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UEFI & EDK II Training

UEFI Aware Operating System

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LESSON OBJECTIVE

- Explain How the OS and UEFI Work together
- Explain the UEFI Requirements for UEFI aware OS
- Explain How Secure Boot Fits with UEFI
- What about MM (Formerly Known as SMM)
- What about coreboot?

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UEFI AWARE OS REQUIREMENTS

Common Requirements

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UEFI OPERATING SYSTEMS

Windows Server 2008 R2

Windows 7

Windows 10

Windows Azure

Microsoft Hyper-V Server 2008 R2

Windows Storage Server 2008 R2 Enterprise

Microsoft

CANONICAL

yocto PROJECT

ubuntu

Its Here!
ubuntu 10.04 LTS
www.ubuntu.com/getubuntu

suse

SUSE® Linux Enterprise 11

RED HAT ENTERPRISE LINUX

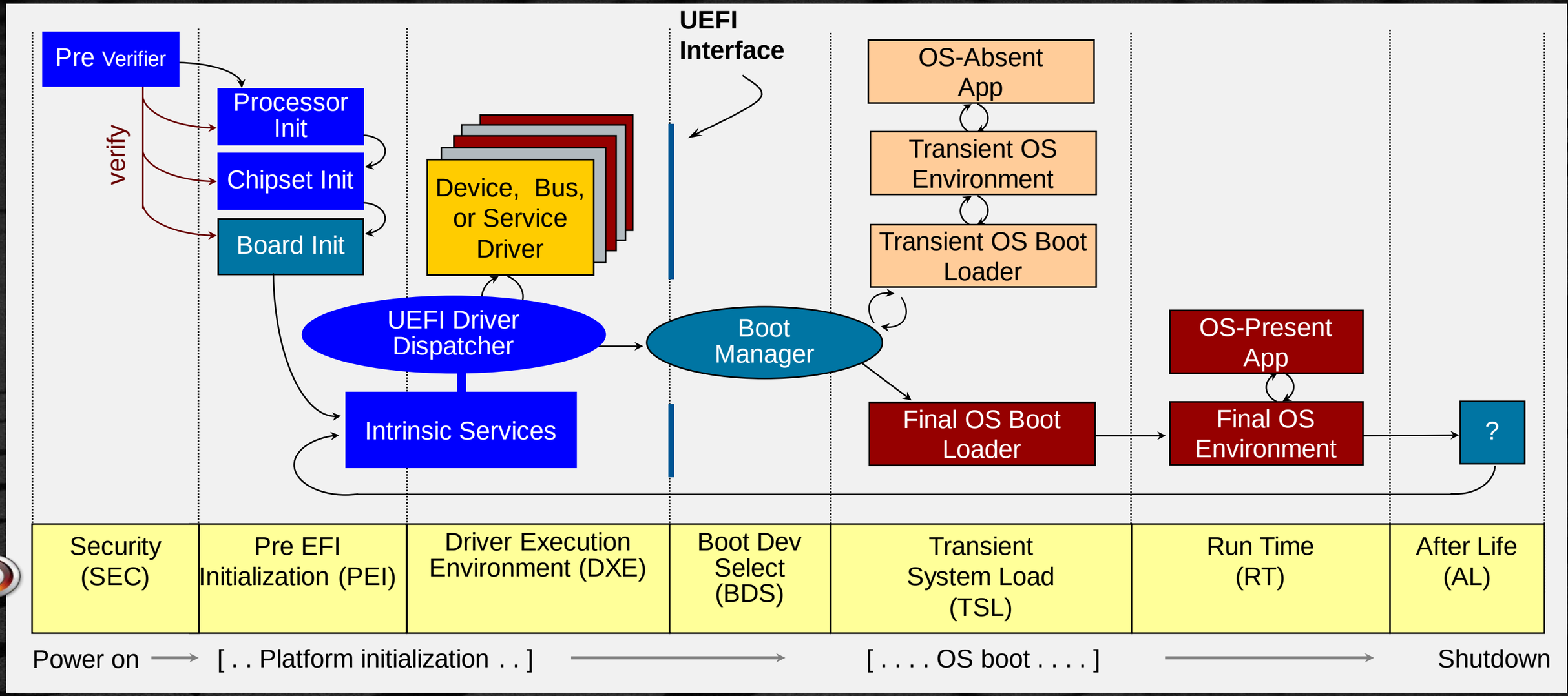
redhat.

Novell

fedora

vmware

UEFI - PI & EDK II Boot Flow - Review



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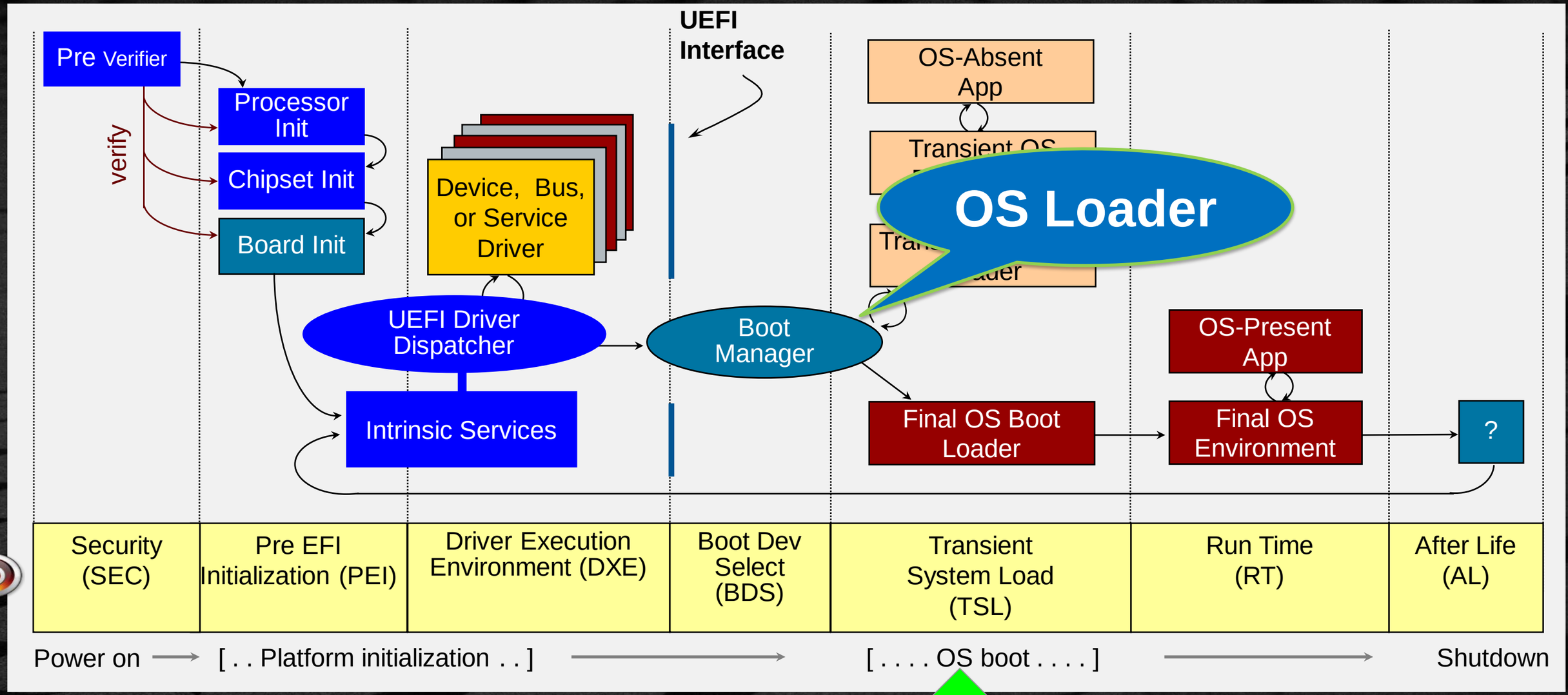

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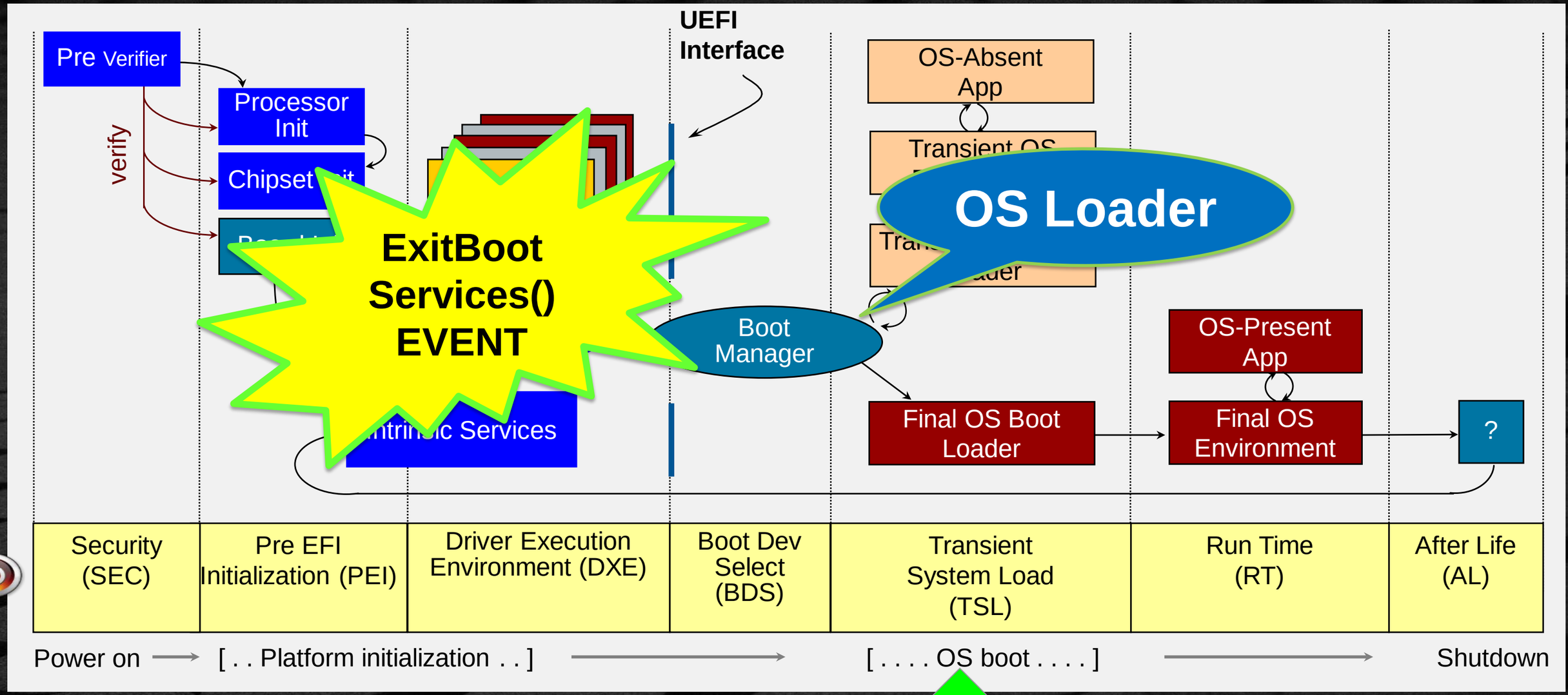

