Testing

V22.0474-001 Software Engineering
Lecture 7, Spring 2008

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(with slides from Alex Aiken, Tom Ball, George Necula)

Reality

- Many proposals for improving software quality
- But in practice this is mostly testing
  - > 50% of the cost of software development

Role of Testing

- Testing is basic to every engineering discipline
  - Design a drug
  - Manufacture an airplane
  - Etc.

- Why?
  - Because our ability to predict how our creations will behave is imperfect
  - We need to check our work, because we will make mistakes

Testing and Development of Software

- In what way is software different?

- Folklore:
  "Optimism is the occupational hazard of programming; testing is the treatment"
  - The implication is that programmers make poor testers

Why Test?

Mars Climate Orbiter

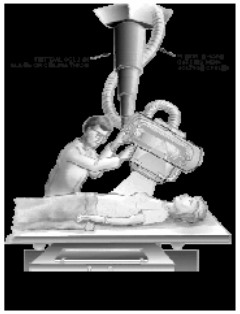
- Purpose: to relay signals from the Mars Polar Lander once it reached the surface of the planet
- Disaster: smashed into the planet instead of reaching a safe orbit
- Why: Software bug - failure to convert English measures to metric values
- $165M

Shooting Down of Airbus 320

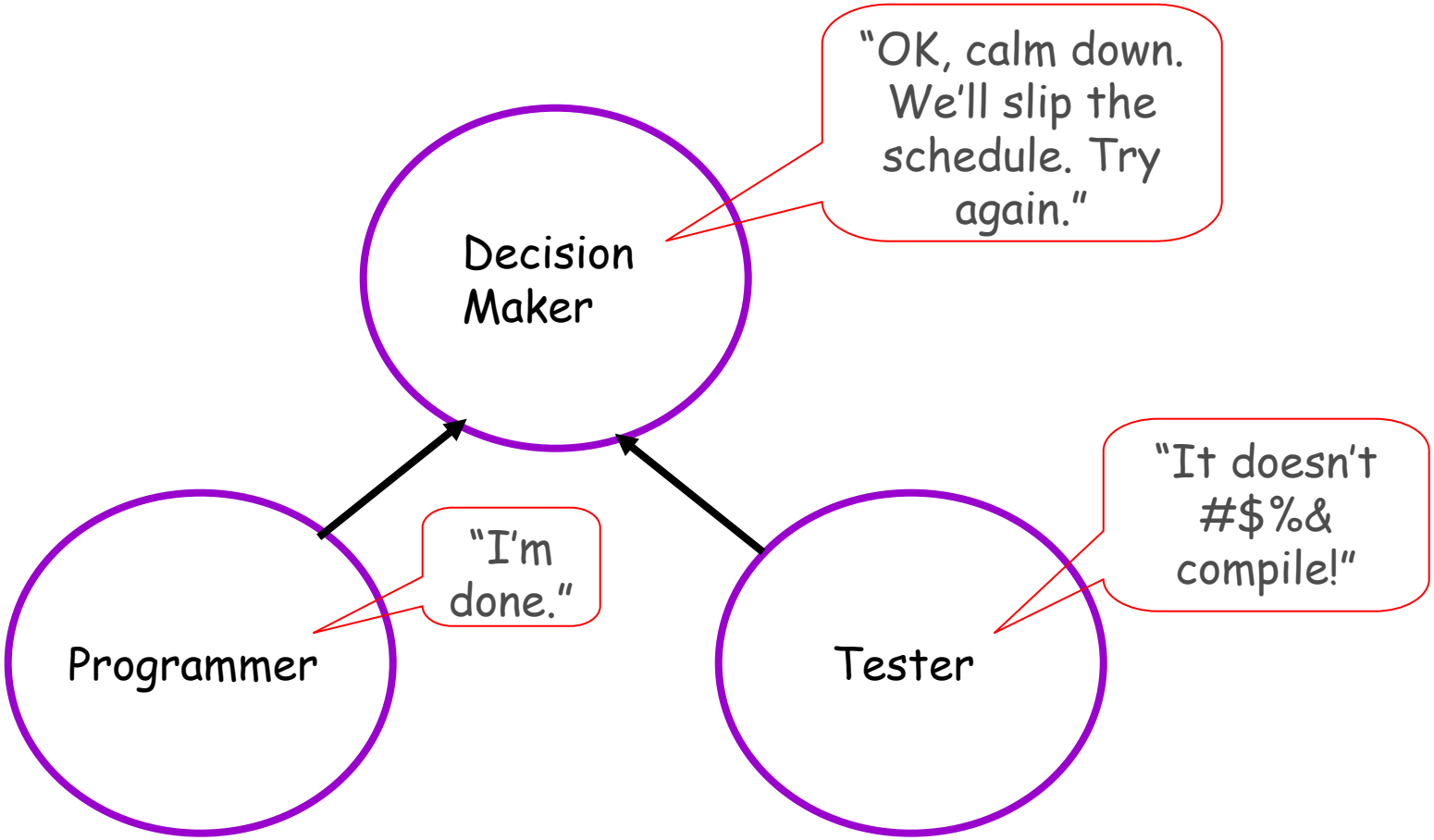
- 1988
- US Vicennes shot down Airbus 320
- Mistook airbus 320 for a F-14
- 290 people dead
- Why: Software bug - cryptic and misleading output displayed by the tracking software

