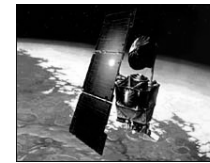


## CMSC737: Fundamentals of Software Testing

- Atif M. Memon ([atif@cs.umd.edu](mailto:atif@cs.umd.edu))
- 4115 A.V. Williams building
- Phone: 301-405-3071
- Office hours
  - Tu.Th. (10:45am-12:00pm)
- Don't wait, don't hesitate, do communicate!!
  - Phone
  - E-mail
  - Office hours
- Course page under
  - <http://www.cs.umd.edu/~atif/teaching.html>

## 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



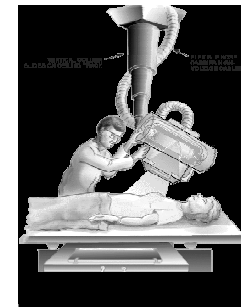
## Shooting Down of Airbus 320

- 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)



## London Ambulance Service

- London Ambulance Service Computer Aided Dispatch (LASCAD)
- Purpose: automate many of the human-intensive processes of manual dispatch systems associated with ambulance services in the UK
  - functions: Call taking
- Failure of the London Ambulance Service on 26 and 27 November 1992

## "Nice of You to Turn Up"

- Load increased
- Emergencies accumulated
- System made incorrect allocations
  - more than one ambulance being sent to the same incident
  - the closest vehicle was not chosen for the emergency
- At 23:00 on October 28 the LAS eventually instigated a backup procedure, after the death of at least 20 patients

## More...

- "Software and its Impact: A Quantitative Assessment," by B.W. Boehm, *Datamation*, 19(5), 48-59 (1973)
  - Errors in medical software have caused deaths

## More...

- "The development of software for ballistic-missile defense," by H. Lin, *Scientific American*, vol. 253, no. 6 (Dec. 1985), p. 48
  - British destroyer H.M.S. Sheffield; sunk in the Falkland Islands war; ship's radar warning system software allowed missile to reach its target
  - An Air New Zealand airliner crashed into an Antarctic mountain
  - North American Aerospace Defense Command reported that the U.S. was under missile attack; traced to faulty computer software - generated incorrect signals
  - Manned space capsule Gemini V missed its landing point by 100 miles; software ignored the motion of the earth around the sun

## More...

- "Software Engineering: Report on a Conference Sponsored by the NATO Science Committee, Brussels, NATO Scientific Affairs Division," 1968, p. 121
  - An error in an aircraft design program contributed to several serious air crashes
- "Ghost in the Machine," Time Magazine, Jan. 29, 1990. p. 58
  - Dallas/Fort Worth air-traffic system began spitting out gibberish in the Fall of 1989 and controllers had to track planes on paper

## More...

- Software Reliability: Principles & Practice, p. 25, by G. J. Myers
  - Apollo 8 spacecraft erased part of the computer's memory
  - Eighteen errors were detected during the 10-day flight of Apollo 14
  - An error in a single FORTRAN statement resulted in the loss of the first American probe to Venus

## More...

- An Airbus A320 crashes at an air show
- A China Airlines Airbus Industries A300 crashes on April 26, 1994 killing 264
- Ariane 5 satellite launcher malfunction was caused by a faulty software exception routine resulting from a bad 64-bit floating point to 16-bit integer conversion

## More...

- ACM SIGSOFT Software Engineering Notes, vol. 6, no. 2
  - F-18 fighter plane crashed due to a missing exception condition
- ACM SIGSOFT Software Engineering Notes, vol. 9, no. 5
  - F-14 fighter plane was lost to uncontrollable spin, traced to tactical software

## More...

- Internet Risks Forum Newsgroup (RISKS), vol. 19, issue 56
  - CyberSitter censors "menu \*/ #define" because of the string "nu...de"
- London's Docklands Light Railway - train stopped in the middle of nowhere due to future station location programmed in software
- ACM SIGSOFT Software Engineering Notes, vol. 12, no. 3
  - Chicago cat owners were billed \$5 for unlicensed dachshunds. A database search on "DHC" (for dachshunds) found "domestic house cats" with shots but no license



## More...

- and many many more ....



