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

Federico Vaga

2022-05-03

Who am I?

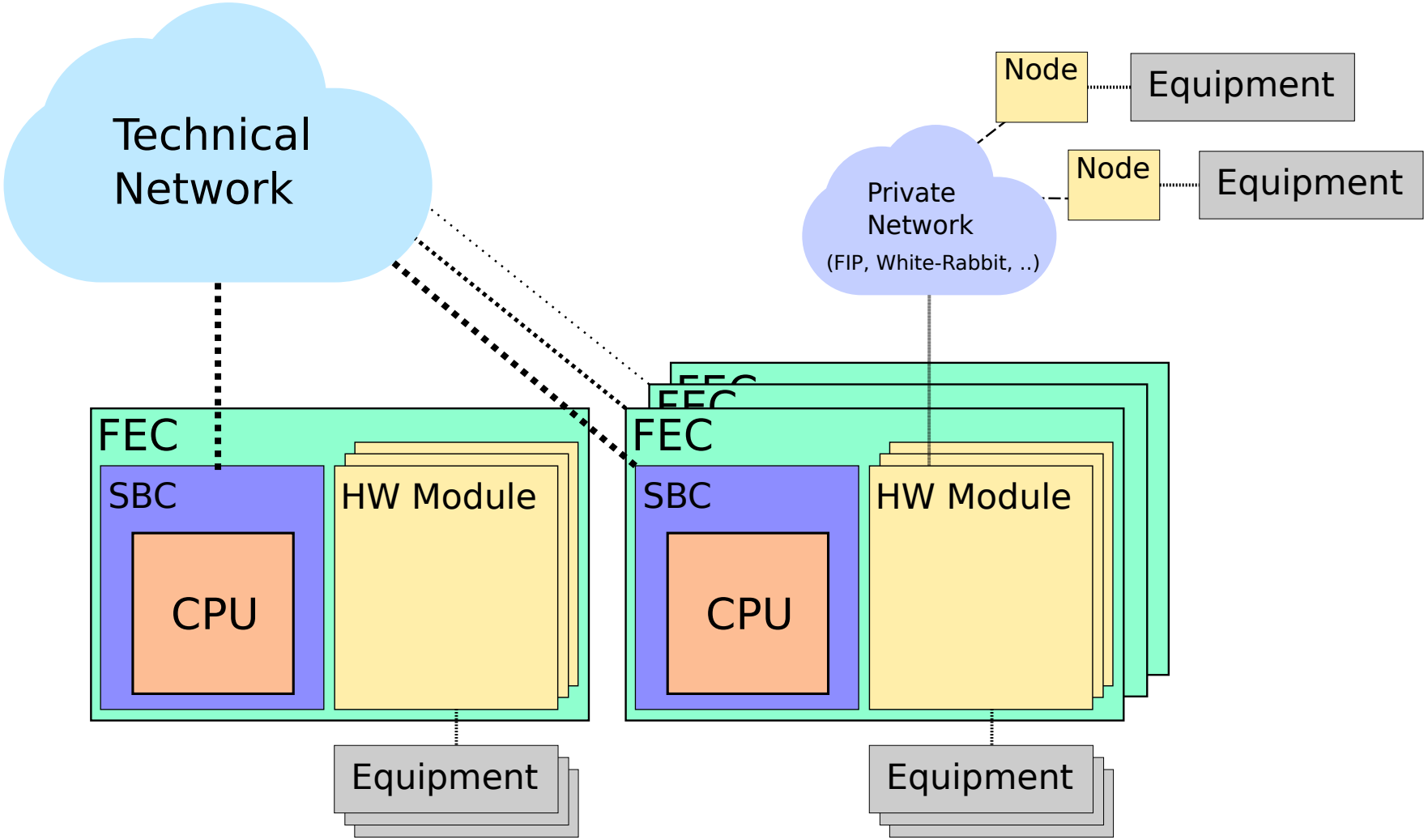
- **I work in CERN BE-CEM-EDL**
- **I'm a Software Engineer, specialized in:**
  - Low-Level Software
  - Linux kernel development
  - Linux systems

Disclaimer

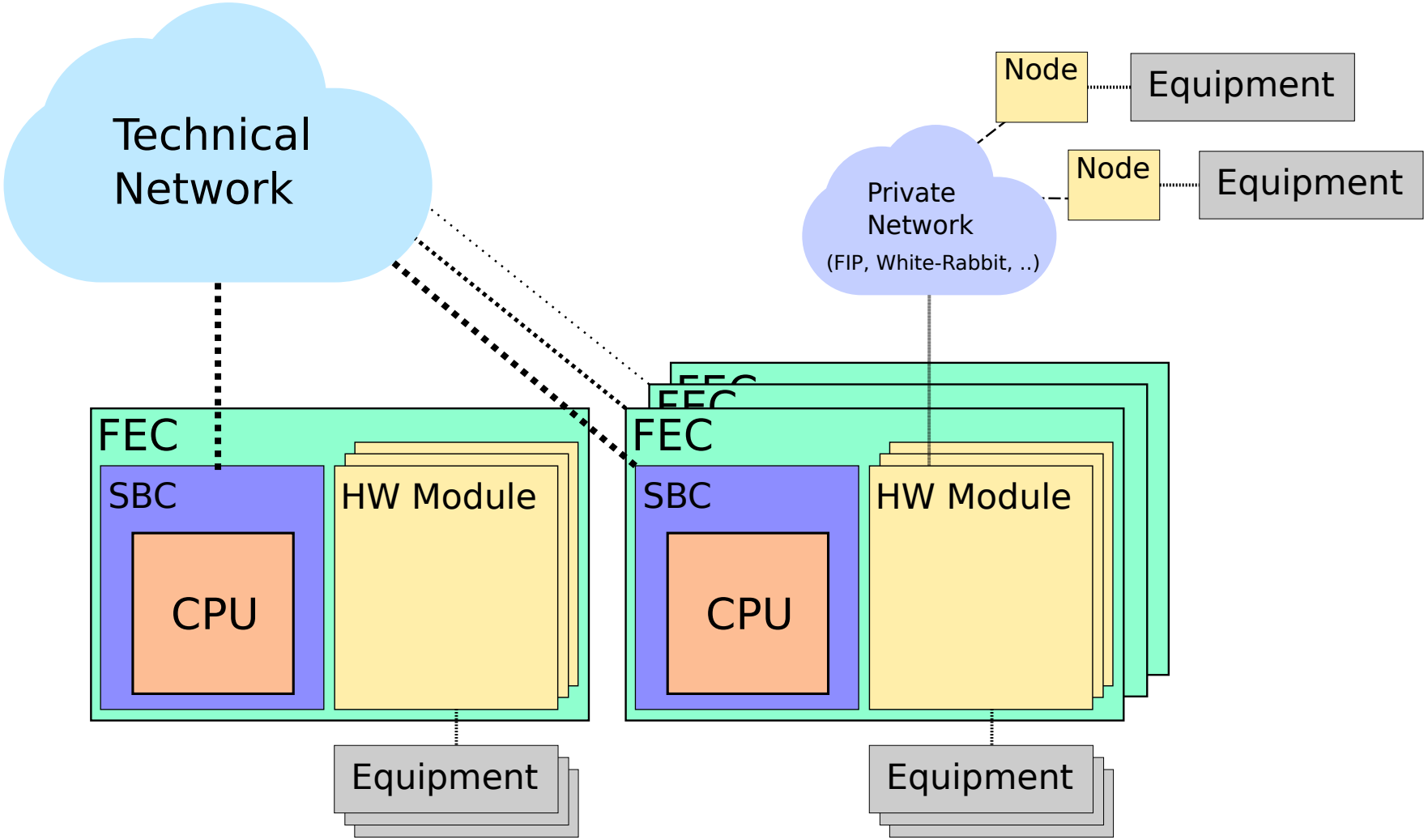
Disclaimer

This is an on-going project

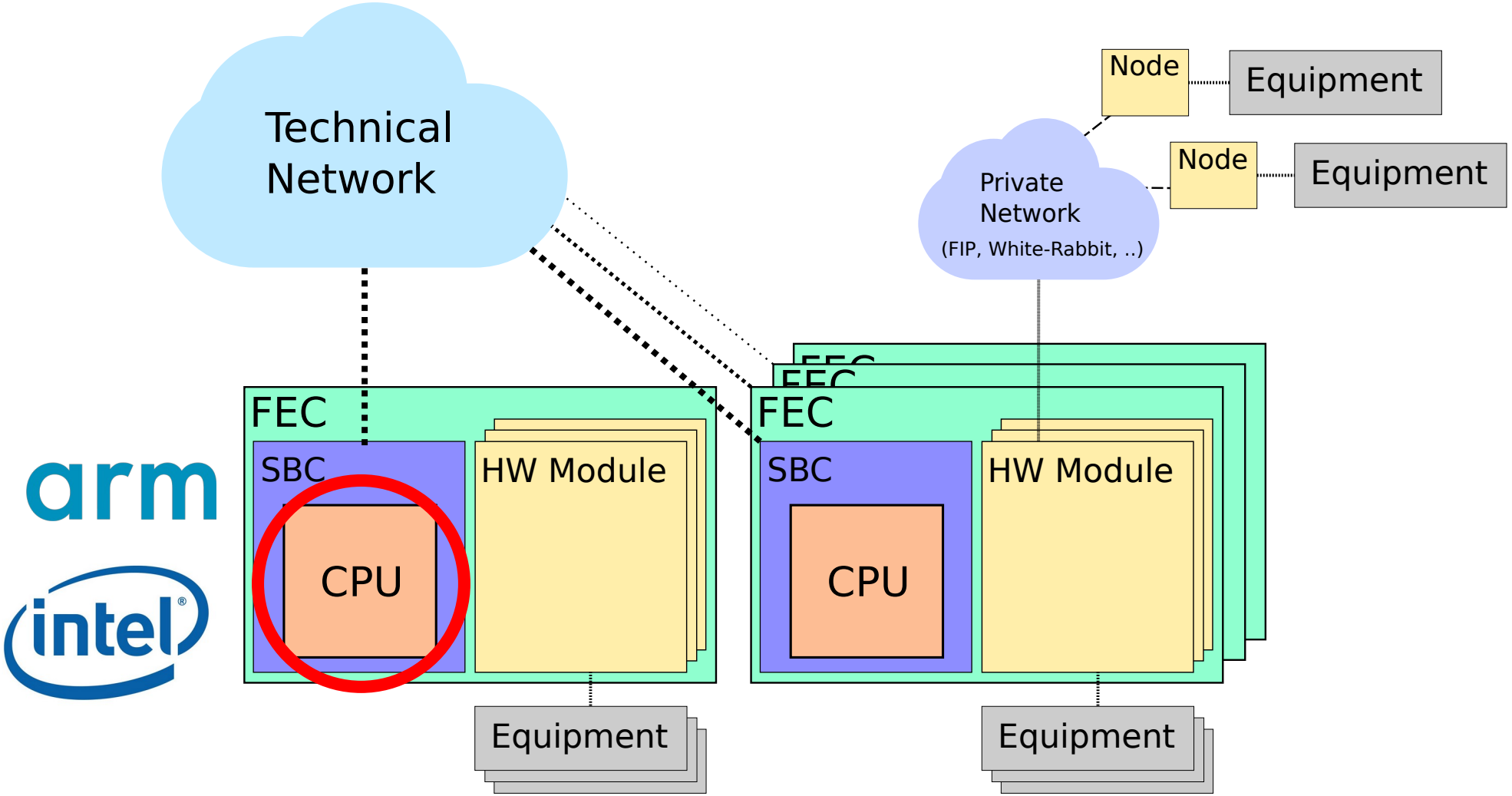
Front-End Computers (FEC): Overview



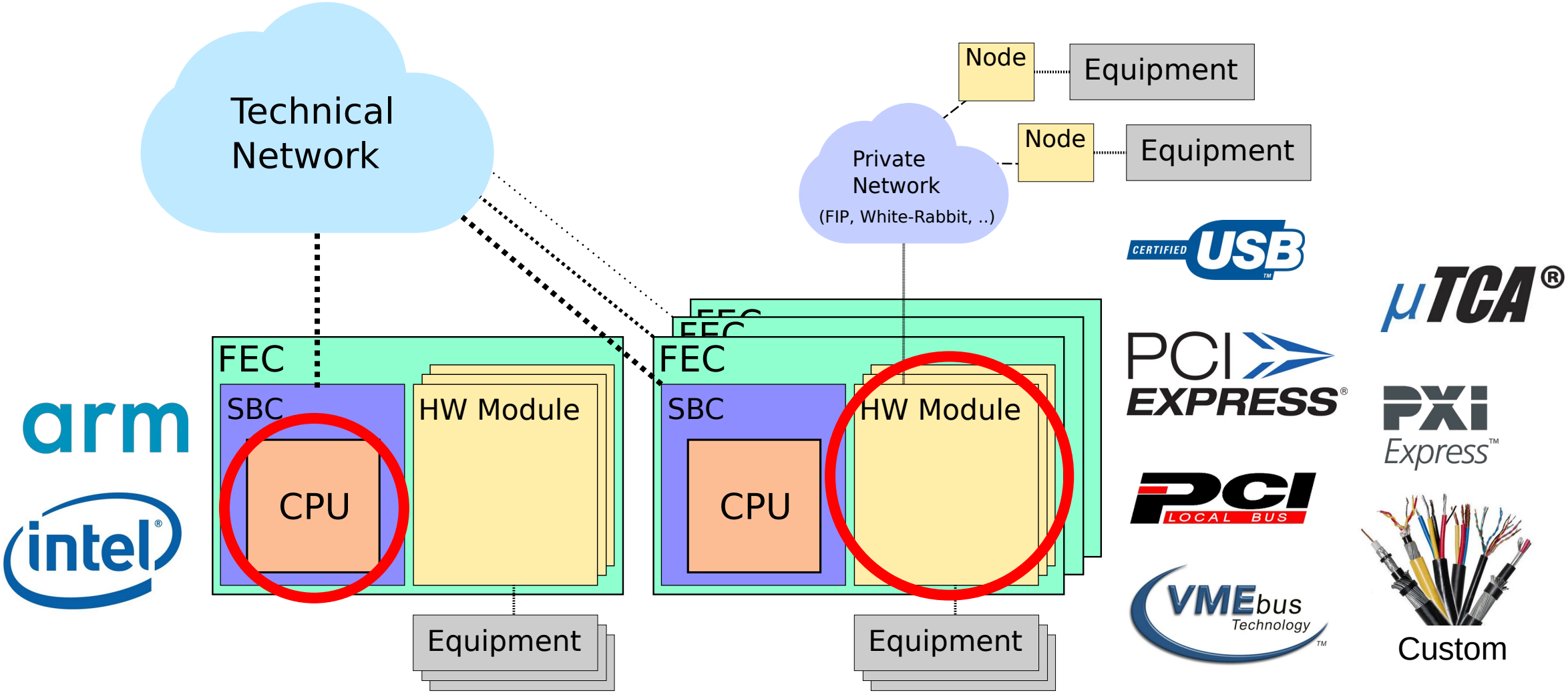
Front-End Computers (FEC): Overview



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

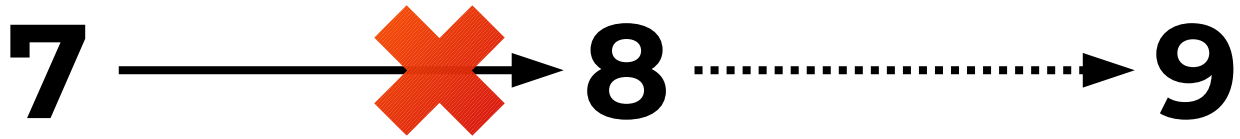
7 → 8 ⇢ 9

(Until June 2024)

