TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute of System Architecture, Operating Systems Group

EXERCISE: L4 BOOTCAMP

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AGENDA

- first contact with a microkernel OS
- talk about system booting
- getting to know QEMU
- compile Fiasco
- compile minimal system environment
- the usual „Hello World“
- look at source and config, play with it

QEMU

- developing your own kernel usually requires a dedicated machine
- we will use a virtual machine
- QEMU is open-source, provides a virtual machine by binary translation
- it emulates a complete x86 PC
- … many other system architectures, too
- our QEMU will boot from an ISO image

BOOTING

BIOS

- Basic Input Output System
- fixed entry point after „power on“ and „reset“
- initializes the CPU in 16-bit real-mode
- detects, checks, and initial-izes platform hardware (RAM, PCI, ATA, …)
- finds the boot device

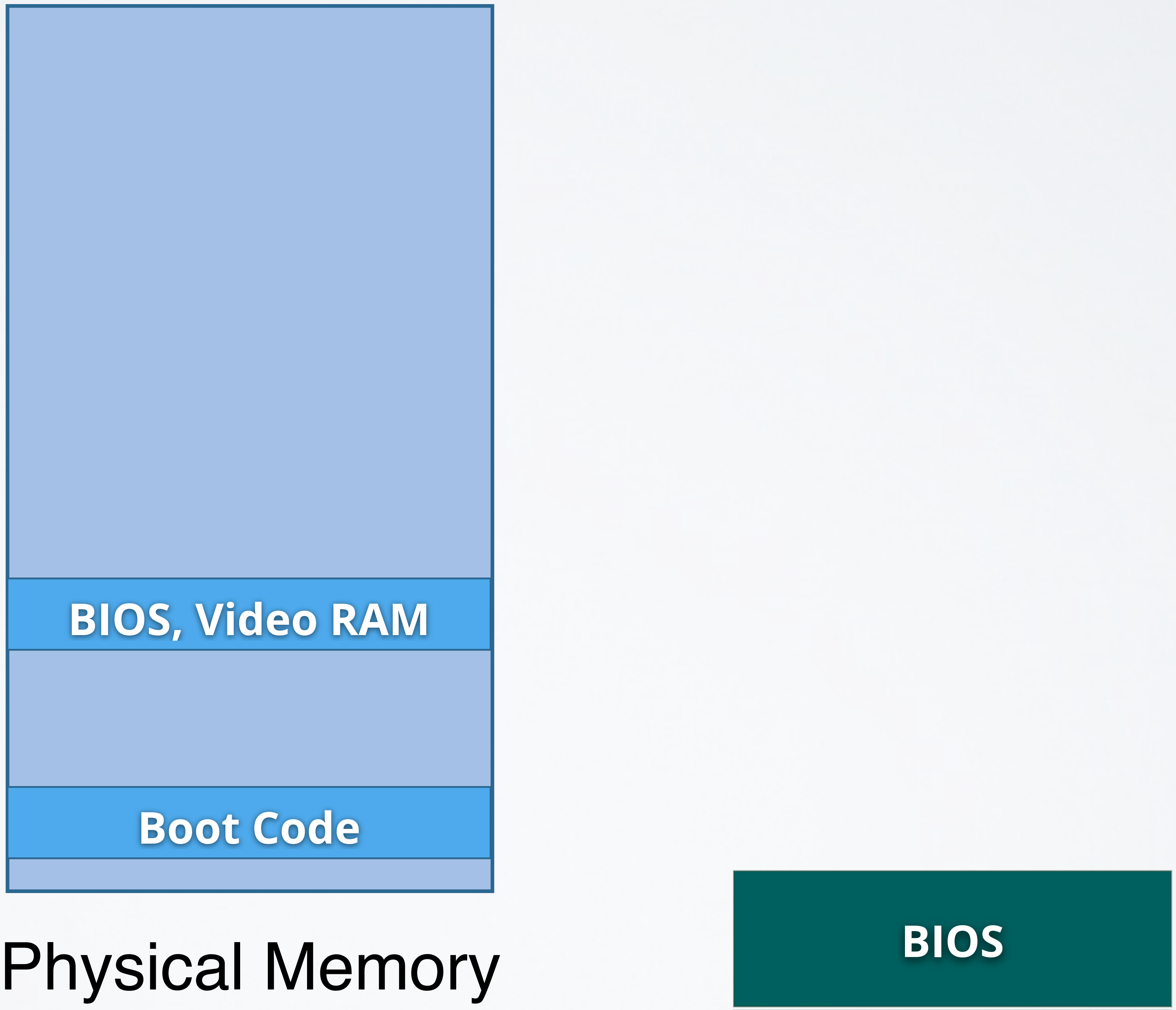
EFI

- Extensible Firmware Interface
  - plug-ins for new hardware
- no legacy PC-AT boot (no A20 gate)
- built-in boot manager
  - more than four partitions, no 2TB limit
  - boot from peripherals (USB)

BOOT SECTOR

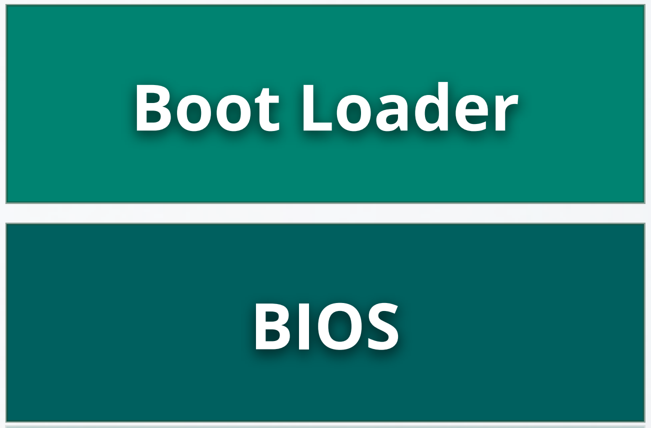
- first sector on boot disk
- 512 bytes
- contains first boot loader stage and partition table
- BIOS loads code into RAM and executes it
- problem: How to find and boot an OS in 512 bytes?

