# CSE 127 Computer Security

Stefan Savage, Fall 2025

## Lecture 1: Introduction

## Course Information

Professor: Stefan Savage

- Lectures: Tu/Th 2:-3:20 ( WLH 2005 106)
- Discussion: F 3-3:50 (PCYNH 109)
- Office Hours: 1pm CSE Building 3106 or by appt
- Final: Dec 12th , 3-6pm (ish)

Class Asisstants

- Henry Feng (TA)
- Eugene Lau (TA)
- Ye Shu (TA)
- Manan Patel (Tutor)

Course Web Page

- https://cseweb.ucsd.edu/classes/fa25/cse127-a/
  (also linked via Canvas)

Piazza (via Canvas)

## Some quick logistics

"First day" survey on Canvas (under Quizzes)

- Please fill this out
- Its not only for us, but it satisfies the financial aid surveillance requirement

## About me

I work at the intersection of computer security, networking and measurement

**Research**

- I'm co-director of the **Center for Networked Systems** (CNS) on campus.
- I'm also a founding member of UCSD's Center for Healthcare Cybersecurity
- 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
- A bunch of time in D.C.; steering committee ACM Law+CS
- I co-taught the graduate cybersecurity policy class in GPS for 10 years and a cyberlaw class in CSE for 4

**Industry**

- Asta Networks (defunct anti-DDoS company)
- Netsift (UCSD-originated worm defense company) -> Cisco
- A fair amount of consulting… (data breaches, LE, Web companies)

## Course Objectives

A solid foundation of security concepts, backed by concrete examples

Security mindset

- How to **think like** an attacker/ security engineer
- Looking beyond the system's intended functionality, to what it can be made to do

Understanding how things work, how they break, and how to fix them

- Technical details of vulnerabilities, attacks, and defenses

Becoming a better engineer

- Minimize number and severity of *vulnerabilities you create*
- Understand the causes and impact of *vulnerabilities that you are alerted to*
- Properly address *vulnerabilities that are identified*

## What you will need to know (for projects)

C programming and bits of assembly, some javascript

A bit of OS (memory protection, address translation, threads)

Some architecture (caches/TLBs) and networking (packets, connections)

I'll try to explain the key ideas when these things come up, but you need to be prepared to learn on your own

- In particular, we aren't teaching any C/asm programming

## Course Material

Textbook: **no mandatory textbook** to buy

Readings from:

- Articles and videos (both academic and… not)

Slides

- Based on slides and notes from Kirill Levchenko, Alex Gantman, Deian Stefan, Nadia Heninger, Alex Dent, Vitaly Shamtikov, Robert Turner, and a host of others

## Tentative Grading

Homework assignments & projects: 30%

Midterm: 35%

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If midterm grade > 0
then midterm = max(midterm,final)
else midterm = 0
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Final: 35%

## Rules

Homework and assignments are *due on the date and time indicated*

- May work in groups of 2 or individually (note: **fate sharing** for groups)
- We're going to have a late day policy (TBD) where you can allocate late days as you see fit

Regrades should be the exception

- We reserve the right to completely regrade your assignments

**No Cheating**

- Read and understand UC San Diego policy on academic integrity
  http://academicintegrity.ucsd.edu
- Cheating includes not doing the assignment yourself, providing answers to others,using LLM tools (e.g., CoPilot/Cursor/Claude/ChatGPT/Gemini) etc.
- Not ok to copy, translate, paraphrase, edit, etc. someone else's work
- If you are not sure if something is cheating, **assume its cheating unless you ask first**
- We will report suspected cheating cases to the academic integrity office

## Ethics

In this class you will learn how to attack the security of computer systems (and some physical systems)

We learn attacks because it is needed to understand how to defend them

You have an obligation to use this knowledge ethically

- You **may not** attack others
  - In addition to being unethical, it may also be a felony
- Many good ***legitimate*** hacking challenges
  - http://overthewire.org/wargames/ (wargames)
  - https://challenges.re/ (reverse engineering challenges)
  - https://ctftime.org/ctfs (Capture the Flag competitions)

