



# Powering the Future of Embedded Vision

Embedded World  
March 2023

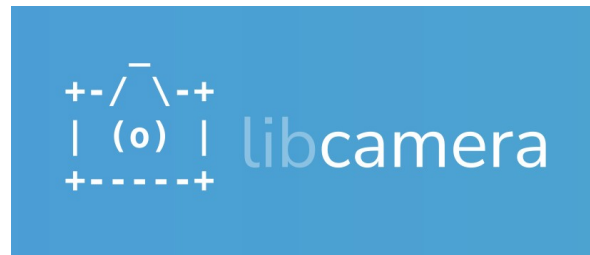
Laurent Pinchart  
Founder & CEO, Ideas on Board  
Kamaros Working Group Member

# Yours Truly

Laurent Pinchart is the founder and CEO of Ideas on Board, a company specialized in delivering camera and display solutions for Linux across all markets.



**Making cameras work**



With 20 years of experience as a Linux kernel developer and maintainer, Laurent has driven the design of the Linux kernel camera API and has participated in multiple industry working groups to standardize camera protocols. Most recently, he has started the libcamera® project to give Linux a full camera stack in collaboration with silicon vendors and OEMs.

# Topics

- Introduction to Khronos and its family of open standard APIs
- Overview of Khronos APIs for Parallel Computation
- Khronos and Safety Critical APIs
- Introduction to the new Kamaros Embedded Camera API in development
- How to get involved!



# Khronos Connects Software to Silicon



Open, royalty-free interoperability standards to harness the power of GPU, XR and multiprocessor hardware

3D graphics, augmented and virtual reality, parallel programming, inferencing and vision acceleration

Non-profit, member-driven standards organization, open to any company

Proven multi-company governance and Intellectual Property Framework

Founded in 2000  
~ 200 Members with ~ 40% US, 30% Europe, 30% Asia

# Khronos Active Standards

3D Graphics  
Desktop, Mobile  
and Web



3D Assets  
Authoring  
and Delivery



Portable XR  
Augmented and  
Virtual Reality



Parallel Computation  
Vision, Camera, Inferencing,  
Machine Learning



Safety Critical APIs

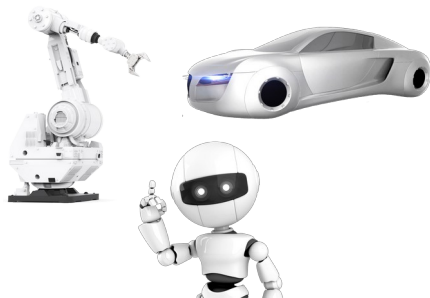
KHRONOS  
SAFETY CRITICAL  
ADVISORY FORUM



# Need for Vision Acceleration Standards

## Increasing Sensor Compute Load

Diverse camera and sensor arrays feed sophisticated processing - including inferencing



Cost and time to integrate and utilize sensors, GPUs and processors in diverse markets has become a major constraint on innovation and efficiency

## Advanced User Interfaces

High quality 3D graphics, augmented reality, diverse display systems



## Open Standard APIs in Embedded Markets

- Enable cross-platform software reusability
- Decouple software and hardware for easier development and integration of new components
- Provide cross-generation reusability
- Facilitate field upgradability

# Khronos Compute Acceleration Standards

**Higher-level Languages and APIs**  
Streamlined development and performance portability



Single source C++ programming with compute acceleration



Graph-based vision and inferencing acceleration



Neural Network Exchange Format Trained Networks



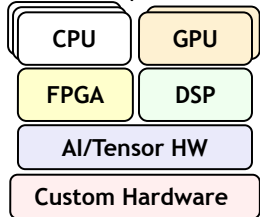
GPU rendering + compute acceleration



Intermediate Representation (IR) supporting parallel execution and graphics



Heterogeneous compute acceleration



**Lower-level Languages and APIs**  
Direct Hardware Control

Increasing industry interest in parallel compute acceleration to combat the 'End of Moore's Law'

# Growing Need for APIs for Functional Safety

Demand for advanced GPU-accelerated graphics and compute is growing in an increasing number of industries where safety is paramount, such as automotive, autonomy, avionics, medical, industrial, and energy



