Software Testing in ½ hour

Overview of concepts
Food for thought
Suggestions for further learning
Topics for discussion

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Why testing software?

To show that it does what it is intended to do

To discover defects before it is put into use

Testing cannot demonstrate
that the software is free of defects
or that it will behave as specified in every circumstance

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

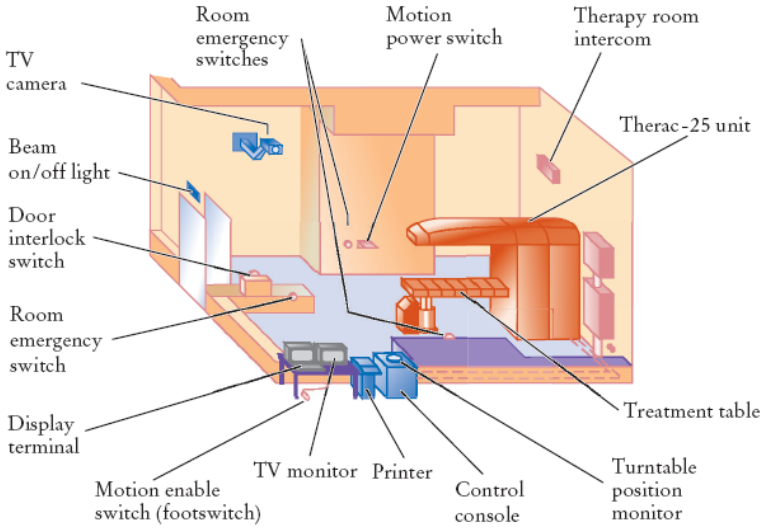
E. W. Dijkstra et al., Structured programming, 1972

Therac 25

Radiation therapy machine

6 massive overdose cases,
1985-1987

Caused by
poor software engineering practices



Typical Therac-25 Facility

A commission concluded that the primary reason should be attributed to **bad software design** and **development practices**, and not explicitly to several coding errors that were found

The software was designed so that it was realistically impossible to test it in a clean automated way

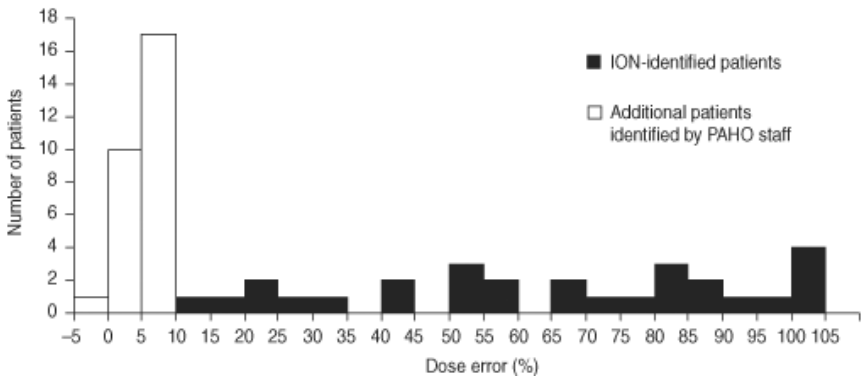
Safety analysis of the system excluded software

N. Leveson, C. S. Turner, **An Investigation of the Therac-25 Accidents**, *IEEE Computer,* vol. 26, no. 7, pp. 18-41, 1993.

The Panama accidents

- 28 radiation therapy patients were overexposed in 2000-2001
- 23 of them had died by September 2005
- 18 of the deaths were from radiation effects

A modified protocol was used
without verification and validation



The software permitted incorrect forms of data entry, which in turn led to miscalculation of treatment time

Therapy planning software from Multidata delivered **different doses** depending on the order in which data were entered

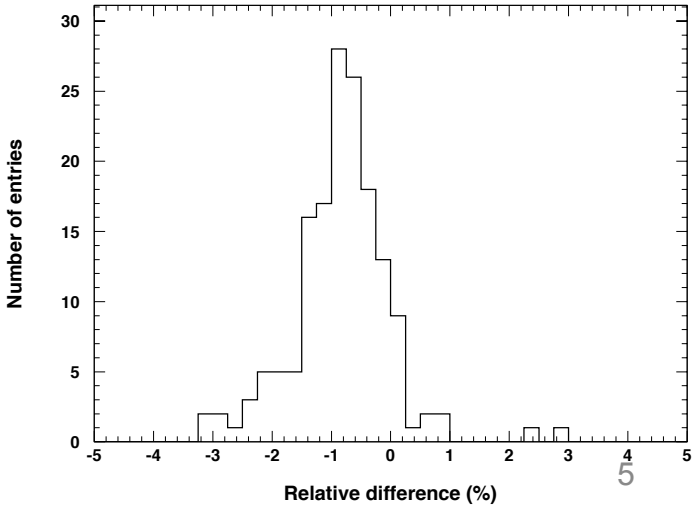
- IAEA, Investigation of an **Accidental Exposure of Radiotherapy Patients** in Panama: Report of a Team of Experts, 2001
- C. Borras et al., Clinical effects in a cohort of **cancer patients overexposed** during external beam pelvic radiotherapy, *Int. J. Radiation Oncology Biol. Phys.*, vol.59, pp. 538-550, 2004
- C. Borras et al., **Overexposure of radiation therapy patients in Panama**: problem recognition and follow-up measures, *Rev. Panam. Salud Publica*, vol.20, n.2-3, pp. 173-187, 2006

