IDF2012
INTEL DEVELOPER FORUM

Intel and McAfee: Hardening and Harnessing the Secure Platform

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EFIS003

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Agenda

- UEFI & PI Security Overview
- Hardening the Platform & Development Assurance Practices
- Introducing McAfee* Endpoint Encryption
- Value Proposition of a Secured Preboot
- Maintaining the Chain of Trust

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Pressure on BIOS

Industry requirements (ex. UEFI 2.3.1+ Ch 27, TCG)

Government requirements (ex: US NIST SP800-147)

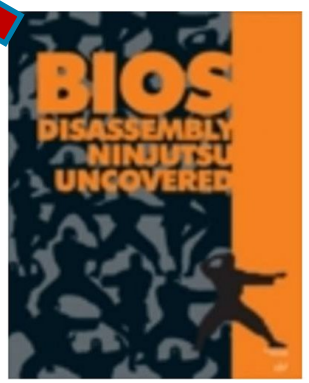
Product dvlp requirements (ex. SDL)

Customers requiring security (ex. US DoD, Corporate IT)

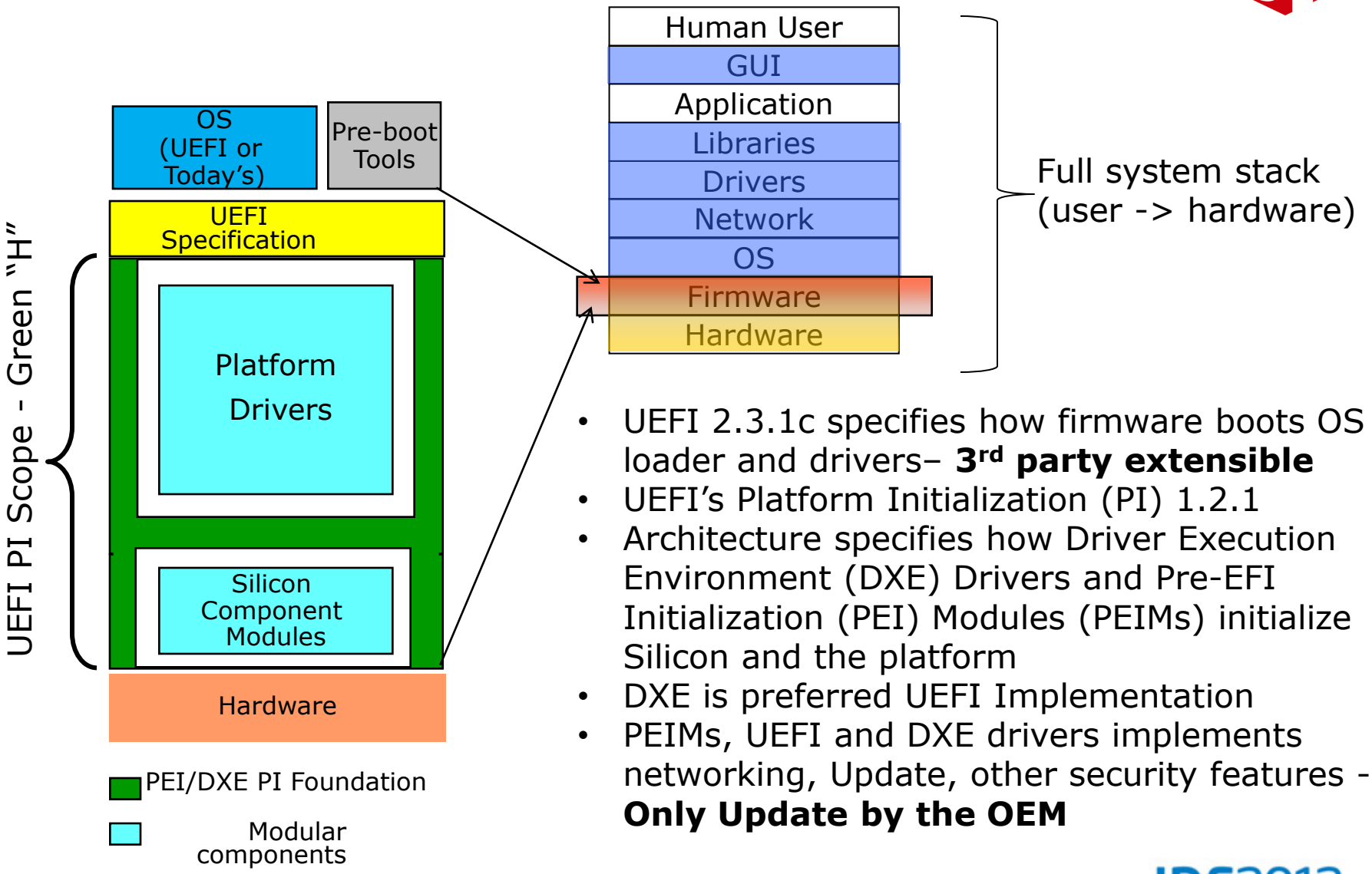
BIOS

Malware (ex. Chernobyl, 2000 Bootkits, 2011 etc)

Researchers (ex. Invisible Things Lab BMP attacks 2004)

