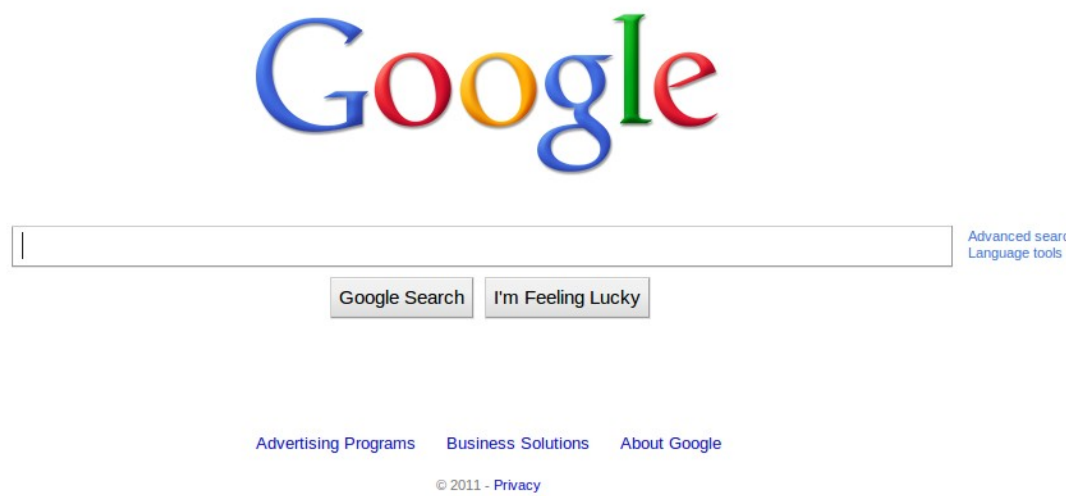
CSCI 6411: Operating Systems

Acknowledgements: Some slide material derived from Silberschatz, et al.

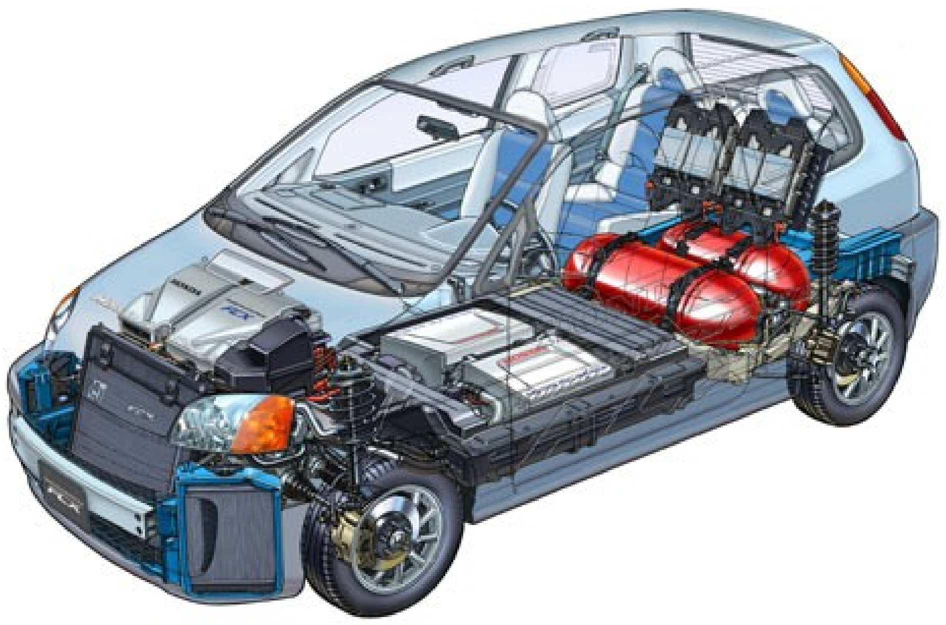
"High-level"



Cars

Computers

...details...

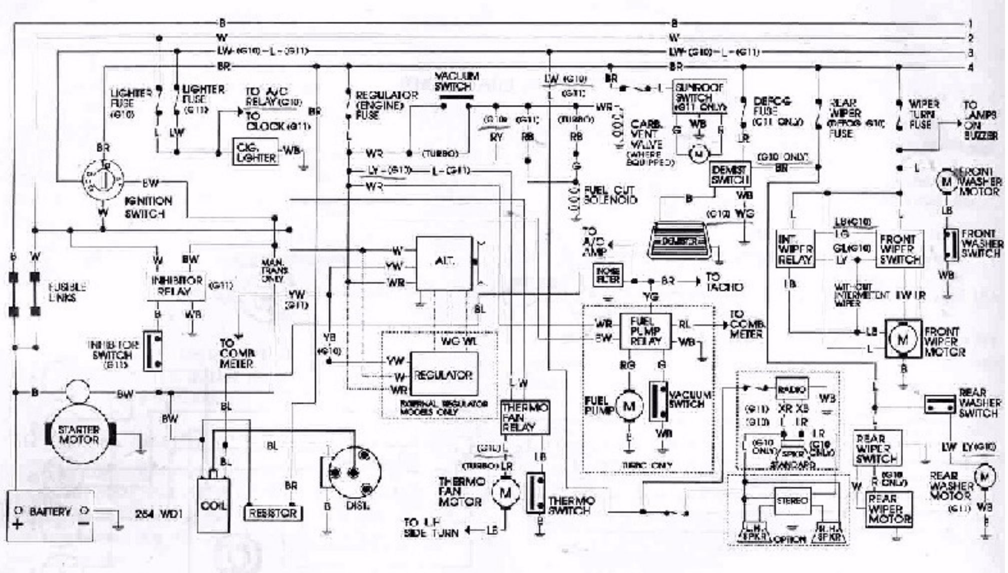


```
/*
 * So far all flags should be taken in the context of the
 * actual invoking thread (they effect the thread switching
 * _from_ rather than the thread to switch _to_) in which case
 * we would want to use the sched_page flags.
 */
flags = rflags;
switch_thread_update_flags(da, &flags);

if (unlikely(flags)) {
        thd = switch_thread_slowpath(curr, flags, curr_spd, rthd_id, da, &ret_c
                                      &curr_sched_flags, &thd_sched_flags);
        /* If we should return immediately back to this
         * thread, and its registers have been changed,
         * return without setting the return value */
        if (ret_code == COS_SCHED_RET_SUCCESS && thd == curr) goto ret;
        if (thd == curr) goto_err(ret_err, "sloooow\n");
} else {
        next_thd = switch_thread_parse_data_area(da, &ret_code);
        if (unlikely(0 == next_thd)) goto_err(ret_err, "data_area\n");

        thd = switch_thread_get_target(next_thd, curr, curr_spd, &ret_code);
        if (unlikely(NULL == thd)) goto_err(ret_err, "get target");
}

/* If a thread is involved in a scheduling decision, we should
 * assume that any preemption chains that existed aren't valid
 * anymore. */
break_preemption_chain(curr);
```

Cars

Computers

...“low-level”



Wiring diagram for the power supply, starting, charging, engine, front and rear wiper, cigarette lighter, sunroof (G11), sound system and rear demister systems. G10, G11 and G11 Turbo models.

