Portable VR and AR Applications using OpenXR and Vulkan
Yokohama, September 2019

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Khronos is an open, member-driven industry consortium developing royalty-free standards, and vibrant ecosystems, to harness the power of silicon acceleration for demanding graphics rendering and computationally intensive applications.

Khronos members are industry leaders from around the world that join to safely cooperate - to advance their own businesses and the industry as a whole.

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Active Khronos Standards

3D Commerce Working Group
Announced at SIGGRAPH, July 2019!
XR = AR + VR

Cross-platform, high-performance access to AR and VR platforms and devices

Virtual Reality

Augmented Reality
OpenXR - Solving XR Fragmentation

Before OpenXR
XR Market Fragmentation

After OpenXR
Wide interoperability of XR apps and devices

* OpenXR 1.0 is focused on enabling cross-platform applications. Optional device plugin interface will be supported post V1.0
** Check OpenXR Landing Page for exact availability of OpenXR in shipping run-times and devices www.khronos.org/openxr
Companies Publicly Supporting OpenXR

OpenXR is a collaborative design
Integrating many lessons from proprietary ‘first-generation’ XR API designs
OpenXR 1.0 Released July 2019!

Significant community feedback - thank you!
Improved OpenXR input subsystem, game engine editor support, loader ...

Provisional Specification
GDC, March 2019

Ratify and Release OpenXR 1.0 Specification
SIGGRAPH, July 2019

Finalize Conformance Test Suite
Enable Officially Conformant Implementations

OpenXR runtime for Windows Mixed Reality headsets
and HoloLens 2 from Microsoft shipping TODAY
PLUS extensions to support HoloLens 2 hand tracking, eye tracking, spatial mapping and spatial anchors by end of year

OpenXR support for Oculus Rift and Oculus Quest
Coming soon

‘Monado’ OpenXR open source implementation from Collabora shipping TODAY

OpenXR 1.0 plugin for Unreal Engine 4.23
Starting with preview 4

Many more coming
OpenXR Win-Win-Win

**XR Vendors**
Can bring more applications onto their platform by leveraging the OpenXR content ecosystem

**XR ISVs**
Can easily ship on more platforms for increased market reach

**XR End-Users**
Can run the apps they want on their system - reducing market confusion and increasing consumer confidence
Khronos APIs for XR

Application or Engine

High-performance, low-latency 3D rendering and composition*
  Multiview
  Context priority
  Front buffer rendering
  Tiled rendering (beam racing)
  Variable rate rendering

Display, composition and optical correction parameters

Cross-platform access to XR
  HMDs and sensors
  XR application lifecycle
  Input device discovery and events
  Sensor tracking and pose calculation
  Frame timing and display composition
  Haptics Control

* OpenXR can be used with other 3D APIs such as Direct3D, OpenGL and OpenGL ES

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Bringing XR to the Web

Native XR Apps

Web XR Apps

Future versions of OpenXR will include cross-platform extended AR functionality

3D Engines

System-exposed AR Capabilities

Close ongoing collaboration between WebXR and OpenXR

Khronos providing the foundation for 3D and XR in the Web and native stacks

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XR and 5G
Leveraging High Bandwidth and Low Latency

MEC (Multi-access Edge Computing) Server
1. Processes sensor data, including machine learning for environmental lighting, occlusion, scene semantics, object reconstruction and UI
2. Generates imagery from 3D models, including stereo, foveal rendering, ray-tracing, optics pre-distortion, varifocal processing

Wireless mobile device with display and sensors

OpenXR APIs can hide the 5G round trip from applications

OpenXR
Display composition

5G
Rich Sensor Data

Location-aware Content Requests

Apps and VMs
NVIDIA Quadro Driver
RTX vGPUs
NVIDIA Virtualization SW
Hypervisor
NVIDIA RTX GPU
RTX Server

Any needed assets loaded from the cloud to edge server

Generated Augmentations & Scenes

OpenXR
Sensor handling

Image: Nreal
Vulkan: Performance, Predictability, Portability

Complex drivers cause overhead and inconsistent behavior across vendors.
Always active error handling.
Full GLSL preprocessor and compiler in driver.
OpenGL vs. OpenGL ES.

