Windows Kernel Internals
Overview

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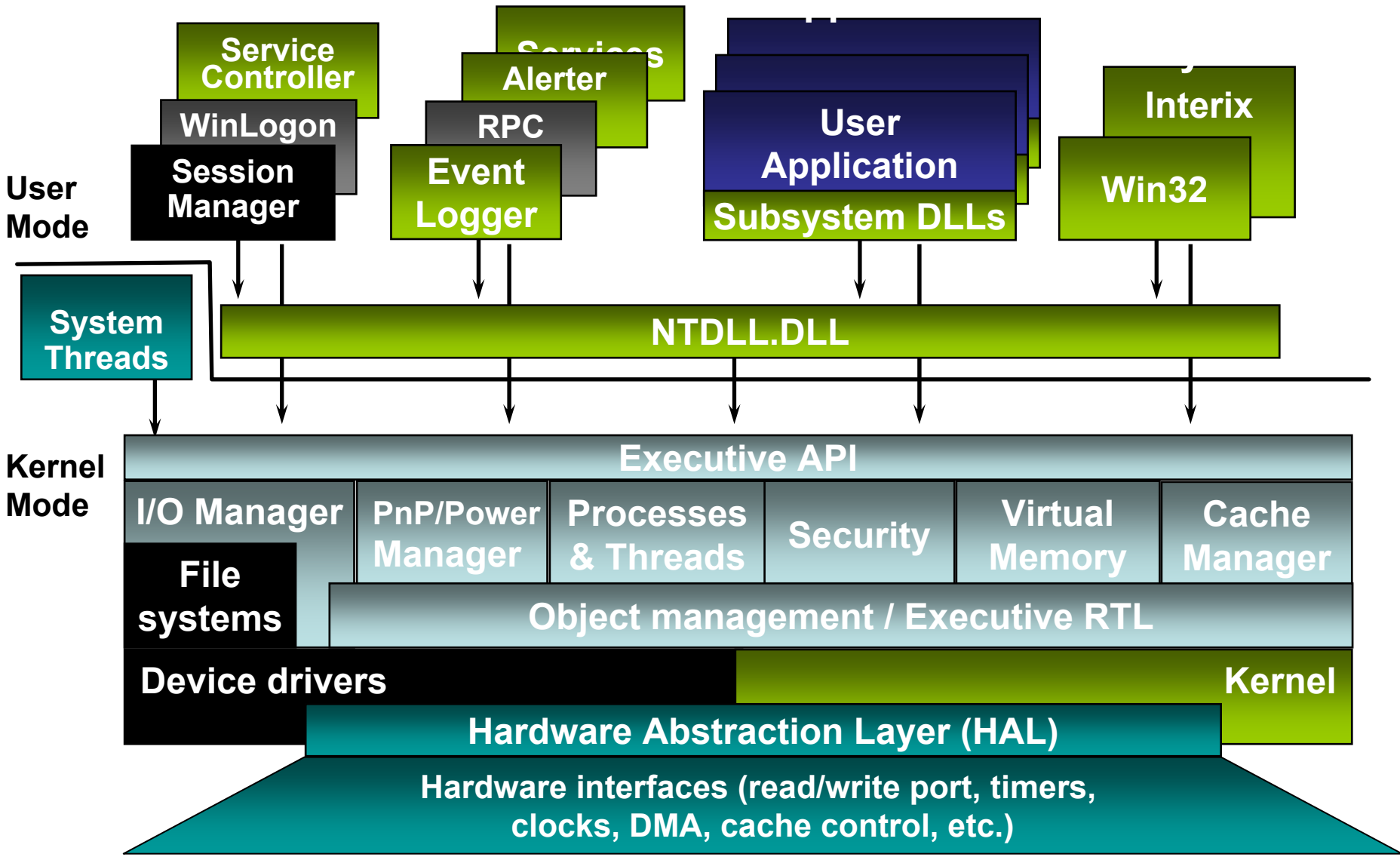
Windows History

- Team formed in November 1988
- Less than 20 people
- Build from the ground up
  - Advanced Operating System
  - Designed for desktops and servers
  - Secure, scalable SMP design
  - All new code
- Rigorous discipline – developers wrote very detailed design docs, reviewed/discussed each others docs and wrote unit tests

Goals of the NT System

- Reliability – Nothing should be able to crash the OS. Anything that crashes the OS is a bug and we won't ship until it is fixed
- Security – Built into the design from day one
- Portability – Support more than one processor, avoid assembler, abstract HW dependencies.
- Extensibility – Ability to extend the OS over time
- Compatibility – Apps must run
- Performance – All of the above are more important than raw speed!

