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CSE 543: Introduction to Computer Security
Module: Security Basics

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Acknowledgements: Some of the slides have been adopted from
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What is security?

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What does it mean for a system to be secure?
Write your own definition?

- Garfinkel and Spafford (1991)
  - "A computer is secure if you can depend on it and its software to behave as expected."
- Harrison, Ruzzo, Ullman (1978)
  - "Prevent access by unauthorized users"
- Not really satisfactory – does not truly capture that security speaks to the behavior of others
  - Expected by whom?
  - Under what circumstances?
  - What are the risks?

A Meta definition

A system is secure if it can maintain well-specified properties
in spite of the actions of well-specified adversaries.

- The set of properties we assume to be correct is called the trust model
- The set of adversaries (and their capability) is called the threat model
- Trust Model + Threat Model = Security Model
- The art and science of secure systems lies in properly identifying these properties, adversaries, and designing mechanisms that achieve this goal.

Example

- I've built a slack clone I call NittanyChat.

- I have designed NittanyChat so that an adversary who can read network packets of users cannot understand the content of the chat messages.

- Q: What are the trust and threat models?
- Q: Is Wolfchat secure if an adversary tries to inject their own messages?

Security Goals/Properties (C, I, A)

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- Confidentiality (secrecy, privacy)
  - only those who are authorized to know can know
- Integrity (also authenticity in communication)
  - only modified by authorized parties and in permitted ways
  - do things that are expected
- Availability
  - those authorized to access can get access

Confidentiality

- Prevent "unauthorized disclosure of information" (Stallings)
- Examples:
  - Keep Alice from reading Bob's files without permission
  - Keep Bob from knowing Alice has a file called ILoveBob.txt
  - Prevent Eve from reading Alice's network traffic
  - Prevent Steve from knowing whether Alice is a patient at a clinic

Integrity

- Prevent unauthorized modification of data (also config, code!)
- Examples:
  - Keep Alice from changing Bob's files without permission
  - Keep Bob from deleting Alice's file
  - Prevent Mallory from modifying Alice's network traffic
    - http://www.goat-simulator.com -> http://www.nastygoatsite.com
  - Prevent Bob from changing an important system binary
    - ls -> sl

Availability

- Prevent "disruption of access to or use of information or information system" (Stallings)
- Examples:
  - Keep Bob from deleting Alice's files
  - Prevent Mallory from crashing eecs.psu.edu
  - Prevent Dave from flooding Bob's computer with network requests

Assets: What we protect

- Assets are the items that we are trying to protect
  - Hardware Resources
  - Network Access
  - Operating Systems
  - Software
  - Data
  - Users
  - User Time
  - Money managed by system
  - Reputation

Risk

- At-risk valued resources that can be misused
  - Monetary
  - Data (loss or integrity)
  - Time
  - Confidence
  - Trust
- What does being misused mean?
  - Confidentiality
  - Integrity
  - Availability
  - Privacy (personal)
- Q: What is at stake in your life?

Principals

- Principals are expected system subjects
  - Computers, agents, people, enterprises, …
  - Depending on context referred to as: servers, clients, users, entities, hosts, routers, … - and some may be adversarial
  - Security is defined with respect to these subjects
    - Implication: every principal may have unique view
- A trusted third party
  - Trusted by all principals for some set of actions
  - Often used as introducer or arbiter

Adversary

- An adversary is any entity trying to circumvent the security infrastructure
  - The curious and otherwise generally clueless (e.g., script-kiddies)
  - Casual attackers seeking to understand systems
  - Venal people with an axe to grind
  - Malicious groups of largely sophisticated users (e.g, chaos clubs)
  - Competitors (industrial espionage)
  - Governments (seeking to monitor activities)

Are users adversaries?

- Have you ever tried to circumvent the security of a system you were authorized to access?
- Have you ever violated a security policy (knowingly or through carelessness)?

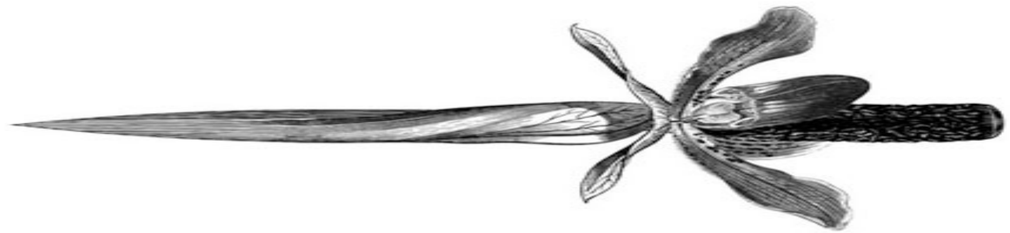
This is known as the insider adversary!