THERAC-25 Radiation Therapy

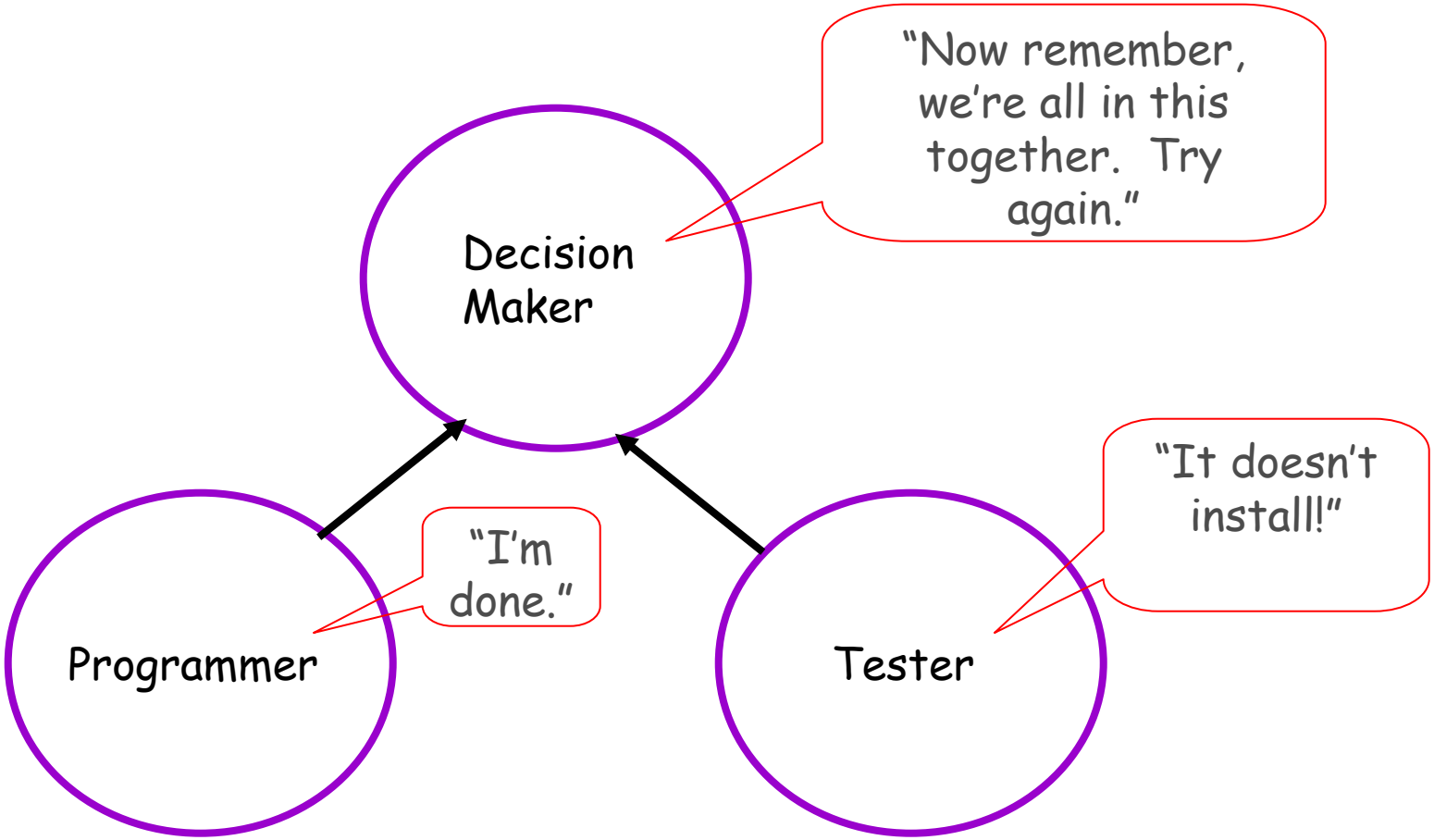
- THERAC-25, a computer-controlled radiation-therapy machine
- 1986: two cancer patients at the East Texas Cancer Center in Tyler received fatal radiation overdoses
- Why: Software bug - mishandled race condition (i.e., miscoordination between concurrent tasks)



