Writing an OS-Loader in Rust with uefi-rs

Philipp Schuster, Cyberus Technology

1. Introduction

1.0 Outlook

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- UEFI is a firmware interface making things easier
  - Hardware manufacturers
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  - Software developers
- `uefi-rs` is a convenient library for UEFI in Rust
- Convenient high-level* abstractions for OS-loaders / bootloaders

*High-level from a low-level perspective. Not Python- or Java-like high-level.

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- Personally met Falk Hartmann at EuroRust 2024 in Vienna

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    Cyberus is responsible for virtualization layer ← My work
  - Soon BSI*-accredited virtualization stack with open-source software
    - Cloud Hypervisor/KVM will be accredited

* BSI: Bundesamt für Sicherheit in der Informationstechnik

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- Conferences, Networking, Meetups

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- **Virtualization requires understanding every concept of the platform and typical software stack.**

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- What is Firmware?
- UEFI: Context + Concepts
- Rust library ("crate") `uefi-rs`
- Code & Demo: Example UEFI OS-loader

* Same thing, different name: OS-loader, OS-specific loader, bootloader

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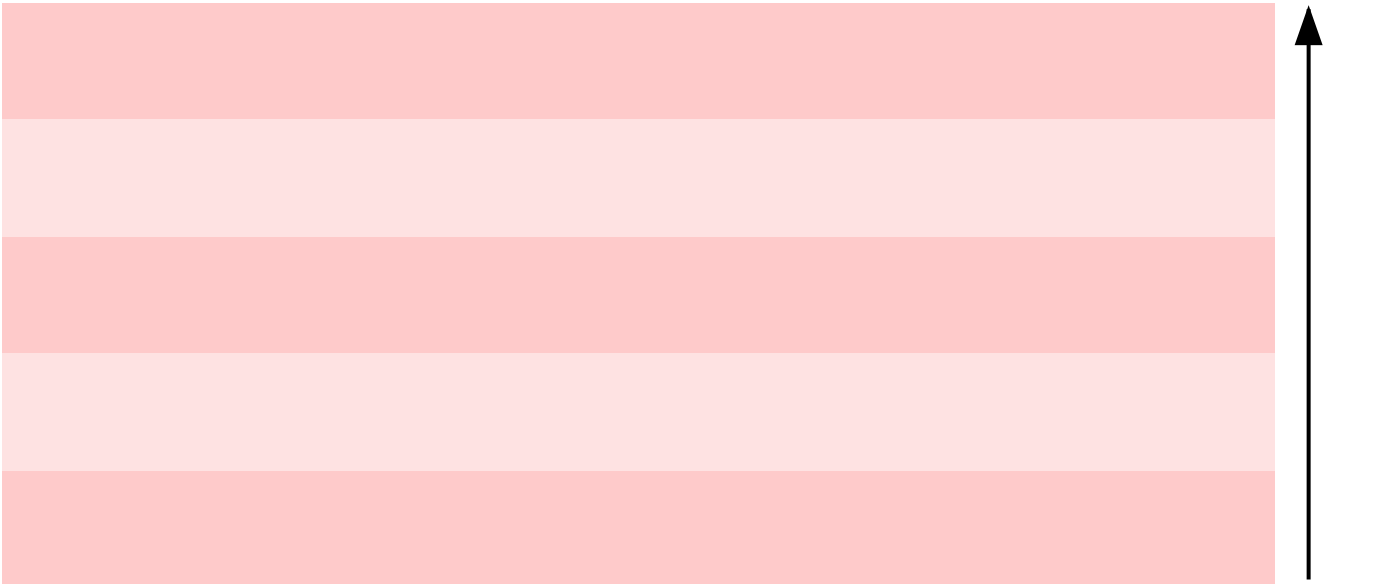
- Fully bootstrapped system (Desktop environment, sound, ...)
- Kernel running in 64-bit mode
- Firmware (UEFI) eventually leads to our kernel being loaded

