CMSC414 Computer and Network Security

Mitigations and Tutorial

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Agenda

- Exploit mitigations
  - Non-executable pages
  - Stack canaries
  - Pointer authentication
  - Address space layout randomization (ASLR)
- Combining mitigations
- Demo related to Project 1

Pointer Authentication

- **Stack Canaries:** place some secret value below pointers (return instruction pointer and saved frame pointer)
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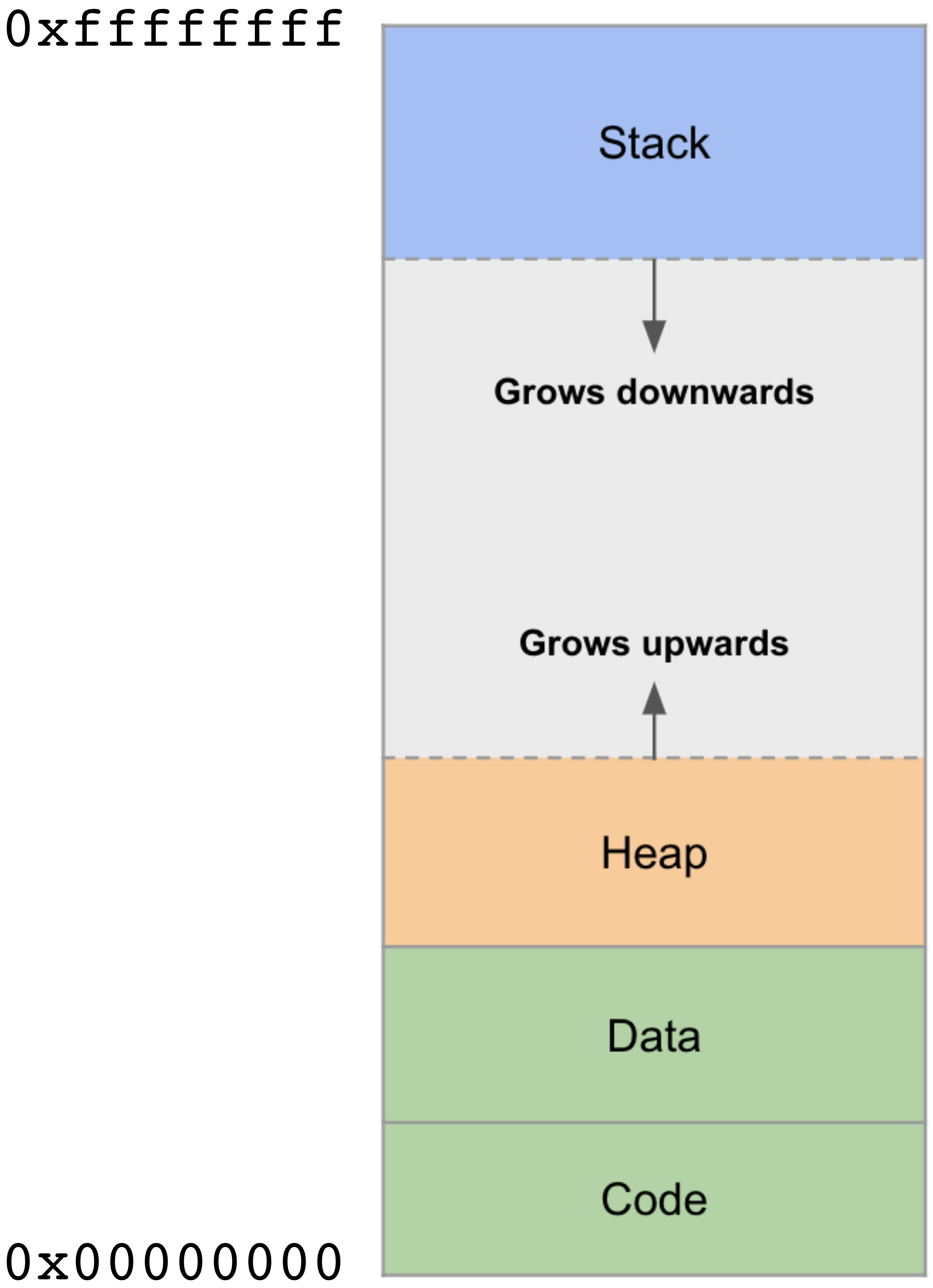
  - Put the secret **(PAC, pointer authentication code)** in unused bits
  - Before using the pointer in memory, check if the PAC is still valid
    - Invalid: crash the program
    - Valid: restore unused bits, use the address normally

