CS 3002 Information Security

Fall 2022

1. Explain key concepts of information security such as design principles, cryptography, risk management,(1)

2. Discuss legal, ethical, and professional issues in information security (6)
3. Analyze real world scenarios, model them using security measures, and apply various security and risk management tools for achieving information security and privacy (2)
4. Identify appropriate techniques to tackle and solve problems of real life in the discipline of information security (3)
5. Understand issues related to ethics in the field of information security(8)

ISO/IEC 27001: 2013

Week # 1 – Lecture # 1, 2, 3

Dr. Nadeem Kafi Khan

InfoSec CLOs and Course outline

Code	Title	Cr.Hrs	Consolidated
CS3002	Information Security	3	1. Explain key concepts of information security such as design principles, cryptography, risk management,(1) 2. Discuss legal, ethical, and professional issues in information security (6) 3. Analyze real world scenarios, model them using security measures, and apply various security and risk management tools for achieving information security and privacy (2) 4. Identify appropriate techniques to tackle and solve problems of real life in the discipline of information security (3) 5. Understand issues related to ethics in the field of information security(8)

CLO	Course Learning Outcome (CLO)	Domain	Taxonomy Level	PLO	Tools
01	**Explain** key concepts of information security such as design principles, cryptography, risk management, and ethics	Cognitive	C2 (Understanding)	**1**	**A1, A2, M1, M2, P, F**
02	**Discuss** legal, ethical, and professional issues in information security.	Cognitive	C2 (Applying)	**2**	**A3, A4, P, M2, F**
03	**Apply** various security and risk management tools for achieving information security and privacy.	Cognitive	C3 (Applying)	**5**	**A3, A4 M2, P, F**
04	**Identify** appropriate techniques to tackle and solve problems in the discipline of information security.	Cognitive	C4 (Analyzing)	**2**	**A1, A2, M1, M2, P, F**
***Tool**: A = Assignment, P = Project, M = Mid-term (M1 and M2), F=Final (End-term)*					

Week #	Topic	Reference Text
1	**Information Security Foundations**: Concepts, Threats and Attacks, Design Principles, Strategy and Standards	Main Textbook, Chapter 1 Sections 1.1, 1.2, 1.4, 1,6, 1,7
2	**Cryptographic Tools**: Confidentiality with Symmetric Encryption, Message Authentication and Hash Functions	Textbook Chapter 2, Sections 2.1 and 2.2 Details in Chapter 20 & 21
3	**Cryptographic Tools:** Public Key Encryption **ASSIGNMENT # 1**	Textbook Chapter 2, Section 2.3 Details in Chapter 21
4	**Cryptographic Tools:** Digital Signatures and Key Management	Textbook Chapter 2, Sections 1.1 and 1.2
5	**User Authentication:** Digital User Authentication Principles, Password based authentication **ASSIGNMENT # 2**	Textbook Chapter 3, Sections 3.1 to 3.6
MIDTERM-I EXAM		

6	**User Authentication:** Token-based, and Biometric authentication and related security issues	Textbook Chapter 3, Sections 3.1 to 3.6
7	**Access Control**: Principles, Discretionary Access Control, Role-based Access Control and Attribute based Access Control **ASSIGNMENT # 3**	Textbook Chapter 4, Sections 4.1 to 4.7
8	**Database Security:** Need, SQL Injection Attacks, Database Access Control and Database Encryption	Textbook Chapter 5, Sections 5.1 to 5.7
9	**Malicious Software:** Types, Propagation, Payload, and Countermeasures **ASSIGNMENT # 4**	Textbook Chapter 6, Sections 6.1 to 6.10
MIDTERM-II EXAM		

10	**Intrusion Detection**: Basics, Types and Examples	Textbook Chapter 8, Sections 8.1 to 8.6
11	**Firewalls and Intrusion Prevention**: Basics, Types, and Prevention Systems	Textbook Chapter 9, Sections 9.1 to 9.3 and 9.6
12	**Software Security:** Software Vulnerabilities and Protection Mechanisms	Textbook Chapter 11, Sections 11.1 to 11.3
13	**IT Security Management and Risk Assessment:** security policies, policy formation and enforcement, risk assessment	Textbook Chapter 14, Sections 14.1 to 14.3
14	**Legal and Ethical Aspects:** Cybercrime, Intellectual Property, Privacy and Anonymity of Data and Ethical Issues. **PROJECT SUBMISSION**	Textbook Chapter 14, Sections 19.1 to 19.4
15	**Topics of Current Interests (Research Topics)** **PROJECT PRESENTATIONS**	IEEE/ ACM and other digital libraries
	END-TERM EXAM	

Assessment Instruments with Weights (homework, quizzes, midterms, final, programming assignments, lab work, etc.)	Labs / Assignments – 10% (minimum 4 Assignments) Project – 10% Mid-Term 1 Exam – 15% Mid-Term 2 Exam – 15% End-Term Exam – 50%

Textbook (or **Laboratory Manual** for Laboratory Courses)	1– Computer Security, Principles and Practice, William Stallings, 4th Edition, Pearson Publication, 2018 (Main Textbook for Theory) 2- Computer and Internet Security, A Hands-On Approach, Wenliang Du, 3rd Edition, Create Space Publications, 2022 (for labs)

Late Submission & Plagiarism Policy Policy	Deadlines are meant to be strictly followed. Any late submission (without and valid reason and justification/ evidence) will be penalized. **The penalty will be 50%. Any delay of more than a week would mean ZERO credit in that particular assessment (assignments, labs, project). Plagiarized assignment will get you ZERO credit.**

