# AN INTRODUCTION TO COMPUTER SECURITY

**Richard A. Kemmerer**
**Computer Science Department**
**University of California**
**Santa Barbara, California, U.S.A.**

**Email: kemm@cs.ucsb.edu**



## Computer Security

- What is computer security?
  - The field of computer science that analyzes the security properties of computer systems
  - The protection of resources (including data and programs) from accidental or malicious modification, destruction, or disclosure
- Why is it important?
  - Information is power and money
  - Computer systems manage information and provide mission-critical support for business, government, and financial institutions



## Why is it so bad?

Computers are everywhere

Computer systems constantly grow in complexity (and size)

Today's networks are very heterogeneous, and critical components are often connected (maybe in indirect ways) to non-critical, poorly managed computer systems

People make mistakes in both the development and the deployment of computer systems



## Why is it so bad?

**Home Users Increase Vulnerabilities**

Today most homes are connected, particularly with the advent of DSL and cable modems

Most home users:

- are unaware of vulnerabilities
- don't use firewalls
- think they have nothing to hide or don't care if others get their data
- don't realize their systems can serve as jump off points for other attacks (*zombies or bots*)



## Why is it so bad?

Computer security is reactive

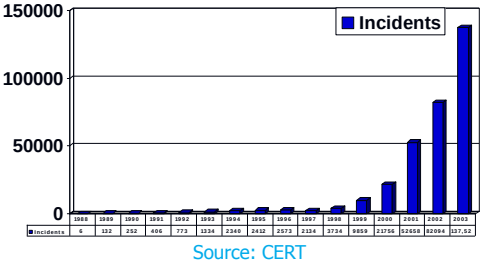
- usually reacting to latest attack
- offense is easier than defense

Security is expensive both in dollars and in time

There is not now, and never will be, a system with perfect security

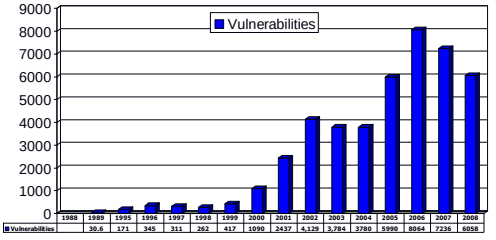


## Security Incidents




Source: CERT

## Security Vulnerabilities




Source: CERT
http://www.cert.org/stats/



## Who are the attackers?

**Script kiddies** download malicious software from hacker web sites

**Hackers** trying to prove to their peers that they can compromise a specific system

**Insiders** are legitimate system users who access data that they have no rights to access

**Organizational level attackers** use the full resources of the organization to attack



## Who are the attackers?

After September 11, 2001 the idea of nation state level cyber attacks being carried out by terrorists became a big concern

More recently, most attacks are financially motivated. There is a complete cyber underground economy



## Outline

Examples of known security threats

Classification of security threats

Security policies

Protection mechanisms

Techniques for assuring system security



## *Most Common Threat* Password Guessing

- Exhaustive search for passwords
- Lists of commonly used passwords
- Distributed default passwords
- Password cracking programs readily available on the Internet



## Spoofing

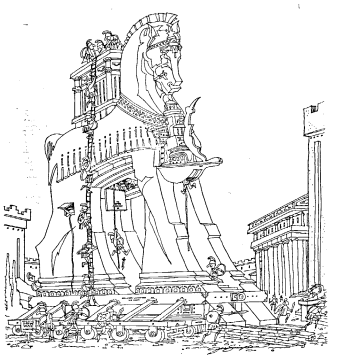
Duping a user into believing that he is talking to the system and revealing information (e.g., password)

## Browsing

After an intruder has gained access to a system he may peruse any files that are available for reading and glean useful information for further penetrations

- Often done by legitimate users





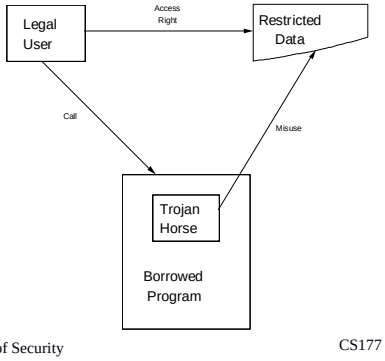


## Trojan Horse

A program that does more than it is supposed to do

- More sophisticated threat
- A text editor that sets all of your files to be publicly readable in addition to performing editing functions
- Every unverified program is suspect (especially games)








