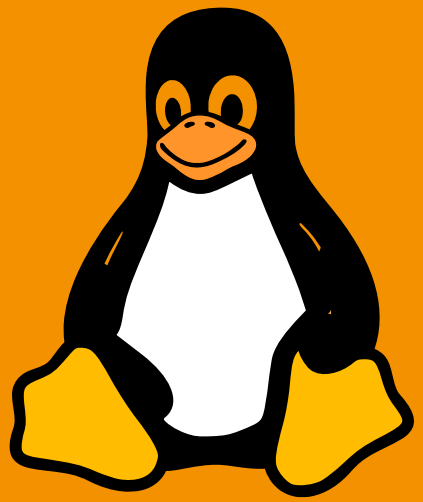
Technische Hochschule Rosenheim
Technical University of Applied Sciences

Prof. Florian Künzner
Technical University of Applied Sciences Rosenheim, Computer Science

OS 4 – System boot; OS architecture



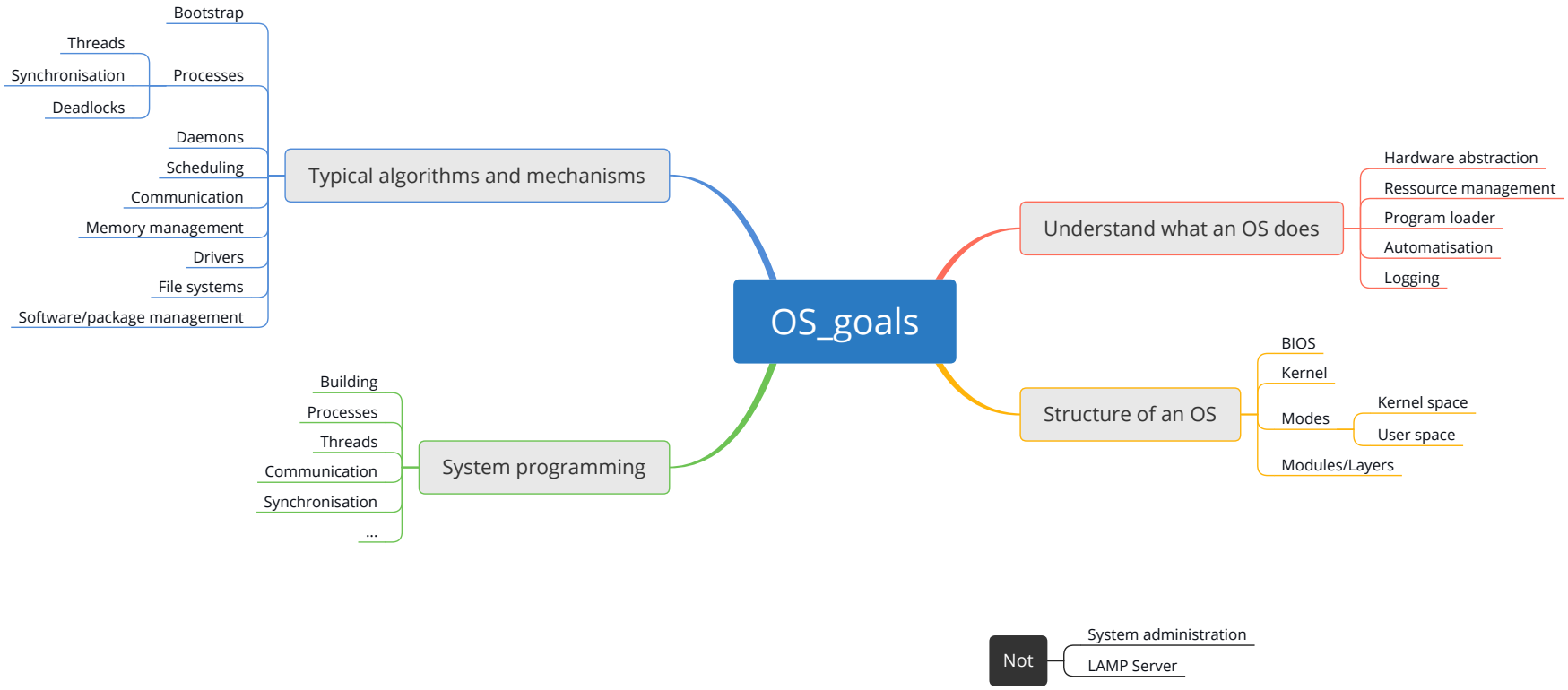
source: iconspng.com

The lecture is based on the work and the documents of Prof. Dr. Ludwig Frank

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Goal



CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Goal

OS::System boot; OS architecture

- Boot procedure
- BIOS/UEFI
- MBR/GPT
- Boot loader: Grub2
- init/systemd
- OS architecture

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

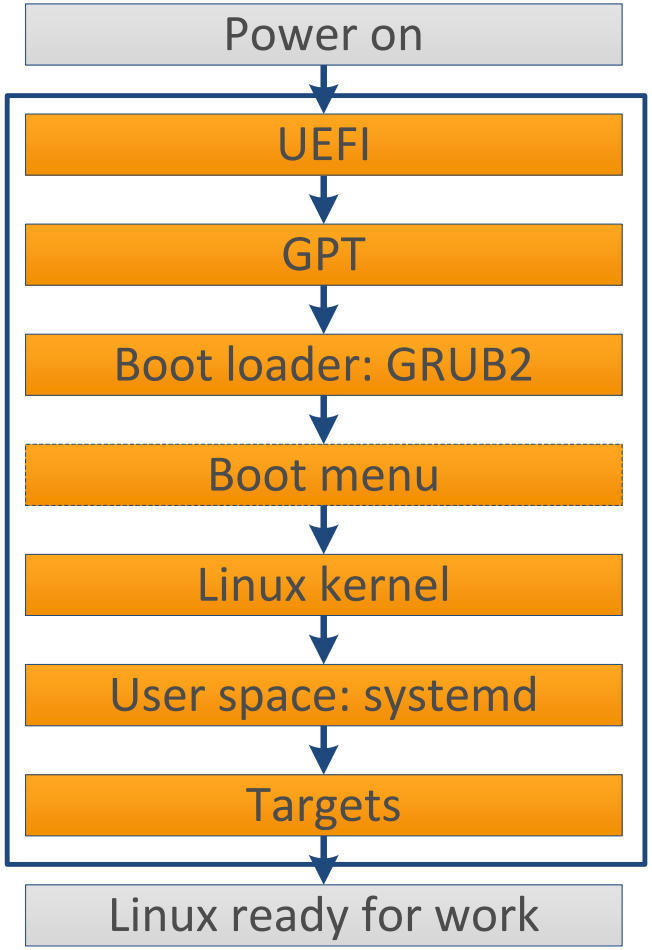
Boot

How does a PC boot into the operating system?

