

**KHRONOS™**  
GROUP

**Vulkan®**

**OpenXR™**

**「ポータブル, 高性能, VR,  
3Dゲーム」開発に最適な  
クロノスAPI最新情報解説**

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[www.khronos.org](http://www.khronos.org)

**CEDEC 2017**  
Computer Entertainment Developers Conference

# クロノスのミッション

PROMOTER MEMBERS

**KHRONOS GROUP**  
Over 100 members worldwide  
Any company is welcome to join

AMD, Apple, arm, EPIC GAMES, Google, HUAWEI, Imagination, intel, NOKIA, QUALCOMM, SAMSUNG, SONY, VALVE, NVIDIA, VeriSilicon

3D Incorporated, Adobe, AMOTIVE, amazon.com, antil latency, AXELL CORPORATION, AXIS COMMUNICATIONS, BASE MARK, BINOMIAL, BLIZZARD ENTERTAINMENT, BROADCOM, BRENWILL, cadence, CANONICAL, CEVA, CAICT, codeplay, CTO, Continental, Coordinate, COREAVI, DASSAULT SYSTEMES, CATAPULT Digital, OMP, ETRI, FUTUREMARK CORPORATION, daijin, HARMAN, HITACHI Inspire the Next, htc, HYPERREAL, igalia, Imperial College London, 財団法人 資通工業振興会, ITRI, AKDAB, KNU, LG, Linaro, logitech, Los Alamos NATIONAL LABORATORY, LUNAR, matrox, MAXON, MEDIATEK, Mentor Graphics, Microsoft, MIT Lincoln Laboratory, MITSUBISHI ELECTRIC, mozilla, mobica, NEC, NIHON UNIVERSITY, Nintendo, NXP, oculus, ON Semiconductor, OSU, owlii, OKIDE, Panasonic, PIXAR, PLUTO, Qt The Qt Company, RAZER, RENESAS, Rockwell Collins, 서울대학교, sensics, Silicon Studio, SIRU, socionext, SPREADTRUM, STREAM COMPUTING Performance Engineers, SYNOPSIS, TAKUMI, TAMPERE UNIVERSITY OF TECHNOLOGY, TU WIEN, Tencent, TEXAS INSTRUMENTS, thinci, Think Silicon, tobii, TOSHIBA, umbra, Unity, UCL, University of BRISTOL, UNIVERSITY OF TORONTO, University of Windsor, UX3D, 兆芯, Visteon, vmware, XILINX, zSpace



クロノスは業界大手企業100社以上が加盟。  
**3Dグラフィックス、VR/AR、並列コンピューティング、ニューラル・ネットワーキング、  
 ビジョン・プロセッシング**向けにソフトウェアがハードウェアにアクセス可能とする、  
**ロイヤリティ無料で、オープンな業界標準API**の策定を行う。

# SIGGRAPH 2017でOpenGL 4.6を発表

OpenGL は今年25周年。今も健在！

Widely used and being evolved to meet customer needs

## SPIR-V をコアに取り込む

- Significant increase in shading language and compiler tooling flexibility e.g. HLSL
- Glslang open source compiler updated to support OpenGL 4.6 functionality



## 新エクステンション

- Launch multiple shader compile threads to improve shader compile throughput
- Vulkan Interop

## 複数のARB/EXT エクステンションをコアに統合

- Anisotropic filtering for improved texture quality (previously IP encumbered)
  - Offset clamp to suppress “light leak” artifacts when rendering shadows
  - Ability to turn off error checking for improved performance
- Improved batched geometry parameter handling to reduce CPU overhead
- Improved shader intrinsics for improved functionality and performance
  - Expanded pipeline queries

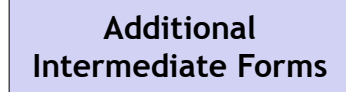
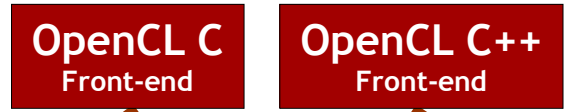
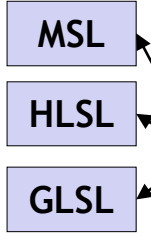
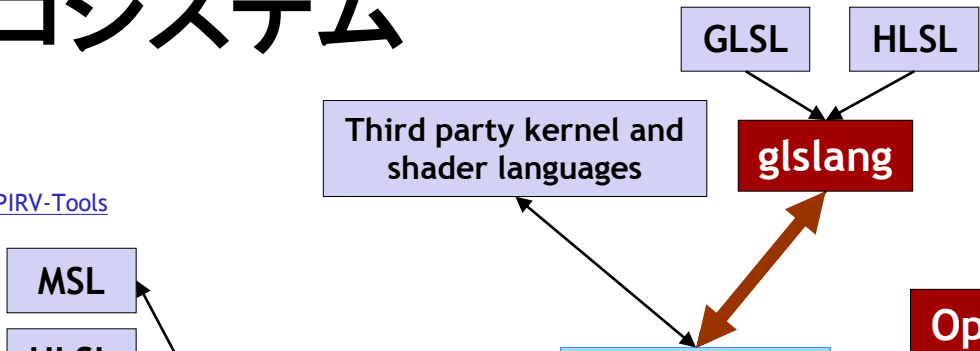
# SPIR-V エコシステム

Khronos open source tools and translators

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

**SPIR-V**

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



```

SPIR-V Magic #: 0x07230203
SPIR-V Version 99
Builder's Magic #: 0x051a00BB
<id> bound is 50
0
OpMemoryModel
Logical
GLSL450
OpEntryPoint
Fragment shader
function <id> 4
OpTypeVoid
<id> is 2
OpTypeFunction
<id> is 3
return type <id> is 2
OpFunction
Result Type <id> is 2
Result <id> is 4
0
Function Type <id> is 3
SPIR
    
```



Khronos liaising with Clang/LLVM Community  
E.g. discussing SPIR-V as supported Clang target



**SPIR-V Optimizations**

- Inlining (exhaustive)
- Store/Load Elimination
- Dead Code Elimination
- Dead Branch Elimination
- Common Uniform Elimination
- Common Subexpression Elimination
- Loop Unrolling and Constant Folding
- Common Uniform Elimination
- Common Subexpression Elimination

Coming

IHV Driver Runtimes



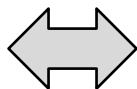
# OpenGL エコシステム

- OpenGL 4.6対応ドライバは発表と同時に公開
  - NVIDIA OpenGL 4.6 ドライバ(ベータ版)公開
  - <https://developer.nvidia.com/opengl-driver>
- OpenGL コンFORMANCEテストを、オープンソースとして公開
  - MESAといったオープンソース・プロジェクトに対応

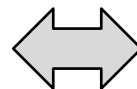


*“The open sourcing of the OpenGL conformance test suite and ongoing work between Khronos and X.org will also allow for non-vendor led open source implementations to achieve conformance in the near future”  
David Airlie, senior principal engineer at Red Hat, and developer on Mesa/X.org projects*

- Vulkan Interop エクステンションをOpenGL 4.6と同時公開



New OpenGL  
Extensions  
Shared Memory  
Semaphores  
Mutexes

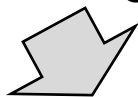


Vulkan Interop with OpenGL provides developers significant flexibility on how they use/transition between both APIs

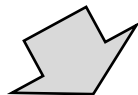
# Khronos APIs が VR/ARに力を！



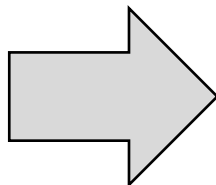
Rich Desktop VR Functionality  
OpenGL 4.6 released August 2017



3D on millions of mobile VR devices  
OpenGL ES 3.2 released August 2015



Powering WebVR in browsers  
WebGL 2.0 Released February 2017



High-performance, Low-latency  
VR/AR RENDERING  
Vulkan 1.0 released February 2016  
Available on diverse platforms



