(Early) Memory Corruption Attacks

CS-576 Systems Security

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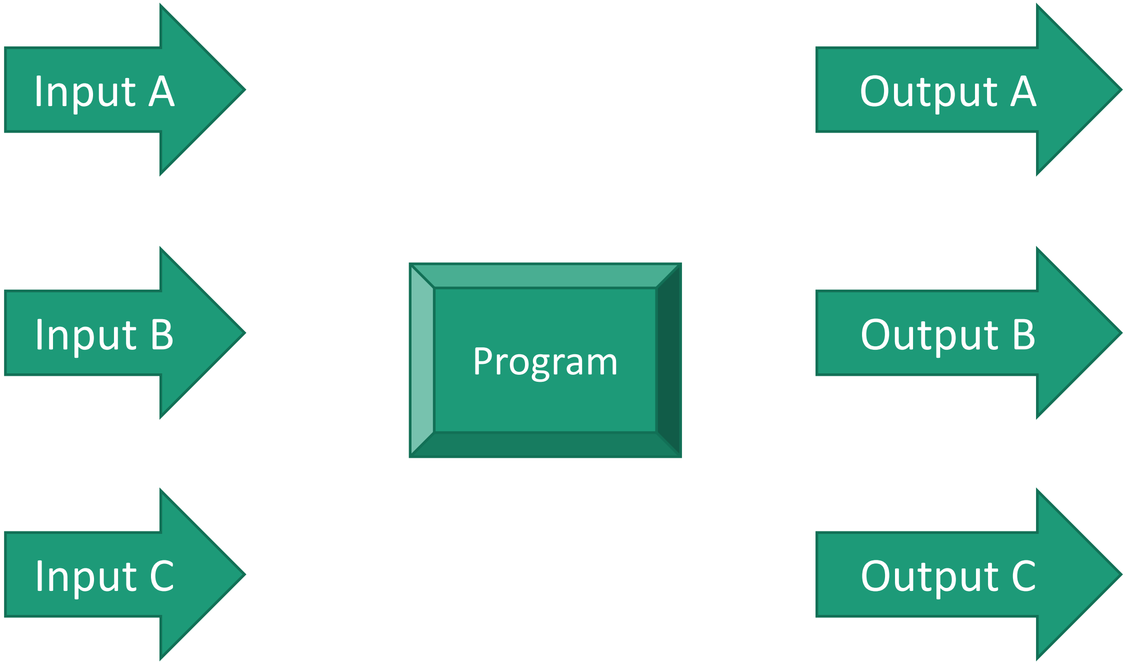
Memory Corruption

“Memory corruption occurs in a computer program when the contents of a memory location are unintentionally modified due to programming errors; this is termed **violating memory safety**.

When the corrupted memory contents are used later in that program, it leads either to program crash or to **strange and bizarre program behavior.** “

--wikipedia

Programs Are Deterministic

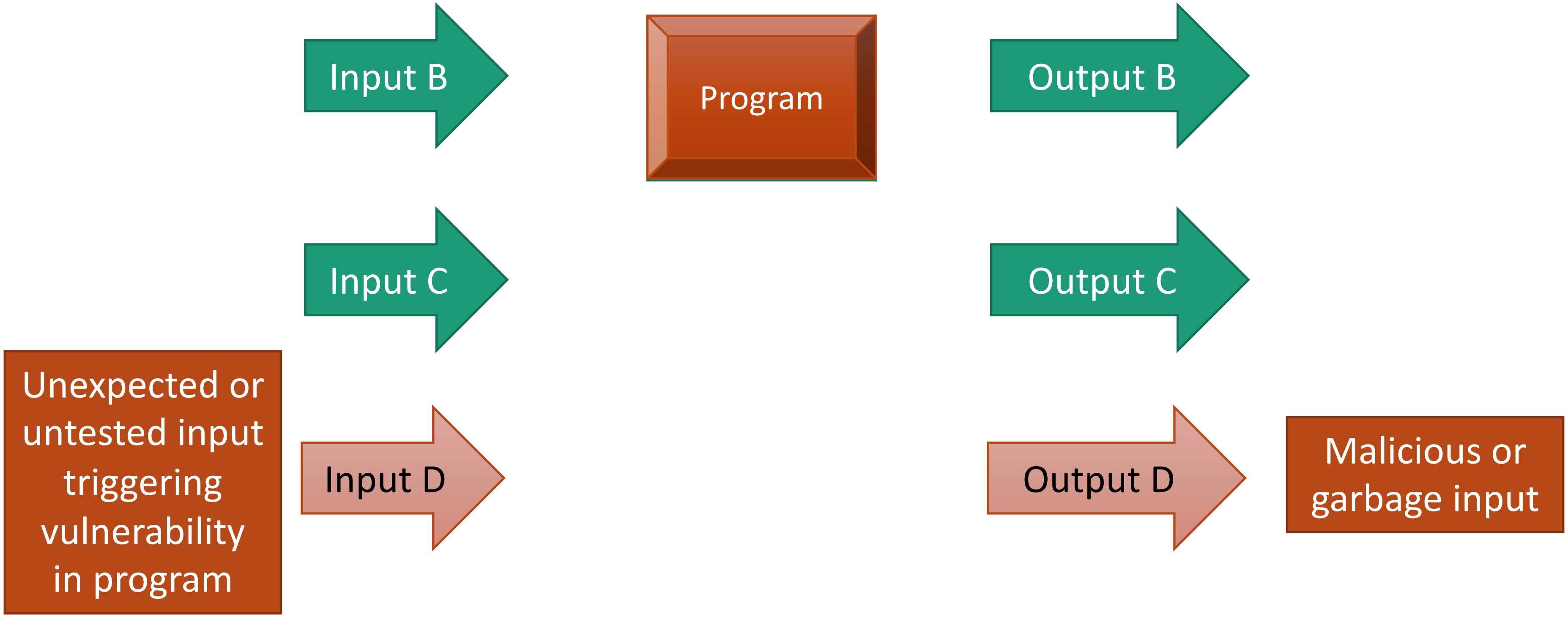


The program implements the functionality intended by the developer

Programs Are Deterministic

Program functionality severely altered

Original program→ arbitrary program based on input



Input B

Program

Output B

Input C

Output C

Unexpected or untested input triggering vulnerability in program

Input D

Output D

Malicious or garbage input

Incorrect handling of untested or incorrect input is one the main causes of software vulnerabilities

Remote Vs. local

Local attacks

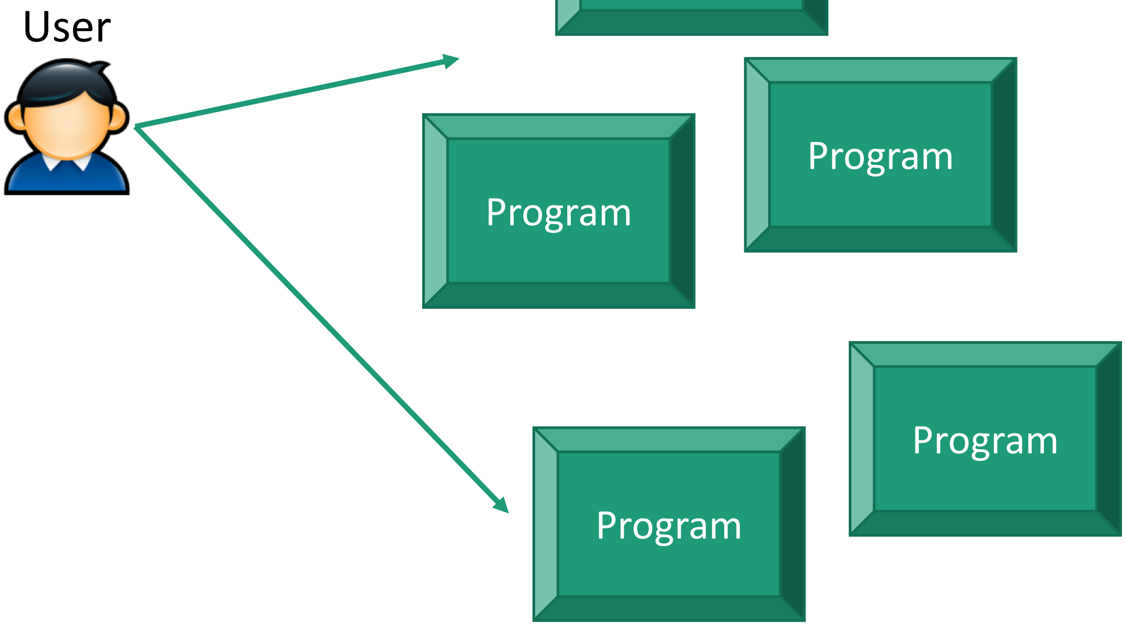
- If the user input can be only provided by a local user