Operating System: Original Plan

CentOS

The Community ENTerprise Operating System

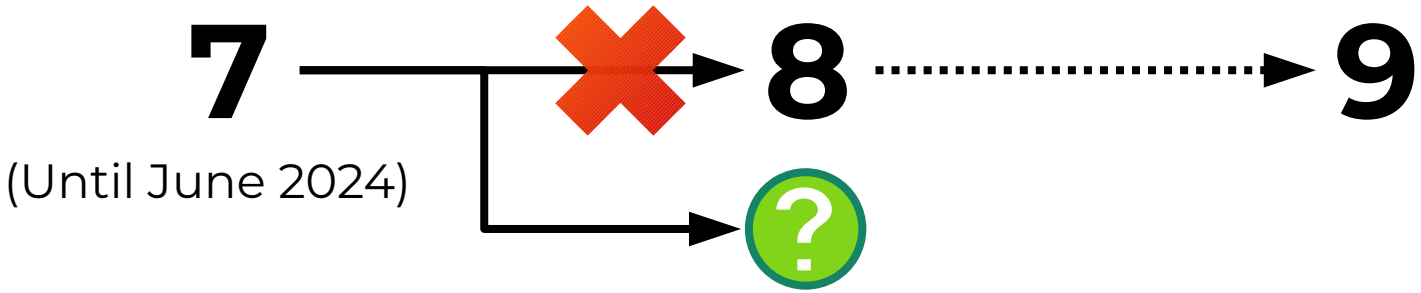


(Until June 2024)

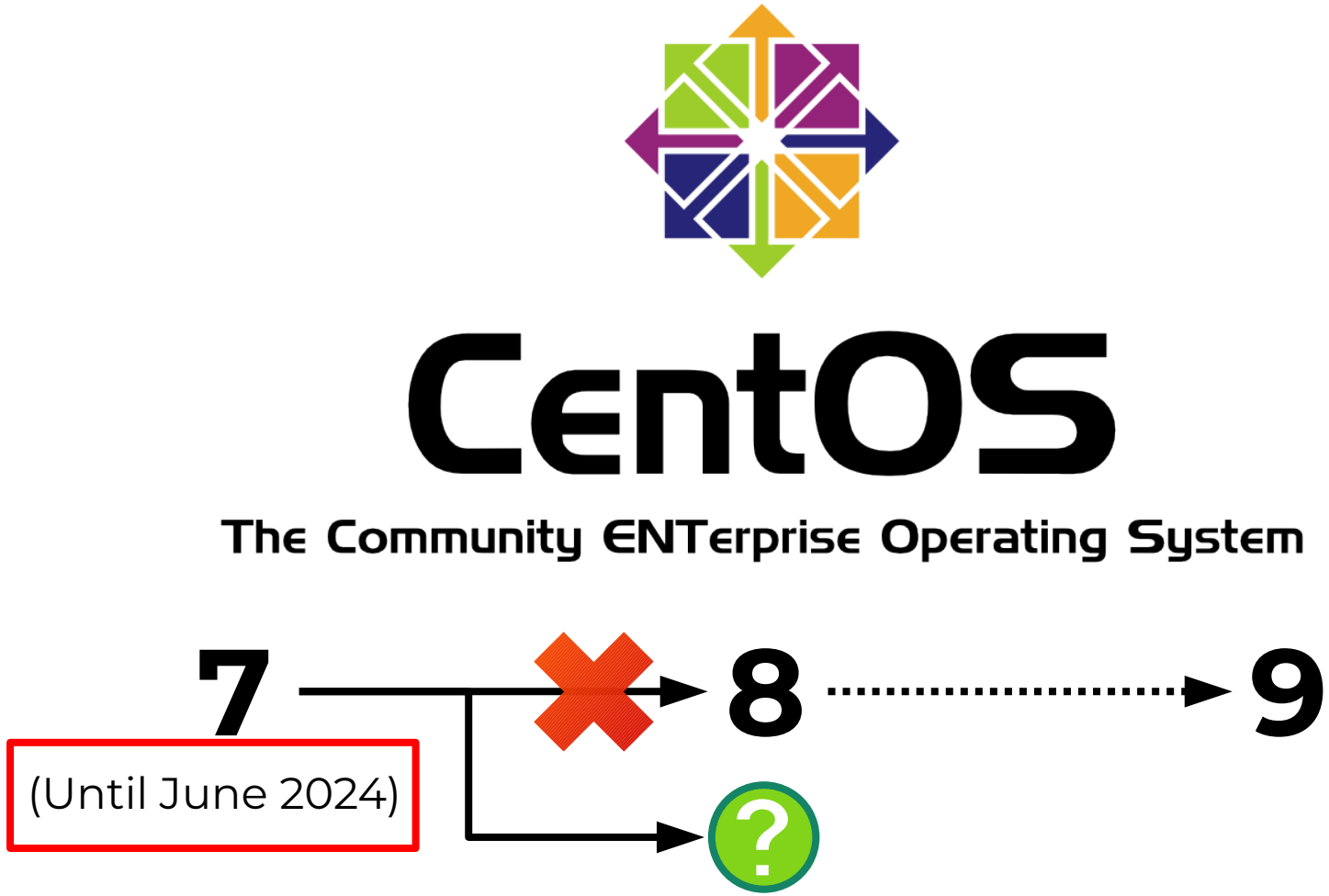
Operating System: Original Plan

CentOS

The Community ENTerprise Operating System

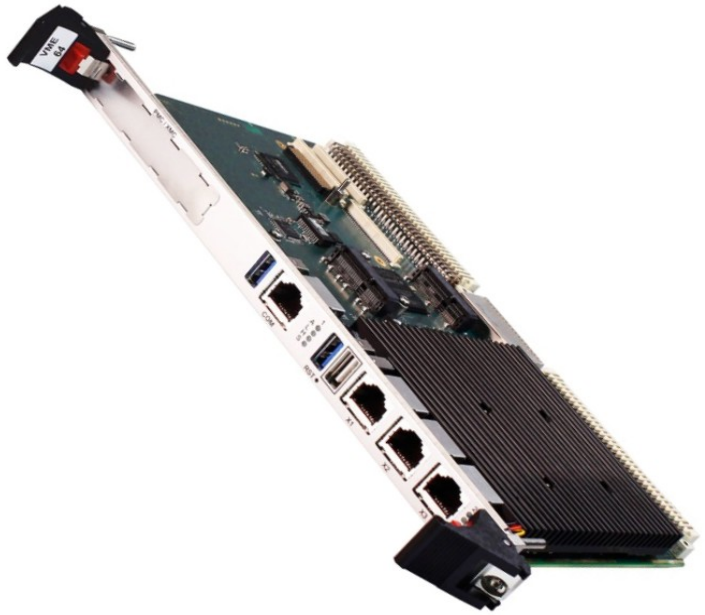


Operating System: Original Plan

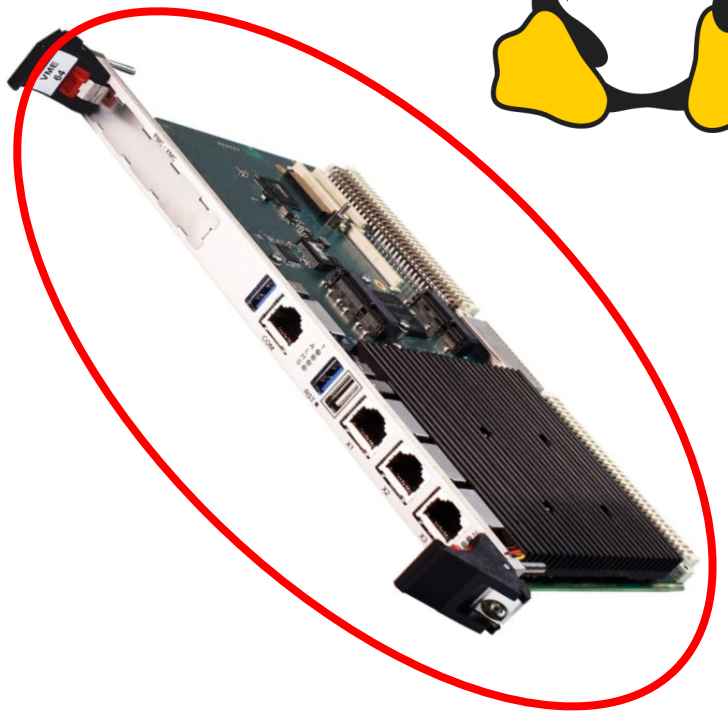


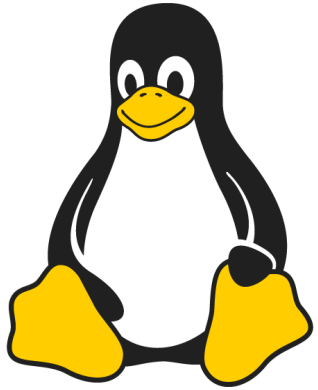
The Next FEC Operating System

How Does The Next OS Boot?

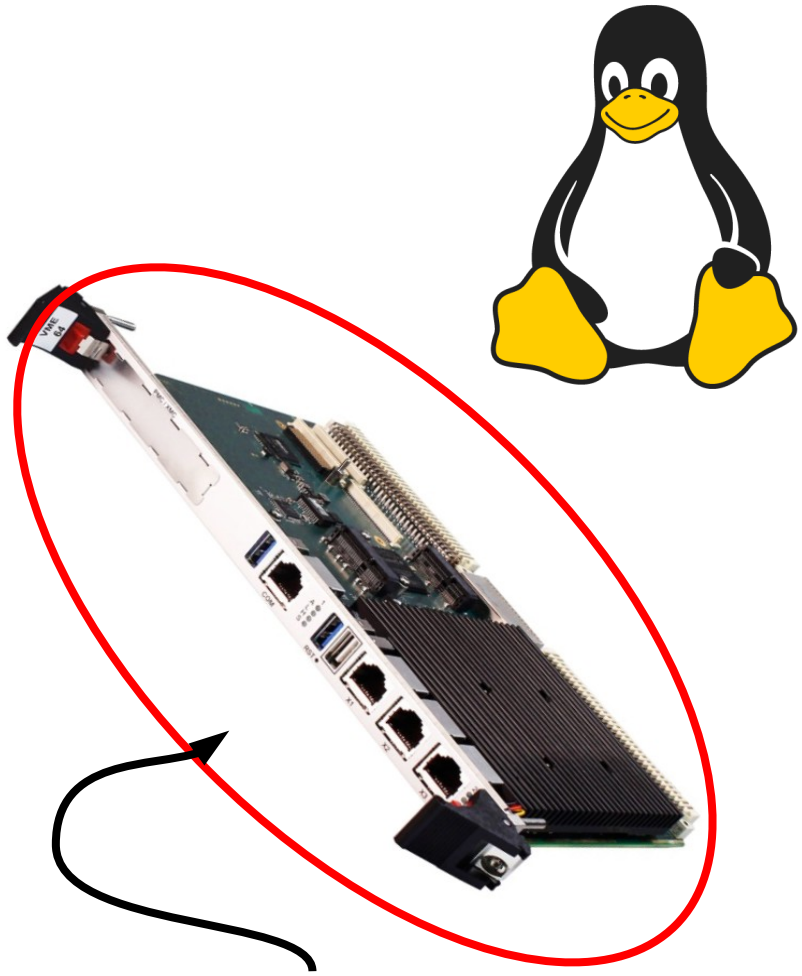


How Does The Next OS Boot?



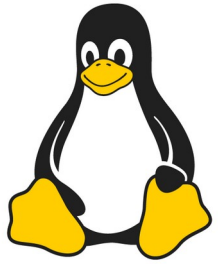


How Does The Next OS Boot?

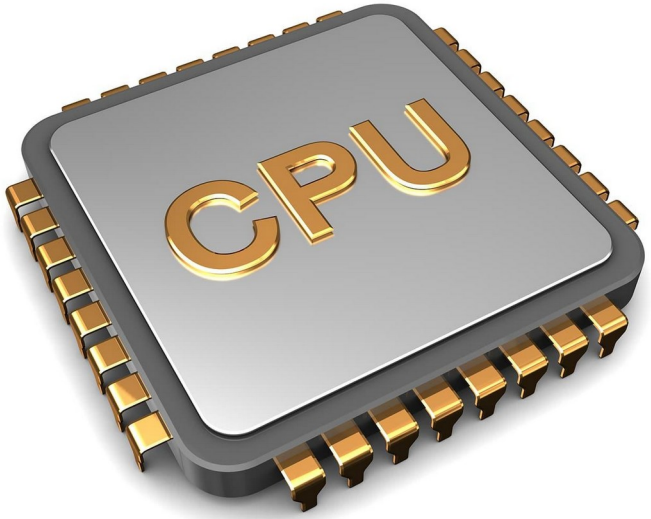


(diskless – network boot)

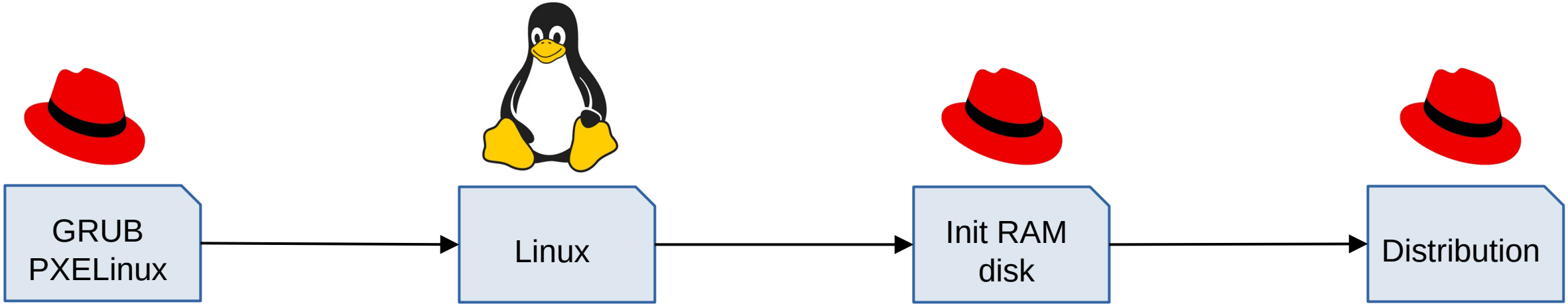
How Does CentOS 7 Boot?

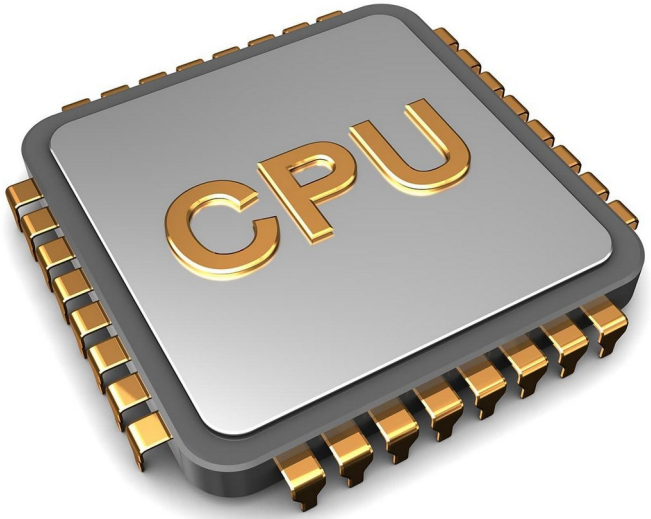


GRUB PXELinux → Linux → Init RAM disk → Distribution



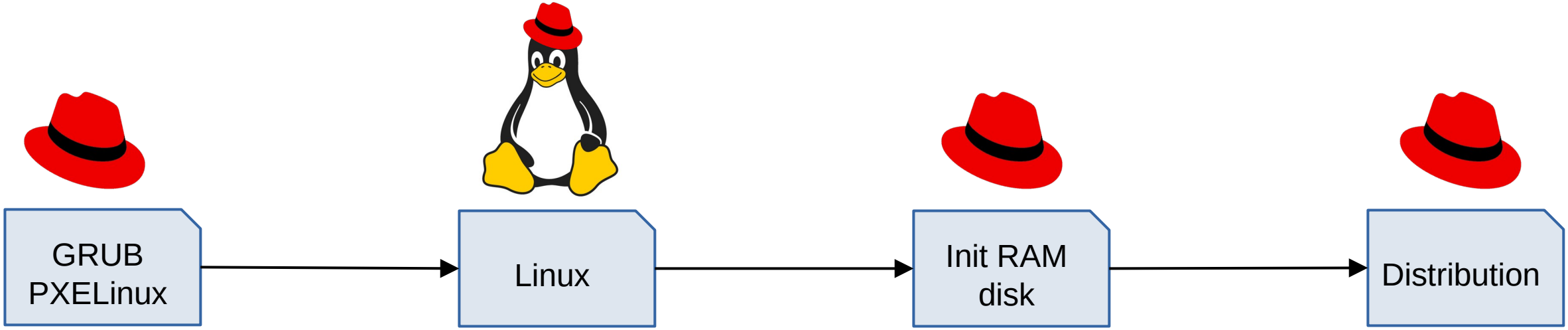
How Does CentOS 7 Boot?

