tinyML® Talks

Enabling Ultra-low Power Machine Learning at the Edge

"Streamlining tinyML application development using open-CMSIS and visual studio code"

Varun Chari – Staff Software Engineer, Arm

May 7, 2024

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Advancing AI research to make efficient AI ubiquitous

Power efficiency

Model design, compression, quantization, algorithms, efficient hardware, software tool

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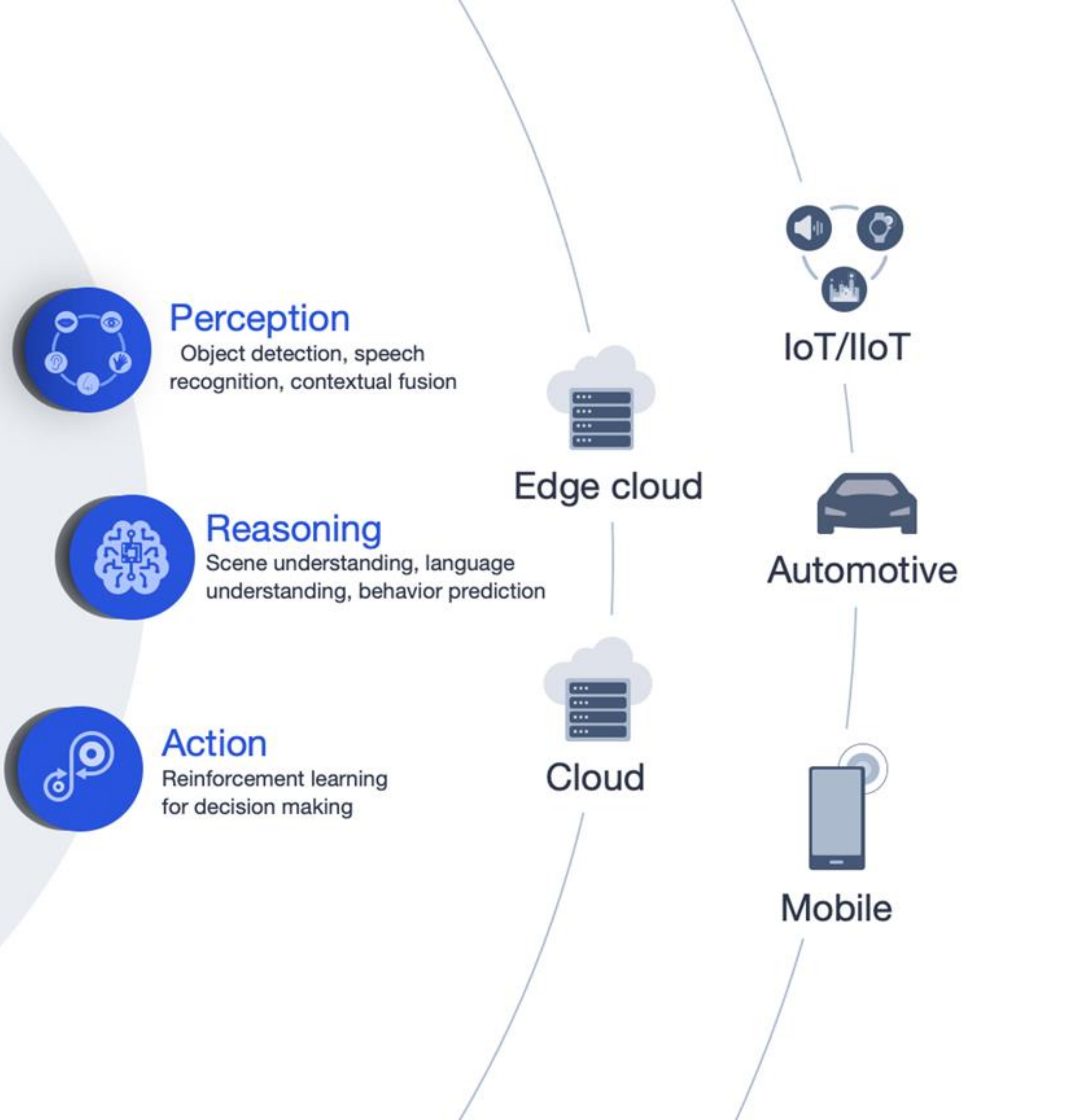

Perception
Object detection, speech recognition, contextual fusion

Reasoning
Scene understanding, language understanding, behavior prediction

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Reinforcement learning for decision making

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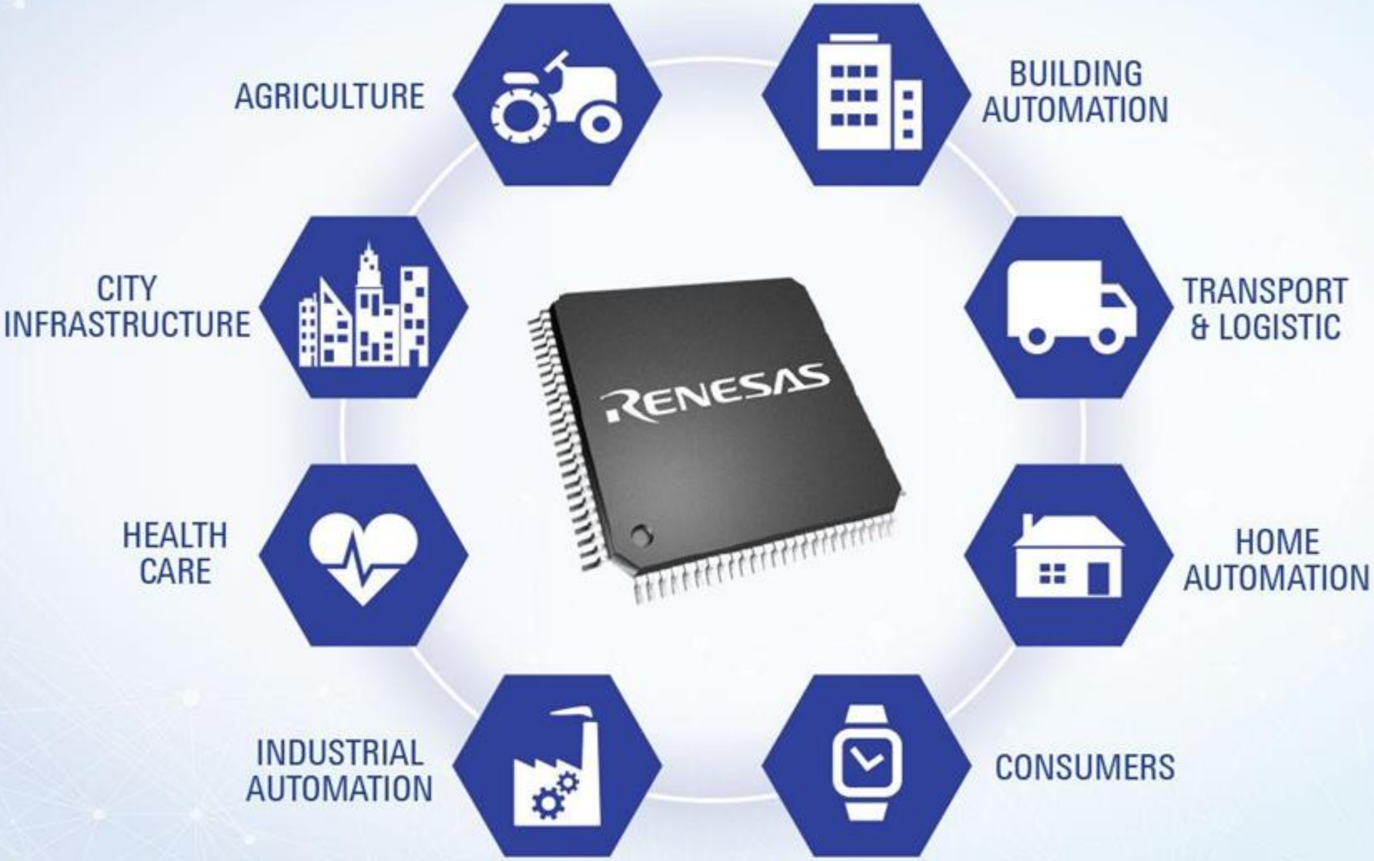

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tinyML - Enabling ultra-low Power ML at the Edge

https://www.meetup.com/tinyML-Enabling-ultra-low-Power-ML-at-the-Edge/

4k members
&
15k followers

The tinyML Community

https://www.linkedin.com/groups/13694488/

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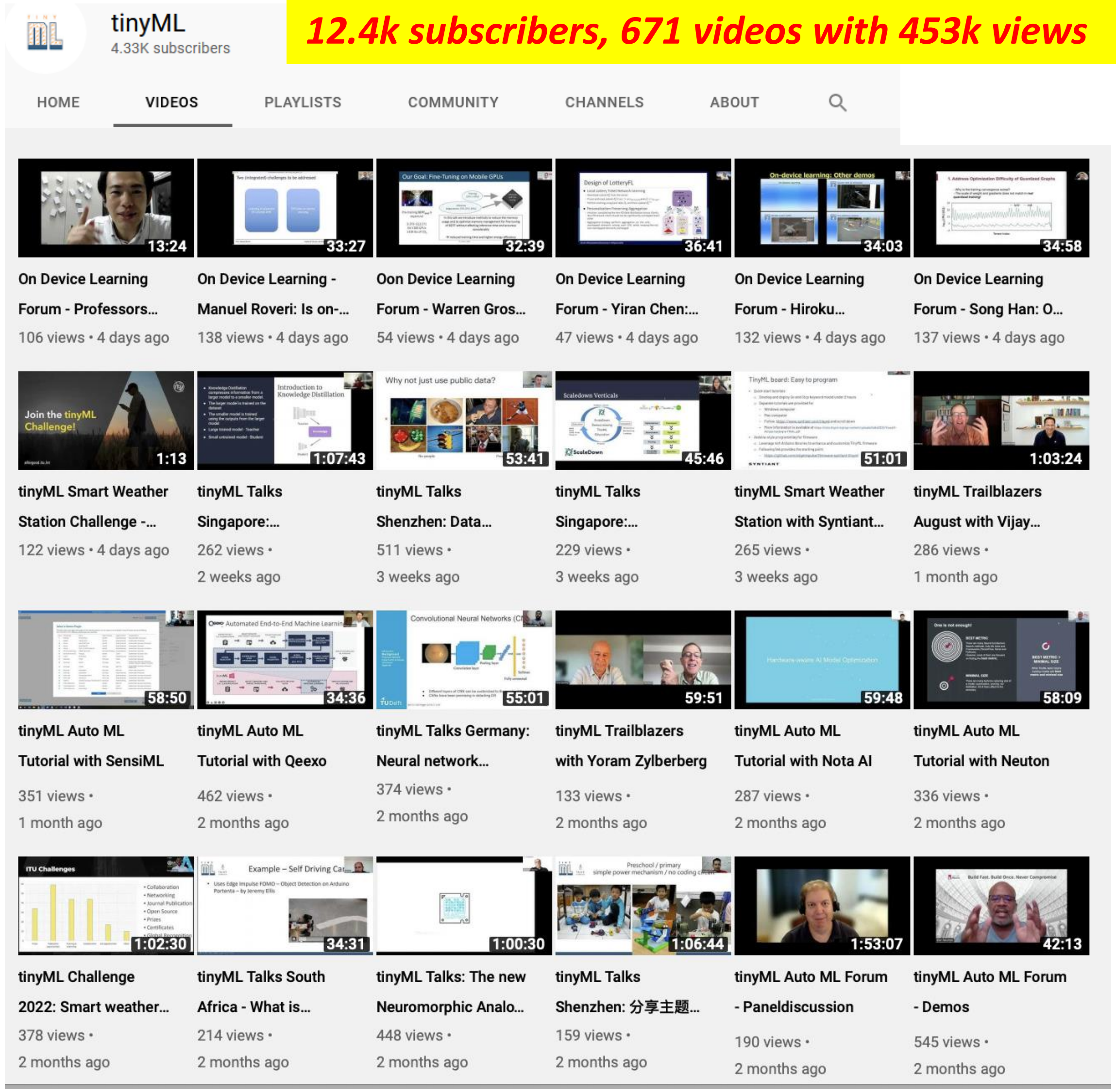
(including this video)

www.youtube.com/tinyML

12.4k subscribers, 671 videos with 453k views



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Amplifying Impact – Unleashing the Potential of TinyML

tinyML EMEA
June 24 -26, 2024 in Milan, Italy

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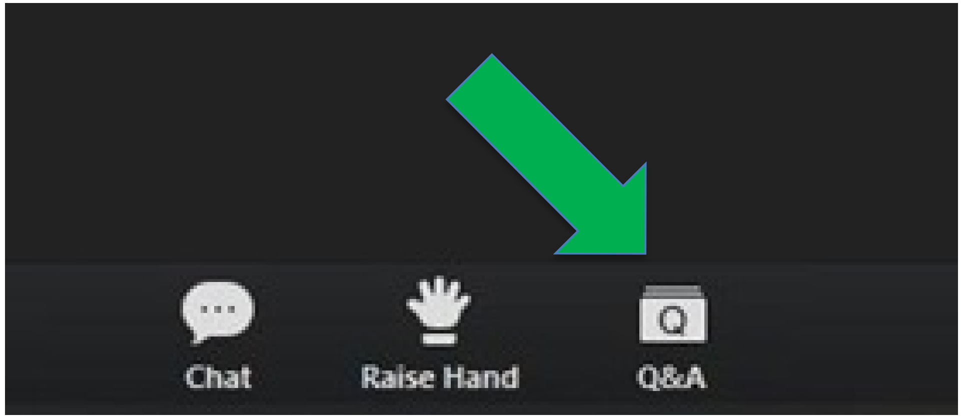
Reminders