CHAPTER 1

OVERVIEW

LEARNING OBJECTIVES

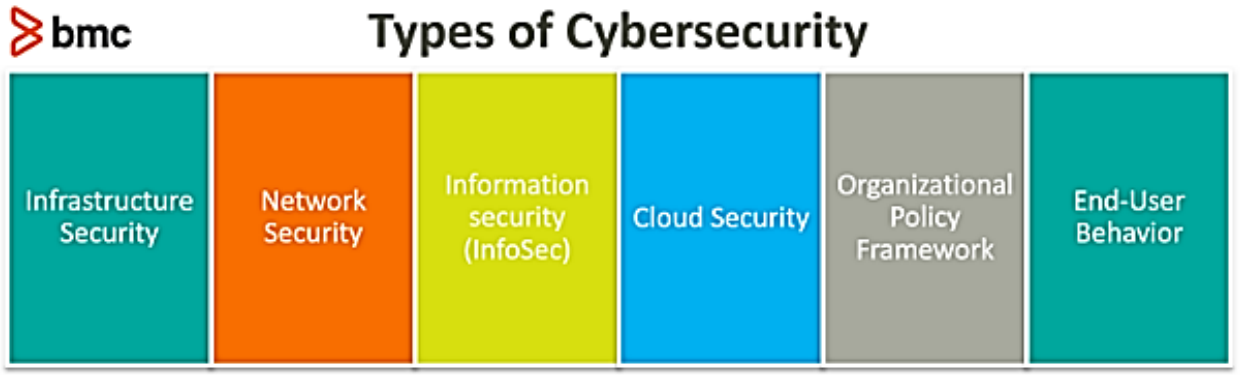
After studying this chapter, you should be able to:

- Describe the key security requirements of confidentiality, integrity, and availability.
- Discuss the types of security threats and attacks that must be dealt with and give examples of the types of threats and attacks that apply to different categories of computer and network assets.
- Summarize the functional requirements for computer security.
- Explain the fundamental security design principles.
- Discuss the use of attack surfaces and attack trees.
- Understand the principle aspects of a comprehensive security strategy.

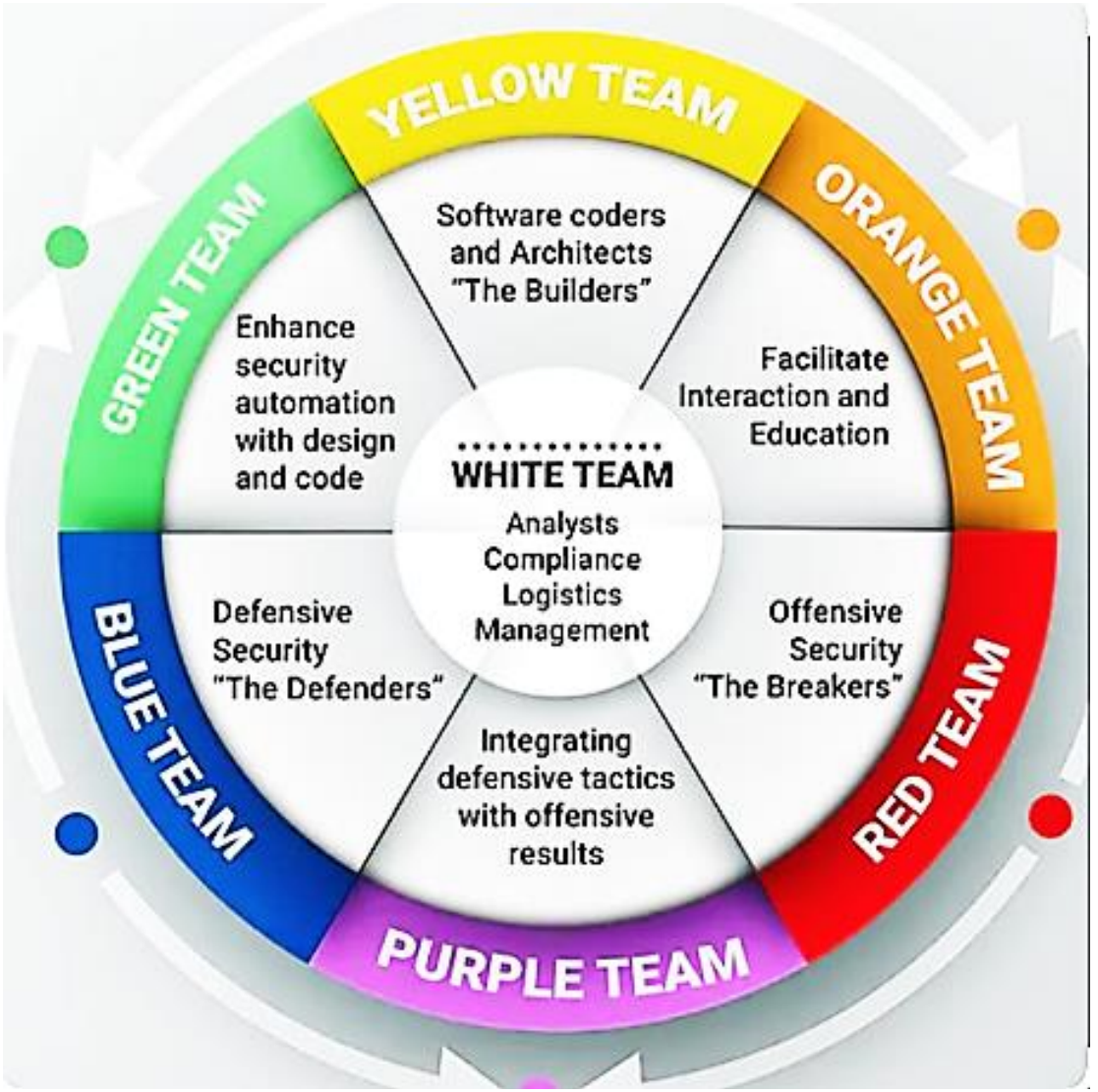
A Definition of Computer Security

The NIST Internal/Interagency Report NISTIR 7298 (*Glossary of Key Information Security Terms*, May 2013) defines the term *computer security* as follows:

Computer Security: Measures and controls that ensure confidentiality, integrity, and availability of information system assets including hardware, software, firmware, and information being processed, stored, and communicated.



