INTRODUCTION
COMPUTER & NETWORK SECURITY

CMSC 414

JAN 25 2018

TODAY

- What is security? Why is it so hard to achieve?
- Administrative
- The security mindset
- Analyzing a system's security
  1. Summarize the system
  2. Identify the assets
  3. Identify the adversaries & threats
  4. Identify the vulnerabilities

WHAT IS COMPUTER & NETWORK SECURITY?

- Normally, we are concerned with <u>correctness</u>
  - Does the software achieve the desired behavior?
- Security is a form of correctness
  - Does the software prevent “undesired” behavior?

The key difference:

Security involves an adversary who is active and malicious.

Attackers seek to circumvent protective measures.

WHAT DOES IT MEAN TO BE SECURE?

There is no such thing as security, only degrees of insecurity.

Goal: Raise the bar for the attacker

- Too difficult
- Too expensive
- Lower ROI than the next target

Ultimately, we want to mitigate undesired behavior

WHAT ARE "UNDESIRED" BEHAVIORS?

- Reveals info users wish to hide (confidentiality)
  - Corporate secrets
  - Private data; personally identifying information (PII)
- Modifies information or functionality (integrity)
  - Destroys records
  - Changes data in-flight (think "the telephone game")
  - Installs unwanted software (spambot, spyware, etc.)
- Denies access to a service (availability)
  - Crashing a website for political reasons
  - Denial of service attack
  - Variant: fairness

This is a subset

ATTACKS ARE COMMON

WHY ARE ATTACKS COMMON?

- Because attacks are derived from design flaws or implementation bugs
- But all software has bugs: so what?
- A *normal user* never sees most bugs
  - Post-deployment bugs are usually rare corner cases
- Too expensive to fix every bug
  - Normal thought process: “Let’s only fix what’s likely to affect normal users”

WHY ARE ATTACKS COMMON?

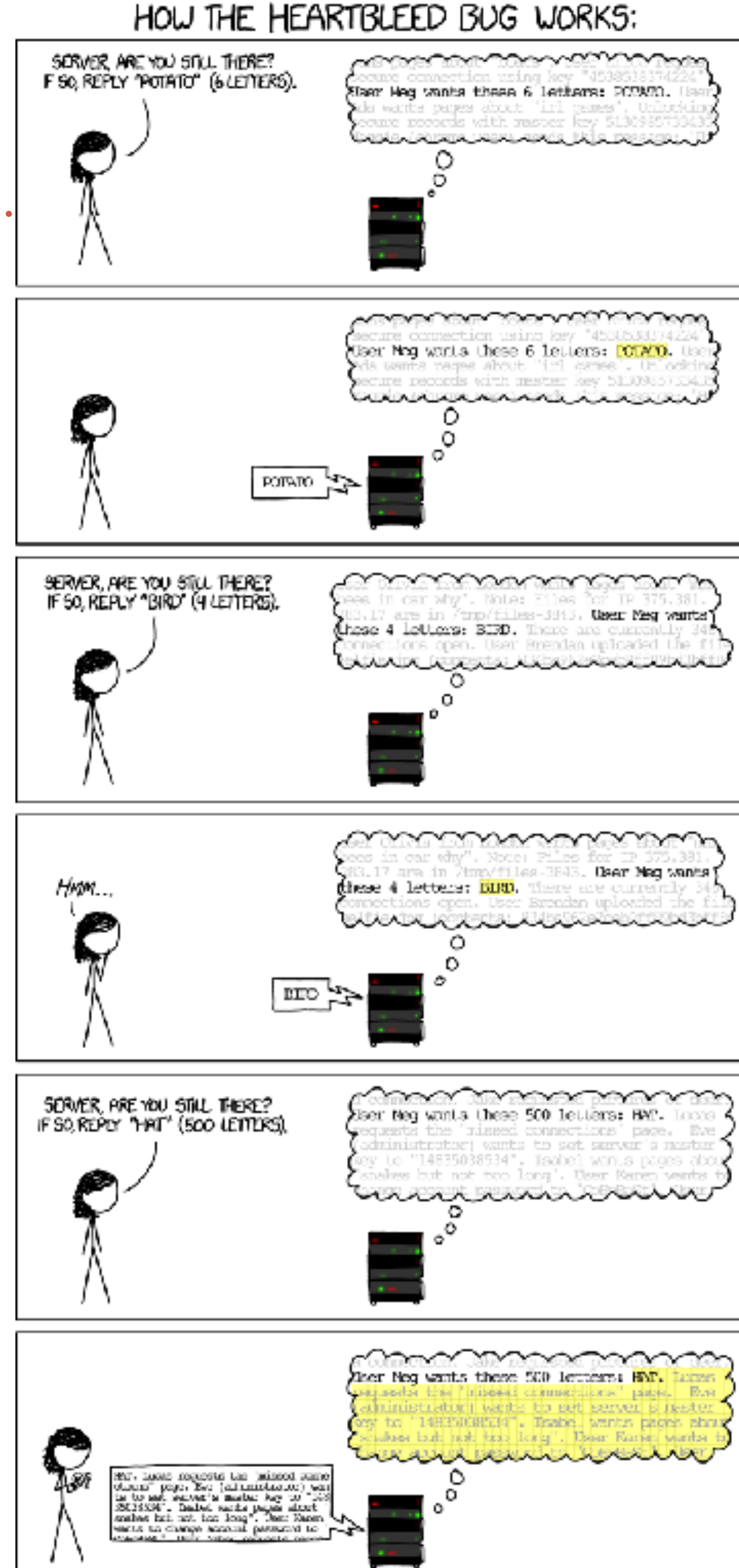
Attackers are not normal users

- Normal users avoid bugs/flaws
- Adversaries seek them out and try to *exploit* them

This extends beyond software:

