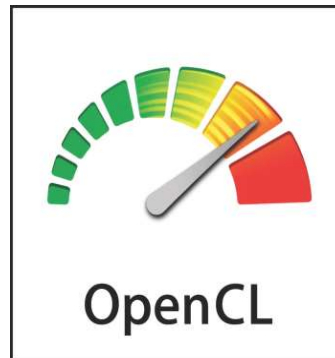


KHRONOS™ GROUP



Ben Ashbaugh
Intel



Adam Lake
Intel

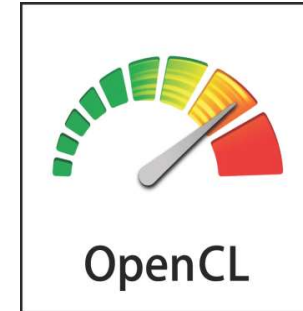


Maria Rovatsou
Codeplay

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

Software

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

Silicon

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...



BOARD OF PROMOTERS



Over 100 members worldwide
any company is welcome to join

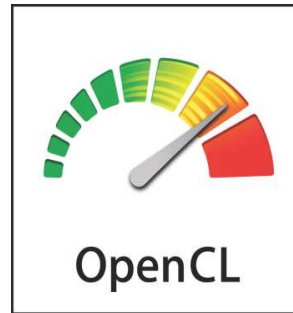


OpenCL Ecosystem

Implementers Desktop/Mobile/FPGA



Single Source C++ Programming



Core API and Language Specs



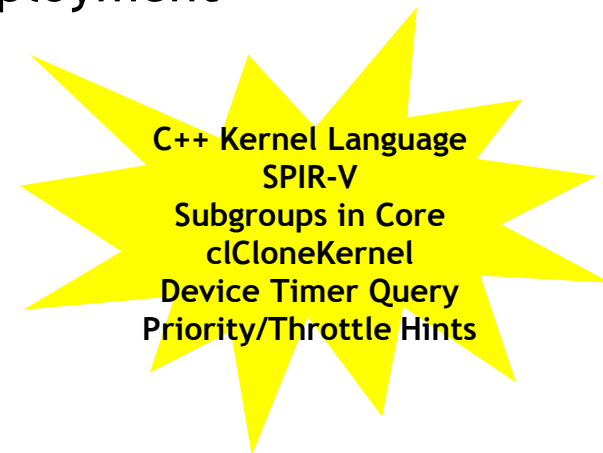
Portable Kernel Intermediate Language

Working Group Members Apps/Tools/Tests/Courseware



OpenCL 2.1 Provisional Released March 2015!

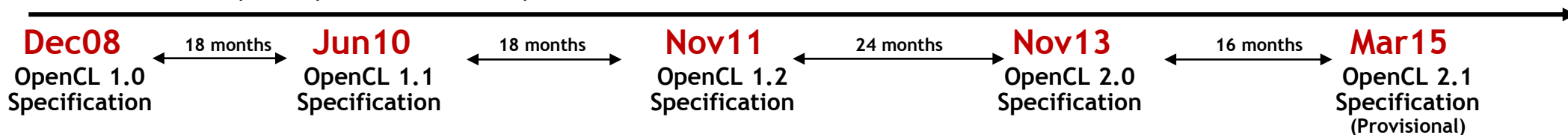
- **New OpenCL C++ Kernel Language**
 - Significantly enhanced programmer productivity and code performance
 - Still supporting OpenCL C to preserve kernel code investment
- **Support for the New Khronos SPIR-V Intermediate Language**
 - Improves portability and simplifies C++ Kernel Language deployment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

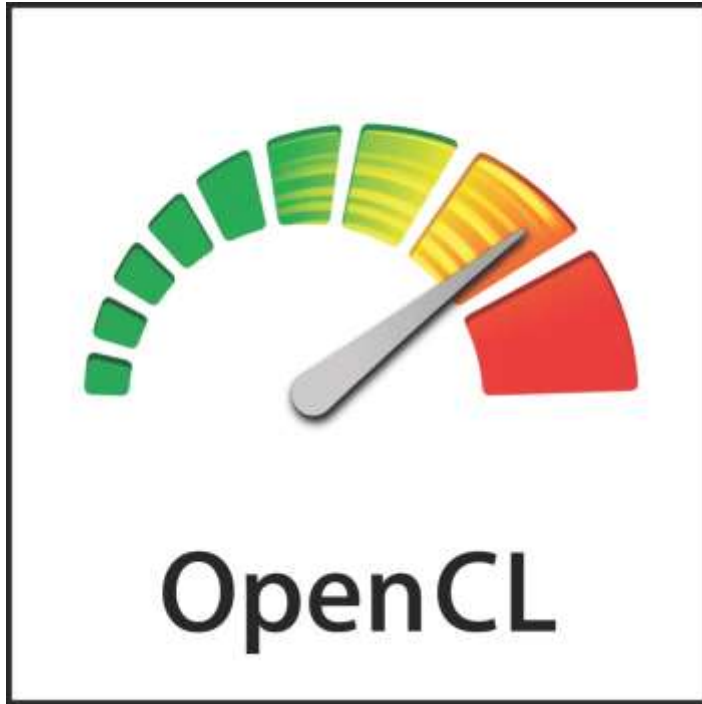


3-component Vectors
Additional Image Formats
Multiple Hosts and Devices
Buffer Region Operations
Enhanced Event-Driven Execution
Additional OpenCL C Built-ins
Improved OpenGL Data/Event Interop

