Attacks

Part I
Hacking in C 2020
Thom Wiggers

iCIS | Digital Security
Radboud University

Recap of last week

Programs are partitioned into different segments

- The code segment `.text` for program code
- `.data` and `.bss` for global and static variables
- These segments are usually found at the low addresses.

Recap of last week (Stack)

Stack stores local function variables

- Starts at high addresses, grows towards lower addresses
- Typically addresses start with `0x7ff` on 64-bit Linux.
- Contains return addresses, function arguments, frame pointer
- Stack is automatically managed (via stack pointer), data is gone when function returns
- Stack overflow: exceed the maximum stack size (often via recursion)

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- Return used memory with `free()`
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- Use `calloc()` to non-lazily allocate zeroed memory.

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Overview

- Everything is in memory
- Breaking stuff with printf
- Buffer overflows
  - Heartbleed
  - Ping
- Why?
  - Why does it work
  - Why do we care
- Inserting our own code
- Homework
  - This week
  - Last week's homework

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Von Neumann Architecture

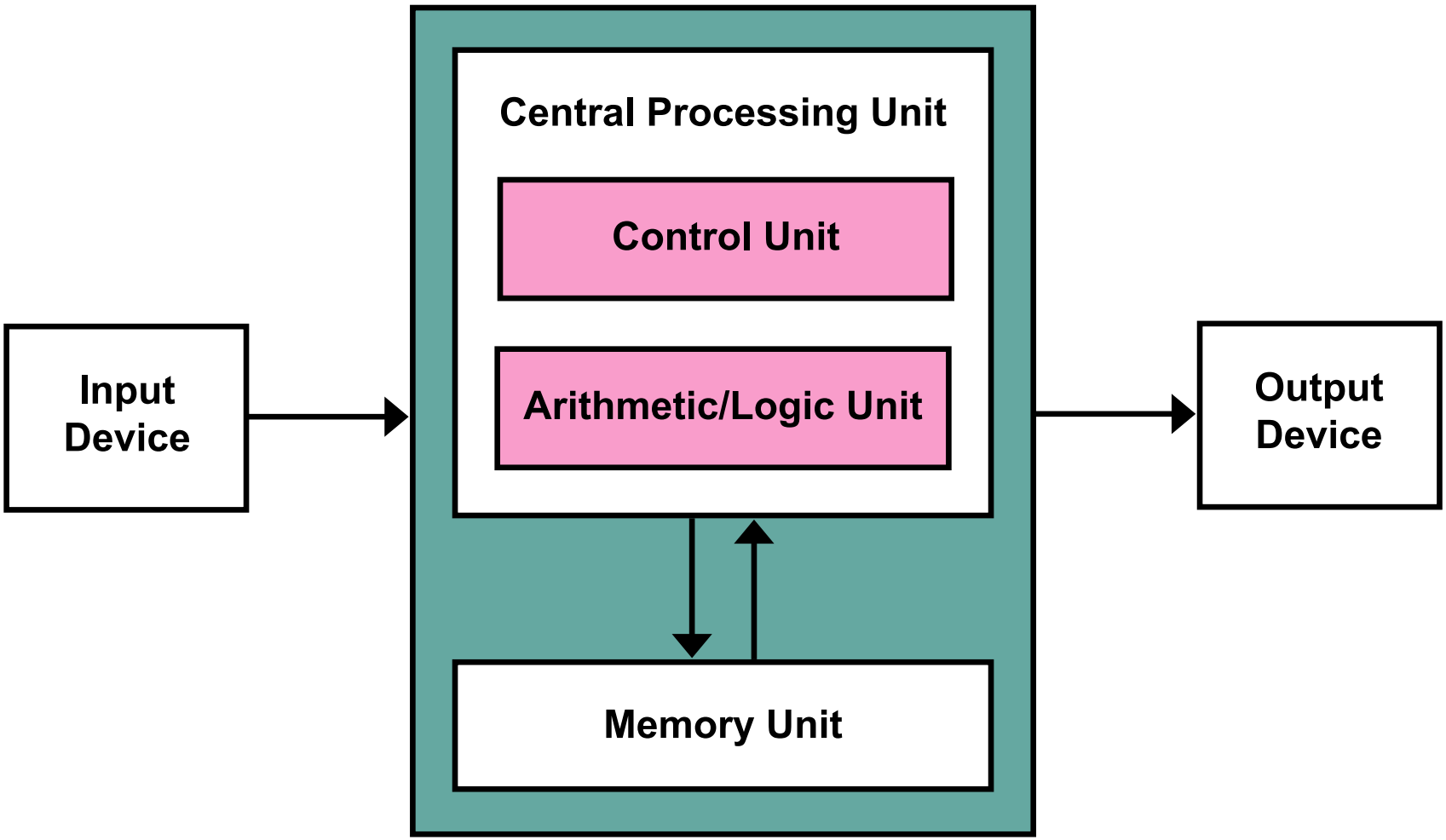
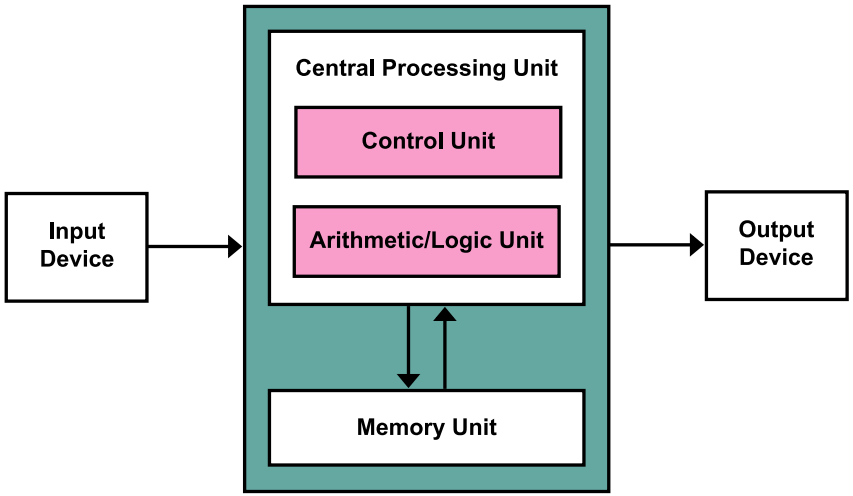


Figure: Von Neumann Architecture

Everything is data

- The Von Neumann architecture doesn't treat programs any different from program data!
- This means that the memory unit is shared between the code of the program and whatever the program does in memory.
- Control data such as return addresses are stored in between your program data.
- The memory bookkeeping is not just about the data of your program, but also the program itself.



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MUST READ: I like Windows 7: Why should I pay to move to Windows 10?

Microsoft: 70 percent of all security bugs are memory safety issues

Percentage of memory safety issues has been hovering at 70 percent for the past 12 years.

By Catalin Cimpanu for Zero Day | February 11, 2019 -- 15:48 GMT (15:48 GMT) | Topic: Security

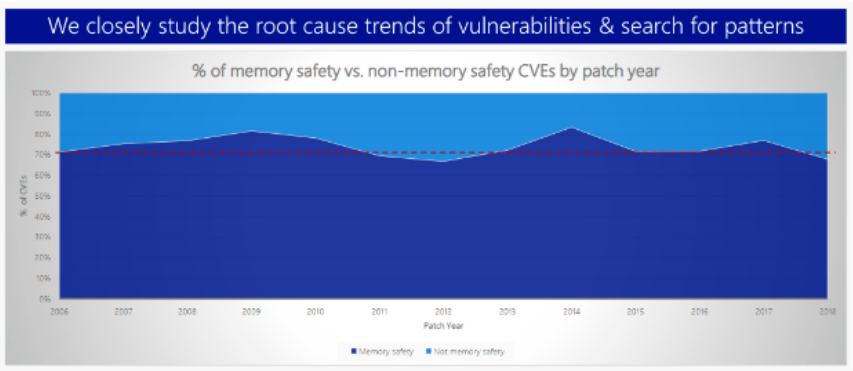

Image: Matt Miller

Around 70 percent of all the vulnerabilities in Microsoft products addressed through a security update each year are memory safety issues; a Microsoft engineer revealed last week at a security conference.

MORE FROM CATALIN CIMPANU


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New macOS security flaw lets malicious apps steal your Safari browsing history


Security
Dirty Sock vulnerability lets attackers gain root access on Linux systems

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Researchers hide malware in Intel SGX enclaves

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- Getting a program to call functions it shouldn't.
- Inject our own code into a program
- Hack into a remote machine

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Recall: `printf`

> *`int printf(const char *format, ...);`*
> *[printf] writes the output under the control of a* ***format string*** *that specifies how subsequent arguments are converted for output.* *`src: man 3 printf`*

If the attacker controls `format`, they can do a lot of nasty things.