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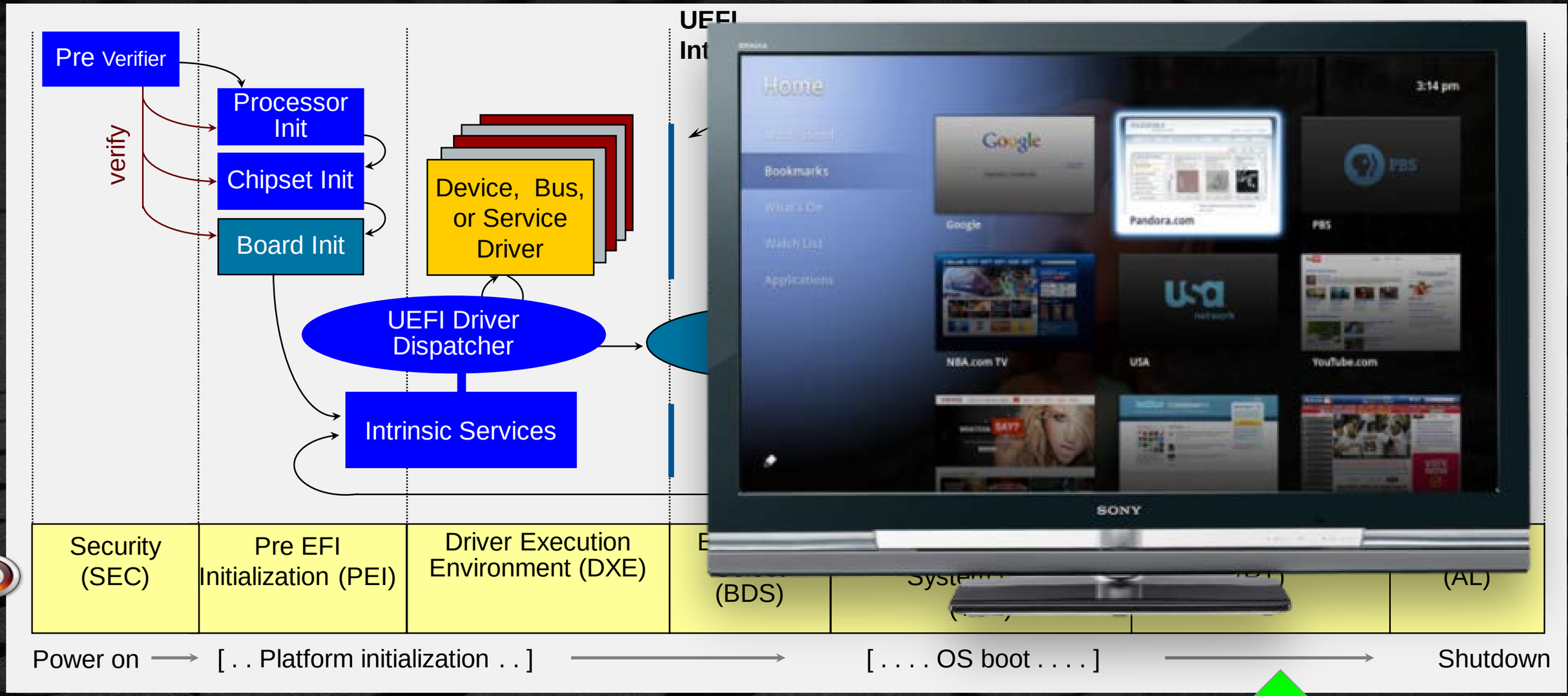

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UEFI OS REQUIREMENTS

UEFI Drivers: Boot devices/console

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UEFI OS installer

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UEFI OS Loader

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Disk Partition/Formats

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Firmware Requirements

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UEFI OS REQUIREMENTS

UEFI Drivers: Boot devices/console

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Disk Partition/Formats

Firmware Requirements

Set Boot Path to Boot to UEFI OS

UEFI System Classes (based on firmware interfaces)

UEFI Class 0

- Boots Legacy - int 19 ONLY
- Legacy BIOS Only (16 bit)
- No UEFI or UEFI PI Interfaces

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UEFI Class 2

- Boots legacy - int 19 or UEFI
- Uses UEFI /PI interfaces
- Runtime exposes UEFI & legacy BIOS interface
- CSM

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UEFI Class 2

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Limited Benefits

- ✓ OEMs/ODMs Internal
- ✓ Double code development & organization
- ✓ Compromised security –(MBR exposure)

UEFI System Classes (based on firmware interfaces)

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- No UEFI or UEFI PI Interfaces

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UEFI Class 2

- Boots legacy - int 19 or UEFI
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- CSM

UEFI Class 3

- Boots only UEFI
- Uses UEFI / PI interfaces
- Runtime exposes only UEFI interfaces

UEFI System Classes (based on firmware interfaces)

UEFI Class 3
Full Benefits
- ✓ UEFI Innovation
- ✓ Smaller code size/ Validation
- ✓ Extensibility

UEFI Class 1
- Boots Legacy - int 19
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UEFI Class 3
- Boots only UEFI
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UEFI System Classes (based on firmware interfaces)

UEFI Class 3 +

Full Benefits

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Only Class after 2020

Enabling *Secure Boot* creates another Class

UEFI Class 1

- Boots Legacy - int 19
- Uses UEFI /PI interfaces
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UEFI Class 3 +

- Boots only UEFI
- Uses UEFI / PI interfaces
- Runtime exposes only UEFI interfaces

UEFI Secure Boot "ON"

Required UEFI Drivers: OS Install & Boot

Boot Device

Required UEFI Drivers: OS Install & Boot

Boot Device

Console Output

Required UEFI Drivers: OS Install & Boot

Boot Device

Console Output

Console Input

Required UEFI Drivers: OS Install & Boot

Boot Device

Console Output

Console Input

NVRAM Driver

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UEFI OS LOADER

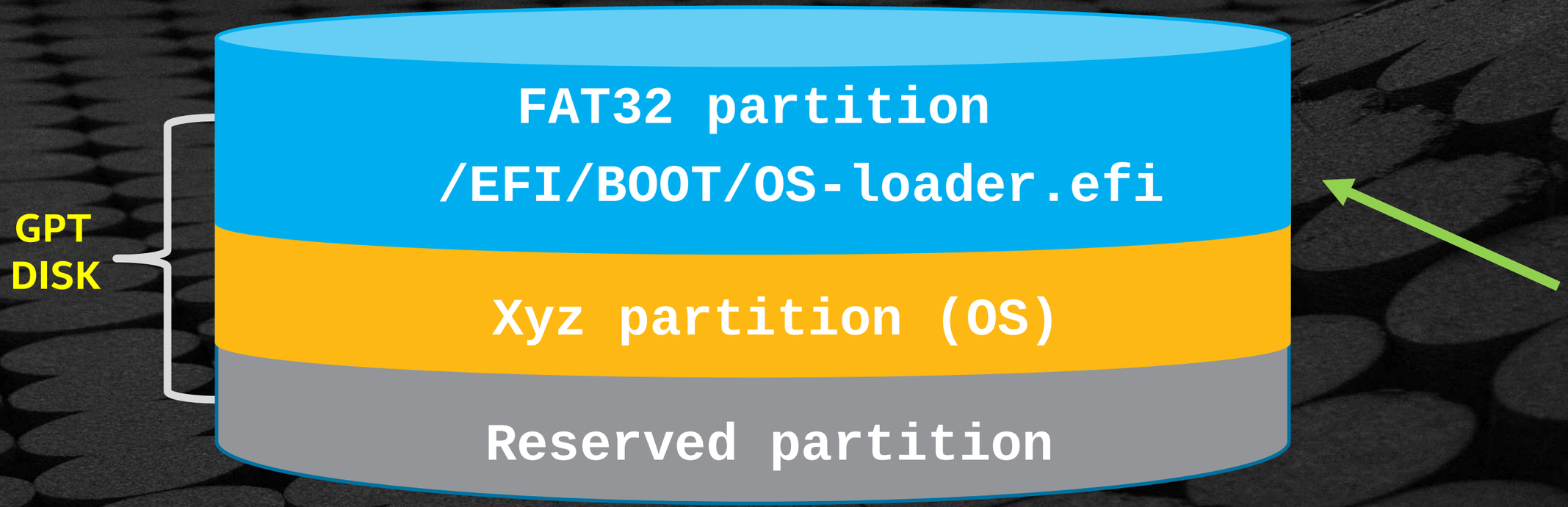
- OS install process includes UEFI loader

  `/efi/boot/bootx64.efi /efi/redhat/grub.efi`
- Call UEFI boot & runtime services to start OS
- Exit UEFI Boot Services
- Transfer control to native OS

UEFI OS INSTALLER

- Discover UEFI storage devices
- Setup storage device: GPT w/ FAT32 boot partition
- Create boot variable `BootXXXX`

