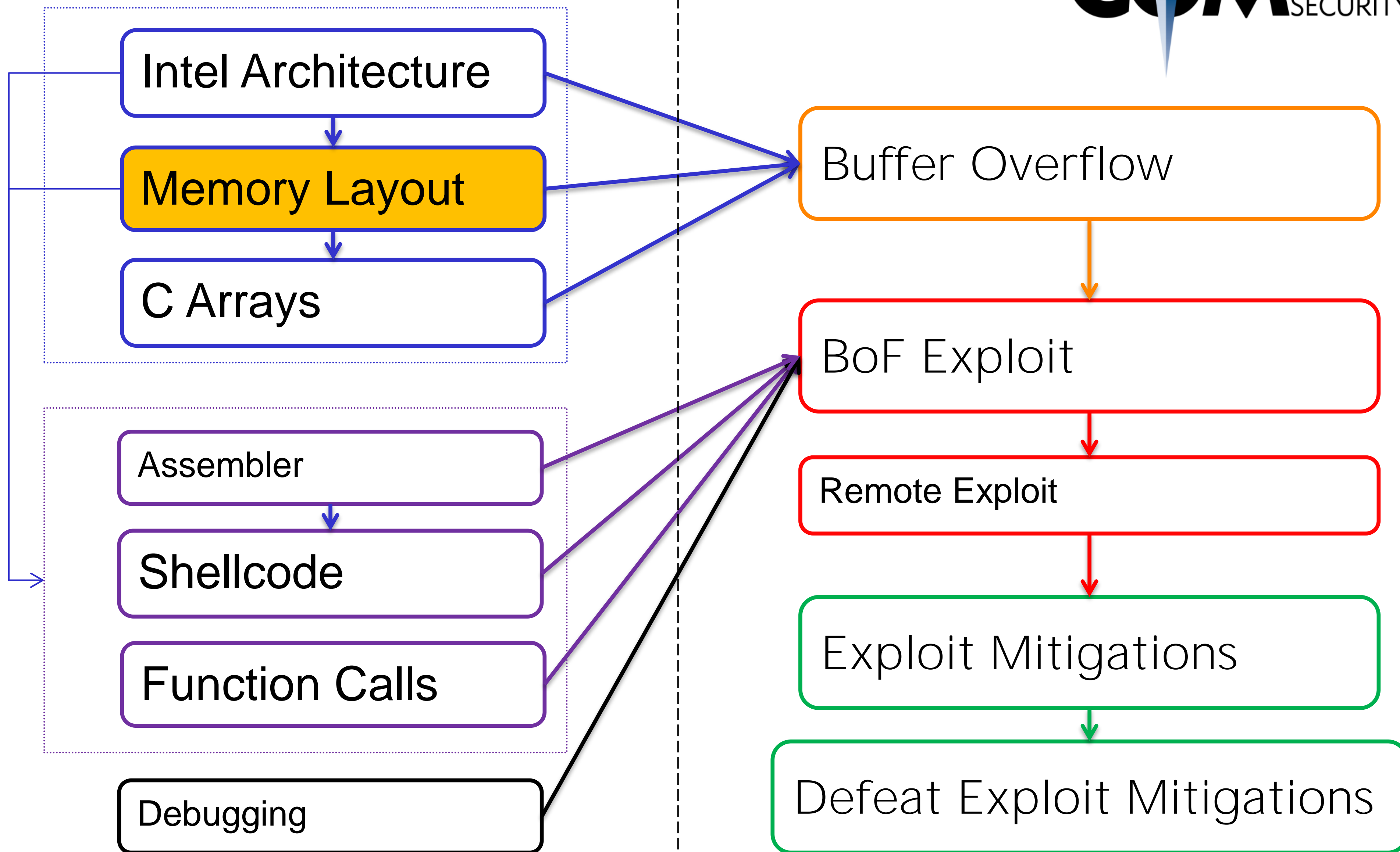
Memory Layout

Linux Userspace Process Memory Layout

Compass Security Schweiz AG
Werkstrasse 20
Postfach 2038
CH-8645 Jona

Tel +41 55 214 41 60
Fax +41 55 214 41 61
team@csnc.ch
www.csnc.ch

Content



Userspace Memory Layout

In x32

Compass Security Schweiz AG
Werkstrasse 20
Postfach 2038
CH-8645 Jona

Tel +41 55 214 41 60
Fax +41 55 214 41 61
team@csnc.ch
www.csnc.ch

x32 Memory Layout

0xc0000000
0xbfffffff

Stack

⇩

⇧

Heap

Code

0x0804800

0x0000000

x32 Memory Layout

0xc0000000
0xbfffffff
Stack
char array[16];
malloc(16)
Heap
Code
mapping
ELF File
0x0804800
0x0000000

x32 Memory Layout

0xc0000000
0xbfffffff
Stack
char array[16];
ESP
malloc(16)
Heap
EIP
Code
mapping
ELF File
0x0804800
0x0000000

x32 Memory Layout

Memory regions:

Stack

- There's one contiguous memory region containing the stack for the process
- LIFO – Last in, First Out
- Contains function **local variables**
- Also contains: **Saved Instruction Pointer (SIP)**
- Current function adds data to the top (bottom) of the stack

Heap

- There's one contiguous memory region containing the heap
- Memory allocator returns specific pieces of the memory region
- For **malloc()**
- Also contains: heap management data

x32 Memory Layout

Memory regions:

Code

- Compiled program code

ELF Format

How do programs on disk look like

Compass Security Schweiz AG
Werkstrasse 20
Postfach 2038
CH-8645 Jona

Tel +41 55 214 41 60
Fax +41 55 214 41 61
team@csnc.ch
www.csnc.ch

ELF Format

Programs are stored in ELF files

ELF: Executable and Linkable Format

- Previously: “a.out” (Linux 1.2)
- Like COFF, PE (EXE), COM, …

ELF types:

