CS 5430

Assurance

Prof. Clarkson
Spring 2017

Review

- **Aspects of security:** confidentiality, integrity, availability
- **Concepts:** Harm, threat, vulnerability, attack, countermeasure
- **Principles:** Accountability, least privilege, defense in depth, open design, ...
- **Goals and Requirements:** What system should not and should do for security

Today: assurance and evaluation

Assurance

- How do you convince yourself that system is secure?
- How do you convince others??
- Assurance is evidence that system will not fail in particular ways
  - Development process (e.g. formal methods, deliberate fault injection and discovery)
  - Skill of developers
  - Experience with deployed system
- Evaluation is process of establishing assurance
  - developers
  - QA teams
  - third party labs

Economics is against us

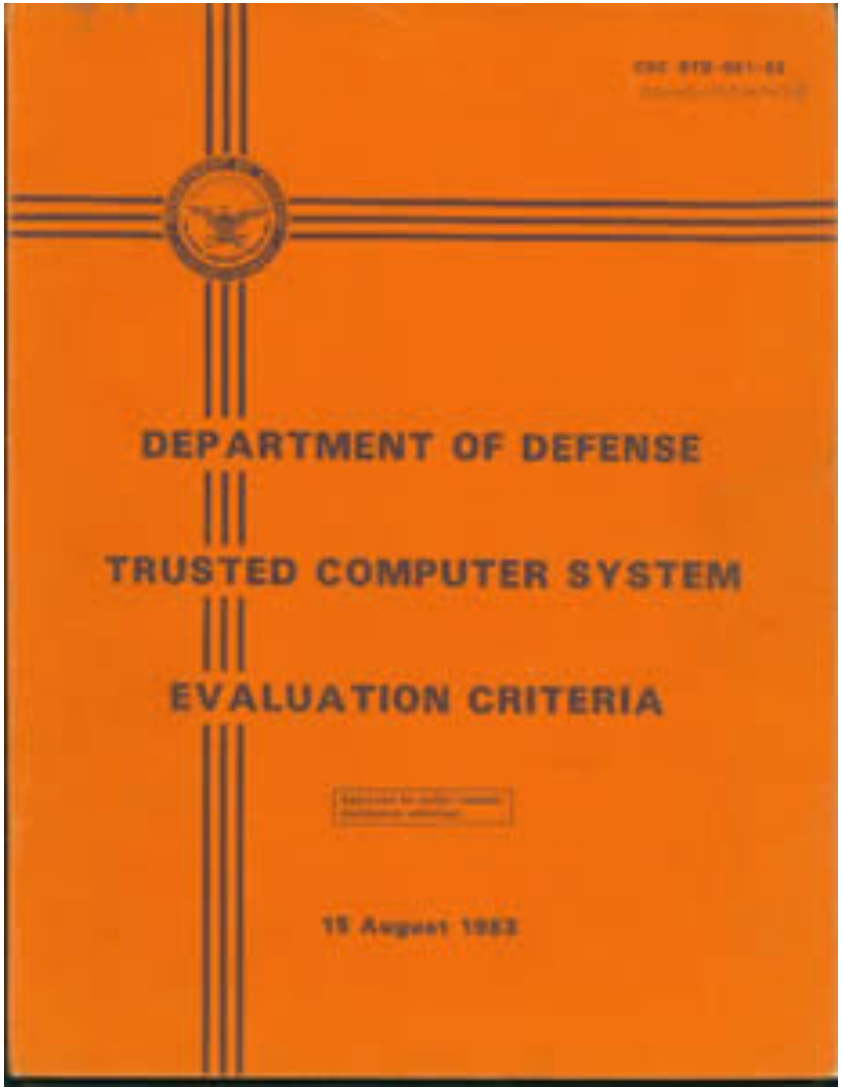
- Companies race to ship innovative product sooner than competitors
  - Little security
  - Wrong security
- Later security is “bolted on” as additional features
  - But incentive is to lock in customers
  - Product is already deployed; too late for major design changes that might be necessary

Build security in

- Integrate security functionality from the beginning of development
  - During requirements engineering
  - During system design
  - During testing
- Accumulate evidence of security as development proceeds
  - Documentation
  - Analysis: by humans, by machines
  - Test suites

