OpenCL Overview

Heterogeneous Parallel Computation

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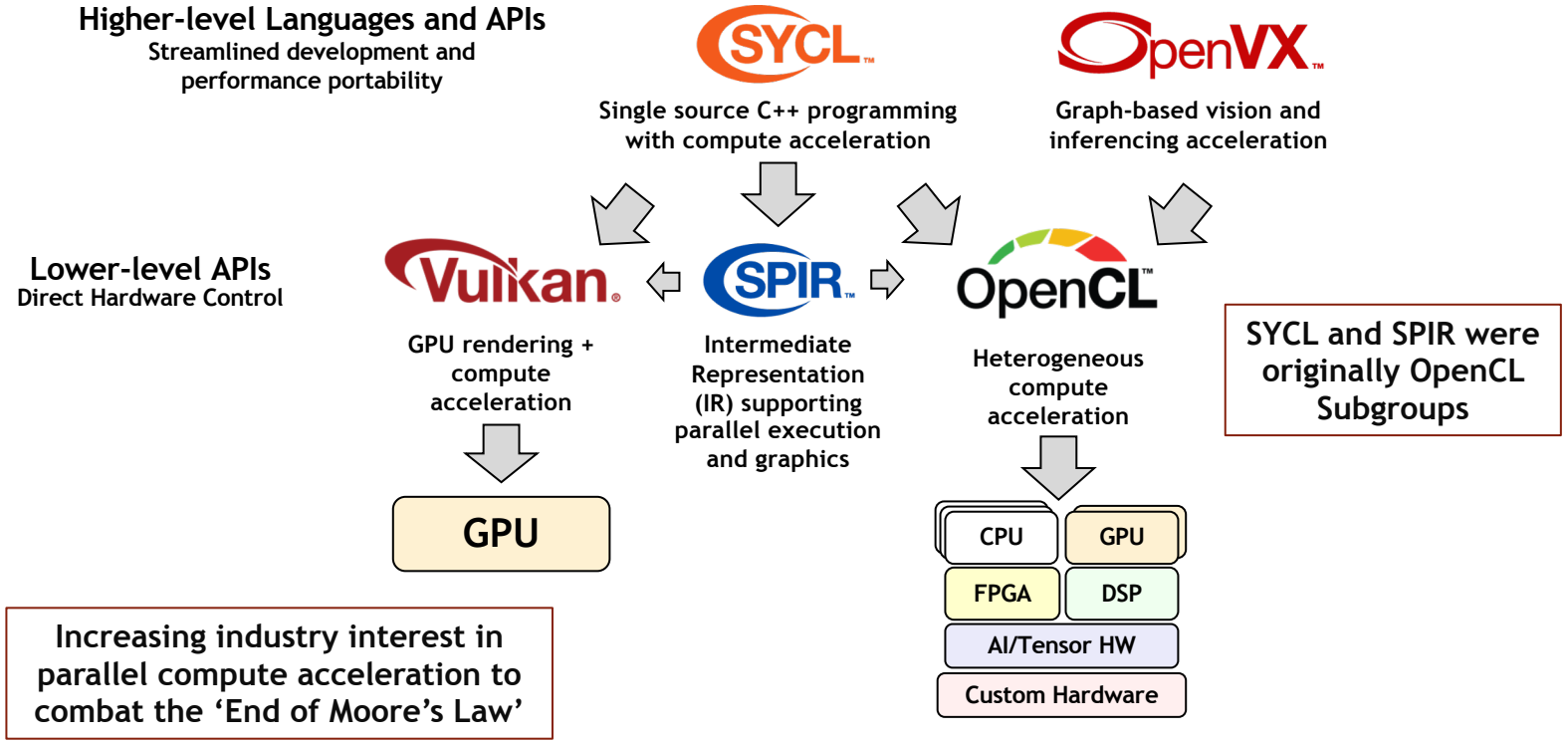
Khronos Compute Acceleration Standards



