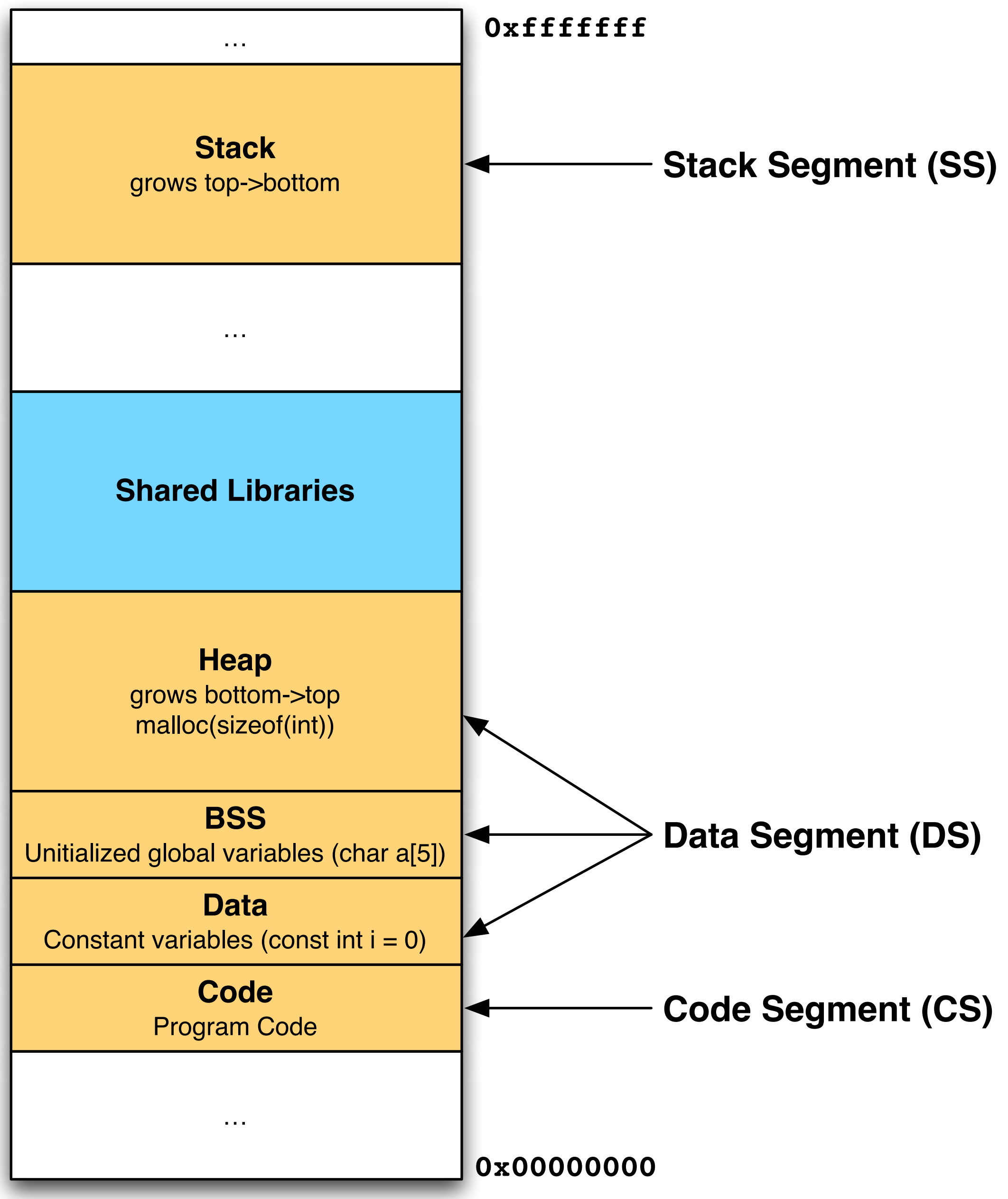
Buffer Overflows

Security

Universidade de Aveiro

Memory Organization Topics

- Kernel organizes memory in pages
  - Typically 4k bytes
- Processes operate in a Virtual Memory Space
  - Mapped to real 4k pages
    - Could live in RAM or be swapped
- Kernel splits program in several segments
  - Increases security
    - segment based permissions
  - Increases performance
    - some are dynamic: invalidated when program terminates
    - some are static: can be retained, speed repeated startup



