Subverting your server through its BMC: the HPE iLO4 case

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Outline

Introduction

Firmware unpacking

Integrity image

Kernel internals

Attack surface

Damn vulnerable web server

Code exec in your BMC

BMC to host

Staying in the place

Conclusion
• Baseboard Management Controller (BMC) embedded in most of HP servers for more than 10 years

• Provides remote administration features:
  • Power Management
  • Remote system console
  • Remote CD/DVD image mounting
  • Several monitoring indicators

This talk will focus on iLO version 4 (latest version until mid-2017) present in HP ProLiant Gen8 and Gen9.

Research has been more specifically performed on iLO4 versions 2.44 and 2.50.
Figure 1: Directly integrated in the server’s motherboard
Standalone system:

- Dedicated ARM processor: GLP/Sabine architecture
- Firmware stored on a NAND flash chip
- Dedicated RAM chip
- Dedicated network interface

iLO runs even if the server is turned off.

There’s a full operating system running in your server as soon as it has a connected power cord!
Privileged access to the server’s hardware:

iL0 is directly connected to the PCI-Express bus.
Summary of well known pentest tricks:

- IPMI Authentication Bypass via Cipher 0
- IPMI 2.0 RAKP Authentication Remote Password Hash Retrieval

Reference papers/publications:

- “IPMI: freight train to hell”, by Dan Farmer
- “A Penetration Tester’s Guide to IPMI and BMCs”
Internet presence of iLO4

TOTAL RESULTS
4,358

TOP COUNTRIES
United States 604
Germany 514
China 322
Netherlands 289
Iran, Islamic Republic of 279

TOP SERVICES
UPnP 4,311
61478 1
60430 1
56710 1
56628 1

TOP ORGANIZATIONS
myLoc managed IT AG 260
CloudRadium L.L.C. 141
LeaseWeb Netherlands B.V. 136
Afranet 93
Nimbus Hosting Ltd. 42

185.65.40.57
Nimbus Hosting Ltd.
Added on 2019-01-22 20:06:15 GMT
United Kingdom

Details
HTTP/1.1 200 OK
ST:upnp:rootdevice
NTS:ssdp:alive
Location:http://[fe00::1658:d0ff:fe5b:b828]:800/upnp/BasicDevice.xml
USN:uuid:4c28e1e9-055b-51ff-848f-10d99e2de95::upnp.rootdevice
Cache-Control:max-age=1230
Server:HP-iLO-4/2.00 UPnP/1.0 HP-iLO/1.0
OPT:“http://schemas.upnp.org/upnp/1/0/";

87.242.75.97
Masterhost is a hosting and technical support org
Added on 2019-01-22 20:01:57 GMT
Russian Federation

Details
HTTP/1.1 200 OK
ST:upnp:rootdevice
NTS:ssdp:alive
Location:http://87.242.75.97:80/upnp/BasicDevice.xml
USN:uuid:92efea45d-99a8-5834-bb2f-221a0ae45cal::upnp.rootdevice
Cache-Control:max-age=1230
Server:HP-iLO-4/2.54 UPnP/1.0 HP-iLO/2.0
Ext:

62.138.234.147
HEG Managed
Added on 2019-01-22 20:02:21 GMT
Germany, Host

Details
HTTP/1.1 200 OK
ST:upnp:rootdevice
NTS:ssdp:alive
Location:http://62.138.234.147:80/upnp/BasicDevice.xml
USN:uuid:fbcd6a91-92db-5b6c-bdf3-f411deded683::upnp.rootdevice
Cache-Control:max-age=1230
Server:HP-iLO-4/2.30 UPnP/1.0 HP-iLO/2.0
Ext:
## Internet presence of iLO4 in September 2017

Around 3604 iLO interfaces version 4 exposed on Internet

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<th>HP-iLO-4/Version</th>
<th>UPnP/1.0</th>
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</table>
Around 3788 iLO interfaces version 4 exposed on Internet

86 Server: HP-iLO-4/2.00 UPnP/1.0 HP-iLO/1.0
117 Server: HP-iLO-4/2.02 UPnP/1.0 HP-iLO/1.0
144 Server: HP-iLO-4/2.03 UPnP/1.0 HP-iLO/1.0
173 Server: HP-iLO-4/2.10 UPnP/1.0 HP-iLO/2.0
169 Server: HP-iLO-4/2.20 UPnP/1.0 HP-iLO/2.0
26 Server: HP-iLO-4/2.22 UPnP/1.0 HP-iLO/2.0
297 Server: HP-iLO-4/2.30 UPnP/1.0 HP-iLO/2.0
2 Server: HP-iLO-4/2.31 UPnP/1.0 HP-iLO/2.0
422 Server: HP-iLO-4/2.40 UPnP/1.0 HP-iLO/2.0
9 Server: HP-iLO-4/2.42 UPnP/1.0 HP-iLO/2.0
83 Server: HP-iLO-4/2.44 UPnP/1.0 HP-iLO/2.0
1020 Server: HP-iLO-4/2.50 UPnP/1.0 HP-iLO/2.0
193 Server: HP-iLO-4/2.53 UPnP/1.0 HP-iLO/2.0
571 Server: HP-iLO-4/2.54 UPnP/1.0 HP-iLO/2.0
474 Server: HP-iLO-4/2.55 UPnP/1.0 HP-iLO/2.0
Our approach

iLO summary

- Critical technology: remote management for HP servers
- Frequently encountered during pentest engagements
- Wildely exposed (Internet or LAN)
- Known weaknesses in the authentication protocol
- Too rarely monitored

Objectives

- Evaluate the trust we can put in a solution/product
- Better understanding of the technology and its internals
- Better understanding of the exposed surface/risk
One critical vulnerability identified

- CVE-2017-12542, CVSSv3 9.8
- Authentication bypass and Remote code execution
- Fixed in iLO 4 versions 2.53 (buggy) and 2.54

Full server compromise

- iLO to Host attack
- iLO firmware backdooring
• Feb 2017 - Vulnerability discovered
• Feb 27 2017 - Vulnerability reported to HP PSIRT by Airbus CERT
• Feb 28 2017 - HP acknowledges receiving the report
• May 5 2017 - HP releases iLO 4 2.53, silently fixing the vulnerability
• July 20 2017 - Airbus CERT contacts MITRE to request a CVE ID
• July 28 2017 - HP PSIRT tells Airbus CERT that they are planning to release a security bulletin
• August 24 2017 - HP releases security bulletin HPESBF03769

https://support.hpe.com/hpsc/doc/public/display?docId=hpesbf03769en_us
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Where to get HP iLO firmware?