Disk Partition and Format



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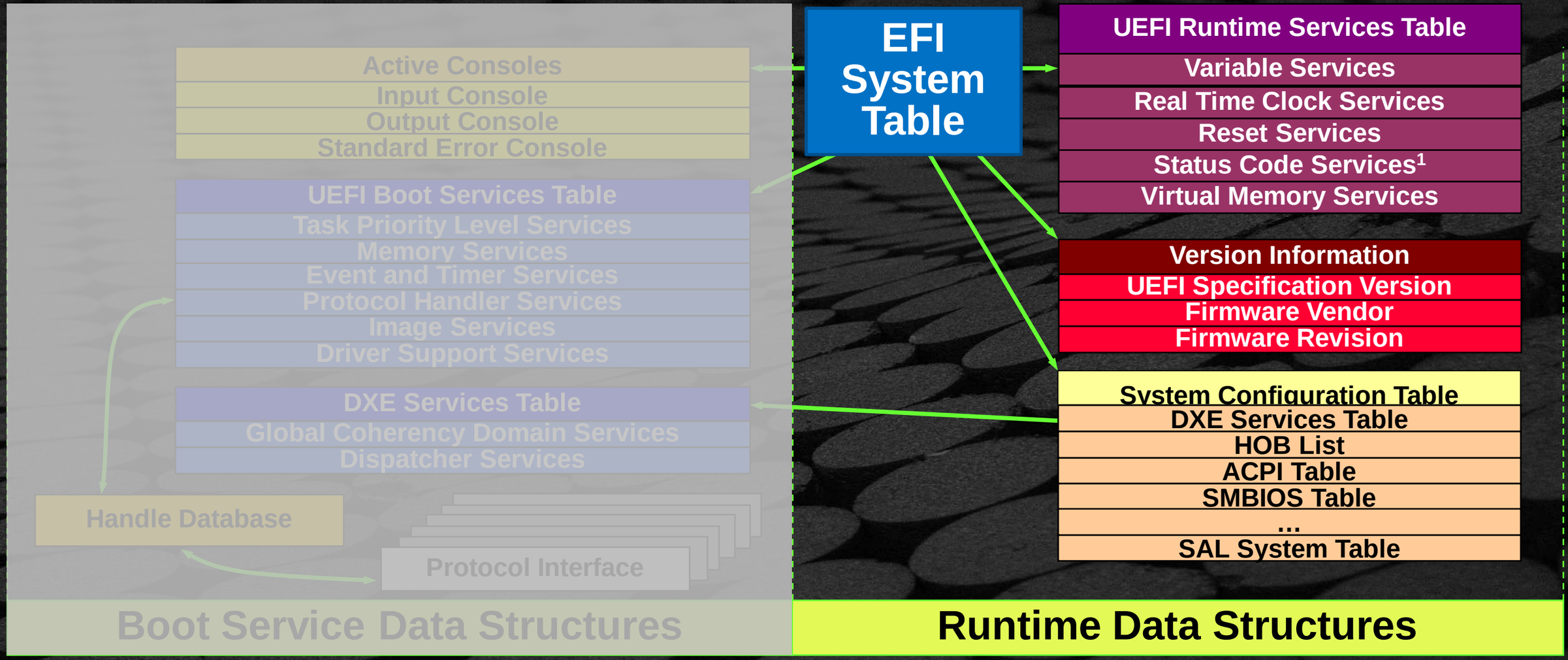
INTERFACE INSIDE OS RUNTIME

UEFI Runtime Services

Runtime Services Available to the UEFI Aware OS



Accessing RT services from Windows API

- GetFirmwareEnvironmentVariable: MSDN Link
- SetFirmwareEnvironmentVariable: MSDN Link
- Example: (determine if UEFI or Legacy BIOS)

```
 int main(int argc, char*argv[])
{
        GetFirmwareEnvironmentVariableA("",
           "{00000000-0000-0000-0000-000000000000}",NULL,0);
        if (GetLastError() ==ERROR_INVALID_FUNCTION) {
              printf("Legacy"); // This.. is.. LEGACY BIOS....
              return 1;
        } else{
              printf("UEFI"); // This.. is.. UEFI
              return 0;
        }
        return 0;
}
```

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ACCESSING RT SERVICES FROM LINUX OS

Firmware Test Suite, it includes a Linux kernel driver to help with it's interactions with UEFI. Note that this is a Linux-centric test suite, solution won't work for other OSes.

- http://kernel.ubuntu.com/git/hwe/fwts.git
- https://bugs.launchpad.net/ubuntu/+source/linux/+bug/1633506
- https://patchwork.kernel.org/patch/9323781/
- http://www.basicinputoutput.com/2016/03/introduction-to-firmware-test-suite-fwts.html

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SECURITY WITH UEFI

How does UEFI ensure the Operating System is trusted?

BOOT SECURITY TECHNOLOGIES

Hardware Root of Trust	• Boot Guard, Intel® TXT
Measured Boot	• Using TPM to store hash values
Verified Boot	• Boot Guard + UEFI Secure Boot

TPM – Trusted Platform Module

Resources: https://firmwaresecurity.com/2015/07/29/survey-of-boot-security-technologies/

HARDWARE ROOT OF TRUST

Boot Guard

CPU verifies signature

Verification occurs before BIOS starts

Hash of signature is fused in CPU

Intel® TXT

Uses a Trusted Platform Module (TPM) & cryptographic

Provides Measurements

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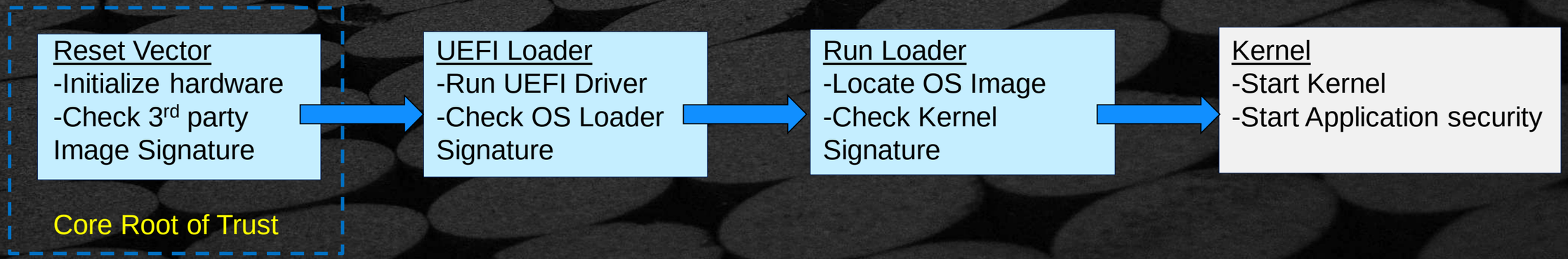
UEFI SECURE BOOT

Software ID checking during every step of the boot flow:

1. UEFI System BIOS (updated via secure process)



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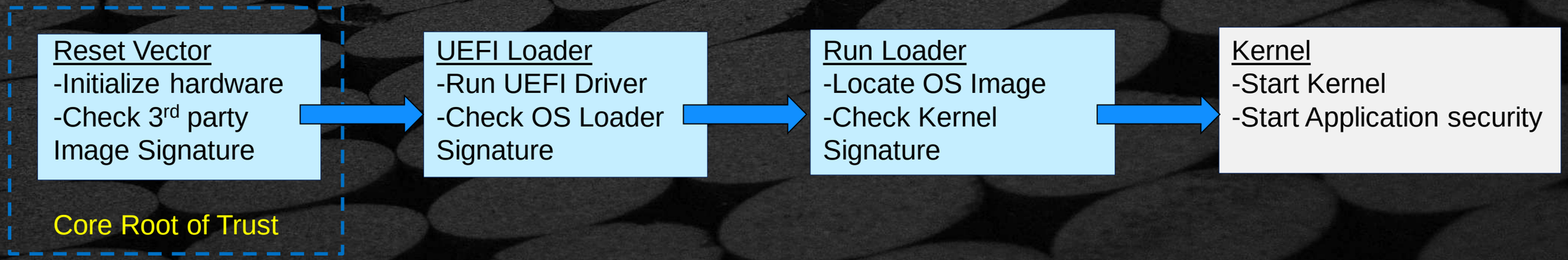

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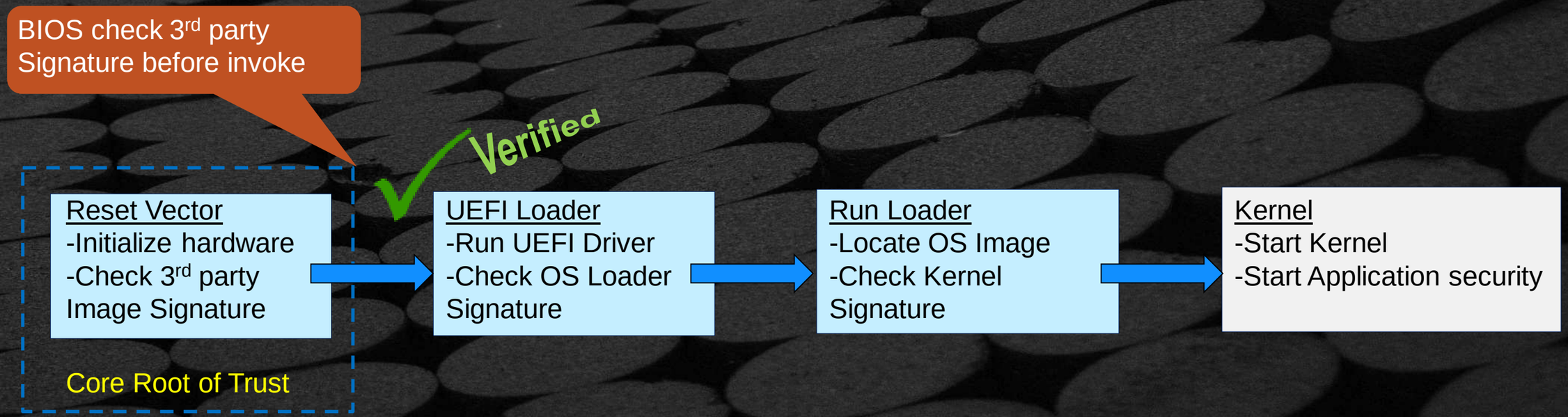

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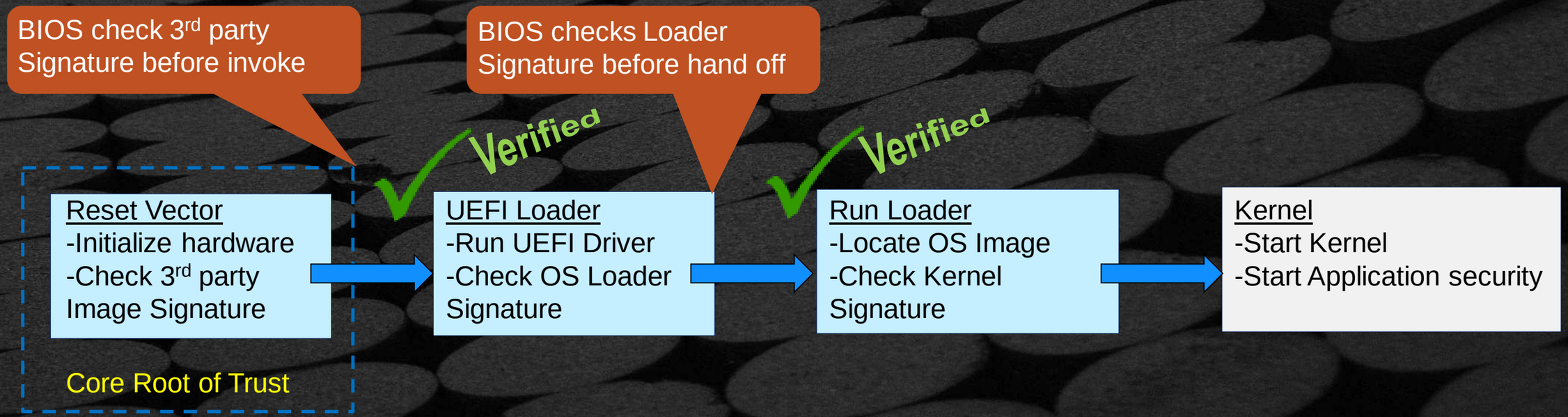