Ariane 5 maiden flight

~40 seconds after initiation of the flight sequence, the launcher veered off its flight path, broke up and exploded

The primary cause was found to be a piece of software retained from the previous launcher systems, which was not required during the flight of Ariane 5. The software contained implicit assumptions about the parameters, which were safe for Ariane 4, but not for Ariane 5.

Relative difference of the energy deposited by ~60 MeV protons in water, when Geant4 Precompound model was used **standalone** or **through the Binary Cascade model**



M. G. Pia et al., Physics-related epistemic uncertainties of proton depth dose simulation, *IEEE Trans. Nucl. Sci.*, vol. 57, no. 5, pp. 2805-2830, 2010

V&V

Testing is part of the process of **Software Verification and Validation**

Verification

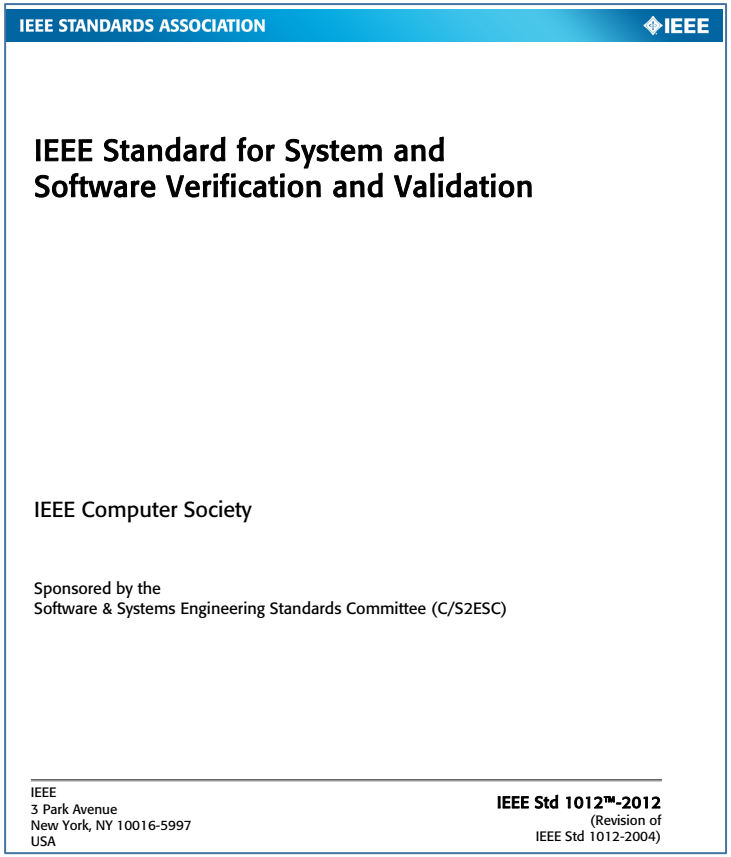
The process of providing objective evidence that the software and its associated products **conform to requirements**.

Are we building the product right?

Validation

The process of providing evidence that the software and its associated products **solve the right problem** *(e.g., correctly model physical laws and use the proper system assumptions),* and **satisfy intended use** and user needs.

Are we building the right product?


IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for System and Software Verification and Validation

IEEE Computer Society

Sponsored by the
Software & Systems Engineering Standards Committee (C/S2ESC)

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1012™-2012
(Revision of
IEEE Std 1012-2004)

How do you trust the software you use?