- Information security
- Infrastructure Hardware (CPU + Box)
- Application Security
- OS security
- Network Security (Router, Switches, + Boxes)

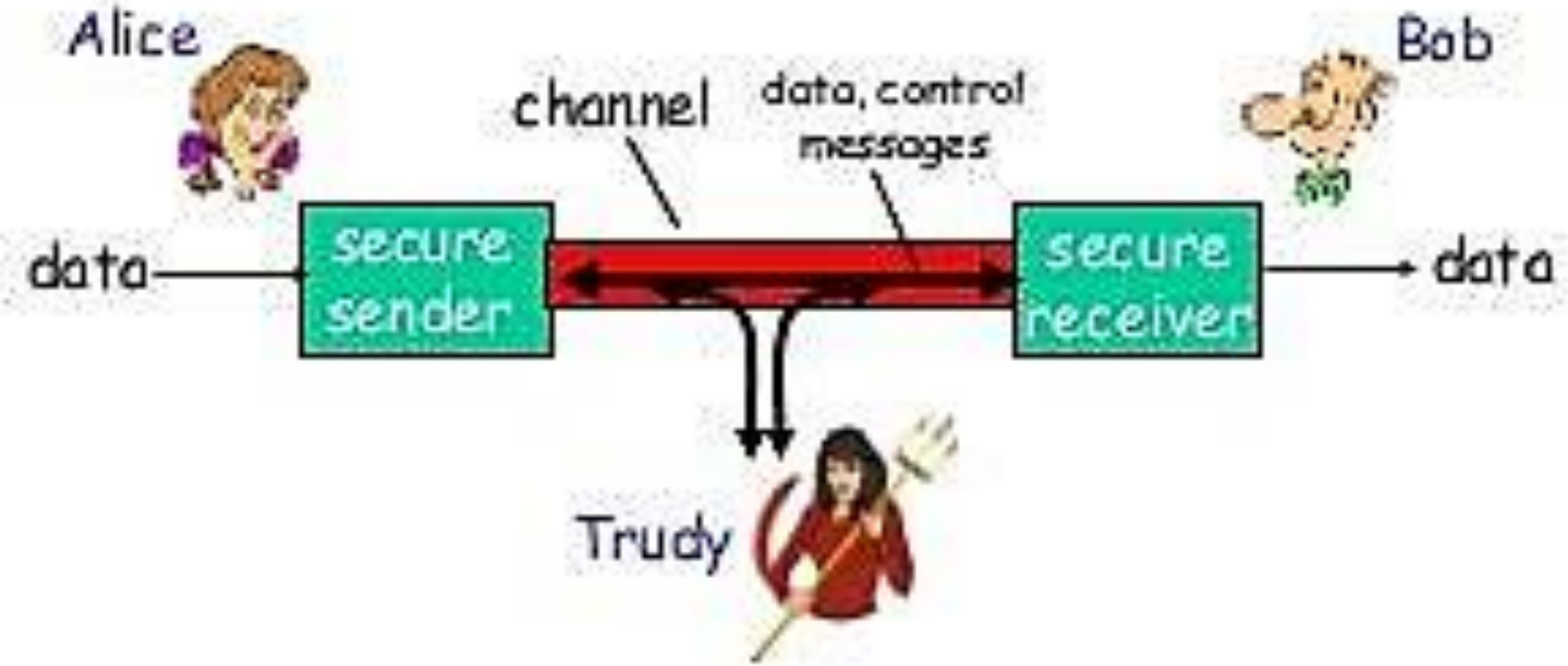


This definition introduces three key objectives that are at the heart of computer security:

- **Confidentiality:** This term covers two related concepts:
  - **Data confidentiality:**[1] Assures that private or confidential information is not made available or disclosed to unauthorized individuals.
  - **Privacy:** Assures that individuals control or influence what information related to them may be collected and stored and by whom and to whom that information may be disclosed.
- **Integrity:** This term covers two related concepts:
  - **Data integrity:** Assures that information and programs are changed only in a specified and authorized manner.
  - **System integrity:** Assures that a system performs its intended function in an unimpaired manner, free from deliberate or inadvertent unauthorized manipulation of the system.
- **Availability:** Assures that systems work promptly and service is not denied to authorized users.

Friends and enemies: Alice, Bob, Trudy

- well-known in network security world
- Bob, Alice want to communicate "securely"
- Trudy (intruder) may intercept, delete, add messages



