REVERSING LABS

Mario Vuksan & Tomislav Pericin

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

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, …
- 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)

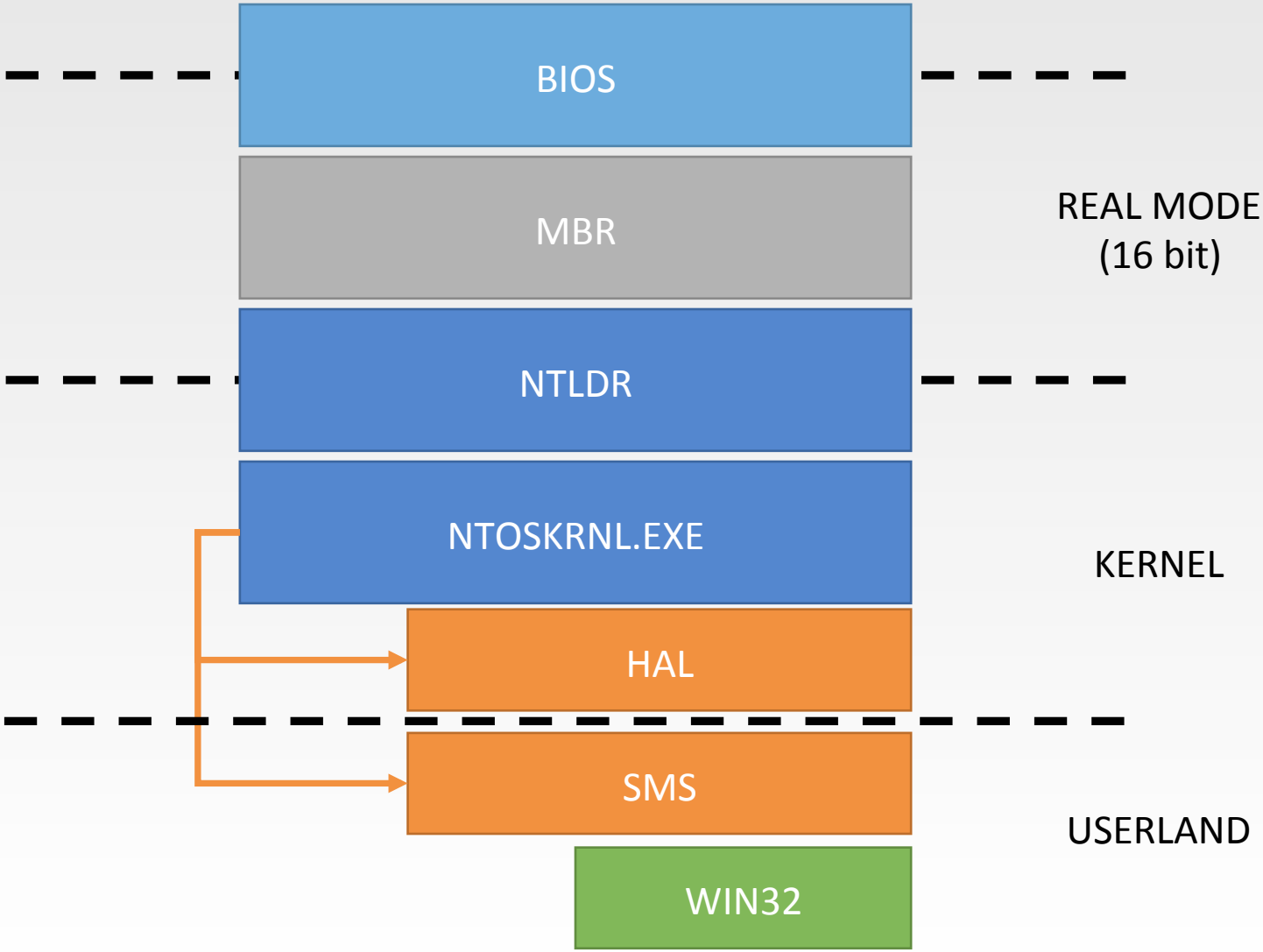
Thanks

- DARPA CFT for sponsoring the project
- Researchers:
  - John Heasman, Black Hat 2007
  - Snare, Assurance, Black Hat 2012
  - Dan Griffin, Defcon 2012
  - Sebastien Kaczmarek, HITB Amsterdam 2013

