CSE 484: Computer Security and Privacy

Software Security: Buffer Overflow Attacks and More

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Logistics

- Things Due:
  - HW1 on Wednesday
  - 584 reading #1 on Friday
- Lab 1:
  - **Start now!**
- Office Hours:
  - On the course page: happening this week!

(SOME MORE OF) SOFTWARE SECURITY

Bugs, Vulnerabilities, and Exploits

- Bug
  - Not working quite right
- Vulnerability
  - A malfunction that can be used for an adversary's goals
- Exploit
  - The mechanical set of operations to make use of a vulnerability

Last time:

- Basic overflows
- Ended with managing to use strncpy wrong!

Consider this homebrewed copy:

```
void mycopy(char *input) {
      char buffer[512];
      int i;

      for (i=0; i<=512; i++) {
            buffer[i] = input[i];
      }

}
```

Consider this homebrewed copy:

```
void mycopy(char *input) {
      char buffer[512];
      int i;

      for (i=0; i<=512; i++) {
            buffer[i] = input[i];
      }

}
```

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

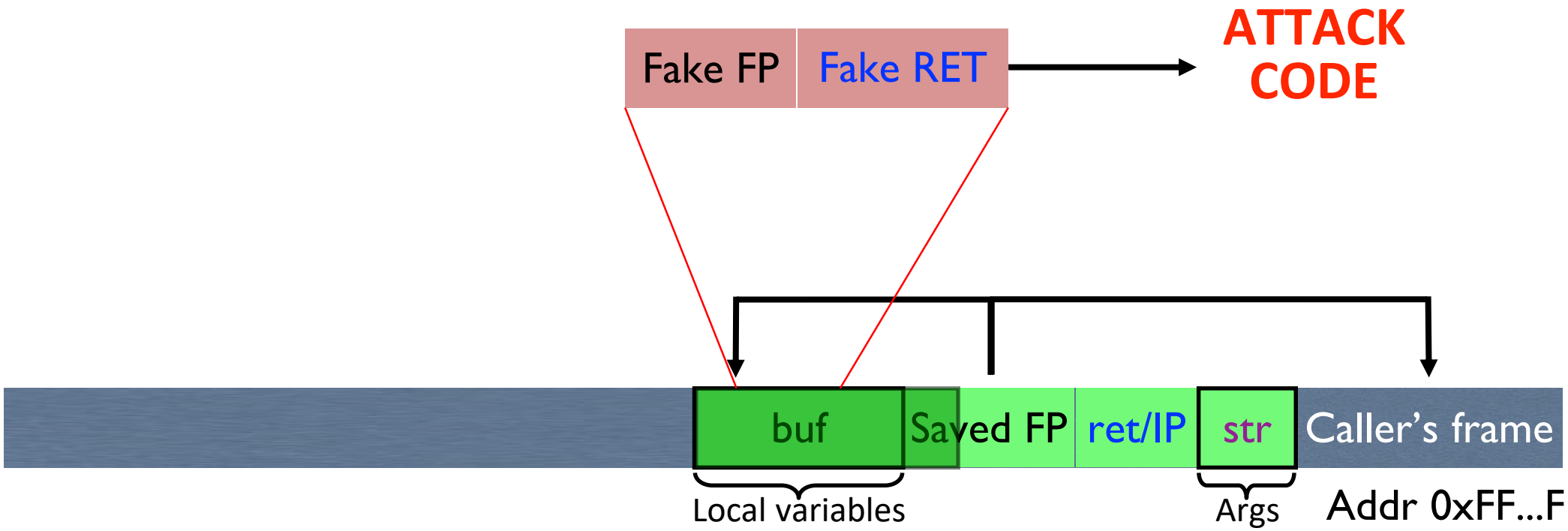
Stack Frame layout


```
…
mycopy(somestring);
…
```

```
void mycopy(char *str) {
        float f;
        char buffer[512];
        int i;
…
}
```

