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IWOCL, May 2015

Agenda

- OpenCL 2.1 Design Methodology
- C++ Kernel Language Overview
- SPIR-V Overview
- OpenCL 2.1 API Enhancements
- SYCL for OpenCL
- Panel Discussion

Core API and Language Specs

Portable Kernel Intermediate Language

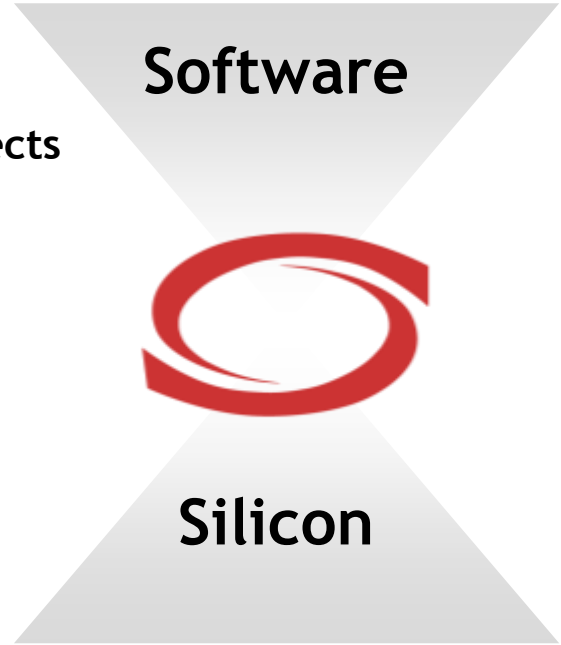
Single Source C++ Programming

Khronos Connects Software to Silicon

Open Consortium creating OPEN STANDARD APIs for hardware acceleration
Any company is welcome – many international members – one company one vote

ROYALTY-FREE specifications
State-of-the art IP framework protects members AND the standards

International, non-profit organization
Membership fees cover operating and engineering expenses



Low-level silicon APIs needed on every platform
Graphics, parallel compute, rich media, vision, sensor and camera processing