Application
Single thread per context

High-level Driver Abstraction
Layered GPU Control
Context management
Memory allocation
Full GLSL compiler
Error detection

GPU
A Graphics API

Vulkan

Application
Memory allocation
Thread management
Explicit Synchronization
Multi-threaded generation of command buffers

Multiple Front-end Compilers
GLSL, HLSL etc.

Thin Driver
Explicit GPU Control

GPU
A GPU API

Simpler drivers - application has the best knowledge for holistic optimization - no 'driver magic'.
Explicit creation of API objects before usage - efficient, predictable execution.
Easier portability - no fighting with different vendor heuristics.
Validation and debug layers loaded only when needed.
SPIR-V intermediate language: shading language flexibility.
Unified API across mobile and desktop platforms.
Multiple graphics, command and DMA queues.

OpenGL vs. OpenGL ES
Simpler drivers - application has the best knowledge for holistic optimization - no ‘driver magic’.
Pervasive Vulkan

Major GPU Companies supporting Vulkan for Desktop and Mobile Platforms

Platforms

- Desktop
- Android (Android 7.0+)
  (Vulkan 1.1 required on Android Q)
- Apple (via porting layers)
- Media Players
- Consoles
- Virtual Reality
- Cloud Services
- Game Streaming
- Embedded

Game Engines

- Epic Games
- CryEngine
- Unity
- Valve
- Croteam
- Serious Engine
- Xenko
- NetEase Games
Vulkan AAA Content Shipping on Desktop...

Vulkan-only AAA Titles on PC

AAA titles on Linux

Titles on PC AND macOS
...and Mobile

Lineage 2 Revolution
Heroes of Incredible Tales
Dream League Soccer...
Vulkan 1.1 Ecosystem Evolution

**Strengthening Tools and Compilers**
- Improved developer tools (SDK, validation/debug layers)
- Shader toolchain improvements (size, speed, robustness)
- Shading language flexibility - HLSL and OpenCL C support
  - More rigorous conformance testing

**Vulkan 1.0 Extensions**
- Maintenance updates plus additional functionality
  - Multiview
  - Multi-GPU
- Enhanced Windows System Integration
- Increased Shader Flexibility:
  - 16-bit storage, Variable Pointers
  - Enhanced Cross-Process and Cross-API Sharing

February 2016
Vulkan 1.0

**Vulkan 1.1**
March 2018
Integration of 1.0 Extensions
- plus new functionality
  - e.g. Subgroup Operations

**Widening Platform Support**
- Pervasive GPU vendor native driver availability
  - Open source drivers - ANV (Intel), AMDVLK/RADV (AMD)
- Vulkan Portability to macOS/iOS and DX12

**Building Vulkan’s Future**
- Listen and prioritize developer needs
  - Drive GPU technology

**Released Vulkan 1.1 Extensions**
- Reduced precision arithmetic types in shaders
  - Bindless resources
- HLSL-compatible memory layouts
- Formal memory model
- Buffer references
- OpenGL-class lines and Interop

[https://www.khronos.org/registry/vulkan/specs/1.1-khr-extensions/html/vkspec.html#extension-appendices-list](https://www.khronos.org/registry/vulkan/specs/1.1-khr-extensions/html/vkspec.html#extension-appendices-list)

**Roadmap Discussions**
- Timeline semaphores
- Machine Learning acceleration
- Ray Tracing
- Video encode / decode
- Generalized subgroup operations

