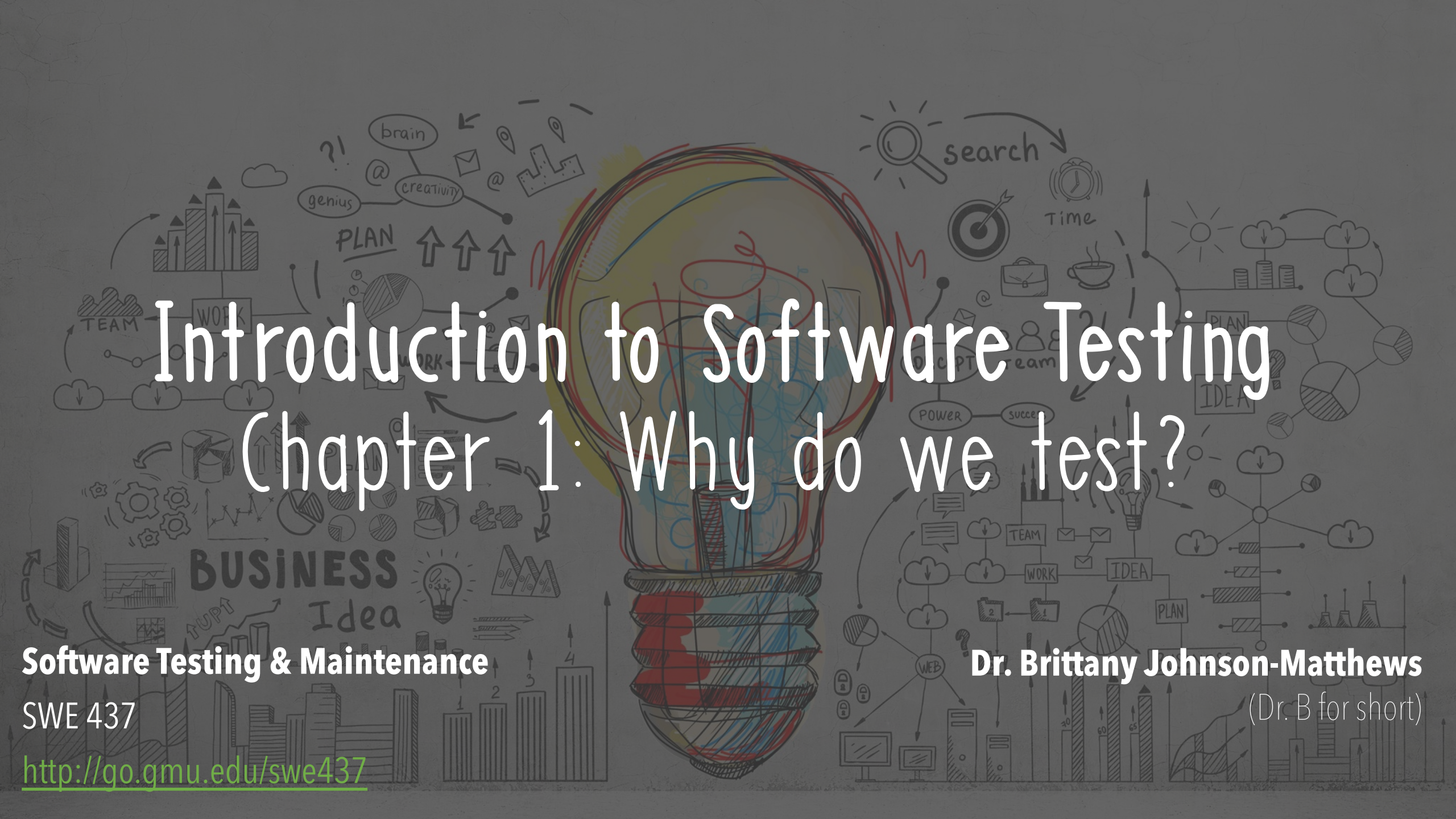


Introduction to Software Testing
Chapter 1: Why do we test?

