KHRONOS™ GROUP

Vulkan™ Overview

February 2016

www.khronos.org/vulkan/

BOARD OF PROMOTERS

KHRONOS GROUP

Over 100 members worldwide
any company is welcome to join

Khronos Connects Software to Silicon

Industry Consortium creating OPEN STANDARD APIs for hardware acceleration
Any company is welcome – one company one vote

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

Software

Silicon

Conformance Tests and Adopters Programs for specification integrity and cross-vendor portability

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

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

Strong industry momentum
100s of man years invested by industry experts
Well over a *BILLION* people use Khronos APIs *Every Day*…

KHRONOS GROUP

The Genesis of Vulkan

Khronos members from all segments of the graphics industry agree the need for new generation cross-platform GPU API

Including an unprecedented level of participation from game engine developers

Significant proposals, IP contributions and engineering effort from many working group members

18 months

A high-energy working group effort

Vulkan

Khronos' first API 'hard launch'

Specification, Conformance Tests, SDKs - all open source…
Reference Materials, Compiler front-ends, Samples…
Multiple Conformant Drivers on multiple OS

Vulkan Working Group Participants

The Need for a New Generation GPU API

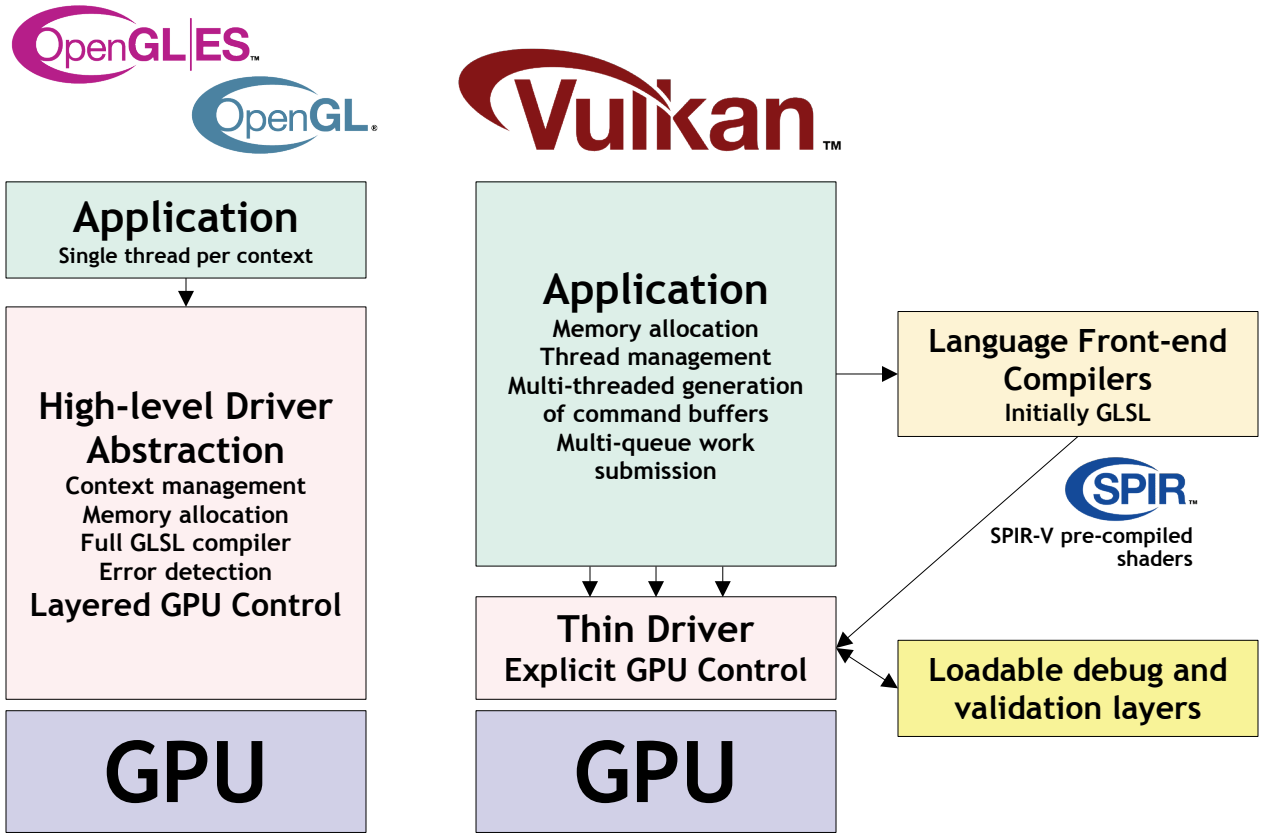
- **Explicit**
  - Open up the high-level driver abstraction to give direct, low-level GPU control
- **Streamlined**
  - Faster performance, lower overhead, less latency
- **Portable**
  - Cloud, desktop, console, mobile and embedded
- **Extensible**
  - Platform for rapid innovation

OpenGL has evolved over 25 years and continues to meet industry needs - but there is a need for a complementary API approach

GPUs are increasingly programmable and compute capable + platforms are becoming mobile, memory-unified and multi-core

GPUs will accelerate graphics, compute, vision and deep learning across diverse platforms: FLEXIBILITY and PORTABILITY are key

Vulkan Explicit GPU Control



Vulkan 1.0 provides access to
OpenGL ES 3.1 / OpenGL 4.X-class GPU functionality
but with increased performance and flexibility

Vulkan Benefits

Simpler drivers:
Improved efficiency/performance
Reduced CPU bottlenecks
Lower latency
Increased portability

Resource management in app code:
Less hitches and surprises

Command Buffers:
Command creation can be multi-threaded
Multiple CPU cores increase performance