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Boot procedure: UEFI (typically)



Unified **E**xtensible **F**irmware **I**nterface
-> executes EFI program files

GUID **P**artition **T**able
-> describes disk partitions

Grand **U**nified **B**ootloader **2**
-> executes boot menu/kernel

Boot menu
-> choose kernel for boot

Kernel
-> executes /bin/systemd

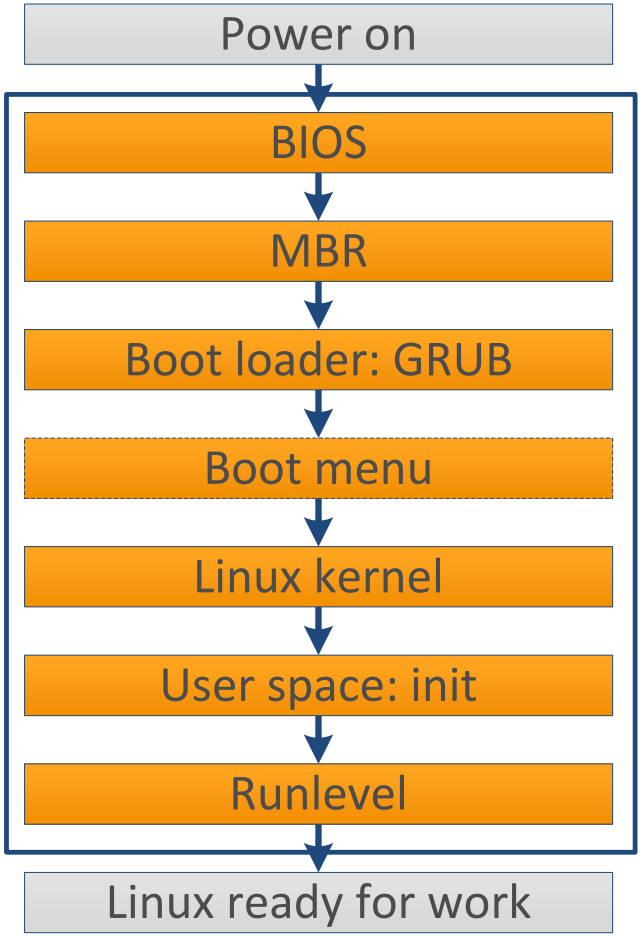
Systemd
-> executes runlevel programs

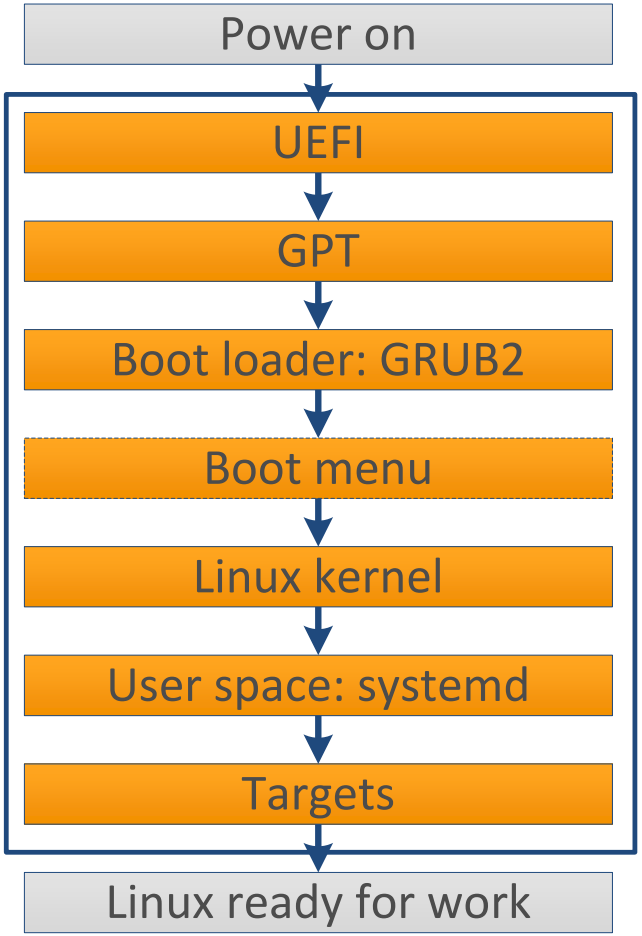
Starts **Targets**
/etc/systemd/system/default.target

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Boot procedure: BIOS vs. UEFI



