SIGPwny

General FA2025 • 2025-10-05

x86-64 Assembly

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Julius White V

- Computer Science AND Economics
- I have windmill dunked a basketball
- Admin in SIGPwny

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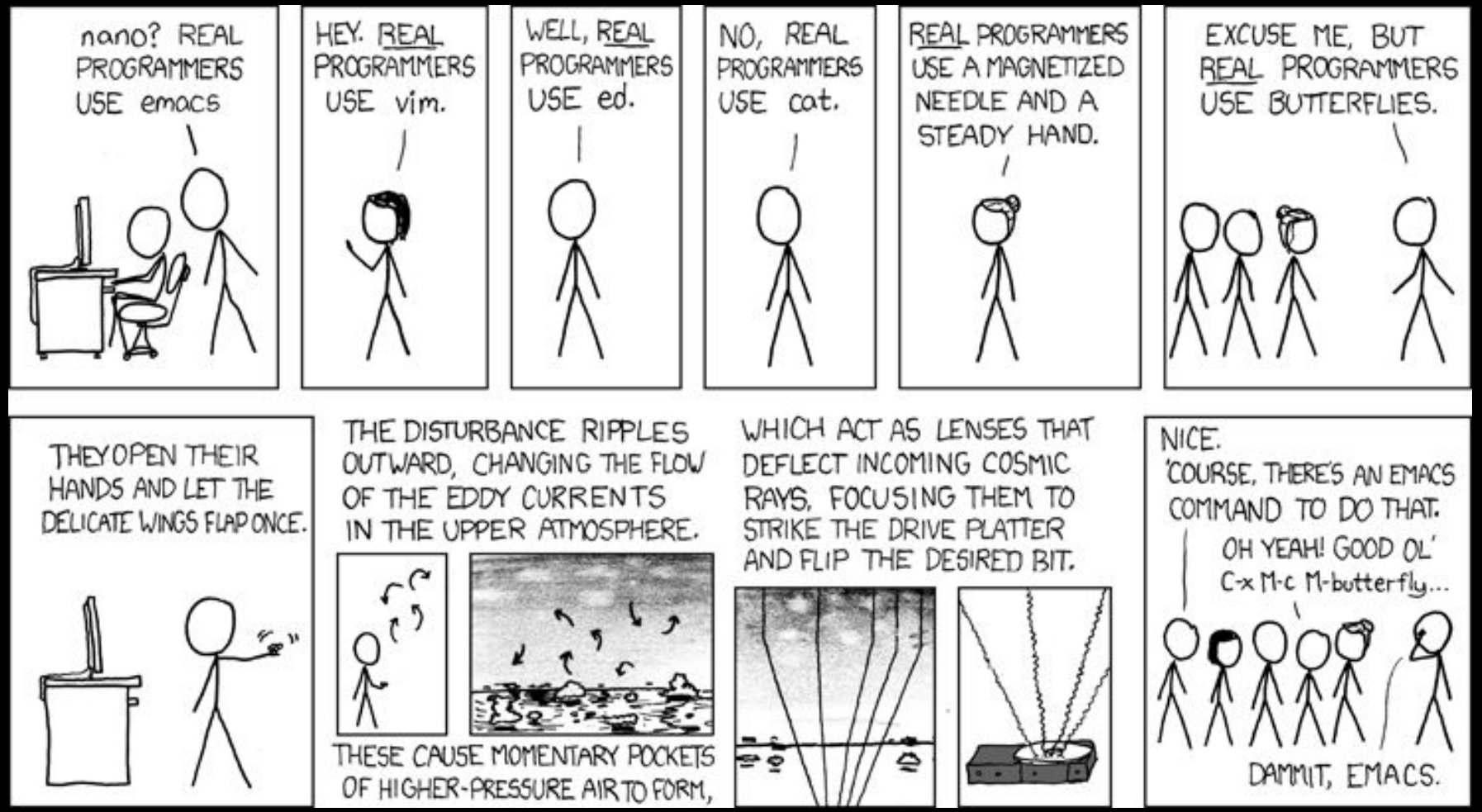


Announcements

- AmateursCTF this weekend is unfortunately canceled
  NEW PLAN: Game night in Siebel with pizza on Friday!
  - Details will be sent in an announcement on Discord

- First lockpicking social Monday 10/13 at 7 PM!
  - Will talk briefly about the history of magstripe and do a demo

What is Assembly?

