Introduction to Software Testing (Ch. 1)

Why Do We Test Software?

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Adapted from slides by Paul Ammann & Jeff Offutt

Testing in the 21st Century

Software defines **behavior**

- network routers, finance, switching networks, etc.

Today's software market:

- is much **bigger**
- is much more **competitive**
- has more **users**

Embedded Control Applications

- airplanes
- watches
- cell phones
- spaceships
- our homes
- automobiles

Agile processes put increased pressure on testers

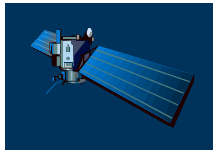
- unit testing critical (with no training or education!)
- Tests are key to functional requirements – but who builds these tests?

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

Software is EVERYWHERE!

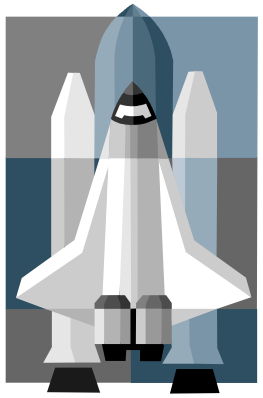
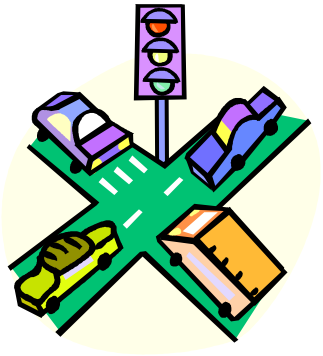










Software faults, errors, & failures

Software fault: A static defect in the software

Software error: An incorrect internal state that is the manifestation of some fault

Software failure: External, incorrect behavior with respect to the requirements or other description of expected behavior

Faults in software are equivalent to design mistakes in hardware.

Software does not degrade.

Failure, fault, and error example
(non-technical)

A patient gives a doctor a list of **symptoms**

- **Failures**

The doctor tries to diagnose the root cause (**ailment**)

- **Fault**

The doctor may look for **abnormal internal conditions** (high blood pressure, irregular heartbeat)

- **Errors**

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

Software faults are put there (or were always there) and do not "appear" when a part gets old or wears out.

A concrete example

```
public static int numZero (int [ ] arr)
{  // Effects: If arr is null throw NullPointe
   // 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;
}
```

Fault: Should start searching at 0, not 1

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

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

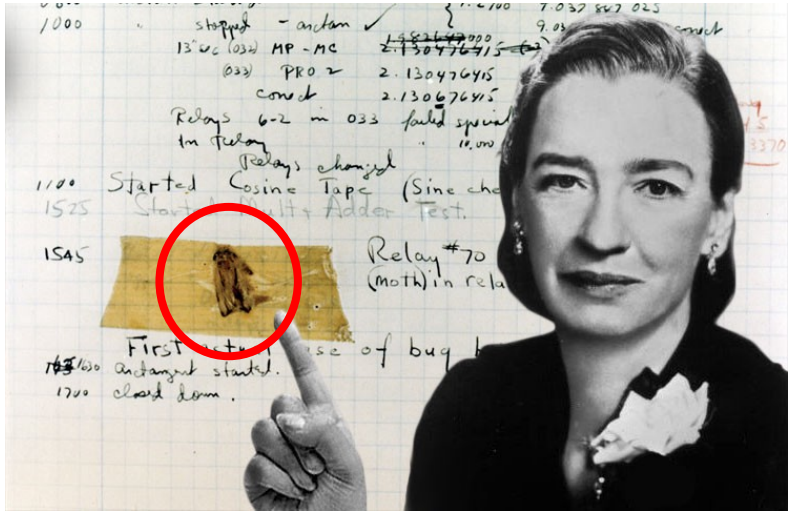
Test 2
[0, 2, 7]
Expected: 1
Actual: 0

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 a fault, sometimes error, sometimes failure



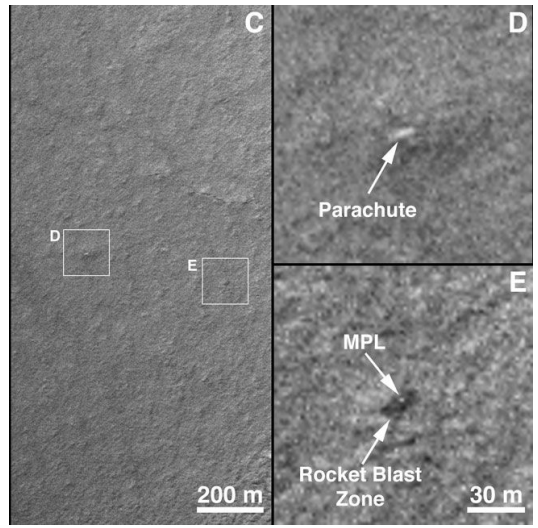
This course will try to avoid using this word so that we understand the **precise** terminology

Though you'll probably use or encounter the term bug informally or at work quite often ☺