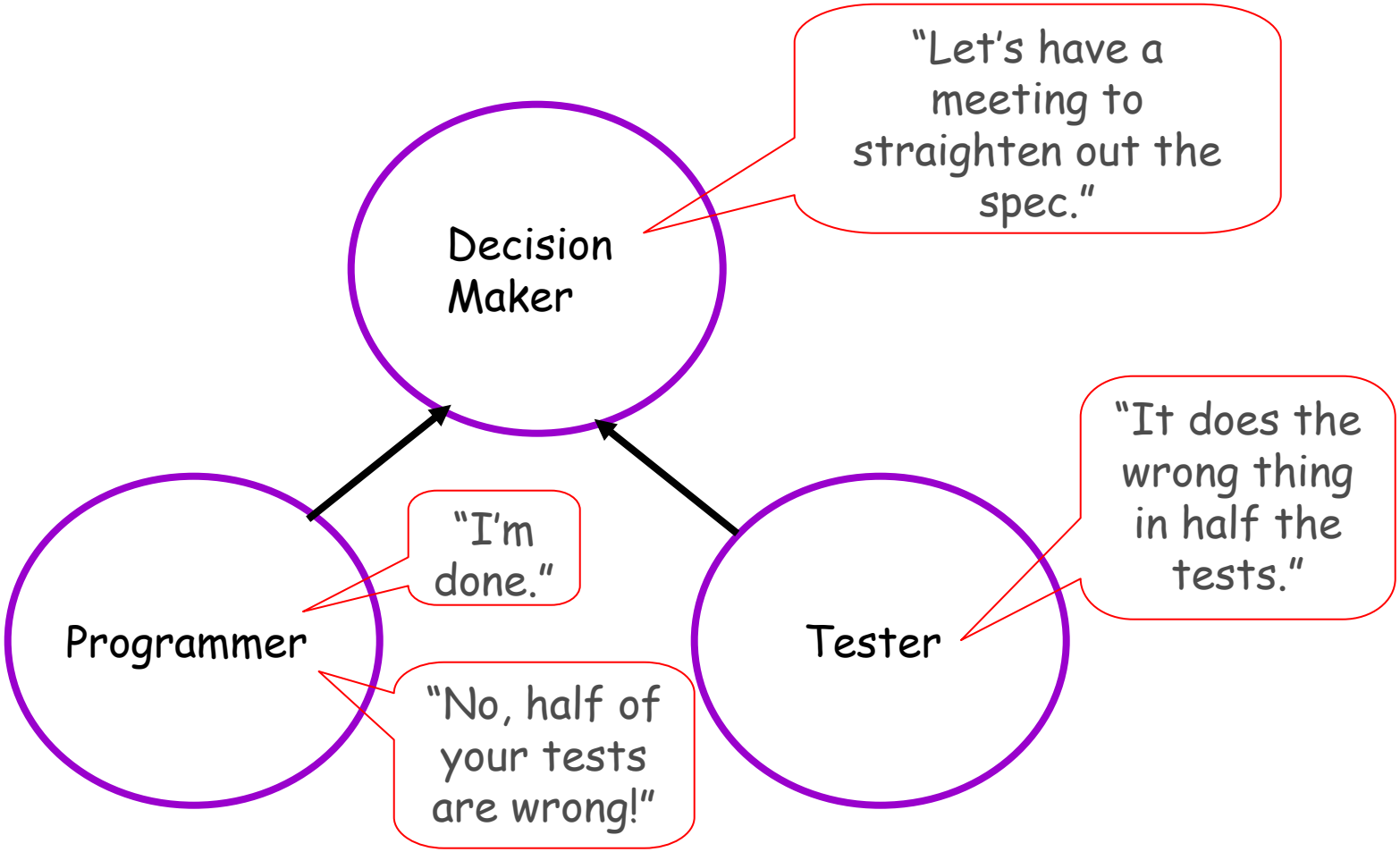
Typical Scenario (1)