...
0xffffffff
Stack
grows top->bottom
Stack Segment (SS)
...
Shared Libraries
Heap
grows bottom->top
malloc(sizeof(int))
BSS
Unitialized global variables (char a[5])
Data Segment (DS)
Data
Constant variables (const int i = 0)
Code
Program Code
Code Segment (CS)
...
0x00000000

mem.c

mem.c

```
Internal Variables (Page = 4096)
&argc  = bfeb8590 -> stack = bfeb8000
malloc = 08435008 -> heap  = 08435000
bssvar = 0804a034 -> bss   = 0804a000
cntvar = 08048920 -> const = 08048000
&main  = 0804865c -> text  = 08048000
```

mem.c

```
Content of /proc/self/maps
08048000-08049000 r-xp 00000000 08:01 26845750   /home/s/seguranca/mem
08049000-0804a000 r--p 00000000 08:01 26845750   /home/s/seguranca/mem
0804a000-0804b000 rw-p 00001000 08:01 26845750   /home/s/mem
08435000-08456000 rw-p 00000000 00:00 0          [heap]
b7616000-b7617000 rw-p 00000000 00:00 0
b7617000-b776a000 r-xp 00000000 08:01 1574823    /lib/tls/i686/cmov/libc-2.11.1.so
b776a000-b776b000 ---p 00153000 08:01 1574823    /lib/tls/i686/cmov/libc-2.11.1.so
b776b000-b776d000 r--p 00153000 08:01 1574823    /lib/tls/i686/cmov/libc-2.11.1.so
b776d000-b776e000 rw-p 00155000 08:01 1574823    /lib/tls/i686/cmov/libc-2.11.1.so
b776e000-b7771000 rw-p 00000000 00:00 0
b777e000-b7782000 rw-p 00000000 00:00 0
b7782000-b7783000 r-xp 00000000 00:00 0          [vdso]
b7783000-b779e000 r-xp 00000000 08:01 1565567    /lib/ld-2.11.1.so
b779e000-b779f000 r--p 0001a000 08:01 1565567    /lib/ld-2.11.1.so
b779f000-b77a0000 rw-p 0001b000 08:01 1565567    /lib/ld-2.11.1.so
bfe99000-bfeba000 rw-p 00000000 00:00 0          [stack]
```

mem.c

```
Stack evolution:
foo [000]: &argc  = bfeb8140 -> stack = bfeb8000
foo [001]: &argc  = bfdb8110 -> stack = bfdb8000
foo [002]: &argc  = bfcb80e0 -> stack = bfcb8000
foo [003]: &argc  = bfbb80b0 -> stack = bfbb8000
foo [004]: &argc  = bfab8080 -> stack = bfab8000
foo [005]: &argc  = bf9b8050 -> stack = bf9b8000
foo [006]: &argc  = bf8b8020 -> stack = bf8b8000
foo [007]: &argc  = bf7b7ff0 -> stack = bf7b7000
foo [008]: &argc  = bf6b7fc0 -> stack = bf6b7000
Segmentation fault
```