Cars

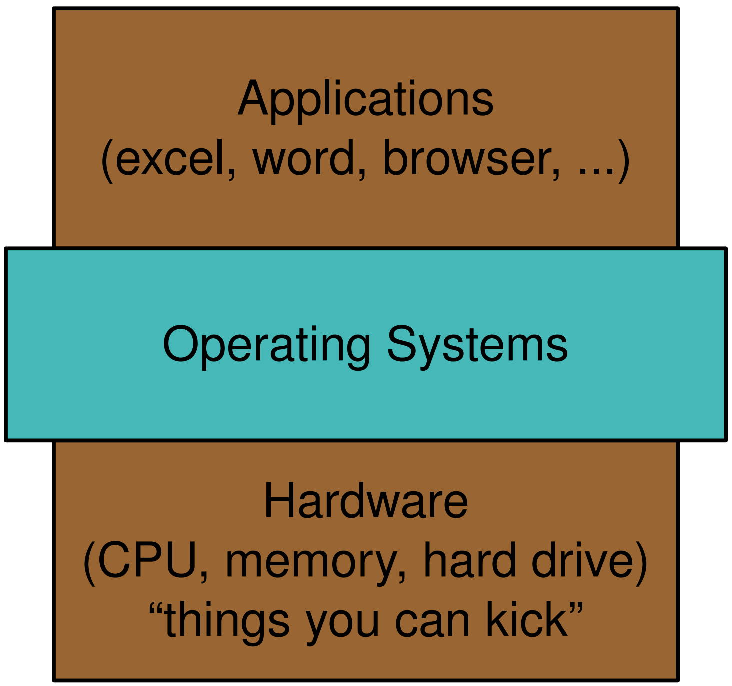
```
00000000004006b0 <__libc_csu_init>:
  4006b0:       48 89 6c 24 d8          mov    %rbp,-0x28(%rsp)
  4006b5:       4c 89 64 24 e0          mov    %r12,-0x20(%rsp)
  4006ba:       48 8d 2d 53 07 20 00    lea    0x200753(%rip),%rbp        # 600e14 <__init_array_end>
  4006c1:       4c 8d 25 4c 07 20 00    lea    0x20074c(%rip),%r12        # 600e14 <__init_array_end>
  4006c8:       4c 89 6c 24 e8          mov    %r13,-0x18(%rsp)
  4006cd:       4c 89 74 24 f0          mov    %r14,-0x10(%rsp)
  4006d2:       4c 89 7c 24 f8          mov    %r15,-0x8(%rsp)
  4006d7:       48 89 5c 24 d0          mov    %rbx,-0x30(%rsp)
  4006dc:       48 83 ec 38             sub    $0x38,%rsp
  4006e0:       4c 29 e5                sub    %r12,%rbp
  4006e3:       41 89 fd                mov    %edi,%r13d
  4006e6:       49 89 f6                mov    %rsi,%r14
  4006e9:       48 c1 fd 03             sar    $0x3,%rbp
  4006ed:       49 89 d7                mov    %rdx,%r15
  4006f0:       e8 33 fd ff ff          callq  400428 <_init>
  4006f5:       48 85 ed                test   %rbp,%rbp
  4006f8:       74 1c                   je     400716 <__libc_csu_init+0x66>
  4006fa:       31 db                   xor    %ebx,%ebx
  4006fc:       0f 1f 40 00             nopl   0x0(%rax)
  400700:       4c 89 fa                mov    %r15,%rdx
  400703:       4c 89 f6                mov    %r14,%rsi
  400706:       44 89 ef                mov    %r13d,%edi
  400709:       41 ff 14 dc             callq  *(%r12,%rbx,8)
  40070d:       48 83 c3 01             add    $0x1,%rbx
  400711:       48 39 eb                cmp    %rbp,%rbx
  400714:       72 ea                   jb     400700 <__libc_csu_init+0x50>
  400716:       48 8b 5c 24 08          mov    0x8(%rsp),%rbx
  40071b:       48 8b 6c 24 10          mov    0x10(%rsp),%rbp
  400720:       4c 8b 64 24 18          mov    0x18(%rsp),%r12
  400725:       4c 8b 6c 24 20          mov    0x20(%rsp),%r13
  40072a:       4c 8b 74 24 28          mov    0x28(%rsp),%r14
  40072f:       4c 8b 7c 24 30          mov    0x30(%rsp),%r15
  400734:       48 83 c4 38             add    $0x38,%rsp
  400738:       c3                      retq
  400739:       90                      nop
  40073a:       90                      nop
  40073b:       90                      nop
  40073c:       90                      nop
  40073d:       90                      nop
  40073e:       90                      nop
  40073f:       90                      nop
```

Computers

What is an Operating System!?

?

What is an OS: Where is it?



What is an OS: Where is it?

Applications
(excel, word, browser, ...)

Operating Systems

Hardware
(CPU, memory, hard drive)
“things you can kick”

COURTESY: KFC

What is an OS: Analogy

You!

Customer_1

Customer_2

Customer_n

What is an OS: Analogy

What is an OS: Analogy

Hardware

Operating System

Applications

You!