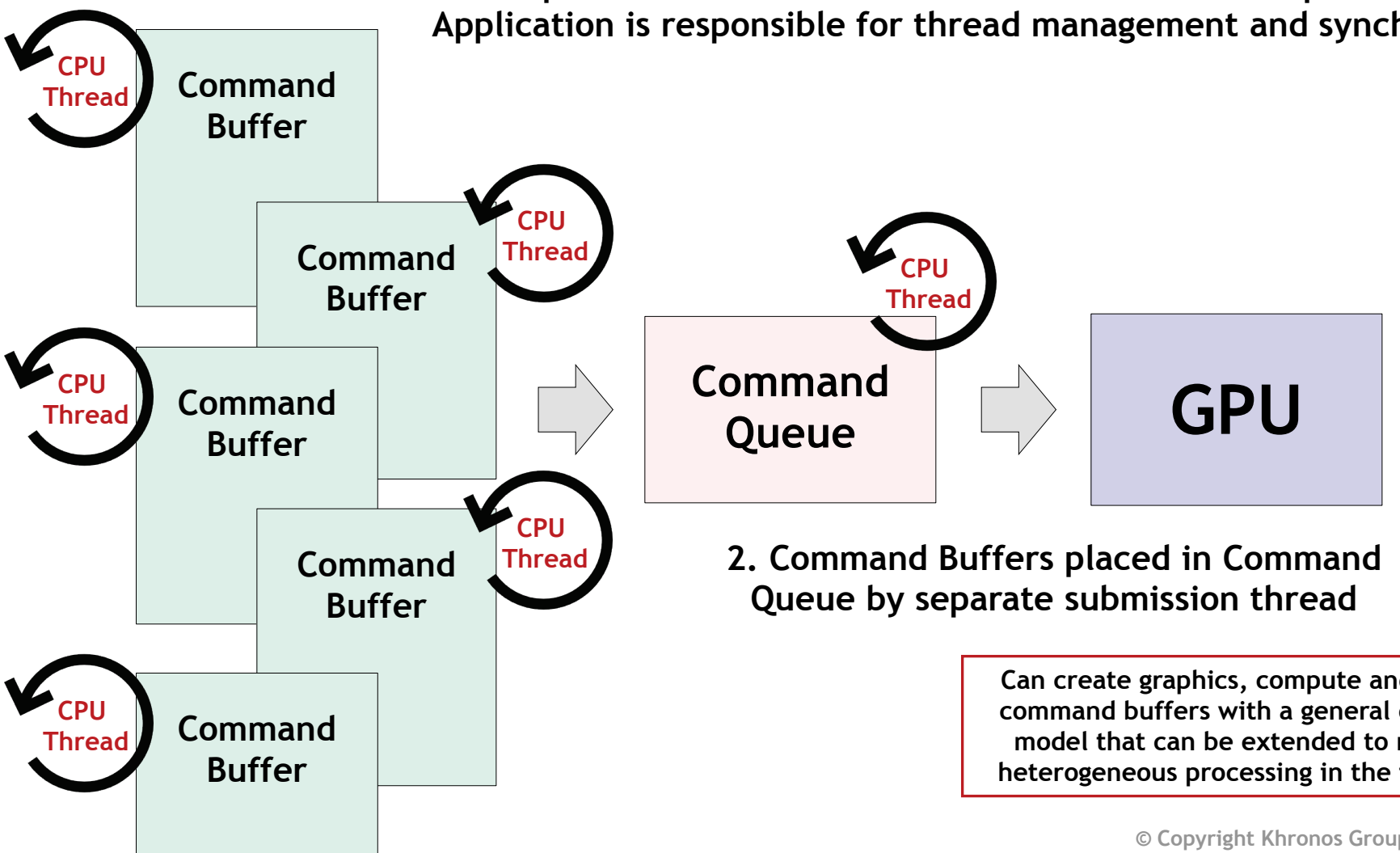
Graphics, compute and DMA queues:
Work dispatch flexibility

SPIR-V Pre-compiled Shaders:
No front-end compiler in driver
Future shading language flexibility

Loadable Layers
No error handling overhead in production code

Vulkan Multi-threading Efficiency

1. Multiple threads can construct Command Buffers in parallel
Application is responsible for thread management and synch



2. Command Buffers placed in Command Queue by separate submission thread

Can create graphics, compute and DMA command buffers with a general queue model that can be extended to more heterogeneous processing in the future

