

REVERSING
LABS



Mario Vuksan & Tomislav PericinBlackHat USA 2013, Las Vegas

PRESS ROOT TO CONTINUE:
DETECTING OSX AND WINDOWS
BOOTKITS WITH RDFU

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Agenda

- Our motivation
- Who are we
- Introduction to...
 - Unified extensible framework interface (UEFI)
 - Previous UEFI bootkit research
- Rootkit detection framework “RDFU”
 - Framework design
 - VMWare implementation demo
- MacOS X bootkit demo

Our motivation

- UEFI is very popular
 - Windows + Android + MacOS + ...
- Full-stack: UEFI is a mini-OS
 - Memory and file manipulation, full network stack
 - Graphics APIs, device management
 - Remote boot
- Attacker's paradise
 - No tools for analysis, low visibility, even no AV, ...
- Some good news though
 - UEFI SecureBoot (Surface RT, Android)

Who are we

- ReversingLabs
 - Founded by Mario Vuksan and Tomislav Pericin in 2009
- Focusing on
 - Deep binary analysis of **PE/ELF/Mach-O/DEX** and firmware
 - System reputation and anomaly detections
- Black Hat presentations and open source projects
 - TitanEngine: PE reconstruction library (2009)
 - NyxEngine: Archive format stego detection tool (2010)
 - TitanMist: Unpacking (2010)
 - Unofficial guide to PE malformations (2011)
 - FDF: disinfection framework (2012)
 - RDFU: UEFI rootkit detection framework (2013)



Thanks

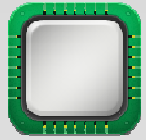
- John Heasman, Black Hat 2007
- Snare, Assurance, Black Hat 2012
- Dan Griffin, Defcon 2012
- Sebastien Kaczmarek, HITB Amsterdam 2013
- DARPA CFT

