Zero Day Malware Cleaning with the Sysinternals Tools

Mark Russinovich
Technical Fellow
Windows Azure

About Me

- Technical Fellow, Windows Azure, Microsoft
- Cofounder and chief software architect of Winternals Software
- Author of Windows Sysinternals tools
- Coauthor of Windows Internals book series
  - With Dave Solomon
- Coauthor of Sysinternals Administrator's Reference
  - With Aaron Margosis
- Author of Zero Day: A Novel

About this Talk

- Learn about Sysinternals tools and techniques for analyzing and cleaning malware
  - Professional antimalware analysis requires
  - But even for professionals, Sysinternals tools can prove useful
- Analyzing:
  - Understanding the impact of malware
  - Can be used to understand malware operation
  - Generates road map for cleaning infestations
- Cleaning:
  - Removing an infestation of a compromised system
  - Attempting a clean can also reveal more information about malware's operation

Malware Cleaning Steps

- Disconnect from network
- Identify malicious processes and drivers
- Suspend and terminate identified processes
- Identify and delete malware autostarts
- Delete malware files
- Reboot and repeat

Identifying Malware Processes

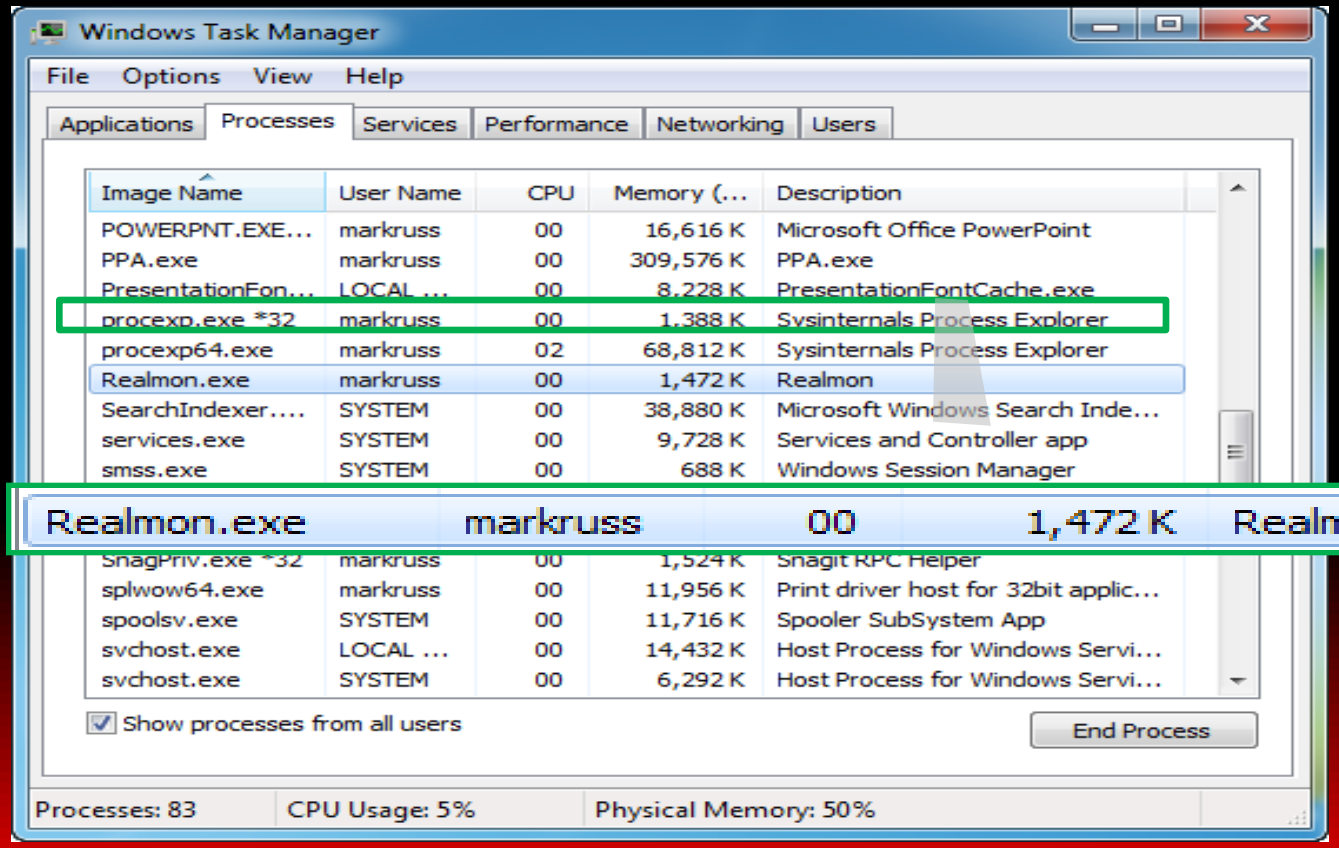
What Are You Looking For?

Investigate processes that…

- …have no icon
- …have no description or company name
- …unsigned Microsoft images
- …live in Windows directory or user profile
- …are packed
- …include strange URLs in their strings
- …have open TCP/IP endpoints
- …host suspicious DLLs or services

What About Task Manager?

- Task Manager provides little information about images that are running

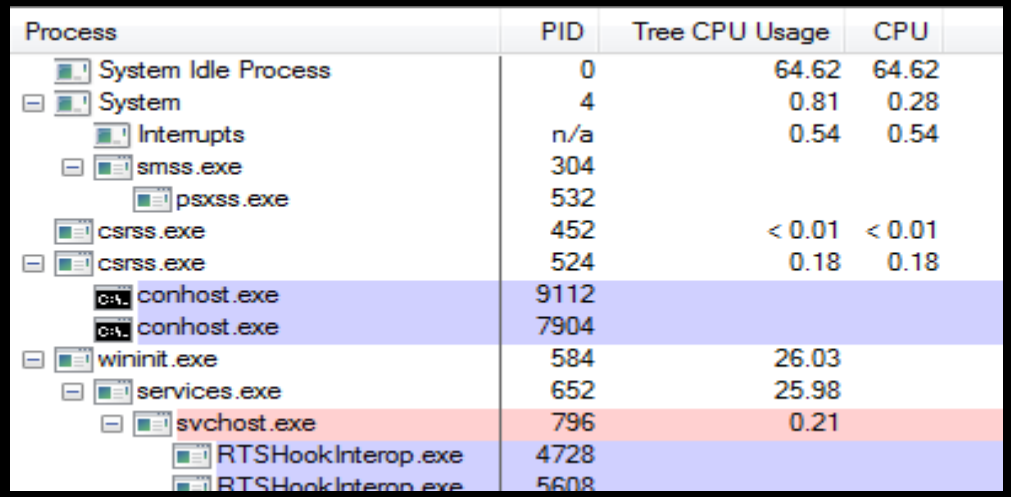


Process Explorer

- Process Explorer is “Super Task Manager”
- Has lots of general troubleshooting capabilities:
  - DLL versioning problems
  - Handle leaks and locked files
  - Performance troubleshooting
  - Hung processes
- We’re going to focus on its malware cleaning capabilities

Process Explorer 2010 Updates

- Versions 12 and 14 included many enhancements, big and small:
  - Network and disk activity
  - Multi-tab system information
  - Tree CPU usage
  - Improved DLL scanning algorithm
  - Command-lines in process tooltips
  - Svchost information
  - Service threads
  - .NET assembly information
  - Support for > 64

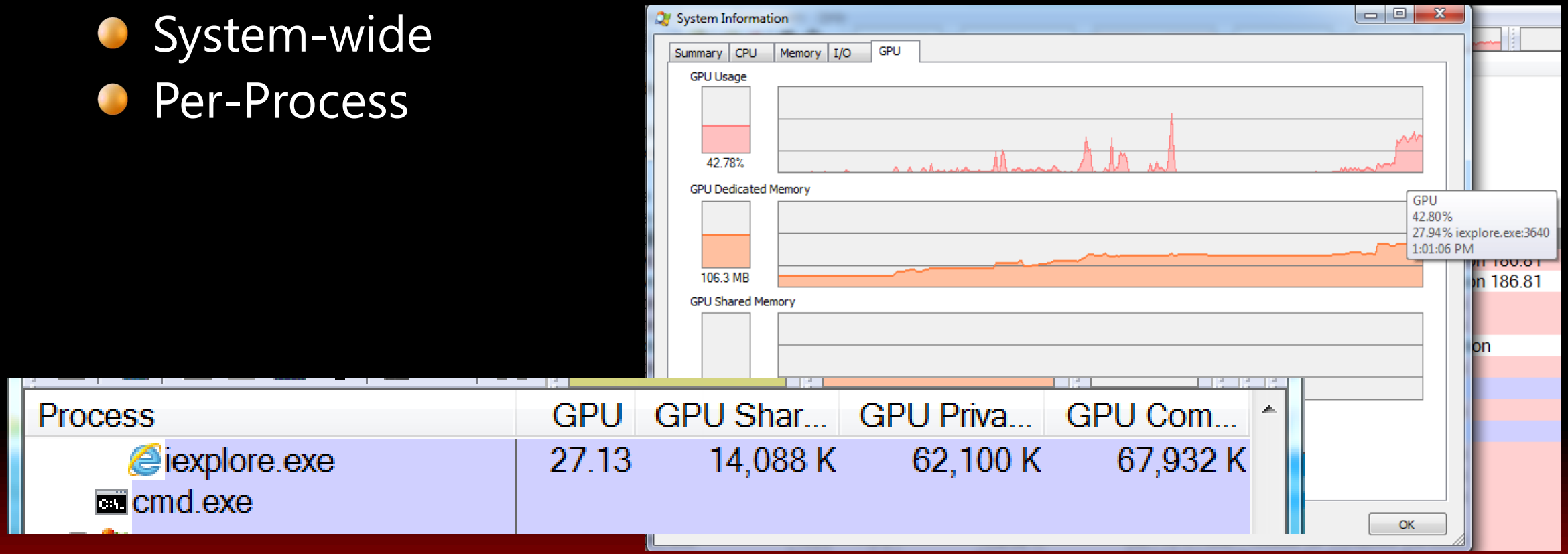


More precise CPU accounting

- Task Manager, Resource Monitor and older Process Explorer versions use time-slice accounting
  - Whatever thread is executing at a timer tick (typically 15.6ms) is charged for the entire time slice
  - Charge is kernel mode if thread is in kernel mode, user mode for user mode
- Process Explorer v14.1 uses cycle counts
  - Full cycle count usage on Win7/Server 2008 R2 because of new API
  - On Vista uses cycle counts to detect < time slice
  - On XP, uses context switches to detect < time slice
- Sub 0.01 usage is shown as < 0.01

