Escaping The Sandbox

(Summer 2010)

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Who I am.

Stephen A. Ridley
Senior Security Researcher (Matasano)

- **Previously:** Senior Security Architect at McAfee, founding member of Security Architecture Group
- **Prior to that:** Researcher at leading Defense contractor. Directly supported U.S. Defense and Intelligence communities in realm of software exploitation and software reverse engineering

- Columnist for/interviewed by IT magazines (Wired, Ping!, HostingTech, Washington Post, etc.)
- Kenshoto DefCon CTF organizers for a few years
- Guest Lecturer/Instructor (New York University, Netherlands Forensics Institute, Department of Defense, Google, et al)
- **My Focus**: software reverse engineering, software development, software exploitation, software security, Kernels (Microsoft ones for now). Increasingly interested in embedded systems and mobile devices

What am I talkin' 'bout today?

★ **Sandboxing Overview (very brief ;-)**

- Goals, Sandbox Architecture (Chrome)

★ **Sandboxes from a User-space Perspective**

- Securable Objects and SID apertures
- Patches/Hooks/Interception
- user32 issues

★ **Sandboxes from a Kernel-space Perspective**

- Between User-space and Kernel-space
- Kernel supported "Quasi Securable Objects", Native API
- Job Objects handle the rest, or do they?

★ **Tools/Techniques/Demos**

- SandKit Toolkit (code injection, copymem, memdiff, hookfix, sa7shell, bincompare, dumptoken, tokenbrute, handlebrute)
- Using Sandbox PoC Project (from Google)
- Using kernel debugger while attacking Chrome
- Triggering Chrome Bugs and where to start

Presentation Focus

- ★ Sandbox implementations are (by their nature) strongly coupled to the Operating System

- ★ This presentation focuses on Microsoft Windows Operating Systems and the NT Kernel (XP and Vista)
  - **Side Note**: Check out OSX's DAC/Sandbox. ("man sandbox-exec", "ls /usr/share/sandbox") It's pretty awesome! Scheme-like rules sent to a DAC engine with a Scheme-like interpreter in the Kernel! Nice idea!
- ★ This presentation uses Google Chromium because it's the most popular of the Sandbox implementations.

- ★ Focus on blackbox/reversing approach to sandboxing technologies (less source source audit of IPC mechanisms, etc). For that approach see Azimuth Security's excellent "The Chrome Sandbox" series)

Sandboxing Overview

The Goal of the Sandbox

★ Localize the damage by “containing” potentially malicious code

★ Trapping malicious code is nuanced and tough but from a high level it consists mostly of:

- Locking down all IPC mechanisms
- Perform process monitoring
- Basically not trusting any code within the Sandbox to do anything on the system without it first being checked by some authority

Chromium Sandbox Architecture

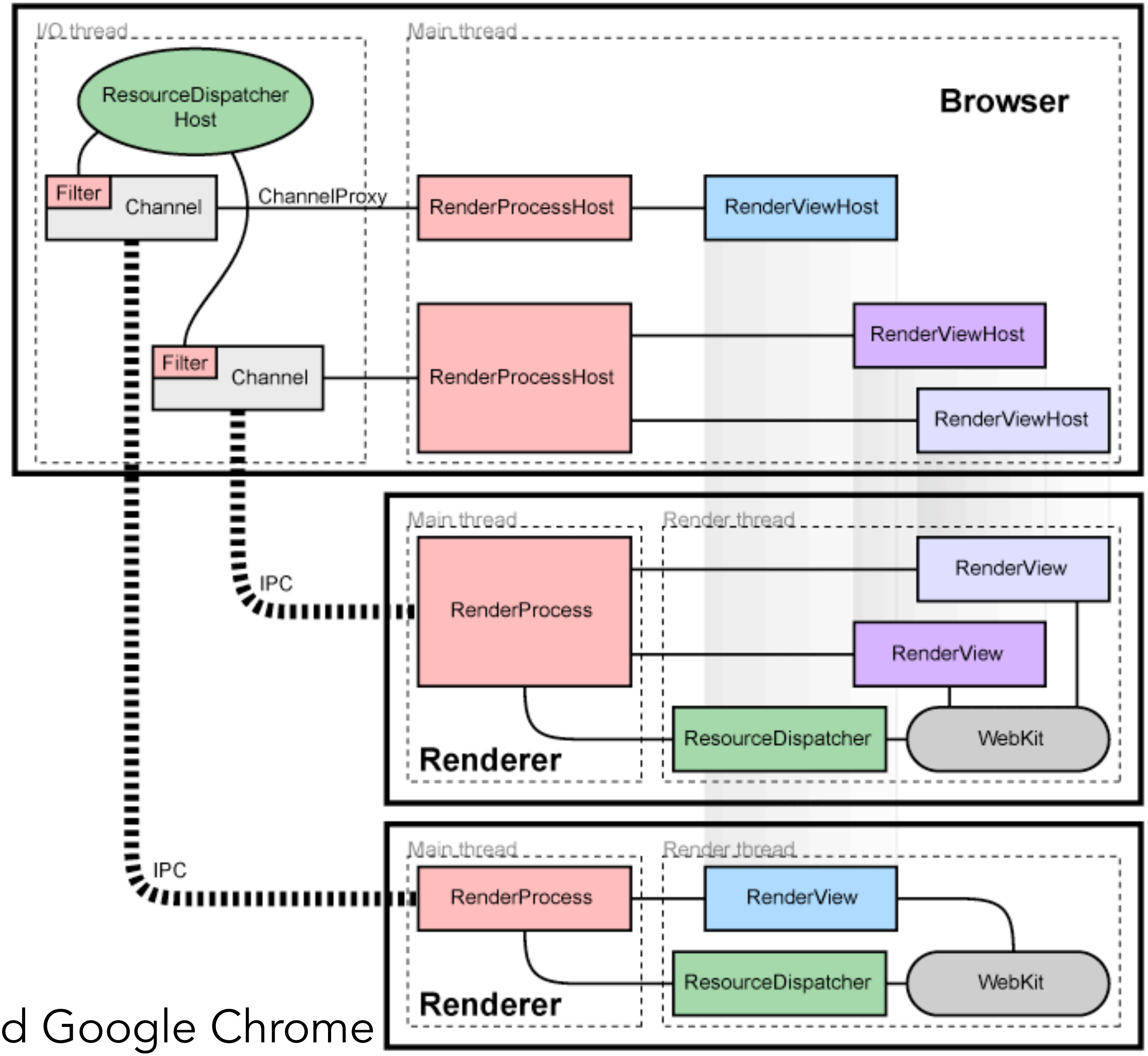
- A great number of resources currently exist on the architecture and design of sandboxes in general, especially for Google Chromium. Not going to echo-chamber.

- Mark Dowd and the team at Azimuth Security began releasing Sandboxing papers that happened to coincide with my talk and paper: http://blog.azimuthsecurity.com/2010/05/chrome-sandbox-part-1-of-3-overview.html

- Google Chrome Design Documents: http://www.chromium.org/developers/design-documents

- The Chromium Design Docs are all you really need, but other small bits can be gleaned from Infosec bloggers and research papers (Robert Hensing, David Leblanc, Nicolas Sylvain, and others). Not much *actual* code/tools/techniques/examples have been released though, this talk hopefully will help with this.

Chromium Sandbox Architecture



Credit: Gartner and Google Chrome

Locking down IPC and IO

- ★ The Operating System is what does all the “hard work” for permissions and restrictions. Developers don’t need to reinvent this technology these days.

- ★ In the NT Kernel this is handled by using the DACL system built into the **Object Manager** and **Security Reference Manager**

- ★ These two components of the NT kernel implement and enforce the permissions system for “NT Securable Objects” like:
  - Files
  - Processes
  - Shared Memory Regions
  - Lots more...

Locking down IPC and IO

- ★ IO and IPC on Windows is performed predominantly using these NT Objects. I really realized this more, the more kernel stuff I began doing.
- ★ "Almost everything in userspace is an NT Object, or is at some point supported by one."....but there are still gaps. "Quasi-securable Objects"
- ★ Most of the functionality for interfacing with/ manipulating these NT Objects is implemented within the Native API
    - Think: OpenFile, OpenProcess, CreateFile, CreateProcess, CreateThread, or basically anything in ntdll or kernel32)
- ★ There are some other public techniques for performing faux-IPC. (we will review these and some less popular ideas/techniques)

Sandboxes from a User-space Perspective

As malicious code, what would you try first?

- ★ Accessing Out of Proc COM Servers?
- ★ Accessing WMI Interfaces?
- ★ Writeable locations on the disk?
- ★ Injecting into Other processes (reading/writing other process memory)?
- ★ Loading Drivers?
- ★ Accessing LPC/RPC/LRPC endpoints?
- ★ Accessing NamedPipes?
- ★ Accessing RunAs Service?
- ★ sending User32 messages?
- ★ ...lots of other stuff?
- ★ **Let's See Why Most of this Won't Work!**

BLOCKED!

- ★ These things are all good places to start. In fact we will demonstrate a new tool in the SandKit that you can use to assist with these kinds of tests. In other implementations you will mostly likely find bugs here.
- ★ HOWEVER, virtually all of these operations under the hood are (or are supported by) Securable Objects which fall under the purview of the Object Manager and Security Reference Manager.
- ★ Therefore, the proper restrictions on security descriptors will kill access to these in one fell swoop!

As malicious code, what would you try first?

- ★ ~~Accessing Out of Proc COM Servers?~~ **COM is NamedPipes**
- ★ ~~Accessing WMI Interfaces?~~ **WMI is COM which is LPC/NamedPipes**
- ★ ~~Writeable locations on the disk?~~ **Handles and IO objects are securable.**
- ★ ~~Injecting into Other processes (reading/writing other process memory)?~~ **Processes/Threads/IO objects are securable.**
- ★ ~~Loading Drivers?~~ **SCManager is all LPC/NamedPipes also “Load Driver” token perm covers it**
- ★ ~~Accessing LPC/RPC/LRPC endpoints?~~ **LPC/LRPC/RPC sit on NamedPipes**
- ★ ~~Accessing NamedPipes?~~ **NamedPipes are obviously securable**
- ★ ~~Accessing RunAs Service?~~ **ShellExecuteA(“runas”) is LPC/NamedPipe to LSASS**
- ★ ~~sending User32 messages?~~ **User32 partitioned by “Desktop” and user32 handles are restricted by Job Object (XP) UAC (Vista)**

Bootstrapping the Sandbox

“The beginning is a very delicate time...”
Frank Herbert’s <u>Dune</u>

- ★ The Broker starts all the Sandbox processes.
- ★ The “Broker” process is the Overseer, he starts the “Sandbox” processes.
- ★ The Broker performs “privileged” actions on behalf of Sandbox processes via code hooks and IPC mechanisms.
- ★ Let’s review the steps the Broker goes through when bootstrapping the Sandbox.

Bootstrapping the Sandbox

1. Before spawning Sandbox, the Broker process creates a restricted token using: CreateRestrictedToken() with the 'SidsToRestrict' array populated.
2. The Broker uses CreateProcess() with the *fdwCreate* argument set to CREATE_SUSPENDED and the restricted token to start sandbox "frozen".
3. It is during this suspended time that the Broker then further restricts the Sandbox process by:
    1. Installing hooks (we will review these shortly)
    2. Performing some other setup

We'll see later that the Broker also continues to "debug" the Sandbox process, catching his exceptions! Annoying for your fuzzing huh? ;-)

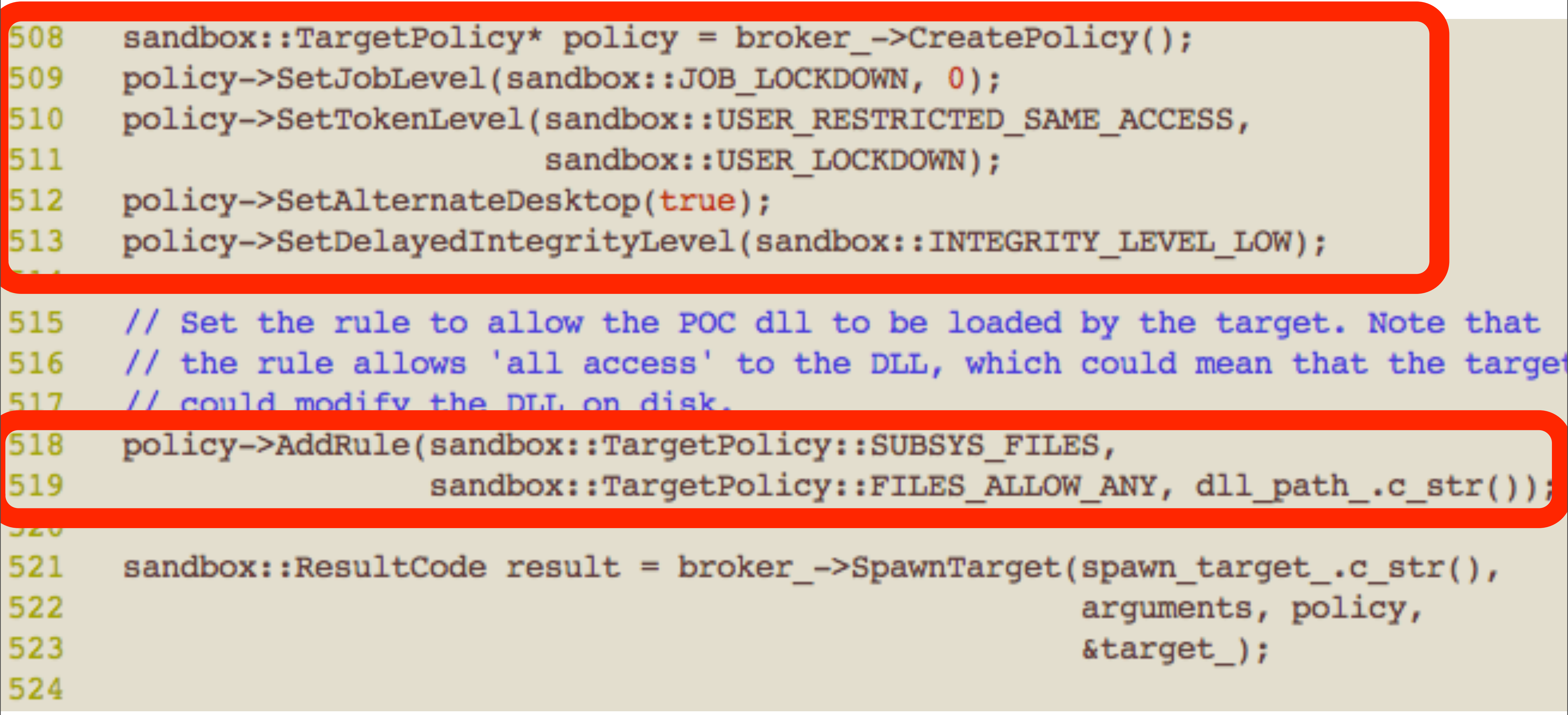
Bootstrapping the Sandbox

4. The Broker further adjusts the Sandbox's Token with AdjustTokenPrivileges()
5. The Broker places the Sandbox into a very restrictive Job Object by setting restrictive members of JOBOBJECT_BASIC_UI_RESTRICTIONS when calling SetInformationJobObject()
6. The Broker can then place the Sandbox into its own Desktop (depending on which "type" of Sandboxed process it is) if XP, or on Vista set low integrity token and use User Interface Privilege Isolation (UIPI which is just "UAC" stuff)
7. The Broker does other stuff I probably didn't notice (or am forgetting ;-) and then resumes the Sandbox's main thread.

Bootstrapping the Sandbox

- Example from “Sandbox PoC” in Chrome Source Code

(/home/chrome-svn/tarball/chromium/src/sandbox/sandbox_poc/main_ui_window.cc)



```
sandbox::TargetPolicy* policy = broker_->CreatePolicy();
policy->SetJobLevel(sandbox::JOB_LOCKDOWN, 0);
policy->SetTokenLevel(sandbox::USER_RESTRICTED_SAME_ACCESS,
                      sandbox::USER_LOCKDOWN);
policy->SetAlternateDesktop(true);
policy->SetDelayedIntegrityLevel(sandbox::INTEGRITY_LEVEL_LOW);

// Set the rule to allow the POC dll to be loaded by the target. Note that
// the rule allows 'all access' to the DLL, which could mean that the targe
// could modify the DLL on disk.
policy->AddRule(sandbox::TargetPolicy::SUBSYS_FILES,
                sandbox::TargetPolicy::FILES_ALLOW_ANY, dll_path_.c_str());

sandbox::ResultCode result = broker_->SpawnTarget(spawn_target_.c_str(),
                                                  arguments, policy,
                                                  &target_);

```

Restricted Token

★ The restricted token pretty much will handle restricting the vast majority (~95%) of the things malicious code will try to do:

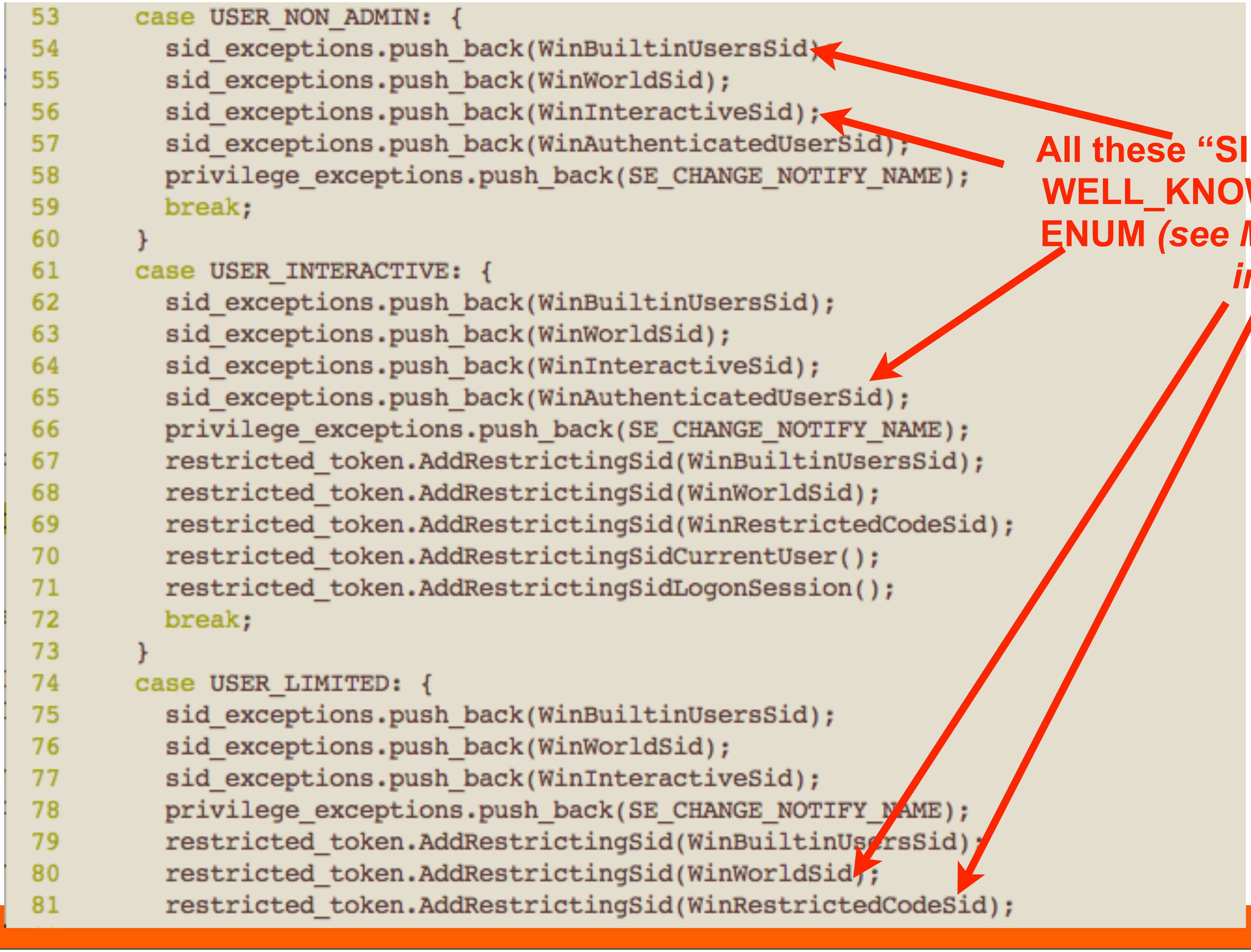
- COM Interfaces
- Files
- Processes
- Shared Memory Regions
- Named Pipes
- Load Drivers (access Drivers)
- LPC/LRPC endpoints

★ When implementing a sandbox however, this doesn’t mean all the work is done for you, you still have to build strong “filter” policies for the Policy Engine!

★ A hole in your SID filters and the whole sandbox falls apart!