Remember:

`%d`	Print `int` as decimal
`%u`	Print `unsigned int` as decimal
`%x`	Print `int` as hexadecimal
`%ld`	Print `long int` as decimal
`%hu`	Print `short int` as unsigned decimal
`%p`	Print variable as pointer (`void*`)
`%s`	Print string from `char*` (ie. characters until we run into `NULL`)
`%0Nx`	Print as hexadecimal integer such that it's at least *N* characters wide. Fill with zeros.
`%N$x`	Print the *N*th argument of `printf` as hexadecimal integer.

Having fun with `printf`

What does the following program do *wrongly*?

```c
// program.c
int main(int argc, char* argv[]) {
    // should have been printf("%s", argv[1]);
    printf(argv[1]);
}
```

What happens if we run `./program %x`?
It will print the second argument of `printf`, even if it's not there!

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- The addresses are randomized each time, because of ASLR!
  - Turn off ASLR in a shell using `setarch -R bash`.

printf is a powerful debugger

```
#include <stdio.h>
void do_print(char* string)
  { printf(string); }

int main(int argc, char** argv) {
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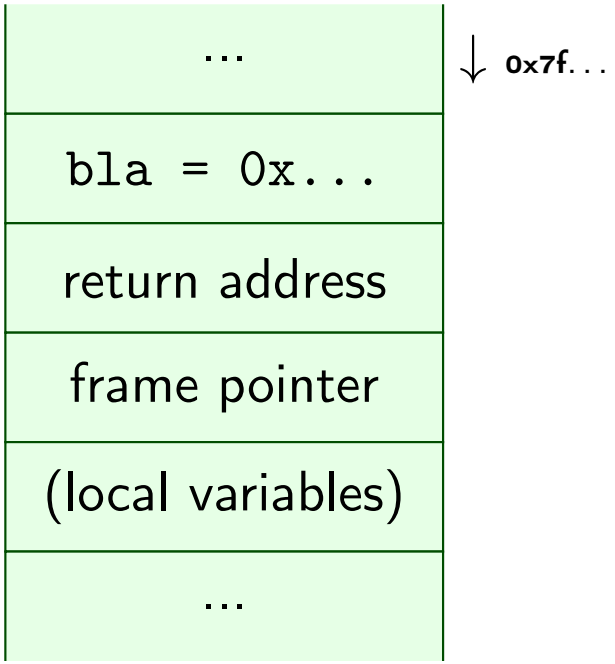

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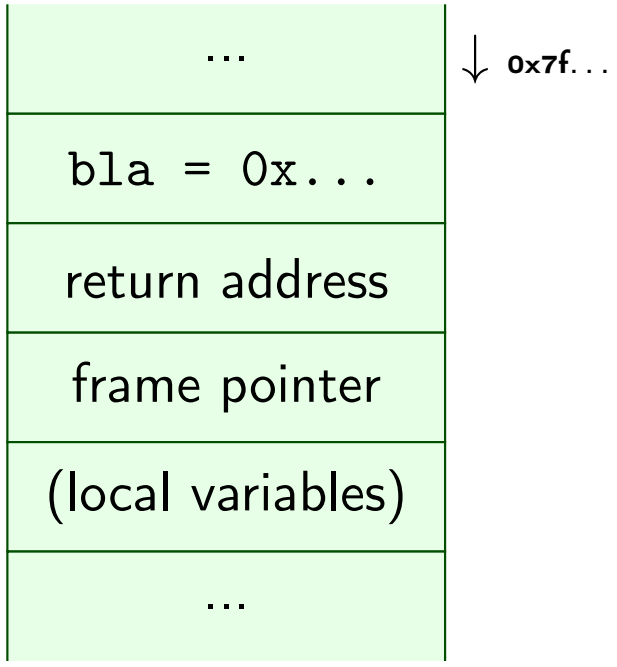


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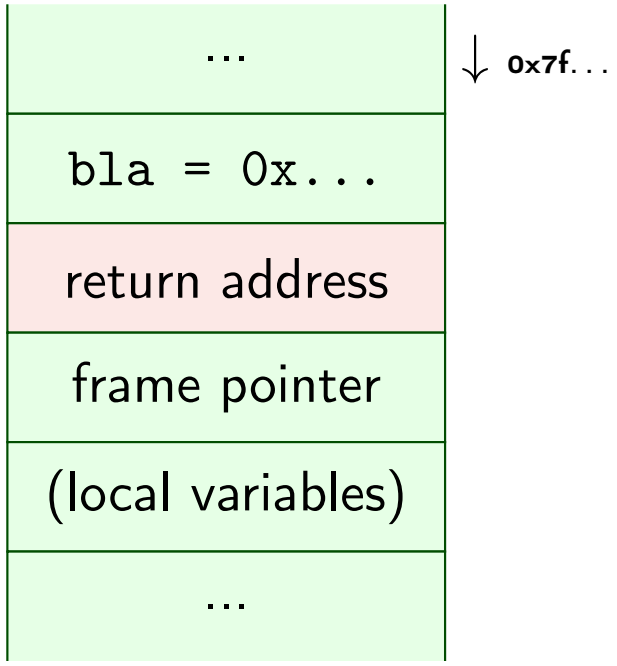


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- Remember the `%s` format character: it gets the argument, interprets it as a `char*`, and reads the string at that address.
- If we put an address in the place where `printf` will read the argument from, we control where `printf` reads!

More on `printf`

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> *`%n` The number of characters written so far is stored into the integer pointed to by the corresponding argument. That argument shall be an `int *`, or variant whose size matches the (optionally) supplied integer length modifier.* *`man 3 printf`*

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Figure: C standard library designers

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  - Writing $\pm 2^{47}$ characters to write a 48-bit (Linux, amd64) address is *impractical* ($\pm$16 TiB).
  - **Solution:** Instead use length modifiers and write in parts: `%hn` writes 16 bits instead.

First format string exploit

```
Exploit for proftpd 1.2.0pre6

From: tymm () COE MISSOURI EDU (Tymm Twillman)
Date: Mon, 20 Sep 1999 14:31:51 -0500

Tested on Linux with standard RedHat 6.0 install (w/glibc 2.0
compatability), proftpd installed with configure/make/make install...

- ftp to host
- login (anonymous or no)

(this should be all on one line, no spaces)

ftp> ls aaaXXXX%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u%u
%u%u%u%u%u%u%u%u%u%653300u%n