**CNN.com.**

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### Russia: Software bug made Soyuz stray

STAR CITY, Russia (AP) --A computer software error likely sent a Russian spacecraft into a rare ballistic descent that subjected the three men on board to chest-crushing gravity loads that made it hard to breathe, space experts said Tuesday.

"For me, for a moment, it felt like I was Atlas and I had the weight of the whole world on my shoulders," astronaut Donald Pettit, still a little woozy, told reporters at a crowded news conference.

**CNN.com.**

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### Spread of buggy software raises new questions

NEW YORK (AP) --When his dishwasher acts up and won't stop beeping, Jeff Seigle turns it off and then on, just as he does when his computer crashes. Same with the exercise machines at his gym and his CD player.

"Now I think of resetting appliances, not just computers," says Seigle, a software developer in Vienna, Virginia.

Malfunctions caused by bizarre and frustrating glitches are becoming harder and harder to escape now that software controls everything from stoves to cell phones, trains, cars and power plants.

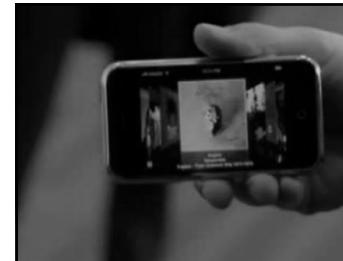
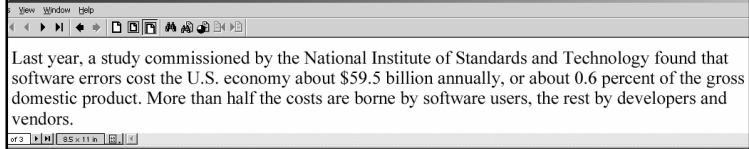
--A poorly programmed ground-based altitude warning system was partly responsible for the 1997 Korean Air crash in Guam that killed 228 people.

--Faulty software in anti-lock brakes forced the recall of 39,000 trucks and tractors and 6,000 school buses in 2000.

--The \$165 million Mars Polar Lander probe was destroyed in its final descent to the planet in 1999, probably because its software shut the engines off 100 feet above the surface.

## Economic Impact

- NIST study  
- On CNN.com - April 27, 2003



Open up albums.  
Browse through the albums in horizontal mode.



Select an album



Play song from the  
selected album



Browse again  
through the albums

Get back to vertical mode.



Now see the browser get back  
to the song that was played in  
vertical mode not the current screen  
that the user were browsing

## Expectation

- Can't we expect software to execute correctly?
- Carefully made programs
  - 5 faults/1000 LOC
  - 1M LOC will have 5000 faults
- Windows XP has 45M LOC
  - How many faults?
  - $45 \times 5000 = 225,000$
- Why not remove the faults?

```
*** STOP: 0x0000000A (0x00000000,0x00000002,0x00000000,8038c240)
IRQL_NOT_LESS_OR_EQUAL*** Address 8038c240 has base at 8038c000 - Ntfs.SYS

CPUID:Genuine Intel 6.3.3 irql:if SYSWER 0xf0000566
```

```
Dll Base DateStamp - Name Dll Base DateStamp - Name
80100000 336546bf - ntoskrnl.exe 80010000 33247f88 - hal.dll
80000100 334d3a53 - atapi.sys 80007000 33248043 - SCSIPORT.SYS
802aa000 33013a6b - epst.mpd 802b5000 336015a2 - Disk.sys
802b9000 336015af - CLASS2.SYS 8038c000 33564637 - Ntfs.sys
802bd000 33d844be - Siwvid.sys 803e4000 33d84553 - NTIsc.sys
f9318000 31ec6c9d - Floppy.SYS f95c9000 31ec6c99 - Null.SYS
f9468000 31e4868b - KSecDD.SYS f95ca000 335e60cf - Beep.SYS
f9358000 335bc82a - i8042prt.sys f9474000 3324806f - mouclass.sys
f947c000 31ec6c94 - kbdclass.sys f95cb000 3373c39d - ctrl2cap.SYS
f9370000 33248011 - WIDBPORT.SYS fe9d7000 3370e7b9 - ati.sys
f9490000 31ec6c6d - vga.sys f93b0000 332480dd - Msfs.SYS
f90f0000 332480d0 - Npfs.SYS fe957000 3356da41 - NDIS.SYS
a0000000 335157ac - win32k.sys fe914000 334ea144 - aci.dll
fe0c9000 335bd30a - Fastfat.SYS fe110000 31ec7c9b - Parport.SYS
fe108000 31ec6c9b - Parallel.SYS f95b4000 31ec6c9d - ParVdm.SYS
f9050000 332480ab - Serial.SYS
```

```
Address dword dump Build [1314] - Name
801afc24 80149905 80149905 ff8e6b8c 80129c2c ff8e6b94 8025c000 - Ntfs.SYS
801afc2c 80129c2c 80129c2c ff8e6b94 00000000 ff8e6b94 80100000 - ntoskrnl.exe
801afc34 801240f2 80124f02 ff8e6df4 ff8e6f60 ff8e6c58 80100000 - ntoskrnl.exe
801afc54 80124f16 80124f16 ff8e6f60 ff8e6c3c 8015ac7e 80100000 - ntoskrnl.exe
801afc64 8015ac7e 8015ac7e ff8e6df4 ff8e6f60 ff8e6c58 80100000 - ntoskrnl.exe
801afc70 80129bda 80129bda 00000000 80088000 80106f00 80100000 - ntoskrnl.exe
```

```
Restart and set the recovery options in the system control panel
or the /CRASHDEBUG system start option. If this message reappears,
contact your system administrator or technical support group.
```