Restricted Token ::CreateRestrictedToken()

/home/chrome-svn/tarball/chromium/src/sandbox/src/restricted_token_utils.cc



```
  case USER_NON_ADMIN: {
    sid_exceptions.push_back(WinBuiltinUsersSid);
    sid_exceptions.push_back(WinWorldSid);
    sid_exceptions.push_back(WinInteractiveSid);
    sid_exceptions.push_back(WinAuthenticatedUserSid);
    privilege_exceptions.push_back(SE_CHANGE_NOTIFY_NAME);
    break;
  }
  case USER_INTERACTIVE: {
    sid_exceptions.push_back(WinBuiltinUsersSid);
    sid_exceptions.push_back(WinWorldSid);
    sid_exceptions.push_back(WinInteractiveSid);
    sid_exceptions.push_back(WinAuthenticatedUserSid);
    privilege_exceptions.push_back(SE_CHANGE_NOTIFY_NAME);
    restricted_token.AddRestrictingSid(WinBuiltinUsersSid);
    restricted_token.AddRestrictingSid(WinWorldSid);
    restricted_token.AddRestrictingSid(WinRestrictedCodeSid);
    restricted_token.AddRestrictingSidCurrentUser();
    restricted_token.AddRestrictingSidLogonSession();
    break;
  }
  case USER_LIMITED: {
    sid_exceptions.push_back(WinBuiltinUsersSid);
    sid_exceptions.push_back(WinWorldSid);
    sid_exceptions.push_back(WinInteractiveSid);
    privilege_exceptions.push_back(SE_CHANGE_NOTIFY_NAME);
    restricted_token.AddRestrictingSid(WinBuiltinUsersSid);
    restricted_token.AddRestrictingSid(WinWorldSid);
    restricted_token.AddRestrictingSid(WinRestrictedCodeSid);
```

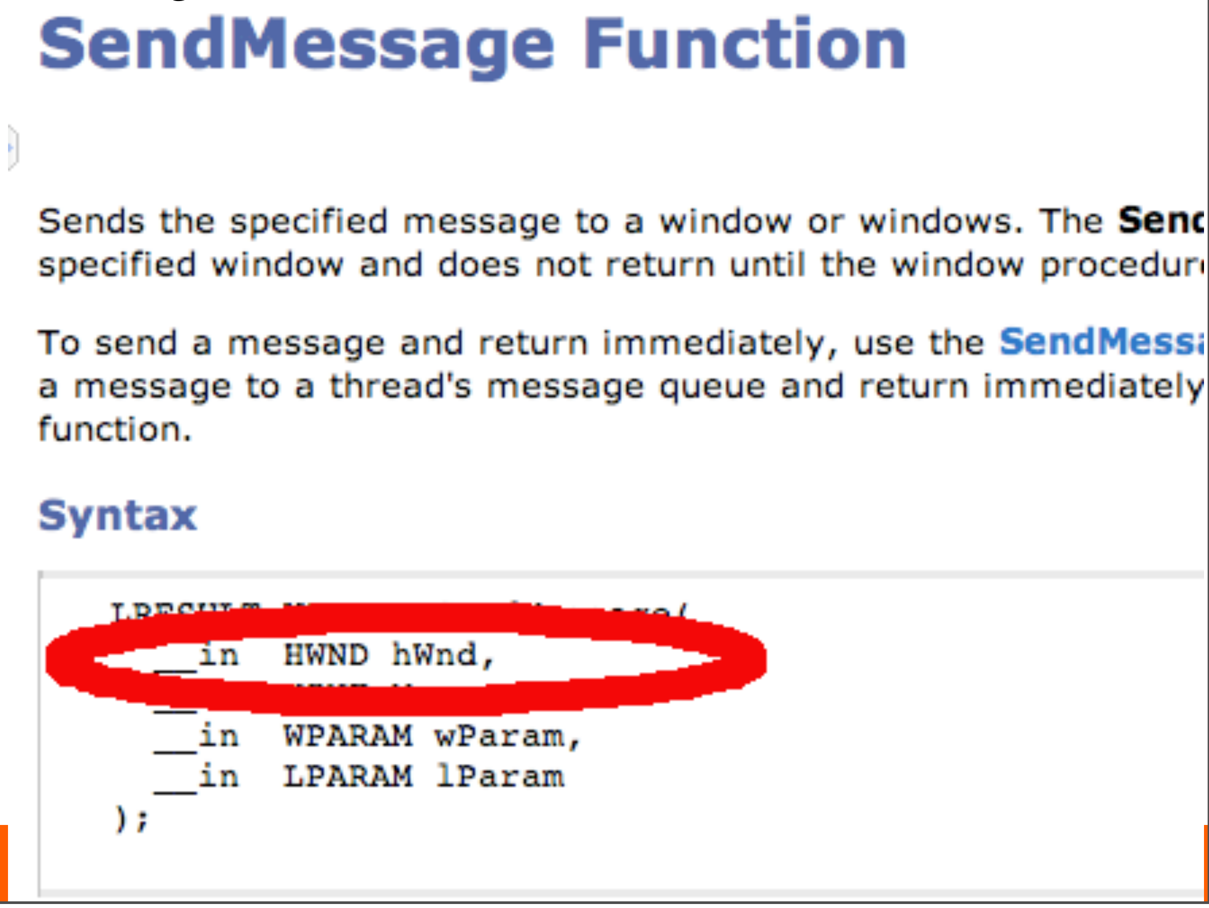
All these "SIDs" defined in: WELL_KNOWN_SID_TYPE ENUM *(see MSDN for more info)*

The Job Object: SetInformationJobObject()

- ★ The restrictions on the Job Object will generally handle restricting the “other” ~4.999% of things malicious code might try to do:
  - Accessing/Writing Clipboard (JOB_OBJECT_UILIMIT_READCLIPBOARD)
  - Switching/Accessing other Desktops (JOB_OBJECT_UILIMIT_DESKTOP)
  - Accessing other USER32 Handles (JOB_OBJECT_UILIMIT_HANDLES) This kills all user32 messaging basically and techniques: SetWindowsHookEx, OpenWindow(), PostMessage(), SendMessage(), PeekMessage())
- ★ The Job Object restrictions also breaks some less popular techniques:
  - SendMessageCallback()
  - GlobalAtom access (JOB_OBJECT_UILIMIT_GLOBALATOMS)
  - ChangeDisplaySettings() (**0-day ALERT!**) This was actually recently silently patched for an integer overflow for User32 WM_DEVICECHANGE messages! (XP all the way up to Vista current ;-) Yes, with this bug, a few weeks ago (May 2010) the right user32 window message could potentially get you ring0 code execution XP & Vista ;-)

The Separate Desktop

- Placing the sandboxed application on a separate desktop is mostly an “XP” (pre-UAC/UIPI technique)
- On XP, user32 functions take only “window handles” as arguments.
- Window Objects are grouped in “Desktops”, so intra-Desktop messaging by Objects, was not possible w/out switching.
- Vista UIPI/UAC fixes this



SendMessage Function

Sends the specified message to a window or windows. The **Send** specified window and does not return until the window procedur

To send a message and return immediately, use the **SendMess** a message to a thread's message queue and return immediately function.

Syntax

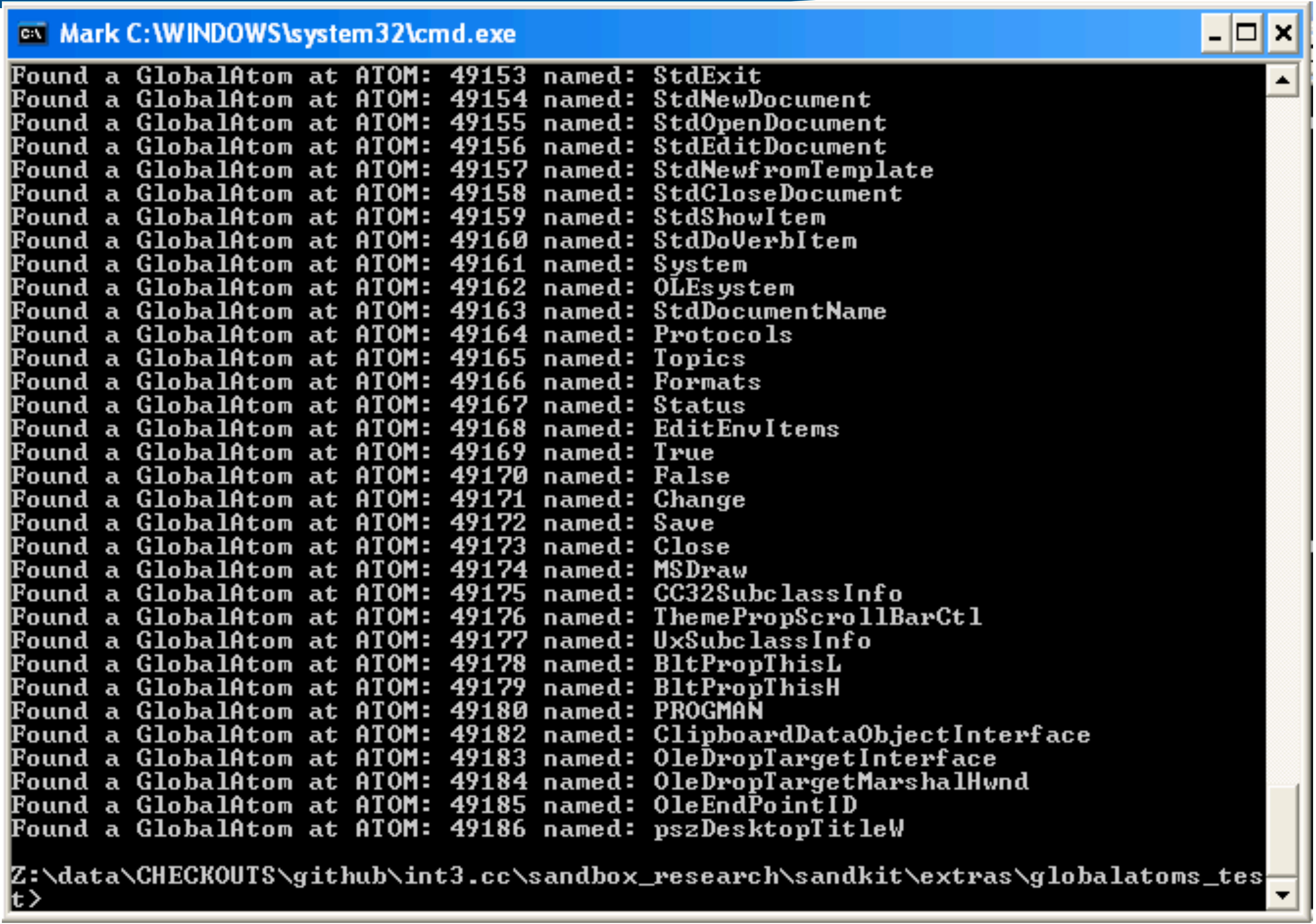
```
LRESULT WINAPI SendMessage(
    __in  HWND hWnd,
    __in  UINT Msg,
    __in  WPARAM wParam,
    __in  LPARAM lParam
);
```

Atom Tables & GlobalAtoms

- What is the deal with Atom Tables? (InitAtom(), AddAtom(), FindAtom(), etc)
- Designed originally to support Microsoft DDE (Dynamic Data Exchange).
- Essentially is a “kernel supported” key/value storage mechanism for simple primitives (strings and integers)
- Atom Tables are generally stored on “per process” basis But you can create “Global Atoms” which are accessible by any process. (GlobalAddAtom(), GlobalFindAtom(), etc)

Note: Sample code for Atoms included in SandKit

GlobalAtoms: (excerpt from Sandkit tool)



```
Found a GlobalAtom at ATOM: 49153 named: StdExit
Found a GlobalAtom at ATOM: 49154 named: StdNewDocument
Found a GlobalAtom at ATOM: 49155 named: StdOpenDocument
Found a GlobalAtom at ATOM: 49156 named: StdEditDocument
Found a GlobalAtom at ATOM: 49157 named: StdNewfromTemplate
Found a GlobalAtom at ATOM: 49158 named: StdCloseDocument
Found a GlobalAtom at ATOM: 49159 named: StdShowItem
Found a GlobalAtom at ATOM: 49160 named: StdDoVerbItem
Found a GlobalAtom at ATOM: 49161 named: System
Found a GlobalAtom at ATOM: 49162 named: OLEsystem
Found a GlobalAtom at ATOM: 49163 named: StdDocumentName
Found a GlobalAtom at ATOM: 49164 named: Protocols
Found a GlobalAtom at ATOM: 49165 named: Topics
Found a GlobalAtom at ATOM: 49166 named: Formats
Found a GlobalAtom at ATOM: 49167 named: Status
Found a GlobalAtom at ATOM: 49168 named: EditEnvItems
Found a GlobalAtom at ATOM: 49169 named: True
Found a GlobalAtom at ATOM: 49170 named: False
Found a GlobalAtom at ATOM: 49171 named: Change
Found a GlobalAtom at ATOM: 49172 named: Save
Found a GlobalAtom at ATOM: 49173 named: Close
Found a GlobalAtom at ATOM: 49174 named: MSDraw
Found a GlobalAtom at ATOM: 49175 named: CC32SubclassInfo
Found a GlobalAtom at ATOM: 49176 named: ThemePropScrollBarCtl
Found a GlobalAtom at ATOM: 49177 named: UxSubclassInfo
Found a GlobalAtom at ATOM: 49178 named: BltPropThisL
Found a GlobalAtom at ATOM: 49179 named: BltPropThisH
Found a GlobalAtom at ATOM: 49180 named: PROGMAN
Found a GlobalAtom at ATOM: 49182 named: ClipboardDataObjectInterface
Found a GlobalAtom at ATOM: 49183 named: OleDropTargetInterface
Found a GlobalAtom at ATOM: 49184 named: OleDropTargetMarshalHwnd
Found a GlobalAtom at ATOM: 49185 named: OleEndPointID
Found a GlobalAtom at ATOM: 49186 named: pszDesktopTitleW

Z:\data\CHECKOUTS\github\int3.cc\sandbox_research\sandkit\extras\globalatoms_tes
t>
```

GlobalAtoms

- ★ GlobalAtoms can thus be used a rudimentary form of IPC.
- ★ MANY standard Microsoft APIs and DLLs use Atom Tables.
- ★ How many Third Party applications misuse them?
- ★ Misuse of AtomTables is like the misuse of User32 WM_USER: Insecure usage happens when developers use it as a form of "quick and dirty" IPC.

The Lesson GlobalAtoms teach us:

- ★ While GlobalAtoms are a known technique with a known mitigation, the "pattern" is a lesson:
- ★ GlobalAtoms are essentially just Kernel/Native API supported storage mechanisms.
- ★ Are there more?
- ★ If so, they can probably be found anywhere there is something abstracted to be accessed via a "descriptor" from userland functions.
- ★ Places to start?
  - NTOSKRNL export "names" list in IDA,
  - MSUICHE's MSDN (http://msdn.msuiche.net),
  - ReactOS, Third-Party Drivers
  - Ionescu's "Native NT Toolkit code"
  - Gary Nebbett's Native API Reference
  - Break on ObCreateObject() and see who dynamically creates objects.

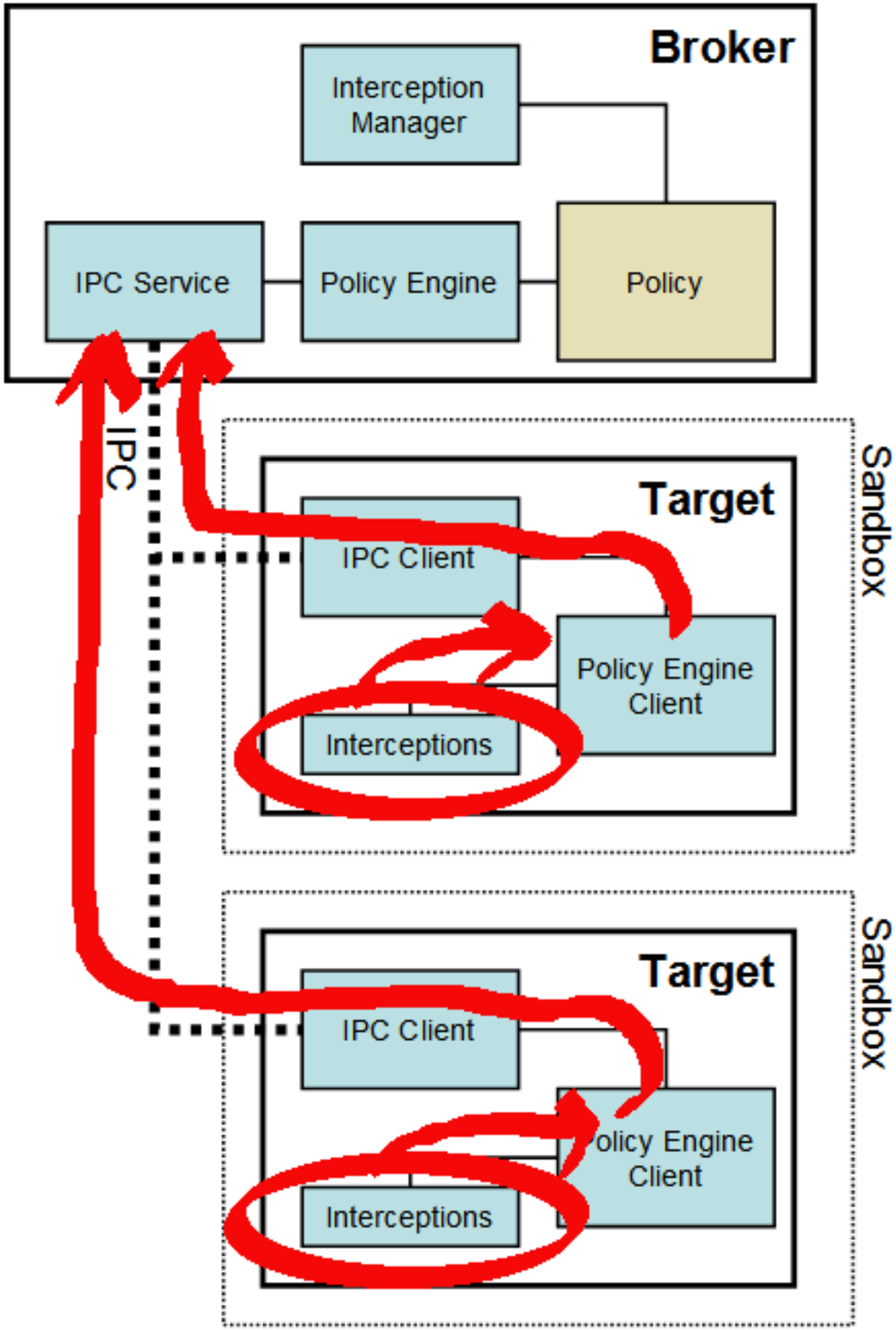
The Hooks: Call Interceptions

"- my one's and my two's got your whole town shook;
You betta listen to your corner, and watch for the hook!"

--Cool Breeze/Goodie Mob/Outkast

"Watch For the Hook"

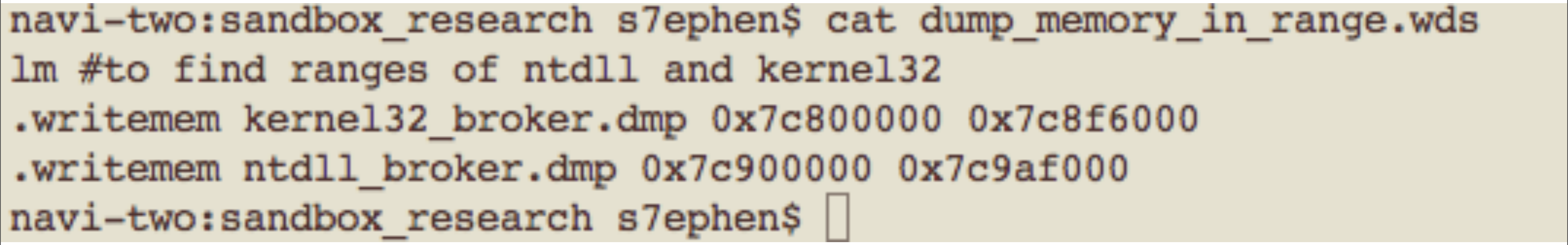
- ★ Intended as a mechanism to assist the Broker/ Sandbox Policy Engine **NOT** an enforcement mechanism itself (so they say).
- ★ In Chromium developer parlance the act of calling into the Broker via IPC mechanisms is called a "CrossCall".
- ★ All library hooks generally reroute to stubs that ultimately perform CrossCalls to the Broker
- ★ The code responsible for "interceptions" is implemented in the Interception Manager


Broker
Interception Manager
IPC Service
Policy Engine
Policy
IPC
Target
IPC Client
Policy Engine Client
Interceptions
Sandbox
Target
IPC Client
Policy Engine Client
Interceptions
Sandbox

Identifying Hooks

- Finding them is easy manually, but SandKit has tools to help you do it automated. “memdiff” in SandKit will compare the same region of memory in two separate processes and log differences.

