Software Improvement Group

Software Analysis and Testing

Métodos Formais em Engenharia de *Software*

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Me

CV

- Technical University of Delft, Computer Science, MSc 1997
- University of Leiden, Philosophy, MA 1997
- CWI (Center for Mathematics and Informatics), PhD 2003
- Software Improvement Group, developer, consultant, etc, 2002-2003
- Universidade do Minho, Post-doc, 2004-2007
- Software Improvement Group, Head of Research, 2007-…

Research

- Grammars, traversal, transformation, generation
- Functional programming, rewriting strategies
- Software quality, metrics, reverse engineering

Software Improvement Group

Company

- Spin-off from CWI in 2000, self-owned, independent
- Management consultancy grounded in source code analysis
- Innovative, strong academic background, award-winning, profitable

Services

- Software Risk Assessments (snapshot) and Software Monitoring (continuous)
- Toolset enables to analyze source code in an automated manner
- Experienced staff transforms analysis data into recommendations
- We analyze over 50 systems annually
- Focus on technical quality, primarily maintainability / evolvability

Services

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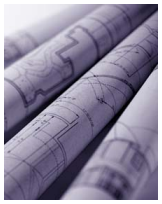

DocGen

- Automated generation of technical documentation
- Reduce learning time, assist impact analysis, support migration, …

Software Risk Assessment

- In-depth investigation of software quality and risks
- Answers specific research questions

Software Monitoring

- Continuous measurement, feedback, and decision support
- Guard quality from start to finish

Software Product Certification

- Five levels of technical quality
- Evaluation by SIG, certification by TÜV Informationstechnik

Who is using our services?

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Financials & insurance companies

Public

Retail/Logistics

Technology

Utilities/Telco

Structure of the lecture

- Introduction SIG

- General overview of software analysis and testing
- Testing
- Patterns
- Quality & metrics
- Reverse engineering

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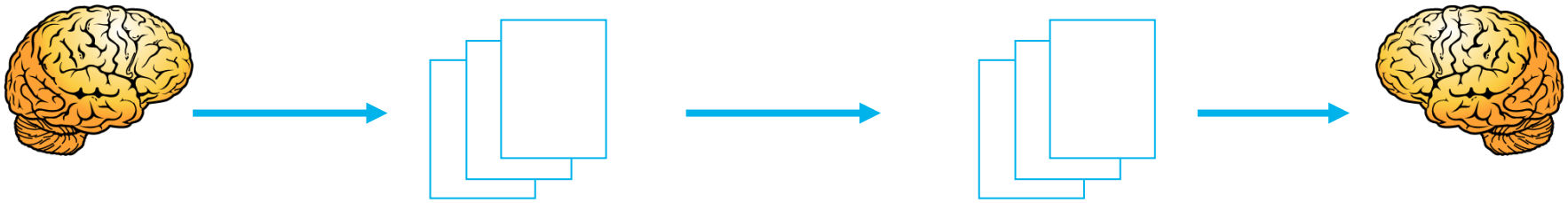
Create → **Change** → **Analyze**

Create	Change	Analyze
requirements analysis design, code, compile configure, install	refactor, fix, patch maintain, renovate evolve, update, improve	understand, assess evaluate, test measure, audit



Software Analysis (and Testing)

