Graphics and Compute Belong Together

GDC, March 2015

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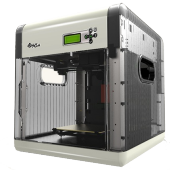
The Need for Vulkan

Ground-up design of a modern open standard API for driving high-efficiency graphics and compute on GPUs used across diverse devices

Vulkan™



In the twenty two years since OpenGL was invented - the architecture of GPUs and platforms has changed radically

GPUs being used for graphics, compute and vision processing on a rapidly *increasing* diversity of platforms - *increasing* the need for cross-platform standards

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Vulkan Explicit GPU Control

Complex drivers lead to driver overhead and cross vendor unpredictability

Error management is always active

Driver processes full shading language source

Separate APIs for desktop and mobile markets

Application	Application responsible for memory allocation and thread management to generate command buffers
Traditional graphics drivers include significant context, memory and error management	Direct GPU Control
GPU	GPU

Simpler drivers for low-overhead efficiency and cross vendor portability

Layered architecture so validation and debug layers can be unloaded when not needed

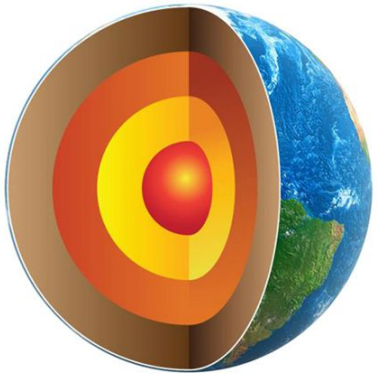
Run-time only has to ingest SPIR-V intermediate language

Unified API for mobile, desktop, console and embedded platforms

Vulkan delivers the maximized performance and cross platform portability needed by sophisticated engines, middleware and apps

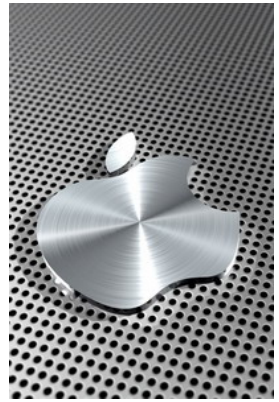
Cross Platform Challenge

- An explicit API that is also cross-platform needs careful design



One family of GPUs

One OS



One GPU on one OS

Vulkan™

All Modern Platforms and GPUs

A challenge that needs...