- Windbg .writemem command and simple Python/Ruby/whatever script can do this as well. Something like the following (in both the sandbox and broker Windbg sessions):

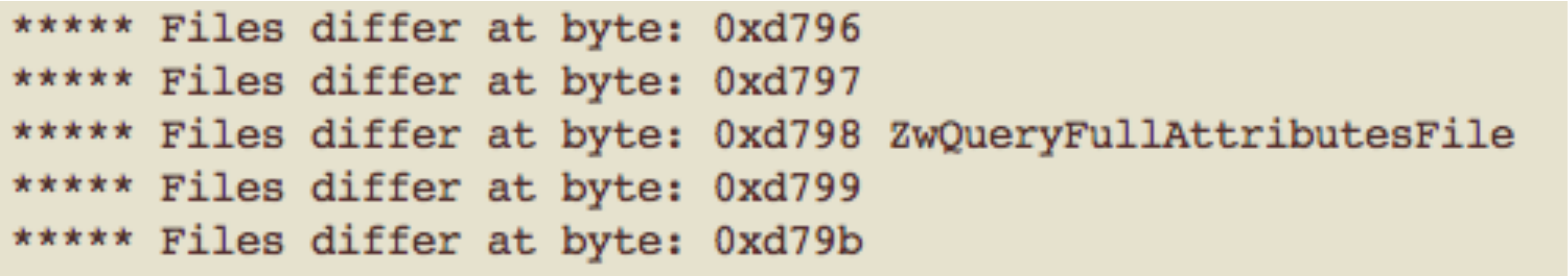


```
navi-two:sandbox_research s7ephen$ cat dump_memory_in_range.wds
lm #to find ranges of ntdll and kernel32
.writemem kernel32_broker.dmp 0x7c800000 0x7c8f6000
.writemem ntdll_broker.dmp 0x7c900000 0x7c9af000
navi-two:sandbox_research s7ephen$ 
```

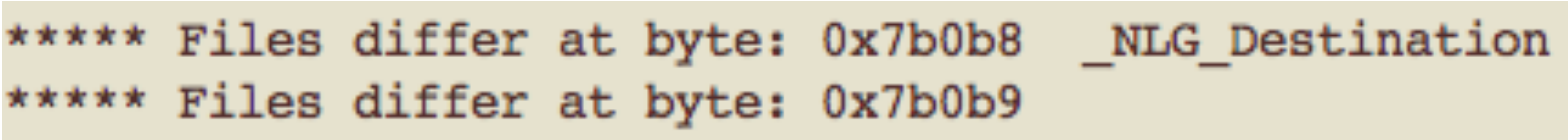
After diffing native library dumps you'll find hooks like:

From NTDLL:

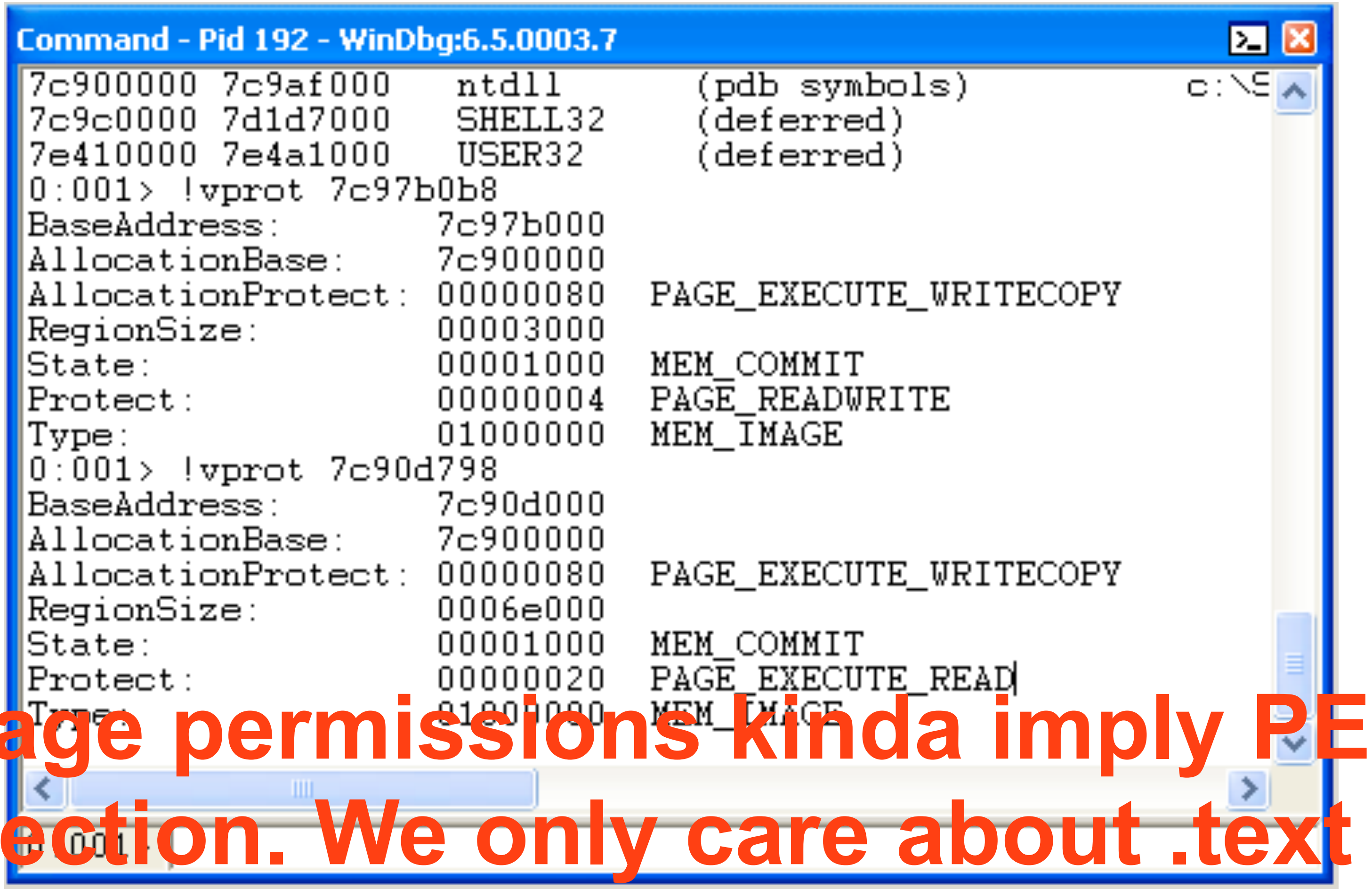
- ZwCreateFile()
- NtOpenFile()
- ZwOpenProcess()
- ZwOpenProcessToken()
- ZwOpenProcessTokenEx()
- NtOpenThread()
- ZwOpenThreadToken()
- NtOpenThreadTokenEx()
- ZwQueryAttributesFile()
- ZwQueryFullAttributesFile()
- NtSetInformationFile()
- many many more



```
***** Files differ at byte: 0xd796
***** Files differ at byte: 0xd797
***** Files differ at byte: 0xd798 ZwQueryFullAttributesFile
***** Files differ at byte: 0xd799
***** Files differ at byte: 0xd79b
```



```
***** Files differ at byte: 0x7b0b8  _NLG_Destination
***** Files differ at byte: 0x7b0b9
```



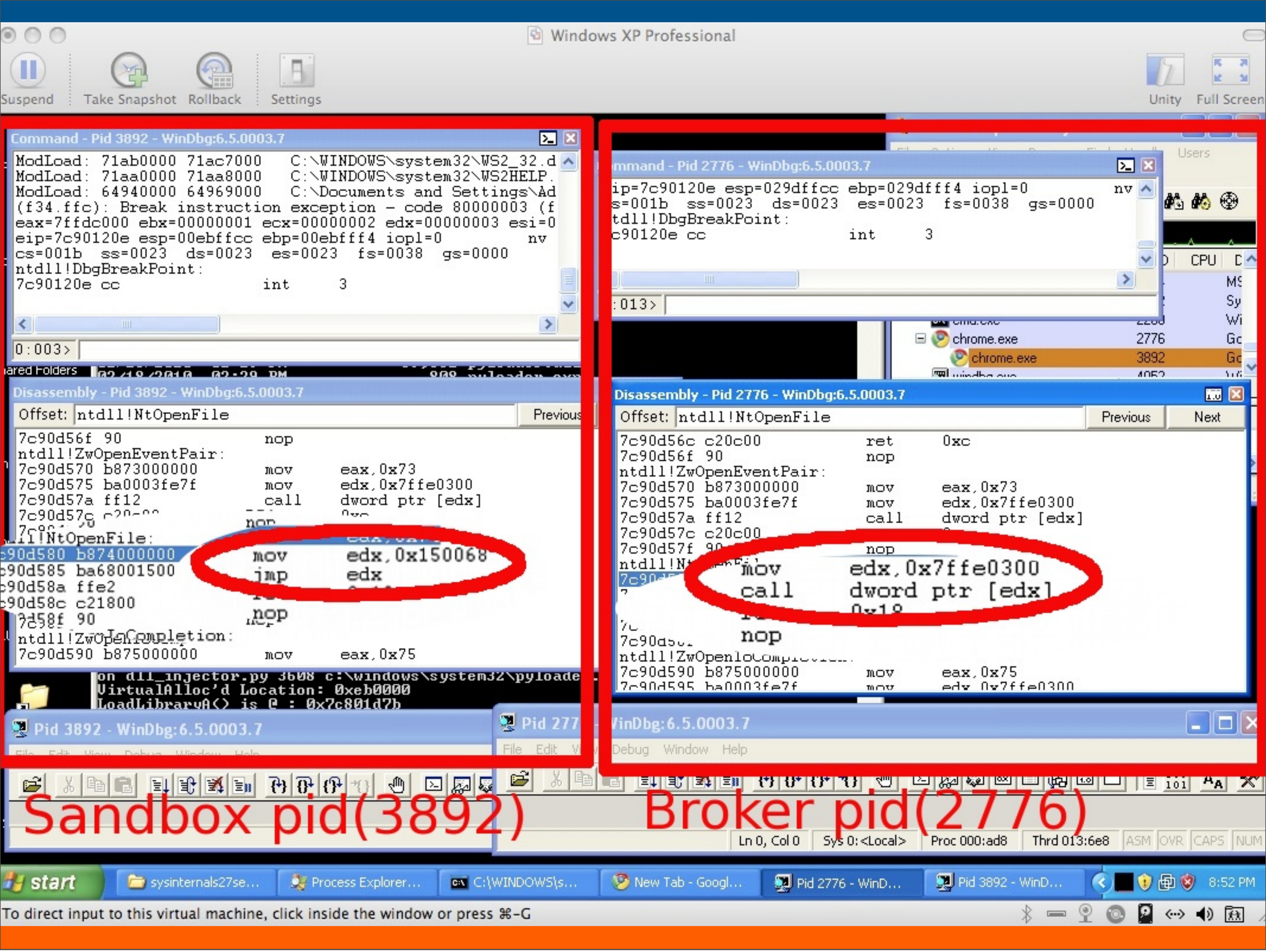
Command - Pid 192 - WinDbg:6.5.0003.7

```
7c900000 7c9af000   ntdll      (pdb symbols)          c:\S
7c9c0000 7d1d7000   SHELL32    (deferred)
7e410000 7e4a1000   USER32     (deferred)
0:001> !vprot 7c97b0b8
BaseAddress:       7c97b000
AllocationBase:    7c900000
AllocationProtect: 00000080  PAGE_EXECUTE_WRITECOPY
RegionSize:        00003000
State:             00001000  MEM_COMMIT
Protect:           00000004  PAGE_READWRITE
Type:              01000000  MEM_IMAGE
0:001> !vprot 7c90d798
BaseAddress:       7c90d000
AllocationBase:    7c900000
AllocationProtect: 00000080  PAGE_EXECUTE_WRITECOPY
RegionSize:        0006e000
State:             00001000  MEM_COMMIT
Protect:           00000020  PAGE_EXECUTE_READ
Type:              01000000  MEM_IMAGE

0:001>
```

Page permissions kinda imply PE section. We only care about .text

Many other libraries are hooked as well.


Windows XP Professional
Suspend
Take Snapshot
Rollback
Settings
Unity
Full Screen
Command - Pid 3892 - WinDbg:6.5.0003.7
Disassembly - Pid 3892 - WinDbg:6.5.0003.7
Offset:
Previous
Pid 3892 - WinDbg:6.5.0003.7
File Edit View Debug Window Help
mmand - Pid 2776 - WinDbg:6.5.0003.7
Disassembly - Pid 2776 - WinDbg:6.5.0003.7
Next
Pid 277 WinDbg:6.5.0003.7
Users
CPU
chrome.exe 2776
chrome.exe 3892
start
sysinternals27se...
Process Explorer...
C:\WINDOWS\s...
New Tab - Googl...
Pid 2776 - WinD...
Pid 3892 - WinD...
8:52 PM
To direct input to this virtual machine, click inside the window or press ⌘-G

Command - Pid 3892:

```
ModLoad: 71ab0000 71ac7000   C:\WINDOWS\system32\WS2_32.d
ModLoad: 71aa0000 71aa8000   C:\WINDOWS\system32\WS2HELP.
ModLoad: 64940000 64969000   C:\Documents and Settings\Ad
(f34.ffc): Break instruction exception - code 80000003 (f
eax=7ffdc000 ebx=00000001 ecx=00000002 edx=00000003 esi=0
eip=7c90120e esp=00ebffcc ebp=00ebfff4 iopl=0         nv
cs=001b  ss=0023  ds=0023  es=0023  fs=0038  gs=0000
ntdll!DbgBreakPoint:
7c90120e cc              int     3
0:003>
```

Disassembly - Pid 3892, Offset: ntdll!NtOpenFile

```
7c90d56f 90              nop
ntdll!ZwOpenEventPair:
7c90d570 b873000000      mov     eax,0x73
7c90d575 ba0003fe7f      mov     edx,0x7ffe0300
7c90d57a ff12            call    dword ptr [edx]
7c90d57c c20c00
ntdll!NtOpenFile:
7c90d580 b874000000
7c90d585 ba68001500      mov     edx,0x150068
7c90d58a ffe2            jmp     edx
7c90d58c c21800
7c90d58f 90              nop
ntdll!ZwOpenIoCompletion:
7c90d590 b875000000      mov     eax,0x75
```

```
on dll_injector.py 3608 c:\windows\system32\pyloade
VirtualAlloc'd Location: 0xeb0000
LoadLibraryA() is @ : 0x7c801d7b
```

Command - Pid 2776:

```
ip=7c90120e esp=029dffcc ebp=029dfff4 iopl=0         nv
s=001b  ss=0023  ds=0023  es=0023  fs=0038  gs=0000
tdll!DbgBreakPoint:
c90120e cc              int     3
:013>
```

Disassembly - Pid 2776, Offset: ntdll!NtOpenFile

```
7c90d56c c20c00          ret     0xc
7c90d56f 90              nop
ntdll!ZwOpenEventPair:
7c90d570 b873000000      mov     eax,0x73
7c90d575 ba0003fe7f      mov     edx,0x7ffe0300
7c90d57a ff12            call    dword ptr [edx]
7c90d57c c20c00
7c90d57f 90              nop
ntdll!NtOpenFile:
                         mov     edx,0x7ffe0300
                         call    dword ptr [edx]
                         nop
ntdll!ZwOpenIoCompletion:
7c90d590 b875000000      mov     eax,0x75
7c90d595 ba0003fe7f      mov     edx,0x7ffe0300
```

Ln 0, Col 0   Sys 0:<Local>   Proc 000:ad8   Thrd 013:6e8   ASM   OVR   CAPS   NUM

Sandbox pid(3892)

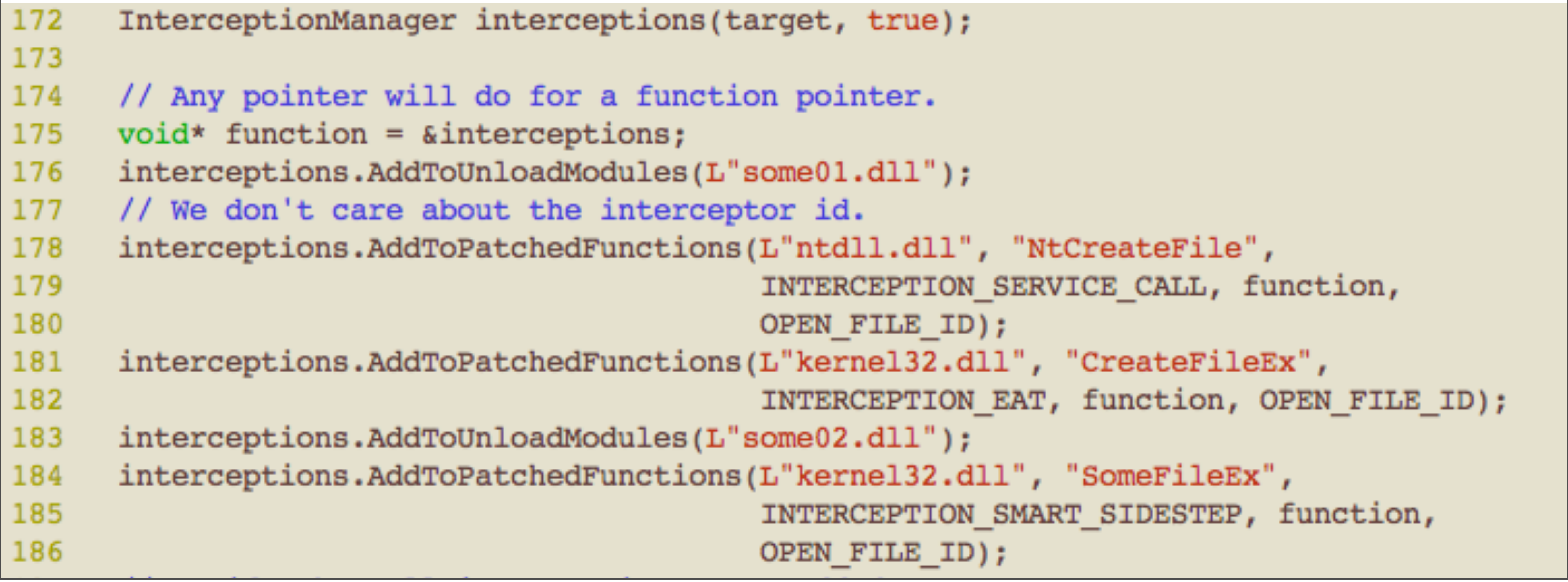
Broker pid(2776)

Thursday, July 1, 2010

The Hooks: In the source.

- Although the Chome Sandbox source (as a framework) is BSD licensed and open, the policies and rules used in the Chrome distribution remain “closed”.
- This is particularly evident when looking through source code for where hooks/interceptions get installed: The only use of the Interception Manager is some of the test code!

/home/chrome-svn/tarball/chromium/src/sandbox/src/interception_unittest.cc



```
  InterceptionManager interceptions(target, true);

  // Any pointer will do for a function pointer.
  void* function = &interceptions;
  interceptions.AddToUnloadModules(L"some01.dll");
  // We don't care about the interceptor id.
  interceptions.AddToPatchedFunctions(L"ntdll.dll", "NtCreateFile",
                                      INTERCEPTION_SERVICE_CALL, function,
                                      OPEN_FILE_ID);
  interceptions.AddToPatchedFunctions(L"kernel32.dll", "CreateFileEx",
                                      INTERCEPTION_EAT, function, OPEN_FILE_ID);
  interceptions.AddToUnloadModules(L"some02.dll");
  interceptions.AddToPatchedFunctions(L"kernel32.dll", "SomeFileEx",
                                      INTERCEPTION_SMART_SIDESTEP, function,
                                      OPEN_FILE_ID);
```

TANGENT: The Hook Catch22

★ Google Chromium Team has long asserted that hooks themselves are not to be relied upon a security enforcement mechanism. This shows they "get it". Hooks can be unhooked.

★ **However** one thing to note is the effectiveness of the "VirtualProtect()/WriteProcessMemory() hook Catch 22" which is:

Malicious code executing in the sandbox would have to use GetCurrentProcess()/VirtualProtect()/WriteProcessMemory() to "unhook".

What if these functions are already hooked? In my opinion, this might be a significant hurdle to deter most exploit developers.

Finding Hooks Via Call Traces

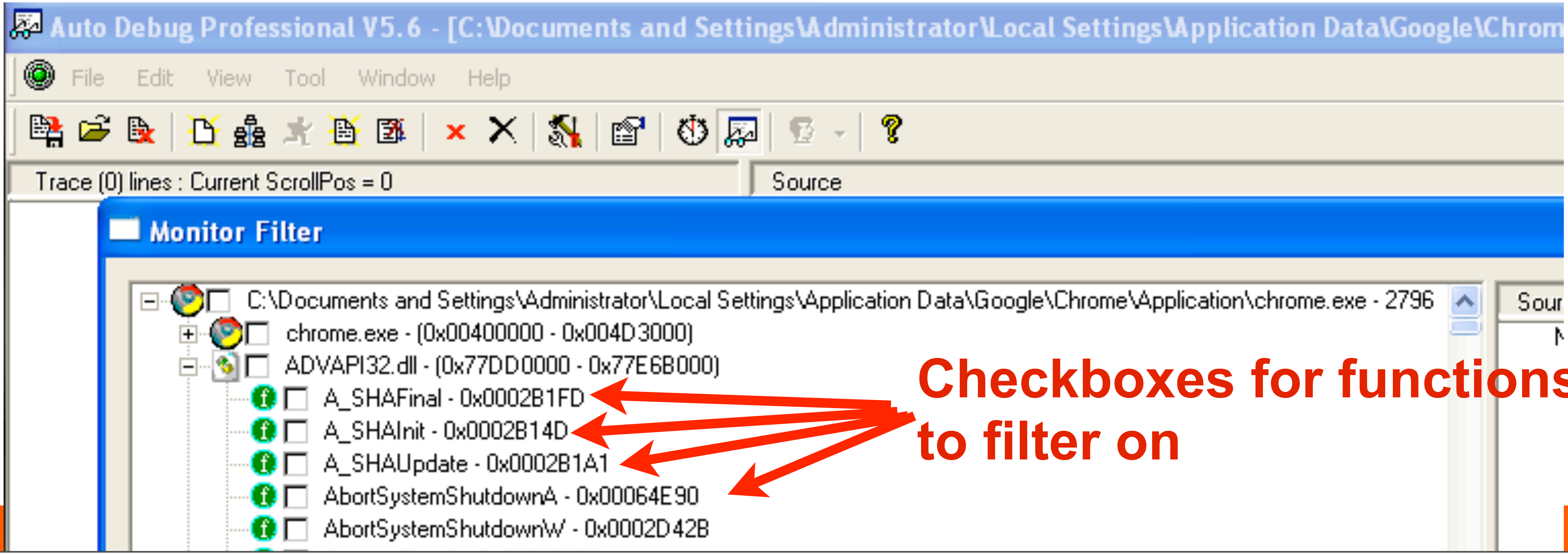
- ★ Although more annoying to do, you can find hooks using call tracing.
- ★ I do my kernel call-tracing using custom tools or in Windbg:

```
bp /p <cid of target> kernel32!CreateFileW "du poi(@esp+4);.process;k;g"
```

Alternatively for Win7 targets you might have to: .process /I /r <cid of target> THEN

```
bp kernel32!CreateFileW "du poi(@esp+4);.process;k;g"
```

- ★ If you are in user-space and want a "point and click" call-tracer, I suggest the surprisingly unpopular but extremely powerful: **AutoDebugPro**



Auto Debug Professional V5.6 - [C:\Documents and Settings\Administrator\Local Settings\Application Data\Google\Chrom

Trace (0) lines : Current ScrollPos = 0

```
⊟ □ C:\Documents and Settings\Administrator\Local Settings\Application Data\Google\Chrome\Application\chrome.exe - 2796
  ⊞ □ chrome.exe - (0x00400000 - 0x004D3000)
  ⊟ □ ADVAPI32.dll - (0x77DD0000 - 0x77E6B000)
      □ A_SHAFinal - 0x0002B1FD
      □ A_SHAInit - 0x0002B14D
      □ A_SHAUpdate - 0x0002B1A1
      □ AbortSystemShutdownA - 0x00064E90
      □ AbortSystemShutdownW - 0x0002D42B
```

Checkboxes for functions to filter on

Thursday, July 1, 2010

Moving closer to kernel/user gap.