$Customer_1$

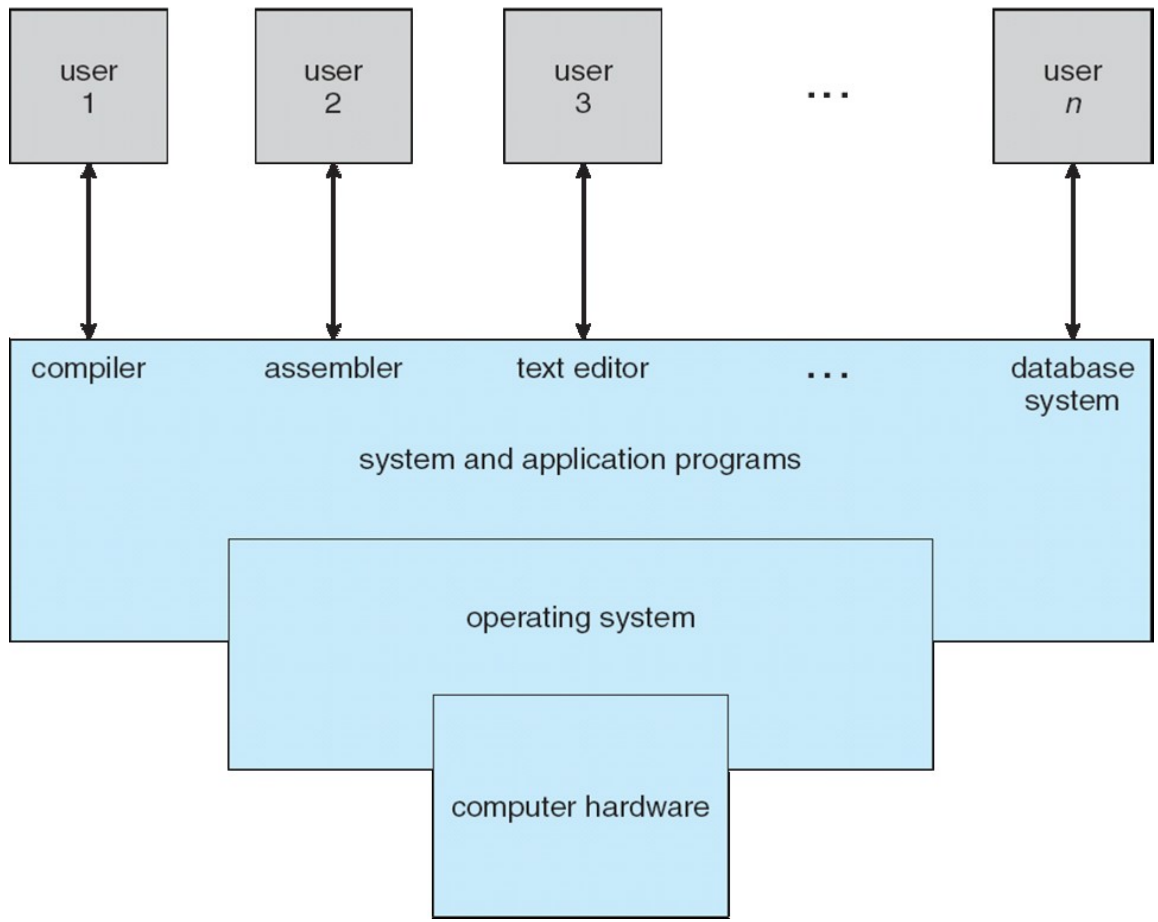
$Customer_2$

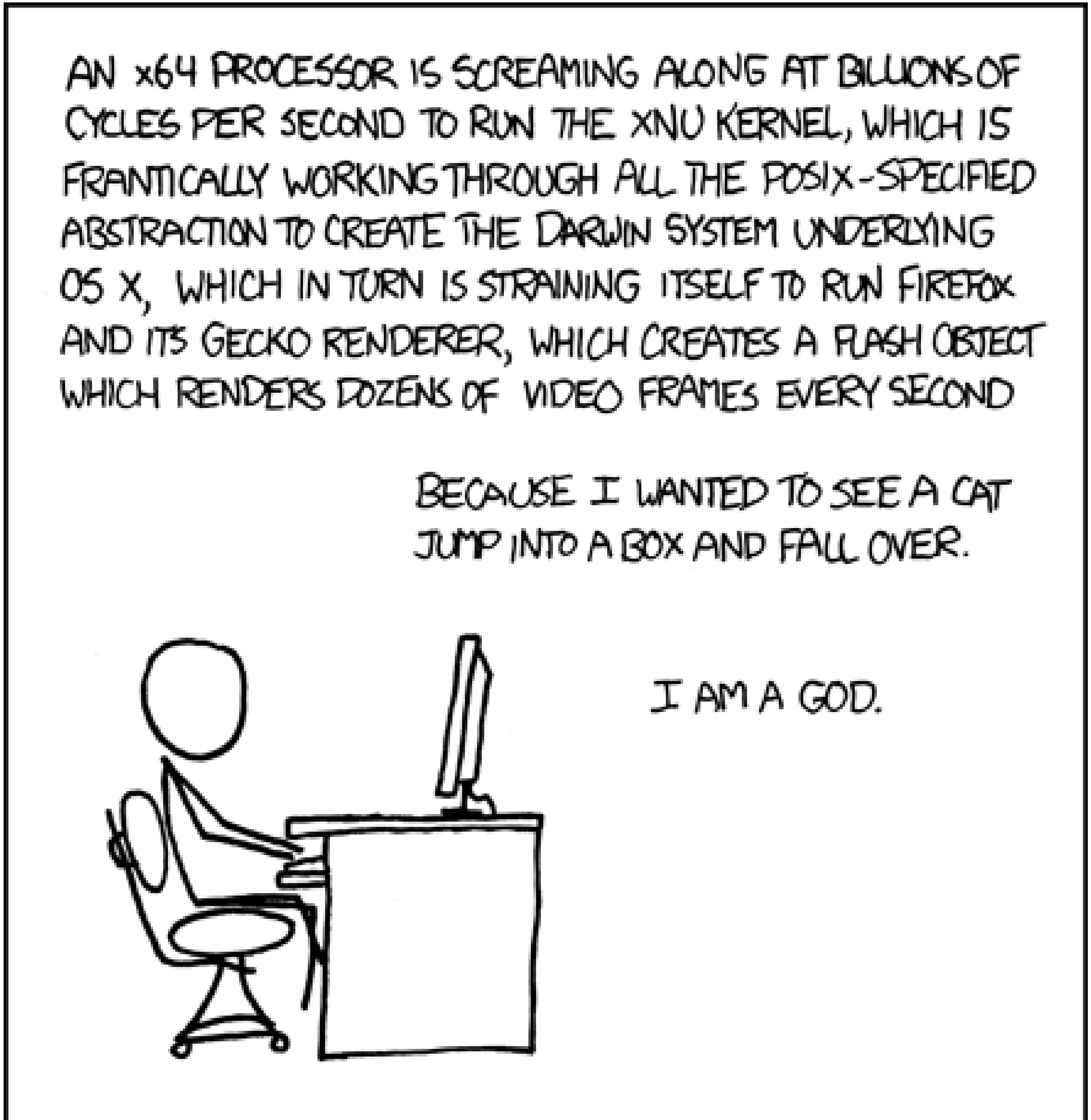
$Customer_n$

Operating System as Abstraction

- *"The effective exploitation of his powers of abstraction must be regarded as one of the most vital activities of a competent programmer."* - Edsger W. Dijkstra
- Provides abstractions for resources (memory, CPU, disk) and controls application execution
- Provide environment for application execution
  - Each application can pretend like it is using the entire computer!
- Allow users to translate intentions into actions
- Aside: Edsger Dijkstra - Discipline in Thought