Slides & Videos will be posted tomorrow

tinyml.org/forums

youtube.com/tinyml

Please use the Q&A window for your questions



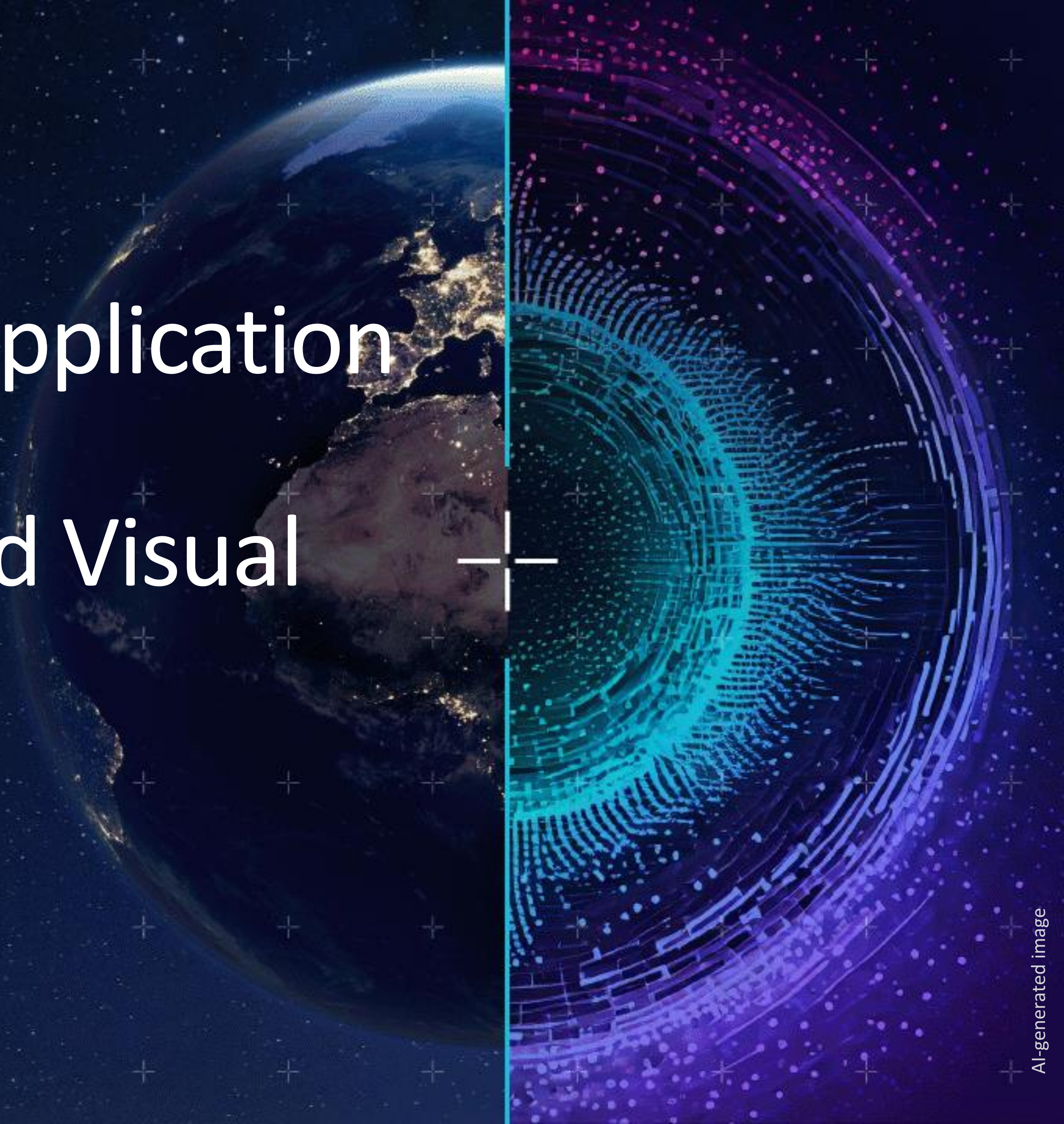
Varun Chari

Varun is a Staff Software Engineer in Strategic Alliances Technical Marketing Team at Arm. He focuses on enabling and leading software strategies on emerging technologies relevant to Arm across the strategic partners (Google, Meta, Amazon, Microsoft) in Machine Learning and IoT space.

Streamlining tinyML application development using Open CMSIS packs and Visual Studio Code

Varun Chari, Arm

07 May 2024



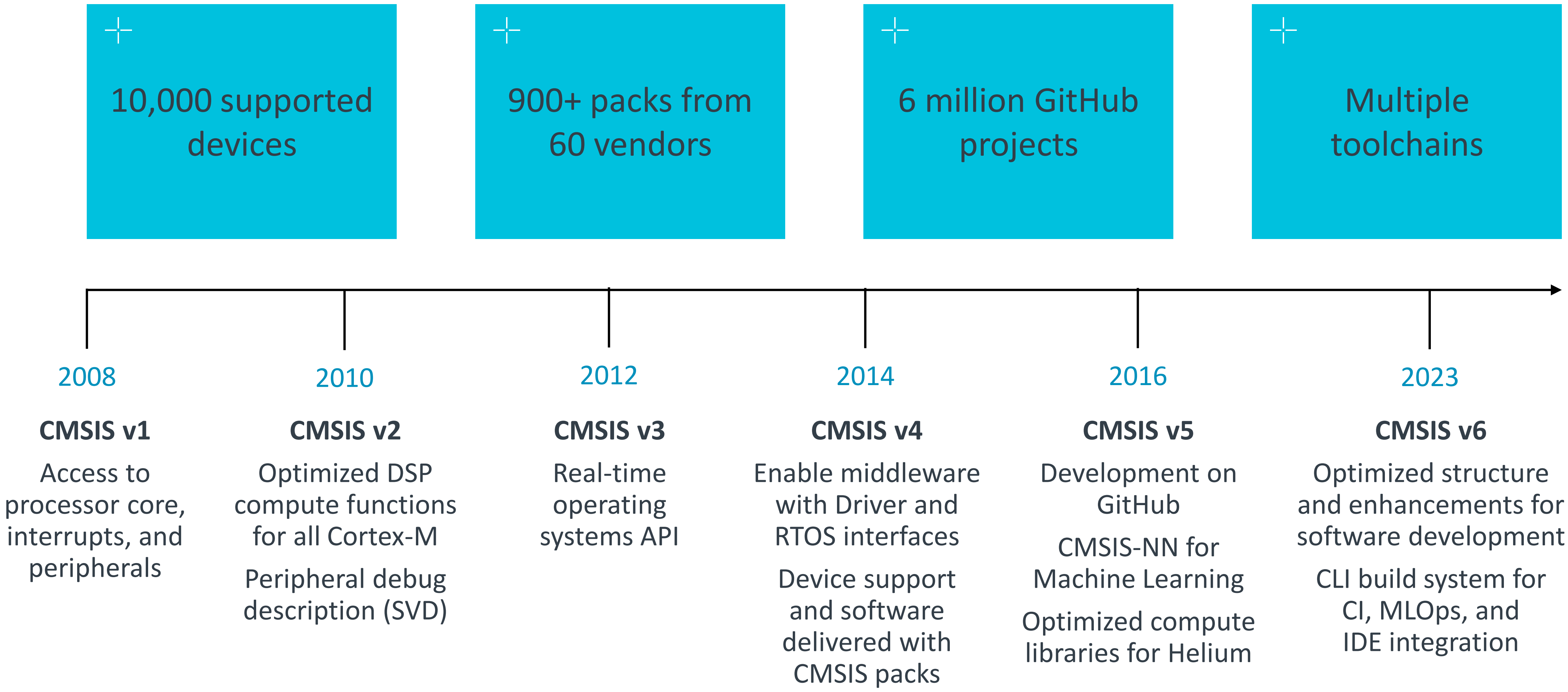
AI-generated image

Current Challenges

- Fragmentation
  - Variety of toolchains/IDEs from silicon providers
- Duplication
  - Duplicate copies of codebase for different projects
- Vulnerability
  - Vulnerable open-source, unmaintained software
- Modularity
  - Monolithic non-modular projects
- Deployment at scale
  - Limited CI/CD integrations and MLOps support
- Connectivity
  - Challenging to add cloud connectivity components
- Security
  - Unsecure codebase sharing

Common Microcontroller Software Interface Standard (CMSIS)

CMSIS



10,000 supported devices

900+ packs from 60 vendors

6 million GitHub projects

Multiple toolchains

2008

CMSIS v1

Access to processor core, interrupts, and peripherals

2010

CMSIS v2

Optimized DSP compute functions for all Cortex-M

Peripheral debug description (SVD)

2012

CMSIS v3

Real-time operating systems API

2014

CMSIS v4

Enable middleware with Driver and RTOS interfaces

Device support and software delivered with CMSIS packs

2016

CMSIS v5

Development on GitHub

CMSIS-NN for Machine Learning

Optimized compute libraries for Helium

2023

CMSIS v6

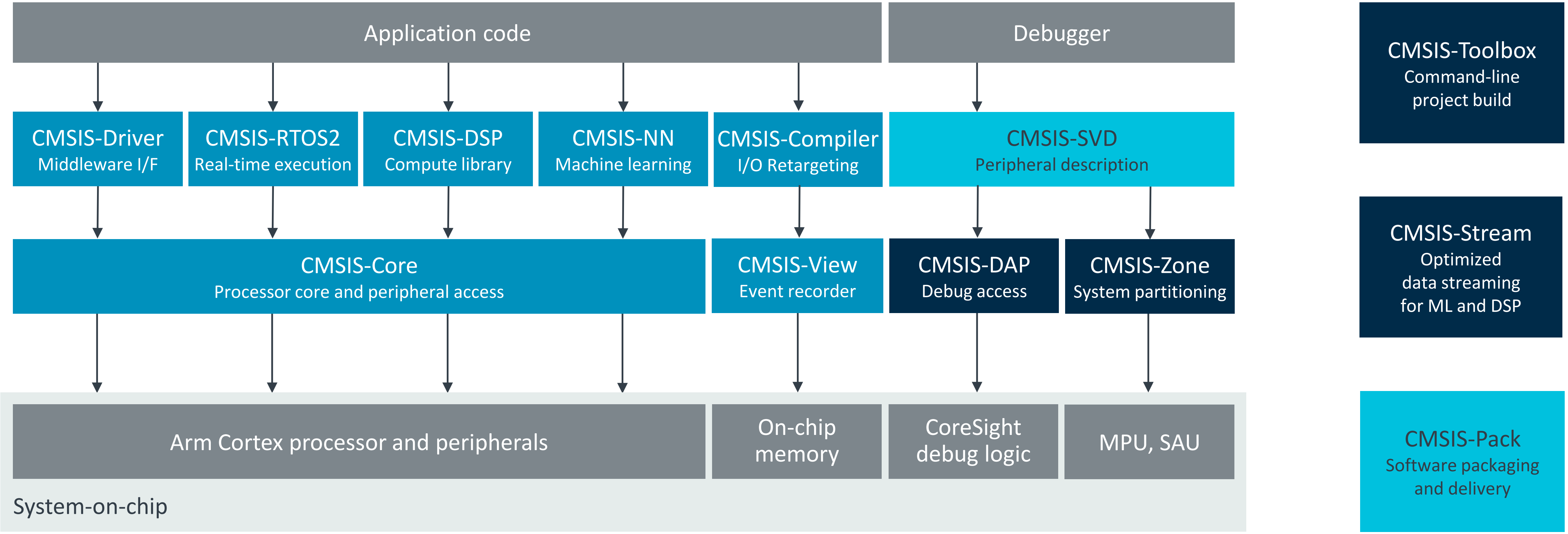
Optimized structure and enhancements for software development

CLI build system for CI, MLOps, and IDE integration

CMSIS Version 6

github.com/ARM-software/CMSIS_6

Consistent software framework for billions of devices



Application code

Debugger

CMSIS-Driver
Middleware I/F

CMSIS-RTOS2
Real-time execution

CMSIS-DSP
Compute library

CMSIS-NN
Machine learning

CMSIS-Compiler
I/O Retargeting

CMSIS-SVD
Peripheral description

CMSIS-Core
Processor core and peripheral access

CMSIS-View
Event recorder

CMSIS-DAP
Debug access

CMSIS-Zone
System partitioning

Arm Cortex processor and peripherals

On-chip memory

CoreSight debug logic

MPU, SAU

System-on-chip

CMSIS-Toolbox
Command-line project build

CMSIS-Stream
Optimized data streaming for ML and DSP

CMSIS-Pack
Software packaging and delivery

■ Software components for the Arm Cortex processor target

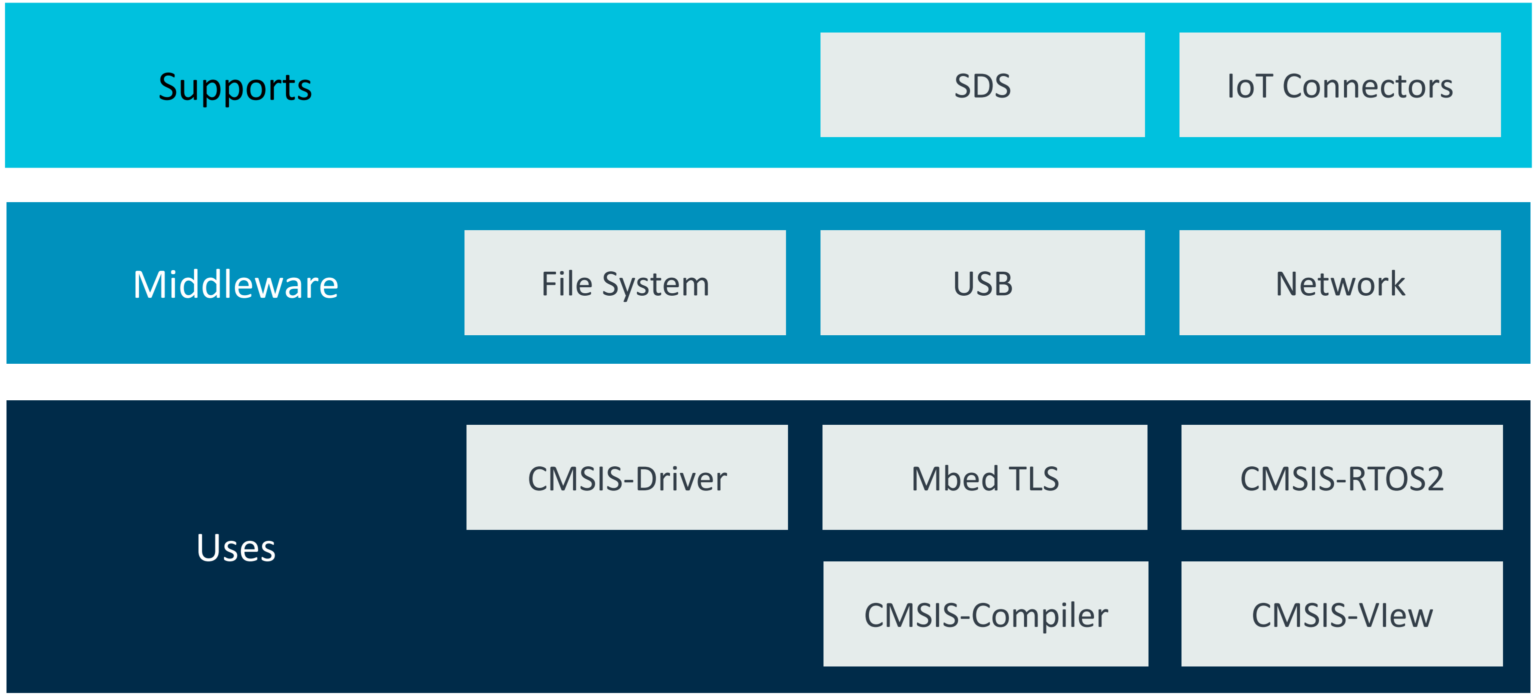
■ Tools for optimizing software development flows

