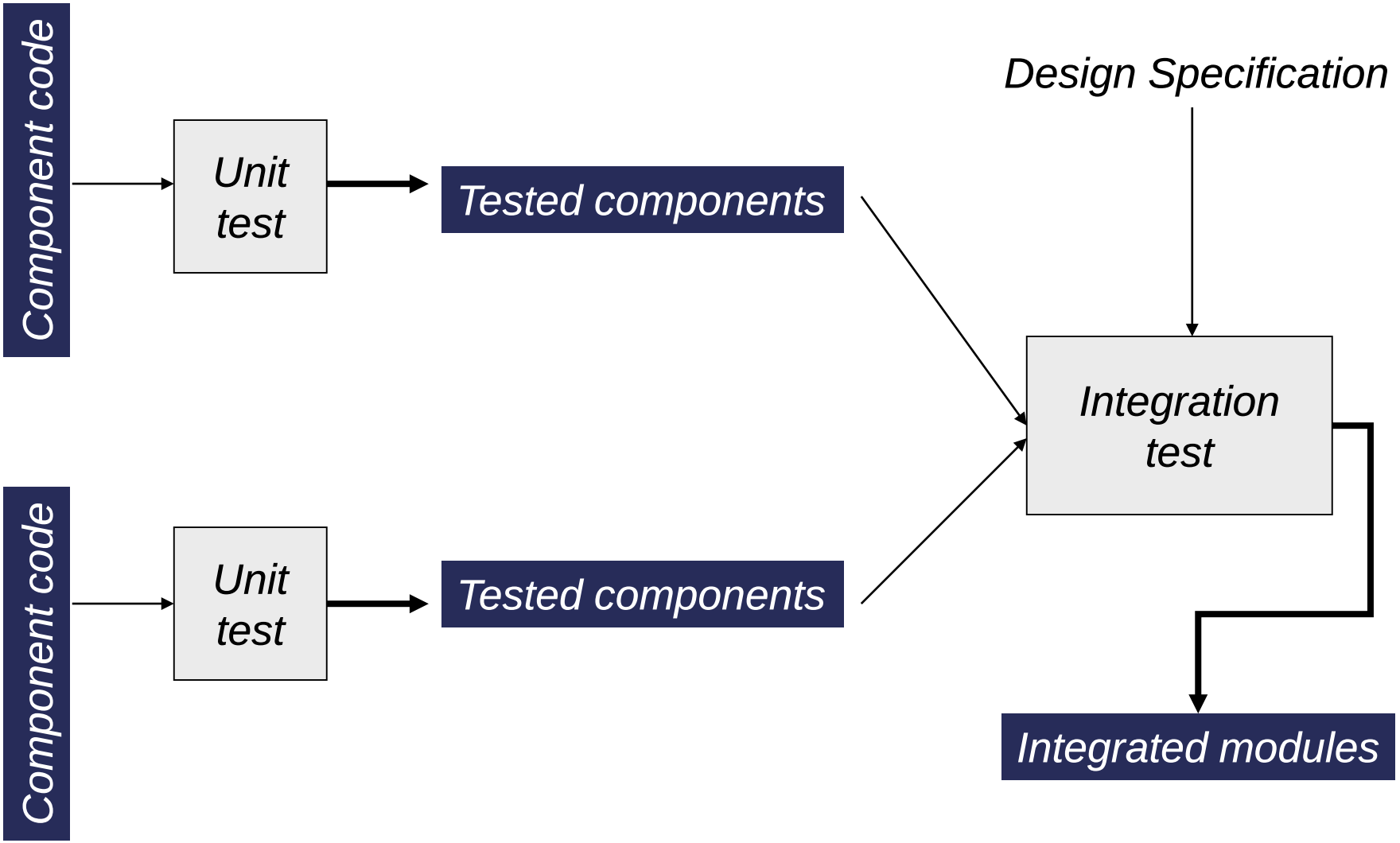