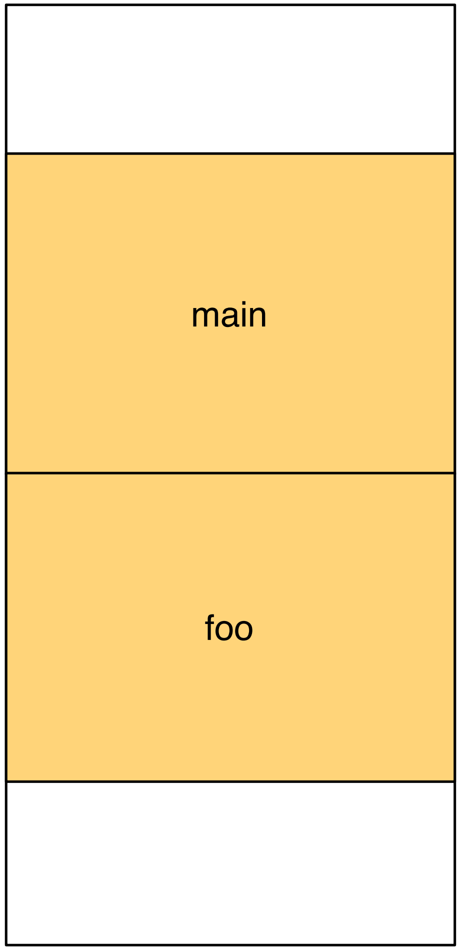
CPU Registers (x86)

- General Purpose: EAX, EBX, ECX, EDX
  - A: 8bits, AX: 16bits, EAX: 32bits, RAX: 64bits
- EBP: Base Pointer
  - Points to Start of Stack
- ESP: Stack Pointer
  - Points to End of Stack
- EIP: Instruction Pointer
  - Points to current instruction
- ESI: Stack Index
  - Points to an address in Stack Segement
- EDI: Data Index
  - Points to an address in Data Segment

Stack Segment

- Stack is used to pass parameters to functions
  - Ex: foo(int a)
- Stack is used to store local variables
  - Ex: int a;
- Values are PUSHed or POPed from stack
  - Ex: push ebp, pop ebp
- Ex: Accessing a variable: ebp+4
- allocating 4 bytes in stack: sub esp,4

stack.c



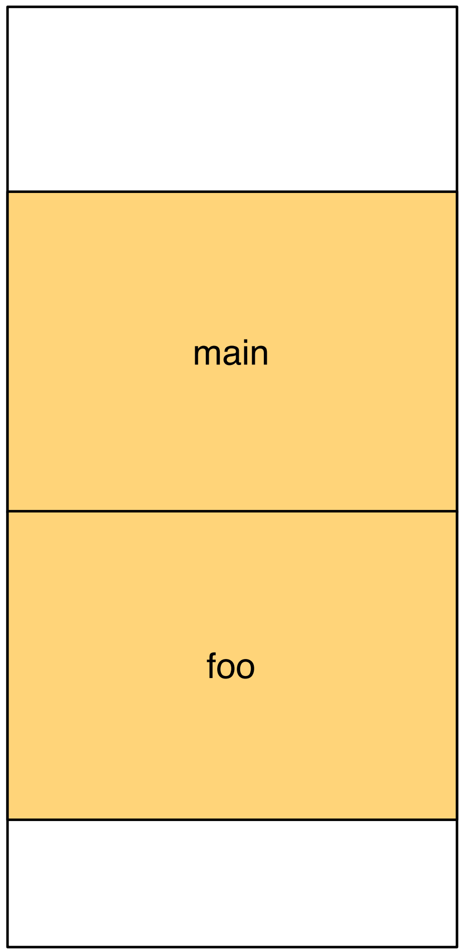
```
0xfffffff


    int foo(int bar)
    {
        return 3;
    }

    int main(int argc, char** argv)
    {
        foo(argc);

        return 0;
    }
```

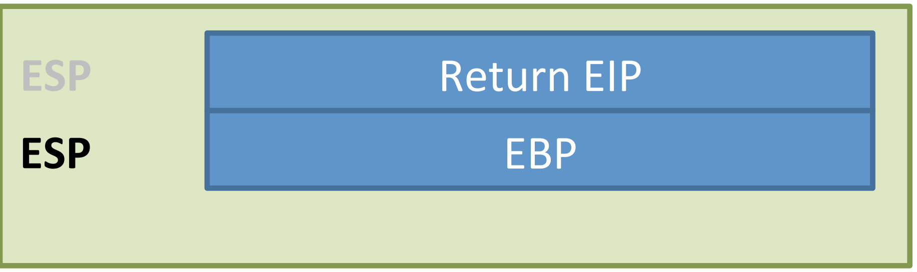
stack.s



```
foo:
  push  ebp
  mov ebp, esp
  mov eax, 3
  pop ebp
  ret
main:
  push  ebp
  mov ebp, esp
  sub esp, 4
  mov eax, DWORD PTR [ebp+8]
  mov DWORD PTR [esp], eax
  call  foo
  mov eax, 0
  leave
  ret
```

