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KHRONOS GROUP

Vulkan®

Adding Vulkan to Pixar's Hydra Storm Renderer

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Agenda

- Intro to Hydra and Storm
- Vulkan, Cross-Platform Hydra Graphics and Tooling at Autodesk
- Software rendering and LavaPipe
- Hydra Graphics Interface

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AUTODESK

"Autodesk makes software for people who design and make things"

ARCHITECTURE, ENGINEERING & CONSTRUCTION

R RVT | C C3D | N MAN | I IWX

PRODUCT DESIGN & MANUFACTURING

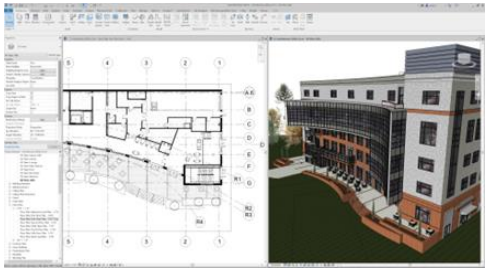
F 360 | I PRO | A CAD | V PRO

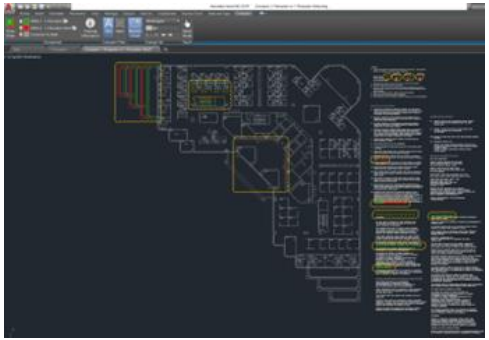
MEDIA & ENTERTAINMENT

M AYA | 3 MAX | A ARN | F FLM

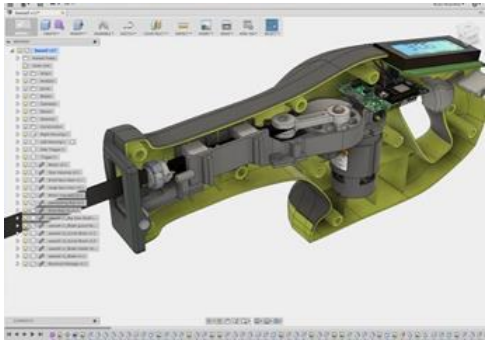
We need a wide range of graphics capabilities