Software Testing & Maintenance

SWE 437

http://go.gmu.edu/swe437

Dr. Brittany Johnson-Matthews

(Dr. B for short)

Software 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**

Systems are **constantly** and **rapidly** evolving.

Testing in the 21st Century

With rapid development of innovative tech comes higher need for **effective validation** of software systems.

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...

& in **everything we do**.

Software is **embedded** in:

- personal devices
- motor vehicles
- criminal justice
- and so much more!

Software faults, errors, & failures

Fault: A static defect in the software

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

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, error (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**

However…

most medical problems result from external attacks (bacteria, viruses) or degradation.

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 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;
}
```

Fault: Should start searching at 0, not 1

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

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

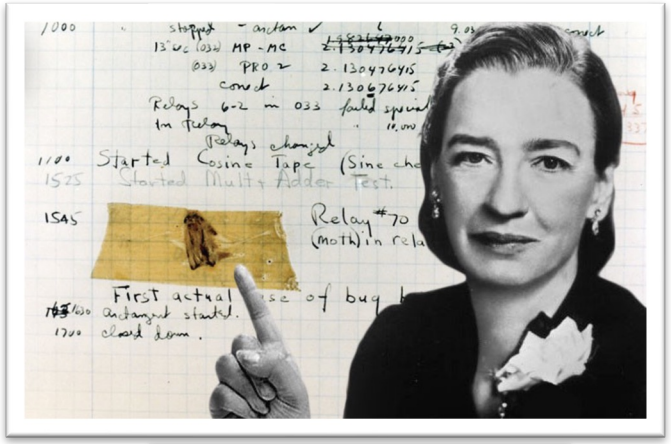
Test 2
arr = [0, 2, 7]
Expected: 1
Actual: 0

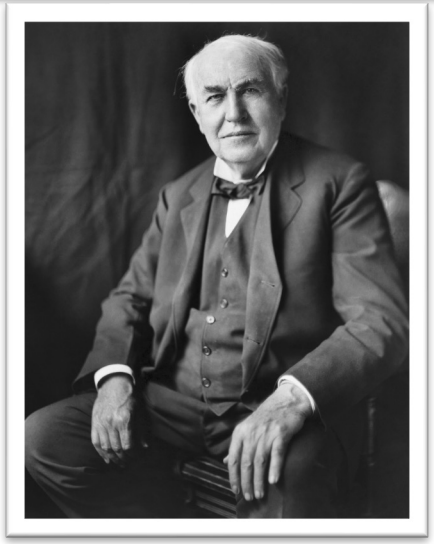
Error: i is 1, not 0
Error propagates to the variable count
Failure: count is 0 at the return statement

The term "bug"

"**Bug**" is used informally

- sometimes a fault, sometimes error, sometimes failure





