CENG 374E - INTRODUCTION TO COMPUTER SECURITY

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Malware and Software Vulnerability
Software Security

Overview

- What is software security ?
  - Understanding the role that software plays
    - in providing security
    - as source of insecurity
- Principles, methods & technologies to make software more secure
  - Practical experience with some of these
- Typical threats & vulnerabilities in software, and how to avoid them

Overview

- Software plays a major role in providing security, and is a major source of security problems
- Software security does not get much attention
  - In programming courses
    - Many future programmers have little training on software security
  - In software company's goal

Overview

- We focus on software security, but don’t forget that security is about many things:
  - people
    - human computer interaction, HCI
    - Attackers, users, employees, sys-admins, programmers
  - access control, passwords, biometrics
  - cryptology, protocols
  - Monitoring, auditing, risk management
  - Policy, legislation
  - public relations, public perception
  - ….

- Security Concepts and Goals

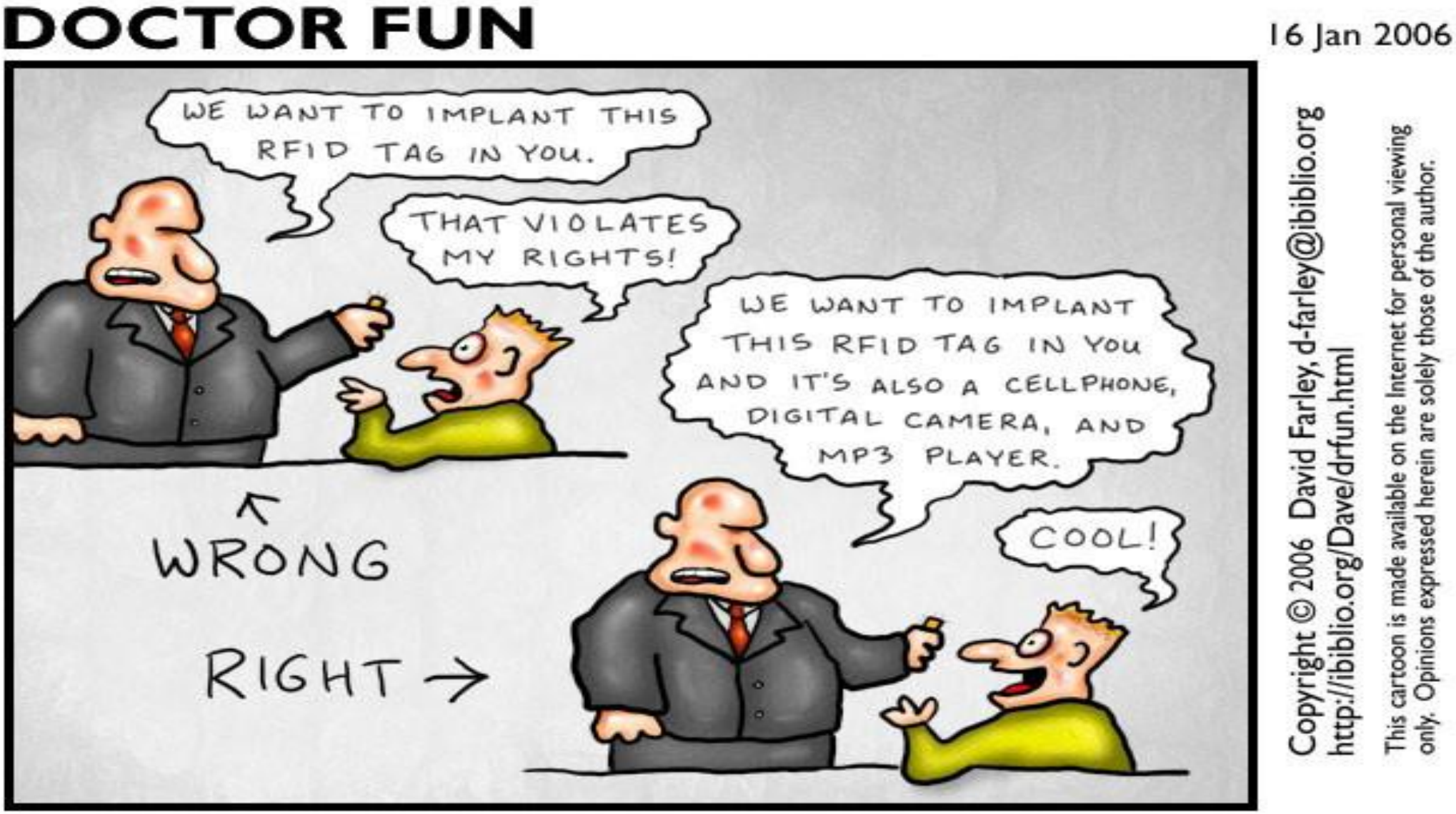
Software and Security

- Security is about *regulating access to assets*
  - E.g., information or functionality
- Software provides *functionality*
  - E.g., on-line exam results
- This functionality comes with certain *risks*
  - E.g., what are risks of on-line exam results?
    - Privacy (score leakage); Modification
- Software security is about *managing these risks*