UEFI SECURE BOOT

Software ID checking during every step of the boot flow:

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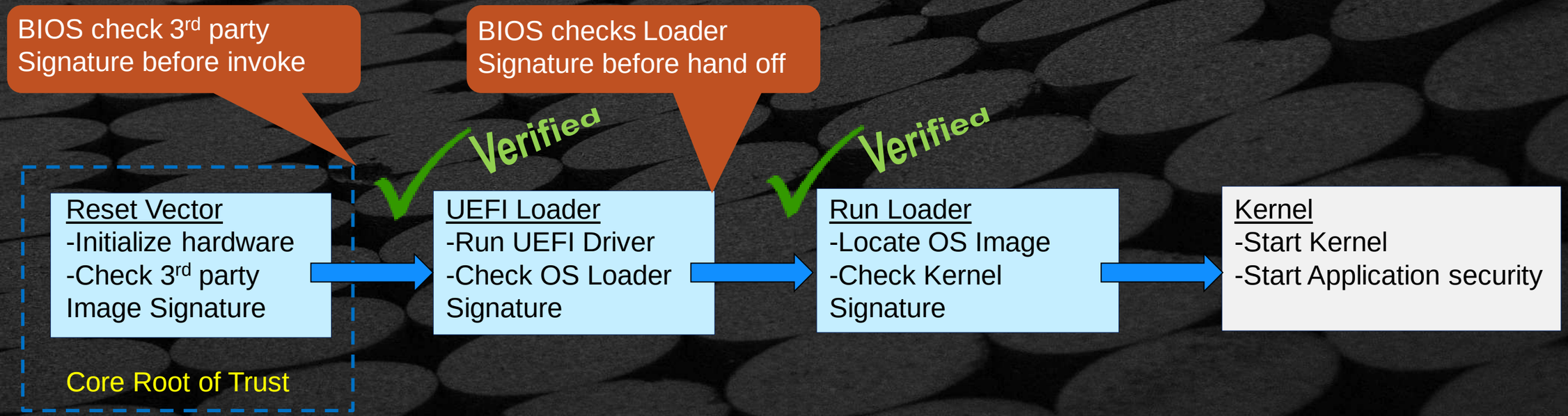
3. OS Boot Loader (checks for “secure mode” at boot)



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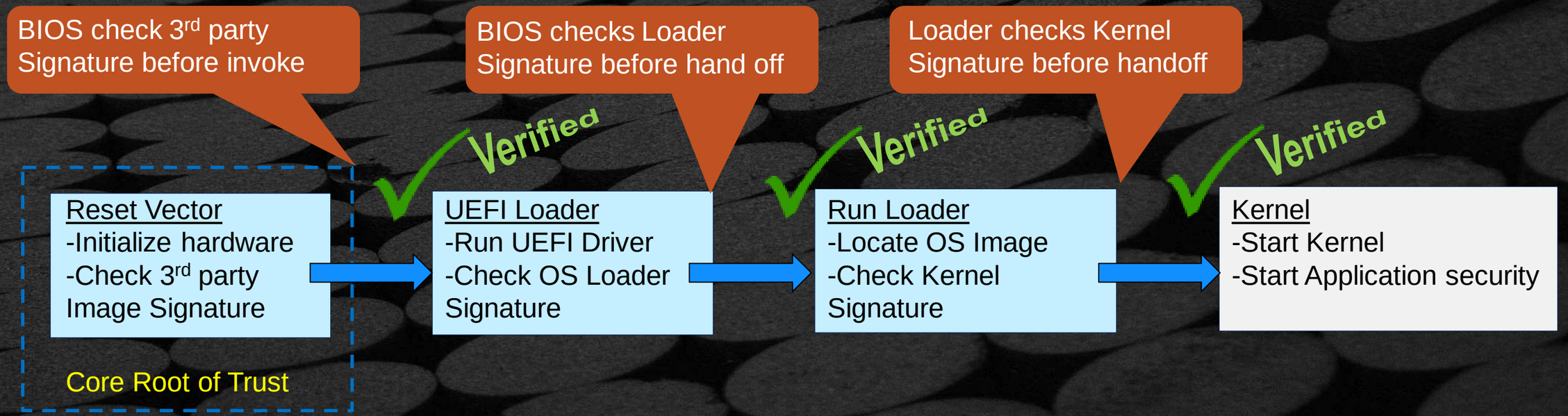

AUTHENTICATED VARIABLES

PK

KEK

DB

DBX

SetupMode

SecureBoot

```
2.0 Shell> dmpstore SecureBoot
Variable - RS+BS - '8BE4DF61-93CA-11D2-AA0D-00E098032B8C:SecureBoot' - DataSize
= 0x01
  00:                                                   00   *.*
```

Security Package Project Page Wiki Link

- Wiki Link: How-to-Enable-Security
- PDK: How to Sign UEFI Images V1.31
- Build command line switch -
  SECURE_BOOT_ENABLE = TRUE
- Install the OpensslLib CryptoPkg :
  OpenSSL-Howto.txt

How To Enable Secure Boot Service

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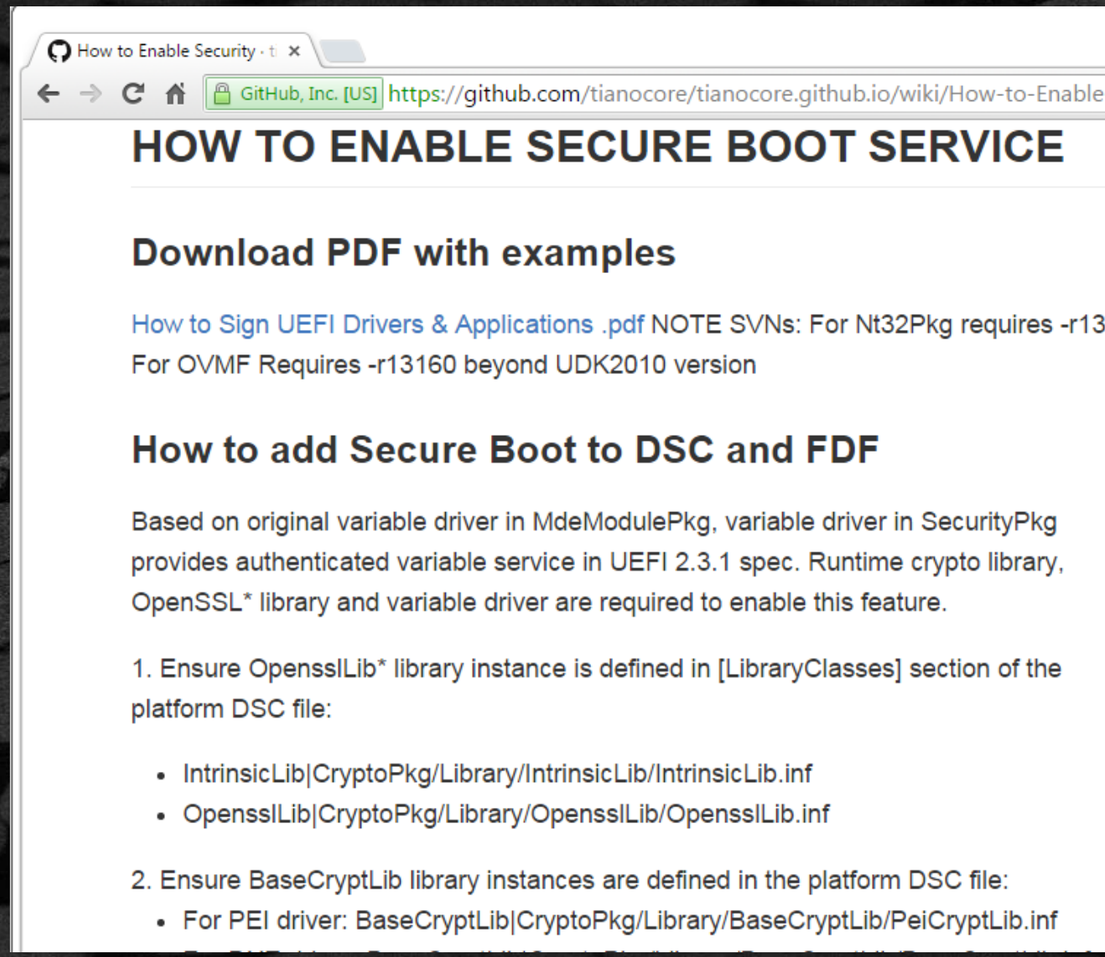
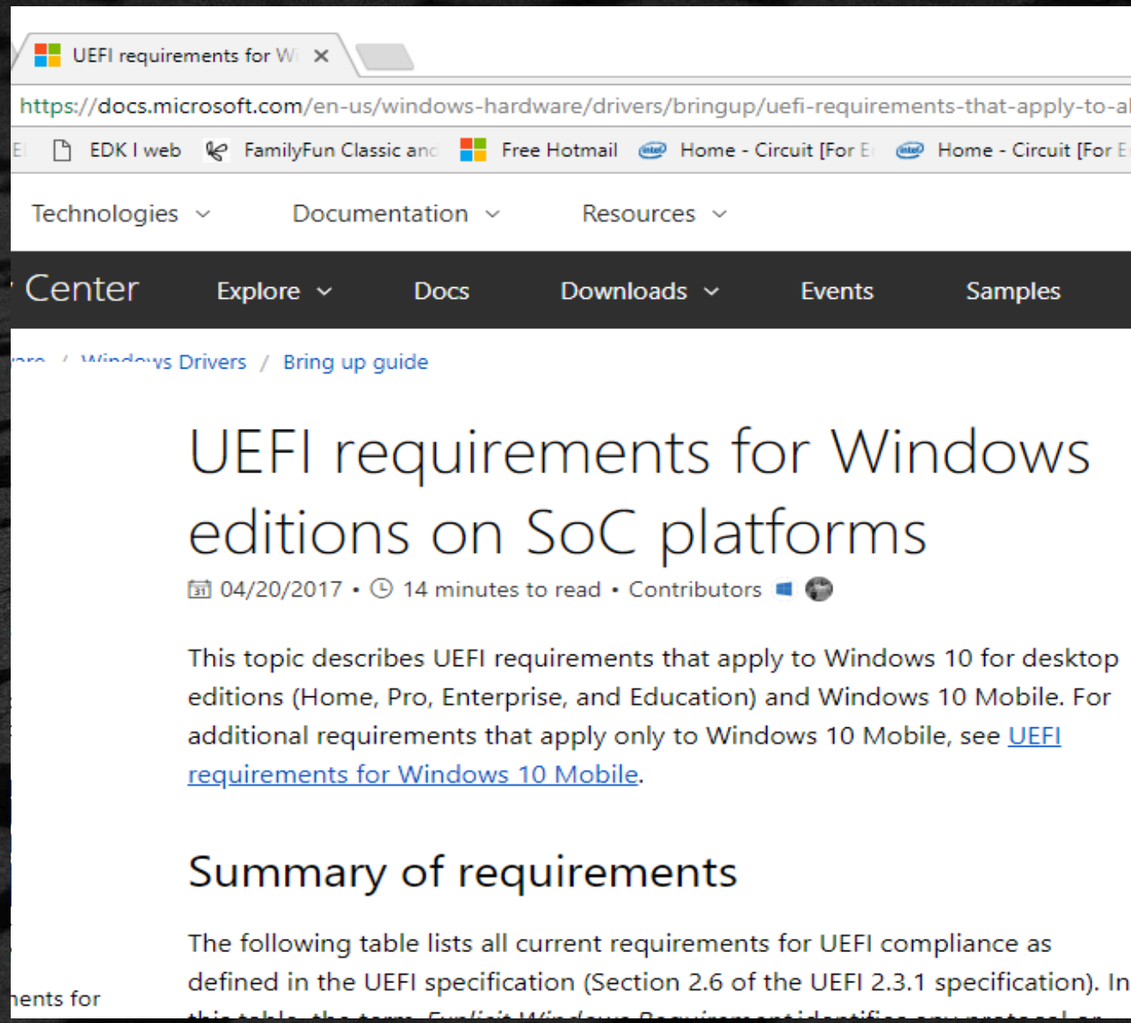


