Logo*FAIL*

Security implications of image parsing during system boot

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Research Scientist @ Binarly

- Vulnerability and Threat Research
- Program analysis
  - Fuzzing, Dynamic analysis

Academic background

- PostDoc @ UCSB SecLab
- Looked at binary code from different angles (binary similarity, fuzzing, forensics)

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LogoFAIL [edition]

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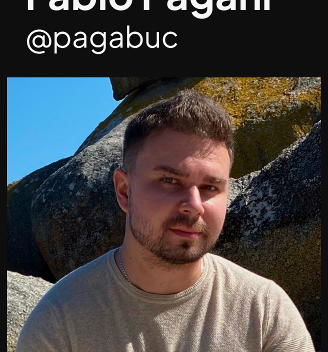

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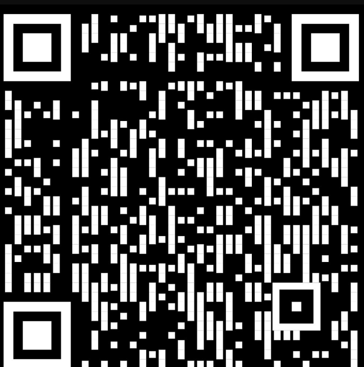
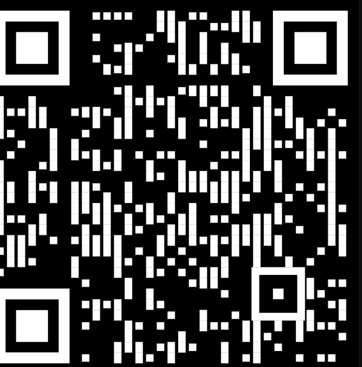
Scan



The Far-Reaching Consequences of LogoFAIL (Blog)



Inside the LogoFAIL Vulnerabilities (Video)

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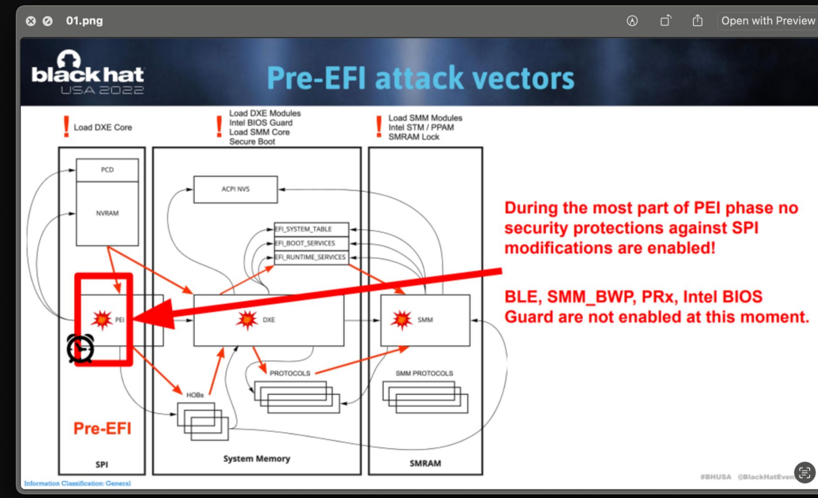
Data-Only Attacks Against UEFI Firmware 🔥

- **Insecure handling of content from R/W areas (NVRAM)**
- **Allow bypassing Secure Boot and hardware-based Verified Boot:**
  - Intel Boot Guard
  - AMD Hardware-Validated Boot
  - ARM TrustZone-based verification
- **Lead to compromise of other protections in Pre-EFI like Intel PPAM**



Breaking Firmware Trust From Pre-EFI: Exploiting Early Boot Phases

https://i.blackhat.com/USA-22/Wednesday/US-22-Matrosov-Breaking-Firmware-Trust-From-Pre-EFI.pdf

Exploring new Attack Surfaces

While looking at vulnerabilities discovered by our platform, we observed that image parsers in firmware are actually quite common.

But why do we even need image parsers during boot?!

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History Repeats Itself

02.png

Open with Preview

```
tiano_edk/source/Foundation/Library/Dxe/Graphics/Graphics.c:

EFI_STATUS ConvertBmpToGopBlt ()
{
...
 if (BmpHeader->CharB != 'B' || BmpHeader->CharM != 'M') {
     return EFI_UNSUPPORTED;
   }

   BltBufferSize = BmpHeader->PixelWidth * BmpHeader->PixelHeight
      * sizeof (EFI_GRAPHICS_OUTPUT_BLT_PIXEL);
   IsAllocated   = FALSE;
   if (*GopBlt == NULL) {
     *GopBltSize = BltBufferSize;
     *GopBlt     = EfiLibAllocatePool (*GopBltSize);
```

blackhat usa+2009

DIGITAL SELF DEFENSE

Attacking Intel BIOS at BlackHat USA 2009 by Rafal Wojtczuk and Alexander Tereshkin

https://www.blackhat.com/presentations/bh-usa-09/WOJTCZUK/BHUSA09-Wojtczuk-AtkIntelBios-SLIDES.pdf

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History Repeats Itself (~15 years later)

- Different image parsers available in UEFI firmware
  - BMP, GIF, PNG, JPEG, PCX, and TGA
- User can pass image data to them
  - Various logo customization features are available
- Image parsing is done during boot
  - DXE phase
  - C-written code (3rd party)
  - No mitigations for exploitation of software vulnerabilities

What could go wrong?!

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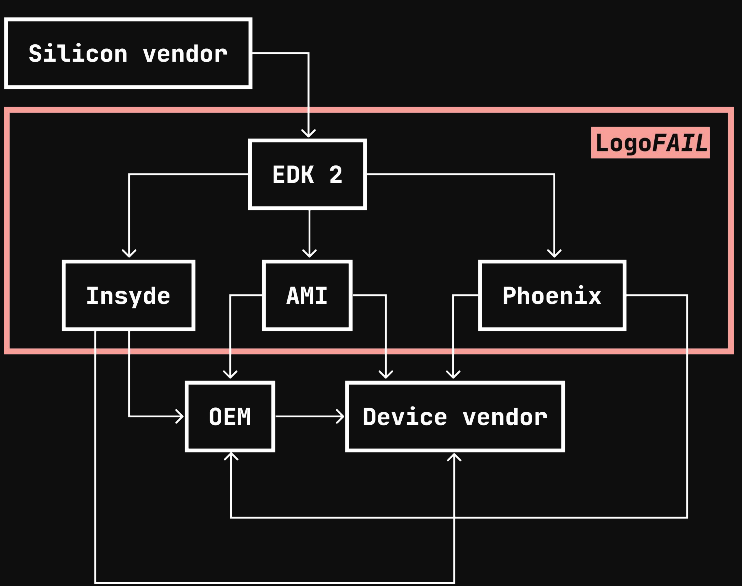
Meet Logo*FAIL*

- New set of security vulnerabilities affecting image parsing libraries used during the device boot process
- LogoFAIL is cross-silicon and impacts x86 and ARM-based devices
- LogoFAIL is UEFI and IBV-specific
- Impacts the entire ecosystem across this reference code and device vendors



