TCG EFI Platform Specification
For TPM Family 1.1 or 1.2

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Disclaimers, Notices, and License Terms

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Table of Contents

Introduction to this Document

Start of informative comment:

This document is about the processes that boot an Extensible Firmware Interface (EFI) platform and load an OS on that platform. Specifically, this specification contains the requirements for measuring EFI unique events into TPM PCRs and adding boot event entries into the Event Log.

In this document, "EFI" refers to either EFI platforms (as defined by the Extensible Firmware Interface Main Specification), or UEFI platforms (as defined by the Unified Extensible Firmware Interface Specifications). See section 1.2.

Software on the platform uses PCR values to seal secrets into blobs and then unseal those secrets if the PCR values are the same as when the secret was sealed.

Software on the platform uses PCR values together with the Event Log entries to reconstruct boot events, which requires a complete Event Log.

Software on other platforms uses the PCR values, together with the Event Log entries, for remote attestation of the EFI platform that holds the PCR values and Event Log.

Structure of this document

The scope of this specification is limited to what EFI can measure.

This document only describes events specific to an EFI or UEFI implementation. Therefore, this specification does not duplicate measurements defined in other TCG documents. The rationale is that the EFI and UEFI Specifications are pure interface specifications that do not imply the specifics of the implementation (other than some behavior in the boot manager chapter). The underlying implementation of a UEFI or EFI system can be based upon the Intel Framework, UEFI Platform Initialization (PI) or other infrastructure code.

Both the *TCG PC Client Specific Implementation Specification for Conventional BIOS* and this specification are needed to gain a full understanding of an EFI or UEFI platform. In the event of conflicts between this specification and the *Conventional Bios Specification,* then the *Conventional Bios Specification* applies, unless otherwise stated.

In addition to the measurements defined in this specification, EFI systems also perform measurements defined in other TCG documents, including mandatory as well as optional measurements.

Events from the *TCG PC Client Implementation Specification for Conventional BIOS* include, but are not limited to: EV_S_CRTM_VERSION, EV_POST_CODE "ACPI DATA" and EV_CPU_MICROCODE.

Events from the *TCG Generic Server Specification* include, but are not limited to: EV_TABLE_OF_DEVICES (for processor physical location).

This specification contains nine other sections.

- Section 2 defines the meaning of three fundamental TCG concepts on an EFI platform: Static Locality, Static CRTM, and the static transitive chain of trust.
- Section 3 is an overview of the platform boot process and the OS boot process on an EFI platform and provides the model for PCR usage and for adding events to the Event Log. If the user of this specification reads this section first, the details in section 4 through 7 will be easier to understand.
- Section 4 contains the requirements for measuring PE/COFF image files.
- Section 5 is the detailed specification for measuring the platform boot process on an EFI platform.

- Section 6 is the detailed specification for measuring the OS boot process on an EFI platform.
- Section 7 is the detailed specification for adding entries to the Event Log during the OS boot process and the platform boot process.
- Section 8 is about using PCRs that are not used to measure the platform and OS boot processes.
- Section 9 is about maintenance of the firmware on an EFI platform that measures OS boot and platform boot events into PCRs. This includes compliance to the *U.S. National Institute of Standards and Technology (NIST) Special Publication 800-147 Bios Protection Guidelines.*
- Section 10 is about certification of an EFI platform that measures OS boot events and platform boot events into PCRs. This includes compliance to the *U.S. National Institute of Standards and Technology (NIST) Special Publication 800-155 BIOS Integrity Measurement Guidelines*.

End of informative comment.

1.1 Conventions Used in this Document

Start of informative comment:

This section gives the data structure description and typographic conventions used in this document.

End of informative comment.

1.1.1 Data Structure Descriptions

All constants and data SHALL be represented as little-endian bit format, which requires the low-order bit on the far left of a constant or data item and the high-order bit on the far right. Exceptions to this, if any, will be explicit in this specification.

All strings SHALL be represented as an array of ASCII bytes with the left-most character placed in the lowest memory location.

In some memory layout descriptions, certain fields are marked reserved. Firmware MUST initialize such fields to zero, and ignore them when read. On an update operation, firmware MUST preserve any reserved field.

1.1.2 Typographic Conventions

The following typographic conventions are used in this document to illustrate programming concepts:

`Prototype`	This typeface indicates prototype code.
`Argument`	This typeface indicates arguments.
`Name`	This typeface indicates actual code or a programming construct.
register	This typeface indicates a processor register

1.2 External Specifications

References to external specifications:

Advanced Configuration and Power Interface (ACPI), Version 2.0, http://www.acpi.info

Extensible Firmware Interface Main Specification Version 1.10, http://www.intel.com/technology/efi

Unified Extensible Firmware Interface Specification (UEFI), Version 2.3.1 or later, http://www.uefi.org

Microsoft Portable Executable and Common Object File Format Specification, Revision 6.0 or later, available at *www.microsoft.com/whdc/ system/platform/firmware/PECOFF.mspx*

Microsoft Windows Authenticode Portable Executable Signature Format, Version 1.0, Microsoft Corporation, March 21, 2008, http://download.microsoft.com/download/9/c/5/ 9c5b2167-8017-4bae-9fde-d599bac8184a/Authenticode PE.docx

System Abstraction Layer (SAL), http://www.intel.com/design/itanium/downloads/245359.htm

TCG TPM Main Specification Version 1.2, https://www.trustedcomputinggroup.org/specs/TPM/

TCG PC Client Specific Implementation Specification for Conventional BIOS, Version 1.21 Revision 1.00, https://www.trustedcomputinggroup.org/specs/PCClient/

TCG EFI Protocol Specification, Version 1.22,
https://www.trustedcomputinggroup.org/specs/PCClient/

TCG Generic Server Specification, Version 1.0, Revision 0.8 dated March 23, 2005,
https://www.trustedcomputinggroup.org/specs/Server/

TCG Itanium Architecture Server Specification, Version 1.0,
https://www.trustedcomputinggroup.org/specs/Server/

TCG ACPI General Specification, Version 1.00, Revision 1.00 dated August 8, 2005,
https://www.trustedcomputinggroup.org/specs/Server/

TCG Generic Server Specification, Version 1.0.

U.S. National Institute of Standards and Technology *(NIST) Special Publication 800-147 Bios Protection Guidelines* available at: http://csrc.nist.gov/publications/nistpubs/800-147/NIST-SP800-147-April2011.pdf

U.S. National Institute of Standards and Technology (NIST) Special Publication 800-155 BIOS Integrity Measurement Guidelines available at: http://csrc.nist.gov/publications/drafts/800-155/draft-SP800-155_Dec2011.pdf

1.3 Abbreviations and Terminology

MAA - Measurement Assessment Authority

RM - Reference Manifest

RoT – Root of Trust

RTR – RoT for Recording

RTS – RoT for Storage

RTM – Rot for Measurement

See section 1.3 of the TCG EFI Protocol for TCG Version 1.2, for definitions of other abbreviations and terminology used in this specification.

2. Conceptual Overview

2.1 Static Locality

Start of informative comment:

For the description of the usages of Locality, refer to sections 3.1 and 3.2 of the *TCG PC Client Specific Implementation Specification for Conventional BIOS, Version 1.21* and/or the *TCG Generic Server Specification, Version 1.0.*

The Normative text within this specification applies only to Locality 0, also known as the static locality.

End of informative comment.

2.2 Static Core Root of Trust for Measurement on an EFI Platform

Start of informative comment:

For the general description of the Static Core Root of Trust for Measurement (S-CRTM), refer to the *TCG PC Client Specific Implementation Specification for Conventional BIOS, Version 1.21* and/or the *TCG Generic Server Specification, Version 1.0.*

The transitive trust chain on a TCG-aware EFI platform is rooted in the S-CRTM component.

On an EFI platform, the S-CRTM is platform firmware from system board motherboard ROM. The S-CRTM either measures the ensuring code on the platform that provides the EFI Boot Services in the System Table or provides the EFI Boot Services itself; in either case, measure this code into PCR [0].

End of informative comment.

2.3 Maintaining the Static Transitive Chain of Trust

Start of informative comment:

In order to maintain the Host Platform Transitive Chain of Trust that is rooted in the S-CRTM, prior to transferring control to another entity within Locality 0, an entity must measure the entity to which it will transfer control.

End of informative comment.

The code which provides the EFI boot services, including LoadImage ( ) and StartImage ( ), MUST be measured into PCR [0].

All successive EFI image loads are measured into PCR [0], PCR [2], or PCR [4]

3. Boot Event and PCR Usage Model

Start of informative comment:

The purpose of this section is to provide the model for PCR usage and for adding events to the Event Log. This entire section is an Informative comment, including Figure 3-1, Figure 3-2, Figure 3-3, and Figure 3-4.