Participation of key players

Proven IP Framework

Battle-tested cooperative model

The *drive* to not let the 3D industry fragment

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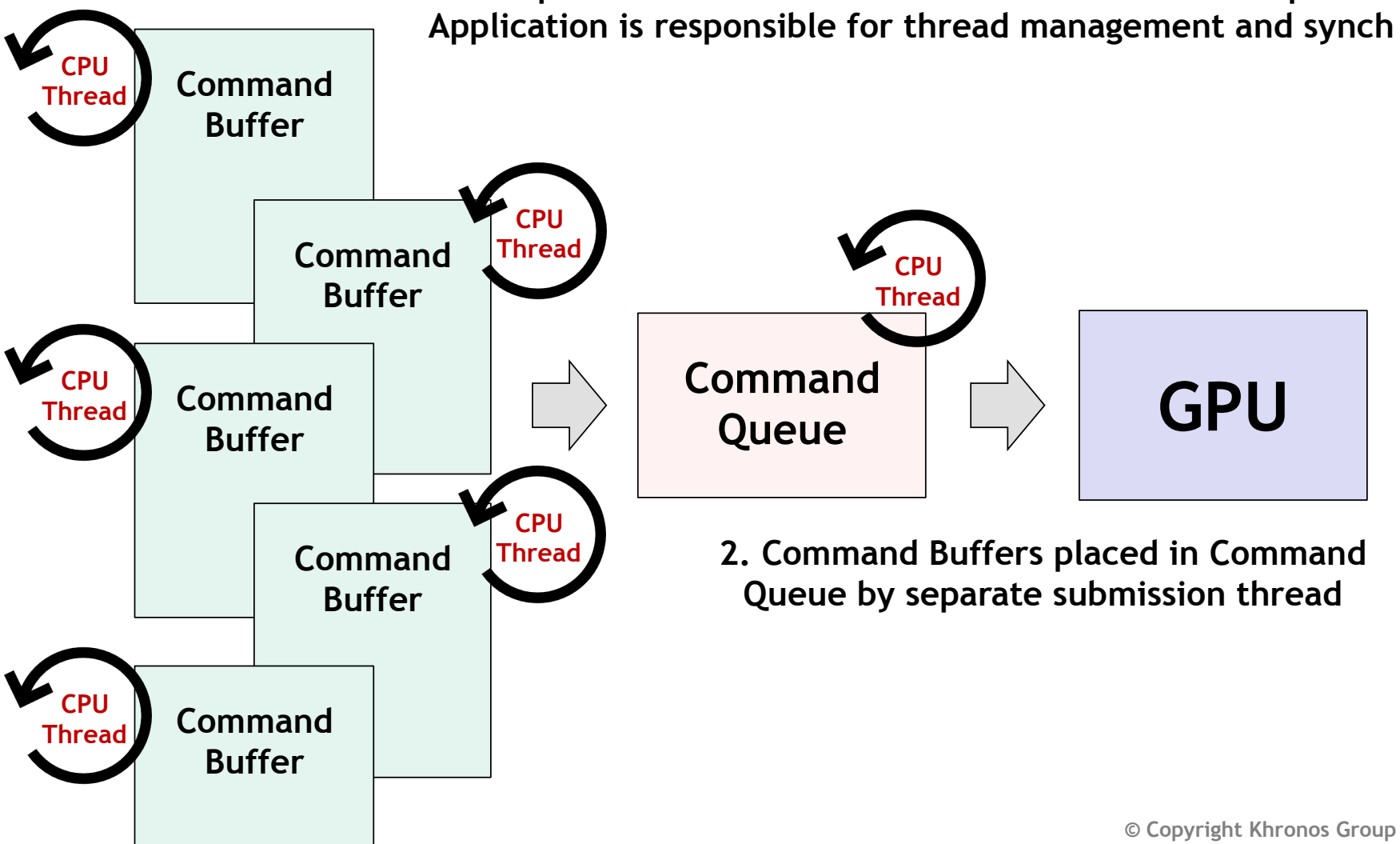
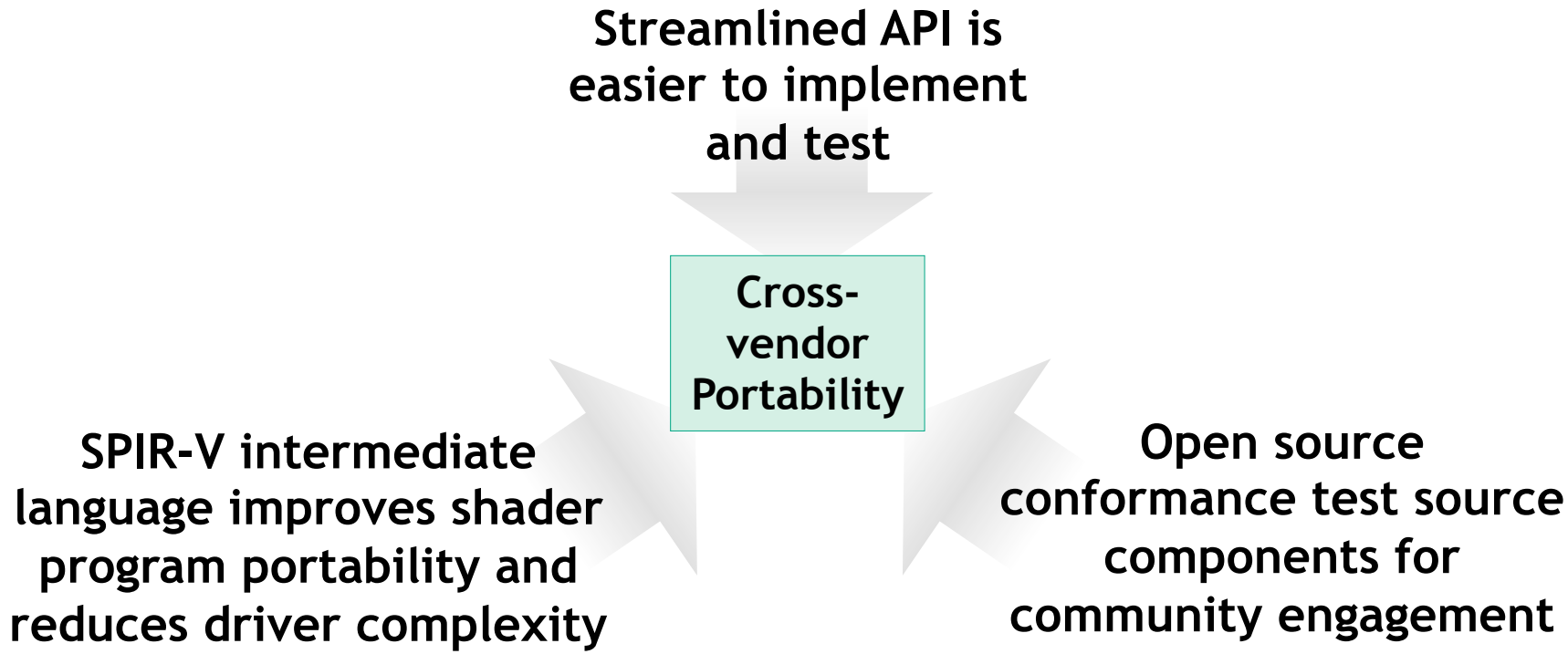
Vulkan Multi-threading Efficiency