"I'm just doing what the other ones are doing"

Multiple perspectives

Levels of testing
- Unit
- Integration
- System
- Acceptance

Static testing

Functional/non-functional testing

Black/white-box testing

Regression testing

Performance testing

Stress testing

Configuration testing

Security testing

Test **coverage**

Test **harness**

Test **automation**

Test **cases**

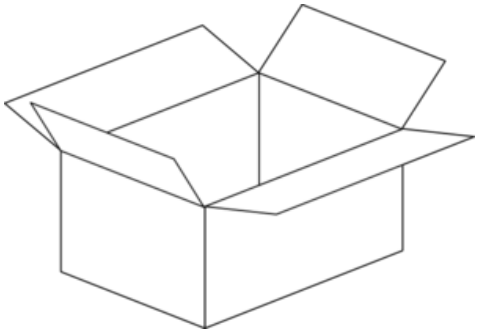
Test **planning**

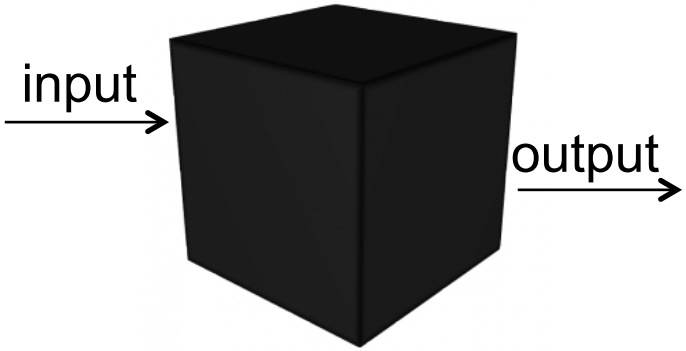
Test **frameworks**

…etc.

No time to cover all topics!

Testing strategies





- Knowledge of the **source code** is used to design defect tests
- **Systematic** approach
- Focus on program **coverage**

- Only considers software **behaviour**
- Based on **functional** specifications

Good practice: a combination of both strategies

Epistemology

How to test it? Calibrated?

…more about "**magic numbers**" in Refactoring

G4HadronElastic

```
G4double dd = 10.;
G4Pow* g4pow = G4Pow::GetInstance();
if (A <= 62) {
bb = 14.5*g4pow->Z23(A);
aa = g4pow->powZ(A, 1.63)/bb;
cc = 1.4*g4pow->Z13(A)/dd;
} else {
bb = 60.*g4pow->Z13(A);
aa = g4pow->powZ(A, 1.33)/bb;
cc = 0.4*g4pow->powZ(A, 0.
}
```

G4ChipsAntiBaryonElasticXS

```
lastPAR[43]=920.+03*a8*a3;
lastPAR[44]=93.+.0023*a12;
```

G4GoudsmitSaundersonMscModel

```
if(i>=19)ws=cos(sqrtA);
```

G4EmCorrections

```
if(15 >= iz) {
if(3 > j) { tet = 0.25*Z2*(1.0 + 5*Z2*alpha2/16.); }
else      { tet = 0.25*Z2*(1.0 + Z2*alpha2/16.); }
}
```

G4UrbanMscModel

```
coeffc1  = 2.3785 - Z13*(4.1981e-1 - Z13*6.3100e-2);
```

Test cases

- Require **domain knowledge**
  - Guidance from use cases, user stories, scenarios…
  - Requirements, specifications and designs provide guidance at a higher level of abstraction and generality
- Require **source code knowledge**
  - Code-based control
  - Logic and sequence defects
  - Initialization and data flow defects

Software testing requires studying both the **problem domain** and the **source code** in depth

Levels of testing

Unit testing	Test **individual pieces** of the system as they are created
Integration testing	Test **sets** of interoperating or communicating **units or components**
System testing	Test the **entire system**
Acceptance testing	Demonstrate that the product is ready for release Usually performed by **users**

Regression testing

A **regression** is a feature *(function, attribute)* that used to work and no longer does

It is usually related to some **change**

1. A change or bug fix creates a new bug
2. A change or bug fix reveals an existing bug
3. A change or bug fix in one area breaks something in another area

Risk mitigation strategies

Run all tests ← requires automation

Run part of the tests based on
- traceability
- change analysis
- quality risk analysis

Not only running code…

Static testing

Inspections and **reviews**

Analyze and check:

- Requirements
- Design models
- Source code
- Proposed tests
- …

Can spot defects that would not be seen through running tests

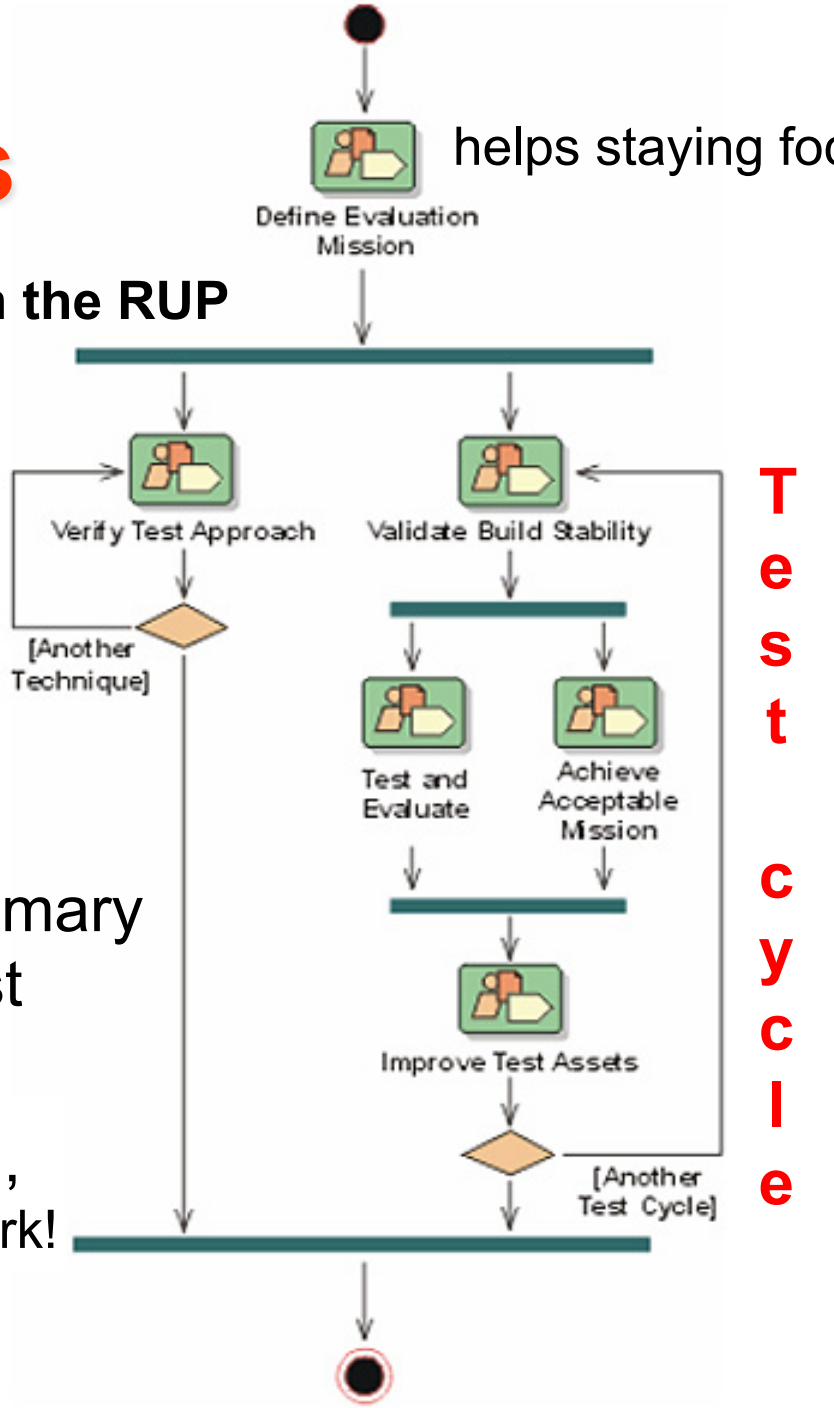
Pair programming can be seen as a static testing method (continuous code review)

Pill of advice: train yourself to do peer reviews!

Test process

helps staying focused

Workflow in the RUP



- Test **Plan**
- Test **Ideas**
- Test **Cases**
- **Tests**
- Test **Suites**
- Test **Evaluation** Summary
- Defect and Defect List
- Workload Model