gcc -S –masm=intel –fno-stack-protector stack.c

stack.s



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   pop ebp
   ret
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```
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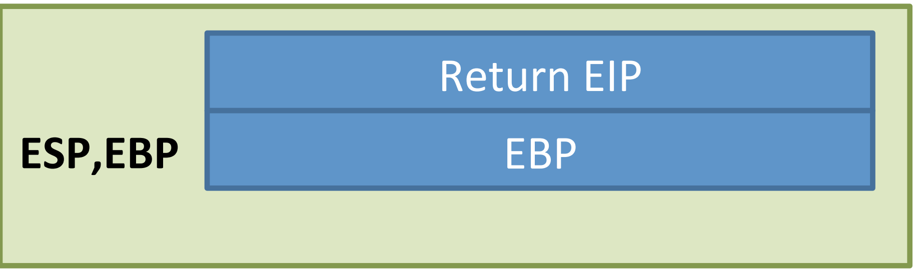
   ret
```

stack.s



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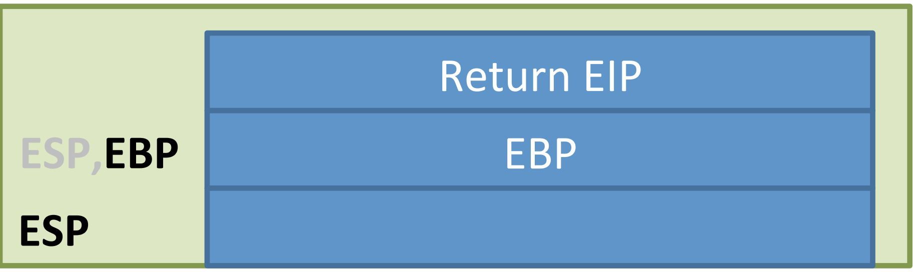
stack.s



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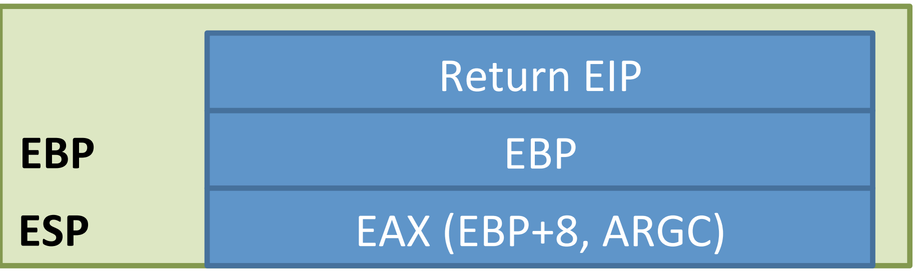
stack.s



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   mov ebp, esp
   mov eax, 3
   pop ebp
   ret
main:
   push  ebp
   mov ebp, esp
   sub esp, 4
   mov eax, DWORD PTR [ebp+8]
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   call  foo
   mov eax, 0
   leave
   ret
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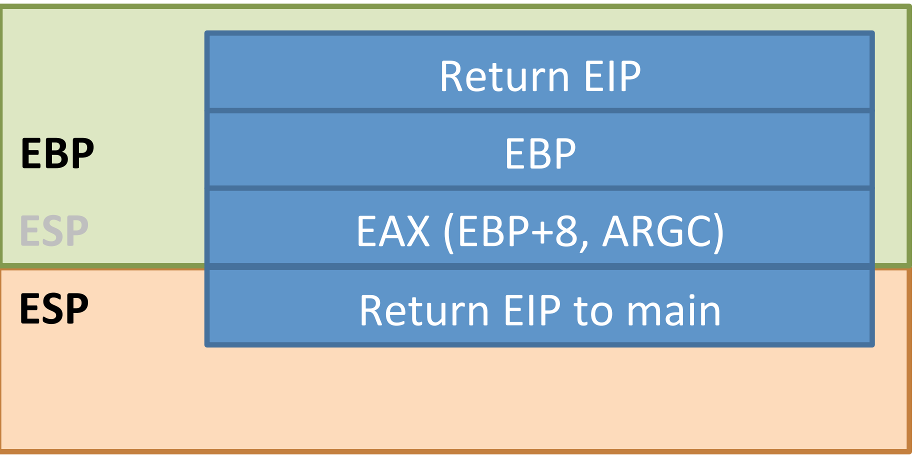
stack.s



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   leave
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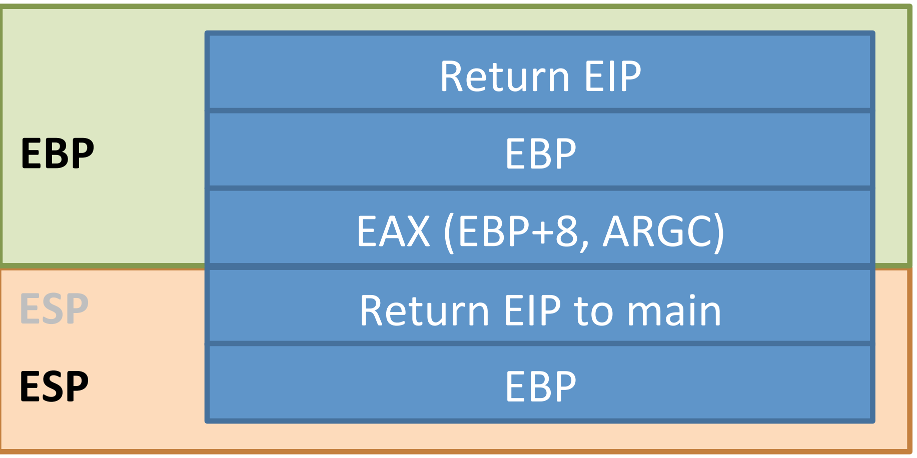
```