Remote attack

- If the user input can be only provided over the network

Local Attacks

All programs run with the privileges of the running user (Effective UID)



User

Program

Program

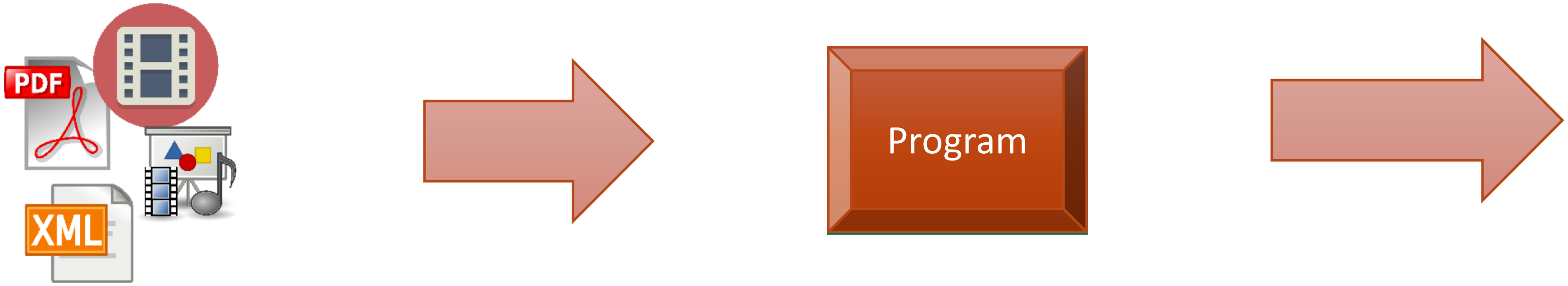
Program

Program

Program

Local Attacks

Input produced by another user

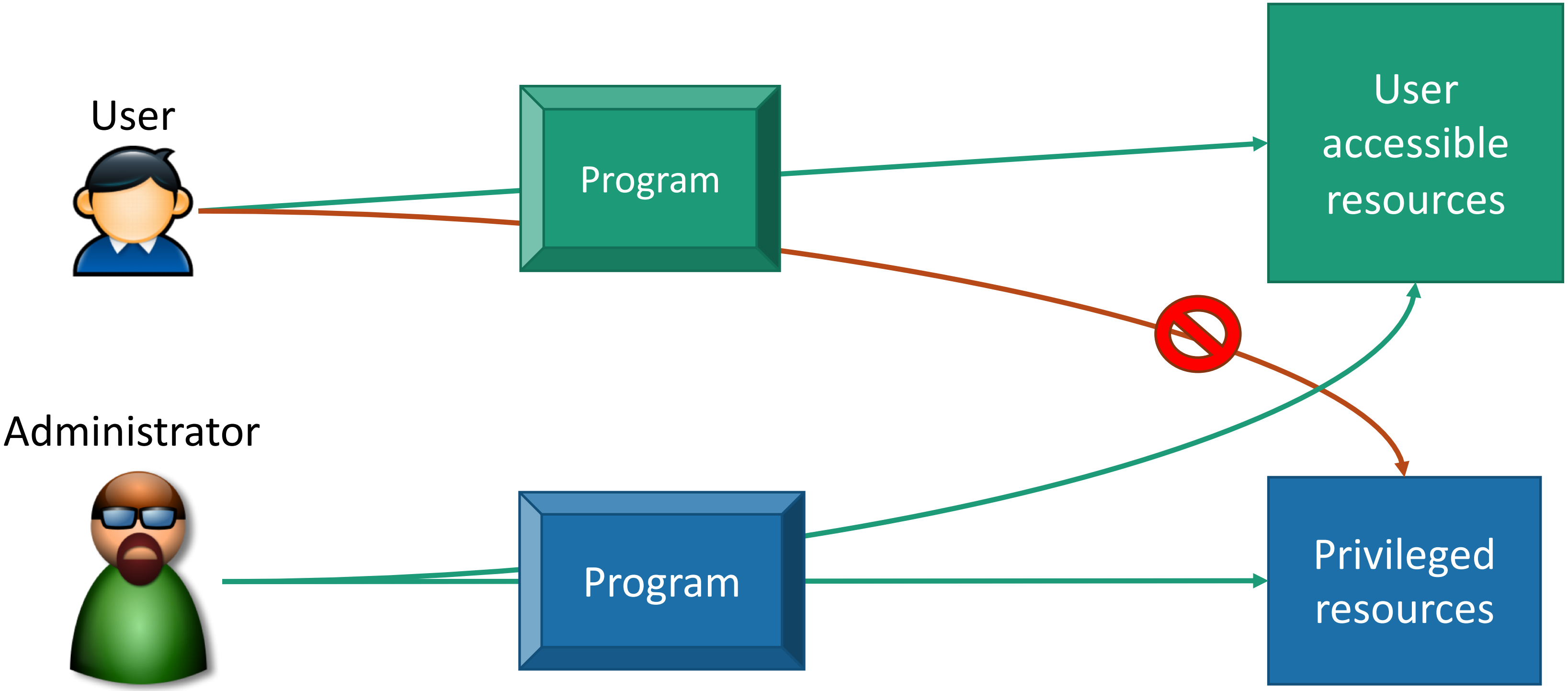


Program

Arbitrary program executes with the rights of the user executing it

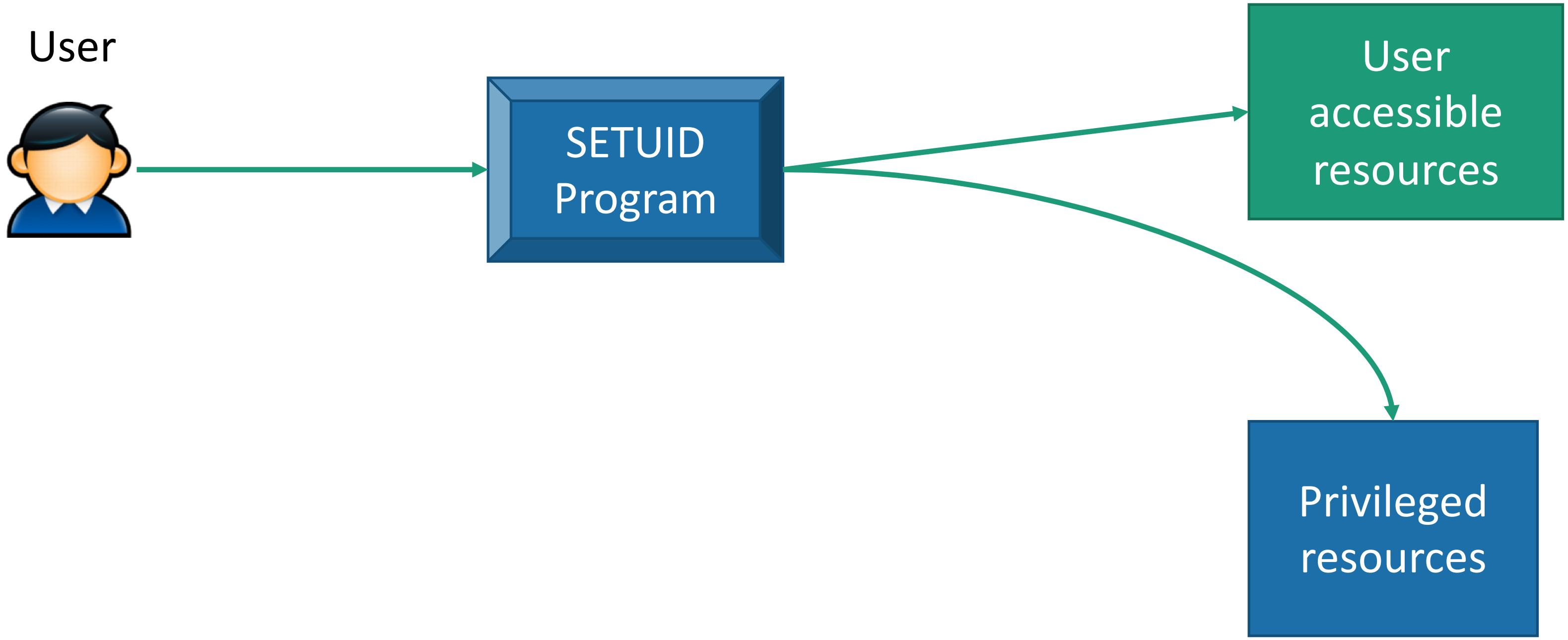
Privileged Resources

KERNEL



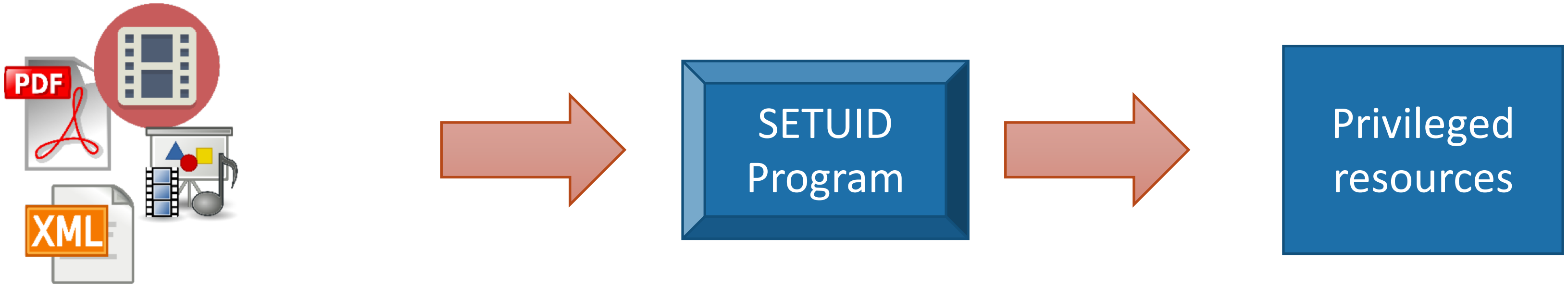