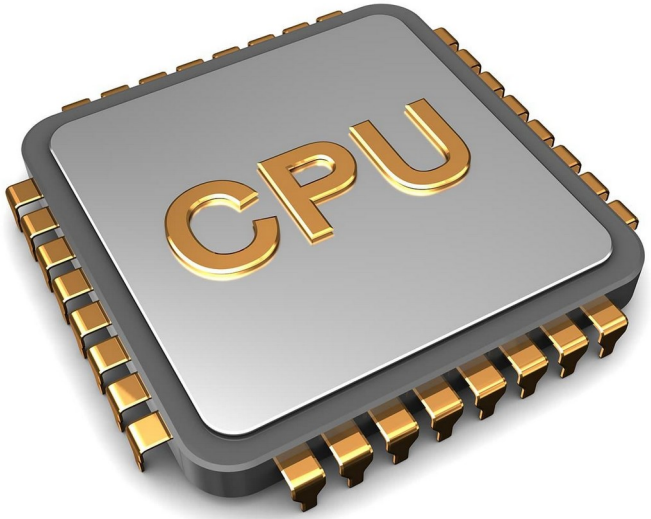




www.redhat.com

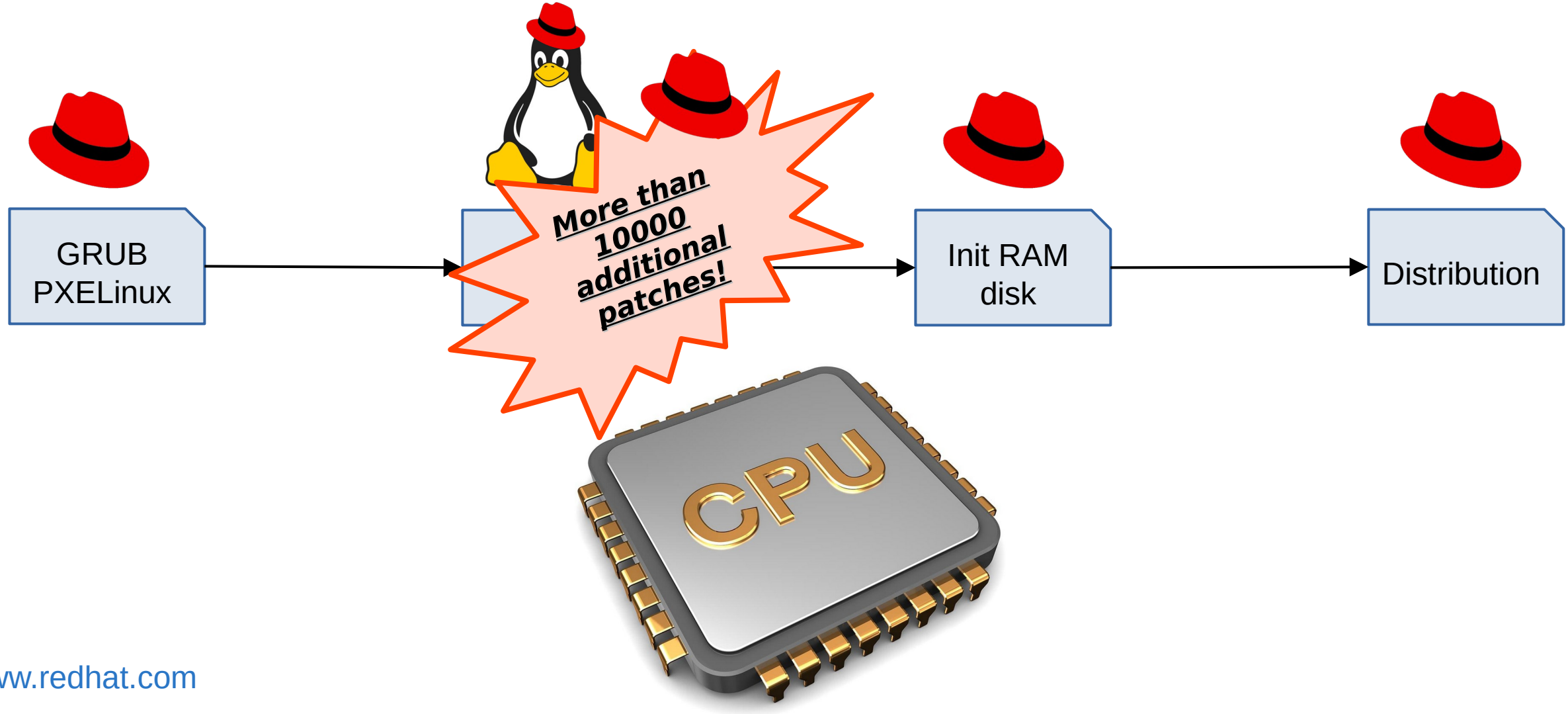
How Does CentOS 7 Boot?





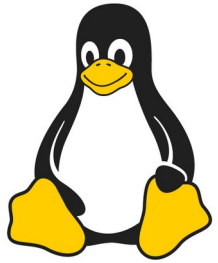
www.redhat.com

How Does CentOS 7 Boot?



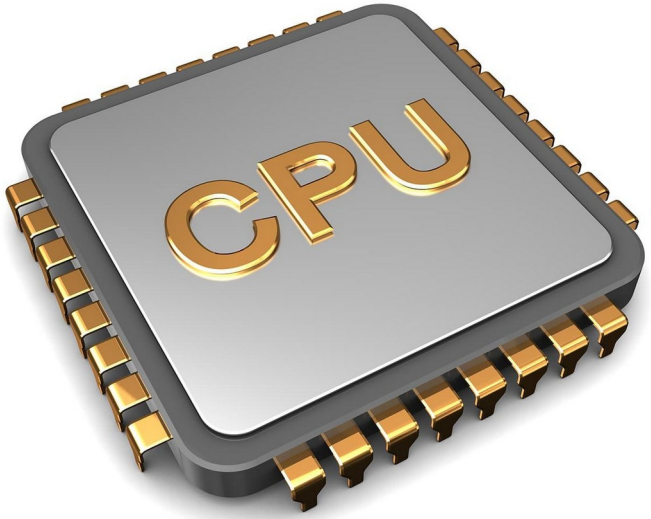
www.redhat.com

How Does The Next OS Boot?

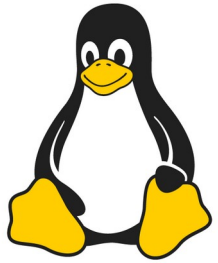


DRA
CUT

GRUB → Linux → Init RAM disk → Distribution



How Does The Next OS Boot?



DRA
CUT

GRUB → Linux → Init RAM disk → Distribution

www.gnu.org/software/grub

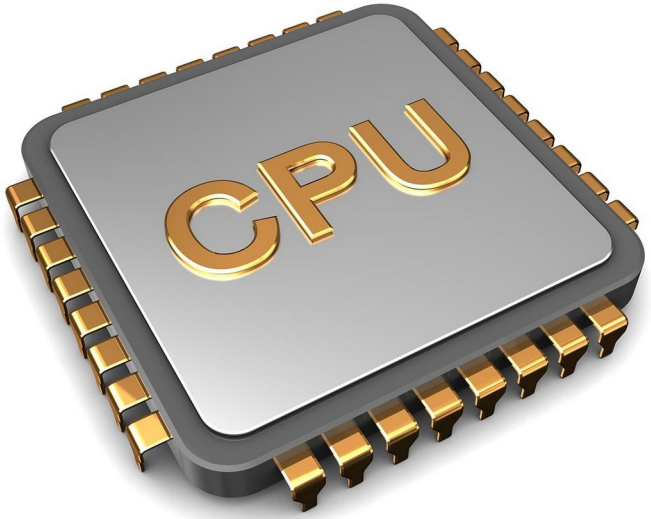
www.kernel.org

dracut.wiki.kernel.org

www.redhat.com

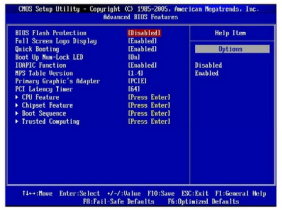
www.centos.org

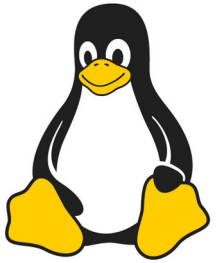
www.debian.org



Isn’t Something Missing?

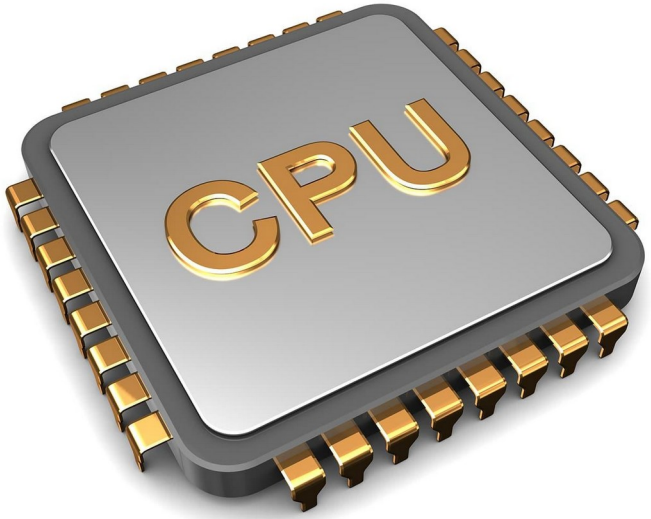
How Does The Next OS Boot?



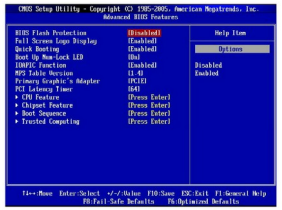


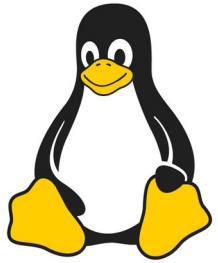
DRA
CUT

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



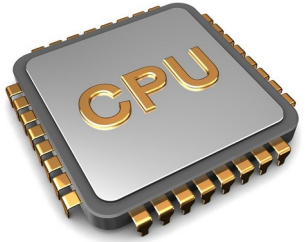
How Does The Next OS Boot Over The Network?



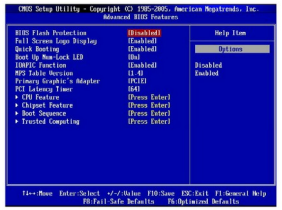


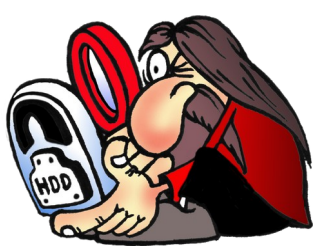
DRA
CUT

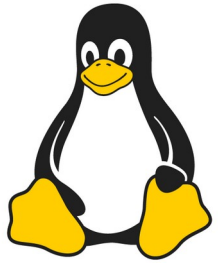
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution



How Does The Next OS Boot Over The Network?

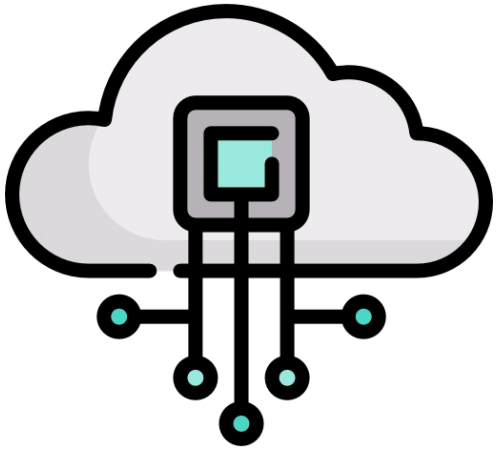


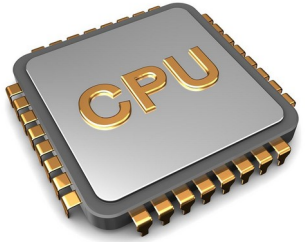




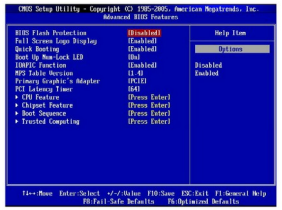
DRA
CUT

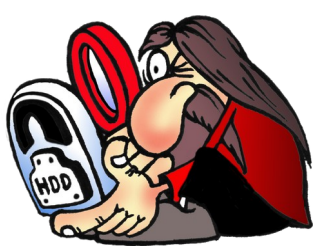
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution

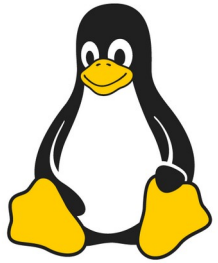




How Does The Next OS Boot Over The Network?

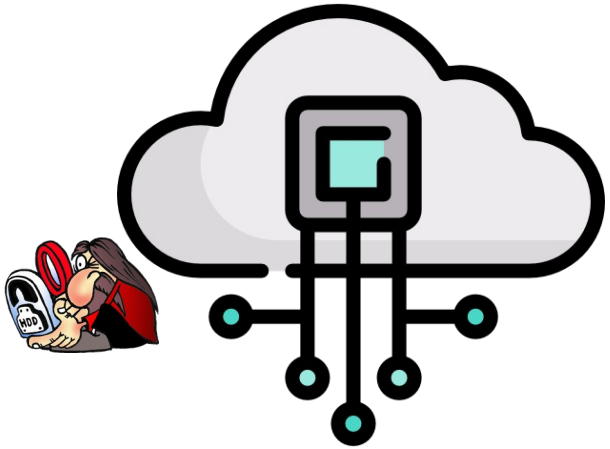


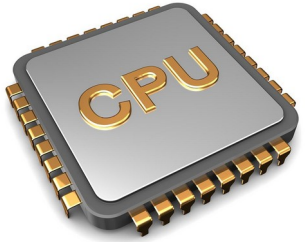




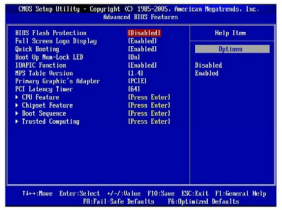
DRA
CUT

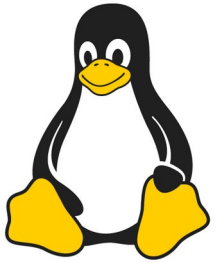
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution





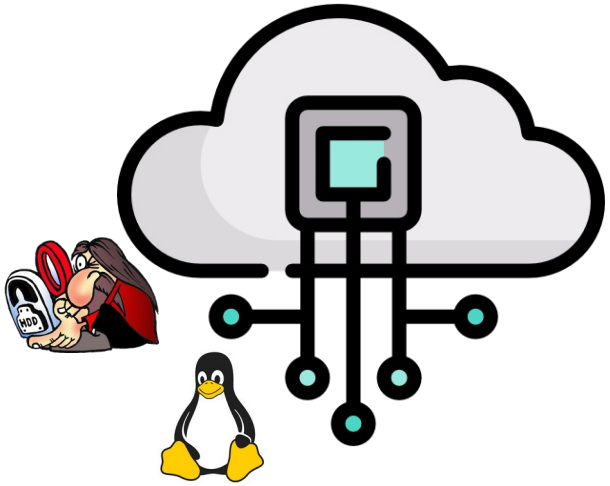
How Does The Next OS Boot Over The Network?

