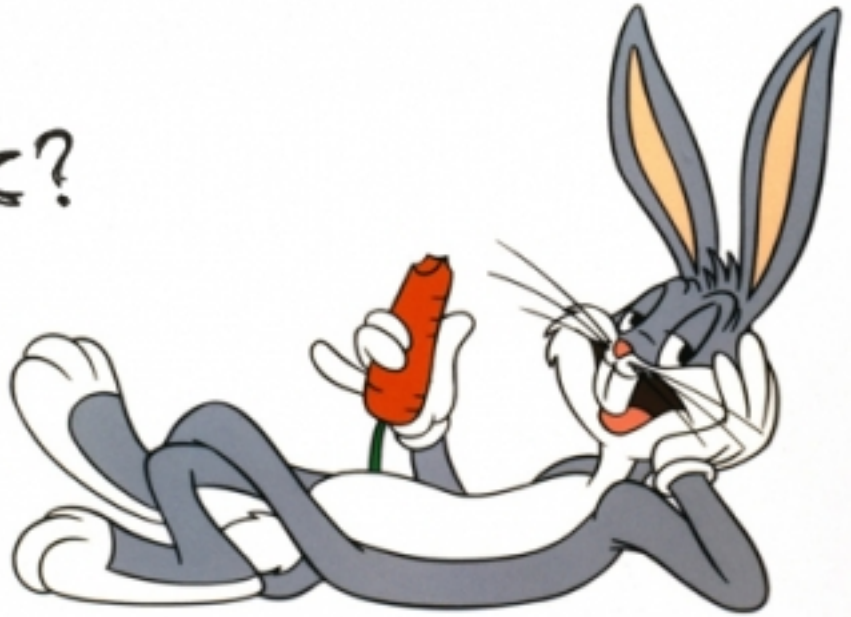

Is there an EFI monster inside your apple?
fG! @ SyScan360 2015

Who am I?

- An Economist.
- Who loves Human Behavior.
- And politics.
- Oh, and a bit of computers.

Translators!

Whats Up Doc?



EFI Monsters?

- Introduction to EFI.
- How to
  - Reverse engineer (U)EFI binaries.
  - Search for (U)EFI rootkits.

WE LIVE IN A CHANGING WORLD

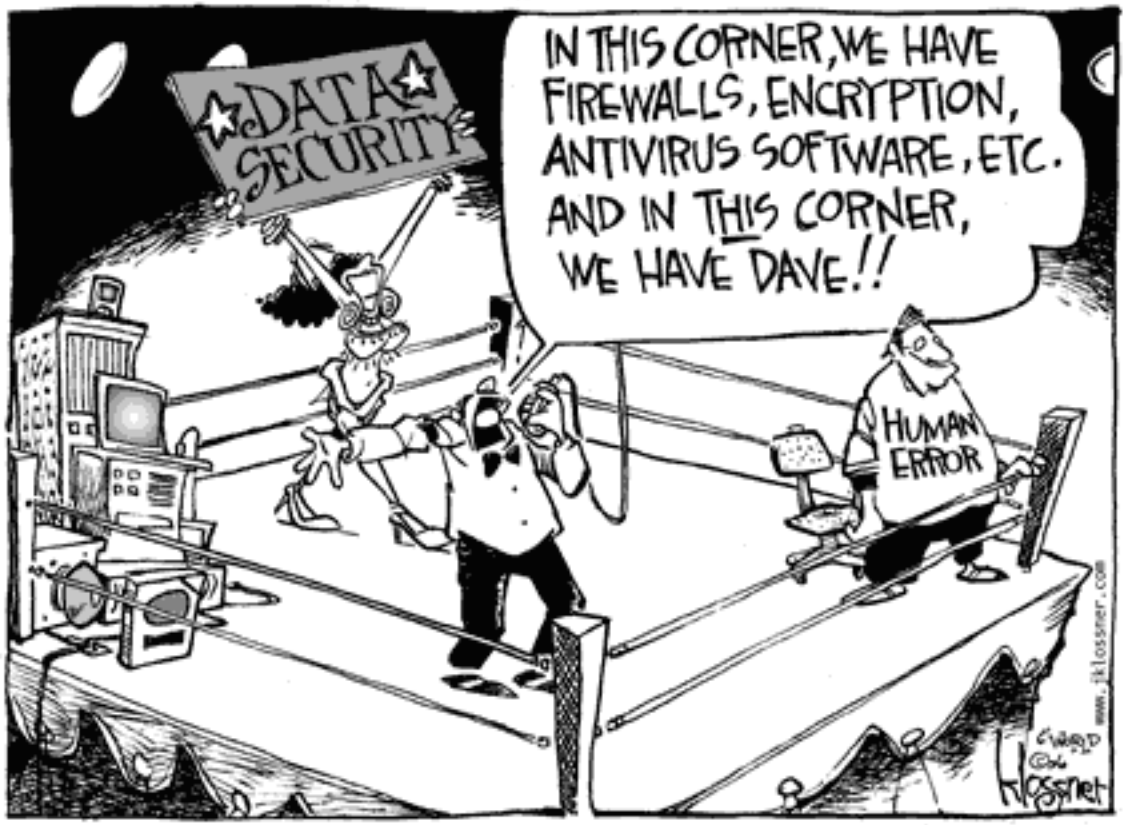
ASSUMPTIONS

"Relax! I know this road perfectly!
I've been driving it all my life!"

Assumptions

- Reference machine
  - MacBook Pro Retina 10,1.
- 64-bit only OS X versions.
- Sandy Bridge or newer.

Why EFI?


DATA SECURITY
IN THIS CORNER, WE HAVE FIREWALLS, ENCRYPTION, ANTIVIRUS SOFTWARE, ETC. AND IN THIS CORNER, WE HAVE DAVE!!
HUMAN ERROR
www.jklossner.com

Why EFI?

- BIOS replacement.
- Initially developed by Intel.
  - http://www.intel.com/content/www/us/en/architecture-and-technology/unified-extensible-firmware-interface/efi-specifications-general-technology.html
- Now UEFI, managed by UEFI consortium.
  - http://www.uefi.org

Why EFI?

- Initializes your machine.
- Access to low level features.
- Modular.
- Feature rich.
- Rather easy development in C.

What evil things can we do?

What evil things can we do?

- Diskless kernel/userland rootkits
- Rootkit data stored in the flash chip.
- Unpack and patch kernel on boot.
- RAM only, never touch hard-disk.
- Check Snare's SyScan 2012 presentation.

What evil things can we do?

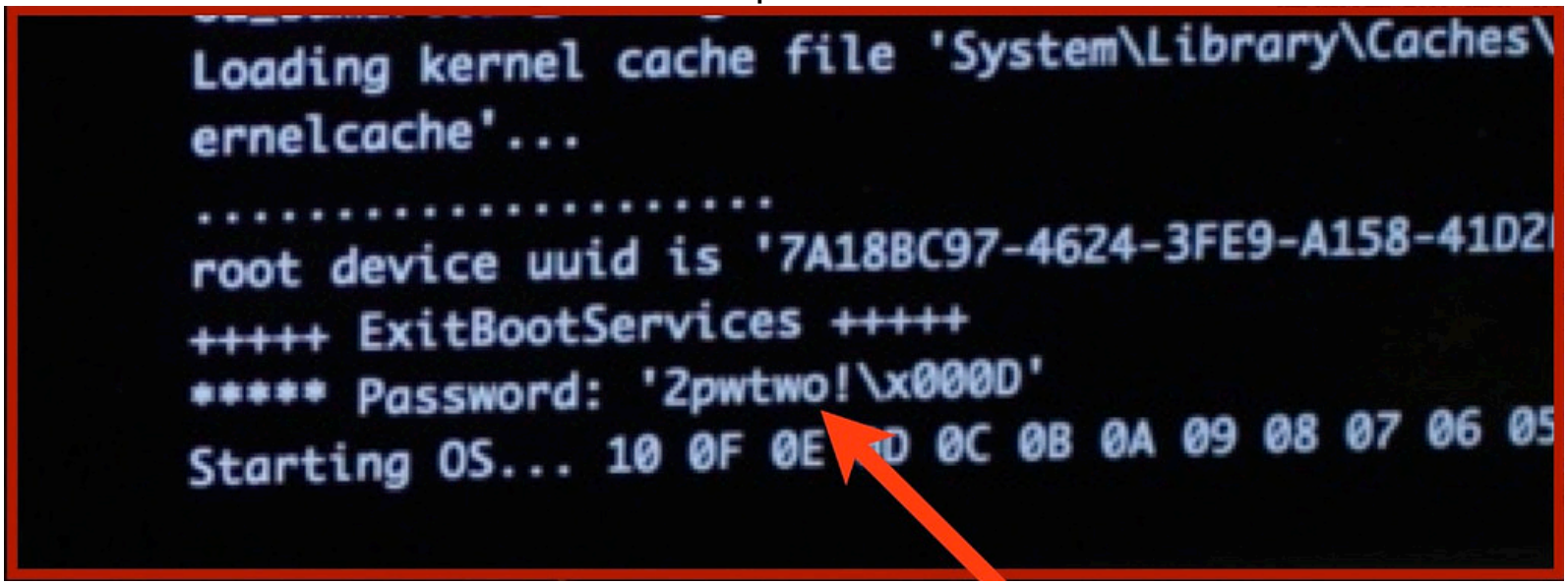
- Can be hard to detect.
- With regular available tools.
- And with some anti-forensics.
- For example anti-memory dumping.

What evil things can we do?

- Persistence across operating system installs
- HackingTeam built a UEFI rootkit.
  - https://github.com/hackedteam/vector-edk
  - https://github.com/informationextraction/vector-edk/blob/master/MdeModulePkg/Application/fsbg/fsbg.c

What evil things can we do?

- Attack full-disk encryption
- Install a keylogger.
- Recover FileVault2 password.



What evil things can we do?

- Attack "secure" operating systems
- For example, Tails.
- Recover PGP keys and/or passphrases.
- https://www.youtube.com/watch?v=sNYsfUNegEA.

What evil things can we do?

- Bootloader
  - Redirect to a custom bootloader.
- SMM backdoors
  - http://blog.cr4.sh/2015/07/building-reliable-smm-backdoor-for-uefi.html


TL;DR
OWN
EVERYTHING!
JOKER
JOKER

Once upon a time...

there was a...

a zero day!

CNN Money Business Markets Tech Personal Finance Small Business Luxury

CNN U.S. Edition Log In

stock tickers

Cyber-Safe

Mac attack! Nasty bug lets hackers into Apple computers

By Jose Pagliery @Jose_Pagliery

The Register®

Biting the hand that feeds IT

DATA CENTRE SOFTWARE NETWORKS SECURITY INFRASTRUCTURE BUSINESS HARDWARE SCIENCE BOOTNOTES FORUMS WEEKEND

Mac bug makes rootkit injection as easy as falling asleep

Apple hacker reveals cracker 0day rootkit whacker

Security

Related topics

Apple, Security

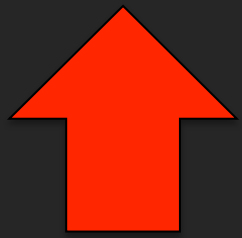
A zero day story...

- Firmware related zero day.
- Disclosed a few months ago.
  - https://reverse.put.as/2015/05/29/the-empire-strikes-back-apple-how-your-mac-firmware-security-is-completely-broken/

A zero day story...

- Failure to lock the flash.
- Write to the flash from userland.
- Similar to Thunderstrike but better.
- Thunderstrike requires physical access.
- Prince Harming allows remote attack.

PERSISTENCE
FIRMWARE FLASH



- Hardware-specific, but it's always there
- Can modify everything
  - SEC, PEI, DXE, BDS, custom drivers, whatever
- Can be written to from the OS
- So awesome. 11/10 A++++ would buy again.

A zero day story...

- Extremely simple to trigger.
- Put machine to sleep.
  - Close, wait for fans to stop, and reopen.
  - Or force sleep with "pmset sleepnow".

A zero day story...

- Sandy Bridge and Ivy Bridge Macs are vulnerable.
- Haswell or newer are not.
- All older machines are vulnerable
  - Core 2 Duo or older.
  - No flash protections at all.

A zero day story...

- Available updates:

MacBook Air	MacBook Pro	Mac Mini	Mac Pro	iMac
4,1	8,1	5,1	6,1	12,1
5,1	9,1	6,1		13,1
6,1	10,1	7,1		14,1
7,1	10,2			14,2
	11,1			14,3
	11,2			14,4
	11,4			15,1
	12,1			

A zero day story...

- Reversing and understanding the vulnerability.
  - https://reverse.put.as/2015/07/01/reversing-prince-harmings-kiss-of-death/
- Contains links to relevant EFI documentation.

A zero day story...

- Venamis aka Dark Jedi was also patched.
  - http://events.ccc.de/congress/2014/Fahrplan/events/6129.html
  - http://blog.cr4.sh/2015/02/exploiting-uefi-boot-script-table.html
- Slightly more complex, same results.

A zero day story...

- The story doesn't end here.
- Check ThunderStrike 2 slides.
- Other unpatched vulnerabilities.
- Can be exploited with remote attack vectors.

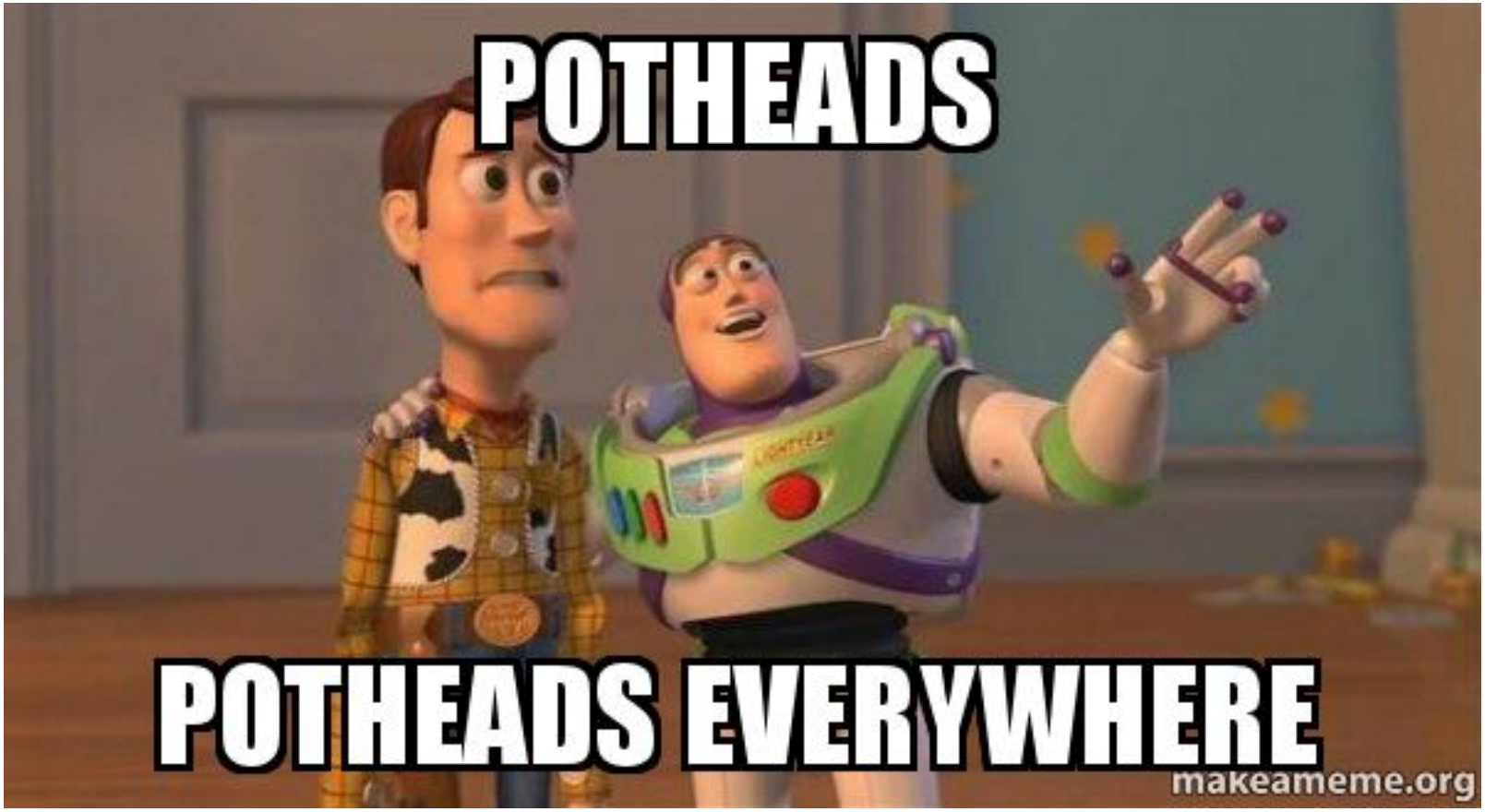
Old bugs, new platforms

Vulnerability	Private disclosure Public disclosure	Status on OSX
Snorlax/PrinceHarming VU #577140	August 2013 July 2015 / May 2015	Patched June 2015
Darth Venamis VU #976132	Sept 2014 Dec 2014	Partial Patch June 2015
SpeedRacer/BIOS_CTNL VU #766164	Dec 2013 Aug 2014	Vulnerable
King's Gambit VU #552286	Dec 2013 Aug 2014	Vulnerable (See HITB-GSEC 2015)
The Sicilian VU #255726	~May 2013 Sep 2013	Vulnerable
Setup UEFI Variable VU #758382	June 2013 Mar 2014	Not vulnerable

Reminder: This talk has 1 main point

- Apple has not been as responsive, or as accurate, as other PC vendors in responding to industry-wide notifications of firmware vulnerabilities. Consequently Mac users have been left vulnerable to attacks that have been fixed on other x86-based PCs.

Apple ...




Where is
EFI?

Where is EFI?

- Usually stored in a CMOS serial flash.
- Two popular chips
  - Macronix MX25L6406E.
  - Micron N25Q064A.

- SPI compatible.
- Most are 64 Mbits/8 Mbytes.

Where is EFI?

- Newer machines flash chip(s)
  - Winbond W25Q64FV.
- Chip list from EfiFlasher.efi:

SST 25VF080	Macronix 25L1605	ST Micro M25P16	WinBond 25X32
SST 25VF016	Macronix 25L3205	ST Micro M25P32	Winbond 25X64
SST 25VF032	Macronix 25L6436E	Eon M25P32	Winbond 25X128
SST 25VF064	Atmel 45DB321	Eon M25P16	Numonyx N25Q064

Where is EFI?

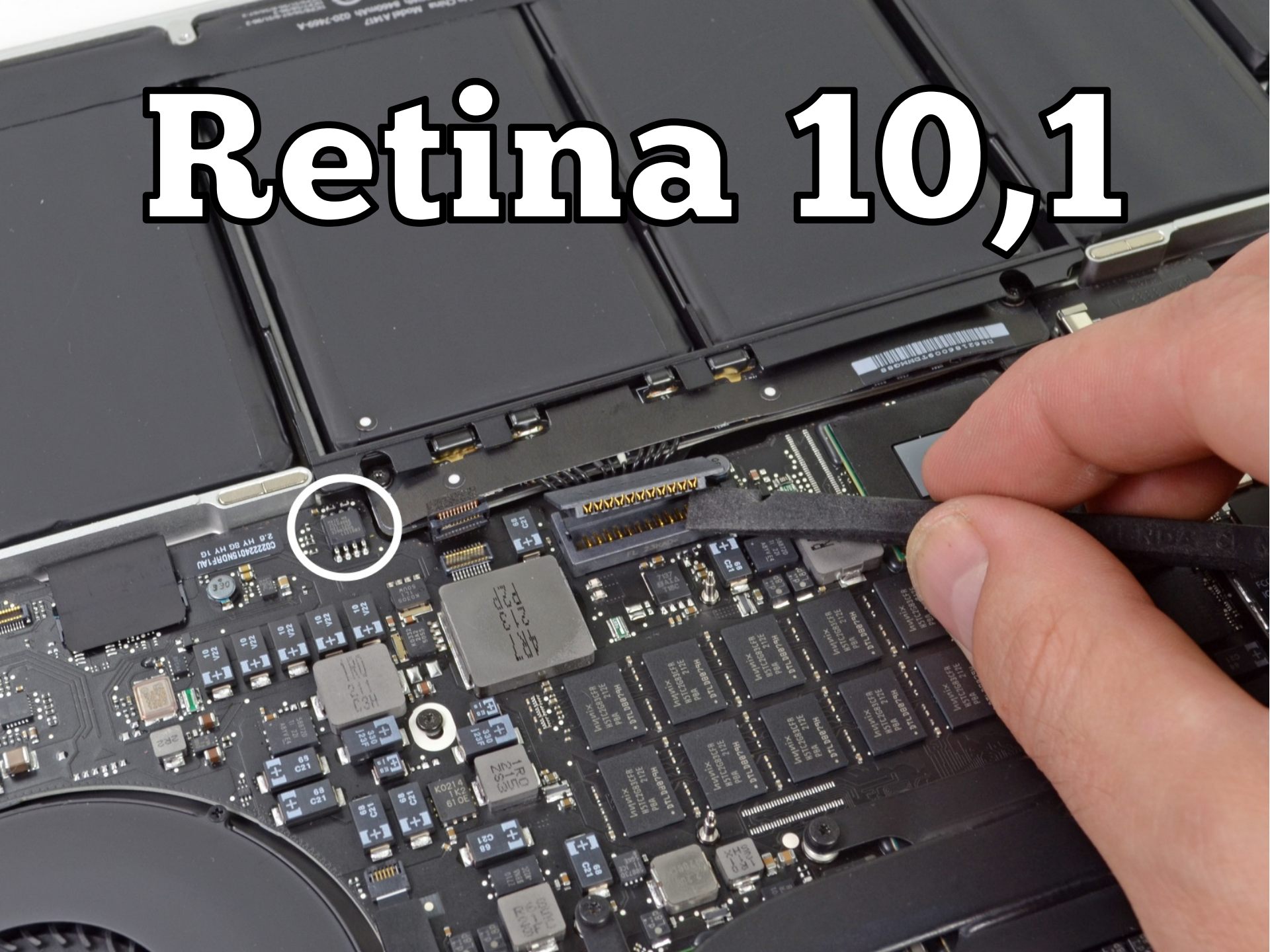
- Most chips are 8 pin SOIC.
- SMD or BGA versions used?
  - Retinas 13"?
  - New MacBook 12"?

Where is EFI?

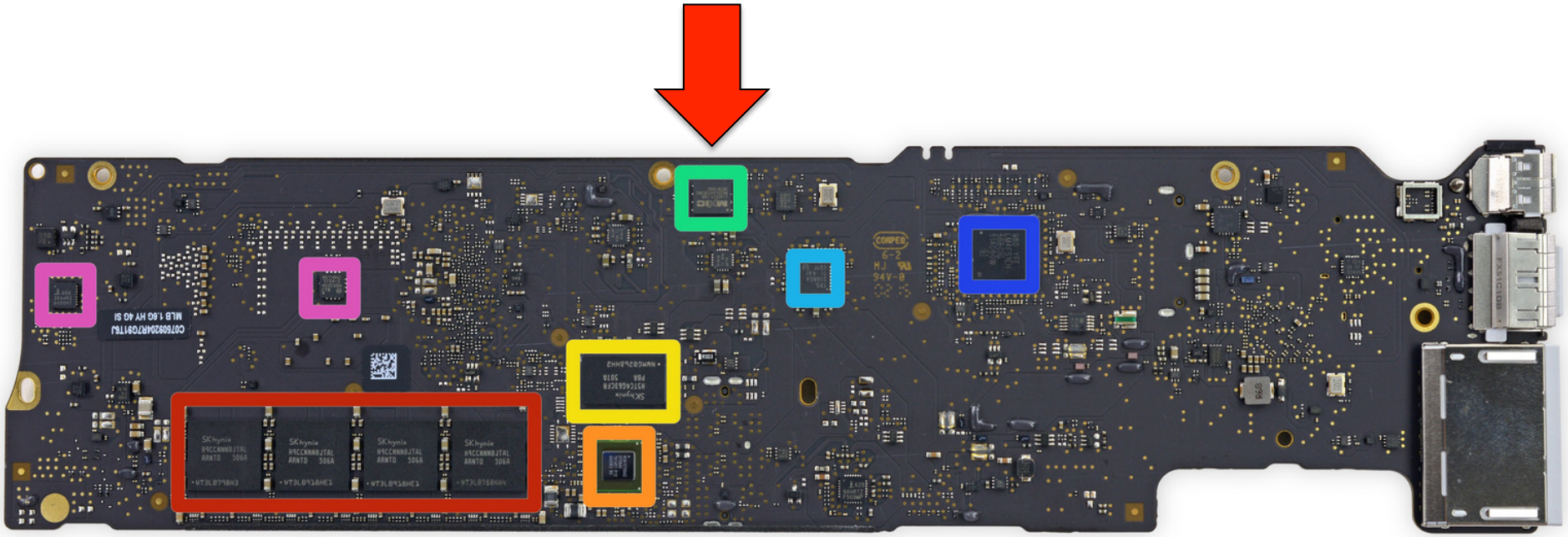
- You can buy the chips bulk and cheap.
- Useful for flashing experiments.
- Good results from Aliexpress.com.
- Around $14 for 10 N25Q064A.
- Around $8 for 10 MX25L640E.