Thinking Like an Adversary

- Computer security experts think like an attacker all the time
  - "What can go wrong?"
  - "How can it go wrong?"
  - "What assumptions might not be correct?"
  - "How can I exploit the system?"

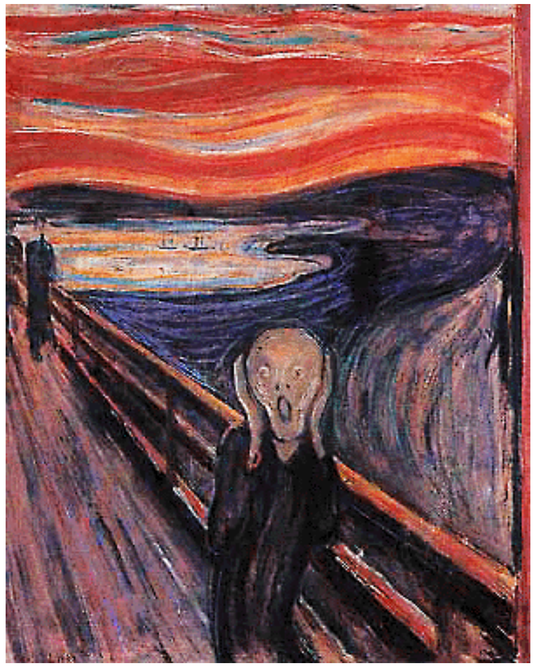
Threats

- A threat is a specific means by which an adversary can put a system at risk
  - An ability/goal of an adversary (e.g., eavesdrop, fraud, access denial)
  - Independent of what can be compromised
- A threat model is a collection of threats that deemed important for a particular environment
  - A collection of adversary(ies) abilities
  - E.g., a powerful adversary can read and modify all communications and generate messages on a communication channel
- Q: What were risks/threats in the introductory examples?
  - Slammer
  - Yale/Princeton
  - Estonia



Vulnerabilities (attack vectors)

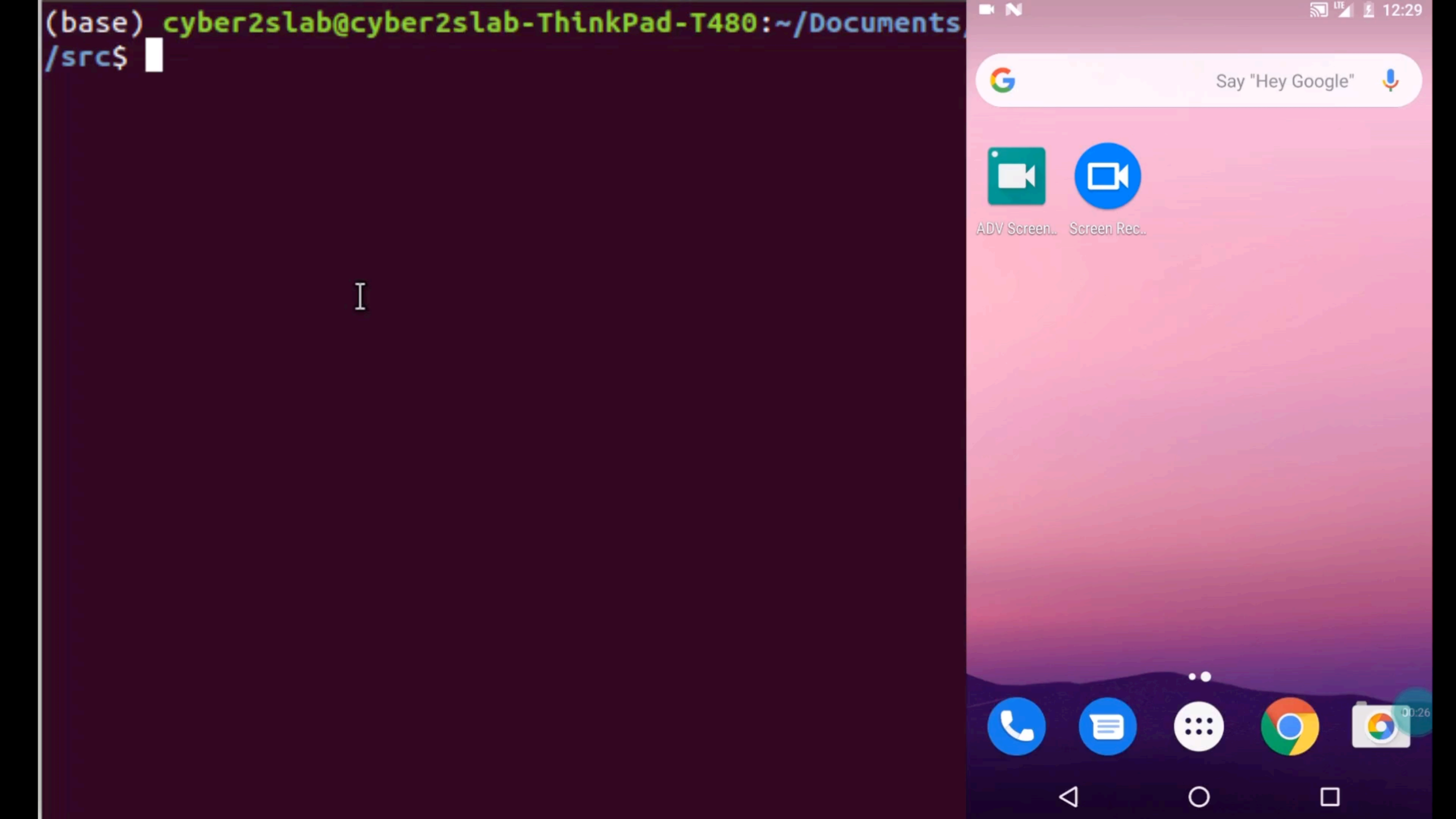
- A vulnerability is a flaw that is accessible to an adversary who can exploit that flaw
- E.g., buffer overflow, file open w/ adversary name
- What is the source of a vulnerability?
  - Bad software (or hardware)
  - Bad design, requirements
  - Bad policy/configuration
  - System Misuse
  - Unintended purpose or environment
    - E.g., student IDs for liquor store



