black hat
ASIA 2019

MODERN SECURE BOOT ATTACKS: BYPASSING HARDWARE ROOT OF TRUST FROM SOFTWARE

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@matrosov

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Doing Security REsearch since 1997

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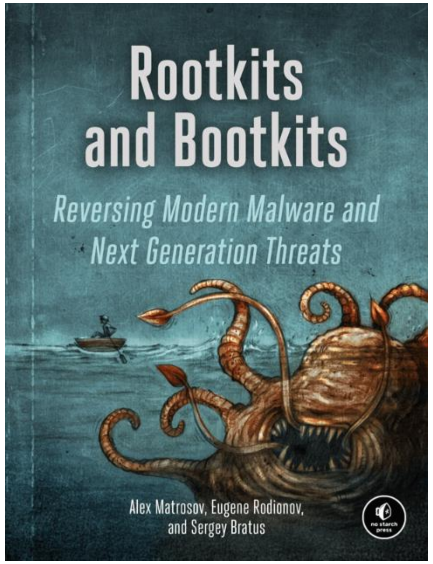
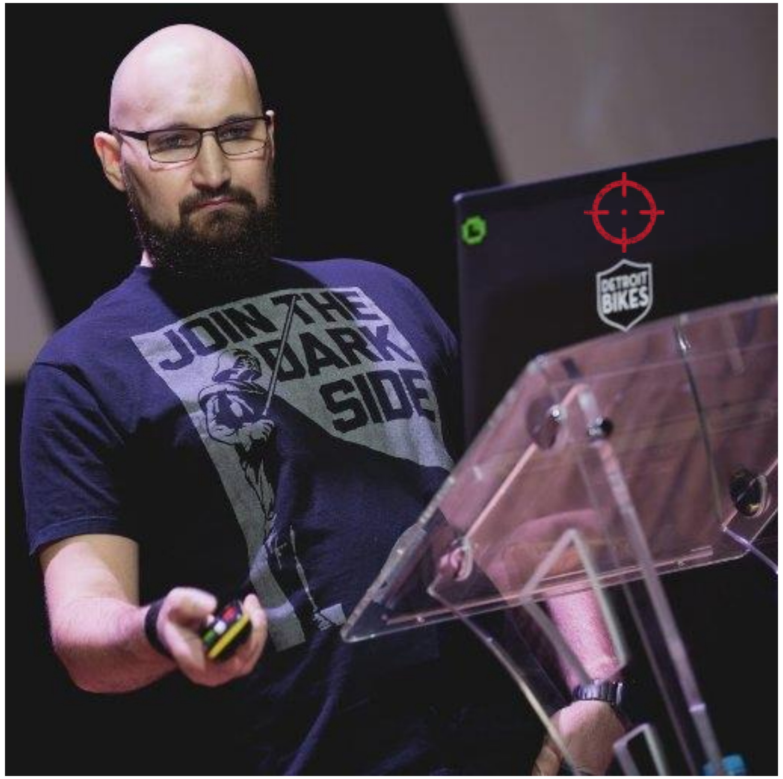

Rootkits and Bootkits
Reversing Modern Malware and Next Generation Threats
Alex Matrosov, Eugene Rodionov, and Sergey Bratus
no starch press



@matrosov

> "Follow in the footsteps of professionals with a record of discovering advanced malware."
> — Rodrigo Rubira Branco

Rootkits and Bootkits will teach you how to understand and counter sophisticated, advanced threats buried deep in a machine's boot process or UEFI firmware.

With the aid of numerous case studies and professional research from three of the world's leading security experts, you'll trace malware development over time from rootkits like TDL3 to present-day UEFI implants and examine how they infect a system, persist through reboot, and evade security software. As you inspect and dissect real malware, you'll learn:

- How Windows boots—including 32-bit, 64-bit, and UEFI mode—and where to find vulnerabilities
- The details of boot process security mechanisms like Secure Boot, including an overview of Virtual Secure Mode (VSM) and Device Guard
- Reverse engineering and forensic techniques for analyzing real malware, including bootkits like Rovnix/Carberp, Gapz, TDL4, and the infamous rootkits TDL3 and Festi
- How to perform static and dynamic analysis using emulation and tools like Bochs and IDA Pro
- How to better understand the delivery stage of threats against BIOS and UEFI firmware in order to create detection capabilities
- How to use virtualization tools like VMware Workstation to reverse engineer bootkits and the Intel Chipsec tool to dig into forensic analysis

Cybercrime syndicates and malicious actors will continue to write ever more persistent and covert attacks, but the game is not lost. Explore the cutting edge of malware analysis with *Rootkits and Bootkits*.

About the Authors

Alex Matrosov is an Offensive Security Research Lead at NVIDIA with over 20 years of experience in reverse engineering, advanced malware analysis, firmware security, and exploitation techniques. **Eugene Rodionov**, PhD, is a Security Researcher at Intel working in BIOS security for Client Platforms. **Sergey Bratus** is a Research Associate Professor in the Computer Science Department at Dartmouth College. He has previously worked at BBN Technologies on natural language processing research.

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Rootkits and Bootkits

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Rootkits and Bootkits

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and Sergey Bratus

Foreword by Rodrigo Rubira Branco

no starch press

⌖Disclaimer⌖

I don’t speak for my employer.
All opinions, information here
are mine responsibilities
😈 (include all bad jokes) 😈

REsearch Target

Lenovo P50

Gigabyte/ASUS/MSI
don’t care about
security
and
it’s too easy targets

- What is Hardware Root of Trust?

😈 **Boot Guard Bypass** 😈

- Computrace Never Dies
  - ✓ OS Enable/Disable
  - ✓ Permanent Disabling is a joke o_O

- SMI over WMI is too evil 😈
  - ✓ SMM communications without ring-0
  - ✓ WMI-based fileless FW rootkits?

- EC is not a security boundary 🤦

(*EC – Embedded Controller)

Hardware Root of Trust

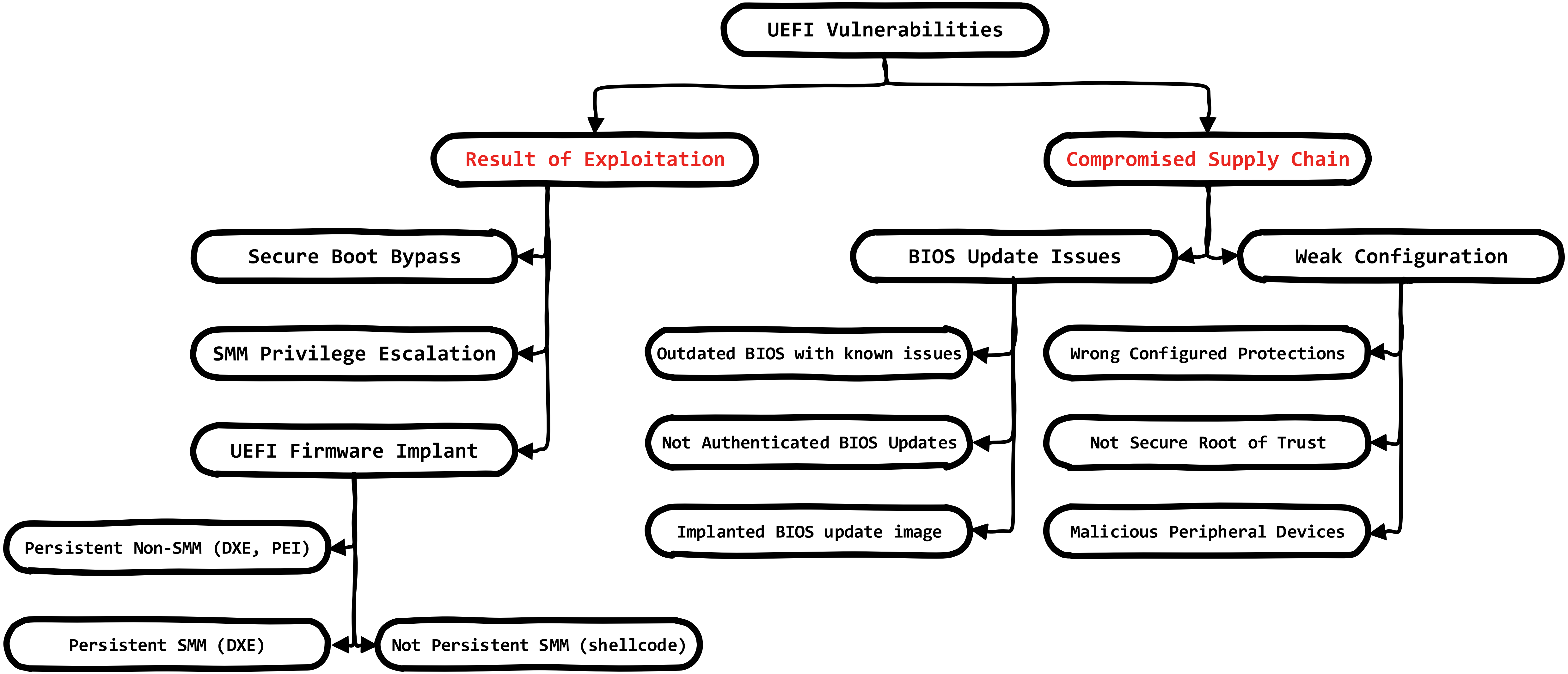
WTF Hardware Root of Trust?

- Root of Trust baked in pure Hardware?
  - ✓ Cant be extracted/modified from software (developed in RTL)?
    - ✓ not flexible with OEM’s
    - ✓ hard to support in the field (updates and etc.)
    - ✓ hard to implement secure way to cooperate with firmware on the same chip

- In the most of the cases Hardware Root of Trust it’s a mix between firmware and locked in the FUSE value or by specific bit.

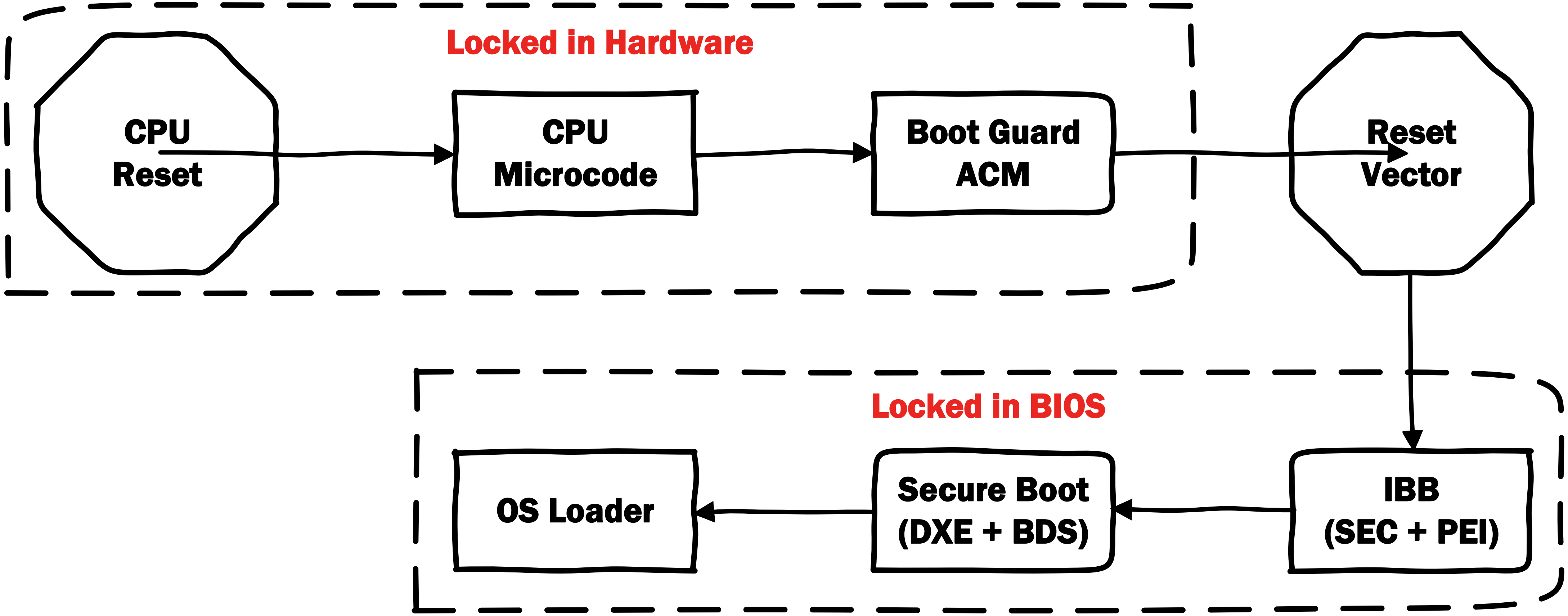
- Secure state transition between hardware and firmware is hard. It’s always something missing.

UEFI vulns classification



https://medium.com/@matrosov/uefi-vulnerabilities-classification-4897596e60af

Boot Guard: Boot Flow in Perfect World



Locked in Hardware

CPU Reset

CPU Microcode

Boot Guard ACM

Reset Vector

Locked in BIOS

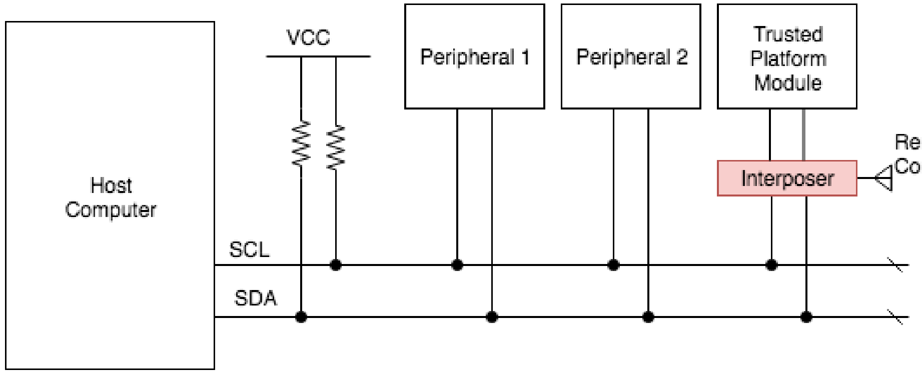
IBB (SEC + PEI)

Secure Boot (DXE + BDS)

OS Loader

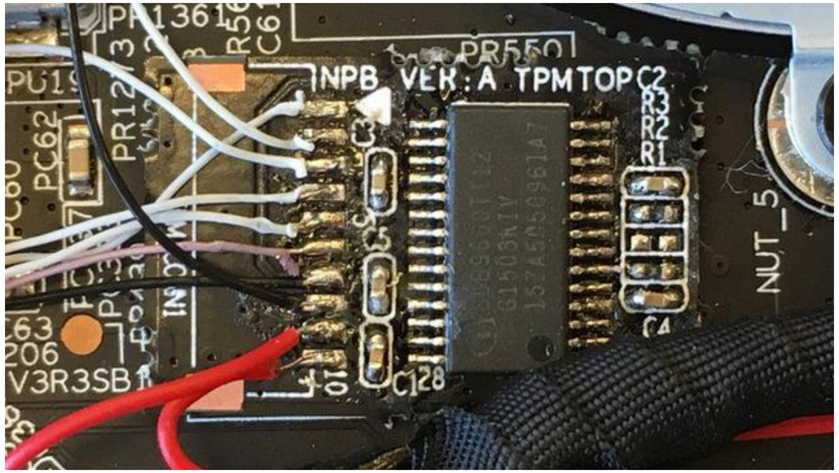
HW Root of Trust: TPM is broken?

@uffeux

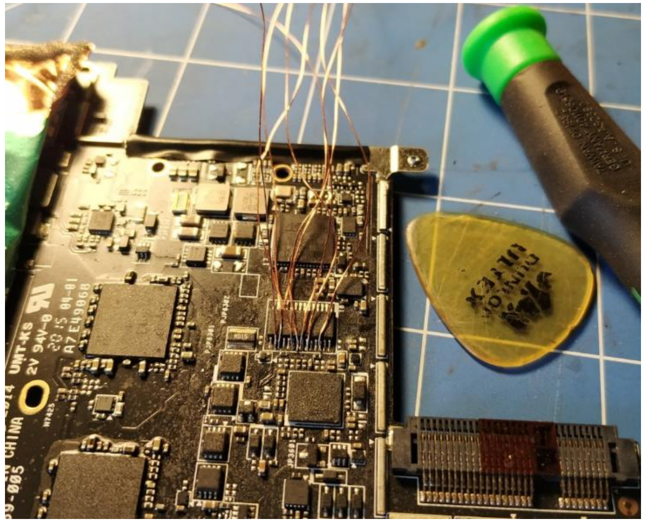


https://github.com/nccgroup/TPMGenie

@qrs

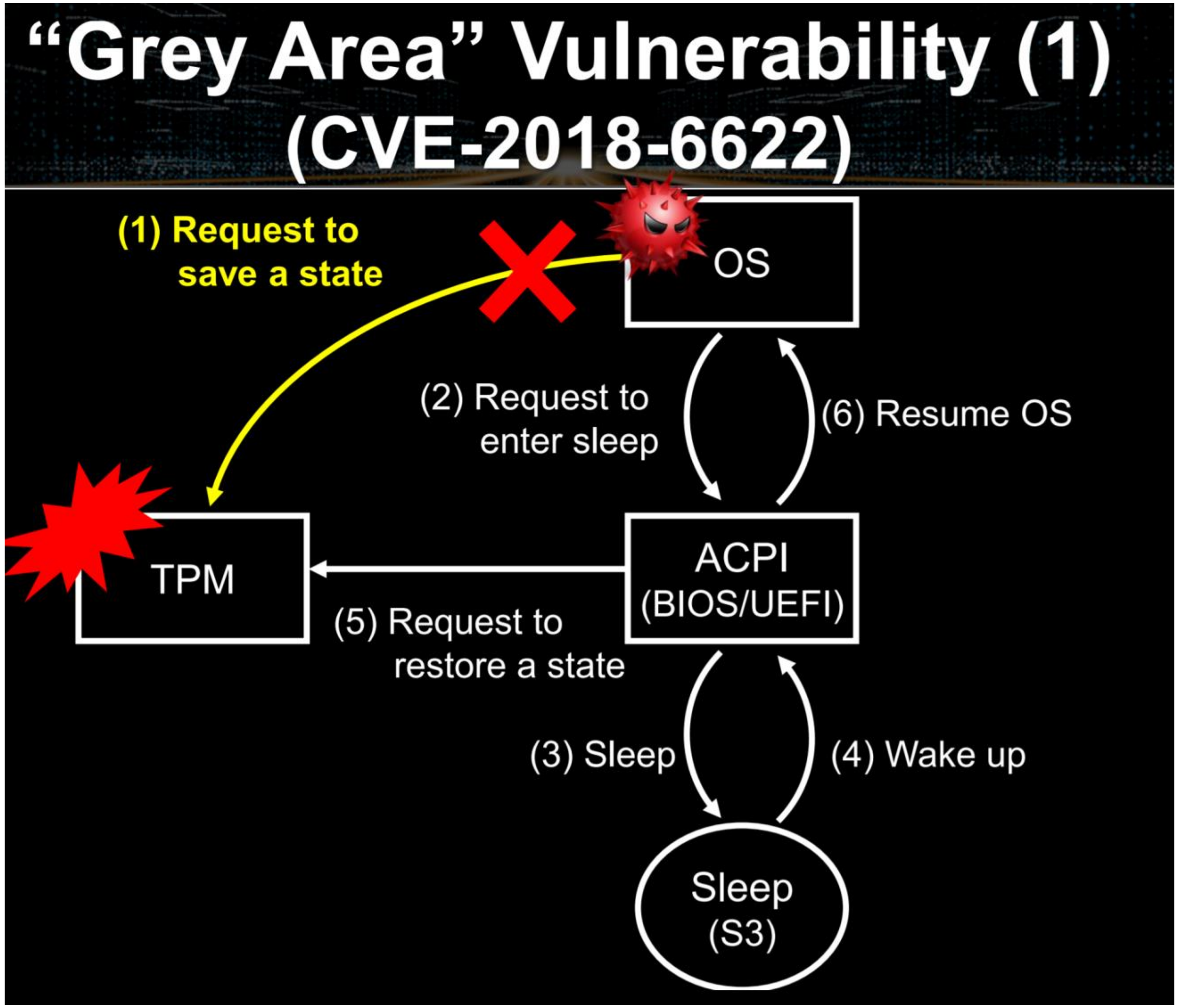


@0x446f49



https://pulsesecurity.co.nz/articles/TPM-sniffing

HW Root of Trust: TPM is broken?

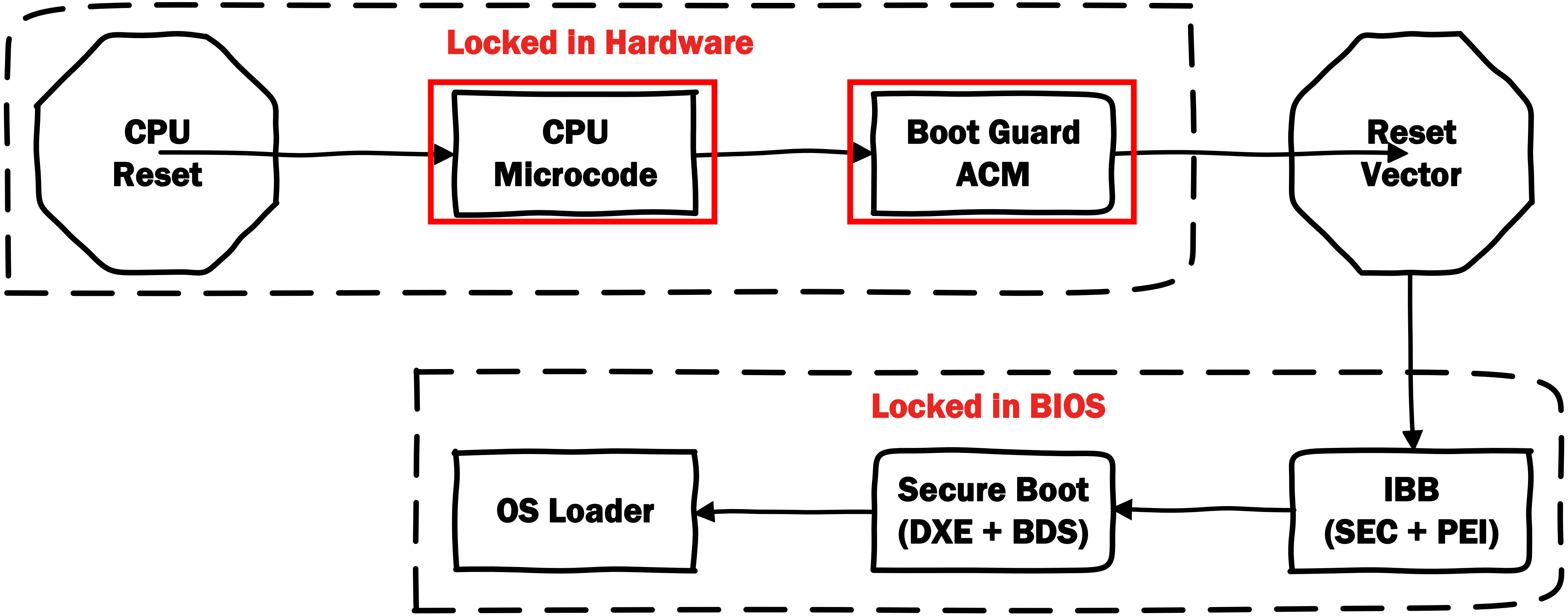


“Grey Area” Vulnerability (1) (CVE-2018-6622)

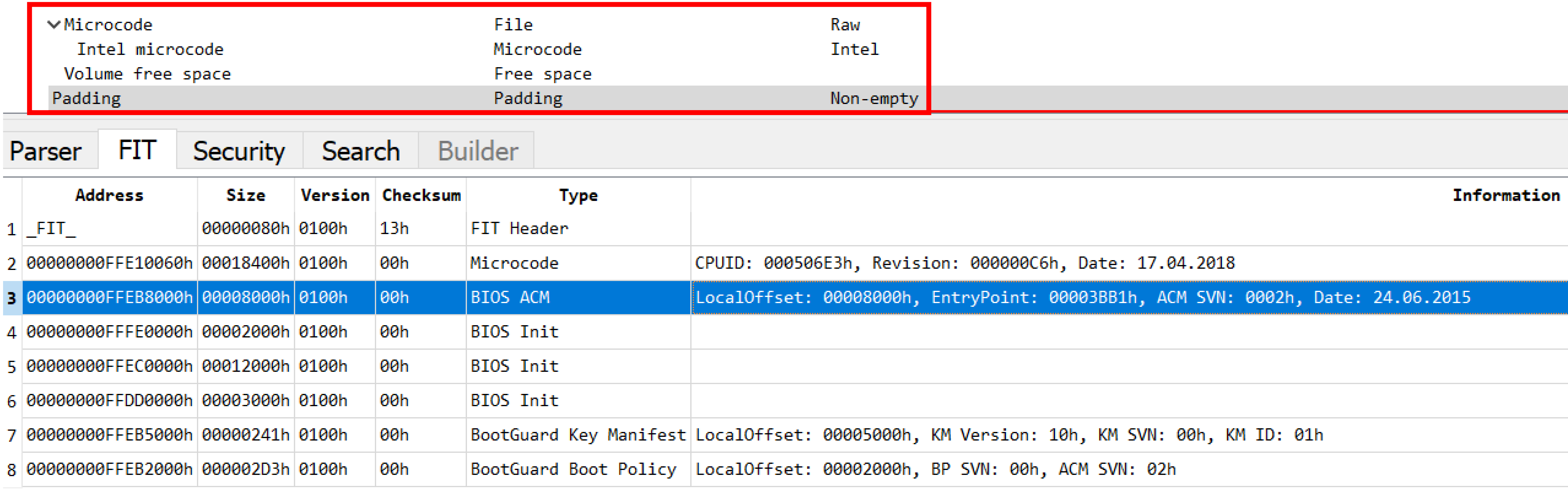
(1) Request to save a state
OS
(2) Request to enter sleep
(6) Resume OS
TPM
ACPI (BIOS/UEFI)
(5) Request to restore a state
(3) Sleep
(4) Wake up
Sleep (S3)

https://i.blackhat.com/asia-19/Thu-March-28/bh-asia-Seunghun-Finally-I-Can-Sleep-Tonight-Catching-Sleep-Mode-Vulnerabilities-of-the-TPM-with-the-Napper.pdf

Boot Guard: Boot Flow in REAL World



But world is not perfect :)



Microcode	File	Raw
Intel microcode	Microcode	Intel
Volume free space	Free space	
Padding	Padding	Non-empty

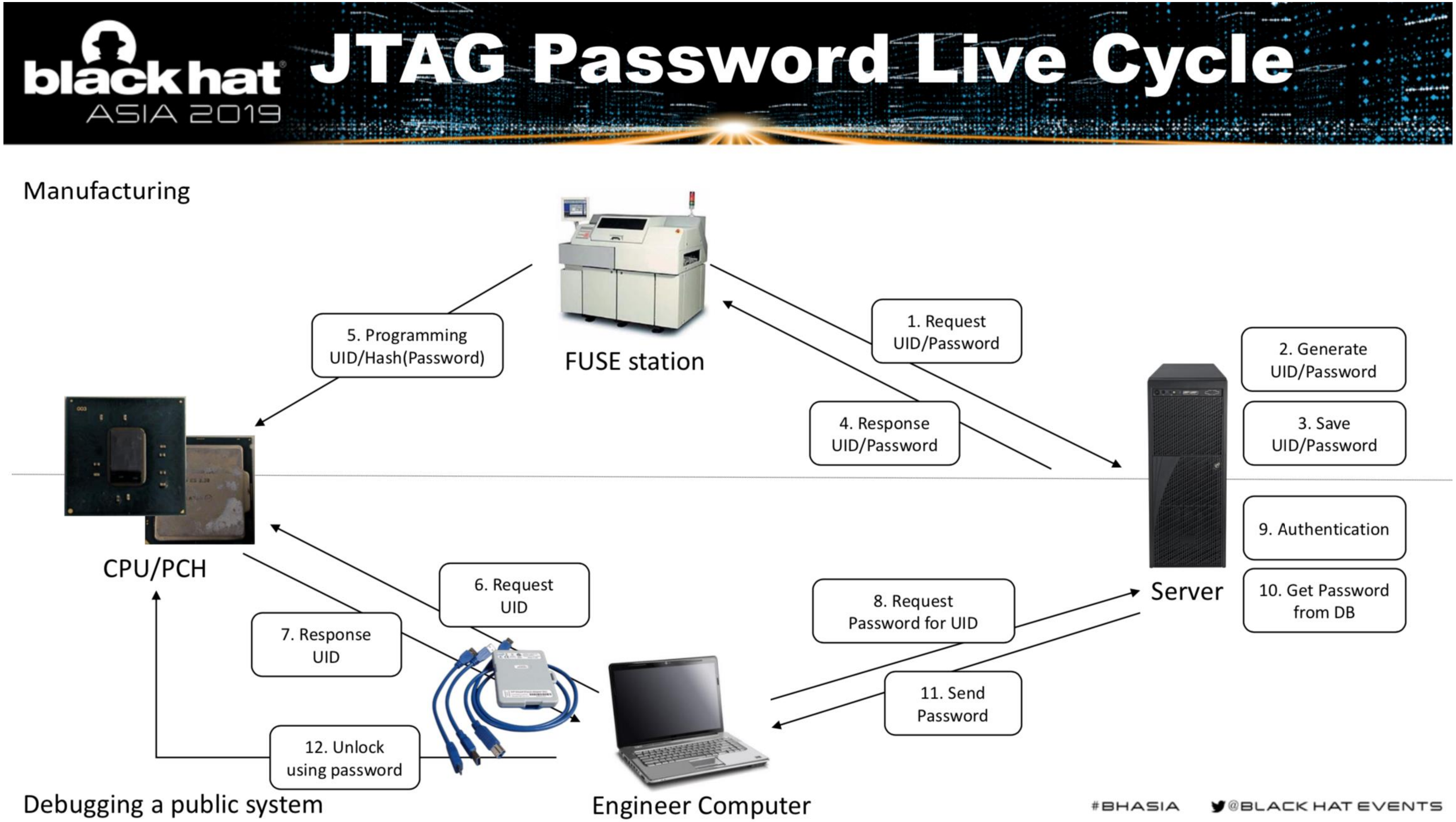
	Address	Size	Version	Checksum	Type	Information
1	_FIT_	00000080h	0100h	13h	FIT Header	
2	00000000FFE10060h	00018400h	0100h	00h	Microcode	CPUID: 000506E3h, Revision: 000000C6h, Date: 17.04.2018
3	00000000FFEB8000h	00008000h	0100h	00h	BIOS ACM	LocalOffset: 00008000h, EntryPoint: 00003BB1h, ACM SVN: 0002h, Date: 24.06.2015
4	00000000FFFE0000h	00002000h	0100h	00h	BIOS Init	
5	00000000FFEC0000h	00012000h	0100h	00h	BIOS Init	
6	00000000FFDD0000h	00003000h	0100h	00h	BIOS Init	
7	00000000FFEB5000h	00000241h	0100h	00h	BootGuard Key Manifest	LocalOffset: 00005000h, KM Version: 10h, KM SVN: 00h, KM ID: 01h
8	00000000FFEB2000h	000002D3h	0100h	00h	BootGuard Boot Policy	LocalOffset: 00002000h, BP SVN: 00h, ACM SVN: 02h

https://github.com/LongSoft/UEFITool

Why don’t lock everything in HW?