UEFI

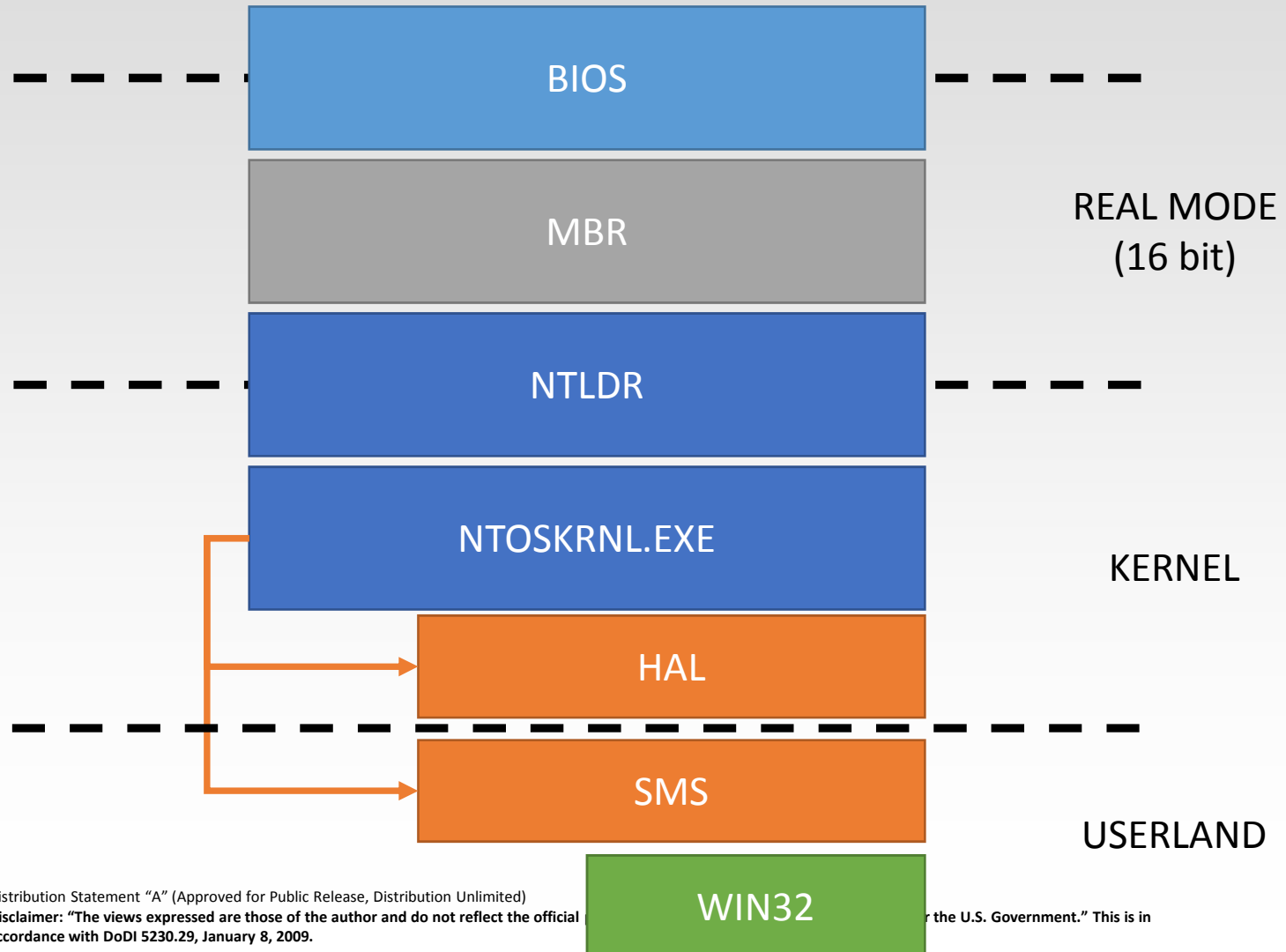
unified extensible firmware
interface

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Booting with BIOS



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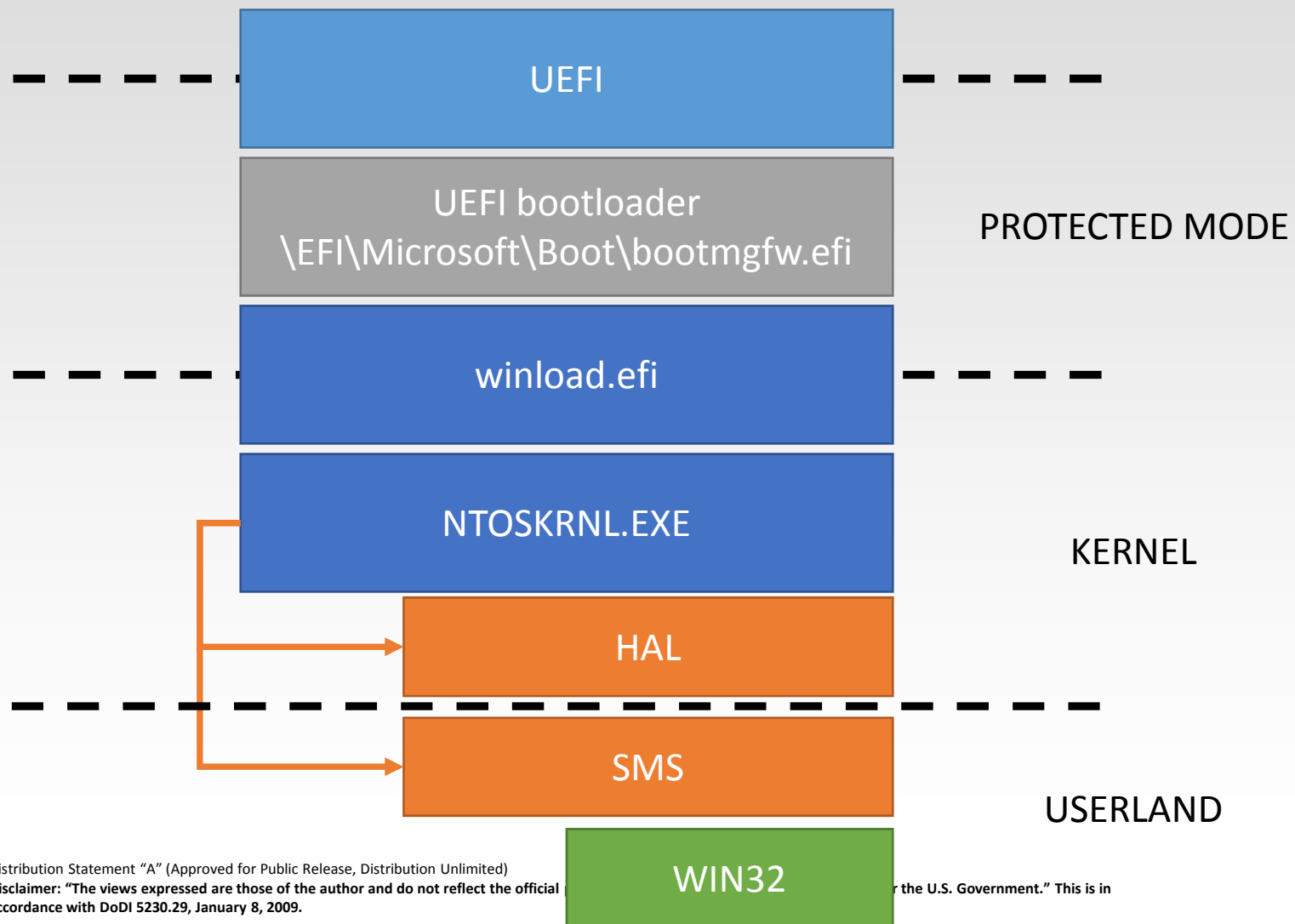


UEFI?

