Make Your Game Friendly for Graphics Debugging and Optimization

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AGENDA

- Introduction
- Basics
- Advanced
- Conclusion

Introduction

Iteration time is critically important

Good engine is not about awesome renderer.
It's about tools – like convenient editor.

- Shorter iteration time
- Good tools

Everyone benefits

Easier to search for bugs and performance optimizations – benefit for:

- developers
- QA
- external partners

Part 1

Basics

Options (1)

Provide configuration options:

- resolution
- display mode: Windowed / Borderless / Exclusive fullscreen
- V-sync On/Off

Options (2)

- texture resolution: important for GPUs with little memory
- texture filtering quality (linear vs anisotropic): impacts performance
- MSAA Disabled/2x/4x/…

- (extra) resolution scaling

Ways to provide options

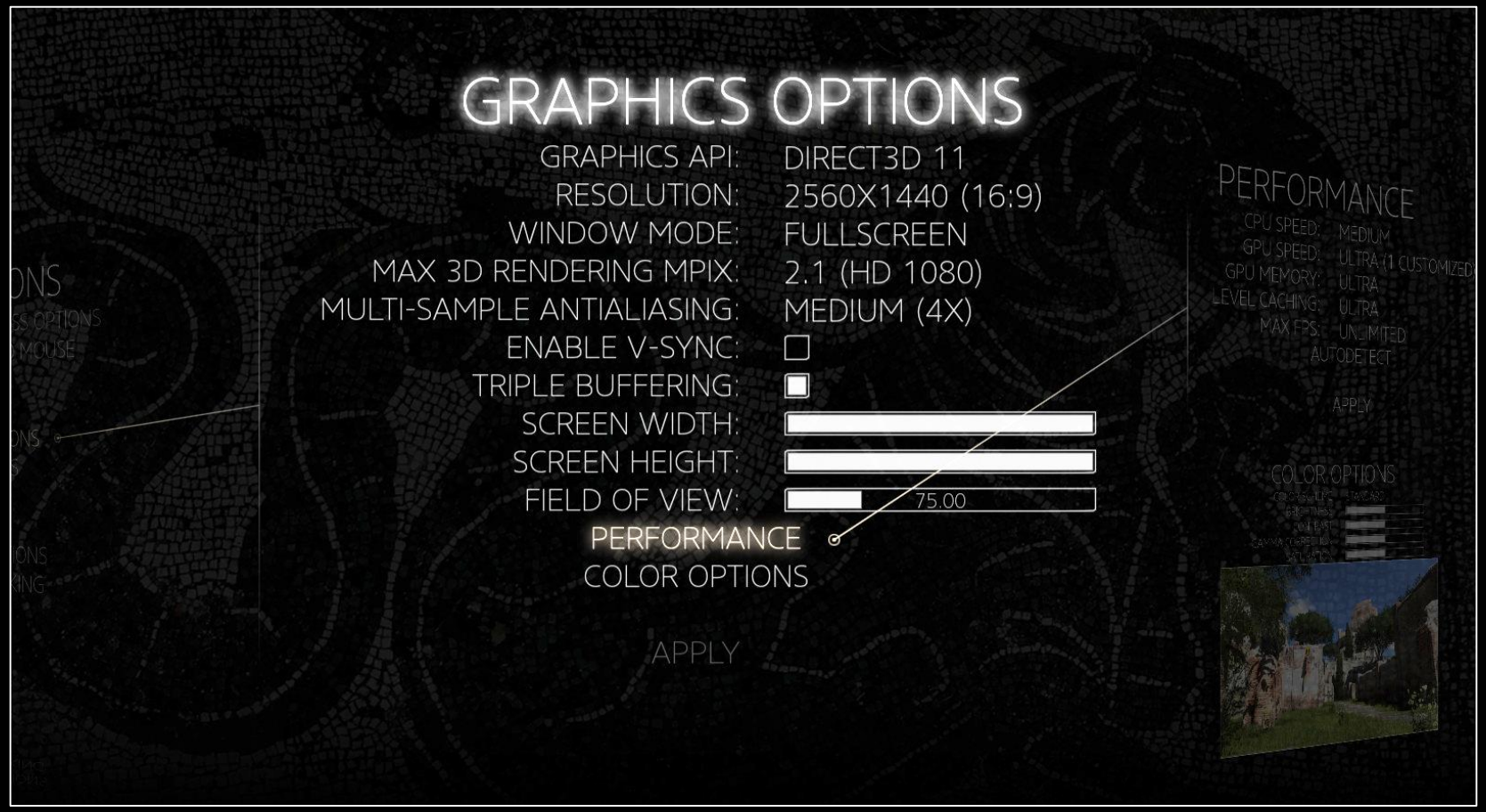
Some may be visible to end users.

- in-game menu
- launcher window (e.g. Unity) or separate app

Some may be hidden.