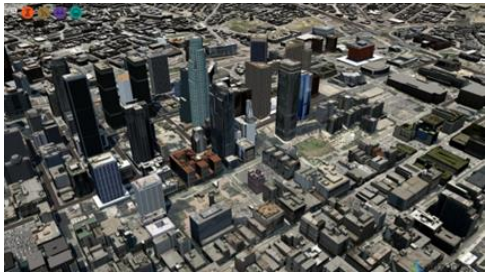
2D & Simple 3D





3D Modeling





Realistic Rendering

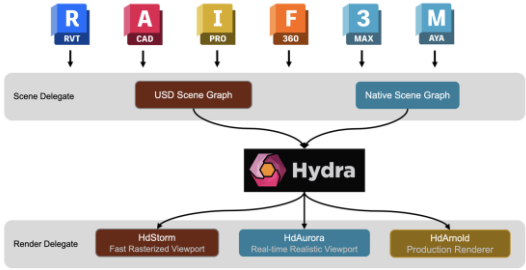
Autodesk’s Graphics Objectives

Modern APIs

Open Standards

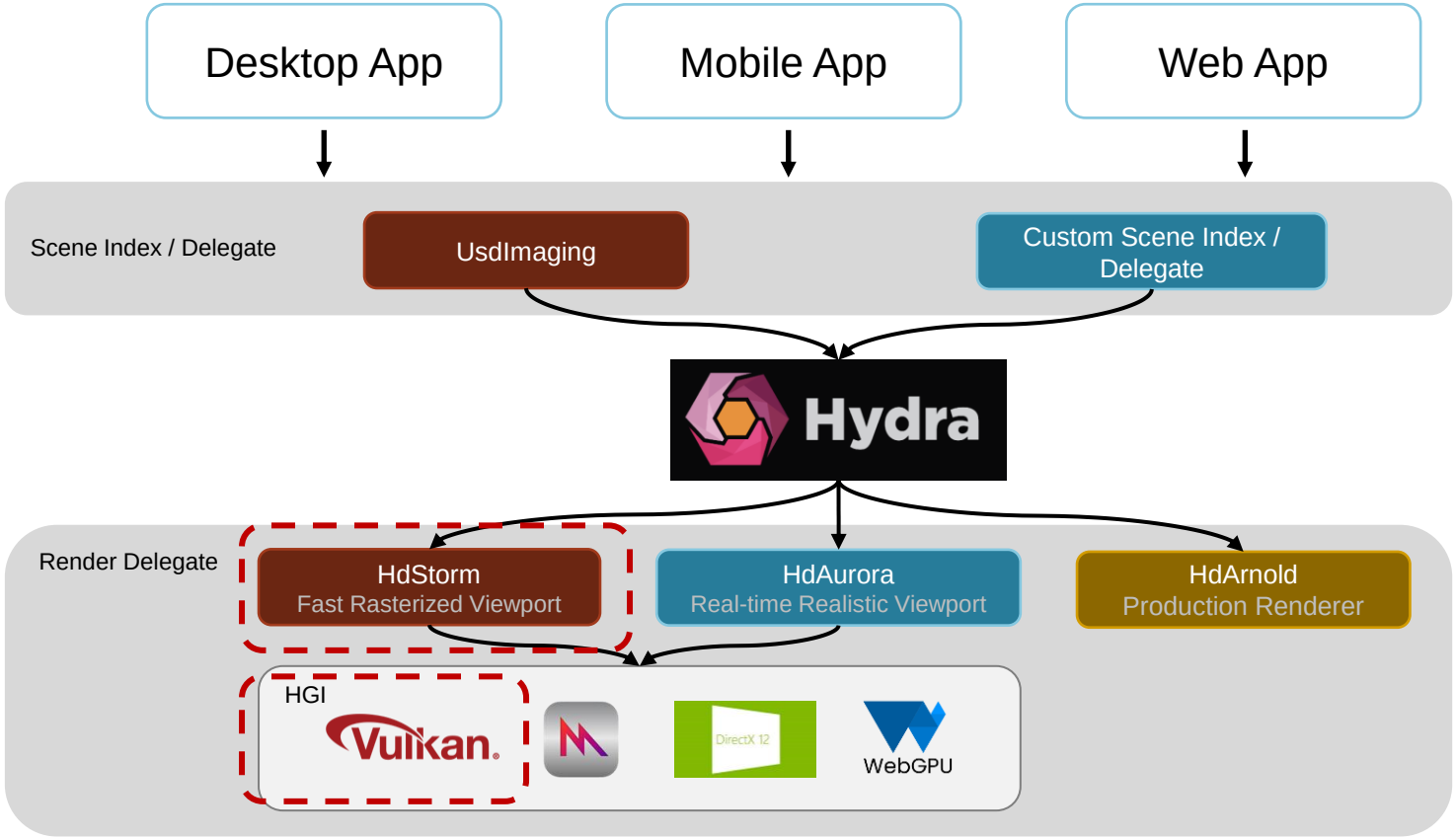
OpenPBR

Decoupled Architecture



Available on Desktop, Mobile, and Web

Hydra and Storm for Autodesk's Viewports



Aurora: An Open Source Real-time Path Tracer

- For quick design / lookdev iteration, *not final-frame production rendering*
- Vendor and platform agnostic
  - *Linux, Windows – NVIDIA, AMD, Intel*
  - *macOS/Metal (work in progress)*
- Supports Hydra, MaterialX, and Standard Surface (OpenPBR coming)
- Recent updates
  - Performance improvements (~2X)
  - OpenUSD 24.08
- 2023 Vulkan BOF presentation: *“Vulkan Ray Tracing in Aurora: An Open Source Real-Time Path Tracer”*
- **Source code:** https://github.com/Autodesk/Aurora