Spectacular Software Failures

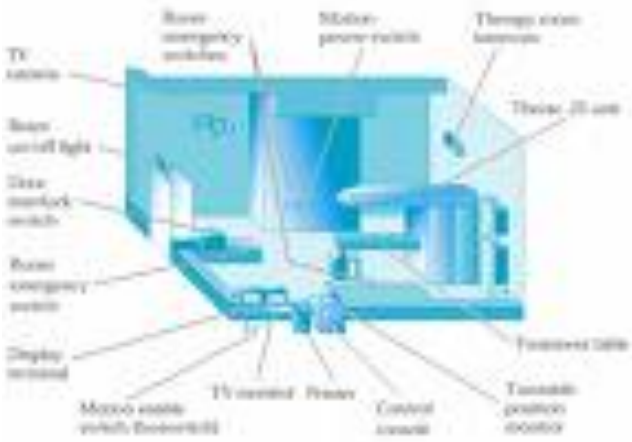
NASA's Mars lander

September 1999; crashed due to unit integration fault



THERAC-25 radiation machine

1980s; poor testing of safety critical software can cost *lives* : 3 patients killed



Spectacular Software Failures

Ariane 5 explosion

Millions of $$ lost from exception handling bug

Intel Pentium FDIV fault

public relations nightmare

Spectacular Software Failures

Boeing A220

Engines failed after software updated allowed excessive vibrations

Boeing 737 Max

Crashed due to overly aggressive software flight overrides

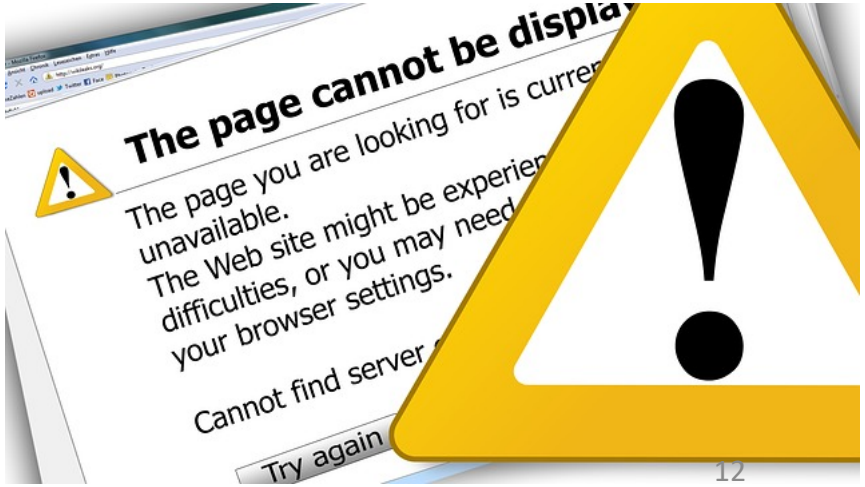
Spectacular Software Failures

Toyota brakes

Dozens dead, thousands of crashes

Heathcare.gov website

Crashed repeatedly on launch – never load tested



We need our software to be <u>dependable</u>.

Testing is *one way* to assess dependability.
Software testers try to find faults *before* the faults find users.

Costly Software Failures

NIST report, "The **Economic Impacts** of Inadequate Infrastructure for Software Testing" (2002)

- Inadequate software testing cost US alone between $22 and $59 billion *annually*

Huge losses due to web app failures

- Financial services: $6.5 million per hour (just in US!)
- Credit card sales apps: $2.4 million per hour (in US)

Symantec (2007) says that most **security vulnerabilities** are due to faulty software

Costly Software Failures

Northeast blackout

2003; 50 million people, $6 *billion* USD lost because of power overload (alarm system failed)

Amazon BOGO no-go

Dec 2006; amazon.com's **BOGO** offer turned into a **double discount**

World-wide monetary loss due to poor software testing and maintenance is staggering!

Testing in the 21st Century

More **safety critical, real-time** software

Embedded software is ubiquitous

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 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 interventions and help!

The *true* cost of a software failure

Analysis of news articles in 2016 revealed:

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

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

Also…super frustrating

So 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 fulfills the requirements established during the previous phase

IV&V stands for "independent verification & validation"

Test 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 explained

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** and **safe**

This is what we typically teach undergraduate CS majors.

Level 1 explained

Purpose is to show **correctness**

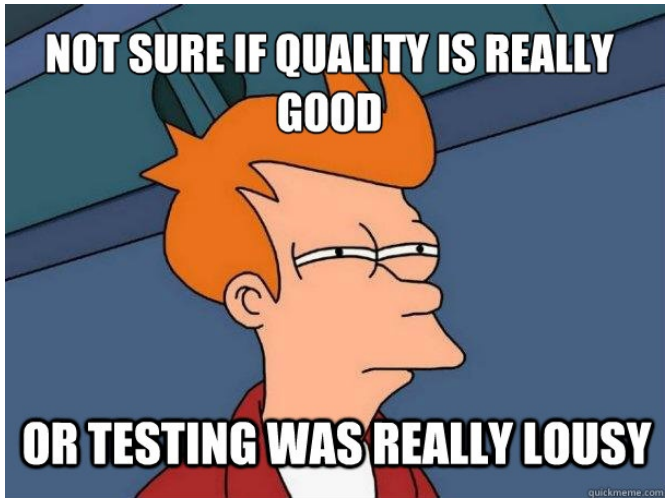
Correctness is **impossible** to achieve

What do we know if **no failures**?