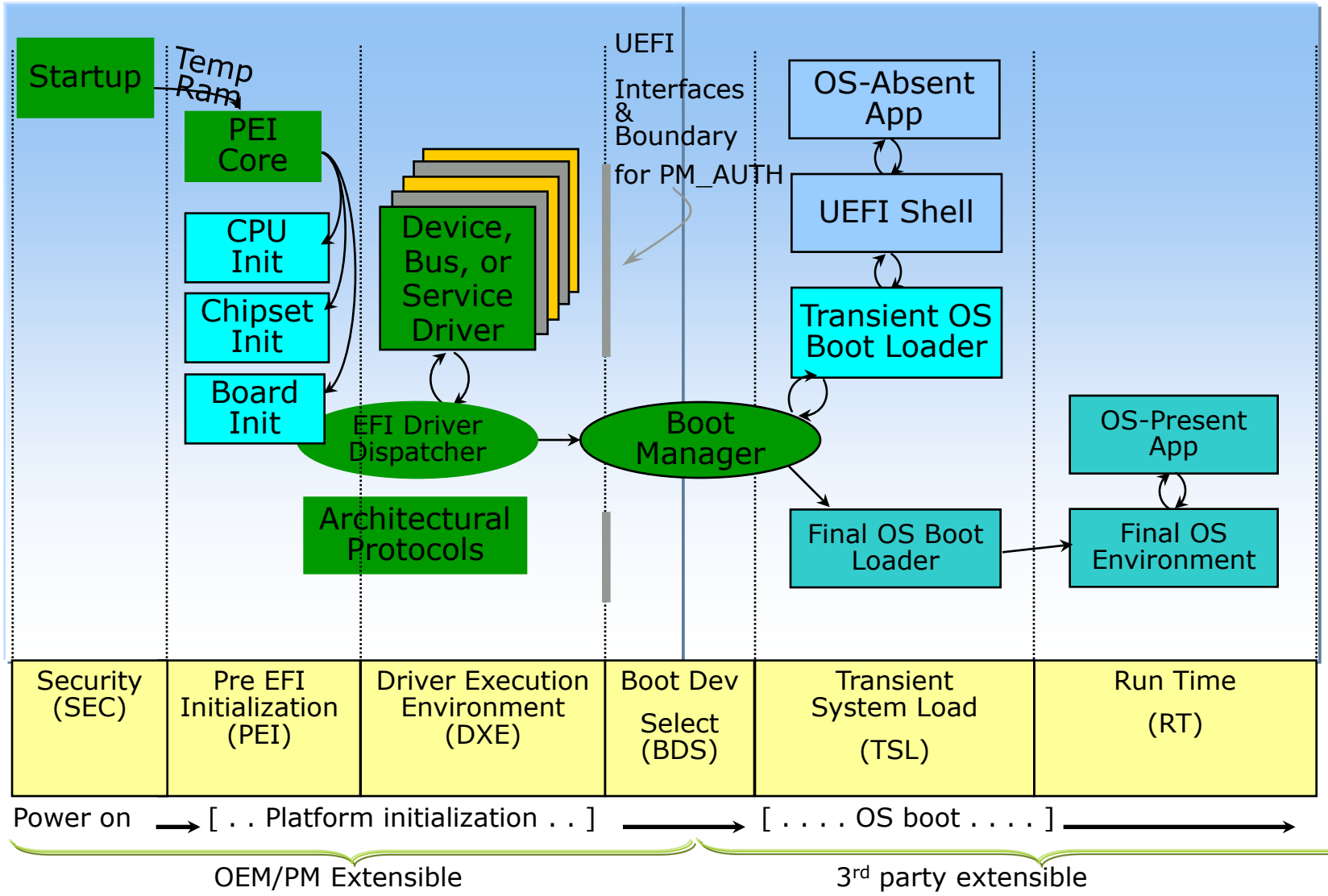


What is UEFI? UEFI Platform Initialization Overview



- UEFI 2.3.1c specifies how firmware boots OS loader and drivers– **3rd party extensible**
- UEFI's Platform Initialization (PI) 1.2.1
- Architecture specifies how Driver Execution Environment (DXE) Drivers and Pre-EFI Initialization (PEI) Modules (PEIMs) initialize Silicon and the platform
- DXE is preferred UEFI Implementation
- PEIMs, UEFI and DXE drivers implements networking, Update, other security features - **Only Update by the OEM**

Boot flow and Integrity



UEFI Protects through the Boot Flow

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Development Practices - Themes

- Practice defense in depth
  - Use several protection layers when designing and implementing security mechanisms
- Do not rely on security by obscurity
- Fail intelligently, Fail Safe
  - Fail secure – fail closed
    - Robust crisis recovery, signed updates/signed recovery FV, etc.
  - Don’t provide hints to hackers (e.g., by disclosing information on failure).
  - Log errors and failures for auditing
    - Trusted Computing Group (TCG) measured boot
- Check all return values
- Keep security critical code short and simple

Design in security from the start

Development Practices – Code Review

- Avoid unsafe calls (e.g., gets() equivalent)
- ASSERTs that should be error checking
- Check for valid input and reject everything else
- Perform sanity checks and bound checks – Check Type, Length, Range, Format
- Validate as much and as deep as possible to prevent unintended errors if code is changed; balance against coding time/performance
- Be careful of boundary conditions (e.g., off-by-one errors, array indices) and conditionals (e.g., reverse logic)
- Don't implement your own crypto algorithms or protocols Intel® UEFI Development Kit 2010 (Intel® UDK2010) uses OpenSSL* to meet the spirit of this

It's not implementing the feature, but also how you write the code

Defensive Coding – Adding Robustness

- Validate input before using
  - Network packet
  - On-disk data structures/GPT
  - UEFI Variables
  - Device paths
- Storing secrets
  - Avoid if possible
  - Clear buffers to zero when done
- Key management
  - Access control storage to PI elements. SMM based authenticated variable driver in Intel® UDK2010.
- Fuzz testing
  - SCTS – positive testing "Does it work with expected input"?
  - Fuzzing is negative testing "What happens with unexpected input?"

It's not just functional verification

Example of Safe Versus Unsafe Code

Example: Validate all input

```
PartEntry = AllocatePool (PrimaryHeader->NumberOfPartitionEntries
                          * sizeof (EFI_PARTITION_ENTRY));                    A
Status = DiskIo->ReadDisk (
    DiskIo,
    MediaId,
    MultU64x32(PrimaryHeader->PartitionEntryLBA, BlockSize),
    PrimaryHeader->NumberOfPartitionEntries * (PrimaryHeader->SizeOfPartitionEntry),   B
    PartEntry                                                                 C
    );
```

Problem:

- The memory is allocated with A
- However, ReadDisk block is with B
- Buffer overflow occurs when the code reads a GPT with C

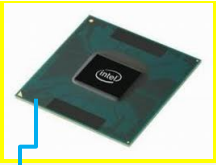
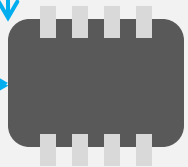
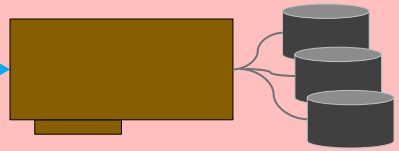
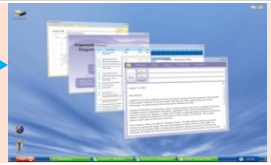
Fix:

```
PartEntry = AllocatePool (PrimaryHeader->NumberOfPartitionEntries
                          * PrimaryHeader->SizeOfPartitionEntry);
```

