COMS W4182: Computer Security II

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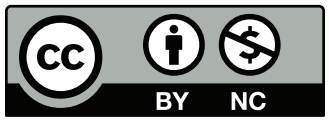
https://www.cs.columbia.edu/~smb/classes/s20



What is this Course?

- Security architecture
- Security engineering
- How to think about security
- ☞ How to think about insecurity. . .
- A successor to COMS W4181, Computer Security I

Who is this Course For?

- Primarily, security professionals
- Security architects, security reviewers, etc.
- (But 4181 is for all programmers)

Prerequisites

- COMS W4181 is a *prerequisite* for this class—I *assume* that you know the material in it
- However—in this very bureaucratic university, SSOL does not enforce prerequisites
- A prerequisite is a *warning*: you are expected to know the material
- I will not ask anyone if they've taken 4181 or not
- But—I will not review encryption algorithms, firewalls, etc.
- If you have any doubts, see me

Security Architecture

- How to put the pieces together
- How to spot the risky parts
- How to evaluate an architecture

Security Engineering

- Putting the pieces together
- Tradeoffs
- Balancing cost, security, usability, acceptability, and more

How to Think About Security

- Security is a property of the overall design
- You do *not* get security by sprinkling on crypto or by forcing people to change their passwords frequently
- Those can sometimes help—but bad guys go around strong security, not through it
- Security is a *systems property*

How to Think About Insecurity. . .

- The bad guys don't follow the rules
- To understand how to secure a system, you have to understand what sort of attacks are possible
- Note that that is *not* the same as actually launching them. . .

Course Structure

- Lecture format
- Syllabus subject to change to discuss current events
- Approximate grading percentages:

Homework	48%
Midterm	21%
Final	31%

  Experience suggests that the exact percentages are not that important (and may change slightly)
- Grades will be posted on Courseworks
- Yes, I curve

Readings

- *Thinking Security: Stopping Next Year's Hackers*, Steven M. Bellovin, Addison-Wesley, 2016, ISBN 0-13-427754-6, 0-13-427754-6. (Only the ebook is available, and not from Amazon. . .)
- Security Engineering, Second Edition, Ross J. Anderson, Wiley, 2008, ISBN-13: 978-0470068526, ISBN-10: 0470068523.
- Some primary source material—I assume you all know how to use the library and/or electronic resources. (Hint: Google does not (yet?) have access to all of the world's knowledge.)
- Note: ACM and IEEE readings are often only easily available from the campus network.

Yes, there is a lot of assigned reading.

Logistics

- For grading issues, approach the TAs within two weeks; if you don't receive a satisfactory answer, contact me.
- For issues relating to *this class*, email smb+4182@cs...
- That lets me auto-sort class-related mail and keep better track of things

Written Assignments

- There will be several written assignments during the term
- The form required *will* be different each time—make sure you read the instructions
- Yes, those matter
- I want *analysis* and not just recounting of facts, i.e., not just “what” but *“why”*

Programming Assignments

- (I haven't quite decided if there will be programming homework)
- All programming homework *must* be done in C or C++ unless otherwise instructed. Don't bother asking for exceptions.
- Turn in a single **`tar`** file, including a Makefile; if necessary, include test data and a README file with execution instructions
- All programs *must* compile and run on Linux on the Google Cloud machines; zero credit for programs that don't compile. Note that this means you must be comfortable compiling and running code on Linux.
- Because most security problems are due to buggy code, there will be copious deductions for bugs or for inadequate documentation

Again:

- Programs must compile and run on Linux on the Google Cloud machines
- You can do your initial development on any platform you want—but you *must* make sure that the submitted version works on Google Cloud

Using Open Source Programs

- Generally, you are free to use any binary software installed on the Google Cloud machines
- Generally, you are welcome to use any open source software if (a) all such files are in a separate subdirectory from anything you write; (b) you clearly identify the origin of all such code; and (c) it all compiles seamlessly if the grader just types 'make' in the parent directory.
- *Exception:* you may not use outside code that accomplishes the primary purpose of the assignment.
- If in doubt, ask me *first*.