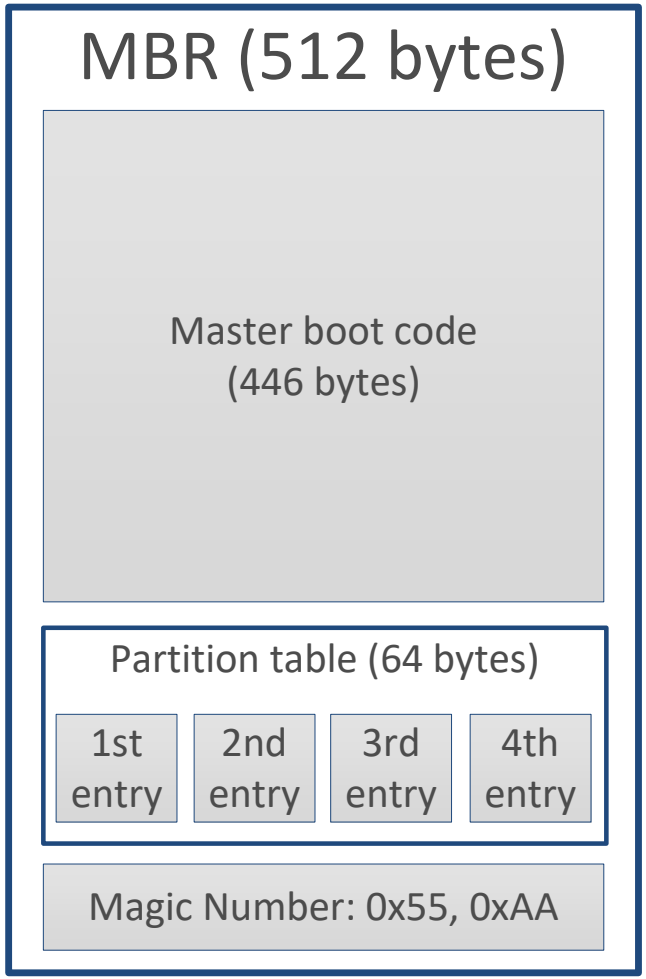


UEFI - Unified ext. firmware interface

- Since 2010 in consumer products
- Graphical user interface (with mouse)
- Fast boot: cache + hibernation (Windows only)
- Secure boot:
  - Protection against malware
  - Prevents against execution of unsigned code
- Network boot
- Modular interface for applications and devices (EFI drivers)
- Supported modes:
  - UEFI mode: Requires an EFI partition on boot device
  - BIOS mode: Old way of booting

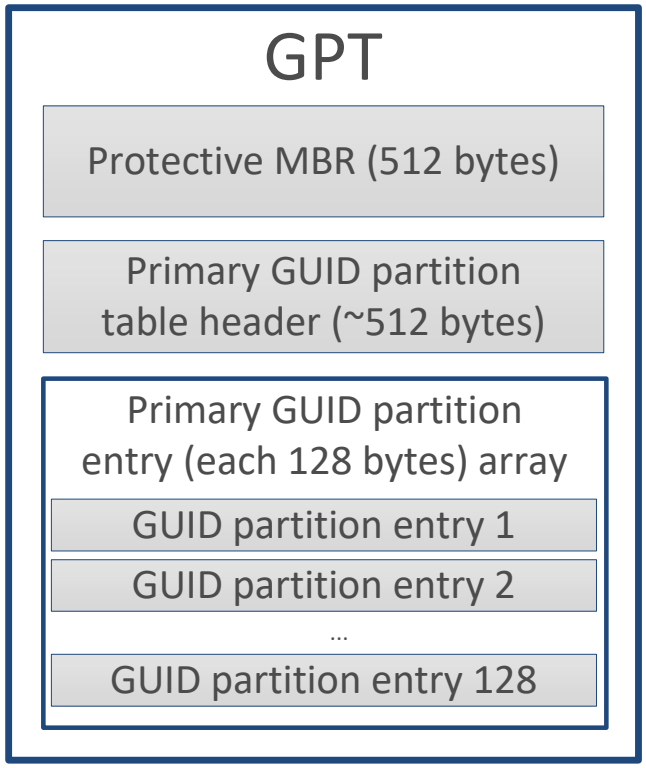
More details: `https://www.marksei.com/bios-uefi-explained`

