Fight crime. Unravel incidents... one byte at a time.

Copyright SANS Institute
Author Retains Full Rights

Interested in learning more?
Check out the list of upcoming events offering
"Advanced Incident Response, Threat Hunting, and Digital Forensics (FOR508)"
GIAC Reverse Engineering Malware Practical Assignment

GREM Version 1.0

Joseph Fresch
SANS - GREM / Las Vegas NV
2004

Submitted
March 3, 2005
Table of Contents

Abstract 1
Document Convention 1
Laboratory Setup 2
Properties of the Malware Specimen 4
Behavioral Analysis 7
Code Analysis 20
Analysis Wrap-Up 34
References 36

List of Figures

Figure 1: Machine specifics for lab environment. 2
Figure 2: Lab Setup with Host Only Networking – 192.168.147.0/24. 3
Figure 3: Properties of msrll.exe. 4
Figure 4: Operating System environments in which the Malware can execute. 5
Figure 5: IRC connection and request for identd information. 13
Figure 6: Randomness of user and nick 14
Figure 7: Attempted connection on port 2200 using telnet 15
Figure 8: Attempted connection on port 2200 using ftp 15
Figure 9: listdlls.exe, list of Dynamically Link Libraries used by msrll.exe 16
Figure 10: listdlls.exe, list of Dynamically Link Libraries used by msrll.exe 19
Figure 11: NetCat.exe commands with results. 23
Figure 12: Whois, ping and version performed on the Malware client. 22
Figure 13: Mutex “m220” setting code from IDA Pro. 22
Figure 14: Code related to the Registry 24
Figure 15: TCPView.exe look at listening and IRC server. 25
Figure 16: Breakpoints used in the investigation. 27
Figure 17: Section of code where the jtram.conf information is encoded. 27
Abstract

Reverse Engineer an unknown piece of Malware using different methods of analysis. Dangerous malicious code needs to have proper precautions to prevent it from entering the wild of the Internet. To this end a set of Virtual Machines have been brought together to form a test environment, with the emphasis placed on safe controlled analysis of this unknown Malware. Once enough data is collected surmise the capabilities of the Malware specimen, what does it do, who would use the program. What can be done to set up defensive measures can be and what can be derived from the analysis to prevent future attacks and eliminate current infections.

Document Convention

When you read this practical assignment, you will see that certain words are represented in different fonts and typefaces. The types of words that are represented this way include the following:

- **command**: Operating system commands are represented in this font style. This style indicates a command that is entered at a command prompt or shell.
- **filename**: Filenames, paths, and directory names are represented in this style.
- **computer output**: The results of a command and other computer output are in this style.
- **URL**: Web URL's are shown in this style.
- **Quotation**: A citation or quotation from a book or website is in this style.
Laboratory Setup

To afford some protection and allow for a controlled analysis of the Malware, software called VMW are was used to create the test environment. The test environment was created using VMW are version 4.5.2 build 8848 on a dual Athlon MP system with 512 MB of RAM and 120GB hard drive. This software allows for the emulation of different hardware and allows for installation of different Operating System software into those emulated collections of hardware.

Configuration and installation of the Operating Systems in the VMWare environment requires knowledge of both VMWare and of Operating System Installation. The network was setup to use Host Only Networking.

Host-only — When you use this type of network connection, the virtual machine is connected to the host operating system on a virtual private network, which normally is not visible outside the host. Multiple virtual machines configured with host-only networking on the same host are on the same network.

<table>
<thead>
<tr>
<th>OS</th>
<th>Version</th>
<th>Service Pack</th>
<th>Memory (MB)</th>
<th>Hard Disk1 (GB)</th>
<th>Hard Disk2 (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Win 98</td>
<td>4.10.1998</td>
<td></td>
<td>128</td>
<td>2</td>
<td>none</td>
</tr>
<tr>
<td>Win NT 4</td>
<td>4.00.1381IE 5</td>
<td>6.0.2800.1106</td>
<td>256</td>
<td>1.29 (4.0)</td>
<td>0.126 (0.512)</td>
</tr>
<tr>
<td>Win 2K</td>
<td>5.00.2195</td>
<td>SP 4</td>
<td>256</td>
<td>2</td>
<td>none</td>
</tr>
<tr>
<td>Win XP</td>
<td>2002</td>
<td>SP 1</td>
<td>128</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Linux RH 9</td>
<td>2002</td>
<td></td>
<td>284</td>
<td>2</td>
<td>none</td>
</tr>
</tbody>
</table>

Figure 1: Machine specifics for lab environment.

As an added precaution it is advised that the researcher install and use a local firewall application like ZoneAlarm. This will help prevent any accidental releases into the LAN or out onto the Internet. The operating systems focused on in this research were Windows XP Professional (Win XP) and Linux Red Hat 9.0 running kernel 2.4.20-8 (RH Linux). The Malware was tested for launch on each of the other four Operating Systems, Windows 98, Windows NT and Windows 2000 and Windows XP Professional. The RH Linux allowed for interaction with the Malware as well as use of tools such as Snort, Net Cat and Internet Relay Chat (IRC). The Windows machines will provide the environment for running the Malware. This is also where the investigation of the specimen will be conducted.

---

1 Host-only information from the VMWare help, search host only network and displaying the first entry, Configuring a Network Adapter (NIC).
2 http://www.zonealarm.com
2: Lab Setup with Host Only Networking – 192.168.147.0/24.

Tools for Analysis:
- **WinZip.exe 9.0 (6028)** – Used to unpack the Malware Specimen.
- **MD5sum.exe** – Used to create MD5 hash of files.
- **RegShot.exe 1.61e5 Final 2003/1/1** – Used for comparison of Registry before and after Malware is launched.
- **RegMon.exe** – Used to show access to the Registry.
- **FileMon.exe 6.07** – Used to show file access.
- **TDIMon.exe 1.01** – Used to view network access similar to netstat –an.
- **UPX 1.24** – Unpacking tool.
- **BinText.exe 3.0** – Used to inspect strings found in the Malware Specimen.
- **LordPE.exe RoyalTS** – Used to Dump the decrypted Malware Specimen from memory.
- **Unaspack.exe 2.0** – BinText.exe showed the string “aspack” a packing software was used to pack the Malware.
- **AspackDie.exe 1.3d** – Utility used to unpack the Malware Specimen.
- **OllyDB.exe 1.0.10.0** – 32 bit Assembler Level Debugger.
- **IDAPro.exe 4.0** – Used to disassemble the Malware Specimen.
- **Snort 2.04 (Build 96)** – Used to monitor network traffic.
- **NetCat.exe 1.10** – Used to set listening ports and move files from Linux to Win XP machine.
- **Ircd-hybrid 2.8/hybrid-6.3.1** – IRC server.
- **Listdlls.exe** – Lists Dynamically Link Libraries and process that is using them.
- **TCPView.exe 2.34** – For viewing TCP/UDP ports being used and the process with ID.
- **VMWare 4.52 build 8848** – Used for the creation of the testing environment.
Properties of the Malware Specimen

The Malware msrll.exe, is an application file, as seen in Figure 3 the msrll.exe Properties.

From the Properties this researcher was able to determine the file size is 41KB (41,984 bytes). It was created on May 10, 2004 at 4:29:54 PM. It was downloaded from the GIAC website as msrll.zip. It was unzipped with WinZip using the password “malware” as stated in the GREM Practical Assignment documentation. The MD5 hash for msrll.exe is 84acfe96a98590813413122c12c11aaa, which was found using the md5sum.exe application. The Malware msrll.exe does not run in DOS mode, as seen in the strings found using BinText.exe. The Malware does, however, run on Windows 98, Windows NT, Windows 2000 and Windows XP Professional, as it
was launched in each within the lab setup VMWare instances. From OllyDbg CPU window we can see in the code that different Operating Systems are usable by the Malware to run. This information also helps the Malware determine the Registry Keys to write to the infected machines Registry to allow it to start up when the system reboots.

Figure 4: Operating System environments in which the Malware can execute.
Figure 5: Unpacking the msrll.exe with AspackDie 1.3d.
It is packed with Aspack.exe 2.12, which AspackDie 1.3d listed as it unpacked the Malware specimen. Simply drag the Malware sample over the AspackDie.exe application and release the mouse button and it will begin processing the Malware file if it is able to unpack the specimen.