- **UEFI:** Unified extensible firmware interface
 - Originally developed by Intel, “Intel boot initiative”
 - Community effort to modernize PC booting process
 - Currently ships as a boot option alongside legacy BIOS
 - Aims to be the only booting interface in the future
 - Used in all Intel Macs and other PC motherboards
 - Managed by Unified Extensible Firmware Interface (UEFI) Forum



Booting with EFI



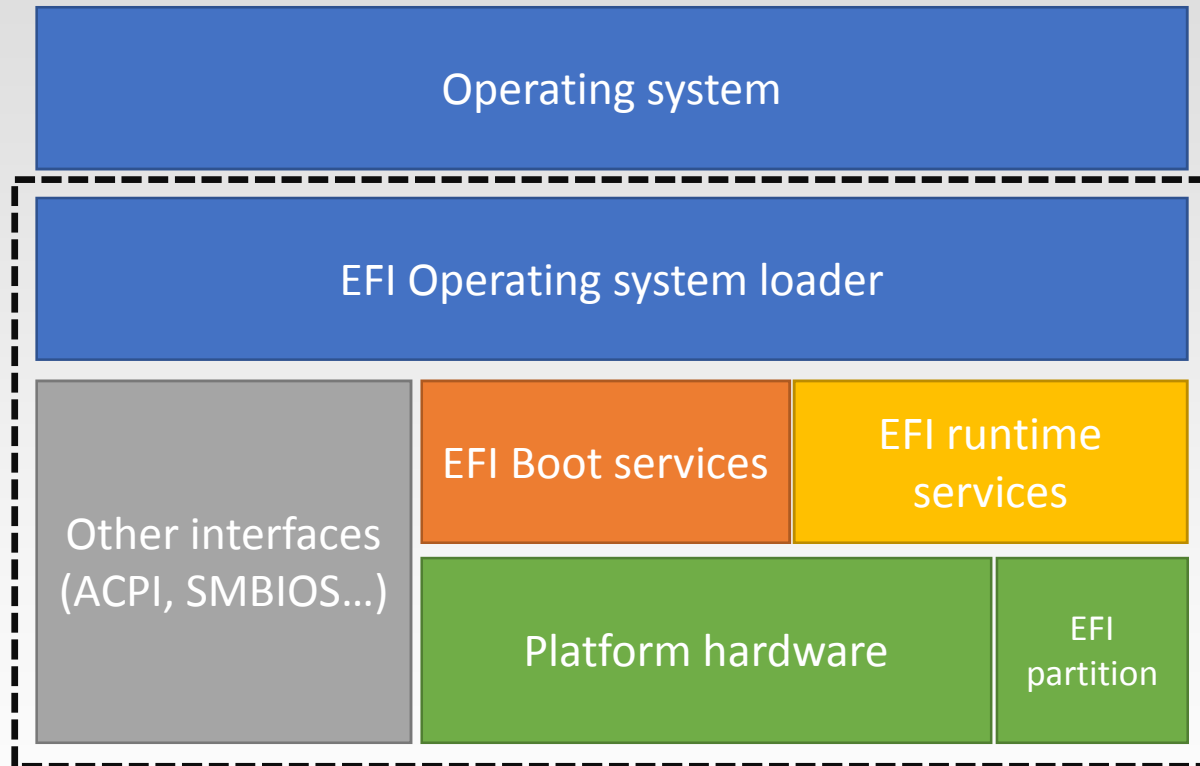
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UEFI Conceptual