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



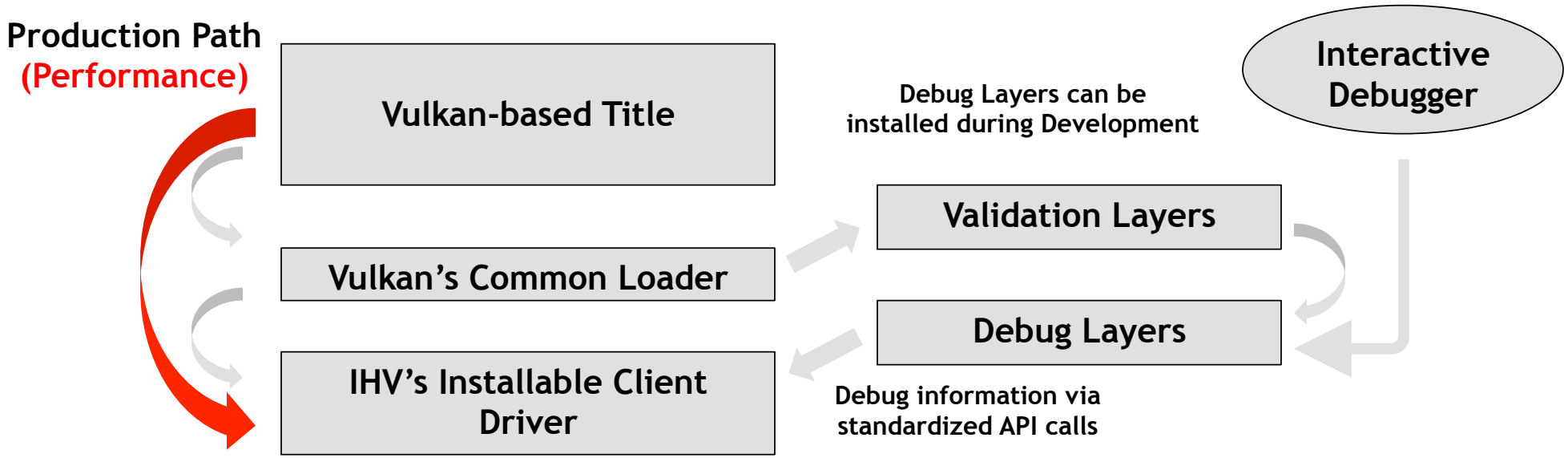
2. Command Buffers placed in Command Queue by separate submission thread