Cross-Platform, Portable VR/AR  
DEVICE MANAGEMENT  
Device discovery  
Movement tracking  
Input and haptics  
Flexible graphics configuration

# Vulkan と新世代 3D APIとの比較



Windows 10のみ対応



Apple のみ対応



Clean, modern architecture | Low overhead, explicit GPU access  
Portable across desktop and mobile | Multi-thread / multi-core friendly  
*Efficient, low-latency, predictable performance*

# Vulkan による明確な GPU 管理

Vulkan = high performance and low latency 3D and GPU Compute. Ideal for VR/AR applications

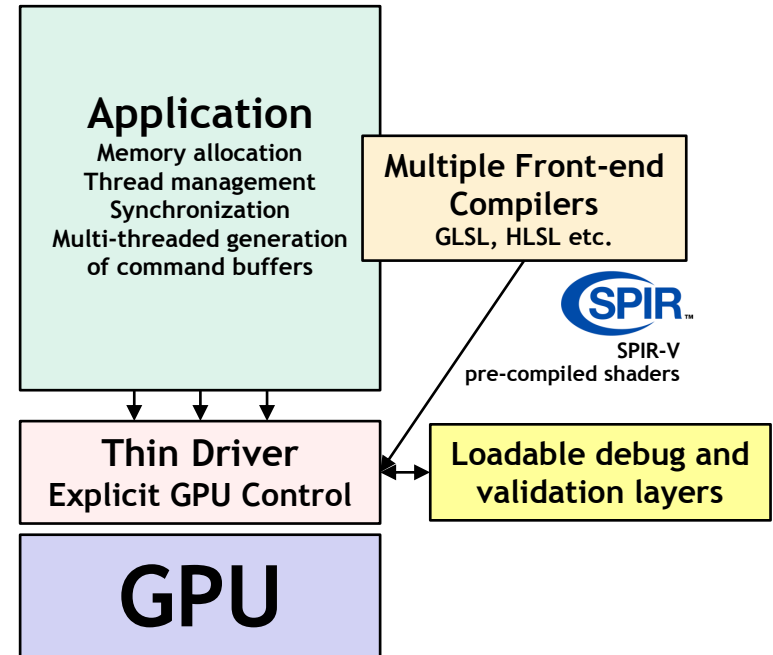
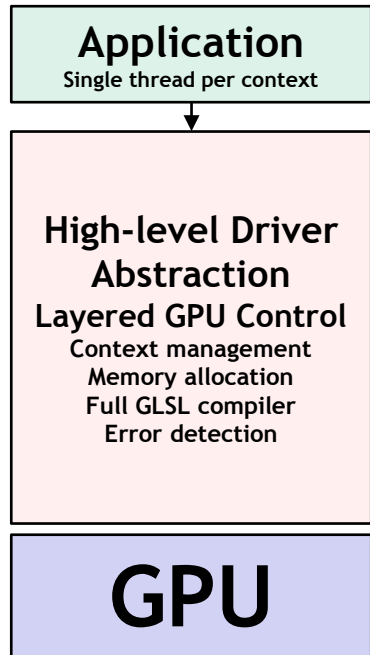


Complex drivers cause overhead and inconsistent behavior across vendors

Always active error handling

Full GLSL preprocessor and compiler in driver

OpenGL vs. OpenGL ES



Resource management offloaded to app: low-overhead, low-latency driver

Consistent behavior: no 'fighting with driver heuristics'

Validation and debug layers loaded only when needed

SPIR-V intermediate language: shading language flexibility

Multi-threaded command creation. Multiple graphics, command and DMA queues

Unified API across all platforms with feature set flexibility

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



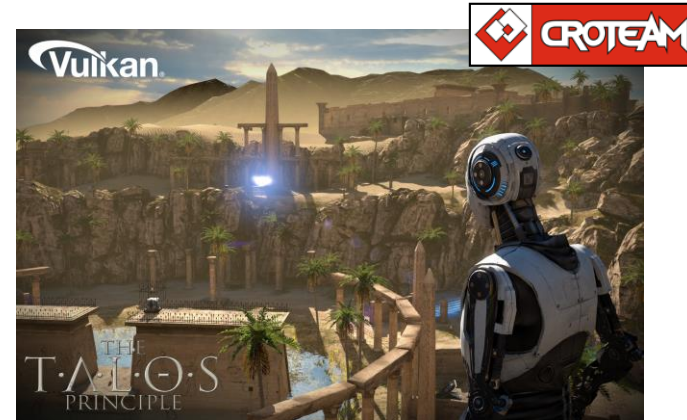
# Vulkan 対応の代表的ゲーム/ゲーム・エンジン



Dota 2 on Vulkan port of Source 2



'ProtoStar' demo on Vulkan port of Unreal Engine 4



Talos Principle on Vulkan port of Serious Engine



Doom's Vulkan patch is a PC performance game-changer

DOOM on Vulkan port of id Tech 6



Vulkan support in Unity 5.6



Vulkan support since V1.8



Vulkan support in V5.4  
5.4 Preview Released on July 25th

# Vulkan をサポートする主要プラットフォーム

All Major GPU Companies shipping Vulkan Drivers for Desktop and Mobile Platforms



<http://vulkan.gpuinfo.org/>

## Mobile, Embedded and Console Platforms Supporting Vulkan

Including phones and tablets from Google, Huawei, Samsung, Sony, Xiaomi - both premium and mid-range devices



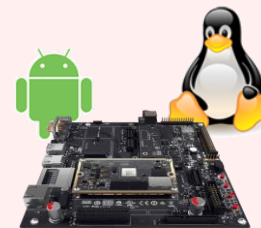
Android 7.0



Nintendo Switch



Android TV



Embedded Linux

## VR Platforms



SteamVR



GearVR



Oculus Rift



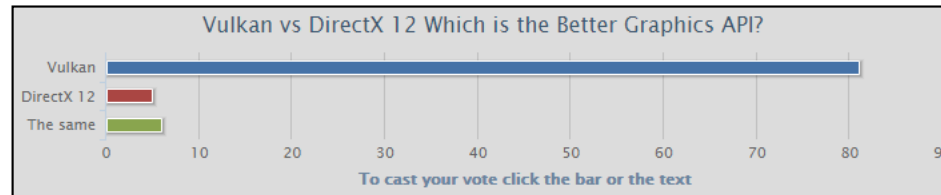
Google Daydream

# Vulkan デベロッパの勢いは止まらない！

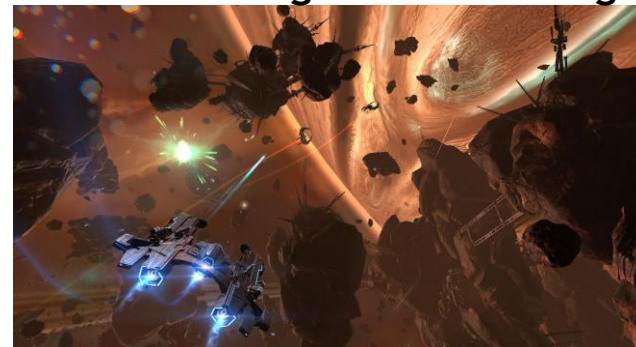
<http://www.game-debate.com/news/22525/star-citizen-directx-11-and-12-support-axed-in-favour-of-vulkan-api>



<http://www.game-debate.com/news/23312/up-for-debate-vulkan-vs-directx-12-which-is-the-better-graphics-api>



Vulkan is Powering Mobile Gaming...