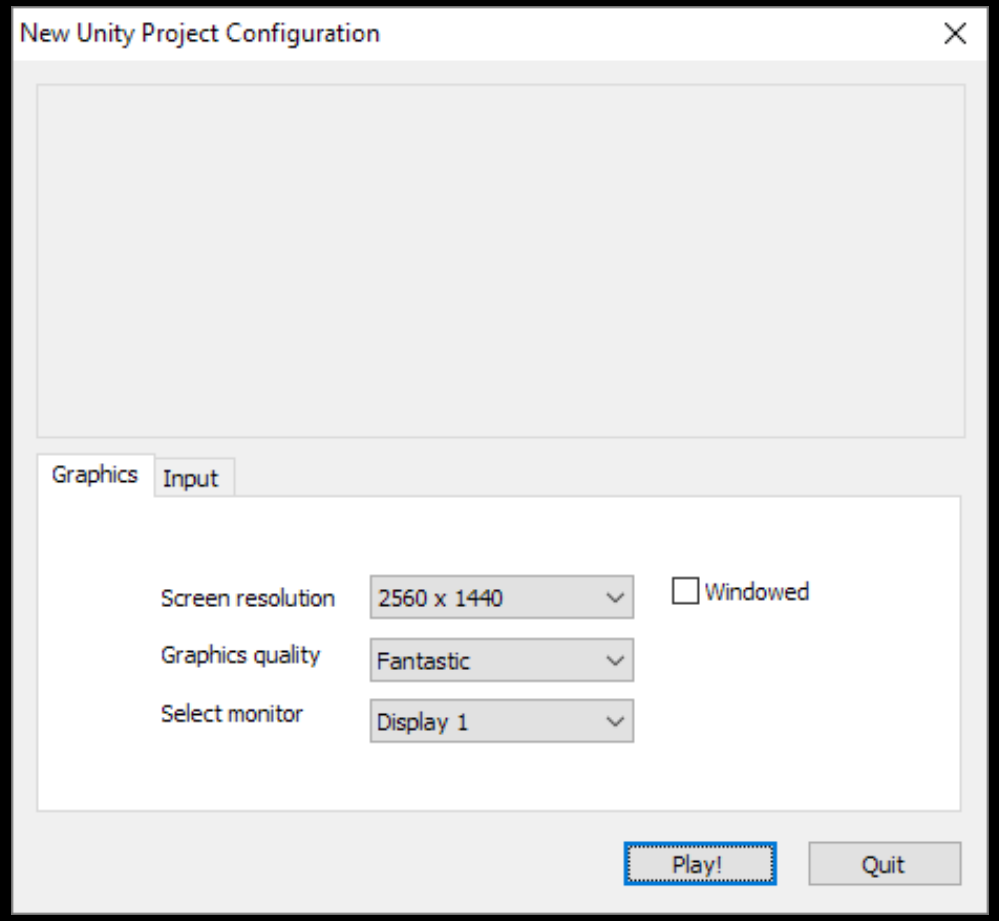
- in-game developer/cheat panel
- in-game console (e.g. Unreal Engine)
- command line options
- configuration file, Windows registry

Options



The Talos Principle – in-game options

Options

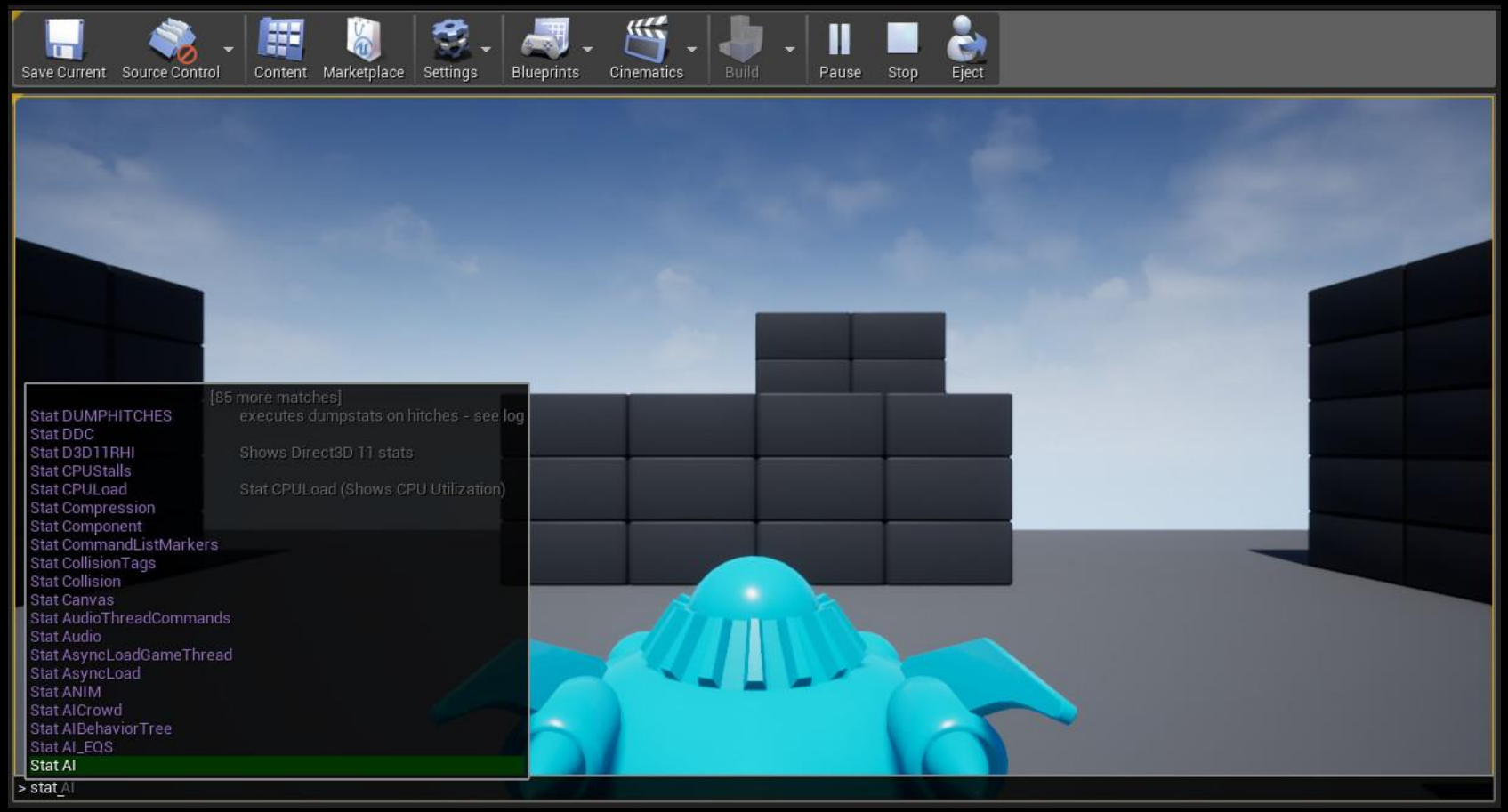


Unity launcher window

Options

War Thunder – custom launcher app

Options



Unreal Engine – in-game console

Options (3)