■ Specifications

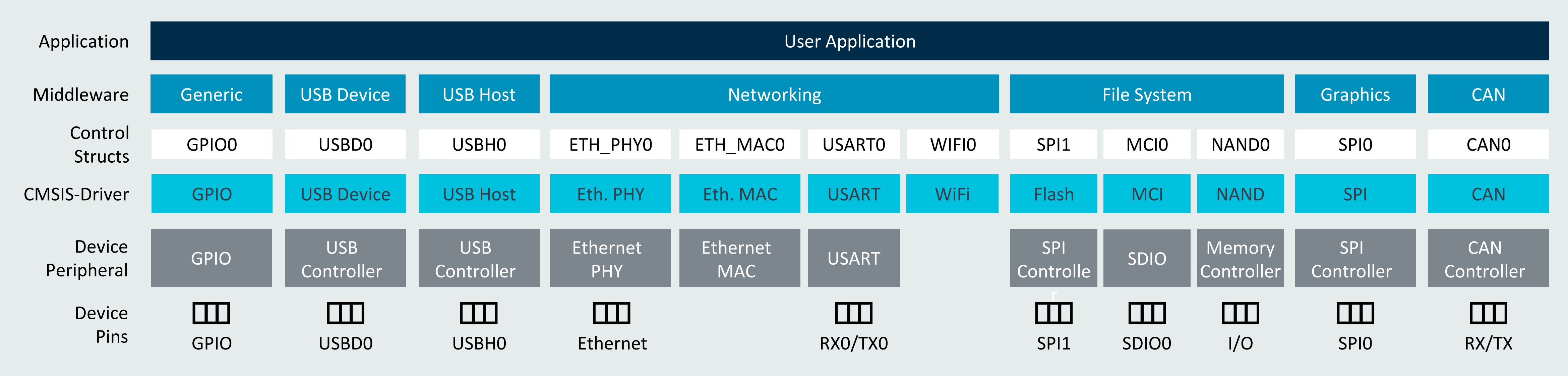
Application Development Using CMSIS Middleware Components

Using CMSIS Components (Middleware)

- File System
  - RAM, Flash, SD/SDHC/MMC memory cards, or USB memory devices.
- USB
  - For USB Device and Host applications with various USB device classes.
- Network
  - Services, protocol sockets, and communication I/Fs supporting IPv4 and IPv6.



Using Standardized Driver Interfaces (CMSIS-Driver)



Application	User Application											
Middleware	Generic	USB Device	USB Host	Networking				File System			Graphics	CAN
Control Structs	GPIO0	USBD0	USBH0	ETH_PHY0	ETH_MAC0	USART0	WIFI0	SPI1	MCI0	NAND0	SPI0	CAN0
CMSIS-Driver	GPIO	USB Device	USB Host	Eth. PHY	Eth. MAC	USART	WiFi	Flash	MCI	NAND	SPI	CAN
Device Peripheral	GPIO	USB Controller	USB Controller	Ethernet PHY	Ethernet MAC	USART		SPI Controlle r	SDIO	Memory Controller	SPI Controller	CAN Controller
Device Pins	GPIO	USBD0	USBH0	Ethernet		RX0/TX0		SPI1	SDIO0	I/O	SPI0	RX/TX

- The unified API follows the similar design principles across all peripherals.
- Driver templates files provide code skeletons for specific peripherals.
- Support for multiple driver instances with Access Struct.
- Driver-Validation Suite provides a set of tests to verify compatibility to CMSIS-Driver API definitions.

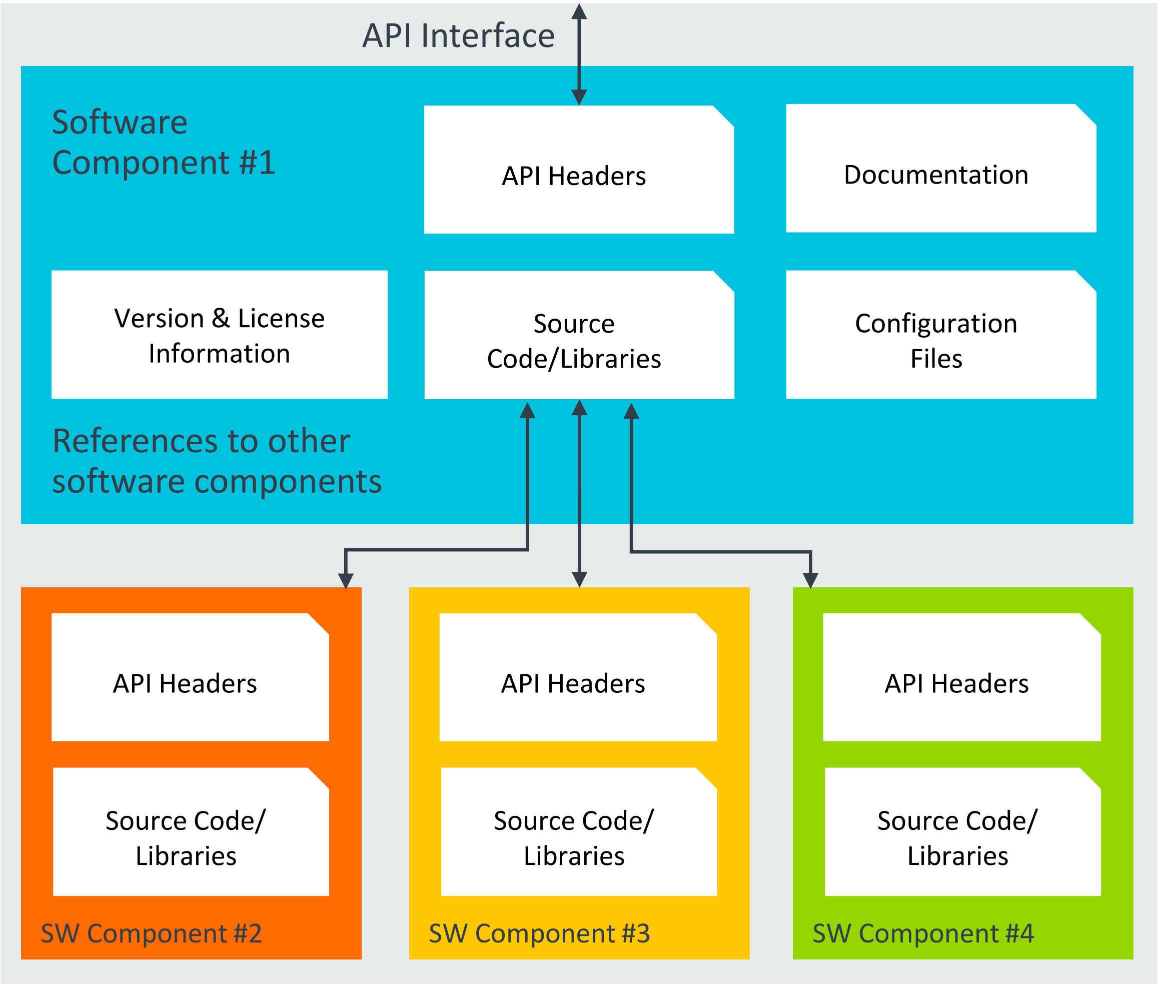
Reusable Software Components

CMSIS-Pack: What is a Software Component?

- XML framed information used by project management utilities from various tools

Software components should have:

- Version and history information
- License information
- API interface definition
- Documentation
- Source files
- Configuration files (optional)
- Requirements to other components (optional)



Read the blog

CMSIS-Pack: Central API Interface Definition

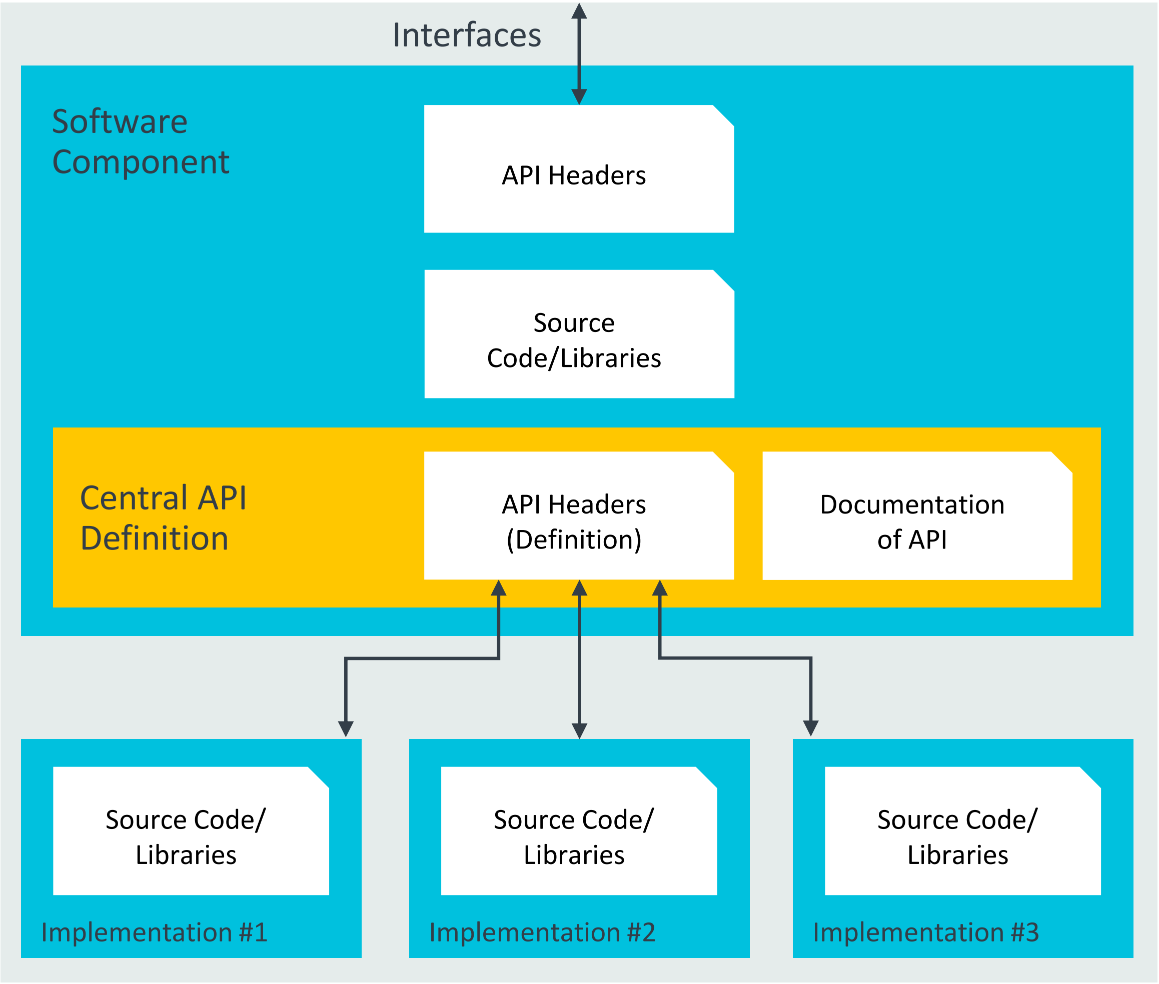
Ensuring consistent interfaces across standard components

A common problem: API headers evolve over time.

A central API definition shares header file and documentation of an API interface across multiple other software components to ensure consistency.

