Advanced x86:
BIOS and System Management Mode Internals
Tools

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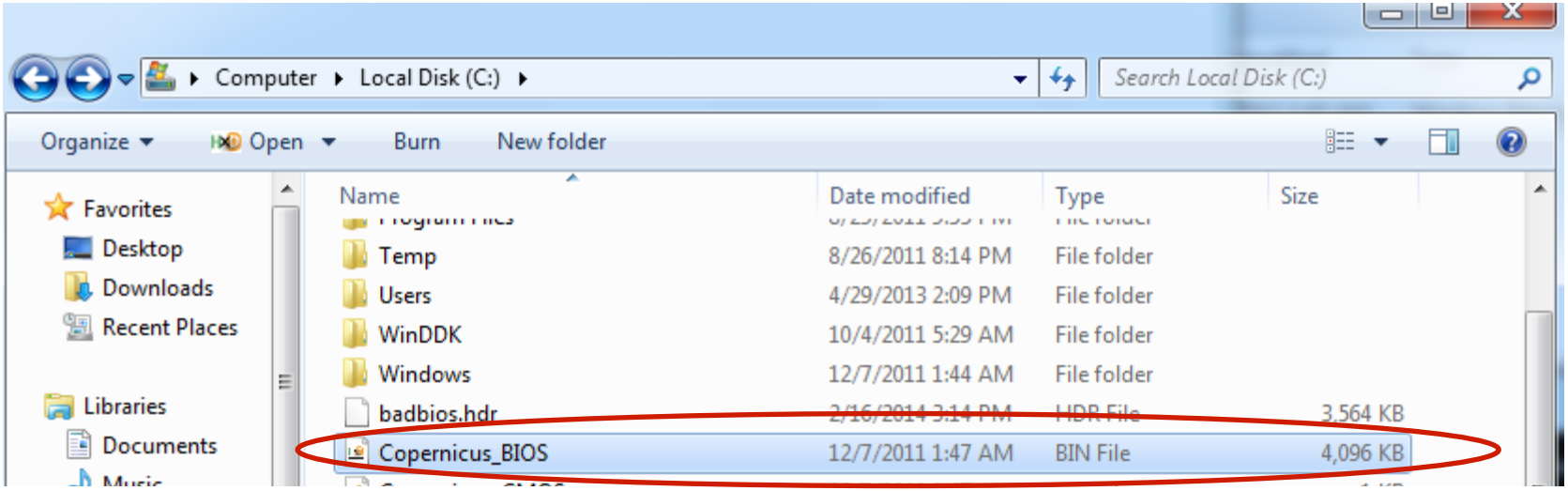
"Is derived from John Butterworth & Xeno Kovah’s ’Advanced Intel x86: BIOS and SMM’ class posted at http://opensecuritytraining.info/IntroBIOS.html”

Running Copernicus

- Can be downloaded from:
- http://www.mitre.org/capabilities/cybersecurity/overview/cybersecurity-blog/copernicus-question-your-assumptions-about
  - ***But in this class, use the one in the Tools folder***
- From admin prompt cd C:\Copernicus and execute standalone.bat

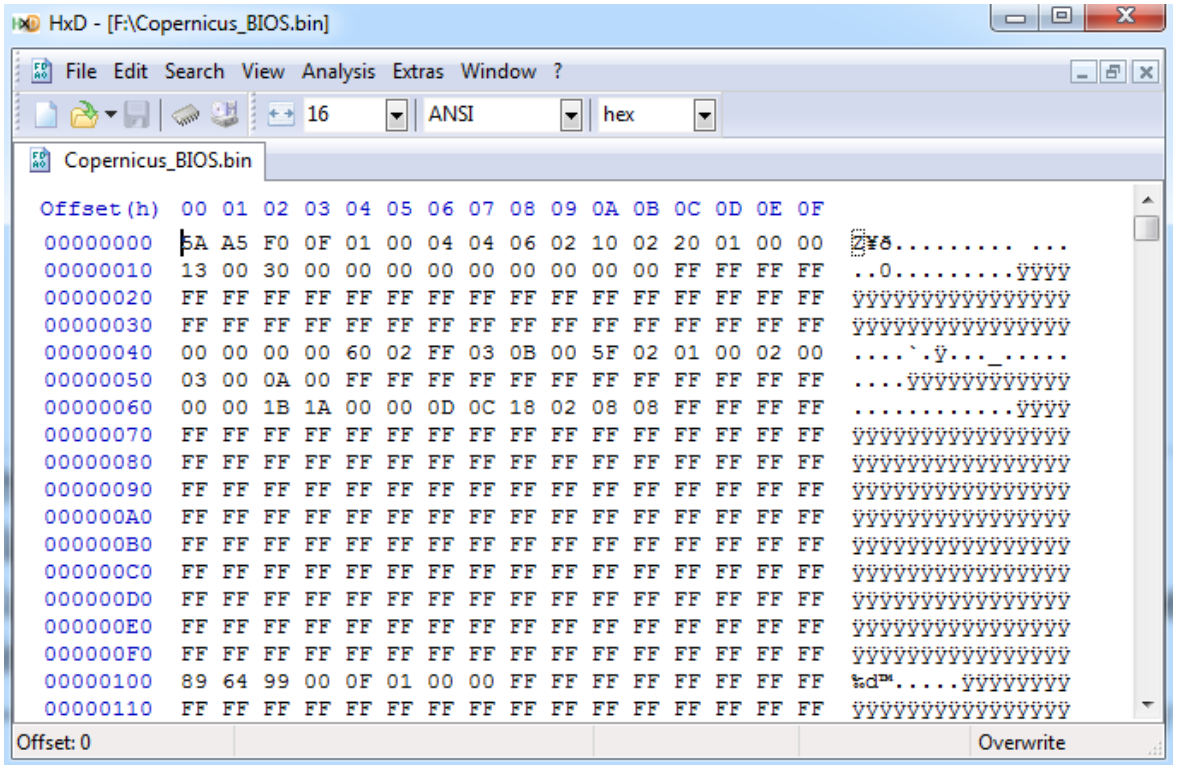
Running Copernicus



- Copernicus drops it's output into the base of the C:\ drive
- We'll talk about a few of these files
- The size of this binary will equal the size of your SPI flash
- Copernicus dumps all the flash contents (whether readable or not)
- For regions which the CPU/BIOS has no permission to read, it writes all 1's (0xFF)

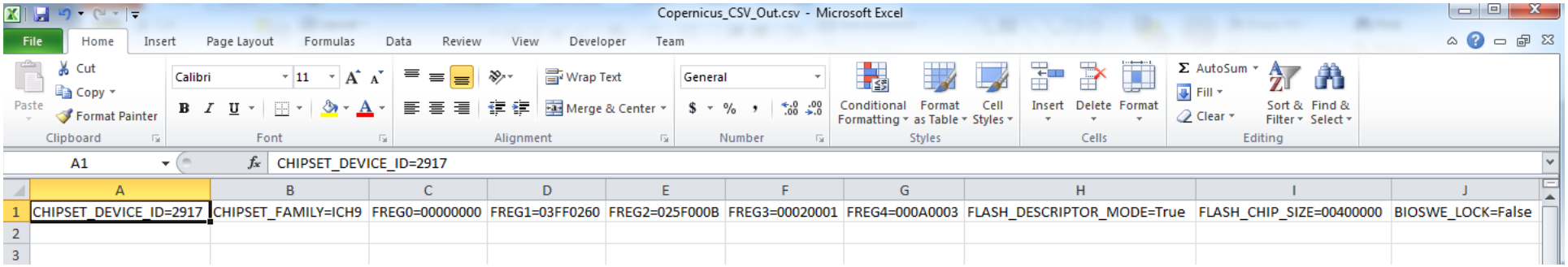
***Note: badbios.hdr is just the joke-name of the vulnerable BIOS image John created for this class**

