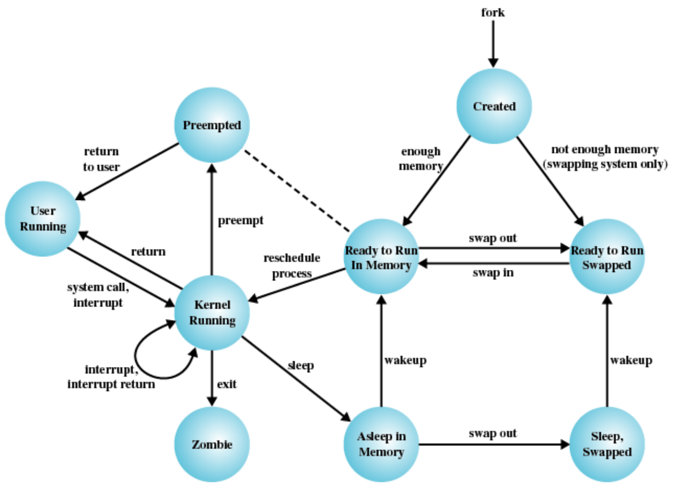
# Operating Systems & Computer Networks

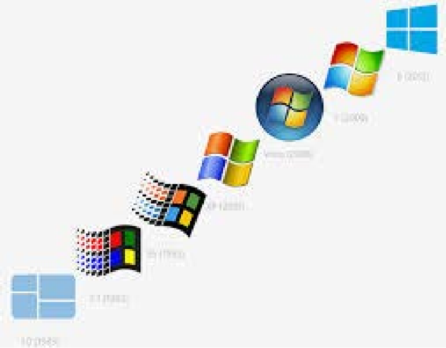
## Introduction and Motivation

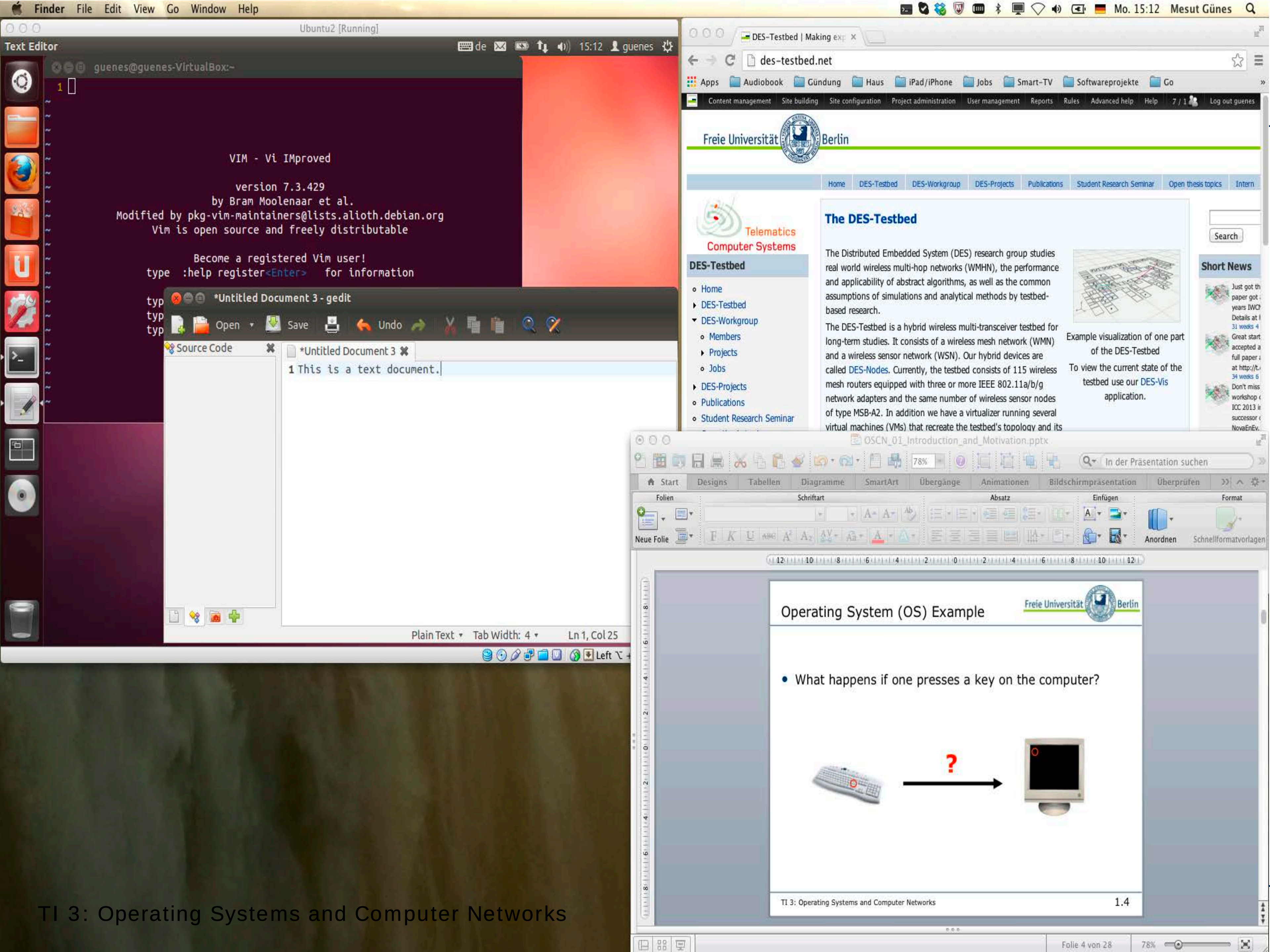


# Content

1. **Introduction and Motivation**
2. Subsystems, Interrupts and System Calls
3. Processes
4. Memory
5. Scheduling
6. I/O and File System
7. Booting, Services, and Security

# Motivation





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guenes@guenes-VirtualBox:~
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Folien Schriftart Absatz Einfügen Format
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Folie 4 von 28 78%

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                    VIM - Vi IMproved

                    version 7.3.429
                by Bram Moolenaar et al.
    Modified by pkg-vim-maintainers@lists.alioth.debian.org
        Vim is open source and freely distributable

            Become a registered Vim user!
    type  :help register<Enter>   for information
```

