Vulkanised 2024

The 6th Vulkan Developer Conference
Sunnyvale, California | February 5-7, 2024

Vulkan Update

Tom Olson, Arm
Vulkan Working Group Chair

Some thoughts about Vulkan in 2024

KHRONOS® GROUP

I’m so glad I don’t need this slide…

What is Vulkan?

A modern graphics and compute API for programming GPUs
- Focus on real-time / high performance applications, especially games
- Focus on cross-platform portability

Design principles
- Explicit control - no driver magic
- Trust the developer

Programmer responsibilities
- Dependency tracking
- Synchronization
- Memory and object lifetime management
- *Optimization!*
- *Writing correct code!*

Maybe Vulkan is growing up?

Budget of about $1.3M / yr for Khronos operations

- Much more than that in member companies

About 40 people on our weekly development call

- Ten elected officers, 5-6 meetings a week
- Well-defined workflows for development and release

Tens of thousands of developers, and a complex ecosystem

- A lot of people are depending on us to get it right
- We take this very seriously. Challenge accepted.
- We need your input

We have plenty of challenges

Fragmentation

- A huge problem for developers
- Drives much of our strategic thinking
- Profiles, Roadmap, etc

High level language ecosystem

- In theory, we don’t care…
- But in practice we have to
- Ecosystem split between GLSL and HLSL
- Glad to see lots of language talks here at Vulkanised!

Outline

Some thoughts about Vulkan in 2024

Vulkan profiles and the roadmap

What's new?

- Vulkan Roadmap 2024
- New features in the API
- Adoption and applications
- Developer support

Vulkan Profiles (again)

Vulkan is caps-intensive

Implementations can differ in many, many ways

- Core version: 1.0, 1.1., 1.2, 1.3
- Extensions:
- Capabilities:
- Properties: how many render targets? How big can they be? …
- Formats: What pixel formats can I use? Which can I sample? Which can I render to?
- And so on…

Result

Very hard to write portable code.

- Unfortunately, it has to be this way…

The good news

- Feature support isn’t completely random!
- De facto standards exist for specific markets

Leads to the idea of profiles

Vulkan Profiles

Minimum capabilities across a set of Vulkan implementations

- Core version
- List of additional requirements for feature, property, and format support
- List of required extensions

Vulkan Profiles

Minimum capabilities across a set of Vulkan implementations

- Core version
- List of additional requirements for feature, property, and format support
- List of required extensions

External to the Vulkan specification

- Spec doesn’t know about them
- Vulkan drivers do not know what profiles they support
- You can write new profiles to describe old hardware.

Vulkan Profile Specification

JSON schema

- Machine-readable

Enables code generation

- Support queries
- Device creation
- Set operations
- …

```
"capabilities": {
    "baseline": {
        "extensions": {
            "VK_KHR_surface": 1,
            "VK_KHR_android_surface": 1,
            "VK_KHR_swapchain": 1,
            "VK_KHR_get_physical_device_properties2": 1,
            "VK_KHR_maintenance1": 1,
            ....
        },
        "features": {
            "VkPhysicalDeviceFeatures": {
                "depthBiasClamp": true,
                "fragmentStoresAndAtomics": true,
                "fullDrawIndexUint32": true,
                "imageCubeArray": true,
                "independentBlend": true,
                "robustBufferAccess": true,
                ....
            },
            "VkPhysicalDeviceMultiviewFeatures": {
                "multiview": true
            },
            ...
        },
        "properties": {
            "VkPhysicalDeviceProperties": {
                "limits": {
                    "maxImageDimension1D": 4096,
```

Why Profiles are Awesome

Why Profiles are Awesome

It’s like having your own personal Vulkan spec

- All your favorite extensions and features are supported

Why Profiles are Awesome

It’s like having your own personal Vulkan spec

- All your favorite extensions and features are supported

No driver update required!

- You can start using it today

Why Profiles are Awesome

It’s like having your own personal Vulkan spec

- All your favorite extensions and features are supported

No driver update required!

- You can start using it today

No code changes required!

- (almost)

For example

Say you're writing an Android game…

- Targeting 3-4 years of devices, 4 GPU vendors, 12 handset OEMS
- Capability management is going to be fun!

Suppose Google says

- "if you target *this* profile, you'll reach 90% of devices"
- Seems like a win!

For example

Say you're writing an Android game…

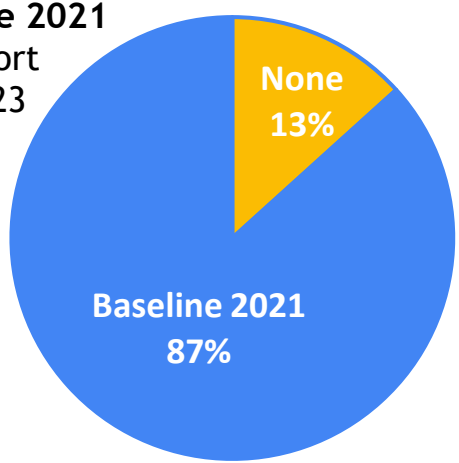
- Targeting 3-4 years of devices, 4 GPU vendors, 12 handset OEMS
- Capability management is going to be fun!