The Malware contains the following significant embedded strings, found by using OllyDB.exe and IDAPro.exe to investigate the unpacked specimen:

```
.aspack
```

<table>
<thead>
<tr>
<th>Location</th>
<th>Command</th>
<th>Location</th>
<th>Command</th>
<th>Location</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>409345</td>
<td>&quot;?si&quot;,0 004093C1</td>
<td>00409436</td>
<td>&quot;?exec&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>409349</td>
<td>&quot;?ssl&quot;,0 004093C6</td>
<td>0040943C</td>
<td>&quot;?md5p&quot;,0 0040943C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0040934E</td>
<td>&quot;?clone&quot;,0 004093CC</td>
<td>00409440</td>
<td>&quot;?kill&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>409355</td>
<td>&quot;?clone&quot;,0 004093D2</td>
<td>00409446</td>
<td>&quot;?killall&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0040935D</td>
<td>&quot;?login&quot;,0 004093D7</td>
<td>0040944F</td>
<td>&quot;?crash&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>409364</td>
<td>&quot;?uptime&quot;,0 004093DF</td>
<td>00409546</td>
<td>&quot;?dcc&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0040936C</td>
<td>&quot;?status&quot;,0 004093EE</td>
<td>00409547</td>
<td>&quot;?get&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>409374</td>
<td>&quot;?jump&quot;,0 004093F4</td>
<td>0040954E</td>
<td>&quot;?set&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>409382</td>
<td>&quot;?nick&quot;,0 004093F9</td>
<td>00409556</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>409388</td>
<td>&quot;?echo&quot;,0 004093FE</td>
<td>00409563</td>
<td>&quot;?free&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00409390</td>
<td>&quot;?clone&quot;,0 0040940A</td>
<td>00409570</td>
<td>&quot;?kill&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00409394</td>
<td>&quot;?get&quot;,0 00409400</td>
<td>00409577</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004093A0</td>
<td>&quot;?dir&quot;,0 00409410</td>
<td>00409584</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004093A4</td>
<td>&quot;?dir&quot;,0 00409415</td>
<td>00409591</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004093A8</td>
<td>&quot;?dir&quot;,0 0040941B</td>
<td>00409598</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0040939A</td>
<td>&quot;?op&quot;,0 0040941F</td>
<td>00409605</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004093B0</td>
<td>&quot;?part&quot;,0 00409423</td>
<td>00409612</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004093B6</td>
<td>&quot;?part&quot;,0 00409428</td>
<td>00409619</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004093BC</td>
<td>&quot;?part&quot;,0 0040942A</td>
<td>00409626</td>
<td>&quot;?clone&quot;,0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

servers
collective7.zxy0.com,collective7.zxy0.com:9999!,collective7.zxy0.com:8080

irc.chan
#mils

mIRC v6.12 Khaled Mardam-Bey

m220 1.0 #2730 Mar 16 11:47:38 2004

jtr.bin
msrll.exe

jtr.id
m220

!This program cannot be run in DOS mode.
Behavioral Analysis

Environment for Analysis

Launch the VMWare Application and launch the WinXP Pro (Created for this analysis) and Linux Red Hat 9.0 (From the CD handed out at the SANS Session in Las Vegas) instances. Log into each accordingly.

Obtaining Malware Specimen

Log into the GIAC website\(^3\) using momgate and the given login information. From section 24.1.5 entitled "Malware Specimen for GREM Practical Assignment", download the Malware specimen. The Malware specimen is in a file named msrll.zip that is protected with the password “malware.” Once downloaded, use the “Drag and Drop” functionality available in VMWare to copy the Malware zip file to the WinXP Pro instance. For my Analysis the zip file was placed into \(E:\Sample\). Using the built-in WinZip\(^4\) menu feature, perform an extract of the file from the \(E:\Sample\) directory. WinZip will require the password “malware”. There should now be a file named msrll.exe in the \(E:\Sample\) directory.

Checking the Specimen

From the Start/Run prompt, type in \texttt{cmd} and hit “Enter”. Within this Command window type \texttt{e:}\>\texttt{md5sum msrll.exe}. The MD5 hash for msrll.exe is 84acfe96a9859081341312c12c11aaa. Launching BinText 3.0 on the newly uncompressed file reveals that the executable is packed with Aspack.

Readying for the First Run

Launch \texttt{RegShot.exe} and select the Shot 1 button to take a snapshot of the Registry before the Malware Specimen is launched. Launch Filemon.exe, TDImon.exe, and Regmon.exe and clear each after pausing the capture of the data. Once all three applications have been cleared, restart capturing for each. Double click on the Malware Specimen msrll.exe. After approximately four seconds it will disappear from the \(E:\Sample\) directory. Launch the Task Manager and note that the Malware msrll.exe now runs under its own name. Select the msrll.exe process from the Task Manager list and click on the “End Process” button and click the “Yes” button to stop the Malware from running. Stop capturing with Filemon.exe, TDImon.exe and Regmon.exe. Save these logs to separate files and name them accordingly for the respective application, the malware and the date (Ex: Filemon-msrll-20041204.log). In

\(^3\) http://giactc.giac.org/cgi-bin/momgate
\(^4\) http://www.winzip.com
RegShot.exe click on the “Shot 2” button to capture the state of the Registry after the Malware was launched and the process was ended. Click on the “Compare” button and then save the resulting Log file following the above naming convention.

**Analyze the Log files**

The Malware will move itself from its point of origin on the Windows computer to the %windows%\System32\mfm\ as a file named msrll.exe with a matching MD5 hash. Note the change in Process ID as the location and active msrll.exe changes.

From the Filemon.exe log file:

```
569  9:22:13 AM msrll.exe:1020 CLOSE E:\Sample\msrll.exe SUCCESS
570  9:22:13 AM msrll.exe:1020 CLOSE C:\WINDOWS\System32\mfm\msrll.exe SUCCESS
1042 9:22:14 AM msrll.exe:1168 DELETE E:\Sample\msrll.exe SUCCESS
1043 9:22:14 AM msrll.exe:1168 CLOSE E:\Sample\msrll.exe SUCCESS
```

In addition, the Malware also creates a file named jtram.conf, which appears to be encrypted.

From the Filemon.exe log file:

```
1615 9:22:30 AM msrll.exe:1168 WRITE C:\WINDOWS\system32\mfm\jtram.conf SUCCESS Offset: 0 Length: 53
```

The Regmon.exe log file shows the Malware querying many Dynamically Linked Libraries for information on the System settings. The TDImon.exe log file shows the Malware Specimen is listening on TCP port 2200 as shown below:

```
156 49.49251315  msrll.exe:1168  81697028 TDI_SET_EVENT_HANDLER TCP:0.0.0.0:2200 SUCCESS   Error Event: NULL
157 49.49256037  msrll.exe:1168  81697028 TDI_SET_EVENT_HANDLER TCP:0.0.0.0:2200 SUCCESS   Disconnect Event: NULL
158 49.49259277  msrll.exe:1168  81697028 TDI_SET_EVENT_HANDLER TCP:0.0.0.0:2200 SUCCESS   Receive Event: NULL
159 49.49263133  msrll.exe:1168  81697028 TDI_SET_EVENT_HANDLER TCP:0.0.0.0:2200 SUCCESS   Expedited Receive Event: NULL
```
Network Analysis with SNORT

Extract another msrll.exe from the msrll.zip file using the password “malware” without the quotation marks. The MD5sum creates the same MD5 hash as before. Login to the Red Hat Linux 9.0 – REM VMware Instance and launch the SNORT network sniffer software using the tee command to split the output to both STDOUT and a file. To do so, execute the following command:

```
#  snort -vd | tee /tmp/sniff-msrll.log
```

Nothing much is occurring at all

The original VMware session for the WinXP Pro instance is set to VMNet5. When the Red Hat Linux 9.0 – REM is set to this network as well communications between the two are lost. Moving both back to the Host Only Network requires shutting down both instances. The commands Start and Shutdown can be used for the WinXP Pro instance and shutdown -h now can be used on the Red Hat Linux instance. Settings also need to be adjusted to use the Host Only Network. (NOTE: I noticed at this point in the practical that the WinXp Pro instance was also missing USB Controller Hardware so I added it as well).

Continuing on

Start up both instances again and login to each with each respective user and password pair. Launch SNORT on the Linux instance using the following command:

```
#  snort -vd | tee /tmp/sniff-msrll2.log
```

Switch to the WinXP Pro instance, log in and launch the previously unzipped msrll.exe file by double clicking it. After a few seconds the file will disappear. Confirm the move of the file to the %windir%\System32\mfm directory and MD5sum to make sure it is still the same file.