GALAXY ON FIRE 3  
MANTICORE



## Ashes of the Singularity: Escalation v2.4 update adds Vulkan support

By Paul Lilly 10 days ago

24th August 2017

And a whole lot more.

f t g+ y COMMENTS



<http://www.pcgamer.com/ashes-of-the-singularity-escalation-v24-update-adds-vulkan-support/>

Publicly announced games as of August 2017

#Vulkan Games = 26

#DX12 Games = 20

[https://en.wikipedia.org/wiki/List\\_of\\_games\\_with\\_Vulkan\\_support](https://en.wikipedia.org/wiki/List_of_games_with_Vulkan_support)



<http://www.intrinsic-engine.com/>

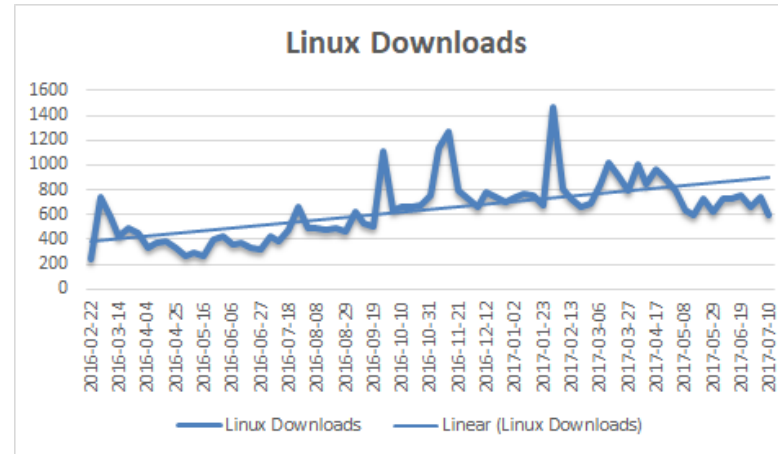
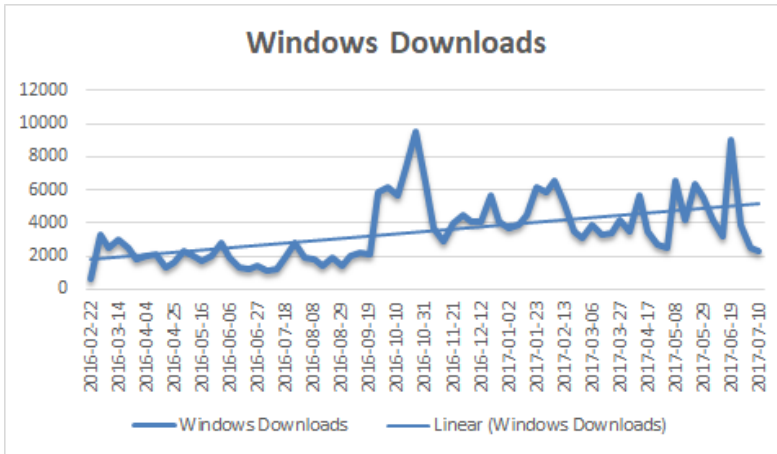


Many more mobile titles coming...

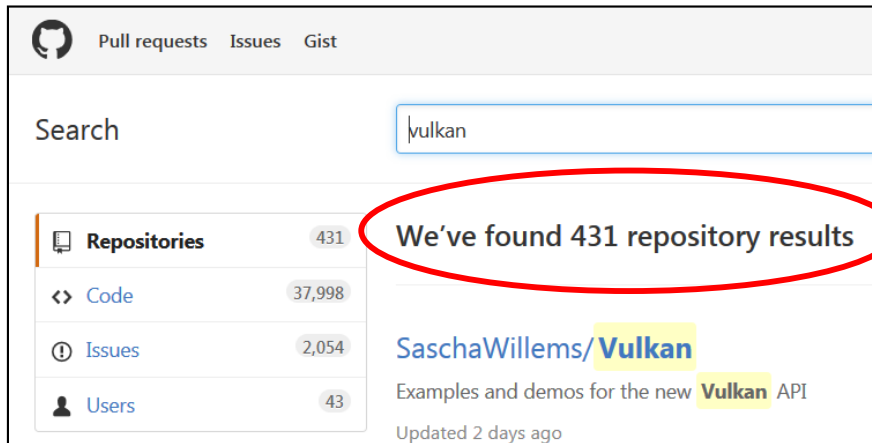
# エコシステムに対する業界の支援と勢い



LunarG Vulkan SDK  
Download rate has more than  
doubled since launch  
<http://vulkan.lunarg.com>

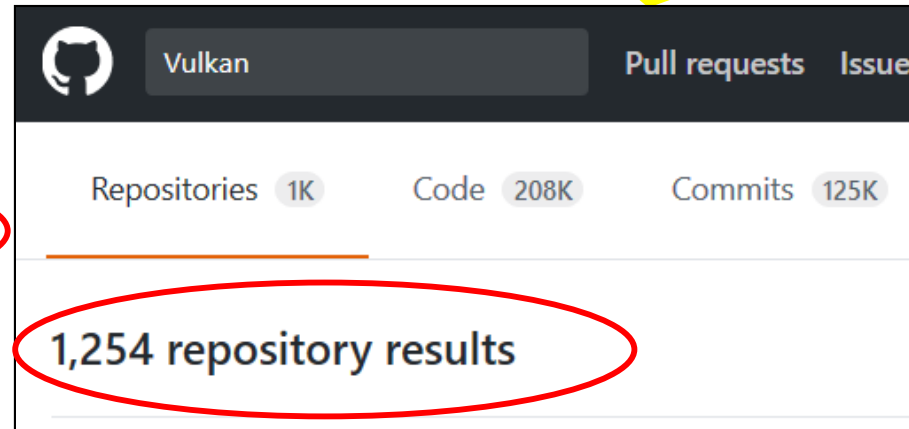


## Vulkan GitHub Open Source Projects - CEDEC 2016



## Today

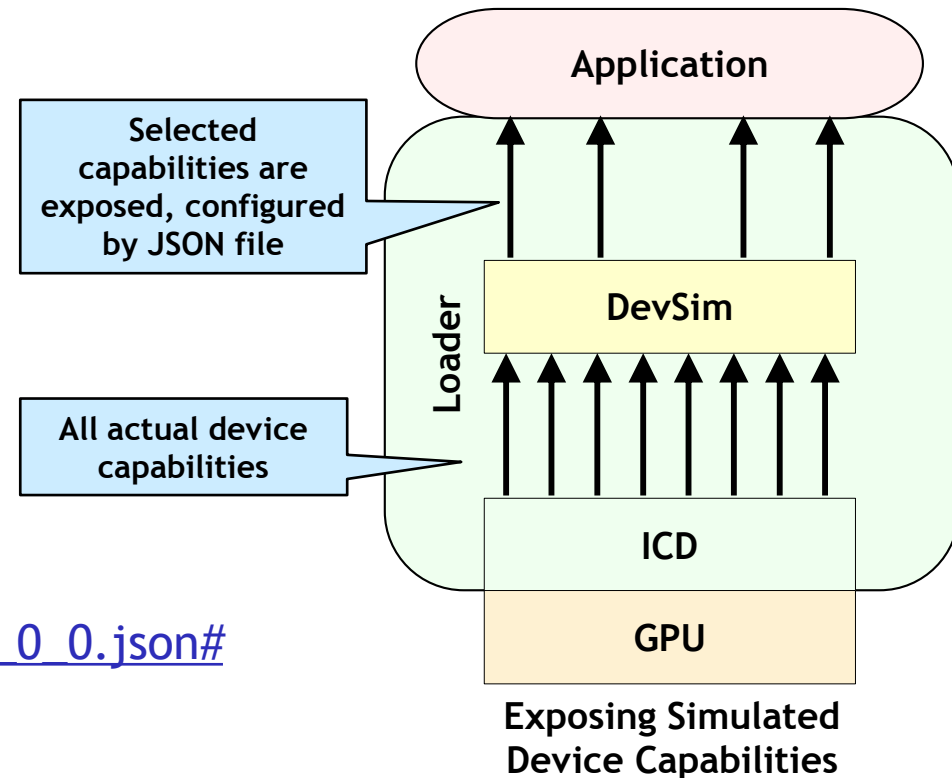
Vulkan Specification on GitHub - now accepting pull requests!



