CSE 484/M584: Computer Security (and Privacy)

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Admin

- Office hours start today!
- Ed board is open
  - Our target is 24hrs for replies
  - Spend time reading/looking up resources before asking questions
- Lab 1 is out
  - Lab 1a (exploit 1+2) are due Wednesday night.
  - See Gradescope for the handins.
  - Reminder about policies
- 584 students: you have a reading due tonight!

Threat Modeling: Again

Gradescope!

- As in, lets *threat model part of Gradescope* todays in-class activity

Gradescope! – Gradescope Group handins

- How do group handins on Gradescope work?
- Who might be an adversary that would abuse this system?
- What might their goal be?
- What might an asset be?
- *How should we think about defense against this threat?*

Thinking about Defense

Approaches to Defense

- Prevention
  - Stop an attack
- Detection
  - Detect an ongoing or past attack
- Response and Resilience
  - Respond to / recover from attacks

- The threat of a response may be enough to deter some attackers

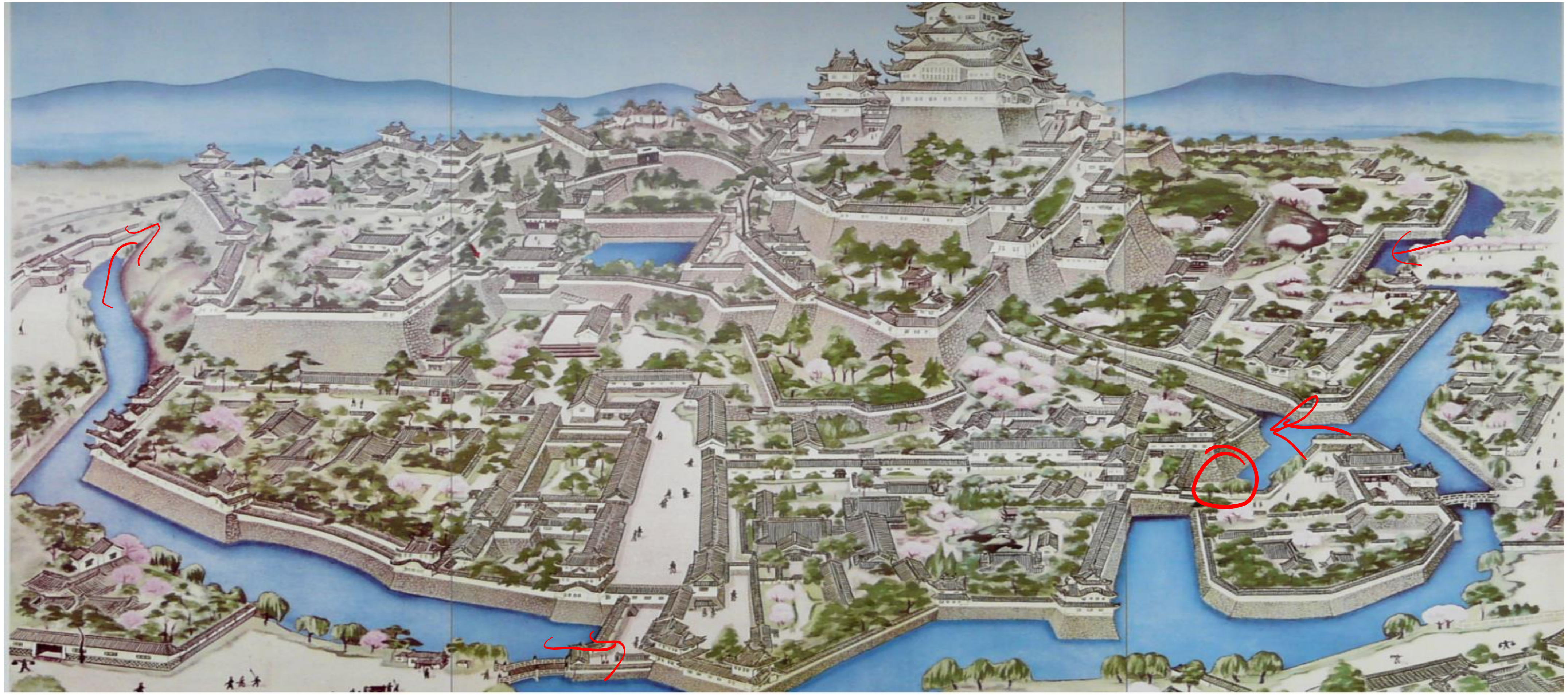
Whole System is Critical

- Securing a system involves a whole-system view
  - Cryptography
  - Implementation
  - People
  - Physical security
  - Everything in between