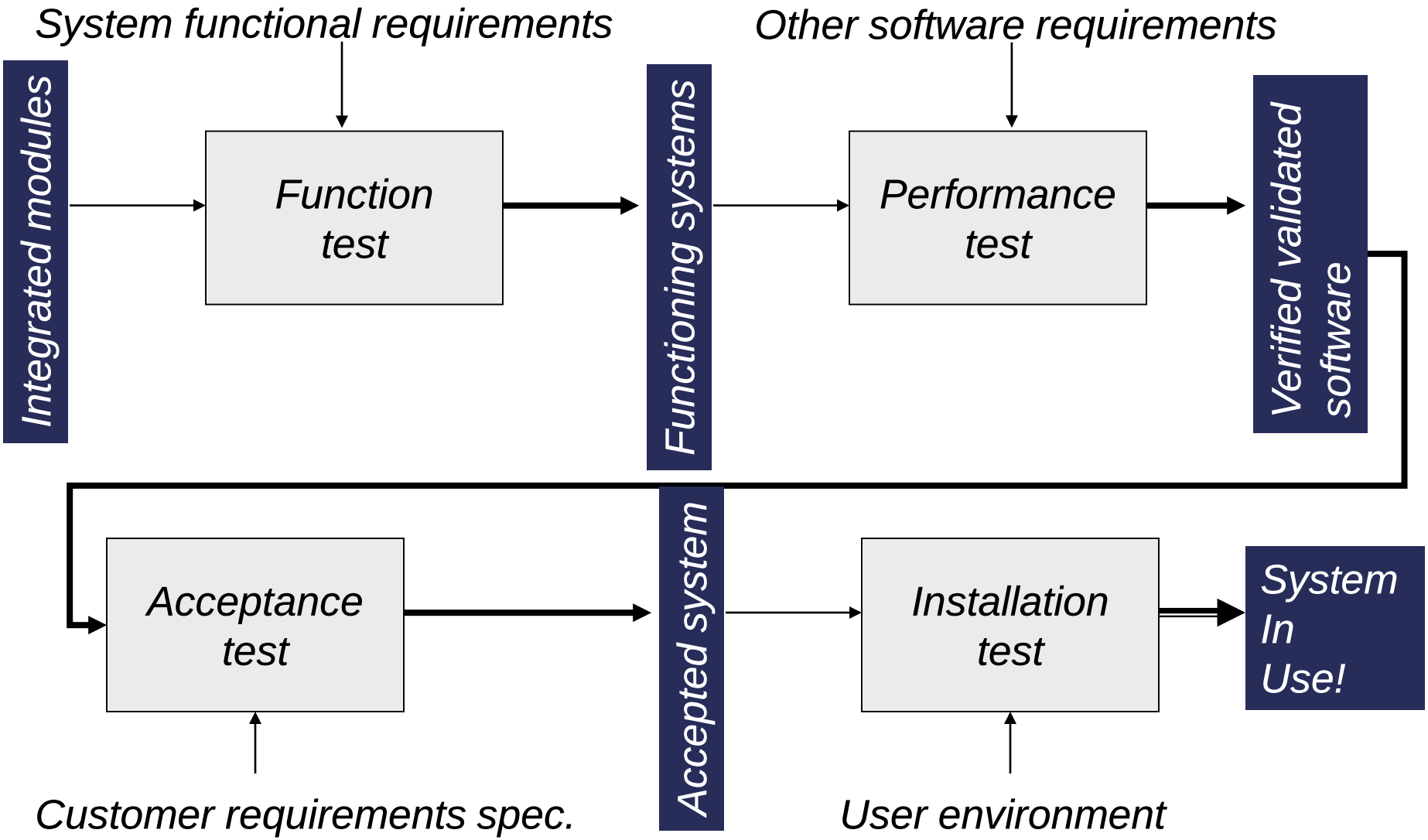
Is sandwich testing smart?