overview

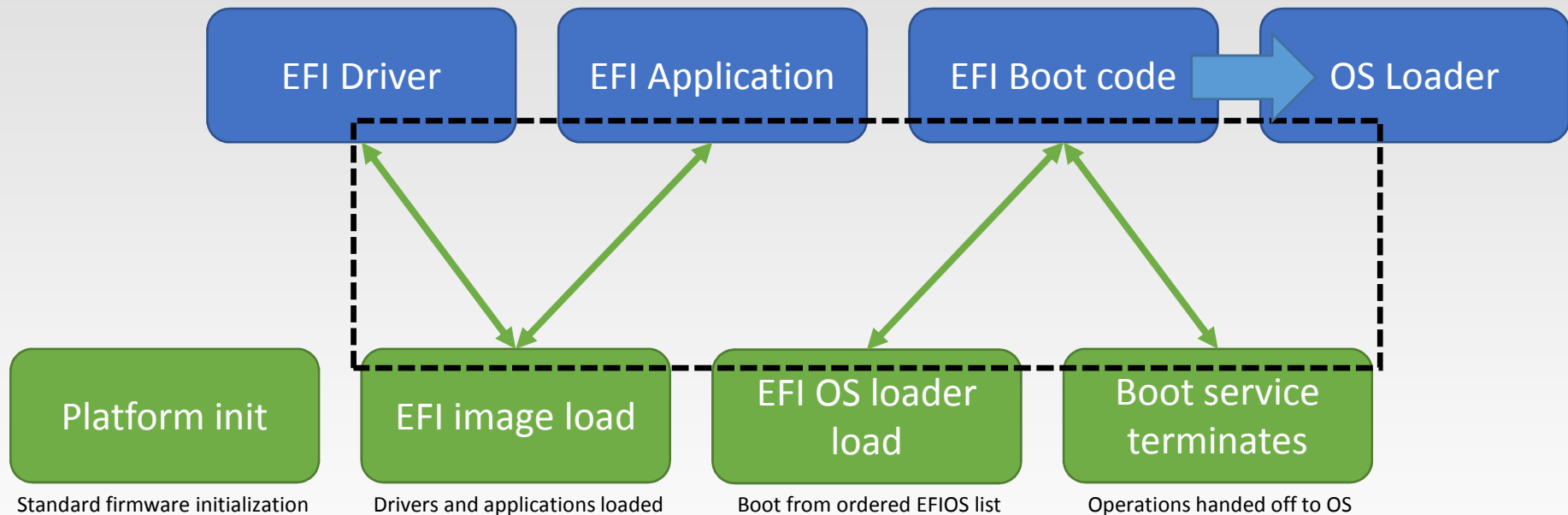


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EFI boot sequence



- Boot Manager
- EFI images



UEFI images

- **UEFI images:**
 - Typically PE32/PE32+ (basic format feature subset)
 - Standard also predicts that other formats can be defined by anyone implementing the specification, e.g. TE defined by Intel and used by Apple



UEFI images

- **UEFI drivers:**
 - Boot service driver
 - Terminated once `ExitBootServices()` is called
 - Runtime service driver
- **UEFI applications:**
 - EFI application
 - Normal EFI applications must execute in pre-boot environment
 - OS loader application
 - Special UEFI application that can take control of the system by calling `ExitBootServices()`



UEFI Boot services

- **UEFI boot services:**
 - Consists of functions that are available before `ExitBootServices()` is called
 - These functions can be categorized as “global”, “handle based” and dynamically created protocols
 - **Global** – System services available on all platforms
 - Event, Timer and Task Priority services
 - Memory allocation services
 - Protocol handler services
 - Image services
 - Miscellaneous services
 - **Handle based** – Specific functionally not available everywhere



UEFI Runtime services

- **UEFI runtime services:**
 - Consists of functions that are available before and after ExitBootServices() is called
 - These functions can be categorized as “global”, “handle based” and dynamically created protocols
 - **Global** – System services available on all platforms
 - Runtime rules and restrictions
 - Variable services
 - Time services
 - Virtual memory services
 - Miscellaneous services
 - **Handle based** – Specific functionally not available everywhere



EDK2

- **EFI development kit**
 - TianoCore – Intel’s reference implementation
 - Enables writing EFI applications and drivers in C
 - Has its own stdlibC implementation that covers a part of the standard library
 - Has a set of packages for shell, crypto, emulation and more
 - Has a set of applications built with stdlibC implementation
 - For example: Python 2.7
 - Has a build system which uses popular compilers (VS, GCC and XCode)
 - Supported CPUs: IA64, x86-64 and ARM



EDK2 -

helloworld.c

```
/**
 * Print a welcoming message.
 *
 * Establishes the main structure of the application.
 *
 * @retval 0      The application exited normally.
 * @retval Other  An error occurred.
 **/
UINTN
EFIAPI
ShellAppMain (
    IN UINTN Argc,
    IN CHAR16 **Argv
)
{
    Print(L"Hello there fellow Programmer.\n");
    Print(L>Welcome to the world of EDK II.\n");

    return(0);
}
```



UEFI -

HelloWorld.c

```
/**
 * Print a welcoming message.
 *
 * Establishes the main structure of the application.
 *
 * @retval 0      The application exited normally.
 * @retval Other  An error occurred.
 **/
INTN
EFIAPI
UEFIAppMain (
    IN EFI_HANDLE ImageHandle,
    IN EFI_SYSTEM_TABLE *SystemTable /** Boot and Runtime services **/
)
{
    Print(L"Hello there fellow Programmer.\n");

    return(0);
}
```