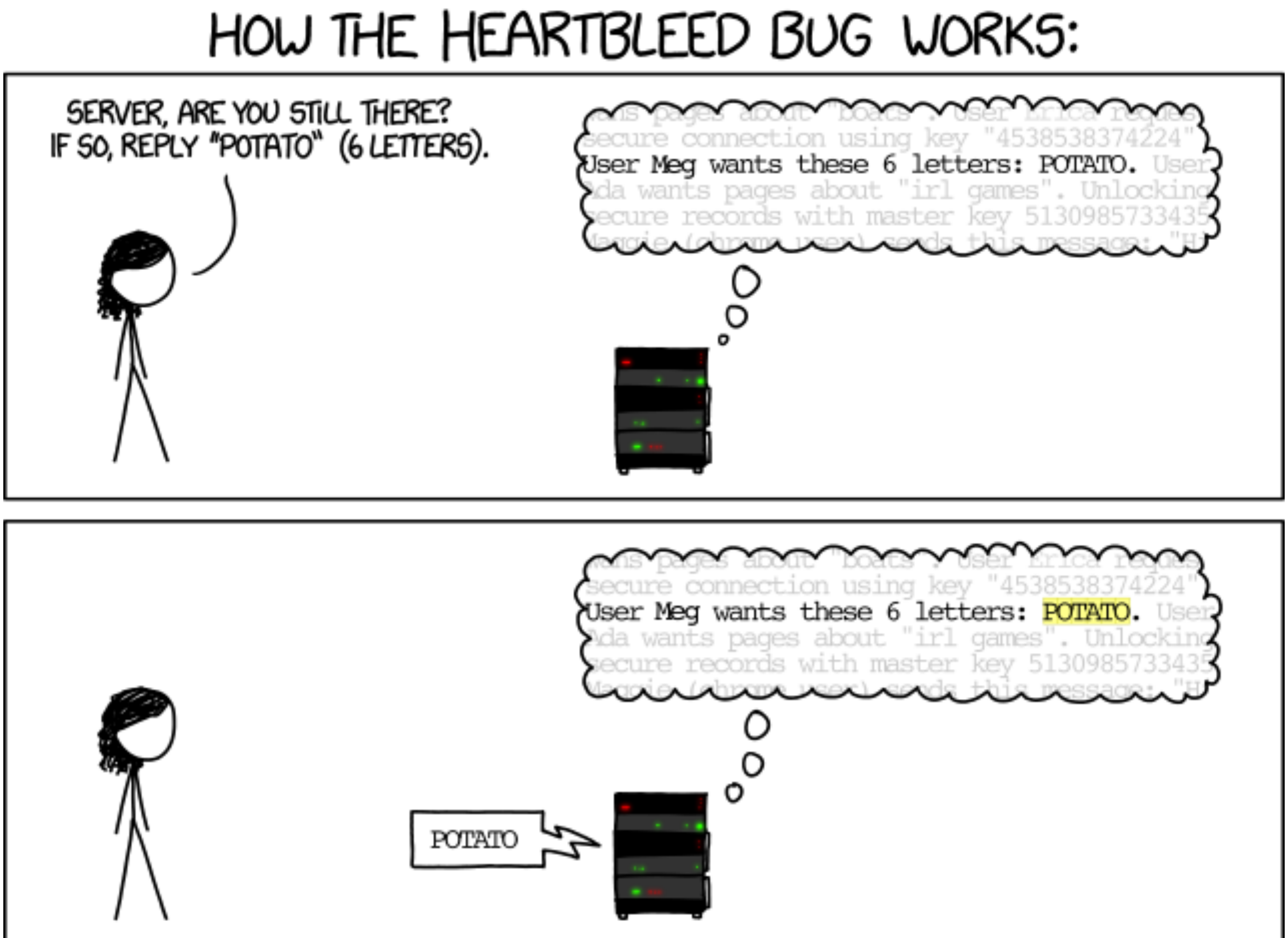
Attacks are possible even with perfect software

HEARTBLEED

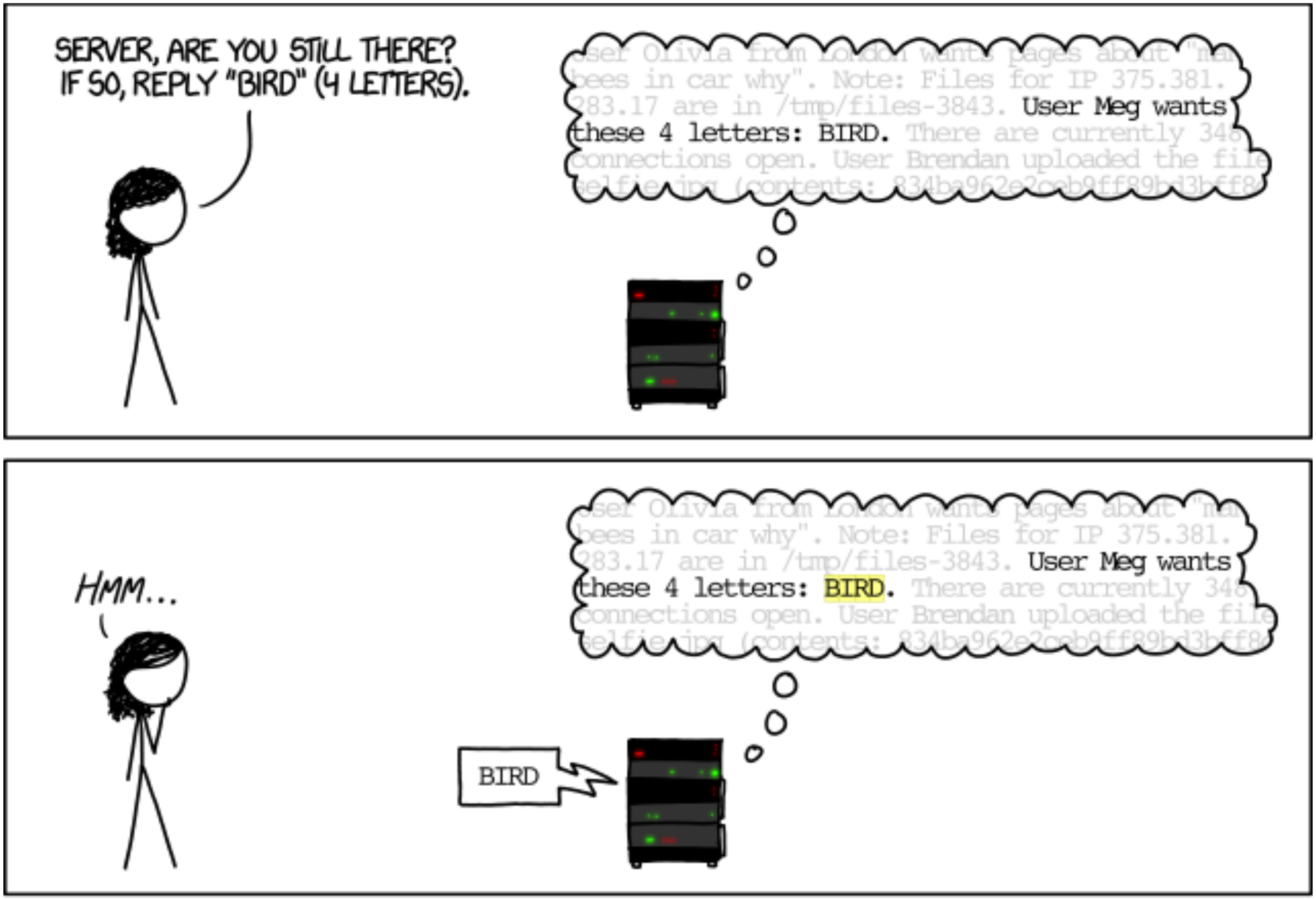


- TLS is the de facto protocol for secure online communication
- Heartbleed was a vulnerability in the most popular TLS server
  - A malformed packet allows you to see server memory
- Fix: don't let the user just tell you how much data to give back
- This was a design flaw

HEARTBLEED


HOW THE HEARTBLEED BUG WORKS:
SERVER, ARE YOU STILL THERE? IF SO, REPLY "POTATO" (6 LETTERS).
secure connection using key "4538538374224"
User Meg wants these 6 letters: POTATO. User
Ada wants pages about "irl games". Unlocking
secure records with master key 5130985733435
POTATO