An Open Source, Community Approach

Contributions

OpenPBR

Communities

Collaboration

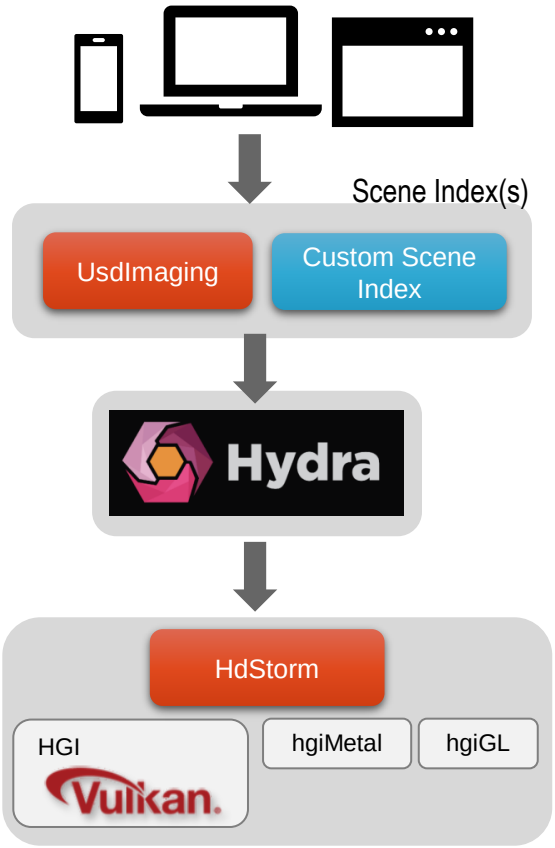
To advance the OpenUSD and Hydra ecosystem

Graphics requirements at Autodesk

- Create and Visualize large models for industry workflows
  - 2D and 3D dataset that can grow exponentially.
    - Billions of primitives (Points, Lines, Triangles, Patches).
  - Texture usage vary based on industry focus.
  - Shading requirements vary based on industry focus
    - Simple unlit to physically correct
- Cross-Platform Graphics and Visualization
  - Windows
  - Linux and Android
  - macOS and iOS
  - Web and Cloud native
  - Virtualized Environments
- Leverage NextGen Hardware capabilities and practices.

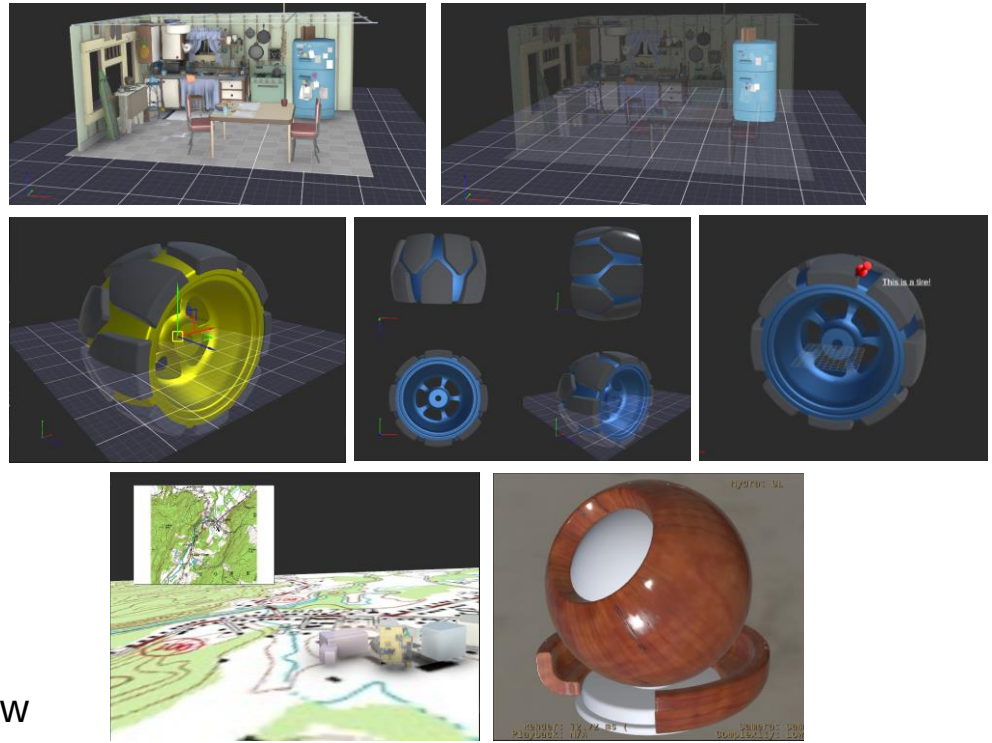
Objectives for Autodesk Graphics Platform (AGP)

