Intro to Software Testing

Chapter 1

Why do we test software?

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(Dr. B for short)

https://go.gmu.edu/SWE637

Adapted from slides by Jeff Offutt and Bob Kurtz

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

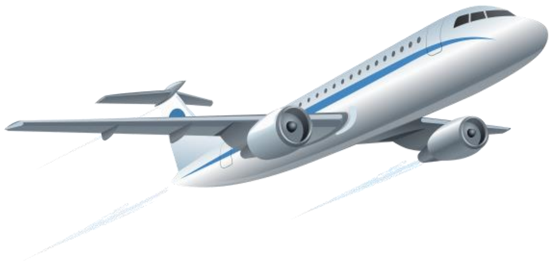
- airplanes
- watches
- cell phones
- spaceships
- our homes
- automobiles

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 the 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** [failure]

The doctor tries to diagnose the root cause or **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

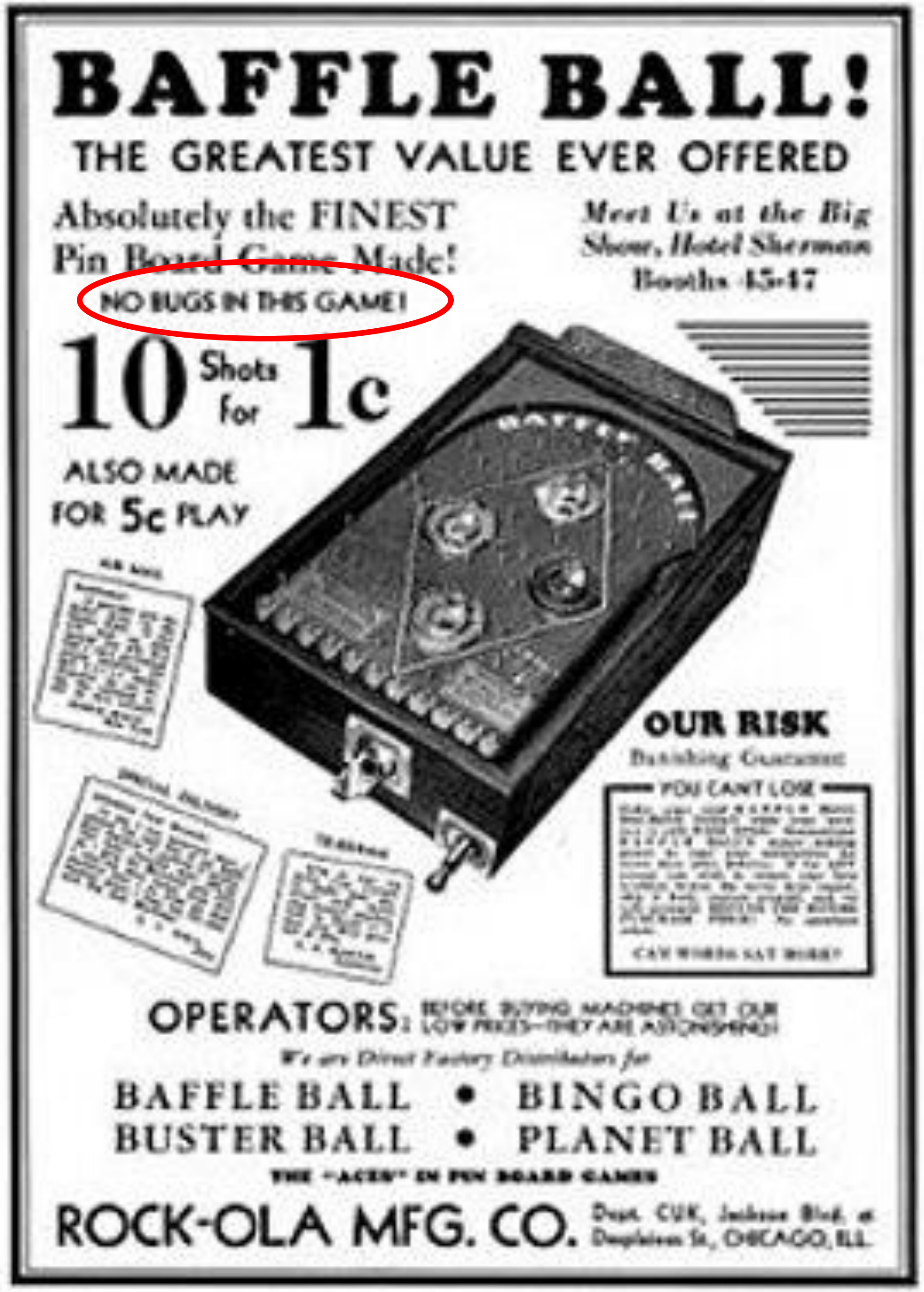
Test 2
[0, 2, 7]
Expected: 1
Actual: 0

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

The term "bug"

*"…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 of Lovelace (notes on Babbage's Analytical Engine), 1843

*"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, 1878



BAFFLE BALL!

THE GREATEST VALUE EVER OFFERED

Absolutely the FINEST
Pin Board Game Made!

NO BUGS IN THIS GAME!

*Meet Us at the Big
Show, Hotel Sherman
Booths 45-47*

10 Shots for 1c

ALSO MADE
FOR 5c PLAY

OUR RISK

Banishing Guarantee

YOU CANT LOSE

[illegible]

CAN WORDS SAY MORE?

OPERATORS: BEFORE BUYING MACHINES GET OUR LOW PRICES—THEY ARE ASTONISHING!

We are Direct Factory Distributors for

BAFFLE BALL • BINGO BALL
BUSTER BALL • PLANET BALL

THE "ACES" IN PIN BOARD GAMES

ROCK-OLA MFG. CO. Dept. CUK, Jackson Blvd. at
Desplaines St., CHICAGO, ILL.

