CSE 484 / CSE M 584: Computer Security and Privacy

Software Security (Misc)

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Franziska (Franzi) Roesner
franzi@cs.washington.edu

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Last Words on Buffer Overflows…

Defenses Discussed Last Time

- Executable space prevention
- Stack canaries
- Address Space Layout Randomization (ASLR)

Other Possible Solutions

- Use safe programming languages, e.g., Java
  - What about legacy C code?
  - (Though Java doesn't magically fix all security issues ☺)
- Static analysis of source code to find overflows
- Dynamic testing: "fuzzing"

Beyond Buffer Overflows…

Another Type of Vulnerability

- Consider this code:

```
int openfile(char *path) {
     struct stat s;
     if (stat(path, &s) < 0)
          return -1;
     if (!S_ISRREG(s.st_mode)) {
          error("only allowed to regular files!");
          return -1;
     }
     return open(path, O_RDONLY);
}
```

- **Goal:** Open only regular files (not symlink, etc)
- What can go wrong?

TOCTOU (Race Condition)

- TOCTOU == Time of Check to Time of Use:

```
int openfile(char *path) {
    struct stat s;
    if (stat(path, &s) < 0)
        return -1;
    if (!S_ISRREG(s.st_mode)) {
        error("only allowed to regular files!");
        return -1;
    }
    return open(path, O_RDONLY);
}
```

- **Goal:** Open only regular files (not symlink, etc)
- Attacker can change meaning of path between stat and open (and access files he or she shouldn't)

Another Type of Vulnerability

- Consider this code:

```
char buf[80];
void vulnerable() {
     int len = read_int_from_network();
     char *p = read_string_from_network();
     if (len > sizeof buf) {
          error("length too large, nice try!");
          return;
     }
     memcpy(buf, p, len);
}
```

```
void *memcpy(void *dst, const void * src, size_t n);
```

```
typedef unsigned int size_t;
```

Implicit Cast

- Consider this code:

If len is negative, may copy huge amounts of input into buf.

```
char buf[80];
void vulnerable() {
    int len = read_int_from_network();
    char *p = read_string_from_network();
    if (len > sizeof buf) {
        error("length too large, nice try!");
        return;
    }
    memcpy(buf, p, len);
}
```

```
void *memcpy(void *dst, const void * src, size_t n);
```

```
typedef unsigned int size_t;
```

Another Example

```
size_t len = read_int_from_network();
char *buf;
buf = malloc(len+5);
read(fd, buf, len);
```

(from www-inst.eecs.berkeley.edu—implflaws.pdf)

Integer Overflow

```
size_t len = read_int_from_network();
char *buf;
buf = malloc(len+5);
read(fd, buf, len);
```

- What if len is large (e.g., len = 0xFFFFFFFF)?
- Then len + 5 = 4 (on many platforms)
- Result: Allocate a 4-byte buffer, then read a lot of data into that buffer.

(from www-inst.eecs.berkeley.edu—implflaws.pdf)

Password Checker

- Functional requirements
  - PwdCheck(RealPwd, CandidatePwd) should:
    - Return TRUE if RealPwd matches CandidatePwd
    - Return FALSE otherwise
  - RealPwd and CandidatePwd are both 8 characters long
- Implementation (like TENEX system)

```
PwdCheck(RealPwd, CandidatePwd)  // both 8 chars
    for i = 1 to 8 do
        if (RealPwd[i] != CandidatePwd[i]) then
            return FALSE
    return TRUE
```

- Clearly meets functional description

Attacker Model

```
PwdCheck(RealPwd, CandidatePwd)  // both 8 chars
    for i = 1 to 8 do
        if (RealPwd[i] != CandidatePwd[i]) then
            return FALSE
    return TRUE
```

- Attacker can guess CandidatePwds through some standard interface
- Naive: Try all 256^8 = 18,446,744,073,709,551,616 possibilities
- Better: Time how long it takes to reject a CandidatePasswd. Then try all possibilities for first character, then second, then third, ...
  - Total tries: 256*8 = 2048

