Outline
Saltzer & Schroeder's principles
Announcements intermission
More secure design principles
Software engineering for security
Secure use of the OS

Economy of mechanism
- Security mechanisms should be as simple as possible
- Good for all software, but security software needs special scrutiny

Fail-safe defaults
- When in doubt, don’t give permission
- Whitelist, don’t blacklist
- Obvious reason: if you must fail, fail safe
- More subtle reason: incentives

Complete mediation
- Every mode of access must be checked
  - Not just regular accesses: startup, maintenance, etc.
- Checks cannot be bypassed
  - E.g., web app must validate on server, not just client

Open design
- Security must not depend on the design being secret
- If anything is secret, a minimal key
  - Design is hard to keep secret anyway
  - Key must be easily changeable if revealed
  - Design cannot be easily changed
Open design: strong version

- "The design should not be secret"
- If the design is fixed, keeping it secret can't help attackers
- But an unscrutinized design is less likely to be secure

Separation of privilege

- Real world: two-person principle
- Direct implementation: separation of duty
- Multiple mechanisms can help if they are both required
  - Password and wheel group in Unix

Least privilege

- Programs and users should have the most limited set of powers needed to do their job
- Presupposes that privileges are suitably divisible
  - Contrast: Unix root

Least privilege: privilege separation

- Programs must also be divisible to avoid excess privilege
- Classic example: multi-process OpenSSH server
- N.B.: Separation of privilege ≠ privilege separation

Least common mechanism

- Minimize the code that all users must depend on for security
- Related term: minimize the Trusted Computing Base (TCB)
- E.g.: prefer library to system call; microkernel OS

Psychological acceptability

- A system must be easy to use, if users are to apply it correctly
- Make the system's model similar to the user's mental model to minimize mistakes
Sometimes: work factor

- Cost of circumvention should match attacker and resource protected
- E.g., length of password
- But, many attacks are easy when you know the bug

Sometimes: compromise recording

- Recording a security failure can be almost as good as preventing it
- But, few things in software can’t be erased by root

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Readings reminder

- It didn’t seem like many people read the CFI paper…
- Link was broken until yesterday, my fault
- Reminder about library proxy bookmarklet

Alternative Saltzer & Schroeder

- Not a replacement for reading the real thing, but:
  - Security Principles of Saltzer and Schroeder, illustrated with scenes from Star Wars (Adam Shostack)

Deadlines reminder

- Exercise set 1: Thursday night
- HW1 early submission: Friday night
- Project progress reports: week from today
- HW1 final submission: week from Friday
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Pop quiz

- What’s the type of the return value of `getchar`?
- Why?

Separate the control plane

- Keep metadata and code separate from untrusted data
- Bad: format string vulnerability
- Bad: old telephone systems

Defense in depth

- Multiple levels of protection can be better than one
- Especially if none is perfect
- But, many weak security mechanisms don’t add up

Canonicalize names

- Use unique representations of objects
- E.g. in paths, remove ., .., extra slashes, symlinks
- E.g., use IP address instead of DNS name

Fail-safe / fail-stop

- If something goes wrong, behave in a way that’s safe
- Often better to stop execution that continue in corrupted state
- E.g., better segfault that code injection
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Modularity

- Divide software into pieces with well-defined functionality
- Isolate security-critical code
  - Minimize TCB, facilitate privilege separation
  - Improve auditability

Minimize interfaces

- Hallmark of good modularity: clean interface
- Particularly difficult:
  - Safely implementing an interface for malicious users
  - Safely using an interface with a malicious implementation

Appropriate paranoia

- Many security problems come down to missing checks
- But, it isn’t possible to check everything continuously
- How do you know when to check what?

Invariant

- A fact about the state of a program that should always be maintained
- Assumed in one place to guarantee in another
- Compare: proof by induction

Pre- and postconditions

- Invariants before and after execution of a function
- Precondition: should be true before call
- Postcondition: should be true after return
Dividing responsibility

- Program must ensure nothing unsafe happens
- Pre- and postconditions help divide that responsibility without gaps

When to check

- At least once before any unsafe operation
- If the check is fast
- If you know what to do when the check fails
- If you don’t trust
  - your caller to obey a precondition
  - your callee to satisfy a postcondition
  - yourself to maintain an invariant

Sometimes you can’t check

- Check that p points to a null-terminated string
- Check that fp is a valid function pointer
- Check that x was not chosen by an attacker

Error handling

- Every error must be handled
  - i.e., program must take an appropriate response action
- Errors can indicate bugs, precondition violations, or situations in the environment

Error codes

- Commonly, return value indicates error if any
- Bad: may overlap with regular result
- Bad: goes away if ignored

Exceptions

- Separate from data, triggers jump to handler
- Good: avoid need for manual copying, not dropped
- May support: automatic cleanup (finally)
- Bad: non-local control flow can be surprising
Testing and security

“Testing shows the presence, not the absence of bugs” – Dijkstra

Easy versions of some bugs can be found by targeted tests:
- Buffer overflows: long strings
- Integer overflows: large numbers
- Format string vulnerabilities: `%x`

Fuzz testing

Random testing can also sometimes reveal bugs

Original ‘fuzz’ (Miller): program
`</dev/urandom`

Modern: small random changes to a benign input

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Avoid special privileges

- Require users to have appropriate permissions
  - Rather than putting trust in programs
- Anti-pattern 1: setuid/setgid program
- Anti-pattern 2: privileged daemon
- But, sometimes unavoidable (e.g., email)

One slide on setuid/setgid

Unix users and process have a user id number (UID) as well as one or more group IDs
Normally, process has the IDs of the use who starts it
A setuid program instead takes the UID of the program binary

Don’t use shells or Tcl

... in security-sensitive applications
String interpretation and re-parsing are very hard to do safely
Eternal Unix code bug: path names with spaces
Prefer file descriptors

- Maintain references to files by keeping them open and using file descriptors, rather than by name.
- References same contents despite file system changes.
- Use `openat`, etc., variants to use FD instead of directory paths.

Prefer absolute paths

- Use full paths (starting with `/`) for programs and files.
- `$PATH` under local user control.
- Initial working directory under local user control.
  - But FD-like, so can be used in place of `openat` if missing.

Prefer fully trusted paths

- Each directory component in a path must be write protected.
- Read-only file in read-only directory can be changed if a parent directory is modified.

Don’t separate check from use

- Avoid pattern of e.g., `access` then `open`.
- Instead, just handle failure of `open`.
  - You have to do this anyway.
- Multiple references allow races.
  - And `access` also has a history of bugs.

Be careful with temporary files

- Create files exclusively with tight permissions and never reopen them.
  - See detailed recommendations in Wheeler.
- Not quite good enough: reopen and check matching device and inode.
  - Fails with sufficiently patient attack.

Give up privileges

- Using appropriate combinations of `set*id` functions.
  - Alas, details differ between Unix variants.
- Best: give up permanently.
- Second best: give up temporarily.
- Detailed recommendations: Setuid Demystified (USENIX’02).
**Whitelist environment variables**

- Can change the behavior of called program in unexpected ways
- Decide which ones are necessary
  - As few as possible
- Save these, remove any others

**Next time**

- Recommendations from the author of qmail
- A variety of isolation mechanisms