HEARTBLEED


SERVER, ARE YOU STILL THERE? IF SO, REPLY "BIRD" (4 LETTERS).
ser Olivia from London wants pages about "ma
bees in car why". Note: Files for IP 375.381.
283.17 are in /tmp/files-3843. User Meg wants
these 4 letters: BIRD. There are currently 34
connections open. User Brendan uploaded the file
selfie.jpg (contents: 834ba962e2ceb9ff89bd3bff8
HMM...
ser Olivia from London wants pages about "ma
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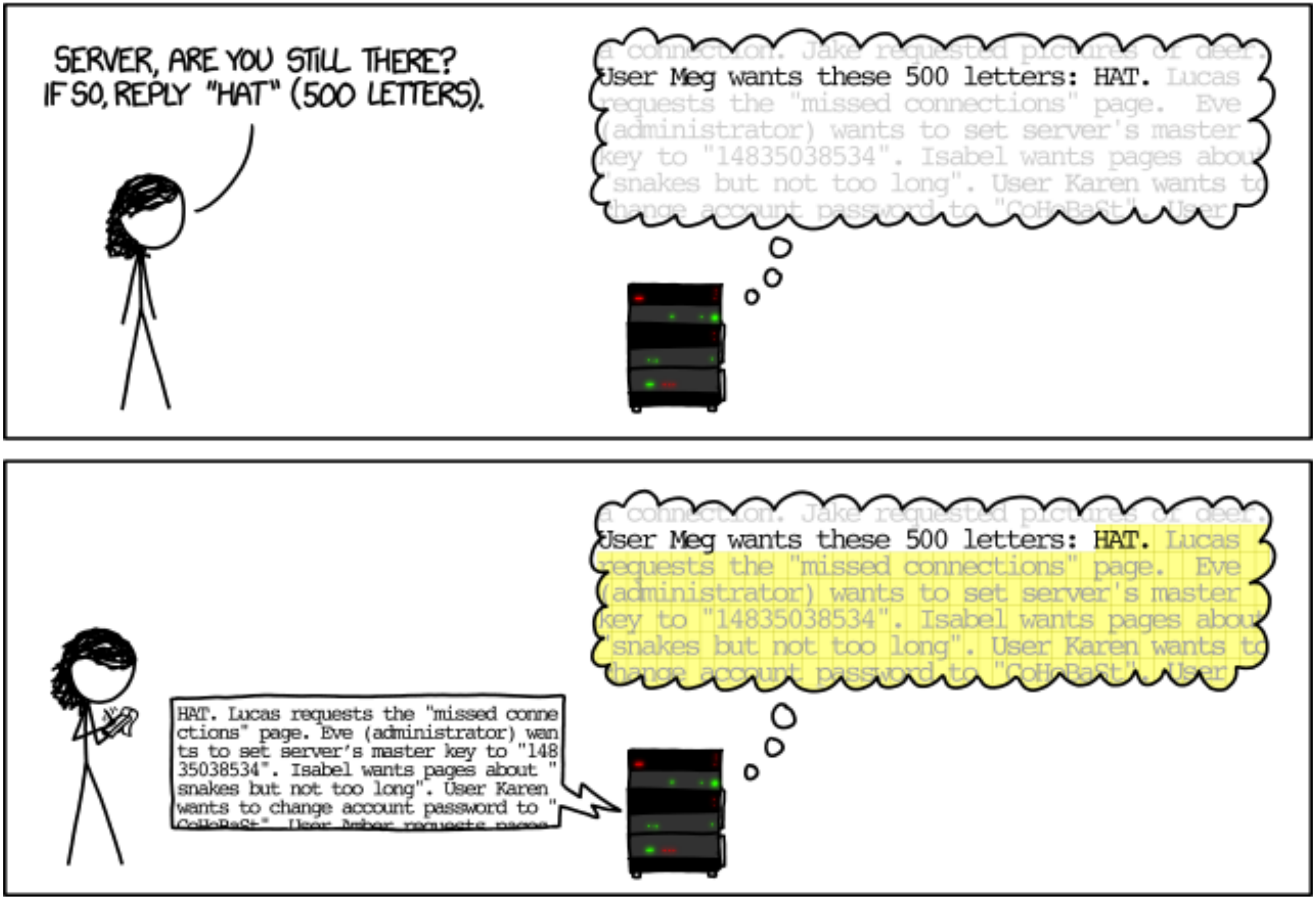
BIRD

HEARTBLEED



User passwords, private keys, personal information…

~40% of “secure” web servers vulnerable

RSA 2011 BREACH

1. **Carefully crafted Flash program**. When run by the vulnerable Flash player, allows the attacker to execute arbitrary code on the running machine.

2. This program could be **embedded in an Excel spreadsheet**, and run automatically when the spreadsheet was opened.

3. Spreadsheet **attached to an email**, masquerading as a trusted party (“spearphishing”)
   - You can forge any “From” address

WHY ARE ATTACKS COMMON?