SETUID Programs

Programs that run with the privileges of their owner, not the executing user



Privilege Escalation Attacks

Input produced by another user



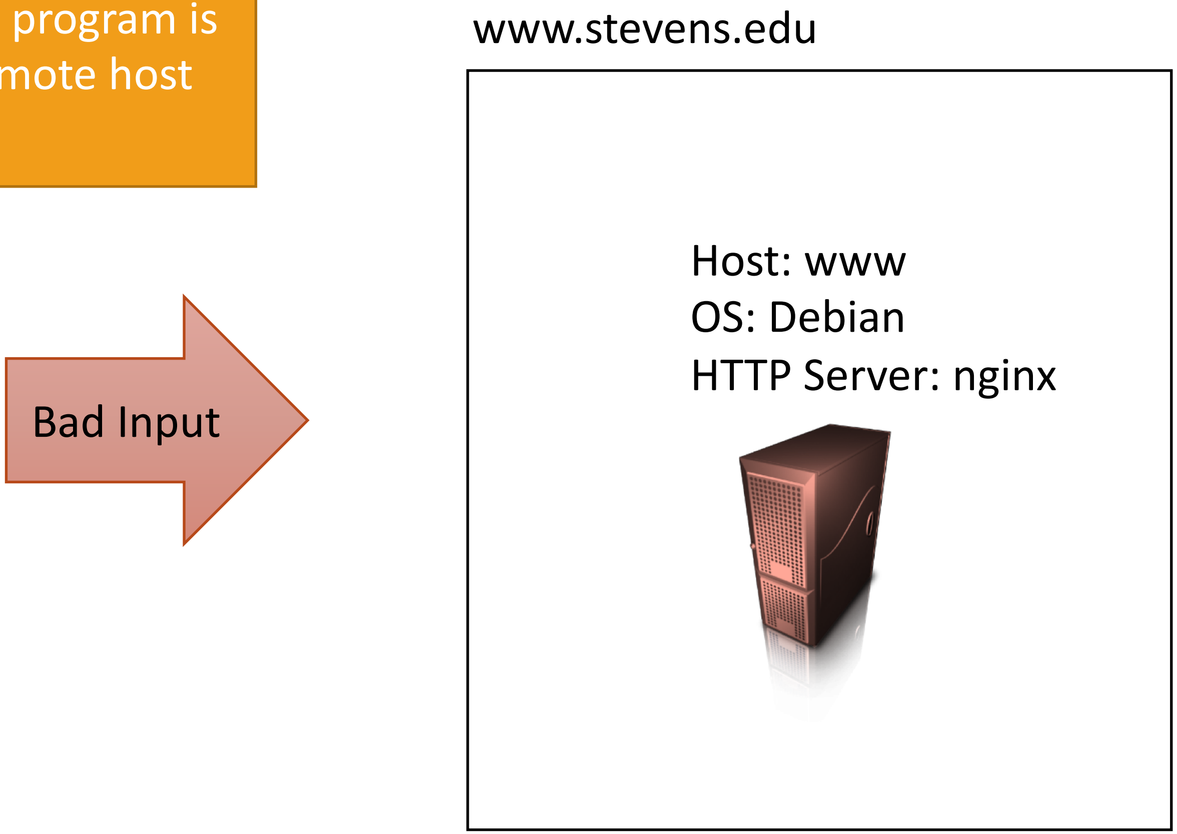
SETUID Program

Privileged resources

The arbitrary program executes with elevated privileges

Remote Attacks

An arbitrary program is run at a remote host



Bad Input

www.stevens.edu

Host: www
OS: Debian
HTTP Server: nginx

Remote Attacks

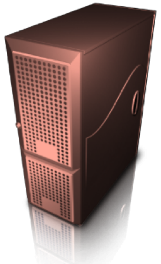
An arbitrary program is run at a remote host