Effects On/Off/quality level:

- user-facing
  - number of objects (e.g. grass distance)
  - shader complexity (e.g. water quality)

Options (4)

Effects On/Off/quality level:

- internal
  - CPU workloads
  - Graphics
  - GPU compute

Optimizations On/Off

Correctness/stability

“Safe mode”

- single threaded
- D3D12, Vulkan®: additional synchronization
- useful for debugging visual corruptions and GPU crashes (TDR)

Developer Game Build

- works as standalone EXE (without Steam, no UWP)
- works offline, no connection to server required
  - Server often down or incompatible during development.
  - Users may be behind restrictive firewall/VPN.
- no DRM/anti-cheat/anti-piracy protection (like Denuvo)

- Provide documentation of available settings, cheats, god mode.
- Provide saves for various locations.

Loading Time

Short loading time is critical.

- simple test scene with just few objects
- loading production scene should still be fast
- performance of debug build also important

Benchmark Mode

- automated testing (continuous integration)
  - correctness
  - performance
- manual testing
  - your developers
  - QA

[van Valburg]

Benchmark Mode

- launched with special command line parameter
- non-interactive – scripted camera flythrough
- representative scene
  - graphics
  - gameplay logic?
- deterministic
  - every run calculates and shows the same

Extra:

- ends automatically
- measures performance, writes results to text file

```
minfps=27.7
avgfps=30.8
score=1882
```

Part 2

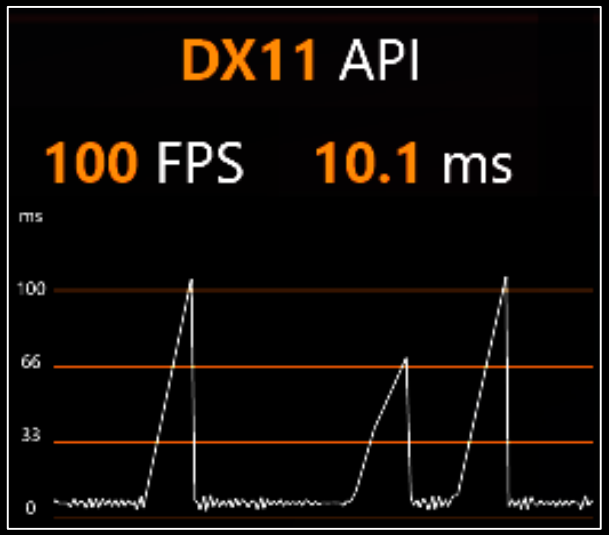
Advanced

Beware! Code ahead.

In-Game Profiler

- FPS and average frame time
- detailed counters – time of render passes

If not available, you can measure frame times with OCAT. [OCAT]

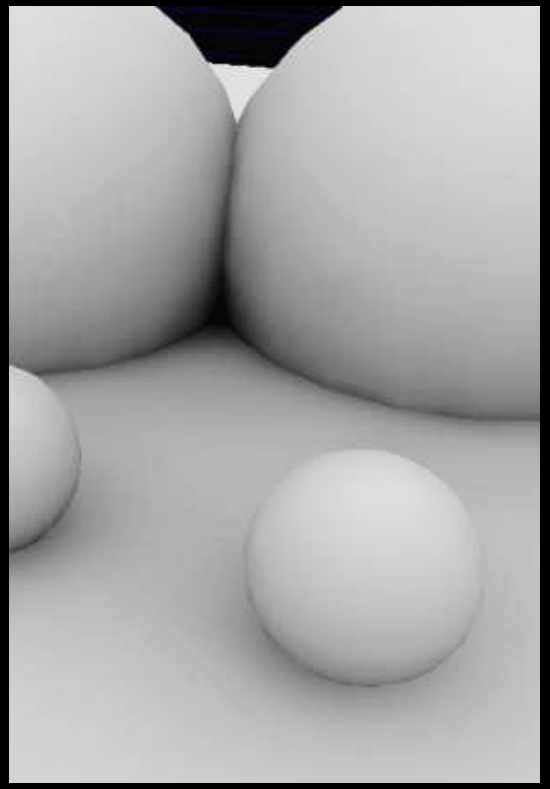


FPS and beyond

- Statistical measures – avg, min, max, percentile (1%, 99%)
- Catch spikes
- Draw frame histogram

In-Game Tools

Debug modes for visualization of intermediate data e.g. ambient occlusion only.