# VK\_LAYER\_LUNARG\_device\_simulation



- Simulate capabilities of mobile and embedded devices
  - Test application without requiring physical device
  - Exercise fall-back code paths, when a capability isn't available
  - Find unintentional assumptions (triggers validation errors)
- Modifies results from Vulkan queries
  - Device configuration defined by JSON file
  - Integrated with Sascha Willems database
- Simulation, NOT Emulation
  - Doesn't add more capabilities not already present in actual device
- Source available now
  - <https://github.com/LunarG/VulkanTools>
  - Please submit issues
- Verify configuration files are correct
  - [https://schema.khronos.org/vulkan/devsim\\_1\\_0\\_0.json#](https://schema.khronos.org/vulkan/devsim_1_0_0.json#)



# Vulkan の進化

## エコシステムならびに SDK の強化

Enhanced developer and debugging tools  
Regression testing for SDK stability  
Enhanced Conformance Testing (API now has 198K test cases - up from 107K last year)  
Compiler robustness - including HLSL support

## Vulkan エクステンション

Maintenance updates plus additional functionality

### Explicit Building Block Extensions for VR

E.g. Multiview, application and presentation engine can access an image at the same time to reduced latency

### Explicit Building Block Extensions for Multi-GPU

NVIDIA SLI and AMD Crossfire in AFR (alternate frame), SFR (Sequential frame) and VR SLI Stereo view modes

### Experimental Extensions (KHx)

For developer feedback  
(NOT recommended for use in production code)

## 広範なプラットフォーム支援

Through Vulkan Portability Initiative  
Including Vulkan on macOS and iOS

## 標準 Vulkan コア公開

Includes integration of proven KHR extensions

### Enhanced Compute

C++ based shading languages and OpenCL Kernel Support

### Increased Shader Language Flexibility

Enhanced HLSL support  
Subgroup operations e.g. vote, broadcast, shuffle, cross-lane/warp

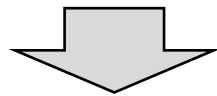
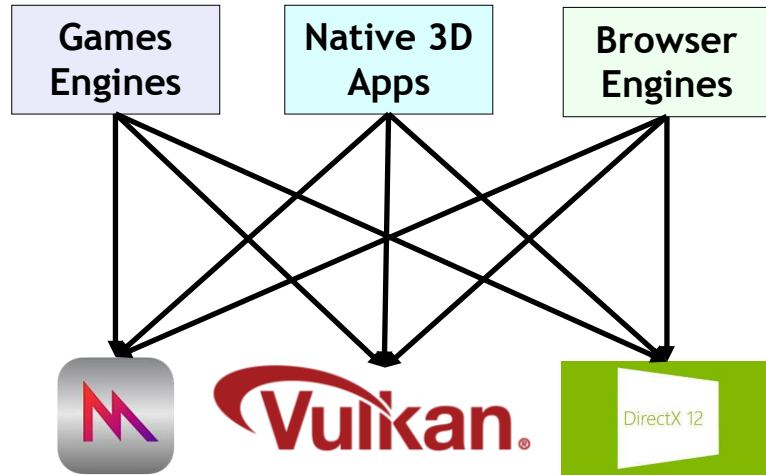
### Enhanced Windows System Integration

Partial and app updates to presentable images  
Full-screen and memory residency control  
Protected memory for DRM protected content  
YCbCr formats with color space conversions

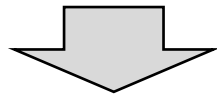


Feb16  
Vulkan 1.0

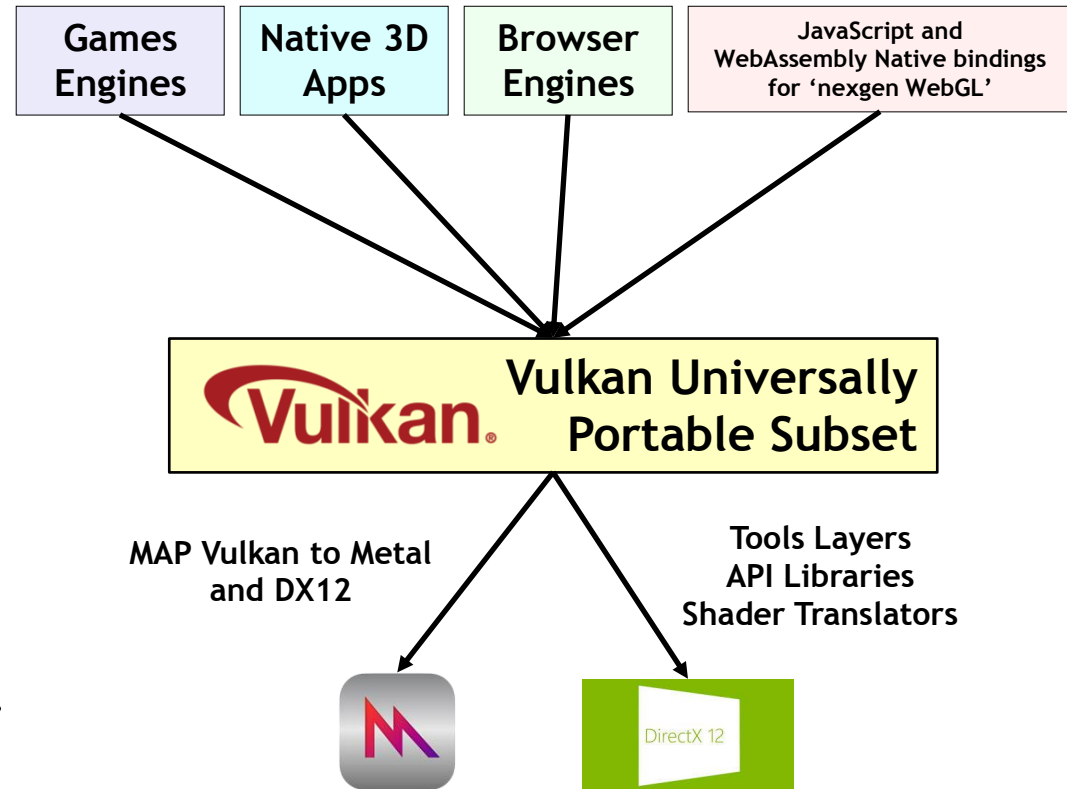
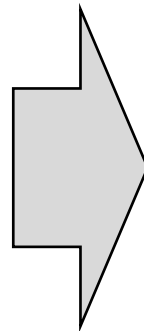
# ユニバーサル3D ポータビリティへの市場の需要



**Community Outreach at GDC 2017**  
Create a hybrid Portability API?



**Feedback - AVOID CREATING A FOURTH API!!!**  
Would need new specification, CTS, Documentation.  
Additional developer learning curve.  
A whole new specification to name, brand, promote.  
Would INCREASE industry fragmentation



# Vulkan ポータビリティに対するTSG プロセス



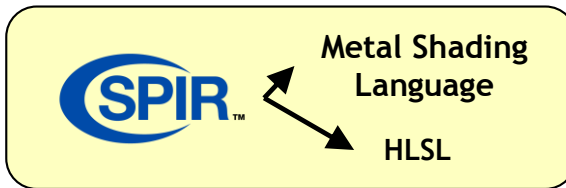
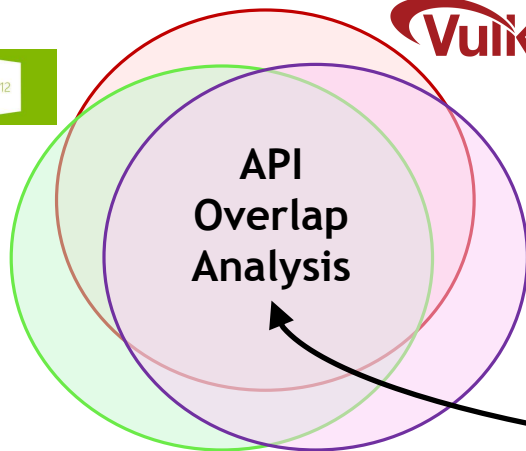
Open source project with similar goals