OS as Abstraction: System Layers

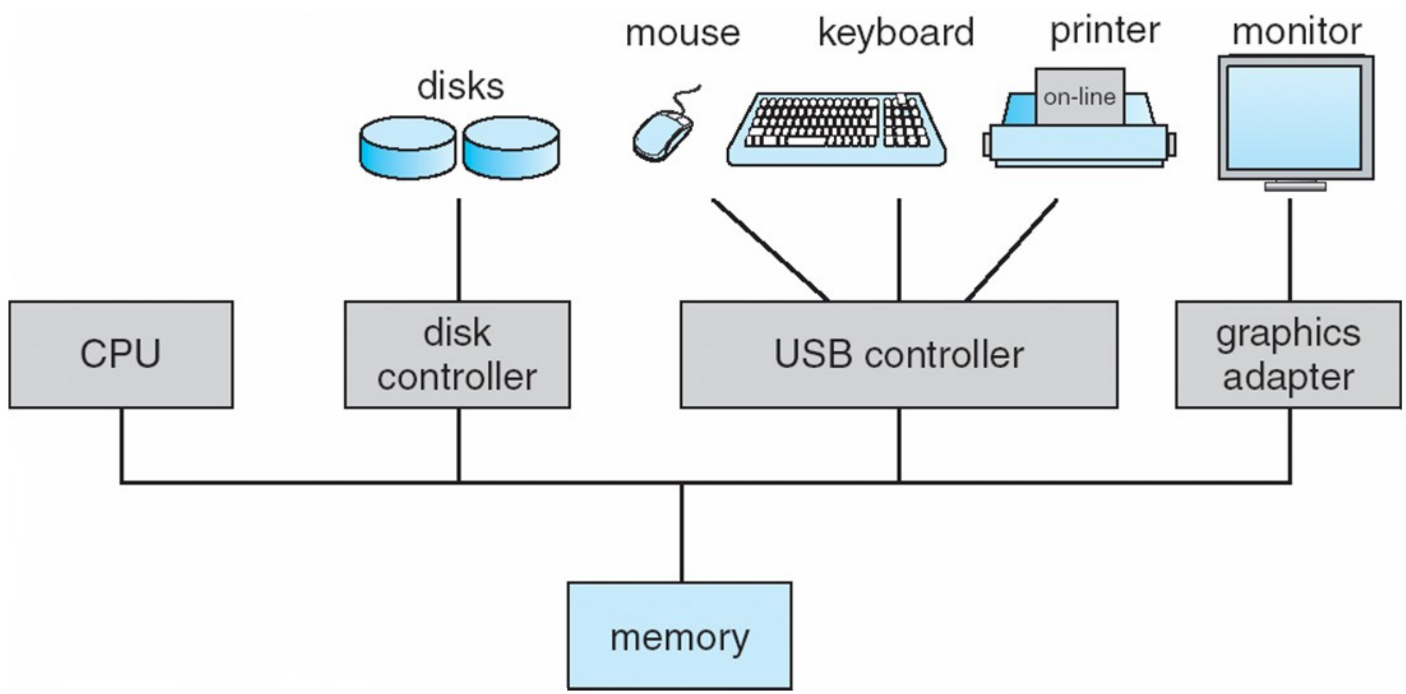




Source: xkcd.com

Computers as Distributed Systems

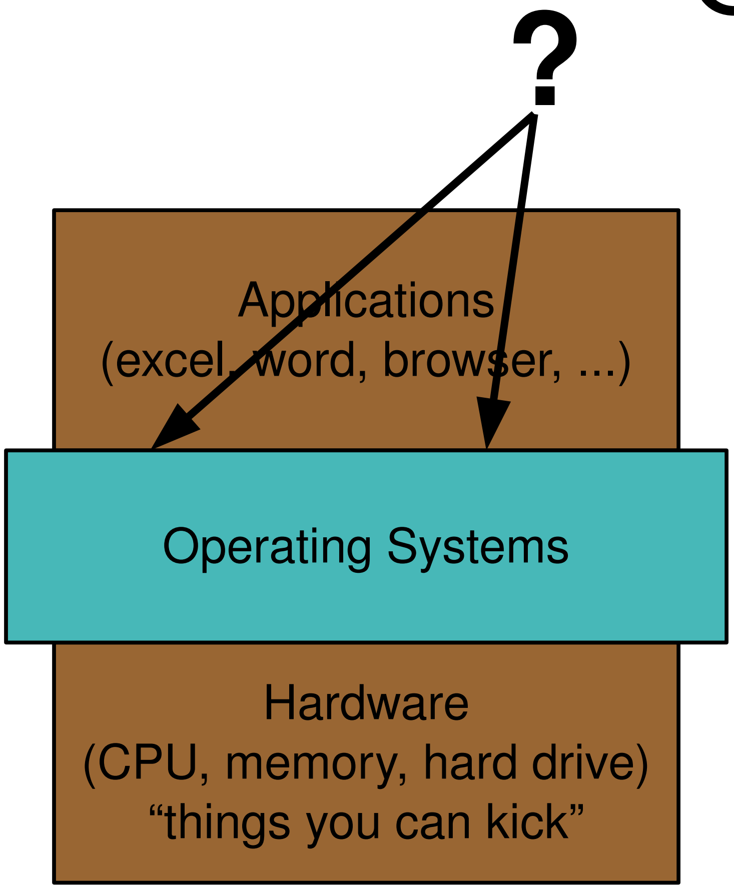
“Hardware: The parts of a computer system that can be kicked.”
- Jeff Pesis

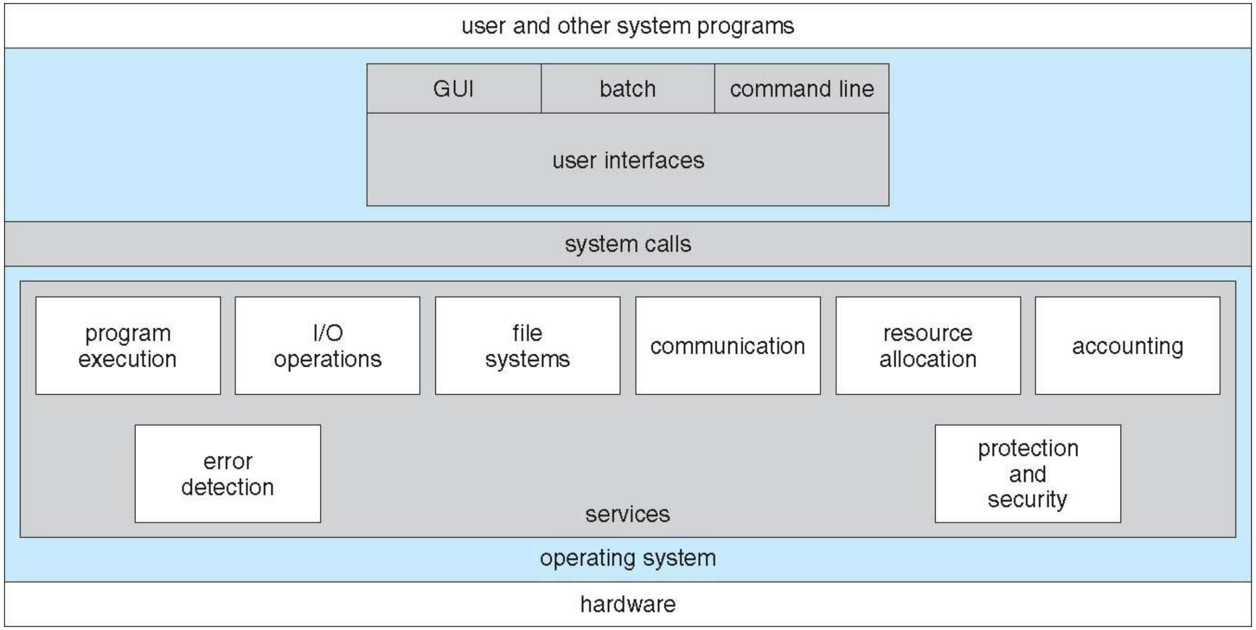


OS as Hardware Manager

- Control a diverse set of hardware
  - Processors
  - Memory
  - Disks
  - Networking cards
  - Video cards
- Coordinates these hardware resources amongst user programs
- OS as a *resource manager/multiplexer*