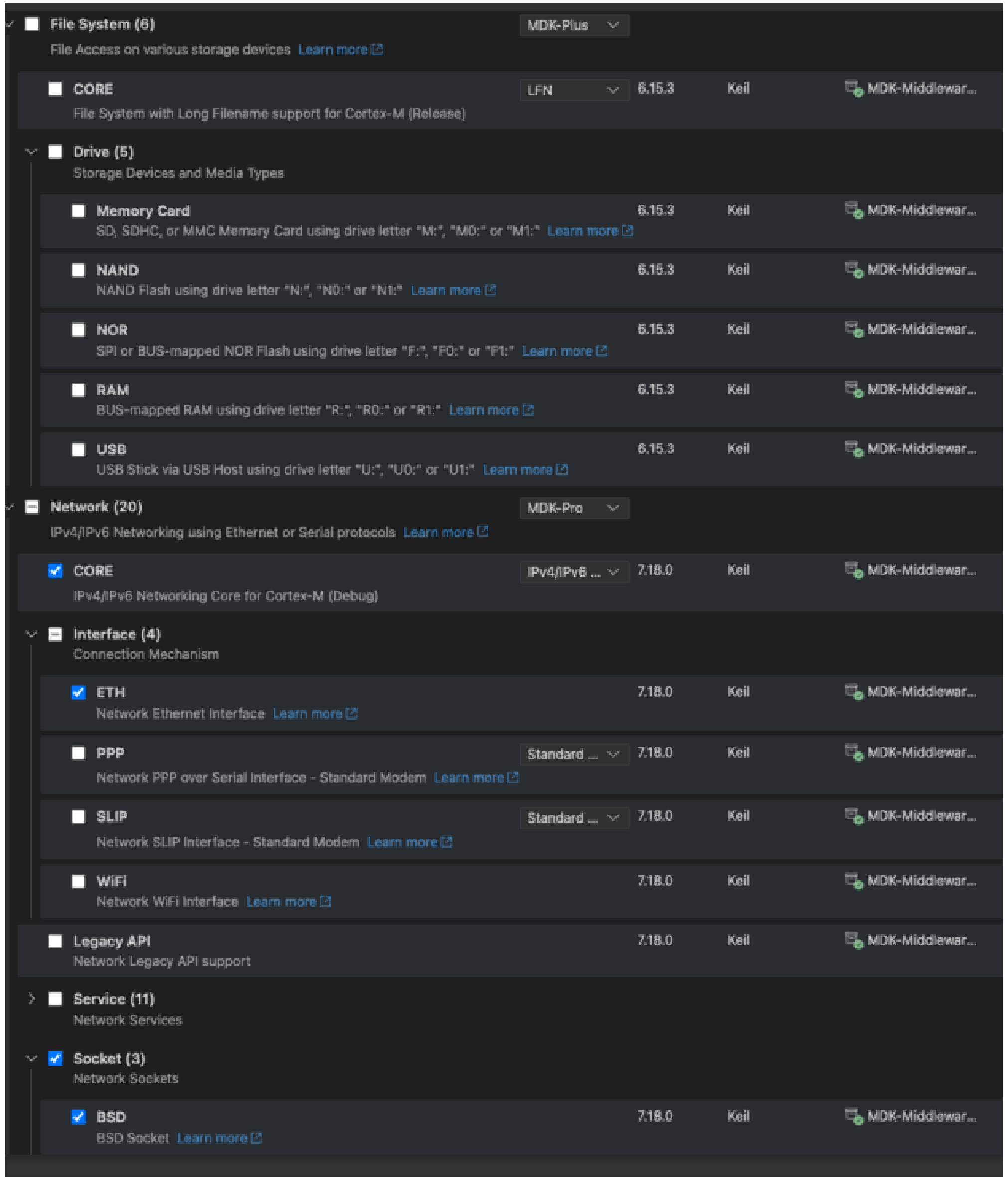
The API interface is distributed separate or as part of the software component that defines this interface. The API header file is therefore consistent.

An example is the CMSIS-Driver pack that contains various Flash, Ethernet and WiFi drivers – all compatible with the CMSIS-Driver APIs that are published in the CMSIS Pack.



Example: MDK Middleware

- Network
  - IPv4/IPv6 TCP/IP connectivity via Ethernet or Serial Connection
- USB
  - USB Host and USB Device support
  - High performance, small footprint
  - No necessity for Windows/Linux drivers
- File System
  - ROM, RAM, Flash, SD/MMC/SDHC
  - FAT32 support
  - Simultaneous device access
- mbedTLS



□ **File System (6)** File Access on various storage devices Learn more	MDK-Plus			
□ **CORE** File System with Long Filename support for Cortex-M (Release)	LFN	6.15.3	Keil	MDK-Middlewar...
□ **Drive (5)** Storage Devices and Media Types				
□ **Memory Card** SD, SDHC, or MMC Memory Card using drive letter "M:", "M0:" or "M1:" Learn more		6.15.3	Keil	MDK-Middlewar...
□ **NAND** NAND Flash using drive letter "N:", "N0:" or "N1:" Learn more		6.15.3	Keil	MDK-Middlewar...
□ **NOR** SPI or BUS-mapped NOR Flash using drive letter "F:", "F0:" or "F1:" Learn more		6.15.3	Keil	MDK-Middlewar...
□ **RAM** BUS-mapped RAM using drive letter "R:", "R0:" or "R1:" Learn more		6.15.3	Keil	MDK-Middlewar...
□ **USB** USB Stick via USB Host using drive letter "U:", "U0:" or "U1:" Learn more		6.15.3	Keil	MDK-Middlewar...
⊟ **Network (20)** IPv4/IPv6 Networking using Ethernet or Serial protocols Learn more	MDK-Pro			
☑ **CORE** IPv4/IPv6 Networking Core for Cortex-M (Debug)	IPv4/IPv6 ...	7.18.0	Keil	MDK-Middlewar...
⊟ **Interface (4)** Connection Mechanism				
☑ **ETH** Network Ethernet Interface Learn more		7.18.0	Keil	MDK-Middlewar...
□ **PPP** Network PPP over Serial Interface - Standard Modem Learn more	Standard ...	7.18.0	Keil	MDK-Middlewar...
□ **SLIP** Network SLIP Interface - Standard Modem Learn more	Standard ...	7.18.0	Keil	MDK-Middlewar...
□ **WiFi** Network WiFi Interface Learn more		7.18.0	Keil	MDK-Middlewar...
□ **Legacy API** Network Legacy API support		7.18.0	Keil	MDK-Middlewar...
□ **Service (11)** Network Services				
☑ **Socket (3)** Network Sockets				
☑ **BSD** BSD Socket Learn more		7.18.0	Keil	MDK-Middlewar...

Providers of Software Packs

keil.arm.com/packs

Graphics

Embedded Wizard
GUI Solutions by TARA Systems

SEGGER
The Embedded Experts

LVGL

Middleware

aws

Mongoose

arm
KEIL

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Mbed
TLS

Machine Learning/DSP

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EDGE IMPULSE

TDK Qeexo

TensorFlow

RTOS

Quantum Leaps
Modern Embedded Software

arm
KEIL

SEGGER
The Embedded Experts

RT-Thread

Embedded Office

free RTOS

Other

EmSA

redlogix

Memfault

CMSIS

CMSIS
CMSIS-RTX
CMSIS-DSP
CMSIS-NN
CMSIS-FreeRTOS

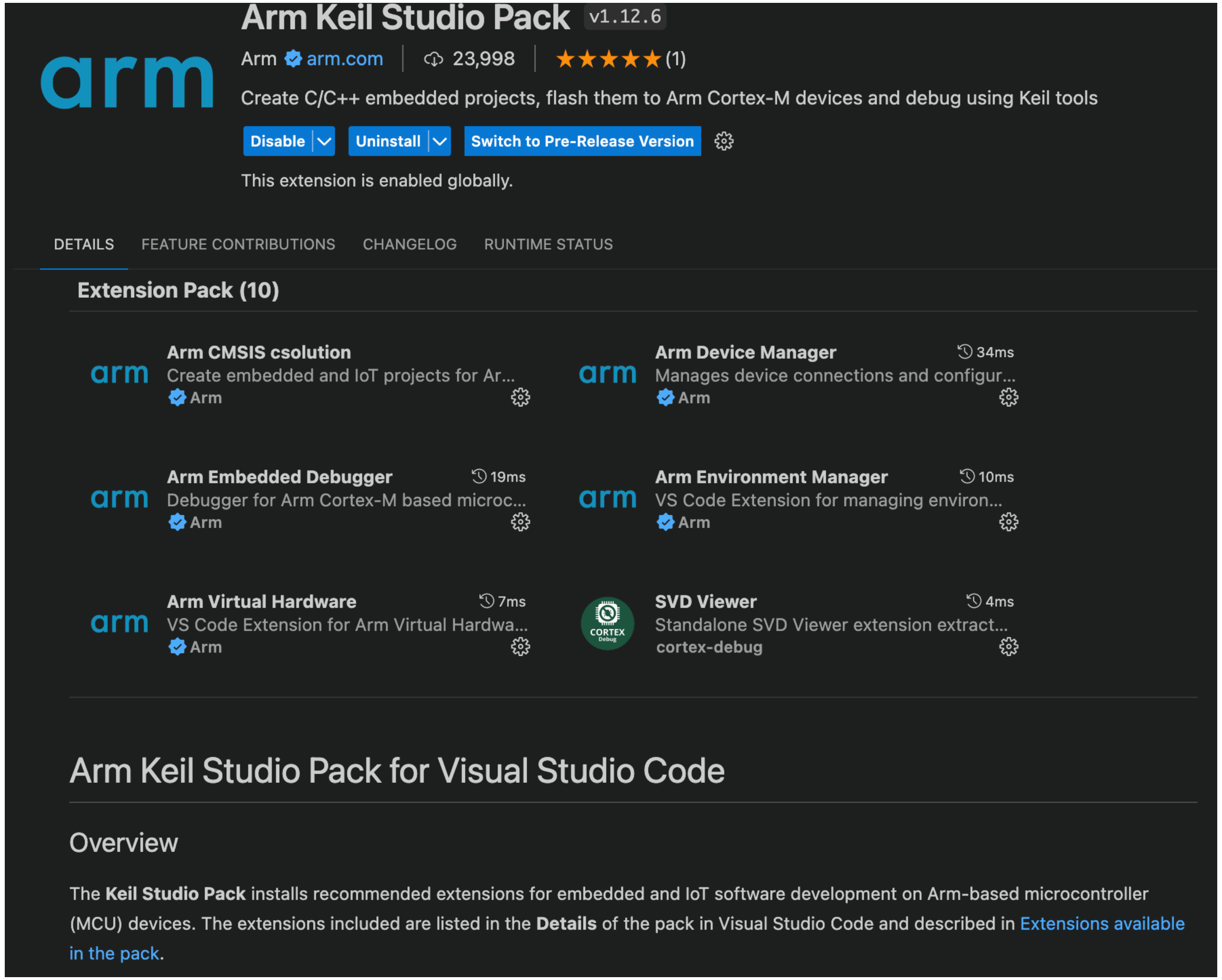
arm

CMSIS-View
CMSIS-Stream
CMSIS-Compiler

Arm Keil Studio Pack VS Code Extension

Introduction

- Comprehensive software development environment for embedded systems and IoT software development on Arm-based microcontroller (MCU) devices
- A composable set of Visual Studio Code extensions
- Plug and play device support for debug probes and development boards
- Access to the CMSIS Pack ecosystem
- Integration of Open-CMSISPack



Arm Keil Studio Pack v1.12.6

Arm arm.com | 23,998 | ★★★★★ (1)

Create C/C++ embedded projects, flash them to Arm Cortex-M devices and debug using Keil tools

This extension is enabled globally.

Extension Pack (10)

Arm CMSIS csolution
Create embedded and IoT projects for Ar...
Arm

Arm Device Manager 34ms
Manages device connections and configur...
Arm

Arm Embedded Debugger 19ms
Debugger for Arm Cortex-M based microc...
Arm

Arm Environment Manager 10ms
VS Code Extension for managing environ...
Arm

Arm Virtual Hardware 7ms
VS Code Extension for Arm Virtual Hardwa...
Arm

SVD Viewer 4ms
Standalone SVD Viewer extension extract...
cortex-debug

Arm Keil Studio Pack for Visual Studio Code

Overview

The **Keil Studio Pack** installs recommended extensions for embedded and IoT software development on Arm-based microcontroller (MCU) devices. The extensions included are listed in the **Details** of the pack in Visual Studio Code and described in Extensions available in the pack.

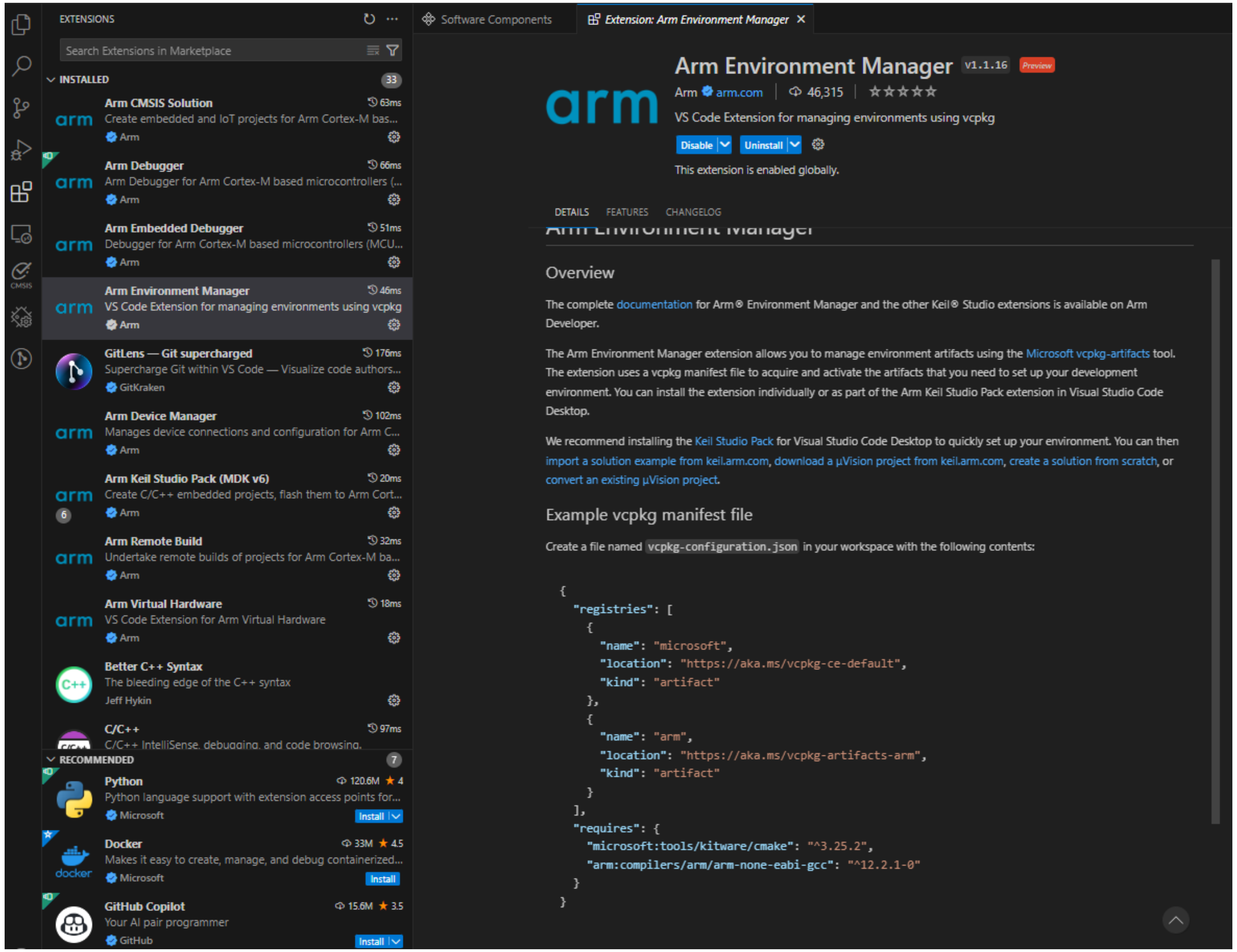
Arm Keil Studio Pack – Essential VS Code Extensions