Co-operation versus Dishonesty

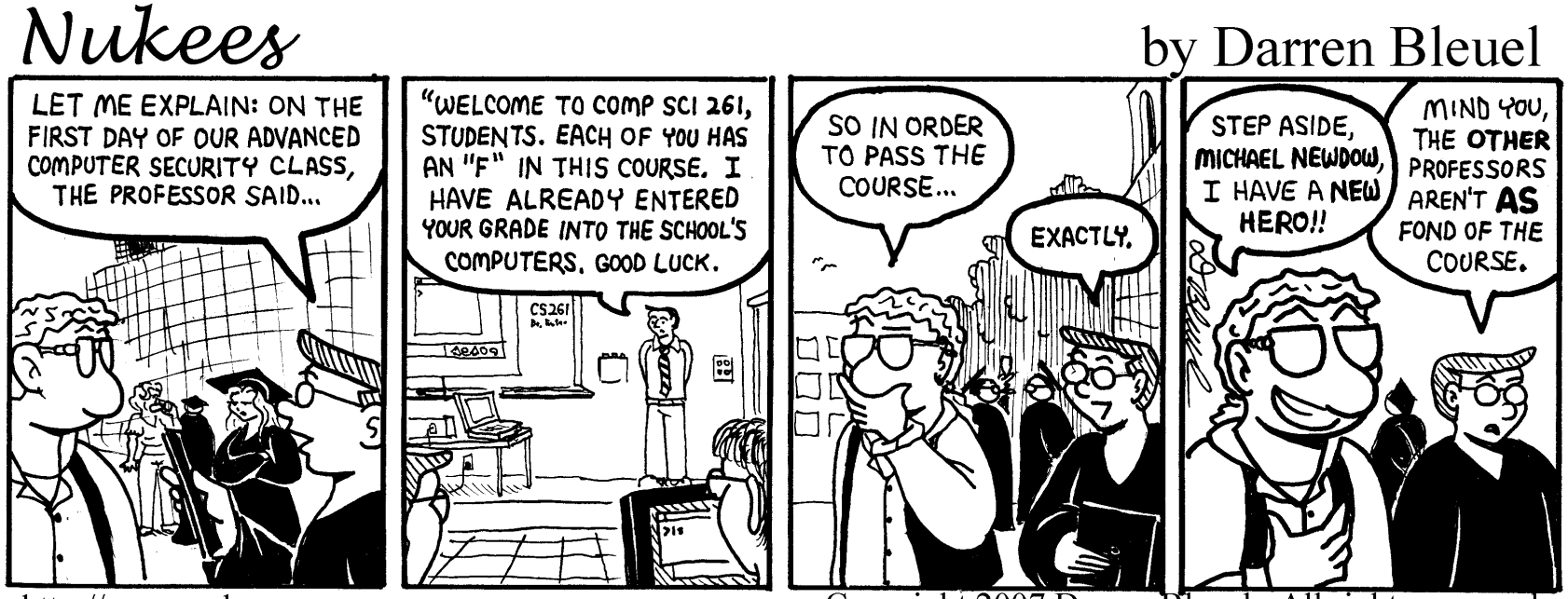
- Discussing homework with others is encouraged—but all programs and written material *must* be individual work unless otherwise instructed.
- Please use appropriate file permission mechanisms to protect your homework. (Looking at other people's work is forbidden.)
- Zero tolerance for cheating
- See the department's honesty policy: `http://www.cs.columbia.edu/education/honesty` I will assume that you have all read it; you are in any event responsible for its terms and provisions.

The Ethics of Security

- Taking a computer security class is *not* an excuse for hacking
- "Hacking" is any form of unauthorized access, including exceeding authorized permissions
- The fact that a file or computer is not properly protected is no excuse for unauthorized access
- *If* the owner of a resource invites you to attack it, such use is authorized
- For more details, see

  `http://www.columbia.edu/cu/policy/network_use.html`
- *Absolutely no Trojan horses, back doors, or other malicious code in homework assignments*

Not How I Teach It!



(Used with permission; see `http://www.nukees.com`)

Contacting Me

- Feel free to drop in during office hours.
- I'll announce changes on my home page
- I'm amenable to meeting other times, by appointment. You're welcome to drop in if my office door is open, but I reserve the right to ask you to come back later
- If you have any questions, please use email rather than telephone; I travel a lot and am not very reachable by phone

Talking to Me

- Drop by just to talk (a good idea if you think you'll want me to write a recommendation. . .)
- You don't need to be in trouble to talk with me. . .
- If my office door is open, just walk in
- But—I travel too much

Class Schedule

- Probable midterm date: March 6
- The final will be held on the date specified by the registrar. The current projection is Friday, May 8, 9:00-12:00—but that's **t**entative. Do *not* make any travel plans that involve leaving campus before that.

TAs

- ???

Lectures

- I prepare slides for each class, and upload them shortly before class time
- Slides (and other information) are uploaded to my web page
- Well, occasionally they're uploaded shortly after class...

Homeworks

- As noted, four homework assignments
- Homeworks are designed for practice, teaching, and evaluation
- Homeworks must be submitted electronically by the start of class
- Homeworks received later that day lose 5%, the next day 10%, two days late 20%, three days late 30%; after that, zero credit
- Exceptions granted only for *unforeseeable* events. Workload, day job, etc., are quite foreseeable.
- No grace period, no freebies
- Problems? See me *before* the due date

Grade Arithmetic

- If four homeworks total 48%, each one is 12%
- If you miss one assignment, that's 12% off your final average
- That's generally more than a single letter grade
- An 88% can be a B. . .