UEFI

unified extensible firmware interface

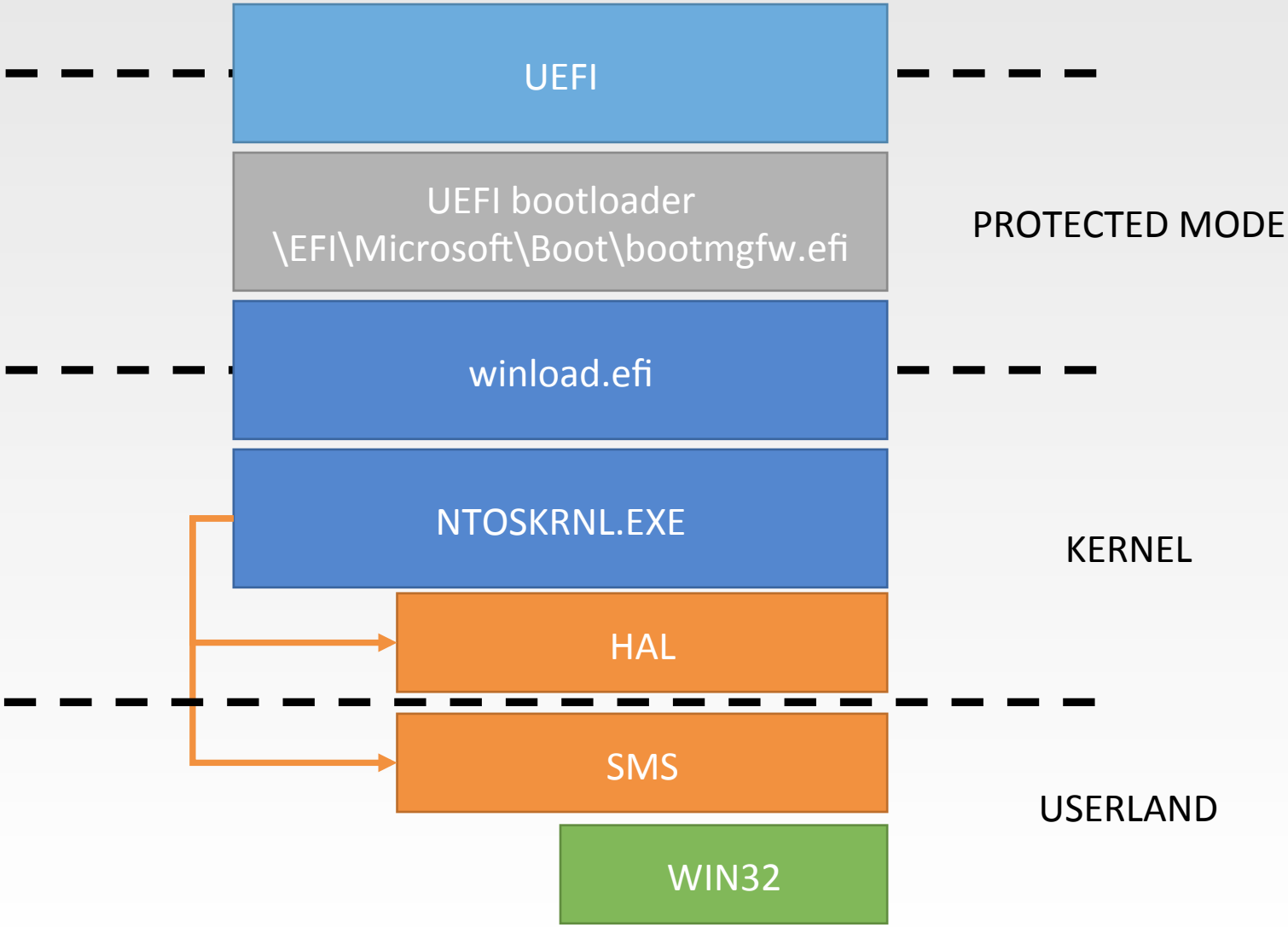