- Figure 3-1 is an architecture drawing that shows the principle firmware and software components defined in the EFI Specification – EFI Boot Services, EFI Runtime Services, and the EFI OS Loader – and their relationship to the platform hardware and the OS software.
- Figure 3-2 shows the sequence of behaviors for the EFI components during the platform boot process and the OS boot process.
- Figure 3-3 maps, in general, the behavioral components on an EFI platform to the PCRs into which each type of behavioral component is measured
- Figure 3-4 shows an example platform and OS boot process on a platform with both BIOS and EFI firmware.

Together, these four diagrams form the boot event and PCR usage model upon which the requirements in sections 4 through 9 of this specification are based.

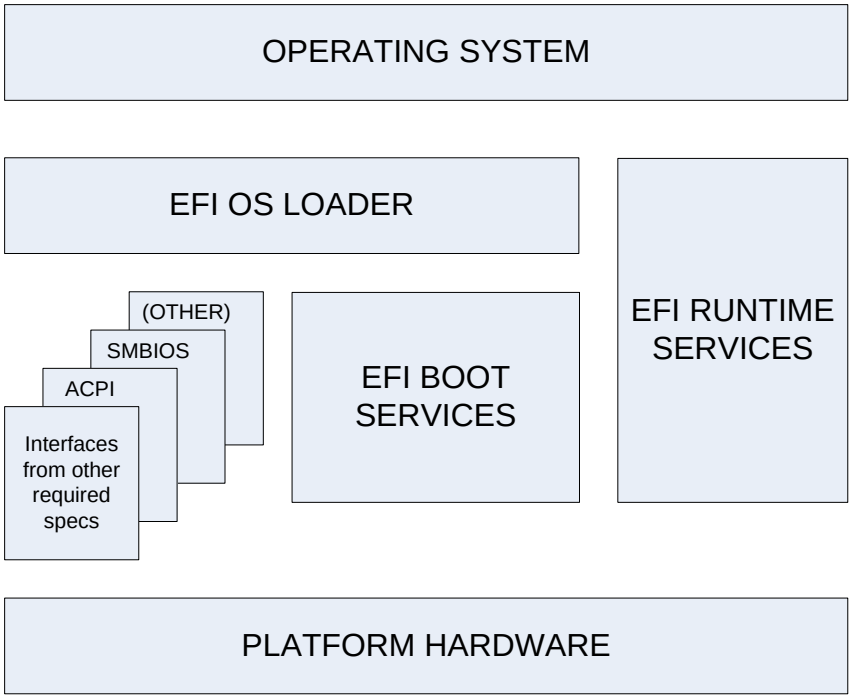
End of informative comment.

Start of informative comment:

Figure 3-1 immediately below, is part of this Informative comment. This diagram illustrates the relationships of various components of an EFI-specification compliant system that accomplish platform boot and OS boot.

End of informative comment.

Figure 3-1 Architecture of an EFI Host Platform, Showing Principle Components for Platform Boot and OS Boot



Start of informative comment:

Figure 3-2, immediately below, is part of this Informative comment and shows the sequence of behaviors for the EFI components during the EFI platform boot process and the EFI OS boot process and, in general, the transitions where events are measured (labeled e0, e1, e2, and so on in the diagram).

In Figure 3-2, each one of the arrows with an "e" annotation represents a transition where a TCG Event is created; an un-annotated arrow does not represent a TCG event measurement. For example, the first measurement action, labeled "e0" is made by the platform initialization code.

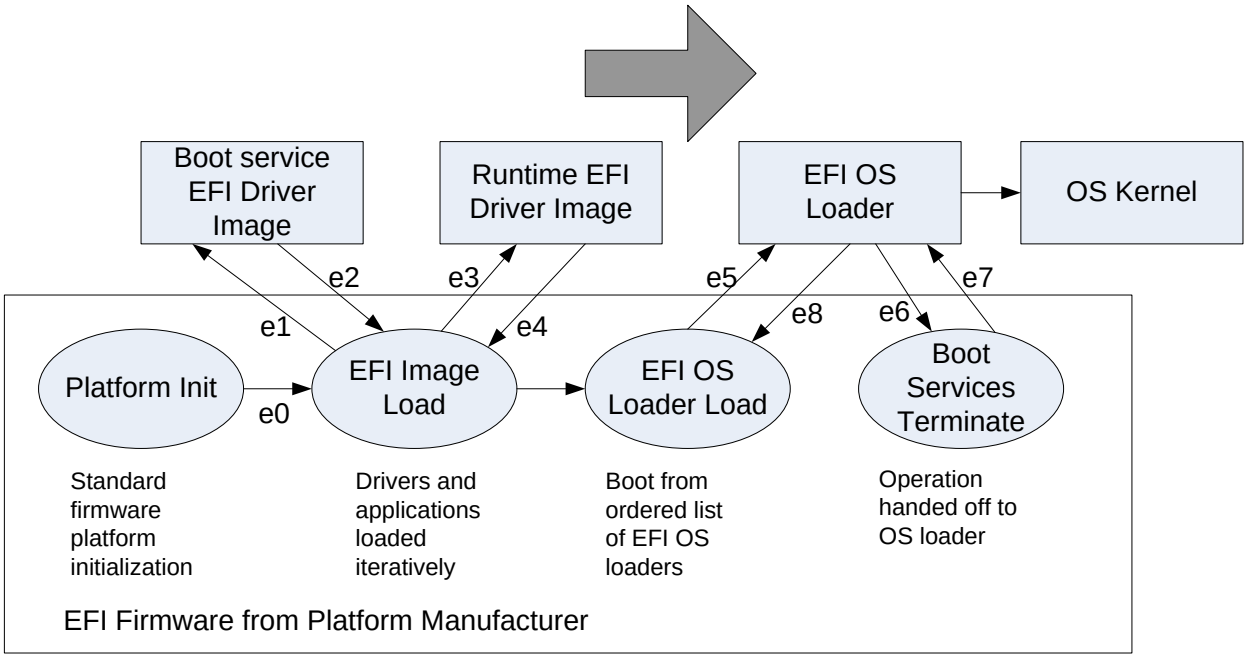
Event "e0" describes the behavior of platform firmware from system board ROM that measures code contained in the rest of the platform EFI firmware and that resides in the CRTM. This measuring agent may or may not contain the EFI Boot and Runtime Services. In the case of a CRTM that does not contain EFI Boot and Runtime Services, this measuring agent must then measure into PCR [0] the code that does contain EFI Boot and Runtime Services. This initial code, if in CRTM, must measure its own version ID into PCR [0].

Event "e5" describes invocation of an EFI application in the boot order list. This is typically an operating system loader. The event "e5" will have associated with it an event that measures the PE/COFF image into PCR [4] and the contents of the boot variable, namely the EFI device path, into PCR [5]. For more information about this measurement action, see Section 7.4, Measuring OS Boot Events on an EFI Platform.

This Informative comment has given a couple of examples of measurement actions associated with particular platform boot transition events, but makes no attempt to describe the measurement events associated with all the transitions shown in Figure 3-2. To see all the measurement events associated with all the transitions shown in Figure 3-2, see Sections 5, 6, and 7 of this specification.

End of informative comment.