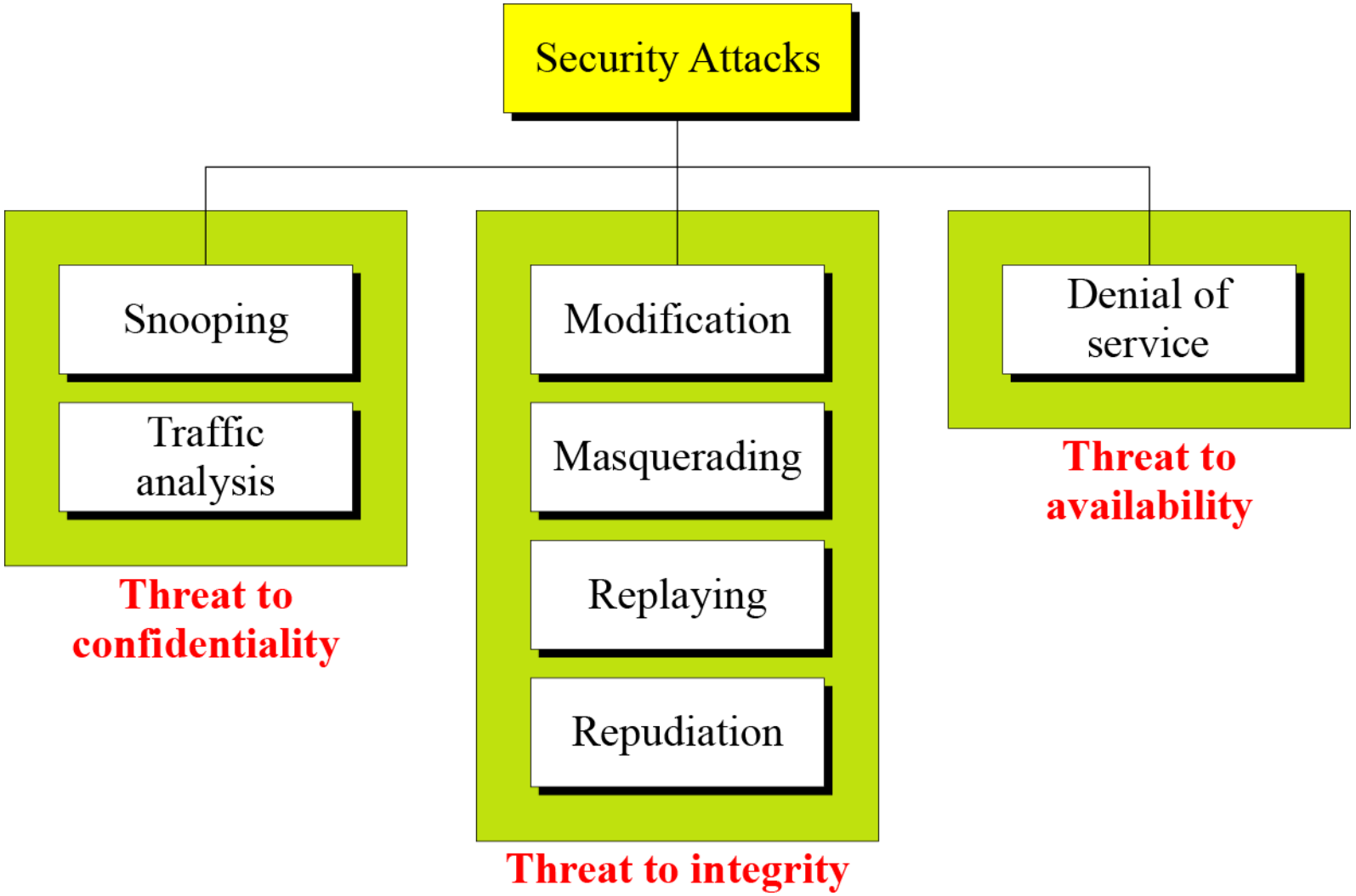
CIA triad

- **Confidentiality:** Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information. A loss of confidentiality is the unauthorized disclosure of information.
- **Integrity:** Guarding against improper information modification or destruction, including ensuring information nonrepudiation and authenticity. A loss of integrity is the unauthorized modification or destruction of information.
- **Availability:** Ensuring timely and reliable access to and use of information. A loss of availability is the disruption of access to or use of information or an information system.

Security Attacks or Threats

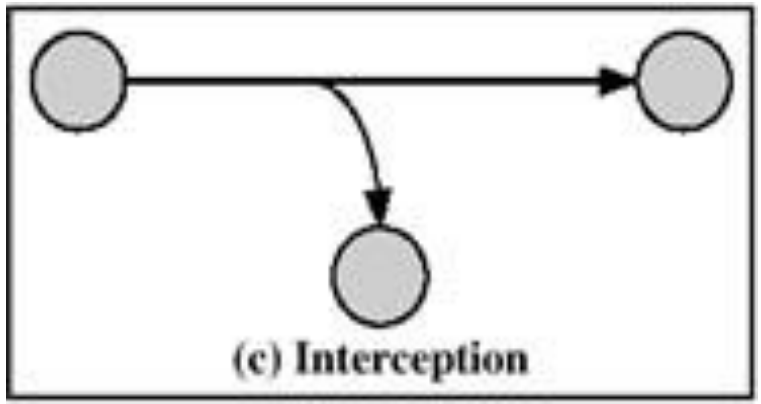
- An *attack* is an action that compromises the security (Confidentiality, Availability, Integrity) of information.
- A *threat* is a danger which could affect the security of information, leading to potential loss or damage.
- Often *attack & threat* are used interchangeably.

Security Attacks



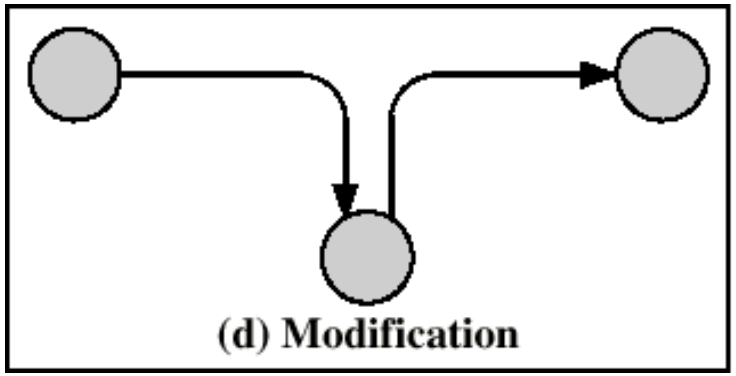
Attacks Threatening Confidentiality

- **Snooping** – unauthorized access to or interception of data.
- **Traffic Analysis** – Obtain some information by monitoring online traffic.

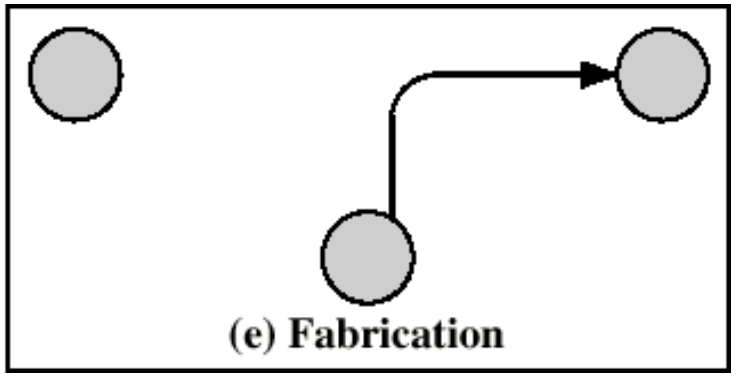


Attacks Threatening Integrity

- **Modification** – the attacker intercepts the message and changes it.
- **Masquerading** or **spoofing** happens when the attacker impersonates somebody else.