**Integration of 1.0 Extensions**
- plus new functionality
  - e.g. Subgroup Operations
Vulkan SDK - Free to Download

- Open source Vulkan application developer tools
  - Available since Vulkan 1.0 launch
- LunarG recently donated the SDK packaging technologies to Khronos
  - Enables Vulkan WG collaboration
- Windows, Linux - Ubuntu packages, Linux- Tarball, macOS
  - [www.vulkan.lunarg.com](http://www.vulkan.lunarg.com)
SPIR-V Ecosystem

SPIR-V (Dis)Assembler

Third party kernel and shader languages

GLSL

HLSL

SPIRV-Cross

SPIRV-Opt | SPIRV-remap

Optimization Tools

GLSL

HLSL

glslang

DXC

SPIR-V Validator

SPIR-V

Khronos-defined cross-API IR
Native graphics and parallel compute support
Easily parsed/extended 32-bit stream
Data object/control flow retained for effective code generation/translation

OpenCL C Front-end

OpenCL C++ Front-end

SPIR-V Magic #: 0x07230203
SPIR-V Version 99
Builder's Magic #: 0x051a09BB
<id> bound is 50
0
OpMemoryModel Logical
GLSL450
OpEntryPoint Fragment shader function <id> is 4
OpTypeVoid <id> is 2
OpTypeFunction <id> is 3
return type <id> is 3
OpFunction
Result Type <id> is 2
Result <id> is 4
0
Function Type <id> is 3

SPIR-V (Dis)Assembler

LLVM to SPIR-V

Bi-directional Translators

clspv

LLVM

SYCL for ISO C++ Front-end

C++ for OpenCL in clang Front-end

Khronos cooperating with clang/LLVM Community

3rd Party-hosted Open Source Projects

Khronos-hosted Open Source Projects

3rd Party-hosted Open Source Projects

https://github.com/KhronosGroup/SPIRV-Tools

Environment spec for each target API used to drive compilation
Deploying OpenCL C Over Vulkan

- **Clspv** - Google’s experimental compiler for OpenCL C to Vulkan SPIR-V
  - Open source - tracks top-of-tree LLVM and clang, not a fork

- Adobe Premiere Rush has 200K lines of OpenCL C kernel code
  - Professional-quality, cross-platform video capture and editing system
  - Now shipping on Android on Vulkan

Prototype open source project
https://github.com/google/clspv

Prototype open source project
https://github.com/kpet/clvk
Vulkan Portability Initiative on Apple

Almost all mandatory Vulkan 1.0 functionality is supported:
- No Triangle Fans
- No separate stencil reference masks

Selected Optional Features and Extensions are added as required - driven by industry input and feedback
- Robust buffer access
- BC texture compressed formats
- Fragment shader atomics
- Tessellation

https://github.com/KhronosGroup/MoltenVK

Khronos and MoltenVK/gfx-rs working on passing Vulkan Conformance Testing for all implemented functionality

SPIRV-Cross
Convert SPIR-V shaders to Metal Shaders

macOS / iOS Run-time
Maps Vulkan to Metal

MoltenVK supports macOS 10.11 / iOS 9.0 and up

Open source SDK to build, run, and debug applications on macOS - including validation layer support
https://vulkan.lunarg.com/

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Open source for MacOS and iOS
Free to use - no fees or royalties including commercial apps

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Vulkan Apps Shipping On Apple

*Forsaken Remastered* was just updated with *Vulkan* support! If you’re on Linux, you’re probably hitting 60fps with the existing OpenGL renderer, but it’s good to be future proof. If you’re on a Mac, though, you *definitely* want to switch. On my MacBook, the framerate goes from around 15 to a solid 60!