circa 1931

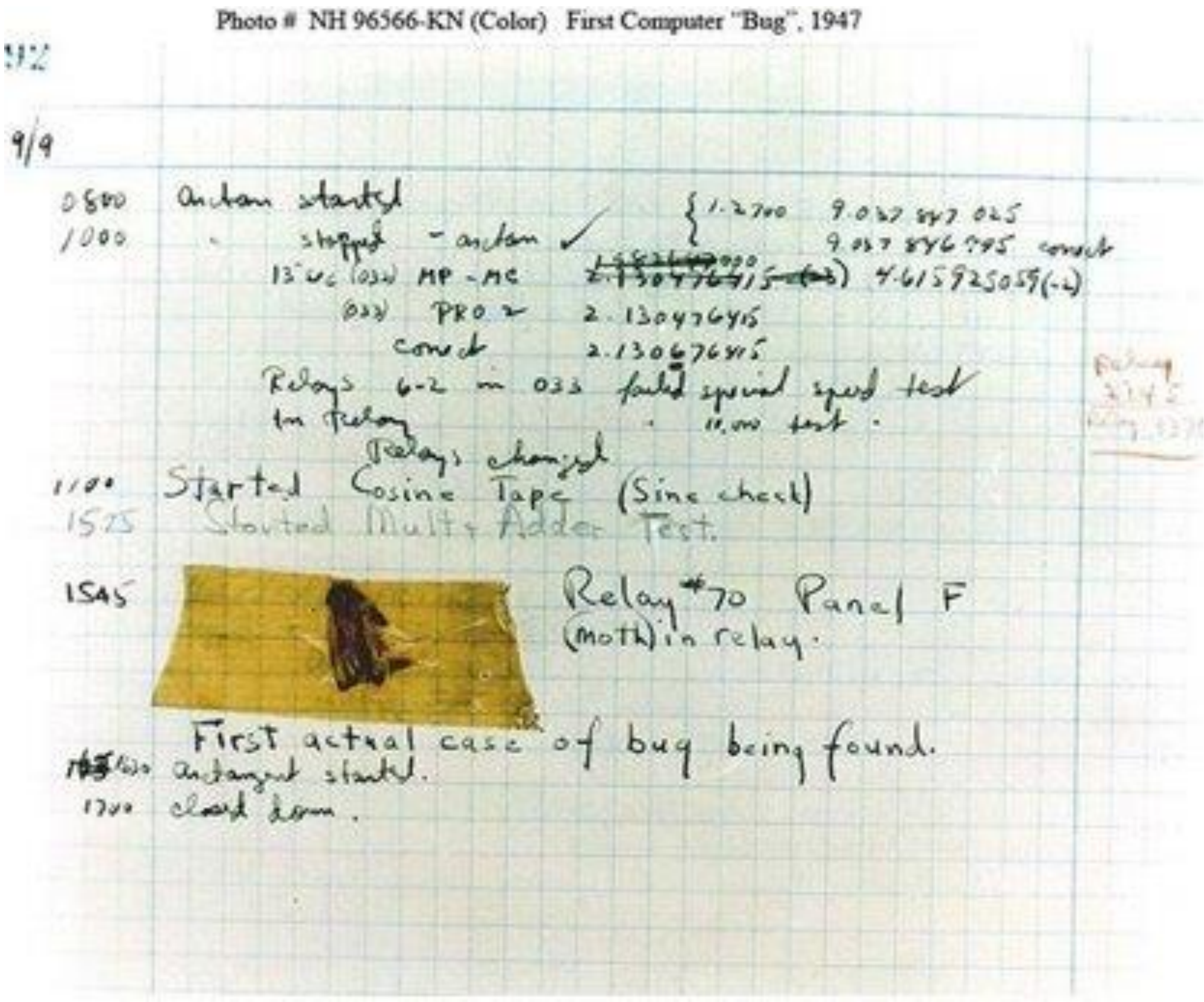


Photo # NH 96566-KN (Color) First Computer "Bug", 1947

9/9

0800 Anctan started

1000 stopped - anctan ✓ {1.2700 9.037 847 025
9.037 846 995 correct

13" UC (032) MP - MC ~~1.982147000~~ ~~2.130476415~~ ~~(-3)~~) 4.615925059(-2)

(033) PRO 2 2.130476415

correct 2.130676415

Relays 6-2 in 033 failed special speed test
In relay . 11,000 test .

Relays changed

1100 Started Cosine Tape (Sine check)

1525 Started Mult + Adder Test.

