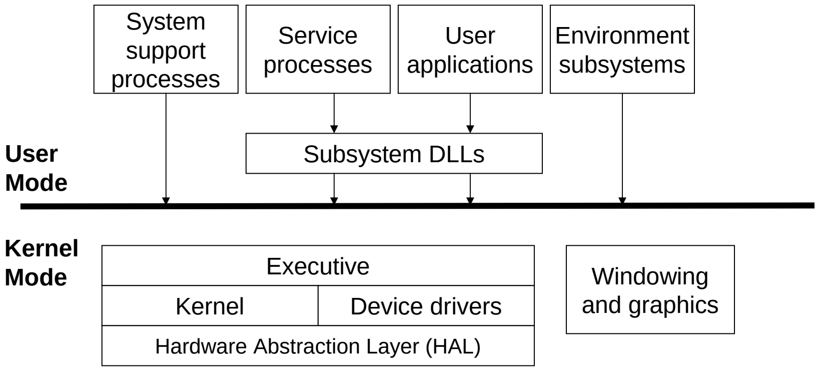
Unit OS2: Operating System Principles

2.1. Structuring of the Windows Operating System

Roadmap for Section 2.1.

- Architecture Overview
- Program Execution Environment
- Kernel Mode Architecture
- System Threads
- System Processes / Services

Simplified OS Architecture



System support processes

Service processes

User applications

Environment subsystems

Subsystem DLLs

User Mode

Kernel Mode

Executive

Kernel

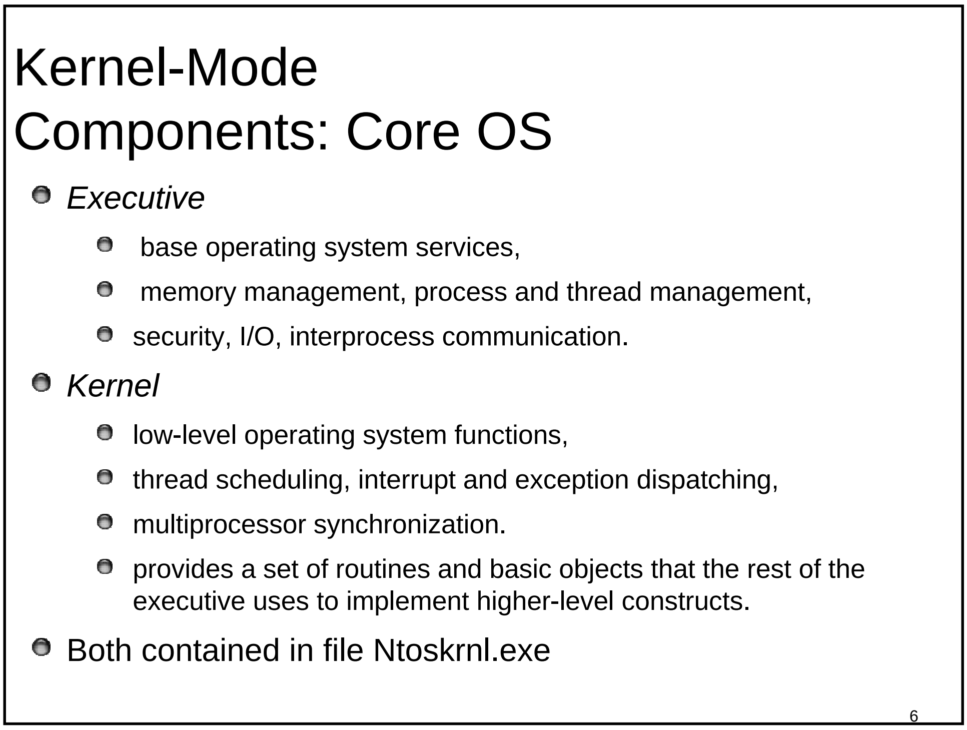
Device drivers

Hardware Abstraction Layer (HAL)

Windowing and graphics

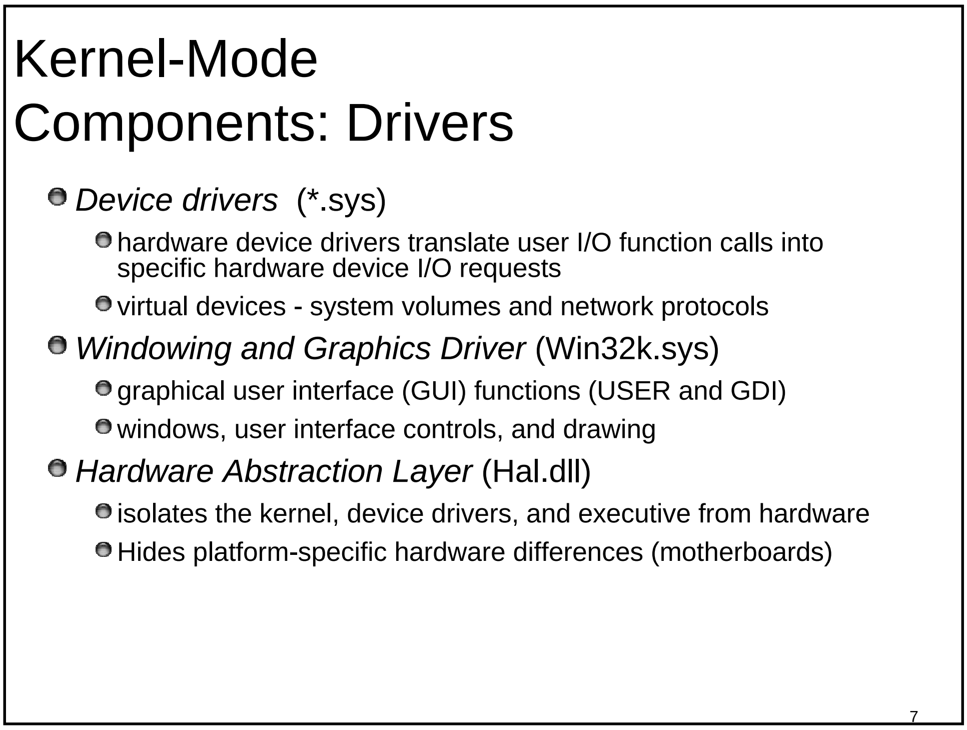
OS Architecture

- Multiple personality OS design
  - user applications don't call the native Windows operating system services directly
- Subsystem DLLs is to translate a documented function into the appropriate internal (and undocumented) Windows system service calls.
- Environment subsystem processes
  - Manage client processes in their world
  - Impose semantics such as process model, security
- Originally three environment subsystems: Windows, POSIX, and OS/2
  - Windows 2000 only included Windows and POSIX
  - Windows XP only includes Windows
    - Enhanced POSIX subsystem available with Services for Unix
    - Included with Windows Server 2003 R2



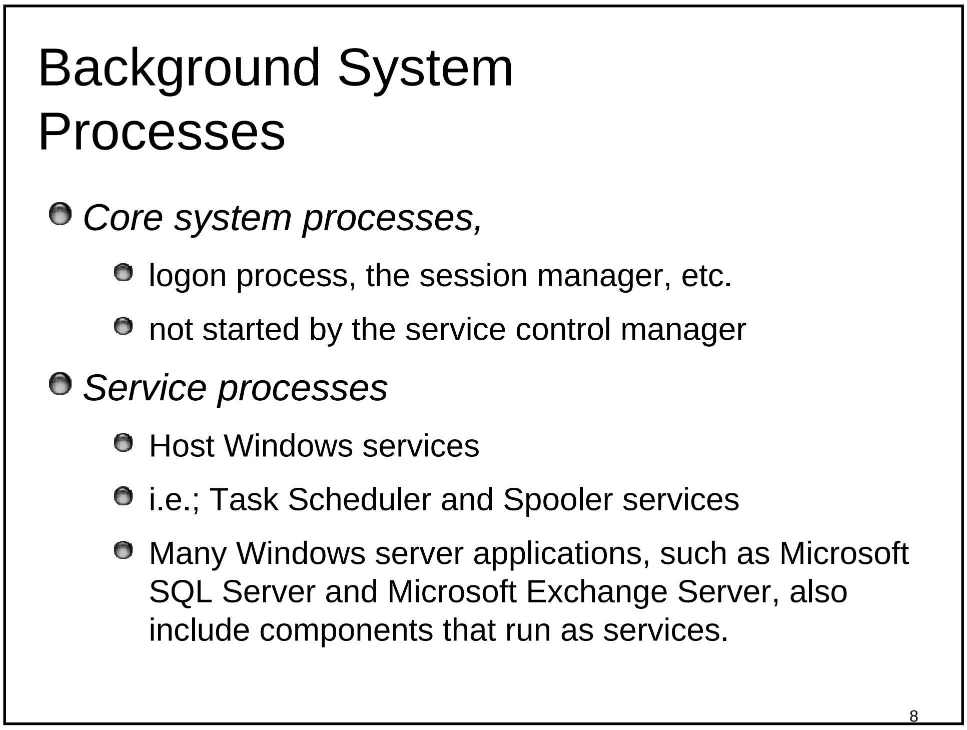
Kernel-Mode Components: Core OS

- *Executive*
  - base operating system services,
  - memory management, process and thread management,
  - security, I/O, interprocess communication.
- *Kernel*
  - low-level operating system functions,
  - thread scheduling, interrupt and exception dispatching,
  - multiprocessor synchronization.
  - provides a set of routines and basic objects that the rest of the executive uses to implement higher-level constructs.
- Both contained in file Ntoskrnl.exe