Bootkits

attacking unified extensible
firmware interface

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Previous work - '07

- Hacking extensible firmware interface
 - John Heasman, NGS Consulting
 - Presented at BlackHat 2007, USA
- Research
 - Modifying NVRAM variables
 - Code injection attacks
 - Shimming boot services
 - Abusing system management mode

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Previous work - '12

- Hacking extensible firmware interface
 - Snare, Assurance
 - Presented at BlackHat 2012, USA
- Research
 - Patching MacOS X kernel
 - Evil maid attack

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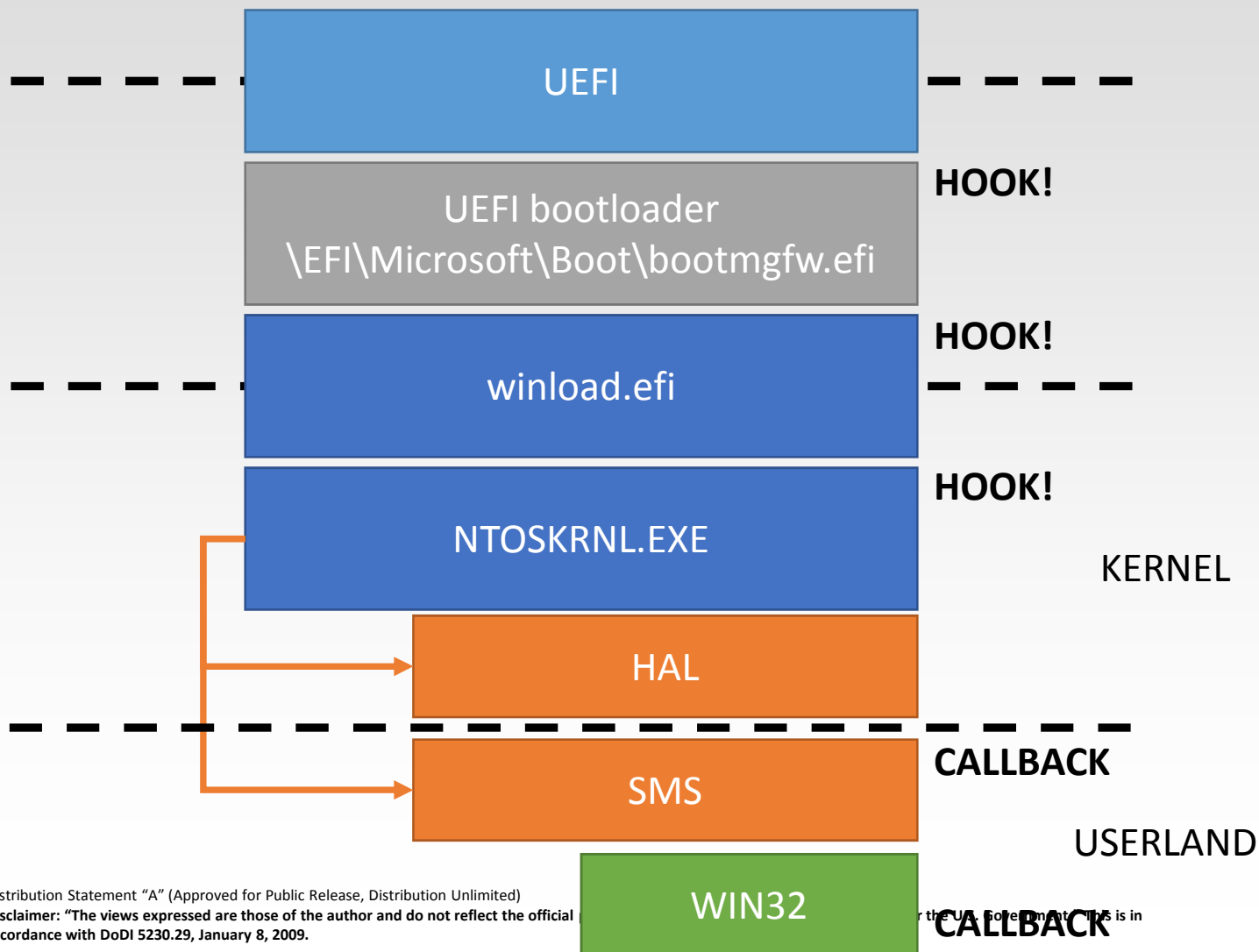
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Previous work - '13

- Dreamboot
 - Windows 8 x64 bootkit
 - Sébastien Kaczmarek, QuarksLab
 - Presented at HackInTheBox 2013, Amsterdam
- Modus operandi
 - Bypasses kernel protections (NX and Patch guard)
 - Bypasses local authentication
 - Elevates process privileges



Dreamboot



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CALLBACK

RDFU

rootkit detection framework for uefi

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What is RDFU?

