THE KERNEL OF OPERATING SYSTEMS

(P. Denning 5/25/19)

The kernel is the core set of functions for process, memory, and digital object management and protection used by all applications. It is typically a small fraction (1% to 5%) of the total OS code.

No	Name	Objects Managed	power of ten	
10	Services	nonterminating processes for specific services such as device drivers, networks, web, VPN, and email	+3	USER
9	Shell	command language	+3	
8	Processes	executing programs with separate address spaces	-2	USER KERNEL
7	Directories	directories	-2	
6	Info objects	files, devices, pipes, streams	-2	
5	Global address space	URLs, capabilities	-2	
4	Inter-process communication (IPC)	messages, ports, sockets, remote procedure calls	-3	MICRO KERNEL
3	Memory management	address space, main and secondary memory, page, segment, replacement, virtual memory, cache	-4	
2	Concurrency control	execution streams, thread control block (TCB), context switch, ready list, semaphore, scheduling	-4	
1	Low level hardware-software interface	device drivers, interrupt handlers, call stack	-5	
0	Hardware levels 0d – interrupt signals 0c – rings 0b – BIOS/EFI 0a – instruction set	logic gates, instruction set, procedures, call stacks, protection rings, supervisor states, interrupts	-12 to -9	

NOTES: numbers in "power" column are powers of 10 orders of magnitude of the times between events.

Levels 1-4 are **microkernel** -- all executed in privileged (supervisor) mode on a single machine; Levels 5-8 are **user kernel**, kernel functions executed in user mode and distributed over the network; Levels 9-10 are **user levels**. Memory used by levels 1-4 is **kernel space**, and by levels 5-10 **user space**.

Functions at a level may be composed of objects of lower levels, but not of higher levels: downward calls, upward returns. Functions of a level cannot call higher level functions.