MBR - Master Boot Record

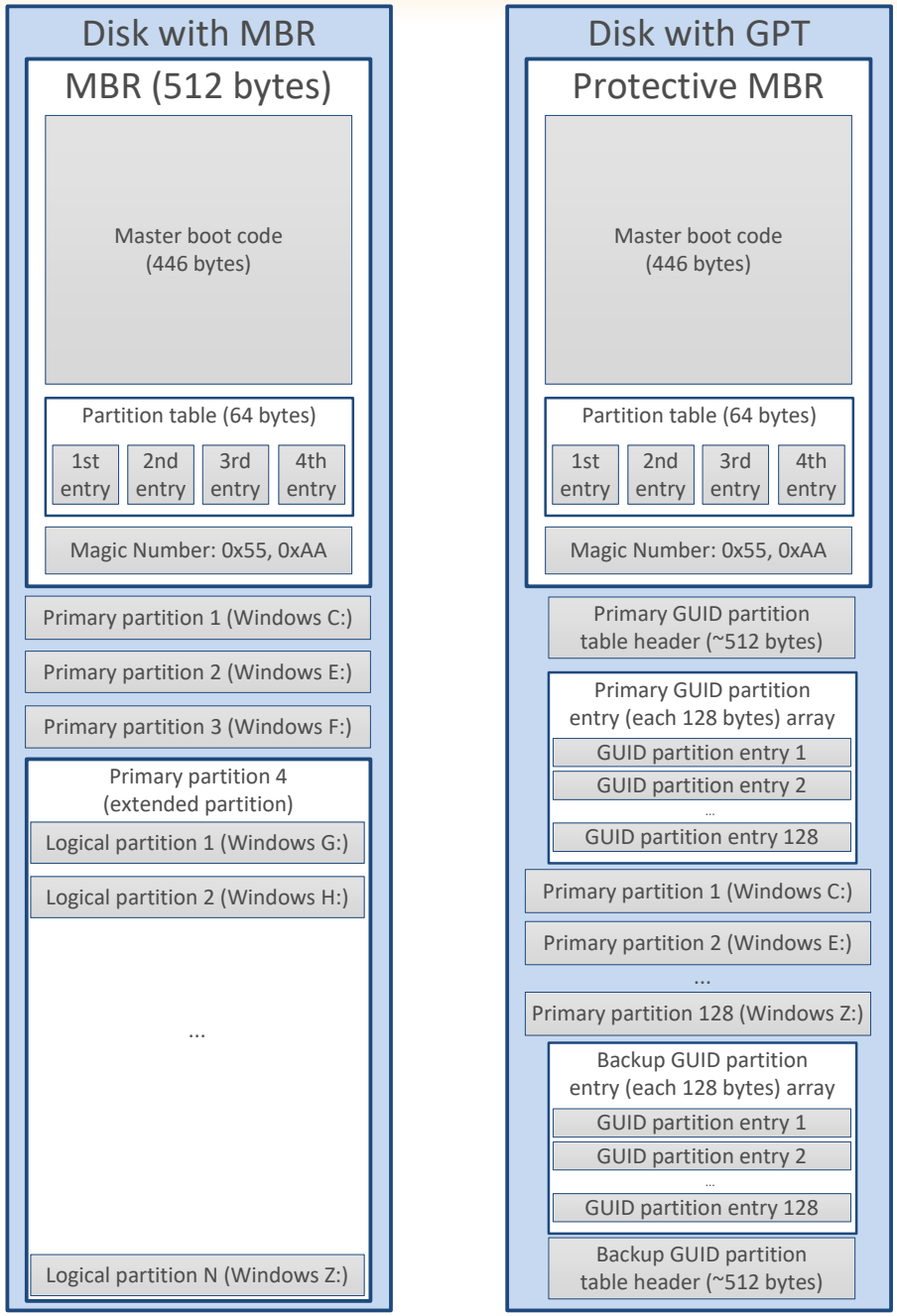


- Supports up to **2 TiB disks**
- Supports up to **2 TiB partitions**
- No safety (**no checksum**)
- Supports **4 primary partitions**
- Supports **one extended partition** (not bootable)

GPT - GUID Partition Table



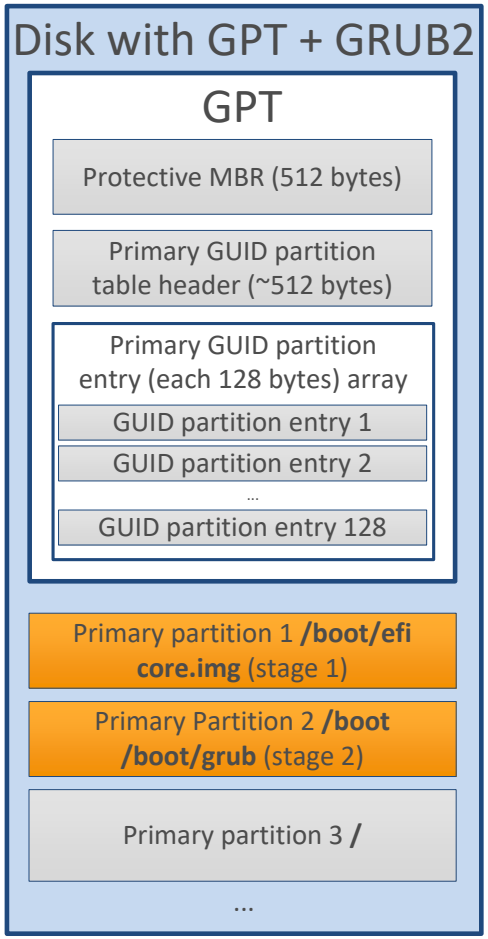
- Supports up to **18 EiB disks**
- Supports up to **18 EiB partitions**
- Safety (**checksum, backup**)
- Version number
- Supports **128 primary partitions**
- Does not have a boot code
- UEFI **boots** from an **EFI partition**


Disk with MBR
MBR (512 bytes)
Master boot code
(446 bytes)
Partition table (64 bytes)
1st entry
2nd entry
3rd entry
4th entry
Magic Number: 0x55, 0xAA
Primary partition 1 (Windows C:)
Primary partition 2 (Windows E:)
Primary partition 3 (Windows F:)
Primary partition 4
(extended partition)
Logical partition 1 (Windows G:)
Logical partition 2 (Windows H:)
...
Logical partition N (Windows Z:)
Disk with GPT
Protective MBR
Master boot code
(446 bytes)
Partition table (64 bytes)
1st entry
2nd entry
3rd entry
4th entry
Magic Number: 0x55, 0xAA
Primary GUID partition
table header (~512 bytes)
Primary GUID partition
entry (each 128 bytes) array
GUID partition entry 1
GUID partition entry 2
...
GUID partition entry 128
Primary partition 1 (Windows C:)
Primary partition 2 (Windows E:)
...
Primary partition 128 (Windows Z:)
Backup GUID partition
entry (each 128 bytes) array
GUID partition entry 1
GUID partition entry 2
...
GUID partition entry 128
Backup GUID partition
table header (~512 bytes)

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

GRUB2 - GRand Unified Bootloader 2



- Boots in stages:
  - **stage1** (core.img): Loads directly stage 2 (/boot/grub), usually from /boot partition. Contains file system drivers.
  - **stage2** (/boot/grub): Loads the default configuration file and any other modules needed.
- Themes, **graphical menus**, scripting support
- Uses **UUIDs** to identify disks
- Supports additionally: PowerPC
- Supports LLVM and RAID
- Boots live CD images from hard drive
- Automated search for other OS (like Windows)

User space: systemd

- `systemd` is the **first process** started by the kernel
- The mother of all subprocesses
- Has always **PID 1**
- Looks in `/etc/systemd/system/default.target` for default target
- **Executes** the default **target** (unit) scripts
- **Starts** the user space **processes** on boot:
  - Daemons (crond, httpd, sshd, inetd, syslogd, ...)
  - Terminals
  - Graphical desktop
  - ...
- Speed-up the boot: starts processes in **parallel** (where possible)

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

User space: systemd (commands)

- Get default target: `systemctl get-default`
- Change runlevel: `systemctl isolate poweroff.target`
- Control a daemon: `/etc/systemd/system/<daemon>.service`
  - `service daemon start`
  - `service daemon stop`
  - `service daemon reload`
  - `service daemon restart`
  - `service daemon status`
  - ...
- Enable a daemon: `systemctl enable daemon.service`
- Disable a daemon: `systemctl disable daemon.service`