Copernicus_BIOS.bin



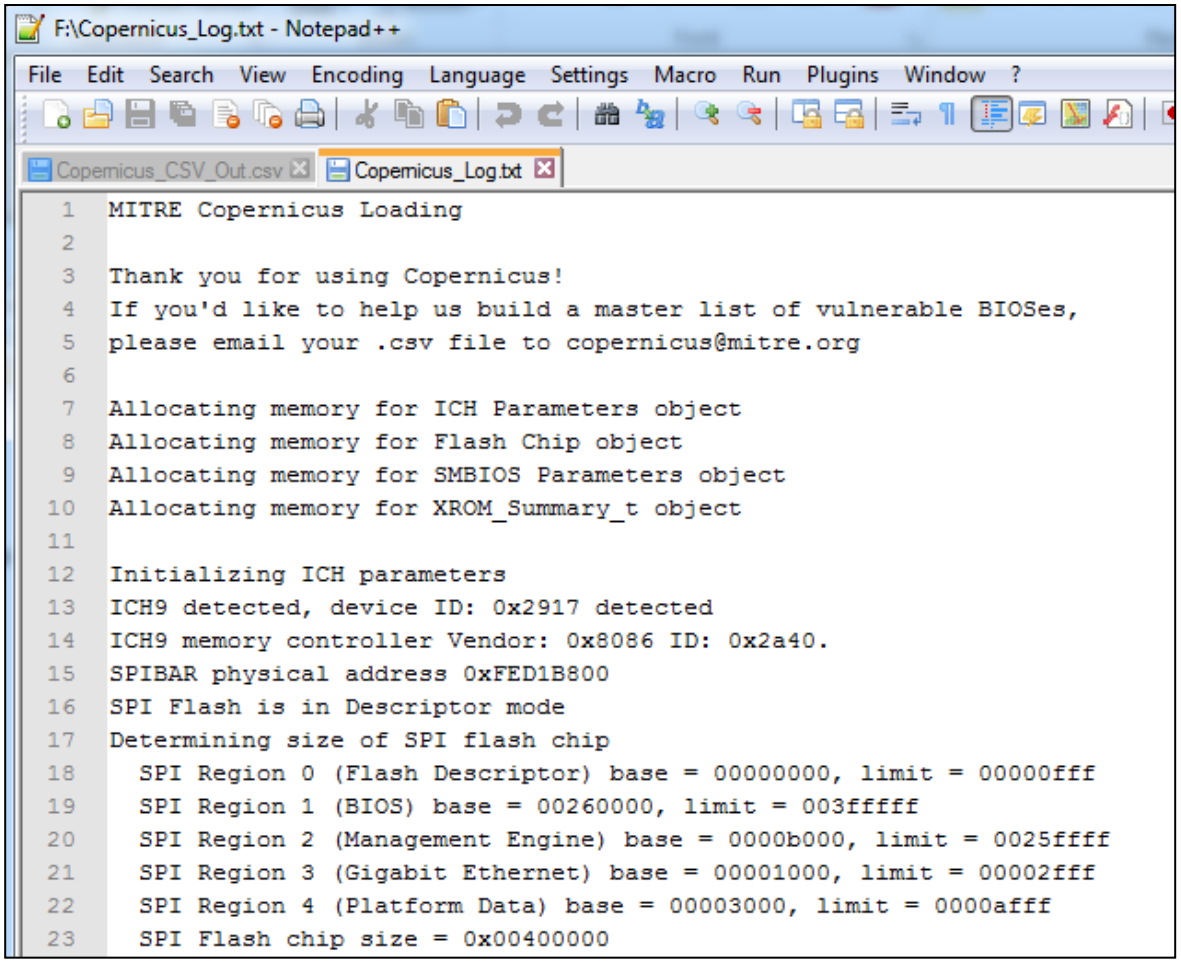
- This is a dump of the entire flash BIOS
- Flash is accessed via the programming registers
- Anything Copernicus can't read (e.g. due to permissions) it just fills in with 0xFFs
  - Reason: to preserve the flash linear address offsets for each region within the binary

Copernicus_CSV_Out.csv



- This is a comma-separated file containing the configuration data that was read from the system
- Not all are security-related
  - what ICH/PCH is present
  - FREG registers (just to determine the size of each region and the chip)
  - Many others
  - Because you are attending this class you can access the full .CSV file measurements
  - otherwise you are limited only to the most simple SMM/BIOS lock/ unlock measurements (but still the most pertinent!)

Copernicus_Log.txt



- Contains a log file of human-readable information about the system which was just measured
- Also exit status to determine which, if any, measurements failed

“see something, say something”

- If your output contains:

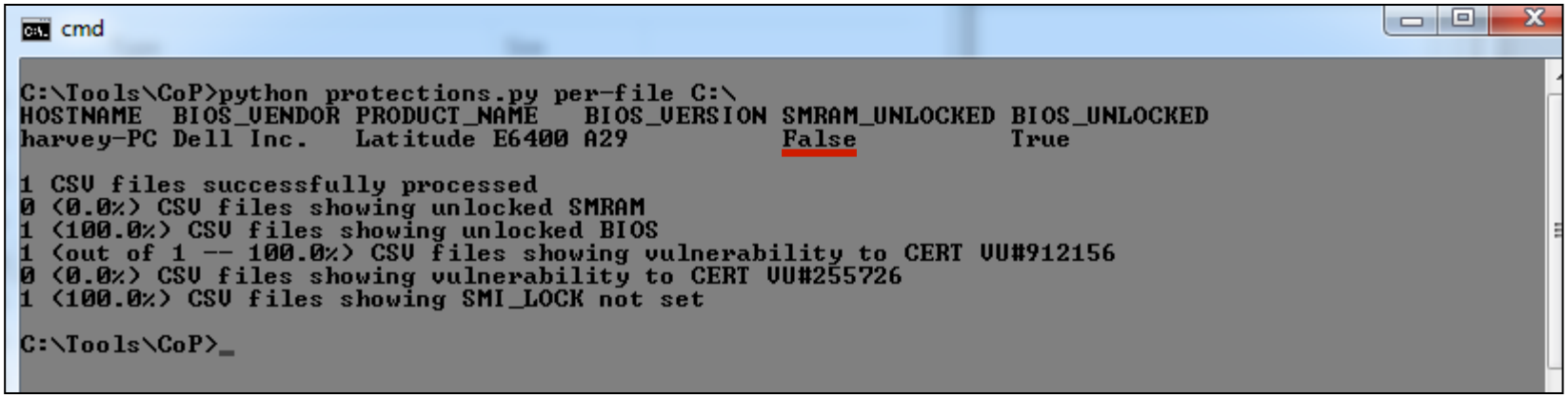
“Email the following to copernicus@mitre.org so we can look into adding support for this architecture.