- A human-readable abstraction over CPU machine codes

```
0100100000000101110111101100000000110111000010011
```

```
48 05 DE C0 37 13
```

```
add rax, 0x1337c0de
```

What is Assembly?

```
int method(int a){
    int b = 6;
    char c = 'c';
    return a+b;
}
```

```
method:
        push    rbp
        mov     rbp, rsp
        mov     DWORD PTR [rbp-20], edi
        mov     DWORD PTR [rbp-4], 6
        mov     BYTE PTR [rbp-5], 99
        mov     edx, DWORD PTR [rbp-20]
        mov     eax, DWORD PTR [rbp-4]
        add     eax, edx
        pop     rbp
        ret
```

Basic CPU Structures

Instruction Memory

```
[0x00401000]
   ;-- section..text:
   ;-- segment.LOAD1:
 entry0 ();
 push    rsp
 pop     rsi
 xor     dl, 0x60
 syscall
 ret
```

Registers

```
*RAX  0x3e8
*RBX  0x401300 (__libc_csu_init) ←
*RCX  0x7ffff7ea311b (getegid+11) ←
 RDX  0x0
*RDI  0x7ffff7fad7e0 (_IO_stdfile_1
 RSI  0x0
 R8   0x0
*R9   0x7ffff7fe0d60 (_dl_fini) ←
*R10  0x400502 ← 0x64696765746567
*R11  0x202
*R12  0x401110 (_start) ← endbr64
*R13  0x7fffffffddc0 ← 0x1
 R14  0x0
 R15  0x0
*RBP  0x7fffffffdcd0 ← 0x0
*RSP  0x7fffffffdcb0 ← 0x0
*RIP  0x401220 (main+42) ← mov
```

Stack

```
0x7fffffffdcb0 ← 0x0
0x7fffffffdcb8 → 0x401110 (_star
0x7fffffffdcc0 → 0x7fffffffddc0
0x7fffffffdcc8 ← 0x0
0x7fffffffdcd0 ← 0x0
0x7fffffffdcd8 → 0x7ffff7de3083
```

Instruction Memory

- Contiguous memory of executable data
- “This is where your compiled program lives in RAM”

- Normally, only read & execute permissions (security feature)

- At very low address space (below the heap!)

- Managed by the special purpose Instruction Pointer register (`rip`) also called program counter

- Simply, Instruction memory is just RAM that holds your program's code. The CPU fetches from it, executes it, and moves on

Registers

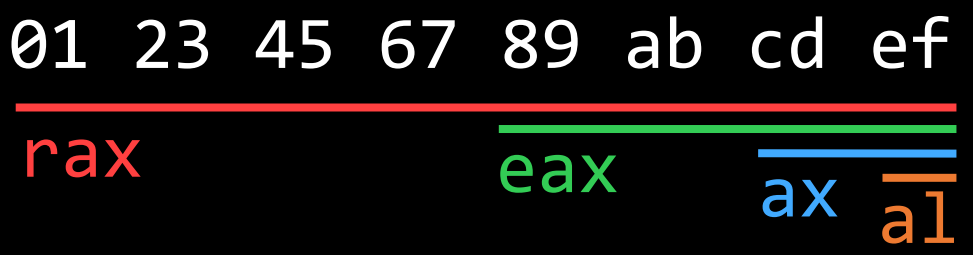
- 16 general purpose "variables" that the CPU can operate on. On a 64 bit architecture, each are 64 bits wide.

- Most can be used for whatever you want within a function, except for:
  - `rbp` which is the "Base Pointer" register
  - `rsp` which is the "Stack Pointer" register