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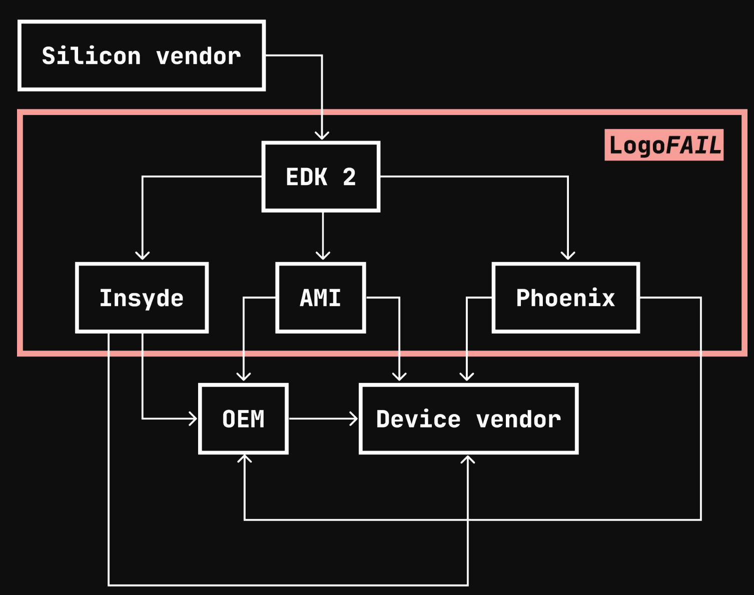

150+ days of embargo lifts TODAY

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Implications of LogoFAIL 💣

Attack Vector	Vulnerability ID	Exploited in-the-wild	Impact	CVSS Score	CWE
LogoFAIL	**VU#811862 CVE-2023-40238 CVE-2023-5058 CVE-2023-39539 CVE-2023-39538 and more ...**	**Unknown**	**HW-based Verified Boot and Secure Boot Bypass x86 and ARM**	**8.2 High 6.7Medium**	**CWE-122: Heap-based Buffer Overflow CWE-125: Out-of-bounds Read**
Baton Drop	CVE-2022-21894 CVE-2023-24932	BLACKLOTUS	Secure Boot Bypass x86	6.7 Medium	CWE-358: Improperly Implemented Security Check for Standard
3rd-party Bootloaders	VU#309662	Unknown	Secure Boot Bypass x86	6.7 Medium	CWE-358: Improperly Implemented Security Check for Standard
BootHole	VU#174059	Unknown	Secure Boot Bypass x86	8.2 High	CWE-120: Buffer Copy without Checking Size of Input

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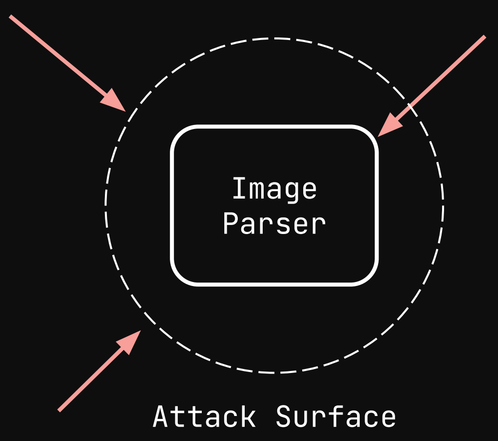
Attack Surface



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Different Shades of UEFI Image Parsers

```
BmpDecoderDxe-A9F634A5-29F1-4456-A9D5-6E24B88BDB65
TgaDecoderDxe-ADCCA887-5330-414A-81A1-5B578146A397
PngDecoderDxe-C1D5258B-F61A-4C02-9293-A005BEB3EAA1
JpegDecoderDxe-2707E46D-DBD7-41C2-9C04-C9FDB8BAD86C
PcxDecoderDxe-A8F634A5-28F1-4456-A9D5-7E24B99BDB65
GifDecoderDxe-1353DE63-B74A-4BEF-80FD-2C5CFA83040B
```

```
SystemImageDecoderDxe-5F65D21A-8867-45D3-A41A-526F9FE2C598
```

```
AMITSE-B1DA0ADF-4F77-4070-A88E-BFFE1C60529A
```

```
MdeModulePkg/Library/BaseBmpSupportLib/BmpSupportLib.c
```

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Identifying the Attack Surface

- All the channels used by firmware to read a logo image
- A lot of reversing with `efiXplorer`
- Start from image parsers, then looks “backwards”

03.png Open with Preview

```
EfiOemBadgingProtocol = 0i64;
Instance = 0;
// Locate the EFI_OEM_BADGING_PROTOCOL
gBS->HandleProtocol(Buffer[v4], &EFI_OEM_BADGING_PROTOCOL_GUID, &EfiOemBadgingProtocol);
if ( EfiOemBadgingProtocol )
  v0 = 1;
if ( v0 )
{
  // Get an image from the EFI_OEM_BADGING_PROTOCOL
  while ( (EfiOemBadgingProtocol->GetImage)(
            EfiOemBadgingProtocol,
            &Instance,
            &v20,
            &ImageData,
            &ImageSize,
            &Attributes,
            &CoordinateX,
            &CoordinateY) >= 0 )
  {
    // Parse the image, the result will be stored in a global variable
    v7 = ParseImage(
           ImageData,
           ImageSize,
           Attributes,
           CoordinateX,
           CoordinateY,
           Another,
           Width,
           Height);
    Another = 0;
    if ( v7 )
      v2 = 0;
```

https://github.com/binarly-io/efiXplorer

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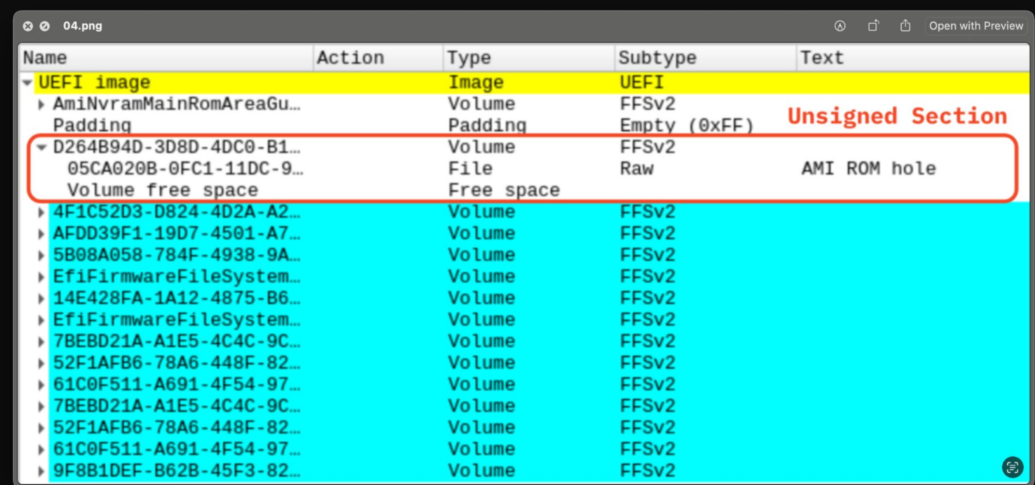
Attack Surface

Several OEM-specific customizations:

1. Logo is read from a fixed location (e.g., “\EFI\OEM\Logo.jpg”)
2. Logo is stored into an unsigned volume of a firmware update
3. An NVRAM variable contains the path of the logo
4. An NVRAM variable contains the logo itself



https://binarly.io/advisories/BRLY-2023-006
https://binarly.io/advisories/BRLY-2023-018

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Fuzzing

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Fuzzing UEFI Image Parsers

- UEFI DXE modules are normal PE files
- The UEFI runtime environment needed to re-hosted
- Fuzzer based on newly-developed emulation capabilities which we integrated with LibAFL

05 Open with Preview

```
mov     rax, cs:gBS_0
lea     r8, [rbp+37h+Interface] ; Interface
xor     edx, edx          ; Registration
lea     rcx, UNKNOWN_PROTOCOL_GUID ; Protocol
call    [rax+EFI_BOOT_SERVICES.LocateProtocol] ; gBS->LocateProtocol()
```

06 Open with Preview

```
.data:0000000000004948 ; EFI_BOOT_SERVICES *gBS_0
.data:0000000000004948 gBS_0           dq 0
.data:0000000000004948
.data:0000000000004950 ; EFI_RUNTIME_SERVICES *gRT
.data:0000000000004950 gRT             dq 0
.data:0000000000004950
.data:0000000000004958 ; EFI_SYSTEM_TABLE *gST_0
.data:0000000000004958 gST_0           dq 0
.data:0000000000004958
```

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Fuzzing Harness

A bridge between the fuzzer and the fuzzed module:

- Module initialization (protocols are installed)
- Prepare call to parsing function
- Forwards fuzzer-generated data to the target module

We are ready to fuzz!