OS Services

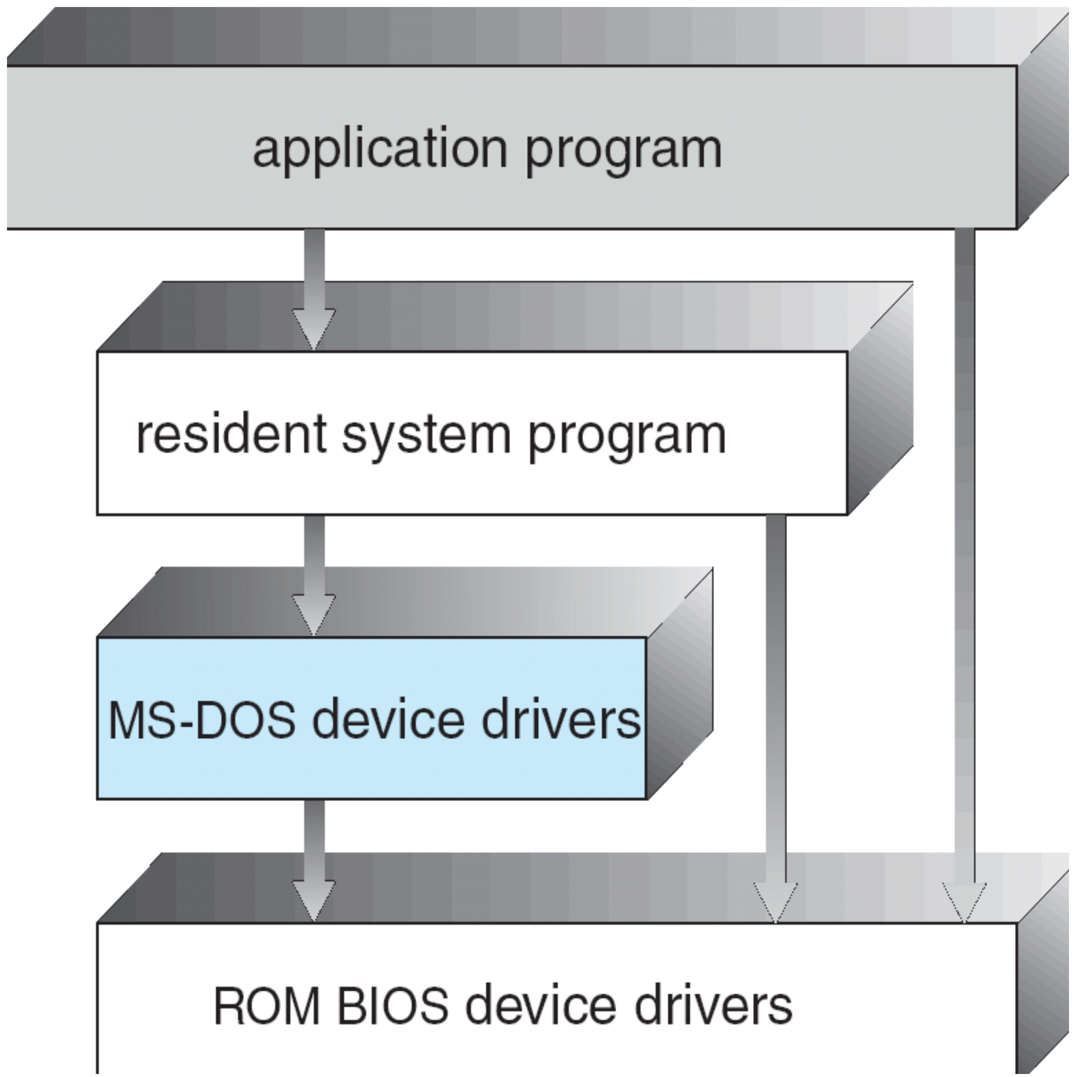

?
Applications
(excel, word, browser, ...)
Operating Systems
Hardware
(CPU, memory, hard drive)
“things you can kick”


user and other system programs
GUI
batch
command line
user interfaces
system calls
program execution
I/O operations
file systems
communication
resource allocation
accounting
error detection
protection and security
services
operating system
hardware

Interrupts, exceptions, and traps – OH MY

- Interrupts thus far: Device ↔ kernel
- Software-triggered events
  - Application state saved (as for interrupt) and can be resumed
  - Exceptions
    - Program faults (divide by zero, general protection fault, segmentation fault)
    - Not requested by executing application
  - Traps/Software Interrupts
    - Requested by application by executing specific instruction: sysenter or int %d on x86

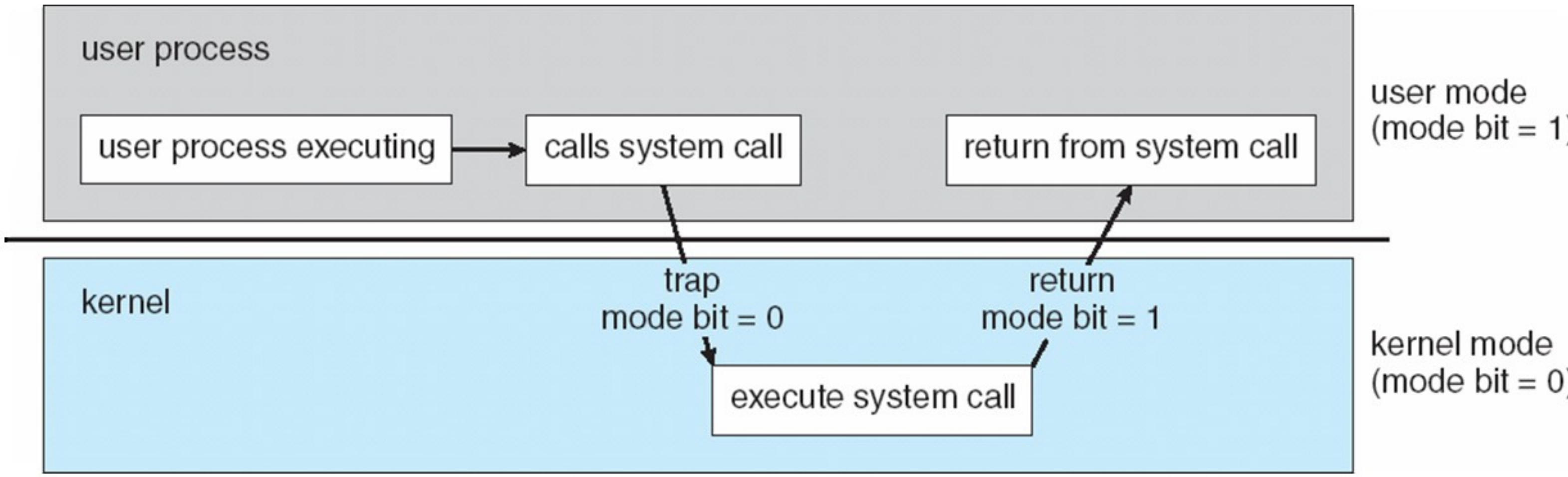
MSDOS: No Structure/Protection



System Calls

- Wait, hardware support for calling the kernel?
  - Why can't I just call it directly (function call)?

System Call w/ Dual-Mode HW



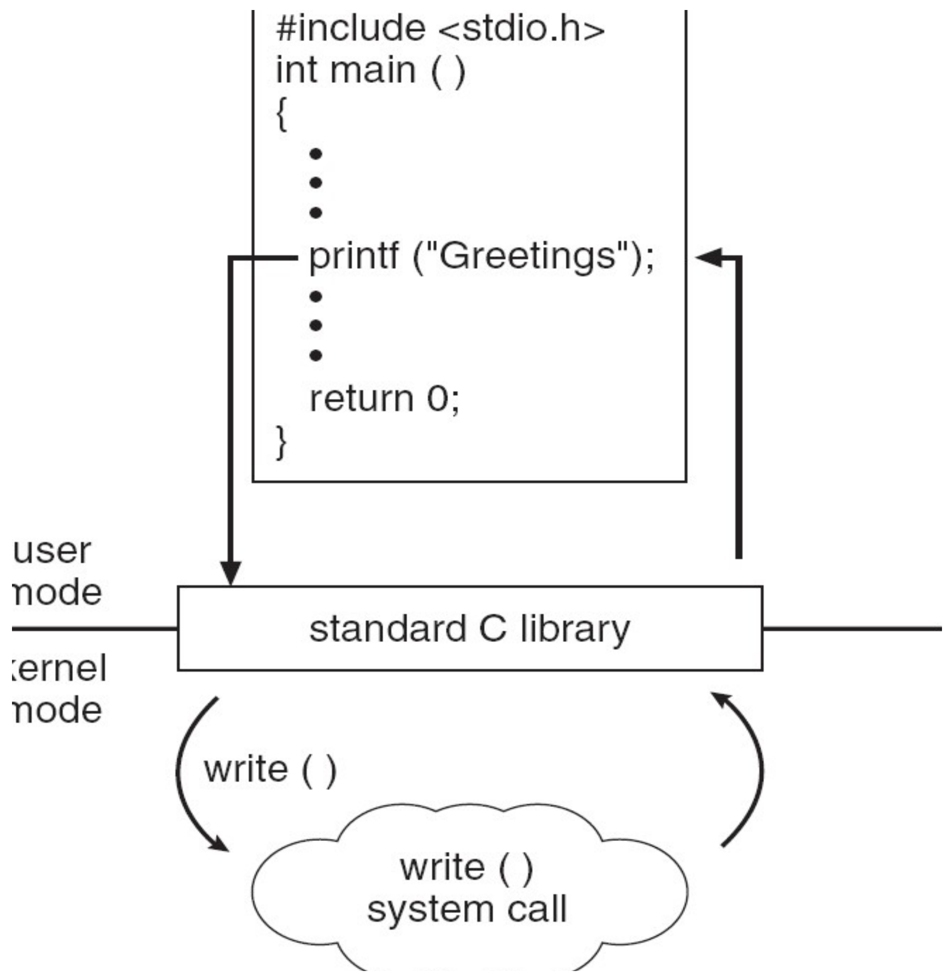
Timesharing systems: 1) protection applications from each other, *and* 2) **kernel from applications** (why the latter?)