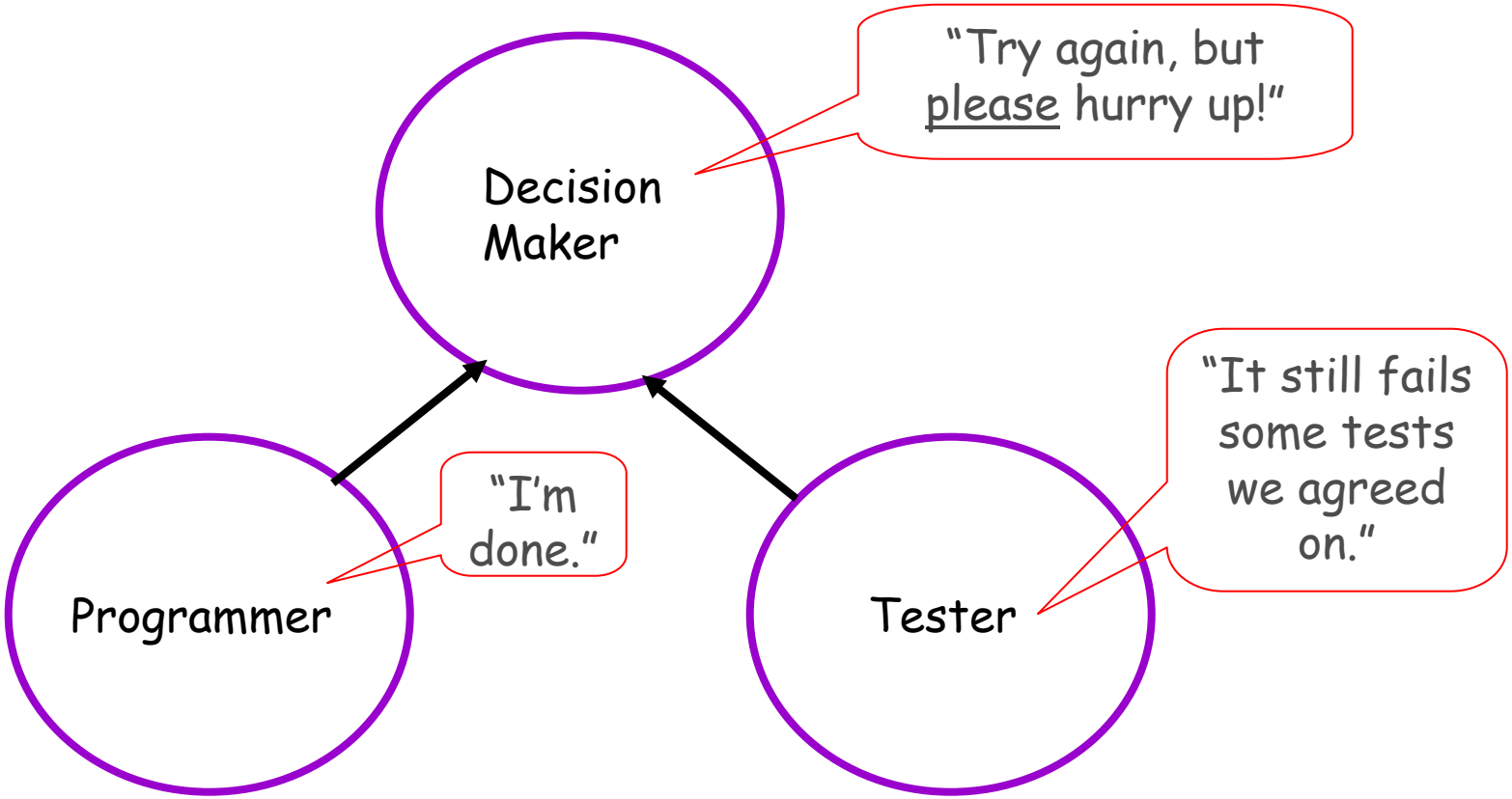
Typical Scenario (2)



