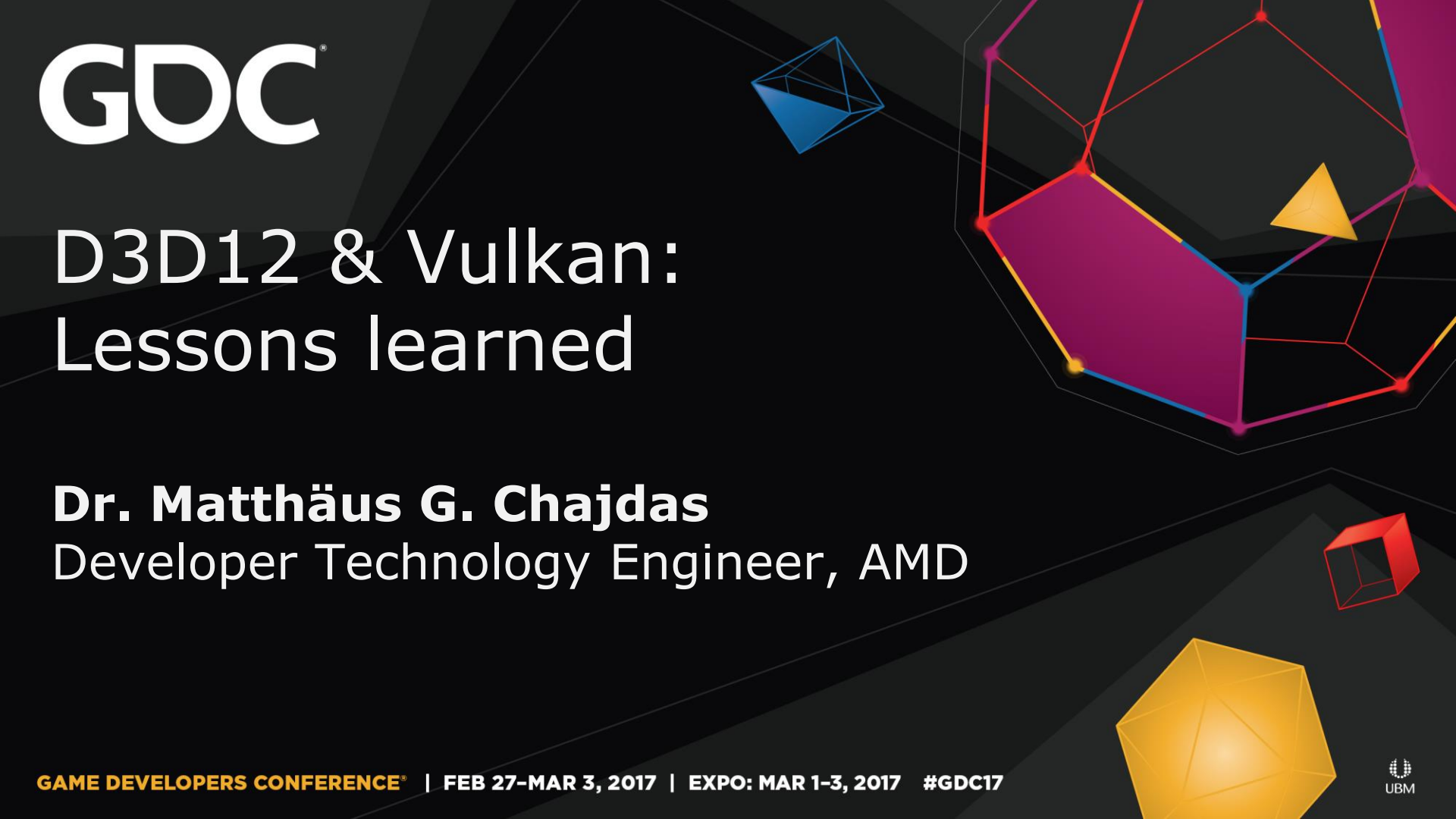


D3D12 & Vulkan: Lessons learned

Dr. Matthäus G. Chajdas
Developer Technology Engineer, AMD

D3D12 – What's new?