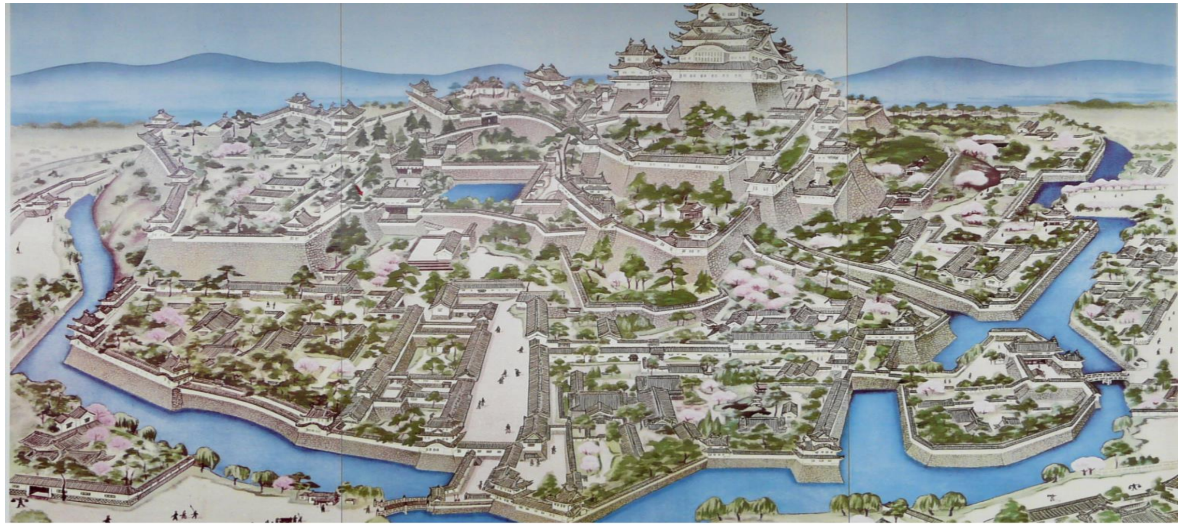
- This is because "security is only as strong as the weakest link," and security can fail in many places
  - No reason to attack the strongest part of a system if you can walk right around it.

Asymmetric advantages in security

Asymmetric advantages in security

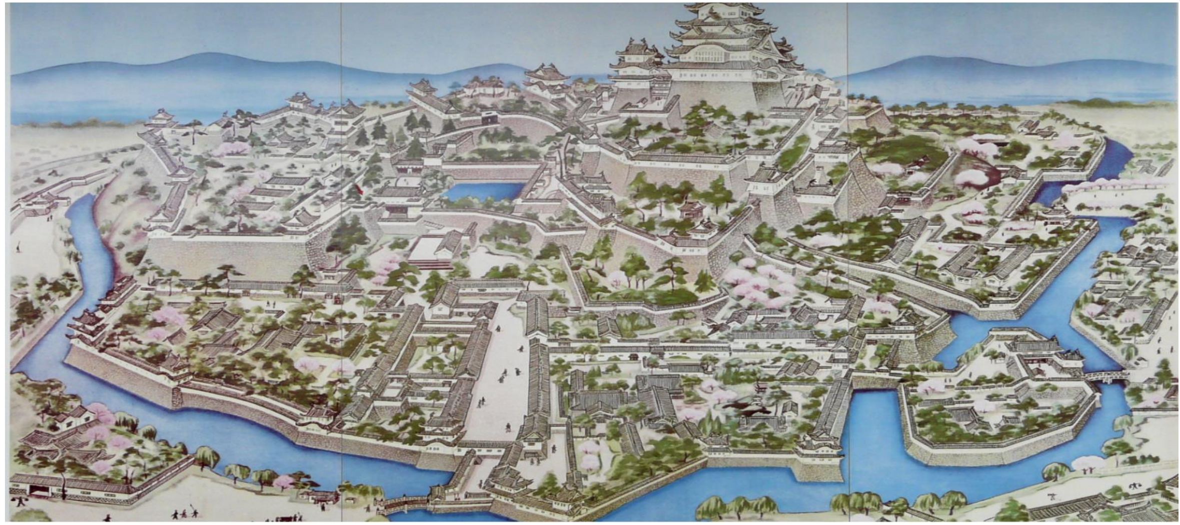


Attacker’s Asymmetric Advantage



- Attacker only needs to win one time, not all the time
- Attackers are professional attackers (maybe)