  → We need to understand UEFI

2. Background

2.1 How does a Computer Boot?



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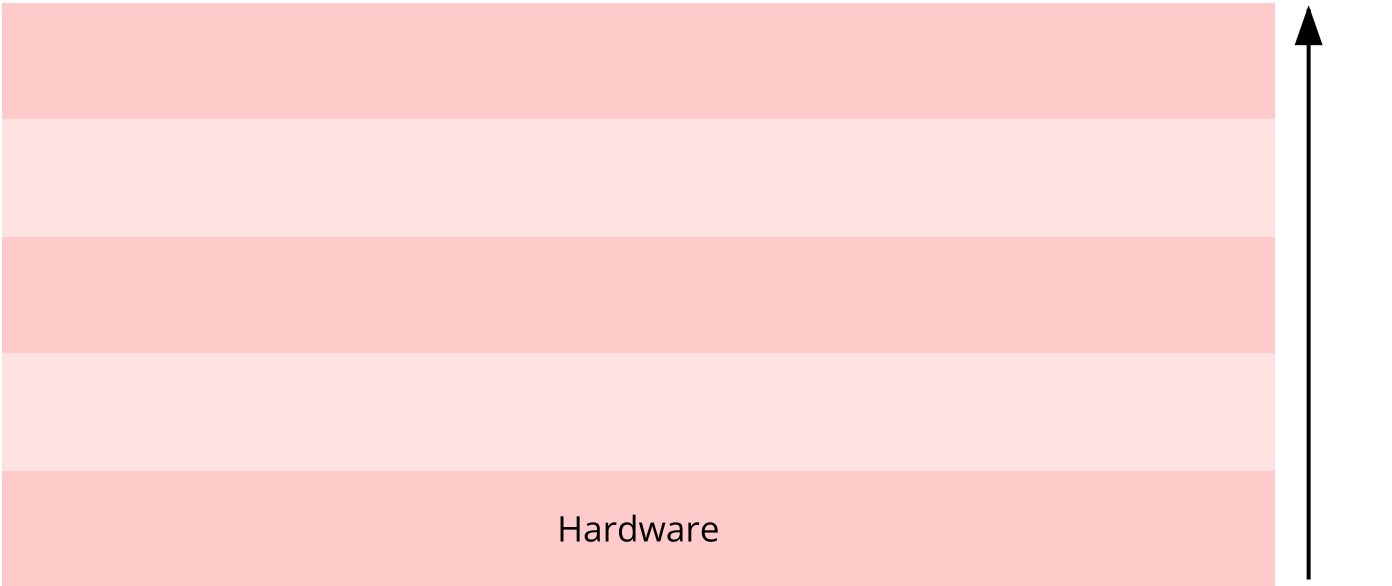