- DXIL
- DXGI & UWP updates
- Root Signature 1.1
- Shader cache
- GPU validation
- PIX

D3D12 / DXIL

- DXBC gets replaced by DXIL
- Language based on LLVM IR
- New open-source frontend based on Clang (**dxc**)

D3D12 / DXIL

```
float4 PSMain(PSInput input) : SV_TARGET
{
        return input.color;
}
```

```
define void @PSMain() {
  %1 = call float @dx.op.loadInput.f32(i32 4, i32 1, i32 0, i8 0, i32 undef)
    ; LoadInput(inputSigId,rowIndex,colIndex,gsVertexAxis)
  %2 = call float @dx.op.loadInput.f32(i32 4, i32 1, i32 0, i8 1, i32 undef)
    ; LoadInput(inputSigId,rowIndex,colIndex,gsVertexAxis)
  %3 = call float @dx.op.loadInput.f32(i32 4, i32 1, i32 0, i8 2, i32 undef)
    ; LoadInput(inputSigId,rowIndex,colIndex,gsVertexAxis)
  %4 = call float @dx.op.loadInput.f32(i32 4, i32 1, i32 0, i8 3, i32 undef)
    ; LoadInput(inputSigId,rowIndex,colIndex,gsVertexAxis)
  call void @dx.op.storeOutput.f32(i32 5, i32 0, i32 0, i8 0, float %1)
    ; StoreOutput(outputtSigId,rowIndex,colIndex,value)
  call void @dx.op.storeOutput.f32(i32 5, i32 0, i32 0, i8 1, float %2)
    ; StoreOutput(outputtSigId,rowIndex,colIndex,value)
  call void @dx.op.storeOutput.f32(i32 5, i32 0, i32 0, i8 2, float %3)
    ; StoreOutput(outputtSigId,rowIndex,colIndex,value)
  call void @dx.op.storeOutput.f32(i32 5, i32 0, i32 0, i8 3, float %4)
    ; StoreOutput(outputtSigId,rowIndex,colIndex,value)
  ret void
}
```

D3D12 / Updated DXGI

- First-class support for variable refresh rate displays - *-Sync
- HDR support

D3D12 / UWP

- Lots of the initial UWP limitations have been lifted
- Capabilities now on par with normal Win32

D3D12 / Root Signature 1.1

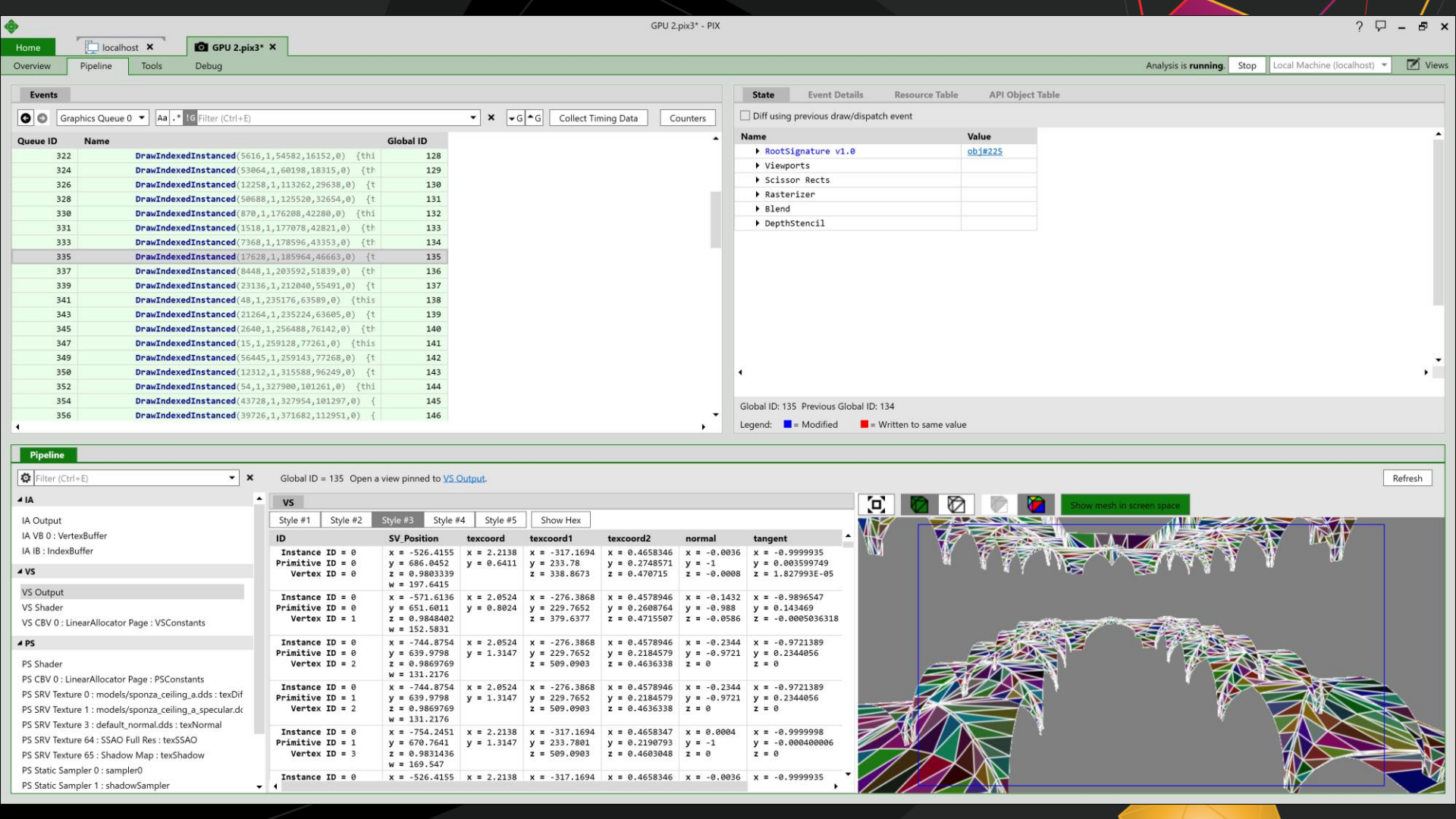
- Allows you to tell the driver that descriptors won’t change
- Can allow some optimizations in the future
- Nice to have, but nothing critical

