

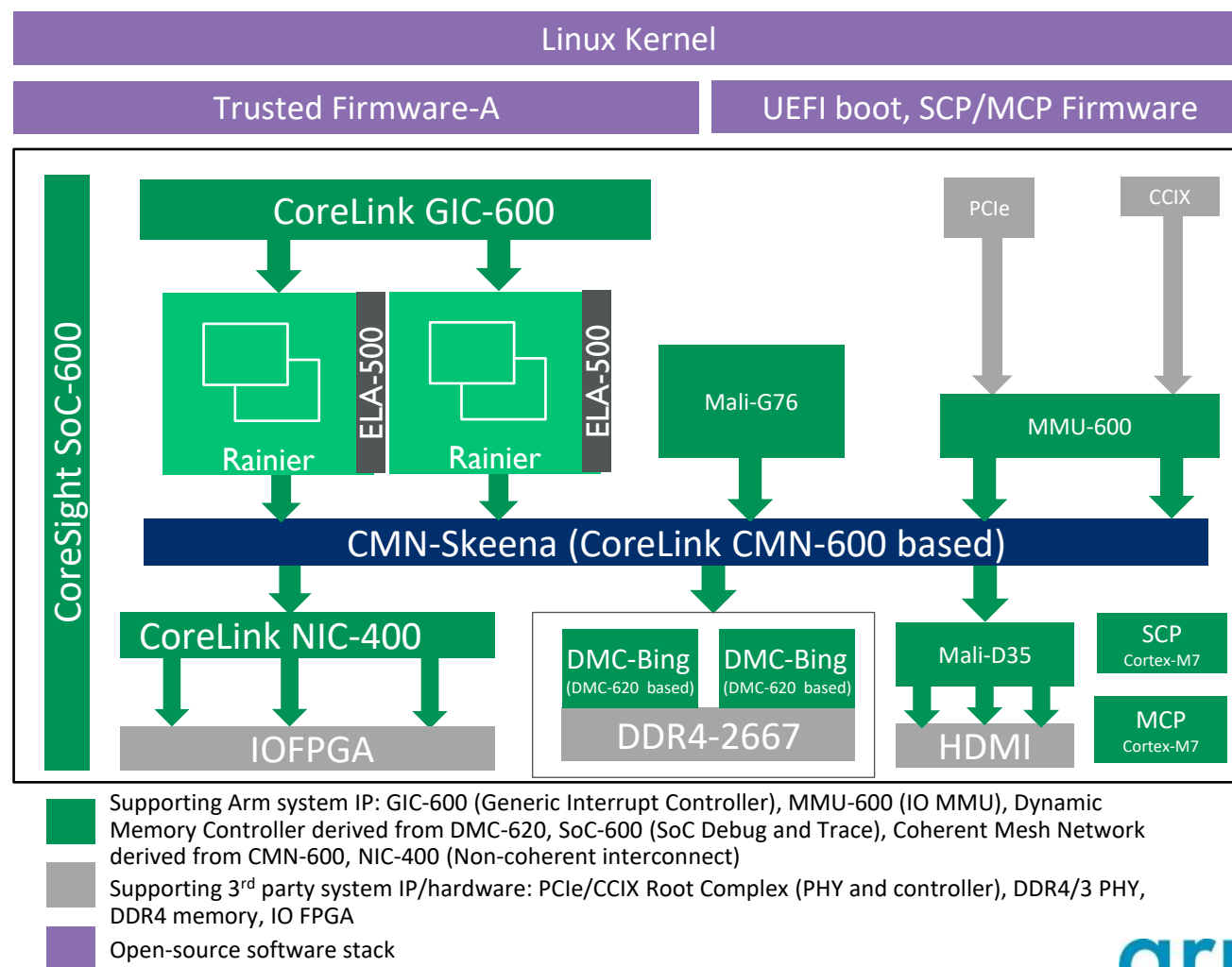


Morello Program Overview