1990s  
Avionics



2010s  
Automotive



2020s...  
Everywhere

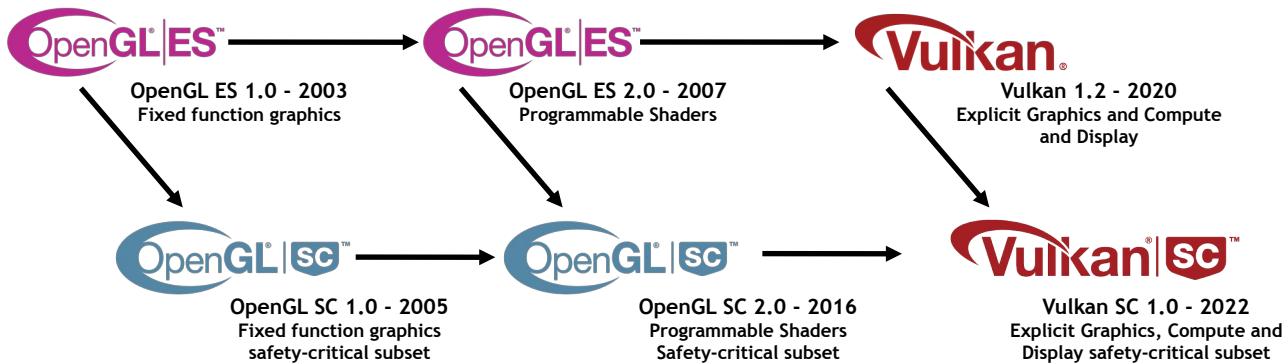
**Safety-critical APIs are designed to reduce system-level safety-critical certification effort and costs**

- 1) Streamlined to reduce documentation and testing surface area
- 2) Deterministic behavior to simplify system design and testing
- 3) Unambiguous and comprehensive fault handling



Industry safety-critical standards include  
[RTCA DO-178C](#) (avionics) | [ISO 26262](#) (automotive)  
[IEC 61508](#) (industrial) | [IEC 62304](#) (medical)

# Khronos Safety Critical Standards Evolution



Khronos has 20 years experience in standards for safety-critical markets

Leveraging proven mainstream standards with shipping implementations and developer tooling and familiarity

A choice of abstraction levels to suit different markets and developer needs



March 2022  
SYCL SC Working Group announced to develop C++-based heterogeneous parallel compute programming framework for safety-critical systems



# The Need for a Camera System API Standard

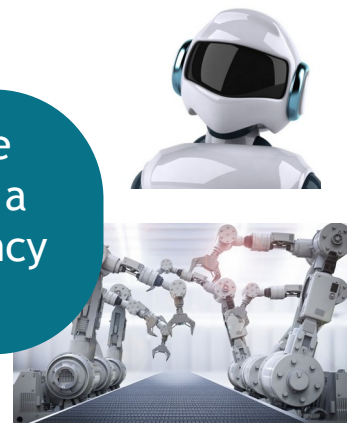
## Increasing Sensor Diversity

Including camera arrays and depth sensors such as Lidar



## Multiple Sensors Per System

Synchronization and coordination become essential



The cost and time to integrate and utilize sensors in embedded systems has become a major constraint on innovation and efficiency in the embedded vision market

## Increasing Sensor Processing Demands

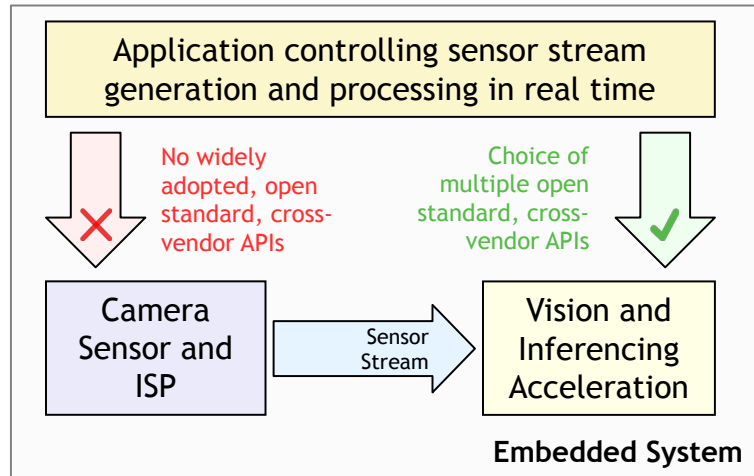
Including inferencing. Sensor outputs need to be flexibly and efficiently generated and streamed into acceleration processors