Suppose Google says

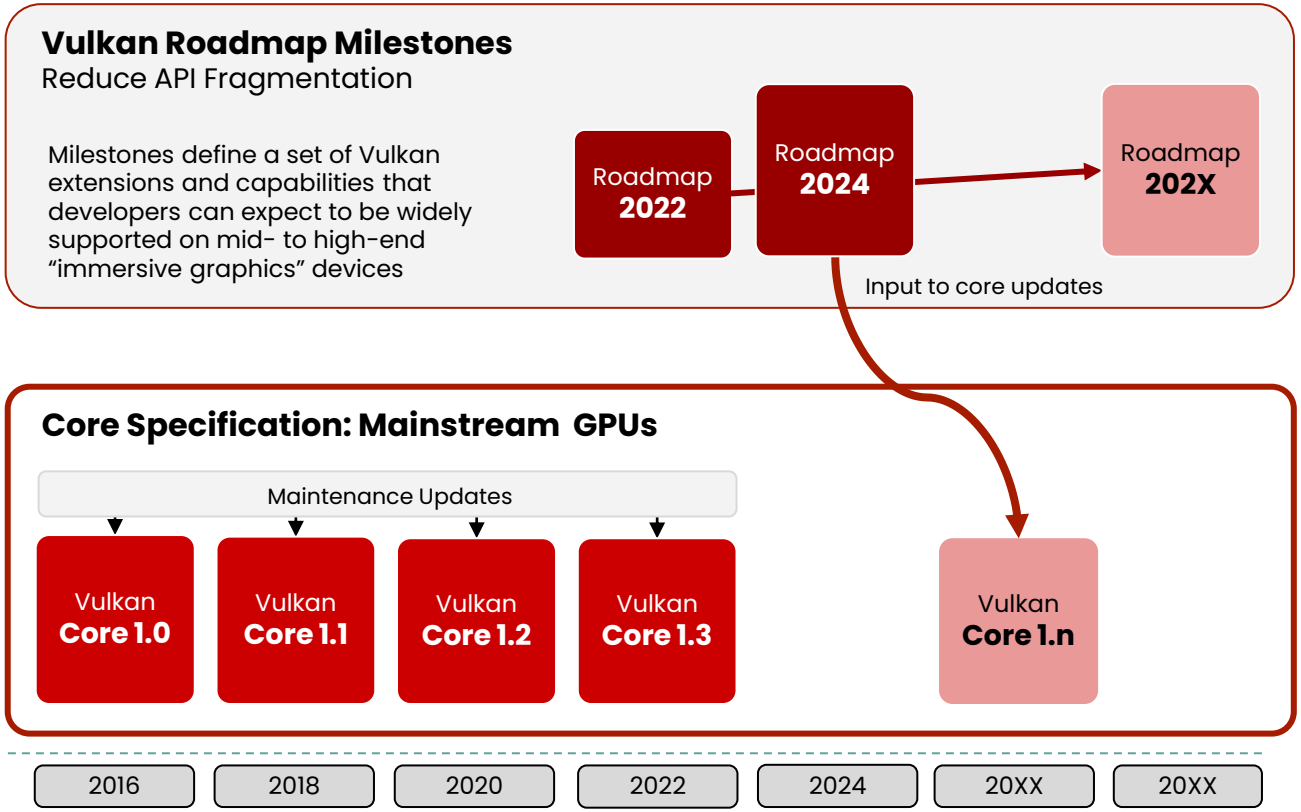
- "if you target *this* profile, you'll reach 90% of devices"
- Seems like a win!

They already have…

Android Baseline 2021
Profile Support
January 2023

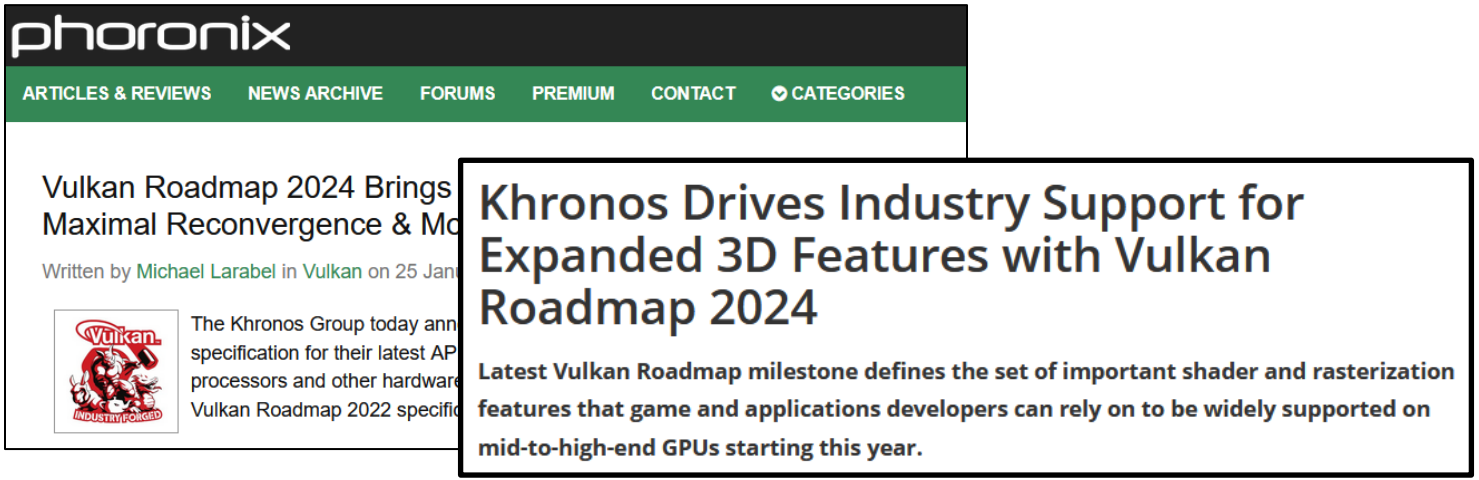


Vulkan Roadmaps



What's new: API

Vulkan Roadmap 2024



Second milestone on the Vulkan Roadmap

- Expressed as a profile, but forward looking
- Captures expected feature set for “immersive graphics” 2024-2026+