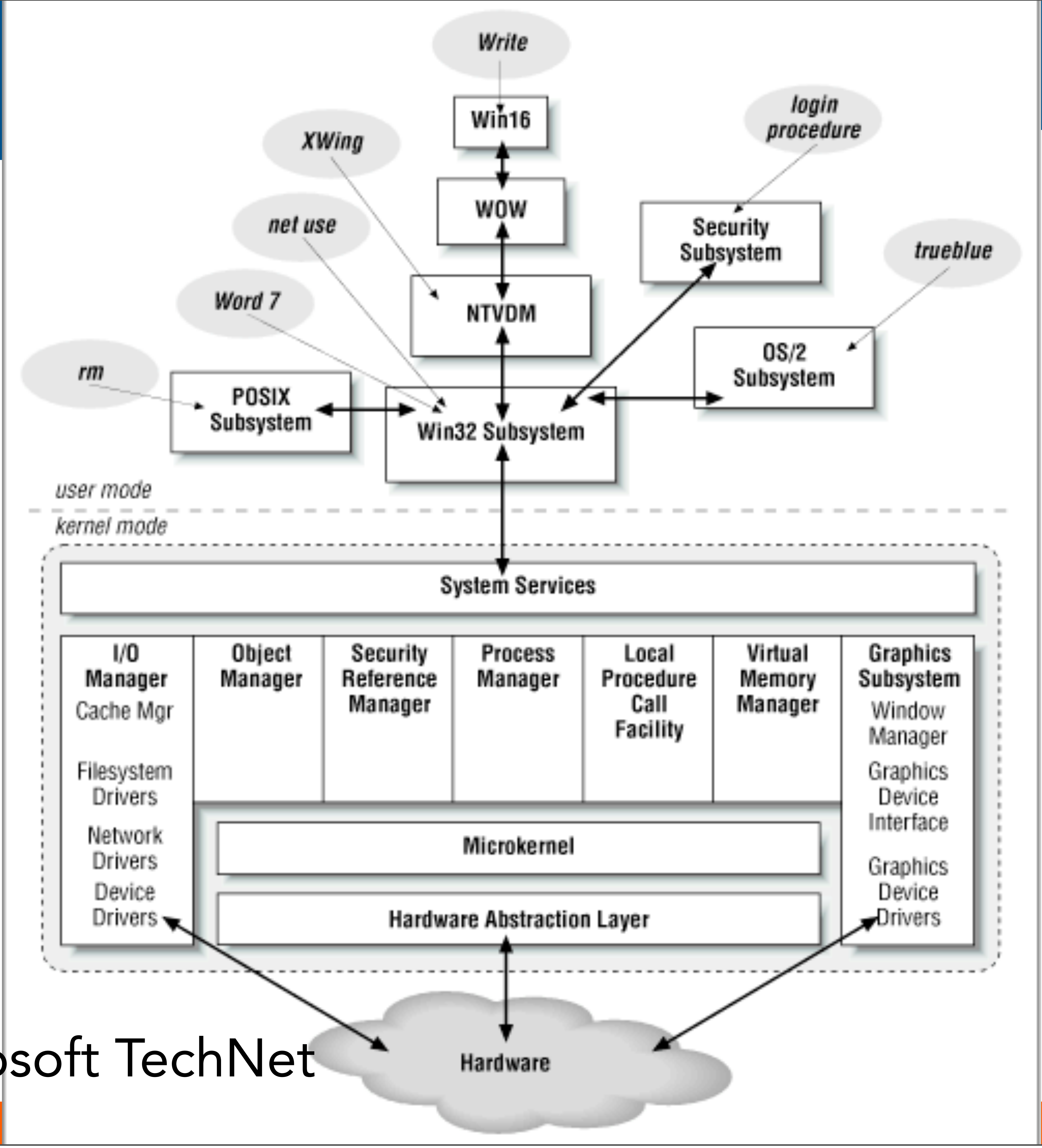
- ★ As we tunnel down to observe the Native API hooks put in place by the Broker we see that many of these are the Zw* Nt*
- ★ These are obviously the functions which are at the "edge of the precipice" between userland and kernel, one or two steps away from SysEnter/SysCall/INT 2e/call gate/etc
- ★ This is where things get interesting and is perfect segue into how we can investigate Sandboxes from up in the Kernel.

(Kernel space is so much more relaxing. Its"quieter".)

Sandboxes from a Kernel-space Perspective

Why Look at Sandboxes from Kernel?

- ★ Perhaps investigating the relationship between Userspace/Kernelspace will reveal new attack surface.
- ★ It’s so much “quieter” in the Kernel. It is a nice reprieve from the hustle and bustle of User-space.
- ★ More control: Pause execution and the whole box freezes. This means the Broker **AND** the Sandbox, no loss of “sync”.
- ★ Windbg Kernel Debugger (Kd) has commands we can’t use from User-space.
- ★ Virtually everything on Windows is performed predominantly using NT Objects, all inspectable from Kd.



(credit) Microsoft TechNet

Kernel Components (refresher!)

- ★ Object Manager (OB)
- ★ Security Reference Monitor (SE)
- ★ Process/Thread Management (PS)
- ★ Memory Manager (MM)
- ★ Cache Manager (CACHE)
- ★ Scheduler (KE)
- ★ I/O Manager, PnP, power, GUI (IO)
- ★ Devices, FS Volumes, Net (DRIVERS)
- ★ Lightweight Procedure Calls (LPC)
- ★ Hardware Abstraction Layer (HAL)
- ★ Executive Functions (EX)
- ★ Run-Time Library (RTL)
- ★ Registry/Consistent Configuration (CONFIG)

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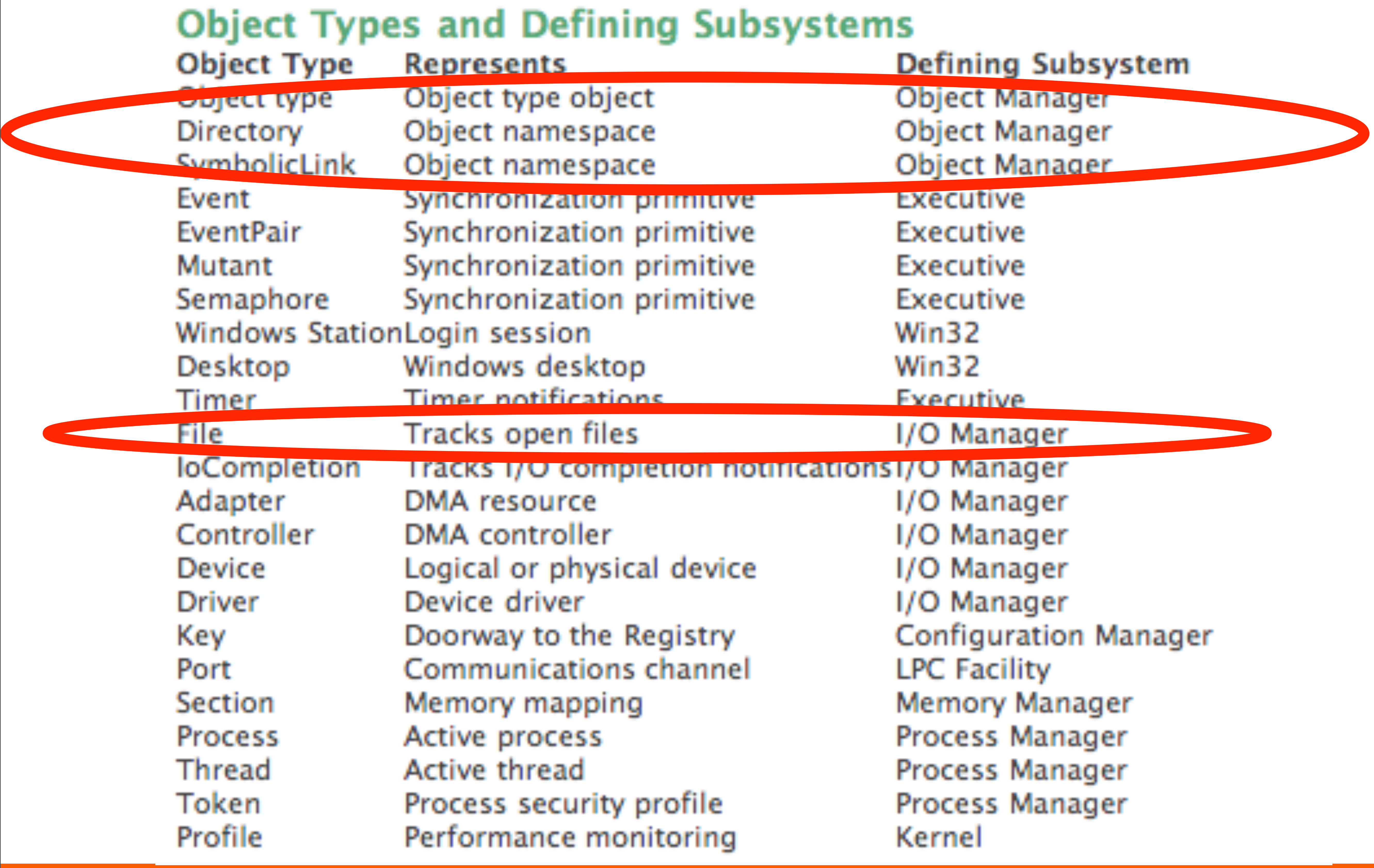
- Registry/Consistent Configuration (CONFIG)

For Sandboxing technologies, these are mostly what we care about.

Here’s why OB/SE/IO matter most:



Object Types and Defining Subsystems

Object Type	Represents	Defining Subsystem
Object type	Object type object	Object Manager
Directory	Object namespace	Object Manager
SymbolicLink	Object namespace	Object Manager
Event	Synchronization primitive	Executive
EventPair	Synchronization primitive	Executive
Mutant	Synchronization primitive	Executive
Semaphore	Synchronization primitive	Executive
Windows Station	Login session	Win32
Desktop	Windows desktop	Win32
Timer	Timer notifications	Executive
File	Tracks open files	I/O Manager
IoCompletion	Tracks I/O completion notifications	I/O Manager
Adapter	DMA resource	I/O Manager
Controller	DMA controller	I/O Manager
Device	Logical or physical device	I/O Manager
Driver	Device driver	I/O Manager
Key	Doorway to the Registry	Configuration Manager
Port	Communications channel	LPC Facility
Section	Memory mapping	Memory Manager
Process	Active process	Process Manager
Thread	Active thread	Process Manager
Token	Process security profile	Process Manager
Profile	Performance monitoring	Kernel

The NT Object Manager (OB):

- ★ Provides underlying NT namespace
- ★ Unifies kernel data structure referencing
- ★ Unifies user-mode referencing via handles/descriptors
- ★ Central facility for security protection Provides device & I/O support
- ★ Important Note: Objects are extensible. You can build your own based on the primitives. Many kernel code does just this dynamically.

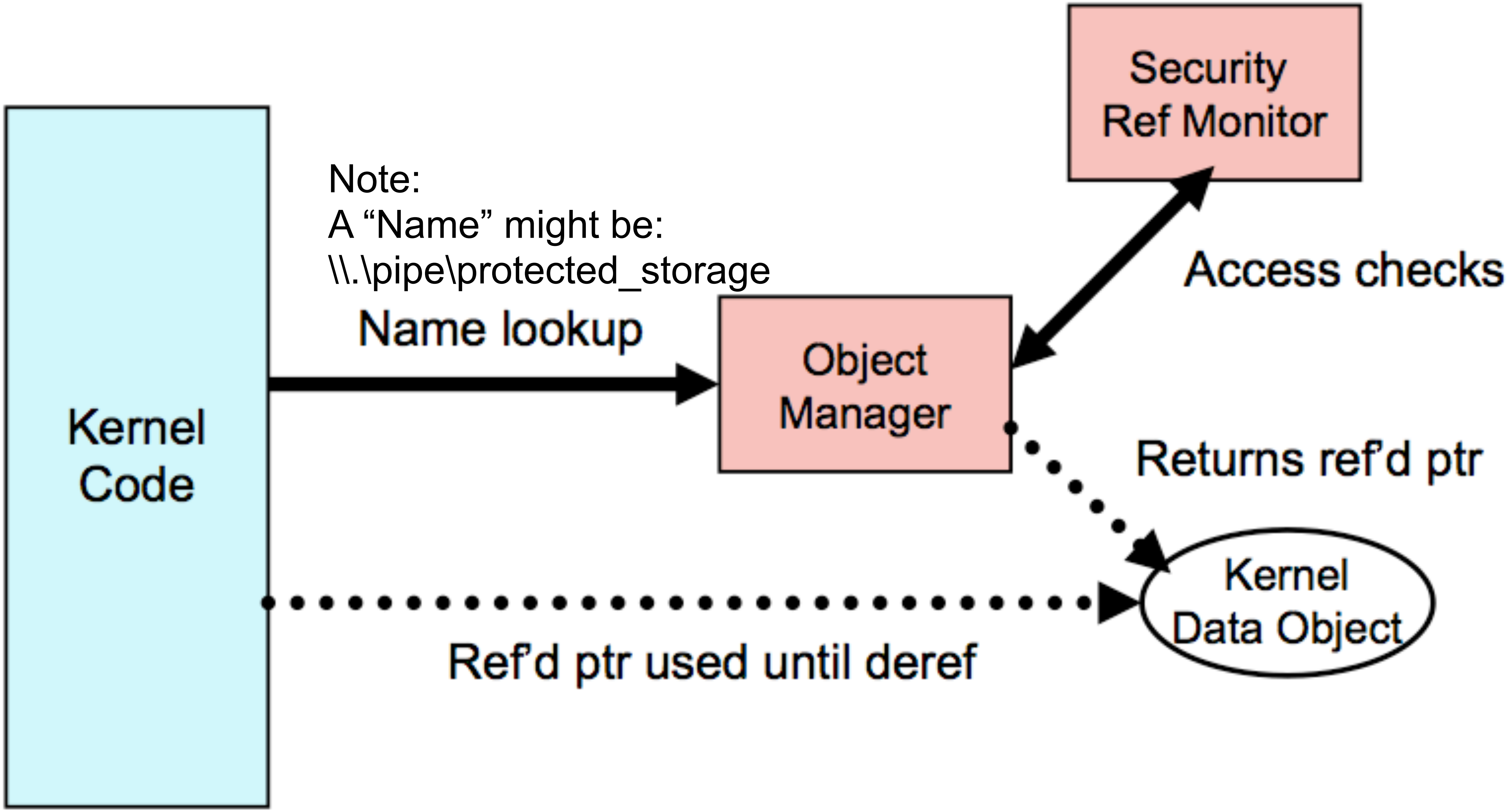
credit: Dave Probert, Ph.D (Singapore 2006), Microsoft Corporation 2006

The Security Reference Monitor (SE):

- Based on discretionary access controls
- Single module for access checks (e.g. SeAccessCheck())
- Implements Security Descriptors, System and Discretionary ACLs, Privileges, and Tokens
- Collaborates with Local Security Authority Service (LSASS) to obtain authenticated credentials
- Provides auditing and fulfills other Common Criteria requirements

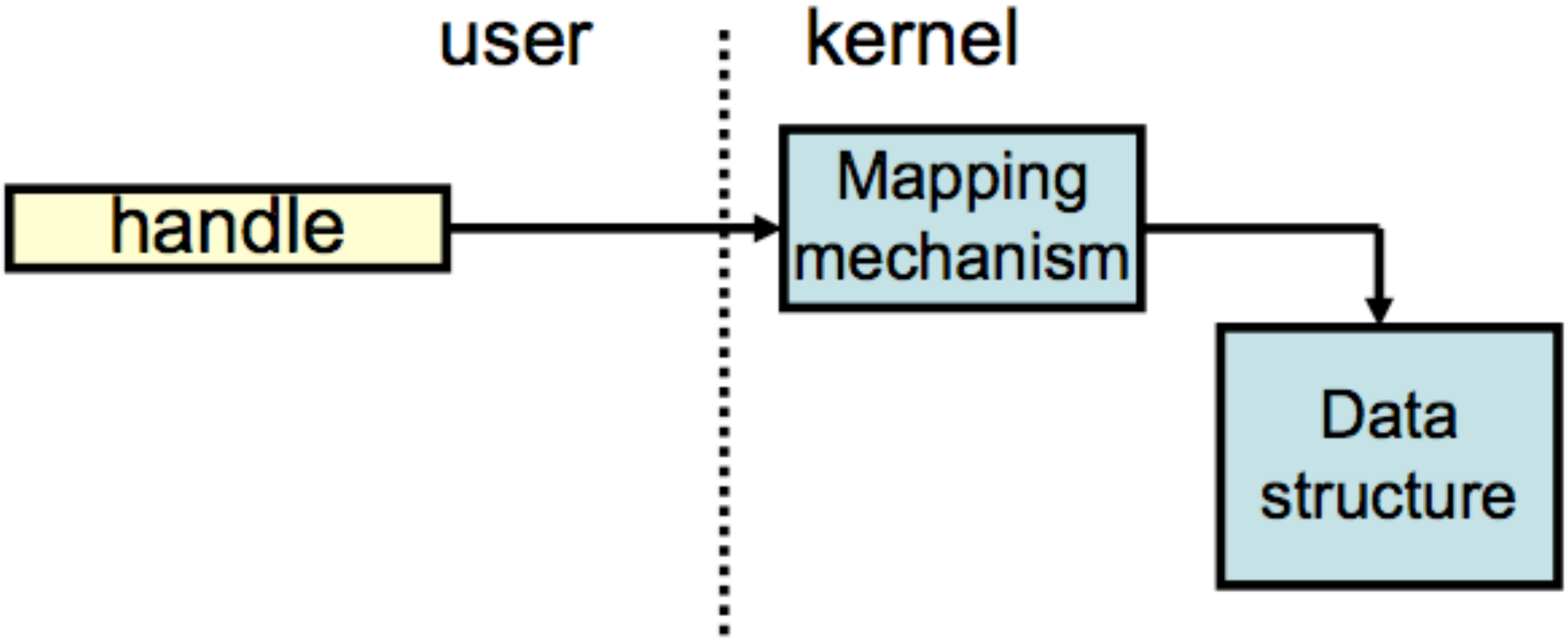
credit: Dave Probert, Ph.D (Singapore 2006), Microsoft Corporation 2006

How OB and SE interact:



credit: Dave Probert, Ph.D (Singapore 2006), Microsoft Corporation 2006

Remember! Handles/Descriptors are just userland abstractions!



credit: Dave Probert, Ph.D (Singapore 2006), Microsoft Corporation 2006
© Microsoft Corporation 2006

