Διάλεξη #1 - Security Fundamentals

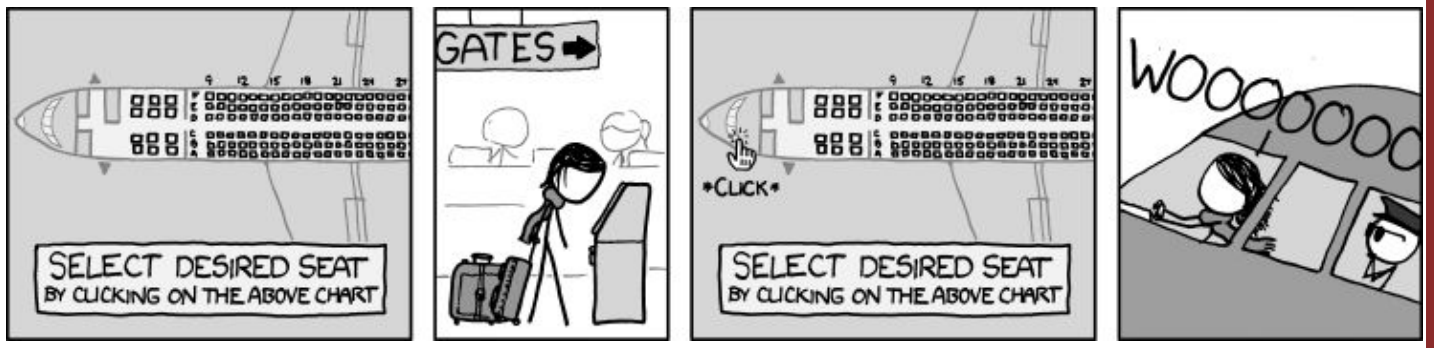
Εθνικό και Καποδιστριακό Πανεπιστήμιο Αθηνών

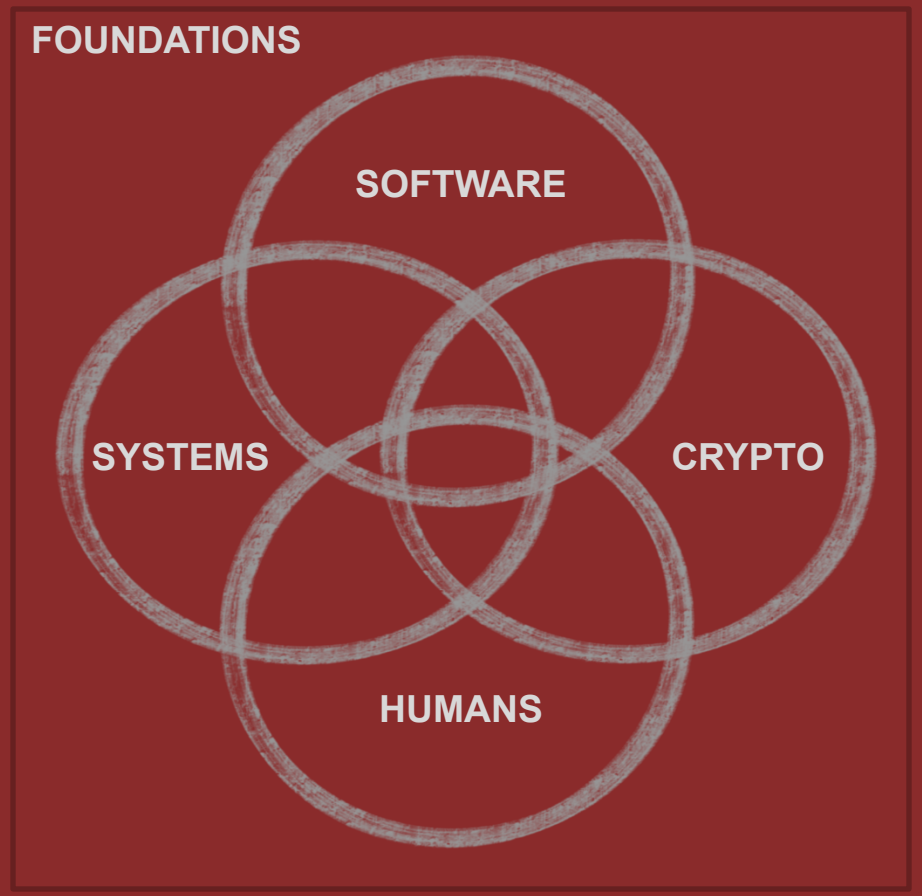
Εισαγωγή στην Ασφάλεια

Θανάσης Αυγερινός

(Security Mindset)

https://xkcd.com/726/





Huge thank you to David Brumley from Carnegie Mellon University for the guidance and content input while developing this class

Ανακοινώσεις / Διευκρινίσεις

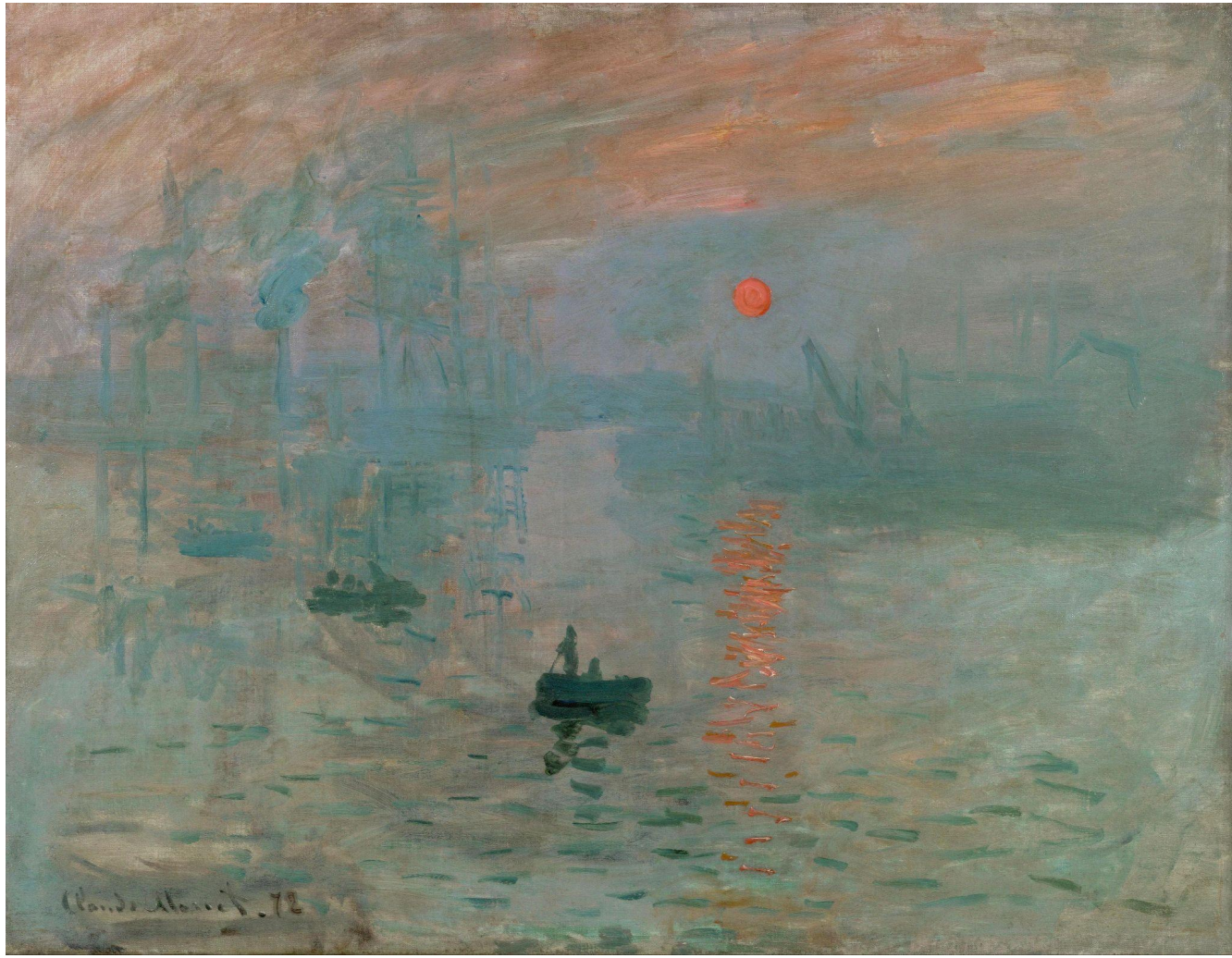
- Ομαδική εργασία; Μία, αλλά δεν έχουμε αποφασίσει τα μεγέθη των ομάδων
- Άρα δεν επιτρέπεται να κάνουμε scanf("%s", buffer);

Την Προηγούμενη Φορά

1. Διαδικαστικά
2. Σκοπός του μαθήματος
3. Ασφάλεια και Συστήματα
4. Σχέδιο για το μάθημα φέτος
5. Το πρώτο μας exploit

Σήμερα

- Security Fundamentals
  - Adversaries
  - Threat Models
  - Security Properties
  - Trusted Computing Base (TCB)
  - Security Principles



Two Concepts (Only a few I need you to memorize)

Defining The Adversary (1/2)

- Adversary = < Goals, Capabilities >
- Goal: What constitutes success?
  - May involve subgoals
  - Example goal: Gain control of X's data
    - Sub-goal: Reconnaissance: search online for info about X
      - Sub-goal: Access: Guess X's ssh password on Linux lab
        - » Sub-goal: Lateral movement: Use ssh account to move to other services / linked accounts
- Capabilities: What resources can the adversary use?
  - 1 computer or millions?
  - Physical or remote access?
  - Access to source code?