Properties of PAC

- Each possible address has its own PAC
- Message Authentication Code (MAC) in the cryptography lectures
- Only someone who knows the CPU’s master secret can generate a PAC for an address
- The CPU’s master secret is not accessible to the program
    - Leaking program memory will not leak the master secret

Address Space Layout Randomization



0xffffffff

Stack

Grows downwards

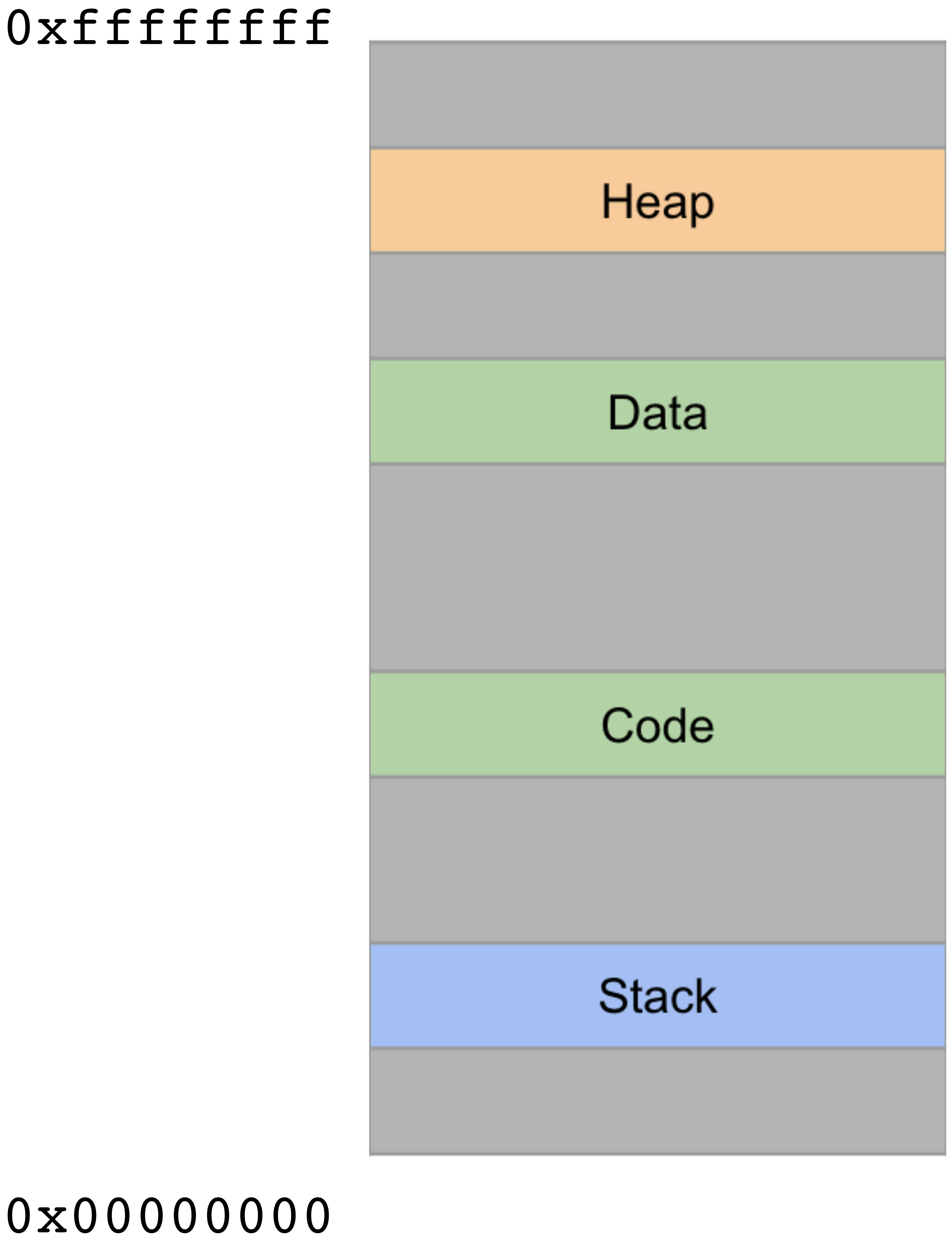
Grows upwards

Heap

Data

Code

0x00000000



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  - Programs are dynamically linked at runtime, so ASLR has almost no overhead
- However…
- Within each segment of memory, relative addresses are the same (e.g. the RIP is always 4 bytes above the SFP)
  - Leak the address of a pointer, whose address relative to your shellcode is known (stack pointer, RIP)
  - Guess the address of your shellcode: Brute-force