Return EIP to main

stack.s



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   mov ebp, esp
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   mov eax, DWORD PTR [ebp+8]
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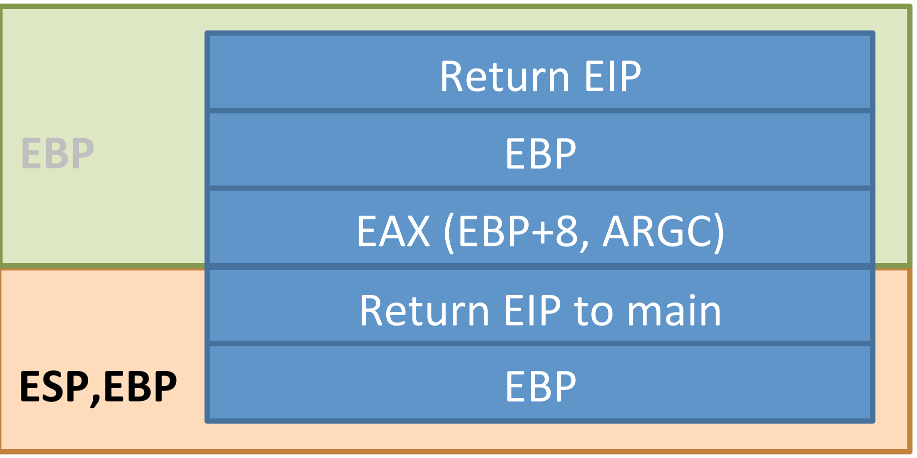
   call  foo
   mov eax, 0
   leave
   ret
```

Return EIP to main

stack.s



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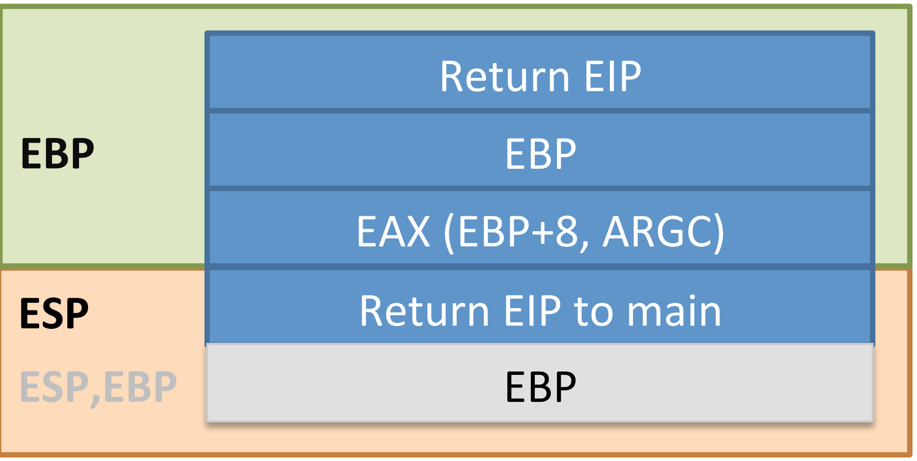
```