Why don't we include adversary's strategy?

Defining The Adversary (1/2)

- Adversary = < Goals, Capabilities >

Why don't we include adversary's strategy?

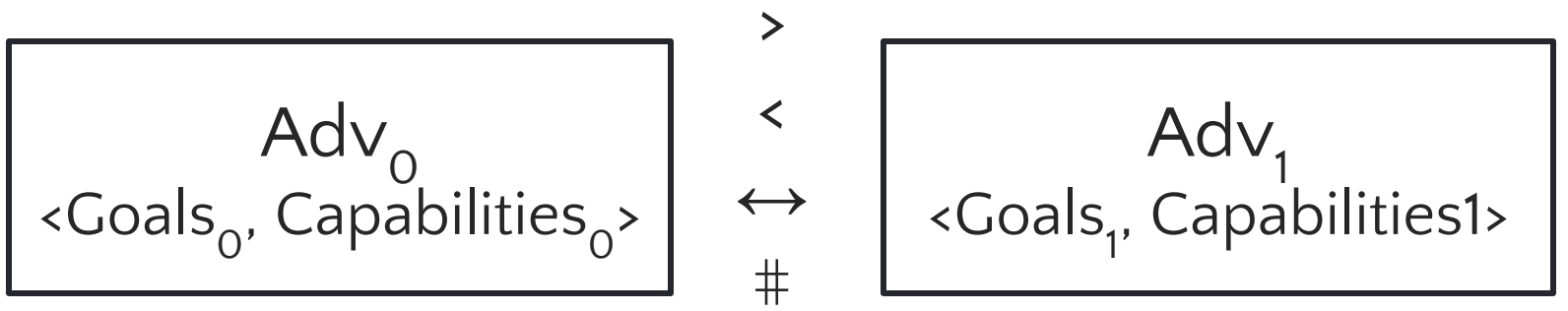
Security Mechanism Classification for a property (2/2)

1. **Prevention**. Prevent issues from happening. Any precautionary measures.
2. **Detection**. Assuming an incident took place, detect them as early and as accurately as possible.
3. **Resilience**. Assuming one or multiple incidents took place, ensure the overall system security degrades gracefully and does not collapse.
4. **Deterrence**. Measures to ensure penalties for actors responsible for security incidents. Policy-based.

Adversaries

Basic Adversary Metrics

Partial Orders



Implication (A0 → A1):
A0's goals and capabilities are a superset of A1's

Separation (A1 ↛ A0):
A1's goals and/or capabilities are not a superset of A0's

Strict Dominance A0 > A1 = A0 → A1 ∧ A1 ↛ A0
Equivalence: A0 ↔ A1 = A0 → A1 ∧ A1 → A0
Incomparable: A0 # A1 = A0 ↛ A1 ∧ A1 ↛ A0

Example Adversary Comparison

Adversary A0

- Goal: Modify the my-studies website
- Capabilities
  - View the website
  - Send data to the website
  - Modify local browser state
  - Access a normal user account on my-studies
  - Invoke system calls on `my-studies.uoa.gr`

Adversary A1

- Goal: Modify the my-studies website
- Capabilities
  - View the website
  - Send data to the website
  - Modify local browser state
  - ~~Access a normal user account on my-studies~~
  - ~~Invoke system calls on my-studies.uoa.gr~~

$A0 \rightarrow A1 \wedge A1 \not\rightarrow A0$ hence A0 > A1, i.e., A0 strictly dominates A1

Threat Models

Threat Modeling

Threat modeling is a process by which potential threats, such as structural vulnerabilities or the absence of appropriate safeguards, can be identified and enumerated, and countermeasures prioritized.

https://en.wikipedia.org/wiki/Threat_model

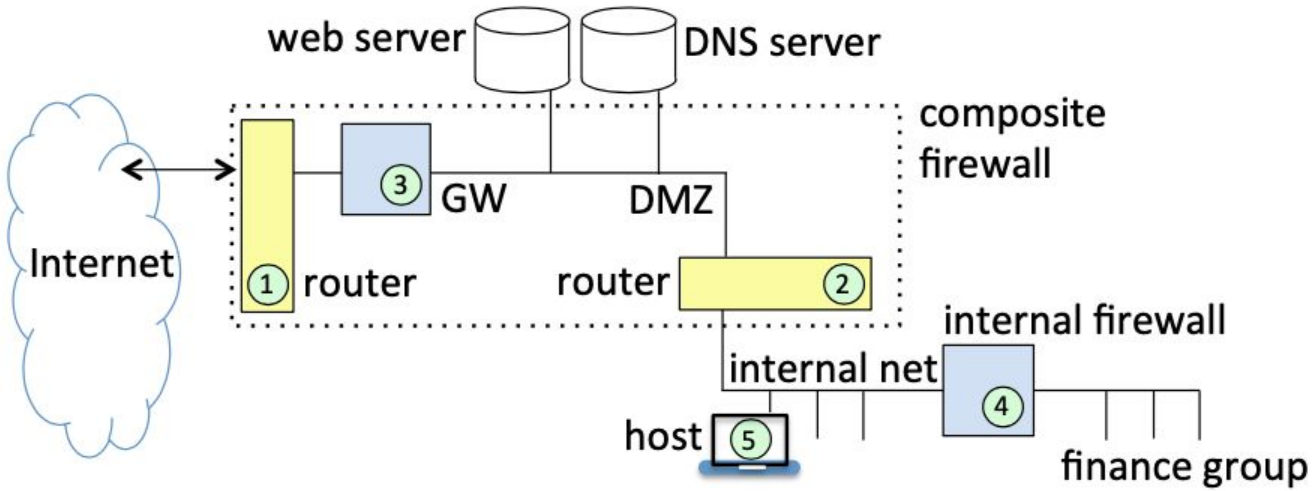
https://www.threatmodelingmanifesto.org/

Threat Model Includes

- Assets
  - What are you protecting?
  - Which matter most?
- System goals (functionality, security)
- Adversary definition – key characteristic
  - Risk assessment – we are in the insurance business!
    - Risk justifies the cost

Systematic Threat Modeling

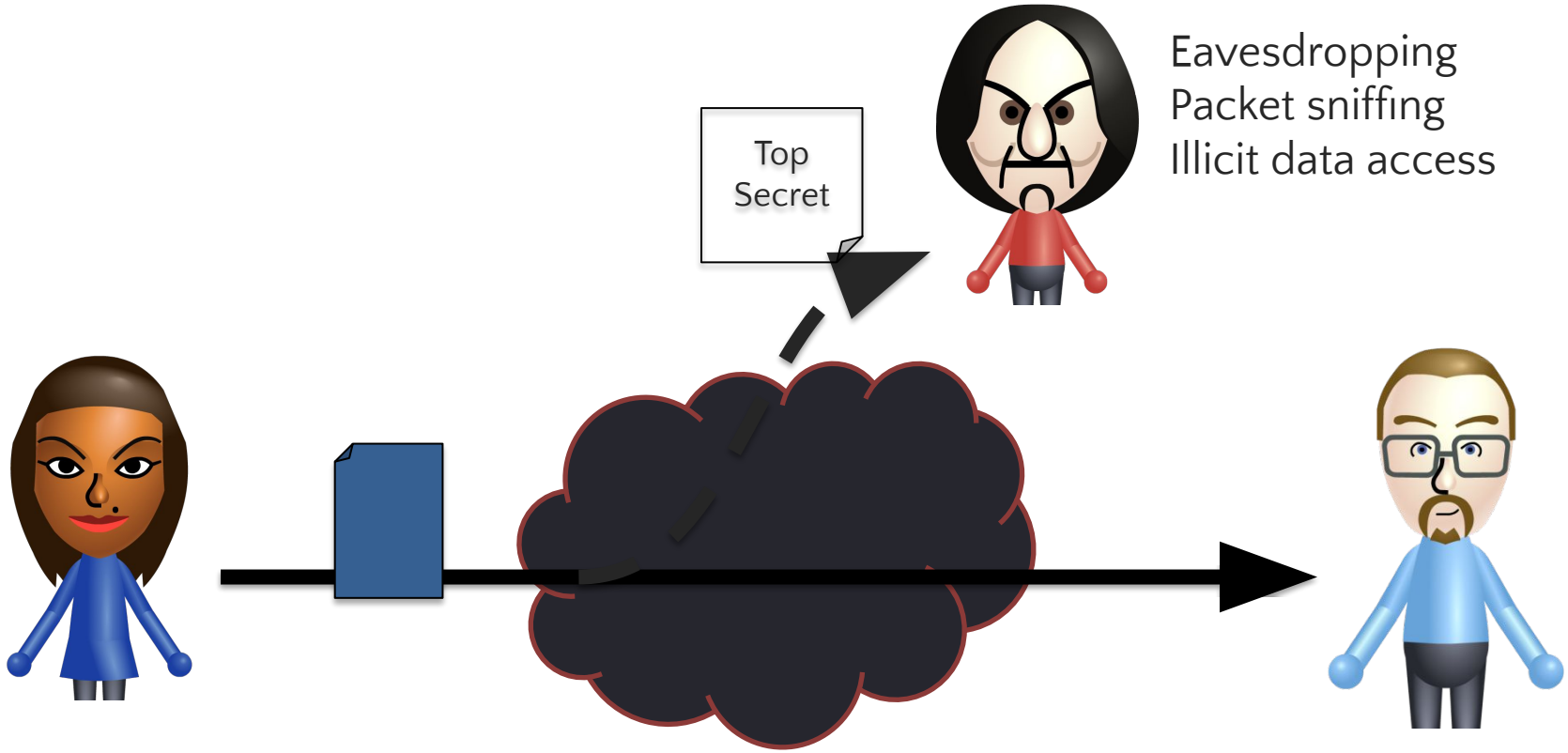
- Diagram-based
- Attack trees
- Checklists
- STRIDE
- MITRE ATT&CK