Windows Server 2003 Architecture



Windows Executive

- Upper layers of the operating system
- Provides “generic operating system” functions (“services”)
  - Creating and deleting processes and threads
  - Memory management
  - I/O initiation and completion
  - Interprocess communication
  - Security
- Almost completely portable C code
- Runs in kernel (“privileged”, ring 0) mode
- Many interfaces to executive services not documented

Windows Kernel

- Lower layers of the operating system
  - Implements processor-dependent functions (x86 vs. Alpha vs. 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 components

HAL - Hardware Abstraction Layer

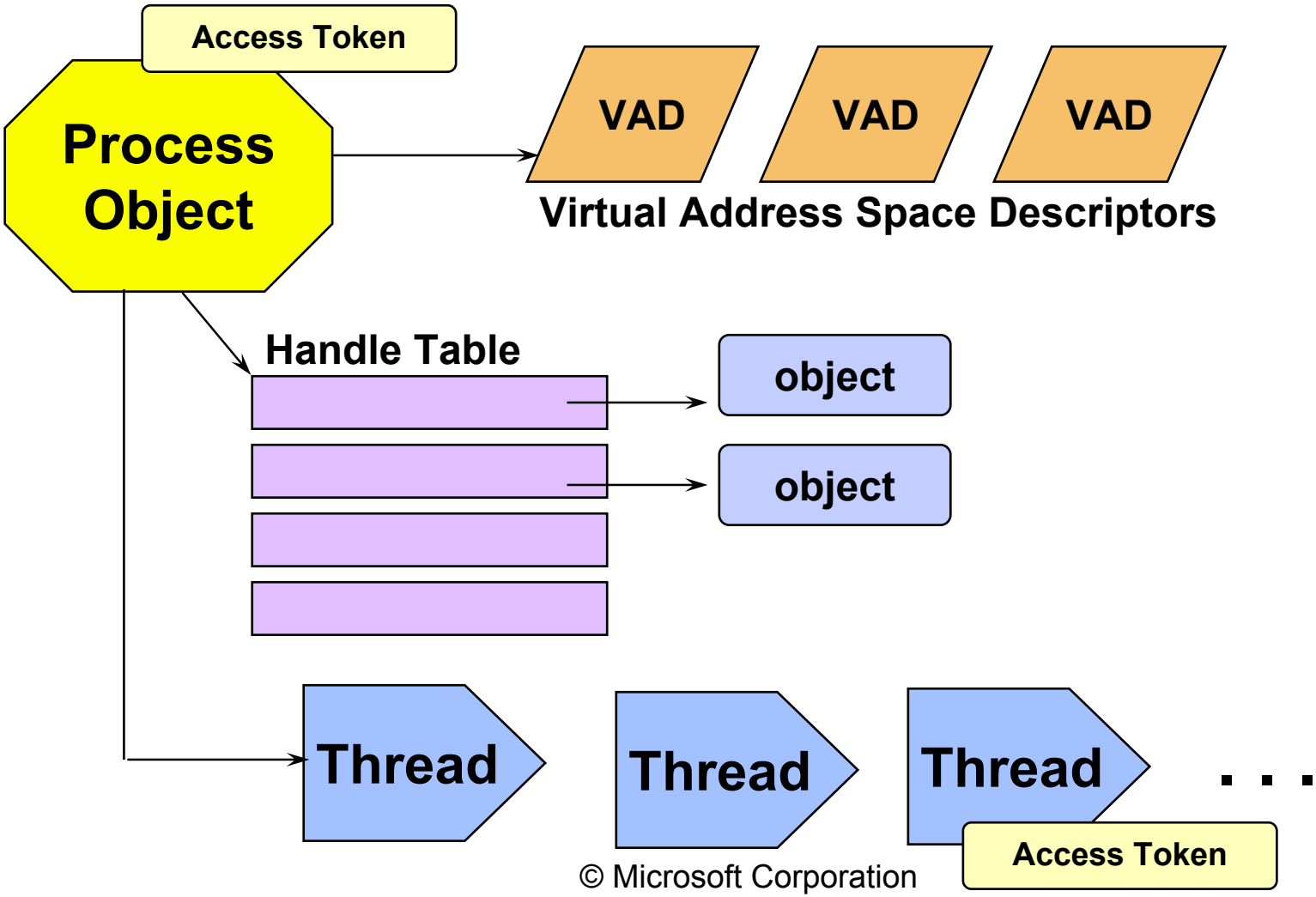
- Subroutine library for the kernel & device drivers
  - Isolates Kernel and Executive from platform-specific details
  - Presents uniform model of I/O hardware interface to drivers
- HAL abstracts:
  - System timers, Cache coherency & flushing
  - SMP support, Hardware interrupt priorities
  - HAL also implements some functions that appear to be in the Executive and Kernel