MEMORY



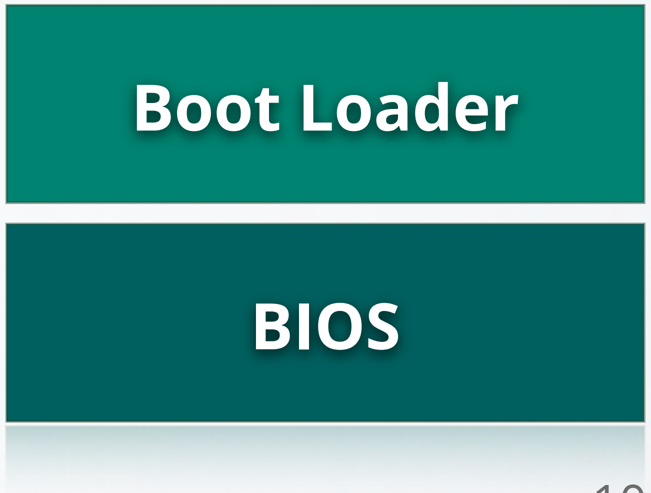
GRUB

- popular boot loader
- used by most (all?) Linux distributions
- uses a two-stage-approach
  - first stage fits in one sector
  - has hard-wired sectors of second stage files
  - second stage can read common file systems



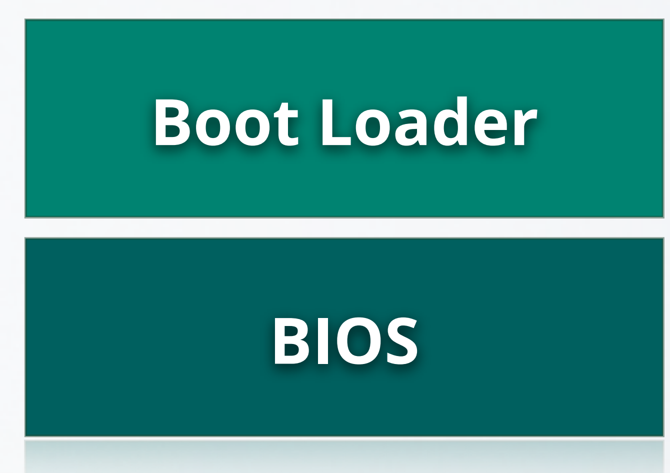
GRUB

- second stage loads a menu.lst config file to present a boot menu
- from there, you can load your kernel
- supports loading multiple modules
- files can also be retrieved from network