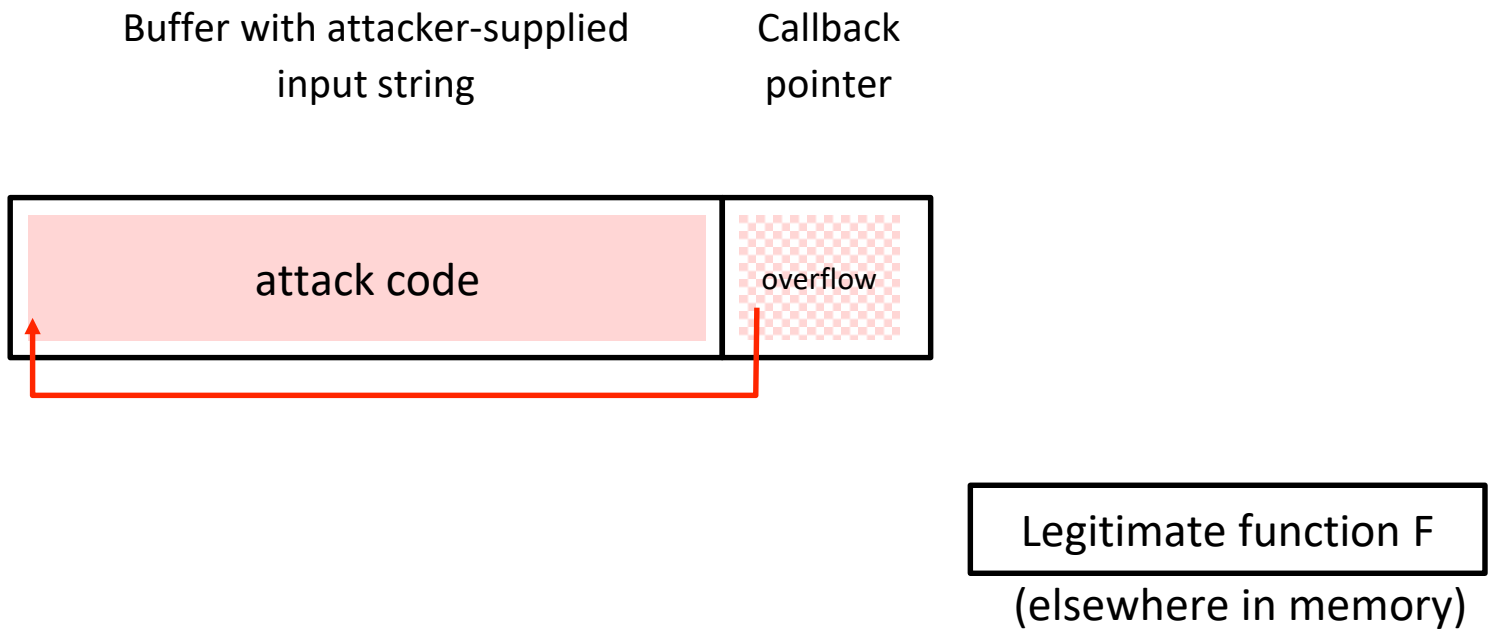
What is past my buffer?

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)(…)



A note on assembly

- You will need to read some assembly
- Its all x86_32 assembly
- There are two syntaxes (I'm sorry)

Other Overflow Targets

- Format strings in C
  - We'll walk through this one today
- Heap management structures used by malloc()
  - Techniques have changed wildly over time

- These are all attacks you can look forward to in Lab #1 😊

Variable Arguments in C

- In C, can define a function with a variable number of arguments
  - Example: void printf(const char* format, …)
- Examples of usage:

```
printf("hello, world");
printf("length of '%s' = %d\n", str, str.length());
printf("unable to open file descriptor %d\n", fd);
```

Format specification encoded by special % characters

`%d,%i,%o,%u,%x,%X` – integer argument
`%s` – string argument
`%p` – pointer argument (void *)
Several others

Format Strings in C

- Proper use of printf format string:

```
int foo = 1234;
printf("foo = %d in decimal, %X in hex",foo,foo);
```

This will print:

```
foo = 1234 in decimal, 4D2 in hex
```

- Sloppy use of printf format string:

```
char buf[14] = "Hello, world!";
printf(buf);
// should've used printf("%s", buf);
```

What happens if buffer contains format symbols starting with % ???