## What is computer security about?

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; its cross-cutting

It is about how some implementation 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

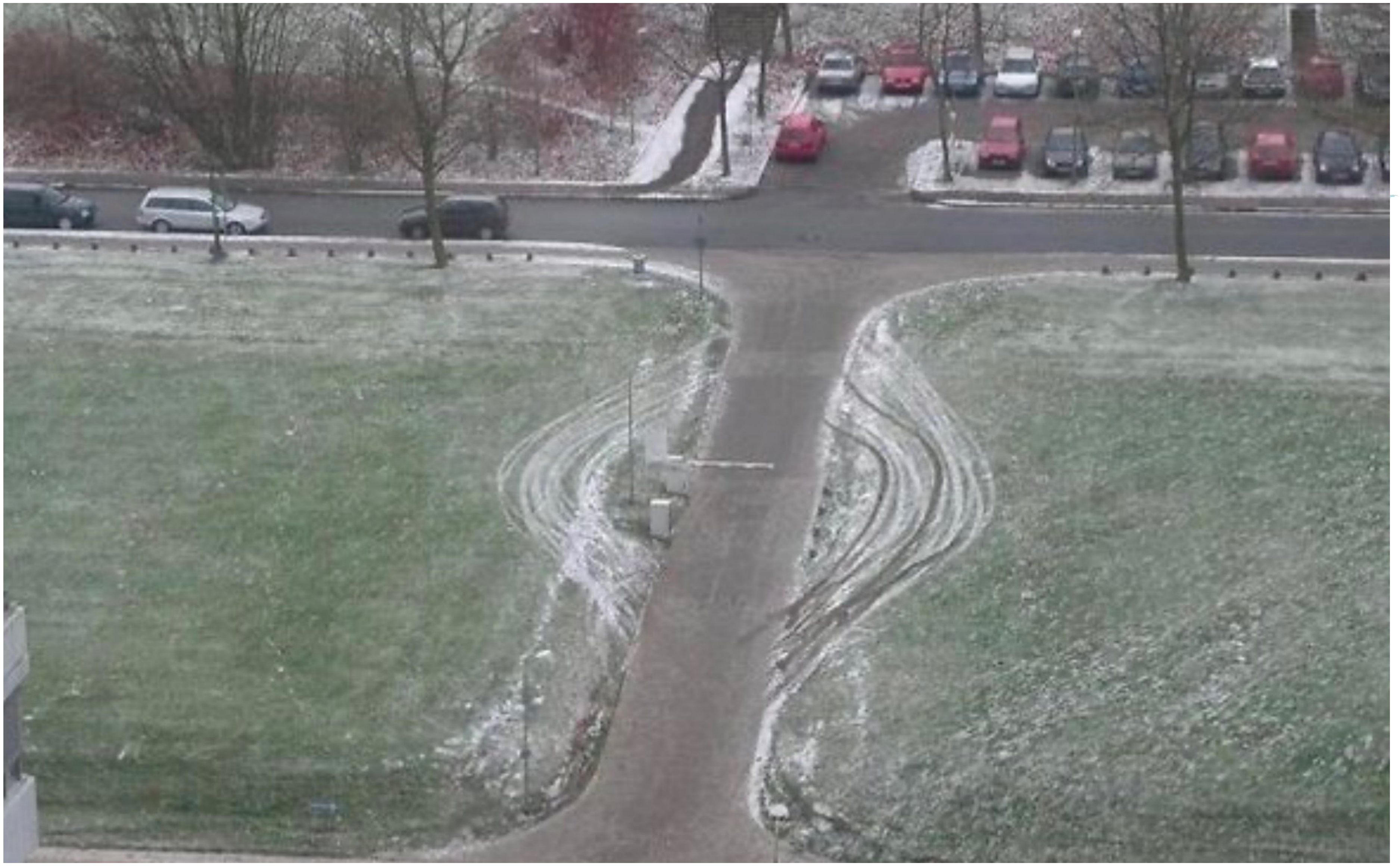