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Root Causes

- We found hundreds of crashes
- Extended Binarly's internal program analysis framework to support us in this task

```
LogoFAIL fuzzer (0.1.0)

generic
run time          0h-0m-3s
clients           1
executions        1967
exec/sec          647

client #1 (l/r arrows to switch)

charts (`g` switch)
speed | corpus | objectives

speed chart
651    exec/sec
325
0                                  time
0h-0m-0s        0h-0m-1s        0h-0m-3s

clients logs (`t` to show/hide)
[Stats      #0] corpus: 59, objectives: 39, executions: 1523, exec/sec: 649.5, edges: 3420/65536 (5%)
[Testcase   #0] corpus: 60, objectives: 39, executions: 1526, exec/sec: 650.8, edges: 3420/65536 (5%)
[Stats      #0] corpus: 60, objectives: 39, executions: 1526, exec/sec: 647.8, edges: 3454/65536 (5%)
[Testcase   #0] corpus: 61, objectives: 39, executions: 1533, exec/sec: 650.8, edges: 3454/65536 (5%)
[Stats      #0] corpus: 61, objectives: 39, executions: 1533, exec/sec: 650.3, edges: 3454/65536 (5%)
[Testcase   #0] corpus: 62, objectives: 39, executions: 1534, exec/sec: 650.7, edges: 3454/65536 (5%)
[Stats      #0] corpus: 62, objectives: 39, executions: 1534, exec/sec: 650.3, edges: 3454/65536 (5%)
[Testcase   #0] corpus: 63, objectives: 39, executions: 1535, exec/sec: 650.7, edges: 3454/65536 (5%)
[Stats      #0] corpus: 63, objectives: 39, executions: 1535, exec/sec: 649.9, edges: 3491/65536 (5%)
[Testcase   #0] corpus: 64, objectives: 39, executions: 1537, exec/sec: 650.7, edges: 3491/65536 (5%)
[Stats      #0] corpus: 64, objectives: 39, executions: 1537, exec/sec: 647.4, edges: 3491/65536 (5%)
[Testcase   #0] corpus: 65, objectives: 39, executions: 1545, exec/sec: 650.8, edges: 3491/65536 (5%)
[Stats      #0] corpus: 65, objectives: 39, executions: 1545, exec/sec: 649.8, edges: 3491/65536 (5%)
[Testcase   #0] corpus: 66, objectives: 39, executions: 1547, exec/sec: 650.7, edges: 3491/65536 (5%)
[Stats      #0] corpus: 66, objectives: 39, executions: 1547, exec/sec: 649.4, edges: 3505/65536 (5%)
[Testcase   #0] corpus: 67, objectives: 39, executions: 1550, exec/sec: 650.7, edges: 3505/65536 (5%)
[Stats      #0] corpus: 67, objectives: 39, executions: 1550, exec/sec: 650.2, edges: 3516/65536 (5%)
[Testcase   #0] corpus: 68, objectives: 39, executions: 1551, exec/sec: 650.6, edges: 3516/65536 (5%)
[Stats      #0] corpus: 68, objectives: 39, executions: 1551, exec/sec: 649.4, edges: 3586/65536 (5%)
[Testcase   #0] corpus: 69, objectives: 39, executions: 1554, exec/sec: 650.6, edges: 3586/65536 (5%)
[Stats      #0] corpus: 69, objectives: 39, executions: 1554, exec/sec: 646.2, edges: 3607/65536 (5%)
[Testcase   #0] corpus: 70, objectives: 39, executions: 1565, exec/sec: 650.8, edges: 3607/65536 (5%)
[Stats      #0] corpus: 70, objectives: 39, executions: 1565, exec/sec: 646.4, edges: 3630/65536 (5%)
[Testcase   #0] corpus: 71, objectives: 39, executions: 1576, exec/sec: 650.9, edges: 3630/65536 (5%)
[Stats      #0] corpus: 71, objectives: 39, executions: 1576, exec/sec: 648.0, edges: 3644/65536 (5%)
[Testcase   #0] corpus: 72, objectives: 39, executions: 1583, exec/sec: 650.9, edges: 3644/65536 (5%)
[Stats      #0] corpus: 72, objectives: 39, executions: 1583, exec/sec: 646.3, edges: 3658/65536 (5%)
[Testcase   #0] corpus: 73, objectives: 39, executions: 1595, exec/sec: 651.2, edges: 3658/65536 (5%)
[Stats      #0] corpus: 73, objectives: 39, executions: 1595, exec/sec: 636.0, edges: 3658/65536 (5%)
[Testcase   #0] corpus: 74, objectives: 39, executions: 1633, exec/sec: 651.1, edges: 3658/65536 (5%)
```

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Root Causes (*Excerpt*)

We found 29 unique root causes, 15 of which are likely exploitable

BRLY ID	CERT/CC ID	Affected IBV	Image Library	Impact	CVSS Score	CWE
BRLY-LOGOFAIL-2023-001	VU#811862	Insyde	BMP	DXE Memory Content Disclosure	Medium	CWE-200: Exposure of Sensitive Information
BRLY-LOGOFAIL-2023-007	VU#811862	Insyde	GIF	DXE Memory Corruption	High	CWE-122: Heap-based Buffer Overflow
BRLY-LOGOFAIL-2023-016	VU#811862	AMI	PNG	DXE Memory Corruption	High	CWE-122: Heap-based Buffer Overflow CWE-190: Integer Overflow
BRLY-LOGOFAIL-2023-022	VU#811862	AMI	JPEG	DXE Memory Corruption	High	CWE-787: Out-of-bounds Write
BRLY-LOGOFAIL-2023-025	VU#811862	Phoenix	BMP	DXE Memory Corruption	High	CWE-122: Heap-based Buffer Overflow
BRLY-LOGOFAIL-2023-029	VU#811862	Phoenix	GIF	DXE Memory Corruption	High	CWE-125: Out-of-bounds Read

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BRLY-LOGOFAIL-2023-006: Memory Corruption

- PixelHeight and PixelWidth are attacker controlled
- When `PixelHeight` and `i` are 0: `BltBuffer[PixelWidth * -1]`
- Arbitrary write anywhere below `BltBuffer`

