PURDUE UNIVERSITY

CS526: Information Security
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Systems: Design Principles

Building Real Systems

- Theory allows formal proof of known security policies
  - For components
  - And collections of components
- What should the security policies be?
- Design principles:
  - Guiding standards that are relatively independent of policy

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Principle of Least Privilege

- A subject should be given only those privileges needed to complete its task

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Fail-Safe Defaults

- Unless a subject is given explicit access to an object, it should be denied access

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Economy of Mechanism

- Security mechanisms should be as simple as possible
  - *But no simpler*

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Complete Mediation

- All accesses to an object must be checked to ensure they are allowed

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Open Design

- Security of a mechanism should not depend on secrecy of the design/implementation

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Separation of Privilege

- A system should not grant permission based on a single condition

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Least Common Mechanism

- Mechanisms used to access resources should not be shared

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Psychological Acceptability

- Security mechanisms should not make the resource more difficult to access than if security mechanisms were not present

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Secure Systems in Practice

- Formal verifications of entire systems *not yet* a practice
  - So what do we mean by secure?
- Trustworthy: Sufficient evidence to believe system will meet requirements
  - How do we measure this?
- Assurance: Confidence a system meets security requirements
  - Often based on development processes
- Trusted System: Evaluated / passed in terms of well-defined requirements, evaluation methods

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High-Assurance Development Methodologies Control:

- Requirements definitions, omissions, mistakes
- System design flaws
- Hardware implementation flaws
- Software implementation errors
- system use/operation errors
- Willful system misuse
- Hardware malfunction
- Natural / environmental effects
- Evolution/maintenance/upgrades/decommission

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Requirements

- Statement of Goals that must be satisfied
- Security Policy is a requirement
- Security Model is a means of detecting/preventing errors, omissions in security policy
- Policy Assurance: Evidence that security policy is complete/consistent/sound
  - *Achieved through use of model*

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Design Assurance

- Evidence that Design meets Security Policy
  - Validation / verification techniques
  - We'll discuss these later

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Implementation Assurance

- Evidence that the implementation meets the design
- Primarily based on standard software engineering practice

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Operational / Administrative Assurance

- Evidence that policy requirements maintained in operation
  - Best: evidence that system *can't* enter non-secure state
- Least Privilege, Separation of Privilege
- Training, documentation

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Software **Engineering**

- Without adequate design/implementation, all our work for naught
- In reality, what we've studied shows how to get good *requirements*
- Turning these into good *systems* beyond the realm of security expert
- Solution: insist on use of appropriate software engineering methodologies
  - Take CS510, ECE574 for more

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Assurance in the Face of Imperfection

- Mistakes will be made
  - Must they lead to security violations?
- Solution: Risk Mitigation
- Definitions:
  - Threat: Potential occurrence leading to undesirable consequences
  - Vulnerability: Weakness enabling threat
  - Exploit: Method for Threat to use Vulnerability
- All must occur for a violation to happen

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Risk Mitigation

- Threat-based
  - Enumerate threats
  - For each threat, eliminate possibility of exploitable vulnerability
- Vulnerability-based
  - Formal verification
  - Testing
  - Architecture / design
- Exploit-based

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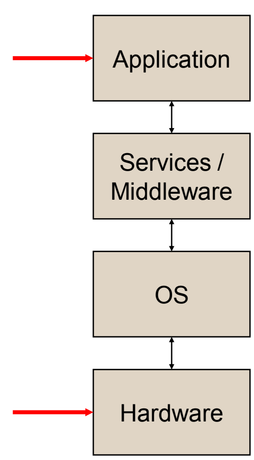
Security in Layered Architectures

- Systems built in layers
- “Perfect” mechanism at high layer doesn’t prevent vulnerabilities beneath
  - Limits threats to lower layers
  - Simpler security abstractions



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Add-On Security

- Implement security in separate module
  - Easier to validate
  - But may be hard to enforce
- Reference Monitor
  - Abstract machine that mediates all accesses
  - Implement with *Reference Validation Mechanism*
- Security Kernel: Implements reference Monitor
- Trusted Computing Base: subset of system that enforces security policy
  - Demands extra protection

