IS 2150 / TEL 2810
Introduction to Security

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Lecture 9
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Authentication, Identity
Vulnerability Analysis

Objectives

- Understand/explain the issues related to, and utilize the techniques
  - Authentication and identification
  - Vulnerability analysis/classification
    - Techniques
    - Taxonomy

Authentication and Identity

What is Authentication?

- Authentication:
  - Binding identity and external entity to subject
- How do we do it?
  - Entity *knows* something (secret)
    - Passwords, id numbers
  - Entity *has* something
    - Badge, smart card
  - Entity *is* something
    - Biometrics: fingerprints or retinal characteristics
  - Entity is in *someplace*
    - Source IP, restricted area terminal

Authentication System: Definition

- *A*: Set of *authentication information*
  - used by entities to prove their identities (e.g., password)
- *C*: Set of *complementary information*
  - used by system to validate authentication information (e.g., hash of a password or the password itself)
- *F*: Set of *complementation functions* (to generate *C*)
  - $f : A \rightarrow C$
  - Generate appropriate $c \in C$ given $a \in A$
- *L*: set of *authentication functions*
  - $l: A \times C \rightarrow \{$ **true, false** $\}$
  - verify identity
- *S*: set of *selection functions*
  - Generate/alter *A* and *C*
  - e.g., commands to change password

Authentication System: Passwords

- Example: plaintext passwords
  - $A = C =$ alphabet*
  - f returns argument: $f(a)$ returns a
  - l is string equivalence: $l(a, b)$ is true if $a = b$

- Complementation Function
  - Null (return the argument as above)
    - requires that c be protected; i.e. password file needs to be protected
  - One-way hash – function such that
    - *Complementary information* $c = f(a)$ easy to compute
    - $f^{-1}(c)$ difficult to compute

Passwords

- Example: Original Unix
  - A password is up to eight characters
    - each character could be one of 127 possible characters;
  - *A* contains approx. 6.9 x 10^{16} passwords
  - Password is hashed using one of 4096 functions into a 11 character string
  - 2 characters pre-pended to indicate the hash function used
  - *C* contains passwords of size 13 characters, each character from an alphabet of 64 characters
    - Approximately 3.0 x 10^{23} strings
  - Stored in file */etc/passwd* (all can read)

Authentication System

- Goal: identify the entities correctly
- Approaches to protecting
  - Hide enough information so that one of *a, c* or *f* cannot be found
    - Make C readable only to root
    - Make F unknown
  - Prevent access to the authentication functions *L*
    - *root* cannot log in over the network

Attacks on Passwords

- Dictionary attack: Trial and error guessing
  - Type 1: attacker knows A, f, c
    - Guess g and compute $f(g)$ for each f in F
  - Type 2: attacker knows A, l
    - l returns **True** for guess g

- Counter: Difficulty based on $|A|$, Time
    - Probability P of breaking in time T
    - G be the number of guesses that can be tested in one time unit
    - $|A| \geq TG/P$
    - Assumptions:
      - time constant; all passwords are equally likely

Password Selection

- Random
  - Depends on the quality of random number generator;
  - Size of legal passwords
    - 8 characters: humans can remember only one

- Pronounceable nonsense
  - Based on unit of sound (phoneme)
  - Easier to remember

- User selection (proactive selection)
  - Controls on allowable
    - At least 1 digit, 1 letter, 1 punctuation, 1 control character
    - Obscure poem verse

Password Selection

- Reusable Passwords susceptible to dictionary attack (type 1)
  - *Salting* can be used to increase effort needed
    - makes the choice of complementation function a function of randomly selected data
    - Random data is different for different user
    - Authentication function is chosen on the basis of the salt
    - Many Unix systems:
      - A salt is randomly chosen from 0..4095
      - Complementation function depends on the salt

Password Selection

- Password aging
  - Change password after some time: based on expected time to guess a password
  - Disallow change to previous *n* passwords
- Fundamental problem is *reusability*
  - Replay attack is easy
  - Solution:
    - Authenticate in such a way that the transmitted password changes each time

Authentication Systems: Challenge-Response

- Pass algorithm
  - authenticator sends message *m*
  - subject responds with *f*(*m*)
    - *f* is a secret encryption function
  - Example: ask for second input based on some algorithm