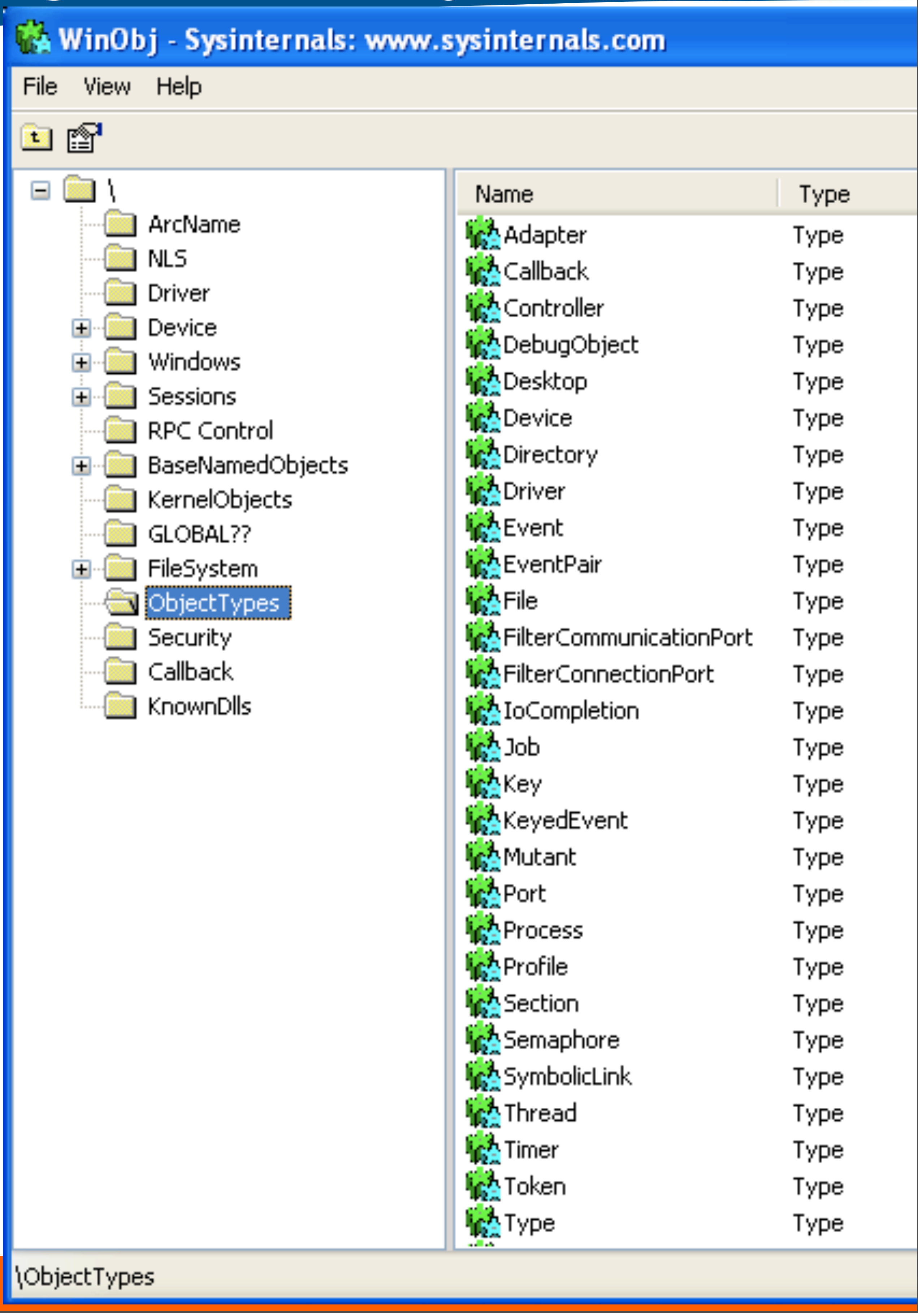
- Handles and Descriptors are just Userland abstractions to access Kernel structures.
- The functions you pass the Handles and Descriptors into (like fopen()) are userland “gateways” to the kernel

NT Objects (the object "primitives")

Adapter	File	Semaphore
Callback	IoCompletion	SymbolicLink
Controller	Job	Thread
DebugObject	Key	Timer
Desktop	KeyedEvent	Token
Device	Mutant	Type
Directory	Port	Waitable Port
Driver	Process	WindowsStation
Event	Profile	WMIGuid
EventPair	Section	

Listing/Investigating NT Objects

- WinObj (SysInternals)
- objdir.exe (DDK)
- ntddk.h
- Ob*() exports of ntoskrnl.exe
- “Undocumented Windows 2000 Secrets” Chapter 7 (w2k_def.h)
- dt nt!_object* (in Windbg (kd))
- !object \ (in Windbg (kd))



- \
  - ArcName
  - NLS
  - Driver
  - Device
  - Windows
  - Sessions
  - RPC Control
  - BaseNamedObjects
  - KernelObjects
  - GLOBAL??
  - FileSystem
  - ObjectTypes
  - Security
  - Callback
  - KnownDlls

Name	Type
Adapter	Type
Callback	Type
Controller	Type
DebugObject	Type
Desktop	Type
Device	Type
Directory	Type
Driver	Type
Event	Type
EventPair	Type
File	Type
FilterCommunicationPort	Type
FilterConnectionPort	Type
IoCompletion	Type
Job	Type
Key	Type
KeyedEvent	Type
Mutant	Type
Port	Type
Process	Type
Profile	Type
Section	Type
Semaphore	Type
SymbolicLink	Type
Thread	Type
Timer	Type
Token	Type
Type	Type

\ObjectTypes

First things first...why go up here?

★ **Reasons for using kernel debugger to assist us with investigating sandboxes:**

1. Sandboxes use many NT Objects that have helpful Windbg commands that don't work from userspace:
   1. Jobs Objects for example! (!job)
   2. LPC inspection (!lpc)
   3. better handle/descriptor visibility/tracking (!htrace)
2. "System-Wide" breakpoints: Breaking on ntdll! NtOpenFile() will hit whenever **any** process on the system calls it!
3. There are also some other less popular benefits to using kernel debugger (will demonstrate these with Google Chrome later :-)

Inspecting Securable Objects with Kernel Debugger

- !process <cid>
- !handle <cid>
- !job
- !token
- !tokenfields
- !object

- !sd *see "Determining the ACL of an Object" in the Windbg help for all the steps to obtaining a detailed security descriptor from an object*
- !acl
- !sid
- !lpc

Side Note: *Did you know you don't need to use gflags.exe to set pageheap/debugheaps? You can use Windbg's* !gflag

Other useful commands

- .tlist : This also lists processes but only by CID and not process identifier.
- !process 0 0 : List all cids/processes
- .process
- .reload /user :Reload userspace symbols
- .sympath symsrv*symsrv.dll*c:\\syms*http://msdl.microsoft.com/download/symbols
  - Autodownload of symbols you dont have... VERY USEFUL!
- lm u :list modules for userspace, needs a .process

A Note on Observing Hooks from Kernel Debugger

- Important to remember: in the kernel only "one copy" of libraries (like ntdll) ever get loaded.
- The "differences" between processes is all done via the magic of Page Table Entries. You will probably not be able to see installed library hooks if you don't do the following in Windbg:
    - use the /p switch with the .process command to force the debugger to update Page Table translation: .process /p <eprocess|cid>
- This is done so that when you view the virtual address for NTDLL or Kernel32 or whatever, it correctly references the physical page, which differ because of the hooks.
- *Note: you may also want to check out the Windbg .pagein command. You might have to use this command as another way to force Windbg to update PTE translation.*

Observing Broker Behaviors

★ There are a number of functions critical to the operation of Sandbox child processes that are interesting and useful to observe the Broker calling. Here are some suggestions:

Note: Most of these are "undocumented".

- Zw/NtDuplicateToken()
- Zw/NtCreateToken()
- Zw/NtSetInformationToken()
- Zw/NtOpenProcess()
- Zw/NtDuplicateObject()
- DuplicateHandle()
- Zw/NtCreateProcess()
- Zw/NtSetSecurityObject()
- NtQueryObject(), NtSetSecurityObject(), NtQuerySecurityObject()
- ExDupHandleTable()/ExDestroyHandleTable (process creation/destruction)
- ExCreateHandle(), ExDestroyHandle()
- user32!UserHandleGrantAccess()

Observing Sandbox Behaviors

★ Because the Sandbox is restricted we care less about what he is doing, but there are a few interesting things to watch for. Here are some suggestions:

Note: Most of these are “undocumented”.

- ZwContinue(): the _NTCONTINUE function that is often hooked by anti-debugging code (not that Chrome does it)
- ZwCreateFile()
- ZwWriteFile()

A Neat thing about Kernel Debuggers

- The kernel gets **ALL** exceptions first!

- Like virtually all Windows functionality, Usermode debuggers rely heavily upon LPC messages.
- “Debugger” processes talk to CSRSS via LPC
- CSRSS receives all debug events for all processes from the kernel and handles dispatching them debugger processes.
- When a Kernel debugger is attached, the Kernel never passes these exceptions on to CSRSS’s waiting LPC channel.
- The most important thing however is that the Kernel gets **all** exceptions first, especially int 3, which is what Chrome sandbox uses to taddle-tell back to the Broker ;-)

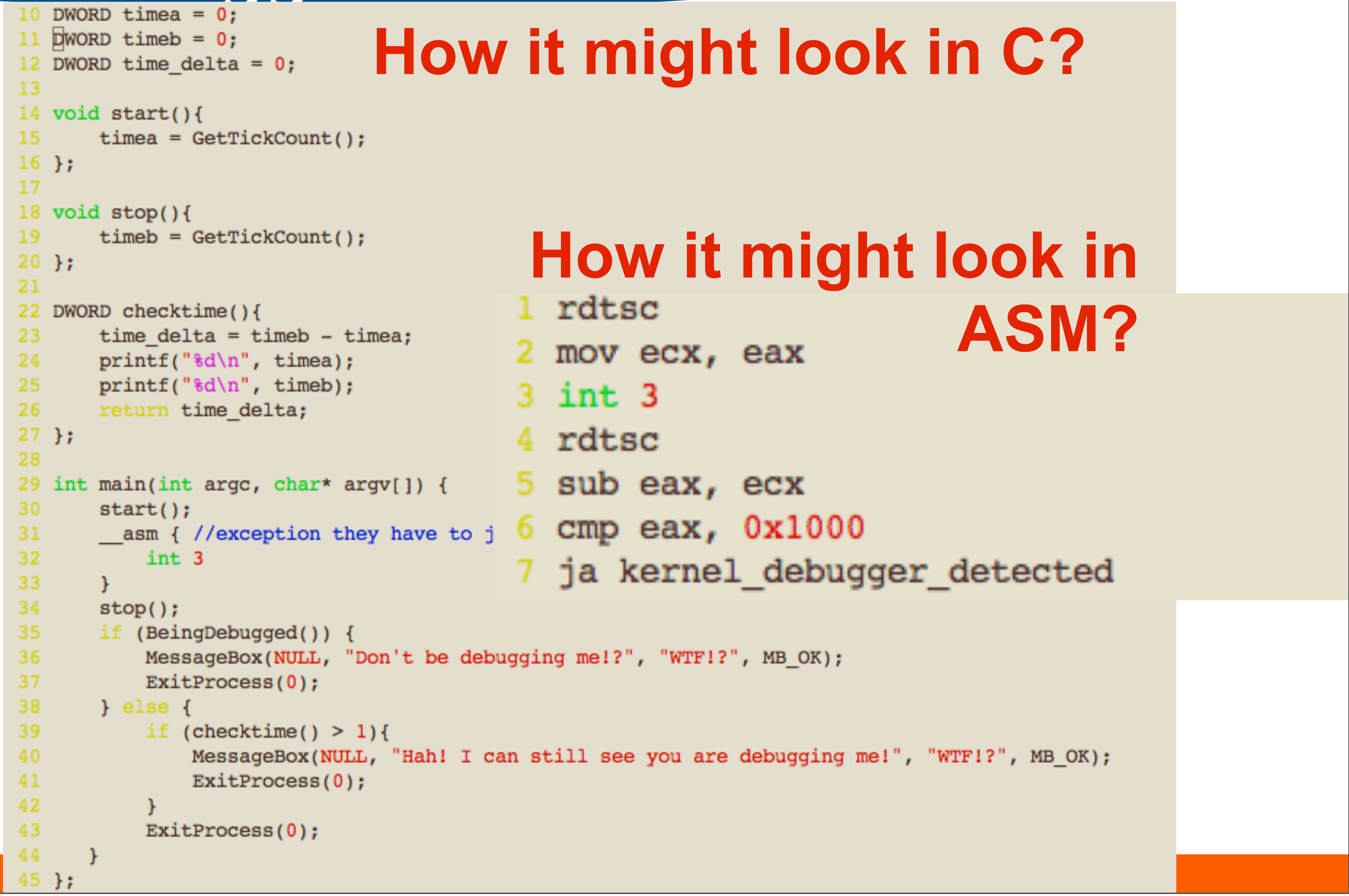
TANGENT: Detecting Kernel Mode Debuggers from Userspace

- ★ Once you know about how Kernel mode debuggers get all exceptions first, the concept is simple:

Use RDTSC single-step detection technique with int3s in-between to detect kernel debugger exception handler timing.

- ★ Furthermore, int3s fired at the “wrong time” break things. See for yourself.
- ★ If you dig a bit under the hood to understand the process around ZwCreateDebugObject, how CSRSS passes debug info, and stuff like the LPC handle in EPROCESS.DebugPort you will probably find better ways to detect Kernel debuggers from userspace

TANGENT: Detecting Kernel Mode Debuggers from Userspace



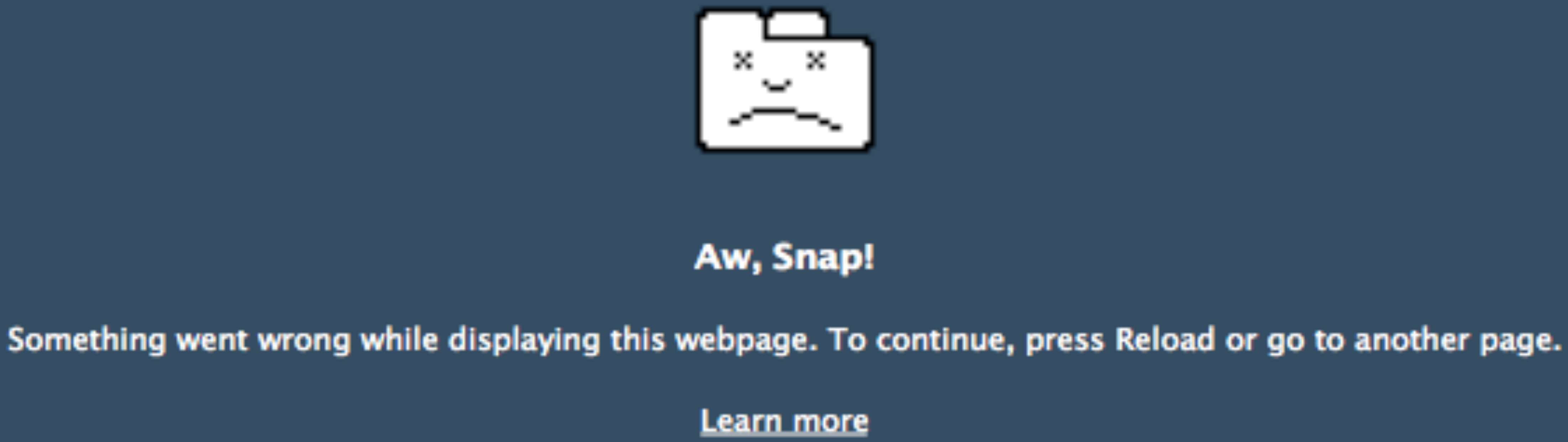
How it might look in C?

```
DWORD timea = 0;
DWORD timeb = 0;
DWORD time_delta = 0;

void start(){
    timea = GetTickCount();
};

void stop(){
    timeb = GetTickCount();
};

DWORD checktime(){
    time_delta = timeb - timea;
    printf("%d\n", timea);
    printf("%d\n", timeb);
    return time_delta;
};

int main(int argc, char* argv[]) {
    start();
    __asm { //exception they have to j
        int 3
    }
    stop();
    if (BeingDebugged()) {
        MessageBox(NULL, "Don't be debugging me!?", "WTF!?", MB_OK);
        ExitProcess(0);
    } else {
        if (checktime() > 1){
            MessageBox(NULL, "Hah! I can still see you are debugging me!", "WTF!?", MB_OK);
            ExitProcess(0);
        }
        ExitProcess(0);
    }
};
```

How it might look in ASM?

```
rdtsc
mov ecx, eax
int 3
rdtsc
sub eax, ecx
cmp eax, 0x1000
ja kernel_debugger_detected
```

If you fuzzed sandboxed processes and had "success" you've probably seen this (I call it "Chrome Mr. Yuck"):



Aw, Snap!

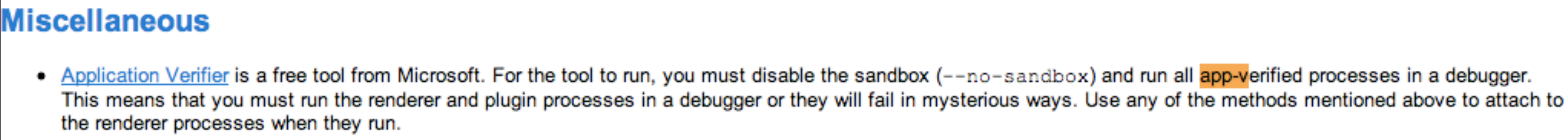
Something went wrong while displaying this webpage. To continue, press Reload or go to another page.

Learn more

but when you attach your user-space debugger....nothing. That's because the Broker catches sandbox exceptions and breakpoints first!

Google being snide about Broker-handled Sandbox exceptions...

On the Chromium website, down in some documentation Google mentions this:



Miscellaneous

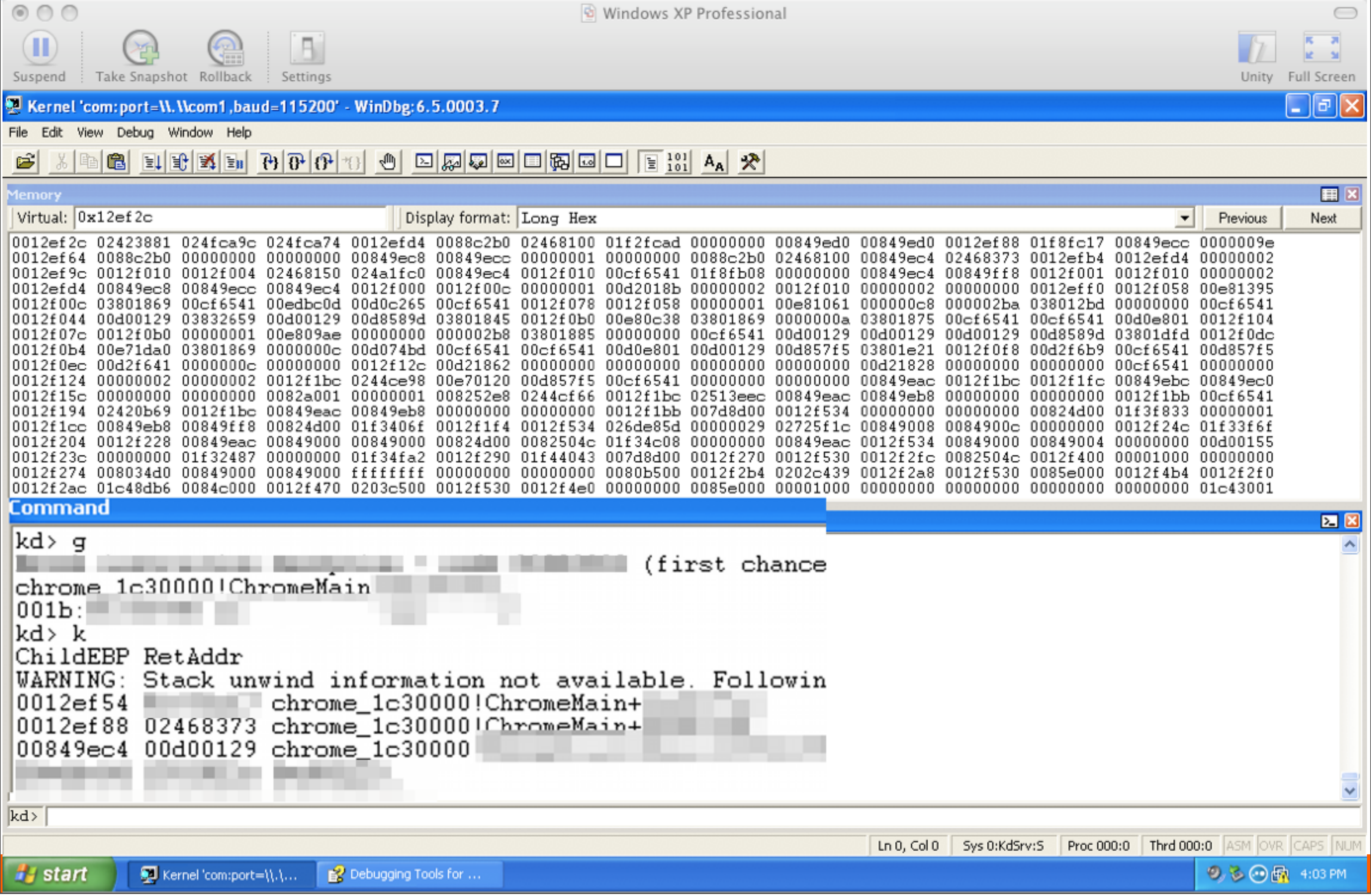
- Application Verifier is a free tool from Microsoft. For the tool to run, you must disable the sandbox (`--no-sandbox`) and run all app-verified processes in a debugger. This means that you must run the renderer and plugin processes in a debugger or they will fail in mysterious ways. Use any of the methods mentioned above to attach to the renderer processes when they run.

This is no mystery at all when you realize that the Sandbox (the debuggee) is coded to intentionally whine to the Broker by throwing exceptions which the Broker (as the debugger) then “handles”.

GOOGLE DOES NOT USE THE OS’S CRASH REPORTING MECHANISMS (like WER in Windows or Crash Reporter in OSX). It uses it’s own custom one called BreakPad.