Figure 3-2 Platform and EFI OS Booting Sequence

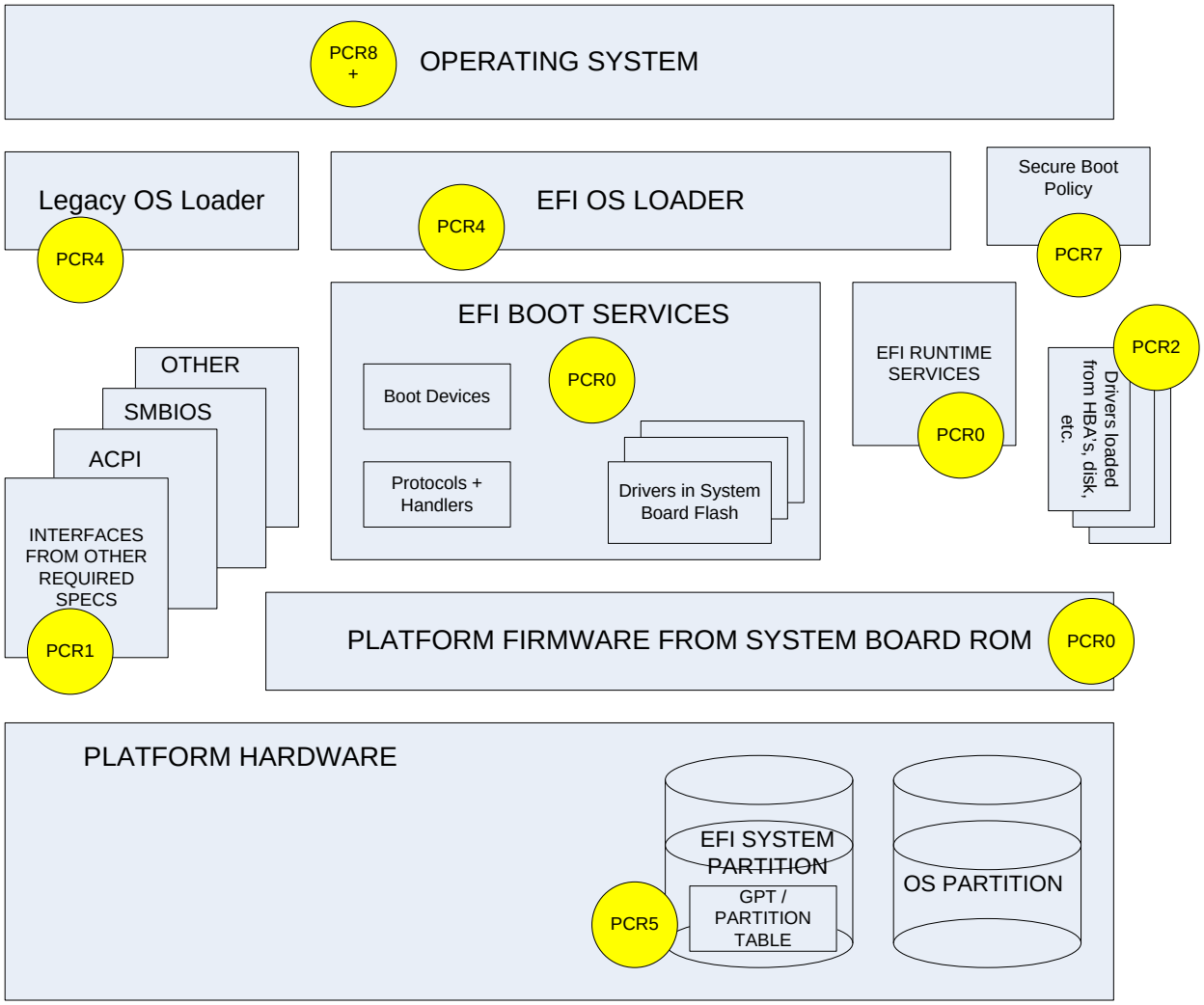


Start of informative comment:

Figure 3-3, immediately below, shows with a picture the general scheme for PCR usage on an EFI platform.

End of informative comment.

Figure 3-3 Mapping of Measured Components to PCRs on an EFI Platform



3.1 Host Platforms with EFI and BIOS Firmware

Start of informative comment:

This subsection applies only to EFI layering on top of traditional BIOS.

The TCG EFI Platform Specification includes requirements for the platform architecture shown in Figure 3-4, immediately below. This drawing shows (reading from left-to-right):

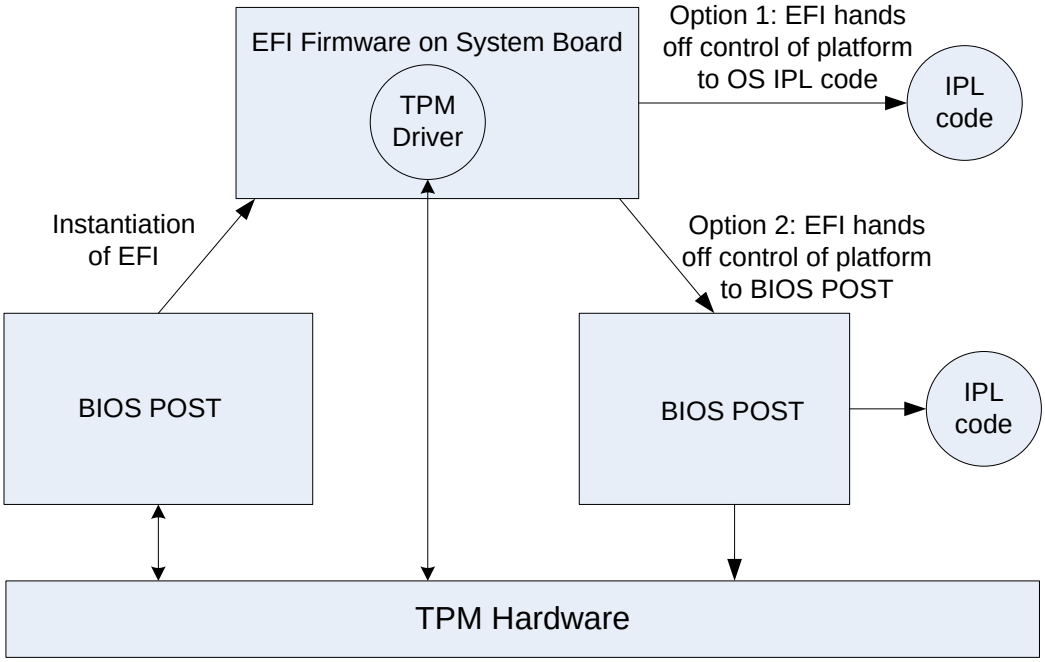
- The Platform Boot Process is primarily done by the BIOS Boot Block, using memory-absent TPM driver code to access the TPM, and some variable part of BIOS POST, using memory-present TPM driver code to access the TPM.
- At some point, BIOS POST instantiates EFI and hands off control to the EFI Firmware on the system board to – primarily – boot the OS; the EFI Firmware uses its own TPM driver to access the TPM.
- The EFI Firmware may hand off control of the platform to the OS IPL code without giving control of the platform back to BIOS POST (shown as Option 1 in the diagram). Although this is most often the case, EFI may hand-off control of the platform back to BIOS POST to complete the OS Boot process.

When the platform is operating as a conventional BIOS, its measurements must comply with the TCG v1.21 PC Client Implementation Specification for Conventional BIOS.

When the platform is operating as an EFI BIOS, its measurements must comply with this specification. See the note in section 7.5 for details.

End of informative comment.

Figure 3-4 Example Platform and OS Boot Process with BIOS and EFI


EFI Firmware on System Board
TPM Driver
Option 1: EFI hands off control of platform to OS IPL code
IPL code
Instantiation of EFI
Option 2: EFI hands off control of platform to BIOS POST
BIOS POST
BIOS POST
IPL code
TPM Hardware

4. Measuring PE/COFF Image Files

Start of informative comment:

PE/COFF images may be recorded into PCR's 0, 2, and 4 depending upon the platform deployment model. These images are measured in their memory-mapped store (ROM for execute-in-place and system memory for loaded images).

The measurement must be made prior to the application of any fix-ups or relocations.

An example of a PE/COFF image file is an EFI OS loader, which would be an OS subsystem type of IMAGE_SUBSYSTEM_EFI_APPLICATION, IMAGE_SUBSYSTEM_EFI_BOOT_SERVICE_DRIVER, and IMAGE_SUBSYSTEM_EFI_RUNTIME_DRIVER (as per PE/COFF specification section 3.4.2).

For EFI images, the data structure used in the TCG_PCR_EVENT.event field will include but is not limited to "where" the image came from, namely its EFI device path, and the address in memory for the shadowed PE image (see the definition of the EFI_IMAGE_LOAD_EVENT structure, in the Mandatory statements below).

The image in physical memory will ultimately have relocations applied (i.e., fix-ups). The event log will detail the load location of the image, so it will be possible to undo relocations by referring to the on-media image.

The *Microsoft Authenticode Portable Executable Signature Format Specification* identifies which PE/COFF image section types EFI measurement agents must measure and which types of PE/COFF image sections are ignorable. What the "measure before applying relocations" described above practically means is that the EFI implementation will perform "LoadImage ( )" actions (e.g., copying PE/COFF to memory, etc), measurement, and then relocation application, and finally, the EFI service "StartImage ( )." As such, EFI implementations of these services must punctuate their flow with this measurement action.

End of informative comment.

Following are the Mandatory requirements for measuring PE/COFF images.

- When measuring a PE/COFF image, the TCG_PCR_EVENT structure Event field MUST contain the EFI_IMAGE_LOAD_EVENT structure defined below.

```
typedef struct {
     EFI_PHYSICAL_ADDRESS   ImageLocationInMemory; // PE/COFF image
     UINTN                  ImageLengthInMemory;
     UINTN                  ImageLinkTimeAddress;  //
     UINTN                  LengthOfDevicePath;    //
     EFI_DEVICE_PATH        DevicePath[1];         // See EFI spec for
                                                   // the encodings.
} EFI_IMAGE_LOAD_EVENT;
```

5. Measuring Code that Boots an EFI Platform

Start of informative comment:

This section of the EFI Platform Specification contains PCR usage requirements for booting an EFI platform.

End of informative comment.

5.1 Measure Code into PCR [0]

Start of informative comment:

This section contains the PCR [0] measurement requirements for an EFI platform.