Process Explorer v15: GPU Monitoring

- Captures GPU utilization and memory usage
  - System-wide
  - Per-Process



The Process View

- The process tree sort shows parent-child relationships
- Icon, description, and company name are pulled from image version information
  - Most malware doesn't have version information
  - What about malware pretending to be from Microsoft?
    - We'll deal with that shortly…
- Use the Window Finder (in the toolbar) to associate a window with its owning process
- Use the Search Online menu entry to lookup unknown processes
  - But malware often uses totally random or pseudo-random names

Refresh Highlighting

- Refresh highlighting highlights changes
  - Red: process exited
  - Green: new process
- Change duration (default 1 second) in Options
- Press space bar to pause and F5 to refresh
- Cause display to scroll to make new processes visible with Show New Processes option
- We'll see how to spot short-lived processes later…

Process-type Highlights

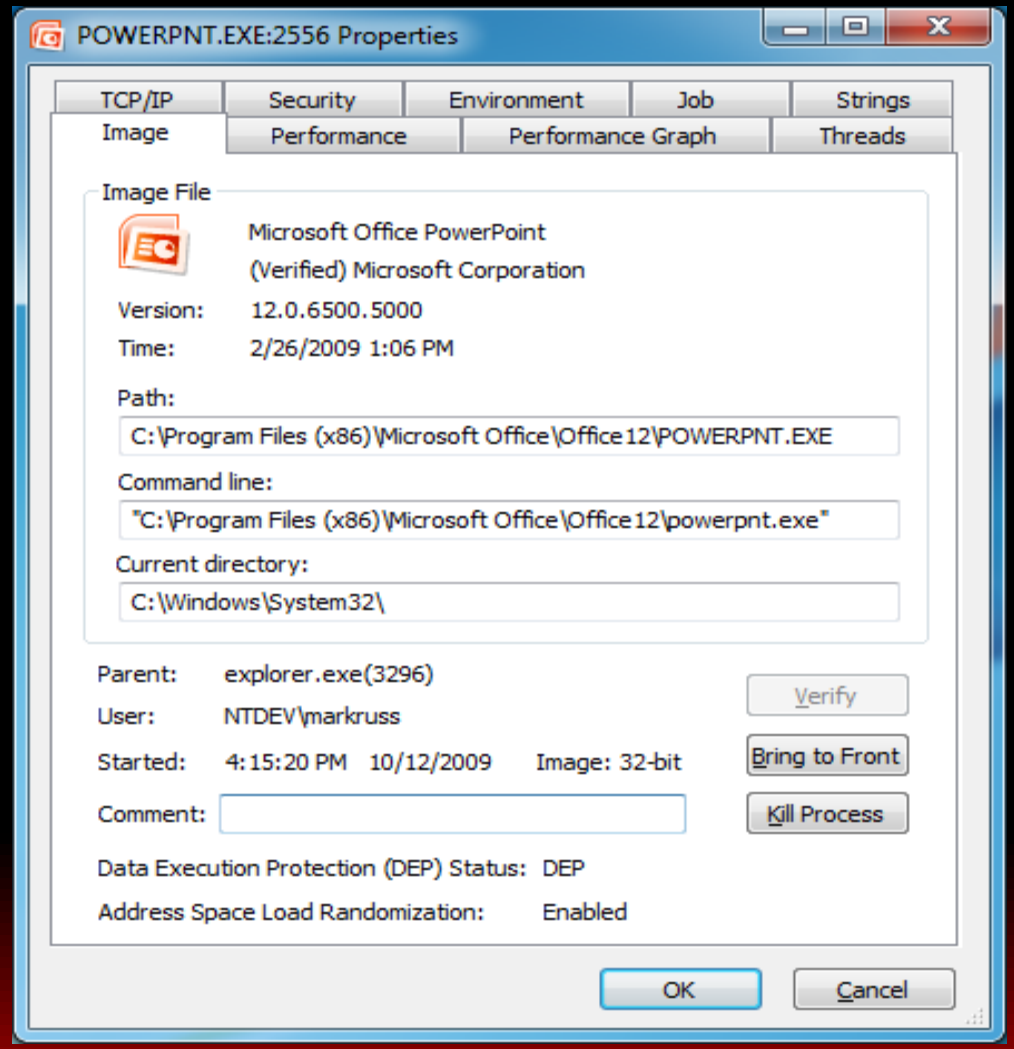
- Blue processes are running in the same security context as Process Explorer
- Pink processes host Windows services (we'll look at services shortly)
- Purple highlighting indicates an image is "packed"
  - Packed can mean compressed or encrypted
  - Malware commonly uses packing (e.g. UPX) to make antivirus signature matching more difficult
  - Packing and encryption also hides strings from view
- There are a few other colors, but they're not important for malware hunting

Tooltips

- Process tooltips show the full path to the process image
- Malware more often hides behind Svchost, Rundll32 and Dllhost
  - Tooltip for Rundll32 processes shows hosted DLL
  - Dllhost tooltip shows hosted COM server
  - Tooltip for service processes shows hosted services
    - Services covered in detail shortly…

Detailed Process Information

- Double-click on a process to see detailed information
- Image tab:
  - Description, company name, version (from .EXE)
  - Full image path
  - Command line used to start process
  - Current directory
  - Parent process
  - User name
  - Start time



Windows Services

- Services can start when the system boots and run independently of the logged-on user
  - Examples include IIS, Themes, Server, Workstation, …
  - Can run as their own process or as a service DLL inside a Svchost.exe
- The services tab shows detailed service information:
  - Registry name (HKLM\System\CurrentControlSet\Services\…)
  - Display name
  - Description (optional)
  - DLL path (for Svchost DLLs)

Image Verification

- All (well, most) Microsoft code is digitally signed
  - Hash of file is signed with Microsoft's private key
  - Signature is checked by decrypting signed hash with the public key
- You can selectively check for signatures with the Verify button on the process image tab
  - Select the Verify Image Signatures option to check all
  - Add the Verified Signer column to see all
- Note that verification will connect to the Internet to check Certificate Revocation List (CRL) servers

Sigcheck and ListDlls

- Scan the system for suspicious executable images

```
sigcheck -e -u -s c:\
```

- Look for same characteristics as suspicious processes
  - Be especially wary of items in the \Windows directory
  - Investigate all unsigned images
- ListDlls will scan running processes for unisigned DLLs

```
listdlls -u
```

Strings

- On-disk and in-memory process strings are visible on the Strings tab
  - There's only a difference if the image is compressed or encrypted
- Strings can help provide clues about unknown processes
  - Look for URLs, names and debug strings
- You can also dump strings with the command-line Strings utility from Sysinternals

```
strings <file>
```

The DLL View

- Malware can hide as a DLL inside a legitimate process
  - We've already seen this with Rundll32 and Svchost
  - Typically loads via an autostart
  - Can load through "dll injection"
  - Packing highlight shows in DLL view as well
- Open the DLL view by clicking on the DLL icon in the toolbar
  - Shows more than just loaded DLLs
  - Includes .EXE and any "memory mapped files"
- Can search for a DLL with the Find dialog
- DLL strings are also viewable from the DLL menu

Loaded Drivers

- There are several tools for viewing configured drivers:
  - Start->Run->Msinfo32
  - Builtin SC command: sc query type= driver
  - Device Manager with View->Show Hidden Devices
- Process Explorer DLL view for the System process shows loaded drivers
  - Even drivers that delete their image files
  - Same path and version info as standard DLL view
- Usually they're not stoppable
  - Delete their files and autostart settings later

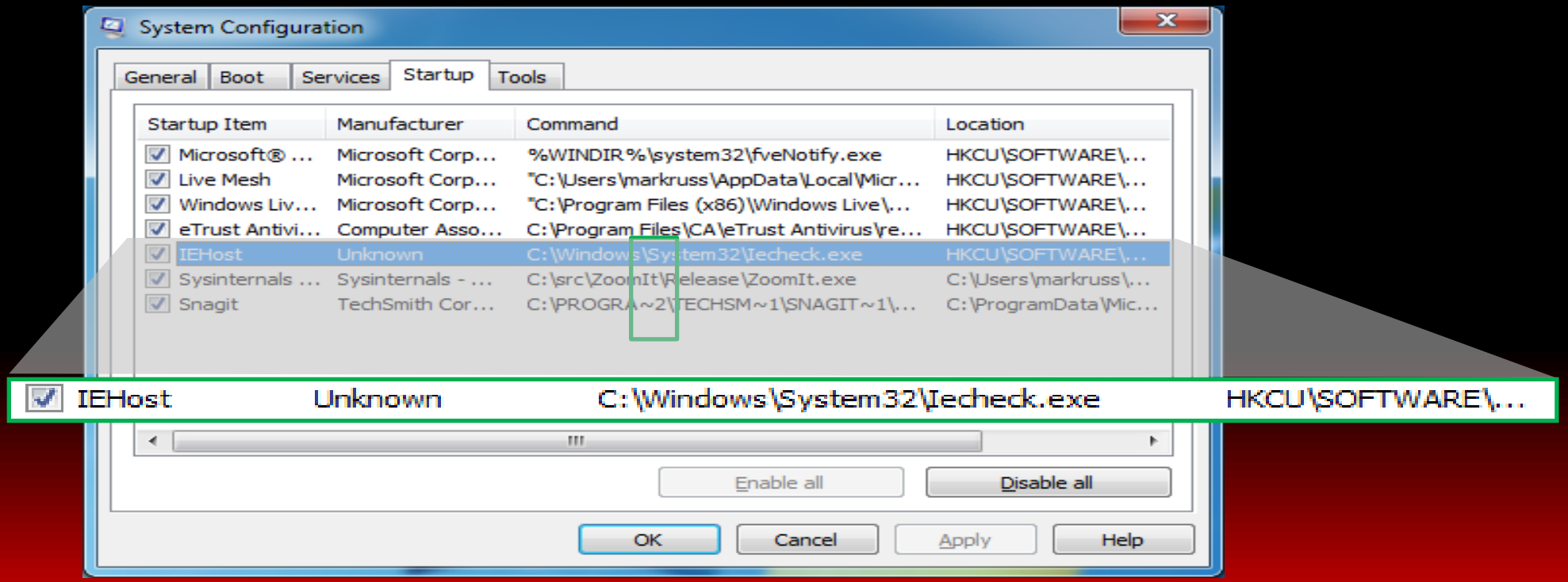
Terminating Malicious Processes

- Don’t kill the processes
  - Malware processes are often restarted by watchdogs
- Instead, suspend them
  - Note that this might cause a system hang for Svchost processes
  - Record the full path to each malicious EXE and DLL
- After they are all asleep then kill them
  - Watch for restarts with new names…