1545 Relay #70 Panel F
(moth) in relay.

First actual case of bug being found.

1630 antangent started.

1700 closed down.

Relay 2145
Relay 3376

Recovered from the Harvard Mark II electromechanical computer

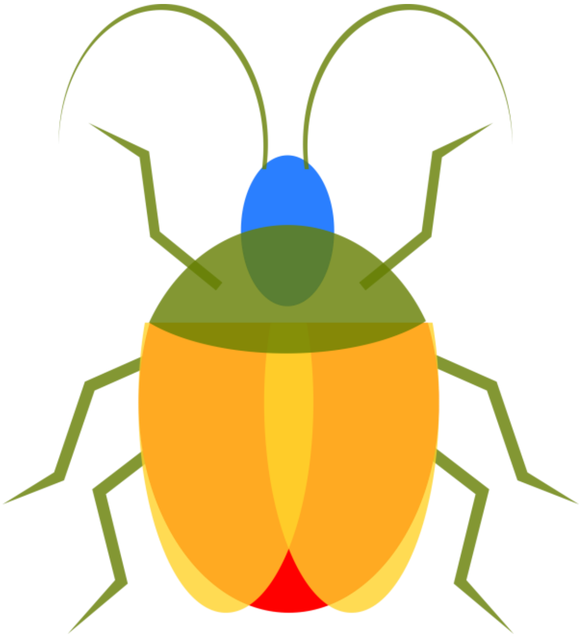
The term "bug"

"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

1985-1987: Therac-25 radiation therapy machine software improperly managed safety lockouts, delivered 100x the planned radiation treatment, 3 patients killed and at least 3 injured