Because it's **profitable**

And because a system is
*only as secure as its **weakest link***

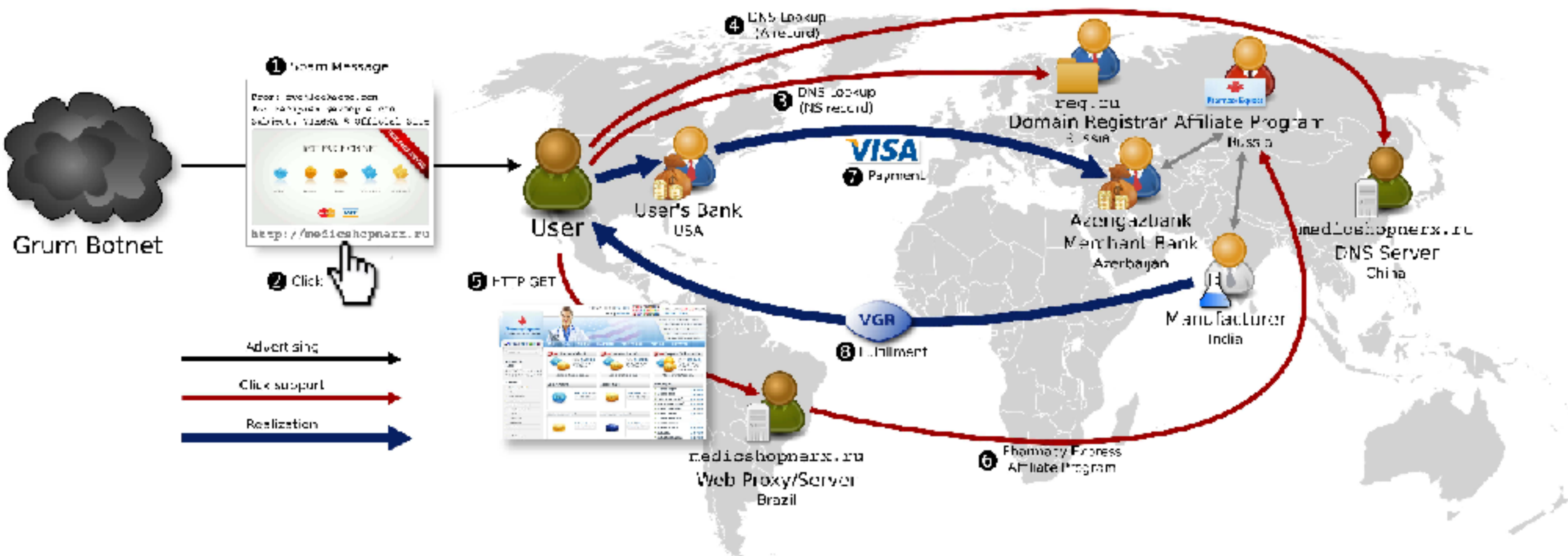


Figure 1: Infrastructure involved in a single URL's value chain, including advertisement, click support and realization steps.

WHY ARE ATTACKS COMMON?

- Security is a property of the systems *we build*
- Many attacks begin by exploiting a vulnerability
  - Vulnerability = defect in hw, sw, protocol, design, … that can be exploited to yield an undesired behavior
  - Software defect = the code doesn't "behave correctly"
- Defects arise due to
  - flaws in the design and/or
  - bugs in the implementation

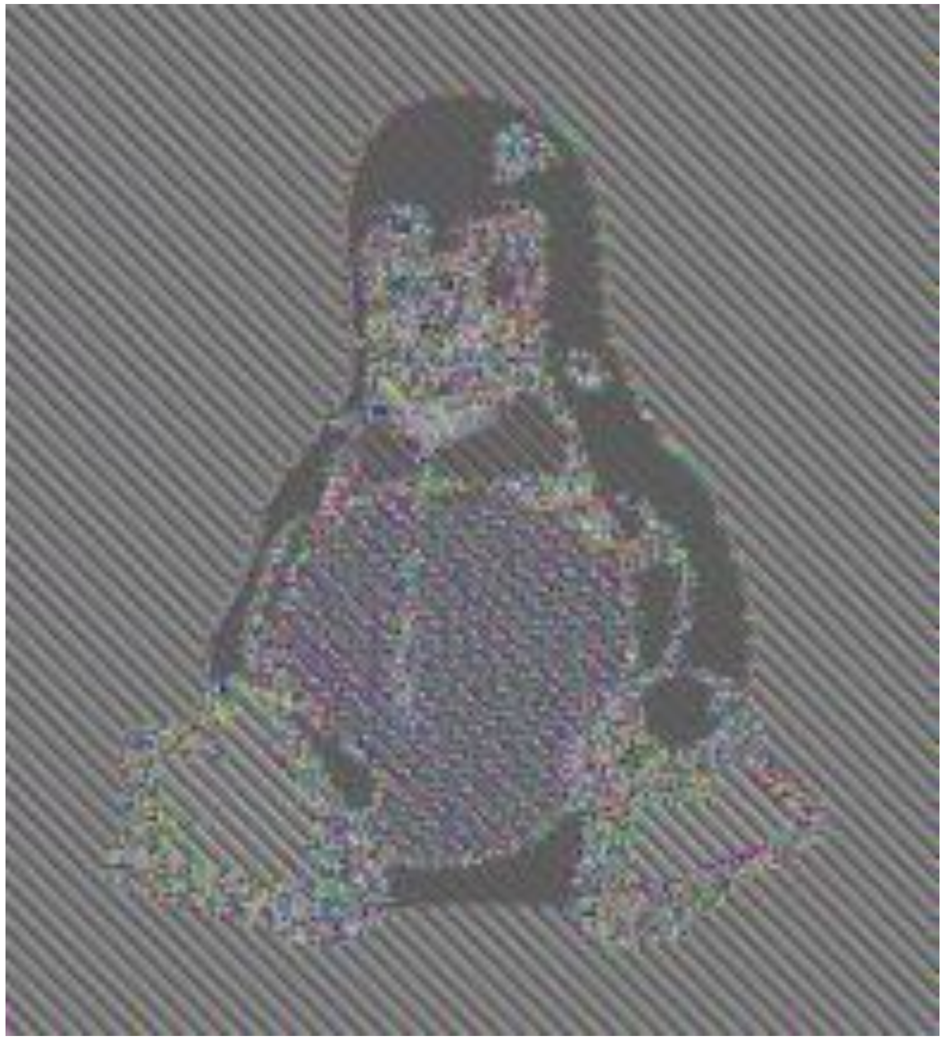
In order to achieve security, we must:

Be able to eliminate bugs and design flaws and/or make them harder to exploit.

Be able to think like attackers.

Develop a foundation for deeply understanding the systems we use and build.

UNDERSTANDING THE SYSTEMS WE USE



This is an encrypted image

50% of Android apps that use crypto encrypt in this manner

GOALS OF CMSC 414

Be able to eliminate bugs and design flaws and/or make them harder to exploit.

Be able to think like attackers.

Develop a foundation for deeply understanding the systems we use and build.

Software **Hardware** **Protocols**

Users **Law** **Economics**

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ADMINISTRATIVE: ONLINE RESOURCES

- Resources and all this info will be on the class website
  - http://www.cs.umd.edu/class/spring2018/cmsc414-0101
- We will be using Piazza
  - You should have been added; let me know if you haven't