Vulkan Roadmap 2024 requirements

Vulkan 1.3 with Vulkan Roadmap 2022 profile

Implementation minima

- maxBoundDescriptorSets >= 7
- maxColorAttachments >= 8

Previously optional features and limits

- multiDrawIndirect
- shaderDrawParameters
- shaderImageGatherExtended
- shaderInt8, shaderInt16, shaderFloat16
- storageBuffer8BitAccess, storageBuffer16BitAccess
- shaderRoundModeRTEFloat16/32

Roadmap 2024 required extensions

Older extensions

- VK_KHR_push_descriptor (2019)
- VK_KHR_subgroup_uniform_control_flow (2020)
- VK_KHR_map_memory2 (March 23)
- VK_KHR_maintenance5 (July 23)

Extensions newly promoted from EXT

- VK_KHR_index_type_uint8 (newly promoted from EXT)
- VK_KHR_line_rasterization (newly promoted from EXT)
- VK_KHR_load_store_op_none (newly promoted from EXT)
- VK_KHR_vertex_attribute_divisor (Dec 2023 promoted from EXT*)

New extensions in Roadmap 2024

VK_KHR_shader_expect_assume

- Compiler hints

VK_KHR_shader_subgroup_rotate

- A handy special case of general permutation

VK_KHR_shader_float_controls2

- Gives Vulkan parity with OpenCL
- Fine-grained control of floating point behavior
- Applies to many more instructions

New extensions in Roadmap 2024

VK_KHR_maximal_reconvergence / VK_KHR_shader_quad_control

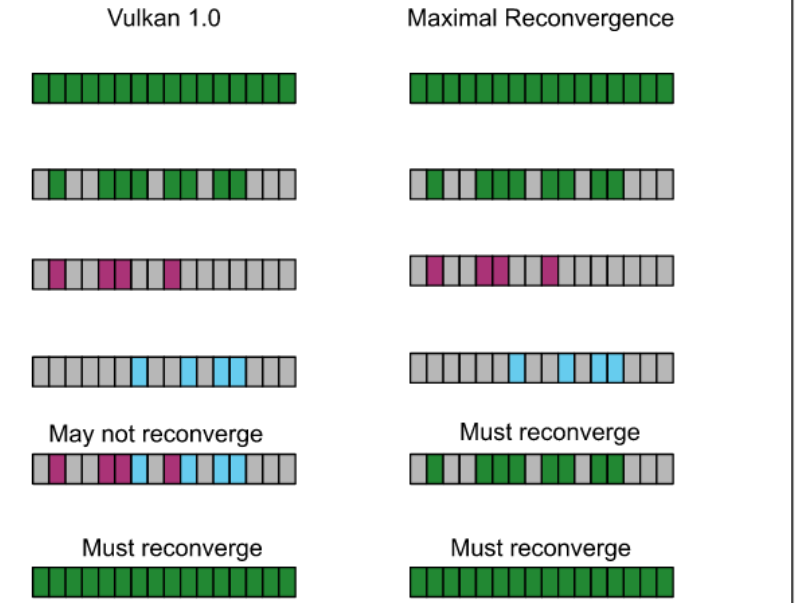
```
if (non_uniform_cond1) {
  // Block A

  if (non_uniform_cond2) {
    // A then

  } else {
    // A else

  }
  // Block B

}
```



See Alan Baker's blog: https://www.khronos.org/blog/khronos-releases-maximal-reconvergence-and-quad-control-extensions-for-vulkan-and-spir-v

New extensions in Roadmap 2024

VK_KHR_dynamic_rendering_local_read

- Allows pipeline barriers within dynamic rendering
- Must include VK_DEPENDENCY_BY_REGION_BIT
- Allows a later fragment shader to read data written by previous fragments
- With VK_KHR_rasterization_order_attachment_access, gives you the functionality of “framebuffer fetch” in dynamic rendering

Blog posts

- https://www.khronos.org/blog/streamlining-subpasses
- https://community.arm.com/arm-community-blogs/b/graphics-gaming-and-vr-blog/posts/framebuffer-fetch-in-vulkan

Other New Extensions

Vulkan Video
VK_KHR_video_encode_queue
VK_KHR_video_encode_h264
VK_KHR_video_encode_h265
VK_KHR_video_maintenance1
VK_KHR_video_decode_av1

Programming model improvements
VK_EXT_attachment_feedback_loop_dynamic_state
VK_EXT_host_image_copy

Maintenance
VK_KHR_maintenance6
VK_EXT_depth_bias_control
VK_EXT_image_sliced_view_of_3D

Tile-based optimizations
VK_EXT_shader_tile_image

Window System Integration
VK_EXT_surface_maintenance1
VK_EXT_swapchain_maintenance1
VK_EXT_pipeline_protected_access