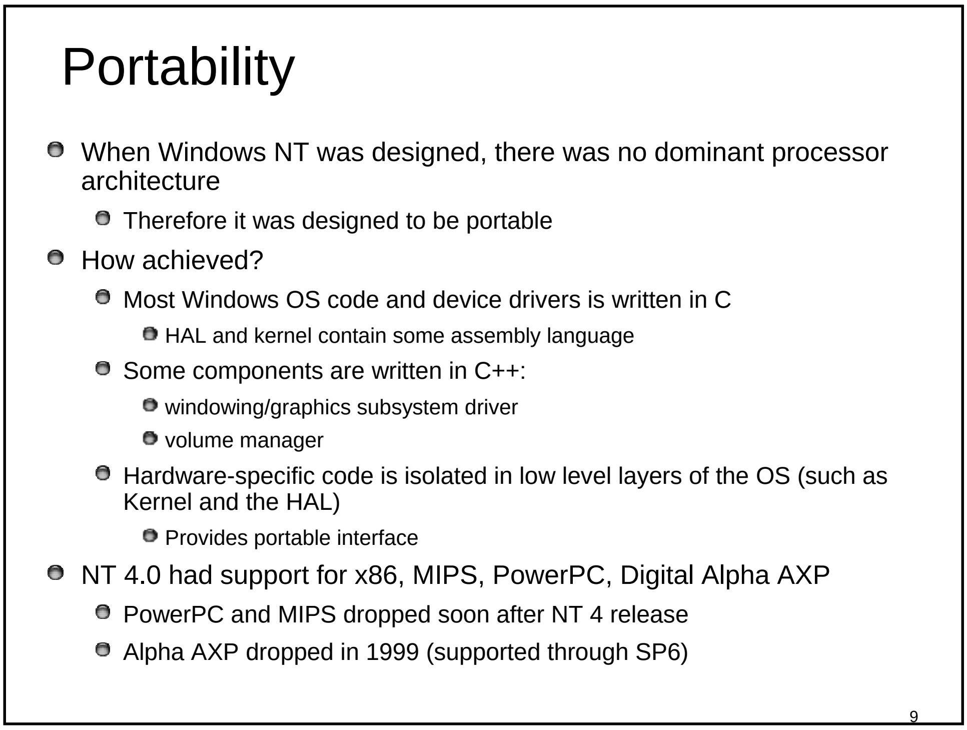
Kernel-Mode Components: Drivers

- *Device drivers* (*.sys)
  - hardware device drivers translate user I/O function calls into specific hardware device I/O requests
  - virtual devices - system volumes and network protocols
- *Windowing and Graphics Driver* (Win32k.sys)
  - graphical user interface (GUI) functions (USER and GDI)
  - windows, user interface controls, and drawing
- *Hardware Abstraction Layer* (Hal.dll)
  - isolates the kernel, device drivers, and executive from hardware
  - Hides platform-specific hardware differences (motherboards)



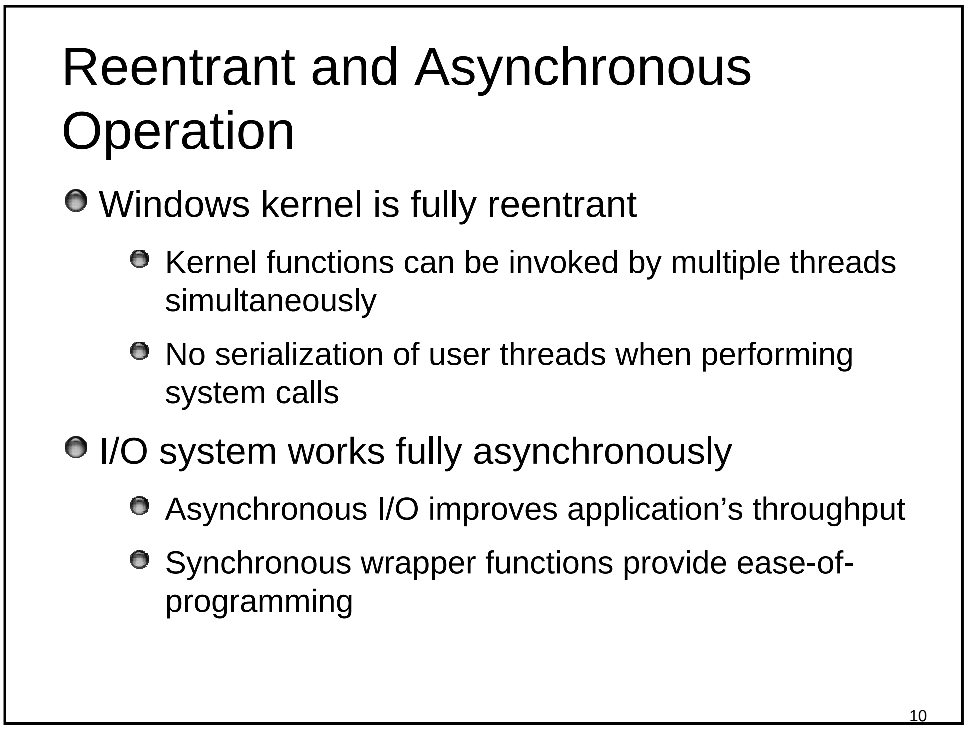
Background System Processes

- *Core system processes,*
  - logon process, the session manager, etc.
  - not started by the service control manager
- *Service processes*
  - Host Windows services
  - i.e.; Task Scheduler and Spooler services
  - Many Windows server applications, such as Microsoft SQL Server and Microsoft Exchange Server, also include components that run as services.



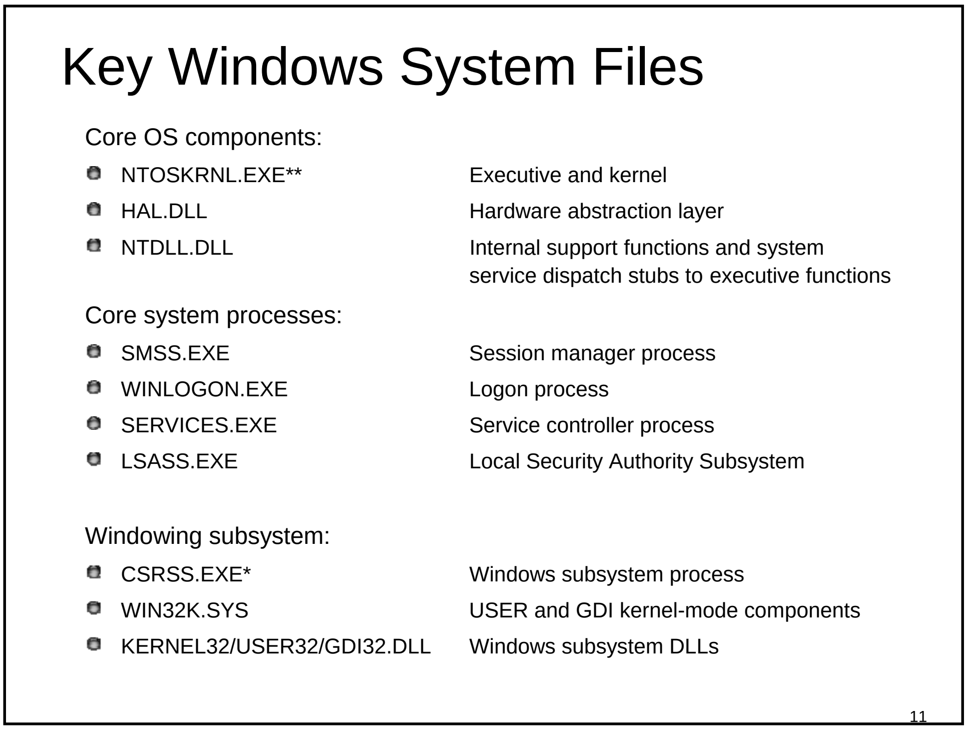
Portability

- When Windows NT was designed, there was no dominant processor architecture
  - Therefore it was designed to be portable
- How achieved?
  - Most Windows OS code and device drivers is written in C
    - HAL and kernel contain some assembly language
  - Some components are written in C++:
    - windowing/graphics subsystem driver
    - volume manager
  - Hardware-specific code is isolated in low level layers of the OS (such as Kernel and the HAL)
    - Provides portable interface
- NT 4.0 had support for x86, MIPS, PowerPC, Digital Alpha AXP
  - PowerPC and MIPS dropped soon after NT 4 release
  - Alpha AXP dropped in 1999 (supported through SP6)



Reentrant and Asynchronous Operation

- Windows kernel is fully reentrant
  - Kernel functions can be invoked by multiple threads simultaneously
  - No serialization of user threads when performing system calls
- I/O system works fully asynchronously
  - Asynchronous I/O improves application’s throughput
  - Synchronous wrapper functions provide ease-of-programming



Key Windows System Files

Core OS components:

NTOSKRNL.EXE**	Executive and kernel
HAL.DLL	Hardware abstraction layer
NTDLL.DLL	Internal support functions and system service dispatch stubs to executive functions