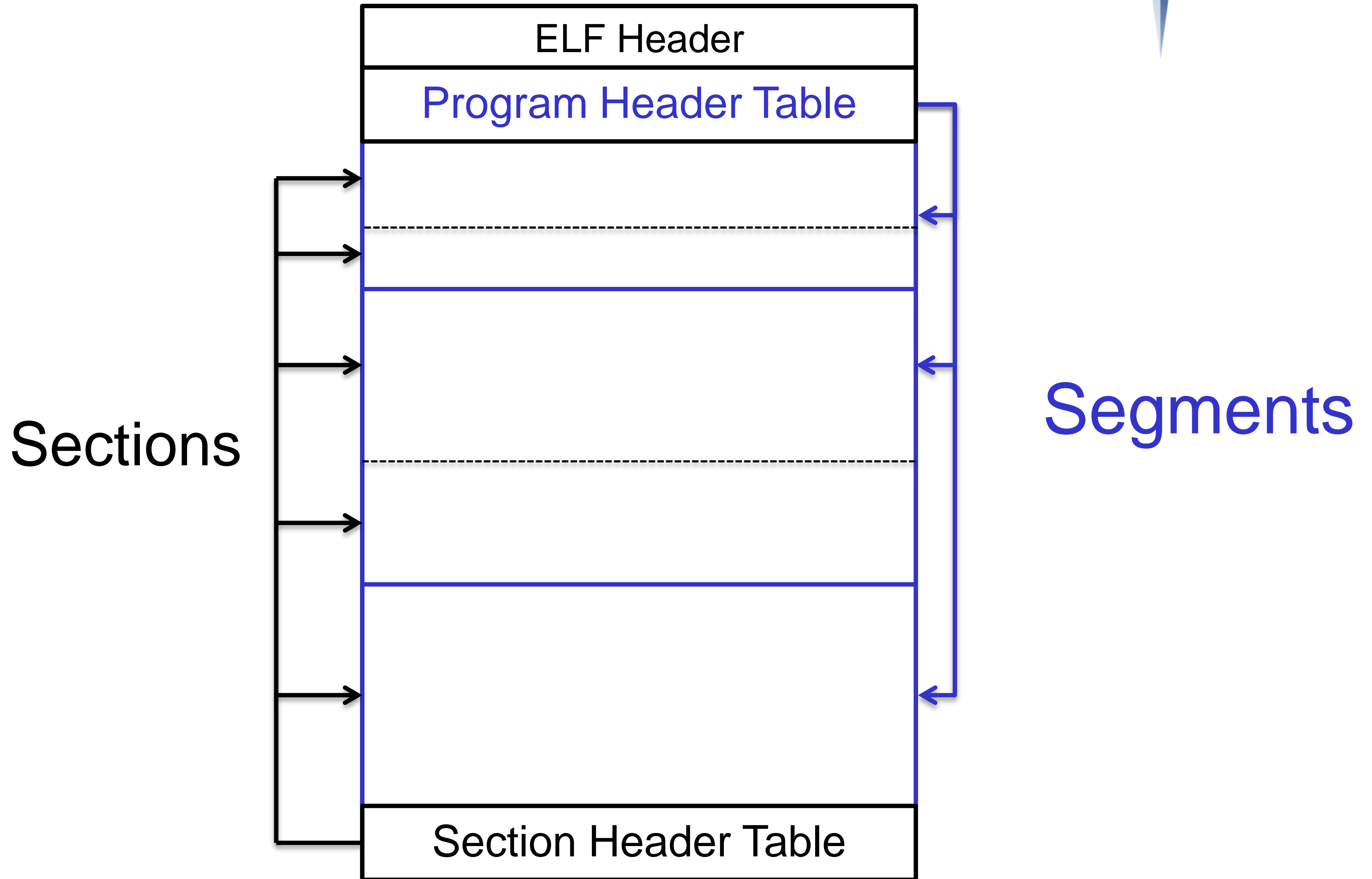
- ET_EXEC: Executable File
- ET_REL: Relocatable File
- ET_DYN: Shared Object File

ELF “views”:

- Sections
- Segments

$ readelf –l <binary>

ELF Format



ELF Format

COMPASS SECURITY

```
Program Headers:
  Type           Offset             VirtAddr           PhysAddr
                 FileSiz            MemSiz              Flags  Align
  PHDR           0x00000040         0x0000400040       0x0000000000400040
                 0x000001c0         0x00000001c0        R E    8
  INTERP         0x00000200         0x0000400200       0x0000000000400200
                 0x0000001c         0x000000001c        R      1
  LOAD           0x00000000         0x0000400000       0x0000000000400000
                 0x00000b24         0x0000000b24        R E    200000
  LOAD           0x00000b28         0x0000600b28       0x0000000000600b28
                 0x00000270         0x0000000278        RW     200000
  DYNAMIC        0x00000b40         0x0000600b40       0x0000000000600b40
                 0x000001e0         0x00000001e0        RW     8
  NOTE           0x0000021c         0x000040021c       0x000000000040021c
                 0x00000044         0x0000000044        R      4
  GNU_EH_FRAME   0x000009ac         0x00004009ac       0x00000000004009ac
                 0x00000044         0x0000000044        R      4
  GNU_STACK      0x00000000         0x0000000000       0x0000000000000000
                 0x00000000         0x0000000000        RW     10
```

ELF Format

```
$ readelf -l challenge0

Section to Segment mapping:
  Segment Sections...
   00
   01     .interp
   02     .interp .note.ABI-tag .note.gnu.build-id .gnu.hash
          .dynsym .dynstr .gnu.version .gnu.version_r
          .rela.dyn .rela.plt .init .plt .text .fini .rodata
          .eh_frame_hdr .eh_frame
   03     .init_array .fini_array .jcr .dynamic .got .got.plt
          .data .bss
   04     .dynamic
   05     .note.ABI-tag .note.gnu.build-id
   06     .eh_frame_hdr
   07
```

