Common Operating System for Front-end Computers and SoCs in CERN-ATS

Federico Vaga
2022-05-03
Who am I?

• I work in CERN BE-CEM-EDL

• I’m a Software Engineer, specialized in:
  
  – Low-Level Software
  
  – Linux kernel development
  
  – Linux systems
Disclaimer
Disclaimer
This is an on-going project
Front-End Computers (FEC): Overview
Front-End Computers (FEC): Overview
Front-End Computers (FEC): Overview
Front-End Computers (FEC): Overview
Operating System

CentOS
The Community ENTerprise Operating System
Operating System: Original Plan

CentOS
The Community ENTerprise Operating System

7 → 8 → 9
(Until June 2024)
Operating System: Original Plan

CentOS
The Community ENTerprise Operating System

7 ➔ 8 ➔ 9
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Operating System: Original Plan

CentOS

The Community ENTerprise Operating System

7 → 8 → 9

(Until June 2024)
Operating System: Original Plan

CentOS
The Community ENTerprise Operating System

7 ➔ 8 ➔ 9
(Until June 2024)
The Next FEC Operating System
How Does The Next OS Boot?
How Does The Next OS Boot?
How Does The Next OS Boot?

(diskless – network boot)
How Does CentOS 7 Boot?

1. GRUB
2. PXELinux
3. Linux
4. Init RAM disk
5. Distribution
How Does CentOS 7 Boot?

GRUB → PXELinux → Linux → Init RAM disk → Distribution

www.redhat.com
How Does CentOS 7 Boot?

GRUB -> PXELinux -> Linux -> Init RAM disk -> Distribution

www.redhat.com
How Does CentOS 7 Boot?

GRUB

PXELinux

More than 10000 additional patches!

Init RAM disk

Distribution

www.redhat.com
How Does The Next OS Boot?

1. GRUB
2. Linux
3. Init RAM disk
4. Distribution

DRA CUT
How Does The Next OS Boot?

GRUB → Linux → Init RAM disk → Distribution

www.gnu.org/software/grub
www.kernel.org
dracut.wiki.kernel.org
www.redhat.com
www.centos.org
www.debian.org
Isn’t Something Missing?
How Does The Next OS Boot?

- BIOS/EFI Firmware
- GRUB
- Linux
- Init RAM disk
- Distribution

DRA CUT
How Does The Next OS Boot Over The Network?

BIOS
EFI Firmware

GRUB

Linux

Init RAM disk

Distribution

DRA CUT
How Does The Next OS Boot Over The Network?

- BIOS
- EFI Firmware
- GRUB
- Linux
- Init RAM disk
- Distribution

Diagram shows the boot process flow from BIOS to Linux, passing through GRUB and Init RAM disk before reaching the distribution.
How Does The Next OS Boot Over The Network?

BIOS
EFI Firmware

GRUB

Linux

Init RAM disk

Distribution

DRA
CUT
How Does The Next OS Boot Over The Network?

BIOS
EFI Firmware

GRUB

Linux

Init RAM disk

Distribution

DRA CUT
How Does The Next OS Boot Over The Network?

BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution

GRUB

Linux

Init RAM disk

Distribution

BIOS
EFI Firmware

GRUB

Linux

Init RAM disk

Distribution

DRA CUT

DRA CUT

DRA CUT

DRA CUT

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How Does The Next OS Boot Over The Network?

BIOS
EFI Firmware

GRUB

Linux

Init RAM disk

Distribution

DRA
CUT

DRA
CUT

CPU
How Does The Next OS Boot Over The Network?

1. BIOS (EFI Firmware)
2. GRUB
3. Linux
4. Init RAM disk
5. Distribution

Diagram:
- BIOS to GRUB
- GRUB to Linux
- Linux to Init RAM disk
- Init RAM disk to Distribution

Additional Elements:
- Cloud with DRA CUT
- CPU
- DRA CUT
- Linux penguin
- Red hat

Date: 03/05/2022
How Does The Next OS Boot Over The Network?

- BIOS
- EFI Firmware
- GRUB
- Linux
- Init RAM disk
- Distribution

Diagram shows the boot process, starting with BIOS/EFI Firmware, followed by GRUB, then Linux, and finally the distribution.
How Does The Next OS Boot Over The Network?