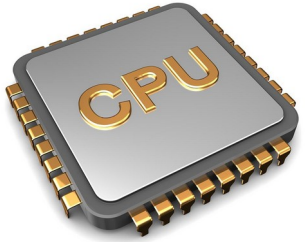




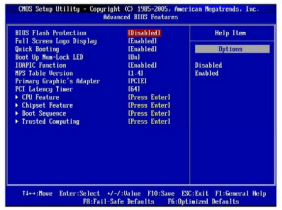
DRA
CUT

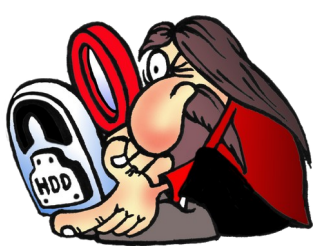
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution

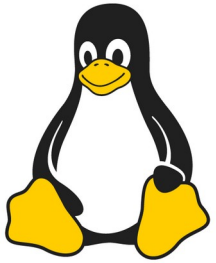




How Does The Next OS Boot Over The Network?

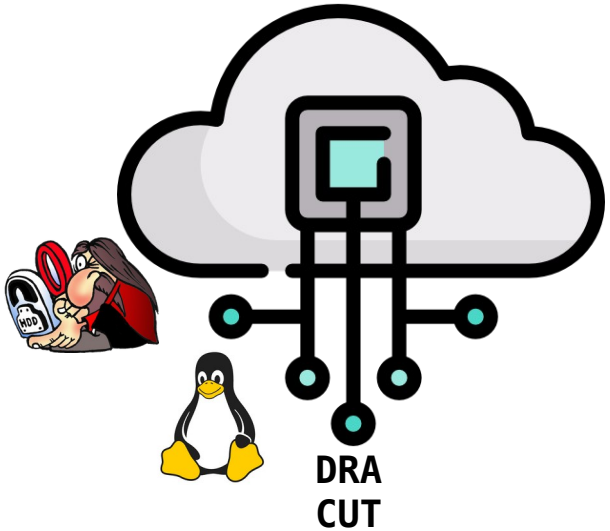


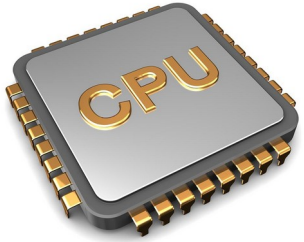




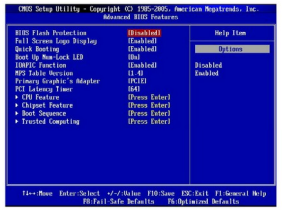
DRA
CUT

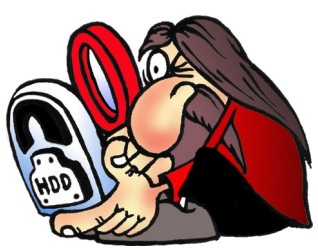
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution

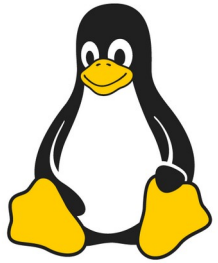




How Does The Next OS Boot Over The Network?

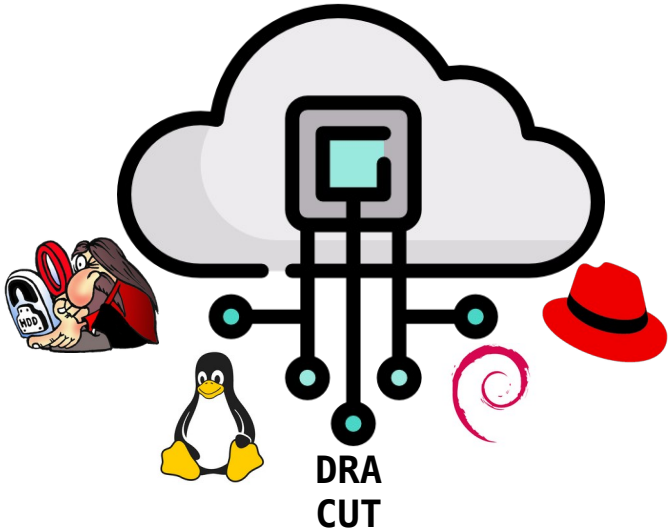


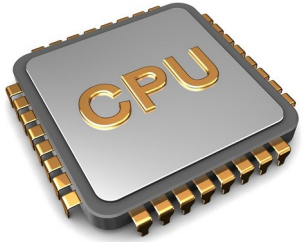




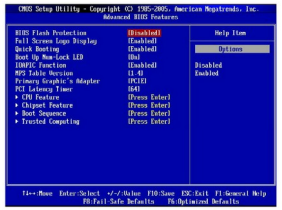
DRA
CUT

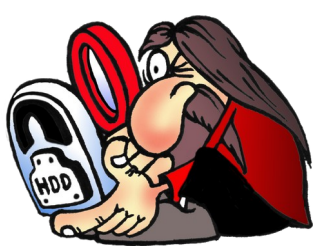
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution

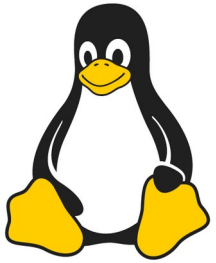




How Does The Next OS Boot Over The Network?

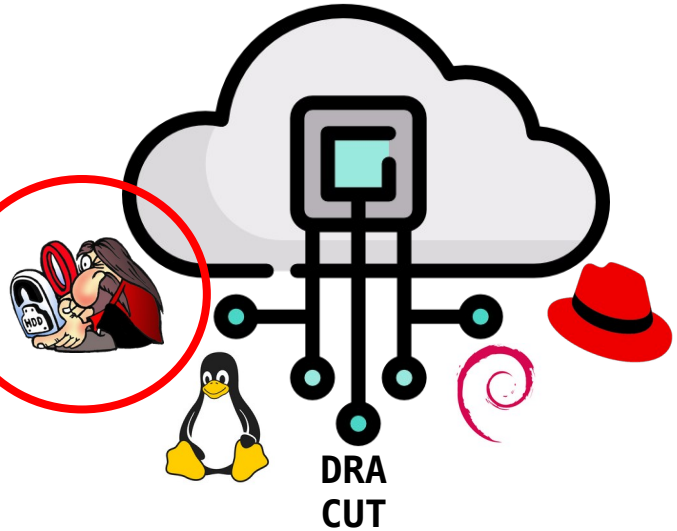


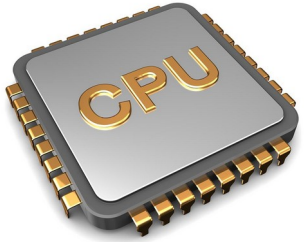




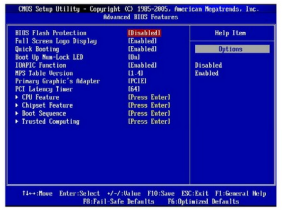
DRA
CUT

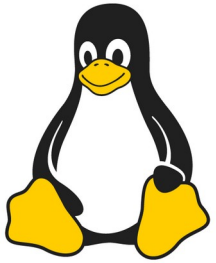
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution





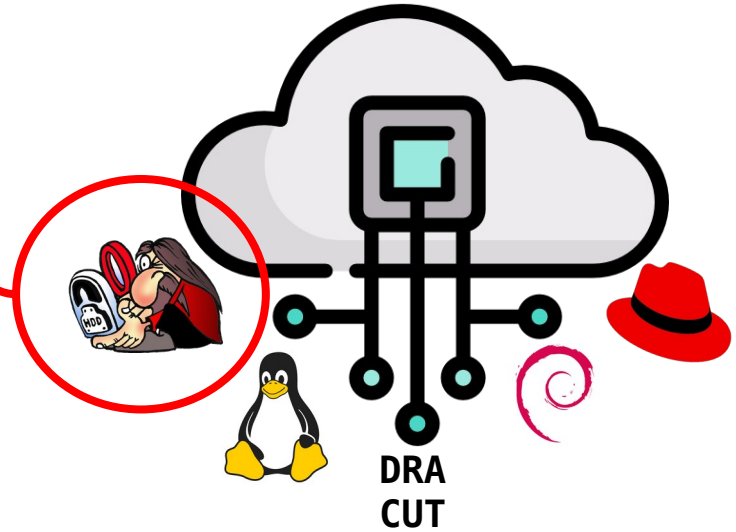
How Does The Next OS Boot Over The Network?

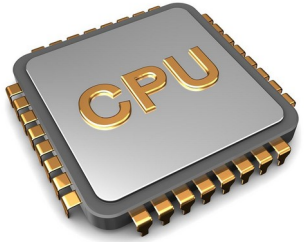




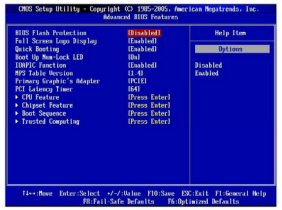
DRA
CUT

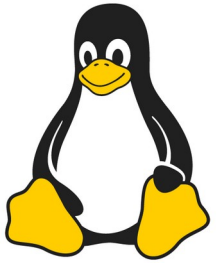
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution





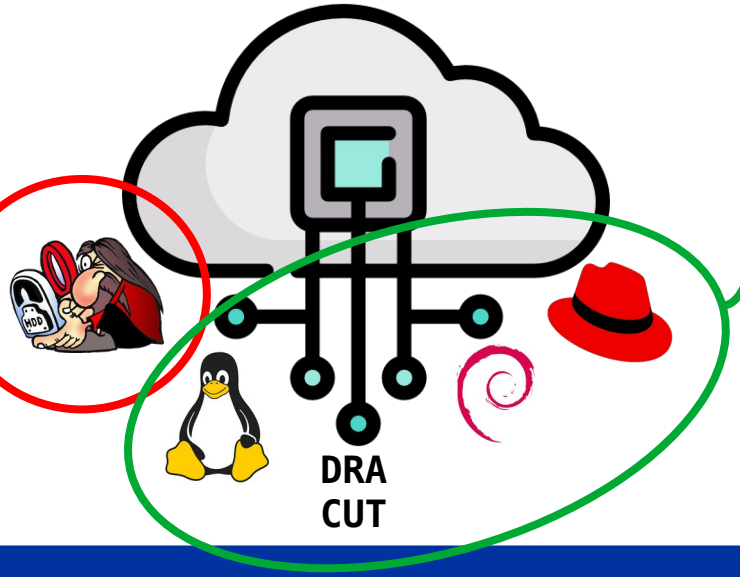
How Does The Next OS Boot Over The Network?

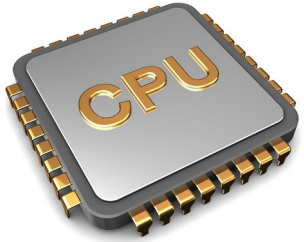




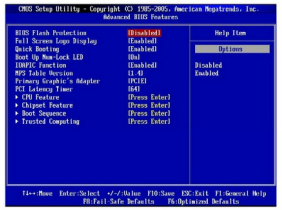
DRA
CUT

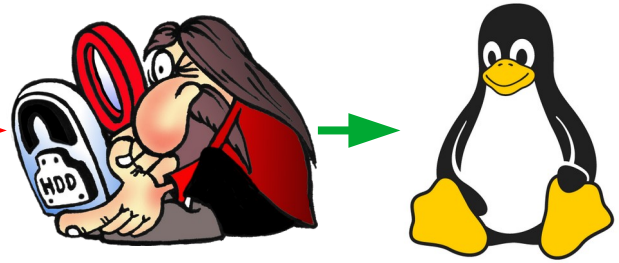
BIOS
EFI Firmware → GRUB → Linux → Init RAM disk → Distribution





How Does The Next OS Boot Over The Network?





DRA
CUT

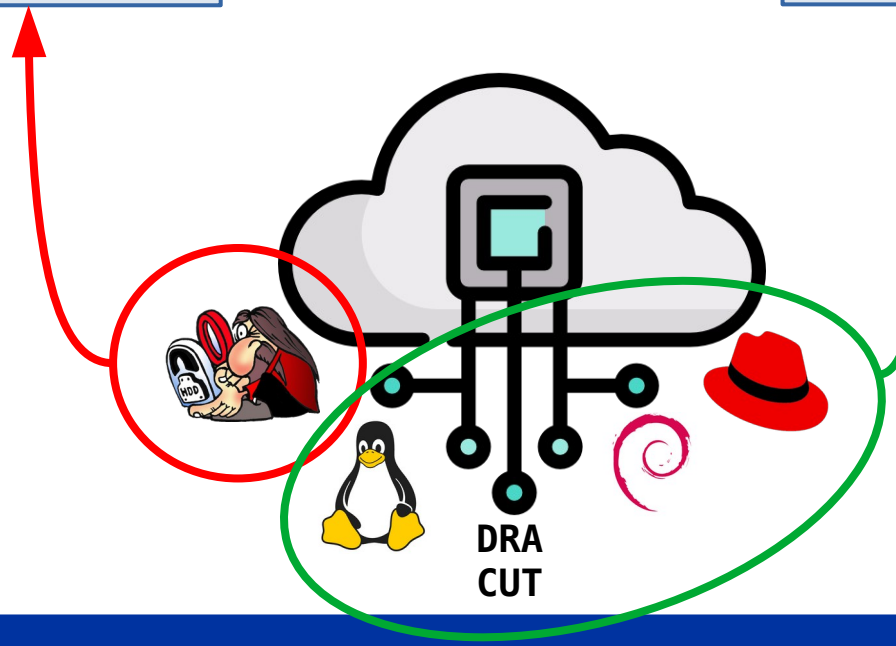
BIOS
EFI Firmware

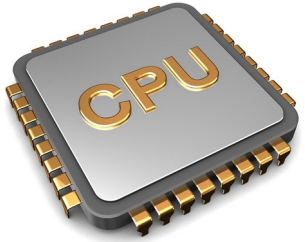
GRUB

Linux

Init RAM
disk

Distribution





Projects References

	Project	Reference	Architectures	Binary Distribution
Bootloader	fec-bootloader	GRUB (2.06)	x86_64 aarch64	Gitlab Registry
Linux	fec-os-kernel	Linux Stable (5.10.x)	x86_64 aarch64 (Zynq UltraScale+)	Gitlab Registry
Init Ramdisk	fec-os-initramfs	Dracut (056)	x86_64 aarch64	Gitlab Registry
Distribution	fec-os-distribution	CentOS Stream (8) Debian (11)	x86_64 aarch64	Manual

Why Two Linux Distributions?

Why Two Linux Distributions?

Why Two Linux Distributions?

- **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

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
- **It is relatively cheap to *maintain* both solutions**
  - After a first investment in portability, it is easy to maintain

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
- **It is relatively cheap to *maintain* both solutions**
  - After a first investment in portability, it is easy to maintain
- **It allows us to have an exit strategy**
  - We can always easily move to the second distribution if needed

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
- **It is relatively cheap to *maintain* both solutions**
  - After a first investment in portability, it is easy to maintain
- **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?

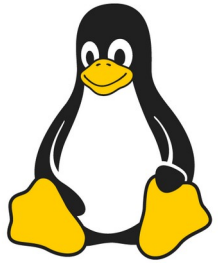
Actually, U-Boot boots GRUB

GRUB On SoC? Why not U-Boot?

Actually, U-Boot boots GRUB

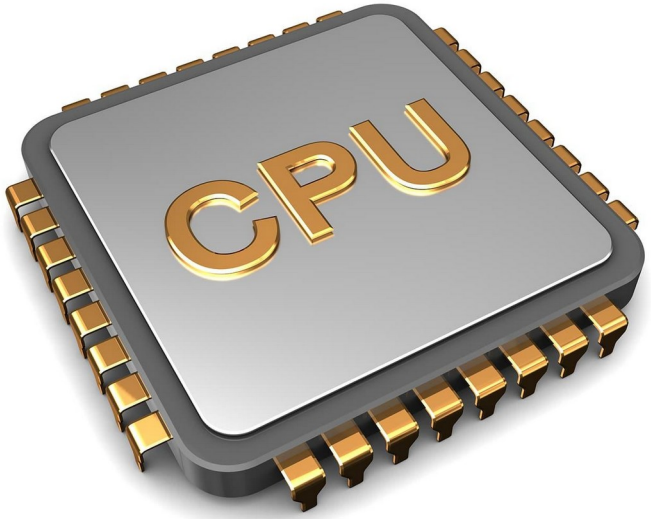
Even more confusing! Why?

How Does The Next OS Boot?