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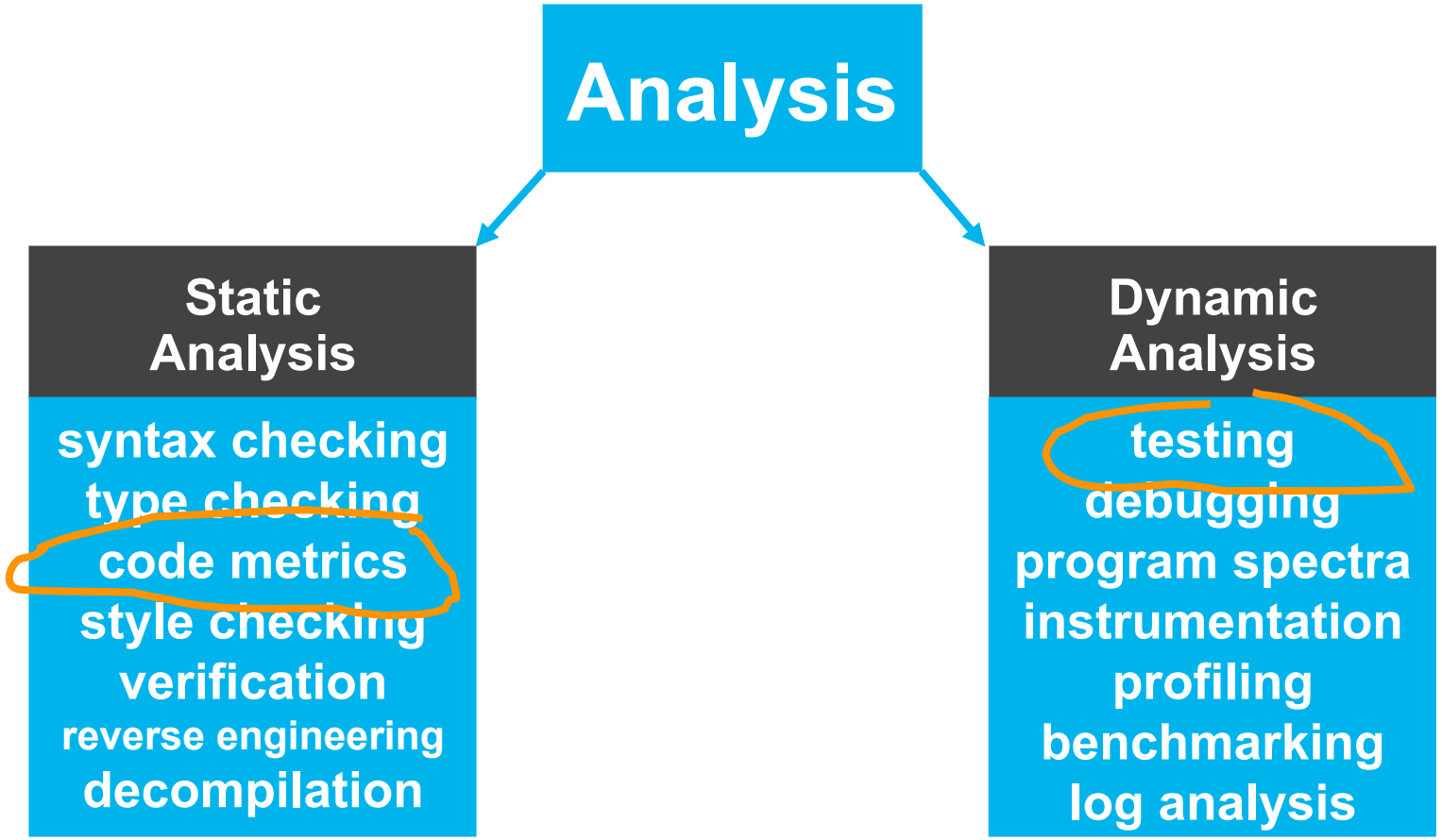

Is testing un-cool?

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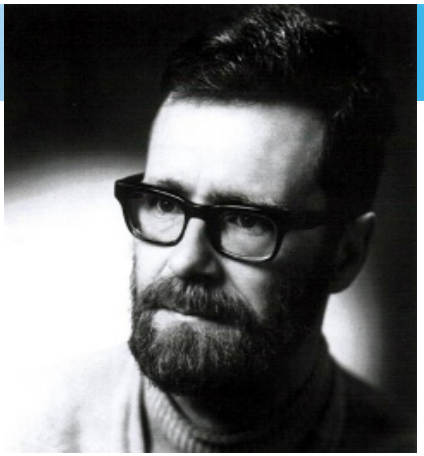
Edsger Wybe Dijkstra (1930 - 2002)



- "Program testing can be used to show the presence of bugs, but never to show their absence!"
  Notes On Structured Programming, 1970

- "Program testing can be a very effective way to show the presence of bugs, but is hopelessly inadequate for showing their absence."
  The Humble Programmer, ACM Turing Award Lecture, 1972

Does not mean: "Don't test!!"

Is testing un-cool?

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Industry

- Testers earn less then developers
- Testing is “mechanical”, developing is “creative”
- Testing is done with what remains of the budget in what remains of the time

Academia

- Testing is not part of the curriculum, or very minor part
- Verification is superior to testing
- Verification is more challenging than testing

Software Analysis. How much?

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50 - 75%

In a typical commercial development organization, the cost of providing [the assurance that the program will perform satisfactorily in terms of its functional and nonfunctional specifications within the expected deployment environments] via appropriate debugging, testing, and verification activities can easily range from 50 to 75 percent of the total development cost. (Hailpern and Santhanam, 2002)

Software Analysis. Enough?