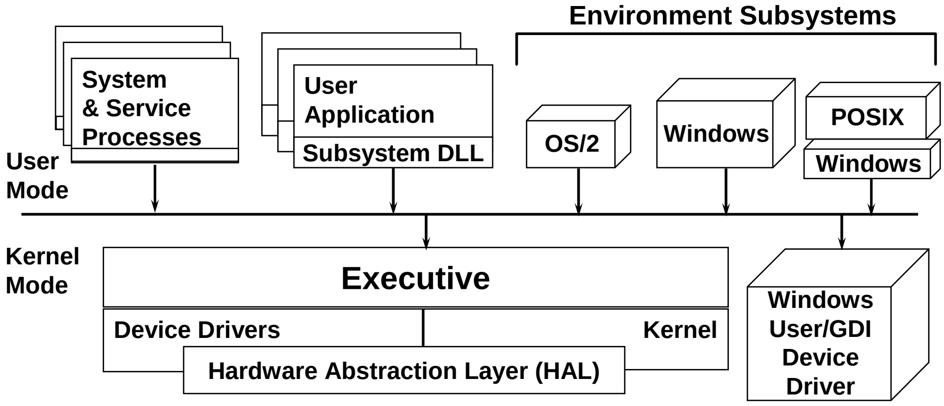
Core system processes:

SMSS.EXE	Session manager process
WINLOGON.EXE	Logon process
SERVICES.EXE	Service controller process
LSASS.EXE	Local Security Authority Subsystem

Windowing subsystem:

CSRSS.EXE*	Windows subsystem process
WIN32K.SYS	USER and GDI kernel-mode components
KERNEL32/USER32/GDI32.DLL	Windows subsystem DLLs

Key System Components



Environment Subsystems

System & Service Processes

User Application

Subsystem DLL

OS/2

Windows

POSIX

Windows

User Mode

Kernel Mode

Executive

Device Drivers

Kernel

Hardware Abstraction Layer (HAL)

Windows User/GDI Device Driver

Multiple OS Personalities

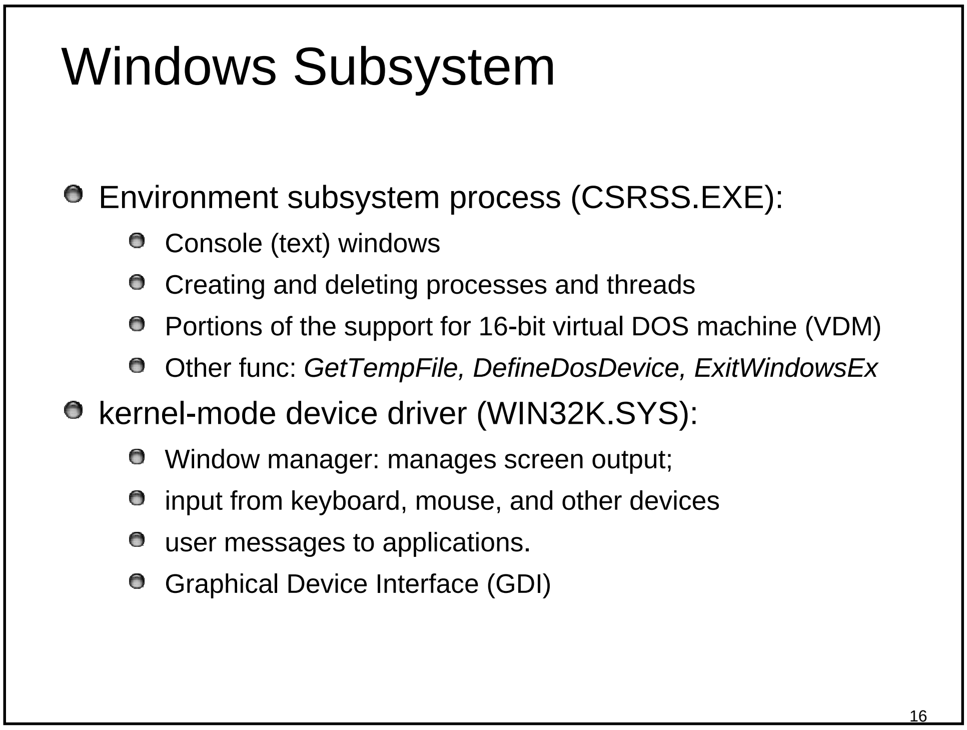
- Windows was designed to support multiple “personalities”, called environment subsystems
  - Programming interface
  - File system syntax
  - Process semantics
- Environment subsystems provide exposed, documented interface between application and Windows native API
  - Each subsystem defines a different set of APIs and semantics
  - Subsystems implement these by invoking native APIs
    - Example: Windows CreateFile in Kernel32.Dll calls native NtCreateFile
- .exes and .dlls you write are associated with a subsystem
  - Specified by LINK /SUBSYSTEM option
  - Cannot mix calls between subsystems

Environment Subsystems

- Three environment subsystems originally provided with NT:
  - Windows –Windows API (originally 32-bit, now also 64-bit)
  - OS/2 - 1.x character-mode apps only
    - Removed in Windows 2000
  - Posix - only Posix 1003.1 (bare minimum Unix services - no networking, windowing, threads, etc.)
    - Removed in XP/Server 2003 – enhanced version ships with Services For Unix 3.0
- Of the three, the Windows subsystem provides access to the majority of native OS functions
- Of the three, Windows is required to be running
  - System crashes if Windows subsystem process exits
  - POSIX and OS/2 subsystems are actually Windows applications
  - POSIX & OS/2 start on demand (first time an app is run)
    - Stay running until system shutdown

App calls Subsystem

- Function is entirely implemented in user mode
  - No message sent to environment subsystem process
  - No Windows executive system service called
  - Examples: *PtInRect(), IsRectEmpty()*
- Function requires one/more calls to Windows executive
  - Examples: Windows *ReadFile() / WriteFile()* implemented using I/O system services *NtReadFile() / NtWriteFile()*
- Function requires some work in environment subsystem process (maintain state of client app)
  - Client/server request (message) to env. Subsystem (LPC facility)
  - Subsystem DLL waits for reply before returning to caller
- Combinations of 2/3: *CreateProcess() / CreateThread()*



Windows Subsystem

- Environment subsystem process (CSRSS.EXE):
  - Console (text) windows
  - Creating and deleting processes and threads
  - Portions of the support for 16-bit virtual DOS machine (VDM)
  - Other func: *GetTempFile, DefineDosDevice, ExitWindowsEx*
- kernel-mode device driver (WIN32K.SYS):
  - Window manager: manages screen output;
  - input from keyboard, mouse, and other devices
  - user messages to applications.
  - Graphical Device Interface (GDI)

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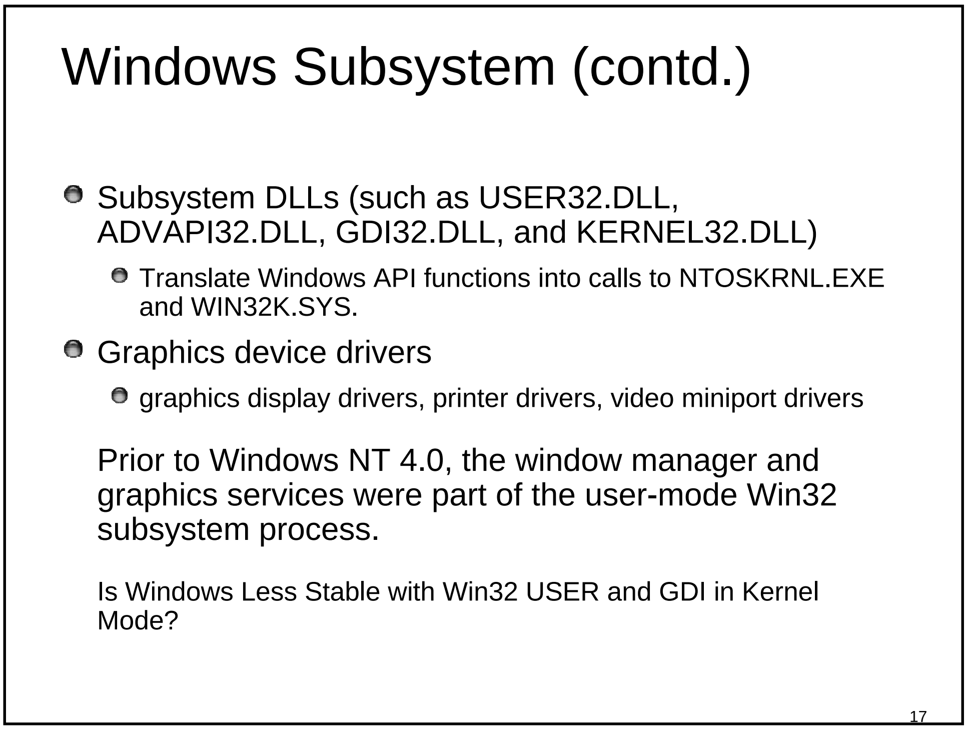

Windows Subsystem (contd.)

- Subsystem DLLs (such as USER32.DLL, ADVAPI32.DLL, GDI32.DLL, and KERNEL32.DLL)
  - Translate Windows API functions into calls to NTOSKRNL.EXE and WIN32K.SYS.
- Graphics device drivers
  - graphics display drivers, printer drivers, video miniport drivers

Prior to Windows NT 4.0, the window manager and graphics services were part of the user-mode Win32 subsystem process.

Is Windows Less Stable with Win32 USER and GDI in Kernel Mode?