07 | Open with Preview

```
PixelHeight = BmpHeader->PixelHeight;
EndOfBMP = 0;
for ( i = 0i64; i <= PixelHeight; ++i )
{
  if ( EndOfBMP )
    break;
  PixelWidth = BmpHeader->PixelWidth;
  v11 = 0i64;
  v12 = 0;
  // BRLY-LOGOFAIL-2023-003
  // when BmpHeader->PixelHeight is 0 Blt will be below BltBuffer
  // (0 - 0 - 1) * BmpHeader->PixelWidth = - BmpHeader->PixelWidth
  // then, writes to the Blt buffer will happen
  Blt = &BltBuffer[PixelWidth * (PixelHeight - i - 1)];
  do
  {
    if ( v12 )
      break;
    FirstByte = *RLE8Image;
    v15 = RLE8Image + 1;
    SecondByte = RLE8Image[1];
    RLE8Image += 2;
    if ( FirstByte )
    {
      Count = FirstByte;
      v11 += FirstByte;
      do
      {
        Blt->Red = BmpColorMap[SecondByte].Red;// arbitrary write
        Blt->Green = BmpColorMap[SecondByte].Green;// arbitrary write
        Blt->Blue = BmpColorMap[SecondByte].Blue;// arbitrary write
        ++Blt;
        --Count;
      }
      while ( Count );
    }
```

BMP parser developed by Insyde

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BRLY-LOGOFAIL-2023-022: Memory Corruption

- Assumption that JPEG can contain only 4 Huffman Tables
- `NumberOfHTs` variable is unchecked
- Overflow on global data with pointers to our image

08 Open with Preview

```
// 0xC4 == HuffmanTableMarker
if ( MarkerPtr == 0xC4 )
{
  // BRLY-LOGOFAIL-2023-022: NumberOfHTs is not
  // checked and can overflow statically
  // allocated HuffamTables array
  v8 = NumberOfHTs++;
  HuffmanTables[v8] = (ImagePtr + 4);
  goto LABEL_26;
}
```

JPEG parser developed by AMI

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Takeaways from Fuzzing

None of these libraries where ever fuzzed by IBVs/OEMs:

- We found crashes in every parser
- First crashes where found after seconds of fuzzing
- Some parsers even crash with images downloaded from the Internet :-)

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Thanks to the Internet Archive!

- One of the parsers is for PCX images
- Finding good corpus for the fuzzer turned out to be more difficult than expected
- Until..

https://archive.org/details/Universe_Of_PCX_1700_PCX_Files

Proof of concept

Let’s PWN a Real Device

- Lenovo ThinkCentre M70s Gen 2
- 11th Gen Intel Core (Tiger Lake)
- BIOS released on June 2023

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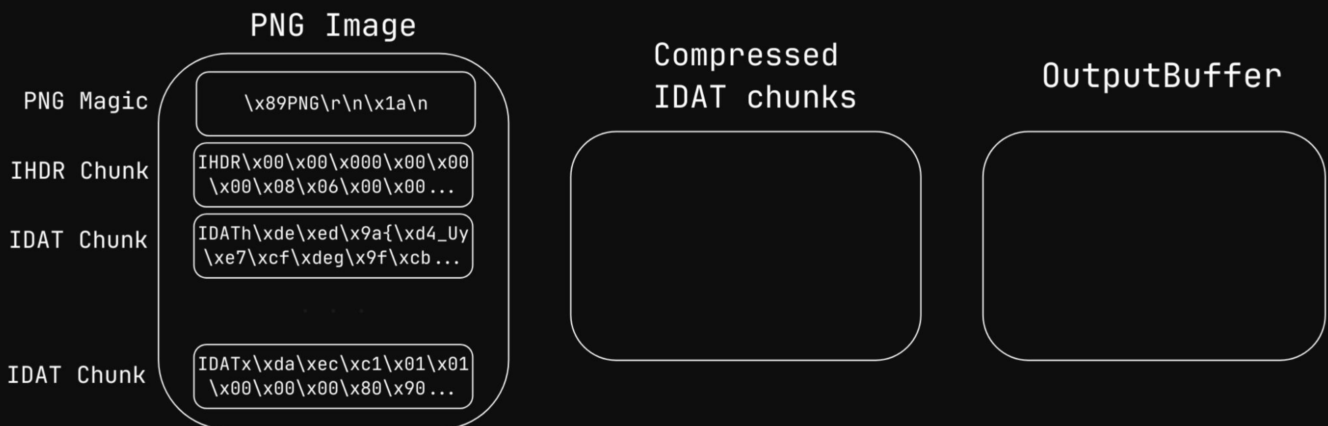
Selecting a Target



Simple format + exploitable crash: PNG parser from AMI

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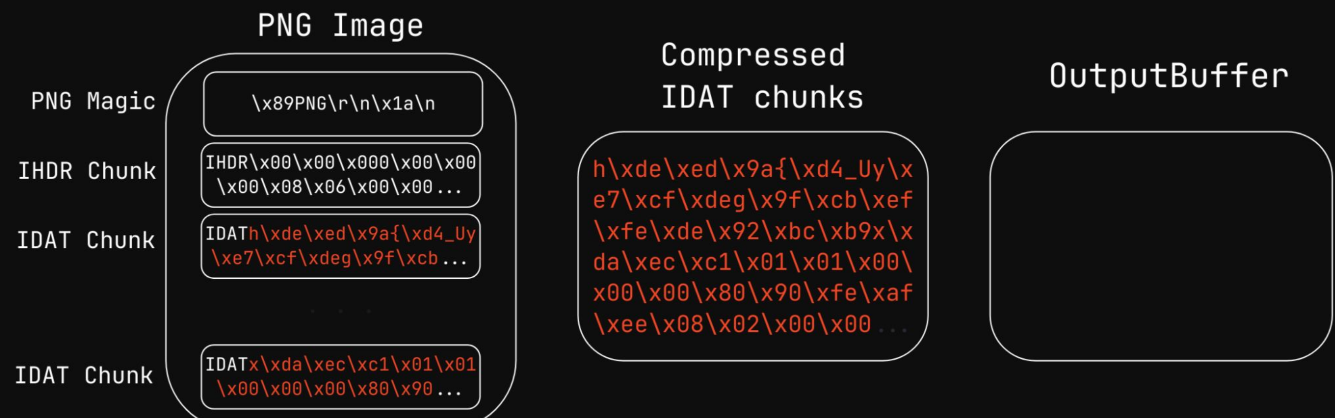
Selecting a Target



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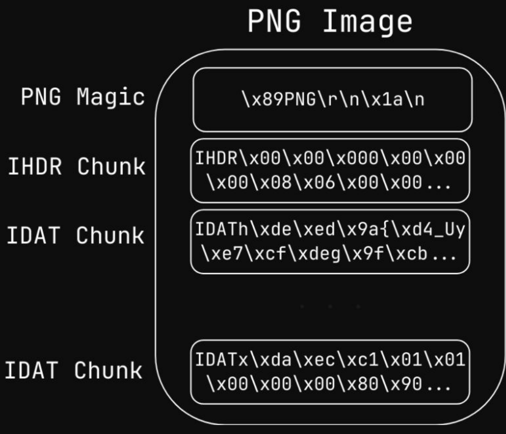

Compressed IDAT chunks

```
h\xde\xed\x9a{\xd4_Uy\x
e7\xcf\xdeg\x9f\xcb\xef
\xfe\xde\x92\xbc\xb9x\x
da\xec\xc1\x01\x01\x00\
x00\x00\x80\x90\xfe\xaf
\xee\x08\x02\x00\x00...
```

OutputBuffer

```
BRLYBRLYBRLYBRLYBRLYBR
LYBRLYBRLYBRLYBRLYBRLY
BRLYBRLYBRLYBRLYBRLYBR
LYBRLYBRLYBRLYBRLYBRLY
BRLYBRLYBRLYBRLYBRLYBR
```

Simple format + exploitable crash: PNG parser from AMI

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Integer Overflow to Heap Overflow

Integer overflow on 32 bit value used as allocation size:

- 2 * 0x20 = 0x40
- 2 * 0x60 = 0xc0
- 2 * 0x80000040 = 0x80

```
// BRLY-LOGOFAIL-2023-016: Integer overflow
// on the argument of EfiLibAllocateZeroPool
OutputBuffer = EfiLibAllocateZeroPool(2 * PngWidth);
v7 = &OutputBuffer[PngWidth];
GlobalInfo.OutputBuffer = OutputBuffer;
```

Compressed IDAT chunks

```
h\xde\xed\x9a{\xd4_Uy\x
e7\xcf\xdeg\x9f\xcb\xef
\xfe\xde\x92\xbc\xb9x\x
da\xec\xc1\x01\x01\x00\
x00\x00\x80\x90\xfe\xaf
\xee\x08\x02\x00\x00...
```

OutputBuffer

```
BRLYBRLYBRLYBRLYBRLYBR
LYBRLYBRLYBRLYBRLYBRLY
BRLYBRLYBRLYBRLYBRLYBR
LYBRLYBRLYBRLYBRLYBRLY
BRLYBRLYBRLYBRLYBRLYBR
```

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- 2 * 0x20 = 0x40
- 2 * 0x60 = 0xc0
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```
// BRLY-LOGOFAIL-2023-016: Integer overflow
// on the argument of EfiLibAllocateZeroPool
OutputBuffer = EfiLibAllocateZeroPool(2 * PngWidth);
v7 = &OutputBuffer[PngWidth];
GlobalInfo.OutputBuffer = OutputBuffer;
```

```
GlobalInfo.OutputBuffer[GlobalInfo.idx] = a1;
```

Compressed IDAT chunks

```
h\xde\xed\x9a{\xd4_Uy\x
e7\xcf\xdeg\x9f\xcb\xef
\xfe\xde\x92\xbc\xb9x\x
da\xec\xc1\x01\x01\x00\
x00\x00\x80\x90\xfe\xaf
\xee\x08\x02\x00\x00...
```

OutputBuffer

```
BRLYBRLYBRLYBRLYBRLYBR
LYBRLYBRLYBRLYBRLYBRLY
BRLYBRLYBRLYBRLYBRLYBR
LYBRLYBRLYBRLYBRLYBRLY
BRLYBRLYBRLYBRLYBRLYBR
0000000000000000000000
000000000000000000000
000000000000000000
```

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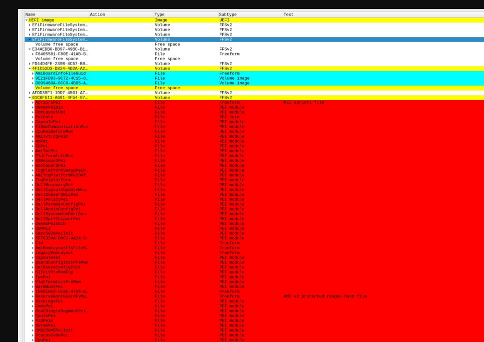
Wait a Minute..

- How does heap exploitation even work for UEFI?
- No debugging capabilities:
  - Intel DCI doesn't work on new CPU models
  - Intel Boot Guard prevents replacing modules
- Not even output on crash :(



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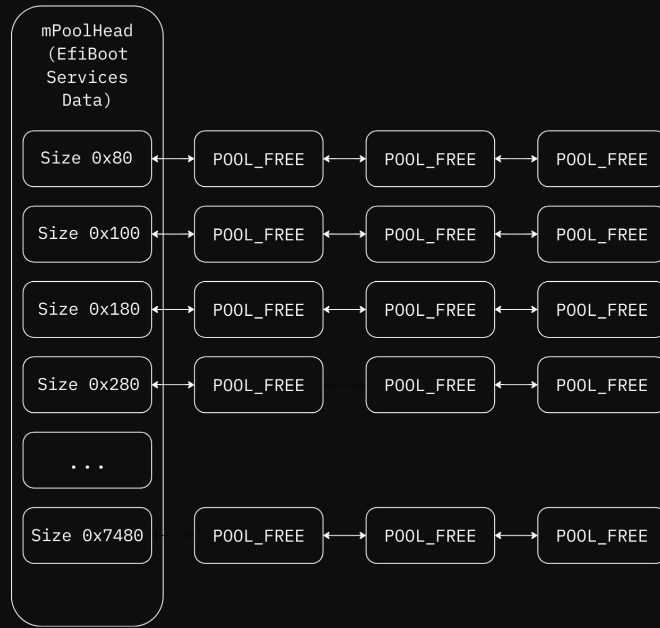
UEFI Heap Internals

- Pool-based heap



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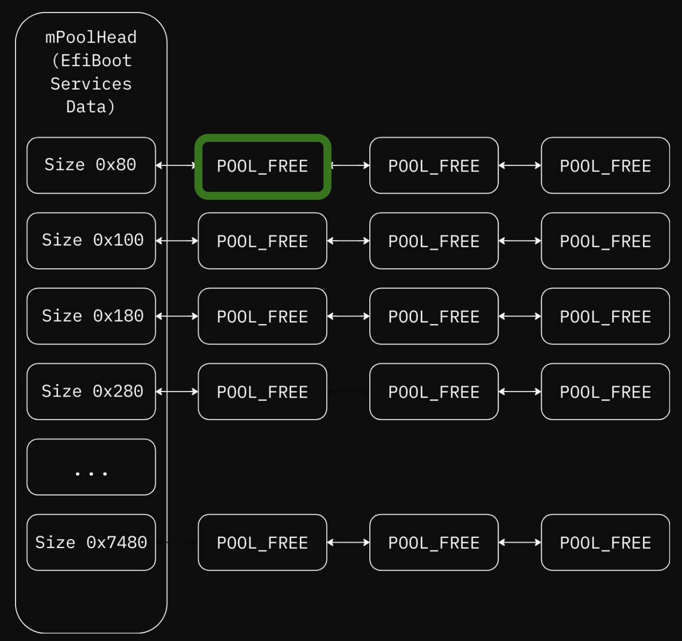
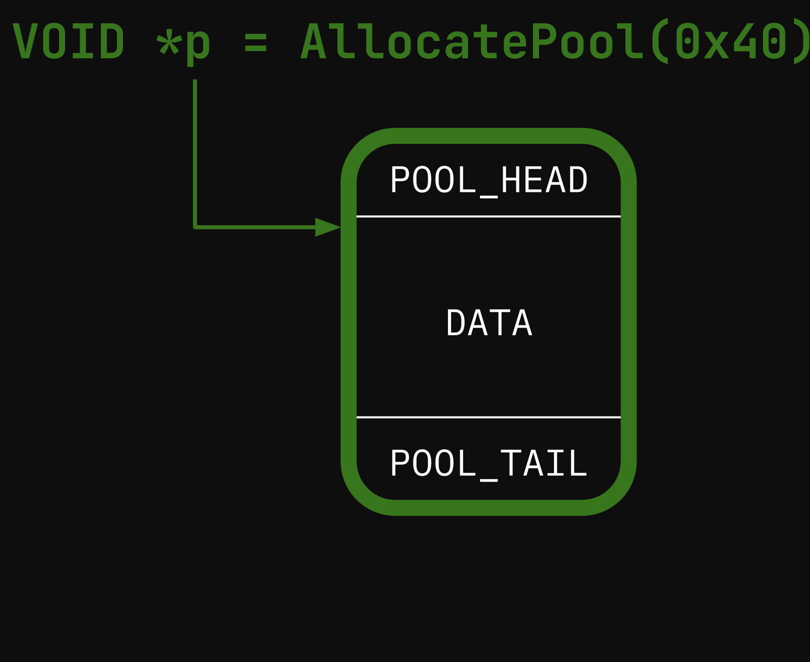
UEFI Heap Internals

- Pool-based heap





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UEFI Heap Internals

- Pool-based heap

mPoolHead (EfiBootServicesData)

Size 0x80	POOL_FREE	POOL_FREE	POOL_FREE
Size 0x100	POOL_FREE	POOL_FREE	POOL_FREE
Size 0x180	POOL_FREE	POOL_FREE	POOL_FREE
Size 0x280	POOL_FREE	POOL_FREE	POOL_FREE
...			
Size 0x7480	POOL_FREE	POOL_FREE	POOL_FREE

POOL_HEAD

DATA

POOL_TAIL

FreePool(p)

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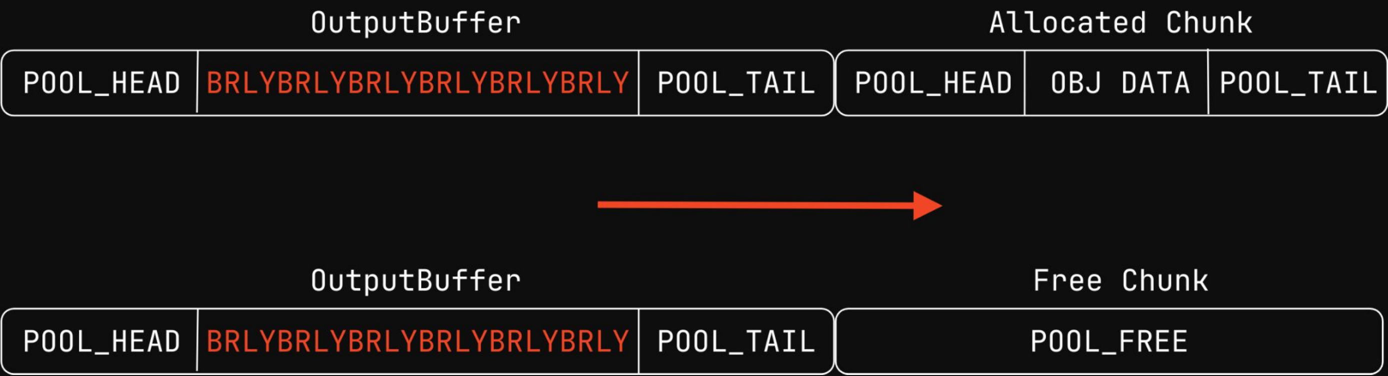
What Are We Even Corrupting?



We don't know!!

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Long Live UEFI Memory

- Memory used by UEFI is not cleared
- If the OS doesn't overwrite it, we can dump it after boot
- `OutputBuffer` is not freed, so it's somewhere in memory!