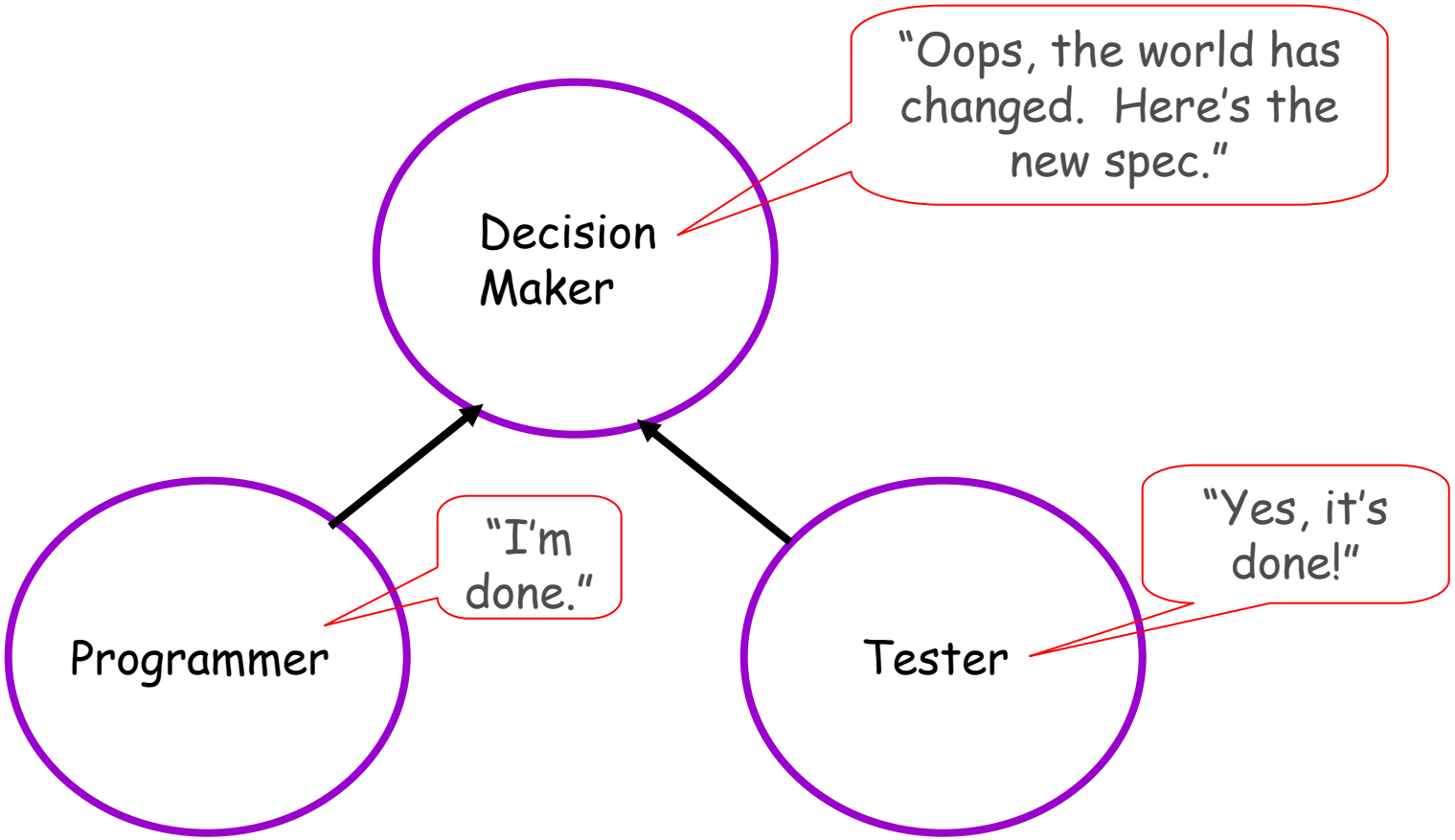
Typical Scenario (3)



Typical Scenario (4)