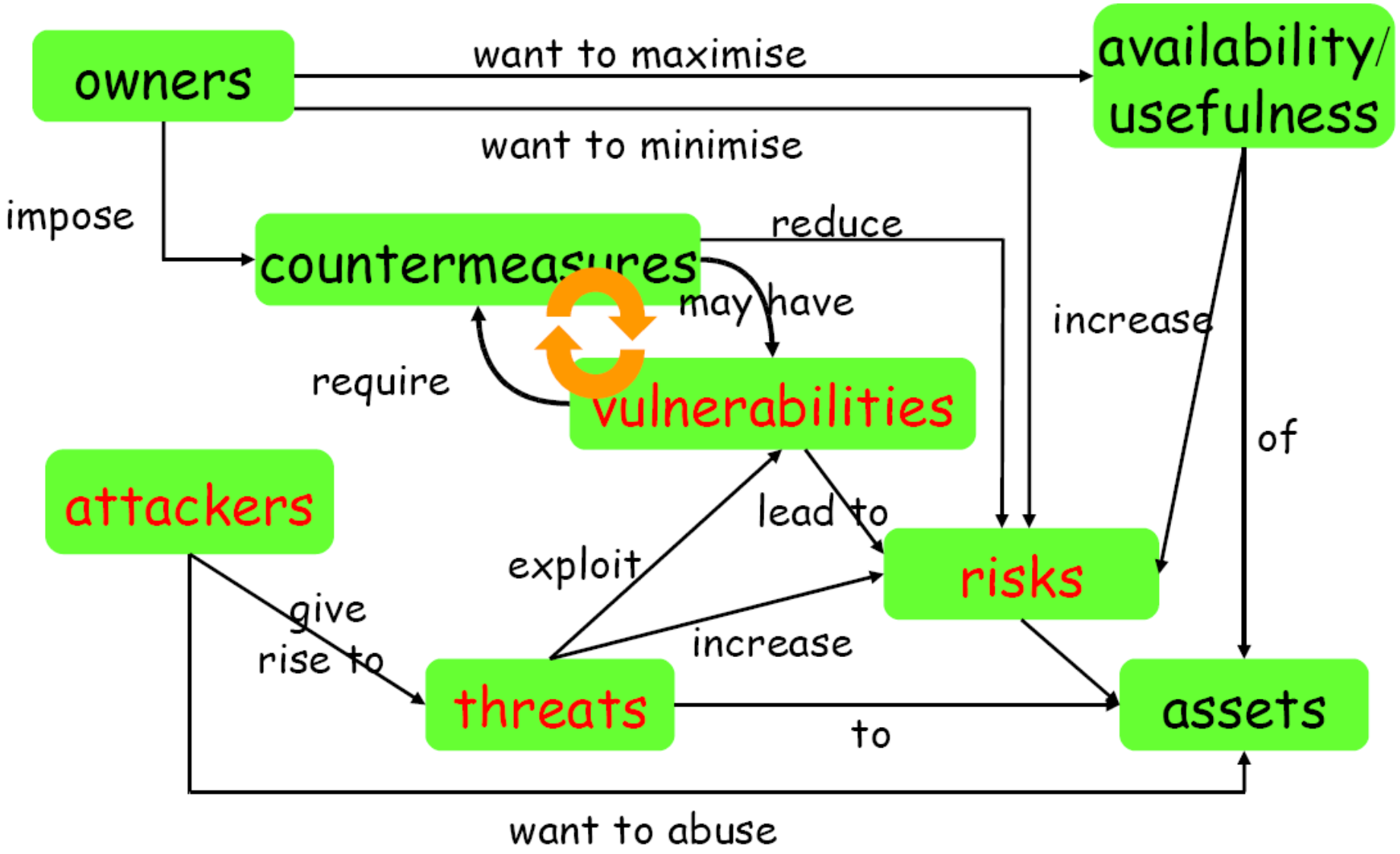
Software and Security

- Security is always a secondary concern
  - Primary goal of software is to provide functionalities or services
  - Managing associated risks is a derived/secondary concern
- There is often a trade-off/conflict between
  - security
  - functionality & convenience
- Security achievement is hard to evaluate when nothing bad happens

Functionality vs Security



Security Concept



Starting Point for Ensuring Security

- Any discussion of security should start with an inventory of
  - the stakeholders (owners, companies…)
  - their assets (data, service, customer info…)
  - the threats to these assets (erase, steal…)
  - Attackers
    - employees, clients, script kiddies, criminals
- Any discussion of security without understanding these issues is meaningless

Security Concepts

- Security is about imposing **countermeasures to reduce risks** to assets to acceptable levels
  - “Perfect security” is not necessary and costly
- A security policy is a specification of what security requirements/goals the countermeasures are intended to achieve
  - secure against what and from whom ?
- Security mechanisms to enforce the policy
  - What actions we should take under an attack?

Security Objectives: CIA

- Confidentiality (or secrecy)
  - unauthorized users cannot read information
- Integrity
  - unauthorized users cannot alter information
- Availability
  - authorized users can always access information

- Non-repudiation for accountability
  - authorized users cannot deny actions
- Others
  - Privacy, anonymity…

Security Goals

- The well-known trio
  - confidentiality, integrity, avaliability (CIA)
- There are more “concrete” goals
  - traceability and auditing (forensics)
  - monitoring (real-time auditing)
  - multi-level security
  - privacy & anonymity
  - …
- and meta-property
  - assurance – that the goals are met
    - “information assurance”

How to Realize Security Objectives? AAAA

- Authentication
  - who are you?
- Access control/Authorization
  - control who is allowed to do what
  - this requires a specification of who is allowed to do what
- Auditing
  - check if anything went wrong
- Action
  - if so, take action

How to Realize Security Objectives?

- Other names for the last three A's
  - Prevention
    - measures to stop breaches of security goals