```
82c83f10: 7068 6430 0000 0000 0400 0000 0000 0000  phd0............
82c83f20: 8000 0000 0000 0000 4252 4c59 4252 4c59  ........BRLYBRLY
82c83f30: 4252 4c59 4252 4c59 4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f40: 4252 4c59 4252                           BRLYBRLYBRLYBRLY
82c83f50: 4252 4c59 4252                           BRLYBRLYBRLYBRLY
82c83f60: 4252 4c59 4252 4c59 4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f70: 4252 4c59 4252 4c59 4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f80: 7074 616c 0000 0000 8000 0000 0000 0000  ptal............
82c83f90: 7068 6430 0000 0000 0400 0000 0000 0000  phd0............
82c83fa0: 6800 0000 0000 0000 6869 7370 0000 0000  h.......hisp....
82c83fb0: 98b7 af82 0000 0000 98a6 af82 0000 0000  ................
82c83fc0: 60b8 af82 0000 0000 60b8 af82 0000 0000  `.......`.......
```

OutputBuffer

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Long Live UEFI Memory

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```
82c83f10: 7068 6430 0000 0000 0400 0000 0000 0000  phd0............
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82c83f40: 4252 4c59 4252 4c59 4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f50: 4252 4c59 4252 4c59 4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f60: 4252 4c59 4252 4c59 4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f70: 4252 4c59 4252 4c59 4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f80:                                          ptal............
82c83f90:                                          phd0............
82c83fa0:                                          h.......hisp....
82c83fb0:                                          ................
82c83fc0:                                          `.......`.......
```

This is NOT the object we can corrupt!

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Preserving Heap Chunks

- New technique to preserve chunks
- Corrupting the signature ensures a chunk is not reused

OutputBuffer			Allocated Chunk		
POOL_HEAD	BRLYBRLYBRLYBRLYBRLYBRLY	POOL_TAIL	phd0....	OBJ DATA	
			POOL_HEAD		POOL_TAIL

OutputBuffer			Allocated Chunk		
POOL_HEAD	BRLYBRLYBRLYBRLYBRLYBRLY	BRLYBRLYBR	Xhd0....	OBJ DATA	
			POOL_HEAD		POOL_TAIL

```
EFI_STATUS
CoreFreePoolI (
  IN VOID                *Buffer,
  OUT EFI_MEMORY_TYPE    *PoolType OPTIONAL
  )
{

  POOL_HEAD   *Head;
  ...

  ASSERT (Buffer != NULL);
  //
  // Get the head & tail of the pool entry
  //
  Head = BASE_CR (Buffer, POOL_HEAD, Data);
  ASSERT (Head != NULL);

  if ((Head->Signature != POOL_HEAD_SIGNATURE) &&
      (Head->Signature != POOLPAGE_HEAD_SIGNATURE))
  {
    ASSERT (
      Head->Signature == POOL_HEAD_SIGNATURE ||
      Head->Signature == POOLPAGE_HEAD_SIGNATURE
      );
    return EFI_INVALID_PARAMETER;
  }
```

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Preserving Heap Chunks

```
82c83f10: 4252 4c59 4252 4c59  4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f20: 4252 4c59 4252 4c59  4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f30: 4252 4c59 4252 4c59  4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f40: 4252 4c59 4252 4c59  4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f50: 4252 4c59 4252 4c59  4252 4c59 4252 4c59  BRLYBRLYBRLYBRLY
82c83f60: 4252 4c59 4252 4c59  4f4f 4f4f 4f4f 4f4f  BRLYBRLYOOOOOOOO
82c83f70:                                           OOOOOOOXhd0....
82c83f80:                                           ........X.......
82c83f90:                                           prtn....iL.....
82c83fa0:                                           (.......(kL.....
82c83fb0:                                           .~........|.....
82c83fc0:                                           ptal....X.......
```

This IS the object we can corrupt!!

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Little Recap

What we achieved so far:

- We have arbitrary overflow on the heap
- We can prevent the next chunk from being freed
- We can inspect the object stored in the next chunk

What's left?