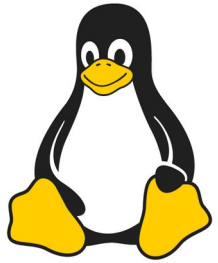


DRA
CUT

GRUB → Linux → Init RAM disk → Distribution

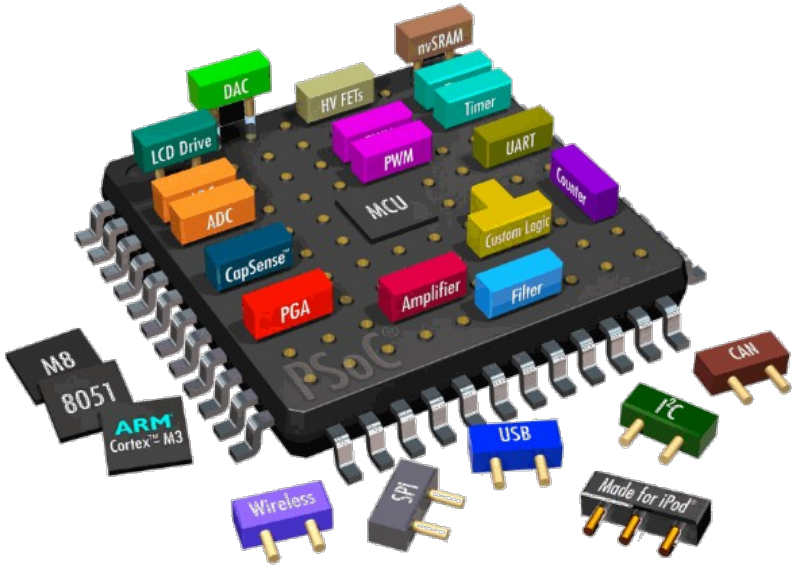


How Does The Next OS Boot On SoC?

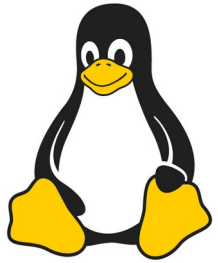


DRA
CUT

GRUB → Linux → Init RAM disk → Distribution

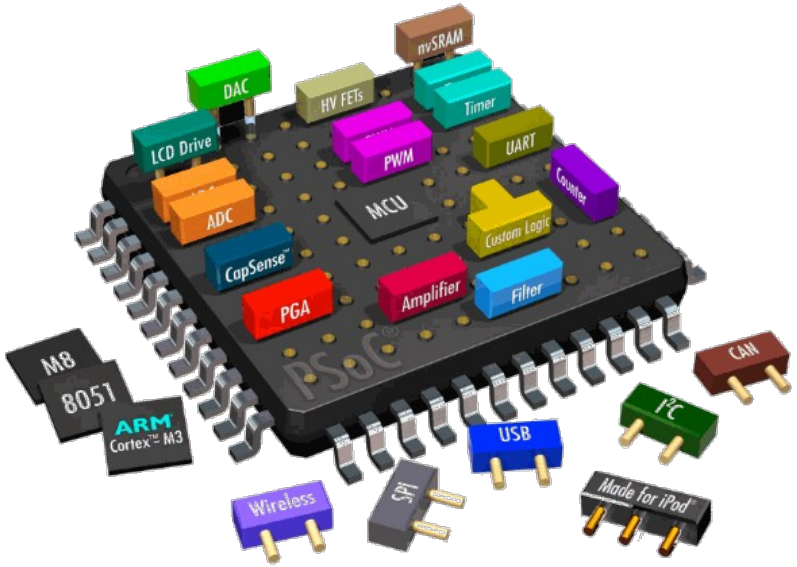


How Does The Next OS Boot On SoC?



DRA
CUT

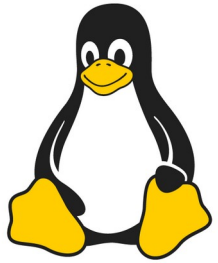
U-Boot → Linux → Init RAM disk → Distribution



GRUB On SoC? Why not U-Boot?

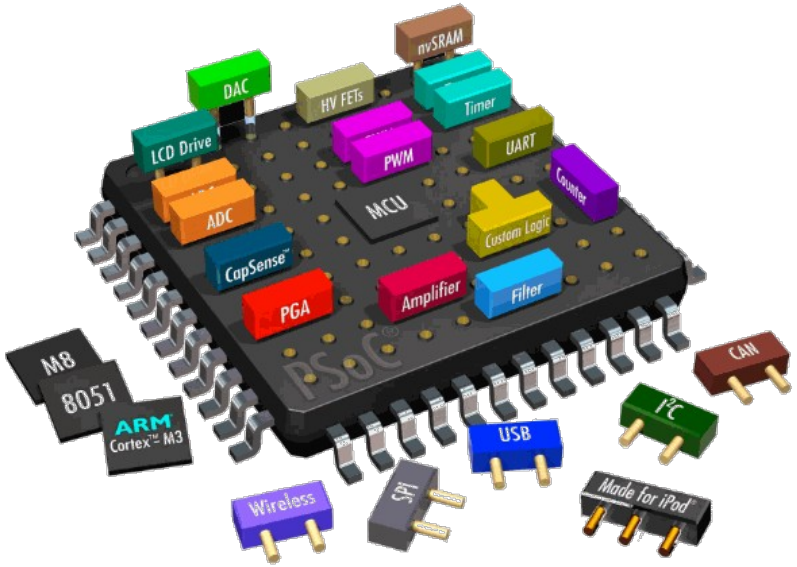
- **It is not a choice based on functional requirements**
  - In terms of functional requirements there is not a clear winner: both would do
- **It is a design choice based on non-functional requirements**
  - We want a uniform installation across all supported platforms
  - We do not want to be exposed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

How Does The Next OS Boot On SoC?

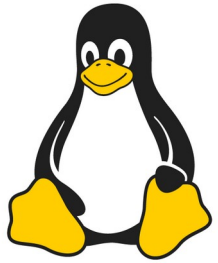


DRA
CUT

GRUB → Linux → Init RAM disk → Distribution

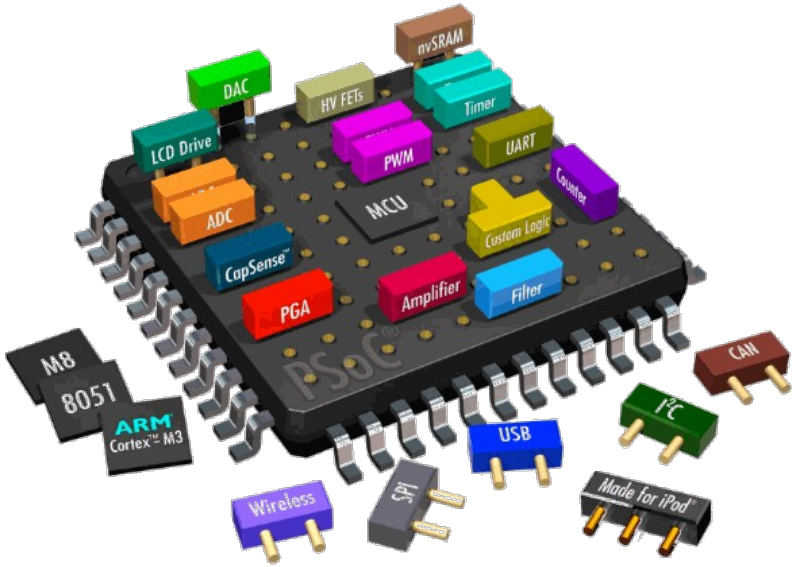


How Does The Next OS Boot On SoC?

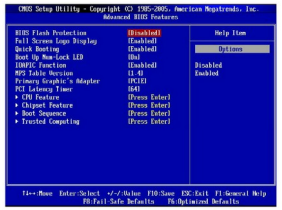


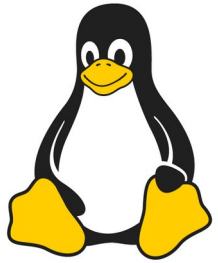
DRA
CUT

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



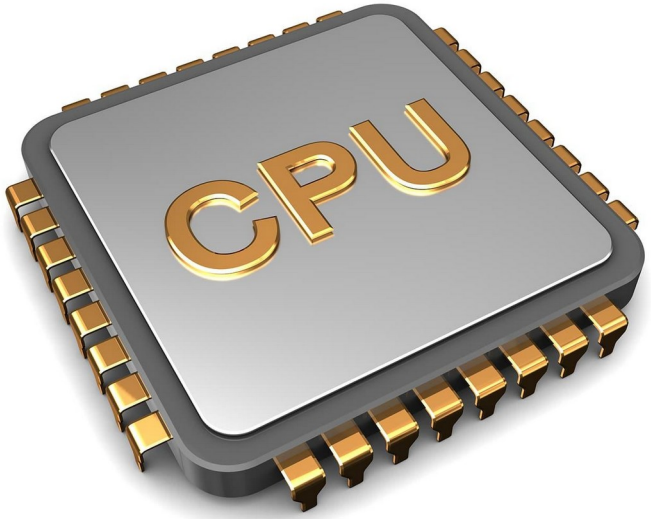
How Does The Next OS Boot?



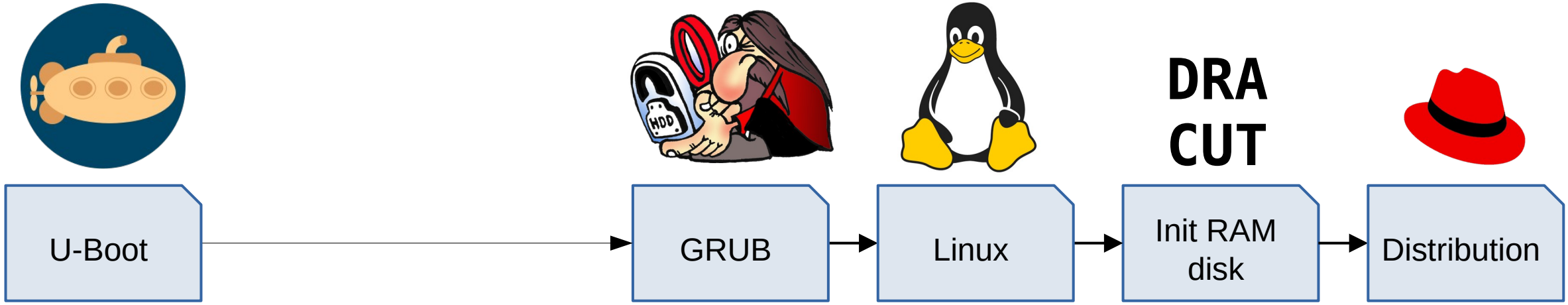


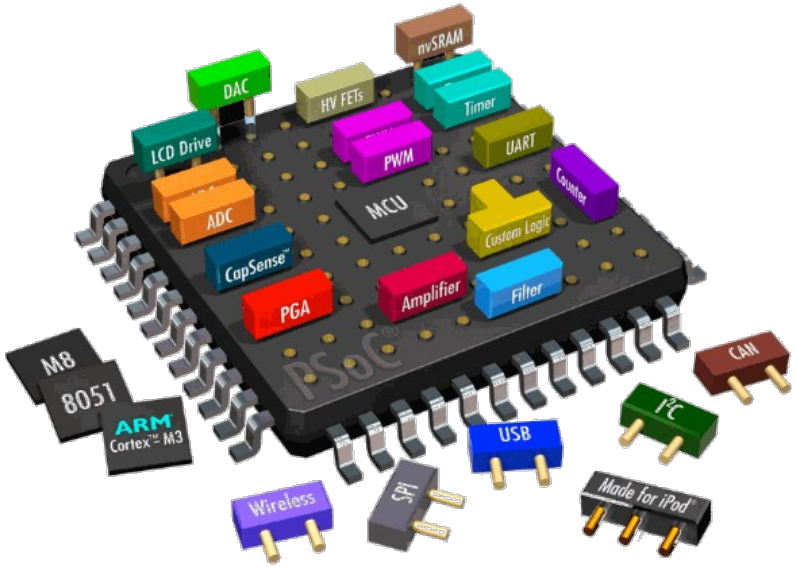
DRA
CUT

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

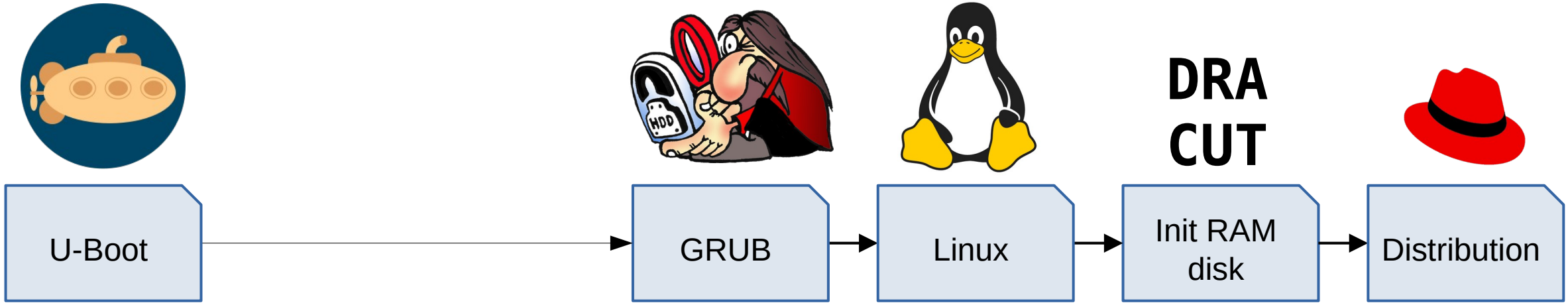


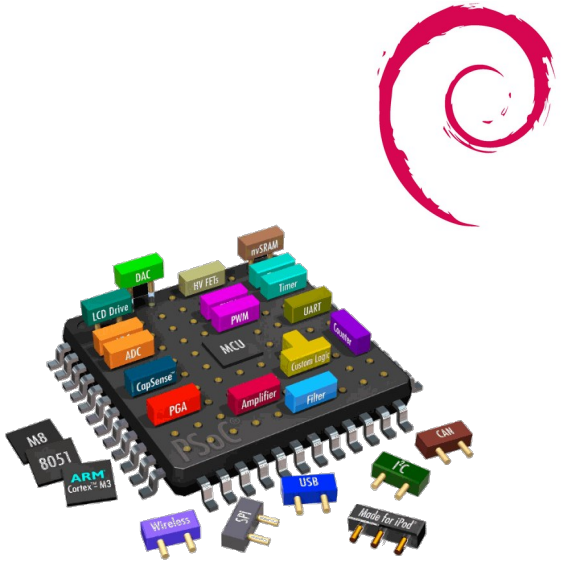
How Does The Next OS Boot On SoC?



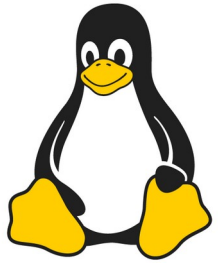


How Does The Next OS Boot On SoC?



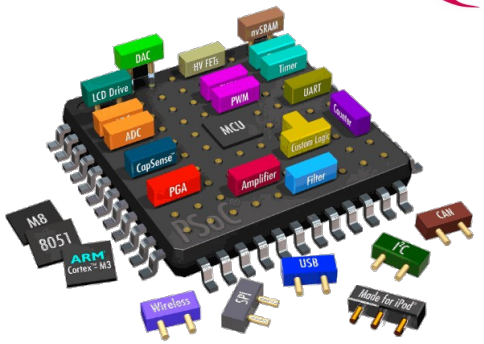


How Does The Next OS Boot On SoC?