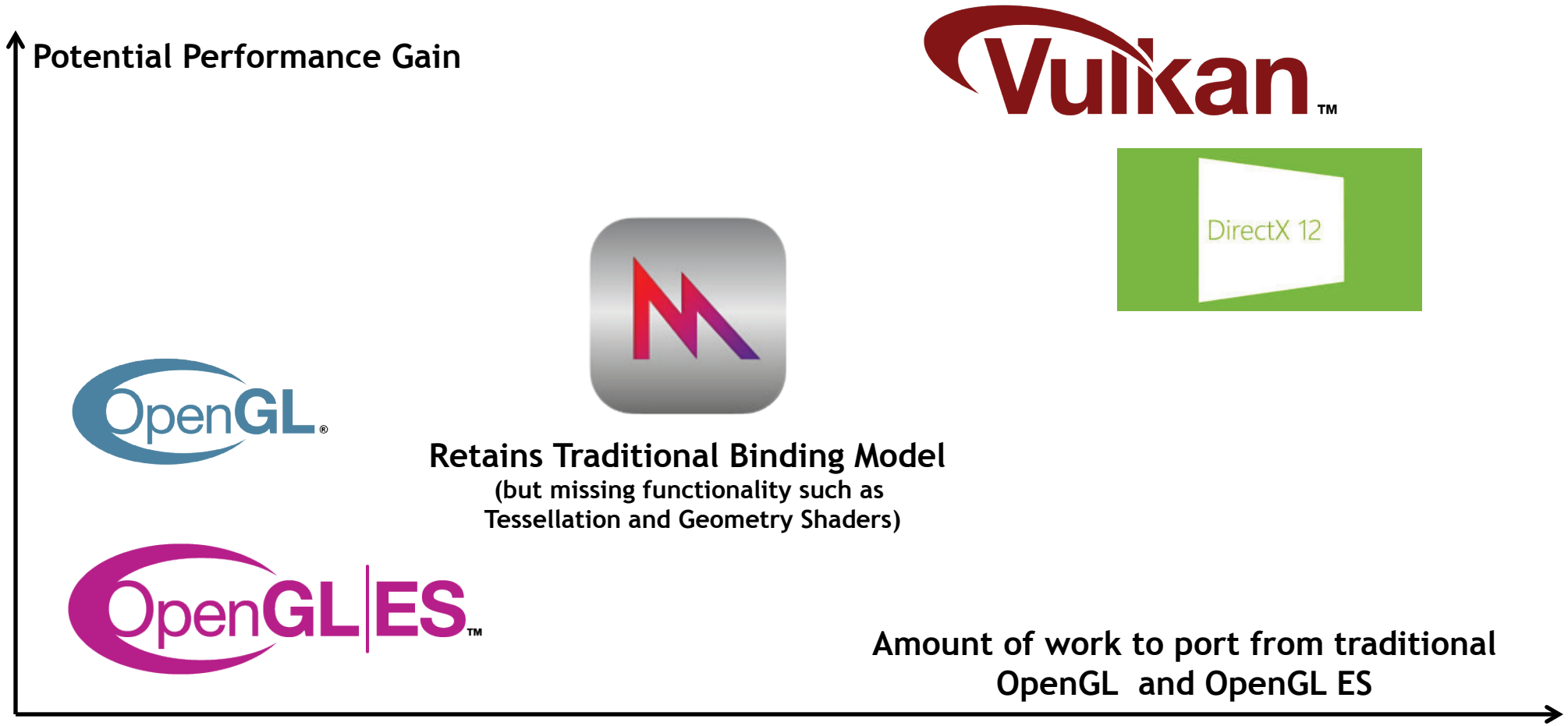
Next Generation GPU APIs

Only Windows 10

Only Apple

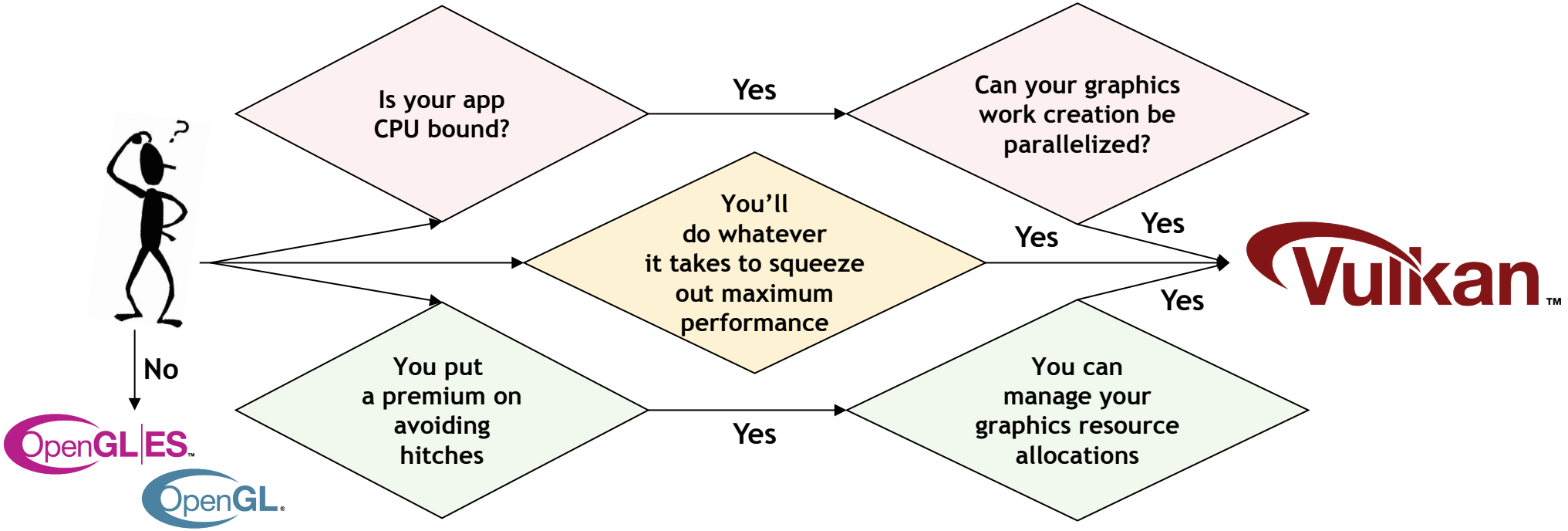
Cross Platform

Vulkan - No Compromise Performance



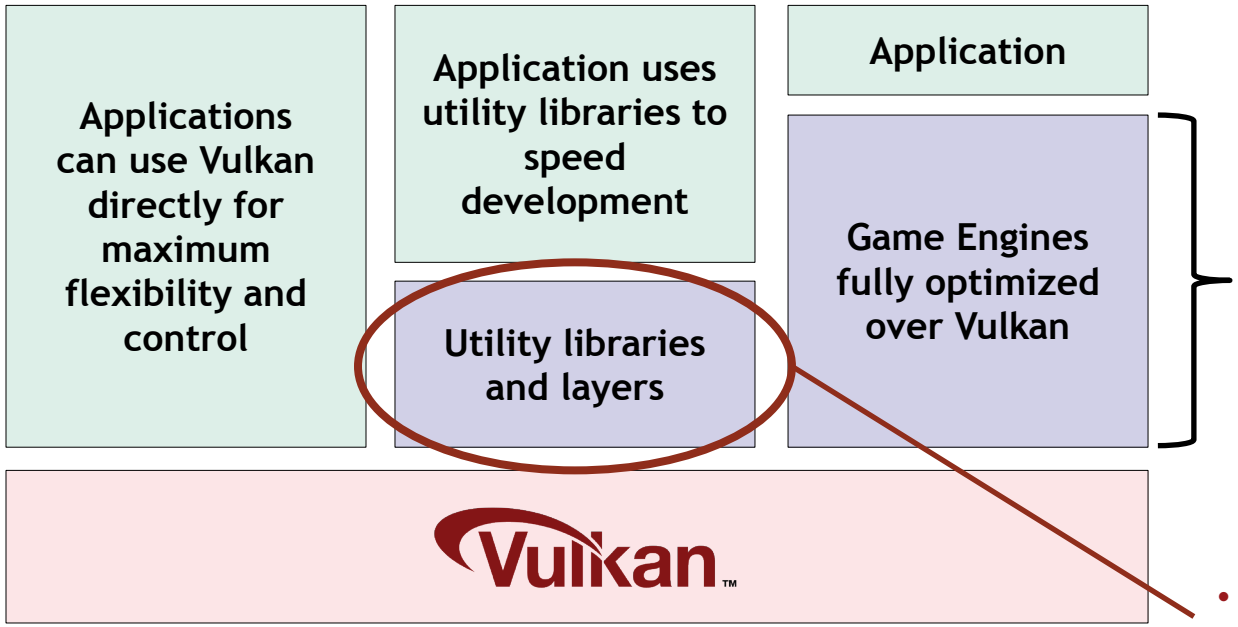
Which Developers Should Use Vulkan?

- **Vulkan puts more work and responsibility into the application**
  - Not every developer will need or want to make that extra investment
- **For many developers OpenGL and OpenGL ES will remain the most effective API**
  - Khronos actively evolving OpenGL and OpenGL ES in parallel with Vulkan



Vulkan provides more choice to developers and can be used to create new classes of end-user experience

The Power of a Three Layer Ecosystem



Applications using game engines will automatically benefit from Vulkan's enhanced performance

OXIDE · LUCASFILM Ltd · BLIZZARD ENTERTAINMENT · EA · unity · EPIC GAMES · VALVE

Rich Area for Innovation

- Many utilities and layers will be in open source
- Layers to ease transition from OpenGL
- Domain specific flexibility

Similar ecosystem dynamic as WebGL

A widely pervasive, powerful, flexible foundation layer enables diverse middleware tools and libraries