Return EIP to main

stack.s



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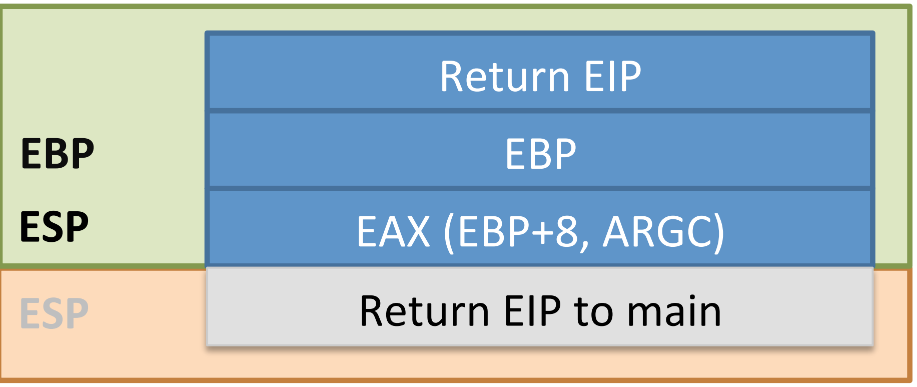
```

Return EIP to main

stack.s



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   pop ebp
   ret
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   push  ebp
   mov ebp, esp
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   mov eax, DWORD PTR [ebp+8]
   mov DWORD PTR [esp], eax
   call  foo
   mov eax, 0
   leave
   ret
```

Return EIP to main

Buffer Overflow

- Write over the boundaries of a buffer
- Consequences
  - Write over other variables in local function
  - Write over Return EIP
    - Jump to any address on return!
  - Put code in stack and jump to stack
    - Execute injected code

bo.c

```
.LC0:
  .string "%s"
  .text

foo:
push  ebp
mov ebp, esp
sub esp, 40
mov eax, OFFSET FLAT:.LC0
lea edx, [ebp-12]
mov DWORD PTR [esp+4], edx
mov DWORD PTR [esp], eax
call  __isoc99_scanf
Leave
ret
```