Source: docs.unrealengine.com

- Pixel inspector window
- Way to distinguish NaN, INF from 0, 1

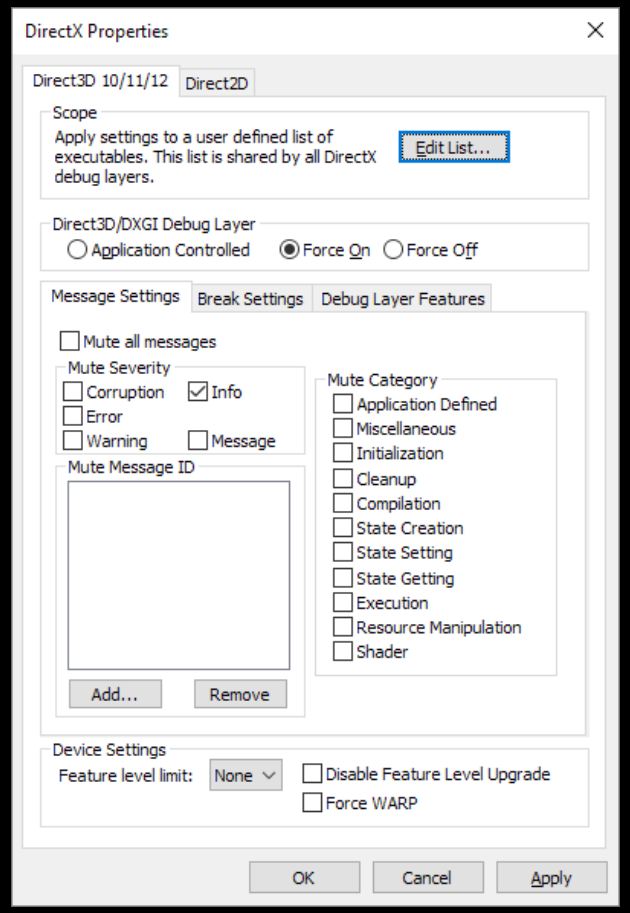
Debug/Validation Layers

- Old APIs (Direct3D 9, OpenGL®): any function can return error.

- New APIs (Direct3D 11, 12, Vulkan®): no error checking.
- Debug/validation layer can be explicitly enabled.

- Use them in regular testing.
- Require to pass on all APIs.