OpenCL - Low-level Parallel Programing

Programming and Runtime Framework for Application Acceleration

Offload compute-intensive kernels onto parallel heterogeneous processors
CPUs, GPUs, DSPs, FPGAs, Tensor Processors
OpenCL C or C++ kernel languages

Platform Layer API

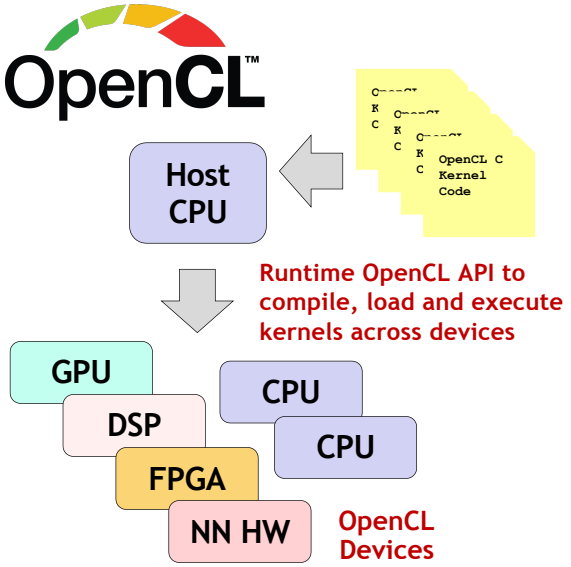
Query, select and initialize compute devices

Runtime API

Build and execute kernels programs on multiple devices

Explicit Application Control

Which programs execute on what device
Where data is stored in memories in the system
When programs are run, and what operations are dependent on earlier operations



Complements GPU-only APIs

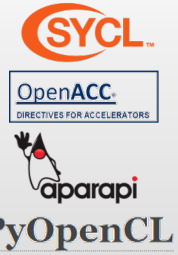
Simpler programming model
Relatively lightweight run-time
More language flexibility, e.g., pointers
Rigorously defined numeric precision

OpenCL is Widely Deployed and Used

The industry's most pervasive, cross-vendor, open standard for low-level heterogeneous parallel programming

Desktop Creative Apps

Parallel Languages



Linear Algebra Libraries

SYCL-BLAS

ViennaCL

CLBlast

Machine Learning Libraries and Frameworks

TI DL Library (TIDL)