4 Key Security Properties

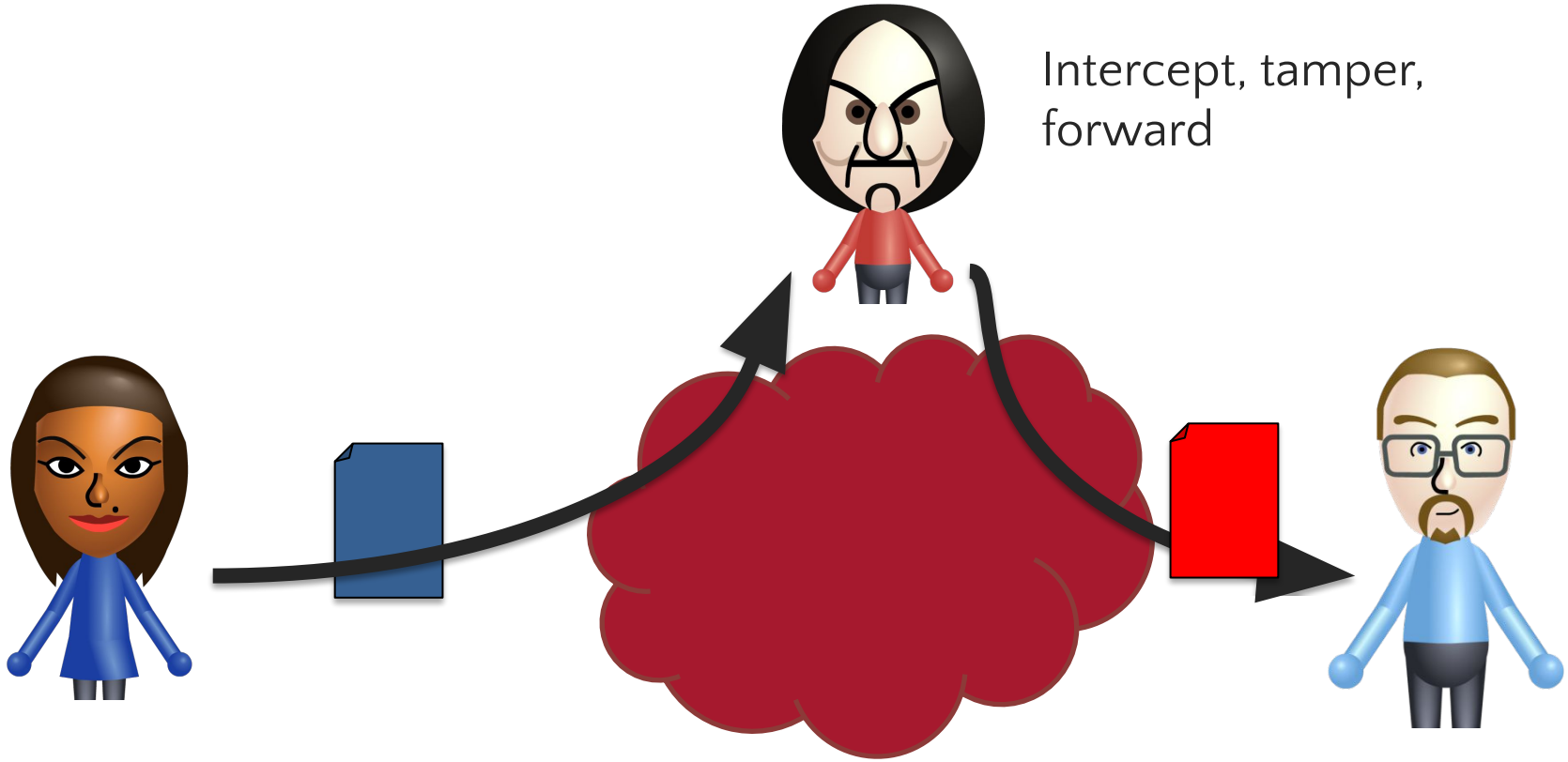
What Properties Do You Care About?

(1) Confidentiality == **Secrecy** == Concealing information



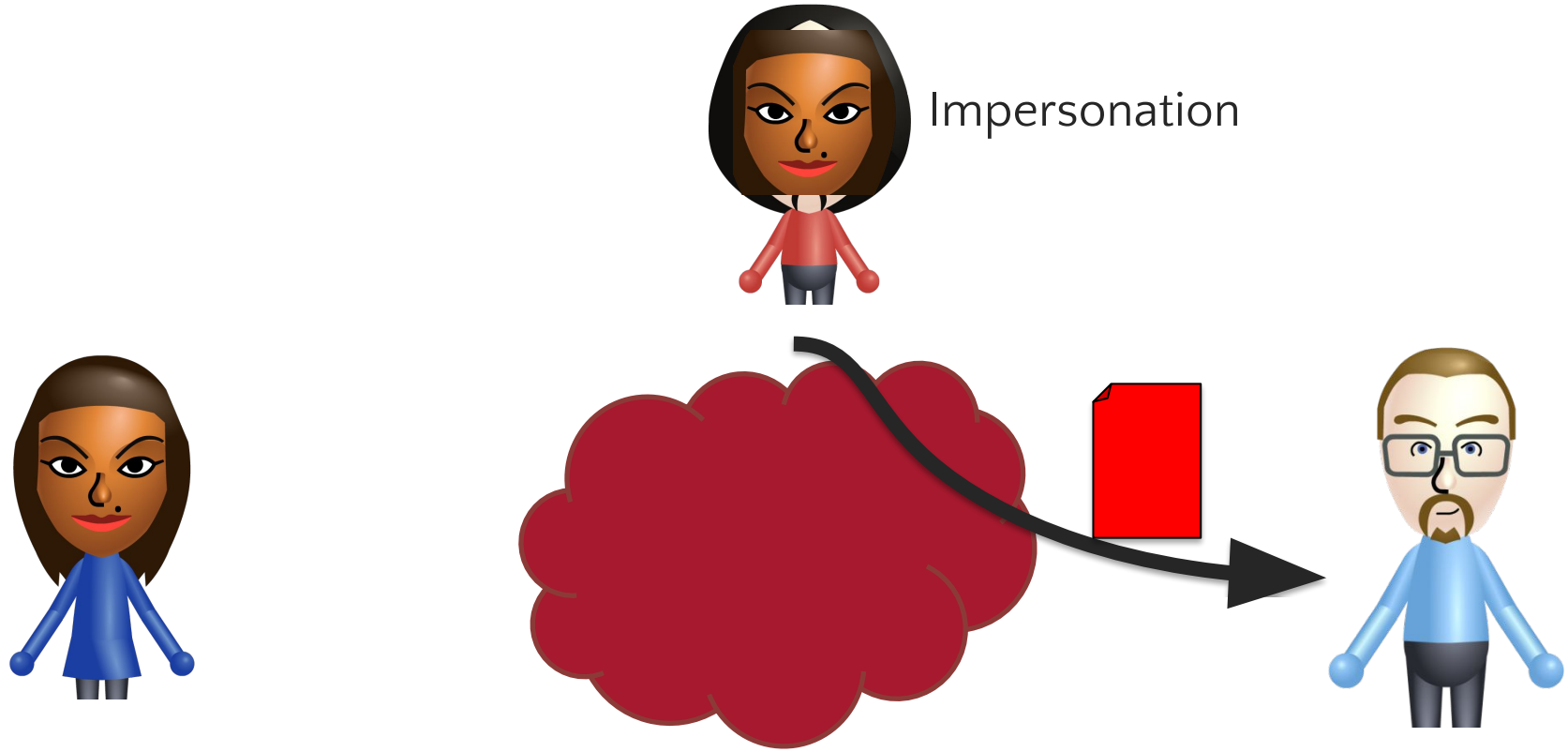
What Properties Do You Care About?