(replace the X's with the characters with ascii values 0xdc,0x4f,0x07,0x08
consecutively)
```

https://seclists.org/bugtraq/1999/Sep/328

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  - Overwriting the return address byte-by-byte means you'll need more than one `%n` and thus more than one address. . .
  - If you only need to overwrite a single byte, still easy.

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In a more perfect world

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If you ever face a decision to choose a programming language, please think about if you really need C(++) or if you can use a safer language such as Rust (good alternative for C), Go (good with concurrency) or Python (if you can take the performance hit).

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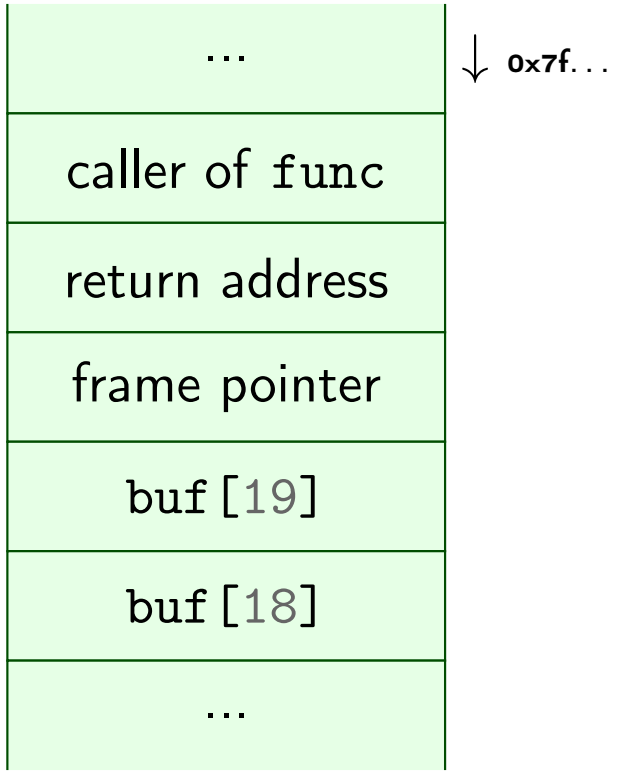

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No bounds checking — what could go wrong?

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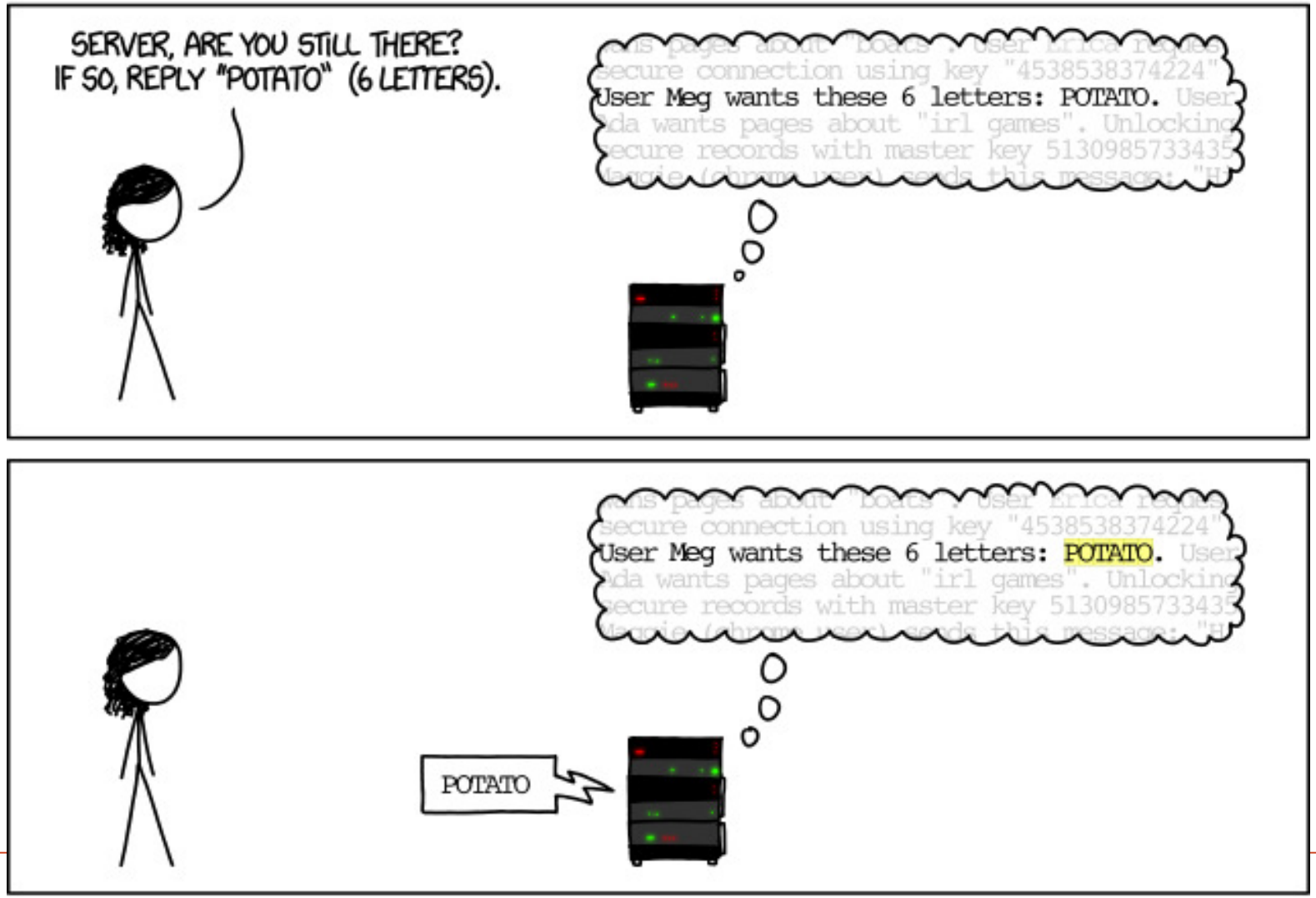
Underlying problem: Out of bounds array access in OpenSSL

How Heartbleed works



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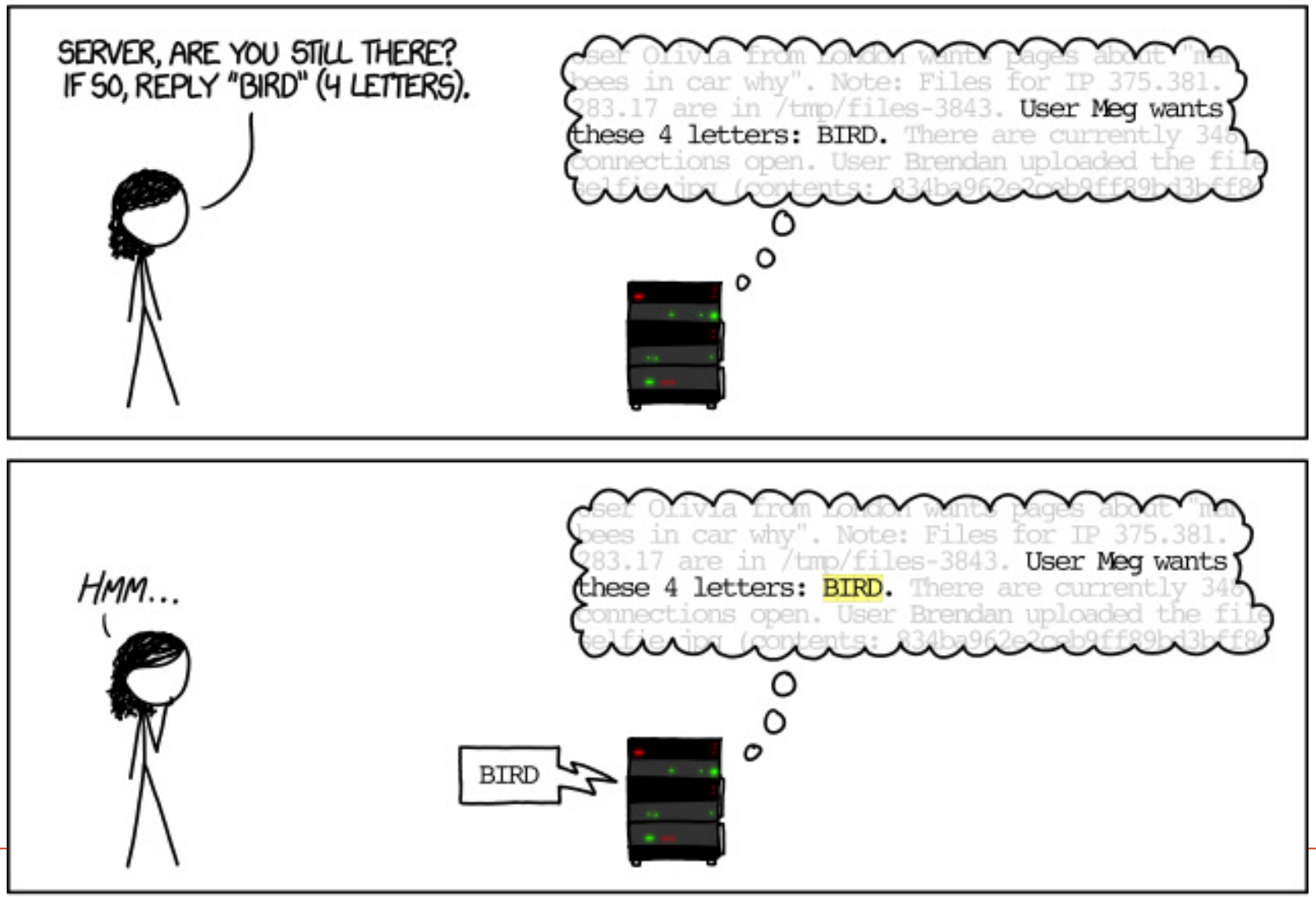

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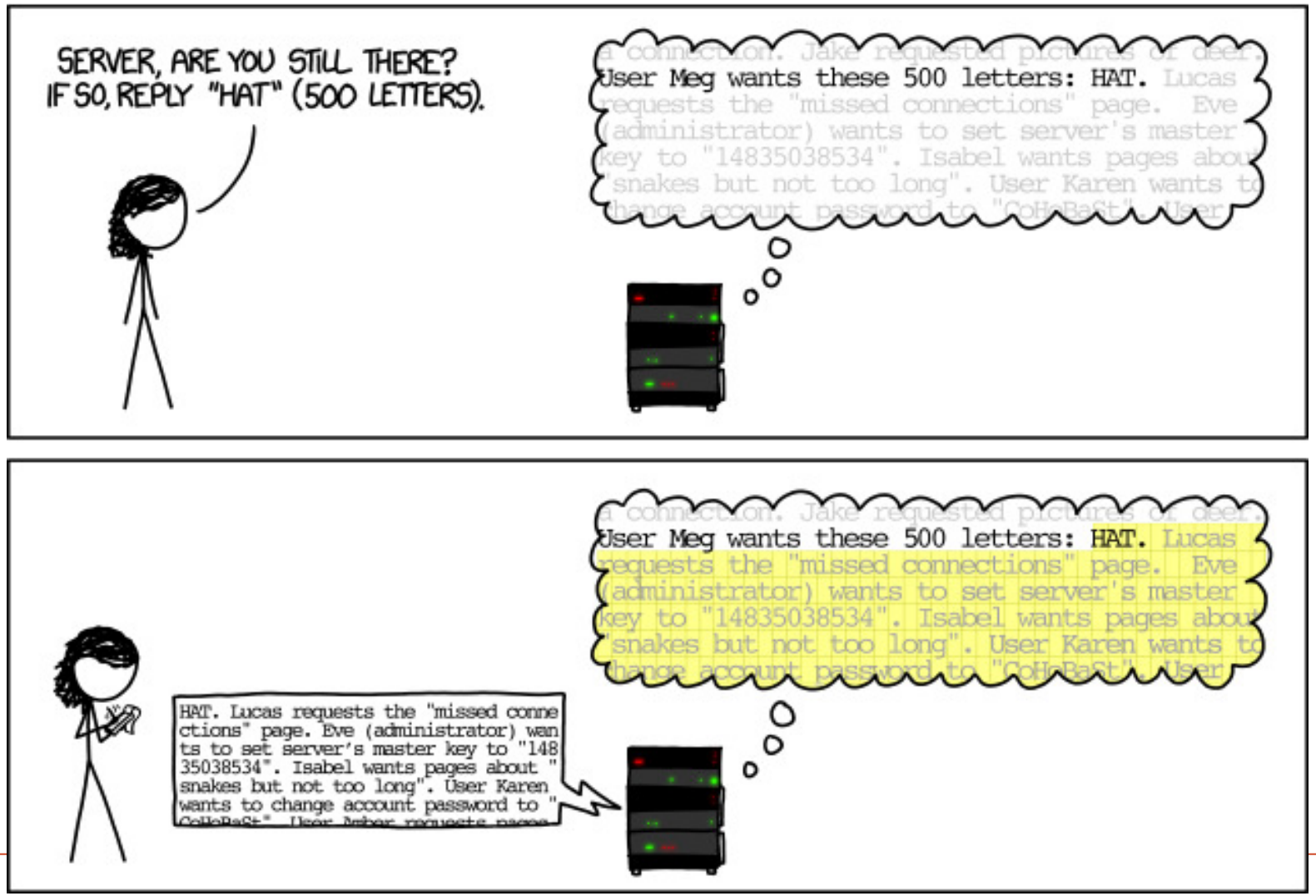

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- Sends an icmp packet to the server, server sends the same thing back.