In general, measure the following types of code into PCR [0] (as shown in Figure 3-3, General Scheme for PCR Usage on an EFI Platform):

- Platform Firmware from system board ROM that either contains or measures the EFI Boot Services and EFI Run Time Services that are loaded from firmware
- Embedded Option ROMs wholly contained within the Platform Firmware on the system board ROM
- EFI Boot Services in the EFI System Table
- EFI Runtime Services in the EFI System Table

An EFI platform measures firmware integrated in the system board into PCR [0]. These are code modules known to be distributed by the Host Platform manufacturer. For an EFI platform, this includes but is not limited to measuring:

- Version of the base firmware that either contains or measures the EFI Boot Services (shown as the Platform Init code module of the EFI Boot Manager in Figure 3-1)

End of informative comment.

The following table lists all the EFI specific measurements that MUST be made into PCR [0] plus any EFI specific optional measurements that MAY be made into PCR [0], along with the type of entry that MUST be made into the Event Log (for more information about types of entries in the Event Log, see Section 7.2, Event Types). Additional measurements defined in other TCG specifications also apply as discussed in section 0.

Table 5-1 Required and Optional PCR [0] Measurements

Measuring Agent	Measured Object	Associated Event Type	Required / Optional
Platform firmware from system board ROM that measures code which either contains or measures the EFI Boot Services and EFI Run Time Services (on an EFI platform, this may be in the CRTM)	Specification Support ID Structure containing versions of the PC Client Conventional Specification and TCG EFII Platform Specification supported by this firmware. See section 7.4	EV_NO_ACTION **Note:** This event is not extended.	Required
Platform firmware from system board ROM that measures code which	VendorId and ReferenceManifestGuid for use by NIST	EV_NO_ACTION	Required only if the platform

Measuring Agent	Measured Object	Associated Event Type	Required / Optional
either contains or measures the EFI Boot Services and EFI Run Time Services (on an EFI platform, this may be in the CRTM)	800-155 Measurement Assessment Authorities. See Chapter 10	**Note:** This event is not extended.	supports NIST 800-155
Platform firmware from system board ROM that measures code which either contains or measures the EFI Boot Services and EFI Run Time Services (on an EFI platform, this may be in the CRTM)	Platform firmware from system board ROM that either contains or measures the EFI Boot Services and EFI Run Time Services; this measured object is the CRTM code including embedded option ROMs	EV_EFI_PLATFORM_FIRMWARE_BLOB	Optional (optional if measured object in CRTM)
Platform firmware from system board ROM that measures code which either contains or measures the EFI Boot Services and EFI Run Time Services (on an EFI platform, this may be in the CRTM)	EFI driver embedded in system ROM by the manufacturer	EV_EFI_BOOT_SERVICES_DRIVER	Optional (optional if measured object in CRTM)
Platform firmware from system board ROM that measures code which either contains or measures the EFI Boot Services and EFI Run Time Services (on an EFI platform, this may be in the CRTM)	EFI driver embedded in system ROM by the manufacturer	EV_EFI_RUNTIME_SERVICES_DRIVER	Optional (optional if measured object in CRTM)

5.2 Measure Data into PCR [1]

Start of informative comment:

This section contains the PCR [1] measurement requirements for an EFI platform.

In general, measure into PCR [1] the data that is associated with the code that has been measured into PCR [0].

For example, for an EFI server platform, this includes but is not limited to

- SAL system table
- SMBIOS Tables

PCR [1] also contains Boot Policy measurements. In order to record the alternate boot behaviors of an EFI system, the EFI platform firmware will measure the EFI Boot#### variables and BootOrder Variable into PCR [1]. These boot variables are just device paths. A description of the device paths and variables can be found in the EFI Specification.

End of informative comment.

- Platform configuration information that is automatically updated, such as clock registers, and system unique information, such as asset numbers or serial numbers, MUST NOT be measured into PCR [1], or any other PCR.
- The following table lists all EFI specific measurements that MUST be made into PCR [1] plus any optional EFI specific measurements that MAY be made into PCR [1], along with the type of entry that MUST be made into the Event Log (for more information about types of entries in the Event Log, see Section 7.2, Event Types). Additional measurements defined in other TCG specifications also apply as discussed in section 0.

Table 5-2 Required and Optional PCR [1] Measurements

Measuring Agent	Measured Object	Associated Event Type	Required / Optional
EFI Firmware from Platform Manufacturer (code measured into PCR [0])	EFI Boot#### variables and BootOrder variable	EV_EFI_VARIABLE_BOOT	Required
CRTM or code measured into PCR [0]	other tables	EV_EFI_HANDOFF_TABLES	Optional
CRTM or code measured into PCR [0]	EFI Variables that impact system configuration	EV_EFI_VARIABLE_DRIVER_CONFIG	Optional

5.3 Measure Code into PCR [2]

Start of informative comment:

This section contains the PCR [2] measurement requirements for an EFI platform.

In general, measure into PCR [2] firmware code modules added to the Host Platform by a Value Added Retailer (VAR), the platform owner, or some unknown entity. The source of these firmware code modules measured into PCR [2] is not the Host Platform manufacturer.

For an EFI platform, this includes but is not limited to

- EFI Drivers loaded from adapter cards
- EFI Applications loaded from adapter cards (e.g., setup utility for RAID controller)
- EFI Applications loaded from external storage media (system or peripheral Flash for example) via embedded option ROM contained within the EFI firmware on the system board.
- Drivers loaded from HBA's/disks and so on (as shown in Figure 3-3, General Scheme for PCR Usage on an EFI Platform

The measuring agent is always the platform firmware (that is, code measured into PCR [0], even in the case where a measuring agent not measured into PCR [0] "requests" the program load, such as an EFI Driver trying to load another EFI Driver or Application). The EFI Driver will use the EFI LoadImage service. Since measurement occurs between shadowing of PE sections and the application of relocations, only the LoadImage service can call the TCG EFI Protocol function TCG_HashLogExtendEvent at the appropriate time.

End of informative comment.

The following table lists all EFI specific measurements that MUST be made into PCR [2] plus optional EFI specific measurements that MAY be made into PCR [2], along with the type of entry that MUST be made into the Event Log (for more information about types of entries in the Event Log, see Section 7.2, Event Types). Additional measurements defined in other TCG specifications also apply as discussed in section 0.

Table 5-3 Required and Optional PCR [2] Measurements

Measuring Agent	Measured Object	Associated Event Type	Required / Optional
Platform firmware from system board ROM that either contains or measures EFI Boot Services and EFI Runtime Services	EFI Boot Services Drivers from adapter or loaded by driver in adapter	EV_EFI_BOOT_SERVICES_DRIVER	Required (aspect of any measuring agent that invokes LoadImage on a TCG platform)
Platform firmware from system board ROM that either contains or measures EFI Boot Services and EFI Runtime Services	EFI Runtime drivers from adapter or loaded by driver in adapter	EV_EFI_RUNTIME_SERVICES_DRIVER	Required (aspect of any measuring agent that invokes LoadImage on a TCG platform)

5.4 Measure Data into PCR [3]

Start of informative comment:

This section contains the PCR [3] measurement requirements for an EFI platform.

In general, entities measure into PCR [3] data that is associated with code modules that are measured into PCR [2]. For example, on an EFI platform, this includes but is not limited to EFI variables defined and managed by drivers. See section 7.8's discussion of measuring EFI Variables.

End of informative comment.

The following table lists all EFI specific measurements that MUST be made into PCR [3] plus any optional EFI specific measurements that MAY be made into PCR [3], along with the type of entry that MUST be made into the Event Log (for more information about types of entries in the Event Log, see Section 7.2, Event Types). Additional measurements defined in other TCG specifications also apply as discussed in section 0.

Table 5-4 Required and Optional PCR [3] Measurements

Measuring Agent	Measured Object	Associated Event Type	Required / Optional
EFI Runtime or Boot service drivers measured into PCR[2]	EFI Variable (see Section 7.8, Measuring EFI Variables, for more information)	EV_EFI_VARIABLE_DRIVER_CONFIG	Optional

6. Measuring Code that Boots an OS

Start of informative comment:

This section of the EFI Platform Specification contains PCR usage requirements for the transition from the EFI Boot Manager to the OS Loader shown in Figure 3-2, above. Note that the term 'EFI OS Loader Load' is a label for a behavior, not necessarily a label for a code module.

Measure code that boots an operating system on an EFI platform into PCR [4] and measure data associated with that code into PCR [5].

End of informative comment.

6.1 Measure Code into PCR [4]

Start of informative comment:

This section contains the PCR [4] measurement requirements for an EFI platform.

In general, entities measure into PCR [4] code modules that could transition the platform from the pre-OS state to the OS-present state. Measure EFI applications into PCR [4]; for an EFI platform, EFI applications include but are not limited to:

- Pre-OS diagnostics
- EFI OS Loader

The measurement values in PCR [4] must be consistent and repeatable across EFI boots.

In the table below, 'measuring entity' means code in the CRTM or code measured into PCR [0] which provides image loading capability and invokes the measurement agent (the 'platform code').

The 'measured object' is a PE/COFF image; see Section 4, Measuring PE/COFF Image Files, for a definition of the methodology for measuring PE/COFF images on a TCG EFI platform.