Defender’s Asymmetric Advantage



- The attacker only succeeds while undetected
- Defender is on ‘home turf’
- Defender has (hopefully) more resources than the attacker
- If the defender can spot them one time, they win

Podcast: https://risky.biz/category/risky-business-news/

Better News

- There are a lot of defense mechanisms
  - We’ll study some, but by no means all, in this course
- It’s important to understand their limitations
  - “If you think cryptography will solve your problem, then you don’t understand cryptography… and you don’t understand your problem” -- Bruce Schneier (… definitely not Bruce)

Binary Exploitation: Continued

A note on assembly

4B

objdump

- Its all x86_32 assembly for Lab 1
- There are two syntaxes (I'm sorry)
  - AT&T (default on Linux, GAS)
  - Intel (easier to read, IMO, default(?) in gef)

mov ebx, ecx

int b = c;

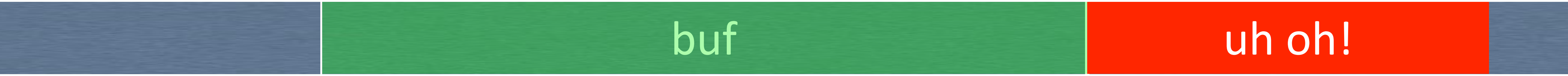
% $

mov ebx, ecx

Attacks on Memory Buffers

- Buffer is a pre-defined data storage area inside computer memory (stack or heap)
- Typical situation:
  - A function takes some input that it writes into a pre-allocated buffer.
  - The developer forgets to check that the size of the input isn’t larger than the size of the buffer.
  - Uh oh.
    - “Normal” bad input: crash
    - “Adversarial” bad input : take control of execution

Stack Buffers



buf

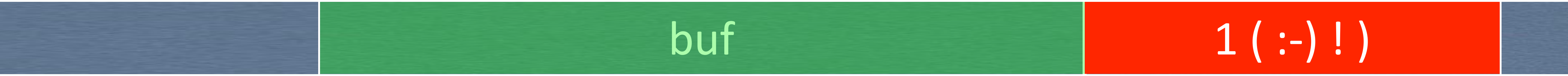
uh oh!

- Suppose Web server contains this function

```
void func(char *str) {
   char buf[126];
   ...
   strcpy(buf,str);
   ...
}
```

- No bounds checking on strcpy()
- If str is longer than 126 bytes
  - Program may crash
  - Attacker may change program behavior

Example: Changing Flags



buf

1 (:-) !)

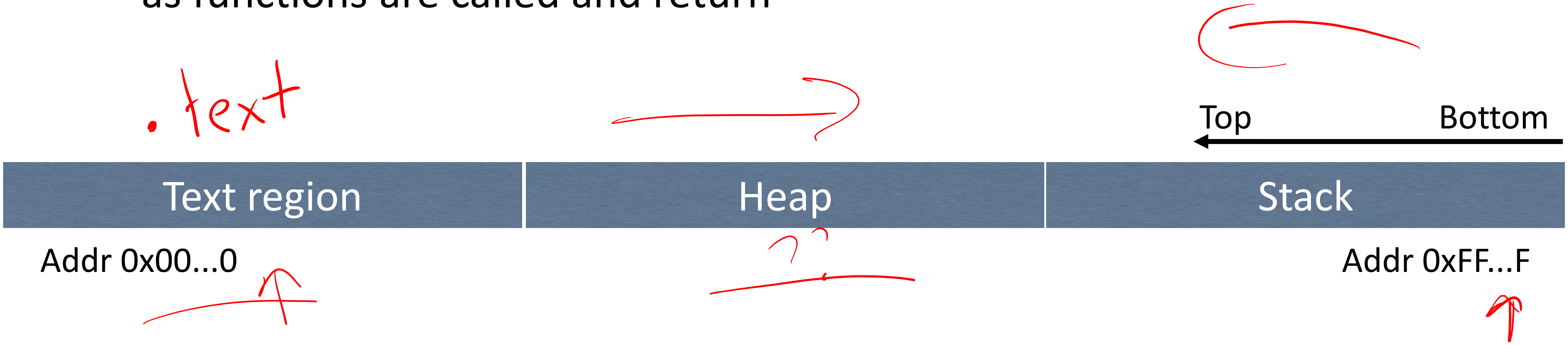
- Suppose Web server contains this function

```
void func(char *str) {
      byte auth = 0;
   char buf[126];
   ...
   strcpy(buf,str);
   ...
}
```