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

User space: systemd (example)

```
1  [Unit]
2  Description=Demo daemon that does something useful
3
4  [Service]
5  Type=forking
6  ExecStart=/usr/sbin/daemon
7  ExecStopPost=/bin/rm /var/run/daemon.pid
8
9  [Install]
10 WantedBy=multi-user.target
```

More details: `https://www.digitalocean.com/community/tutorials/understanding-systemd-units-and-unit-files`

Init runlevel vs. system targets

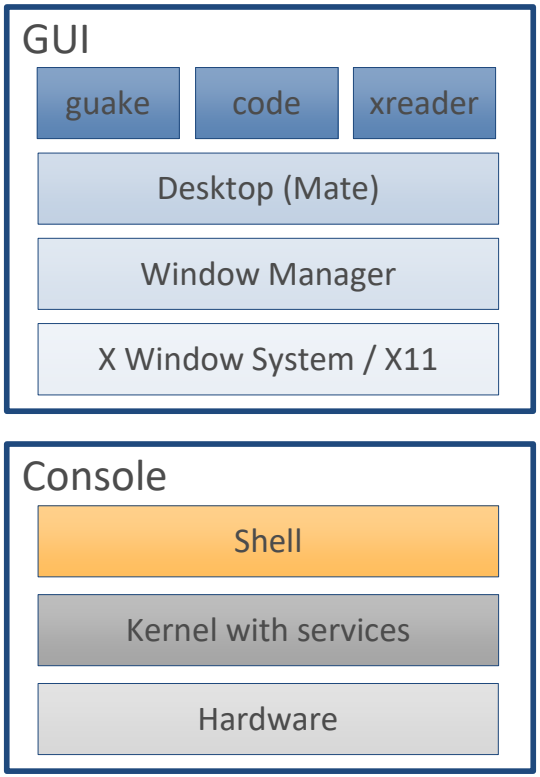
init runlevel	systemd target	systemd target aliases	Description
	halt.target		Halts the system without powering it down.
0	**poweroff.target**	runlevel0.target	Halts the system and turns the power off.
S	emergency.target		Single user mode. No services are running; filesystems are not mounted.
1	rescue.target	runlevel1.target	A base system including mounting the filesystems with only the most basic services running and a rescue shell on the main console.
2		runlevel2.target	Multiuser, without NFS but all other non-GUI services running.
3	multi-user.target	runlevel3.target	All services running but command line interface (CLI) only.
4		runlevel4.target	Unused.
5	**graphical.target**	runlevel5.target	Multiuser with a GUI.
6	reboot.target	runlevel6.target	Reboot.
	default.target		This target is always aliased with a symbolic link to either multi-user.target or graphical.target. systemd always uses the default.target to start the system.

More details: `https://opensource.com/article/17/2/linux-boot-and-startup`

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Linux high level overview (1)



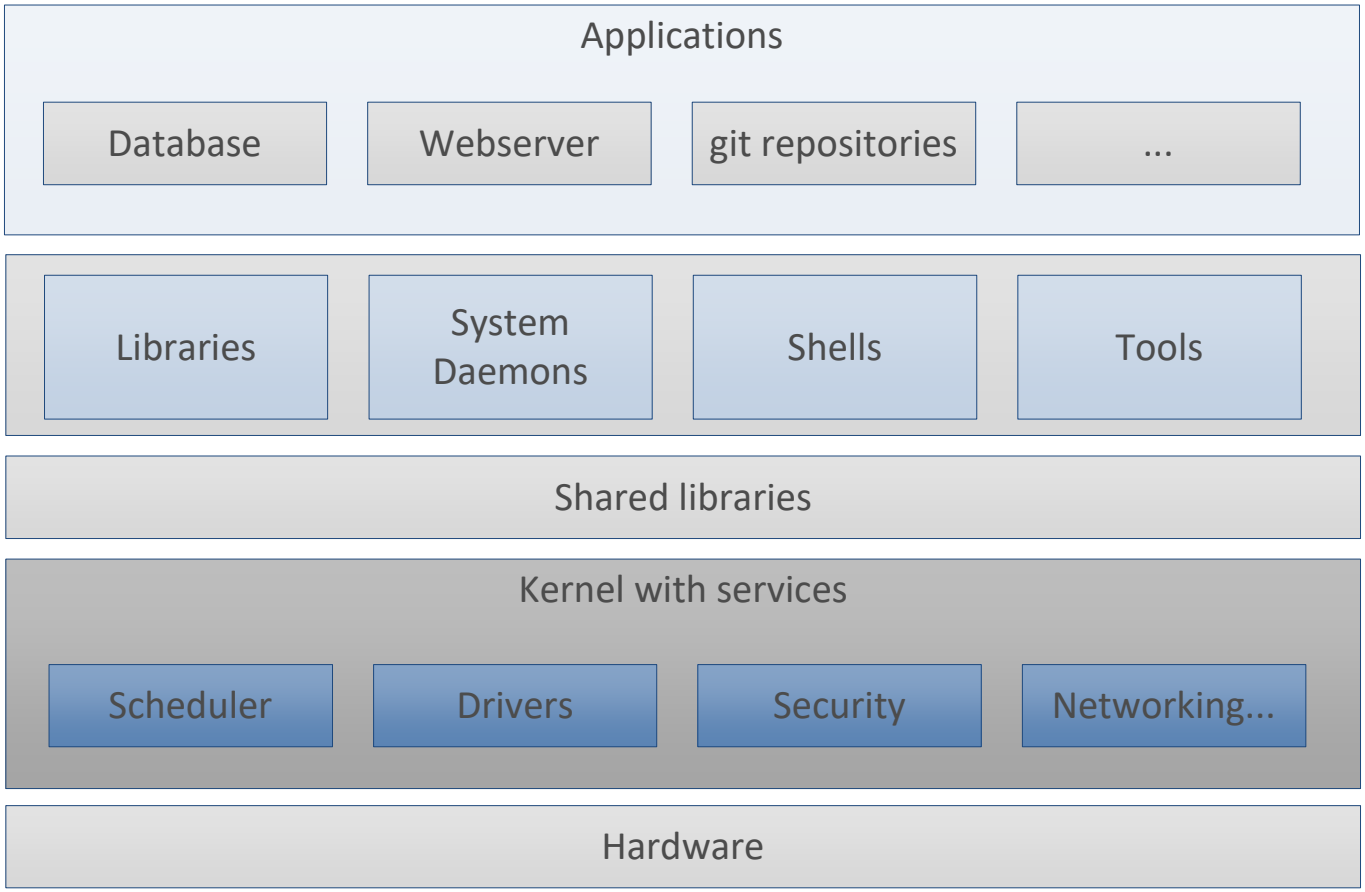
OS tasks

- Execute (graphical) user applications
- Provide desktop environment
- Draw windows (graphical elements)
- Provide shells
- Manage resources
- Support, abstract and virtualise hardware