Copernicus Error: Unidentified IO Controller Hub vendor=8086, device=9c45

Memory Controller: vendor=8086, device=0a04”

- Then email it in so they can add support for the hardware

Running Protections.py



- Let's look at the .CSV file in Notepad
- By the end of the course you'll know what these mean
- Open a CMD prompt in directory C:\Tools\CoP\
- > python protections.py per-version C:\
  - Can also run per-file, affects the sorting of output
- This analyzes our .CSV file for the most basic configuration settings
- SMRAM unlocked in the image above is a bug that should be fixed in the version you're using
- Anyway, let's get started on the course!

Some Useful Tools of the Trade

Copernicus

- Question your assumptions
- Copernicus is a tool we wrote to determine how prevalent vulnerable BIOS' are "in the wild"
- Collects the information we are discussing during this class
  - BIOS_CNTL, SPI, Chipset settings, etc.
  - Data can be analyzed offline to determine the vulnerability of BIOS' in an organization
- So far it has been run on nearly 10,000 systems
- Runs as a Windows driver (32-bit and 64-bit supported)
- Will eventually be released to open source when we have collected enough data to support a whitepaper on our findings
  - Source code released in a code for data agreement
  - Data run on many, many systems

Chipsec

```
[+] imported chipsec.modules.common.bios_wp
[x][ ================================================================================
[x][ Module: BIOS Region Write Protection
[x][ ================================================================================
BIOS Control (BDF 0:31:0 + 0xDC) = 0x2A
[05]    SMM_BWP = 1 (SMM BIOS Write Protection)
[04]    TSS     = 0 (Top Swap Status)
[01]    BLE     = 1 (BIOS Lock Enable)
[00]    BIOSWE  = 0 (BIOS Write Enable)

[+] BIOS region write protection is enabled (writes restricted to SMM)

[*] BIOS Region: Base = 0x00500000, Limit = 0x00FFFFFF
SPI Protected Ranges
------------------------------------------------------------
PRx (offset) | Value    | Base     | Limit    | WP? | RP?
------------------------------------------------------------
PR0 (74)     | 00000000 | 00000000 | 00000000 | 0   | 0
PR1 (78)     | 8FFF0F40 | 00F40000 | 00FFF000 | 1   | 0
PR2 (7C)     | 8EDF0EB1 | 00EB1000 | 00EDF000 | 1   | 0
PR3 (80)     | 8EB00EB0 | 00EB0000 | 00EB0000 | 1   | 0
PR4 (84)     | 8EAF0C00 | 00C00000 | 00EAF000 | 1   | 0

[!] SPI protected ranges write-protect parts of BIOS region (other parts of BIOS can be
modified)

[+] PASSED: BIOS is write protected
```

- Intel's open source firmware measurement tool
- Yuriy Bulygin and John Loucaidis (Intel) introduced this tool at CanSecWest 2014
- https://github.com/chipsec/chipsec
- Developers can add new measurement modules to it
- Can be run from Windows, Linux, or UEFI Shell

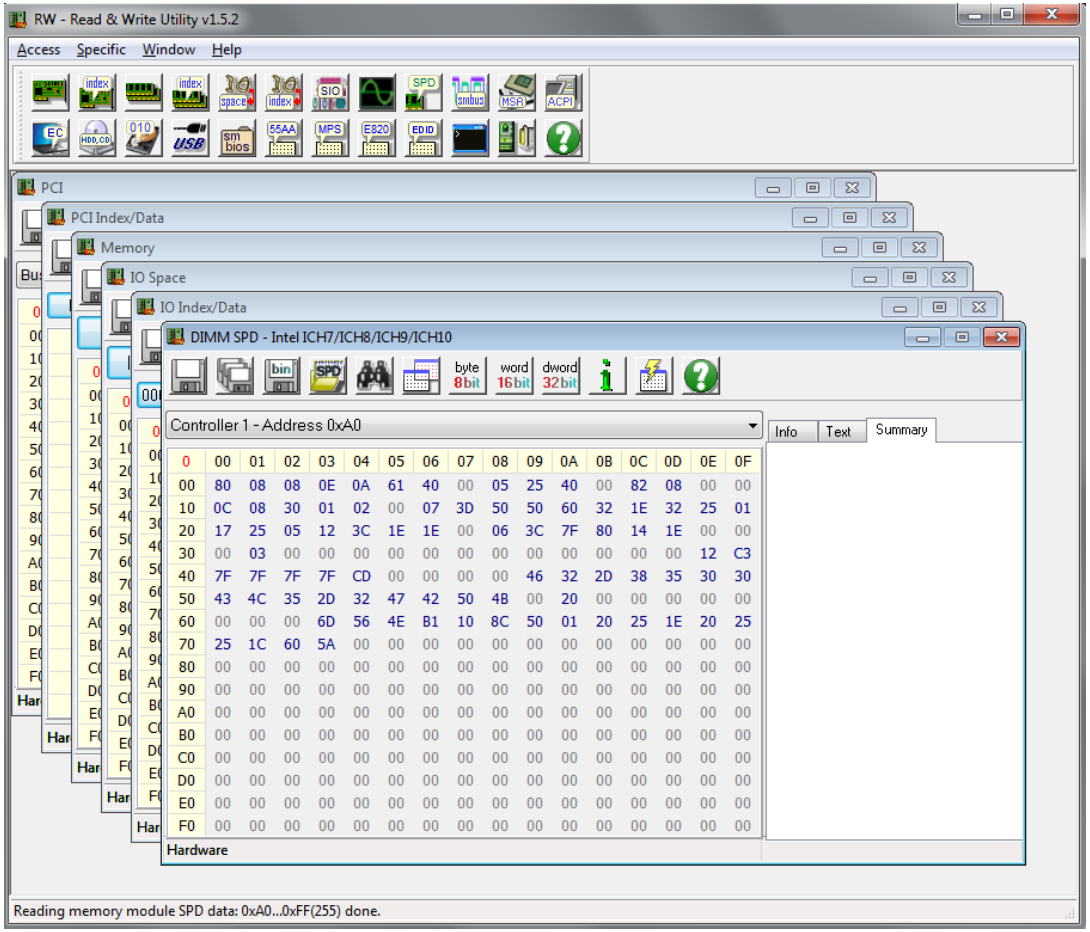
Flashrom

- *NIX tool that gives you the ability to read from a variety of SPI flash chips
- I've only ever used this on Mac (where there's no Cop/Chipsec support) or as a backup when combined with a BusPirate hardware reader when my DediProg hardware reader didn't work
- I don't think they ever patched the issue that makes it untrustworthy, even though we called it out specifically and showed the source code in our CanSecWest 2013 presentation