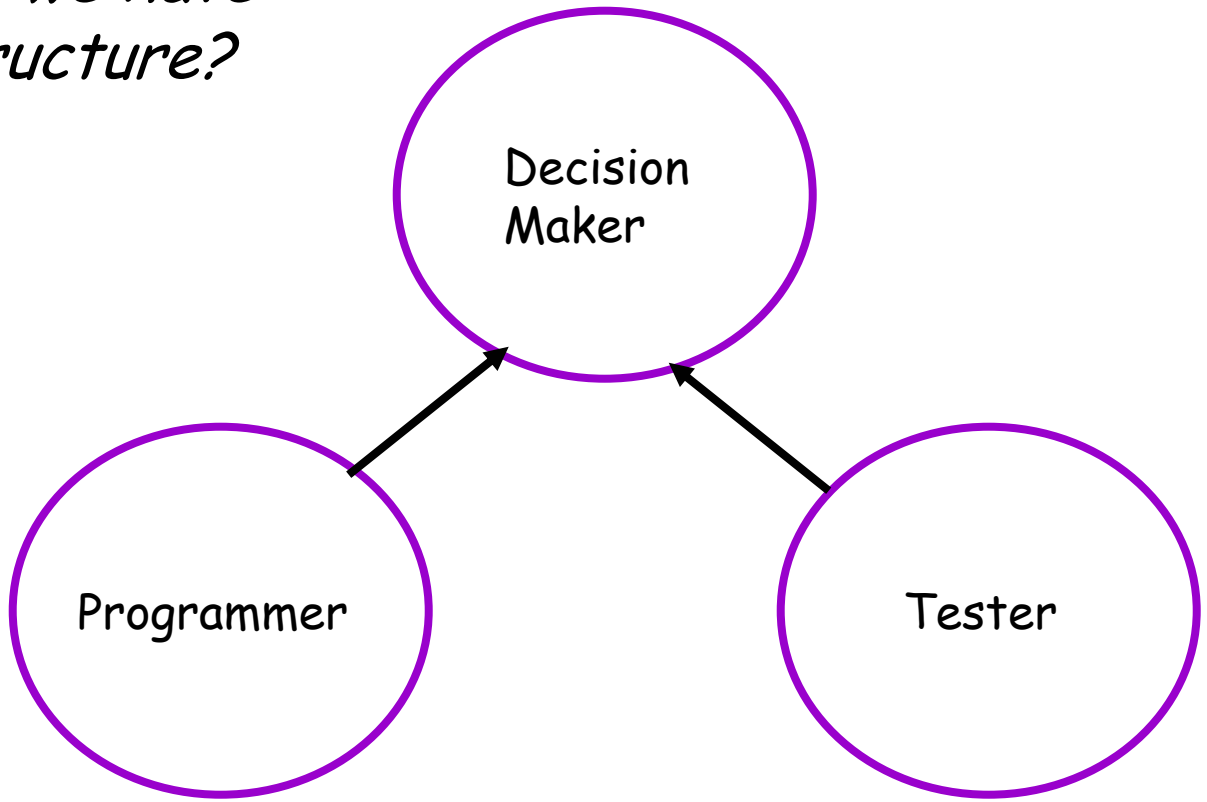


Typical Scenario (5)



Software Development Today

Why do we have this structure?



Key Assumptions

- Human organizations need decision makers
  - To manage (finite) resources (including time)

- Development and testing must be independent

Independent Testing

- Programmers have a hard time believing they made a mistake
  - Plus a vested interest in not finding mistakes
- Design and programming are constructive tasks
  - Testers must seek to break the software

Independent Testing

- Wrong conclusions:
  - The developer should not be testing at all
    - Recall "test before you code"
  - Testers only get involved once software is done
  - Toss the software over the wall for testing
    - Testers and developers collaborate in developing the test suite
  - Testing team is responsible for assuring quality
    - Quality is assured by a good software process

The Purpose of Testing

- Two purposes:
- Find bugs
  - Find important bugs
- Elucidate the specification
  - When testing the prototype or strawman