COMPASS SECURITY

Sections:

- .text: Executable instructions
- .bss: Unitialized data (usually the heap)
- .data: initialized data
- .rodata: Read-Only data
- .got: Global Offset Table
- .plt: Procedure Linkage Table
- .init/.fini: Initialization instructions ("glibc")

ELF Format

Program Headers:

	Type	Offset / FileSiz	PhysAddr / Flags Align
	Type	Offset	PhysAddr
		FileSiz	Flags Align
(02)	**LOAD**	0x0000000000000000	**0x0000000000400000**
		0x0000000000000b24	**R E** 200000
(03)	**LOAD**	0x0000000000000b28	**0x0000000000600b28**
		0x0000000000000270	**RW** 200000
(07)	**GNU_STACK**	0x0000000000000000	0x0000000000000000
		0x0000000000000000	**RW** 10

02	.init **.plt** **.text** .fini **.rodata**
03	**.got** **.got.plt** **.data** **.bss**
07	

COMPASS SECURITY

Compass Security Schweiz AG
Werkstrasse 20
Postfach 2038
CH-8645 Jona

Tel +41 55 214 41 60
Fax +41 55 214 41 61
team@csnc.ch
www.csnc.ch

ELF Format

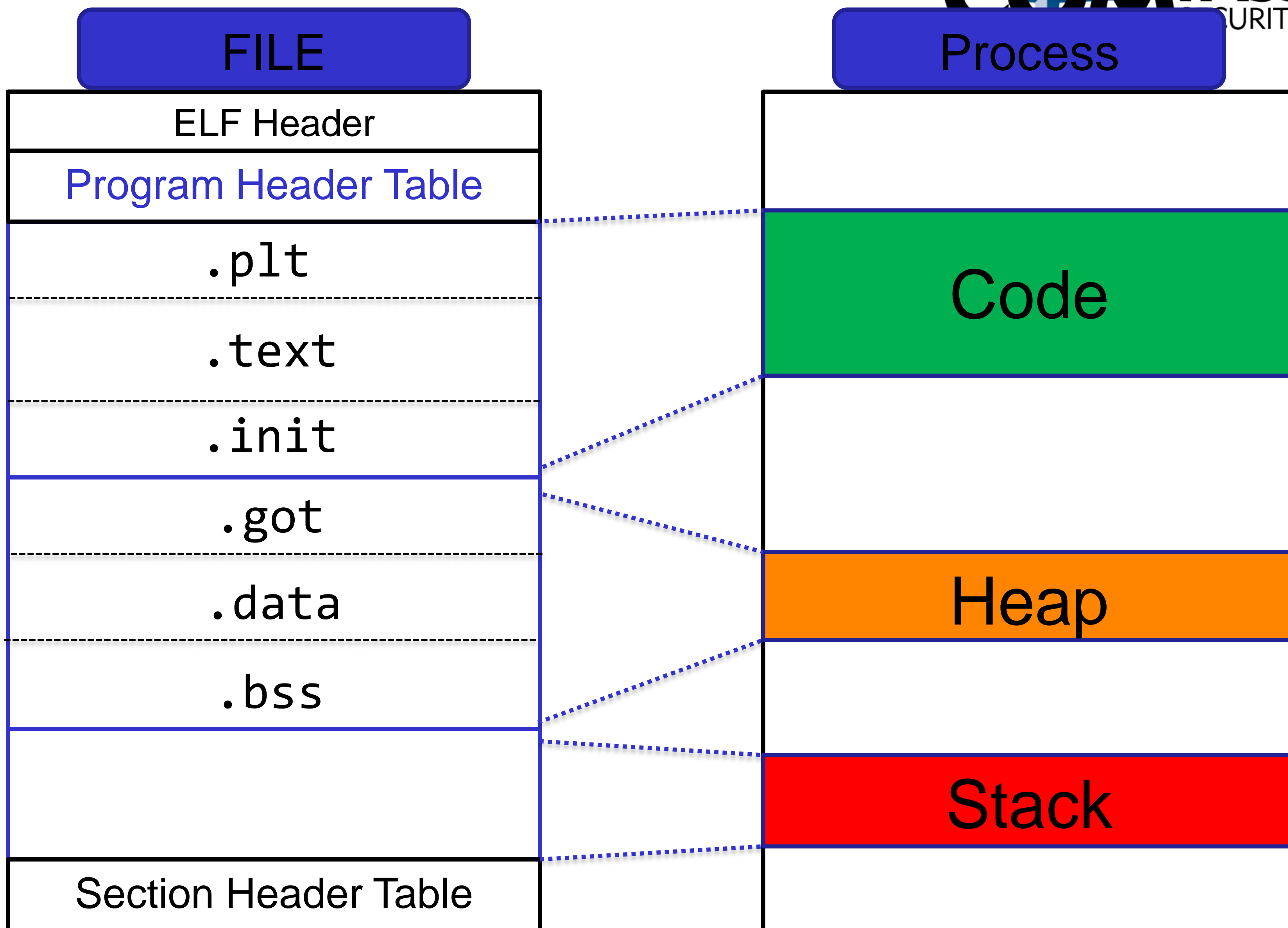
ELF Header
Program Header Table
.plt
.text
.init
.got
.data
.bss
Section Header Table