Debug Layer – Direct3D 11, 12

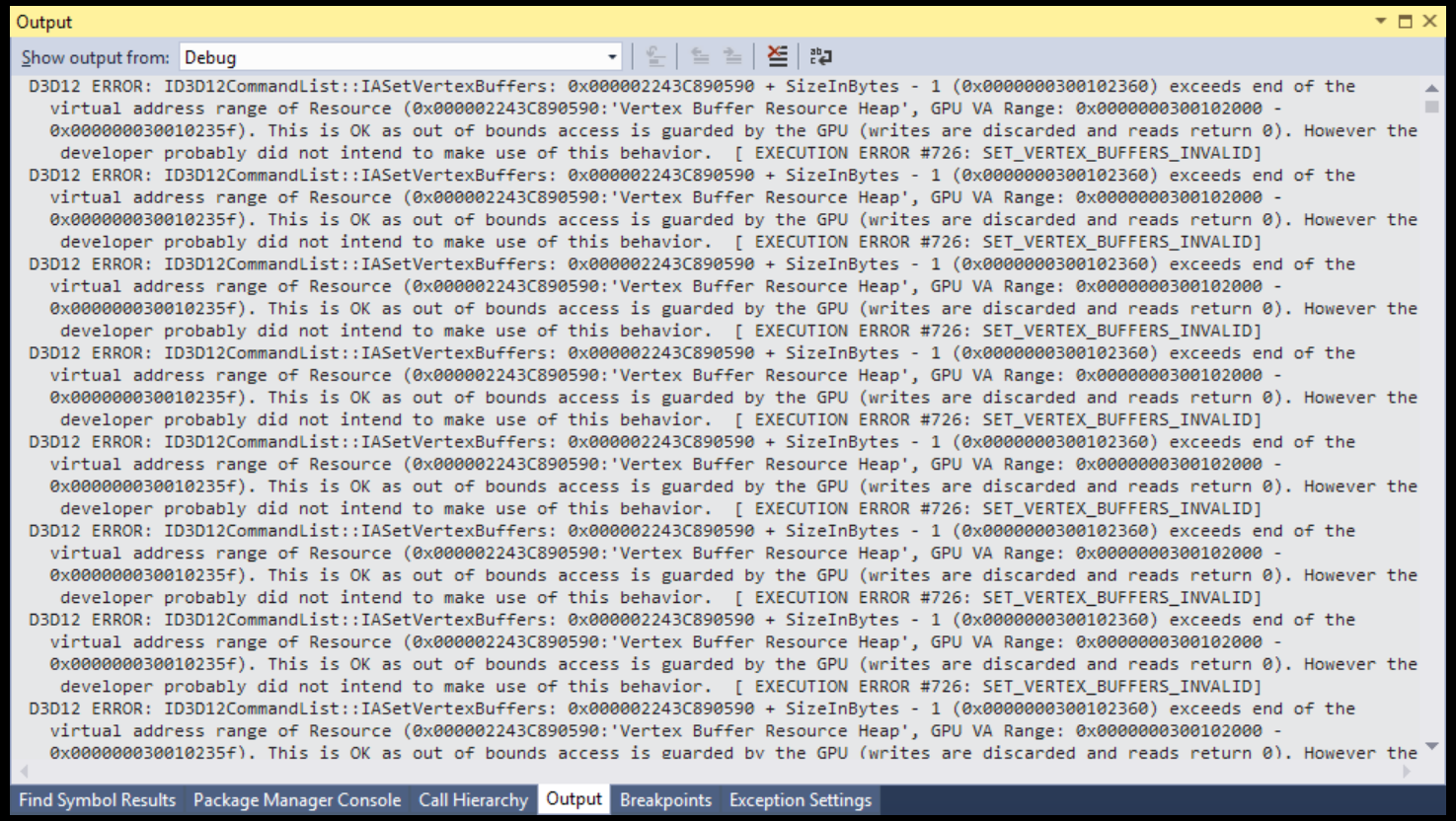


dxcpl

```
D3D11_CREATE_DEVICE_DEBUG
```

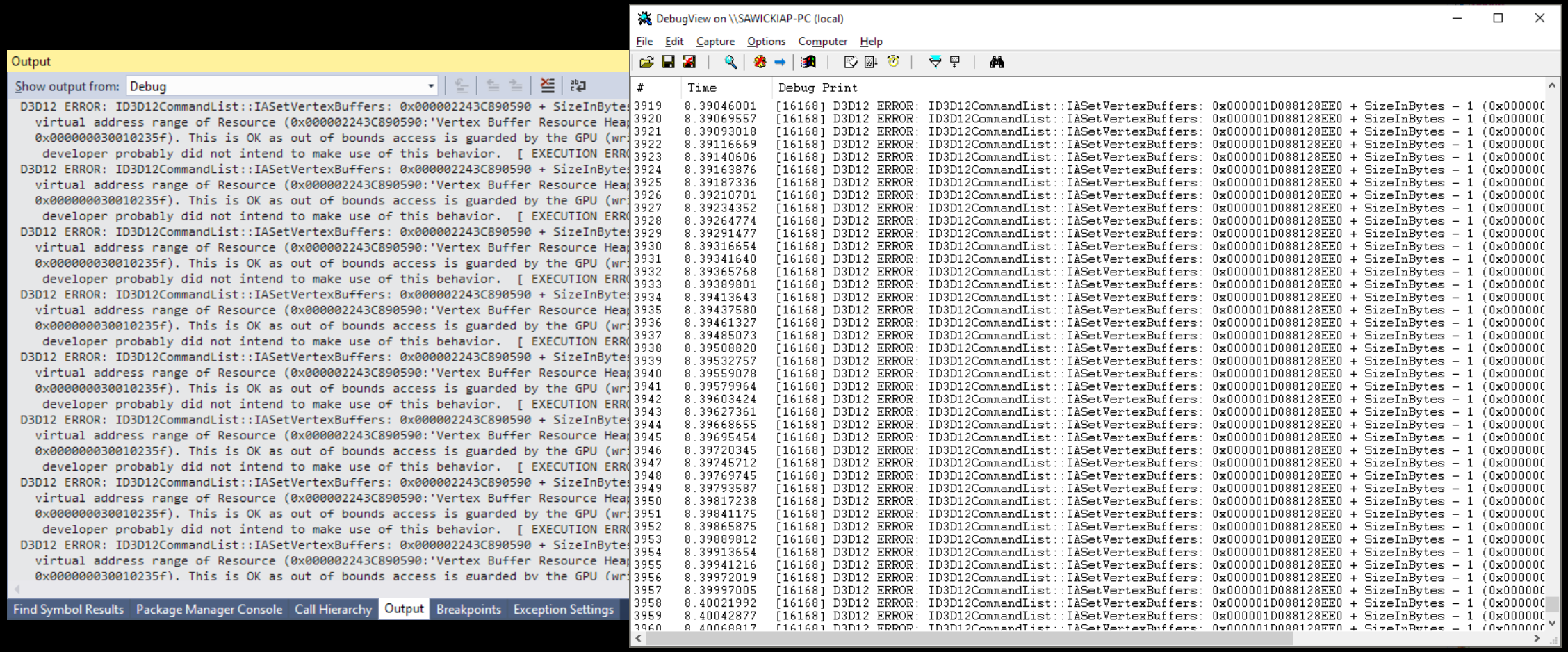
```
CComPtr<ID3D12Debug> debug;
if(SUCCEEDED(D3D12GetDebugInterface(
    IID_PPV_ARGS(&debug))))
    debug->EnableDebugLayer();
```

Debug Layer – Direct3D



Visual Studio – Output

Debug Layer – Direct3D



DebugView from SysInternals

Validation Layers – Vulkan®

VK_LAYER_LUNARG_standard_validation

- enable programmatically or
- `set VK_INSTANCE_LAYERS=VK_LAYER_LUNARG_standard_validation`

- messages delivered as callback

Driver Bug?

OGL, D3D11:

- driver handling complex logic
- crashes not expected – if crashed, driver bug very likely

Vulkan®, D3D12:

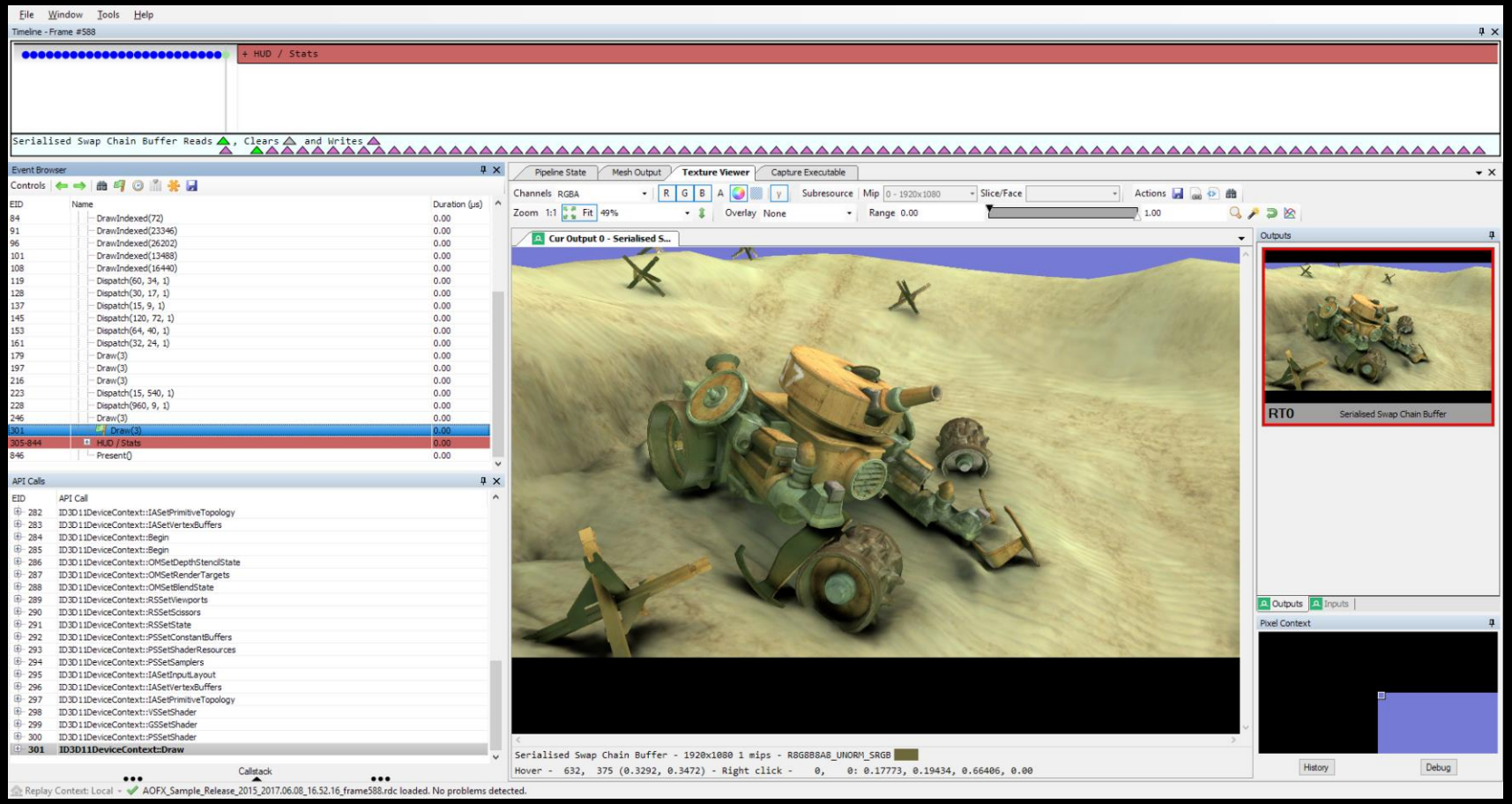
- game/engine responsible for most logic
- API is low level, driver is thin
- if crashing, most likely your bug

GPU-Assisted Validation

- Available in Vulkan (“GPU-assisted validation”) and Direct3D 12 (“GPU-based validation”).
- Enabled programmatically or externally.
- Injects additional code to shaders.

- Finds bugs in dynamic resource indexing - useful for “bindless”.

