Welcome
Course info

• Stefan Savage
  – Web: http://www.cs.ucsd.edu/~savage
  – E-mail: savage@cs.ucsd.edu
  – Office hours: Th 2-3pm (or by appt, or drop by)
    CSE 3106

• Ariana Mirian: TA

• Course Web pages (mostly empty now)
  – http://www.cse.ucsd.edu/classes/fa19/cse227-a/
This is a class that is perpetually “in progress”
About me

▪ I work primarily on applied computer security research

▪ Research
  – I’m director of the Center for Networked Systems (CNS) on campus and the Center for Evidence Based Security Research (evidencebasedsecurity.org) w/UCSD and UCB.
  – Lots of work on security measurement, ecrime, security of cyberphysical systems (esp cars and planes)

▪ Policy
  – National Research Council’s Cybersecurity Research group
  – Institute for Defense Analysis’ ISAT advisory group
  – National Science Foundation CISE Advisory Committee
  – Way too much time in D.C.
  – I co-teach the graduate cybersecurity policy class in GPS

▪ Industry
  – Asta Networks (defunct anti-DDoS company)
  – Netsift (UCSD-originated worm defense company) -> Cisco
  – A fair amount of consulting...
How I got into security...

- Originally OS kernels...  
  and networking...
- Came to Security by accident  
  - Misbehaving TCP receivers – think like a bad guy  
  - DDoS traceback – in response to 2000 attacks
- Startup and...  
  - synchronicity (David Moore @ UCSD found indirect evidence of spoofed DoS attacks, hmmm... general analysis possible)  
  Startup was a huge failure, analysis technique was golden
- Code Red  
  - Same technique allowed measuring worm outbreaks  
  - Interest * opportunity snowballed...
What are we (UCSD) known for in security?

- **Measurement**
  - Cybercrime: Malware, spam, captcha solving, ad fraud, account abuse, etc
  - Attacks: worms, scanning, ddos, breaches
  - Defenses: threat intelligence, cyber hygiene

- **Embedded security**
  - Vulnerabilities in automobiles, voting machines, airplanes, credit card skimmers, medical devices

- **Web security and PLsec**
  - Cookies, information flow

- **Intersection of crypto and sec**

- Check out cryptosec.ucsd.edu (also sysnet.ucsd.edu)
Goals and non-goals of this course

▪ **Goals**
  - Learn how to read papers; not just for content but context (why does this paper exist?)
  - Explore range of current problems and tensions in modern computer security
  - Understand how to identify security issues in your own work and how to address them
  - Figure out if security is an area of interest for you
  - Get feet wet in security research (research project)

▪ **Non-goals**
  - Review of all standard security mechanisms
    ▪ Read a textbook or take CSE127
  - Significant examination of applied cryptography
    ▪ Take one of our great crypto courses
Readings

- There is **no textbook** for this class
  - We’ll read a bunch of papers and occasionally from some books

- However, in general I recommend:
  - Security Engineering by Ross Anderson
    Free!

- For those who want some general “backup”, check out
  - *The Craft of System Security*
    - Authors: Sean W. Smith, John Marchesini
Topics we’ll be covering

- Human factors/usability
- Measurement/analysis studies
- System design/implementation
  - Protection, small TCB, etc
- Information exposure
  - Privacy, anonymity, side & covert channels
- Software vulnerabilities & malware
  - Vulnerability research, viruses, botnets, defenses, etc
- I’m open to more topics... got any?
The work in this class

- Reading
  - Lots of it and we expect you to do it for class discussion

- Discussion in class
  - The papers and concepts we’ve covered
  - 15% of grade is participation

- Project
  - This is the purpose of the class (85% of grade)

No other homework, midterm, or final
Projects

▪ Some kind of *research project* in security

▪ Best in a group of 2-3
  – If you can’t find partner(s) let us know and we can try to help

▪ Please try to form group by Oct 8th
  – Send me and Ariana e-mail identifying your group members by then