## Thinking like an attacker

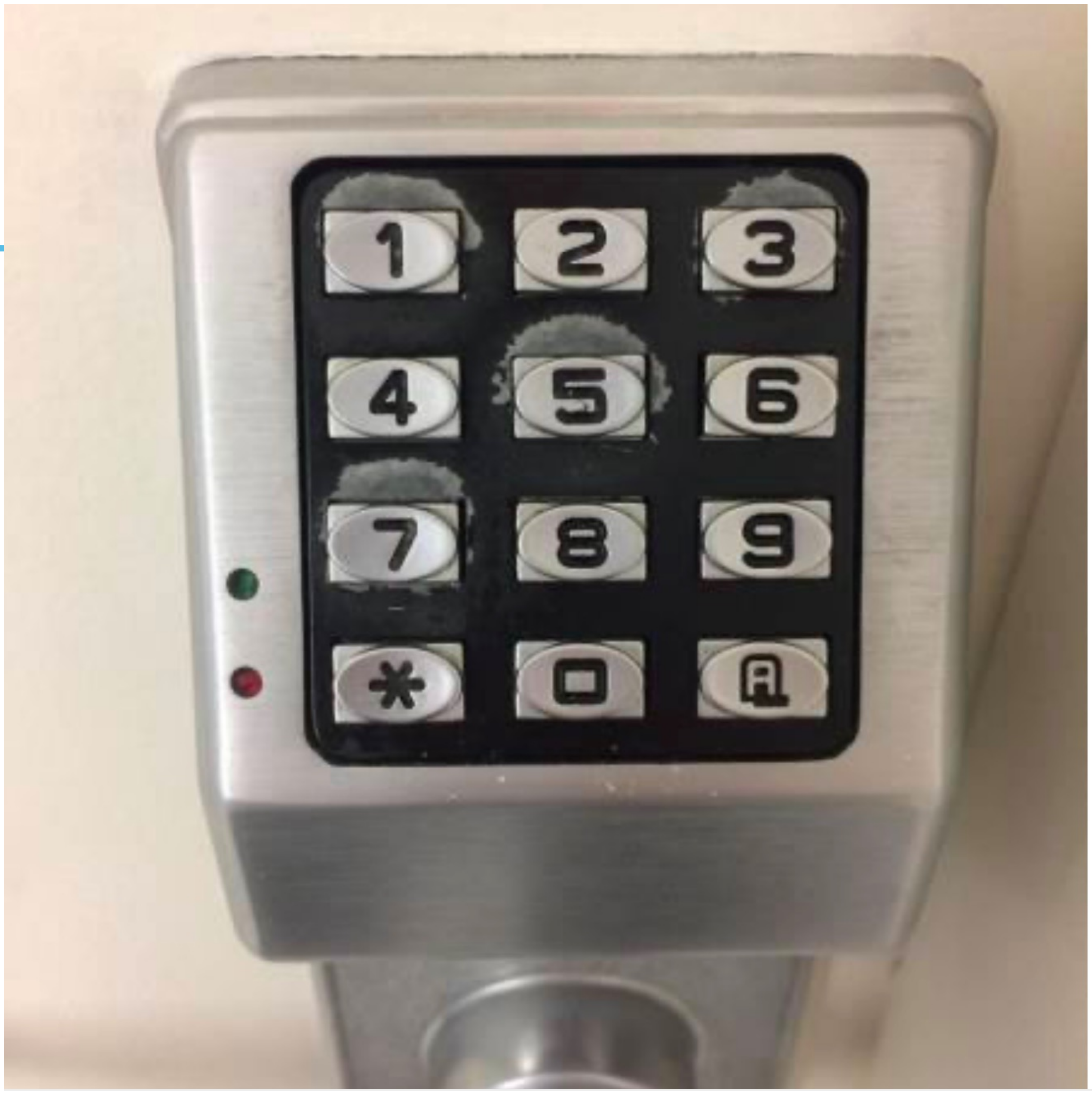
Look for the weakest links

Identify the **assumptions** that security depends on. Are they guaranteed to always be true? Can you make them false?

