Games Engineering II

Why Do We Test Software?

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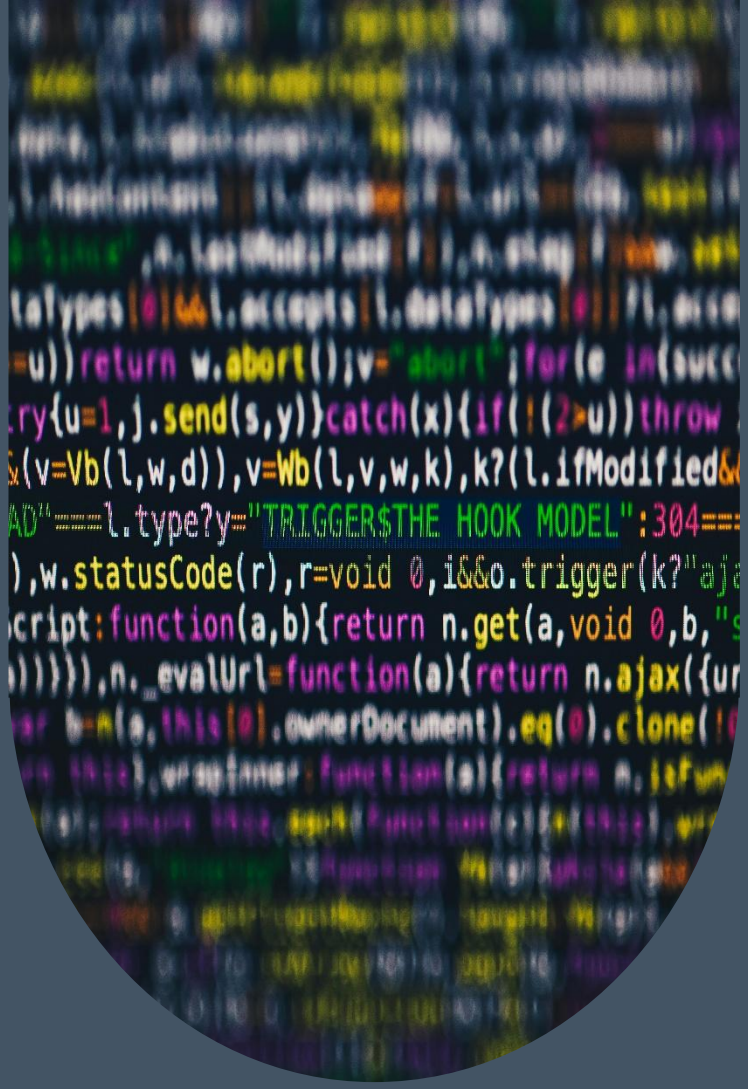

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INSPIRING FUTURES

Module Information

Games Engineering II – COMP H4204

Course Textbook:

"***Introduction to Software Testing***", Paul Ammann, Jeff Offutt, 2nd Edition, Cambridge Press, ISBN: 978-0-511-39330-3

Assessment Criteria:

Continuous Assessment (20%) – Every Week

Project (20%) – End of Semester

Practical (20%) – Every Second Week (2,4,6,8)

End of Module Examination (40%)

Instructor

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Availability: Wed (1500 – 1700 hrs)

- BSc (Hons) Computer Systems Engineering
- MSc Communications Engineering
- PhD Electrical and Wireless Engineering
- **Specialization (s):** Wireless Sensor Networks, Machine Learning, Computer Networks, Testing & Quality Assurance
- **Research Area (s):** Biomedical and Health care, smart cities, smart agriculture, embedded device power optimization

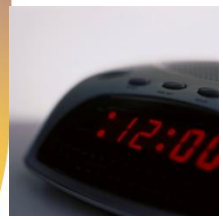
Testing in the 21st Century

- Software defines **behavior**
  - network routers, finance, switching networks, other infrastructure
- Today's software market :
  - is much bigger
  - is more competitive
  - has more users

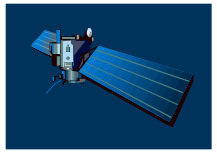
Industry is going through a revolution in what testing means to the success of software products

- **Embedded Control** Applications
  - airplanes, air traffic control
  - spaceships
  - watches
  - ovens
  - remote controllers
  - Mobile phones
  - smart TVs, Smart Washing Machine
  - Games Consoles
  - Garage door openers
  - Modern Cars
- Agile processes put increased pressure on testers
  - Programmers must unit test – with no training or education!
  - Tests are key to functional requirements – but who builds those tests ?