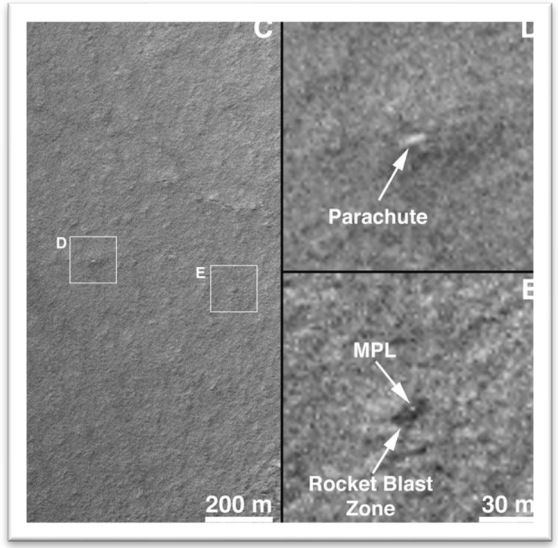
This course will try to avoid using this word so that we understand the **precise terminology**

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

Infamous software failures

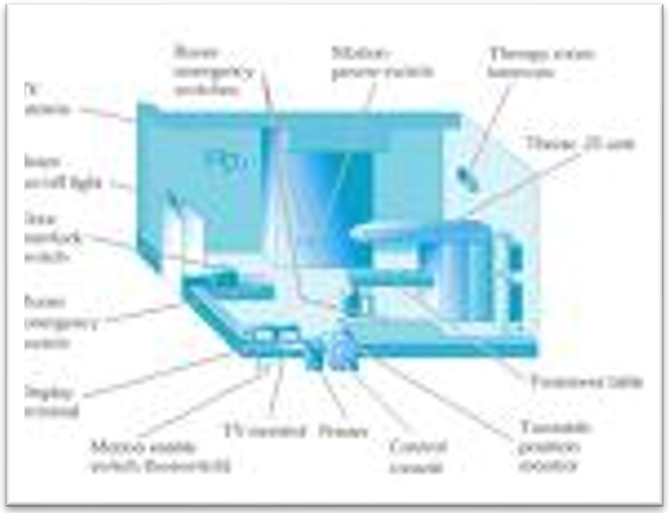
NASA's Mars lander

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



Infamous software failures

Ariane 5 explosion

Millions of $$ lost from exception handling bug

Intel Pentium FDIV fault

public relations nightmare

Infamous software failures

Boeing A220

Engines failed after software updated allowed excessive vibrations

Boeing 737 Max

Crashed due to overly aggressive software flight overrides

Infamous 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 dependable.

Testing is *one way* to assess dependability.

Software testers try to find faults *before* the faults find users.

Software failures are expensive!

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 [& **higher impact**!]

Paradoxically, *free* software *increases* our expectations.

Testing in the 21st century

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 and must be highly reliable

And now we have software that relies on **artificial intelligence**

(unclear if and to what extent existing techniques scale)

Testing in the 21st century

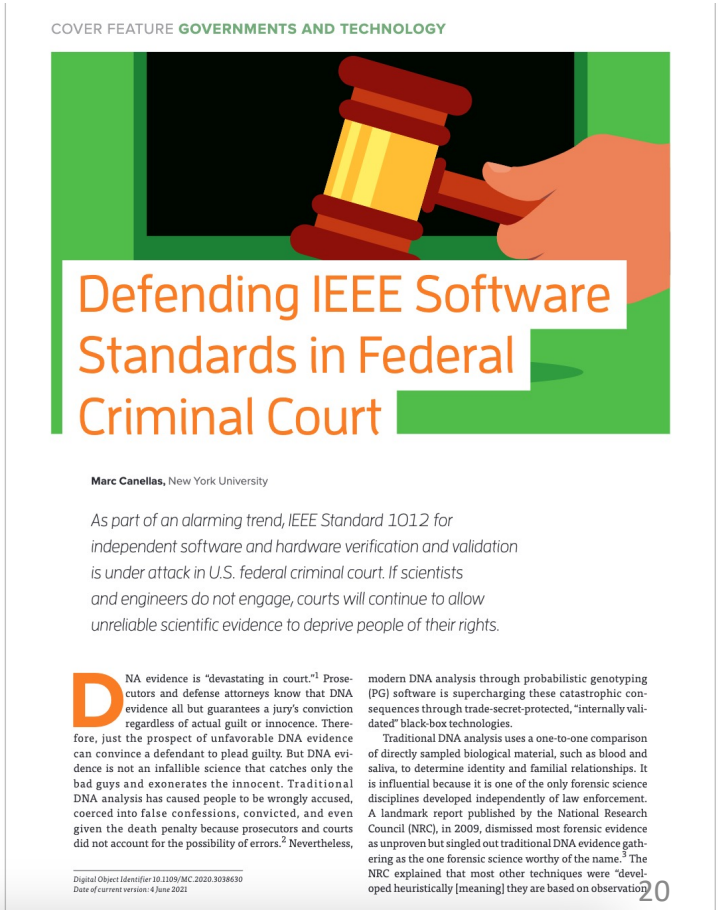
The potential for **detrimental impact** is *increasing* by the day.

Software used in life-altering scenarios

- criminal justice