BIOS
EFI Firmware

GRUB

Linux
Init RAM disk
Distribution

DRA CUT

DRA CUT
How Does The Next OS Boot Over The Network?

- BIOS/EFI Firmware
- GRUB
- Linux
- Init RAM disk
- Distribution

Diagram:
- BIOS/EFI Firmware to GRUB
- GRUB to Linux
- Linux to Init RAM disk
- Init RAM disk to Distribution
## Projects References

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<td>x86_64 aarch64</td>
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<td>Linux</td>
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<td>Linux Stable (5.10.x)</td>
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<td>x86_64 aarch64</td>
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<td>Distribution</td>
<td>fec-os-distribution</td>
<td>CentOS Stream (8) Debian (11)</td>
<td>x86_64 aarch64</td>
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Why Two Linux Distributions?
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● It enforces software portability
  – Everything must work on different Linux environments
Why Two Linux Distributions?

• It enforces software portability
  - Everything must work on different Linux environments

• It reduces the total cost of ownership
  - It reduces the exit costs and it prevents lock-in
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- It is relatively cheap to *maintain* both solutions
  - After a first investment in portability, it is easy to maintain
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  - We can always easily move to the second distribution if needed
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- It allows us to have an exit strategy
  - We can always easily move to the second distribution if needed

- We will never support two distributions at the same time
  - Only one distribution will be officially supported (primary)
  - The second distribution will be our exit strategy (secondary)
GRUB On SoC? Why not U-Boot?
GRUB On SoC? Why not U-Boot?

Actually, U-Boot boots GRUB
GRUB On SoC? Why not U-Boot?

Actually, U-Boot boots GRUB

Even more confusing! Why?
How Does The Next OS Boot?

GRUB → Linux → Init RAM disk → Distribution

DRA CUT
How Does The Next OS Boot On SoC?

GRUB → Linux → Init RAM disk → Distribution

DRA CUT
How Does The Next OS Boot On SoC?

- U-Boot
  - Linux
  - Init RAM disk
  - Distribution

Diagram:
- U-Boot
- Linux
- Init RAM disk
- Distribution

Keywords:
- DRA
- CUT
- Linux
- Init RAM disk
- Distribution
GRUB On SoC? Why not U-Boot?

- It is not a choice based on functional requirements
  - In terms of functional requirements there is not a clear winner: both would do
- It is a design choice based on non-functional requirements
  - We want a uniform installation across all supported platforms
  - We do not want to be exposed to platform specific details
    - Decoupling the hardware specificities from the general purpose OS
How Does The Next OS Boot On SoC?

GRUB → Linux → Init RAM disk → Distribution

DRA CUT

Distribution
How Does The Next OS Boot On SoC?

U-Boot → GRUB → Linux → Init RAM disk → Distribution

DRA CUT
How Does The Next OS Boot?

BIOS
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GRUB

Linux

Init RAM disk

Distribution

DRA
CUT

CPU
How Does The Next OS Boot On SoC?

U-Boot → GRUB → Linux → Init RAM disk → Distribution
How Does The Next OS Boot On SoC?

U-Boot → GRUB → Linux → Init RAM disk → Distribution

DRA CUT
How Does The Next OS Boot On SoC?

FSBL and friends -> U-Boot -> GRUB -> Linux -> Init RAM disk -> Distribution
How Does The Next OS Boot On SoC?

FSBL and friends → U-Boot → GRUB → Linux → Init RAM disk → Distribution
How Does The Next OS Boot On SoC?

Platform development and support
- Hardware setup
- DeviceTree
- FPGA Configuration

FSBL and friends → U-Boot → GRUB → Linux → Init RAM disk → Distribution

DRA CUT
How Does The Next OS Boot On SoC?

Platform development and support
- Hardware setup
- DeviceTree
- FPGA Configuration

Operating System development and support
- Network booting infrastructure
- GRUB configuration
  - Only supported architectures
  - Use SMBIOS info to start Linux
- Linux configuration
  - Only supported platforms
- Linux distribution
  - Only supported architectures
How Does The Next OS Boot On SoC?