D3D12 / Shader cache

- The shader cache was not sufficient in D3D12 RTM
- Big improvements in the “Anniversary” edition – now usable
- Note: Drivers may have yet another shader cache!

D3D12 / GPU validation

- Checks descriptors at draw time
- Discovers various hard-to-find bugs (stale descriptors, etc.)
- Rather slow - run over night for regression testing


GPU 2.pix3* - PIX
Home
localhost
GPU 2.pix3*
Overview
Pipeline
Tools
Debug
Analysis is running.
Stop
Local Machine (localhost)
Views
Events
Graphics Queue 0
Filter (Ctrl+E)
Collect Timing Data
Counters
Queue ID
Name
Global ID
322 DrawIndexedInstanced(5616,1,54582,16152,0) {thi 128
324 DrawIndexedInstanced(53064,1,60198,18315,0) {th 129
326 DrawIndexedInstanced(12258,1,113262,29638,0) {t 130
328 DrawIndexedInstanced(50688,1,125520,32654,0) {t 131
330 DrawIndexedInstanced(870,1,176208,42280,0) {thi 132
331 DrawIndexedInstanced(1518,1,177078,42821,0) {th 133
333 DrawIndexedInstanced(7368,1,178596,43353,0) {th 134
335 DrawIndexedInstanced(17628,1,185964,46663,0) {t 135
337 DrawIndexedInstanced(8448,1,203592,51839,0) {th 136
339 DrawIndexedInstanced(23136,1,212040,55491,0) {t 137
341 DrawIndexedInstanced(48,1,235176,63589,0) {this 138
343 DrawIndexedInstanced(21264,1,235224,63605,0) {t 139
345 DrawIndexedInstanced(2640,1,256488,76142,0) {th 140
347 DrawIndexedInstanced(15,1,259128,77261,0) {this 141
349 DrawIndexedInstanced(56445,1,259143,77268,0) {t 142
350 DrawIndexedInstanced(12312,1,315588,96249,0) {t 143
352 DrawIndexedInstanced(54,1,327900,101261,0) {thi 144
354 DrawIndexedInstanced(43728,1,327954,101297,0) { 145
356 DrawIndexedInstanced(39726,1,371682,112951,0) { 146
State
Event Details
Resource Table
API Object Table
Diff using previous draw/dispatch event
Name
Value
RootSignature v1.0
obj#225
Viewports
Scissor Rects
Rasterizer
Blend
DepthStencil
Global ID: 135 Previous Global ID: 134
Legend: = Modified = Written to same value
Pipeline
Filter (Ctrl+E)
Global ID = 135 Open a view pinned to VS Output.
Refresh
IA
IA Output
IA VB 0 : VertexBuffer
IA IB : IndexBuffer
VS
VS Output
VS Shader
VS CBV 0 : LinearAllocator Page : VSConstants
PS
PS Shader