Booting with BIOS



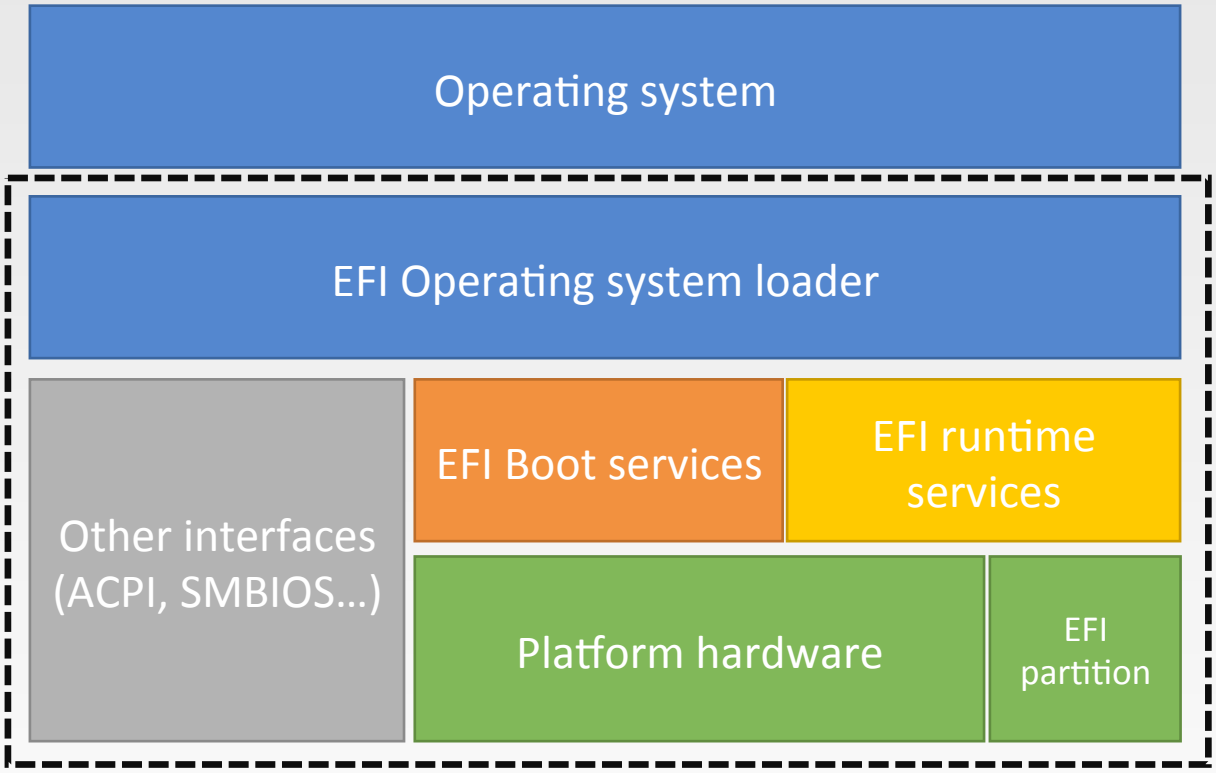
UEFI?