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Planning Report 02-3

The Economic Impacts of Inadequate Infrastructure for Software Testing

$\$60 \times 10^9$

Table ES-4. Costs of Inadequate Software Testing Infrastructure on the National Economy

	The Cost of Inadequate Software Testing Infrastructure (billions)	Potential Cost Reduction from Feasible Infrastructure Improvements (billions)
Software developers	$21.2	$10.6
Software users	$38.3	$11.7
Total	$59.5	$22.2

of total impacts, and software users accounted for the about 60 percent.

Software Analysis. More?

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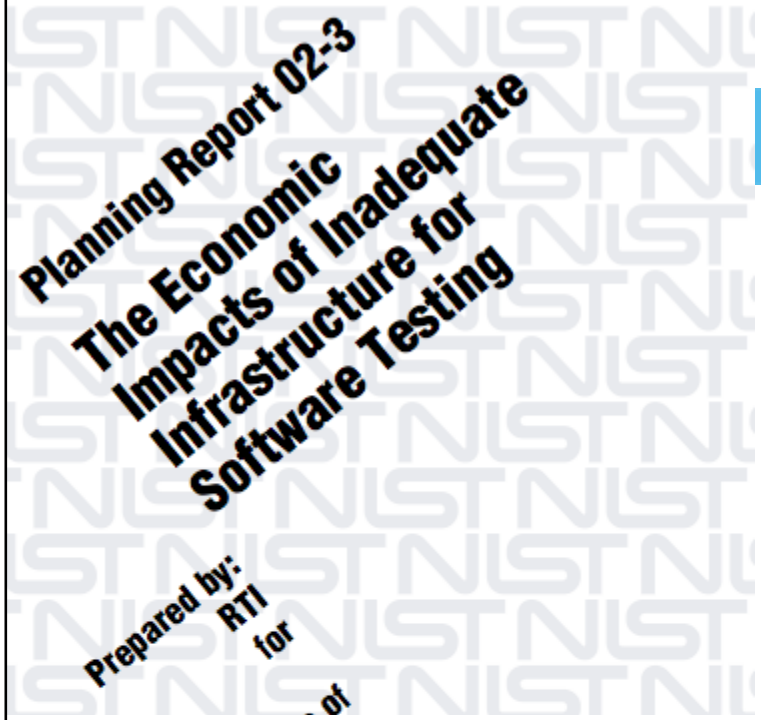

Table 1-4. Recent Aerospace Losses due to Software Failures

	Airbus A320 (1993)	Ariane 5 Galileo Poseidon Flight 965 (1996)	Lewis Pathfinder USAF Step (1997)	Zenit 2 Delta 3 Near (1998)	DS-1 Orion 3 Galileo Titan 4B (1999)
Aggregate cost		$640 million	$116.8 million	$255 million	$1.6 billion
Loss of life	3	160			
Loss of data		Yes	Yes	Yes	Yes

Software Analysis
Room for improvement?

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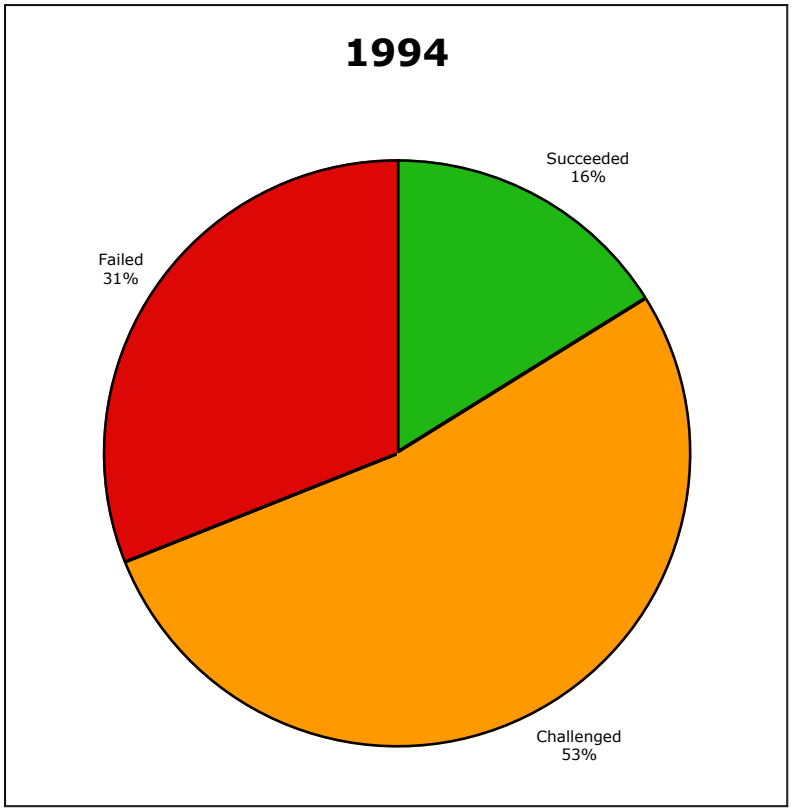