<https://github.com/gfx-rs/gfx>



Vulkan on iOS and macOS

<https://moltengl.com/moltenvk/>



- Vulkan Portability Deliverables**
1. Vulkan Subset Diff Spec
  2. Vulkan Subset Development Layer
  3. Vulkan Subset API Library over DX12/Metal
  4. SPIRV-Cross Translator
  5. Vulkan Subset Conformance Tests

Layers, APIs, Translators and Tests all to be developed and released in open source



Possible proposals for Vulkan extensions for enhanced portability (and possibly Web robustness) sent to Vulkan WG

New Vulkan functionality may affect the overlap analysis



# VulkanのHLSL

- **Glslang (Khronos/Google/LunarG)**
  - First compiler to support HLSL in Vulkan
  - HLSL support is complete enough for real world projects
    - DOTA 2 (Valve), Ashes of Singularity (Oxide Games)
  - Mostly SM5.0 and some SM5.1 - largely driven by community asks
- **Shaderc (Google)**
  - Depends on glslang so HLSL support is roughly the same
  - Can optionally execute spirv-opt as part of the build process
- **DXC (Google/Microsoft)**
  - Actively being merged into dxc mainline - only supports HLSL
  - Based on LLVM and Clang 3.7, targets SM6.0 and higher
  - Google contributing SPIR-V codegen (spiregg)



# OpenCL と Vulkanの関係

C++ AMP  
Accelerated Massive Parallelism  
with Microsoft Visual C++

Single source C++ programming.  
Great for supporting C++ apps,  
libraries and frameworks



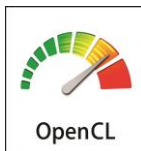
Industry working to bring  
Heterogeneous compute to  
standard ISO C++  
C++17 Parallel STL hosted by Khronos  
Executors - for scheduling work  
“Managed pointers” or “channels” -  
for sharing data



SYCL 1.2  
C++11 Single source  
programming

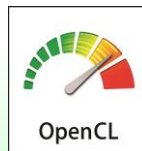


SYCL 2.2  
C++14 Single source  
programming



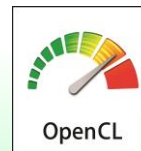
2011

OpenCL 1.2  
OpenCL C Kernel  
Language



2015

OpenCL 2.1  
SPIR-V in Core



2017

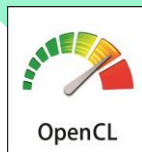
OpenCL 2.2  
C++ Kernel Language



OpenCL クラスのコンピ  
ュート性能を Vulkanで  
実現支援

OpenCL for DSPs

- Embedded imaging, vision and inferencing
- Flexible reduced precision
- Conformance without IEEE 32 Floating Point
- Explicit DMA



