Often Overlooked Security Vectors

(SDWest 2009)

Who I am.

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Senior Security Researcher/Consultant (Matasano Security)

- Previously Senior Security Architect at McAfee Inc.
- Intrusion Engineer at ManTech Security and Mission Assurance (supporting U.S. Defense and Intelligence)
- columnist for/interviewed by IT magazines (Wired, Ping!, HostingTech, Washington Post, etc.)
- Kenshoto DefCon CTF organizers
- focus: Software Reverse Engineering, tool development, software security

Unfortunately Absent

Colin Delaney
Software Security Engineer
McAfee Inc.

- Security Testing/Training
- Dev and QA
- Code Audits/Threat Modeling

Matasano: What We Do.

- **Independent Security R&D firm (New York, and Chicago**

- **Work with vendors and enterprises at all phases of the software development life-cycle to pinpoint and eradicate security flaws:**
  - Penetration Testing
  - Reverse Engineering
  - Source Code Review
  - Custom tool development

- **Our customers span the Fortune 500**

Matasano: What We've Done.

- Former @stake co-founders
- First published X86 Stack Overflow
- Invented IDS/IPS evasion attacks
- First published iSCSI protocol vulnerability
- First VT-x (hypervisor) Rootkit proof-of-concept and detection

Check out our blog...

http://www.matasano.com/log

What am I talkin' about today?

- **DCOM Object**
  - Overview
  - Security Considerations
  - Tools
- **File Mapping Objects**
  - Overview
  - Permissions/Security Structures
  - Auditing Usage
- **Intro to Kernel Security**
  - Kernel Dev Overview
  - Reverse Engineering Drivers
  - Testing Kernel Components (Fuzzing, et al)

Focus

★ Security Minded Engineers

- Developers
- QA Engineers
- Project Managers

Please feel free to interrupt.

Please feel free to interrupt me, I like my presentations to be conversational...

DCOM Objects

DCOM?

★ **Like COM but just remote!**

- Distributed Component Object Model
- A distributed way to perform tasks...
- An interfaces for remote execution

Authentication

- **Authentication Level (RPC_C_AUTHN_LEVEL_xxx)**
  - Set via dsAuthnLevel parameter in CoInitializeSecurity() and CoSetProxyBlanket()
- **Client and server auth levels compared during handshake (the higher is used)**
  - Default
  - None
  - Connect
  - Call
  - Packet
  - Packet Integrity
  - Packet Privacy

Permissions

★ Launch and Activation Permissions

- Controls which users have the permissions to launch/ activate server locally and remotely
  - **Local Launch**
  - **Remote Launch**
  - **Local Activation**
  - **Remote Activation**

★ Access Permission

- Controls which users have permission to access server locally and remotely
  - **Local Access**
  - **Remote Access**

Configuration/Identity

★ Configuration Permissions

- Controls which users have the permission to configure the server
  - **Full Control**
  - **Read**
  - **Special Permissions**

★ Identity

- The account that is used to run the application
  - **Interactive User (at the console)**
  - **Launching User**
  - ***This* user (specified)**
  - **System User (services)**

Tools

★ Tool Gap

- Auditing COM and DCOM security attributes is a pain to do manually
- Tools to *some* checks but not others.
- Cross-referencing is painstaking

★ New Tools by us!

- COM Enumerator
  - **Parses a binary for TypeLib information**
  - **Manually extracts TypeLib data from Portable Executables**
  - **Identifies Portable Executables with embedded TypeLib data**
- DCOM Enumerator
  - **Parses registry at HKEY_CLASSES_ROOT\AppID**
  - **Extracts security attributes**

TypeLib hubbub (DEMO)

- **TypeLib/IDL**
  - Whats the difference?
- **TLB's embedded in Resource Section**
- **LoadTypeLib() peeks into TLB in the resource section, but how do *we* access it?**
- **OleView**
- **PEView**
- **who_has_tlb.exe**
- **tlb_extract.exe**

File Mapping Objects

What are they?

- ★ Like mmap() for *nix developers
- ★ Create a virtual “map” of a file into memory.
- ★ Different than “allocating” and then “reading”
- ★ System32 subsystem and NT Kernel have special place for file maps

DCOM Object Perm Auditing

CreateFileMapping()

- Creates/opens a named or unnamed file mapping object for file
- Takes a security descriptor (SD)
- A NULL SD causes the object to get the default SD
- Default SD ACLs are the creator's primary or impersonation token

```
HANDLE CreateFileMapping(
  HANDLE hFile,
  LPSECURITY_ATTRIBUTES lpAttributes,
  DWORD flProtect,
  DWORD dwMaximumSizeHigh,
  DWORD dwMaximumSizeLow,
  LPCTSTR lpName );
```

DCOM Object Perm Auditing

- Need to check the lpSecurityDescriptor for the passed-in SECURITY_ATTRIBUTES structure

```
typedef struct _SECURITY_ATTRIBUTES {
 DWORD nLength;
 LPVOID lpSecurityDescriptor;
 BOOL bInheritHandle;
} SECURITY_ATTRIBUTES, *PSECURITY_ATTRIBUTES;
```

- Note: A NULL S_A structure is not the same as granting access to everyone by assigning a NULL discretionary access control list (DACL)

DCOM Object Perm Auditing

- Follow the SECURITY_ATTRIBUTES structure back to its discretionary access control list (DACL)

```
BOOL WINAPI SetSecurityDescriptorDacl(
  __inout   PSECURITY_DESCRIPTOR pSecurityDescriptor,
  __in      BOOL bDaclPresent,
  __in_opt  PACL pDacl,
  __in      BOOL bDaclDefaulted
);
```

pDacl

- A pointer to an ACL structure that specifies the DACL for the security descriptor
- If this parameter is NULL, a NULL DACL is assigned to the security descriptor, which allows all access to the object

DCOM Object Perm Auditing

Auditing guidelines

- Locate all instances of CreateFileMapping() usage
- Check the LPSECURITY_ATTRIBUTES parameter
- If NULL, the default security descriptor is applied
  - Check the ACLs of the creator's primary or impersonation token
- If it points to a SECURITY_ATTRIBUTES structure…
  - Check the lpSecurityDescriptor parameter of the SA
    - If NULL, the default is used (check the caller)
    - If not NULL, check for where the DACL is set
      - Look for SetSecurityDescriptor*()
    - If a NULL pDacl parameter is used this creates a NULL DACL will allows all access to the object

NT Kernel Intro

The “why” is obvious!

“[The Agents] are the gatekeepers Neo, they are guarding all the doors, they are holding all the keys…”

–Morpheus “The Matrix”

The Layout of the Kernel

★ **There are a few presentations on this, most notably:**

- "Windows Kernel Internals Overview" (9 Oct 2008) Dave Probert: Windows Kernel Group

★ **Several great books:**

- "Undocumented Windows 2000 Secrets"
- Gary Nebbett's "The Windows 2000 Native API Reference"
- "Windows Internals" Russinovich (several editions)

Organized in 3 major groups

★ NTOS (Kernel Mode Services)

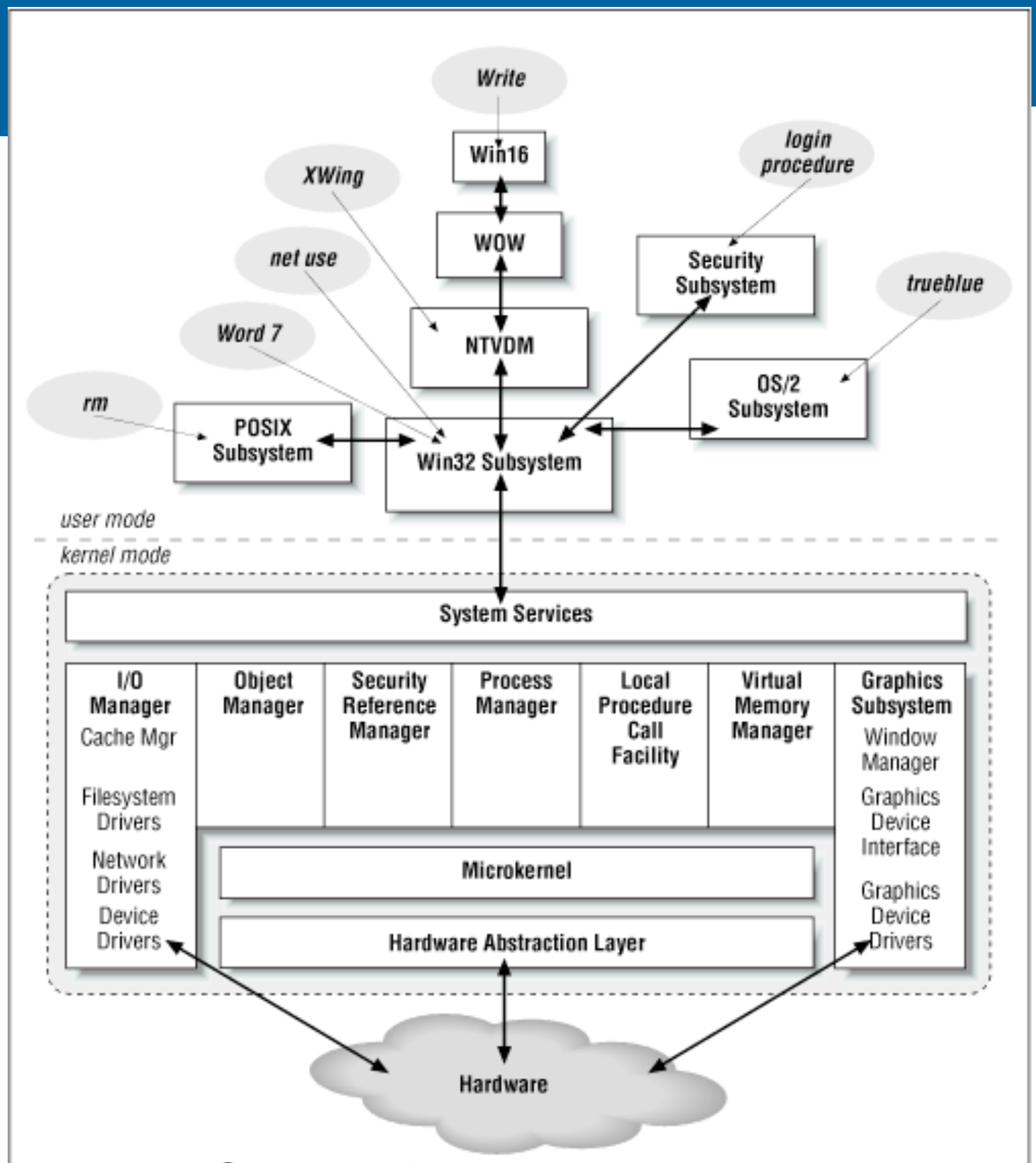
- RTL stuff, executive services, object management, I/O stuff, memory stuff, process loading, scheduling/ priority queuing, etc.