Project & Build	Description	Used Services
Arm CMSIS csolution (*)	Create and Manage CMSIS based projects	CMSIS-Toolbox (CMake, Ninja), Compiler (AC6, GCC, LLVM) Arm License Manager – for activation of Arm Compiler
Arm Environment Manager	Arm Tools installation and activation	MSFT vcpkg Arm License Manager – for activation of Arm Compiler
clangd (LLVM)	Intellisense	
YAML (RedHat)	YAML Language Support	

Debug	Description	Used Services
Arm Debugger	Debug for Cortex-M/A processors	Arm CLI Debugger, MSDAP
Arm Device Manager	Manages device connections and configuration for Arm Cortex-M	ULINK series, CMSIS-DAP, ST-Link, Arm Fixed Virtual Platforms
Eclipse CDT Cloud Memory Inspector Peripheral Inspector Web Socket	Memory Window SVD supported access to peripherals	MSDAP

Arm Environment Manager

- Part of extension for Microsoft VS Code
- Manage development environment artifacts using the Microsoft vcpkg-artifacts tool.
- Use vcpkg manifest file to acquire and activate the artifacts that you need to set up your development environment.
- Arm tools antifactory provides access to all tools.
- Microsoft vcpkg enables tool installation across various host systems
- Arm tools antifactory provides access to all tools.



Arm CMSIS Solution 63ms
Create embedded and IoT projects for Arm Cortex-M bas...
Arm

Arm Debugger 66ms
Arm Debugger for Arm Cortex-M based microcontrollers (...
Arm

Arm Embedded Debugger 51ms
Debugger for Arm Cortex-M based microcontrollers (MCU...
Arm

Arm Environment Manager 46ms
VS Code Extension for managing environments using vcpkg
Arm

GitLens — Git supercharged 176ms
Supercharge Git within VS Code — Visualize code authors...
GitKraken

Arm Device Manager 102ms
Manages device connections and configuration for Arm C...
Arm

Arm Keil Studio Pack (MDK v6) 20ms
Create C/C++ embedded projects, flash them to Arm Cort...
Arm

Arm Remote Build 32ms
Undertake remote builds of projects for Arm Cortex-M ba...
Arm

Arm Virtual Hardware 18ms
VS Code Extension for Arm Virtual Hardware
Arm

Better C++ Syntax
The bleeding edge of the C++ syntax
Jeff Hykin

C/C++ 97ms
C/C++ IntelliSense, debugging, and code browsing.

Python 120.6M ★ 4
Python language support with extension access points for...
Microsoft

Docker 33M ★ 4.5
Makes it easy to create, manage, and debug containerized...
Microsoft

GitHub Copilot 15.6M ★ 3.5
Your AI pair programmer
GitHub

Arm Environment Manager

Arm arm.com | 46,315 | ☆☆☆☆☆

VS Code Extension for managing environments using vcpkg

This extension is enabled globally.

Overview

The complete documentation for Arm® Environment Manager and the other Keil® Studio extensions is available on Arm Developer.

The Arm Environment Manager extension allows you to manage environment artifacts using the Microsoft vcpkg-artifacts tool. The extension uses a vcpkg manifest file to acquire and activate the artifacts that you need to set up your development environment. You can install the extension individually or as part of the Arm Keil Studio Pack extension in Visual Studio Code Desktop.

We recommend installing the Keil Studio Pack for Visual Studio Code Desktop to quickly set up your environment. You can then import a solution example from keil.arm.com, download a µVision project from keil.arm.com, create a solution from scratch, or convert an existing µVision project.

Example vcpkg manifest file

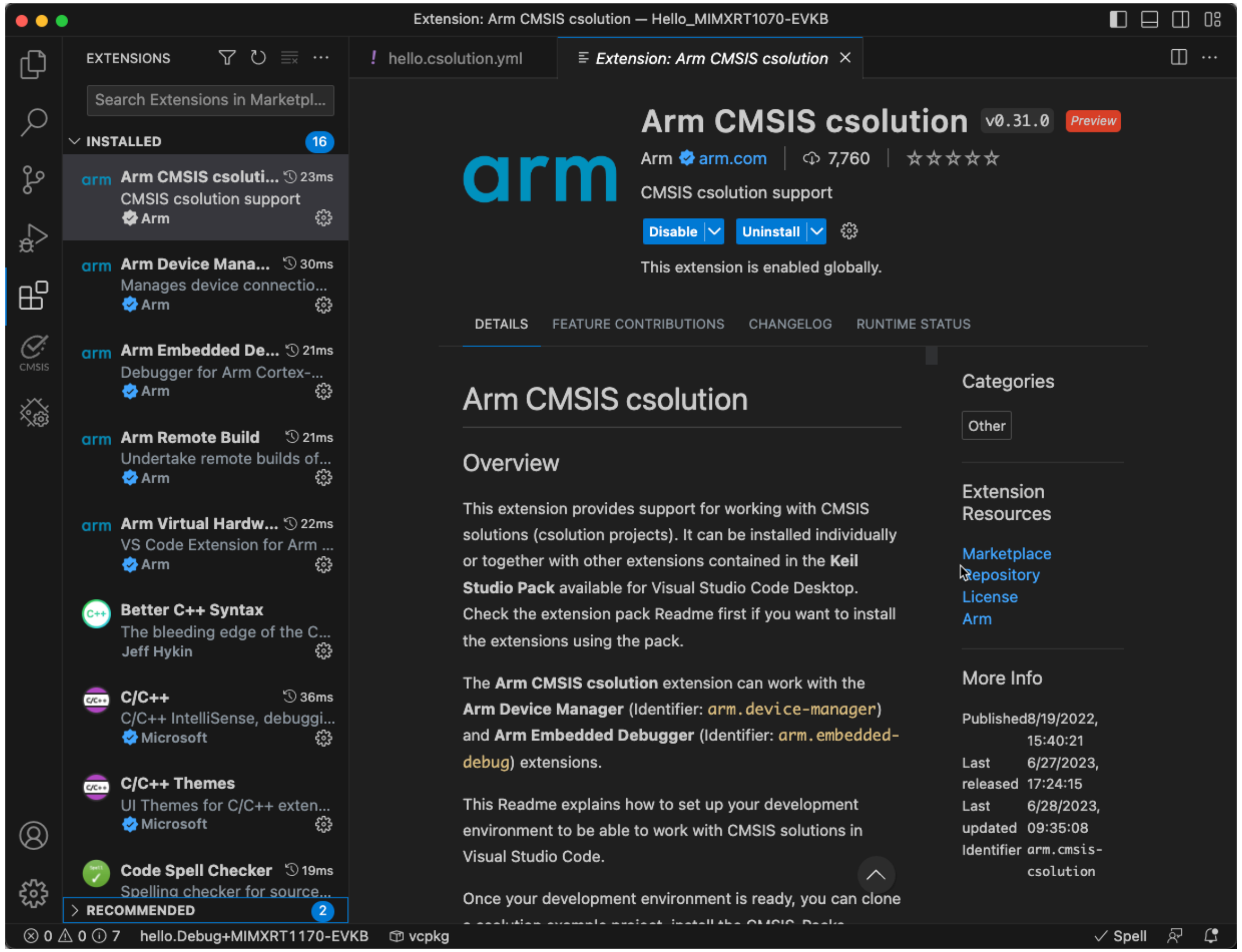
Create a file named `vcpkg-configuration.json` in your workspace with the following contents:

```
{
  "registries": [
    {
      "name": "microsoft",
      "location": "https://aka.ms/vcpkg-ce-default",
      "kind": "artifact"
    },
    {
      "name": "arm",
      "location": "https://aka.ms/vcpkg-artifacts-arm",
      "kind": "artifact"
    }
  ],
  "requires": {
    "microsoft:tools/kitware/cmake": "^3.25.2",
    "arm:compilers/arm/arm-none-eabi-gcc": "^12.2.1-0"
  }
}
```

CMSIS-Toolbox - Introduction

The basis for next generation software tooling

- Part of extension for Microsoft VS Code
- Based on CMSIS standards
- Multi-compiler support (Arm, Clang, GCC, IAR)
- CLI and IDE workflows
- Supports all major host operating systems



Extension: Arm CMSIS csolution — Hello_MIMXRT1070-EVKB
EXTENSIONS
Search Extensions in Marketpl...
INSTALLED 16
RECOMMENDED 2
CMSIS
hello.csolution.yml
Extension: Arm CMSIS csolution
Preview
Disable
Uninstall
DETAILS
FEATURE CONTRIBUTIONS
CHANGELOG
RUNTIME STATUS
⊗ 0 ⚠ 0 ⓘ 7 hello.Debug+MIMXRT1170-EVKB
vcpkg
✓ Spell

Arm CMSIS csoluti... 23ms
CMSIS csolution support
Arm

Arm Device Mana... 30ms
Manages device connectio...
Arm

Arm Embedded De... 21ms
Debugger for Arm Cortex-...
Arm

Arm Remote Build 21ms
Undertake remote builds of...
Arm

Arm Virtual Hardw... 22ms
VS Code Extension for Arm ...
Arm

Better C++ Syntax
The bleeding edge of the C...
Jeff Hykin

C/C++ 36ms
C/C++ IntelliSense, debuggi...
Microsoft

C/C++ Themes
UI Themes for C/C++ exten...
Microsoft

Code Spell Checker 19ms
Spelling checker for source...

Arm CMSIS csolution v0.31.0

Arm arm.com | 7,760 | ☆☆☆☆☆

CMSIS csolution support

This extension is enabled globally.

Arm CMSIS csolution

Overview

This extension provides support for working with CMSIS solutions (csolution projects). It can be installed individually or together with other extensions contained in the **Keil Studio Pack** available for Visual Studio Code Desktop. Check the extension pack Readme first if you want to install the extensions using the pack.

The **Arm CMSIS csolution** extension can work with the **Arm Device Manager** (Identifier: `arm.device-manager`) and **Arm Embedded Debugger** (Identifier: `arm.embedded-debug`) extensions.

This Readme explains how to set up your development environment to be able to work with CMSIS solutions in Visual Studio Code.

Once your development environment is ready, you can clone

Categories

Other

Extension Resources

Marketplace
Repository
License
Arm

More Info

Published	8/19/2022, 15:40:21
Last released	6/27/2023, 17:24:15
Last updated	6/28/2023, 09:35:08
Identifier	arm.cmsis-csolution

