SoCks

A Build Framework for Heterogeneous High Performance System-on-Chips

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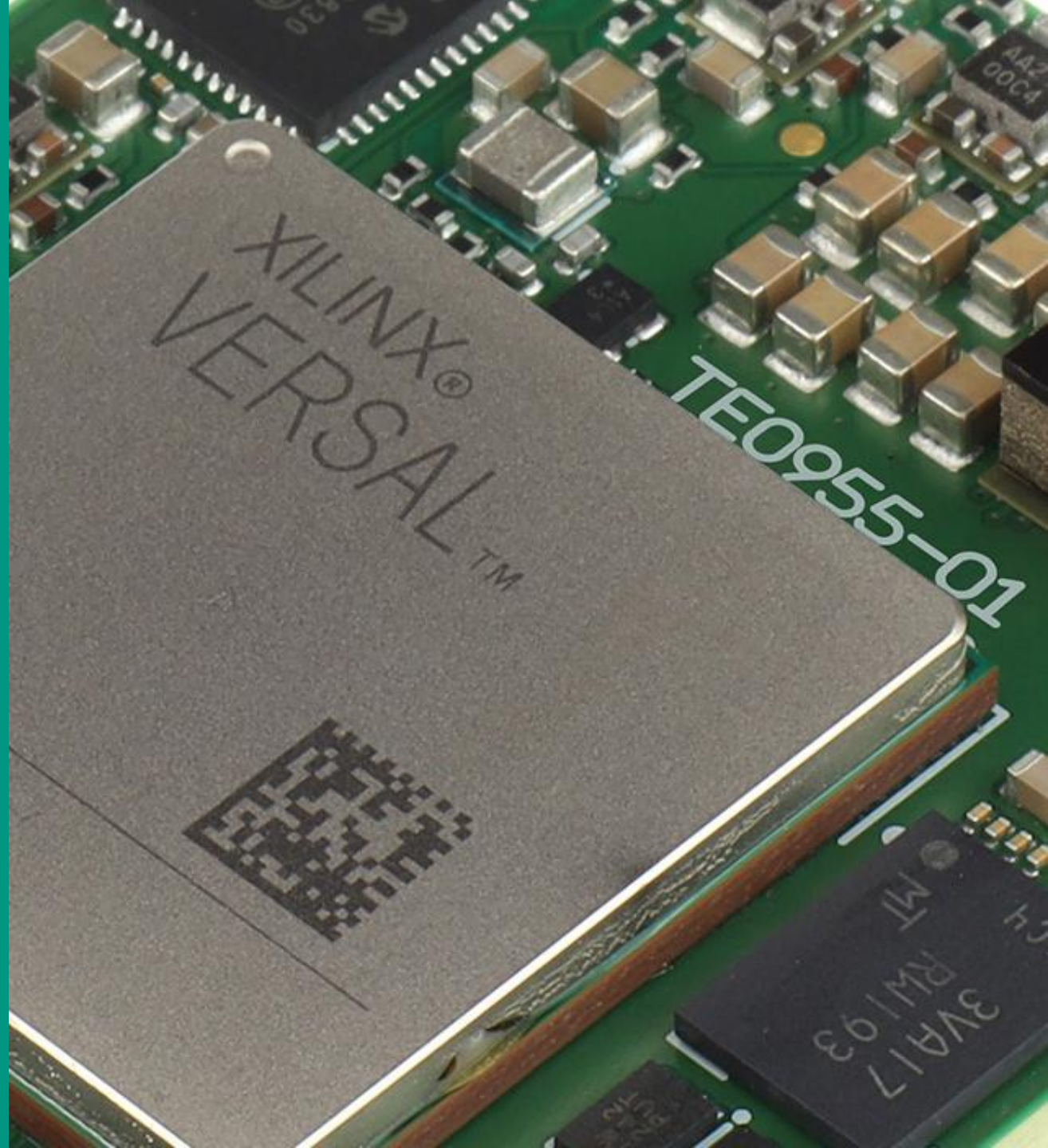
Timo Muscheid, Oliver Sander,
& Luis Ardila-Perez

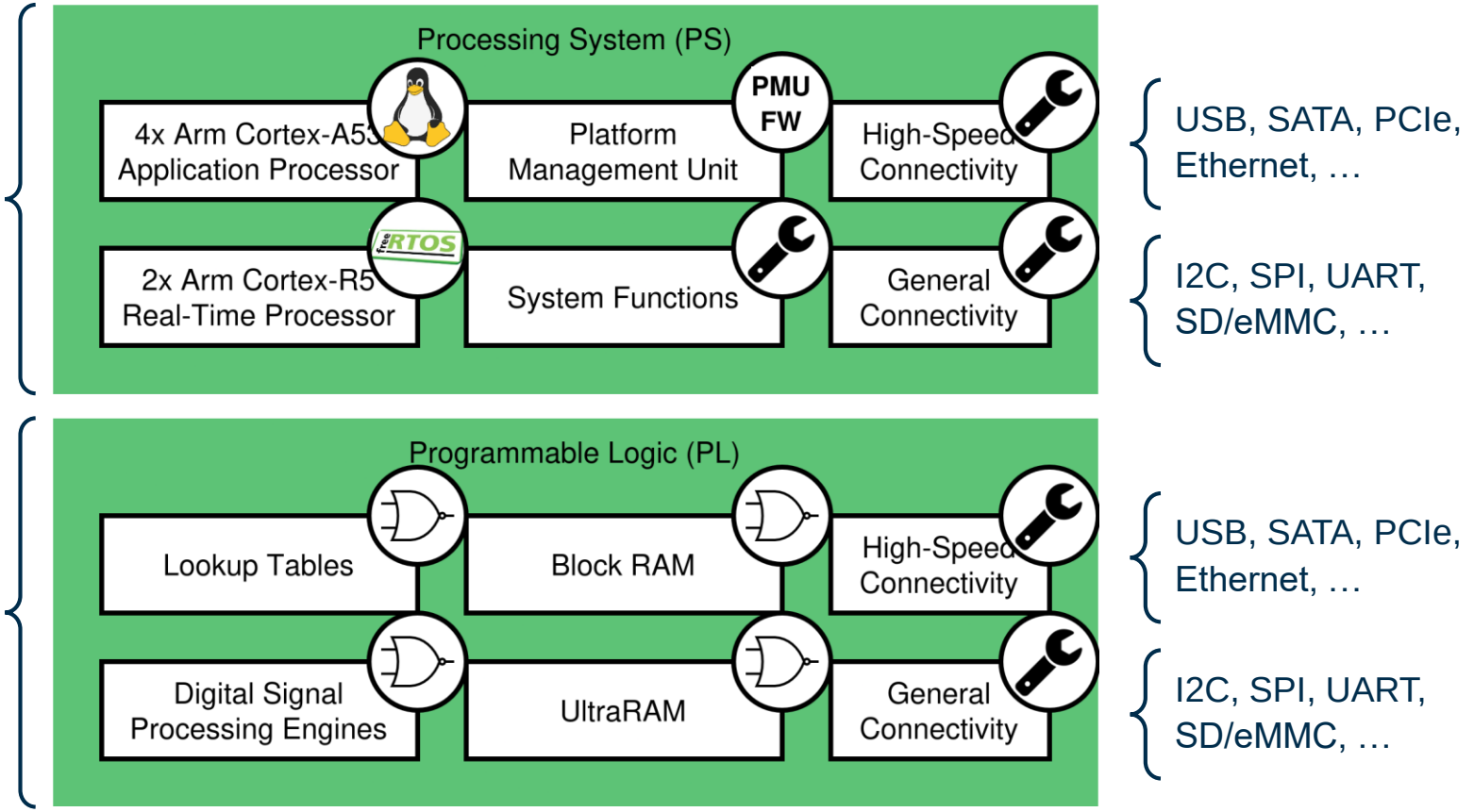
4th CERN SoC Workshop



Heterogeneous High Performance System-on-Chips

Processors
e.g. to provide
a user interface

FPGA Fabric
e.g. for parallel real-
time data processing



AMD Zynq UltraScale+ MPSoC

How to build an image for an AMD ZynqMP device?

Vivado:

- FPGA firmware development
- Low-level SoC configuration

Vitis:

- High-level development environment
- Bare metal software, HLS, AI, …

PetaLinux:

- Entry level Linux OS development
- Based on Yocto

Yocto:

- Advanced Linux OS development
- Recommended for production

AMD Vivado

AMD Vitis

AMD PetaLinux Tools

https://xilinx-wiki.atlassian.net/wiki/spaces/A/pages/18842250/PetaLinux

yocto PROJECT

https://xilinx-wiki.atlassian.net/wiki/spaces/A/pages/18841883/Yocto

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PetaLinux:

- En… ols
- Based on Yocto

PetaLinux is being discontinued, and AMD will instead focus on supporting the Yocto workflow!
(https://xilinx-wiki.atlassian.net/wiki/spaces/A/pages/2907766785/Yocto+Project+Machine+Configuration+Support#PetaLinux-Relationship-to-Yocto-Project)

Yocto:

- Advanced Linux OS development
- Recommended for production

https://xilinx-wiki.atlassian.net/wiki/spaces/A/pages/18841883/Yocto

How to build images for such SoCs in general?

Two widely used frameworks with similar advantages and disadvantages

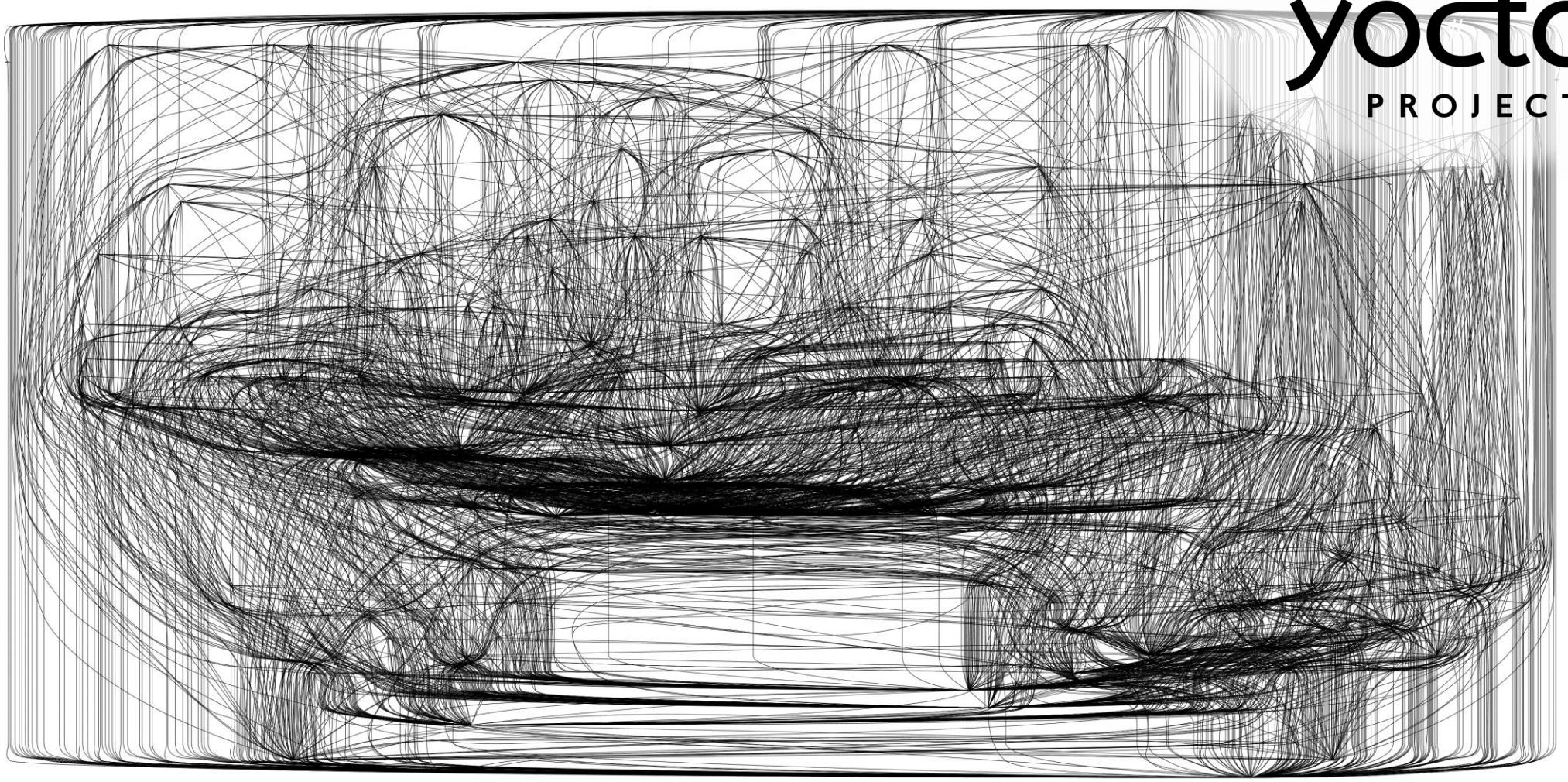
Advantages:

- Well established frameworks
- Supported by manufacturer

Disadvantages:

- Frameworks for building Linux distribution
- Flat hierarchy of hundreds of components
- Training is time consuming
- Hard to manage over time

The Downside of the Yocto Approach



Dependencies of a complete AMD Zynq US+ image in Yocto

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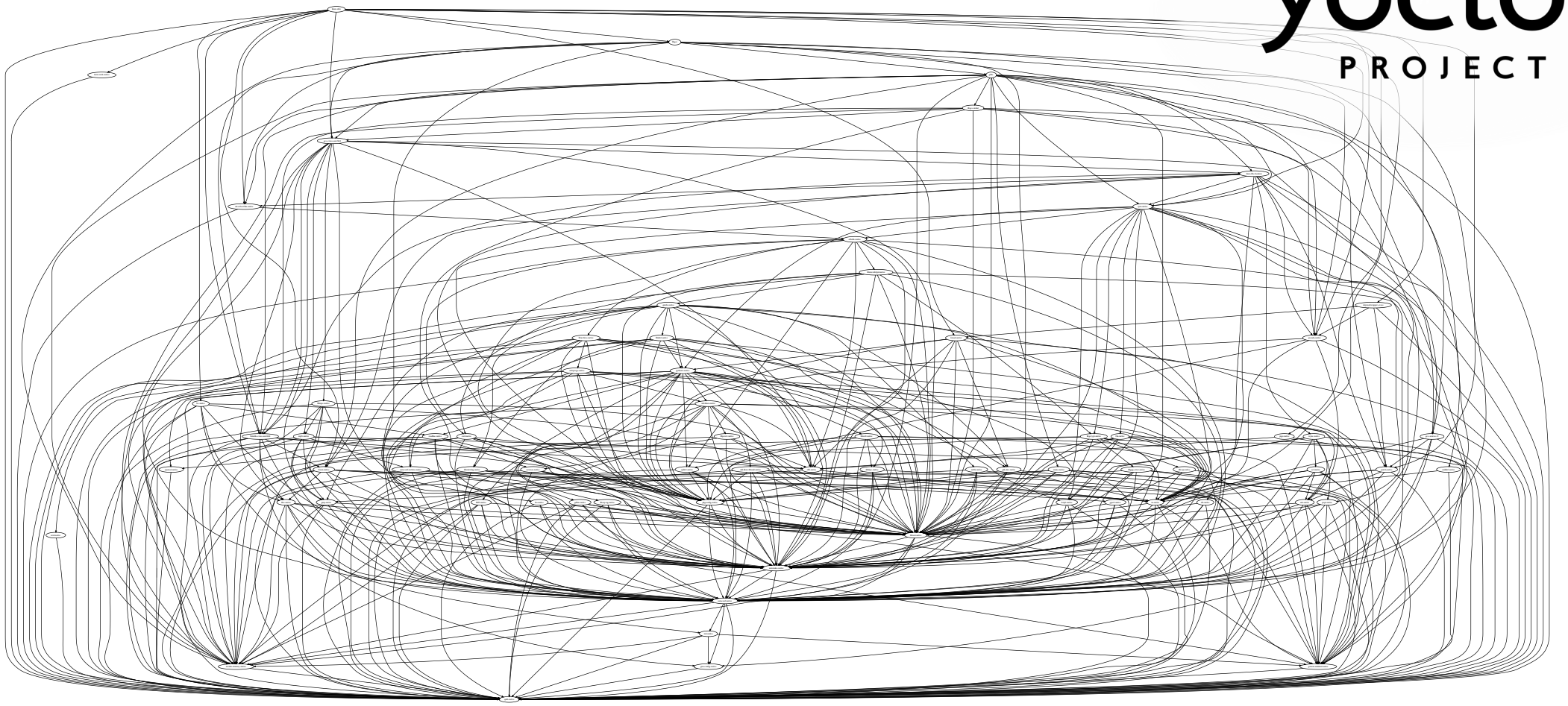

Dependencies of the Linux Kernel recipe in yocto

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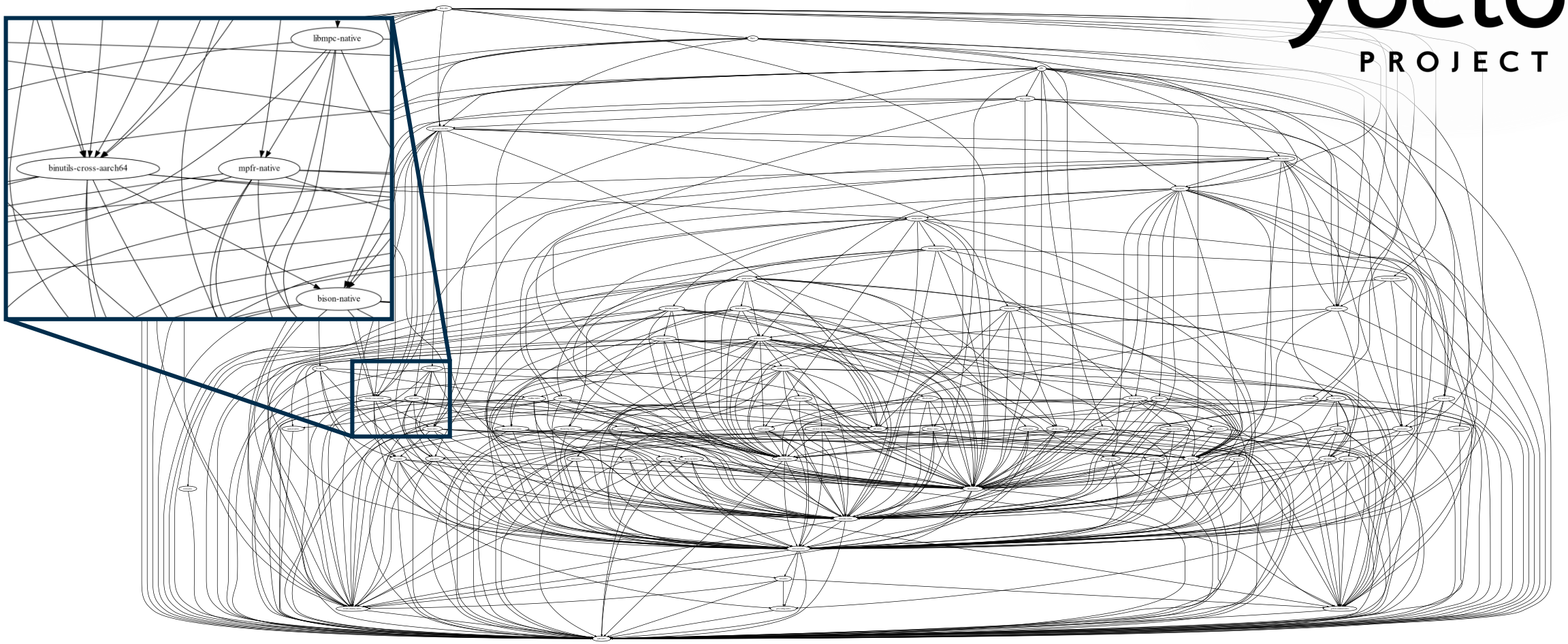

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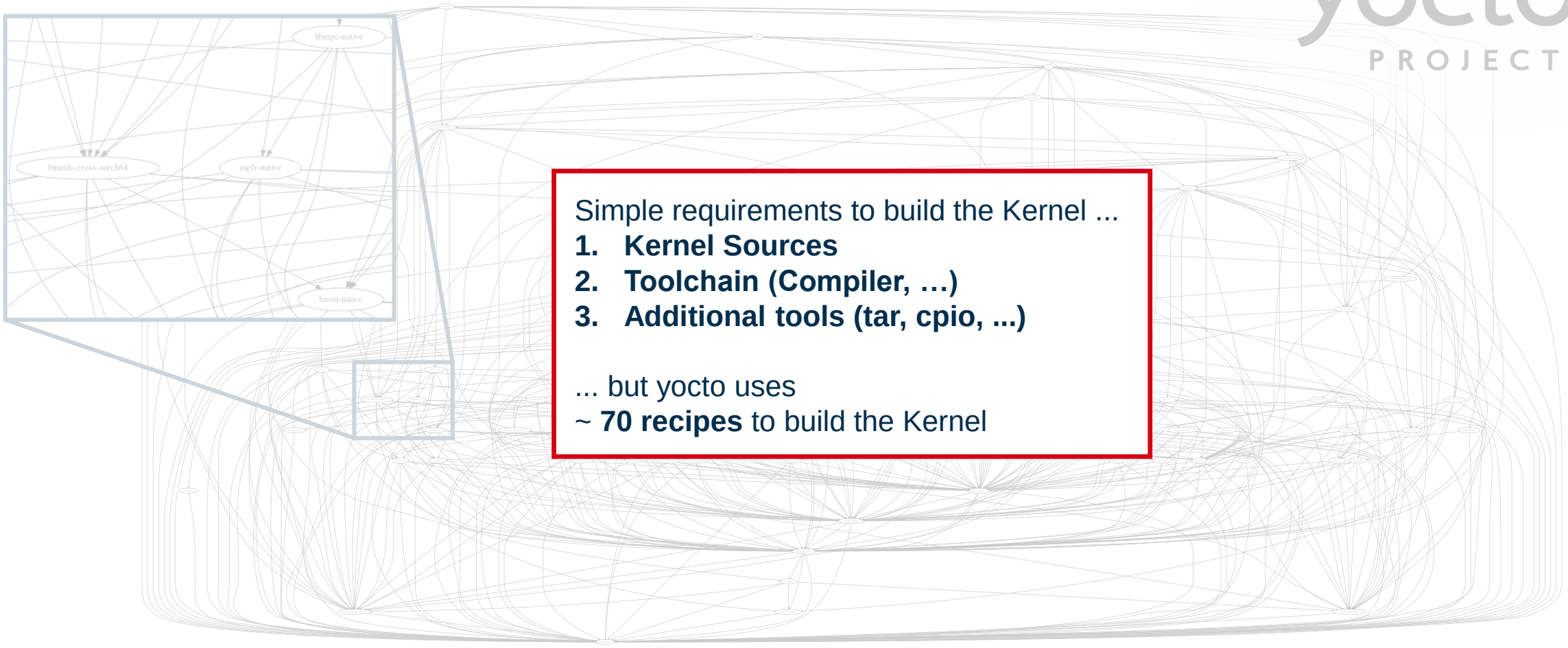

Simple requirements to build the Kernel ...

1. **Kernel Sources**
2. **Toolchain (Compiler, …)**
3. **Additional tools (tar, cpio, ...)**

... but yocto uses
~ **70 recipes** to build the Kernel

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How could a simpler approach look like?