Rationale for Input Validation

UDK2010 example:
http://edk2.svn.sourceforge.net/svnroot/edk2/trunk/edk2/MdeModulePkg/Universal/Disk/PartitionDxe/Gpt.c

Technologies – Putting it Together

Reset	Assets	Threats
	**BIOS Flash** Hardware protection	ROM Swap Bit rot
	**System BIOS** -PEI recovery. -SMM,UEFI Core. -PK,KEK. CRTM	Erase flash part Overwrite flash part
	**Option ROMs** UEFI drivers	Erase op ROM Overwrite op ROM
	**Network Boot** IPv6 for the cloud	Network attacks
	**Pre-OS UEFI application** OS Boot loader, ***McAfee** ***Endpoint Encryption***	Spoof UEFI application

TCG Measurements into PCRs 0..7

Intel® Silicon

SP800-147 Capsules

UEFI 2.3.1c

Different colors for different vendors

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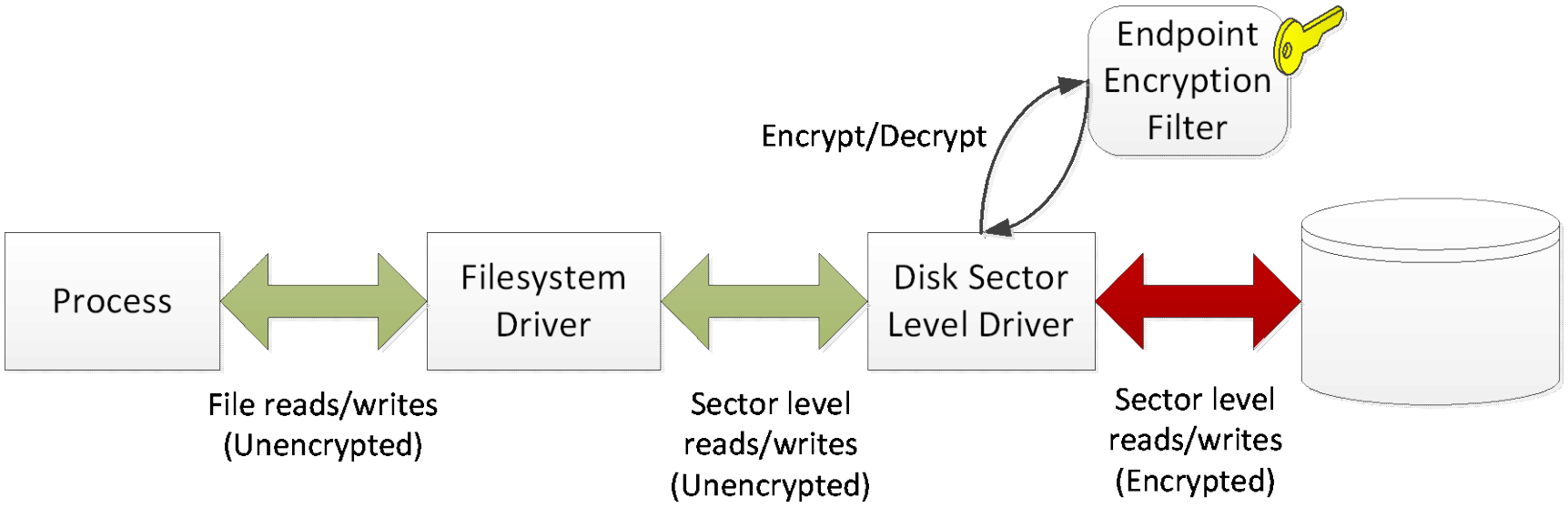
- UEFI & PI Security Overview
- Hardening the Platform & Development Assurance Practices
- Introducing McAfee* Endpoint Encryption
  - Product Overview
  - What is Full Disk Encryption?
  - UEFI Preboot Application
  - GPT Disks
  - Endpoint Encryption and the Boot process
- Value proposition of a Secured Preboot
- Maintaining the Chain of Trust

Product Overview

- McAfee endpoint encryption is a Full Disk Encryption product
  - Provides "data at rest" protection
  - Operating system data and user data is encrypted at the sector level
- Strong encryption algorithms protect data
  - Various methods of encrypting data are available
    - Software based AES256 CBC
    - Hardware accelerated AES256 CBC using AES-NI instructions
    - Self encrypting disks

What is Full Disk Encryption?

- Full Disk Encryption encrypts data at the sector level
  - The product has no knowledge of directories or files
  - The encryption is completely transparent to the file system
  - A disk can be partially encrypted and still operate normally; this allows the system to be encrypted online