- Finding a good target for corruption
- Get code execution out of it

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Enter the UEFI Heap Feng Shui

- Heap exploitation often requires strong allocation and deallocation primitives
- We can influence the heap by adding PNG chunks or changing their sizes

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Enter the UEFI Heap Feng Shui

- Heap exploitation often requires strong allocation and deallocation primitives
- We can influence the heap by adding PNG chunks or changing their sizes

```
83119a00: 4252 4c59 4252 4c59  4252 4c59 4252 4c59   BRLYBRLYBRLYBRLY
83119a10: 4252 4c59 4252 4c59  4252 4c59 4252 4c59   BRLYBRLYBRLYBRLY
83119a20: 4252 4c59 4252 4c59  4252 4c59 4252 4c59   BRLYBRLYBRLYBRLY
83119a30: 4252 4c59 4252 4c59  4252 4c59 4252 4c59   BRLYBRLYBRLYBRLY
83119a40: 4252 4c59 4252 4c59  4252 4c59 4252 4c59   BRLYBRLYBRLYBRLY
83119a50: 4252 4c59 4252 4c59  4f4f 4f4f 4f4f 4f4f   BRLYBRLYOOOOOOOO
83119a60: 4f4f 4f4f 4f4f 5859  5a68 6430 0400 0000   OOOOOOXYZhd0....
83119a70: 0400 0000 0000 0000  7000 0000 0000 0000   ........p.......
83119a80: 7072 7465 0000 0000  205f 1183 0000 0000   prte.... _......
83119a90: 20b4                                fd4c    .......X..mI..L
83119aa0: 99aa                                0000   ....H...8.......
83119ab0: 389e 1183 0000 0000  509b 1183 0000 0000   8.......P.......
83119ac0: 509b 1183 0000 0000  7074 616c 0000 0000   P.......ptal....
```

PROTOCOL_ENTRY

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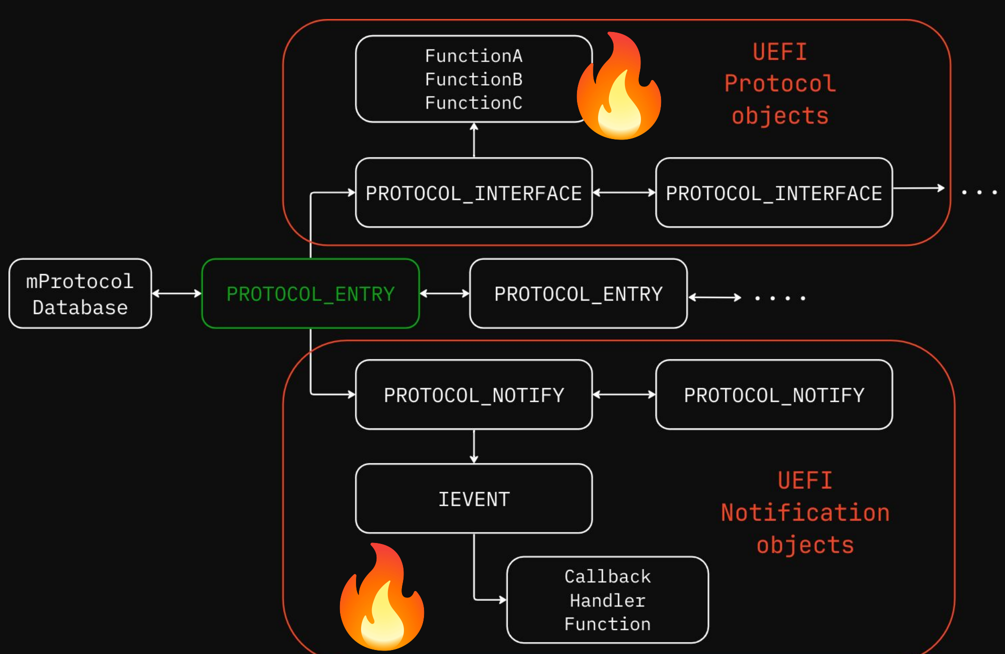
PROTOCOL_ENTRY, tell me more..

- Protocols are a core concept in UEFI
- PROTOCOL_ENTRY has multiple pointers to objects with function pointers



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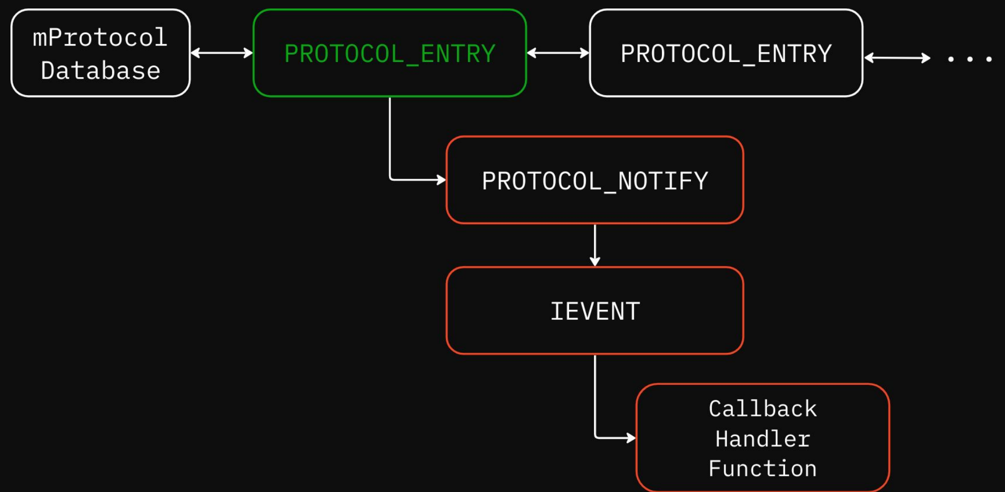
UEFI Event System

- Events are generated when protocols are installed



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Arbitrary Code Exec in UEFI

- Memory region where NVRAM variables is often executable and always mapped at the same fixed address
- We can just store a shellcode there
- Our shellcode can:
  - Disable Secure Boot (zero a global variable)
  - Start a second-stage payload from disk:
    - Unload current NTFS driver (no write support)
    - Load new NTFS driver (with write support)
    - Creates a file on the Windows filesystem

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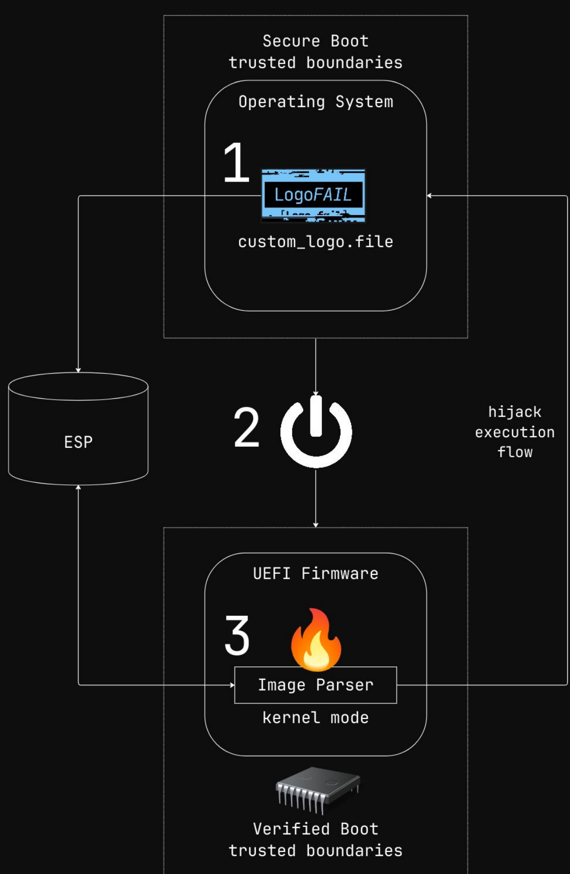
Putting it All Together

- Preparation:
    1. Malicious PNG on the ESP (or in NVRAM)
    2. `PROTOCOL_NOTIFY`, `IEVENT` and `Shellcode` in NVRAM
    3. Second-stage payload on disk: `\Users\user\LogoFAIL\SecondStageWin.efi`
- Reboot the system
- UEFI firmware will parse our PNG
- Heap overflow corrupts a `PROTOCOL_ENTRY` with pointers to `PROTOCOL_NOTIFY` and `IEVENT`
- When the protocol will be installed, we achieve arbitrary code execution
- Shellcode + Second stage payload execution