Dependencies of the Linux Kernel recipe in yocto

SoCks (SoC Blocks)

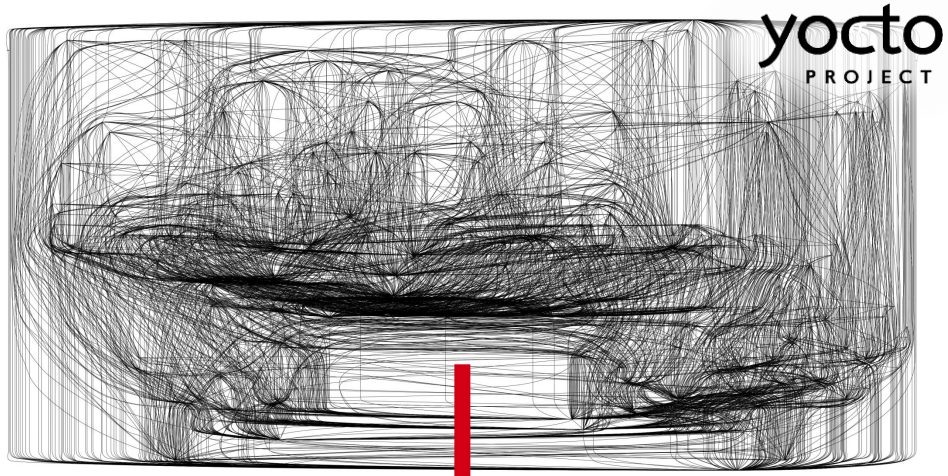
Objectives:

- Reduced complexity
- Easy to learn and use
- Fast and reliable
- Simple debugging of projects
- Full compatibility with GitLab CI/CD
- Encourage reuse of software and firmware

Ideas:

- Divide and conquer
- Introduce a new abstraction layer (blocks)
- Use existing Linux distributions

SoCks (SoC Blocks)



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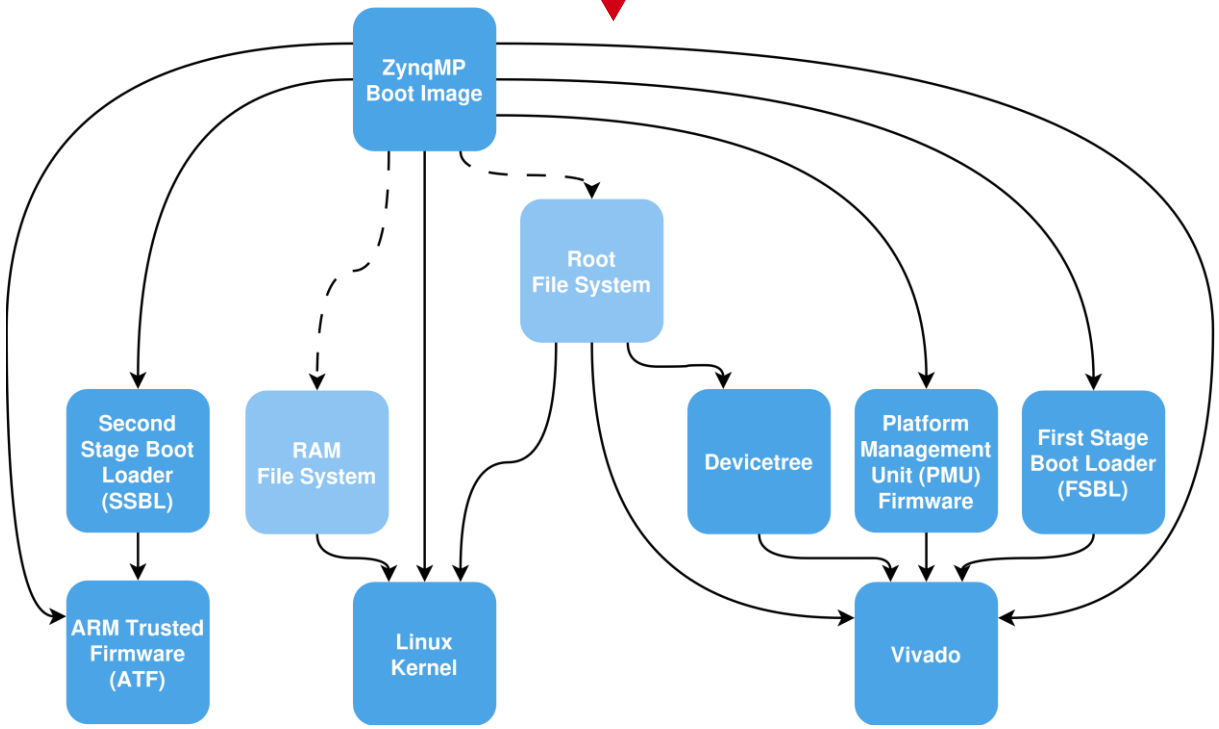

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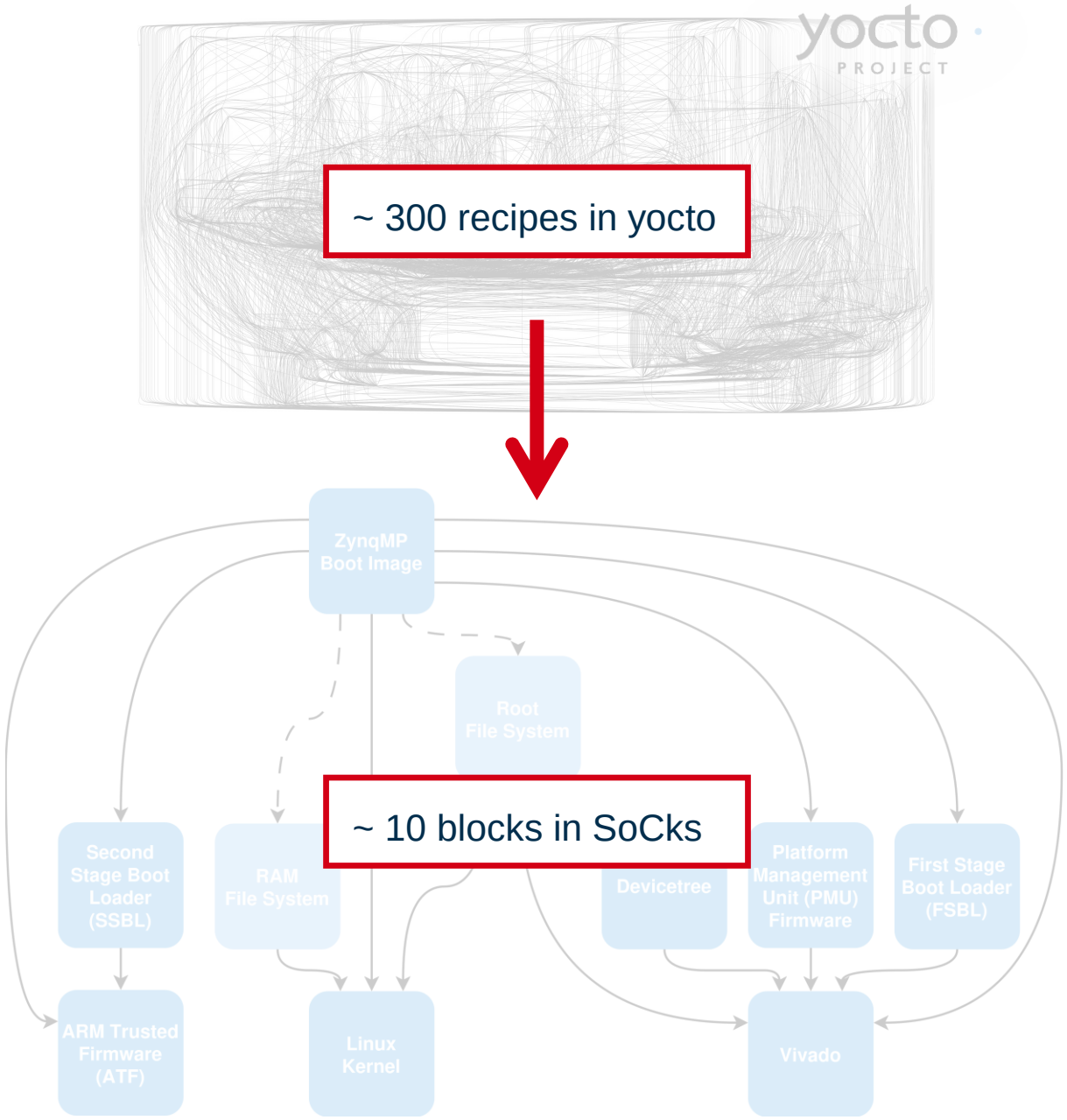
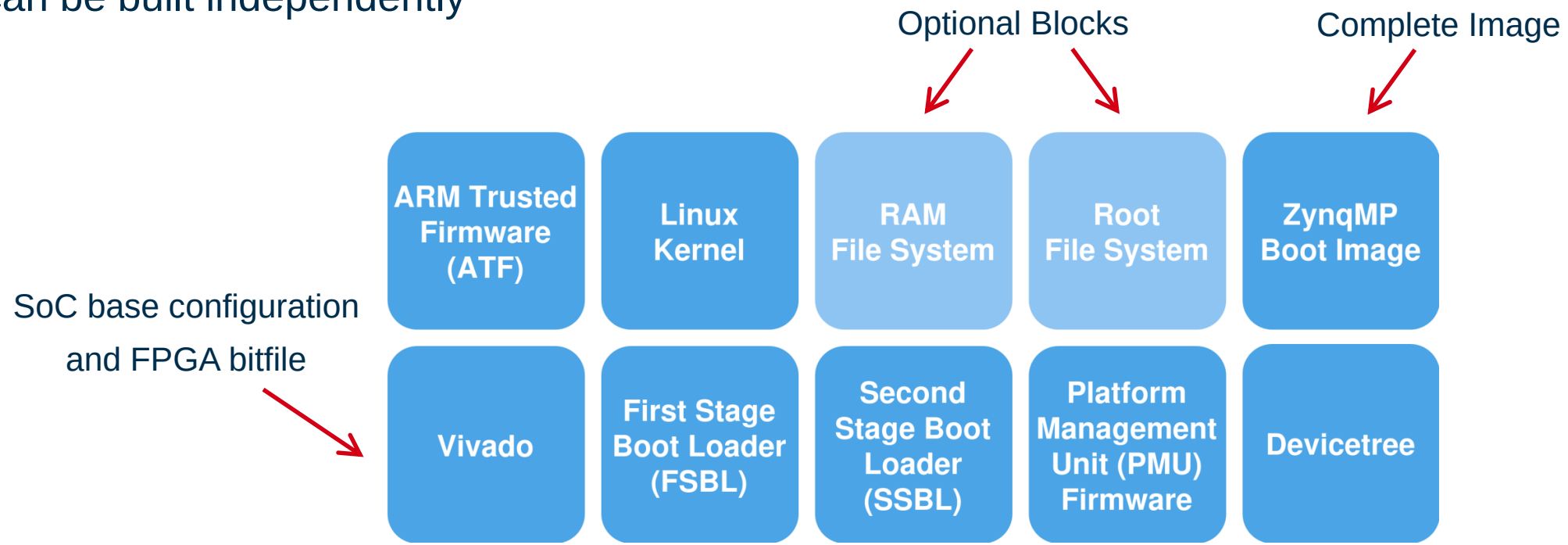


SoCks Software and Firmware Image

Image:

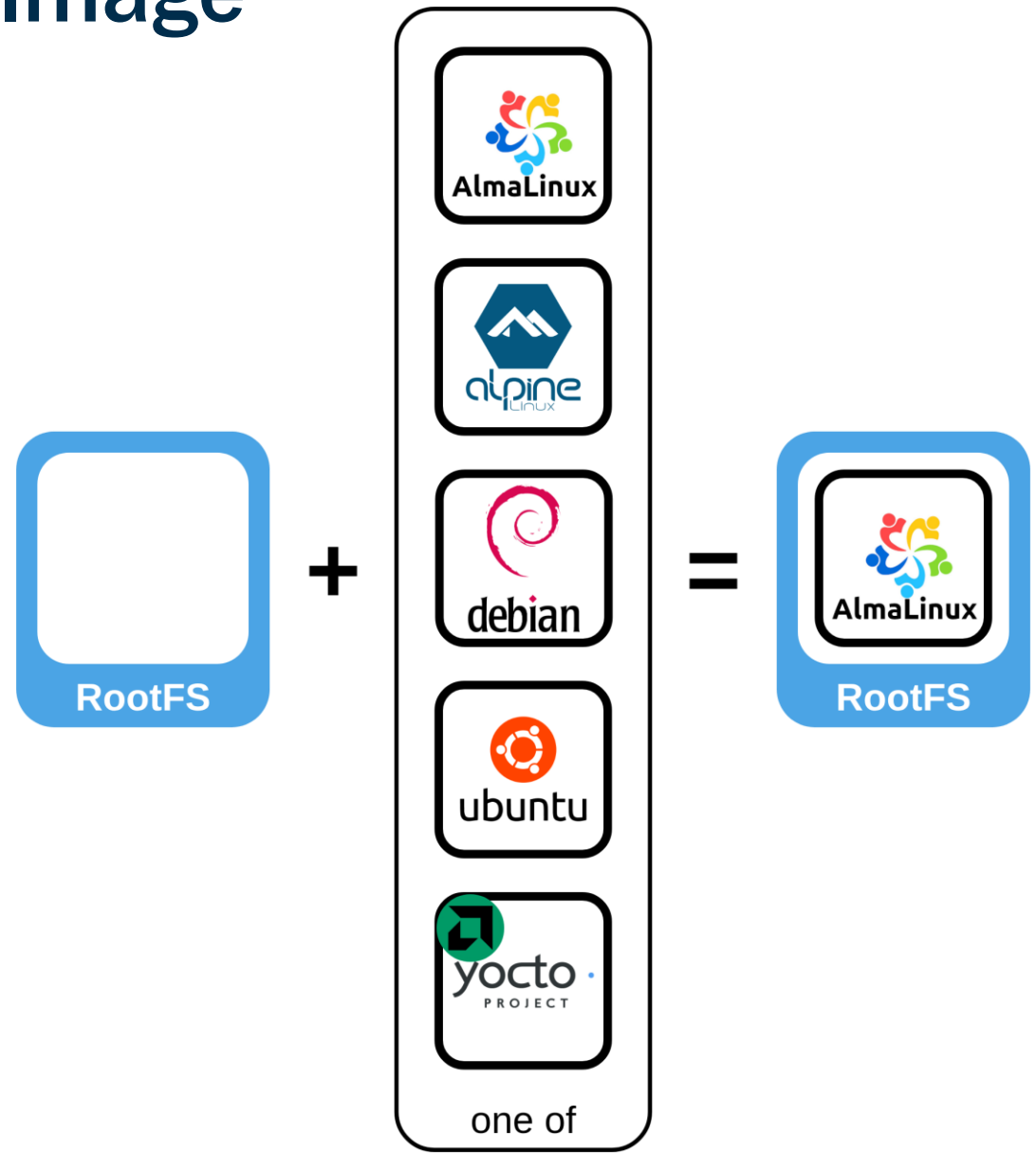
- Composed of reusable blocks
- Clear interfaces between blocks
- Blocks can be built independently