Arm Compute Library

Molecular Modelling Libraries

Machine Learning Compilers

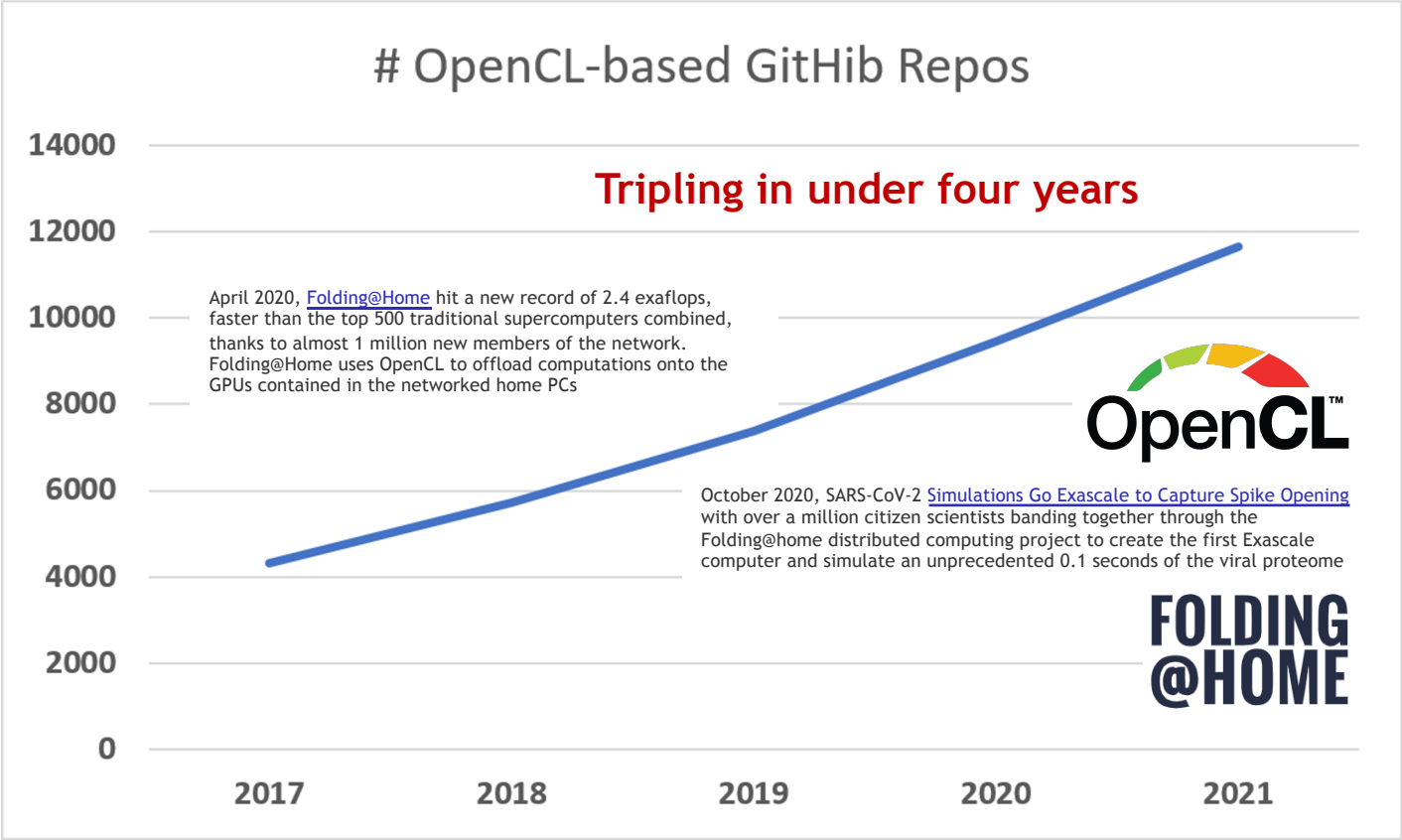
Vision, Imaging and Video Libraries

Math and Physics Libraries

Accelerated Implementations

https://en.wikipedia.org/wiki/List_of_OpenCL_applications

OpenCL Open-Source Ecosystem Momentum



OpenCL 3.0

Increased Ecosystem Flexibility

All functionality beyond OpenCL 1.2 queryable plus macros for optional OpenCL C language features
New extensions that become widely adopted will be integrated into new OpenCL core specifications

OpenCL C++ for OpenCL

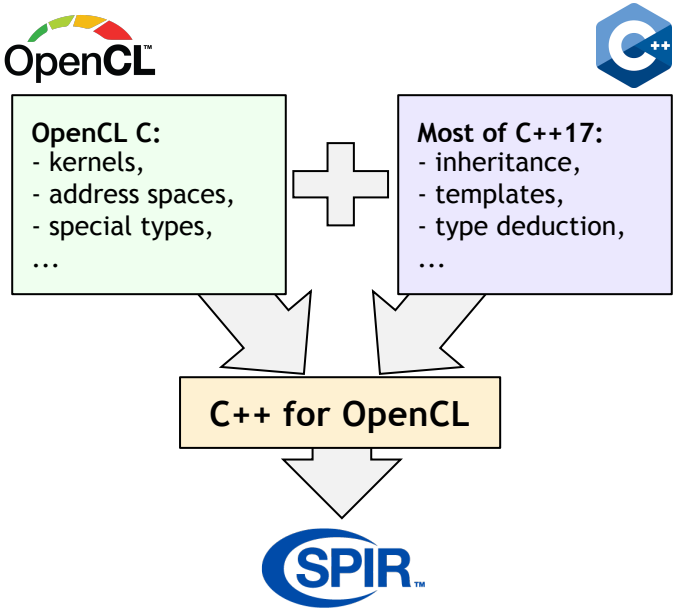
Open-source C++ for OpenCL front end compiler combines OpenCL C and C++17 replacing OpenCL C++ language specification