Implementation of Variable Args

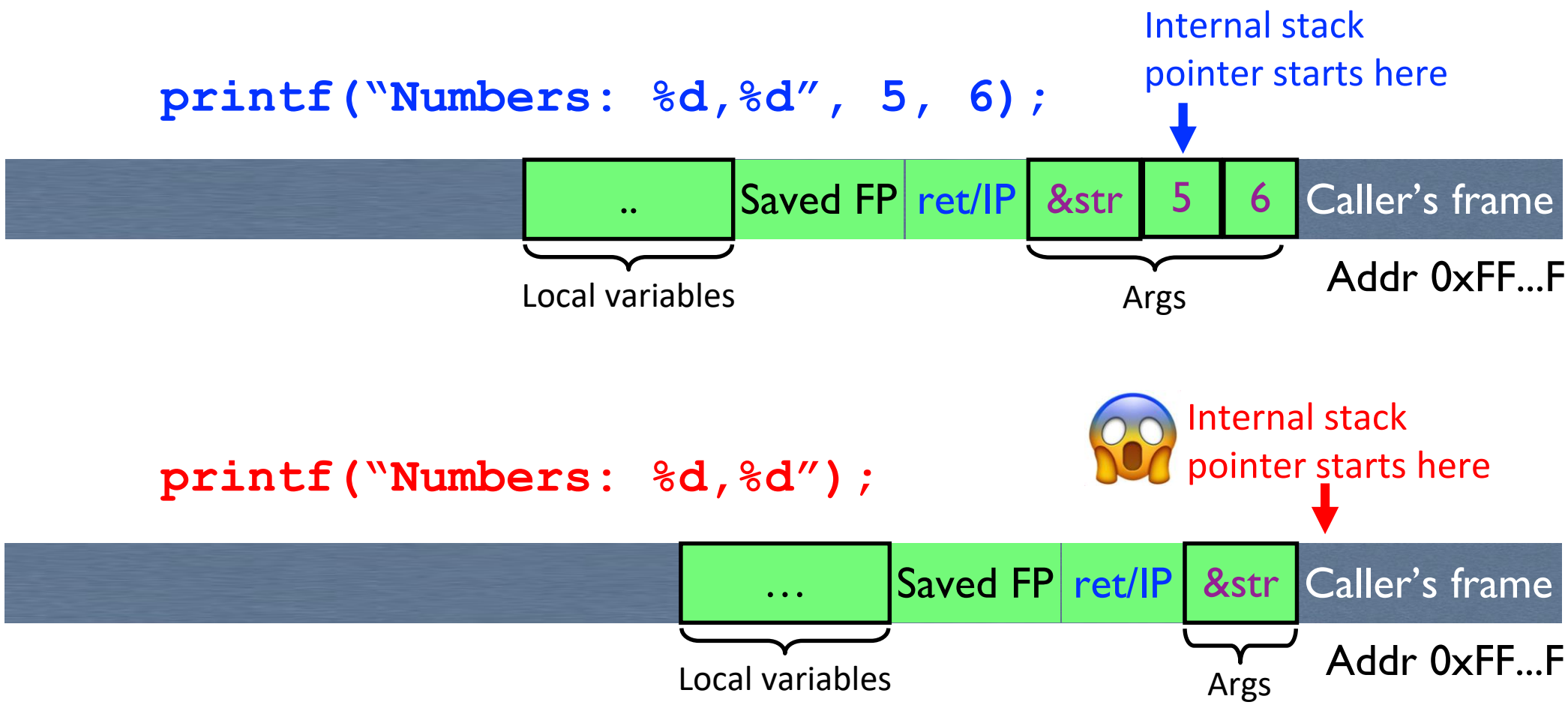
- Special functions va_start, va_arg, va_end compute arguments at run-time

```
void printf(const char * format, ...)
{
  int i; char c; char * s; double d;
  va_list ap; /* declare an "argument pointer" to a variable arg list */
  va_start(ap, format); /*initialize arg pointer using last known arg */
  for (char *p = format; *p != '\0'; p++) {
    if (*p == '%') {
      switch (*++p) {
        case 'd':
          i = va_arg(ap, int); break;
        case 's':
          s = va_arg(ap, char*); break;
        case 'c':
          c = va_arg(ap, char); break;
        ... /* etc for each % specification */
      }
    }
  }
  ...
  va_end(ap); /* restore any special stack manipulations */

}
```