Cleaning Autostarts

Investigating Autostarts

- Windows XP Msconfig (Start->Run->Msconfig) falls short when it comes to identifying autostarting applications
  - It knows about few locations
  - It provides little information

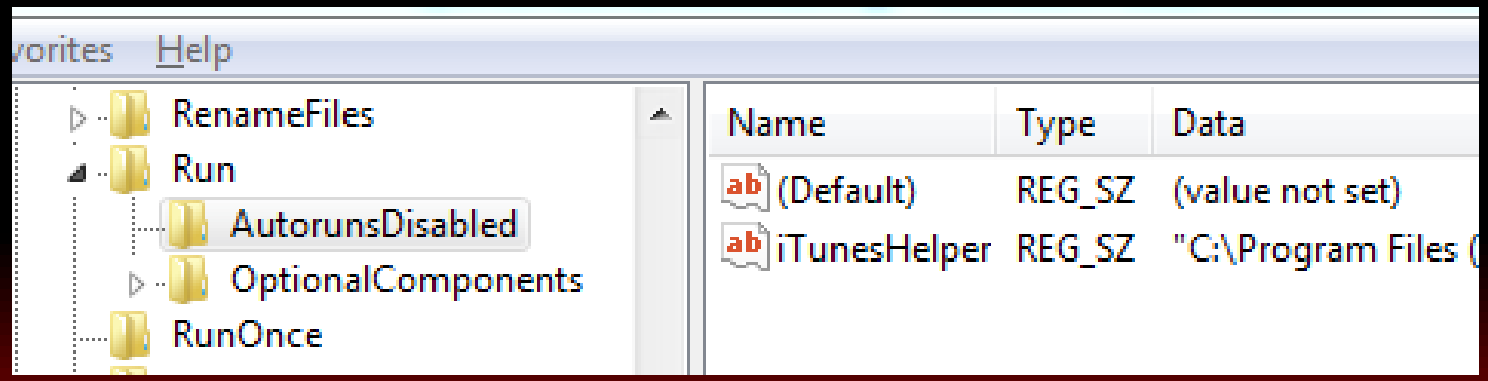


Autoruns

- Shows standard system extension points
  - Standard Run keys and Startup folders
  - Shell, userinit
  - Services and drivers
  - Tasks
  - Winlogon notifications
  - Explorer and IE addins (toolbars, Browser Helper Objects, …)
  - More and ever growing…
- Each startup category has its own tab and all items display on the Everything tab
  - Startup name, image description, company and path

How Autoruns Works

- Many different formats and rules for extension points
  - Shared scan routine for common types
- Disabling moves an entry to a subkey or folder named AutorunsDisabled

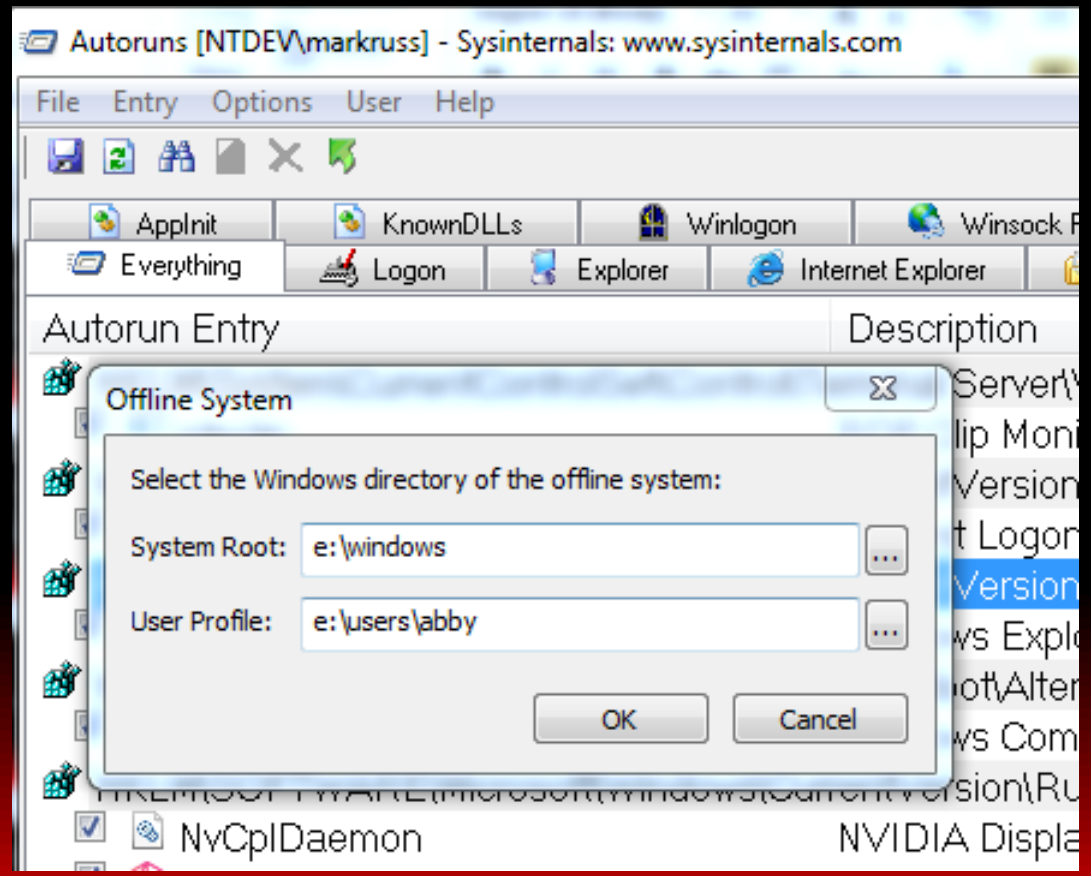


Identifying Malware Autostarts

- Zoom-in on add-ons (including malware) by selecting these options:
  - Verify Code Signatures
  - Hide Microsoft Entries
- Select an item to see more in the lower window
  - Online search unknown images
  - Double-click on an item to look at where its configured in the Registry or file system
- Has other features:
  - Can display other profiles
  - Can also show empty locations (informational only)
  - Includes compare functionality
  - Includes equivalent command-line version, Autorunsc.exe

Analyzing Offline Systems

- Autoruns includes support for scanning offline systems



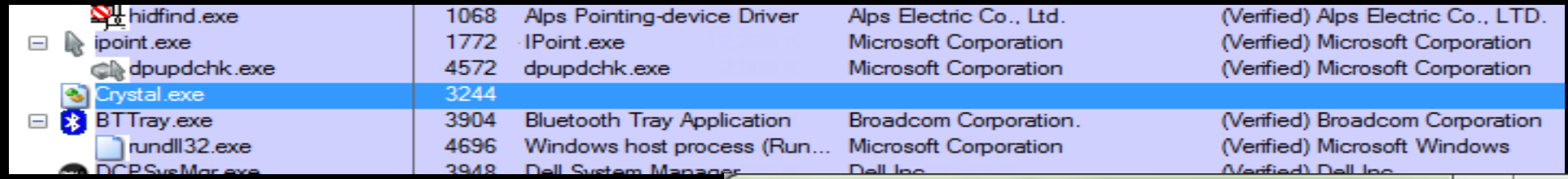
The Case of the Son's Adware

- Web page automatically opened on logon after father got laptop back from son
  - http://www.e -markettop.com/

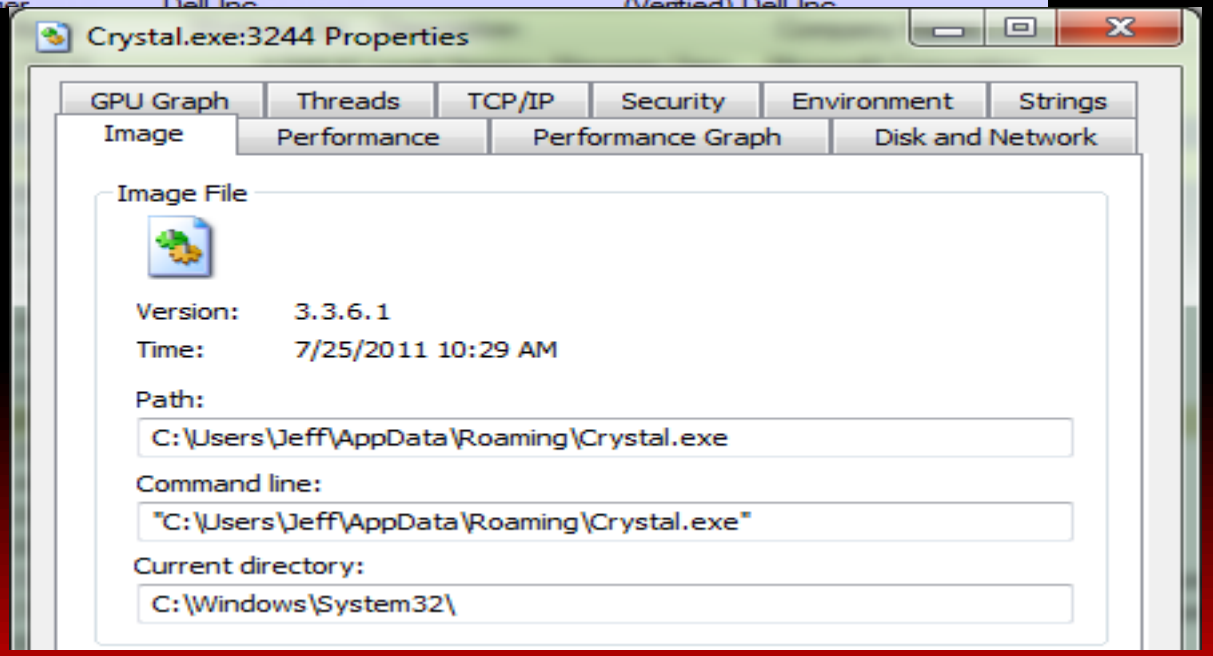
- Tried running Malwarebytes, but it would immediately close