PS CBV 0 : LinearAllocator Page : PSConstants
PS SRV Texture 0 : models/sponza_ceiling_a.dds : texDif
PS SRV Texture 1 : models/sponza_ceiling_a_specular.dc
PS SRV Texture 3 : default_normal.dds : texNormal
PS SRV Texture 64 : SSAO Full Res : texSSAO
PS SRV Texture 65 : Shadow Map : texShadow
PS Static Sampler 0 : sampler0
PS Static Sampler 1 : shadowSampler
VS
Style #1
Style #2
Style #3
Style #4
Style #5
Show Hex
ID
SV_Position
texcoord
texcoord1
texcoord2
normal
tangent
Instance ID = 0 Primitive ID = 0 Vertex ID = 0 x = -526.4155 y = 686.0452 z = 0.9803339 w = 197.6415 x = 2.2138 y = 0.6411 x = -317.1694 y = 233.78 z = 338.8673 x = 0.4658346 y = 0.2748571 z = 0.470715 x = -0.0036 y = -1 z = -0.0008 x = -0.9999935 y = 0.003599749 z = 1.827993E-05
Instance ID = 0 Primitive ID = 0 Vertex ID = 1 x = -571.6136 y = 651.6011 z = 0.9848402 w = 152.5831 x = 2.0524 y = 0.8024 x = -276.3868 y = 229.7652 z = 379.6377 x = 0.4578946 y = 0.2608764 z = 0.4715507 x = -0.1432 y = -0.988 z = -0.0586 x = -0.9896547 y = 0.143469 z = -0.0005036318
Instance ID = 0 Primitive ID = 0 Vertex ID = 2 x = -744.8754 y = 639.9798 z = 0.9869769 w = 131.2176 x = 2.0524 y = 1.3147 x = -276.3868 y = 229.7652 z = 509.0903 x = 0.4578946 y = 0.2184579 z = 0.4636338 x = -0.2344 y = -0.9721 z = 0 x = -0.9721389 y = 0.2344056 z = 0
Instance ID = 0 Primitive ID = 1 Vertex ID = 2 x = -744.8754 y = 639.9798 z = 0.9869769 w = 131.2176 x = 2.0524 y = 1.3147 x = -276.3868 y = 229.7652 z = 509.0903 x = 0.4578946 y = 0.2184579 z = 0.4636338 x = -0.2344 y = -0.9721 z = 0 x = -0.9721389 y = 0.2344056 z = 0
Instance ID = 0 Primitive ID = 1 Vertex ID = 3 x = -754.2451 y = 670.7641 z = 0.9831436 w = 169.547 x = 2.2138 y = 1.3147 x = -317.1694 y = 233.7801 z = 509.0903 x = 0.4658347 y = 0.2190793 z = 0.4603048 x = 0.0004 y = -1 z = 0 x = -0.9999998 y = -0.000400006 z = 0
Instance ID = 0 x = -526.4155 x = 2.2138 x = -317.1694 x = 0.4658346 x = -0.0036 x = -0.9999935
Show mesh in screen space

D3D12 / PIX

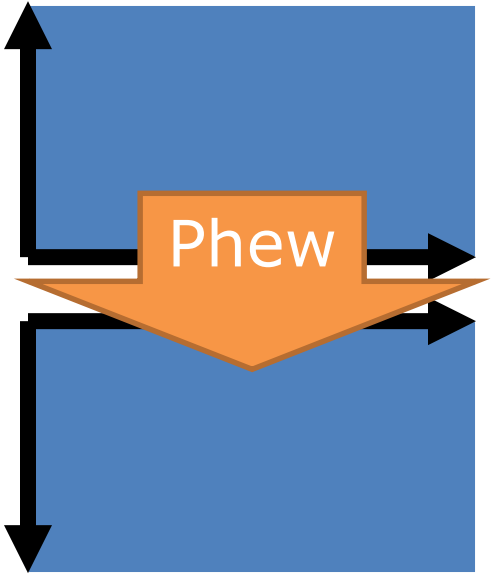
- Alternative to RenderDoc
- More than just a debugger
  - Profiling
  - Easy access to shader ISA

Vulkan – What's new?