Unified Specification

All versions of OpenCL in one specification for easier maintenance, evolution and accessibility
Source on Khronos GitHub for community feedback, functionality requests and bug fixes

Moving Applications to OpenCL 3.0

OpenCL 1.2 applications – no change
OpenCL 2.X applications - no code changes if all used functionality is present
Queries recommended for future portability



C++ for OpenCL
Supported by Clang and uses the LLVM compiler infrastructure
OpenCL C code is valid and fully compatible
Supports most C++17 features
Generates SPIR-V kernels

Asynchronous DMA Extensions

OpenCL embraces a new class of Embedded Processors

Many DSP-like devices have Direct Memory Access hardware

Transfer data between global and local memories via DMA transactions

Transactions run asynchronously in parallel to device compute enabling wait for transactions to complete

Multiple transactions can be queued to run concurrently or in order via fences

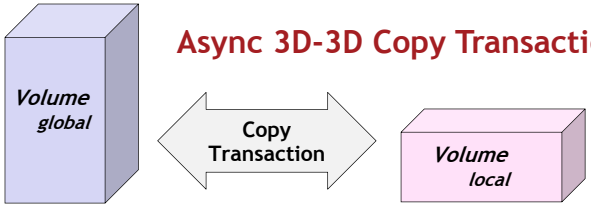
OpenCL abstracts DMA capabilities via extended asynchronous workgroup copy built-ins

(New!) 2- and 3-dimensional async workgroup copy extensions support complex memory transfers

(New!) async workgroup fence built-in controls execution order of dependent transactions

New extensions complement the existing 1-dimensional async workgroup copy built-ins

Async 3D-3D Copy Transaction



Reshaping possible

$V_{global} = V_{local}$

Async Fence controls order of dependent transactions

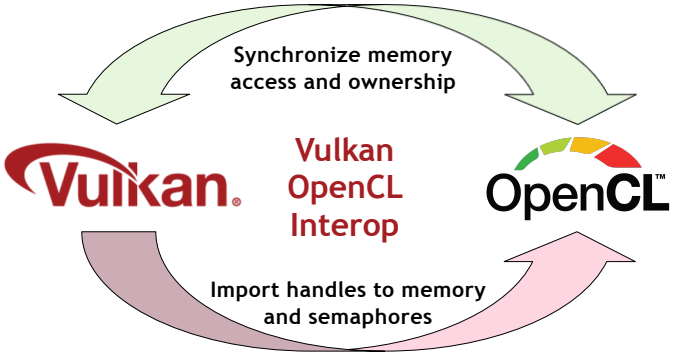
async_copy$_1$
async_copy$_2$
async_fence
async_copy$_3$

All transactions prior to async_fence must complete before any new transaction starts, without a synchronous wait

The first of significant upcoming advances in OpenCL to enhance support for embedded processors

Roadmap: External Memory Sharing

- **Generic extension to import external memory and semaphores exported by other APIs**
  - Explicitly hand-off memory ownership with OpenCL
  - Wait and signal imported external semaphores
- **Layer with API-specific interop extensions**
  - Vulkan interop first
  - DX12 and other APIs in the future
- **Improved flexibility over previous interop APIs using implicit resources**
  - As were used for DX9-11 and OpenGL



Google Ports TensorFlow Lite to OpenCL

TensorFlow Blog

Search the Blog

TensorFlow Lite

Even Faster Mobile GPU Inference with OpenCL

August 17, 2020

Posted by Juhyun Lee and Raman Sarokin, Software Engineers

While the TensorFlow Lite (TFLite) GPU team continuously improves the existing OpenGL-based mobile GPU inference engine, we also keep investigating other technologies. One of those experiments turned out quite successful, and we are excited to announce the official launch of OpenCL-based mobile GPU inference engine for Android, which offers up to ~2x speedup over our existing OpenGL backend, on reasonably sized neural networks that have enough workload for the GPU.