The Case of the Son's Adware (Cont)

- Process Explorer showed one unsigned process, Crystal.exe:

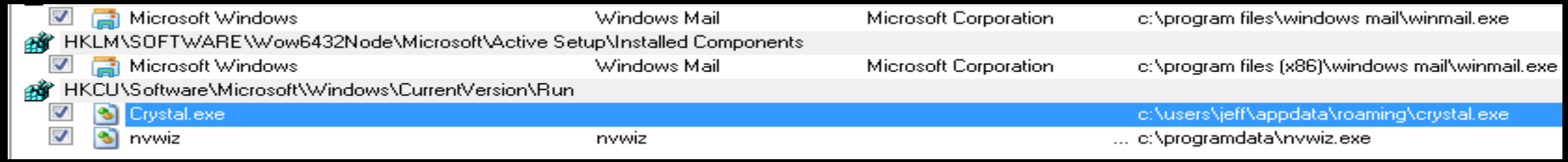


- After suspending Crystal, Malwarebytes ran to completion
  - No malware reported
  - McAfee didn't report any malware, either



The Case of the Son's Adware (Cont)

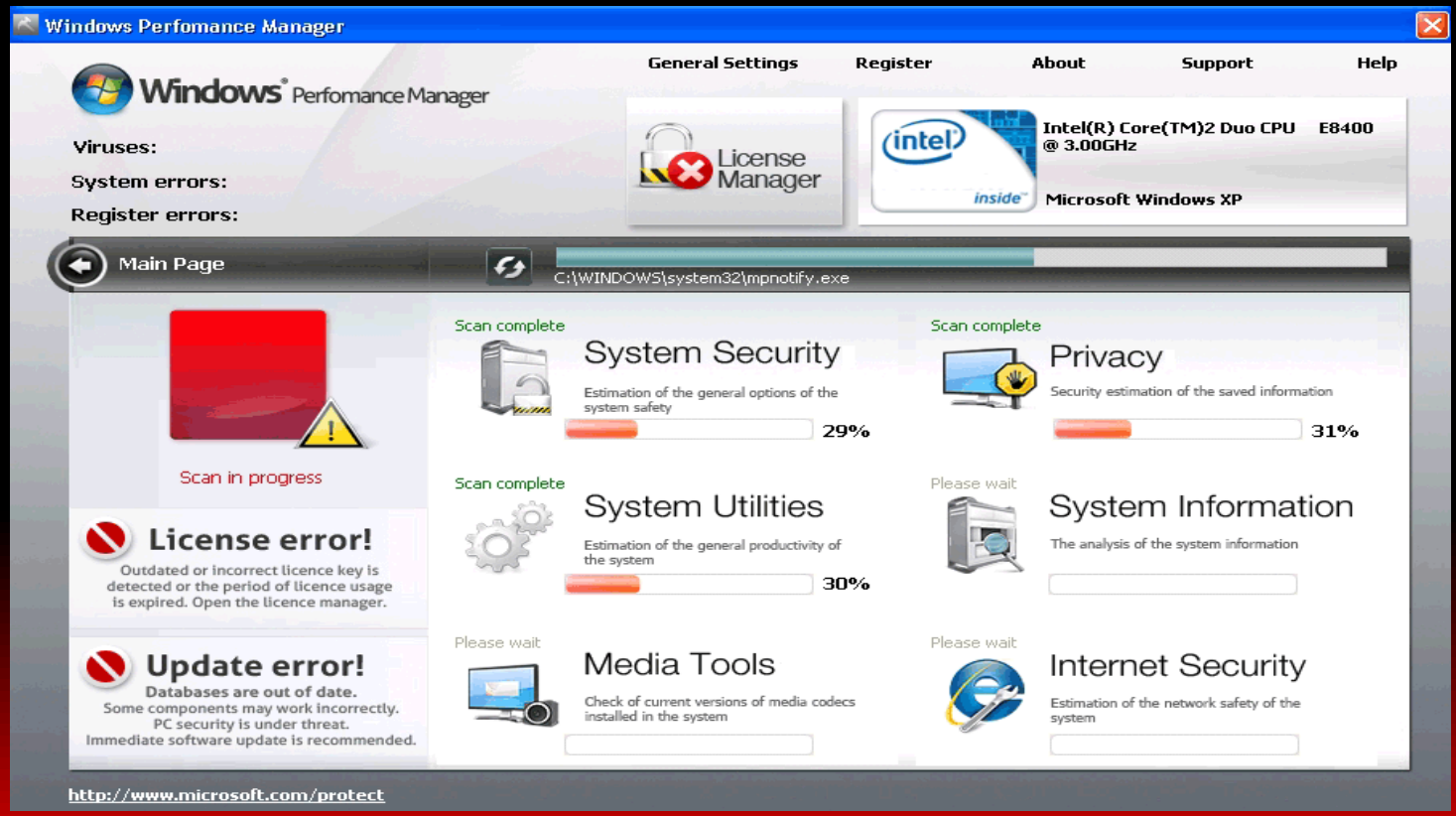
- Ran Autoruns and found Crystal in the Run key:



- Disabled it, rebooted and system operated normally: problem solved
  - Web search revealed that it was the Bifrost trojan: http://comprolive.com/remove/trojan/bifrost/crystal-exe-usb-exe-cleaner-exe

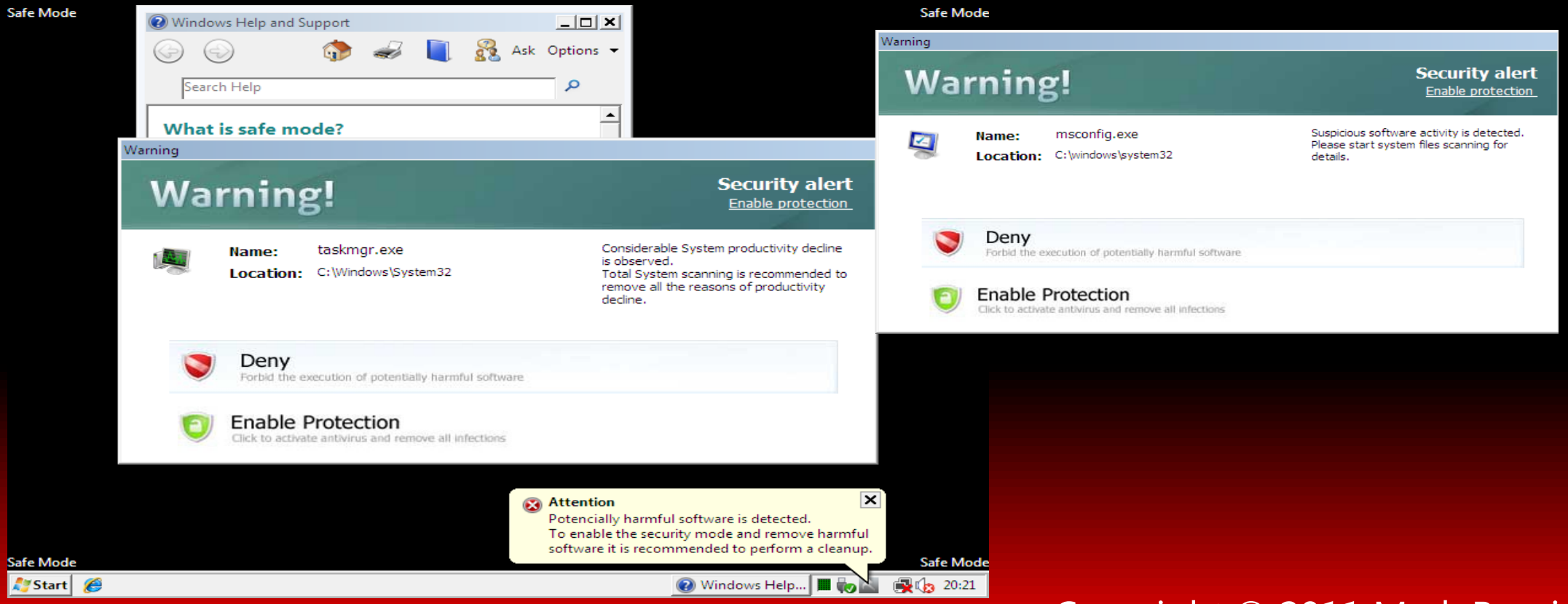
The Case of the Scareware

- A user's father-in-law complained that there was an application that wouldn't exit:



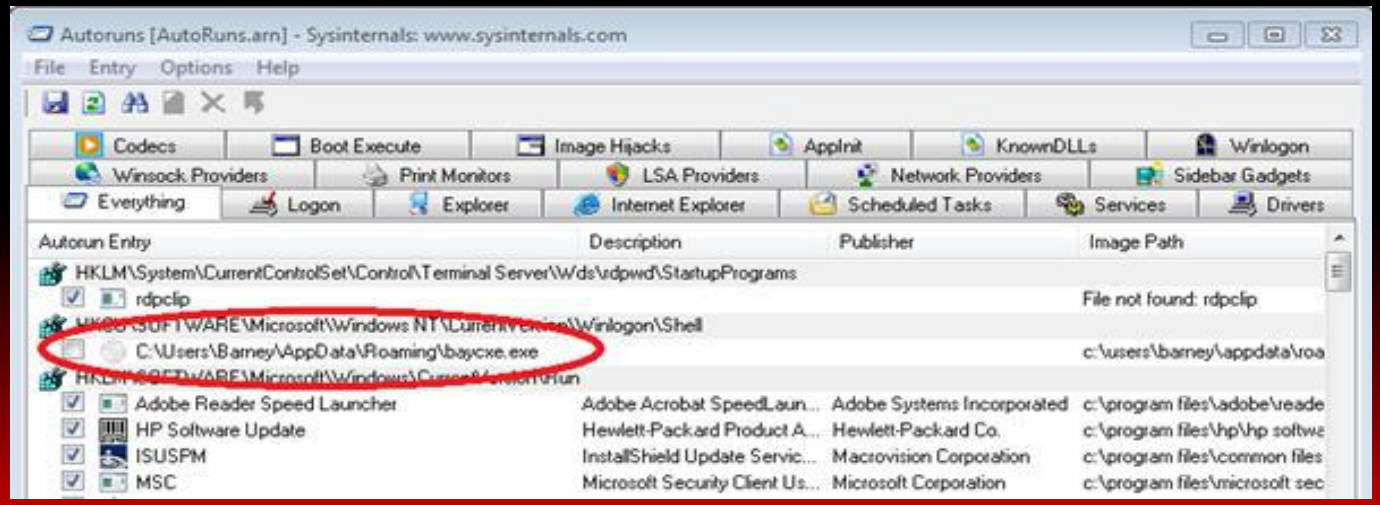
The Case of the Scareware (Cont)

- When a user tries to run Task Manager or MsConfig, they get errors, even in Safe Mode:



The Case of the Scareware: Solved

- Ran Autoruns and one entry stood out as suspicious
  - No company name or description
  - Installed in user's profile
  - Replaces shell
- Right-clicked and "jumped" to the Shell registry entry
  - Replaced malware name with "Explorer"
  - Rebooted
- Problem solved



The Case of the Unusable System

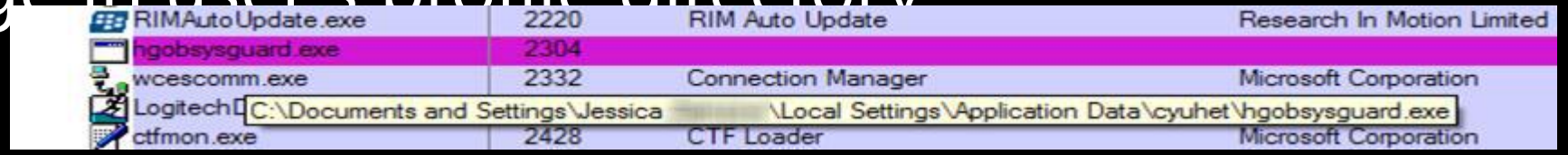
http://blogs.technet.com/b/markrussinovich/archive/2011/03/14/3412374.aspx

- Friend's of a friend's computer became infected with malware
- It was unable to run anything:

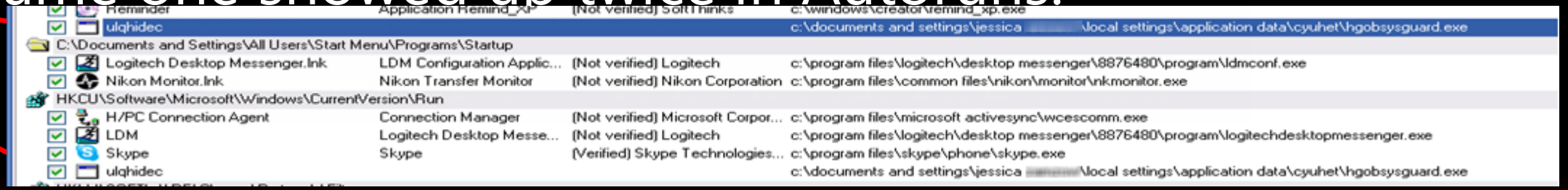
- Could have used Safemode, but wanted to see if I could run something at logon before malware activated
  - Logged off and back on
  - Was able to run Process Explorer and Autoruns

The Case of the Unusable System: Solved

- Process Explorer had one unsigned, random-name, packed image in user's profile directory:



- Same one showed up twice in Autoruns:



- Used Sigcheck to look for other suspicious files: none
- Killed process, deleted autostarts: system clean

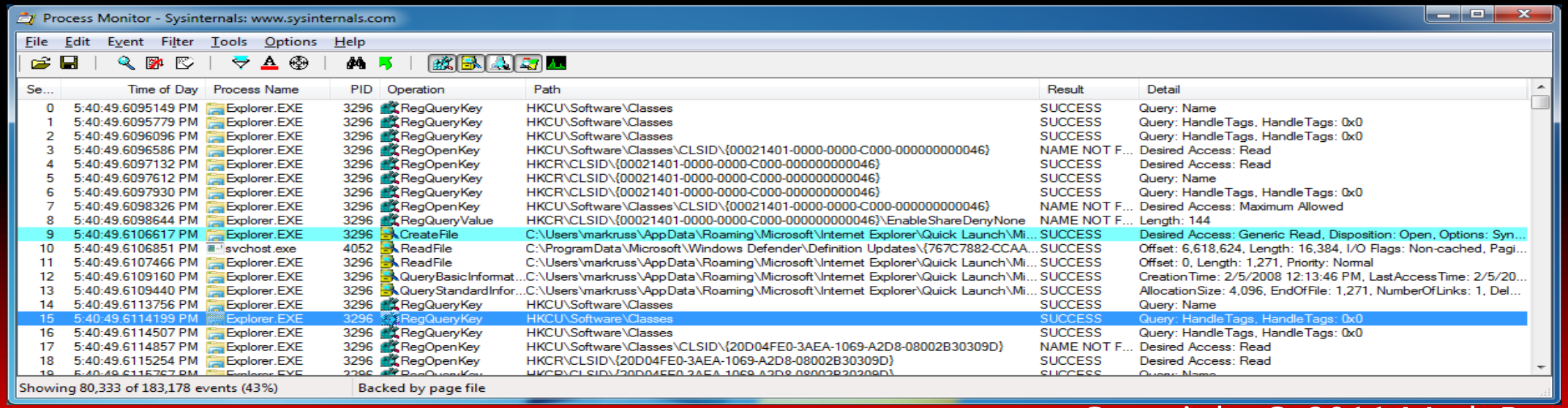
Deleting Autostarts

- Disable suspicious autostarts
  - First rule of troubleshooting: make reversible changes
- After you're done do a full refresh
- If they come back, run Process Monitor to see who's putting them back
  - You might have misidentified a malware process
  - It might be a hidden, system, or legitimate process

Tracing Malware Activity

Tracing Malware

- Tracing activity can reveal the system impact of malware
  - Tracing shows initial infection, before cloaking is applied
  - Can reveal the internals of "buddy system" and other infection-protection mechanisms
- Process Monitor makes tracing easy
  - A simple filter can identify all system modifications
  - Investigating stacks can distinguish legitimate activity from malicious activity