▪ Initial project proposals due Oct 15th
  – One page
  – What you would like to do, why it is interesting, how you plan to do it, what the challenges/risks are (and/or what resources you need)
  – We will go over proposals and ok project or help you refine

▪ Ultimately 6 pages and short talk (10-15mins)
  – High standards: we’ve published well over a dozen papers from this class
Some class project alumni...
Generally speaking

- **Most projects will fall into the category of:**

  - **Analysis:** evaluate the security of a system of interest
  - **Attack:** identify some new attack/vulnerability, develop/test it and discuss the possible ramifications, mitigations, etc
  - **Measurement:** measure some aspect of adversarial behavior (real or potential), user behavior, code behavior, characterize it, explore its limits, etc
  - **Design/Implementation:** design and/or build a new system that addresses a problem in a new way
Things to think about…

- Pick good problems
  - Why is this problem interesting or will become interesting?
  - Look at what others are doing:
    - Non-academic conferences: BlackHat, Defcon, HITB, ShmooCon, INFILTRATE, various blogs

- Pick problems that are achievable
  - What resources would you need to investigate the problem?

- Think about how to evaluate your work
Random ideas

- On the class Web page (shortly)
  - This is not a list you must pick from!
  - Just examples to give you ideas and make sure you understand how broad the scope is
Resources for projects

- Data: lots of spam, malware, various kinds of traffic traces
- Computing: servers, network bandwidth
- Equipment: telescope, DSLR camera, lots of low-level stuff in the embedded lab (scopes, probes, etc), fingerprinting supplies
- Lots of experience in doing unusual things

- If there is something you need to do your project and you’re not sure how to get it – ask.
Questions about project?
What is security?

- Merriam-Webster online dictionary:

  Function: *noun*
  1: the quality or state of being *secure*: as
     a: freedom from danger: *SAFETY*  
     b: freedom from fear or anxiety  
     c: freedom from the prospect of being laid off  
     <job security>
  2 a: something given, deposited, or pledged to make certain the fulfillment of an obligation
     b: *SURETY*
  3: an instrument of investment in the form of a document (as a stock certificate or bond) providing evidence of its ownership
  4 a: something that *secures*: *PROTECTION*  
     b (1): measures taken to guard against espionage or sabotage, crime, attack, or escape  
     (2): an organization or department whose task is security
Computer security?

- Most of computer science is about providing **functionality**:
  - UX/UI
  - Software Architecture
  - Algorithms
  - Operating Systems/Networking/Databases
  - Compilers/PL
  - Microarchitecture
  - VLSI/CAD

- Computer security is **not** about functionality

- It is about how the embodiment of functionality behaves **in the presence of an adversary**

- Holistic property
  - “Software security is about integrating security practices into the way you build software, not integrating security features into your code” – Gary McGraw
History: two competing philosophies

- **Binary** model  [secure vs insecure]
  - Traditional crypto and trustworthy systems
  - Assume adversary limitations X and define security policy Y
  - If Y cannot be violated without needing X then system is secure, else insecure
  - You know people are invoking some version of this model if they say “proof of security”, “secure by design” “trustworthy systems”

- **Risk management** model. [more secure vs less secure]
  - Most commercial software development
    (and much real-world security... e.g., terrorism)
  - Try to minimize biggest risks and threats
  - Improve security where most cost effective (expected value)
  - You know people are in this model if they use the words “risk”, “mitigation”, “defenses”, “resilience”, etc.
Classic example (binary model): perfect substitution cipher

$p_1\ p_2\ p_3\ \ldots\ p_n$

$\oplus b_1\ b_2\ b_3\ \ldots\ b_n$

$c_1\ c_2\ c_3\ \ldots\ c_n$

- Invited by combination of Vernam & Mauborgne (~1919)
- Choose a string of random bits the same length as the plaintext, XOR them to obtain the ciphertext.
- **Perfect Secrecy** (proved by Claude Shannon)
  - Probability that a given message is encoded in the ciphertext is unaltered by knowledge of the ciphertext
  - Proof: Give me any plaintext message and any ciphertext and I can construct a key that will produce the ciphertext from the plaintext. Zero information in ciphertext
Classic example (risk management): Concrete barricades

