What comes before Linux …

or BSD, Windows, macOS, Haiku, Oberon, Plan 9, …?

Daniel Maslowski aka CyReVolt

Hello, I am Daniel aka CyReVolt :-)

Work and education

- IT security and computer science
- software engineering
- infrastructure and web
- apps, UIs, ecommerce

Open Source contributions

- hardware and firmware
- operating systems
- software distributions
- reverse engineering

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I created Fiedka the firmware editor (https://fiedka.app) and started the Platform System Interface project: https://github.com/platform-system-interface/

Agenda

- Bootloaders and Firmware
- Classification, Scopes and Goals
- Projects
- Platform Ownership

Bootloaders and Firmware

What is a Bootloader?

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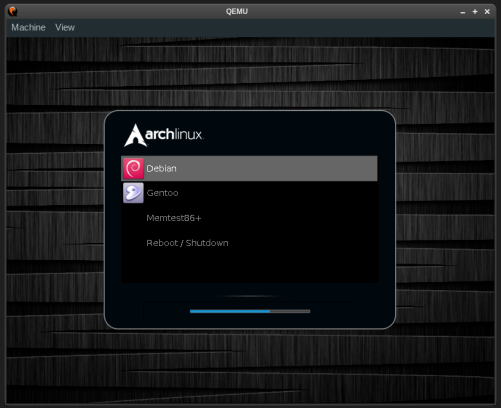

- target application may rely on a specific protocol
- often configurable via files or customizable at build time
- can offer an interactive menu, e.g. for switching OSs
- well-known examples
  - GRUB
  - sd-boot
  - U-Boot (proper)

image source: https://github.com/hartwork/grub2-theme-preview

Between Firmware and OS

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Platform Initialization

aka *firmware*

- SoC
- clocks
- GPIOs
- DRAM controller

Bootloader

today's topic

- needs *flexibility*
- fetches OS kernel
- checks for integrity
- maybe interactive menu

Operating System

- Linux
- FreeBSD
- Plan 9
- Oberon
- Haiku
- …

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- abstract concepts, e.g., file systems
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See also my talk on webboot:

- https://programm.froscon.org/2021/events/2703.html
- https://av.tib.eu/media/59579
- https://www.youtube.com/watch?v=nZgRV7gvZRw

Security Insights

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Incidents increase:

- OEM compromise (e.g., MSI)
- vulnerabilities in firmware interfaces, such as
  - UEFI, e.g. Option ROMs[a], parsing variables[b]
  - ACPI WPBT (Windows Platform Binary Table)[c]
  - LogoFAIL[d], PixieFail[e], …

[a] https://uefi.org/sites/default/files/resources/UEFI%20Firmware%20-%20Security%20Concerns%20and%20Best%20Practices.pdf

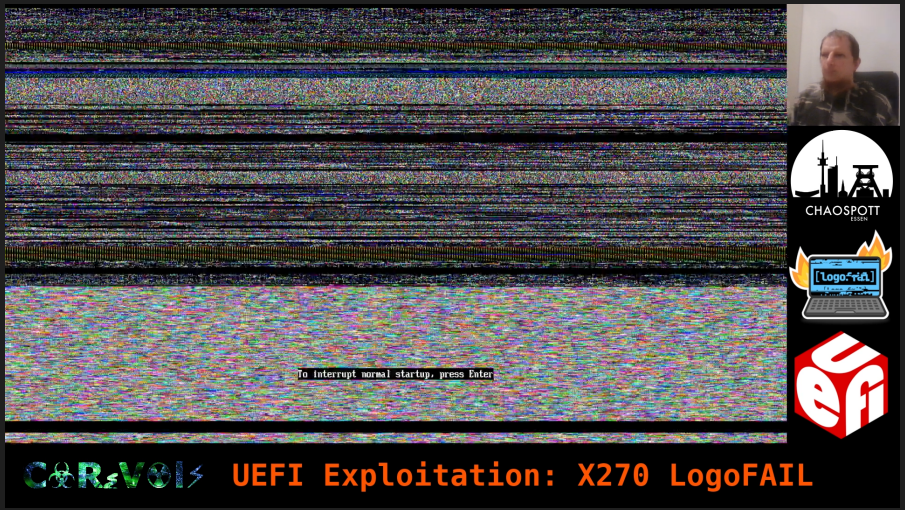
[b] https://www.binarly.io/advisories/BRLY-2021-007/index.html

[c] https://eclypsium.com/research/everyone-gets-a-rootkit/

[d] https://binarly.io/posts/finding_logofail_the_dangers_of_image_parsing_during_system_boot/