Darwin Dumper

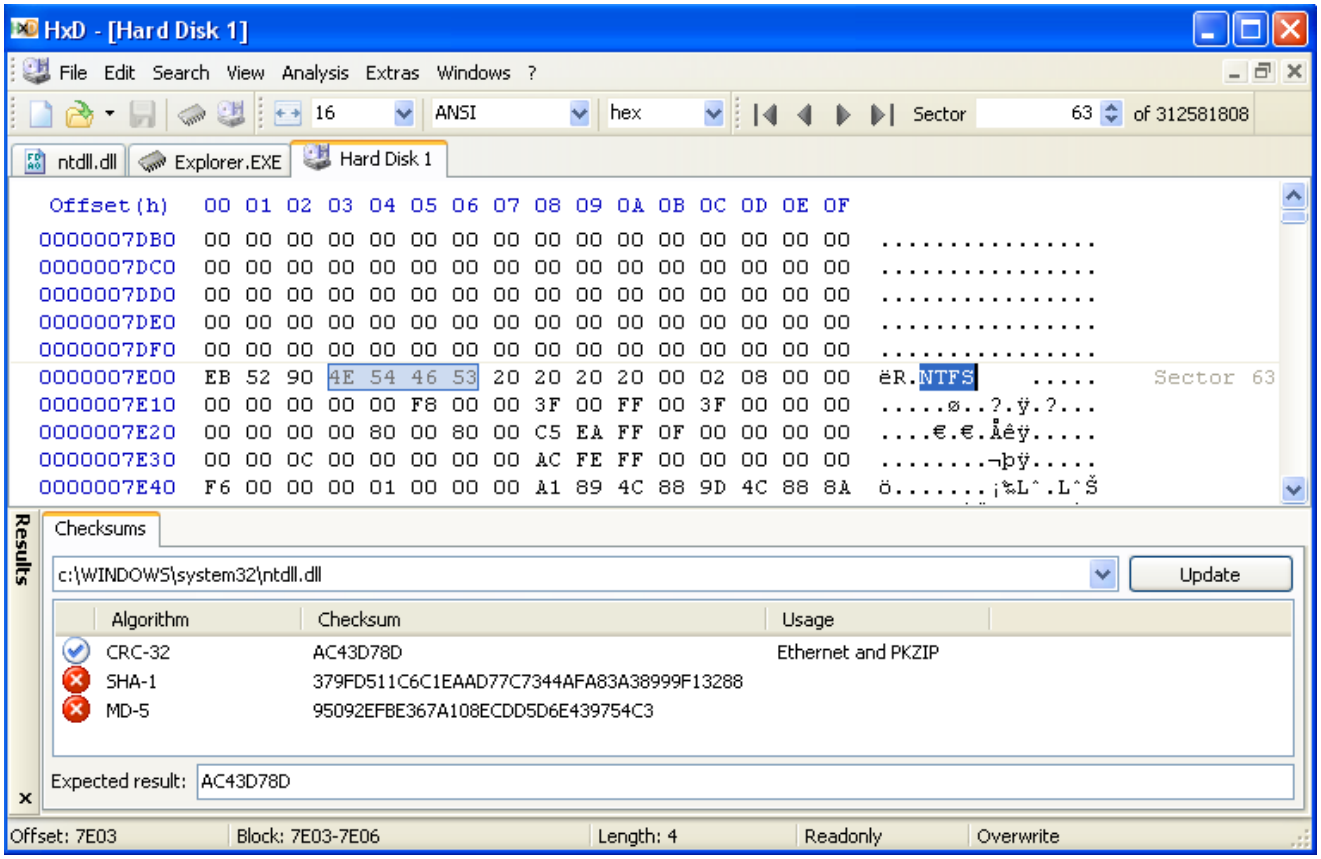
- https://bitbucket.org/blackosx/darwindumper/downloads
- Finally got around to using this for our Apple vulnerability research work :)
- Dumps SPI chip & a bunch of other stuff (also pulls EFI variables off the SPI chip, not through parsing, but through using Apple's API)
- Uses a precompiled flashrom and supporting DirectHW.kext behind the scenes.
  - DirectHW.kext probably won't work in the future since Apple recognizes it's a problem

RW Everything (RW-E)



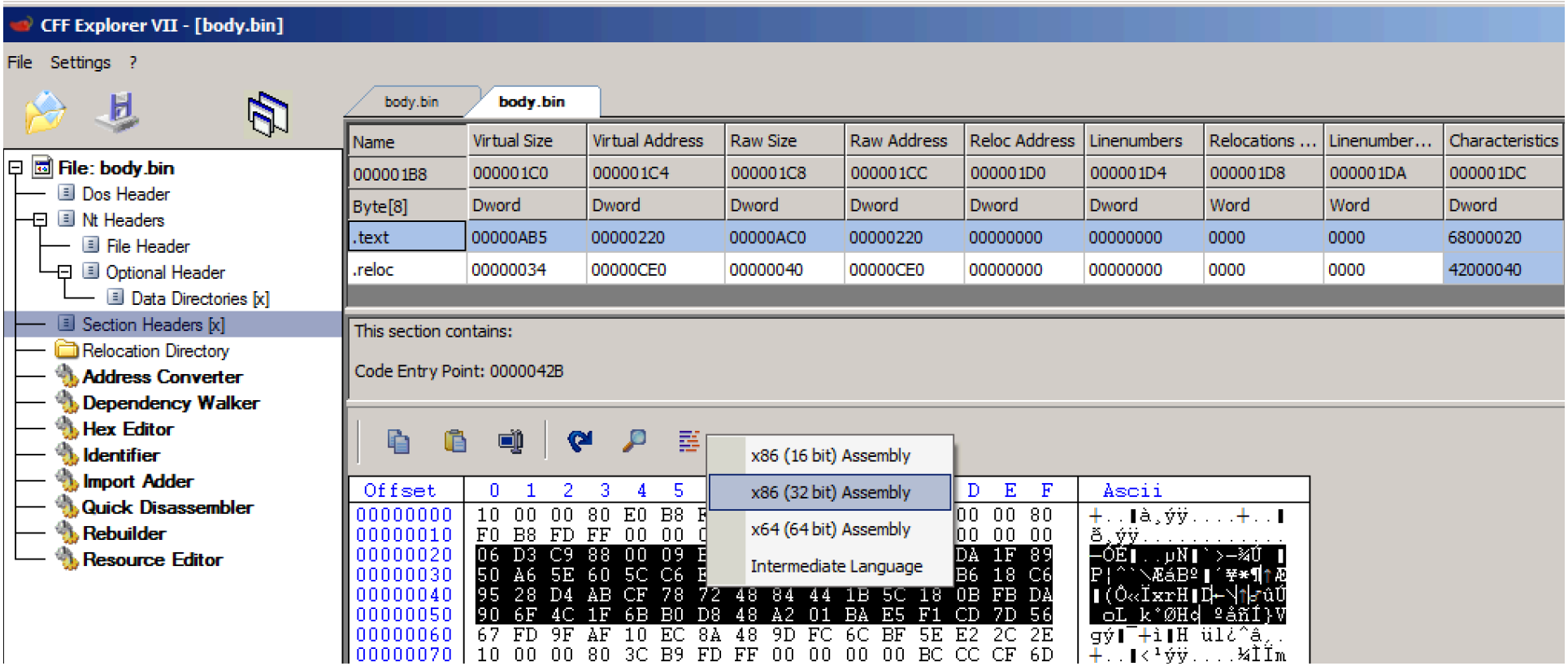
- http://rweverything.com/
- Powerful utility to observe and/or modify platform hardware configurations
- Scriptable so you can test ideas without writing a driver
- Access to PCI Config space, IO space, physical memory
- Freeware, not open source

HxD (hex editor for Windows)