```
1 This is a text document.
```

### The DES-Testbed

The Distributed Embedded System (DES) research group studies real world wireless multi-hop networks (WMHN), the performance and applicability of abstract algorithms, as well as the common assumptions of simulations and analytical methods by testbed-based research.

The DES-Testbed is a hybrid wireless multi-transceiver testbed for long-term studies. It consists of a wireless mesh network (WMN) and a wireless sensor network (WSN). Our hybrid devices are called DES-Nodes. Currently, the testbed consists of 115 wireless mesh routers equipped with three or more IEEE 802.11a/b/g network adapters and the same number of wireless sensor nodes of type MSB-A2. In addition we have a virtualizer running several virtual machines (VMs) that recreate the testbed's topology and its

Example visualization of one part of the DES-Testbed

To view the current state of the testbed use our DES-Vis application.

Operating System (OS) Example

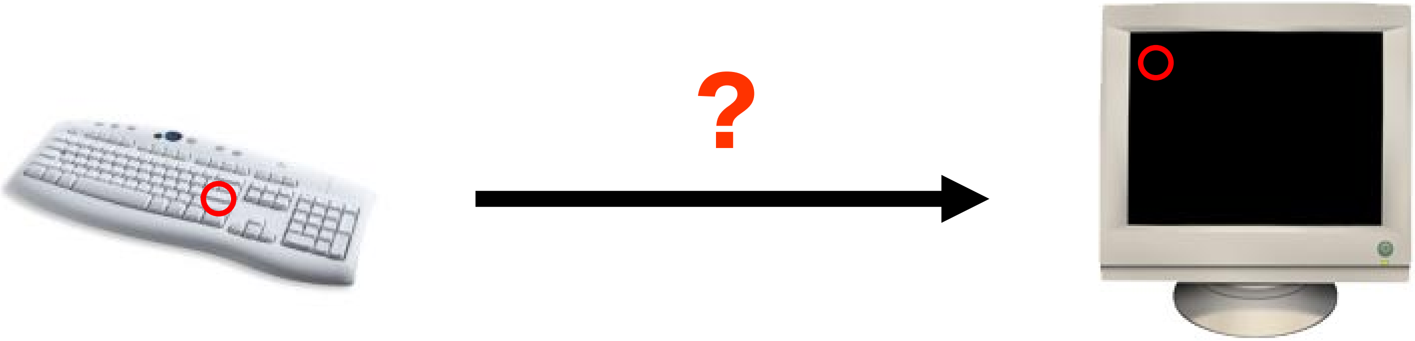
- What happens if one presses a key on the computer?

?

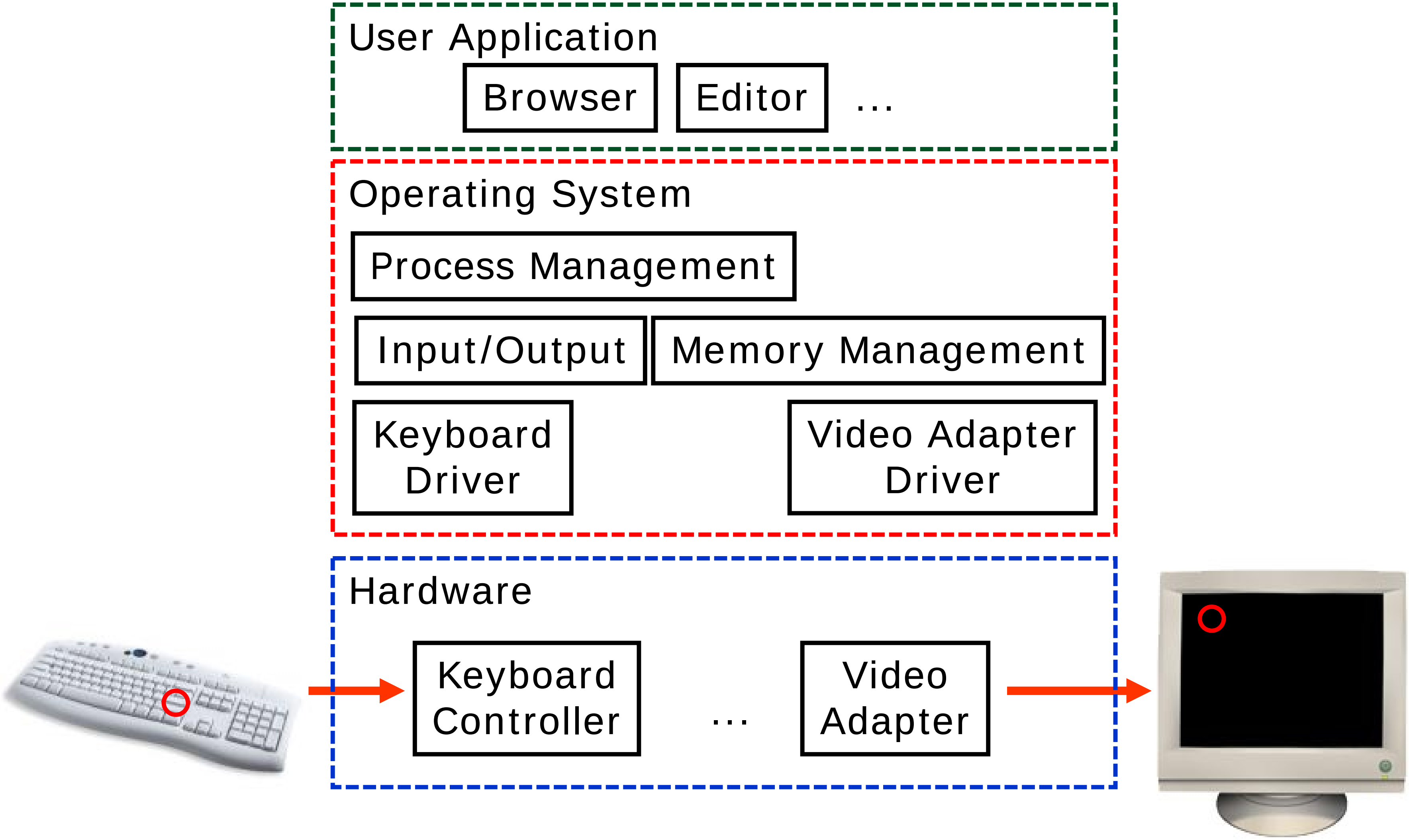
TI 3: Operating Systems and Computer Networks 1.4

# Operating System (OS) Example

- What happens if one presses a key on the computer?



# Operating System Example



User Application

Browser

Editor

...

Operating System

Process Management

Input/Output

Memory Management

Keyboard Driver

Video Adapter Driver

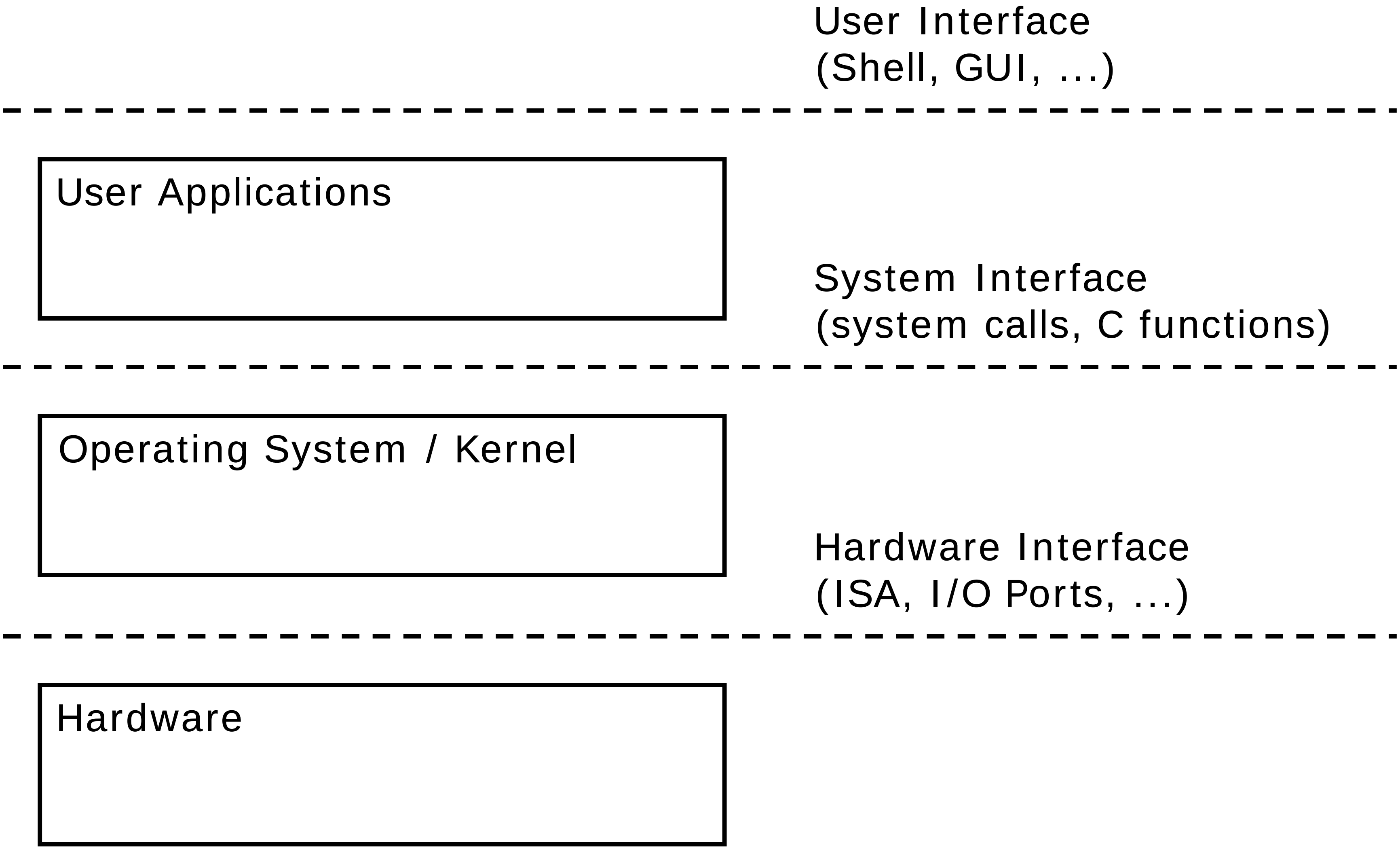
Hardware

Keyboard Controller

...

Video Adapter

# Layers of Abstraction



User Interface
(Shell, GUI, ...)

User Applications

System Interface
(system calls, C functions)