[e] https://blog.quarkslab.com/pixiefail-nine-vulnerabilities-in-tianocores-edk-ii-ipv6-network-stack.html

It really works



https://www.youtube.com/watch?v=X2X18h5Hnfk

Classification, Scopes and Goals

Interactive vs non-interactive

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Flexible devices are designed to run custom operating systems and software.
Security note: Runtime configurability leaves space for *vulnerabilities*.
Offer a rich user interface to

[1] https://archive.fosdem.org/2022/schedule/event/fw_settings_and_menus/

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Offer a rich user interface to

- change settings
- set up a trust anchor
- enjoy colorful graphics

For more, see my talk on firmware settings and menus[1].

[1] https://archive.fosdem.org/2022/schedule/event/fw_settings_and_menus/

Applications

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General purpose

General purpose bootloaders can be hard to customize.
Design them to be clear to end users for distribution and integration.

[2] https://danielmangum.com/posts/risc-v-bytes-exploring-custom-esp32-bootloader/

Applications

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Special purpose

Special purpose bootloaders often need to be tailored[2] toward a single use case. With a clear execution flow, it is easier to understand their behavior.

[2] https://danielmangum.com/posts/risc-v-bytes-exploring-custom-esp32-bootloader/

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Customizing code from the beginning requires a concept of *ownership*.

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- Project Mu, Tianocore EDK2 (UEFI)
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- coreboot
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- oreboot
  - bt0 stage
- U-Boot
  - SPL, rarely TPL

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A bootloader for a rich OS relies on DRAM being initialized.

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Note: Documentation on DRAM controllers is very sparse.
Chip vendors rarely describe how initial parts of their platforms work.

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Boot ROM / Loader Tools

- Allwinner: `sunxi-fel`, `xfel`, `aw-fel-cli`
- Rockchip: `rkflashtool`, `rkdeveloptool`
- Amlogic: `pyamlboot`, `aml_boot`
- NXP: `uuu`, `imx_usb_loader`
- StarFive JH7110: `vf2-loader`
- Android: `fastboot` (details vary per vendor)
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Provided by Bootloader

- U-Boot `sf` command
- Linux MTD (memory technology device) drivers

Projects

Tianocore EDK2 / UEFI

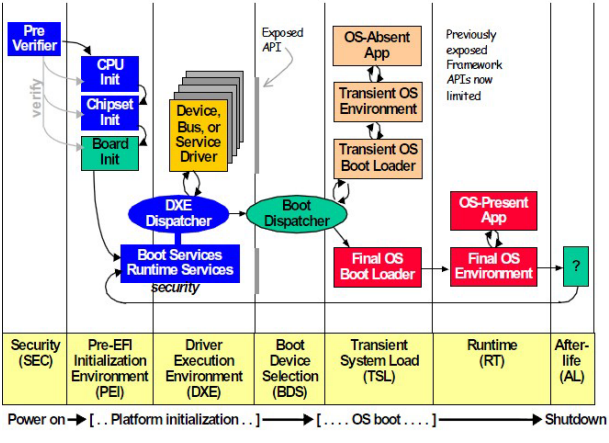

Figure 1-2. Framework Firmware Phases

DXE and BDS are effectively the UEFI bootloader, can be replaced with Linux.

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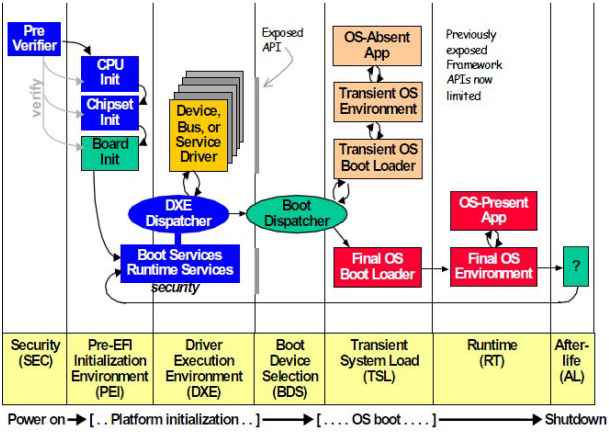

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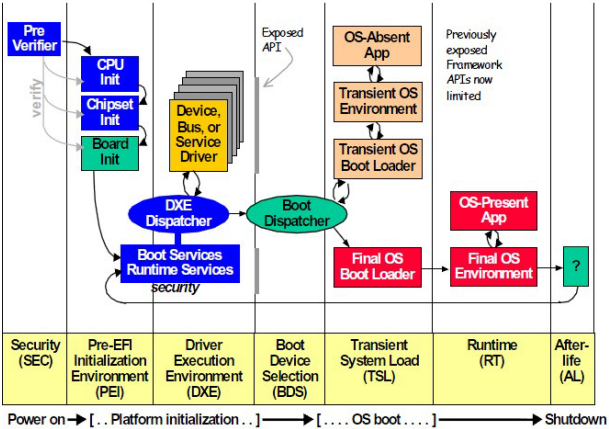

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See also “BIOS modding”.