```
~ $ ping -c2 10.8.0.1
PING 10.8.0.1 (10.8.0.1) 56(84) bytes of data.
64 bytes from 10.8.0.1: icmp_seq=1 ttl=64 time=15.4 ms
64 bytes from 10.8.0.1: icmp_seq=2 ttl=64 time=14.10 ms

--- 10.8.0.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 3ms
rtt min/avg/max/mdev = 14.992/15.213/15.435/0.253 ms
```

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Signed integer overflow Compilers may assume that `x` will never be smaller than `INT_MAX` and remove the `if` block, but `func(1)` will *probably* return a large negative number.

```
#include <limits.h>
void func(unsigned int foo) {
    int x = INT_MAX;
    x += foo;
    // probably removed:
    if (x < INT_MAX) bar();
    return value;
}
```

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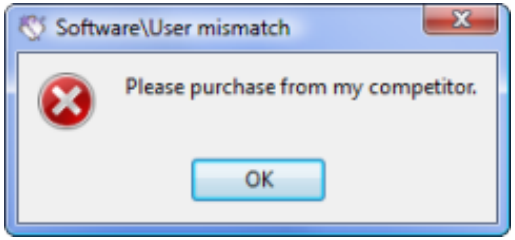

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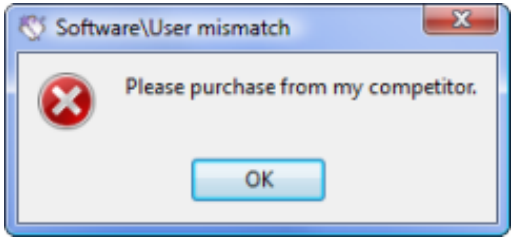

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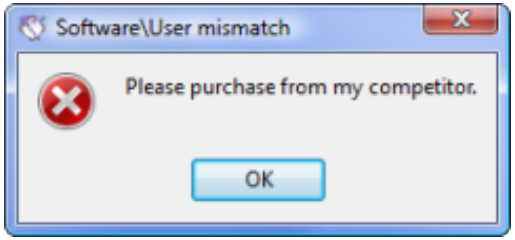

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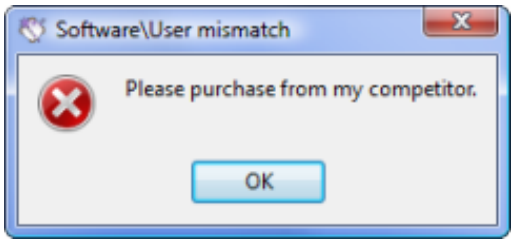

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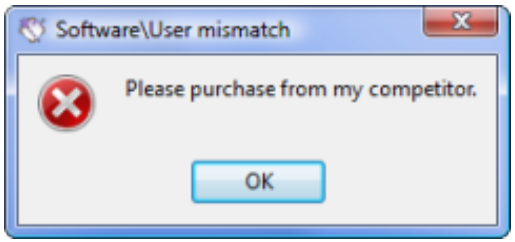

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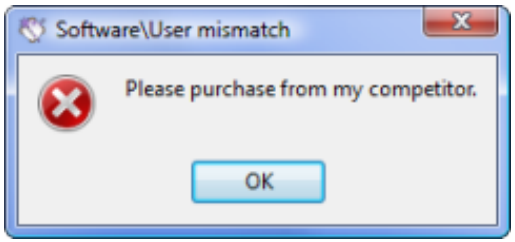

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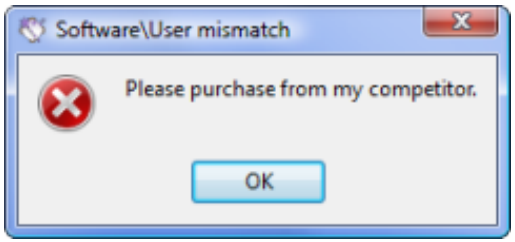

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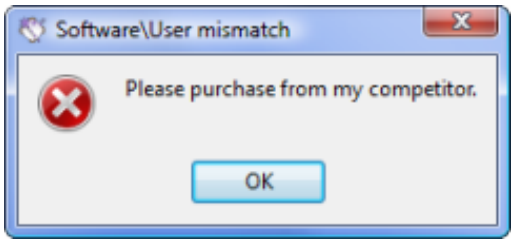
  - *The file name of your program*: `argv[0]`



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Inspecting a buffer with `printf`

```
void func(char* string) {
    char buf[20];
    for (int i = 0; i < 20; i++)
        buf[i] = 'A' + i;
    printf(string);  // our debugger
}
int main(int argc, char* argv[]) {
    func(argv[1]);
}
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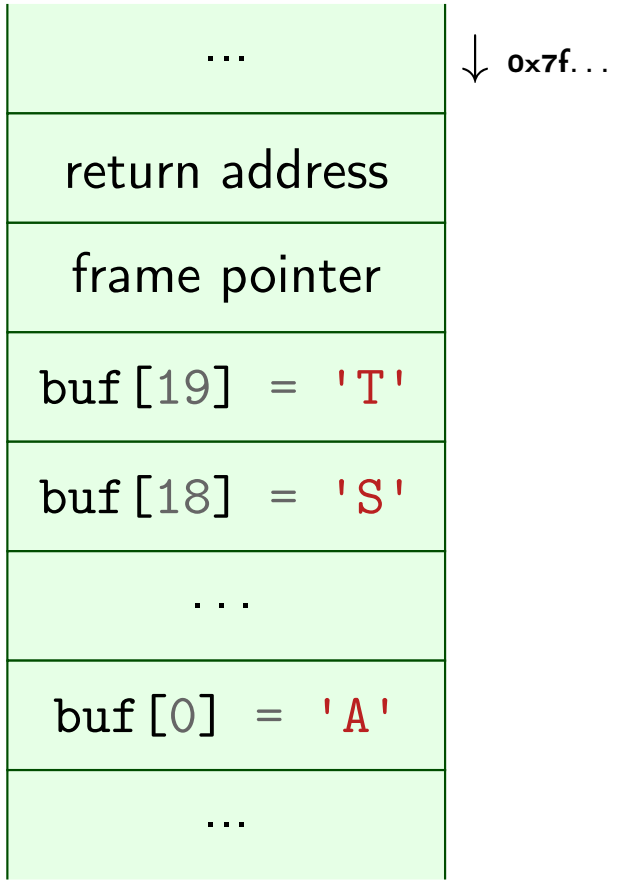

man gets

```
GETS(3)                    Linux Programmer's Manual                    GETS(3)

NAME
       gets - get a string from standard input (DEPRECATED)

SYNOPSIS
       #include <stdio.h>

       char *gets(char *s);

DESCRIPTION
       Never use this function.

       gets() reads a line from stdin into the buffer pointed to by s until either a termi-

       nating newline or EOF, which it replaces with a null byte ('\0').  No check for buf-

       fer overrun is performed (see BUGS below).

BUGS
       Never use gets().  Because it is impossible to tell  without  knowing  the  data  in
       advance  how  many  characters gets() will read, and because gets() will continue to
       store characters past the end of the buffer, it is extremely dangerous to  use.   It
       has been used to break computer security.  Use fgets() instead.
```