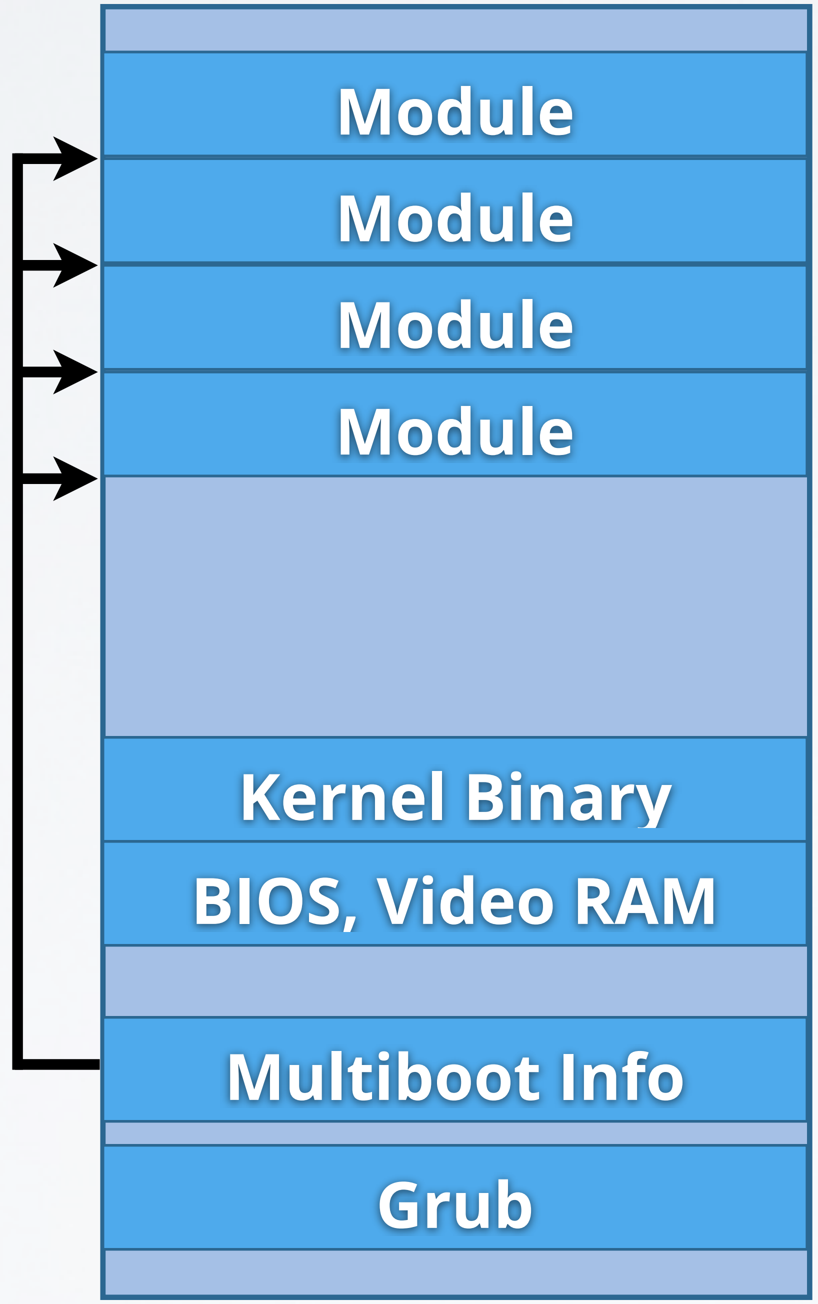


GRUB

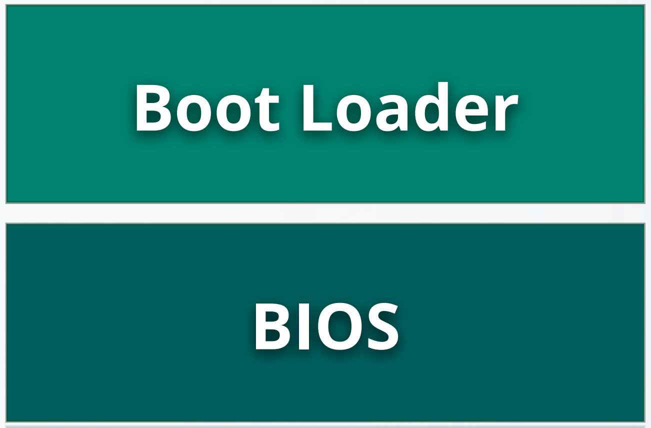
- switches CPU to 32-bit protected mode
- loads and interprets the „kernel“ binary
- loads additional modules into memory
- sets up multiboot info structure
- starts the kernel



MEM LAYOUT

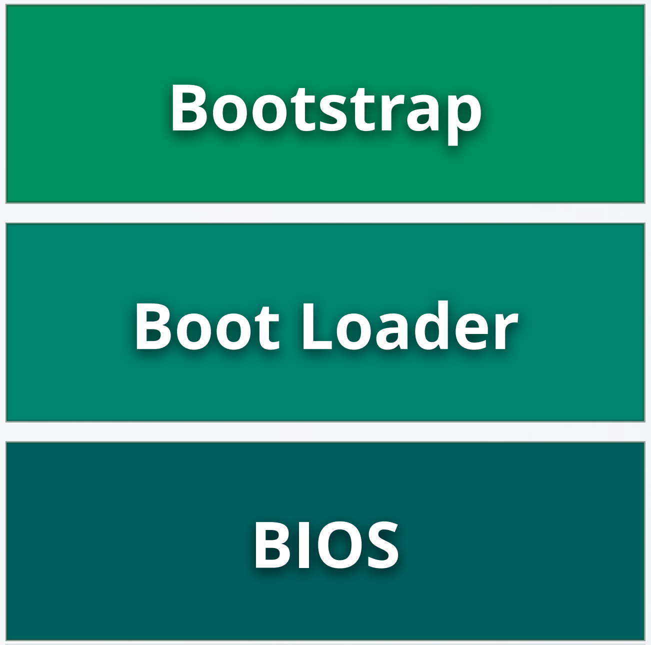


Physical Memory



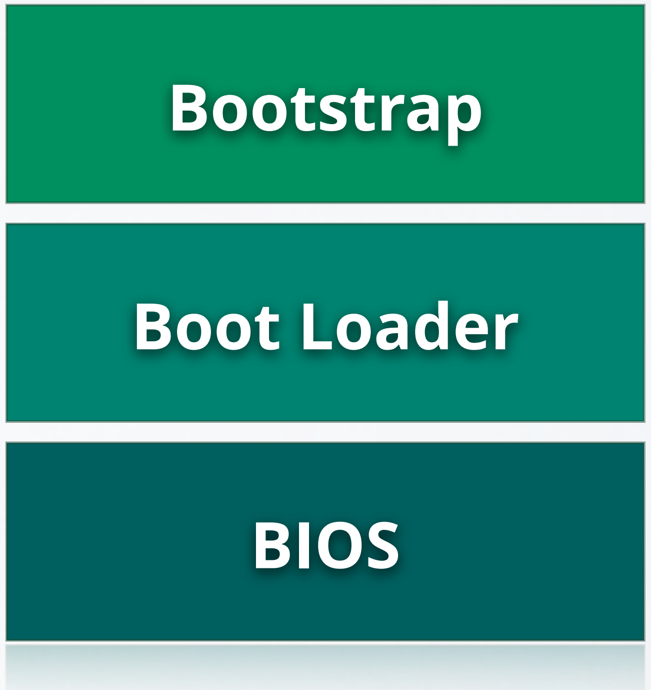
BOOTSTRAP

- our modules are ELF files: executable and linkable format
- contain multiple sections
  - code, data, BSS
- bootstrap interprets the ELF modules
- copies sections to final location in physical memory