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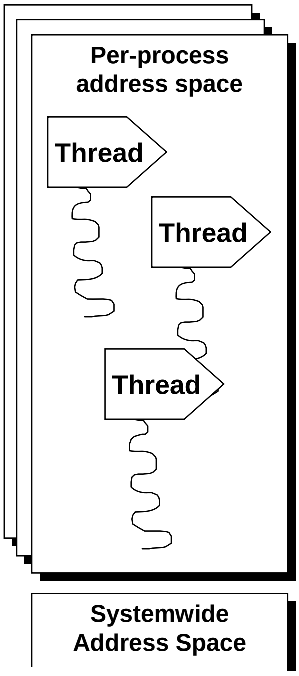
Processes and Threads

- **What is a process?**
  - Represents an instance of a running program
    - you create a process to run a program
    - starting an application creates a process
  - Process defined by:
    - Address space
    - Resources (e.g. open handles)
    - Security profile (token)
- **What is a thread?**
  - An execution context within a process
  - Unit of scheduling (threads run, processes don't run)
  - All threads in a process share the same per-process address space
    - Services provided so that threads can synchronize access to shared resources (critical sections, mutexes, events, semaphores)
  - All threads in the system are scheduled as peers to all others, without regard to their "parent" process
- **System calls**
  - Primary argument to CreateProcess is image file name (or command line)
  - Primary argument to CreateThread is a function entry point address



Per-process address space

Thread

Thread

Thread

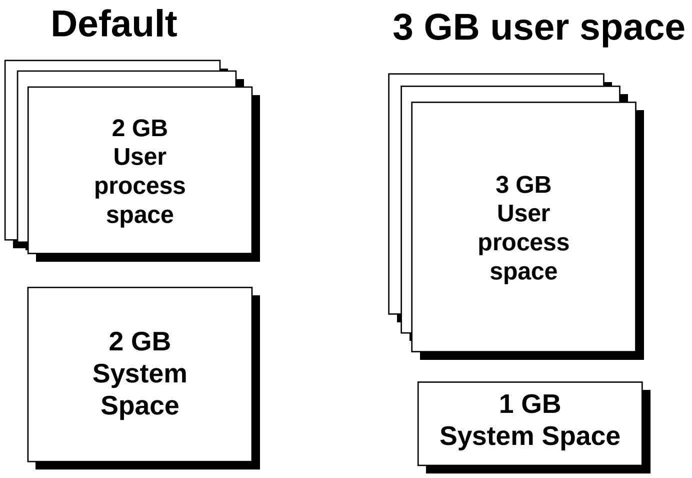
Systemwide Address Space

Memory Protection Model

- No user process can touch another user process address space (without first opening a handle to the process, which means passing through Windows security)
  - Separate process page tables prevent this
  - "Current" page table changed on context switch from a thread in 1 process to a thread in another process
- No user process can touch kernel memory
  - Page protection in process page tables prevent this
  - OS pages only accessible from "kernel mode"
    - x86: Ring 0, Itanium: Privilege Level 0
  - Threads change from user to kernel mode and back (via a secure interface) to execute kernel code
    - Does not affect scheduling (not a context switch)

32-bit x86 Address Space

- 32-bits = 4 GB



Default

2 GB User process space

2 GB System Space

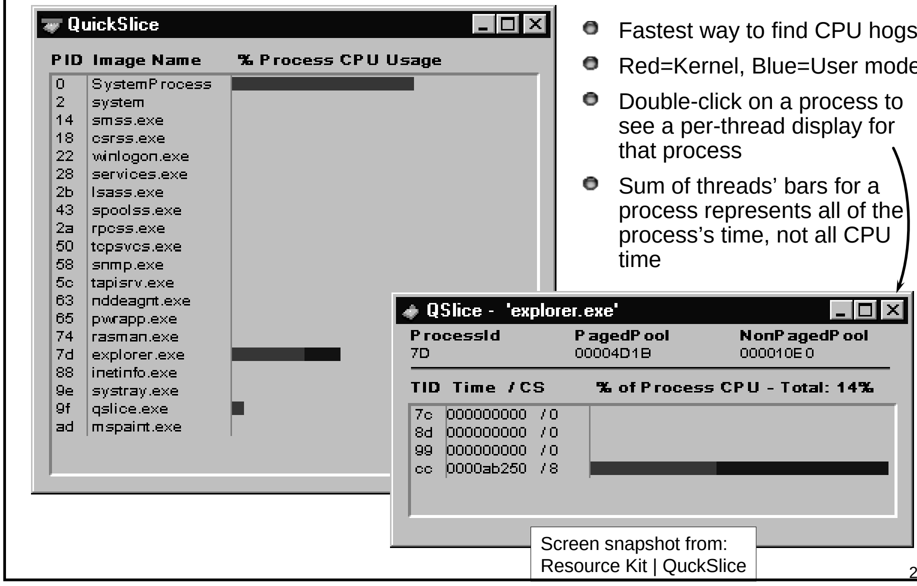
3 GB user space

3 GB User process space

1 GB System Space

Kernel-Mode vs User-Mode

QuickSlice (qslice.exe)



```
QuickSlice

PID  Image Name        % Process CPU Usage
0    SystemProcess
2    system
14   smss.exe
18   csrss.exe
22   winlogon.exe
28   services.exe
2b   lsass.exe
43   spoolss.exe
2a   rpcss.exe
50   tcpsvcs.exe
58   snmp.exe
5c   tapisrv.exe
63   nddeagnt.exe
65   pwrapp.exe
74   rasman.exe
7d   explorer.exe
88   inetinfo.exe
9e   systray.exe
9f   qslice.exe
ad   mspaint.exe
```

```
QSlice - 'explorer.exe'

ProcessId       PagedPool       NonPagedPool
7D              00004D1B        000010E0

TID  Time  / CS         % of Process CPU - Total: 14%
7c   000000000  / 0
8d   000000000  / 0
99   000000000  / 0
cc   0000ab250  / 8
```

- Fastest way to find CPU hogs
- Red=Kernel, Blue=User mode
- Double-click on a process to see a per-thread display for that process
- Sum of threads' bars for a process represents all of the process's time, not all CPU time

Screen snapshot from: Resource Kit | QuckSlice

Task Manager: Processes vs Applications Tabs

- Processes tab: List of processes
- Applications tab: List of top level visible windows

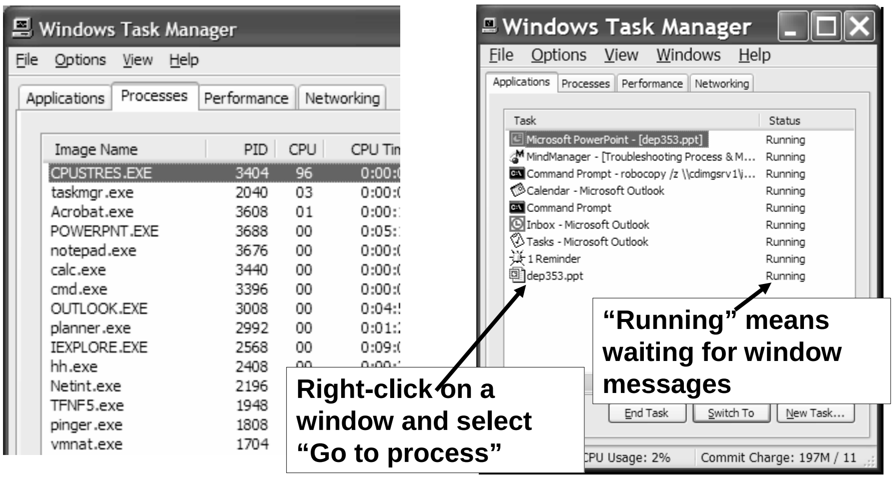

Windows Task Manager
File Options View Help
Applications Processes Performance Networking

Image Name	PID	CPU	CPU Tin
CPUSTRES.EXE	3404	96	0:00:
taskmgr.exe	2040	03	0:00:
Acrobat.exe	3608	01	0:00:
POWERPNT.EXE	3688	00	0:05:
notepad.exe	3676	00	0:00:
calc.exe	3440	00	0:00:
cmd.exe	3396	00	0:00:
OUTLOOK.EXE	3008	00	0:04:
planner.exe	2992	00	0:01:
IEXPLORE.EXE	2568	00	0:09:
hh.exe	2408	00	0:00:
Netint.exe	2196		
TFNF5.exe	1948		
pinger.exe	1808		
vmnat.exe	1704		

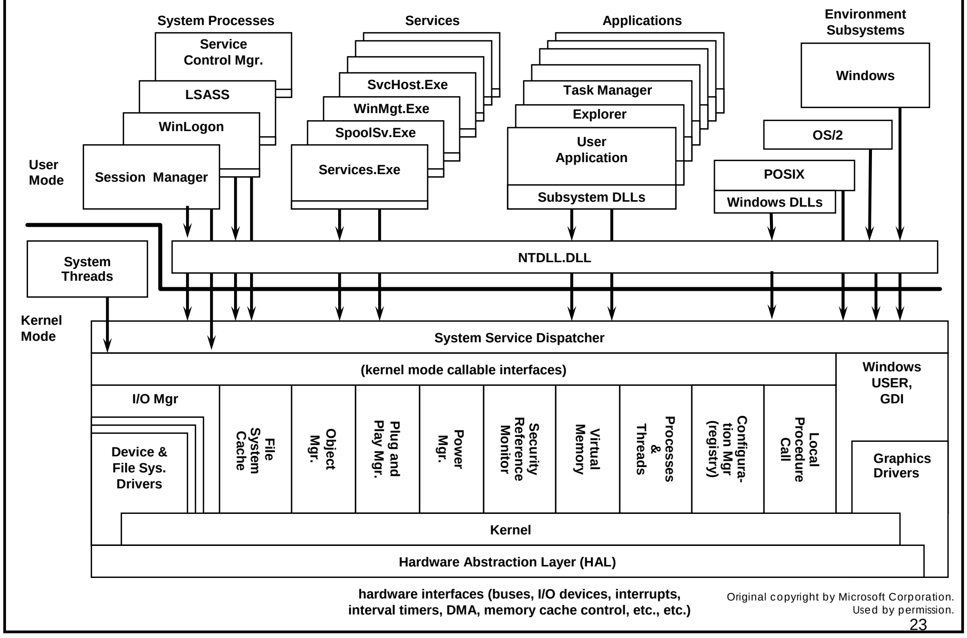
Windows Task Manager
File Options View Windows Help
Applications Processes Performance Networking