Bad Input

With high privileges

www.stevens.edu

Host: www
OS: Debian
HTTP Server: nginxd



Running as root

Common Vulnerabilities

Overflows: Writing beyond the end of a buffer

Underflows: Writing beyond the beginning of a buffer

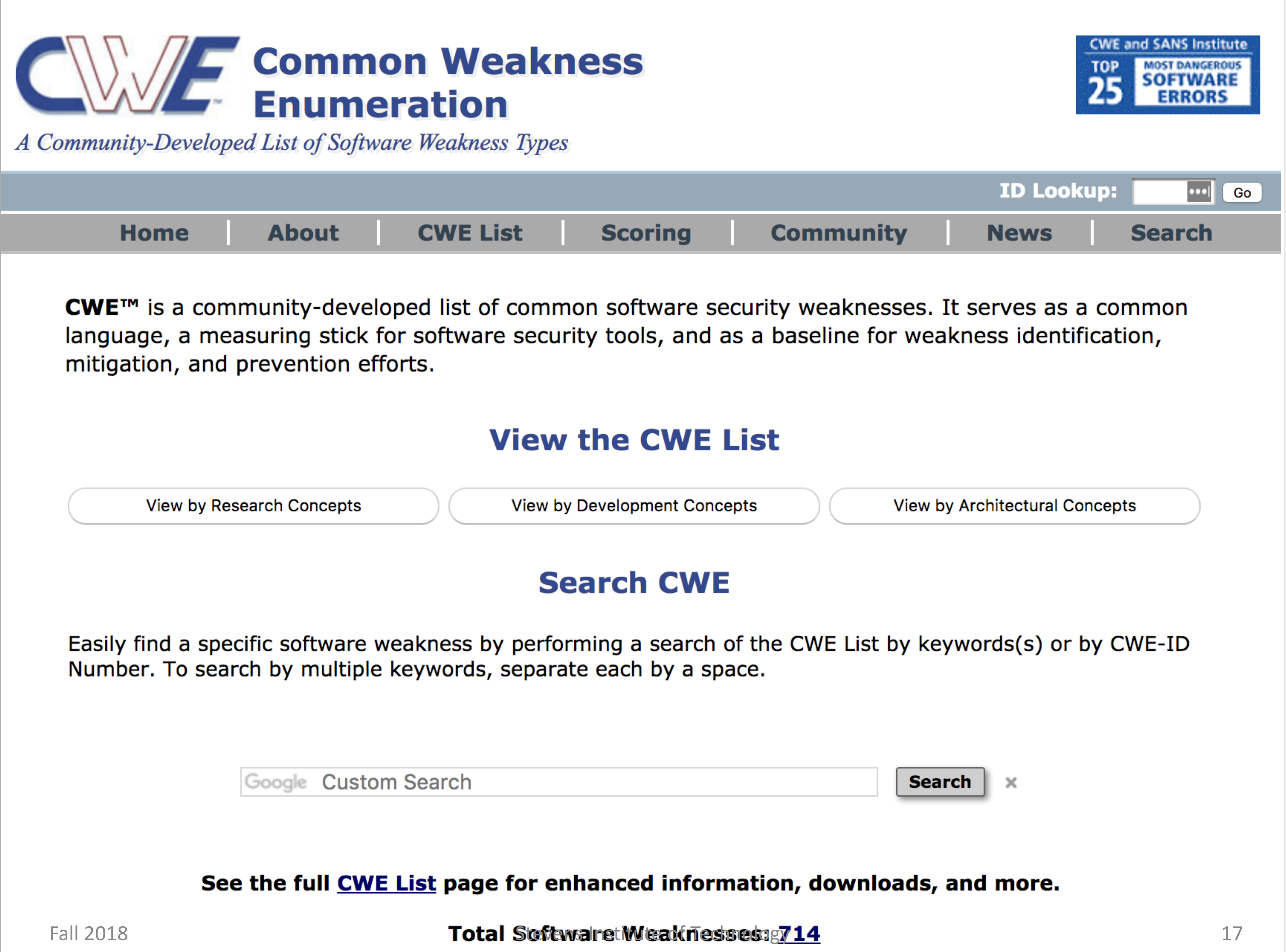
Use-after-free: Using memory after it has been freed

Uninitialized memory: Using pointer before initialization

Null pointer dereferences: Using NULL pointers

Type confusion: Assume a variable/object has the wrong type

HW errors: Hammering memory to cause bit flips to non-owned memory


CWE
Common Weakness Enumeration
A Community-Developed List of Software Weakness Types
CWE and SANS Institute TOP 25 MOST DANGEROUS SOFTWARE ERRORS
ID Lookup:
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CWE™ is a community-developed list of common software security weaknesses. It serves as a common language, a measuring stick for software security tools, and as a baseline for weakness identification, mitigation, and prevention efforts.

View the CWE List

View by Research Concepts
View by Development Concepts
View by Architectural Concepts

Search CWE

Easily find a specific software weakness by performing a search of the CWE List by keywords(s) or by CWE-ID Number. To search by multiple keywords, separate each by a space.

See the full CWE List page for enhanced information, downloads, and more.

Total Software Weaknesses: 714

Buffer Overflows

Buffer Overflows

Writing outside the boundaries of a buffer

Common programmer errors that lead to it …

- Insufficient input checks/wrong assumptions about input
- Unchecked buffer size
- Integer overflows

Stack Overflows

Stack Overflow Example

```
int mytest(char *str)
{
        char buf[16];

        strcpy(buf, str);

        printf("%s\n", buf);

        return strlen(buf);
}
```

Stack Overflow Example

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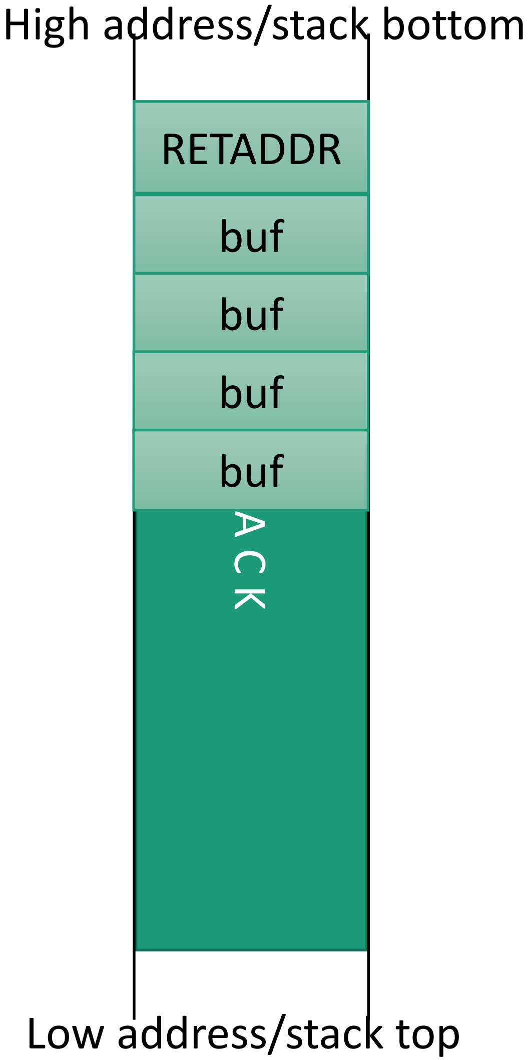

Stack Overflow Example

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        char buf[16];

        strcpy(buf, str);