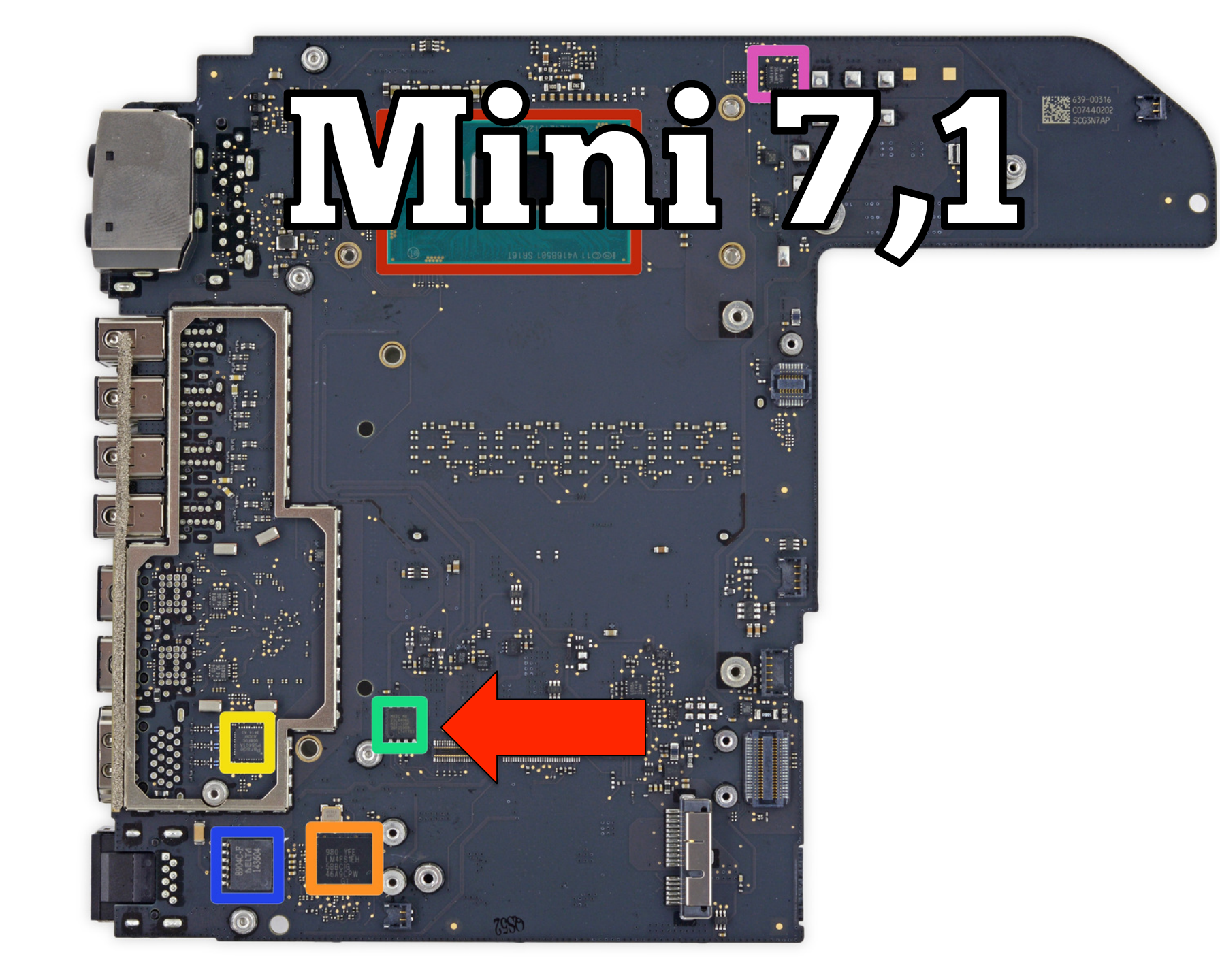
Where is EFI?

- Easy access on some models.
  - Retinas 15" are the easiest.
- Extensive disassembly required on others.
- Still, a MacBook Pro 8,1 can be disassembled in 5 mins or less.

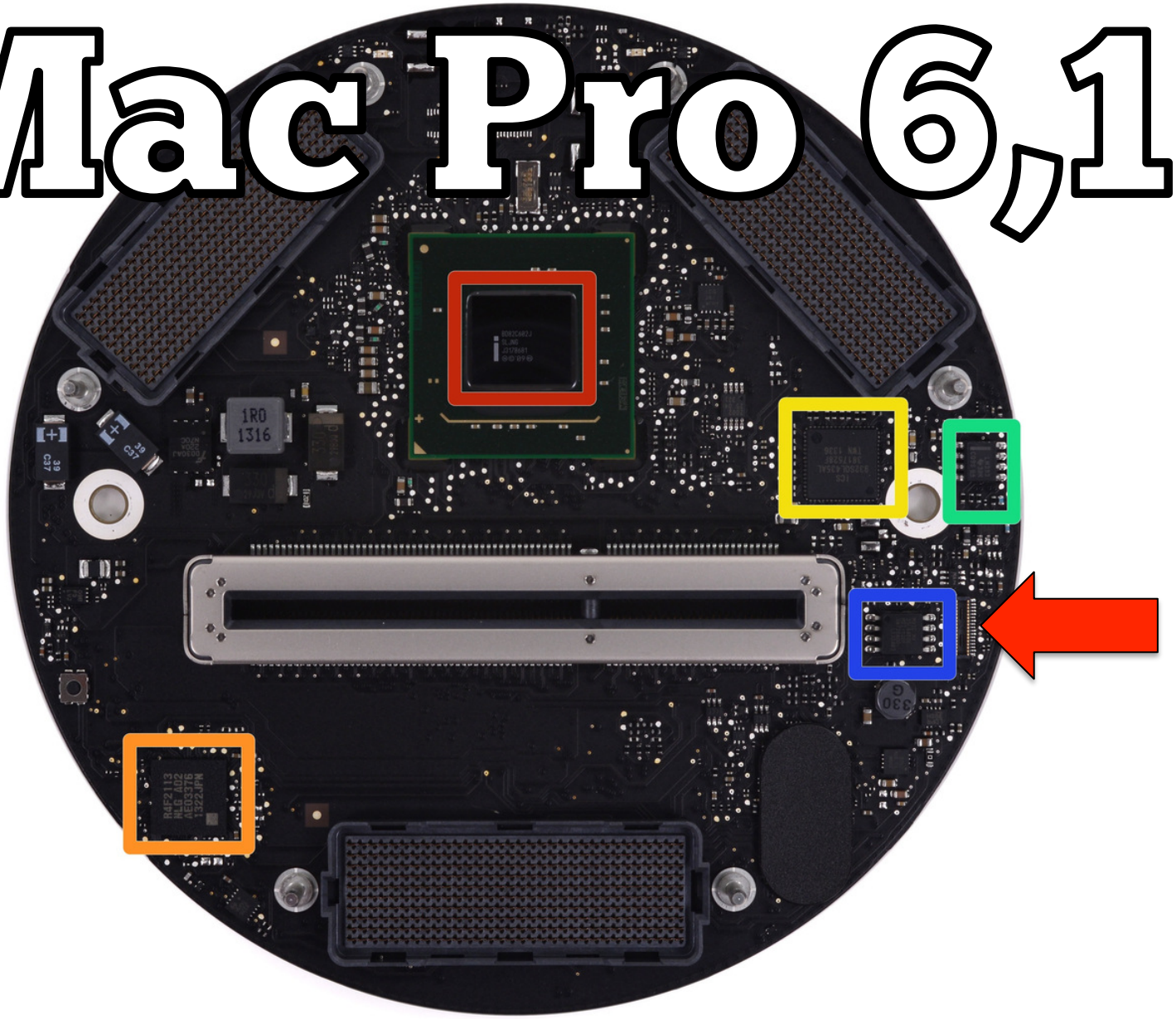

Retina 10,1

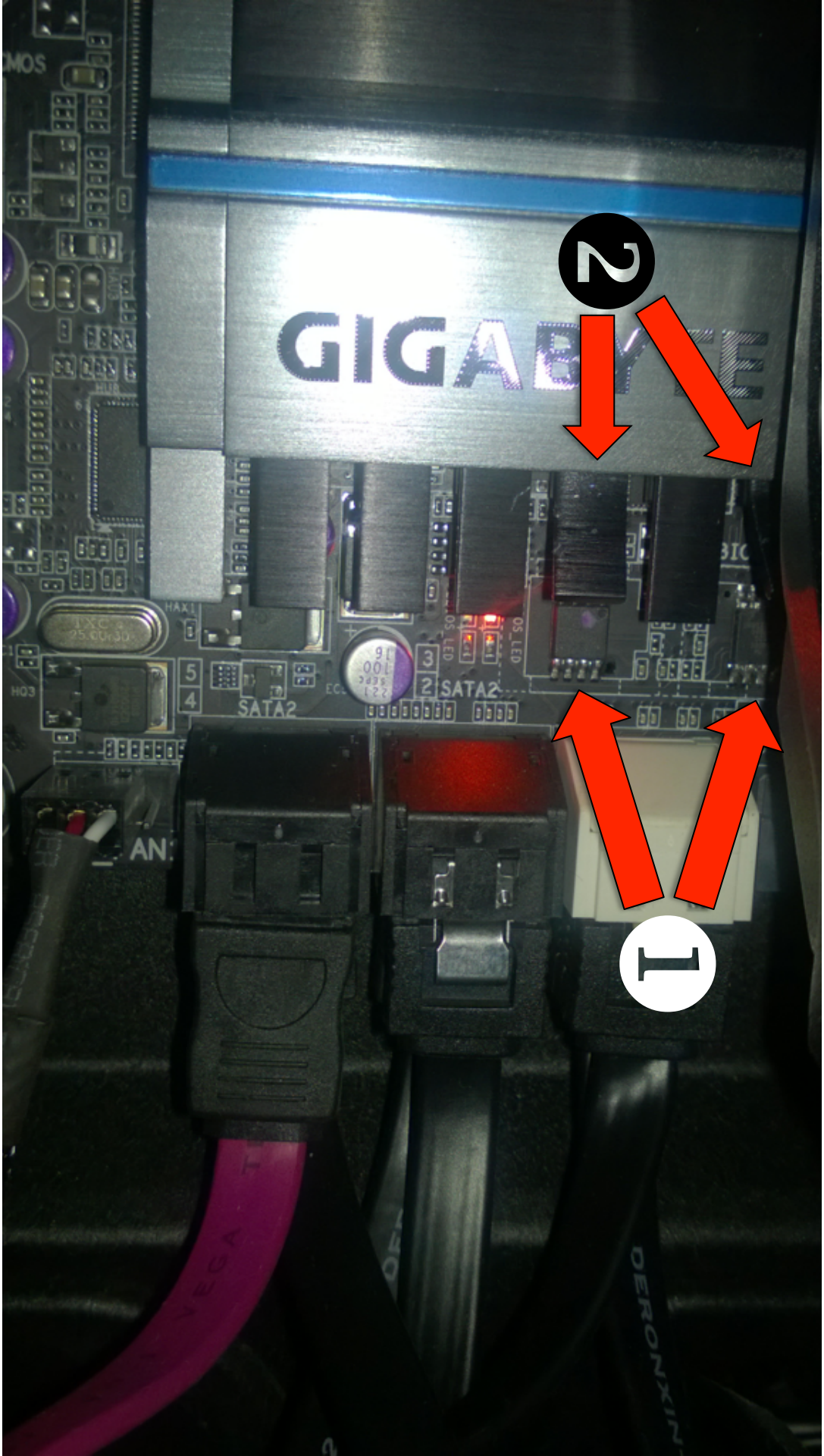
Air 7,2

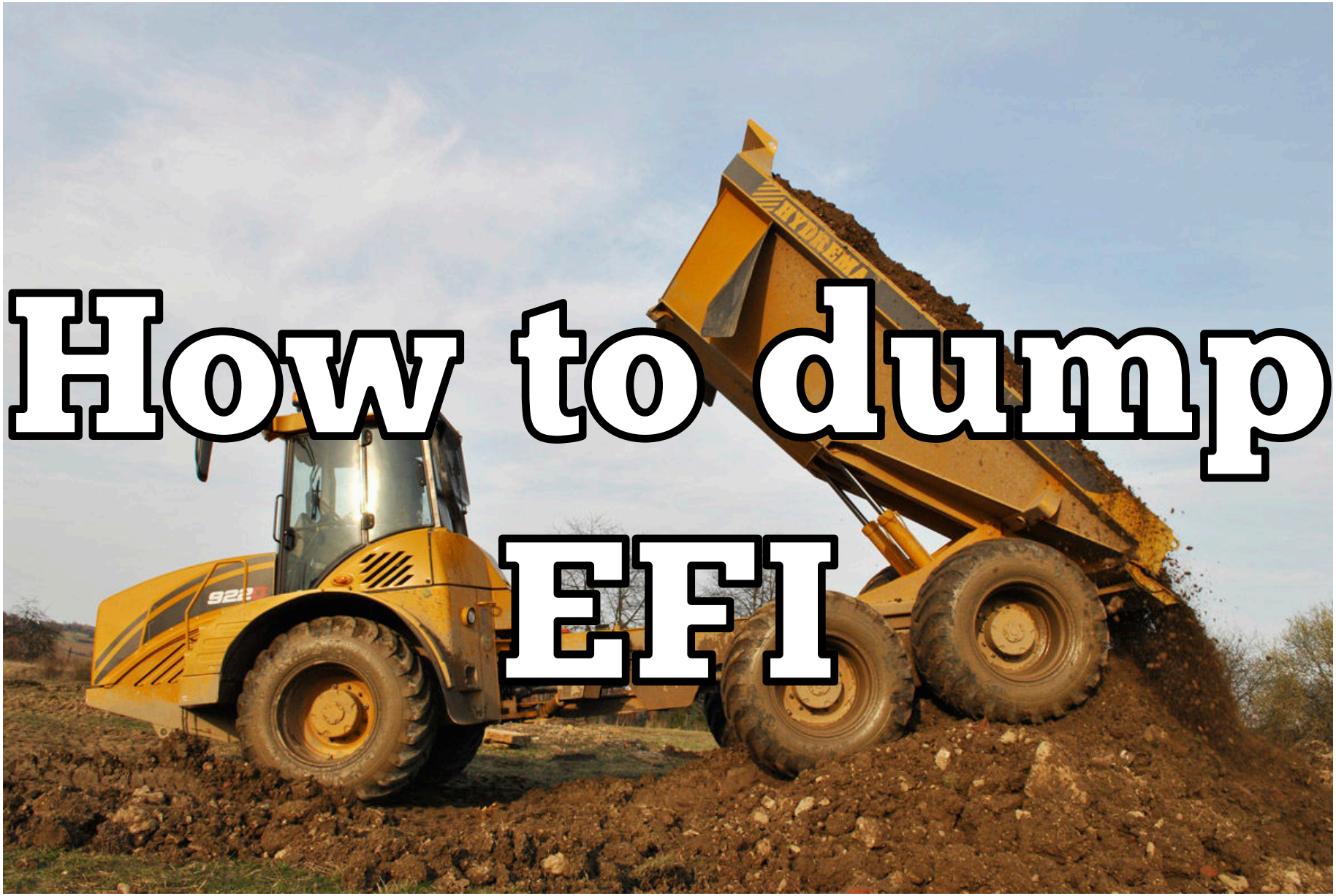



Mini 7,1

Mac Pro 6,1




2
1
SATA2
SATA2


How to dump
EFI

How to dump EFI

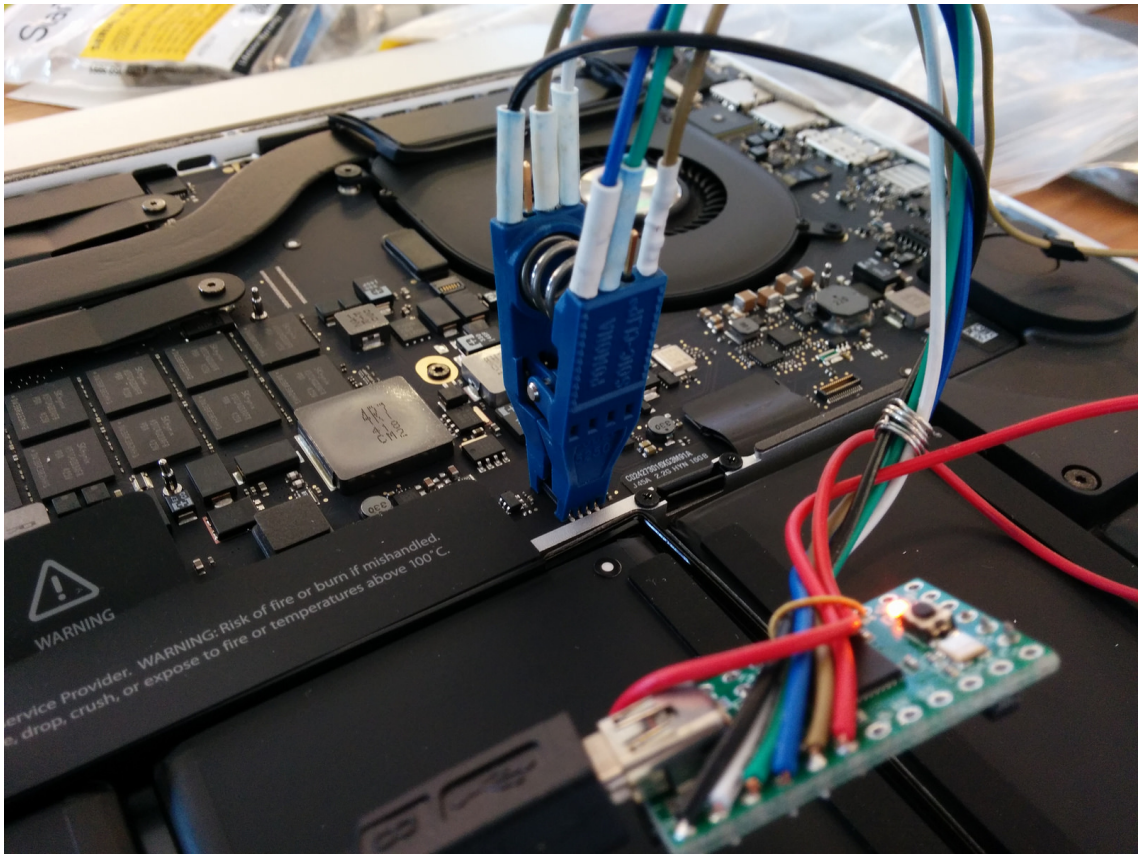
- Hardware
  - The best and most reliable way.
  - Trustable.
- Software
  - Possible if chip supported by flashrom.
  - Not (very) trustable.

Hardware

- Any SPI compatible programmer.
  - http://flashrom.org/Supported_programmers
- I use Trammell Hudson's SPI flasher.
  - https://trmm.net/SPI

Hardware

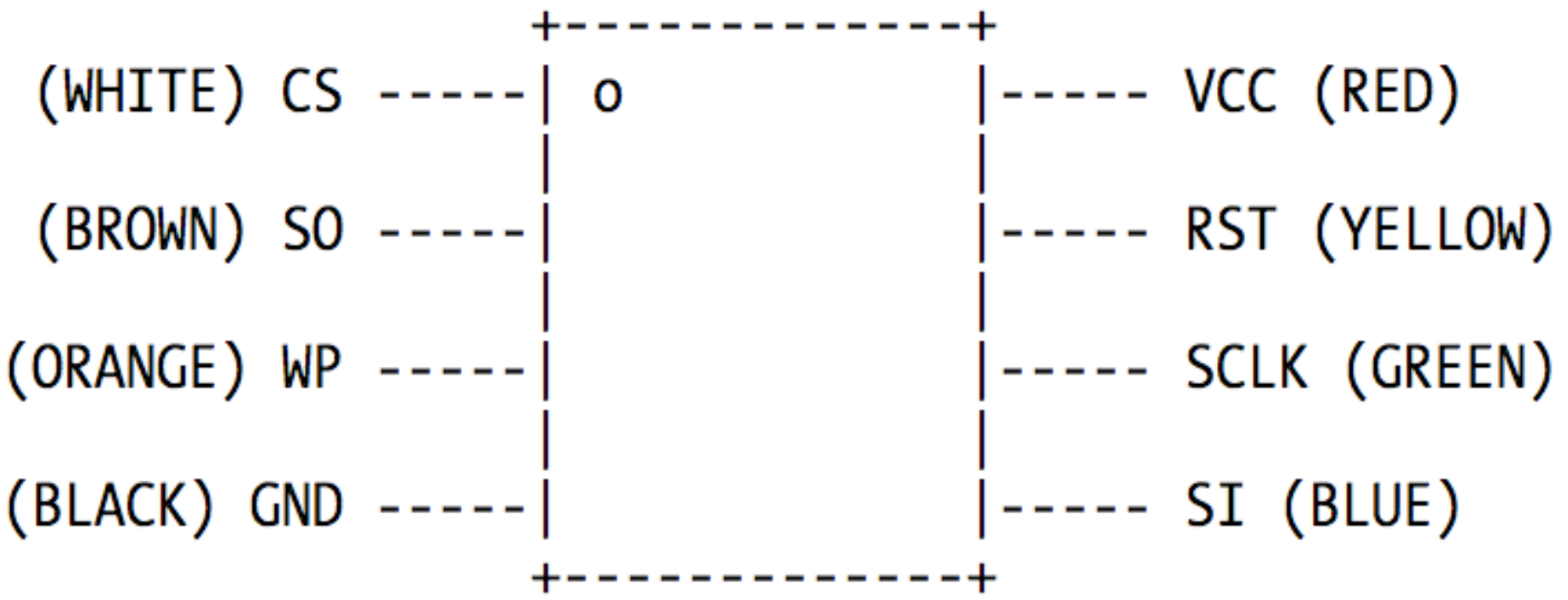
- Based on Teensy 2.0 or 3.x.



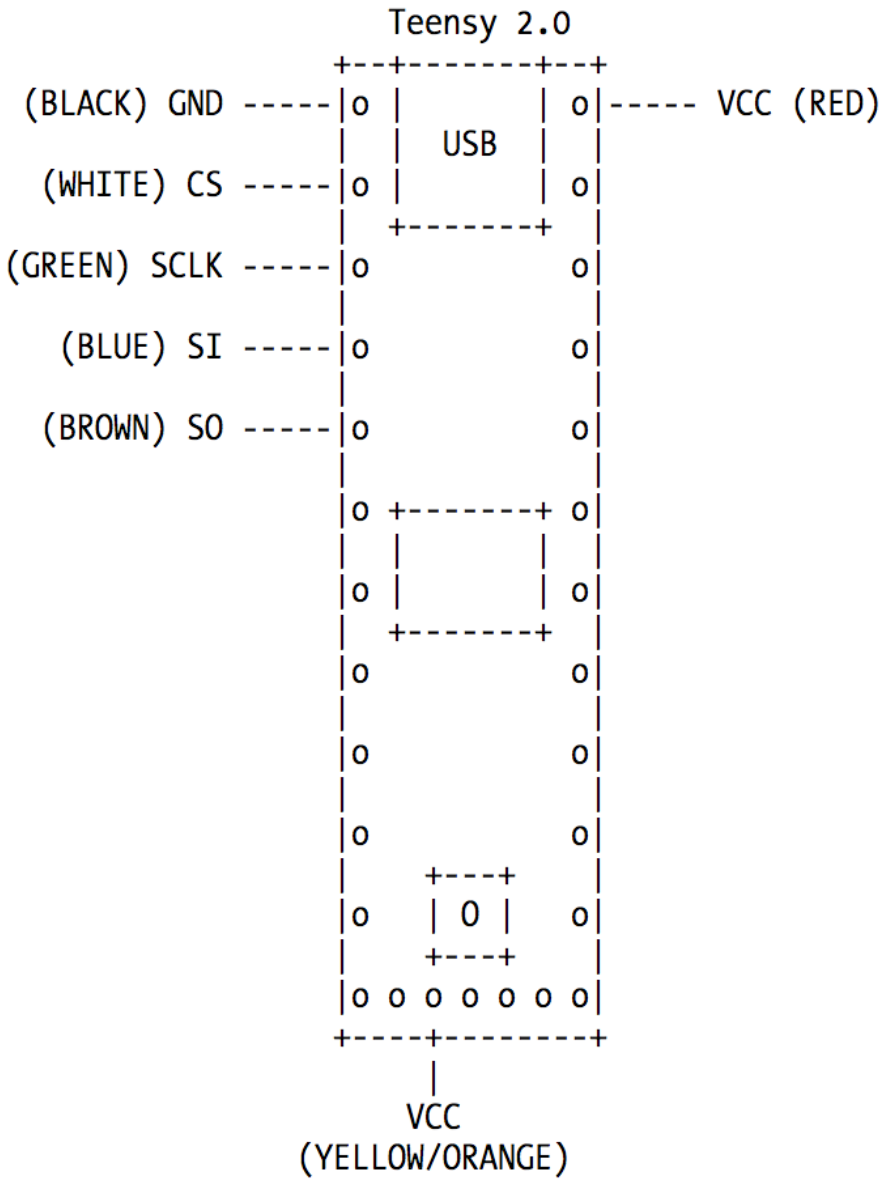
Hardware

- Easy to build.
- Cheap, ~ $30.
- Fast, dumps a 64Mbit flash in 8 mins.
- The Teensy 3 version is even faster.
- It just works!