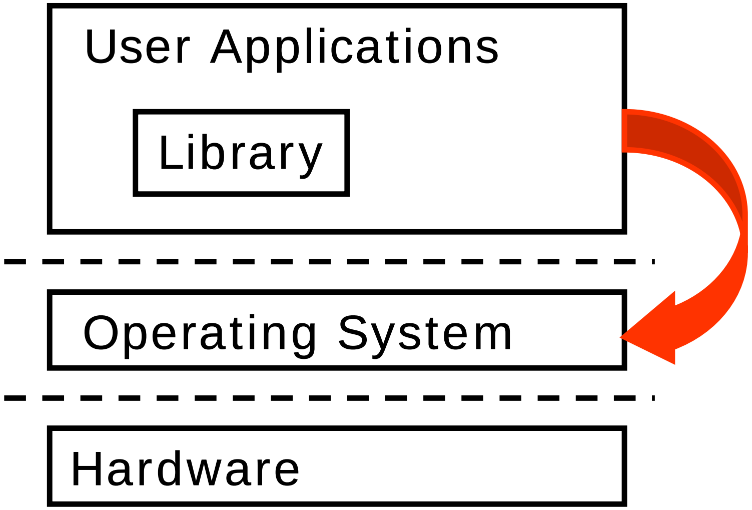
Operating System / Kernel

Hardware Interface
(ISA, I/O Ports, ...)

Hardware

# System Interface and System Calls

- System interface is the only way for user applications to interact with the operating system.
- System interface consists of system calls (supervisor calls) → POSIX.



- High-level programming languages hide systems calls in library routines.

# POSIX

- Portable Operating System Interface (POSIX)
  - http://standards.ieee.org/develop/wg/POSIX.html
- POSIX defines
  - Application programming interface (API)
  - Command line shells
  - Utilities
- UNIX like Operating Systems
- POSIX oriented operating systems
  - Unix
  - Linux
  - Windows
  - Mac OS X
  - ...

# Tasks of an Operating System

- Typical services of a **general** purpose OS includes:
  - Program execution
  - Access to I/O-devices
    - Hardware abstraction
  - Controlled access to files
    - Non-volatile memory
  - Access control
    - Security / user management
  - Error detection and error handling
    - Both hardware and software
  - Logging

- Special purpose operating systems focus on different services, e.g., real-time or communication requirements.

# Goals of an Operating System

- Ease of use for users and programmers
- Efficiency when managing limited resources
- Possibility to evolve
  - New hardware standards
  - Changing user requirements

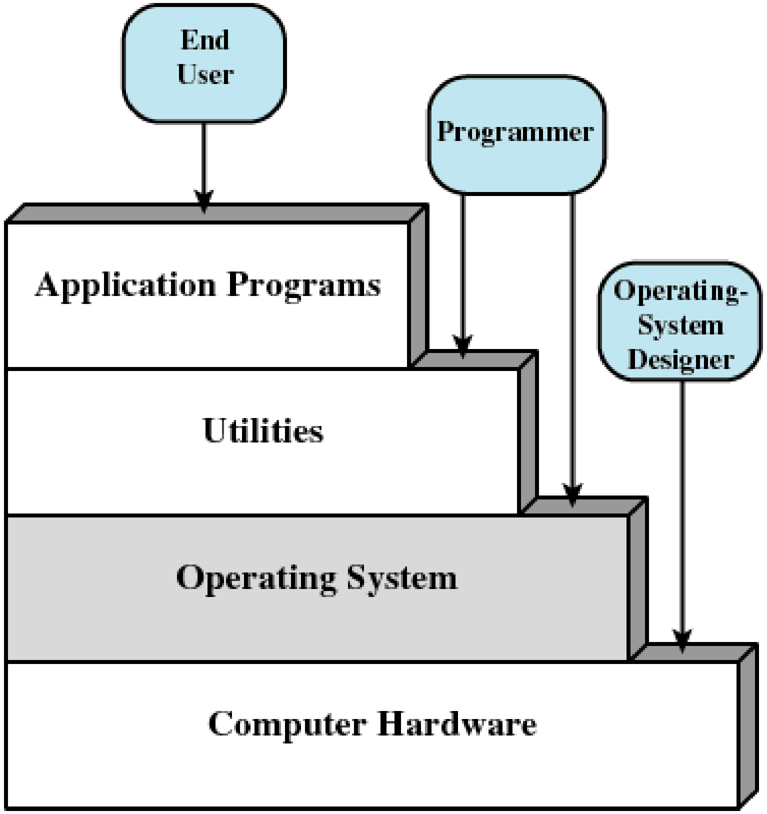
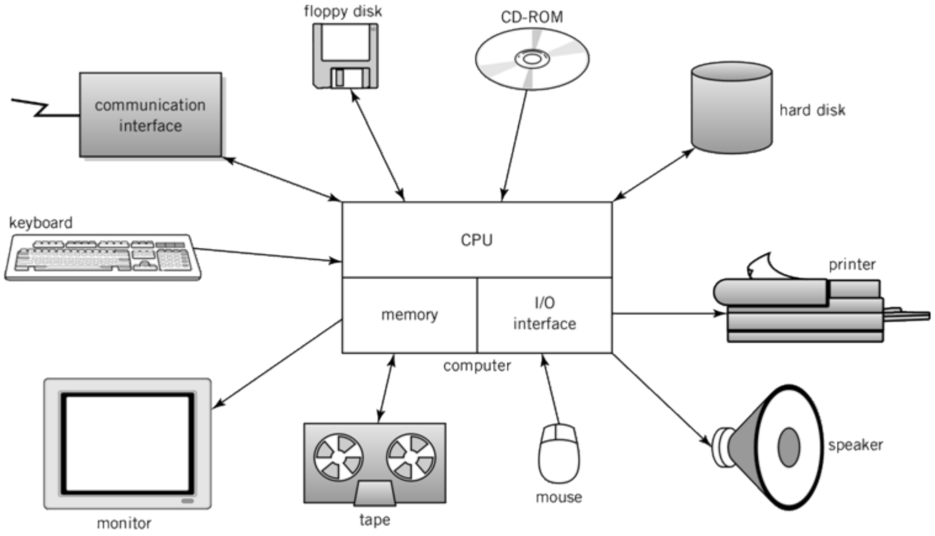


Figure 2.1 Layers and Views of a Computer System

# Managing Resources

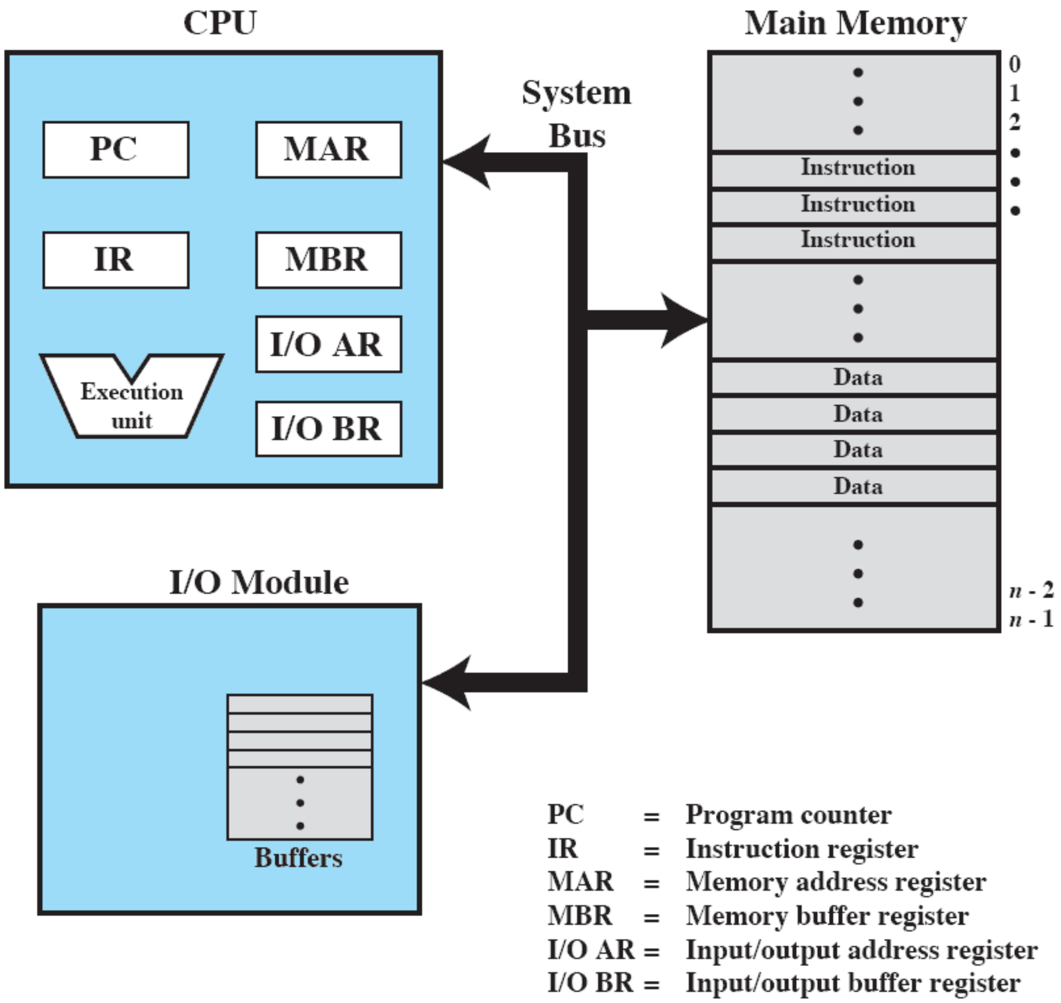
- Hardware provides the basic computing resources such as
  - Processor(s)
  - Memory
  - Persistent storage