EVALUATION

Orange Book evaluation



Orange Book evaluation

- Used approx. 1985-2000 for US government systems
- http://csrc.nist.gov/publications/history/dod85.pdf
- Evaluation classes (selected traits):
  - **D:** meets no higher requirements
  - **C1:** DAC & authentication (but maybe not at the level of individual users), TCB with integrity verification, security testing, documentation of security features/testing/design
  - **C2:** improved DAC (at the level of single users, failsafe defaults, limits on propagation), audit (of specified security relevant events and details of those events)
    - IBM mainframes and Windows NT got this certification

Orange Book evaluation

- Evaluation classes, continued:
  - **B1:** informal security policies, mandatory access control (multilevel security)
  - **B2:** formal security policies, clearly defined TCB, covert channel analysis
  - **B3:** minimal TCB with complete mediation, automated intrusion detection
  - **A1:** formal verification of design
    - only a handful of systems ever achieved this level

Legacy of Orange Book

- Evaluation didn't succeed in commercial market
  - Too costly; costs diverted to government and customers
  - Too long to get evaluated (>1 year) compared to short product cycles
- Raised awareness of security for vendors and government
  - Major operating systems did incorporate discretionary access control; would that have happened without evaluation?
  - But few systems ever incorporated the multilevel security the US DoD wanted
- Unpopular security features mandated by higher levels
  - Research still ongoing on how to make such features usable
- Led to international standards for evaluation...

Common Criteria (CC)

- Evolved in the 1990s out of criteria in Europe, Canada, and US
- Different evaluation model:
  - Define *protection profile* and *security target*
    - think of these as customized security goals/requirements
    - e.g., for OS, for smartphone, for VPN client
    - not one-size-fits-all like Orange Book
  - Increasingly strict evaluation criteria for how well system meets profile/target
- Evaluation done by independent labs

Protection profile (PP)

- Written for a category of products or systems that meet specific consumer needs
- Implementation independent
- Security environment:
  - assumptions about intended usage
  - threats of concern
- Security goals and requirements [using our terminology]
  - Hundreds of pages of pre-written proto-requirements: http://www.commoncriteriaportal.org/files/ccfiles/CCPART2V3.1R2.pdf
- PP itself can be evaluated (complete, consistent, technically sound)

Security target (ST)

- Can be based on multiple protection profiles, or created from scratch
- Customized to a specific Target of Evaluation (TOE), i.e., product or system
- Argues (provides evidence) how the system meets the security goals and requirements
  - Assurance argument

Evaluation Assurance Level (EAL)

- **EAL1:** Functionally Tested
  - Analysis of specifications, documentation; independent testing
  - Some confidence desired but threat is not serious
- **EAL2:** Structurally Tested
  - Analysis also of high-level design, of developer's testing; vulnerability analysis
  - Low level of assurance, perhaps for legacy systems
- **EAL3:** Methodically Tested and Checked
  - Also requires use of development environment controls and configuration management

