SysSoft Security

A quick refresher on Memory corruption and ABI

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Lecture(s) Agenda

- Motivation (non-technical)
- Background
  - C to assembly
  - Memory layout

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- Example – Stack buffer Overflow

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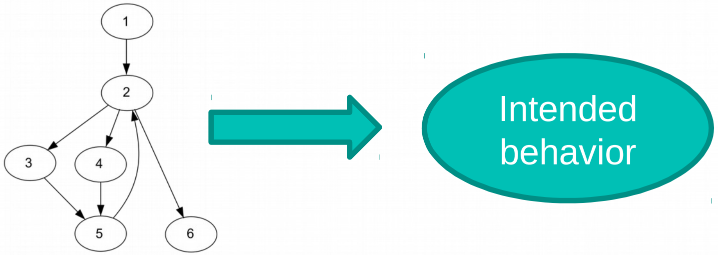

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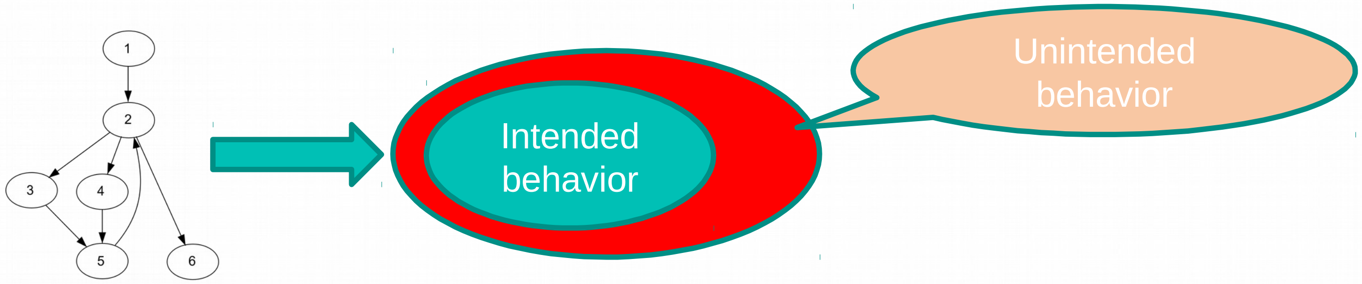

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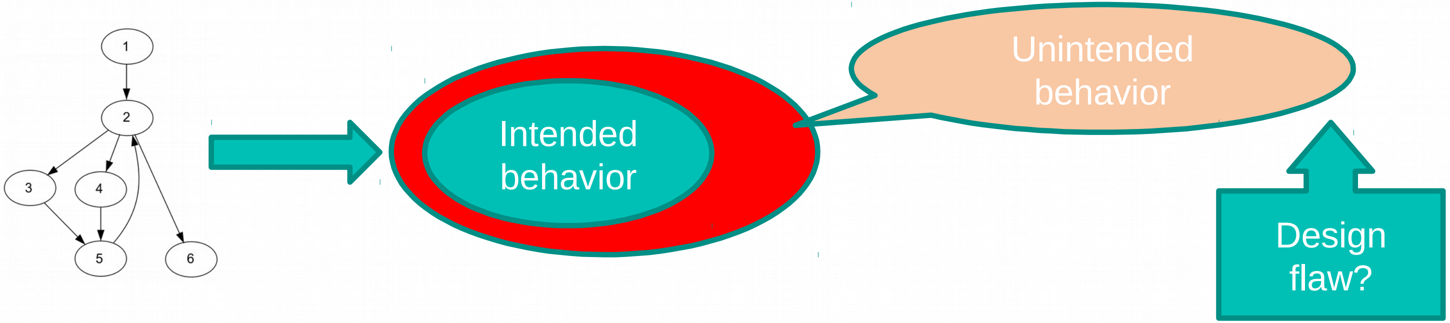