ADMINISTRATIVE: THE TEAM

Michael Bartner

Nirat Saini

Nishant Rodrigues

Omer Akgul

Ronald Cheng

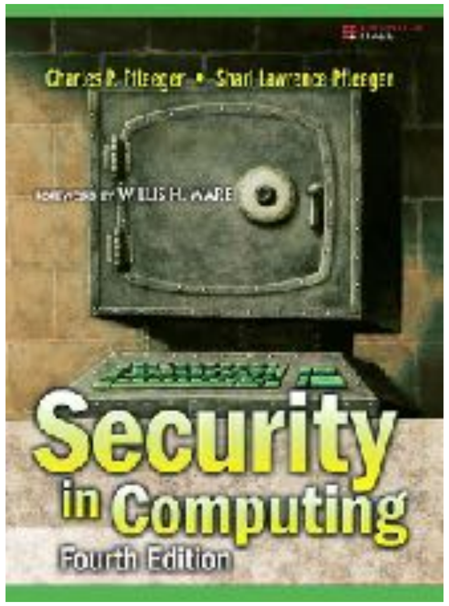
Soumya Indela

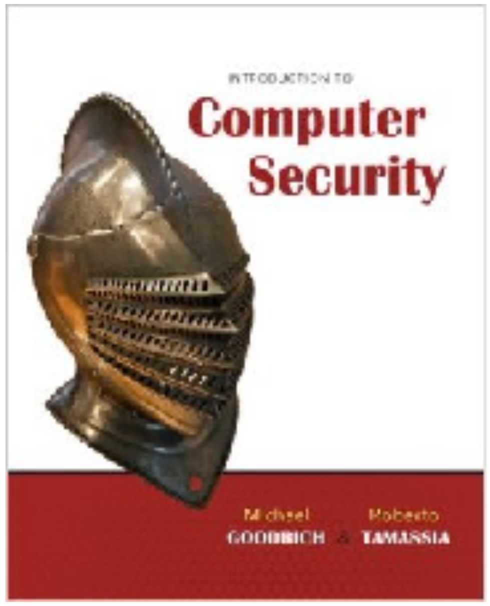
Tommy Hegarty

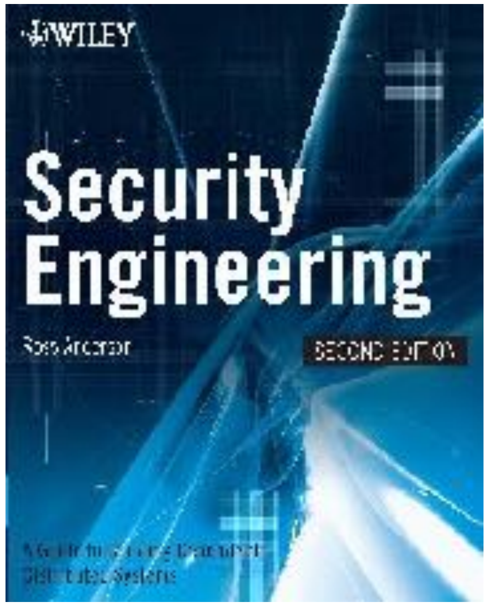
ADMINISTRATIVE: TEXTBOOKS

- None required
  - Mostly in-class and papers posted on website

- Recommended texts, if you are so inclined
  - "Security in Computing", Pfleeger & Pfleger
  - "Introduction to Computer Security", Goodrich & Tamassia
  - "Security Engineering", Ross Anderson
    - Free online: http://www.cl.cam.ac.uk/~rja14/book.html







ADMINISTRATIVE: OUTSIDE READING

- The best way to learn is to reinforce
- *Lots* of security resources (something is always breaking).
  - Krebs on security
  - Bruce Schneier's blog
  - reddit.com/r/netsec
  - Any other favorites? Let us know on Piazza

WHAT'S IN THIS COURSE

Software Security

How do we build software that is secure?

Memory safety

Malware

Web security

Static analysis

Design principles

WHAT'S IN THIS COURSE

Crypto

What it is, and how to use it responsibly

A black-box approach to crypto

Designing protocols that *use* crypto

Authentication: proving who you are

Anonymity: hiding who you are

WHAT'S IN THIS COURSE

Attacks on TCP & DNS

Botnets

Underground spam economies

Network Security

How to build secure networked systems.

WHAT'S IN THIS COURSE

Software Security	***How do we build software that is secure?***
Crypto	***What it is, and how to use it responsibly***
Network Security	***How to build secure networked systems.***

Attacks and defenses across all of these

Brief Listing of the Top 25

This is a brief listing of the Top 25 items, using the general ranking.

NOTE: 16 other weaknesses were considered for inclusion in the Top 25, but their general scores were not high enough. They are listed in a separate "On the Cusp" page.

Rank	Score	ID	Name
[1]	93.8	CWE-89	Improper Neutralization of Special Elements used in an SQL Command ('SQL Injection')
[2]	83.3	CWE-78	Improper Neutralization of Special Elements used in an OS Command ('OS Command Injection')
[3]	79.0	CWE-120	Buffer Copy without Checking Size of Input ('Classic Buffer Overflow')
[4]	77.7	CWE-79	Improper Neutralization of Input During Web Page Generation ('Cross-site Scripting')
[5]	76.9	CWE-306	Missing Authentication for Critical Function
[6]	76.8	CWE-862	Missing Authorization
[7]	75.0	CWE-798	Use of Hard-coded Credentials
[8]	75.0	CWE-311	Missing Encryption of Sensitive Data
[9]	74.0	CWE-434	Unrestricted Upload of File with Dangerous Type
[10]	73.8	CWE-807	Reliance on Untrusted Inputs in a Security Decision
[11]	73.1	CWE-250	Execution with Unnecessary Privileges
[12]	70.1	CWE-352	Cross-Site Request Forgery (CSRF)

ETHICS AND LEGALITY

- You will be learning about (and implementing and *launching*) attacks, many of which are in active use today.
- ***This is not an invitation to use them without the explicit written consent of all parties involved***
- If you want to try something out, then *let me know* and I will try to help create a safe environment
- This is not just a question of ethics; to do otherwise would risk violating UMD policies and MD/USA laws

PREREQUISITE KNOWLEDGE

- You should be reasonably proficient in C and Unix
- You should also be creative and resourceful (those who try to attack your systems will be!)
- Otherwise, this course **won't** require any prior knowledge in networking or crypto

WHAT ARE GRADES BASED ON?

- Grade breakdown
  - 50%: Projects (P1-P3: 10%, P4: 20%)
  - Midterms (2 x 12% each)
  - Final (25%)
  - Meet your professor (1%)

MEET YOUR PROFESSOR (THAT'S ME!)

- You come by my office at some point ***before the last day of classes*** and we chat
- Gives me a chance to get to know each of you, learn about your interests, chat plans/research…
- Again: if you are booked during my office hours, just email me to set up a time.

EXAMS

Expected dates

Midterm #1:	Midterm #2:	Final exam:
Mar 8	Apr 19	May 18
12%	**12%**	**25%**

Please see the syllabus for information about excused absences

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THE SECURITY MINDSET

To anticipate attackers
we must be able to think like attackers

SMARTWATER +  = *Proof of ownership*

Uniquely identifiable liquid

What would an attacker do?

Paint it on *someone else's* property
and then call the cops

THE SECURITY MINDSET

To anticipate attackers
we must be able to think like attackers

Fill out a card with your address

⟹

They deliver a box of live ants to you

What would an attacker do?