Attacks

- An attack occurs when an adversary attempts to exploit a vulnerability
- Kinds of attacks
  - Passive (e.g., eavesdropping)
  - Active (e.g., password guessing)
  - Denial of Service (DOS)
    - Distributed DOS – using many endpoints

- A compromise occurs when an attack is successful
  - Typically associated with taking over/altering resources


(base) cyber2slab@cyber2slab-ThinkPad-T480:~/Documents/
/src$
12:29
Say "Hey Google"
ADV Screen..
Screen Rec..
00:26

Risk

- •Risk is often defined as

- $R = T * V * C$, where …
  - T = threat information (probability instantiated at a given time)
  - V = existence of vulnerabilities
  - C = cost of impact
- Sometimes just $R = P * C$
  - Where P = probability attacker is successful

Threat Model

- A Threat Model is a systematic identification of the threats a system faces
- One approach (from "Writing Secure Code"):
  - Brainstorm known threats
  - Rank the threats by risk (likelihood and impact)
  - Choose threat responses, techniques, and implementations
- VERY IMPORTANT
- If your threat model is wrong, you are vulnerable!
-

Threat Modeling (Academic Papers)

- Often called "Threat Model and Assumptions"
- Part 1 (the actual threat model)
  - Who are potential adversaries?
  - What are their goals and motivations?
  - What are their capabilities?
- Part 2 (actually a trust model --- defined in a few slides)
  - What is the Trusted Computing Base (TCB)
  - What other assumptions does the paper make?

Threat Modeling Approaches

- Diagram-driven
  - Architectural diagram
  - Data flow diagram
  - User workflow
  - Ask: what could go wrong?
- Attack Tree
  - Attacker goal at top
  - Branches are ways to get to the goal

- Checklists
  - From past experiences

- STRIDE
  - Spoofing
  - Tampering
  - Repudiation
  - Information disclosure
  - Denial of service
  - Escalation of privilege