SNORT log file information should

---

5 http://www.snort.org
be visible on the screen. The SNORT log shows a request for DNS information using UDP port 53 from the infected machine to the 192.168.147.x subnets gateway located at 192.168.147.1. The request will be for the IP address of collective7.zxy0.com. Use “Control-z” to pause the SNORT application. Next at the command prompt type in:

```bash
# ps -ux
```

This command will give the Process Identification number (PID) for the SNORT process that has just been stopped. Use the `kill` command:

```bash
# kill -9 (SNORT PID)
```

The following shows the DNS request on UDP port 53 in the SNORT log file:

```
12/06-15:05:38.058348 192.168.147.129:1027 -> 192.168.147.1:53
UDP TTL:128 TOS:0x0 ID:374 IpLen:20 DgmLen:66
Len: 38
00 39 01 00 00 01 00 00 00 00 00 00 0B 63 6F 6C
6C 65 63 74 69 76 65 37 04 7A 78 79 30 03 63 6F
lective7.zxy0.co
6D 00 00 01 00 01
```

Next, use the following command to determine the IP address of the Red Hat Linux 9.0 VMWare instance.

```
Ipconfig eth0
```

The IP address for the Red Hat Linux instance will display as 192.168.147.128. Switch to the WinXP Pro VMWare instance and launch The Task Manager and end the `msrll.exe` process. Edit the `hosts` file located in the `%windir%\System32\drivers\etc` directory. Add to the end of the hosts file the IP address of the Red Hat Linux instance and match this to the `collective7` name as follow:

```
192.168.147.128 collective7.zxy0.com collective7
```

Save this change. Next, unzip another `msrll.exe` to the E:\Sample directory. Double click the file to launch this application. After a few seconds it will disappear again. Switch to the Linux session and launch SNORT using:

```
# snort -vd | tee /tmp/sniff-msrll3.log
```

The same DNS request for `collective7.zxy0.com` will appear followed by attempts to connect to `collective7.zxy0.com` on TCP port 6667, a typical IRC port. The following SNORT log file excerpt shows the Malware looking for the IRC server:
12/06-15:07:51.457856 ARP who-has 192.168.147.128 tell 192.168.147.129

12/06-15:07:51.457973 ARP reply 192.168.147.128 is-at 0:C:29:A5:4E:4E

TCP TTL:128 TOS:0x0 ID:375 IpLen:20 DgmLen:48 DF
*****S* Seq: 0x3EF4C409 Ack: 0x0 Win: 0xFAF0 TcpLen: 28
TCP Options (4) => MSS: 1460 NOP NOP SackOK

Stop the SNORT application using the following commands:

Control-z
ps –ux
kill –9 (SNORT PID)
kill –9 (PID of the tee /tmp/sniff-msrll3.log)

Switch to the WinXP Pro VMWare instance and launch the The Task Manager and end the msrll.exe process. Extract another msrll.exe from the msrll.zip file using the password “malware” minus the quotation marks. The MD5sum creates the same MD5 hash as before. Switch to the Red Hat Linux instance and start the IRC server with the following steps:

# SU – ircd
$ ./ircd
$ exit
# ps –u ircd
PID TTY TIME CMD
1638 ? 00:00:00 ircd
# irc

This will connect you to the Internet Relay Chat server version 2.8 / hybrid – 6.3.1 which was created on Tue June 4, 2002 at 16:59:45. If the last line is not completed, you can use a Windows client like mIRC 6.12 to connect to the collective7.zxy0.com 6667 IRC server. In the Red Hat Linux instance start the SNORT sniffer application and begin logging to the STDOUT and to a log file using the following command.

# snort –vd | /tmp/sniff-msrll4.log

Extract another msrll.exe from the msrll.zip file using the password “malware” minus the quotation marks. The MD5sum will create the same MD5 hash as before.

IRC session

Connect to the IRC server either through the Red Hat Linux instance using the command:
# irc

or by launching a Windows32-based IRC client like mIRC 6.12. From the SNORT log file you will see that the Malware specimen connects to the IRC server on TCP port 6667.

The IRC server connection being established is displayed below:

```
12/06-15:07:51.469686 192.168.147.128:6667 ->  
192.168.147.129:1033
TCP TTL:64 TOS:0x0 ID:0 IpLen:20 DgmLen:48 DF
***A**S* Seq: 0xBC345638 Ack: 0x3EF4C40A Win: 0x16D0 TcpLen: 28
TCP Options (4) => MSS: 1460 NOP NOP SackOK
```

```
12/06-15:07:51.481980 192.168.147.129:1033 ->  
192.168.147.128:6667
TCP TTL:128 TOS:0x0 ID:376 IpLen:20 DgmLen:40 DF
***A**** Seq: 0x3EF4C40A Ack: 0xBC345639 Win: 0xFAF0 TcpLen: 20
```

The infected machine sets up an ident server that listens on TCP port 113. This will gather information on computers accessing the infected machine.

![Figure 6: IRC connection and request for identd information.](image)

The same identd information is displayed below as seen in the SNORT log file:

```
12/06-15:07:51:498045 192.168.147.128:32771 ->  
192.168.147.129:113
```
The Malware will next join the #mils IRC channel using a randomly generated user and nick.

Figure 7: Randomness of user and nick

The TCP ports 6667, 9999 and 8080 are cycled through when connecting to the IRC server. It will stop once it has found the IRC server on the hosting machine, collective7.zxy0.com.

**Attempted Interaction with the Malware Specimen**

On the listening TCP port 2200 attempts were made from the RH Linux machine to connect to the infected machine using telnet and ftp. This attempt resulted in a shell like prompt of “#:”. Several attempts to type commands did not result in any information returned to the sessions on the RH Linux machine.
Moving logs from the Linux Instance

At the Las Vegas SANS Conference in the Fall of 2004, Lenny Zeltzer taught a Reverse-Engineering Malware class\(^6\) that illustrated how NetCat can be used to create a unidirectional connection between the Red Hat Linux instance and the WinXP Pro instance. This type of connection can be utilized to move log files from the Red Hat Linux to the WinXP Pro Instances. To create this connection in the WinXP Pro instance perform the following command:

\[
C:\> nc –l –p 5555
\]

In the Linux instance perform the following command:

\[
\# \text{cat} \ /\text{tmp}/\text{sniff-msrll.log} \ | \ nc \ 192.168.147.129 \ 5555
\]

Do the same for the remaining `sniff-msrll(numbered).log` files

Dynamically Link Libraries

---

Figure 10: `listdlls.exe`, list of Dynamically Link Libraries used by msrl1.exe

The system’s Dynamically Link Libraries (DLLs), as seen in Figure 10, will be used by the Malware specimen to interact with the system and connect through the network to the IRC server. The Malware specimen `msrl1.exe` can be seen in this screenshot below from the program `listdlls.exe`.

The Malware will add registry entries to run itself as a service when the infected machine is started up. It will add values to the registry entries it creates. It changes the values in the `HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Cryptography\RNG\Seed`

In Windows 9x environments the Malware will create a Registry entry in:

`HKEY_LOCAL_MACHINE\Software\Microsoft\Windows\CurrentVersion\Run`

Using the value:
Rll enhanced drive = "%System%\mfm\msrll.exe"

In Windows NT, Windows 2000 and Windows XP the Malware will create an entry in:

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm
```

This will cause the Malware in either environment to restart when the machine it has infected is rebooted.

The `RegShot.exe` compare log from the Windows XP is shown below:

```
REGSHOT LOG 1.61e5
Comments:
Computer:VMWAREXP , VMWAREXP
Username:

----------------------------------
Keys added
----------------------------------
HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\mfm
HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\mfm\Security
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm\Security
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\CurrentVersion\Explorer\ComDlg32\OpenSaveMRU\LOG
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\CurrentVersion\Explorer\FileExts\LOG
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\CurrentVersion\Explorer\FileExts\OpenWithList
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\CurrentVersion\Explorer\RecentDocs\LOG
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\ShellNoRoam\BagMRU\4
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\ShellNoRoam\Bags\27
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\ShellNoRoam\Bags\27\Shell
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\NT\CurrentVersion\TaskManager
```