- Hewlett Packard Enterprise Support Center (obviously)
- Great repository of archived versions:
  http://pingtool.org/latest-hp-ilo-firmwares/

Decap the first layers of CP030133.exe (iLO 4 firmware v2.44):

- Self-extracting/script based archive:
  - total 17M
  - `rw-r-xr-x` 1 user None 198K Jul 21 2016 CP030133.xml*
  - `rw-r-xr-x` 1 user None 490K Apr 1 2016 flash_ilo4*
  - `rw-r-xr-x` 1 user None 17M Jul 21 2016 ilo4_244.bin*
  - `rw-r-xr-x` 1 user None 9.9K Jul 21 2016 Readme.txt*
- flash_ilo4: flashing tool, x86 code
- ilo4_244.bin: actual firmware, concatenation of:
  - HP Signed File header

```
--=</Begin HP Signed File Fingerprint\>=--
Fingerprint Length: 000527
Key: label_HPBBatch
Hash: sha256
Signature: WtLLCUv/ergBGLM6fULxgUUvffHNPNblf5KQFUY0BKxYznzepQggzhF/UsuU2z1rd0D
+KH0YN0OdkycgVDKjilkD1nCgPrfL0yjZLI22A0NZ0uEle3uW+Gvkj3s178Zt1RJizAYLXU/vAG47G
0R1MjKmB8ca5tzJKxuRi1AxtRcfU7DaVtHTPZ7ro5QL+JH7/EeBIZbi79CsHTgOkVdiPNaVLQ1eYb
uKljLwHptuTm0AmpvPnZ6oQi8FDmtHSeEIY4nCB17GwBTYMYVUMwDcI8qypuwna0dAeUy4z2/xYcIu
kbwlZNREDt4QPHZzCP52c1JIRhtwsjdD2SUwj3jGA== Fingerprint Length: 000527
--=</End HP Signed File Fingerprint\>=--
```

- 3 HP certificates
- HPIMAGE blob
- Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

00000000 48 50 49 4D 41 47 45 00 01 01 00 00 9D 7B 31 2F HPIMAGE......{1/
00000010 E3 C9 76 4D BF F6 B9 D0 D0 85 A9 52 01 00 00 00 ................
00000020 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
00000030 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 E0 07 07 13 ............ãá...
00000040 32 2E 34 34 00 00 00 00 00 00 00 00 00 00 00 00 2.44.........
00000050 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
00000060 69 4C 4F 20 34 00 00 00 00 00 00 00 00 00 00 00 iLO 4.........

- Magic: HPIMAGE
- Size: 0x4B8
- Version and GUID, not that much interesting info
- Strip the header, size of mapped firmware: 0x1000000 bytes
• Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

00FFFFC0 76 20 30 2E 31 2E 37 39 2B 20 32 35 2D 4A 75 6E v 0.1.79+ 25-Jun
00FFFFFFD0 2D 32 30 31 35 00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF -2015.........
00FFFFFFE0 FF FF FF FF 00 00 01 00 00 00 00 00 00 00 00 ................
00FFFFFFF0 6B 09 7C 77 B3 00 00 2B BC FB 00 00 69 4C 4F 34 ................iLO4

• “mirrored” blob header: iLO4 magic at the end

• 0xFBBC: negative offset from the end of the file (0x444)

• Points to the cryptographic parameters, size 0x444

```python
class SignatureParams(LittleEndianStructure):
    _fields_ = [
        ("sig_size", c_uint),
        ("modulus", c_byte * 0x200),
        ("exponent", c_byte * 0x200)
    ]
```

• Used later for image signature verification
• **0x10000 from the end of the file**

• **Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F**

```
00FEFFE0  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF ..........  
00FEFFFF0  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF ..........  
00FF0000  09 00 00  EA 7C 03 00  EA E1 07 00  EA D5 03 00  EA ..........  
00FF0010  E7 03 00  EA FE FF FF EA 66 03 00  EA 0A 04 00  EA ..........  
00FF0020  7C 0E FF FF A8 02 FF FF 10 80 00 D0 68 07 00 EB ..........  
```

• **This is ARM code!**

• **ARM processor bootstrap code**

• **Load (and check integrity) image from the HPIMAGE blob**
● Concatenated to the HPIMAGE header, a set of IMG_HEADER:

Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

00000000 69 4C 4F 34 20 76 20 32 2E 34 2E 37 20 31 39 iLO4 v 2.44.7 19
00000010 2D 4A 75 6C 2D 32 30 16 1A 00 FF FF FF FF FF -Jul-2016........
00000020 08 00 00 10 F8 0A 00 00 57 5F 10 00 E0 02 68 01 .................
00000030 D3 EA D0 00 FF FF FF FF 00 00 00 FF FF FF FF ..........[...]
00000040 68 3C 5A 2A E9 DF A1 6A C2 D6 96 43 85 54 4E D0 .................

● iLO4 magic

● Images are signed (RSA sig)

● 3 images for this firmware: userland, kernel (main, recovery)

● Possibly compressed (LZ-like algorithm found in the bootstrap code)
class ImgHeader(LittleEndianStructure):

    _fields_ = [
        ('il0_magic', c_byte * 4),
        ('build_version', c_char * 0x1C),
        ('type', c_ushort),
        ('compression_type', c_ushort),
        ('field_24', c_uint),
        ('field_28', c_uint),
        ('decompressed_size', c_uint),
        ('raw_size', c_uint),
        ('load_address', c_uint),
        ('signature', c_byte * 0x200),
        ('padding', c_byte * 0x200)
    ]
• [-] iLO Header 0: iLO4 v 2.44.7 19-Jul-2016
  > magic : iLO4
  > build_version : v 2.44.7 19-Jul-2016
  > type : 0x08
  > compression_type : 0x1000
  > field_24 : 0xaf8
  > field_28 : 0x105f57
  > decompressed_size : 0x16802e0
  > raw_size : 0xd0ead3
  > load_address : 0xffffffff
  > field_38 : 0x0
  > field_3C : 0xffffffff
  > signature
     0000 68 3c 5a 2a e9 df a1 6a c2 d6 96 43 85 54 4e d0 h<Z*...j...C.TN.
     0010 c3 a4 e1 6f cb 2d 0f b6 0c 28 cd 31 88 db 07 6c ...o.-....(.1...1