- Prevent incursion by car bombers
Problems with the binary model: Abstract design != Concrete artifact

- Many assumptions are **brittle** in real systems
  - Real artifacts fragile, imperfect, have bugs/limitations
    - Don’t do precisely what spec says or documentation says
    - E.g., what is an integer?
  - Large gap between abstraction and implementation
    - Example: secret key in chip used to decrypt data; key leaks via the current the chip draws for different operations
Problems with the binary model: security evolution

- As engineers, we often delude ourselves into thinking that we understand our own creations
  - or that we can create complex systems to do only what we meant them to do
- But ... nobody knows how these systems really work
  - Complexity of computer systems is approaching complexity of biological organisms
    - 3 billion base pairs in human genome
    - 10+ billion transistors in modern CPUs
- Complex systems co-evolve with attacks against them
  - How we use systems, how we depend on them and how they might be attacked – all change over time
  - Systems deemed secure today may not be resilient to new threats
Problems with the risk management model: One vulnerability can matter...
Problems with the risk management model: You never win

- Creates arms race – forced co-evolution

  Adversary invents new attack

  Defender creates new defense

- The best you can hope for is **stalemate**
Problems with the risk management model: How to measure

- It's fine to say security is a spectrum, but how to evaluate risk or reward?
  - How many units of security does your anti-virus product give you?

- Big question: how do we measure security?
  - How is this different from car safety?
  - Or drug safety?
Key meta issues in Security

- Policy
- Assets, Risks & Threats
- Value
- Protection
- Deterrence
Policy

- What is a bad thing?

- Remarkably tricky to define for known threats
  - The software on your computer likely has 100s of security options... How should you set them?
  - What might be a good security policy for who gets to access faculty salary data?

- Even harder for unknown threats
  - SPAM

- Should a highly privileged user have more rights on a system or less?
Assets, Risks & threats

- **Assets**
  - What you want to protect

- **Threats**
  - Actions likely to cause damage, harm or loss
  - Includes both kinds of attacks (e.g., virus, social engineering) and kinds of attackers (e.g., script kiddie vs state sponsored actor)
  - Need to reason about requirements of each threat (what capabilities does the attacker need) and what it enables (what harm might come? What motivations might drive such a threat)

- **Risk**
  - What is the potential likelihood of a something bad happening (i.e., what threats are likely)

- These tend to be well formalized in some communities (e.g. finance sector) and less in others (e.g. energy sector)
- We’ll talk more about threat models next class...
Value

- What is the cost if the bad thing happens?
- What is the cost of preventing the bad thing?

- Example: credit card fraud
  - Who pays if someone steals your credit card # and buys a TV with it?

- Example: Permissive Action Links for nuclear weapons
Protection

- The mechanisms used to protect resources against threats
  - This is most of academic and industrial computer security

- Many classes of protections
  - Cryptographic protection of data
  - Software guards
  - Communication guards
  - User interface design (protect user against own limitations)

- Can be either proactive or reactive
Deterrence

- There is some non-zero expectation that there is a future cost to doing a bad thing
  - i.e. going to jail, having a missile hit your house, having your assets seized, etc
  - Criminal cost-benefit: \( M_b + P_b > O_{cp} + O_{cm} P_a P_c \) [Clark&Davis 95]
    - \( M_b \): Monetary benefit
    - \( P_b \): Psychological benefit
    - \( O_{cp} \): Cost of committing crime
    - \( O_{cm} \): Monetary cost of conviction
    - \( P_a \): Probability of getting caught
    - \( P_c \): Probability of conviction

- Need meaningful forensic capabilities
  - Audit actions, assign identity to evidence, etc
  - Must be cost effective relative to positive incentives
That’s it for today

- For next time, read
  - Low-level Software Security by Example
  - Exploit Programming: From Buffer Overflows to “Weird Machines”

- Write down questions you have as reading

- Also, spend a few minutes looking into the background of the authors and the citations and ask yourself:
  - Why are they writing this paper? Why them? Why then? Why there?