Overflowing a buffer

```
void func() {
    char *result;
    char buf[100];
    printf("Enter your name: ");
    result = gets(buf);
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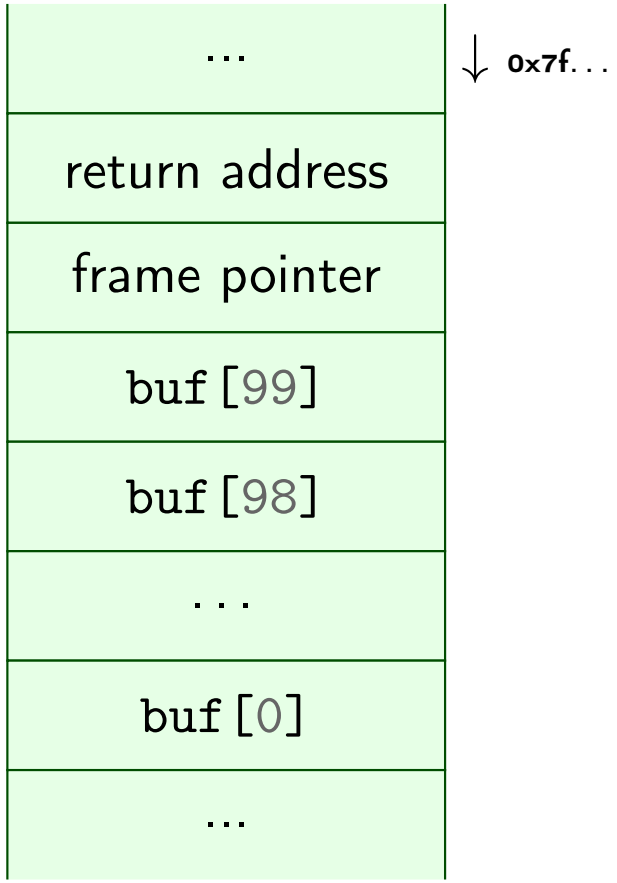
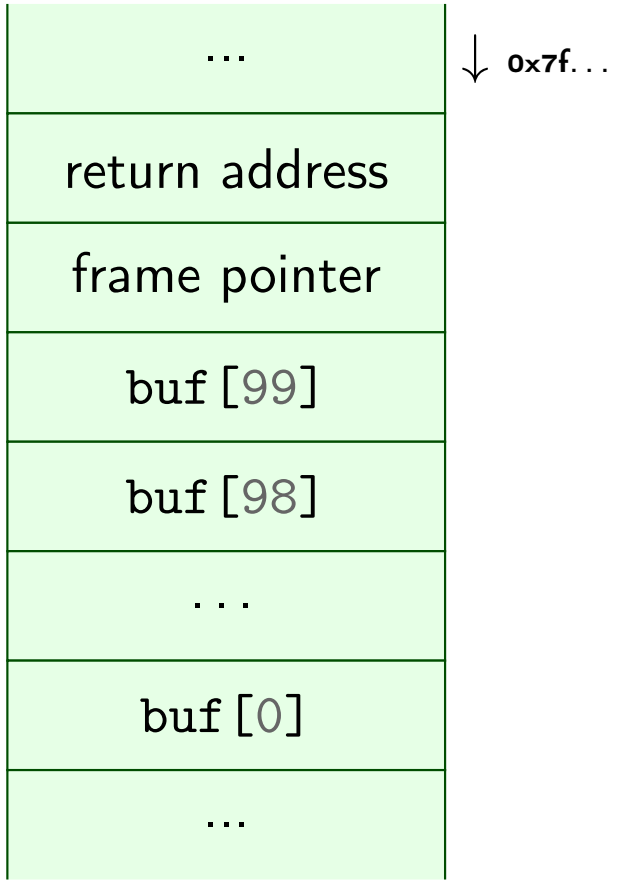
```
./buffer-vuln.c:6: warning: the 'gets' function is dangerous and should not be used.
```



Taking control of the return address

So what if we feed this program `'A'x116`?



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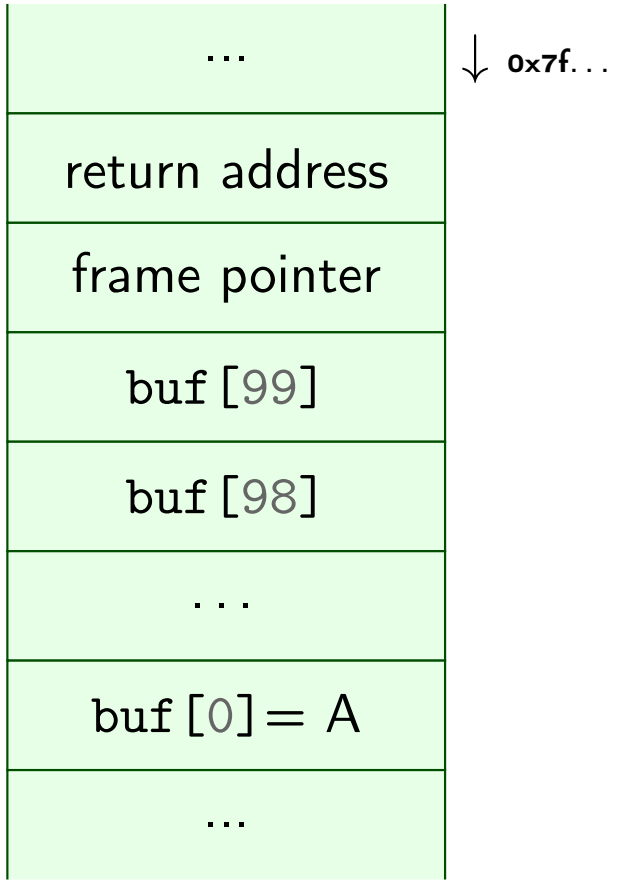

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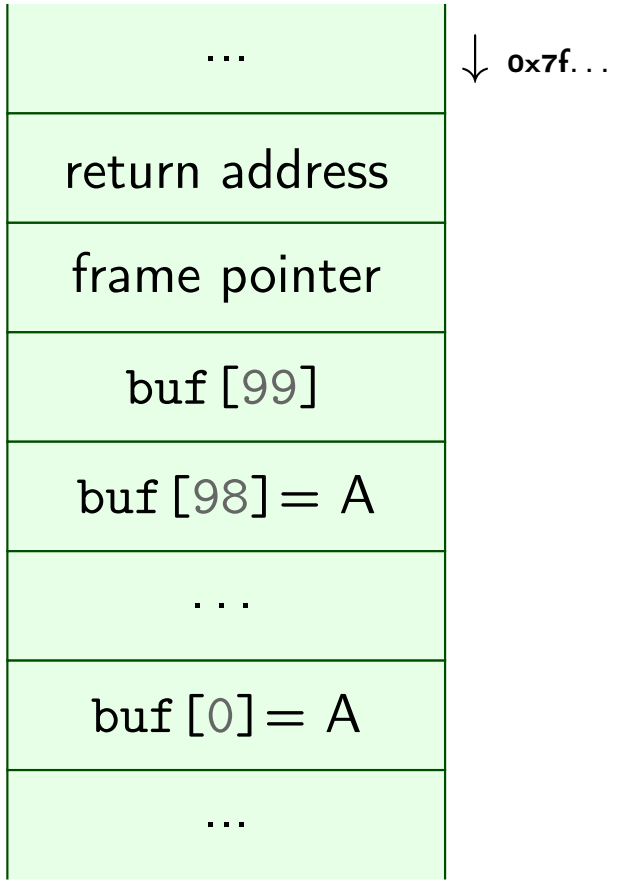

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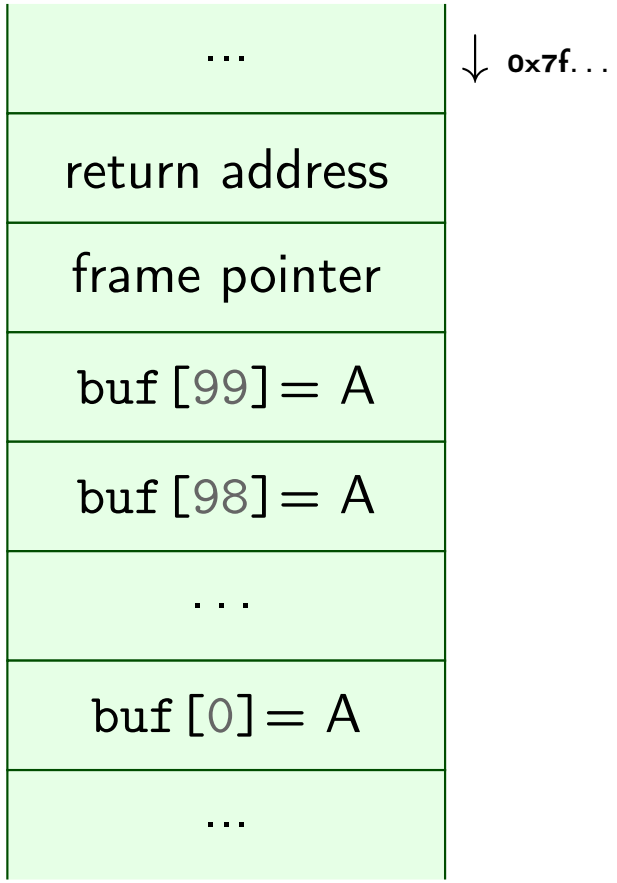