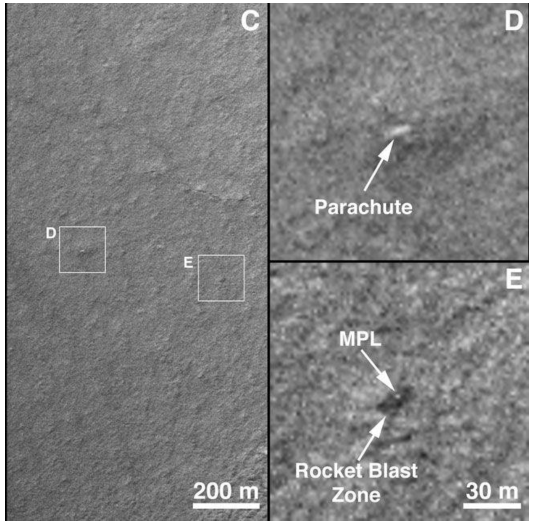
Spectacular Software Failures

1996: Maiden launch of the European Space Agency's Ariane 5 rocket destroyed when the guidance system had a numeric overflow, $370M loss

Spectacular Software Failures

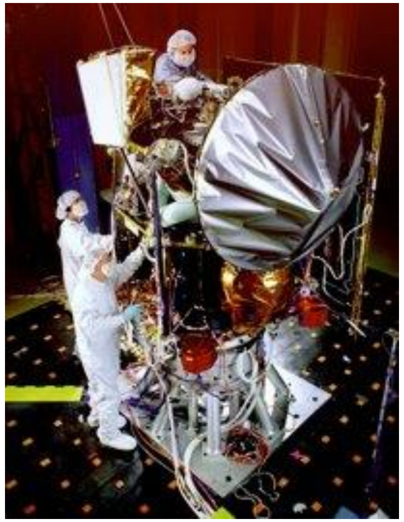
NASA's Mars lander

September 1999; crashed due to unit integration fault



NASA Mars Climate Orbiter

1999; lost due to ground control software error confusing pound-force seconds (lbf-s) with newton-seconds (N-s)



Spectacular Software Failures

2002-2009: Unintended acceleration in Toyota Lexus vehicles linked to **engine controller software defects,** 89 people killed

Spectacular Software Failures

Heathcare.gov website

Crashed repeatedly on launch – never load tested

The page cannot be displa

The page you are looking for is curren
unavailable.
The Web site might be experien
difficulties, or you may need
your browser settings.

Cannot find server

Try again

Intel Pentium FDIV fault

public relations nightmare

Spectacular Software Failures

2018-2019: Two Boeing 737 MAX-8 airliners crash attributed to* **untested input conditions** from a failed angle of attack sensor (along with pilot error and maintenance failures), **346 people killed**

* Based on the final accident report by the Indonesian National Transportation Safety Committee (NTSC) and the preliminary accident report by the Ethiopian Ministry of Transport.

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.

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)**

In Dec 2006, amazon.com's BOGO offer turned into a double discount

Symantec (2007):