Exploratory / Experimental
VK_EXT_shader_object
VK_AMDX_shader_enqueue

Ray Tracing
VK_KHR_ray_tracing_position_fetch

Vulkan Video Extensions

VK_KHR_video_maintenance1

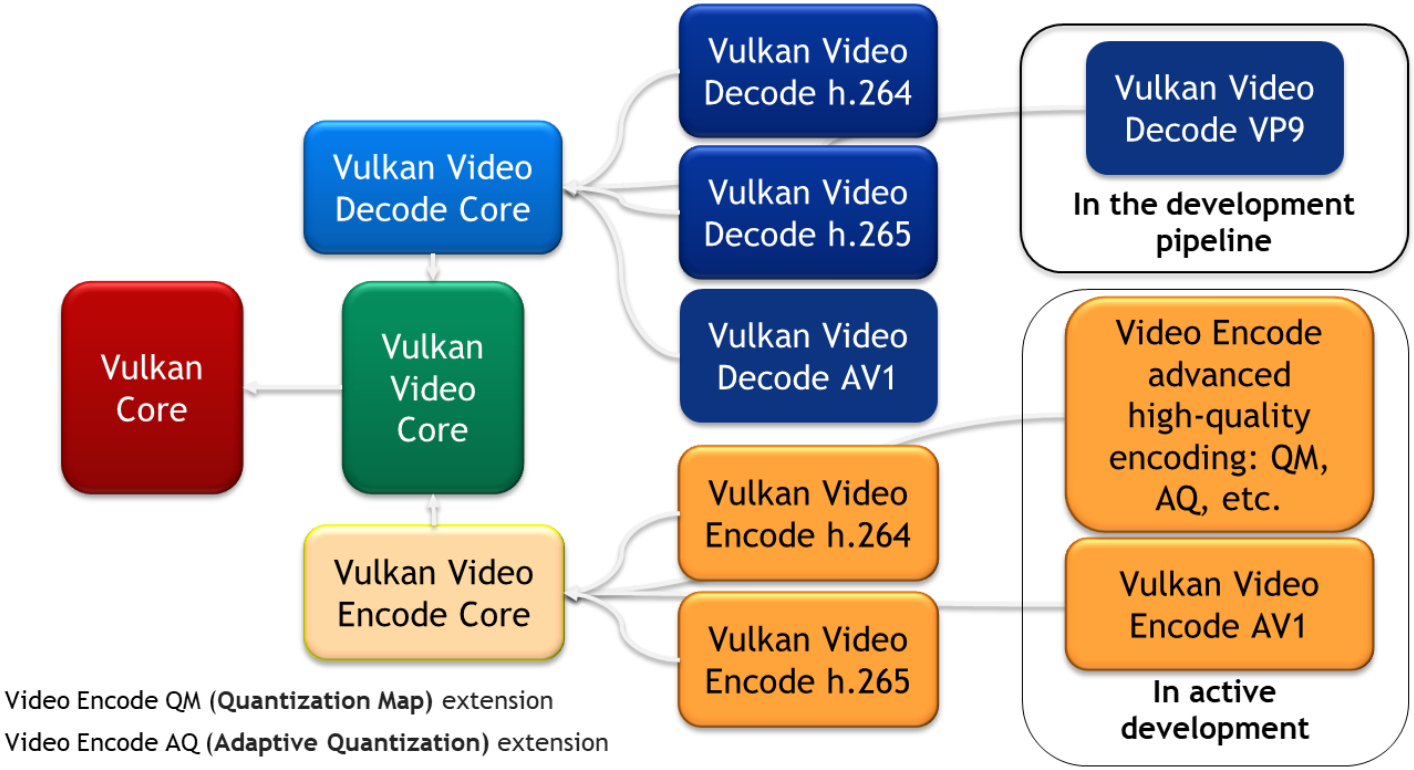
- Cleanup and small enhancements

Video encode stack is now final

- VK_KHR_video_encode_queue
- VK_KHR_video_encode_h264
- VK_KHR_video_encode_h265

VK_KHR_video_decode_av1

Vulkan Video Extensions

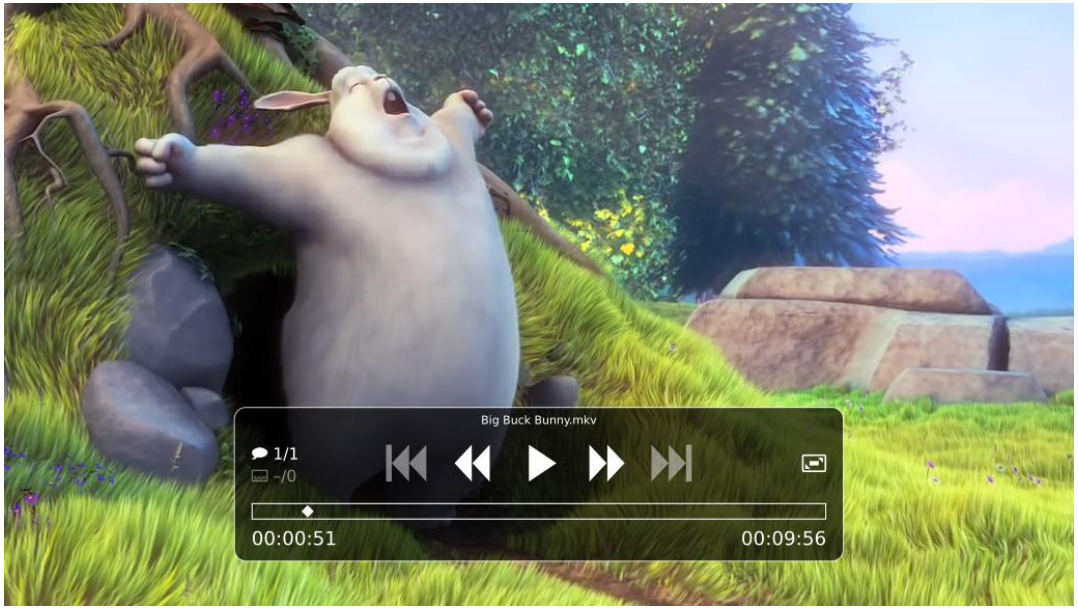


Vulkan Video is a Thing!