- Authenticated variable non-zero when user has extra privileges
- Morris worm also overflowed a buffer to overwrite an authenticated flag in fingerd

Memory Layout

- Text region: Executable code of the program
- Heap: Dynamically allocated data
- Stack: Local variables, function return addresses; grows and shrinks as functions are called and return



Stack Buffers

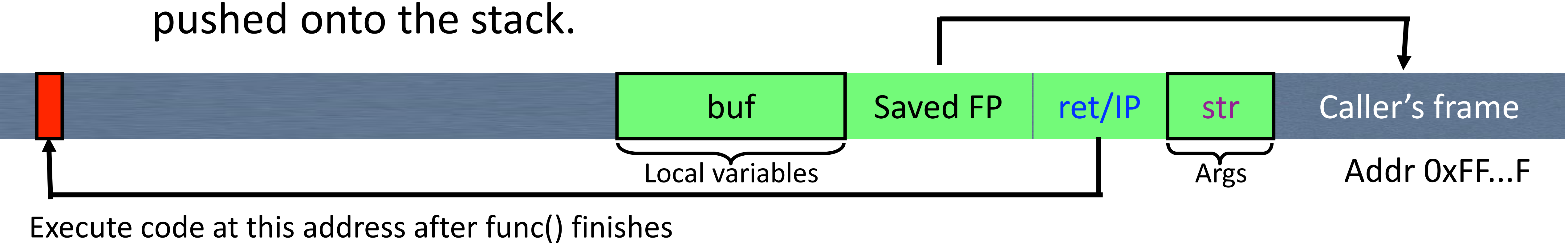
- Suppose Web server contains this function:

```
void func(char *str) {
        char buf[126];
        strcpy(buf,str);
}
```

Allocate local buffer
(126 bytes reserved on stack)

Copy argument into local buffer

- When this function is invoked, a new frame (activation record) is pushed onto the stack.



Execute code at this address after func() finishes

What if Buffer is Overstuffed?

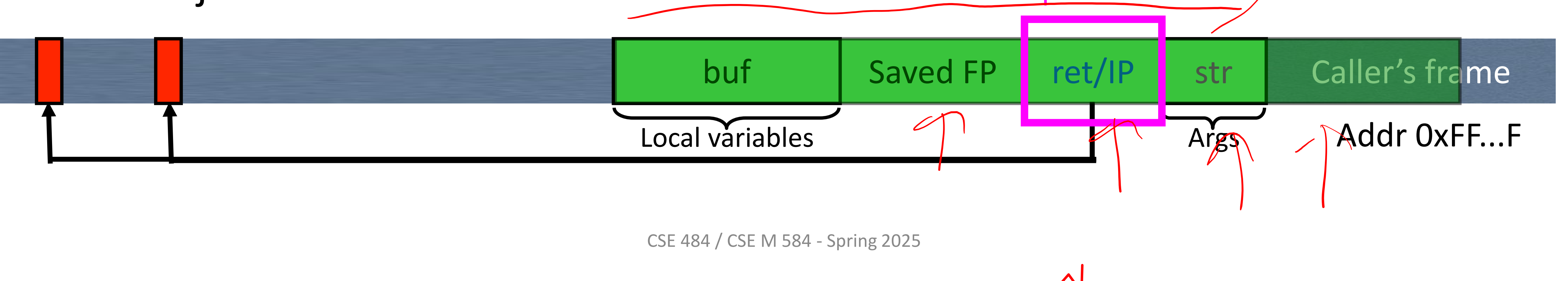
- Memory pointed to by str is copied onto stack…

```
void func(char *str) {
        char buf[126];
        strcpy(buf,str);
}
```

strcpy does NOT check whether the string at *str contains fewer than 126 characters