- KHR_maintenance1
- EXT_shader_subgroup
- KHR_get_physical_device_properties2
- KHR_shader_draw_parameters
- And many (>**20**) more …

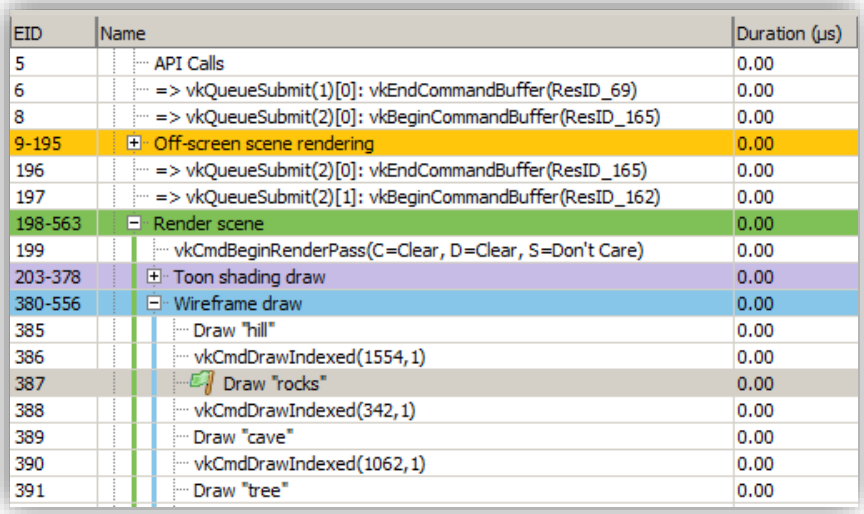
Vulkan / Usability

- `KHR_maintenance1`
- Window origin fix (`AMD_negative_viewport_height`)
- Various other small fixes



Vulkan / Usability

- VK_EXT_debug_marker
  - Markup scene just like in D3D with annotations
  - Supported by tools!



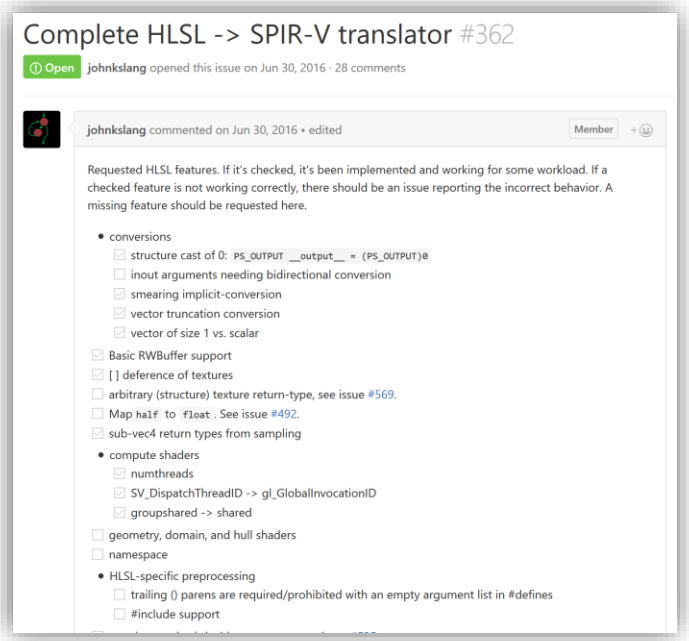
EID	Name	Duration (µs)
5	API Calls	0.00
6	=> vkQueueSubmit(1)[0]: vkEndCommandBuffer(ResID_69)	0.00
8	=> vkQueueSubmit(2)[0]: vkBeginCommandBuffer(ResID_165)	0.00
9-195	⊞ Off-screen scene rendering	0.00
196	=> vkQueueSubmit(2)[0]: vkEndCommandBuffer(ResID_165)	0.00
197	=> vkQueueSubmit(2)[1]: vkBeginCommandBuffer(ResID_162)	0.00
198-563	⊟ Render scene	0.00
199	vkCmdBeginRenderPass(C=Clear, D=Clear, S=Don't Care)	0.00
203-378	⊞ Toon shading draw	0.00
380-556	⊟ Wireframe draw	0.00
385	Draw "hill"	0.00
386	vkCmdDrawIndexed(1554,1)	0.00
387	Draw "rocks"	0.00
388	vkCmdDrawIndexed(342,1)	0.00
389	Draw "cave"	0.00
390	vkCmdDrawIndexed(1062,1)	0.00
391	Draw "tree"	0.00