CMSIS-Toolbox - Navigation

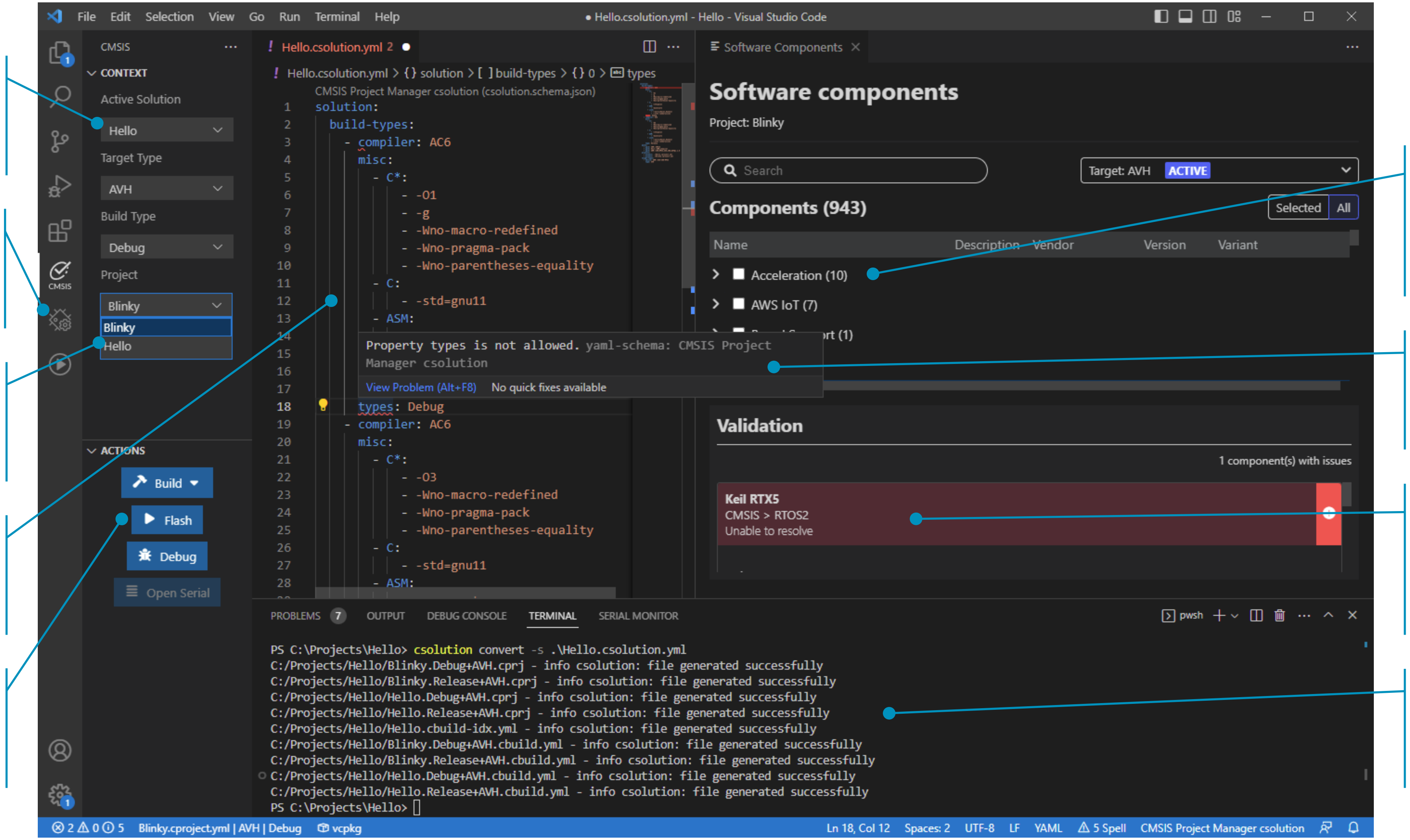
Select project context of the solution

Detect connected hardware

Manage related projects

Solution and project build script

Available project actions



```yaml
solution:
  build-types:
    - compiler: AC6
      misc:
        - C*:
          - -O1
          - -g
          - -Wno-macro-redefined
          - -Wno-pragma-pack
          - -Wno-parentheses-equality
        - C:
          - -std=gnu11
        - ASM:
```

```
Property types is not allowed. yaml-schema: CMSIS Project
Manager csolution
View Problem (Alt+F8)    No quick fixes available
```

```yaml
      types: Debug
    - compiler: AC6
      misc:
        - C*:
          - -O3
          - -Wno-macro-redefined
          - -Wno-pragma-pack
          - -Wno-parentheses-equality
        - C:
          - -std=gnu11
        - ASM:
```

```
PS C:\Projects\Hello> csolution convert -s .\Hello.csolution.yml
C:/Projects/Hello/Blinky.Debug+AVH.cprj - info csolution: file generated successfully
C:/Projects/Hello/Blinky.Release+AVH.cprj - info csolution: file generated successfully
C:/Projects/Hello/Hello.Debug+AVH.cprj - info csolution: file generated successfully
C:/Projects/Hello/Hello.Release+AVH.cprj - info csolution: file generated successfully
C:/Projects/Hello/Hello.cbuild-idx.yml - info csolution: file generated successfully
C:/Projects/Hello/Blinky.Debug+AVH.cbuild.yml - info csolution: file generated successfully
C:/Projects/Hello/Blinky.Release+AVH.cbuild.yml - info csolution: file generated successfully
C:/Projects/Hello/Hello.Debug+AVH.cbuild.yml - info csolution: file generated successfully
C:/Projects/Hello/Hello.Release+AVH.cbuild.yml - info csolution: file generated successfully
PS C:\Projects\Hello>
```

Manage CMSIS software components

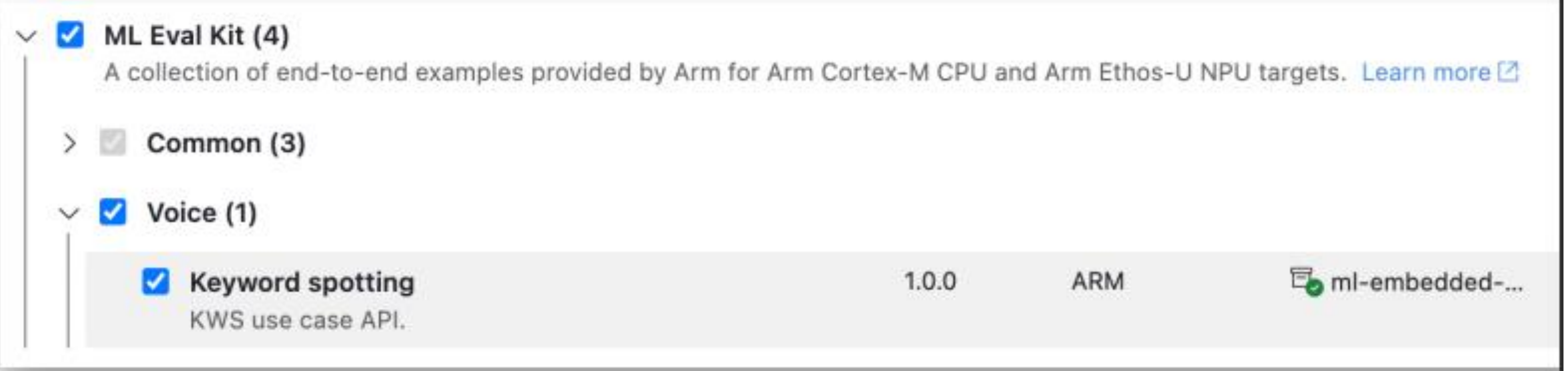
IntelliSense

Validate software component dependency

Command line build (optional)

Validate middleware dependencies

- **Choose from professional middleware in thousands of CMSIS-Packs**
- Resolve dependencies across your stack automatically
- Download and install required CMSIS-Packs with a single click



☑ ML Eval Kit (4)
A collection of end-to-end examples provided by Arm for Arm Cortex-M CPU and Arm Ethos-U NPU targets. Learn more

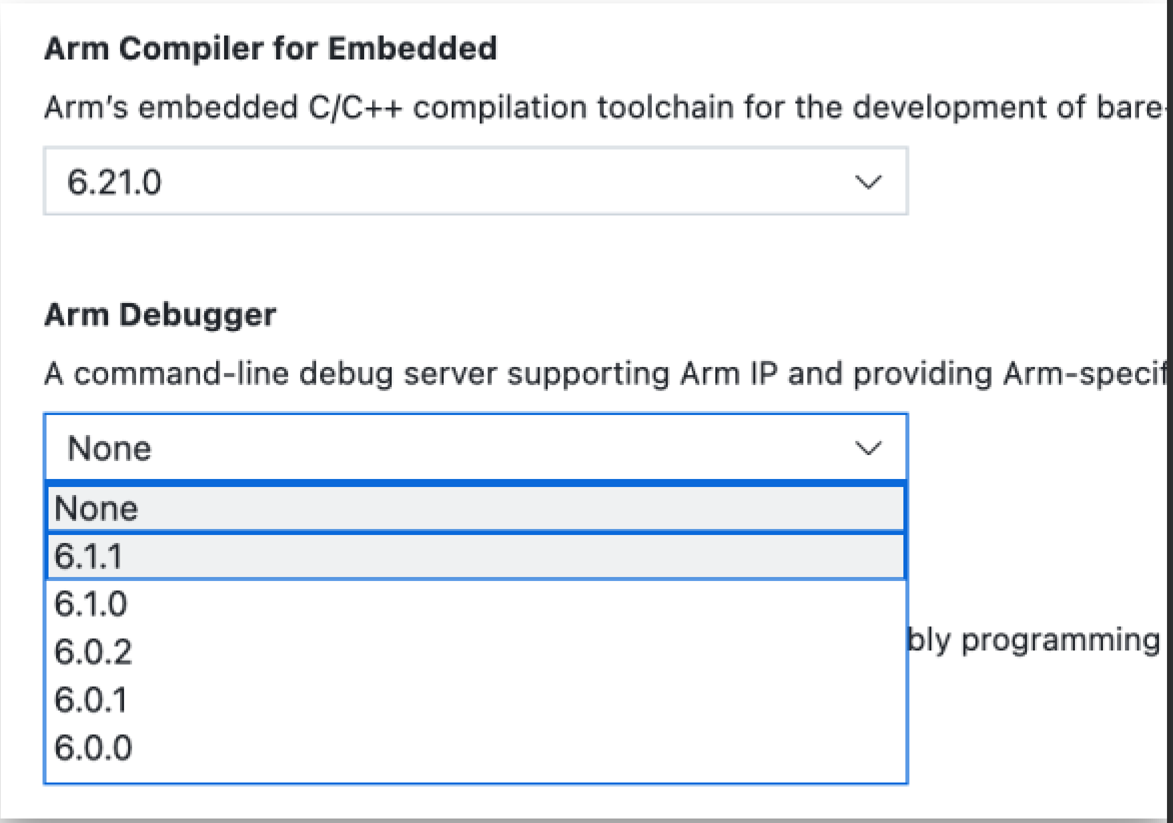
☑ Common (3)

☑ Voice (1)

☑ Keyword spotting 1.0.0 ARM ml-embedded-...
KWS use case API.

Pin tools versions

- **Keep your engineering team in sync across tools, source code and project settings**
- Create reproducible builds that pin your compiler, debugger, CMSIS toolbox and third party build tools like ninja
- Share your configuration with your team through source control



Arm Compiler for Embedded

Arm's embedded C/C++ compilation toolchain for the development of bare

6.21.0

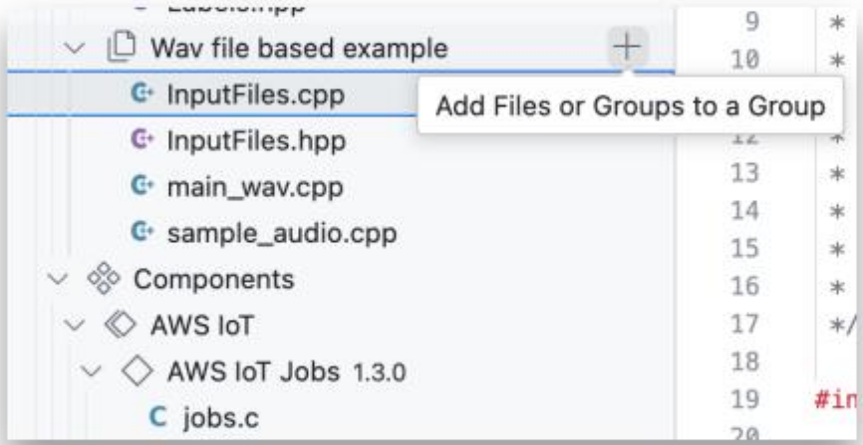
Arm Debugger

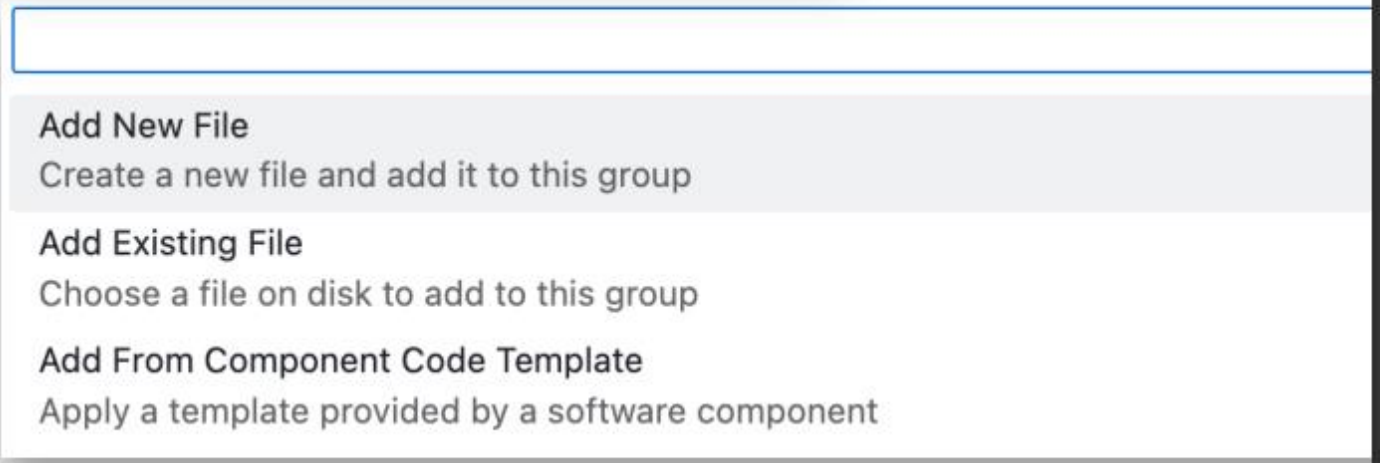
A command-line debug server supporting Arm IP and providing Arm-specif