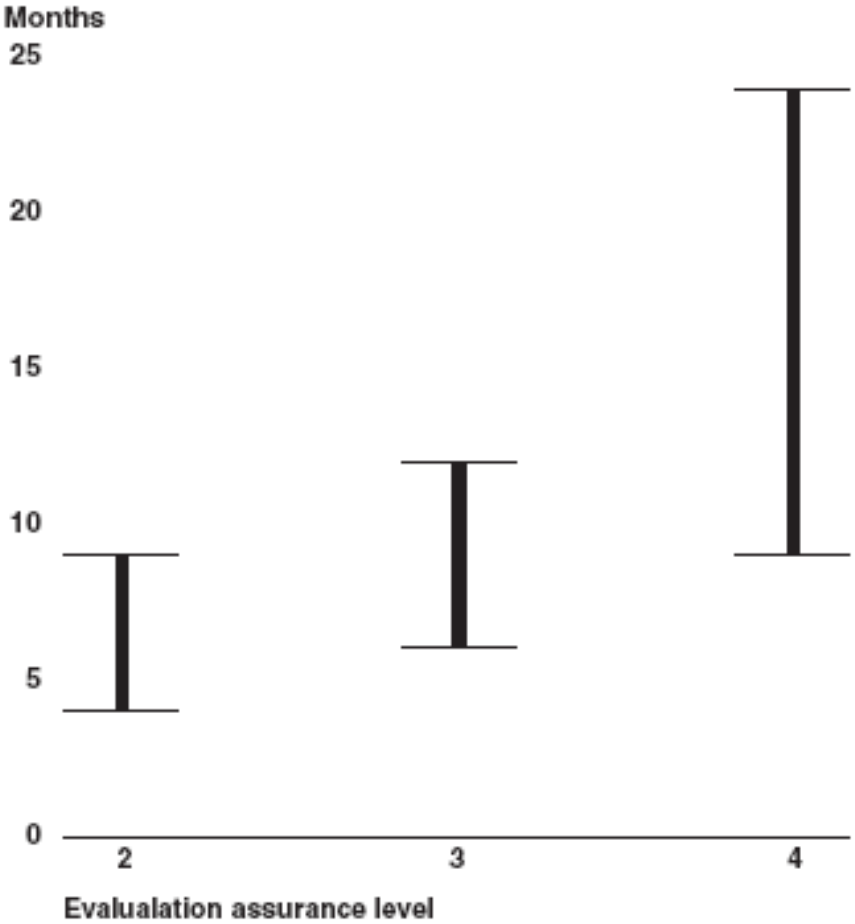
Evaluation Assurance Level (EAL)

- **EAL4:** Methodically Designed, Tested, and Reviewed
  - Also analyze low-level design, some of the implementation; developers must provide informal model of product or security policy
  - Moderate level of assurance, probably highest likely to achieve for pre-existing systems
  - Common level for commercial OS
- **EAL5 through EAL 7**
  - Increasing demands for formal verification, penetration testing, independent testing
- Higher EAL does not mean more secure—rather, means assurance in claimed security is based on stronger evidence

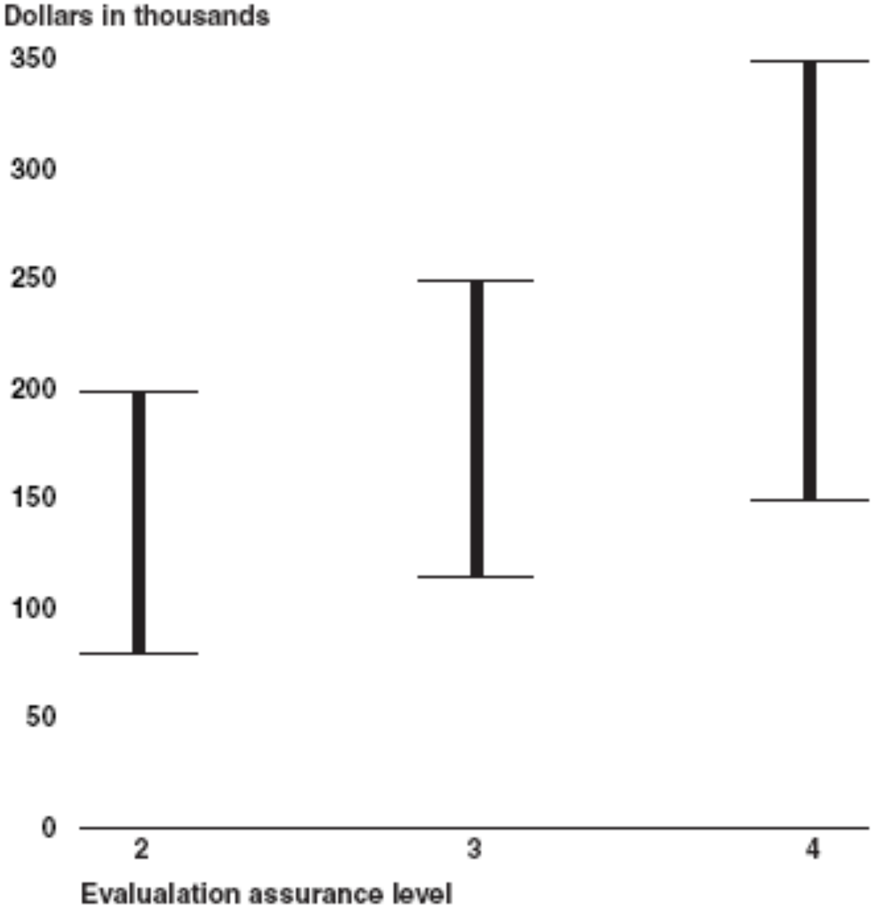
Legacy of Common Criteria

- “When presented with a security product, you must always consider whether the salesman is lying or mistaken.” – Ross Anderson
- Is the PP really what you want?
- Is the evaluation facility trustworthy?
  - Paid by developer
  - Controlled by governments
- What vulnerabilities have been discovered after evaluation?