API Specifications AND Conformance
Tests for cross-vendor portability

Strong industry momentum
100s of man years invested by industry experts

Well over a *BILLION* people use Khronos APIs *Every Day*…

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OpenCL Ecosystem

Implementers
Desktop/Mobile/FPGA

Single Source C++ Programming

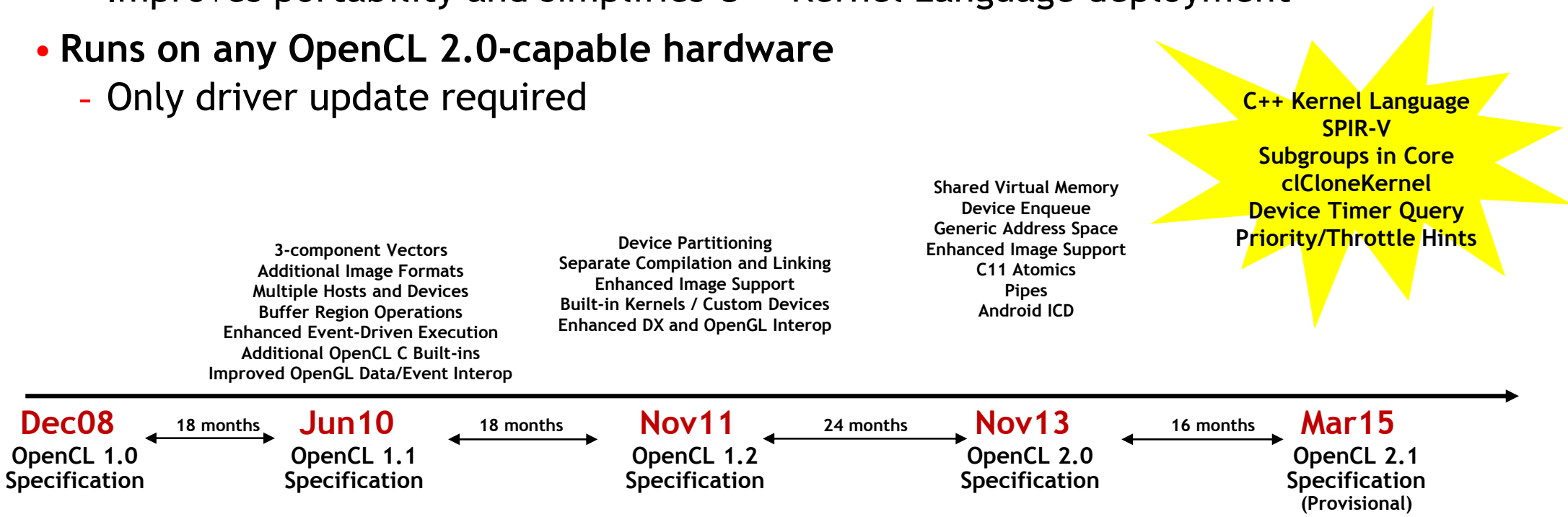
Core API and Language Specs

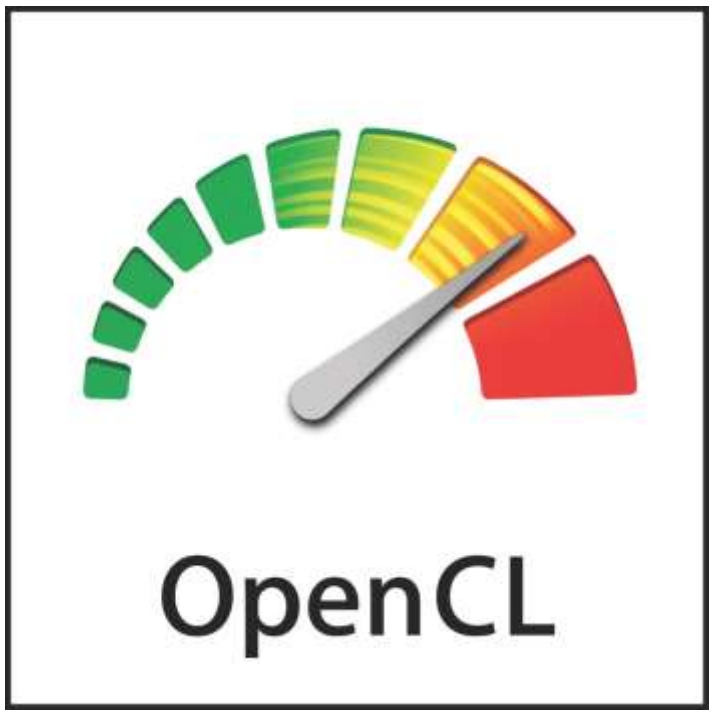
Portable Kernel Intermediate Language

Working Group Members
Apps/Tools/Tests/Courseware

OpenCL 2.1 Provisional Released March 2015!

- **New OpenCL C++ Kernel Language**
  - Significantly enhanced programmer productivity and code performance
  - Still supporting OpenCL C to preserve kernel code investment
- **Support for the New Khronos SPIR-V Intermediate Language**
  - Improves portability and simplifies C++ Kernel Language deployment
- **Runs on any OpenCL 2.0-capable hardware**
  - Only driver update required





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OpenCL 2.1 C++ Kernel Language

OpenCL C++ Kernel Language Overview

- **A "Static Subset" of C++14**
  - Frees developers from low-level coding details without sacrificing performance

- **In: Classes, templates, function and operator overloading, more...**
  - Reusable device libraries and containers - fast and elegant sharable code
  - Templates enables meta-programming for highly adaptive software
- **In: Upgraded Standard Library**
  - Leverages C++ standard library features
  - Examples: atomics, images, device queues, math functions

- **Out: Virtual Functions, Exceptions, Type Identification, C++ Standard Library...**