U-Boot

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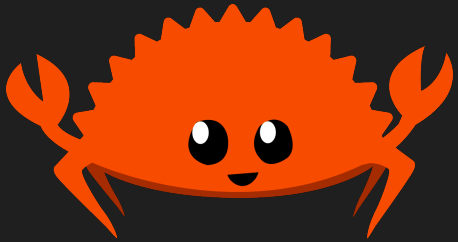
See also:

- State of the U-Boot, 2017 - Thomas Rini
  https://www.youtube.com/watch?v=dKBUSMa6oZI
- Implementing State-of-the-Art U-Boot Port, 2018 Edition - Marek Vasut
  https://www.youtube.com/watch?v=rJtlAi8rxgs

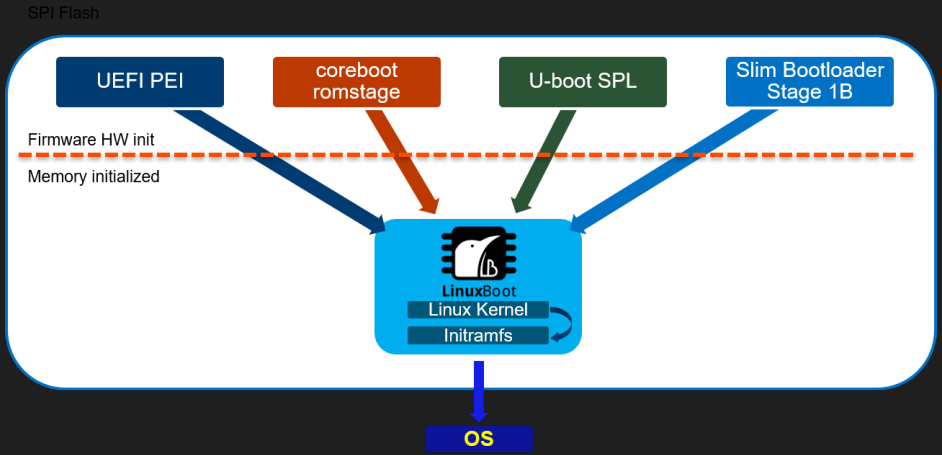
oreboot

oreboot is firmware written in Rust.



https://github.com/oreboot

LinuxBoot



Linux is a well-known environment, so finding fitting engineers is easy.

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FreeBSD

kboot: Booting FreeBSD with LinuxBoot[3]

FreeBSD's kboot is a Linux binary that loads FreeBSD's kernel, modules, tuneables and other metadata via the kexec(2) API

[3] https://www.bsdcan.org/events/bsdcan_2023/schedule/session/138-kboot-booting-freebsd-with-linuxboot/

Sooooo many Operating Systems

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How many do you know?

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- Windows
- Unix (Multics, … AIX, …)
- SunOS, Solaris, Illumos …
- {Free,Open,Net,DragonFly}BSD
- macOS (Darwin, MACH + FreeBSD)
- MINIX
- xv6
- Linux (many distros)
- Amoeba (where Python came from)
- Oberon (Niklaus Wirth et al)
- Plan 9 from Bell Labs, Inferno
- beOS, Haiku
- FreeRTOS
- Zephyr
- LiteOS
- … too many to name here :)

Platform Ownership

Let's talk!

Full ownership?

- locked bootloaders (phones), can sometimes be unlocked
- signed firmware (e.g., Intel BootGuard), sometimes misconfigured :-)
- projects (OpenWrt, OpenIPC, …) often replace vendor software partially
- control from start allows for more customization, easier development

Sustainability

What do we do with hardware solely made for a cloud based service?

- services are being turned off over time
- Google Stadia: offered Bluetooth upgrade for controller
- Magenta Smart Speaker: now only a Bluetooth speaker
- cheap TV boxes and tablets with unmaintained Android
- single board computers that rely on community (us!)

Thanks! :)

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Daniel Maslowski

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