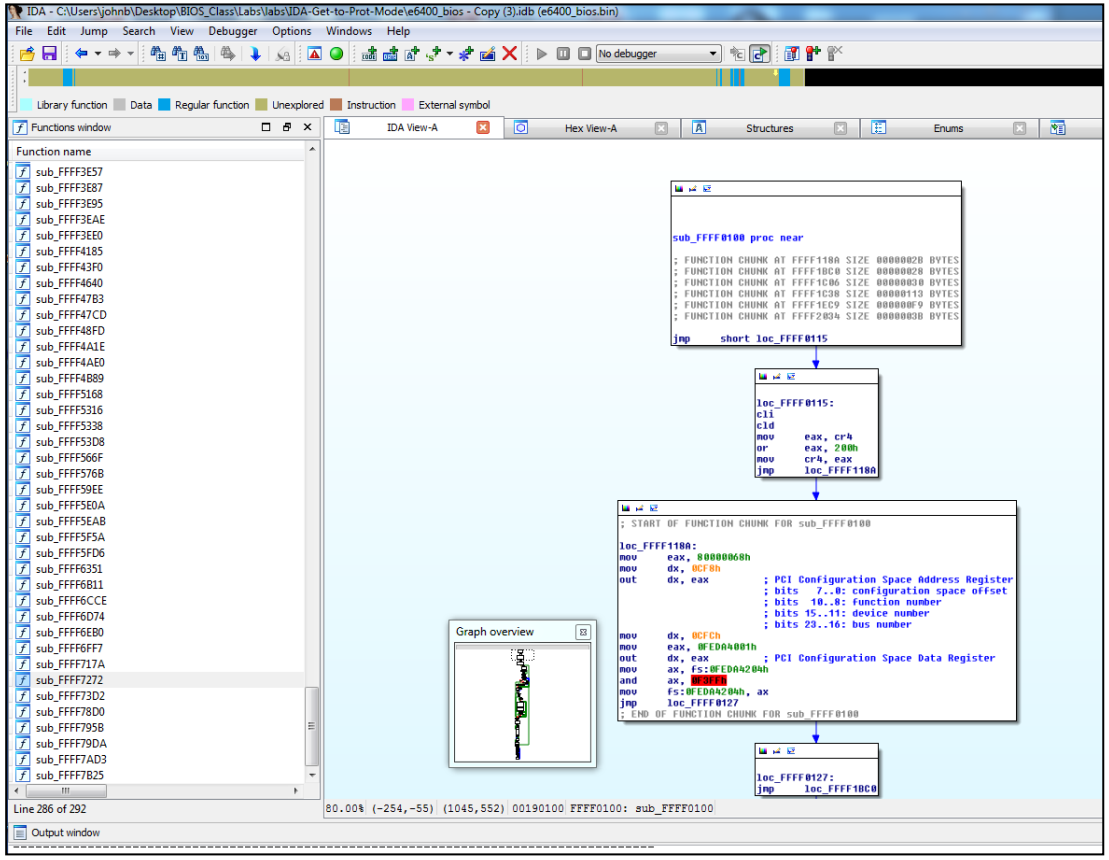
- http://mh-nexus.de/en/hxd/
- Good & solid hex editor for Windows
- Some useful features includ file diffing & raw HD access

CFF Explorer



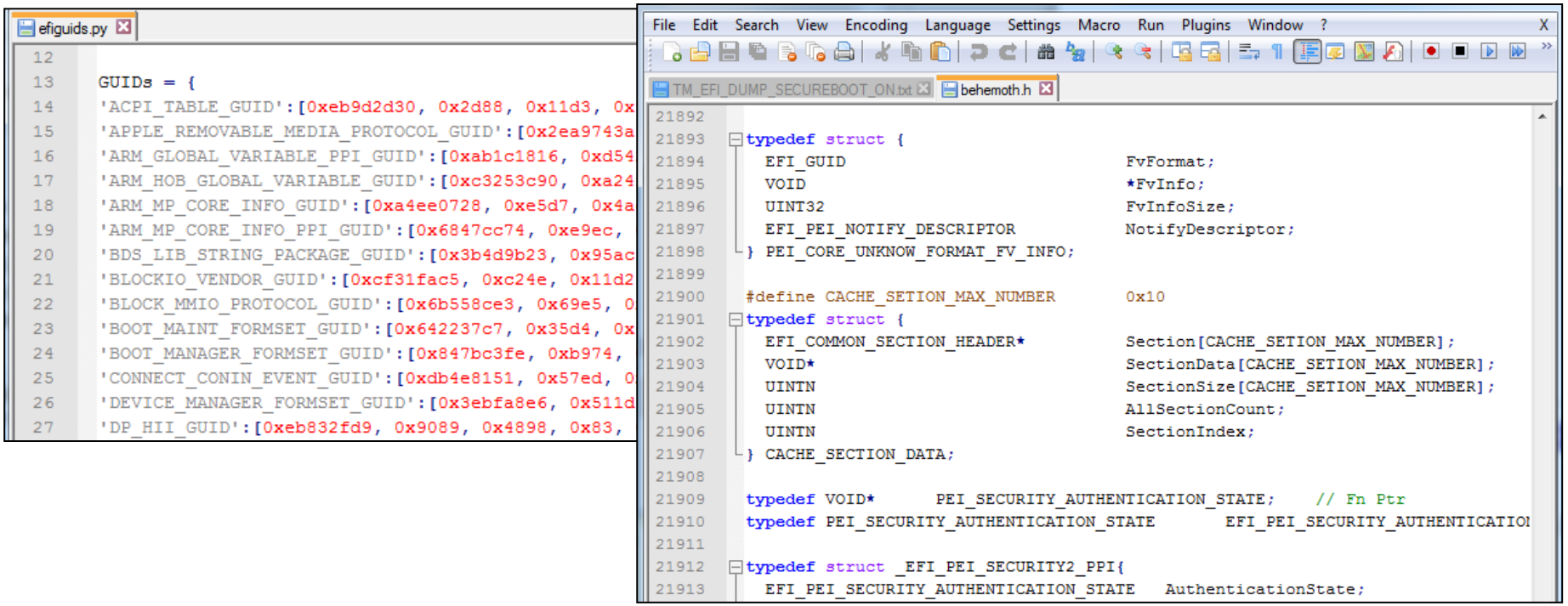
- http://www.ntcore.com/exsuite.php
- For for analyzing PE files (which lots of BIOS files turn out to be).
- Has a hex view and a basic 16/32/64 bit disassembler which can be useful for disassembly some arbitrary bytes
- Covered more extensively in the Life of Binaries class