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Example: A Simple OpenCL C++ Kernel

```
#include <opencl_stdlib>
using namespace cl;

template<typename T>
void add_vectors(const T* srcA, const T* srcB, T* dst)
{
    size_t id = get_global_id(0);
    dst[id] = srcA[id] + srcB[id];
}

kernel void
add_vectors_float(const float* srcA, const float* srcB, float* dst)
{
    add_vectors(srcA, srcB, dst);
}

kernel void
add_vectors_float4(const float4* srcA, const float4* srcB, float4* dst)
{
    add_vectors(srcA, srcB, dst);
}
```

New! Kernel Language Functions Organized into Header Files

New! Kernel Language Functions in the `cl` Namespace

New! Full support for Templates

OpenCL C++ Address Spaces

- **OpenCL C has *global*, *local*, *constant* and *private* address space type qualifiers**

- **OpenCL C++ 2.1 does not need address space qualifiers**
  - Pointers refer to allocations in the generic address space

- **For local memory allocations, use the following types:**
  - *local_ptr<typename T>*
    local_array<typename T, size_t N>
    local<T>

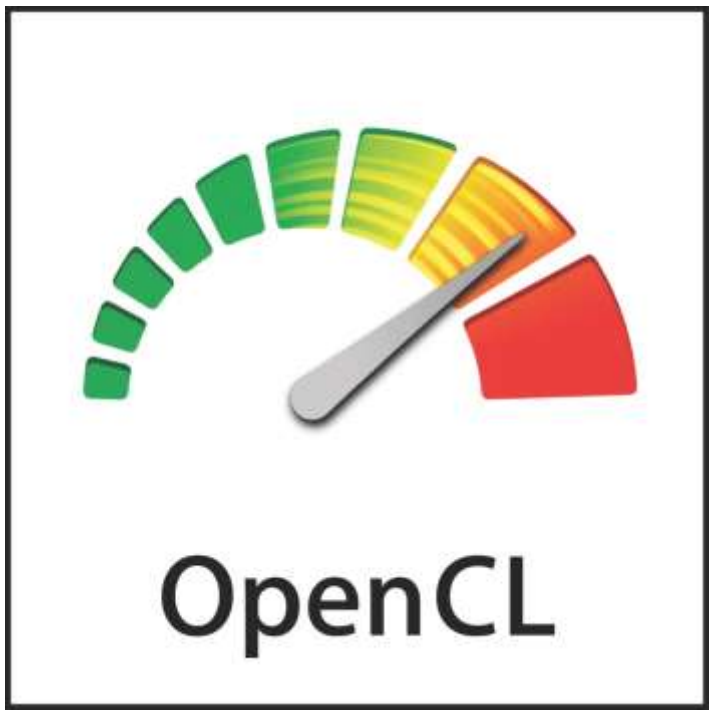
- **For constant memory allocations, use the following types:**
  - *constant_ptr<typename T>*
    constant_array<typename T, size_t N>
    constant<T>

OpenCL C++ Device-Side Enqueue Syntax

- **Kernels can independently launch work on the device**
  - without host interaction
  - control execution order with event dependencies (user events or markers)

- **Kernels can enqueue:**
  - a kernel function or
  - code represented as a kernel lambda function

- **A kernel lambda function is described as:**
  - [capture-list] (params) **kernel** { body }



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OpenCL 2.1
SPIR-V

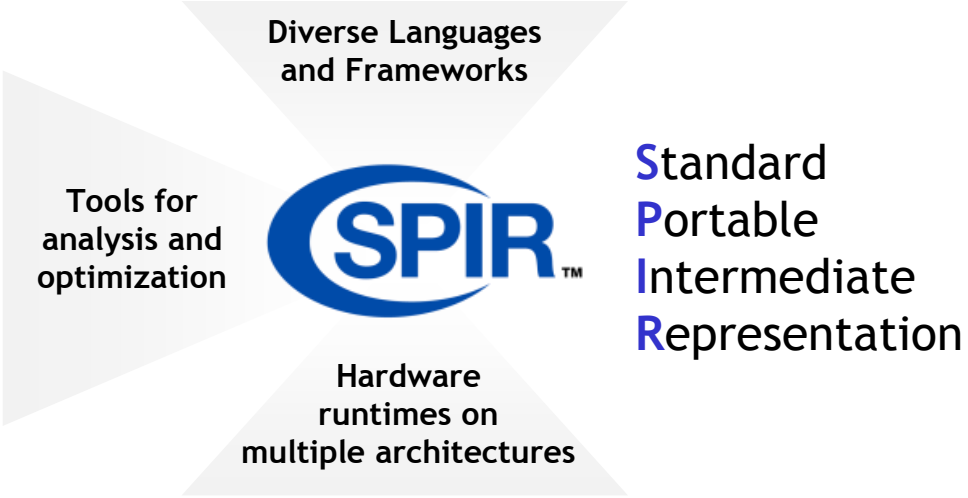
What is SPIR-V?