Authentication Systems: Challenge-Response

- One-time password: *invalidated after use*
  - f changes after use
- S/Key uses a hash function (MD4/MD5)
  - User chooses an initial seed k
  - Key generator calculates
    - $k_1 = h(k)$, $k_2 = h(k_1)$ …, $k_n = h(k_{n-1})$
  - Passwords used in the order
    - $p_1 = k_n$, $p_2 = k_{n-1}$, …, $p_n = k_1$
  - Suppose $p_1 = k_n$ is intercepted;
    - the next password is $p_2 = k_{n-1}$
    - Since $h(k_{n-1}) = k_n$, the attacker needs to invert h to determine the next password

Authentication Systems: Biometrics

- Used for human subject identification based on physical characteristics that are tough to copy
  - Fingerprint (optical scanning)
    - Camera's needed (bulky)
  - Voice
    - Speaker-verification (identity) or speaker-recognition (info content)
  - Iris/retina patterns (unique for each person)
    - Laser beaming is intrusive
  - Face recognition
    - Facial features can make this difficult
  - Keystroke interval/timing/pressure

Attacks on Biometrics

- Fake biometrics
  - fingerprint “mask”
  - copy keystroke pattern
- Fake the interaction between device and system
  - Replay attack
  - Requires careful design of entire authentication system

Vulnerability Analysis

Vulnerability Analysis

- Vulnerability or security flaw: specific failures of security controls (procedures, technology or management)
  - Errors in code
  - Human violators
  - Mismatch between assumptions
- Exploit: Use of vulnerability to violate policy
- Attacker: Attempts to exploit the vulnerability

Techniques for Detecting Vulnerabilities

- System Verification
  - Determine preconditions, post-conditions
  - Validate that system ensures post-conditions given preconditions

  Can prove the absence of vulnerabilities
- Penetration testing
  - Start with system/environment characteristics
  - Try to find vulnerabilities

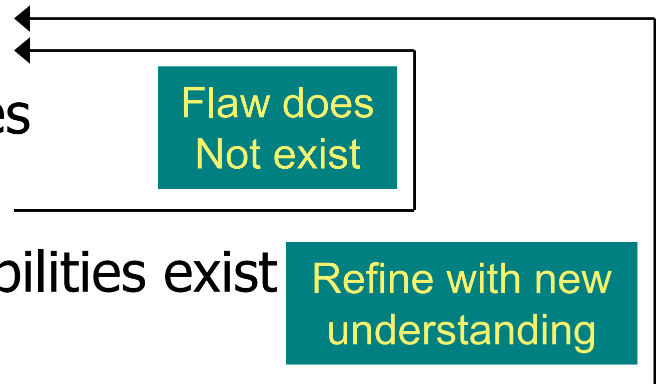
  Can not prove the absence of vulnerabilities

Types/layers of Penetration Testing

- Black Box (External Attacker)
  - External attacker has no knowledge of target system
  - Attacks built on human element – Social Engineering
- System access provided (External Attacker)
  - Red team provided with limited access to system
  - Goal is to gain normal or elevated access
- Internal attacker
  - Red team provided with authorized user access
  - Goal is to elevate privilege / violate policy

Red Team Approach Flaw Hypothesis Methodology:

- Information gathering
  - Examine design, environment, system functionality
- Flaw hypothesis
  - Predict likely vulnerabilities
- Flaw testing
  - Determine where vulnerabilities exist
- Flaw generalization
  - Attempt to broaden discovered flaws
- Flaw elimination (often not included)
  - Suggest means to eliminate flaw



Problems with Penetration Testing

- Nonrigorous
  - Dependent on insight (and whim) of testers
  - No good way of evaluating when “complete”
- How do we make it systematic?
  - Try all classes of likely flaws
  - *But what are these?*
- Vulnerability Classification!

Vulnerability Classification

- Goal: describe spectrum of possible flaws
  - Enables design to avoid flaws
  - Improves coverage of penetration testing
  - Helps design/develop intrusion detection
- How do we classify?
  - By how they are exploited?
  - By where they are found?
  - By the nature of the vulnerability?