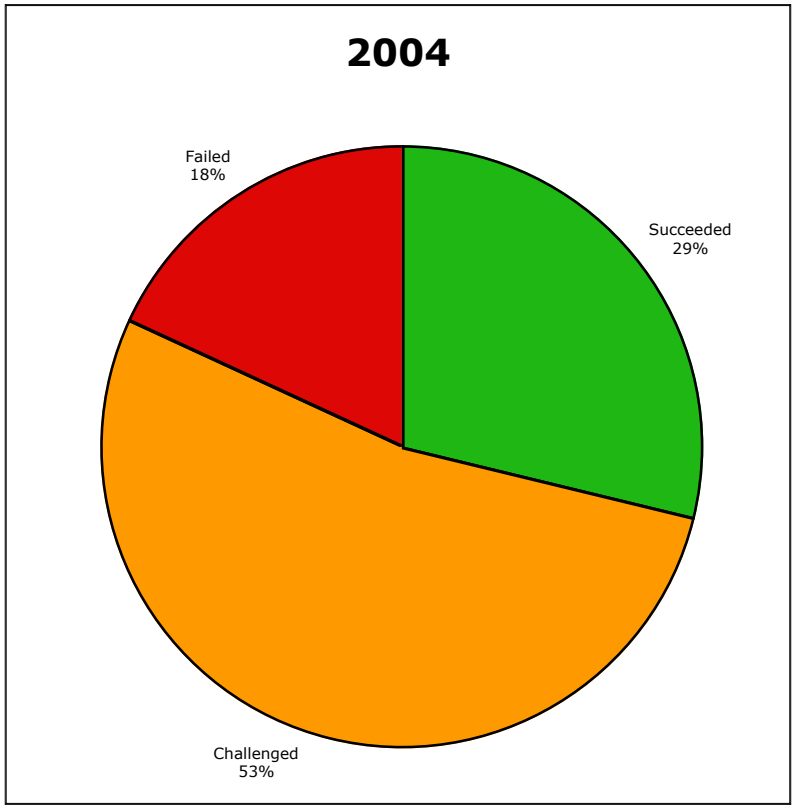

Standish Group, *"The CHAOS Report"*

So

- Testing ⊂ Dynamic analysis ⊂ Analysis ⊂ S.E.
- Analysis is a major and essential part of software engineering
- Inadequate analysis costs billions

- More effective and more efficient methods are needed
- Interest will keep growing in both industry and research

Structure of the lectures

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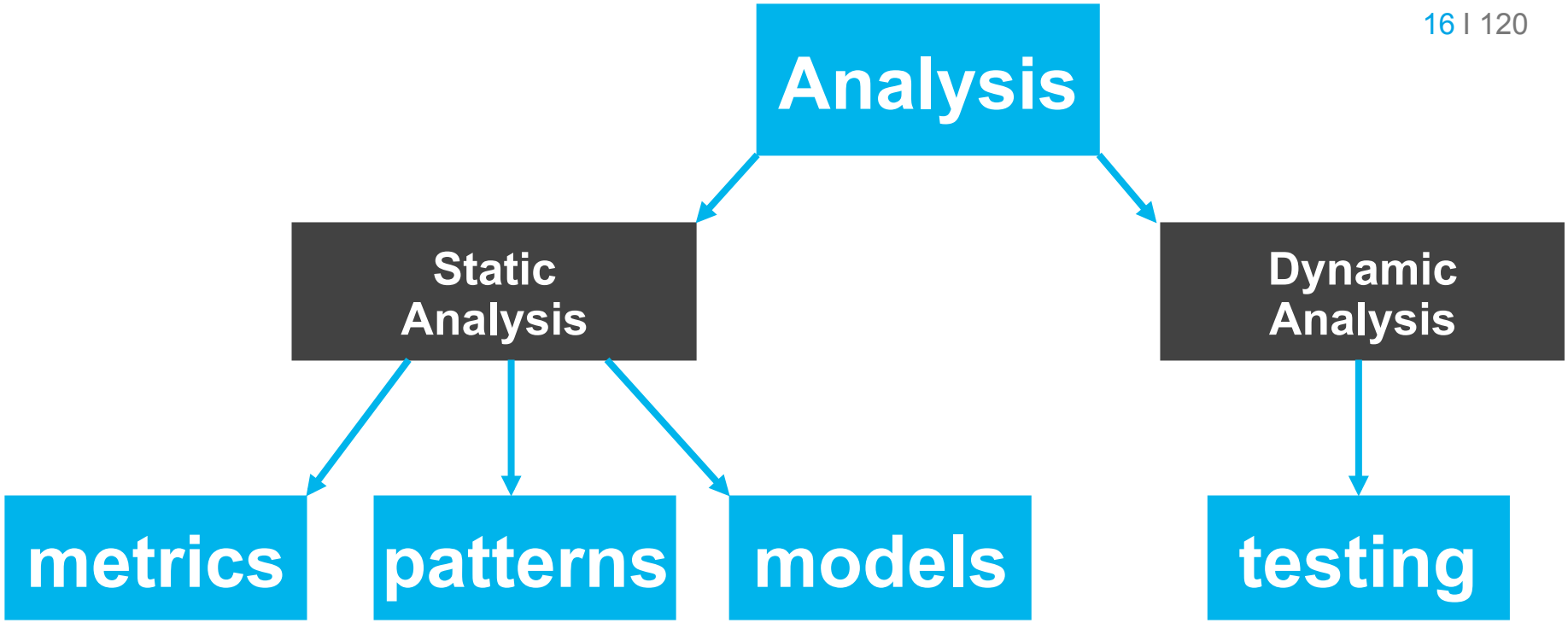


