ECE560
Computer and Information Security

Fall 2024

Reverse Engineering

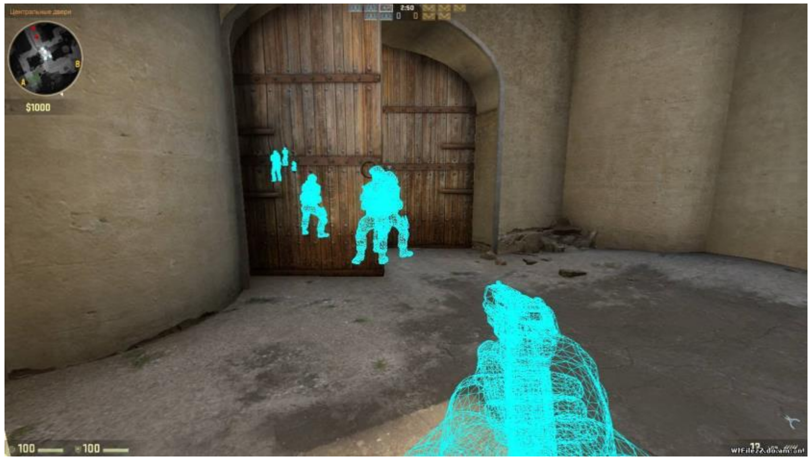
Tyler Bletsch

Duke University

With additional content by Jiaming Li, NC State University, 2015

What is software reverse engineering?

- Determine and possibly change program logic
  - "Logic" ≠ Just observed behavior
- Ethics
  - Useful for good:
    - Analyze malware
    - Understand undocumented legacy code
    - Watch/read/play the stuff you paid for
  - Useful for evil
    - "Crack" software (remove restrictions)
    - Find exploits
    - Cheat at games



Types of tools

Static analysis

- **Disassembler**
  - Turn compiled program into assembly
  - Usually good, but can get confused: can't discern code from data if binary is weirdly laid out
- **Decompiler**
  - Attempts to turn assembly back into source code.
  - Usually awful at machine code (though they're getting better), but managed code (e.g. Java, Python) often produces decent results.
- **Hex editor**
  - Understand binary data;
    make changes to binaries

Dynamic analysis

- **Debugger**
  - Step through running program
  - Very powerful: Gives control over time, order of execution, and content of data
  - Environment sometimes differs from normal execution in subtle ways ☹
- **Monitoring tools**
  - Watch system calls, library calls, etc.

Examples of tools

- Linux:
  - Disassember: objdump (free), **IDA Pro** (free and paid versions), Ghidra (free, from NSA!)
  - Debugger: **gdb** and its front-ends
  - Hex editor: okteta, bless, lots more…
  - Monitoring: **strace**, ltrace

IDA Pro eats basically anything

- Windows:
  - Disassembler: **IDA Pro** (free and paid versions), Ghidra (free, from NSA!)
  - Debugger: WinDBG (basic), **OllyDbg** (shareware), SoftICE ($1000+)
  - Hex editor: XVI32, Notepad++ with plugin, etc.
  - Monitoring tools: Process Monitor, Explorer, and more.

- X86 in general: A hypervisor (VMware, KVM, etc.)

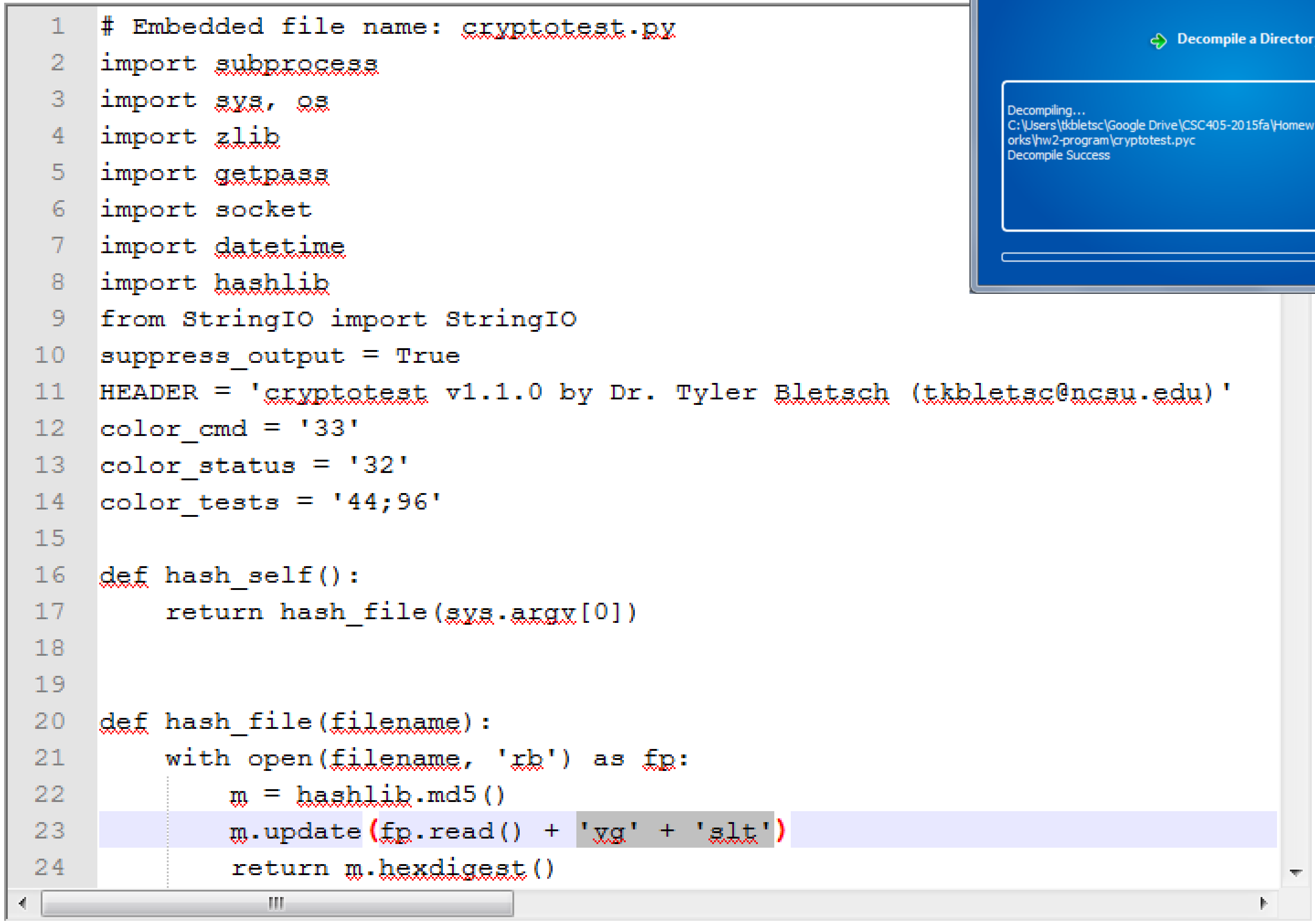
Debug or disassemble? Both.

- Disassembler gives **static** results
  - Good overview of program logic
  - But need to "mentally execute" program
  - Difficult to jump to specific functionality in the code
- Debugger is **dynamic**
  - Can set break points; fast forward to code for relevant functionality
  - Can treat complex code as "black box"
  - Not all code disassembles correctly
- Disassembler **and** debugger both required for any serious reverse engineering task

From "Computer Science 654 Lecture 5: Software Reverse Engineering" by Wayne Patterson, Howard Univ. 2009.

Example 1: HW2 auto-grader

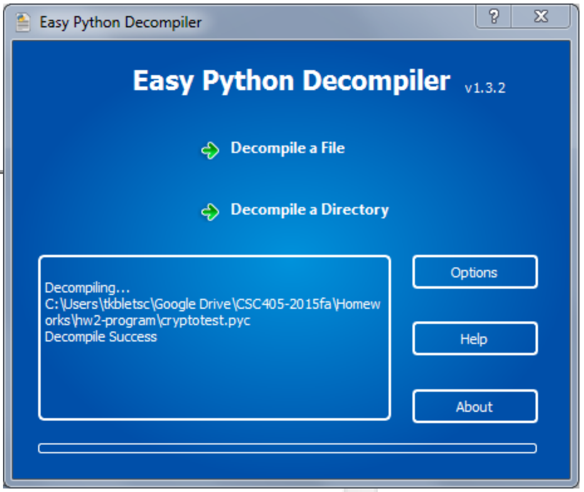
- Python decompiles very easily



```
# Embedded file name: cryptotest.py
import subprocess
import sys, os
import zlib
import getpass
import socket
import datetime
import hashlib
from StringIO import StringIO
suppress_output = True
HEADER = 'cryptotest v1.1.0 by Dr. Tyler Bletsch (tkbletsc@ncsu.edu)'
color_cmd = '33'
color_status = '32'
color_tests = '44;96'

def hash_self():
    return hash_file(sys.argv[0])


def hash_file(filename):
    with open(filename, 'rb') as fp:
        m = hashlib.md5()
        m.update(fp.read() + 'vg' + 'slt')
        return m.hexdigest()
```



```
Decompiling...
C:\Users\tkbletsc\Google Drive\CSC405-2015fa\Homeworks\hw2-program\cryptotest.pyc
Decompile Success
```

Example 2: Minecraft

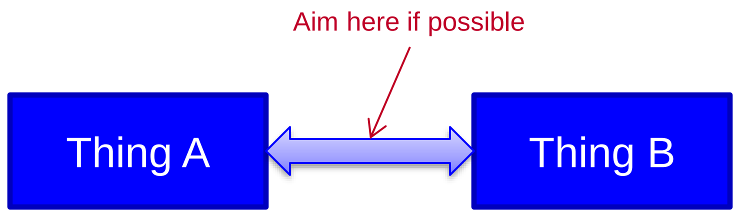
- Minecraft is a Java program, no mod support
- All mods use something like the Mod Coder Pack (MCP):

> "Use MCP to decompile the Minecraft client and server jar files.
>
> Use the decompiled source code to create mods for Minecraft.
>
> Recompile modified versions of Minecraft.
>
> Reobfuscate the classes of your mod for Minecraft."

- Entire mod community is built on reverse engineering!

Examining multi-component systems

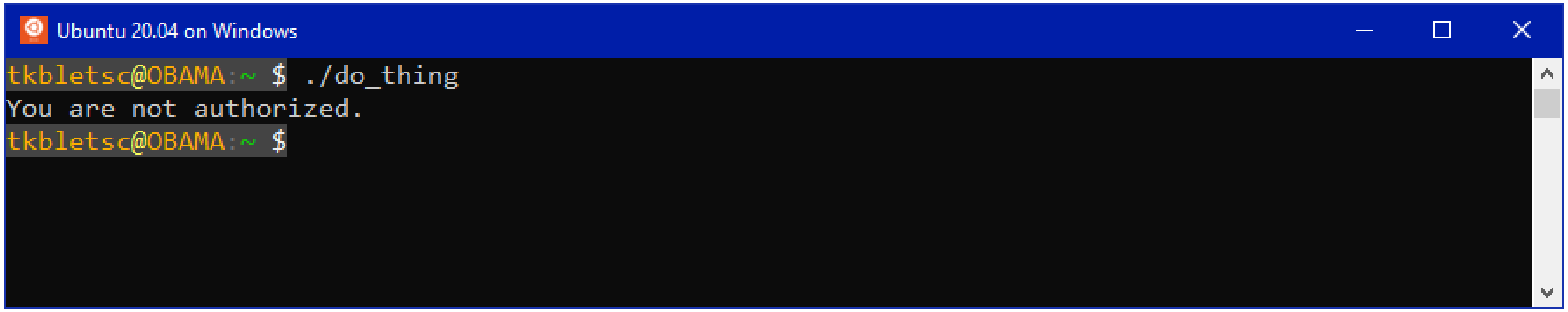
- Weaknesses often at the seams – where parts of system come together
  - Most visible, often exploitable
  - Example: SQL inspection (program/database boundary)
- If not the seams, at least focus on the least protected part



- Most common example: **user code** and **the kernel**
  - Known interface (system calls)
  - Inescapable – user code MUST use kernel to do stuff!