Vulkan / Porting

- `VK_AMD_draw_indirect_count`
  - Multi-draw-indirect with **count from buffer**
  - Feature-parity with OpenGL
- `KHR_shader_draw_parameters`
  - `gl_drawID`, `gl_BaseVertex`, `gl_BaseInstance`
  - Again, feature parity

Vulkan / Porting

- glslang accepts HLSL now
- Already usable for many real-world shaders!



Complete HLSL -> SPIR-V translator #362

Open johnkslang opened this issue on Jun 30, 2016 · 28 comments

johnkslang commented on Jun 30, 2016 • edited — Member

Requested HLSL features. If it's checked, it's been implemented and working for some workload. If a checked feature is not working correctly, there should be an issue reporting the incorrect behavior. A missing feature should be requested here.

- conversions
  - [x] structure cast of 0: `PS_OUTPUT __output__ = (PS_OUTPUT)0`
  - [ ] inout arguments needing bidirectional conversion
  - [x] smearing implicit-conversion
  - [x] vector truncation conversion
  - [x] vector of size 1 vs. scalar
- [x] Basic RWBuffer support
- [x] [ ] deference of textures
- [ ] arbitrary (structure) texture return-type, see issue #569.
- [ ] Map `half` to `float`. See issue #492.
- [x] sub-vec4 return types from sampling
- compute shaders
  - [x] numthreads
  - [x] SV_DispatchThreadID -> gl_GlobalInvocationID
  - [x] groupshared -> shared
- [ ] geometry, domain, and hull shaders
- [ ] namespace
- HLSL-specific preprocessing
  - [ ] trailing () parens are required/prohibited with an empty argument list in #defines
  - [ ] #include support

Vulkan extensions / Performance

- `VK_AMD_rasterization_order`
  - Relaxed rasterization order
  - A stepping stone towards more declarative rendering