  - Network connection



Englander: The Architecture of Computer Hardware and Systems Software, 2nd edition Chapter 1, Figure 01-06

- OS **virtualizes** resources to permit controlled sharing and isolation
  - virtual instances of a resource are created
- OS provides virtual resources for user applications

# Computer Components



| | | |
|---|---|---|
| PC | = | Program counter |
| IR | = | Instruction register |
| MAR | = | Memory address register |
| MBR | = | Memory buffer register |
| I/O AR | = | Input/output address register |
| I/O BR | = | Input/output buffer register |

**Figure 1.1 Computer Components: Top-Level View**

# Virtual Resources

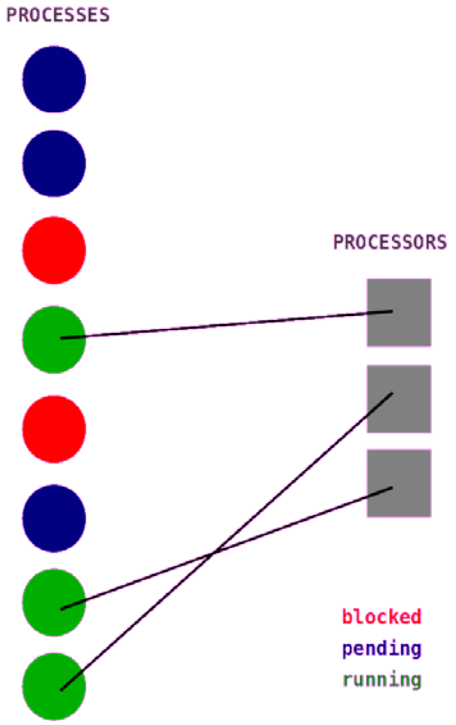
- Virtual resources and corresponding real resources:

| | |
|---|---|
| Processes | processor(s) |
| Virtual Memory | main memory |
| Files | persistent memory |
| Ports | network adapter |

- Advantages:
  - Easy to use through procedural interface (system calls)
  - Secure against hardware and software errors or manipulation

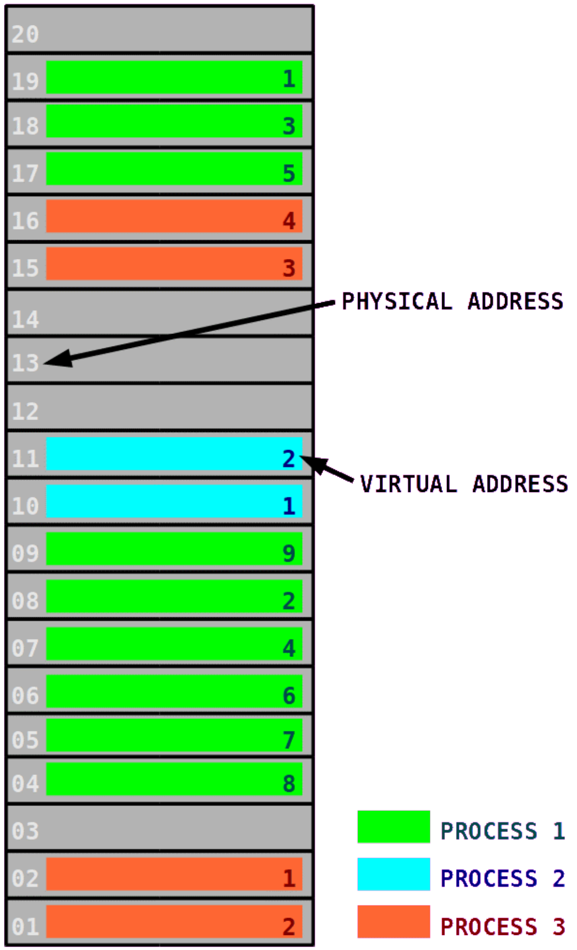
# Processes

- Number of processes is not limited by the number of processors: **Multitasking**
- Processor is used efficiently: Time is not wasted by processes that are waiting on I/O devices
- Reduced latency (=response time)
- Different **process states**, e.g.,
  - running – executing
  - pending – ready to execute
  - blocked – not ready to execute



# Virtual Memory

- Managed by the Memory Management Unit (MMU)
- Transportability:
  - position independent code – program does not depend on memory architecture
- Security:
  - memory access is restricted to memory units “owned” by a process