Flash chip SPI pinout



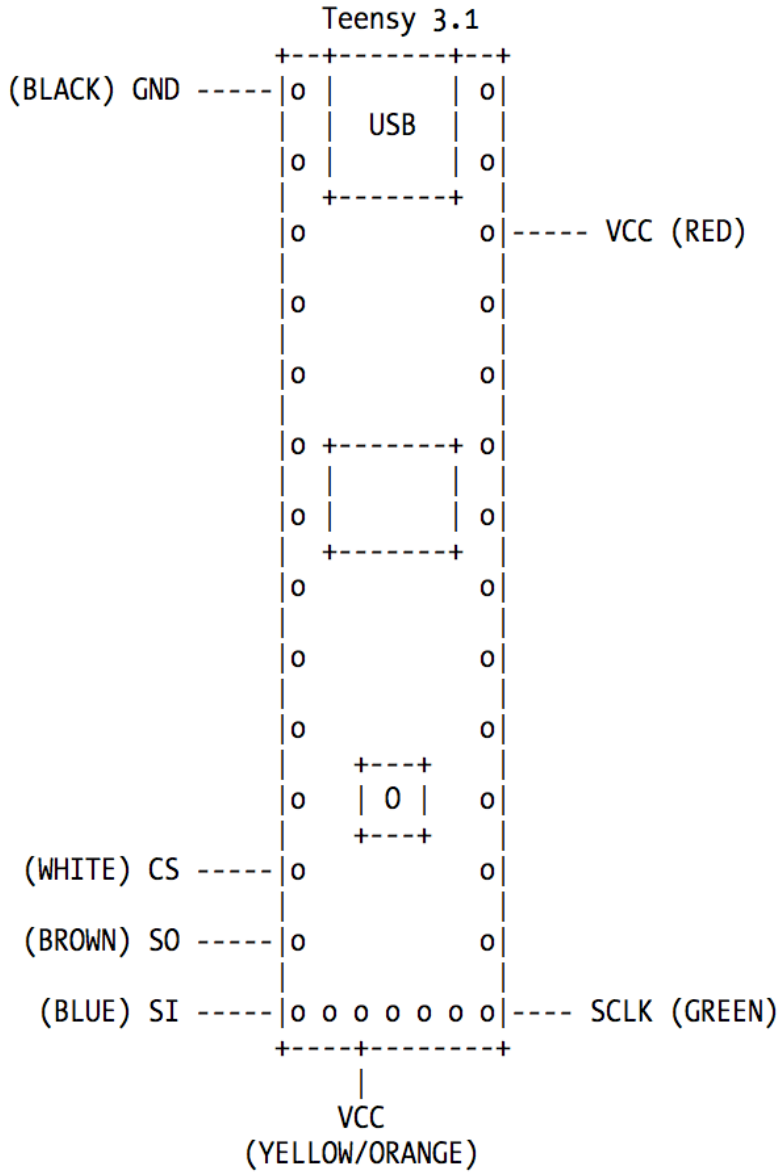
Teensy 2.0 pinout



Teensy 2.0 pinout

- Teensy 2 default voltage is 5v.
- Flash chips are 3.3.v.
- Requires voltage regulator MCP1825.
- https://www.pjrc.com/store/mcp1825.html

Teensy 3.1 pinout



Tips & Tricks

- Shunt WP and RST pins to VCC.
- Different SPI pins names
  - SCLK, SCK, CLK.
  - MOSI, SIMO, SDO, DO, DOUT, SO, MTSR.
  - MISO, SOMI, SDI, DI, DIN, SI, MRST.
  - SS, nCS, CS, CSB, CSN, nSS, STE, SYNC.

Hardware

- How to read entire flash

```
$ time lrx -X -O </dev/cu.usbmodem12341 >/dev/cu.usbmodem12341 Retina-09-07-2015-Secuinside.bin

lrx: ready to receive Retina-09-07-2015-Secuinside.bin
^Clrx: caught signal 2; exiting

real    6m58.773s
user    0m0.774s
sys 0m1.726s

$ ls -la Retina-09-07-2015-Secuinside.bin
-rw-------  1 reverser  staff  8388608 Jul  9 16:47 Retina-09-07-2015-Secuinside.bin
```

Hardware

- How to write entire 64MB flash

```
spi
>Help:
i: print ID
r: read 16 bytes from address - r0<enter>
R: read XX bytes from address - R0 10<enter>
d: dump to console
w: write enable interactive
e: erase sector interactive
u: upload
b: upload bios area only
1: flash first ffs
2: flash second ffs
3: flash third ffs
x: download

u
>0 800000
(exit to shell)
# pv new-efi.bin > /dev/cu.usbmodem12341
```

Hardware

- Linux works best to write the flash.
- Some issues with OS X version.
- pv or serial driver issues?
  - http://www.ivarch.com/programs/pv.shtml

Software

- Requirements
  - Flashrom
  - DirectHW.kext
- Rwmem by Trammell also works.
- Or readphysmem.

Software

- DarwinDumper.
- Contains binary versions of flashrom and DirectHW.kext.
- Kernel extension is not code signed.
- (Still) Whitelisted by Apple.

Software

- http://flashrom.org/Flashrom
- http://www.coreboot.org/DirectHW
- https://bitbucket.org/blackosx/darwindumper/downloads
- https://github.com/osresearch/rwmem
- https://github.com/gdbinit/readphysmem

```
sh-3.2# kextload DirectHW.kext/

sh-3.2# ./flashrom -r bios_dump.bin -V -p internal
flashrom v0.9.7-r1711 on Darwin 14.4.0 (x86_64)
flashrom is free software, get the source code at http://www.flashrom.org

flashrom was built with libpci 3.1.7, LLVM Clang 6.0 (clang-600.0.56), little endian
Command line (5 args): ./flashrom -r bios_dump.bin -V -p internal
(...)
Found chipset "Intel HM77" with PCI ID 8086:1e57.
This chipset is marked as untested. If you are using an up-to-date version
of flashrom *and* were (not) able to successfully update your firmware with it,
then please email a report to flashrom@flashrom.org including a verbose (-V) log.
Thank you!
```

```
SPI Read Configuration: prefetching disabled, caching enabled, OK.
The following protocols are supported: FWH, SPI.
(..)
Probing for Micron/Numonyx/ST N25Q064..3E, 8192 kB: probe_spi_rdid_generic: id1 0x20, id2 0xba17
Found Micron/Numonyx/ST flash chip "N25Q064..3E" (8192 kB, SPI) at physical address 0xff800000.
Chip status register is 0x00.
Chip status register: Status Register Write Disable (SRWD, SRP, ...) is not set
Chip status register: Block Protect 3 (BP3) is not set
Chip status register: Top/Bottom (TB) is top
Chip status register: Block Protect 2 (BP2) is not set
Chip status register: Block Protect 1 (BP1) is not set
Chip status register: Block Protect 0 (BP0) is not set
Chip status register: Write Enable Latch (WEL) is not set
Chip status register: Write In Progress (WIP/BUSY) is not set
(...)
```

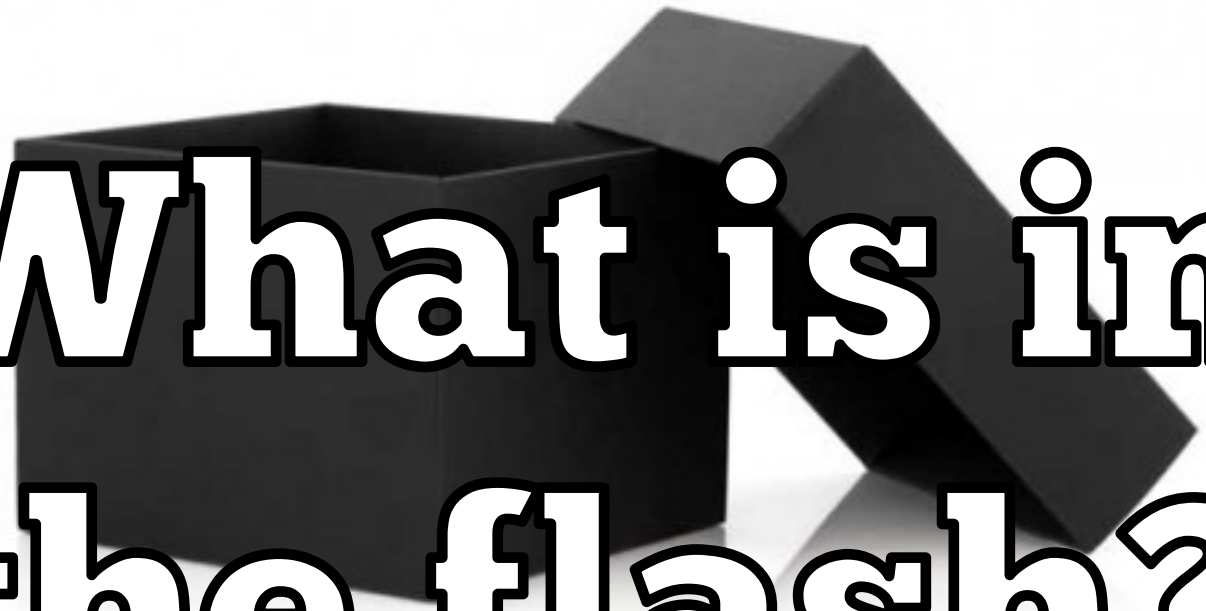
```
Found Micron/Numonyx/ST flash chip "N25Q064..3E" (8192 kB, SPI).
This chip may contain one-time programmable memory. flashrom cannot read
and may never be able to write it, hence it may not be able to completely
clone the contents of this chip (see man page for details).
Reading flash... done.
Restoring MMIO space at 0x10ae098a0
Restoring PCI config space for 00:1f:0 reg 0xdc

sh-3.2# ls -la bios_dump.bin
-rw-r--r--  1 root  staff  8388608 Jul  8 01:23 bios_dump.bin
```

Software

- AppleHWAccess.kext.
- readphysmem utility.
- Can read bios without external kext.
- Default on Mavericks and Yosemite.
- Not anymore on El Capitan.

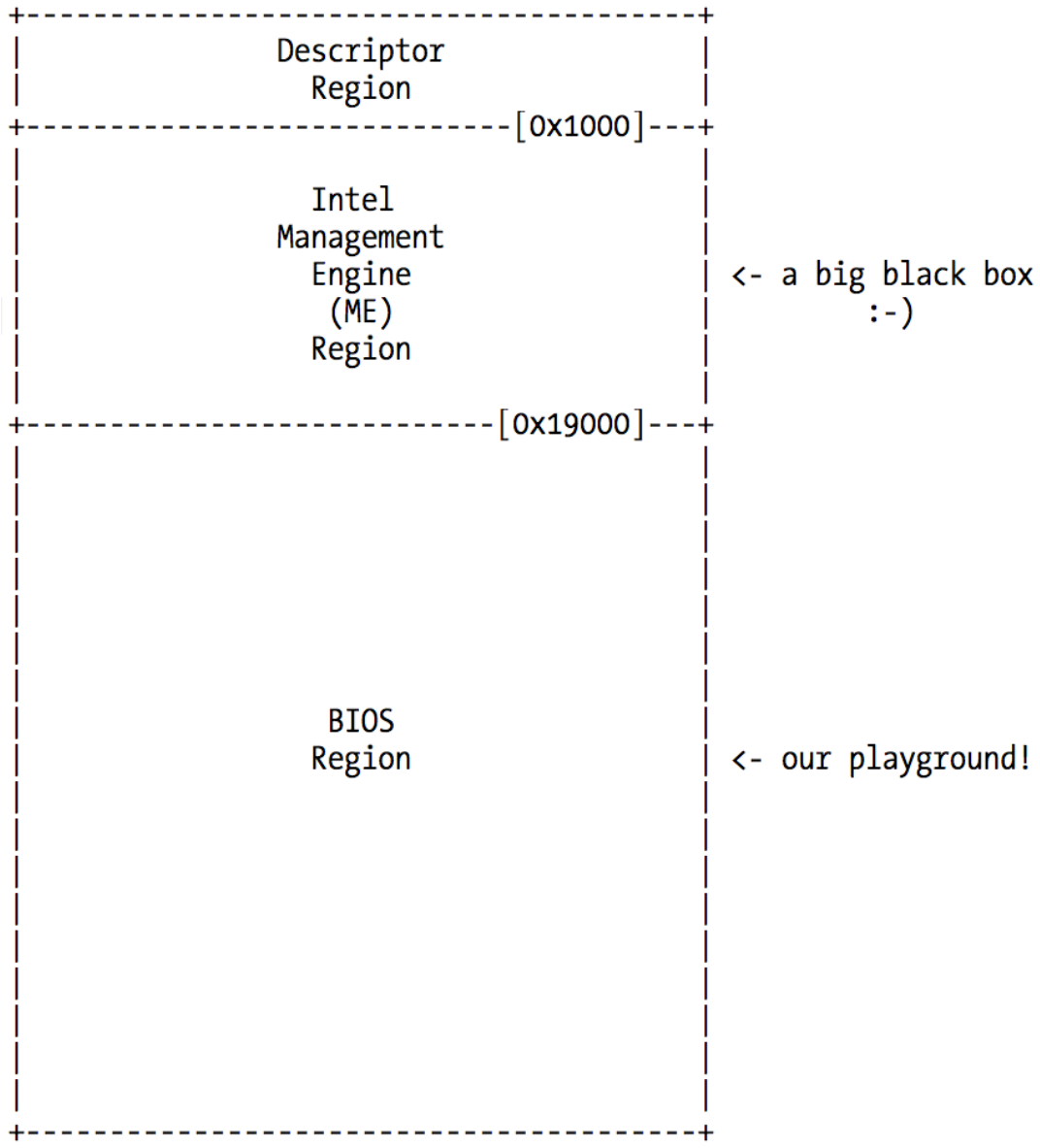
Software

- Good enough to play around.
- Mostly useless to chase (U)EFI rootkits.
- Unless it is made by HackingTeam.
  - Their version makes no attempt to hide itself from software dumps.

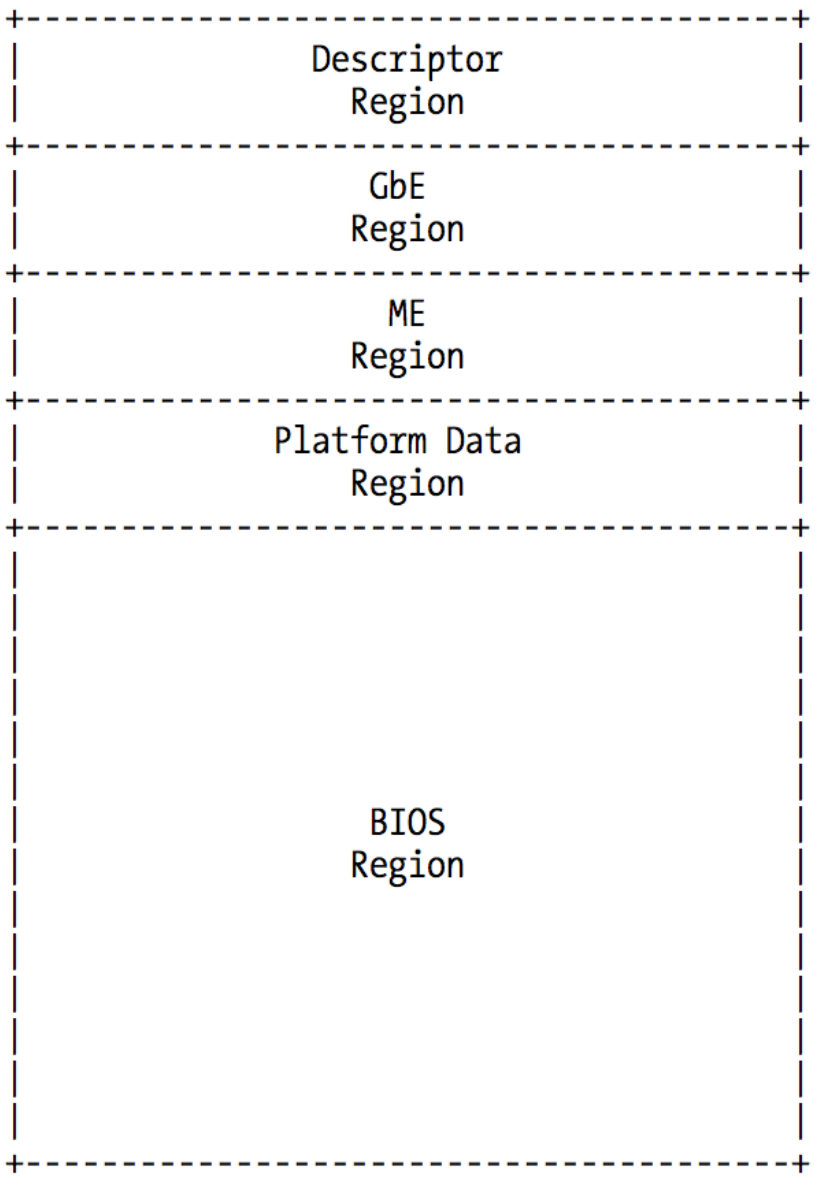


What is in the flash?

What's in the flash



What's in the flash



What's in the flash

UEFITool 0.20.6 - Retina-08-07-2015-after-SyScan-dump-and-EFI-update-09.bin

Structure

Name	Action	Type	Subtype	Text
Intel image		Image	Intel	
Descriptor region		Region	Descriptor	
ME/TXE region		Region	ME/TXE	
BIOS region		Region	BIOS	
7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFS0
7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFS0
7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFS0
E3B980A9-5FE3-48E5-9B92-2798385A9027		Volume	Unknown	AppleCRC32 AppleFS0
7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFS0
7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFS0
153D2197-29BD-44DC-AC59-887F70E41A6B		Volume	Unknown	AppleCRC32
153D2197-29BD-44DC-AC59-887F70E41A6B		Volume	Unknown	AppleCRC32
FFF12B8D-7696-4C8B-A985-2747075B4F50		Volume	Unknown	
7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFS0
7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFS0
04ADEEAD-61FF-4D31-B6BA-64F8BF901F5A		Volume	FFSv2	AppleCRC32 AppleFS0
04ADEEAD-61FF-4D31-B6BA-64F8BF901F5A		Volume	FFSv2	AppleFS0

Information

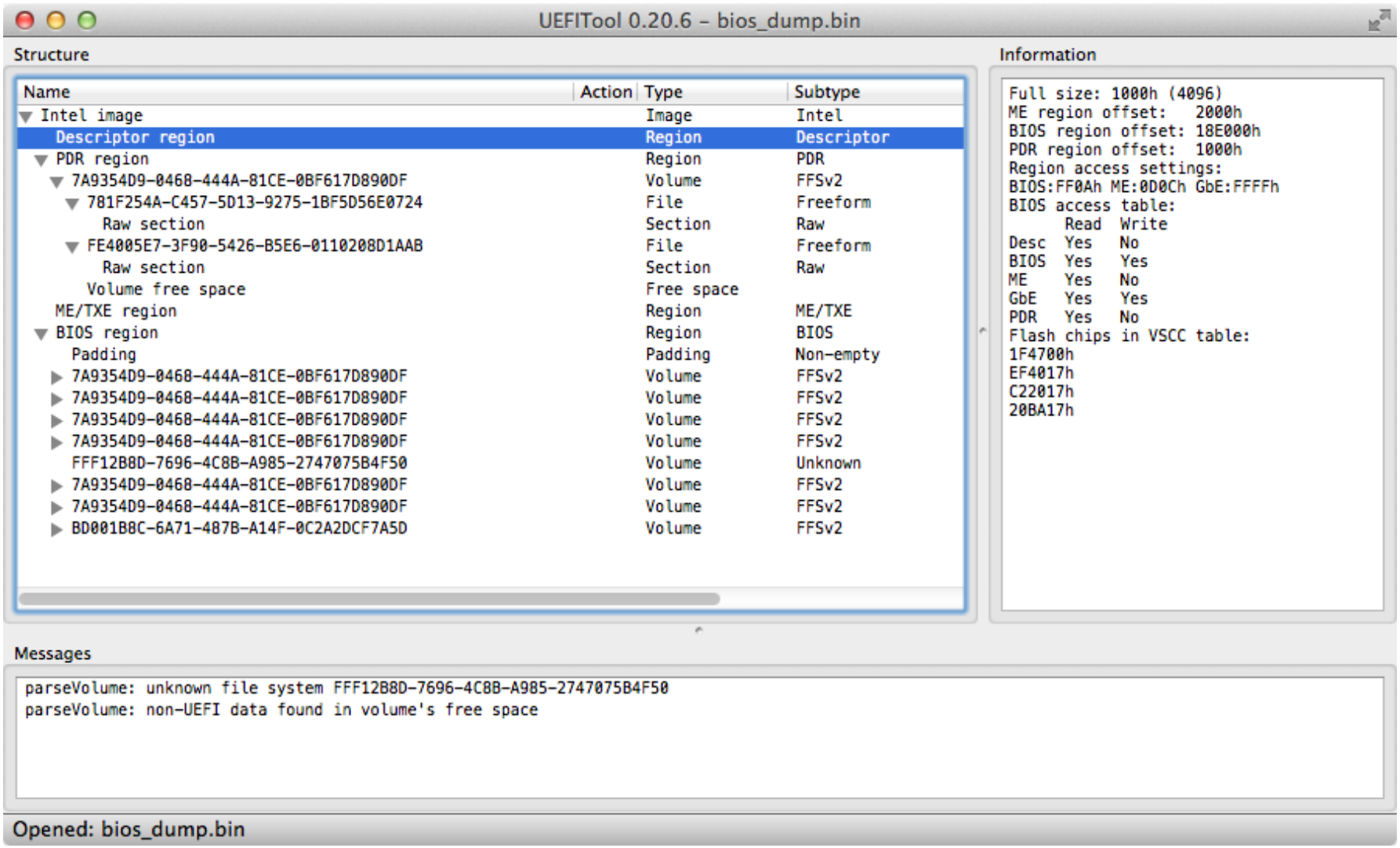
```
Full size: 1000h (4096)
ME region offset:   1000h
BIOS region offset: 190000h
Region access settings:
BIOS:FFFFh ME:FFFFh GbE:FFFFh
BIOS access table:
      Read  Write
Desc  Yes   Yes
BIOS  Yes   Yes
ME    Yes   Yes
GbE   Yes   Yes
PDR   Yes   Yes
Flash chips in VSCC table:
1F4700h
EF4017h
C22017h
BF254Bh
20BA17h
```

Messages

```
parseVolume: unknown file system E3B980A9-5FE3-48E5-9B92-2798385A9027
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
```

Opened: Retina-08-07-2015-after-SyScan-dump-and-EFI-update-09.bin

What's in the flash



Descriptor region

- Location of other regions.
- Access permissions.
  - OS/BIOS shouldn't access ME region.
- VSCC configures ME flash access.

Intel ME region

- A CPU inside your CPU ☺.
- Runs Java.
- Can be active with system powered off.
- Out of band network access!
- No access from BIOS and OS.