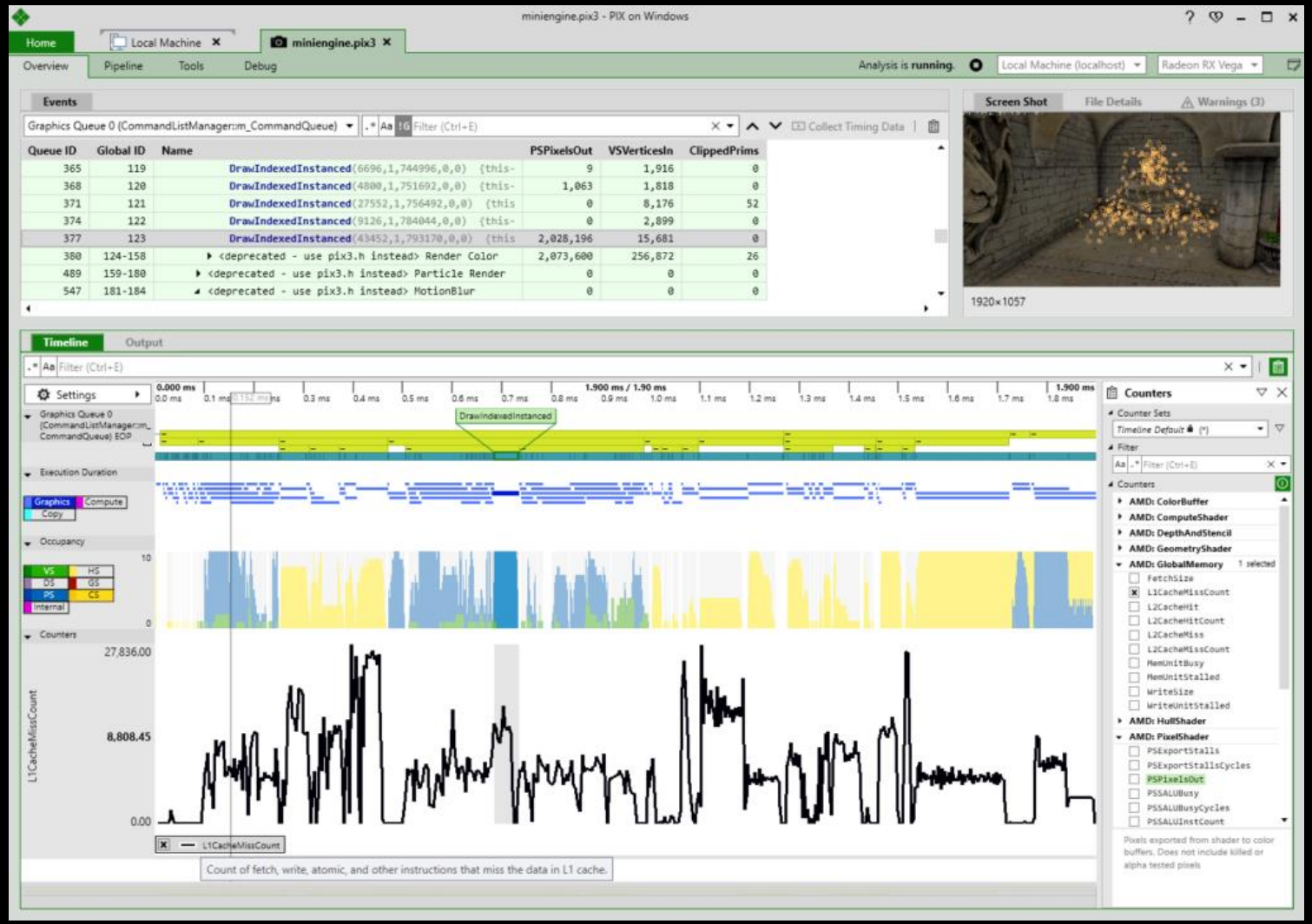
Tools – RenderDoc



[RenderDoc]

Alternatives: Nvidia® Nsight™, Intel® Graphics Performance Analyzers (GPA)

Tools – PIX

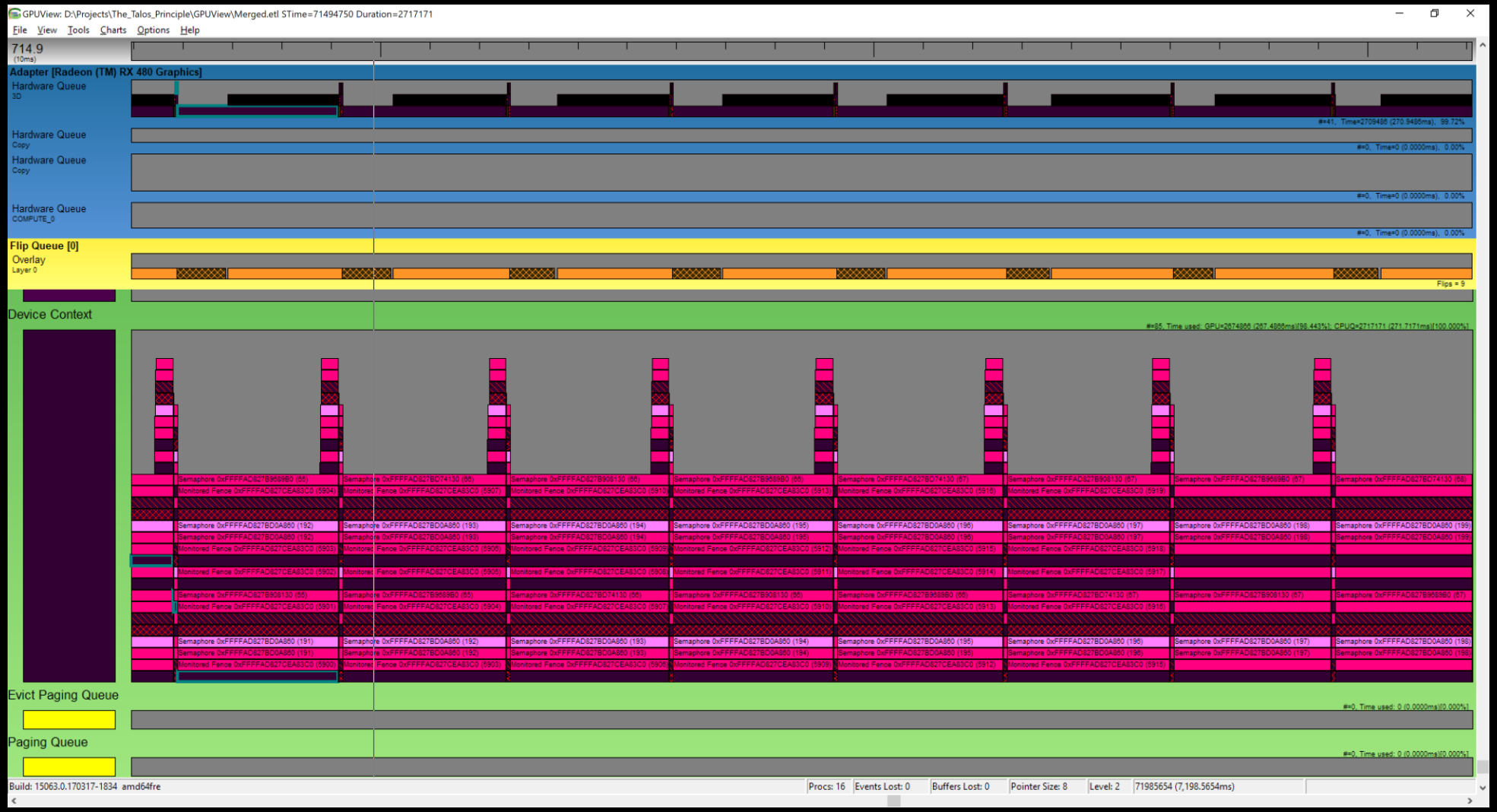


[PIX]

Tools – Radeon GPU Profiler

[RGP]