- Build on OpenUSD
  - Extend Hydra Abstraction Layer
  - Enhance HdStorm renderer with capabilities for Autodesk.
- Community partnership to explore solutions together and contribute to Open-Source Projects.
- Support Large Model Viewing with HgiVulkan.
- **Production ready HgiVulkan for Autodesk products on Windows, Linux and Android.**
- Thanks to Apple for contributing macOS & iOS enhancements to hgiMetal!



Feature requirements for AGP

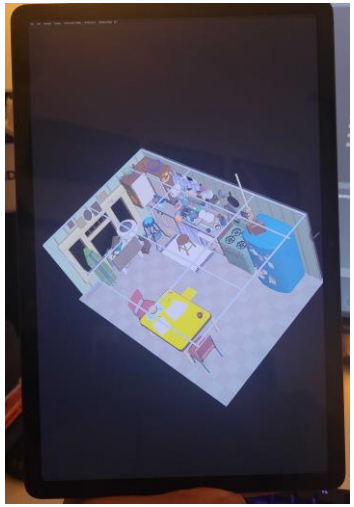
- Viewport representations
- Multiple Viewports
- Visual styles
- In-Canvas UI integration
- Materials (unlit, shaded, realistic …)
- Ray tracing
- Industry specific requirements
  - Lines, Line Styles, Text, Markups, 2D, Draw Order
  - and more...

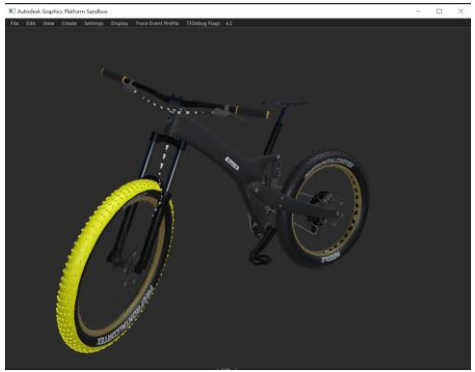


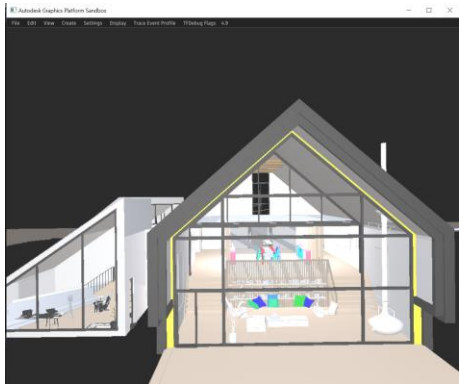
Autodesk’s Next-Generation Viewport System [S62312]
https://www.nvidia.com/gtc/sessions/openusd-day/

Current State of Vulkan in AGP

- In-house hdStorm based application for validating features.
- Capable of rendering mid to large models.
- Cross platform: Windows, Linux & Android
- Thin Vulkan layer that acquires handles from HgiVulkan.
- Composition and presentation performed in application layer.
- Provides ease of debugging and integration with analysis tools.