This is simplified code, e.g., handles %d but not %10d

Closer Look at the Stack



Format Strings in C

- Proper use of printf format string:

```
int foo=1234;
 printf("foo = %d in decimal, %X in hex",foo,foo);
```

This will print:

```
foo = 1234 in decimal, 4D2 in hex
```

- Sloppy use of printf format string:

```
char buf[14] = "Hello, world!";
printf(buf);
// should've used printf("%s", buf);
```

Format Strings in C

If the buffer contains format symbols starting with %, the location pointed to by printf's internal stack pointer will be interpreted as an argument of printf.

This can be exploited to move printf's internal stack pointer!

```
) ;
```

```
166 = 1234 in decimal, 4D2 in hex
```

- Sloppy use of printf format string:

What happens if buffer contains format symbols starting with % ???

```
char buf[14] = "Hello, world!";
printf(buf);
// should've used printf("%s", buf);
```

Viewing Memory

- %x format symbol tells printf to output data on stack

```
printf("Here is an int:  %x",i);
```

- What if printf does not have an argument?

```
char buf[16]="Here is an int:  %x";
printf(buf);
```

- Or what about:

```
char buf[16]="Here is a string:  %s";
printf(buf);
```

Viewing Memory

- %x format symbol tells printf to output data on stack

```
printf("Here is an int:  %x",i);
```

- What if printf does not have an argument?

```
char buf[16]="Here is an int:  %x";
printf(buf);
```

  - Stack location pointed to by printf's internal stack pointer will be interpreted as an int. (What if crypto key, password, ...?)

- Or what about:

```
char buf[16]="Here is a string:  %s";
printf(buf);
```

  - Stack location pointed to by printf's internal stack pointer will be interpreted as a pointer to a string

Writing Stack with Format Strings

- %n format symbol tells printf to write the number of characters that have been printed

```
printf("Overflow this!%n",&myVar);
```

  - Argument of printf is interpreted as destination address
  - This writes 14 into myVar ("Overflow this!" has 14 characters)

- What if printf does not have an argument?

```
char buf[16]="Overflow this!%n";
printf(buf);
```

  - Stack location pointed to by printf's internal stack pointer will be **interpreted as address** into which the number of characters will be written.