★ HAL (Hardware Abstraction Layer)

- Abstraction layer so that NTOS and drivers don't need to know about the nitty-gritty hardware details.
- Has all the API stuff you'd expect for dealing with hardware (timers, mutexes, locks, spinlocks, etc.)

★ Drivers

- Kernel extensions



(credit) Microsoft TechNet

Kernel's Major Components

- ★ 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)

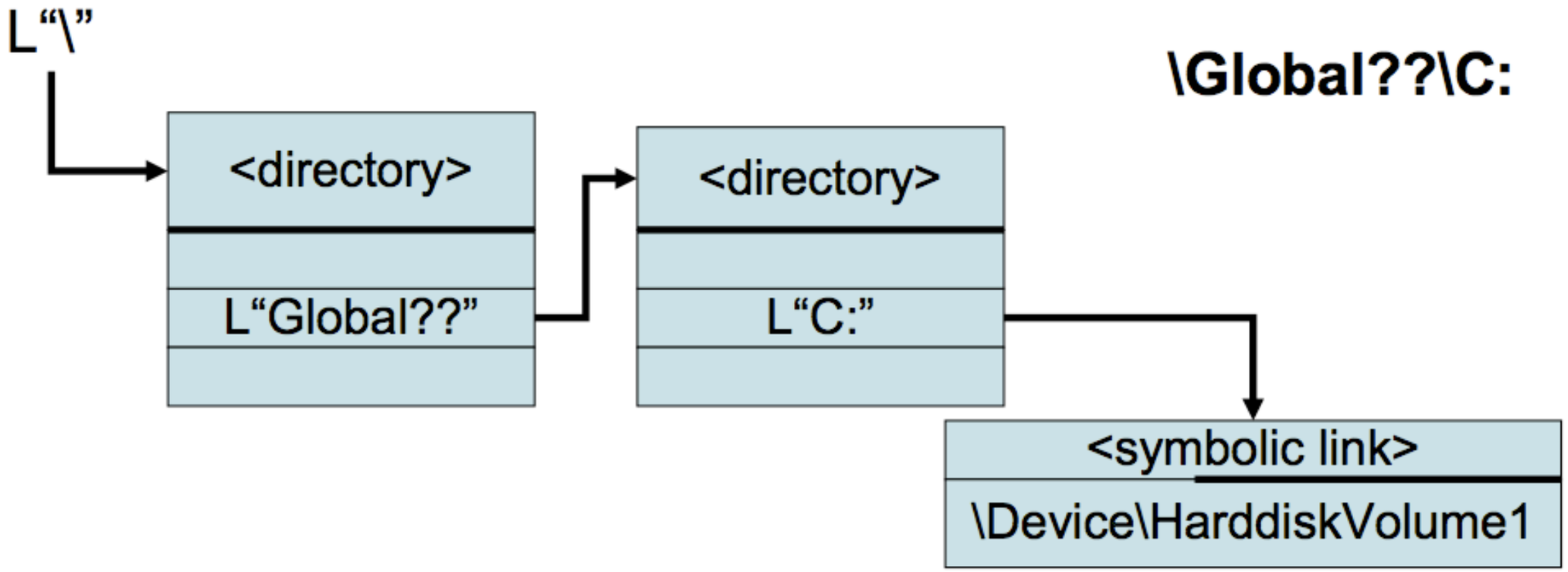
The stuff we care about...

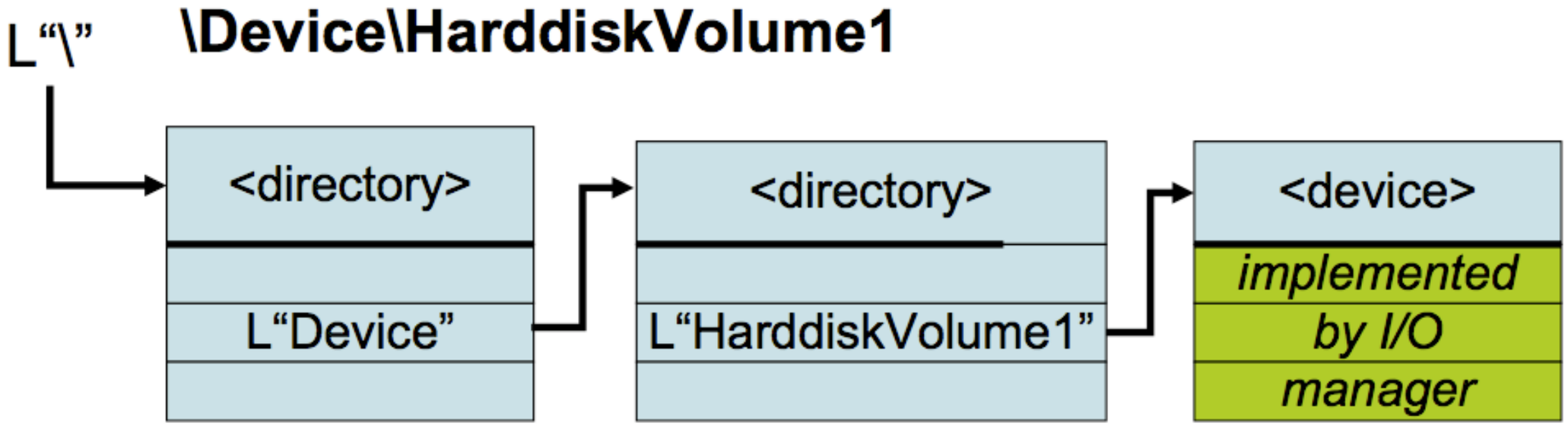
- ★ **Object Manager** (OB)
- ★ **Security Reference Monitor (SE)**
- ★ **Process/Thread Management (PS)**
- ★ **Memory Manager (MM)**
- ★ **Cache Manager (CACHE)**
- ★ **Scheduler (KE)**
- ★ **I/O Manager, PnP, power, GUI** (IO)
- ★ **Devices, FS Volumes, Net** (DRIVERS)
- ★ **Lightweight Procedure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

Object Manager

- **An "abstraction layer": the same thing maybe be known by many names**
- **Handles/Descriptors are a perfect example of this. You do OpenFile() and get back a number...**
- **It provides operations (read, write, delete, etc.)**
- **Since the Object Manager does this "name conversion" this is the perfect place to also do security checks!**
  - Security Reference Monitor sits "behind" the Object Manager to check ACLs and stuff...