Order them to *someone else*

THE SECURITY MINDSET

The ability to view a large, complex system and be able to reason about:

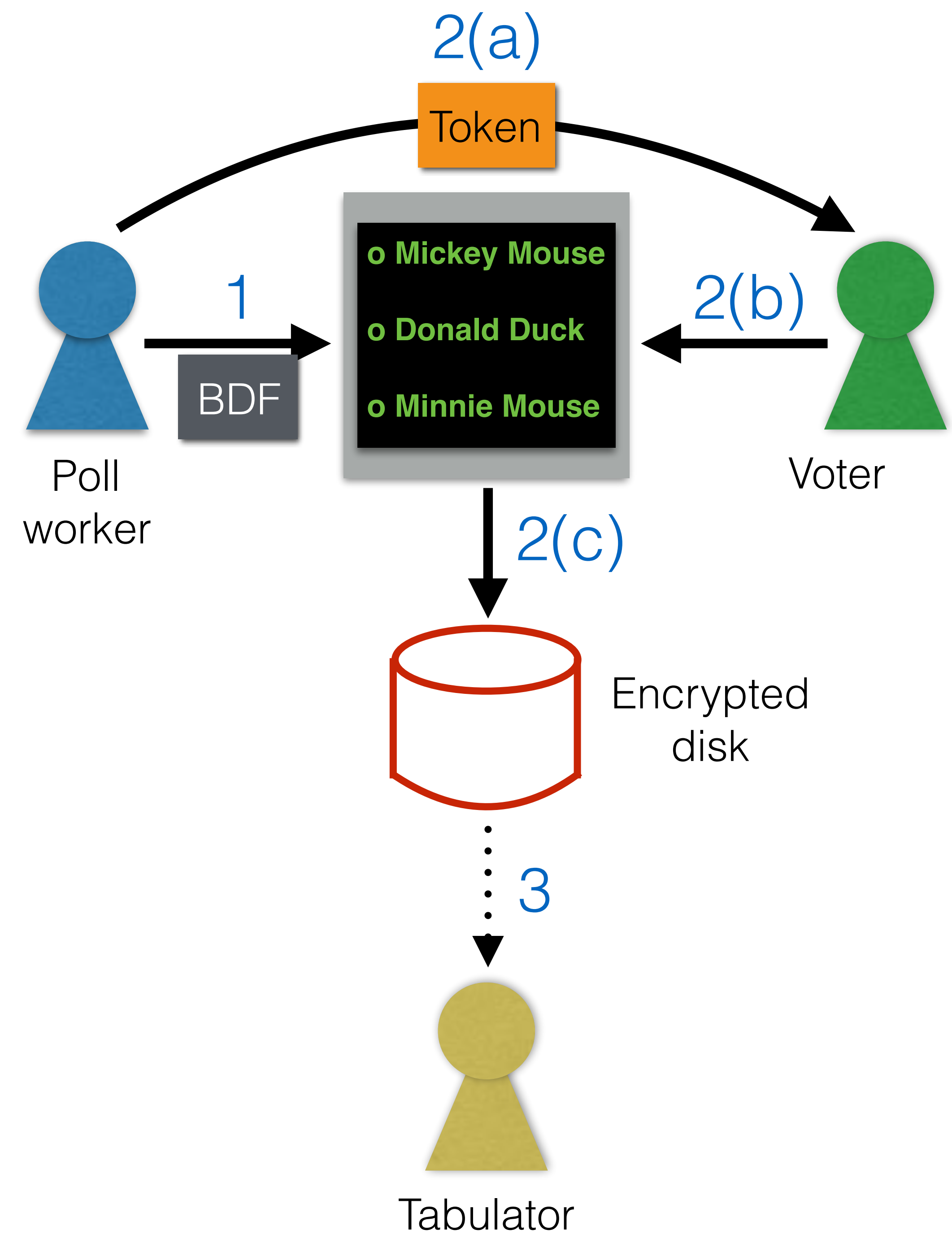
- What are the potential security threats?
- What are the hidden assumptions?
- Are the *explicit* assumptions true?
- How can we mitigate the risks of the system?

Be creative! (Attackers will be)

E-voting analysis

1. Summarize the system as clearly and concisely as possible

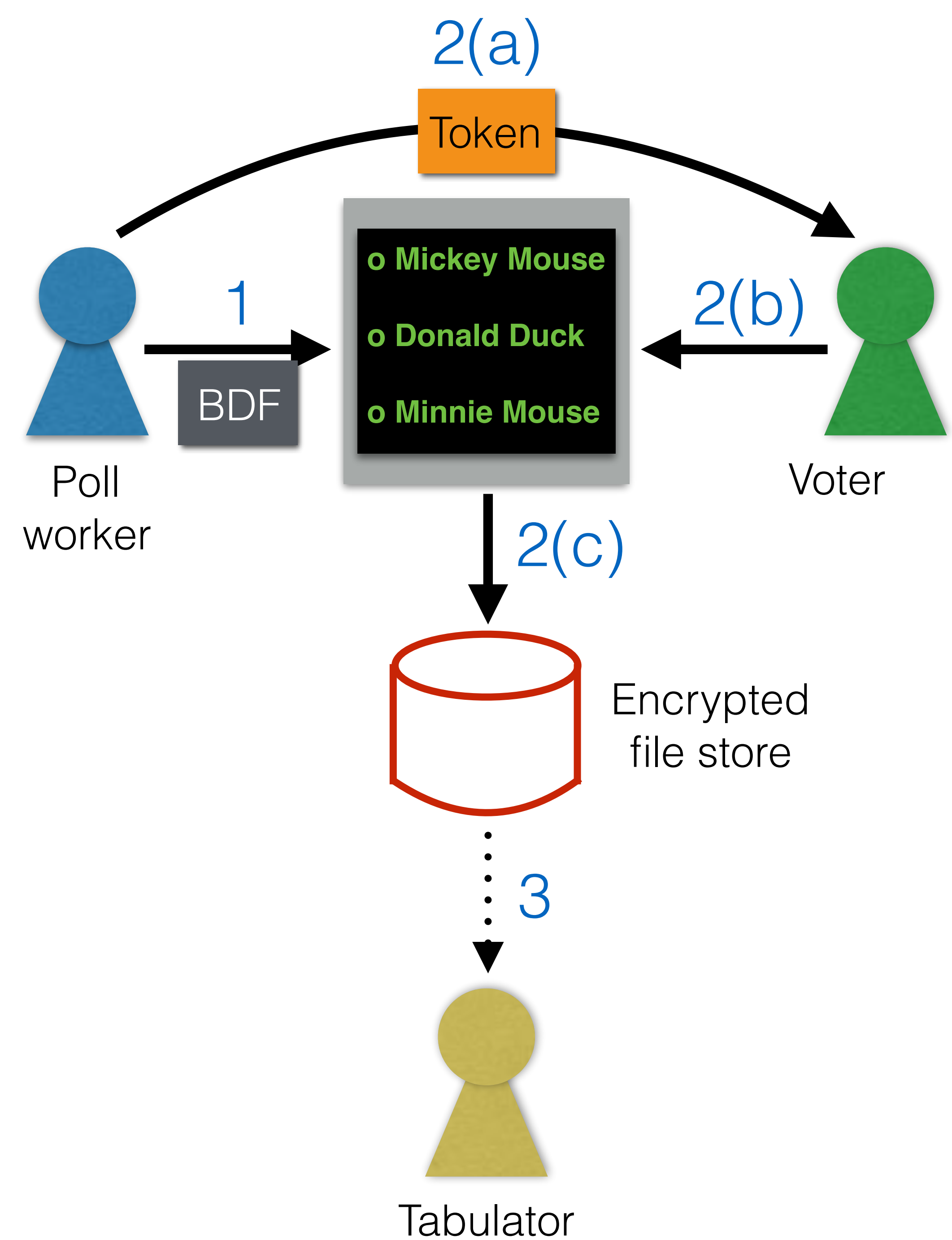
1. Pre-election phase
   - Poll worker loads a "ballot definition file" (defines who's running, colors on the screen, and many more things) on the voting machines with, e.g., USB
2. Voting phase
   (a) Voter obtains a single-use token from poll workers (on smartcard)
   (b) Voter uses the token to interactively vote
   (c) Vote stored encrypted on disk
   (d) Voter token canceled
3. Post-election phase
   - Stored votes decrypted and transported to tabulator
   - Tabulator counts and announces vote