KHRONOS GROUP

Vulkan Feature Sets

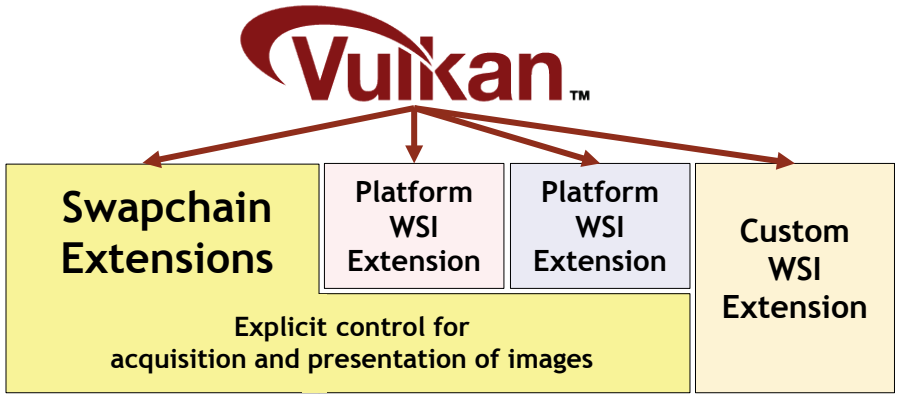
- **Vulkan supports hardware with a wide range of hardware capabilities**
  - Mobile OpenGL ES 3.1 up to desktop OpenGL 4.5 and beyond
- **One unified API framework for desktop, mobile, console, and embedded**
  - No "Vulkan ES" or "Vulkan Desktop"
- **Vulkan precisely defines a set of "fine-grained features"**
  - Features are specifically enabled at device creation time (similar to extensions)
- **Platform owners define a Feature Set for their platform**
  - Vulkan provides the mechanism but does not mandate policy
  - Khronos will define Feature Sets for platforms where owner is not engaged
- **Khronos will define feature sets for Windows and Linux**
  - After initial developer feedback

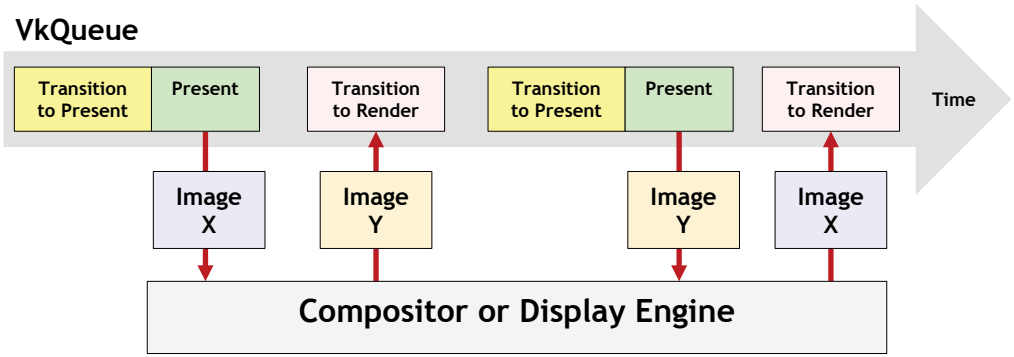
KHRONOS GROUP

Vulkan™

Vulkan Window System Integration (WSI)

- **Explicit control for acquisition and presentation of images**
  - Designed to fit the Vulkan API and today's compositing window systems
  - Cleanly separates device creation from window system
- **Platform provides an array of persistent presentable images = Vulkan Swapchain**
  - Device exposes which queues support presentation
  - Application explicitly controls which image to render and present
- **Standardized extensions - unified API for multiple window systems**
  - Works across Android, Mir, Windows (Vista and up), Wayland and X (with DRI3)
  - Platforms can extend functionality, define custom WSI stack, or have no display at all





SPIR-V Transforms the Language Ecosystem

- **First multi-API, intermediate language for parallel compute and graphics**
  - Native representation for Vulkan shader and OpenCL kernel source languages
  - https://www.khronos.org/registry/spir-v/papers/WhitePaper.pdf
- **GL_KHR_vulkan_glsl spec released - adds the GLSL features needed for Vulkan**
  - Descriptor sets, push constants, specialization constants
  - Separate images/samplers, sub pass input images…
  - Updated front-end open source compiler in Khronos GitHub

Multiple Developer Advantages

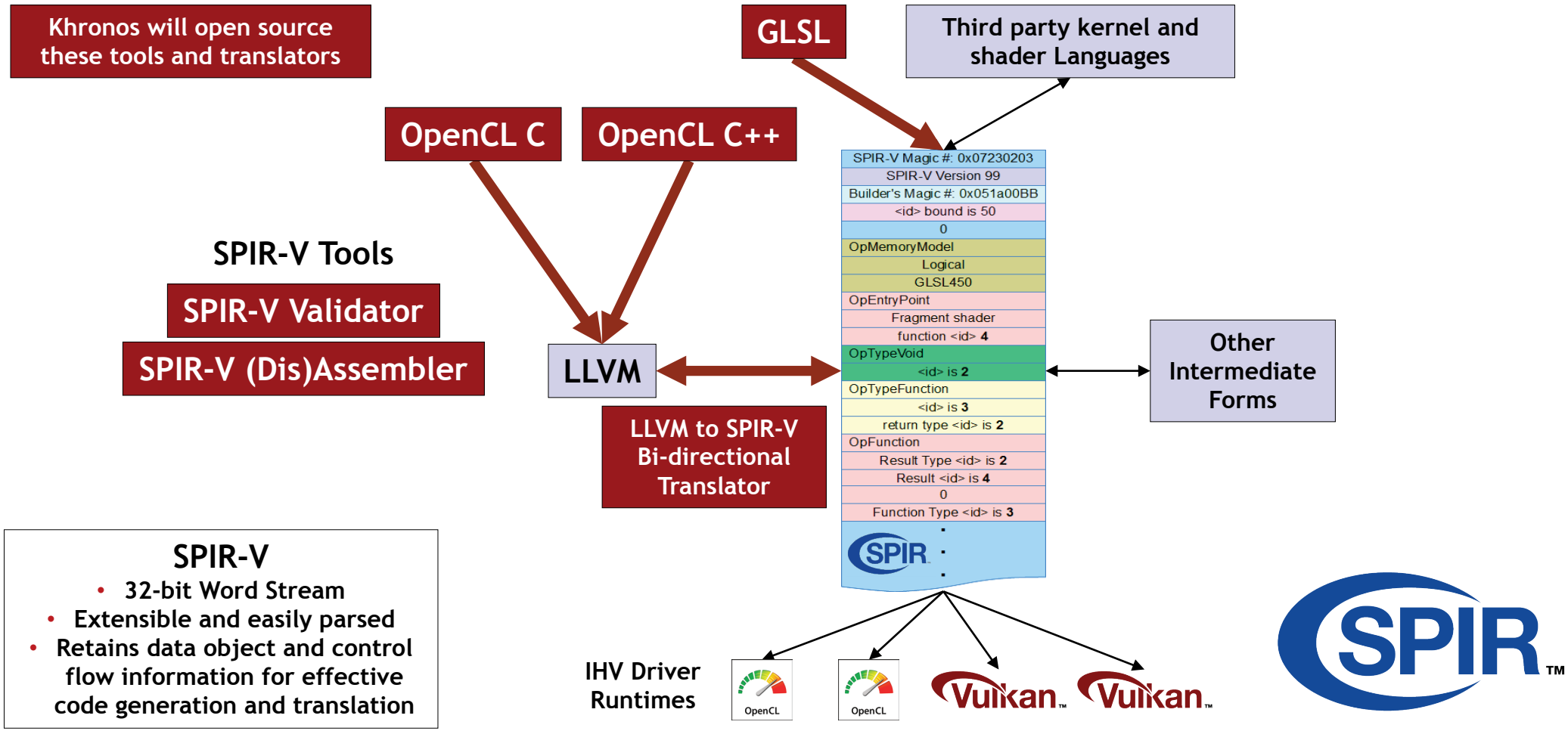
Same front-end compiler for multiple platforms
Reduces runtime kernel compilation time
Don't have to ship shader/kernel source code
Drivers are simpler and more reliable