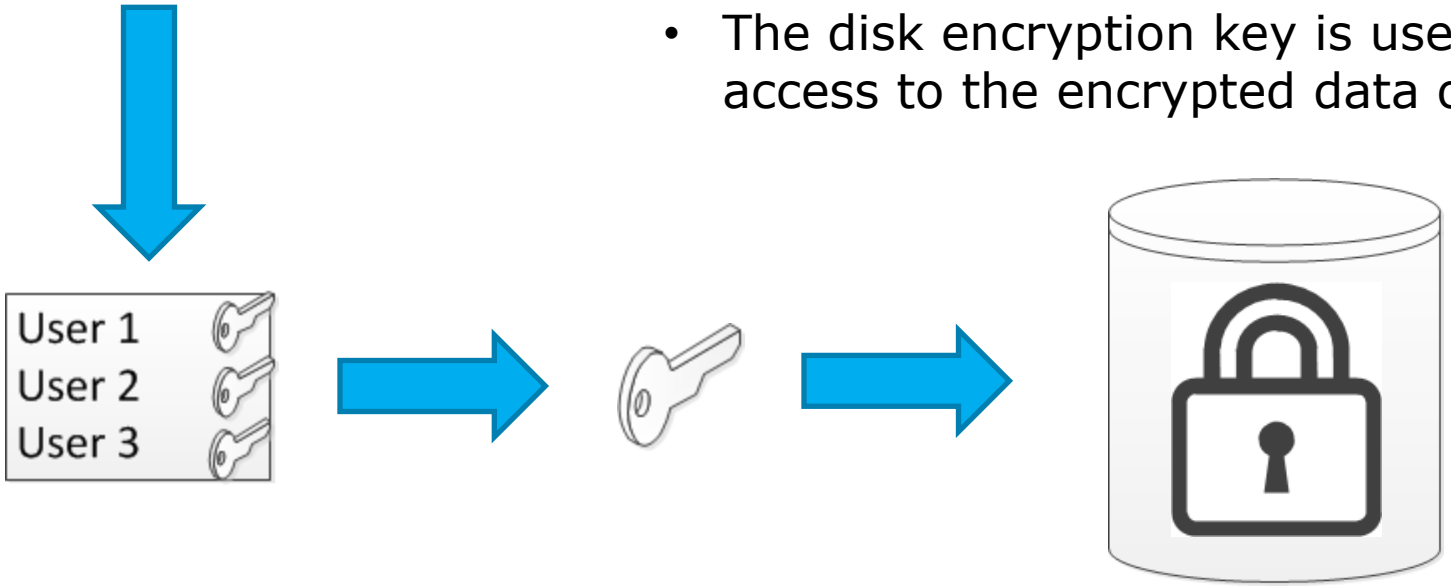
Endpoint Encryption Pre-Boot Application

- Encrypted disk data cannot be accessed until a user authenticates and the encryption key is obtained
- Operating system kernel and critical files lie within the encrypted data on disk
- A "Pre-Boot Application" (PBA) is required to authenticate and unlock the disk

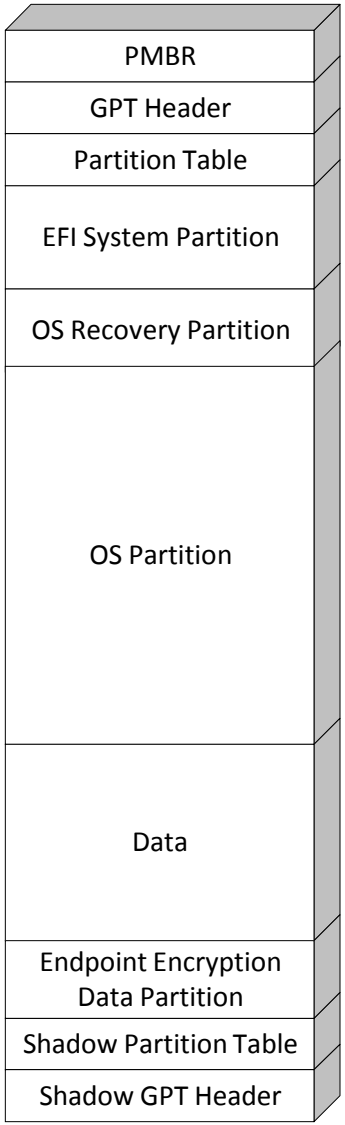
- The McAfee* Endpoint Encryption PBA is a UEFI application
  - Started by the UEFI Boot Manager before the Windows* bootloader
  - Uses standard UEFI protocols for GUI implementation (Graphics Output Protocol, Simple Pointer Protocol, etc.)
  - Supports USB smartcard readers and tokens using standard USB protocol

McAfee* PBA: Unlocking Your Data

- Disk is unlocked by authenticating using McAfee* Endpoint Encryption Pre-Boot Application (PBA)
- User authenticates using token; password, smartcard, recovery process, etc.
- Once authenticated, the token releases the disk encryption key
- The disk encryption key is used to gain access to the encrypted data on disk

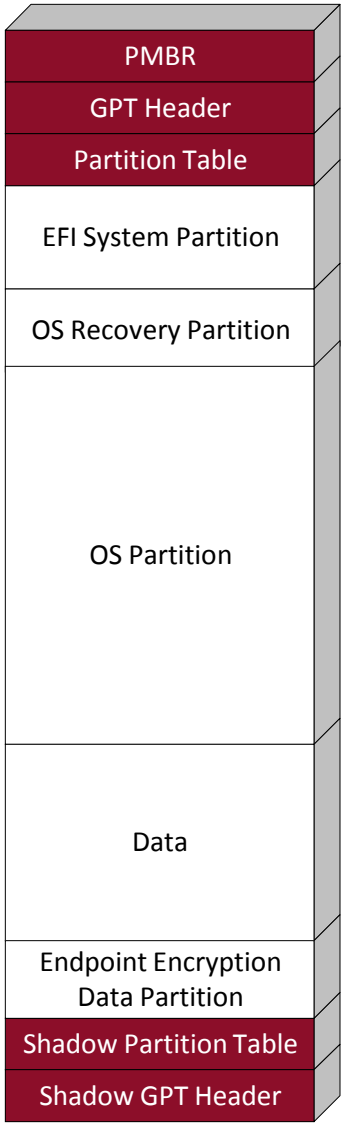


GPT Disks: What's Encrypted?



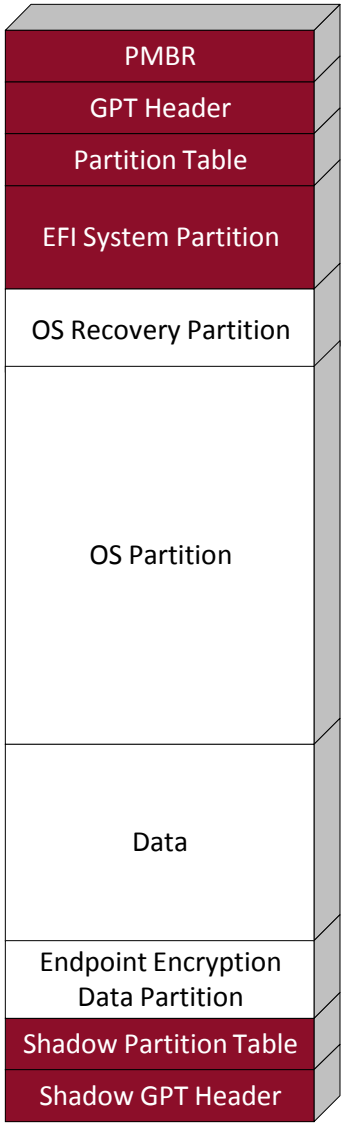
- Some parts of the disk need to remain unencrypted
  - Endpoint Encryption PBA is not implemented in firmware
  - PBA needs to be loaded from disk by UEFI boot manager
  - Disk must be recognisable by UEFI partition and file system drivers in order to load PBA

GPT Disks: What's Encrypted?