- We can access lower bits using various namings for each register

Registers

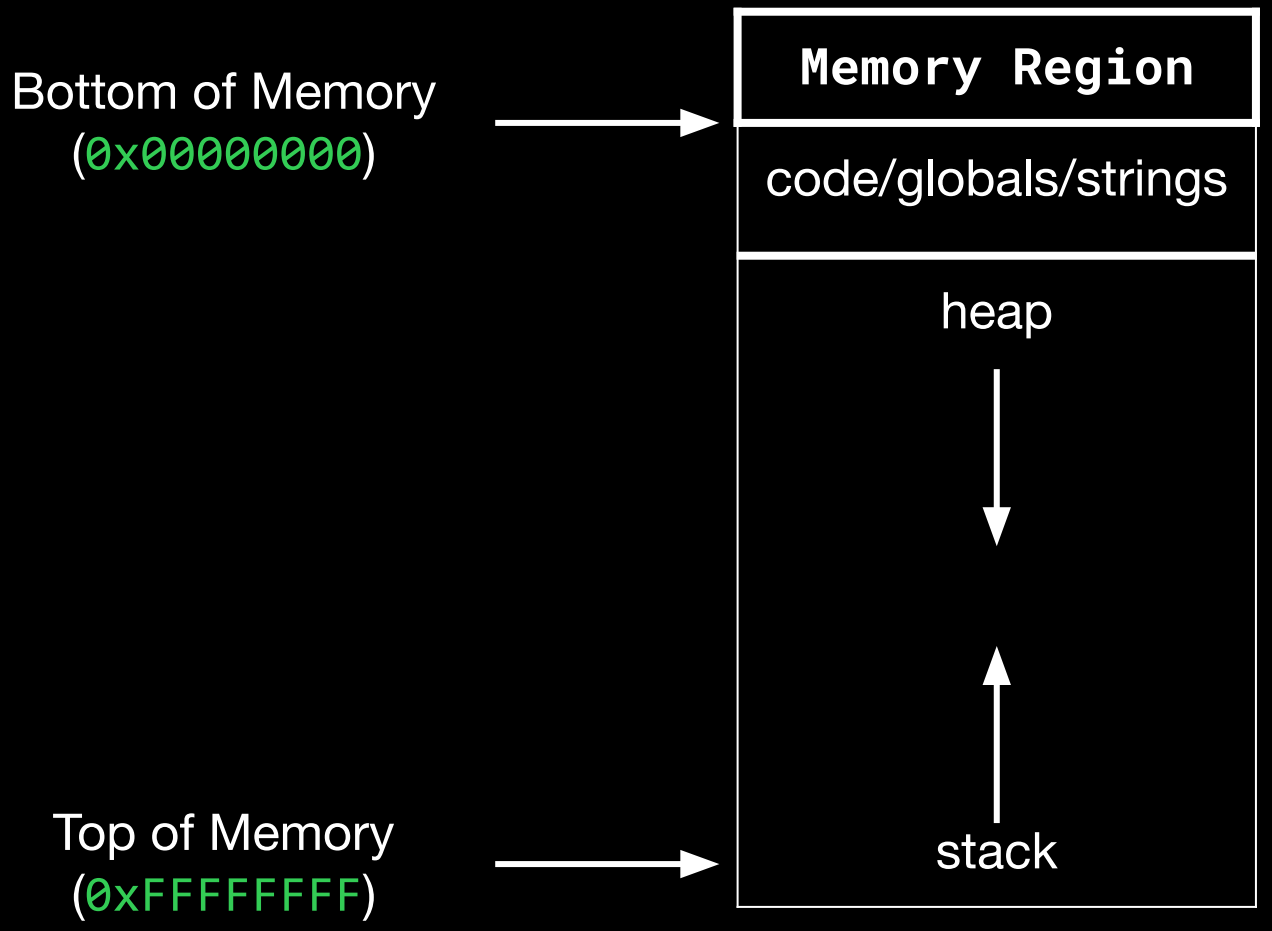
8 Byte	4 Byte	2 Byte	1 Byte
rax	eax	ax	al
rbx	ebx	bx	bl
rcx	ecx	cx	cl
rdx	edx	dx	dl
rsi	esi	si	sil
rdi	edi	di	dil
rsp	esp	sp	spl
rbp	ebp	bp	bpl
rX	rXd	rXw	rXb



← These registers are named r8 through r15

Stack

- The region of memory dedicated to functions and local variables
- Push to the stack to add data, pop to remove newest element. (LIFO)
- If the heap and stack meet you get a stack overflow or out of memory error