TESTING

Testing

Kinds

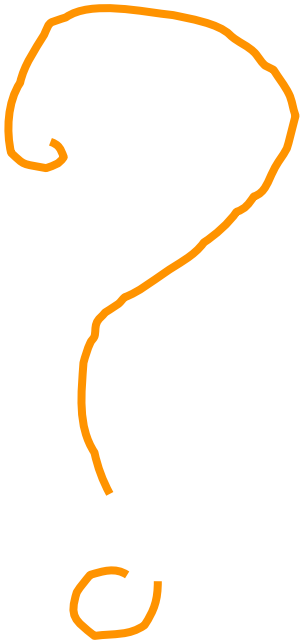
- Conformance
- Interoperability
- Performance
- Functional
- White-box
- Black-box
- Acceptance
- Integration
- Unit
- Component
- System
- Smoke
- Stress

Ways

- Manual
- Automated
- Randomized
- Independent
- User
- Developer

With

- Plans
- Harness
- Data
- Method
- Frameworks



Testing
V-model

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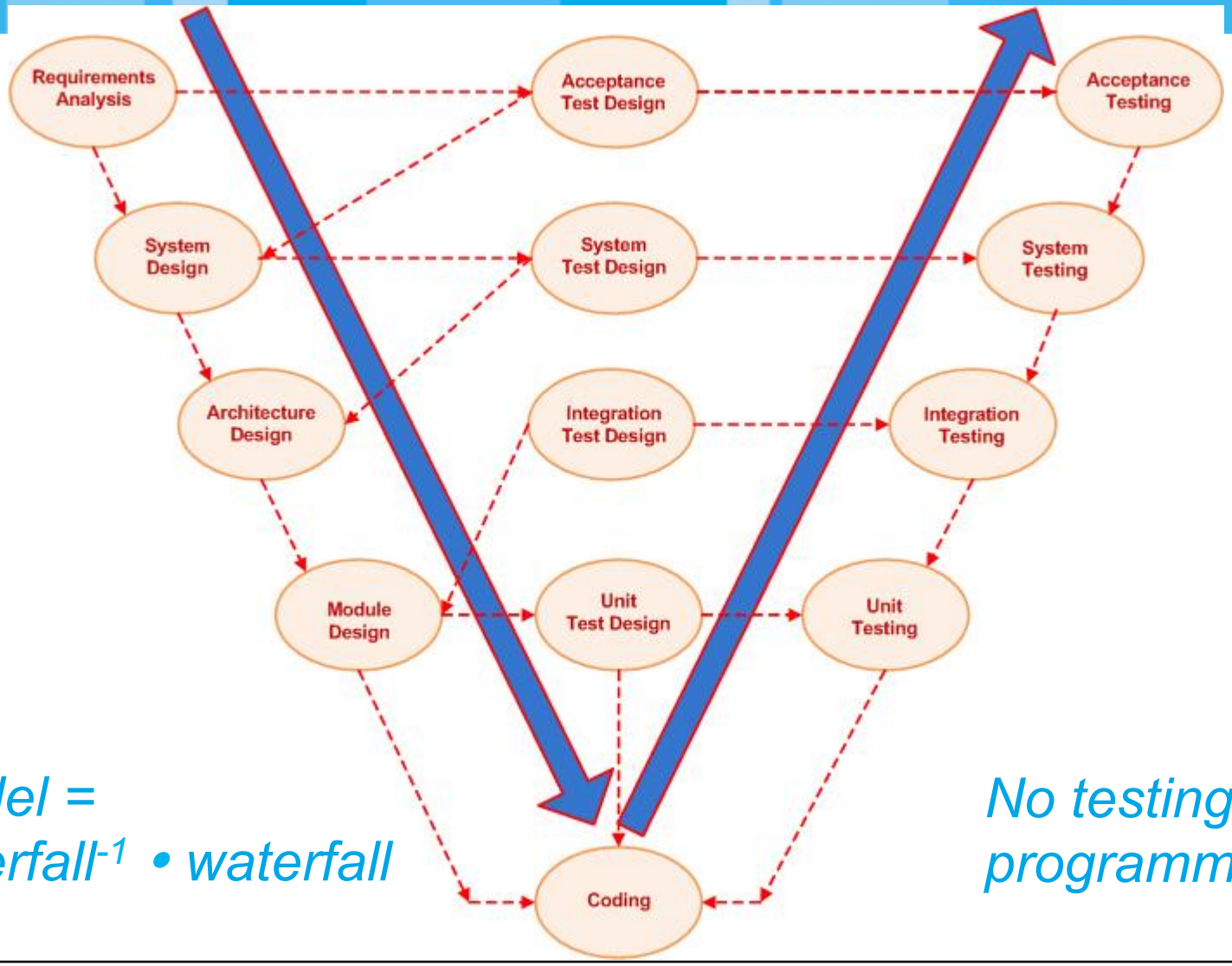