- **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

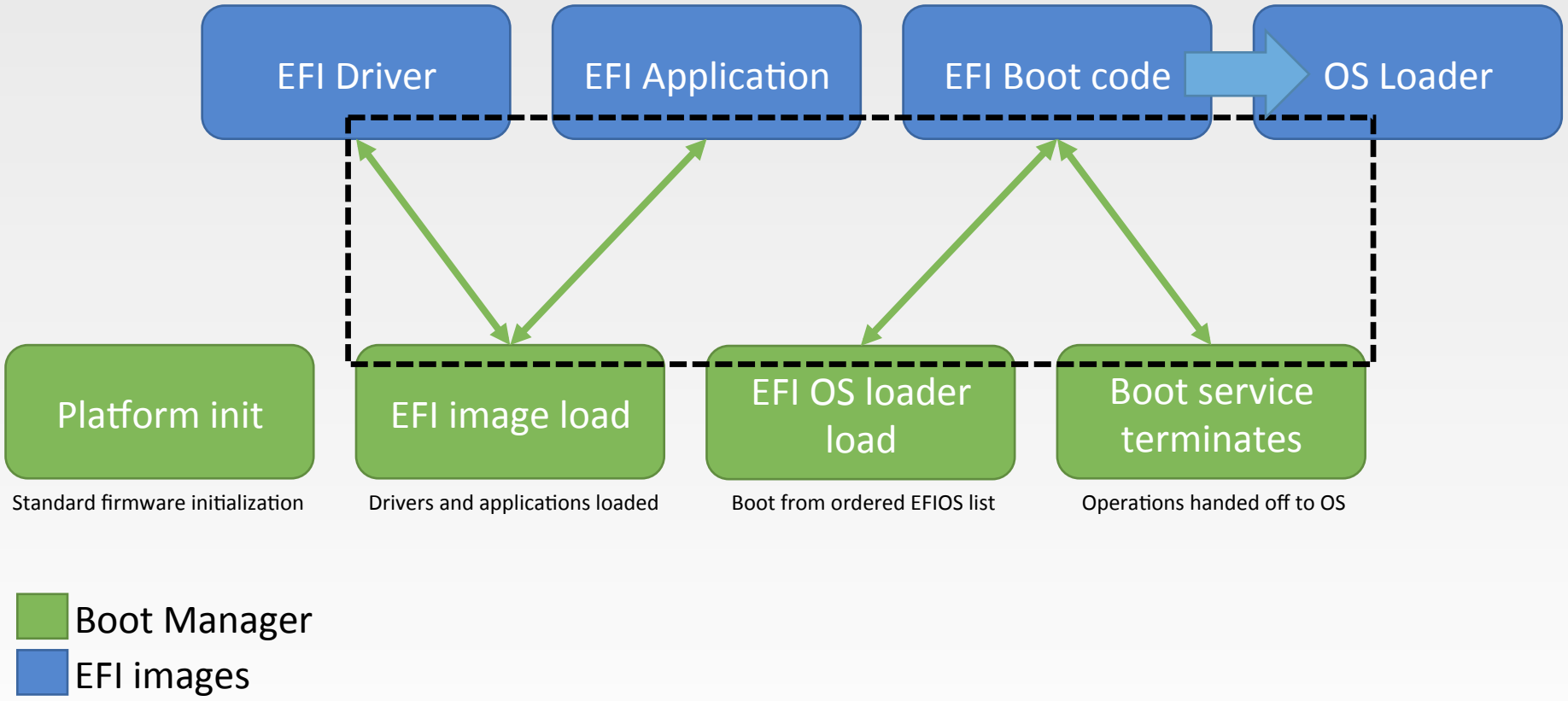
Booting with EFI



UEFI Conceptual overview



EFI boot sequence



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.
***/
INTN
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