- Top and Bottom Layer Tests can be done in parallel
- Problems:
- Does not test the individual subsystems on the target layer thoroughly before integration

System Testing




Component code
Unit test
Tested components
Component code
Unit test
Tested components
Design Specification
Integration test
Integrated modules


System functional requirements
Other software requirements
Integrated modules
Function test
Functioning systems
Performance test
Verified validated software
Acceptance test
Accepted system
Installation test
System In Use!
Customer requirements spec.
User environment

Function testing/Thread testing

(testing one function at a time)

functional requirements

A function test checks that the integrated system performs its function as specified in the requirement

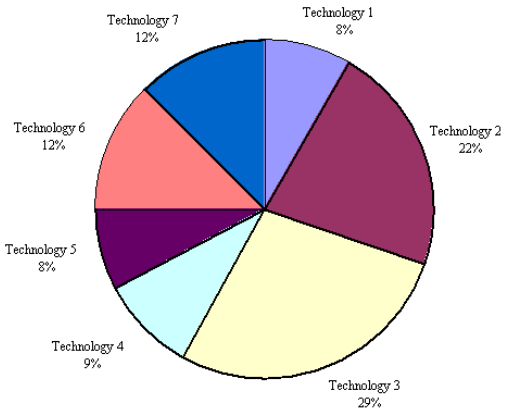
- Guidelines
  - use a test team **independent** of the designers and programmers
  - know the expected actions and output
  - test both valid and invalid input
  - never modify the system just to make testing easier
  - have stopping criteria

Performance Testing nonfunctional requirements

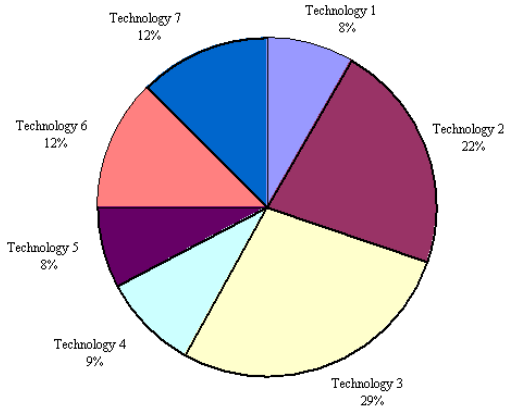
- Stress tests
- Timing tests
- Volume tests
- Configuration tests
- Compatibility tests
- Regression tests
- Security tests
- (physical) Environment tests
- Quality tests
- Recovery tests
- Maintenance tests
- Documentation tests
- Human factors tests / usability tests

Software reliability engineering

- Define target failure intensity
- Develop operational profile
- Plan tests
- Execute test
- Apply data to decisions



usage *testing*



Acceptance Testing

Customers, users needs

***Benchmark test**: a set of special test cases*

***Pilot test**: everyday working*

Alpha test: at the developer's site, controlled environment

Beta test: at one or more customer site.

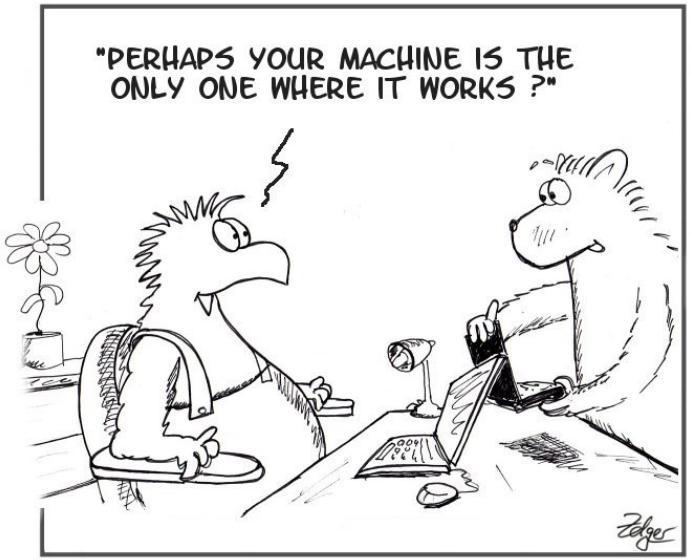
***Parallel test**: new system in parallel with previous one*

Installation Testing at client site

Acceptance test at developers site

→ installation test at users site,

otherwise installation test might not be needed!