Pro-tip: If fuzzing Chrome, be sure to set your ZoneAlarm/LittleSnitch/whatever to disallow Chrome outbound. Or better yet, disable the NIC entirely for that VM ;-)

Example of Remotely Triggered (client side) overflow (handled)



Virtual: 0x12ef2c

Display format: Long Hex

```
0012ef2c 02423881 024fca9c 024fca74 0012efd4 0088c2b0 02468100 01f2fcad 00000000 00849ed0 00849ed0 0012ef88 01f8fc17 00849ecc 0000009e
0012ef64 0088c2b0 00000000 00000000 00849ec8 00849ecc 00000001 00000000 0088c2b0 02468100 00849ec4 02468373 0012efb4 0012efd4 00000002
0012ef9c 0012f010 0012f004 02468150 024a1fc0 00849ec4 0012f010 00cf6541 01f8fb08 00000000 00849ec4 00849ff8 0012f001 0012f010 00000002
0012efd4 00849ec8 00849ecc 00849ec4 0012f000 0012f00c 00000001 00d2018b 00000002 0012f010 00000002 00000000 0012eff0 0012f058 00e81395
0012f00c 03801869 00cf6541 00edbc0d 00d0c265 00cf6541 0012f078 0012f058 00000001 00e81061 000000c8 000002ba 038012bd 00000000 00cf6541
0012f044 00d00129 03832659 00d00129 00d8589d 03801845 0012f0b0 00e80c38 03801869 0000000a 03801875 00cf6541 00cf6541 00d0e801 0012f104
0012f07c 0012f0b0 00000001 00e809ae 00000000 000002b8 03801885 00000000 00cf6541 00d00129 00d00129 00d00129 00d8589d 03801dfd 0012f0dc
0012f0b4 00e71da0 03801869 0000000c 00d074bd 00cf6541 00cf6541 00d0e801 00d00129 00d857f5 03801e21 0012f0f8 00d2f6b9 00cf6541 00d857f5
0012f0ec 00d2f641 0000000c 00000000 0012f12c 00d21862 00000000 00000000 00000000 00000000 00d21828 00000000 00000000 00cf6541 00000000
0012f124 00000002 00000002 0012f1bc 0244ce98 00e70120 00d857f5 00cf6541 00000000 00000000 00849eac 0012f1bc 0012f1fc 00849ebc 00849ec0
0012f15c 00000000 00000000 0082a001 00000001 008252e8 0244cf66 0012f1bc 02513eec 00849eac 00849eb8 00000000 00000000 0012f1bb 00cf6541
0012f194 02420b69 0012f1bc 00849eac 00849eb8 00000000 00000000 0012f1bb 007d8d00 0012f534 00000000 00000000 00824d00 01f3f833 00000001
0012f1cc 00849eb8 00849ff8 00824d00 01f3406f 0012f1f4 0012f534 026de85d 00000029 02725f1c 00849008 0084900c 00000000 0012f24c 01f33f6f
0012f204 0012f228 00849eac 00849000 00849000 00824d00 0082504c 01f34c08 00000000 00849eac 0012f534 00849000 00849004 00000000 00d00155
0012f23c 00000000 01f32487 00000000 01f34fa2 0012f290 01f44043 007d8d00 0012f270 0012f530 0012f2fc 0082504c 0012f400 00001000 00000000
0012f274 008034d0 00849000 00849000 ffffffff 00000000 00000000 0080b500 0012f2b4 0202c439 0012f2a8 0012f530 0085e000 0012f4b4 0012f2f0
0012f2ac 01c48db6 0084c000 0012f470 0203c500 0012f530 0012f4e0 00000000 0085e000 00001000 00000000 00000000 00000000 00000000 01c43001
```

```
kd> g
[redacted] (first chance
chrome_1c30000!ChromeMain[redacted]
001b:[redacted]
kd> k
ChildEBP RetAddr
WARNING: Stack unwind information not available. Followin
0012ef54 [redacted] chrome_1c30000!ChromeMain+[redacted]
0012ef88 02468373 chrome_1c30000!ChromeMain+[redacted]
00849ec4 00d00129 chrome_1c30000[redacted]
[redacted]
```

kd>

Tools & Techniques: Introducing The SandKit

The SandKit

A Collection of tools to assist with the investigation and testing of Sandboxes.

(Also intended to give ideas about tools you might want to write yourself.)

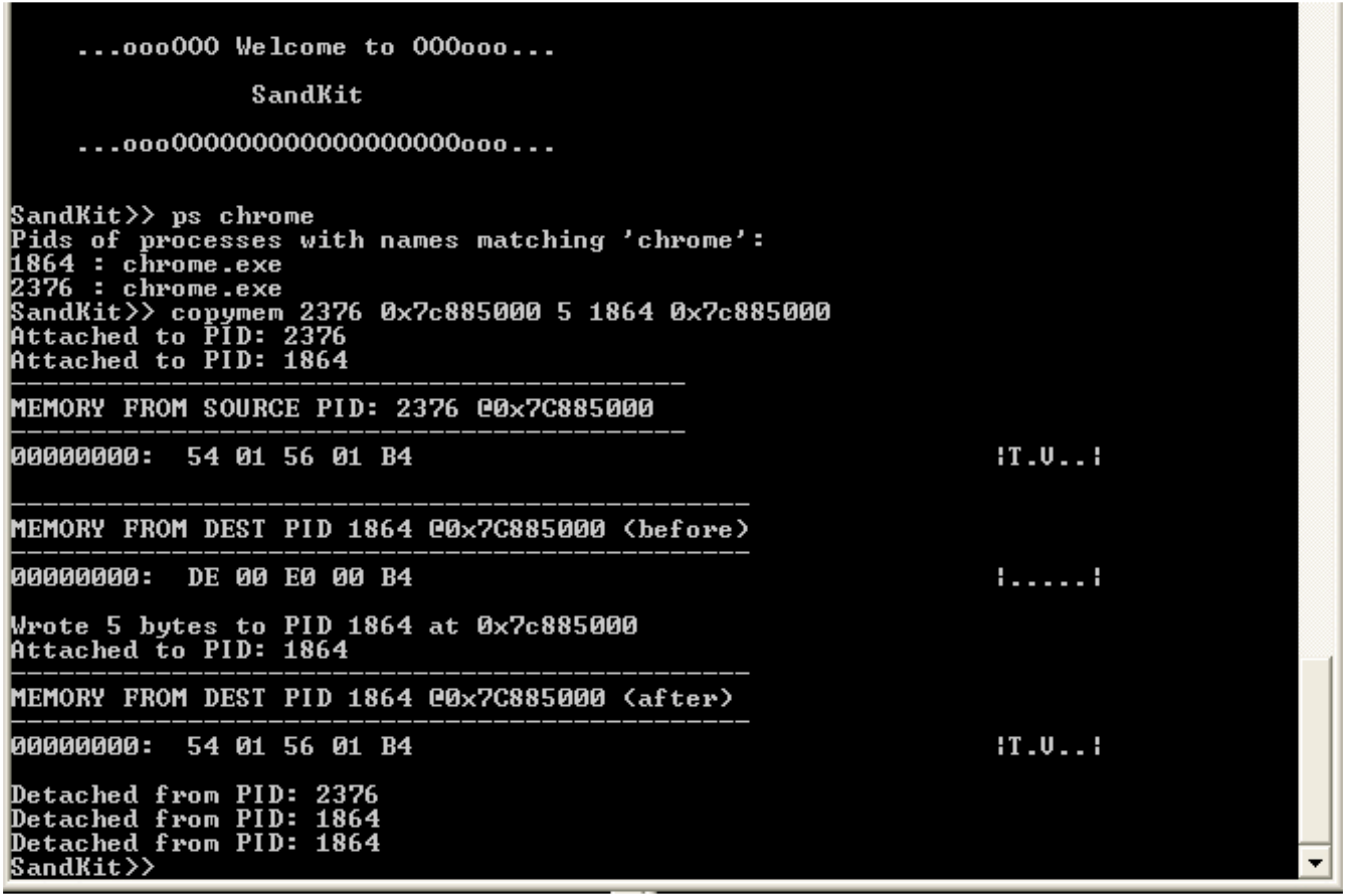
- Code Injection Techniques (vanilla dll injection, reflective dll injection, kernel-to-userspace dll injection?)
- CopyMem
- MemDiff
- DumpMem
- HookFix
- Sa7Shell
- BinCompare
- DumpToken Redux
- TokenBrute/HandleBrute
- Sandbox_Poc (Google Chrome source “sub-project”)
  - **Download the Chrome source and find it in:**
  - **/home/chrome-svn/tarball/chromium/src/sandbox/sandbox_poc/**
  - **It comes with visual studio solution and everything!**

Code Injection

- ★ Sandkit implements “Vanilla DLL injection” to inject a DLL into a target process.
  - This injection technique is the VERY common: OpenProcess()/VirtualAllocEx()/CreateRemoteThread()->LoadLibraryA() technique.
- ★ Reflective DLL injection
  - for “harder” injection targets such as restricted processes or heavily hooked executables.
  - some minimal unhooking would still necessary
  - Sandkit may eventually include this.
- ★ Kernel-to-userspace Injection?
  - Use documented APC Injection/Thread Notifier technique to have kernel injected code run in a usermode Thread’s context
  - Combine this with basic Reflective DLL injection technique
  - MANY caveats: accounting for PTE changes when injected code executes (hooks still in place), modifying PTE for usermode context, etc.

CopyMem

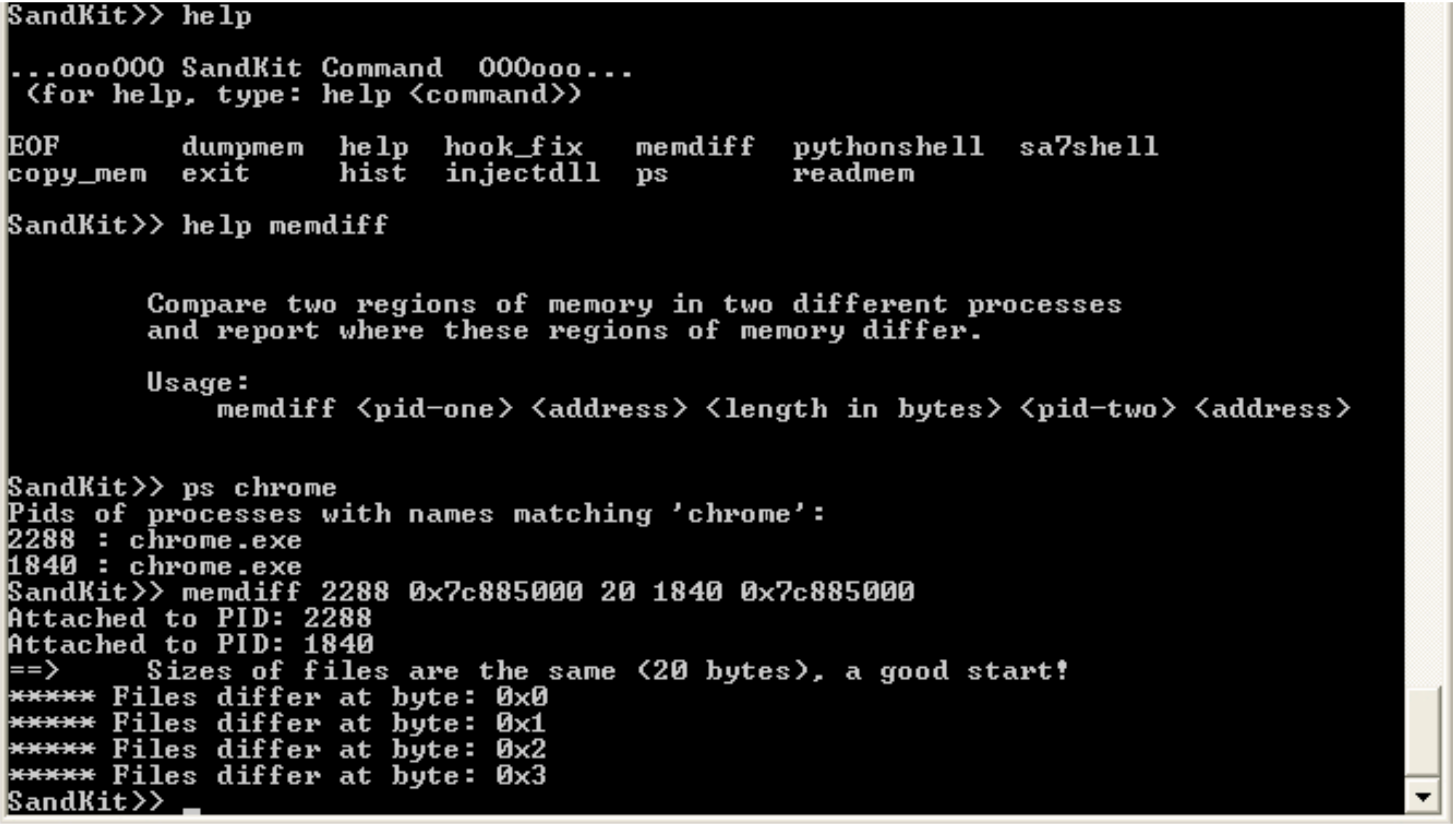
- Copy memory from one process into another. This tool is the basis for the HookFix application



```
    ...oooOOO Welcome to OOOooo...

                SandKit

    ...oooOOOOOOOOOOOOOOOOOOOOooo...


SandKit>> ps chrome
Pids of processes with names matching 'chrome':
1864 : chrome.exe
2376 : chrome.exe
SandKit>> copymem 2376 0x7c885000 5 1864 0x7c885000
Attached to PID: 2376
Attached to PID: 1864
------------------------------------------
MEMORY FROM SOURCE PID: 2376 @0x7C885000
------------------------------------------
00000000:  54 01 56 01 B4                                    |T.V..|

----------------------------------------------
MEMORY FROM DEST PID 1864 @0x7C885000 (before)
----------------------------------------------
00000000:  DE 00 E0 00 B4                                    |.....|

Wrote 5 bytes to PID 1864 at 0x7c885000
Attached to PID: 1864
----------------------------------------------
MEMORY FROM DEST PID 1864 @0x7C885000 (after)
----------------------------------------------
00000000:  54 01 56 01 B4                                    |T.V..|

Detached from PID: 2376
Detached from PID: 1864
Detached from PID: 1864
SandKit>>
```

MemDiff

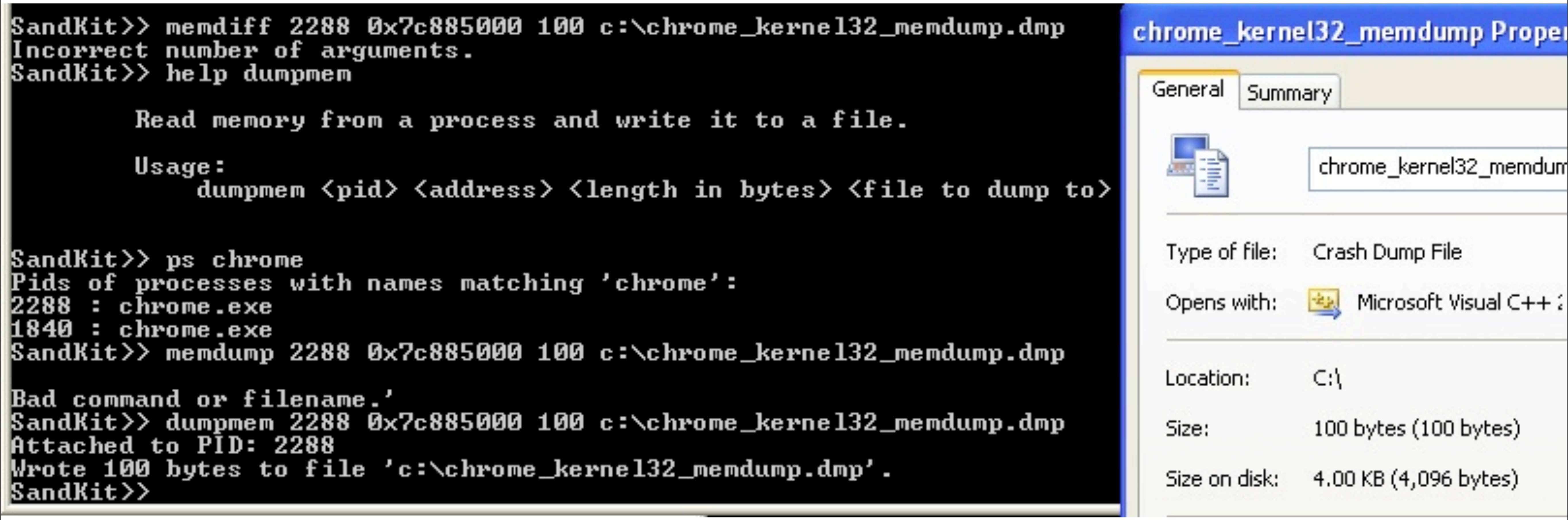
- Take a look into memory in two different processes and compare it. Log where the two regions of memory begin to differ.
- Simple but time-saving tool for the detection of hooks



```
SandKit>> help

...oooOOO SandKit Command  OOOooo...
 (for help, type: help <command>)

EOF        dumpmem  help  hook_fix   memdiff  pythonshell  sa7shell
copy_mem   exit     hist  injectdll  ps       readmem

SandKit>> help memdiff


        Compare two regions of memory in two different processes
        and report where these regions of memory differ.

        Usage:
            memdiff <pid-one> <address> <length in bytes> <pid-two> <address>


SandKit>> ps chrome
Pids of processes with names matching 'chrome':
2288 : chrome.exe
1840 : chrome.exe
SandKit>> memdiff 2288 0x7c885000 20 1840 0x7c885000
Attached to PID: 2288
Attached to PID: 1840
==>     Sizes of files are the same (20 bytes), a good start!
***** Files differ at byte: 0x0
***** Files differ at byte: 0x1
***** Files differ at byte: 0x2
***** Files differ at byte: 0x3
SandKit>> _
```

DumpMem

- Similar to the .writemem command in Windbg. Just write raw memory from a process to a file



```
SandKit>> memdiff 2288 0x7c885000 100 c:\chrome_kernel32_memdump.dmp
Incorrect number of arguments.
SandKit>> help dumpmem

        Read memory from a process and write it to a file.

        Usage:
            dumpmem <pid> <address> <length in bytes> <file to dump to>


SandKit>> ps chrome
Pids of processes with names matching 'chrome':
2288 : chrome.exe
1840 : chrome.exe
SandKit>> memdump 2288 0x7c885000 100 c:\chrome_kernel32_memdump.dmp

Bad command or filename.'
SandKit>> dumpmem 2288 0x7c885000 100 c:\chrome_kernel32_memdump.dmp
Attached to PID: 2288
Wrote 100 bytes to file 'c:\chrome_kernel32_memdump.dmp'.
SandKit>>
```

chrome_kernel32_memdump Prope

chrome_kernel32_memdum

Type of file: Crash Dump File

Opens with: Microsoft Visual C++ 2

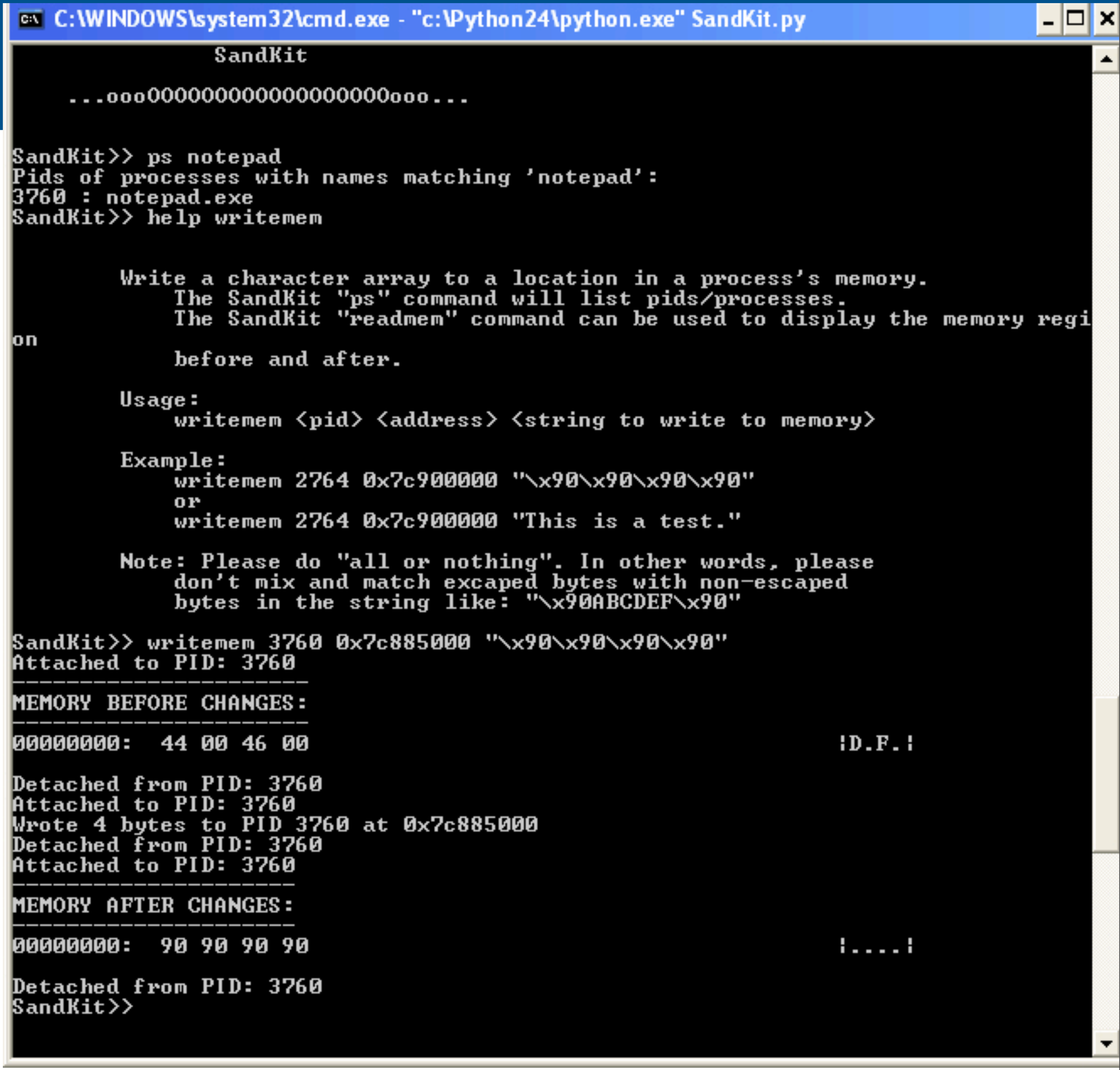
Location: C:\

Size: 100 bytes (100 bytes)

Size on disk: 4.00 KB (4,096 bytes)

WriteMem

- Write a string or character array directly to the memory of a process.