• Once extracted and decompressed: an ELF!
  Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

  00000000  7F 45 4C 46 01 01 00 00 00 00 00 00 00 00 00 00 .ELF............
  00000010  02 00 28 00 01 00 00 00 00 00 00 00 00 00 34 00 ..(..........4...
  00000020  A0 A2 67 01 00 0C 17 00 34 00 20 00 66 02 28 00 ..........4. .f(..
  00000030  68 02 67 02 01 00 00 00 F4 4C 00 00 00 00 00 00 h.g.............
Key takeaways

- Understanding of the HPIMAGE firmware format
- HPIMAGE blob is signed, verified by the x86 code (flashing tool)
- Collection of images
- Each of them is signed, verified by the ARM bootstrap code
- The main image is a 23Mo ELF file!
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**Integrity image**

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Conclusion
ELF Header:

- Magic: 7f 45 4c 46 01 01 01 00 00 00 00 00 00 00 00 00
- Class: ELF32
- Data: 2’s complement, little endian
- Version: 1 (current)
- OS/ABI: UNIX - System V
- ABI Version: 0
- Type: EXEC (Executable file)
- Machine: ARM
- Version: 0x1
- Entry point address: 0x0
- Start of program headers: 52 (bytes into file)
- Start of section headers: 23569056 (bytes into file)
- Flags: 0x170c00, GNU EABI, VFP, Maverick FP, <unknown>
- Size of this header: 52 (bytes)
- Size of program headers: 32 (bytes)
- Number of program headers: 614
- Size of section headers: 40 (bytes)
- Number of section headers: 616
- Section header string table index: 615
## Section Headers:

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</tbody>
</table>
Strings for the win

Lots of build paths, root:

/home/delphyne2/autobuild/intbuild112210-000317-47/

File names:

rtos-i10.0/build(binary)/rtos/modules/ghs/posix/pthread_create.c
rtos-i10.0/build(binary)/rtos/modules/ghs/posix/posix_server.c
rtos-i10.0/build(binary)/rtos/modules/ghs/posix/ptls.c
rtos-i10.0/build(binary)/rtos/modules/ghs/posix/posix_env.c
rtos-i10.0/build(binary)/rtos/modules/ghs/posix/ghsposix.c
rtos-i10.0/build(binary)/rtos/modules/ghs/posix/pthread_sched.c
rtos-i10.0/build(binary)/rtos/INTEGRITY-libs/util/getopt.c

Integrity
The ELF binary is an applicative image (userland) packaged by HP, running on Integrity real-time OS, developed by Green Hills Software\textsuperscript{5}

\textsuperscript{5}http://www.ghs.com/products/rtos/integrity.html
• Two ELF sections are critical to understand the memory layout: `.secinfo` & `.boottable`.

• `.secinfo`: linked list of `SECTION_INFO` structures:

```c
struct SECTION_INFO
{
    SECTION_INFO *next;
    void  *name;
    int    section_offset;
    int    section_size;
    int    rights;
    int    field_14;
};
```
section_offset is an offset into the main ELF file. rights can take three values:

- 0x1 for executable section
- 0x9 for statically defined data
- 0xC for uninitialized data (stack, heap, bss)
The .boottable section:

- Is more complex
- Relies upon the .secinfo section
- Contains all the information needed to rebuild the virtual memory mapping of the Integrity image.

```assembly
.boottable:03DA5000 AREA .boottable, DATA, ALIGN=0
.boottable:03DA5000 dword_3DA5000 DCD 0x31
.boottable:03DA5004 DCD TASK_CONF
.boottable:03DA5008 DCD 0x30
.boottable:03DA500C DCD LIST_INITITIAL
.boottable:03DA5010 DCD 0xFFFFFFFF
.boottable:03DA5014 DCD 1
.boottable:03DA5018 DCD 0
.boottable:03DA501C DCD 0
.boottable:03DA5020 DCD 0
.boottable:03DA5024 DCD LIST_INITITIAL
.boottable:03DA5028 DCD 0
.boottable:03DA502C DCD 6
.boottable:03DA5030 DCD 6
.boottable:03DA5034 DCD LIST_CORE
```
List of shared modules (CORE_ENTRY):

```c
struct CORE_ENTRY
{
    int name;
    int mod_size;
    int mod_index;
    int field_C;
    int field_10;
};
```

-----------------[ Shared modules ]------------------

> mod 0x00 -   libINTEGRITY.so size 0x000047ec, id 0x001e, flags 0xffffffff,0xffffffff
> mod 0x01 -   libc.so size 0x00033b84, id 0x0020, flags 0xffffffff,0xffffffff
> mod 0x02 -   libevlog.so size 0x00032cf0, id 0x0023, flags 0xffffffff,0xffffffff
> mod 0x03 -   VComCShared_RM.so size 0x00005ba8, id 0x0033, flags 0xffffffff,0xffffffff
> mod 0x04 -   libsslc.so size 0x0009d010, id 0x0070, flags 0xffffffff,0xffffffff
List of task descriptors (TASK_INFO):

```c
struct TASK_INFO
{
    int type;
    int vmem_space_count;
    void *vmem_space_array;
    int field_C;
    int var_count;
    void *var_array;
    int field_18;
    int field_1C;
    int field_20;
    int field_24;
    int field_28;
    int field_2C;
    int field_30;
    int field_34;
    int field_38;
    int field_3C;
};
```

The type field seems to take two values: 0x0 for the kernel task, 0x21 otherwise.
Tasks’ virtual memory

vmem_space_array: a pointer to an array of MEM_RANGE descriptors, used to fully describe the virtual memory space of the task:

```c
struct MEM_RANGE {
    int present;
    int rights;
    int range_base;
    int range_size;
    int id;
    int field_14;
    int field_18;
    int field_1C;
};
```

- **present**: 1 if the range is loaded from the content of a section from the ELF image (see the id field)
- **rights**: 5 for executable range, 7 for data (no distinction between .data, .stack or .heap).
- **id**: shifted index of the ELF section. The shift is equal to the number of modules.
Full memory mapping