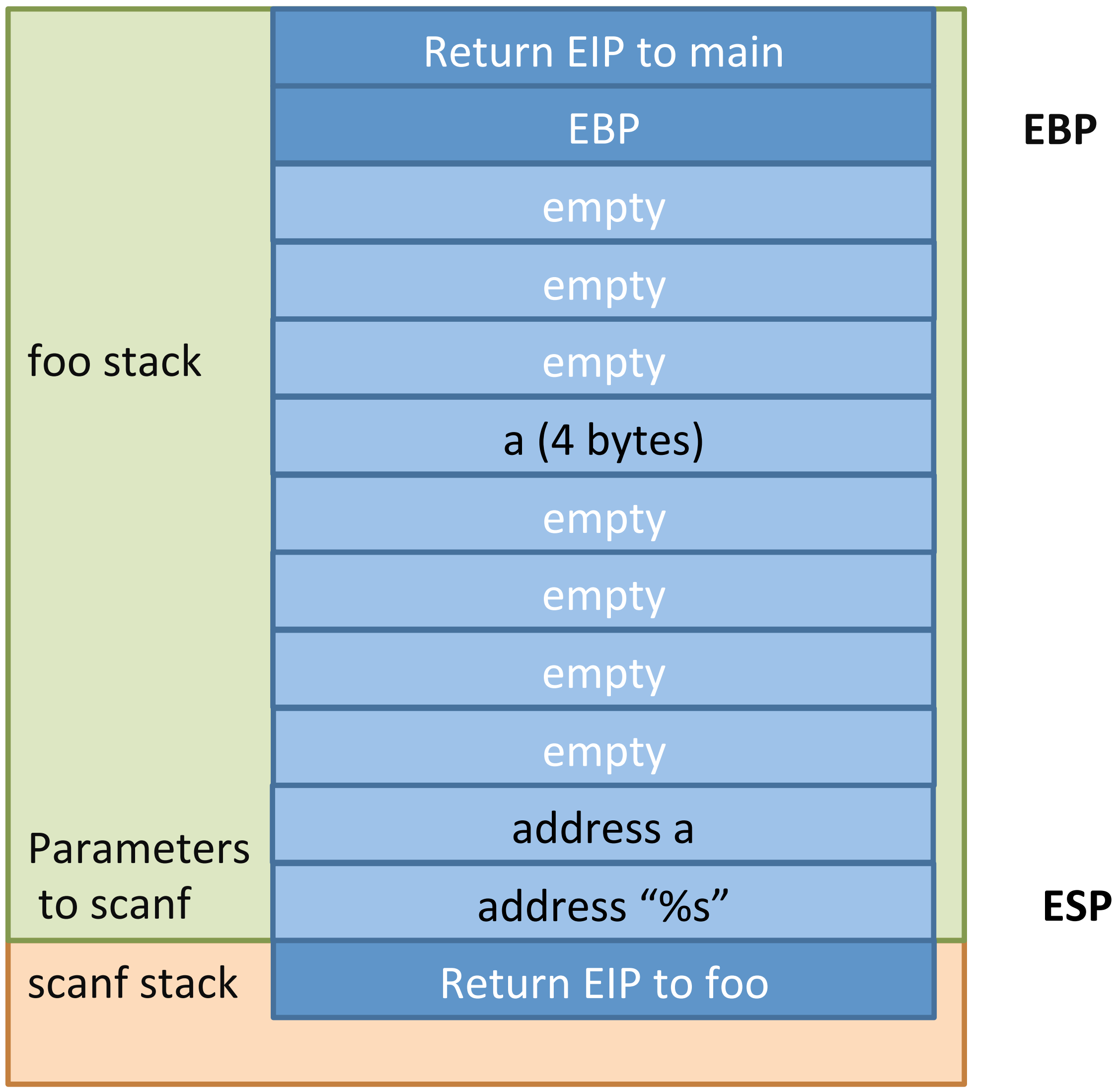
```
int foo(int bar)
{
  char a[4];
  scanf("%s",a);
}
```