- ➢ **Hardware not flexible and expensive**
  - ✓ **OEM’s don’t like locked secrets (supply chain)**
  - ✓ **The cost for the vulnerabilities very high (no updates)**
- ➢ **All the vendors reducing HW locked secrets**
  - ✓ **Even one locked bit in HW allow to say about HW locked feature**
  - ✓ **Mix Hardware + Firmware is common in actual implementation**

HW manufacturing supply chain is very complex



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JTAG Password Live Cycle

Manufacturing

FUSE station

1. Request UID/Password

2. Generate UID/Password

3. Save UID/Password

4. Response UID/Password

5. Programming UID/Hash(Password)

CPU/PCH

Server

6. Request UID

7. Response UID

8. Request Password for UID

9. Authentication

10. Get Password from DB

11. Send Password

12. Unlock using password

Engineer Computer

Debugging a public system

#BHASIA @BLACK HAT EVENTS

https://www.blackhat.com/asia-19/briefings/schedule/index.html#intel-visa-through-the-rabbit-hole-13513

Intel Boot Guard:

New Ways to Bypass

oops I did it again

How HW-based Root of Trust become a SW

- Recovery mode is evil 😈

- Secure transition Chain of Trust on different boot stages is ~~slow~~ hard

- In most of the cases without hard reset Root of Trust moves to pure software for performance

- Enterprise hardware need remote update tools

- Nobody use Intel BIOS Guard even Intel :)

How H a SW

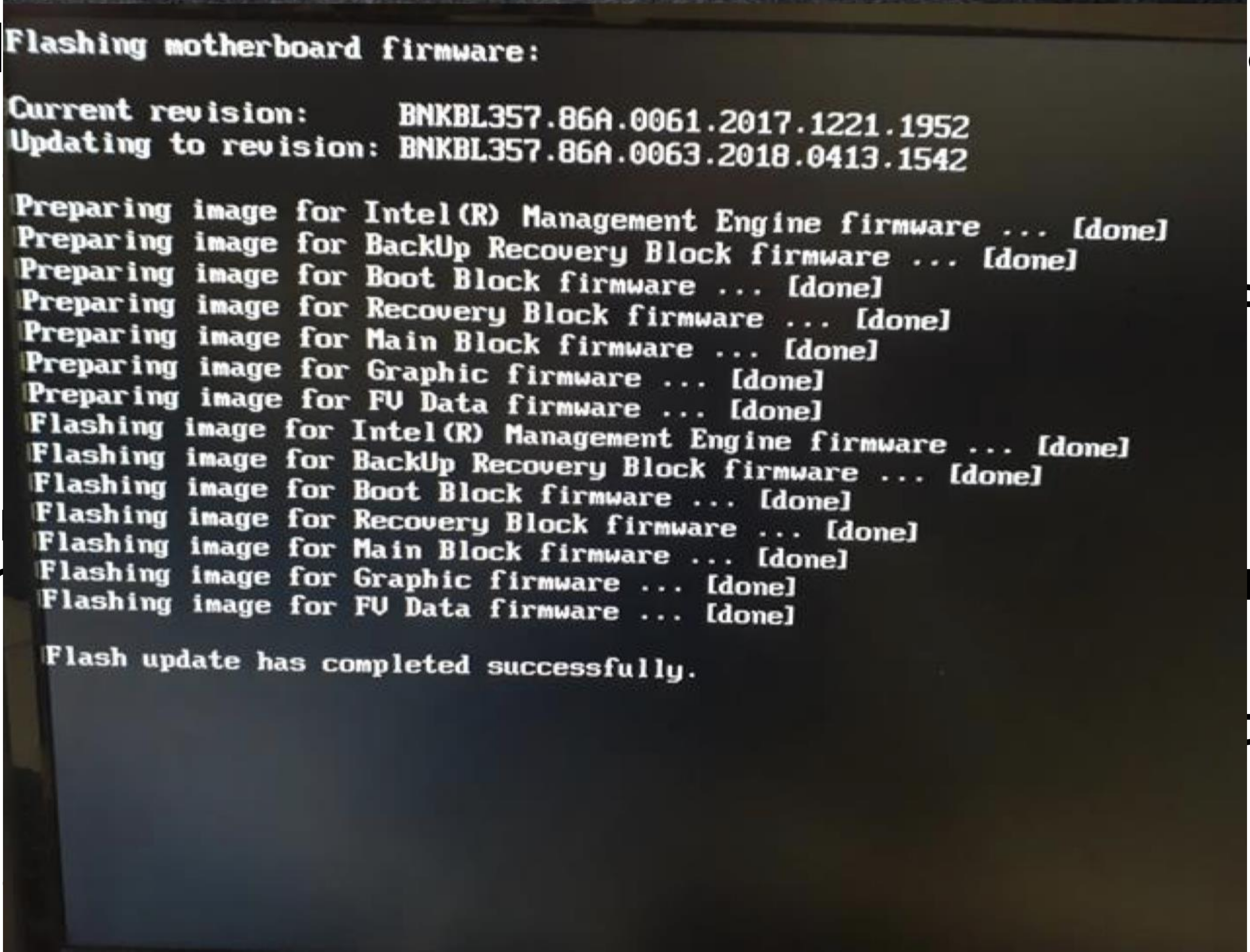
- Rec

- Sec ferent boot

- In Root of Tr rmance

- Ent tools

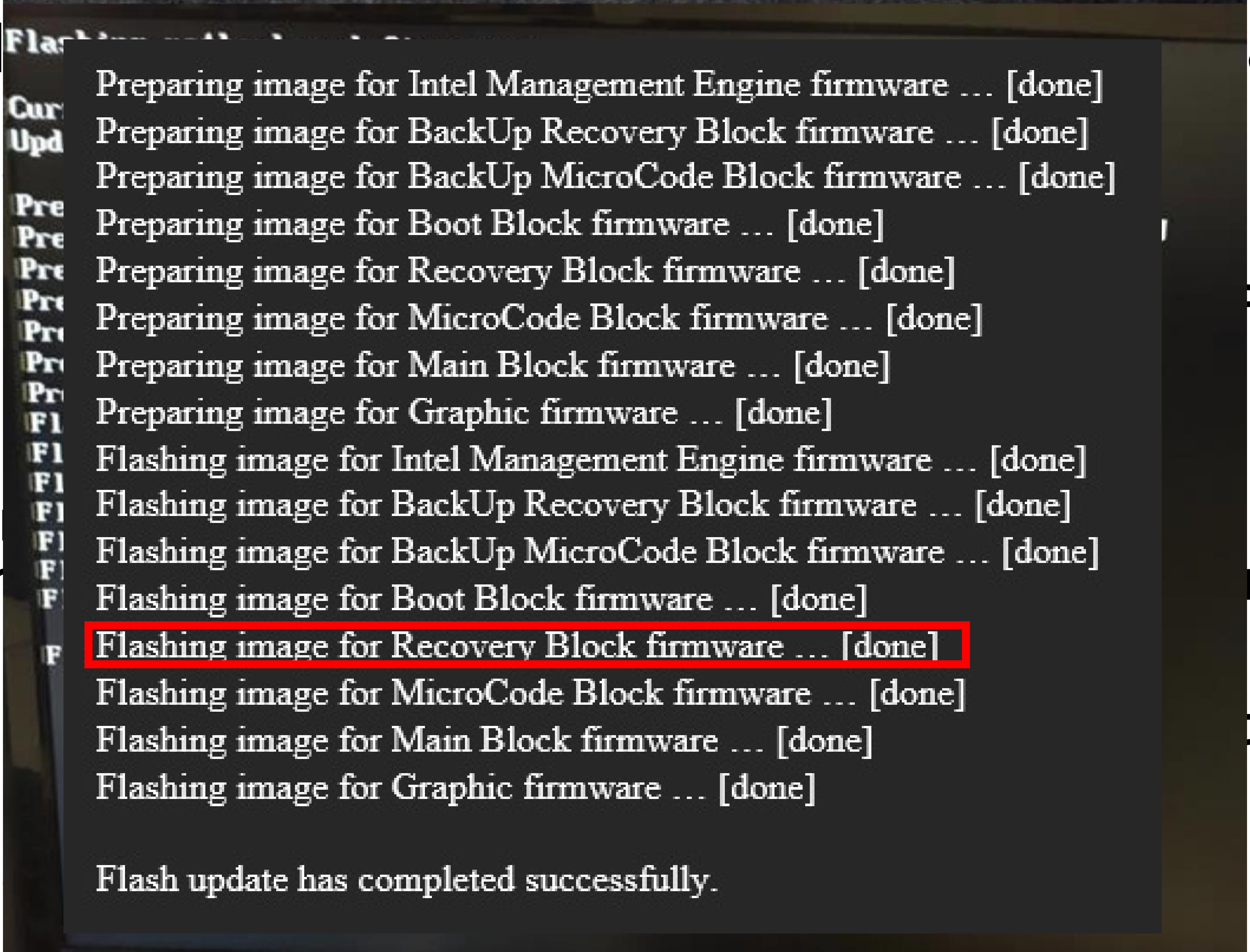
- Nob)



```
Flashing motherboard firmware:

Current revision:     BNKBL357.86A.0061.2017.1221.1952
Updating to revision: BNKBL357.86A.0063.2018.0413.1542

Preparing image for Intel(R) Management Engine firmware ... [done]
Preparing image for BackUp Recovery Block firmware ... [done]
Preparing image for Boot Block firmware ... [done]
Preparing image for Recovery Block firmware ... [done]
Preparing image for Main Block firmware ... [done]
Preparing image for Graphic firmware ... [done]
Preparing image for FV Data firmware ... [done]
Flashing image for Intel(R) Management Engine firmware ... [done]
Flashing image for BackUp Recovery Block firmware ... [done]
Flashing image for Boot Block firmware ... [done]
Flashing image for Recovery Block firmware ... [done]
Flashing image for Main Block firmware ... [done]
Flashing image for Graphic firmware ... [done]
Flashing image for FV Data firmware ... [done]

Flash update has completed successfully.
```

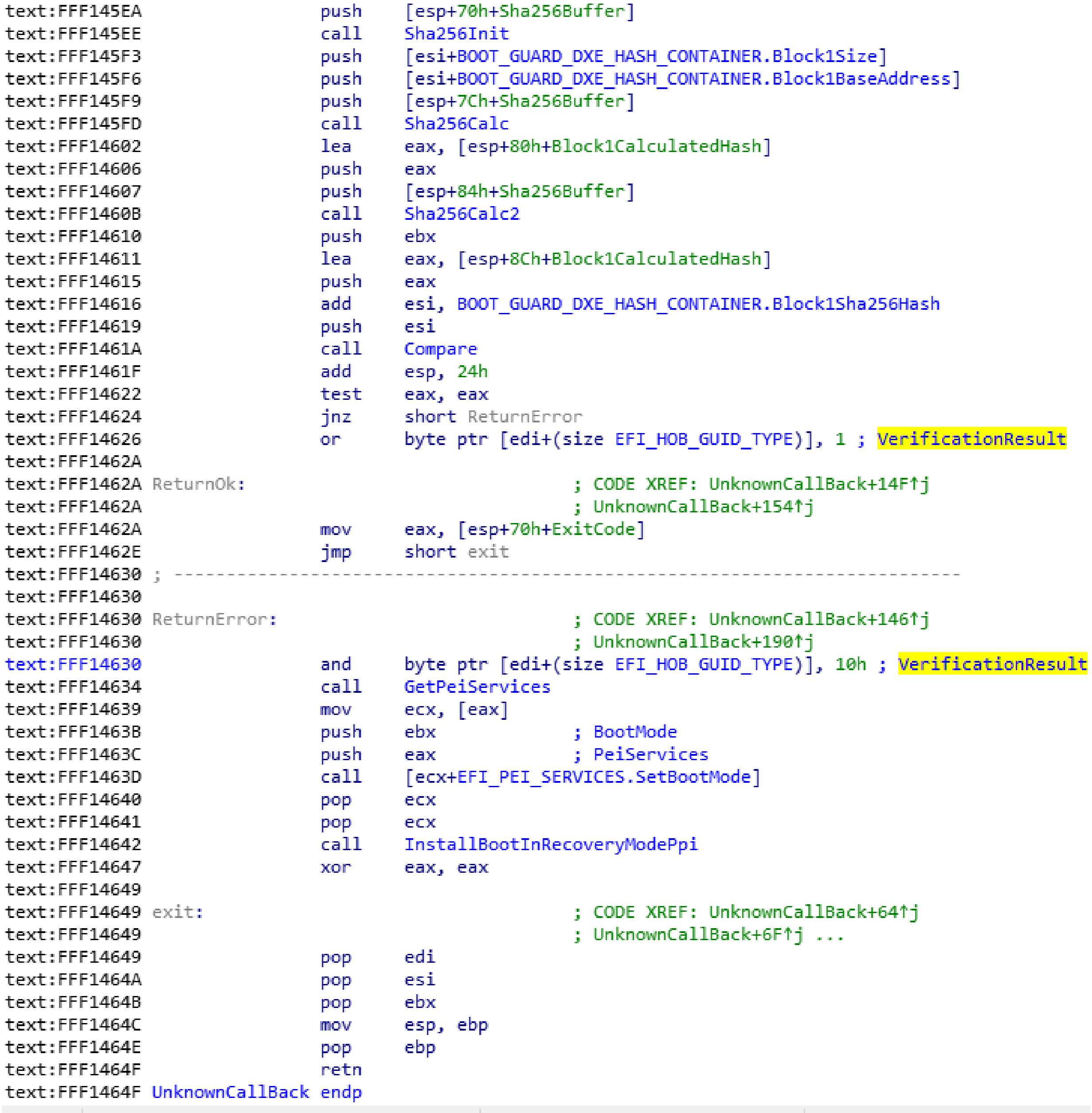
How H a SW

- Rec
- Sec ferent
  boot
- In Root
  of Tr rmance
- Ent tools
- Nob)



```
Preparing image for Intel Management Engine firmware ... [done]
Preparing image for BackUp Recovery Block firmware ... [done]
Preparing image for BackUp MicroCode Block firmware ... [done]
Preparing image for Boot Block firmware ... [done]
Preparing image for Recovery Block firmware ... [done]
Preparing image for MicroCode Block firmware ... [done]
Preparing image for Main Block firmware ... [done]
Preparing image for Graphic firmware ... [done]
Flashing image for Intel Management Engine firmware ... [done]
Flashing image for BackUp Recovery Block firmware ... [done]
Flashing image for BackUp MicroCode Block firmware ... [done]
Flashing image for Boot Block firmware ... [done]
Flashing image for Recovery Block firmware ... [done]
Flashing image for MicroCode Block firmware ... [done]
Flashing image for Main Block firmware ... [done]
Flashing image for Graphic firmware ... [done]

Flash update has completed successfully.
```

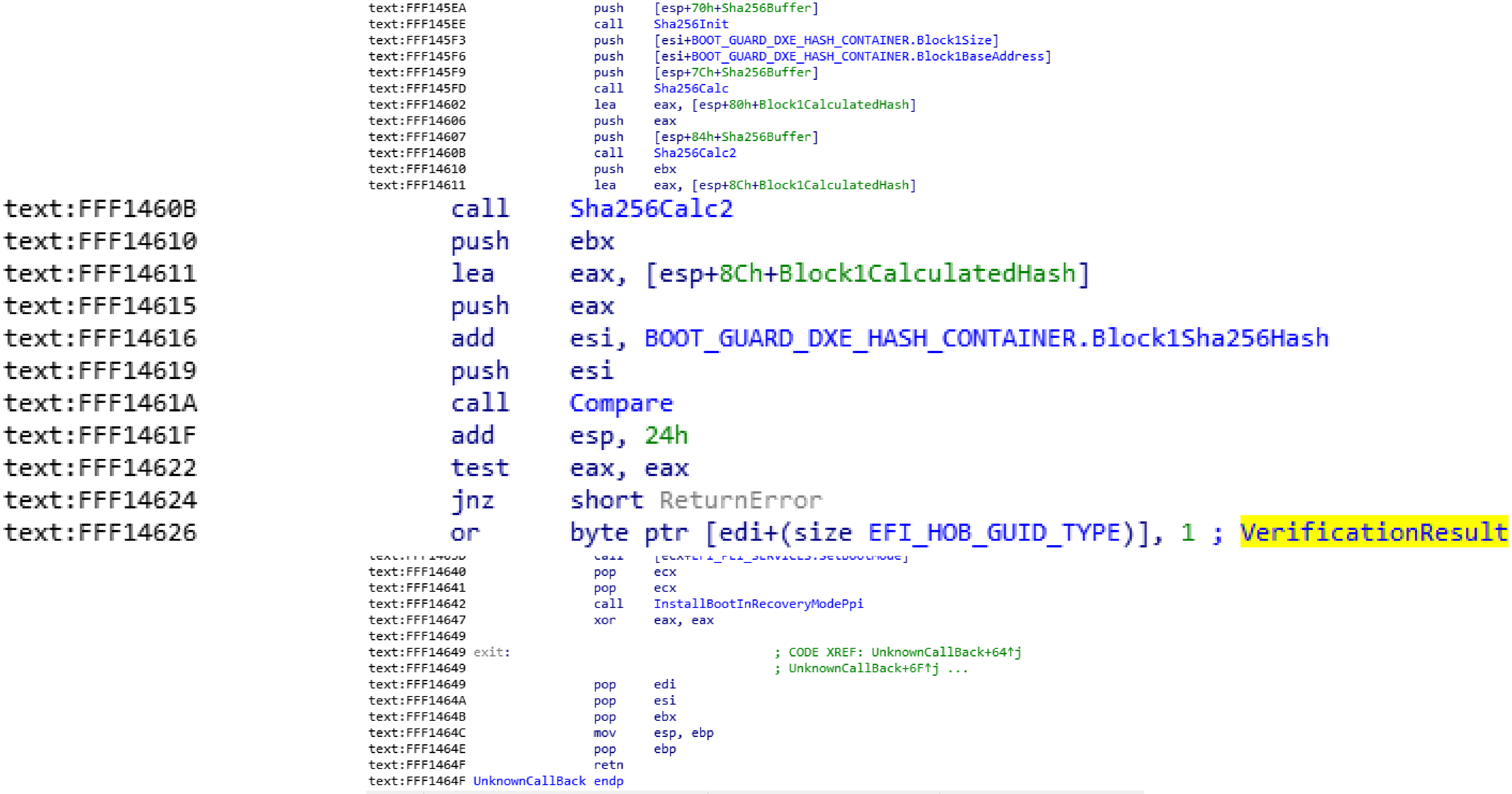
How HW-based Root of Trust become a SW



```
text:FFF145EA                 push    [esp+70h+Sha256Buffer]
text:FFF145EE                 call    Sha256Init
text:FFF145F3                 push    [esi+BOOT_GUARD_DXE_HASH_CONTAINER.Block1Size]
text:FFF145F6                 push    [esi+BOOT_GUARD_DXE_HASH_CONTAINER.Block1BaseAddress]
text:FFF145F9                 push    [esp+7Ch+Sha256Buffer]
text:FFF145FD                 call    Sha256Calc
text:FFF14602                 lea     eax, [esp+80h+Block1CalculatedHash]
text:FFF14606                 push    eax
text:FFF14607                 push    [esp+84h+Sha256Buffer]
text:FFF1460B                 call    Sha256Calc2
text:FFF14610                 push    ebx
text:FFF14611                 lea     eax, [esp+8Ch+Block1CalculatedHash]
text:FFF14615                 push    eax
text:FFF14616                 add     esi, BOOT_GUARD_DXE_HASH_CONTAINER.Block1Sha256Hash
text:FFF14619                 push    esi
text:FFF1461A                 call    Compare
text:FFF1461F                 add     esp, 24h
text:FFF14622                 test    eax, eax
text:FFF14624                 jnz     short ReturnError
text:FFF14626                 or      byte ptr [edi+(size EFI_HOB_GUID_TYPE)], 1 ; VerificationResult
text:FFF1462A
text:FFF1462A ReturnOk:                               ; CODE XREF: UnknownCallBack+14F↑j
text:FFF1462A                                         ; UnknownCallBack+154↑j
text:FFF1462A                 mov     eax, [esp+70h+ExitCode]
text:FFF1462E                 jmp     short exit
text:FFF14630 ; ---------------------------------------------------------------------------
text:FFF14630
text:FFF14630 ReturnError:                            ; CODE XREF: UnknownCallBack+146↑j
text:FFF14630                                         ; UnknownCallBack+190↑j
text:FFF14630                 and     byte ptr [edi+(size EFI_HOB_GUID_TYPE)], 10h ; VerificationResult
text:FFF14634                 call    GetPeiServices
text:FFF14639                 mov     ecx, [eax]
text:FFF1463B                 push    ebx             ; BootMode
text:FFF1463C                 push    eax             ; PeiServices
text:FFF1463D                 call    [ecx+EFI_PEI_SERVICES.SetBootMode]
text:FFF14640                 pop     ecx
text:FFF14641                 pop     ecx
text:FFF14642                 call    InstallBootInRecoveryModePpi
text:FFF14647                 xor     eax, eax
text:FFF14649
text:FFF14649 exit:                                   ; CODE XREF: UnknownCallBack+64↑j
text:FFF14649                                         ; UnknownCallBack+6F↑j ...
text:FFF14649                 pop     edi
text:FFF1464A                 pop     esi
text:FFF1464B                 pop     ebx
text:FFF1464C                 mov     esp, ebp
text:FFF1464E                 pop     ebp
text:FFF1464F                 retn
text:FFF1464F UnknownCallBack endp
```

https://embedi.org/blog/nuclear-explotion/

How HW-based Root of Trust become a SW



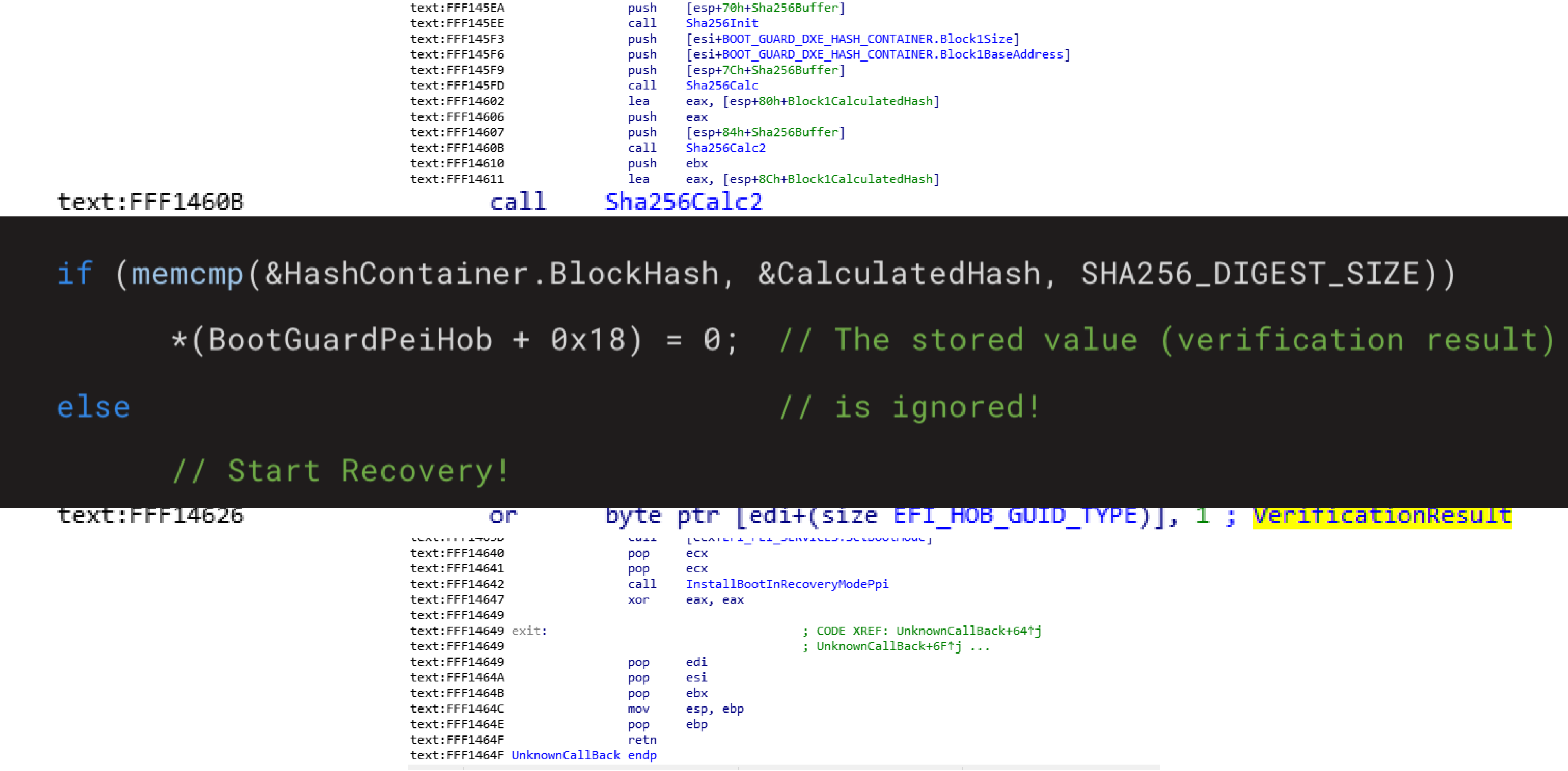
```
text:FFF145EA                 push    [esp+70h+Sha256Buffer]
text:FFF145EE                 call    Sha256Init
text:FFF145F3                 push    [esi+BOOT_GUARD_DXE_HASH_CONTAINER.Block1Size]
text:FFF145F6                 push    [esi+BOOT_GUARD_DXE_HASH_CONTAINER.Block1BaseAddress]
text:FFF145F9                 push    [esp+7Ch+Sha256Buffer]
text:FFF145FD                 call    Sha256Calc
text:FFF14602                 lea     eax, [esp+80h+Block1CalculatedHash]
text:FFF14606                 push    eax
text:FFF14607                 push    [esp+84h+Sha256Buffer]
text:FFF1460B                 call    Sha256Calc2
text:FFF14610                 push    ebx
text:FFF14611                 lea     eax, [esp+8Ch+Block1CalculatedHash]
```

```
text:FFF1460B           call    Sha256Calc2
text:FFF14610           push    ebx
text:FFF14611           lea     eax, [esp+8Ch+Block1CalculatedHash]
text:FFF14615           push    eax
text:FFF14616           add     esi, BOOT_GUARD_DXE_HASH_CONTAINER.Block1Sha256Hash
text:FFF14619           push    esi
text:FFF1461A           call    Compare
text:FFF1461F           add     esp, 24h
text:FFF14622           test    eax, eax
text:FFF14624           jnz     short ReturnError
text:FFF14626           or      byte ptr [edi+(size EFI_HOB_GUID_TYPE)], 1 ; VerificationResult
```

```
text:FFF1463D                 call    [ecx+EFI_PEI_SERVICES.SetBootMode]
text:FFF14640                 pop     ecx
text:FFF14641                 pop     ecx
text:FFF14642                 call    InstallBootInRecoveryModePpi
text:FFF14647                 xor     eax, eax
text:FFF14649
text:FFF14649 exit:                                   ; CODE XREF: UnknownCallBack+64↑j
text:FFF14649                                         ; UnknownCallBack+6F↑j ...
text:FFF14649                 pop     edi
text:FFF1464A                 pop     esi
text:FFF1464B                 pop     ebx
text:FFF1464C                 mov     esp, ebp
text:FFF1464E                 pop     ebp
text:FFF1464F                 retn
text:FFF1464F UnknownCallBack endp
```

https://embedi.org/blog/nuclear-explotion/

How HW-based Root of Trust become a SW



```
text:FFF145EA                 push    [esp+70h+Sha256Buffer]
text:FFF145EE                 call    Sha256Init
text:FFF145F3                 push    [esi+BOOT_GUARD_DXE_HASH_CONTAINER.Block1Size]
text:FFF145F6                 push    [esi+BOOT_GUARD_DXE_HASH_CONTAINER.Block1BaseAddress]
text:FFF145F9                 push    [esp+7Ch+Sha256Buffer]
text:FFF145FD                 call    Sha256Calc
text:FFF14602                 lea     eax, [esp+80h+Block1CalculatedHash]
text:FFF14606                 push    eax
text:FFF14607                 push    [esp+84h+Sha256Buffer]
text:FFF1460B                 call    Sha256Calc2
text:FFF14610                 push    ebx
text:FFF14611                 lea     eax, [esp+8Ch+Block1CalculatedHash]
```

```
text:FFF1460B                 call    Sha256Calc2
```

```
if (memcmp(&HashContainer.BlockHash, &CalculatedHash, SHA256_DIGEST_SIZE))
    *(BootGuardPeiHob + 0x18) = 0;  // The stored value (verification result)
else                                // is ignored!
    // Start Recovery!
```

```
text:FFF14626                 or      byte ptr [edi+(size EFI_HOB_GUID_TYPE)], 1 ; VerificationResult
```

```
text:FFF1463D                 call    [ecx+EFI_PEI_SERVICES.SetBootMode]
text:FFF14640                 pop     ecx
text:FFF14641                 pop     ecx
text:FFF14642                 call    InstallBootInRecoveryModePpi
text:FFF14647                 xor     eax, eax
text:FFF14649
text:FFF14649 exit:                                   ; CODE XREF: UnknownCallBack+64↑j
text:FFF14649                                         ; UnknownCallBack+6F↑j ...
text:FFF14649                 pop     edi
text:FFF1464A                 pop     esi
text:FFF1464B                 pop     ebx
text:FFF1464C                 mov     esp, ebp
text:FFF1464E                 pop     ebp
text:FFF1464F                 retn
text:FFF1464F UnknownCallBack endp
```

https://embedi.org/blog/nuclear-explotion/

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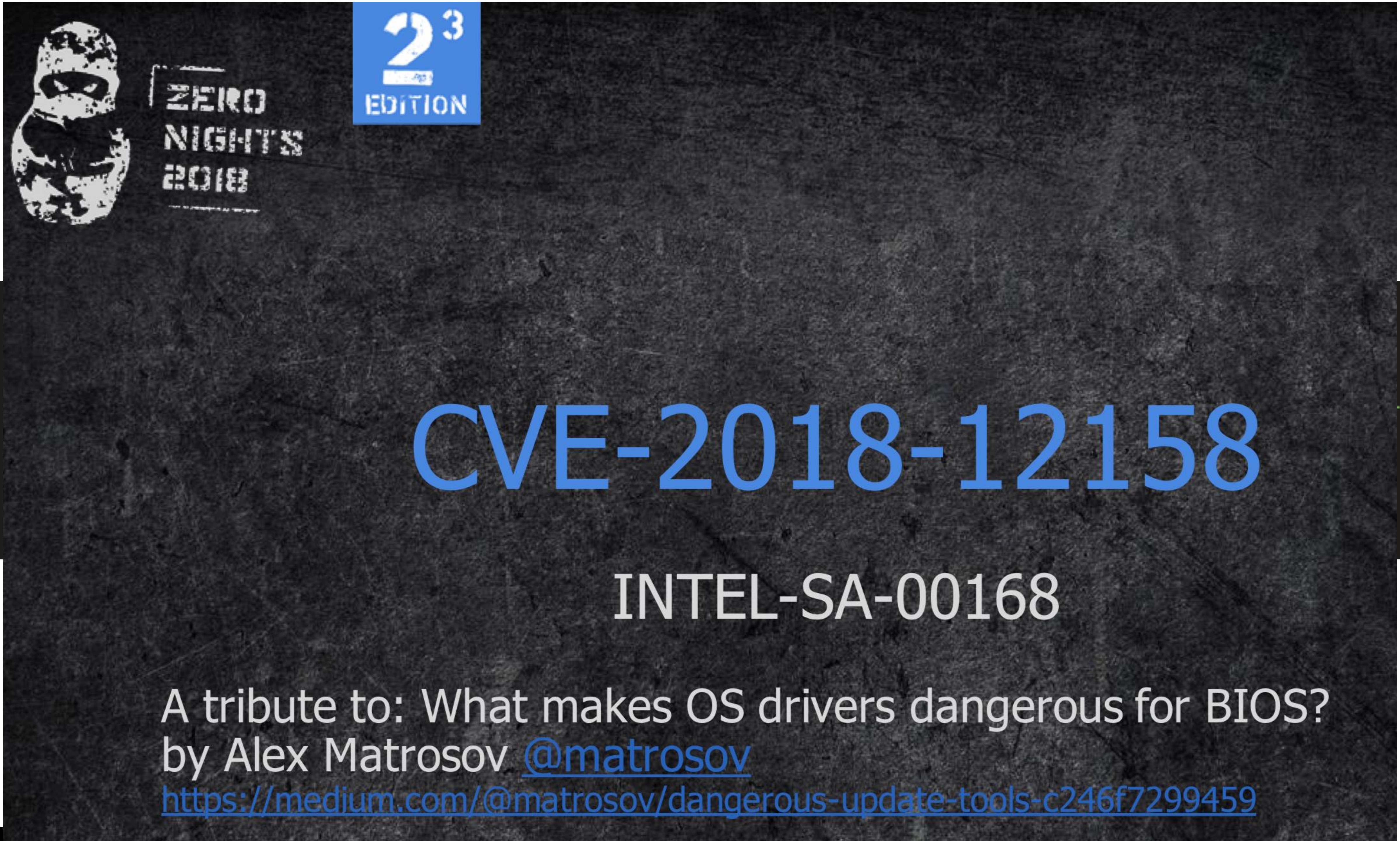