Device Partitioning
Separate Compilation and Linking
Enhanced Image Support
Built-in Kernels / Custom Devices
Enhanced DX and OpenGL Interop

Shared Virtual Memory
Device Enqueue
Generic Address Space
Enhanced Image Support
C11 Atomics
Pipes
Android ICD





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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...**

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

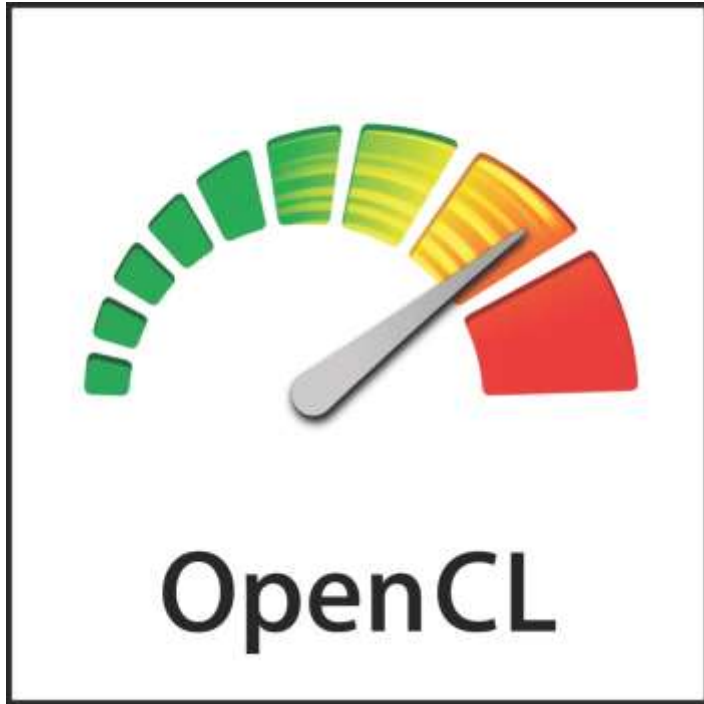
New! Full support for Templates

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 }

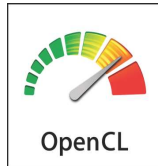


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OpenCL 2.1
SPIR-V

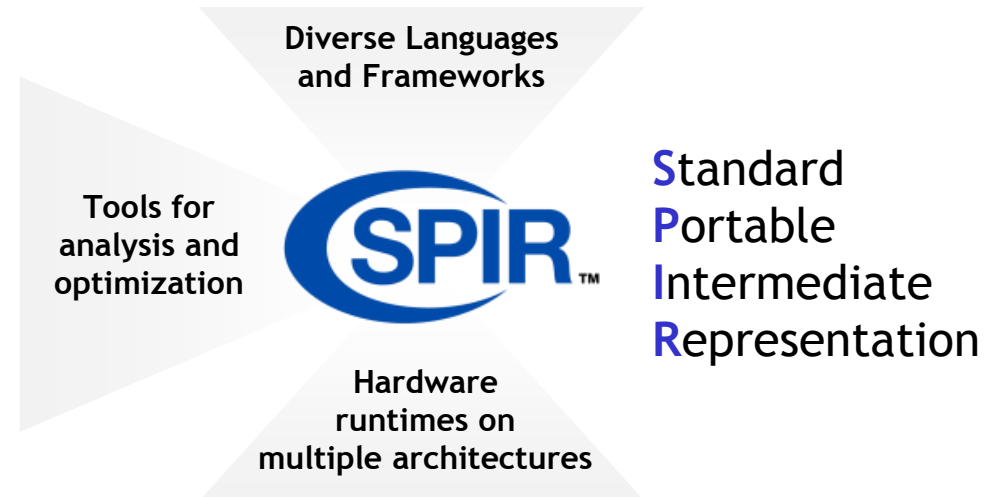
What is SPIR-V?