NT Object Conversion

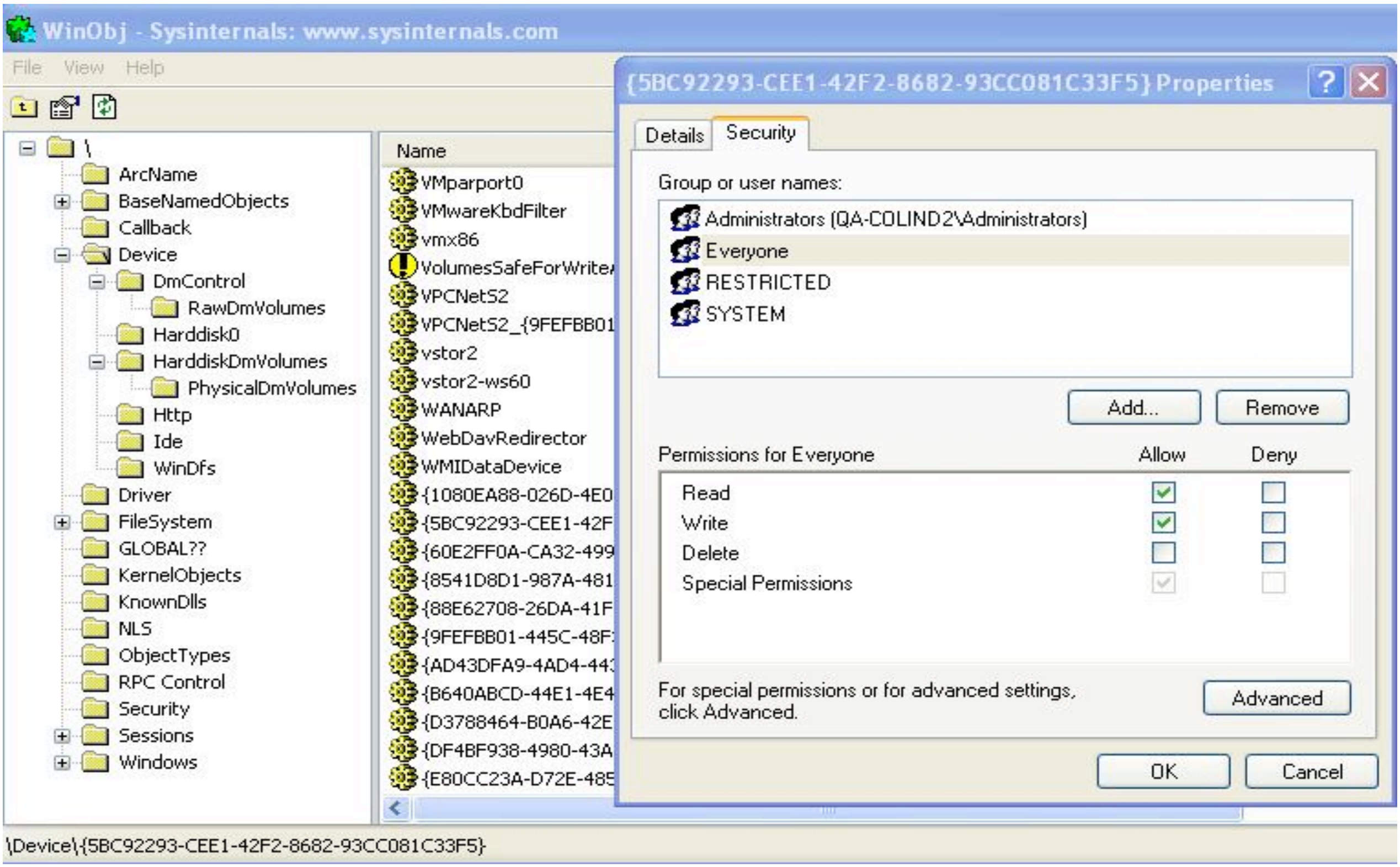




Many Object Types in NT NS

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	

Peeking at the NT Object NS



Kernel I/O

- **The Kernel has to communicate with stuff somehow!**

- **Drivers communicate with userland components in a number of ways most commonly via IOCTLs**

IOCTLs

- IOCTLs are like “special functions” called from userland processes that kernel drivers “listen” for.

- Each driver “listens” by registering a unique identifier (called an IOControlCode) to listen for

- I like think of this mechanism much like User32. How everything evolves around a few “extensible” functions (like SendMessage(), PeekMessage(), etc.)

Kernel I/O

- The DRIVER_OBJECT structure is how your driver registers a “dispatch” function. This dispatch is just a callback that gets called...

- Think of this an oldskool token ring network. Every driver gets all data and decides whether it wants it.

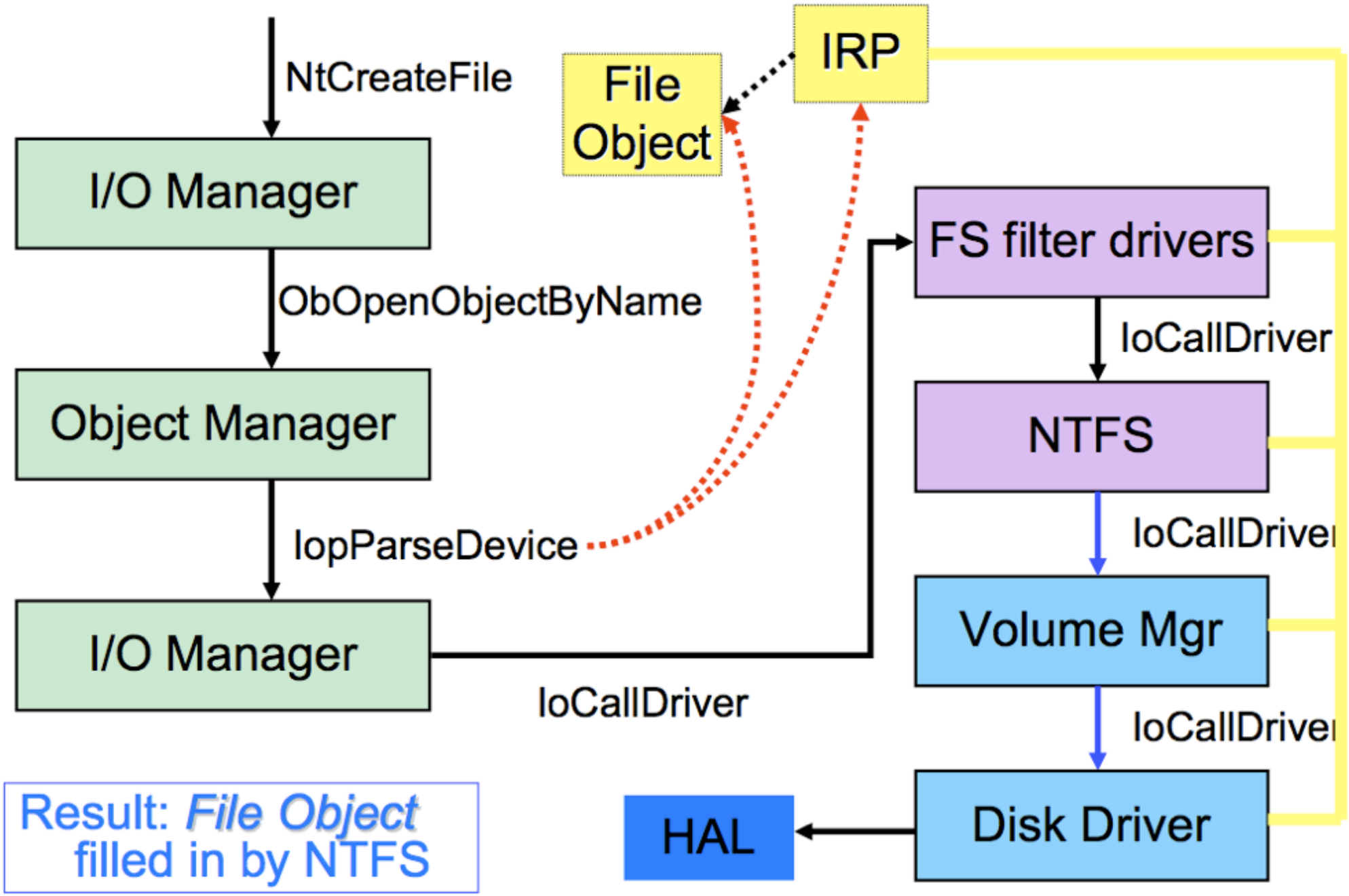
DRIVER_OBJECT (Kernel I/O)

- The DRIVER_OBJECT "registration" would look something like:

  DriverObject->MajorFunction[IRP_MJ_DEVICE_CONTROL] = mydispatchfunc;

- mydispatchfunc then gets called when anyone sends an IOCTL to the driver stack
- IOCTL data comes in as a special structure called Interrupt Request Packet (_IRP)
- Keep in mind the actual IOCTL "opcode" can be reversed out of a binary (.sys, .dll, etc) More on that later.