Operating System development and support
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FSBL and friends → Barebox → GRUB → Linux → Init RAM disk → Distribution
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FSBL and friends ➔ Barebox ➔ GRUB ➔ FreeBSD ➔ Init RAM disk ➔ Distribution

DRA
CUT
How Does The Next OS Boot On SoC?

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- Network booting infrastructure
- GRUB configuration
  - Only supported architectures
  - Use SMBIOS info to start Linux
- Linux configuration
  - Only supported platforms
- Linux distribution
  - Only supported architectures

FSBL and friends → U-Boot → U-Boot → FreeBSD → Init RAM disk → Distribution
GRUB On SoC? Why not U-Boot?

- It is our design choice
- Use U-Boot as an EFI firmware (in other words: the old BIOS)
  - Pre-installed on local memory
  - Rarely update
  - Hardware knowledge and description
- Use GRUB to boot the Operating System
  - Downloaded from a server
  - Updatable whenever needed with little constraints
  - Knowledge about the OS booting sequence
How to Make It Work?
How To Make It Work?

- **Build GRUB targeting arm64-efi**
  - Note that GRUB will be built as an EFI application

- **Build U-Boot (or equivalent) with EFI boot support**
  - The firmware must be able to execute EFI applications

- **For network booting**
  - Configure a TFTP Server
    - deploy the GRUB binary and configuration file in the tftp server root directory
  - Configure the DHCP server (e.g. `dchpd.conf(5)`):
    - set the `next-server` field to point to the TFTP server
    - set the `filename` field to point to the grub arm64-efi binary deployed on the TFTP server
  - Configure U-boot to automatically:
    - do a DHCP request
    - use the DHCP answer to fetch GRUB over TFTP (`next-server`, and `filename` fields in `dchpd.conf(5)`)
How To Make It Work? - A Quick Practical Example
How To Make It Work? - A Quick Practical Example

Xilinx EK ZCU106
How To Make It Work? - A Quick Practical Example

Xilinx EK ZCU106
How To Make It Work? - A Quick Practical Example

Xilinx EK ZCU106

```
$ ls -1 /var/lib/tftpboot/vgupta/L868-arm/
  grub.arm64-efi.img
  grub.cfg
  system.dtb
```

TFTP

deploy
How To Make It Work? - A Quick Practical Example

From network.cern.ch device ZCU106

- HCP Next Server: CWE-513-VPL256.CERN.CH
- HCP Image path: /vgupta/L868-arm/grub.arm64-efi.img

Xilinx EK ZCU106

```
$ ls -l /var/lib/tftpboot/vgupta/L868-arm/
grub.arm64-efi.img
grub.cfg
system.dtb
```
How To Make It Work? - A Quick Practical Example

Xilinx EK ZCU106

U-Boot

TFTP
deploy

$ ls -1 /var/lib/tftpboot/vgupta/L868-arm/
grub.arm64-efi.img
grub.cfg
system.dtb

DHCP

From network.cern.ch device ZCU106

- HCP Next Server: CWE-513-VPL256.CERN.CH
- HCP Image path: /vgupta/L868-arm/grub.arm64-efi.img
How To Make It Work? - A Quick Practical Example

Xilinx EK ZCU106

U-Boot

flash

TFTP

deploy

$ ls -l /var/lib/tftpboot/vgupta/L868-arm/
grub.arm64-efi.img
grub.cfg
system.dtb

From network.cern.ch device ZCU106

- HCP Next Server: CWE-513-VPL256.CERN.CH
- HCP Image path: /vgupta/L868-arm/grub.arm64-efi.img
How To Make It Work? - A Quick Practical Example

```bash
> setenv kernel_addr_r 0x--------
> setenv fdt_addr_r 0x--------
> setenv bootcmd 'dhcp $kernel_addr_r &&
tftpboot $fdt_addr_r /path/to/system.dtb &&
bootefi $kernel_addr_r $fdt_addr_r'
> saveenv
```

From `network.cern.ch` device ZCU106

- HCP Next Server: CWE-513-VPL256.CERN.CH
- HCP Image path: /vgupta/L868-arm/grub.arm64-efi.img
Many More Details
Many More Details

But little time to show them
This Was Not Enough! I Want To Know More!