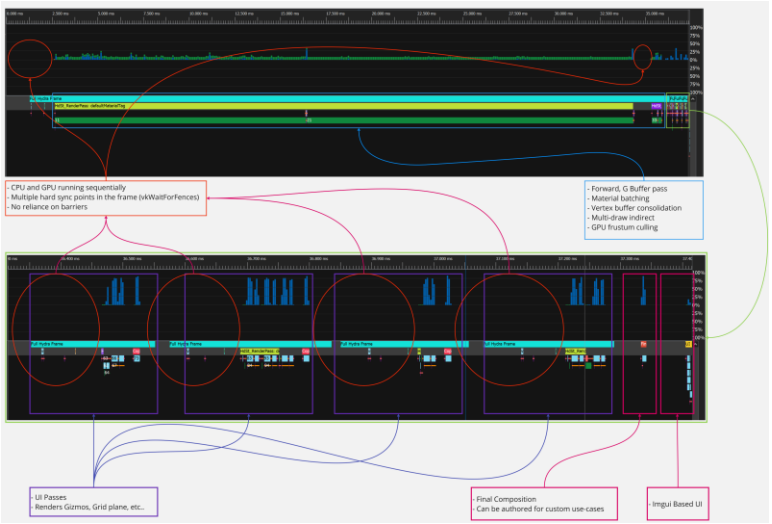
Vulkan Graphics analysis tools

Usage	Windows/Linux (desktop)	Android (Mobile)
API Validation	Vulkan Debug and Validation Layers	
Vulkan Profiler	VkTimestampQuery based profiler	
CPU + GPU Profiling (occupancy & bottleneck)	GPUView (Windows) GPUVis (Linux)	Streamline Performance Analyzer (ARM) *Snapdragon Profiler* (Qualcomm)
GPU Memory Profiling	VMA Dump VK_EXT_device_memory_report AMD Memory Visualizer	?
Playback Frame Debugger	RenderDoc NVIDIA Nsight Systems	RenderDoc & AGI (ARM) *Snapdragon Profiler* (Qualcomm)
Vendor Specific Profiler	AMD – Radeon™ GPU Profiler NVIDIA – Nsight Systems	ARM – Streamline Performance Analyzer Qualcomm – Snapdragon Profiler

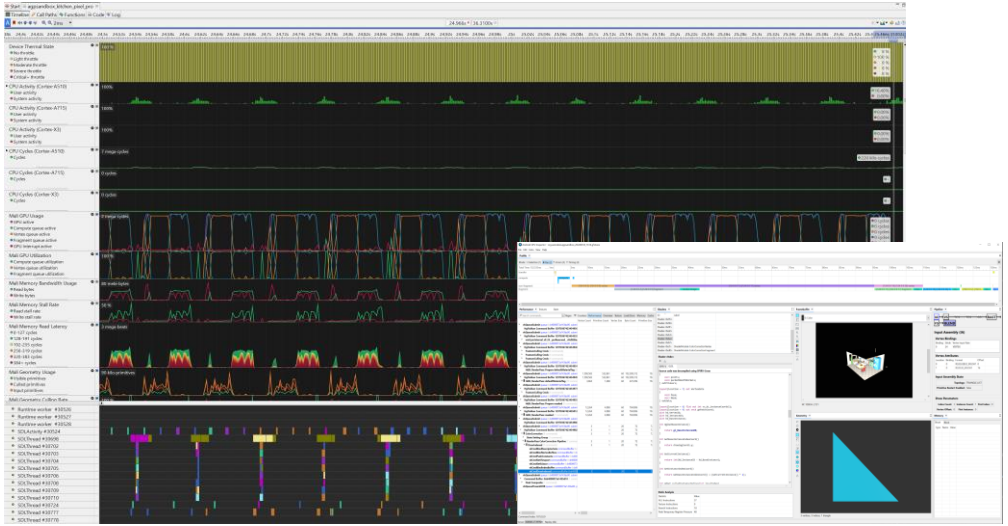
Huge thanks to all providers for excellent tooling support!