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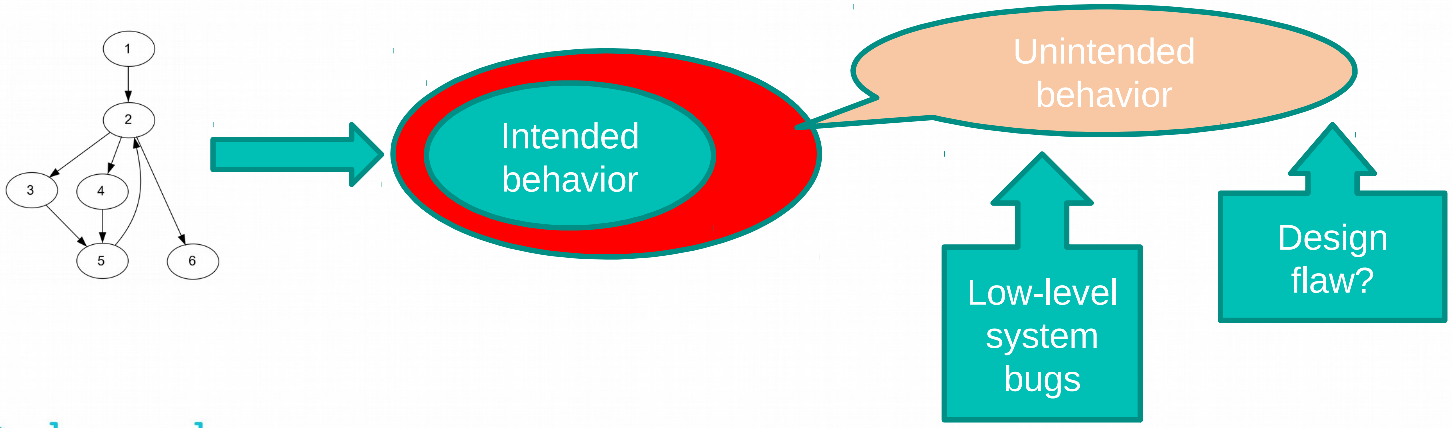

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- **Vulnerability** is the intersection of three elements: a system susceptibility or flaw, attacker access to the flaw, and attacker capability to exploit the flaw (there are mitigations!)

Exploits

- Exploit:
  - An *exploit* is a piece of software or technique that takes advantage of a security vulnerability to violate an explicit or implicit security policy.
  - Vulnerabilities in software are subject to exploitation.
  - Exploits can take many forms, including worms, viruses, and trojans.

Exploits

- Exploit:
  - Proof-of-concept exploits are developed to prove the existence of a vulnerability.
  - Proof-of-concept exploits are beneficial when properly managed (for example?).
  - Proof-of-concept exploit in the wrong hands can be quickly transformed into a worm or virus or used in an attack.

Memory Corruption Vulnerabilities

- WYSINWYX: What You See Is Not What You eXecute by G. Balakrishnan et. al.
  - Higher level code -> low-level representation
  - Seemingly separate variables -> contiguous memory addresses
- Contiguous memory locations allow for boundary violations!
- We need to peep into the memory layout to understand → ABI

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- Sensitive data corruption
- Control data corruption (control hijacking)

If done properly-exploit

Otherwise crash!

Generic Approach to Vulnerability Detection

1. Find the weakness in the Software (sink)
2. Find the source of *tainted input* (source)
3. Find the tainted path from source to sink.

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You may have to do this at binary level

Mitigations

- Mitigation:
  - *Mitigations* are methods, techniques, processes, tools, or runtime libraries that can prevent or limit exploits against vulnerabilities.
  - At the code level, compiler assisted canary technique OR control flow integrity.
  - At a system or network level, a mitigation might involve turning off a port or filtering traffic to prevent an attacker from accessing a vulnerability OR OS provided techniques (ASLR, e.g.).

C and C++

- C and C++:
  - Popular programming languages.
  - Many vulnerabilities that have been reported to the CERT/CC have occurred in programs written in one of these two languages.
  - By design, these are *memory unsafe language.*

What is the Problem with C?

- Programmer errors
  - Failing to prevent writing beyond the boundaries of an array,
  - Failing to catch integer overflows and truncations,
- Lack of *type safety.*
  - Operations can legally act on signed and unsigned integers of differing lengths using implicit conversions and producing unrepresentable results.

Legacy Code

- A significant amount of legacy C code was created (and passed on) before the standardization of the language.
- Legacy C code is at higher risk for security flaws because of the looser compiler standards and is harder to secure because of the resulting coding style.