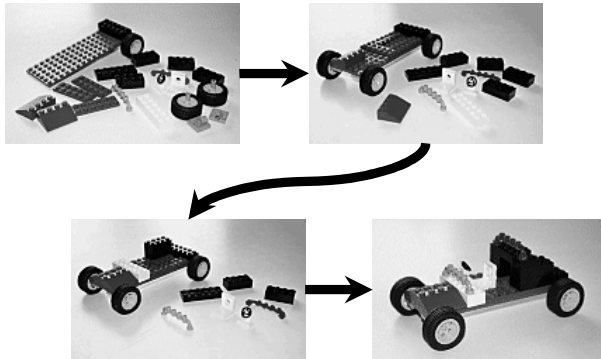
## Joke?

- "If the automobile industry had developed like the software industry, we would all be driving \$25 cars that get 1,000 miles to the gallon."
- "Yeah, and if cars were like software, they would crash twice a day for no reason, and when you called for service, they'd tell you to reinstall the engine."

## How Cars Are Engineered (A Simple View)

- User requirements
  - Engine power, all-wheel, seating, comfort, MP3 player!!
- Detailed design
  - Blueprints, design documents
- Verify design
  - Simulation, prototyping
- Develop parts (components)
  - Test each component
  - Components may be reused
  - Mass produced
- Assemble the car
  - Test the car (Front/side crash tests, Stability tests)
  - Usability testing (Feedback from drivers/passengers)

## How Cars Are REALLY Engineered (A Detailed View)

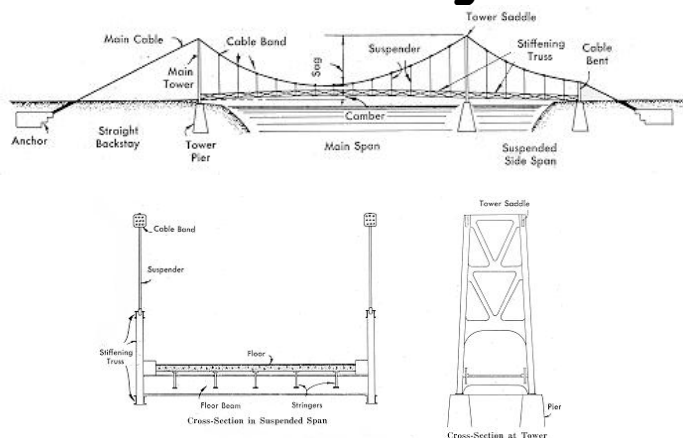


## But Seriously



- Features of many LEGO parts
  - Modularity
  - Reusability
    - Each part can be used in different places and ways
  - Flexibility of design
  - Compatibility
    - With other LEGO sets
- Building-blocks

## Similar Techniques Used by Builders: Bridges



## Detailed Design and Specifications

Galvanized Bridge Wire for Parallel Wire Bridge Cables. Recommended diameter .196 inch.