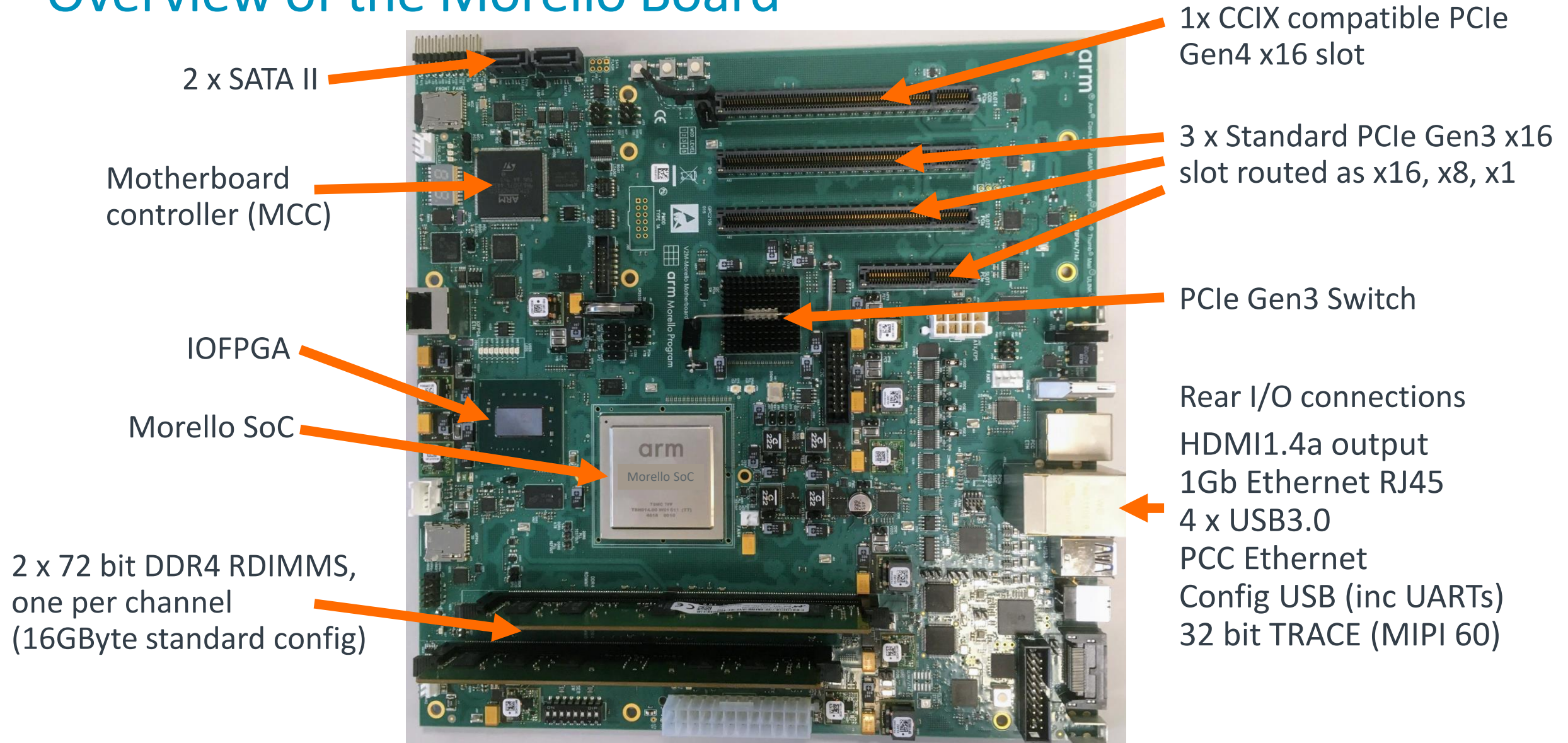
Mark Inskip, Program Director
Arm Central Engineering
5 October 2021