Figure 1. Duo's AR effects are powered by our OpenCL backend.

Improvements over the OpenGL Backend

Historically, OpenGL is an API designed for rendering vector graphics. Compute shaders were added with OpenGL ES 3.1, but its backward compatible API design decisions were limiting us

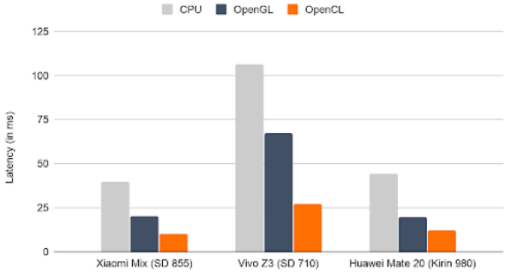


Figure 2. Inference latency of MNASNet 1.3 on select Android devices with OpenCL.

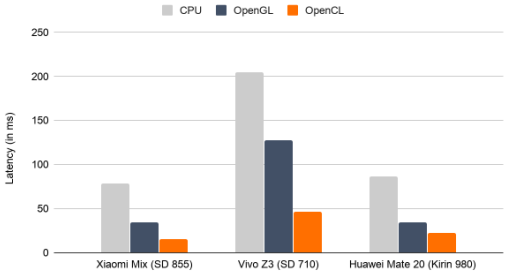


Figure 3. Inference latency of SSD MobileNet v3 (large) on select Android devices with OpenCL.

OpenCL providing ~2x inferencing speedup over OpenGL ES acceleration

TensorFlow Lite uses OpenGL ES as a backup if OpenCL not available …

…but most mobile GPU vendors provide OpenCL drivers - even if not exposed directly to Android developers

OpenCL is increasingly used as acceleration target for higher-level framework and compilers

ML Compiler Steps

	tvm.ai	plaidML	GLOW	XLA
	amazon	intel		Google
Import Formats	Caffe, Keras, MXNet, ONNX	TensorFlow Graph, MXNet, PaddlePaddle, Keras, ONNX	PyTorch, ONNX	TensorFlow Graph, PyTorch, ONNX
Front-end / IR	NNVM / Relay IR	nGraph / Stripe IR	Glow Core / Glow IR	XLA HLO MLIR
Output	OpenCL, LLVM, CUDA, Metal	OpenCL, LLVM, CUDA	OpenCL LLVM	LLVM, TPU IR, XLA IR TensorFlow Lite / NNAPI (inc. HW accel)

Embedded NN Compilers
CEVA Deep Neural Network (CDNN)
Cadence Xtensa Neural Network Compiler (XNNC)