Task	Status
Microsoft PowerPoint - [dep353.ppt]	Running
MindManager - [Troubleshooting Process & M...	Running
Command Prompt - robocopy /z \\cdimgsrv1\i...	Running
Calendar - Microsoft Outlook	Running
Command Prompt	Running
Inbox - Microsoft Outlook	Running
Tasks - Microsoft Outlook	Running
1 Reminder	Running
dep353.ppt	Running

"Running" means waiting for window messages

Right-click on a window and select "Go to process"

Windows Architecture



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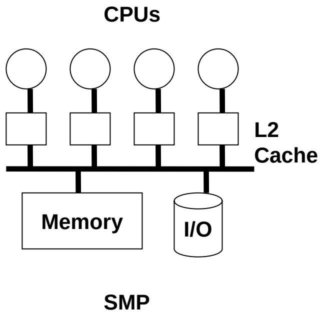
Microkernel OS?

- Is Windows a microkernel-based OS?
  - No – not using the academic definition (OS components and drivers run in their own private address spaces, layered on a primitive microkernel)
  - All kernel components live in a common shared address space
    - Therefore no protection between OS and drivers
- Why not pure microkernel?
  - Performance – separate address spaces would mean context switching to call basic OS services
  - Most other commercial OSs (Unix, Linux, VMS etc.) have the same design
- But it does have some attributes of a microkernel OS
  - OS personalities running in user space as separate processes
  - Kernel-mode components don't reach into one another's data structures
    - Use formal interfaces to pass parameters and access and/or modify data structures
  - Therefore the term "modified microkernel"

Symmetric Multiprocessing (SMP)

- No master processor
  - All the processors share just one memory space
  - Interrupts can be serviced on any processor
  - Any processor can cause another processor to reschedule what it's running
- Maximum # of CPUs stored in registry
  - HKLM\System\CurrentControlSet \Control\Session Manager \LicensedProcessors
- Current implementation limit is # of bits in a native word
  - 32 processors for 32-bit systems
  - 64 processors for 64-bit systems
  - Not an architectural limit—just implementation

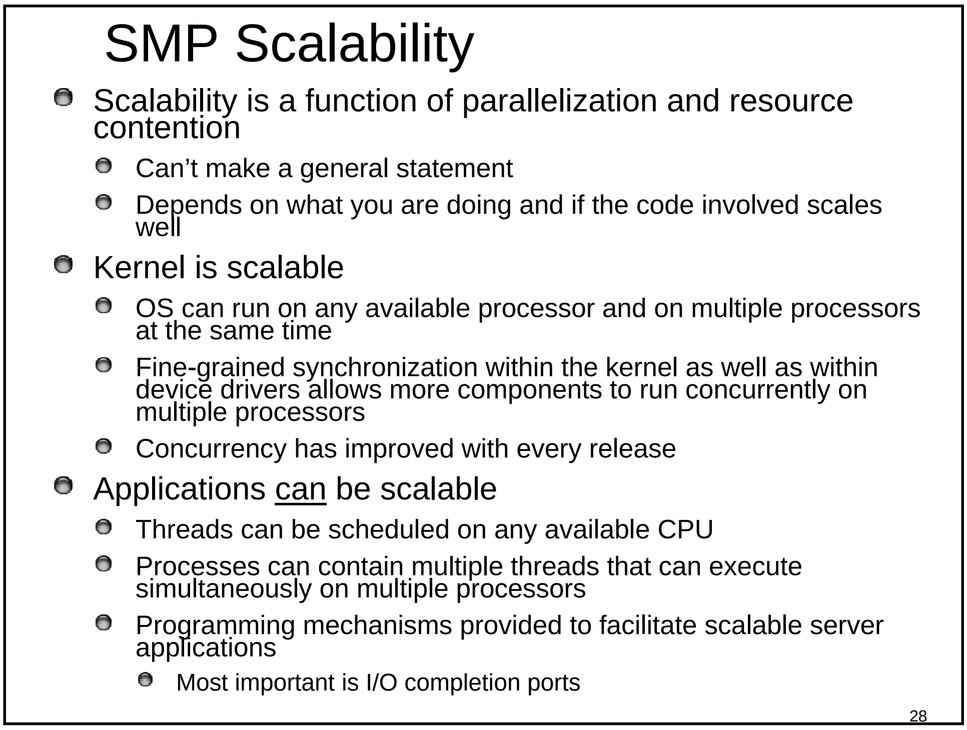


Hyperthreading

- New technology in newer Xeon & Pentium 4 processors
  - Makes a single processor appear as a dual processor to the OS
  - Also called simultaneous multithreading technology (SMT)
- Chip maintains two separate CPU states (“logical processors”)
  - Execution engine & onboard cache is shared
- Works with Windows 2000, but only XP & Server 2003 are “hyperthreading aware”
  - Logical processors don’t count against physical processor limits
  - Scheduling algorithms take into account logical vs physical processors
    - Applications can also optimize for it (new Windows function in Server 2003)

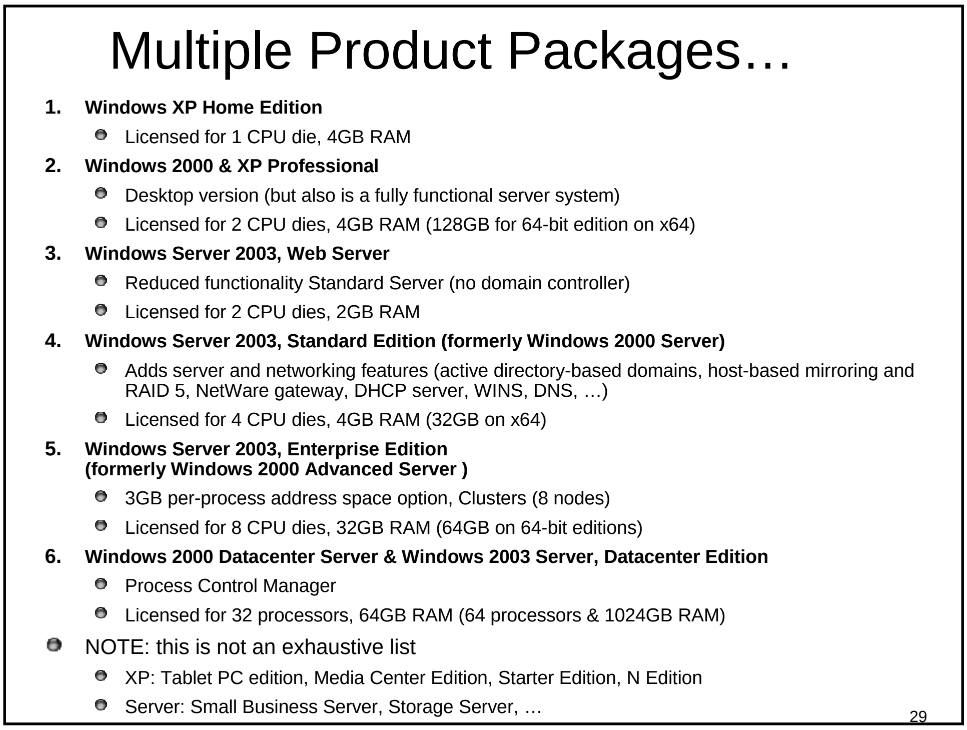
NUMA

- NUMA (non uniform memory architecture) systems
  - Groups of physical processors (called “nodes”) that have local memory
    - Connected to the larger system through a cache-coherent interconnect bus
  - Still an SMP system (e.g. any processor can access all of memory)
    - But node-local memory is faster
- Scheduling algorithms take this into account
  - Tries to schedule threads on processors within the same node
  - Tries to allocate memory from local memory for processes with threads on the node
- New Windows APIs to allow applications to optimize



SMP Scalability

- Scalability is a function of parallelization and resource contention
  - Can’t make a general statement
  - Depends on what you are doing and if the code involved scales well
- Kernel is scalable
  - OS can run on any available processor and on multiple processors at the same time
  - Fine-grained synchronization within the kernel as well as within device drivers allows more components to run concurrently on multiple processors
  - Concurrency has improved with every release
- Applications can be scalable
  - Threads can be scheduled on any available CPU
  - Processes can contain multiple threads that can execute simultaneously on multiple processors
  - Programming mechanisms provided to facilitate scalable server applications
    - Most important is I/O completion ports