Timing Attacks

- Assume there are no “typical” bugs in the software
  - No buffer overflow bugs
  - No format string vulnerabilities
  - Good choice of randomness
  - Good design
- The software may still be vulnerable to timing attacks
  - Software exhibits input-dependent timings
- Complex and hard to fully protect against

Other Examples

- Plenty of other examples of timings attacks
  - Timing cache misses
    - Extract cryptographic keys…
    - Recent Spectre/Meltdown attacks
- Also many other side channels
  - Power analysis
  - Other sensors
    - Example: Accelerometer to extract phone passcode

Software Security:
So what do we do?

Fuzz Testing

- Generate “random” inputs to program
  - Sometimes conforming to input structures (file formats, etc.)
- See if program crashes
  - If crashes, found a bug
  - Bug may be exploitable
- Surprisingly effective

- Now standard part of development lifecycle

General Principles

- Check inputs

Shellshock

- Check inputs: **not just to prevent buffer overflows**
- Example: Shellshock (September 2014)
  - Vulnerable servers processed input from web requests
  - Passed (user-provided) environment variables (like user agent, cookies…) to CGI scripts
  - Maliciously crafted environment variables exploited a bug in bash to execute arbitrary code

```
env x='() { :;}; echo Vulnerable'
   bash -c "echo Real Command"
```

General Principles

- Check inputs
- Check all return values
- Least privilege
- Securely clear memory (passwords, keys, etc.)
- Failsafe defaults
- Defense in depth
  - Also: prevent, detect, respond

- NOT: security through obscurity

General Principles

- Reduce size of trusted computing base (TCB)
- Simplicity, modularity
  - But: Be careful at interface boundaries!
- Minimize attack surface
- Use vetted component
- Security by design
  - But: tension between security and other goals
- Open design? Open source? Closed source?
  - Different perspectives