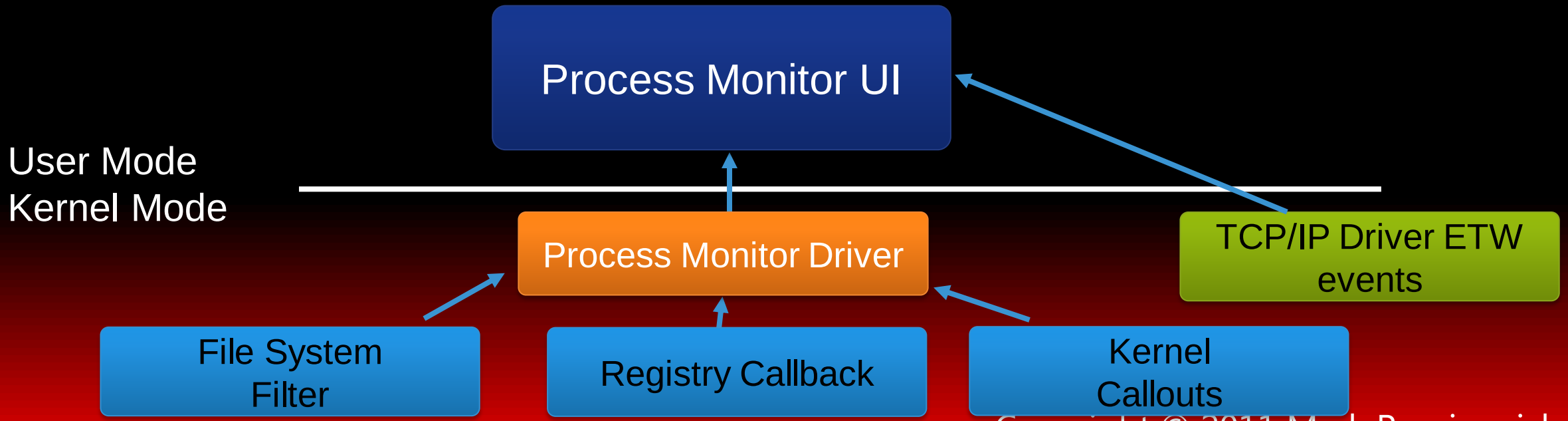
Se...	Time of Day	Process Name	PID	Operation	Path	Result	Detail
0	5:40:49.6095149 PM	Explorer.EXE	3296	RegQueryKey	HKCU\Software\Classes	SUCCESS	Query: Name
1	5:40:49.6095779 PM	Explorer.EXE	3296	RegQueryKey	HKCU\Software\Classes	SUCCESS	Query: HandleTags, HandleTags: 0x0
2	5:40:49.6096096 PM	Explorer.EXE	3296	RegQueryKey	HKCU\Software\Classes	SUCCESS	Query: HandleTags, HandleTags: 0x0
3	5:40:49.6096586 PM	Explorer.EXE	3296	RegOpenKey	HKCU\Software\Classes\CLSID\{00021401-0000-0000-C000-000000000046}	NAME NOT F...	Desired Access: Read
4	5:40:49.6097132 PM	Explorer.EXE	3296	RegOpenKey	HKCR\CLSID\{00021401-0000-0000-C000-000000000046}	SUCCESS	Desired Access: Read
5	5:40:49.6097612 PM	Explorer.EXE	3296	RegQueryKey	HKCR\CLSID\{00021401-0000-0000-C000-000000000046}	SUCCESS	Query: Name
6	5:40:49.6097930 PM	Explorer.EXE	3296	RegQueryKey	HKCR\CLSID\{00021401-0000-0000-C000-000000000046}	SUCCESS	Query: HandleTags, HandleTags: 0x0
7	5:40:49.6098326 PM	Explorer.EXE	3296	RegOpenKey	HKCU\Software\Classes\CLSID\{00021401-0000-0000-C000-000000000046}	NAME NOT F...	Desired Access: Maximum Allowed
8	5:40:49.6098644 PM	Explorer.EXE	3296	RegQueryValue	HKCR\CLSID\{00021401-0000-0000-C000-000000000046}\EnableShareDenyNone	NAME NOT F...	Length: 144
9	5:40:49.6106617 PM	Explorer.EXE	3296	CreateFile	C:\Users\markruss\AppData\Roaming\Microsoft\Internet Explorer\Quick Launch\Mi...	SUCCESS	Desired Access: Generic Read, Disposition: Open, Options: Syn...
10	5:40:49.6106851 PM	svchost.exe	4052	ReadFile	C:\ProgramData\Microsoft\Windows Defender\Definition Updates\{767C7882-CCAA...	SUCCESS	Offset: 6,618,624, Length: 16,384, I/O Flags: Non-cached, Pagi...
11	5:40:49.6107466 PM	Explorer.EXE	3296	ReadFile	C:\Users\markruss\AppData\Roaming\Microsoft\Internet Explorer\Quick Launch\Mi...	SUCCESS	Offset: 0, Length: 1,271, Priority: Normal
12	5:40:49.6109160 PM	Explorer.EXE	3296	QueryBasicInformat...	C:\Users\markruss\AppData\Roaming\Microsoft\Internet Explorer\Quick Launch\Mi...	SUCCESS	CreationTime: 2/5/2008 12:13:46 PM, LastAccessTime: 2/5/20...
13	5:40:49.6109440 PM	Explorer.EXE	3296	QueryStandardInfor...	C:\Users\markruss\AppData\Roaming\Microsoft\Internet Explorer\Quick Launch\Mi...	SUCCESS	AllocationSize: 4,096, EndOfFile: 1,271, NumberOfLinks: 1, Del...
14	5:40:49.6113756 PM	Explorer.EXE	3296	RegQueryKey	HKCU\Software\Classes	SUCCESS	Query: Name
15	5:40:49.6114199 PM	Explorer.EXE	3296	RegQueryKey	HKCU\Software\Classes	SUCCESS	Query: HandleTags, HandleTags: 0x0
16	5:40:49.6114507 PM	Explorer.EXE	3296	RegQueryKey	HKCU\Software\Classes	SUCCESS	Query: HandleTags, HandleTags: 0x0
17	5:40:49.6114857 PM	Explorer.EXE	3296	RegOpenKey	HKCU\Software\Classes\CLSID\{20D04FE0-3AEA-1069-A2D8-08002B30309D}	NAME NOT F...	Desired Access: Read
18	5:40:49.6115254 PM	Explorer.EXE	3296	RegOpenKey	HKCR\CLSID\{20D04FE0-3AEA-1069-A2D8-08002B30309D}	SUCCESS	Desired Access: Read

Process Monitor

- Process Monitor is a real-time file, registry, process and thread monitor
- It replaces Filemon and Regmon
  - More advanced filtering
  - Operation call stacks
  - Boot-time logging
  - Data mining views
  - Process tree to see short-lived processes
- When in doubt, run Process Monitor!
  - It will often show you the cause for error messages
  - It many times tells you what is causing sluggish performance

How Process Monitor Works

- Process Monitor uses a device driver
  - Extracts the driver to \Windows\System32\Drivers
  - Installs the driver
  - Deletes the driver file
- Requires “Debug Programs” user right
  - First run requires the “Load Driver” user right



How Process Monitor Works (cont.)

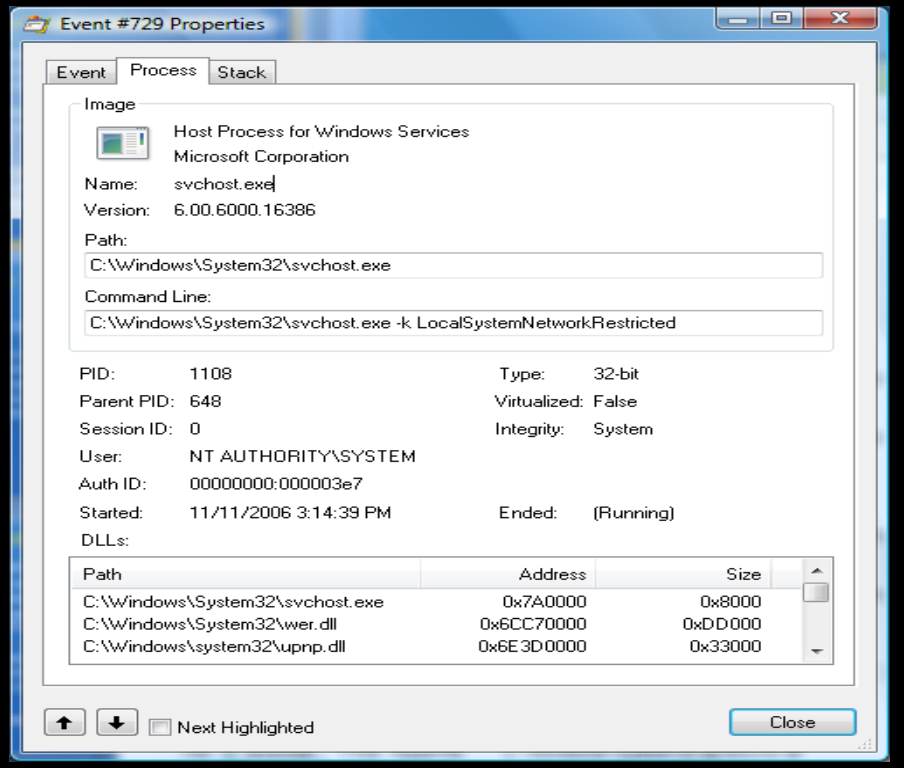
- Registry monitoring:
  - On Windows 2000, Windows XP 32-bit: system-call hooking
  - On Windows XP 64-bit, Server 2003, and Vista: registry callback
- File system monitoring:
  - File system mini-filter driver (causes Windows version requirements)
- Image loads:
  - Memory-manager image load callback
- Process/Thread create/exit:
  - Kernel process/thread callback
- TCP/IP
  - ETW events emitted by TCPIP.sys

Event Classes

- File system (Filemon)
  - Includes I/O command input and output details
- Registry (Regmon)
  - Includes all data (First 16-bytes part of REG_BINARY and first 2048-bytes for other types)
- Process
  - Process create and exit
  - Thread create and exit
  - Image loads, including drivers
- Network
  - ETW network tracing
- Profiling
  - Toolhelp thread snapshots

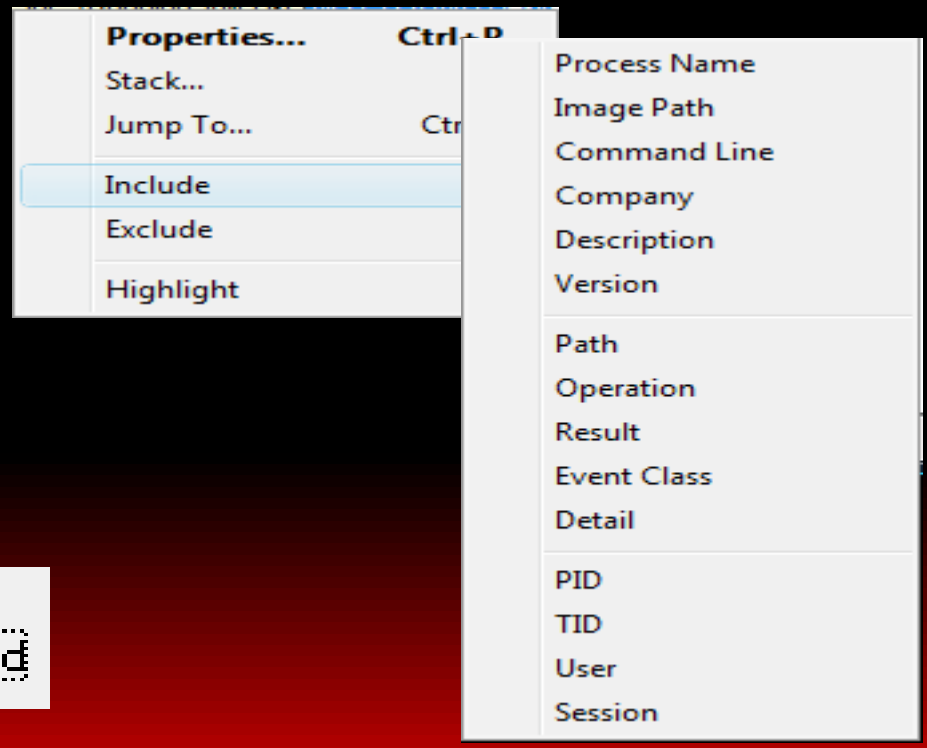
Event Properties

- Event details
  - Duration, process, thread, details, etc.
- Process information
  - Command line
  - User
  - Session and logon session
  - Image information
  - Start time
- Thread stack at time of event



Filtering

- To filter on a value, right-click on the line and select the attribute from the Include, Exclude or Highlight submenus
  - You can select multiple values simultaneously
- When you set a highlight filter you can move through highlighted event properties