gcc -S –masm=intel –fno-stack-protector bo.c

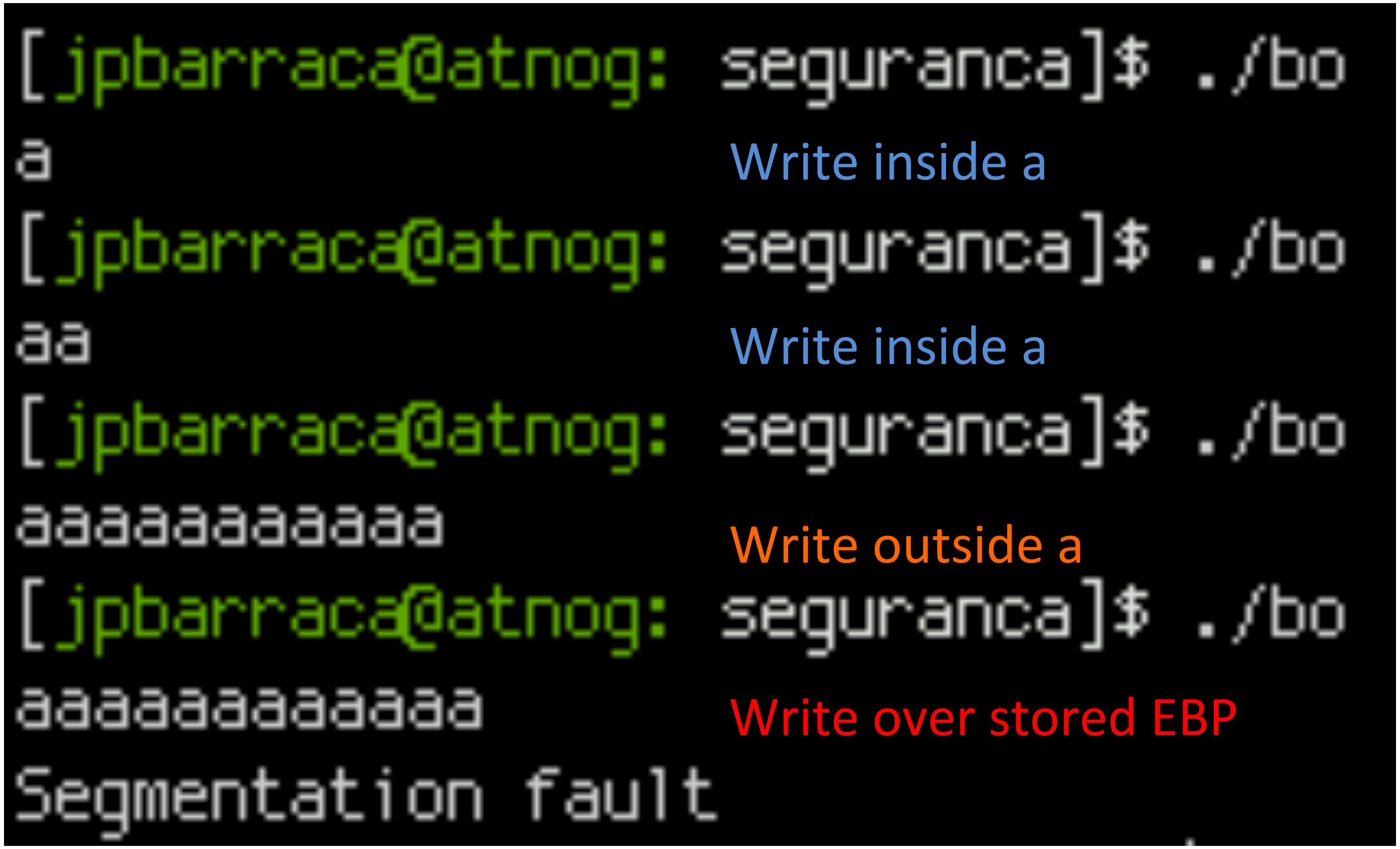
bo.s

```
.LC0:
  .string "%s"
  .text

foo:
push  ebp
mov ebp, esp
sub esp, 40
mov eax, OFFSET FLAT:.LC0
lea edx, [ebp-12]
mov DWORD PTR [esp+4], edx
mov DWORD PTR [esp], eax
call  __isoc99_scanf
Leave
ret
```



Buffer Overflow



```
[jpbarraca@atnog: seguranca]$ ./bo
a
[jpbarraca@atnog: seguranca]$ ./bo
aa
[jpbarraca@atnog: seguranca]$ ./bo
aaaaaaaaaaa
[jpbarraca@atnog: seguranca]$ ./bo
aaaaaaaaaaaa
Segmentation fault
```