Vulkan - Enhancing Driver Reliability



Vulkan Tools Architecture

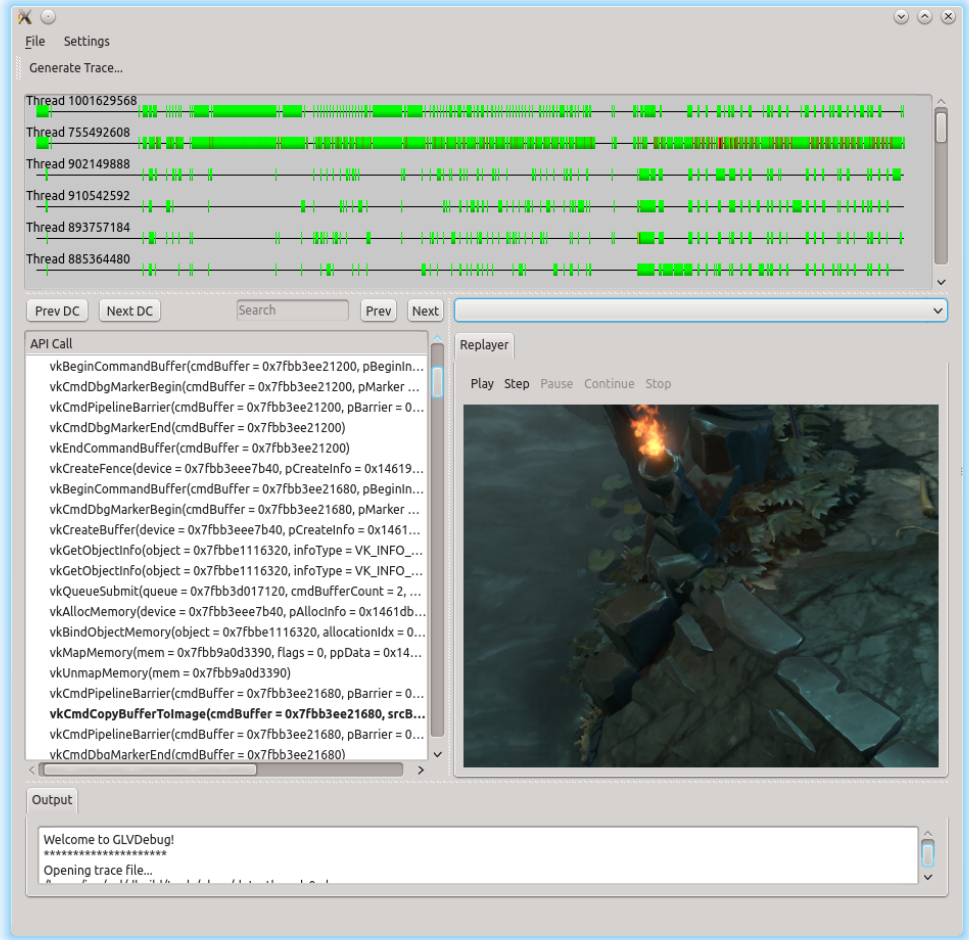
- **Layered design for cross-vendor tools innovation and flexibility**
  - IHVs plug into a common, extensible architecture for code validation, debugging and profiling during development without impacting production performance
- **Common Loader used to enable use of tools layers during debug**
  - Cross-vendor API calls provide debug data