Intel ME region

- Mostly a blackbox.
- Three presentations by Igor Skochinsky.
- Definitely requires more research!
- Unpacker
  - http://io.smashthestack.org/me/

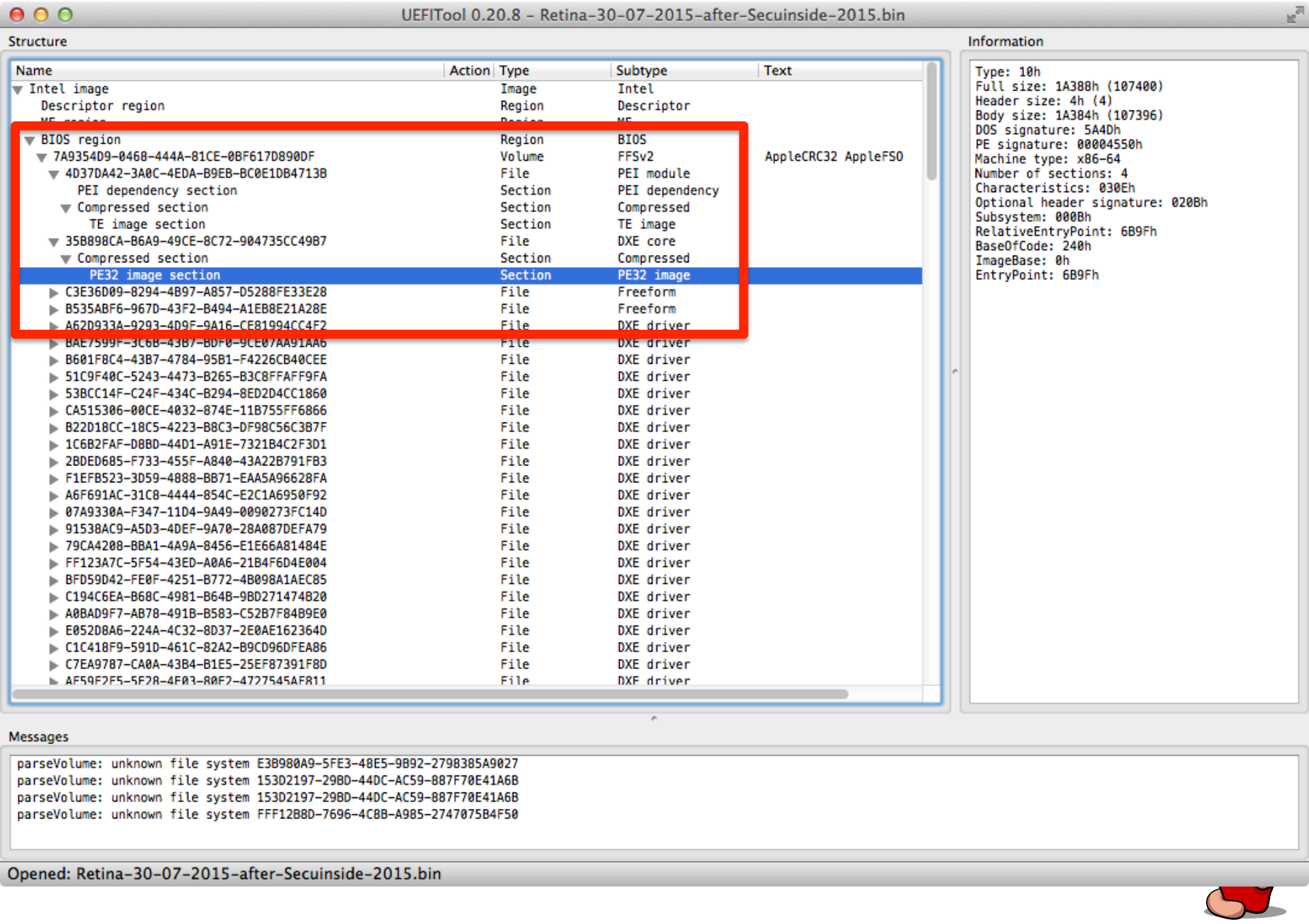
Intel ME region

- Rootkit in your laptop: Hidden code in your chipset and how to discover what exactly it does
- Intel ME Secrets
- Intel ME: Two years later
- https://github.com/skochinsky/papers

BIOS region

- Contains
  - EFI binaries for different phases.
  - NVRAM.
  - Microcode (not for some models).
- Each on its own firmware volume (FVH).

```
+----------------------------[0x19000]---+
|  7A9354D9-0468-444A-81CE-0BF617D890DF  |
+----------------------------------------+
|  7A9354D9-0468-444A-81CE-0BF617D890DF  |
+----------------------------------------+
|  7A9354D9-0468-444A-81CE-0BF617D890DF  |
+----------------------------------------+
|  E3B980A9-5FE3-48E5-9B92-2798385A9027  |
+----------------------------------------+
|  7A9354D9-0468-444A-81CE-0BF617D890DF  |
+----------------------------------------+
|  7A9354D9-0468-444A-81CE-0BF617D890DF  |
+----------------------------------------+
|  153D2197-29BD-44DC-AC59-887F70E41A6B  | <- Microcode
+----------------------------------------+
|  153D2197-29BD-44DC-AC59-887F70E41A6B  | <- Microcode
+----------------------------------------+
|  FFF12B8D-7696-4C8B-A985-2747075B4F50  | <- NVRAM
+----------------------------------------+
|  7A9354D9-0468-444A-81CE-0BF617D890DF  |
+----------------------------------------+
|  7A9354D9-0468-444A-81CE-0BF617D890DF  |
+----------------------------------------+
|  04ADEEAD-61FF-4D31-B6BA-64F8BF901F5A  | <- Boot Volume
+----------------------------------------+
|  04ADEEAD-61FF-4D31-B6BA-64F8BF901F5A  | <- Boot Volume
+----------------------------------------+
```


UEFITool 0.20.8 - Retina-30-07-2015-after-Secuinside-2015.bin
Structure
Name
Action
Type
Subtype
Text
Intel image
Image
Intel
Descriptor region
Region
Descriptor
BIOS region
Region
BIOS
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
AppleCRC32 AppleFSO
4D37DA42-3A0C-4EDA-B9EB-BC0E1DB4713B
File
PEI module
PEI dependency section
Section
PEI dependency
Compressed section
Section
Compressed
TE image section
Section
TE image
35B898CA-B6A9-49CE-8C72-904735CC49B7
File
DXE core
Compressed section
Section
Compressed
PE32 image section
Section
PE32 image
C3E36D09-8294-4B97-A857-D5288FE33E28
File
Freeform
B535ABF6-967D-43F2-B494-A1EB8E21A28E
File
Freeform
A62D933A-9293-4D9F-9A16-CE81994CC4F2
File
DXE driver
BAE7599F-3C6B-43B7-BDF0-9CE07AA91AA6
File
DXE driver
B601F8C4-43B7-4784-95B1-F4226CB40CEE
File
DXE driver
51C9F40C-5243-4473-B265-B3C8FFAFF9FA
File
DXE driver
53BCC14F-C24F-434C-B294-8ED2D4CC1860
File
DXE driver
CA515306-00CE-4032-874E-11B755FF6866
File
DXE driver
B22D18CC-18C5-4223-B8C3-DF98C56C3B7F
File
DXE driver
1C6B2FAF-D8BD-44D1-A91E-7321B4C2F3D1
File
DXE driver
2BDED685-F733-455F-A840-43A22B791FB3
File
DXE driver
F1EFB523-3D59-4888-BB71-EAA5A96628FA
File
DXE driver
A6F691AC-31C8-4444-854C-E2C1A6950F92
File
DXE driver
07A9330A-F347-11D4-9A49-0090273FC14D
File
DXE driver
91538AC9-A5D3-4DEF-9A70-28A087DEFA79
File
DXE driver
79CA4208-BBA1-4A9A-8456-E1E66A81484E
File
DXE driver
FF123A7C-5F54-43ED-A0A6-21B4F6D4E004
File
DXE driver
BFD59D42-FE0F-4251-B772-4B098A1AEC85
File
DXE driver
C194C6EA-B68C-4981-B64B-9BD271474B20
File
DXE driver
A0BAD9F7-AB78-491B-B583-C52B7F84B9E0
File
DXE driver
E052D8A6-224A-4C32-8D37-2E0AE162364D
File
DXE driver
C1C418F9-591D-461C-82A2-B9CD96DFEA86
File
DXE driver
C7EA9787-CA0A-43B4-B1E5-25EF87391F8D
File
DXE driver
Information
Type: 10h
Full size: 1A388h (107400)
Header size: 4h (4)
Body size: 1A384h (107396)
DOS signature: 5A4Dh
PE signature: 00004550h
Machine type: x86-64
Number of sections: 4
Characteristics: 030Eh
Optional header signature: 020Bh
Subsystem: 000Bh
RelativeEntryPoint: 6B9Fh
BaseOfCode: 240h
ImageBase: 0h
EntryPoint: 6B9Fh
Messages
parseVolume: unknown file system E3B980A9-5FE3-48E5-9B92-2798385A9027
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
Opened: Retina-30-07-2015-after-Secuinside-2015.bin

BIOS region

- Everything is labeled with a GUID.
- No filenames.
- Many GUID can be found in EFI specs.
- Others are vendor specific/private.
- Google and luck are your friends!

Branch: **master** ▾ **ida-efiutils** / **efiguids_ami.py**

snare on May 28, 2013 Anon contribution of GUIDs

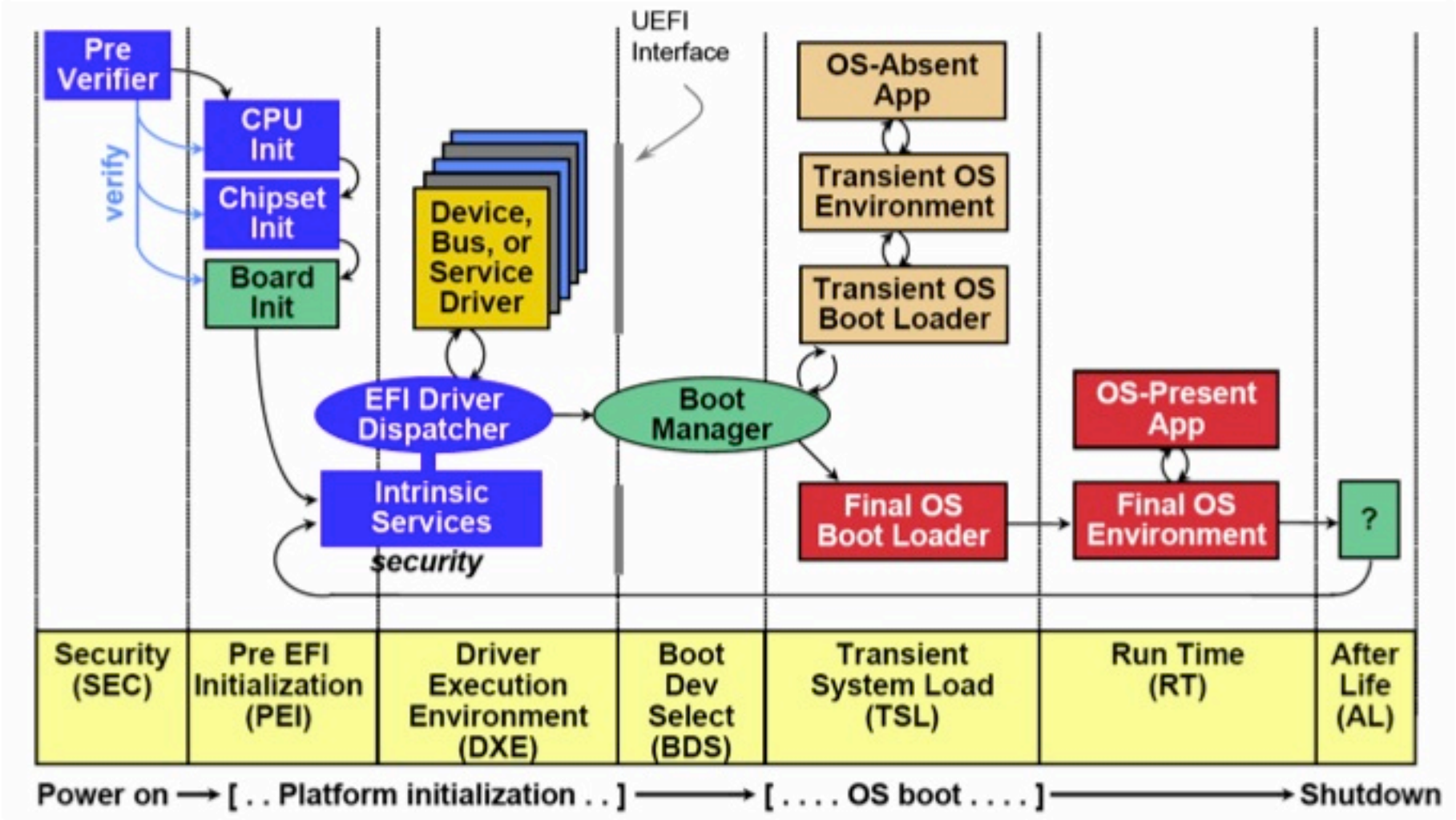
1 contributor

911 lines (906 sloc) | 96.802 kB | Raw | Blame | History

```
"""
efiguids_ami.py

GUIDs found in the AMI source

See the following URL for more info and the latest version:
https://github.com/snarez/ida-efiutils

"""

GUIDs = {
'ACOUSTIC_SETUP_PROTOCOL_GUID':[0xc1d7859d, 0x5719, 0x46c3, 0xa2, 0x98, 0xd0, 0x71, 0xe3, 0x2, 0x64, 0xd1],
'ADD_BOOT_OPTION_GUID':[0x19d96d3f, 0x6a6a, 0x47d2, 0xb1, 0x95, 0x7b, 0x24, 0x32, 0xda, 0x3b, 0xe2],
'ADVANCED_FORM_SET_GUID':[0xe14f04fa, 0x8706, 0x4353, 0x92, 0xf2, 0x9c, 0x24, 0x24, 0x74, 0x6f, 0x9f],
'AHCI_BUS_INIT_PROTOCOL_GUID':[0xB2FA4764, 0x3B6E, 0x43D3, 0x91, 0xDF, 0x87, 0xD1, 0x5A, 0x3E, 0x56, 0x68],
'AHCI_SMM_PROTOCOL_GUID':[0xB2FA5764, 0x3B6E, 0x43D3, 0x91, 0xDF, 0x87, 0xD1, 0x5A, 0x3E, 0x56, 0x68],
'AMICSM_PCIBUSNUM_XLAT_PROTOCOL_GUID':[0xcb5c54c0, 0x230d, 0x43db, 0x92, 0x2c, 0x24, 0xd3, 0x4f, 0x8c, 0x91, 0x5c],
'AMITSESETUP_GUID':[0xc811fa38, 0x42c8, 0x4579, 0xa9, 0xbb, 0x60, 0xe9, 0x4e, 0xdd, 0xfb, 0x34],
'AMITSE_ADMIN_PASSWORD_VALID_GUID':[0x541d5a75, 0x95ee, 0x43c7, 0x9e, 0x5d, 0x23, 0x94, 0xdc, 0x48, 0x62, 0x49],
'AMITSE_AFTER_FIRST_BOOT_OPTION_GUID':[0xC48D651C, 0x9D0E, 0x4ce7, 0xAD, 0x39, 0xED, 0xD1, 0xAB, 0x83, 0x6B, 0x30],
'AMITSE_BOOT_ORDER_CHANGE_GUID':[0x1b6bc809, 0xc986, 0x4937, 0x93, 0x4f, 0x1e, 0xa5, 0x86, 0x22, 0xfe, 0x50],
'AMITSE_DRIVER_HEALTH_CTRL_GUID':[0x58279c2d, 0xfb19, 0x466e, 0xb4, 0x2e, 0xcd, 0x43, 0x70, 0x16, 0xdc, 0x25],
```

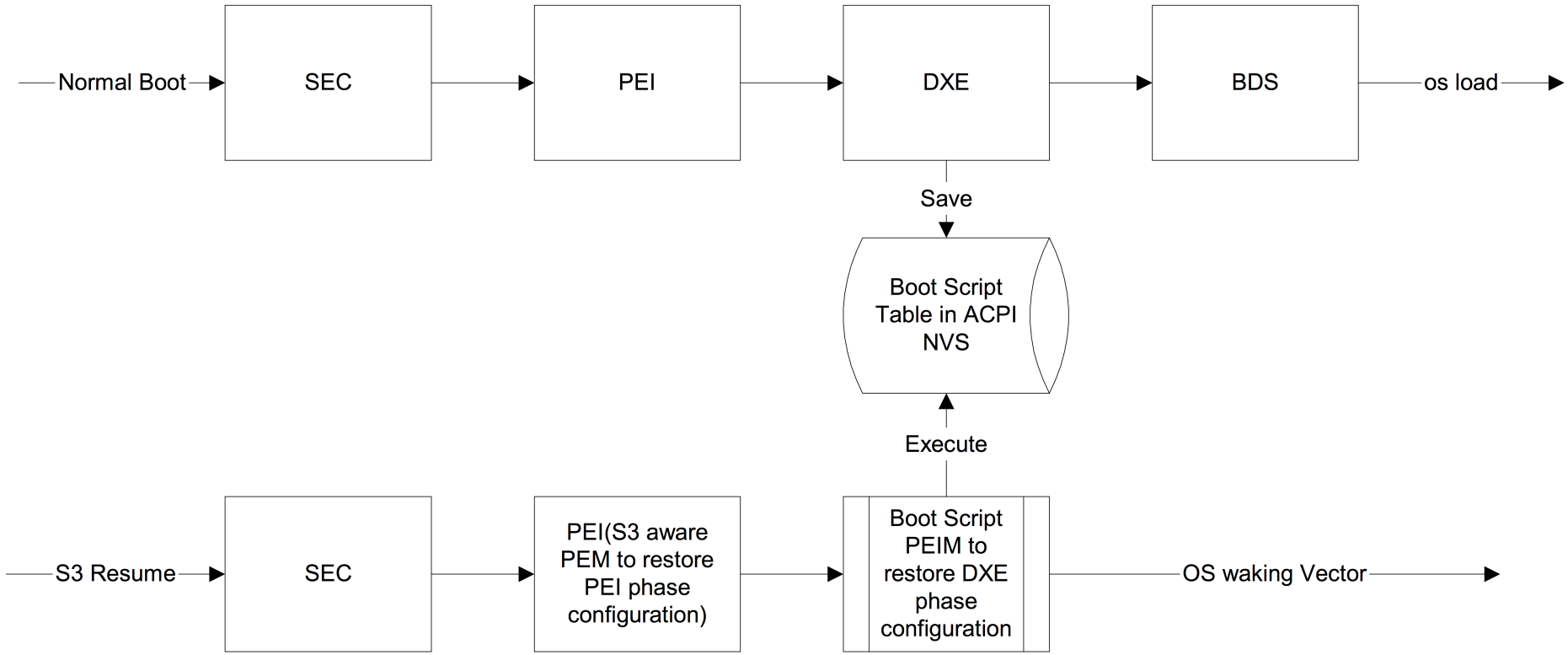

EFI
Boot Flow

PI Boot Phases



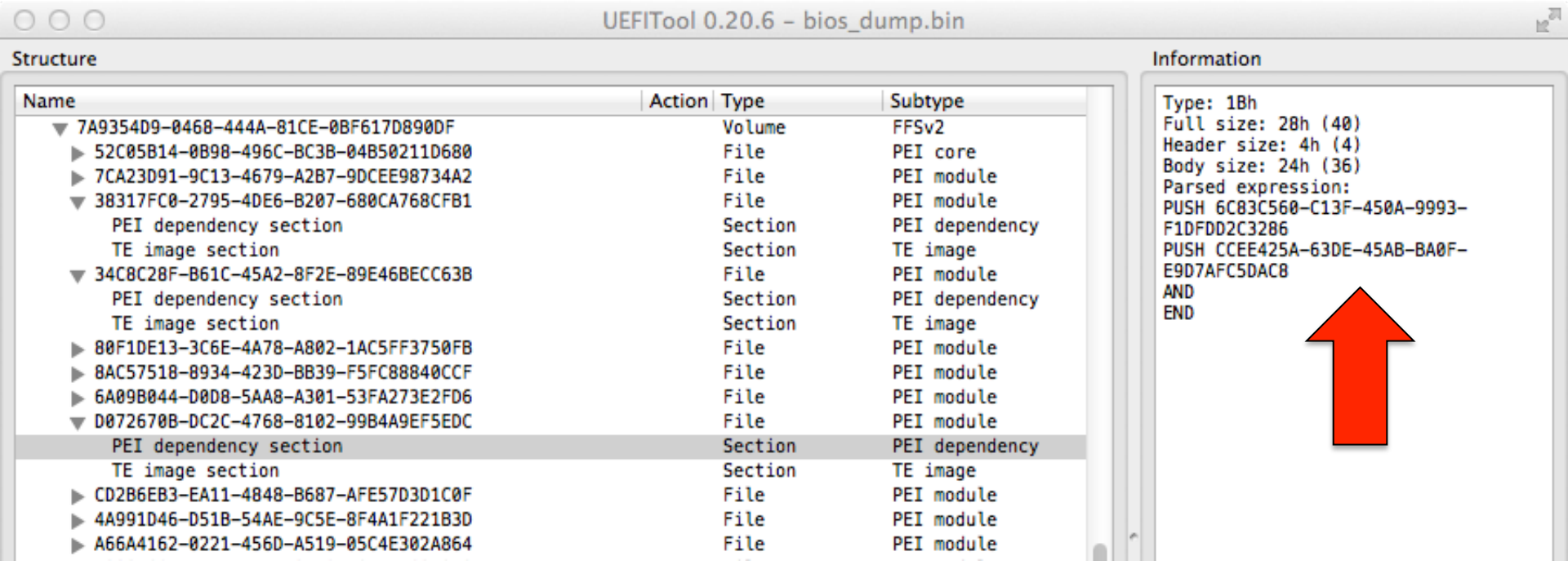
EFI Boot Phases

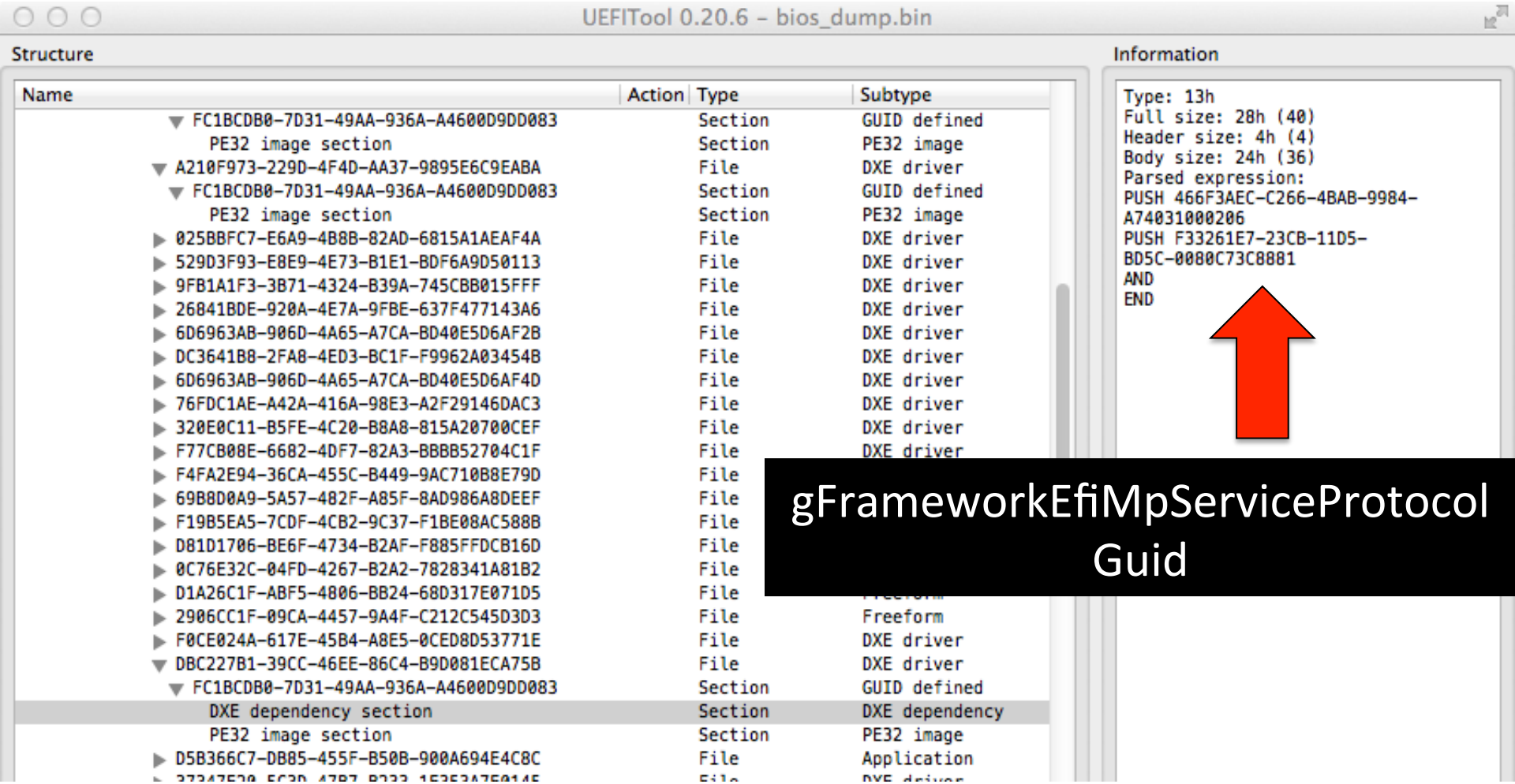
- Different initialization phases.
- Make resources available to next phase.
- Memory for example.

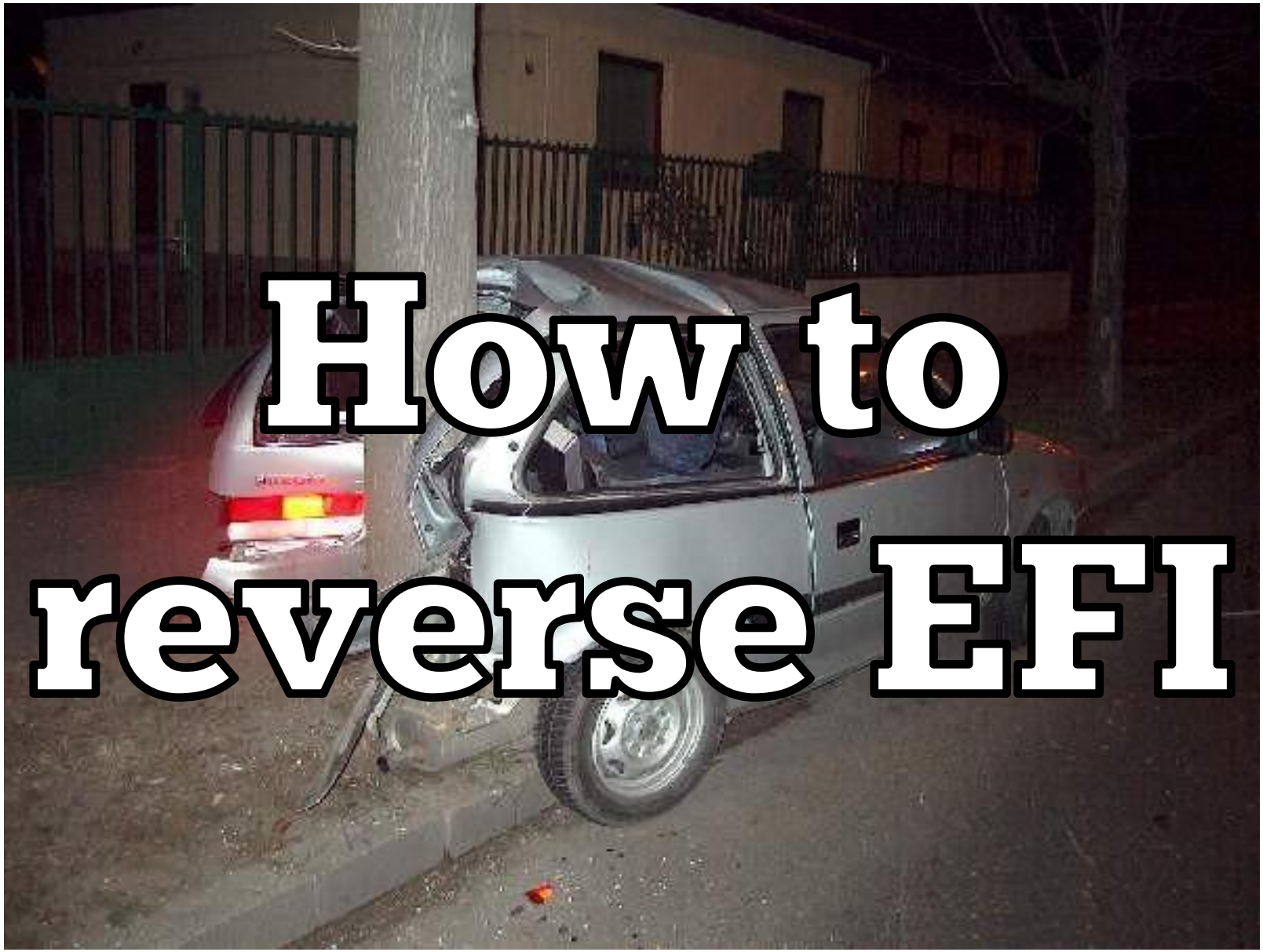

Normal Boot
SEC
PEI
DXE
BDS
os load
Save
Boot Script Table in ACPI NVS
Execute
S3 Resume
SEC
PEI(S3 aware PEM to restore PEI phase configuration)
Boot Script PEIM to restore DXE phase configuration
OS waking Vector

The PEI/DXE Dispatchers

- PEI and DXE phases have a dispatcher.
- Guarantees dependencies and load order.
- Dependency expressions.
- Available as a section.