CVE-2018-12158

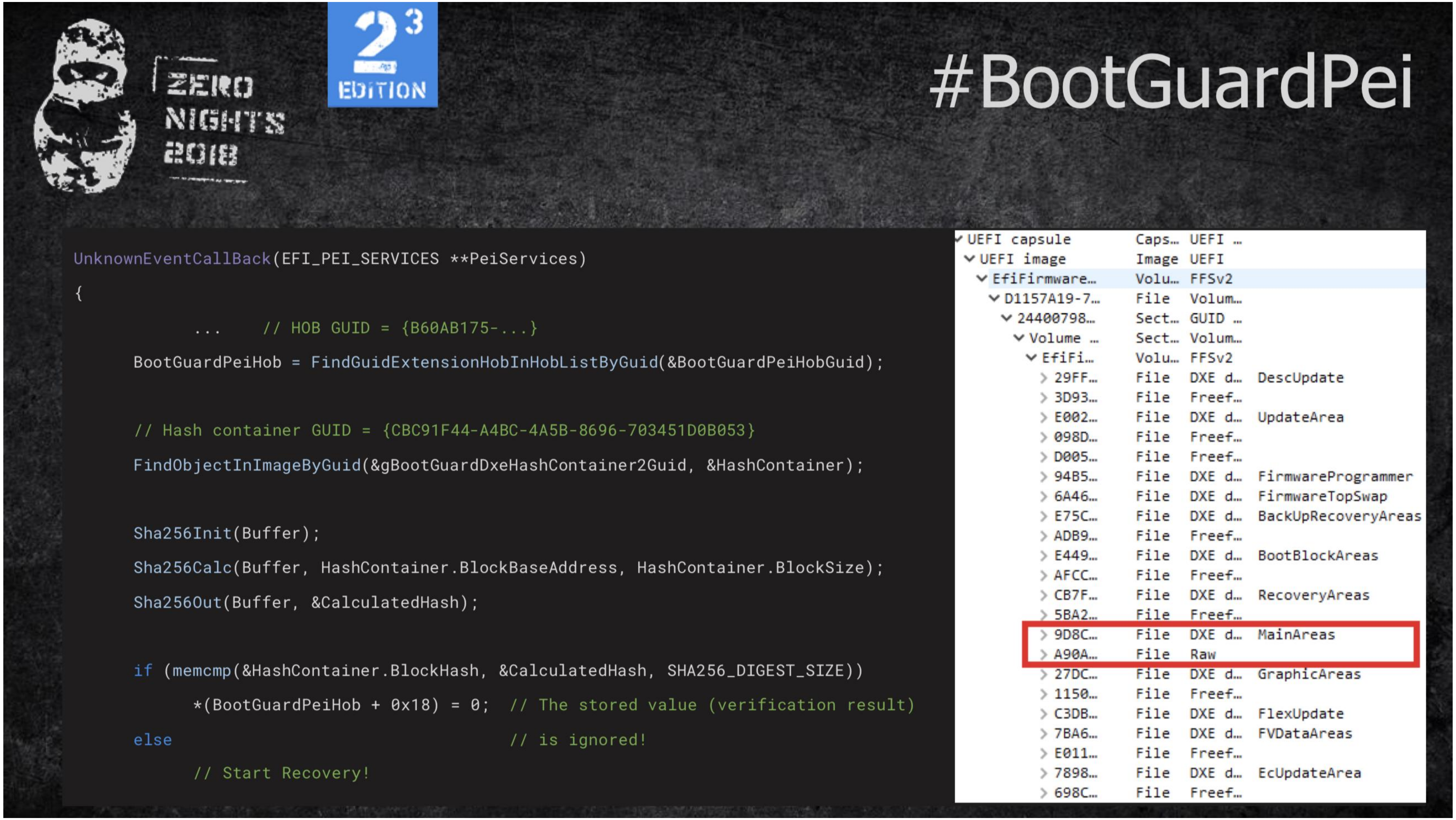
INTEL-SA-00168

A tribute to: What makes OS drivers dangerous for BIOS?
by Alex Matrosov @matrosov
https://medium.com/@matrosov/dangerous-update-tools-c246f7299459

.t)

htt

How HW-based Root of Trust become a SW



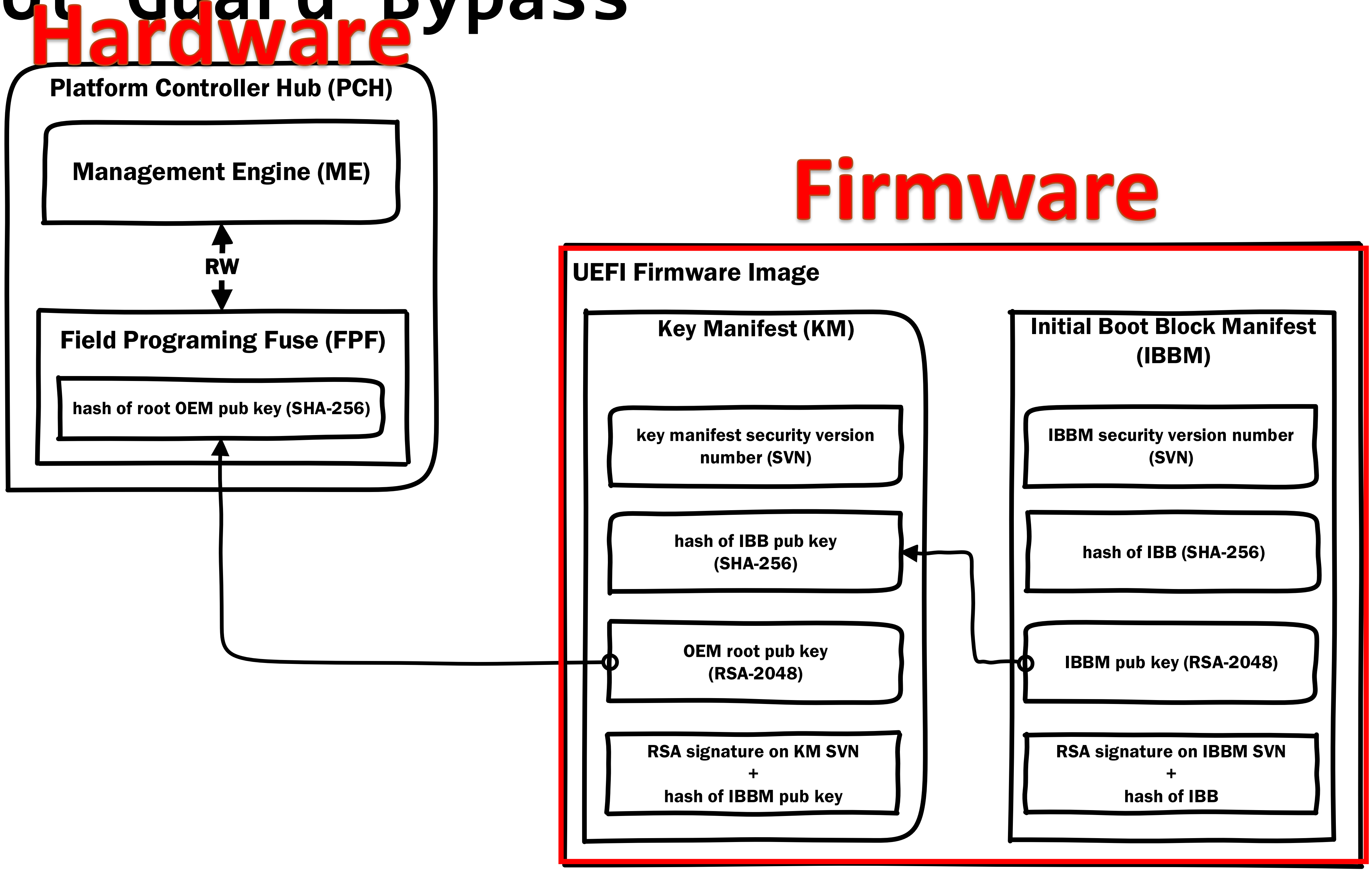
#BootGuardPei

```
UnknownEventCallBack(EFI_PEI_SERVICES **PeiServices)
{
        ...    // HOB GUID = {B60AB175-...}
    BootGuardPeiHob = FindGuidExtensionHobInHobListByGuid(&BootGuardPeiHobGuid);

    // Hash container GUID = {CBC91F44-A4BC-4A5B-8696-703451D0B053}
    FindObjectInImageByGuid(&gBootGuardDxeHashContainer2Guid, &HashContainer);

    Sha256Init(Buffer);
    Sha256Calc(Buffer, HashContainer.BlockBaseAddress, HashContainer.BlockSize);
    Sha256Out(Buffer, &CalculatedHash);

    if (memcmp(&HashContainer.BlockHash, &CalculatedHash, SHA256_DIGEST_SIZE))
        *(BootGuardPeiHob + 0x18) = 0;  // The stored value (verification result)
    else                                // is ignored!
        // Start Recovery!
```

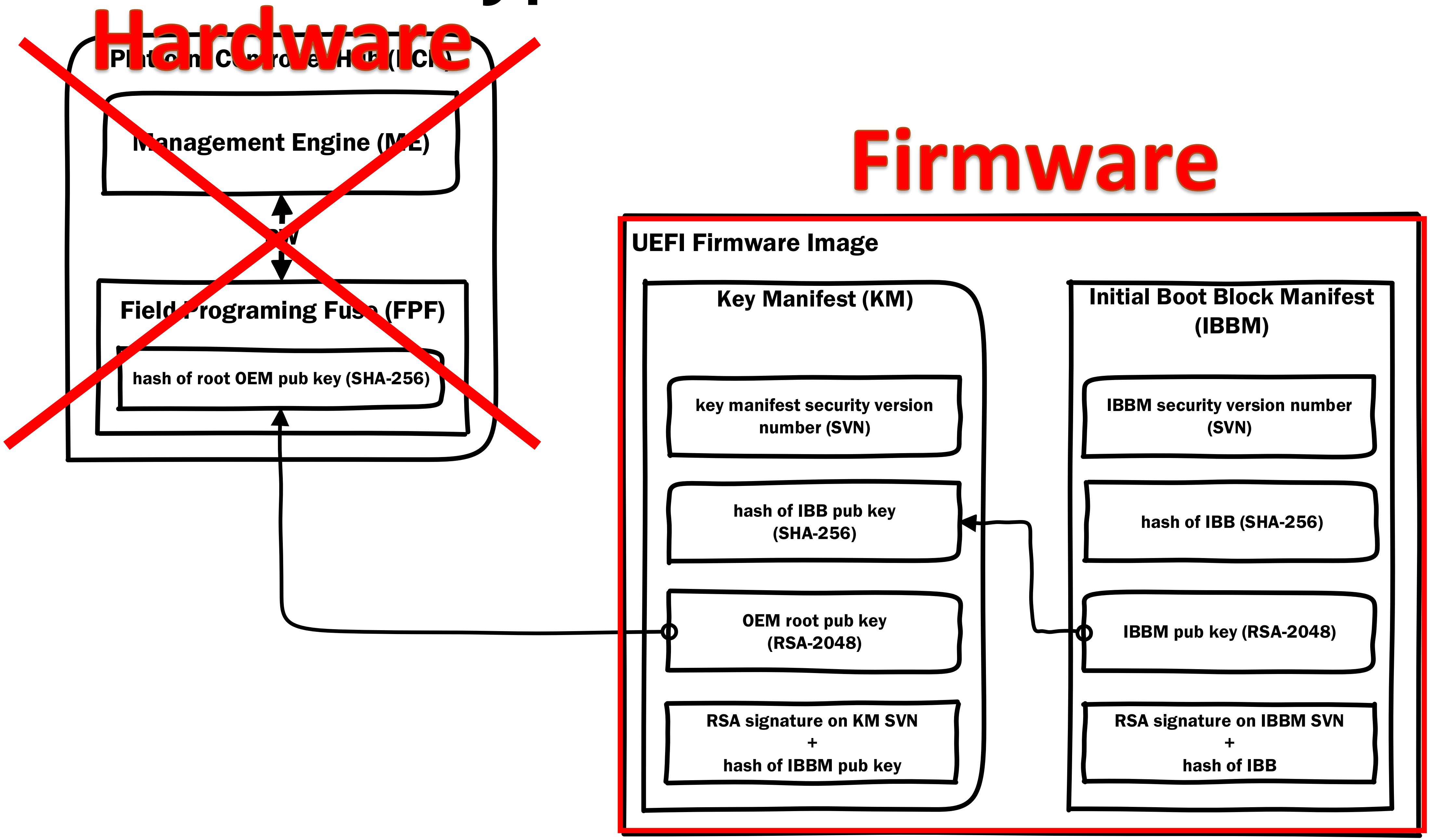
```
v UEFI capsule             Caps…  UEFI …
 v UEFI image              Image  UEFI
  v EfiFirmware…           Volu…  FFSv2
   v D1157A19-7…           File   Volum…
    v 24400798…            Sect…  GUID …
     v Volume …            Sect…  Volum…
      v EfiFi…             Volu…  FFSv2
       > 29FF…             File   DXE d…  DescUpdate
       > 3D93…             File   Freef…
       > E002…             File   DXE d…  UpdateArea
       > 098D…             File   Freef…
       > D005…             File   Freef…
       > 94B5…             File   DXE d…  FirmwareProgrammer
       > 6A46…             File   DXE d…  FirmwareTopSwap
       > E75C…             File   DXE d…  BackUpRecoveryAreas
       > ADB9…             File   Freef…
       > E449…             File   DXE d…  BootBlockAreas
       > AFCC…             File   Freef…
       > CB7F…             File   DXE d…  RecoveryAreas
       > 5BA2…             File   Freef…
       > 9D8C…             File   DXE d…  MainAreas
       > A90A…             File   Raw
       > 27DC…             File   DXE d…  GraphicAreas
       > 1150…             File   Freef…
       > C3DB…             File   DXE d…  FlexUpdate
       > 7BA6…             File   DXE d…  FVDataAreas
       > E011…             File   Freef…
       > 7898…             File   DXE d…  EcUpdateArea
       > 698C…             File   Freef…
```

https://2018.zeronights.ru/en/wp-content/uploads/materials/06-NUClear-explotion.pdf

Boot Guard Bypass


Hardware
Platform Controller Hub (PCH)
Management Engine (ME)
RW
Field Programing Fuse (FPF)
hash of root OEM pub key (SHA-256)
Firmware
UEFI Firmware Image
Key Manifest (KM)
key manifest security version number (SVN)
hash of IBB pub key (SHA-256)
OEM root pub key (RSA-2048)
RSA signature on KM SVN + hash of IBBM pub key
Initial Boot Block Manifest (IBBM)
IBBM security version number (SVN)
hash of IBB (SHA-256)
IBBM pub key (RSA-2048)
RSA signature on IBBM SVN + hash of IBB

Boot Guard Bypass



Hardware

Platform Controller Hub (PCH)

Management Engine (ME)

RW

Field Programing Fuse (FPF)

hash of root OEM pub key (SHA-256)

Firmware

UEFI Firmware Image

Key Manifest (KM)

key manifest security version number (SVN)

hash of IBB pub key (SHA-256)

OEM root pub key (RSA-2048)

RSA signature on KM SVN + hash of IBBM pub key

Initial Boot Block Manifest (IBBM)

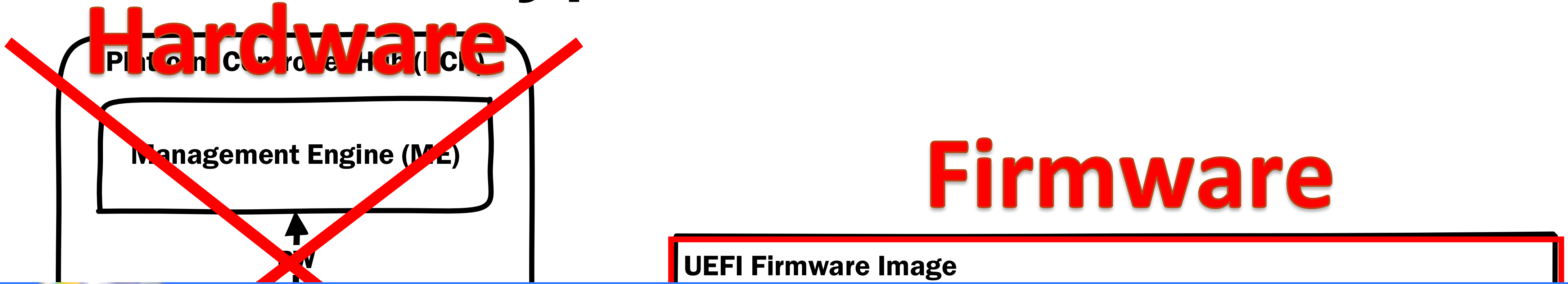
IBBM security version number (SVN)

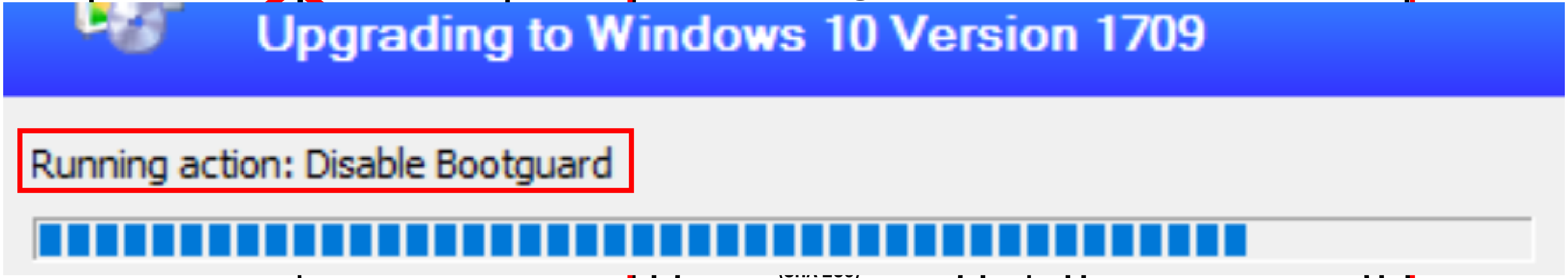
hash of IBB (SHA-256)

IBBM pub key (RSA-2048)

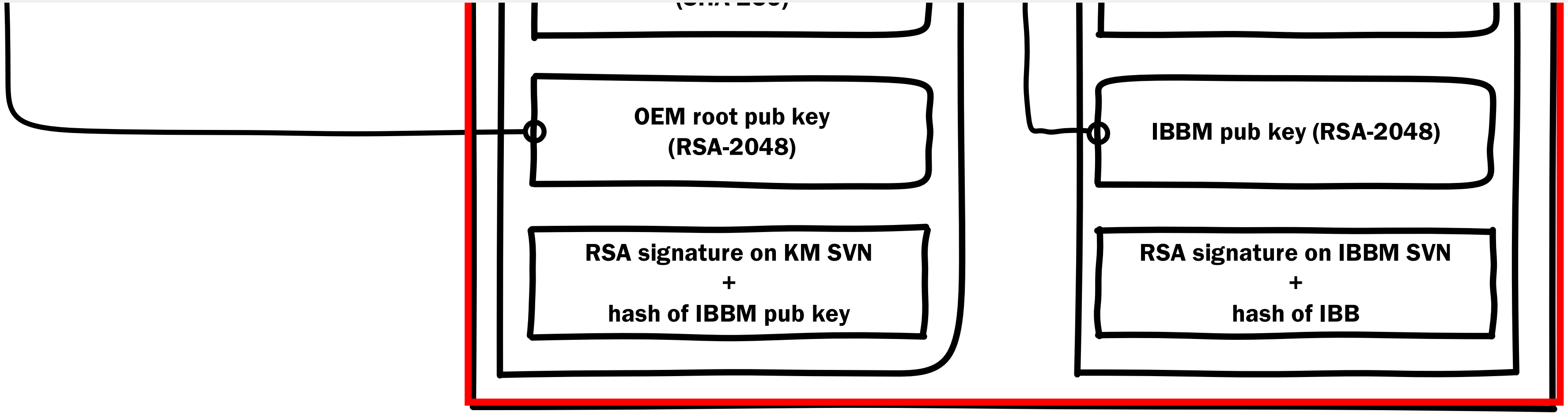
RSA signature on IBBM SVN + hash of IBB

Boot Guard Bypass

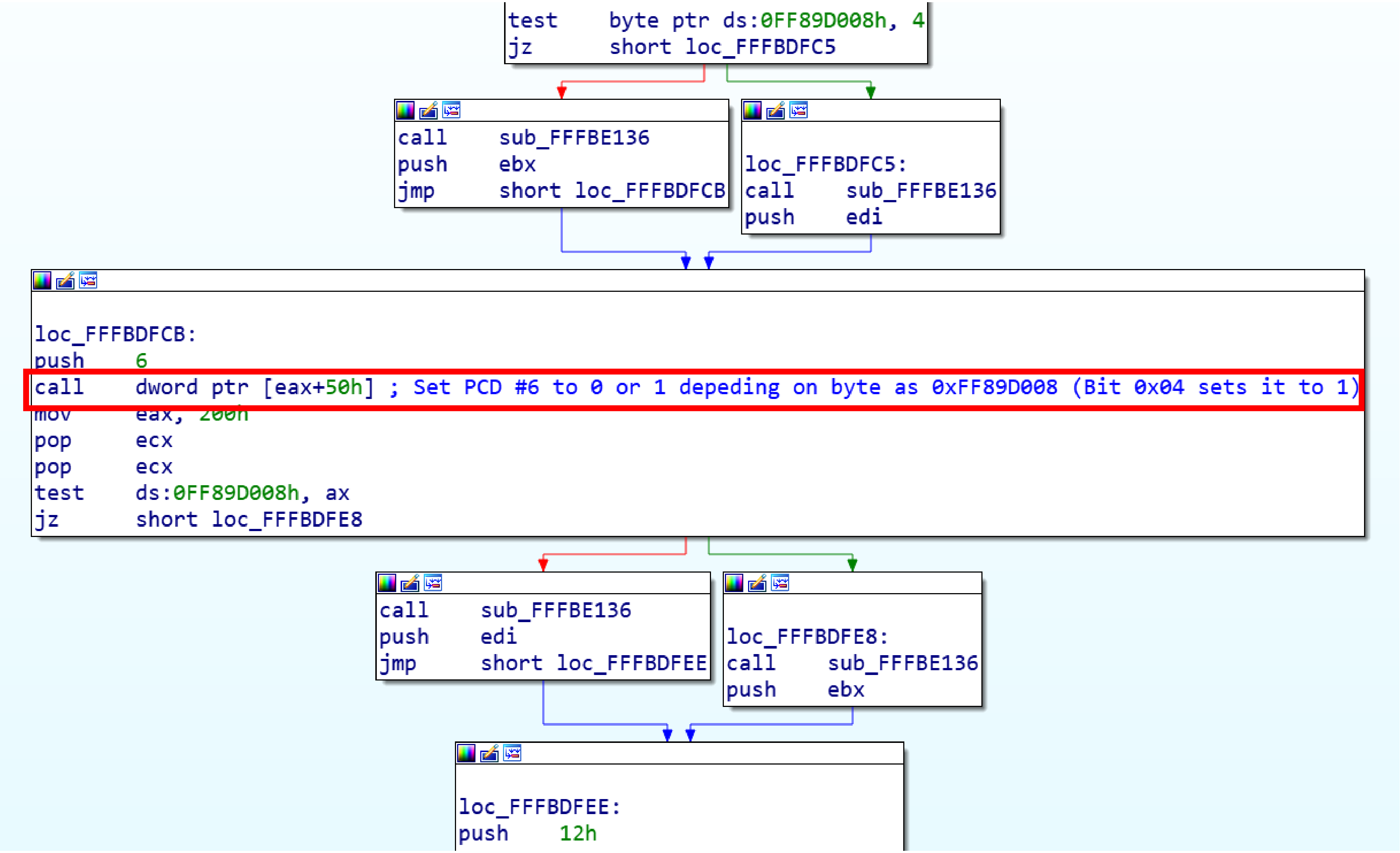




Running action: Disable Bootguard



Boot Guard Bypass: LenovoPcdInit



```
test     byte ptr ds:0FF89D008h, 4
jz       short loc_FFFBDFC5
```

```
call     sub_FFFBE136
push     ebx
jmp      short loc_FFFBDFCB
```

```
loc_FFFBDFC5:
call     sub_FFFBE136
push     edi
```

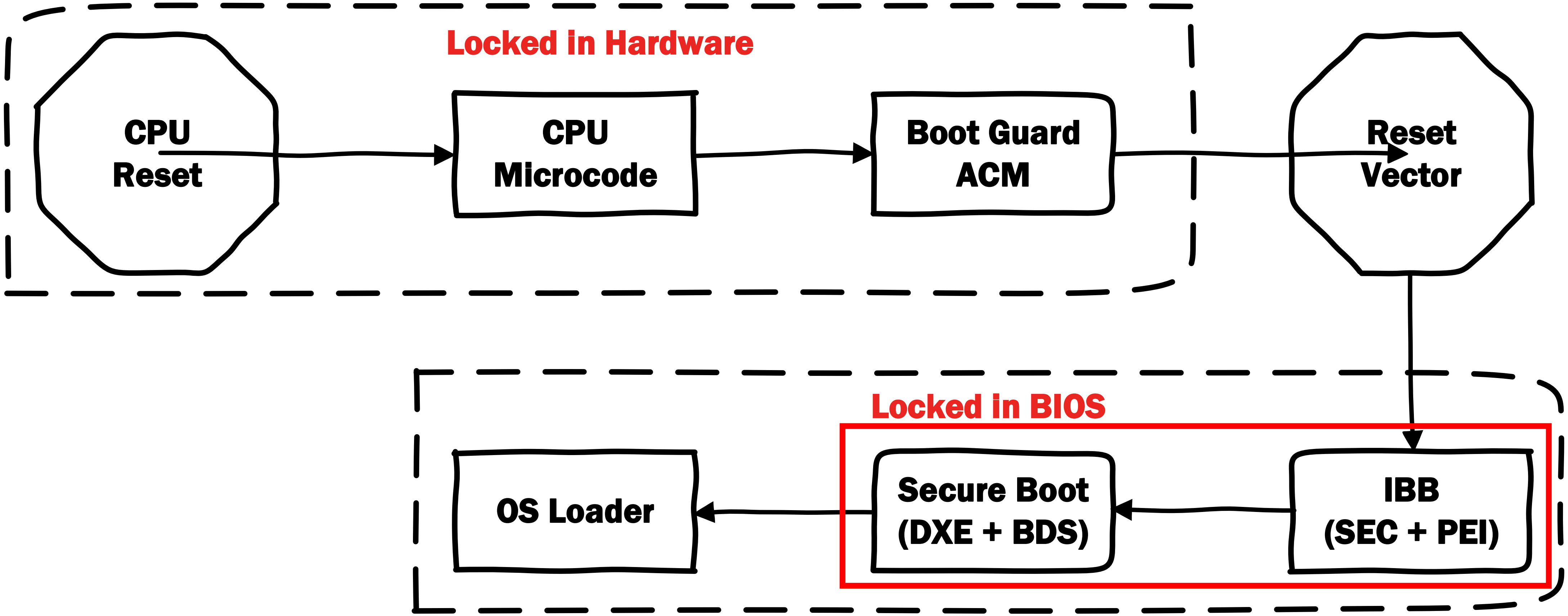
```
loc_FFFBDFCB:
push     6
call     dword ptr [eax+50h] ; Set PCD #6 to 0 or 1 depeding on byte as 0xFF89D008 (Bit 0x04 sets it to 1)
mov      eax, 200h
pop      ecx
pop      ecx
test     ds:0FF89D008h, ax
jz       short loc_FFFBDFE8
```

```
call     sub_FFFBE136
push     edi
jmp      short loc_FFFBDFEE
```

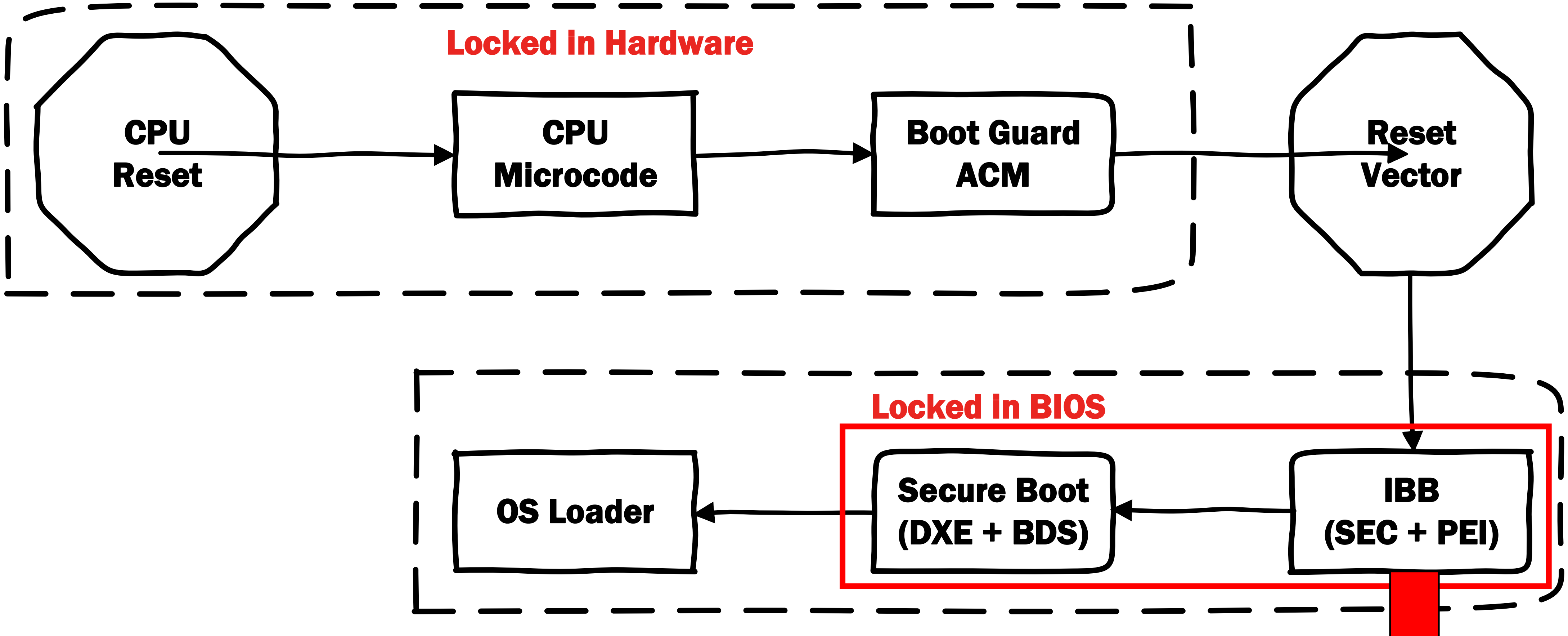
```
loc_FFFBDFE8:
call     sub_FFFBE136
push     ebx
```