Windows Secure Boot Key Creation and Management Guidance

- Windows - Secure Boot Key Creation & Management Guide
- Creation and management of the Secure Boot keys and certificates in a manufacturing environment.
- Addresses questions related to creation, storage and retrieval of Platform Keys (PKs), secure firmware update keys, and third party Key Exchange Keys (KEKs).

Many Platforms are Requiring UEFI Secure Boot Enabled

- Secure Boot now mandated for specific platforms
- See “Security requirements” on UEFI requirements for Windows editions on SoC Platforms



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OS BOOTS, NOW WHAT?

UEFI and Management Mode (formerly known as SMM)

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Platform Initialization (PI) Specification Introduces Management Mode (MM)**

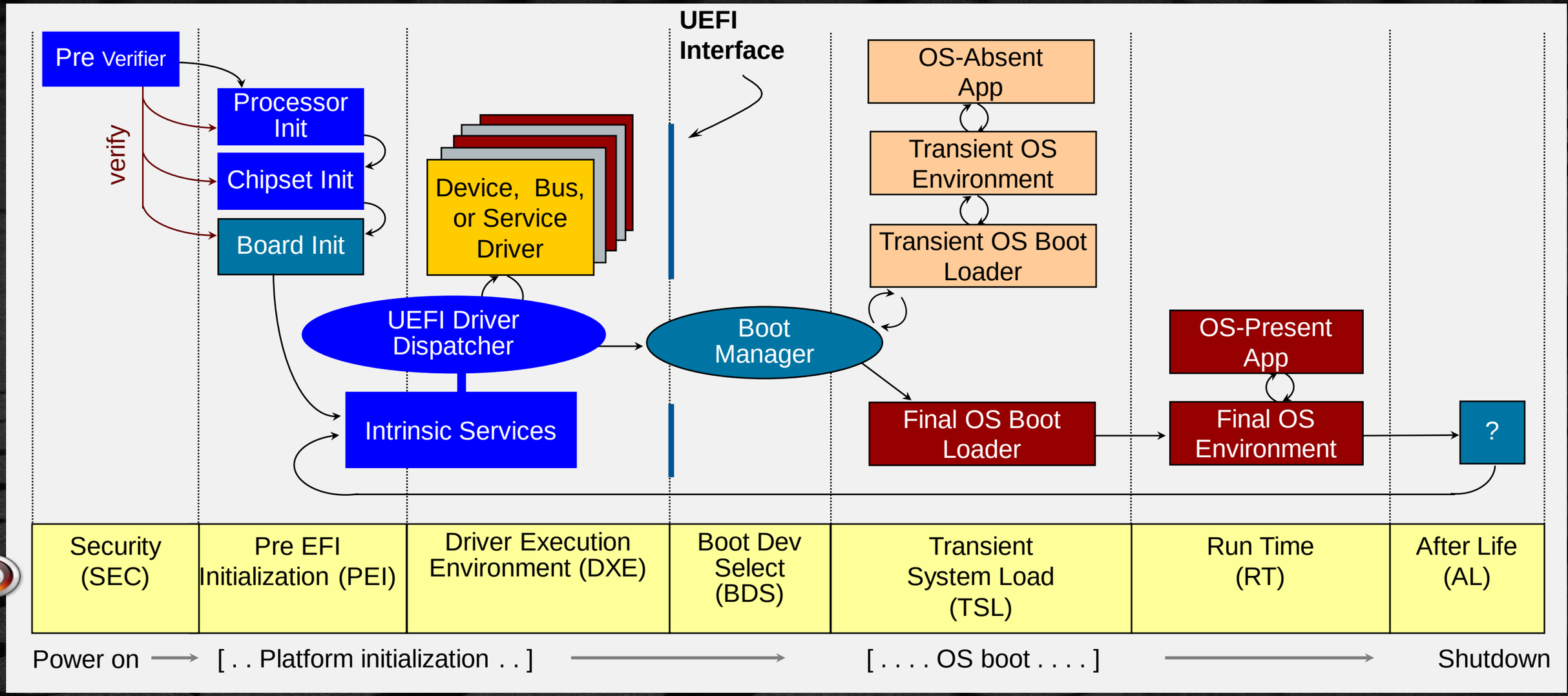
UEFI PI-standard for creating a protected execution environment using hardware resources

- Dedicated, protected memory space, entry point and hardware resources, such as timers and interrupt controllers
- Implemented using SMM (Intel® Architecture) or TrustZone(Arm)
- Highest-privilege operating mode (Ring 0) with greatest access to system memory and hardware resources

Presented at UEFI Plugfest Fall 2017: Presentation link

**Formerly known as SMM in PI specification

UEFI - PI & EDK II Boot Flow - SMM



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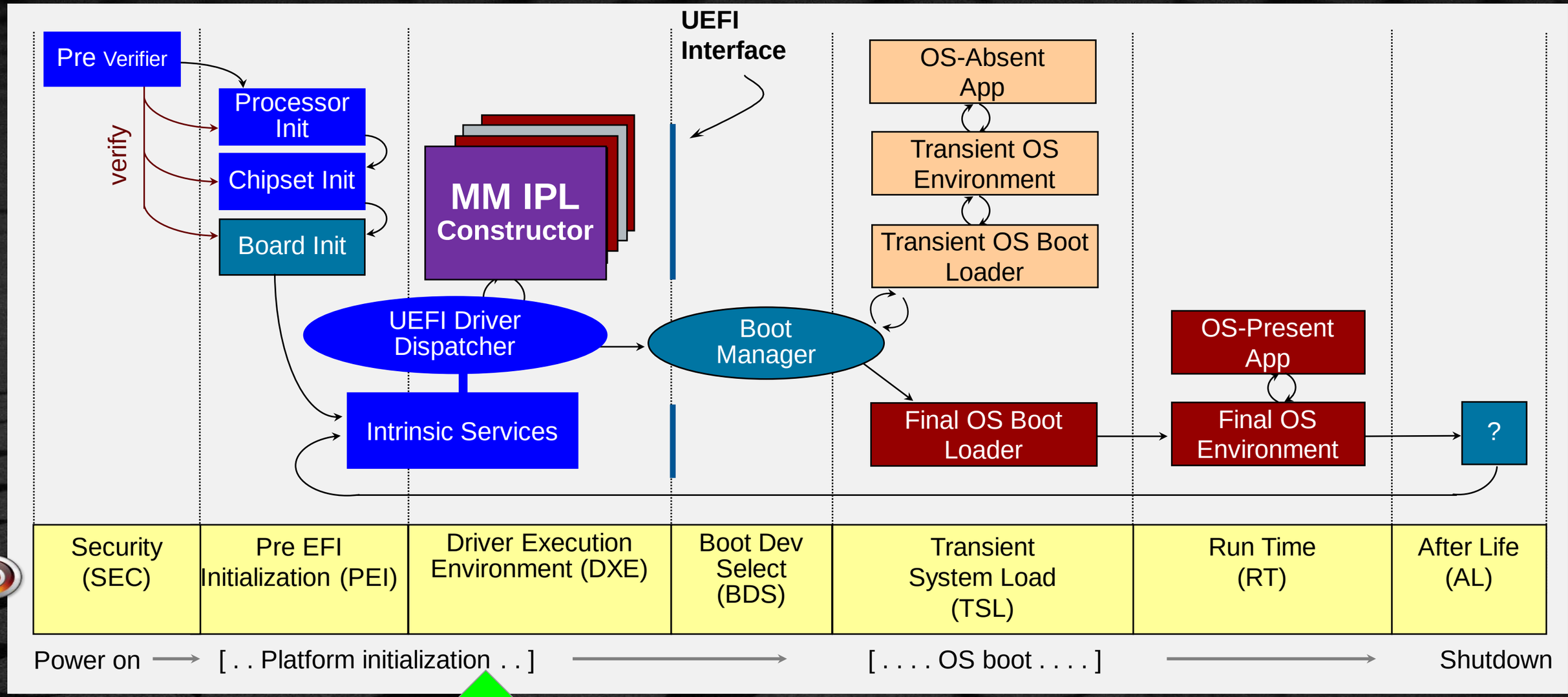