> task 0x27 (webserv.elf) - 0x00000049 entries

  range: dw1 0x00 - dw2 0x007 - base 0x0001000 - size 0x00F000 - id 0xffffffff
  range: dw1 0x01 - dw2 0x005 - base 0x0010000 - size 0x02B6000 - id 0x000001e2 - .webserv.elf.text
  range: dw1 0x00 - dw2 0x007 - base 0x02c6000 - size 0x002000 - id 0xffffffff
  range: dw1 0x01 - dw2 0x007 - base 0x02c8000 - size 0x112000 - id 0x000001e3 - .webserv.elf.data
  range: dw1 0x00 - dw2 0x007 - base 0x03db000 - size 0x002000 - id 0x000001ef - .webserv.Initial.stack
  range: dw1 0x01 - dw2 0x007 - base 0x03dd000 - size 0x190000 - id 0x000001f0 - .webserv.heap
  range: dw1 0x00 - dw2 0x007 - base 0x056d000 - size 0x004000 - id 0xffffffff
  range: dw1 0x00 - dw2 0x007 - base 0x0571000 - size 0x98F000 - id 0xffffffff
  range: dw1 0x00 - dw2 0x107 - base 0x0f00000 - size 0x100000 - id 0xffffffff
  range: dw1 0x01 - dw2 0x007 - base 0x1000000 - size 0x680000 - id 0xffffffff
  range: dw1 0x01 - dw2 0x007 - base 0x1680000 - size 0x190000 - id 0xffffffff
  range: dw1 0x00 - dw2 0x007 - base 0x16b3000 - size 0x001000 - id 0xffffffff
  range: dw1 0x01 - dw2 0x007 - base 0x16b4000 - size 0x001000 - id 0xffffffff
  range: dw1 0x00 - dw2 0x007 - base 0x16b5000 - size 0x003000 - id 0xffffffff
  range: dw1 0x01 - dw2 0x007 - base 0x16b8000 - size 0x001000 - id 0xffffffff

[...]
Key takeaways

• Extensive understanding of the Integrity applicative image format
• Tasks (or processes) are isolated into their own virtual memory space
• Their base address is always 0x10000 (main .text)
• Automatization: pack all this stuff into a script that generates a complete IDB
• Let’s check the kernel!
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Integrity micro-kernel

- No technical documentation available to us
- Only commercial information:

![Diagram of Integrity micro-kernel](https://www.ghs.com/products/rtos/integrity.html)

**Figure 2:** https://www.ghs.com/products/rtos/integrity.html

- All the information presented further is based on our analysis; it may be wrong/incomplete.
Kernel modules

Micro-kernel architecture build upon a small set of core modules:

ROM:200BCBF0 BOOT_MODULES BOOT_MOD <0x200BCC58, 0x200BCC7C, 0x200C0E6C,
0x200BFC6C, 0x200C10C4, 0x200C1264,
0x200C1288, 0x200C12AC, 0>

Each entry is a pointer to a BOOT_MOD structure:

```c
struct BOOT_MOD
{
    void *constructor;
    void *destructor;
    char *name;
    void *dependencies;
    MOD_STATUS mod_status;
};
```
Kernel modules

Parsing loader’s components list:

> component "Resource Manager", constructor 0x20009aa4, destructor 0x00000000

> component "Dynamic Loader", constructor 0x20009bd8, destructor 0x20009c94
   > dependencies (0x200bcca0):
      Resource Manager (0x200b70fc)

> component "TCP/IP", constructor 0x200448bc, destructor 0x00000000
   > dependencies (0x200c0e90):
      Resource Manager (0x200b8a38)
      System Resources (0x200b8a4c)
      UMAC (0x200b8a60)

> component "UMAC", constructor 0x20030854, destructor 0x00000000
   > dependencies (0x200c0dd4):
      Resource Manager (0x200b7dec)
      System Resources (0x200b7e00)

[...]

They all depends upon the "Resource Manager" component!
Example of object instantiation:

```c
rsr_c_mgr_reglink_msg (OBJ_LoaderConnection,
                     "__LoaderConnection",
                     "!systempassword")
```

The code above setup and sends a request made of:

- A verb: “reglink”
- The name of the object: “__LoaderConnection”
- A password: “!systempassword”

List of supported verbs:

- “procure”
- “delete”
- “register”
- “reglink”
- “procure-delete”
There is an equivalent of the ELF .secinfo section in the kernel:

> parsing .secinfo entries:

```
.romstart - base 0xf8000000 - size 0x00000000 - access : 0x4
.romend - base 0xf8000000 - size 0x00000000 - access : 0x4
.ramstart - base 0x20001000 - size 0x00000000 - access : 0x4
.picbase - base 0x20001000 - size 0x00000000 - access : 0x4
.vector - base 0x20001000 - size 0x000000a8 - access : 0x1
.probe_agent - base 0x200010a8 - size 0x00000038 - access : 0xc
.fasttext - base 0x20004000 - size 0x00001f6c - access : 0x9
.rtext - base 0x20005f6c - size 0x00000000 - access : 0x4
.text - base 0x20005f6c - size 0x000b0a9c - access : 0x1
.loadertext - base 0x200b6a08 - size 0x00000000 - access : 0x4
.syscall - base 0x200b6a08 - size 0x00000008 - access : 0x1
.intercall - base 0x200b6a10 - size 0x00000000 - access : 0x4
.interfunc - base 0x200b6a10 - size 0x00000006 - access : 0x1
.fixaddr - base 0x200b6a16 - size 0x00000000 - access : 0x4
.fixtype - base 0x200b6a16 - size 0x00000000 - access : 0x4
.secinfo - base 0x200b6a18 - size 0x0000067c - access : 0x2
[...]```
• Early initialization phase
• The kernel parses some kind of memory region descriptors
• Informative error message:

```c
errlog("Failed to build memory map\n");
raise("F:;\bspwd\;\int1002\;\modules\;\ghs\;bspsrc\;support\;bsp_common.c", 130);
```

• Each of these descriptors is then registered as resource (exposed)