## Proprietary APIs Hinder Innovation

Vendor-specific APIs to control cameras, sensors and close-to-sensor ISPs prevent rapid integration of new technologies

# Benefits of Embedded Camera API Standard

An effective open, cross-vendor open standard for camera, sensor and ISP control could provide multiple benefits



Cross-vendor portability of camera/sensor code for easier system integration of new sensors

Preservation of application code across multiple generations of cameras and sensors

Sophisticated control over sensor stream generation increases effectiveness of downstream accelerated processing

*Development of Camera and sensor APIs may also generate new requirements for downstream vision and inferencing acceleration APIs*

# Camera System API Exploratory Group

Throughout 2021 EMVA and Khronos hosted an open cross-industry Exploratory Group to consider the needs for a camera API and how they should be addressed

<b>33</b> Weekly Calls	<b>23</b> Use Cases
<b>33</b> Presentations	<b>60</b> Requirements
<b>73</b> Companies	<b>1</b> Glossary
<b>107</b> Unique Attendees	<b>1</b> Statement of Work

Scope of Work document captures generated consensus on terminology, scope, requirements, and design methodology



**KHRONOS**  
GROUP

## Camera System API Working Group Scope of Work

December 2021

*Approved by Exploratory Group vote on 8th December 2021*

This document has been produced and agreed by the Embedded Camera Exploratory Group jointly hosted by the EMVA and The Khronos Group which met over the period of March to December 2021.

Created under the Khronos New Initiative Process, this document identifies the industry need, and outlines the scope, requirements, and design methodology for a new open standard Camera System API. Deliverables and proposed timeline for the standard's design and deployment by a working group are discussed.

**SOW is downloadable [here](#)**

# What is Kamaros?



## EMBEDDED CAMERA SYSTEM API

---

Jointly promoted by Khronos and the European Machine Vision Association (EMVA), the Kamaros API Working Group is now developing an open, royalty-free standard for controlling camera system runtimes in embedded, mobile, industrial, XR, automotive, and scientific markets

# The Timeline So Far

Feb 2021

Dec 2021

Mar 2022

Nov 2022

2023

## Camera API Exploratory Group

In response to industry requests the EMVA and Khronos create a group to explore industry interest for an open camera API standards, and consensus on use cases and requirements

Over 70 companies join and contribute to the discussions and approve the proposed scope of work

## Scope of Work

Exploratory group publishes the scope, requirements and design methodology for a new open standard Camera System API