  - Detection
    - measures to detect breaches of security goals
  - Reaction
    - measures to recover assets, repair damage, and persecute (and deter) offenders

- Good prevention does not make detection & reaction superfluous
  - E.g., breaking into any house with windows is trivial; despite this absence of prevention, detection & reaction still deter burglars

Threats vs Security Requirements

- information disclosure
  - confidentiality
- tampering with information
  - integrity
- denial-of-service (DoS)
  - availability
- spoofing
  - authentication
- unauthorized access
  - access control

Countermeasures

- Countermeasures can be non-IT related
  - physical security of building
  - screening of personnel
  - legal framework to deter criminals
  - training employee

- but we won’t consider these

Countermeasures and More Vulnerabilities

- Countermeasures can lead to new vulnerabilities
  - E.g., if we only allow three incorrect logins, as a countermeasure to brute-force attacks (account be frozen), which new vulnerability do we introduce?
    - **Denial of Service attack**
  - If a countermeasure relies on new software, bugs in this new software may mean
    - that it is ineffective, or
    - worse still, that it introduces more weaknesses
    - E.g., Witty worm appeared in Mar 2004 exploited ISS security software
      - http://en.wikipedia.org/wiki/Witty_%28computer_worm%29

Example: insecurities in SSH

- From www.cert.org/advisories for (Open)SSH
  - CA-2001-35 Recent Activity Against Secure Shell Daemon (Dec 13)
    - Multiple vulnerabilities in several implementations of SSH. ...
  - CA-2002-18 OpenSSH Vulnerability in challenge-response handling (Jun 26)
    - Vulnerabilities in challenge response handling code ...
  - CA-2002-23 Multiple Vulnerabilities in OpenSSH (July 30)
    - Four remotely exploitable buffer overflows in ...
  - CA-2002-24 Trojan Horse OpenSSH Distribution (Aug 1)
    - Some copies of the source code of OpenSSH package contain a Trojan horse.
  - CA-2002-36 Multiple Vulnerabilities in SSH Implementations (Dec 16)
    - Multiple vendors' implementations of SSH contain vulnerabilities...
  - CA-2003-24: Buffer Management Vulnerability in OpenSSH (Sept 16)
    - There is a remotely exploitable buffer overflow in versions of OpenSSH prior to 3.7. ...