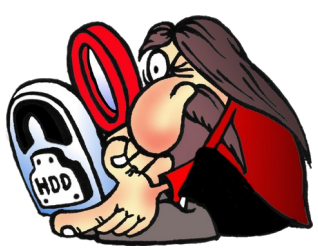


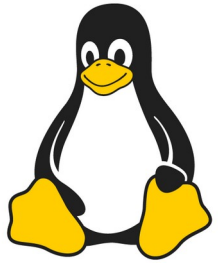
DRA
CUT

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



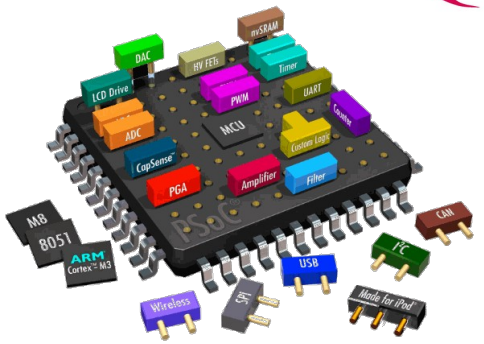
How Does The Next OS Boot On SoC?



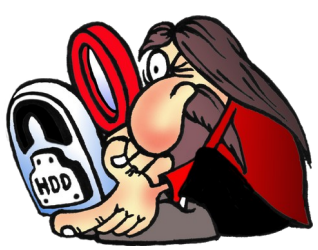


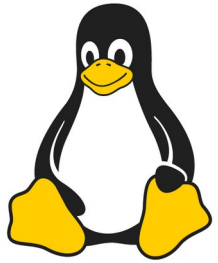
DRA
CUT

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



How Does The Next OS Boot On SoC?

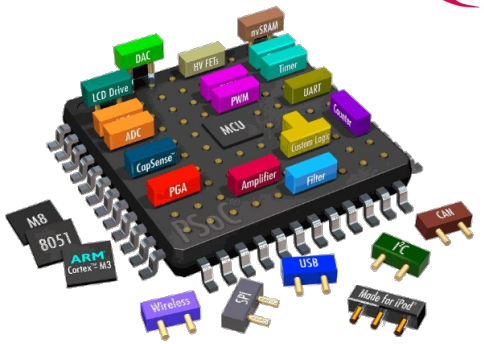




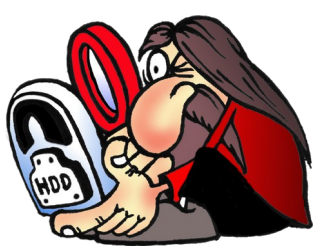
DRA
CUT

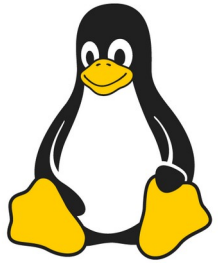
FSBL and friends → U-Boot → GRUB → Linux → Init RAM disk → Distribution

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



How Does The Next OS Boot On SoC?



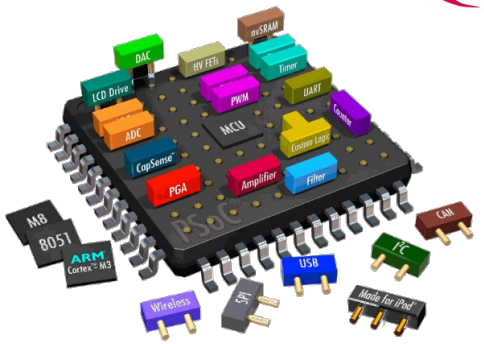


DRA
CUT

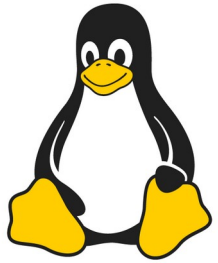
FSBL and friends → U-Boot → GRUB → Linux → Init RAM disk → Distribution

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

Operating System development and support
- Network booting infrastrucutre
- 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?

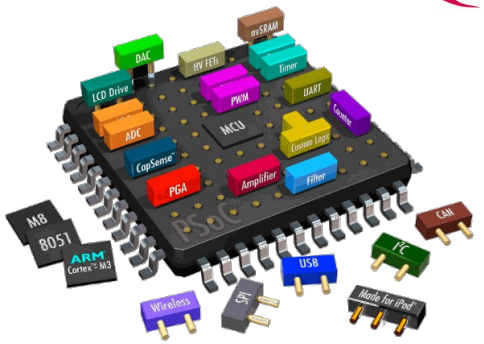


DRA
CUT

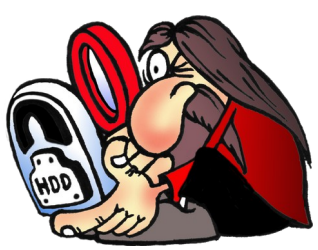
FSBL and friends → Barebox → GRUB → Linux → Init RAM disk → Distribution

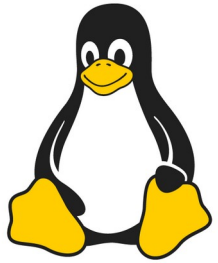
Platform development and support
- Hardware setup
- DeviceTree
- FPGA Configuration

Operating System development and support
- Network booting infrastrucutre
- 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?



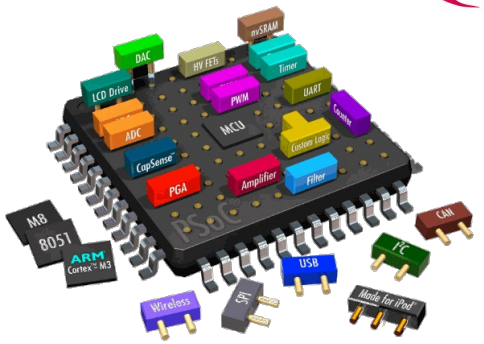


DRA
CUT

FSBL and friends → Barebox → GRUB → Linux → Init RAM disk → Distribution

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

Operating System development and support
- Network booting infrastrucutre
- GRUB configuration
  - Only supported architectures
  - Use SMBIOS info to start Linux
- Linux configuration
  - Only supported platforms
- Linux distribution
  - Only supported architectures



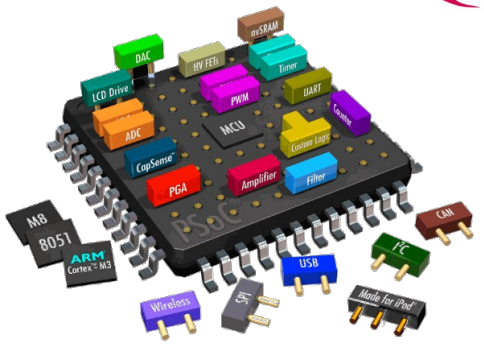
How Does The Next OS Boot On SoC?

DRA CUT

FSBL and friends → Barebox → GRUB → FreeBSD → Init RAM disk → Distribution

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

Operating System development and support
- Network booting infrastrucutre
- GRUB configuration
  - Only supported architectures
  - Use SMBIOS info to start Linux
- Linux configuration
  - Only supported platforms
- Linux distribution
  - Only supported architectures



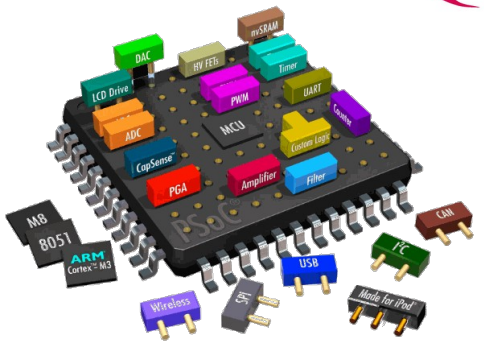
How Does The Next OS Boot On SoC?

DRA CUT

FSBL and friends → U-Boot → U-Boot → FreeBSD → Init RAM disk → Distribution

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

Operating System development and support
- Network booting infrastrucutre
- GRUB configuration
  - Only supported architectures
  - Use SMBIOS info to start Linux
- Linux configuration
  - Only supported platforms
- Linux distribution
  - Only supported architectures



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))
    - execute GRUB as an EFI application

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

TFTP

deploy

```
$ ls -1 /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

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

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

flash

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

flash

U-Boot