- Efficiency:
  - external fragmentation is avoided



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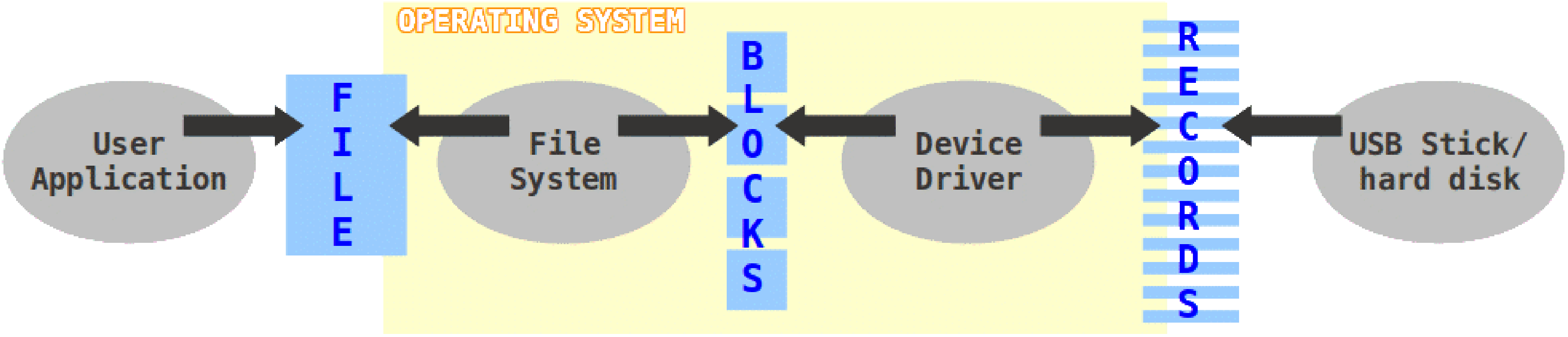
# Files

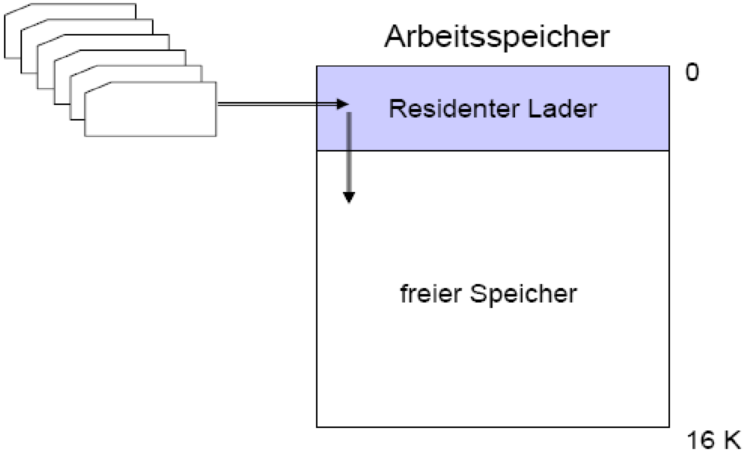
- Managed by a file system
- Persistent objects for long-term data storage
- Stored in secondary memory (e.g., tape, hard disk, USB flash drive)
- Similar to virtual memory - file name instead of virtual address



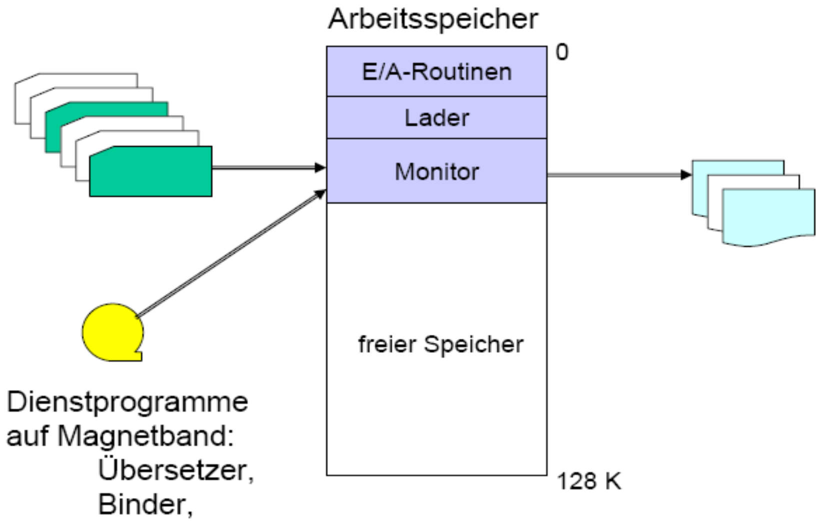
# History of Operating Systems

- Development of operating systems follows changes in computer architecture

- Loader (1950, IBM 704)
  - Loads programs into memory

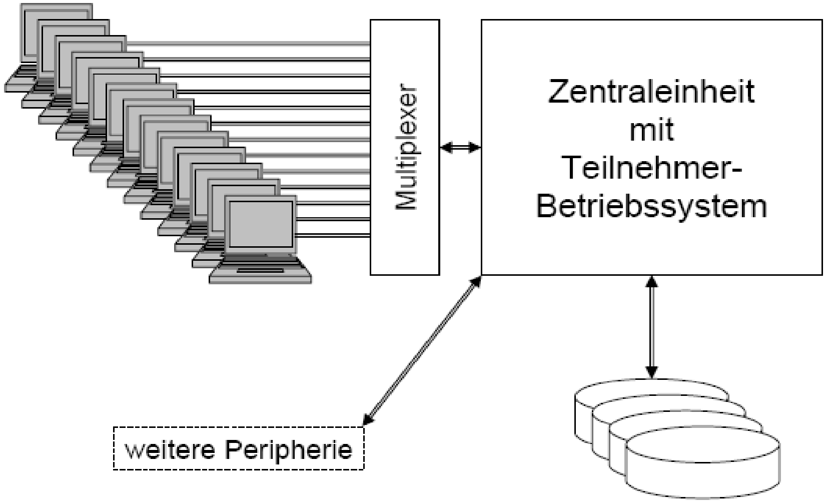


- Batch System
  (1960,IBM 7090, Zuse Z 23, Telefunken TR4)
  - Processing of jobs stored on punch cards
  - Manual job control by human operator

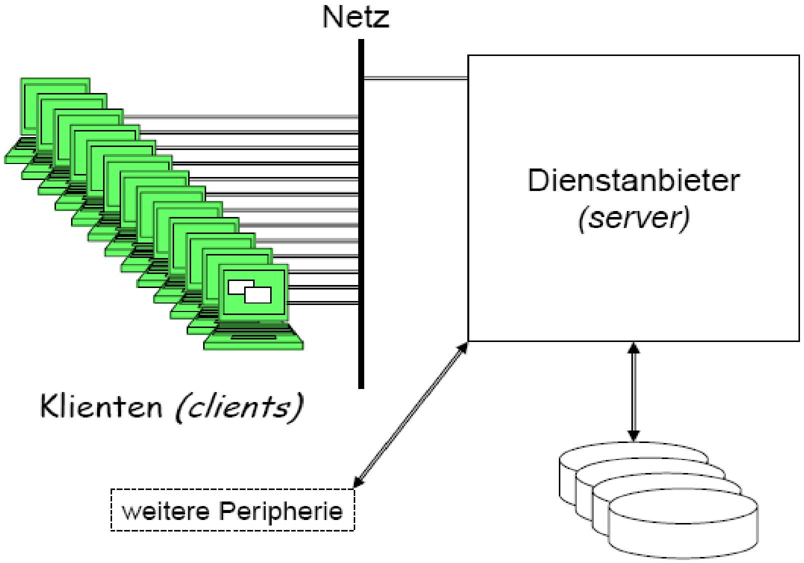


# History of Operating Systems

- Multi-User / Time Sharing Systems
  (1970, IBM OS/360, TSS, T.H.E., Multics, UNIX)
  - Many terminals connected to one computer
  - Interactive control for users
  - Multitasking

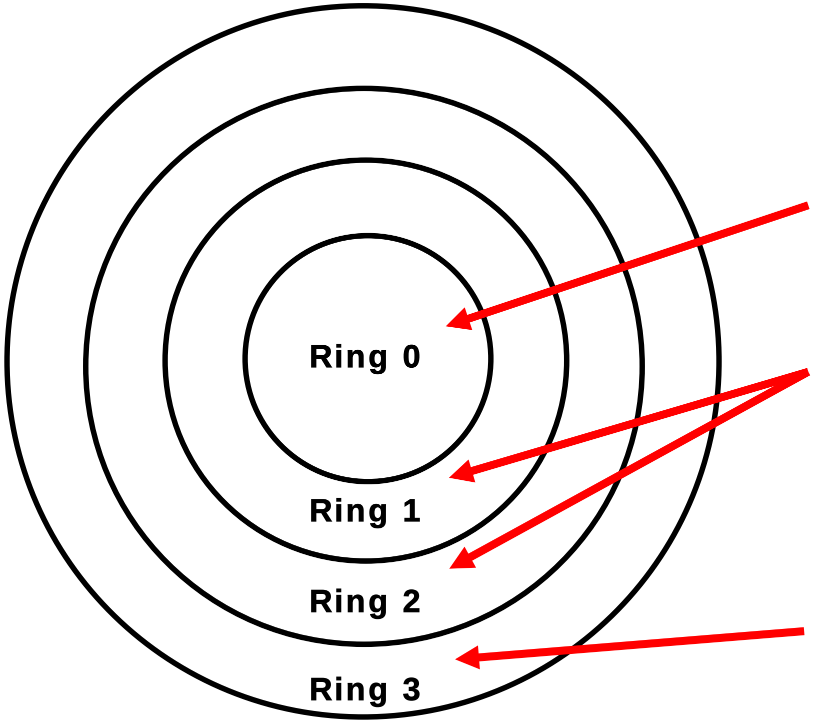


- Personal Computing und Client/Server
  (1980/90, Apple Lisa, MS Windows, Linux, Solaris, HP-UX)
  - Intelligent workstations
  - GUI / Window mode



# Protection Rings

- Hardware provides hierarchical privilege levels
  - Inner rings have access to outer rings’ resources
  - Outer rings may access inner rings through predefined gateways



Operating system kernel
(highest privilege)

Operating system services (e.g. device drivers, libraries)
➢**Unused in PCs**

Applications
(lowest privilege)

# Operating System Kernel

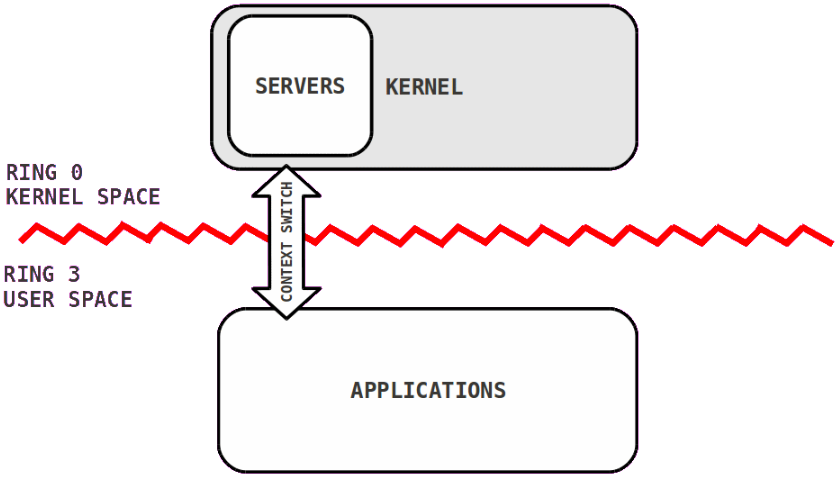