The measuring agent is always the platform firmware (that is, code measured into PCR [0]). The measuring agent will typically measure the measurement object code as part of the LoadImage ( ) action. Since measurement occurs between shadowing of PE sections and the application of relocations, only the LoadImage service can call the TCG EFI Protocol function TCG_HashLogExtendEvent at the appropriate time. This contrasts with the Conventional BIOS Option ROMs that do not have access to an image load service; these code modules must invoke the measurement INT 1Ah call directly.

This model purposely precludes pre-OS agents from loading and invoking code outside the EFI LoadImage Service. Only the PCR [4] application, such as the EFI OS Loader, can use a different code load and measurement methodology, but the target PCR for this action will be in the range PCR [8] and above and outside the scope of this specification.

End of informative comment.

The measuring entity MUST measure normalized code for all EFI applications into PCR [4].

The code modules measured into PCR [4] MUST be measured in the same order every boot, in absence of a system configuration change.

The following table lists all EFI specific measurements that MUST be made into PCR [4] plus any optional EFI specific measurements that MAY be made into PCR [4], along with the type of entry that MUST be made into the Event Log (for more information about types of entries in the Event Log, see Section 7.2, Event Types). Additional measurements defined in other TCG specifications also apply as discussed in section 0.

Table 6-1 Required and Optional PCR [4] Measurements

Measuring Agent	Measured Object	Associated Event Type	Required / Optional
EFI Firmware from Platform Manufacturer (code measured into PCR [0])	EFI application (e.g., EFI OS Loader)	EV_EFI_BOOT_SERVICES_APPLICATION	Required
EFI Firmware from Platform Manufacturer (code measured into PCR [0])	EFI application (e.g., HBA system configuration utility, such as RAID setup)	EV_EFI_BOOT_SERVICES_APPLICATION	Required
EFI Firmware from Platform Manufacturer (code measured into PCR [0])	EFI application (e.g., OS loader spawning a separate pre-OS application, such as EfiChkDsk.efi or Diskpart.efi)	EV_EFI_BOOT_SERVICES_APPLICATION	Required

6.2 Measure Data into PCR [5]

Start of informative comment:

This section contains the PCR [5] measurement requirements for an EFI platform.

In general, entities measure into PCR [5] data associated with the code modules measured into PCR [4]. For an EFI platform, this includes but is not limited to

- The GPT/Partition Table (as shown in Figure 3-3, General Scheme for PCR Usage on an EFI Platform)

Additional variables that may impact system behavior beyond the boot options that are measured into PCR[1] may be optionally measured by the EFI boot application. These loader variables shall be measured into PCR [5]. The source of these additional variables may be the EFI Specification or private variables. These variables can include, but are not limited to, language code, and so on.

End of informative comment.

The following table lists all EFI specific measurements that MUST be made into PCR [5] plus any optional EFI specific measurements that MAY be made into PCR [5], along with the type of entry that MUST be made into the Event Log (for more information about types of entries in the Event Log, see Section 7.2, Event Types). Additional measurements defined in other TCG specifications also apply as discussed in section 0.

Table 6-2 Required and Optional PCR [5] Measurements

Measuring Entity	Measured Entity	Associated Event Type	Required / Optional
EFI Firmware from Platform Manufacturer (code measured into PCR [0])	GPT Table	EV_EFI_GPT_EVENT	Optional
EFI application measured into PCR[4] (e.g., OS loader)	EFI variables, either defined in the EFI spec or private, that typically do not change from boot-to-boot and contain system configuration information.	EV_EFI_VARIABLE_DRIVER_CONFIG	Optional

6.3 Measure Data into PCR [6]

Start of informative comment:

There are no EFI specific PCR[6] measurements. Please refer to section 3.3.3.7 of the *TCG v1.21 PC Client Implementation Specification for Conventional BIOS.*

This PCR is reserved for use by the Host Platform manufacturer. This allows the Host Platform manufacturer-specific applications to use this PCR.

Previously defined measurements for PCR[6] from the PC Client Implementation Specification for Conventional BIOS have been deprecated.

End of informative comment.

6.4 Measure Data into PCR [7]

Start of informative comment:

This section contains the PCR [7] measurement requirements for an EFI platform.

Note that the Host Platform Manufacturer Control Measurements described in section 3.3.3.8 of the *TCG v1.21 PC Client Implementation Specification for Conventional BIOS* are also allowed on EFI Platforms.

In addition, PCR[7] is used to record secure boot policy information as described below. See Chapter 27 of the UEFI Specification for more information on UEFI Secure Boot.

End of informative comment.

PCR[7] is used to reflect the UEFI 2.3.1 Secure Boot policy. This policy relies on the firmware authenticating all boot components launched prior to the UEFI environment and the UEFI platform initialization code (or earlier firmware code) invariantly recording the Secure Boot policy information into PCR[7].

Platform firmware adhering to the policy MUST therefore measure the following values into PCR[7]:-

The contents of the SecureBoot variable

The contents of the PK variable

2. The contents of the KEK variable

3. The contents of the EFI_IMAGE_SECURITY_DATABASE variable

4. The contents of the EFI_IMAGE_SECURITY_DATABASE1 variable

5. Entries in the EFI_IMAGE_SECURITY_DATABASE that are used to validate EFI Drivers or EFI Boot Applications in the boot path

For all EFI variable value events, the EventType SHALL be EV_EFI_VARIABLE_DRIVER_CONFIG and the Event value SHALL be the value of the EFI_VARIABLE_DATA structure (this structure SHALL be considered byte-aligned).

The measurement digest MUST be the SHA-1 hash of the event data which is the EFI_VARIABLE_DATA structure. (Note: This is a different digest than the one used in the previous version of this specification.) The EFI_VARIABLE_DATA.UnicodeNameLength value is the number of CHAR16 characters (not the number of bytes). The EFI_VARIABLE_DATA.UnicodeName contents MUST NOT include a null terminator.

Images that LoadImage fails to load due to (a) signature verification failure or (b) because the image does not comply with currently enforced UEFI 2.3.1 Secure Boot policy do not need to be measured in a PCR.

If reading the EFI variable returns EFI_NOT_FOUND, the EFI_VARIABLE_DATA.VariableDataLength field MUST be set to zero and EFI_VARIABLE_DATA.VariableData field will have a size of zero.

Entities that MUST be measured if the TPM is activated:

1. If the platform provides a firmware debugger mode which may be used prior to the UEFI environment or if the platform provides a debugger for the UEFI environment, then the platform SHALL extend an EV_EFI_ACTION event into PCR[7] before allowing use of the debugger. The event string SHALL be “UEFI Debug Mode”. Further, the platform MUST create a TCG Event Log entry as follows:

TCG_PCR_EVENT.PCRIndex = 7

TCG_PCR_EVENT.EventType = EV_EFI_ACTION

TCG_PCR_EVENT.Digest = <the SHA- 1 digest of the string value “UEFI Debug Mode” without the terminating NULL character>

TCG_PCR_EVENT.EventSize = strlen(“UEFI Debug Mode”)

TCG_PCR_EVENT.Event = “UEFI Debug Mode”

The platform MAY build similar event log entries for other supported Event Log formats.

2. Before executing any code not cryptographically authenticated as being provided by the Platform Manufacturer, the Platform Manufacturer firmware MUST measure the following values, in the order listed using the EV_EFI_VARIABLE_DRIVER_CONFIG event type to PCR[7]:

SecureBoot variable value

The PK variable value

The KEK variable value

The EFI_IMAGE_SECURITY_DATABASE_GUID /EFI_IMAGE_SECURITY_DATABASE variable value

The EFI_IMAGE_SECURITY_DATABASE_GUID /EFI_IMAGE_SECURITY_DATABASE1 variable value

3. If the platform supports changing any of the following UEFI policy variables after they are initially measured in PCR[7] and before ExitBootServices ( ) has completed, the platform MUST be restarted. Additionally the normal update process for setting any of the UEFI variables below MUST occur before the initial measurement in PCR[7] or after the call to ExitBootServices() has completed.

SecureBoot variable value

The PK variable value

The KEK variable value

The EFI_IMAGE_SECURITY_DATABASE_GUID /EFI_IMAGE_SECURITY_DATABASE variable value

The EFI_IMAGE_SECURITY_DATABASE_GUID /EFI_IMAGE_SECURITY_DATABASE1 variable value

4. The system SHALL measure the EV_SEPARATOR event in PCR[7]. (This occurs at the same time the separator is measured to PCR[0] through PCR[7].)

5. Before launching an EFI Driver or an EFI Boot Application (and regardless of whether the launch is due to the EFI Boot Manager picking an image from the DriverOrder or BootOrder UEFI variables or an already launched image calling the UEFI LoadImage() function), the UEFI firmware SHALL determine if the entry in the EFI_IMAGE_SECURITY_DATABASE_GUID/EFI_IMAGE_SECURITY_DATABASE variable that was used to validate the EFI image has previously been measured with the EV_EFI_VARIABLE_AUTHORITY event type in PCR[7]. If it has not been, it MUST be measured into PCR[7] as follows. If it has been measured previously, it MUST NOT be measured again. The measurement SHALL occur in conjunction with image load.