- Protective MBR, GPT Headers and Partition Tables cannot be encrypted
  - The data in these regions is required before the disk is unlocked
  - The disk would not be recognised as a valid GPT disk and the system would be unable to boot

GPT Disks: What's Encrypted?



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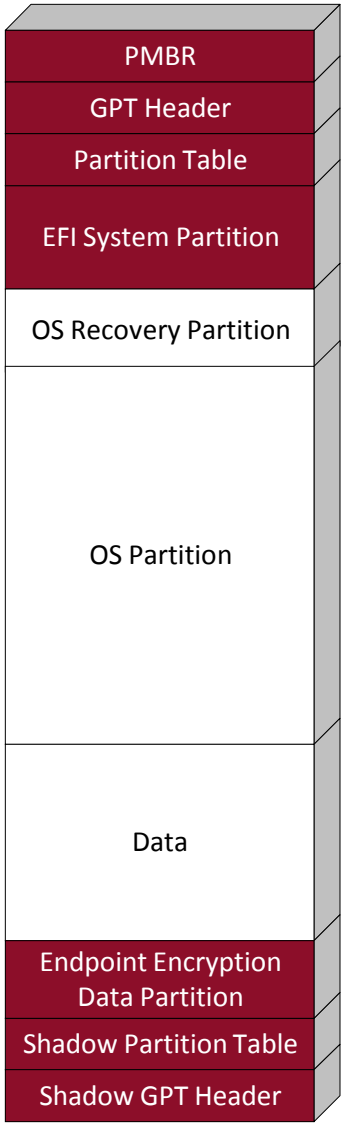
- EFI System Partition cannot be encrypted
  - Contains the executable McAfee* Endpoint Encryption preboot application image that is run by the UEFI Boot Manager
  - Also contains the Block I/O driver that performs the sector level encryption/decryption when authenticated

GPT Disks: What's Encrypted?



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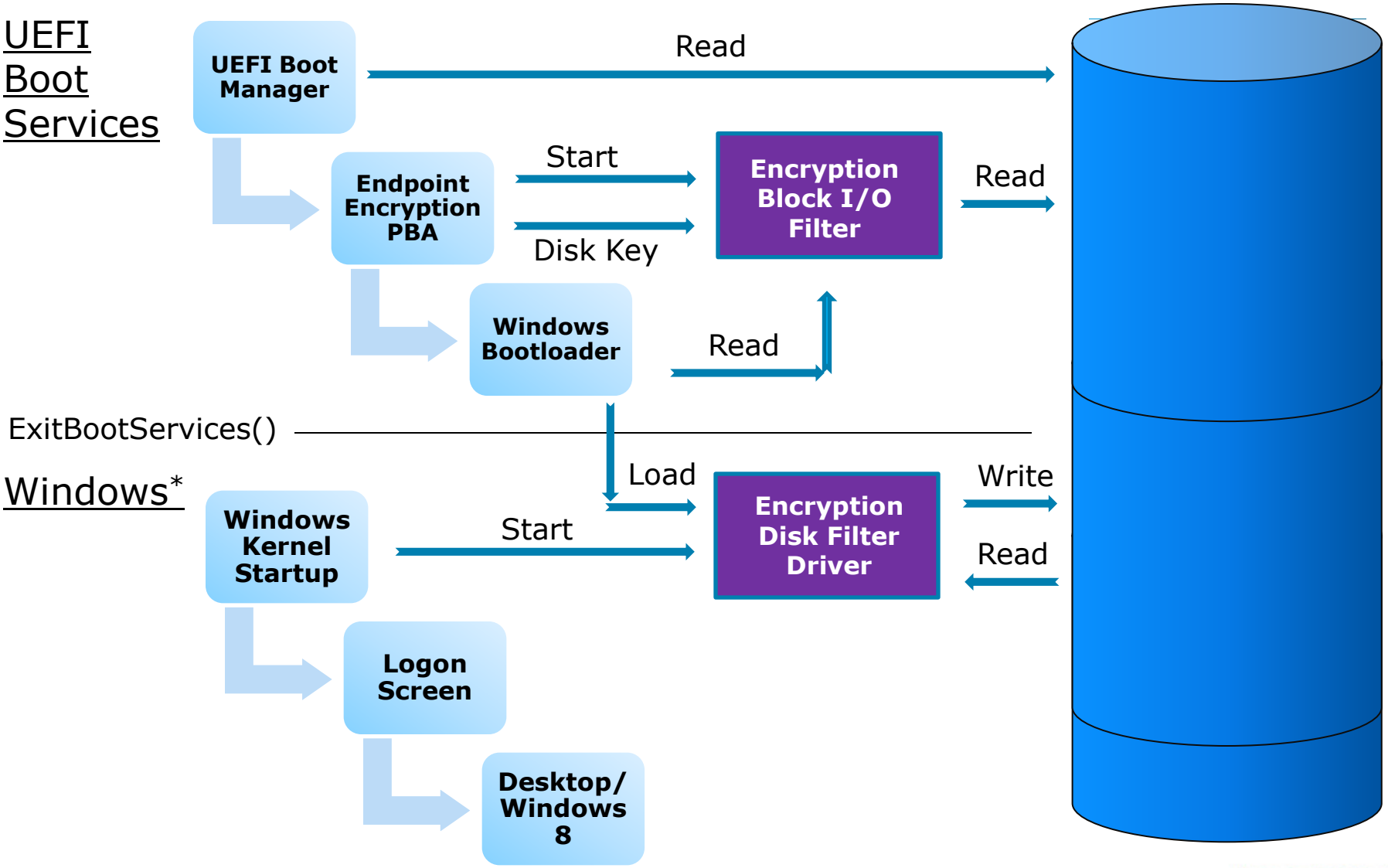
- EFI System Partition cannot be encrypted
  - Contains the executable McAfee* Endpoint Encryption preboot application image that is run by the UEFI Boot Manager
  - Also contains the Block I/O driver that performs the sector level encryption/decryption when authenticated
- Endpoint Encryption Data Partition cannot be encrypted
  - Contains themes and localisation data for PBA
  - Contains database of users and token data
  - All data is required by the PBA prior to the disk being unlocked

The Boot Process



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- Introducing McAfee* Endpoint Encryption
- Value proposition of a Secured Preboot
  - What does "Secure Platform" Mean for Endpoint Encryption?
  - Malware Threat for Endpoint Encryption preboot
- Maintaining the Chain of Trust

What does "Secure Platform" Mean?