Each iteration can contain multiple test cycles

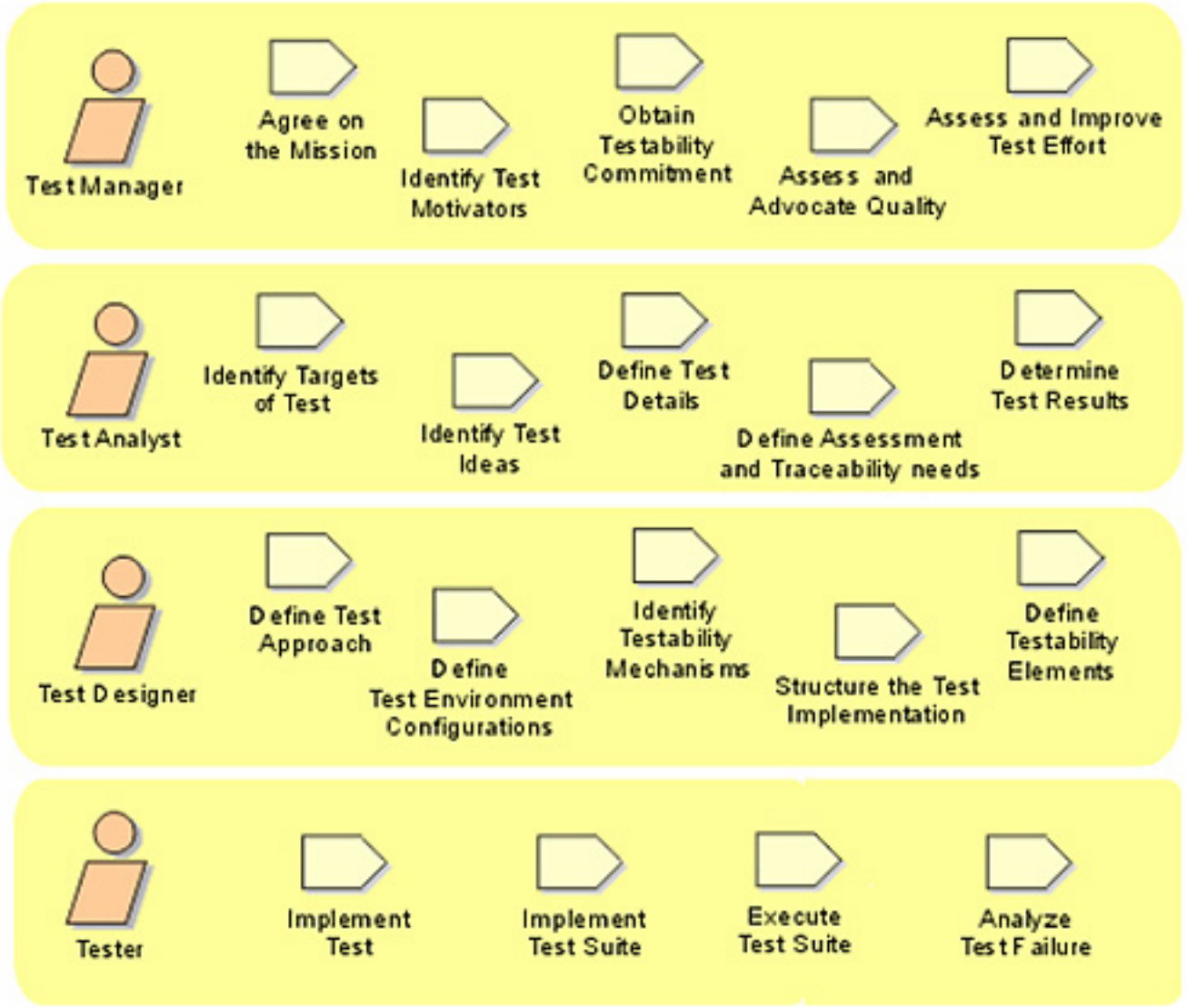
Focus on **concepts**,
not on formalities or paperwork!