Responsibility

- You're all adults
- You're all responsible for your own actions
- If there's something missing, you have to tell me

Practical Focus

- This is not a pure academic-style security course
- A lot of (in)security is about doing the unexpected
- The ability to “think sideways” is a big advantage

The First Question

"What are you trying to protect, and against whom?"

- Some assets are more valuable than others
- Different enemies have different goals
- Different enemies have different abilities

You don't want to spend too much—but you also don't want to spend too little.

What is Security?

Security is keeping unauthorized entities from doing things you don't want them to do.

This definition is too informal. . .

What is Security?

The standard definition: CIA

- **C**onfidentiality
- **I**ntegrity
- **A**vailability

Confidentiality

- "The property that information is not made available or disclosed to unauthorized individuals, entities, or processes [i.e., to any unauthorized system entity]." [definitions from RFC 4949]. Not the same as *privacy*.
- Contrast with *privacy*: "The right of an entity (normally a person), acting in its own behalf, to determine the degree to which it will interact with its environment, including the degree to which the entity is willing to share information about itself with others." Privacy is a reason for confidentiality
- The traditional focus of computer security

Integrity

- **data integrity**: “The property that data has not been changed, destroyed, or lost in an unauthorized or accidental manner.”
- **system integrity**: “The quality that a system has when it can perform its intended function in a unimpaired manner, free from deliberate or inadvertent unauthorized manipulation.”
- Often of more commercial interest than confidentiality

Availability

- "The property of a system or a system resource being accessible and usable upon demand by an authorized system entity, according to performance specifications for the system; i.e., a system is available if it provides services according to the system design whenever users request them."
- Turning off a computer provides confidentiality and integrity, but hurts availability. . .
- Denial of service attacks are direct assaults on availability

They Interact

- It's obvious that violations of integrity can be used to compromise confidentiality
- In some situations, violations of availability can be used that way as well

Where Did CIA Come From?

- Oldest known source: Saltzer and Schroeder, 1975, which used different language: “unauthorized information release,” “unauthorized information modification,” and “unauthorized denial of use.”
- A 1991 National Academies study did use the CIA terminology
- The actual source: a 1990 NASA booklet, drawing on earlier presentations by Ross Leo

However…

- I don't really like that definition
- Example: is a modification to a log file an integrity violation?
- Example: what about RAM-resident malware?
- Example: what if I cryptanalyze a site's private key but don't use it?
- Most important: it doesn't give us any guidance on how to secure a system

Proposed Definition

Definition 1 (Security) A system is secure if there are no unauthorized changes possible to the execution environment of any user.

Definition 2 (Functional Security) A system is functionally secure if it is *infeasible* for an attacker to *materially* change the execution environment of any user.

These definitions will be used throughout the semester.

Execution Environments

At any point, every user of a system can perform certain operations on certain resources. We call this the *execution environment*.

There are sometimes authorized transitions to different execution environments, e.g., after logging in

Similar to *access control matrices*

In Other Words. . .

- Insecurity is defined as someone having unintended abilities
- It doesn't matter how they obtained those abilities or if they've used them

Access Control Matrix

- List all proceses and files in a matrix
- Each row is a process (“subject”)
- Each column is a file (“object”)
- Each matrix entry is the access rights that subject has for that object

Sample Access Control Matrix

Subjects *p* and *q*

Objects *f*, *g*, *p*, *q*

Access rights **`r`** (read), **`w`** (write), **`x`** (execute), **`o`** (owner)

	f	*g*	*p*	*q*
p	rwo	r	rwx	w
q	-	r	r	rwxo

Other Permissions

- Append
- Delete file
- Owner (can change ACL)
- Many more are possible

Access Control Matrix Operations

- System can transition from one ACM state to another
- Primitive operations: create subject, create object; destroy subject, destroy object; add access right; delete access right
- Transitions are, of course, conditional

Conditional ACM Changes

Process p wishes to give process q read access to a file f owned by p.

command *grant_read_file(p, f, q)*
  if o **in** $a[p, f]$
  then
    enter "r" **into** $a[q, f]$
  else
    (signal error condition)
  fi
end

Security is a System Problem

- You can't solve it one component at a time
- It's not a matter of adding crypto or using better passwords
- Firewalls don't do it, either
- All of these things help—but all of the components interact

More Definitions

vulnerability An error or weakness in the design, implementation, or operation of a system

attack A means to exploit some vulnerability in a system

threat An adversary that is motivated and capable of exploiting a vulnerability

(Definitions from *Trust in Cyberspace*)