It works on my machine

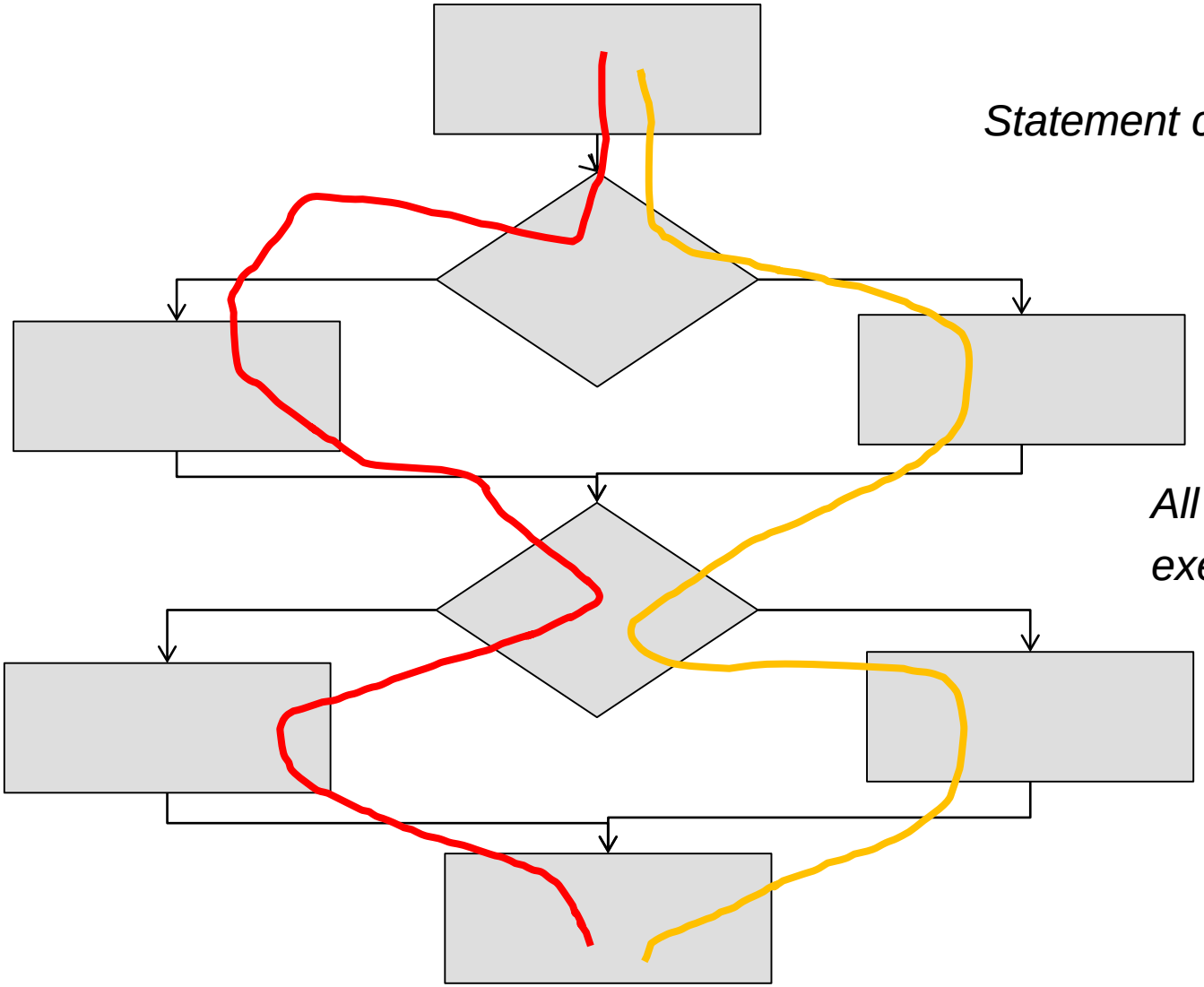
Termination Problem : How decide when to stop testing

- The main problem for managers!