Frameworks

FFmpeg

gstreamer



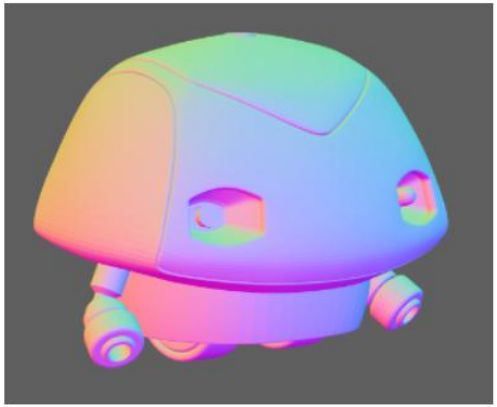
Status tracked at https://blogs.igalia.com/vjaquez/vulkan-video-status/

Several talks here at Vulkanised!

Vulkan Ray Tracing

VK_KHR_ray_tracing_position_fetch

- Query vertex positions after a ray hit
- Motivated by need for triangle normals in Lumen
- Substantial perf win!



Example : Visualization of Surface Normals computed via ray traced acceleration structure positions.
PICA model courtesy SEED.EA

```
/** Without ray tracing position fetch */
uint triIndex0 = indexBuffer[firstIndex + gl_PrimitiveID*3 + 0];
uint triIndex1 = indexBuffer[firstIndex + gl_PrimitiveID*3 + 1];
uint triIndex2 = indexBuffer[firstIndex + gl_PrimitiveID*3 + 2];

vec3 vertPos0 = vertexBuffer[triIndex0];
vec3 vertPos1 = vertexBuffer[triIndex1];
vec3 vertPos2 = vertexBuffer[triIndex2];

payload.geoNormal = cross(vertPos1 - vertPos0, vertPos2 - vertPos0);
```

```
/** With ray tracing position fetch */
vec3 vertPos0 = gl_HitTriangleVertexPositionsEXT[0];
vec3 vertPos1 = gl_HitTriangleVertexPositionsEXT[1];
vec3 vertPos2 = gl_HitTriangleVertexPositionsEXT[2];

payload.geoNormal = cross(vertPos1 - vertPos0, vertPos2 - vertPos0);
```

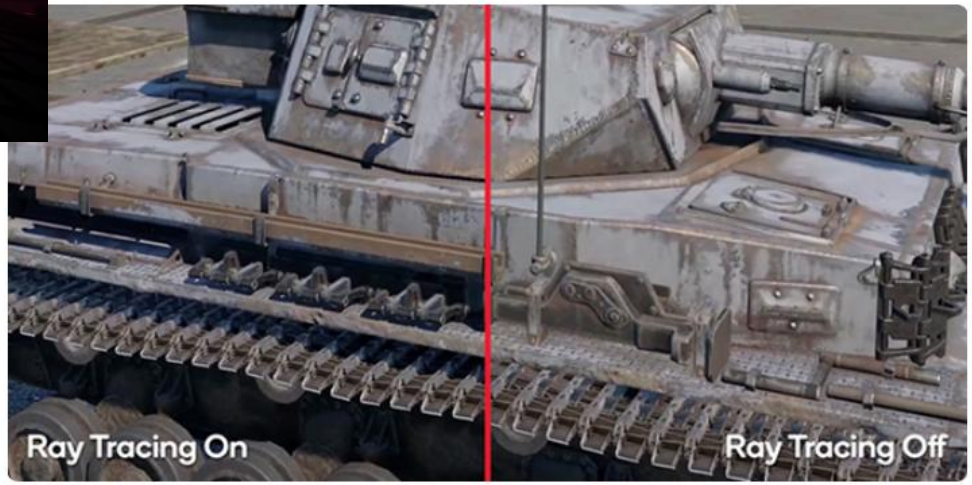
- https://www.khronos.org/blog/introducing-vulkan-ray-tracing-position-fetch-extension

Ray tracing in mobile is a Thing too!

arm

See Wednesday morning's talk by Iago Calvo Lista!