- Mode bit == 0
  - Access kernel memory segments
  - Protected instructions
    - Access I/O: instructions to read/write to device control registers (in/out on x86)
    - Sensitive instructions
- *What happens to the registers, and stack?*

Syscall Mechanics

printf(“print me!”)

- write(1, “print me!”)
- put syscall number for write (4), file descriptor (1), and pointer to “print me!” into registers
- **sysenter**: mode bit = 0
  - Change to kernel stack
- Call address in syscall tbl at index 4
- Execute write system call
- **sysexit**: mode bit = 1
  - Restore application registers



Abstraction for syscalls: APIs

- Application Programmer Interfaces (APIs)
  - Hide the details of how a syscall is carried out
  - POSIX (UNIX, Linux)
  - Win32 (Windows)
  - .Net (Windows XP and later)
  - Cocoa (OS X)

System Structure

- *System Structure* – How different parts of software

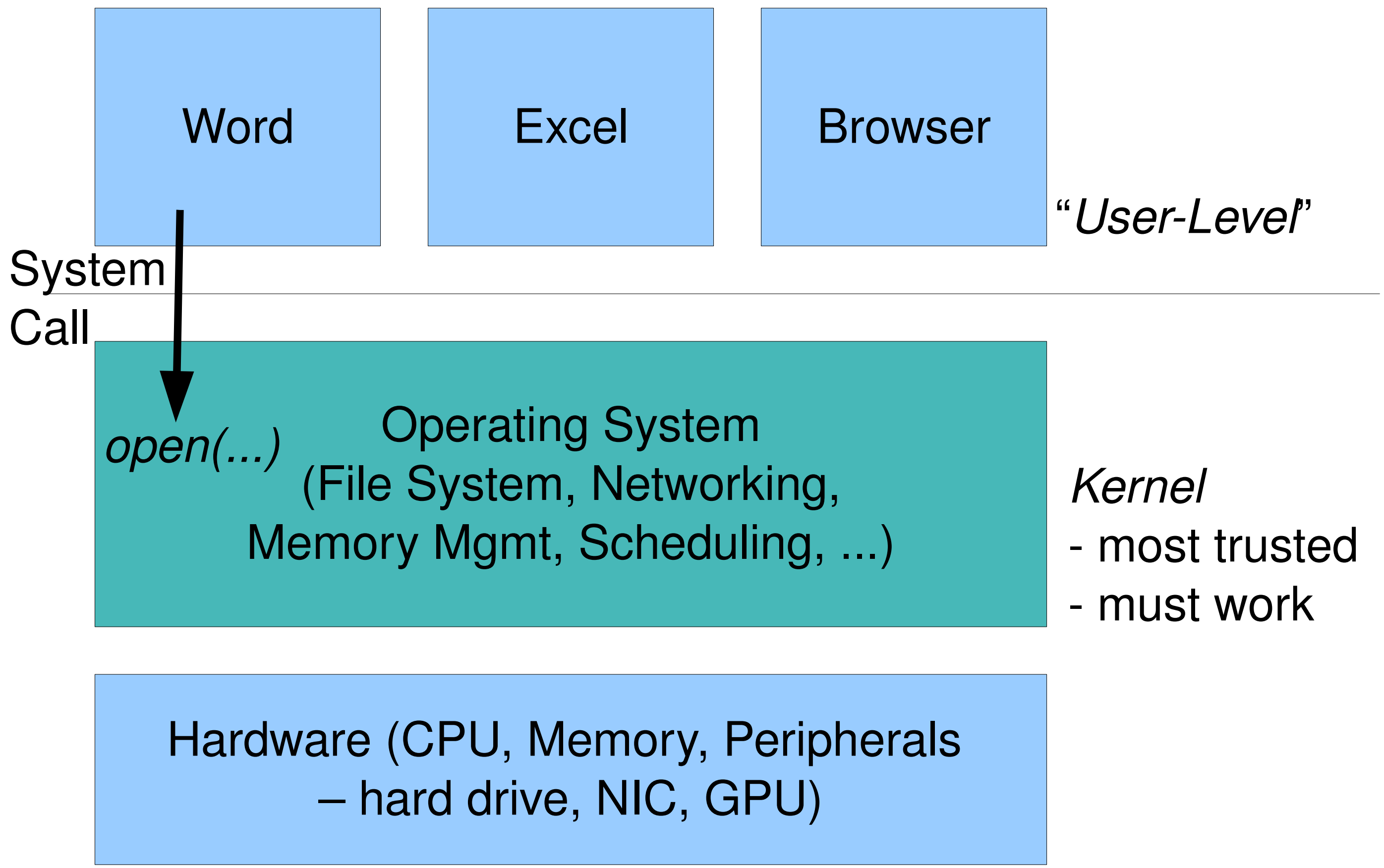
  1) Are separated from each other (*Why?)*

  2) Communicate

- How does a system use
  - dual mode
  - v*irtual address spaces*
- Implications on
  - Security/Reliability
  - Programming style/Maintainability