Documentation at
fecos.docs.cern.ch

Info at
fec-os-support@cern.ch
or
federico.vaga@cern.ch
BACKUP SLIDES
How Do We Build The Linux Images?
How Do We Build The Linux Images?
How Do We Build The Linux Images?

CentOS 8 Stream
How Do We Build The Linux Images?

- CentOS 8 Stream
- Debian 11
How Do We Build The Linux Images?

- CentOS 8 Stream
- Debian 11
How Do We Build The Linux Images?

CentOS 8 Stream

Debian 11
How Do We Build The Linux Images?

Packery

Packer
packer.io

CentOS 8 Stream

Debian 11
How Do We Build The Linux Images?

- Packer
- HCL Configuration file
- Custom Scripts

- packer.io
- CentOS 8 Stream
- Debian 11
How Do We Build The Linux Images?

- Packer
  - HCL Configuration file
  - Custom Scripts
  - packer.io

- elbe
  - elbe-rfs.org

- CentOS 8 Stream
- Debian 11
How Do We Build The Linux Images?

- **Packer**
  - HCL Configuration file
  - Custom Scripts

- **ELBE**
  - XML Configuration File

- packer.io

- elbe-rfs.org

- CentOS 8 Stream

- Debian 11
What Is The Project Schedule?
CentOS 7 Extended Support
# CentOS 7 Extended Support

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<th>Year</th>
<th>2021</th>
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- **Today**: Run 3
- **CentOS 7 EOL**: Long Shutdown 3 (LS3)

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<th>Year</th>
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<th>2031</th>
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- **Run 4**: LS4
- **Run 5**: Run 5
CentOS 7 Extended Support

Today
CentOS 7 EOL
CentOS 7 on FECs
Long Shutdown 3 (LS3)
Run 3
Run 4
LS4
Run 5
CentOS 7 Extended Support

![CentOS 7 Extended Support Diagram]

Today

CentOS 7 EOL

CentOS 7 on FECs

2021

2022

2023

2024

2025

2026

2027

2028

2029

Run 3

Long Shutdown 3 (LS3)

Run 4

LS4

Run 5

2030

2031

2032

2033

2034

2035

2036

2037

2038

03/05/2022

Federico Vaga | FEC-OS

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FEC OS Renovation Schedule

---

2021-2022: Run 3

2023: CentOS 7 EOL

2024-2025: CentOS 7 on FECs

2026-2027: Long Shutdown 3 (LS3)

2028-2029:

2030-2031: Run 4

2032-2033: LS4

2034-2035: Run 5

---
FEC OS Renovation Schedule

- **2021**
- **2022**
- **2023**
- **2024**
- **2025**
- **2026**
- **2027**
- **2028**
- **2029**

- **Today**
- **Run 3**
- **CentOS 7 EOL**
- **Long Shutdown 3 (LS3)**
- **Run 4**
- **LS4**
- **Run 5**

- **2030**
- **2031**
- **2032**
- **2033**
- **2034**
- **2035**
- **2036**
- **2037**
- **2038**
#### FEC OS Renovation Schedule

- **Run 3**: 2021 - 2022
- **Long Shutdown 3 (LS3)**: 2026 - 2027
- **Run 4**: 2030 - 2031
- **LS4**: 2033 - 2034
- **Run 5**: 2036 - 2037

**Key Events**:
- **Today**: CentOS 7 EOL on FECs

**Dates**:
- **03/05/2022**
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**Legend**:
- *New OS Image*:
- *Run 3*:
- *Long Shutdown 3 (LS3)*:
- *Run 4*:
- *LS4*:
- *Run 5*:
FEC OS Renovation Schedule

Development and Deployment

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- **Run 3**
- **Long Shutdown 3 (LS3)**

- **Today**
- **CentOS 7 EOL**
- **CentOS 7 on FECs**

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<td>JASOND</td>
<td>JFMAM</td>
</tr>
</tbody>
</table>

- **Run 4**
- **LS4**
- **Run 5**
FEC OS Renovation Schedule

2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029
---|---|---|---|---|---|---|---|---
Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep
Run 3

CentOS 7 EOL

Today

2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038
---|---|---|---|---|---|---|---|---
Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep
Run 4

Long Shutdown 3 (LS3)

Run 5