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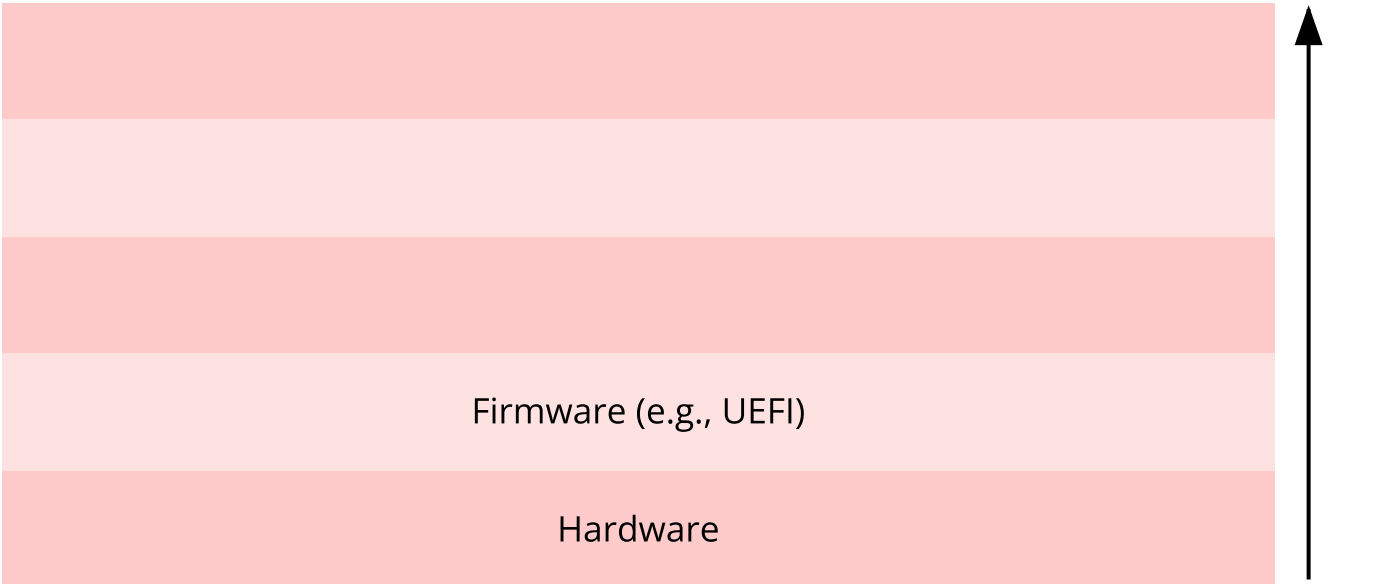

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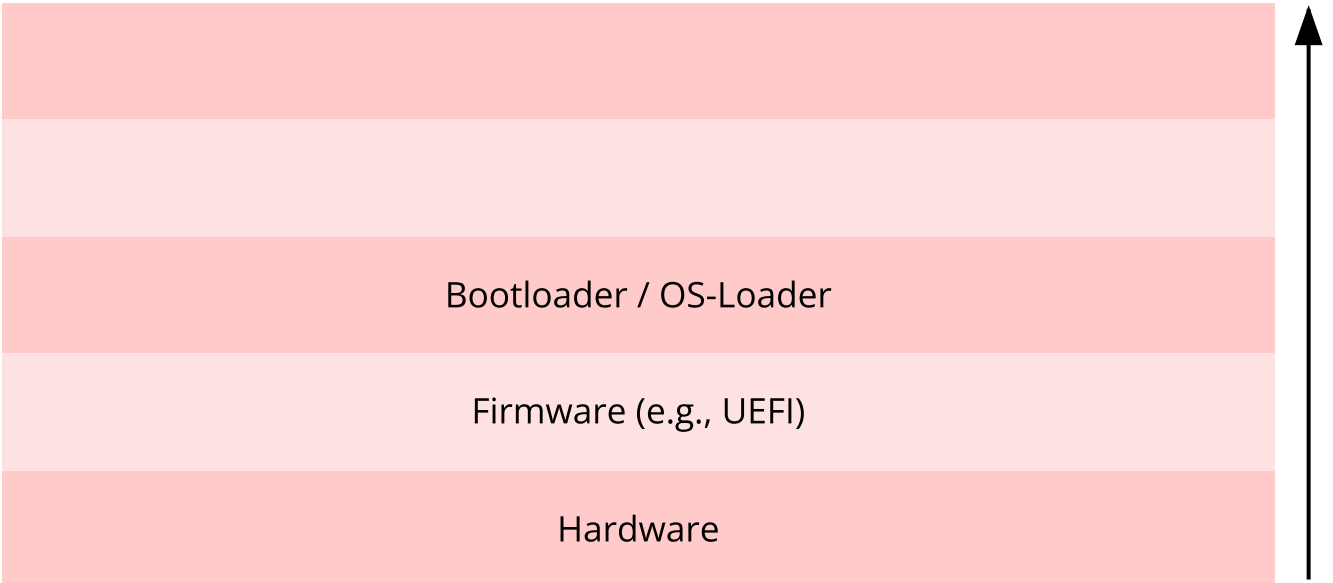