V-model = waterfall^{-1} • waterfall

No testing while programming!

Testing
Eliminate waste

Waste

- Coding and debugging go hand-in-hand
- Coding effort materializes in the delivered program
- Debugging effort? Evaporates!

Automated tests

- Small programs that capture debugging effort.
- Invested effort is consolidated …
- … and can be re-used without effort ad-infinitum

Unit testing

What is unit testing?

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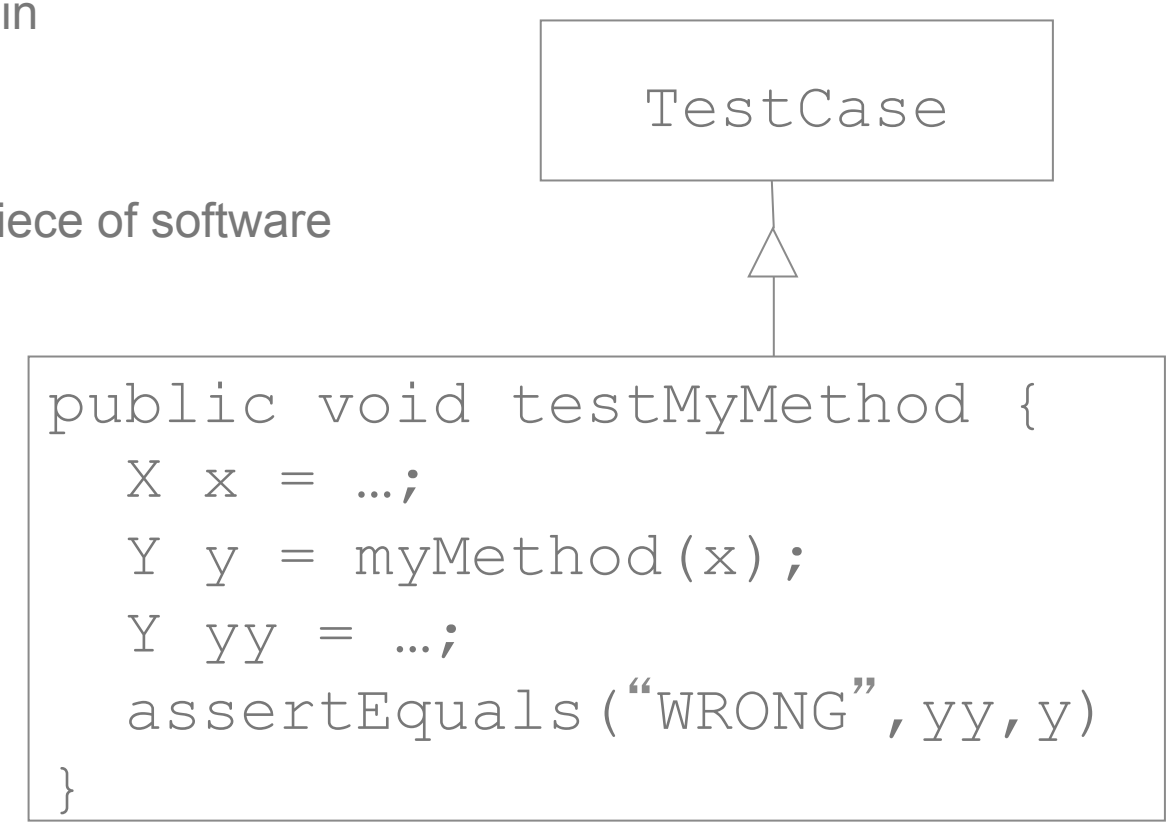
A unit test is …