Summary of Printf Risks

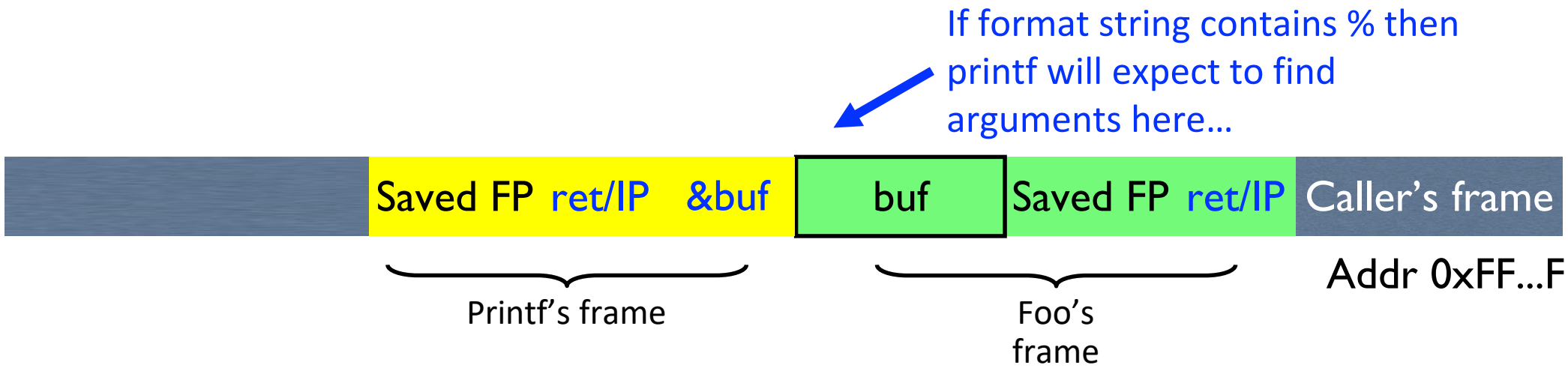
- Printf takes a variable number of arguments
  - E.g., printf("Here's an int: %d", 10);
- Assumptions about input can lead to trouble
  - E.g., printf(buf) when buf="Hello world" versus when buf="Hello world %d"
  - Can be used to advance printf's internal stack pointer
  - Can read memory
    - E.g., printf("%x") will print in hex format whatever printf's internal stack pointer is pointing to at the time
  - Can write memory
    - E.g., printf("Hello%n"); will write "5" to the memory location specified by whatever printf's internal SP is pointing to at the time

“Weird Machines”

- Way of thinking about exploits (the best way 😊)
- Treat each discrete side-effect as an ‘instruction’
- Synthesize a ‘program’ from these instructions
- This is now your exploit!

How Can We Attack This?

```
foo() {
       char buf[…];
       strncpy(buf, readUntrustedInput(), sizeof(buf));
       printf(buf); //vulnerable
}
```

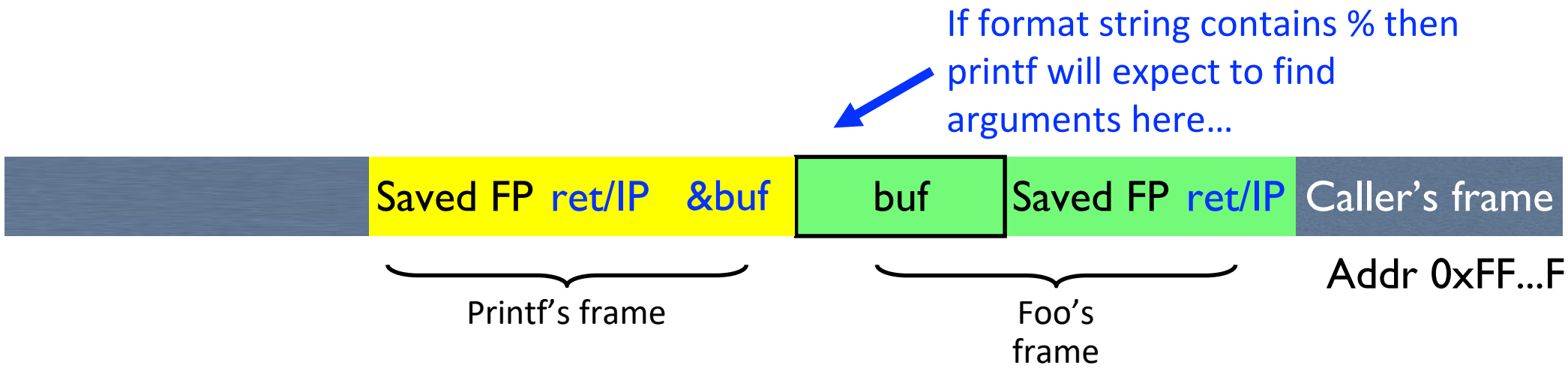


What should the string returned by readUntrustedInput() contain?