- **Cross Vendor Intermediate Representation**
  - Language front-ends can easily access multiple hardware run-times
  - Acceleration hardware can leverage multiple language front-ends
  - Encourages tools for program analysis and optimization in SPIR form
- **SPIR-V - first multi-API, intermediate language for parallel compute and graphics**
  - Native representation for Vulkan shader and OpenCL kernel source languages

Vulkan™ OpenCL

SPIR-V is supported in both Vulkan and OpenCL 2.1

SPIR-V is a significant convergence point in the language ecosystem for graphics and parallel computation

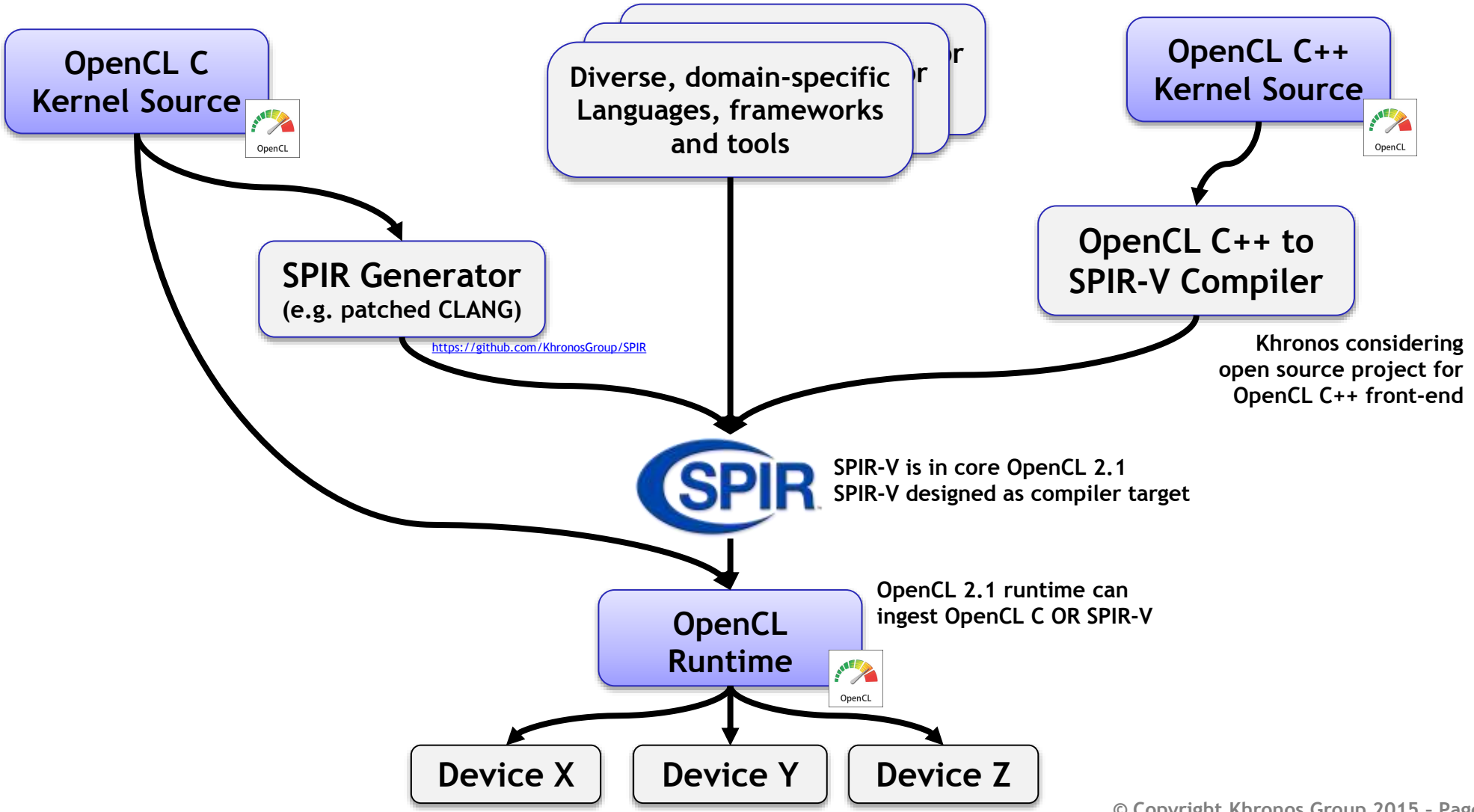


Evolution of SPIR

- **SPIR-V is the First Fully Specified Khronos-defined SPIR standard**