```
----------------------------------
Values deleted
----------------------------------
HKEY_USERS\S-1-5-21-1935655697-1715567821-725345543-500\Software\Microsoft\Windows\CurrentVersion\Explorer\RecentDocs\LOG
```

© SANS Institute 2005
Joseph Fresch - GREM Behavioral Analysis

Values added

----------------------------------
HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\mfm\Security: 01 00 14 80 90 00 00 00 9C 00 00 00 14 00 00 00 30 00 00 00 02 00 1C 00 01 00 00 00 02 80 14 00 FF 01 0F 00 01 01 00 00 00 00 00 05 20 00 00 00 20 02 00 00 00 00 00 01 00 00 00 00 05 12 00 00 00 01 01 00 00 00 00 00 05 12 00 00 00 00 00 1A 00 00 00
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm\Type: 0x00000120
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm\Start: 0x00000002
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm\ErrorControl: 0x00000002
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm\ImagePath: "C:\WINDOWS\System32\mfm\msrll.exe"
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm\DisplayName: "Rll enhanced drive"
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm\ObjectName: "LocalSystem"
Values modified

HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Cryptography\RNG\Seed: 05
A9 8E C4 4A 70 B9 28 E5 23 3F 0C E7 50 3D 36 58 CA 39 65 66 46
46 2E 9B B0 E1 B1 48 9F AA D7 21 06 1A 81 CB BB CA DA C9 9B 28
AC F2 43 6D 60 FF 9A E1 26 6A F4 4B 89 96 AA 4C 41 F6 A6 8C 33
6E 90 55 7A 2A E8 7B CE 9F 20 A3 6A 5B C1 D6 70
HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Cryptography\RNG\Seed: F0
CB 37 6E AB 38 EF 3B 26 9A C4 02 F0 DE A3 D3 5C A4 ED 20 B2 99
B9 F6 11 99 00 77 4D 08 74 4D FD 25 18 F2 C2 E9 68 BA 8D BB 5E
13 9D 36 02 4F E4 77 DD D0 E8 6B 3E 6E 5E 77 87 21 50 8D C8 C7
50 41 BA 72 C2 00 E2 5B 45 95 23 CA 5A 9D 31 7B

The information written to the HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\mfm is information needed to start the service. The information written to the HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet001\Services\mfm helps the Malware to still start as a service even after the owner of the infected machine attempts to use the F8 troubleshooting option and then selects boot with last known good.

The Cryptographic sections help with encrypting the jtram.conf data file and decrypting it. There are several encryption algorithms available in the Malware.

Figure 11: The Malware’s Built-in Ciphers.
The built in Ciphers from the output from BinText 3.0:

000110F0 004110F0 0 LibTomCrypt 0.83
00011102 00411102 0 Endianess: little (32-bit words)
00011123 00411123 0 Clean stack: disabled
00011139 00411139 0 Ciphers built-in:
0001114B 0041114B 0 Blowfish
00011157 00411157 0 RC2
0001115E 0041115E 0 RC5
00011165 00411165 0 RC6
0001116C 0041116C 0 Serpent
00011177 00411177 0 Safer+
00011181 00411181 0 Safer
0001118A 0041118A 0 Rijndael
00011196 00411196 0 XTEA
0001119E 0041119E 0 Twofish
000111A9 004111A9 0 CAST5
000111A2 004111A2 0 Noekeon
000111BF 004111BF 0 Hashes built-in:
000111D0 004111D0 0 SHA-512
000111DB 004111DB 0 SHA-384
000111E6 004111E6 0 SHA-256
000111F1 004111F1 0 TIGER
000111FA 004111FA 0 SHA1
00011202 00411202 0 MD5
00011209 00411209 0 MD4
00011210 00411210 0 MD2
00011218 00411218 0 Block Chaining Modes:
0001122E 0041122E 0 CFB
00011235 00411235 0 OFB
0001123C 0041123C 0 CTR
00011244 0041244 0 PRNG:

<table>
<thead>
<tr>
<th>File pos</th>
<th>Mem pos</th>
<th>ID</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------</td>
<td>-------</td>
<td>-------</td>
<td>--------------------</td>
</tr>
<tr>
<td>0001124A</td>
<td>0041124A</td>
<td>0</td>
<td>Yarrow</td>
</tr>
<tr>
<td>00011254</td>
<td>00411254</td>
<td>0</td>
<td>SPRNG</td>
</tr>
<tr>
<td>0001125D</td>
<td>0041125D</td>
<td>0</td>
<td>RC4</td>
</tr>
<tr>
<td>00011265</td>
<td>00411265</td>
<td>0</td>
<td>PK Algs:</td>
</tr>
<tr>
<td>0001126E</td>
<td>0041126E</td>
<td>0</td>
<td>RSA</td>
</tr>
<tr>
<td>00011275</td>
<td>00411275</td>
<td>0</td>
<td>DH</td>
</tr>
<tr>
<td>0001127B</td>
<td>0041127B</td>
<td>0</td>
<td>ECC</td>
</tr>
<tr>
<td>00011282</td>
<td>00411282</td>
<td>0</td>
<td>KR</td>
</tr>
<tr>
<td>00011289</td>
<td>00411289</td>
<td>0</td>
<td>Compiler:</td>
</tr>
<tr>
<td>00011293</td>
<td>00411293</td>
<td>0</td>
<td>WIN32 platform detected.</td>
</tr>
<tr>
<td>000112AF</td>
<td>004112AF</td>
<td>0</td>
<td>GCC compiler detected.</td>
</tr>
<tr>
<td>000112CA</td>
<td>004112CA</td>
<td>0</td>
<td>Various others: BASE64 MPI HMAC</td>
</tr>
<tr>
<td>00011313</td>
<td>0041313</td>
<td>0</td>
<td>/dev/random</td>
</tr>
<tr>
<td>00011430</td>
<td>00411430</td>
<td>0</td>
<td>Microsoft Base Cryptographic Provider v1.0</td>
</tr>
</tbody>
</table>
**Code Analysis**

**Checking for Strings and Unpacking**

Loading the Malware specimen into BinText 3.0 just after it is unzipped from the msrll.zip file will show several readable strings, including Aspack. A Google.com web search for “Aspack unpacking” resulted in Aaron’s Homepage located at http://www.exetools.com/unpackers.htm which included several unpackers. The first unpacker attempted is UPX to confirm that it is not packed with this packing tool. This was an attempt to follow the procedures from the SANS Lecture. The result will be a failure to unpack the msrll.exe file. The next attempted unpacker is Aspack unpacker v2.0. It will also fail to unpack the msrll.exe Malware specimen. Looking further down the page at Aaron’s Homepage you will find a listing for AspackDie 1.3d, which contains support for an unknown Aspack version. AspackDie 1.3d is a program created by Yoda the creator of LordPE Memory dumping software. An attempt to unpack the Malware specimen using AspackDie 1.3d will prove successful. AspackDie 1.3d will find the Malware file is packed with ASPack version 2.12. The unpacked version of the Malware specimen will be 1.12 MB (1,175,552 bytes) and have an MD5 hash of:

```markdown
E:\Sample>md5sum unpacked.exe
dc0c6b598c87f8a7d5c0bcb75ee5d6ea *unpacked.exe
```

Unpacking with AspackDie 1.3d can be completed by dragging the Malware specimen over the top of the AspackDie application and releasing the mouse button. The result is a small window generated by the AspackDie application that describes the results of the unpacking process, See Figure 5 above.

**Further searching after unpacking**

Within the unpacked Malware sample there will be a line containing mIRC v6.12 Khaled Mardam-Bey. A Google.com search for this string will supply a link to http://www.mirc.com/index.html which will have information about the IRC client and the creator of the software. The site will include a useful help file on mIRC 6.12 software that explains the usage of common IRC commands. This can lead one to believe that the Malware uses this sting to represent itself to other IRC channel users if they query the version of the Malware IRC user, like camouflage.

---

7 http://www.google.com
8 http://www.exetools.com/unpackers.htm
9 http://www.google.com
10 http://www.mirc.com/index.html
Figure 12: Whois, ping and version performed on the Malware client.

From the version command we can see that the mIRC v6.12 Khaled Mardam-Bey found earlier in the strings of the Malware is used as camouflage, hiding the fact that it is Malware.

Another interesting string is m220 1.0 #2730 Mar 16 11:47:38 2004, which looks similar to the name, version, build and build date of the Malware.

Figure 13: Mutex “m220” setting code from IDA Pro.

The Malware also will set a Mutex of “m220” to keep other instances of it from starting up. There are several commands in the strings of the msrll.exe file that look like they are able to control and infect a machine.

Below is a list of embedded strings that may be special or unique to the
Malware and code:

<table>
<thead>
<tr>
<th>Location</th>
<th>Command</th>
<th>Location</th>
<th>Command</th>
<th>Location</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>00409345</td>
<td>&quot;?si&quot;,0</td>
<td>00409364</td>
<td>&quot;?exec&quot;,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00409349</td>
<td>&quot;?ssl&quot;,0</td>
<td>00409366</td>
<td>&quot;?md5&quot;,0</td>
<td>0040943C</td>
<td>&quot;?ps&quot;,0</td>
</tr>
<tr>
<td>00409354</td>
<td>&quot;?cclone&quot;,0</td>
<td>00409440</td>
<td>&quot;?free&quot;,0</td>
<td>00409446</td>
<td>&quot;?kill&quot;,0</td>
</tr>
<tr>
<td>00409355</td>
<td>&quot;?clones&quot;,0</td>
<td>00409446</td>
<td>&quot;?raw&quot;,0</td>
<td>00409450</td>
<td>&quot;?killall&quot;,0</td>
</tr>
<tr>
<td>0040935D</td>
<td>&quot;?login&quot;,0</td>
<td>00409456</td>
<td>&quot;?update&quot;,0</td>
<td>00409464</td>
<td>&quot;?crash&quot;,0</td>
</tr>
<tr>
<td>00409364</td>
<td>&quot;?uptime&quot;,0</td>
<td>00409456</td>
<td>&quot;?hostname&quot;,0</td>
<td>00409456</td>
<td>&quot;?dcc&quot;,0</td>
</tr>
<tr>
<td>00409366</td>
<td>&quot;?reboot&quot;,0</td>
<td>4.09E+12</td>
<td>&quot;?ff&quot;,0</td>
<td>0040945B</td>
<td>&quot;?get&quot;,0</td>
</tr>
<tr>
<td>00409374</td>
<td>&quot;?status&quot;,0</td>
<td>00409460</td>
<td>&quot;?!f&quot;,0</td>
<td>00409460</td>
<td>&quot;?say&quot;,0</td>
</tr>
<tr>
<td>0040937C</td>
<td>&quot;?jump&quot;,0</td>
<td>00409465</td>
<td>&quot;?del&quot;,0</td>
<td>00409465</td>
<td>&quot;?msg&quot;,0</td>
</tr>
<tr>
<td>00409382</td>
<td>&quot;?nick&quot;,0</td>
<td>0040946A</td>
<td>&quot;?pwd&quot;,0</td>
<td>0040946A</td>
<td>&quot;?kb&quot;,0</td>
</tr>
<tr>
<td>00409388</td>
<td>&quot;?echo&quot;,0</td>
<td>0040946E</td>
<td>&quot;?play&quot;,0</td>
<td>0040946E</td>
<td>&quot;?sklist&quot;,0</td>
</tr>
<tr>
<td>0040938E</td>
<td>&quot;?thush&quot;,0</td>
<td>409404</td>
<td>&quot;?copy&quot;,0</td>
<td>409404</td>
<td>&quot;?unset&quot;,0</td>
</tr>
<tr>
<td>00409394</td>
<td>&quot;?wget&quot;,0</td>
<td>0040949A</td>
<td>&quot;?move&quot;,0</td>
<td>0040949A</td>
<td>&quot;?attr&quot;,0</td>
</tr>
<tr>
<td>0040939A</td>
<td>&quot;?join&quot;,0</td>
<td>409404</td>
<td>&quot;?dir&quot;,0</td>
<td>409404</td>
<td>&quot;?dcmsk&quot;,0</td>
</tr>
<tr>
<td>004093A0</td>
<td>&quot;?top&quot;,0</td>
<td>409415</td>
<td>&quot;?sums&quot;,0</td>
<td>409415</td>
<td>&quot;?con&quot;,0</td>
</tr>
<tr>
<td>004093A4</td>
<td>&quot;?aop&quot;,0</td>
<td>0040941B</td>
<td>&quot;?ls&quot;,0</td>
<td>0040941B</td>
<td>&quot;?killsk&quot;,0</td>
</tr>
<tr>
<td>004093A9</td>
<td>&quot;?akick&quot;,0</td>
<td>0040941F</td>
<td>&quot;?cd&quot;,0</td>
<td>0040941F</td>
<td>&quot;VERSION&quot;,0</td>
</tr>
<tr>
<td>004093B0</td>
<td>&quot;?part&quot;,0</td>
<td>409423</td>
<td>&quot;?rmdir&quot;,0</td>
<td>409423</td>
<td>&quot;PING&quot;,0</td>
</tr>
<tr>
<td>004093B6</td>
<td>&quot;?dump&quot;,0</td>
<td>0040942A</td>
<td>&quot;?mkdir&quot;,0</td>
<td>0040942A</td>
<td>&quot;IDENT&quot;,0</td>
</tr>
<tr>
<td>004093BC</td>
<td>&quot;?set&quot;,0</td>
<td>409431</td>
<td>&quot;?run&quot;,0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ports will also show up in the unpacked Malware specimen. These will be backup ports to connect to an IRC server. If the IRC server is down on port 6667 then the Malware will cycle through the alternate TCP ports, 9999 and 8080. Setting NetCat up on the Red Hat Linux instance to listen on these ports will reveal whether or not this is the information sent to the ports. Listening using NetCat can be done using the following command statement:

```
For port 8080: nc -l -p 8080
For port 9999: nc -l -p 9999
```

![NetCat.exe commands with results.](image)

Figure 14: **NetCat.exe commands with results.**

More embedded strings from the Malware are below:

```
servers
  collective7.zxy0.com,collective7.zxy0.com:9999!,collective7.zxy0.com:8080
```

The Malware will connect to the IRC channel #mils which will also be seen in
the **SNORT** log files.

The **SNORT** log file will look as follows:

```
12/06-15:08:19.580789 192.168.147.128:6667 ->
192.168.147.129:1033
TCP TTL:64 TOS:0x0 ID:36437 IpLen:20 DgmLen:113 DF
***AP*** Seq: 0xBC345C71  Ack: 0x3EF4C45F  Win: 0x16D0  TcpLen: 20
3A 6C 6F 63 61 6C 68 6F 73 74 2E 6C 6F 63 61 6C
:localhost.local
64 6F 6D 61 69 6E 30 32 20 41 55 78 73 45 6E 51 53 4D 20 3A 41 55 78 73 45 6E 51 53 4D 3D
AUxsEnQSM=
2B 72 47 73 73 40 31 39 32 2E 31 36 38 2E 31
+GssN@192.168.1
34 37 2E 31 32 39 20 0D 0A
```

Malware will join the #mils IRC Channel and perform the **/who #mils** command:

```
12/06-15:08:23.568340 192.168.147.129:1033 ->
192.168.147.128:6667
TCP TTL:128 TOS:0x0 ID:388 IpLen:20 DgmLen:53 DF
***AP*** Seq: 0x3EF4C45F  Ack: 0xBC345CBA  Win: 0xFAA7  TcpLen: 20
4A 4F 49 4E 20 23 6D 69 6C 73 20 3A 0A
```

Also evidenced in the output from **BinText 3.0** as seen below:

```
irc.chan
#mils
```

When the Malware is renamed and launched on a Windows machine it will name itself back to the original **msrll.exe** as it is moved into the %windir%\System32\mfm directory.

```
jtr.bin
msrll.exe
```

The Malware application **msrll.exe** will not run in DOS mode but will run on the Windows 32 platforms.

```
!This program cannot be run in DOS mode.
```

The Malware specimen will create several Registry entries as well as querying the Registry for System Setting information. This can be seen in the screen shot below from IDA Pro.
The Connection to the IRC server through port 6667 will allow the controller of the Malware to get information to and from the infected system. The listening on TCP port 2200 created by the Malware allows the controller of the Malware to connect to the infected machine. The Malware continues to listen on TCP port 1033 for information from the IRC session on channel #mils. This can be seen in the screenshot from TCPview.exe in Figure 16.

Researching the content of the jtram.conf file

After far too many F7 key presses, within OllyDBg, to count had elapsed, many starting from a copy of the unpacked.exe file and and dragging it to the OllyDBg application. This however does not work well, in the process of launching the unpacked.exe malware it copies itself to the directory structure it creates C:\Windows\System32\mfm (jtr.home) as msrll.exe then it deletes

11 http://www.sysinternals.com
itself and removes itself from memory as the newly created msrll.exe starts up. It will build Registry entries to cause itself to launch when the infected machine is rebooted, either as an application to launch or as a service depending on the Windows Operating System of the machine the Malware is infecting. For Windows NT and above it even sets Registry entries that go back to the last known good, using the ControlSet001 under services. With the original unpacked.exe deleted OllyDBG is no longer able to track the process.

With this learned, using the msrll.exe that is located in the jtr.home directory structure is a better method for researching the contents of the jtram.conf file.

First run of msrll.exe gives the following jtram.conf file:

e/8RAOYI3FLMh+yKj9pMUCVRkuDs5h5wngcxcaiQdHjcp6a4P==
mAMRAEVLdp9B2xz9sdoiFhavguo9hmxSWoBgy8Y0Xxt2AGN1YQ==
ZAARAPPHUHYCgCAPVh2sCytd3Yzrj5SesiHkGyG1CdM/6/2k9A==
5/4RALdGqE+vgyRE01shs1+ChPdoaB4HouWBl1YLJwQlJTwA==
fwaRAALLMuphCrKyzrbbw9vxucWEIP34RMd9q19pq6189syaiqg==
CP8RAEKZS7CNY7DVGnca1RbZfVkUjhp+nbSIVIMA4IHRKQ==
fhgERAK2dOm0LFPRK6eqMUS/EsSUTHHyG77Vulvm+RciokXPA==
7QQRADsf/WWjQkQPO30jNPZrbEzDE13Jb7jWya6sZf08eNrrg==
4P1KAktctx/nAPsmZVLk2LzVgucUR0HXbuog4DbAaupBzbNTLDjieg62f0++yF0
4MxGRPfE2onGLAbKBUB4e+kj68RoC5FR9ysw9sEs5E4ccoBVbOupGxQ167Q==
bwIRALvnK3B4n/qxQww/dYMnLO'IH1xqbrjg8WNNWq9KjqlBPFA==
gf0RAAS0xOjfjWvTHn1jClcggcys5U3GyjJLFhpKrwiRxw==
If4RAOJRzZMqZvTM1E6nK4y1yDF+QhGqmmV+HyLb9J8vSp0GCg==
XwARAhJhrzuNYZARAJOpUiuVze8hcnlUph5J8BxVQOFov8r/s==
h/4RAAeFbkoFXg91Sm082cvkQ8sVDVThOizqe/ENeXShyJDa==
7A1jAPs035efvXxMrzWzbVzTMa+hvALGKEKz49/09RSFpy+B RJ2vbsxV8djtL
LjRQVwhDkq==
6gARApksNK24L6CMvWs09Hmb5ss5t6FXHsqCThzdtAxw29nw==
nAERAFwd6x74LqSbvp4efDh153cDzIPunb60nJeh0xV2mog==
OQErjA4nvoYrhk6SPwr8vU9YF8O+d86mMHTNCzWpvXGQR9U9C8VgIBaNMQ+Z+0
PvhEsnn/RA==

Second run of msrll.exe gives the following jtram.conf file:

+voRAJj2f67PEhA0AvSLRjt/Tx0MqUP3UnkOGvPKR/UlntC7AmSw==
mgARAC4uGR1ke7676IYiQZBRCV/LrokwRbU00q2c0wRJ/jQGQ==
hv8RAFUY4QqcsSp01hpnmn1M0Cus3p3TXau+1/lj3PLYNAxhDA==
awERAPVEqxsMIIzeSOKa0942ycetPNjBi7gJHyekNIH2kcbVfhg==
6v4RAJ7cMAvckJCSxYlWe8s88/cnxv7UhjqHHELkgkJ940P1zg==
awARRA6XCSq+nrRvwvCUC5LY57Rlz47SujopwTSsttzMYkioqRg==
8v0RAKe08dvaGOT1wgc0yrcOKHqsp0x0KWONFeT33+2dLO4eW
Jf0RA060l+n0/+lLb/R4KoCaem5XocolUJCOO0kPIbjzy1Npw==
Lv5KAMshsBBJF2bcpwHTAhT/mPdOorW2cMvIlf10p9/rRQo2zHSLV/IkW1kI1LPTp
Mw+4R5761noBl2GwGfEHHe5MGXzSLkesD1M1lP+6+K7XCFJcp87146n7ylurg==
kv8RAA7EY/3mmTodSyianpLVLynNvqAUs4WtaZi6xal+Eev3aAA==
4QARAPMmOrYPlwvVCLDJe2fiHGab8dYVvJ3gbsfSyKpjhG7MQ==
df4RALr9I905s1ESRMoSOCPOIgbaJtqoStexBL7mQ/IqNdvsFQ==
LAARRAJxehWlCcxBH93Dv5a5p0x8nvG+crza/yOC1ZIkwnZVA==
bgiRAFk+RFOQ6uIs9RV1TzNp/0/Q1hjll/XYoc3qJv4CbdQ==
Checking to see what the Malware did if the `jtram.conf` file was deleted and it had to build another copy of the data file was the starting point. This file was removed from the `C:\Windows\System32\mfm` directory. To begin debugging with OllyDbg, the current running Malware process was ended using Task Manager. Highlight the `msrll.exe` process and hit the End Process button and then the yes button when asked if ending the process is really what is wanted. Once the current process is ended debugging with OllyDbg can begin by simply dragging and dropping the Malware from the `jtram.home` directory, `C:\Windows\System32\mfm` onto the OllyDbg application and release the mouse button. OllyDbg will launch and the focus will be the `msrll.exe` Malware specimen.

Looking at memory marker `00409DE4` in the `msrll.exe` module near a piece of coded data “DiCHFc2ioiVmb3cb4zZ7zWZH1oM=” a section with `Arg1` and `Arg2` shows promise. Setting a breakpoint at this memory marker and running the Malware back to the breakpoint was very helpful and informative.
Figure 18: Section of code where the jtram.conf information is encoded.

Setting a breakpoint on the 00409DE4 memory address and hitting the F9 key allowing the running of the Malware and stopping at this set breakpoint results in the following information being revealed.