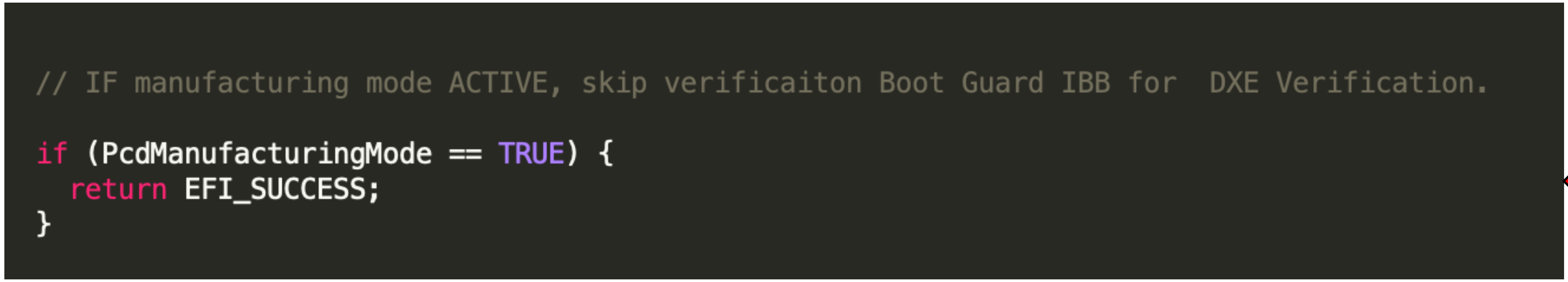
```
loc_FFFBDFEE:
push     12h
```

Boot Guard: Boot Flow in ACTIVE manufacturing mode



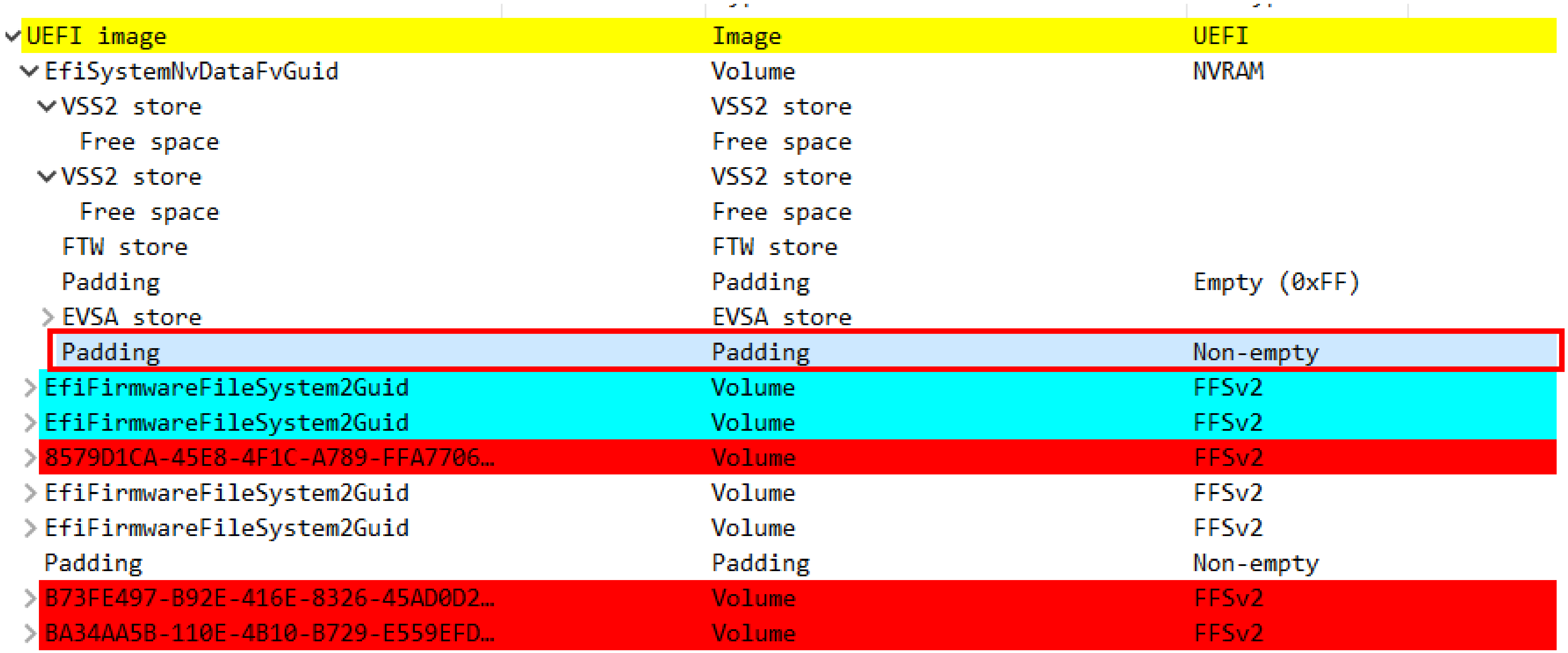
Boot Guard: Boot Flow in ACTIVE manufacturing mode



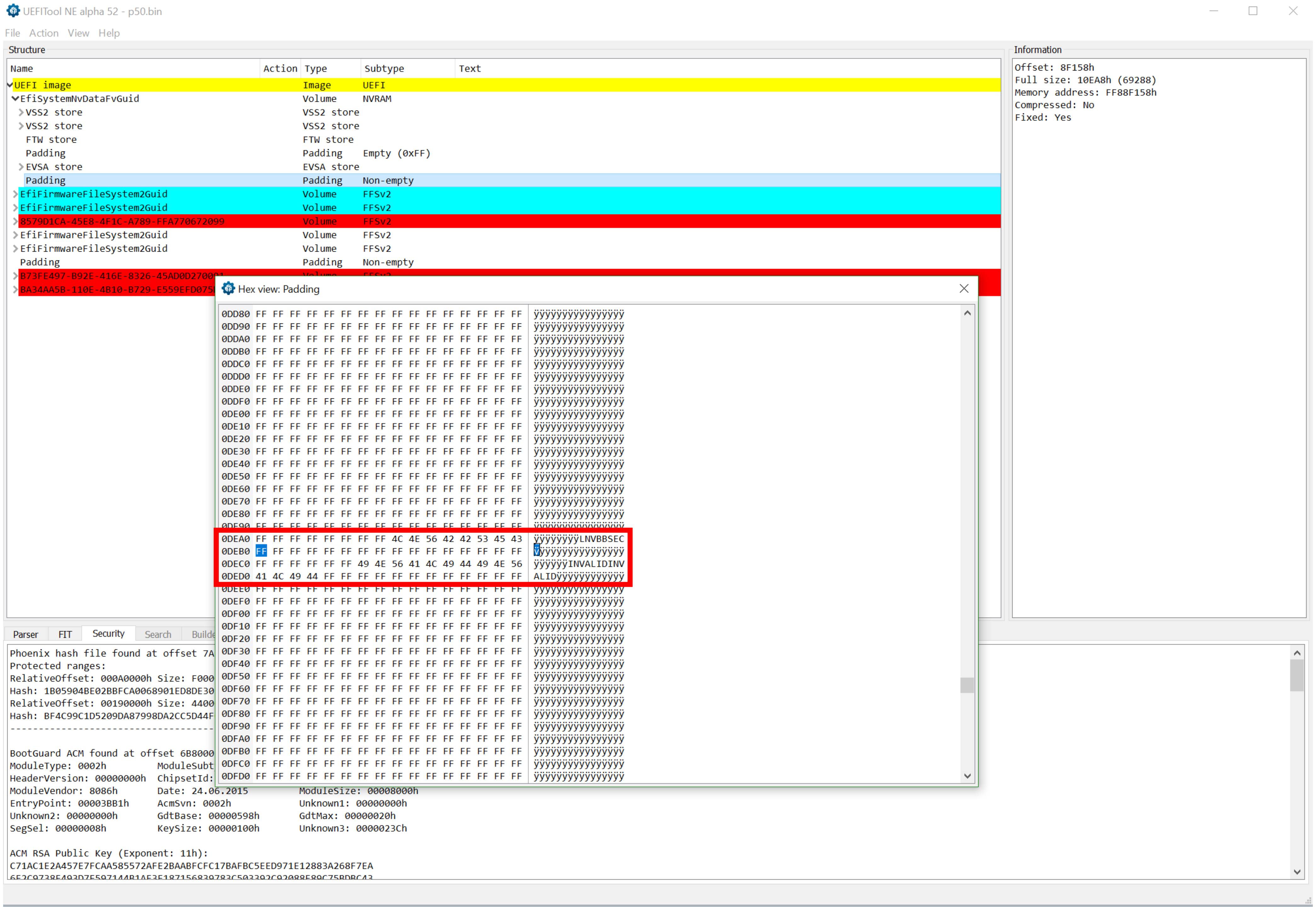


```
// IF manufacturing mode ACTIVE, skip verificaiton Boot Guard IBB for  DXE Verification.

if (PcdManufacturingMode == TRUE) {
  return EFI_SUCCESS;
}
```

Boot Guard Bypass: Where Lenovo PCD stored?



```
v UEFI image                              Image                 UEFI
 v EfiSystemNvDataFvGuid                  Volume                NVRAM
  v VSS2 store                            VSS2 store
     Free space                           Free space
  v VSS2 store                            VSS2 store
     Free space                           Free space
    FTW store                             FTW store
    Padding                               Padding               Empty (0xFF)
  > EVSA store                            EVSA store
    Padding                               Padding               Non-empty
 > EfiFirmwareFileSystem2Guid             Volume                FFSv2
 > EfiFirmwareFileSystem2Guid             Volume                FFSv2
 > 8579D1CA-45E8-4F1C-A789-FFA7706…       Volume                FFSv2
 > EfiFirmwareFileSystem2Guid             Volume                FFSv2
 > EfiFirmwareFileSystem2Guid             Volume                FFSv2
   Padding                                Padding               Non-empty
 > B73FE497-B92E-416E-8326-45AD0D2…       Volume                FFSv2
 > BA34AA5B-110E-4B10-B729-E559EFD…       Volume                FFSv2
```



Name	Action	Type	Subtype	Text
UEFI image		Image	UEFI	
EfiSystemNvDataFvGuid		Volume	NVRAM	
VSS2 store		VSS2 store		
VSS2 store		VSS2 store		
FTW store		FTW store		
Padding		Padding	Empty (0xFF)	
EVSA store		EVSA store		
Padding		Padding	Non-empty	
EfiFirmwareFileSystem2Guid		Volume	FFSv2	
EfiFirmwareFileSystem2Guid		Volume	FFSv2	
8579D1CA-45E8-4F1C-A789-FFA770672099		Volume	FFSv2	
EfiFirmwareFileSystem2Guid		Volume	FFSv2	
EfiFirmwareFileSystem2Guid		Volume	FFSv2	
Padding		Padding	Non-empty	
B73FE497-B92E-416E-8326-45AD0D27000		Volume	FFSv2	
BA34AA5B-110E-4B10-B729-E559EFD075				

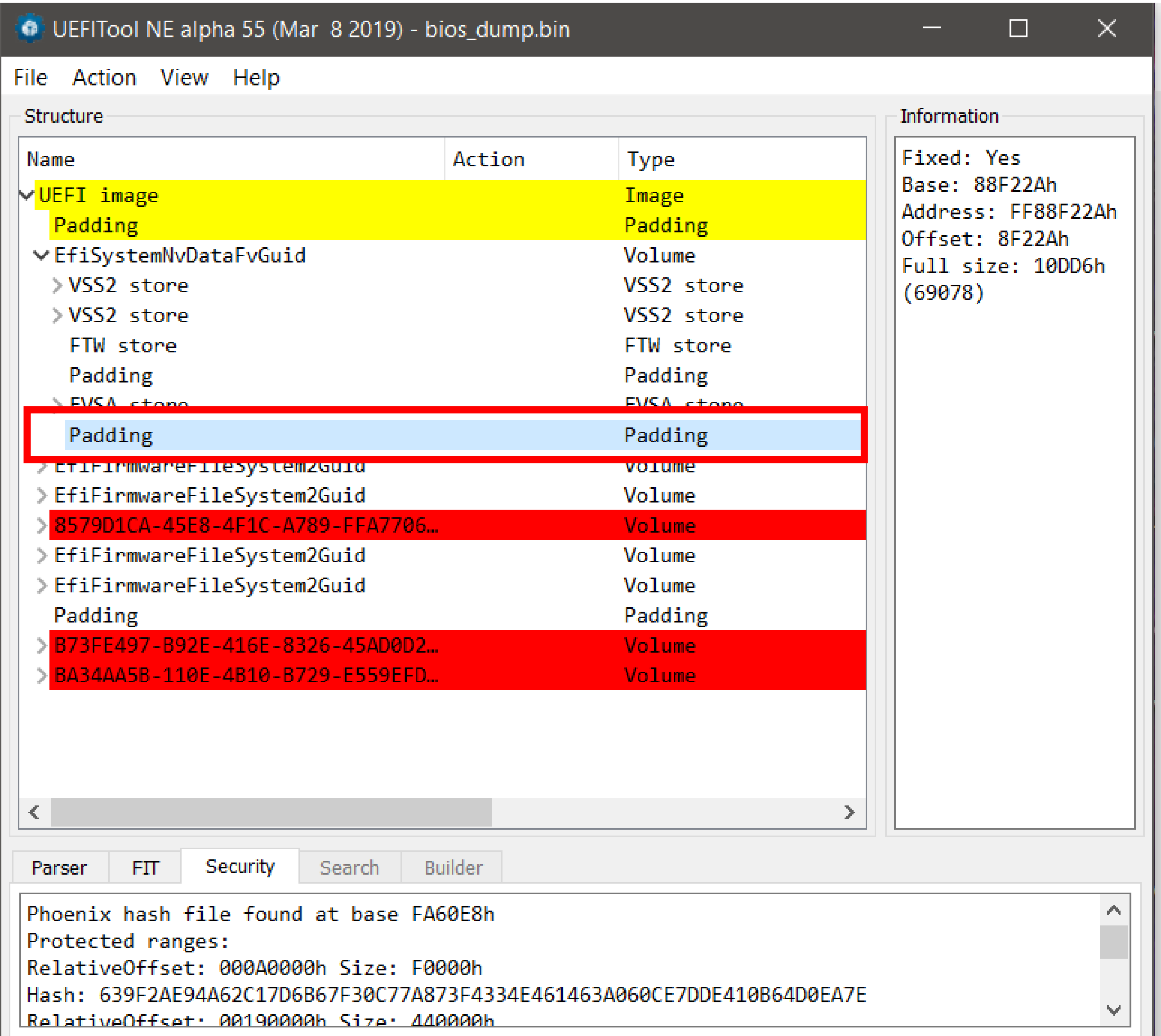
```
Offset: 8F158h
Full size: 10EA8h (69288)
Memory address: FF88F158h
Compressed: No
Fixed: Yes
```

Hex view: Padding

```
0DD80 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DD90 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DDA0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DDB0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DDC0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DDD0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DDE0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DDF0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE10 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE20 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE30 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE40 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE50 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE60 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE70 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE80 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DE90 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DEA0 FF FF FF FF FF FF FF FF 4C 4E 56 42 42 53 45 43  ÿÿÿÿÿÿÿÿLNVBBSEC
0DEB0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DEC0 FF FF FF FF FF FF 49 4E 56 41 4C 49 44 49 4E 56  ÿÿÿÿÿÿINVALIDINV
0DED0 41 4C 49 44 FF FF FF FF FF FF FF FF FF FF FF FF  ALIDÿÿÿÿÿÿÿÿÿÿÿÿ
0DEE0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DEF0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF10 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF20 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF30 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF40 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF50 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF60 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF70 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF80 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DF90 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DFA0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DFB0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DFC0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
0DFD0 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
```

```
Phoenix hash file found at offset 7A
Protected ranges:
RelativeOffset: 000A0000h Size: F000
Hash: 1B05904BE02BBFCA0068901ED8DE30
RelativeOffset: 00190000h Size: 4400
Hash: BF4C99C1D5209DA87998DA2CC5D44F
-----------------------------------

BootGuard ACM found at offset 6B8000
ModuleType: 0002h          ModuleSubt
HeaderVersion: 00000000h   ChipsetId:
ModuleVendor: 8086h        Date: 24.06.2015          ModuleSize: 00008000h
EntryPoint: 00003BB1h      AcmSvn: 0002h             Unknown1: 00000000h
Unknown2: 00000000h        GdtBase: 00000598h        GdtMax: 00000020h
SegSel: 00000008h          KeySize: 00000100h        Unknown3: 0000023Ch

ACM RSA Public Key (Exponent: 11h):
C71AC1E2A457E7FCAA585572AFE2BAABFCFC17BAFBC5EED971E12883A268F7EA
```

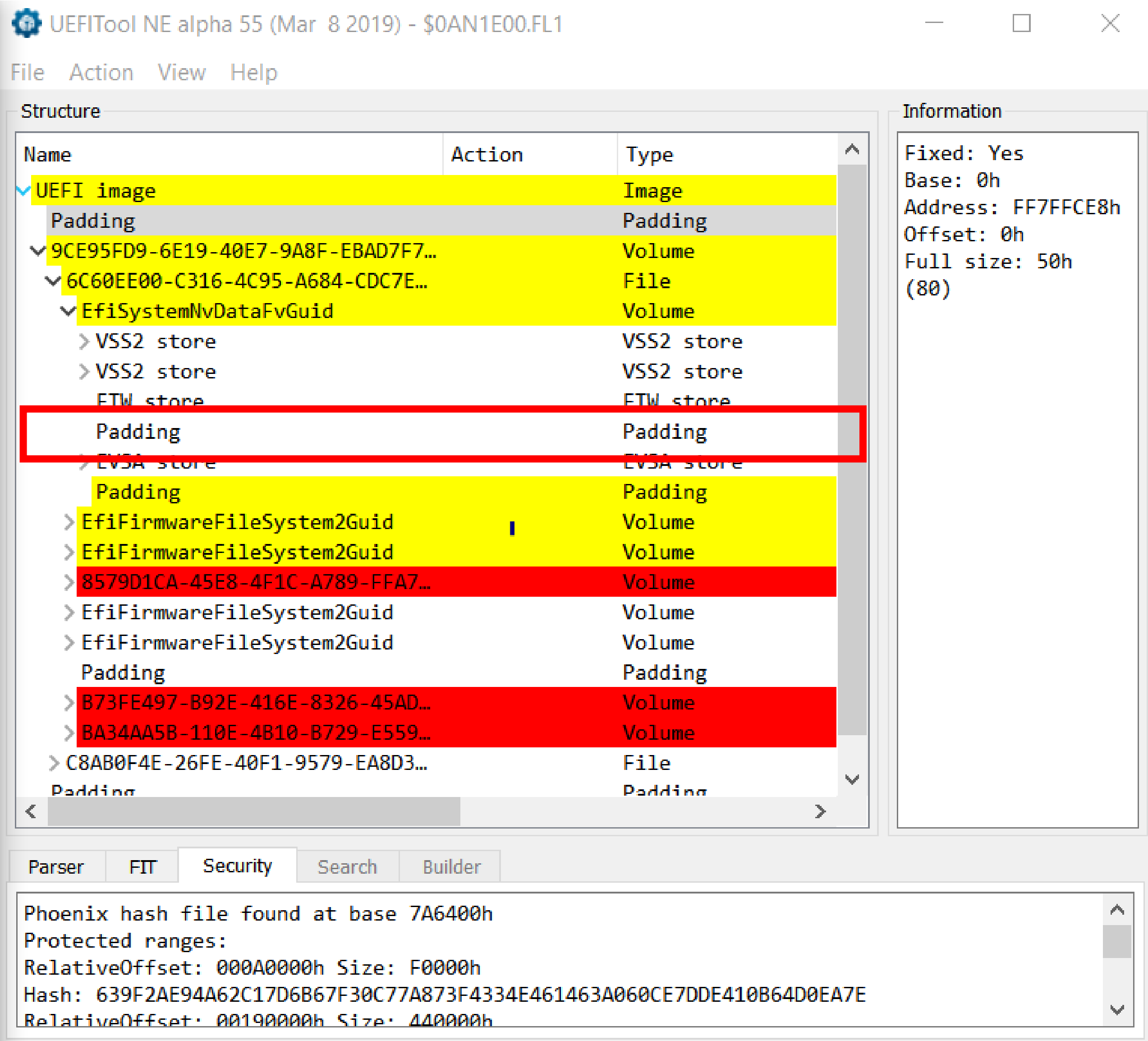
Boot Guard Bypass: Going deeper with SPI dump



Name	Action	Type
UEFI image		Image
Padding		Padding
EfiSystemNvDataFvGuid		Volume
VSS2 store		VSS2 store
VSS2 store		VSS2 store
FTW store		FTW store
Padding		Padding
EVSA store		EVSA store
Padding		Padding
EfiFirmwareFileSystem2Guid		Volume
EfiFirmwareFileSystem2Guid		Volume
8579D1CA-45E8-4F1C-A789-FFA7706…		Volume
EfiFirmwareFileSystem2Guid		Volume
EfiFirmwareFileSystem2Guid		Volume
Padding		Padding
B73FE497-B92E-416E-8326-45AD0D2…		Volume
BA34AA5B-110E-4B10-B729-E559EFD…		Volume

```
Fixed: Yes
Base: 88F22Ah
Address: FF88F22Ah
Offset: 8F22Ah
Full size: 10DD6h
(69078)
```

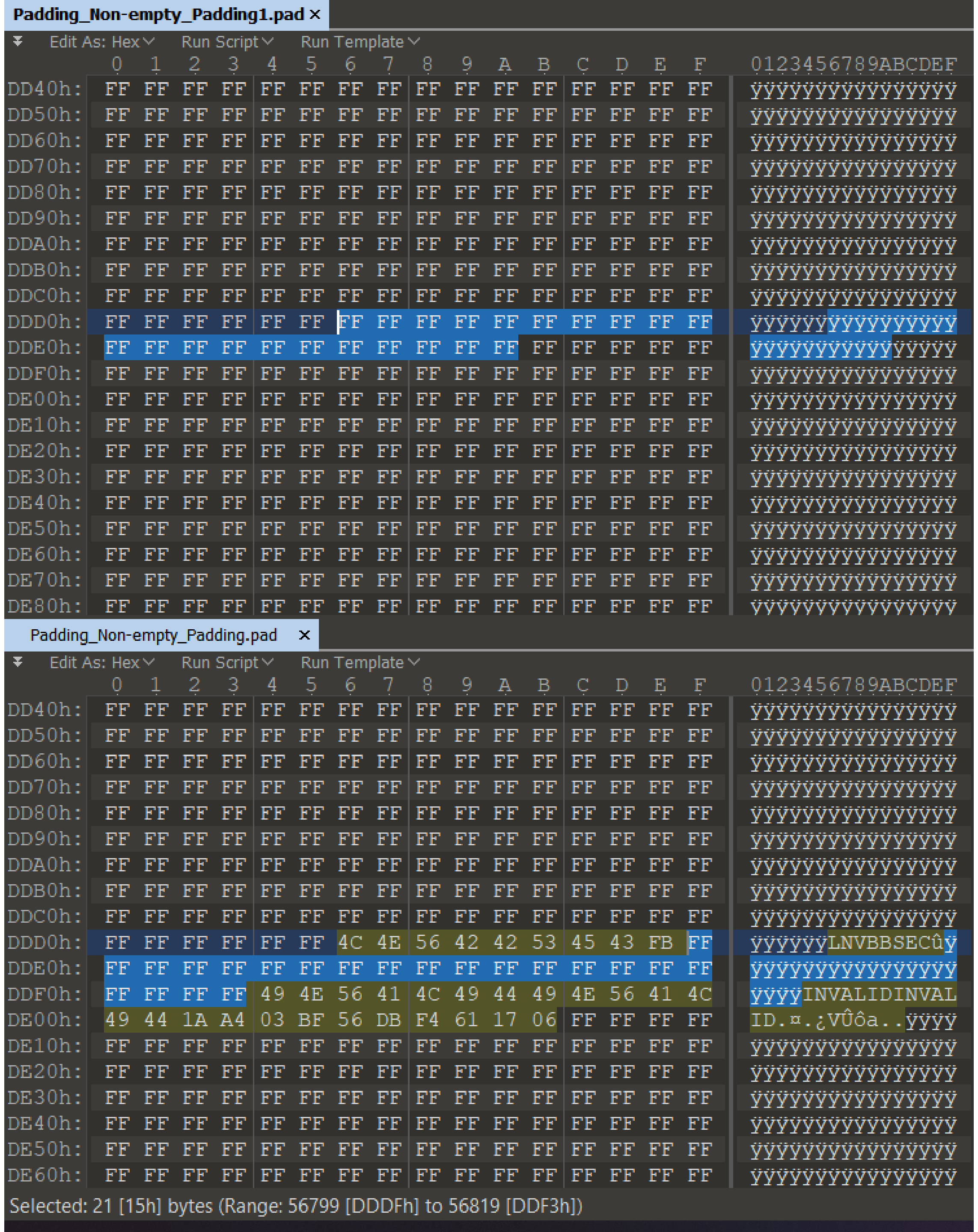
```
Phoenix hash file found at base FA60E8h
Protected ranges:
RelativeOffset: 000A0000h Size: F0000h
Hash: 639F2AE94A62C17D6B67F30C77A873F4334E461463A060CE7DDE410B64D0EA7E
RelativeOffset: 00190000h Size: 440000h
```



Name	Action	Type
UEFI image		Image
Padding		Padding
9CE95FD9-6E19-40E7-9A8F-EBAD7F7…		Volume
6C60EE00-C316-4C95-A684-CDC7E…		File
EfiSystemNvDataFvGuid		Volume
VSS2 store		VSS2 store
VSS2 store		VSS2 store
FTW store		FTW store
Padding		Padding
EVSA store		EVSA store
Padding		Padding
EfiFirmwareFileSystem2Guid		Volume
EfiFirmwareFileSystem2Guid		Volume
8579D1CA-45E8-4F1C-A789-FFA7…		Volume
EfiFirmwareFileSystem2Guid		Volume
EfiFirmwareFileSystem2Guid		Volume
Padding		Padding
B73FE497-B92E-416E-8326-45AD…		Volume
BA34AA5B-110E-4B10-B729-E559…		Volume
C8AB0F4E-26FE-40F1-9579-EA8D3…		File
Padding		Padding

```
Fixed: Yes
Base: 0h
Address: FF7FFCE8h
Offset: 0h
Full size: 50h
(80)
```

```
Phoenix hash file found at base 7A6400h
Protected ranges:
RelativeOffset: 000A0000h Size: F0000h
Hash: 639F2AE94A62C17D6B67F30C77A873F4334E461463A060CE7DDE410B64D0EA7E
RelativeOffset: 00190000h Size: 440000h
```



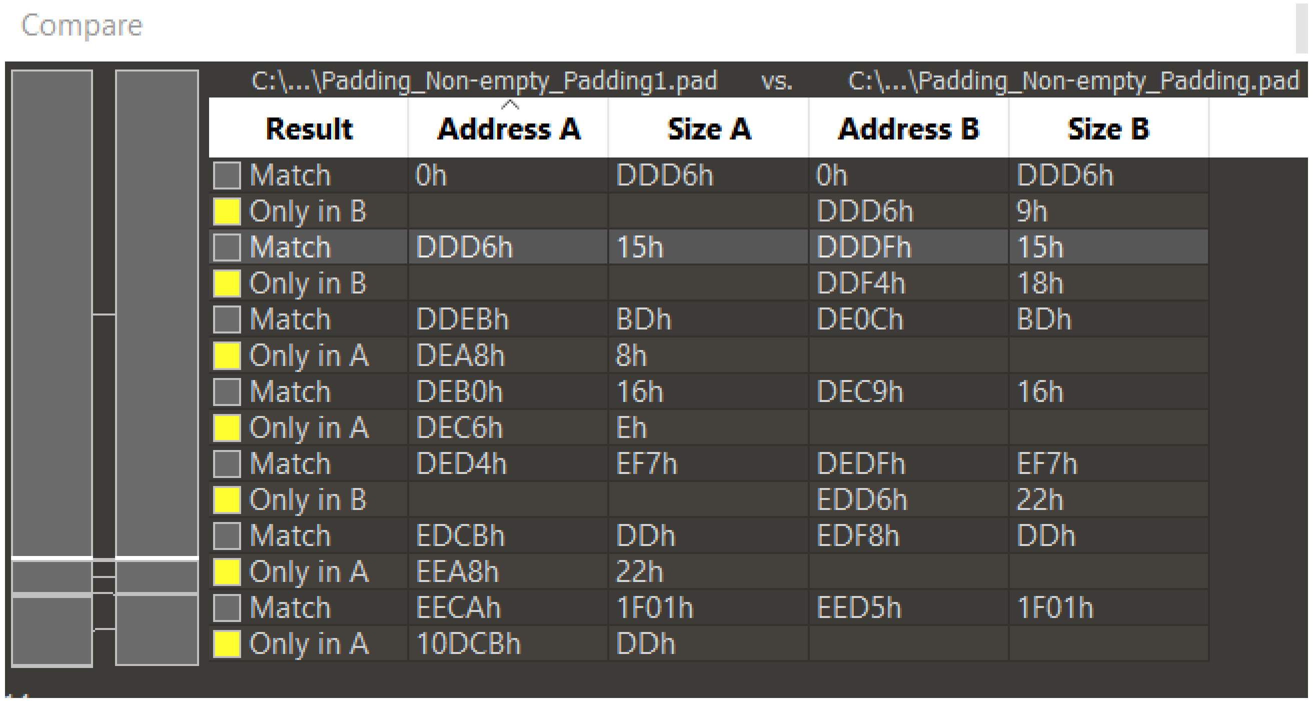
Padding_Non-empty_Padding1.pad

```
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F    0123456789ABCDEF
DD40h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD50h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD60h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD70h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD80h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD90h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDA0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDB0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDC0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDD0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDE0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDF0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE00h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE10h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE20h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE30h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE40h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE50h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE60h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE70h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE80h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
```

Padding_Non-empty_Padding.pad

```
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F    0123456789ABCDEF
DD40h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD50h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD60h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD70h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD80h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DD90h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDA0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDB0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDC0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDD0h: FF FF FF FF FF FF 4C 4E 56 42 42 53 45 43 FB FF    ÿÿÿÿÿÿLNVBBSECûÿ
DDE0h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DDF0h: FF FF FF FF 49 4E 56 41 4C 49 44 49 4E 56 41 4C    ÿÿÿÿINVALIDINVAL
DE00h: 49 44 1A A4 03 BF 56 DB F4 61 17 06 FF FF FF FF    ID.¤.¿VÛôa..ÿÿÿÿ
DE10h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE20h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE30h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE40h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE50h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
DE60h: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
```

Selected: 21 [15h] bytes (Range: 56799 [DDDFh] to 56819 [DDF3h])



Compare

C:\...\Padding_Non-empty_Padding1.pad vs. C:\...\Padding_Non-empty_Padding.pad

Result	Address A	Size A	Address B	Size B
□ Match	0h	DDD6h	0h	DDD6h
🟨 Only in B			DDD6h	9h
□ Match	DDD6h	15h	DDDFh	15h
🟨 Only in B			DDF4h	18h
□ Match	DDEBh	BDh	DE0Ch	BDh
🟨 Only in A	DEA8h	8h		
□ Match	DEB0h	16h	DEC9h	16h
🟨 Only in A	DEC6h	Eh		
□ Match	DED4h	EF7h	DEDFh	EF7h
🟨 Only in B			EDD6h	22h
□ Match	EDCBh	DDh	EDF8h	DDh
🟨 Only in A	EEA8h	22h		
□ Match	EECAh	1F01h	EED5h	1F01h
🟨 Only in A	10DCBh	DDh		

Why vendors leave this “backdoors”?

- Creating recover process for broken BIOS updates possible (even remotely).

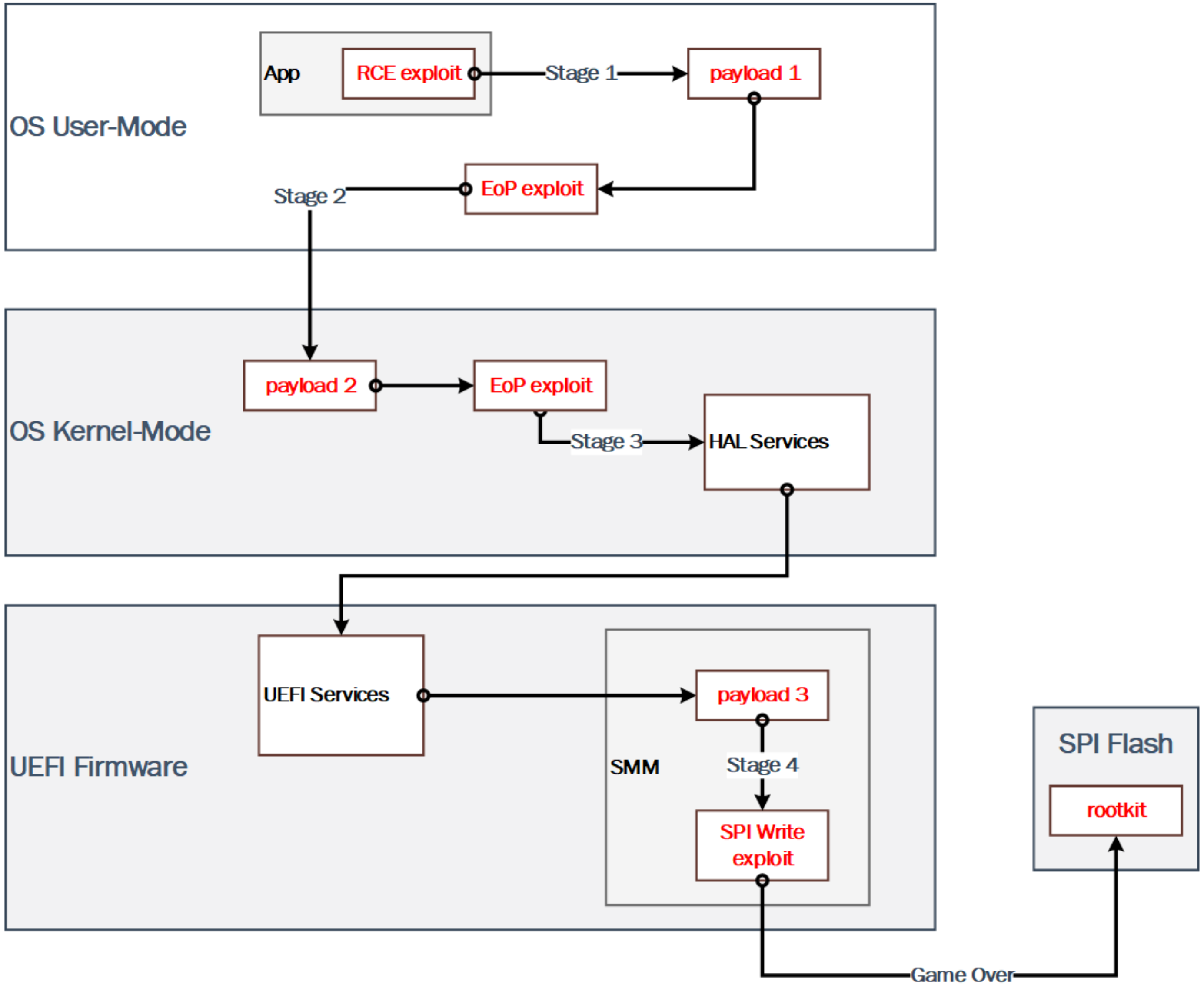
- But leaving “backdoors” is always create another problems even more serious.