  - Isolated from LLVM roadmap changes
  - Includes full flow control, graphics and parallel constructs beyond LLVM
  - Khronos considering open source SPIR-V <-> LLVM IR conversion tools

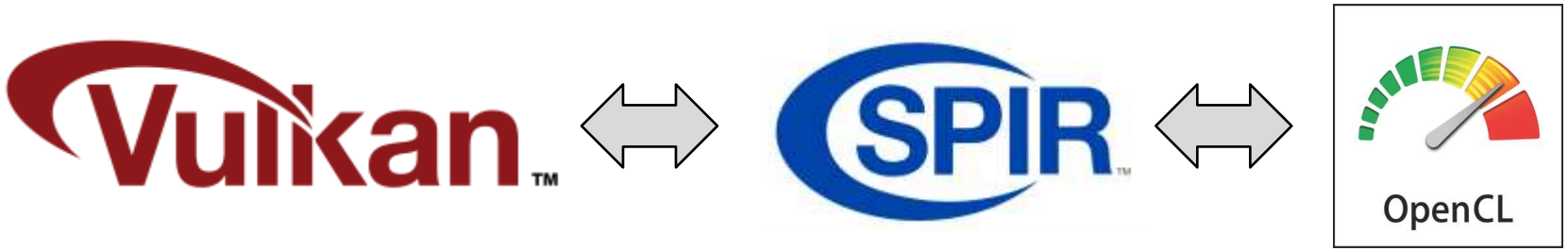
SPIR	SPIR 1.2	SPIR 2.0 (Provisional)	SPIR-V
LLVM Interaction	*Uses LLVM 3.2 IR*	*Uses LLVM 3.4 IR*	*100% Khronos Defined*
Compute Constructs	Metadata/Intrinsics	Metadata/Intrinsics	Native
Graphics Constructs	*No*	*No*	*Native*
Supported Language Feature Set	OpenCL C 1.2	OpenCL C 1.2 OpenCL C 2.0	OpenCL C 1.2 / 2.0 OpenCL C++ GLSL
OpenCL Consumption	*OpenCL 1.2 Extension*	*OpenCL 2.0 Extension*	*OpenCL 2.1 CORE*
Vulkan Consumption	-	-	Vulkan CORE