Vulkan Tools Ecosystem

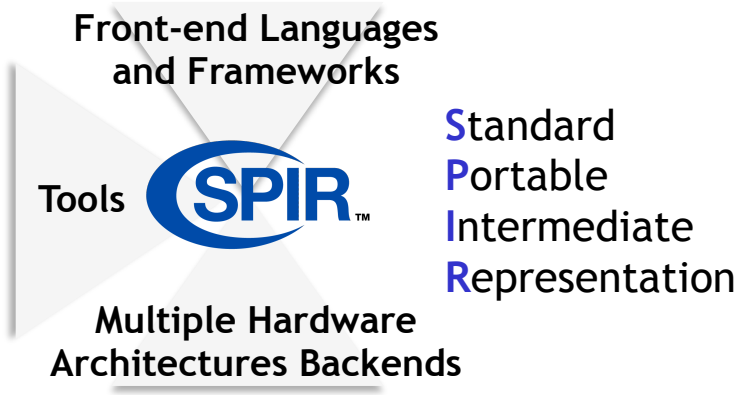
- Extensible modular architecture encourages many fine-grained layers - new layers can be added easily
- Khronos encouraging open community of tools e.g. shader debugging
- Valve, LunarG, Codeplay and others are already driving the development of open source Vulkan tools
- Customized interactive debugging and validation layers will be available together with first drivers

Prototype Vulkan Debugger from Valve and LunarG



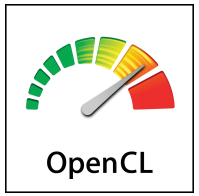
SPIR-V Unleashes Language Innovation

- **First open standard cross-API intermediate language for parallel compute and graphics**
  - Can natively represent Vulkan and OpenCL source languages
  - Including full flow control, graphics and parallel constructs not in LLVM
- **Fully specified Khronos-defined standard**
  - Khronos is working on creating SPIR-V <-> LLVM conversion tools
- **Splitting the Compiler Chain enables parallel software/hardware innovation**
  - Front-ends for languages can access multiple production quality backends
  - Back-ends using multicore, GPU, vector, VLIW or other technologies can reuse production quality language frontends and abstractions
  - Tooling – encourages innovation in advanced program analysis and optimization of programs in SPIR form



SPIR-V for Developers

- **Developers can use same front-end compiler across multiple platforms**
  - Eliminating major source of cross-vendor portability
- **Reduces runtime shader compilation time**
  - Driver only has to process SPIR-V not full source language
- **Don't have to ship shader source code**
  - Provides a measure of IP protection
- **SPIR-V is core in OpenCL 2.1 AND Vulkan**
  - Exposes machine model for OpenCL 1.2, 2.0, 2.1 and Vulkan
  - Supports OpenCL 1.2, 2.0, 2.1 kernel languages
  - Supports GLSL shader language (under development)