Attack Archetypes

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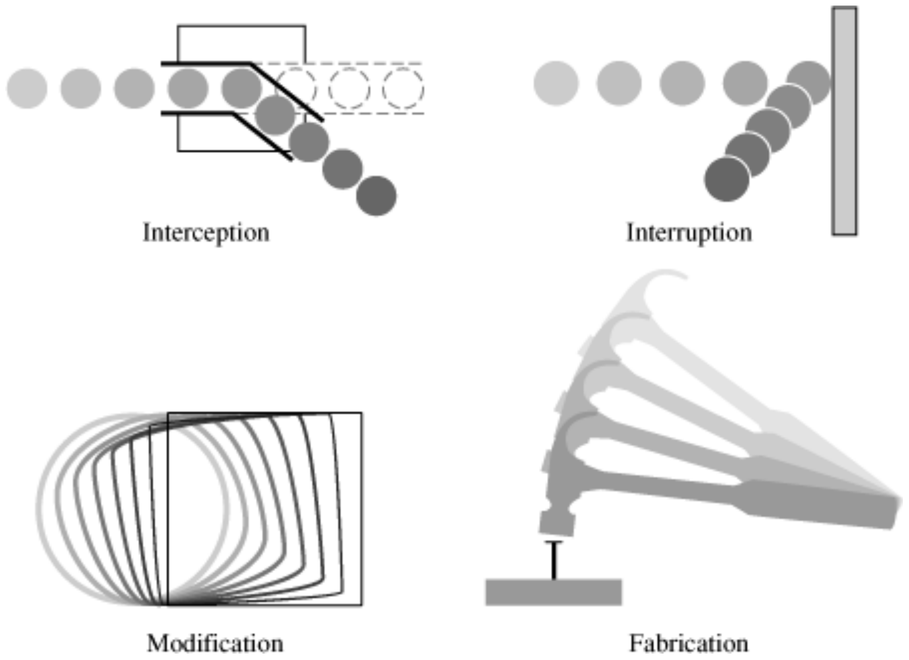
Attacks will typically fall into one of four "Archetypes":

- Interception — unauthorized access to an asset
- Modification — unauthorized changes to an asset
- Fabrication — creation of fake objects
  - Files, Messages, etc.
- Interruption — asset is "lost, unavailable, unusable"

Attach Archetypes

- Are these "archetypes" mutually exclusive?
- Does modification require interception?
- Can a victim detect interception?



Thinking Like a Defender

- Security Policy
- Threat Model
- Risk Assessment
- Countermeasures

Defenses

- Measures taken to reduce the potential or impact of an attack
- AKA "Controls" or "Countermeasures"
- There are Five Defense Archetypes:
  - Prevention — "block the attack or close the vulnerability" (P&P)
  - Deterrence — Make attack harder (but not impossible)
  - Deflection — Make target less desirable than others
  - Detection — Detect attack in progress (and try to do something about it)
  - Recovery — Assume attack and just plan to fix things later

Defenses

- Is prevention feasible?
- Can deflection be an effective strategy?
- Can we prevent/deter attacks that we can't detect?

Authentication

- Authentication means “Who are you?"
- Why is this an important security question?
- Why is it alone not enough?

Authorization

- Authorization means "What are you allowed to do?"
- Physical world examples?
- Can we have access control without authentication?

Trust

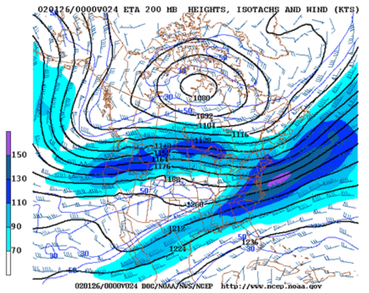
- Trust refers to the degree to which a principal is expected to behave
  - What the principal not expected to do?
    - E.g., not expose password
  - What the principal is expected to do (obligations)?
    - E.g., obtain permission, refresh
- A trust model describes, for a particular environment, who is trusted to do what?
- Note: you make trust decisions every day
  - Q: What are they?
  - Q: Whom do you trust?

Trusted vs. Trustworthy

- Trusted and trustworthy are often confused
- "A **trusted** system or component is one whose failure can break the security policy." (Anderson)
  - **Trusted Computing Base (TCB)** is the parts of the system you trust.
- "A trustworthy system or component is one that won't fail." (Anderson)

Security Model

- A security model is the combination of a trust and threat models that address the set of perceived risks
  - The "security requirements" used to develop some cogent and comprehensive design
  - Every design must have security model
    - LAN network or global information system
    - Java applet or operating system
- This class is going to talk a lot about security models
  - What are the security concerns (risks)?
  - Who are our adversaries?
  - What are the threats?
  - Who do we trust and to do what?
- Systems must be explicit to be secure.



A Security Model Example

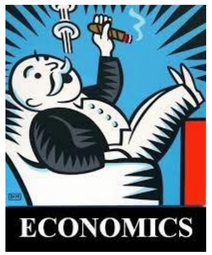
- Assume we have a University website that hosts courses through the web (e.g., Canvas)
  - Syllabus, other course information
  - Assignments submissions
  - Online grading

- In class: elements of the security model
  - Principals (Trusted)
  - Adversaries
  - Risks
  - Threats

Economics

- Security is practically always a cost
- This is one factor why computer systems are not assecure as they technologically could be
- Security potentially adds another point of failure in complex systems

- What are the costs of computer security?