(d) Modification



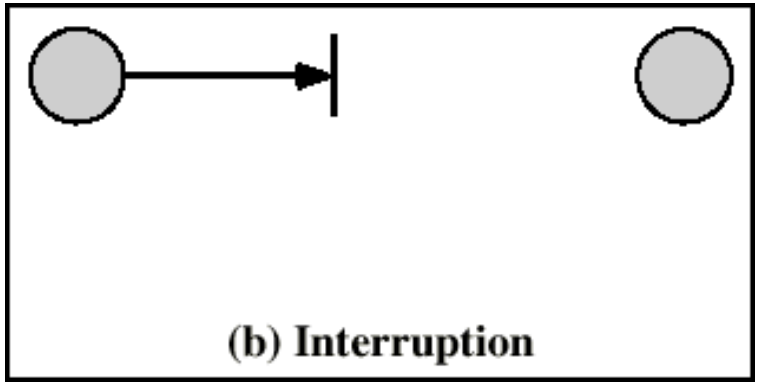
(e) Fabrication

Attacks Threatening Integrity

- **Replaying** – the attacker obtains a copy of a message sent by a user and later tries to replay it.
- **Repudiation**
  - sender of the message might later deny that she has sent the message;
  - the receiver of the message might later deny that he has received the message

Attacks Threatening Availability

- **Denial of service (DoS)** – It may slow down or totally interrupt the service of a system.



(b) Interruption

Passive vs. Active Attacks

- Passive attack:
  - attacker's goal is just to obtain
- information
  - the attack does not modify data or harm
- the system
  - difficult to detect
- Active attack:
  - may change the data or harm the system
  - easier to detect than to prevent

Passive vs. Active Attacks

Attacks	*Passive/Active*	*Threatening*
Snooping Traffic analysis	Passive	Confidentiality
Modification Masquerading Replaying Repudiation	Active	Integrity
Denial of service	Active	Availability

Lecture # 2

Two additional concepts are needed to present a complete picture

- **Authenticity:** The property of being genuine and being able to be verified and trusted; confidence in the validity of a transmission, a message, or message originator. This means verifying that users are who they say they are and that each input arriving at the system came from a trusted source.
- **Accountability:** The security goal that generates the requirement for actions of an entity to be traced uniquely to that entity. This supports nonrepudiation, deterrence, fault isolation, intrusion detection and prevention, and after-action recovery and legal action. Because truly secure systems are not yet an achievable goal, we must be able to trace a security breach to a responsible party. Systems must keep records of their activities to permit later forensic analysis to trace security breaches or to aid in transaction disputes.

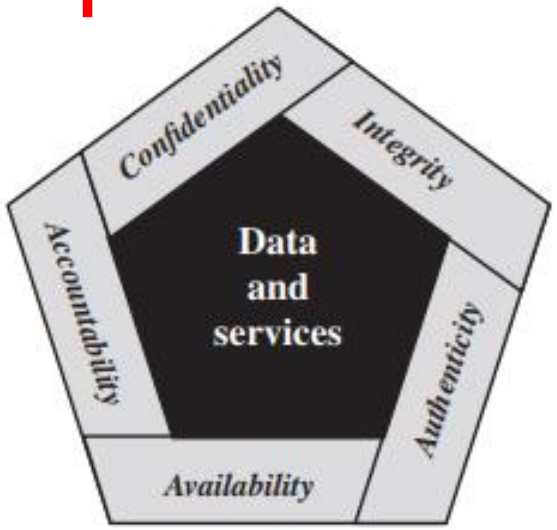


Figure 1.1 **Essential Network and Computer Security Requirements**

three levels of impact on organizations

- Low
- Moderate
- High

FIPS (**Federal Information Processing Standards**)

Real World Examples: Confidentiality, Integrity and Availability

Impact of Risk: Low Moderate High

Confidentiality Student grade information is an asset whose confidentiality is considered to be highly important by students. In the United States, the release of such information is regulated by the Family Educational Rights and Privacy Act (FERPA). Grade information should only be available to students, their parents, and employees that require the information to do their job. Student enrollment information may have a moderate confidentiality rating. While still covered by FERPA, this information is seen by more people on a daily basis, is less likely to be targeted than grade information, and results in less damage if disclosed. Directory information, such as lists of students or faculty or departmental lists, may be assigned a low confidentiality rating or indeed no rating. This information is typically freely available to the public and published on a school's website.

Real World Examples: Confidentiality, Integrity and Availability

INTEGRITY Several aspects of integrity are illustrated by the example of a hospital patient's allergy information stored in a database. The doctor should be able to trust that the information is correct and current. Now, suppose an employee (e.g., a nurse) who is authorized to view and update this information deliberately falsifies the data to cause harm to the hospital. The database needs to be restored to a trusted basis quickly, and it should be possible to trace the error back to the person responsible. Patient allergy information is an example of an asset with a high requirement for integrity. Inaccurate information could result in serious harm or death to a patient, and expose the hospital to massive liability.

An example of an asset that may be assigned a moderate level of integrity requirement is a website that offers a forum to registered users to discuss some specific topic. Either a registered user or a hacker could falsify some entries or deface the website. If the forum exists only for the enjoyment of the users, brings in little or no advertising revenue, and is not used for something important such as research, then potential damage is not severe. The Webmaster may experience some data, financial, and time loss.

An example of a low integrity requirement is an anonymous online poll. Many websites, such as news organizations, offer these polls to their users with very few safeguards. However, the inaccuracy and unscientific nature of such polls is well understood.

Real World Examples: Confidentiality, Integrity and Availability

AVAILABILITY The more critical a component or service is, the higher will be the level of availability required. Consider a system that provides authentication services for critical systems, applications, and devices. An interruption of service results in the inability for customers to access computing resources and staff to access the resources they need to perform critical tasks. The loss of the service translates into a large financial loss in lost employee productivity and potential customer loss.

An example of an asset that would typically be rated as having a moderate availability requirement is a public website for a university; the website provides information for current and prospective students and donors. Such a site is not a critical component of the university's information system, but its unavailability will cause some embarrassment.

An online telephone directory lookup application would be classified as a low availability requirement. Although the temporary loss of the application may be an annoyance, there are other ways to access the information, such as a hardcopy directory or the operator.