E-voting analysis

2. Identify the assets / goals of the system

- Confidentiality
  - No one knows for whom any given voter voted (except for the voter)
- Integrity
  - Every voter's vote counted *once*
  - No voter's vote changed
- Availability
  - Everyone has the ability to cast their vote
- Usability
  - Easy for the voter to vote (correct language, good UI)
  - Easy for the tabulator to count votes

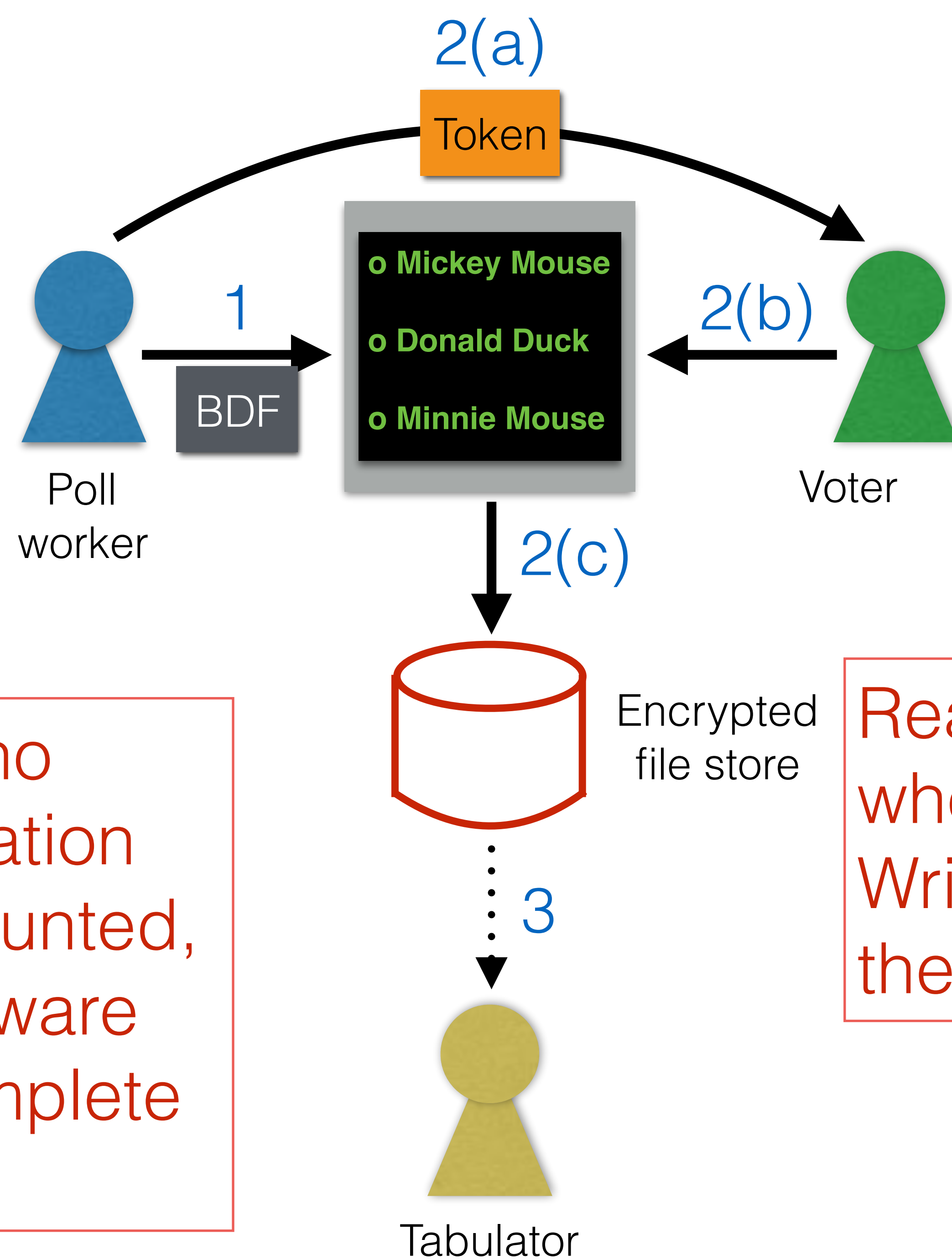


E-voting analysis

3. Identify the adversaries and threats

Poll worker could set BDF to print “Mickey Mouse” but record as “Minnie Mouse”

Voter could attempt to generate their own tokens & get ≥2 votes



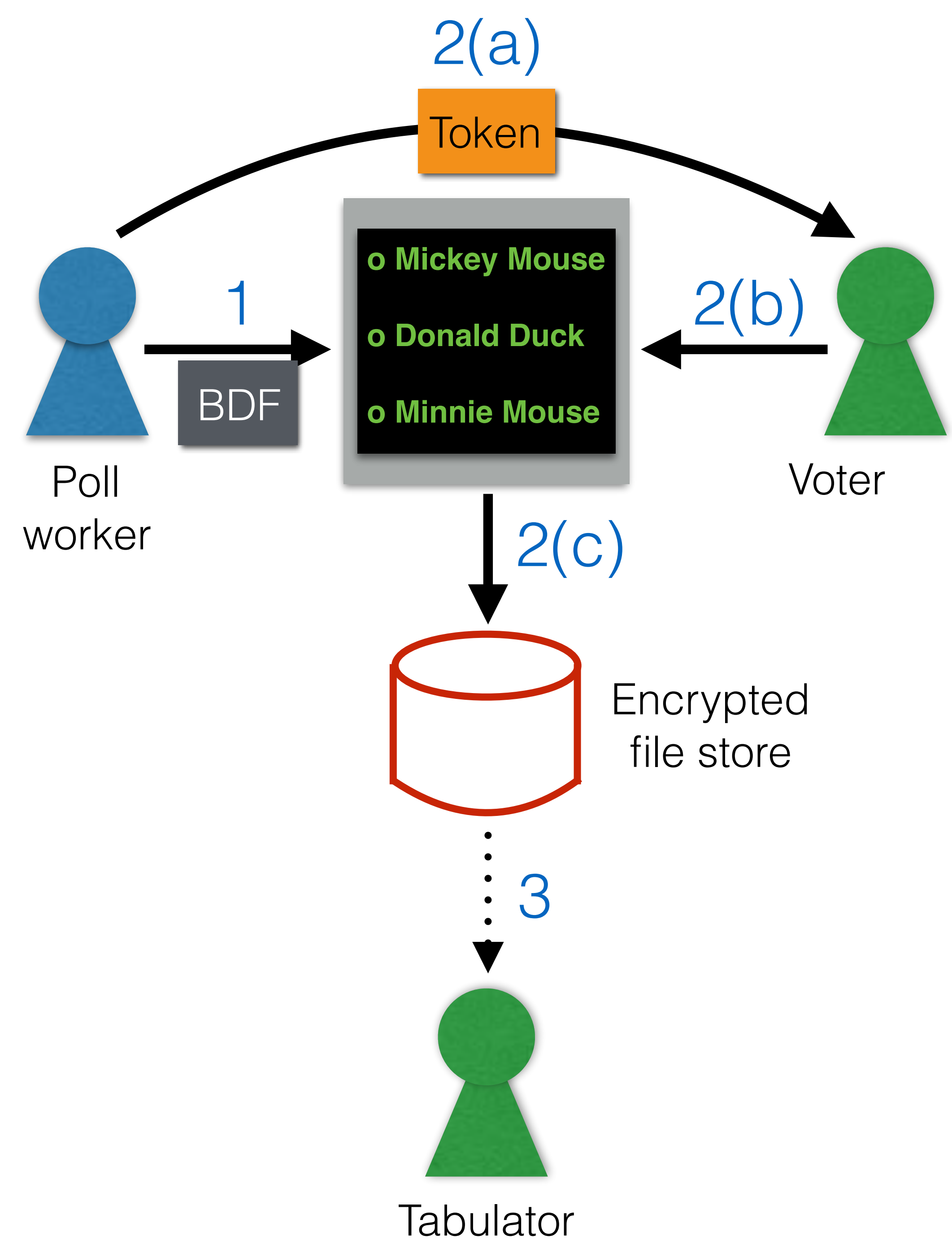
Because there is no end-to-end verification that a vote was counted, modifying the software could result in complete control