UEFITool 0.20.6 - bios_dump.bin
Structure
Information
Name
Action
Type
Subtype
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
52C05B14-0B98-496C-BC3B-04B50211D680
File
PEI core
7CA23D91-9C13-4679-A2B7-9DCEE98734A2
File
PEI module
38317FC0-2795-4DE6-B207-680CA768CFB1
File
PEI module
PEI dependency section
Section
PEI dependency
TE image section
Section
TE image
34C8C28F-B61C-45A2-8F2E-89E46BECC63B
File
PEI module
PEI dependency section
Section
PEI dependency
TE image section
Section
TE image
80F1DE13-3C6E-4A78-A802-1AC5FF3750FB
File
PEI module
8AC57518-8934-423D-BB39-F5FC88840CCF
File
PEI module
6A09B044-D0D8-5AA8-A301-53FA273E2FD6
File
PEI module
D072670B-DC2C-4768-8102-99B4A9EF5EDC
File
PEI module
PEI dependency section
Section
PEI dependency
TE image section
Section
TE image
CD2B6EB3-EA11-4848-B687-AFE57D3D1C0F
File
PEI module
4A991D46-D51B-54AE-9C5E-8F4A1F221B3D
File
PEI module
A66A4162-0221-456D-A519-05C4E302A864
File
PEI module
Type: 1Bh
Full size: 28h (40)
Header size: 4h (4)
Body size: 24h (36)
Parsed expression:
PUSH 6C83C560-C13F-450A-9993-F1DFDD2C3286
PUSH CCEE425A-63DE-45AB-BA0F-E9D7AFC5DAC8
AND
END


UEFITool 0.20.6 - bios_dump.bin
Structure
Information
Name
Action
Type
Subtype
FC1BCDB0-7D31-49AA-936A-A4600D9DD083 Section GUID defined
PE32 image section Section PE32 image
A210F973-229D-4F4D-AA37-9895E6C9EABA File DXE driver
FC1BCDB0-7D31-49AA-936A-A4600D9DD083 Section GUID defined
PE32 image section Section PE32 image
025BBFC7-E6A9-4B8B-82AD-6815A1AEAF4A File DXE driver
529D3F93-E8E9-4E73-B1E1-BDF6A9D50113 File DXE driver
9FB1A1F3-3B71-4324-B39A-745CBB015FFF File DXE driver
26841BDE-920A-4E7A-9FBE-637F477143A6 File DXE driver
6D6963AB-906D-4A65-A7CA-BD40E5D6AF2B File DXE driver
DC3641B8-2FA8-4ED3-BC1F-F9962A03454B File DXE driver
6D6963AB-906D-4A65-A7CA-BD40E5D6AF4D File DXE driver
76FDC1AE-A42A-416A-98E3-A2F29146DAC3 File DXE driver
320E0C11-B5FE-4C20-B8A8-815A20700CEF File DXE driver
F77CB08E-6682-4DF7-82A3-BBBB52704C1F File DXE driver
F4FA2E94-36CA-455C-B449-9AC710B8E79D File
69B8D0A9-5A57-482F-A85F-8AD986A8DEEF File
F19B5EA5-7CDF-4CB2-9C37-F1BE08AC588B File
D81D1706-BE6F-4734-B2AF-F885FFDCB16D File
0C76E32C-04FD-4267-B2A2-7828341A81B2 File
D1A26C1F-ABF5-4806-BB24-68D317E071D5 File
2906CC1F-09CA-4457-9A4F-C212C545D3D3 File Freeform
F0CE024A-617E-45B4-A8E5-0CED8D53771E File DXE driver
DBC227B1-39CC-46EE-86C4-B9D081ECA75B File DXE driver
FC1BCDB0-7D31-49AA-936A-A4600D9DD083 Section GUID defined
DXE dependency section Section DXE dependency
PE32 image section Section PE32 image
D5B366C7-DB85-455F-B50B-900A694E4C8C File Application
Type: 13h
Full size: 28h (40)
Header size: 4h (4)
Body size: 24h (36)
Parsed expression:
PUSH 466F3AEC-C266-4BAB-9984-A74031000206
PUSH F33261E7-23CB-11D5-BD5C-0080C73C8881
AND
END
gFrameworkEfiMpServiceProtocol Guid


How to
reverse EFI

Tools

- UEFITool and UEFIExtract
  - https://github.com/LongSoft/UEFITool
- Snare's IDA EFI Utils
  - https://github.com/snare/ida-efiutils/
- UEFI Firmware parser
  - https://github.com/snare/ida-efiutils/
- CHIPSEC
  - https://github.com/chipsec/chipsec

EFI file types

- Two executable file types.
- PE32/PE32+ (as in Windows).
- TE – Terse Executable.
- 16/32/64 bit code, depending on phase.

TE file format

- TE is just a stripped version of PE.
- Unnecessary PE headers are removed.
- To save space.
- Used by SEC and PEI phase binaries.

TE file format

- IDA unable to correctly disassemble.
- Fails to parse the TE headers.
- Afaik, still not fixed in 6.8.
- Solution is to build your own TE loader.
- https://github.com/gdbinit/TELoader


Where is
libc?

EFI Services

- No standard libraries to link against.
- Instead there are services.
- Basic functions made available on each phase.
- Access via function pointers.

EFI Services

```
typedef struct _EFI_PEI_SERVICES {
  EFI_TABLE_HEADER                Hdr;
  EFI_PEI_INSTALL_PPI             InstallPpi;       <----.
  EFI_PEI_REINSTALL_PPI           ReInstallPpi;           |
  EFI_PEI_LOCATE_PPI              LocatePpi;              |
  EFI_PEI_NOTIFY_PPI              NotifyPpi;              |
  EFI_PEI_GET_BOOT_MODE           GetBootMode;            |
  EFI_PEI_SET_BOOT_MODE           SetBootMode;            |
  EFI_PEI_GET_HOB_LIST            GetHobList;             |
  EFI_PEI_CREATE_HOB              CreateHob;              |
  EFI_PEI_FFS_FIND_NEXT_VOLUME    FfsFindNextVolume;      |
  EFI_PEI_FFS_FIND_NEXT_FILE      FfsFindNextFile;        |
  EFI_PEI_FFS_FIND_SECTION_DATA   FfsFindSectionData;     |
  EFI_PEI_INSTALL_PEI_MEMORY      InstallPeiMemory;       |
  EFI_PEI_ALLOCATE_PAGES          AllocatePages;          |
  EFI_PEI_ALLOCATE_POOL           AllocatePool;           |
  EFI_PEI_COPY_MEM                CopyMem;                |
  EFI_PEI_SET_MEM                 CopyMem;                |
  EFI_PEI_REPORT_STATUS_CODE      CopyMem;                |
  EFI_PEI_RESET_SYSTEM            ResetSystem;            |
  EFI_PEI_CPU_IO_PPI              CpuIo;                  |
  EFI_PEI_PCI_CFG_PPI             PciCfg;           <----'
} EFI_PEI_SERVICES;
```

EFI Services

```
typedef struct {
  EFI_TABLE_HEADER                Hdr;
  EFI_GET_TIME                    GetTime;                    <----.
  EFI_SET_TIME                    SetTime;                         |
  EFI_GET_WAKEUP_TIME             GetWakeupTime;                   |
  EFI_SET_WAKEUP_TIME             SetWakeupTime;                   |
  EFI_SET_VIRTUAL_ADDRESS_MAP     SetVirtualAddressMap;            |
  EFI_CONVERT_POINTER             ConvertPointer;                  |
  EFI_GET_VARIABLE                GetVariable;                     |
  EFI_GET_NEXT_VARIABLE_NAME      GetNextVariableName;             |
  EFI_SET_VARIABLE                SetVariable;                     |
  EFI_GET_NEXT_HIGH_MONO_COUNT    GetNextHighMonotonicCount;       |
  EFI_RESET_SYSTEM                ResetSystem;                     |
  EFI_UPDATE_CAPSULE              UpdateCapsule;                   |
  EFI_QUERY_CAPSULE_CAPABILITIES  QueryCapsuleCapabilities;        |
  EFI_QUERY_VARIABLE_INFO         QueryVariableInfo;          <----'
} EFI_RUNTIME_SERVICES;
```

EFI Services

- Each phase has different services.
- Entrypoint function contains a pointer to the tables.

```
typedef
EFI_STATUS
 (*EFI_IMAGE_ENTRY_POINT)(
  IN EFI_HANDLE ImageHandle,
  IN EFI_SYSTEM_TABLE *SystemTable <------ this one
);
```

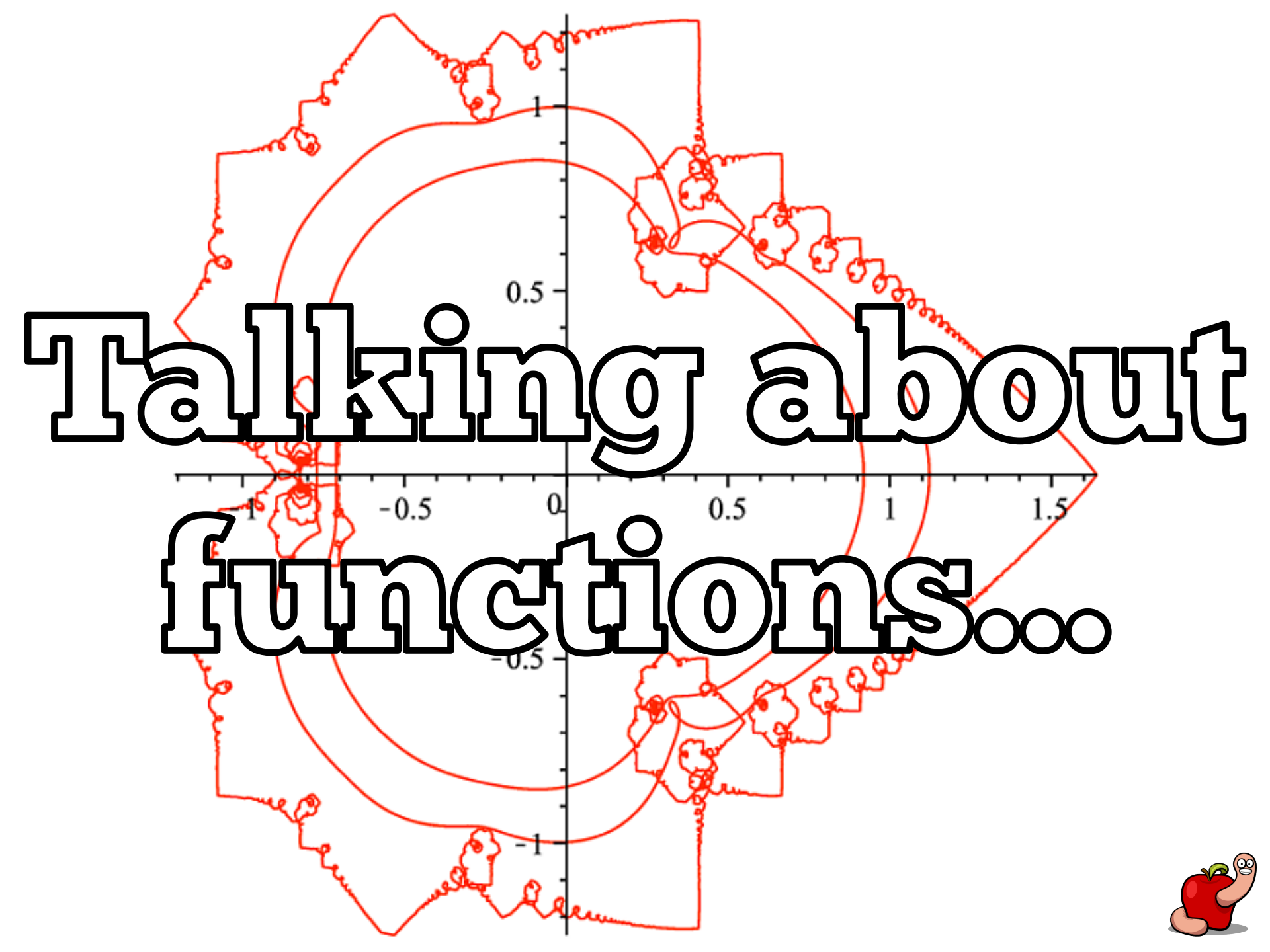
EFI Services

```
typedef struct {
  EFI_TABLE_HEADER Hdr;
  CHAR16 *FirmwareVendor;
  UINT32 FirmwareRevision;

  EFI_HANDLE ConsoleInHandle;
  EFI_SIMPLE_TEXT_INPUT_PROTOCOL *ConIn;
  EFI_HANDLE ConsoleOutHandle;
  EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL *ConOut;
  EFI_HANDLE StandardErrorHandle;
  EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL *StdErr;

  EFI_RUNTIME_SERVICES *RuntimeServices; <- EFI_RUNTIME_SERVICES
  EFI_BOOT_SERVICES *BootServices;       <- EFI_BOOT_SERVICES

  UINTN NumberOfTableEntries;
  EFI_CONFIGURATION_TABLE *ConfigurationTable;
} EFI_SYSTEM_TABLE;
```

EFI Services

- Code that you often see in DXE drivers

```
.text:0000000000000240 GetSystemTables proc near    ; CODE XREF: start+16
.text:0000000000000240                 mov     cs:SystemTable, rdx
.text:0000000000000247                 mov     rax, [rdx+60h]
.text:000000000000024B                 mov     cs:BootServices, rax
.text:0000000000000252                 mov     rax, [rdx+58h]
.text:0000000000000256                 mov     cs:RunTimeServices, rax
.text:000000000000025D                 xor     eax, eax
.text:000000000000025F                 retn
.text:000000000000025F GetSystemTables endp
```



Talking about functions...

Calling conventions

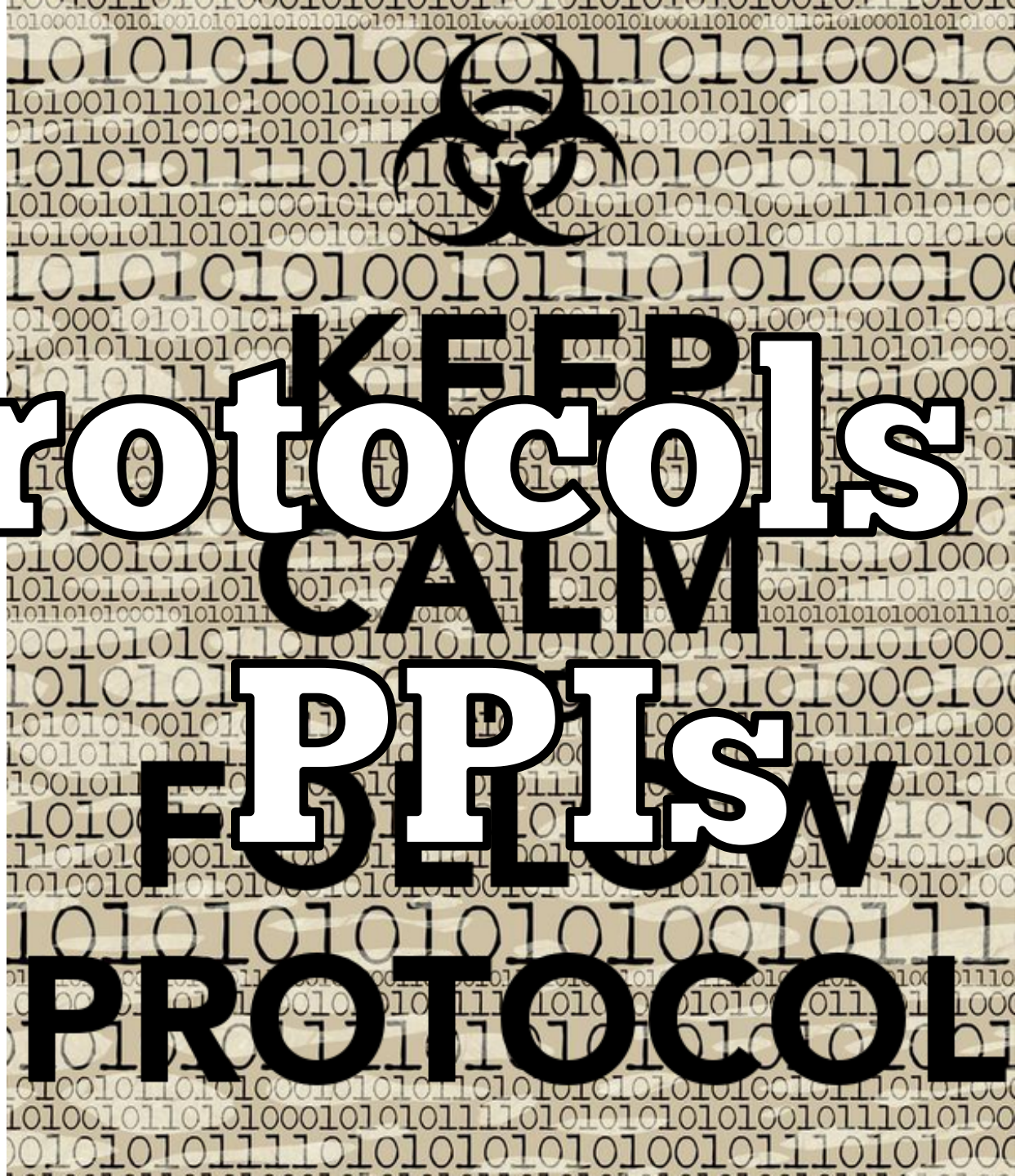
- 32-bit binaries use standard C convention
  - Arguments passed on the stack.
  - SEC/PEI phase binaries.

```
call    PeiPerfMeasure  ;     PEI_PERF_START (&PrivateData.PS,L"PreMem", NULL, mTick);
lea     eax, [ebp+var_C8]
mov     [esp+8], eax
lea     eax, [ebp-268h]
mov     [esp+4], eax
mov     [esp], edi
call    PeiDispatcher   ;   PeiDispatcher (PeiStartupDescriptor, &PrivateData, DispatchData);
cmp     [ebp+var_9B], 1
jz      short loc_FFEA736E
mov     [esp], esi
mov     dword ptr [esp+0Ch], offset aPrivatedata_pe ; "PrivateData.PeiMemoryInstalled == ((BOO"...
mov     dword ptr [esp+8], 16Ch
mov     dword ptr [esp+4], offset a_EdkFoundati_4 ; "./Edk/Foundation/Core/Pei/PeiMain/PeiMa"...
call    PeiDebugAssert  ;   PEI_ASSERT(&PrivateData.PS, PrivateData.PeiMemoryInstalled == TRUE);
```

Calling conventions

- 64-bit binaries use Microsoft's x64
  - First four arguments: RCX, RDX, R8, R9.
  - Remaining on the stack.
  - 32-byte shadow space on stack.
  - First stack argument starts at offset 0x20.
  - DXE phase binaries.

```
mov     rax, cs:1F688h
mov     dword ptr [rsp+28h], 2 <- 6th
mov     qword ptr [rsp+20h], 0 <- 5th
lea     rdx, qword_1D7A0       <- 2nd
lea     r8, [rbp+var_38]       <- 3rd
mov     rcx, rdi               <- 1st
xor     r9d, r9d               <- 4th
call    qword ptr [rax+118h]
```



Protocols & FPLs

Protocols & PPIs

- The basic services aren't enough.
- How are more services made available?
- Via Protocols and PPIs.
- Installed (published) by (U)EFI binaries.
- Others can locate and use them.

Protocols & PPIs

- Protocol (and PPI) is a data structure.
- Contains an identification, GUID.
- Optionally, function pointers and data.

```
[ Protocol ]
#define EFI_ACPI_S3_SAVE_GUID { 0x125f2de1, 0xfb85, 0x440c, 0xa5, 0x4c,
                                0x4d, 0x99, 0x35, 0x8a, 0x8d, 0x38 }


typedef struct _EFI_ACPI_S3_SAVE_PROTOCOL {
 EFI_ACPI_GET_LEGACY_MEMORY_SIZE GetLegacyMemorySize;
 EFI_ACPI_S3_SAVE S3Save;
} EFI_ACPI_S3_SAVE_PROTOCOL;

[ Function Pointers]
typedef
EFI_STATUS
(EFIAPI *EFI_ACPI_S3_SAVE)(
  IN EFI_ACPI_S3_SAVE_PROTOCOL      * This,
  IN VOID                           * LegacyMemoryAddress
  );

typedef
EFI_STATUS
(EFIAPI *EFI_ACPI_GET_LEGACY_MEMORY_SIZE)(
  IN  EFI_ACPI_S3_SAVE_PROTOCOL     * This,
  OUT UINTN                         * Size
);
```

Protocols & PPIs

- Protocols exist in DXE phase.
- PPIs exist in PEI phase.
- In practice we can assume they are equivalent.

Sample PPI usage

- First, locate the PPI.

```
EFI_STATUS      Status;
EFI_BOOT_MODE   BootMode;
PEI_CAPSULE_PPI *Capsule;

Status = (*PeiServices)->LocatePpi ((const EFI_PEI_SERVICES **)PeiServices,
                                    &gPeiCapsulePpiGuid,
                                    0,
                                    NULL,
                                    (VOID **)&Capsule
                                    );
```

Sample PPI usage

- Second, use it.

```
if (Status == EFI_SUCCESS) {
  if (Capsule->CheckCapsuleUpdate ((EFI_PEI_SERVICES**)PeiServices) == EFI_SUCCESS) {
    BootMode = BOOT_ON_FLASH_UPDATE;
    Status = (*PeiServices)->SetBootMode((const EFI_PEI_SERVICES **)PeiServices, BootMode);
    ASSERT_EFI_ERROR (Status);
  }
}
```

Sample Protocol usage

```
#define EFI_BOOT_SCRIPT_SAVE_GUID \
{ 0x470e1529, 0xb79e, 0x4e32, 0xa0, 0xfe, 0x6a,0x15, 0x6d, 0x29, 0xf9, 0xb2 }

typedef struct _EFI_BOOT_SCRIPT_SAVE_PROTOCOL {
    EFI_BOOT_SCRIPT_WRITE Write;
    EFI_BOOT_SCRIPT_CLOSE_TABLE CloseTable;
} EFI_BOOT_SCRIPT_SAVE_PROTOCOL;
```

```
.data:0000000000009D20 ; EFI_GUID gEfiBootScriptSaveProtocolGuid
.data:0000000000009D20 gEfiBootScriptSaveProtocolGuid dd 470E1529h
.data:0000000000009D20                                dw 0B79Eh
.data:0000000000009D20                                dw 4E32h
.data:0000000000009D20                                db 0A0h, 0FEh, 6Ah, 15h, 6Dh, 29h, 0F9h, 0B2h
```

```
locate_bootscript_save_protocol proc near ; CODE XREF: sub_180C+21
        push    rbp
        mov     rbp, rsp
        sub     rsp, 20h
        mov     rax, [rdx+60h] <- BootServices
        lea     rcx, gEfiBootScriptSaveProtocolGuid <- GUID to locate
        lea     r8, Boot_Script_Save_Interface <- store pointer to table
        xor     edx, edx
        call    qword ptr [rax+140h] <- BootServices->LocateProtocol()
        test    rax, rax
        jns     short loc_281
        mov     rcx, 800000000000014h
        cmp     rax, rcx
        jz      short loc_281
        mov     cs:Boot_Script_Save_Interface, 0

loc_281:                ; CODE XREF: locate_bootscript_save_protocol+25
                        ; locate_bootscript_save_protocol+34
        xor     eax, eax
        add     rsp, 20h
        pop     rbp
        retn
locate_bootscript_save_protocol endp
```

```
save_script_dispatch_opcode proc near   ; CODE XREF: sub_2D0F+6C
                                        ; sub_3C1A+83 ...
                push    rbp
                mov     rbp, rsp
                sub     rsp, 20h
                mov     r9, rdx  <- EntryPoint
                mov     rdx, 8000000000000000Eh
                mov     rax, cs:Boot_Script_Save_Interface
                test    rax, rax <- NULL ptr?
                jz      short loc_3E1
                movzx   edx, cx  <- TableName
                mov     rcx, rax <- *This
                mov     r8d, 8   <- OpCode
                call    qword ptr [rax] <- BootScriptSave->Write()
                xor     edx, edx

loc_3E1:                                ; CODE XREF: save_script_dispatch_opcode+1F
                mov     rax, rdx
                add     rsp, 20h
                pop     rbp
                retn
save_script_dispatch_opcode endp
```

Apple EFI customizations

Apple Computer Inc.