- Enterprise market need stable solutions right? ☺

- Replace broken HW is expensive way but only one which guarantees security process for system recovery

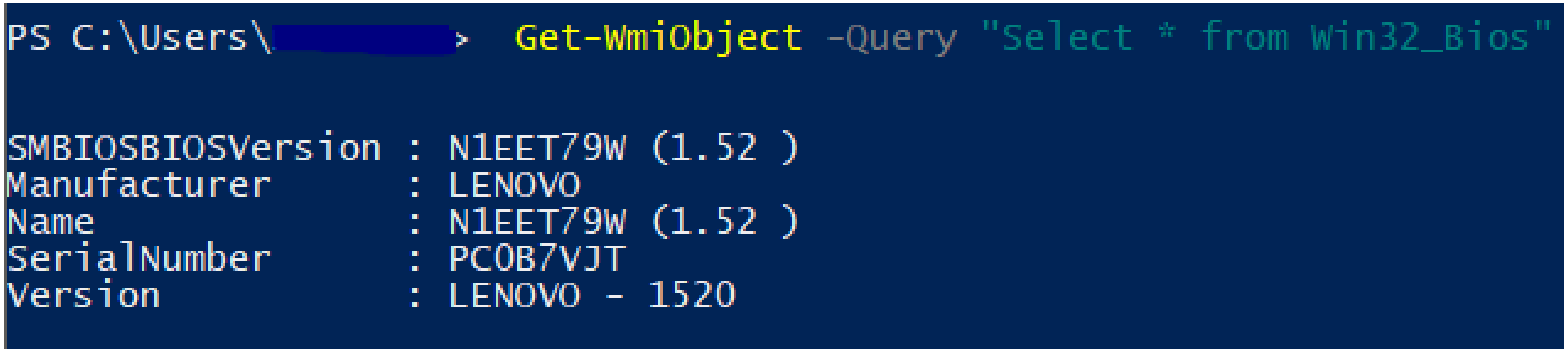
SMI over WMI is evil

How many exploits you need?

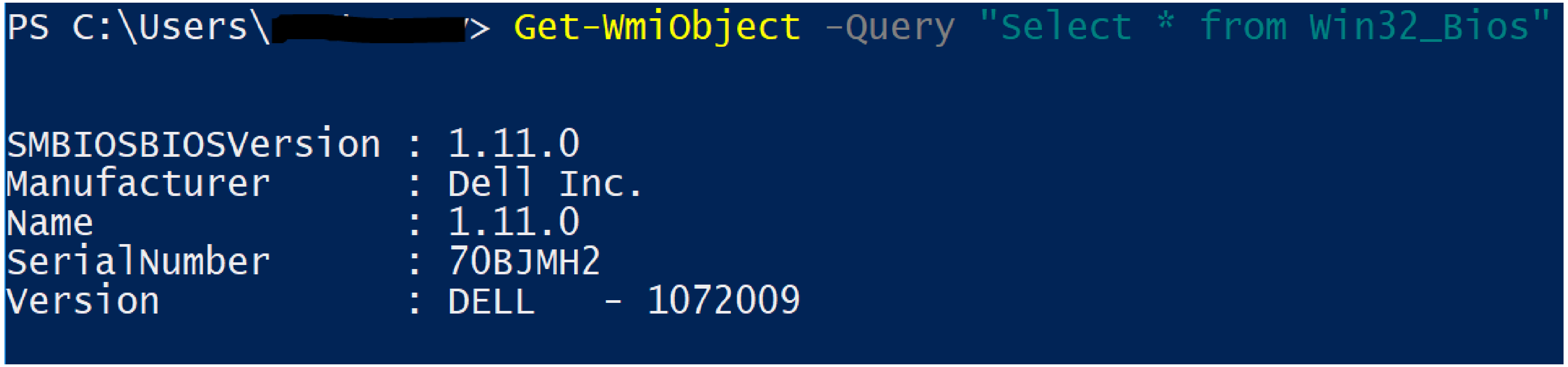


https://medium.com/@matrosov/dangerous-update-tools-c246f7299459

How this REsearch get started?



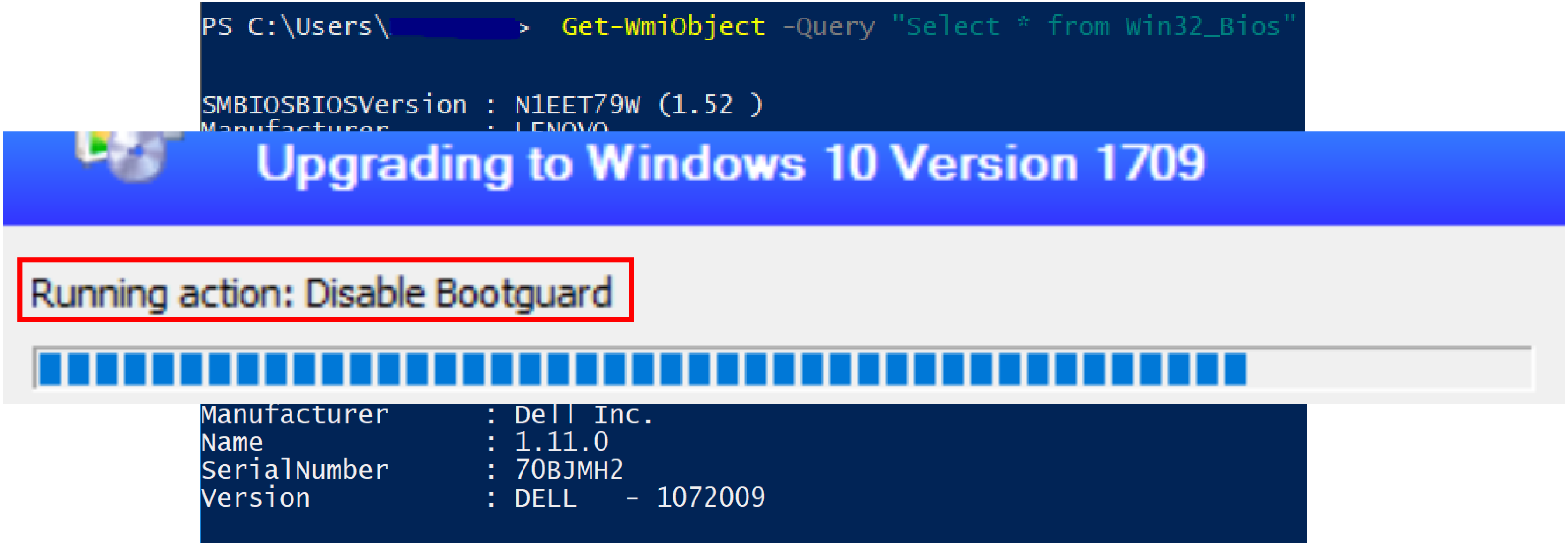
```
PS C:\Users\[redacted]>  Get-WmiObject -Query "Select * from Win32_Bios"


SMBIOSBIOSVersion : N1EET79W (1.52 )
Manufacturer      : LENOVO
Name              : N1EET79W (1.52 )
SerialNumber      : PC0B7VJT
Version           : LENOVO - 1520
```



```
PS C:\Users\[redacted]> Get-WmiObject -Query "Select * from Win32_Bios"


SMBIOSBIOSVersion : 1.11.0
Manufacturer      : Dell Inc.
Name              : 1.11.0
SerialNumber      : 70BJMH2
Version           : DELL   - 1072009
```

https://docs.microsoft.com/en-us/windows/desktop/cimwin32prov/win32-bios

How this REsearch get started?



```
PS C:\Users\[redacted]>  Get-WmiObject -Query "Select * from Win32_Bios"


SMBIOSBIOSVersion : N1EET79W (1.52 )
Manufacturer      : LENOVO
```

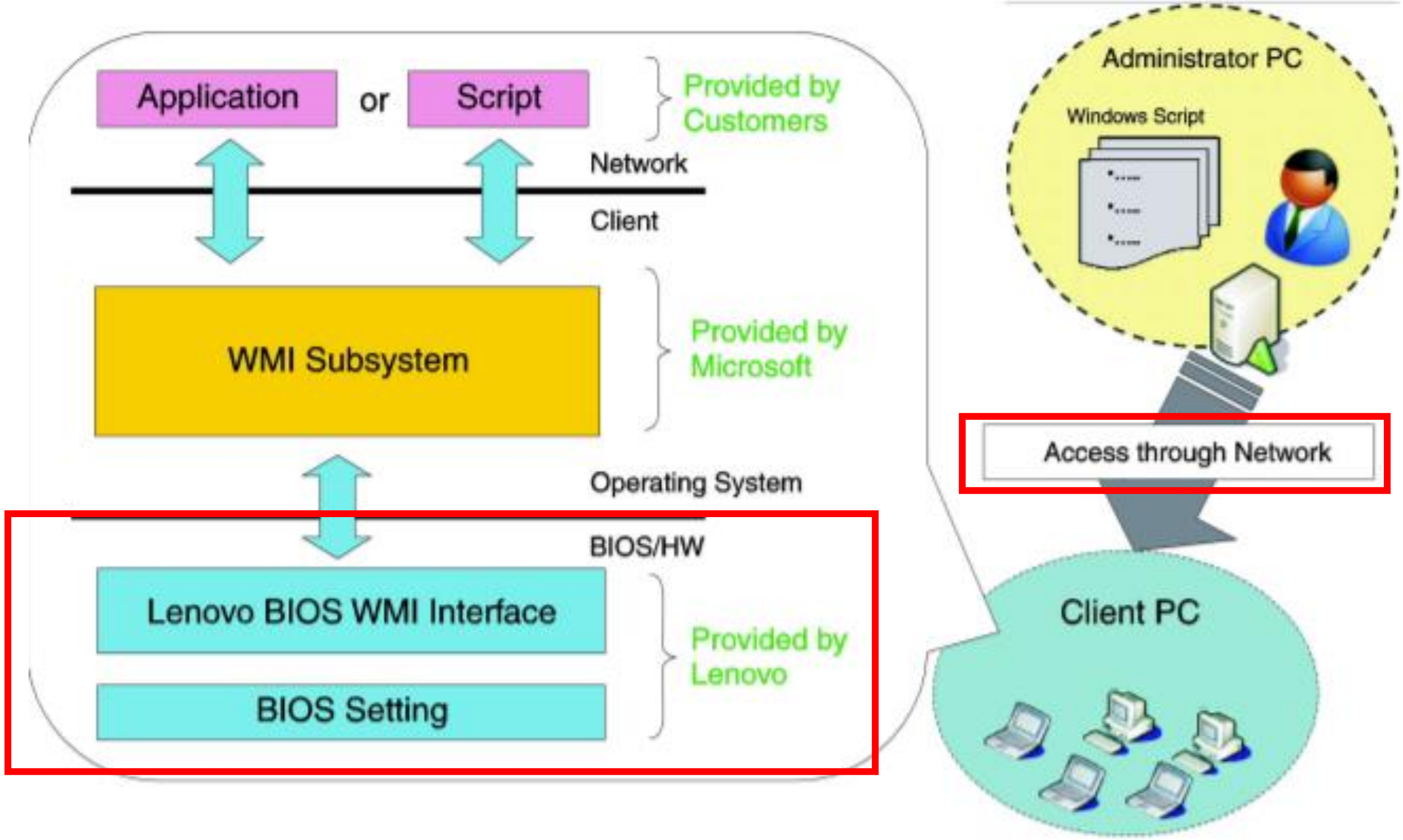
Upgrading to Windows 10 Version 1709

Running action: Disable Bootguard

```
Manufacturer      : Dell Inc.
Name              : 1.11.0
SerialNumber      : 70BJMH2
Version           : DELL   - 1072009
```

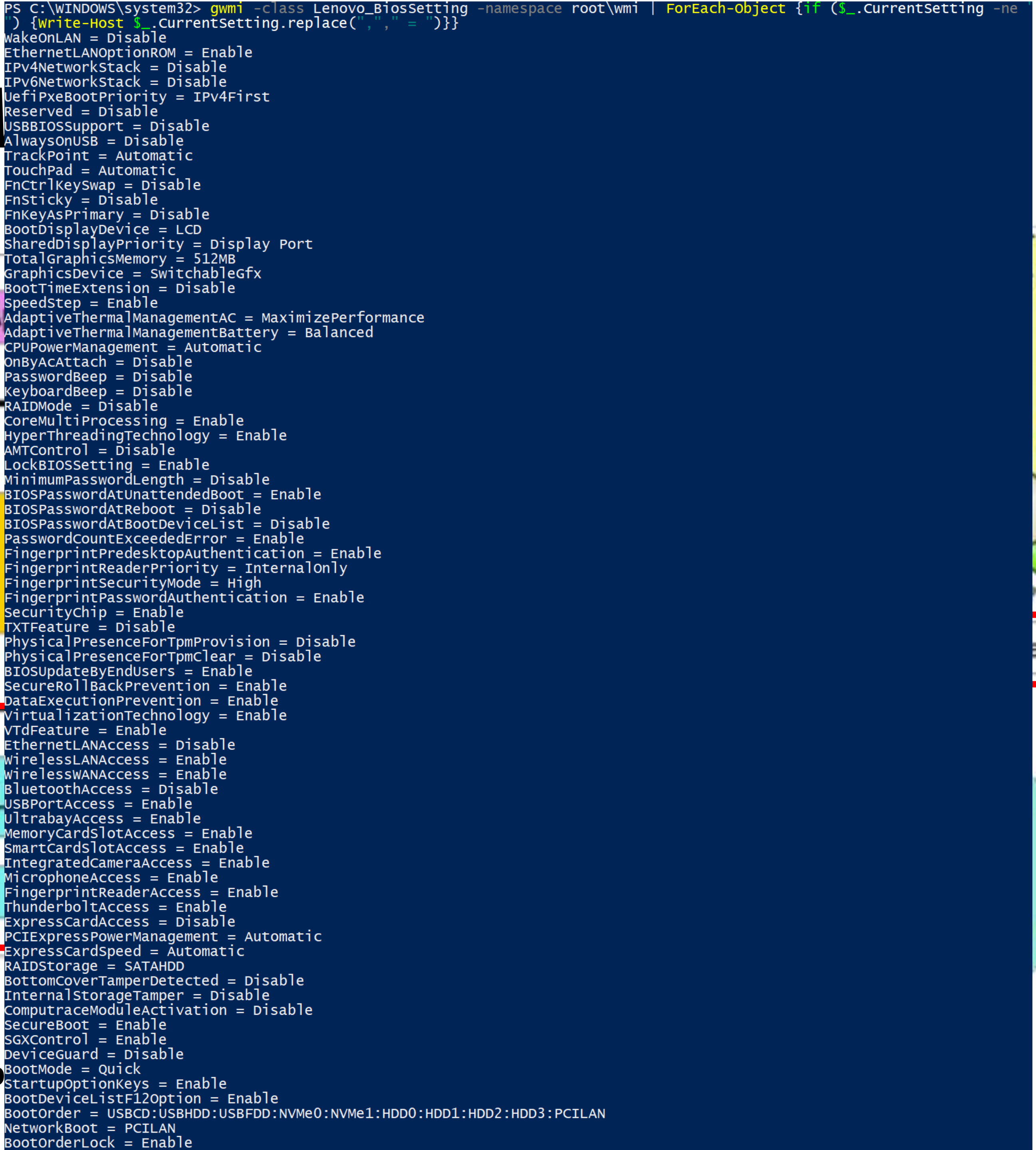
https://docs.microsoft.com/en-us/windows/desktop/cimwin32prov/win32-bios

SMI over WMI is evil



https://download.lenovo.com/pccbbs/mobiles_pdf/kbl-r_deploy_01.pdf

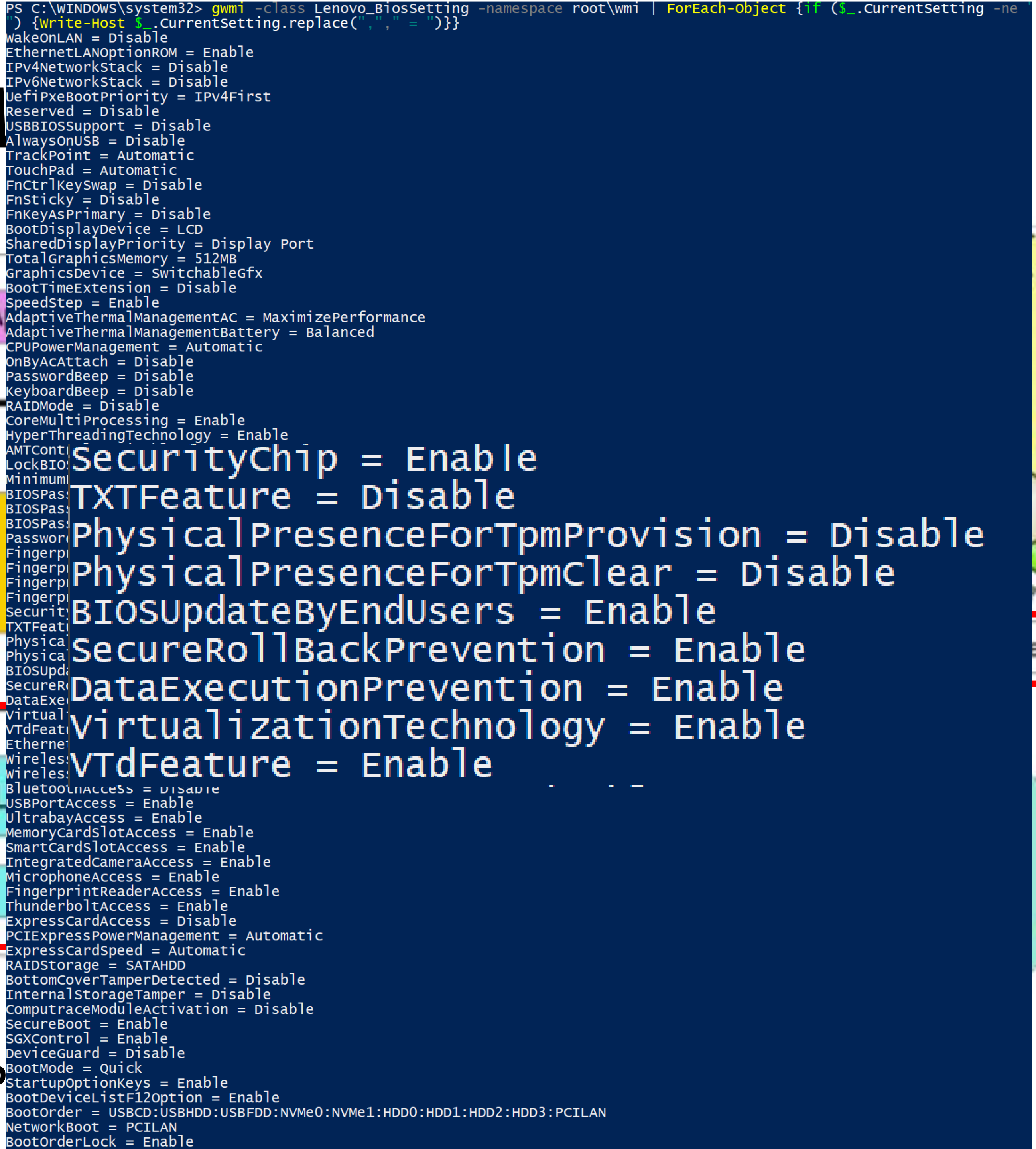
SMI over W



```
PS C:\WINDOWS\system32> gwmi -class Lenovo_BiosSetting -namespace root\wmi | ForEach-Object {if ($_.CurrentSetting -ne "
") {Write-Host $_.CurrentSetting.replace(","," = ")}}
WakeOnLAN = Disable
EthernetLANOptionROM = Enable
IPv4NetworkStack = Disable
IPv6NetworkStack = Disable
UefiPxeBootPriority = IPv4First
Reserved = Disable
USBBIOSSupport = Disable
AlwaysOnUSB = Disable
TrackPoint = Automatic
TouchPad = Automatic
FnCtrlKeySwap = Disable
FnSticky = Disable
FnKeyAsPrimary = Disable
BootDisplayDevice = LCD
SharedDisplayPriority = Display Port
TotalGraphicsMemory = 512MB
GraphicsDevice = SwitchableGfx
BootTimeExtension = Disable
SpeedStep = Enable
AdaptiveThermalManagementAC = MaximizePerformance
AdaptiveThermalManagementBattery = Balanced
CPUPowerManagement = Automatic
OnByAcAttach = Disable
PasswordBeep = Disable
KeyboardBeep = Disable
RAIDMode = Disable
CoreMultiProcessing = Enable
HyperThreadingTechnology = Enable
AMTControl = Disable
LockBIOSSetting = Enable
MinimumPasswordLength = Disable
BIOSPasswordAtUnattendedBoot = Enable
BIOSPasswordAtReboot = Disable
BIOSPasswordAtBootDeviceList = Disable
PasswordCountExceededError = Enable
FingerprintPredesktopAuthentication = Enable
FingerprintReaderPriority = InternalOnly
FingerprintSecurityMode = High
FingerprintPasswordAuthentication = Enable
SecurityChip = Enable
TXTFeature = Disable
PhysicalPresenceForTpmProvision = Disable
PhysicalPresenceForTpmClear = Disable
BIOSUpdateByEndUsers = Enable
SecureRollBackPrevention = Enable
DataExecutionPrevention = Enable
VirtualizationTechnology = Enable
VTdFeature = Enable
EthernetLANAccess = Disable
WirelessLANAccess = Enable
WirelessWANAccess = Enable
BluetoothAccess = Disable
USBPortAccess = Enable
UltrabayAccess = Enable
MemoryCardSlotAccess = Enable
SmartCardSlotAccess = Enable
IntegratedCameraAccess = Enable
MicrophoneAccess = Enable
FingerprintReaderAccess = Enable
ThunderboltAccess = Enable
ExpressCardAccess = Disable
PCIExpressPowerManagement = Automatic
ExpressCardSpeed = Automatic
RAIDStorage = SATAHDD
BottomCoverTamperDetected = Disable
InternalStorageTamper = Disable
ComputraceModuleActivation = Disable
SecureBoot = Enable
SGXControl = Enable
DeviceGuard = Disable
BootMode = Quick
StartupOptionKeys = Enable
BootDeviceListF12Option = Enable
BootOrder = USBCD:USBHDD:USBFDD:NVMe0:NVMe1:HDD0:HDD1:HDD2:HDD3:PCILAN
NetworkBoot = PCILAN
BootOrderLock = Enable
```

https://download.lenovo.co

SMI over W



```
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") {Write-Host $_.CurrentSetting.replace(","," = ")}}
WakeOnLAN = Disable
EthernetLANOptionROM = Enable
IPv4NetworkStack = Disable
IPv6NetworkStack = Disable
UefiPxeBootPriority = IPv4First
Reserved = Disable
USBBIOSSupport = Disable
AlwaysOnUSB = Disable
TrackPoint = Automatic
TouchPad = Automatic
FnCtrlKeySwap = Disable
FnSticky = Disable
FnKeyAsPrimary = Disable
BootDisplayDevice = LCD
SharedDisplayPriority = Display Port
TotalGraphicsMemory = 512MB
GraphicsDevice = SwitchableGfx
BootTimeExtension = Disable
SpeedStep = Enable
AdaptiveThermalManagementAC = MaximizePerformance
AdaptiveThermalManagementBattery = Balanced
CPUPowerManagement = Automatic
OnByAcAttach = Disable
PasswordBeep = Disable
KeyboardBeep = Disable
RAIDMode = Disable
CoreMultiProcessing = Enable
HyperThreadingTechnology = Enable
AMTCont
LockBIOS
Minimum
BIOSPass
BIOSPass
BIOSPass
Passwor
Fingerpr
Fingerpr
Fingerpr
Fingerpr
Security
TXTFeat
Physica
Physica
BIOSUpda
SecureR
DataExe
Virtual
VTdFeat
Etherne
Wireless
Wireless
BluetoothAccess = Disable
USBPortAccess = Enable
UltrabayAccess = Enable
MemoryCardSlotAccess = Enable
SmartCardSlotAccess = Enable
IntegratedCameraAccess = Enable
MicrophoneAccess = Enable
FingerprintReaderAccess = Enable
ThunderboltAccess = Enable
ExpressCardAccess = Disable
PCIExpressPowerManagement = Automatic
ExpressCardSpeed = Automatic
RAIDStorage = SATAHDD
BottomCoverTamperDetected = Disable
InternalStorageTamper = Disable
ComputraceModuleActivation = Disable
SecureBoot = Enable
SGXControl = Enable
DeviceGuard = Disable
BootMode = Quick
StartupOptionKeys = Enable
BootDeviceListF12Option = Enable
BootOrder = USBCD:USBHDD:USBFDD:NVMe0:NVMe1:HDD0:HDD1:HDD2:HDD3:PCILAN
NetworkBoot = PCILAN
BootOrderLock = Enable
```
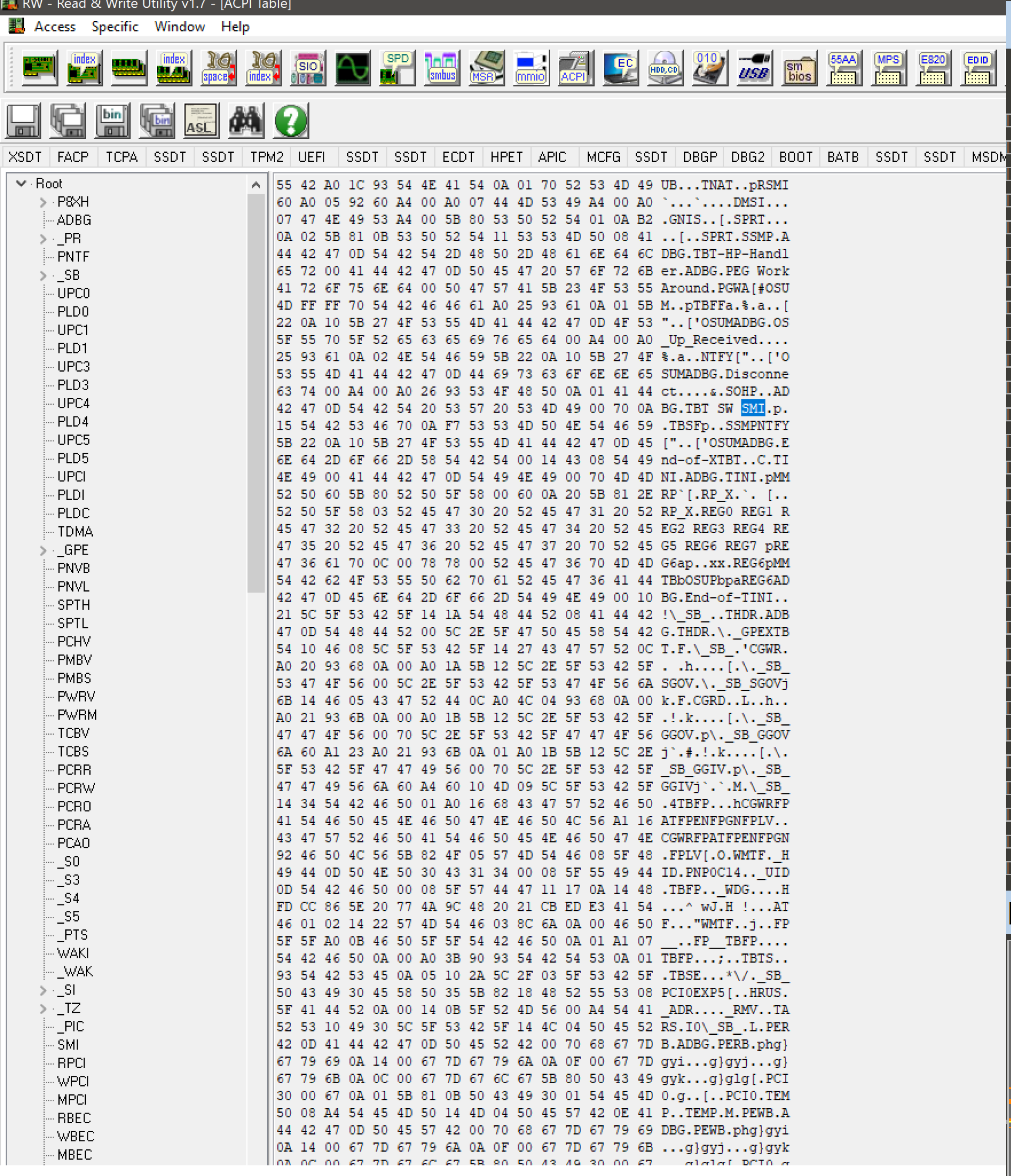
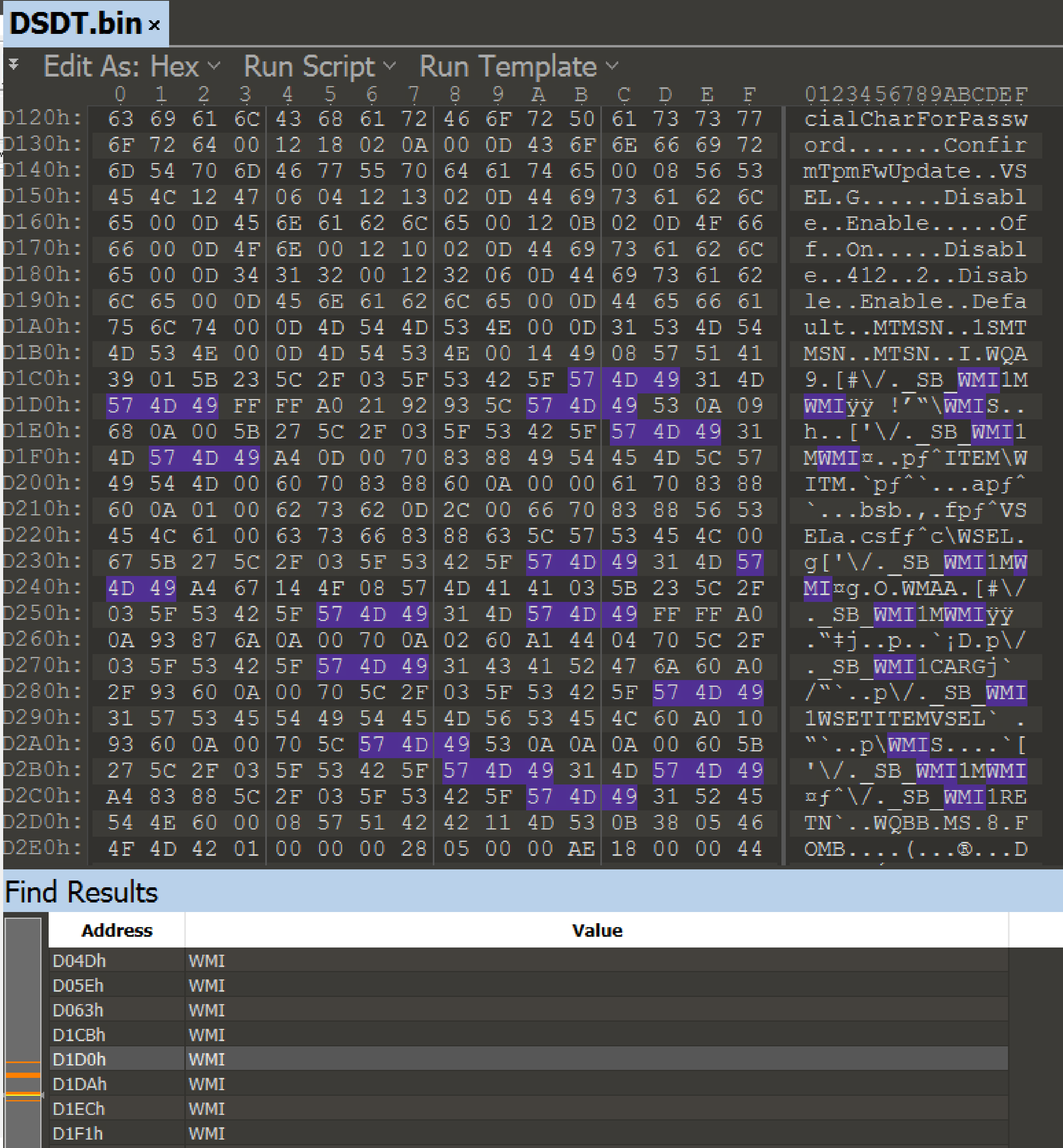

```
SecurityChip = Enable
TXTFeature = Disable
PhysicalPresenceForTpmProvision = Disable
PhysicalPresenceForTpmClear = Disable
BIOSUpdateByEndUsers = Enable
SecureRollBackPrevention = Enable
DataExecutionPrevention = Enable
VirtualizationTechnology = Enable
VTdFeature = Enable
```