(2) Integrity == Prevention of unauthorized changes



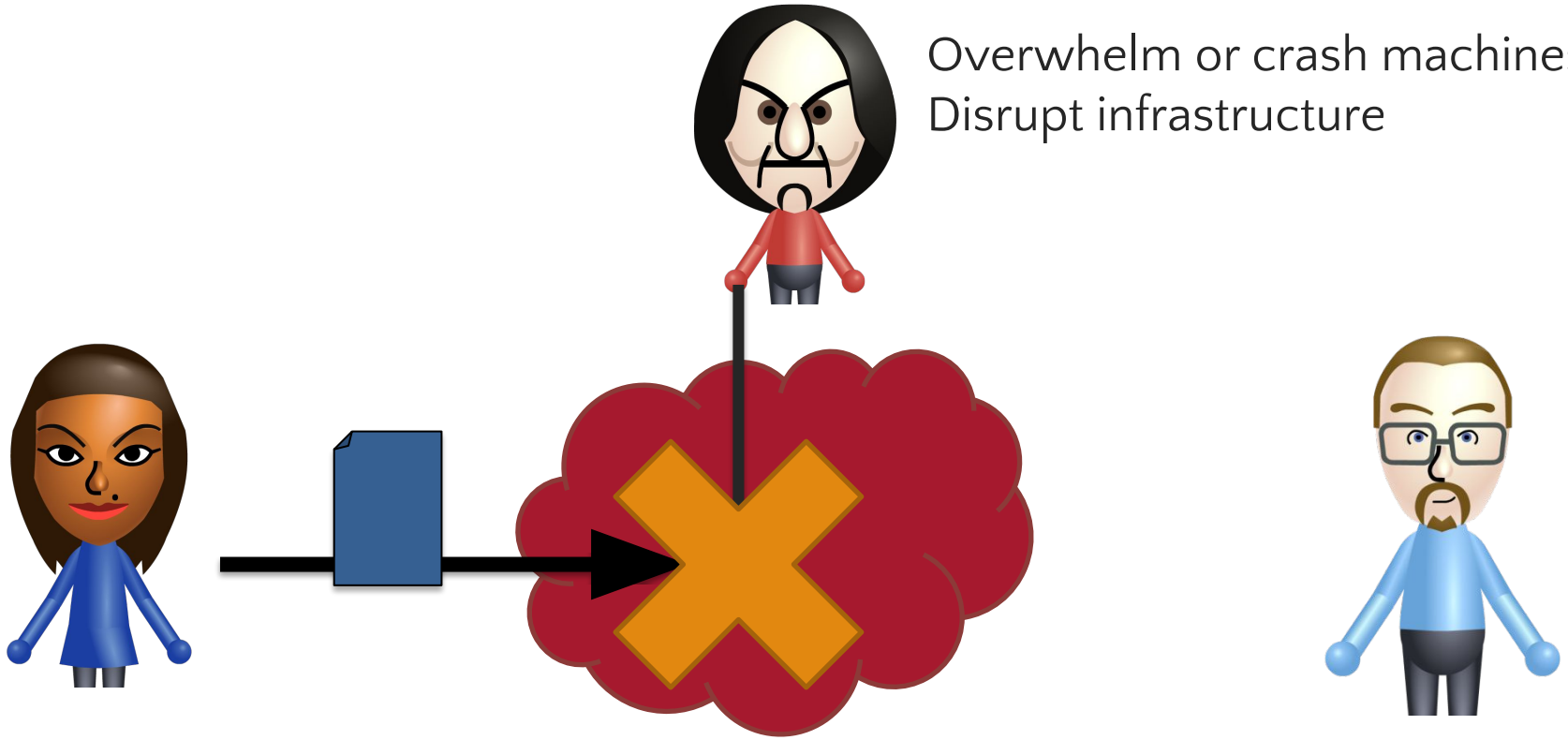
What Properties Do You Care About?

(3) Authenticity == Data and actions attributed to correct person



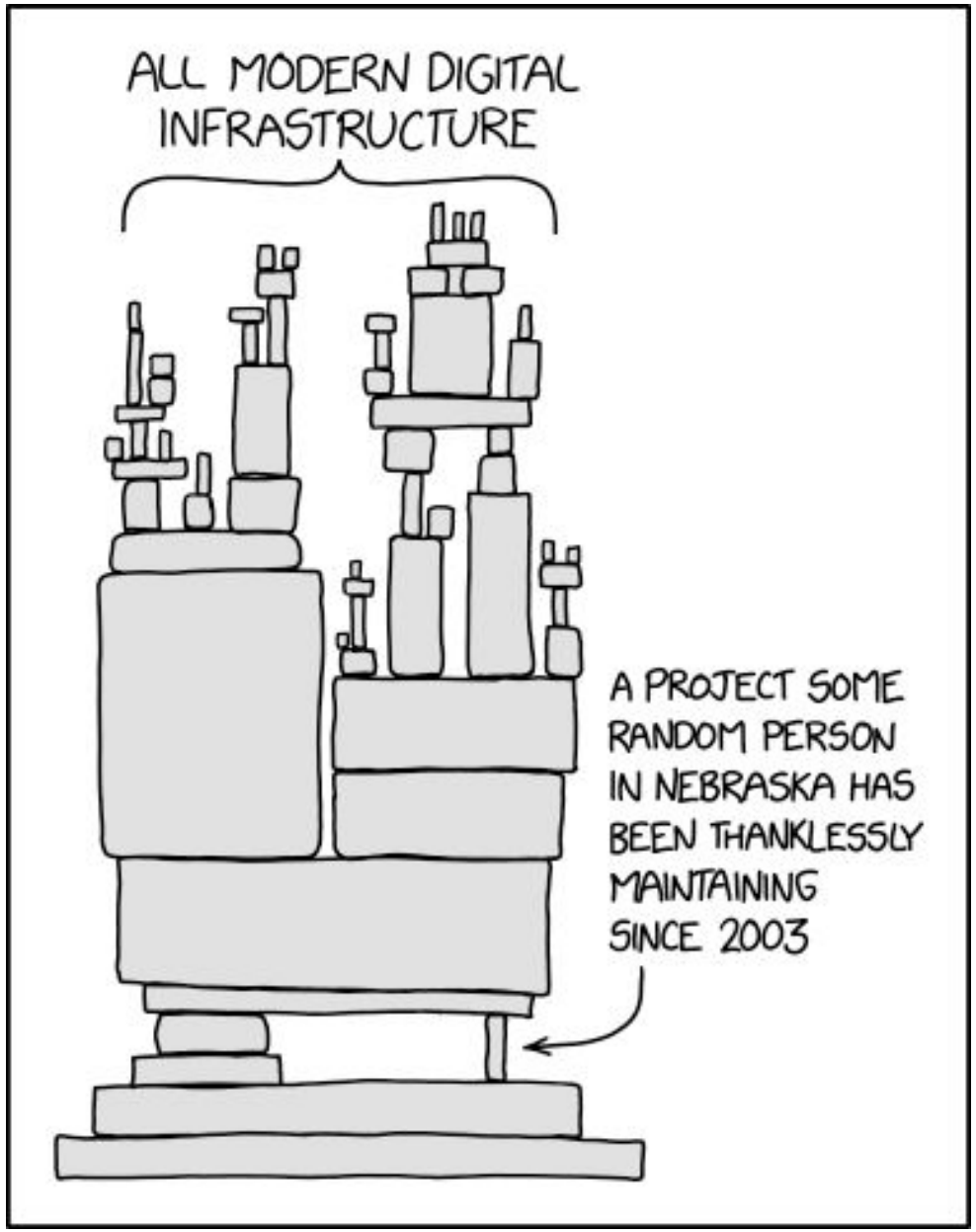
What Properties Do You Care About?

(4) Availability == Ability to use resources when needed



Overwhelm or crash machines,
Disrupt infrastructure

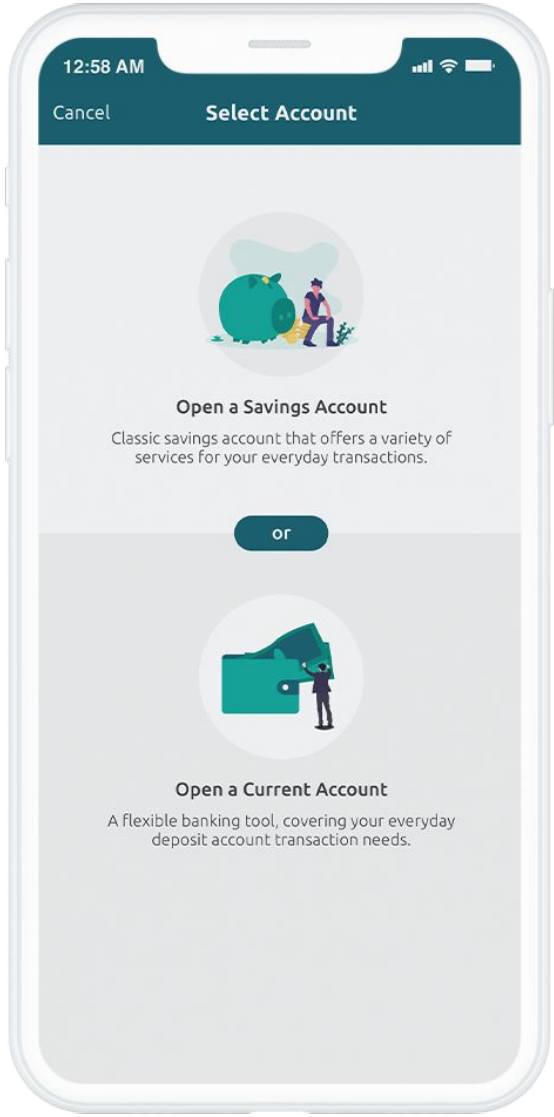
Trusted Computing Base (TCB)



https://xkcd.com/2347/

Why Should I Trust This?

What does this application rely on for its security?