IDA Pro



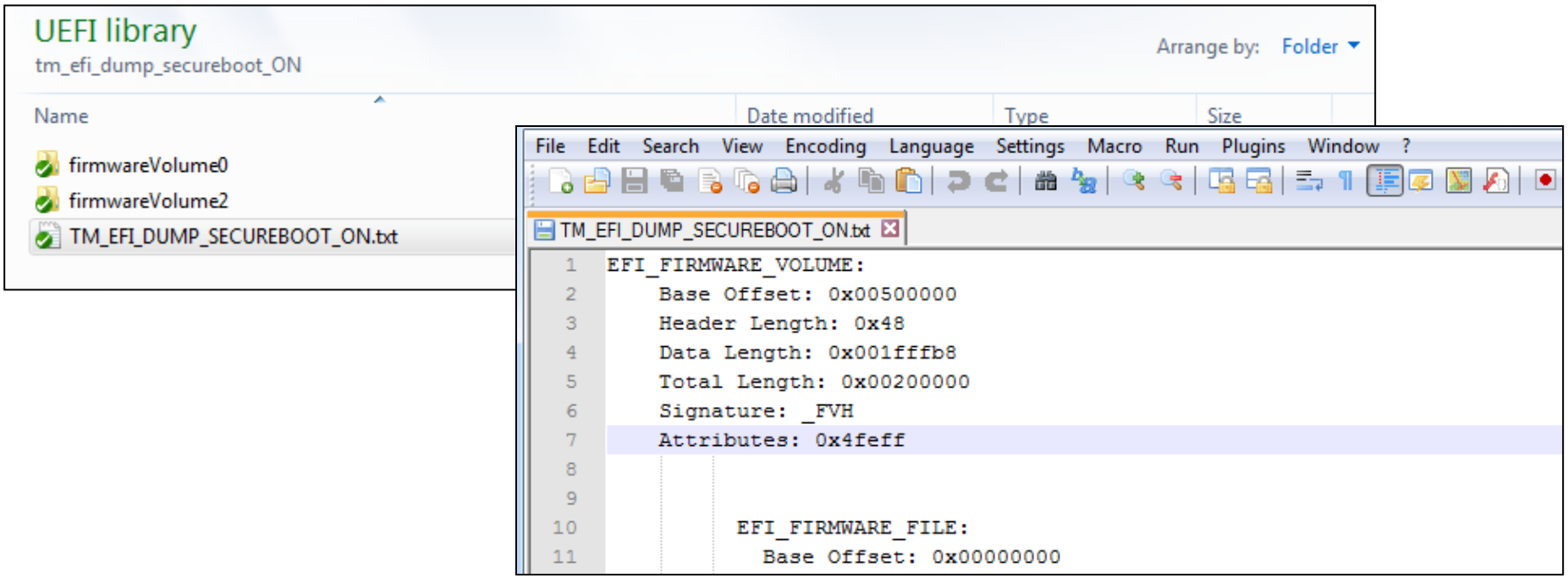
- https://www.hex-rays.com/products/ida/
- Free version (5.0) works for this class (minus pseudo-code of course)
  - https://www.hex-rays.com/products/ida/support/download_freeware.shtml

Snare's ida-efi Utilities



- https://github.com/snarez/ida-efiutils
- Behemoth.h
  - UEFI structures to import into IDA Pro, makes code readable
- EfiGuids.py
  - Big list of EFI Guids parsed from various sources
- And others, but the above two we use most often

EFIPWN (by G33KatWork)

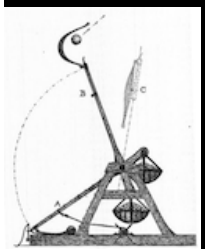


- https://github.com/G33KatWork/EFIPWN
- EFI image parser, pulls out .efi modules/drivers
- Written in Python, so it can be a bit slow
- Prints the PE file structure of an image
- Can Dump the PE file contents into a file system structure
- This is used behind the scenes for Copernicus' bios_diff.py. Not necessarily because it's the best, but because it was the first available when we started the work.

UEFI Firmware Parser (by Teddy Reed)

- https://github.com/theopolis/uefi-firmware-parser
- Can now also extract some stuff that EFIPWN misses
- Prints UEFI non-volatile variables
- Automatically identifies the possible usage of a file based on the file GUID
  - But it can misidentify things which may use the same GUIDs across different vendors (but misidentification is not that big of a deal, since it still gives you a potentially useful name, which is valuable for knowing what it might do, if the file doesn't have a proper name)

```
Flash Descriptor (Intel PCH) chips 0, regions 3, masters 2, PCH straps 16, PROC straps 0, ICC entries 0
  Flash Region type= bios, size= 0x300000 (3145728 bytes) details[ read: 11, write: 10, base: 1280, limit:
    Firmware Volume: 7a9354d9-0468-444a-ce81-0bf617d890df attr 0xffff8eff, rev 1, cksum 0x4c89, size 0x150
      Firmware Volume Blocks:  (21, 0x10000)
      File 0: 4a538818-5ae0-4eb2-ebb2-488b23657022 type 0x05, attr 0x40, state 0x07, size 0x134490 (126273
        Section 0: type 0x01, size 0x134478 (1262712 bytes) (Compression section)
          Section 0: type 0x19, size 0x700010 (7340048 bytes) (Raw section)
            Firmware Volume: 7a9354d9-0468-444a-ce81-0bf617d890df attr 0xffff8eff, rev 1, cksum 0x4bd3, si
              Firmware Volume Blocks:  (112, 0x10000)
              File 0: 35b898ca-b6a9-49ce-728c-904735cc49b7 (LENOVO_DXE_MAIN_GUID) type 0x05, attr 0x40, sta
                Section 0: type 0x10, size 0xe304 (58116 bytes) (PE32 image section)
                Section 1: type 0x15, size 0x14 (20 bytes) (User interface name section)
                Name: DxeMain
              File 1: 4d37da42-3a0c-4eda-ebb9-bc0e1db4713b (LENOVO_SYSTEM_PPIS_NEEDED_BY_DXE_CORE_GUID) ty
                Section 0: type 0x1b, size 0x6 (6 bytes) (PEI dependency expression section)
                Section 1: type 0x10, size 0x2bc4 (11204 bytes) (PE32 image section)
                Section 2: type 0x15, size 0x2c (44 bytes) (User interface name section)
                Name: PpisNeededByDxeCore
              File 2: fea2bc49-33d1-4d3c-229b-8b0d4a798109 type 0x07, attr 0x40, state 0x07, size 0x687c (
                Section 0: type 0x02, size 0x6864 (26724 bytes) (Guid Defined section)
                  Guid-Defined: fc1bcdb0-7d31-49aa-6a93-a4600d9dd083 offset= 0x1c attrs= 0x2 (AUTH_VALID)
                    Section 0: type 0x13, size 0x4c (76 bytes) (DXE dependency expression section)
                    Section 1: type 0x20, size 0x8 (8 bytes) (unknown section)
                    Section 2: type 0x10, size 0x67c4 (26564 bytes) (PE32 image section)
                    Section 3: type 0x15, size 0x2e (46 bytes) (User interface name section)
                    Name: HpQuickLookTrebuchet
```



UEFITool (by NikolajSchlej)

- Frequently succeeds in extracting files that EFIPWN or UEFI Firmware Parser misses

UEFITool File Action

UEFITool 0.17.10

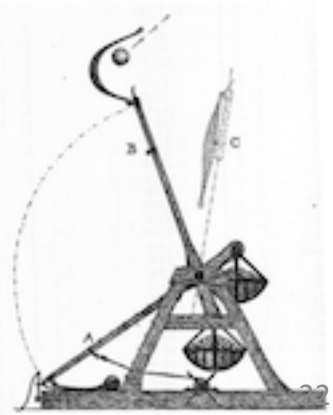
Structure

Name	Action	Type	Subtype
▼Intel image		Image	Intel
Descriptor region		Region	Descriptor
GbE region		Region	GbE
ME region		Region	ME
▼BIOS region		Region	BIOS
Padding		Padding	
▼7A9354D9-0468-444A-81CE-0…		Volume	
▼4A538818-5AE0-4EB2-B2EB…		File	DXE core
▼Compressed section		Section	Compressed
▼Raw section		Section	Raw
Padding		Padding	
▼7A9354D9-0468-444A…		Volume	
▶35B898CA-B6A9-49C…		File	DXE core
▶4D37DA42-3A0C-4ED…		File	PEI module
▼FEA2BC49-33D1-4D3…		File	DXE driver
▼FC1BCDB0-7D31-4…		Section	GUID defined
DXE dependenc…		Section	DXE dependency
Unknown secti…		Section	Unknown
PE32+ image s…		Section	PE32+ image
User interfac…		Section	User interface
▶7367B3B6-DAAF-4A2…		File	DXE driver
▶ED31ED0E-E974-456…		File	DXE driver
▶53AC75F6-D2F2-453…		File	DXE driver
▶8F2B9D3B-9AE8-446…		File	DXE driver
▶85D5DF6C-E3A1-11D…		File	DXE driver
▶85D5DF6C-E3A1-11D…		File	DXE driver
▶1C4709C6-CC81-461…		File	DXE driver
▶B2DE1A6E-3045-409…		File	DXE driver
▶325F9B82-45C8-446…		File	DXE driver
▶470B83AC-33C7-49B…		File	DXE driver