Example: insecurities in SSH

- SSH was meant to provide security, namely as countermeasure against eavesdropping on network, but is a source of new vulnerabilities

- Crypto is not the cause of these vulnerabilities, and could not solve/prevent these vulnerabilities
  - Protocol, implementation errors (e.g., WEP in WiFi)
  - Programming errors (buffer overflow)
  - Distribution errors (trojan)

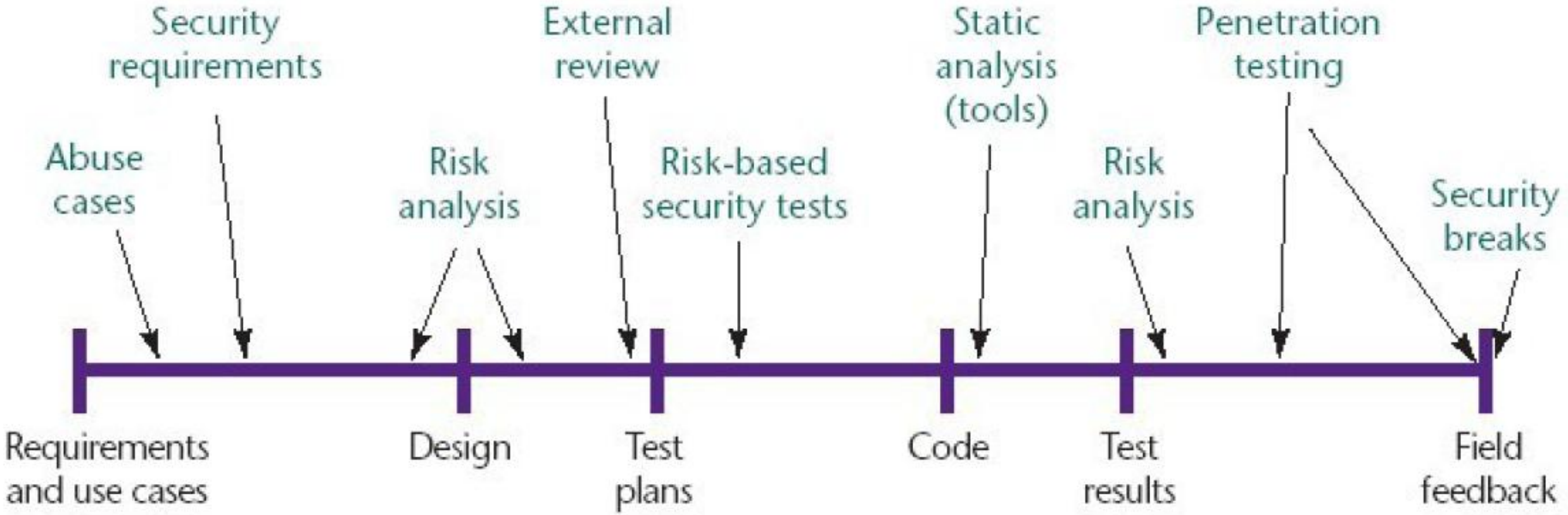
- Bruce Schneier: “Currently encryption is the strongest link we have. Everything else is worse: software, networks, people. There's absolutely no value in taking the strongest link and making it even stronger”

Software Security

Two Sides to Software Security

- What are the methods and technologies, available to us if we want to provide security?
  - security in the software development lifecycle
  - engineering & design principles
  - security technologies
- What are the methods and technologies available to the enemy who wants to break security ?
  - What are the threats and vulnerabilities we're up against?
  - What are the resources and tools available to attackers?

Security in Software Development Life Cycle



- Source: Gary McGraw, Software security, Security & Privacy Magazine, IEEE, Vol 2, No. 2, pp. 80-83, 2004.