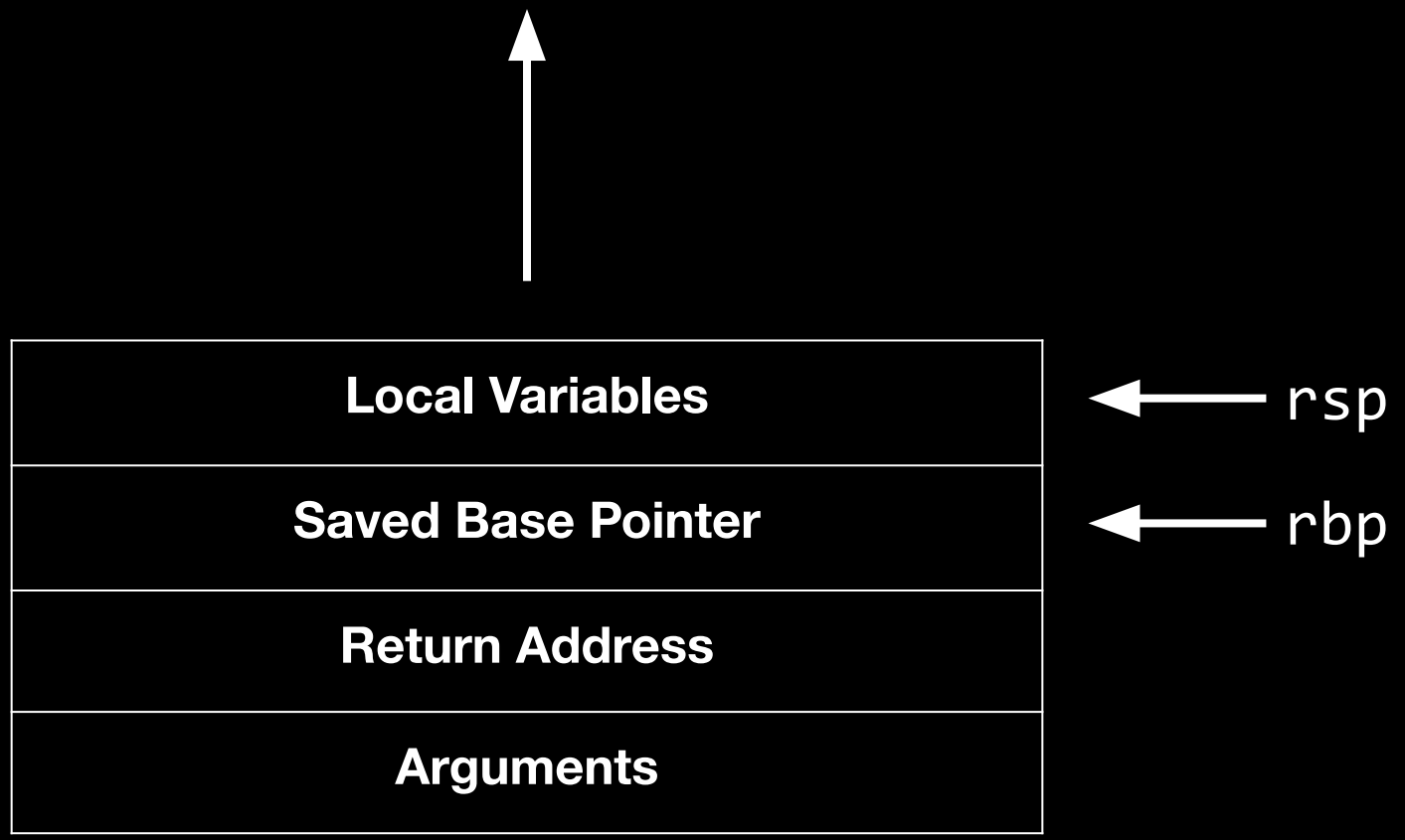
Stack & Registers

- There are two registers dedicated to managing the stack

- `rsp` - holds the address of the *top* of the stack
  - If you want to allocate memory on the stack, you subtract from `rsp`
  - Likewise to deallocate, add to `rsp`.

- `rbp` - holds the address of the start of the stack frame
  - The value at the address holds the base ptr of the calling function

Stack & Functions



Saved Base Pointer vs Return Address

(what's the difference?)

saved base pointer - the scope of the previous function

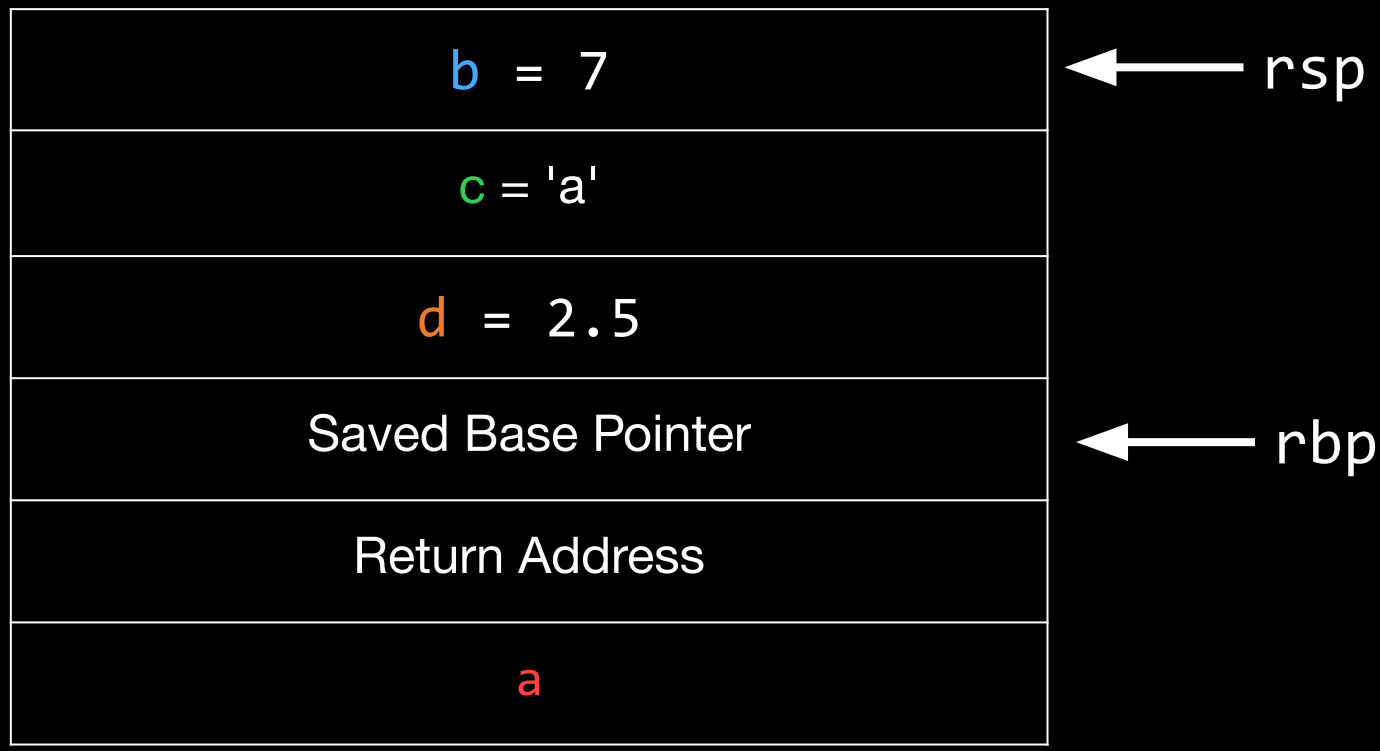
return address – the line to go back to in the previous function

```
1  helper(int arg0) {
2
3      int temp = 67; // lol
4
5      int temp2 = 100;
6
7      return;
8  }
9  main() {
10
11     helper(3);
12
13 }
```