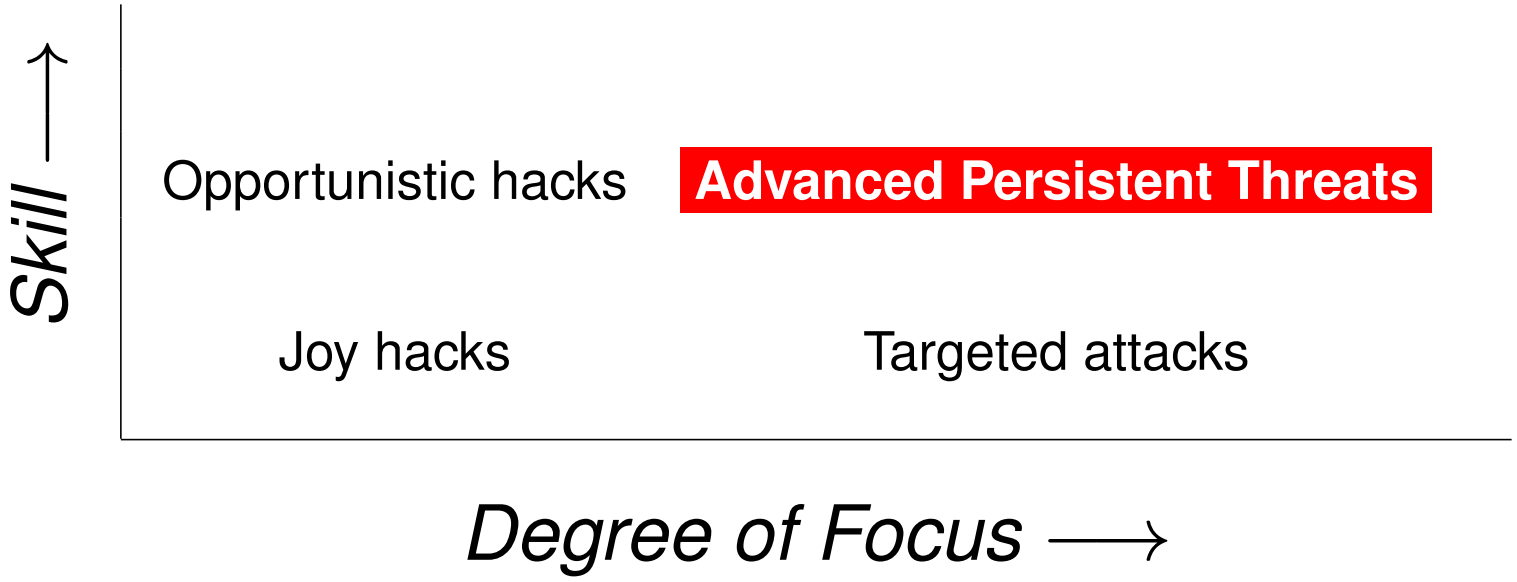
Vulnerabilities

- The technical failing in a system
- The primary focus of most computer security classes
- If you can close the vulnerabilities, the threats don't matter
- Or do they?

Threats

- Different enemies have different abilities
- Teenage joy-hackers can't crack a modern cryptosystem
- Serious enemies can exploit the "three Bs": burglary, bribery, and blackmail
- But are they motivated to attack you?
- You can't design a security system unless you know who the enemy is

The Threat Matrix



Types of Attackers

Joy hackers Beginners; doing it for fun; little knowledge or focus

Opportunistic attackers Often very good but will hit any vulnerable target

Targetiers Focuses on particular target; gathers background information, but not necessarily skilled

APT Skilled and focused.

Advanced Persistent Threats

- The most dangerous attacker
- Still a wide range, from skilled criminals to some governments to very advanced cyberwarfare and cyberespionage activities—think Stuxnet
- The US? China? Russia? Israel? North Korea? (I'm blaming the "Andromedans"...)
- Caution: many corporations blame ordinary penetrations on APTs

Don't Neglect the Human Element

"Humans are incapable of securely storing high-quality cryptographic keys, and they have unacceptable speed and accuracy when performing cryptographic operations. They are also large, expensive to maintain, difficult to manage, and they pollute the environment. It is astonishing that these devices continue to be manufactured and deployed, but they are sufficiently pervasive that we must design our protocols around their limitations."

Network Security: Private Communication in a Public World, Kaufman, Perlman, and Speciner

Engineering

- Sometimes, requirements are inconsistent and/or incomplete
- Conflicts:
  - Security versus cost
  - Security versus performance
  - Security versus acceptability and culture
  - Security versus usability
  - Security versus security!
- We'll discuss how to detect and analyze such conflicts

Designing Security

- The problem is overconstrained
- Among the contraints are cost, human behavior, and ease of operation
- In the real world, realistic security is often far more important than theoretical security
- *What are you trying to protect against whom?*

What this Course is About

- Thinking about security
- Mechanisms
- Threat analysis
- Security architecture
- Assurance
- In short, *engineering* secure systems