Evolution of SPIR Family

- **SPIR-V is first fully specified Khronos-defined SPIR standard**
  - Does not use LLVM to isolate from LLVM roadmap changes
  - Includes full flow control, graphics and parallel constructs beyond LLVM
  - Khronos will open source SPIR-V <-> LLVM conversion tools

SPIR	SPIR 1.2	SPIR 2.0	SPIR-V 1.0
LLVM Interaction	Uses LLVM 3.2	Uses LLVM 3.4	100% Khronos defined Round-trip lossless conversion
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 Ingestion	OpenCL 1.2 Extension	OpenCL 2.0 Extension	OpenCL 2.1 Core
Vulkan Ingestion	-	-	Vulkan Core

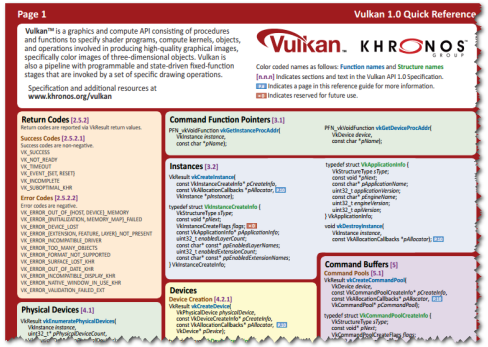
Driving the SPIR-V Open Source Ecosystem



SPIR-V

- 32-bit Word Stream
- Extensible and easily parsed
- Retains data object and control flow information for effective code generation and translation

Vulkan Developer Resources at Launch



KHRONOS GROUP

GET INVOLVED! HELP US EVOLVE THE VULKAN ECOSYSTEM

Khronos has placed an unprecedented amount of materials into open source so you can provide feedback, showcase your work, fix bugs, and extend Vulkan capabilities for the future. Get engaged AND show the world what YOU are doing with Vulkan.

Vulkan resources on Github

Discussions

Issue Trackers:

- **Vulkan Specification, Reference Pages, and API Registry**
- **Vulkan CTS**
- **Vulkan Loader and Validation Tools**
- **Vulkan Sample Code**
- **Data Format specification**

Khronos.org Canonical Resources

Specifications, Header Files
Feature Set Definitions
(Windows and Linux - post developer feedback)
Quick Reference and Reference Pages
Conformance Test Source and Test Process

Materials to Build SDKs and Tools

Compiler toolchain sources
Validation Layer Source
Loader Source
Layers and Loader documentation
(open source resources in github.com/KhronosGroup)

Everything needed to create SDKs for any platform or market

LunarG

Windows and Linux Installable SDKs
Loader and Validation Layer binaries
Tools Layers - source and binaries
Samples - source and binaries
Windows get started guide

IHV Websites

Drivers and Loader
Vendor tools and layers

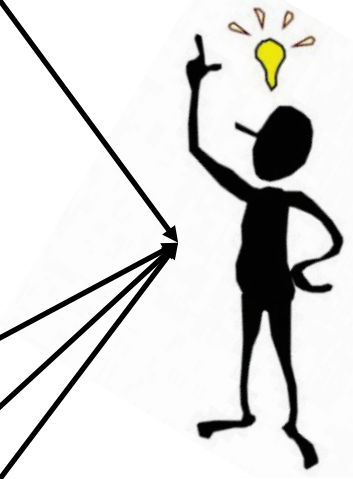
Third Party Websites

Layers, Samples etc.

VULKAN DRIVERS

Behind every great API are the drivers that bring it life on your GPU. Download the latest drivers for your system that now include Vulkan 1.0.

AMD Imagination intel NVIDIA QUALCOMM



DEMOS AND SAMPLES

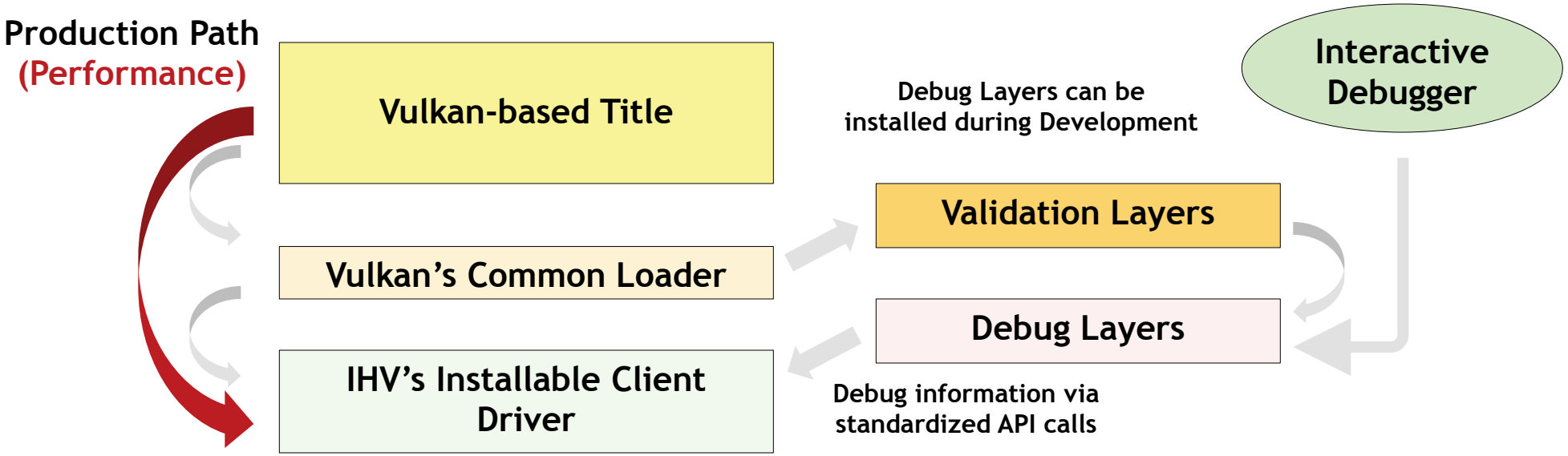
Download demos and open source samples to take your new Vulkan API for a test drive - and get a heads up on Vulkan resources which will be arriving soon…

ARM LUNARG Imagination LUNARG MetalVK

Norbert Nopper NVIDIA Sascha Willems

Vulkan Tools Architecture

- **Layered design for cross-vendor tools innovation and flexibility**
  - IHVs plug into a common, extensible architecture for code validation, debugging and profiling during development without impacting production performance
- **Khronos Open Source Loader enables use of tools layers during debug**
  - Finds and loads drivers, dispatches API calls to correct driver and layers