**Production Dota 2 on Mac**
- Ships - up to 50% more perf than Apple’s OpenGL

**First iOS Apps using MoltenVK**
- ship through app store

**Qt Running on Mac through MoltenVK**

**Multiple iOS and macOS apps shipping e.g.**
- *Forsaken Remastered*

**Google Filament PBR Renderer on Mac**

**Initial ports of DX games in progress using Vulkan on Mac**

**RPCS3 PlayStation 3 Emulator on Mac**

**Artifact from Steam ships on MoltenVK on macOS - first Vulkan-only Valve app on Mac**

**Dolphin GameCube and Wii Emulator working on MacOS**

**Artifact from Steam ships on MoltenVK on macOS - second Vulkan-only Valve app on Mac**

**Diligent Engine runs on MacOS**

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June 2018

September 2018

November 2018

January 2019

June 2019

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Running DX Games on Linux Over Vulkan

- **DXVK** - Direct3D 10/11 emulator running over Vulkan
  - Open source on GitHub - developed by Philip Rebohle with support from Valve
- **Vulkan has added multiple extensions to support efficient layering of D3D**
  - Removing impedance mismatches between the two APIs
- **DXVK, Wine Windows Compatibility Layer and Valve Proton tool**
  - Enable thousands of PC games on Linux

Extensions created in response to DXVK issues
- VK_EXT_transform_feedback
- VK_EXT_depth_clip_enable
- VK_EXT_host_query_reset
- VK_EXT_texel_buffer_alignment
- VK_EXT_shader_demote_to_helper_invocation

Other extensions used by DXVK
- VK_EXT_conditional_rendering
- VK_EXT_memory_budget
- VK_EXT_memory_priority
- VK_EXT_shader_viewport_index_layer
- VK_EXT_vertex_attribute_divisor
- VK_KHR_draw_indirect_count
- VK_KHR_shader_draw_parameters

https://www.protondb.com
glTF - The JPEG of 3D!

- **Audio**: MP3
- **Video**: H.264
- **Images**: JPEG
- **3D**: glTF

**Efficient, reliable transmission**
- Compact to Transmit
- Simple and Fast to Load
- Describes Full Scenes
- Runtime Neutral
- Open and Extensible

**glTF 1.0 - December 2015**
- Primarily for WebGL
- Uses GLSL for materials

**glTF 2.0 - June 2017**
- Native AND Web APIs
- Physically Based Rendering
- Metallic-Roughness and Specular-Glossiness

**glTF spec development on open GitHub - get involved!**
https://github.com/KhronosGroup/glTF
Universal Textures for glTF

- Fragmentation of GPU texture formats is significant issue for developers
  - Binomial’s ‘Basis Universal’ technology enables JPEG-sized texture assets
  - Transcodable on-the-fly to natively supported compressed GPU formats

- glTF Universal Texture extension uses KTX2 subset as a flexible container
  - Precisely defined for consistent, cross-vendor generation and validation
  - Wide range of (un)(super)compressed texture formats used in Vulkan/DirectX/Metal
  - Supports streaming and full random access to MIP levels
  - Open source tools to create, transcode and upload to WebGL, OpenGL and Vulkan
  - [https://github.com/KhronosGroup/KTX-Software/tree/ktx2](https://github.com/KhronosGroup/KTX-Software/tree/ktx2)
Universal Textures: Compression Ratios

FlightHelmet_baseColor
2048 x 2048, RGB

<table>
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<th>Format</th>
<th>Uncompressed</th>
<th>PNG</th>
<th>JPEG</th>
<th>ETC1S</th>
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<td>315,619</td>
<td>2,097,152</td>
<td>232,104</td>
</tr>
<tr>
<td>GPU Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bytes
0 3,500,000 7,000,000 10,500,000 14,000,000
glTF Evolution

Extensions in Development
- Draco Mesh Compression
- Universal Compressed Textures
- Second generation PBR (absorption/attenuation, clear coat, subsurface scattering, anisotropy)
- Subdivision surfaces

Baseline of significant industry adoption

glTF 2.0 - June 2017
Native AND Web Apps
- Metallic-Roughness and Specular-Glossiness PBR

Topologies
- Advanced Animation
- LOD and Streaming
- Compressed Point Clouds
- Cross-asset linking
- Enhanced Metadata
- Composability
- Instancing
- CAD/BIM model support
- Encryption and security
- 3D Printing