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II NOT TO REPRODUCE OR COPY IT
III NOT TO REVEAL OR PUBLISH IN WHOLE OR PART

Apple EFI customizations

- Apple specific modifications.
- To reserved fields.
- Must be taken care of.
- Else bricked firmware.
- UEFITool v0.27+ handles everything.

EFI_FIRMWARE_VOLUME_HEADER

Summary

Describes the features and layout of the firmware volume.

Prototype

```
typedef struct {
  UINT8                    ZeroVector[16];
  EFI_GUID                 FileSystemGuid;
  UINT64                   FvLength;
  UINT32                   Signature;
  EFI_FVB_ATTRIBUTES_2     Attributes;
  UINT16                   HeaderLength;
  UINT16                   Checksum;
  UINT16                   ExtHeaderOffset;
  UINT8                    Reserved[1];
  UINT8                    Revision;
  EFI_FV_BLOCK_MAP         BlockMap[];
} EFI_FIRMWARE_VOLUME_HEADER;
```

Parameters

ZeroVector

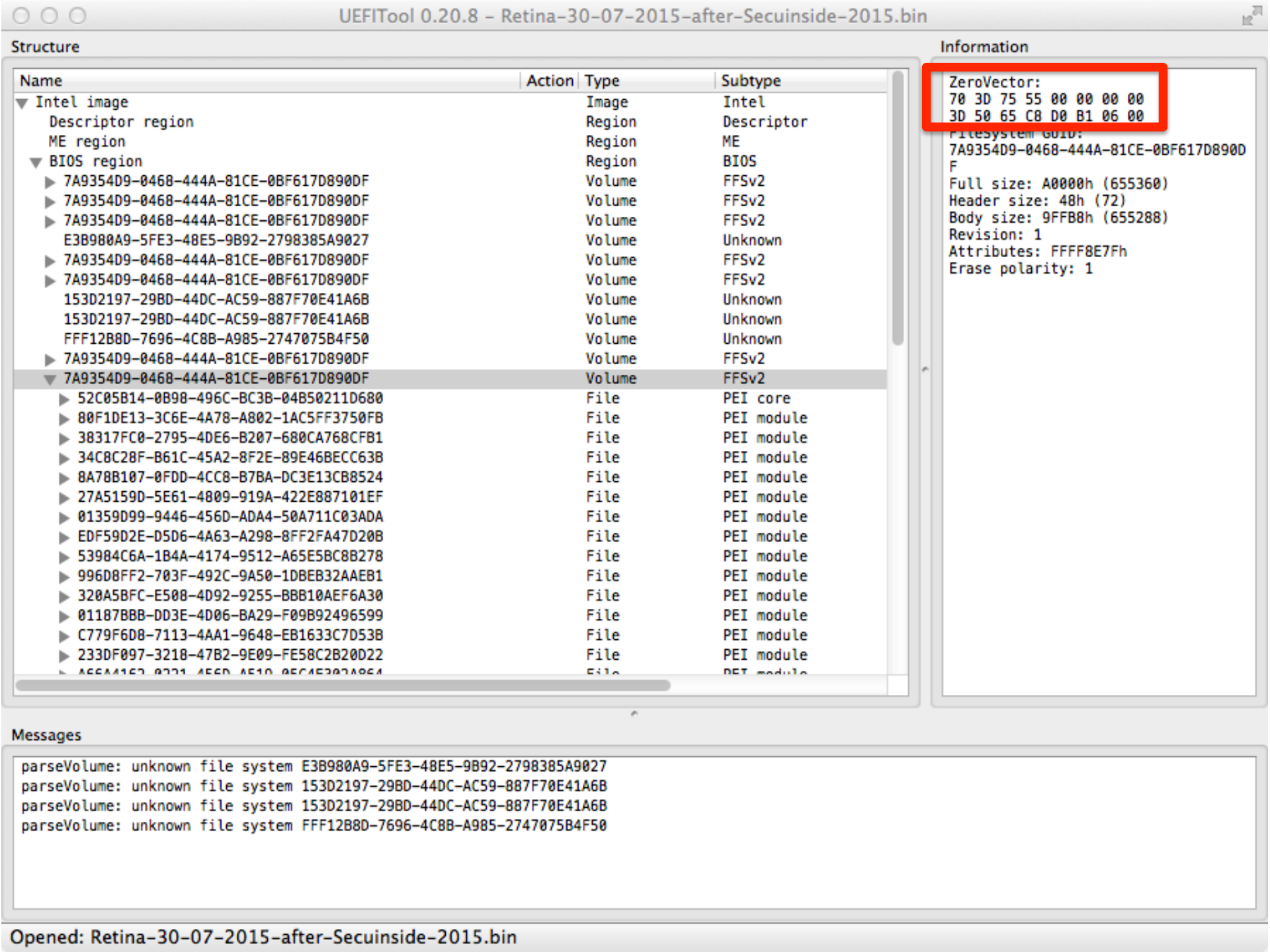
The first 16 bytes are reserved to allow for the reset vector of processors whose reset vector is at address 0.

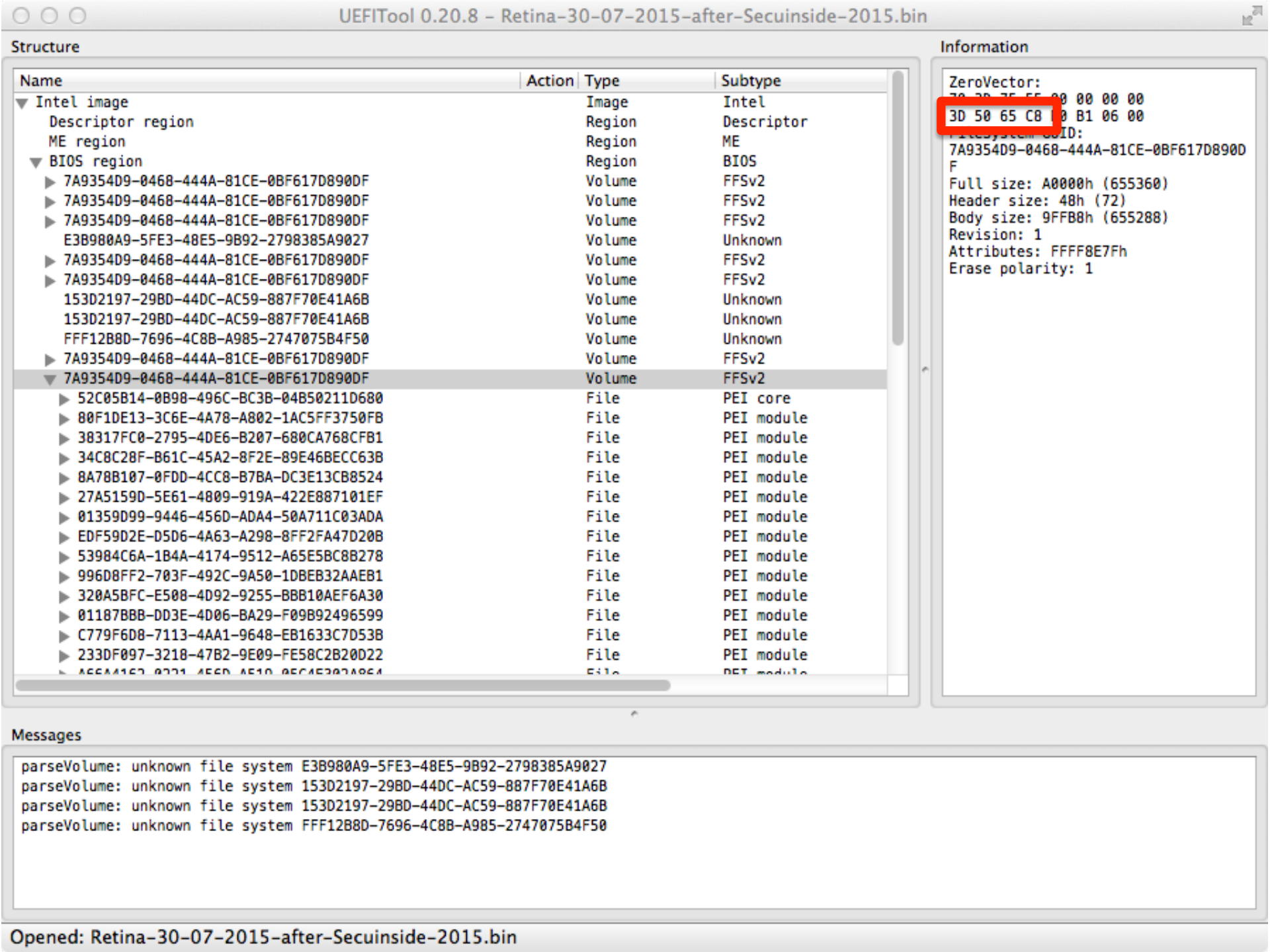
Apple EFI customizations

- The first 8 bytes.
- Constant between firmware volumes with the same GUID.
- Changes between versions?
- Unknown meaning, doesn't seem relevant.

Apple EFI customizations

- Next 4 bytes.
- CRC32 value.
- Of the firmware volume contents.
- By spec, header got its own 16-bit checksum.


UEFITool 0.20.8 - Retina-30-07-2015-after-Secuinside-2015.bin
Structure
Name
Action
Type
Subtype
Intel image
Image
Intel
Descriptor region
Region
Descriptor
ME region
Region
ME
BIOS region
Region
BIOS
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
E3B980A9-5FE3-48E5-9B92-2798385A9027
Volume
Unknown
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
153D2197-29BD-44DC-AC59-887F70E41A6B
Volume
Unknown
153D2197-29BD-44DC-AC59-887F70E41A6B
Volume
Unknown
FFF12B8D-7696-4C8B-A985-2747075B4F50
Volume
Unknown
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
52C05B14-0B98-496C-BC3B-04B50211D680
File
PEI core
80F1DE13-3C6E-4A78-A802-1AC5FF3750FB
File
PEI module
38317FC0-2795-4DE6-B207-680CA768CFB1
File
PEI module
34C8C28F-B61C-45A2-8F2E-89E46BECC63B
File
PEI module
8A78B107-0FDD-4CC8-B7BA-DC3E13CB8524
File
PEI module
27A5159D-5E61-4809-919A-422E887101EF
File
PEI module
01359D99-9446-456D-ADA4-50A711C03ADA
File
PEI module
EDF59D2E-D5D6-4A63-A298-8FF2FA47D20B
File
PEI module
53984C6A-1B4A-4174-9512-A65E5BC8B278
File
PEI module
996D8FF2-703F-492C-9A50-1DBEB32AAEB1
File
PEI module
320A5BFC-E508-4D92-9255-BBB10AEF6A30
File
PEI module
01187BBB-DD3E-4D06-BA29-F09B92496599
File
PEI module
C779F6D8-7113-4AA1-9648-EB1633C7D53B
File
PEI module
233DF097-3218-47B2-9E09-FE58C2B20D22
File
PEI module
Information
ZeroVector:
70 3D 75 55 00 00 00 00
3D 50 65 C8 D0 B1 06 00
FileSystem GUID:
7A9354D9-0468-444A-81CE-0BF617D890DF
Full size: A0000h (655360)
Header size: 48h (72)
Body size: 9FFB8h (655288)
Revision: 1
Attributes: FFFF8E7Fh
Erase polarity: 1
Messages
parseVolume: unknown file system E3B980A9-5FE3-48E5-9B92-2798385A9027
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
Opened: Retina-30-07-2015-after-Secuinside-2015.bin


UEFITool 0.20.8 - Retina-30-07-2015-after-Secuinside-2015.bin
Structure
Name
Action
Type
Subtype
Intel image
Image
Intel
Descriptor region
Region
Descriptor
ME region
Region
ME
BIOS region
Region
BIOS
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
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Volume
FFSv2
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Volume
Unknown
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Volume
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Volume
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Volume
Unknown
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FFSv2
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Volume
FFSv2
52C05B14-0B98-496C-BC3B-04B50211D680
File
PEI core
80F1DE13-3C6E-4A78-A802-1AC5FF3750FB
File
PEI module
38317FC0-2795-4DE6-B207-680CA768CFB1
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PEI module
34C8C28F-B61C-45A2-8F2E-89E46BECC63B
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File
PEI module
C779F6D8-7113-4AA1-9648-EB1633C7D53B
File
PEI module
233DF097-3218-47B2-9E09-FE58C2B20D22
File
PEI module
Information
ZeroVector:
3D 50 65 C8
B1 06 00
7A9354D9-0468-444A-81CE-0BF617D890DF
Full size: A0000h (655360)
Header size: 48h (72)
Body size: 9FFB8h (655288)
Revision: 1
Attributes: FFFF8E7Fh
Erase polarity: 1
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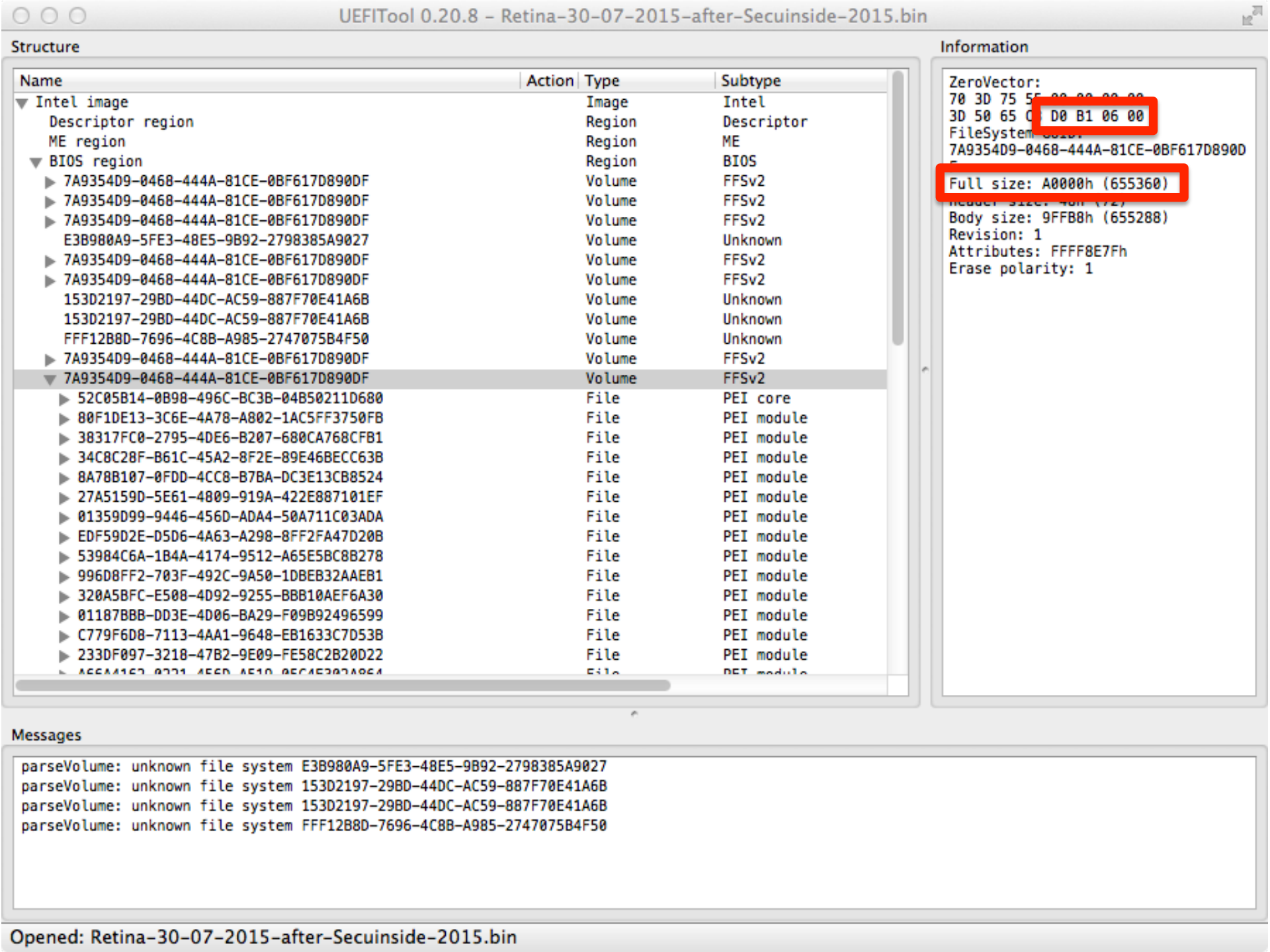
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
Opened: Retina-30-07-2015-after-Secuinside-2015.bin

Apple EFI customizations

- Last 4 bytes.
- Total space used by firmware files.
- Must be updated if there are any modifications to volume free space.
- Bricked firmware if wrong.


UEFITool 0.20.8 - Retina-30-07-2015-after-Secuinside-2015.bin
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7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
E3B980A9-5FE3-48E5-9B92-2798385A9027
Volume
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7A9354D9-0468-444A-81CE-0BF617D890DF
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Volume
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FFF12B8D-7696-4C8B-A985-2747075B4F50
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File
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PEI module
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PEI module
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File
PEI module
C779F6D8-7113-4AA1-9648-EB1633C7D53B
File
PEI module
233DF097-3218-47B2-9E09-FE58C2B20D22
File
PEI module
Information
ZeroVector:
70 3D 75 5
3D 50 65 C
D0 B1 06 00
FileSystem
7A9354D9-0468-444A-81CE-0BF617D890D
Full size: A0000h (655360)
Body size: 9FFB8h (655288)
Revision: 1
Attributes: FFFF8E7Fh
Erase polarity: 1
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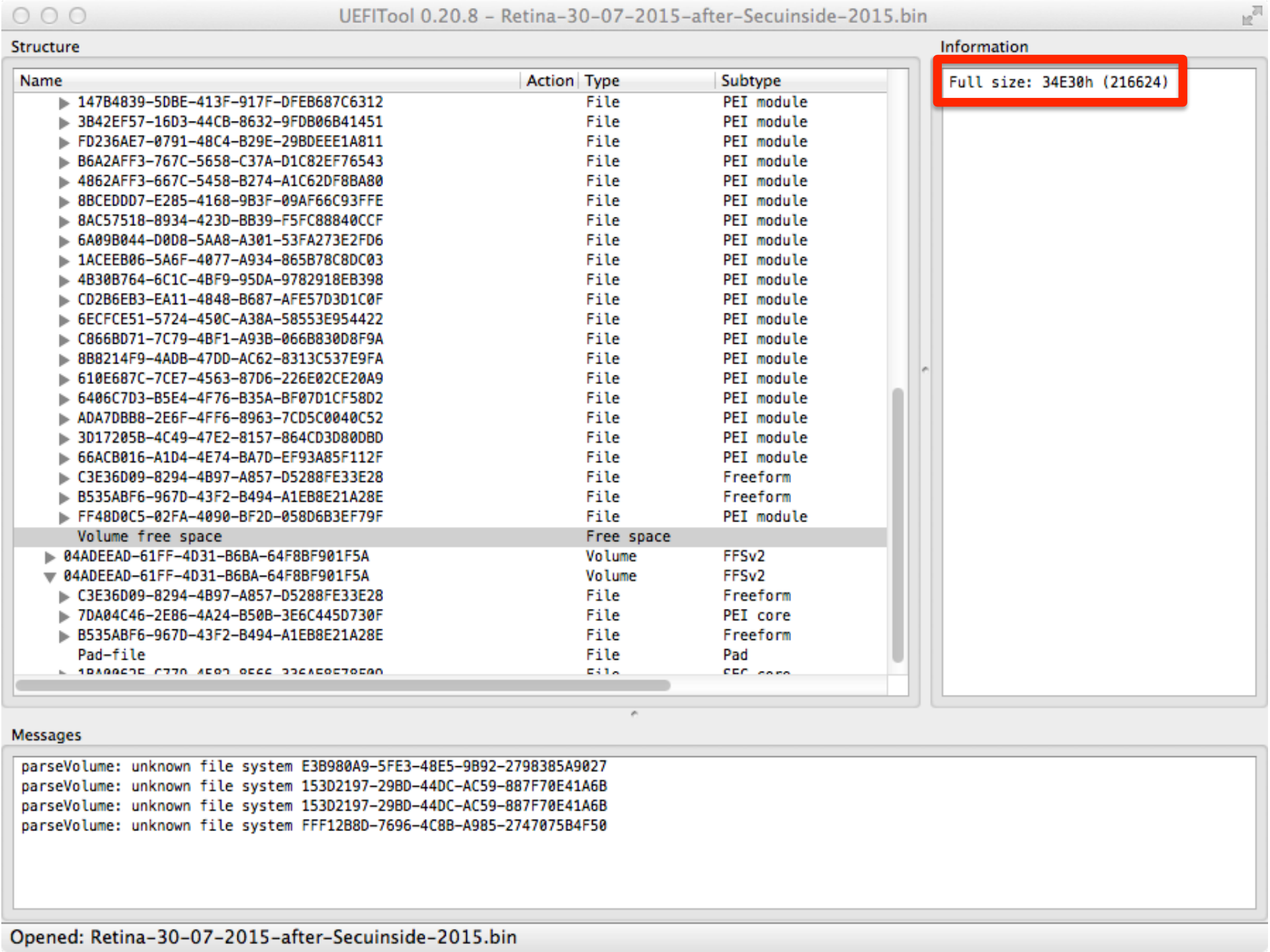
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
Opened: Retina-30-07-2015-after-Secuinside-2015.bin


UEFITool 0.20.8 - Retina-30-07-2015-after-Secuinside-2015.bin
Structure
Information
Full size: 34E30h (216624)
Name
Action
Type
Subtype
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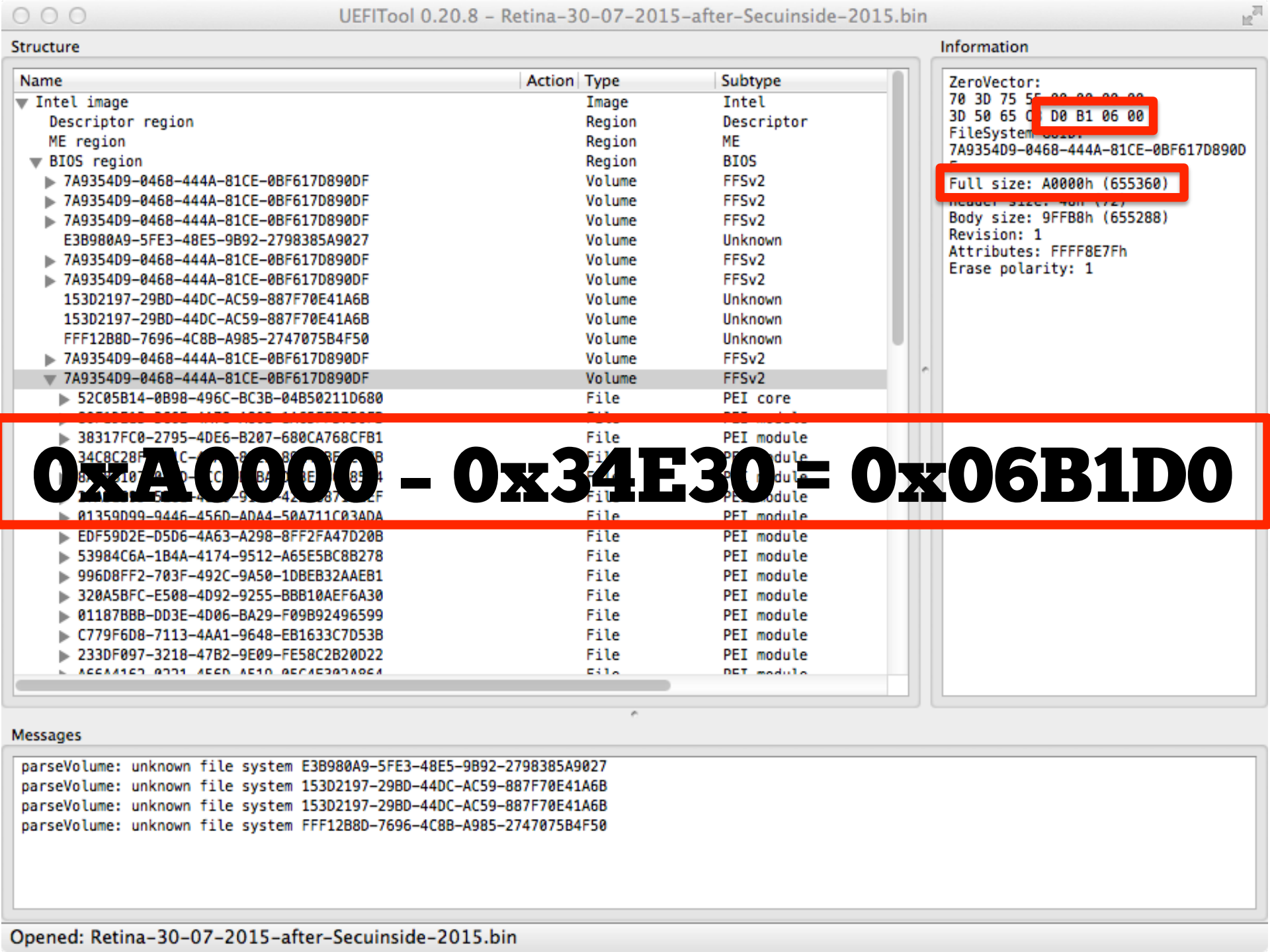
3B42EF57-16D3-44CB-8632-9FDB06B41451 File PEI module
FD236AE7-0791-48C4-B29E-29BDEEE1A811 File PEI module
B6A2AFF3-767C-5658-C37A-D1C82EF76543 File PEI module
4862AFF3-667C-5458-B274-A1C62DF8BA80 File PEI module
8BCEDDD7-E285-4168-9B3F-09AF66C93FFE File PEI module
8AC57518-8934-423D-BB39-F5FC88840CCF File PEI module
6A09B044-D0D8-5AA8-A301-53FA273E2FD6 File PEI module
1ACEEB06-5A6F-4077-A934-865B78C8DC03 File PEI module
4B30B764-6C1C-4BF9-95DA-9782918EB398 File PEI module
CD2B6EB3-EA11-4848-B687-AFE57D3D1C0F File PEI module
6ECFCE51-5724-450C-A38A-58553E954422 File PEI module
C866BD71-7C79-4BF1-A93B-066B830D8F9A File PEI module
8B8214F9-4ADB-47DD-AC62-8313C537E9FA File PEI module
610E687C-7CE7-4563-87D6-226E02CE20A9 File PEI module
6406C7D3-B5E4-4F76-B35A-BF07D1CF58D2 File PEI module
ADA7DBB8-2E6F-4FF6-8963-7CD5C0040C52 File PEI module
3D17205B-4C49-47E2-8157-864CD3D80DBD File PEI module
66ACB016-A1D4-4E74-BA7D-EF93A85F112F File PEI module
C3E36D09-8294-4B97-A857-D5288FE33E28 File Freeform
B535ABF6-967D-43F2-B494-A1EB8E21A28E File Freeform
FF48D0C5-02FA-4090-BF2D-058D6B3EF79F File PEI module
Volume free space Free space
04ADEEAD-61FF-4D31-B6BA-64F8BF901F5A Volume FFSv2
04ADEEAD-61FF-4D31-B6BA-64F8BF901F5A Volume FFSv2
C3E36D09-8294-4B97-A857-D5288FE33E28 File Freeform
7DA04C46-2E86-4A24-B50B-3E6C445D730F File PEI core
B535ABF6-967D-43F2-B494-A1EB8E21A28E File Freeform
Pad-file File Pad
Messages
parseVolume: unknown file system E3B980A9-5FE3-48E5-9B92-2798385A9027
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
Opened: Retina-30-07-2015-after-Secuinside-2015.bin