- Set of EFI applications and drivers that enable:
 - Listing all EFI drivers loaded into memory
 - Probing entire memory range, scanning for executable
 - Monitoring newly loaded drivers until operating system starts
 - Listing and scanning EFI BOOT SERVICES and EFI RUNTIME SERVICES for modified function pointers
 - Continually monitoring EFI BOOT SERVICES and EFI RUNTIME SERVICES while operating system is being loaded
 - Displaying memory map and dumping all suitable regions
 - Listing and monitoring EVENT callbacks that can be used by rootkits/malware
 - Working in a standalone mode without the EFI shell

What does RDFU ~~support?~~

- Supported UEFI implementations:
 - UEFI 2.x specification for 32-bit and 64-bit Implementations
 - UEFI 1.x specification
 - MacOS UEFI implementation
 - VirtualBox
 - VMWare
- Not supported UEFI implementations:
 - UEFI ARM implementation (only on Surface RT, has secure boot enabled)

How does RDFU work?

- DXE driver loaded via UEFI shell
- DXE driver loaded from USB thumb drive
- Scanner application run from UEFI shell
- Logging and dumping is done to the mounted hard drive or the USB thumb drive

Continue
Boot Manager
Boot Maintenance Manager

Select from the
available operating
systems or devices.



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Boot Manager

Bootable Operating Systems and Devices

Windows Boot Manager

EFI VMware Virtual SCSI Hard Drive (0.0)

EFI VMware Virtual IDE CDROM Drive (IDE 1:0)

EFI Network

EFI Internal Shell (Unsupported option)

EFI VMware Virtual SCSI Hard Drive (1.0)

EFI VMware Virtual SCSI Hard Drive (2.0)

Device Path:

MemoryMapped (0xB, 0xBEFDB0
00, 0xBF33BFFF) /File (C57
AD6B7-0515-40A8-9D21-5516
52854E37)