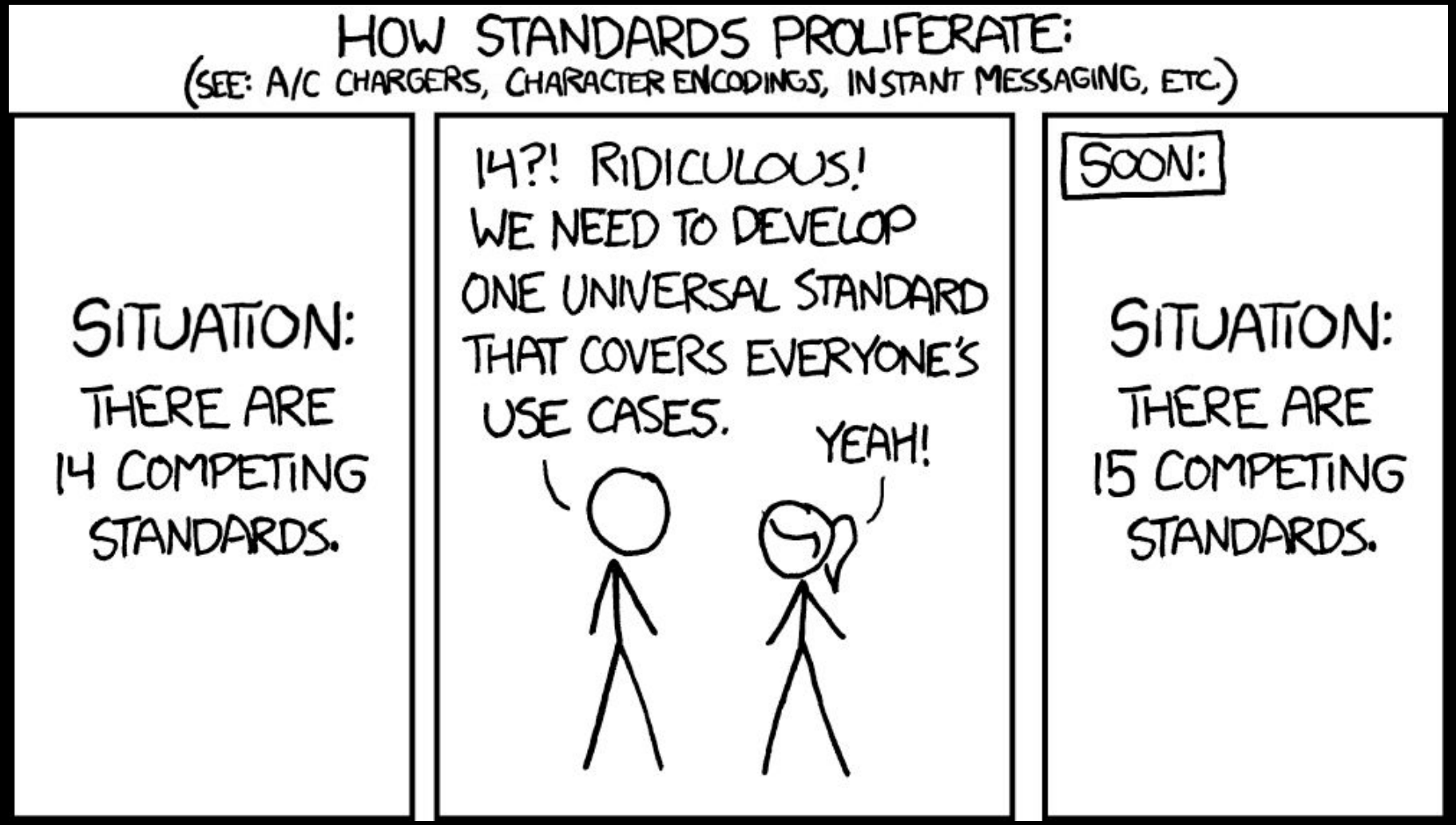
temp = 67 = "we are holding 67 in a register"
Saved base pointer = "you were running the main() function"
Return Address = "you were at line 11 in main()
arguments = arg0 = 3