https://download.lenovo.co

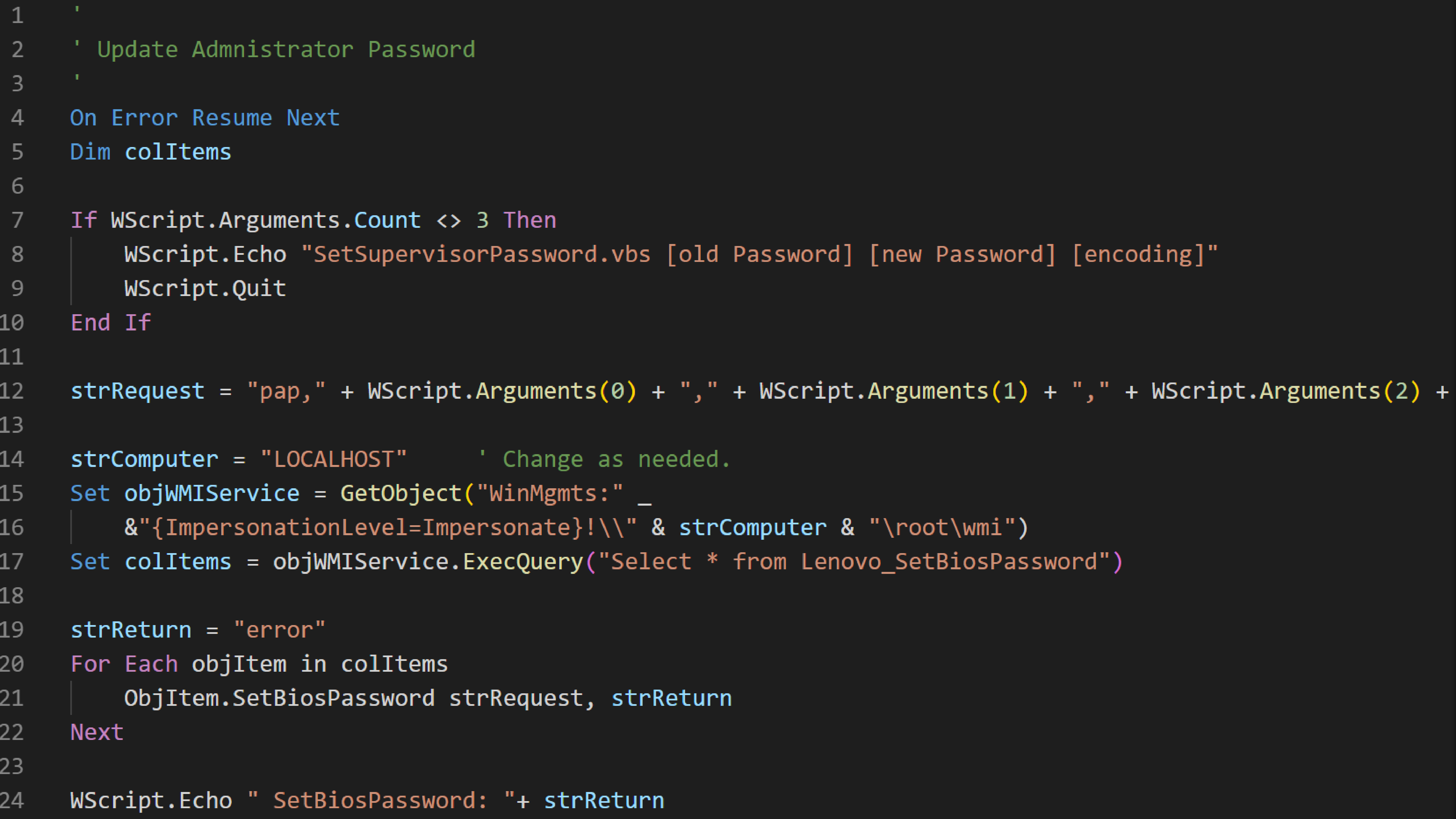


```
55 42 A0 1C 93 54 4E 41 54 0A 01 70 52 53 4D 49 UB...TNAT..pRSMI
60 A0 05 92 60 A4 00 A0 07 44 4D 53 49 A4 00 A0 `...`....DMSI...
07 47 4E 49 53 A4 00 5B 80 53 50 52 54 01 0A B2 .GNIS..[.SPRT...
0A 02 5B 81 0B 53 50 52 54 11 53 53 4D 50 08 41 ..[..SPRT.SSMP.A
44 42 47 0D 54 42 54 2D 48 50 2D 48 61 6E 64 6C DBG.TBT-HP-Handl
65 72 00 41 44 42 47 0D 50 45 47 20 57 6F 72 6B er.ADBG.PEG Work
41 72 6F 75 6E 64 00 50 47 57 41 5B 23 4F 53 55 Around.PGWA[#OSU
4D FF FF 70 54 42 46 46 61 A0 25 93 61 0A 01 5B M..pTBFFa.%.a..[
22 0A 10 5B 27 4F 53 55 4D 41 44 42 47 0D 4F 53 "..['OSUMADBG.OS
5F 55 70 5F 52 65 63 65 69 76 65 64 00 A4 00 A0 _Up_Received....
25 93 61 0A 02 4E 54 46 59 5B 22 0A 10 5B 27 4F %.a..NTFY["..['O
53 55 4D 41 44 42 47 0D 44 69 73 63 6F 6E 6E 65 SUMADBG.Disconne
63 74 00 A4 00 A0 26 93 53 4F 48 50 0A 01 41 44 ct....&.SOHP..AD
42 47 0D 54 42 54 20 53 57 20 53 4D 49 00 70 0A BG.TBT SW SMI.p.
15 54 42 53 46 70 0A F7 53 53 4D 50 4E 54 46 59 .TBSFp..SSMPNTFY
5B 22 0A 10 5B 27 4F 53 55 4D 41 44 42 47 0D 45 ["..['OSUMADBG.E
6E 64 2D 6F 66 2D 58 54 42 54 00 14 43 08 54 49 nd-of-XTBT..C.TI
4E 49 00 41 44 42 47 0D 54 49 4E 49 00 70 4D 4D NI.ADBG.TINI.pMM
52 50 60 5B 80 52 50 5F 58 00 60 0A 20 5B 81 2E RP`[.RP_X.`. [..
52 50 5F 58 03 52 45 47 30 20 52 45 47 31 20 52 RP_X.REG0 REG1 R
45 47 32 20 52 45 47 33 20 52 45 47 34 20 52 45 EG2 REG3 REG4 RE
47 35 20 52 45 47 36 20 52 45 47 37 20 70 52 45 G5 REG6 REG7 pRE
47 36 61 70 0C 00 78 78 00 52 45 47 36 70 4D 4D G6ap..xx.REG6pMM
54 42 62 4F 53 55 50 62 70 61 52 45 47 36 41 44 TBbOSUPbpaREG6AD
42 47 0D 45 6E 64 2D 6F 66 2D 54 49 4E 49 00 10 BG.End-of-TINI..
21 5C 5F 53 42 5F 14 1A 54 48 44 52 08 41 44 42 !\_SB_..THDR.ADB
47 0D 54 48 44 52 00 5C 2E 5F 47 50 45 58 54 42 G.THDR.\._GPEXTB
54 10 46 08 5C 5F 53 42 5F 14 27 43 47 57 52 0C T.F.\_SB_.'CGWR.
A0 20 93 68 0A 00 A0 1A 5B 12 5C 2E 5F 53 42 5F . .h....[.\._SB_
53 47 4F 56 00 5C 2E 5F 53 42 5F 53 47 4F 56 6A SGOV.\._SB_SGOVj
6B 14 46 05 43 47 52 44 0C A0 4C 04 93 68 0A 00 k.F.CGRD..L..h..
A0 21 93 6B 0A 00 A0 1B 5B 12 5C 2E 5F 53 42 5F .!.k....[.\._SB_
47 47 4F 56 00 70 5C 2E 5F 53 42 5F 47 47 4F 56 GGOV.p\._SB_GGOV
6A 60 A1 23 A0 21 93 6B 0A 01 A0 1B 5B 12 5C 2E j`.#.!.k....[.\.
5F 53 42 5F 47 47 49 56 00 70 5C 2E 5F 53 42 5F _SB_GGIV.p\._SB_
47 47 49 56 6A 60 A4 60 10 4D 09 5C 5F 53 42 5F GGIVj`.`.M.\_SB_
14 34 54 42 46 50 01 A0 16 68 43 47 57 52 46 50 .4TBFP...hCGWRFP
41 54 46 50 45 4E 46 50 47 4E 46 50 4C 56 A1 16 ATFPENFPGNFPLV..
43 47 57 52 46 50 41 54 46 50 45 4E 46 50 47 4E CGWRFPATFPENFPGN
92 46 50 4C 56 5B 82 4F 05 57 4D 54 46 08 5F 48 .FPLV[.O.WMTF._H
49 44 0D 50 4E 50 30 43 31 34 00 08 5F 55 49 44 ID.PNP0C14.._UID
0D 54 42 46 50 00 08 5F 57 44 47 11 17 0A 14 48 .TBFP.._WDG....H
FD CC 86 5E 20 77 4A 9C 48 20 21 CB ED E3 41 54 ...^ wJ.H !...AT
46 01 02 14 22 57 4D 54 46 03 8C 6A 0A 00 46 50 F..."WMTF..j..FP
5F 5F A0 0B 46 50 5F 5F 54 42 46 50 0A 01 A1 07 __..FP__TBFP....
54 42 46 50 0A 00 A0 3B 90 93 54 42 54 53 0A 01 TBFP...;..TBTS..
93 54 42 53 45 0A 05 10 2A 5C 2F 03 5F 53 42 5F .TBSE...*\/._SB_
50 43 49 30 45 58 50 35 5B 82 18 48 52 55 53 08 PCI0EXP5[..HRUS.
5F 41 44 52 0A 00 14 0B 5F 52 4D 56 00 A4 54 41 _ADR...._RMV..TA
52 53 10 49 30 5C 5F 53 42 5F 14 4C 04 50 45 52 RS.I0\_SB_.L.PER
42 0D 41 44 42 47 0D 50 45 52 42 00 70 68 67 7D B.ADBG.PERB.phg}
67 79 69 0A 14 00 67 7D 67 79 6A 0A 0F 00 67 7D gyi...g}gyj...g}
67 79 6B 0A 0C 00 67 7D 67 6C 67 5B 80 50 43 49 gyk...g}glg[.PCI
30 00 67 0A 01 5B 81 0B 50 43 49 30 01 54 45 4D 0.g..[..PCI0.TEM
50 08 A4 54 45 4D 50 14 4D 04 50 45 57 42 0E 41 P..TEMP.M.PEWB.A
44 42 47 0D 50 45 57 42 00 70 68 67 7D 67 79 69 DBG.PEWB.phg}gyi
0A 14 00 67 7D 67 79 6A 0A 0F 00 67 7D 67 79 6B ...g}gyj...g}gyk
0A 0C 00 67 7D 67 6C 67 5B 80 50 43 49 30 00 67 ...g}glg[.PCI0.g
```



```
       0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F   0123456789ABCDEF
D120h: 63 69 61 6C 43 68 61 72 46 6F 72 50 61 73 73 77  cialCharForPassw
D130h: 6F 72 64 00 12 18 02 0A 00 0D 43 6F 6E 66 69 72  ord.......Confir
D140h: 6D 54 70 6D 46 77 55 70 64 61 74 65 00 08 56 53  mTpmFwUpdate..VS
D150h: 45 4C 12 47 06 04 12 13 02 0D 44 69 73 61 62 6C  EL.G......Disabl
D160h: 65 00 0D 45 6E 61 62 6C 65 00 12 0B 02 0D 4F 66  e..Enable.....Of
D170h: 66 00 0D 4F 6E 00 12 10 02 0D 44 69 73 61 62 6C  f..On.....Disabl
D180h: 65 00 0D 34 31 32 00 12 32 06 0D 44 69 73 61 62  e..412..2..Disab
D190h: 6C 65 00 0D 45 6E 61 62 6C 65 00 0D 44 65 66 61  le..Enable..Defa
D1A0h: 75 6C 74 00 0D 4D 54 4D 53 4E 00 0D 31 53 4D 54  ult..MTMSN..1SMT
D1B0h: 4D 53 4E 00 0D 4D 54 53 4E 00 14 49 08 57 51 41  MSN..MTSN..I.WQA
D1C0h: 39 01 5B 23 5C 2F 03 5F 53 42 5F 57 4D 49 31 4D  9.[#\/._SB_WMI1M
D1D0h: 57 4D 49 FF FF A0 21 92 93 5C 57 4D 49 53 0A 09  WMIÿÿ !'"\WMIS..
D1E0h: 68 0A 00 5B 27 5C 2F 03 5F 53 42 5F 57 4D 49 31  h..['\/._SB_WMI1
D1F0h: 4D 57 4D 49 A4 0D 00 70 83 88 49 54 45 4D 5C 57  MWMI¤..pƒˆITEM\W
D200h: 49 54 4D 00 60 70 83 88 60 0A 00 00 61 70 83 88  ITM.`pƒˆ`...apƒˆ
D210h: 60 0A 01 00 62 73 62 0D 2C 00 66 70 83 88 56 53  `...bsb.,.fpƒˆVS
D220h: 45 4C 61 00 63 73 66 83 88 63 5C 57 53 45 4C 00  ELa.csfƒˆc\WSEL.
D230h: 67 5B 27 5C 2F 03 5F 53 42 5F 57 4D 49 31 4D 57  g['\/._SB_WMI1MW
D240h: 4D 49 A4 67 14 4F 08 57 4D 41 41 03 5B 23 5C 2F  MI¤g.O.WMAA.[#\/
D250h: 03 5F 53 42 5F 57 4D 49 31 4D 57 4D 49 FF FF A0  ._SB_WMI1MWMIÿÿ 
D260h: 0A 93 87 6A 0A 00 70 0A 02 60 A1 44 04 70 5C 2F  ."‡j..p..`¡D.p\/
D270h: 03 5F 53 42 5F 57 4D 49 31 43 41 52 47 6A 60 A0  ._SB_WMI1CARGj` 
D280h: 2F 93 60 0A 00 70 5C 2F 03 5F 53 42 5F 57 4D 49  /"`..p\/._SB_WMI
D290h: 31 57 53 45 54 49 54 45 4D 56 53 45 4C 60 A0 10  1WSETITEMVSEL` .
D2A0h: 93 60 0A 00 70 5C 57 4D 49 53 0A 0A 0A 00 60 5B  "`..p\WMIS....`[
D2B0h: 27 5C 2F 03 5F 53 42 5F 57 4D 49 31 4D 57 4D 49  '\/._SB_WMI1MWMI
D2C0h: A4 83 88 5C 2F 03 5F 53 42 5F 57 4D 49 31 52 45  ¤ƒˆ\/._SB_WMI1RE
D2D0h: 54 4E 60 00 08 57 51 42 42 11 4D 53 0B 38 05 46  TN`..WQBB.MS.8.F
D2E0h: 4F 4D 42 01 00 00 00 28 05 00 00 AE 18 00 00 44  OMB....(...®...D
```

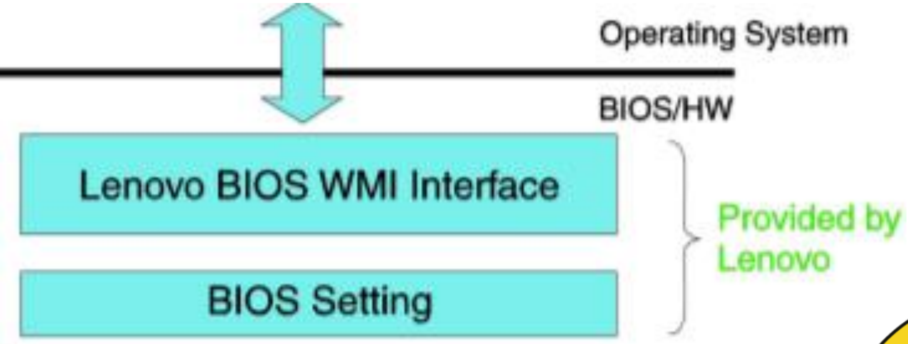
Address	Value
D04Dh	WMI
D05Eh	WMI
D063h	WMI
D1CBh	WMI
D1D0h	WMI
D1DAh	WMI
D1ECh	WMI
D1F1h	WMI

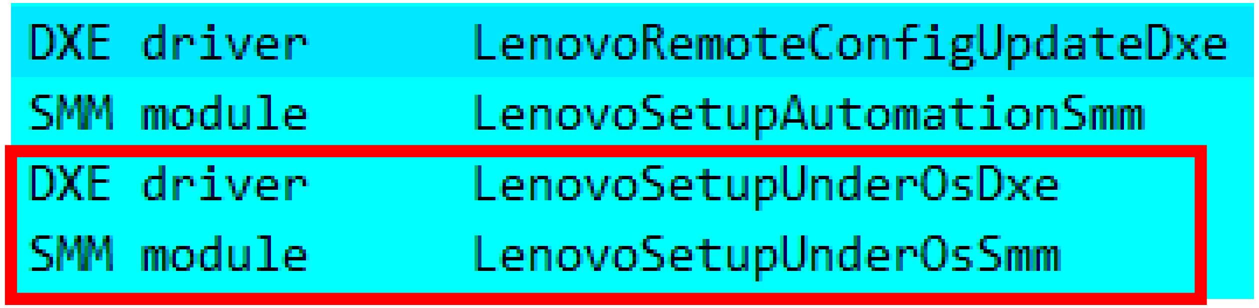


```
'
' Update Admnistrator Password
'
On Error Resume Next
Dim colItems

If WScript.Arguments.Count <> 3 Then
    WScript.Echo "SetSupervisorPassword.vbs [old Password] [new Password] [encoding]"
    WScript.Quit
End If

strRequest = "pap," + WScript.Arguments(0) + "," + WScript.Arguments(1) + "," + WScript.Arguments(2) +

strComputer = "LOCALHOST"     ' Change as needed.
Set objWMIService = GetObject("WinMgmts:" _
    &"{ImpersonationLevel=Impersonate}!\\" & strComputer & "\root\wmi")
Set colItems = objWMIService.ExecQuery("Select * from Lenovo_SetBiosPassword")

strReturn = "error"
For Each objItem in colItems
    ObjItem.SetBiosPassword strRequest, strReturn
Next

WScript.Echo " SetBiosPassword: "+ strReturn
```

BRAVE NEW WORLD

How this REsearch get started?





DXE driver	LenovoRemoteConfigUpdateDxe
SMM module	LenovoSetupAutomationSmm
DXE driver	LenovoSetupUnderOsDxe
SMM module	LenovoSetupUnderOsSmm

WTF LenovoSetupUnderOs (Smm/Dxe)?

- ➢ **LenovoSetupUnderOsDxe** (0D648466-36BD-42c6-B287-7C3BAA2575C0)
  - ✓ Communicate with LenovoPasswordManagerDxe

- ➢ **LenovoSetupUnderOsSmm** (65A72030-B02E-4bf3-8424-BA5F2FC56DE7)
  - ➢ Multiple WSMI Handlers (~12 SMI handlers):
    - ✓ Get/Set BiosPassword
    - ✓ Get/Set BiosSettings

- ➢ **LenovoHiddenSetting**
  - ✓ ComputraceDisable
  - ✓ CpuDebugEnable

Setup Automation SMI?

- ChangeConfiguration 0x04
- ChangePassword 0x81
- ChangeBootOrder 0xA7
- SecureBootConfiguration 0xAE

- It’s more: 0x0f, 0x80, 0x82, 0x9F, 0xB4/B6/B8

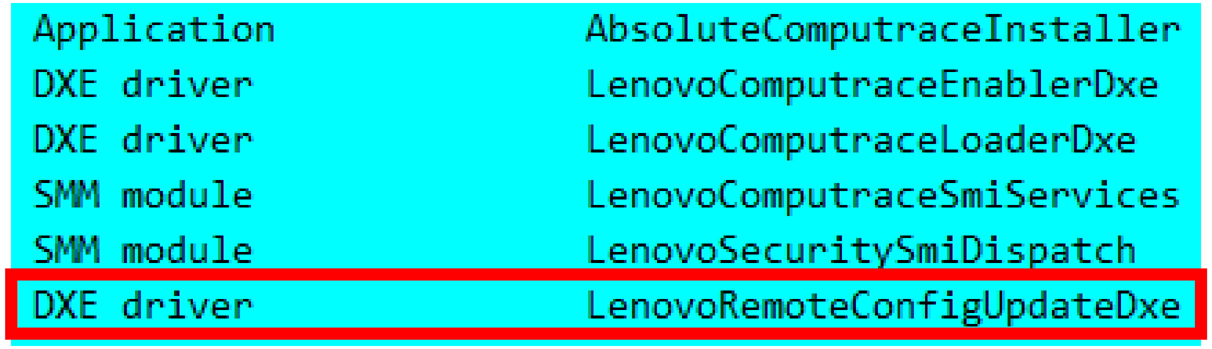
Setup Automation SMI?

- ChangeConfiguration 0x04
- ChangePassword 0x81
- ChangeBootOrder 0xA7
- SecureBootConfiguration 0xAE

- It’s more: 0x0f, 0x80, 0x82, 0x9F, 0xB4/B6/B8

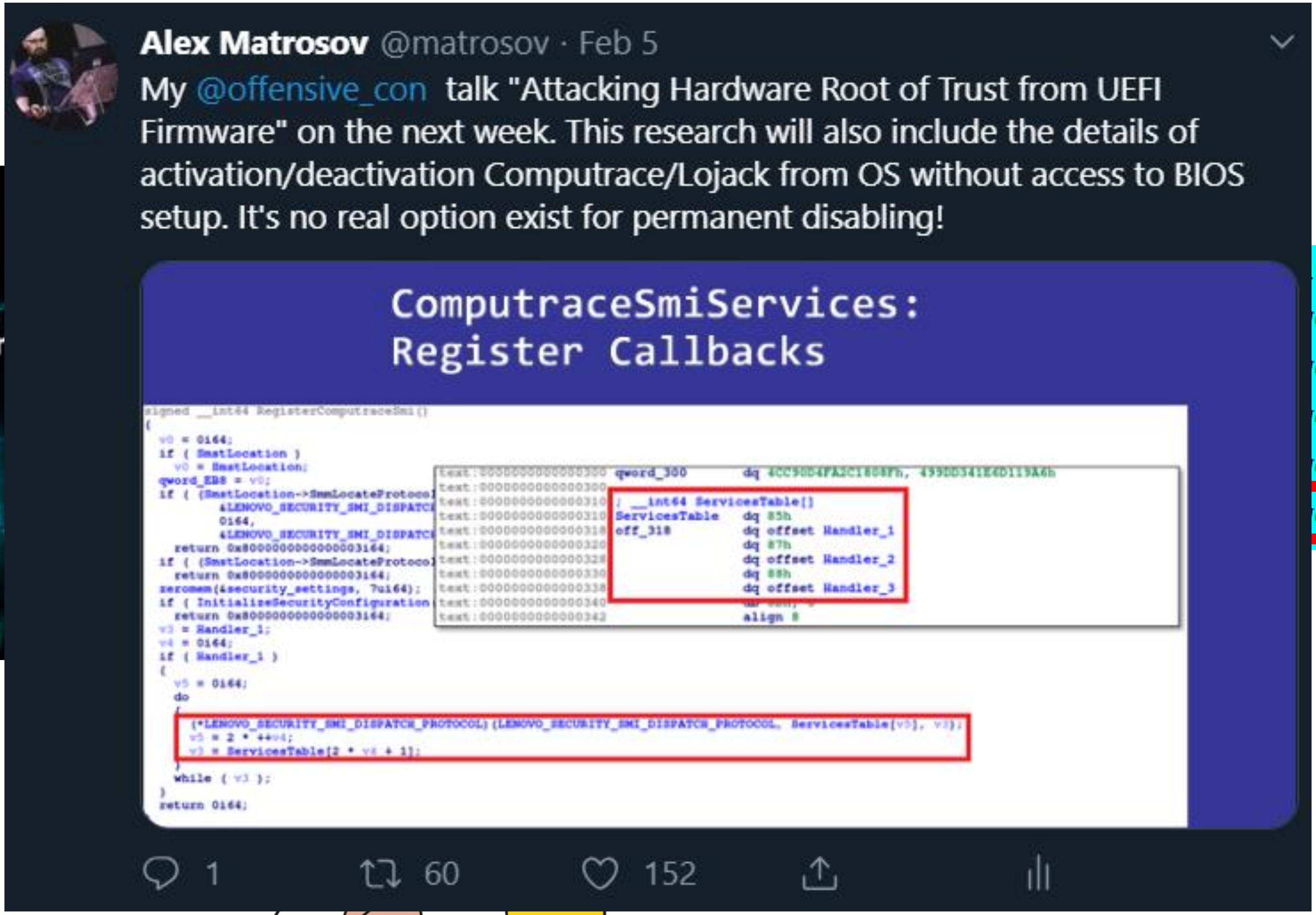
Computrace Never Dies

How I back to my old Computrace REsearch



```
Application          AbsoluteComputraceInstaller
DXE driver           LenovoComputraceEnablerDxe
DXE driver           LenovoComputraceLoaderDxe
SMM module           LenovoComputraceSmiServices
SMM module           LenovoSecuritySmiDispatch
DXE driver           LenovoRemoteConfigUpdateDxe
```

How I back to my old Computrace REsearch



Alex Matrosov @matrosov · Feb 5

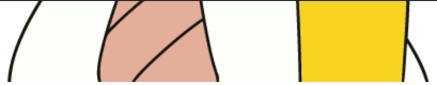
My @offensive_con talk "Attacking Hardware Root of Trust from UEFI Firmware" on the next week. This research will also include the details of activation/deactivation Computrace/Lojack from OS without access to BIOS setup. It's no real option exist for permanent disabling!

ComputraceSmiServices:
Register Callbacks

```
signed __int64 RegisterComputraceSmi()
{
  v0 = 0i64;
  if ( SmstLocation )
    v0 = SmstLocation;
  qword_EB8 = v0;
  if ( (SmstLocation->SmmLocateProtocol
           &LENOVO_SECURITY_SMI_DISPATCH
           0i64,
           &LENOVO_SECURITY_SMI_DISPATCH
    return 0x8000000000000003i64;
  if ( (SmstLocation->SmmLocateProtocol
    return 0x8000000000000003i64;
  zeromem(&security_settings, 7ui64);
  if ( InitializeSecurityConfiguration
    return 0x8000000000000003i64;
  v3 = Handler_1;
  v4 = 0i64;
  if ( Handler_1 )
  {
    v5 = 0i64;
    do
    {
      (*LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL)(LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL, ServicesTable[v5], v3);
      v5 = 2 * ++v4;
      v3 = ServicesTable[2 * v4 + 1];
    }
    while ( v3 );
  }
  return 0i64;
```

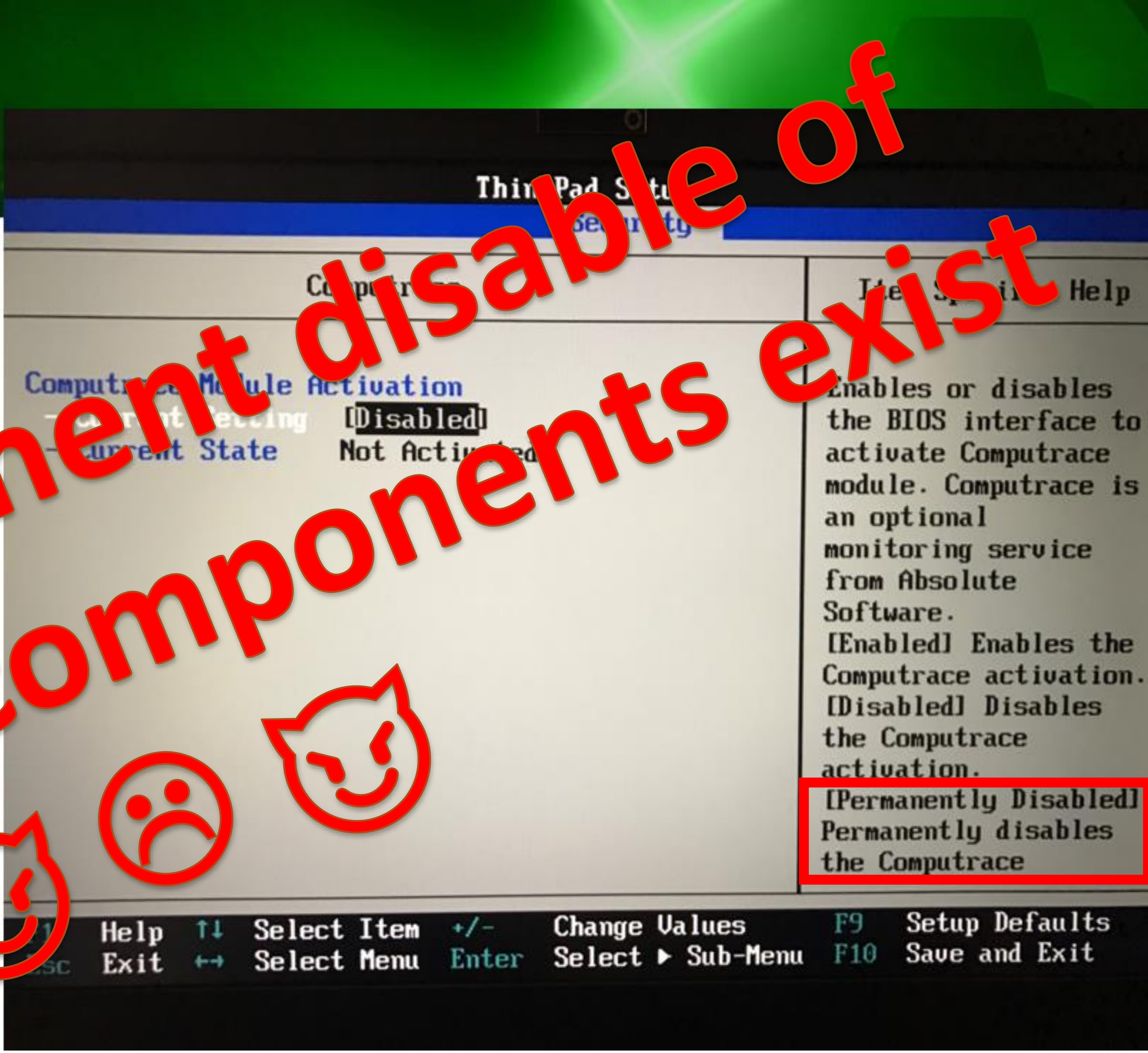
```
text:0000000000000300 qword_300       dq 4CC9D04FA2C1808Fh, 499DD341E4D119A6h
text:0000000000000300
text:0000000000000310 ; __int64 ServicesTable[]
text:0000000000000310 ServicesTable   dq 85h
text:0000000000000318 off_318         dq offset Handler_1
text:0000000000000320                 dq 87h
text:0000000000000328                 dq offset Handler_2
text:0000000000000330                 dq 88h
text:0000000000000338                 dq offset Handler_3
text:0000000000000340
text:0000000000000342                 align 8
```

```
uteComputraceInstaller
oComputraceEnablerDxe
oComputraceLoaderDxe
oComputraceSmiServices
oSecuritySmiDispatch
oRemoteConfigUpdateDxe
```