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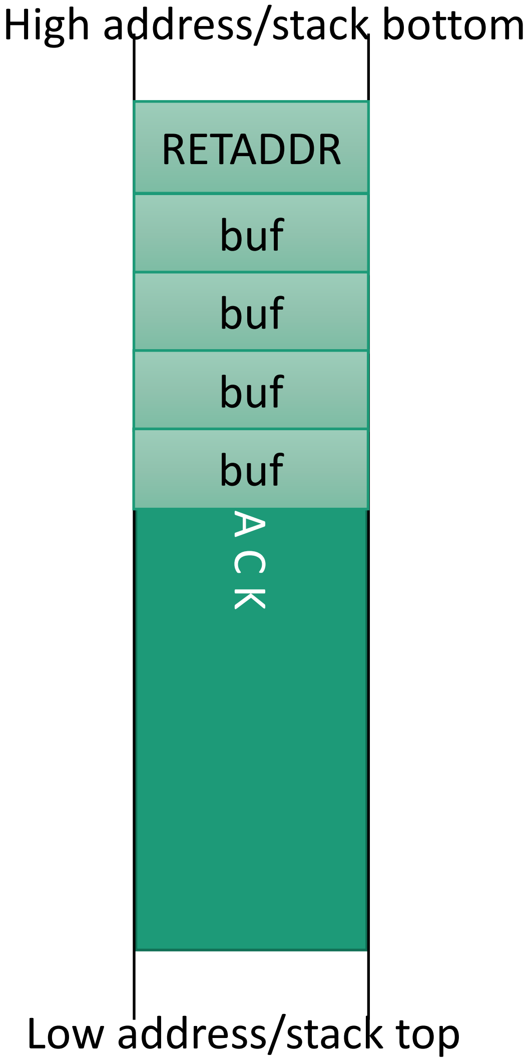
}
```

```
./mytest AAAAA
```



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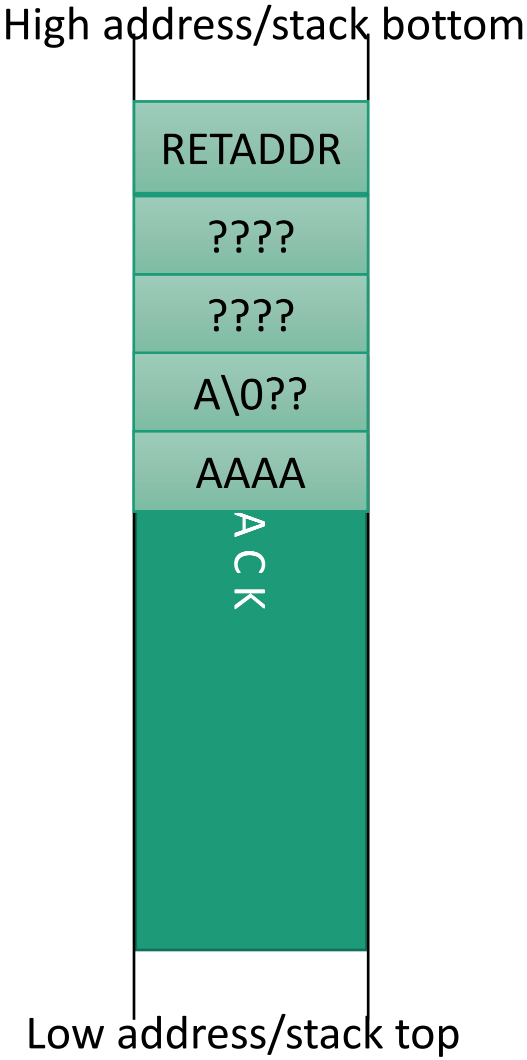

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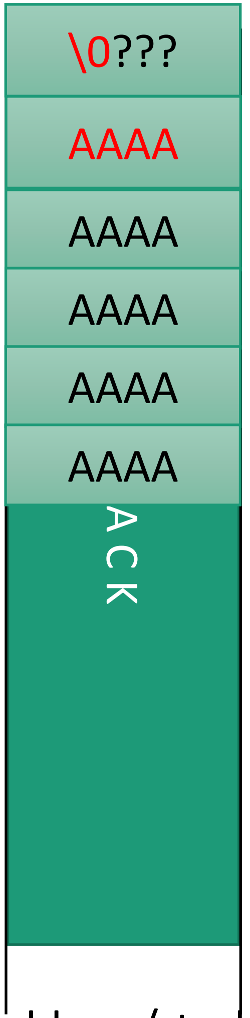

High address/stack bottom

Low address/stack top

Stack Overflow Example

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int mytest(char *str)
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        char buf[16];

        strcpy(buf, str);

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        return strlen(buf);
}
```
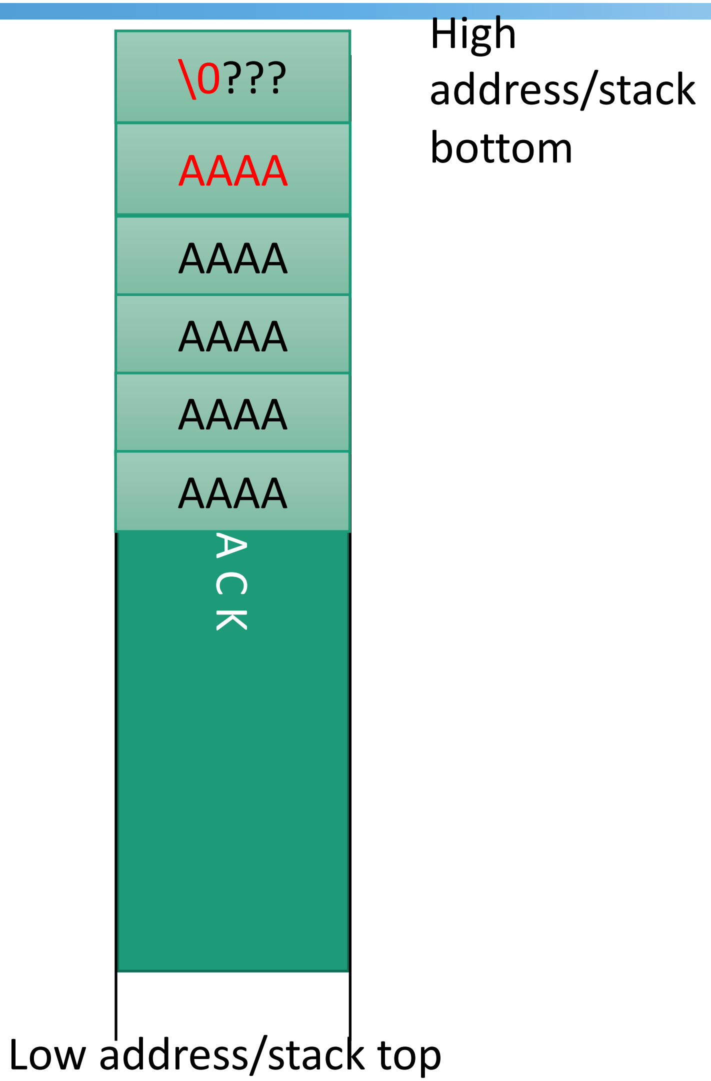

```
./mytest AAAAAAAAAAAAAAAAAAAA
```