Stack & Functions

```
method_1(int a){
   int b = 7;
   char c = 'a';
   float d = 2.5;
   return a+b
}
```



A Note on Syntax



Intel vs AT&T

	Intel	**AT&T**
Registers	`rax, rsp, r15`	`%rax, %rsp, %r15`
Immediates (Constants)	`0x123`	`$0x123`
Command Order / Typing	`add eax, bx`	`addzqd %bx, %eax`
Comments	`; this is a comment.`	`// this is, too.`

Basic Assembly

```
mnemonic destination, source(s)
```

e.g.

```
add rax, rbx
sub dx, 0x1235
and rsp, rbp
xor rsi, rsi
inc ecx
```

```
nop
mov rbp, rsp
imul r8, r10, 0x20
shl rcx
sar rdi, 5
```

Logic Flow

- We can use `jmp addr` to jump to nearby addresses in our instruction code

- near/short jumps are relative, but when writing we can use labels!

- This is one of the few ways to modify `rip` (hopefully) safely.

Logic Flow

- Assembly compares values by subtracting values (a-b)
  - If we get 0, a=b
  - If we get a positive number, a>b, otherwise, a<b

- `cmp` subtracts two registers and sets flags (RFLAGS register) for later use

- `jCC` jumps to address if condition is met, based on flags set by `cmp`. There's 64 of them.

Logic Flow

```
mov rbx, 0x20    ; move 32 into rbx
mov rax, 0x15    ; move 21 into rax
foo:
    cmp rax, rbx ; compare rax and rbx
    jne bar      ; if not equal, jump to bar label
    xor rax, rax ; zero out rax
    ret          ; return
bar:
    dec rbx      ; decrement rbx
    jmp foo      ; jump to foo label
```

Logic Flow

```
first = 32    # move 32 into rbx
second = 21   # move 21 into rax

while (first != second): # compare first and second
    first -= 1           # decrement first

return          # why are python and x86 different
                # (in terms of returning variables)
```

Logic Flow

```
push rdi
mov rdi, 0x20    ; move 32 into rdi

mov rax, 0x15    ; move 21 into rax

assembly logic ...

pop rdi ; we expect our return value to be in rax
```

Using the Stack

- Use `push (reg/imm)` to push a 16 bit, 32 bit or 64 bit value onto the stack.
  - `rsp` is *automatically* decremented

- Use `pop reg` to pop a value from the stack into a register
  - `rsp` is *automatically* incremented

push:

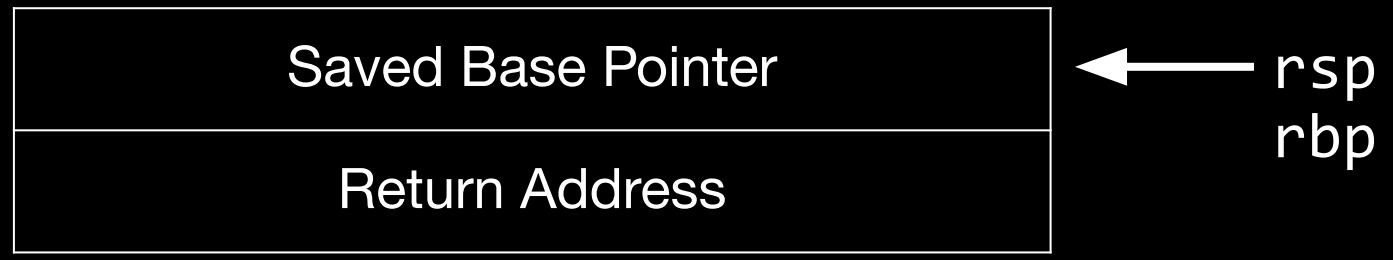
- mov rsp, reg
- rsp -= 4

pop:

- mov reg, rsp
- rsp += 4

Using the Stack

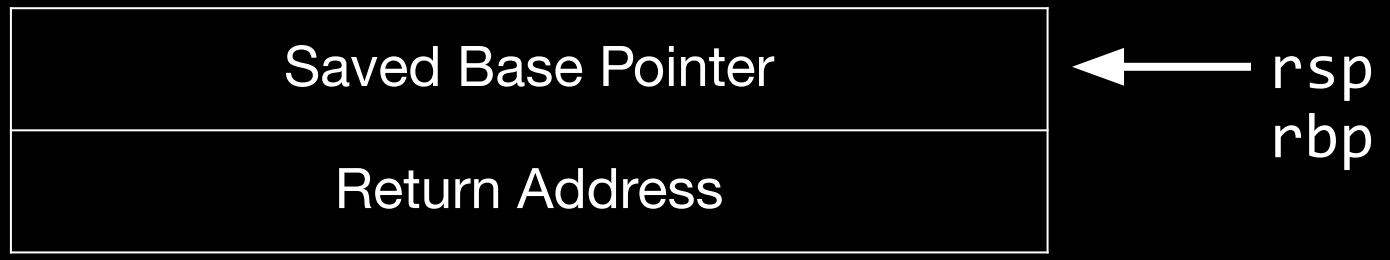
```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x1234567890abcdef
rbx: 0x1234567890abcdef
```

Using the Stack

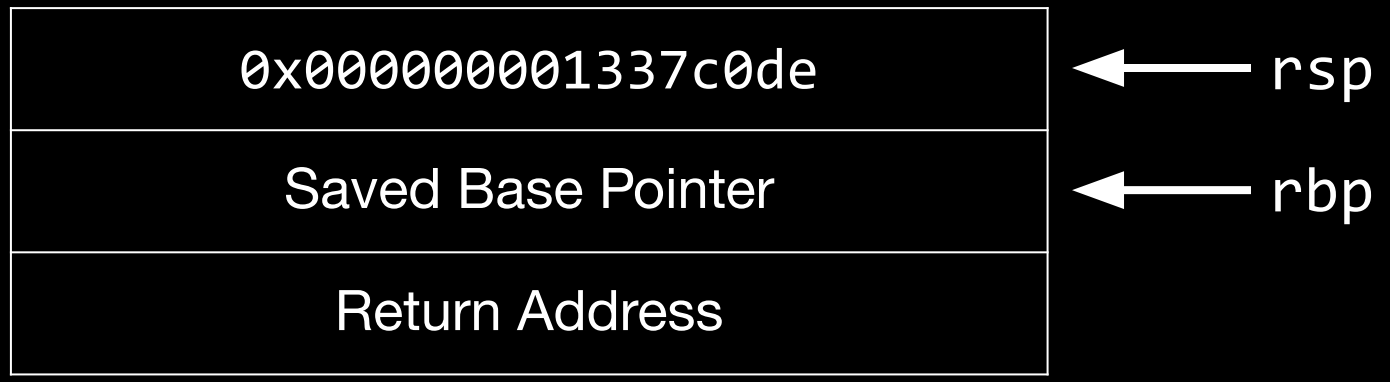
```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x000000001337c0de
rbx: 0x1234567890abcdef
```

Using the Stack

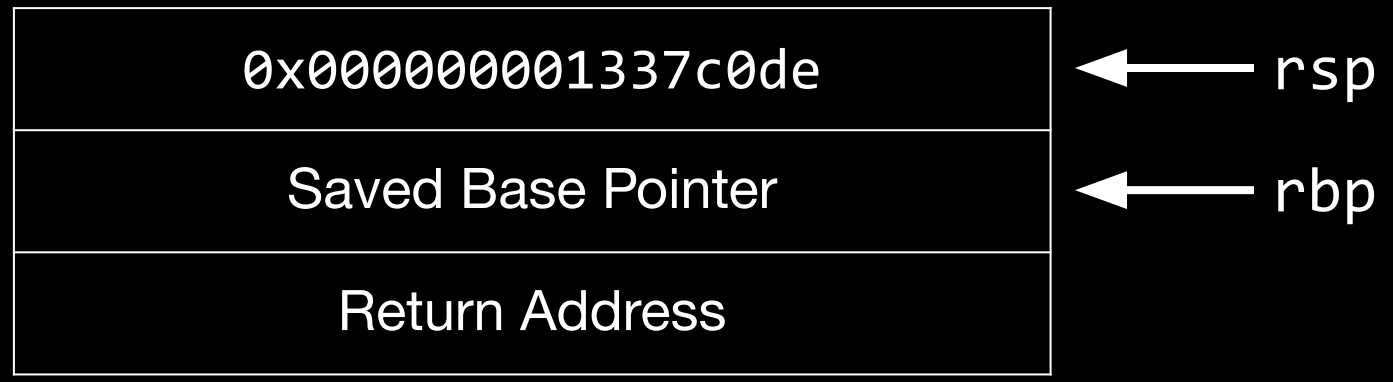
```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x000000001337c0de
rbx: 0x1234567890abcdef
```