Qualcomm

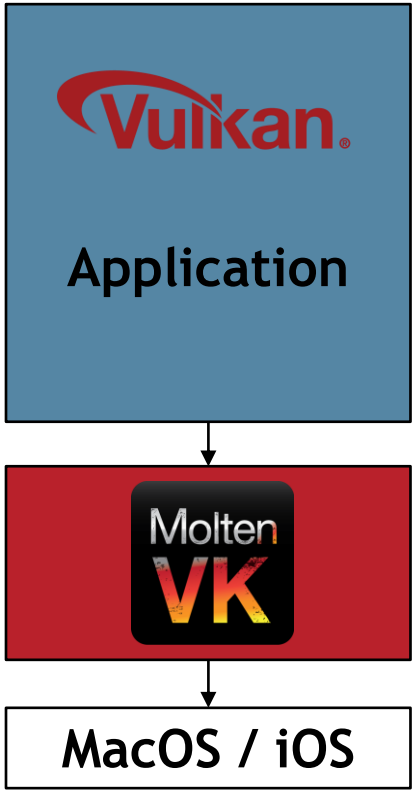


https://www.qualcomm.com/news/onq/2023/05/hardware-accelerated-ray-tracing-improves-lighting-effects-in-mobile-gaming

What's New:

Platforms

Vulkan on MacOS / iOS



The problem

- How do you run Vulkan apps without a driver?

MoltenVK

- Shim library for MacOS/iOS
- Maps Vulkan calls to native Metal API
- Shaders translated at create time
- Supports only an efficient subset

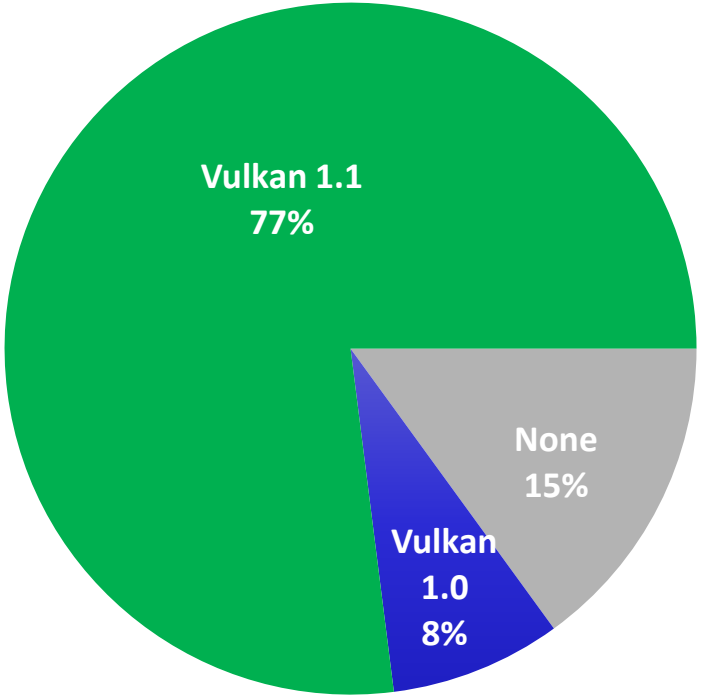
Current status

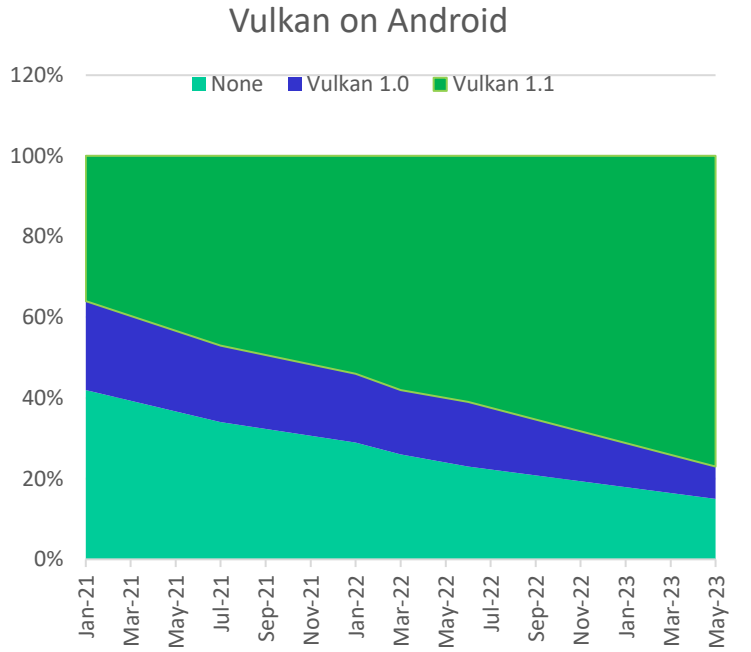
- Fully supported in LunarG SDK
- Vulkan 1.2 feature (sub)set (and growing)
- Will be Vulkan 1.0 conformant soon

Applications and Engines Using MoltenVK

- **Games shipping with MoltenVK**
  - DOTA 2
  - Metro Exodus
  - Final Fantasy XIV
  - Dark Souls: Remastered
  - Dark Souls III
  - DOTA Underlords
  - Aerofly Flight Simulator 2
  - Path of Exile
  - Raft
  - The Elder Scrolls Online
  - Celeste
  - Transport Fever 2
  - Shadow Warrior 2
  - Streets of Rage 4
  - Jupiter Hell
  - Wreckfest
  - Victoria 3
  - Artifact
  - GZDOOM
  - vkQuake/vkQuake2
- **Games runnable by users via Crossover and MoltenVK**
  - Halo: Combat Evolved
  - God of War (2018)
  - Grand Theft Auto V
  - World Of Tanks
  - Forsaken Remastered
  - Elder Scrolls V Skyrim: SE
  - Guild Wars 2
  - Battlefield 1
  - Battlefront II
  - Age of Empires II: Definitive Edition
  - Witcher 3
- **Applications shipping with MoltenVK**
  - Autodesk Fusion 360
  - NAP
  - Autodesk Flame
- **Engines using MoltenVK**
  - Google Filament
  - Facebook IGL
  - LightweightVK
  - Defold
  - Clausewitz Engine (Paradox)
  - Ultra Engine
  - Diligent Engine
  - Ncnn
  - Godot
- **Platform emulators using MoltenVK**
  - VKD3D (Direct3D 12)
  - DXVK (Direct3D 9/10/11)
  - Google Android Emulator
  - Dolphin (Wii & GameCube)
  - Ryujinx (Switch)
  - Cemu (Wii U)
  - RPCS3 (PS3)
  - PCSX2 (PS2)