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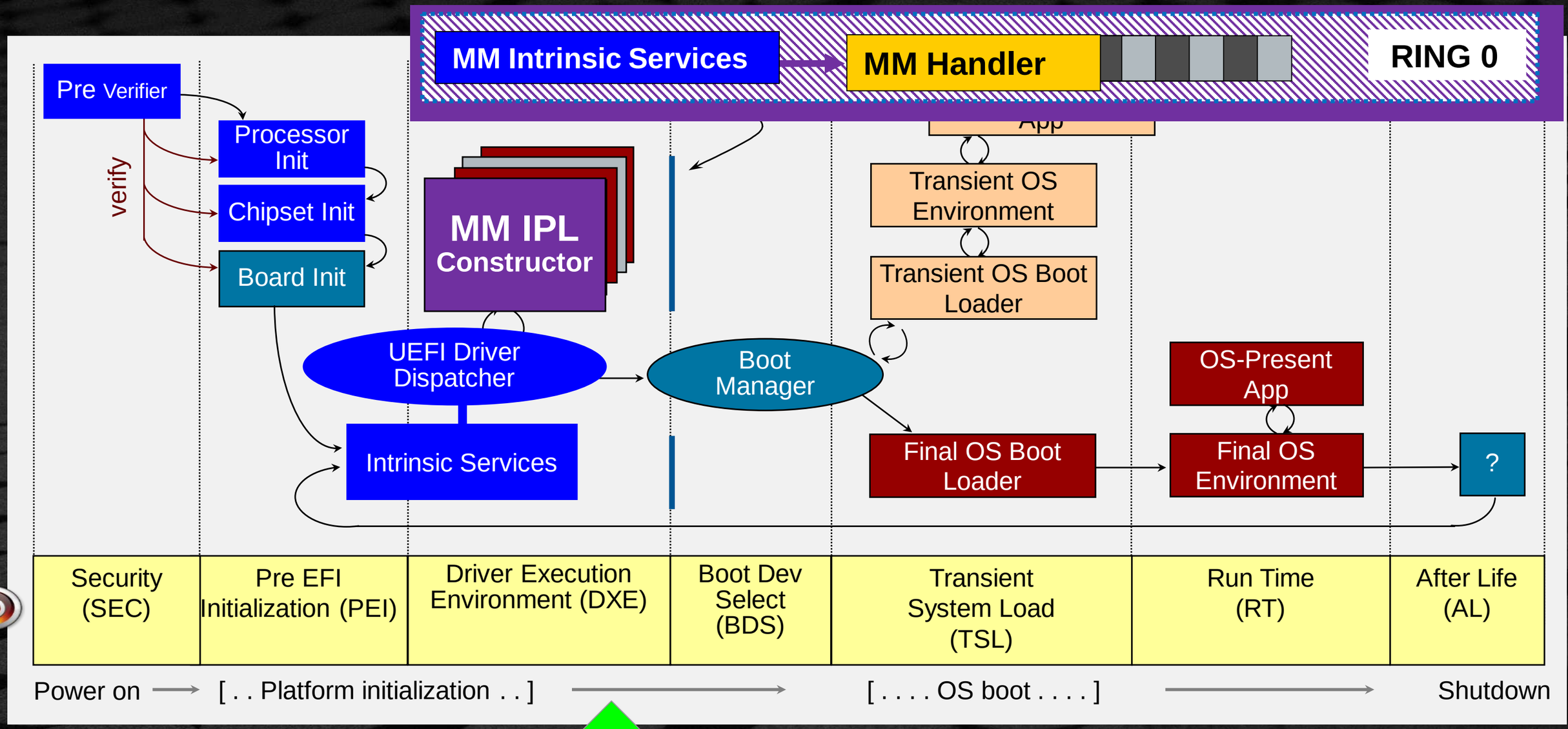

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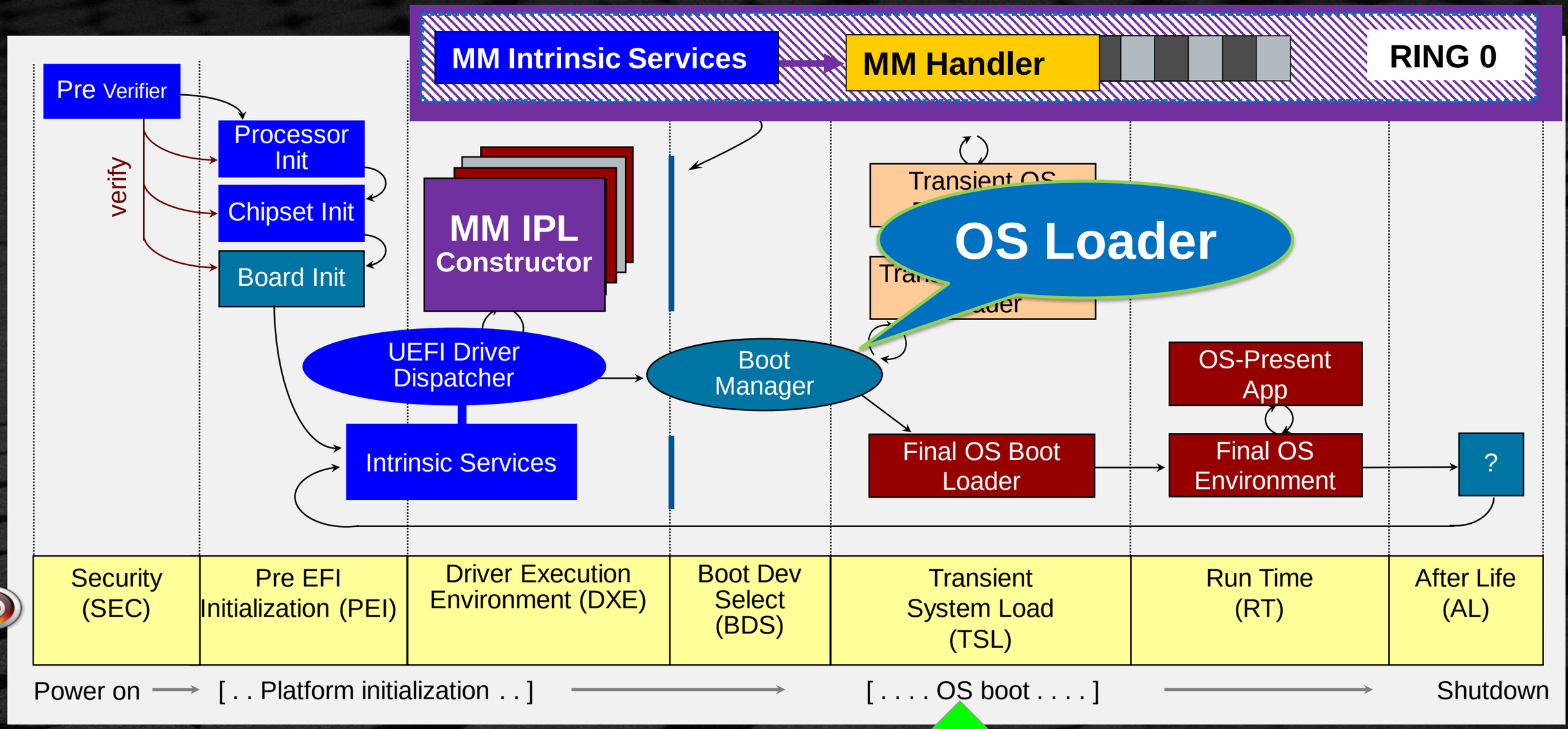

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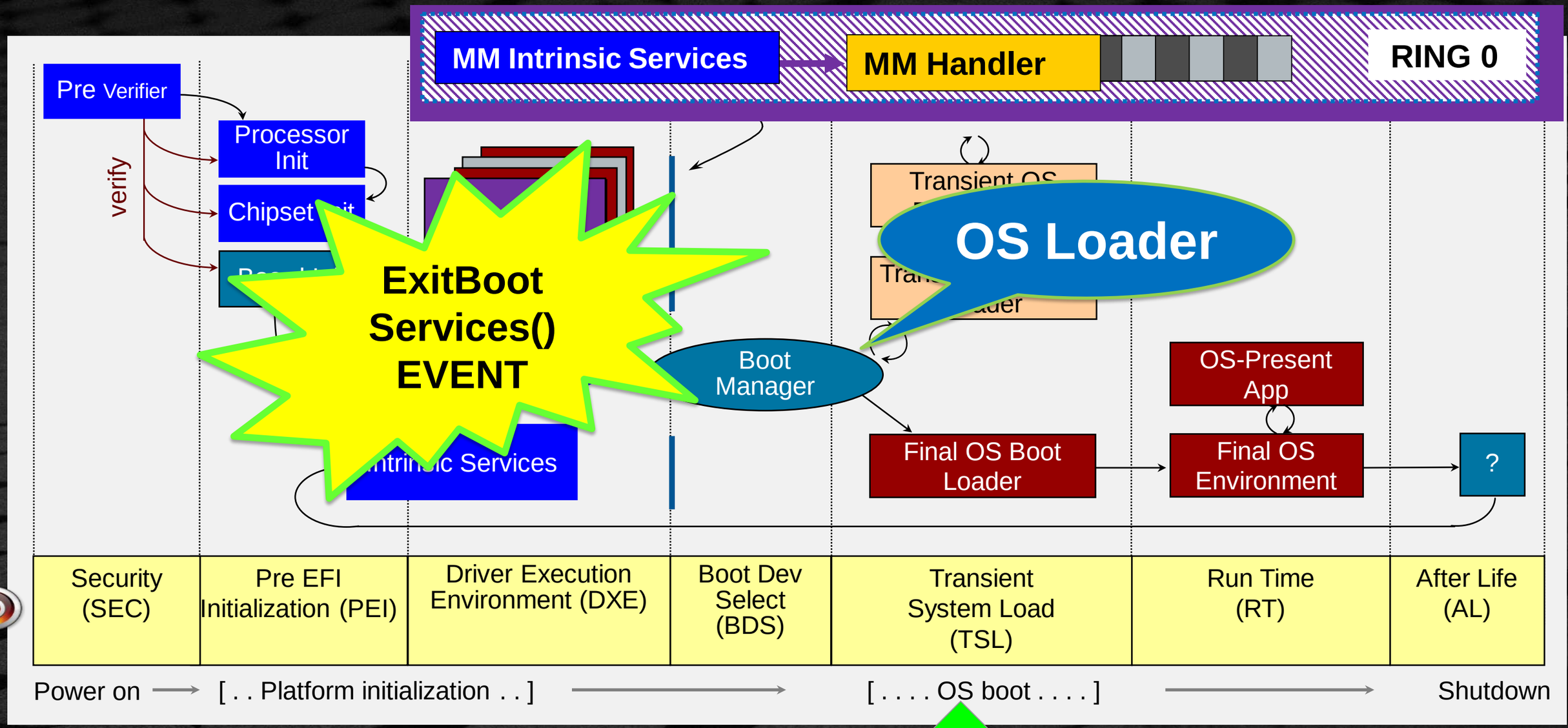