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

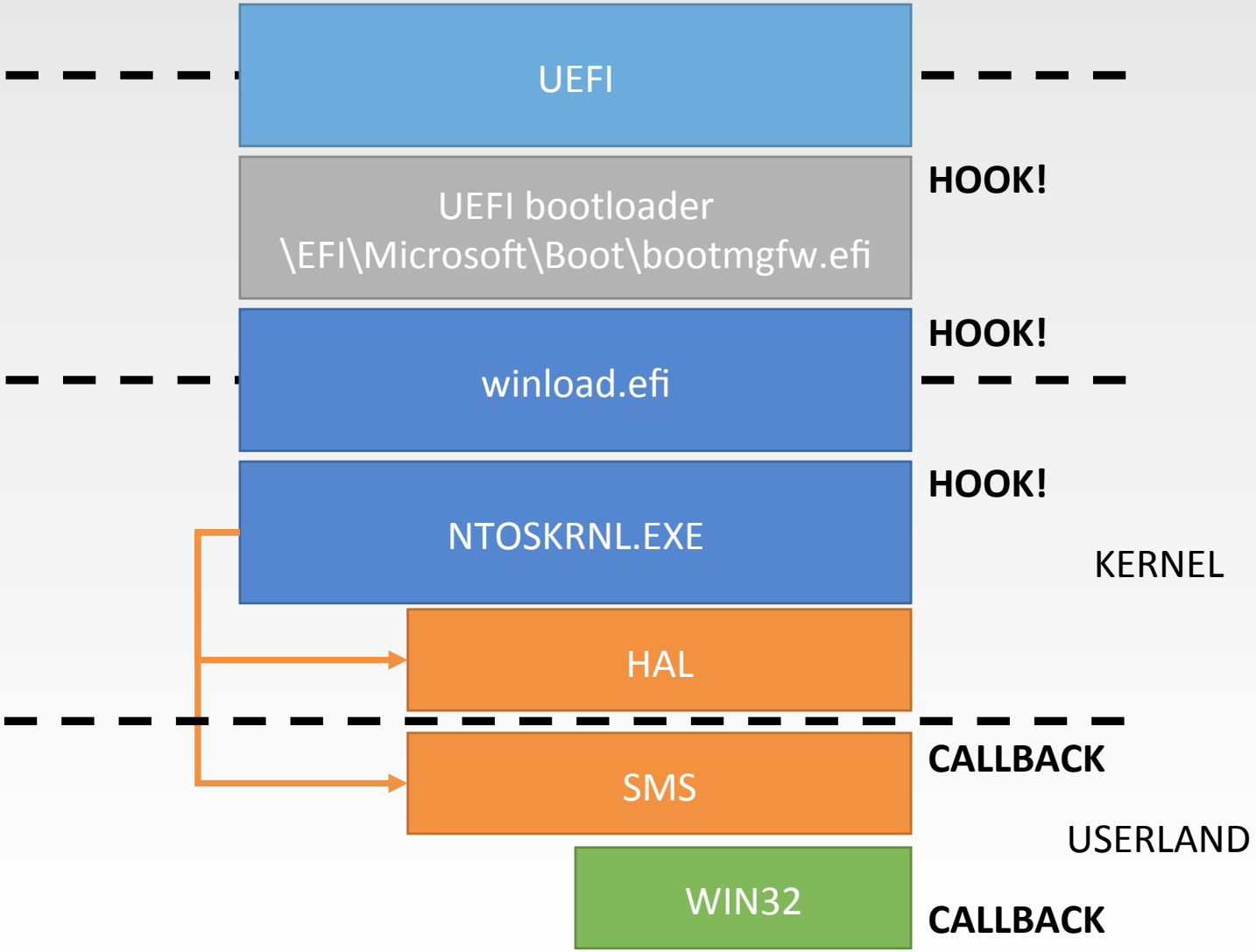
Previous work – ‘12

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

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


UEFI
UEFI bootloader
\EFI\Microsoft\Boot\bootmgfw.efi
HOOK!
winload.efi
HOOK!
NTOSKRNL.EXE
HOOK!
KERNEL
HAL
SMS
CALLBACK
USERLAND
WIN32
CALLBACK