It’s no permanent disable of Computrace components exist

😈 ☹ 😈


ThinkPad Setup

Security

Computrace

Item Specific Help

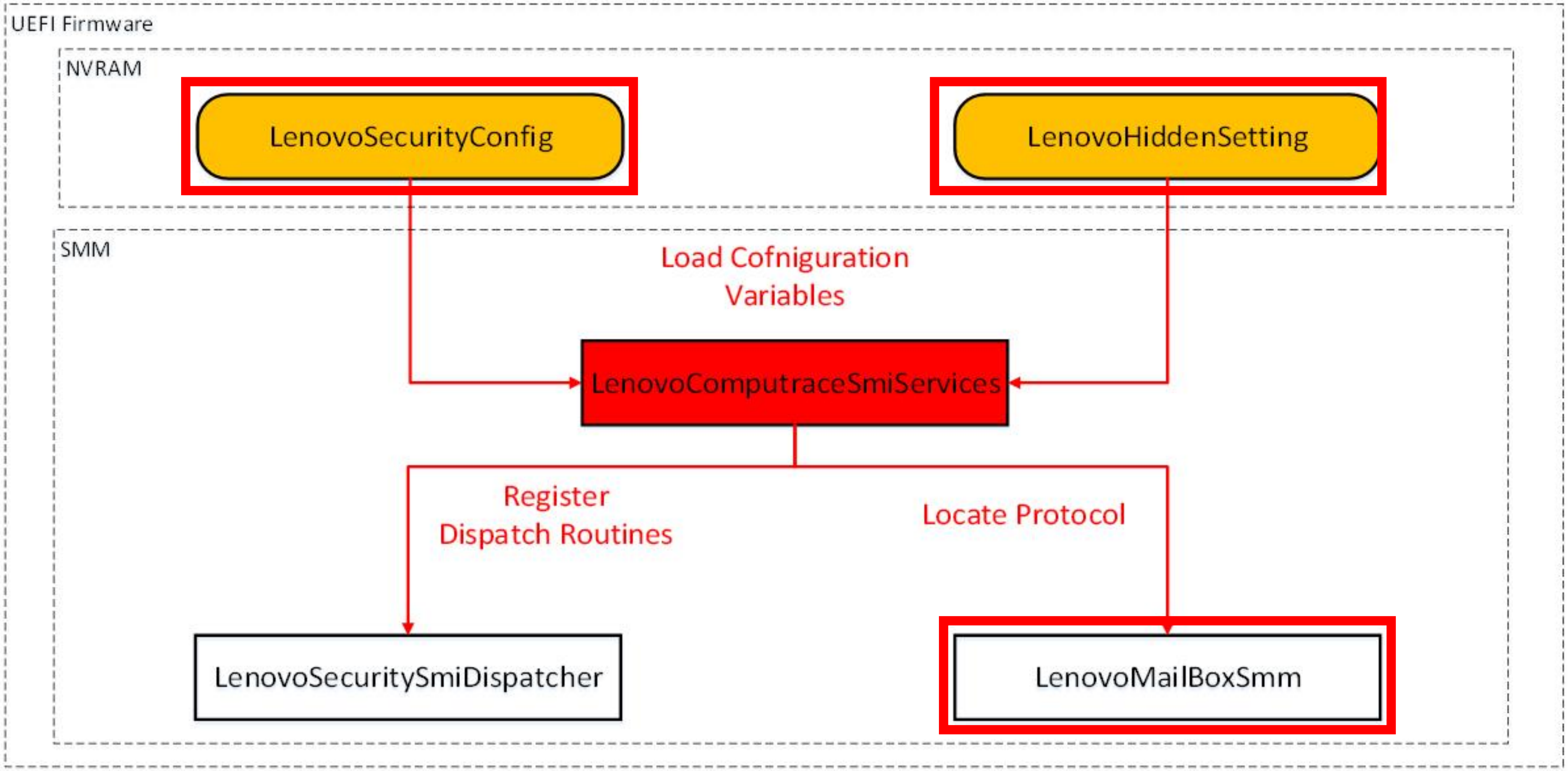
Computrace Module Activation
- Current Setting [Disabled]
- Current State Not Activated

Enables or disables the BIOS interface to activate Computrace module. Computrace is an optional monitoring service from Absolute Software.
[Enabled] Enables the Computrace activation.
[Disabled] Disables the Computrace activation.
[Permanently Disabled] Permanently disables the Computrace

```
F1  Help  ↑↓ Select Item  +/-   Change Values      F9  Setup Defaults
Esc Exit  ↔  Select Menu  Enter Select ▸ Sub-Menu  F10 Save and Exit
```

https://github.com/REhints/Publications/tree/master/Conferences/UEFI%20Firmware%20Rootkits%20Myths%20and%20Reality

ComputraceSmiServices: Components



UEFI Firmware

NVRAM

LenovoSecurityConfig

LenovoHiddenSetting

SMM

Load Cofniguration Variables

LenovoComputraceSmiServices

Register Dispatch Routines

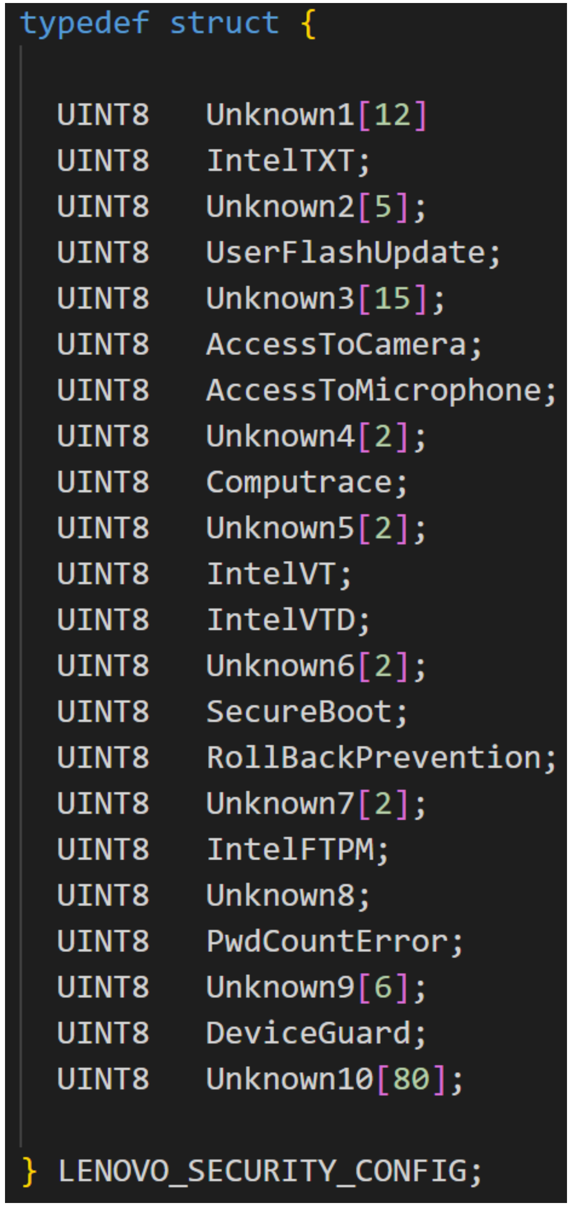
Locate Protocol

LenovoSecuritySmiDispatcher

LenovoMailBoxSmm

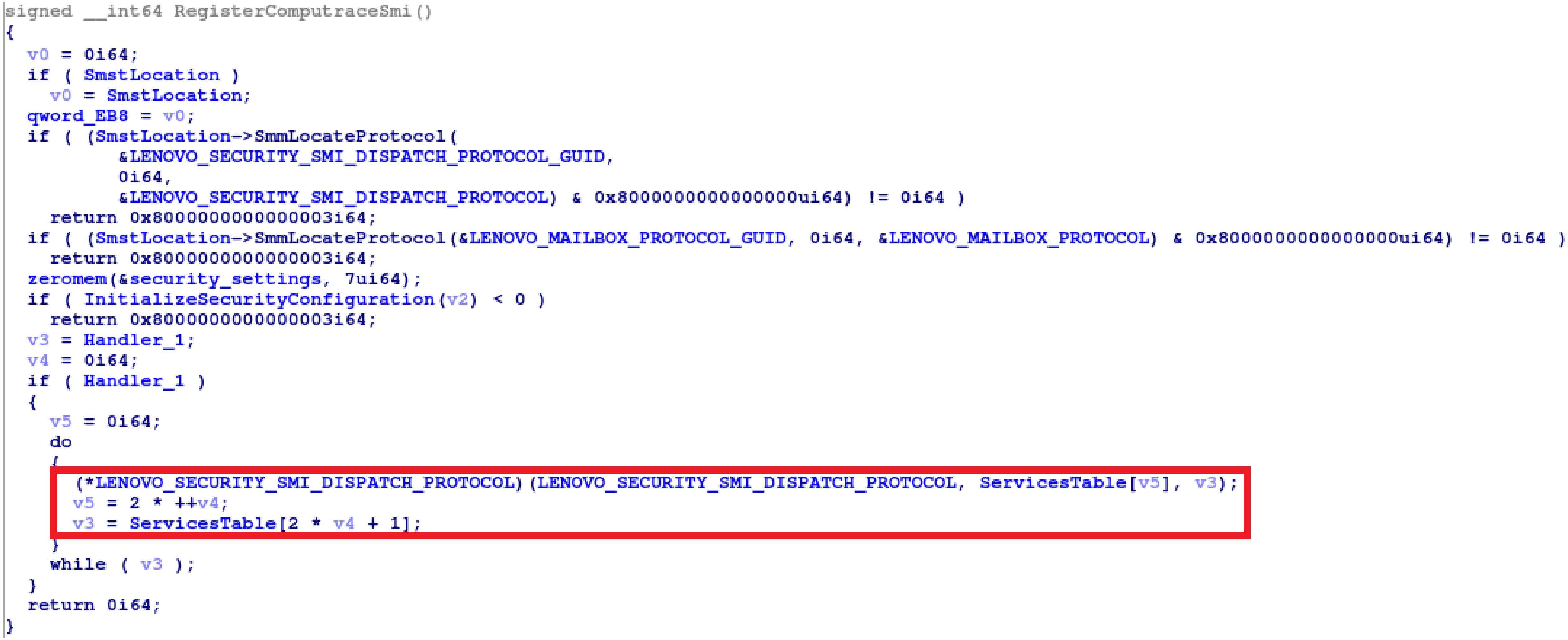
https://github.com/REhints/Publications/tree/master/Conferences/UEFI%20Firmware%20Rootkits%20Myths%20and%20Reality

Lenovo security configs



```
typedef struct {

  UINT8   Unknown1[12]
  UINT8   IntelTXT;
  UINT8   Unknown2[5];
  UINT8   UserFlashUpdate;
  UINT8   Unknown3[15];
  UINT8   AccessToCamera;
  UINT8   AccessToMicrophone;
  UINT8   Unknown4[2];
  UINT8   Computrace;
  UINT8   Unknown5[2];
  UINT8   IntelVT;
  UINT8   IntelVTD;
  UINT8   Unknown6[2];
  UINT8   SecureBoot;
  UINT8   RollBackPrevention;
  UINT8   Unknown7[2];
  UINT8   IntelFTPM;
  UINT8   Unknown8;
  UINT8   PwdCountError;
  UINT8   Unknown9[6];
  UINT8   DeviceGuard;
  UINT8   Unknown10[80];

} LENOVO_SECURITY_CONFIG;
```

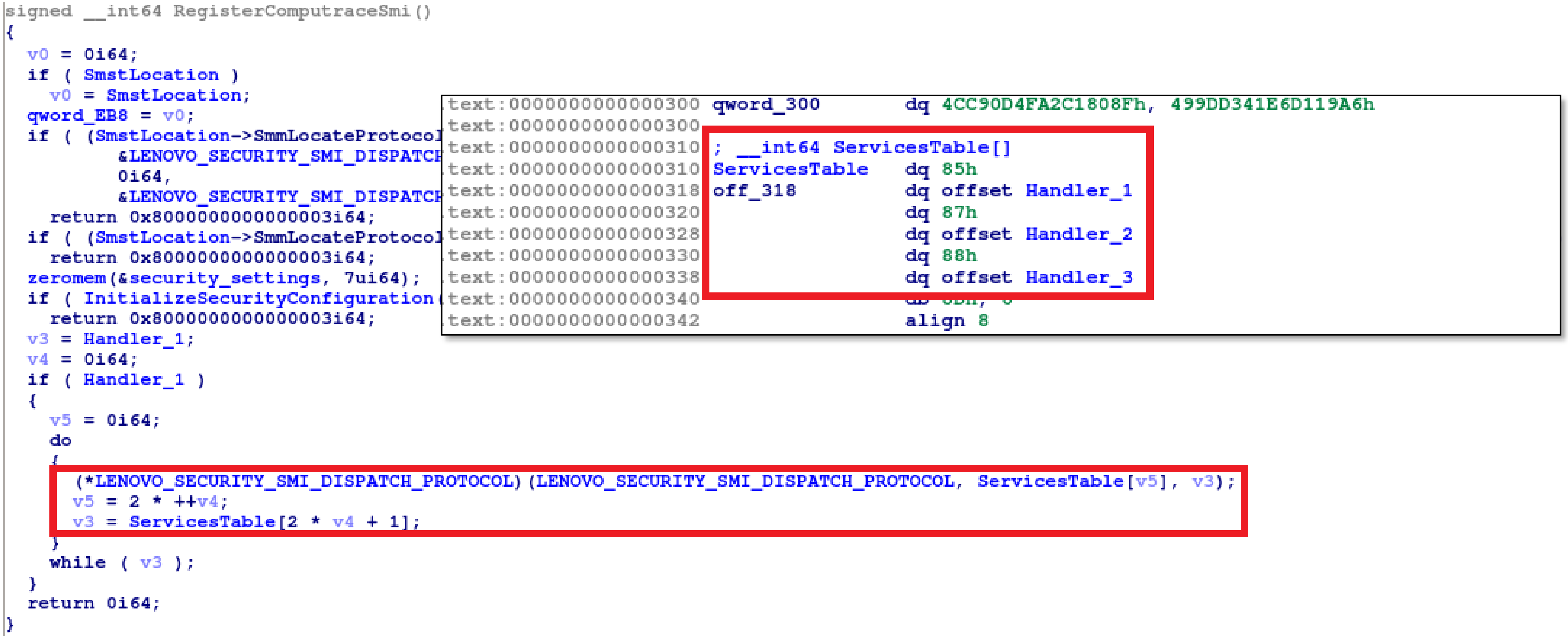
ComputraceSmiServices->Register Callbacks



```
signed __int64 RegisterComputraceSmi()
{
  v0 = 0i64;
  if ( SmstLocation )
    v0 = SmstLocation;
  qword_EB8 = v0;
  if ( (SmstLocation->SmmLocateProtocol(
          &LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL_GUID,
          0i64,
          &LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL) & 0x8000000000000000ui64) != 0i64 )
    return 0x8000000000000003i64;
  if ( (SmstLocation->SmmLocateProtocol(&LENOVO_MAILBOX_PROTOCOL_GUID, 0i64, &LENOVO_MAILBOX_PROTOCOL) & 0x8000000000000000ui64) != 0i64 )
    return 0x8000000000000003i64;
  zeromem(&security_settings, 7ui64);
  if ( InitializeSecurityConfiguration(v2) < 0 )
    return 0x8000000000000003i64;
  v3 = Handler_1;
  v4 = 0i64;
  if ( Handler_1 )
  {
    v5 = 0i64;
    do
    {
      (*LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL)(LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL, ServicesTable[v5], v3);
      v5 = 2 * ++v4;
      v3 = ServicesTable[2 * v4 + 1];
    }
    while ( v3 );
  }
  return 0i64;
}
```

https://github.com/REhints/Publications/tree/master/Conferences/UEFI%20Firmware%20Rootkits%20Myths%20and%20Reality

ComputraceSmiServices->Register Callbacks



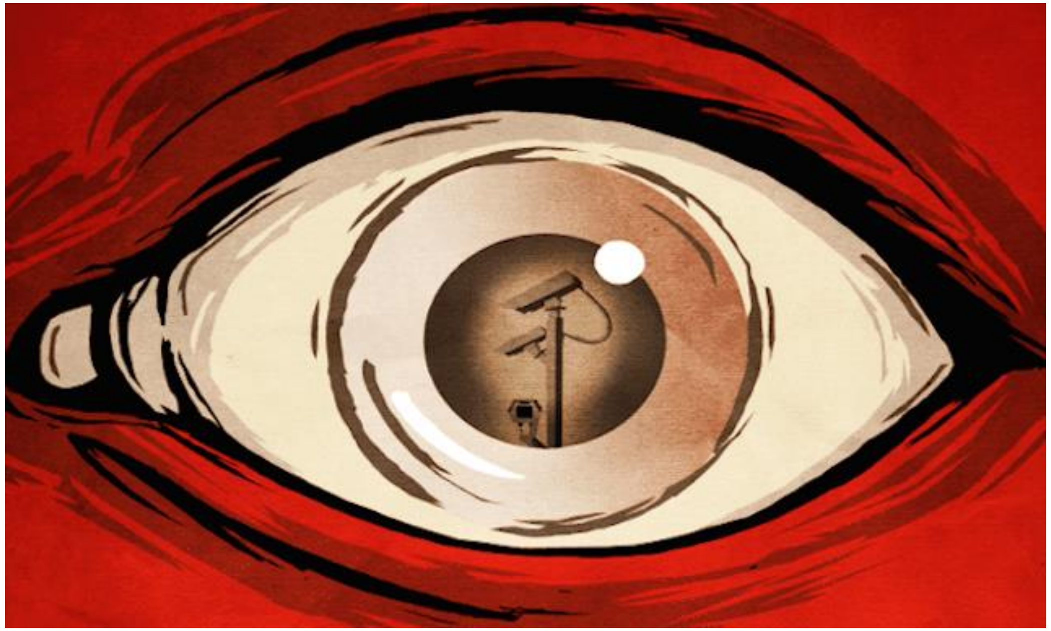
```
signed __int64 RegisterComputraceSmi()
{
  v0 = 0i64;
  if ( SmstLocation )
    v0 = SmstLocation;
  qword_EB8 = v0;
  if ( (SmstLocation->SmmLocateProtocol
          &LENOVO_SECURITY_SMI_DISPATCH
          0i64,
          &LENOVO_SECURITY_SMI_DISPATCH
    return 0x8000000000000003i64;
  if ( (SmstLocation->SmmLocateProtocol
    return 0x8000000000000003i64;
  zeromem(&security_settings, 7ui64);
  if ( InitializeSecurityConfiguration(
    return 0x8000000000000003i64;
  v3 = Handler_1;
  v4 = 0i64;
  if ( Handler_1 )
  {
    v5 = 0i64;
    do
    {
      (*LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL)(LENOVO_SECURITY_SMI_DISPATCH_PROTOCOL, ServicesTable[v5], v3);
      v5 = 2 * ++v4;
      v3 = ServicesTable[2 * v4 + 1];
    }
    while ( v3 );
  }
  return 0i64;
}
```

```
.text:0000000000000300 qword_300       dq 4CC90D4FA2C1808Fh, 499DD341E6D119A6h
.text:0000000000000300
.text:0000000000000310 ; __int64 ServicesTable[]
.text:0000000000000310 ServicesTable   dq 85h
.text:0000000000000318 off_318         dq offset Handler_1
.text:0000000000000320                 dq 87h
.text:0000000000000328                 dq offset Handler_2
.text:0000000000000330                 dq 88h
.text:0000000000000338                 dq offset Handler_3
.text:0000000000000340                 db 0Bh, 0
.text:0000000000000342                 align 8
```

https://github.com/REhints/Publications/tree/master/Conferences/UEFI%20Firmware%20Rootkits%20Myths%20and%20Reality

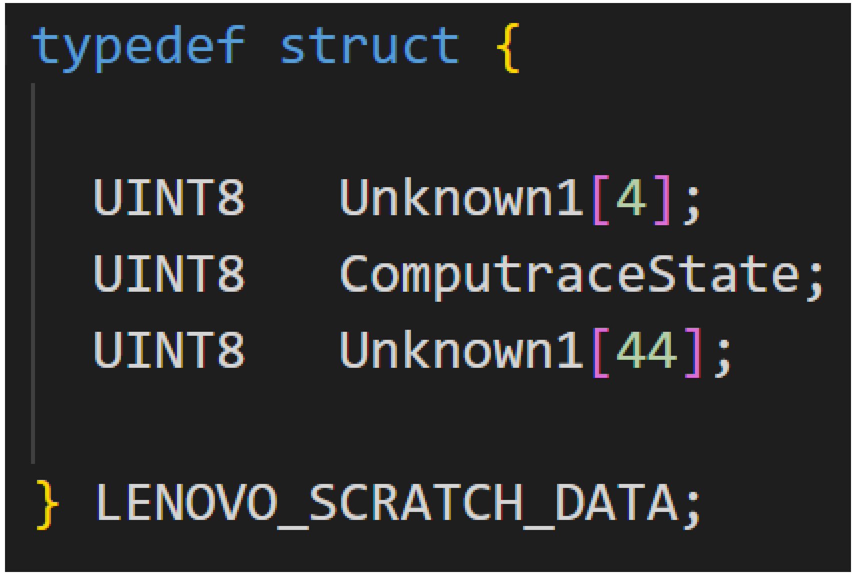
Computrace SMI Handlers

- ComputraceEnable = 0x85
- ComputraceDisable = 0x87
- ComputraceState = 0x88

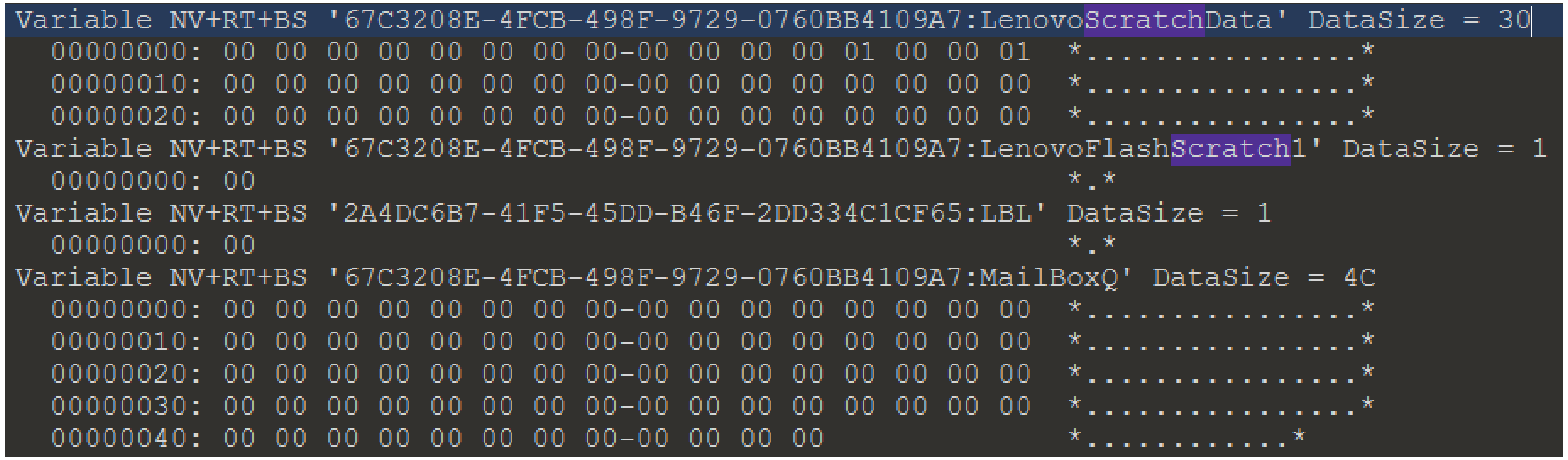


- ComputraceEnableAction = 0x8d
- ComputraceDisableAction = 0x8e

ComputraceSmiServices->Register Callbacks

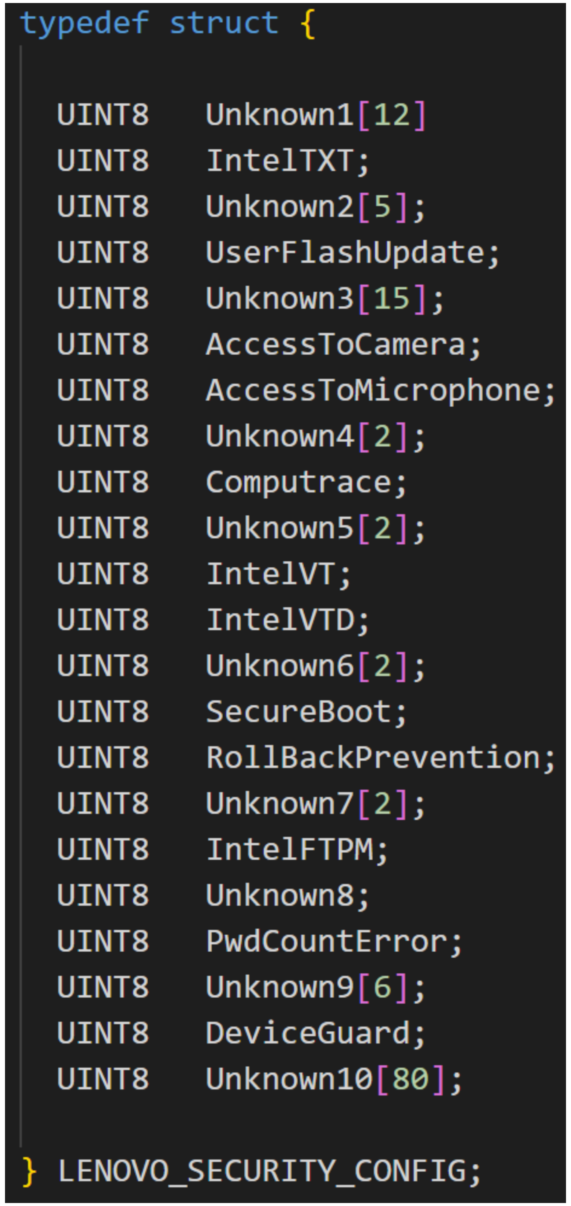


```
typedef struct {

  UINT8    Unknown1[4];
  UINT8    ComputraceState;
  UINT8    Unknown1[44];

} LENOVO_SCRATCH_DATA;
```

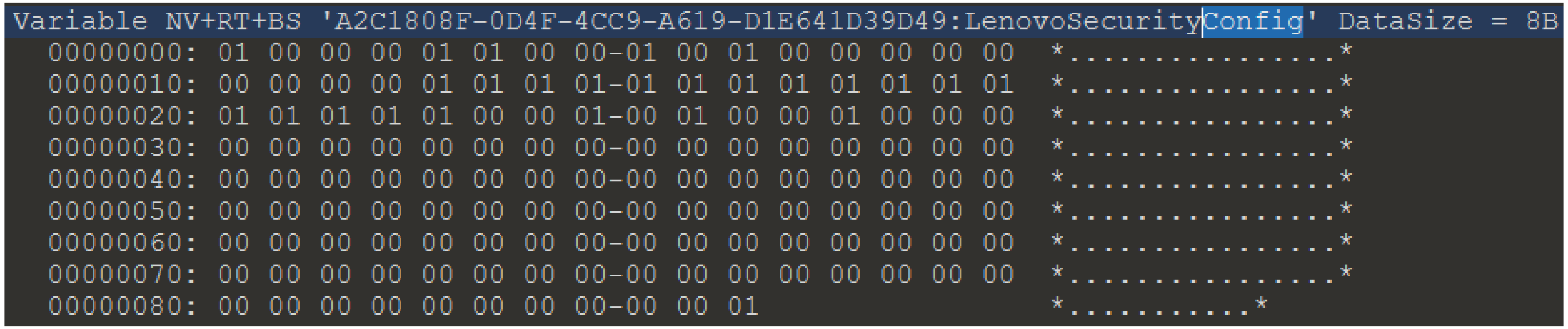


```
Variable NV+RT+BS '67C3208E-4FCB-498F-9729-0760BB4109A7:LenovoScratchData' DataSize = 30
  00000000: 00 00 00 00 00 00 00 00-00 00 00 00 01 00 00 01  *................*
  00000010: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000020: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
Variable NV+RT+BS '67C3208E-4FCB-498F-9729-0760BB4109A7:LenovoFlashScratch1' DataSize = 1
  00000000: 00                                               *.*
Variable NV+RT+BS '2A4DC6B7-41F5-45DD-B46F-2DD334C1CF65:LBL' DataSize = 1
  00000000: 00                                               *.*
Variable NV+RT+BS '67C3208E-4FCB-498F-9729-0760BB4109A7:MailBoxQ' DataSize = 4C
  00000000: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000010: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000020: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000030: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000040: 00 00 00 00 00 00 00 00-00 00 00 00              *............*
```

ComputraceSmiServices->Register Callbacks

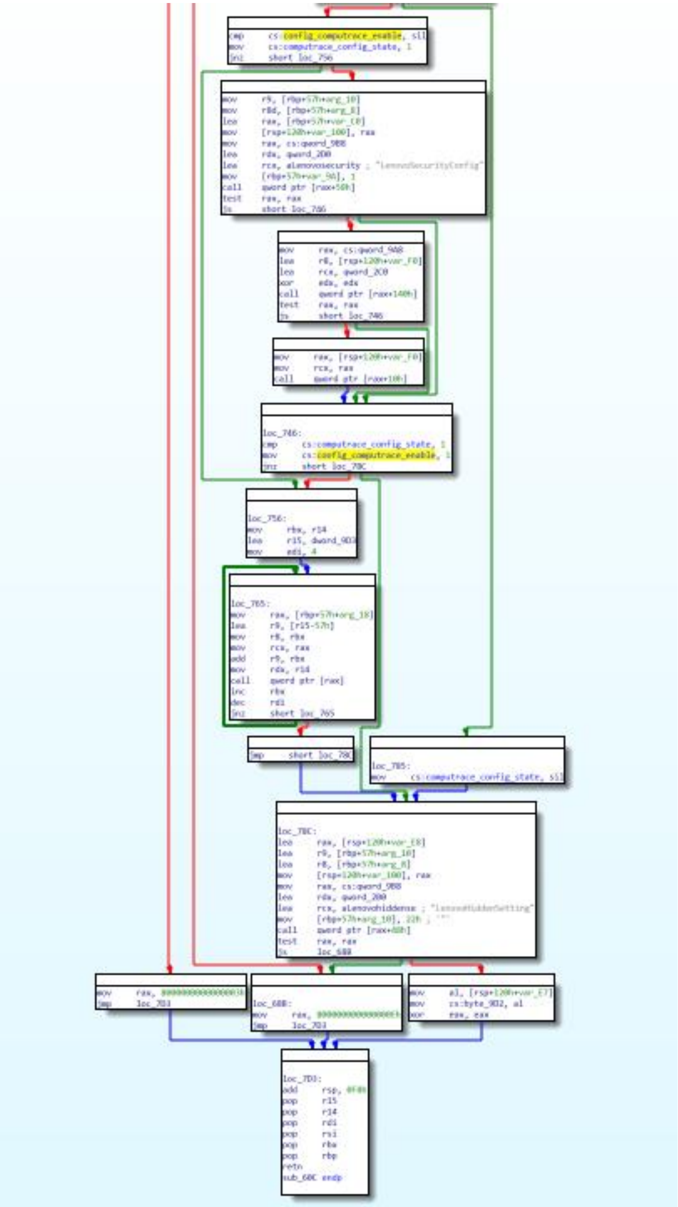


```
typedef struct {

  UINT8    Unknown1[12]
  UINT8    IntelTXT;
  UINT8    Unknown2[5];
  UINT8    UserFlashUpdate;
  UINT8    Unknown3[15];
  UINT8    AccessToCamera;
  UINT8    AccessToMicrophone;
  UINT8    Unknown4[2];
  UINT8    Computrace;
  UINT8    Unknown5[2];
  UINT8    IntelVT;
  UINT8    IntelVTD;
  UINT8    Unknown6[2];
  UINT8    SecureBoot;
  UINT8    RollBackPrevention;
  UINT8    Unknown7[2];
  UINT8    IntelFTPM;
  UINT8    Unknown8;
  UINT8    PwdCountError;
  UINT8    Unknown9[6];
  UINT8    DeviceGuard;
  UINT8    Unknown10[80];

} LENOVO_SECURITY_CONFIG;
```



```
Variable NV+RT+BS 'A2C1808F-0D4F-4CC9-A619-D1E641D39D49:LenovoSecurityConfig' DataSize = 8B
  00000000: 01 00 00 00 01 01 00 00-01 00 01 00 00 00 00 00  *................*
  00000010: 00 00 00 00 01 01 01 01-01 01 01 01 01 01 01 01  *................*
  00000020: 01 01 01 01 01 00 00 01-00 01 00 00 01 00 00 00  *................*
  00000030: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000040: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000050: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000060: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000070: 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00  *................*
  00000080: 00 00 00 00 00 00 00 00-00 00 01                 *...........*
```