```c
rsrMgr_reglink_msg(memory_object, entry->name, "!systempassword")
```
```c
struct MEMORY_REGION
{
    int id;
    int field_4;
    int low;
    int high;
    int field_10;
    int field_14;
    int field_18;
    int field_1C;
    const char *mr_name;
    int field_24;
    MEMORY_REGION *next;
    MEMORY_REGION *self;
    int field_30;
};
```
BSP: memory ranges

>> id: 0x0507 - reg: MRSRAM_ASM - low 0xd0000000 / high 0xd0007fff
>> id: 0x0507 - reg: MRSRAM_CFG - low 0xd000a000 / high 0xd003ffff
>> id: 0x0507 - reg: MRC0008 - low 0xc0008000 / high 0xc0008fff
>> id: 0x0507 - reg: MRDOWNLOAD - low 0x207ba000 / high 0x221ba000
>> id: 0x0507 - reg: MRVIDEORAM - low 0x00000000 / high 0x00000fff
[...]
>> id: 0x0507 - reg: MR80108 - low 0x80108000 / high 0x8010bfff
>> id: 0x0507 - reg: MR801F0 - low 0x801f0000 / high 0x801f0fff
>> id: 0x0507 - reg: MR80200 - low 0x80200000 / high 0x80200fff
[...]
>> id: 0x0507 - reg: MRC0000 - low 0xc0000000 / high 0xc0000fff
>> id: 0x0507 - reg: MRC0001 - low 0xc0001000 / high 0xc0001fff
>> id: 0x0507 - reg: MRC0002 - low 0xc0002000 / high 0xc0002fff
[...]
>> id: 0x0507 - reg: MRD1000 - low 0xd1000000 / high 0xd1000fff
>> id: 0x0507 - reg: __ghs_bncsi_buffers - low 0x00000000 / high 0x000005ff
>> id: 0x0407 - reg: __ghs_umac_descriptors - low 0x00000000 / high 0x000007ff
>> id: 0x0507 - reg: __ghs_umadcv_mirror_buffers - low 0x00000000 / high 0x00005fff
>> id: 0x0507 - reg: __ghs_tcpip_buffers - low 0x00000000 / high 0x00017fff
>> id: 0x0507 - reg: __ghs_ktstncsi_phy_buffers - low 0x00000000 / high 0x00005fff
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HP provides access to iLO from the host operating system

- iLO is seen as a PCI device
- Driver is provided in the Linux kernel

Handled on iLO side by the CHIF task

- Various command handlers
- Gives access to Redfish API
- CHIF can also pass some commands to other tasks, such as embmedia
Commands are passed through shared memory

- Linux driver implements 8 to 24 channels in the device shared memory
- Commands are sent in a FIFO

```c
struct chif_command
{
    int size;
    short command_id;
    short destination_id;
    char data[];
};
```
iLO access from host is privileged

- No authentication required
- Ability to add new users/administrators
- Ability to access the Redfish API

Example: access the default settings stored in EEPROM (CHIF command 0x70):

```python
>>> f=open("/dev/hpilo/d0c0cb1", "wb+")
>>> data = "MFGDiag\x00" + pack("<L", 1) # Read eeprom, offset 0
>>> f.write(pack("<L2H", len(data)+8, 0x70, 0) + data)
>>> resp = f.read(4)
>>> resp += f.read(unpack_from("<L", resp)[0] - 4)
>>> print hexdump(resp)
0000 8c 00 00 00 70 80 00 00 00 00 00 01 00 00 00 ....p............
0010 43 5a 31 37 31 35 30 31 47 39 20 20 20 20 20 CZ171501G9
0020 00 00 00 00 00 00 00 00 02 00 00 00 ff ff ff ff ..............
0030 ff ff ff ff 41 64 6d 69 6e 69 73 74 72 61 74 6f ....Administrato
0040 72 00 00 00 00 00 00 00 00 00 00 00 47 xx xx xx r.........G***
0050 36 4e 4a 37 00 00 00 00 00 00 00 00 00 6NJ7............
0060 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ..............
0070 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ..............
0080 00 00 00 00 61 2b ff ff ff ff ff ff ....a+......
```
• Network scan:

Host is up (0.015s latency).
Not shown: 996 closed ports

<table>
<thead>
<tr>
<th>PORT</th>
<th>STATE</th>
<th>SERVICE</th>
<th>VERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>22/tcp</td>
<td>open</td>
<td>ssh</td>
<td>HP Integrated Lights-Out mpSSH 0.2.1 (protocol 2.0)</td>
</tr>
<tr>
<td>80/tcp</td>
<td>open</td>
<td>http</td>
<td>HP Integrated Lights-Out web interface 1.30</td>
</tr>
<tr>
<td>443/tcp</td>
<td>open</td>
<td>ssl/http</td>
<td>HP Integrated Lights-Out web interface 1.30</td>
</tr>
<tr>
<td>17988/tcp</td>
<td>open</td>
<td>ilo-vm</td>
<td>HP Integrated Lights-Out Virtual Media</td>
</tr>
</tbody>
</table>

Summary of exposed endpoints:

- SSH server (mpSSH)
- WWW server
- iLO RESTful API, Redfish
- iLO virtual media port
- IPMI
- SNMP
- UPnP
Outline

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## Processor 1

**Processor Name**: Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.60GHz  
**Processor Status**: OK  
**Processor Speed**: 2600 MHz  
**Execution Technology**: 8/8 cores, 16 threads  
**Memory Technology**: 64-bit Capable  
**Internal L1 cache**: 256 KB  
**Internal L2 cache**: 2048 KB  
**Internal L3 cache**: 20480 KB

## Processor 2

**Processor Name**: Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.60GHz  
**Processor Status**: OK  
**Processor Speed**: 2600 MHz  
**Execution Technology**: 8/8 cores, 16 threads  
**Memory Technology**: 64-bit Capable  
**Internal L1 cache**: 256 KB  
**Internal L2 cache**: 2048 KB  
**Internal L3 cache**: 20480 KB
Web server provides:

- A shiny web interface
- An XML API
- A Redfish API
- A remote console through a Java applet

**GOOD**
Access to almost all pages is authenticated.

**BAD**
An /xmlData endpoint can be accessed without authentication.
Getting information: /xmldata?item=all
Getting information: /xmldata?item=all

<PN>Integrated Lights-Out 4 (iLO 4)</PN>
<RIMP>
<HSI>
<SBSN>CZ24370KKL</SBSN>
<SPN>ProLiant DL380p Gen8</SPN>
<UUID>653200CZ24370KKL</UUID>
<SP>1</SP>
<FWRI>2.55</FWRI>
<BBLK>03/05/2013</BBLK>
<HWRI>ASIC: 12</HWRI>
<SN>ILOCZ24370KKL</SN>
<UUID>IL0653200CZ24370KKL</UUID>
<IPM>1</IPM>
<SSO>0</SSO>
<PWRM>3.3.0</PWRM>
Getting external and **internal** network interfaces information? /xmldata?item=all
Getting external and internal network interfaces information? /xmldata?item=all

<NIC>
<PORT>1</PORT>
<DESCRIPTION>iLO 4</DESCRIPTION>
<LOCATION>Embedded</LOCATION>
<MACADDR>9c:b6:52:b1:2a:62</MACADDR>
<IPADDR>10.123.48.19</IPADDR>
<STATUS>OK</STATUS>
</NIC>

<NIC>
<PORT>2</PORT>
<DESCRIPTION>iLO 4</DESCRIPTION>
<LOCATION>Embedded</LOCATION>
<MACADDR>9c:b6:52:b1:2a:63</MACADDR>
<IPADDR>192.168.1.152</IPADDR>
<STATUS>OK</STATUS>
</NIC>
Getting a **free Advanced License**? /xmldata?item=CpqKey
Getting a **free Advanced License?**