For this event, the EventType SHALL be EV_EFI_VARIABLE_AUTHORITY and the Event value SHALL be the value of the EFI_VARIABLE_DATA structure. The EFI_VARIABLE_DATA.VariableData value SHALL be the EFI_SIGNATURE_DATA value from the EFI_SIGNATURE_LIST that contained the authority that was used to validate the image and the EFI_VARIABLE_DATA. VariableName SHALL be set to EFI_IMAGE_SECURITY_DATABASE_GUID . The EFI_VARIABLE_DATA.UnicodeName SHALL be set to the value of EFI_IMAGE_SECURITY_DATABASE. The value MUST NOT include the terminating NULL character.

6. The EV_EFI_VARIABLE_AUTHORITY measurement in step 5 is not required if the value of the SecureBoot variable is 00h (off). In such cases, no validation occurs against the SecureBoot databases.

Entities that MAY be measured if the TPM is activated:

Host Platform Manufacturer Control Measurements as described in section 3.3.3.8 of the TCG v1.21 *PC Client Implementation Specification for Conventional BIOS.*

7. Event Logging on an EFI Platform

Start of informative comment:

The value within a PCR is used for sealed storage, attestation, and re-construction of the boot flow. The raw hash value in a PCR is sufficient for sealed storage, but not for attestation or replay.

Event Log entries add value to the raw hash values in PCRs for attestation as well as for re-constructing the events that triggered the measurements into the PCRs.

Section 3.1.3 of the TCG EFI Protocol Specification defines the structure that an entry in the Event Log must have, but a copy of that structure is in Section 7.1, for the convenience of the reader.

Table 7-1, in Section 7-2, Event Types, lists the EFI specific Event Types for an EFI platform.

End of informative comment.

7.1 Event Log Entry Structure Definition

This section shows a copy of the Event Log entry data structure specified in the TCG EFI Protocol Specification. The data elements MUST be in big endian format and byte-aligned/packed data structures.

```
typedef struct {
  TCG_PCRINDEX   PCRIndex; //PCRIndex event extended to
  TCG_EVENTTYPE  EventType;//See Table 7-1, below
  TCG_DIGEST     Digest;   //Value extended into PCRIndex
  UINT32         EventSize;//Size of the event data
  UINT8          Event[1]; //The event data
} TCG_PCR_EVENT;           //Structure to be added to the
                           //Event Log
```

7.2 Event Types

Start of informative comment:

One element in an Event Log entry is TCG_PCR_EVENT.EventType (see section 7.1). Table 7-1, below, is normative and specifies all the event types that can be used in an Event Log entry for the measurement events specified in this document for an EFI platform.

The value associated with these EFI specific platform event types must not overlap with the event type values already defined for other TCG platform architecture specifications.

EFI platforms *may* also use non-EFI specific events from the *PC Client Implementation Specification for Conventional BIOS*, including but not limited to, EV_POST_CODE, EV_SEPARATOR, EV_S_CRTM_VERSION, EV_S_CRTM_CONTENTS and EV_NO_ACTION. This specification does not speak to measurement of optional tagged events, as defined in the TCG v1.21 *PC Client Implementation Specification for Conventional BIOS*, section 10.4.2. A composite platform that supports EFI and conventional BIOS may have such entries in the Event Log.

End of informative comment.

The value associated with an EFI specific platform event type MUST not overlap with any of the event type values specified for other TCG platform architecture specifications including, but not limited to, the *TCG v1.21 PC Client Implementation Specification for Conventional BIOS* and the *TCG IPF Architecture Server Specification.* The value associated with an EFI specific platform event type MUST be in the range between 0x80000000 and 0x800000FF, inclusive.

For all EFI platform-specific events, the TCG_PCR_EVENT.EventType field in the Event Log entry MUST be one of the values listed in Table 7-1.

Table 7-1 EFI Platform Event Types

Label	Value	Description
EV_EFI_EVENT_BASE	0x80000000	Base value for all EFI platform event type values below
EV_EFI_VARIABLE_DRIVER_CONFIG	EV_EFI_EVENT_BASE + 0x1	TCG_PCR_EVENT.PCRIndex = 1, 3 or 5 TCG_PCR_EVENT.digest = SHA-1 (Variable data, GUID, Unicode string) TCG_PCR_EVENT.Event[1] = EFI_VARIABLE_DATA structure
EV_EFI_VARIABLE_BOOT	EV_EFI_EVENT_BASE + 0x2	TCG_PCR_EVENT.PCRIndex = 1 TCG_PCR_EVENT.digest = SHA-1 Hash of the EFI Boot#### variables and the BootOrder variable TCG_PCR_EVENT.Event[1] = EFI_VARIABLE_DATA structure
EV_EFI_BOOT_SERVICES_APPLICATION	EV_EFI_EVENT_BASE + 0x3	TCG_PCR_EVENT.PCRIndex = 2, 4 TCG_PCR_EVENT.digest = SHA-1 Hash of the normalized code from the loaded EFI Boot Services application TCG_PCR_EVENT.Event[1] = EFI_IMAGE_LOAD_EVENT structure
EV_EFI_BOOT_SERVICES_DRIVER	EV_EFI_EVENT_BASE + 0x4	TCG_PCR_EVENT.PCRIndex = 0, 2 TCG_PCR_EVENT.digest = SHA-1 Hash of the normalized code from the loaded EFI Boot Services driver TCG_PCR_EVENT.Event[1] = EFI_IMAGE_LOAD_EVENT structure
EV_EFI_RUNTIME_SERVICES_DRIVER	EV_EFI_EVENT_BASE + 0x5	TCG_PCR_EVENT.PCRIndex = 0, 2 TCG_PCR_EVENT.digest = SHA-1 Hash of the normalized code from the loaded EFI Runtime Services driver TCG_PCR_EVENT.Event[1] = EFI_IMAGE_LOAD_EVENT structure
EV_EFI_GPT_EVENT	EV_EFI_EVENT_BASE + 0x6	TCG_PCR_EVENT.PCRIndex = 5 TCG_PCR_EVENT.digest = SHA-1 Hash of the GPT Table TCG_PCR_EVENT.Event[1] = EFI_GPT_DATA structure
EV_EFI_ACTION	EV_EFI_EVENT_BASE	TCG_PCR_EVENT.PCRIndex =

Label	Value	Description
	+ 0x7	Depends on the specific string value in the Event [1] field (see Table 7-2). TCG_PCR_EVENT.digest = SHA-1 Hash of Event [1] field TCG_PCR_EVENT.Event [1] = See Table 7.2 for the specific string values that can be used in this field for an EFI platform
EV_EFI_PLATFORM_FIRMWARE_BLOB	EV_EFI_EVENT_BASE + 0x8	TCG_PCR_EVENT.PCRIndex = >1 (non-PE/COFF image load) TCG_PCR_EVENT.digest = SHA-1 Hash of all the code (PE/COFF .text sections or other). TCG_PCR_EVENT.Event[1] = EFI_PLATFORM_FIRMWARE_BLOB structure This allows for non-PE/COFF images in PCR [2] or PCR [4]. PCR [0] already has EV_POST_CODE for this type of code.
EV_EFI_HANDOFF_TABLES	EV_EFI_EVENT_BASE + 0x9	TCG_PCR_EVENT.PCRIndex = 1 TCG_PCR_EVENT.digest = SHA-1 Hash of the system configuration tables which are referenced by entries in EFI_HANDOFF_TABLE_POINTERS TCG_PCR_EVENT.Event[1] = EFI_HANDOFF_TABLE_POINTERS
EV_EFI_VARIABLE_AUTHORITY	EV_EFI_EVENT_BASE + 0xE0	TCG_PCR_EVENT.PCRIndex =7 TCG_PCR_EVENT.digest = SHA-1 Hash of the EFI_SIGNATURE_DATA value from the EFI_SIGNATURE_LIST used to validate the image. TCG_PCR_EVENT.Event[1] = EFI_VARIABLE_DATA. See section 6.4 item 5.

7.3 Event Type EV_EFI_ACTION Strings

Start of informative comment:

The EV_EFI_ACTION event type defined in Table 7-1, above, extends into a specific PCR the measurement of a specific string value that indicates a specific event occurred during the platform or OS boot process. See the EV_EFI_ACTION event type definition in Table 7-1 for the format of the entry that is added to the Event Log when such an event occurs.

NOTE: The opening and closing quote characters shown in the String Value column of Table 7-2 must not be included in the TCG_PCR_EVENT [1] field and must not be included in the input to the measurement function.