- Kernel implements basic layer of abstraction

- Runs with full access to hardware (Ring 0)

- Context Switch: switching from one process to another
  - A certain amount of time is required for doing the administration, e.g., saving and loading registers.

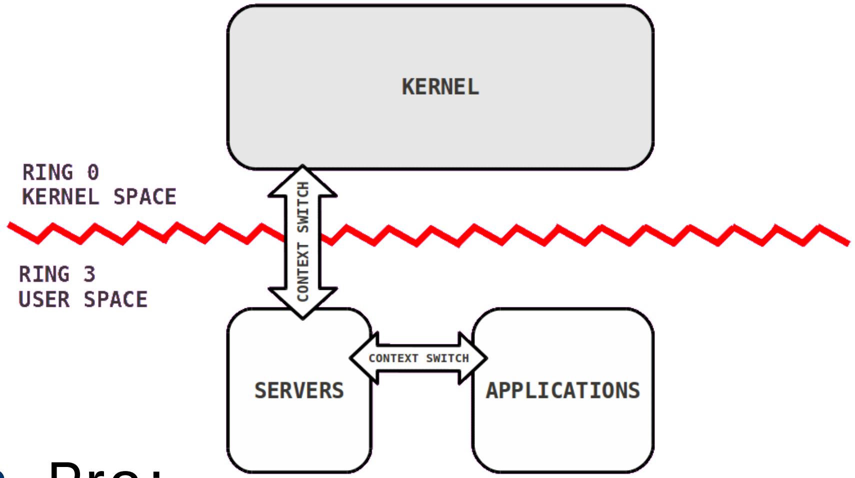
# Monolithic versus Microkernel

- Monolithic Kernel



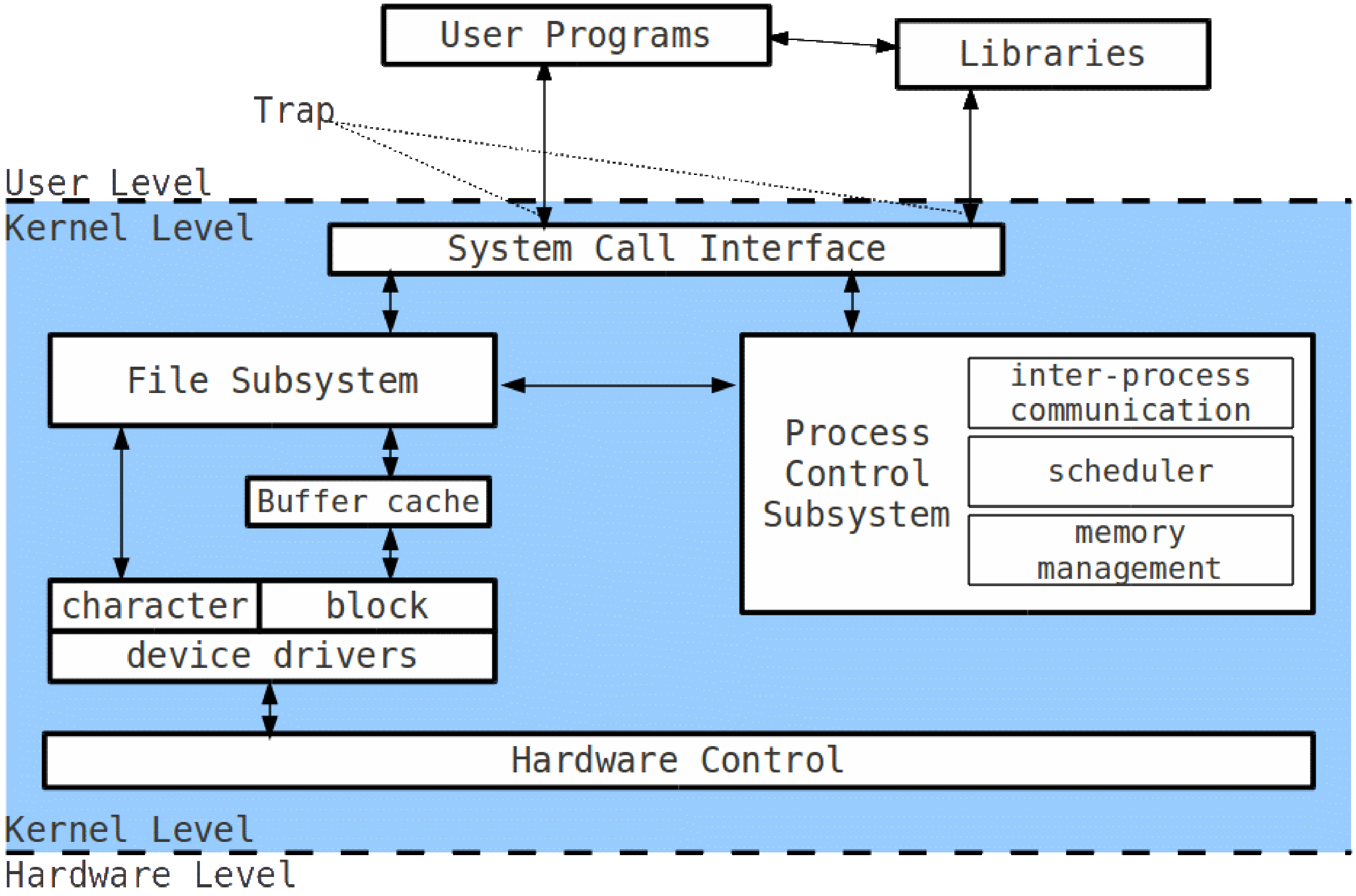
- Pro:
  - less context switches
  - no expensive communication
- Contra:
  - complications when exchanging functionality

- Microkernel

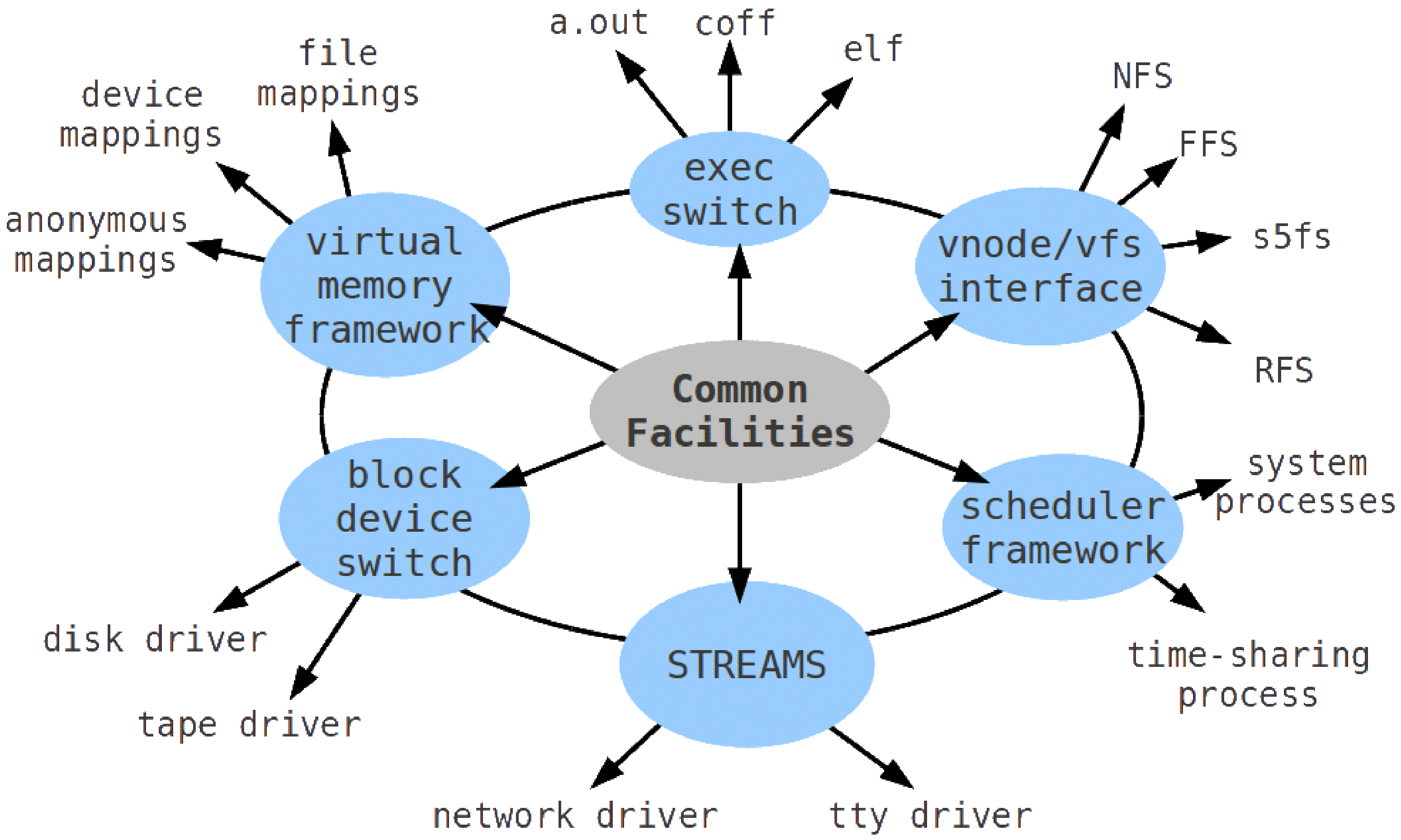


- Pro:
  - strict interfaces
  - less complexity, clear structure
- Contra:
  - speed
  - synchronization

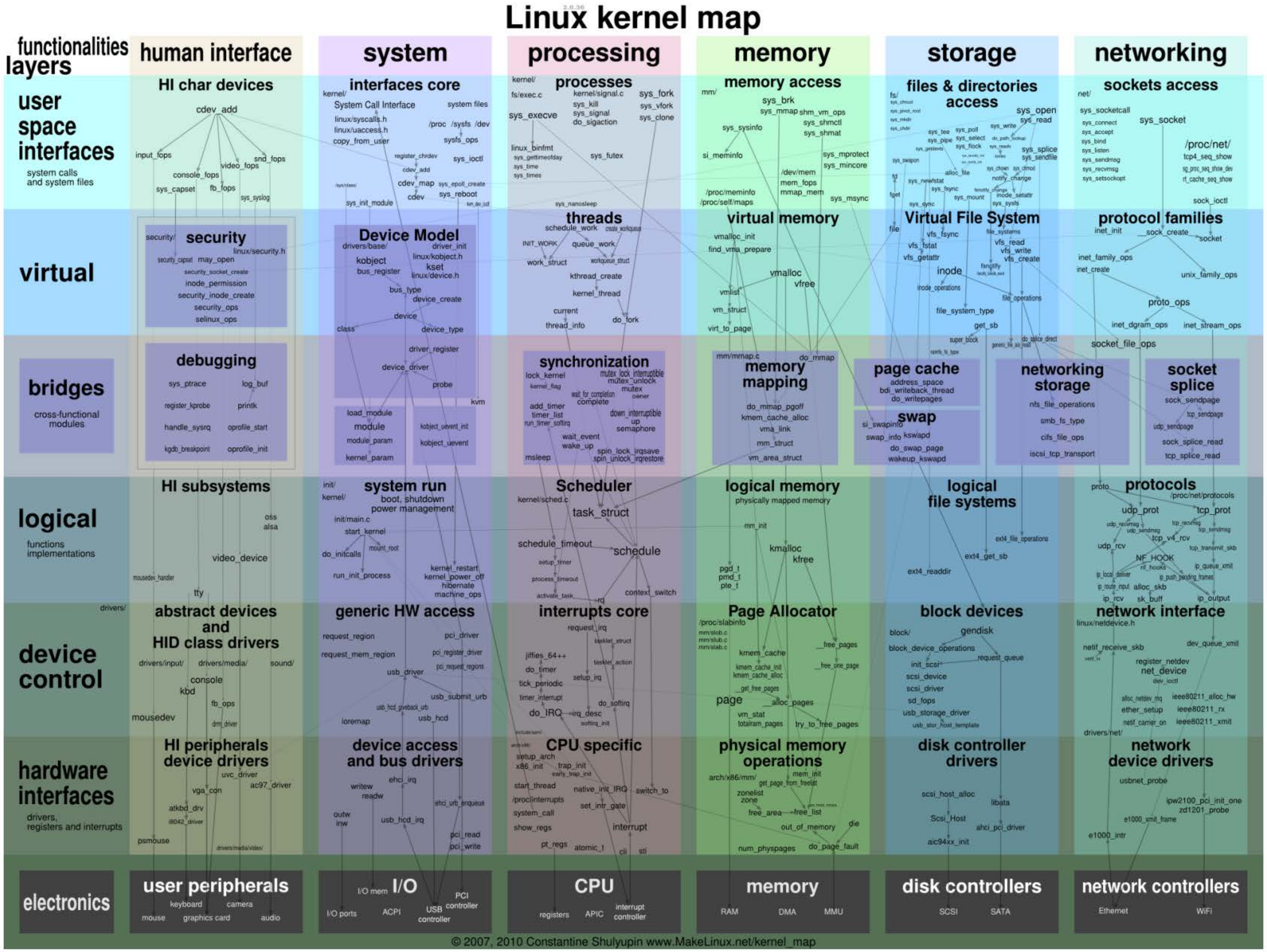
# Examples – UNIX



# Examples – UNIX by Services



# Examples – Linux



Source: http://www.makelinux.net/kernel_map

# A Word About Synchronization

- Concurrency handling is outside the scope of this lecture.
  - ➢Course “Nichtsequentielle Programmierung” in summer term

**Some pointers/methods/ideas:**

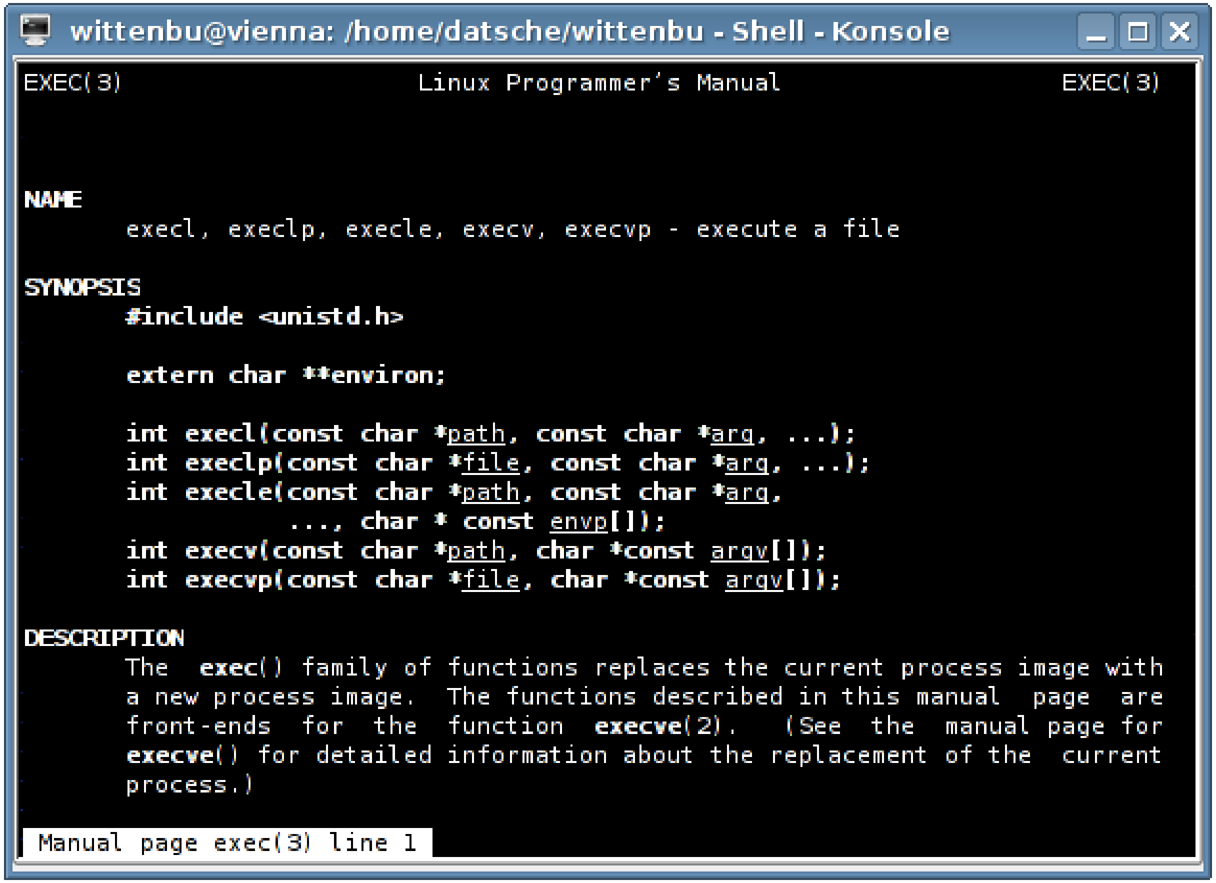
- In hardware:
  - Atomic operations:
    - ISA instructions that are guaranteed by design to run to completion
  - Interrupts:
    - Enable/disable interrupts via special ISA instructions
    - Allows other interrupt handlers to run to completion

- In software:
  - Spinlocks (busy waiting):
    - Short-term synchronization mechanism
    - Low overhead, avoid re-scheduling, wasteful on resources
  - Semaphores (wait queues):
    - Long-term synchronization mechanism
    - Synchronize for events on special purpose data structures

# Manual Pages

- UNIX-utility **man**

e.g. **man exec**