Kernel Mode Execution

Code is run in kernel mode for one of three reasons:

1. Requests from user mode (system calls)
   - Via the system service dispatch mechanism
   - Kernel-mode code runs in the context of the requesting thread
2. Interrupts from external devices
   - Interrupts (like all traps) are handled in kernel mode
   - NT-supplied interrupt dispatcher invokes the interrupt service routine
   - ISR runs in the context of the interrupted thread (so-called “arbitrary thread context”)
   - ISR often requests the execution of a “**DPC routine**”, which also runs in kernel mode
3. Dedicated kernel-mode threads
   - Some threads in the system stay in kernel mode at all times (mostly in the “System” process)
   - Scheduled, preempted, etc., like any other threads

Processes & Threads



Each process has its own…

- Virtual address space (including program global storage, heap storage, threads' stacks)
  - processes cannot corrupt each other's address space by mistake
- Working set (physical memory "owned" by the process)
- Access token (includes security identifiers)
- Handle table for Win32 kernel objects
- These are common to all threads in the process, but separate and protected between processes

Each thread has its own…

- Stack (automatic storage, call frames, etc.)
- Instance of a top-level function
- Scheduling state (Wait, Ready, Running, etc.) and priority
- Current access mode (user mode or kernel mode)
- Saved CPU state if it isn't Running
- Access token (optional -- overrides process's if present)

Windows Past, Present, Future

PAST: Personal computer, 16->32 bits, MSDOS, Windows 9x code base, desktop focus

- Features, usability, compatibility, platform
- Windows 98

PRESENT: Enterprise computing, 32/64 bits, NT code base, solid desktop, datacenter