```
00409DE3 | . 56    | push esi
00409DE4 | . FF33  | push dword ptr ds:[ebx]
       |  | Arg1 = 003D5898 ASCII "set"

00409DE3 | . 56    | push esi
00409DE4 | . FF33  | push dword ptr ds:[ebx]
       |  | Arg1 = 003D5880 ASCII "bot.port"

00409DE3 | . 56    | push esi
00409DE4 | . FF33  | push dword ptr ds:[ebx]
       |  | Arg1 = 003D58A0 ASCII "2200"

00409DE3 | . 56    | push esi
00409DE4 | . FF33  | push dword ptr ds:[ebx]
       |  | Arg1 = 003D5910 ASCII "set"
```

© SANS Institute 2005

Author retains full rights.
Joseph Fresch - GREM

Code Analysis

; /Arg2 = 0022EE80 ASCII "5/4RAIDqE+vgYRE0k1nHs1+ChPdAoB4H0tWB1XYLhJwxQ1JT"aw== "
00409DE4  |. FF33  | push dword ptr ds:[ebx]
; /Arg1 = 003D5930 ASCII "irc.quit"

00409DE3  |. 56  | push esi
; /Arg2 = 0022EE80 ASCII "fwARALMuphCrKzYrrbw9vxucWEIP34RMD9q19pq61894yaiqq== "
00409DE4  |. FF33  | push dword ptr ds:[ebx]
; /Arg1 = 003D5958

00409DE3  |. 56  | push esi
; /Arg2 = 0022EE80 ASCII "CP8RAEKS7CN7YDWXGpoallRbZfVkJhj+nbSIV1MA4IHRKQ== "
00409DE4  |. FF33  | push dword ptr ds:[ebx]
; /Arg1 = 003D59C8 ASCII "set"

00409DE3  |. 56  | push esi
; /Arg2 = 0022EE80 ASCII "hqERAkDZvm0LFP6kgqMUS/EsSUthigZYg77Vulvm+RcIokXPA== "
00409DE4  |. FF33  | push dword ptr ds:[ebx]
; /Arg1 = 003D59E8 ASCII "servers"

00409DE3  |. 56  | push esi
; /Arg2 = 0022EE80 ASCII "7QQRAdfsf/WwjQKQPO3ojNPZrbEzDE13jby6a6sZf08eNmIrrg== "
00409DE4  |. FF33  | push dword ptr ds:[ebx]
; /Arg1 = 003D5A08 ASCII "set"

00409DE3  |. 56  | push esi
; /Arg2 = 0022EE80 ASCII "bwIRA1vnK3B4N/gxQwx/dYmlEORH1hxqbrjgW8NNWqK9jq1BP== "
00409DE4  |. FF33  | push dword ptr ds:[ebx]
; /Arg1 = 003D5A08 ASCII "#mils"

00409DE3  |. 56  | push esi
; /Arg2 = 0022EE80 ASCII "gf0RAASOxOfjVWTiiNHn1DcsgLcscY55L5u3GYjJLFhpKRwiRxLw== "
00409DE4  |. FF33  | push dword ptr ds:[ebx]
; /Arg1 = 003D5B08 ASCII "#mils"

00409DE3  |. 56  | push esi
; /Arg2 = 0022EE80 ASCII "If4RAOJRzZMrZTvTM1E6nK41yDF+QhGqmmV+HyLb9J8VSp0qGCg== "

© SANS Institute 2005

Author retains full rights.
Key fingerprint = AF19 FA27 2F94 998D FDB5 DE3D F8B5 06E4 A169 4E46

Joe Fresh - GREM Code Analysis

Take2:

Take2:
Joseph Fresch - GREM Code Analysis

; /Arg2 = 0022EE80 ASCII
"mgARAC4uGR1kve761YiRQZBRCV/LrokwRrBU00q2c0wRJ/jOGQ== "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D59D0 ASCII "2200"

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"hv8RAFU4QqccSp0ihmnlMOCus3pzTXau+l/jj3PLYNAXhdA== "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D5B48 ASCII "set"

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"awERAPVEwxMIxeS0Ka5o942ycestPNjBi7gJHeykNIH2kcbVhfg== "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D5B98 ASCII "irc.quit"

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"6v4RAJ7oMAvcKJcSxxYWe8s88/cnXv7UjhgHHLEKkgKj940PzIg== "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D5BE8

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"awARAA6XCSg+mRVwvVcULH57RLzD47SujopwTSsttzMYkiogRg== "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D5D60 ASCII "set"

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"8v0RAKe08dva0t1wgoc0yrqOKHjqsP0x0KWONFeT33+2dLO4Ew== "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D5DB0 ASCII "servers"

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"Jf0RAo6O1+nO/+IlBz/R4KoCemm5Xc0luCJ00OkPbjobzylNpw== "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D5E00 ASCII
"collective7.zxy0.com,collective7.zxy0.com:9999!,collective7.zxy0.com:8080"

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"Lv5KAMshsBBJBFP2bcpwHTAht/mPd0orW2oMVf10p9/rq02hSVL/IkW1kiZ1LPTpWw+4R5761noB12GwgfDVHe5MGxSLkesD1MIlp+6+k7X5fCJp87146n7tylurg= "
00409DE4  |. FF33  ||push dword ptr ds:[ebx]
; |Arg1 = 003D5FC8 ASCII "set"

00409DE3  |. 56  ||push esi
; /Arg2 = 0022EE80 ASCII
"kv8RAA7EY/3mmrLOdSyianpblYFNvQAUs4WtaZi6xal+Eev3aA== "

© SANS Institute 2005
Author retains full rights.
Pulling the important information together from this harvested from the running Malware during take2:

Take2:
"set"
"+v0RAJ2f67PEhA0AvSLrjT/x0MqUP3UnkOGvPKR/U1ntC7AmSw== "

00409DE4 |. FF33 | |push dword ptr ds:[ebx] ; |Arg1 = 003D6018 ASCII "irc.chan"
00409DE3 |. 56 | |push esi ; |Arg2 = 0022EE80 ASCII
"4QARAPMmOrYPLwvVCDJbe2fiHGAB8DyVvJ3qbSFzSYKpjhGM7Q== "
00409DE4 |. FF33 | |push dword ptr ds:[ebx] ; |Arg1 = 003D6068 ASCII "#mils"
00409DE3 |. 56 | |push esi ; |Arg2 = 0022EE80 ASCII
"df4RAL1rI905slESRmSOCPoIgbaJotgostexBL7mQ/IqNdvsfQ== "
00409DE4 |. FF33 | |push dword ptr ds:[ebx] ; |Arg1 = 003D61E0 ASCII "set"
00409DE3 |. 56 | |push esi ; |Arg2 = 0022EE80 ASCII
"LAAARAJXhEhWlCcxBH93Dva55p0xg8nvG+crZa/yOClZIkwZvA== "
00409DE4 |. FF33 | |push dword ptr ds:[ebx] ; |Arg1 = 003D6280 ASCII "$1$KZLPLKdf$W8kl8jr1X8DOH2smIp9qq0"
00409DE3 |. 56 | |push esi ; |Arg2 = 0022EE80 ASCII
"hxAjAOJBFn529ZlUoAccONjmxYDN2XWrVWhQmR1qq0RqnnfxZBo7jA7MwS59cZG X+rmyNMwoDw== "
00409DE4 |. FF33 | |push dword ptr ds:[ebx] ; |Arg1 = 003D6410 ASCII "set"
00409DE3 |. 56 | |push esi ; |Arg2 = 0022EE80 ASCII
"av8RAMWT6ATyq98htz51rnH7Iks7Bxy3iIFQ7KZwXzh/Jmfg== "
00409DE4 |. FF33 | |push dword ptr ds:[ebx] ; |Arg1 = 003D6460 ASCII "dcc.pass"
00409DE3 |. 56 | |push esi ; |Arg2 = 0022EE80 ASCII
"CQERAKvO1qtavym1PNJMKBF09iIA1oxGcUZw7eyJOGDosn3T+Q== "
00409DE4 |. FF33 | |push dword ptr ds:[ebx] ; |Arg1 = 003D64B0 ASCII "$1$KZLPLKdf$55isA11TvamR7bjAdBzix."
"bot.port"
"mgARAC4uGR1kve76IYiRQZBRCV/Lr0kwRrBU00q2c0wRJ/jOGQ=="

"2200"
"hv8RAFUY4QqccSpOlhpmn1eM0Cus3pzTXau+1/lj3PLYNAxhDA=="

"set"
"awERAPVEqxMIxeSOKa5o942ycetPNjBi7gJHyekNIH2kcbVhfg=="

"irc.quit"
"6v4RAJ7oMAvcKJcSkkxEWe8s88/cnXv7UhrjgHHELkgKj940PzIg=="

003D5BE8
"awARAA6XCSq+mRVwvVcULH57RLzD47SujopwTSsttzMYkioRGg=="

"set"
"8v0RAKe08dvaGOrlwgc0yrqOKHjqsP0x0KWONFeT33+2dLO4Ew=="

"servers"
"Jf0RA0601+n0/+ILbZ/R4KoCaemm5XculoCJ000kPlbjzy1NpW=="

"collective7.zxy0.com,collective7.zxy0.com:9999!,collective7.zxy0.com:8080"
"Lv5KAMshsBBJBF2bcpwHTAht/mPdOorW2oMVf10p9/rQo2hSVL/Ikw1kiz1LPTpMw+4R5761noB12GwgfDVHe5MGzxSLkesD1Mi1p+6+K7XcfCJp87146n7tylurgr=="

"set"
"kv8RAA7EY/3mmRL0dSyianpbLYFNvQAus4WtaZi6xal+Eev3aA=="

"irc.chan"
"4QARAPMmOrYPLwvVCDJbe2fiHGab8DyVv3qBSFzSYKpjhGM7Q=="

"#mils"
"df4RAL1rI9O5s1ESRmS0CPoIgbaJotqoStexBL7mQ/IqNdvsfQ=="