Example Security Technologies

- Cryptography
  - for threats related to insecure communication and storage
  - Covered in other courses
- Access control
  - for threats related to misbehaving users
  - E.g., role-based access control
- Language-based security
  - for threats related to misbehaving programs
    - typing, memory-safety
    - sandboxing
  - E.g., Java, .NET/C#

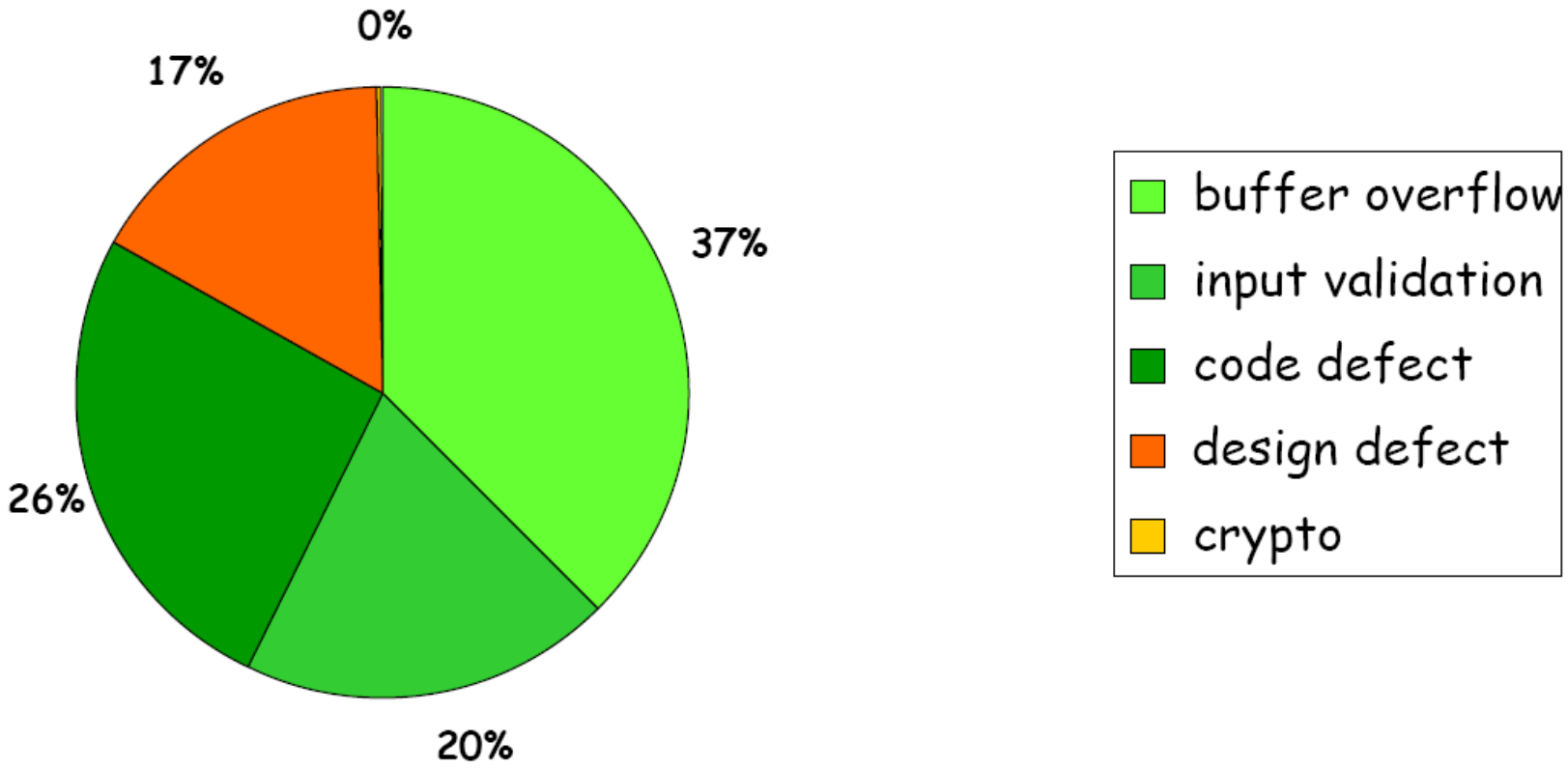
Example Security Technologies

- These technologies may be provided by the infrastructure/platform an application builds on,
  - networking infrastructure
    - which may e.g. use SSL
  - operating system or database system
    - providing e.g. access control
  - programming platform
    - for instance Java or .NET sandboxing
- Of course, software in such infrastructures implementing security has to be secure