- Reliability, performance, IT Features
- Windows XP, Windows Server 2003

FUTURE: Managed code **(.NET Framework)**

- Productivity, innovation, empowerment
- Longhorn

.Net: Making it Simple

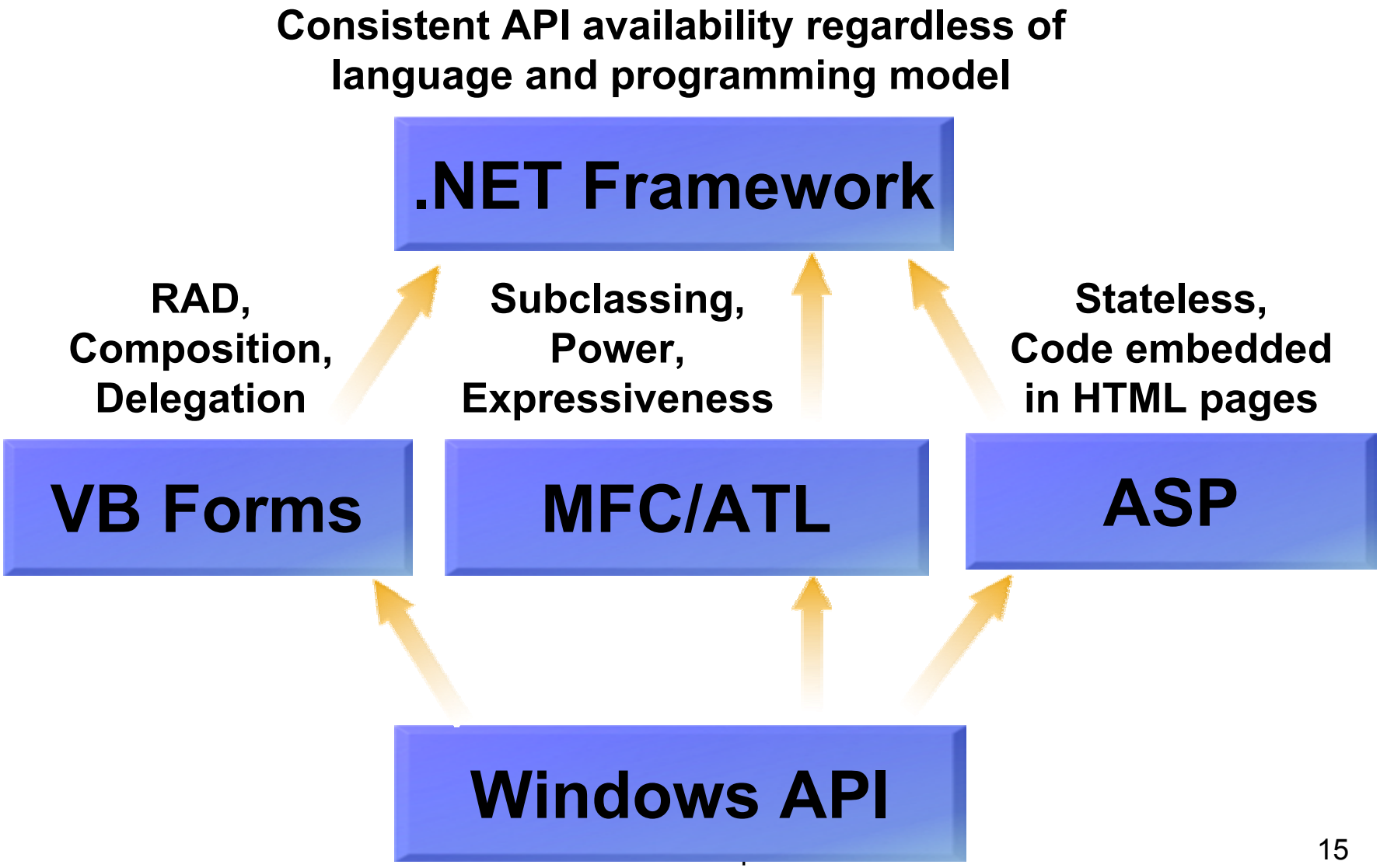
Windows API

```
HWND hwndMain = CreateWindowEx(
    0, "MainWClass", "Main Window",
    WS_OVERLAPPEDWINDOW | WS_HSCROLL | WS_VSCROLL,
    CW_USEDEFAULT, CW_USEDEFAULT,
    CW_USEDEFAULT, CW_USEDEFAULT,
    (HWND)NULL, (HMENU)NULL, hInstance, NULL);
ShowWindow(hwndMain, SW_SHOWDEFAULT);
UpdateWindow(hwndMain);
```