None

Rapid prototyping with code templates

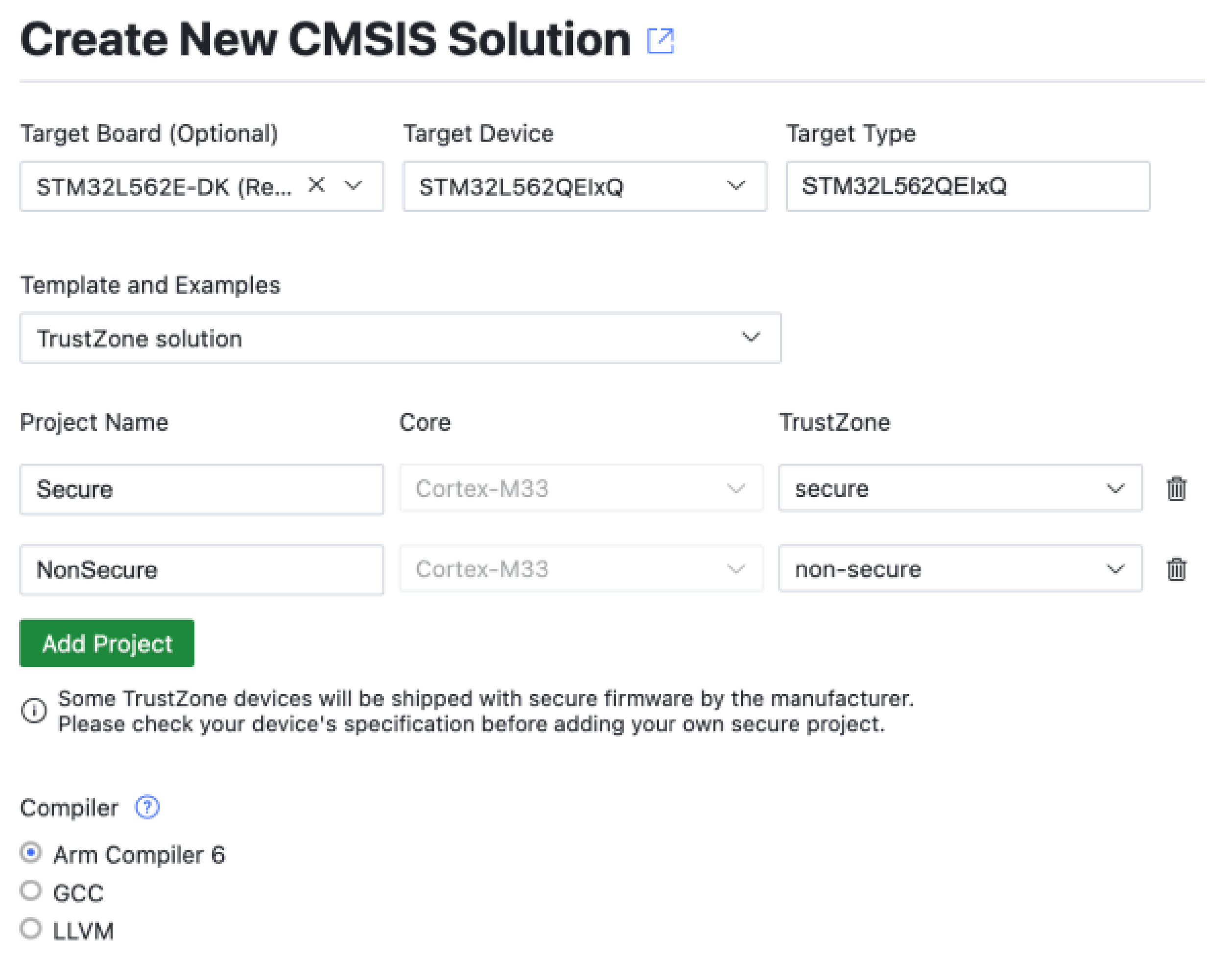
- **Copy code template files directly into your application to build up your solution quickly**
- Software components are shipped with example templates
- Once a component has been added, you can select the template easily from the solution outline view




Add New File
Create a new file and add it to this group
Add Existing File
Choose a file on disk to add to this group
Add From Component Code Template
Apply a template provided by a software component

New solutions

- **Create your next solution from a basic template, or start from one of thousands of examples**
- Pre-set device and core information for 10,000+ MCUs and hundreds of development boards
- Pick from Arm Compiler 6, GCC or LLVM to get started
- Handle complex edits and flags directly in the Open CMSIS Pack yml files



Create New CMSIS Solution

Target Board (Optional)	Target Device	Target Type
STM32L562E-DK (Re...	STM32L562QEIxQ	STM32L562QEIxQ

Template and Examples: TrustZone solution

Project Name	Core	TrustZone
Secure	Cortex-M33	secure
NonSecure	Cortex-M33	non-secure

ⓘ Some TrustZone devices will be shipped with secure firmware by the manufacturer. Please check your device's specification before adding your own secure project.

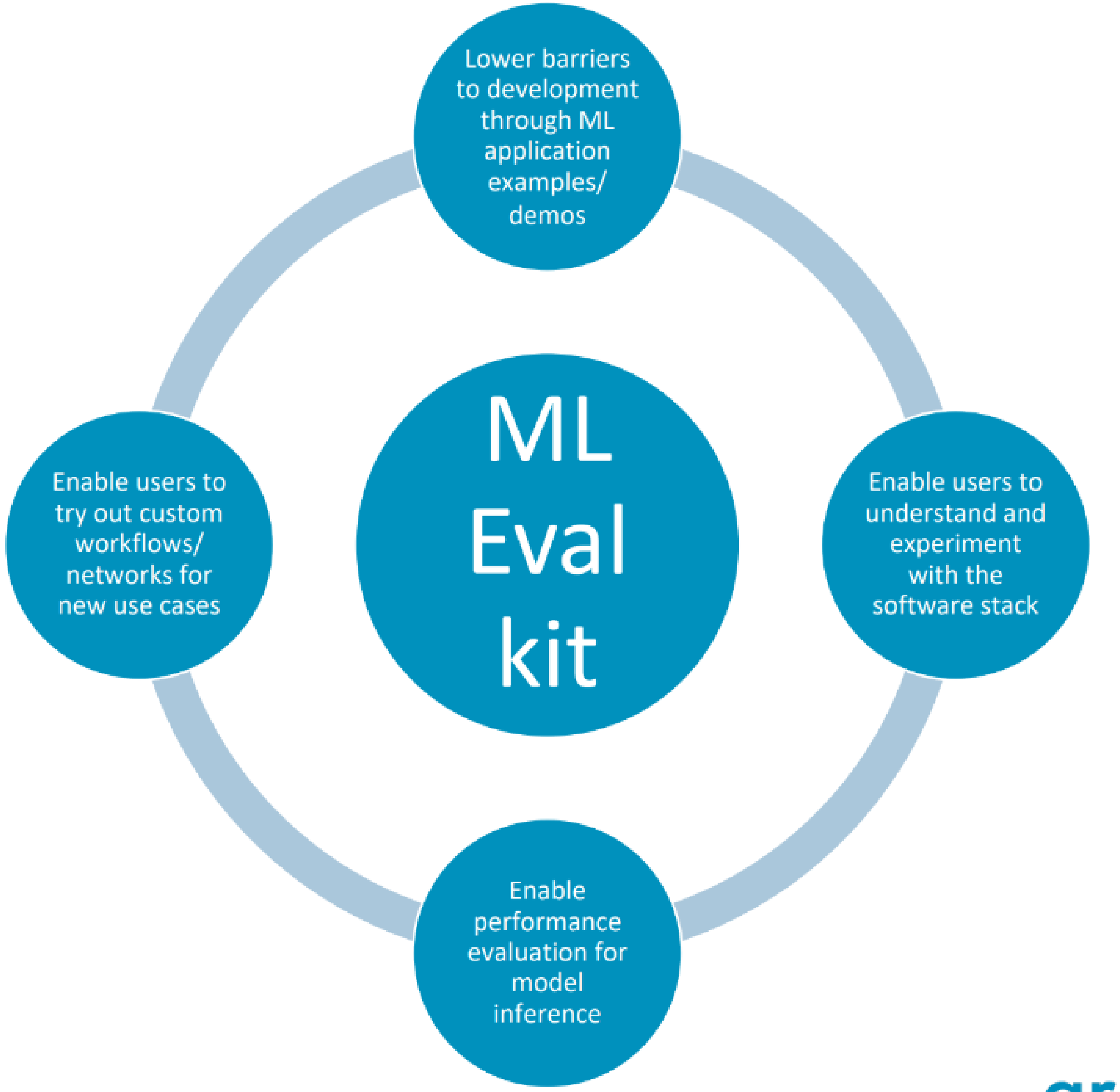
Compiler

● Arm Compiler 6
○ GCC
○ LLVM

Arm ML Eval Kit

ML Eval Kit - Introduction

- Introduce users to ML software stack used to run models Arm MCUs and NPUs
- Help to evaluate performance of the most common ML use-cases – end to end ML applications
- Help to run and evaluate users' custom models



ML Eval kit

Lower barriers to development through ML application examples/ demos

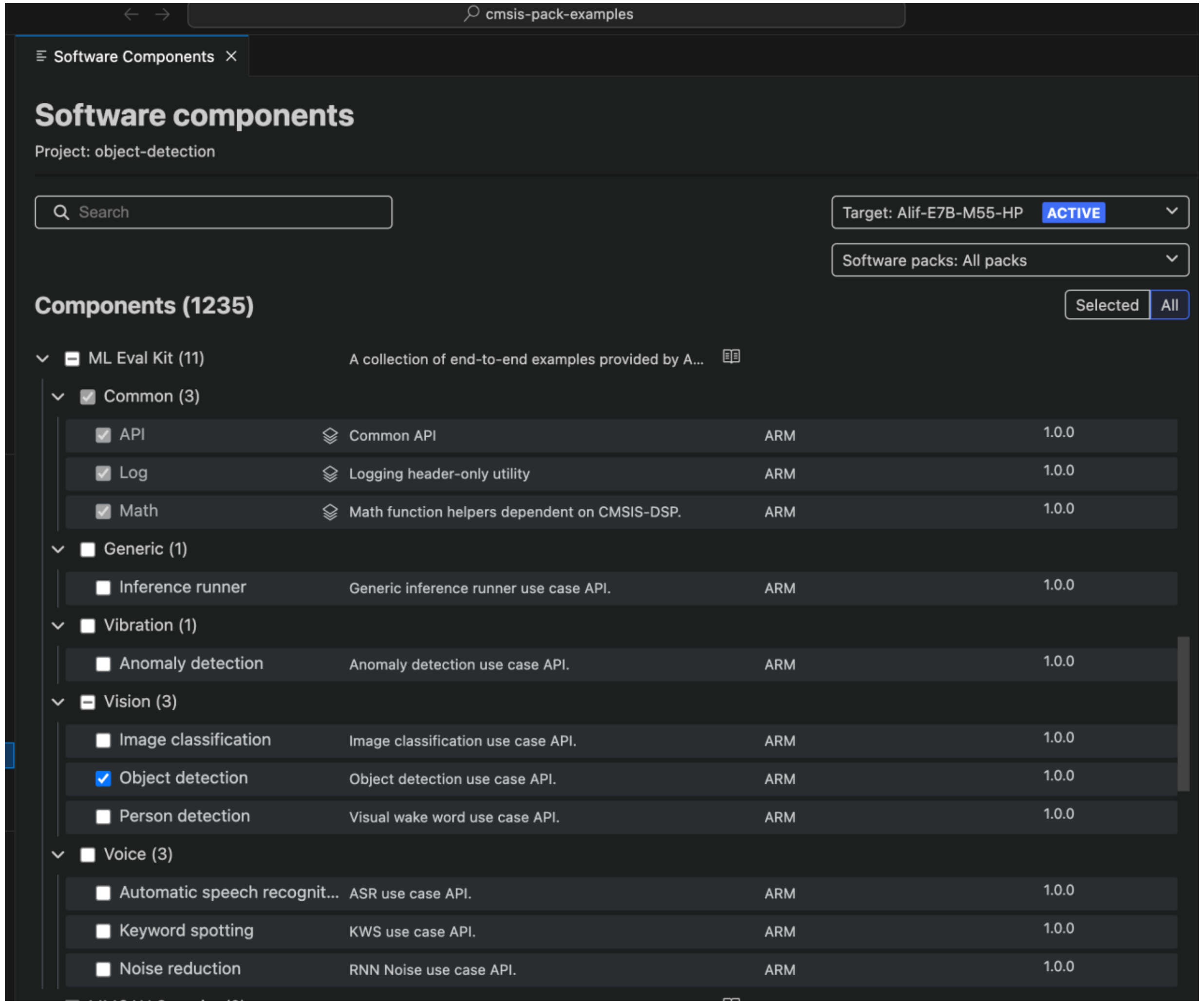
Enable users to understand and experiment with the software stack

Enable performance evaluation for model inference

Enable users to try out custom workflows/ networks for new use cases

ML Eval Kit – CMSIS Pack

- Generalized abstracted APIs to interface with **TensorFlow Lite for Microcontrollers** as a CMSIS-Pack
- The APIs address basic vision and audio-based use cases:
  - Anomaly/Person/Object detection
  - Keyword spotting, Speech recognition, Noise reduction
- Offers support for:
  - Logging
  - Math functions
- Model zoo with hardware optimized models for above use cases



Software components

Project: object-detection

Target: Alif-E7B-M55-HP ACTIVE

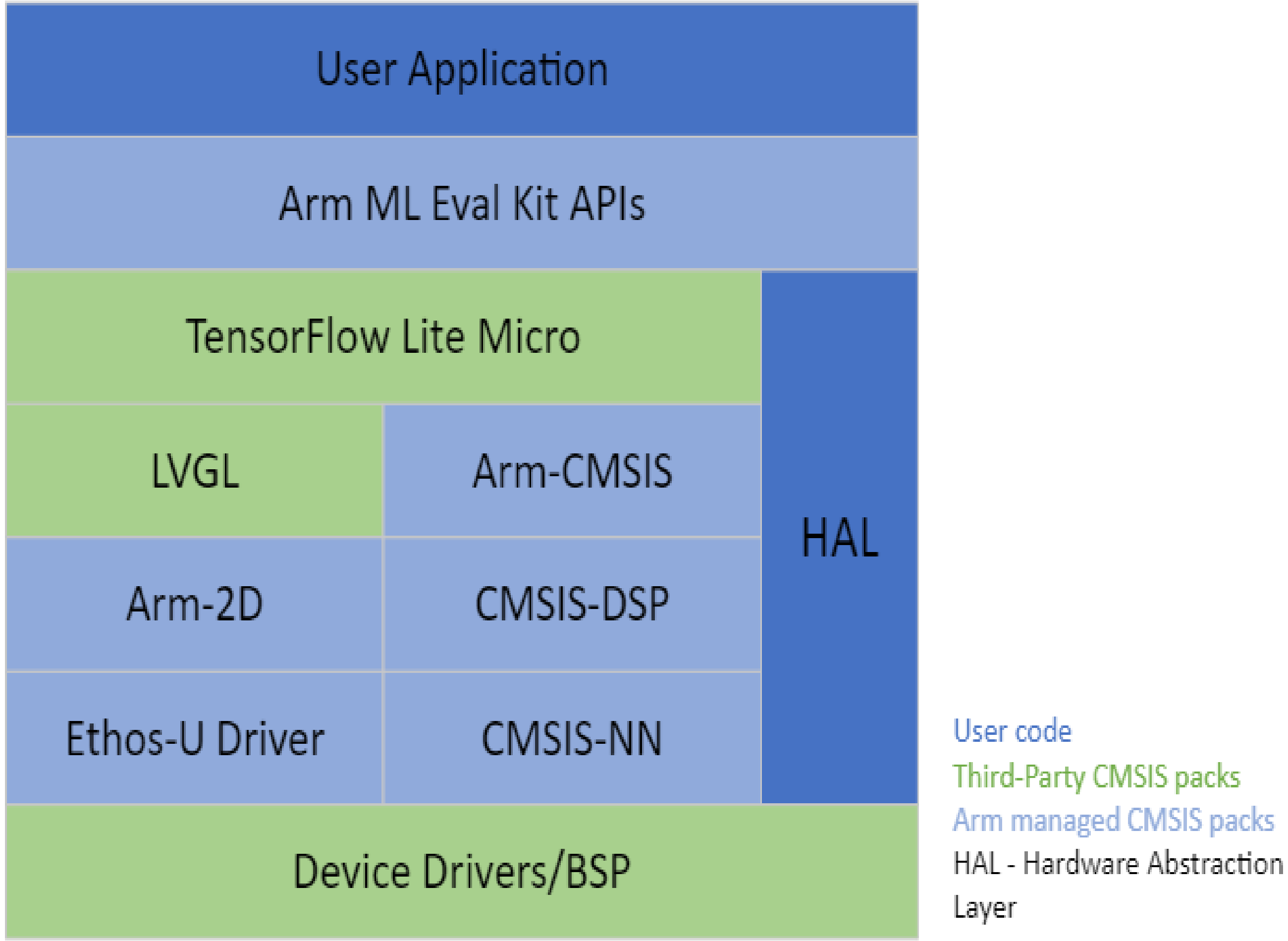
Software packs: All packs

Components (1235)