Example flaw: xterm log

- *xterm* runs as root
  - Generates a log file
  - Appends to log file if file exists
- Problem: ln /etc/passwd log_file
- Solution

```
if (access(“log_file”, W_OK) == 0)
    If ((fd = open(“log_file”, O_WRONLY|O_APPEND)) < 0) {
    -  error handling
    }
```

What can go wrong?

Example: Finger Daemon *(exploited by Morris worm)*

- *finger* sends name to *fingerd*
  - *fingerd* allocates 512 byte buffer on stack
  - Places name in buffer
  - Retrieves information (local finger) and returns
- Problem: If name > 512 bytes, overwrites return address
- Exploit: Put code in "name", pointer to code in bytes 513+
  - Overwrites return address

RISOS:Research Into Secure Operating Systems (7 Classes)

1. Incomplete parameter validation
   - E.g., buffer overflow –
2. Inconsistent parameter validation
   - Different routines with different formats for same data
3. Implicit sharing of privileged / confidential data
   - OS fails to isolate processes and users
4. Asynchronous validation / inadequate serialization
   - Race conditions and TOCTTOU flaws
5. Inadequate identification /authentication / authorization
   - Trojan horse; accounts without passwords
6. Violable prohibition / limit
   - Improper handling of bounds conditions (e.g., in memory allocation)
7. Exploitable logic error
   - Incorrect error handling, incorrect resource allocations etc.

Protection Analysis Model Classes

- Pattern-directed protection evaluation
  - Methodology for finding vulnerabilities
- Applied to several operating systems
  - Discovered previously unknown vulnerabilities
- Resulted in two-level hierarchy of vulnerability classes
  - Ten classes in all

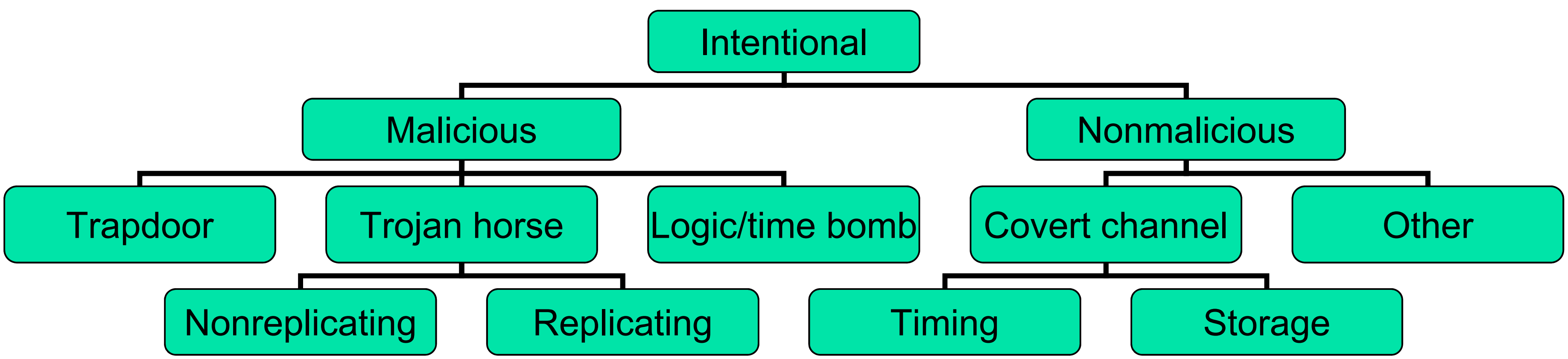
PA flaw classes

1. Improper protection domain initialization and enforcement
   a. *domain*: Improper choice of initial protection domain
   b. *exposed representations*: Improper isolation of implementation detail (Covert channels)
   c. *consistency of data over time*: Improper change
   d. *naming*: Improper naming (two objects with same name)
   e. *residuals*: Improper deallocation or deletion
2. Improper validation *validation of operands, queue management dependencies*:
3. Improper synchronization
   a. *interrupted atomic operations*: Improper indivisibility
   b. *serialization*: Improper sequencing
4. Improper choice of operand or operation *critical operator selection errors*

NRL Taxonomy

- Three classification schemes
  - How did it enter
  - When was it "created"
  - Where is it