Test process

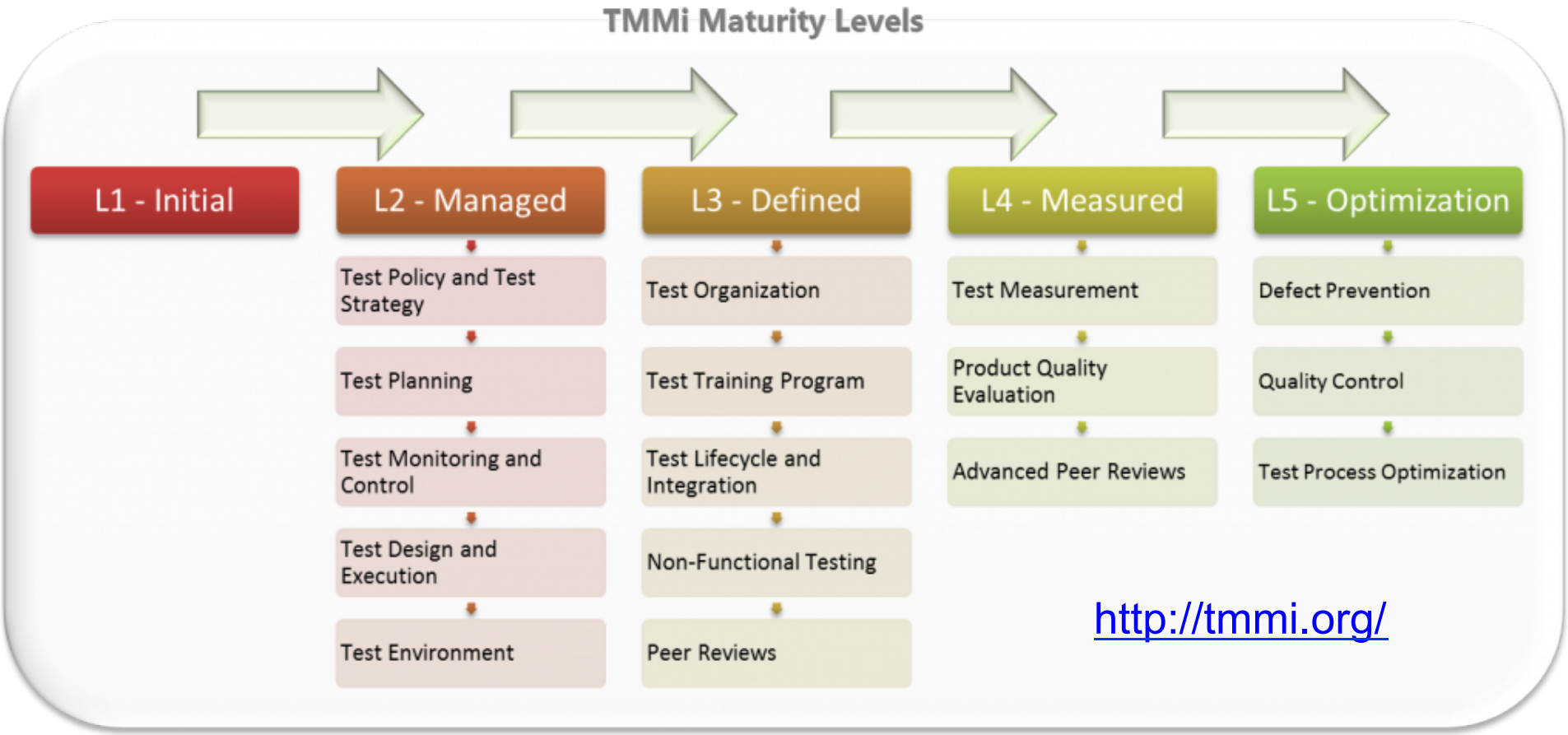
A person can play multiple roles

Roles
and **activities**
in the RUP

Guidance
rather than
prescription



How good is my testing process?



http://tmmi.org/

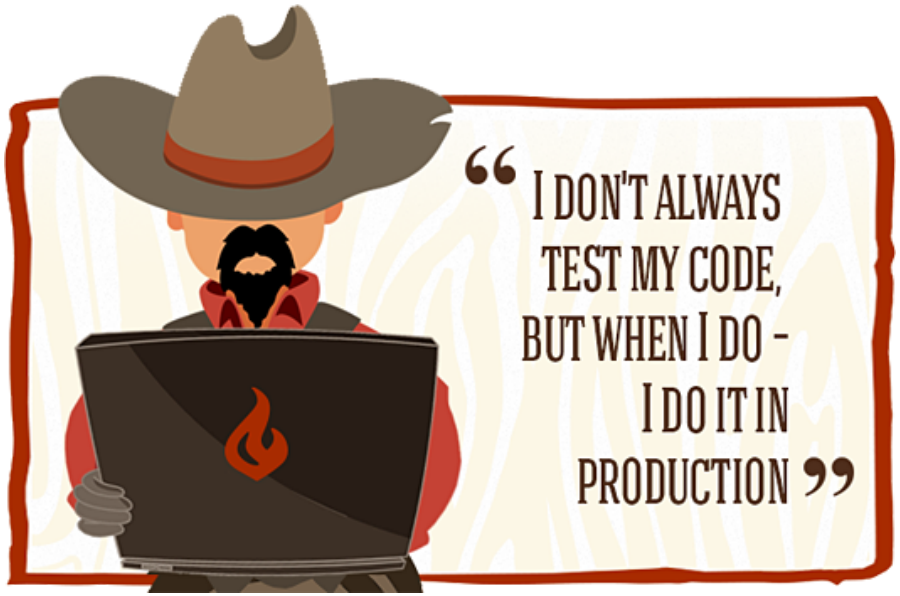
Inspiration and guidance for improvement