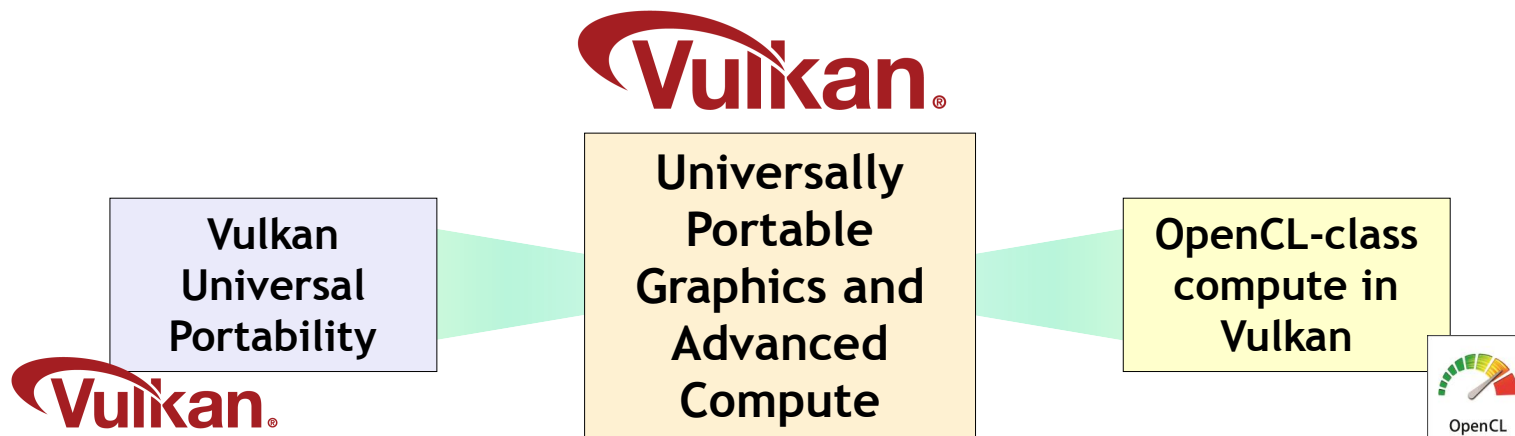
# Clspv OpenCL C を Vulkan コンパイラに



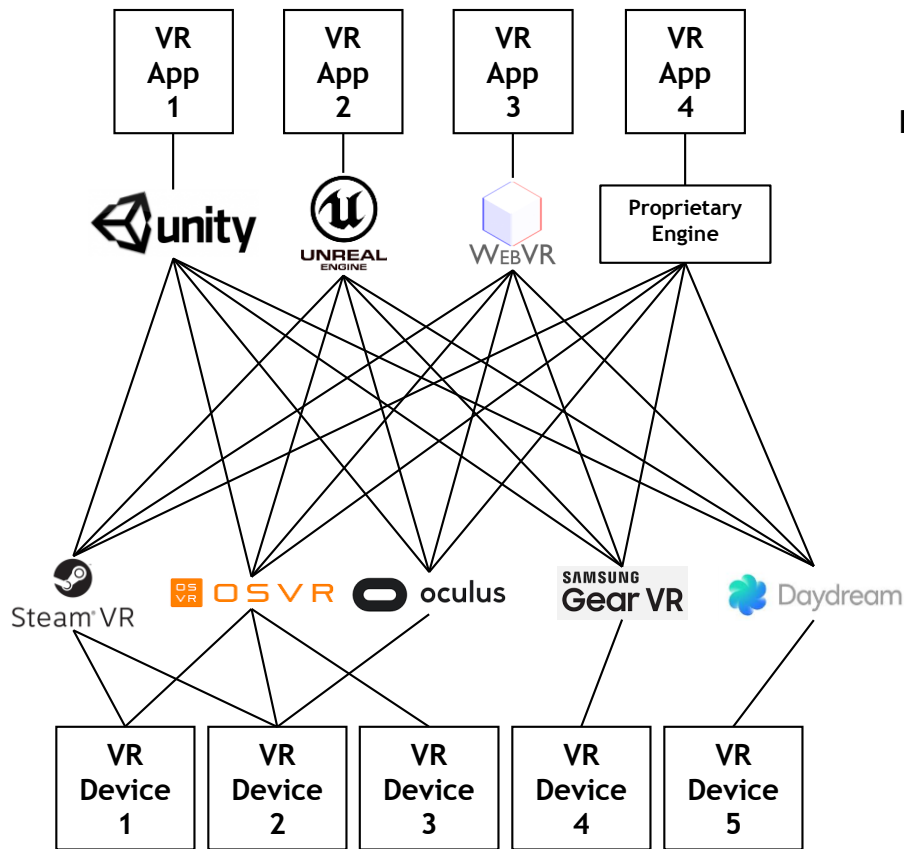
Adobe



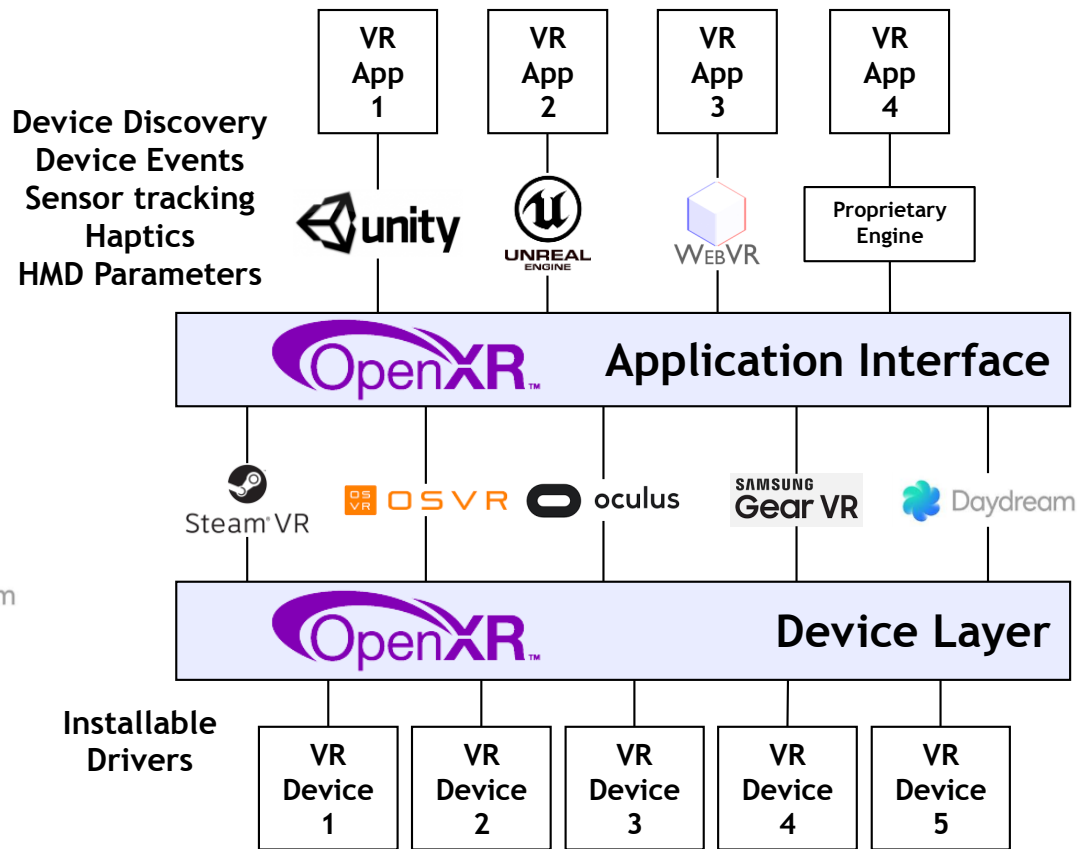
- Experimental collaboration between Google, Codeplay, and Adobe
  - Successfully tested on over 200K lines of Adobe OpenCL C production code
  - Released in open source <https://github.com/google/clspv>
  - Tracks top-of-tree LLVM and clang, not a fork
- Uses new Vulkan extensions to support OpenCL C compute operations
  - VK\_KHR\_16bit\_storage/SPV\_KHR\_16bit\_storage
  - VK\_KHR\_variable\_pointers/SPV\_KHR\_variable\_pointers
- Compiles OpenCL C's programming model to Vulkan's SPIR-V execution environment
  - Proof-of-concept that OpenCL compute can be brought seamlessly to Vulkan



# OpenXR - AR/VR のフラグメンテーションを解決



**OpenXR採用前**  
VR 市場のフラグメンテーション



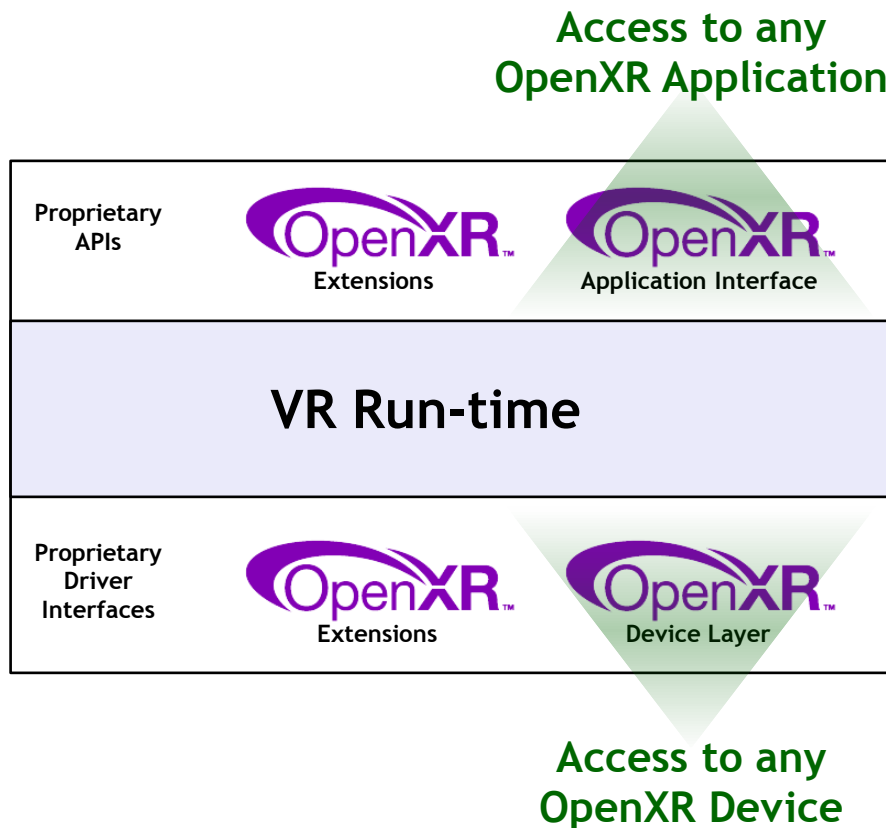
**OpenXR 採用後**  
VR アプリケーション/機器の  
広範なインターオペラビリティ