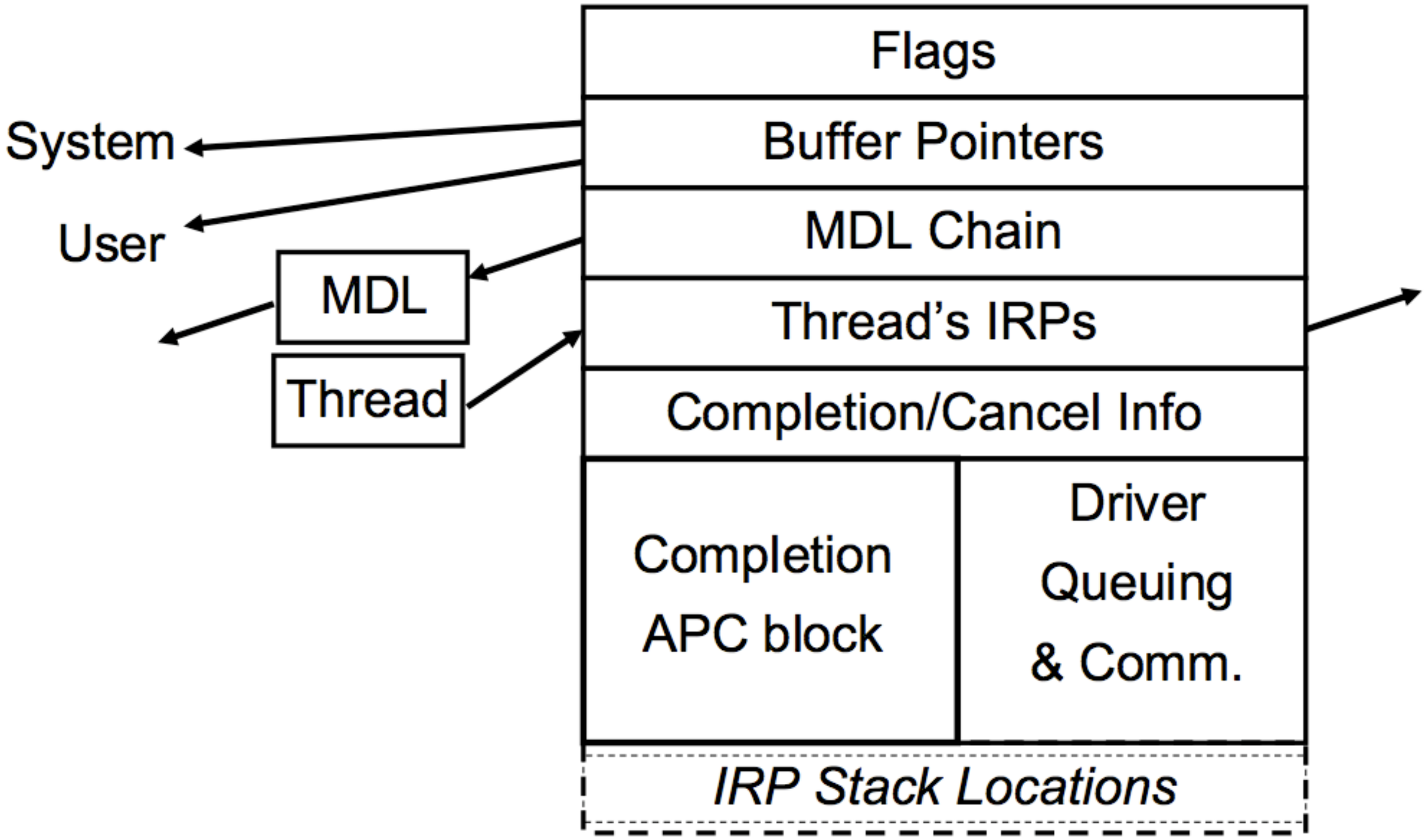
Kernel I/O … IRP



IRP Structure

- In windows *all* I/O events boil down to some IRP structure being passed to some dispatch somewhere.
- Again it helps to think of this as User32 where every action (even movement of the mouse) is a SendMessage() to some window *somewhere*.
- The associated IOControlCode ("opcode") is inside the _IRP structure and is how drivers decide they care about the interrupt.

IRP Structure



Device “Layering”/the Stack

- Drivers are “layered” one on top of the other when they “register” using the IOAttachDevice() API

- (Actually I’ve never used that function, I’ve used IOCreateDevice()/ IoCreateSymoliclink(), same thing but creates instead of attaching to existing)

Device "Layering"/the Stack

- The I/O manager sends all IRPs to the top of the stack
- Drivers are linked together as a linked list, so each driver has pointer to next device driver down.
- Driver "unregistering" and deconstruction happens with IODetachDevice() (I've only ever used IODeleteDevice())

Synchronous vs Asynchronous

- **The way that the driver handles the Interrupt request when it comes in is more or less what determines what I/O mode the driver uses.**

- **If the DriverEntry() (the “main” of a driver returns “STATUS_PENDING”) then its asynchronous and can continue processing and notify the manager using IOCompleteRequest())**

Getting started Dev'ing

Getting Debuggers setup...

- **WinDBG users are vindicated! You endured ridicule before, but now that SoftIce is gone *now* everyone is using your debugger like it was always cool.**
- **Extremely well documented**
- **Powerful scripting engine (you get to keep your old WinDBG scripts :-)**

Debugging Over Serial

★ **Edit boot.ini on debugee**

★ **Serial Debugging and VMWare makes it all possible without a “hardware box”.**

★ **Works by creating “virtual serial port” that is a named pipe on host OS.**

★ **On VMWare Fusion some virtual serial port configuration “gotchas”**

- Found solutions in VMWare developer forums.

Debugee (server) VMX file

Terminal — vim — 81×30

```
49 uuid.action = "create"
50
51 virtualHW.productCompatibility = "hosted"
52
53 unity.wasCapable = "TRUE"
54 vmotion.checkpointFBSize = "134217728"
55
56 hgfs.mapRootShare = "TRUE"
57 hgfs.linkRootShare = "TRUE"
58 isolation.tools.hgfs.disable = "FALSE"
59
60 gui.fullScreen
61 gui.viewModeAtPowerOn = "windowed"
62
63 serial0.present = "TRUE"
64 serial0.fileType = "pipe"
65 serial0.yieldOnMsrRead = "TRUE"
66 serial0.startConnected = "TRUE"
67 serial0.fileName = "/data/kernel_debug_serial_port"
68
69 pciBridge0.present = "TRUE"
70 ehci.present
71 pciBridge4.present = "TRUE"
72 pciBridge4.virtualDev = "pcieRootPort"
73 pciBridge4.pciSlotNumber = "21"
74 pciBridge4.functions = "8"
75 pciBridge5.present = "TRUE"
76 pciBridge5.virtualDev = "pcieRootPort"
77 pciBridge5.pciSlotNumber = "22"
```

Debugger (client) VMX file

Terminal — vim — 86×30

```
50 vmotion.checkpointFBSize = "134217728"
51 checkpointFBSize = "16777216"
52 sharedFolder0.present = "TRUE"
53 sharedFolder0.enabled = "TRUE"
54 sharedFolder0.readAccess = "TRUE"
55 sharedFolder0.writeAccess = "TRUE"
56 sharedFolder0.hostPath = "/data"
57 sharedFolder0.guestName = "data"
58 sharedFolder0.expiration = "never"
59
60 ethernet0.connectionType = "nat"
61
62 ether[illegible].startConnected = "TRUE"
63
64 serial0.present = "TRUE"
65 serial0.fileType = "pipe"
66 serial0.pipe.endPoint = "client"
67 serial0.yieldOnMsrRead = "TRUE"
68 serial0.startConnected = "TRUE"
69 serial0.fileName = "/data/kernel_debug_serial_port"
70
71
72 gui.fullScreenAtPowerOn = "FALSE"
73 gui.viewModeAtPowerOn = "windowed"
74
75 pciBridge0.present = "TRUE"
76 ehci.present = "TRUE"
77 pciBridge4.present = "TRUE"
78 pciBridge4.virtualDev = "pcieRootPort"
```

Finally connected.

Visual Studio .NET 2003 Command Prompt - kd.exe

```
C:\Program Files\Debugging Tools for Windows>kd.exe

Microsoft (R) Windows Debugger  Version 6.5.0003.7
Copyright (c) Microsoft Corporation. All rights reserved.

Opened \\.\com1
Waiting to reconnect...
Connected to Windows XP 2600 x86 compatible target, ptr64 FALSE
Kernel Debugger connection established.
Symbol search path is: *** Invalid ***
*******************************************************************************
* Symbol loading may be unreliable without a symbol search path.              *
* Use .symfix to have the debugger choose a symbol path.                      *
* After setting your symbol path, use .reload to refresh symbol locations.    *
*******************************************************************************
Executable search path is:
*******************************************************************************
* Symbols can not be loaded because symbol path is not initialized.           *
*                                                                             *
* The Symbol Path can be set by:                                              *
*   using the _NT_SYMBOL_PATH environment variable.                           *
*   using the -y <symbol_path> argument when starting the debugger.           *
*   using .sympath and .sympath+                                              *
*******************************************************************************
*** ERROR: Symbol file could not be found.  Defaulted to export symbols for ntkr
nlpa.exe -
Windows XP Kernel Version 2600 (Service Pack 2) UP Free x86 compatible
Product: WinNt, suite: TerminalServer SingleUserTS
Built by: 2600.xpsp_sp2_gdr.080814-1233
Kernel base = 0x804d7000 PsLoadedModuleList = 0x80553420
Debug session time: Fri Feb 27 22:21:29.969 2009 (GMT-8)
System Uptime: 0 days 0:37:52.968
Break instruction exception - code 80000003 (first chance)
*******************************************************************************
*                                                                             *
*   You are seeing this message because you pressed either                    *
*       CTRL+C (if you run kd.exe) or,                                        *
*       CTRL+BREAK (if you run WinDBG),                                       *
*   on your debugger machine's keyboard.                                      *
*                                                                             *
*                   THIS IS NOT A BUG OR A SYSTEM CRASH                       *
*                                                                             *
* If you did not intend to break into the debugger, press the "g" key, then   *
* press the "Enter" key now.  This message might immediately reappear.  If it *
* does, press "g" and "Enter" again.                                          *
*                                                                             *
*******************************************************************************
nt!DbgBreakPointWithStatus+0x4:
80526fe8 cc              int     3
kd>
```

Bite the bullet.

- **If you are like me you prefer to dev with ViM or something and use a CLI compiler.**
- **You still can!**
  - VMWare Shared Folders and batch files that use cl.exe
- **You can, but Visual Studio really will make your life easier if you let it.**
- **Visual Studio can seem overwhelming at first, if you aren't used to IDEs. Don't let it intimidate you :-) ...**

Getting everything...