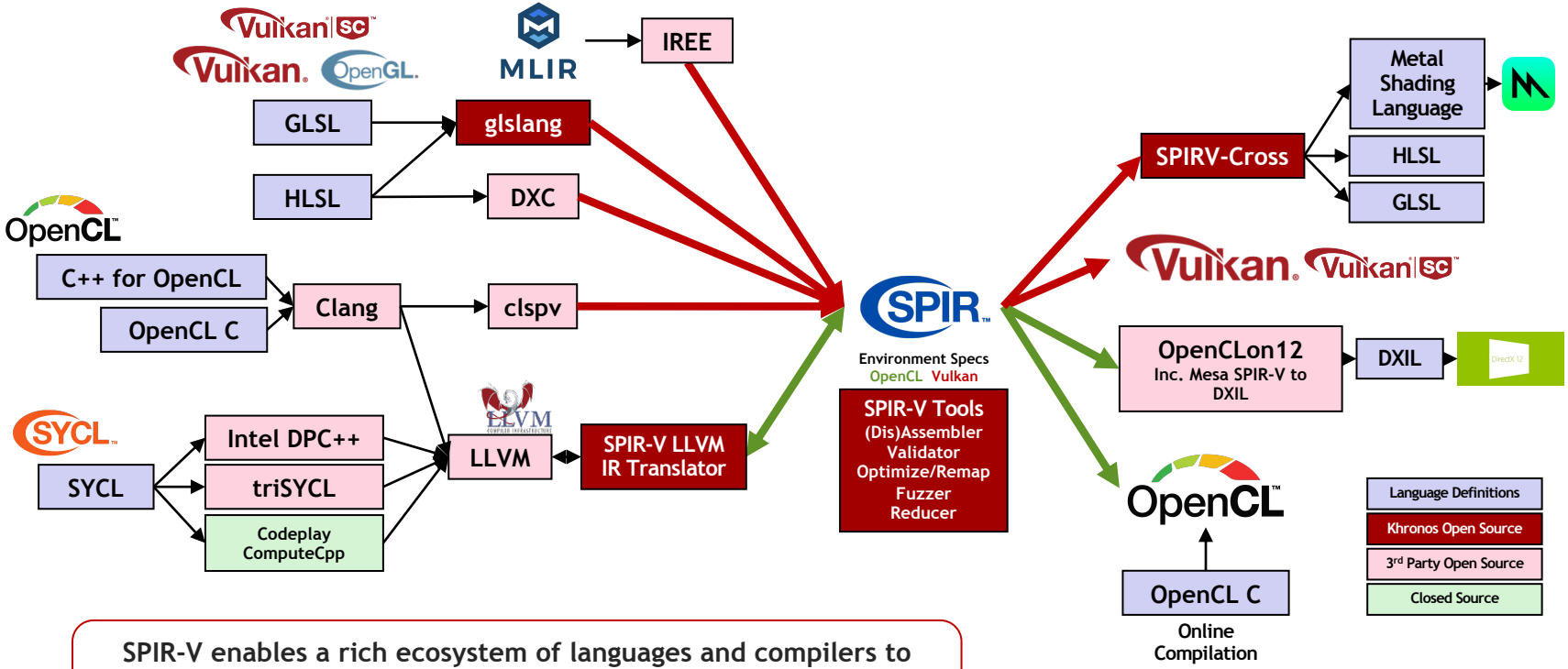
SPIR

Consistent Steps

1. Import Trained Network Description
2. Apply graph-level optimizations e.g., node fusion, node lowering and memory tiling
3. Decompose to primitive instructions and emit programs for accelerated run-times

Fast progress but still area of intense research
If compiler optimizations are effective - hardware accelerator APIs can stay 'simple' and won't need complex metacommands (e.g., combined primitive commands like DirectML)

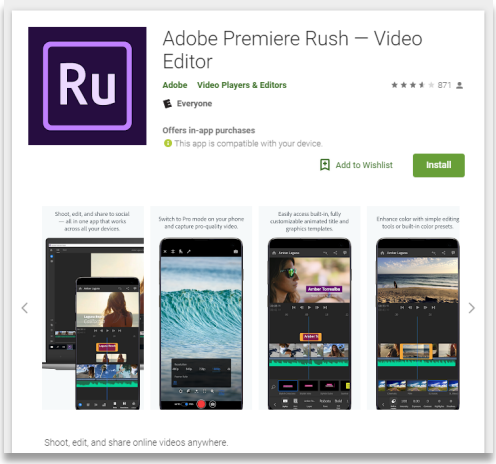
SPIR-V Language Ecosystem

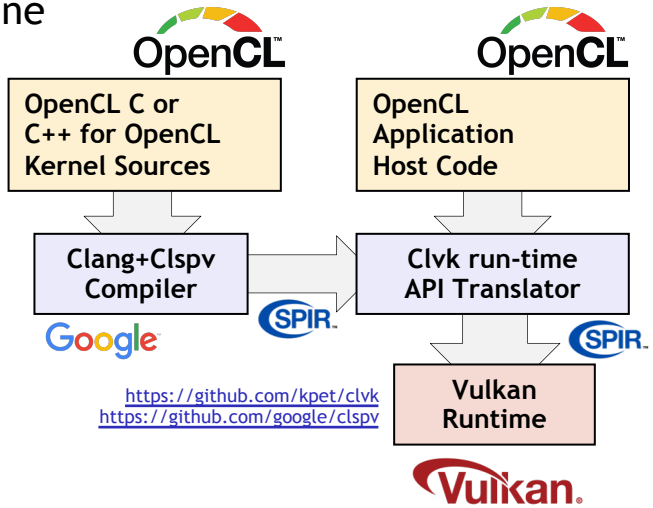


SPIR-V enables a rich ecosystem of languages and compilers to target low-level APIs such as Vulkan and OpenCL, including deployment flexibility: e.g., running OpenCL C kernels on Vulkan