- fully automated and repeatable
- easy to write and maintain
- non-intrusive
- documenting
- applies to the simplest piece of software

Tool support

- JUnit and friends



Testing goals

Unit testing has the following goals:

- Improve quality
  - Test as specification
  - Test as bug repellent
  - Test as defect localization
- Help to understand
  - Test as documentation
- Reduce risk
  - Test as a safety net
  - Remove fear of change

Observing unit-testing maturity in the wild (characterization of the population)

Organization

- public, financial, logistics
- under contract, in house, product software
- with test departments, without test departments

Architecture & Process

- under architecture, using software factories
- model driven, handwritten
- open source frameworks, other frameworks
- using use-cases/requirements
- with blackbox tools, t-map

Technology

- information systems, embedded
- webbased, desktop apps
- java, c#, 4GL's, legacy
- latest trend: in-code asserts (java.spring)

Stage 1
No unit testing

Observations:

- Very few organizations use unit testing
- Also brand new OO systems without any unit tests
- Small software shops and internal IT departments
- In legacy environments: programmers describe in words what tests they have done.

Symptoms:

- Code is instable and error-prone
- Lots of effort in post-development testing phases

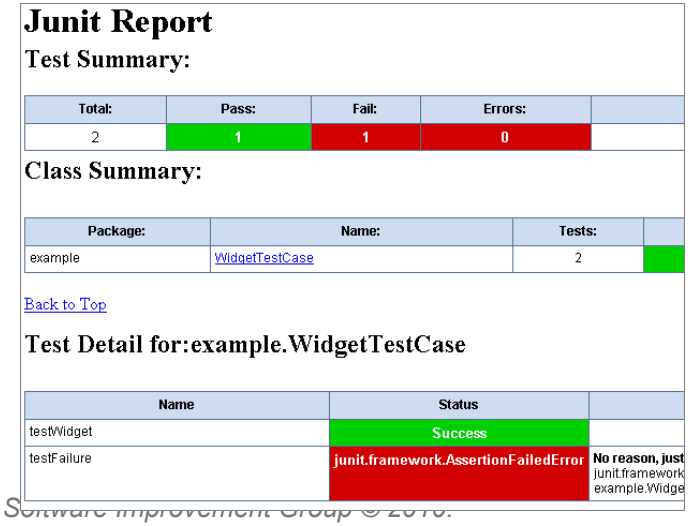
Stage 1
No unit testing

Excuses:

- “It is just additional code to maintain”
- “The code is changing too much”
- “We have a testing department”
- “Testing can never prove the absence of errors”
- “Testing is too expensive, the customer does not want to pay for it”
- “We have black-box testing”

Action

- Provide standardized framework to lower threshold
- Pay for unit tests as deliverable, not as effort



Junit Report

Test Summary:

Total:	Pass:	Fail:	Errors:	
2	1	1	0	

Class Summary:

Package:	Name:	Tests:	
example	WidgetTestCase	2	

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Test Detail for:example.WidgetTestCase

Name	Status	
testWidget	Success	
testFailure	junit.framework.AssertionFailedError	**No reason, just** junit.framework example.Widge

Stage 2
Unit test but no coverage measurement

Observations

- Contract requires unit testing, not enforced
- Revealed during conflicts
- Unit testing receives low priority
- Developers relapse into debugging practices without unit testing
- Good initial intentions, bad execution
- Large service providers

Symptoms:

- Some unit tests available
- Excluded from daily build
- No indication when unit testing is sufficient
- Producing unit test is an option, not a requirement

Stage 2
Unit test but no coverage measurement

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Excuses:

- “There is no time, we are under pressure”
- “We are constantly stopped to fix bugs”

Actions

- Start measuring coverage
- Include coverage measurement into nightly build
- Include coverage result reports into process