Performance challenges

Cross platform - Performance optimizations needed



Desktop



Mobile/Tablets

Strategy:

1. Collect traces, analyze and fix as needed across platforms.
2. Repeat.

Software Rasterization

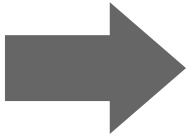
- Customers with large deployments need stable CPU fallback.
  - Reason: Driver instability, GPU feature support, sustainability, cost, business continuity etc.
- For Products: Small well scoped workloads can be executed using Software Rasterization.
- For Engineering teams: Cloud hosted environments and Cost of GPU virtualization is a limiting factor for CI and testing workflows
- For DirectX users: WARP is Natively available on Windows
  https://devblogs.microsoft.com/directx/announcing-warp-preview-with-shader-model-6-7-support/
- Lack of Stable Software Rasterization is a go-no-go deal breaker for Vulkan adoption.

Software rasterization for Vulkan

- Early evaluation with SwiftShader
- Switched to llvmpipe/LavaPipe based on community feedback
  - thank you Vulkanised 2024!!
- Worked through build challenges on Windows.
- Evaluated llvmpipe/LavaPipe using Vulkan samples
- Problem solved?

Sascha Willems (https://github.com/SaschaWillems/Vulkan)

llvmpipe/LavaPipe: HdStorm



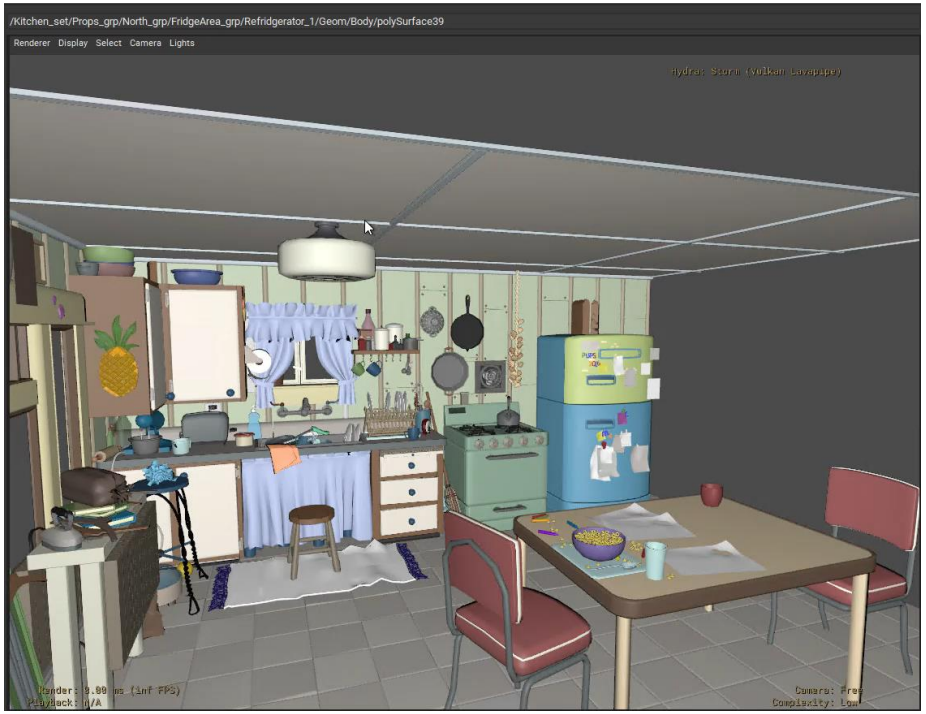
LLVM ERROR: Instruction Combining did not reach a fixpoint after 1 iterations

```
test 722
      Start 722: testUsdImagingGLBasicDrawing

722: Test command:
...
722: image diffing with ['idiff.exe', '-fail', '0.2', '-failpercent', '0.5', '-p',
'F:\\source\\USD-origin-
vulkan\\out\\relwithdebuginfo\\tests\\ctest\\testUsdImagingGLBasicDrawing\\baseline\\testUsdImag
ingGLBasicDrawing.png', 'testUsdImagingGLBasicDrawing.png']
 1/10 Test #722: testUsdImagingGLBasicDrawing ......................   Passed    5.73 sec
```