Think outside the box. Ignore the limited worldview of the system's designers

This is something you can start doing now and all the time. When you interact with a system (computerized or not) think about what that system depends on and how it might be exploited

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## History: two competing philosophies about securing systems

**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" or "trustworthy systems"

**Risk management** model. [more secure vs less secure]

- Most commercial software development
  (and much real-world security… e.g., terrorism)
- Try to identify most significant risks to security and minimize them
- 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

$$\begin{array}{rl} & p_1\ p_2\ p_3\ \ldots\ p_n \\ \oplus & \underline{b_1\ b_2\ b_3\ \ldots\ b_n} \\ & c_1\ c_2\ c_3\ \ldots\ c_n \end{array}$$

- Invented by combination of Vernam & Mauborgne (~1919)
- Choose a string of **random** bits the same length as the plaintext (key), XOR them with plaintext to obtain the ciphertext
  - Assume key is only known to sender and receiver
- ***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

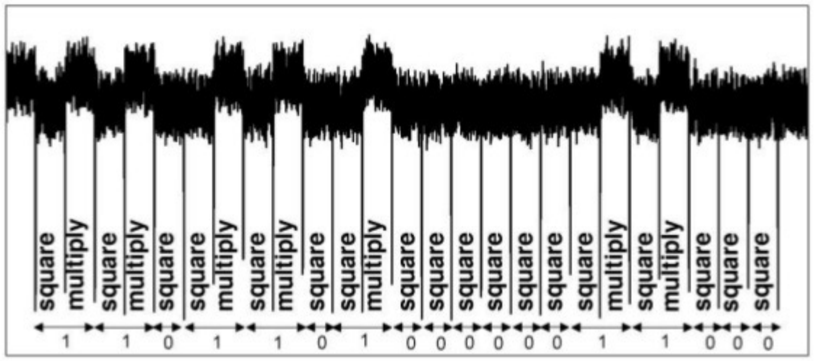
## Classic example (risk management): Concrete barricades

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



Courtesy Oswald

## 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

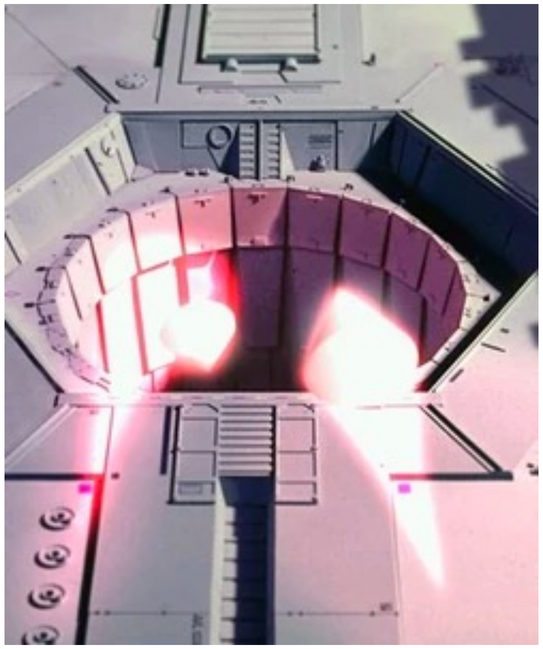
But … **nobody knows how these systems really work**

- Complexity of computer systems is approaching complexity of biological organisms
  - 3 billion base pairs in human genome
  - 10+ billion transistors in modern CPUs
  - And that's even before LLMs and modern AI…