- For driver development (beginners like us) most of what I have been talking about implies NT5.

- Grab the Windows Driver Development Kit (DDK) and the Platform SDK from Microsoft.

- MSDN is your friend! We all may dislike Microsoft products but you must agree how well documented many are. You'll find this even more so in the DDK.

Taking a look at my driver...

- **Starting out you will probably develop two things:**
  - a kernel mode component to do your first ‘thing’.
  - a “controller” to speak to the driver from userspace
- **DriverEntry()**
- **CreateDevice()**
- **MajorFunction registration**
- **The driver guts...**
- **DeleteDevice()**
- **return to IO Manager**

KHD: Kernel Humpty Dumpty

- **My old shellcode test harness "Humpty Dumpty" (HD) was for regular userland shellcoding**
  - Loaded compiled assembly from disk and executed
  - It had features to load libraries (for you to practice algorithms on), do user32 injection, dll injection, etc.
- **KHD is the "kernel version" that simply loads compiled assembly from IOCTL and jumps into it.**
- **We can use this to see basic structure of a driver**

The start (driver entrypoint)

```
NTSTATUS DriverEntry(IN PDRIVER_OBJECT DriverObject, IN PUNICODE_STRING RegistryPath) {
    NTSTATUS status;
    UNICODE_STRING devName, devLink;
    int i;


    RtlInitUnicodeString(&devName, L"\\Device\\sa7");
    RtlInitUnicodeString(&devLink, L"\\DosDevices\\sa7");

    status = IoCreateDevice(DriverObject,
                            0,
                            &devName,
                            KTRACER_DRV,
                            0,
                            TRUE,
                            &g_devObj);

    if(!NT_SUCCESS(status)){
        IoDeleteDevice(DriverObject->DeviceObject);
        DbgPrint("Failed to create device\n");
        return status;
    }

    status = IoCreateSymbolicLink(&devLink, &devName);
    if(!NT_SUCCESS(status)) {
        IoDeleteDevice(DriverObject->DeviceObject);
        DbgPrint("Failed to create symbolic link\n");
        return status;
    }

    for(i=0; i <= IRP_MJ_MAXIMUM_FUNCTION; i++) {
        DriverObject->MajorFunction[i] = KHDDispatch;
    }
    DriverObject->MajorFunction[IRP_MJ_DEVICE_CONTROL]   = KHDIoControl;
    DriverObject->DriverUnload = KHDUnload;
```

Device Control dispatch

```
NTSTATUS KHDIoControl(IN PDEVICE_OBJECT DeviceObject,IN PIRP Irp){
    PIO_STACK_LOCATION irpStack;
    ULONG ioControl;
    NTSTATUS status = STATUS_SUCCESS;
    ULONG information = 0;
    PVOID inBuf, outBuf;
    ULONG inLen, outLen;
    irpStack = IoGetCurrentIrpStackLocation(Irp);
    inBuf = Irp->AssociatedIrp.SystemBuffer;
    inLen = irpStack->Parameters.DeviceIoControl.InputBufferLength;
    outBuf = Irp->AssociatedIrp.SystemBuffer;
    outLen = irpStack->Parameters.DeviceIoControl.OutputBufferLength;
    ioControl = irpStack->Parameters.DeviceIoControl.IoControlCode;
    switch(ioControl) {
    case IOCTL_EXEC_SHELLCODE:
            // Do a buncha stuff omitted for screenshot
    default:
        DbgPrint("Unknown IOCTL\n");
        status = STATUS_INVALID_DEVICE_REQUEST;
    }
    // complete IRP
    // http://msdn.microsoft.com/en-us/library/ms796109.aspx
    Irp->IoStatus.Status = status;
    Irp->IoStatus.Information = information;
    IoCompleteRequest(Irp, IO_NO_INCREMENT);
    return status;
}
```

The IOCTL Code

```
#ifndef __KHD_H__
#define __KHD_H__

// driver IOCTLs
#define KHD      0xd3adb33f
#define IOCTL_EXEC_SHELLCODE    CTL_CODE(KHD, 0x07, METHOD_BUFFERED, FILE_READ_ACCESS)

#endif
```

Extracted from winioctl.h

```
#define CTL_CODE( DeviceType, Function, Method, Access ) (                  \
    ((DeviceType) << 16) | ((Access) << 14) | ((Function) << 2) | (Method) \
)
```

Cleanup and “blank” dispatch

```
void KHDUnload(IN PDRIVER_OBJECT DriverObject) {
// Do nothing.  free memory or something if we cared.
}

NTSTATUS KHDDispatch(IN PDEVICE_OBJECT DeviceObject,IN PIRP Irp){
    Irp->IoStatus.Status = STATUS_SUCCESS;
    IoCompleteRequest(Irp, IO_NO_INCREMENT);
    return STATUS_SUCCESS;
}
```

Ok...

Now that we have taken a look at a skeletal driver, let's take a step back and remember why we even started.

1. **Writing drivers ourselves to do....fun tasks for us >:-)**
2. **Vulnerability research of existing drivers.**

Poking at Drivers

Poking at stuff...

- Often times as security people we miss the “big picture”...
- As a security person, sometime it’s best to initially approach a project (or technology) as just a “curious developer” (as we did earlier in this presentation)
- Now that we know what “regular” kernel developers start with, lets look take a look with the purpose of vuln research...

Approaching a target...

- **Take a look at the driver list with Kartoffel:**

  "a extensible command-line tool developed with the aim of helping developers to test the security and the reliability of a driver."

  http://kartoffel.reversemode.com/

1. **kartoffel.exe -r > drivers-clean.txt**
2. **Install the software to be tested**
3. **kartoffel.exe -r > drivers-installed.txt**
4. **diff the two text files**

Approaching a target...

★ Check NTObj ACLs with WinObj:

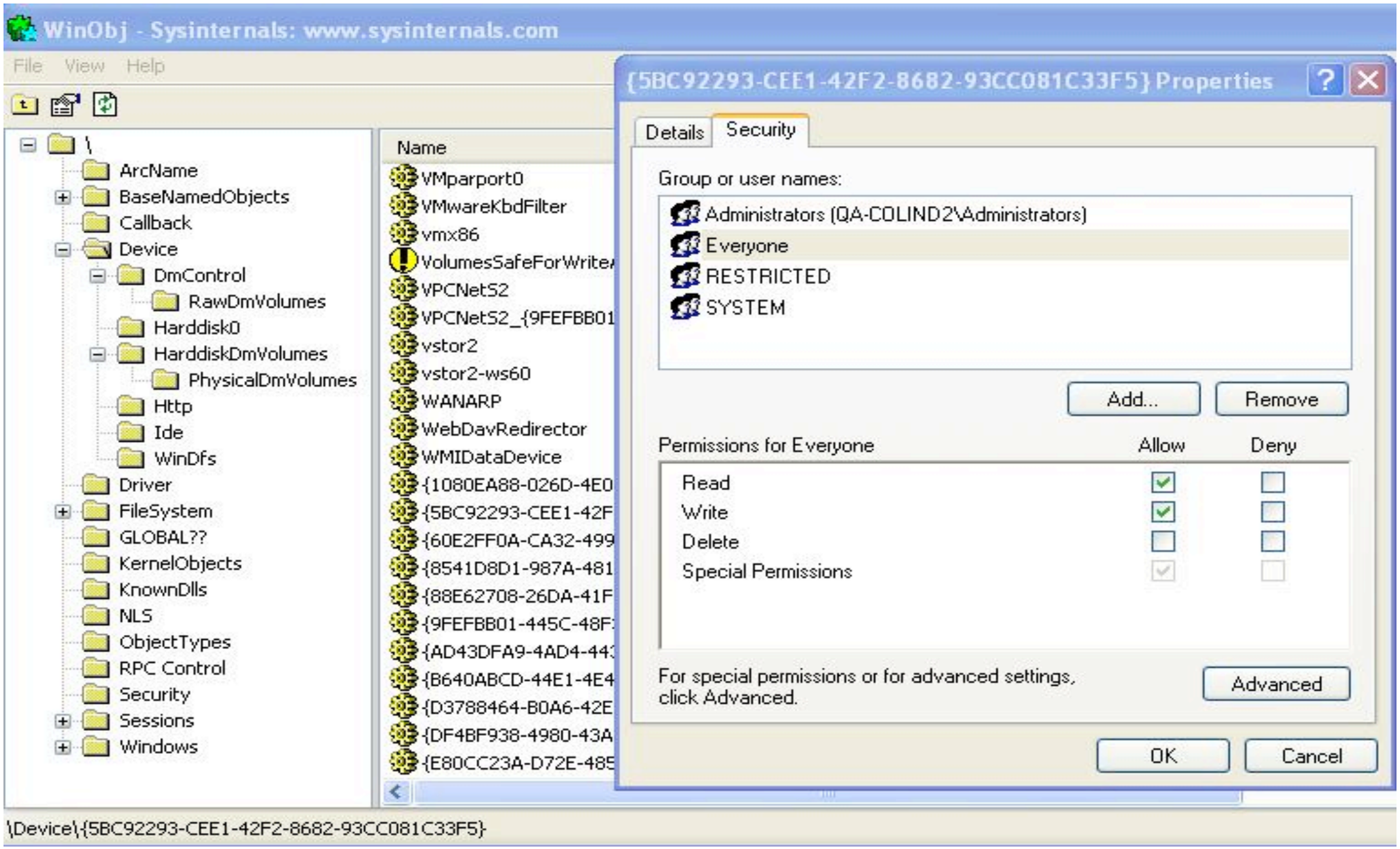
"a 32-bit Windows NT program that uses the native Windows NT API to access and display information on the NT Object Manager's name space."

http://technet.microsoft.com/en-us/sysinternals/bb896657.aspx

1. Launch WinObj
2. Open the \Device node
3. For each driver, right-click / Properties
4. Navigate to the Security tab
5. Select the Everyone group
6. Audit the allowed permissions

Approaching a target...