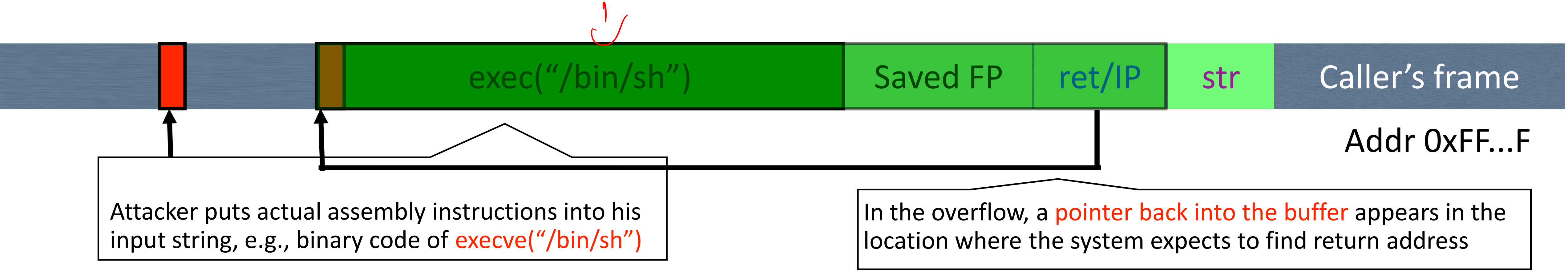
- If a string longer than 126 bytes is copied into buffer, it will overwrite adjacent stack locations.

This will be interpreted as return address!



Executing Attack Code

- Suppose buffer contains attacker-created string
  - For example, str points to a string received from the network as the URL



Attacker puts actual assembly instructions into his input string, e.g., binary code of execve("/bin/sh")

In the overflow, a pointer back into the buffer appears in the location where the system expects to find return address

- When function exits, code in the buffer will be executed, giving attacker a shell **("shellcode")**
  - Root shell if the victim program is setuid root

Buffer Overflows Can Be Tricky to exploit…

- The input string must write the correct address of attack code in the saved return address
  - The value overwriting the saved return address must point to executable code
    - Otherwise application will (probably) crash with segfault

- Attacker must also correctly store executable code somewhere…
  - And then know the address of that code!

0xFFAACCDD

Classic problem: Lack of bounds checks

- `strcpy(buf, str)`
  - strcpy does not check input size
  - simply copies memory contents into buf starting from *str until “\0” (NUL/NULL byte) is encountered, ignoring the size of area allocated to buf

0x00

- Many C library functions are unsafe in this way!
  - `strcpy(char *dest, const char *src)`
  - `strcat(char *dest, const char *src)`
  - `gets(char *s)`

0x00

- Or other interesting ways
  - `scanf(const char *format, …)`
  - `printf(const char *format, …)`

“0x00”

When Does Bounds Checking Help?

- `strncpy(char *dest, const char *src, size_t n)`
  - Limits copy length to whatever ‘n’ is

“user”“:”“cpw”

- Potential overflow in htpasswd.c (Apache 1.3):

```
strcpy(record, user);
strcat(record, ”:”);
strcat(record, cpw);
```

Copies username (“user”) into buffer (“record”), then appends “:” and hashed password (“cpw”)