Vulkan Adoption on Android





https://developer.android.com/about/dashboards

In January 2023 Vulkan was available on 85% of active Android devices

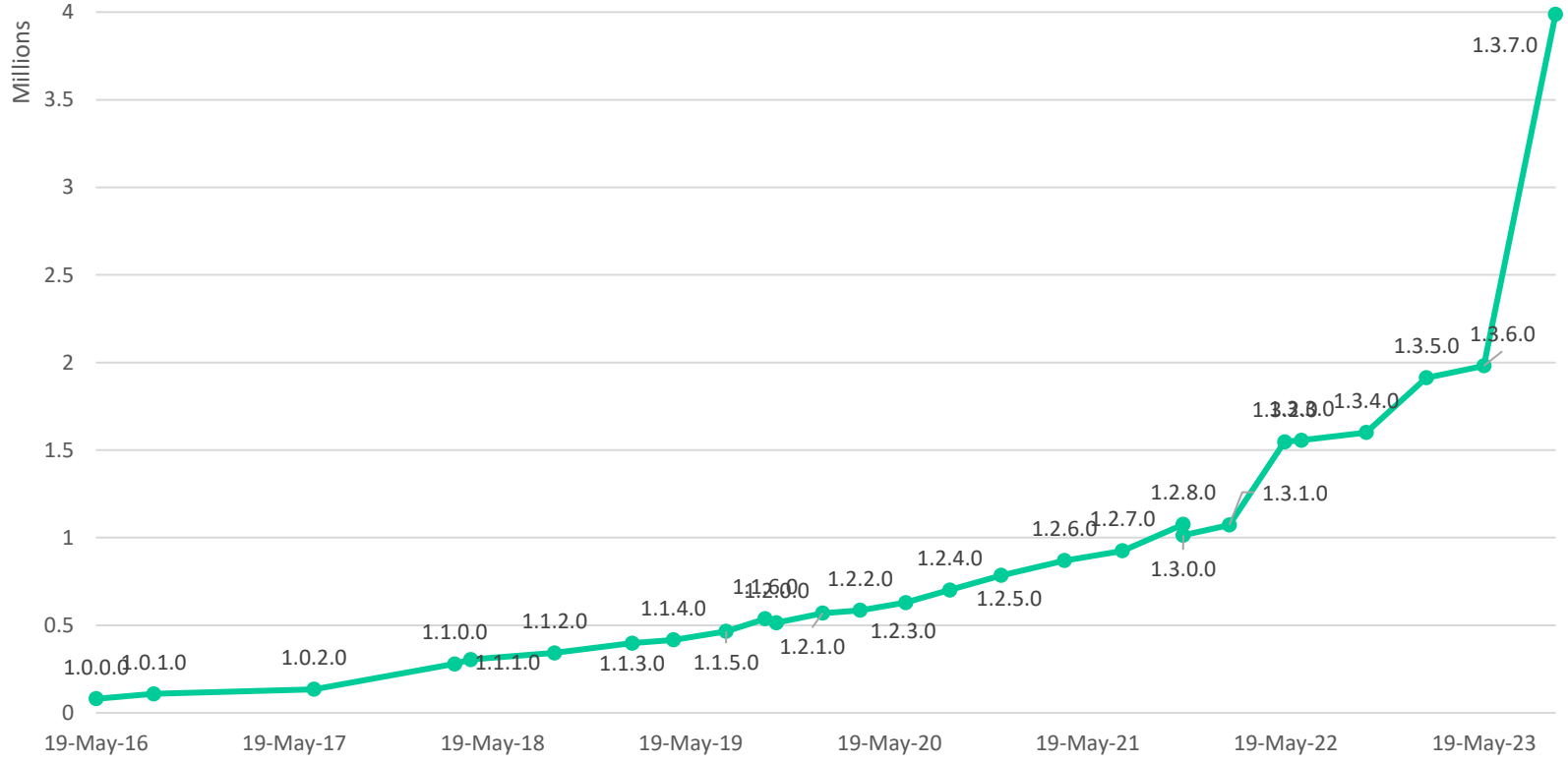
What's New:

Conformance Testing

KHRONOS® GROUP

Vulkan Conformance Test Suite (CTS)

~3.9 million tests as of May 2023



What's New:

SDK and Tools

Hi Karen!