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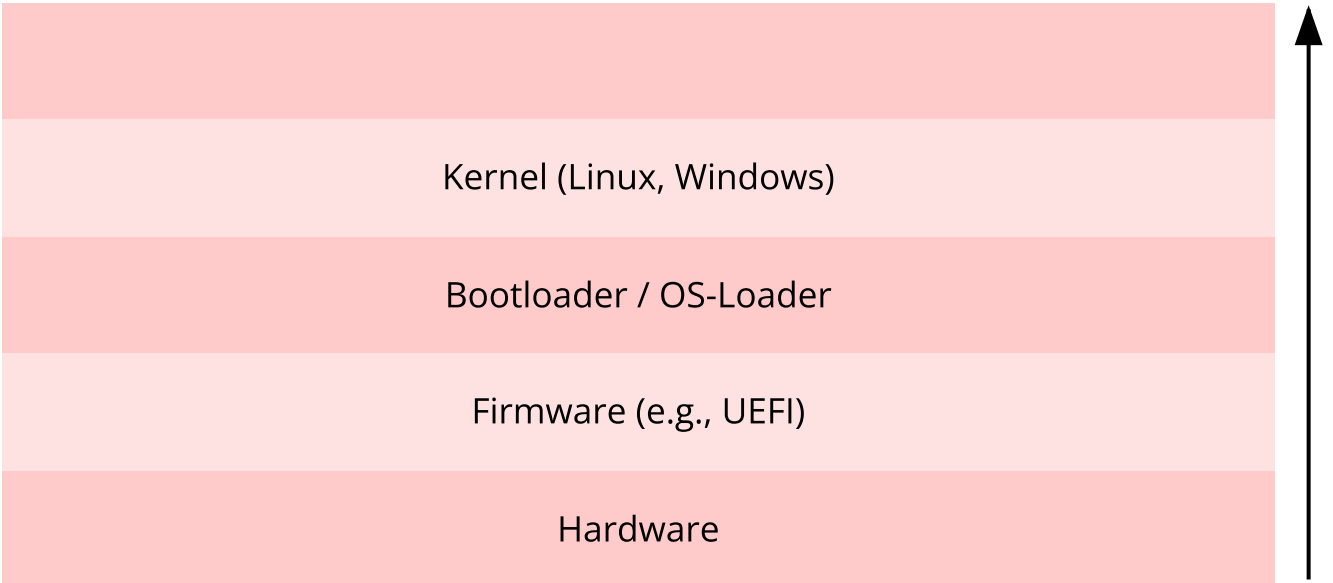