Morello Board: Capability Hardware Prototype Platform

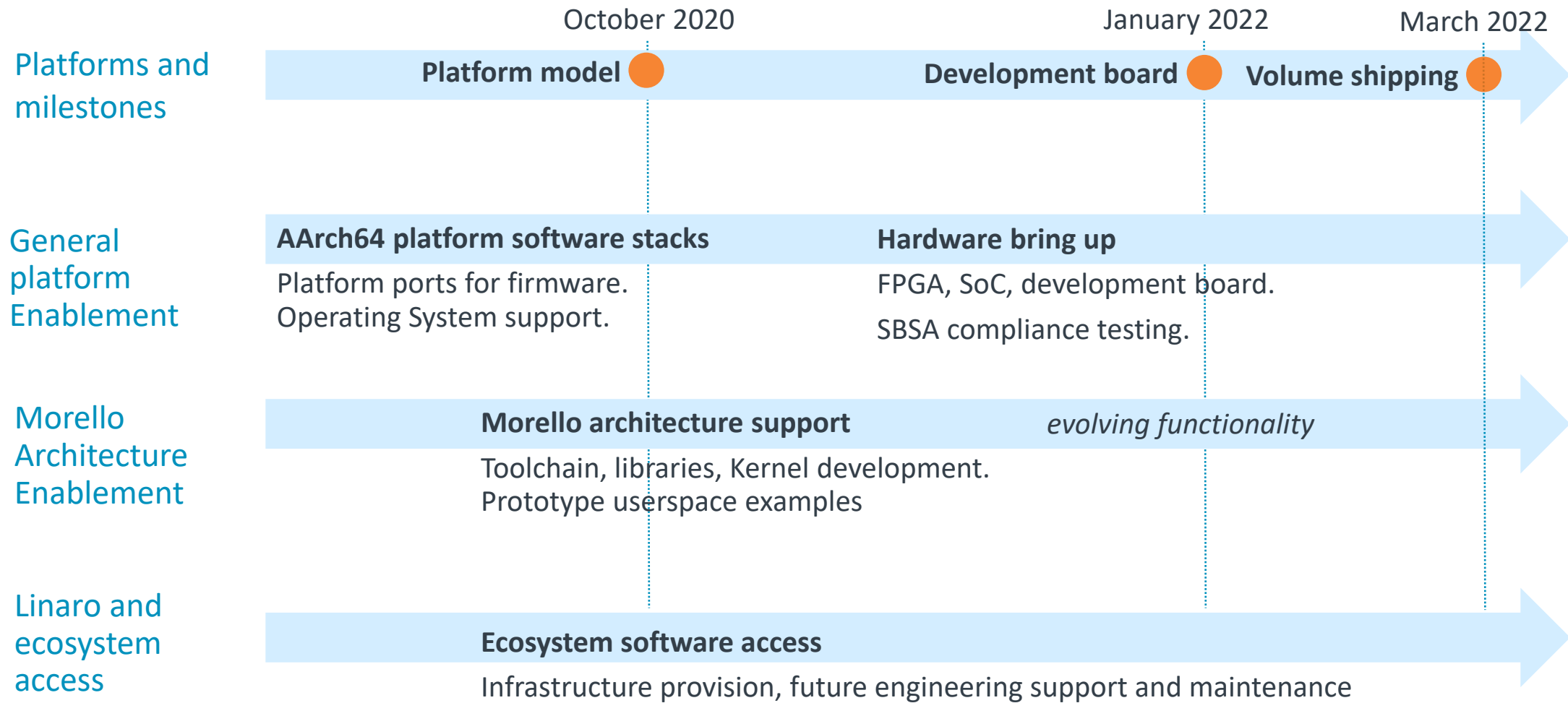
- Silicon implementation of a Capability Hardware CPU Instruction Set Architecture
 - Implements Morello Profile for A-class Prototype Architecture
 - Two clusters each of two Rainier CPUs
 - Interconnect and Memory Controller support for tagged memory
 - Two channel DDR4 DRAM interface
 - PCIe Gen3 and Gen4 x16 interface
 - CCIX (Cache Coherent Interconnect for Accelerators) interface
 - Mid-range GPU, display processor and HDMI output
 - On standard uATX form factor board