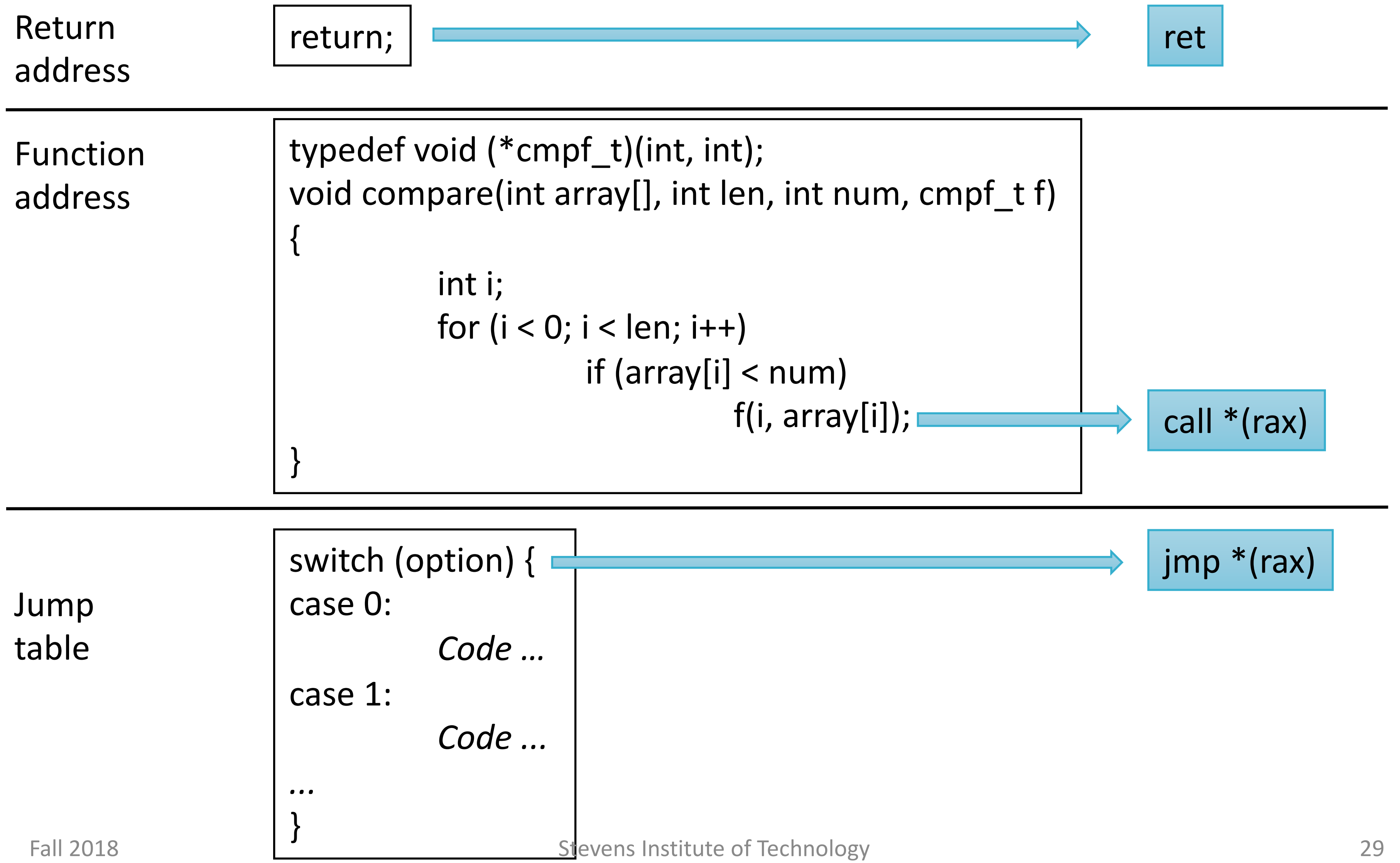
Control-Flow Hijacking

The saved return address is a code pointer stored in memory

- Controlling it grants control of a control-flow instruction (e.g., ret)

Untrusted inputs that lead to corruption of a code pointer lead to **control-flow hijacking attacks**

Other Code Pointers



Return address

```
return;
```

ret

Function address

```
typedef void (*cmpf_t)(int, int);
void compare(int array[], int len, int num, cmpf_t f)
{
        int i;
        for (i < 0; i < len; i++)
                if (array[i] < num)
                        f(i, array[i]);
}
```

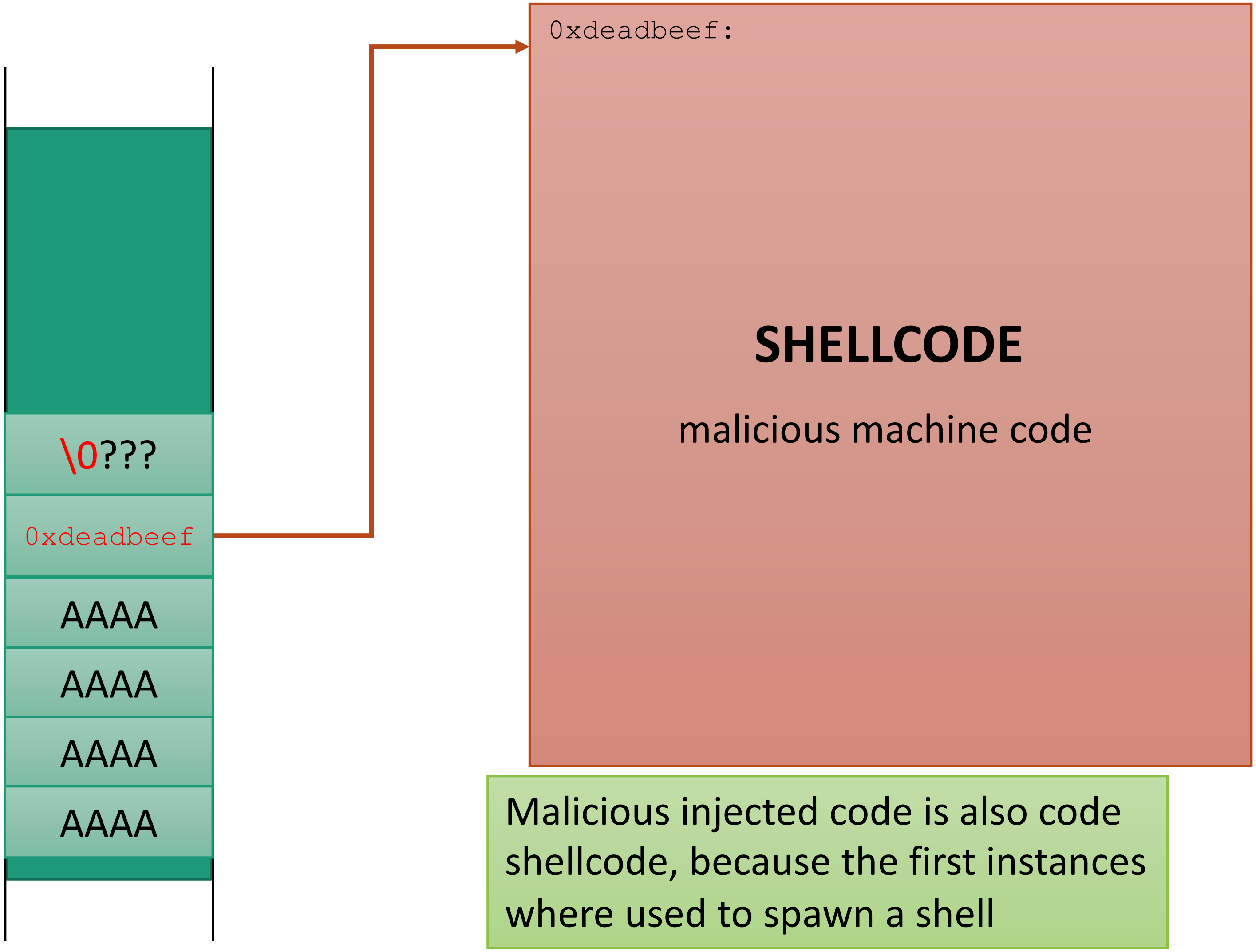
call *(rax)

Jump table

```
switch (option) {
case 0:
        Code ...
case 1:
        Code ...
...
}
```