Combining Mitigations

- **Defense in depth**
- Example: Combining ASLR and non-executable pages
- To defeat ASLR and non-executable pages, the attacker needs to find two vulnerabilities
  - First, find a way to leak memory and reveal the address randomization (defeat ASLR)
  - Second, find a way to write to memory and write a ROP chain (defeat non-executable pages)

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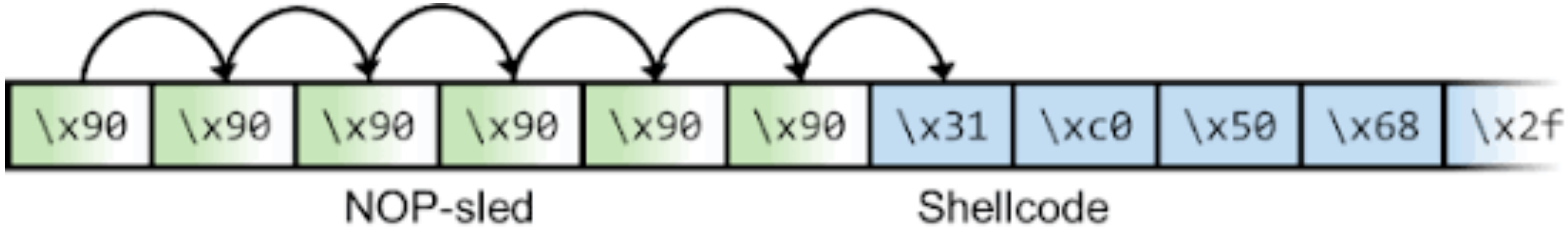
NOP Slide



- NOP: no operation
  - "slide" the CPU's instruction execution flow to its final, desired destination
- Return instruction pointer to anywhere in NOP can then execute the Shellcode

https://www.coengoedegebure.com/buffer-overflow-attacks-explained/

https://en.wikipedia.org/wiki/NOP_slide

`run <input>`

Run the program with `input` as the command-line arguments

`print <var>`
(or just "**`p <var>`**")

Print the value of variable `var`
(Can also do some operations: `p  &x`)

