After an Attack
Sometimes the Bad Guys Win

- What do you do if a machine is compromised?
- How do you assess the damage?
- How do you recover?
- What else should you do?
How Can Machines be Compromised?

- 0-day attacks?
- Carelessness?
- Insider attacks?
- In some sense, it doesn’t matter; you still have to recover
Damage Assessment — Why?

- What has to be thrown out?
- What can be saved?
- How did the bad guys get in?
A General Rule

- It is frequently impossible to cleanse an infected system
- Hiding back doors is relatively easy
- The usual advice: reformat your disks and reinstall
Hidden Back Doors

- Cron jobs
- Standard services — with a twist
- Programs buried in someone’s `.profile`
- Jobs started via `at` or `batch`
- Trojan horses in commands likely to be executed by `root`
- More ways? Of course
The Network

• The attacker has access to all network-accessible resources of the compromised machine

• Attack shared file systems

• (Many worms spread that way)

• The compromised machine is on the inside of the firewall

• The compromised machine is on your LAN
Trust Patterns

- Your users will (probably) trust an insider more than an outsider
- The attacker can gain knowledge to use in a subsequent attack
- Were any password files compromised?
Backups Are Your Friend

- Back up your system frequently
- Make sure you have a 0-day backup, from before the system went live
- Recover your data — but not your programs — from the backups
Suppose there’s some non-sensitive application with a buffer overflow

- It reads one of your “secure” data files

- The attacker puts the buffer overflow into the data file, triggering a new penetration when the data files are restored after reinstalling the code

- Oops...
If you have good backups, you could restore to another machine and compare files.

Very time-consuming.

Besides, some files change.
Tripwire

- Create a cryptographic checksum of each file
- To detect changes, recalculate the checksums and compare against the stored copy
- Easier said than done...
Changes

• Can you trust your master list of checksums?
• Can you trust the software that’s calculating the new checksums?
• An attack: detect when Tripwire is running and give a different answer
A Real Example

• A (Linux) loadable kernel module intercepted file system operations
• If pid 1 tried to open `/sbin/init`, it got the Trojan horse version
• If any other process did the open, it got the real version
• Tripwire wouldn’t detect the substitution!
Safely Using Tripwire

- Store the checksum file on (physically safe) media
- Use another machine to read the disk you’re checking
- Don’t trust any software on the (possibly) compromised machine
Dual-Ported Disk
Analyzing a Hacked System

- Suppose you want to analyze a compromised system
- What if the bad guy tried to hide?
- How do you proceed?
Work with a Copy

- Never try to work with a live disk
- You don’t want to destroy metadata
- Be careful of the malware!
- Make a copy — preferably an image copy; failing that, use dump/restore
- Don’t use anything that will change file access times
Live CDs

- If you don’t have a spare machine (with compatible hardware), trying booting a “live” CD
- A live CD is a bootable, runnable system
- Example: Knoppix; Ubuntu installer
Mounting the Image

- Always mount it read-only, with the “noexec” and “nodev” options
- Most newer systems allow you to mount a file as a block device (\texttt{vnd} on BSD; \texttt{lofiadm} on Solaris; loopback device on Linux; .dmg files on Mac OS; etc.)
Things to Look For

- What files were changed recently?
- Note: look at `ctime`, not just `mtime` (why?)
- Or run Tripwire against either the 0-day Tripwire dump or a known-good installation disk
Funky Filenames

- Files and directories can be hidden by using strange file names.
- Examples: “...” (3 dots), “bin ” (trailing blank), /usr/lbb (instead of /usr/lib), C:\WINDOWS\system32\Com\Inf\[4 BLANK SPACES].exe

- Names resembling real filenames:
  C:\WINDOWS\Windows Explorer.exe
Finding Deleted Files

- Deleting a file doesn’t delete the data
- Instead, it changes some metadata — the filename on FAT filesystems; the i-node number and i-list entry on traditional BSD filesystems
- The blocks are returned to the freelist — but they may not be reallocated immediately
- Clever tools can recover deleted files
Digression: Serious Threats

• Even overwriting a block doesn’t delete physical traces of the data
• There are (classified?) techniques to recover data
• At a minimum, disks need to be overwritten three times — and sometimes, you just destroy the disk *thoroughly*
Rebuilding Deleted Files

- Suppose there are no clues in directories or the i-list
- Sometimes, it’s possible to do magic with the freelist
- Files aren’t random...
File Types

- Different file types have different byte distributions
- Example: C has lots of { and }; text has distinctive capitalization patterns, etc.
- Sort blocks by (probable) type
Contact Probabilities

- Look for matches between the end of one block and the start of the next
- Look for syntactically correct statements
- Log files have timestamps!
Are Deleted Files Better for Forensics?

- A normal file can be overwritten easily
- A deleted file can’t be touched
- Block allocation policies are invisible to the application
- Some claim that deleted files are *more* likely to be intact
Looking at Memory

- If the system is still up, dump main memory (/dev/kmem)
- Can often find plaintext of the malware
- Encrypting file systems write ciphertext to disk — but where’s the plaintext? Often, in RAM
- The decryption key is in RAM, too, if the file system is mounted
Digression: Doing Crypto

- Always zero out plaintext as soon as possible
- That’s even more true for keys
- Especially do this before program exit, when pages are handed back to the OS
- Also, lock the pages into memory, to make sure there’s no copy in a swap file
Criminal Prosecution

• Suppose you want to prosecute the bad guys
• Should you do these forensics?
• No!
Evidence Procedures

- Evidence must be handled *very* carefully
- Must avoid defense charges of tampering, forgery, misinterpretation (to say nothing of legal issues such as proper warrants)
- Parties with more interest in a case can be portrayed as biased
Techniques

- Chain of custody
- Rigorous marking, labeling, logging, etc.
- Careful records of all analysis
- Not a job for amateurs
Conclusions

• A lot can be learned from compromised systems

• A really thorough analysis is difficult, and probably more time-consuming than reinstallation

• For special situations, get expert help