Cost of Security

- Performance
  - Usability
  - Time
    - Developers, Sys Admins, Educators, Users
- Capital
  - HW Firewalls, Replace outdated devices, more servers to support load of encryption
- Services
  - DoS protection, AV subscriptions, Monitoring

The Security Mindset

- Thinking like an attacker
  - Understanding how to circumvent security
  - Look for where security can fall down
- Thinking like a defender
  - What are you defending and from whom
  - Weigh benefits vs. costs: No system is ever completely secure!

Reading papers …

- What is the purpose of reading research papers?
  - Purpose:
    - Get paper's contributions (what?)
    - Understand the techniques (how?)
    - Critically analyze the worthiness of the paper
    - Where it fits in to the existing body of knowledge
- How do you read research papers?

Understanding what you read

- Things you should be getting out of a paper
  - (Q1) What is the central idea proposed/explored in the paper?
    - Abstract
    - Introduction
    - Conclusions

    These are the best areas to find an overview of the contribution
  - Motivation: What is the problem being addressed?
  - (Q2) How does this work fit into others in the area?
    - Related work - often a separate section, sometimes not, every paper should detail the relevant literature. Papers that do not do this or do a superficial job are almost sure to be bad ones.
    - An informed reader should be able to read the related work and understand the basic approaches in the area, and why they do not solve the problem effectively

Understanding what you read (cont.)

- (Q3) What claims do the authors make? (examine the abstract, intro, conclusion for high-level claims, the "design/analysis" section for more precise claims)
- What scientific devices are the authors using to communicate their point?
  - Methodology - this is how they evaluate their solution.
    - Theoretical papers typically validate a model using mathematical arguments (e.g., proofs)
    - Experimental papers evaluate results based on a design of a test apparatus (e.g., measurements, data mining, synthetic workload simulation, trace-based simulation).
      - Empirical research evaluates by measurement.
    - Some papers have no evaluation at all, but argue the merits of the solution in prose (e.g., paper design papers)

Understanding what you read (cont.)

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- What do the authors claim?
  - Results - statement of new scientific discovery.
    - Typically some abbreviated form of the results will be present in the abstract, introduction, and/or conclusions.
    - Note: just because a result was accepted into a conference or journal does necessarily not mean that it is true. Always be circumspect.
- What should you remember about this paper?
  - Take away - what general lesson or fact should you take away from the paper.
  - Note that really good papers will have take-aways that are more general than the paper topic.

Summarize Thompson Article

- Contribution
- Motivation
- Related work
- Methodology
- Results
- Take away

A Sample Summary

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- Contribution: Ken Thompson shows how hard it is to trust the security of software in this paper. He describes an approach whereby he can embed a Trojan horse in a compiler that can insert malicious code on a trigger (e.g., recognizing a login program).
- Motivation: People need to recognize the security limitations of programming.
- Related Work: This approach is an example of a Trojan horse program. A Trojan horse is a program that serves a legitimate purpose on the surface, but includes malicious code that will be executed with it. Examples include the Sony/BMG rootkit: the program provided music legitimately, but also installed spyware.
- Methodology: The approach works by generating a malicious binary that is used to compile compilers. Since the compiler code looks OK and the malice is in the binary compiler compiler, it is difficult to detect.
- Results: The system identifies construction of login programs and miscompiles the command to accept a particular password known to the attacker.
- Take away: *What is the transcendent truth?????* (see next slide)

Coming Attractions

- Software security: Program vulnerabilities

Security Zen

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‘Powerdir’ New macOS Bug Let Hackers Accessed Unauthorized User Data Access

By **Balaji N** - January 12, 2022 0

A new macOS vulnerability has been detected recently by the security team of Microsoft that is tracked as “powerdir,” and this vulnerability is identified as CVE-2021-30970.

This security flaw allows any threat actors to bypass one of the crucial technologies of macOS, Transparency, Consent, and Control (TCC).

Evading the Transparency, Consent, and Control (TCC) technology of macOS means gaining unauthorized access to the protected data of macOS users.

‘Powerdir’ New macOS Bug Let Hackers Accessed Unauthorized User Data Access

January 12, 2022

Heap-overflow Vulnerability Affects Multiple VMware Products

January 6, 2022

Beware of Fake RedLine Stealer That Distributed As Fake Omicron Stats Counter

January 13, 2022

Acknowledgements

Acknowledgement: Materials for the class lectures are taken from Trent Jaeger (Penn State), Ninghui Li (Purdue), Christina Garman (Purdue), and William Enck (NCSU).

My Research Group SyNSec (Systems and Network Security) is hiring!