Nexgen glTF
Version and timing not yet decided
Incorporate popular extensions (with fallbacks)

The glTF Roadmap is Driven by Developer Feedback
Join the GitHub Discussion!
https://github.com/KhronosGroup/glTF/issues/1442

Images from https://dassaultsystemes-technology.github.io/EnterprisePBRShadingModel/
The Opportunity

Retailers have been experimenting with 3D product representations on the Web, and in Virtual and Augmented Reality applications, to enable users to view and interact with products. The results have been exciting, but thus far **NOT ACTIONABLE at an INDUSTRIAL SCALE**

- Products don’t come with 3D data - and I can’t physically scan them all fast enough!
- CAD tools don’t let me easily generate the data I need for E Commerce!
- The green couch looks blue on some devices - lots of product returns are expensive!
- Many models on my e-commerce web-site first appear upside down! I have to hand tune everything!
- I wish I had high quality, realistic 3D models for virtual promotional photoshoots!
- Everyone defines their product data for sizes and colors differently - nothing is consistent!

IKEA catalog uses augmented reality to give a virtual preview of furniture in a room - August 2013
Khronos New Initiative Process

Proposal
March 2019
A group of companies including Google, Unity, IKEA, Wayfair and Target identify the need for industry cooperation and makes proposal to Khronos

Exploratory Group
March-July 2019
Khronos invites any company to join an Exploratory Group to drive industry consensus on what is the problem, and what how can we work together to fix it?

Working Group Announced
SIGGRAPH 2019
Detailed design work to execute SOW will start by Khronos Members
https://www.khronos.org/3dcommerce/

Initiative Proposal

Scope of Work

Broad Industry Participation
Over 70 retail AND technology companies creating an agreed Scope of Work

Open to any company under NDA, no membership fee or IP commitment

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Khronos 3D Commerce Working Group Goals

Create specifications and guidelines to align the 3D asset workflow from product design through manufacturing, through each stage of retail to end-user delivery platforms.

Guidelines for tools and product designers to create assets with consistent data to be used through the 3D Commerce pipeline.

Structured metadata for product management and configurability of viewing.

Visual realism and consistency no matter where the model is displayed.

Reduce production, distribution and marketing costs.

Product display configurability with consistency and authenticity.
3D Commerce Khronos Synergy

3D Asset Format

WebGL™

Interactive 3D on the Web

Khronos 3D Commerce

Portable AR and VR Apps

High-performance cross-platform 3D graphics

Vision processing and inferencing for AR and scanning
The Value of Khronos Participation

Gain early insights into industry trends and directions

Influence the design and direction of key open standards that will drive your business

Accelerate your time-to-market with early access to specification drafts

Gather industry requirements for future open standards

Draft Specifications Confidential to Khronos members

Publicly Release Specifications and Conformance Tests

Network with domain experts from diverse companies in your industry

State-of-the-art IP Framework protects your Intellectual Property

Enhance your company reputation as an industry leader through Khronos outreach

Khronos membership is open to any company for access to all standardization initiatives
Annual membership fees start at $3,500 for smaller companies

https://www.khronos.org/members/
Thank You and Resources

- Khronos is creating cutting-edge royalty-free open standards
  - For gaming and AR/VR - native and on the Web
  - www.khronos.org

- Khronos encourages your participation
  - We welcome members from Japan and Asia

- Dedicated developer resources
  - Khronos Developer Forum: https://community.khronos.org/
  - Khronos Developer Slack Channel: www.khr.io/slack

- We are happy to help answer any questions!
  - Neil Trevett, Khronos President: ntrevett@nvidia.com, @neilt3d
  - Hitoshi Kasai; Khronos Japan: kasai@miacis.com
  - Khronos Developer Relations, Kris Rose: kris@khronos.org, @kristoferrose