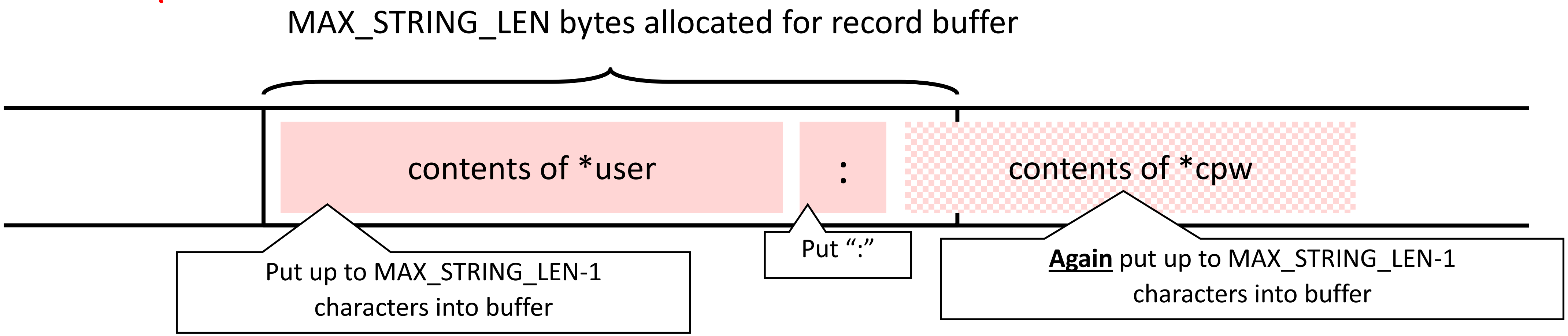
- Published fix:

```
strncpy(record, user, MAX_STRING_LEN-1);
strcat(record, ”:”);
strncat(record, cpw, MAX_STRING_LEN-1);
```

Misuse of strncpy in htpasswd "Fix"

- Published "fix" for Apache htpasswd overflow:

```
strncpy(record, user, MAX_STRING_LEN-1);
strcat(record, ":");
strncat(record, cpw, MAX_STRING_LEN-1);
```



MAX_STRING_LEN bytes allocated for record buffer
contents of *user
:
contents of *cpw
Put up to MAX_STRING_LEN-1 characters into buffer
Put ":"
Again put up to MAX_STRING_LEN-1 characters into buffer

What About This? – Homebrew copy?

```
void mycopy(char *input) {
    char buffer[512]; int i;
    for (i=0; i<=512; i++)
        buffer[i] = input[i];
    }  "\0"

void main(int argc, char *argv[]) {
    if (argc==2)
        mycopy(argv[1]);
    }
```

What About This? – Homebrew copy?

```
void mycopy(char *input) {
    char buffer[512]; int i;
    for (i=0; i<=512; i++)
        buffer[i] = input[i];
    }
void main(int argc, char *argv[]) {
    if (argc==2)
        mycopy(argv[1]);
    }
```

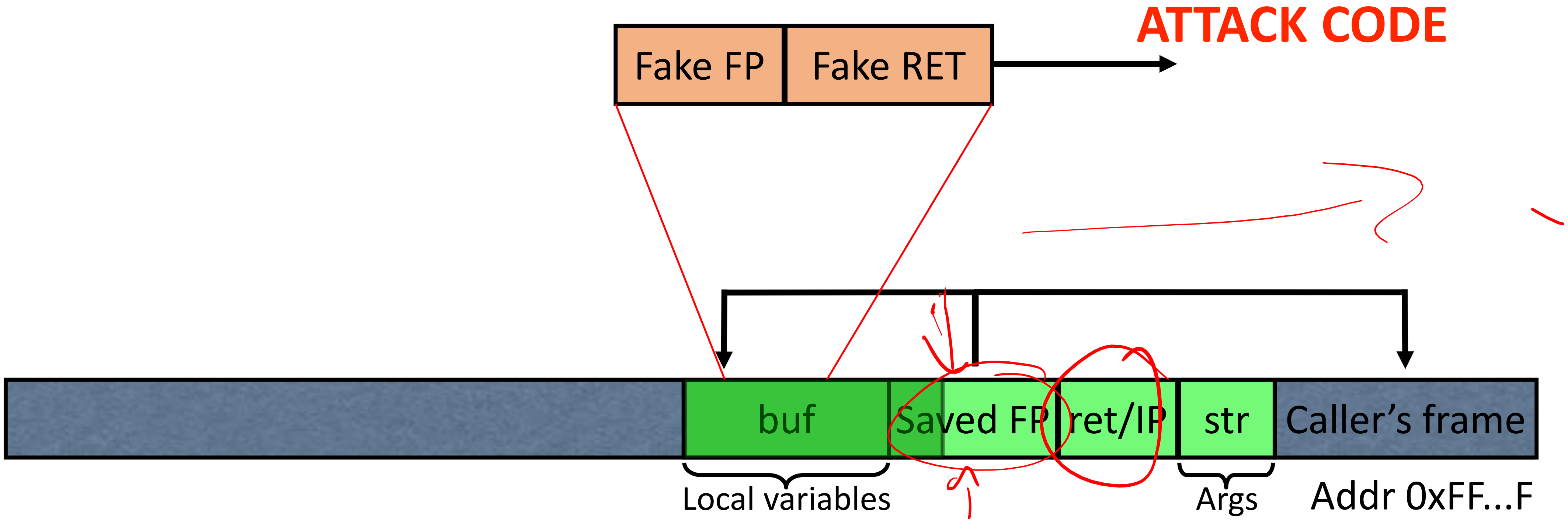
This will copy **513** characters into buffer. Oops!