Different compilers / compiler options / architectures might vary

Pollev and Discussion Time

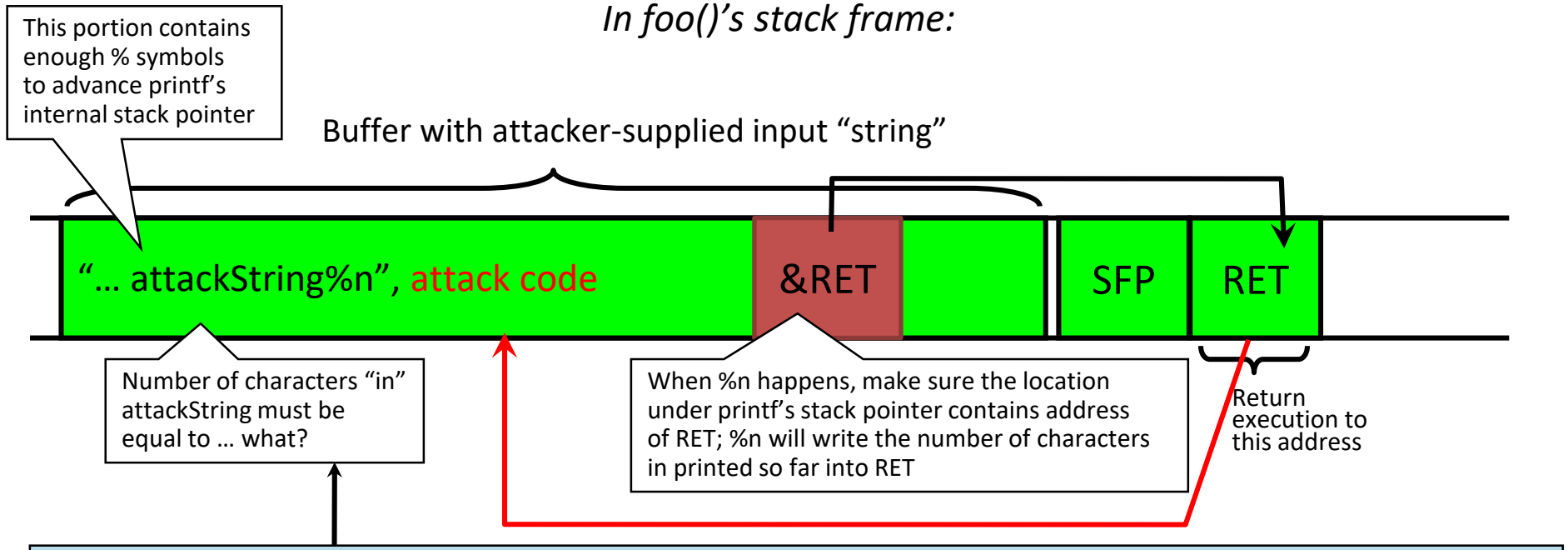
```
foo() {
       char buf[2048];
       strncpy(buf, readUntrustedInput(), sizeof(buf));
       printf(buf); //vulnerable
}
```



What should the string returned by readUntrustedInput() contain?

Different compilers / compiler options / architectures might vary

Using %n to Overwrite Return Address



Why is "in" in quotes? C allows you to concisely specify the "width" to print, causing printf to pad by printing additional blank characters without reading anything else off the stack.

Example: printf("%5d%n", 10) will print three spaces followed by the integer: " 10"
That is, the %n will write 5, not 2.

Key idea: do this 4 times with the right numbers to overwrite the return address byte-by-byte. (4x %n to write into &RET, &RET+1, &RET+2, &RET+3)

Lab 1:

- Start getting familiar with the targets, gdb, etc.
- Significant help from doing these readings:
  - Smashing the Stack for Fun and Profit
  - Exploiting Format String Vulnerabilities