Example

- Test case

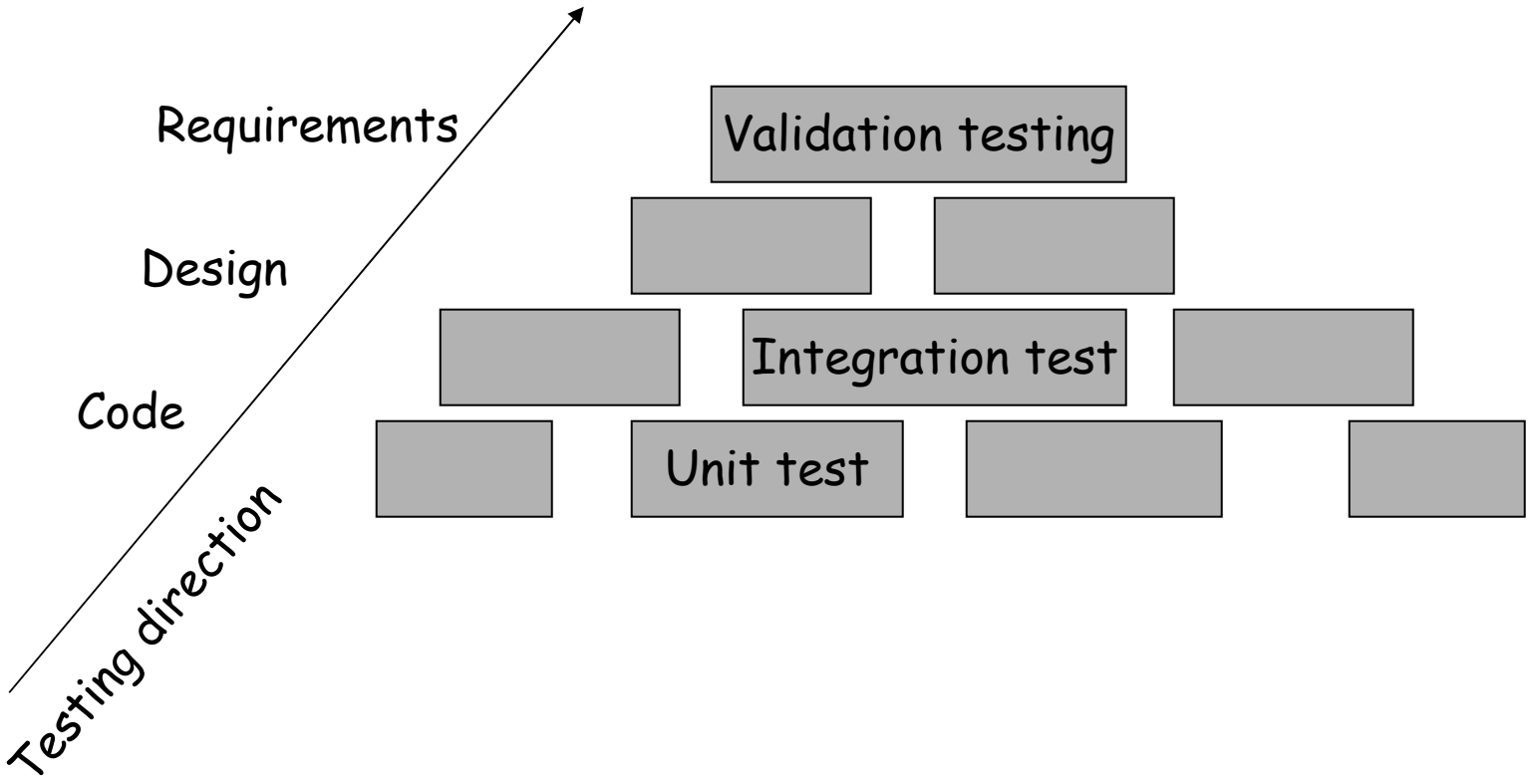
  Add a child to Mary Brown's record

- Version 1
  - Check that Ms. Brown's # of children is one more
- Version 2
  - Also check Mr. Brown's # of children
- Version 3
  - Check that no one else's child counts changed

Specifications

- Good testers clarify the specification
  - This is creative, hard work
- There is no hope tools will automate this
  - This part will stay hard work

Testing Strategies



Unit Tests

- Focus on smallest unit of design
  - A procedure, a class, a component
- Test the following
  - Local data structures
  - Basic algorithm
  - Boundary conditions
  - Error handling
- May need drivers and stubs
- Good idea to plan unit tests ahead

Integration Testing

- If all parts work, how come the whole doesn't?
- For software, the whole is more than the sum of the parts
  - Individual imprecision is magnified (e.g., races)
  - Unclear interface design
- Don't try the "big bang" integration !
- Do incremental integration
  - Top-down integration
  - Bottom-up integration

Top-Down Integration

- Test the main control module first
- Slowly replace stubs with real code
  - Can go depth-first
    - Along a favorite path, to create a working system quickly
  - Or, breadth first

- Problem: you may need complex stubs to test higher-levels

Bottom-Up Integration

- Integrate already tested modules
- No stubs, but need drivers
  - Often the drivers are easier to write
- Example:
  - Financial code that depends on subroutine for computing roots of polynomials
  - We cannot test the code without the subroutine
    - A simple stub might not be enough
  - We can develop and test the subroutine first
- Plan for testability !

Validation Testing

- Culmination of integration testing
  - The software works, but does it do what we need?
- Run acceptance tests
  - Get your customer to define them

- Alpha-testing (in controlled environment)
  - With developer looking over the shoulder
- Beta-testing
  - At end-user sites

Other Forms of High-Level Testing

- System testing
  - Involves non-software components
- Security testing
  - Red-team testing
- Performance testing
  - E.g., real-time systems
- Stress testing …

Stress Testing

- Push system into extreme situations
  - And see if it still works . . .

- Stress
  - Performance
    - Feed data at very high, very low rates
  - Interfaces
    - Replace APIs with badly behaved stubs
  - Internal structures
    - Works for any size array? Try sizes 0 and 1.
  - Resources
    - Set memory artificially low.
    - Same for # of file descriptors, network connections, etc.

Stress Testing (Cont.)

- Stress testing will find many obscure bugs
  - Explores the corner cases of the design

  "Bugs lurk in corners, and congregate at boundaries"

- Some may not be worth fixing
  - Too unlikely in practice

- A corner case now is tomorrow's common case
  - Data rates, data sizes always increasing
  - Your software will be stressed

Assertions

- Use assert(…) liberally
  - Documents important invariants
  - Makes your code self-checking
  - And does it on *every* execution!

- Opinion: Most programmers don't use assert enough

A Problem

- Testing is weak
  - Can never test more than a tiny fraction of possibilities
- Testers don't know as much about the code as the developers
  - But developers can only do so much testing
- What can we do?

Code Inspections

- Here's an idea: Understand the code!
  - One person explains to a group of programmers how a piece of code works
- Key points
  - Don't try to read too much code at one sitting
    - A few pages at most
  - Everyone comes prepared
    - Distribute code beforehand
  - No blame
    - Goal is to understand, clarify code, not roast programmers

Experience with Inspections

- Inspections work!
  - Finds 70%-90% of bugs in studies
  - Dramatically reduces cost of finding bugs
- Other advantages
  - Teaches everyone the code
  - Finds bugs earlier than testing
- Bottom line: More than pays for itself

Notes

- Some distinguish "walkthroughs" and "inspections"
- Walkthroughs are informal
- Inspections are formal
  - Extensive records kept
  - Metrics computed
  - Etc.