exploit 2

1-byte overflow: can’t change RET, but can change pointer to previous stack frame…

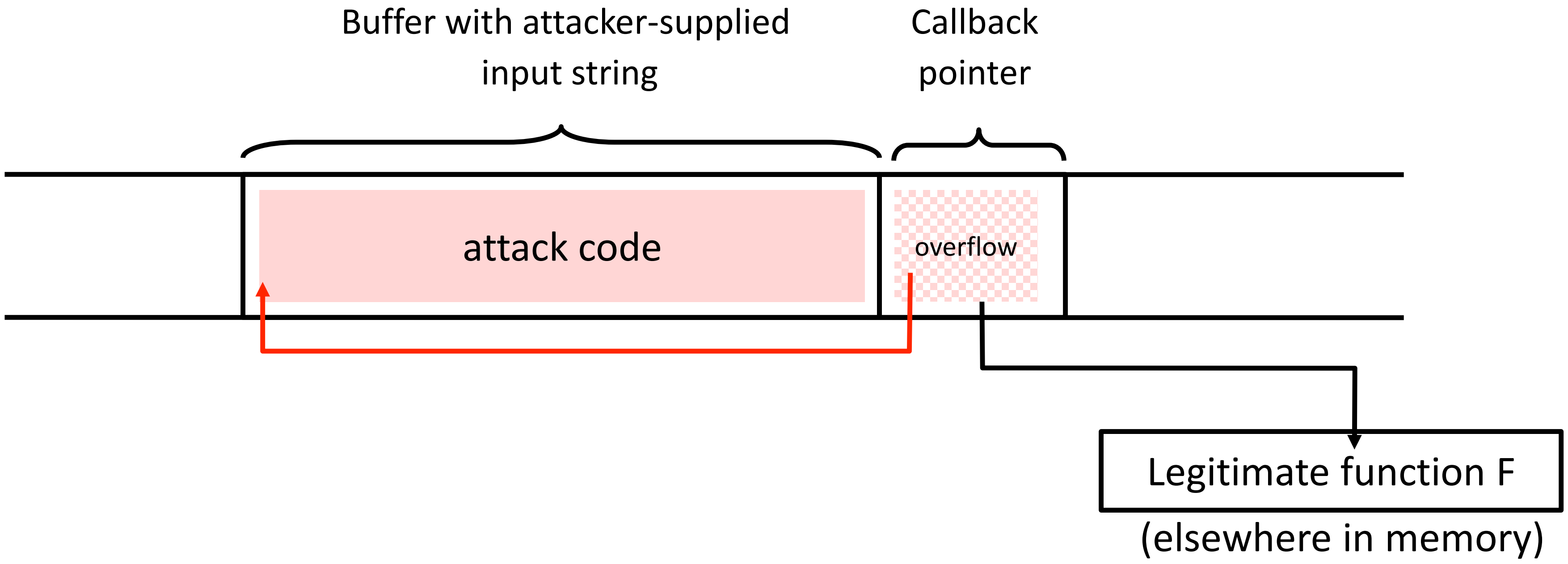
Frame pointers (and saved frame pointers)

Frame Pointer Overflow



Another Variant: Function Pointer Overflow

- C uses function pointers for callbacks: if pointer to F is stored in memory location P, then one can call F as (*P)(…)


Buffer with attacker-supplied input string
Callback pointer
attack code
overflow
Legitimate function F
(elsewhere in memory)