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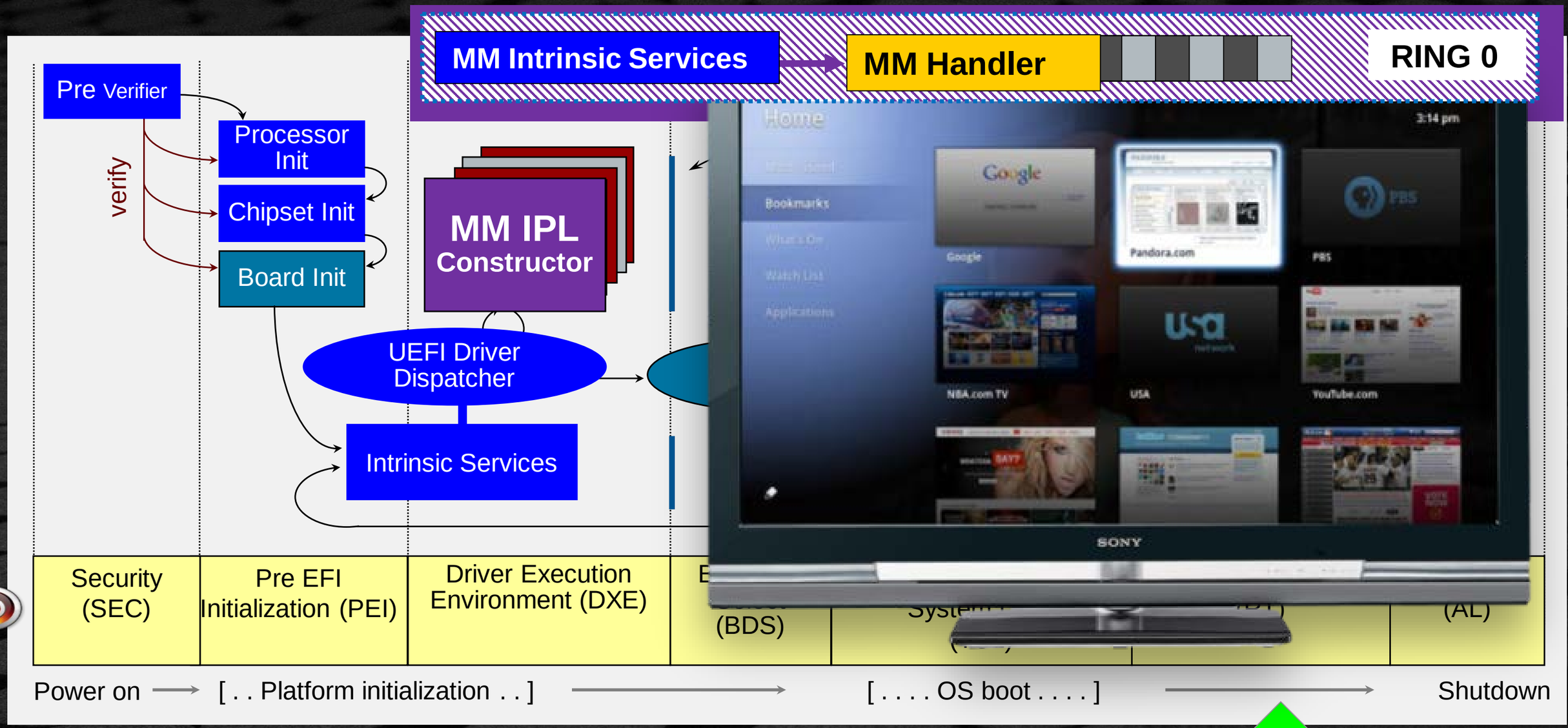

Software Management Mode Interrupts (Software MMIs)

- Management Mode Interrupts generated by software synchronously are called Software MMIs
  - Generated using I/O resources or CPU instructions
- Used to provide firmware services to the
  - OS (ACPI, TPM)
  - OS drivers (device handoff, CPU management)
  - UEFI runtime support (variables, capsule, etc.)
  - BIOS vendor applications (flash utilities, setup access)
  - OEM/ODM applications

Why are Software MMI Vulnerabilities Dangerous?

Why are Software MMI Vulnerabilities Dangerous?

Software MMIs can be asked to perform:

- Privileged operations: Flash BIOS, flash EC, write to MMIO, write to MMRAM, etc.
- Overwrite OS code/data
- Copy protected OS data to another unprotected location
- Copy protected firmware data to another unprotected location
- Overwrite BIOS code/data

UEFI Platform Firmware Assumptions

- Memory protected by the OS cannot be snooped while in use by the OS application or OS driver
  - No protection from MM, VMs or hardware snooping

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- Flash protected by hardware cannot be modified outside of MM after the end of DXE
  - Not worried about snooping since no secrets are stored in BIOS
  - Not worried about flash-altering hardware attacks

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- Software MMIs cause CPUs to enter SMM in SMRAM at a fixed location
- MMRAM cannot be altered from outside SMM

Key Points for More Secure Software MMI Handlers

- Allocate The Buffer In PEI/DXE
- Never Trust That Pointers Point To The Buffer
- Prohibit Input/Output Buffer Overlap
- Don’t Trust Structure Sizes
- Verify Variable-Length Data

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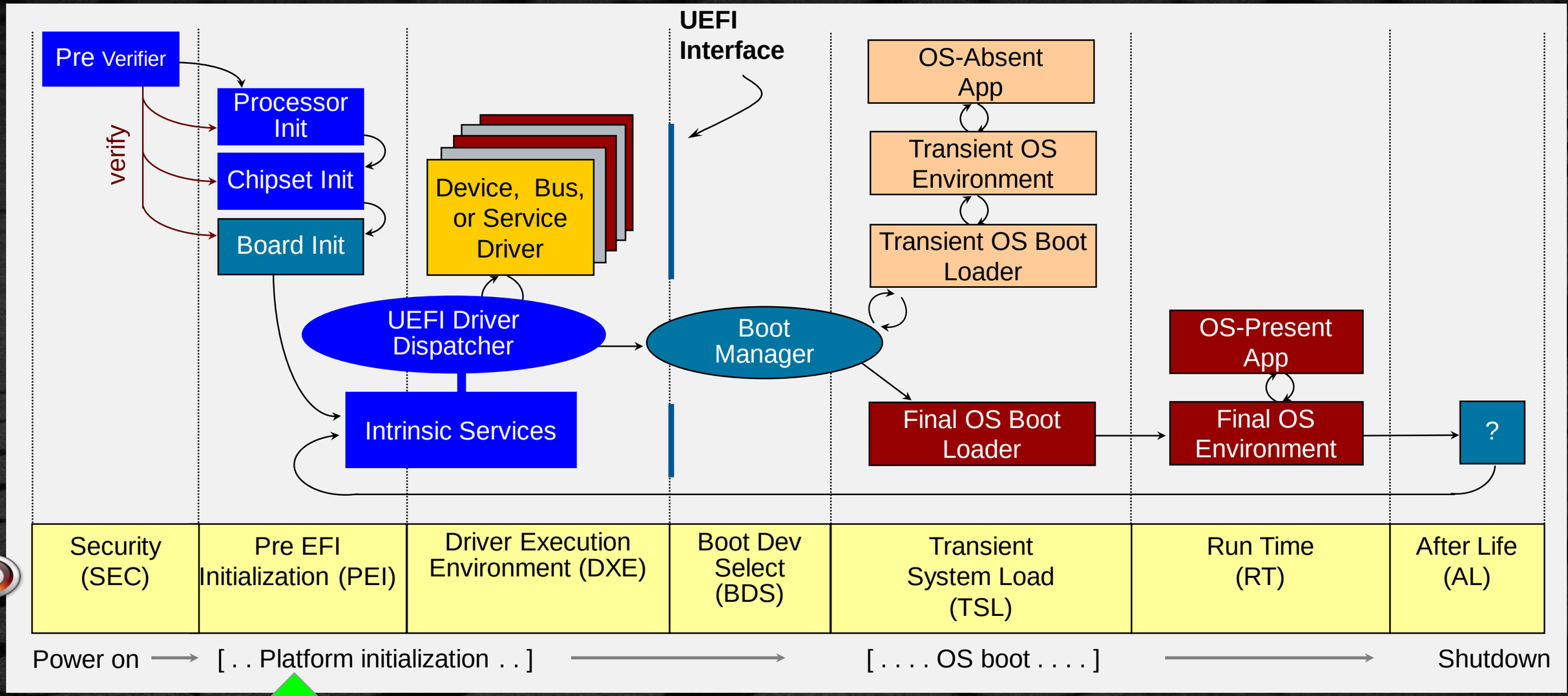
COREBOOT

How does coreboot work with UEFI

UEFI - PI & EDK II Boot Flow - coreboot



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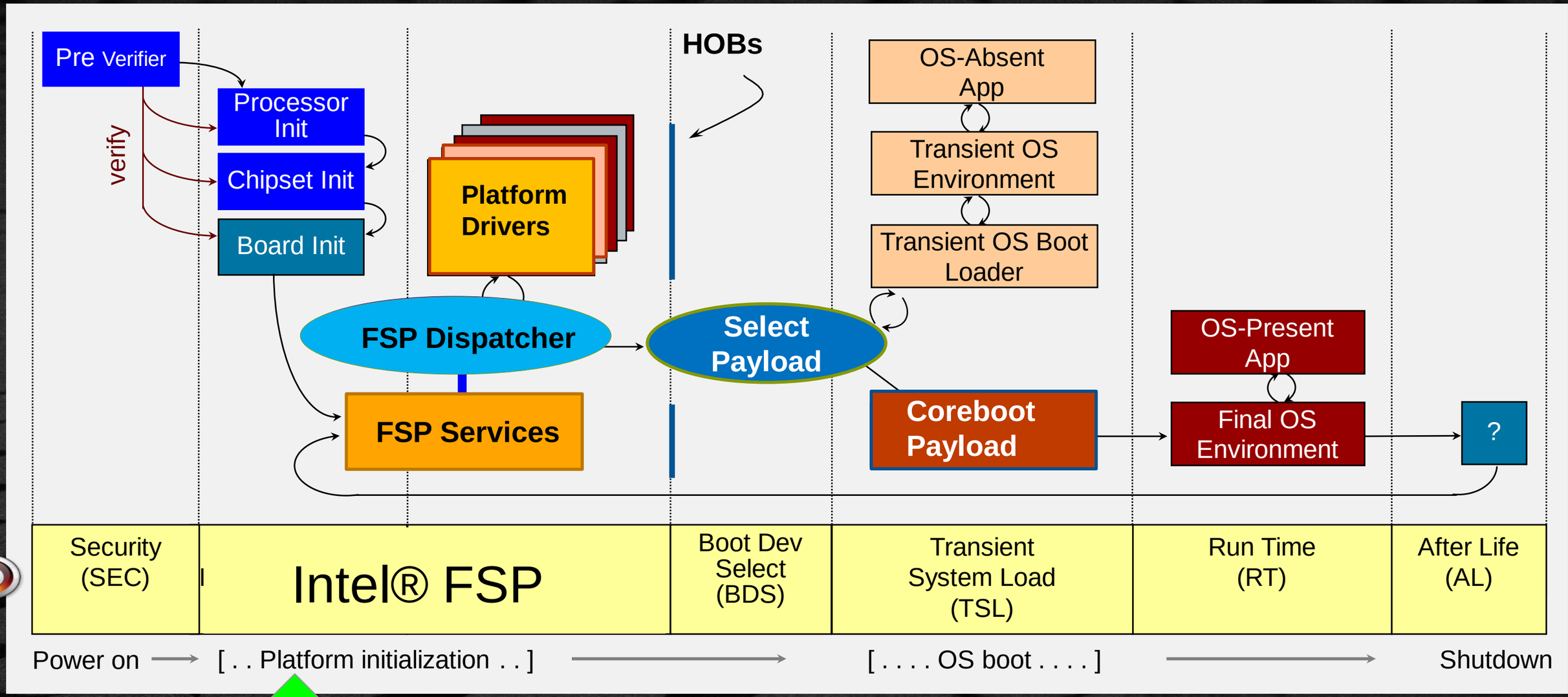