```
EXEC(3)                Linux Programmer's Manual               EXEC(3)



NAME
       execl, execlp, execle, execv, execvp - execute a file

SYNOPSIS
       #include <unistd.h>

       extern char **environ;

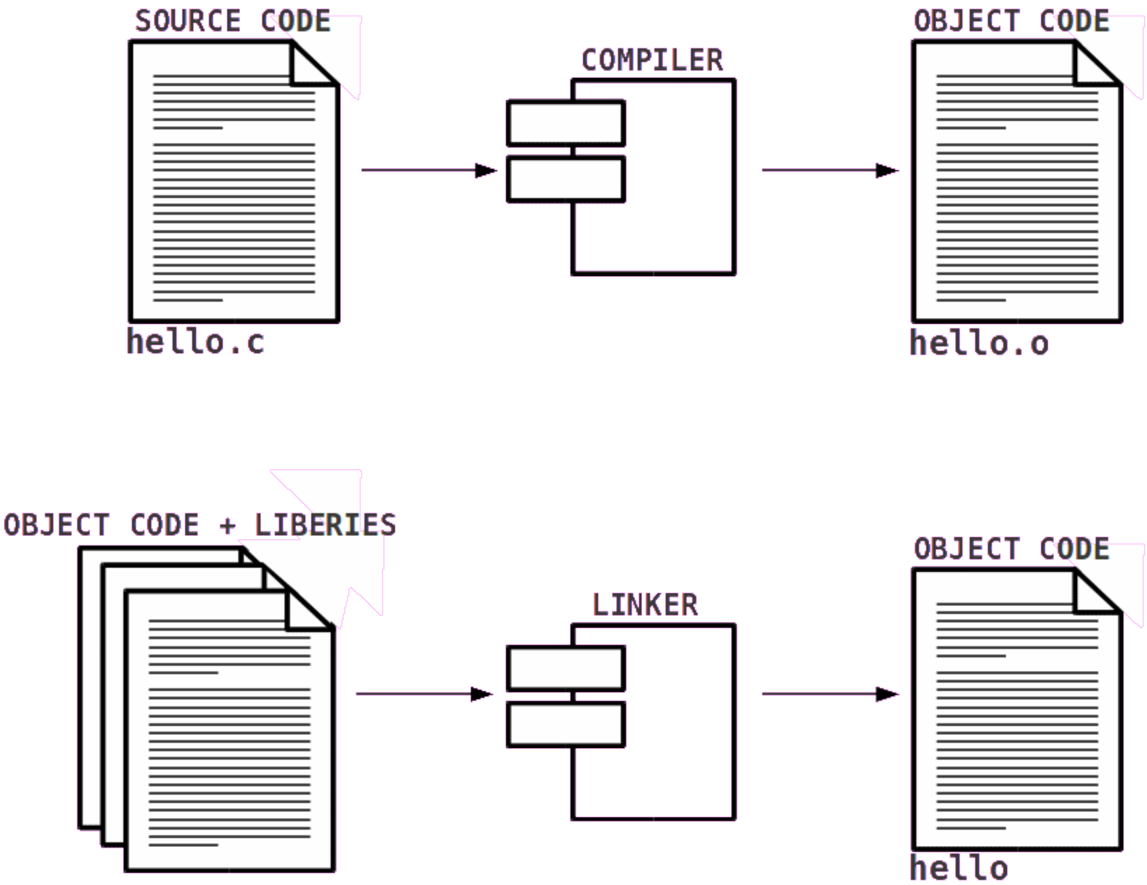
       int execl(const char *path, const char *arg, ...);
       int execlp(const char *file, const char *arg, ...);
       int execle(const char *path, const char *arg,
                  ..., char * const envp[]);
       int execv(const char *path, char *const argv[]);
       int execvp(const char *file, char *const argv[]);

DESCRIPTION
       The  exec() family of functions replaces the current process image with
       a new process image.  The functions described in this manual  page  are
       front-ends  for  the  function  execve(2).   (See  the  manual page for
       execve() for detailed information about the replacement of the  current
       process.)