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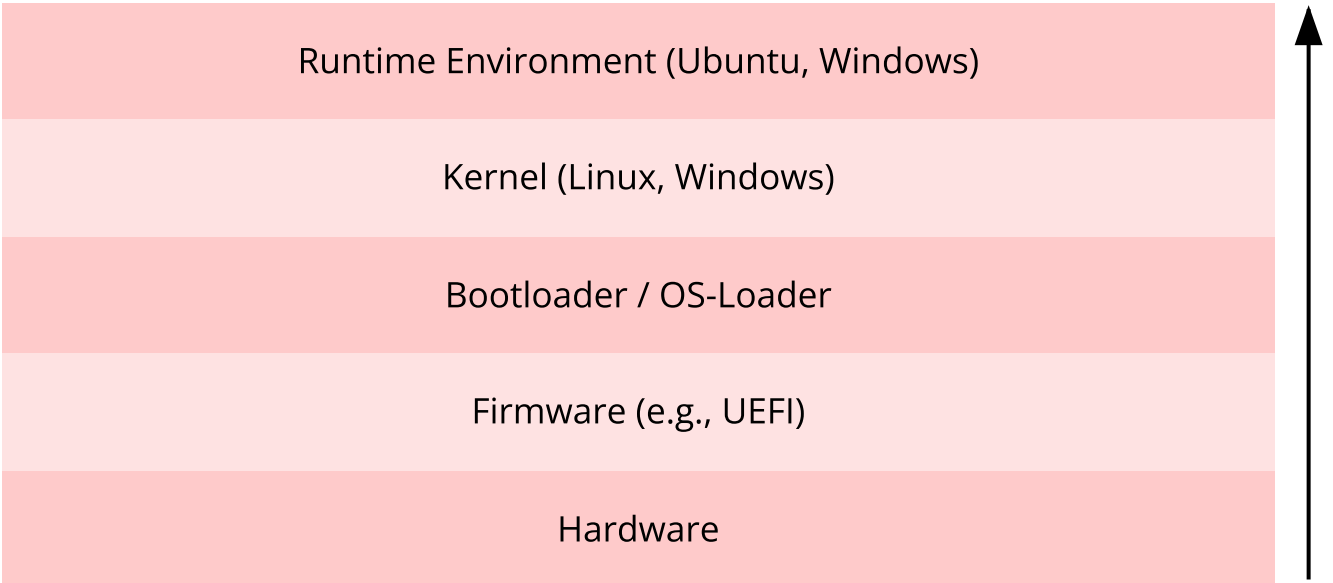

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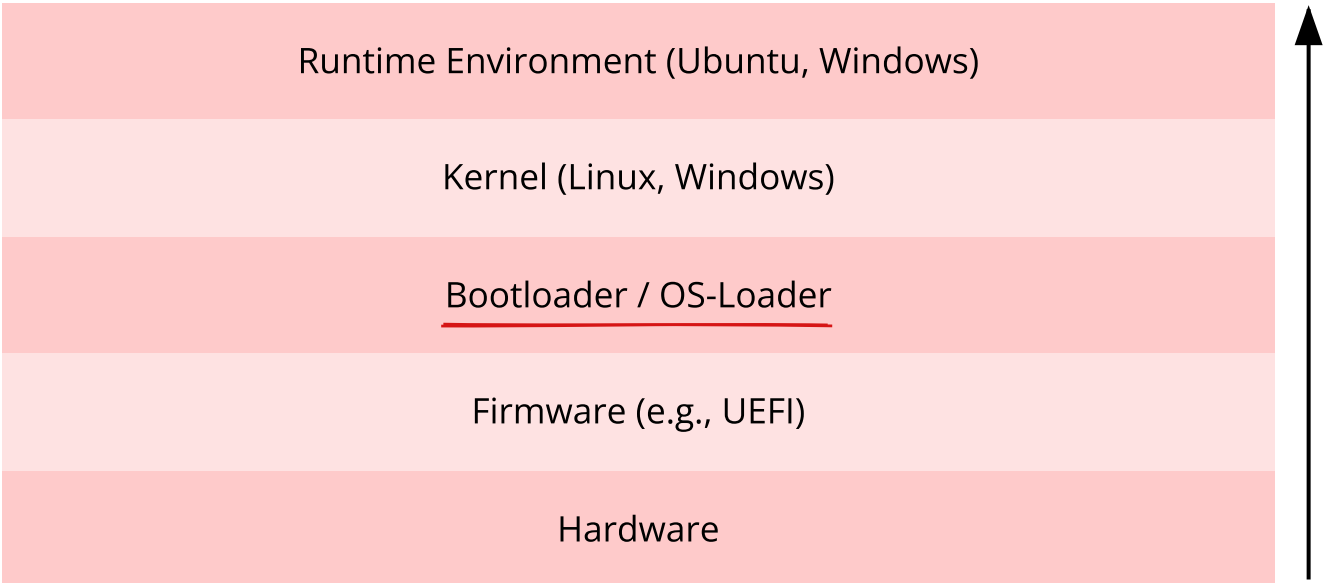