Evaluation Assurance Level (EAL)



Source: GAO analysis of data provided by laboratories.



Source: GAO analysis of data provided by laboratories.

Source: US government report GAO-06-392, 2006

VERIFICATION AND TESTING

Approaches to reliability

- Social
  - Code reviews
  - Extreme/Pair programming
- Methodological
  - Design patterns
  - Test-driven development
  - Version control
  - Bug tracking
- Technological
  - Static analysis
    ("lint" tools, FindBugs, …)
  - Fuzzers
- Mathematical
  - Sound type systems
  - Formal verification

Less formal: Techniques may miss problems in programs

All of these methods should be used!

Even the most formal can still have holes:

- did you prove the right thing?
- do your assumptions match reality?

More formal: eliminate *with certainty* as many problems as possible.

Testing vs. Verification

Testing:

- Cost effective
- Guarantee that program is correct on tested inputs and in tested environments

Verification:

- Expensive
- Guarantee that program is correct on all inputs and in all environments

Edsger W. Dijkstra

(1930-2002)

Turing Award Winner (1972)

For eloquent insistence and practical demonstration that programs should be composed correctly, not just debugged into correctness

"Program testing can at best show the presence of errors but never their absence."

Verification

Formal verification: prove system correct w.r.t. mathematical models

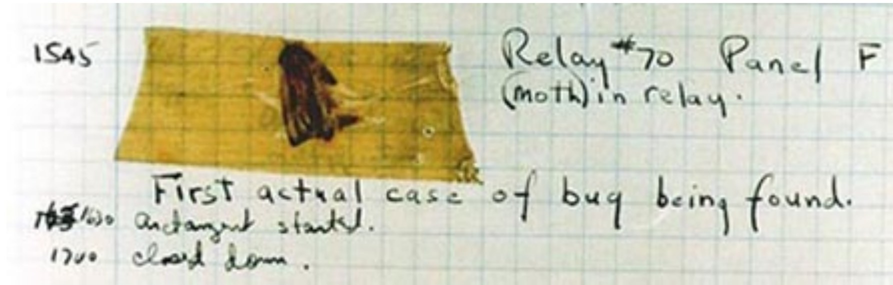
- Typically done for small and/or safety-critical systems
- In the 1970s, scaled to about tens of LOC
- Now, research projects scale to real software:
  - CompCert: verified C compiler
  - seL4: verified microkernel OS
  - Ynot: verified DBMS, web services

Verification

Lightweight kinds of verification:

- Type systems
  - Guarantee certain misbehaviors won't occur
  - Good tradeoff of usability vs. guarantees
- Researchers continue working to find other sweet spots
- For lightweight security verification?
  - FindBugs: project from UMD, used by Google, Oracle, Wells Fargo, Bank of America, etc.
  - Eclipse plugin and standalone tool
  - A subset of Fortify SCA tool
  - What does it do...?

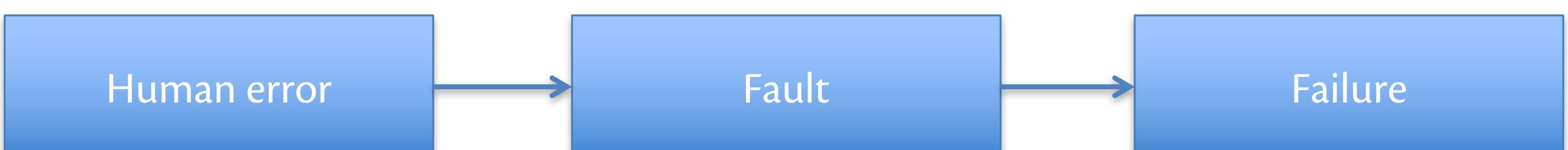
Bugs



"bug": suggests something just wandered in

[IEEE 729]