Unit testing

Unit = smallest testable part

Procedural Programming: a **function**

Object Oriented Programming: a **class**



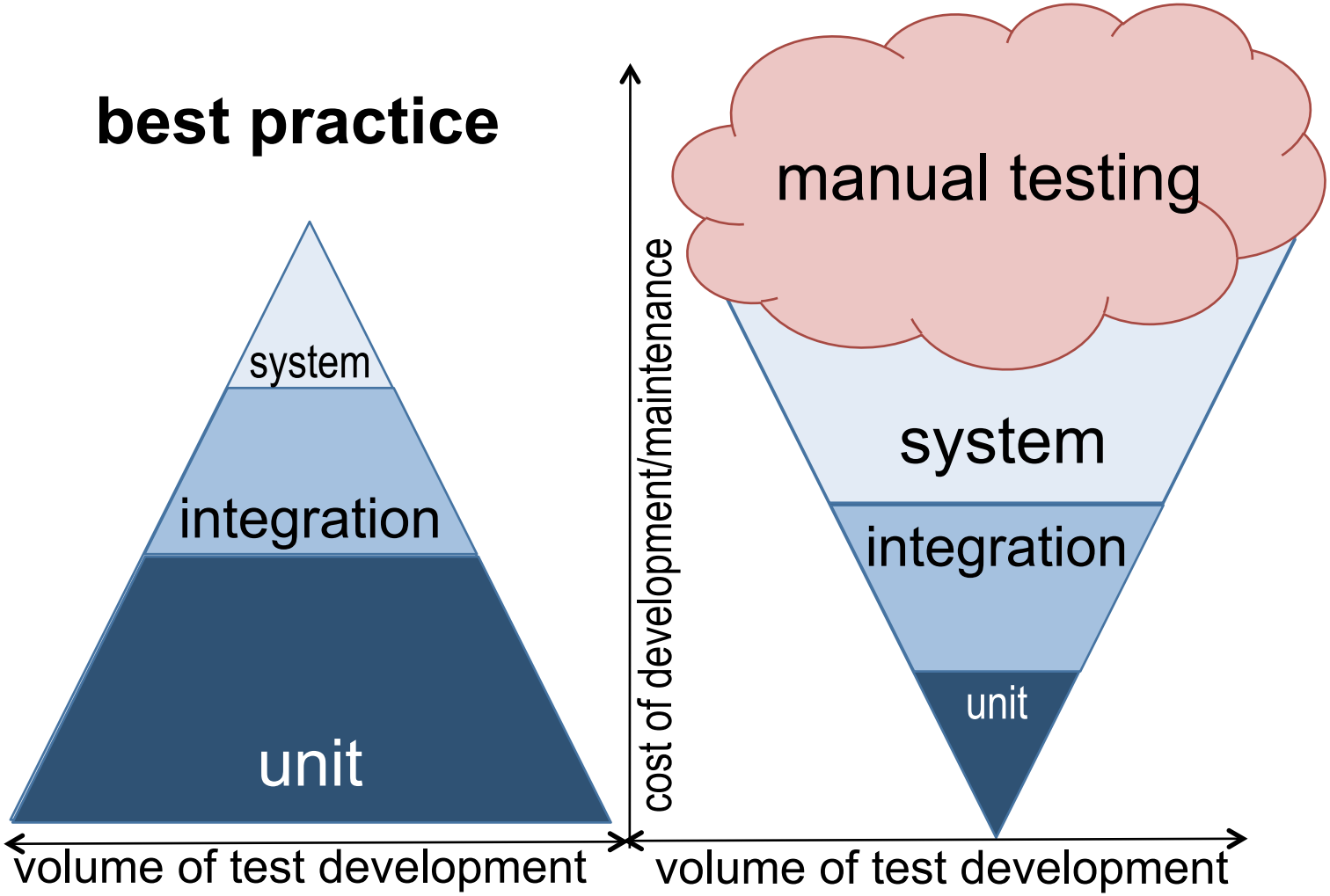
Unit testing contributes to **risk mitigation**:

- Issues are found at an early stage
- Can be resolved minimizing the impact on other parts of the code
- Helps in changing and maintaining the code
- Facilitates regression testing

Good characteristics of unit tests

- It should be **automated** and **repeatable**
  - Unit test frameworks
- Once a test is written, it should remain for future use
  - Unit tests should be **documented**
  - Planning and infrastructure for running
- Anyone should be able to run existing unit tests
  - Domain knowledge required to design a test
  - Not to execute it: **self-explaining** result

Pyramid and ice-cream testing



Unit test frameworks

Tools enabling programmers to:

- describe every test as a simple script
- specify the **test configuration**, the **input** and an assertion describing the expected pass/fail criteria *(oracle)*
- run a set of tests as an automated process

- Pioneers: xUnit family
  - JUnit, CppUnit…
- Modern tools
  - Boost Test Library, Google Test, catch, cgreen…

Google unit test framework

AKA Google Test, googletest, gtest

- Unit testing framework for C++ code
- Follows xUnit concept
- Open source

Assertion	Check whether a condition is true *Success, non-fatal failure, fatal failure*
Tests	Use assertions
Test case	Contains one or more tests
Test program	Can contain multiple test cases
Test fixture	A class for common objects and functionality shared by multiple tests

Example: unit test for a square root function

```
double square-root (const double);
```

```
#include "gtest/gtest.h"
TEST(SquareRootTest, PositiveNos) {
    EXPECT_EQ (18.0, square-root (324.0));
    EXPECT_EQ (25.4, square-root (645.16));
    EXPECT_EQ (50.3321, square-root (2533.310224));
}

TEST (SquareRootTest, ZeroAndNegativeNos) {
    ASSERT_EQ (0.0, square-root (0.0));
    ASSERT_EQ (-1, square-root (-22.0));
}

int main(int argc, char **argv) {
  ::testing::InitGoogleTest(&argc, argv);
  return RUN_ALL_TESTS();
}
```