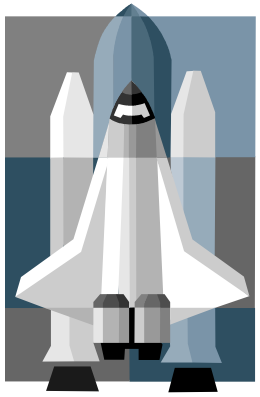
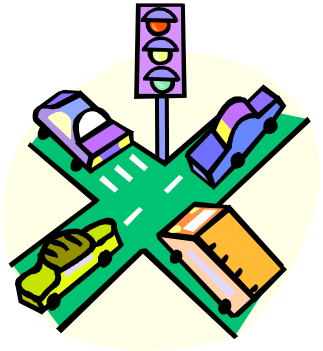
“Software is a Skin that Surrounds Our Civilization”









Software Faults, Errors & Failures

- **Software Fault** : A static defect in the software
- **Software Failure** : External, incorrect behavior with respect to the requirements or other description of the expected behavior
- **Software Error** : An incorrect internal state that is the manifestation of some fault

Faults in software are equivalent to design mistakes in hardware.

Software does not degrade.

Fault and Failure Example

- A patient gives a doctor a list of symptoms (***Failures***)
- The doctor tries to diagnose the root cause, the ailment (***Fault***)
- The doctor may look for anomalous internal conditions (high blood pressure, irregular heartbeat, bacteria in the blood stream) (***Errors***)

Most medical problems result from external attacks (bacteria, viruses) or physical degradation as we age.

Software faults were there at the beginning and do not "appear" when a part wears out.

A Concrete Example

Fault: Should start searching at 0, not 1

```
public static int numZero (int [ ] arr)
{  // Effects: If arr is null throw NullPointerException
   // else return the number of occurrences of 0 in arr
   int count = 0;
   for (int i = 1; i < arr.length; i++)
   {
      if (arr [ i ] == 0)
      {
         count++;
      }
   }
   return count;
}
```

Test 1
[2, 7, 0]
Expected: 1
Actual: 1

Error: i is 1, not 0, on the first iteration
Failure: none

Test 2
[0, 2, 7]
Expected: 1
Actual: 0

Error: i is 1, not 0
Error propagates to the variable count
Failure: count is 0 at the return statement

The Term Bug

- *Bug* is used informally
- Sometimes speakers mean fault, sometimes error, sometimes failure … often the speaker doesn't know what it means !
- This class will try to use words that have precise, defined, and unambiguous meanings

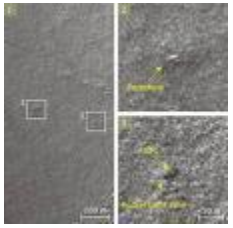
"It has been just so in all of my inventions. The first step is an intuition, and comes with a burst, then difficulties arise—this thing gives out and *[it is]* then that 'Bugs'—as such little faults and difficulties are called—show themselves and months of intense watching, study and labor are requisite. . ." – Thomas Edison

"an analyzing process must equally have been performed in order to furnish the Analytical Engine with the necessary operative data; and that herein may also lie a possible source of error. Granted that the actual mechanism is unerring in its processes, the cards may give it wrong orders. " – Ada, Countess Lovelace (notes on Babbage's Analytical Engine)

Spectacular Software Failures

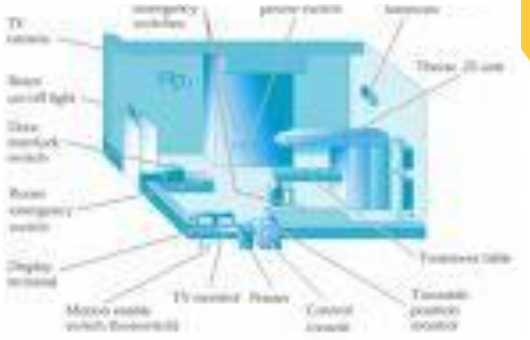
Spectacular Software Failures

- NASA's Mars lander: September 1999, crashed due to a units integration fault



Mars Polar Lander crash site?