- Fault: result of human error in software system
  - E.g., implementation doesn't match design, or design doesn't match requirements
  - Might never appear to end user
- Failure: violation of requirement
  - Something goes wrong for end user



FindBugs

- Looks for *patterns* in code that are likely faults and that are likely to cause failures
- Categorizes and prioritizes bugs for presentation to developer
  - Sample output on JDK 7 source
- Watch video of Prof. Bill Pugh, developer of FindBugs, present it to a Google audience:

  https://www.youtube.com/watch?v=8eZ8YWVl-2s

Testing

- Goal is to expose existence of faults, so that they can be fixed
- **Unit testing:** isolated components
- **Integration testing:** combined components
- **System testing:** functionality, performance, acceptance

Testing

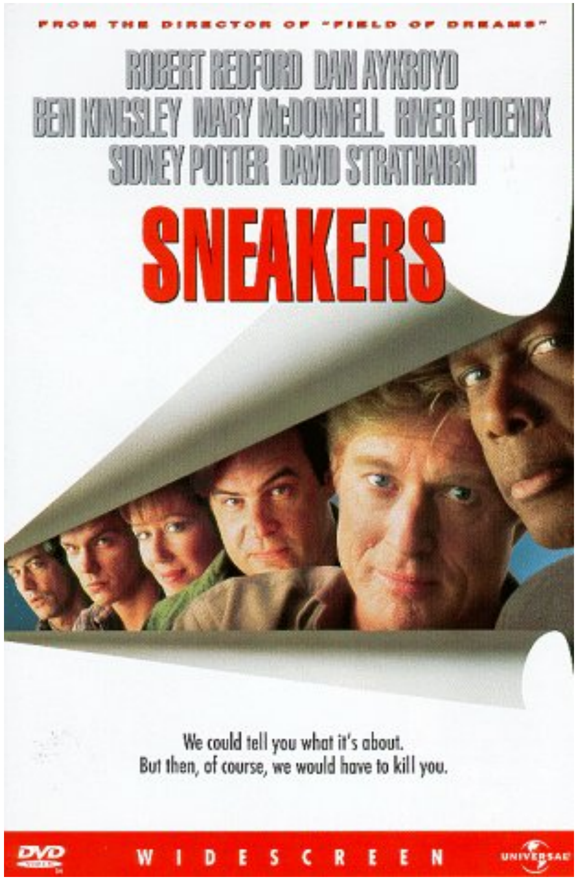
When do you stop testing?

- **Bad answer:** when time is up
- **Bad answer:** what all tests pass
- **Fun fact:** Pr[undetected faults] increases with # detected faults [Myers 1979, 2004]
- **Better answer:** when methodology is complete (code coverage, paths, boundary cases, etc.)
- **Future answer:** statistical estimation says Pr[undetected faults] is low enough (active research)

Testing for security?

Penetration testing

- Experts attempt to attack
  - Internal vs. external
  - Overt vs. covert
- Typical vulnerabilities exploited:
  - Passwords (cracking)
  - Buffer overflows
  - Bad input validation
  - Race conditions / TOCTOU
  - Filesystem misconfiguration
  - Kernel flaws



Fuzz testing

[Barton Miller, 1989, 2000, 2006]

- *"It was a dark and stormy night..."*
- Generate random inputs and feed them to programs:
  - Crash? hang? terminate normally?
  - Of ~90 utilities in '89, crashed about 25-33% in various Unixes
  - Crash implies buffer overflow potential
- Since then, "fuzzing" has become a standard practice for security testing
- Results have been repeated for X-windows system, Windows NT, Mac OS X
  - Results keep getting **worse** in GUIs but better on command line

Fuzz testing

Testing strategy:

- Purely random no longer so good, just gets low-hanging fruit
- Better:
  - Use grammar to generate inputs
  - Or randomly mutate good inputs in small ways
    - especially for testing of network protocols
  - Research: use analysis of source code to guide mutation of inputs

Upcoming events

- [today] Add deadline
- [next Wed] A1 due

One unerring mark of the love of truth is not entertaining any proposition with greater assurance than the proofs it is built upon will warrant.
– John Locke