Overview of the Morello Board



Overview – Morello Program Timeline





Morello Technology Demonstrator September 2021 update

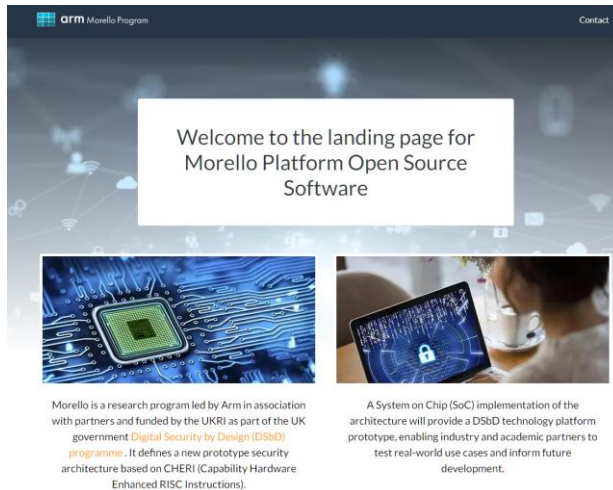
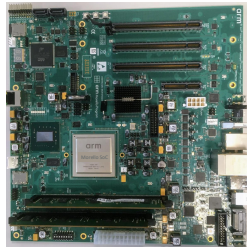
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Technology Manager

Arm Central Engineering: Open Source Software

Morello software ecosystem enablement

Platforms



<https://www.morello-project.org/>

Software workstreams

Platform firmware & bring up

Toolchains & Libs (LLVM** & GCC)