Stage 3
Coverage, not approaching 100%

Observations

- Coverage is measured but gets stuck at 20%-50%
- Ambitious teams, lacking experience
- Code is not structured to be easily unit-testable

Symptoms:

- Complex code in GUI layer
- Libraries in daily build, custom code not in daily build

Stage 3
Coverage, not approaching 100%

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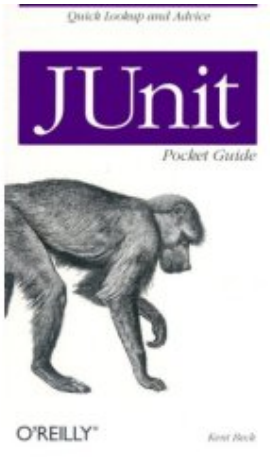
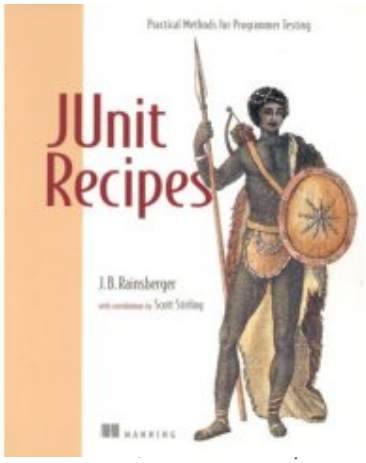
Excuses

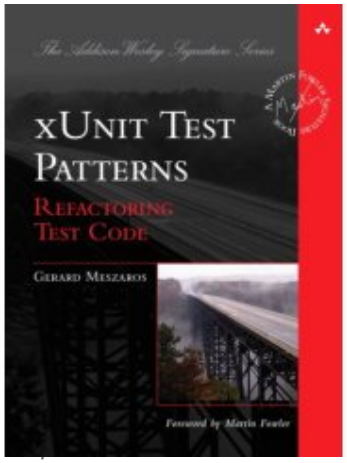
- “we test our libraries thoroughly, that affects more customers”

Actions:

- Refactor code to make it more easily testable
- Teach advance unit testing patterns
- Invest in set-up and mock-up







Stage 4
Approaching 100%, but no test quality

Observations

- Formal compliance with contract
- Gaming the metrics
- Off-shored, certified, bureaucratic software factories

Symptoms:

- Empty tests
- Tests without asserts.
- Tests on high-level methods, rather than basic units

- Need unit tests to test unit tests

Stage 4
Approaching 100%, but no test quality

Anecdotes:

- Tell me how you measure me, and I tell you how I behave
- We have generated our unit tests (at first this seems a stupid idea)

Action:

- Measure test quality
- Number of asserts per unit test
- Number of statements tested per unit test
- Ratio of number of execution paths versus number of tests

Stage 5
Measuring test quality

Enlightenment:

- Only one organization: a Swiss company
- Measure:
  - Production code incorporated in tests
  - number of assert and fail statements
  - low complexity (not too many ifs)
- The process
  - part of daily build
  - “stop the line process”, fix bugs first by adding more tests
  - happy path and exceptions
  - code first, test first, either way

Testing
Intermediate conclusion

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Enormous potential for improvement:

- Do unit testing
- Measure coverage
- Measure test quality

- May not help Ariane 5
- Does increase success ratio for “normal” projects

Randomized Testing (quickcheck)

Randomized testing:

- QuickCheck: initially developed for Haskell
- Parameterize tests in the test data
- Property = parameterized test
- Generate test data randomly
- Test each property in 100 different ways each time

Test generation

Model-driven testing

Fault-injection

```
-- | Range of inverse is domain.
prop_RngInvDom r
  = rng (inv r) == dom r
    where
      types = r::Rel Int Integer
```

Is testing un-cool?

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Edsger Wybe Dijkstra (1930 - 2002)

- "Program testing can be used to show the presence of bugs, but never to show their absence!"

Martin Fowler

- "Don't let the fear that testing can't catch all bugs stop you from writing the tests that will catch most bugs."

Simple test metrics

Line coverage

- Nr of test lines / nr of tested lines

Decision coverage

- Nr of test methods / Sum of McCabe complexity index

Test granularity

- Nr of test lines / nr of tests

Test efficiency

- Decision coverage / line coverage

Testing
Exercises

Write unit tests

- Using JUnit
- E.g. for one of your own projects

Measure coverage

- E.g. using Emma plug-in for Eclipse

Randomize one of your unit tests

- Turn test into property with *extract method* refactoring
- Write generator for test data
- Instantiate property 100 times with random test data
- Solution to j.visser@sig.eu