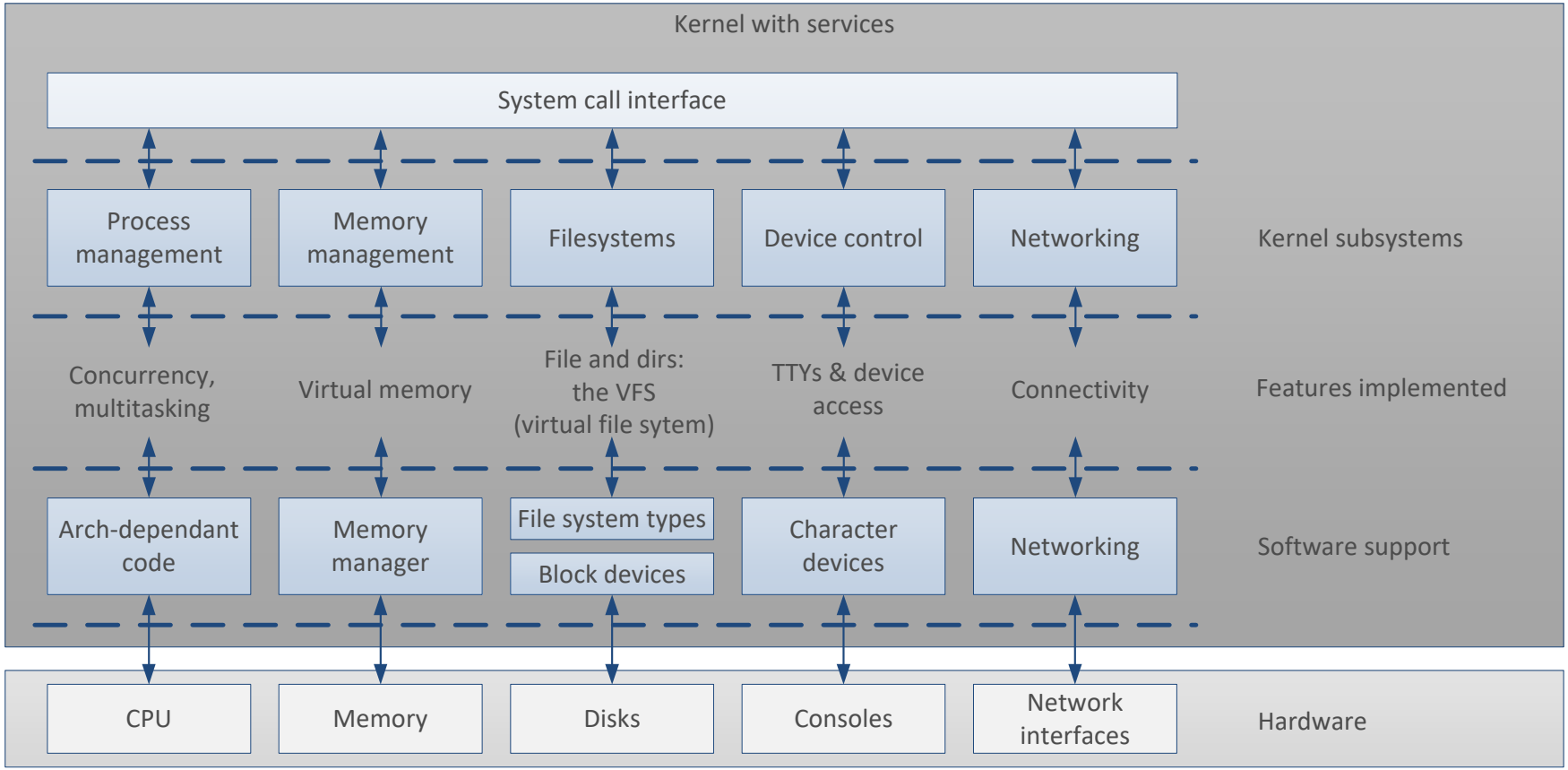
CAMPUS Rosenheim
Computer Science

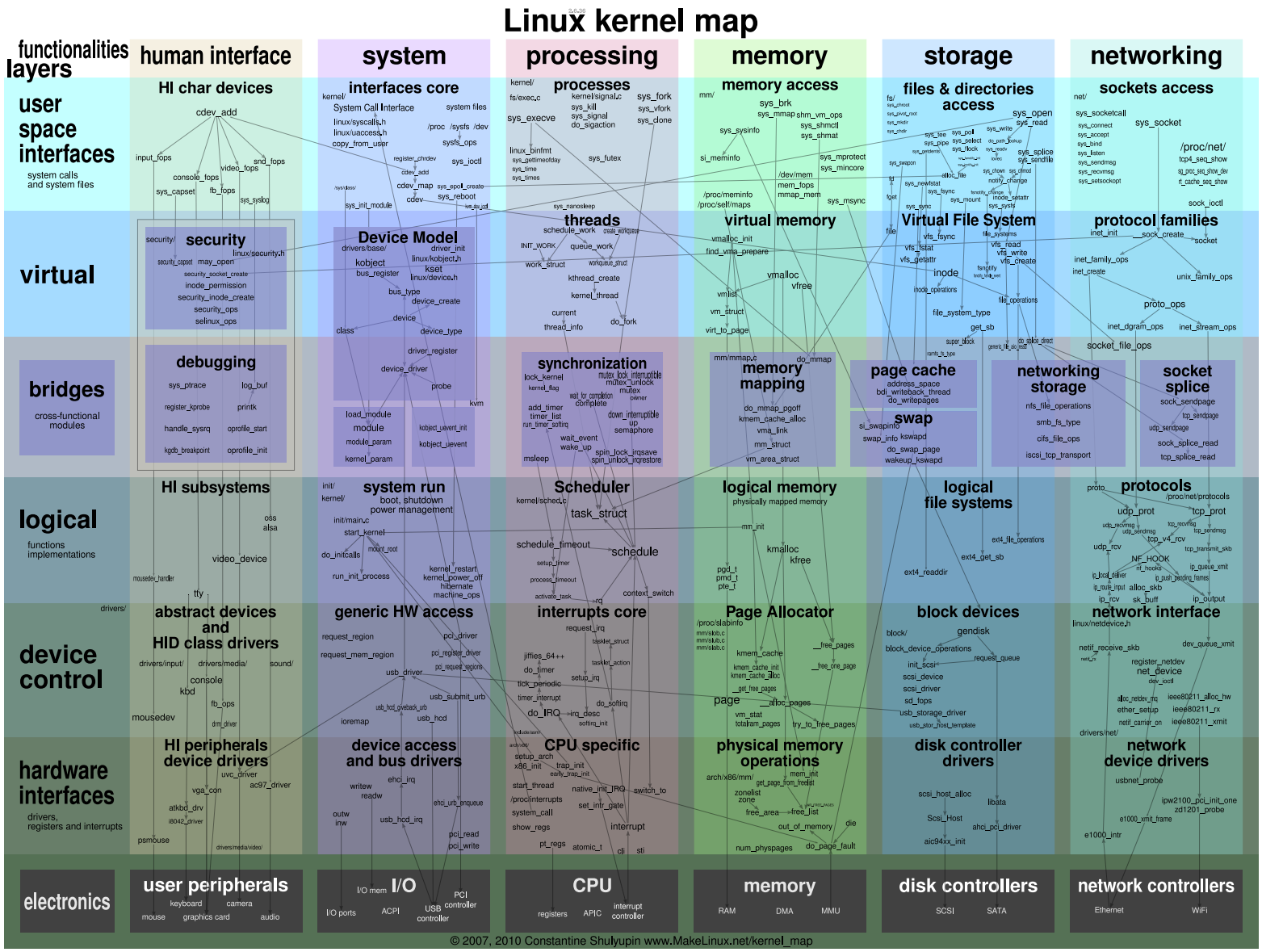
Technische Hochschule Rosenheim
Technical University of Applied Sciences

Linux high level overview (2)