SoCks Software and Firmware Image

Builder:

- Builds one version of the block
- Multiple builders per block available
- Select one builder per block



SoCks Software and Firmware Image

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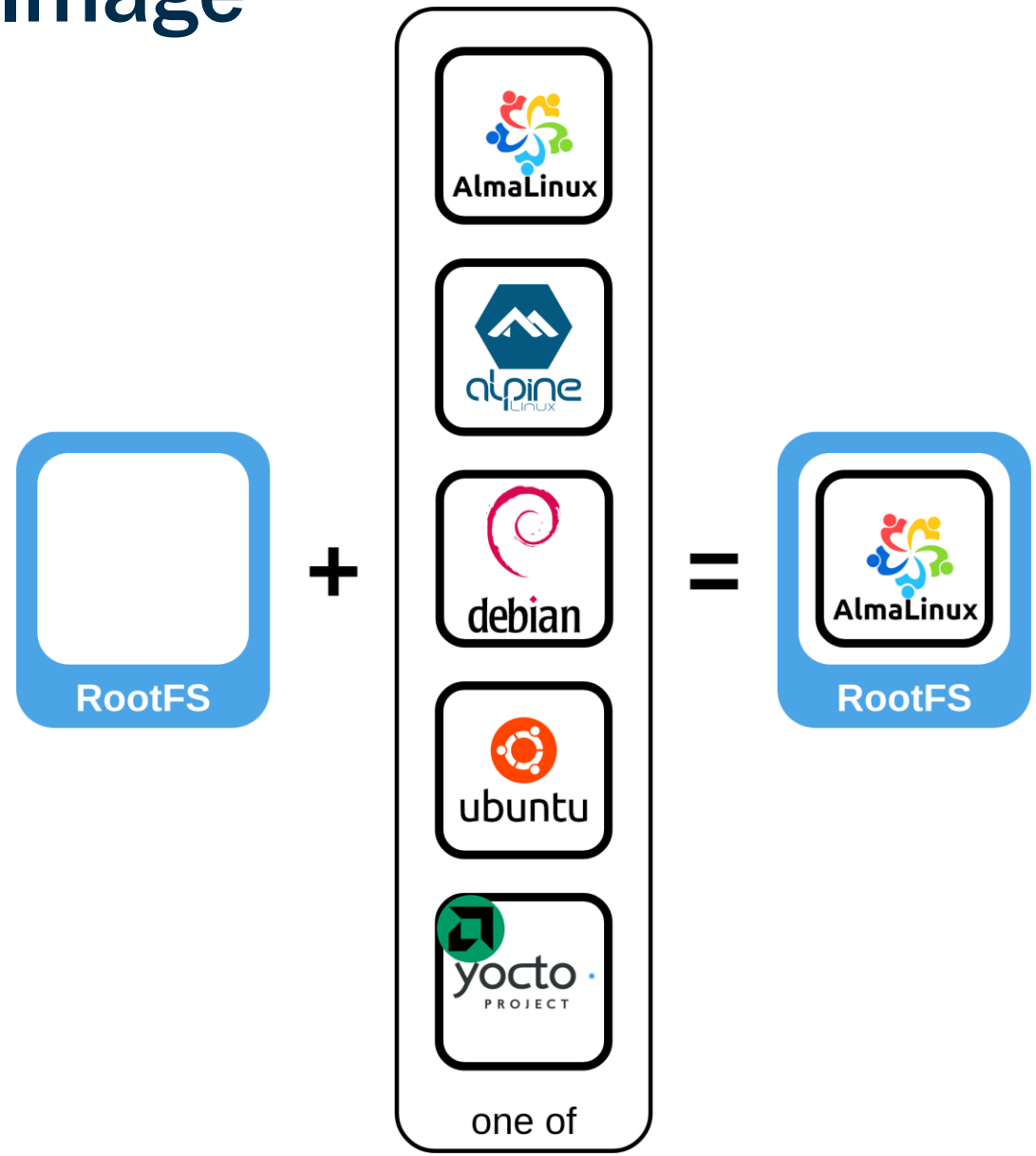
```
rootfs:
  source: build
  builder: ZynqMP_AlmaLinux_RootFS_Builder
  project:
    release: 9
    addl_pkgs: ["python3", "nano", "rsync", "git"]
    ...
    users:
      - name: root
        pw_hash: $1$X6DWcY5/$GQ3ZFNgCGxOSgOZMT6Bkc1
    dependencies:
      kernel: temp/kernel/output/bp_kernel_*.tar.gz
      ...
  container:
    image: alma9-rootfs-builder-alma9
    tag: socks
```

RootFS section in project.yml



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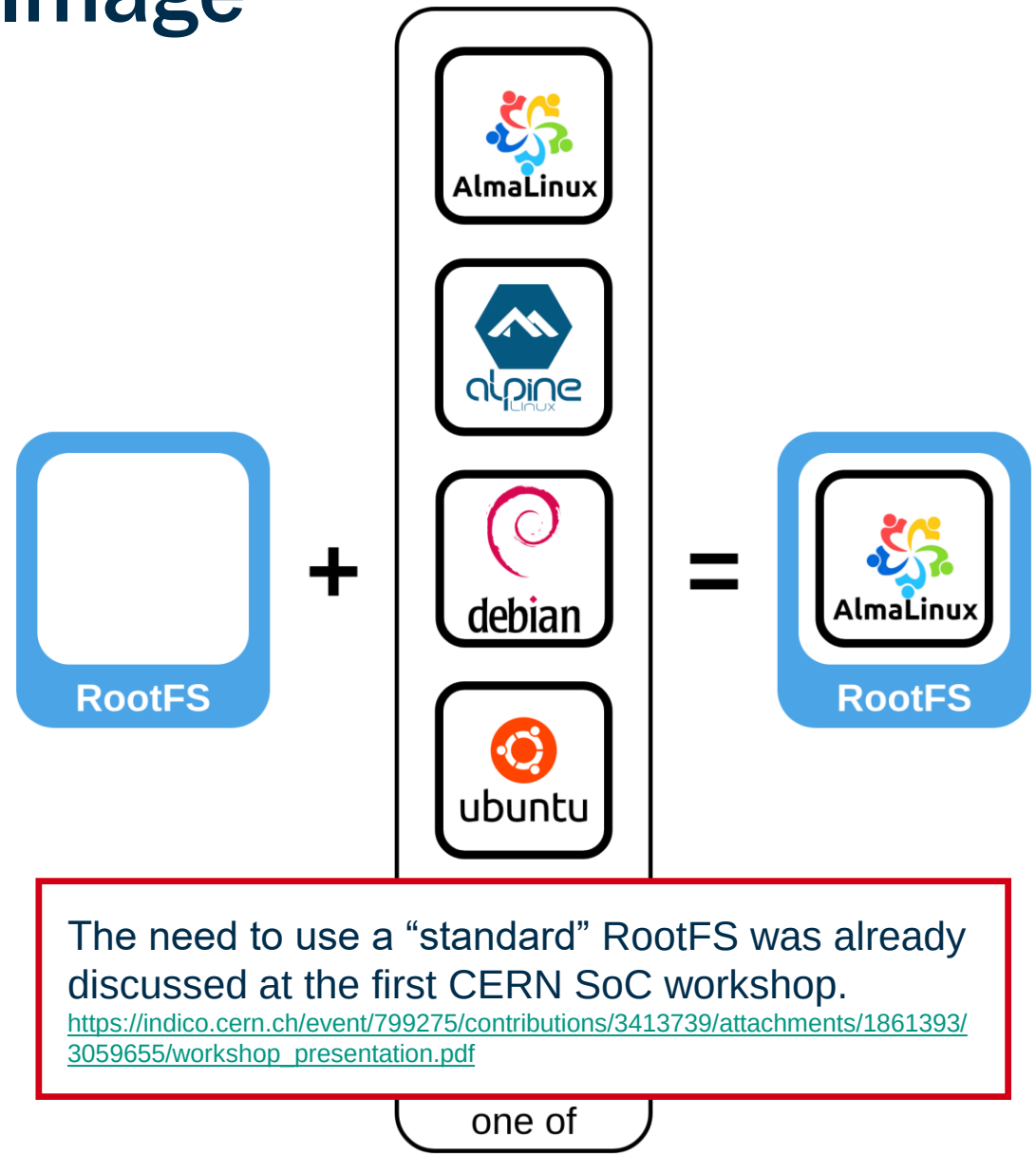
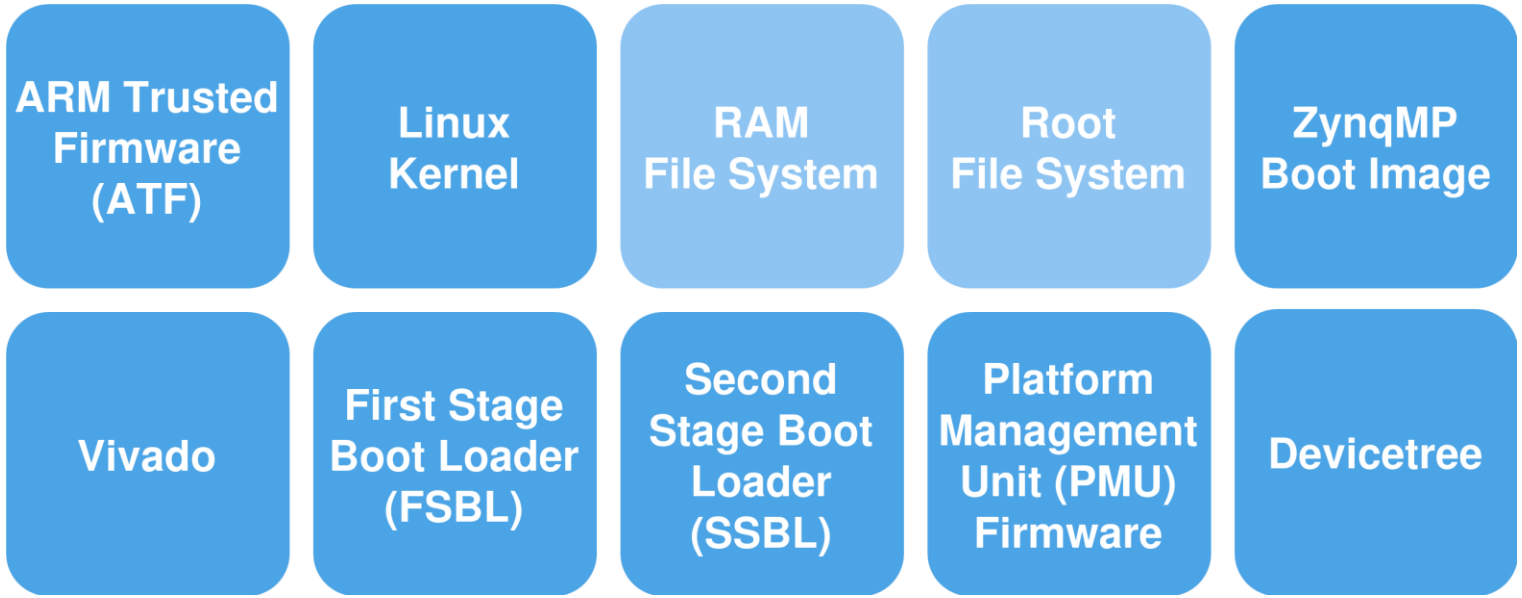