THERAC-25 design



- THERAC-25 radiation machine : Poor testing of safety-critical software can cost *lives* : 3 patients were killed
- Ariane 5 explosion : Millions of $$
- Intel's Pentium FDIV fault : Public relations nightmare

Ariane 5: exception-handling bug : forced self destruct on maiden flight (64-bit to 16-bit conversion: about 370 million $ lost)

We need our software to be dependable !
Testing is *one* way to assess dependability

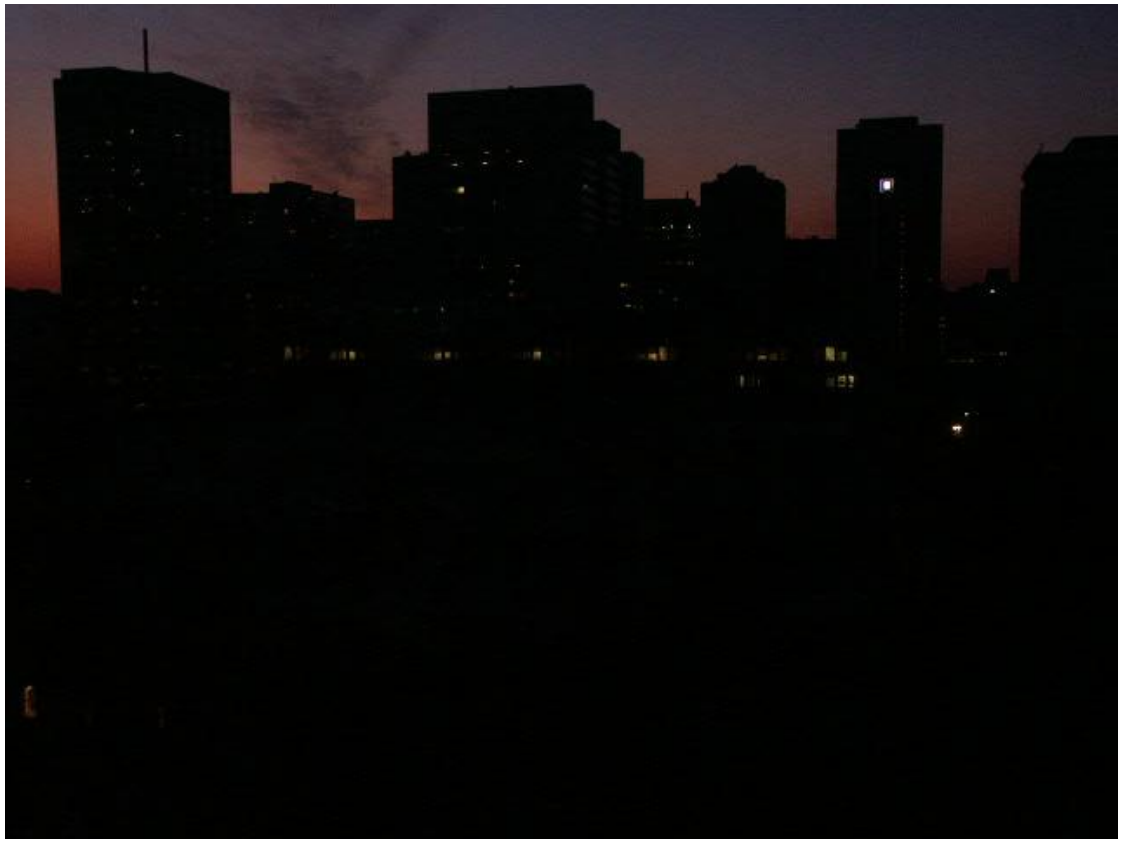
Northeast Blackout of 2003

508 generating units and 256 power plants shut down

Affected 10 million people in Ontario, Canada

Affected 40 million people in 8 US states

Financial losses of $6 Billion USD



The alarm system in the energy management system failed due to a software error and operators were not informed of the power overload in the system