The reason this specification measures OS boot event strings into PCR [5] instead of PCR [4] is that the path or control flow information is typically measured into PCR [5] (for example, EFI Boot Variables) and the identity of code modules is measured into PCR [4]. In Table 7-2 below, for example, the string "Returned EFI NOT SUCCESS" helps to interpret the path of code measurements in the Event Log; for example, the next OS Loader to try after the previous one failed. Each OS Loader code image is extended into PCR [4], but the strings extended into PCR [5], along with the Event Log entry, will say why an additional EFI application was invoked.

End of informative comment.

Table 7-2, below, specifies all the specific string values that can be used for EV_EFI_ACTION on an EFI platform.

Table 7-2 Event Type EV_EFI_ACTION Strings

String Value	Meaning of that String Value	PCR to Extend Hash of String Value Into
"Calling EFI Application from Boot Option"	For now, See Section 7.5	PCR [4]
"Returning from EFI Application from Boot Option"	For now, See Section 7.5	PCR [4]
"Exit Boot Services Invocation"	For now, See Section 7.5	PCR [4]
"Exit Boot Services Returned with Failure"	For now, See Section 7.5	PCR [4]
"Exit Boot Services Returned with Success"	For now, See Section 7.5	PCR [4]

7.4 EV_NO_ACTION Event Types

Start of informative comment:

EV_NO_ACTION events are used to indicate the specification version supported by a platform's BIOS. Since this specification references the Conventional BIOS Specification, the supported versions of both specifications are needed.

See section 4.4.4 of the *PC Client Implementation Specification for Conventional BIOS* v1.21 for how that specification's version is indicated.

The version of this specification that is supported is indicated in the same manner referenced above, but using the TCG_EfiSpecIDEventStruct (defined below) instead of the TCG_PCClientSpecIDEventStruct.

Note that EV_NO_ACTION events are NOT extended.

Note that the *PC Client Implementation Specification for Conventional BIOS* v1.21 section 4.4.4.1 requires that its EV_NO_ACTION Specification Event be the first event in the event log. That is also true of platforms supporting this specification per section 5.1. In addition, that event must be immediately followed by the EV_NO_ACTION EFI Specification ID Event described below.

This specification uses several data structures defined in the UEFI 2.3.1 Specification that contain UINTN members. Since UINTN resolve to UINT32 on 32 bit platforms and UINT64 on 64 bit platforms, when analyzing an event log on a platform that did not generate the event log, it is necessary to know the size of UINTN used when creating the event log. This is indicated by the UINTN size field of the TCG_EfiSpecIDEventStruct defined below.

However, the only requirement is that the UINTN size used in the construction of the event log is reported. A platform is not required to use its native size. That is, a 32 bit platform could choose to create its event log with UINT64's for the UINTN members.

Note that these SpecIDEventStructs were added in version 1.21 of the *PC Client Implementation Specification for Conventional BIOS* and version 1.22 of this specification. So firmware supporting earlier versions does not contain these events.

Regarding Table 7-4 below, VendorID and referenceManifestGuid are required for compatibility with NIST 800-155. They identify the manufacturer and platform model, but do not identify an individual platform. This information is needed for an external agent to determine which golden measurements should be compared to the measurements from this platform. See Chapter 10 for more information.

End of informative comment.

- The EFI Firmware MUST indicate if it supports *PC Client Implementation Specification for Conventional BIOS v1.21* as indicated in section 3.3.3.1, 4.4.4 and 4.4.4.1 of that specification. See section 5.1of this specification regarding when this measurement is performed.
- The EFI Firmware MUST indicate if it supports v1.22 of this specification using the TCG_EfiSpecIDEventStruct (defined below). See section 5.1of this specification regarding when this measurement is performed.

The EFI Firmware MUST populate the Event LOG with the following structure:

```
typedef struct tdTCG_EfiSpecIdEventStruct {
   BYTE[16]             signature;
   UINT32               platformClass;
   UINT8                specVersionMinor;
   UINT8                specVersionMajor;
   UINT8                specErrata;
   UINT8                uintnSize;
   UINT8                vendorInfoSize;
   BYTE[VendorInfoSize] vendorInfo;
} TCG_EfiSpecIDEventStruct;
```

Table 7-3 Specification Identifier Event Structure

Type	Name	Description
BYTE[16]	signature	The null terminated ASCII string "Spec ID Event02". MUST be set to {0x53, 0x70, 0x65, 0x63, 0x20, 0x49, 0x44, 0x20, 0x45, 0x76, 0x65, 0x6e, 0x74, 0x30, 0x32, 0x00}.
UINT32	platformClass	The value for the Platform Class. The enumeration is defined in the TCG ACPI Specification Client Common Header.
UINT8	specVersionMinor	The TCG EFI Platform Specification minor version number this BIOS supports. Any BIOS supporting this version (1.22) MUST set this value to 02h.
UINT8	specVersionMajor	The TCG EFI Platform Specification major version number this BIOS supports. Any BIOS supporting this version (1.22) MUST set this value to 01h.
UINT8	specErrata	The TCG EFI Platform Specification errata for this specification this BIOS supports. Any BIOS supporting this version and errata (1.22) MUST set this value to 02h.
UINT8	uintnSize	Specifies the size of the UINTN fields used in various data structures used in this specification. 0x01 indicates UINT32 and 0x02 indicates UINT64.
UINT8	vendorInfoSize	Size in bytes of the VendorInfo field. Maximum value MUST be FFh bytes.

BYTE[vendorInfoSize]	vendorInfo	Provided for use by the BIOS implementer. The value might be used, for example, to provide more detailed information about the specific BIOS such as BIOS revision numbers, etc. The values within this field are not standardized and are implementer-specific. Platform-specific or -unique information MUST NOT be provided in this field.

This structure is used to record an event for PCR[0] in the log, but it does not extend the PCR. See Section 5.1.

- EFI Firmware meeting the requirements of the U.S. National Institute of Standards and Technology (NIST) Special Publication 800-155 BIOS Integrity Measurement Guidelines SHALL produce one or more identifiers used to associate the platform with its reference manifest (RM). These identifiers are EV_NO_ACTION log events containing an event of type TCG_Sp800-155-PlatformId_EventStruct. See Chapter 10.

```
typedef struct  {
  UINT32        VendorId;
  EFI_GUID      ReferenceManifestGuid;
} TCG_Sp800-155-PlatformId_EventStruct;
```

Table 7-4 TCG_Sp800-155-PlatformId_EventStruct

Type	Name	Description
UINT32	VendorId	Where Vendor ID is an integer defined at http://www.iana.org/assignments/enterprise-numbers
EFI_GUID	ReferenceManifestGuid	ReferenceManifestGuid is the 16-byte identifier of a given platform's static configuration of code.

7.5 Measuring OS Boot Events on an EFI Platform

Start of informative comment:

An Event Log enables a challenger to determine the state of trust of the EFI platform and enables software on the EFI platform to reconstruct boot events. The Operating System handoff code needs to fill the Event Log with information about the boot devices used to get to the Operating System. The EFI platform functions designed for computing hash values and extending PCRs should automatically log the extended events.

However, there are events that must be added to the Event Log that are not the result of a PCR extend operation.

The purpose of this section is to specify all the required events added to the Event Log for OS boot, including events that do not result from a PCR extend operation.

Note: If an attempt is made to boot a non-EFI OS Loader (e.g., an Int 19h invocation into a Conventional BIOS boot), continue with measurement as defined in the *TCG v1.21 PC Client Implementation Specification for Conventional BIOS*.

End of informative comment.

- The EFI firmware MUST measure the event EV_SEPARATOR into PCR [0-7] once for each EFI platform boot cycle and the measurement of that event MUST draw the line between leaving the pre-Boot environment and entering the post-Boot environment. The data within the event field of the EV_SEPARATOR event MUST be a 32-bit (double-word) of 0's (that is, 0x00000000).

- The EFI OS Loader Load code MUST measure, into PCR [4], every attempt to load and execute an EFI OS Loader (an EFI application).
- A boot device has an EFI application. The boot variable describes the location of the application. The EFI firmware launches the application. If the application returns back to EFI firmware, this affects the transitive trust chain and MUST be measured.
- Sequence of measuring OS boot events MUST proceed as specified below.