C:\WINDOWS\system32\cmd.exe - "c:\Python24\python.exe" SandKit.py

```
               SandKit

    ...oooOOOOOOOOOOOOOOOOOOOooo...


SandKit>> ps notepad
Pids of processes with names matching 'notepad':
3760 : notepad.exe
SandKit>> help writemem


        Write a character array to a location in a process's memory.
            The SandKit "ps" command will list pids/processes.
            The SandKit "readmem" command can be used to display the memory regi
on
            before and after.

        Usage:
            writemem <pid> <address> <string to write to memory>

        Example:
            writemem 2764 0x7c900000 "\x90\x90\x90\x90"
            or
            writemem 2764 0x7c900000 "This is a test."

        Note: Please do "all or nothing". In other words, please
            don't mix and match excaped bytes with non-escaped
            bytes in the string like: "\x90ABCDEF\x90"

SandKit>> writemem 3760 0x7c885000 "\x90\x90\x90\x90"
Attached to PID: 3760
----------------------
MEMORY BEFORE CHANGES:
----------------------
00000000:  44 00 46 00                                       ¦D.F.¦

Detached from PID: 3760
Attached to PID: 3760
Wrote 4 bytes to PID 3760 at 0x7c885000
Detached from PID: 3760
Attached to PID: 3760
---------------------
MEMORY AFTER CHANGES:
---------------------
00000000:  90 90 90 90                                       ¦....¦

Detached from PID: 3760
SandKit>>
```

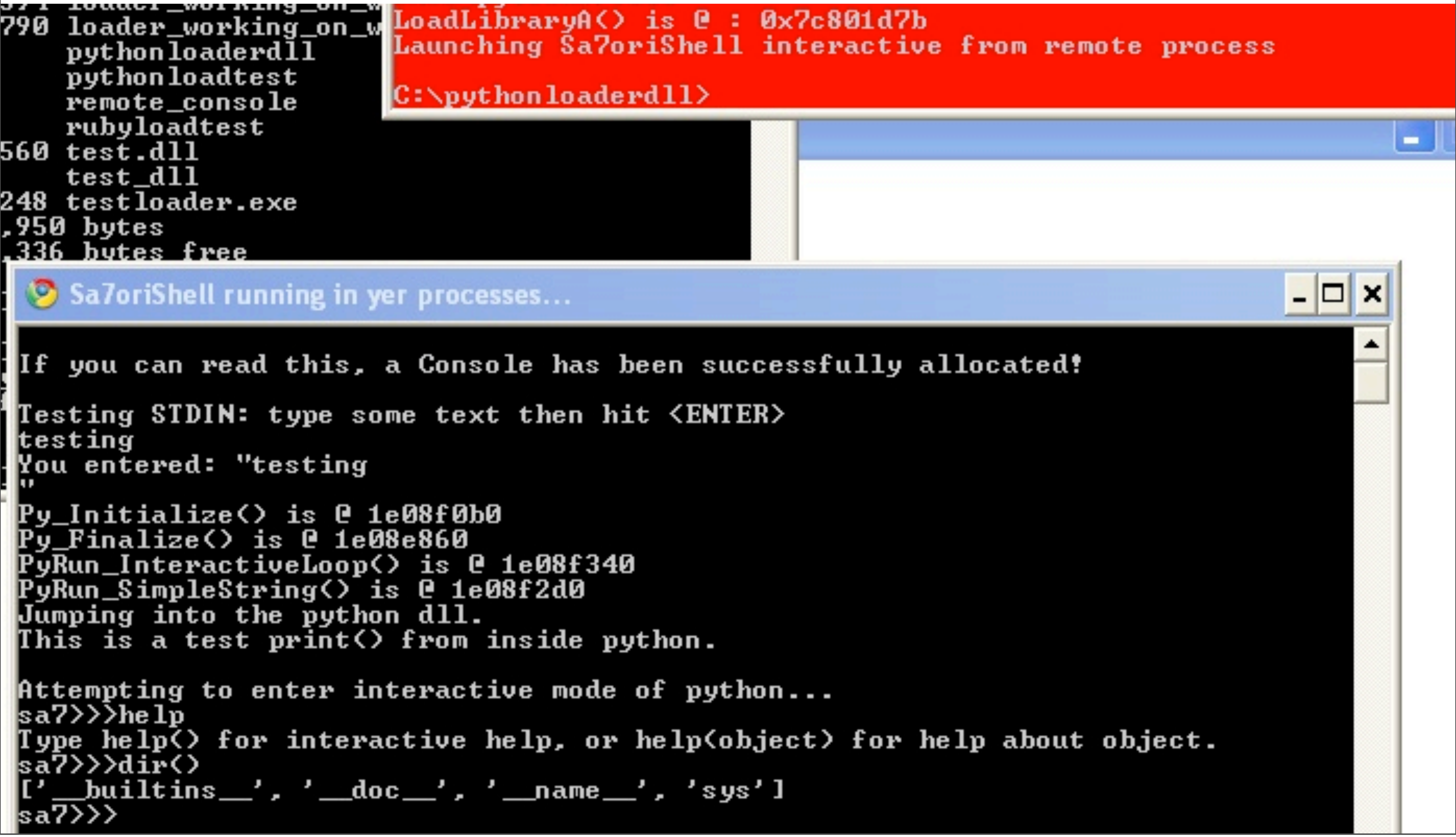
HookFix

- **HookFix just uses CopyMem to fix the specific hooks put in placed into the Sandbox by the Broker.**
- **There is no magic here, we just:**
  1. Borrow the .text region of a "normal" process with our module loaded (in this case the Broker).
  2. Locate the differences between the "normal" and modified .text regions within the Sandbox
  3. Save the Sandbox modules .text region first (for restoration).
  4. Overwrite the Sandbox module's .text region

Note: We have to just be careful to not to borrow stuff outside of .text, because there
are "process specific" variables in the address space of dlls like ntdll.
Such as:
ntdll!__security_cookie

Sa7Shell

After using the Sandkit DLL injector, you get a console window!



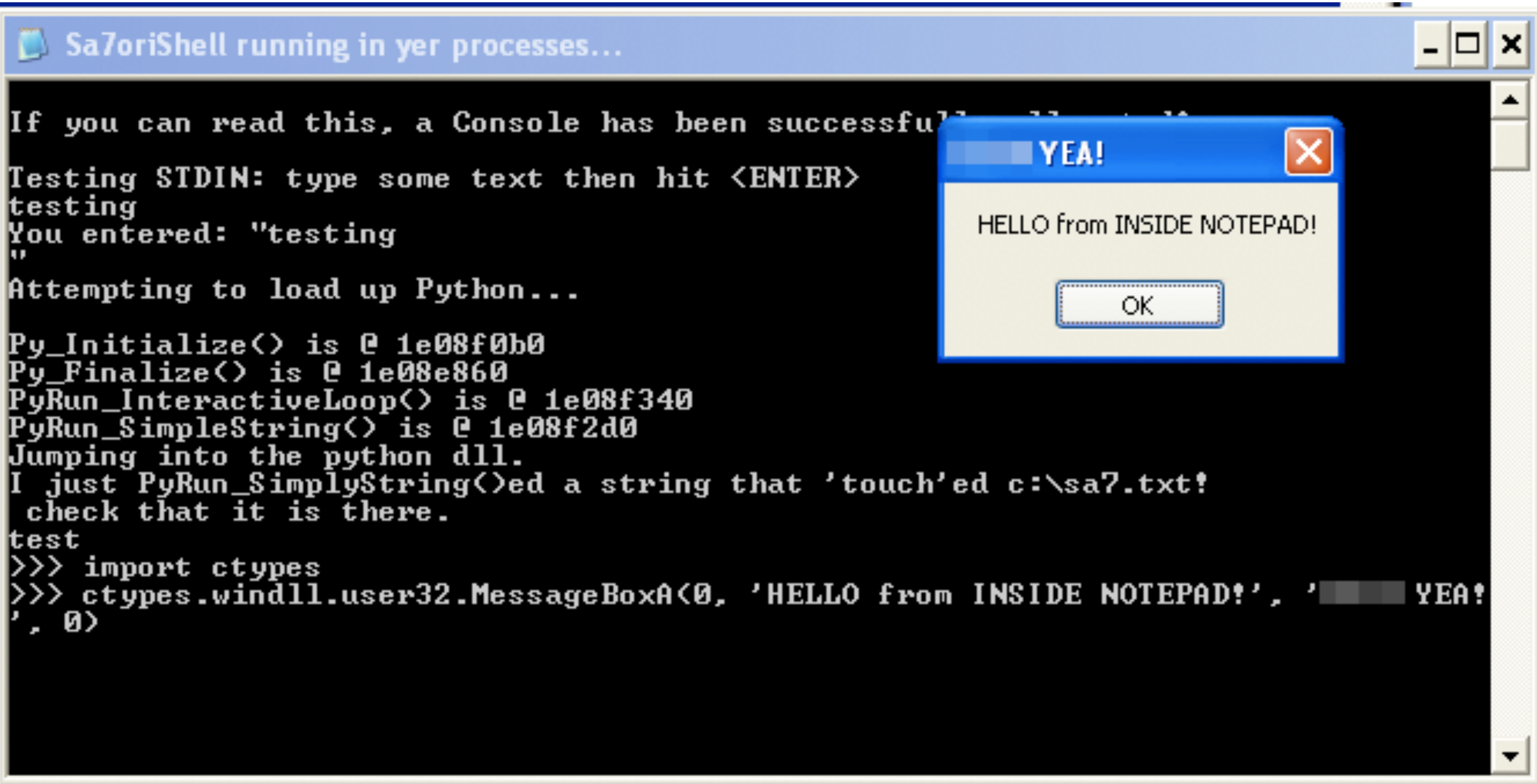
```
790 loader_working_on_w
    pythonloaderdll
    pythonloadtest
    remote_console
    rubyloadtest
560 test.dll
    test_dll
248 testloader.exe
,950 bytes
,336 bytes free
```

```
LoadLibraryA() is @ : 0x7c801d7b
Launching Sa7oriShell interactive from remote process

C:\pythonloaderdll>
```

```
If you can read this, a Console has been successfully allocated!

Testing STDIN: type some text then hit <ENTER>
testing
You entered: "testing
"
Py_Initialize() is @ 1e08f0b0
Py_Finalize() is @ 1e08e860
PyRun_InteractiveLoop() is @ 1e08f340
PyRun_SimpleString() is @ 1e08f2d0
Jumping into the python dll.
This is a test print() from inside python.

Attempting to enter interactive mode of python...
sa7>>>help
Type help() for interactive help, or help(object) for help about object.
sa7>>>dir()
['__builtins__', '__doc__', '__name__', 'sys']
sa7>>>
```

Sa7Shell

Messing around inside the process (notepad.exe) like Message Box popups!



```
If you can read this, a Console has been successfu

Testing STDIN: type some text then hit <ENTER>
testing
You entered: "testing
"
Attempting to load up Python...

Py_Initialize() is @ 1e08f0b0
Py_Finalize() is @ 1e08e860
PyRun_InteractiveLoop() is @ 1e08f340
PyRun_SimpleString() is @ 1e08f2d0
Jumping into the python dll.
I just PyRun_SimplyString()ed a string that 'touch'ed c:\sa7.txt!
 check that it is there.
test
>>> import ctypes
>>> ctypes.windll.user32.MessageBoxA(0, 'HELLO from INSIDE NOTEPAD!', '[redacted] YEA!
', 0)
```

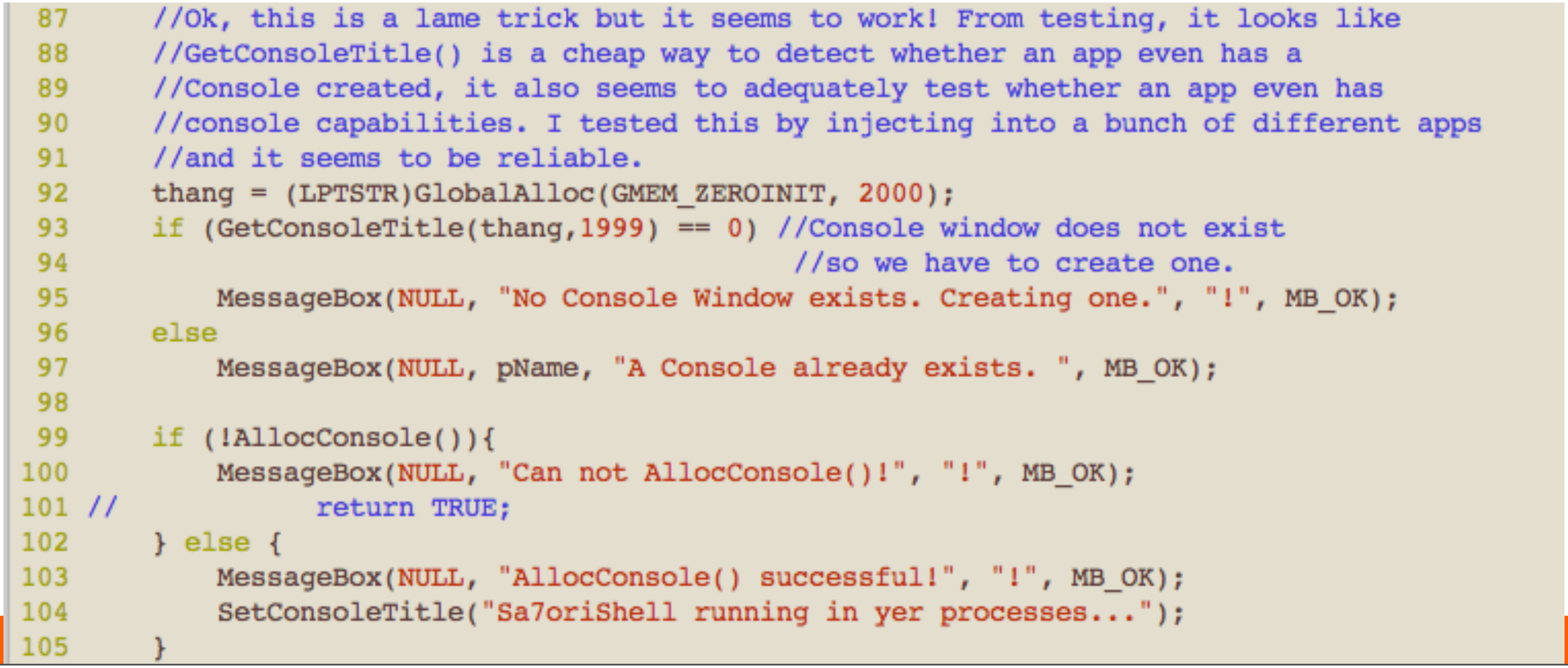
[redacted] YEA!

HELLO from INSIDE NOTEPAD!

Sa7Shell: How does it work?

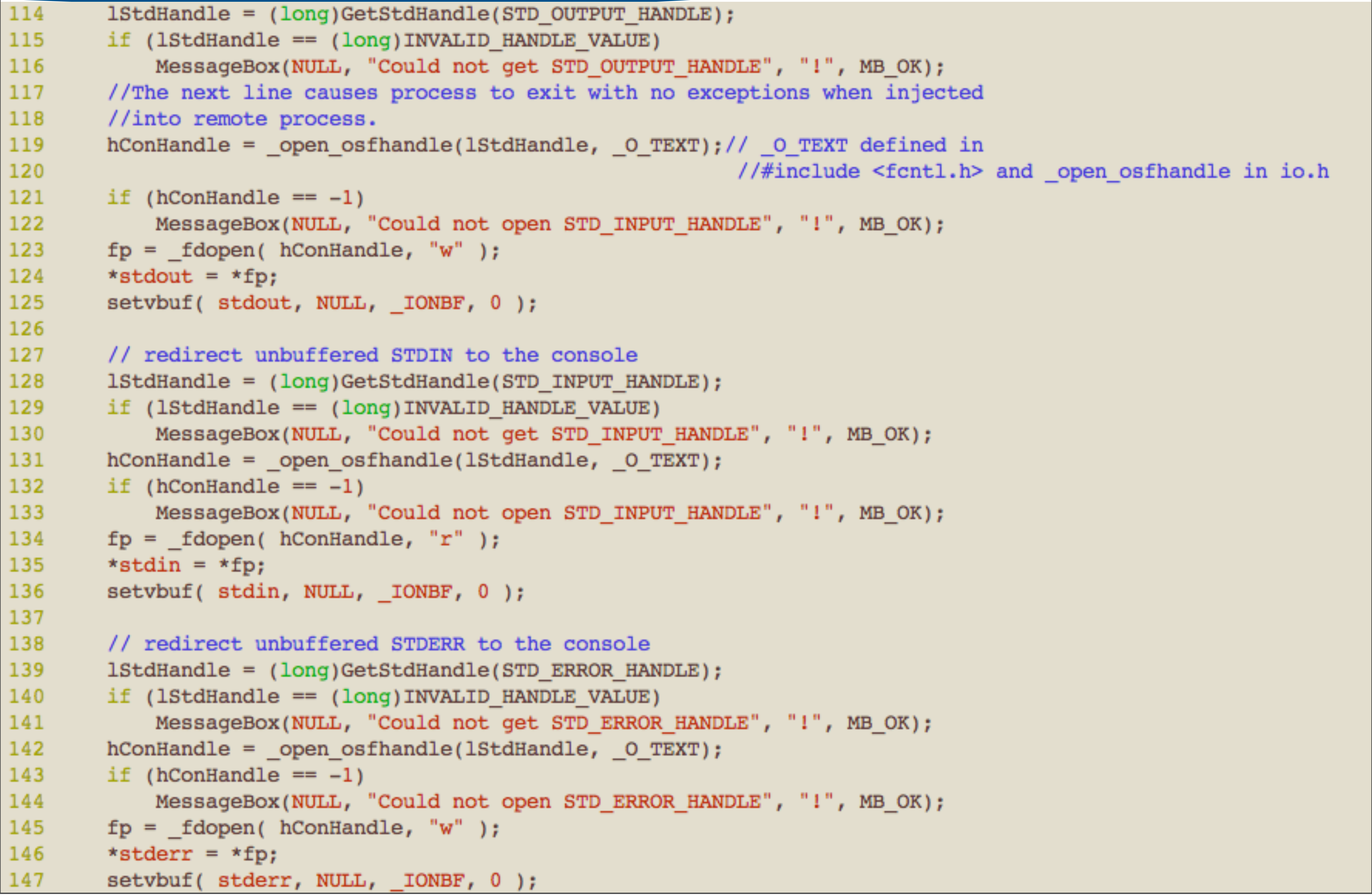
★ Inject the full Python interpreter into a target process, and mess around with it internally!