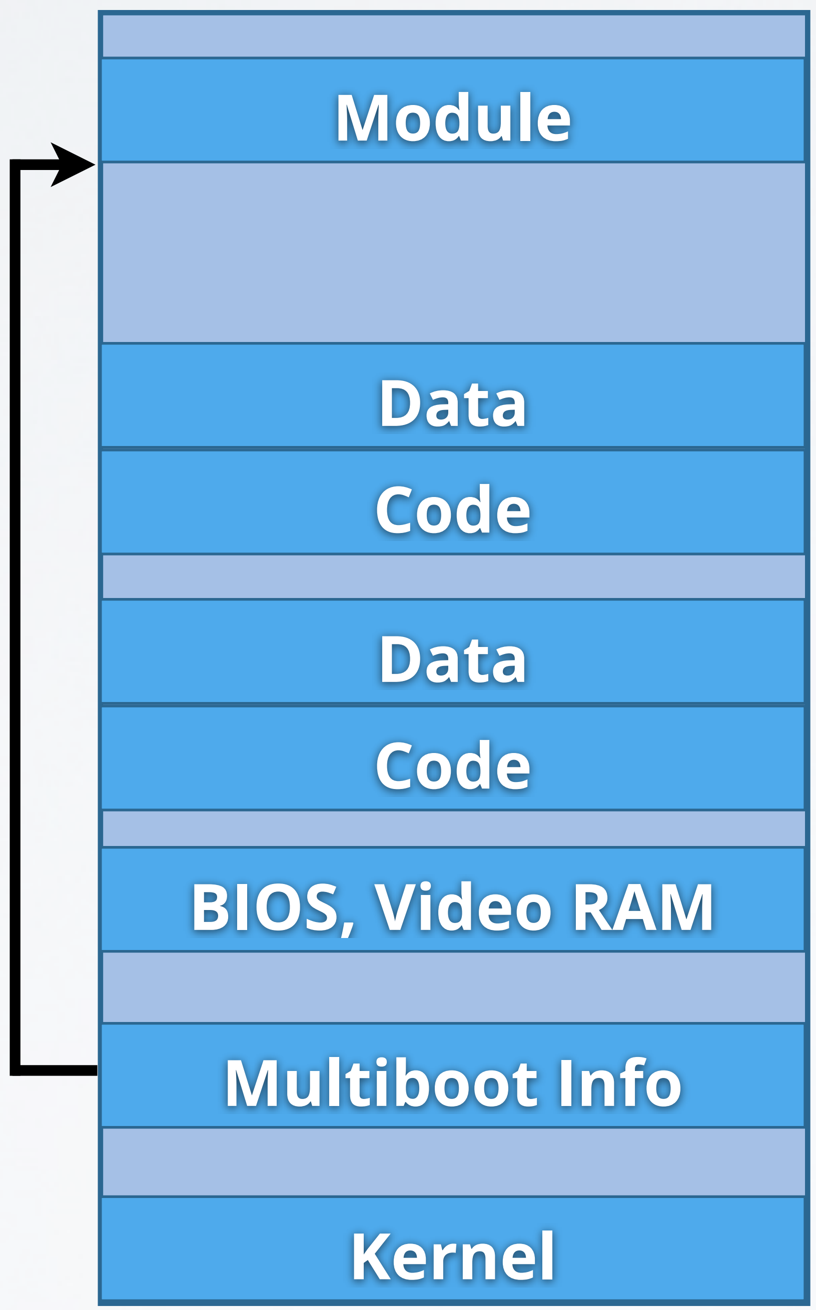


BOOTSTRAP

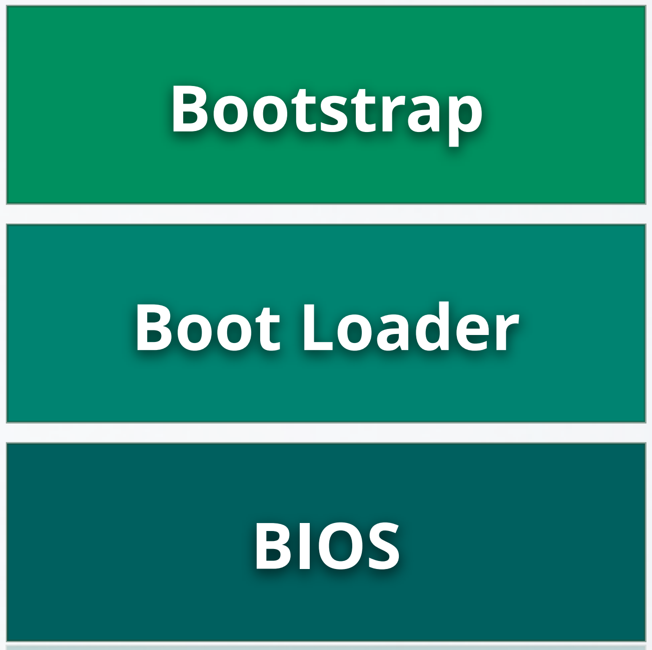
- actual L4 kernel is the first of the modules
- must know about the other modules
- bootstrap sets up a kernel info page
  - contains entry point + stack pointer of sigma0 and moe
- passes control to the kernel