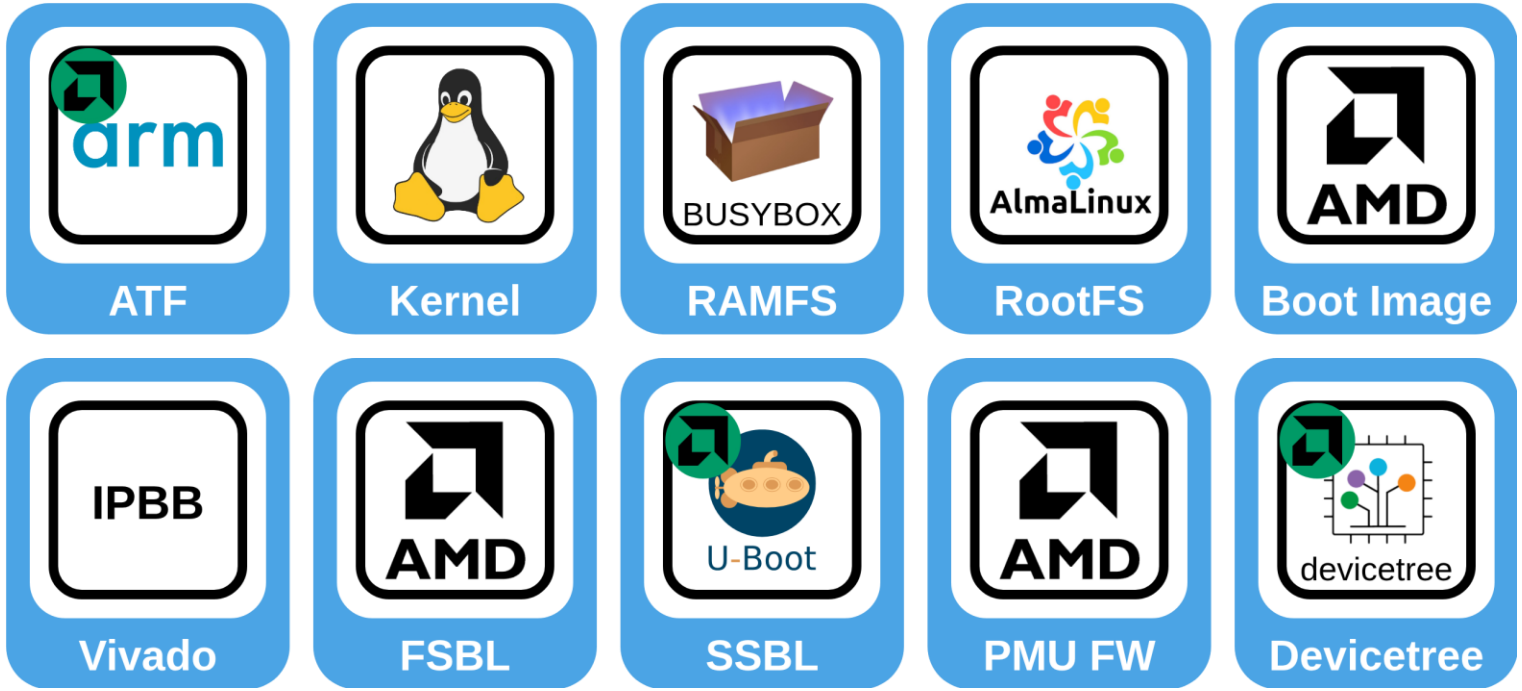
The need to use a “standard” RootFS was already discussed at the first CERN SoC workshop.
https://indico.cern.ch/event/799275/contributions/3413739/attachments/1861393/3059655/workshop_presentation.pdf

SoCks Software and Firmware Image



Layout of an AMD Zynq US+ image

SoCks Software and Firmware Image



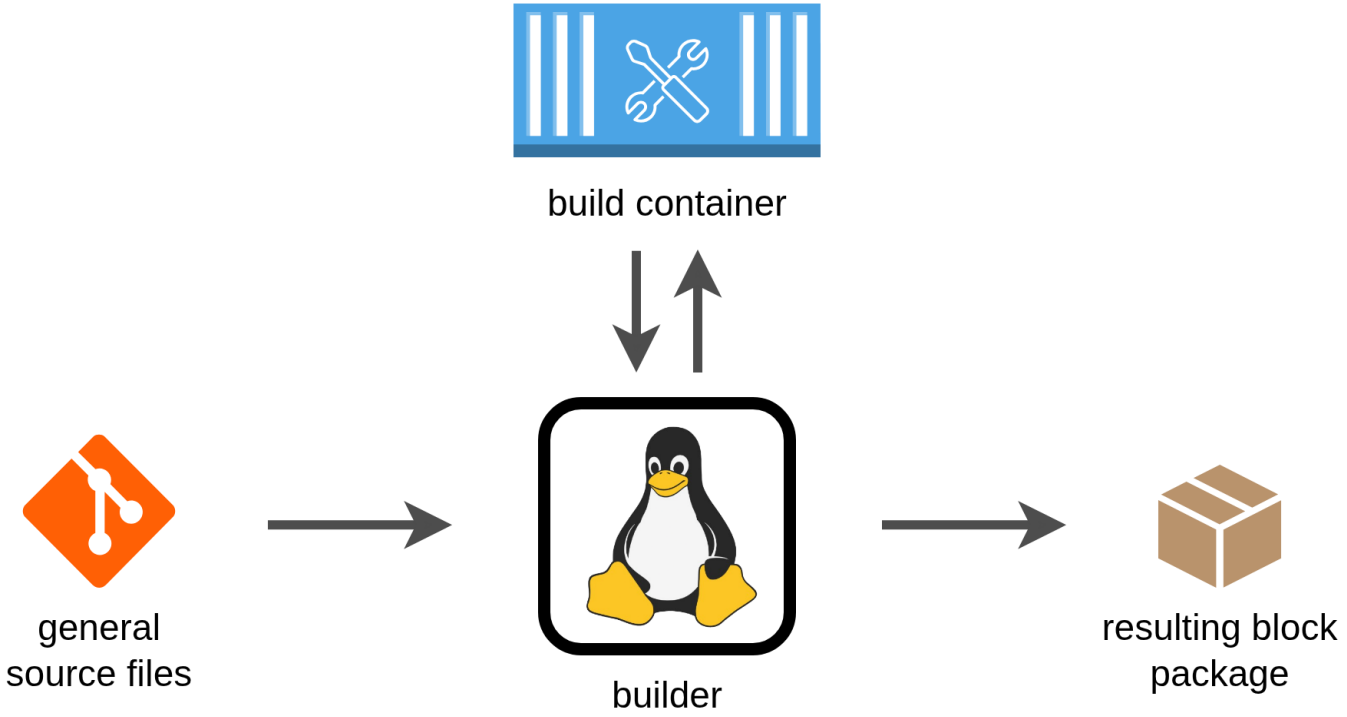
Example of a configured AMD Zynq US+ image

How is a block built?

Building the **Linux Kernel** with SoCks:

Shell Command:

```
$ socks kernel build
```

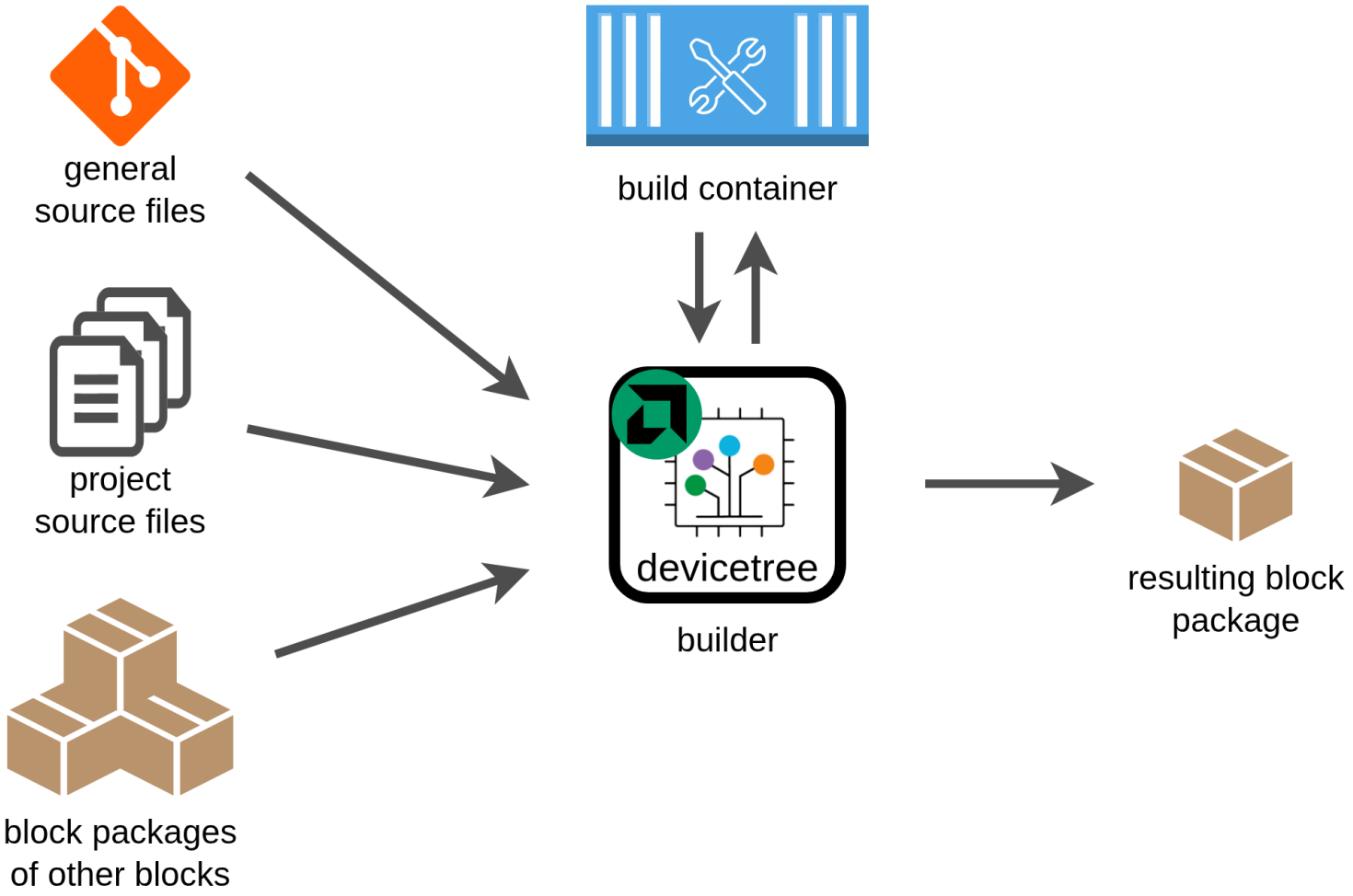


How is a block built?

Building the **Devicetree** with SoCks:

Shell Command:

```
$ socks devicetree build
```



How is a block built?

Building the **Devicetree** with SoCks:

Shell Command:

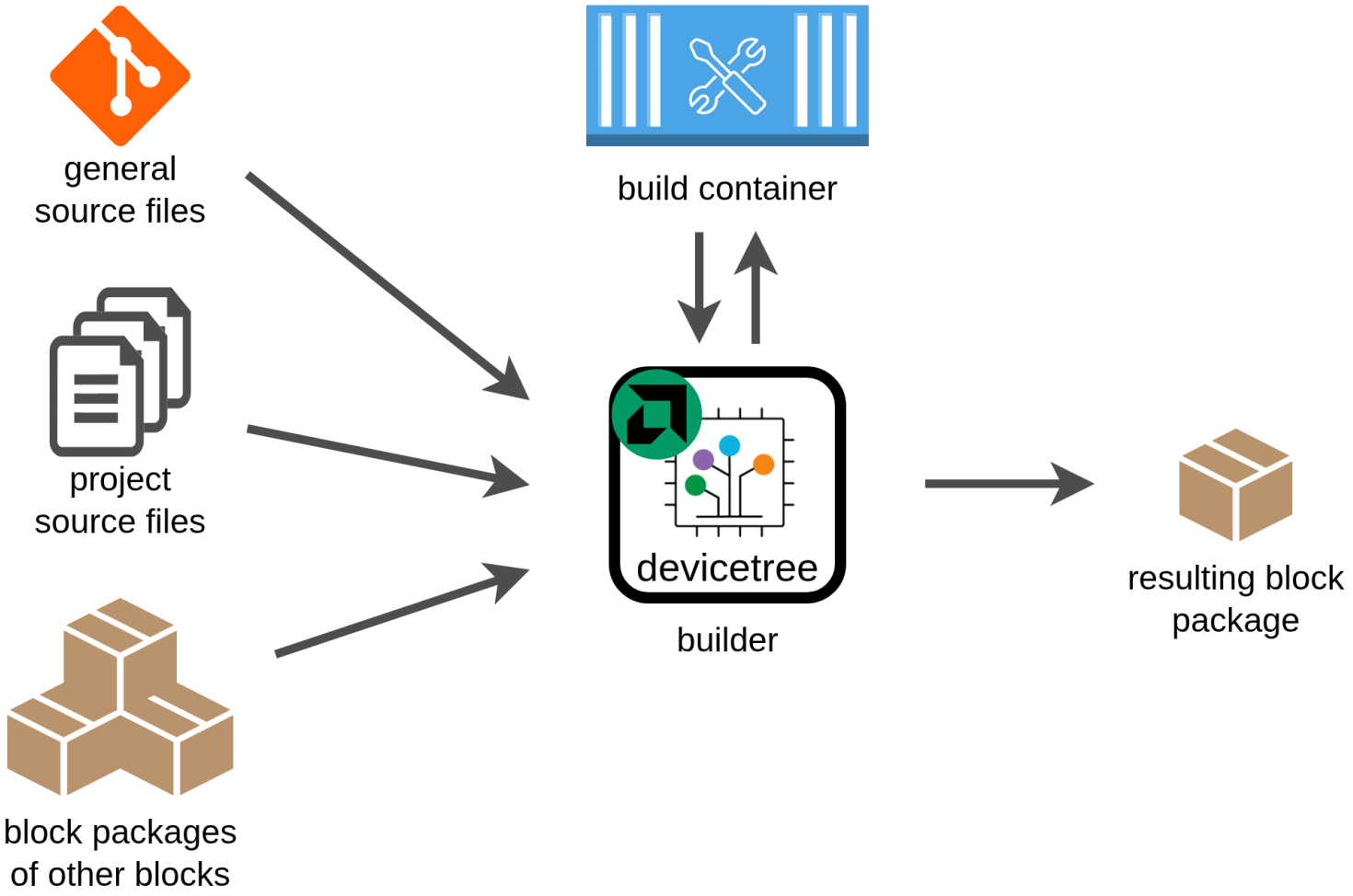
```
$ socks devicetree build
```

Supported container tools:

- Docker
- Podman
- None

Tested host systems:

- Ubuntu 24.04 LTS
- AlmaLinux 8



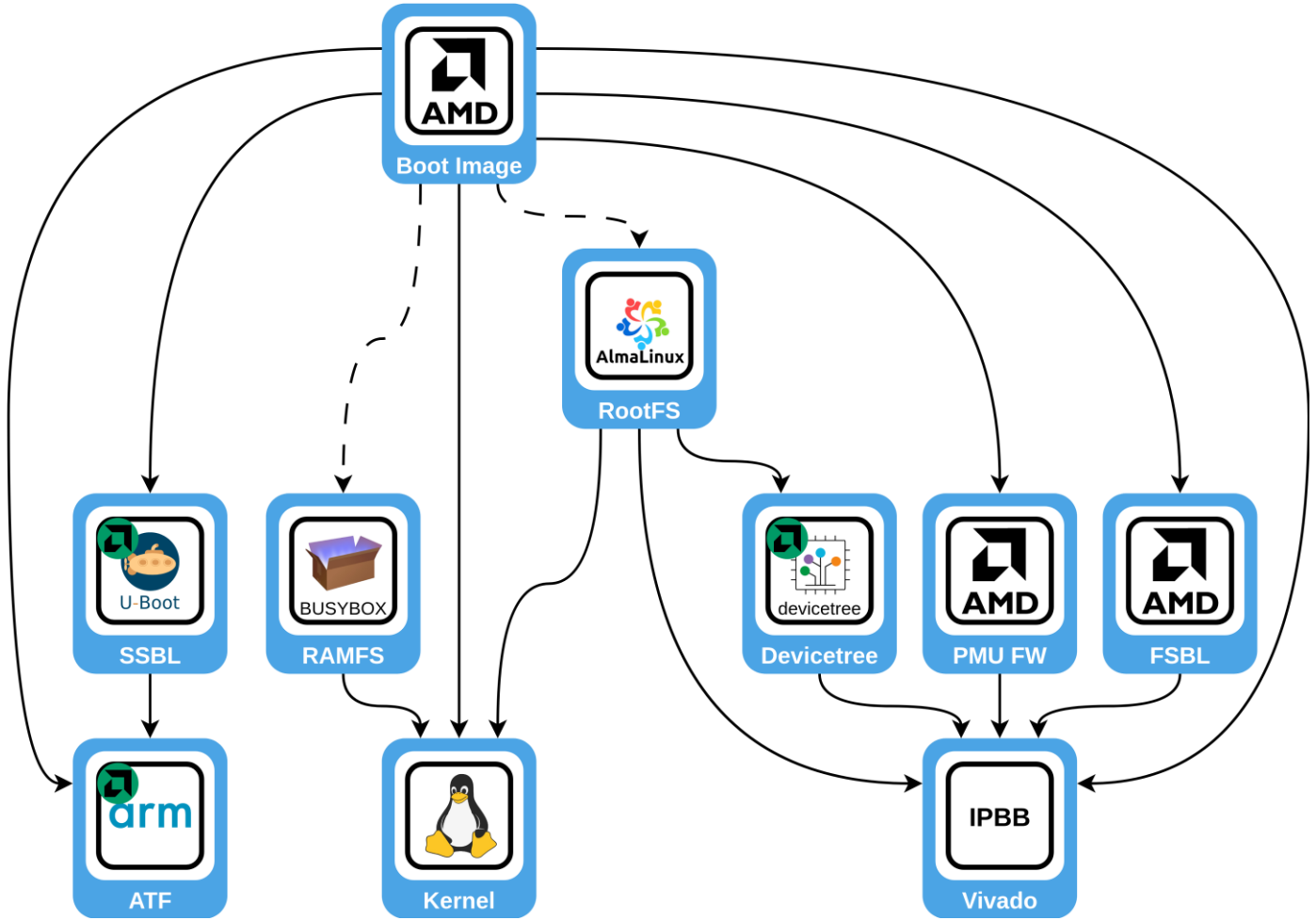
How are multiple blocks built?

Building a **Complete Image** with SoCks:

Shell Command:

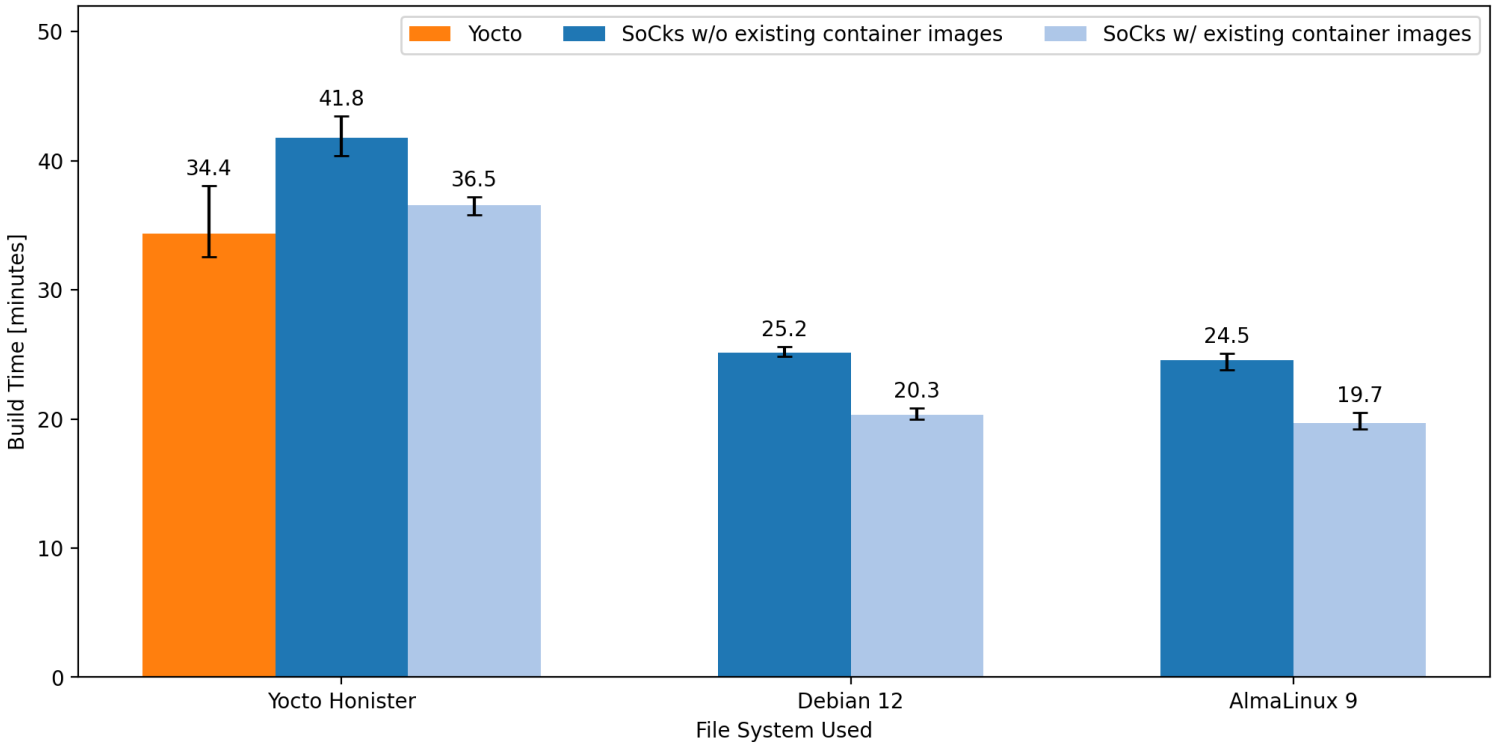
```
$ socks all build
```

- Sequential building of blocks, internal parallelization
- Processing sequence is determined by dependencies



Build Performance – Complete Images

- Equivalent Yocto and SoCks projects
- Linux OS files system has major influence on build time
- SoCks is fast in building complete images
  - Only with a Yocto file system SoCks is slower than Yocto
  - SoCks uses Yocto internally to create the Yocto file system
- Container images are only built if they do not already exist

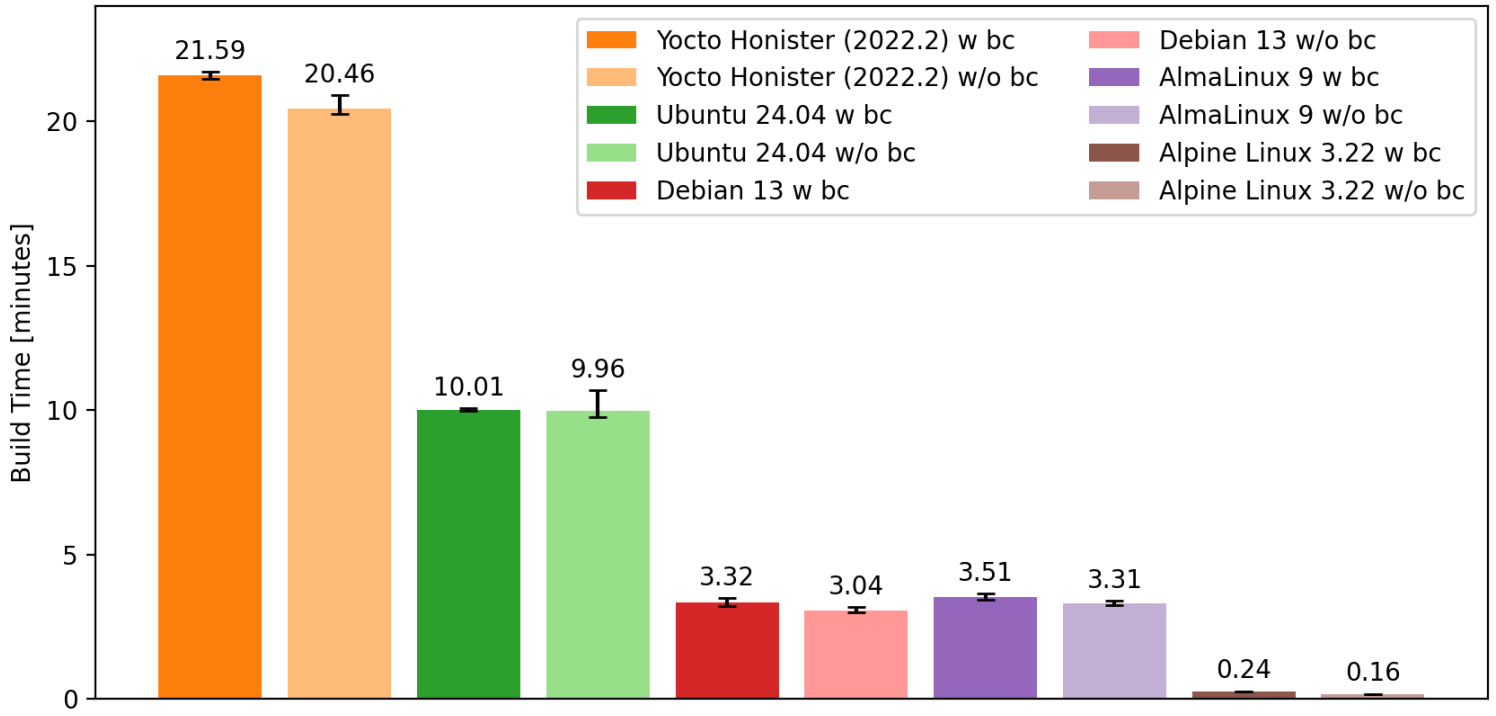


Test image: ZCU102

Test system: Intel Core i9 14900K, 128 GB of DDR5 memory, 2 TB Samsung 990 EVO NVMe SSD