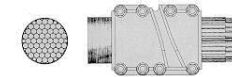
Galvanized Bridge Strand--consists of several bridge wires, of various diameters twisted together.



Galvanized Bridge Rope--consists of six strands twisted around a strand core.

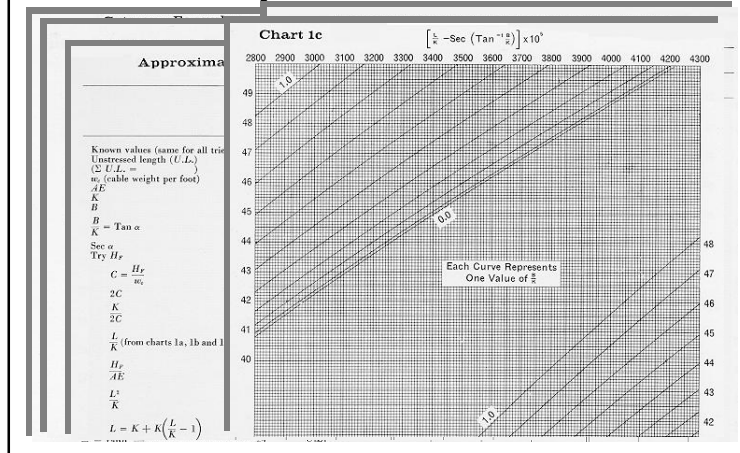


Parallel Wire Cable

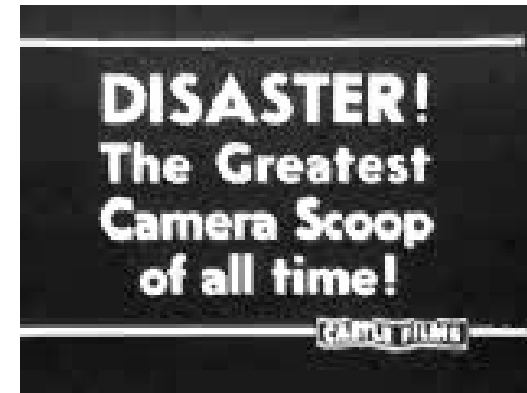


Detail of Main Cable and Cable Band. The wrapping wire is omitted at the right for clarity. Note the closed construction and aluminum fillers.

## More Detailed Design and Specifications



## Tacoma Narrows Bridge Disaster



## They Make Mistakes Too!

- Even good design cannot guarantee a perfect product
- Need testing of all products including software

## Interests

- Testing
- Apply it to different types of software (such as web)
- Student introductions and their interests!



## Goals of the Course

- Discuss software testing techniques
- Two parts of the course
  - Review testing fundamentals
  - State-of-the-art & emerging techniques
- What do I expect from students?

## MS and Ph.D. Qualifying

- Is the course is valid for PhD qualifying coursework?
  - Yes (Software Engineering/Programming Languages)
- Is the course is valid for MS qualifying coursework?
  - Yes (Software Engineering/Programming Languages)
- Is the course is valid for MS comps?
  - Yes (Both Midterm and Final exams count towards the MS comps.)

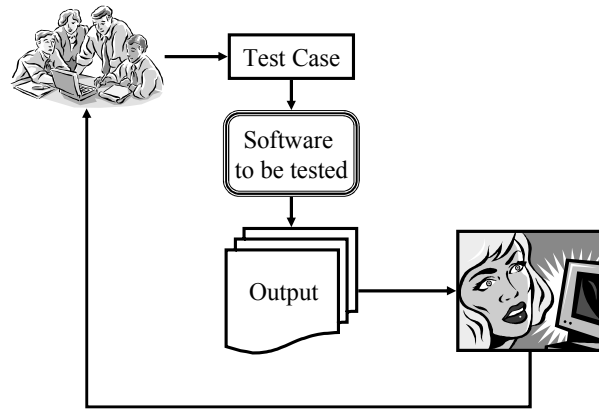
## Assessment

- 25% Mid-term Exam
- 25% Final Exam
- 50% Project
  - Project report
  - Project Presentation