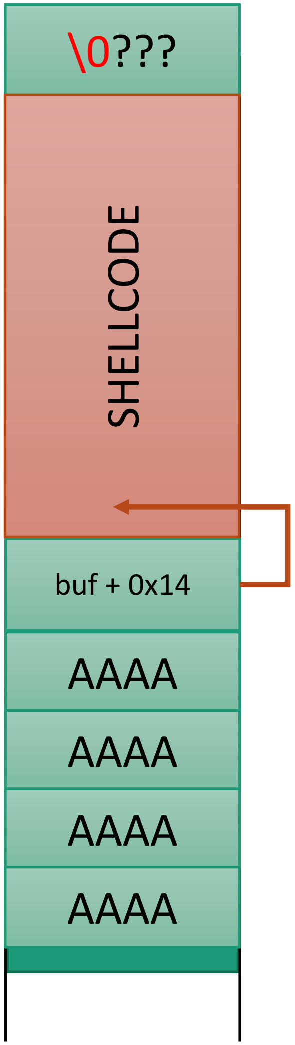
jmp *(rax)

Where to Point Execution



Malicious injected code is also code shellcode, because the first instances where used to spawn a shell

Injecting Shellcode

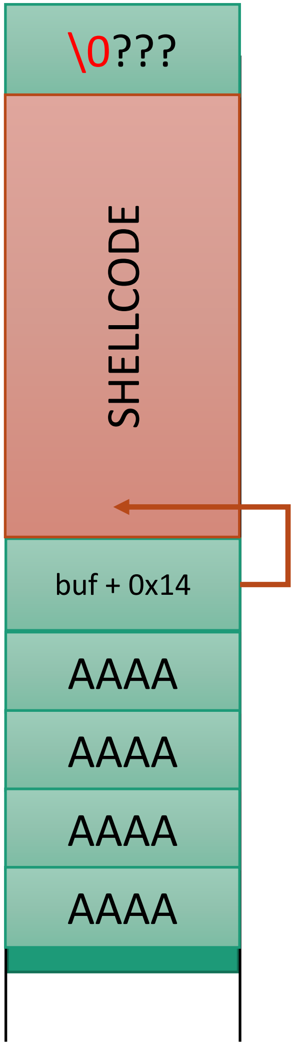


Code Injection

Code injection (CI) - Injecting machine code into a vulnerable program’s memory

Code injections attacks inject code and use control-flow hijacking to execute that code

Shellcode Limitations



Injected shellcode cannot include a null byte because of strcpy()

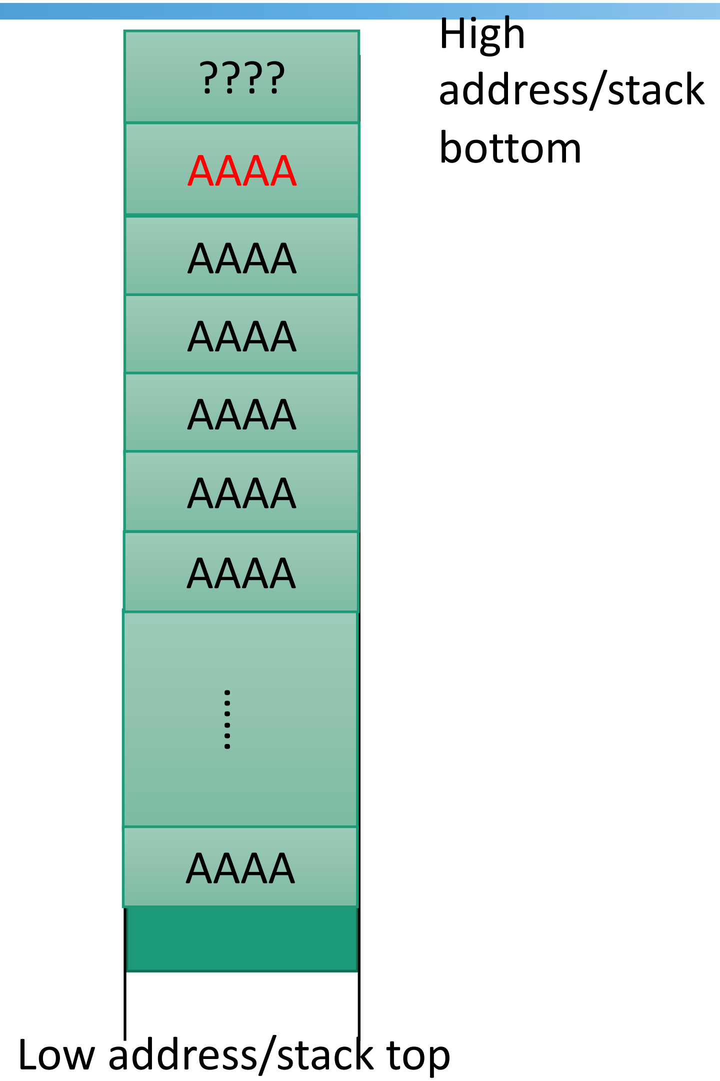
Shellcode needs to be carefully crafted to avoid disallowed bytes

Other methods of copying data may not have the same limitation: memcpy(), gets(), read(), fread(), custom copy routines, etc.

Stack Overflow Using read()

```
static void getURL(void)
{
        char buf[64];

        read(STDIN_FILENO, buf, 128);
        get_webpage(buf);
}
```

No limitation on bytes read.



Stack Overflow with FP

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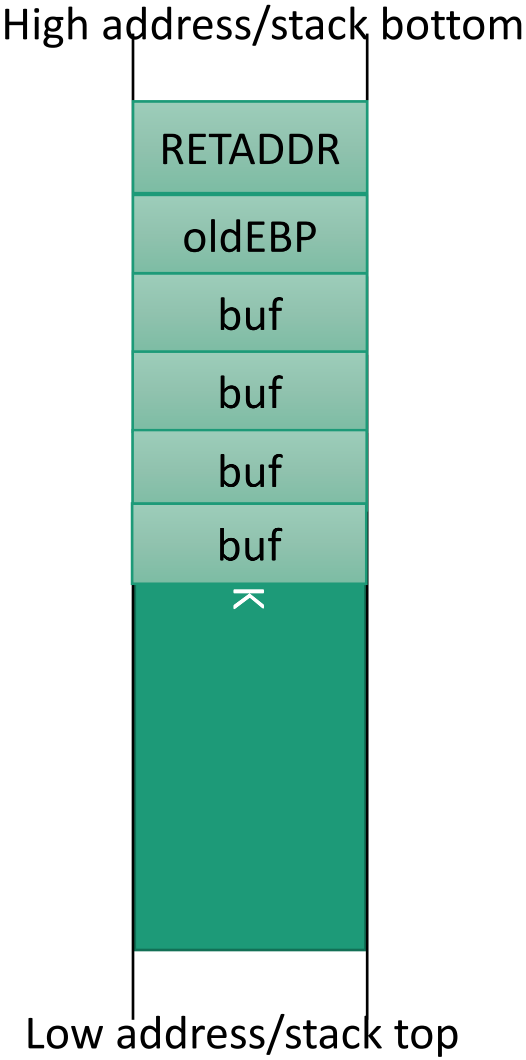