UEFITool 0.20.8 - Retina-30-07-2015-after-Secuinside-2015.bin
Structure
Information
Name
Action
Type
Subtype
Intel image
Image
Intel
Descriptor region
Region
Descriptor
ME region
Region
ME
BIOS region
Region
BIOS
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
E3B980A9-5FE3-48E5-9B92-2798385A9027
Volume
Unknown
153D2197-29BD-44DC-AC59-887F70E41A6B
Volume
Unknown
FFF12B8D-7696-4C8B-A985-2747075B4F50
Volume
Unknown
52C05B14-0B98-496C-BC3B-04B50211D680
File
PEI core
38317FC0-2795-4DE6-B207-680CA768CFB1
File
PEI module
01359D99-9446-456D-ADA4-50A711C03ADA
File
PEI module
EDF59D2E-D5D6-4A63-A298-8FF2FA47D20B
File
PEI module
53984C6A-1B4A-4174-9512-A65E5BC8B278
File
PEI module
996D8FF2-703F-492C-9A50-1DBEB32AAEB1
File
PEI module
320A5BFC-E508-4D92-9255-BBB10AEF6A30
File
PEI module
01187BBB-DD3E-4D06-BA29-F09B92496599
File
PEI module
C779F6D8-7113-4AA1-9648-EB1633C7D53B
File
PEI module
233DF097-3218-47B2-9E09-FE58C2B20D22
File
PEI module
ZeroVector:
70 3D 75
3D 50 65
D0 B1 06 00
FileSystem
7A9354D9-0468-444A-81CE-0BF617D890D
Full size: A0000h (655360)
Body size: 9FFB8h (655288)
Revision: 1
Attributes: FFFF8E7Fh
Erase polarity: 1
0xA0000 - 0x34E30 = 0x06B1D0
Messages
parseVolume: unknown file system E3B980A9-5FE3-48E5-9B92-2798385A9027
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-887F70E41A6B
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
Opened: Retina-30-07-2015-after-Secuinside-2015.bin

How to find EFI monsters

How to find EFI monsters

- Dump the flash contents.
  - Via hardware, if possible.
- Have a known good image.
  - A previously certified/trusted dump.
  - Or firmware updates.

How to find EFI monsters

- Firmware updates available from Apple.
- Direct downloads.
  - https://support.apple.com/en-us/HT201518
- Or combined with OS installer or updates.
- No hashes from Apple available (yet).

How to find EFI monsters

- Only useful for machines with available updates.
- Newly released machines need to wait for a firmware update.

How to find EFI monsters

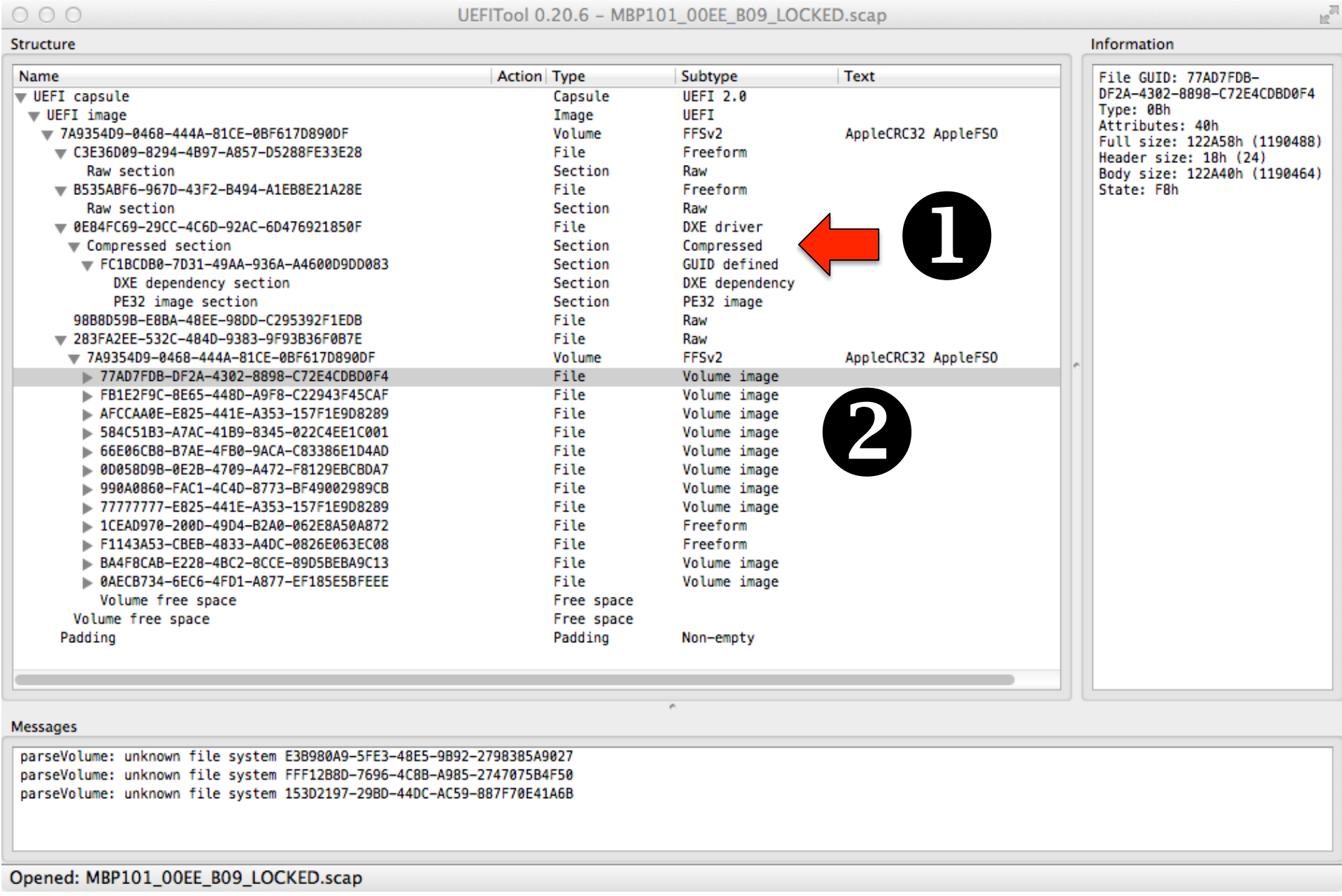
- Firmware & signatures vault
  - https://github.com/gdbinit/firmware_vault
- Signed by my PGP key.
- Extracted from available Apple updates.
- Soon, the SMC updates.

How to find EFI monsters

- Two file formats used for updates.
- SCAP (most common).
- FD (some newer and older models).
- UEFITool can process both.

SCAP

- EFI Capsule.
- Used to deliver updates.
- Recommended delivery mechanism.
- Composed by firmware volumes.
- Flash dumps parser can be reused.


UEFITool 0.20.6 - MBP101_00EE_B09_LOCKED.scap
Structure
Information
Name
Action
Type
Subtype
Text
UEFI capsule
Capsule
UEFI 2.0
UEFI image
Image
UEFI
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
AppleCRC32 AppleFSO
C3E36D09-8294-4B97-A857-D5288FE33E28
File
Freeform
Raw section
Section
Raw
B535ABF6-967D-43F2-B494-A1EB8E21A28E
File
Freeform
Raw section
Section
Raw
0E84FC69-29CC-4C6D-92AC-6D476921850F
File
DXE driver
Compressed section
Section
Compressed
FC1BCDB0-7D31-49AA-936A-A4600D9DD083
Section
GUID defined
DXE dependency section
Section
DXE dependency
PE32 image section
Section
PE32 image
98B8D59B-E8BA-48EE-98DD-C295392F1EDB
File
Raw
283FA2EE-532C-484D-9383-9F93B36F0B7E
File
Raw
7A9354D9-0468-444A-81CE-0BF617D890DF
Volume
FFSv2
AppleCRC32 AppleFSO
77AD7FDB-DF2A-4302-8898-C72E4CDBD0F4
File
Volume image
FB1E2F9C-8E65-448D-A9F8-C22943F45CAF
File
Volume image
AFCCAA0E-E825-441E-A353-157F1E9D8289
File
Volume image
584C51B3-A7AC-41B9-8345-022C4EE1C001
File
Volume image
66E06CB8-B7AE-4FB0-9ACA-C83386E1D4AD
File
Volume image
0D058D9B-0E2B-4709-A472-F8129EBCBDA7
File
Volume image
990A0860-FAC1-4C4D-8773-BF49002989CB
File
Volume image
77777777-E825-441E-A353-157F1E9D8289
File
Volume image
1CEAD970-200D-49D4-B2A0-062E8A50A872
File
Freeform
F1143A53-CBEB-4833-A4DC-0826E063EC08
File
Freeform
BA4F8CAB-E228-4BC2-8CCE-89D5BEBA9C13
File
Volume image
0AECB734-6EC6-4FD1-A877-EF185E5BFEEE
File
Volume image
Volume free space
Free space
Volume free space
Free space
Padding
Padding
Non-empty
1
2
File GUID: 77AD7FDB-DF2A-4302-8898-C72E4CDBD0F4
Type: 0Bh
Attributes: 40h
Full size: 122A58h (1190488)
Header size: 18h (24)
Body size: 122A40h (1190464)
State: F8h
Messages
parseVolume: unknown file system E3B980A9-5FE3-48E5-9B92-2798385A9027
parseVolume: unknown file system FFF12B8D-7696-4C8B-A985-2747075B4F50
parseVolume: unknown file system 153D2197-29BD-44DC-AC59-8B7F70E41A6B
Opened: MBP101_00EE_B09_LOCKED.scap

SCAP

- ❶ is the EfiFlasher.efi or also known as UpdateDriverDxe.
- ❷ are the BIOS region contents.
- Encapsulated on different GUIDs.

Name	Action	Type	Subtype	Text
▶ 0E84FC69-29CC-4C6D-92AC-6D476921850F		File	DXE driver	
98B8D59B-E8BA-48EE-98DD-C295392F1EDB		File	Raw	
▼ 283FA2EE-532C-484D-9383-9F93B36F0B7E		File	Raw	
▼ 7A9354D9-0468-444A-81CE-0BF617D890DF		Volume	FFSv2	AppleCRC32 AppleFSO
▶ 77AD7FDB-DF2A-4302-8898-C72E4CDBD0F4		File	Volume image	
▶ FB1E2F9C-8E65-448D-A9F8-C22943F45CAF		File	Volume image	
▶ AFCCAA0E-E825-441E-A353-157F1E9D8289		File	Volume image	
▶ 584C51B3-A7AC-41B9-8345-022C4EE1C001		File	Volume image	
▶ 66E06CB8-B7AE-4FB0-9ACA-C83386E1D4AD		File	Volume image	
▼ 0D058D9B-0E2B-4709-A472-F8129EBCBDA7		File	Volume image	
▼ Compressed section		Section	Compressed	
▼ FC1BCDB0-7D31-49AA-936A-A4600D9DD083		Section	GUID defined	
▼ Volume image section		Section	Volume image	
FFF12B8D-7696-4C8B-A985-2747075B4F50		Volume	Unknown	
▼ 990A0860-FAC1-4C4D-8773-BF49002989CB		File	Volume image	
▼ Compressed section		Section	Compressed	
▼ FC1BCDB0-7D31-49AA-936A-A4600D9DD083		Section	GUID defined	
▼ Volume image section		Section	Volume image	
153D2197-29BD-44DC-AC59-887F70E41A6B		Volume	Unknown	AppleCRC32
▼ 77777777-E825-441E-A353-157F1E9D8289		File	Volume image	
▼ Compressed section		Section	Compressed	
▼ FC1BCDB0-7D31-49AA-936A-A4600D9DD083		Section	GUID defined	
▼ Volume image section		Section	Volume image	
▶ 04ADEEAD-61FF-4D31-B6BA-64F8BF901F5A		Volume	FFSv2	AppleCRC32 AppleFSO
▶ 1CEAD970-200D-49D4-B2A0-062E8A50A872		File	Freeform	
▶ F1143A53-CBEB-4833-A4DC-0826E063EC08		File	Freeform	
▶ BA4F8CAB-E228-4BC2-8CCE-89D5BEBA9C13		File	Volume image	
▶ 0AECB734-6EC6-4FD1-A877-EF185E5BFEEE		File	Volume image	
Volume free space		Free space		
Volume free space		Free space		
Padding		Padding	Non-empty	

1

2

3

SCAP

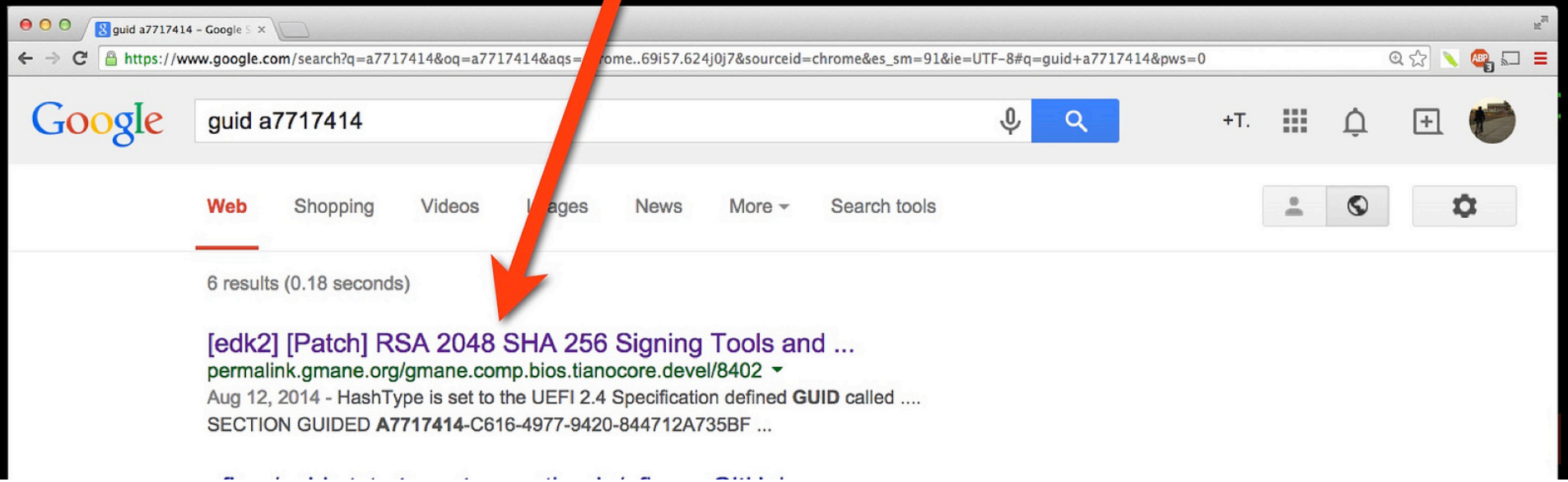
- ❶ is NVRAM region.
- ❷ is Microcode.
- ❸ is Boot volume.

SCAP

- SCAP is signed.
- RSA2048 SHA256.
- Apple backported from UEFI.
- First reported by Trammell Hudson.

```
% xxd -g 1 MBP101_00EE_B02_LOCKED.scap | tail -40 | head
0810030: ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff  ................
0810040: ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff  ................
0810050: 14 74 71 a7 16 c6 77 49 94 20 84 47 12 a7 35 bf  .tq...wI. .G..5.
0810060: cf fd 3e 6b fe 66 ec 15 f4 4b 7e 2e 0e d2 63 98  ..>k.f.u.K~...c.
0810070: 08 a9 8d 10 ac 37 8e 55 1c aa 0e 1c 1d 85 ef 6c  .....7.U.......l
0810080: d5 1c 75 8c 75 18 16 ff 59 9f be da ef 4d 6b 0c  ..u.u...Y....Mk.
```

GUID a7717414-c616-4977-9420844712a735bf



How to find EFI monsters

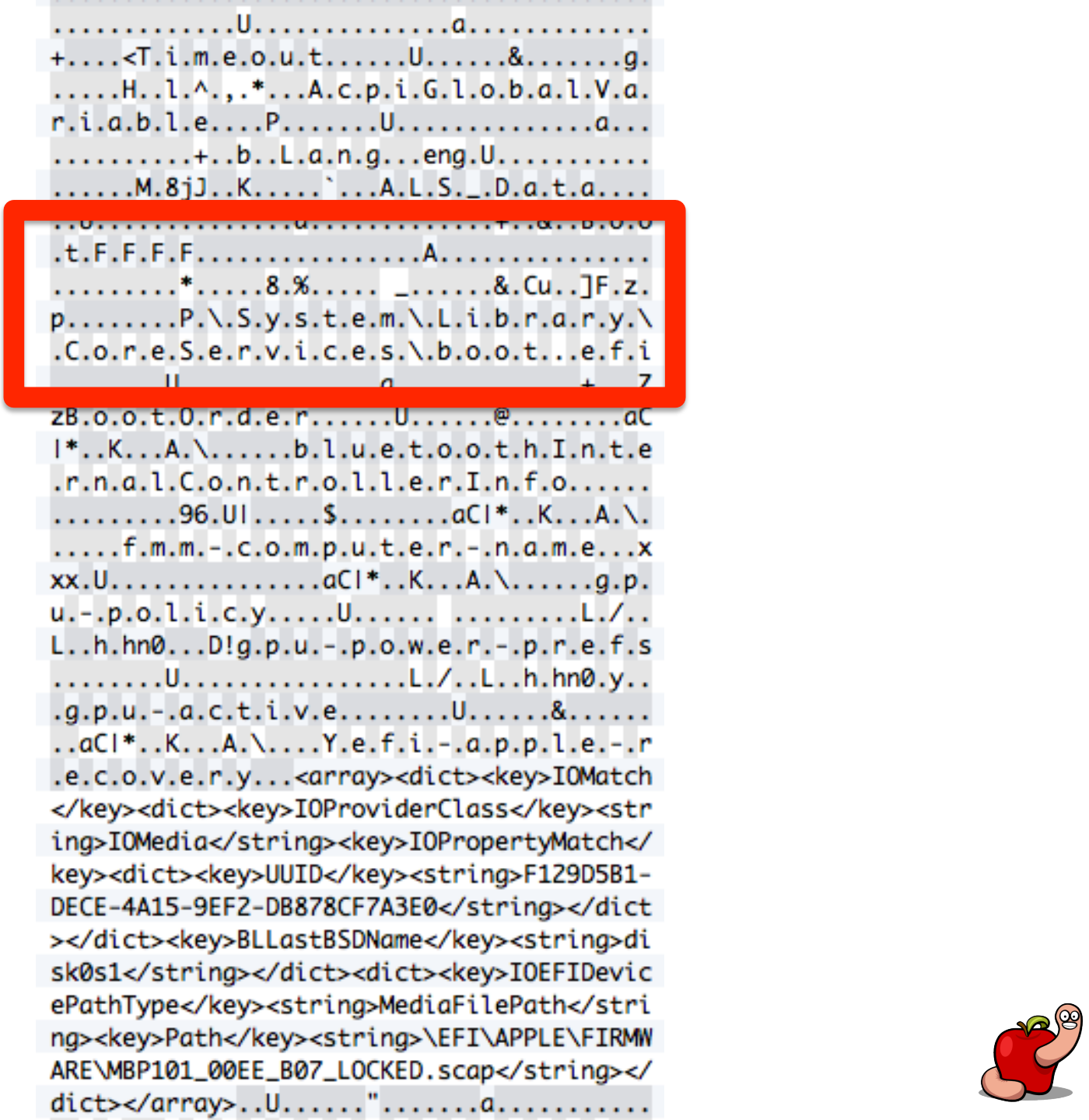
- Compare the flash dump against SCAP.
- Locate all EFI binaries in the dump.
- Checksum against SCAP contents.

How to find EFI monsters

- We also need to verify:
  - New files.
  - Missing files.
  - Free/padding space?

How to find EFI monsters

- Verify NVRAM contents!
- Boot device is stored there.
- HackingTeam had a new variable there.
  - A simple "fuse" to decide to infect or not target system.


.....U.....a.....
+....<T.i.m.e.o.u.t.....U.....&.....g.
.....H..l.^.,.*...A.c.p.i.G.l.o.b.a.l.V.a.
r.i.a.b.l.e....P.....U.....a...
.....+..b..L.a.n.g...eng.U.....
.....M.8jJ..K.....`...A.L.S._.D.a.t.a....
.t.F.F.F.F.....A.....
.....*.....8.%..... _.....&.Cu..]F.z.
p.....P.\.S.y.s.t.e.m.\.L.i.b.r.a.r.y.\
.C.o.r.e.S.e.r.v.i.c.e.s.\.b.o.o.t...e.f.i
zB.o.o.t.O.r.d.e.r.....U.....@.....aC
|*..K...A.\.....b.l.u.e.t.o.o.t.h.I.n.t.e
.r.n.a.l.C.o.n.t.r.o.l.l.e.r.I.n.f.o.....
.....96.U|.....$.....aC|*..K...A.\.
.....f.m.m.-.c.o.m.p.u.t.e.r.-.n.a.m.e...x
xx.U.....aC|*..K...A.\.....g.p.
u.-.p.o.l.i.c.y.....U..... .....L./..
L..h.hn0...D!g.p.u.-.p.o.w.e.r.-.p.r.e.f.s
.....U.....L./..L..h.hn0.y..
.g.p.u.-.a.c.t.i.v.e.....U.....&.....
..aC|*..K...A.\....Y.e.f.i.-.a.p.p.l.e.-.r
.e.c.o.v.e.r.y...<array><dict><key>IOMatch
</key><dict><key>IOProviderClass</key><str
ing>IOMedia</string><key>IOPropertyMatch</
key><dict><key>UUID</key><string>F129D5B1-
DECE-4A15-9EF2-DB878CF7A3E0</string></dict
></dict><key>BLLastBSDName</key><string>di
sk0s1</string></dict><dict><key>IOEFIDevic
ePathType</key><string>MediaFilePath</stri
ng><key>Path</key><string>\EFI\APPLE\FIRMW
ARE\MBP101_00EE_B07_LOCKED.scap</string></
dict></array>..U.....".....a.....

```
BOOLEAN
EFIAPI
CheckfTA()
{
    EFI_STATUS                    Status = EFI_SUCCESS;

    UINTN  VarDataSize;
    UINT8  VarData;

    VarData=0;
    VarDataSize=sizeof(VarData);
    Status=gRT->GetVariable(L"fTA", &gEfiGlobalFileVariableGuid, NULL, &VarDataSize, (UINTN*)&VarData);

    if(Status!=EFI_SUCCESS || VarData==0)
    {
#ifdef FORCE_DEBUG
        Print(L"Devo Infettare\n");
#endif
        return FALSE;
    }

#ifdef FORCE_DEBUG
    Print(L"NON Devo Infettare\n");
#endif
    return TRUE;
}
```

INFECT SYSTEM

DO NOT INFECT SYSTEM

How to find EFI monsters

- Don't forget boot.efi.
- Not very stealth.
- Always keep in mind that sophistication is not always required!
- If it works, why not?