Example 3: ‘do_thing’

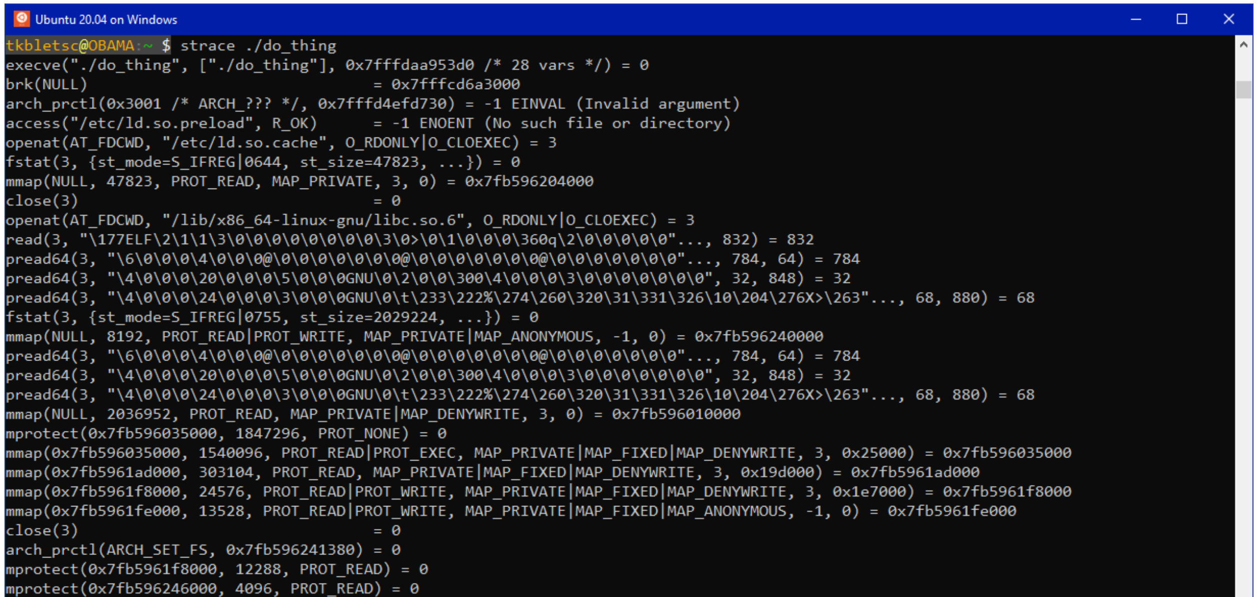
- You have a program that mysteriously says you’re not authorized:



Ubuntu 20.04 on Windows

```
tkbletsc@OBAMA:~ $ ./do_thing
You are not authorized.
tkbletsc@OBAMA:~ $
```

- Could debug, disassemble, etc., but here’s something cheap: `strace`: find out what system calls it’s doing to check authorization!



Ubuntu 20.04 on Windows

```
tkbletsc@OBAMA:~ $ strace ./do_thing
execve("./do_thing", ["./do_thing"], 0x7fffdaa953d0 /* 28 vars */) = 0
brk(NULL)                               = 0x7fffcd6a3000
arch_prctl(0x3001 /* ARCH_??? */, 0x7fffd4efd730) = -1 EINVAL (Invalid argument)
access("/etc/ld.so.preload", R_OK)      = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
fstat(3, {st_mode=S_IFREG|0644, st_size=47823, ...}) = 0
mmap(NULL, 47823, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fb596204000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\360q\2\0\0\0\0\0"..., 832) = 832
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
pread64(3, "\4\0\0\0\20\0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0", 32, 848) = 32
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\t\233\222%\274\260\320\31\331\326\10\204\276X>\263"..., 68, 880) = 68
fstat(3, {st_mode=S_IFREG|0755, st_size=2029224, ...}) = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7fb596240000
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
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mmap(NULL, 2036952, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fb596010000
mprotect(0x7fb596035000, 1847296, PROT_NONE) = 0
mmap(0x7fb596035000, 1540096, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x25000) = 0x7fb596035000
mmap(0x7fb5961ad000, 303104, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x19d000) = 0x7fb5961ad000
mmap(0x7fb5961f8000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1e7000) = 0x7fb5961f8000
mmap(0x7fb5961fe000, 13528, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fb5961fe000
close(3)                                = 0
arch_prctl(ARCH_SET_FS, 0x7fb596241380) = 0
mprotect(0x7fb5961f8000, 12288, PROT_READ) = 0
mprotect(0x7fb596246000, 4096, PROT_READ) = 0
```

Example 3: reading strace

- You learn to see through the noise with practice

```
execve("./do_thing", ["./do_thing"], 0x7fffdaa953d0 /* 28 vars */) = 0
brk(NULL)                               = 0x7fffcd6a3000
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fstat(3, {st_mode=S_IFREG|0644, st_size=47823, ...}) = 0
mmap(NULL, 47823, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fb596204000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\360q\2\0\0\0\0\0"..., 832) = 832
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fstat(3, {st_mode=S_IFREG|0755, st_size=2029224, ...}) = 0
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pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
pread64(3, "\4\0\0\0\20\0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0", 32, 848) = 32
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\t\233\222%\274\260\320\31\331\326\10\204\276X>\263"..., 68, 880) = 68
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mmap(0x7fb5961fe000, 13528, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fb5961fe000
close(3)                                = 0
arch_prctl(ARCH_SET_FS, 0x7fb596241380) = 0
mprotect(0x7fb5961f8000, 12288, PROT_READ) = 0
mprotect(0x7fb596246000, 4096, PROT_READ) = 0
mprotect(0x7fb59623d000, 4096, PROT_READ) = 0
munmap(0x7fb596204000, 47823)           = 0
brk(NULL)                               = 0x7fffcd6a3000
brk(0x7fffcd6c4000)                     = 0x7fffcd6c4000
openat(AT_FDCWD, ".hidden_authorization_file", O_RDONLY) = -1 ENOENT (No such file or directory)
fstat(1, {st_mode=S_IFCHR|0660, st_rdev=makedev(0x4, 0x1), ...}) = 0
ioctl(1, TCGETS, {B38400 opost isig icanon echo ...}) = 0
write(1, "You are not authorized.\n", 24You are not authorized.
) = 24
exit_group(1)                           = ?
+++ exited with 1 +++
```

Boring stuff to start the program (load shared libraries, prepare heap)

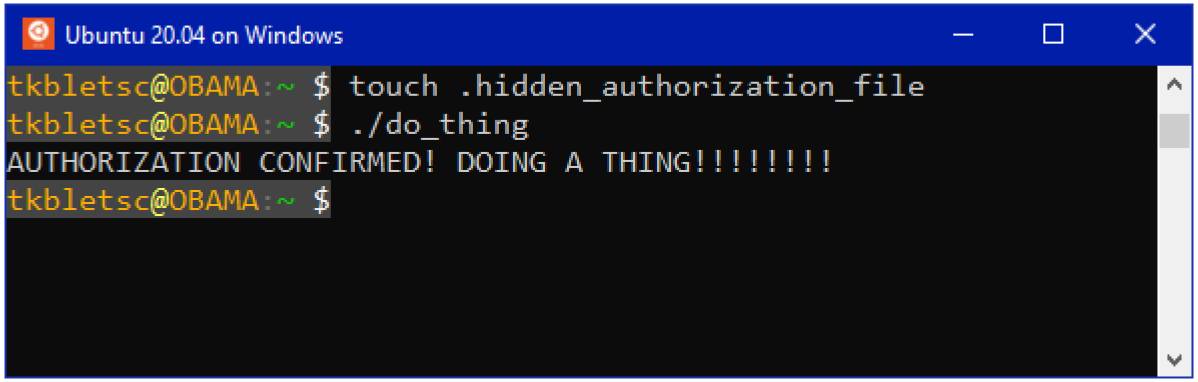
Potentially relevant syscalls

Error message that we hate

Example 3: success

```
openat(AT_FDCWD, ".hidden_authorization_file", O_RDONLY) = -1 ENOENT (No such file or directory)
```

- It appears to check for a file called ".hidden_authorization_file" and doesn't find it
- What if it *did* find it? Let's try:



```
tkbletsc@OBAMA:~ $ touch .hidden_authorization_file
tkbletsc@OBAMA:~ $ ./do_thing
AUTHORIZATION CONFIRMED! DOING A THING!!!!!!!!!
tkbletsc@OBAMA:~ $
```

- Success!
- But what if it the program actually looked inside the file and needed to see certain data in there?
  - Can't see *computation* from here, just IO, so that's when you use disassembler/debugger

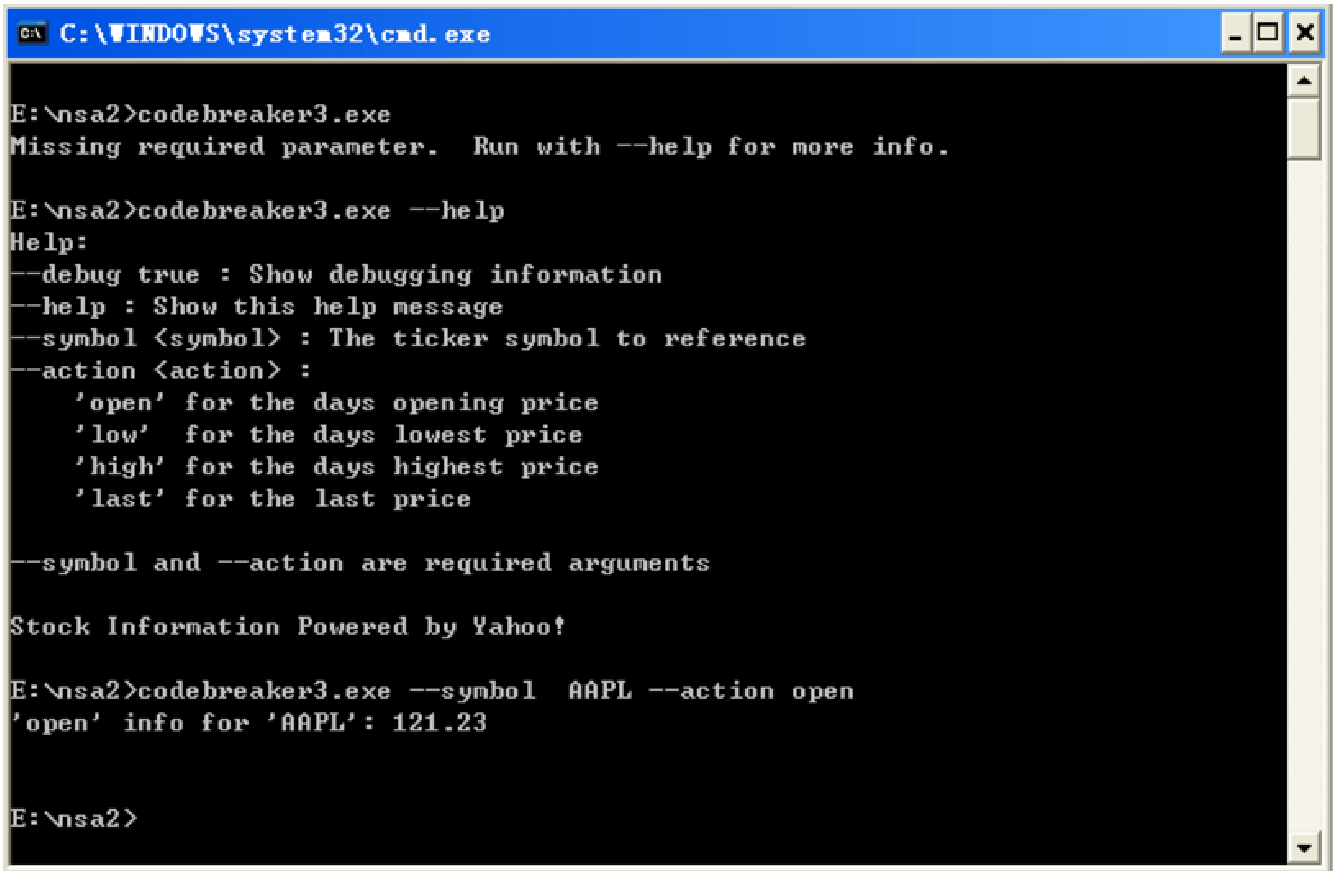
Example 4: NSA Codebreaker challenge, 2015

- Scenario:
  - Terrorists using a cryptography program to decrypt/authenticate messages from leadership
  - What we have:
    - The program: **`codebreaker3.exe`**
    - A member's key: **`tier1_key.pem`**
    - A text file with a hidden message: **`tier1_msg.txt`**
  - At first glance, the program appears to simply check stock information, but that's a ruse.
  - Need to reverse engineer it:
    Challenge has 4 tasks, we'll do 2.