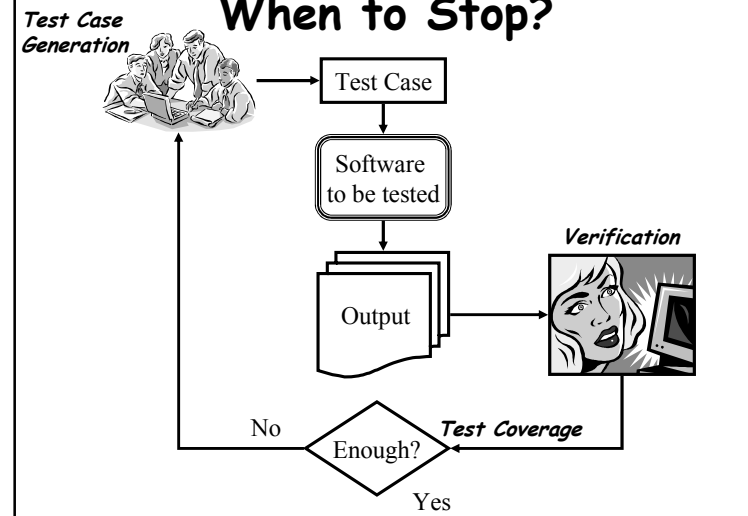
## Exam Contents

- Midterm
  - Everything discussed in class
- Final exam
  - Everything discussed/presented after midterm