*** Primary toolchain*

Linux Kernel

Development environments

Infrastructure & hosting

Initial FVP
release

Oct 20

Hardware
availability

Apr 22

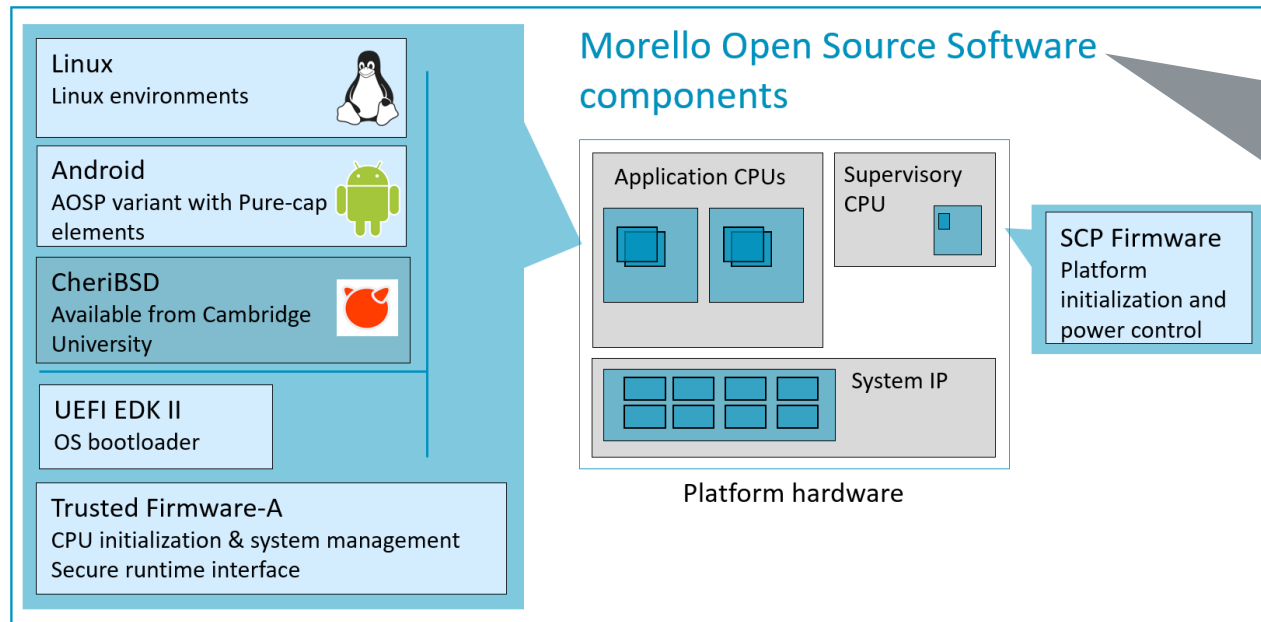
Incremental releases

Program
close

2024



Software stack foundations to support ecosystem research



Stacks intended to bootstrap research activities across a wide range of possible areas:

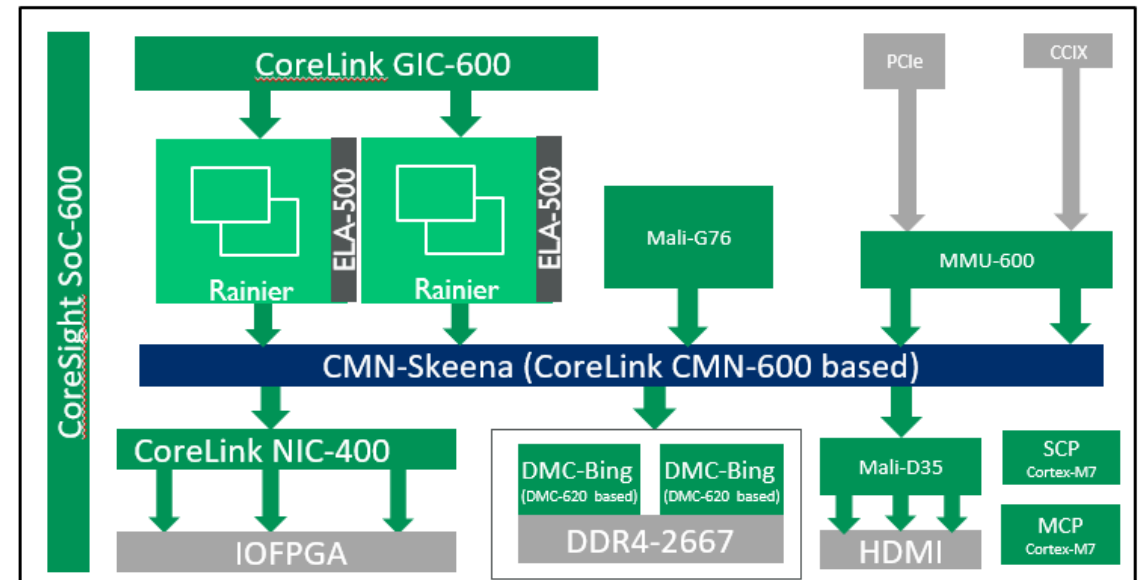
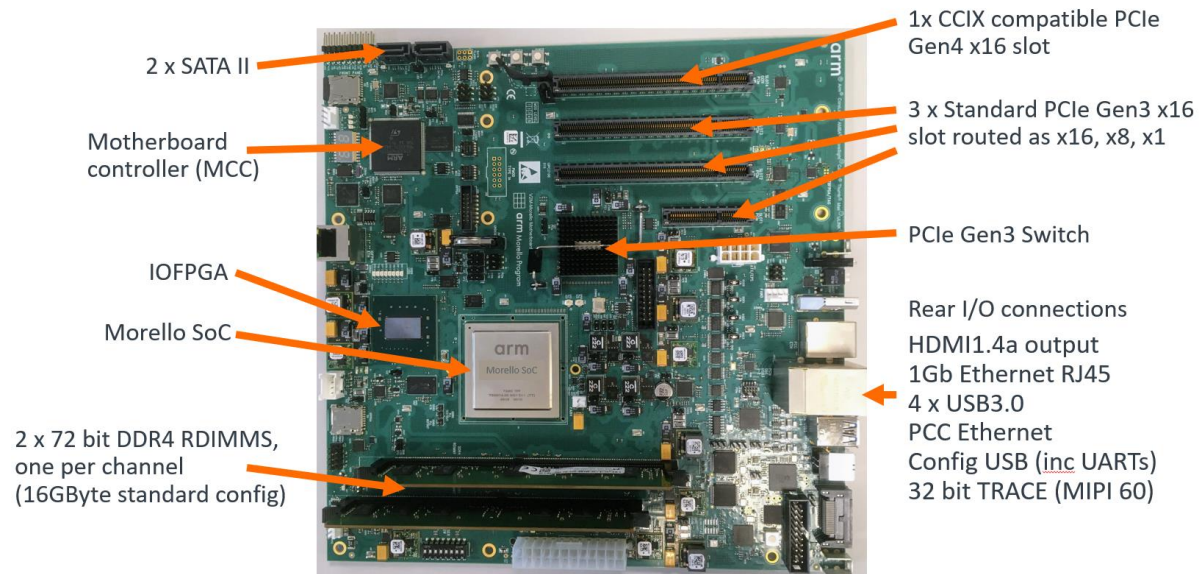
- Pure capability kernel extensions
- RTOS & embedded stacks
- Workloads (webservers, databases)
- Managed languages & runtimes (Python, Java, Javascript, WebAsm)
- Browsers
- Graphics stacks
- Tooling (optimization, porting, debug, performance & security analysis)