`b <function>`

Set a breakpoint at `function`

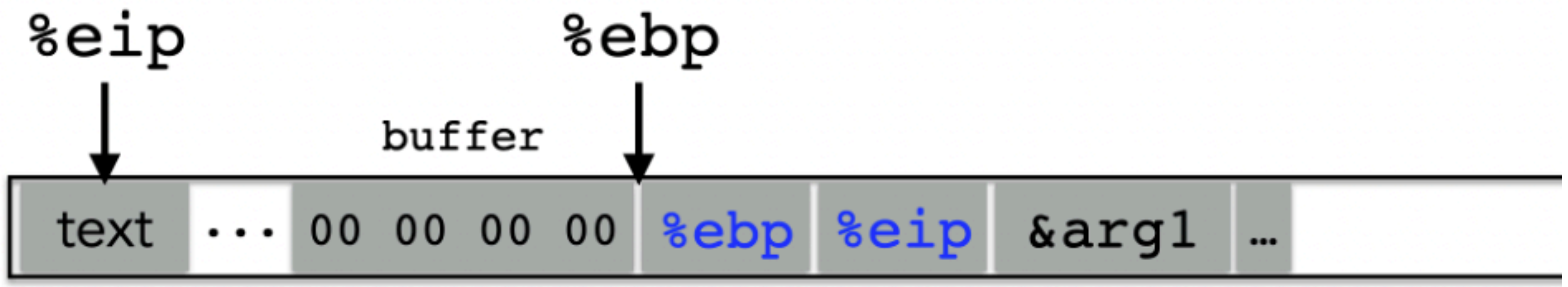
`s`
`c`

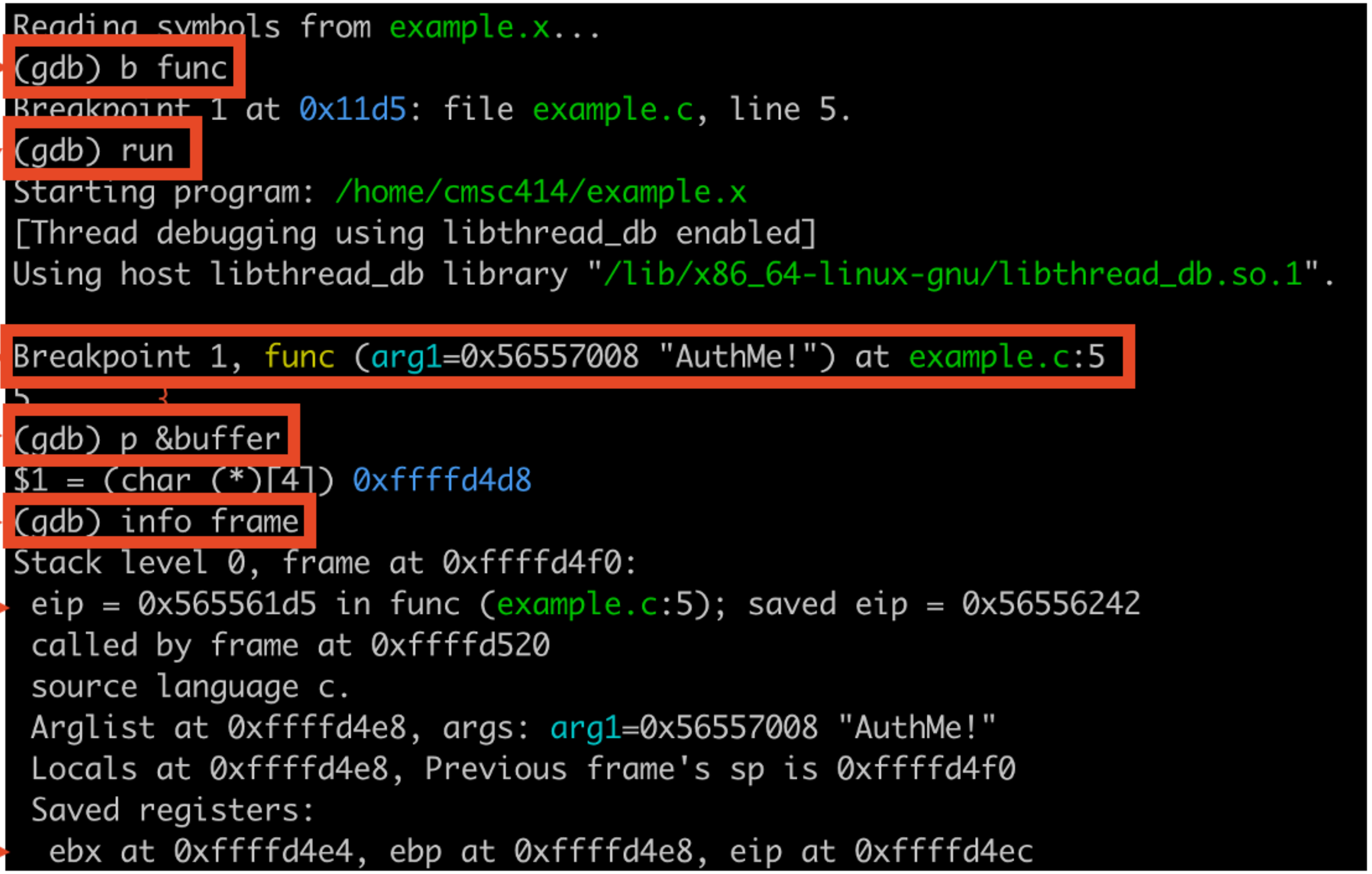
step through execution (into calls)
continue execution (no more stepping)

`info frame` (or just "`i f`")	Show **i**nfo about the current **f**rame (prev. frame, locals/args, %ebp/%eip)
`info reg` (or just "`i r`")	Show **info** about **reg**isters (%ebp, %eip, %esp, etc.)
`x/<n> <addr>`	E**x**amine <n> bytes of memory starting at address <addr>

gdb example

```
void func(char *arg1)
{
    char buffer[4];
    sprintf(buffer, arg1);
    ...
}
```





Set a breakpoint at func()

Run the program

Breakpoint reached

Print buffers' addr

Frame info

Current/saved eip

Where on the stack registers are saved

```
Reading symbols from example.x...
(gdb) b func
Breakpoint 1 at 0x11d5: file example.c, line 5.
(gdb) run
Starting program: /home/cmsc414/example.x
[Thread debugging using libthread_db enabled]
Using host libthread_db library "/lib/x86_64-linux-gnu/libthread_db.so.1".

Breakpoint 1, func (arg1=0x56557008 "AuthMe!") at example.c:5
5
(gdb) p &buffer
$1 = (char (*)[4]) 0xffffd4d8
(gdb) info frame
Stack level 0, frame at 0xffffd4f0:
 eip = 0x565561d5 in func (example.c:5); saved eip = 0x56556242
 called by frame at 0xffffd520
 source language c.
 Arglist at 0xffffd4e8, args: arg1=0x56557008 "AuthMe!"
 Locals at 0xffffd4e8, Previous frame's sp is 0xffffd4f0
 Saved registers:
  ebx at 0xffffd4e4, ebp at 0xffffd4e8, eip at 0xffffd4ec
```

Tutorial on Computer