## Kamaros

Kamaros name adopted for Working Group and API

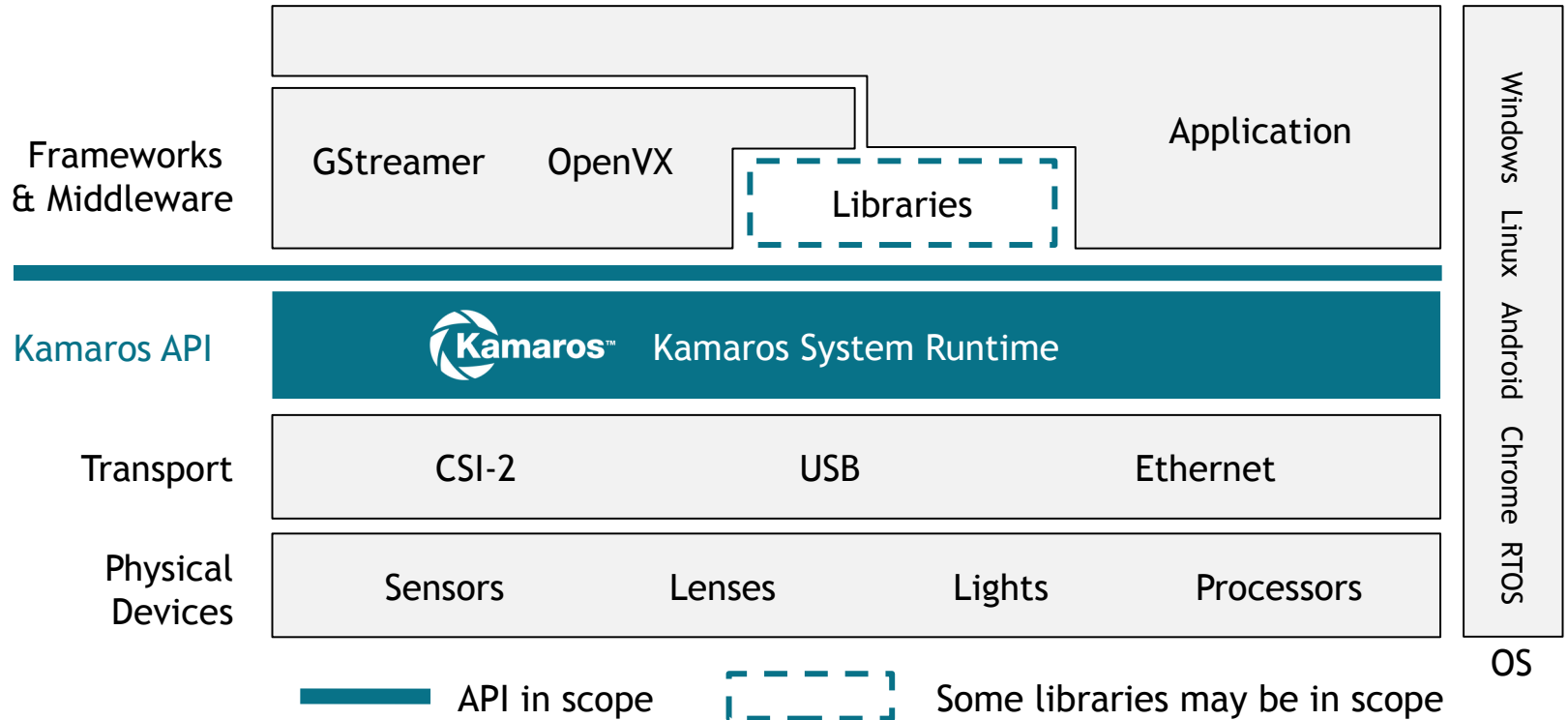
## Camera Working Group

Working Group formed under the Khronos membership and IP framework. Work starts on the detailed specification of the API, guided by the scope of work

## Draft Spec

Expected release of draft 1.0 specification for community feedback

# Typical Kamaros Software Stack



*Names of transport layers, framework and operating systems are illustrative examples*

# Primary Design Influences and Inputs

Kamaros will fill an ecosystem gap for a cross-vendor embedded camera system API

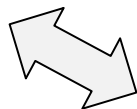
May complement existing APIs

e.g., be used in their implementation, or be implemented over them



android

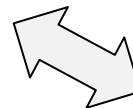
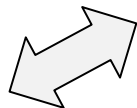
Android Camera2  
Framework API



Open-source camera stack  
and framework for Linux,  
Android, and ChromeOS

GEN*i*CAM

Hosted by EMVA including  
GenTL, SFNC (Standard  
Features Naming Convention  
and PFNC (pixel format naming  
convention))

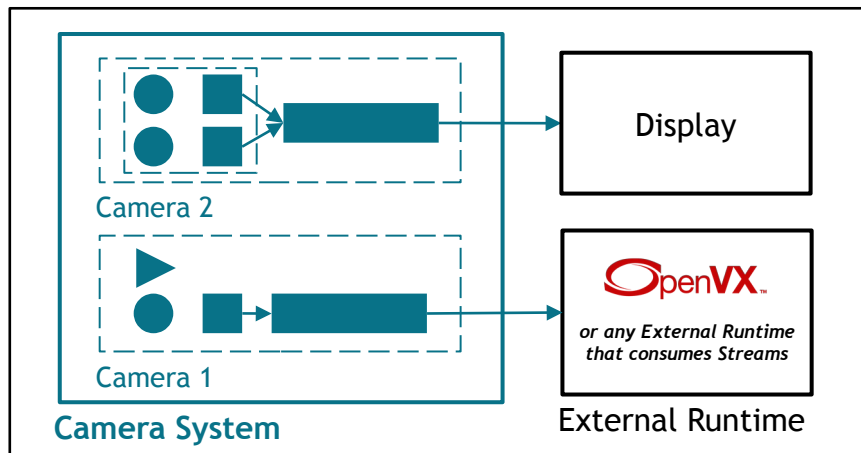


NVIDIA

libArgus API for acquiring  
images and associated  
metadata from cameras

# Design Principles

- Physical Devices = queryable and controllable via a Device ID:
- Logical Device = set of Devices queried and controlled via a single Device ID
- Frame = Image + Metadata accessed via Frame ID
- Stream = sequence of Frames
- Camera = a Logical Device that exports one or more Streams from the Camera System