Information

```
Type: 15
Size: 00002a
Text: HpQuickLookTrebuchet
```

HP's too cool for a trampoline, they use trebuchets!



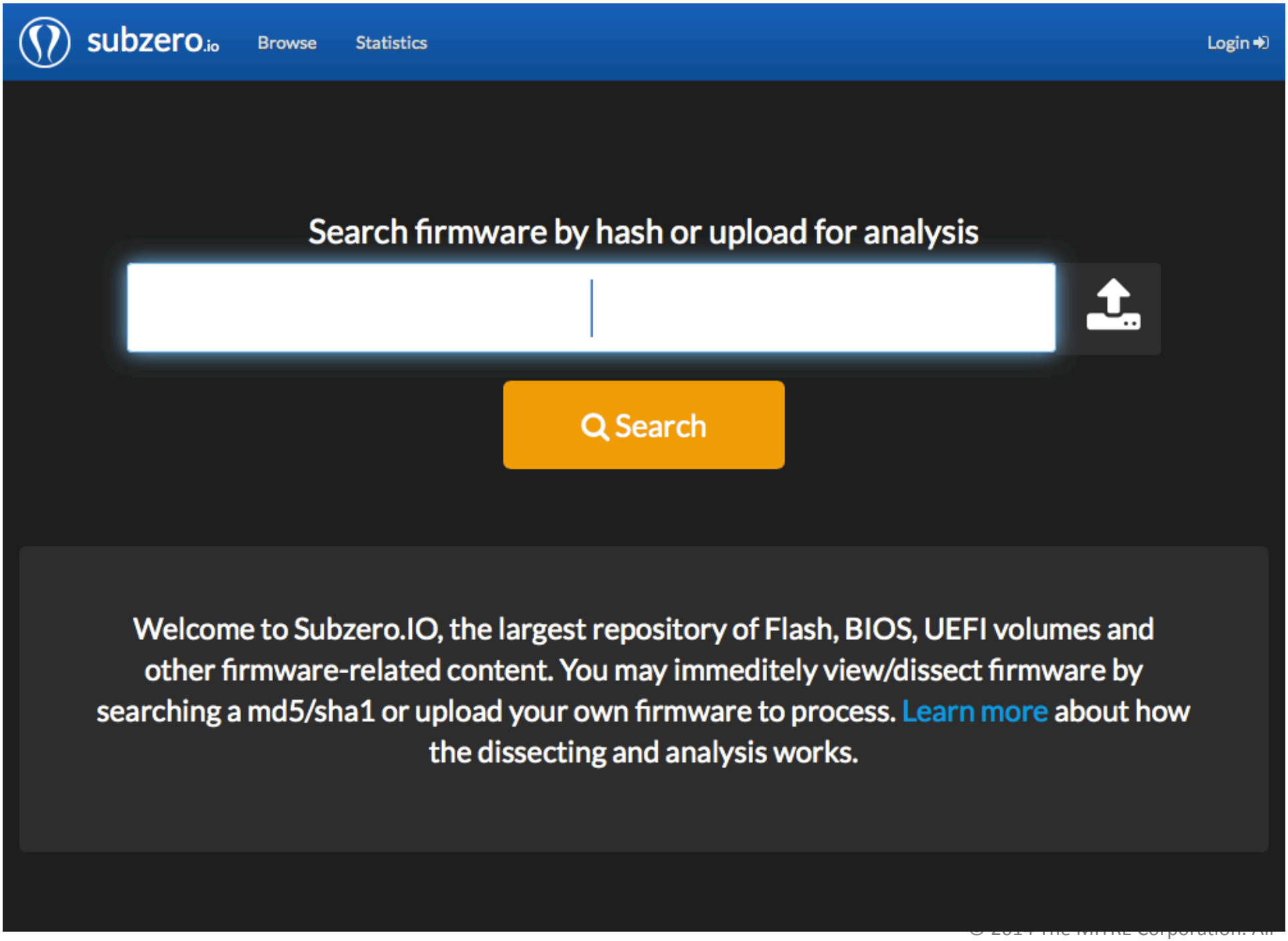
https://github.com/LongSoft/UEFITool

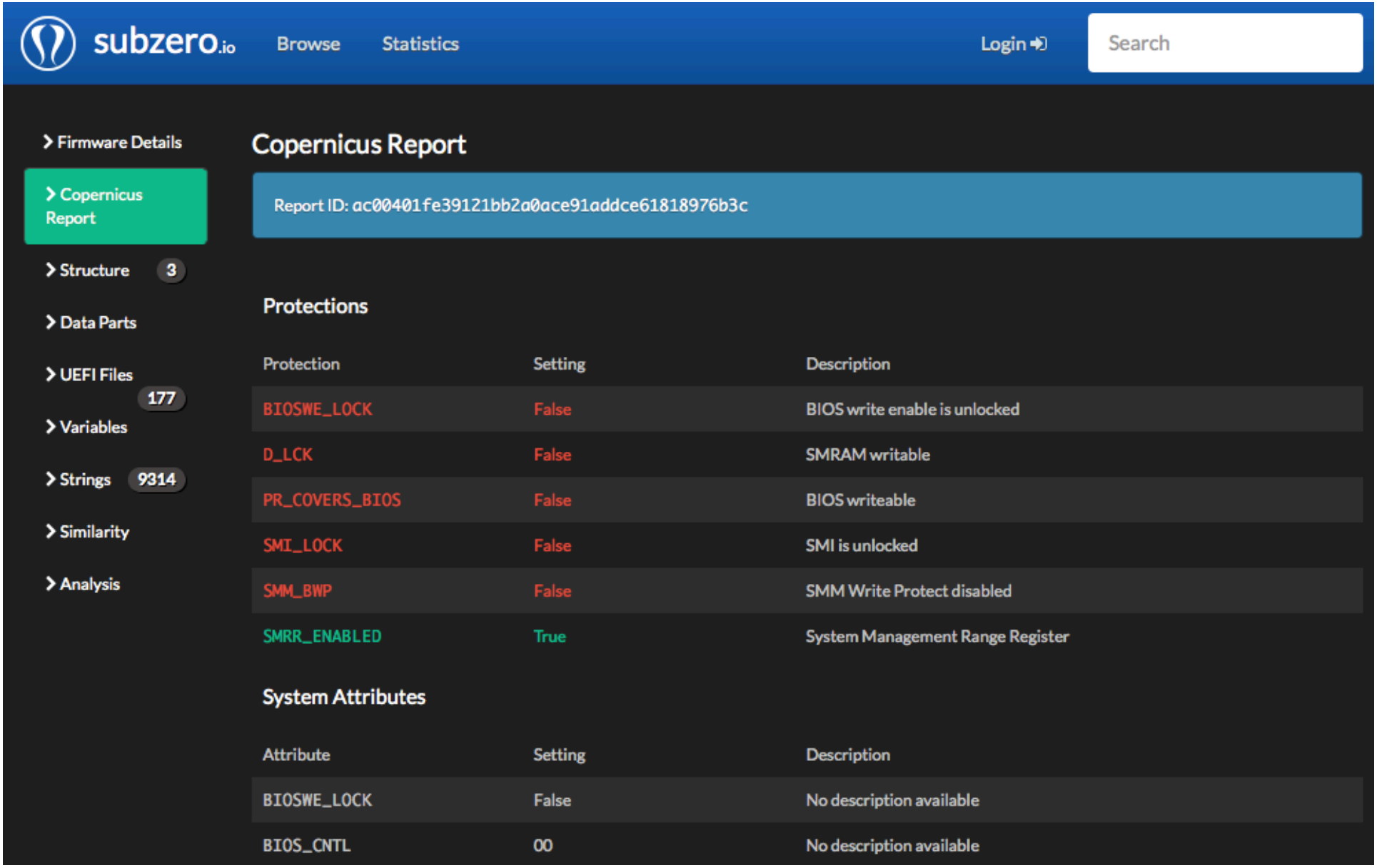
UEFIExtract

- Run as “UEFIExtract <bios.bin>”
- Will create folder in current directory labeled <bios.bin>.dump
- Will then use the same core logic as UEFITool to extract *all* the files at once into their filesystem structure
- Good for when you want to search through all files, rather than extract a single target file
- Be warned, because of the way it extracts every level of binary at every level of the filesystem, this leads to a massive expansion
  - E.g. a 12MB BIOS can turn into a 200MB dump

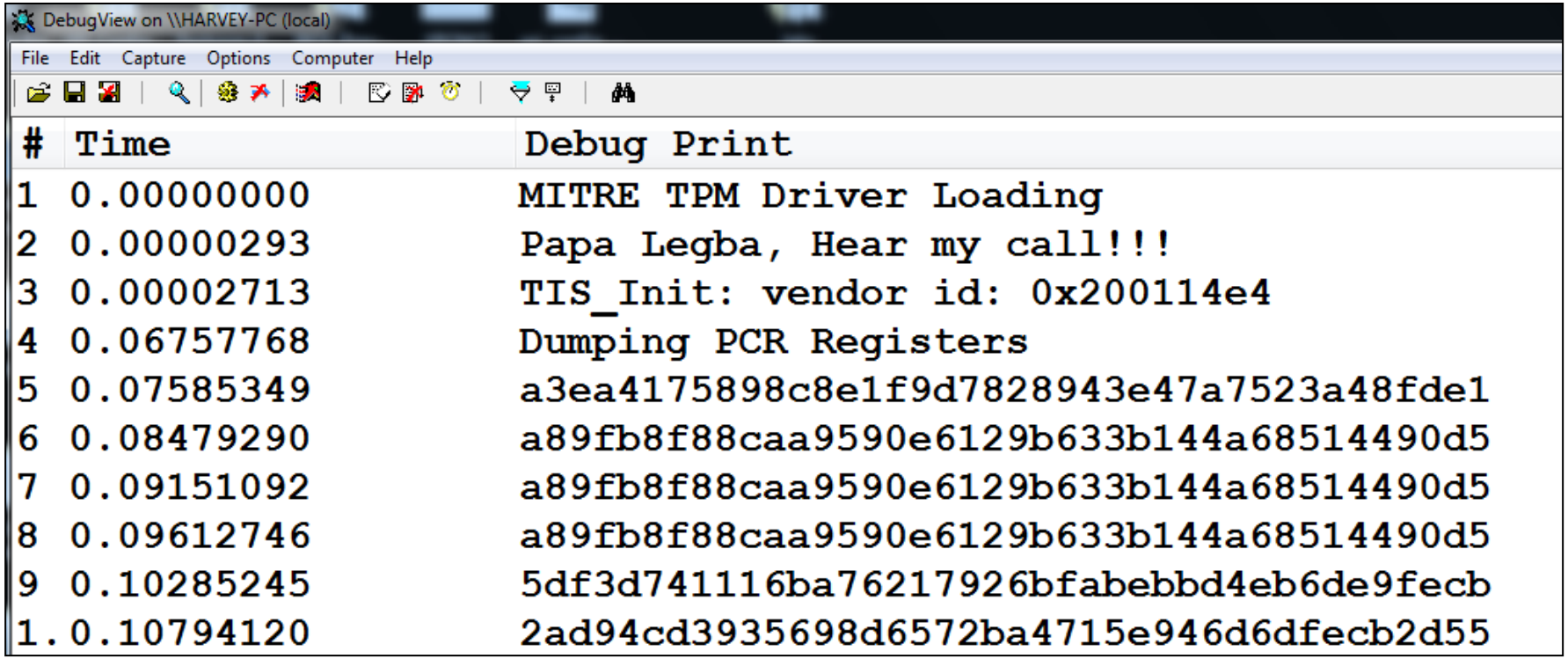
Subzero.io

- Ted Reed has created a website that allows you to upload BIOS files, and they will be processed with his UEFI firmware parser
  - Similar to firmware.re, but PC BIOS specific
  - Does one thing and does it well
- Just in time for BH EUR, he also started parsing Copernicus CSV output with protections.py in order to report whether your BIOS is vulnerable or not
  - Run “submit.bat”
- The site will serve to crowd source what good BIOSes look like, so that we can report when we see something that doesn't look like everyone elses