MEM LAYOUT

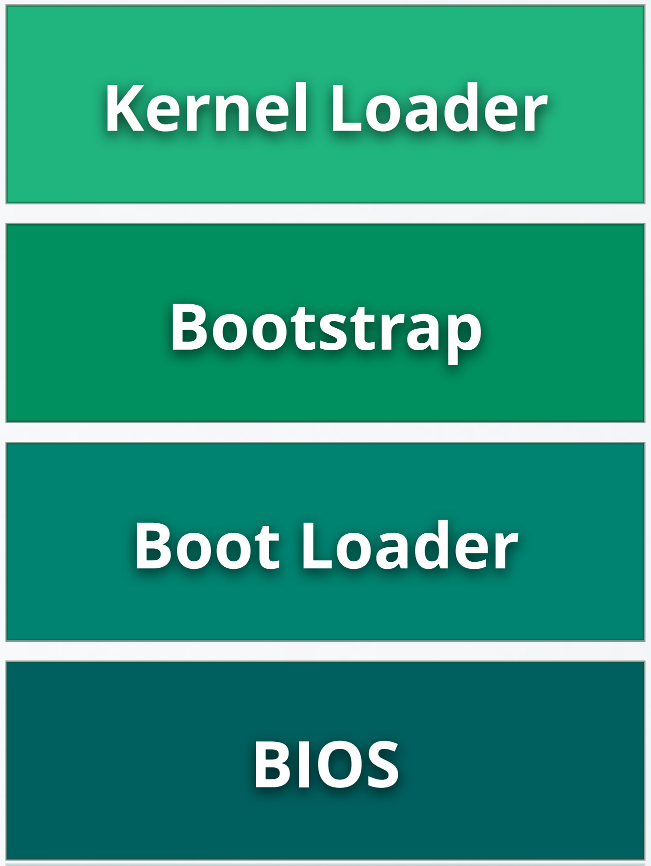


Physical Memory

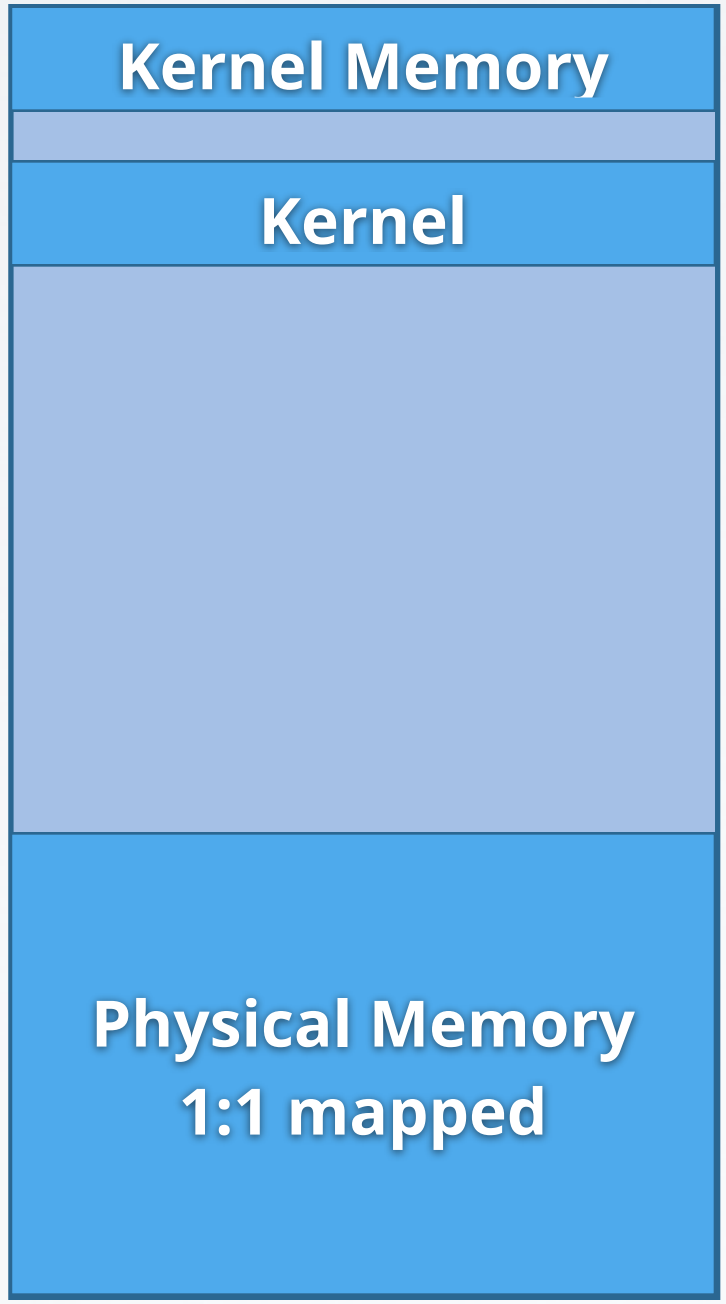


KERNEL LOADER

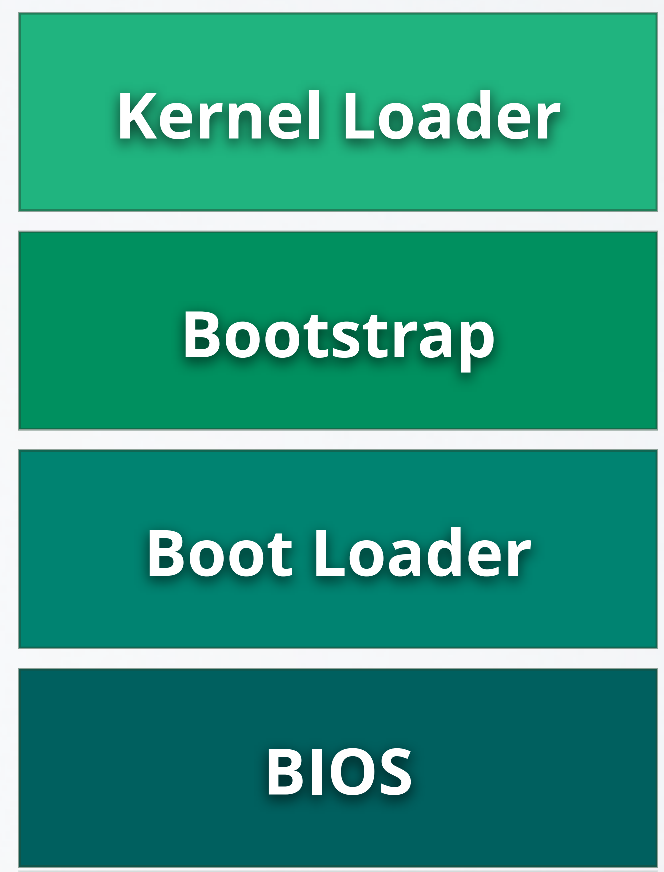
- initial kernel code
- basic CPU setup
  - detecting CPU features
  - setup various CPU-tables
- sets up basic page table
- enables virtual memory mode
- runs the actual kernel code