Reading this could reveal who voted for whom. Writing it could change the outcome altogether

E-voting analysis

4. Identify the vulnerabilities

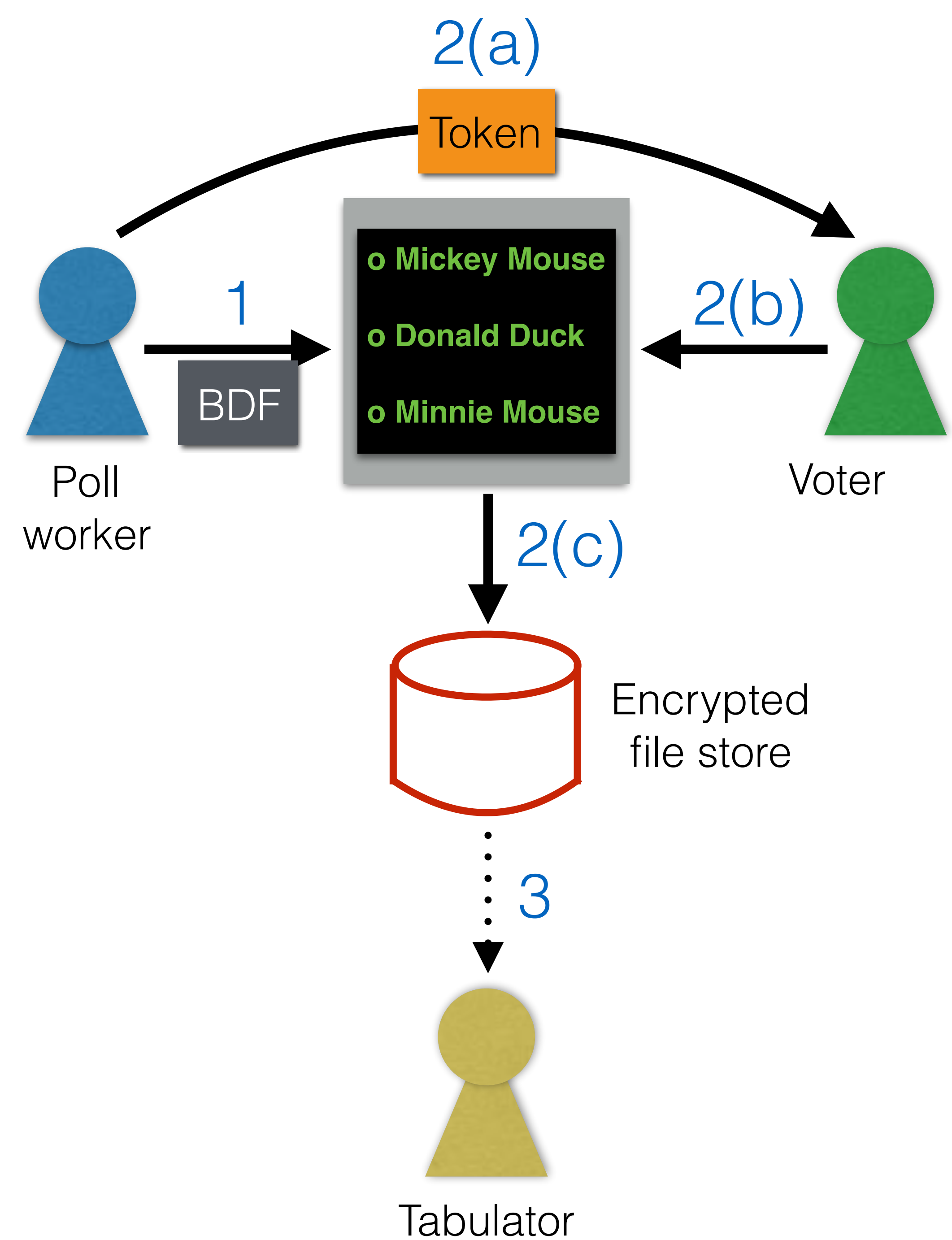
- Ballot definition files are not authenticated
  - How do we know they're from the election board?
  - Can redefine "Candidate A" as "Candidate B"
  - Viruses
- Smartcards are not authenticated
  - How do we know they're not user-generated?
  - Possible to make your own and vote multiple times.
- Specific software vulnerabilities
  - Every machine has the same encryption key!
  - Break one, and they all fall
- Votes are shipped unencrypted!
- Votes are stored in the order cast
  - If one can view the data unencrypted, this violates our confidentiality goal



E-voting analysis

Takeaway points

- Analyzing security requires a whole-systems view
  - Hardware
  - Software
  - Data
  - People
- Security is only as strong as the weakest link
  - May have been difficult to break into the building
  - But if the data is sent unencrypted…
- Securing a system can be difficult
  - Interdisciplinary (software, hardware, UI design)
  - Humans are in the loop
- Security through obscurity does not work
  - Especially for high-value assets
  - It's only a matter of time until someone finds out



NEXT TIME

We will begin our 1st section:

Software Security

By investigating

Buffer overflows

and other memory safety vulnerabilities

To prepare: you may want to brush up on your C

Particularly if this seems foreign to you:

```
char buf[32];
unsigned *ptr = (unsigned*) (buf + 12);
*ptr += 0x1a;
```