# OpenXR ワーキング・グループ 会員企業



仕様策定作業は2016年12月に開始  
V1.0仕様発表まで、通常は開始から12~18ヵ月

# OpenXR と VR ランタイム - a Win-Win



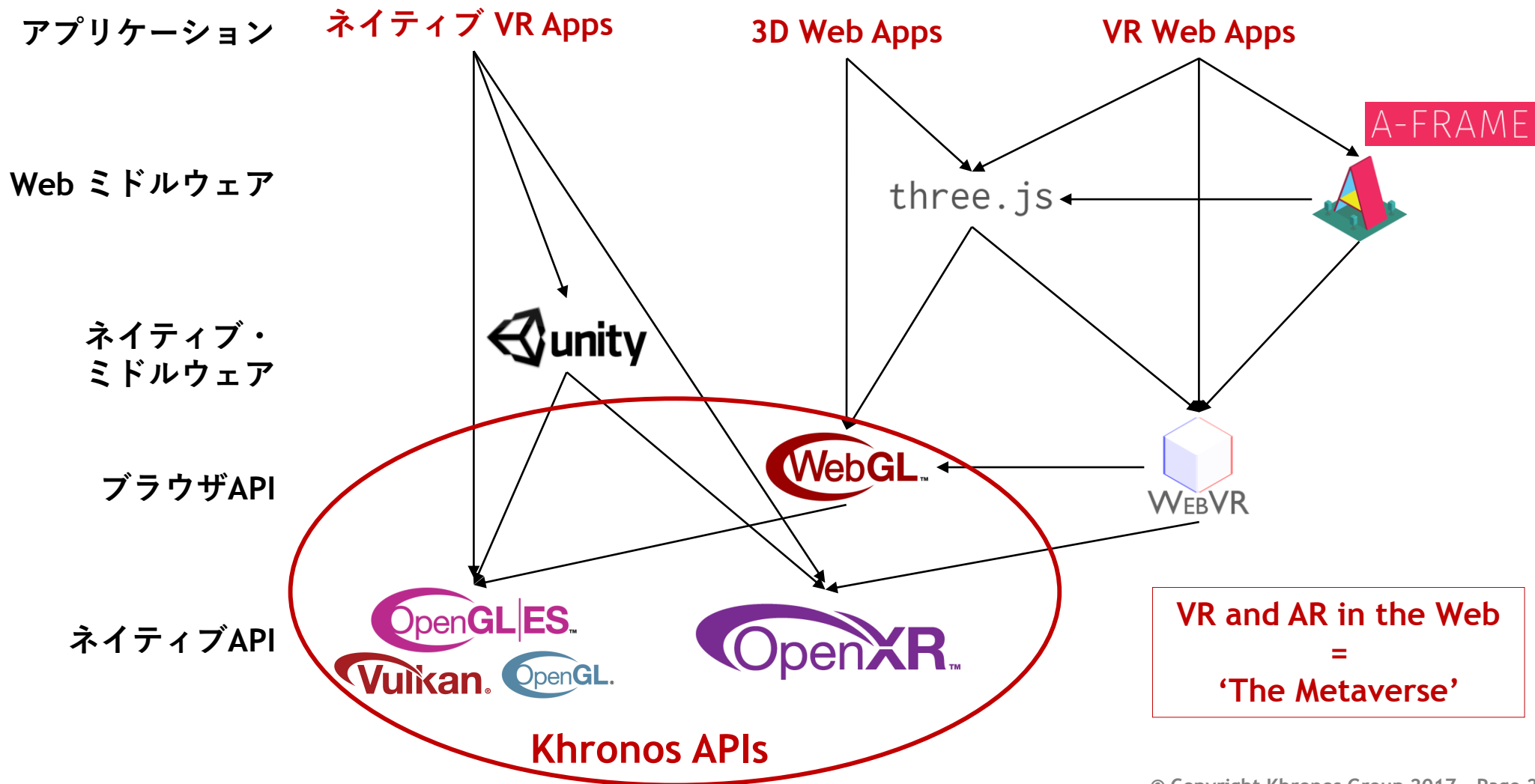
Any successful standard encourages and enables healthy industry competition

OpenXR will not replace VR run-times - or 'outlaw' existing interfaces

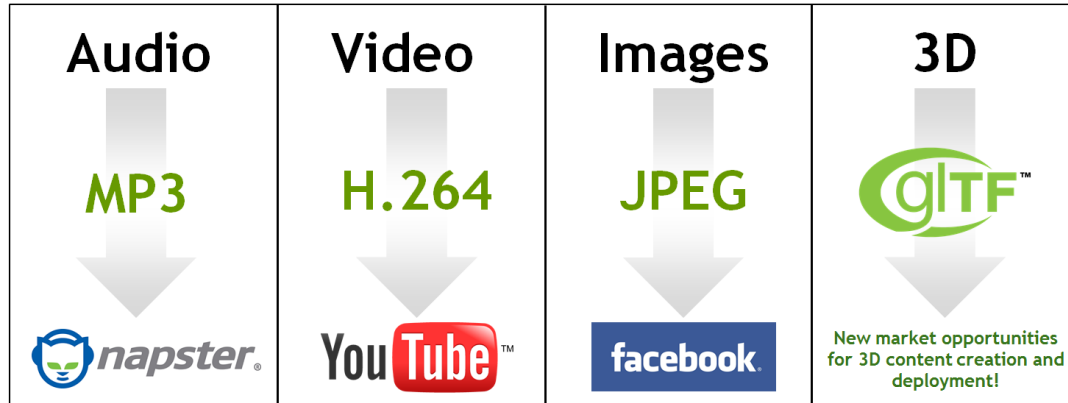
OpenXR will simply provide cross-vendor APIs that can be exposed by a runtime to access more apps and devices

**OpenXR for portable AR AND VR apps and devices with *initial* focus on VR**


# 階層化されたエコシステムと VR



# glTF - クロス・プラットフォーム 3D アセット変換



All glTF spec development  
on open GitHub:  
<https://github.com/KhronosGroup/glTF>

- 
- Compact to Transmit ✓
  - Fast to Load ✓
  - Describes Full Scenes ✓
  - Runtime Neutral ✓
  - Open and Extensible ✓

OpenGL Transmission Format  
Efficient transmission of 3D  
scenes and assets



**glTF 1.0**  
Aimed at loading assets into WebGL apps  
Uses GLSL for materials  
Released December 2015



**glTF 2.0 has PBR!**  
Cool, portable materials  
Rendering API independence  
Released June 2017



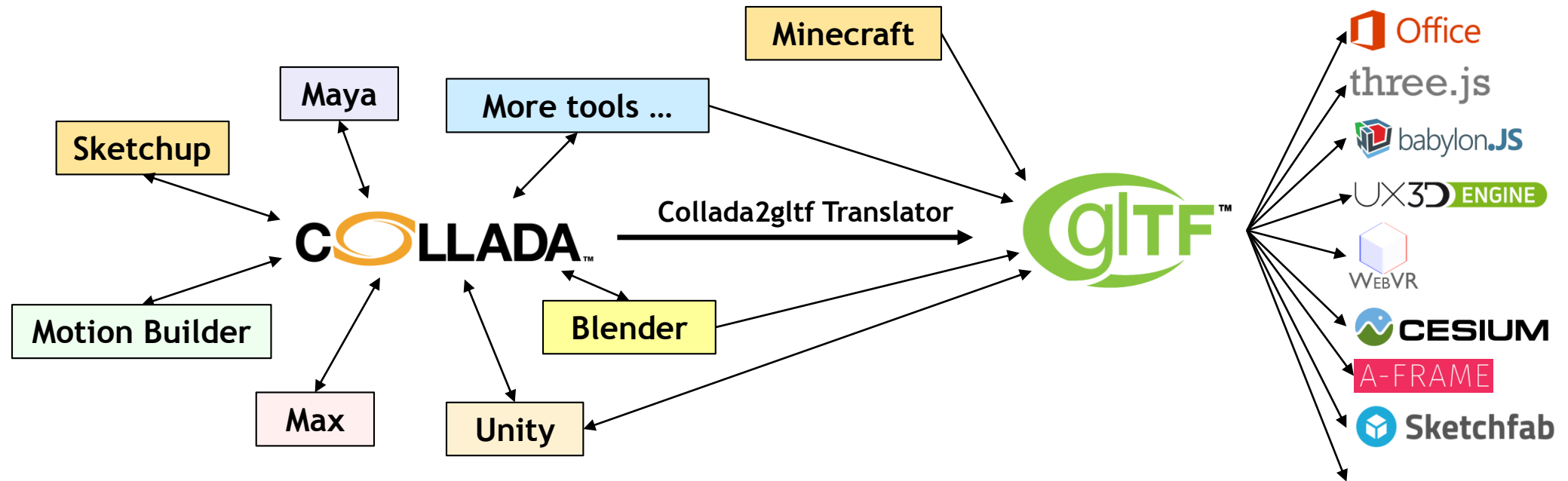
# COLLADA と glTF 3D アセット・フォーマット

## COLLADA FOR AUTHORIZING INTERCHANGE

Retains extensive data to enable editable assets to be passed between authoring tools