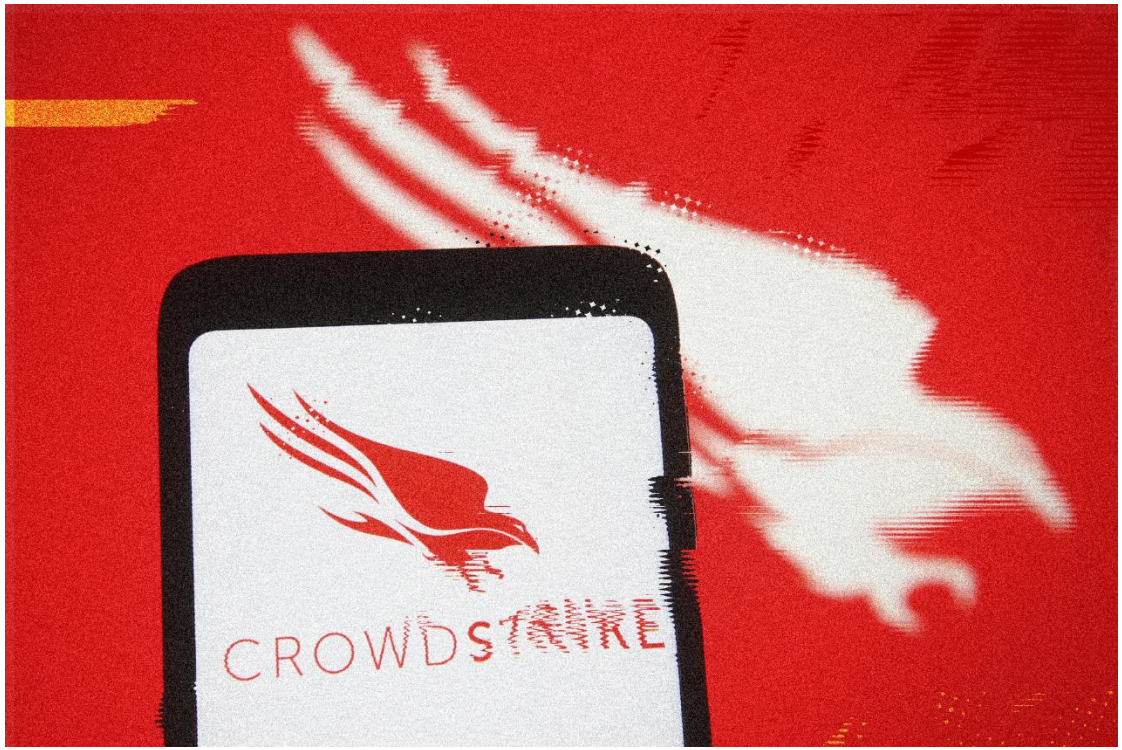
The CrowdStrike Outage of 2024

8.5 millions devices affected globally

72 hours downtime for major organizations

Estimated $3 billions loss

Banking, Healthcare, and Transportation sectors impacted



A ***misconfigured update*** clashed with existing Windows configurations, leading to widespread crashes. This underscored the need for ***comprehensive testing*** across diverse environments before deployment.

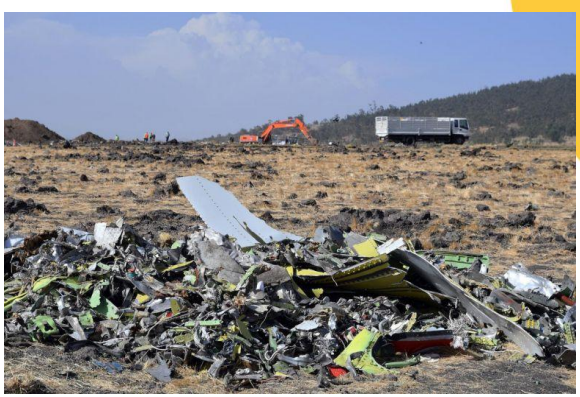
Costly Software Failures

- NIST report, "The Economic Impacts of Inadequate Infrastructure for Software Testing" (2002)
  - Inadequate software testing costs the US alone between $22 and $59 billion annually
  - Better approaches could cut this amount in half
- Huge losses due to web application failures
  - Financial services : $6.5 million per hour (just in USA!)
  - Credit card sales applications : $2.4 million per hour (in USA)
- 2007 : Symantec says that most ***security vulnerabilities*** are due to faulty software

World-wide monetary loss due to poor software is staggering

Spectacular software Failures

- **Boeing A220** : Engines failed after software update allowed excessive vibrations
- **Boeing 737 Max** : Crashed due to overly aggressive software flight overrides (MCAS)



Toyota brakes : Dozens dead, thousands of crashes

- **Healthcare website** : Crashed repeatedly on launch—never load tested

- **Northeast blackout** : 50 million people, $6 billion USD lost … alarm system failed

Software testers try to find faults before the faults find users

Testing in the 21st Century

- More safety critical, real-time software
- Embedded software is ubiquitous … check your pockets
- Enterprise applications means bigger programs, more users
- Paradoxically, free software increases our expectations !
- Security is now all about software faults
- Secure software is reliable software
- The web offers a new deployment platform
- Very competitive and very available to more users
- Web apps are distributed
- Web apps must be highly reliable

Industry desperately needs our inventions !