Manual Testing

- Test cases are lists of instructions
  - "test scripts"
- Someone manually executes the script
  - Do each action, step-by-step
    - Click on "login"
    - Enter username and password
    - Click "OK"
    - …
  - And manually records results
- Low-tech, simple to implement

Manual Testing

- Manual testing is very widespread
  - Probably not dominant, but very, very common
- Why? Because
  - Some tests can't be automated
    - Usability testing
  - Some tests shouldn't be automated
    - Not worth the cost

Manual Testing

- Those are the best reasons

- There are also not-so-good reasons
  - Not-so-good because innovation could remove them
  - Testers aren't skilled enough to handle automation
  - Automation tools are too hard to use
  - The cost of automating a test is 10x doing a manual test

Automated Testing

- Idea:
  - Record manual test
  - Play back on demand

- This doesn't work as well as expected
  - E.g., Some tests can't/shouldn't be automated

Fragility

- Test recording is usually very fragile
  - Breaks if environment changes anything
  - E.g., location, background color of textbox
- More generally, automation tools cannot generalize
  - They literally record exactly what happened
  - If anything changes, the test breaks
- A hidden strength of manual testing
  - Because people are doing the tests, ability to adapt tests to slightly modified situations is built-in

Breaking Tests

- When code evolves, tests break
  - E.g., change the name of a dialog box
  - Any test that depends on the name of that box breaks

- Maintaining tests is a lot of work
  - Broken tests must be fixed; this is expensive
  - Cost is proportional to the number of tests
  - Implies that more tests is not necessarily better

Improved Automated Testing

- Recorded tests are too low level
  - E.g., every test contains the name of the dialog box
- Need to abstract tests
  - Replace dialog box string by variable name X
  - Variable name X is maintained in one place
    - So that when the dialog box name changes, only X needs to be updated and all the tests work again
- This is just structured programming
  - Just as hard as any other system design

Regression Testing

- Idea
  - When you find a bug,
  - Write a test that exhibits the bug,
  - And always run that test when the code changes,
  - So that the bug doesn't reappear

- Without regression testing, it is surprising how often old bugs reoccur

Regression Testing (Cont.)

- Regression testing ensures forward progress
  - We never go back to old bugs
- Regression testing can be manual or automatic
  - Ideally, run regressions after every change
  - To detect problems as quickly as possible
- But, regression testing is expensive
  - Limits how often it can be run in practice
  - Reducing cost is a long-standing research problem

Regression Testing (Cont.)

- Other tests (besides bug tests) can be checked for regression
  - Requirements/acceptance tests
  - Performance tests

- Ideally, entire suite of tests is rerun on a regular basis to assure old tests still work

Nightly Build

- Build and test the system regularly
  - Every night
- Why? Because it is easier to fix problems earlier
  - Easier to find the cause after one change than after 1,000
  - Avoids new code from building on the buggy code
- Test is usually subset of full regression test
  - "smoke test"
  - Just make sure there is nothing horribly wrong

Discussion

- Testers have two jobs
  - Clarify the specification
  - Find (important) bugs
- Only the latter is subject to automation
- Helps explain why there is so much manual testing
- Nevertheless, automate as much as you can

Back to Design

- Testing has a profound impact on design
  - Because some designs are easier to test
- Design software so it can be tested!
- Or at least avoid designing software that cannot be tested

Principles of Testability

- Avoid unpredictable results
  - No unnecessary non-deterministic behavior

- Design in self-checking
  - At appropriate places have system check its own work
    - Asserts
  - May require adding some redundancy to the code

Principles of Testability

- Avoid system state
  - System retains nothing across units of work
    - A transaction, a session, etc.
  - System returns to well-known state after each task is complete
    - Easiest system to test
- Minimize interactions between features
  - Number of interactions can easily grow huge
  - Rich breeding ground for bugs
- Have a test interface

Testing Frameworks

- Key components of a test system are
  - Building the system to test
    - May build many different versions to test
  - Running the tests
  - Deciding whether tests passed/failed
    - Sometimes a non-trivial task (e.g., compilers) !
  - Reporting results

- Testing frameworks provide these functions
  - E.g., Tinderbox, JUnit

Summary

- Testing requires a certain mindset
  - Want to break the code
- Good testing is hard work
  - Requires real insight into the nature of the system
  - Will help elucidate the spec

Project

- Design and Test Document Assignment due Feb. 21
- Design Presentations on Feb. 26th
- It's not too early to start writing code: e.g. prototype pieces that you think may be challenging.