- There are some considerations for deploying UEFI applications and drivers on a secure platform
  - All UEFI applications and drivers must be signed
  - The image hashes or signing certificate must be trusted by the platform
  - UEFI applications and drivers need to be careful not to execute untrusted code
- Secure Boot provides benefits to Endpoint Encryption
  - Without Secure Boot, the PBA is vulnerable to malware attacks; keyloggers, denial of service
  - Tamper-resistant PBA provides platform for checking integrity of configuration files – signed policies

Maintain the Chain of Trust!

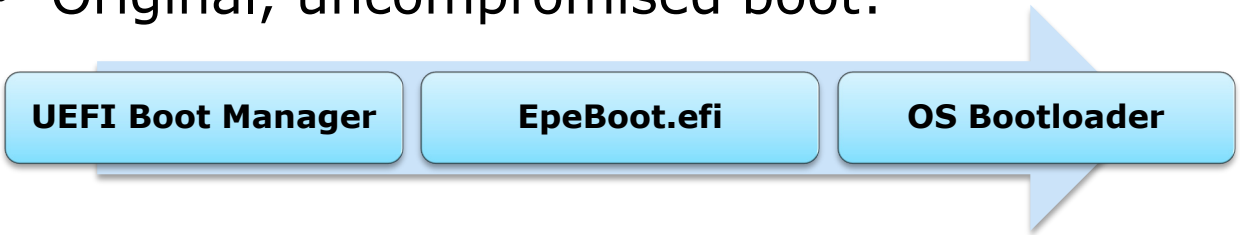
Malware Threat: Keylogger

```
A  BS->LocateHandleBuffer(ByProtocol, &simple_text_input_ex_protocol_guid, NULL, &num_handles,
                          &handles);
   for (i = 0; i < num_handles; ++i) {
B    BS->OpenProtocol(handles[i], &simple_text_input_ex_protocol_guid, &st, ImageHandle,
                      NULL, EFI_OPEN_PROTOCOL_GET_PROTOCOL);
C    hooked_protocols[i].st = st;
     hooked_protocols[i].orig_read_key_ex = st->ReadKeyStrokeEx;
     st->ReadKeyStrokeEx = keylogger_read_keystroke_ex;
   }
D    // Now chain load the original bootcode "EpeBoot.efi"
```

- All devices supporting EFI_SIMPLE_TEXT_INPUT_EX_PROTOCOL are enumerated representing keyboards and input devices at A
- A pointer to each protocol is obtained at B
- The function pointer that is used to obtain keystrokes is replaced with a function that logs the keystrokes and chains to the original at C
- The keylogger application loads and executes the original subverted UEFI application at D

Malware Threat: Keylogger Installation

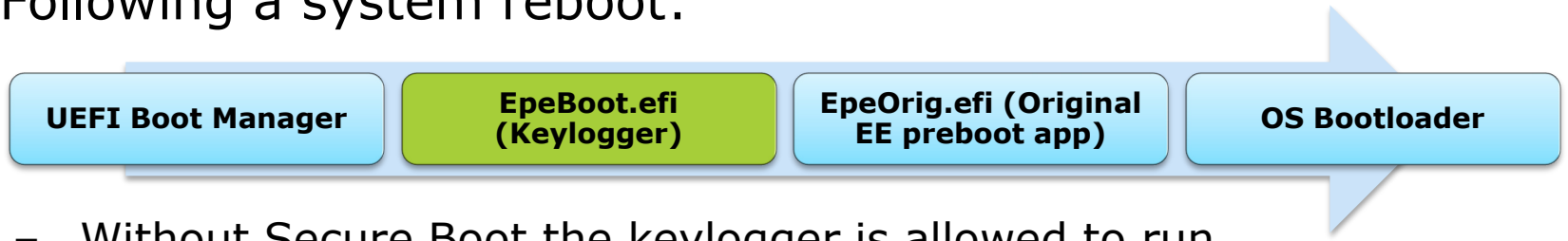
- Original, uncompromised boot:



- Without Secure Boot, installation of the keylogger is simple:

```
C:\> mountvol /s z:
C:\> copy z:\EFI\McAfee\EpeBoot.efi z:\EFI\McAfee\EpeOrig.efi
C:\> copy f:\keylogger.efi z:\EFI\McAfee\Epe\EpeBoot.efi
```

- Following a system reboot:



  - Without Secure Boot the keylogger is allowed to run
  - Endpoint Encryption PBA will execute but all keystrokes will be logged to disk

Malware Threat: Keylogger Installation

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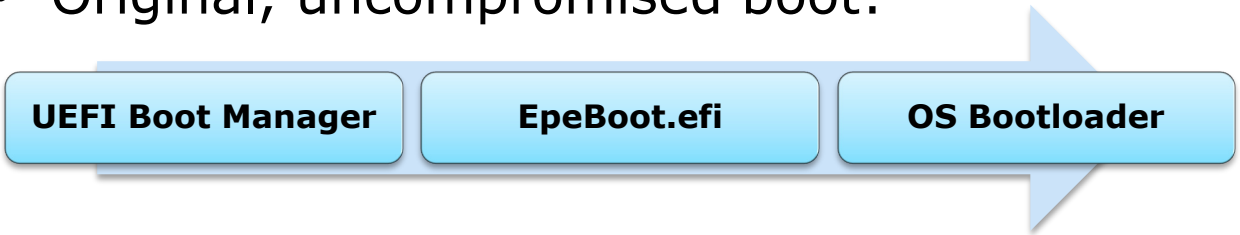