Adapted from content by Jiaming Li, NC State University, 2015

Codebreaker Task 1: Decrypt

- Need to decode message we have.
- The program:



C:\WINDOWS\system32\cmd.exe

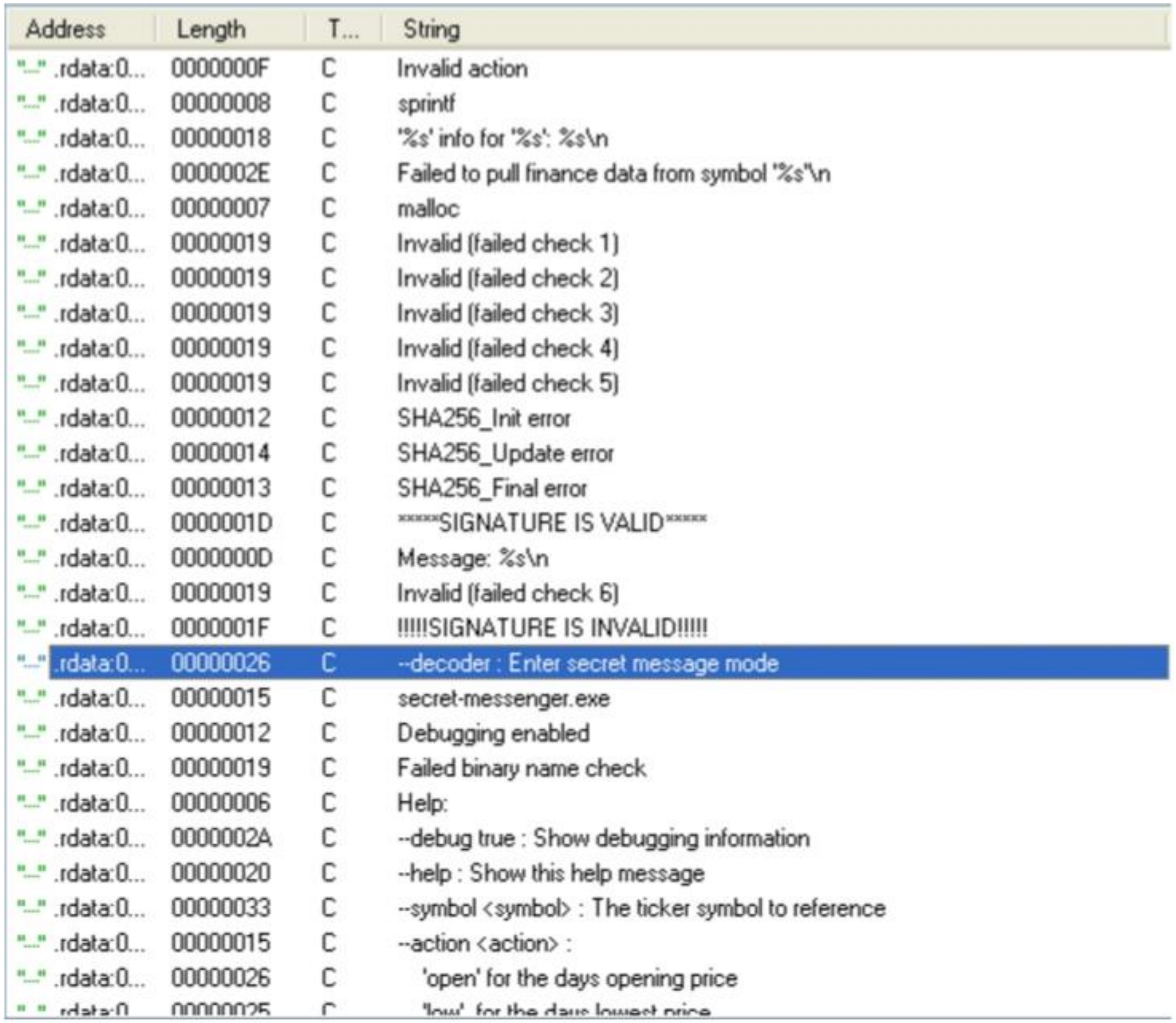
```
E:\nsa2>codebreaker3.exe
Missing required parameter.  Run with --help for more info.

E:\nsa2>codebreaker3.exe --help
Help:
--debug true : Show debugging information
--help : Show this help message
--symbol <symbol> : The ticker symbol to reference
--action <action> :
    'open' for the days opening price
    'low'  for the days lowest price
    'high' for the days highest price
    'last' for the last price

--symbol and --action are required arguments

Stock Information Powered by Yahoo!

E:\nsa2>codebreaker3.exe --symbol  AAPL --action open
'open' info for 'AAPL': 121.23


E:\nsa2>
```

Codebreaker Task 1: Decrypt

- Do static analysis with IDA Pro
  - Load binary
  - Confirm binary format options
  - Process:
    - Code is disassembled
    - Call graph of assembly code built
    - All memory references are cross-referenced, especially string literals

Codebreaker Task 1: Decrypt

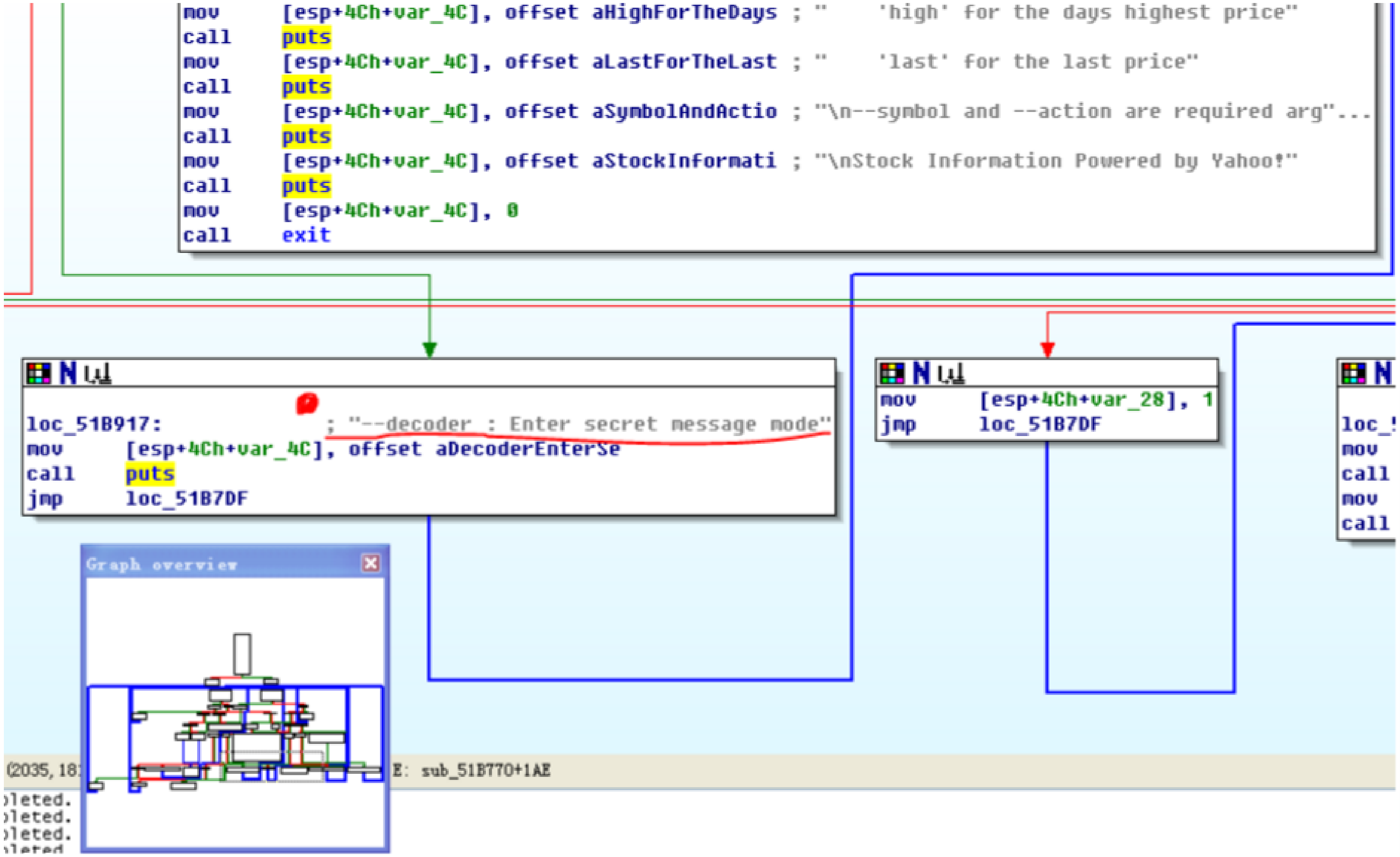
- Do static analysis with IDA Pro, check the all string information



Address	Length	T...	String
.rdata:0...	0000000F	C	Invalid action
.rdata:0...	00000008	C	sprintf
.rdata:0...	00000018	C	'%s' info for '%s': %s\n
.rdata:0...	0000002E	C	Failed to pull finance data from symbol '%s'\n
.rdata:0...	00000007	C	malloc
.rdata:0...	00000019	C	Invalid (failed check 1)
.rdata:0...	00000019	C	Invalid (failed check 2)
.rdata:0...	00000019	C	Invalid (failed check 3)
.rdata:0...	00000019	C	Invalid (failed check 4)
.rdata:0...	00000019	C	Invalid (failed check 5)
.rdata:0...	00000012	C	SHA256_Init error
.rdata:0...	00000014	C	SHA256_Update error
.rdata:0...	00000013	C	SHA256_Final error
.rdata:0...	0000001D	C	*****SIGNATURE IS VALID*****
.rdata:0...	0000000D	C	Message: %s\n
.rdata:0...	00000019	C	Invalid (failed check 6)
.rdata:0...	0000001F	C	!!!!!SIGNATURE IS INVALID!!!!!
.rdata:0...	00000026	C	--decoder : Enter secret message mode
.rdata:0...	00000015	C	secret-messenger.exe
.rdata:0...	00000012	C	Debugging enabled
.rdata:0...	00000019	C	Failed binary name check
.rdata:0...	00000006	C	Help:
.rdata:0...	0000002A	C	--debug true : Show debugging information
.rdata:0...	00000020	C	--help : Show this help message
.rdata:0...	00000033	C	--symbol <symbol> : The ticker symbol to reference
.rdata:0...	00000015	C	--action <action> :
.rdata:0...	00000026	C	'open' for the days opening price
.rdata:0	00000025	C	'low' for the days lowest price

Codebreaker Task 1: Decrypt

- Press x, this leads us to the location where this string appears:



```
mov     [esp+4Ch+var_4C], offset aHighForTheDays ; "    'high' for the days highest price"
call    puts
mov     [esp+4Ch+var_4C], offset aLastForTheLast ; "    'last' for the last price"
call    puts
mov     [esp+4Ch+var_4C], offset aSymbolAndActio ; "\n--symbol and --action are required arg"...
call    puts
mov     [esp+4Ch+var_4C], offset aStockInformati ; "\nStock Information Powered by Yahoo!"
call    puts
mov     [esp+4Ch+var_4C], 0
call    exit
```