most security vulnerabilities are due to faulty software

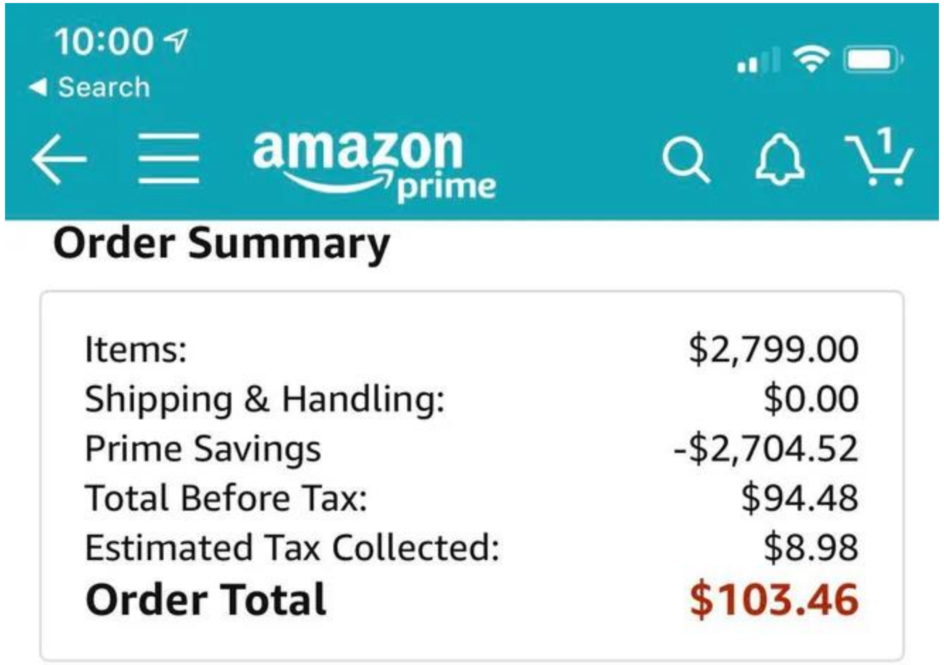
Costly Software Failures

2003: Overloaded electric transmission wires shorted in Cleveland, OH and a **race condition in the monitoring software** prevented alarm generation; cascading failures blacked out 55 million people across eight states in the northeast US and Ontario, Canada; $**6 billion in economic losses**

Costly Software Failures

Dec 2006: Amazon's website offered **BOGO** that turned into a **double discount**

July 2019: Amazon Prime Day glitch gives 99% discount on $3,000 camera



Order Summary

Items:	$2,799.00
Shipping & Handling:	$0.00
Prime Savings	-$2,704.52
Total Before Tax:	$94.48
Estimated Tax Collected:	$8.98
Order Total	**$103.46**

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

Testing in the 21^{st} 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 <u>not</u> distinguish between incorrect behavior and mistakes in the program

Does <u>not</u> 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***

NOT SURE IF QUALITY IS REALLY GOOD
OR TESTING WAS REALLY LOUSY
quickmeme.com

This is what hardware engineers often expect.

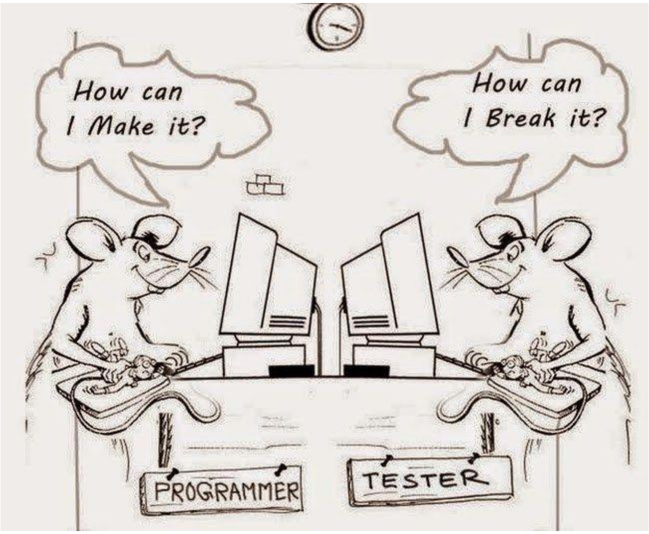
Level 2 explained

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 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"

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."