## Testing: Our Experiences

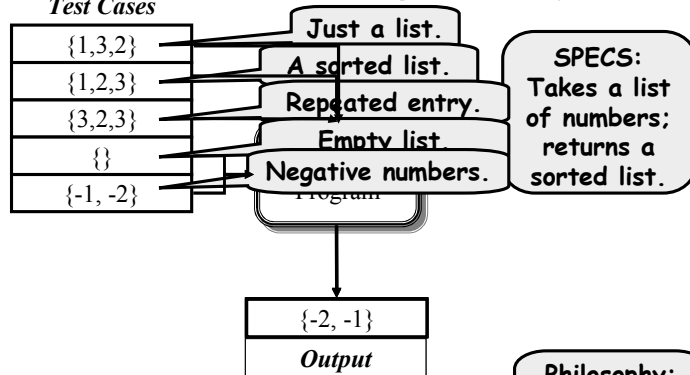


## When to Stop?



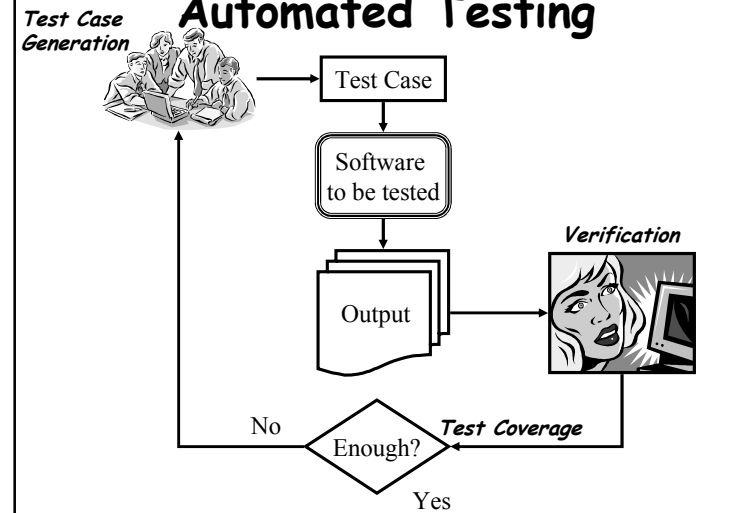
## A Real Testing Example

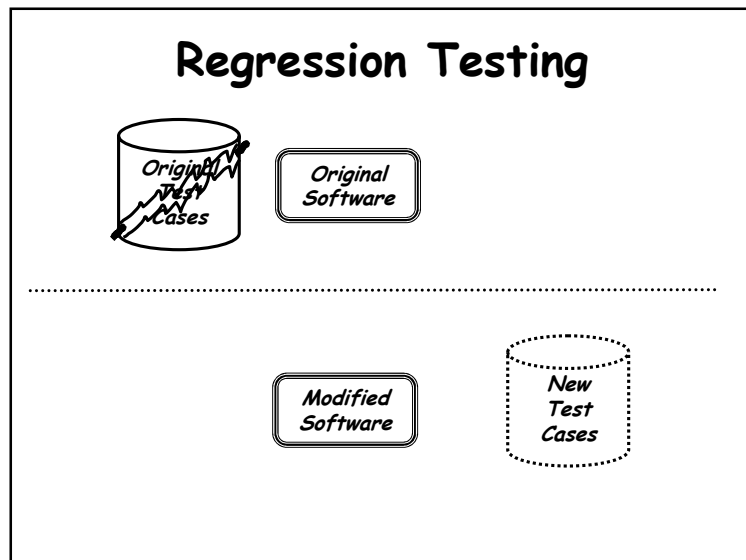
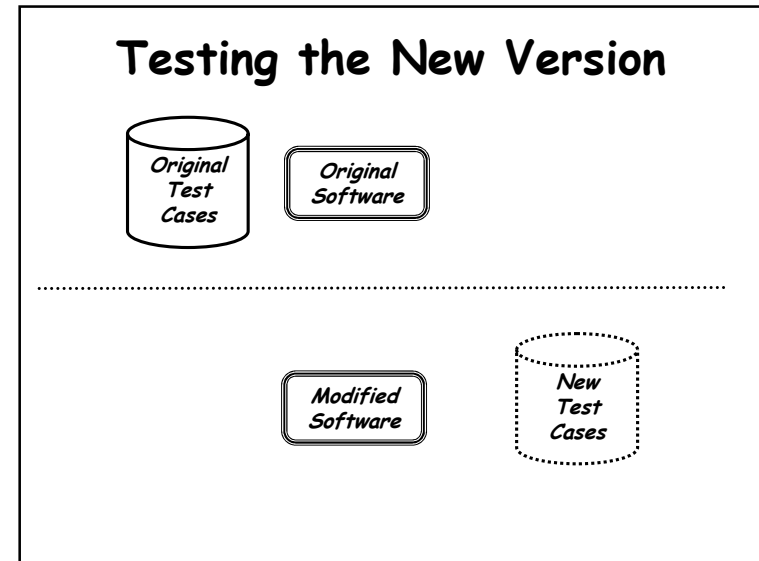
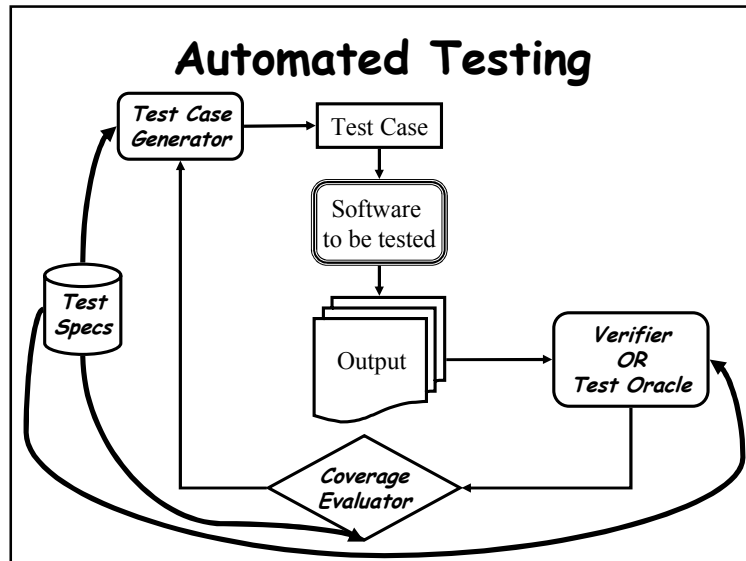
*Test Cases*



**Philosophy:** What are we trying to do?

## Automated Testing





- ### Discussion
- Different Software Types
    - Object-oriented
    - Component-based
    - Concurrent
    - Distributed
    - Graphical-user Interfaces
    - Web
  - Different goals of testing
    - Usability
    - Security
    - Correctness
    - Performance ...