Collaboration on foundational enablement & feedback is welcome

- Some research activities may be dependent on future work
- Arm's contributions will continue throughout lifetime of Program and functionality will evolve in stages

Morello hardware development platform – initial support

- Developments boards (Q1 2022 onwards) will be supported by the same software stacks as existing FVP
- Software releases for initial boards may not include mature support, examples:
 - Support for DDR & PCIe may not initially be performant
 - Satellite peripherals (such as audio and video IPs) may not have driver support
 - Secondary features such as power management and network boot may not be available
- Firmware pre-installed on boards should be updated to the latest versions immediately after first validation of boot



Baremetal Enablement

Firmware stack supports exit at two points

- Post SCP execution: System IP initialized. Develop from lead processor reset
- Post TF-A execution: Lead Application processor initialized. Runtime services available.

Arm Development Studio Morello Edition

- Eclipse based integrated environment for bare-metal configurations
- Supports debug on FVP and (in 2022) development board

CheriBSD

- Details presented by University of Cambridge
- Provides a BSD based memory-safe kernel and userspace
- Above common Morello firmware stack

Android Enablement

Evolving releases since Oct 2020



Current (nano) headless profile for FVP

- Support for purecap applications & example ports (libjpeg-turbo, logd, BoringSSL, etc) integrated into minimal 64bit AOSP
- Purecap Bionic C library variant (CHERI LLVM/Clang + libshim)

Future work (2022 onwards)

- Full Android boot on development board
- Staged Morello Kernel PCuABI features (Q1 on)
- Bionic evolution
- Investigation: Android Runtime + zygote
- Purecap graphics frameworks



Linux Enablement

Under development

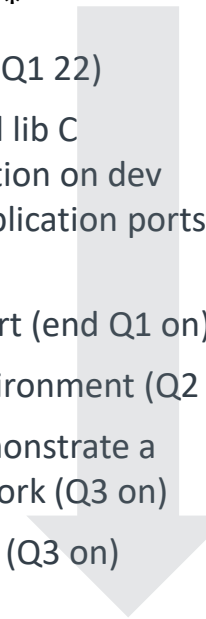


Initial Proof of Concept (end 2021 for FVP)

- Purecap “Hello world” integrated into standard (64bit) rootfs
- Purecap musl libC (CHERI LLVM/Clang + libshim). Early prototype/limited features.