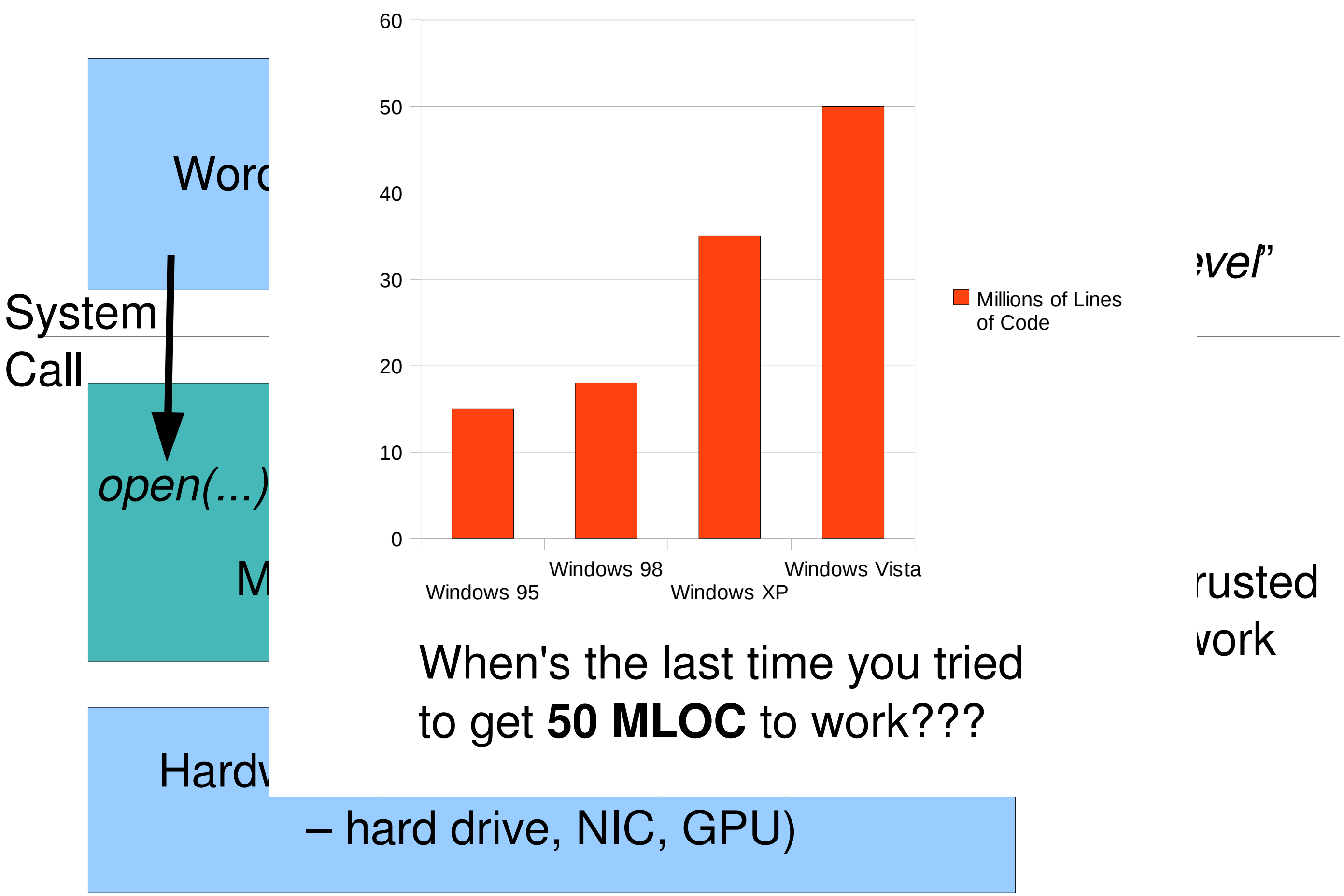
Monolithic System Structure

- Includes Unix/Windows/OSX



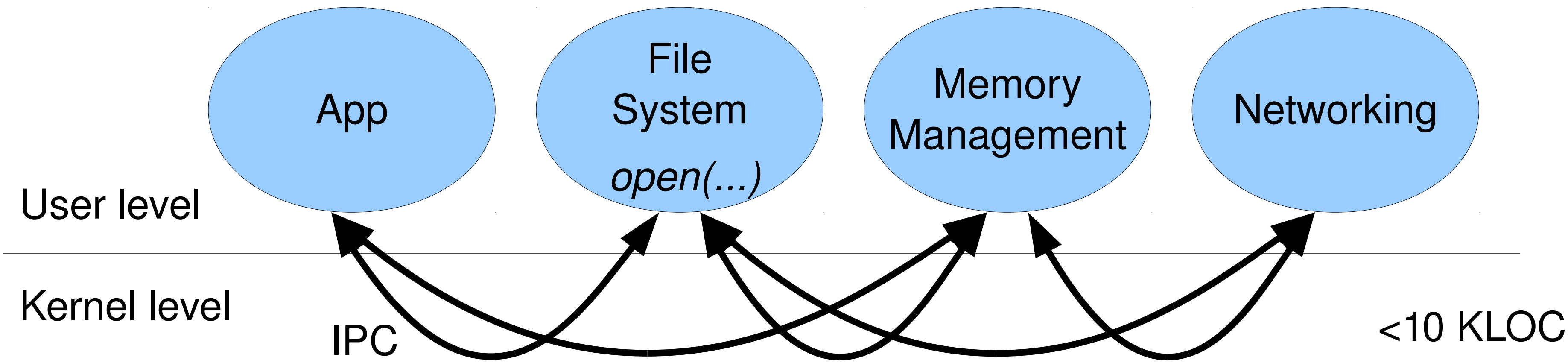
Monolithic System Structure

- Includes Unix/Windows/OSX



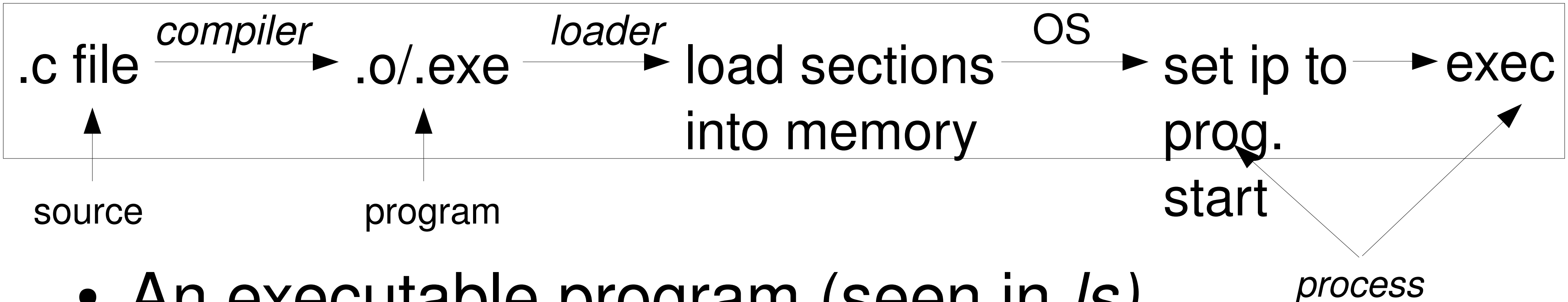
When's the last time you tried to get **50 MLOC** to work???

Microkernel System Structure



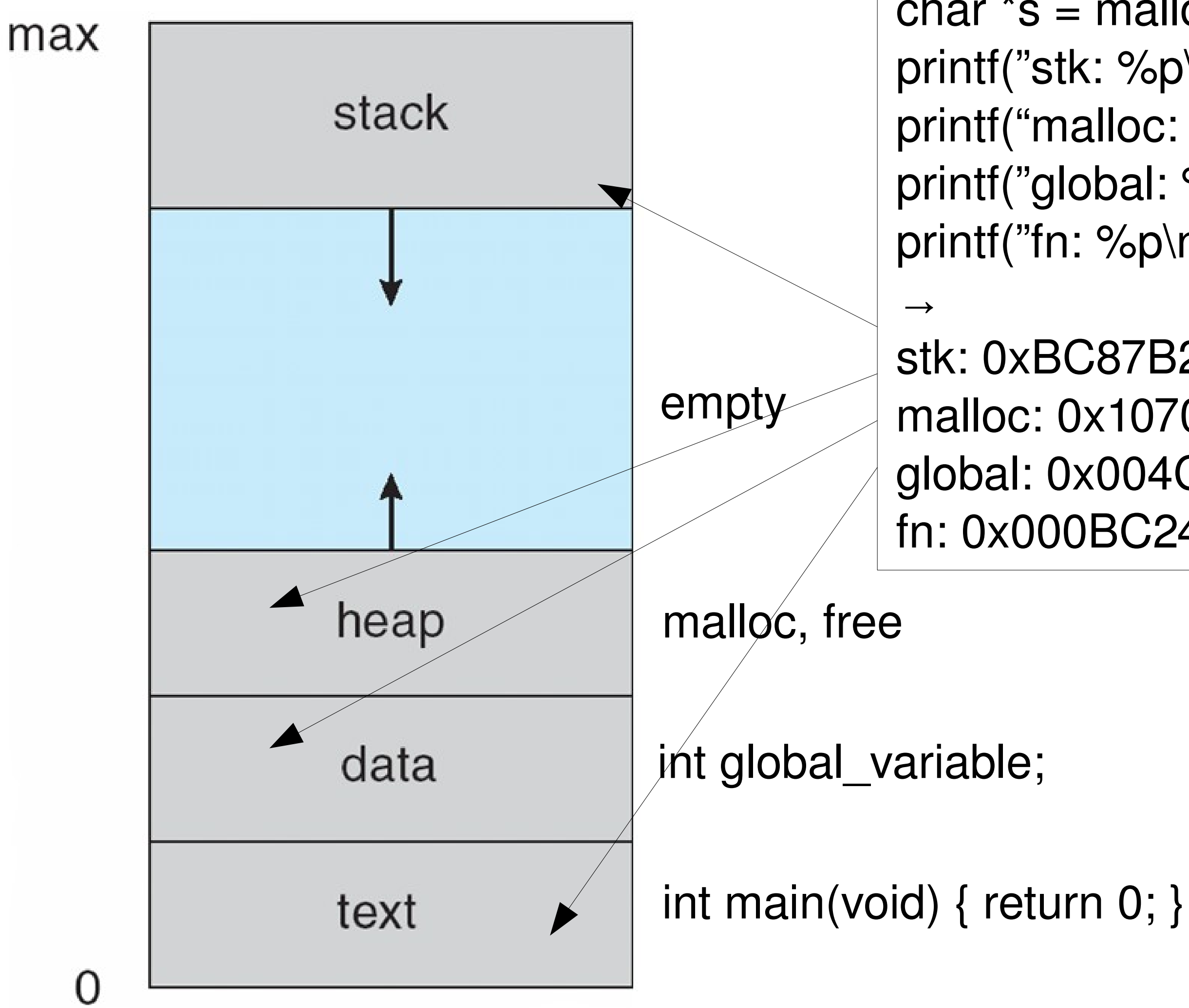
- Moves functionality from the kernel to "*user*" space
- Communication takes place between user *servers* using inter-process communication (IPC)
- Benefits:
  - Easier to add functionality
  - More reliable (less code is running in kernel mode)
  - More secure
- Detriments: performance! (why?)