Complex systems co-evolve with attacks against them

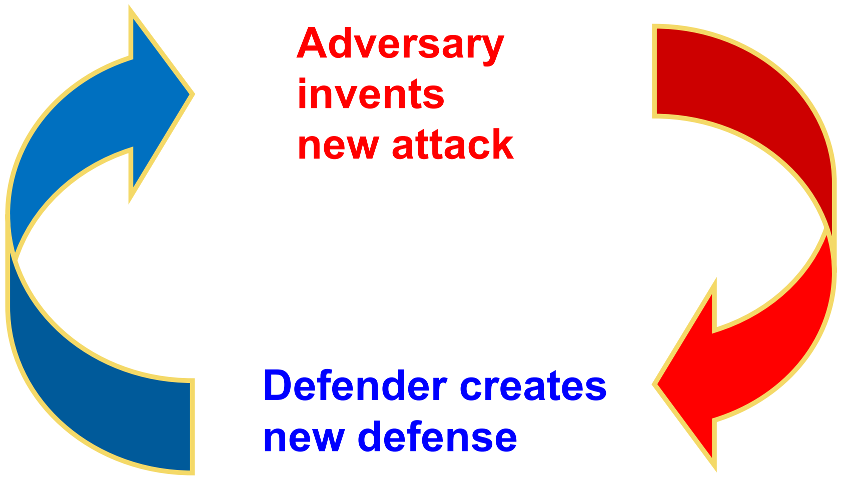
- How we use systems, how we depend on them and how they might be attacked – all change over time
- Systems deemed secure today may not be resilient to new threats

## 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



Can just produce **stalemate**

## Problems with the risk management model: How to measure

Its fine to say security is a spectrum, but how to **evaluate** risk or reward?

- How many **units of security** does your anti-virus or EDR 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

Identity & Reputation

## Policy

What **is** a bad thing?

Remarkably tricky to define for known threats

- What is the right security policy for a Web browser?
  - It has many dozens of security configuration options… How should you set them?
- What might be a good security policy for who gets to access employee salary data?

Even harder for unknown threats

- SPAM – **who** should be allowed to send **you** e-mail?

Should a highly privileged user be able to read the public files of less privileged users?

## 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., malware, social engineering) and kinds of attackers (e.g., random online troll 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., water distribution)

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 uses it to buy an iPhone from Amazon?

Example: Permissive Action Links for nuclear weapons

- http://www.cs.columbia.edu/~smb/nsam-160/pal.html

## 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: $M_b + P_b > O_{cp} + O_{cm}P_aP_c$ [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 (i.e., attribution), etc
- Must be cost effective relative to positive incentives

## Switching gears: Identity

Identity is implicit in virtually all security questions…. but we rarely think about it much

We have strong intuitions about identities though

- How do you feel about a self-proclaimed cypherpunk named "Black Unicorn"?
- How about *A.S.L. von Bernhardi,* the Swiss investment banker?

## Identity

What is it?

- One def: *The distinct personality of an individual regarded as a persisting entity; individuality* (*courtesy Black Unicorn*)
- Another: *A unique identifier – distinguishing mark* (*courtesy A.S.L. von Bernhardi* )

But these are different: **identity** vs **identifier**

- Identify is abstract, Identifier is a concrete object (e.g., SSN, email address)
- Identifiers allows naming; *to establish an assertion about reputation*

Reputation?

- A specific characteristic or trait ascribed to a person or thing: e.g., *"a reputation for paying promptly"*
- Potentially a predictor of behavior, a means of valuation and as a means for third-party assessment

Value comes from binding reputation and identifiers

But how to make this binding?

## Due diligence and trust

### Due diligence

- Work to acquire multiple independent pieces of evidence establishing identity/reputation linkage; particularly via direct experience
- Expensive

### Trust

- *Reliance on something in the future; hope*
- Allows cheap form of due-diligence: **third-party attestation**
  - E.g., being asked to show your drivers license or passport when buying something
  - Long history – e.g., wax seals in the middle ages
- Tricky
  - What is a third-party qualified to attest to?
  - But scales well…

## For next class

Read:

- *Reflections on Trusting Trust* by Ken Thompson

  https://www.cs.cmu.edu/~rdriley/487/papers/Thompson_1984_ReflectionsonTrustingTrust.pdf

We will try to post first project soon (ideally next week)

- Getting comfortable with the debugger and project submission system

## Next Lecture…

Security Foundations: Threat Models and Risk Analysis