- **Driver endpoint permissions are commonly overlooked... ”Read/Write Everyone” is generally not good...**



Approaching a target...

- Next you want to identify the IOCTLs used by the driver
- If source is available you are looking for the main switch/if statements in the IoControlCode dispatch
- If source is not available then we have to reverse the control codes out

Reversing out IOCTL codes...

There are a number of great papers and presentations on this already:

(all of these links provided later)

- (SK of Scan Associates) XCon 2004 presentation
- Ruben Santamarta's Reversemode MRXDMB.SYS paper
- Justin Seitz's (of Immunity Inc.) "Driver Impersonation Attack paper".
- Barnaby Jack's seminal "Step Into The Ring" papers
- NGS Security's "Attacking the Windows Kernel"

Not going to echo-chamber...

- **But let's take a quick look at how to reverse out IOCTLs from a driver: AFD.SYS**

- **Why AFD?**
  - Because there have been bugs there in the past >:-)
  - AFD happens to handle many IOCTLs...

Reversing out IOCTL codes...

- Fire up IDA!

- Everyone has a different technique but I am new so I just start at DriverEntry() since the IOManager has to ;-)

- There are apparently Driver Development Frameworks within the DDK (RDBSS) that can sometimes obscure my simple technique of starting at DriverEntry (but I have yet to see those for myself)

Reversing out IOCTL codes...

★ **Locate "DriverEntry"**

IDA View-A | Hex View-A | Exports | Imports | Names | Fur

Name	Address	P
AfdSanFastResetEvents(x,x,x,x,x,x,x,x,x)	0002CBA9	
AfdSanFastCompleteAccept(x,x,x,x,x,x,x,x,x)	0002CCFE	
AfdSanFastRefreshEndpoint(x,x,x,x,x,x,x,x,x)	0002CF60	
AfdSanCancelRequest(x,x)	0002D141	
AfdSanRedirectRequest(x,x)	0002D200	
AfdSanFastCompleteRequest(x,x,x,x,x,x,x,x,x)	0002D34A	
AfdSanAcquireContext(x,x)	0002D612	
AfdInitializeData()	0002DB05	
AfdComputeTpInfoSize(x,x,x)	0002DC76	
AfdInitializeBufferManager()	0002DCAD	
GsDriverEntry(x,x)	0002DEC0	P
DriverEntry(x,x)	0002DF04	
aDeviceAfd	0002E190	
AfdInitializeGroup()	0002E1B1	
AfdCreateSecurityDescriptor()	0002E1FB	
AfdBuildDeviceAcl(x)	0002E30C	

Reversing out IOCTL codes...

★ We start reading....

IDA View-A | Hex View-A | Exports | Imports | Names | Functions | Strings | Structures | Enums

```
; Attributes: bp-based frame

; void DriverEntry
_DriverEntry@8 proc near

DeviceName= LSA_UNICODE_STRING ptr -0Ch
var_4= dword ptr -4
DriverObject= dword ptr  8

; FUNCTION CHUNK AT 0002EB0C SIZE 000000EF BYTES

mov     edi, edi
push    ebp             ; Tag
mov     ebp, esp
sub     esp, 0Ch        ; Free
push    ebx             ; Allocate
push    esi             ; Lookaside
push    edi
push    offset word_2E18E ; SourceString
lea     eax, [ebp+DeviceName]
push    eax             ; DestinationString
call    ds:__imp__RtlInitUnicodeString@8 ; RtlInitUnicodeString(x,x)
push    offset _AfdDeviceObject ; DeviceObject
xor     ebx, ebx
```

Reversing out IOCTL codes...

- **Reading through DriverEntry you stumble upon:**

Hex View-A | Exports | Imports | Names | Functions | Strings | Structures | Enums

```
mov     edx, [ebp+DriverObject]
push    1Ch
lea     edi, [edx+38h]
pop     ecx
mov     eax, offset _AfdDispatch@8 ; AfdDispatch(x,x)
rep stosd
mov     dword ptr [edx+70h], offset _AfdDispatchDeviceControl@8 ; AfdDispatchDeviceControl(x,x)
mov     dword ptr [edx+28h], offset _AfdFastIoDispatch
mov     dword ptr [edx+34h], offset _AfdUnload@4 ; AfdUnload(x)
mov     eax, _AfdDeviceObject
or      dword ptr [eax+1Ch], 10h
mov     eax, _AfdDeviceObject
mov     cl, _AfdIrpStackSize
mov     [eax+30h], cl
call    ds:__imp__IoGetCurrentProcess@0 ; IoGetCurrentProcess()
cmp     _AfdParametersNotifyHandle, ebx
mov     _AfdSystemProcess, eax
jnz     loc_2EBF0
```

Reversing out IOCTL codes...

★ Following into _AfdDispatchDeviceControl we see:

IDA View-A | Hex View-A | Exports | Imports | Names | Functions | Strings | Structures | Enums

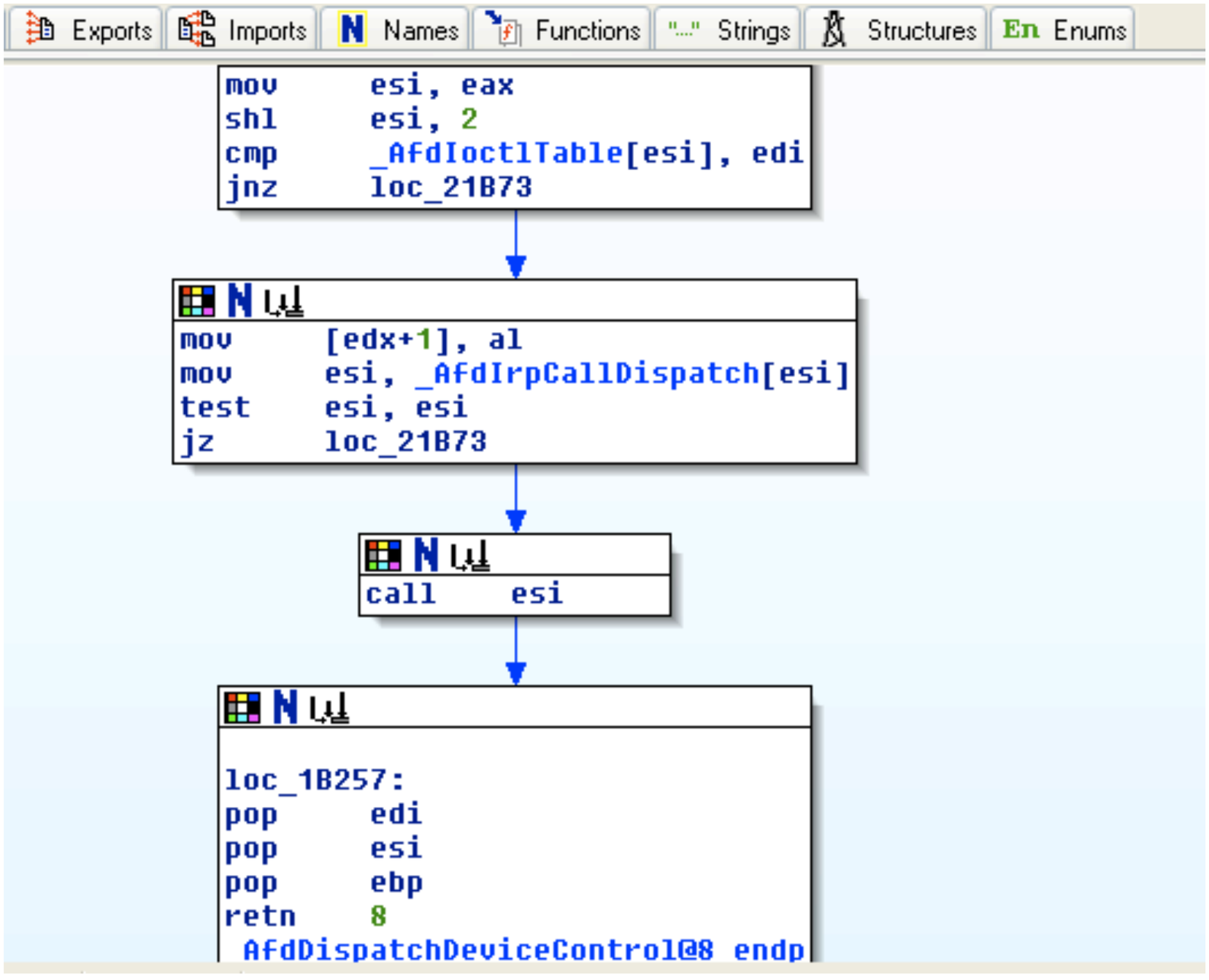
```
; __stdcall AfdDispatchDeviceControl(x, x)
_AfdDispatchDeviceControl@8 proc near

arg_4= dword ptr  0Ch

mov     edi, edi
push    ebp
mov     ebp, esp
mov     ecx, [ebp+arg_4]
mov     edx, [ecx+60h]
push    esi
push    edi
mov     edi, [edx+0Ch]
mov     eax, edi
shr     eax, 2
and     eax, 3FFh
cmp     eax, 46h
jnb     loc_21B73
```

```
mov     esi, eax
shl     esi, 2
cmp     _AfdIoctlTable[esi], edi
jnz     loc_21B73
```

★ +60h IoGetCurrentIrpStack thnx Lawler!