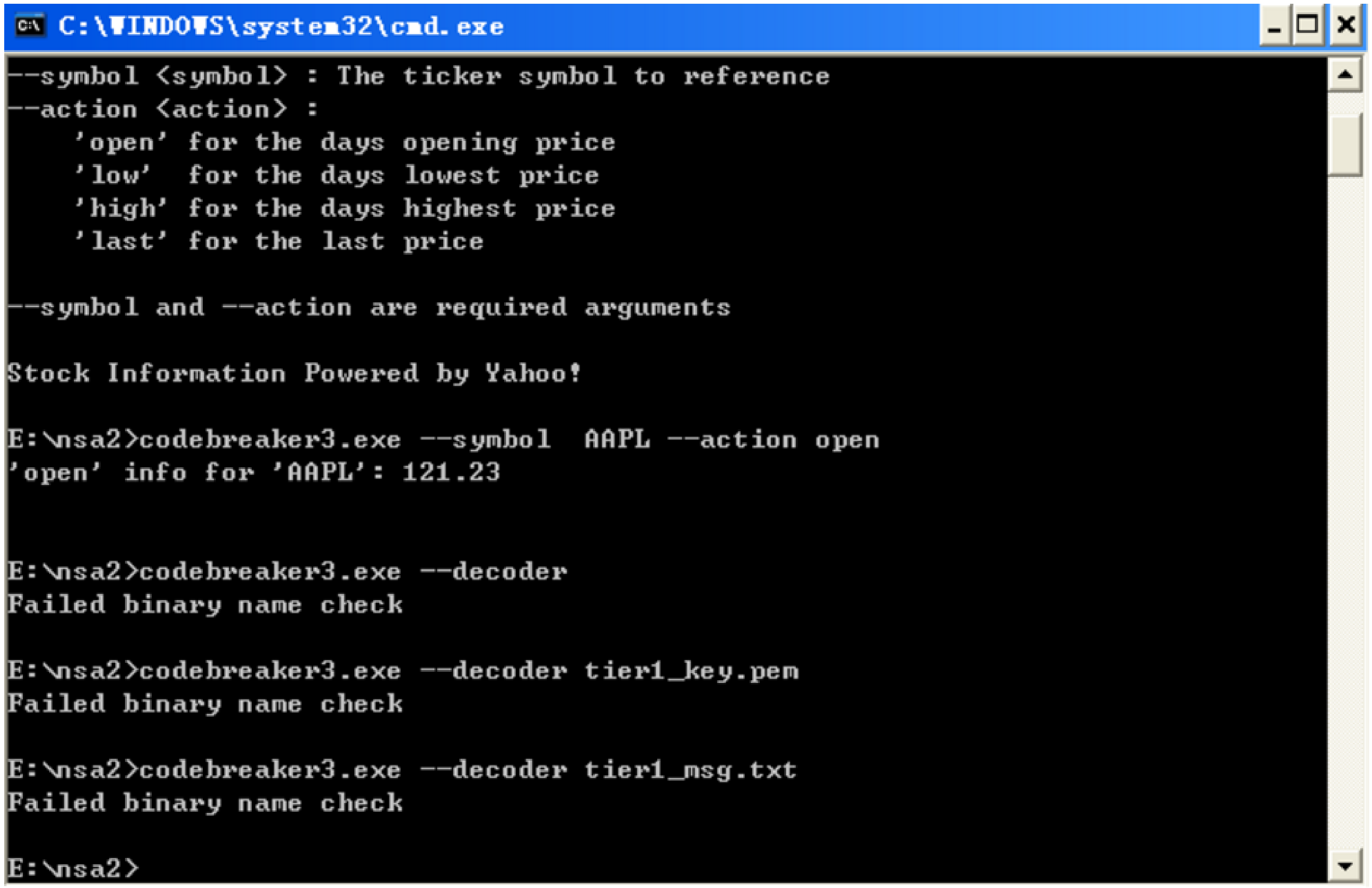
```
loc_51B917:                             ; "--decoder : Enter secret message mode"
mov     [esp+4Ch+var_4C], offset aDecoderEnterSe
call    puts
jmp     loc_51B7DF
```

```
mov     [esp+4Ch+var_28], 1
jmp     loc_51B7DF
```

```
loc_
mov
call
mov
call
```

Codebreaker Task 1: Decrypt

- OK, let's try "decoder" parameter:



C:\WINDOWS\system32\cmd.exe

```
--symbol <symbol> : The ticker symbol to reference
--action <action> :
    'open' for the days opening price
    'low'  for the days lowest price
    'high' for the days highest price
    'last' for the last price

--symbol and --action are required arguments

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E:\nsa2>codebreaker3.exe --symbol  AAPL --action open
'open' info for 'AAPL': 121.23


E:\nsa2>codebreaker3.exe --decoder
Failed binary name check

E:\nsa2>codebreaker3.exe --decoder tier1_key.pem
Failed binary name check

E:\nsa2>codebreaker3.exe --decoder tier1_msg.txt
Failed binary name check

E:\nsa2>
```
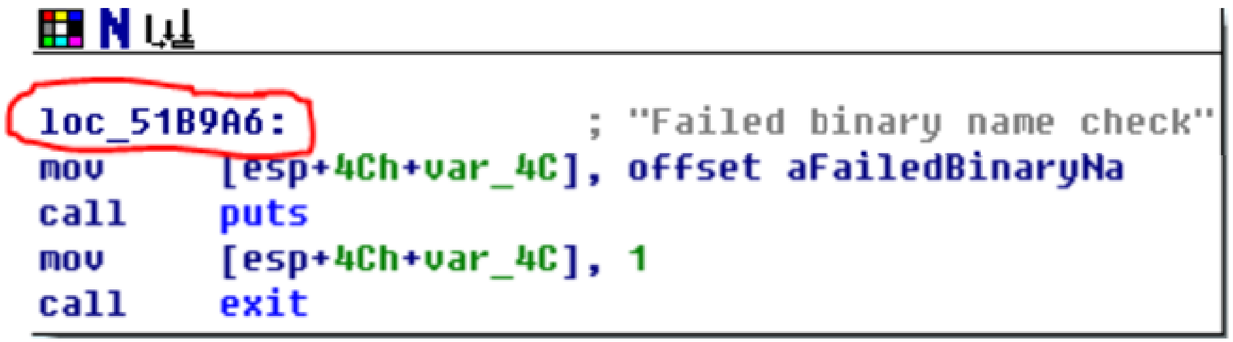
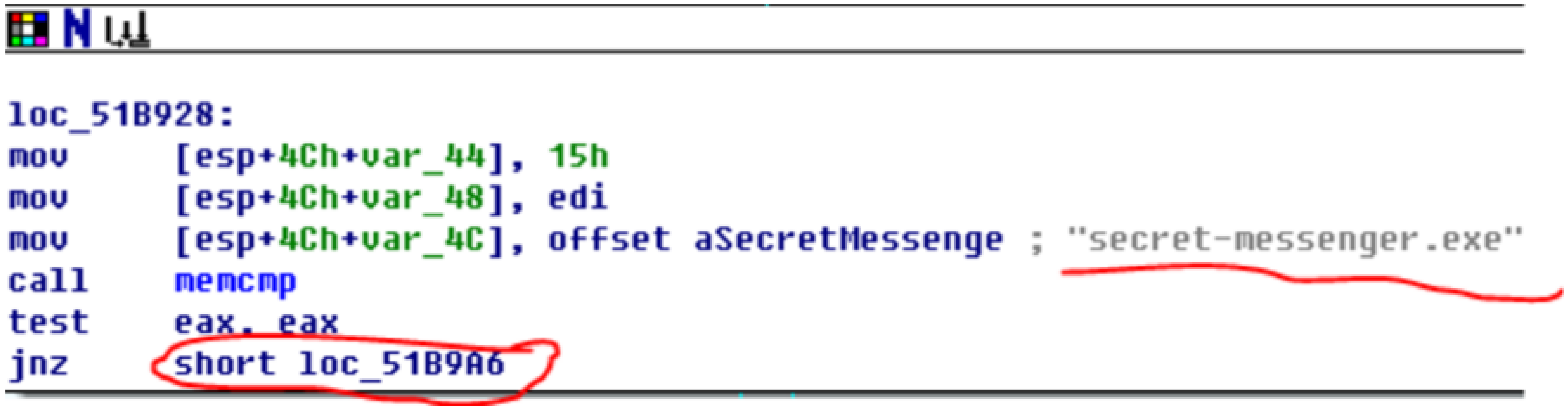

Codebreaker Task 1: Decrypt

- We need to find where "Failed binary name check" appears:



```
loc_51B9A6:                    ; "Failed binary name check"
mov     [esp+4Ch+var_4C], offset aFailedBinaryNa
call    puts
mov     [esp+4Ch+var_4C], 1
call    exit
```

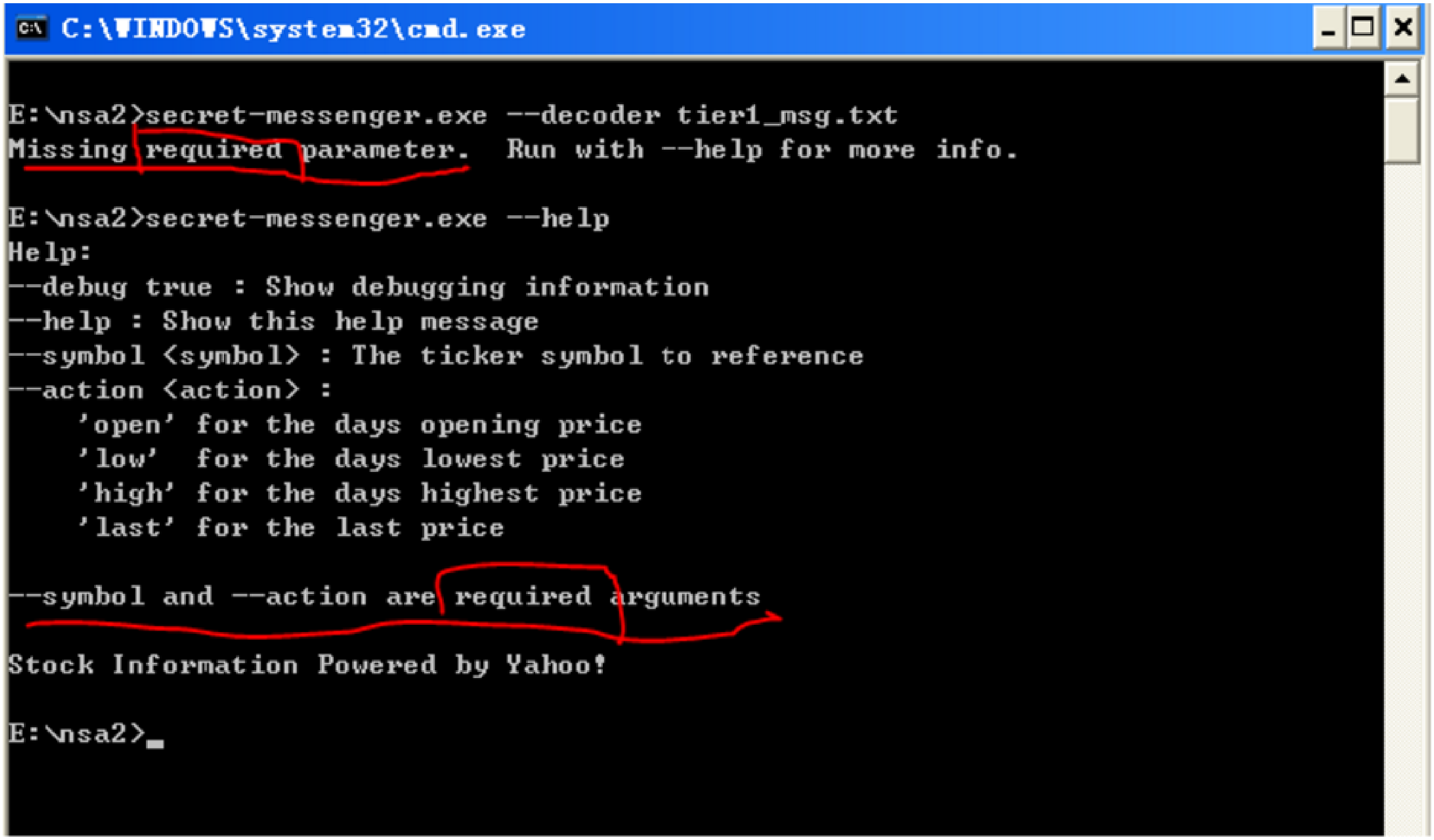
- and this comes from:



```
loc_51B928:
mov     [esp+4Ch+var_44], 15h
mov     [esp+4Ch+var_48], edi
mov     [esp+4Ch+var_4C], offset aSecretMessenge ; "secret-messenger.exe"
call    memcmp
test    eax, eax
jnz     short loc_51B9A6
```

Codebreaker Task 1: Decrypt

- Then we change our program name to "secret-messenger.exe" and try again:



C:\WINDOWS\system32\cmd.exe

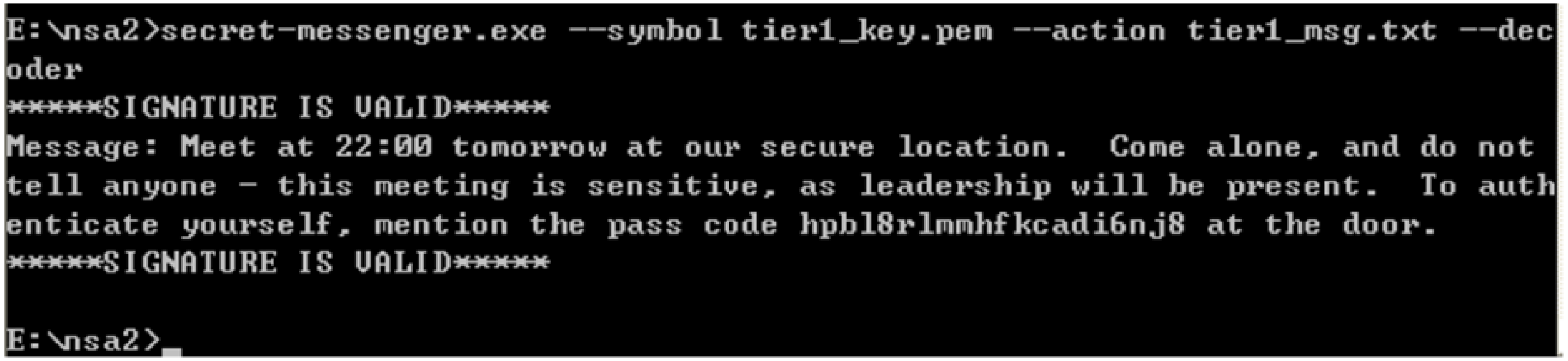
```
E:\nsa2>secret-messenger.exe --decoder tier1_msg.txt
Missing required parameter.  Run with --help for more info.

E:\nsa2>secret-messenger.exe --help
Help:
--debug true : Show debugging information
--help : Show this help message
--symbol <symbol> : The ticker symbol to reference
--action <action> :
    'open' for the days opening price
    'low'  for the days lowest price
    'high' for the days highest price
    'last' for the last price

--symbol and --action are required arguments

Stock Information Powered by Yahoo!

E:\nsa2>_
```

Adapted from content by Jiaming Li, NC State University, 2015

Codebreaker Task 1: Decrypt

- Ideas?