Termination is influenced by:

- Deadlines, e.g. release deadlines, testing deadlines;
- Test cases completed with certain percentage passed;
- Test budget has been depleted;
- **Coverage of code**, functionality, or requirements reaches a specified point;

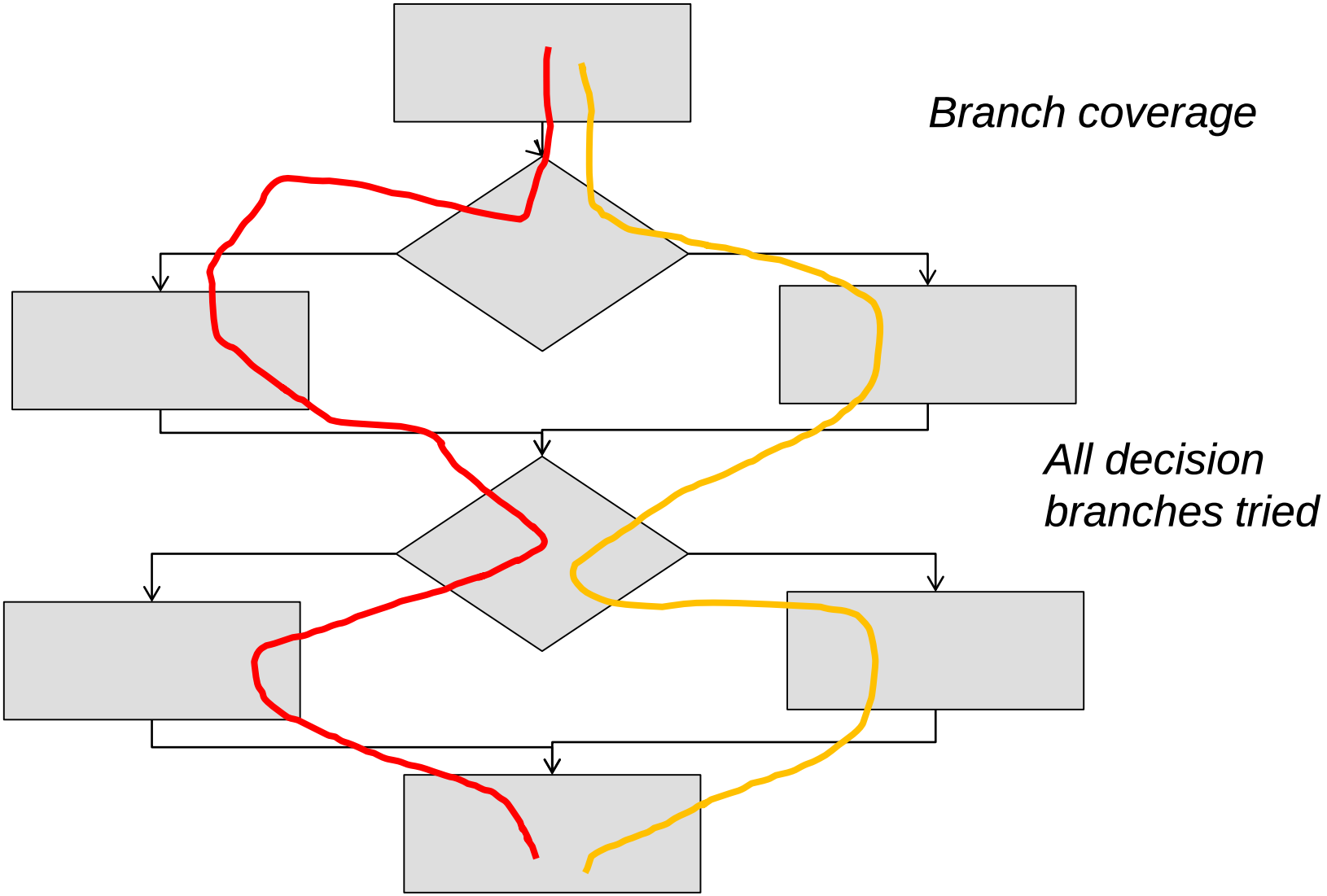
Control-flow based coverage



Statement coverage

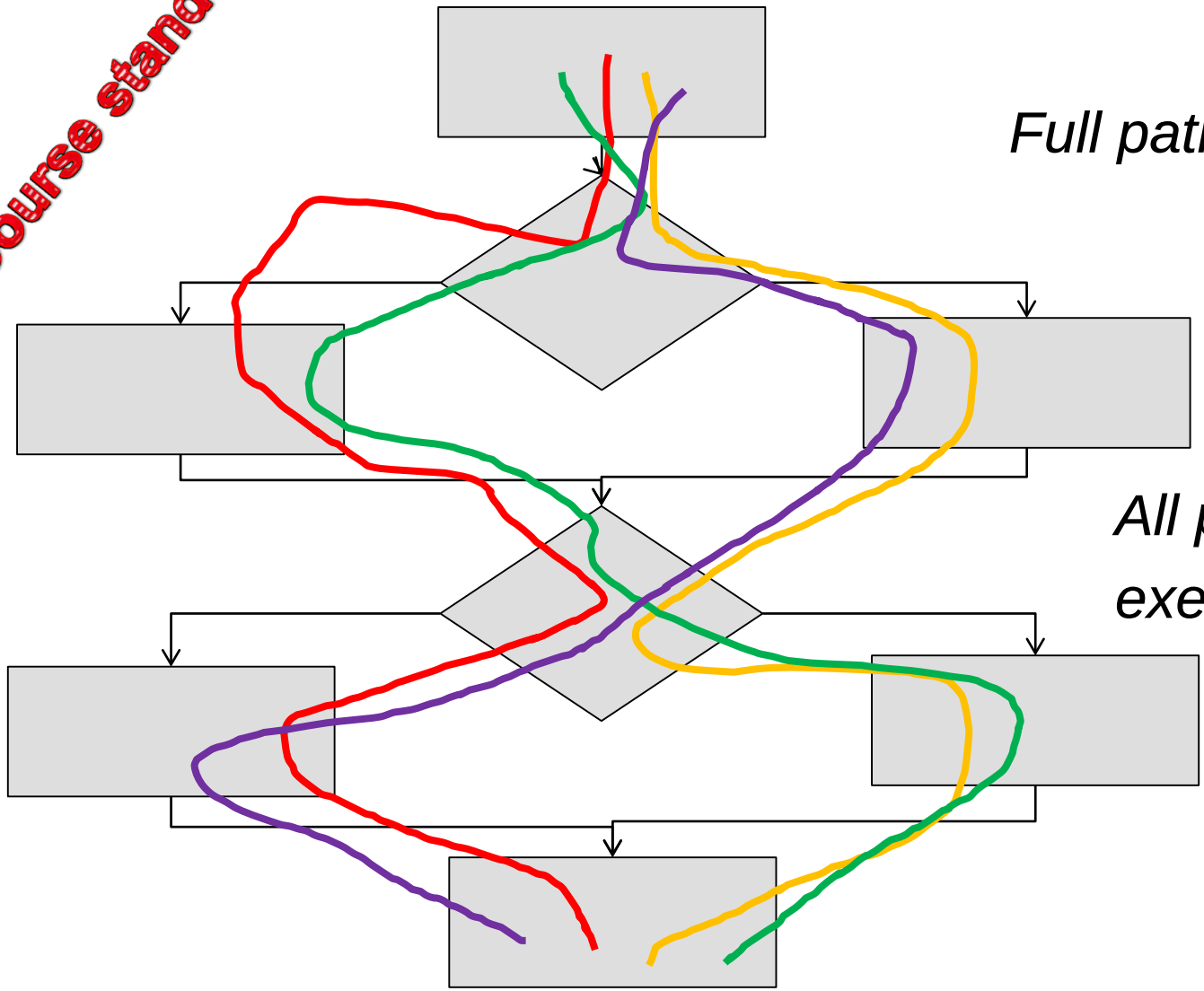
All statements executed

Control-flow based coverage



Control-flow based coverage

Course standard



Full path coverage

All possible paths executed

GUI Testing

- GUI application is **event driven**; users can cause any of several events in **any order**
- GUI applications offer one small benefit to testers:
  - There is a **little need** for integration testing
- Unit testing is typically at the "button level"; that is **buttons have functions**, and these can be tested in the usual unit-level sense.
- The essence of **system-level testing** for GUI applications is to exercise the event-driven nature of application

A wide range of GUI testing tools has appeared on the market over the past few years.

TDDC88 has a lab on Selenium

Smoke test

- Important selected tests on module, or system
- Possible to run fast
- Build as large parts as possible as often as possible
- Run smoke tests to make sure you are on the right way

The end. Thank you! Questions?

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