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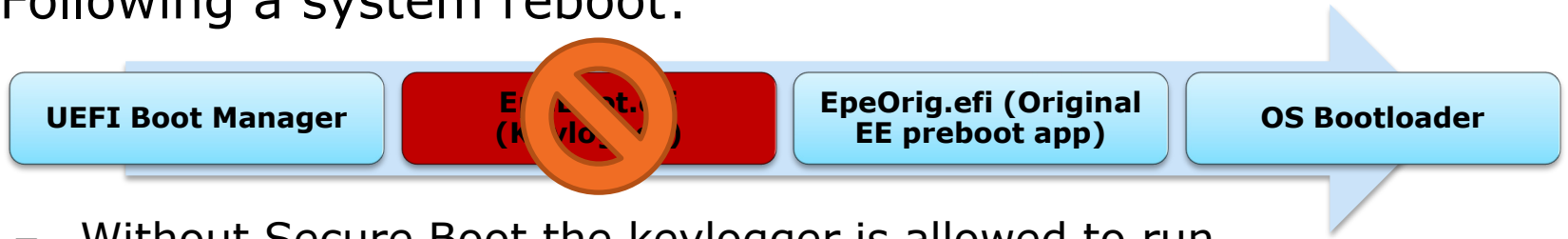

  - Without Secure Boot the keylogger is allowed to run
  - Endpoint Encryption PBA will execute but all keystrokes will be logged to disk

With Secure Boot, execution of the keylogger is prevented

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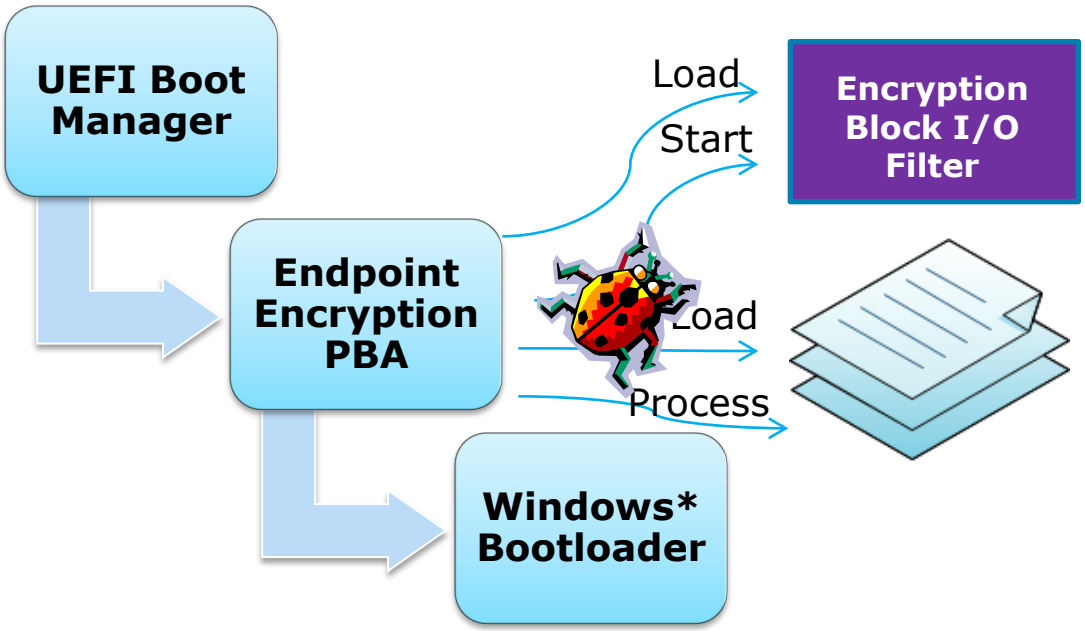
- Hardening the Platform & Development Assurance Practices
- Introducing McAfee* Endpoint Encryption
- Value proposition of a Secured Preboot
- Maintaining the Chain of Trust
  - Chain of Trust Considerations
  - What can go wrong?
  - Handling Loadable Modules/Data Files
  - Example Data File Breach

Chain of Trust: Considerations

- Why is the chain of trust important to Endpoint Encryption?
  - The chain of trust prevents malware from performing malicious actions such as keylogging or preventing the system from booting
  - Hardened boot process enables Endpoint Encryption PBA to validate configuration files – *Trusted Data*
    - Policy files and other important configuration files can be signed using a certificate
    - Certificate can be embedded in trusted UEFI application
- What needs to be considered?
  - Care must be taken to ensure the Chain of Trust can not be broken by unauthorised loadable modules or invalid data

What Can go Wrong?

- Even with Secure Boot the chain of trust can be broken if care is not taken



- Secure Boot ensures the Endpoint Encryption PBA and Windows* Bootloader are authentic
- PBA loads and executes Block I/O filter driver
- PBA loads and processes configuration and data files
- Careless coding may provide an exploitable bug to malware

Chain of Trust: Loadable Modules

- The Endpoint Encryption UEFI application allows for plugin modules
  - Used for adding support for USB smartcard readers
- **This poses a risk to the chain of trust**
  - It is the responsibility of the Endpoint Encryption UEFI application to ensure untrusted code cannot be executed
- The problem is easily solved:
  - Loadable modules are built as UEFI drivers
  - The modules are loaded using the Boot Services "LoadImage()" function
  - If the loadable module is not trusted by the platform, "LoadImage()" returns EFI_SECURITY_VIOLATION
  - **The chain of trust is maintained!**

Chain of Trust: Data Files

- Why are data files a threat to the Chain of Trust?
  - The McAfee* Endpoint Encryption PBA uses many configuration files
  - Malware may maliciously modify configuration files to attempt to crash the PBA
  - Modified configuration files can be engineered to execute malicious code
    - Common exploits overflow stack variables to modify function return address to jump to unauthorised code
    - ***The chain of trust is broken!***
- How can this be prevented?
  - ***All*** buffers that are populated from disk are carefully checked to prevent overflow
  - Data file signing can be used to verify authenticity of files