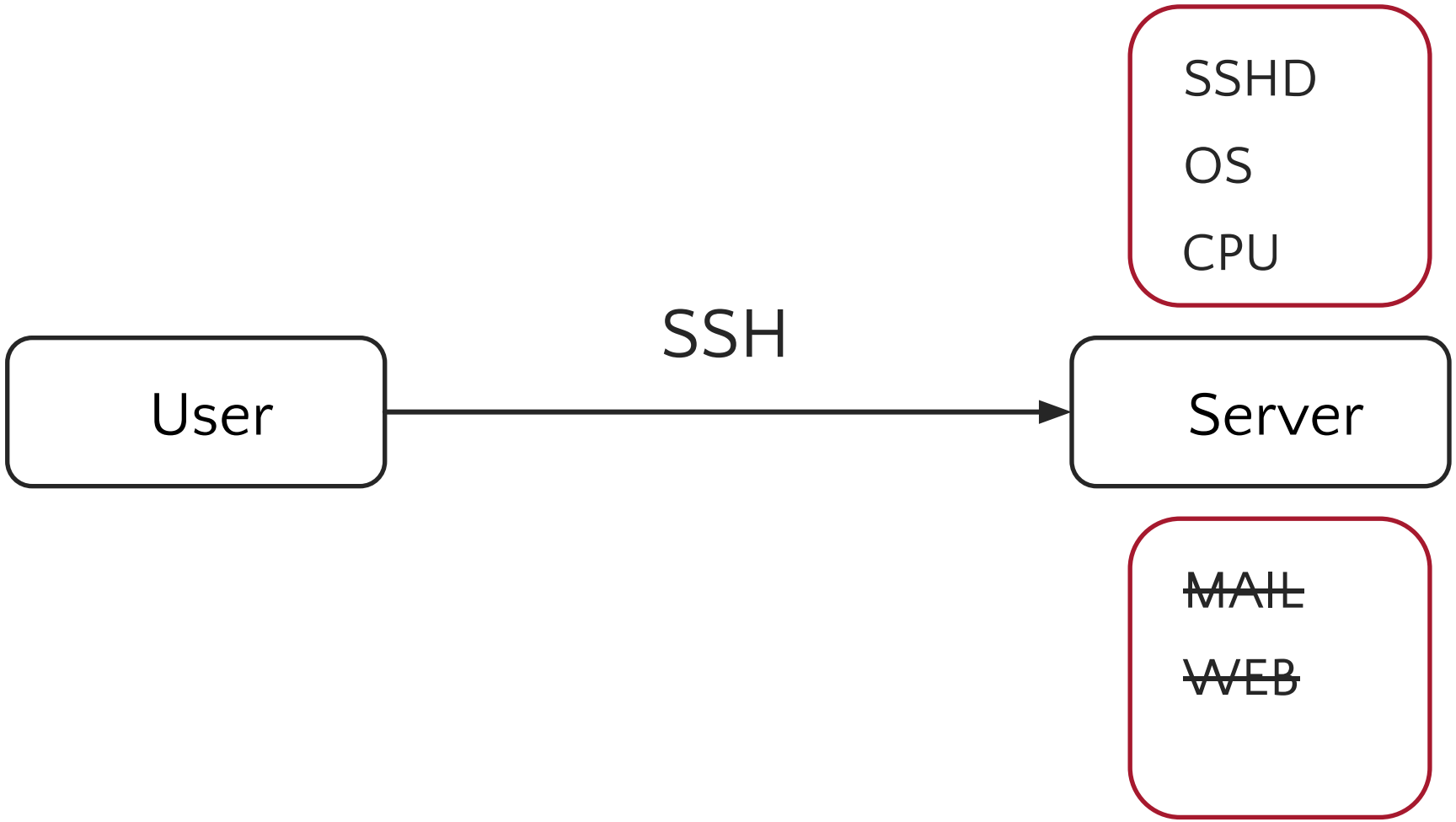


Trusted Computing Base (TCB)

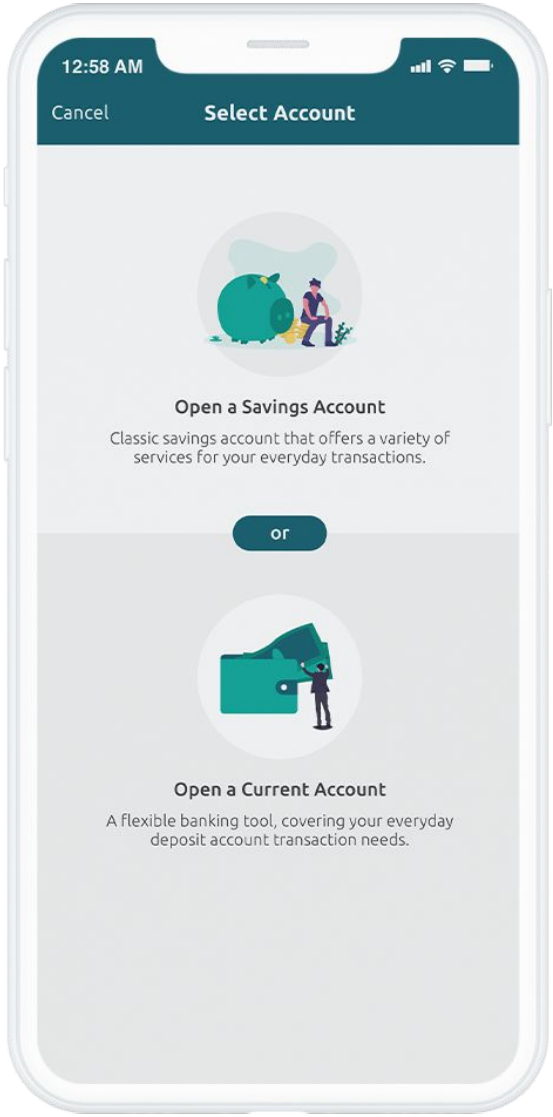
- Component X's TCB is all other components that must operate securely for X to be secure
- Corollary 1: If TCB is secure, X has a chance of being secure
- Corollary 2: If TCB misbehaves, no guarantees about X's security!
- Trusted != Trustworthy

Example of TCB

Example of TCB



What is the TCB here?



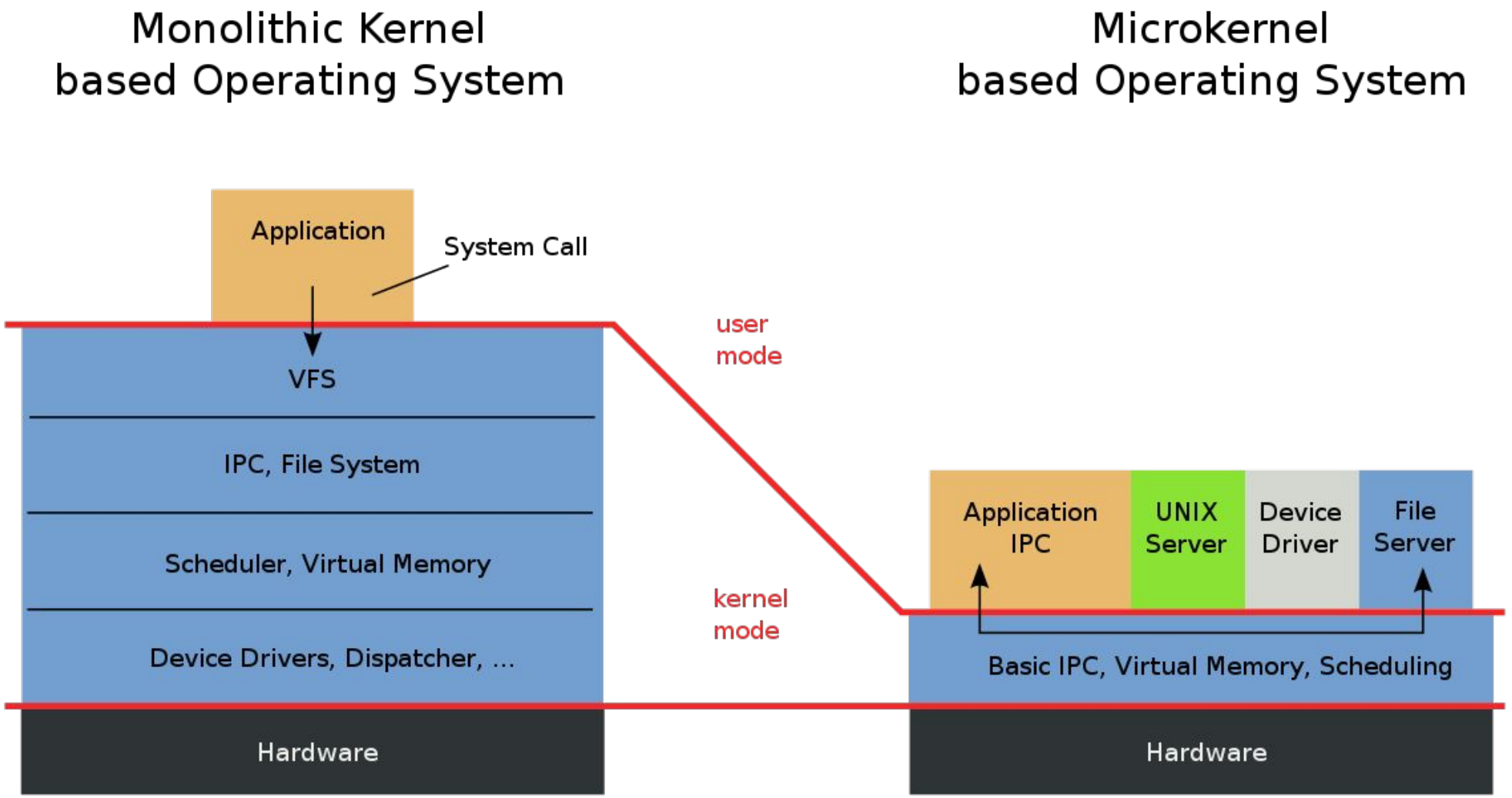
Ideal TCB Design

- Verifiable
  - Implies you want TCB to be as small as possible
    - (even when not verifiable, smaller = less buggy)
- Tamper proof
  - E.g., must prevent messing with the SSHD or OS executables

Why Do We Care About a TCB?