Creates a hierarchy named SquareRootTest

PositiveNos is a test

execution continues even if there is a failure

aborts if there is a failure

initializes the framework

automatically detects and runs all the tests defined using the TEST macro

A test fixture class

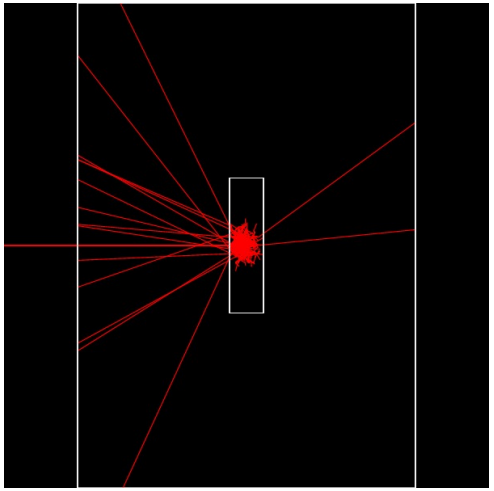
Use with the **TEST_F** macro instead of TEST

```
class myTestFixture1: public ::testing::test {
public:
   myTestFixture1( ) {
       // initialization code here
   }

   void SetUp( ) {
       // code here will execute just before the test ensues
   }

   void TearDown( ) {
       // code here will be called just after the test completes
       // ok to through exceptions from here if need be
   }

   ~myTestFixture1( )  {
       // cleanup any pending stuff, but no exceptions allowed
   }

   // put in any custom data members that you need
};
```

derived from the ::testing::test class in gtest.h

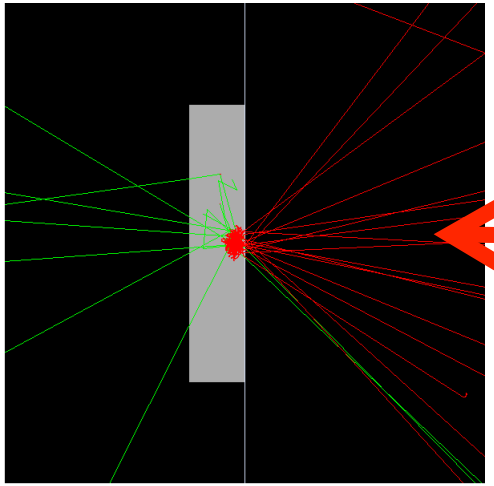
Passed ≠ exempt from flaws

"Testing shows the presence, not the absence of bugs." E.W. Dijkstra,
Software Engineering Techniques, J. N. Buxton and B. Randell eds., 1970

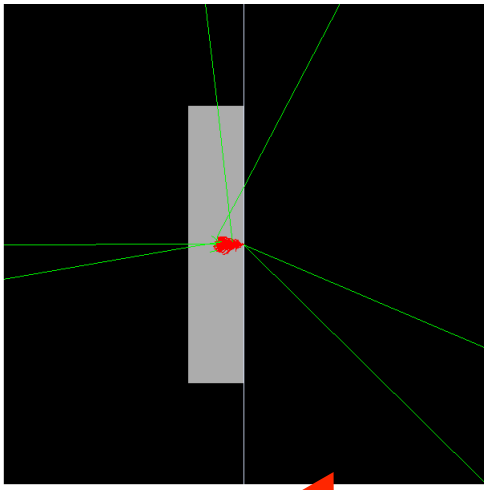


G4eSingleCoulombScatteringModel
Geant4 10.2

Developer's test



Physical expectation: a fraction of electrons is backscattered
(consistent with experiment)



No backscattered electrons are observed

Testable software

- Detector design, experimental strategies, physics results depend critically on software
- …which is often untested *(partially tested)* because it is untestable
  - or became untestable in the course of its evolution
- **Making software testable**
  - Improving software design *(refactoring)*
  - Breaking dependencies *(techniques à la Feathers)*
  - **Embedding testability in the software design**
- Testability must be **maintained**
  - through the evolution of the whole software system
- **Epistemological** issues
  - domain knowledge and implementation details

Discipline of software engineering

- Most of these problems can be easily solved if we simply write tests as we develop our code
  - …and we **maintain** the tests
  - …and we **regularly execute** them
  - …and we **investigate** the reasons for failure

If a test is hard to write, that means that we have to find a different design which is testable

- It is always possible
- **Software design reviews**: care about testability

Hands-on exercise

- Refactoring is intertwined with unit testing
- In the refactoring exercise get acquainted with:
  - Associating software development and change with unit testing
  - A unit test framework: **GoogleTest**
  - Test **automation**
  - **Regression** testing

Apply what you learn at the APC school to your own software development environment!