RDFU

rootkit detection framework for uefi

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

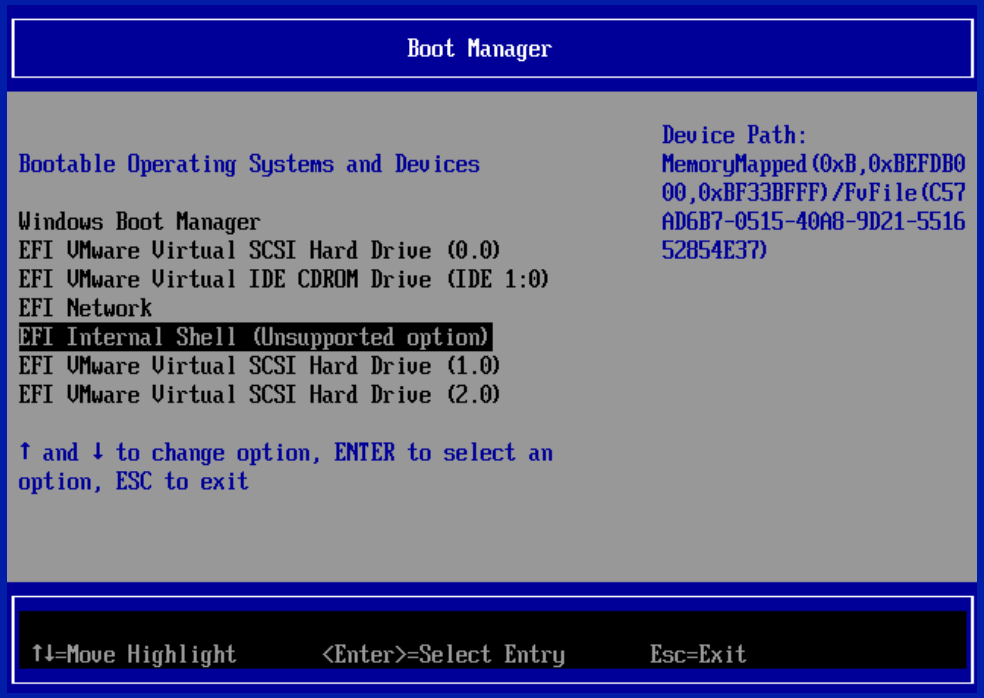
What does RDFU support?

- 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.
VMWARE


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)
↑ and ↓ to change option, ENTER to select an option, ESC to exit
Device Path:
MemoryMapped(0xB,0xBEFDB000,0xBF33BFFF)/FvFile(C57AD6B7-0515-40A8-9D21-551652854E37)
↑↓=Move Highlight
<Enter>=Select Entry
Esc=Exit

VMWARE

```
          PciRoot(0x0)/Pci(0x15,0x0)/Pci(0x0,0x0)/Scsi(0x1,0x0)/HD(1,MBR,0x61E7
B881,0x80,0x1FE800)
  blk2    :Removable HardDisk - Alias hd19c0b fs2
          PciRoot(0x0)/Pci(0x15,0x0)/Pci(0x0,0x0)/Scsi(0x2,0x0)/HD(1,MBR,0x61E7
B89E,0x800,0xBFE800)
  blk3    :BlockDevice - Alias (null)
          PciRoot(0x0)/Pci(0x7,0x1)/Ata(Secondary,Master,0x0)
  blk4    :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)
  blk5    :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)
  blk6    :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)
  blk7    :Removable BlockDevice - Alias (null)
          PciRoot(0x0)/Pci(0x15,0x0)/Pci(0x0,0x0)/Scsi(0x0,0x0)
  blk8    :Removable BlockDevice - Alias (null)
          PciRoot(0x0)/Pci(0x15,0x0)/Pci(0x0,0x0)/Scsi(0x1,0x0)
  blk9    :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> _
```