- Securing every piece of a system is hard!
- Identifying the TCB allows us to separate a system into a part that **must** be trusted and a part that **doesn't have to** be
- Can focus security efforts on the trusted piece
  - Reason about security more rigorously
- Caveat: Determining TCB is easier said than done

Example: Operating system kernel



Participation Question

Which of the following is ***NOT*** in the TCB of a *web browser* on your laptop?

A. The laptop's OS
B. JavaScript the browser downloads when you visit a website
C. The laptop's hardware
D. The browser's cryptographic library

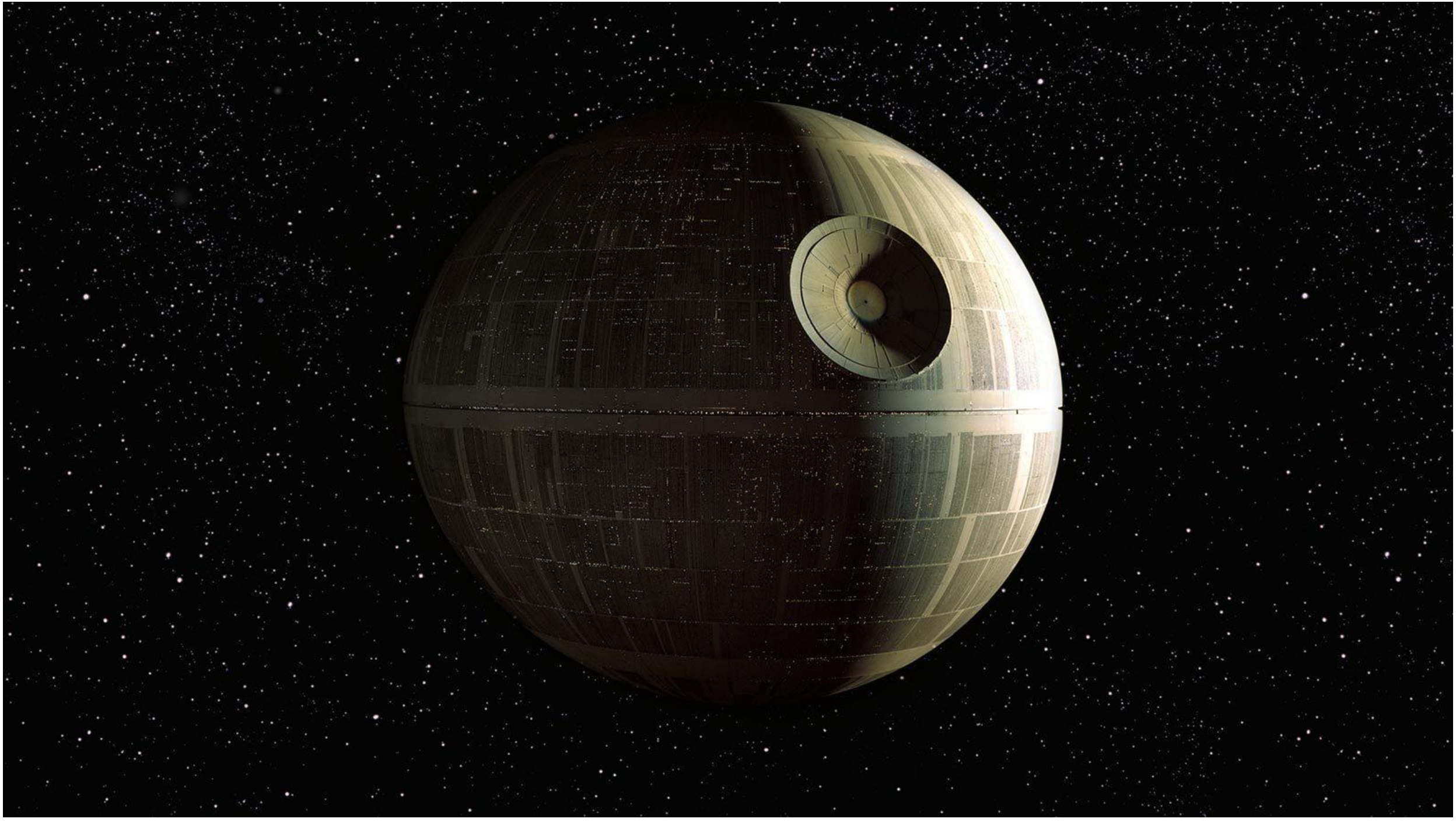
Designing Secure Systems

The Key Principles

- **Economy of mechanism a.k.a. KISS**
- Fail-safe defaults
- Don't rely on security by obscurity
- Complete mediation
- Least privilege
- Separation of duty
- Defense in depth
- Factor in users/acceptance/psychology
- Work factor/economics

} Later

See the reading for more useful principles



Keep It Simple, Stupid (KISS)

- Rule of thumb:
  1–5 defects per 1K lines of code
- Windows 10 = 50M LOC; Linux 6.7 = 27M LOC
  - In both cases, essentially all in the TCB
- Smaller, simpler TCB is easier to reason about
  - e.g.: seL4 (a formally verified microkernel) = 89k LOC

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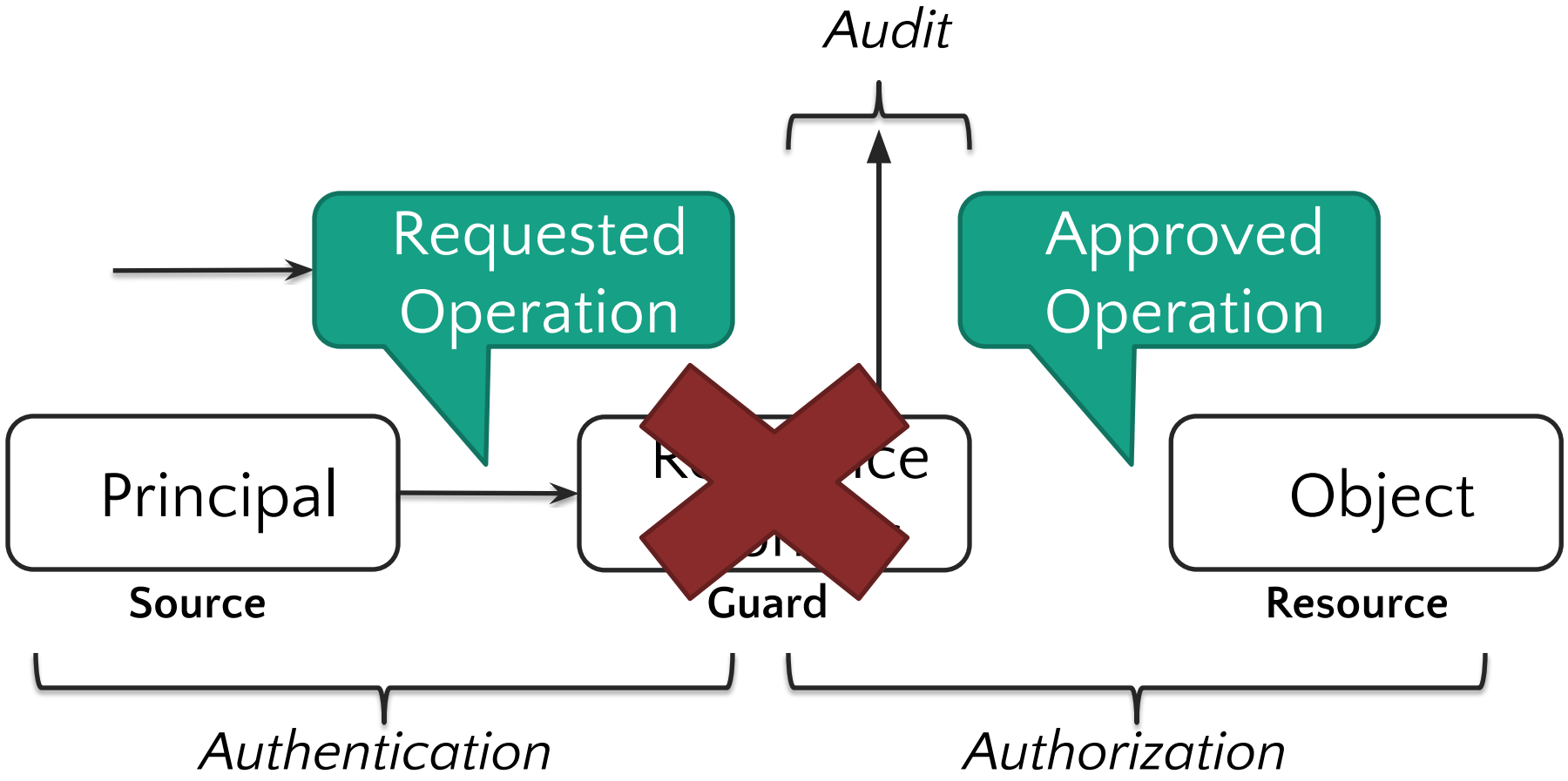
Fail-safe Defaults (Fail Closed)