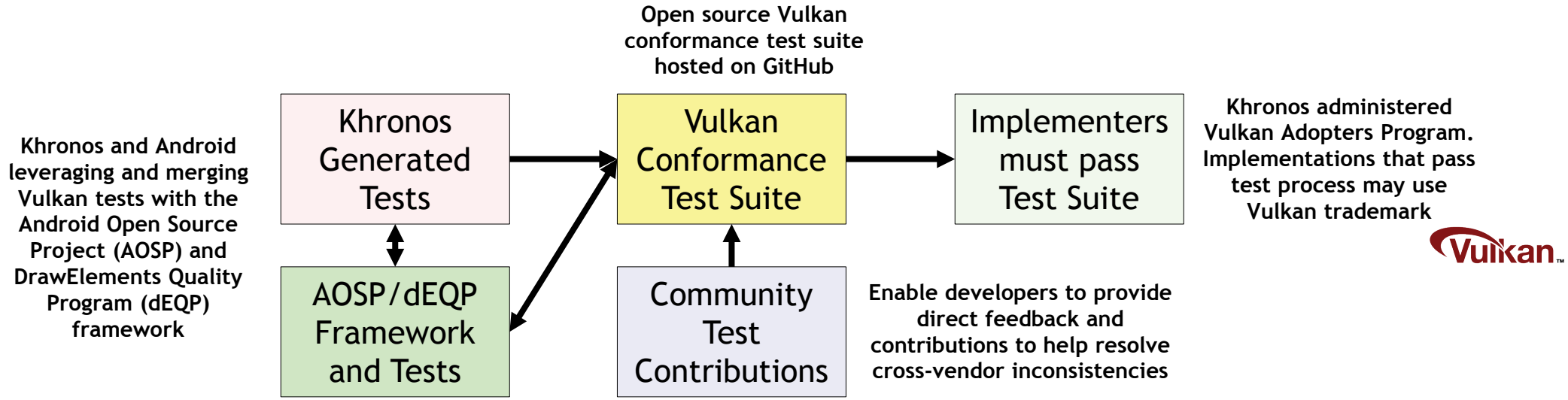
LunarG SDK for Vulkan

- **Valve sponsored LunarG to develop a free, open source SDK for Vulkan**
  - Utilities, samples, debugging tools, documentation
  - For Windows and Linux on launch – Android coming soon
- **Validation Layer – checks many aspects of Vulkan code:**
  - Device limits, draw state, parameter values
  - Multi-thread object access rules, texture and render target formats
  - Object Tracker, Memory Tracker
- **Other SDK Tools**
  - Trace and replay tools
  - GLSL Validator
  - SPIR-V Disassembler and Assembler
- **RenderDoc Graphics debugger**
  - Free and open source
  - Adding Vulkan support
  - https://github.com/baldurk/renderdoc

vulkan.lunarg.com

Conformant Vulkan Drivers at Launch

- **30 Driver submissions passed conformance at Vulkan 1.0 launch**
  - ARM: Linux
  - Imagination Technologies: Linux
  - Intel: Linux
  - NVIDIA: Android 6.0, Linux (desktop and embedded), Windows 7-10
  - Qualcomm: Android 6.0
  - www.khronos.org/conformance/adopters/conformant-products
- **Drivers in test submission review at Vulkan 1.0 launch**
  - AMD: Windows



One Week Since Launch of Vulkan 1.0

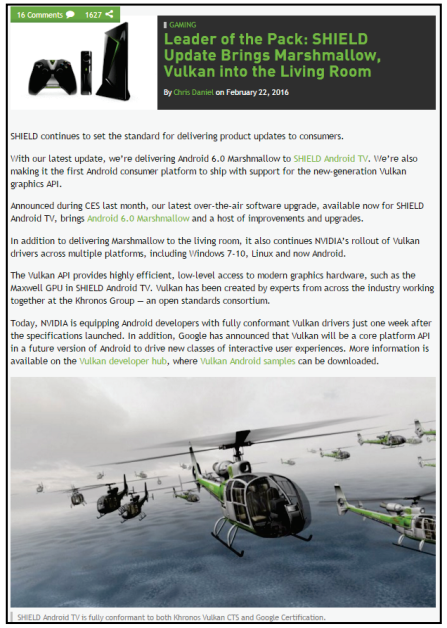
http://www.pcworld.com/article/3035020/linux/valves-steamos-now-supports-vulkan-the-cross-platform-alternative-to-directx-12.html

Valve's SteamOS now supports Vulkan, the cross-platform alternative to DirectX 12

Nvidia leads the pack, with Intel and AMD not far behind, signalling a new dawn for Linux gaming.

Credit: Scott Robinson via Flickr/Creative Commons

http://blogs.nvidia.com/blog/2016/02/22/shield-marshmallow-vulkan/



16 Comments 1627

GAMING

Leader of the Pack: SHIELD Update Brings Marshmallow, Vulkan into the Living Room

By Chris Daniel on February 22, 2016

SHIELD continues to set the standard for delivering product updates to consumers.

With our latest update, we're delivering Android 6.0 Marshmallow to SHIELD Android TV. We're also making it the first Android consumer platform to ship with support for the new-generation Vulkan graphics API.

Announced during CES last month, our latest over-the-air software upgrade, available now for SHIELD Android TV, brings Android 6.0 Marshmallow and a host of improvements and upgrades.

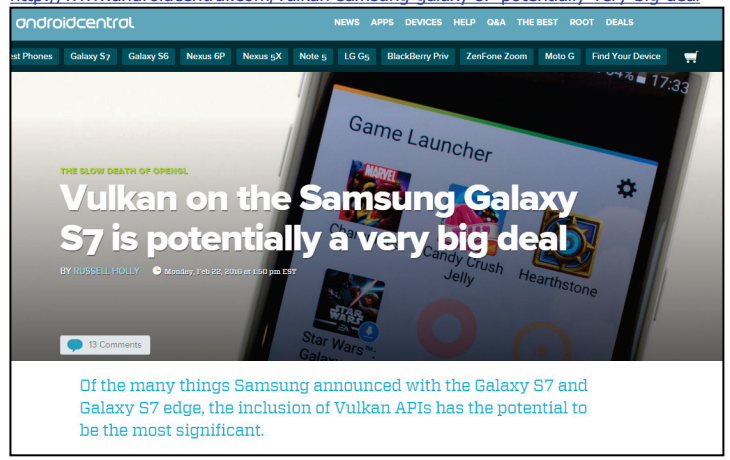
In addition to delivering Marshmallow to the living room, it also continues NVIDIA's rollout of Vulkan drivers across multiple platforms, including Windows 7-10, Linux and now Android.

The Vulkan API provides highly efficient, low-level access to modern graphics hardware, such as the Maxwell GPU in SHIELD Android TV. Vulkan has been created by experts from across the industry working together at the Khronos Group – an open standards consortium.