 Manual page exec(3) line 1
```

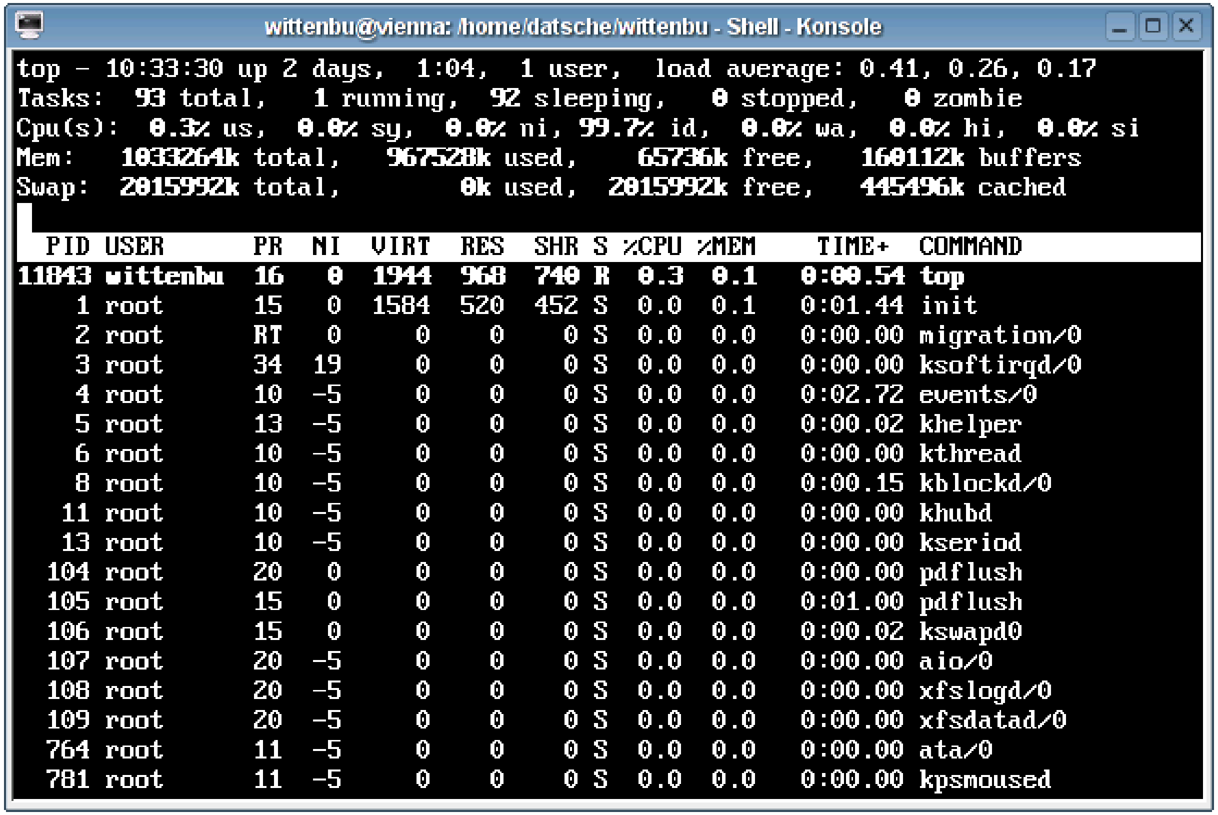
# Program Building

- Toolchain: set of programming tools that are used to build a product (executable)



# Process Monitor

- UNIX utility **top**:



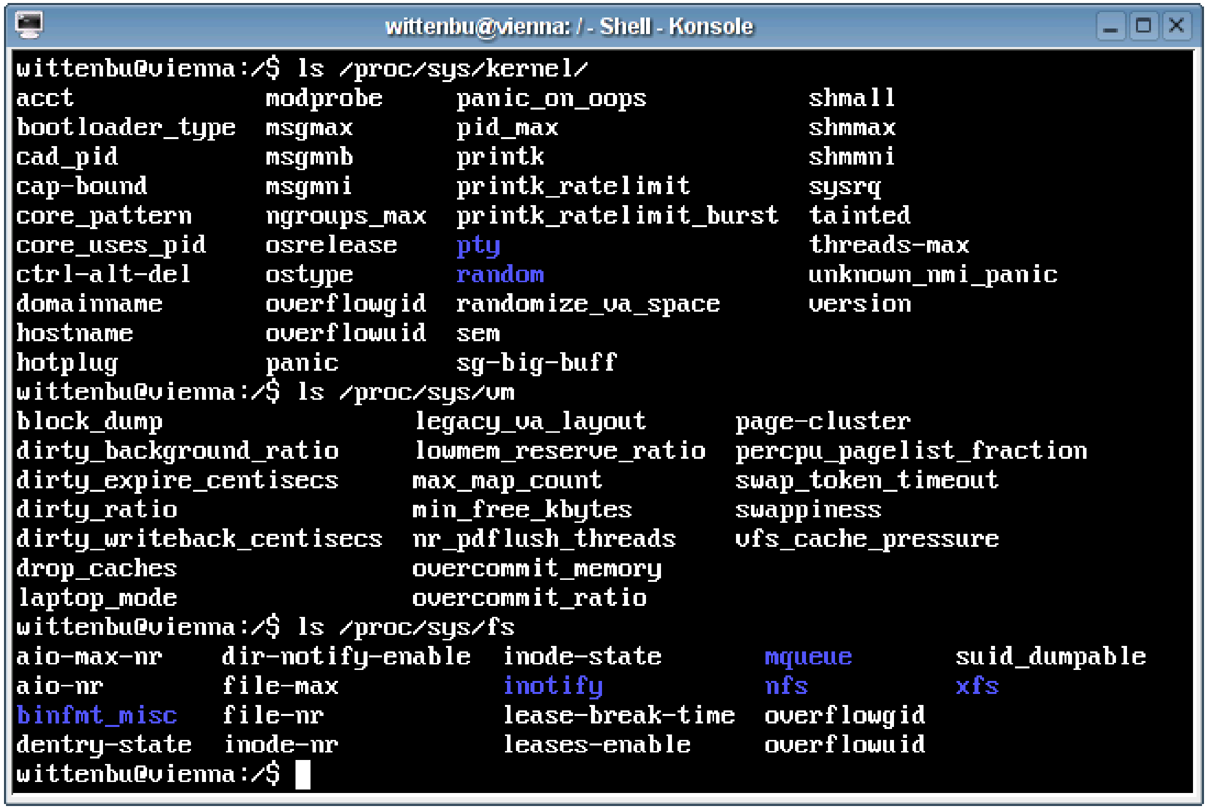
```
top - 10:33:30 up 2 days,  1:04,  1 user,  load average: 0.41, 0.26, 0.17
Tasks:  93 total,   1 running,  92 sleeping,   0 stopped,   0 zombie
Cpu(s):  0.3% us,  0.0% sy,  0.0% ni, 99.7% id,  0.0% wa,  0.0% hi,  0.0% si
Mem:   1033264k total,   967528k used,    65736k free,   160112k buffers
Swap:  2015992k total,        0k used,  2015992k free,   445496k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
11843 wittenbu  16   0  1944  968  740 R  0.3  0.1   0:00.54 top
    1 root      15   0  1584  520  452 S  0.0  0.1   0:01.44 init
    2 root      RT   0     0    0    0 S  0.0  0.0   0:00.00 migration/0
    3 root      34  19     0    0    0 S  0.0  0.0   0:00.00 ksoftirqd/0
    4 root      10  -5     0    0    0 S  0.0  0.0   0:02.72 events/0
    5 root      13  -5     0    0    0 S  0.0  0.0   0:00.02 khelper
    6 root      10  -5     0    0    0 S  0.0  0.0   0:00.00 kthread
    8 root      10  -5     0    0    0 S  0.0  0.0   0:00.15 kblockd/0
   11 root      10  -5     0    0    0 S  0.0  0.0   0:00.00 khubd
   13 root      10  -5     0    0    0 S  0.0  0.0   0:00.00 kseriod
  104 root      20   0     0    0    0 S  0.0  0.0   0:00.00 pdflush
  105 root      15   0     0    0    0 S  0.0  0.0   0:01.00 pdflush
  106 root      15   0     0    0    0 S  0.0  0.0   0:00.02 kswapd0
  107 root      20  -5     0    0    0 S  0.0  0.0   0:00.00 aio/0
  108 root      20  -5     0    0    0 S  0.0  0.0   0:00.00 xfslogd/0
  109 root      20  -5     0    0    0 S  0.0  0.0   0:00.00 xfsdatad/0
  764 root      11  -5     0    0    0 S  0.0  0.0   0:00.00 ata/0
  781 root      11  -5     0    0    0 S  0.0  0.0   0:00.00 kpsmoused
```

# Kernel Parameters

- Directories **/proc** and **/sys**

  virtual directories that reflect general kernel behaviors (“everything is a file”)



```
wittenbu@vienna:/$ ls /proc/sys/kernel/
acct             modprobe     panic_on_oops           shmall
bootloader_type  msgmax       pid_max                 shmmax
cad_pid          msgmnb       printk                  shmmni
cap-bound        msgmni       printk_ratelimit        sysrq
core_pattern     ngroups_max  printk_ratelimit_burst  tainted
core_uses_pid    osrelease    pty                     threads-max
ctrl-alt-del     ostype       random                  unknown_nmi_panic
domainname       overflowgid  randomize_va_space      version
hostname         overflowuid  sem
hotplug          panic        sg-big-buff
wittenbu@vienna:/$ ls /proc/sys/vm
block_dump                 legacy_va_layout      page-cluster
dirty_background_ratio     lowmem_reserve_ratio  percpu_pagelist_fraction
dirty_expire_centisecs     max_map_count         swap_token_timeout
dirty_ratio                min_free_kbytes       swappiness
dirty_writeback_centisecs  nr_pdflush_threads    vfs_cache_pressure
drop_caches                overcommit_memory
laptop_mode                overcommit_ratio
wittenbu@vienna:/$ ls /proc/sys/fs
aio-max-nr    dir-notify-enable  inode-state      mqueue       suid_dumpable
aio-nr        file-max           inotify          nfs          xfs
binfmt_misc   file-nr            lease-break-time overflowgid
dentry-state  inode-nr           leases-enable    overflowuid
wittenbu@vienna:/$
```

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