```
> 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
```

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

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

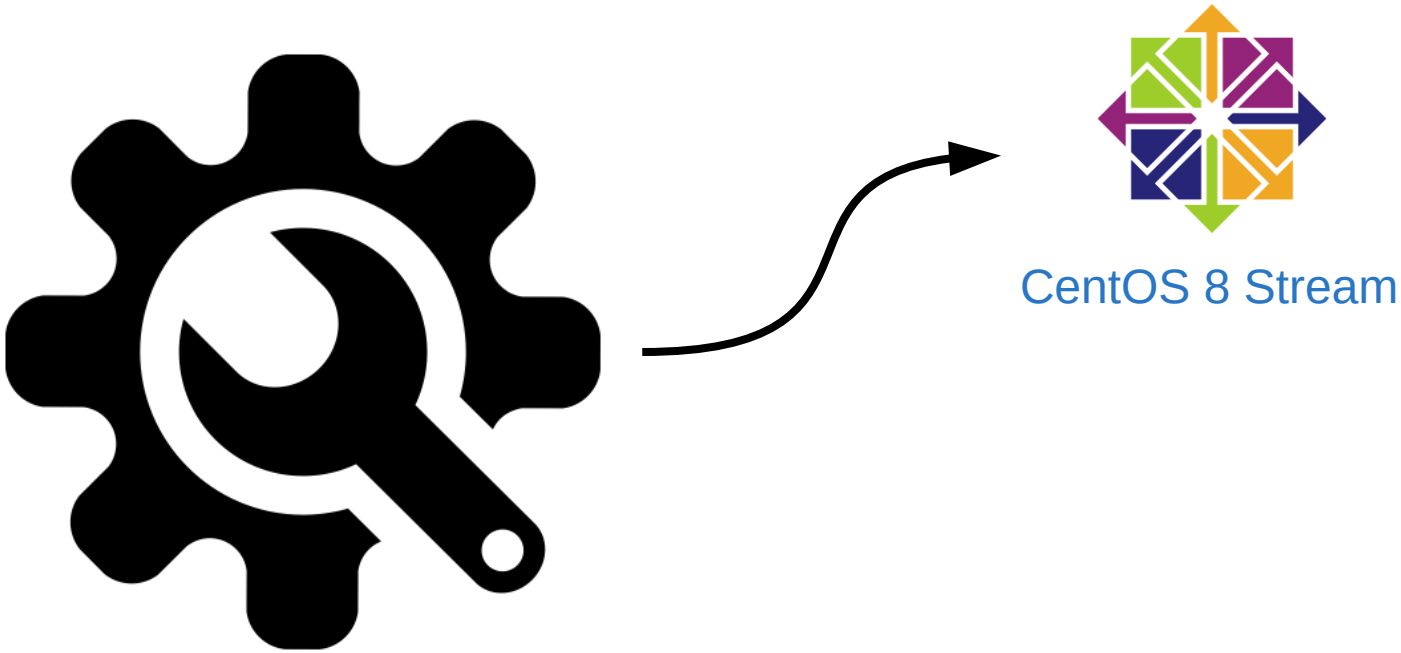
Info at
fec-os-support@cern.ch
or
federico.vaga@cern.ch

BACKUP SLIDES

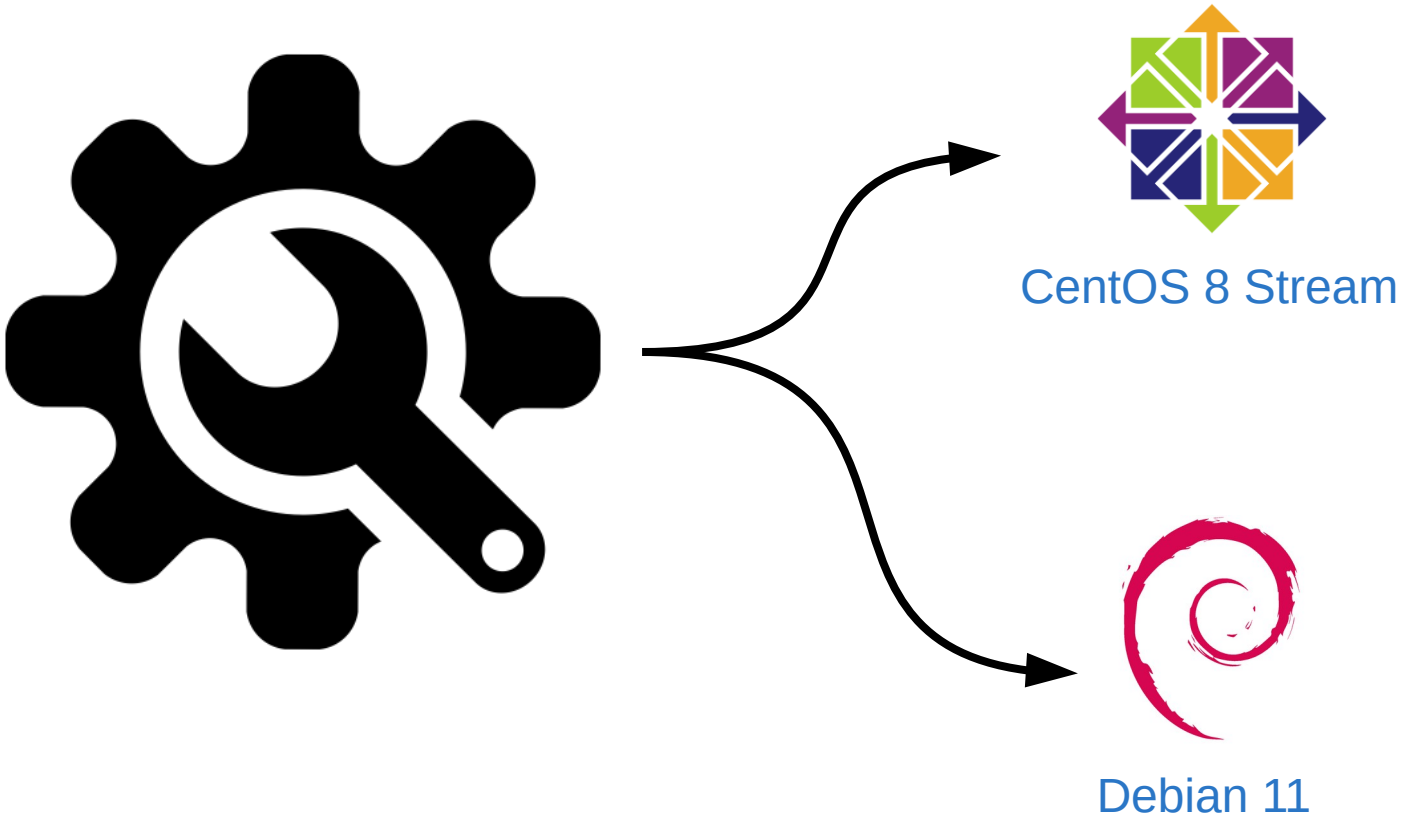
How Do We Build The Linux Images?

How Do We Build The Linux Images?

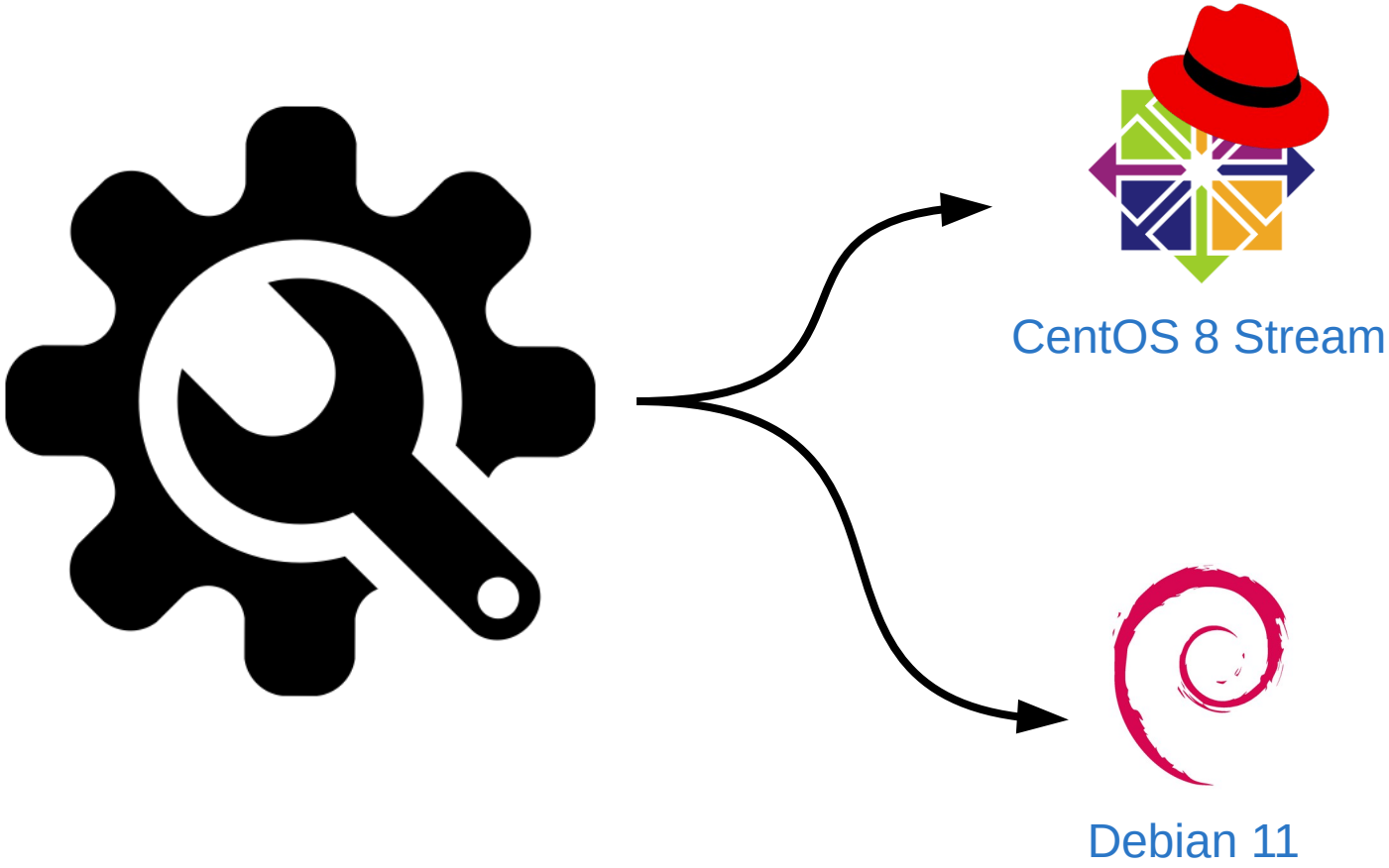
How Do We Build The Linux Images?



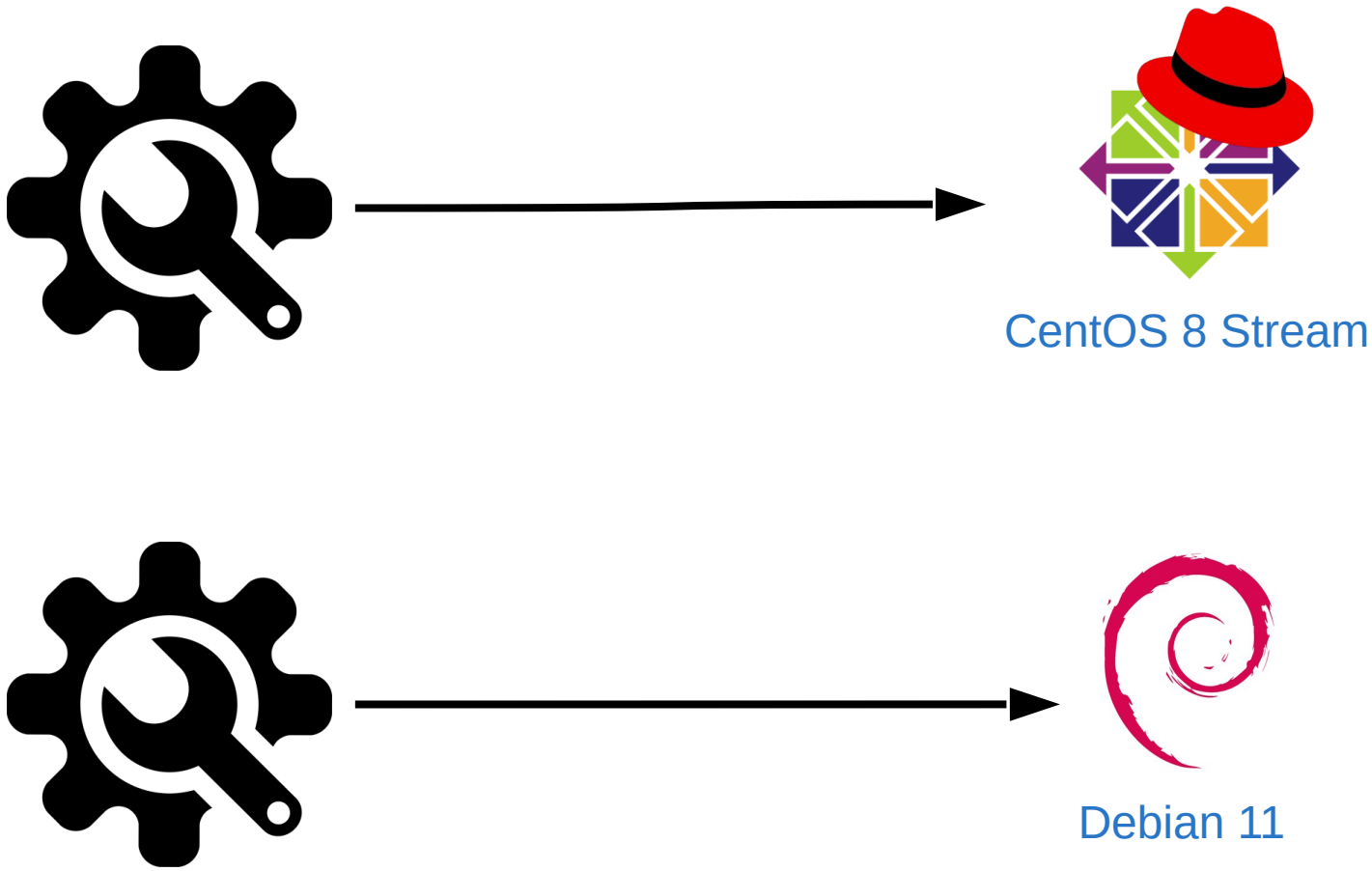
How Do We Build The Linux Images?



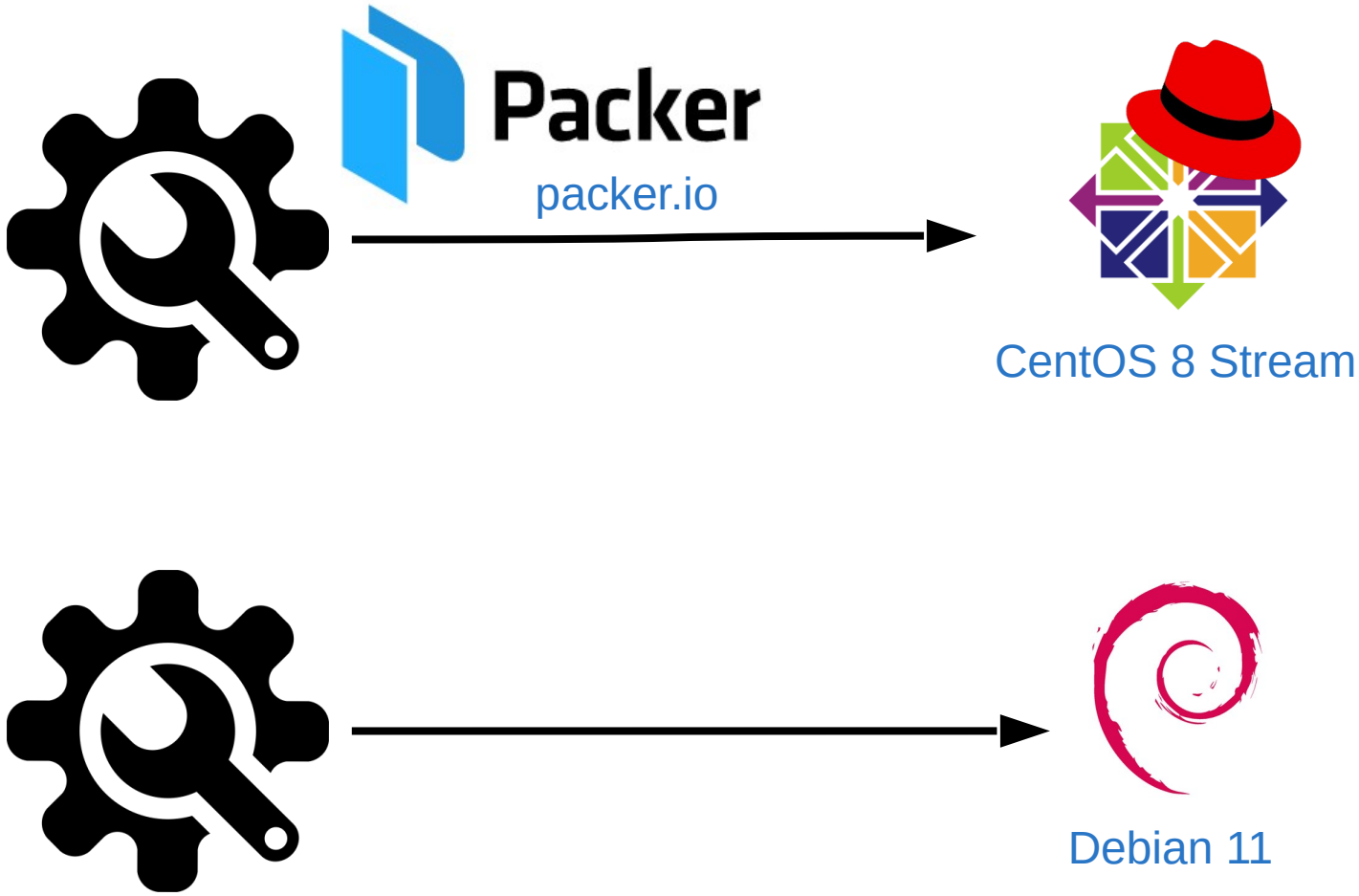
How Do We Build The Linux Images?



How Do We Build The Linux Images?



How Do We Build The Linux Images?



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