The Challenges of Computer Security

Computer security is both fascinating and complex. Some of the reasons are as follows:

1. Computer security is not as simple as it might first appear to the novice. The requirements seem to be straightforward; indeed, most of the major requirements for security services can be given self-explanatory one-word labels: confidentiality, authentication, nonrepudiation, and integrity. But the mechanisms used to meet those requirements can be quite complex, and understanding them may involve rather subtle reasoning.
2. In developing a particular security mechanism or algorithm, one must always consider potential attacks on those security features. In many cases, successful attacks are designed by looking at the problem in a completely different way, therefore exploiting an unexpected weakness in the mechanism.
3. Because of Point 2, the procedures used to provide particular services are often counterintuitive. Typically, a security mechanism is complex, and it is not obvious from the statement of a particular requirement that such elaborate measures are needed. Only when the various aspects of the threat are considered do elaborate security mechanisms make sense.
4. Having designed various security mechanisms, it is necessary to decide where to use them. This is true both in terms of physical placement (e.g., at what points in a network are certain security mechanisms needed) and in a logical sense [e.g., at what layer or layers of an architecture such as TCP/IP (Transmission Control Protocol/Internet Protocol) should mechanisms be placed].
5. Security mechanisms typically involve more than a particular algorithm or protocol. They also require that participants be in possession of some secret information (e.g., an encryption key), which raises questions about the creation, distribution, and protection of that secret information. There may also be a reliance on communications protocols whose behavior may complicate the task of developing the security mechanism. For example, if the proper functioning of the security mechanism requires setting time limits on the transit time of a message from sender to receiver, then any protocol or network that introduces variable, unpredictable delays may render such time limits meaningless.
6. Computer security is essentially a battle of wits between a perpetrator who tries to find holes, and the designer or administrator who tries to close them. The great advantage that the attacker has is that he or she need only find a single weakness, while the designer must find and eliminate all weaknesses to achieve perfect security.
7. There is a natural tendency on the part of users and system managers to perceive little benefit from security investment until a security failure occurs.
8. Security requires regular, even constant monitoring, and this is difficult in today's short-term, overloaded environment.
9. Security is still too often an afterthought to be incorporated into a system after the design is complete, rather than being an integral part of the design process.
10. Many users and even security administrators view strong security as an impediment to efficient and user-friendly operation of an information system or use of information.

A Model for Computer Security

We start with the concept of a **system resource** or **asset**, that users and owners wish to protect. The assets of a computer system can be categorized as follows:

- **Hardware:** Including computer systems and other data processing, data storage, and data communications devices.
- **Software:** Including the operating system, system utilities, and applications.
- **Data:** Including files and databases, as well as security-related data, such as password files.
- **Communication facilities and networks:** Local and wide area network communication links, bridges, routers, and so on.

A Model for Computer Security

In the context of security, our concern is with the **vulnerabilities** of system resources. [NRC02] lists the following general categories of vulnerabilities of a computer system or network asset:

- The system can be **corrupted**, so it does the wrong thing or gives wrong answers. For example, stored data values may differ from what they should be because they have been improperly modified.
- The system can become **leaky**. For example, someone who should not have access to some or all of the information available through the network obtains such access.
- The system can become **unavailable** or very slow. That is, using the system or network becomes impossible or impractical.

These three types of vulnerability correspond to the concepts of integrity, confidentiality, and availability

A Model for Computer Security

Corresponding to the various types of vulnerabilities to a system resource are **threats** that are capable of exploiting those vulnerabilities. A threat represents a potential security harm to an asset. An **attack** is a threat that is carried out (threat action) and, if successful, leads to an undesirable violation of security, or threat consequence. The agent carrying out the attack is referred to as an attacker or **threat agent**. We can distinguish two types of attacks:

- **Active attack:** An attempt to alter system resources or affect their operation.
- **Passive attack:** An attempt to learn or make use of information from the system that does not affect system resources.

We can also classify attacks based on the origin of the attack:

- **Inside attack:** Initiated by an entity inside the security perimeter (an "insider"). The insider is authorized to access system resources but uses them in a way not approved by those who granted the authorization.
- **Outside attack:** Initiated from outside the perimeter, by an unauthorized or illegitimate user of the system (an "outsider"). On the Internet, potential outside attackers range from amateur pranksters to organized criminals, international terrorists, and hostile governments.

A Model for Computer Security

Finally, a **countermeasure** is any means taken to deal with a security attack. Ideally, a countermeasure can be devised to **prevent** a particular type of attack from succeeding. When prevention is not possible, or fails in some instance, the goal is to **detect** the attack then **recover** from the effects of the attack. A countermeasure may itself introduce new vulnerabilities. In any case, residual vulnerabilities may remain after the imposition of countermeasures. Such vulnerabilities may be exploited by threat agents representing a residual level of **risk** to the assets. Owners will seek to minimize that risk given other constraints.

Table 1.1 **Computer Security Terminology**

Adversary (threat agent)
Individual, group, organization, or government that conducts or has the intent to conduct detrimental activities.

Attack
Any kind of malicious activity that attempts to collect, disrupt, deny, degrade, or destroy information system resources or the information itself.

Countermeasure
A device or techniques that has as its objective the impairment of the operational effectiveness of undesirable or adversarial activity, or the prevention of espionage, sabotage, theft, or unauthorized access to or use of sensitive information or information systems.

Risk
A measure of the extent to which an entity is threatened by a potential circumstance or event, and typically a function of 1) the adverse impacts that would arise if the circumstance or event occurs; and 2) the likelihood of occurrence.

Security Policy
A set of criteria for the provision of security services. It defines and constrains the activities of a data processing facility in order to maintain a condition of security for systems and data.

System Resource (Asset)
A major application, general support system, high impact program, physical plant, mission critical system, personnel, equipment, or a logically related group of systems.

Threat
Any circumstance or event with the potential to adversely impact organizational operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, or the Nation through an information system via unauthorized access, destruction, disclosure, modification of information, and/or denial of service.

Vulnerability
Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited or triggered by a threat source.