## Trap Door

A system modification installed by a penetrator that opens the system on command

- May be introduced by a system developer
- Bogus system engineering change notice



## Virus

A program that can infect other programs by modifying them to include a possibly evolved copy of itself

## Examples

*Amiga Virus*

- Resident on boot block

*IBM Christmas Virus*

- Names and netlog files
- Denial of service

*Census Bureau*

- County and City Data Book CD-ROM

*WWW Pages Containing Applets*

*MIME-encoded Mail*

*Code Red Worm*

*Blaster*

*Sasser*



## THREAT

## CLASSIFICATION



## Security

*Confidentiality* - Keeping data and resources hidden or protected from unauthorized disclosure

*Integrity* - ensures that the data and programs are modified or destroyed only in a specified and authorized way
- Data integrity (integrity)
- Origin integrity (authentication)

*Availability* - ensures that the resources of the system will be usable whenever they are needed by an authorized user



## Browsing

Searching through main and secondary memory for residue information

## Leakage

Transmission of data to an unauthorized user from a process that is allowed to access the data

## Inference

Deducing confidential data about an individual by correlating unrelated statistics about groups of individuals



## Tampering

Making unauthorized changes to the value of information

## Accidental Data Destruction

Unintentional modification of information



## Masquerading

Gaining access to the system under another user's account

## Denial of Service

Prevention of authorized access to computer resources or the delaying of time-critical operations

## Computer Security Threats

Browsing
Leakage
Inference

Tampering
Accidental destruction

Masquerading

Denial of services



## Bishop Threat Definitions

*Threat* is a potential violation of security

*Attacks* are those actions which could cause a threat to occur

*Attackers* are those who execute an attack

Confidentiality, integrity, availability are enforced to counter the threats to the security of a system and foil attacks



## Cerias Definitions

*Vulnerability* is a flaw in a system that allows a policy to be violated

*Exploit* is the act of exercising a vulnerability
Also used to refer to an actual program, binary or script that automates an attack

*Exposure* is an information leak that may assist an attacker



## Bishop Classes of Threats

- Disclosure (unauthorized access to information)
  - Snooping, wiretapping, eavesdropping
  - These threats are mostly addressed by confidentiality services
- Deception (acceptance of false data)
  - Modification, spoofing, repudiation of origin, denial of receipt
  - These threats are mostly addressed by integrity services
- Disruption (interruption or prevention of correct operation)
  - Modification
  - These threats are mostly addressed by integrity services
- Usurpation (unauthorized control of some part of the system)
  - Modification, spoofing, delay, denial of service
  - These threats are addressed by integrity and availability services



## Security Policy

A security policy is a statement of what is and what is not allowed

It defines the concept of "security" for a computer system
It can be defined formally or informally
When defined formally, it provides a precise characterization of the secure states of a system



## Simple Example Policy

- Policy disallows cheating
  - Includes copying homework, with or without permission
- CS class has students do homework on computer
- Anne forgets to read-protect her homework file
- Bill copies it

- Who cheated?
  - Anne, Bill, or both?

## Answer Part 1

Bill cheated

- Policy forbids copying homework assignment
- Bill copied
- System entered unauthorized state (Bill having a copy of Anne's assignment)



## Answer Part 2

- Anne didn't protect her homework
  - Not required by security policy
- She didn't breach security
- If policy said students had to read-protect homework files, then Anne would have breached security
  - She didn't



## Access Control

A means of limiting a user's access to only those entities that the policy determines should be accessed

*Subjects* - Active entities in the system (e.g. , users, processes, programs)

*Objects* - Resources or passive entities in the system (e.g. , files, programs, devices)

*Access Modes* - Read, write, execute, append, update

*Access Control Mechanisms* - Determine for each subject what access modes it has for each object



## Access Control

*Discretionary Access Control (DAC)*
The owner specifies to the system what other users can access his files
(Access is at the user's discretion)

*Mandatory Access Control (MAC)*
The system determines whether a user can access a file *based on the fixed security attributes* of the user and of the file
(Non-discretionary access)



## Access Control Matrix

| | Objects | | | | |
|---|---|---|---|---|---|
| **Subjects** | **O1** | **O2** | **O3** | **O4** | **O5** |
| **S1** | | | **W** | **RW** | **W** |
| **S2** | **R** | **E** | | **R** | |
| **S3** | | **RW** | **E** | | |
| **S4** | **RE** | | **RW** | | **RE** |