## glTF FOR RUN-TIME TRANSMISSION

Compact file size and efficient processing/import

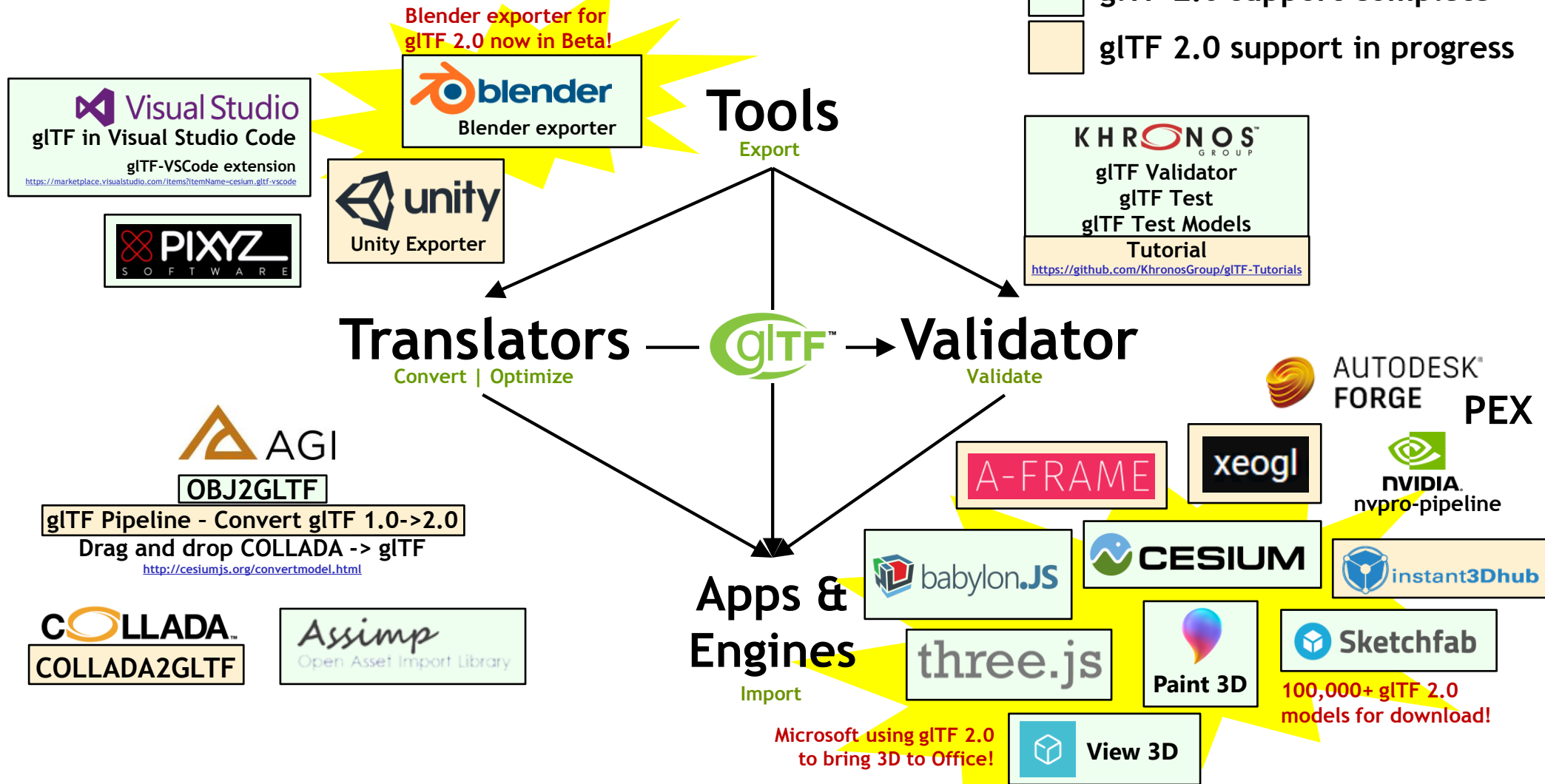


Apps and Engines  
Based on any 3D API



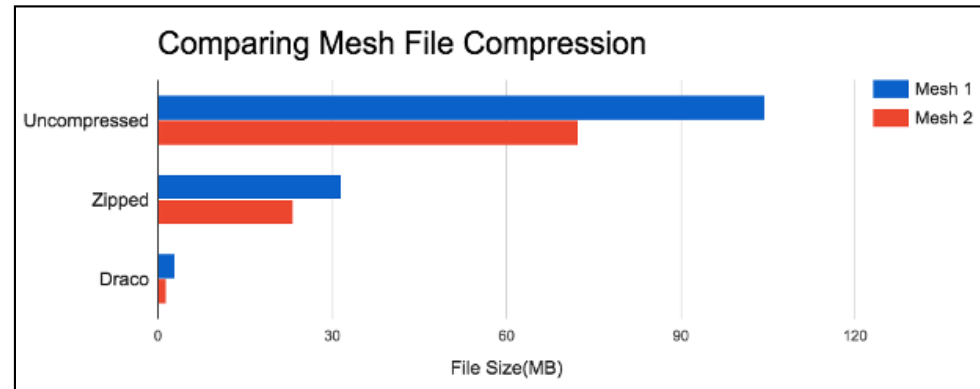
# glTF エコシステムに対する支援

- glTF 2.0 support complete
- glTF 2.0 support in progress



# Google Draco glTF エクステンション公開!

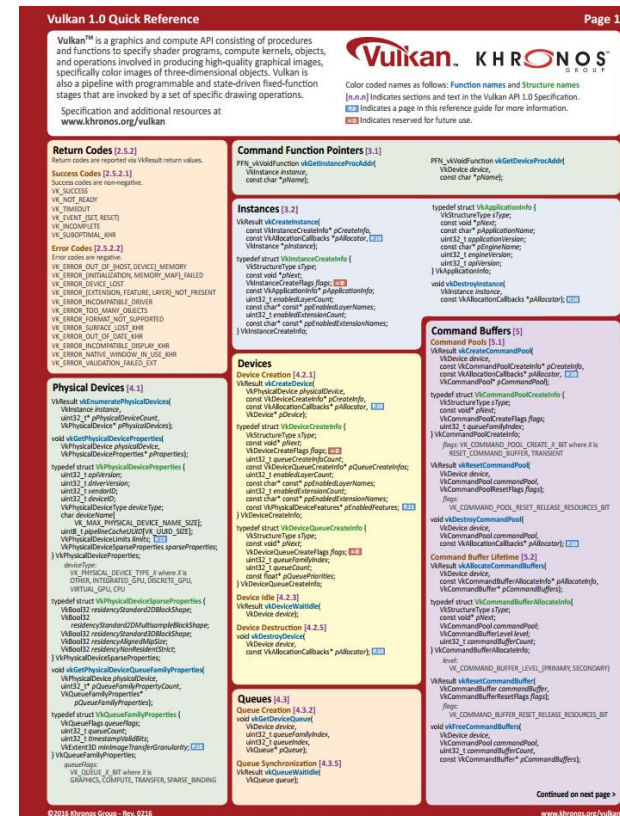
- Library for compressing and decompressing 3D geometric meshes and point clouds
  - <https://github.com/google/draco>
- Google has released Draco encoders and decoders in open source
  - C++ source code encoder to compress 3D data
  - C++ and JavaScript decoders for the encoded data
- Draco glTF extension is in progress and ready for feedback!
  - Draco designed and built for compression efficiency and speed - great fit with glTF!
  - <https://github.com/KhronosGroup/glTF/pull/874>



Typical Draco compression ratios

# ご清聴ありがとうございました!

- Vulkan エコシステムに対する貢献
  - 仕様、ツール、コンフォーマンス・レポジトリ: 全て公開
  - [www.khronos.org/vulkan/](http://www.khronos.org/vulkan/)
- 皆さまのVulkan採用製品プロモーションを支援します
  - ツール、アプリケーション、デモ
  - ご連絡先: [marketing@khronos.org](mailto:marketing@khronos.org)
- Vulkan, OpenXR, glTF など全APIの進化のために、すべての企業の皆さまからのご意見をお待ちしています。
  - [www.khronos.org](http://www.khronos.org)



<https://www.khronos.org/files/vulkan10-reference-guide.pdf>