Data File Threat

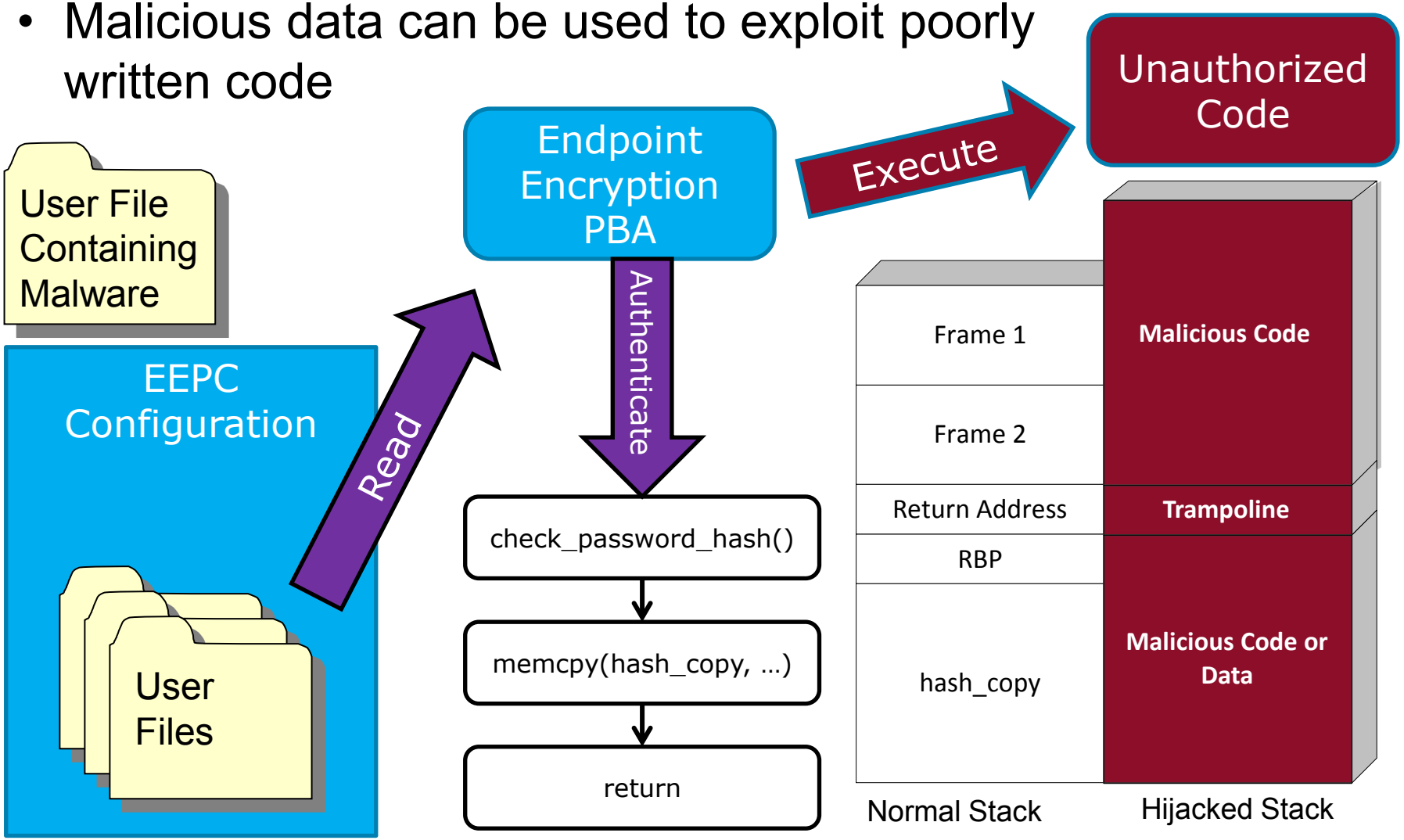
```
A struct USER_DATA {
    char    username[MAX_USERNAME_LENGTH + 1];
    long    hash_length;
    char    password_hash[MAX_PASSWORD_HASH_LENGTH];
  }
  int check_password_hash(USER_DATA* user_data, char* hash) {
B   char hash_copy[MAX_PASSWORD_HASH];
    // Take a copy of the hash so we can modify the buffer
    // !! No check to ensure the hash length is valid !!
C   memcpy(hash_copy, user_data->password_hash, user_data->hash_length);
    // Perform some calculation on the copied buffer

D   return success;
  }
```

- Structure that mimics user file on disk is defined at A
- Fixed length buffer assigned on stack at B
- Memory copied from disk buffer to stack without validating input at C. Stack has been compromised
- Return address D from function jumps to malicious code

Example: Malicious Data

- Malicious data can be used to exploit poorly written code



Validate all configuration and input!

Summary

- Platform security is maintained by a combination of hardware and software using many technologies and specifications
- UEFI Secure Boot is a vital part of the chain that keeps the platform protected
- Malware infiltration during the boot process is prevented by the Chain of Trust
- McAfee* Endpoint Encryption adds data security to the hardened security provided by the Secure Boot process
- Precautions need to be taken when writing software to prevent the Chain of Trust from being breached

Get More Information

- Intel UEFI Community - http://intel.com/udk
- UEFI Forum Learning Center
  - http://www.uefi.org/learning_center/
- Use the TianoCore edk2-devel mailing list for support from other UEFI developers
- Read the "A Tour Beyond BIOS into UEFI Secure Boot" whitepaper at tianocore.org

- Technical Showcase Booth #946

Other UEFI Sessions @ IDF

Session	Title	RM	Day	Date	Time
✓ EFIS001	Developing UEFI Support for Linux*	2008	Tue	11-Sep	10:30
✓ EFIS002	Using Wind River Simics* Virtual Platforms to Accelerate Firmware Development	2008	Tue	11-Sep	12:45
✓ EFIS003	Intel and McAfee: Hardening and Harnessing the Secure Platform	2008	Tue	11-Sep	3:30
EFIS004	Microsoft* Windows* 8 Firmware Developments and Intel® Platforms	2008	Wed	12-Sep	10:30
SECS004	Security Innovations in Intel® Platforms and Microsoft* Windows* 8	2008	Wed	12-Sep	2:00
EFIC001	Poster: Intel® UEFI Development Kit Debugger Tool	Poster	Thur	13-Sep	11:15
EFIC002	Poster: UEFI Driver Development Tools	Poster	Thur	13-Sep	11:15

✓ = DONE

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Q&A

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Rev. 5/4/12