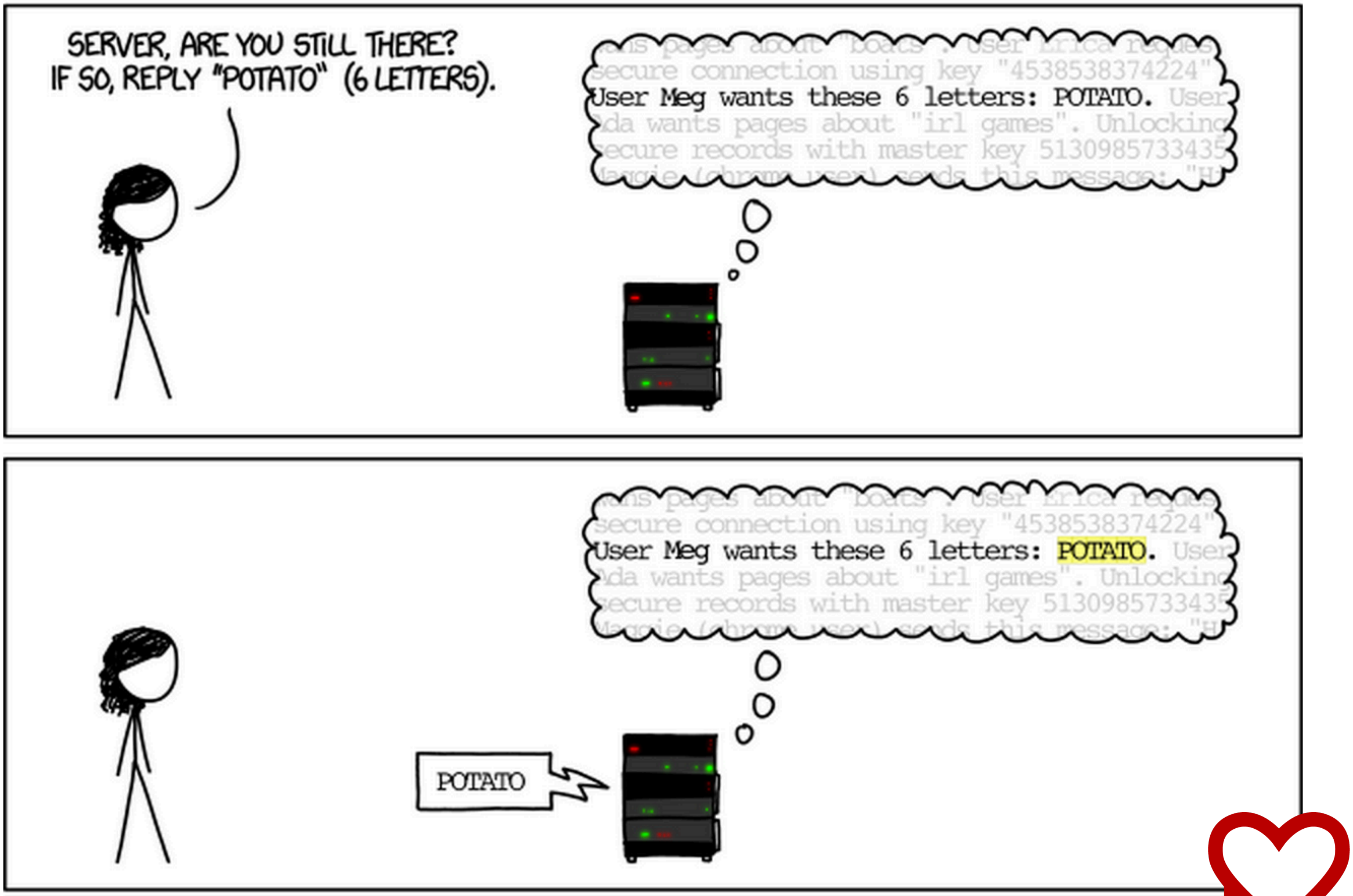
Does Open Source Help?

- Different perspectives…

- Happy example:
  - Linux kernel backdoor attempt thwarted (2003)
    (http://www.freedom-to-tinker.com/?p=472)

- Sad example:
  - Heartbleed (2014)
    - Vulnerability in OpenSSL that allowed attackers to read arbitrary memory from vulnerable servers (including private keys)