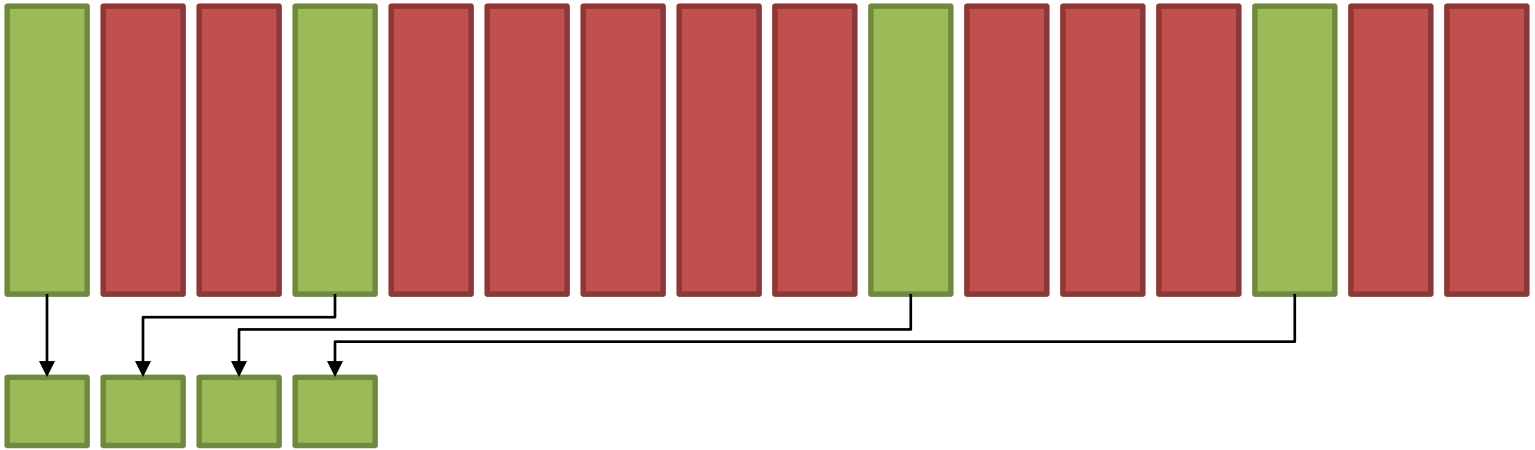
What's new – D3D12 & Vulkan

- Wave-wide
- FP16

Vulkan & D3D12 / Wave-wide

- Wave-wide instructions are now core in both APIs
  - Shader Model 6.0 for HLSL
  - `SPV_KHR_shader_ballot`, `EXT_shader_subgroup_*` for SPIR-V
- Console-like programing everywhere!

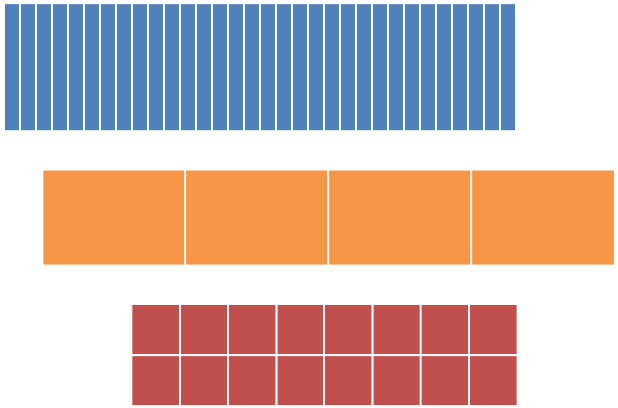
Vulkan & D3D12 / Wave-wide



Compact wave-wide using a wave-wide prefix sum: Now in SM6 and SPIR-V!

Vulkan & D3D12 / Wave-wide

- Use the right atomics at the right level



Wavefront - **Intrinsic**

Threadgroup - **Local memory**

Dispatch - **Global memory**

Vulkan & D3D12 / Wave-wide

- Your data is wave-uniform but your shader compiler doesn't know it
- Express it now in SM6 and SPIR-V!
  - `readFirstLane`
  - `WaveReadFirstLane`

Vulkan & D3D12 / Wave-wide

- Another typical use:
  - Iterate over light sources
  - Tell compiler light index is uniform wave-wide
  - Data goes into SGPR instead of VGPR
  - Profit!

Vulkan & D3D12 / FP16

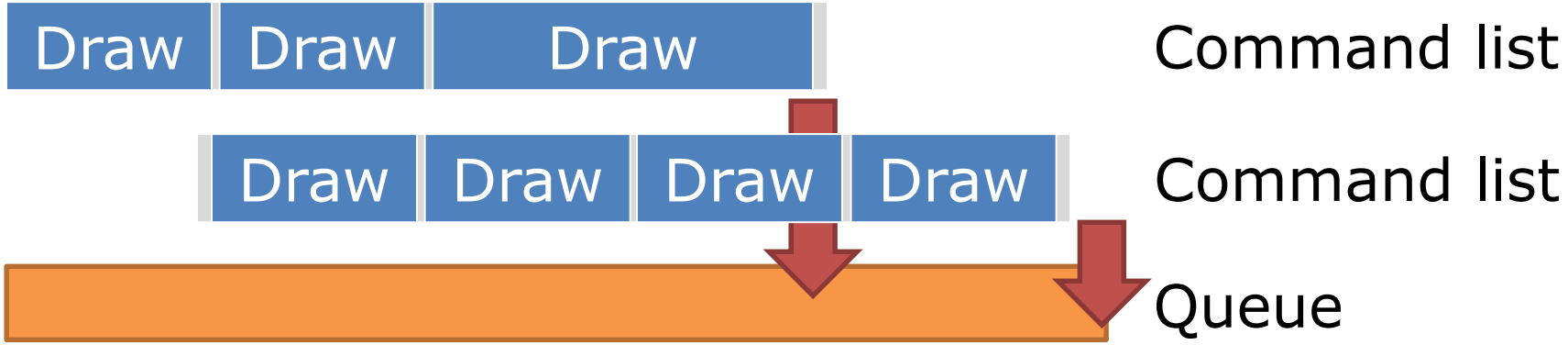
- Same benefits on PC as on console
  - Reduced register count (and LDS usage!)
  - Better performance
- Simplifies porting between console & mobile

Dawn of a new era

- Peak performance requires new concepts!