```
<PROLIANTKEY>
<LNAME>iLO Advanced</LNAME>
<IDATE>Thu Nov 19 03:02:39 2015</IDATE>
<KEY>35DQ5-*****-8YTD2-*****-X5W7R</KEY>
</PROLIANTKEY>
```
*Teasing for later*

After authentication, a hidden debug page can be accessed.

- **pci_info**
  - 0.
    - Fn0 PCI-E Status Reg CSMPCISR : 0x0010
    - Fn2 PCI-E Status Reg CHIFPCISR : 0x0010
    - Fn3 PCI-E Status Reg WDGPCISR : 0x0010
    - Fn4 PCI-E Status Reg UHCIPCISR : 0x0010
    - Fn5 PCI-E Status Reg VSPPCISR : 0x0010
    - Fn6 PCI-E Status Reg IPMIPCISR : 0x0010
    - Fn0 PCI-E Device Status Reg : 0x0008
    - Fn2 PCI-E Device Status Reg : 0x0008
    - Fn3 PCI-E Device Status Reg : 0x0000
    - Fn4 PCI-E Device Status Reg : 0x0000
    - Fn5 PCI-E Device Status Reg : 0x0000
    - Fn6 PCI-E Device Status Reg : 0x0000
    - PCI-E Err Stat Reg PERSTAT : 0xf0000400
    - Sys Flt Stat Reg SYSFAULT : 0x0000
    - CSM NMI Stat Reg (Fn0) NMISTAT : 0x00
    - SIIRQ config Reg : 0x00
    - Fn0 PCI-E I/O BAR : 0x000003001
    - Fn2 PCI-E I/O BAR : 0x000003001
    - Fn3 PCI-E I/O BAR : 0x000000001
    - Fn6 PCI-E Memory BAR : 0x000000000
What about the web server architecture?

- Web server has 4 concurrent threads
- Each thread handles a connection
- Supports HTTP and HTTPS
What about the web server architecture?

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- Each thread handles a connection
- Supports HTTP and HTTPS

New connection handling:

- Each request is parsed line by line
What about the web server architecture?

- Web server has 4 concurrent threads
- Each thread handles a connection
- Supports HTTP and HTTPS

New connection handling:

- Each request is parsed line by line
- Various `strcmp()`, `strstr()` and `sscanf()` calls
What about the web server architecture?

- Web server has 4 concurrent threads
- Each thread handles a connection
- Supports HTTP and HTTPS

New connection handling:

- Each request is parsed line by line
- Various `strcmp()`, `strstr()` and `sscanf()` calls
- What could possibly go wrong?
sscanf() is hard!
sscanf() is hard!
sscanf() is hard!
sscanf() is hard!

```
ADD R1, R6, #8
ADD R0, R6, #4
STMEA
MVU R3, R8
ADD R2, SP, #0x27C+var_20
ADR R1, a951023sHttpD_D ; "%s %1023s HTTP/%d.%d"
MVU R0, R5
BL sscanf
ADR R2, aAuthorization ; "Authorization:"
MVU R1, R5
MVU R0, R7
MVU R3, #0x8E
DL strncmp
CMP R0, #0
BNE loc_14F9C
MVU R0, R6
BL sub_17B6C
ADD R2, SP, #0x27C+var_40
MVU R3, R0
ADR R1, a15S16383S ; "%s %15s %16383s"
MVU R0, R5
DL sscanf

ADR R2, aContentLength ; "Content-length:"
MVU R1, R5
MVU R0, R7
MVU R3, #0xF
strncmp
R0, #0
loc_14FDC
R0, [SP,#0x27C+var_26C]
ADR R2, SP, #0x27C+var_26C
ADR R1, aSD ; "%s %d"
MVU R0, R5
BL sscanf
ADR R2, aConnection ; "Connection:"
MVU R1, R5
MVU R0, R7
MVU R3, #0xB
BL strncmp
CMP R0, #0
ADDEQ R2, R7, #0xC
ADREQ R1, aSS_0 ; "%s %5"
MVUEQ R0, R5
BLEQ
```

OK

FAIL
The web server parses the HTTP headers from user’s request:

```c
else if ( !strnicmp(request, http_header, "Content-length:", 0xFu) )
{
    content_length = 0;
    sscanf(http_header, "\%s \%d", &content_length);
    state_set_content_length(global_struct_, content_length);
}
else if ( !strnicmp(request, http_header, "Cookie:", 7u) )
{
    cookie_buffer = state_get_cookie_buffer(global_struct_);
    parse_cookie(request, http_header, cookie_buffer);
}
else if ( !strnicmp(request, http_header, "Connection:", 0xBu) )
{
    sscanf(http_header, "\%s \%s", https_connection->connection);
}
```
• String parsing function:

```c
int sscanf ( const char * s, const char * format, ...);
```

• Definition: *Read formatted data from string.* Reads data from `s` and stores them according to parameter `format` into the locations given by the additional arguments.

**Parsing is hard**

```c
sscanf(http_header, "%s %s", https_connection->connection);
```

• Basically says “*copy whatever you can into connection*” buffer

• No sanitization/bound checking

• Destination buffer is only 16 bytes ⇒ **buffer overflow**
Buffalo overflow

R7 points to a `https_connection` object.
R7+0xC points to a fixed-size buffer.