- healthcare

But is this software being adequately tested?

(recent article points out some aren't!)



COVER FEATURE **GOVERNMENTS AND TECHNOLOGY**

Defending IEEE Software Standards in Federal Criminal Court

Marc Canellas, New York University

As part of an alarming trend, IEEE Standard 1012 for independent software and hardware verification and validation is under attack in U.S. federal criminal court. If scientists and engineers do not engage, courts will continue to allow unreliable scientific evidence to deprive people of their rights.

DNA evidence is "devastating in court."[1] Prosecutors and defense attorneys know that DNA evidence all but guarantees a jury's conviction regardless of actual guilt or innocence. Therefore, just the prospect of unfavorable DNA evidence can convince a defendant to plead guilty. But DNA evidence is not an infallible science that catches only the bad guys and exonerates the innocent. Traditional DNA analysis has caused people to be wrongly accused, coerced into false confessions, convicted, and even given the death penalty because prosecutors and courts did not account for the possibility of errors.[2] Nevertheless, modern DNA analysis through probabilistic genotyping (PG) software is supercharging these catastrophic consequences through trade-secret-protected, "internally validated" black-box technologies.

Traditional DNA analysis uses a one-to-one comparison of directly sampled biological material, such as blood and saliva, to determine identity and familial relationships. It is influential because it is one of the only forensic science disciplines developed independently of law enforcement. A landmark report published by the National Research Council (NRC), in 2009, dismissed most forensic evidence as unproven but singled out traditional DNA evidence gathering as the one forensic science worthy of the name.[3] The NRC explained that most other techniques were "developed heuristically [meaning] they are based on observation

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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 can have real ramifications.

Also…it's 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 = debugging

Does not distinguish between incorrect behavior and mistakes in the program

Does not help develop software that is reliable and safe

This is (unfortunately) what we typically learn as 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.

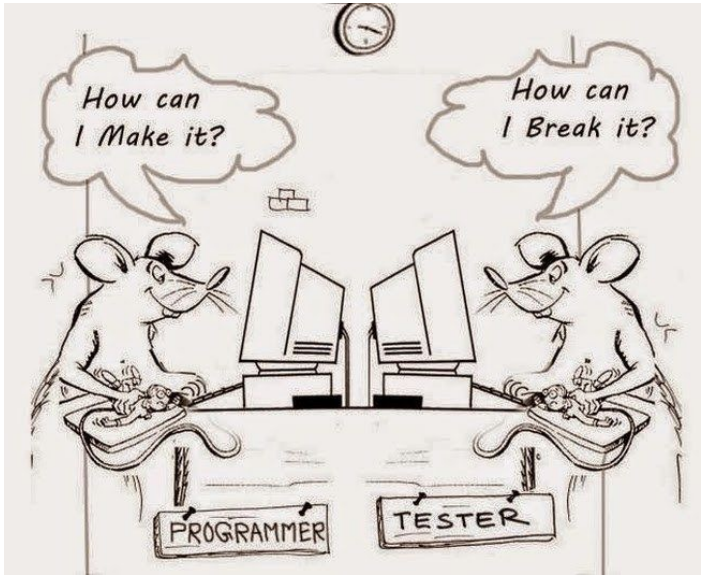
Level 2 explained

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 (a mental discipline) explained

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" who advocate 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."

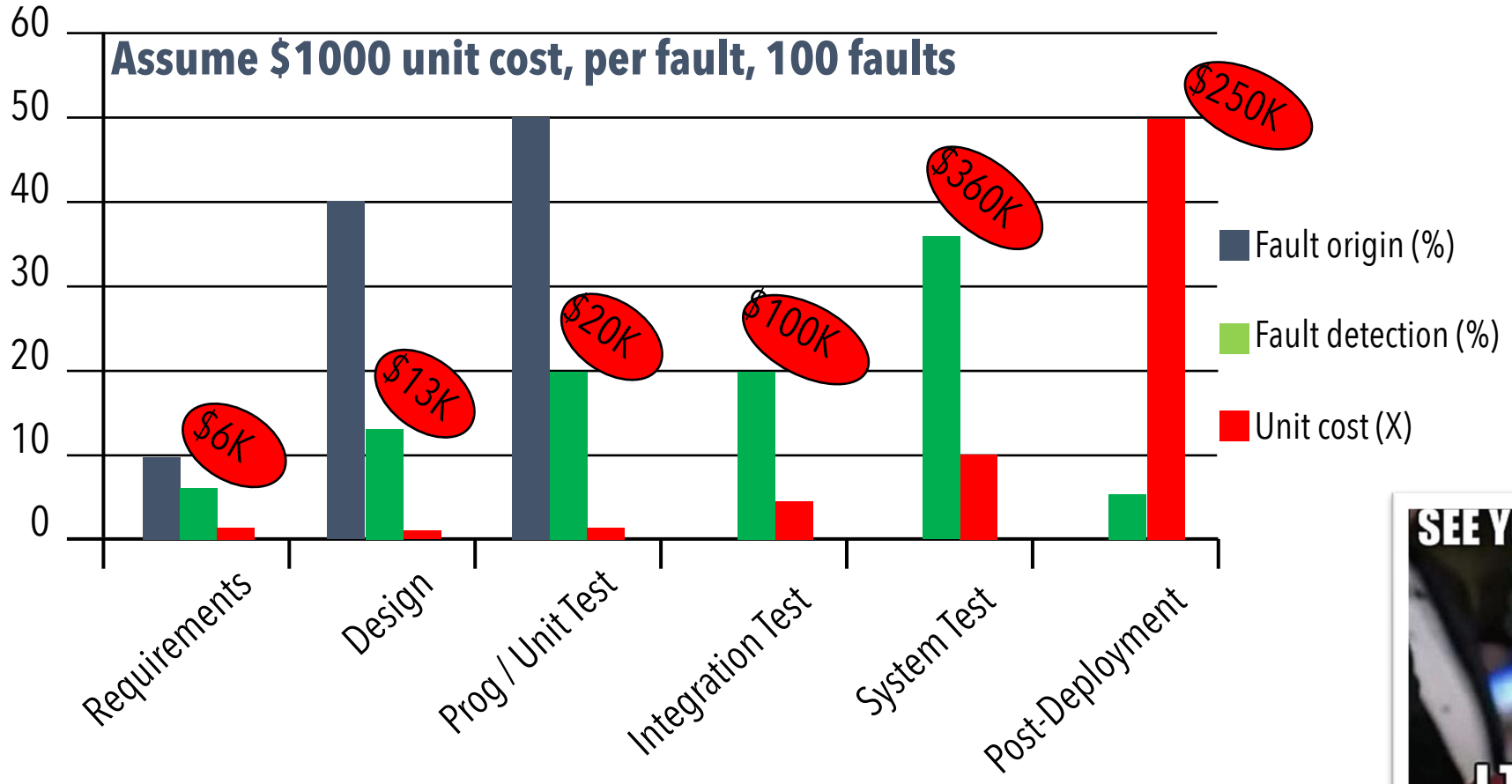
Testing is the **most time consuming** and **expensive** part of software development

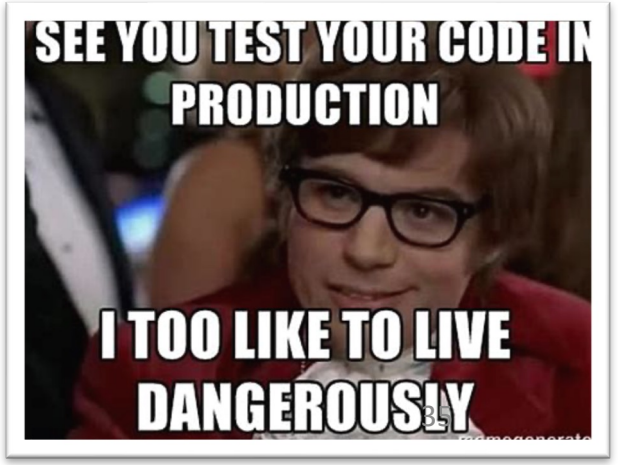
Not testing is even **more expensive**

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** ✓