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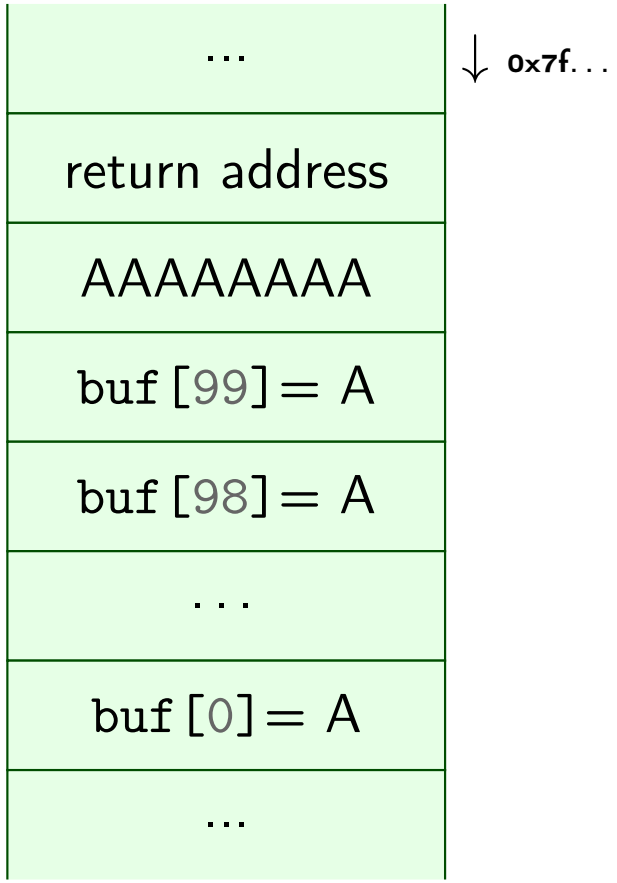

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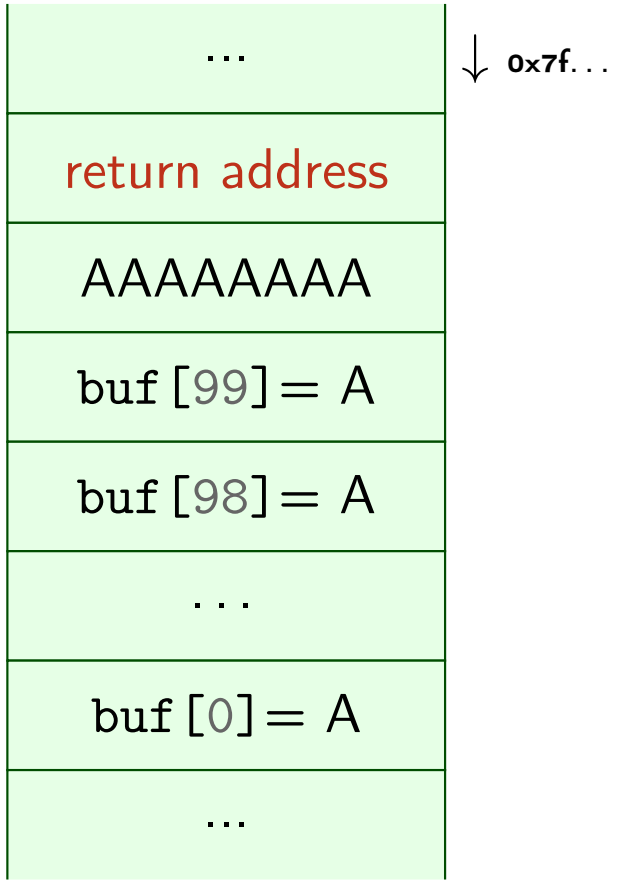

Taking control of the return address

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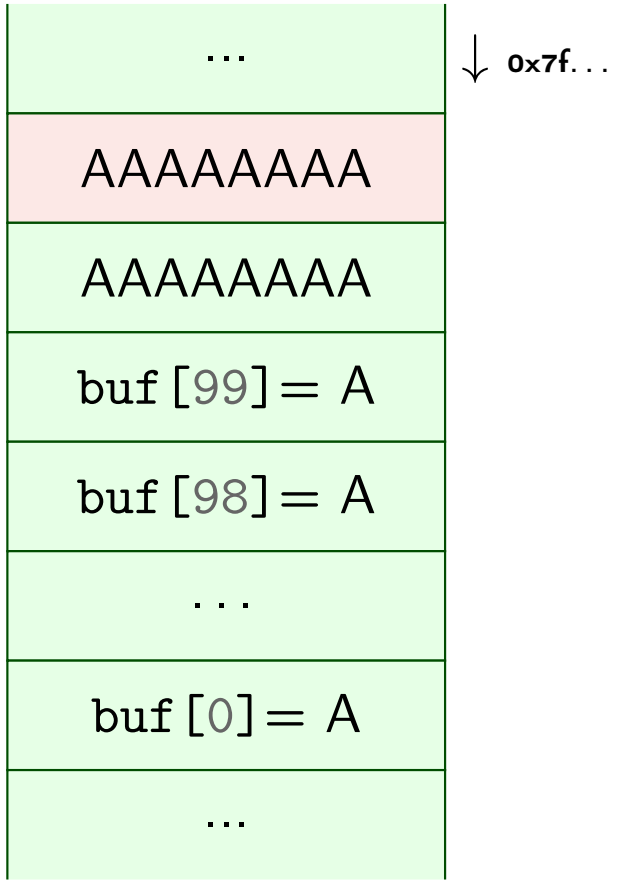
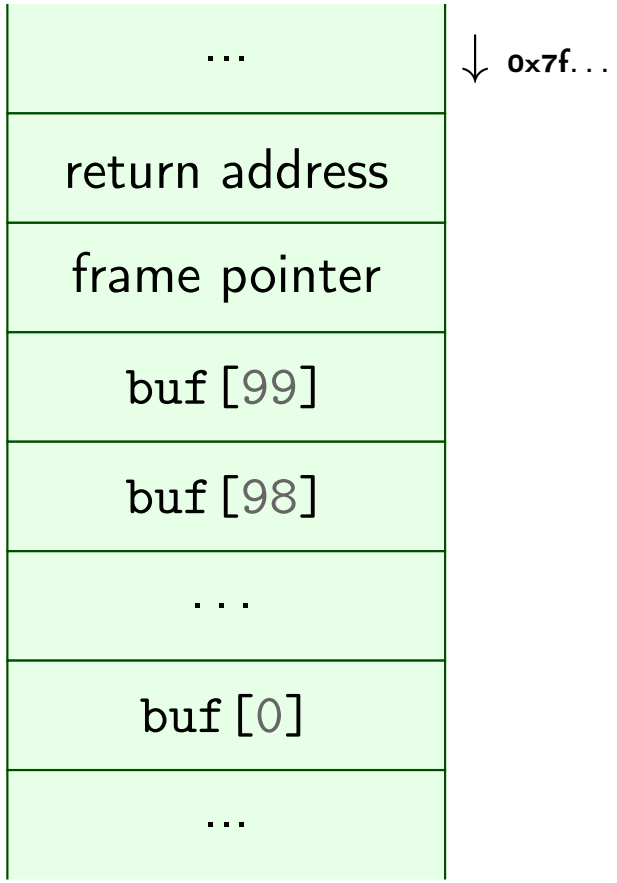


Taking control of the return address

So what if we feed this program
`'A'x108 +"\xDE\x0D\xDC\xAD\x0B"`?



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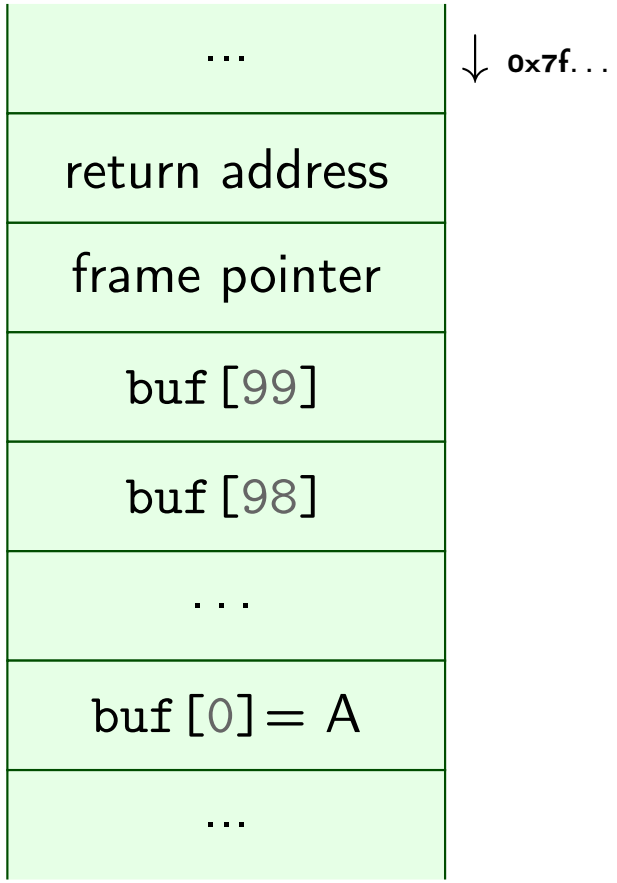

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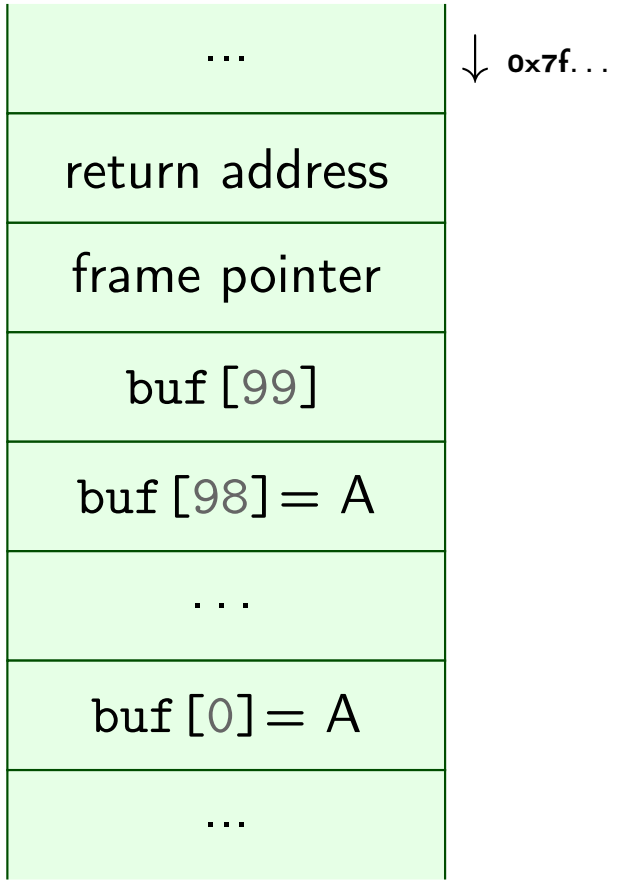

Taking control of the return address

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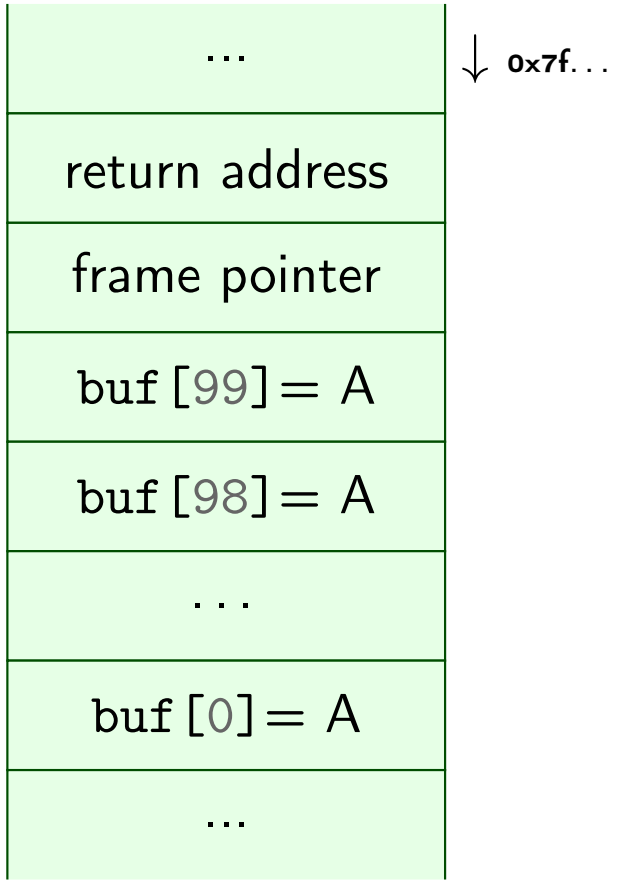