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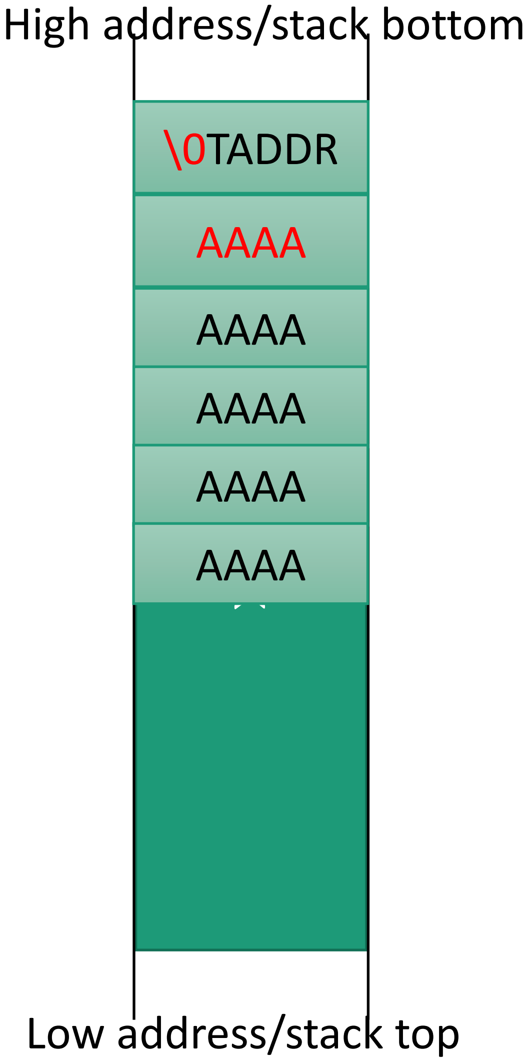
}
```

```
./mytest AAAAAAAAAAAAAAAAAAAA
```



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}
```
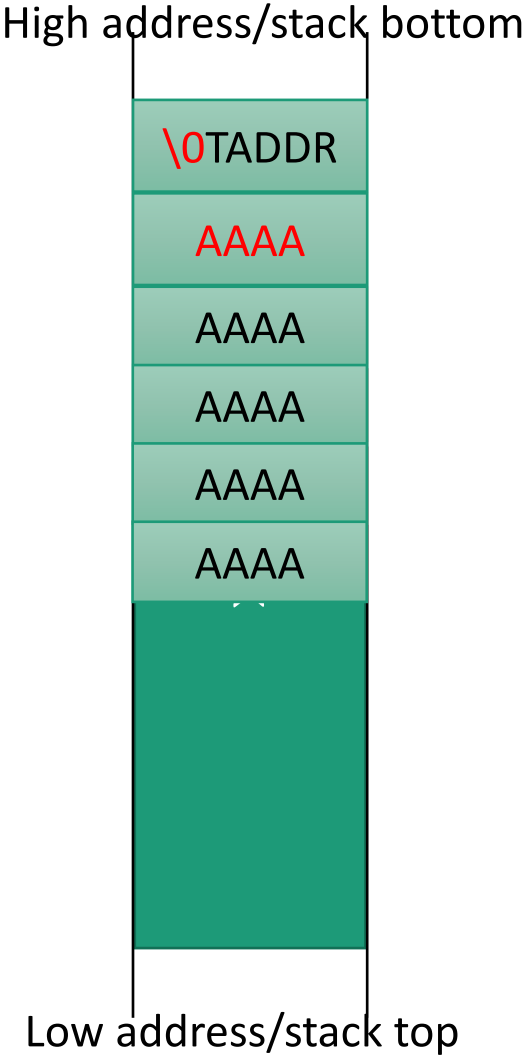

```
./mytest AAAAAAAAAAAAAAAAAAAA
```

```
80484e1: c9                    leave
80484e2: c3                    ret
```



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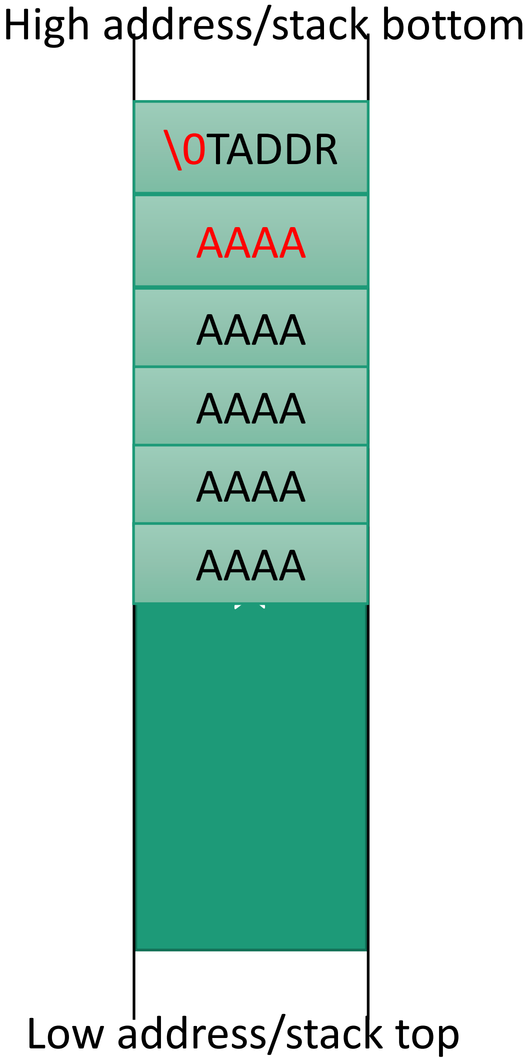
}
```

```
./mytest AAAAAAAAAAAAAAAAAAAA
```

```
8048                                   ve
8048
```

Function exit (LEAVE)

```
movl      %ebp, %esp
pop       %ebp
```



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{
        char buf[16];

        strcpy(buf, str);

        printf("%s\n", buf);

        return strlen(buf);
}
```
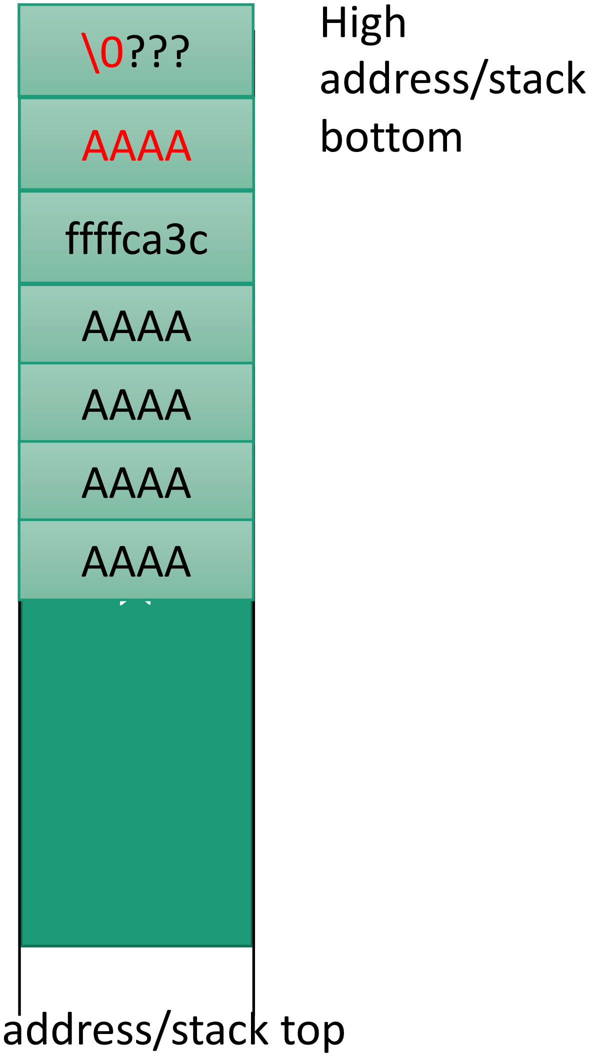

```
./mytest AAAAAAAAAAAAAAAA\x3c\xca\xff\xffAAAA
```

```
8048                                       ve
8048
```

Function exit (LEAVE)

```
movl     %ebp, %esp
pop      %ebp
```


\0???
AAAA
ffffca3c
AAAA
AAAA
AAAA
AAAA
High address/stack bottom
Low address/stack top