Software Infrastructure

- Applications are built on top of "infrastructure" consisting of
  - operating system
  - programming language/platform/middleware
    - programming language itself
      - interface to CPU & RAM
    - libraries and APIs
      - interface to peripherals (socket, interrupt…)
      - provider of building blocks
  - other applications & utilities
    - E.g., database
- This infrastructure provides security mechanisms, but is also a source of insecurity

Typical Software Security Vulnerabilities



Security bugs found in Microsoft bug fix

Sources of Software Vulnerabilities

- Bugs in the application or its infrastructure
  - i.e. doesn't do what it should do
    - E.g., access flag can be modified by user input
- Inappropriate features in the infrastructure
  - i.e. does something that it shouldn't do
    - functionality winning over security
    - E.g., a search function that can display other users info
- Inappropriate use of features provided by the infrastructure

- Main causes:
  - complexity of these features
    - functionality winning over security, again
  - ignorance of developers

Functionality vs Security

Lost battles?

- operating systems
  - huge OS, with huge attack surface (API),
- programming languages
  - buffer overflows, format strings, ... in C
  - public fields in Java
  - lots of things in PHP
- webbrowsers
  - plug-ins for various formats, javascript, VBscript, ...
- email clients

Threat Modeling

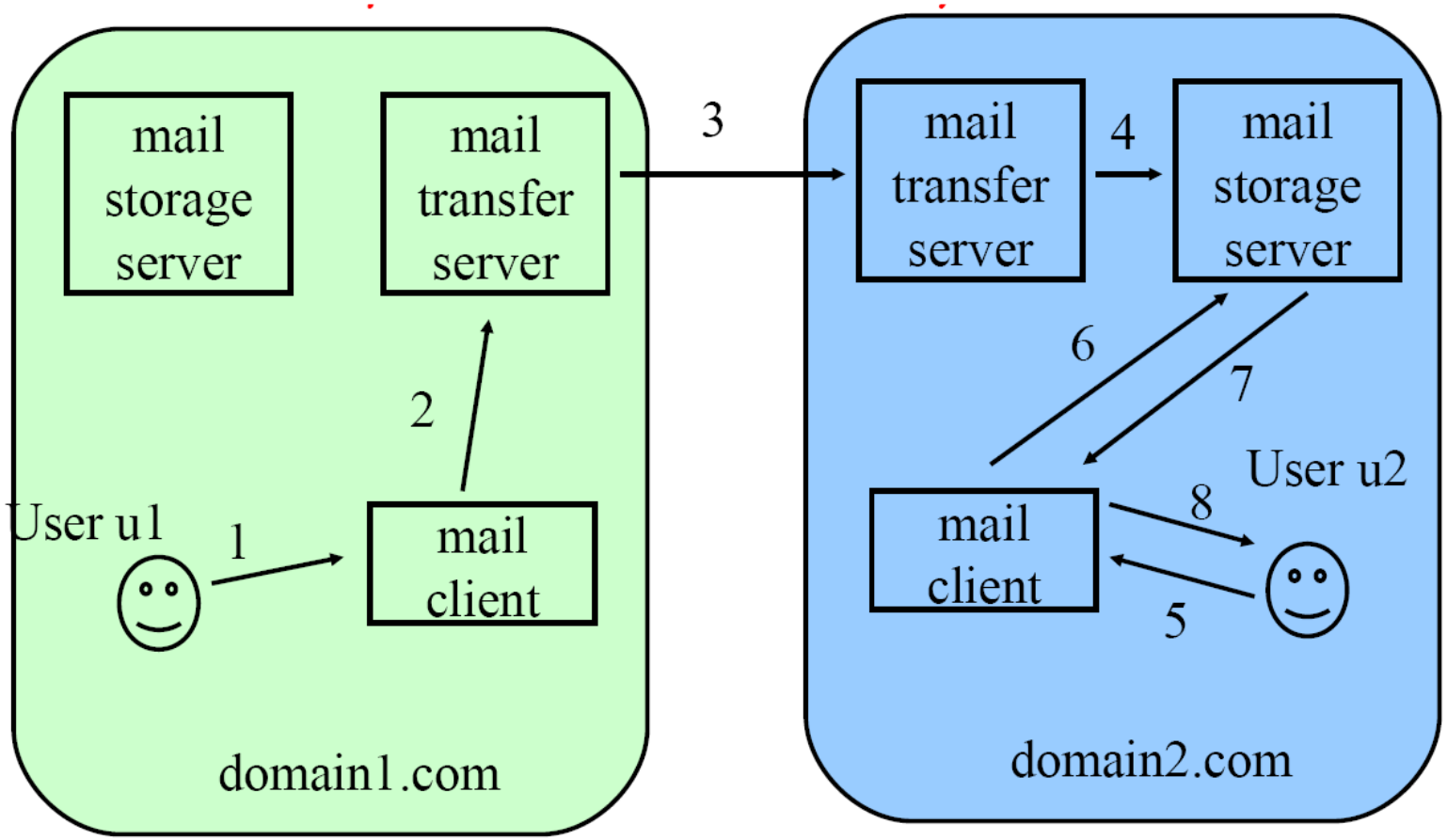
Threat Modeling

- Aka security/risk/requirements analysis
- A first step, not just for software
  - Identify assets & stakeholders
  - Consider architecture of application & its environment
  - Brainstorm about known threats
  - Define security assumptions
  - Rank threats by risk
    - ≈ impact x likelihood
  - Decide which threats to respond to
  - Decide how to mitigate these threats
    - which techniques & technologies

Example Techniques to Mitigate Threats

- Spoofing Identity
  - authentication, protect keys & passwords, ...
- Tampering with Data
  - access control, hashes, digital signatures, MACs (message authentication codes), write-once storage...
- Repudiation
  - logging, audit trails, digital signatures, ...
- Information Disclosure
  - access control, encryption, not storing secrets, ...
- Denial of Service
  - graceful degradation, filtering, increase server resources
- Elevation of Privilege
  - access control, sandboxing, ...

Example: Email System