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- Often fluid transitions and overlaps (architecture, manufacturer, platform)

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- **64-bit mode** ("64-bit IA-32e mode"$_{\text{Intel}}$, "long mode"$_{\text{AMD}}$)

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- Trivia: Mainboard manufacturer buys chipset IC(s) from Intel (e.g. Z390) and wires PCI lanes, memory bus, device slots. etc. as needed by the corresponding PCH spec + additional custom things

IC: Integrated Circuit

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  - 10.1 INITIALIZATION OVERVIEW
    - 10.1.4 First Instruction Executed

      → Hardware software co-design

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The interface is in the form of data tables that contain platform-related information, and boot and runtime service calls that are available to the OS loader and the OS. Together, these provide a standard environment for booting an OS.

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- Other implementations exists

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  - UEFI functionality is callable from EFI image

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    - Tiny fraction of remaining functionality: System time, UEFI variables

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 UINT64                                          Revision;
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- OS-loader typically exits boot services
- Kernel has its own drivers (PCIe, NVMe)

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From Developer Perspective

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- EDK2 is default UEFI implementation
- UEFI provides higher level abstractions to access e.g. files
- OS-loaders / bootloaders are EFI applications

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- Code powers ChromeOS Flex notebooks and also runs in Amazon AWS

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The device path protocol, also called a *device path*, is a flexible and structured sequence of binary nodes that describes a route from the UEFI root to a particular device, controller, or file.

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  - Integration of UEFI's allocator into Rust's global allocator

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}
```

3. uefi-rs: Code Example: Hello World

Creating a `no_std` binary (executable)

```
#![no_main]
#![no_std]

use uefi::prelude::*;

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```
#[unsafe(export_name = "efi_main")]
extern "efiapi" fn main(
    internal_image_handle: ::uefi::Handle,
    internal_system_table: *const ::core::ffi::c_void,
) -> uefi::Status {
    unsafe {
        ::uefi::boot::set_image_handle(internal_image_handle);
        ::uefi::table::set_system_table(internal_system_table.cast());
    }
    Status::SUCCESS
}
```

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3. uefi-rs: Code Example: Hello World

Creating a `no_std` binary (executable)

```
#![no_main]
#![no_std]

use log::info;
use uefi::prelude::*;

#[entry]
fn main() -> Status {
    uefi::helpers::init().unwrap();
    info!("Hello world!");
    Status::SUCCESS
}
```

3. uefi-rs: Code Example: Hello World

Creating a `no_std` binary (executable)

```
#![no_main]
#![no_std]

use core::time::Duration;
use log::info;
use uefi::prelude::*;

#[entry]
fn main() -> Status {
    uefi::helpers::init().unwrap();
    info!("Hello world!");
    boot::stall(Duration::from_secs(10));
    Status::SUCCESS
}
```

3. uefi-rs: Code Example: Reading File

```
#[entry]
fn main() -> Status {
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#[entry]
fn main() -> Status {
    helpers::init().unwrap(); // enable `log`-crate
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3. uefi-rs: Code Example: Reading File

```
#[entry]
fn main() -> Status {
    helpers::init().unwrap(); // enable `log`-crate
    let sfs_proto = boot::get_image_file_system(boot::image_handle()).unwrap();
    Status::SUCCESS
}
```

3. uefi-rs: Code Example: Reading File

```
#[entry]
fn main() -> Status {
    helpers::init().unwrap(); // enable `log`-crate
    let sfs_proto = boot::get_image_file_system(boot::image_handle()).unwrap();
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    Status::SUCCESS
}
```