The True Cost of Software Failure

Fail watch analyzed news articles for 2016

- 606 reported software failures
- Impacted half the world's population
- Cost a combined $1.7 trillion US dollars

Poor software is a significant drag on the world's economy

What Does This Mean?

Software testing is getting more important

What are we trying to do when we test ?

What are our goals ?

Validation & Verification (*IEEE*)

- **Validation** : The process of evaluating software at the end of software development to ensure compliance with intended usage

- **Verification** : The process of determining whether the products of a given phase of the software development process fulfill the requirements established during the previous phase

Test Players & Maturity Levels

Test Players

- **Test Engineer**:
  - Design
  - Execute
  - Evaluate Tests
- **Test Manager**: Responsibilities include:
  - Sets policies and processes
  - Interacts with other managers on project
  - Help engineers execute their tasks properly

Testing Goals Based on Test Process Maturity

- **Level 0** : There's no difference between ***testing and debugging***
- **Level 1** : The purpose of testing is to show ***correctness***
- **Level 2** : The purpose of testing is to show that the software ***doesn't work***
- **Level 3** : The purpose of testing is not to prove anything specific, but to ***reduce the risk*** of using the software
- **Level 4** : Testing is a ***mental discipline*** that helps all IT professionals develop higher quality software

Level 0 Thinking

- Testing is the ***same*** as debugging
- Does not distinguish between incorrect ***behavior*** and mistakes in the program
- Does not help develop software that is ***reliable*** or ***safe***

This is what we teach undergraduate CS majors

Level 1 Thinking

- Purpose is to show ***correctness***
- Correctness is ***impossible*** to achieve
- What do we know if ***no failures***?
- Good software or bad tests?
- ***Test engineers*** have no:
- Strict goal
- Real stopping rule
- Formal test technique
- Test managers are ***powerless***

This is what hardware engineers often expect

Level 2 Thinking

- Purpose is to show ***failures***
- Looking for failures is a ***negative*** activity
- Puts testers and developers into an ***adversarial*** relationship
- What if there are ***no failures***?

This describes most software companies.

How can we move to a *team approach* ??

Level 3 Thinking

- Testing can only show the ***presence of failures***
- Whenever we use software, we incur some ***risk***
- Risk may be ***small*** and consequences unimportant
- Risk may be ***great*** and consequences catastrophic
- Testers and developers cooperate to ***reduce risk***

This describes a few "enlightened" software companies

Level 4 Thinking

A mental discipline that increases quality

- Testing is only ***one way*** to increase quality
- Test engineers can become ***technical leaders*** of the project
- Primary responsibility to ***measure and improve*** software quality
- Their expertise should ***help the developers***

This is the way "traditional" engineering works

Where Are You?

Are you at level 0, 1, or 2 ?

Is your organization at work at level 0, 1, or 2 ?

Or 3?

We hope to teach you to become "**change agents**" in your workplace …

Advocates for level 4 thinking

Test Types

Tactical Goals : Why Each Test ?

If you don't know why you're conducting each test, it won't be very helpful

- ***Written test objectives*** and requirements must be documented
- What are your planned ***coverage*** levels?
- How much testing is ***enough***?
- Common objective – ***spend the budget*** … test until the ship-date …
  - Sometimes called the "***date criterion***"