02 Executable Segment
r-x

03 Data Segment
rw-

07 Stack
rw-

ELF Format



x64 Memory Layout

0x7ffffffe000

Stack

Heap

0x600000

Code

0x400000

0x000000

ELF Format

```
char *globalVar = "Global";

void main(void) {
        char stackVar[16];
        char *heapVar = (char *) malloc(4);

        printf("Global var: %p\n", globalVar);
        printf("Heap var: %p\n", heapVar);
        printf("Stack var: %p\n", stackVar);
}
```

ELF Format

```
Global var:  0x400654
Heap var:    0x601010
Stack var:   0x7fffffffe990


(2)  LOAD            0x0000000000400000
                     R E     200000
(3)  LOAD            0x0000000000600b28
                     RW      200000
(7)  GNU_STACK       0x0000000000000000
                     RW      10
```

ELF Format

See it at runtime

```
# cat /proc/self/maps
00400000-0040c000 r-xp 00000000 08:01 391694     /bin/cat
0060b000-0060c000 r--p 0000b000 08:01 391694     /bin/cat
0060c000-0060d000 rw-p 0000c000 08:01 391694     /bin/cat
…
7ffffffde000-7ffffffff000 rw-p 00000000 00:00 0 [stack]
```

ELF Format

Show Code section, and disassemble:

```
$ objdump -d ./challenge1
./challenge1:      file format elf64-x86-64
Disassembly of section .init:
0000000000400588 <_init>:
…
000000000040077f <handleData>:
  40077f:   55                push   %rbp
  400780:   48 89 e5          mov    %rsp,%rbp
  400783:   48 83 ec 30       sub    $0x30,%rsp
  400787:   48 89 7d d8       mov    %rdi,-0x28(%rbp)
  40078b:   48 89 75 d0       mov    %rsi,-0x30(%rbp)
```

ELF Format

The process of creating a process from an ELF file is called:

- "Linking and Loading"

Sections:

- Are for compiler (gcc), to link several object files together (.o)

Segments:

- Are for the loader, to create the process
- Consists of one ore more sections

ELF Format

Recap:

- Program Code is stored in ELF Files
- ELF Files contain segments
- Segments are copied 1:1 in the memory