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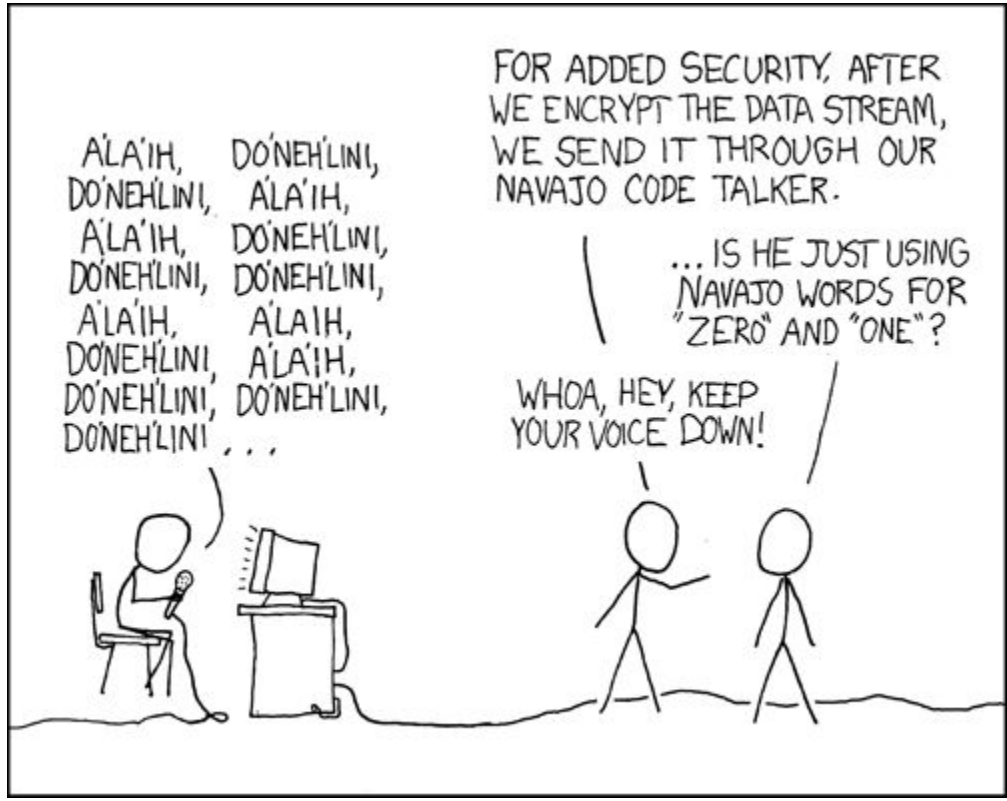
No Security by Obscurity

- Common fallacy: System is more secure if the design remains secret
- Keeping designs secret is hard!
  - Someone has to build/implement it
  - Users interact with it
  - The design may be sold to lots of people
- Finding flaws in your own design is hard!



https://xkcd.com/257/

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Complete Mediation

- Every access to every object is checked by the reference monitor
- Easier said than done!
- TOCTTOU problems

Mediation: TOCTTOU Vulnerabilities

Time-Of-Check-To-Time-Of-Use

```
int openfile(char *path){
  struct stat s;
  if (stat(path,&s) < 0))
    return -1;

  if (!S_ISREG(s.st_mode)){
    error("only regular files allowed");
    return -1;
  }
  return open(path,O_RDONLY)
}
```

Change path

Mediation: TOCTTOU Vulnerabilities

Time-Of-Check-To-Time-Of-Use

```
void withdraw(int w){
  b = getbalance();
  if (b<w)
    error("not enough $$");

  b = b-w;
  send(w)
}
```

The Key Principles

- Economy of mechanism a.k.a. KISS
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- Don't rely on security by obscurity
- Complete mediation
- **Least privilege**
- Separation of duty
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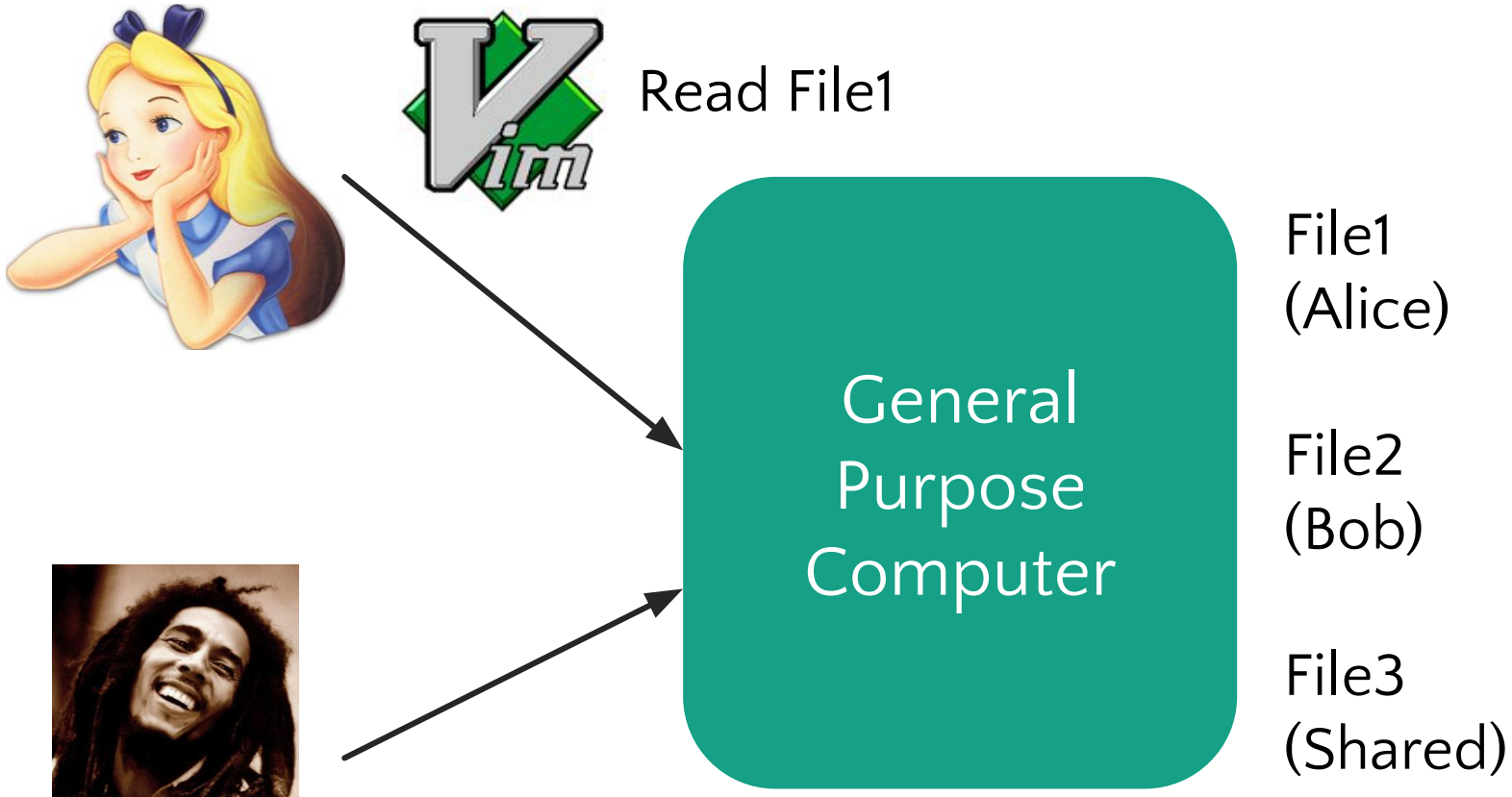
} Later

Least Privilege

A user or entity should only have access to the specific data, resources and applications needed to complete a required task and nothing more.