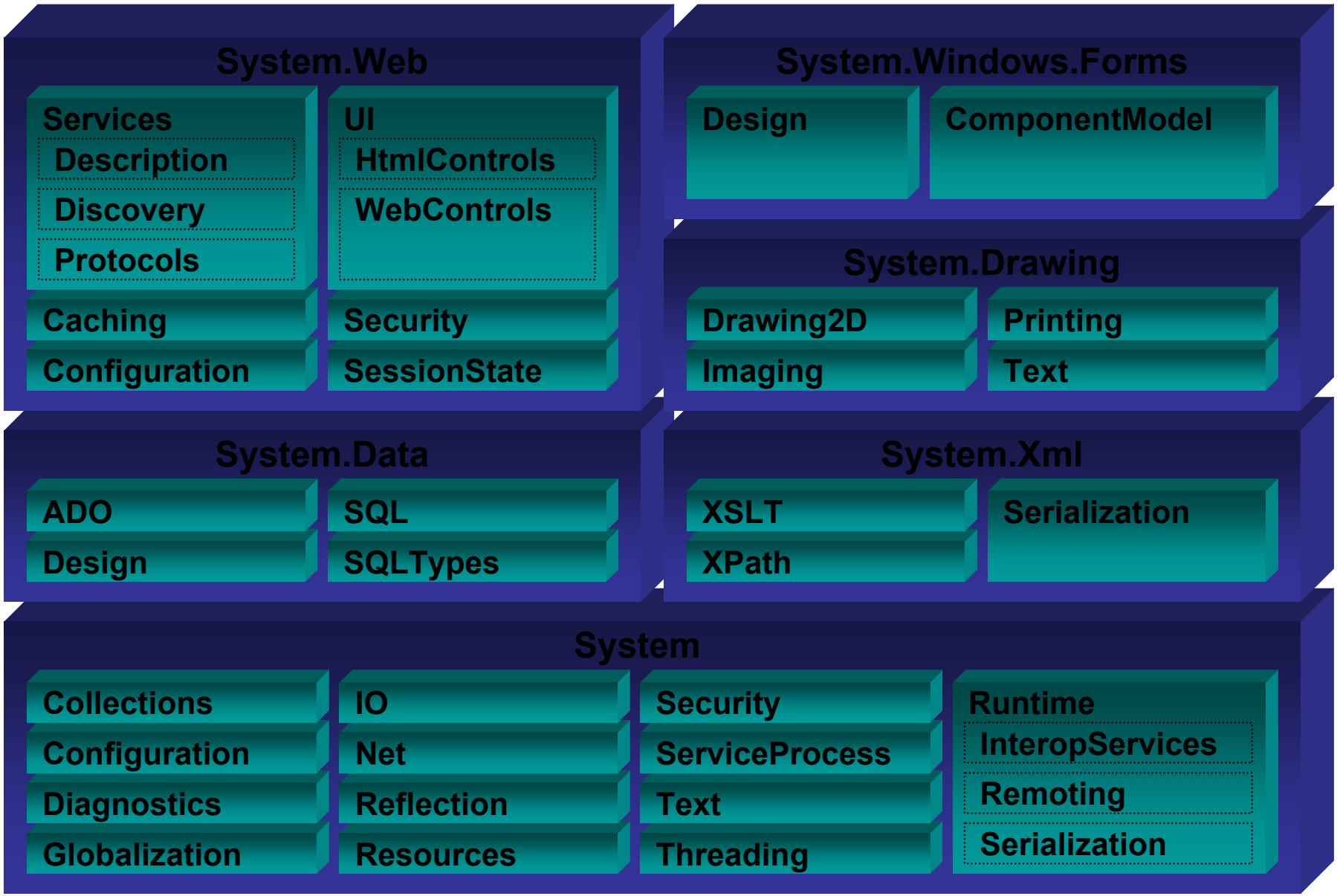
.Net Framework

```
Window w = new Window();
w.Text = "Main Window";
w.Show();
```

.Net: Unify Programming Models



.Net: API Organization



.Net: Languages

- The Managed Platform is Language Neutral
  - All languages are first class players
  - You can leverage your existing skills
- Common Language Specification
  - Set of features guaranteed to be in all languages
  - C# enforcement: [assembly:CLSCompliant(true)]
- We are providing
  - VB, C++, C#, J#, JScript
- Third-parties are building
  - APL, COBOL, Pascal, Eiffel, Haskell, ML, Oberon, Perl, Python, Scheme, Smalltalk…

Unmanaged vs. Managed

Unmanaged Code	Managed Code
Binary standard	**Type standard**
Type libraries	**Assemblies**
Immutable	**Resilient bind**
Reference counting	**Garbage collection**
Type unsafe	**Type safe**
Interface based	**Object based**
HRESULTs	**Exceptions**
GUIDs	**Strong names**

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Lectures

- Object Manager
- Virtual Memory
- Thread Scheduling
- Synchronization
- I/O Manager
- I/O Security
- Power Management
- NT File System
- Registry
- Lightweight Proc Calls
- Windows Services
- System Bootstrap
- Traps / Ints / Exceptions
- Processes
- Adv. Virtual Memory
- Cache Manager
- User-mode heap
- Win32k.sys
- WoW64
- Common Errors

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Projects

Device Drivers and Registry Hooking

Dragos Sambotin – Polytech. Inst. of Bucharest

Using LPC to build native client/server apps

Adrian Marinescu – University of Bucharest

Threads and Fibers

Arun Kishan – Stanford University

Doing virtual memory experiments from user-mode

Arun Kishan – Stanford University

Discussion