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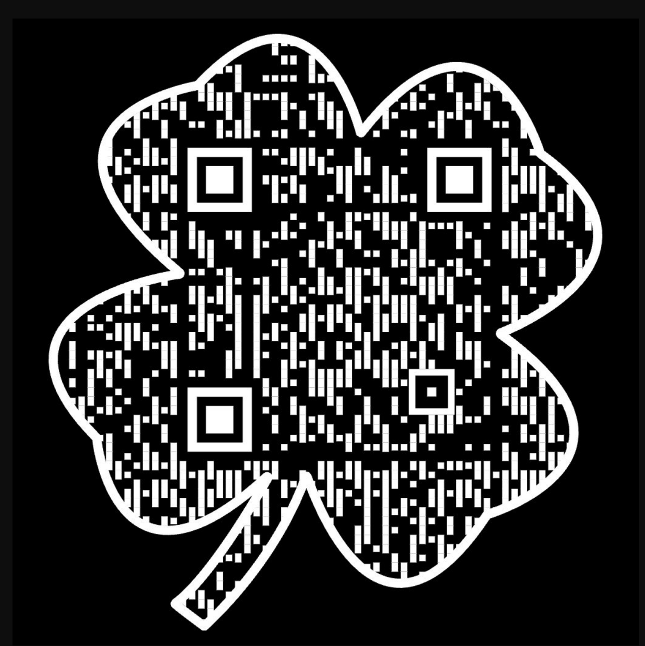
Demo



https://www.youtube.com/watch?v=Eufe0Pe6eqk

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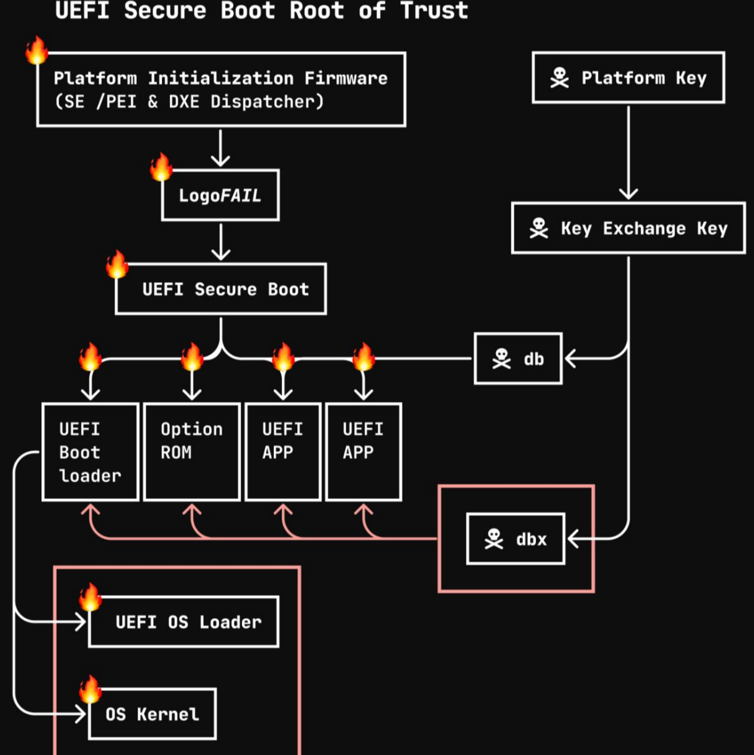
Running the PoC

Logo*FAIL*

- Majority of UEFI firmware contains vulnerable images parsers
- Hundreds of devices from Lenovo, Intel and Acer allow logo customizations thus are exploitable
- Doesn't require any physical access to the device
- Targets UEFI specific code that affects both x86 and ARM devices
- Modern "below-the-OS" defenses, such as Secure Boot are completely ineffective against it



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Thanks to CERT/CC for coordinating this massive industry-wide disclosure! 🙏

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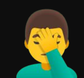
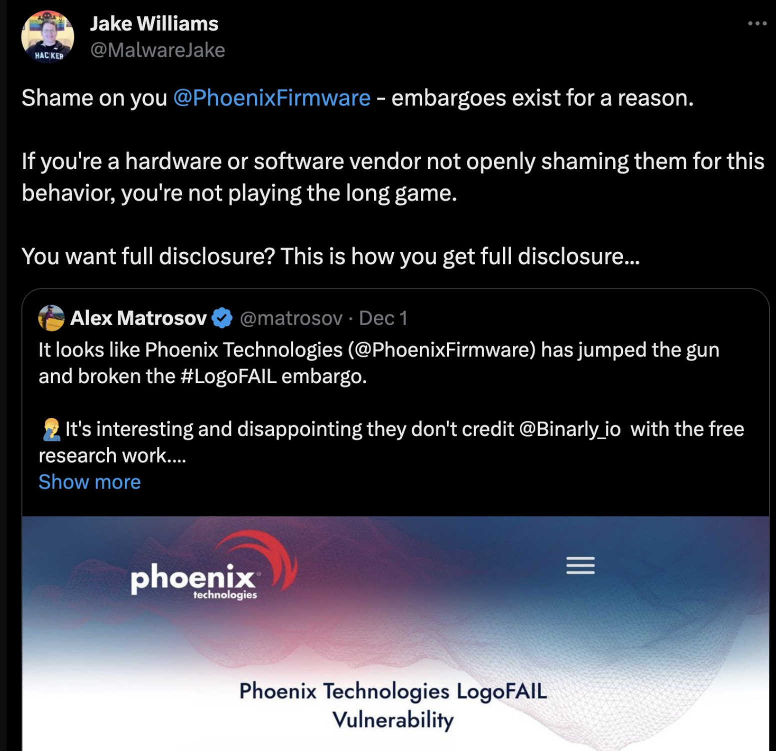
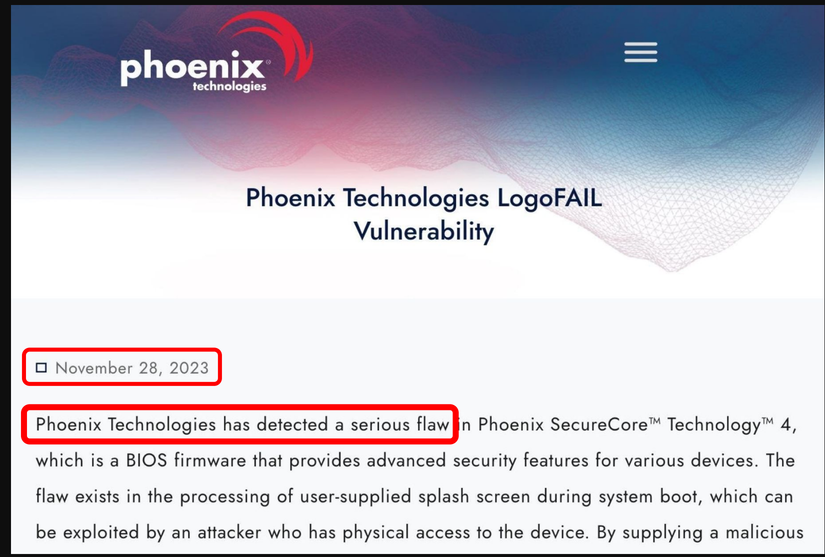
Phoenix Technology 





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*https://webcache.googleusercontent.com/search?q=cache:cWlnW4oat9sJ:https://www.phoenix.com/security-notifications/cve-2023-5058/

That's all folks, thank you for your attention…

… and don't forget to update your firmware!

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