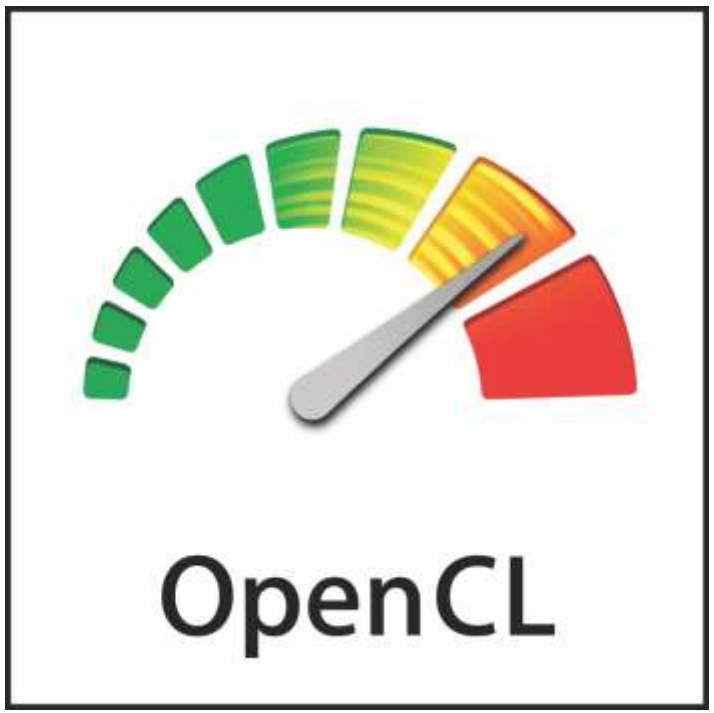
New OpenCL 2.1 Compiler Ecosystem



SPIR-V Advantages for Developers

- **Eliminates a major source of cross-vendor portability**
  - Developers can use same front-end compiler across multiple platforms
- **Reduces runtime shader/kernel compilation time**
  - Driver only has to process SPIR-V, not full source language
- **Provides a measure of IP protection**
  - Don't have to ship shader/kernel source code
- **Drivers are simpler and more reliable**
  - No need to include front-end compilers
- **SPIR-V Whitepaper**
  - https://www.khronos.org/registry/spir-v/papers/WhitePaper.pdf





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OpenCL 2.1 API

OpenCL 2.1 API Enhancements

- **clCreateProgramWithIL**
  - Clearly distinguish between SPIR-V and source/binary programs
- **clCloneKernel: deep copy of kernel, including arguments**
  - Safely pass kernels to threads or wrapper classes
- **cl_khr_subgroups: now a core feature**
  - Exposes hardware threads / warps / wavefronts and their cross-lane operations
- **Low-Latency Device Timer Query**
  - Synchronize host and device clock domains
- **Usability Enhancements**
  - Zero-sized dispatches are valid, support events and wait lists
  - NULL local work size supported with reqd_work_group_size kernels

OpenCL 2.1 API Extensions

- **Priority Hint**
  - Optionally, assign a “priority” to a command queue
  - Provides guidance when commands from two queues are ready to run
- **Throttle Hint**
  - Optionally, assign a “throttle level” to a command queue
  - Provides guidance to make appropriate power/performance tradeoffs

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SYCL Update

What is SYCL™?

- **SYCL**
  - Pronounced SICKLE

- **Royalty-free, cross platform, cross-toolchain C++ programming layer**
  - No language extensions, any standard C++ compilers can build SYCL source code, can have multiple device compilers linking into final executable

- **Full OpenCL feature set in a modern C++ single-source programming model**

- **A system that follows closely the developments in both C++ and OpenCL and enables projects that can serve as a dialog for both communities.**

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What does SYCL™ achieve?

- **Single source C++11 programming model for OpenCL 1.2**
- **Ease of use**
  - SYCL source compiled for host and device(s) (No language extensions, variety of environments and compilers for host and device)
  - Ease of integration with C++ libraries and applications optimized for other technologies
  - Development/Debugging on host
  - Programming interface based on abstraction of OpenCL components
- **Provides the full OpenCL feature set and seamless integration with existing OpenCL code**
- **Enables the creation of higher level programming models and C++ templated libraries based on OpenCL**

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Call to Action

- **Khronos seeking feedback on OpenCL 2.1 and SPIR-V**
  - Links provided on Khronos forums
  - https://www.khronos.org/opencl/opencl_feedback_forum
  - https://www.khronos.org/spir_v_feedback_forum
- **Or, give feedback to the panel *RIGHT NOW!***

- **Reminder: Any company or organization is welcome to join Khronos for a voice and a vote in any of these standards**
  - www.khronos.org

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