Build Performance – OS File System Comparison

- All file systems in this test were built with SoCks
- Yocto is the most demanding because it is built from source
- All other file systems are built from official binary packages
- Yocto and Alpine Linux images are very similar in size



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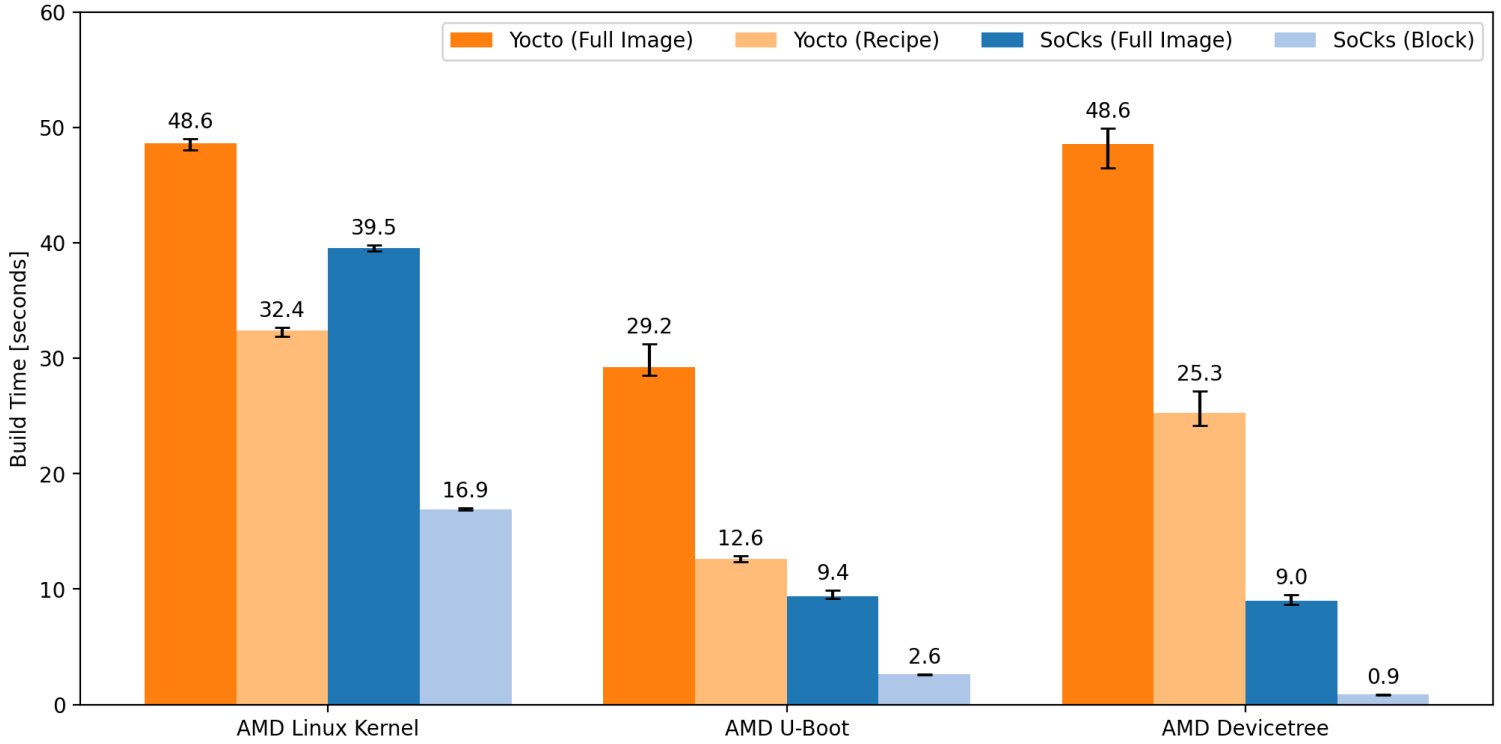
Build Performance – Rebuild

- SoCks is fast at building components and images after source code modifications
- Only one line of code was changed for the measurements
  - Value of a variable toggled
- Devicetree modifications are particularly relevant in practice



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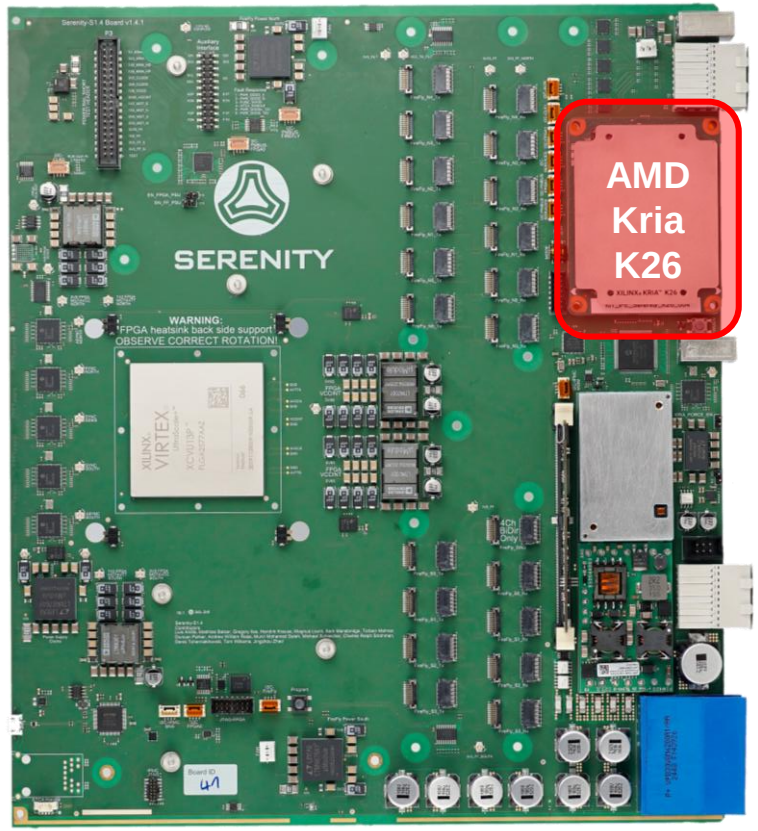
Supported SoC Architectures

- SoCks is currently mainly used at KIT
- Various devices have already been tested
- Most advanced for AMD Zynq US+
- Raspberry Pi for demonstration purposes

AMD Zynq US+	AMD Versal	Raspberry Pi
Kria K26 SoM	VEK280 AI Edge Eval. Kit	Raspberry Pi 4B
ZCU102 MPSoC Eval. Kit		Raspberry Pi 5
ZCU208 RFSoC Eval. Kit		
ZCU216 RFSoC Eval. Kit		
DTS-100G (custom)		
iWave iW-RainboW-G42M SoM		



Current usage at CERN: AMD Kria K26 SoM on Serenity-S

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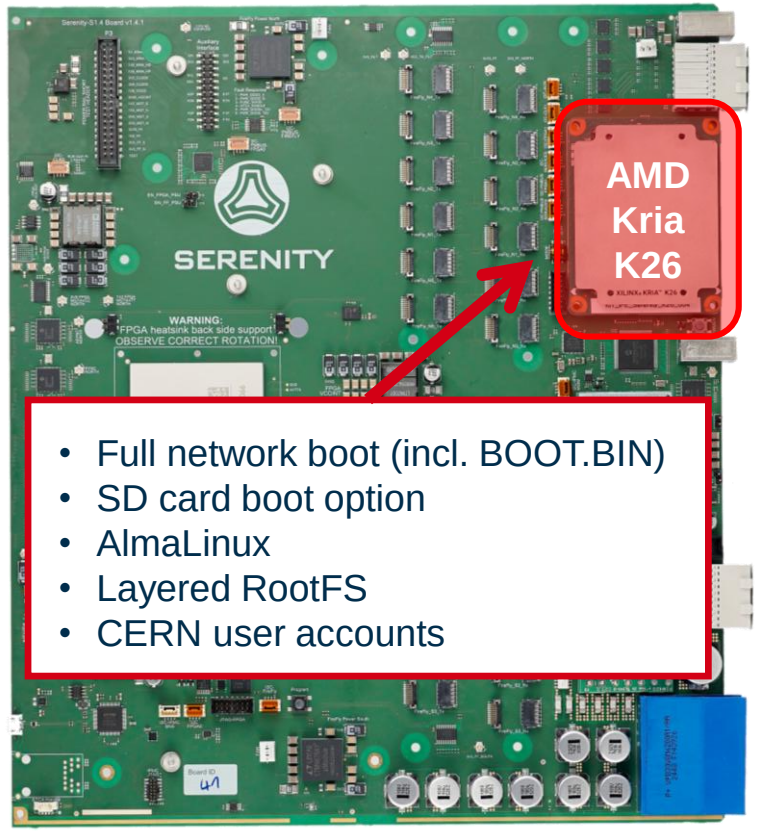
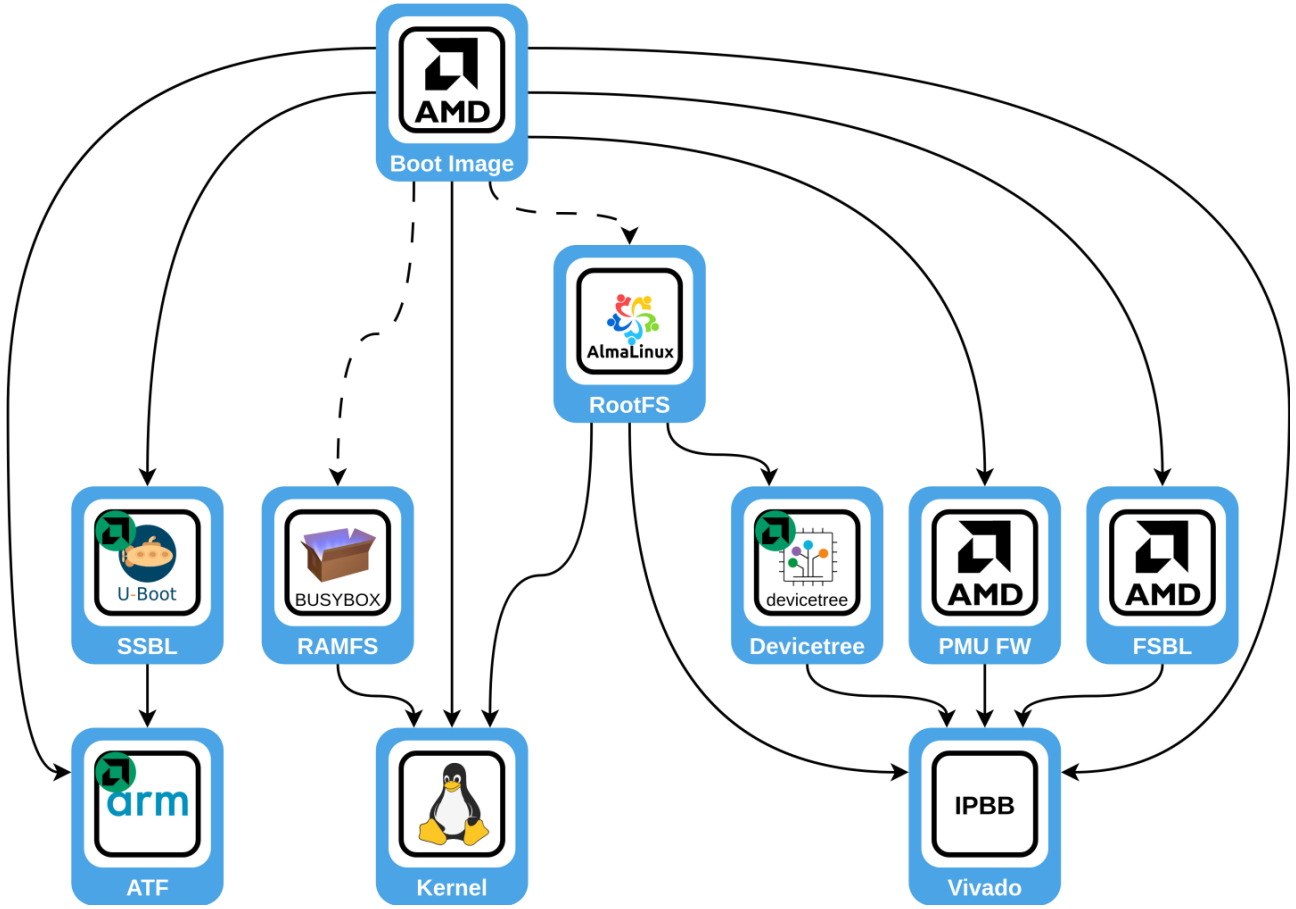