Multiple Product Packages…

1. **Windows XP Home Edition**
   - Licensed for 1 CPU die, 4GB RAM
2. **Windows 2000 & XP Professional**
   - Desktop version (but also is a fully functional server system)
   - Licensed for 2 CPU dies, 4GB RAM (128GB for 64-bit edition on x64)
3. **Windows Server 2003, Web Server**
   - Reduced functionality Standard Server (no domain controller)
   - Licensed for 2 CPU dies, 2GB RAM
4. **Windows Server 2003, Standard Edition (formerly Windows 2000 Server)**
   - Adds server and networking features (active directory-based domains, host-based mirroring and RAID 5, NetWare gateway, DHCP server, WINS, DNS, …)
   - Licensed for 4 CPU dies, 4GB RAM (32GB on x64)
5. **Windows Server 2003, Enterprise Edition**
   (formerly Windows 2000 Advanced Server)
   - 3GB per-process address space option, Clusters (8 nodes)
   - Licensed for 8 CPU dies, 32GB RAM (64GB on 64-bit editions)
6. **Windows 2000 Datacenter Server & Windows 2003 Server, Datacenter Edition**
   - Process Control Manager
   - Licensed for 32 processors, 64GB RAM (64 processors & 1024GB RAM)

- NOTE: this is not an exhaustive list
  - XP: Tablet PC edition, Media Center Edition, Starter Edition, N Edition
  - Server: Small Business Server, Storage Server, …

…Built On the Same Core OS

- **Through Windows 2000, core operating system executables were identical**
  - NTOSKRNL.EXE, HAL.DLL, xxxDRIVER.SYS, etc.
  - As stated earlier, XP & Server 2003 have different kernel versions
- **Registry indicates system type (set at install time)**
  - HKEY_LOCAL_MACHINE\System\CurrentControlSet\Control \ProductOptions
    - ProductType: WinNT=Workstation, ServerNT=Server not a domain controller, LanManNT=Server that is a Domain Controller
    - ProductSuite: indicates type of Server (Advanced, Datacenter, or for NT4: Enterprise Edition, Terminal Server, …)
- **Code in the operating system tests these values and behaves slightly differently in a few places**
  - Licensing limits (number of processors, number of network connections, etc.)
  - Boot-time calculations (mostly in the memory manager)
  - Default length of time slice
  - See DDK: MmIsThisAnNtasSystem

NTOSKRNL.EXE

- **Core operating system image**
  - contains Executive & Kernel
  - Also includes entry points for routines actually implemented in Hal.Dll
  - Many functions are exposed to user mode via NtDll.Dll and the environment subsystems (t.b.d.)
- **Four retail variations:**

NTOSKRNL.EXE	Uniprocessor
NTKRNLMP.EXE	Multiprocessor

  - Windows 2000 adds PAE (page address extension) versions – must boot /PAE (32-bit Windows only); also used for processors with hardware no execute support (explained in Memory Management unit)

NTKRNLPA.EXE	Uniprocessor w/extended addressing support
NTKRPAMP.EXE	Multiprocessor w/extended addressing support

- **Two checked build (debug) variations:**

NTOSKRNL.EXE,	
NTKRNLMP.EXE	Debug multiprocessor
NTKRNLPA.EXE,	
NTKRPAMP.EXE	Debug multiprocessor w/extended addressing

UP vs MP File Differences

- These files are updated when moving from UP to MP:

Name of file on system disk	*Name of uniprocessor version on CD-ROM*	*Name of multiprocessor version on CD-ROM*
NTOSKRNL.EXE	**\I386\NTOSKRNL.EXE**	**\I386\NTKRNLMP.EXE**
NTKRNLPA.EXE	**\I386\NTKRNLMP.EXE**	**\I386\NTKRPAMP.EXE**
HAL.DLL	**Depends on system type**	**Depends on system type**

- Everything else is the same (drivers, EXEs, DLLs)
  - NT4: Win32k.sys, Ntdll.dll, and Kernel32.dll had uniprocessor versions

Debug Version (“Checked Build”)

- **Special debug version of system called “Checked Build”**
  - Multiprocessor versions only (runs on UP systems)
    - helps catch synchronization bugs that are more visible on MP systems
  - Primarily for driver testing, but can be useful for catching timing bugs in multithreaded applications
- **Built from same source files as “free build” (aka “retail build”)**
  - But with “DBG” compile-time symbol defined
  - This enables:
    - error tests for “can’t happen” conditions in kernel mode (ASSERTs)
    - validity checks on arguments passed from one kernel mode routine to another

```
#ifdef DBG
    if (something that should never happen has happened)
        KeBugCheckEx(…)
#endif
```

- **Since no checked Windows 2000 Server provided, can copy checked NTOSKRNL, HAL, to a normal Server system**
  - Select debug kernel & HAL with Boot.ini /KERNEL=, /HAL= switches
- **Windows Server 2003 has its own checked build**
- **See Knowledge base article 314743 (HOWTO: Enable Verbose Debug Tracing in Various Drivers and Subsystems)**

Executive

- Upper layer of the operating system
- Provides “generic operating system” functions (“services”)
  - Process Manager
  - Object Manager
  - Cache Manager
  - LPC (local procedure call) Facility
  - Configuration Manager
  - Memory Manager
  - Security Reference Monitor
  - I/O Manager
  - Power Manager
  - Plug-and-Play Manager
- Almost completely portable C code
- Runs in kernel (“privileged”, ring 0) mode
- Most interfaces to executive services not documented

Kernel

- Lower layers of the operating system
  - Implements processor-dependent functions (x86 vs. Itanium etc.)
  - Also implements many processor-independent functions that are closely associated with processor-dependent functions
- Main services
  - Thread waiting, scheduling & context switching
  - Exception and interrupt dispatching
  - Operating system synchronization primitives (different for MP vs. UP)
  - A few of these are exposed to user mode
- Not a classic “microkernel”
  - shares address space with rest of kernel-mode components

HAL - Hardware Abstraction Layer

- Responsible for a small part of “hardware abstraction”
  - Components on the motherboard not handled by drivers
    - System timers, Cache coherency, and flushing
    - SMP support, Hardware interrupt priorities
- Subroutine library for the kernel & device drivers
  - Isolates Kernel and Executive from platform-specific details
  - Presents uniform model of I/O hardware interface to drivers
- Reduced role as of Windows 2000
  - Bus support moved to bus drivers
  - Majority of HALs are vendor-independent
- HAL also implements some functions that appear to be in the Executive and Kernel
- Selected at installation time
  - See \windows\repair\setup.log to find out which one
  - Can select manually at boot time with /HAL= in boot.ini
- HAL kit
  - Special kit only for vendors that must write custom HALs (requires approval from Microsoft)
  - see http://www.microsoft.com/whdc/ddk/HALkit/default.mspx

Sample HAL routines:

HalGetInterruptVector
HalGetAdapter
WRITE_PORT_UCHAR

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Kernel-Mode Device Drivers

- Separate loadable modules (drivername.SYS)
  - Linked like .EXEs
  - Typically linked against NTOSKRNL.EXE and HAL.DLL
  - Only one version of each driver binary for both uniprocessor (UP) and multiprocessor (MP) systems…
  - … but drivers call routines in the kernel that behave differently for UP vs. MP Versions
- Defined in registry
  - Same area as Windows services (t.b.d.) - differentiated by Type value
- Several types:
  - “ordinary”, file system, NDIS miniport, SCSI miniport (linked against port drivers), bus drivers
  - More information in I/O subsystem section
- To view loaded drivers, run drivers.exe
  - Also see list at end of output from pstat.exe – includes addresses of each driver
- To update & control:
  - System properties->Hardware Tab->Device Manager
  - Computer Management->Software Environment->Drivers

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System Threads

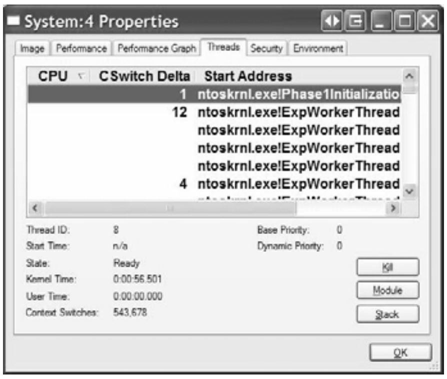
- Functions in OS and some drivers that need to run as real threads
  - E.g., need to run concurrently with other system activity, wait on timers, perform background “housekeeping” work
  - Always run in kernel mode
  - *Not* non-preemptible (unless they raise IRQL to 2 or above)
  - For details, see DDK documentation on PsCreateSystemThread
- What process do they appear in?
  - “System” process (NT4: PID 2, W2K: PID 8, XP: PID 4)
  - In Windows 2000 & later, windowing system threads (from Win32k.sys) appear in “csrss.exe” (Windows subsystem process)

Examples of System Threads

- Memory Manager
  - Modified Page Writer for mapped files
  - Modified Page Writer for paging files
  - Balance Set Manager
  - Swapper (kernel stack, working sets)
  - Zero page thread (thread 0, priority 0)
- Security Reference Monitor
  - Command Server Thread
- Network
  - Redirector and Server Worker Threads
- Threads created by drivers for their exclusive use
  - Examples: Floppy driver, parallel port driver
- Pool of Executive Worker Threads
  - Used by drivers, file systems, …
  - Work queued using ExQueueWorkItem
  - System thread (ExpWorkerThreadBalanceManager) manages pool

Identifying System Threads: Process Explorer

- With Process Explorer:
  - Double click on System process
  - Go to Threads tab – sort by CPU time
- As explained before, threads run between clock ticks (or at high IRQL) and thus don't appear to run
  - Sort by context switch delta column