- This may sound trivial to do with vanilla DLL injection and it (for the most part is).
- However you have to handle special cases like: If your injected DLL does printf()s, where does STDOUT go in a GUI app?
- Answer: AllocateConsole() and then my “handle shenanigans”



```
    //Ok, this is a lame trick but it seems to work! From testing, it looks like
    //GetConsoleTitle() is a cheap way to detect whether an app even has a
    //Console created, it also seems to adequately test whether an app even has
    //console capabilities. I tested this by injecting into a bunch of different apps
    //and it seems to be reliable.
    thang = (LPTSTR)GlobalAlloc(GMEM_ZEROINIT, 2000);
    if (GetConsoleTitle(thang,1999) == 0) //Console window does not exist
                                            //so we have to create one.
        MessageBox(NULL, "No Console Window exists. Creating one.", "!", MB_OK);
    else
        MessageBox(NULL, pName, "A Console already exists. ", MB_OK);

    if (!AllocConsole()){
        MessageBox(NULL, "Can not AllocConsole()!", "!", MB_OK);
//              return TRUE;
    } else {
        MessageBox(NULL, "AllocConsole() successful!", "!", MB_OK);
        SetConsoleTitle("Sa7oriShell running in yer processes...");
    }
```

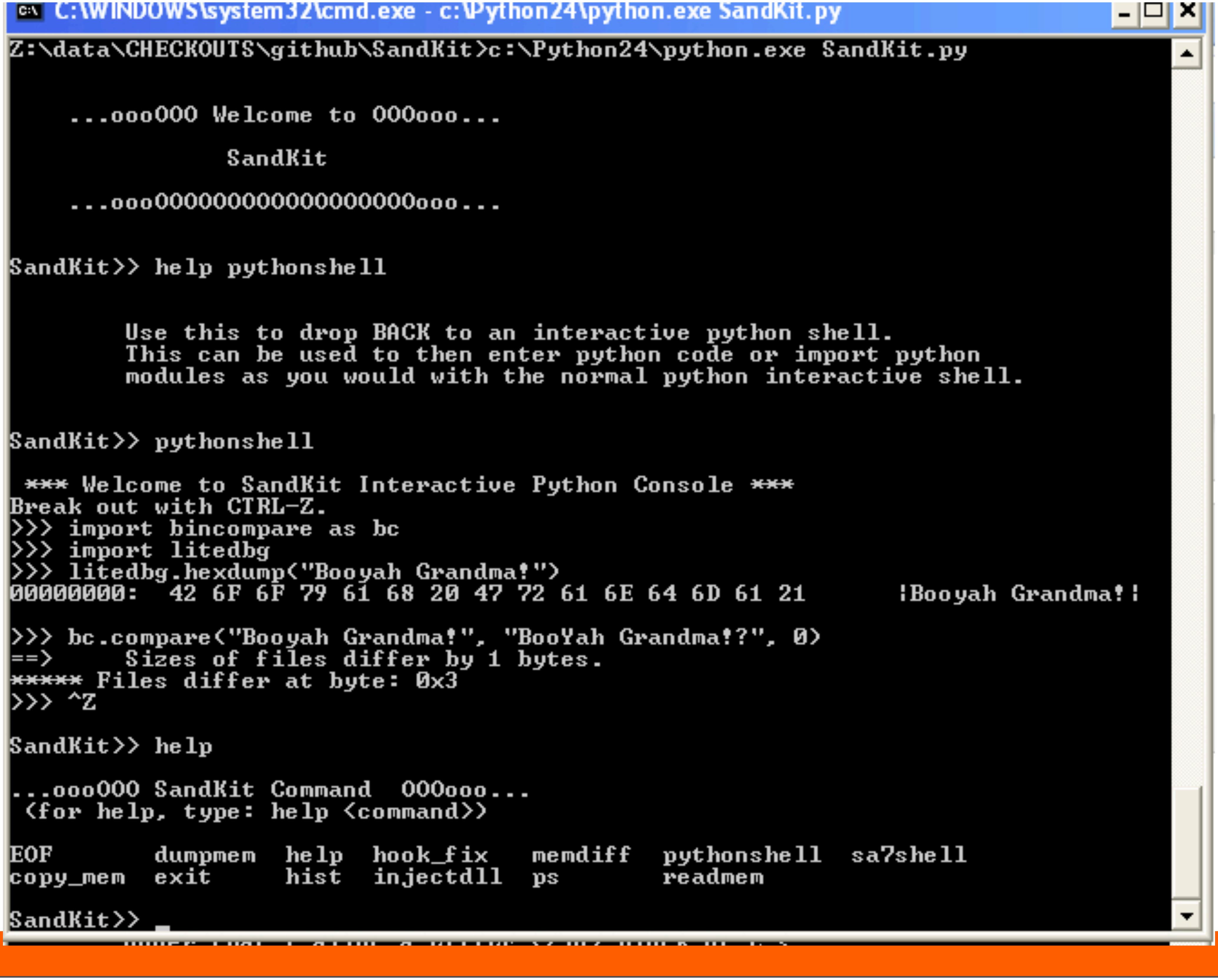
Sa7Shell: Handle Shenanigans



```
    lStdHandle = (long)GetStdHandle(STD_OUTPUT_HANDLE);
    if (lStdHandle == (long)INVALID_HANDLE_VALUE)
        MessageBox(NULL, "Could not get STD_OUTPUT_HANDLE", "!", MB_OK);
    //The next line causes process to exit with no exceptions when injected
    //into remote process.
    hConHandle = _open_osfhandle(lStdHandle, _O_TEXT);// _O_TEXT defined in
                                                        //#include <fcntl.h> and _open_osfhandle in io.h
    if (hConHandle == -1)
        MessageBox(NULL, "Could not open STD_INPUT_HANDLE", "!", MB_OK);
    fp = _fdopen( hConHandle, "w" );
    *stdout = *fp;
    setvbuf( stdout, NULL, _IONBF, 0 );

    // redirect unbuffered STDIN to the console
    lStdHandle = (long)GetStdHandle(STD_INPUT_HANDLE);
    if (lStdHandle == (long)INVALID_HANDLE_VALUE)
        MessageBox(NULL, "Could not get STD_INPUT_HANDLE", "!", MB_OK);
    hConHandle = _open_osfhandle(lStdHandle, _O_TEXT);
    if (hConHandle == -1)
        MessageBox(NULL, "Could not open STD_INPUT_HANDLE", "!", MB_OK);
    fp = _fdopen( hConHandle, "r" );
    *stdin = *fp;
    setvbuf( stdin, NULL, _IONBF, 0 );

    // redirect unbuffered STDERR to the console
    lStdHandle = (long)GetStdHandle(STD_ERROR_HANDLE);
    if (lStdHandle == (long)INVALID_HANDLE_VALUE)
        MessageBox(NULL, "Could not get STD_ERROR_HANDLE", "!", MB_OK);
    hConHandle = _open_osfhandle(lStdHandle, _O_TEXT);
    if (hConHandle == -1)
        MessageBox(NULL, "Could not open STD_ERROR_HANDLE", "!", MB_OK);
    fp = _fdopen( hConHandle, "w" );
    *stderr = *fp;
    setvbuf( stderr, NULL, _IONBF, 0 );
```

PythonShell command in Sandkit

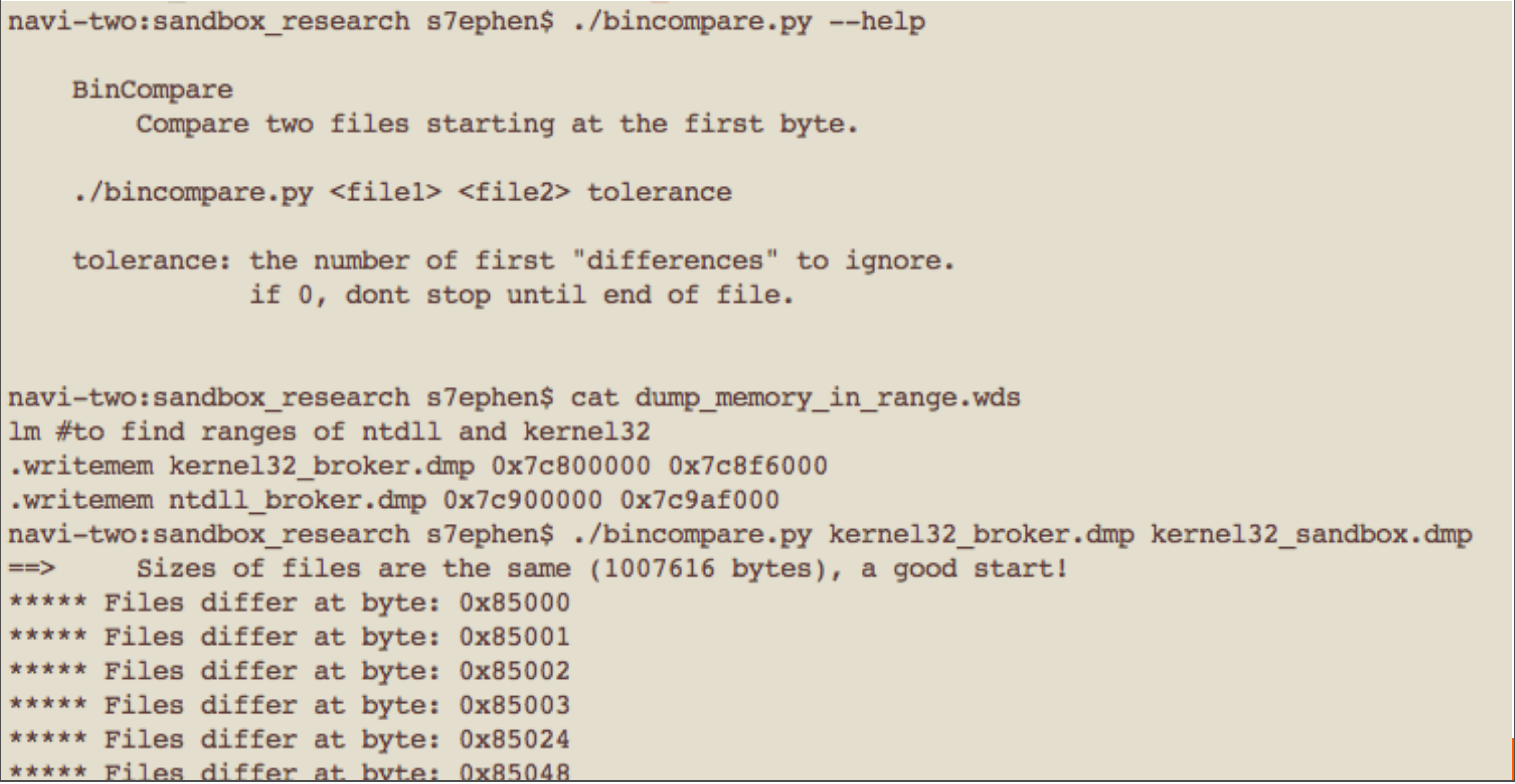
Drop directly into a python shell from Sandkit to fiddle:


C:\WINDOWS\system32\cmd.exe - c:\Python24\python.exe SandKit.py

```
Z:\data\CHECKOUTS\github\SandKit>c:\Python24\python.exe SandKit.py


    ...oooOOO Welcome to OOOooo...

               SandKit

    ...oooOOOOOOOOOOOOOOOOOOooo...


SandKit>> help pythonshell


        Use this to drop BACK to an interactive python shell.
        This can be used to then enter python code or import python
        modules as you would with the normal python interactive shell.


SandKit>> pythonshell

 *** Welcome to SandKit Interactive Python Console ***
Break out with CTRL-Z.
>>> import bincompare as bc
>>> import litedbg
>>> litedbg.hexdump("Booyah Grandma!")
00000000:  42 6F 6F 79 61 68 20 47 72 61 6E 64 6D 61 21      |Booyah Grandma!|

>>> bc.compare("Booyah Grandma!", "BooYah Grandma!?", 0)
==>     Sizes of files differ by 1 bytes.
***** Files differ at byte: 0x3
>>> ^Z

SandKit>> help

...oooOOO SandKit Command  OOOooo...
 (for help, type: help <command>)

EOF       dumpmem  help  hook_fix   memdiff  pythonshell  sa7shell
copy_mem  exit     hist  injectdll  ps       readmem

SandKit>> _
```

BinCompare (stand-alone)

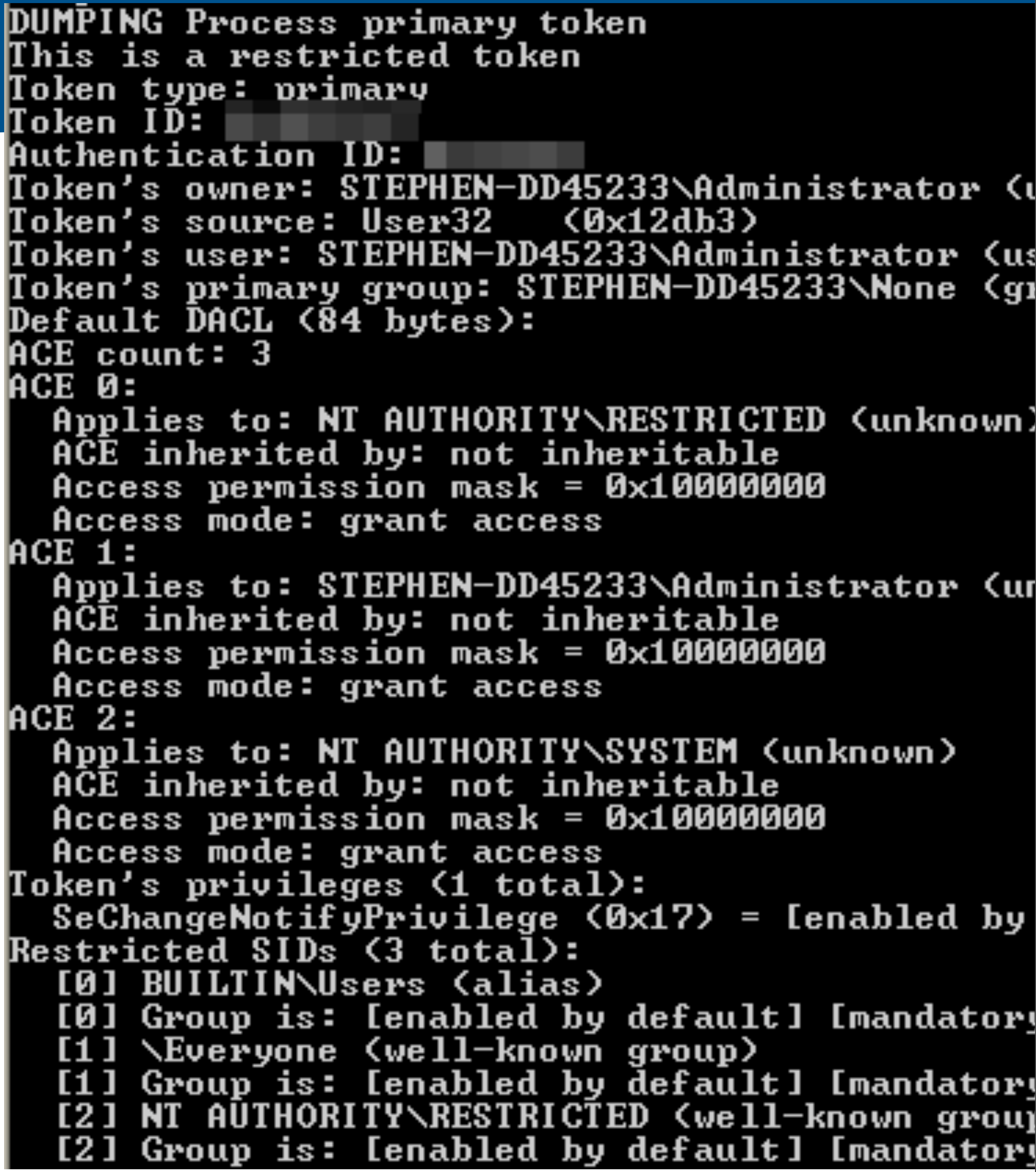
- ★ A standalone tool that does the same thing that memdiff does but specifically for files instead of just memory.
- ★ One of those stupidly simple things that is massively useful.



```
navi-two:sandbox_research s7ephen$ ./bincompare.py --help

    BinCompare
        Compare two files starting at the first byte.

    ./bincompare.py <file1> <file2> tolerance

    tolerance: the number of first "differences" to ignore.
               if 0, dont stop until end of file.


navi-two:sandbox_research s7ephen$ cat dump_memory_in_range.wds
lm #to find ranges of ntdll and kernel32
.writemem kernel32_broker.dmp 0x7c800000 0x7c8f6000
.writemem ntdll_broker.dmp 0x7c900000 0x7c9af000
navi-two:sandbox_research s7ephen$ ./bincompare.py kernel32_broker.dmp kernel32_sandbox.dmp
==>     Sizes of files are the same (1007616 bytes), a good start!
***** Files differ at byte: 0x85000
***** Files differ at byte: 0x85001
***** Files differ at byte: 0x85002
***** Files differ at byte: 0x85003
***** Files differ at byte: 0x85024
***** Files differ at byte: 0x85048
```

DumpToken Redux

- A Dll'd and .h'd version of Matt Conover's DumpToken tool with additional native API helpers such as NtQuerySystemObject
- The .h and .dll make it easily reusable in your injectable code.

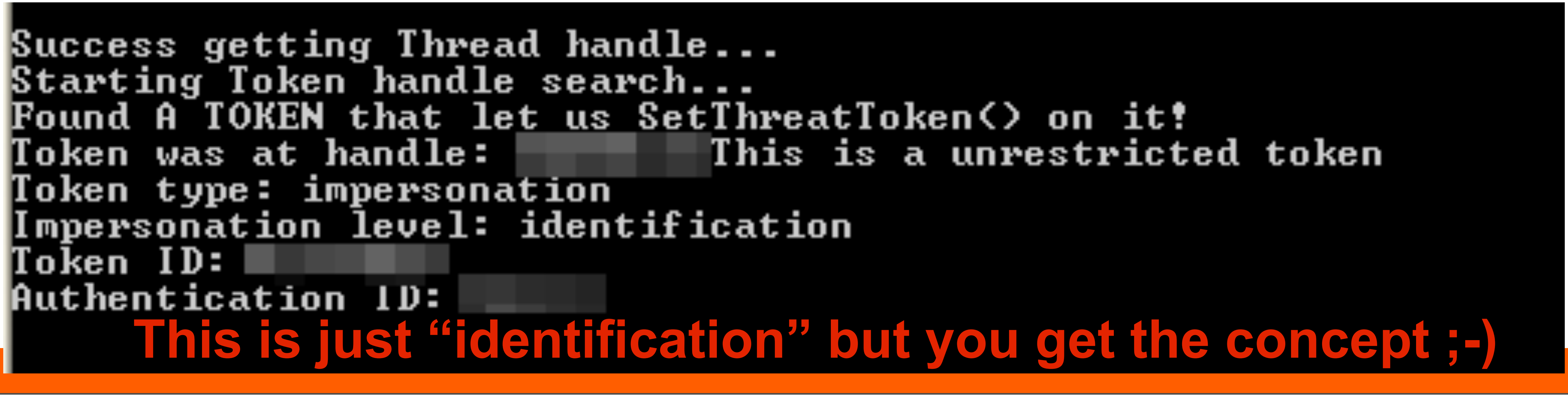


```
DUMPING Process primary token
This is a restricted token
Token type: primary
Token ID: [redacted]
Authentication ID: [redacted]
Token's owner: STEPHEN-DD45233\Administrator (u
Token's source: User32    (0x12db3)
Token's user: STEPHEN-DD45233\Administrator (us
Token's primary group: STEPHEN-DD45233\None (gr
Default DACL (84 bytes):
ACE count: 3
ACE 0:
  Applies to: NT AUTHORITY\RESTRICTED (unknown)
  ACE inherited by: not inheritable
  Access permission mask = 0x10000000
  Access mode: grant access
ACE 1:
  Applies to: STEPHEN-DD45233\Administrator (un
  ACE inherited by: not inheritable
  Access permission mask = 0x10000000
  Access mode: grant access
ACE 2:
  Applies to: NT AUTHORITY\SYSTEM (unknown)
  ACE inherited by: not inheritable
  Access permission mask = 0x10000000
  Access mode: grant access
Token's privileges (1 total):
  SeChangeNotifyPrivilege (0x17) = [enabled by
Restricted SIDs (3 total):
  [0] BUILTIN\Users (alias)
  [0] Group is: [enabled by default] [mandatory
  [1] \Everyone (well-known group)
  [1] Group is: [enabled by default] [mandatory
  [2] NT AUTHORITY\RESTRICTED (well-known grou
  [2] Group is: [enabled by default] [mandatory
```

This screenshot is from code that has been injected into an app using Sandbox_PoC from Google Chrome.

TokenBrute/HandleBrute: A Token/ Handle Sniper

- Inspired by a part of Cesar Cerrudo’s (MS04-044) PoC
- a Dll’d and .h’d tool that “snipes” or “steals” tokens granted into a process by brute forcing token handles
- Not magic. surprisingly simple actually. Iterates 0 to MAX_HANDLES (10,000 on XP) in separate thread.
- Also uses DumpToken Redux to display info if token is found.



```
Success getting Thread handle...
Starting Token handle search...
Found A TOKEN that let us SetThreatToken() on it!
Token was at handle: [redacted] This is a unrestricted token
Token type: impersonation
Impersonation level: identification
Token ID: [redacted]
Authentication ID: [redacted]
```

This is just “identification” but you get the concept ;-)

Where do I get all this stuff?

How can I follow up after this talk?

Where to get it?

- ★ Sandkit and this presentation is here:

http://s7ephen.github.com/SandKit

- ★ Get these slides there.
- ★ Follow on Github for updates. (As I package/sanitize my private tools for public release I will be adding them to the SandKit project.)

In a nutshell:

For Bug Hunters:
Things to look into.

For Sandbox Developers:
Things to look out for.

Notes for Sandbox Developers

- ★ Auditing sandboxes is entirely a “configuration” audit game.
- ★ Applications written without sandboxing in mind have the worst trouble shoe-horning into a sandbox
- ★ Exhaustively check everything from the inside of the Sandbox out. Try to make these test cases integral parts of your build/release process.
- ★ Don’t “cheat” and pass tokens/handles/etc into the sandbox! Even for a “quick moment”.
- ★ Merely having the sandbox doesn’t secure you. You must should how to configure it (build PolicyFilters, install your own Intercepts even!)

Notes for Sandbox Pen-testers/ Reversers

- ★ **There are really two audits: Audit of the "Sandbox" itself and Audit of the "Sandbox implementation"**
  - "Sandbox" bugs will be where the Sandbox meets the OS/Kernel or the IPC channels back into the "Broker". These are harder and higher value ;-)
  - "Sandbox implementation" bugs will be where the Sandbox meets the application's requirements. These are specific to the app.
- ★ **Applications written without sandboxing from the ground up will have difficulty shoe-horning into a sandbox**
  - The larger the application, the higher probability **something** (a legacy library, thread, etc) will require lax token restrictions and SID filters.
- ★ **If you have code execution inside the sandbox, don't be afraid to have your code "wait patiently" for the proper execution environment.**

Do you need any work like this?

- ★ Software Reverse Engineering?
- ★ Penetration Testing?
- ★ Source Code Auditing?
- ★ Security Architecture Analysis?
- ★ Embedded System Security?
- ★ Security Consultation?
- ★ Cryptography Implementations?
- ★ Blackbox auditing of software/hardware?
- ★ Whitebox auditing of software/hardware?
- ★ Web application penetration testing?

Matasano does all of this!

Contact Me for more Info!

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Special Thanks and Contact Info

SPECIAL THANKS

Stephen C. Lawler

Mathieu “Sandwich” Suiche

Stephania Vu

Google Security Team

My Mt. Whitney Summit Team

(Hai, Quynh, Rick, Nick)

The “customer” who approved and cleared me to give this talk ;-)

matasano SECURITY

THANKS FOR Listening!
I hope this is helpful.

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