Reversing out IOCTL codes...

- **We can see that this is really our dispatch, let's Investigate _AfdIoctlTable**



Reversing out IOCTL codes...

- **IDA once again "helped" us too much, lets CTRL-O and fix these values:**

View-A | Hex View-A | Exports | Imports | Names | Functions | Strings | Structures | Enums

```
.data:0001209B                  db    0
.data:0001209C                  db    0
.data:0001209D                  db    0
.data:0001209E                  db    0
.data:0001209F unk_1209F        db    0                 ; DATA XREF: .data:0001213C↓o
.data:000120A0 _AfdIoctlTable   dd offset _AfdMediumBufferSize+3 ; DATA XREF: .data:00012140↓o
.data:000120A0                                          ; AfdFastIoDeviceControl(x,x,x,x,x,x,x,x,x)
.data:000120A4 off_120A4        dd offset _AfdSmallBufferSize+3 ; DATA XREF: .data:00012144↓o
.data:000120A8 off_120A8        dd offset _AfdDefaultTransmitWorker+3
.data:000120A8                                          ; DATA XREF: .data:00012148↓o
.data:000120AC off_120AC        dd offset _AfdStandardAddressLength
.data:000120AC                                          ; DATA XREF: .data:0001214C↓o
.data:000120B0 off_120B0        dd offset _AfdIrpStackSize ; DATA XREF: .data:00012150↓o
.data:000120B4 off_120B4        dd offset _AfdFastSendDatagramThreshold+3
.data:000120B4                                          ; DATA XREF: .data:00012154↓o
.data:000120B8 off_120B8        dd offset _AfdTPacketsCopyThreshold+3
.data:000120B8                                          ; DATA XREF: .data:00012158↓o
.data:000120BC                  dd offset _AfdMaxFastTransmit+3
.data:000120C0 off_120C0        dd offset _AfdMaxFastCopyTransmit+3
.data:000120C0                                          ; DATA XREF: .data:00012160↓o
.data:000120C4 off_120C4        dd offset _AfdUseTdiSendAndDisconnect
.data:000120C4                                          ; DATA XREF: .data:00012164↓o
.data:000120C8 off_120C8        dd offset _AfdDefaultTpInfoElementCount+3
.data:000120C8                                          ; DATA XREF: .data:00012168↓o
.data:000120CC off_120CC        dd offset unk_1202F     ; DATA XREF: .data:0001216C↓o
```

Reversing out IOCTL codes...

Voila!
(our IOCTLs)

IDA View-A | Hex View-A | Exports | Imports | Names | Functions | Strings | Structures | Enums

```
.data:0001209D                  db    0
.data:0001209E                  db    0
.data:0001209F unk_1209F        db    0                 ; DATA XREF: .data:0001213C↓o
.data:000120A0 _AfdIoctlTable   dd 12003h               ; DATA XREF: .data:00012140↓o
.data:000120A0                                          ; AfdFastIoDeviceControl(x,x,x,
.data:000120A4 dword_120A4      dd 12007h               ; DATA XREF: .data:00012144↓o
.data:000120A8 dword_120A8      dd 1200Bh               ; DATA XREF: .data:00012148↓o
.data:000120AC dword_120AC      dd 1200Ch               ; DATA XREF: .data:0001214C↓o
.data:000120B0 dword_120B0      dd 12010h               ; DATA XREF: .data:00012150↓o
.data:000120B4 dword_120B4      dd 12017h               ; DATA XREF: .data:00012154↓o
.data:000120B8 dword_120B8      dd 1201Bh               ; DATA XREF: .data:00012158↓o
.data:000120BC                  dd 1201Fh
.data:000120C0 dword_120C0      dd 12023h               ; DATA XREF: .data:00012160↓o
.data:000120C4 dword_120C4      dd 12024h               ; DATA XREF: .data:00012164↓o
.data:000120C8 dword_120C8      dd 1202Bh               ; DATA XREF: .data:00012168↓o
.data:000120CC dword_120CC      dd 1202Fh               ; DATA XREF: .data:0001216C↓o
.data:000120CC                                          ; AfdFastIoDeviceControl(x,x,x,
.data:000120D0 dword_120D0      dd 12033h               ; DATA XREF: .data:00012170↓o
.data:000120D4 dword_120D4      dd 12037h               ; DATA XREF: .data:00012174↓o
.data:000120D8 dword_120D8      dd 1203Bh               ; DATA XREF: .data:00012178↓o
.data:000120DC dword_120DC      dd 1203Fh               ; DATA XREF: .data:0001217C↓o
.data:000120E0 dword_120E0      dd 12043h               ; DATA XREF: .data:00012180↓o
.data:000120E4 dword_120E4      dd 12047h               ; DATA XREF: .data:00012184↓o
.data:000120E8 dword_120E8      dd 1204Bh               ; DATA XREF: .data:00012188↓o
.data:000120EC dword_120EC      dd 1204Fh               ; DATA XREF: .data:0001218C↓o
```

Fuzzing Drivers

- **Now with all the information gathered you can begin fuzzing**
  - IOCTLs, DRIVER_OBJECT, endpoints, etc.
- **Kartoffel seems to be the most popular fuzzer for kernel things**
- **I am more partial to doing this with custom tools, I personally use my fuzzer called Ruxxer (www.ruxxer.org) as the "engine" for test case generation.**
- **Python and CTypes is excellent for the "glue code" that gets test-cases into the driver.**
  - Opening devices, making IOCTLS, etc.

Kernel Shellcoding...

Kernel Shellcoding...

- **Shellcode "loaders" make it so that you don't have to statically code in function addresses**

- **Everyone basically ripped off the same userspace loader:**
  - The fs:30 hashing "ror 0xd" GetProcAddress loader (probably originally by Dino Dai Zovi)
  - I am guilty of ripping this off as well ;-)

- **This loader found PEB Base via FS:30 then from there basically found GetProcAddress, and resolved functions**

Kernel Shellcoding...

Terminal — vim — 111×44

```
_start:     ; tell linker entry point, oh and also tell nasm the grow the fuck up
            ; and learn how to calculate relative offsets like an adult.
    mov ebp, esp
    sub esp, byte 0xc    ;sub esp, SIZEOF_BSS_IMPORTER   I need to find a way for nasm to calc and i
s value
    jmp GetHashDataAddr0     ;jmp GetHashDataAddr0

    GetHashDataAddr1:
        pop esi
        mov [ebp-0xc], esi   ;mov bss.pHashStart, esi...why not mov [esp], esi?
        jmp short GetDoImportsAddr0 ;jmp GetDoImportsAddr0

GetDoImportsAddr1:
    pop edi
    ;Find kernel32 handle, walk through PEB module list to second entry
    mov eax, [fs:0x30]  ;PEB
    mov eax, [eax+0xc]  ;PEB_LDR_DATA
    mov eax, [eax+0x1c]     ;initorder link_entry in ldr_module for ntdll
    push byte 0x2       ;number of ntdll imports !!!CHANGE THIS BASED ON YOUR HASH TABLE SIZE
    push dword [eax+0x8]    ;ntdll handle
    mov eax, [eax]      ;initorder, link_entry in ldr_module for kernel32.dll
    push byte 0xd       ;number of kernel32 imports 13
    push dword [eax+0x8]    ;push Kernel32 base address
    call edi          ;call doImports
    ;call edi         ;call doImports this second one got in here somehow
```

Kernel Shellcoding...

- A “new” Kernel loader at: www.dontstuffbeansupyournose.com
- Uses FS:34 to find base of ntoskrnl.exe and from there uses similar hash technique to locate function exports.
- Proof of Concept shellcode resets VGA driver and displays a neat message...

Kernel Shellcoding...