SIGNIFICANT OPPORTUNITY TO LEVERAGE AND CONVERGE LANGUAGES FOR GRAPHICS AND COMPUTE

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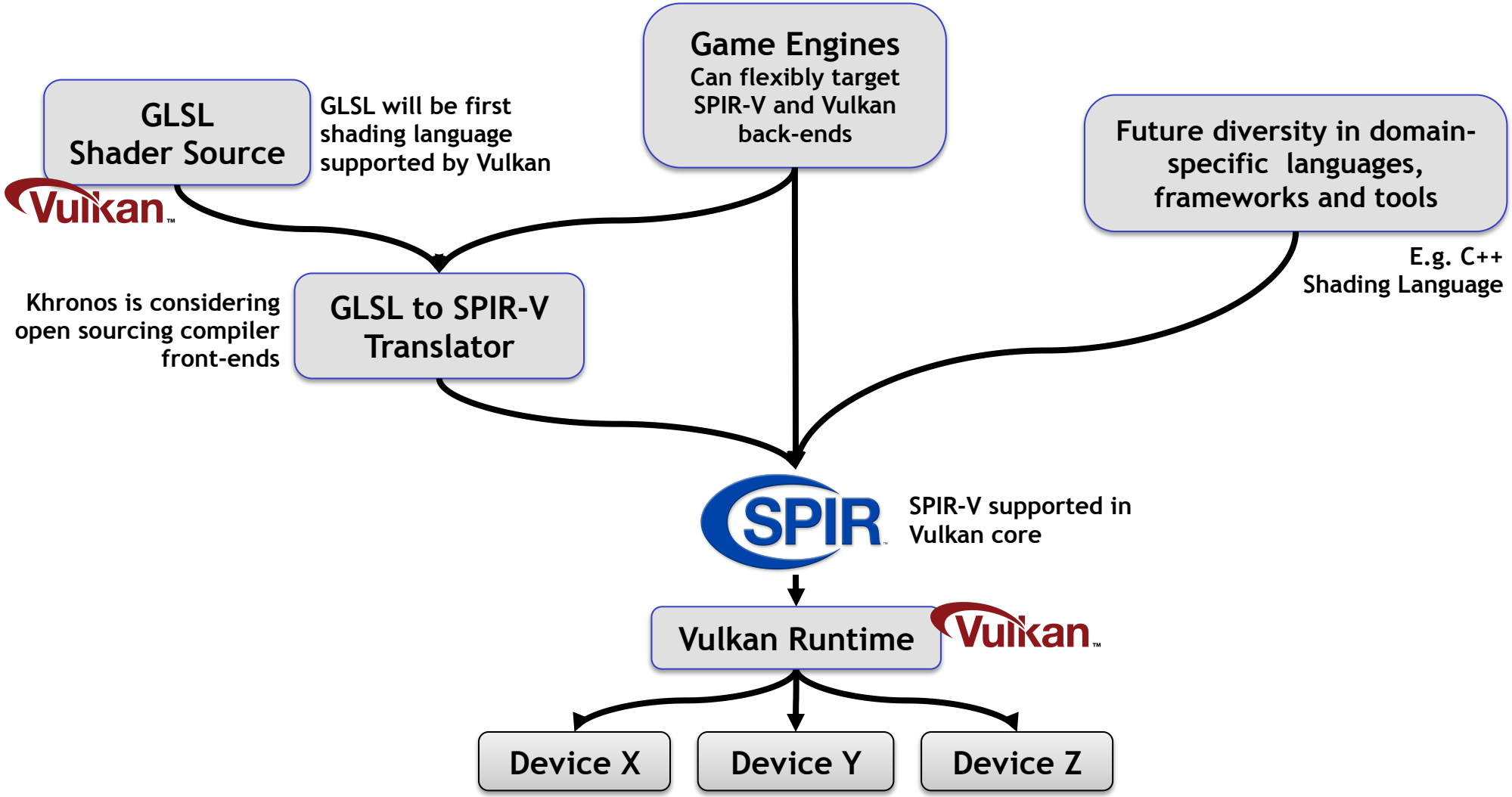
Vulkan Language Ecosystem



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Ground-up Explicit API Redesign

OpenGL	Vulkan
Originally architected for graphics workstations with direct renderers and split memory	Matches architecture of modern platforms including mobile platforms with unified memory, tiled rendering
Driver does lots of work: state validation, dependency tracking, error checking. Limits and randomizes performance	Explicit API – the application has direct, predictable control over the operation of the GPU
Threading model doesn't enable generation of graphics commands in parallel to command execution	Multi-core friendly with multiple command buffers that can be created in parallel
Syntax evolved over twenty years – complex API choices can obscure optimal performance path	Removing legacy requirements simplifies API design, reduces specification size and enables clear usage guidance
Shader language compiler built into driver. Only GLSL supported. Have to ship shader source	SPIR-V as compiler target simplifies driver and enables front-end language flexibility and reliability
Despite conformance testing developers must often handle implementation variability between vendors	Simpler API, common language front-ends, more rigorous testing increase cross vendor functional/performance portability