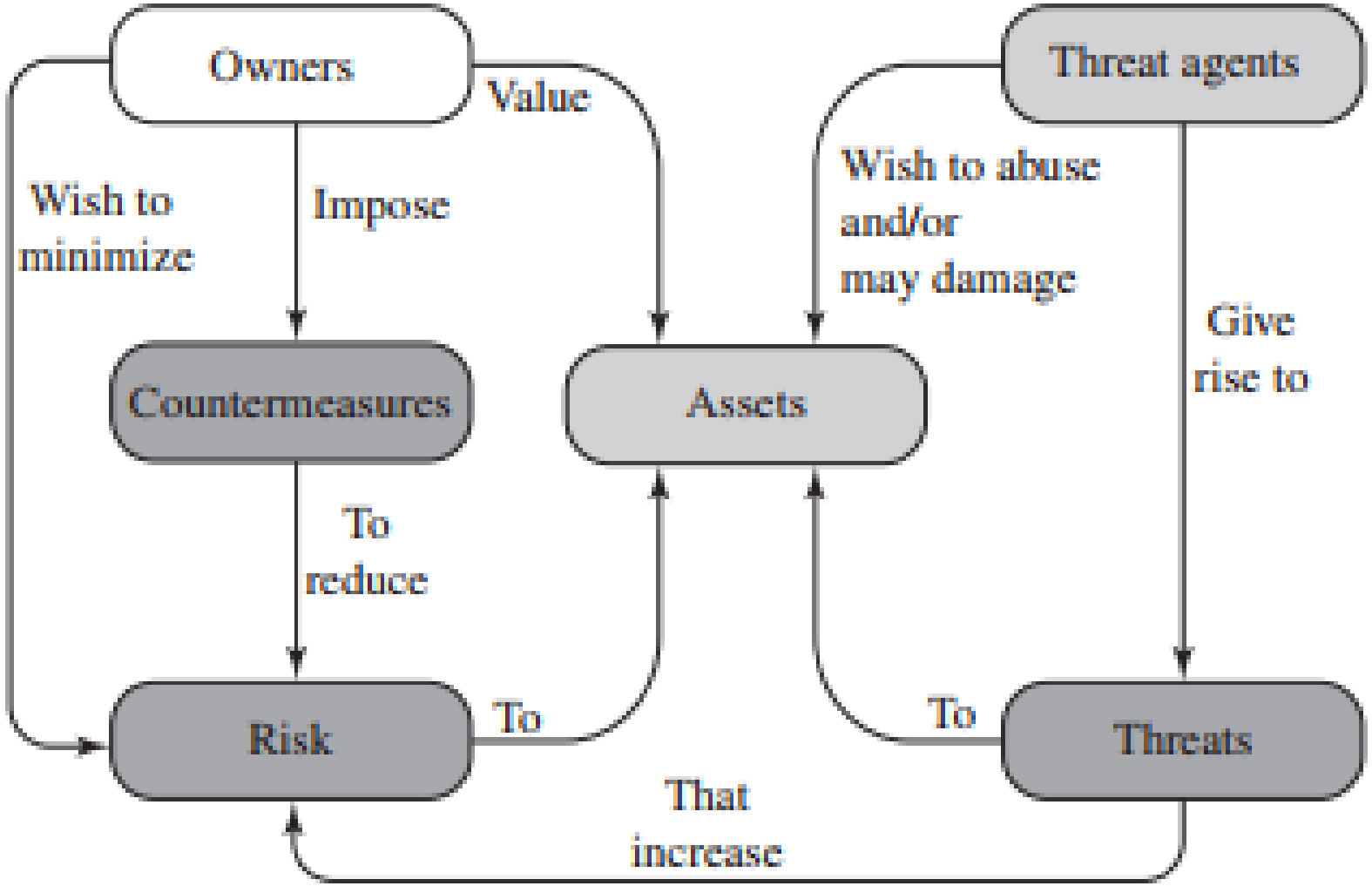


Figure 1.2 Security Concepts and Relationships

Table 1.2 **Threat Consequences, and the Types of Threat Actions that Cause Each Consequence**

Threat Consequence	Threat Action (Attack)
Unauthorized Disclosure A circumstance or event whereby an entity gains access to data for which the entity is not authorized.	**Exposure:** Sensitive data are directly released to an unauthorized entity. **Interception:** An unauthorized entity directly accesses sensitive data traveling between authorized sources and destinations. **Inference:** A threat action whereby an unauthorized entity indirectly accesses sensitive data (but not necessarily the data contained in the communication) by reasoning from characteristics or by-products of communications. **Intrusion:** An unauthorized entity gains access to sensitive data by circumventing a system's security protections.
Deception A circumstance or event that may result in an authorized entity receiving false data and believing it to be true.	**Masquerade:** An unauthorized entity gains access to a system or performs a malicious act by posing as an authorized entity. **Falsification:** False data deceive an authorized entity. **Repudiation:** An entity deceives another by falsely denying responsibility for an act.
Disruption A circumstance or event that interrupts or prevents the correct operation of system services and functions.	**Incapacitation:** Prevents or interrupts system operation by disabling a system component. **Corruption:** Undesirably alters system operation by adversely modifying system functions or data. **Obstruction:** A threat action that interrupts delivery of system services by hindering system operation.
Usurpation A circumstance or event that results in control of system services or functions by an unauthorized entity.	**Misappropriation:** An entity assumes unauthorized logical or physical control of a system resource. **Misuse:** Causes a system component to perform a function or service that is detrimental to system security.