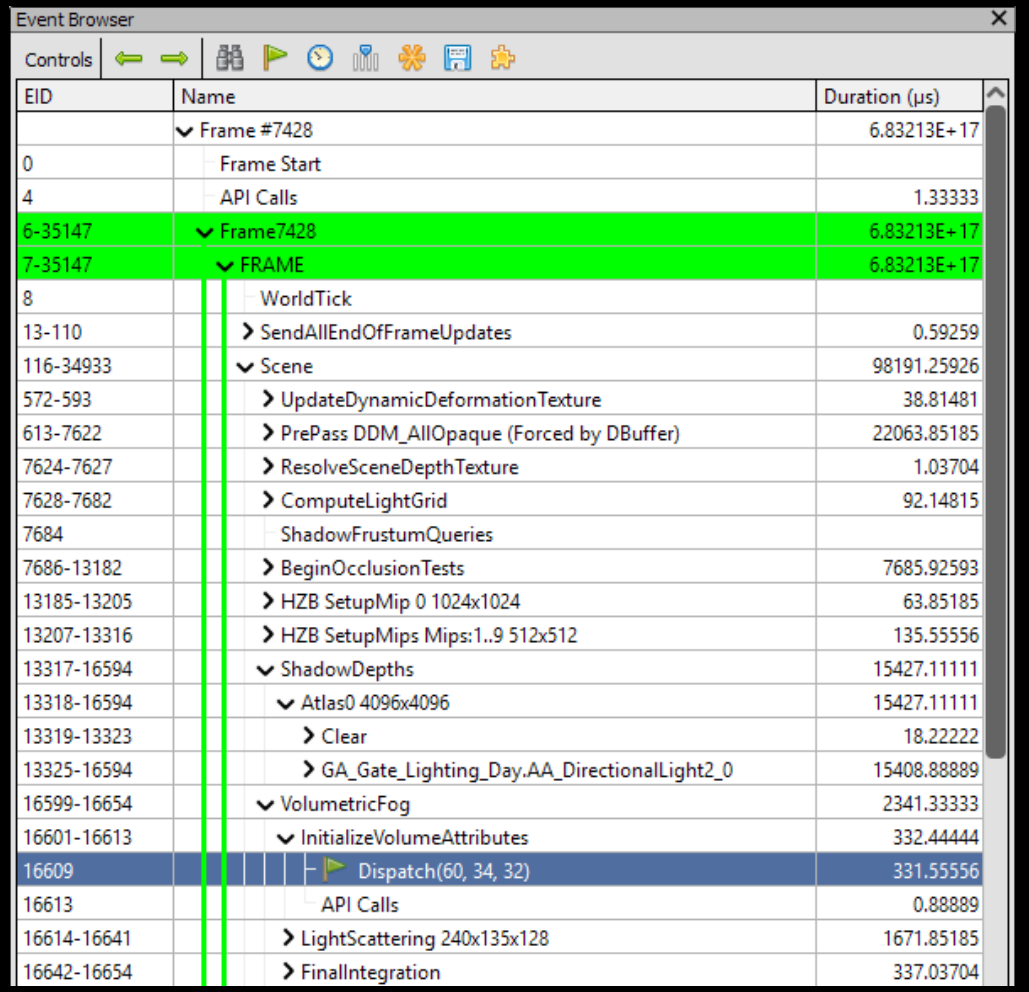
Tools – GPUView



[GPUView]

Debug Markers

- Aka “labels”, “annotations”
- Wrap passes with Begin…End markers with custom names.
- Give names to resources.
- Supported by many tools.



Debug Markers

- D3D9+: D3DPERF_BeginEvent(), D3DPERF_EndEvent()
- D3D11.1+: ID3DUserDefinedAnnotation::BeginEvent(), EndEvent()
- Vulkan®: VK_EXT_debug_utils
  - previously: VK_EXT_debug_marker

Debugging GPU crash/hang

Crash/hang of driver/GPU doesn’t crash whole system.

- Handled by Timeout Detection & Recovery (TDR).

`VK_ERROR_DEVICE_LOST`

`DXGI_ERROR_DEVICE_REMOVED`

Difficult to debug.

Debugging GPU crash/hang

- Solution: markers written on GPU between draw calls.
- After crash: inspect last written value, deduce culprit draw call.

- Vulkan®: vkCmdFillBuffer()
- Vulkan® + AMD: VK_AMD_buffer_marker
- D3D12: ID3D12GraphicsCommandList2:: WriteBufferImmediate()
- D3D12 + AMD: breadcrumb markers in AGS [AGS]
- D3D11/D3D12 + NVIDIA: NVIDIA Aftermath [Aftermath]

Debugging GPU crash/hang

Heavyweight solution: record each draw call state to a blob.

- Support serialized states and draw calls.
- Recreate state, reproduce the crash.
- Even better: record command buffers.

Conclusion

Good Practices

- first stability, then correctness, then performance

- test early, test often
- test on various GPUs
  - AMD, NVIDIA, Intel
  - low-end, high-end

- track regressions

Conclusion

- Good tools and short iterations time is important.
- Ensure them with:
  - development practices
  - your code
  - external tools
- Everyone benefits ☺

References

- [van Valburg] Automated testing for Call of Duty, Jan van Valburg (Activision), Digital Dragons 2018
  - https://www.youtube.com/watch?v=6OVFbLnIFR4
- [OCAT] The Open Capture and Analytics Tool
  - https://github.com/GPUOpen-Tools/OCAT
- [AGS] AMD GPU Services (AGS)
  - https://gpuopen.com/gaming-product/amd-gpu-services-ags-library/
- [Aftermath] NVIDIA Aftermath
  - https://developer.nvidia.com/nvidia-aftermath
- [RenderDoc] RenderDoc
  - http://renderdoc.org/
- [PIX] PIX on Windows
  - https://devblogs.microsoft.com/pix/
- [RGP] Radeon GPU Profiler
  - https://gpuopen.com/gaming-product/radeon-gpu-profiler-rgp/
- [GPUView] GPUView
  - https://graphics.stanford.edu/~mdfisher/GPUView.html

QUESTIONS?

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