- **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




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

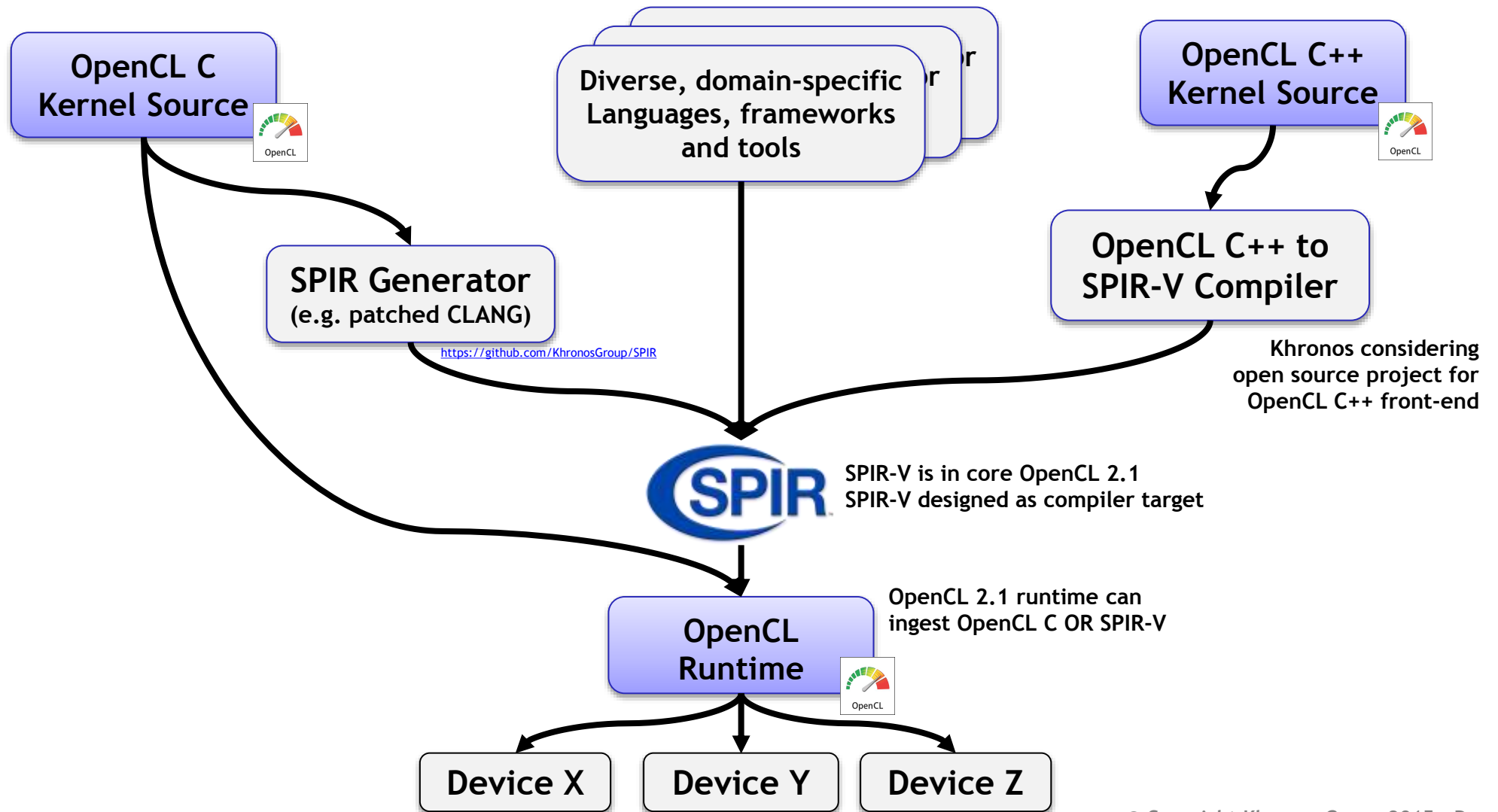


Evolution of SPIR

- 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

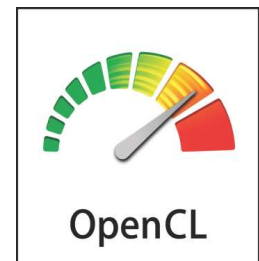
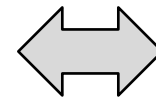
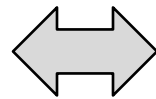
|  | SPIR 1.2 | SPIR 2.0 (Provisional) | SPIR-V |
|---|-----------------------------|--------------------------------------|---|
| <i>LLVM Interaction</i> | <i>Uses LLVM 3.2 IR</i> | <i>Uses LLVM 3.4 IR</i> | <i>100% Khronos Defined</i> |
| Compute Constructs | Metadata/Intrinsics | Metadata/Intrinsics | Native |
| <i>Graphics Constructs</i> | 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 |
| <i>OpenCL Consumption</i> | <i>OpenCL 1.2 Extension</i> | <i>OpenCL 2.0 Extension</i> | <i>OpenCL 2.1 CORE</i> |
| 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**
 - 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.**

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

Call to Action

- Khronos seeking feedback on OpenCL 2.1 and SPIR-V
 - Links provided on Khronos forums
 - https://www.khronos.org/opencvl/opencvl_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