Source: Based on RFC 4949

Lecture # 3

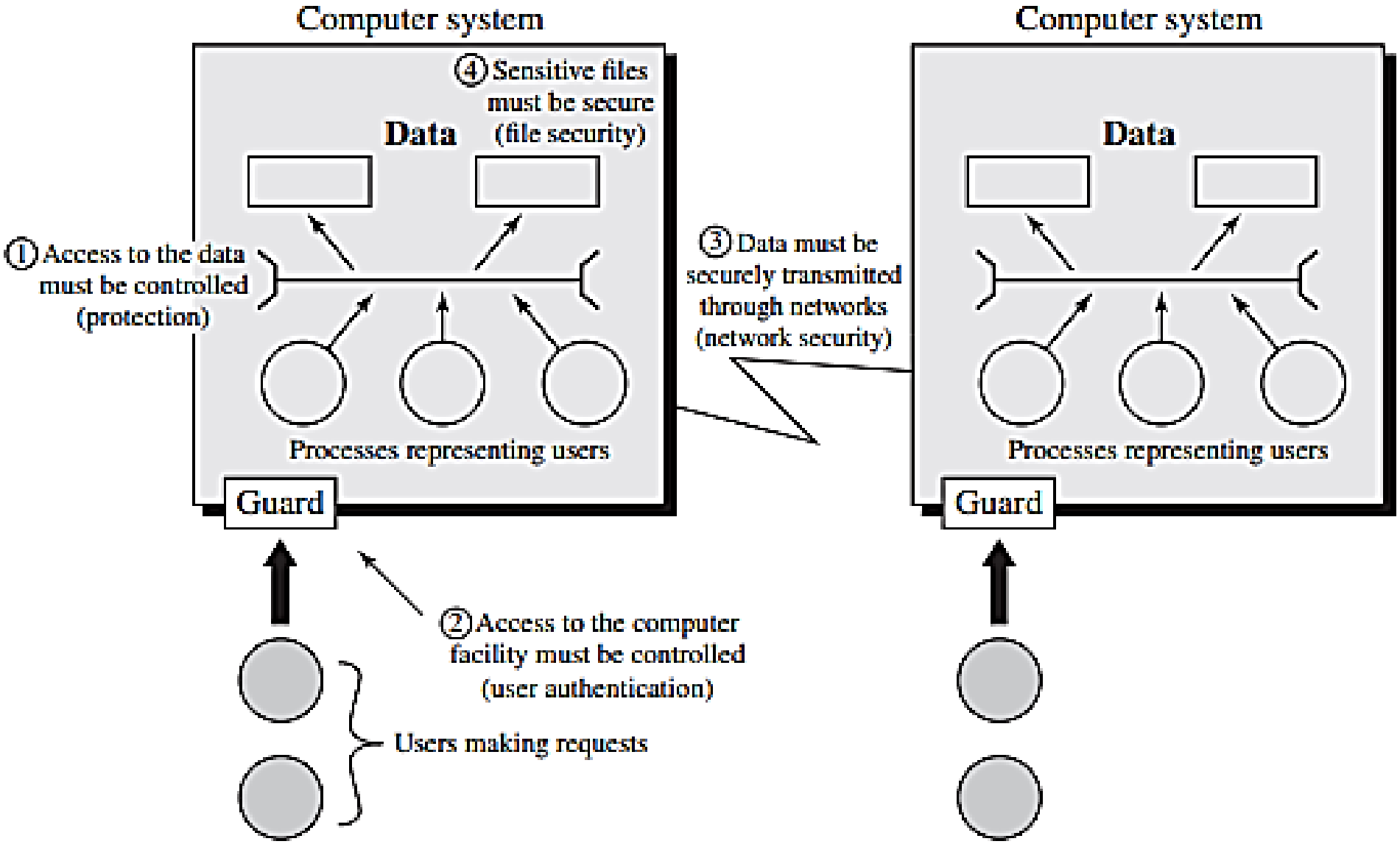


Figure 1.3 **Scope of Computer Security**

Note: This figure depicts security concerns other than physical security, including controlling of access to computers systems, safeguarding of data transmitted over communications systems, and safeguarding of stored data.

Table 1.3 **Computer and Network Assets, with Examples of Threats**

	Availability	Confidentiality	Integrity
Hardware	Equipment is stolen or disabled, thus denying service.	An unencrypted USB drive is stolen.	
Software	Programs are deleted, denying access to users.	An unauthorized copy of software is made.	A working program is modified, either to cause it to fail during execution or to cause it to do some unintended task.
Data	Files are deleted, denying access to users.	An unauthorized read of data is performed. An analysis of statistical data reveals underlying data.	Existing files are modified or new files are fabricated.
Communication Lines and Networks	Messages are destroyed or deleted. Communication lines or networks are rendered unavailable.	Messages are read. The traffic pattern of messages is observed.	Messages are modified, delayed, reordered, or duplicated. False messages are fabricated.

1.4 FUNDAMENTAL SECURITY DESIGN PRINCIPLES

Despite years of research and development, it has not been possible to develop security design and implementation techniques that systematically exclude security flaws and prevent all unauthorized actions. In the absence of such foolproof techniques, it is useful to have a set of widely agreed design principles that can guide the development of protection mechanisms. The National Centers of Academic Excellence in Information Assurance/Cyber Defense, which is jointly sponsored by the U.S. National Security Agency and the U. S. Department of Homeland Security, list the following as fundamental security design principles [NCAE13]:

- Economy of mechanism
- Fail-safe defaults
- Complete mediation
- Open design
- Separation of privilege
- Least privilege
- Least common mechanism
- Psychological acceptability
- Isolation
- Encapsulation
- Modularity
- Layering
- Least astonishment

1.6 COMPUTER SECURITY STRATEGY

We conclude this chapter with a brief look at the overall strategy for providing computer security. [LAMP04] suggests that a comprehensive security strategy involves three aspects:

- **Specification/policy:** What is the security scheme supposed to do?
- **Implementation/mechanisms:** How does it do it?
- **Correctness/assurance:** Does it really work?

1.7 STANDARDS

- **National Institute of Standards and Technology:** NIST is a U.S. federal agency that deals with measurement science, standards, and technology related to U.S. government use and to the promotion of U.S. private sector innovation. Despite its national scope, NIST Federal Information Processing Standards (FIPS) and Special Publications (SP) have a worldwide impact.

- **ITU-T:** The International Telecommunication Union (ITU) is a United Nations agency in which governments and the private sector coordinate global telecom networks and services. The ITU Telecommunication Standardization Sector (ITU-T) is one of the three sectors of the ITU. ITU-T's mission is the production of standards covering all fields of telecommunications. ITU-T standards are referred to as Recommendations.

- **Internet Society:** ISOC is a professional membership society with worldwide organizational and individual membership. It provides leadership in addressing issues that confront the future of the Internet, and is the organization home for the groups responsible for Internet infrastructure standards, including the Internet Engineering Task Force (IETF) and the Internet Architecture Board (IAB). These organizations develop Internet standards and related specifications, all of which are published as Requests for Comments (RFCs).

- **ISO:** The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from more than 140 countries. ISO is a nongovernmental organization that promotes the development of standardization and related activities with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological, and economic activity. ISO's work results in international agreements that are published as International Standards.