System

## OS-agnostic

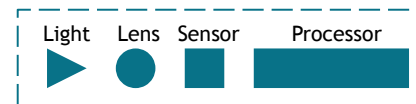
- Including support for minimal embedded OS

## Multiple Language Bindings

- Object-oriented API enabling efficient bindings to C, C++, Python, and other programming languages

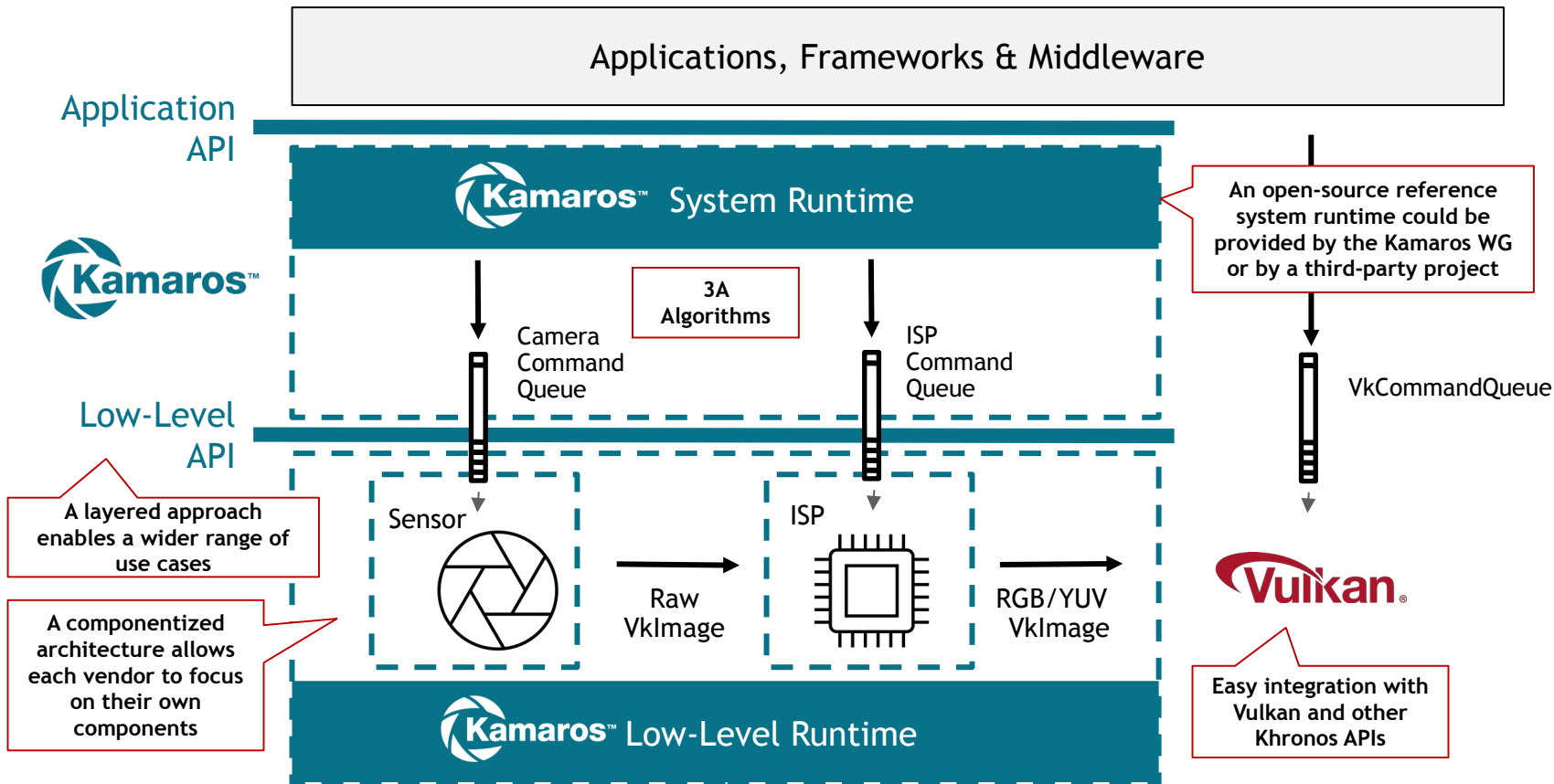
## Loadable Layers

- Command dispatch system to enable developers to use installable layers for validation, profiling, and debugging, etc.