## Access Control List *(Authorization List)*

- Associated with each object
- Contains subject name and type of access allowed
- Corresponds to column in the matrix

## Capability List *(C-list)*

– Associated with each subject

– Contains object name and type of access allowed

– Corresponds to a row in the matrix

– Defines the environment or domain that the subject may access



## Mandatory Control Policy

– Each subject has an access class (authorization)
– Each object has an access class (classification)
– Access class made up of
  * level
  * category set
– Comparison of access classes
  * equal (=)
  * less than (<)
  * greater than (>)
  * not comparable (**NC**)



## Example Mandatory Controls

– Three security levels
*Unclassified, Confidential, Secret*

– Three security categories
*Crypto, Nuclear, Intelligence*

Comparisons
SECRET/ {CRYPTO} = SECRET/ {CRYPTO}
SECRET/ {CRYPTO} > CONFIDENTIAL/ {CRYPTO}
SECRET/ {CRYPTO} < SECRET/ {CRYPTO, NUCLEAR}
SECRET/ {CRYPTO} *NC* SECRET/ {NUCLEAR}



## Access Rules

*Simple security property*
Read permission if:
Access class (subject) $\geq$ Access class (object)

*– *Property*
Write permission if:
Access class (subject) $\leq$ Access class (object)



## Policies and Mechanisms

- A security policy is a statement of what is, and what is not, allowed
- A security mechanism is a method, tool, or procedure to enforce a security policy
  – Different mechanisms can be used to enforce the same policy
- For example:
  – Policy: students should not copy other students' assignments
  – Mechanism: % chmod 700 *



## Goals of Security

- Given a security policy's definition of secure and insecure states, the corresponding security mechanisms can perform different functions
- Prevention
  – Prevent attackers from violating security policy
  – Example: use of passwords
- Detection
  – Detect attackers' violations of security policy
  – Example: use of logging of sensitive operations
- Recovery
  – Stop attack, assess, and repair damage
  – Example: use of checkpointing and virtualization
  – Continue to function correctly even if attack succeeds

## Approaches to Security

- Procedural
- Functions and Mechanism
- Assurance



## Procedural Approaches

Prescribe appropriate behavior for a user interacting with the system

- periods processing
- guidelines for managing passwords
- appropriate handling of removable storage devices
- electronic voting systems



## Periods Processing

Split the day into periods and run different classification jobs in each period



## Functions and Mechanisms

Enforce security policy

Examples are the 3As

- **A**uthentication: *assures that a particular user is who he/she claims to be*
- **A**ccess control: *a means of limiting a user's access to only those entities that the policy determines should be accessed*
- **A**udit: *a form of transaction record keeping. The data collected is called an audit log*



## Authentication Mechanisms

Authenticates users at login time

- Secure attention key
- One way functions



## Secure Attention Key

- Foils attempts at spoofing
- Guarantees trusted path to the system
- User must use it

## One-Way Function

A function whose inverse is computationally infeasible to determine

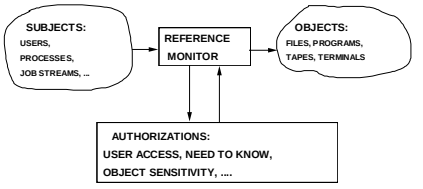
– Enciphered passwords are stored in a password file

– At login time password presented by the user is enciphered and compared to what is in the password file



## Reference Monitor

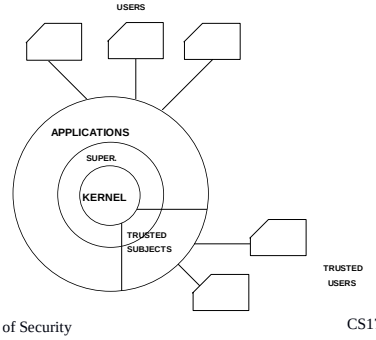
Provides mediation of all accesses to assure that the access control policy is enforced




Reference Monitor must be
- Invoked on every reference
- Tamperproof
- Subject to analysis/test whose completeness can be assured



## Security Kernel






*Kernel* must handle parts of the operating system that manage resources shared by multiple users

*Supervisor* contains functions that provide useful common facilities but do not manage anything shared among users

*Trusted subjects* are used to extend the security policy
– May perform actions not permitted by the access checks
– Must be subject to analysis and test just like the security kernel