```c
struct https_connection {
    ...
    0xC: char connection[0x10];
    ...
    0x28: char localConnection;
    ...
}
```
Host system can talk to iLO through shared memory

- Redfish API can be requested from host
- Authentication is not required!
- Web server uses the localConnection boolean to check if the connection comes from the host
Host system can talk to iLO through shared memory

- Redfish API can be requested from host
- Authentication is not required!
- Web server uses the localConnection boolean to check if the connection comes from the host

Redfish API allows unauthenticated access when localConnection is not zero
Host system can talk to iLO through shared memory

- Redfish API can be requested from host
- Authentication is not required!
- Web server uses the localConnection boolean to check if the connection comes from the host

**Redfish API allows unauthenticated access when localConnection is not zero**

What about a nice cup of AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA?
DEMO
Key takeaways

- Pre-auth buffer overflow in web server HTTP headers handling
- Vulnerability was reported to HP on February 2017
- Vulnerability can be exploited for authentication bypass
  - Ability to add a new administrator account
  - Access to the remote console
  - Ability to restart the server on an arbitrary ISO
- We need to go deeper!
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Web server objects have their vtable pointer at the end of the structure:

```c
struct https_connection {
    ...
    0x0C: char connection[0x10];
    ...
    0x28: char localConnection;
    ...
    0xB8: void *vtable;
}
```
Turning overflow into code execution

Web server objects have their \textit{vtable} pointer at the end of the structure:

```c
struct https_connection {
    ...
    0x0C: char connection[0x10];
    ...
    0x28: char localConnection;
    ...
    0xB8: void *vtable;
}
```

There is \textbf{no} ASLR.
Web server objects have their \textit{vtable} pointer at the end of the structure:

\begin{verbatim}
struct https_connection {
    ... 
    0x0C: char connection[0x10];
    ... 
    0x28: char localConnection;
    ... 
    0xB8: void *vtable;
}
\end{verbatim}

There is \textbf{no} ASLR.

There is \textbf{no} NX.
Web server objects have their *vtable* pointer at the end of the structure:

```c
struct https_connection {
    ...
    0x0C: char connection[0x10];
    ...
    0x28: char localConnection;
    ...
    0xB8: void *vtable;
}
```

There is **no** ASLR.

There is **no** NX.

Each web server thread has a *working buffer* at a fixed address.
Working buffers receive each line during HTTP request parsing.
Working buffers receive each line during HTTP request parsing.

**Working buffers can be populated with controlled data!**
The plan

Write shellcode in working buffer

Working buffer  Shellcode
The plan

Write shellcode in working buffer

Write fake *vtable* in working buffer
The plan

1. Write shellcode in working buffer

   Working buffer  |  Shellcode

2. Write fake *vtable* in working buffer

   Working buffer  |  Fake vtable  |  Shellcode

3. Trigger the buffer overflow to overwrite the object’s *vtable* pointer!
RCE: what can be done?

We can craft an arbitrary shellcode which:

- Reads contents of the password file on the iLO filesystem
  - Passwords are stored in cleartext
- Sends back results through the HTTPS socket

DEMO
Key takeaways

- Buffer overflow can be turned into a reliable RCE
- We can now execute an arbitrary shellcode in the webserver context
- We need to go deeper! iLO should be able to access the main physical memory.
Outline

Introduction
Firmware unpacking
Integrity image
Kernel internals
Attack surface
Damn vulnerable web server
Code exec in your BMC

BMC to host
Staying in the place
Conclusion
While reversing the **Channel Interface (CHIF)** task, there were mentions of **WHEA** records parsing:

```
whea: invalid info from SMBIOS type_229 : offset=%X, size=%X
whea: found whea_info at %p
whea: NO $WHE found!
[...]
whea: sawbase access failed
[...]
whea : re-running whea HostRAM detect
```

**Keywords:** SMBIOS type_229, $WHE, HostRAM
Type 229 is OEM defined. Let’s dump it from our Linux!

0000 24 44 46 43 00 50 fe f1 00 00 00 00 04 00 00 $DFC.P...........
0010 24 43 52 50 00 50 f9 f1 00 00 00 00 00 05 00 $CRP.P...........
0020 24 48 44 44 00 30 f9 f1 00 00 00 00 00 20 00 00 $HDD.0...........
0030 24 4f 43 53 00 f0 f8 f1 00 00 00 00 00 40 00 00 $OCS...........@
0040 24 4f 43 42 00 f0 f7 f1 00 00 00 00 00 00 01 00 $OCB............
0050 24 53 41 45 45 00 e0 f7 f1 00 00 00 00 10 00 00 $SAE.............

Looks like structures:

```c
struct entry229 {
    char tag[4];
    void *pointer64;
    int flags;
};
```
Let’s check one of these pointers in physical memory...

root@ilo-server-ubuntu:~# xxd -s $(0xf1f95000) /dev/mem|head -n 8

f1f95000: 2452 4253 0000 0000 0001 0069 0813 0400 $RBS.......i....
f1f95010: 0113 0400 0101 6f00 0000 0001 6752 4f4d ......o.....gROM
f1f95020: 2d42 6173 6564 2053 6574 7570 2055 7469 -Based Setup Uti
f1f95030: 6c69 7479 2c20 5665 7273 696f 6e20 332e lity, Version 3.
f1f95040: 3030 0d0a 436f 7079 7269 6768 7420 3139 00..Copyright 19
f1f95050: 3030 0d0a 436f 7079 7269 6768 7420 3139 00..Copyright 19
f1f95060: 2d50 6163 6b61 7264 2044 6576 656f 70 -Packard Develop
f1f95070: 6d65 6e74 2043 6f6d 7061 6e79 2c20 4c2e ment Company, L.

Looks great!
char whea_header[0x18];
int *ptr_entry = find_in_smbios_229("$WHE");
if (ptr_entry) {
    int phy_ptr_low = ptr_entry[1];
    int phy_ptr_high = ptr_entry[2];

    void *whea_ptr = func_XXX(phy_ptr_low, phy_ptr_high);
    sawbase_memcpy_s(whea_header, whea_ptr, 0x18);
    [...]
}

<table>
<thead>
<tr>
<th>func_XXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV</td>
</tr>
<tr>
<td>STMF</td>
</tr>
<tr>
<td>SUB</td>
</tr>
<tr>
<td>LDR</td>
</tr>
<tr>
<td>MOV</td>
</tr>
<tr>
<td>ORR</td>
</tr>
<tr>
<td>LDRB</td>
</tr>
<tr>
<td>BIC</td>
</tr>
<tr>
<td>ORR</td>
</tr>
<tr>
<td>LDR</td>
</tr>
<tr>
<td>STR</td>
</tr>
<tr>
<td>BIC</td>
</tr>
<tr>
<td>ADD</td>
</tr>
<tr>
<td>LDHDB</td>
</tr>
</tbody>
</table>

; End of function func_XXX
Mysterious function