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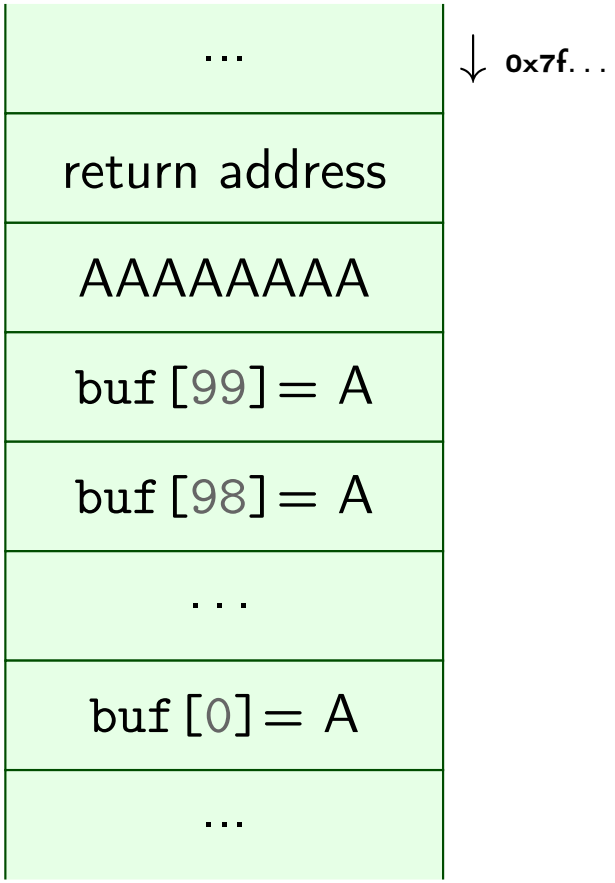

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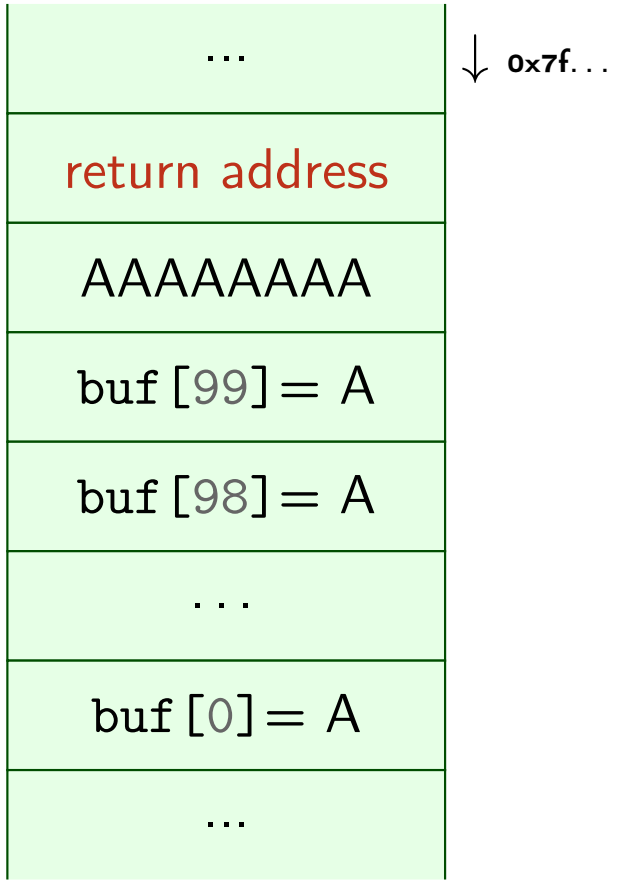

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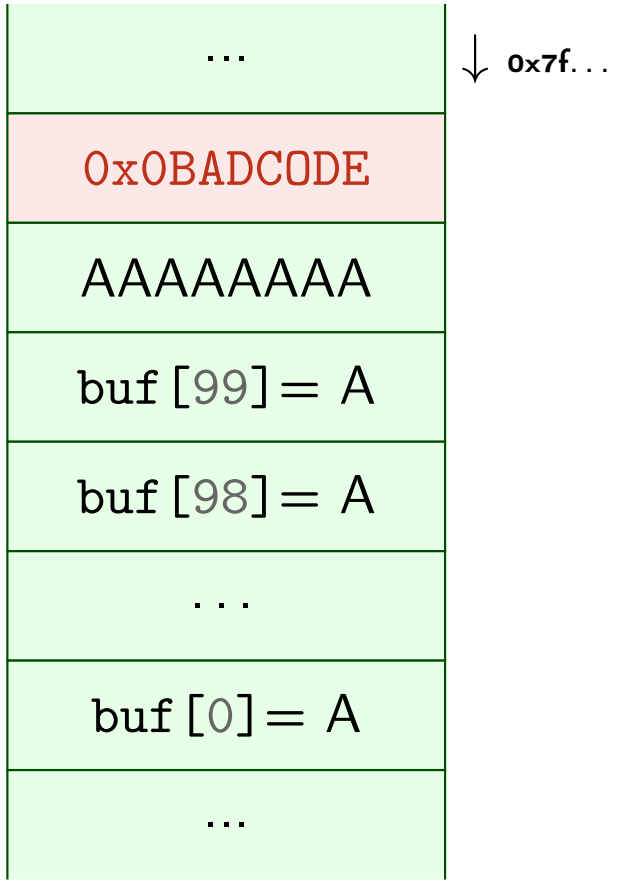

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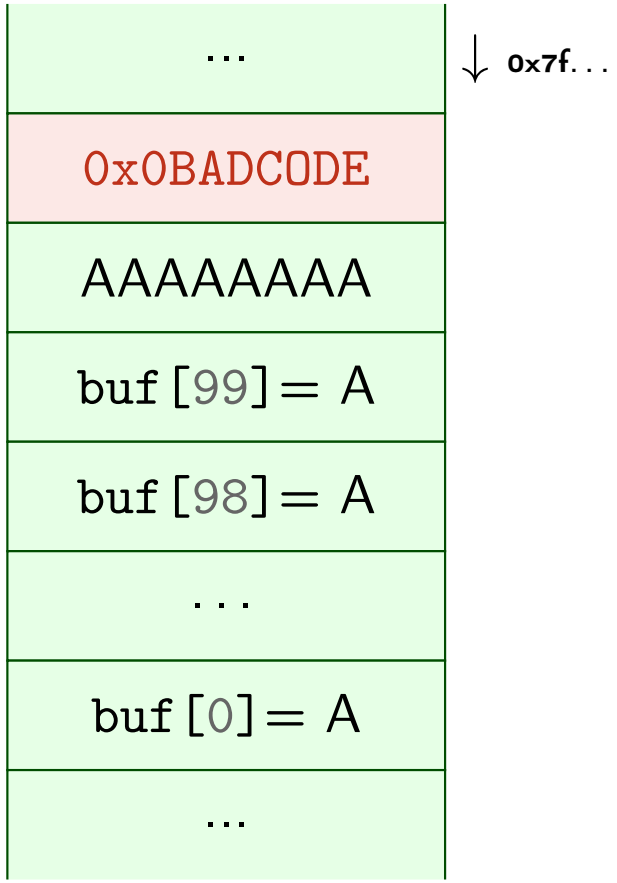

Taking control of the return address

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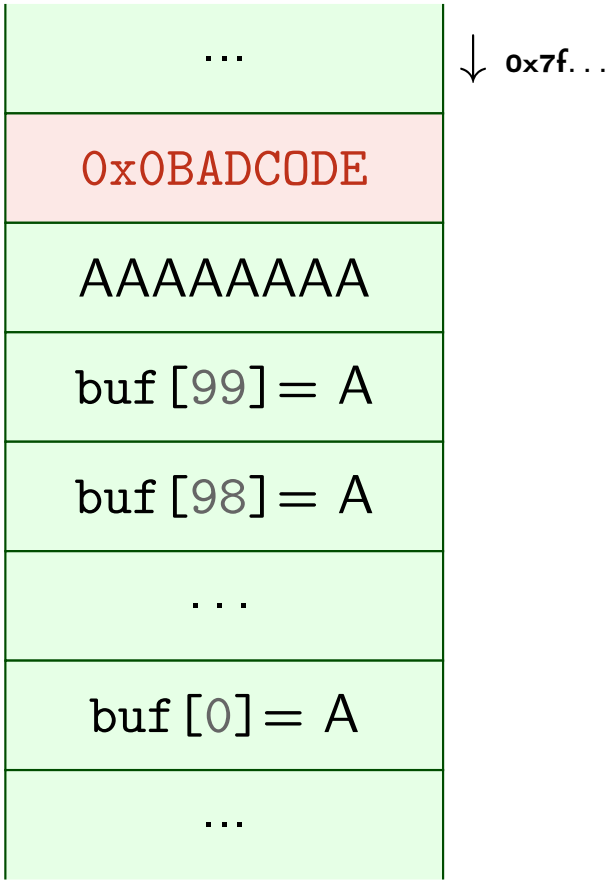
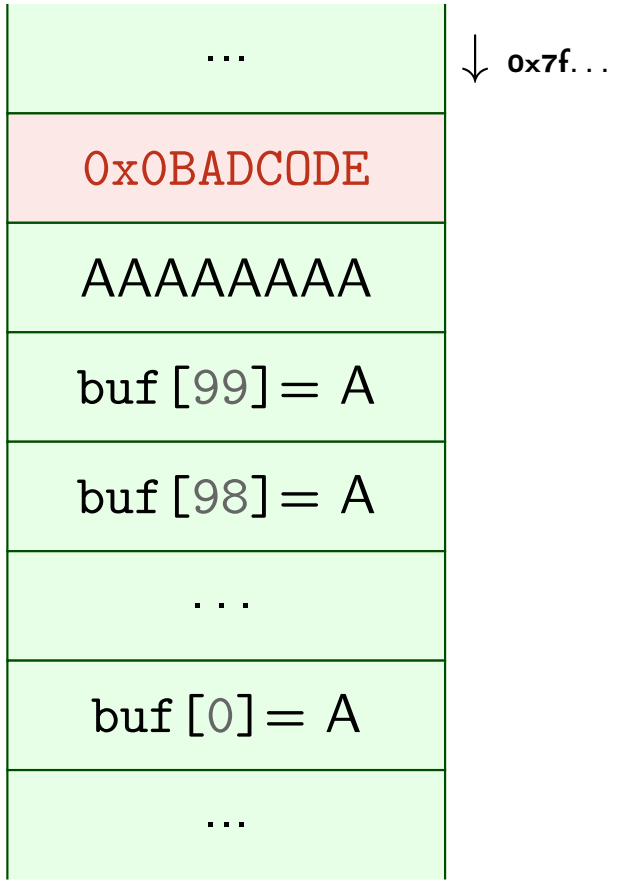
Note the endianness!



Taking control of the return address

So what if we feed this program
`'A'x108`[1]`+"\xDE\x0D\xDC\xAD\x0B"`?

Note the endianness!



1) actual values for the offset will vary with alignment, sizes of buffers and other local variables.

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This week's homework

- Simple buffer overflow to corrupt memory
- Find a vulnerability using `gdb` and exploit it
  - Use the links and follow a `gdb` tutorial!
- Redirect a program to call a function that it shouldn't have called.

Hint about last week's homework

For the `magic_function.c` exercise:

- Draw some pictures about what's going on on the stack when you call `magic_function()`
- Make sure that the compiler doesn't remove unused variables!
  - For example, print the result to make it 'used'
  - You could try to mark a buffer as `volatile`

```
volatile char bla[1000];
```

Crashes

- Exercise 2 (`malloc`) shouldn't crash.
- Exercise 4 does crash: it's leaking memory