Today, NVIDIA is equipping Android developers with fully conformant Vulkan drivers just one week after the specifications launched. In addition, Google has announced that Vulkan will be a core platform API in a future version of Android to drive new classes of interactive user experiences. More information is available on the Vulkan developer hub, where Vulkan Android samples can be downloaded.

SHIELD Android TV is fully conformant to both Khronos Vulkan CTS and Google Certification.

http://www.androidcentral.com/vulkan-samsung-galaxy-s7-potentially-very-big-deal

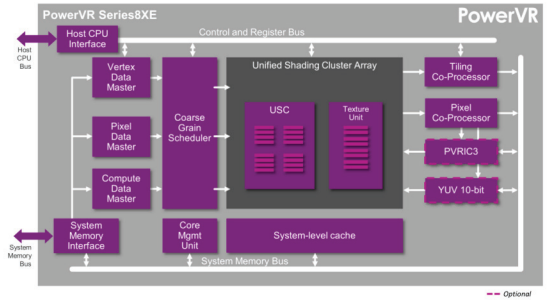


Of the many things Samsung announced with the Galaxy S7 and Galaxy S7 edge, the inclusion of Vulkan APIs has the potential to be the most significant.

Imagination introduces PowerVR Series8XE GPUs, brings OpenGL ES 3.2 and Vulkan to the ultra-affordable market

by: PREETAM NATH
FEBRUARY 22, 2016

296 shares



http://www.androidauthority.com/powervr-series8xe-673991/

SOFTPEDIA® DESKTOP MOBILE WEB NEWS

Softpedia > News > Linux

Ubuntu 16.04 LTS to Ship with Full Support for Vulkan in Mir Display Server

Canonical is jumping on the Vulkan train

Feb 17, 2016 18:49 GMT · By Silviu Stahie

Ubuntu 16.04 LTS (Xenial Xerus) is going to integrate full support in Mir for the latest Vulkan 1.0 specifications.

Vulkan is stealing all the headlines in the Linux world and with good reason. It's an incredible leap forward for the open source platform, even if Vulkan is technically aimed at all the major operating systems, including Windows, Android, and even Tizen.

http://news.softpedia.com/news/ubuntu-16-04-lts-to-ship-with-full-support-for-vulkan-in-mir-display-server-500543.shtml

HEXUS

HOME TECH GAMING BUSINESS CONSUMER MOBILE HEXUS.TV TRUST COMPETITIONS FORUMS

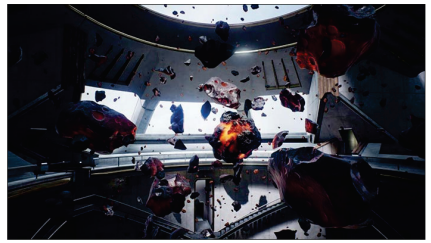
YOU ARE HERE: ANDROID SOFTWARE INDUSTRY NEWS

Epic showcases real-time Vulkan graphics on Samsung Galaxy S7

by Mark Tyson on 23 February 2016, 12:31

Tags: Samsung (005935.KS), NVIDIA (NASDAQ:NVDA), Khronos Group
Quick Link: HEXUS.net/qacjuv
Add to My Vault:

Epic Games is the first major games graphics engine maker to add support for Vulkan. To demonstrate its prowess on portable and mobile devices Epic was at the Samsung Galaxy Unpacked event showcasing what mobile games may look like in the future. Watching the 'experience' demo it seems like the Vulkan API compatible UE4 combined with the powerful new Samsung Galaxy S7 smartphone is capable of some impressive real-time 3D graphics.



"The new industry-standard Vulkan API brings key elements of high-end console graphics technology to mobile devices, and Samsung is leading the way with the amazing new Galaxy S7," Epic Games CEO Tim Sweeney said in a statement. "As the first engine supporting Vulkan, Unreal Engine 4 provides a solid foundation for developers joining in the mobile graphics revolution".

https://www.youtube.com/watch?v=FnKu7MLB7vQ

Vulkan Ecosystem Active at Launch

Molten

THE BRENWILL WORKSHOP
Graphics Technology Expertise

MetalVK MetalGL

Vulkan and OpenGL ES over Metal - in development

"By building your application or game using the Vulkan API, you can run your modern graphics application or game unchanged across an entire industry of platforms and development tools"
Brenwill Workshop

"Vulkan has a huge potential! We're only scratching the surface of what can be done with it, and porting The Talos Principle to Vulkan should be seen as a proof of concept," said Dean Sekulic graphics engine specialist at Croteam. "Vulkan in just one sentence? The endless war between performance and portability is finally over!"

Talos Principle on Steam has beta Vulkan back-end

CROTEAM

KHRONOS GROUP

Vulkan at GDC!

- **Many deep dive sessions**
  - Much more detail than we have time for today
- **Vulkan sessions at GDC – March 14-18**
  - http://schedule.gdconf.com/search-sessions/vulkan
- **Khronos Sessions co-located with GDC – March 16 – free - no need for GDC Badge!**
  - https://www.khronos.org/news/events/2016-khronos-sessions-san-francisco
  - All Khronos sessions will be live streamed and posted