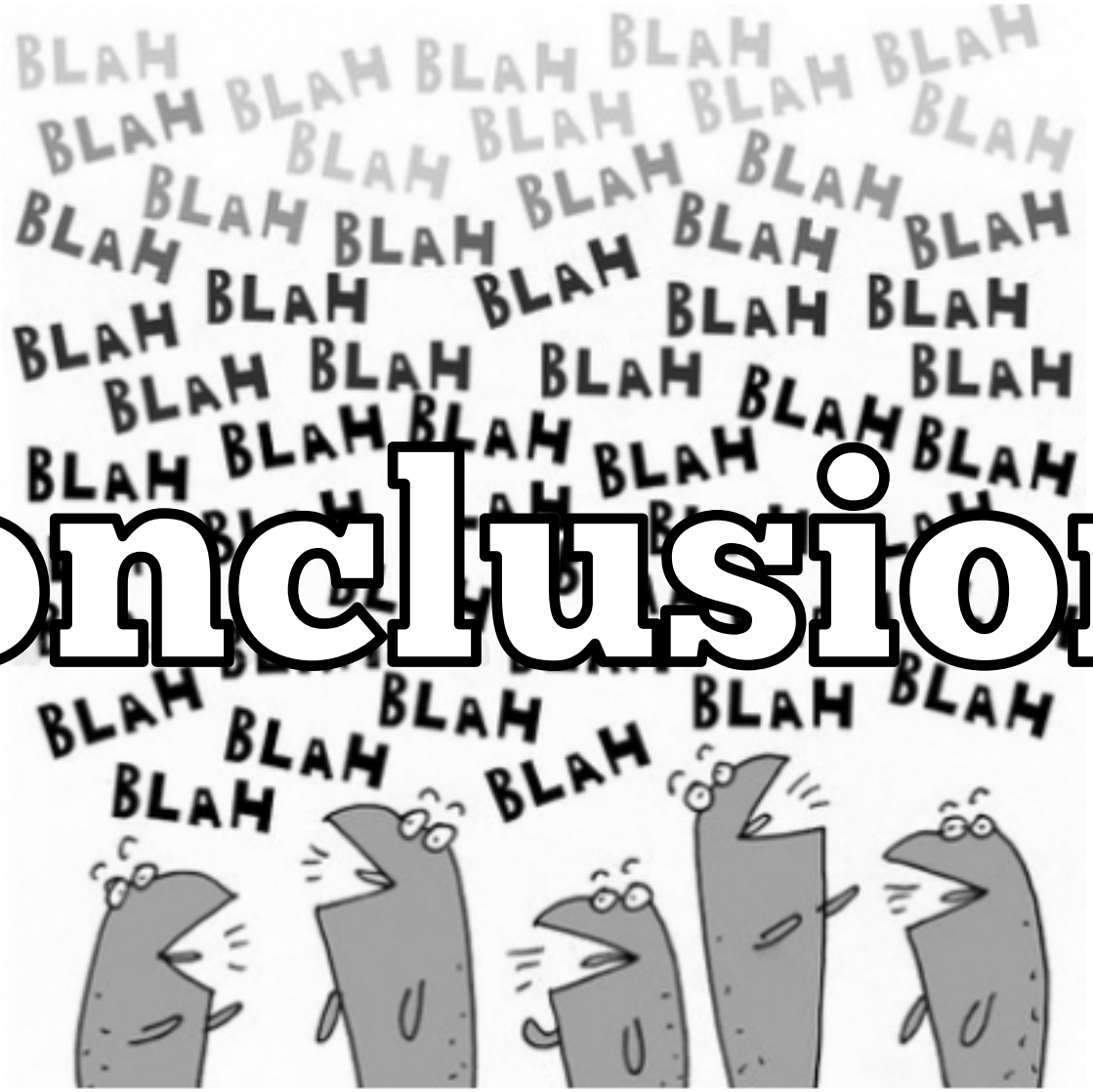
How to find EFI monsters

- SCAP is used by EfiFlasher.
- We can stitch our own firmware.
- Extract files from SCAP and build it.
- Reflash via SPI.
- Assumption that SCAP is legit.

How to find EFI monsters

- Stitch utility still in TODO list.
- Potential issues:
  - NVRAM contents?
  - Serial numbers?
- Use current dump and just replace binaries?

Conclusions



Conclusions

- (U)EFI rootkits aren't unicorns.
- Although they are very rare.
- Honestly, we don't know what's out there.
- HackingTeam developed one in 2014.
- Although it was too simple and not advanced.

Conclusions

- Chasing them requires hardware assistance.
- Disassembling computers monthly is not scalable/efficient/viable.
- How to deal with this at enterprise level?

Conclusions

- Vendors are usually slow releasing updates.
- If they ever do it.
- Check legbacore.com work.

Conclusions

- SMC is another interesting chip.
- Alex Ionescu and Andrea Barisani did some work in this area.
- Great rootkit possibilities?

Conclusions

- Intel Management Engine (ME).
- Big Pandora Box?
- Security researchers should have easier access to it.

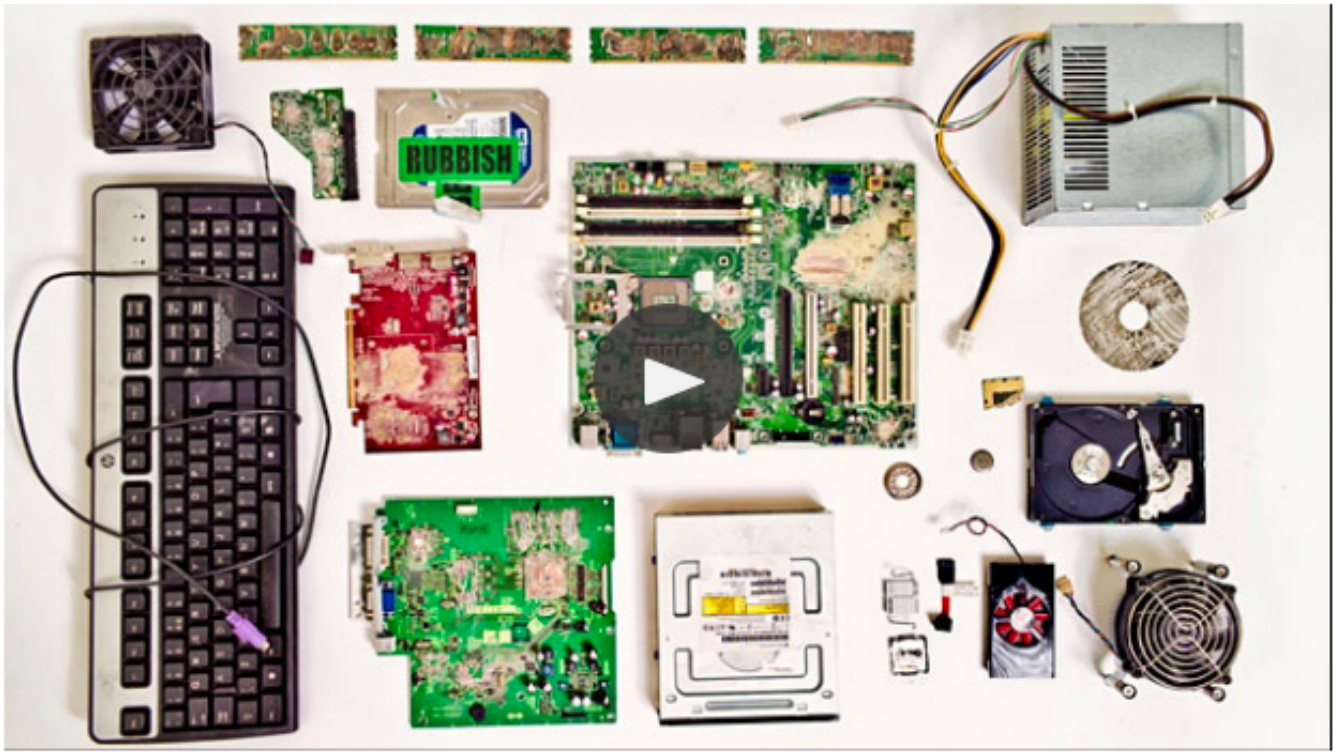
Conclusions

- Option ROMs.
- Still an issue with Apple's EFI implementation.
- No SecureBoot (signed OptionROMs).
- Check Thunderstrike 2 OptionROM worm.

Footage released of Guardian editors destroying Snowden hard drives

GCHQ technicians watched as journalists took angle grinders and drills to computers after weeks of tense negotiations

- Watch the footage of the hard drives being destroyed



New video footage has been released for the first time of the moment Guardian editors destroyed computers used to store top-secret documents leaked by the NSA whistleblower Edward Snowden.

Photo: John Stillwell/PA Wire/AP

Jenna McLaughlin

Aug. 26 2015, 4:05 p.m.

The Way GCHQ Obliterated The Guardian's Laptops May Have Revealed More Than It Intended

In July 2013, GCHQ, Britain's equivalent of the U.S. National Security Agency, forced journalists at the London headquarters of *The Guardian* to completely obliterate the memory of the computers on which they kept copies of top-secret documents provided to them by former NSA contractor and whistle-blower Edward Snowden.

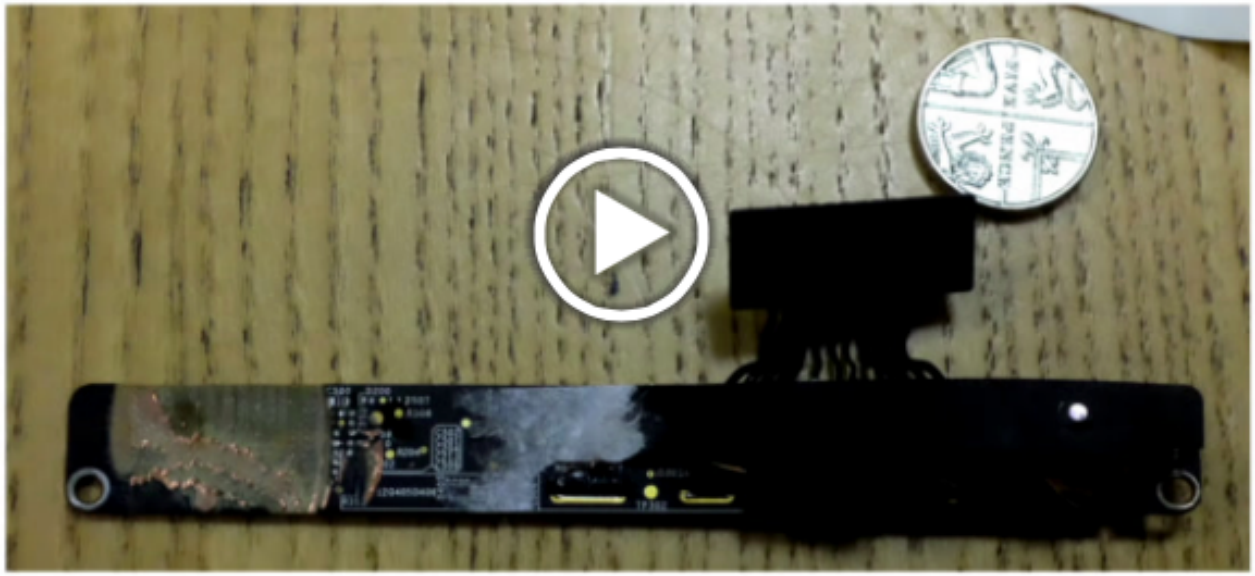
How to Destroy a Laptop with Top Secrets

How did GCHQ do it to the Guardian's copy of Snowden's files?

Mustafa Al-Bassam and Richard Tynan

Video | Audio | Download | Share

Power Controller



58 min | 2015-08-17 | 29209 | events.ccc.de

Conclusions

- Trolling?
- Real?
- Maybe a mix of both.
- Check Apple logic board schematics.
- There's a ton of interconnected stuff.

Conclusions

- We need trusted hardware solutions.
- If we can't trust hardware we are wasting a lot of time solving some software problems.

Conclusions

- Bring back physical protections?
- Switches to enable:
  - Flash writes.
  - MIC.
  - Camera.
  - Etc...

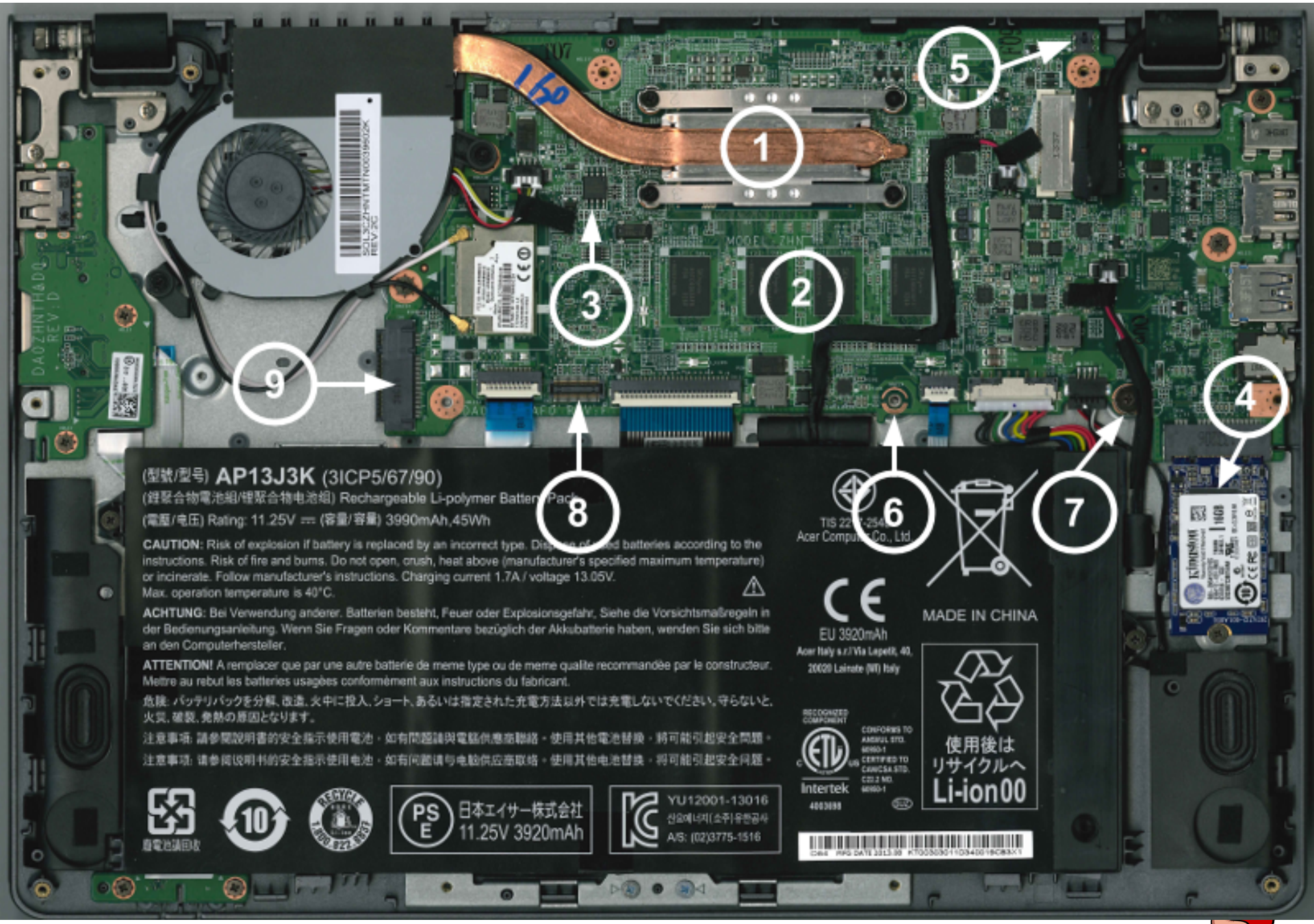
Conclusions

Jumper JP4: BIOS Flash Protect

The system BIOS and CMOS Setup Utility are stored in Flash memory on the motherboard, which provides permanent storage, but is rewritable, allowing for BIOS updates. Jumper JP4 controls the protection scheme that prevents accidental damage to or rewriting of the data stored in Flash memory.

JP4: BIOS Flash Protect

Setting	Function
Short 1-2 	Protection mode selected in BIOS CMOS Setup Utility [Default]
Short 2-3 	Protection enabled in hardware
Open [Remove Cap]	No BIOS Flash Protection


1
2
3
4
5
6
7
8
9
(型號/型号) AP13J3K (3ICP5/67/90)
(鋰聚合物電池組/锂聚合物电池组) Rechargeable Li-polymer Battery Pack
(電壓/电压) Rating: 11.25V ⎓ (容量/容量) 3990mAh,45Wh
CAUTION: Risk of explosion if battery is replaced by an incorrect type. Dispose of used batteries according to the instructions. Risk of fire and burns. Do not open, crush, heat above (manufacturer's specified maximum temperature) or incinerate. Follow manufacturer's instructions. Charging current 1.7A / voltage 13.05V.
Max. operation temperature is 40°C.
ACHTUNG: Bei Verwendung anderer. Batterien besteht, Feuer oder Explosionsgefahr. Siehe die Vorsichtsmaßregeln in der Bedienungsanleitung. Wenn Sie Fragen oder Kommentare bezüglich der Akkubatterie haben, wenden Sie sich bitte an den Computerhersteller.
ATTENTION! A remplacer que par une autre batterie de meme type ou de meme qualite recommandée par le constructeur. Mettre au rebut les batteries usagées conformément aux instructions du fabricant.
危険: バッテリパックを分解、改造、火中に投入、ショート、あるいは指定された充電方法以外では充電しないでください。守らないと、火災、破裂、発熱の原因となります。
注意事项: 請參閱說明書的安全指示使用電池，如有問題請與電腦供應商聯絡。使用其他電池替換，將可能引起安全問題。
注意事项: 请参阅说明书的安全指示使用电池，如有问题请与电脑供应商联络。使用其他电池替换，将可能引起安全问题。
TIS 22[illegible]-254[illegible]
Acer Computer Co., Ltd
EU 3920mAh
Acer Italy s.r.l Via Lepetit, 40,
20020 Lainate (MI) Italy
MADE IN CHINA
使用後は
リサイクルへ
Li-ion00
Intertek
4003098
日本エイサー株式会社
11.25V 3920mAh
YU12001-13016
A/S: (02)3775-1516

Conclusions

- Acer C720 & C720P Chromebook.
  - https://www.chromium.org/chromium-os/developer-information-for-chrome-os-devices/acer-c720-chromebook
- #7 is a write-protect screw.

Conclusions

- Might require new hardware design?
- NVRAM needs to be writable.
- An independent flash chip for writable regions?
- BOM/space restrictions?

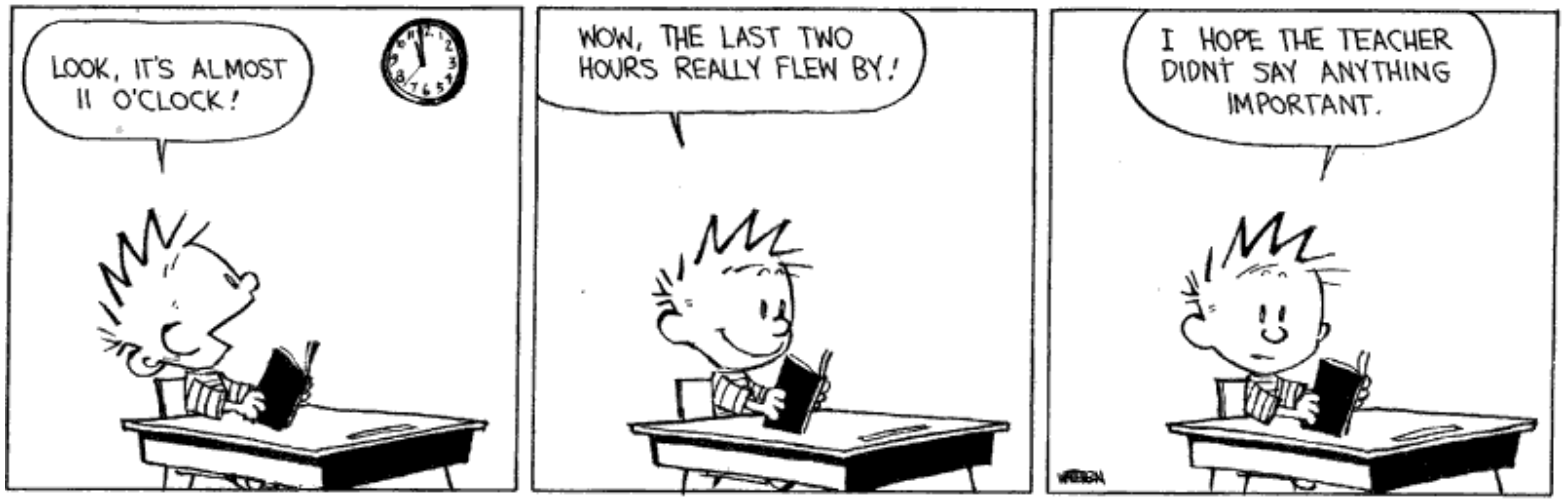
Conclusions

- Apple has a great opportunity here.
- Full control of design and supply chain.
- Can improve designs.
- Can force faster updates.
- Only matched by Chromebook?


FIRMWARE
SECURITY IS
CRITICAL!

Greetings

- SyScan360 team, Snare, Trammell, Xeno, Corey, Saure, cr4sh.



https://reverse.put.as

https://github.com/gdbinit

reverser@put.as

@osxreverser

#osxre @ irc.freenode.net

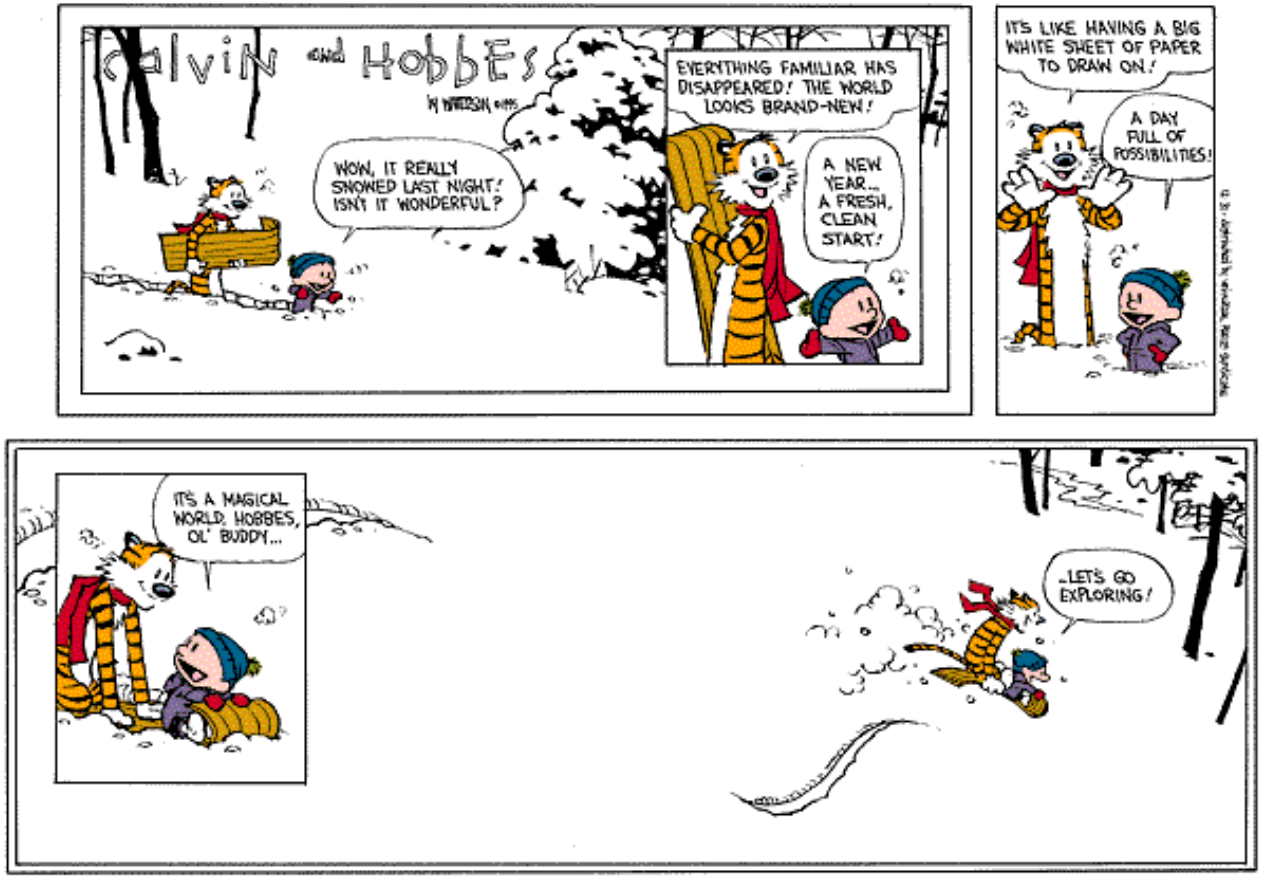
PGP key

https://reverse.put.as/wp-content/uploads/2008/06/publickey.txt

PGP Fingerprint

7B05 44D1 A1D5 3078 7F4C E745 9BB7 2A44 ED41 BF05

A day full of possibilities!



Let's go exploring!

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  - https://reverse.put.as/2015/07/01/reversing-prince-harmings-kiss-of-death/
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  - https://www.youtube.com/watch?v=sJnliPN0104&app=desktop