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#[entry]
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    helpers::init().unwrap(); // enable `log`-crate
    let sfs_proto = boot::get_image_file_system(boot::image_handle()).unwrap();
    let mut fs = FileSystem::new(sfs_proto); // Abstraction similar to `std::fs`
    for entry in fs.read_dir(cstr16!("EFI\\BOOT")).unwrap() {
    }
    Status::SUCCESS
}
```

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#[entry]
fn main() -> Status {
    helpers::init().unwrap(); // enable `log`-crate
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    for entry in fs.read_dir(cstr16!("EFI\\BOOT")).unwrap() {
        let entry = entry.unwrap();
        let kind = if entry.is_directory() { "dir" } else { "file" };
        info!("Found: {kind} {}", entry.file_name());
    }
    Status::SUCCESS
}
```

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3. uefi-rs: Code Example: Reading File

```rust
#[entry]
fn main() -> Status {
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    let sfs_proto = boot::get_image_file_system(boot::image_handle()).unwrap();
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    for entry in fs.read_dir(cstr16!("EFI\\BOOT")).unwrap() {
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        let kind = if entry.is_directory() { "dir" } else { "file" };
        info!("Found: {kind} {}", entry.file_name());
    }
    Status::SUCCESS
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```

```
[ INFO]:  src/main.rs@165: Found: dir .
[ INFO]:  src/main.rs@165: Found: dir ..
[ INFO]:  src/main.rs@165: Found: file BOOTX64.EFI
```

3. uefi-rs: Code Example: Device Paths

```
let handles = boot::find_handles::<DevicePath>().unwrap();
for handle in handles.iter() {
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```

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```
let handles = boot::find_handles::<DevicePath>().unwrap();
for handle in handles.iter() {
    let maybe_dvp = unsafe {
        boot::open_protocol::<DevicePath>(
            OpenProtocolParams { handle: *handle,
              agent: boot::image_handle(),
              controller: None, },
            OpenProtocolAttributes::GetProtocol,
        )
    };
    // Pattern matching: Unwrap happy path or continue
    let Ok(dvp) = maybe_dvp else { continue };
    let string = dvp.to_string(DisplayOnly(true), AllowShortcuts(false)).unwrap();
    info!("Device path: {}", string);
}
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let handles = boot::find_handles::<DevicePath>().unwrap();
for handle in handles.iter() {
    let dvp = /* .. */;
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    let string = dvp.to_string(DisplayOnly(true), AllowShortcuts(false)).unwrap();
    info!("Device path: {}", string);
}
```

```
[ INFO]:  src/main.rs@178: Device path: Fv(7CB8BDC9-F8EB-4F34-AAEA-3EE4AF6516A1)
[ INFO]:  src/main.rs@178: Device path: MemoryMapped(0xB,0x1FEDC000,0x1FF5FFFF)
[ INFO]:  src/main.rs@178: Device path: PciRoot(0x0)
[ INFO]:  src/main.rs@178: Device path: VenHw(EBF8ED7C-0DD1-4787-84F1-F48D537DCACF)
[ INFO]:  src/main.rs@178: Device path: VenHw(28A03FF4-12B3-4305-A417-BB1A4F94081E)
[ INFO]:  src/main.rs@178: Device path: VenHw(2A46715F-3581-4A55-8E73-2B769AAA30C5)
[ INFO]:  src/main.rs@178: Device path: VenHw(D9DCC5DF-4007-435E-9098-8970935504B2)
[ INFO]:  src/main.rs@178: Device path: PciRoot(0x0)/Pci(0x0,0x0)
```

3. uefi-rs: How to Test? How to Run?

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- On real hardware, i.e., developer laptop

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  - e.g., QEMU or Cloud Hypervisor with OVMF firmware
  - OVMF is an EDK2 build for Virtual Machines

4. Code

GitHub: phip1611/uefi-systemd-chainloader

5. Summary & Conclusion

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- Tries to be a modern OS-like environment but sticks to decade old concepts
  - A single global address space for everything
  - No real multitasking
  - Limited error handling and debugging

Thank you for your attention!