↑ and ↓ to change option, ENTER to select an
option, ESC to exit

↑↓=Move Highlight

<Enter>=Select Entry

Esc=Exit



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```
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x1,0x0) /HD (1, MBR, 0x61E7
BB81,0x80,0x1FE800)
b1k2 :Removable HardDisk - Alias hd19c0b fs2
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x2,0x0) /HD (1, MBR, 0x61E7
BB9E,0x800,0xBFEB00)
b1k3 :BlockDevice - Alias (null)
      PciRoot (0x0) /Pci (0x7,0x1) /Ata (Secondary,Master,0x0)
b1k4 :Removable HardDisk - Alias (null)
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x0,0x0) /HD (1, GPT, 33CFF8
5C-8C4B-4D3A-8647-6032AF807592, 0x800, 0x96000)
b1k5 :Removable HardDisk - Alias (null)
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x0,0x0) /HD (3, GPT, D9F75F
07-41D3-4FCC-8CA2-89E60B106533, 0xC8800, 0x40000)
b1k6 :Removable HardDisk - Alias (null)
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x0,0x0) /HD (4, GPT, 05AADA
36-592C-4EE6-B72C-0EB7BEA23CDF, 0x108800, 0x76F7000)
b1k7 :Removable BlockDevice - Alias (null)
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x0,0x0)
b1k8 :Removable BlockDevice - Alias (null)
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x1,0x0)
b1k9 :Removable BlockDevice - Alias (null)
      PciRoot (0x0) /Pci (0x15,0x0) /Pci (0x0,0x0) /Scsi (0x2,0x0)
```

Press ESC in 4 seconds to skip **startup.nsh**, any other key to continue.

Shell> _



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RDFU

ROOTKIT DETECTION FRAMEWORK
FOR UEFI



Menu :

- [0] - List all handles
- [1] - List all images
- [2] - Dump all images to disk
- [3] - Check BootServices/RuntimeServices/SystemTable pointers in images
- [4] - Install image sniffer (SniffImage, requires residency)
- [5] - List all events
- [6] - Install event scanner (requires residency)
- [7] - Scan memory for PE images (bruteforce) and dump them to disk
- [8] - Display memory map

- [9] - Display and dump memory map
- [A] - Display and dump memory map (skip Reserved and MemoryMappedIO mem)
- [B] - Display EFI services
- [C] - Install EFI services scanner (requires residency)
- [D] - Display IDT