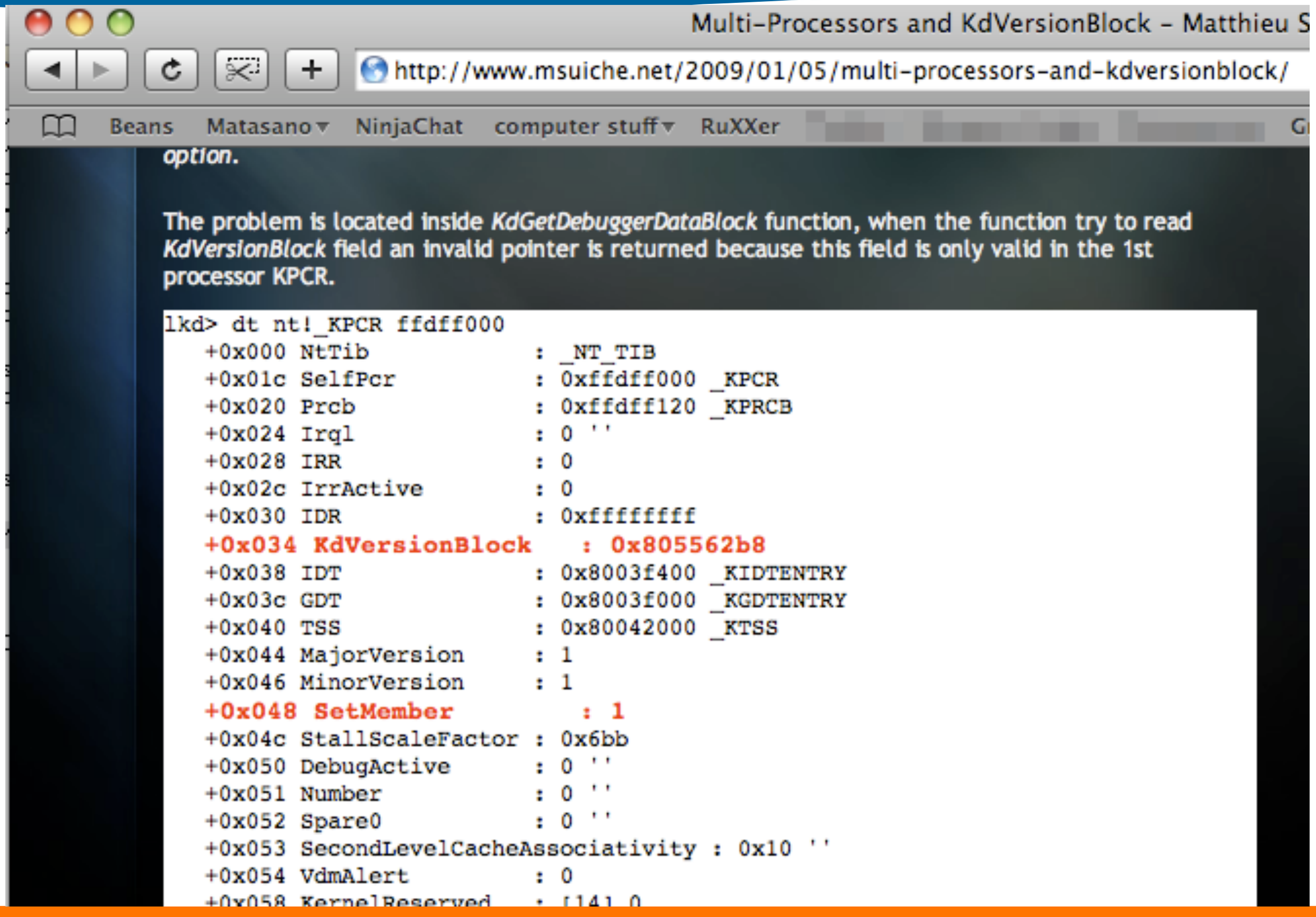
Terminal — vim — 104×40

```
; Kernel loader with ResetDisplay VGA Text Mode PoC
;  www.dontstuffbeansupyournose.com



CPU 686
BITS 32

    ; Not optimized for size, space, speed, or much of anything
    pushad
    mov ebx, [fs:0x34] ; KdVersionBlock in NTOSKRNL -> NOT VERIFIED this always points at NTOSKRNL
    mov edx, 0x1000
    ; page-align
    dec edx
    not edx
    and ebx, edx
    not edx
    inc edx

    ; ok, i got lazy here with register allocation, i'm bored of this, just import my funcs will ya!
    jmp functable
get_funcs:
    pop ebp
    ; this - terrible
```

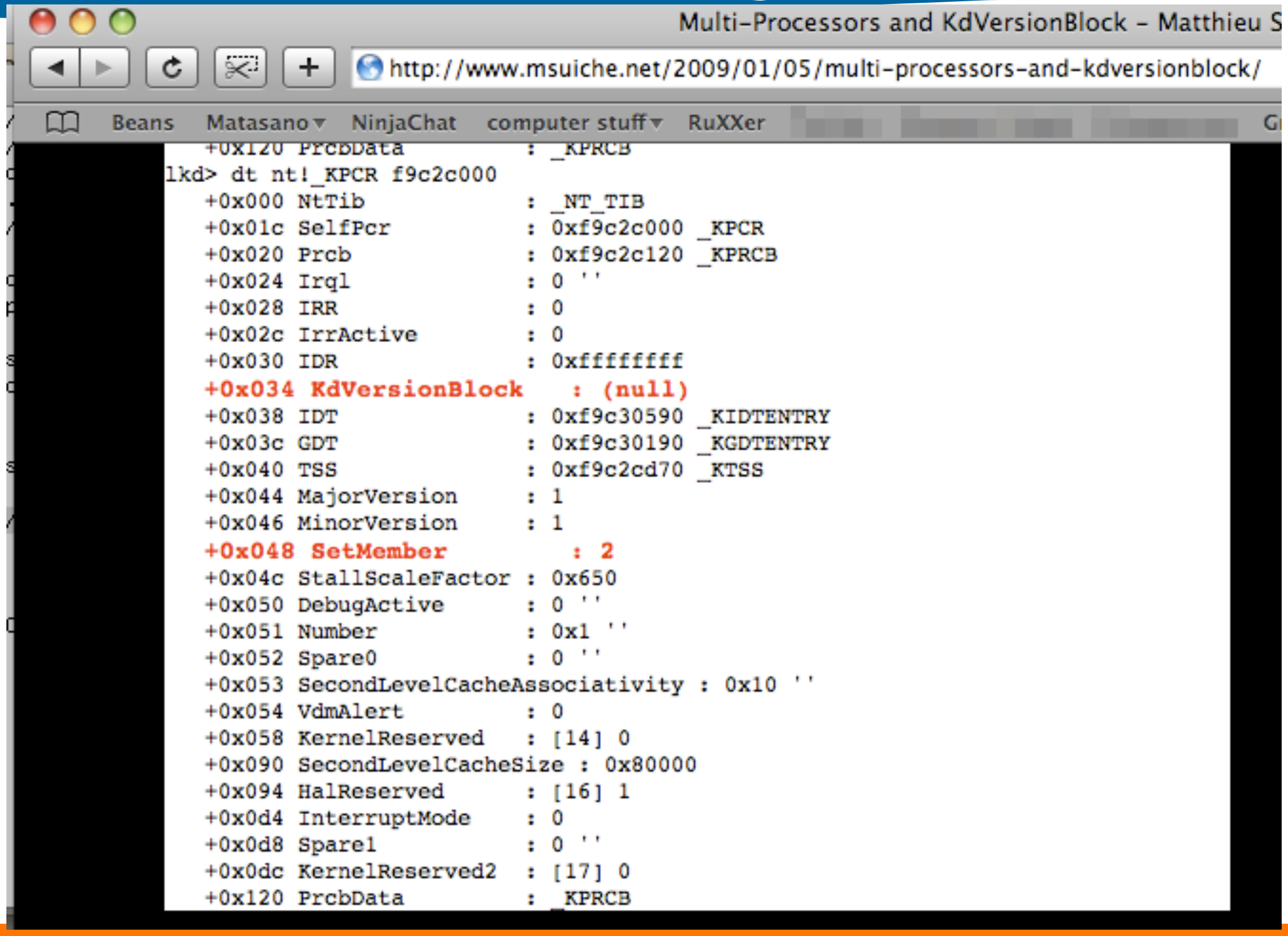
Kernel Shellcoding...

- **Interestingly, the structure we reference at FS:0x34 (KPCR!KdVersionBlock) is not guaranteed to exist in multiprocessor systems if you are not executing on the first processor.**

Kernel Shellcoding...



Kernel Shellcoding...



Kernel Shellcoding...

- Mathieu Suiche (www.msuiche.net) has a note on this (instead of directly referencing KdVersionBlock) you first reference “selfPCR” at fs:0x1C

- This is an example of interesting stuff you learn while developing/coding for the kernel! ;-)

Kernel Shellcoding...

Multi-Processors and KdVersionBlock - Matthieu Suiche's blog !

http://www.msuiche.net/2009/01/05/multi-processors-and-kdversionblock/

Beans Matasano NinjaChat computer stuff RuXXer Twitter Gmail Netflix P

```
//
// Multi Processors (MP)
// To ensure that it's running on a specific processor.
//
                                (1);
 _asm {
    mov eax, fs:[0x1C]  // SelfPCR
    mov eax, [eax + 0x34] // KdVersionBlock
    mov KdVersionBlock, eax
}
 //
 // Go back to default affinity.
 //
                                    ();
```

Conclusions

- **When developing, it can be difficult to keep security in mind, but try**

- **Consider security audits on your projects by “fresh eyes” (third party’s)**

- **Remember: Esoteric technologies don’t provide “security through obscurity”**

Links, Notes, References...

Get links to everything in this presentation at:

www.dontstuffbeansupyournose.com/sdwest09

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Special Thanks

SDWest

Matasano

Colin Delaney

THANK YOU FOR LISTENING!

Good Luck!

matasano SECURITY