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Evaluating Assurance

- How do we gather *evidence* that system meets security requirements?
- Process-based techniques: Was system constructed using proper methods?
  - SEI CMM
  - ISO 9000
- System Evaluation
  - Requirements Tracing
  - Representation Correspondence
  - Reviews
  - Formal Methods

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Process Based Techniques

- Software Engineering Institute Capability Maturity Model (SEI CMM)
  - Specifies levels of process maturity
  - Criteria to evaluate level of an organization
- ISO 900[0-?] similar
  - More directed to manufacturing than software
- Configuration Management
  - Log/track changes
  - Ensure process followed
  - Regression testing / update, release control

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System Evaluation

- Requirements Tracing
  - Track requirement to mechanism
  - Ensures nothing forgotten
  - *Doesn’t ensure it is correct*
- Representation Correspondence
  - Requirements tracing between levels
- Validating Correctness:
  - Informal arguments
  - Formal verification
    - May use automated tools

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System Evaluation: Reviews

- Formal Process of “passing” on specification / design / implementation
  - Team evaluates component
  - Provides independent evidence that component meets requirements
- Review is a structured process
  - Materials presented to reviewers
  - Reviewers evaluate using agreed on methods
  - Review meeting: collect comments and discuss
  - Report: List of comments, reviewer agreement/disagreement

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Implementation Management

- Assume a secure design
  - How to ensure implementation will be secure?
- Constrained Implementation Environment
  - Strong typing
  - Built-in buffer checks
  - Virtual machines
- Coding Standards
  - Restrict how language is used
  - Meeting standards eliminates use of “unsafe” features

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Implementation Management: Configuration Management

- Control changes made
  - Development
  - Production / operation
- Version control and tracking
  - Audit
- Change Authorization
- Enforce integration procedures
- Automated production tools

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Configuration Management: CVS

- Concurrent Versions System (CVS)
  - Commonly used in DoD, elsewhere?
  - Client-Server / network approach
- CVS tree: "official" versions at server
- Check-out: Get a local copy of a version
- Check-in: merges your updates into tree
  - Creates new version
  - Forces you to comment why changed
  - Flags conflicts
  - Ignores files you've created that aren't in official tree

http://www.cvshome.org

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Testing

- Functional (specification based) vs. Structural (code based) testing
- Levels: Unit, System, Independent
- Security Testing:
  - Functional
  - Structural
  - Requirements (separate from functional?)
- Automated Test Suites

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Process Guidance Working Group Test Model

- Test Matrix: Maps requirements to lower levels
  - At lowest level, test assertion
  - Used to develop test cases
- Divides checks into six areas
  - Discretionary Access Control
  - Privileges
  - Identification and Authorization
  - Object Reuse
  - Audit
  - System Architecture Constraints

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Top-Level Matrix: OS Example

Component	*DAC*	*PRIV*	*I&A*	*OR*	*Audit*	*Arch*
Process Management					✓	
Process Control	✓	✓		✓	✓	✓
File Management	✓	✓		✓	✓	✓
Audit		✓	✓	✓	✓	✓
I/O interfaces	✓	✓	✓	✓	✓	
I/O device drivers		✓		✓	✓	✓
IPC management	✓	✓		✓	✓	✓
Memory management	✓	✓		✓	✓	✓

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PGWG Test Model

- Each row generates lower level matrix
- Continue until test assertions possible
  – Verify only root can use *stime* successfully
  – Verify audit record generated for call to *stime*
- Develop test case specification for each assertion
  – Call *stime* as root: time should change, audit generated
  – Call *stime* as non-root: no change, fail, audit generated
- Develop test for each specification

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Operation/Maintenance

- Fixes / maintenance
  - Hot fix: quick solution
    - Possibly security testing only
    - May limit functionality
  - Regular fix: more thorough testing
    - Reintroduce functionality while maintaining security
- Procedures to track flaws
  - Reporting
  - Test to detect flaw
  - Regression test: ensure flaw not “unfixed”

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Next: Formal Methods

- Software verification beyond scope of course
  - But important to achieve security
- Limited software verification
  - Verify the security subsystems
  - *Confine* the rest

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