- [E] - Display GDT
- [F] - Display Context
- [G] - Dump firmware from ROM
- [H] - Install all resident scanners
- [Q] - Quit

-

DEMO

rootkit detection framework for uefi

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MAC OS 10.7.x
bootkit

first Mac OS X bootkit example

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Bootkit goals

- Create hidden folders
- Hiding (with un-hiding) processes
- Execute shell with root privileges
- Retrieve FileVault password



Running the MacOS

ootkit



Mac OS X 10.7.x - Lion

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Running the MacOS

bootkit



Boot the OS from an USB thumb drive

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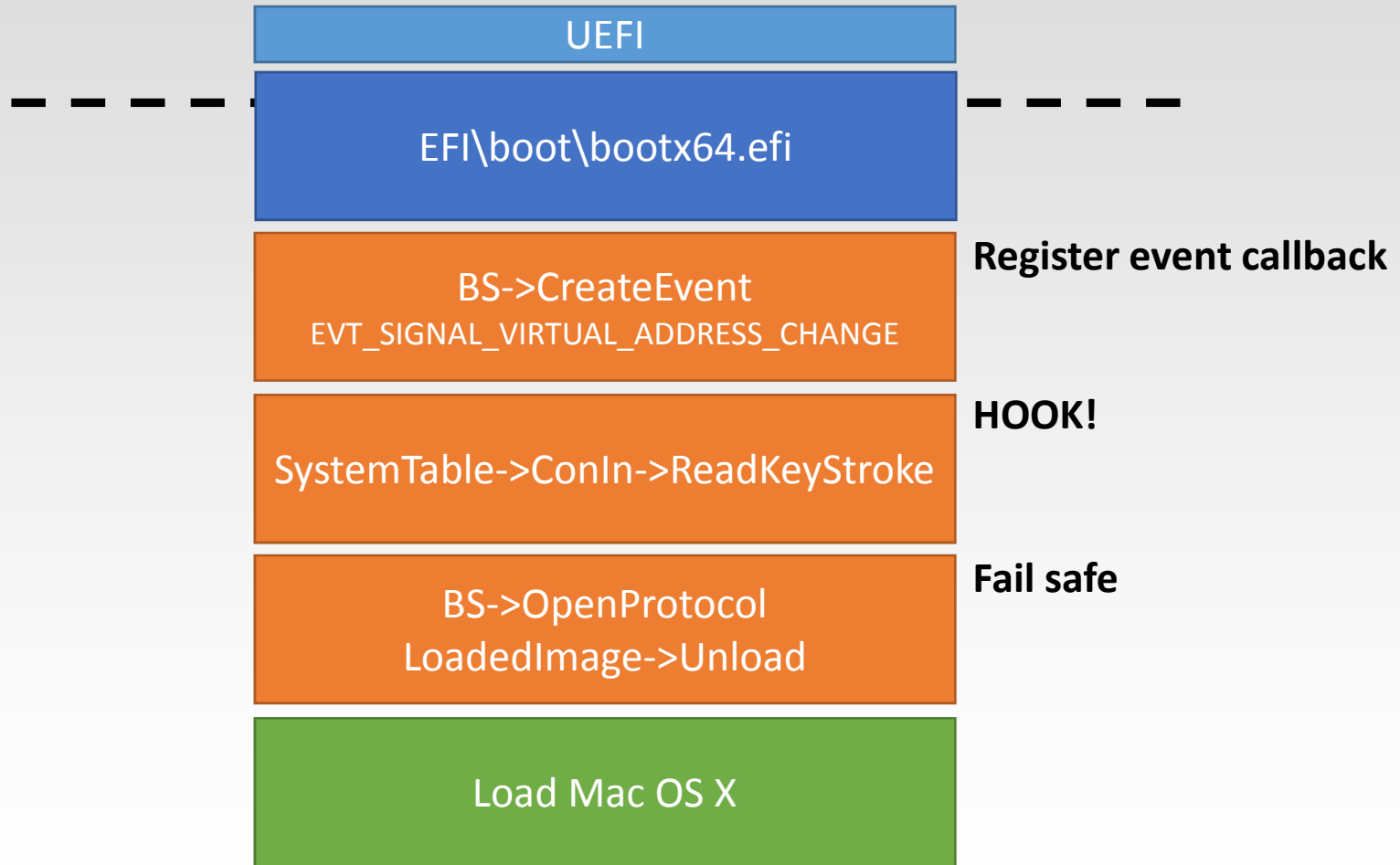
VMWare / MacOS

bootkit

- MacOS can also be run in VMWare if you don't have a MacBook Pro handy
- Running MacOS under VMWare requires an "unofficial patch" – *wink wink nudge nudge*
- Once patched we need to change the VMX file
 - firmware = "efi"
- After that MacOS can be installed with EFI 1.10

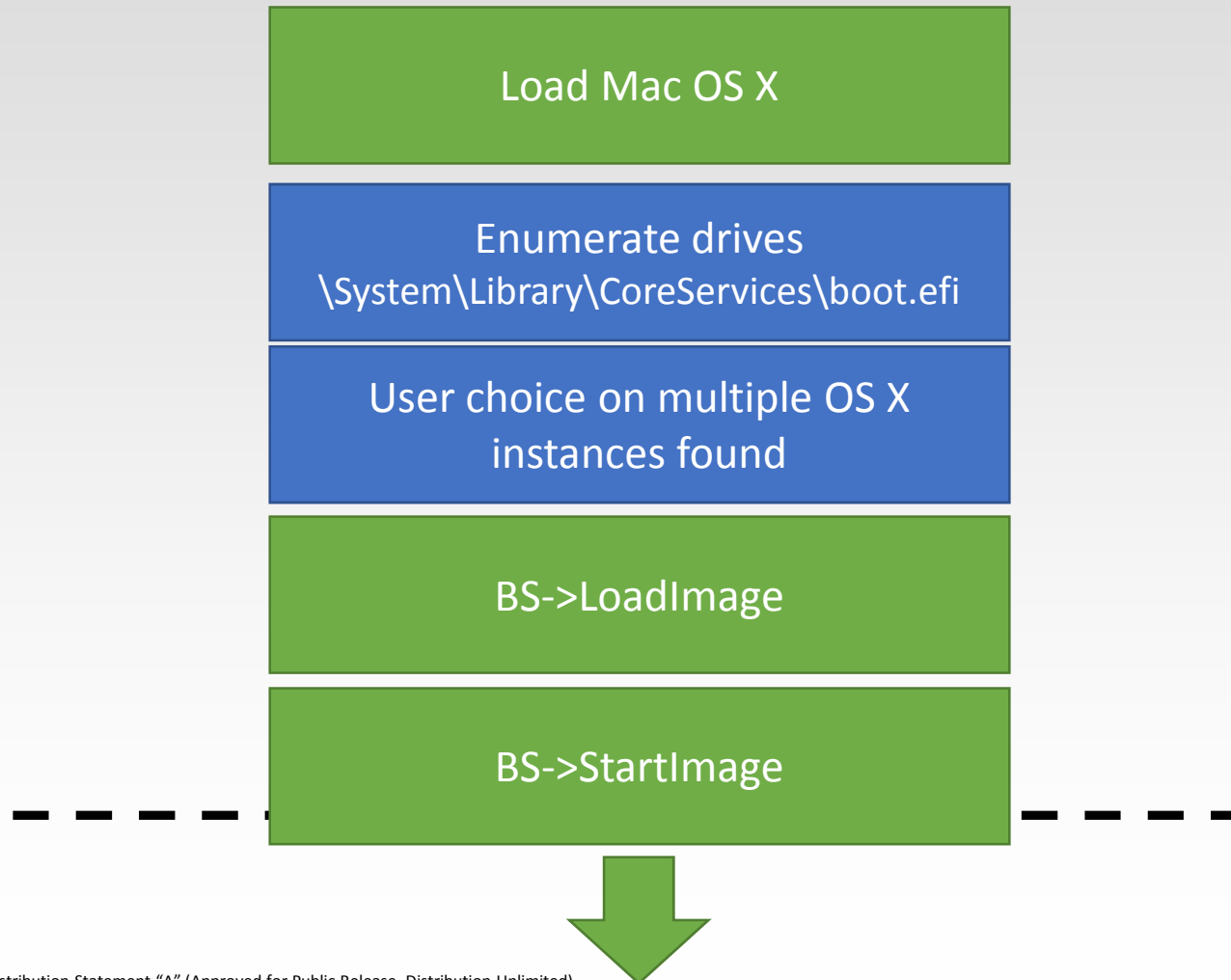


Bootkit workflow





Bootkit workflow



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Bootkit workflow



SIGNAL

EVT_SIGNAL_VIRTUAL_ADDRESS_CHANGE

EVENT

Locate syscall table

Hook syscalls: setuid, getdentries,
getdentriesattr & sysctl

HOOK!

SetVirtualAddressMap()



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Getting ROOT

```
/**
 * executes shell with root rights
 */
#define HIDDEN_UID 1911

int main( void )
{
    setuid(HIDDEN_UID);
    system("/bin/sh");
}
```



Hiding processes

```
/**
 * sends the pid to the rootkit that should be hidden
 */
int main(int argc, char *argv[])
{
    pid_t pid = atoi(argv[1]);
    printf("Adding pid %d (%08x) hide list\n", pid, pid);

    int name[] = { CTL_ADD_PID, pid, KERN_PROC_ALL, 0 };

    err = sysctl((int *)name, (sizeof(name) / sizeof(*name)) - 1, NULL,
&length, NULL, 0);

    printf("All done, sysctl returned 0x%08x\n", err);
    return EXIT_SUCCESS;
}
```

DEMO

MacOS X bootkit

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Q A

Thanks!

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