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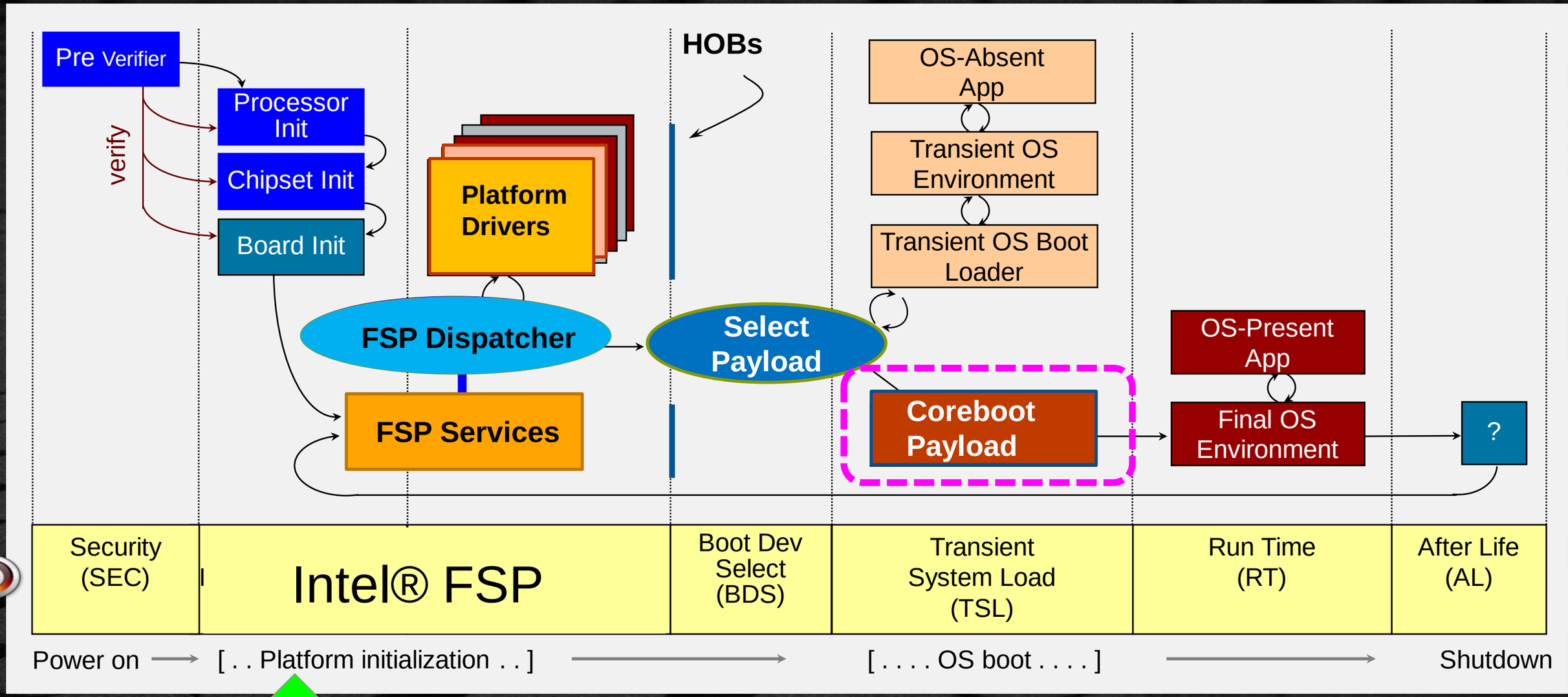
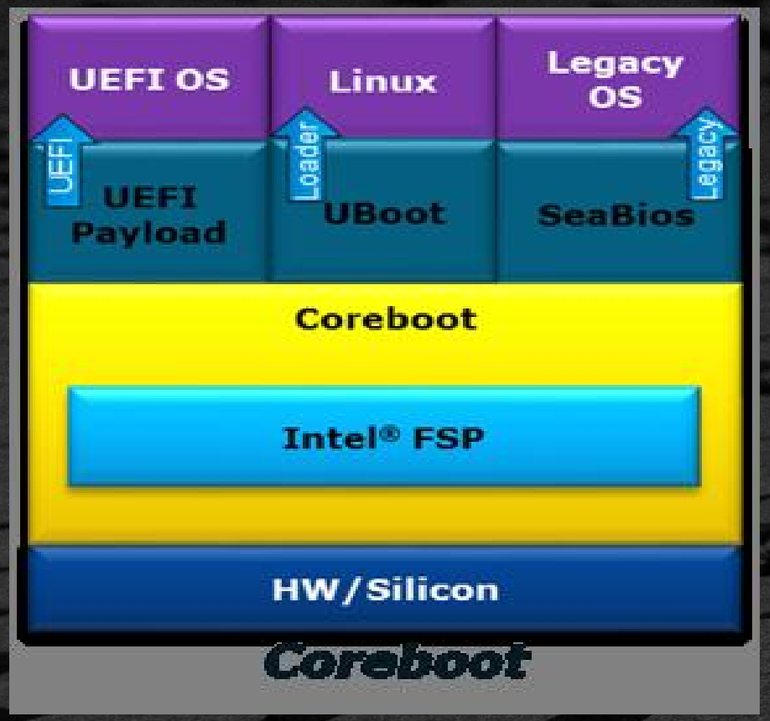
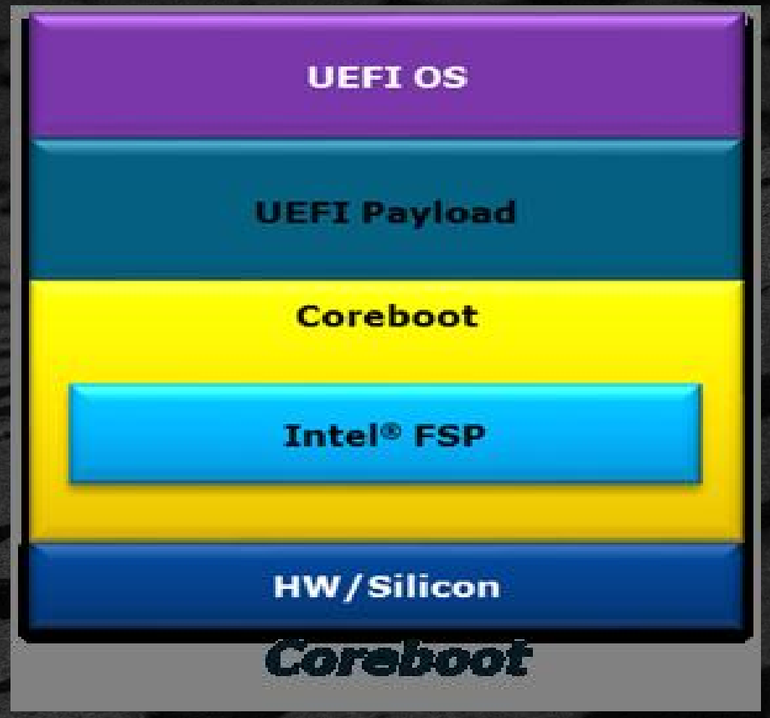


Coreboot Payload



Coreboot in itself is "only" minimal code for initializing hardware. It does not have the media drivers nor does it provide services required by an OS. After the initialization, it jumps to a payload which can provide services required to load and boot an OS.



UEFI payload provides UEFI services on top of coreboot that allows UEFI OS boot.

Consumers: EDK II firmware and coreboot

Functionality	coreboot	UEFI / PI
The reset vector and pre cache-as-ram setup	bootblock	Security Phase (SEC)
Cache as Ram setup, early silicon initialization, memory setup. Covered largely by Intel® Firmware Support Package	romstage	Pre-EFI Initialization (PEI) Create HOBs
Normal device setup and mainboard configuration. Publish SMBIOS/ACPI Tables	ramstage	Early Driver Execution Environment (DXE)
Memory map hand-off	CBMEM	UEFI Memory Map
The OS or application bootloader	payload	DXE BDS and UEFI Drivers

Demo Windows with Secure Boot

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SUMMARY

- Explain How the OS and UEFI Work together
- Explain the UEFI Requirements for UEFI aware OS
- Explain How Secure Boot Fits with UEFI
- What about MM (Formerly Known as SMM)
- What about coreboot?

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Questions?


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Backup

UEFI Secure Boot

- Deficiency: Boot path malware targets
- UEFI and Secure Boot harden the boot process
- Firmware/software in the boot process must be signed by a trusted Certificate Authority (CA)
- Firmware image is hardware-protected
- 3rd party drivers signed using CA-holding trusted keys
- Trusted signing key's database factory-initialized and OS-updated

WHY??? SECURE BOOT WITH UEFI

Without

Possible corrupted or destroyed data

- BootKit virus – MBR Rootkits
- Network boot attacks e.g. PXESPOILT
- Code Injection Attacks

With

- **Data integrity**
- **Trusted boot to OS**
- **Trusted drivers**
- **Trusted Applications**

UEFI Secure Boot Flow