OS overview: Linux kernel



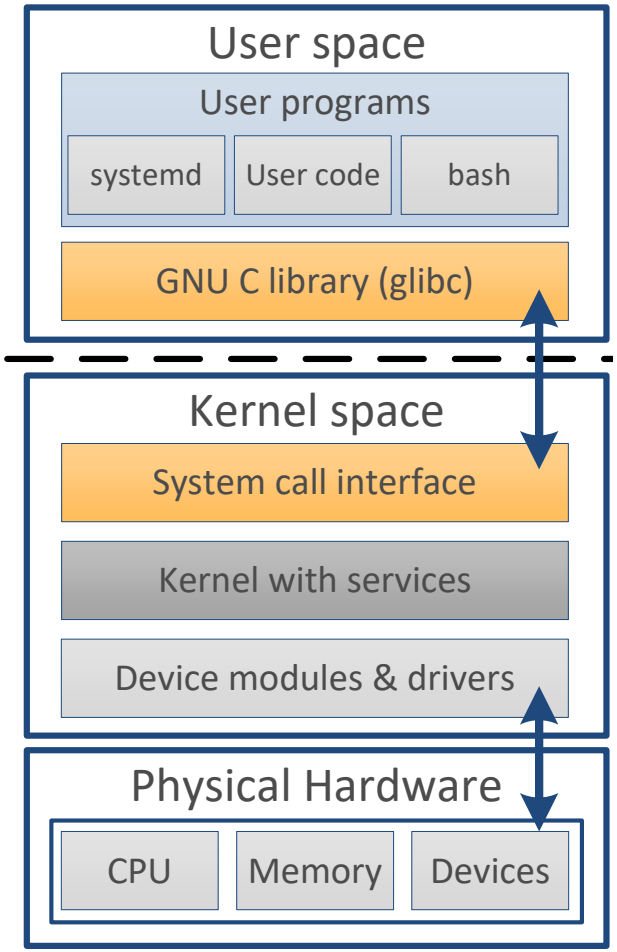


Source: http://www.makelinux.net/kernel_map

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Protection: user vs. kernel space