MEM LAYOUT

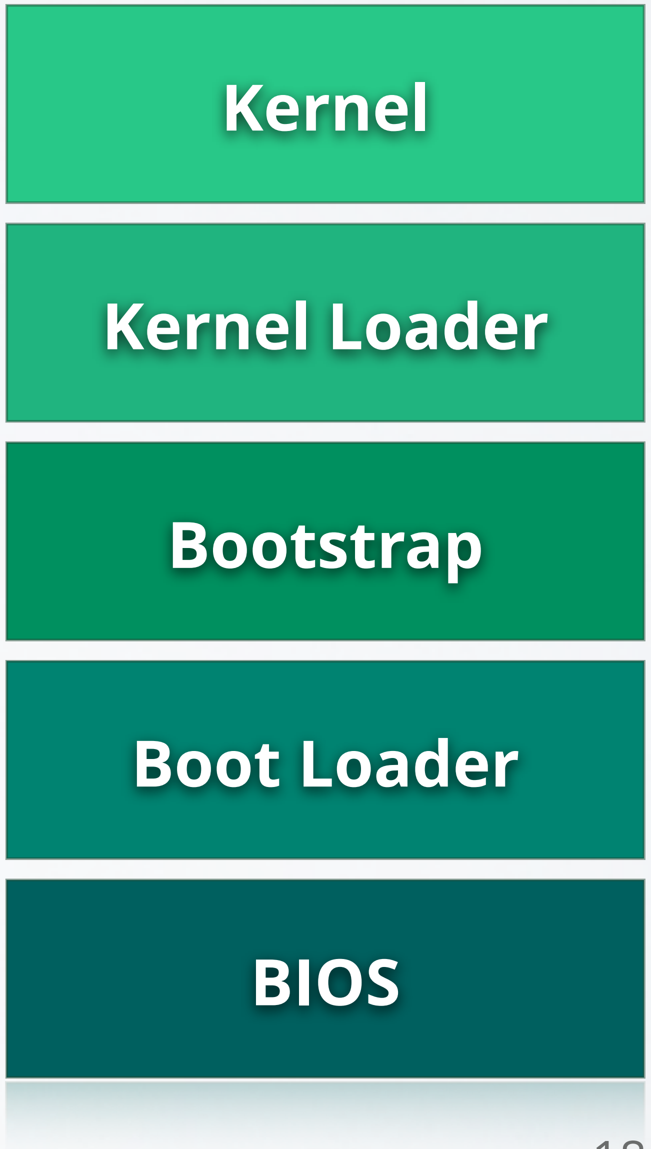


Virtual Memory



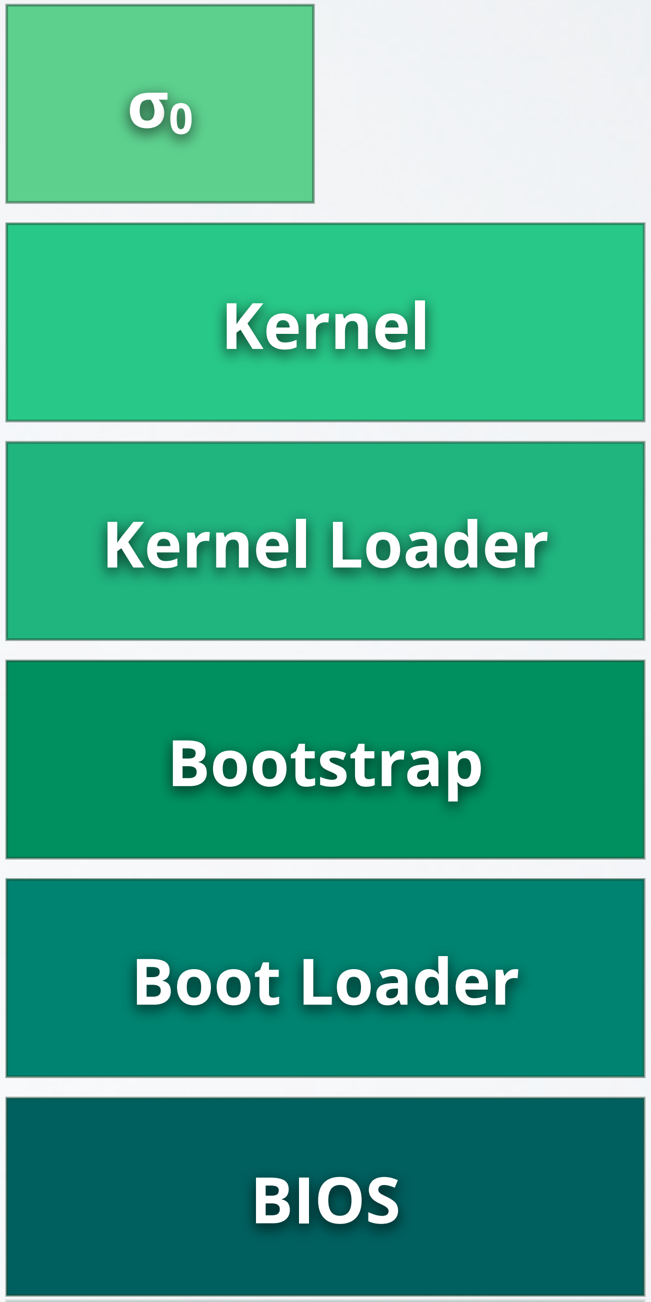
FIASCO

- sets up kernel structures
- sets up scheduling timer
- starts first pager
- starts first task
- starts scheduling
- scheduler hands control to userland for the first time