"set"
"LAARAJXhEhWlCcxBH93Dva55p0xg8nvG+crZa/y0C1ZIKwn2VA=="

"pass"
"bgIRAFk+rFOQ6uIs9RV1TznP0/Q1Hjll1/XYocC3qJv4CcbdQ=="

"$1$KZLPLKDF$W8kl8Jr1X8DOHZsmIp9qq0"
"hwAjaOJBFn529ZIUoAccONjqxYDN2XwrVwhQmR1qq0RQnnfxZBo7jA7Mw59cZGXR+rmyNMwoDw=="

"set"
"av8RAMWT6ATYqw98Htz51rnH7k8S7Bxy3i1FQ7KzwXzh/Jmfg=="

"dcc.pass"
"CQERAKv0Iqtavym1PNJMBF09iIAloxCUz7eyJOGDoSn3T+Q=="
"$1$KZLPLKdf$55isAlITvamR7bjAdBziX."
"YP4jAFMI9kJCjRb6Cz5WBktuIZrkPQLlQ/B87YWxL5QXQUTxnwLmO5/yF8t0mxKcv8BW7wHznGw== "

When the jtram.conf file is not deleted it still rewrites the file. Each time the Malware launches it rewrites the jtram.conf file. There are several built-in ciphers that might aid in this process. Though the resulting content of the file is different each time the data encoded is the same. The Registry entry that had the SEED written to it is used to generate the encryption of the jtram.conf file’s data. This would make it near impossible to just decode the jtram.conf file with some scripted algorithm. This SEED Registry entry, \texttt{HKEY\_LOCAL\_MACHINE\ SOFTWARE\Microsoft\Cryptography\RNG\Seed}, is modified with the current SEED for each launching of the Malware specimen.

From this exercise we now have much needed information to help control and interact with the Malware specimen.

"pass" = "$1$KZLPLKdf$W8k18Jr1X8DOHZsmIp9qq0"
"dcc.pass" = "$1$KZLPLKdf$55isAlITvamR7bjAdBziX."

Next we can attempt taking over the clients and controlling them through the IRC session on the IRC channel #mils. From information about controlling viruses with IRC found at \url{http://swatit.org/bots/12} and at the Las Vegas SANS Conference in the Fall of 2004, Lenny Zeltzer taught a Reverse-Engineering Malware class\textsuperscript{13} that illustrated how to control a Malware specimen with IRC. Within the IRC session Commands that were found embedded in the Malware as strings should be able to run and reveal more information about the Malware and its functionality. This process started with trying the \texttt{PASS} command. \texttt{PASS} alone or with the password found in the jtram.conf file with variations of leading characters like “!@”, “!?”, “?”, “$!$”,”!@?” nor “!” did not return results like those from the SANS Conference, while controlling the Tnnbtib.exe Trojan file. In the lecture Lenny Zeltzer was able to use the !@login command to connect to the Malware being investigated.

If the use of “!pass $1$KZLPLKdf$W8k18Jr1X8DOHZsmIp9qq0” had worked and control of the bots logged into the IRC session was obtained, the next steps would be to interact with the Malware and then remove the threat on the infected machines. Using embedded commands like ?rmdir to remove the C:\%windows%\System32\mfm directory and then running ?die or ?kill to stop the msrll.exe process.

\textsuperscript{12} \url{http://swatit.org/bots/}
\textsuperscript{13} SANS Reverse-Engineering Malware: Controlling the Trojan, 2004 Pg 54-56.
Analysis Wrap-Up

Capabilities and What It Does

The Malware msrll.exe operates as a backdoor on the computer it is infecting. It is able to report statistics to the Malware controller via its connection to collective7.zxy0.com. It sets up a listening TCP port on 2200 to accept connection from the Malware controller. It is able to create directories, move files, copy files, compute MD5 sums, crash systems, reboot the infected machine, and accept login information from the controller. When launched initially it moves itself to a directory it creates at %windir%\system32\mfm. Malware msrll.exe runs under its file name in the The Task Manager and does not attempt to hide its presence. The Malware used mIRC version 6.12 created by Khaled Mardam-Bey as camouflage, to hide that it was Malware, when a request for version information is sent to it. The Malware msrll.exe referred to as “m220” in the Malware code includes its own version information: m220 1.0 #2730 Mar 16 11:47:38 2004. The Malware creates a mutex called m220 to keep other instances from starting. This m220 also might also relate to the TCP port 2200 that the Malware uses to listen for connections from its creator. It requests information on collective7.zxy0.com and once it locates the IP address it connects to a running IRC server with a default TCP port of 6667. The code also listed TCP ports 8080 and 9999, if the default IRC port is not found it will cycle through the other two TCP ports, looking for an IRC server on one of these ports on the server set in the code “collective7.zxy0.com”. The Malware uses random usernames, nicks and joins the IRC channel #mils. Registry entries are created and populated with values that allow the Malware msrll.exe to run on reboot for Windows 98, Windows NT, Windows 2000 and Windows XP Professional machines that are able to do this functionality. Machines that are able to run services get msrll.exe setup to start as a service and display "RII enhanced drive". Other Operating Systems were not available for installing into the VMWare environment as test machines.

Who would use the program?

The user of this malicious program would be someone with several possible goals. They might be using this program for bragging rights either having the biggest BOT army or to have completed the challenge of creating and controlling such an enterprise. They may also want to use hard disk space on machines that are not theirs for purposes like file sharing.

Defensive measures and elimination of current infections

Defending against this and similar Malware can begin with simply adding a firewall to the environment to introduce a barrier to intrusion. The firewall would be used to control traffic in and out of the protected internal environment.

---

14 http://www.mirc.com/index.html
Blocking TCP and UDP traffic at a firewall would eliminate the beginning steps such Malware use to identify themselves and set up connections with their creators, namely the IRC servers and the created listening port on the infected machines. On a PIX firewall these rules can be added to stop internal traffic from infected machines from contacting the IRC session on the collective7.zxy0.com server.