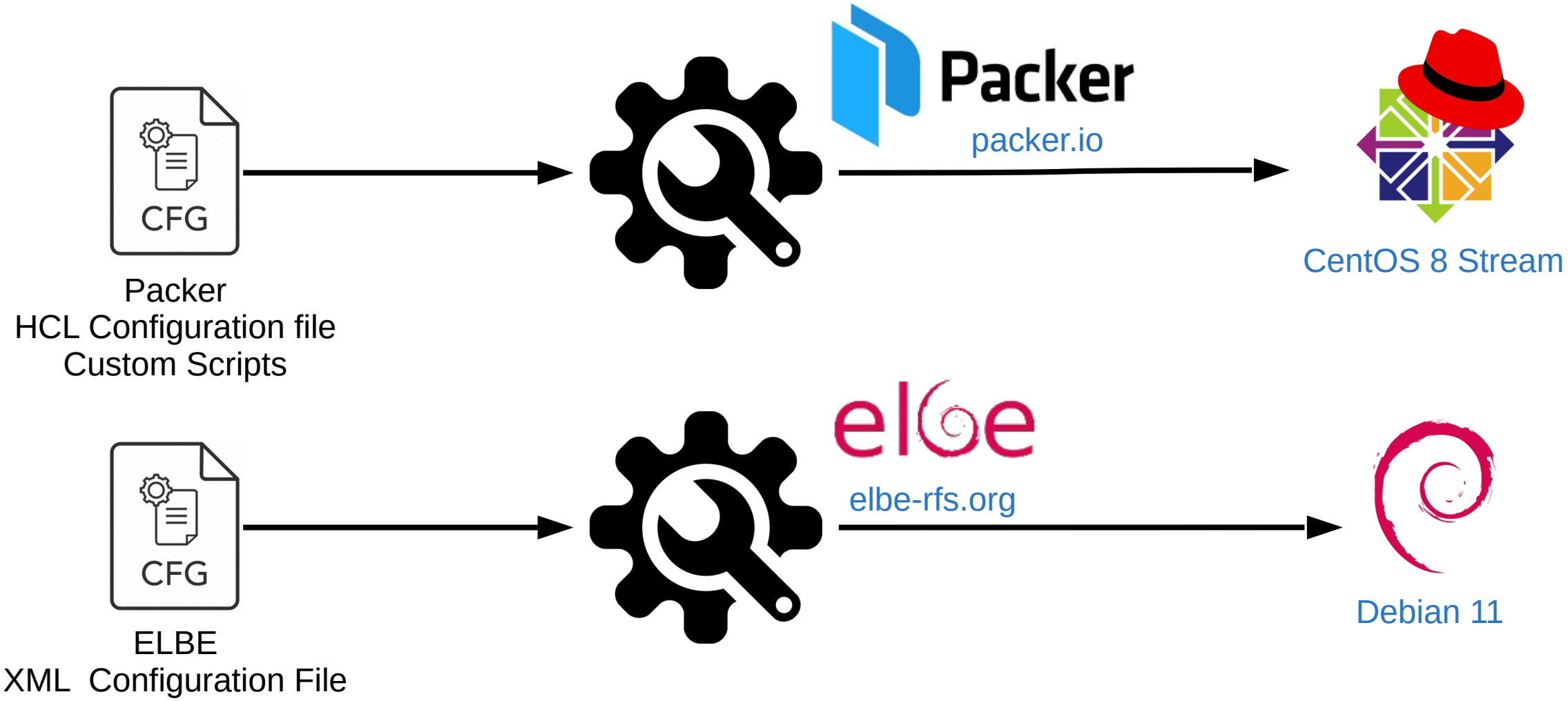
Packer
packer.io

CentOS 8 Stream

elbe
elbe-rfs.org

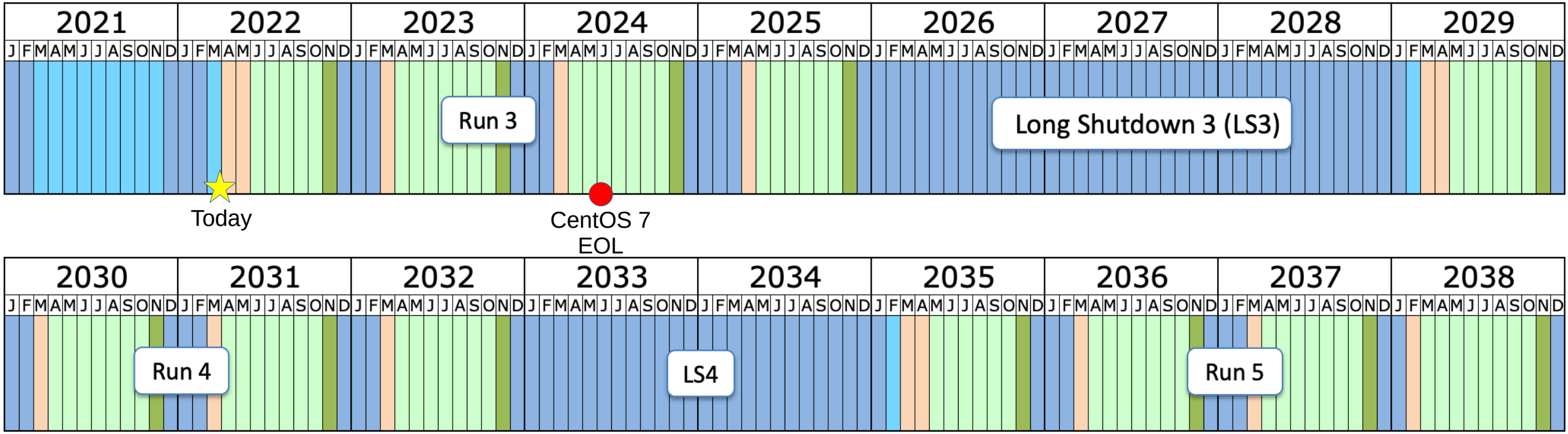
Debian 11

How Do We Build The Linux Images?

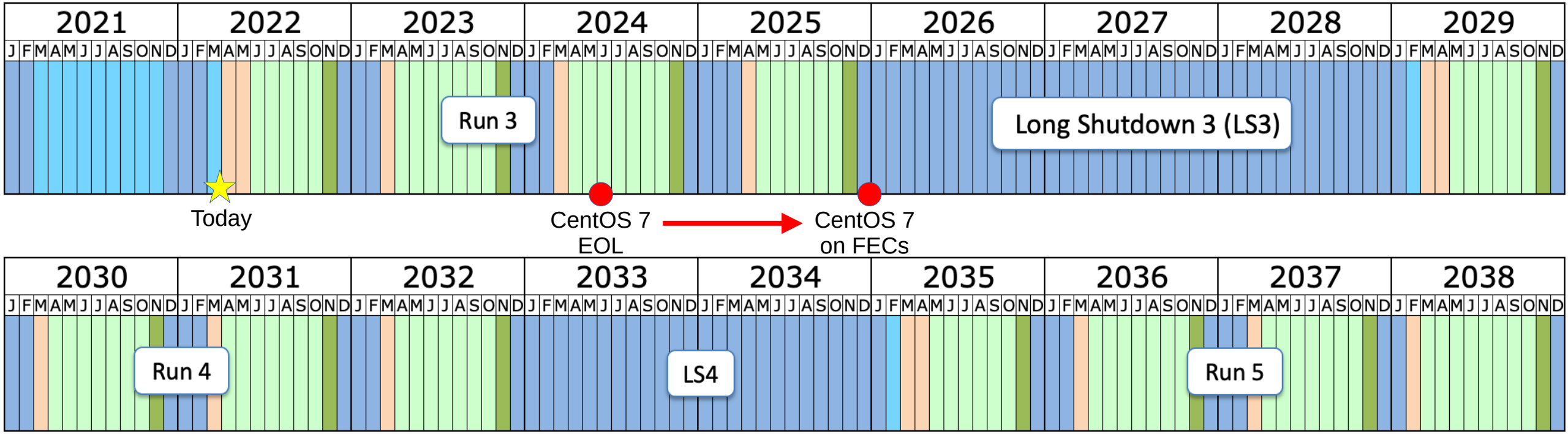


What Is The Project Schedule?

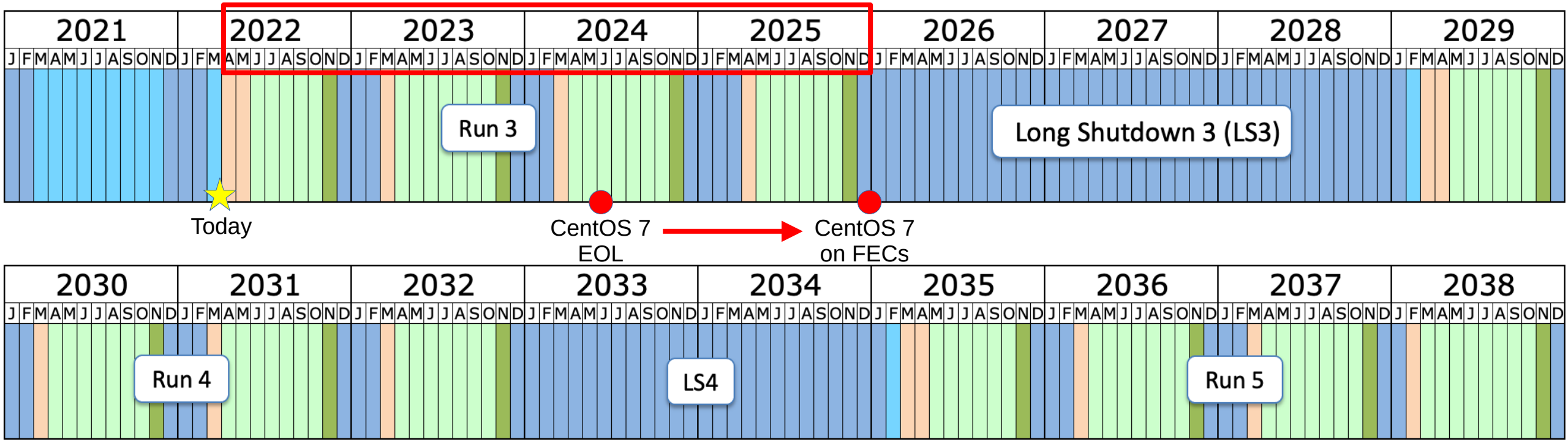
CentOS 7 Extended *Support*



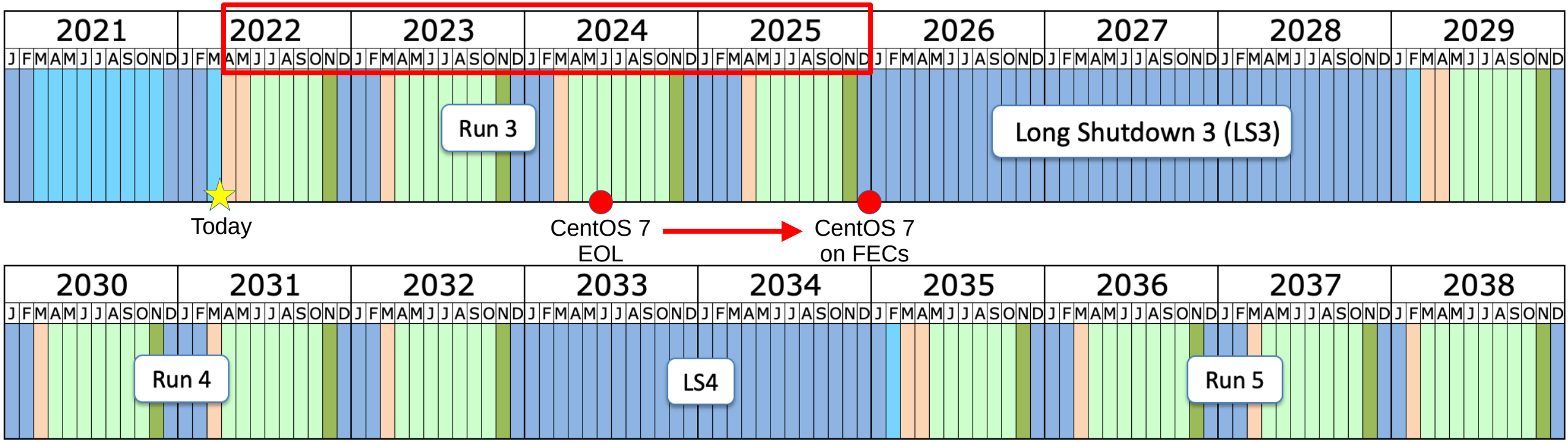
CentOS 7 Extended *Support*



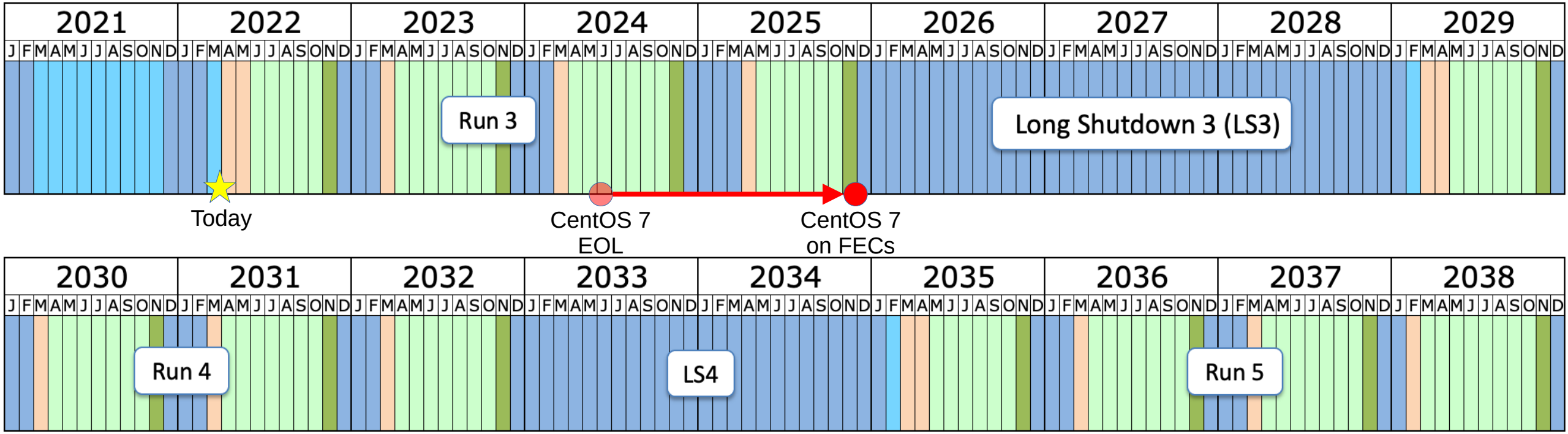
CentOS 7 Extended *Support*



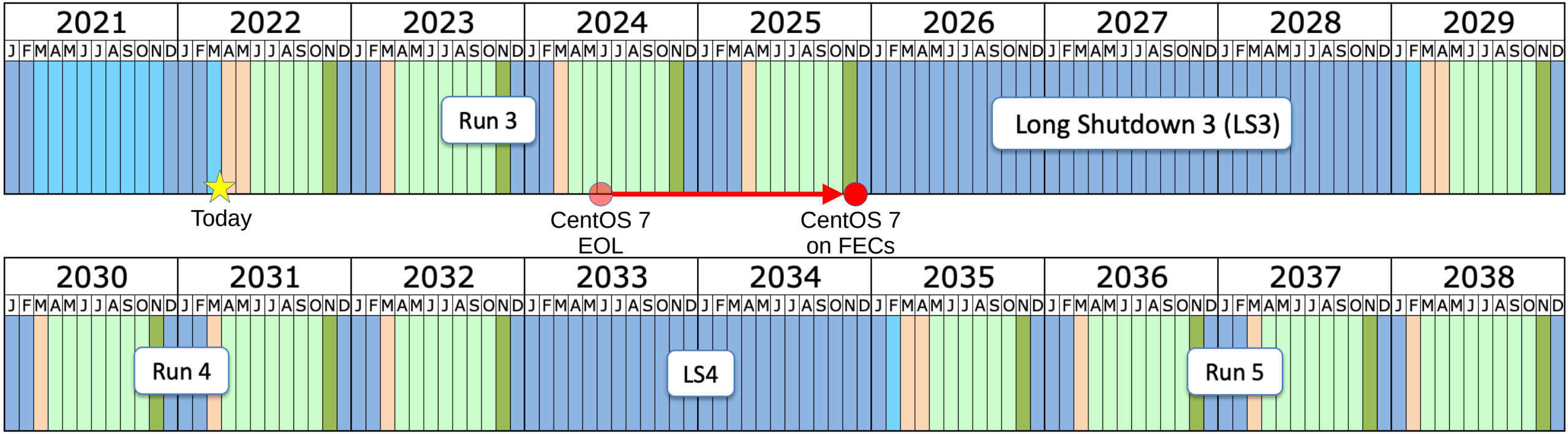
CentOS 7 Extended *Support*



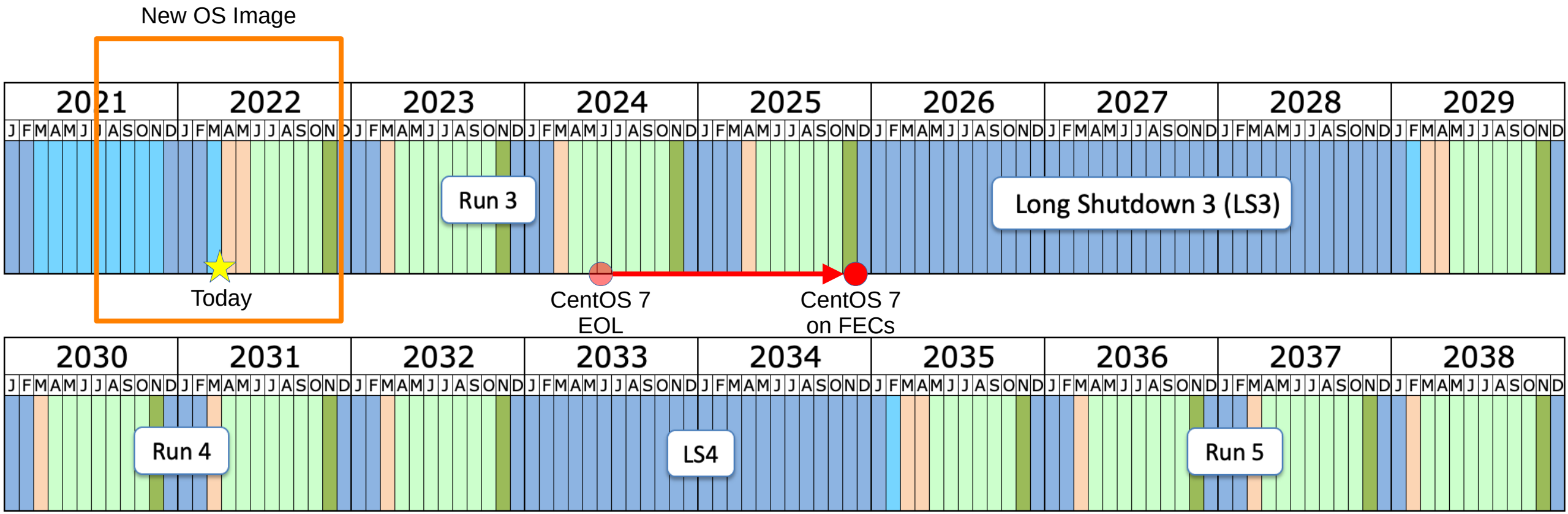
FEC OS Renovation Schedule



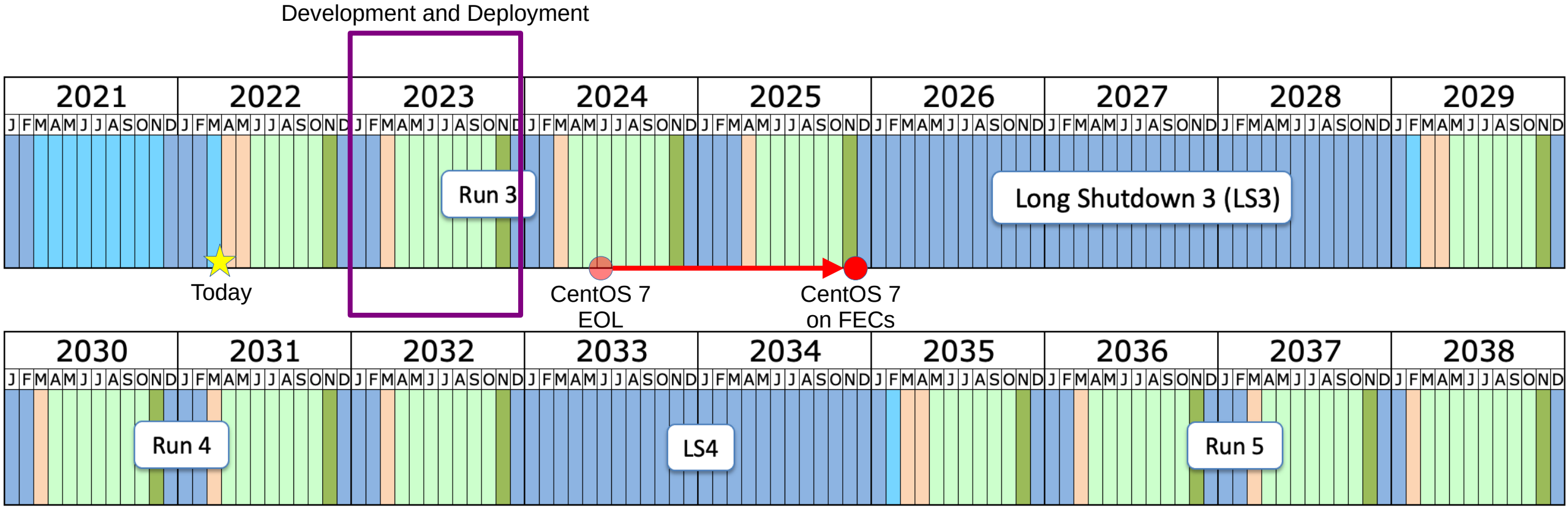
FEC OS Renovation Schedule



FEC OS Renovation Schedule



FEC OS Renovation Schedule



FEC OS Renovation Schedule