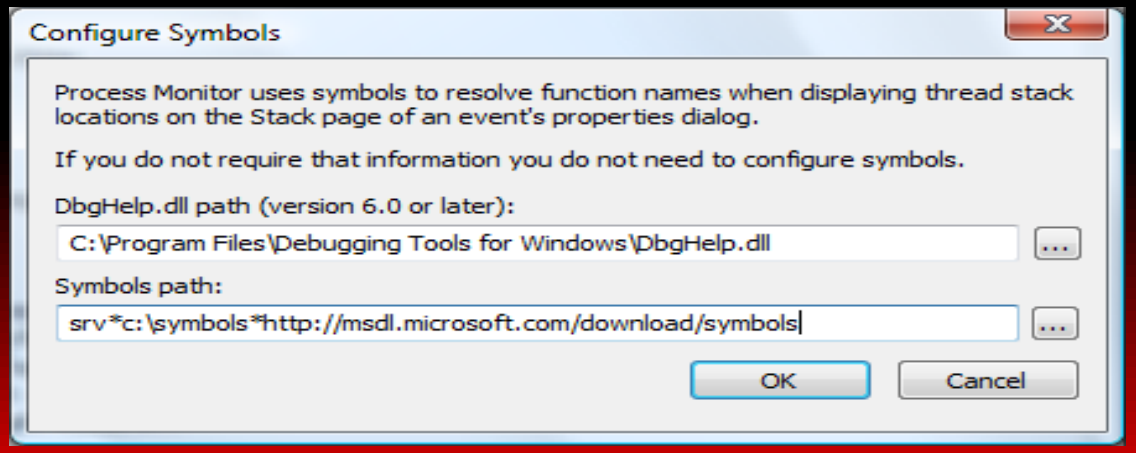


Demo: Watching a File Save

- Run Process Monitor, then:
  - Run Notepad
  - Type some text
  - Save the file as test.txt
- Find the real file save in the log file
  - Set a highlight filter on the saved file path

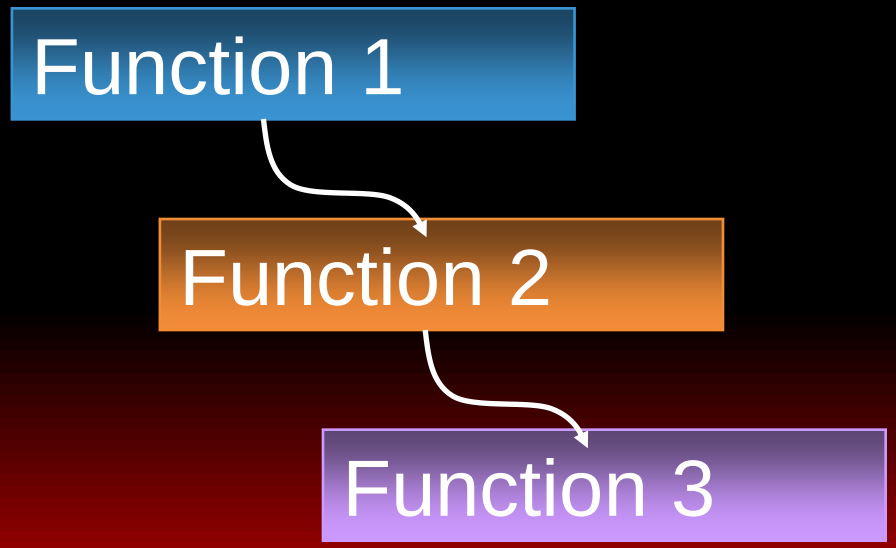
Symbols

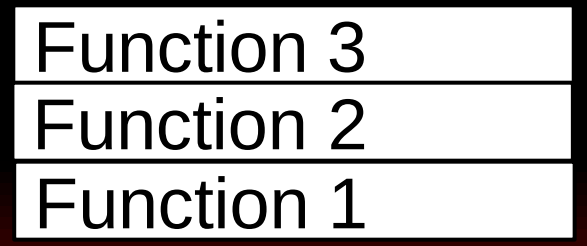
- Download the latest Debugging Tools for Windows from Microsoft (free)
- Configure Process Monitor's symbol engine:
  - Use dbghelp.dll from the Debugging Tools
  - Point at the Microsoft public symbol server
- To grab symbols for offline access, use Symchk, part of the Debugging Tools



Event Properties: Stack

- The stack tab shows the stack of the thread executing the operation
  - Stack is function-call history
  - Thread stacks can show root cause
  - Uses symbol engine

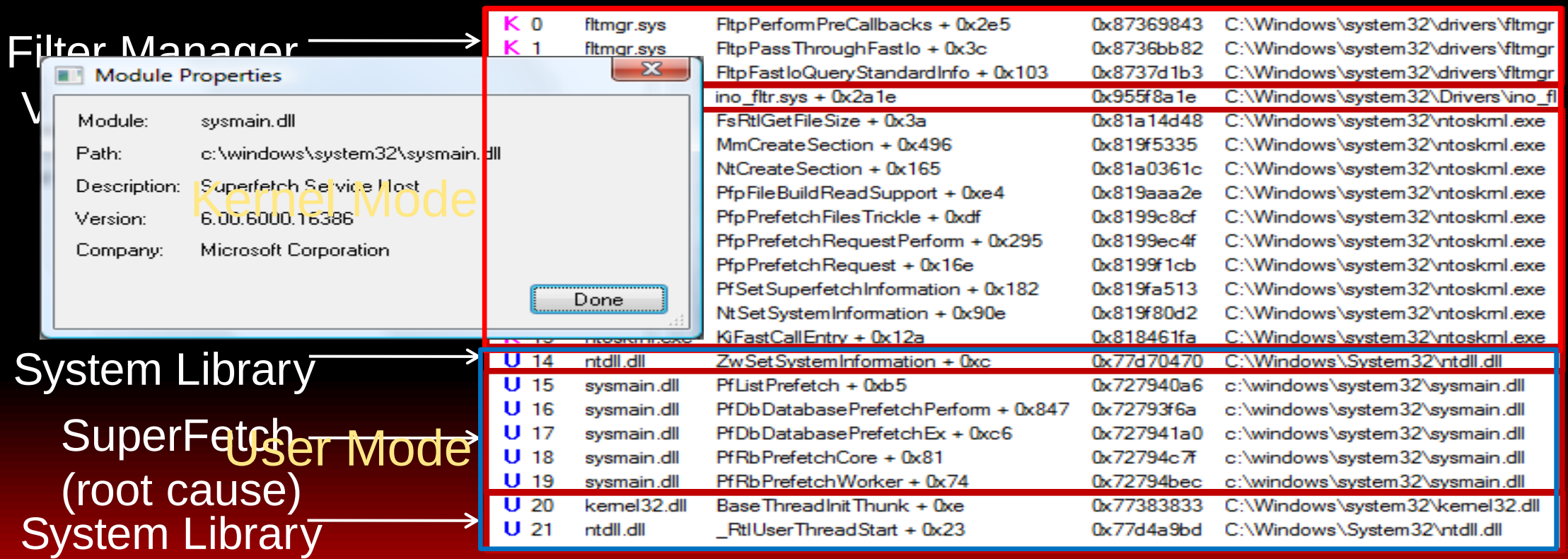




Stack Display

Analyzing a Stack

- Look at the function names and DLLs to identify the root cause
  - Double-click on a line to see the DLL properties



Note: user stack captured on 64-bit version of Windows 7/Server 2008 R2

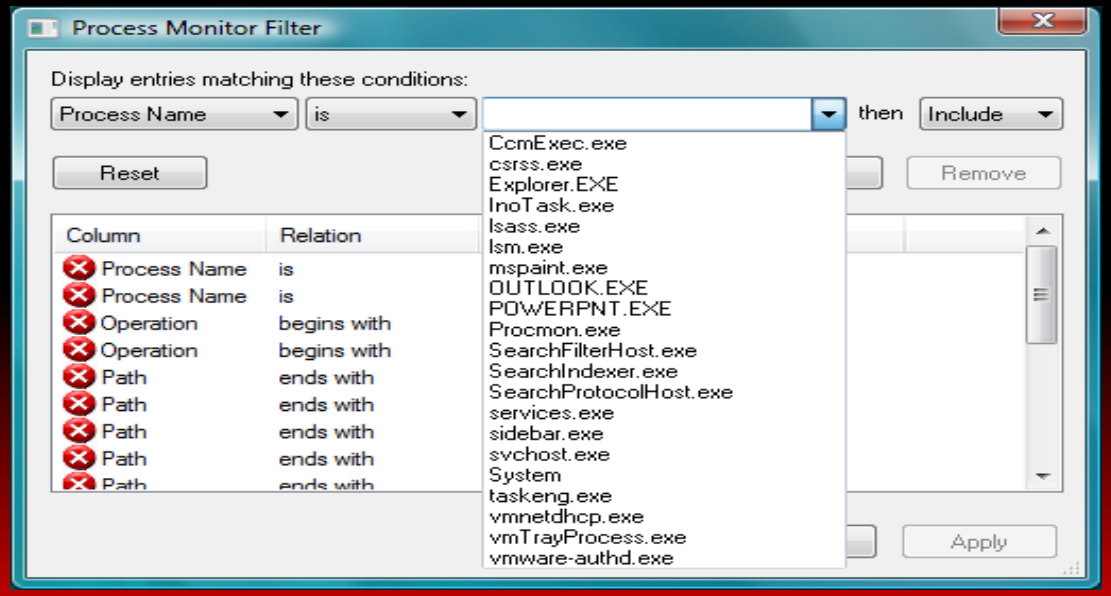
Analyzing Process Startup with Stacks

- There are lots of file system I/Os and Registry operations during Notepad's startup
- Using the stack we can identify three phases:
  - Prefetch
    - Reads in directories
    - Faults in DLLs
  - DLL initialization
    - Loader walks import tables
  - Application initialization
    - Initializes DLLs e.g. OLE
    - Reads global settings