Cost of Not Testing

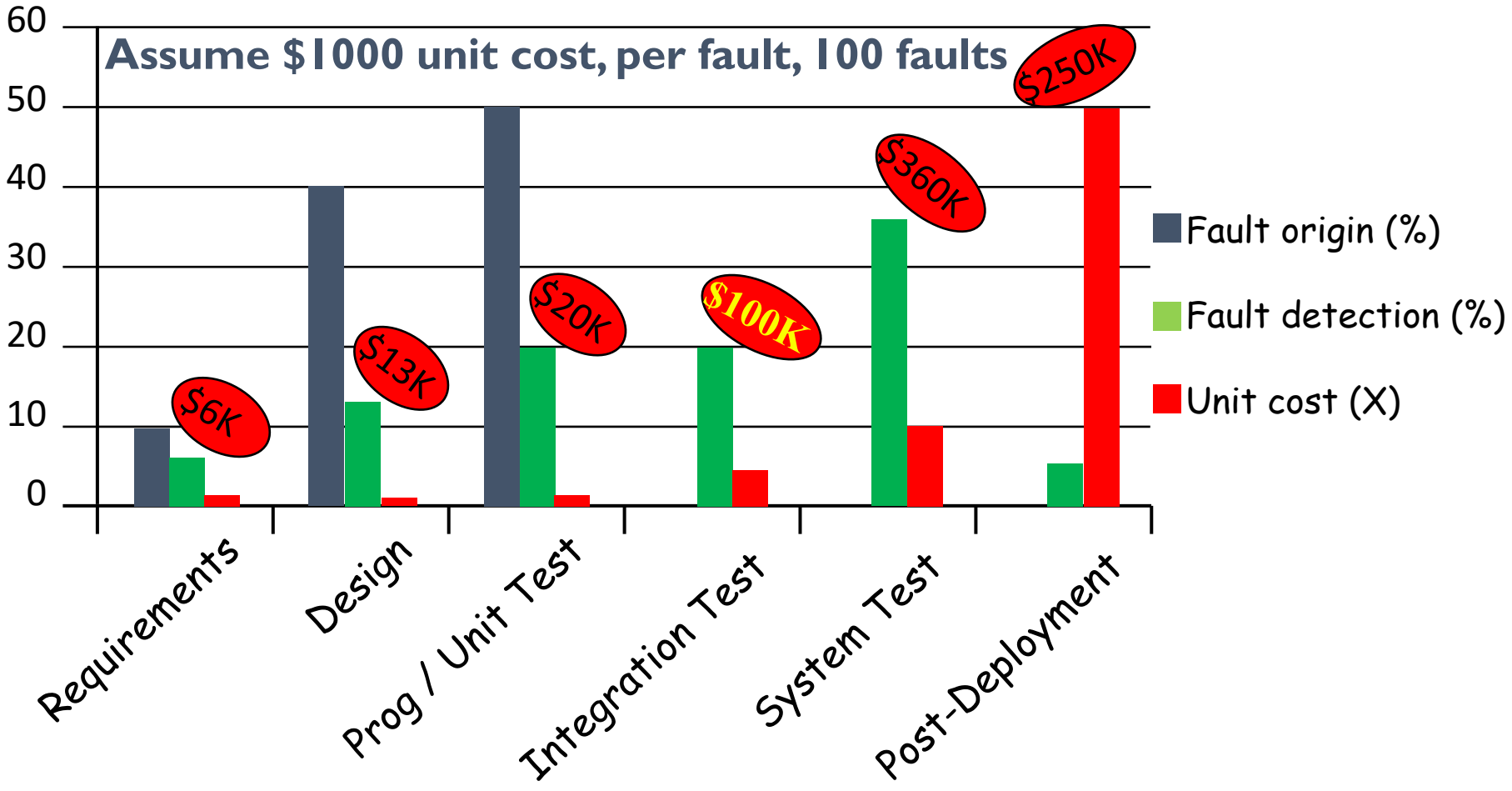
Poor Program Managers might say:
"Testing is too expensive."

- Testing is the most time consuming and expensive part of software development
- Not testing is even ***more expensive***
- If we have too little testing effort early, the cost of testing increases
- Planning for testing after development is ***prohibitively*** expensive

Testing Levels

- **Acceptance Testing:** *Assessment with reference to the software requirements.*
- **System Testing:** *Assessment with reference to the Architectural design.*
- **Integration Testing:** *Assessment with reference to sub-system design.*
- **Module Testing:** *Assessment with reference to the detailed design.*
- **Unit Testing:** *Assessment with reference to the implementation.*
- **Regression Testing:** *usually performed after the changes made;*
- *Test Early and often*
- *Develop tests throughout the development cycle.*

Cost of Late Testing



Software Engineering Institute; Carnegie Mellon University; Handbook CMU/SEI-96-HB-002

Summary:
Why Do We Test Software ?

A tester's goal is to eliminate faults as early as possible

- Improve quality
- Reduce cost
- Preserve customer satisfaction

Questions & Feedback?

Please feel free to email for your queries.

Course materials will be uploaded to Blackboard after every lecture.

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