## ASSURANCE TECHNIQUES



## Assumptions and Trust

- A policy describes the security of a system in a certain environment and under certain assumptions
  – A policy that states that students should not copy other students' files, which is enforced by using file system access control mechanisms, is valid under the assumption that students don't share passwords and that they set file access privileges correctly
- Assumptions about policies
  – A policy unambiguously partitions a system's states into secure and nonsecure
  – A policy correctly captures the security requirements of the real world

## Assumptions and Trust

- Assumptions about mechanisms
  - The security mechanisms enforce the policy and prevent the system from entering a nonsecure state
  - The mechanisms can be trusted
    - Are implemented correctly
    - Are installed and administered correctly



## Assurance

- Assurance is a measure of how well the system meets its requirements
  - In other words, how much one can trust the system to do what it is supposed to do
- Assurance is derived by analyzing the specification, design, and implementation of a system



## Assurance Techniques

Penetration analysis

Covert channel analysis

Formal verification



## Penetration Analysis

Uses a collection of known flaws, generalizes the flaws, and tries to apply them to the system being analyzed

– Penetration team known as "Tiger Team"

– Demonstrates the presence not the absence of protection failures



## Covert Channels

Security analysis of both overt and covert channels is necessary

*Overt channel* – Uses the system's protected data objects to transfer information

*Covert channel* – Uses entities not normally viewed as a data object to transfer information

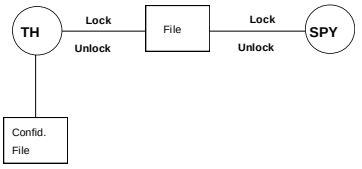


## Two Types of Covert Channels

*Storage channels* – the sender alters the value of a data item and the receiver detects and interprets the altered value to receive information covertly

*Timing channels* – the sender modulates the amount of time required for the receiver to perform a task or detect a change in an attribute, and the receiver interprets the delay or lack of delay to receive information covertly

## File Lock Example

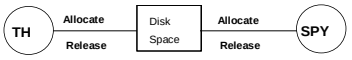



Trojan Horse locks a file if it wants to signal a 1 and doesn't lock it if it wants to signal a 0

Spy attempts to lock the file
- If lock fails spy interprets it as a 1
- If lock succeeds spy interprets it as a 0



## Disk Quota Example



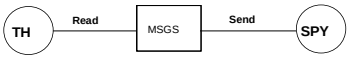

Trojan Horse allocates or releases disk space to send a 1 or a 0

Spy attempts to allocate disk space
- allocate fails if no more space is available

***This is a resource exhaustion channel***



## IPC Quota Example

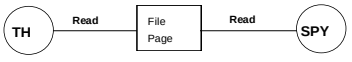



Trojan Horse reads a message to release a message slot or does nothing

Spy sends a message
- Send fails if the queue is full
- Send succeeds if their is space in the queue



## Paging Example




Trojan Horse reads a page or does nothing

Spy reads a page

The read operation
- returns immediately if the page is in main memory
- loads page in main memory, with a noticeable delay, if the page has not been read lately

***This is a timing channel***



## What About Privacy?

*Confidentiality* - ensures that sensitive information is not disclosed to unauthorized recipients

*Integrity* - ensures that the data and programs are modified or destroyed only in a specified and authorized way

*Availability* - ensures that the resources of the system will be usable whenever they are needed by an authorized user

*Privacy* - ensures that only the information that an individual wishes to disclose is disclosed



## Other Privacy Concerns

Privacy is more than just confidentiality

Privacy advocates consider it important to be able to verify the integrity of personal information, especially when that information can be used against them (e.g., credit reports)

## Internet Privacy

- The ability to control what information one reveals about oneself over the Internet, and to control who can access that information.
- These concerns include whether email can be stored or read by third parties without consent, or whether third parties can track the web sites someone has visited.
- Another concern is whether web sites which are visited collect, store, and possibly share personally identifiable information about users.

*http://en.wikipedia.org/wiki/Privacy#Informational*



## Web Sites and Mailing Lists

- History of computer security
  - http://csrc.nist.gov/publications/history/
- Security surveys/statistics
  - CERT statistics: http://www.cert.org/stats
  - CSI/FBI survey: http://gocsi.com/survey



## More Web Sites and Mailing Lists

- SecurityFocus.com
  - Bugtraq
  - Focus-ids
  - …
- Slashdot.org/stories/security
- Zone-h.org