Current usage at CERN: AMD Kria K26 SoM on Serenity-S

Conclusion

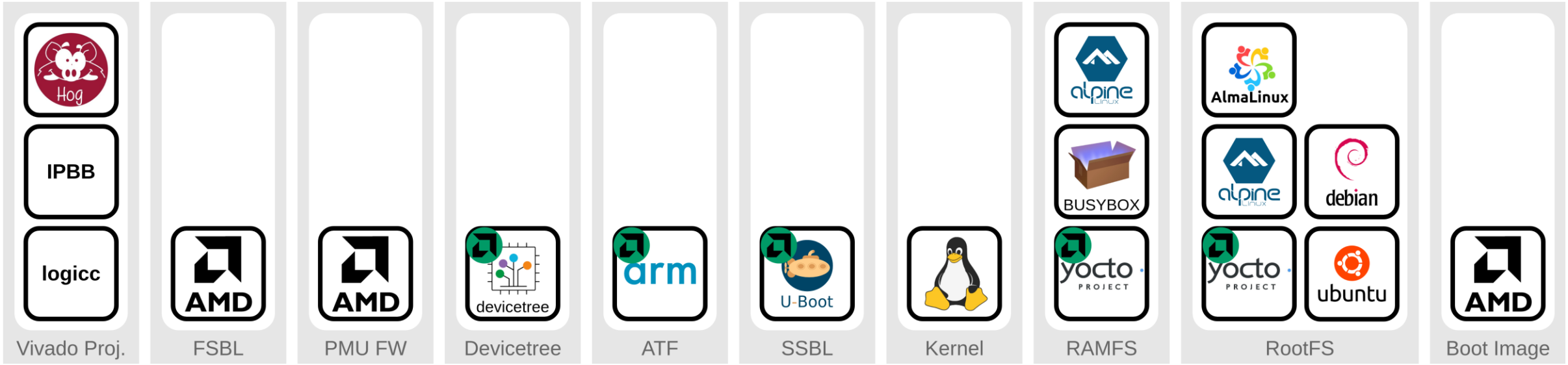
- SoCks is a lightweight framework to build SoC images
- Containerized builds
- Modular and expandable
- Fully compatible to GitLab CI/CD
- Can replace PetaLinux in many cases

- **SoCks is open source!**
  - https://github.com/kit-ipe/SoCks
  - https://arxiv.org/abs/2510.15910



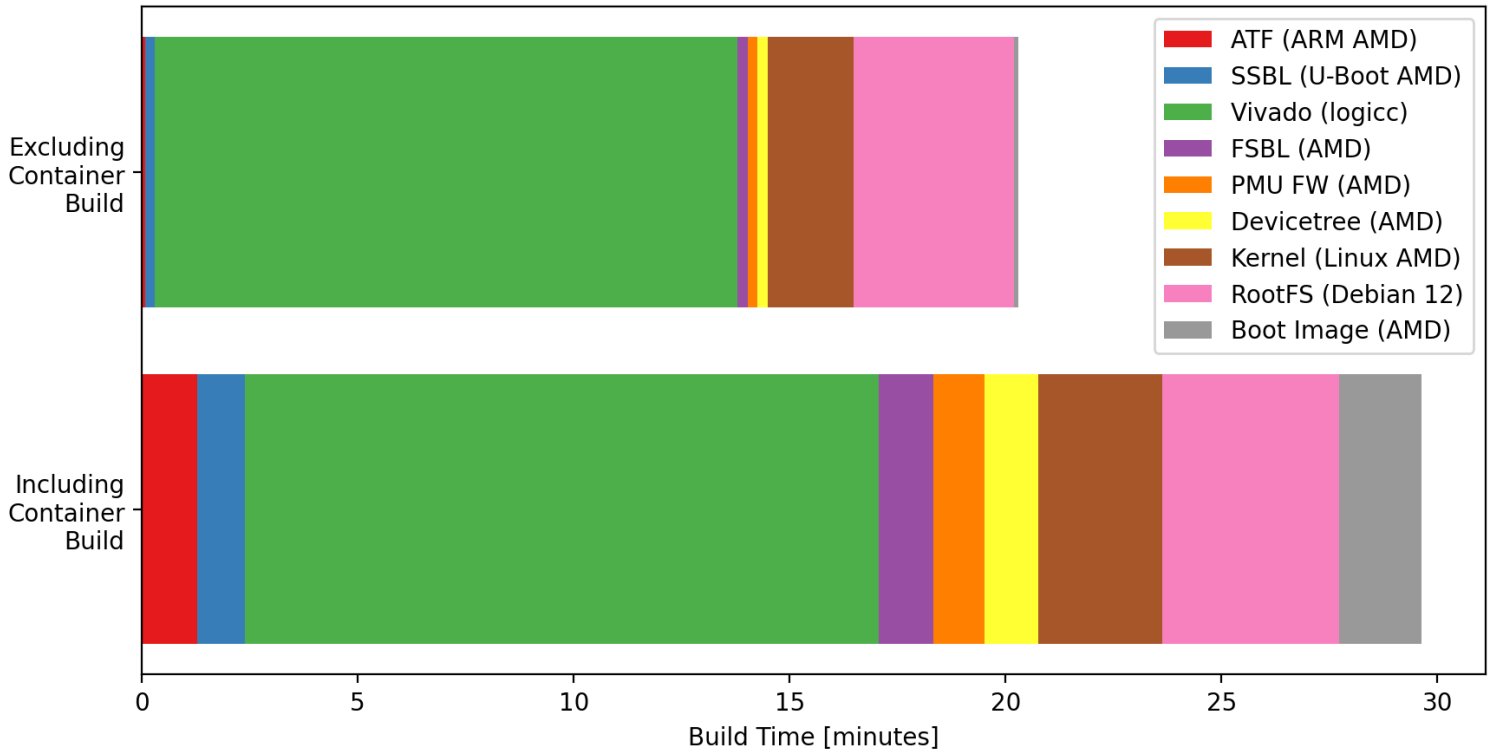
Backup

Overview of Builders Currently Available in SoCks



Build Performance – Individual Blocks of a SoCks Image

- The Vivado project has the longest building time
  - Depends heavily on the Vivado project
- The RootFS of the OS has the second longest building time
  - Depends heavily on the distribution/framework
- The Linux kernel has the third longest building time
  - Depends heavily on the kernel configuration



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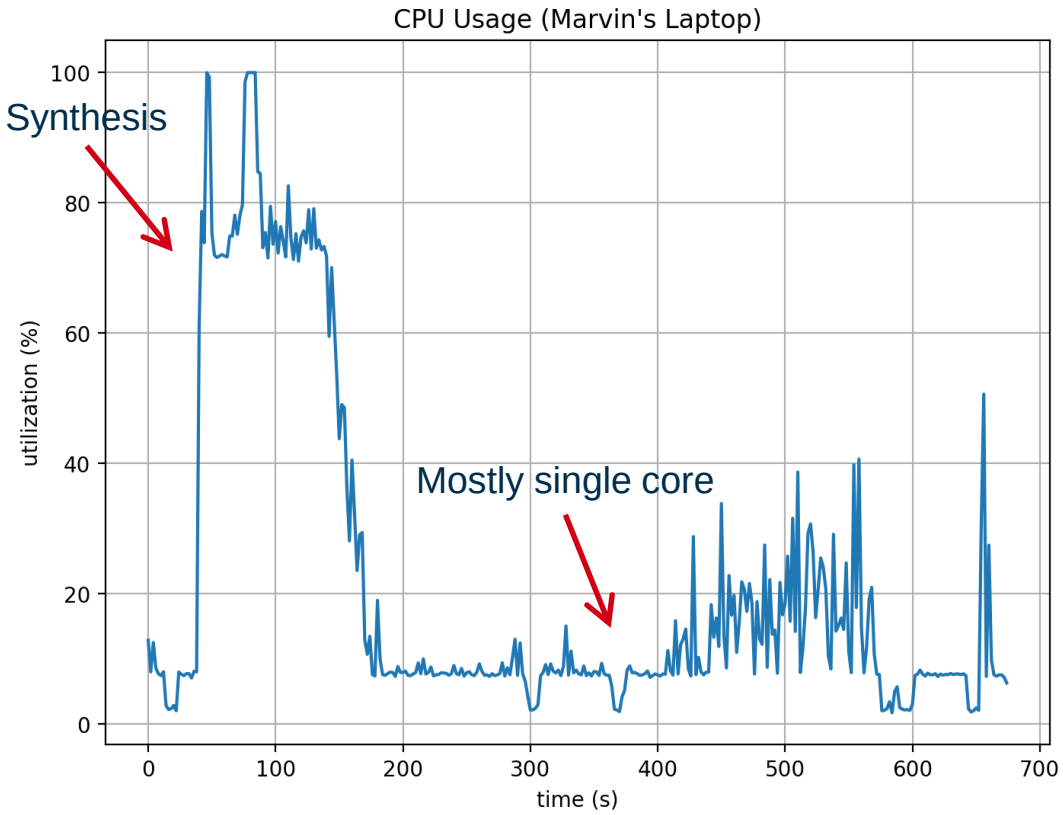
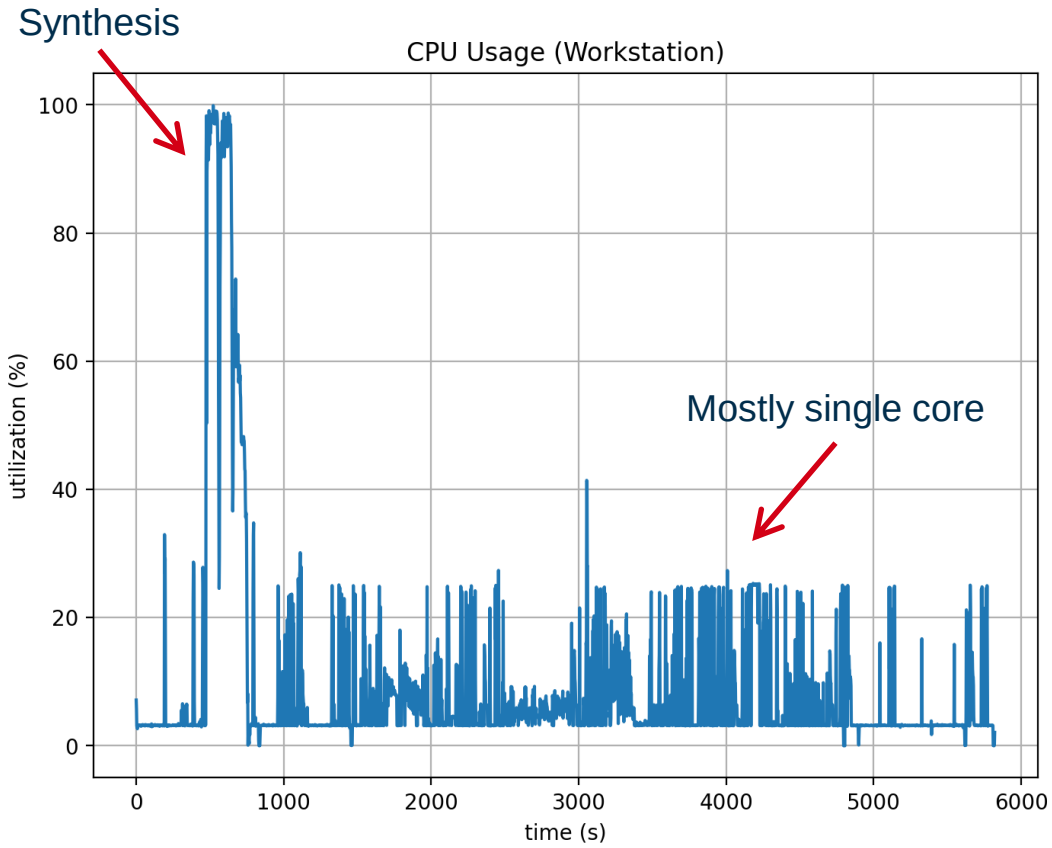
CPU Utilization During a Vivado Project Build



Project: Vivado project A
Test system: Lenovo ThinkPad P14s Gen 2a, AMD Ryzen 7 PRO 5850U, 32 GB of DDR4 memory, 1 TB SK Hynix HFS001TDE9X081N SSD



Project: Vivado project B
Test system: Intel Core i9 14900K, 128 GB of DDR5 memory, 2 TB Samsung 990 EVO NVMe SSD