subzero.io
Browse
Statistics
Login
Search firmware by hash or upload for analysis
Search
Welcome to Subzero.IO, the largest repository of Flash, BIOS, UEFI volumes and other firmware-related content. You may immeditely view/dissect firmware by searching a md5/sha1 or upload your own firmware to process. Learn more about how the dissecting and analysis works.



OpenTPM



- https://code.google.com/p/opentpm/
- Open Source utility written by Corey Kallenberg
- Allows you to retrieve quotes of your TPM PCRs (will be covered in Trusted Computing portion of the class)
- Linux users can use the tpm_bios and tpm modules to do this

Backup

- Tools I haven’t tested

FMEM (Linux)

- FMEM is a little known Linux kernel module that provides you access to all physical memory in a system
- FMEM creates /dev/fmem
- Very useful, since /dev/mem restricts access to various regions
- http://hysteria.sk/~niekt0/fmem/

- Examples of its use:
- Dumps the last 2 MB of system RAM (FFE00000h – FFFFFFFFh)
- dd = /dev/fmem of=~/foo.bin bs=1048576 skip=4094 count=2
- Therefore, to dump the last 4 MB of memory:
- dd = /dev/fmem of=~/bar.bin bs=1048576 skip=4092 count=4

- Block size (bs) is 1 MB decimal, you can play with bs, skip, and count to make it less obfuscated (or script it)
- So we're skipping <skip> blocks, then reading <count> blocks