VMWARE

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RDFU

ROOTKIT DETECTION FRAMEWORK
FOR UEFI

VMWARE

```
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
_
```

VMWARE

DEMO

rootkit detection framework for uefi

MAC OS 10.7.x bootkit

first MacOS X bootkit example

Bootkit goals

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

Running the MacOS bootkit

Mac OS X 10.7.x - Lion

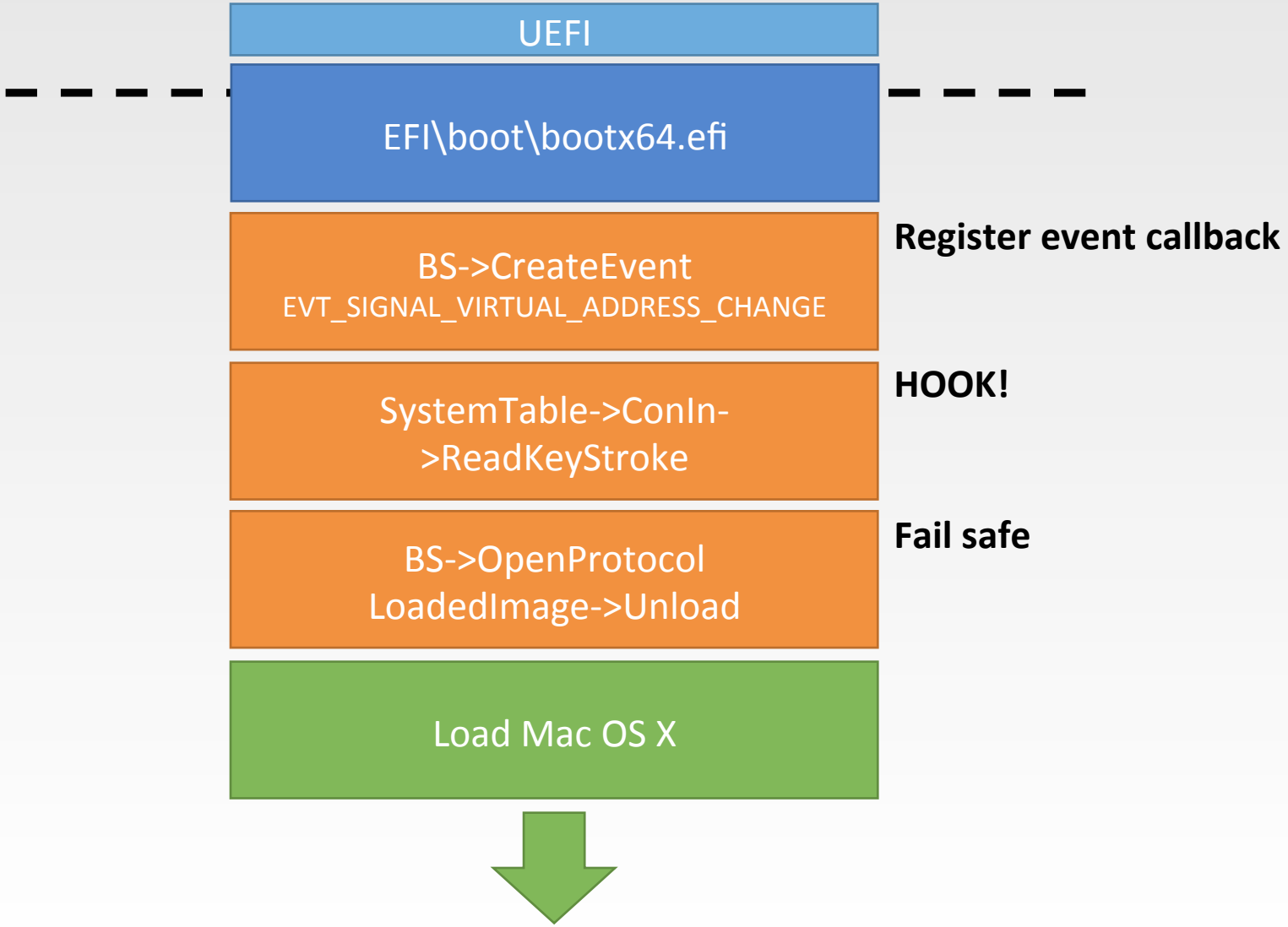
Running the MacOS bootkit

Boot the OS from an USB thumb drive

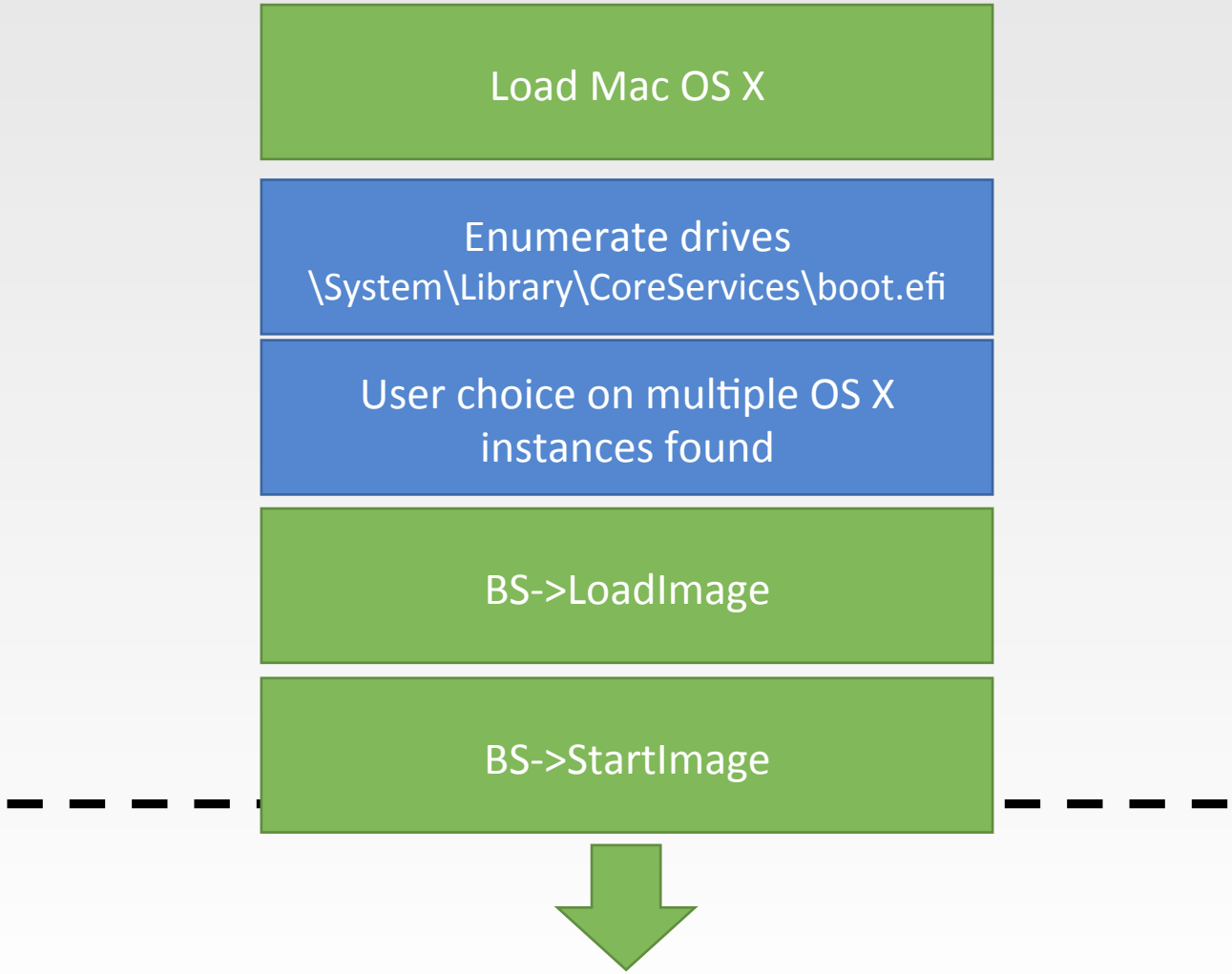
VMWare / MacOS bootkit

- 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



Bootkit workflow

SetVirtualAddressMap()

SIGNAL

EVT_SIGNAL_VIRTUAL_ADDRESS_CHANGE

EVENT

Locate syscall table

Hook syscalls: setuid, getdirentries, getdirentriesattr & sysctl

HOOK!

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

What can I do with RDFU?

- Use some of the EFI shell even when there's no EFI shell available
- Check installed and loaded EFI components
- Scan EFI environment for hidden components
- Modify the source to act like secure boot

Where can I get RDFU?

http://www.reversinglabs.com

QA

Thanks!