⊟ ML Eval Kit (11)	A collection of end-to-end examples provided by A...		
☑ Common (3)			
☑ API	Common API	ARM	1.0.0
☑ Log	Logging header-only utility	ARM	1.0.0
☑ Math	Math function helpers dependent on CMSIS-DSP.	ARM	1.0.0
□ Generic (1)			
□ Inference runner	Generic inference runner use case API.	ARM	1.0.0
□ Vibration (1)			
□ Anomaly detection	Anomaly detection use case API.	ARM	1.0.0
⊟ Vision (3)			
□ Image classification	Image classification use case API.	ARM	1.0.0
☑ Object detection	Object detection use case API.	ARM	1.0.0
□ Person detection	Visual wake word use case API.	ARM	1.0.0
□ Voice (3)			
□ Automatic speech recognit...	ASR use case API.	ARM	1.0.0
□ Keyword spotting	KWS use case API.	ARM	1.0.0
□ Noise reduction	RNN Noise use case API.	ARM	1.0.0

ML Eval Kit - Architecture

- Single project supporting various boards/devices using ‘clayer’, and various use cases using ‘cproject’, thus enabling faster scaling
- Distributed software management, vendors update and maintain CMSIS-Packs; developers only need to manage and update application code
- Faster agile development, avoiding duplication, leveraging and integrating existing solutions
- Single pane of glass for dependency tree
- Faster update cycles, using plug and play CMSIS-Packs



User Application

Arm ML Eval Kit APIs

TensorFlow Lite Micro

LVGL

Arm-CMSIS

Arm-2D

CMSIS-DSP

Ethos-U Driver

CMSIS-NN

HAL

Device Drivers/BSP

User code

Third-Party CMSIS packs

Arm managed CMSIS packs

HAL - Hardware Abstraction Layer

Demo

Arm ML Tools

Corstone FVP and AVH

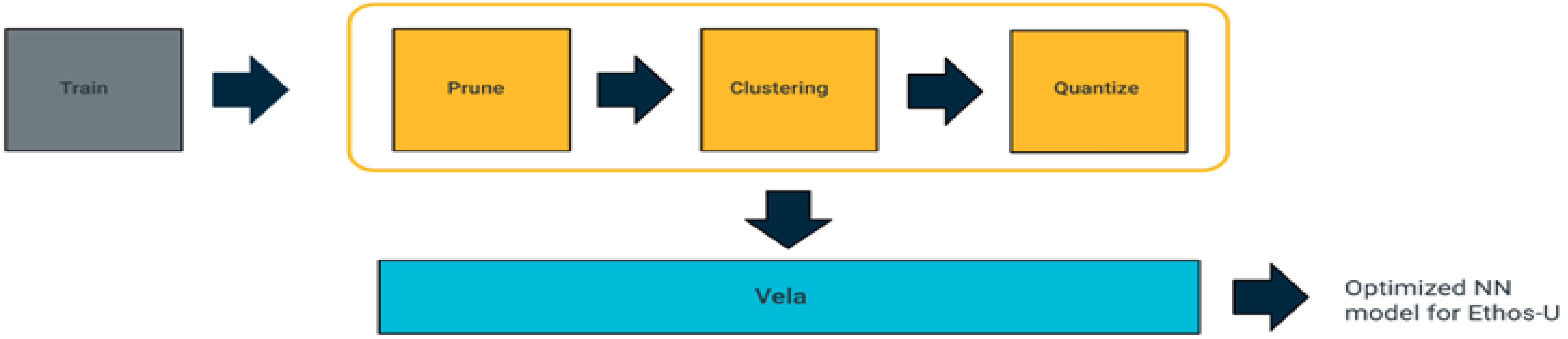
- Accelerate development using Arm’s Fixed Virtual Platforms
  - Start bare metal or OS-hosted software development for Arm
  - Remove the bottleneck of starting software design only after the hardware is available.
  - Virtual prototypes are easier to scale and maintain
- Leverage Arm Virtual Hardware to scale development and deployment
  - Replace physical hardware with a mature, instruction-accurate, and extensible modeling engine
  - Easily run and scale CI infrastructure in the cloud with potentially thousands of virtual boards being launched in seconds

arm CORSTONE

arm CORTEX-M

arm CORTEX-A

Vela Compiler

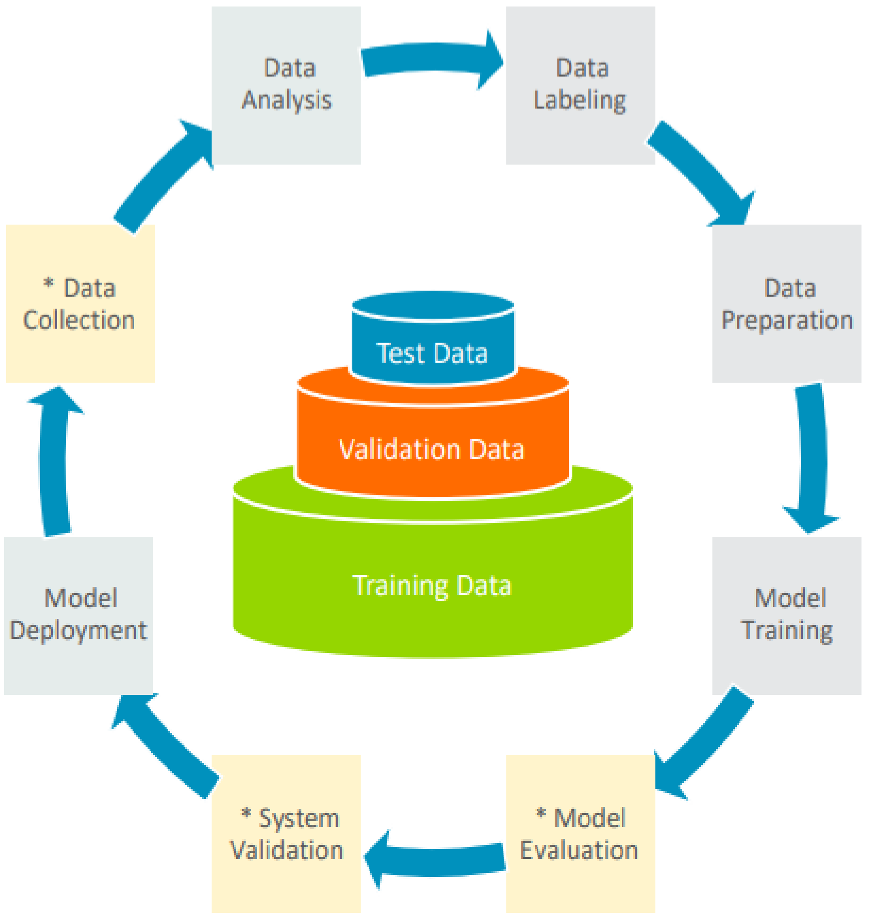


- Open-source hardware aware optimizer, which optimizes the quantized ML model to run efficiently on intended hardware.
- Investigates the graph and tags the operators that can be offloaded to Arm’s Ethos-U NPU for increased efficiency and performance.

MLOps

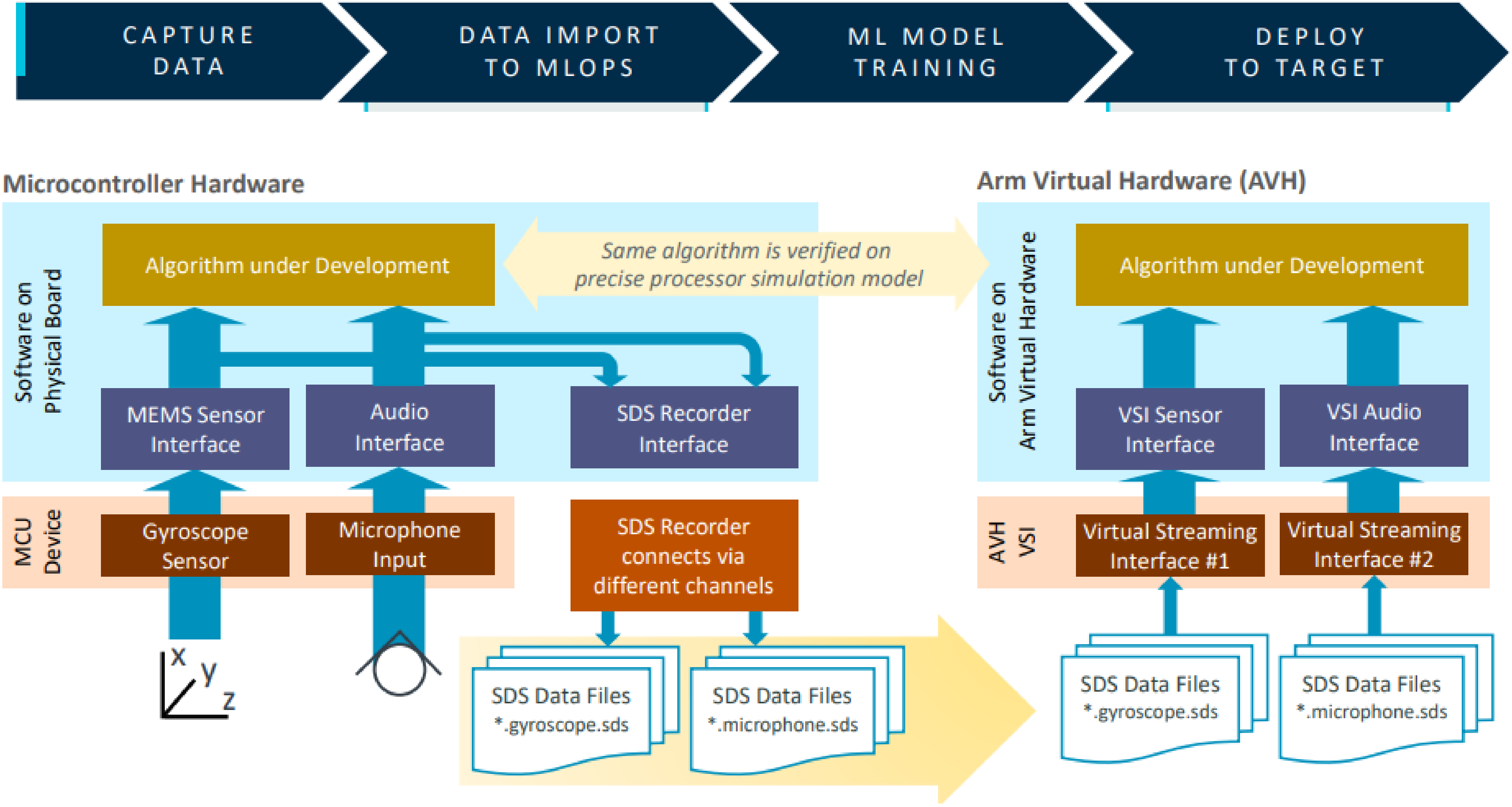
MLOps: deploy and maintain Machine Learning (ML) models

- ML models are tested and developed in isolated systems
- MLOps is an iterative process to transition the ML model to production systems.
- Evaluation and validation require the model to run on target hardware.
- Data collection requires frequently inputs of the final target system



* Supported by Arm Virtual Hardware and SDS Framework

MLOps: Example flow


CAPTURE DATA
DATA IMPORT TO MLOPS
ML MODEL TRAINING
DEPLOY TO TARGET
Microcontroller Hardware
Software on Physical Board
Algorithm under Development
Same algorithm is verified on precise processor simulation model
MEMS Sensor Interface
Audio Interface
SDS Recorder Interface
MCU Device
Gyroscope Sensor
Microphone Input
SDS Recorder connects via different channels
x
y
z
SDS Data Files *.gyroscope.sds
SDS Data Files *.microphone.sds
Arm Virtual Hardware (AVH)
Software on Arm Virtual Hardware
Algorithm under Development
VSI Sensor Interface
VSI Audio Interface
AVH VSI
Virtual Streaming Interface #1
Virtual Streaming Interface #2
SDS Data Files *.gyroscope.sds
SDS Data Files *.microphone.sds

Thank You
Danke
Gracias
Grazie
谢谢
ありがとう
Asante
Merci
감사합니다
धन्यवाद
Kiitos
شكرًا
ধন্যবাদ
תודה
ధన్యవాదములు

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