- Good software or bad/not enough 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 explained

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 explained

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 handful of "enlightened" software companies.

Level 4 explained

A mental discipline that increases quality

Testing is only **one way** to increase quality

Test engineers can become **technical leaders** of 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 maybe 3?

We hope to teach you to become "change agents"…
Advocates for level 4 thinking

Tactical goals: why each test?

If you don't know <u>why</u> 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"

Why each test?

If you don't start planning for each test when the functional requirements are formed, you'll never know why you're conducting the test.

1980: "The software shall be easily **maintainable:**

Threshold **reliability** requirements?

What fact does each test try to **verify**?

Requirements definition teams *need testers*!

Cost of not testing

Poor program managers might say:

"Testing is too expensive."

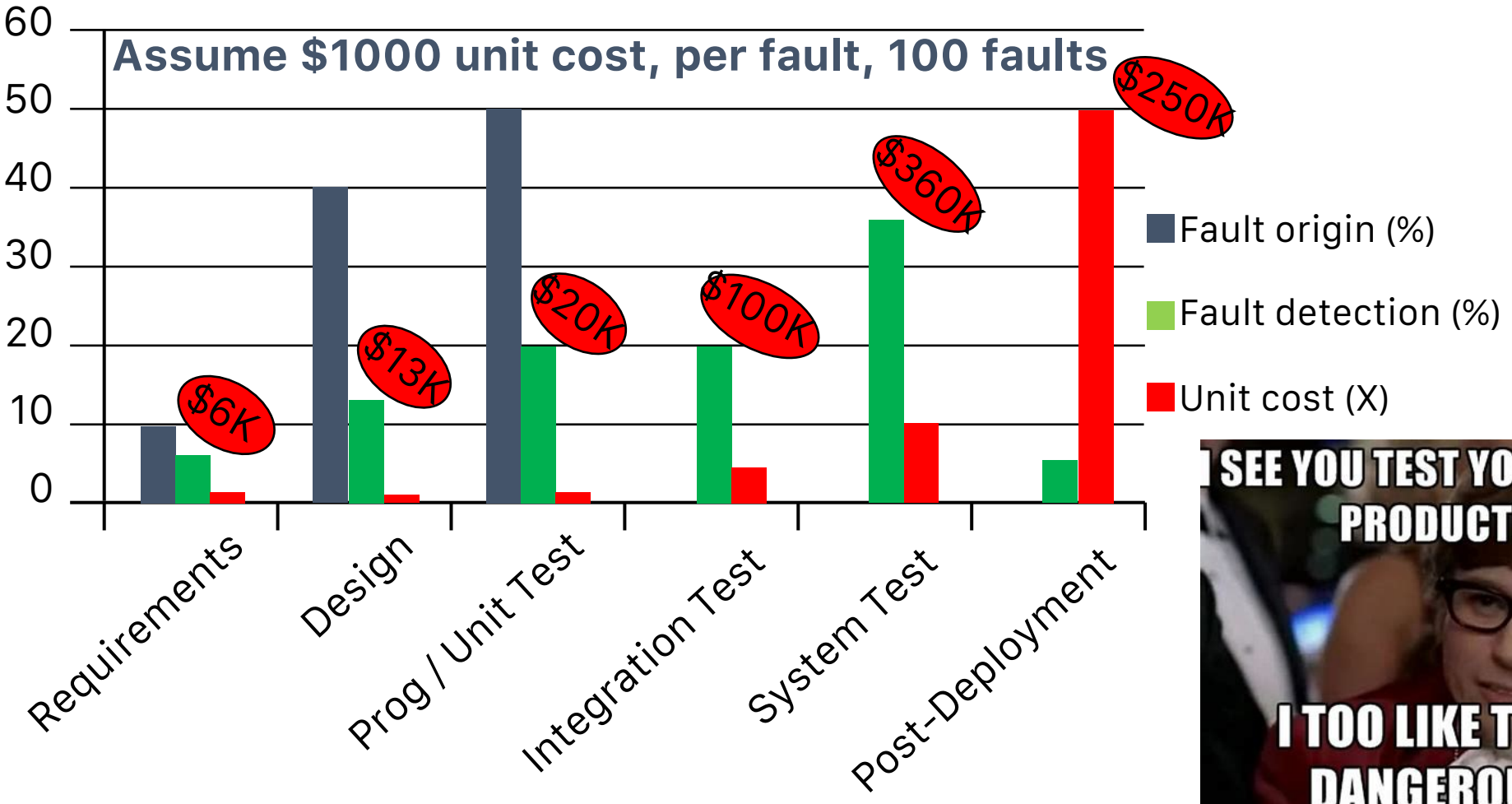
Testing is the **most time consuming** and **expensive** part of software development

Not testing is even **more expensive**

If we have too little testing effort early, the cost **increases**

Planning for testing after development is **prohibitively** expensive

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 ✓