CPU	CSwitch Delta	Start Address
	1	ntoskrnl.exe!Phase1Initializatio
	12	ntoskrnl.exe!ExpWorkerThread
		ntoskrnl.exe!ExpWorkerThread
		ntoskrnl.exe!ExpWorkerThread
		ntoskrnl.exe!ExpWorkerThread
	4	ntoskrnl.exe!ExpWorkerThread

Thread ID: 8
Start Time: n/a
State: Ready
Kernel Time: 0:00:56.501
User Time: 0:00:00.000
Context Switches: 543,678
Base Priority: 0
Dynamic Priority: 0

Process-Based Code

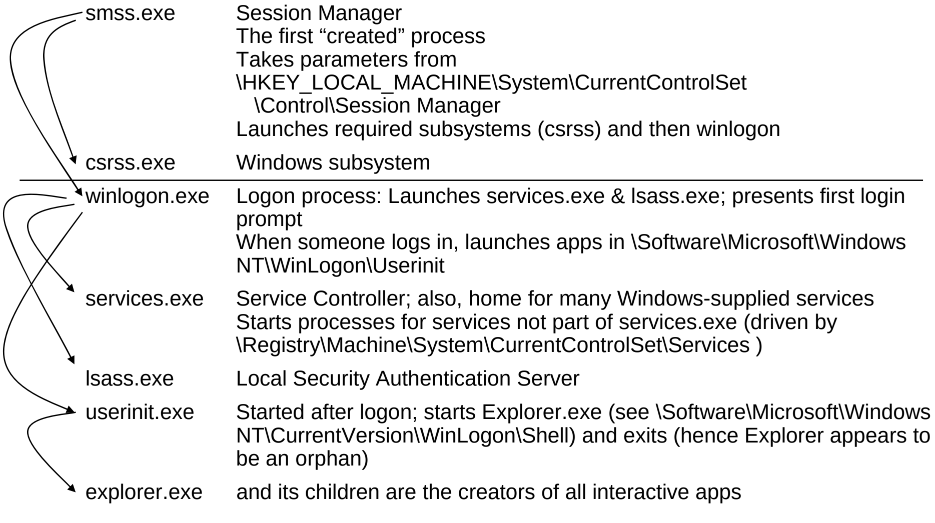
- OS components that run in separate executables (.exe's), in their own processes
  - Started by system
  - Not tied to a user logon
- Three types:
  - Environment Subsystems (already described)
  - System startup processes
    - note, "system startup processes" is not an official MS-defined name
  - Windows Services
- Let's examine the system process "tree"
  - Use Tlist /T or Process Explorer

Process-Based Windows Code:
System Startup Processes

- First two processes aren't real processes
  - not running a user mode .EXE
  - no user-mode address space
  - different utilities report them with different names
  - data structures for these processes (and their initial threads) are "pre-created" in NtosKrnl.Exe and loaded along with the code

(Idle)	Process id 0 Part of the loaded system image Home for idle thread(s) (not a real process nor real threads) Called "System Process" in many displays
(System)	Process id 2 *(8 in Windows 2000; 4 in XP)* Part of the loaded system image Home for kernel-defined threads (not a real process) Thread 0 (routine name Phase1Initialization) launches the first "real" process, running smss.exe... ...and then becomes the zero page thread

Process-Based Windows Code:
System Startup Processes (cont.)



smss.exe	Session Manager The first "created" process Takes parameters from \HKEY_LOCAL_MACHINE\System\CurrentControlSet \Control\Session Manager Launches required subsystems (csrss) and then winlogon
csrss.exe	Windows subsystem
winlogon.exe	Logon process: Launches services.exe & lsass.exe; presents first login prompt When someone logs in, launches apps in \Software\Microsoft\Windows NT\WinLogon\Userinit
services.exe	Service Controller; also, home for many Windows-supplied services Starts processes for services not part of services.exe (driven by \Registry\Machine\System\CurrentControlSet\Services)
lsass.exe	Local Security Authentication Server
userinit.exe	Started after logon; starts Explorer.exe (see \Software\Microsoft\Windows NT\CurrentVersion\WinLogon\Shell) and exits (hence Explorer appears to be an orphan)
explorer.exe	and its children are the creators of all interactive apps

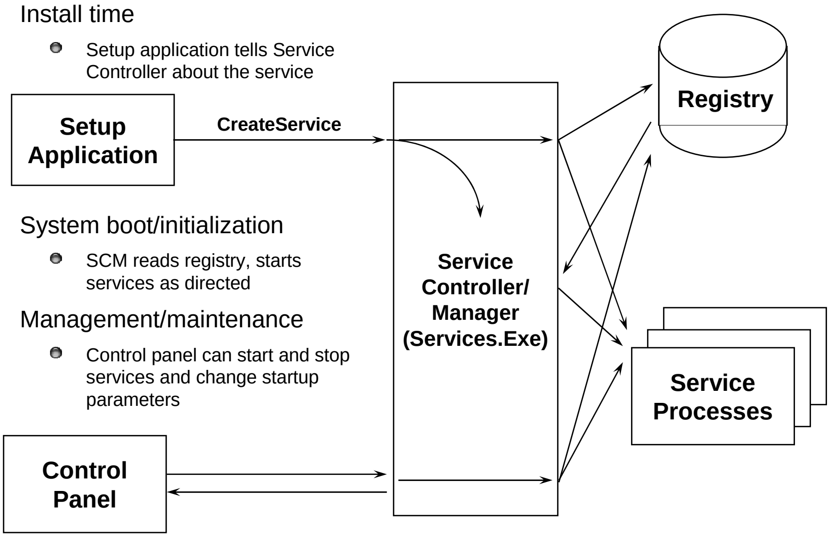
Where are Services Defined?

- Defined in the registry:

  HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services
  - one key per installed service
- Mandatory information kept on each service:
  - Type of service (Windows, Driver, ...)
  - Imagename of service .EXE
    - Note: some .EXEs contain more than one service
  - Start type (automatic, manual, or disabled)
- Optional information:
  - Display Name
  - New in W2K: Description
  - Dependencies
  - Account & password to run under
- Can store application-specific configuration parameters
  - “Parameters” subkey under service key

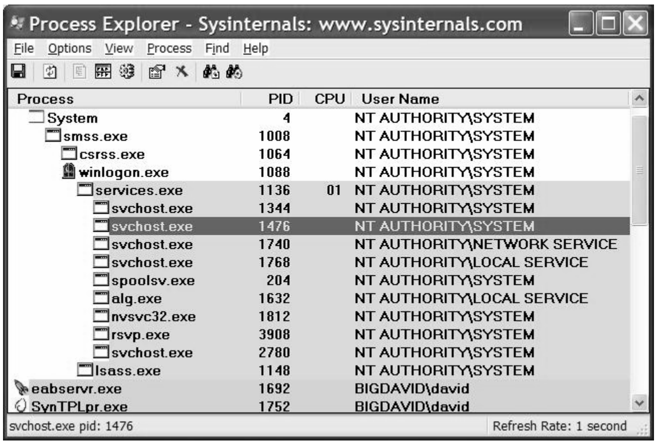
Life of a Service

- Install time
  - Setup application tells Service Controller about the service
- System boot/initialization
  - SCM reads registry, starts services as directed
- Management/maintenance
  - Control panel can start and stop services and change startup parameters



Process Explorer: Service Information

- Process Explorer identifies Service Processes
  - Click on Options->Highlight Services



Process	PID	CPU	User Name
System	4		NT AUTHORITY\SYSTEM
smss.exe	1008		NT AUTHORITY\SYSTEM
csrss.exe	1064		NT AUTHORITY\SYSTEM
winlogon.exe	1088		NT AUTHORITY\SYSTEM
services.exe	1136	01	NT AUTHORITY\SYSTEM
svchost.exe	1344		NT AUTHORITY\SYSTEM
svchost.exe	1476		NT AUTHORITY\SYSTEM
svchost.exe	1740		NT AUTHORITY\NETWORK SERVICE
svchost.exe	1768		NT AUTHORITY\LOCAL SERVICE
spoolsv.exe	204		NT AUTHORITY\SYSTEM
alg.exe	1632		NT AUTHORITY\LOCAL SERVICE
nvsvc32.exe	1812		NT AUTHORITY\SYSTEM
rsvp.exe	3908		NT AUTHORITY\SYSTEM
svchost.exe	2780		NT AUTHORITY\SYSTEM
lsass.exe	1148		NT AUTHORITY\SYSTEM
eabservr.exe	1692		BIGDAVID\david
SynTPLpr.exe	1752		BIGDAVID\david

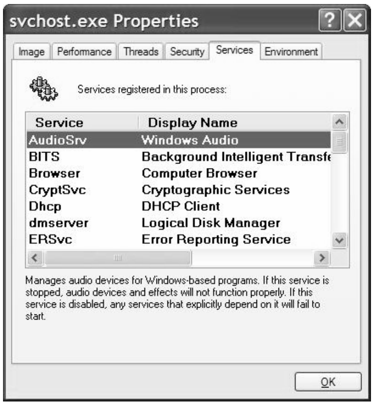
svchost.exe pid: 1476 Refresh Rate: 1 second

Service Processes

- A process created & managed by the Service Control Manager (Services.exe)
  - Similar in concept to Unix daemon processes
  - Typically configured to start at boot time (if started while logged on, survive logoff)
  - Typically do not interact with the desktop
- Note: Prior to Windows 2000 this was the only way to start a process on a remote machine
  - Now you can do it with WMI