ComputraceSmiServices->Register Callbacks



```
cmp     cs:config_computrace_enable, sil
mov     cs:computrace_config_state, 1
jnz     short loc_756
```

```
mov     r9, [rbp+57h+arg_10]
mov     r8d, [rbp+57h+arg_8]
lea     rax, [rbp+57h+var_C0]
mov     [rsp+120h+var_100], rax
mov     rax, cs:qword_9B8
lea     rdx, qword_2D0
lea     rcx, aLenovosecurity ; "LenovoSecurityConfig"
mov     [rbp+57h+var_9A], 1
call    qword ptr [rax+58h]
test    rax, rax
js      short loc_7A6
```

```
mov     rax, cs:qword_9A8
lea     r8, [rsp+120h+var_F0]
lea     rcx, qword_2C0
xor     edx, edx
call    qword ptr [rax+140h]
test    rax, rax
js      short loc_7A6
```

```
mov     rax, [rsp+120h+var_F0]
mov     rcx, rax
call    qword ptr [rax+10h]
```

```
loc_7A6:
cmp     cs:computrace_config_state, 1
mov     cs:config_computrace_enable, 1
jnz     short loc_7BC
```

```
loc_756:
mov     rbx, r14
lea     r15, dword_903
mov     edi, 4
```

```
loc_765:
mov     rax, [rbp+57h+arg_18]
lea     r9, [r15-57h]
mov     r8, rbx
mov     rcx, rax
add     r9, rbx
mov     rdx, r14
call    qword ptr [rax]
inc     rbx
dec     rdi
jnz     short loc_765
```

```
jmp     short loc_7BC
```

```
loc_785:
mov     cs:computrace_config_state, sil
```

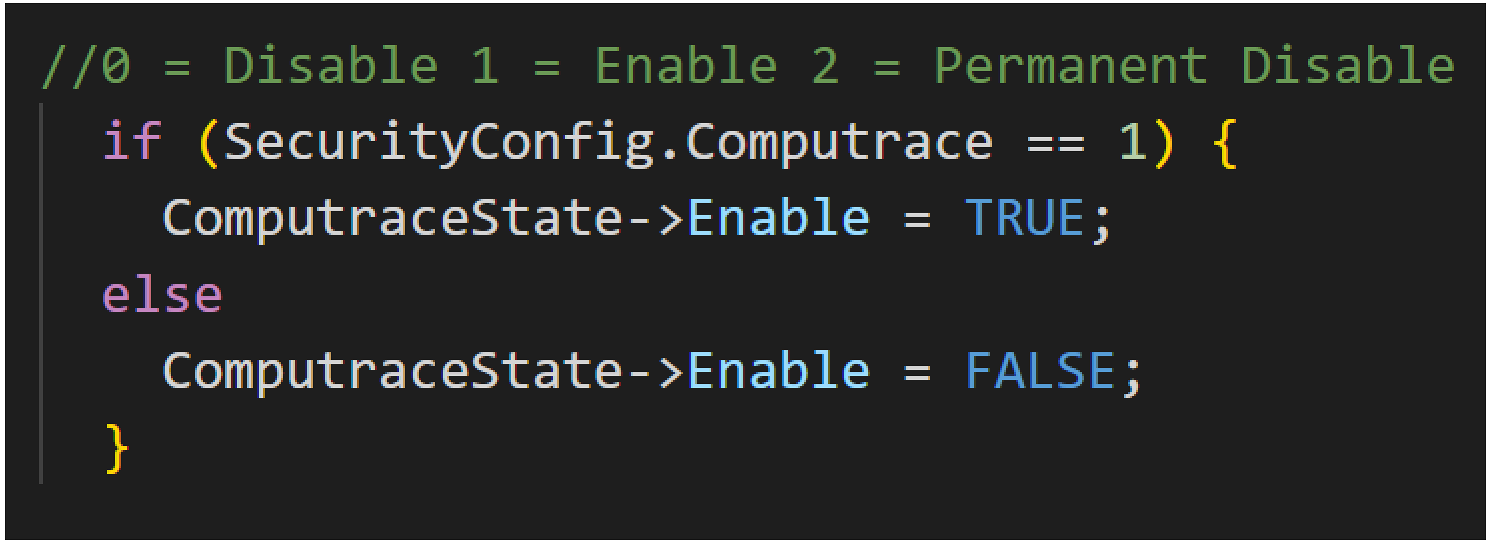
```
loc_7BC:
lea     rax, [rsp+120h+var_E8]
lea     r9, [rbp+57h+arg_10]
lea     r8, [rbp+57h+arg_8]
mov     [rsp+120h+var_100], rax
mov     rax, cs:qword_9B8
lea     rdx, qword_2B0
lea     rcx, aLenovohiddense ; "LenovoHiddenSetting"
mov     [rbp+57h+arg_10], 22h ; '"'
call    qword ptr [rax+48h]
test    rax, rax
js      loc_688
```

```
mov     rax, 8000000000000003
jmp     loc_7D3
```

```
loc_688:
mov     rax, 800000000000000E
jmp     loc_7D3
```

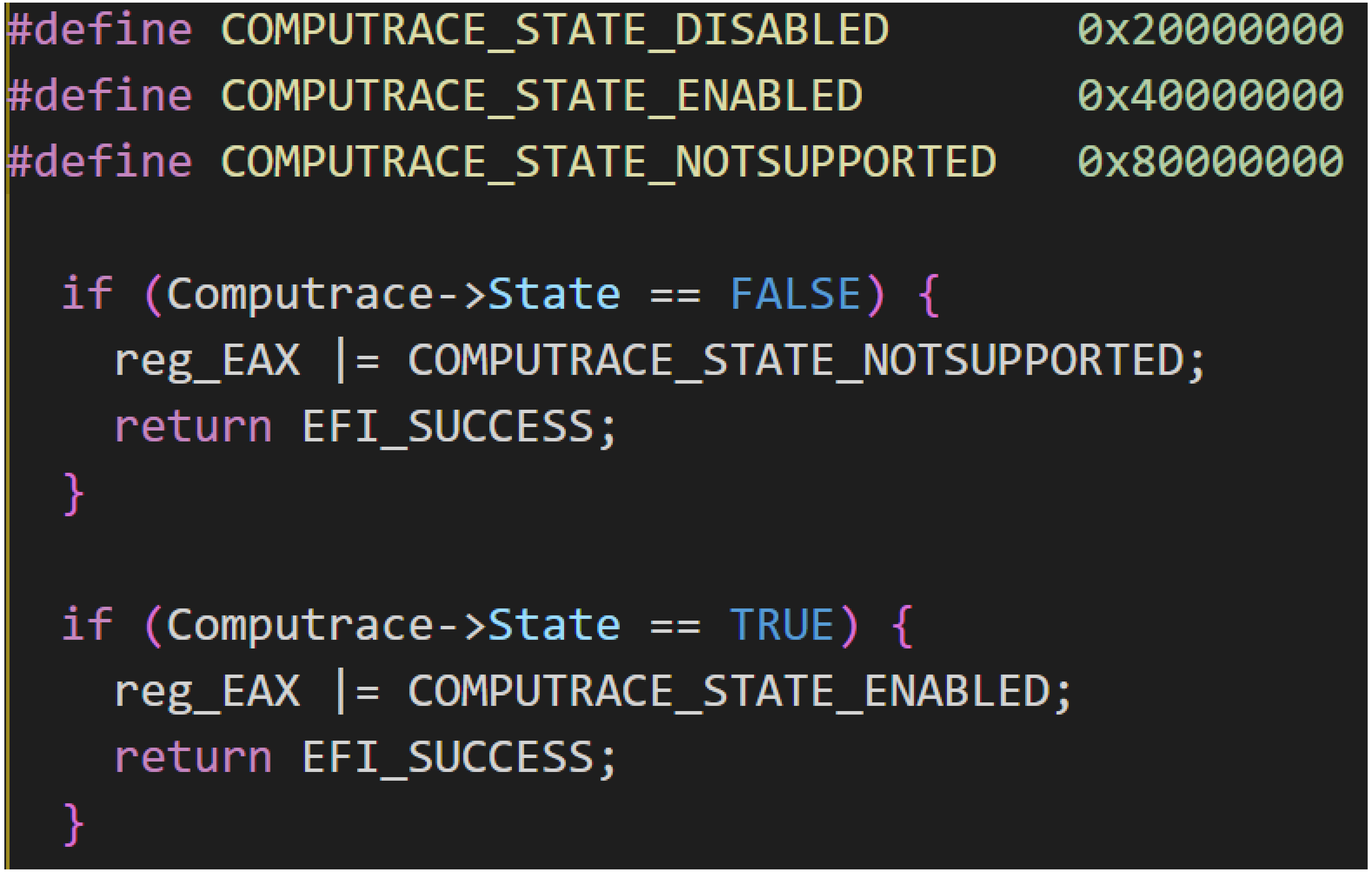
```
mov     al, [rsp+120h+var_E7]
mov     cs:byte_9D2, al
xor     eax, eax
```

```
loc_7D3:
add     rsp, 0F0h
pop     r15
pop     r14
pop     rdi
pop     rsi
pop     rbx
pop     rbp
retn
sub_68C endp
```



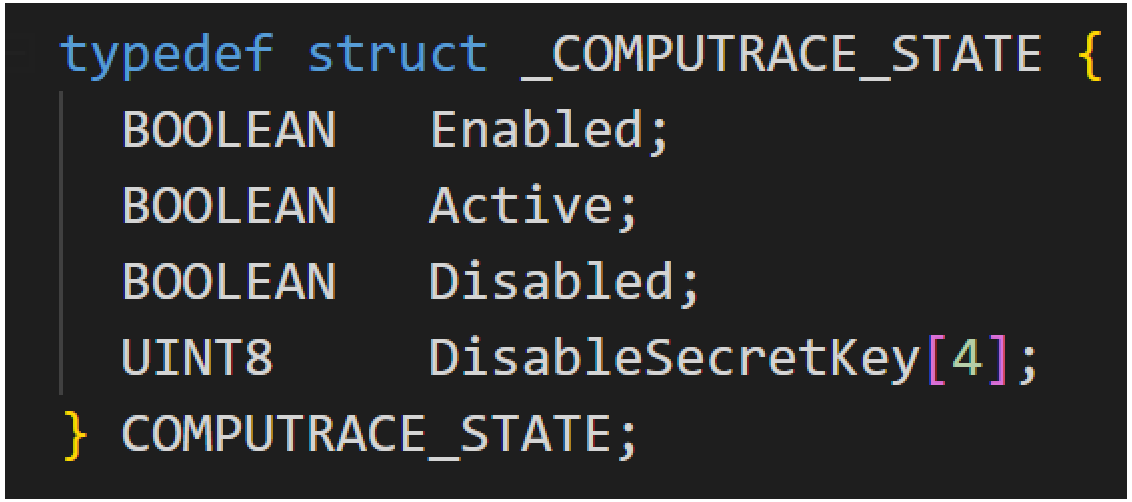
```
//0 = Disable 1 = Enable 2 = Permanent Disable
  if (SecurityConfig.Computrace == 1) {
    ComputraceState->Enable = TRUE;
  else
    ComputraceState->Enable = FALSE;
  }
```

SmiComputraceEnable = 0x85

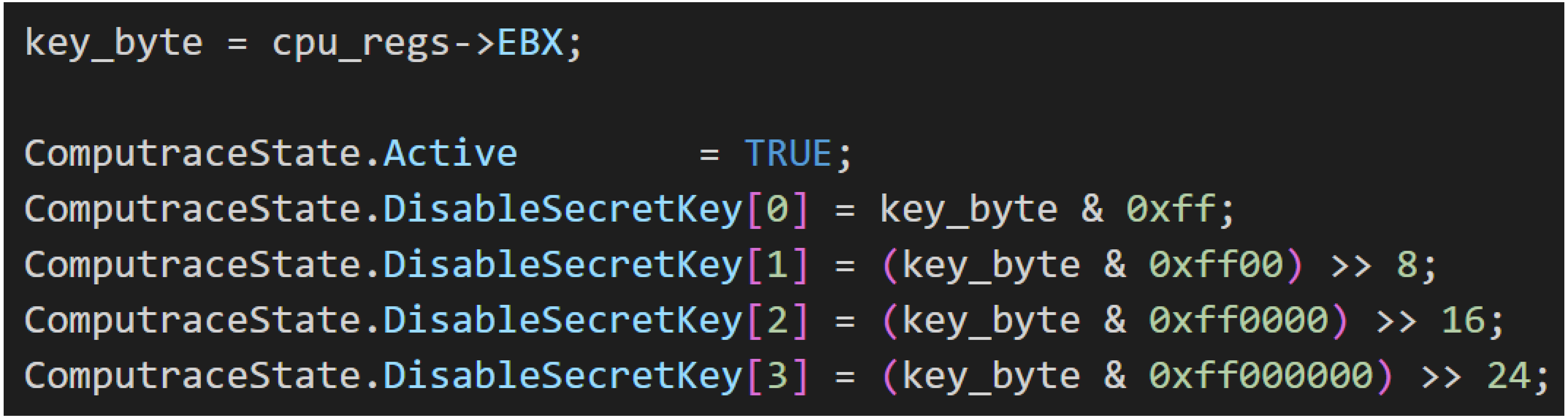


```
#define COMPUTRACE_STATE_DISABLED       0x20000000
#define COMPUTRACE_STATE_ENABLED        0x40000000
#define COMPUTRACE_STATE_NOTSUPPORTED   0x80000000

  if (Computrace->State == FALSE) {
    reg_EAX |= COMPUTRACE_STATE_NOTSUPPORTED;
    return EFI_SUCCESS;
  }

  if (Computrace->State == TRUE) {
    reg_EAX |= COMPUTRACE_STATE_ENABLED;
    return EFI_SUCCESS;
  }
```

SmiComputraceDisable = 0x87

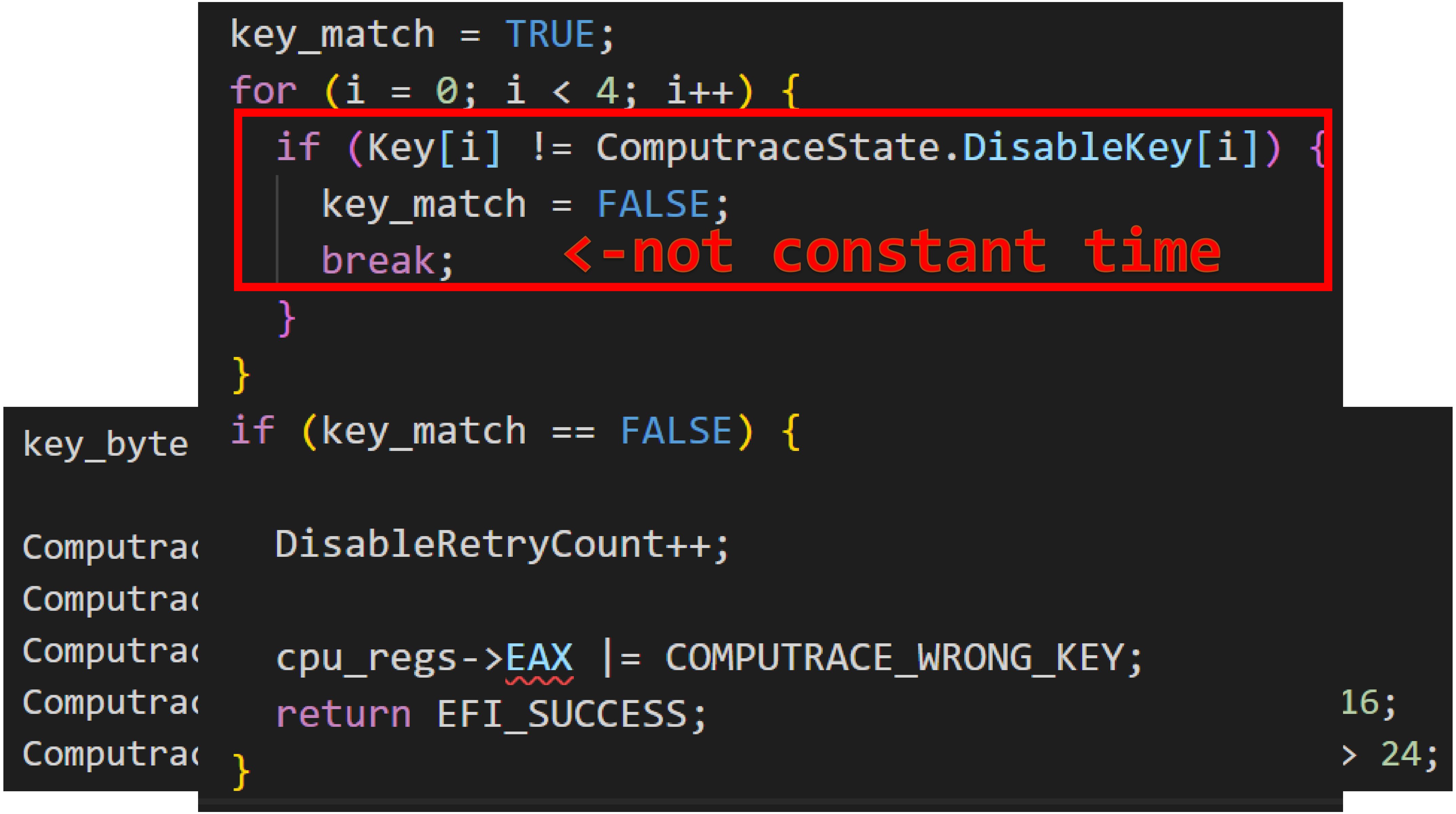


```
typedef struct _COMPUTRACE_STATE {
  BOOLEAN   Enabled;
  BOOLEAN   Active;
  BOOLEAN   Disabled;
  UINT8     DisableSecretKey[4];
} COMPUTRACE_STATE;
```



```
key_byte = cpu_regs->EBX;

ComputraceState.Active        = TRUE;
ComputraceState.DisableSecretKey[0] = key_byte & 0xff;
ComputraceState.DisableSecretKey[1] = (key_byte & 0xff00) >> 8;
ComputraceState.DisableSecretKey[2] = (key_byte & 0xff0000) >> 16;
ComputraceState.DisableSecretKey[3] = (key_byte & 0xff000000) >> 24;
```

SmiComputraceDisable = 0x87



```
key_match = TRUE;
for (i = 0; i < 4; i++) {
  if (Key[i] != ComputraceState.DisableKey[i]) {
    key_match = FALSE;
    break;
  }
}
if (key_match == FALSE) {

  DisableRetryCount++;

  cpu_regs->EAX |= COMPUTRACE_WRONG_KEY;
  return EFI_SUCCESS;
}
```

<-not constant time

```
key_byte

Computra
Computra
Computra
Computra                                                    16;
Computra                                                  > 24;
```

Brutforce Lenovo Computrace Disable Key

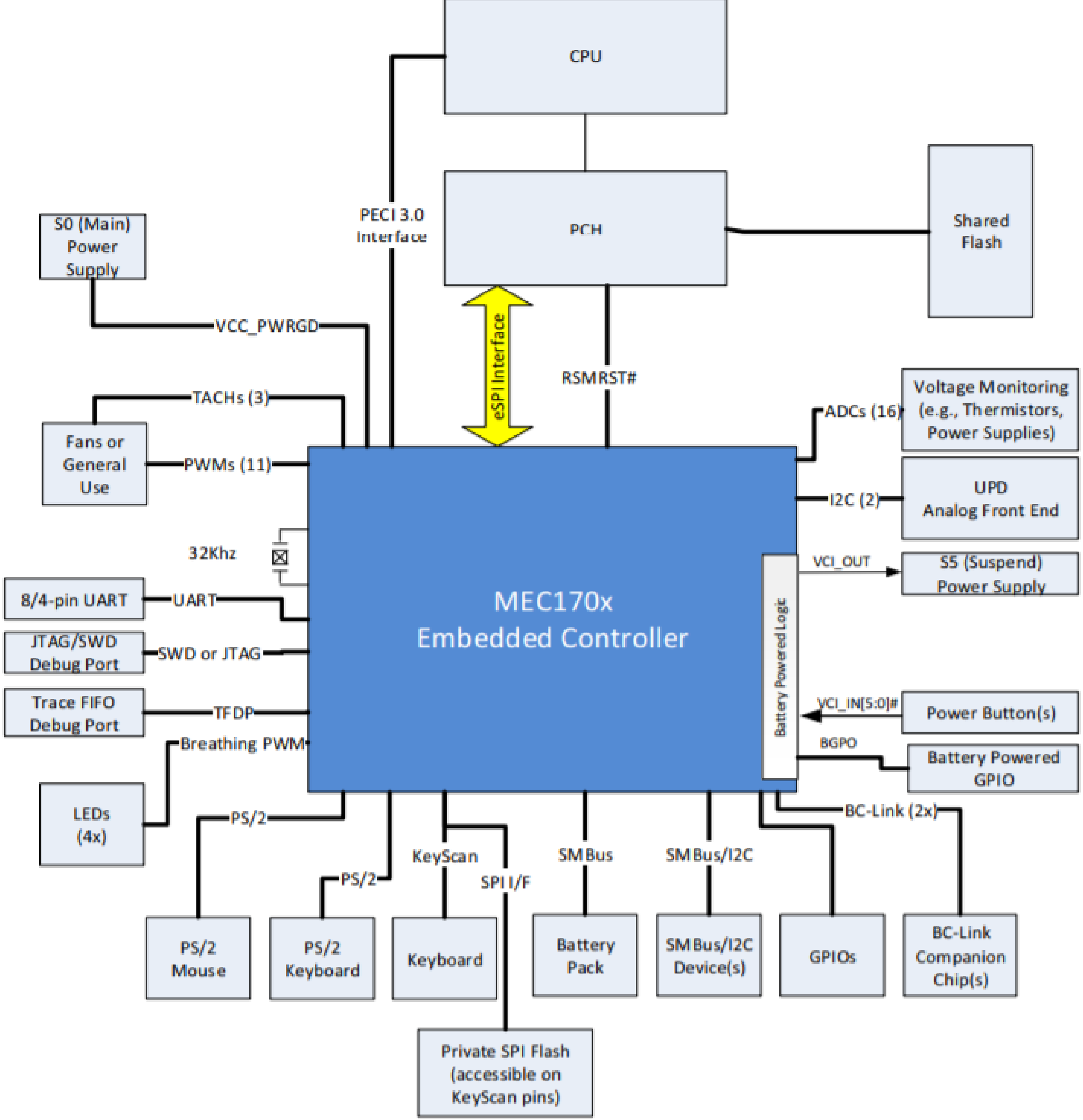
- ➢ Computrace Disable Secret Key
  - ✓ 1 BYTE secret value ☺ stored in SPI flash (NVRAM)
  - ✓ Can be different by laptop model line
    (my sweet victims p50 and t540p has a different keys)

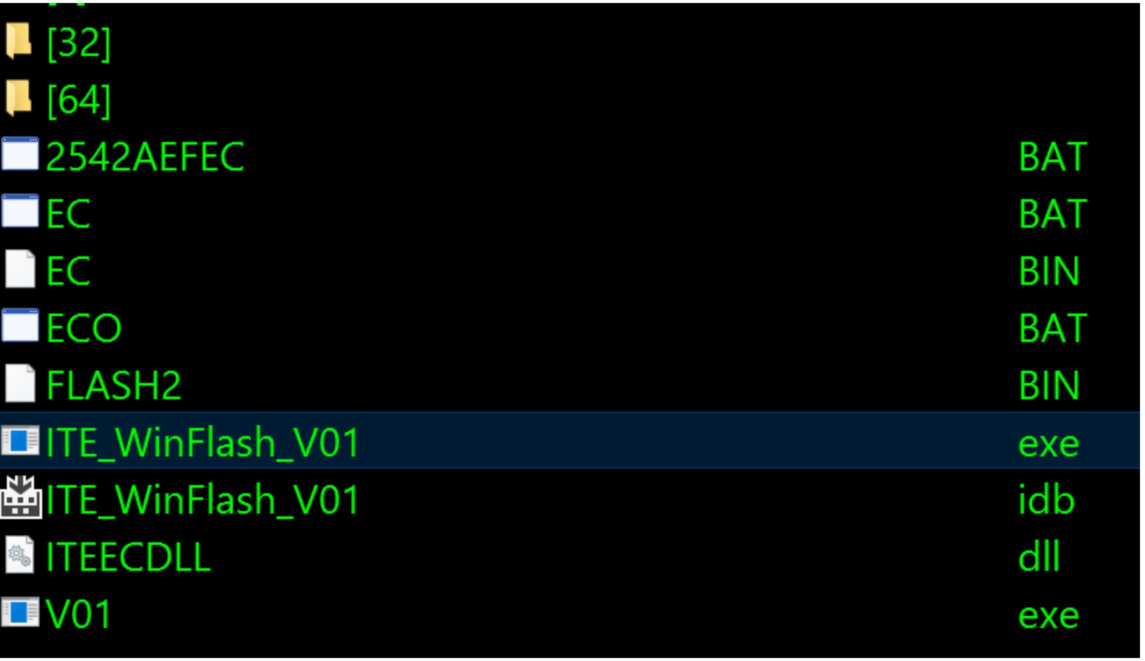
```
for i in range(0,256):
        chipsec_util smi 0x0 0x85 0x0 hex(i)
```

Fuzz->Check->Repeat->Profit!

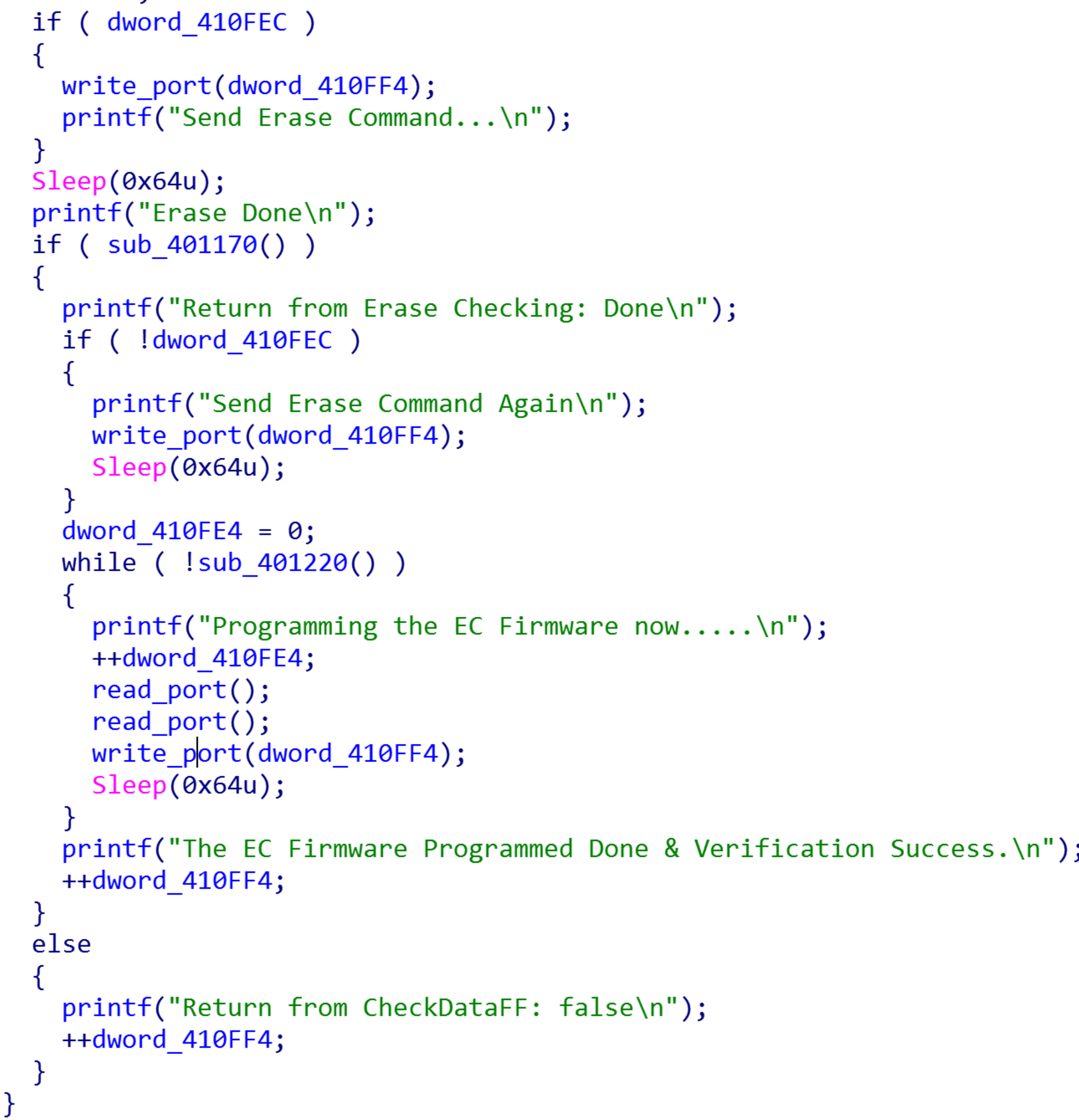
DisableSecretKey == 0x57 o_O

Embedded Controller is not a security boundary


CPU
PCH
Shared Flash
S0 (Main) Power Supply
PECI 3.0 Interface
VCC_PWRGD
eSPI Interface
RSMRST#
TACHs (3)
Fans or General Use
PWMs (11)
ADCs (16)
Voltage Monitoring (e.g., Thermistors, Power Supplies)
I2C (2)
UPD Analog Front End
32Khz
VCI_OUT
S5 (Suspend) Power Supply
8/4-pin UART
UART
MEC170x Embedded Controller
Battery Powered Logic
JTAG/SWD Debug Port
SWD or JTAG
Trace FIFO Debug Port
TFDP
VCI_IN[5:0]#
Power Button(s)
Breathing PWM
BGPO
Battery Powered GPIO
LEDs (4x)
PS/2
BC-Link (2x)
PS/2
KeyScan
SPI I/F
SMBus
SMBus/I2C
PS/2 Mouse
PS/2 Keyboard
Keyboard
Battery Pack
SMBus/I2C Device(s)
GPIOs
BC-Link Companion Chip(s)
Private SPI Flash (accessible on KeyScan pins)



```
[32]
[64]
2542AEFEC                                   BAT
EC                                          BAT
EC                                          BIN
ECO                                         BAT
FLASH2                                      BIN
ITE_WinFlash_V01                            exe
ITE_WinFlash_V01                            idb
ITEECDLL                                    dll
V01                                         exe
```



```
  if ( dword_410FEC )
  {
    write_port(dword_410FF4);
    printf("Send Erase Command...\n");
  }
  Sleep(0x64u);
  printf("Erase Done\n");
  if ( sub_401170() )
  {
    printf("Return from Erase Checking: Done\n");
    if ( !dword_410FEC )
    {
      printf("Send Erase Command Again\n");
      write_port(dword_410FF4);
      Sleep(0x64u);
    }
    dword_410FE4 = 0;
    while ( !sub_401220() )
    {
      printf("Programming the EC Firmware now.....\n");
      ++dword_410FE4;
      read_port();
      read_port();
      write_port(dword_410FF4);
      Sleep(0x64u);
    }
    printf("The EC Firmware Programmed Done & Verification Success.\n");
    ++dword_410FF4;
  }
  else
  {
    printf("Return from CheckDataFF: false\n");
    ++dword_410FF4;
  }
}
```

😈 More EC fun coming this summer 😈

Stay tuned!!

Summary:

- The usability in enterprise world in many cases the main enemy of security
- The vendors understand “Permanent Disable” option differently
- When Hardware-based Root of Trust transfer the state of Chain of Trust to software, it’s not hardware anymore

Thank you for your attention!

@matrosov

black hat®
ASIA 2019