The Key Principles

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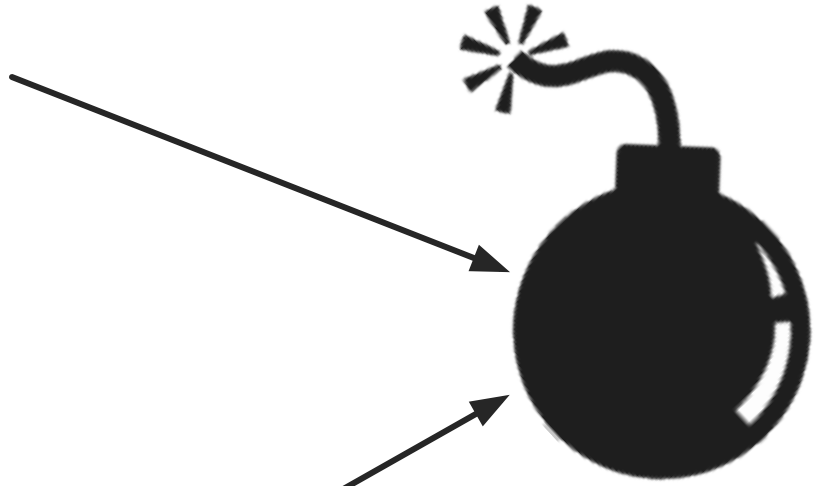
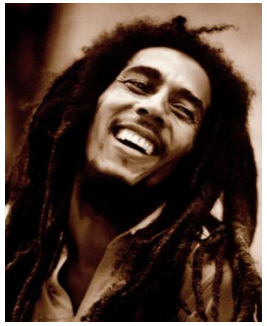
} Later

Separation of Duty (SoD)

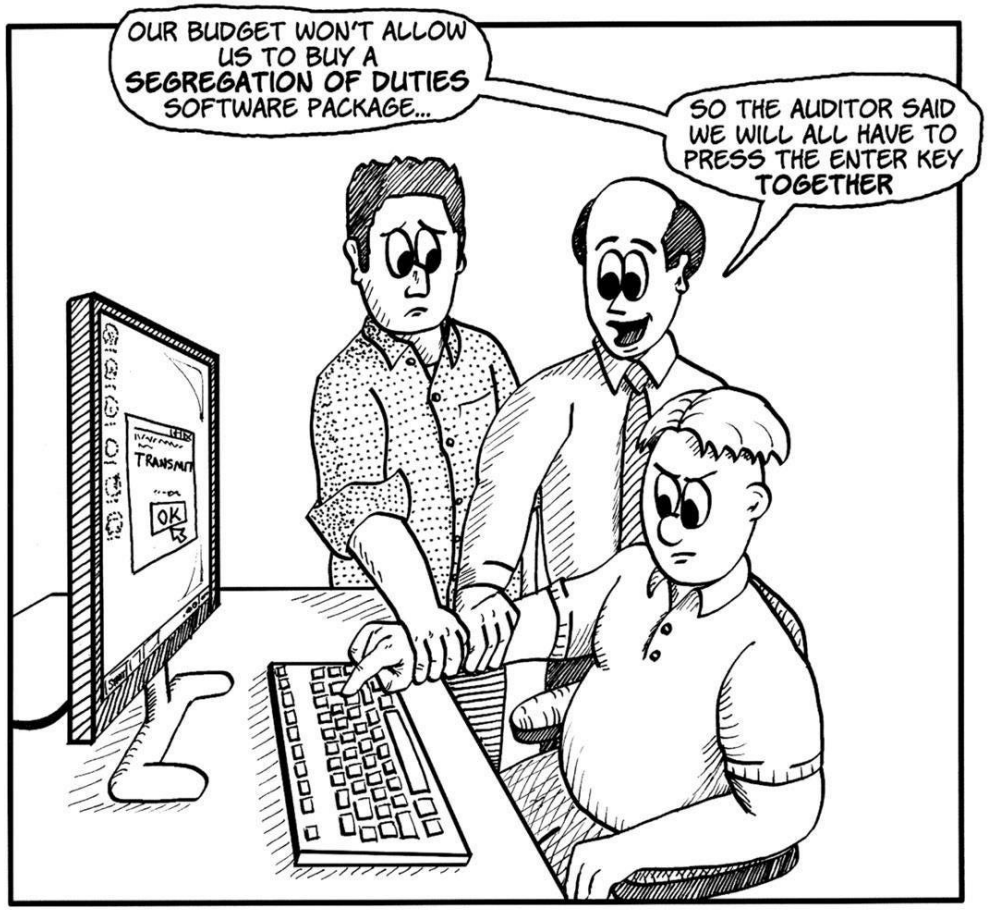
Having more than one person required to complete a task!

Push Pull Request
Launch Missile





Approve Pull Request
Launch Missile



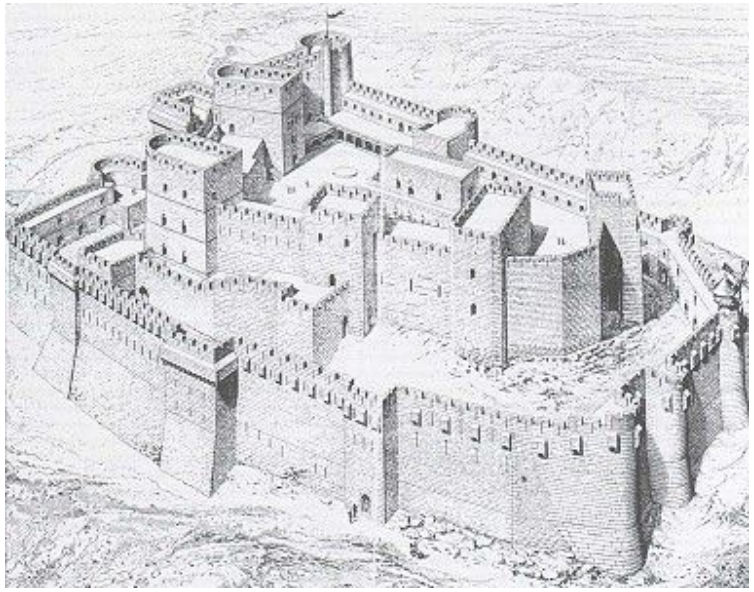
The Key Principles

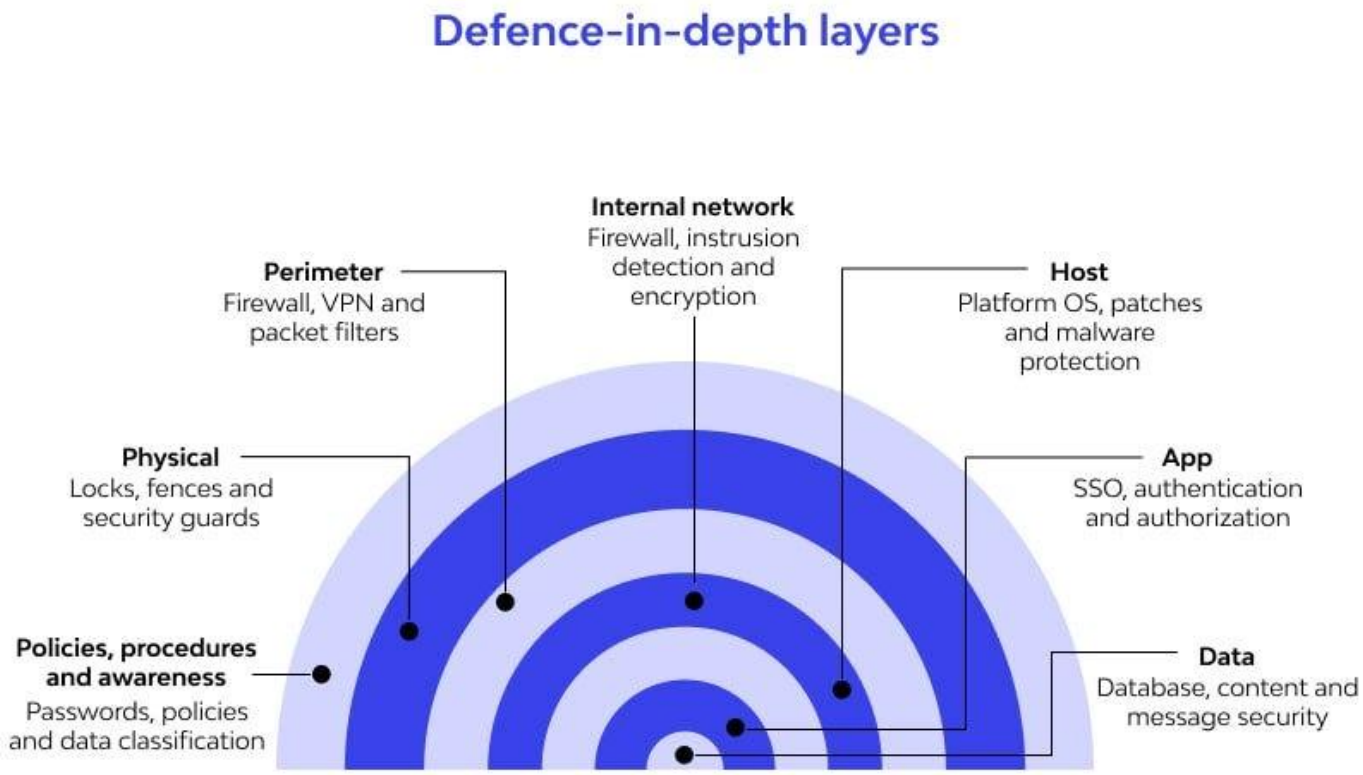
- Economy of mechanism a.k.a. KISS
- Fail-safe defaults
- Don't rely on security by obscurity
- Complete mediation
- Least privilege
- Separation of duty
- **Defense in depth**
- Factor in users/acceptance/psychology
- Work factor/economics

} Later

Defense in Depth

- Few defensive measures are perfect
- Plan for failures
- Beware risk compensation!





Participation Question

Systems based on ACLs (like UNIX) typically deny access entirely if a subject is not listed on the relevant ACL. This is an example of which principle?

A. Fail-safe defaults
B. Complete mediation
C. Separation of duty
D. Defense in depth

I Followed All Security Principles - Am I Secure?

Ευχαριστώ και καλή μέρα εύχομαι!

Keep hacking!