Mapping Services to Service Processes

- Tlist /S (Debugging Tools) or Tasklist /svc (XP/2003) list internal name of services inside service processes
- Process Explorer shows more: external display name and description



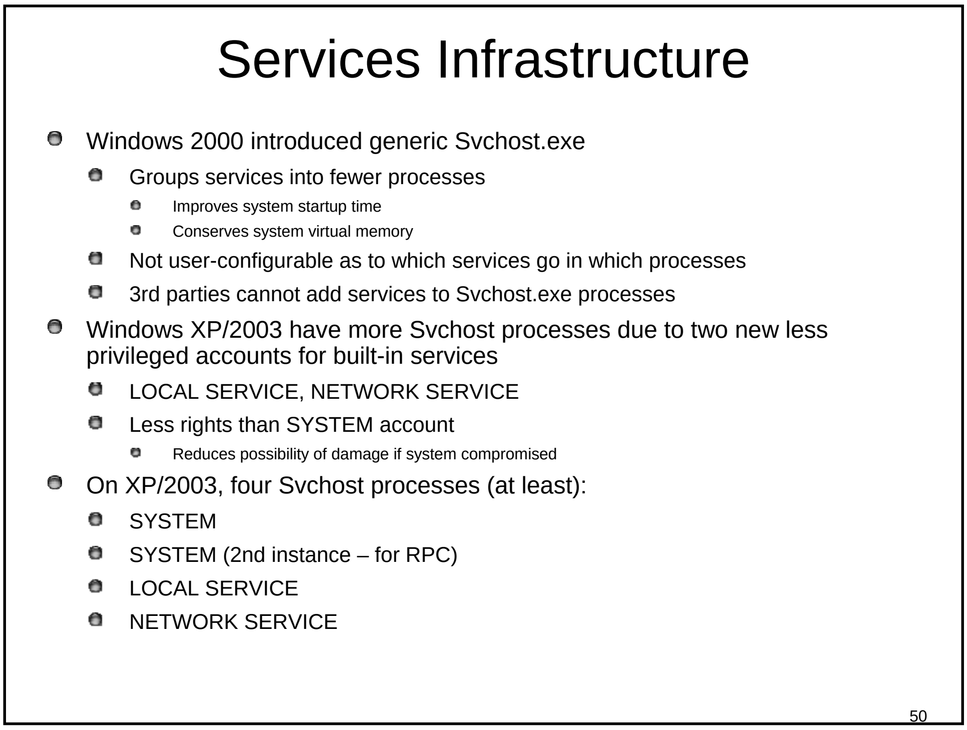
Services registered in this process:

Service	Display Name
AudioSrv	Windows Audio
BITS	Background Intelligent Transfe
Browser	Computer Browser
CryptSvc	Cryptographic Services
Dhcp	DHCP Client
dmserver	Logical Disk Manager
ERSvc	Error Reporting Service

Manages audio devices for Windows-based programs. If this service is stopped, audio devices and effects will not function properly. If this service is disabled, any services that explicitly depend on it will fail to start.

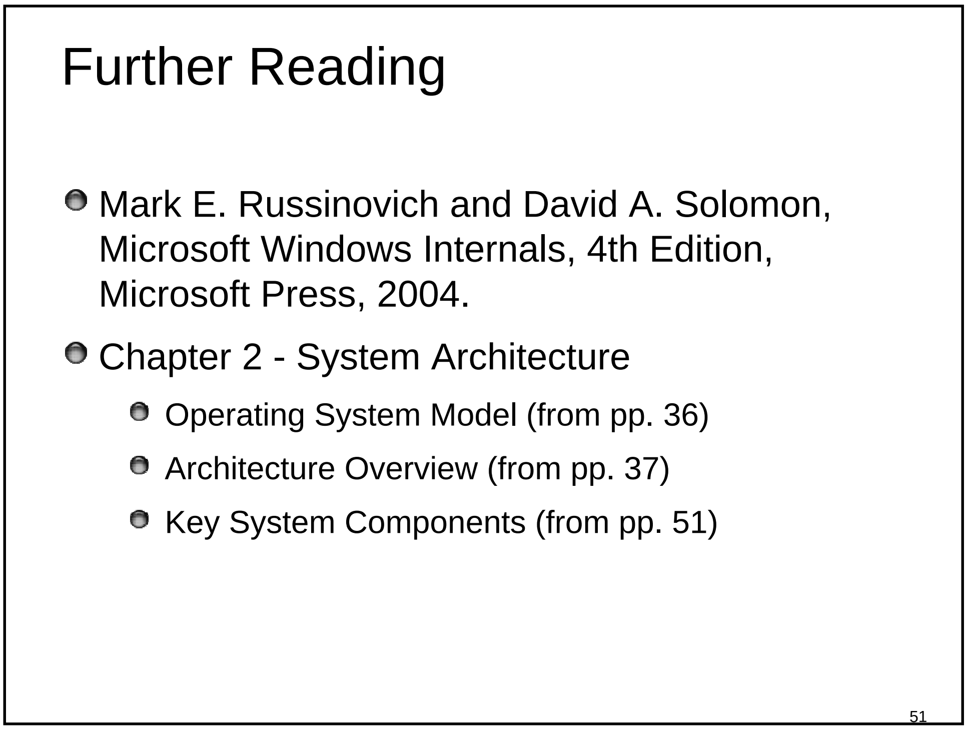
Service Control Tools

- Net start/stop – local system only
- Sc.exe (built in to XP/2003; also in Win2000 Resource Kit)
  - Command line interface to <u>all</u> service control/configuration functions
  - Works on local or remote systems
- Psservice (Sysinternals) – similar to SC
- Other tools in Resource Kit
  - Instsrv.exe – install/remove services (command line)
  - Srvinstw.exe – install/remove services (GUI)
  - Why are service creation tools included in Reskit?
    - Because Reskit comes with several services that are not installed as services when you install the Reskit



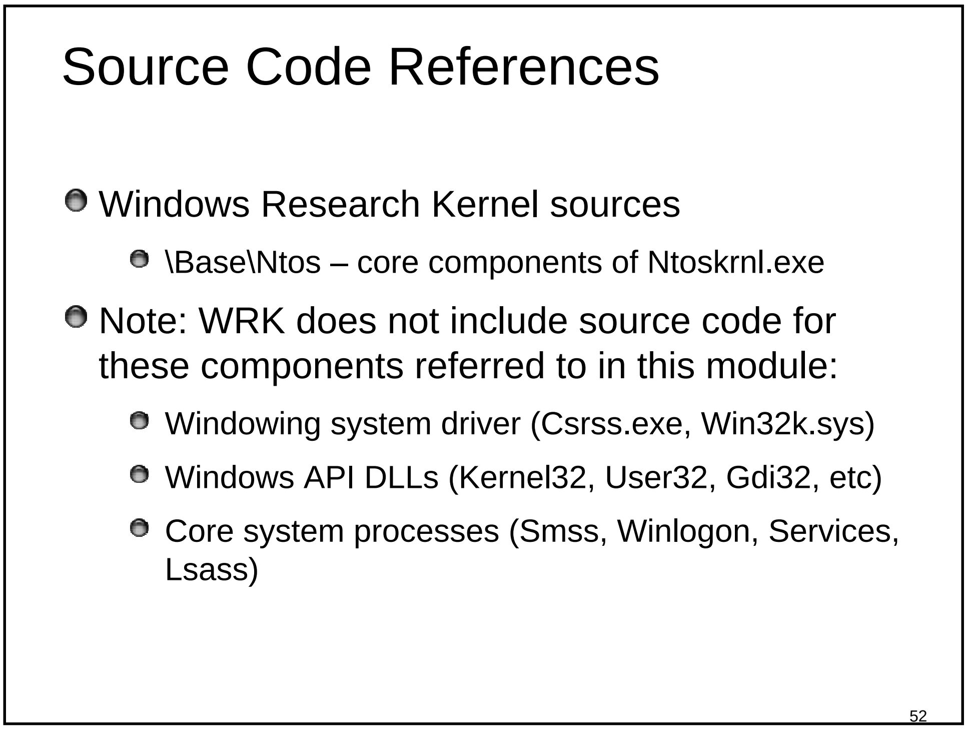
Services Infrastructure

- Windows 2000 introduced generic Svchost.exe
  - Groups services into fewer processes
    - Improves system startup time
    - Conserves system virtual memory
  - Not user-configurable as to which services go in which processes
  - 3rd parties cannot add services to Svchost.exe processes
- Windows XP/2003 have more Svchost processes due to two new less privileged accounts for built-in services
  - LOCAL SERVICE, NETWORK SERVICE
  - Less rights than SYSTEM account
    - Reduces possibility of damage if system compromised
- On XP/2003, four Svchost processes (at least):
  - SYSTEM
  - SYSTEM (2nd instance – for RPC)
  - LOCAL SERVICE
  - NETWORK SERVICE



Further Reading

- Mark E. Russinovich and David A. Solomon, Microsoft Windows Internals, 4th Edition, Microsoft Press, 2004.
- Chapter 2 - System Architecture
  - Operating System Model (from pp. 36)
  - Architecture Overview (from pp. 37)
  - Key System Components (from pp. 51)



Source Code References

- Windows Research Kernel sources
  - \Base\Ntos – core components of Ntoskrnl.exe
- Note: WRK does not include source code for these components referred to in this module:
  - Windowing system driver (Csrss.exe, Win32k.sys)
  - Windows API DLLs (Kernel32, User32, Gdi32, etc)
  - Core system processes (Smss, Winlogon, Services, Lsass)