```c
void *func Xxx(void *ptr_low, void *ptr_hi) {
    int magic = (flag << 24) |
                (((ptr_hi << 8) | (ptr_low >> 24)) & 0x00ffffff);
    *(0x1f02064) = magic;
    return (ptr_low & 0x00ffffff) | 0x600000;
}
```

- Passed 64-bits pointer is truncated to a 16MB boundary
- Flag is set to 2
- What is mapped at 0x1F02064?
- What is mapped at 0x600000?
Memory Regions (MR)

- Range of iLO physical memory
- Mapped in a userland task virtual memory
- Requested as a resource from userland

```c
sprintf(mr_name, "MR%X", mr_physical >> 12);
RequestResource(&mr_object, mr_name, "!systempassword");
```

- RequestResource setup and sends a request to the kernel, made of:
  - A verb: "procure"
  - The name of the object, ex: "MR80200"
  - A password: "!systempassword"

Each task has a list of Memory Region which can be mapped in its virtual memory, by calling memmap().
CHIF task maps the following Memory Region:

<table>
<thead>
<tr>
<th>Physical</th>
<th>Virtual</th>
<th>Size</th>
<th>MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x80000000</td>
<td>0x1F00000</td>
<td>0x1000</td>
<td>MR80000</td>
</tr>
<tr>
<td>0x800F0000</td>
<td>0x1F01000</td>
<td>0x1000</td>
<td>MR800F0</td>
</tr>
<tr>
<td>0x80200000</td>
<td>0x1F02000</td>
<td>0x1000</td>
<td>MR80200</td>
</tr>
<tr>
<td>0x802F0000</td>
<td>0x1F03000</td>
<td>0x1000</td>
<td>MR802F0</td>
</tr>
<tr>
<td>0x804F0000</td>
<td>0x1F07000</td>
<td>0x1000</td>
<td>MR804F0</td>
</tr>
<tr>
<td>0x82000000</td>
<td>0x600000</td>
<td>0x10000000</td>
<td>MR82000</td>
</tr>
<tr>
<td>0xC0000000</td>
<td>0x1F10000</td>
<td>0x1000</td>
<td>MRC0000</td>
</tr>
<tr>
<td>0xD1000000</td>
<td>0x1F14000</td>
<td>0x1000</td>
<td>MRD1000</td>
</tr>
</tbody>
</table>

We now have our virtual ⇔ physical mapping:

- 0x1F02064 is the mapping of 0x80200064
- 0x600000 is the mapping of 0x82000000
Remember the dbug.html page?
Reversing it gives information about the 0x1F00000 memory range.

1f01006   Fn0 PCI-E Status Reg  CSMPCISR
1f01010   Fn0 PCI-E I/O BAR
1f010ca   Fn0 PCI-E Device Status Reg
1f02078   PCI-E Err Stat Reg PERSTAT
1f020b4   Sys Flt Stat Reg SYSFAULT
1f03006   Fn2 PCI-E Status Reg CHIFPCISR
1f03010   Fn2 PCI-E I/O BAR
1f030ca   Fn2 PCI-E Device Status Reg
1f05006   Fn3 PCI-E Status Reg WDGPCISR
1f050ca   Fn3 PCI-E Device Status Reg
1f07006   Fn4 PCI-E Status Reg UHCIPCISR
1f070ca   Fn4 PCI-E Device Status Reg
1f09006   Fn5 PCI-E Status Reg  VSPPCISR
1f09010   Fn5 PCI-E I/O BAR
1f090ca   Fn5 PCI-E Device Status Reg
1f0b006   Fn6 PCI-E Status Reg IPMIIPCISR
1f0b010   Fn6 PCI-E Memory BAR
1f0b0ca   Fn6 PCI-E Device Status Reg

0x1F02064 should be an unknown PCI register.
How to access host memory?

- Reversing CHIF told us how to access host memory
- Let’s implement this technique in the webserver task through a shellcode

Shellcode will fill a 16MB Memory Region with host memory.

- Take a host physical memory address
- Shift it right by 24
- Add flag
- Write the value in register 0x1F02064
- ???
- Profit by accessing MR82000!

After testing, we can access almost any memory address in the host physical memory, with read and write access.
Our host runs an up-to-date Ubuntu Linux.

The plan:

- Dump the Linux kernel address space
- Do some recon to find interesting offsets
- Replace some unused functions with our shellcode
- Hijack the syscall table to redirect execution to our shellcode

DEMO
We have fully compromised the platform, how to remain persistent across reboot without modifying the file system of the host?

Let’s investigate!
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Many advantages:

- Survives an OS reinstallation
- Extremely stealth: who can do forensics on iLO?

Not so simple (theoretically):

- Updates are signed
- Boot-time integrity check
Firmware updates can be performed through the web interface, or directly from the host.

Update mechanism analysis shows two important points:

- Downgrading is possible! Long life to vulnerabilities!
- Signature is correctly checked

However, if we get RCE, we can bypass this signature check and write our own firmware on the flash chip.
According to HP:

At boot time, each piece has its signature validated before it is allowed to execute. Subsequent pieces are checked by the previous ones until iLO is fully booted.

However... who checks the bootloader signature?
The perfect backdoor

Gaining persistence in 6 steps:

- Patch bootloader signature check of the kernel
- Patch kernel signature check of the userland
- Inject a malicious payload in a userland task
- Patch the firmware update userland task to reinject the backdoor in case of firmware update
- Rebuild a correct image (ELF structure, compression)
- Flash the new image using a custom shellcode
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iLO4 key takeaways

- Documentation of the Integrity image internals
- Huge exposed attack surface
- IPMI v2 authentication **weak by design**
- One critical vulnerability discovered, fixed by the vendor\(^6\)
- Unpatched server ⇒ **trivial remote authentication bypass** and **full compromise** (code execution) of the iLO system
- **New DMA based exploitation technique** ⇒ full compromise of the host system from the iLO system
- No hardware root of trust: open doors to compromised firmware\(^7\)
- Remote administration services should be isolated in a dedicated administration VLAN

---

\(^6\) CVE-2017-12542, CVSSv3 9.8

\(^7\) Fix proposed in iLO5, released mid-2017, see “silicon root of trust”,
https://support.hpe.com/hpsc/doc/public/display?docId=a00018320en_us
Thank you for your attention

Questions?

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