Future work (2022 onwards) **

- Development board support (Q1 22)
- Evolution of CHERI LLVM musl lib C environment: Native compilation on dev board, purecap userspace application ports (Q1 22)
- Morello Kernel PCuABI support (end Q1 on)
- Initial Morello GCC/Glibc environment (Q2 on)
- Proof of concept work to demonstrate a Morello aware Distro framework (Q3 on)
- Purecap graphics frameworks (Q3 on)



** *uncommitted estimates*

Morello Kernel, C libraries & libshim

Morello Linux kernel (Development through 2022)

- Focus on new kernel-user ABI to support purecap userspace software
- Work in associated C libraries (Bionic, Musl, Glibc) – both developed against a PCuABI (Pure Capability userspace ABI) specification
- Enabling Linux environments supporting mix of purecap and “COMPAT” 64 bit userspace components

Linux and Android built C libraries and libshim

- C libraries initially implemented using concept of a [libshim](#) translation layer
- Allows functional development and porting in userspace ahead of mature kernel ABI support
- Does not provide a secure implementation, but allows support for a full set of system calls

Aim 1: PCuABI functional support

- Aim: Native support for user-space applications built against the purecap ABI
- Limited set of syscalls, expanded over time. Allows incremental reduction of reliance on libshim

Aim 2: PCuABI memory safety & security

- Use of capabilities to improve memory safety at the kernel-user boundary

uncommitted estimates

Initial (lightly modified) ACK – reliant on libshim	Releases in 2021
Initial Kernel Infrastructure, core purecap functionality	Dev underway
Base 64bit COMPAT (hybrid 64bit & purecap userspace)	
Initial PCuABI spec implementation in Kernel	End Q1 2022
Enforcement of capability metadata (security model)	Q2 2022 on
Full PCuABI specification implementation	Q3 2022 on
Full PCuABI support for Bionic (Android) & musl (Linux)	
Full PCuABI support for Glibc (Linux)	

Kernel PCuABI support

Media Enablement

- Media support for Morello Mali-D35 (Display Processor) and Mali-G76 (GPU) based around Open Source Software
 - Mali-D35 supported by existing upstream Kernel driver.
 - GPU support will be based on the Open Source Panfrost driver framework for Mali Bifrost GPU architectures
- Timelines
 - Initial UI support for the Morello development board will be based on software rendering.
 - Panfrost GPU driver platform port (64bit) starts Q1 2022
 - purecap ports of graphics libraries will be an ongoing activity through 2022 & beyond

arm

Thank You

Danke

Merci

谢谢

ありがとう

Gracias

Kiitos

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Morello LLVM & GNU Toolchain timelines

LLVM (Primary toolchain)

- **Ongoing:** Regular re-bases to CHERI LLVM.
- **CY21Q1** (Done):
 - C++ exceptions (static linking).
- **CY21Q2** (Done):
 - Performance optimisations.
 - Descriptor ABI (spec, codegen, LLD, LLDB).
- **CY21Q3** (in review):
 - C++ exceptions (dynamic linking).
- **CY22Q1:**
 - More extensive public test.
- **CY22Q2:**
 - Code generation for DDC offsetting mode.

GNU Tools

- **CY21Q3** (Done):
 - GDB (BET)
- **CY21Q3:**
 - GDB (REL)
- **CY21Q4:**
 - GCC C Lang Support (BET)
- **CY22Q1:**
 - GCC intrinsics
 - Glibc (DEV)
- **CY22Q2 onward:**
 - GCC Hybrid cap support
 - GCC C++ Language Support