http://xkcd.com/1354/


SERVER, ARE YOU STILL THERE? IF SO, REPLY "POTATO" (6 LETTERS).
ants pages about "boats". User Erica reques 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 Maggie (chrome user) sends this message: "H
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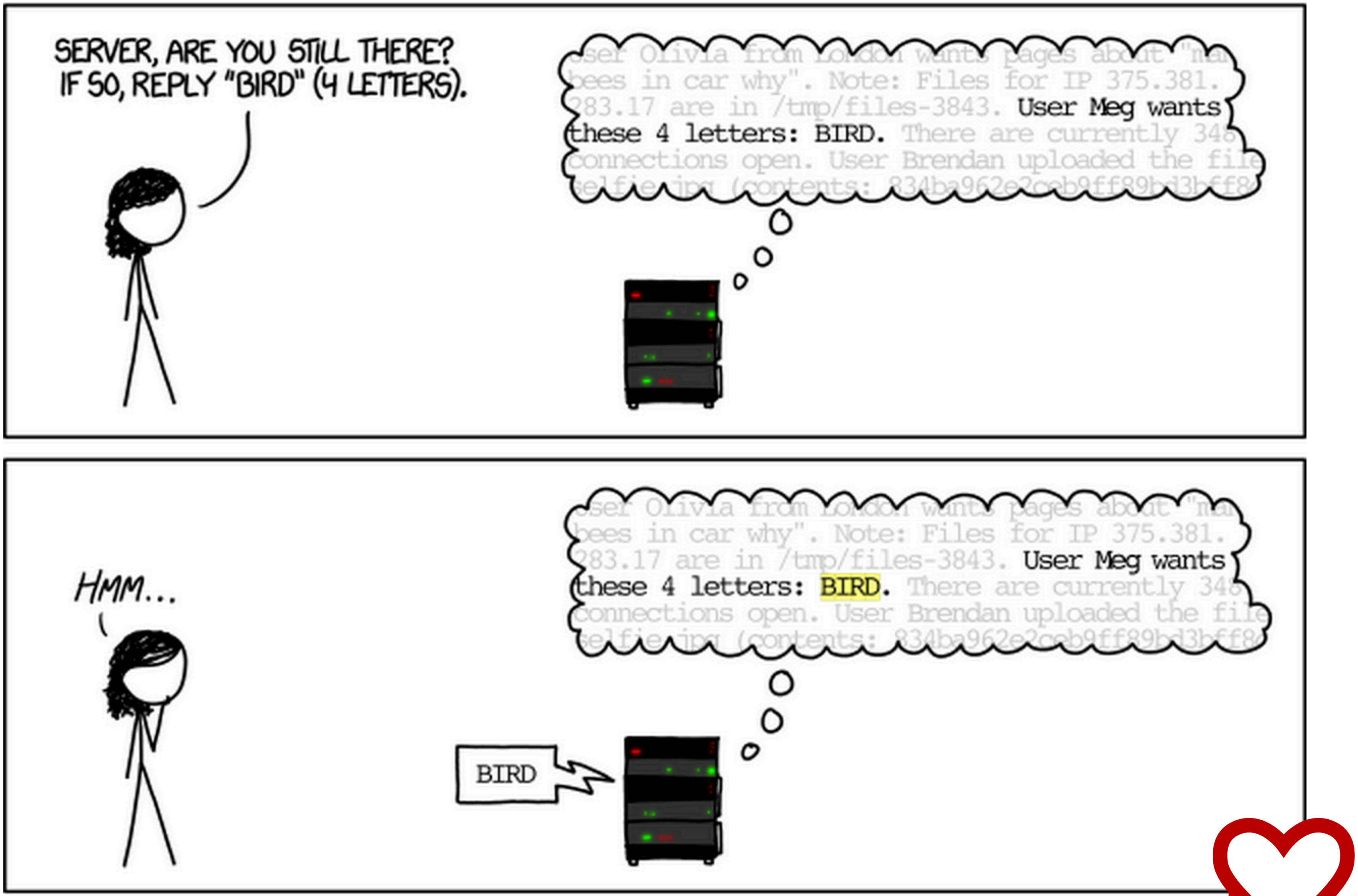
SERVER, ARE YOU STILL THERE? IF SO, REPLY "BIRD" (4 LETTERS).
User Olivia from London wants pages about "ma bees in car why". Note: Files for IP 375.381. 283.17 are in /tmp/files-3843. User Meg wants these 4 letters: BIRD. There are currently 346 connections open. User Brendan uploaded the file selfie.jpg (contents: 834ba962e2ceb9ff89bd3bff8
HMM...
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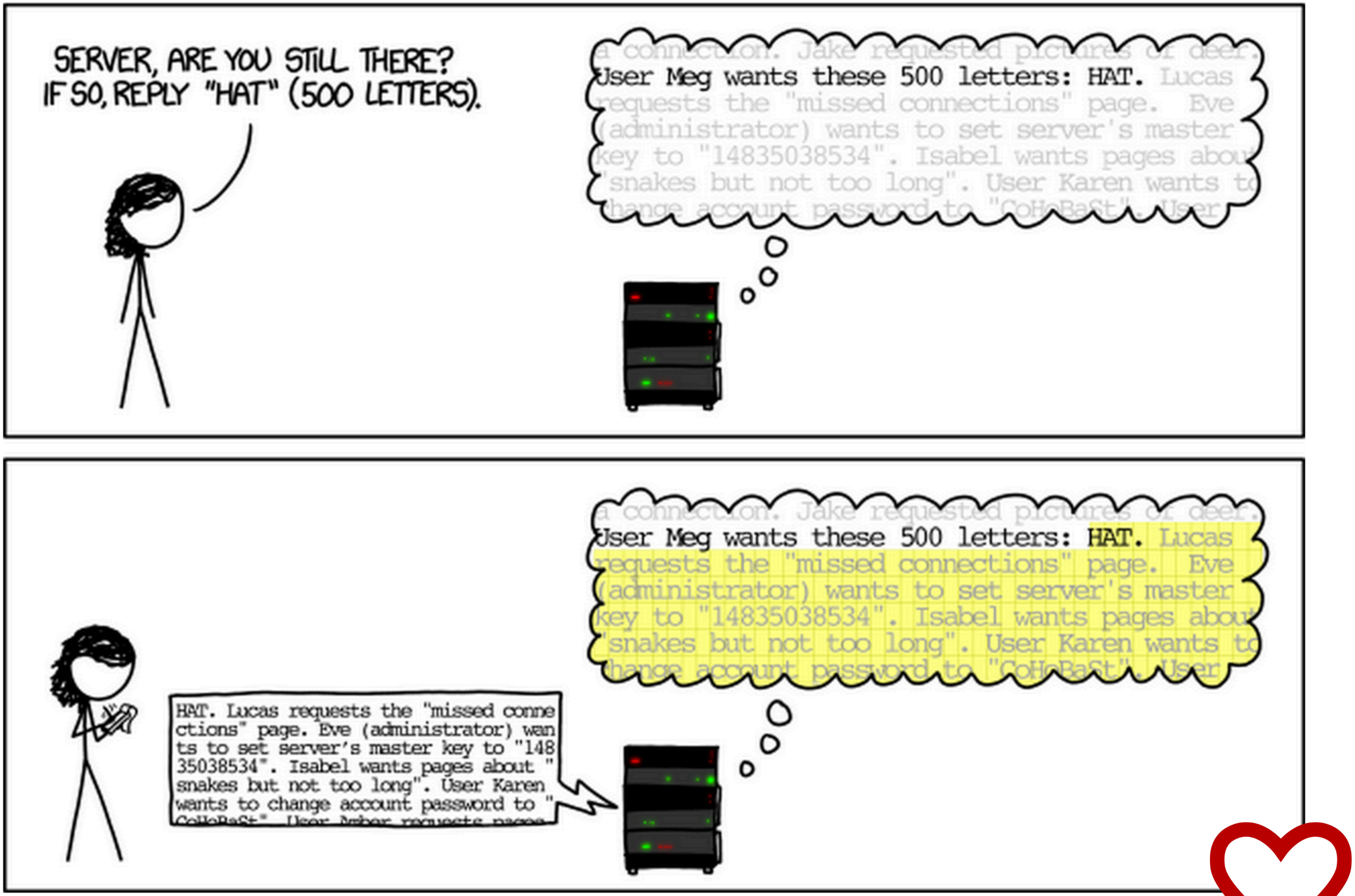
SERVER, ARE YOU STILL THERE? IF SO, REPLY "HAT" (500 LETTERS).
a connection. Jake requested pictures of deer. User Meg wants these 500 letters: HAT. Lucas requests the "missed connections" page. Eve (administrator) wants to set server's master key to "14835038534". Isabel wants pages about "snakes but not too long". User Karen wants to change account password to "CoHoBaSt". User
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HAT. Lucas requests the "missed connections" page. Eve (administrator) wants to set server's master key to "14835038534". Isabel wants pages about "snakes but not too long". User Karen wants to change account password to "CoHoBaSt". User Amber requests pages

Vulnerability Analysis and Disclosure

- What do you do if you've found a security problem in a real system?
- Say
  - A commercial website?
  - UW grade database?
  - Boeing 787?
  - TSA procedures?