Potential threats to the e-mail system

- Eavesdropping on e-mail
  - Communication over the Internet is relatively easy to eavesdrop
  - Hence, content of e-mail is by no means confidential
  - Critical information can be encrypted and in email attachment
- Modifying e-mail
  - Interception of the communication (e.g. between the two MTS's) allows an attacker to modify the e-mail
  - Hence, integrity of the e-mail is not guaranteed
- Spoofing e-mail
  - MTS blindly believes other MTS about who the sender of the e-mail is
  - Hence, no guarantee about the identity of the sender
- Attacks against the mail servers
  - Server is a "trusted software layer", making a limited functionality (sending/receiving mail) available to all clients
- Email as an attack dispersion channel

Attack Formats

- Spam
  - Marketer can send massive amounts of unsolicited e-mail
- Denial-of-service attacks
  - Amount of storage space on mail server can be exhausted by receiving too many very big e-mails
  - A mail server is slowed down by too many received emails
  - A client receives thousands of garbage emails and hence missing real email
- Phishing
  - Email clients trust received spoofed email
  - Give out their private data (e.g., back account) accordingly
    - Direct reply back
    - Input in a directed fake website
- Email malware
  - E-mail client is again a trusted software layer
  - Executable attachments make virus-spreading easy

Possible Defenses

- Many other threats
  - Privacy threat: detecting when an e-mail is read
  - Repudiation of sending: sender can deny having sent a message
  - Repudiation of receiving: receiver can deny having ever received a particular message
- Eavesdropping and modification
  - Can be countered by cryptographic techniques
- Spoofing
  - Can be countered by strong authentication protocols
- Attacks against servers
  - Can be countered by
    - Careful software coding
    - Clear access control model
    - Strong authentication
- However, email spam, phishing are hard to defend
  - Phishing: there are always users without security knowledge!

Vulnerabilities in Countermeasures

- Each of the discussed countermeasures can again have vulnerabilities:
  - Bad choice of cryptographic algorithm
  - Protocol design weakness
  - Implementation bug
  - …
  - Example: Witty worm
    - Compromise a class of security software from Internet Security Systems (ISS) now IBM Internet Security Systems installed on user computers
    - http://en.wikipedia.org/wiki/Witty_%28computer_worm%29