Layered OpenCL over Vulkan

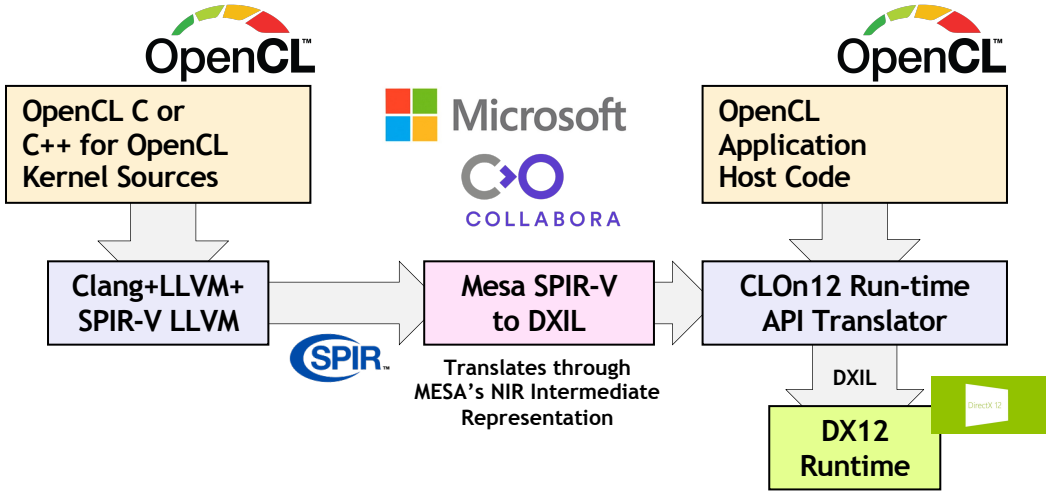
- **Clspv - Google's open-source OpenCL kernel to Vulkan SPIR-V compiler**
  - Tracks top-of-tree LLVM and Clang, not a fork
- **Clvk - prototype open-source OpenCL to Vulkan run-time API translator**
- **Used for shipping production apps and engines on Android**
  - Adobe Premiere Rush video editor – 200K lines of OpenCL C kernel code
  - Butterfly Network iQ Ultrasound on Android
  - Experimenting with Xiaomi MACE inferencing engine





Layered OpenCL over DirectX12

- **GPU-accelerated OpenCL on any system with DX12**
  - PC (x86 or Arm) and Cloud
- **OpenCLOn12 - Microsoft and COLLABORA leveraging Clang/LLVM and MESA**
  - OpenCL 1.2 over DX12 is in development
  - Also, OpenGLOn12 – OpenGL 3.3 over DX12
  - https://devblogs.microsoft.com/directx/in-the-works-opencl-and-opengl-mapping-layers-to-directx/



Get Involved!

- **OpenCL 3.0 increases deployment flexibility and sets the stage for raising the bar on pervasively available functionality**
  - https://www.khronos.org/registry/OpenCL/
- **OpenCL specification feedback on GitHub**
  - https://github.com/KhronosGroup/OpenCL-Docs/issues
- **We want to know what you need next from OpenCL on the Khronos Forums!**
  - https://community.khronos.org/c/opencl
- **Engage with Khronos and help OpenCL evolve**
  - Join as a Khronos member for a voice and a vote in any Khronos standard
  - Or request an invite to the OpenCL Advisory Panel
  - https://www.khronos.org/members/
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