LUNARG

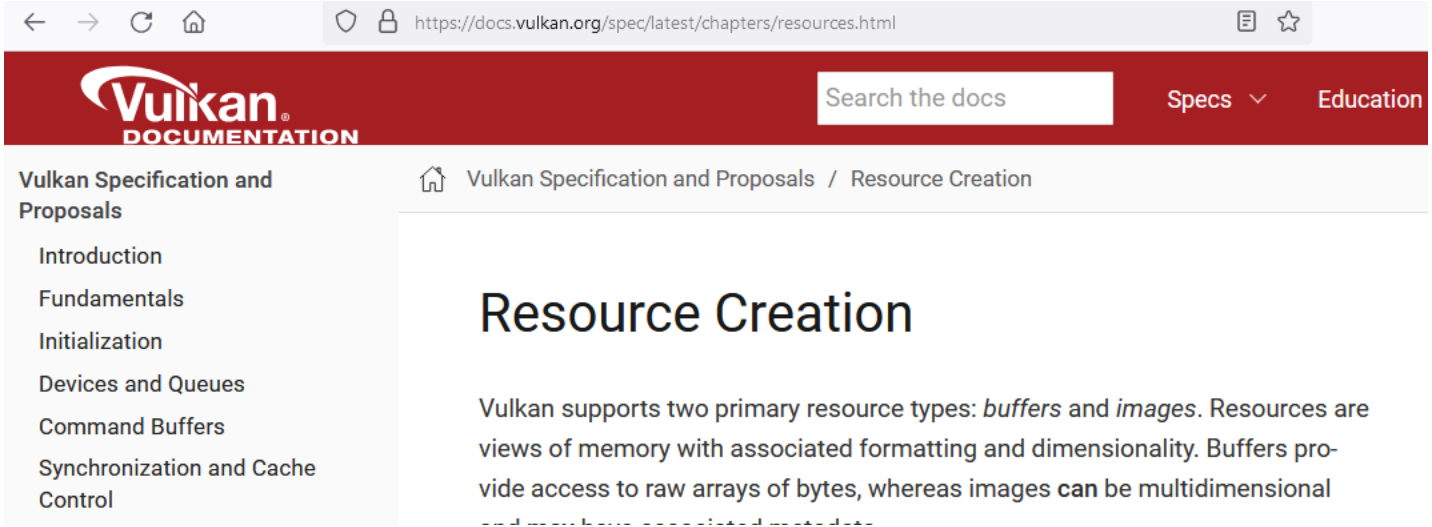
What's New:

Documentation and Developer Support

Vulkan Documentation Project

Bring Vulkan documentation together in one place

- Specification, Vulkan Guide, Proposal documents, Samples…
- Easy navigation and cross-linking
- https://docs.vulkan.org
- Please report issues at https://github.com/KhronosGroup/Vulkan-Site



New Vulkan Guide articles

HLSL in Vulkan

- Coming soon: HLSL / GLSL Mapping (Sascha Willems)

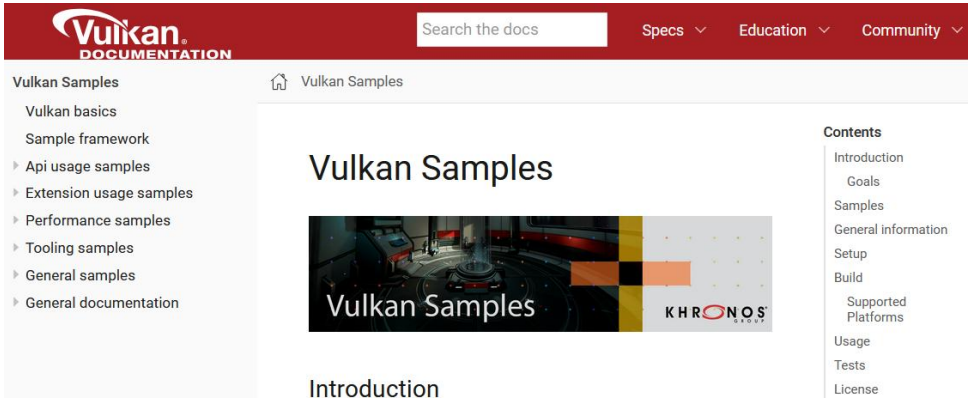
Vulkan Samples Repository

A home for Vulkan sample code

- Intended to help you learn to use Vulkan effectively
- GPU, OS, and platform neutral, well tested
- On github in open source (Apache 2.0)
- Access via docs.Vulkan.org or at github/KhronosGroup/Vulkan-Samples

A community effort

- Khronos member ISVs, IHVs, contractors
- Interested community members

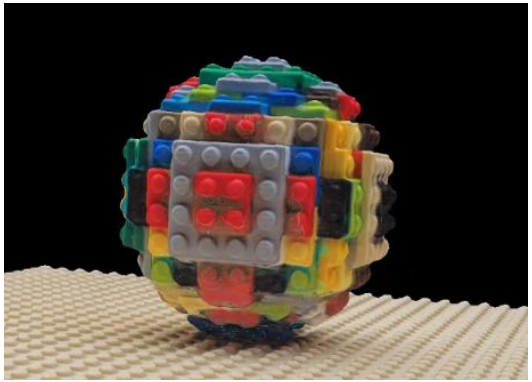


Some recently added samples

Sparse Image / virtual texture (Mobica)

OIT using per-pixel linked lists (community)

Mobile NeRF (Qualcomm)



https://developer.qualcomm.com/blog/generating-3d-scenes-2d-images-more-efficiently-mobile-nerf-rendering-using-vulkan-adreno-gpu

Vulkanised!

First full-scale Vulkanised was held in February 2023

- Hosted by Google in Munich, Germany
- Three days of talks, panels, demos, and a Vulkan course
  - All on line at https://vulkan.org/learn#videos

Welcome to Vulkanised 2024!