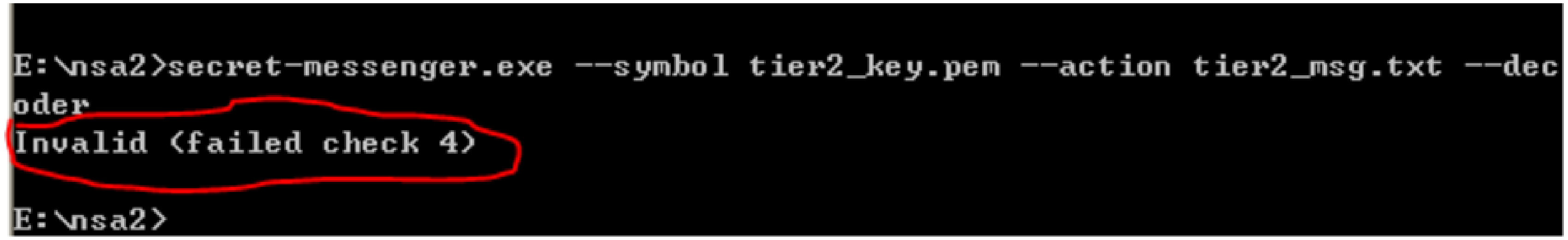
- Let's jam the stuff into symbol and action fields



```
E:\nsa2>secret-messenger.exe --symbol tier1_key.pem --action tier1_msg.txt --dec
oder
*****SIGNATURE IS VALID*****
Message: Meet at 22:00 tomorrow at our secure location.  Come alone, and do not
tell anyone - this meeting is sensitive, as leadership will be present.  To auth
enticate yourself, mention the pass code hpbl8rlmmhfkcadi6nj8 at the door.
*****SIGNATURE IS VALID*****

E:\nsa2>_
```

Codebreaker Task 2: Bypass access limitation

- We've collected a **new message file** - this one to a different field operative **whose key we also have**.
- Each operative has their own decrypt tool, each tool will only decrypt content "addressed" to its owner.
- Need to defeat this access limitation to decrypt the message.

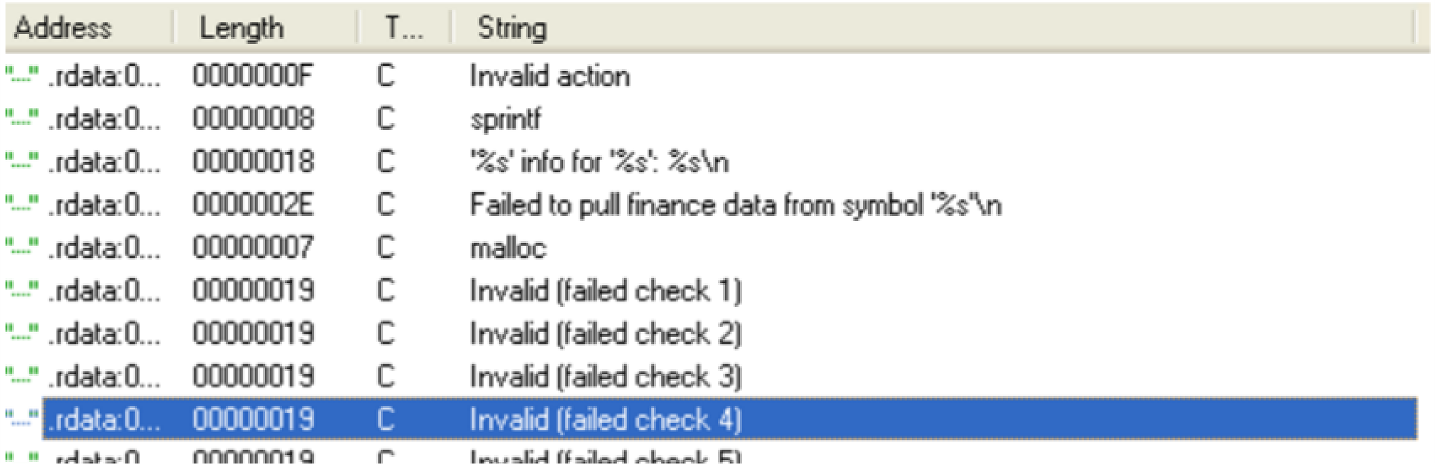


```
E:\nsa2>secret-messenger.exe --symbol tier2_key.pem --action tier2_msg.txt --dec
oder
Invalid (failed check 4)

E:\nsa2>
```

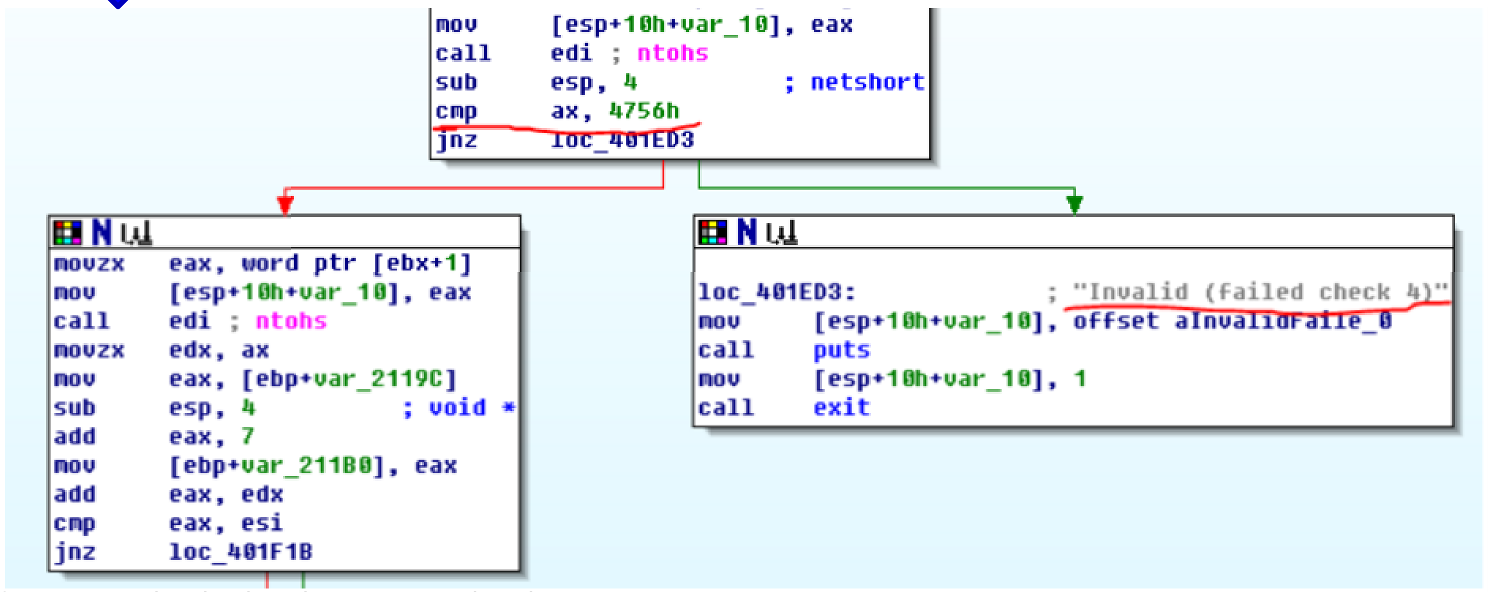
Adapted from content by Jiaming Li, NC State University, 2015

Codebreaker Task 2: Bypass access limitation

- Let's go back to IDA to find where this error appears:



Address	Length	T...	String
.rdata:0...	0000000F	C	Invalid action
.rdata:0...	00000008	C	sprintf
.rdata:0...	00000018	C	'%s' info for '%s': %s\n
.rdata:0...	0000002E	C	Failed to pull finance data from symbol '%s'\n
.rdata:0...	00000007	C	malloc
.rdata:0...	00000019	C	Invalid (failed check 1)
.rdata:0...	00000019	C	Invalid (failed check 2)
.rdata:0...	00000019	C	Invalid (failed check 3)
.rdata:0...	00000019	C	Invalid (failed check 4)
.rdata:0	00000019	C	Invalid (failed check 5)



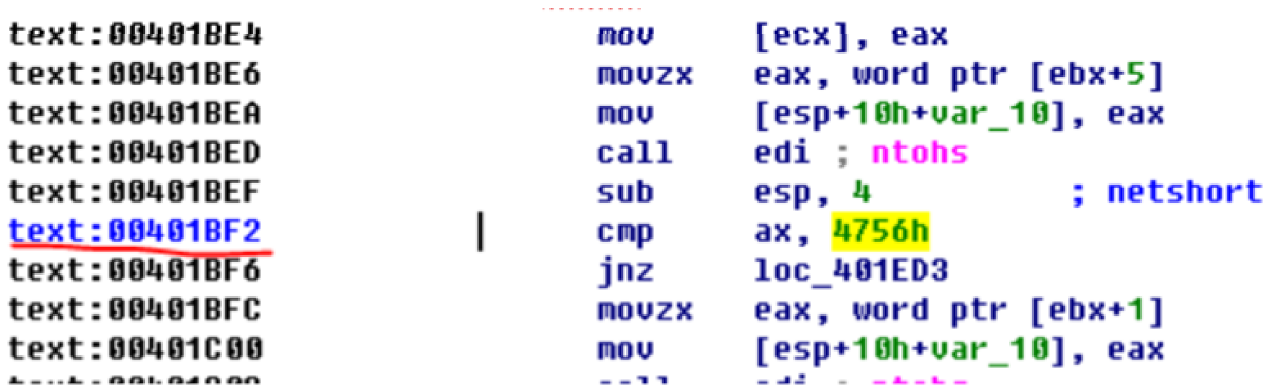
```
mov     [esp+10h+var_10], eax
call    edi ; ntohs
sub     esp, 4                  ; netshort
cmp     ax, 4756h
jnz     loc_401ED3
```

```
movzx   eax, word ptr [ebx+1]
mov     [esp+10h+var_10], eax
call    edi ; ntohs
movzx   edx, ax
mov     eax, [ebp+var_2119C]
sub     esp, 4                  ; void *
add     eax, 7
mov     [ebp+var_211B0], eax
add     eax, edx
cmp     eax, esi
jnz     loc_401F1B
```

```
loc_401ED3:                     ; "Invalid (failed check 4)"
mov     [esp+10h+var_10], offset aInvalidFaile_0
call    puts
mov     [esp+10h+var_10], 1
call    exit
```

Codebreaker Task 2: Bypass access limitation

- Note down the address of “cmp ax,4756h”, press SPACE:

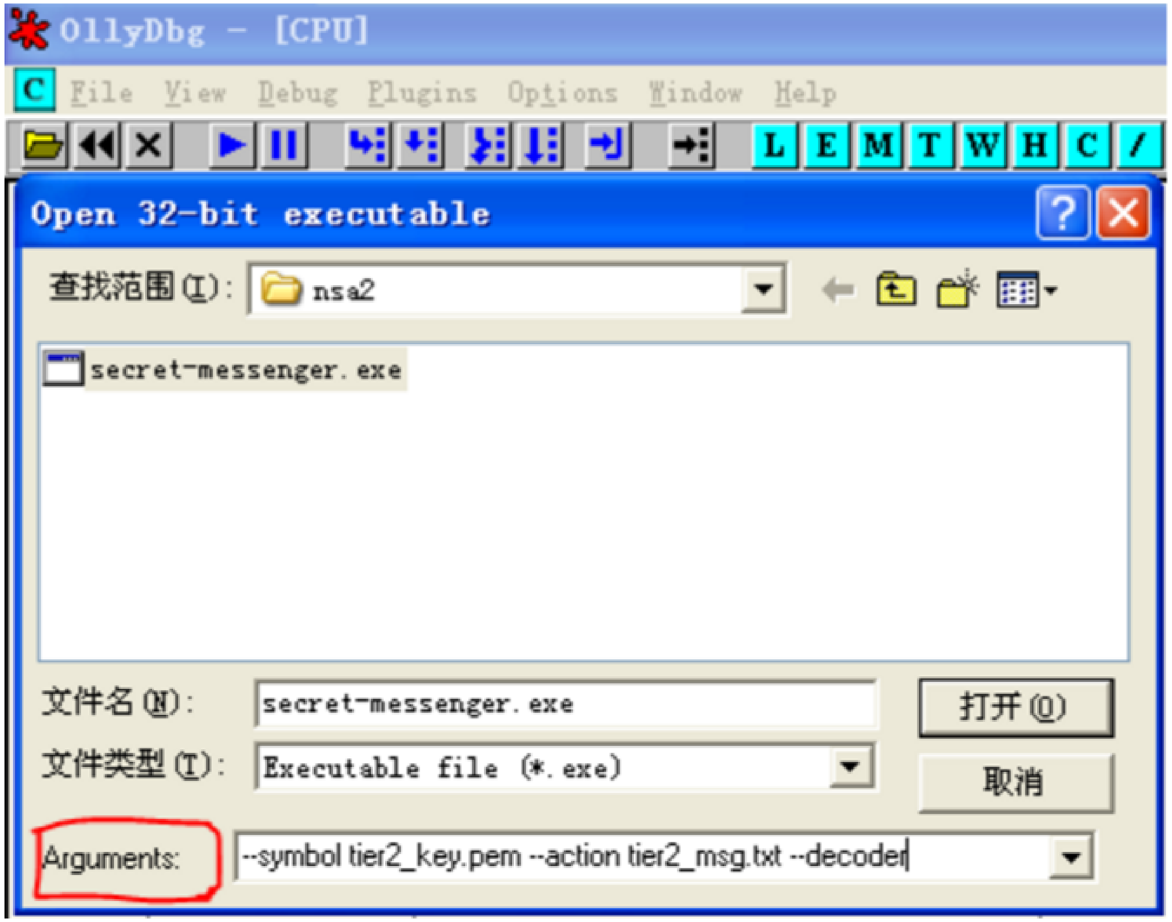


```
text:00401BE4                 mov     [ecx], eax
text:00401BE6                 movzx   eax, word ptr [ebx+5]
text:00401BEA                 mov     [esp+10h+var_10], eax
text:00401BED                 call    edi ; ntohs
text:00401BEF                 sub     esp, 4           ; netshort
text:00401BF2                 cmp     ax, 4756h
text:00401BF6                 jnz     loc_401ED3
text:00401BFC                 movzx   eax, word ptr [ebx+1]
text:00401C00                 mov     [esp+10h+var_10], eax
```

- How to test if this is the check?
- How to bypass the check?

Codebreaker Task 2: Bypass access limitation

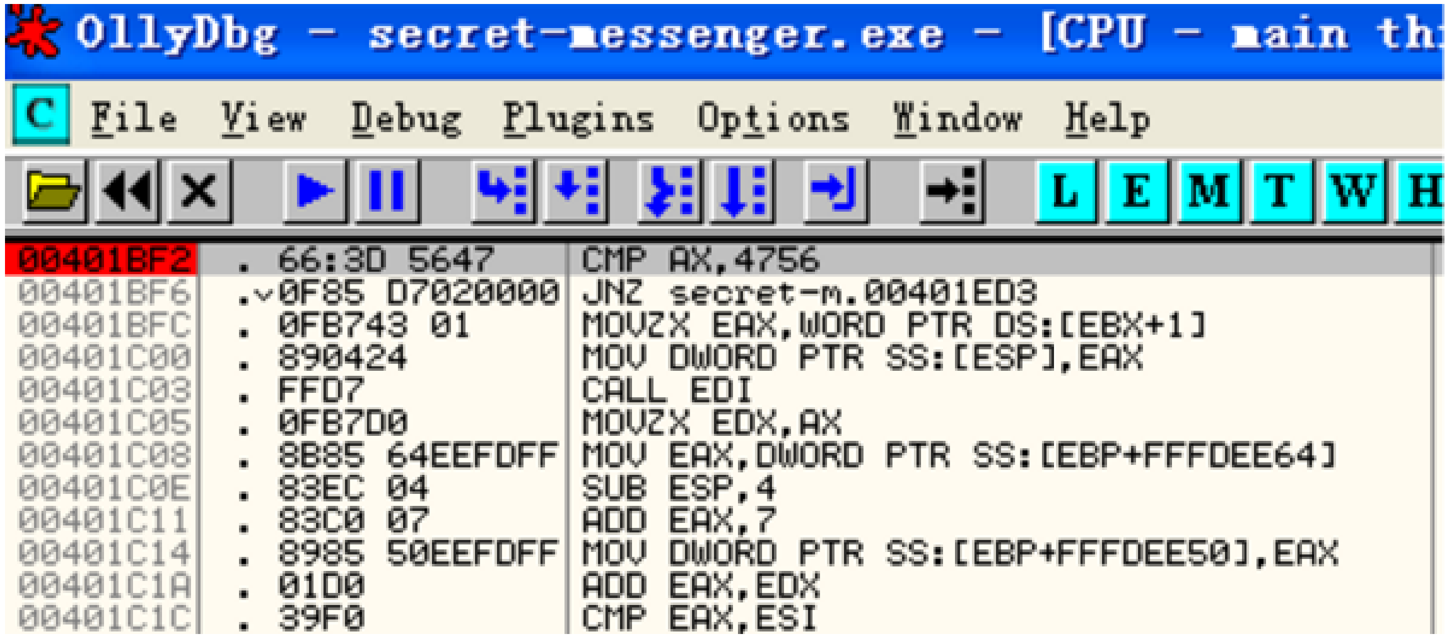
- In order to bypass this check as easily as possible, we can just modify the assembly code or change the specific flag during execution. Load the program with ollydbg:



文件名(N): secret-messenger.exe
文件类型(T): Executable file (*.exe)
Arguments: --symbol tier2_key.pem --action tier2_msg.txt --decoder

Codebreaker Task 2: Bypass access limitation

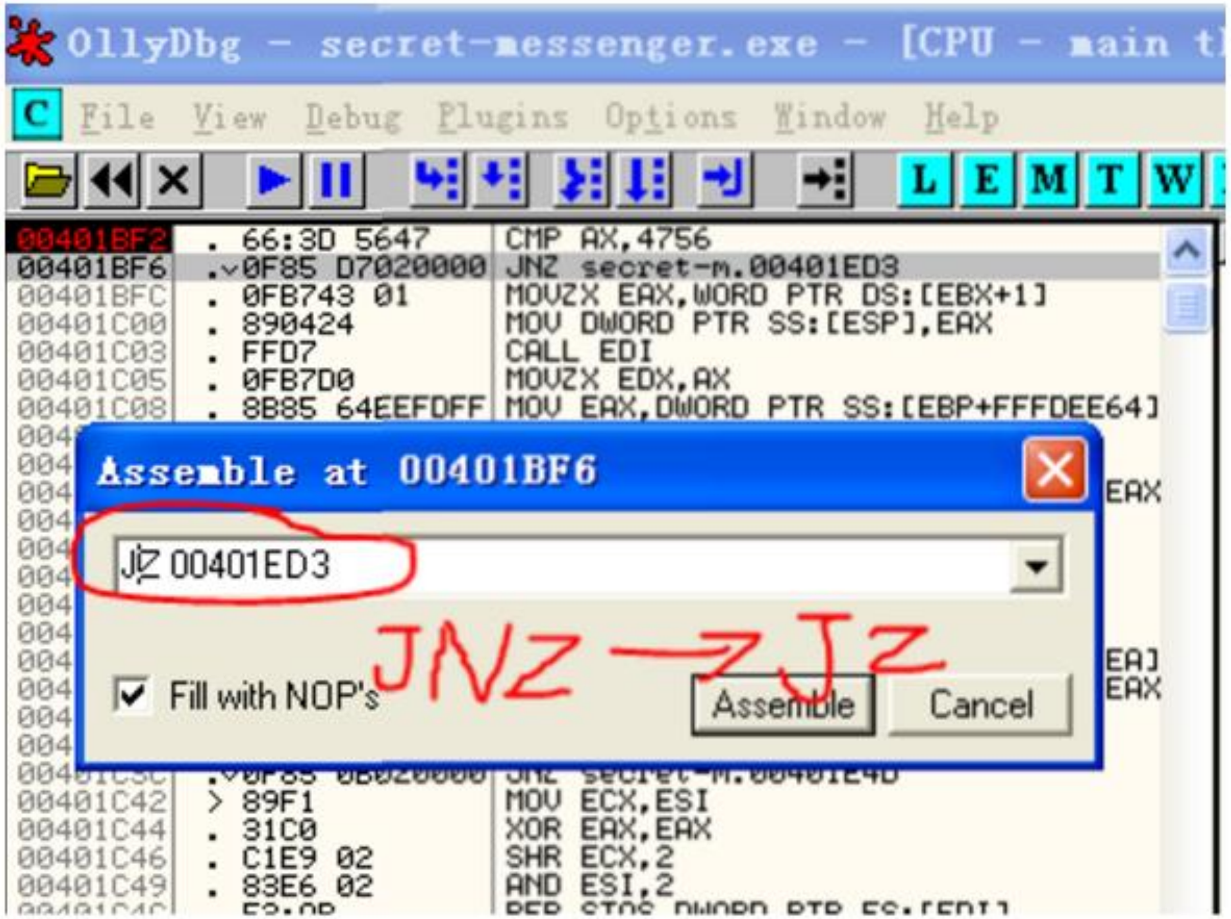
- Press CTRL+g go to the address 00401bf2, press F2 set breakpoint:


OllyDbg - secret-messenger.exe - [CPU - main th
C File View Debug Plugins Options Window Help
L E M T W H

```
00401BF2   .  66:3D 5647     CMP AX,4756
00401BF6   .v 0F85 D7020000  JNZ secret-m.00401ED3
00401BFC   .  0FB743 01      MOVZX EAX,WORD PTR DS:[EBX+1]
00401C00   .  890424         MOV DWORD PTR SS:[ESP],EAX
00401C03   .  FFD7           CALL EDI
00401C05   .  0FB7D0         MOVZX EDX,AX
00401C08   .  8B85 64EEFDFF  MOV EAX,DWORD PTR SS:[EBP+FFFDEE64]
00401C0E   .  83EC 04        SUB ESP,4
00401C11   .  83C0 07        ADD EAX,7
00401C14   .  8985 50EEFDFF  MOV DWORD PTR SS:[EBP+FFFDEE50],EAX
00401C1A   .  01D0           ADD EAX,EDX
00401C1C   .  39F0           CMP EAX,ESI
```

Codebreaker Task 2: Bypass access limitation

- Let's run the program and it will stop at this breakpoint, press F8 to run one more step and we modify the conditional JUMP instruction manually:

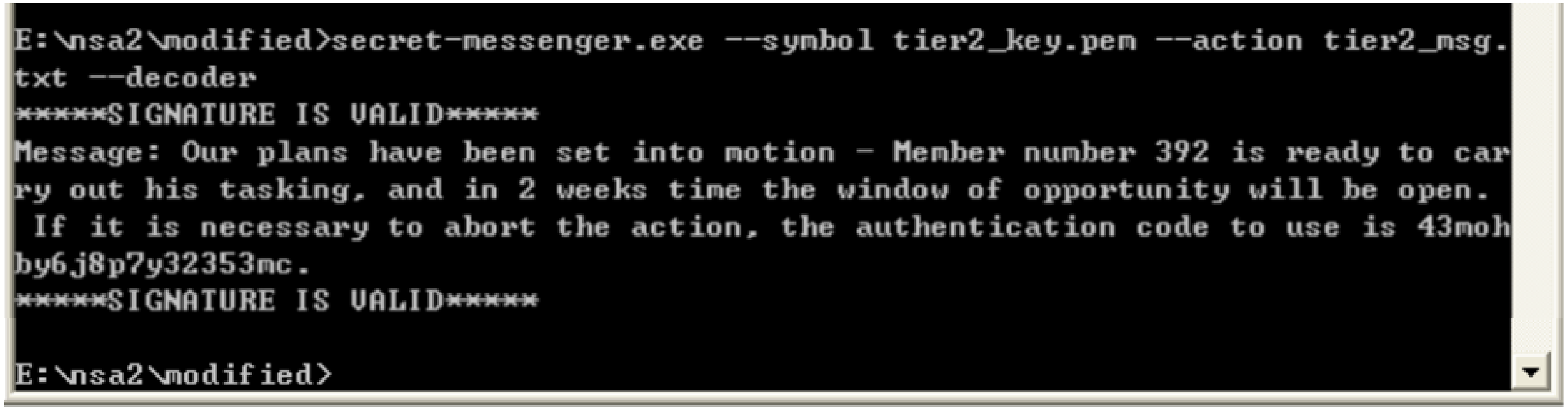

OllyDbg - secret-messenger.exe - [CPU - main t
File View Debug Plugins Options Window Help
L E M T W
Assemble at 00401BF6
Fill with NOP's
Assemble
Cancel
JNZ → JZ

```
00401BF2  . 66:3D 5647     CMP AX,4756
00401BF6  .v0F85 D7020000  JNZ secret-m.00401ED3
00401BFC  . 0FB743 01      MOVZX EAX,WORD PTR DS:[EBX+1]
00401C00  . 890424         MOV DWORD PTR SS:[ESP],EAX
00401C03  . FFD7           CALL EDI
00401C05  . 0FB7D0         MOVZX EDX,AX
00401C08  . 8B85 64EEFDFF  MOV EAX,DWORD PTR SS:[EBP+FFFDEE64]
00401C42  > 89F1           MOV ECX,ESI
00401C44  . 31C0           XOR EAX,EAX
00401C46  . C1E9 02        SHR ECX,2
00401C49  . 83E6 02        AND ESI,2
```

```
JZ 00401ED3
```

Codebreaker Task 2: Bypass access limitation

- Then, right click → copy to executable→ all modification, so we just saved our new program, let's try to run it:



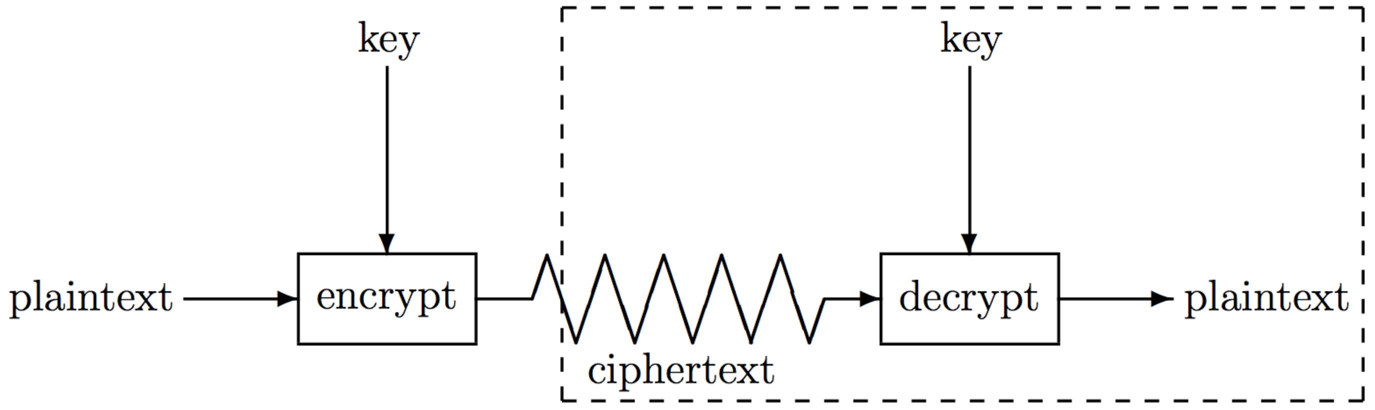
```
E:\nsa2\modified>secret-messenger.exe --symbol tier2_key.pem --action tier2_msg.
txt --decoder
*****SIGNATURE IS VALID*****
Message: Our plans have been set into motion - Member number 392 is ready to car
ry out his tasking, and in 2 weeks time the window of opportunity will be open.
 If it is necessary to abort the action, the authentication code to use is 43moh
by6j8p7y32353mc.
*****SIGNATURE IS VALID*****

E:\nsa2\modified>
```

Anti-reverse engineering

- **Basics:**
  - Turn off debug symbols (omit -g)
  - Strip other symbols (e.g. "strip" tool on *NIX)
  - Consider static linking (no external calls to standard libraries to trace)
- **Anti-disassembly:**
  - Encrypted or self-modifying code
  - Code riddled with junk that is jumped over
    - Can especially confuse x86 assemblers due to variable-length instructions
- **Anti-debugging:**
  - Identify if debugger is in use (effects on real time, use of debug registers, etc.) and act differently
  - Use threads in complex ways to get less deterministic behavior
- **Tamper resistance:**
  - Hash parts of own code/data and verify periodically
  - The verification code is also code, though…
- **Obfuscation:**
  - Include lots of unreachable code to increase work the reverse engineer must do

DRM: Digital Rights Management

- Attempt to restrict what users can do with *data they have* on a *computer they own*
- Almost every implementation looks like this:

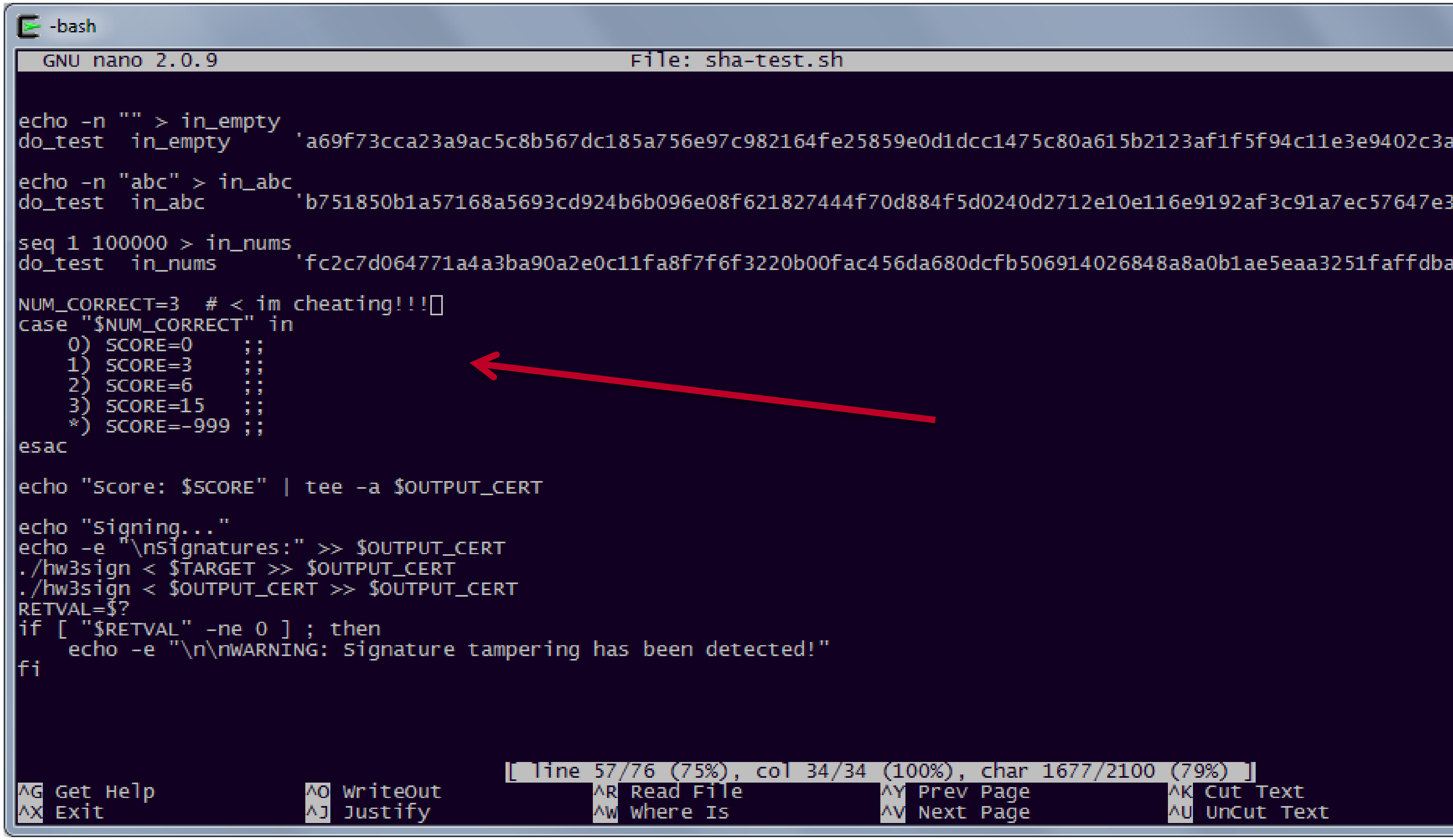


  - Customer gets everything in the dashed box
  - Problem?

Extra content

Example 3: Auto-grader for a homework question you didn't get

- Naïve attack: Just change the script

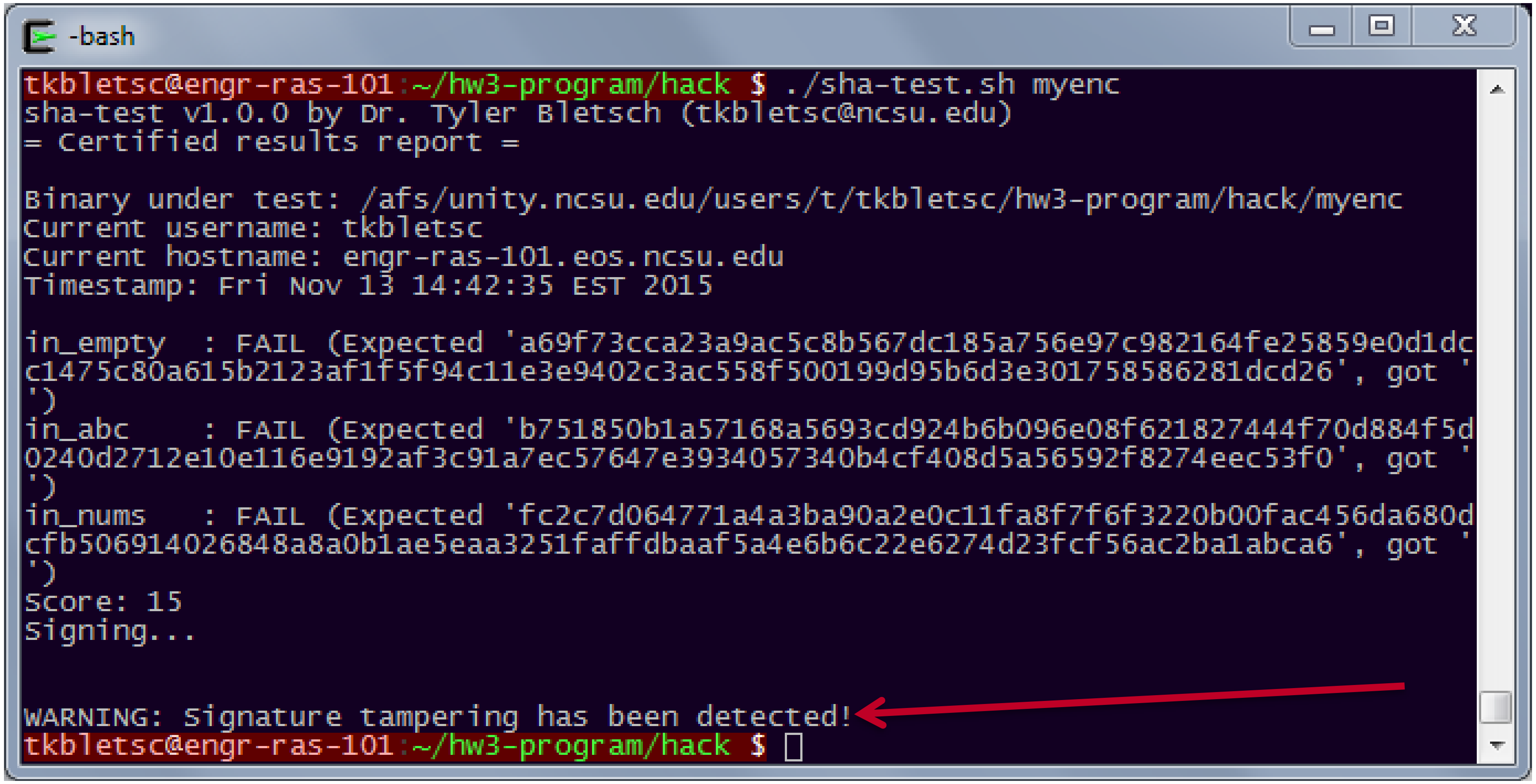


-bash

```
 GNU nano 2.0.9                                File: sha-test.sh


echo -n "" > in_empty
do_test  in_empty      'a69f73cca23a9ac5c8b567dc185a756e97c982164fe25859e0d1dcc1475c80a615b2123af1f5f94c11e3e9402c3a

echo -n "abc" > in_abc
do_test  in_abc        'b751850b1a57168a5693cd924b6b096e08f621827444f70d884f5d0240d2712e10e116e9192af3c91a7ec57647e3

seq 1 100000 > in_nums
do_test  in_nums       'fc2c7d064771a4a3ba90a2e0c11fa8f7f6f3220b00fac456da680dcfb506914026848a8a0b1ae5eaa3251faffdba

NUM_CORRECT=3  # < im cheating!!!
case "$NUM_CORRECT" in
    0) SCORE=0    ;;
    1) SCORE=3    ;;
    2) SCORE=6    ;;
    3) SCORE=15   ;;
    *) SCORE=-999 ;;
esac

echo "Score: $SCORE" | tee -a $OUTPUT_CERT

echo "Signing..."
echo -e "\nSignatures:" >> $OUTPUT_CERT
./hw3sign < $TARGET >> $OUTPUT_CERT
./hw3sign < $OUTPUT_CERT >> $OUTPUT_CERT
RETVAL=$?
if [ "$RETVAL" -ne 0 ] ; then
    echo -e "\n\nWARNING: Signature tampering has been detected!"
fi



                                               [ line 57/76 (75%), col 34/34 (100%), char 1677/2100 (79%) ]
^G Get Help          ^O WriteOut          ^R Read File          ^Y Prev Page          ^K Cut Text
^X Exit              ^J Justify           ^W Where Is           ^V Next Page          ^U UnCut Text
```