Motivating example

```
#include <stdio.h>
int get_cookie()
{
return rand();//random number
}
int main()
{
    int guess;    char name[20];
    guess=get_cookie();
    printf("Enter your name:\n");
    gets(name);
    if(guess == 0x41424344)
    {   printf("Hurray... you win Dear %s\n",name);    }
    else printf("Sorry, Better luck next time :( \n");
   return 0;
}
```

Motivating example conti..

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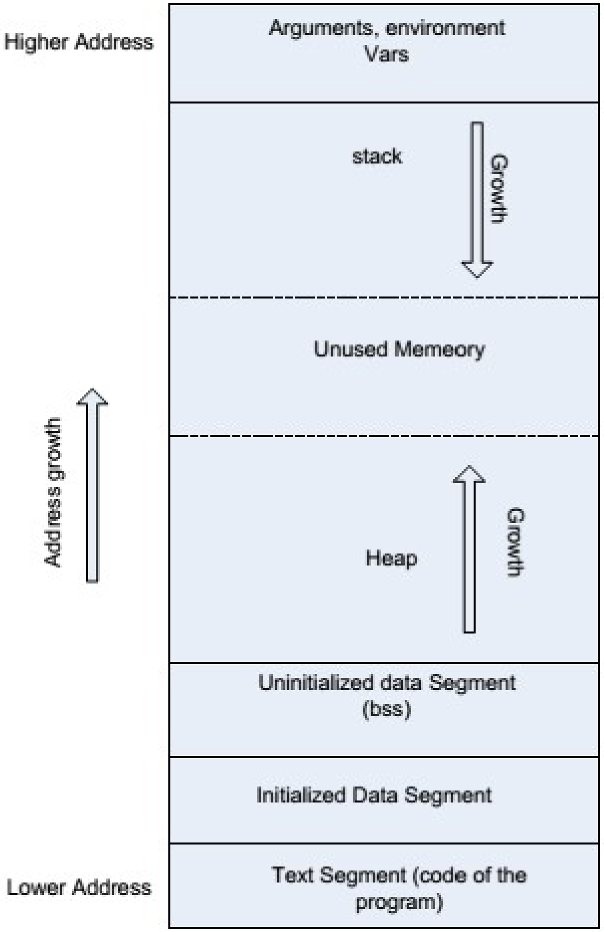
Typical Memory Layout

- Windows PE and Linux ELF file formats
- Main segments of a compiled code:
  - The executable code (text segment)
  - The initialized data (data segment)
  - The uninitialized data (bss segment)
  - The heap (dynamic memory allocation)
  - The executable code and data of needed shared libraries (dynamically loaded into the space)
  - The program stack


Higher Address
Arguments, environment Vars
stack
Growth
Unused Memeory
Address growth
Heap
Growth
Uninitialized data Segment (bss)
Initialized Data Segment
Lower Address
Text Segment (code of the program)

x86 Assembly (32-bit)

- 6 general purpose registers
  - EAX, EBX, ECX, EDX, ESI EDI
- 2 special registers ESP, EBP
- 1 very special register EIP
- 100s of instructions
  - Data movement
  - Arithmetic
  - jump

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X86-64

%rax
%rcx
%rdx
%rbx
%rsi
%rdi
%rsp
%rbp
%r8
%r9
%r10
%r11
%r12
%r13
%r14
%r15

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Generic code syntax/semantic

- Two address mode
  - `Opcode operand1, operand2`
  - Intel- operand1 is destination, `mov rax, 10`
  - AT&T- operand2 is destination, `mov 10, rax`
- `Arithmetic`
  - `Add, sub, mul…` `add rax, rbx -> rax=rax+rbx`
- `Data movement`
  - `Mov, push pop…` `mov rax, 10 -> rax=10; mov eax, [ebx]`
- `Jump`
  - `Jmp <address>`

Calling conventions x86-32

- cdecl – parameters are pushes onto the stack, caller cleans the stack
- stdcall- parameters are pushes onto the stack, callee cleans the stack
- fastcall- first 3 parameters passed in EAX, EDX, ECX, rest on stack.
- thiscall- OOP, pointer to class object in ecx, rest are on stack.