Using the Stack

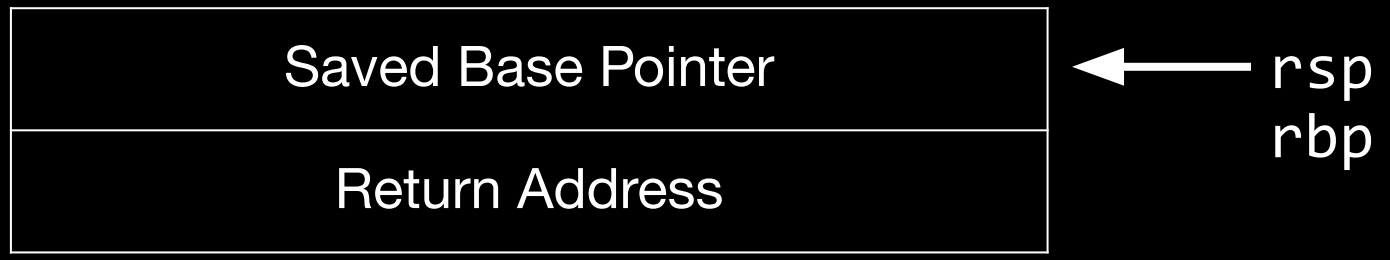
```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x0000000000000000
rbx: 0x1234567890abcdef
```

Using the Stack

```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x0000000000000000
rbx: 0x000000001337c0de
```

Syscalls

- The linux kernel provides a set of functions to interface with the OS.

- glibc provides wrappers, so *most* programs use glibc calls
  - But you can inline system calls without calling glibc at all!

- Examples of system calls: `read`, `exit`, `open`, `execve`

Calling a Syscall

- Load the syscall id into `rax`
  - The most up-to-date resource of ids to syscalls is the abi table: https://github.com/torvalds/linux/blob/master/arch/x86/entry/syscalls/syscall_64.tbl

- Load your arguments into the registers, in order, as follows:

  `rdi, rsi, rdx, r10, r8, r9`

- Use the `syscall` instruction
- return value, if needed, is stored in `rax`

Calling a Syscall

```
exit(10);
```

```
mov rax, 0x3c
mov rdi, 0x0a
syscall
```

```
execve("/bin/sh",
NULL, NULL);
```

```
mov rax, 0x3B
mov rdi, rsp ; /bin/sh is on the stack
xor rsi, rsi
xor rdx, rdx
syscall
```

Pointers and Dereferencing

- At a *high level*, use braces to dereference a pointer

```
mov rax, [rbx] ; moves the memory pointed by rbx to rax
```

- You may use a index register, a scale for that index, and a displacement in a dereference

```
mov rax, [rbx + rcx*4 + 0x1a]
```

  - This is useful for iterating through arrays

- Writing to memory can be done the same way

```
inc [rsp] ; increments the top value on the stack by 1
```

A little history lesson (respect your elders)

- **Commercial blockbuster**
  - Sold millions of copies and successfully competed in the late 1990s gaming market

- **Massive scope**
  - pathfinding algorithms
  - financial systems
  - ride physics
  - intricate game logic

ALL IN X86 ASSEMBLY?!?!?!?!?

A little technical history lesson

(respect your elders)

- **99% x86 assembly written by one developer**
  - Chris Sawyer coded the entire game in assembly, not a higher-level language
- **Ran on 16MB RAM**
  - Managed thousands of guests and complex simulations on minimal hardware
- **Tiny executable of ~15-16 MB**
  - The main program file was remarkably compact, with total installation around 180 MB including all assets

Resources

RTFM: https://www.felixcloutier.com/x86/

Online Assembler: defuse.ca/online-x86-assembler

Syscall Table & Argument Convention:
https://syscalls.pages.dev/

Flat Assembler/Fasm: https://flatassembler.net/

Compiler Explorer: https://godbolt.org/

Challenges

- 1 - asm_adder
- 2 - asm_leaver
- 3 - asm_reader
- 4 - asm_shellcode
- 5 - asm_modifier

Use pwntools! An example script:

```
from pwn import *
conn = process("./chal") # or remote("link", port)
conn.sendline(b'your shellcode here')
conn.interactive()
```

Next Meetings

2025-10-09 - This Thursday

- Reverse Engineering II
- Learn how to reverse engineer x86 binaries!

2025-10-10 - This Friday

- AmateursCTF 2025 is canceled, so we're going to do a game night with pizza instead!!

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Meeting content can be found at sigpwny.com/meetings.

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