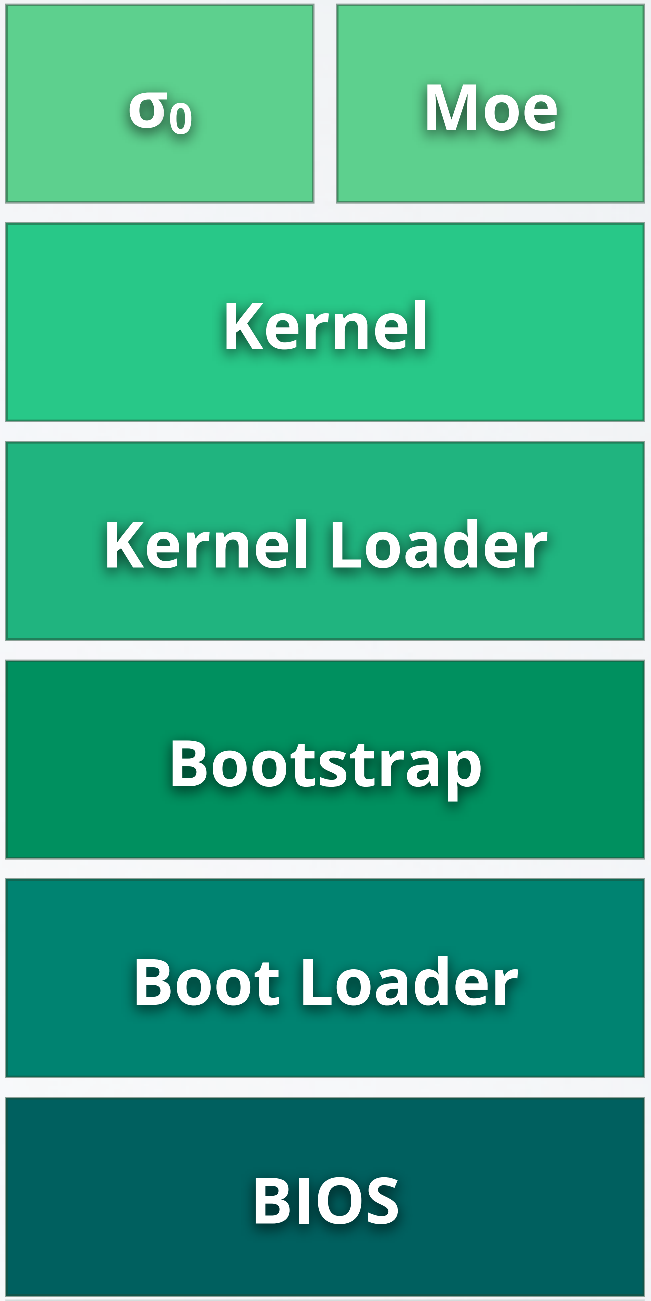
SIGMA0

- is first pager in the system
- initially receives a 1:1 mapping of physical memory
- … and other platform-level resources (I/O ports)
- sigma0 is the root of the pager hierarchy
- pager for moe