Calling conventions x86-64

- Microsoft x64 calling convention
  - Registers RCX, RDX, R8, R9 for the first four integer or pointer arguments (in that order)
  - XMM0, XMM1, XMM2, XMM3 are used for floating point arguments
  - Additional arguments are pushed onto the stack (right to left)

- Unix like systems
  - The first six integer or pointer arguments are passed in registers RDI, RSI, RDX, RCX, R8, R9
  - XMM0, XMM1, XMM2, XMM3, XMM4, XMM5, XMM6 and XMM7 are used for certain floating point arguments
  - Additional arguments are passed on the stack
  - The return value is stored in RAX and RDX

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If any of these argument registers are ***read first***, before writing, it is fastcall / x86-64 calling convention

Stack operation

```
push    %rbp
mov     %rsp,%rbp
sub     $0x20,%rsp
mov     %edi,-0x14(%rbp)
mov     %rsi,-0x20(%rbp)
movl    $0x6c726f57,-0x7(%rbp)
movw    $0x2164,-0x3(%rbp)
movb    $0x0,-0x1(%rbp)
mov     -0x20(%rbp),%rax
add     $0x8,%rax
mov     (%rax),%rax
mov     %rax,%rdi
callq   0x64a <buf_copy>
mov     $0x0,%eax
leaveq
retq
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sub     $0x30,%rsp
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mov     -0x28(%rbp),%rdx
lea     -0x20(%rbp),%rax
mov     %rdx,%rsi
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callq   0x520 <strcpy@plt>
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```

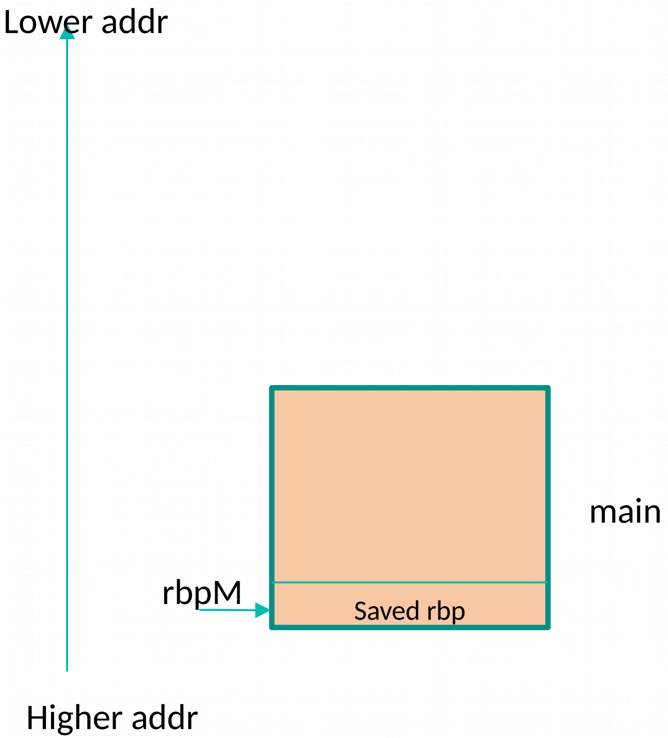

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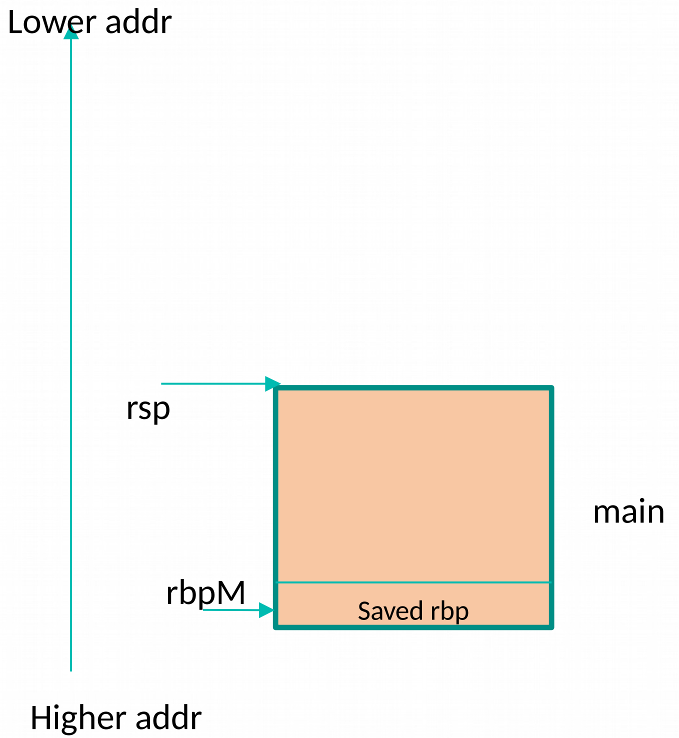

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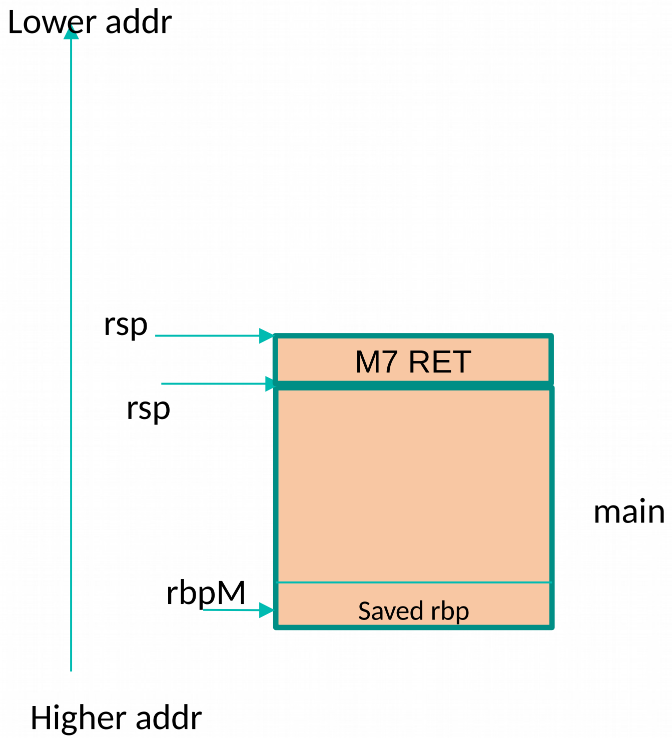

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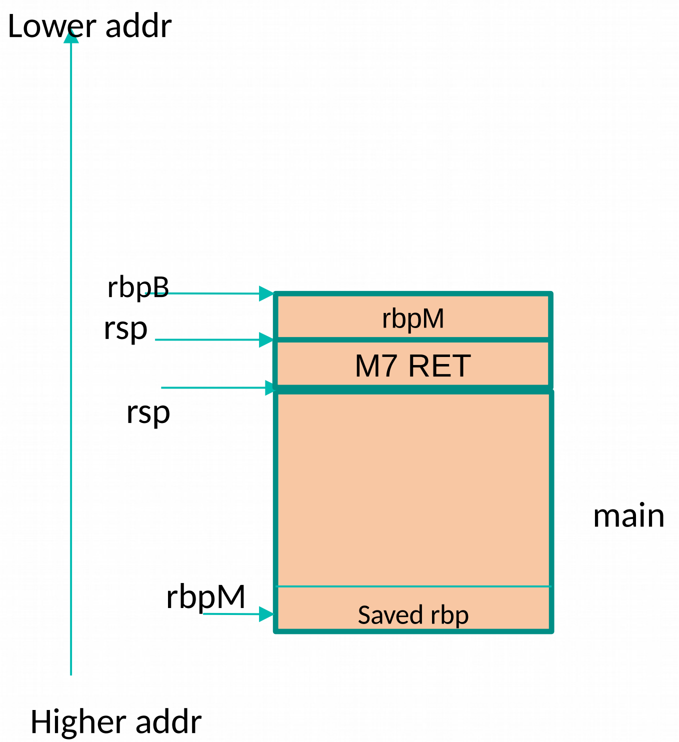

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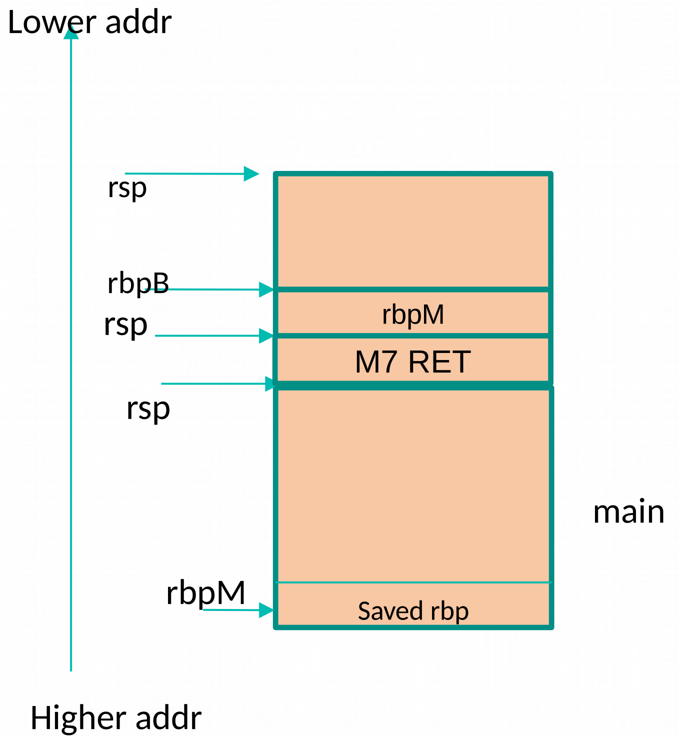

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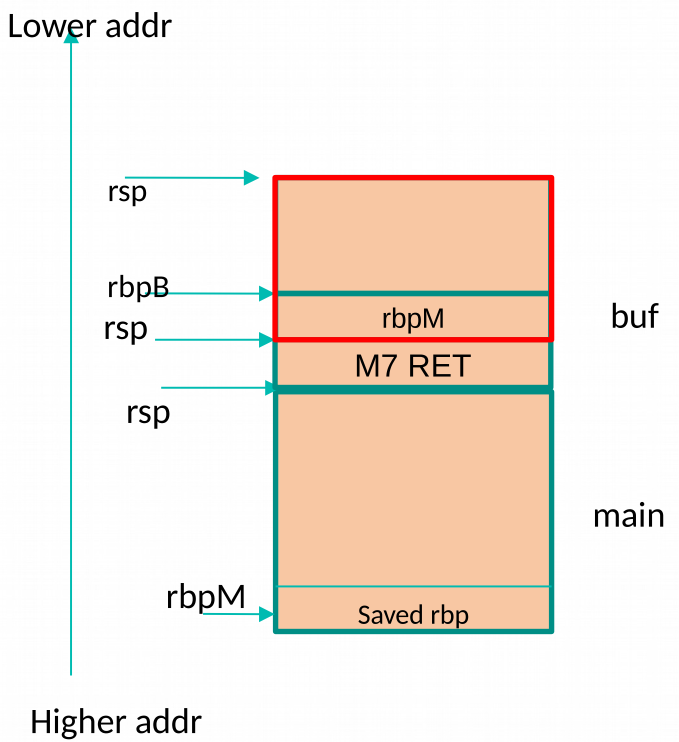

Example: C to assembly

```c
int main(int argc, char *argv[]) {
        char name[]="World!";
        buf_copy(argv[1]);
                return 1;
                }
```

```c
int buf_copy(char *string) {
        char buffer[20];
      strcpy(buffer, string);
            return 1;
              }
```

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Know your Tools

- Disassembler/debugger
  - Windows: OllyDbg, PyDbg, Immunity Debugger, IDA Pro
  - Linux: GDB ▮▮ , Evan's Debugger (EDB), IDA Pro
- Language: Your choice, Python (my choice)
- Hex viewer: HxD HexEditor

compiling options

Useful

- GCC:
  - gcc -fno-stack-protector -z execstack vulnerable.c
    - -fno-stack-protector disables SSP (stack guard)
    - -z execstack marks the stack as executable
  - -mno-accumulate-outgoing-args -mpush-args
    - ## forcing GCC to push the arguments on the stack

- Windows CL
- /GS-

Coming back to vulnerability

Coming back to vulnerability

- Finding vulnerability is first thing.
  - Find it and Patch it OR
  - How to exploit it?
  - Hijacking the control -> controlling which instruction(s) will be executed next.
  - Candidates: saved return addr, function pointers, SEH etc.