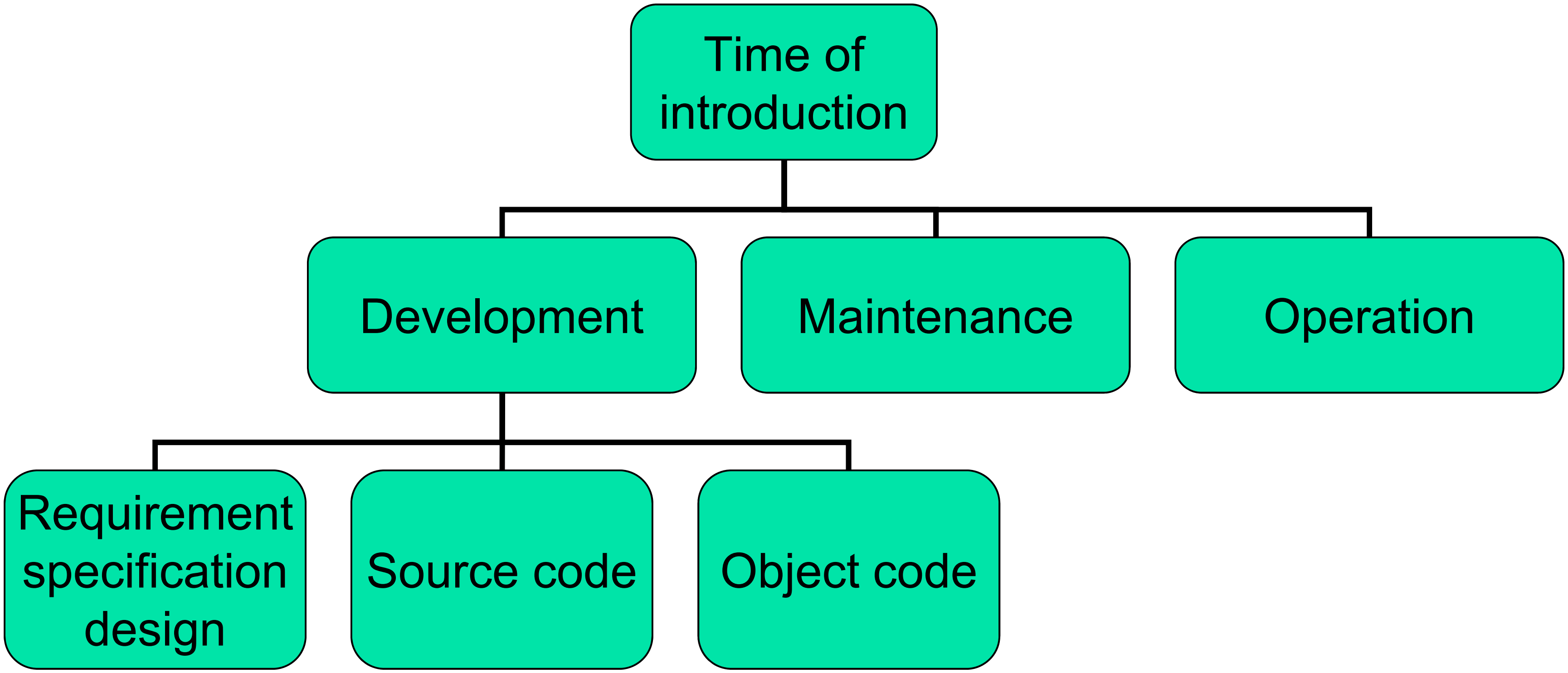
Genesis



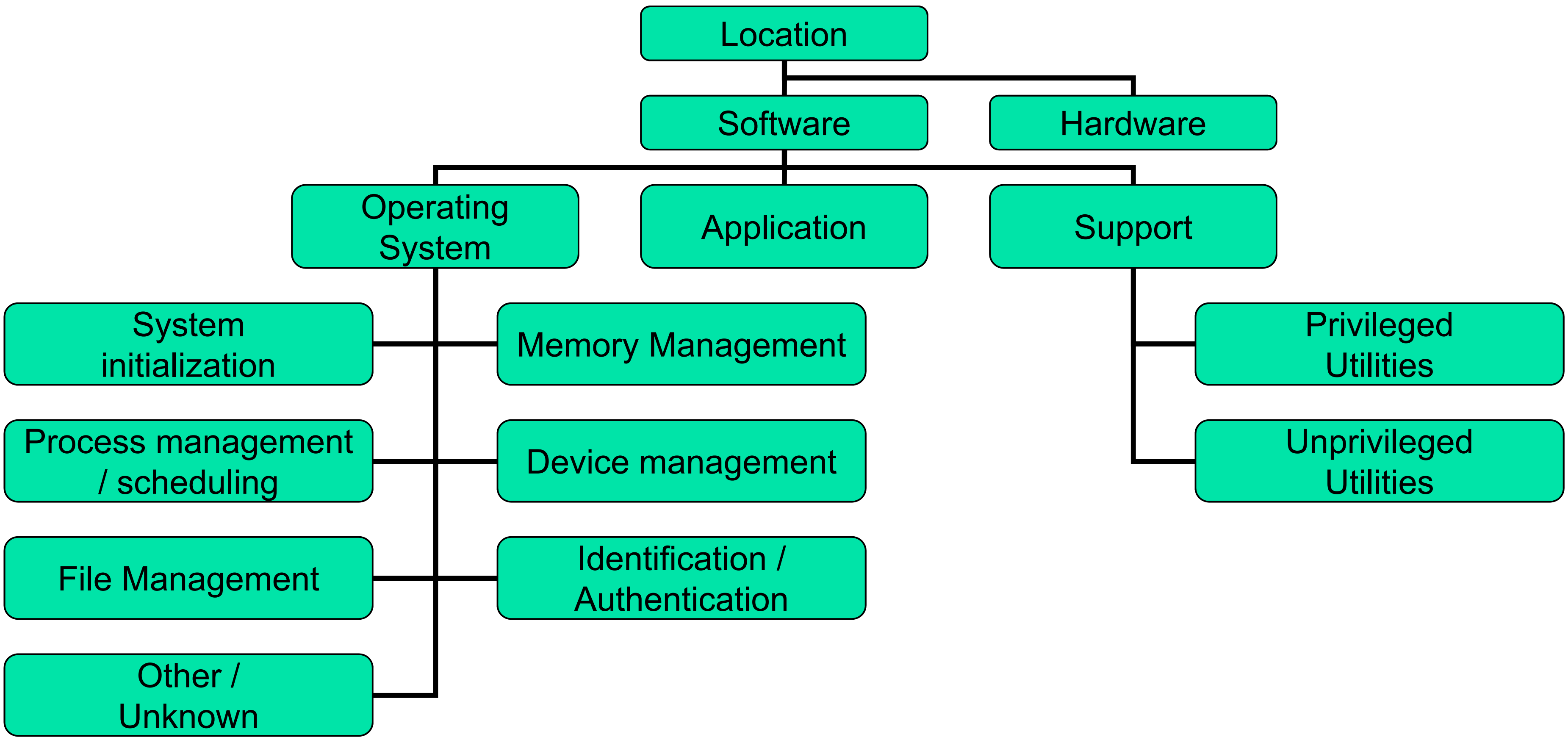
NRL Taxonomy (Genesis)

Inadvertent	Validation error (Incomplete/Inconsistent)
	Domain error (including object re-use, residuals, and exposed representation errors
	Serialization/aliasing (including TCTTOU errors)
	Boundary conditions violation (including resource exhaustion and violable constraint errors)
	Other exploitable logic error

NRL Taxonomy: Time



NRL Taxonomy: Location



Aslam's Model

- Attempts to classify faults unambiguously
  - Decision procedure to classify faults
- Coding Faults
  - Synchronization errors
    - Timing window
    - Improper serialization
  - Condition validation errors
    - Bounds not checked
    - Access rights ignored
    - Input not validated
    - Authentication / Identification failure
- Emergent Faults
  - Configuration errors
    - Wrong install location
    - Wrong configuration information
    - Wrong permissions
  - Environment Faults

Common Vulnerabilities and Exposures (cve.mitre.org)

- Captures *specific* vulnerabilities
  - Standard name
  - Cross-reference to CERT, etc.
- Entry has three parts
  - Unique ID
  - Description
  - References

Name	CVE-1999-0965
Description	Race condition in xterm allows local users to modify arbitrary files via the logging option.

References
•CERT:CA-93.17
•XF:xterm