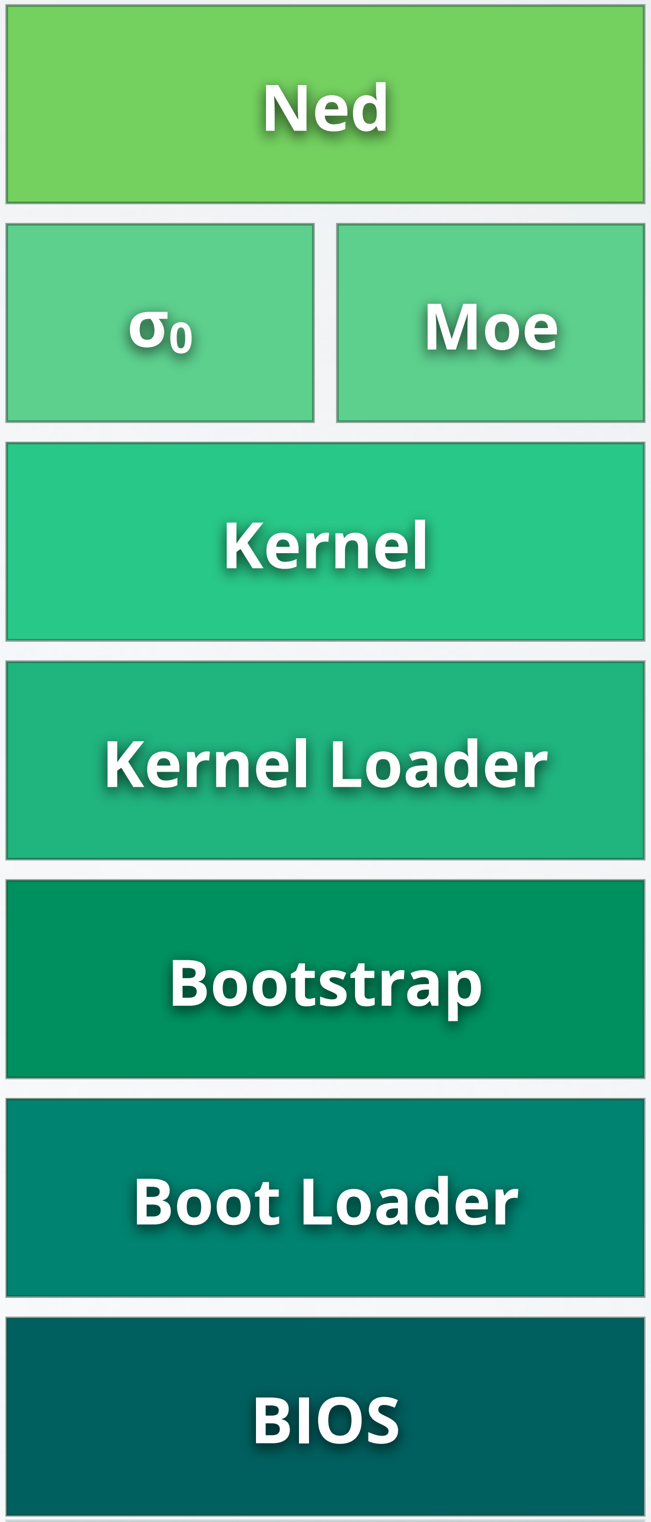
MOE

- manages initial resources
  - namespace
  - memory
  - VESA framebuffer
- provides logging facility
- mini-filesystem for read-only access to boot-modules



NED

- script-driven loader for further programs
  - startup-scripts written in Lua
- additional software can be loaded by retrieving binaries via disk or network
- ned injects common service code into every task



Setup

- download the source tarball from https://os.inf.tu-dresden.de/Studium/KMB/WS2023/Exercise1.tar.bz2
- unpack the tarball
  - it comes with a working directory
  - `cd` in there and have a look around

Compiling the System

- initialize the environment with `make setup` in the toplevel directory you unpacked
- run `make` within the toplevel directory

Test-Driving QEMU

- create a bootable ISO image
  - the `iso` subdirectory is for the ISO's content
  - run `isocreator` from `src/l4/tool/bin` on this directory
- your ISO will contain a minimal grub installation
- launch QEMU with the resulting ISO:
  `qemu-system-x86_64 -m 512 -cdrom boot.iso`

Booting Fiasco

- copy some files to the ISO directory
  - `fiasco` from the Fiasco build directory `obj/fiasco/amd64/`
  - `bootstrap` from `obj/l4/amd64/bin/amd64_gen/`
  - `sigma0`, `moe` , `l4re` and `ned` from `obj/l4/amd64/bin/amd64_gen/l4f/`

Booting Fiasco

- edit `iso/boot/grub/menu.lst`:

```
title Getting Started
kernel /bootstrap -serial
modaddr 0x2000000
module /fiasco
module /sigma0
module /moe
module /l4re
module /ned
```

- rebuild the ISO and run `qemu`

Preparing for Hello

- create the file `hello.lua` in the `iso` directory with this content:
```
local L4 = require("L4");
L4.default_loader:start({},
"rom/hello");
```
- pass `ned` this new startup script
  - add this line to `menu.lst`:
    ```
    module /hello.lua
    ```
  - pass `rom/hello.lua` as parameter to `moe`
- load the future `hello` module in `menu.lst`

Exercise 1: Hello World

- create a directory for your hello-project
- create a Makefile with the following content:

```
PKGDIR    ?= .
L4DIR     ?= absolute path to L4 source tree
OBJ_BASE   = absolute path to L4 build tree
TARGET     = hello
SRC_C      = hello.c
include $(L4DIR)/mk/prog.mk
```

- fill in `hello.c` and compile with `make`
- run in `qemu`

Exercise 2: Ackermann Function

- write a program that spawns six threads
  - you can use pthreads in our system
  - add the line
    `REQUIRES_LIBS = libpthread`
    to your `Makefile`
- each thread should calculate one value a(3,0..5) of the Ackermann function:
  - a(0,m) = m+1
  - a(n,0)= a(n-1,1)
  - a(n,m) = a(n-1,a(n,m-1))