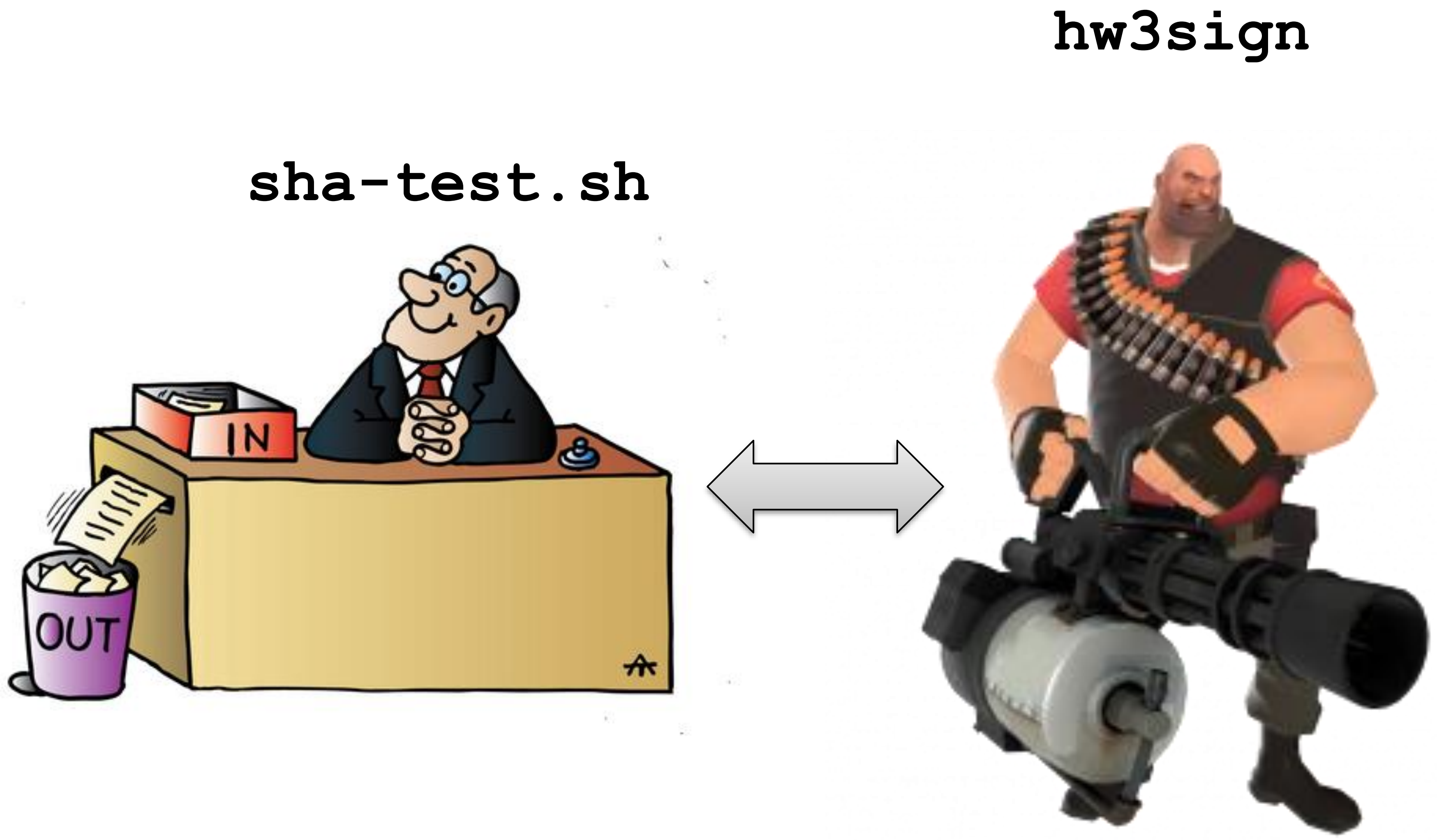
Example 3: Lost HW autograder

- Naïve attack: Just change the script
  - Failed: **`hw3sign`** must be checking it somehow!



```
-bash
tkbletsc@engr-ras-101:~/hw3-program/hack $ ./sha-test.sh myenc
sha-test v1.0.0 by Dr. Tyler Bletsch (tkbletsc@ncsu.edu)
= Certified results report =

Binary under test: /afs/unity.ncsu.edu/users/t/tkbletsc/hw3-program/hack/myenc
Current username: tkbletsc
Current hostname: engr-ras-101.eos.ncsu.edu
Timestamp: Fri Nov 13 14:42:35 EST 2015

in_empty  : FAIL (Expected 'a69f73cca23a9ac5c8b567dc185a756e97c982164fe25859e0d1dc
c1475c80a615b2123af1f5f94c11e3e9402c3ac558f500199d95b6d3e301758586281dcd26', got '
')
in_abc    : FAIL (Expected 'b751850b1a57168a5693cd924b6b096e08f621827444f70d884f5d
0240d2712e10e116e9192af3c91a7ec57647e3934057340b4cf408d5a56592f8274eec53f0', got '
')
in_nums   : FAIL (Expected 'fc2c7d064771a4a3ba90a2e0c11fa8f7f6f3220b00fac456da680d
cfb506914026848a8a0b1ae5eaa3251faffdbaaf5a4e6b6c22e6274d23fcf56ac2ba1abca6', got '
')
Score: 15
Signing...


WARNING: Signature tampering has been detected!
tkbletsc@engr-ras-101:~/hw3-program/hack $ 
```

Example 3: Lost HW autograder Topology



Example 3: Lost HW autograder

- Could look at behavior with **strace**:

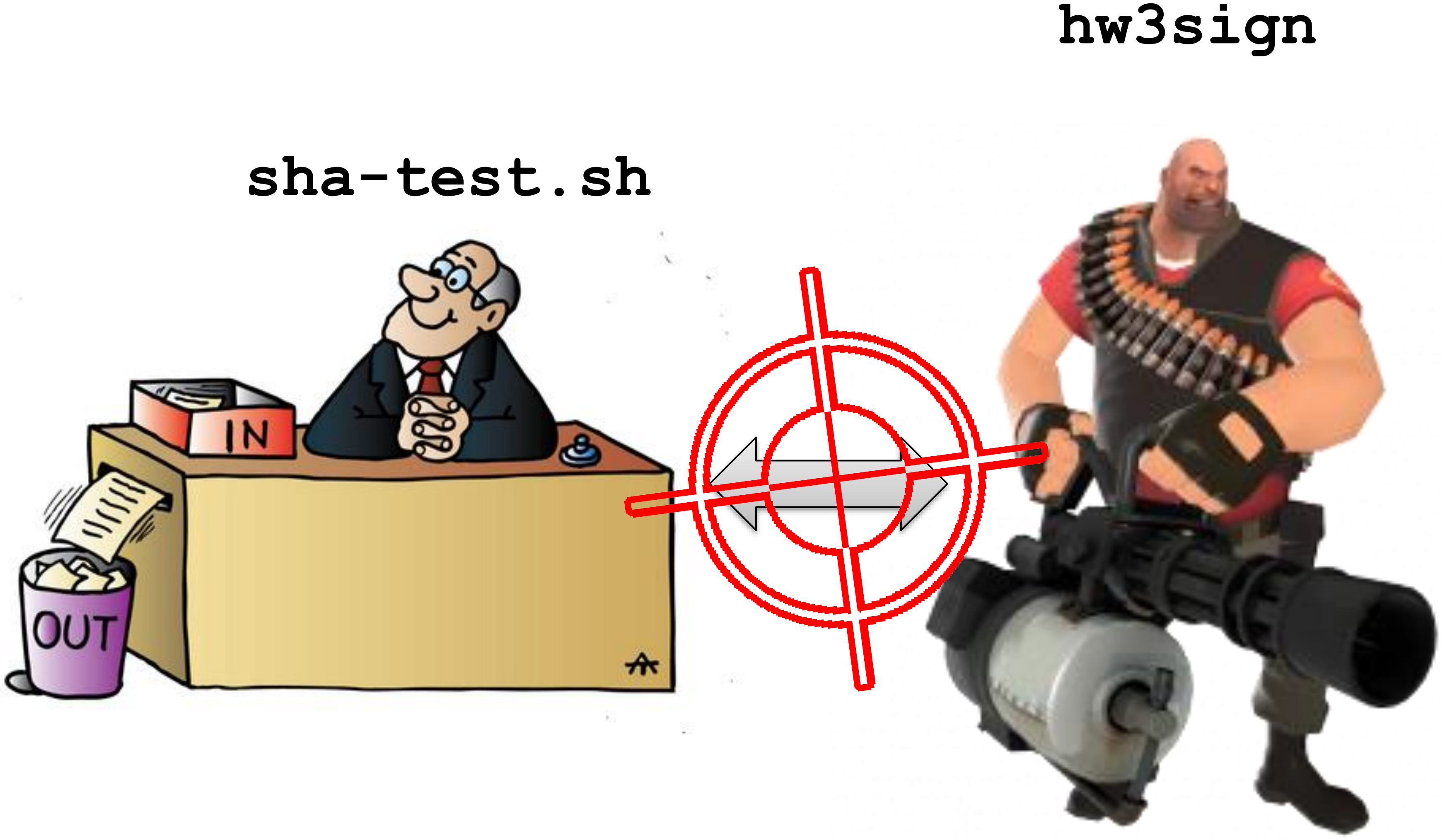
```
$ strace -f -o trace.txt ./sha-test.sh myenc
        ...
$ cat trace.txt
4127  execve("./sha-test.sh", ["./sha-test.sh", "myenc"], [/* 46 vars */]) = 0
4127  brk(0)                                      = 0x1700000
4127  mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0)
    = 0x7f55d5a17000
4127  access("/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or
    directory)
4127  open("/etc/ld.so.cache", O_RDONLY) = 3
4127  fstat(3, {st_mode=S_IFREG|0644, st_size=210058, ...}) = 0
4127  mmap(NULL, 210058, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f55d59e3000
4127 close(3)                                     = 0
        ...
```

- But `hw3sign` never appears to open `sha-test.sh`:

```
$ grep open trace.txt | grep sha-test.sh
4127  open("./sha-test.sh", O_RDONLY)    = 3
```

  - This one line is from when `sha-test.sh` itself is started
  - There's more mystery here that I'll leave to you…

Example 3: Lost HW autograder
Best place to attack?



Example 3: Lost HW autograder

- Two past successful student attacks
- **Black box attack:**
  - hw3sign signs the binary, then the certificate itself
  - What if we ask it to “test” a doctored certificate as a binary – it will sign it for us! No understanding needed!
- **Chameleon attack:**
  - Add cheating to sha-test.sh; also add code to copy a legit sha-test.sh over itself before doing signings
  - Malicious behavior occurs then hides before check occurs
  - Example of a TOCTOU attack (Time-Of-Check/Time-Of-Use)!