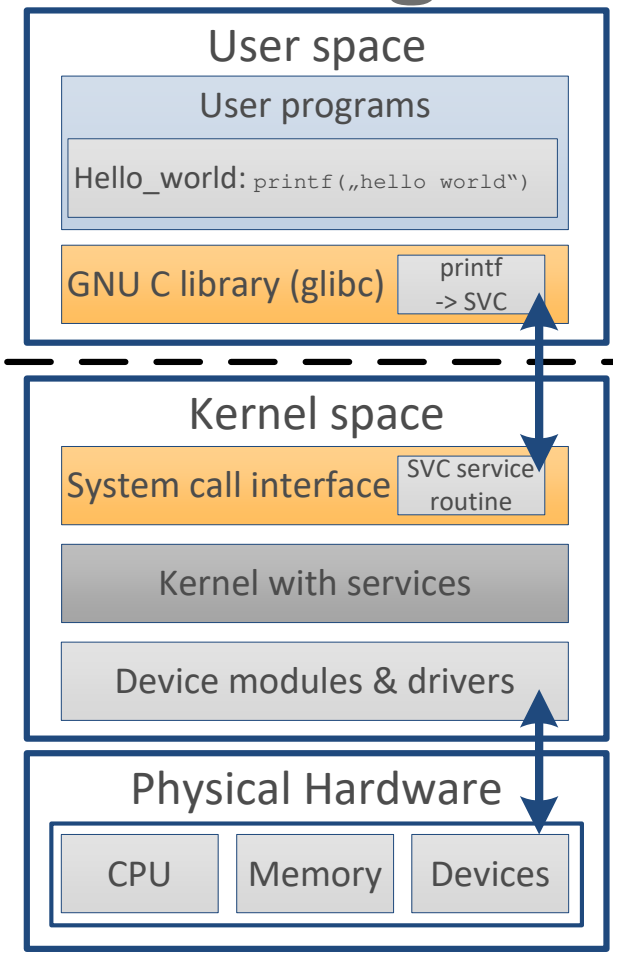
User space

- All code outside the kernel
- Also called “userland”
- **Restricted** (encapsulated) **access** to the **hardware**
- Can **only** use a **subset of CPU instructions**
- Can **only** access the **assigned memory** addresses
- **Crashes** in a user process: **only stops these process**.

Kernel space

- **Complete** and **unrestricted access** to the **hardware**
- Can execute **any CPU instruction**
- Can access **any memory address**
- **Crashes** in kernel are “catastrophic”: **system stop**!

Accessing the kernel: supervisor call



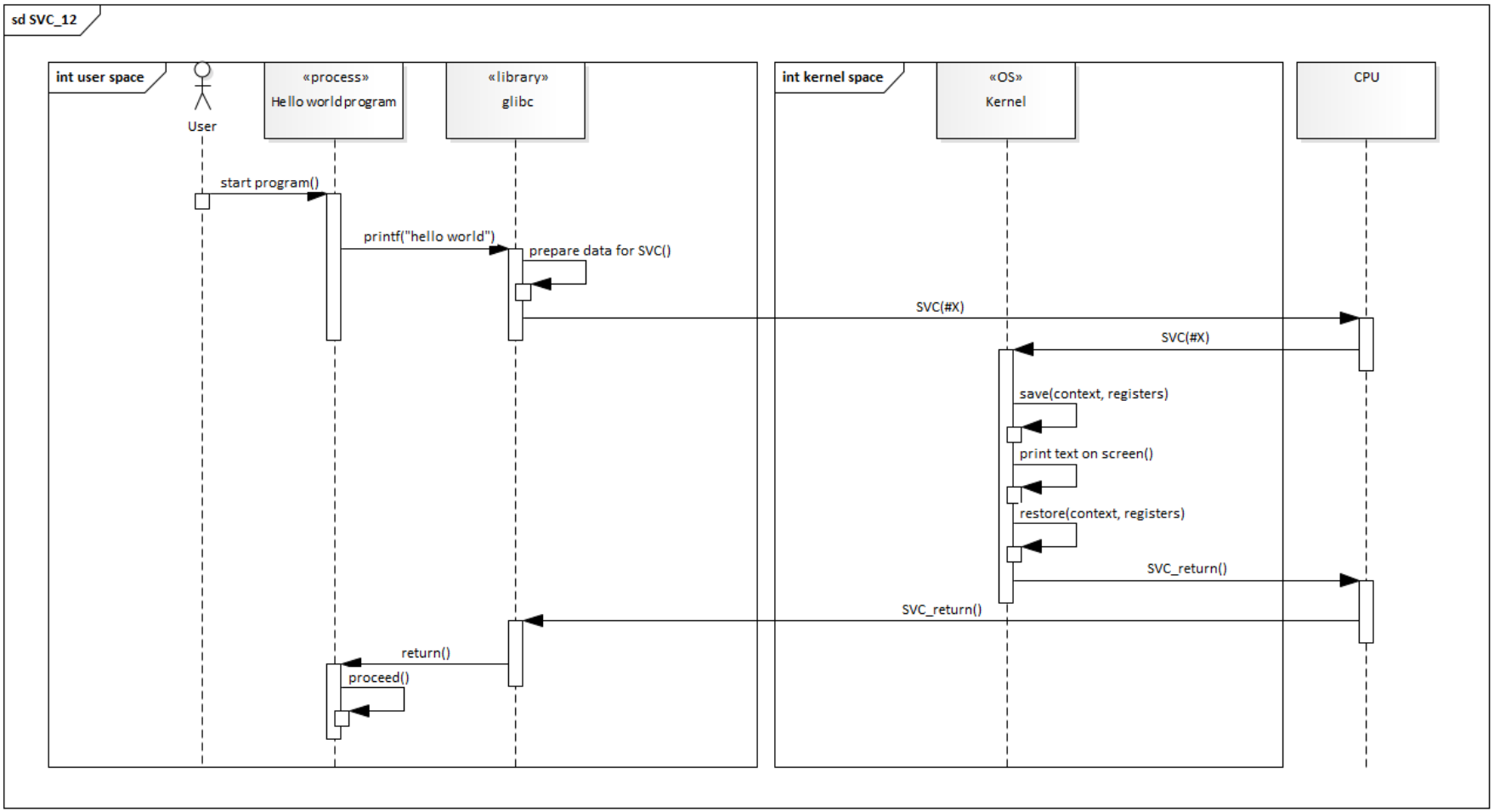
Supervisor call (SVC)

- **CPU instruction** to give control to the OS/kernel
- **Requests** for an **OS service**:
  - Start process
  - Allocate memory
  - File open/close/read/write/...
  - Print something on terminal (TTY) or screen
  - Send data over network
  - ...
- SVCs are **numbered**
- The calling **process is interrupted** while the kernel executes the SVC.

CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Supervisor call (SVC) example sequence



CAMPUS Rosenheim
Computer Science

Technische Hochschule Rosenheim
Technical University of Applied Sciences

Summary and outlook

Summary

- Boot procedure
- BIOS/UEFI
- MBR/GPT
- Boot loader: Grub2
- init/systemd
- OS architecture

Outlook

- Processes vs. Threads
- Parallelisation