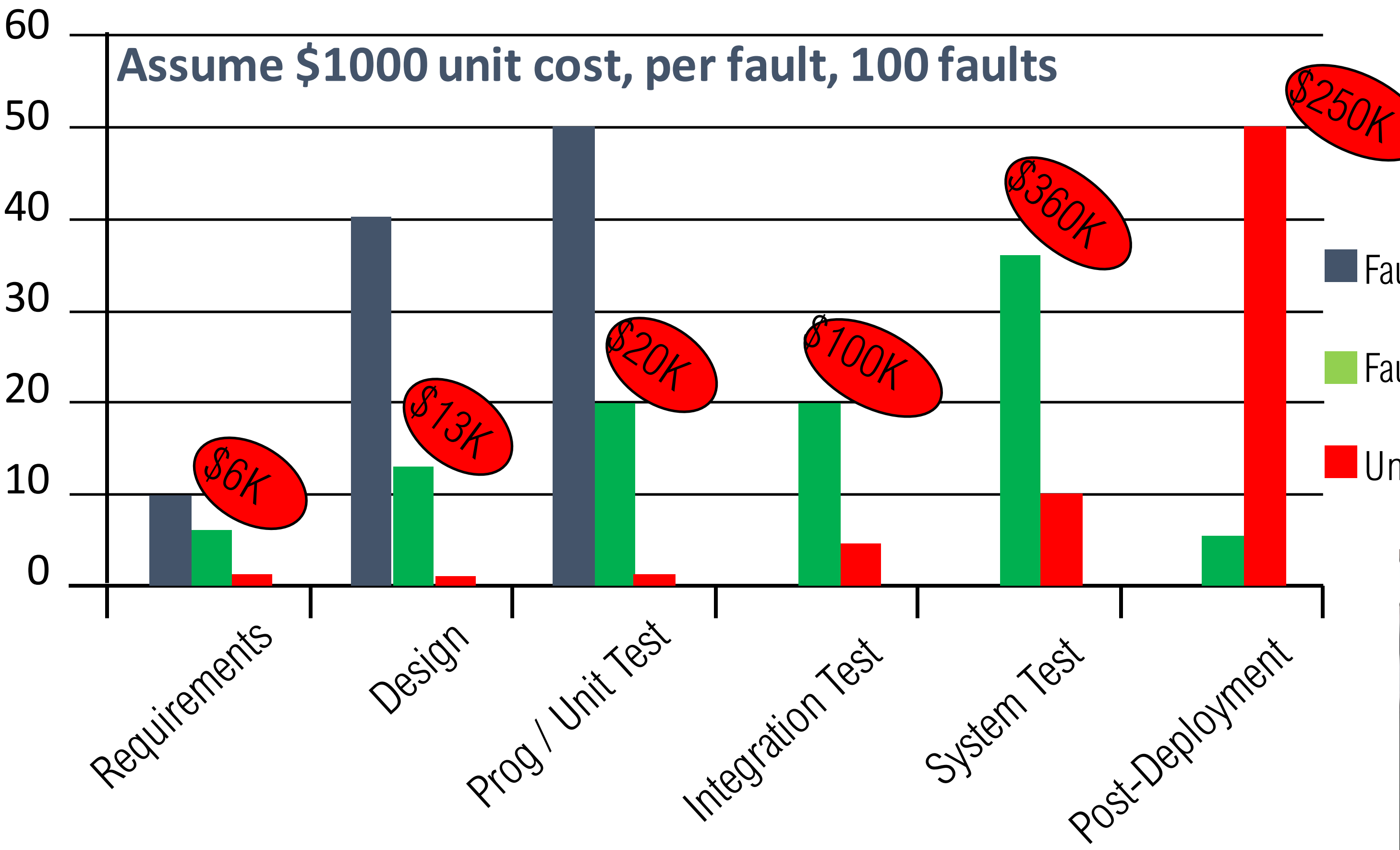
Testing is the **most time consuming** and **expensive** part of software development

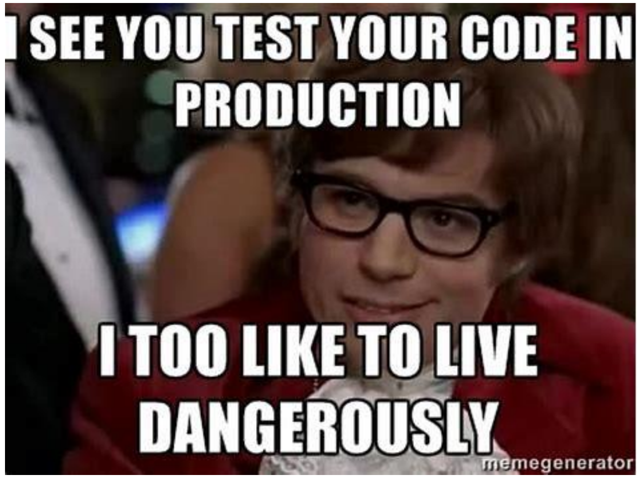
Not testing is even **more expensive**

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

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

Cost of late testing




I SEE YOU TEST YOUR CODE IN PRODUCTION
I TOO LIKE TO LIVE DANGEROUSLY
memegenerator

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 ✓