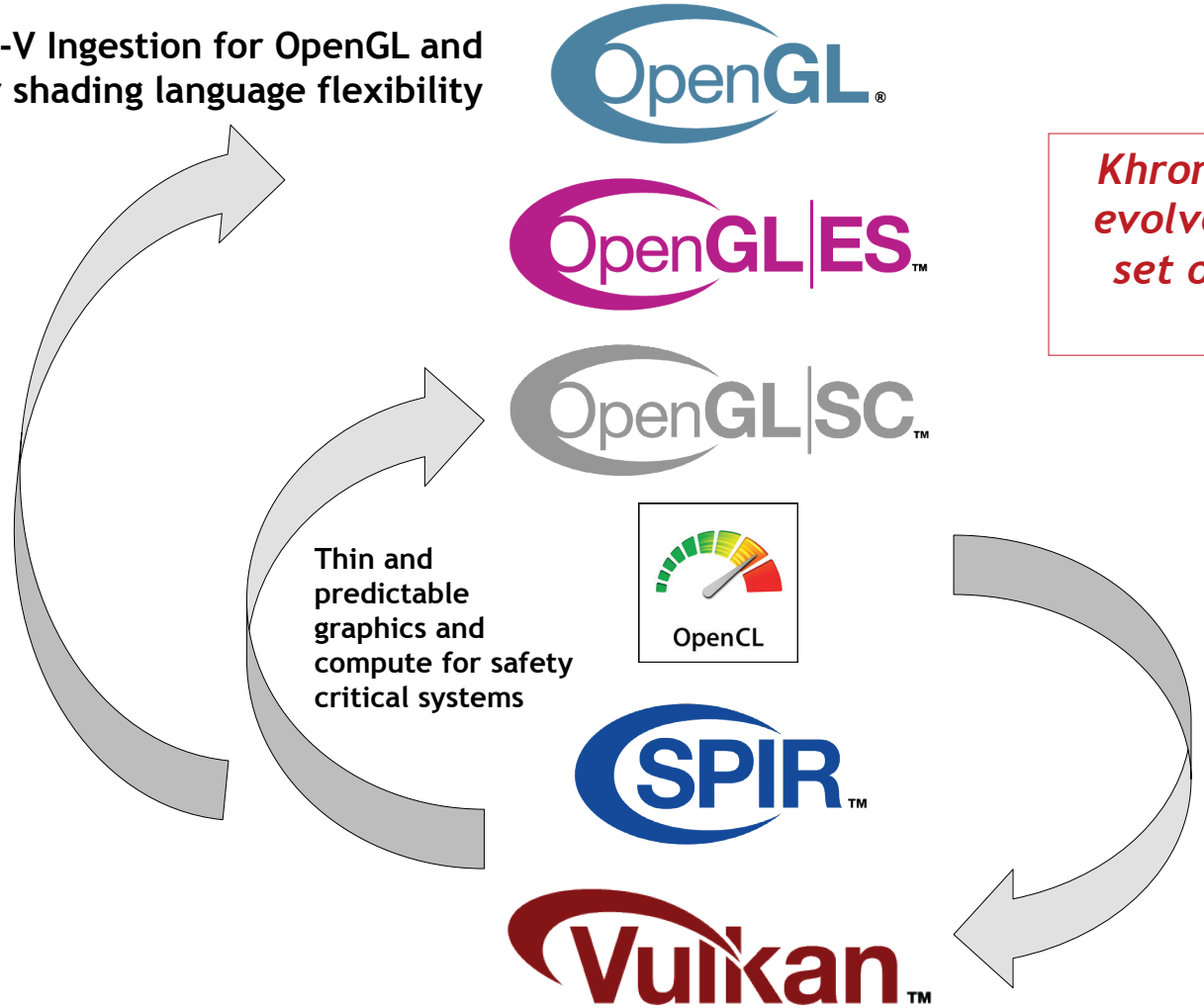
GDC

Khronos Vulkan sessions co-located with GDC

Time	Descripton	View Session	Register
Wednesday, March 16th 9:00am – 10:00am	Jon Peddie Research Press Sessions	View	
Wednesday, March 16th 12:00pm – 1:00pm	WebGL + glTF: Mobile Graphics	View	Register
Wednesday, March 16th 1:00pm – 2:00pm	Khronos Chapters Lunch	View	Register
Wednesday, March 16th 2:00pm – 7:00pm	Vulkan: The API for Graphics & Compute	View	Register
Wednesday, March 16th 7:00pm – 9:30pm	Khronos Evening Social	View	Register

Khronos Roadmap Discussions

SPIR-V Ingestion for OpenGL and OpenGL ES for shading language flexibility

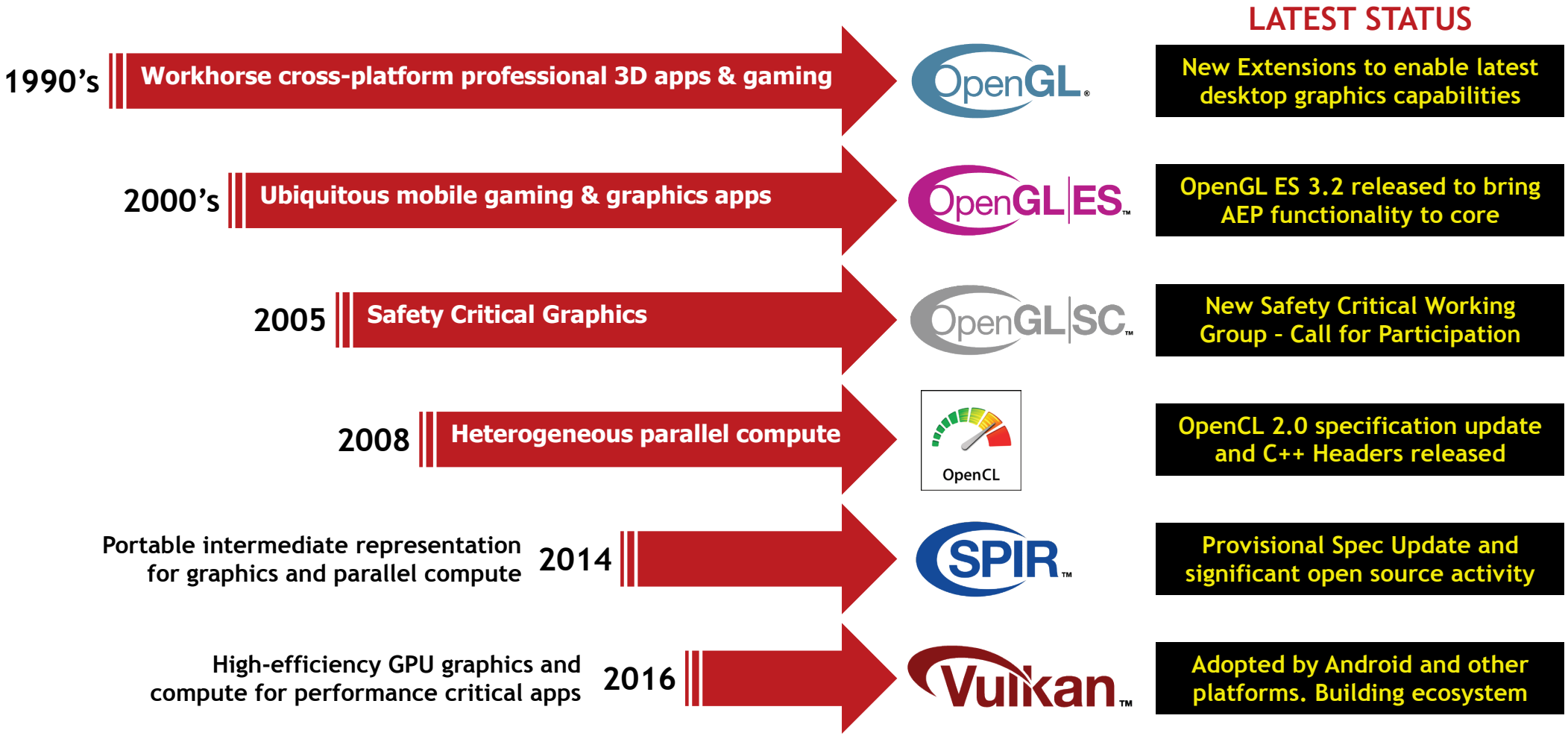


Thin and predictable graphics and compute for safety critical systems

Khronos members decide how to evolve and mix and match a rich set of APIs and technologies to meet market needs

OpenCL-class Heterogeneous Compute to Vulkan runtime:
- C++ Shading Language
- Tiered precision
- Shared virtual memory
- Dynamic parallelism…

Khronos Open Standards for Graphics and Compute



KHRONOS GROUP