Advanced Filters

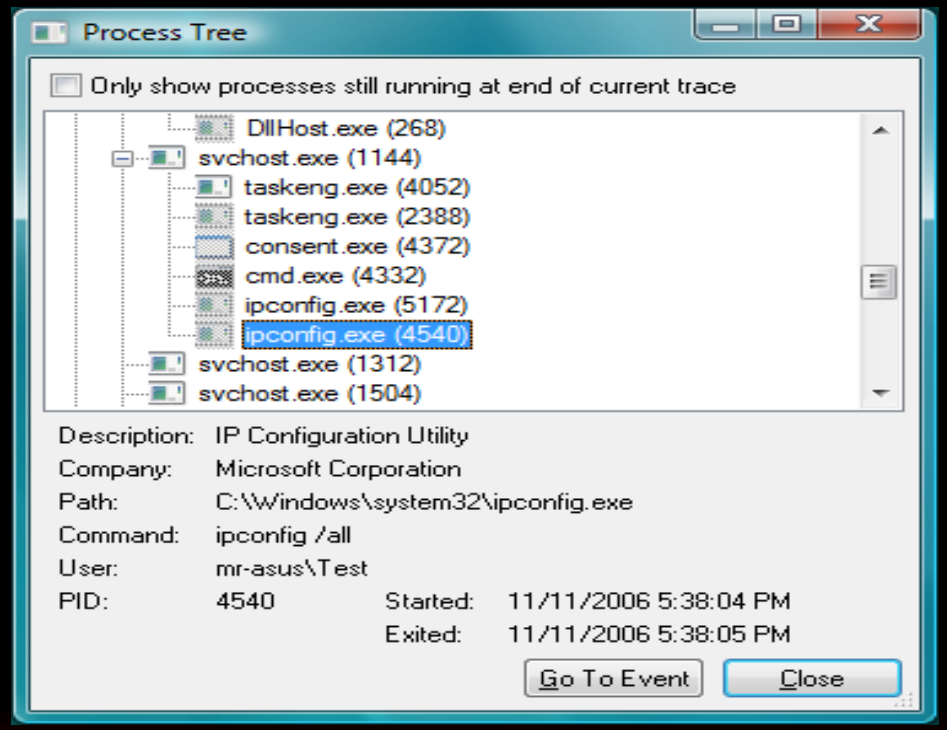
- Multiple-filter behavior:
  - Values from different attributes are AND'd
  - Values for the same attribute are OR'd
- More complex filtering is available in the Filter dialog
  - Outlook-style rule definition
- You can save and restore filters
- Filter for watching malware impact:

  ò C a t e g o r y i s



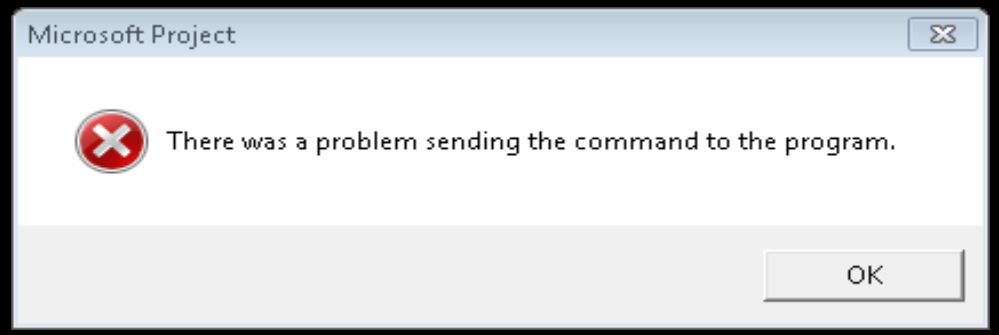
The Process Tree

- Tools->Process Tree
  - Shows all processes that have been seen in the trace (including parents)
  - Can toggle on and off terminated processes
- The process tree provides an easy way to see process relationships
  - Short-lived processes
  - Command lines
  - User names



The Case of the Slow Project File Opens

- Customer reported that opens of Project files from a network were slow and 1 of 10 opens resulted in an error:



- Microsoft support asked them to captured a Process Monitor trace

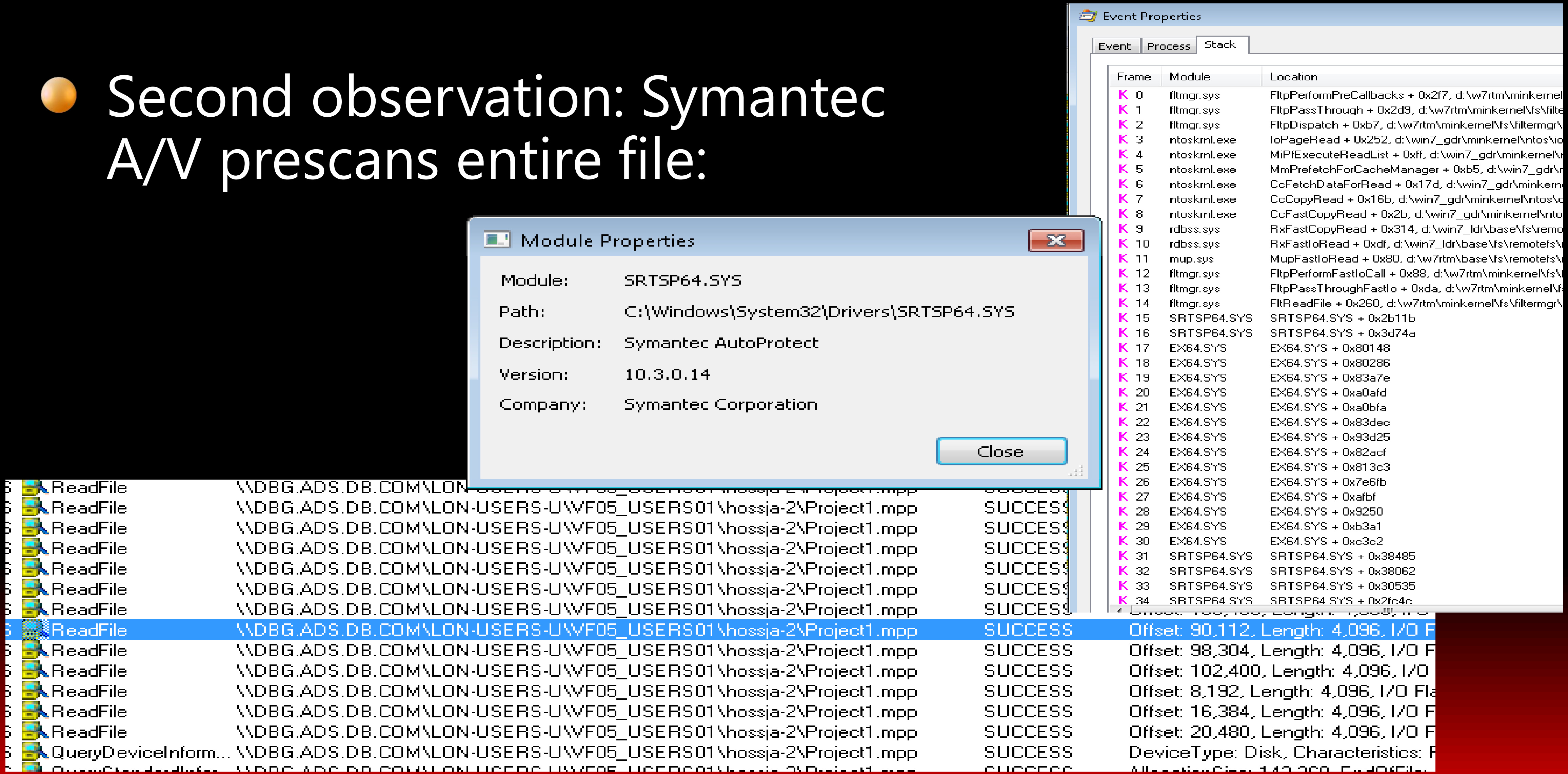
The Case of the Slow Project File Opens (Cont)

- First observation: tremendous number of access to share because user-profiles stored there:

Total Events	Path
4,103	<Total>
2,038	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2\config\AppData\Microsoft\MS Project\...
577	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2\config\AppData\Microsoft\Windows\R...
451	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2\Project1.mpp
271	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2\config\AppData\Microsoft\Windows\R...
110	\\DBG.ADS.DB.COM\LON-USERS-U\
100	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2
88	\\Dbg.ads.db.com\lon-users-u\
56	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2\config\AppData
45	\\Dbg.ads.db.com\lon-users-u\VF05_USERS01\hossja-2
24	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01
24	\\Dbg.ads.db.com\lon-users-u\VF05_USERS01
22	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2\config\AppData\Microsoft
22	\\DBG.ADS.DB.COM\LON-USERS-U\VF05_USERS01\hossja-2\config\AppData\Microsoft\Office\Rec...
22	\\Dbg.ads.db.com\lon-users-u\VF05_USERS01\hossja-2\config\AppData\Microsoft\Windows\Recent\...

The Case of the Slow Project File Opens (Cont)

- Second observation: Symantec A/V prescans entire file:



The Case of the Slow Project File Opens: Solved

- Recommendation 1: Move user profile AppData folders to local system
- Recommendation 2: Disable local scanning of files on network share since the server also has antivirus
- After recommendations followed, no more issues: problem solved

The Case of the Sysinternals-Blocking Malware

http://blogs.technet.com/b/markrussinovich/archive/2011/03/08/3392087.aspx

- Friend asked user to take a look at system suspected of being infected with malware
  - Boot and logons took a long time
  - Microsoft Security Essentials (MSE) malware scan would never complete
  - Nothing jumped out in Task Manager
- Tried running Sysinternals tools, but all exited immediately after starting:
  - Autoruns
  - Process Monitor
  - Process Explorer
  - Even Notepad opening a text file named “Process Explorer” would also terminate

The Case of the Sysinternals-Blocking Malware (Cont)

- Looking through Sysinternals suite, noticed Desktops utility
  - Hoped malware might not be smart enough to monitor additional desktops
- Sure enough, was able to launch Process Monitor and other tools:
  - Malware probably looks for tools in window titles
  - Window enumeration only returns windows of current desktop