1. Upon selecting a boot device, the EFI firmware measures the event type EV_EFI_ACTION "Calling EFI Application from Boot Option" into PCR [4].
2. Measure EV_SEPARATOR into PCR [0], PCR [1], PCR [2], PCR [3], PCR [4], PCR [5], PCR [6], and PCR [7]. This occurs only once in the flow.
3. If UEFI Secure Boot is enabled, measure the entry in the EFI_IMAGE_SECURITY_DATABASE_GUID/EFI_IMAGE_SECURITY_DATABASE that was used to validate the EFI image into PCR[7] as described in section 6.4 steps 5 and 6.
4. In this optional step, measure GPT with event type equal to EV_EFI_GPT_EVENT with the data structure EFI_GPT_DATA into PCR [5].
5. Measure the selected EFI application code PE/COFF image described by boot variable into PCR [4] using event type = EV_EFI_BOOT_SERVICES_APPLICATION.
6. Execute EFI application from boot variable.
    a. In this optional step, if the executing code from step 6 loads additional applications or drivers prior to successive steps (ie., return or exit boot services), the loaded applications MUST be measured into PCR[4]. If the load is a driver, it is measured into PCR[4].
7. Measure event type = EV_EFI_ACTION "Returning from EFI Application from Boot Option" into PCR [4].
8. If need to select a next boot device, the EFI firmware MUST jump to step 4.
9. If ExitBootServices ( ) is invoked, then the event type = EV_EFI_ACTION MUST be measured. The return value of ExitBootServices ( ) MUST be reflected in a measured event, into PCR [4], of either "Exit Boot Services Returned with Failure" or "Exit Boot Services Returned with Success", depending upon the return code from the ExitBootServices ( ) call.

7.6 Measuring Industry-Standard Tables and Data Structures

Start of informative comment:

An EFI platform may support several industry-standard tables and data structures. These include, but are not limited to, ACPI, SMBIOS, and so on.

From the EFI Specification, EFI_CONFIGURATION_TABLE must be:

```
typedef struct {
      EFI_GUID          VendorGuid;
      VOID              *VendorTable;
} EFI_CONFIGURATION_TABLE;
```

End of informative comment.

Event EV_EFI_HANDOFF_TABLES MUST be used to describe the measurement of industry-standard tables and data structure regions. The event structure MUST be:

```
typedef struct {
     UINTN                    NumberOfTables;
```

```
      EFI_CONFIGURATION_TABLE  TableEntry[1];
} EFI_HANDOFF_TABLE_POINTERS;
```

7.7 EFI_PLATFORM_FIRMWARE_BLOB Structure Definition

- When the CRTM measures the platform firmware from system board ROM that materializes EFI Boot Services and EFI Run Time Services, the CRTM MUST measure the code contained in the Host Platform system board firmware.
- The CRTM MUST also add an entry of event type = EV_S_CRTM_CONTENTS to the Event Log (see Table 7-1). Beyond the CRTM contents, other system board code MUST also be measured using event type EV_POST_CODE. All of the "code" events MUST use the EFI_PLATFORM_FORMWARE_BLOB event structure.
- Below is the definition of the EFI_PLATFORM_FIRMWARE_BLOB structure that the CRTM MUST put into the Event Log entry TCG_PCR_EVENT.event[1] field for events EV_POST_CODE and EV_S_CRTM_CONTENTS.

```
typedef struct {
     EFI_PHYSICAL_ADDRESS   BlobBase;
     UINTN                  BlobLength;
} EFI_PLATFORM_FIRMWARE_BLOB;
```

7.8 Measuring EFI Variables

Start of informative comment:

This section defines the event data structures associated with the measurement of EFI variables.

EFI variables are key/value pairs that consist of identifying information with attributes (the key) and arbitrary data (the value) used to store information passed between the platform and EFI applications such as OS loaders. See section 7.2 of the UEFI Specification for more information.

The only EFI variables requiring measurement are those that effect boot policy (that is, where to get the OS Loader), and if UEFI Secure Boot is enabled those that affect the UEFI Secure Boot policy as described in section 6.4 steps 2 and 3. Other EFI variables, such as language, or private variables (that is, GUIDs not defined in the EFI Specification) are measured into the appropriate PCR, depending upon usage (that is, into PCR [1], PCR [3], or PCR [5]); for more information, see sections 5 and 6 of this specification. Even for boot variables that point to the same UEFI application but with different optional data, the measurements is distinct as the measurement will cover the entire EFI_LOAD_OPTION.

End of informative comment.

For Event types = EV_EFI_VARIABLE_DRIVER_CONFIG and EV_EFI_VARIABLE_BOOT, the event log entries share a common data structure, namely EFI_VARIABLE_DATA.
EV_EFI_VARIABLE_DRIVER_CONFIG is used to designate the measurement of ANY EFI variable, with the exception of the boot variables listed below.

```
typedef struct {
  EFI_GUID     VariableName;
  UINTN        UnicodeNameLength;
```

```
  UINTN        VariableDataLength;
  CHAR16       UnicodeName[1];
  INT8         VariableData[1];   // Driver or platform-specific data
} EFI_VARIABLE_DATA;
```

For the boot variable measurement, the data to be recorded are precisely described in the EFI specification. Specifically, there is event type EV_EFI_VARIABLE_BOOT. The EFI firmware MUST measure BootOrder and EFI Boot#### variables. The event structure for this measurement shares EFI_VARIABLE_DATA.

EFI, unlike conventional BIOS, does not need active partition table flags to dictate which OS loader to choose. The OS loader choice is mediated by the EFI boot options in variables. But the disk partition topology is still important to reflect the system configuration. This configuration information is contained in an EFI_GPT_DATA structure. The event EV_EFI_GPT_EVENT designates the measurement of this on-disk geometry, and the event log data structure is described below.

```
typedef struct {
  EFI_PARTITION_TABLE_HEADER EfiPartitionHeader;
  UINTN                      NumberOfPartitions;
  EFI_PARTITION_ENTRY        Partitions [1];
} EFI_GPT_DATA;
```

7.9 ACPI Table Usage

Start of informative comment:

See the *TCG v1.21 PC Client Implementation Specification for BIOS*.

End of informative comment.

8. Other PCR Usages on an EFI Platform

Start of informative comment:

See the *TCG v1.21 PC Client Implementation Specification for BIOS*.

End of informative comment.

9. EFI Firmware Upgrade

Start of informative comment:

EFI firmware upgrades must meet the firmware upgrade requirements of the platform. For example, see the TCG Generic Server Specification.

End of informative comment.

The EFI Firmware SHOULD meet the requirements of the U.S. National Institute of Standards and Technology *(NIST) Special Publication 800-147 Bios Protection Guidelines* available at: http://csrc.nist.gov/publications/nistpubs/800-147/NIST-SP800-147-April2011.pdf.

10. TCG Certificates and Verification on an EFI Platform

Start of informative comment:

The Unified EFI Specification describes a methodology for providing credentials in a PE/COFF image.

End of informative comment.

Start of informative comment:

This section describes the obligations of a platform that supports *NIST SP 800-155 BIOS Integrity Measurement Guidelines*. In addition to defining obligations of the different RoT's (RTR, RTM, RTS), 800-155 defines two additional entities: the Measurement Assessment Authority (MAA) and a Reference Manifest (RM). Both the MAA and the RM are outside of the UEFI firmware, but the UEFI firmware needs to provide some indicia so that the MAA can ascertain the appropriate RM for the platform.

For UEFI, the RM will cover PCR 0 through exit boot services. The RM's that OEM's produce would be for PCR's 0 and 2. Since PCR 1, 3 and 5, contain data for EFI variables, no RM could or should be delivered.

The TCG_Sp800-155-PlatformId_EventStruct definition does not include extensible code objects such as option ROM's.

An event log contains one or more TCG_Sp800-155-PlatformId_EventStruct's that the MAA uses to identify the corresponding vendor and RM using that structure's *VendorId* and *ReferenceManifestGuid* components. The MAA obtains RM(s) by a mechanism outside the scope of this specification. When the event log contains multiple TCG_Sp800-155-PlatformId_EventStruct's structures then multiple RM's are needed, where each RM contains different sets of golden measurements.

The following example is for illustrative purposes only and in no way implies a recommended implementation.

For a platform's flash containing the following firmware volumes (FV):

PEI FV (CRTM) – c1

DXE FV (Main compressed BIOS – c2

OEM DXE Extension FV – c3

Variable Block

OEM Vital Product Data (VPD)

For a boot sequence where FV c1 and c2 executed, the corresponding event log could contain the following events:

Conventional Bios Spec Id Event

EFI Platform Spec Id Event

TCG_Sp800-155-PlatformId_EventStruct 1

TCG_Sp800-155-PlatformId_EventStruct 2

PCR0: CRTM Version Event – hash of c1's version

PCR0: DXE FV Event – hash of c2

PCR1 events

PCR2 events

Etc.

In this example: TCG_Sp800-155-PlatformId_EventStruct 1 could identify the RM containing the golden measurement for c1 while TCG_Sp800-155-PlatformId_EventStruct 2 could identify the RM containing the golden measurement for c2.

End of informative comment.

The EFI Firmware SHOULD meet the requirements of the U.S. National Institute of Standards and Technology (NIST) Special Publication 800-155 BIOS Integrity Measurement Guidelines available at: http://csrc.nist.gov/publications/drafts/800-155/draft-SP800-155_Dec2011.pdf.

See section 7.4.

For the NIST 800-155 platform attributes (i.e.: hardware protection of the flash, or 800-147 support), if static, this should be in the RM. If not static, then an optional log entry into PCR 1, which could contain those characteristics using the EV_PLATFORM_CONFIG_FLAGS event should be created.