Processes



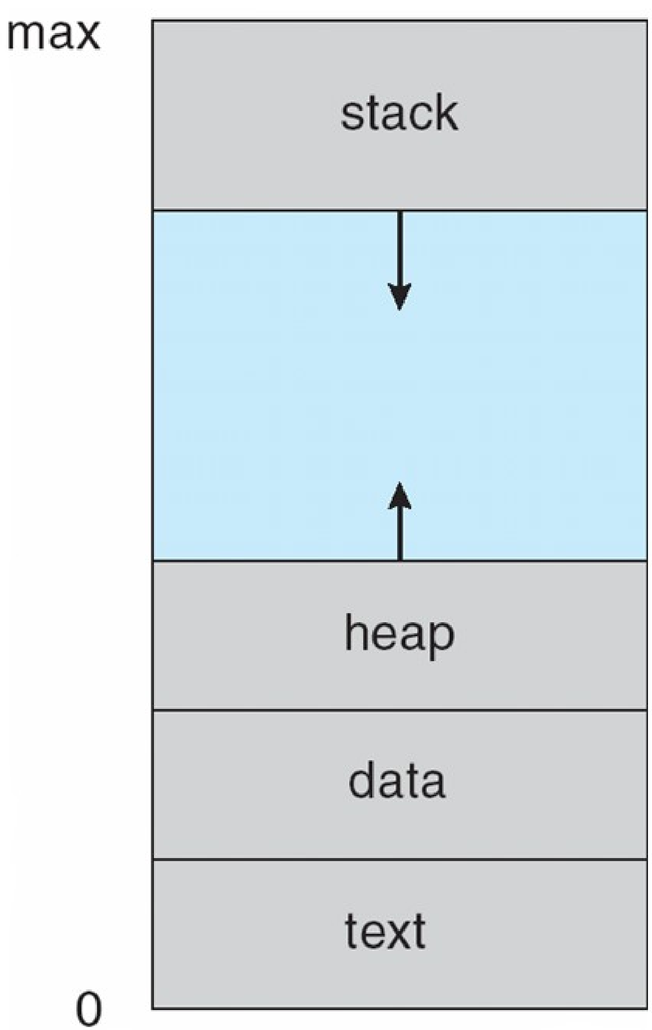
- An executable program (seen in *ls)*
- passive collection of code and data; kept in file
- UNIX Process: active entity that includes (seen in *ps)*
  - Registers (instruction counter, stack pointer, etc..)
  - Execution stack
  - Heap
  - Data and text (code) segments

Process in Memory



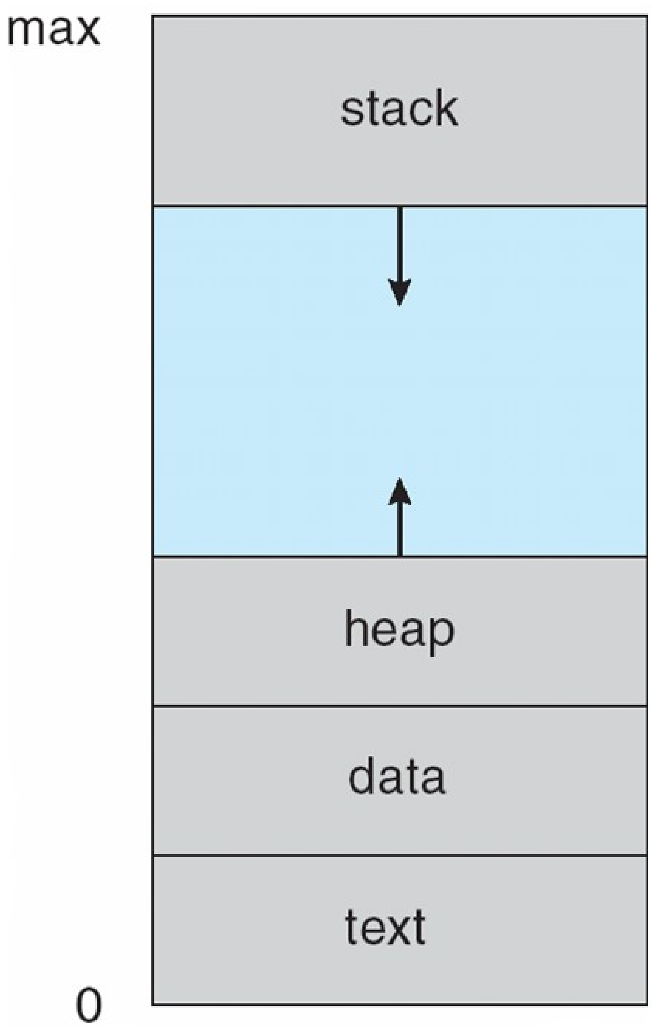

```
char *s = malloc(10);
printf(”stk: %p\n”, &s);
printf(“malloc: %p\n”, s);
printf(”global: %p\n”, &global_variable);
printf(”fn: %p\n”, main);
→
stk: 0xBC87B240
malloc: 0x1070B4F0
global: 0x004C72A0
fn: 0x000BC240
```

OS Support for Process Memory



- OS uses HW to provide virtual address space (VAS)
  - Each process thinks it has all memory
    - OS abstraction!!!
  - Provides protection between processes
  - Only subset of that address space is populated by actual memory

OS Support for Process Memory II



- Kernel must manage virtual address spaces
  - Create mapping between virtual and actual memory
  - Switch between apps == switch between VAS
  - Only mode 0 can switch VAS!

Process Control Block (PCB)

- Kernel, per-process, data-structure includes:
  - CPU registers (including instruction counter)
  - Scheduling state (priority)
  - Memory management information (amount of memory allocated, virtual address space mapping, stack location)
  - CPU accounting info (exec time at user/kernel level)
  - File info (open files)
  - Process state