# Leveraging Vulkan?

The Kamaros WG is exploring the option of additionally providing a lower-level API to ease integration of sensors and ISPs in a Kamaros System Runtime, by leveraging applicable concepts from the Vulkan API



# Kamaros Deliverables

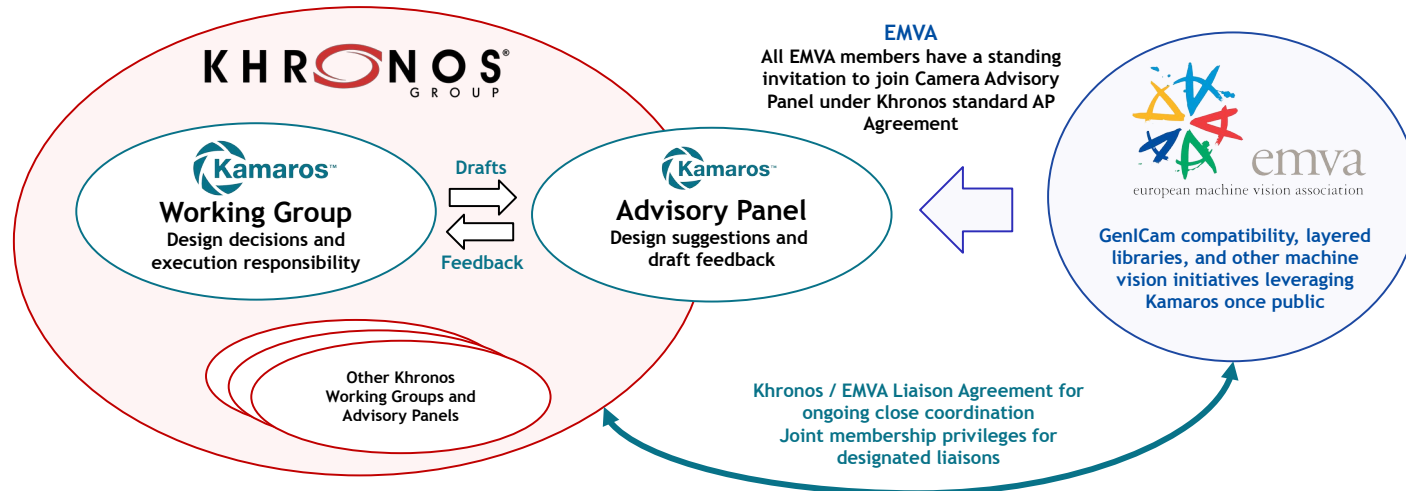
The API shall be made openly available to the industry under royalty-free licensing terms as defined by the Khronos Intellectual Property (IP) Framework

## Working Group Deliverables

- Camera System API specification for use by implementers and developers
- Central extension namespace registry for Working Group and vendor extensions
- Open-source conformance test suite, including a precise definition of conformance
- Adopters Program to enable implementations to become officially conformant
- Trademark and logo for promotion and use on conformant implementations
- A conformant portable open-source sample implementation of the API
- Open-source samples and documentation
- Open-source SDK, tools and Libraries



# Kamaros Working Group Organization



Any company is welcome to join Khronos for access to any Khronos Working Groups

EMVA Members - reach out to EMVA for details on joining the Kamaros Advisory Panel

# Get Involved!

Any company is welcome to join Khronos to influence standards development

<https://www.khronos.org/members/> or email [memberservices@khronosgroup.org](mailto:memberservices@khronosgroup.org)

More information on any Khronos APIs

<https://www.khronos.org/>

Khronos members can participate in the Kamaros Camera Working Group

EMVA Members can join the Kamaros Advisory panel

<https://www.khronos.org/kamaros>

**Khronos is developing a growing family of open, royalty-free API standards relevant to embedded and safety-critical markets**