llvmpipe/LavaPipe: USDView (HdStorm)

- USDView (HdStorm – Vulkan Lavapipe)
  - Mesa 24.1.4 (2024-07-17)
  - llvmpipe (LLVM 19.0.0, 256 bits)
  - VK_PHYSICAL_DEVICE_TYPE_CPU
- Autodesk Contributions to Mesa
  (Aleksi Sapon, Autodesk)
  - Lavapipe basic macOS support
  - gallivm: Fix LLVMPipe codegen issues discovered on Apple Silicon
  - *llvmpipe: sampler matrix cache is slow because of mutex lock: 650% speedup by using RCU*



USDView with lavapipe running **headless** via Remote Desktop on Windows 11 from MacOS

llvmpipe/LavaPipe: Loader workflow

- Testing done using VK_ICD_FILENAMES override
  `e.g., SET VK_ICD_FILENAMES=%MESA_DIR%\build\install\share\vulkan\icd.d\lvp_icd.x86_64.json`

- Improve/simplify loader workflow
  e.g., from DirectX documentation
  https://learn.microsoft.com/en-us/windows/win32/api/d3d12/nf-d3d12-d3d12createdevice#examples

```
if (m_useWarpDevice){
    ComPtr<IDXGIAdapter> warpAdapter;
    factory->EnumWarpAdapter(IID_PPV_ARGS(&warpAdapter));
    D3D12CreateDevice(warpAdapter.Get(),D3D_FEATURE_LEVEL_11_0, IID_PPV_ARGS(&m_device)));
}
```

- *How may we simplify CPU fallback workflows by ensuring lvp_icd is always available?*

Next steps

- Prepare hgiVulkan for production usage
  - Specification compatibility.
  - Unit testing and coverage.
- Performance improvements
  - Improve CPU and GPU synchronization.
  - Render Graph support.
  - Optimize Vulkan usage on Desktop, Mobile (Android) and WebGPU.
  - Adopt Compute driven workflows esp. for current Geometry shader uses.
  - Occlusion Culling and HLOD integration.
- Software rasterization
  - Improve LavaPipe performance, deployment and loader.

Make Anything

Links and references

- OpenUSD homepage: https://openusd.org/
- OpenUSD GitHub: https://github.com/PixarAnimationStudios/OpenUSD
- Hydra intro: https://openusd.org/files/Siggraph2019_Hydra.pdf
- Alliance for OpenUSD: https://aousd.org/
- AOUSD Forum: https://forum.aousd.org/
- Vulkan SIGGRAPH BOF 2023 (recording on YouTube):
  - *"Vulkan and Open Source Graphics at Autodesk"*
  - *"Vulkan for Cross-Platform Viewing of Large AEC Models"*
  - *"Vulkan Ray Tracing in Aurora: An Open Source Real-Time Path Tracer"*
- Autodesk Graphics Platform team contact: agp@autodesk.com
- Hydra contributions: https://github.com/Autodesk/openusd-hydra-contributions
- Aurora source code: https://github.com/Autodesk/Aurora
- Aurora contact: aurora@autodesk.com
- Autodesk Open Source landing page: https://opensource.autodesk.com/