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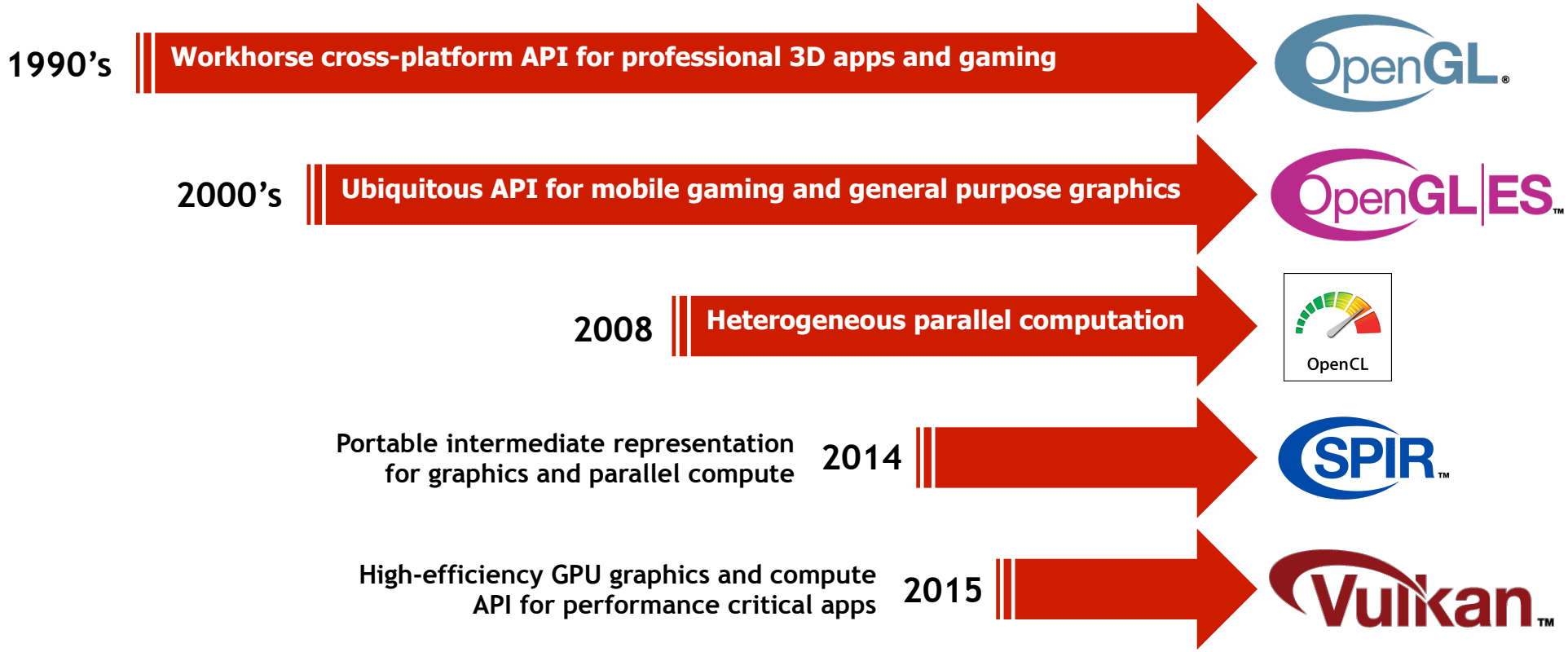
Vulkan Status

- **Rapid progress since June 2014**
  - Significant proposals and IP contributions received from members
- **Participants come from all segments of the graphics industry**
  - Including an unprecedented level of participation from game engine ISVs
- **Initial specs and implementations expected this year**
  - Will work on any platform that supports OpenGL ES 3.1 and up

Working Group Participants

Khronos Open Standards for Graphics and Compute

A comprehensive family of APIs to address the full spectrum of developer requirements



All APIs will be evolved and maintained to meet industry needs.
Rich mix of open technologies for future innovation

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