```
access-list inside deny tcp any any eq 6667
access-list inside deny tcp any any eq 8080
access-list inside deny tcp any any eq 9999
```

Access from outside on the internet to the 2200 port would be in a state of deny by default. Additionally there would have to be a NAT set to allow those attempts and a rule to allow these connections from outside to inside.

Add adware and spyware removal software to the desktop and laptop machines that reside both inside and outside the firewall. Include antivirus software in this strategy. Most importantly, keep the environment updated with current patches and up-to-date signature files (virus.dat files). Establish regularly scheduled machine scans with these defenses. Keep Operating System software patched against the latest known exploits. Research on the web to ensure that vulnerabilities are known and defenses can be put in place if possible before malicious code is written to take advantage of it. Most viruses are designed to exploit sometimes known and sometimes unknown vulnerabilities in software that may be running on machines in the company’s enterprise environment. Finally, be sure to include web browser software in any update and patching strategy.

**Current Removal**

To remove the current infection do debugging with the AspackDie 1.3d unpacked sample and determine the login password to access the Malware on the TCP port 2200 that is set to listening or send a command through IRC to killall. Use the IRC command `/who #mils` to get a listing of the machine IP addresses that are infected and use an application like DameWare\(^{15}\) to login remotely and edit the Registry and remove the files through the hidden share C\$, that are placed there by the Malware.

Sending a sample of the virus to the antivirus vendor so that a signature file can be made to detect and cure the infection. Once a signature is created it can be distributed through the company’s Antivirus software already existing signature distribution method.

Building a script that is accessed by the login script could help with removal. It would need to remove the `%windir%\system32\mfm` directory and the files within it as well as the registry entries created by msrll.exe noted with Regshot.exe. Since the Malware `msrll.exe` does not have a built in network distribution system it would not be necessary to add a dummy file with the same

\(^{15}\) [http://www.dameware.com/](http://www.dameware.com/)
name as the Malware but as an empty read-only file.

**Deduced Information**

The m220 command set that was found in the miRC v6.12 code could be used to perform Social Engineering. Commands like "?echo" could be used to talk on the IRC and get real users to accept DCC connections and thus do file transfer to move the Malware to a new machine. If the use of "!pass $1$KZLPLKDf$W8kl8Jr1X8DOHZsm1p9qq0" had worked and control of the bots logged into the IRC session was obtained, the next steps would be to interact with the Malware and then remove the threat on the infected machines. Using embedded commands like \rmdir to remove the C:\%windows%\System32\mfm directory and then running \die or \kill to stop the msrll.exe process.
References

GIAC login, 14 Dec 2004
http://giactc.giac.org/cgi-bin/momgate

WinZip, 14 Dec 2004
www.winzip.com

Sysinternals Analysis tools, 14 Dec 2004
www.sysinternals.com

SNORT, 14 Dec 2004
www.snort.org

Google, 14 Dec 2004
www.google.com

Hybrid 7 IRC, 14 Dec 2004
http://irc.carnet.hr/docs/hybrid7docs


SANS Reverse-Engineering Malware: Controlling the Trojan, 2004 Pg 54-56.

Aaron’s Homepage, 14 Dec 2004
www.exetools.com/unpackers.htm

mIRC version 6.12, 14 Dec 2004
www.mirc.com/index.html

A parked domain name listed in the Malware msrll.exe strings, 14 Dec 2004
http://collective7.zxy0.com

DameWare Development
http://www.dameware.com/

All About Bots. Trojans And Worms! – section 4.d.
http://swatit.org/bots/
# Upcoming SANS Forensics Training

<table>
<thead>
<tr>
<th>Event Name</th>
<th>Location</th>
<th>Date Range</th>
<th>Venue Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFIR Summit &amp; Training 2020</td>
<td>Virtual - US Eastern,</td>
<td>Jul 16, 2020 - Jul 25, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Summer of Cyber</td>
<td>Jul 27</td>
<td>NC</td>
<td>Jul 27, 2020 - Aug 01, 2020</td>
</tr>
<tr>
<td>SANS Special Investigations 2020</td>
<td>United Arab Emirates</td>
<td>Aug 03, 2020 - Aug 08, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>South by Southeast Asia Online 2020</td>
<td>Singapore</td>
<td>Aug 03, 2020 - Aug 14, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>Instructor-Led Training</td>
<td>Aug 3 MT</td>
<td>CA</td>
<td>Aug 03, 2020 - Aug 08, 2020</td>
</tr>
<tr>
<td>SANS Reboot - NOVA 2020 - Live Online</td>
<td>Arlington, VA</td>
<td>Aug 10, 2020 - Aug 15, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>FOR498 Australia Live Online 2020</td>
<td>Australia</td>
<td>Aug 10, 2020 - Aug 15, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS FOR508 Canberra August 2020</td>
<td>Canberra, Australia</td>
<td>Aug 17, 2020 - Aug 22, 2020</td>
<td>Live Event</td>
</tr>
<tr>
<td>SANS Summer Forensics Europe 2020</td>
<td>United Arab Emirates</td>
<td>Aug 17, 2020 - Aug 28, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>Instructor-Led Training</td>
<td>Aug 17 ET</td>
<td>DC</td>
<td>Aug 17, 2020 - Aug 22, 2020</td>
</tr>
<tr>
<td>Cyber Defence APAC Live Online 2020</td>
<td>Singapore</td>
<td>Aug 17, 2020 - Aug 22, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Amsterdam August 2020 Part 2</td>
<td>Amsterdam, Netherlands</td>
<td>Aug 17, 2020 - Aug 22, 2020</td>
<td>Live Event</td>
</tr>
<tr>
<td>Instructor-Led Training</td>
<td>Aug 24 MT</td>
<td>CA</td>
<td>Aug 24, 2020 - Aug 29, 2020</td>
</tr>
<tr>
<td>SANS Virginia Beach 2020 - Live Online</td>
<td>Virginia Beach, VA</td>
<td>Aug 30, 2020 - Sep 04, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Virginia Beach 2020</td>
<td>Virginia Beach, VA</td>
<td>Aug 30, 2020 - Sep 04, 2020</td>
<td>Live Event</td>
</tr>
<tr>
<td>SANS Japan Bi-Lingual Live Online</td>
<td>Japan</td>
<td>Aug 31, 2020 - Sep 05, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Philippines 2020</td>
<td>Manila, Philippines</td>
<td>Sep 07, 2020 - Sep 19, 2020</td>
<td>Live Event</td>
</tr>
<tr>
<td>SANS London September 2020</td>
<td>London, United Kingdom</td>
<td>Sep 07, 2020 - Sep 12, 2020</td>
<td>Live Event</td>
</tr>
<tr>
<td>SANS London September 2020 - Live Online</td>
<td>London, United Kingdom</td>
<td>Sep 07, 2020 - Sep 12, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Baltimore Fall 2020</td>
<td>Baltimore, MD</td>
<td>Sep 08, 2020 - Sep 13, 2020</td>
<td>Live Event</td>
</tr>
<tr>
<td>SANS Baltimore Fall 2020 - Live Online</td>
<td>Baltimore, MD</td>
<td>Sep 08, 2020 - Sep 13, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>Threat Hunting &amp; Incident Response Summit &amp; Training 2020</td>
<td>Virtual - US Eastern,</td>
<td>Sep 10, 2020 - Sep 19, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Munich September 2020</td>
<td>Munich, Germany</td>
<td>Sep 14, 2020 - Sep 19, 2020</td>
<td>Live Event</td>
</tr>
<tr>
<td>SANS Munich September 2020 - Live Online</td>
<td>Munich, Germany</td>
<td>Sep 14, 2020 - Sep 19, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Network Security 2020 - Live Online</td>
<td>Las Vegas, NV</td>
<td>Sep 20, 2020 - Sep 25, 2020</td>
<td>CyberCon</td>
</tr>
<tr>
<td>SANS Australia Spring 2020</td>
<td>Australia</td>
<td>Sep 21, 2020 - Oct 03, 2020</td>
<td>Live Event</td>
</tr>
</tbody>
</table>