Command lists

- Separate **recording** from **submission**
- Much higher throughput!

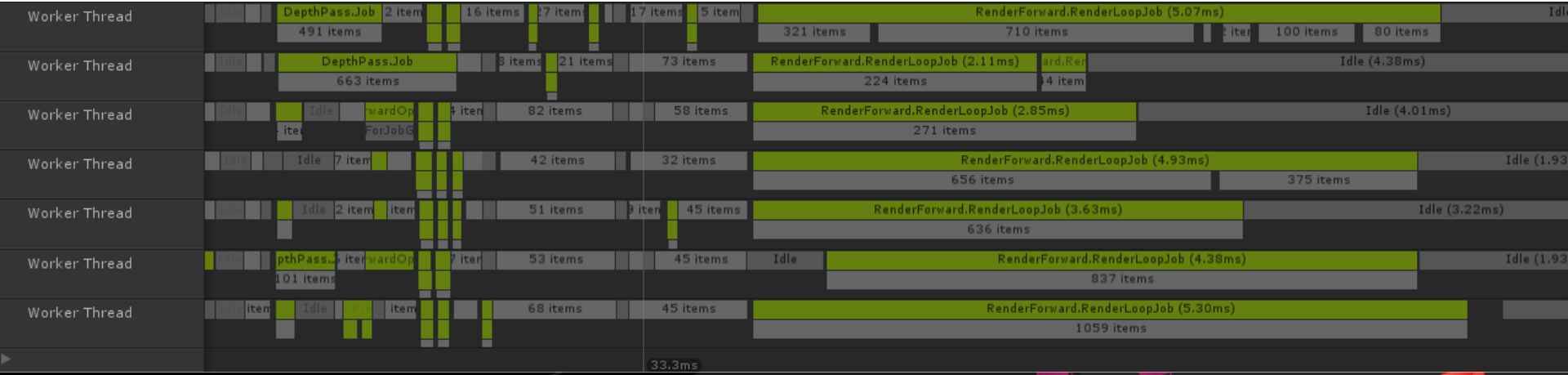


Engine evolution / Multithreading

- It's not just Ashes any more ☺
- Engines are getting ready for *massive* multithreading

Engine evolution / Multithreading

- Here's Unity firing up all cores!

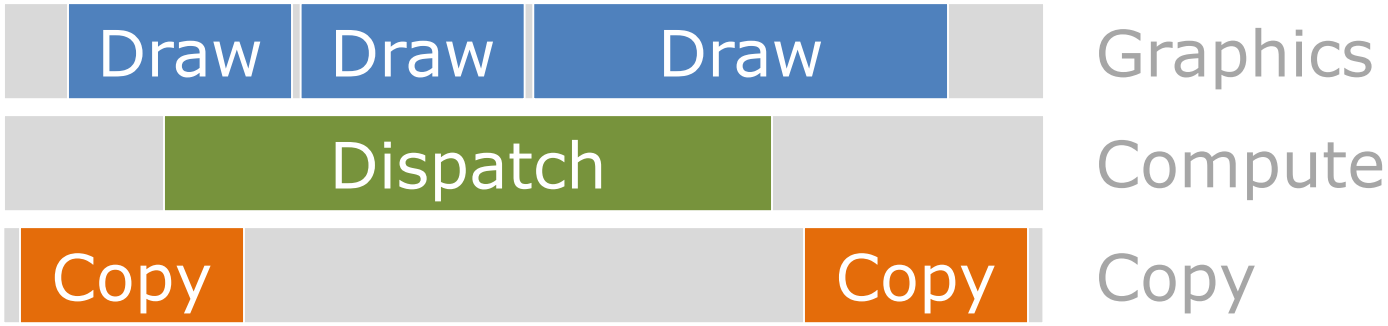


Engine evolution / Multithreading

- Plan for >10 threads
  - Increase draw call count – high/ultra settings on *new APIs only*
  - Or: Cut latency! Twitchy 144 fps games, anyone?

Graphics, compute, copy queues

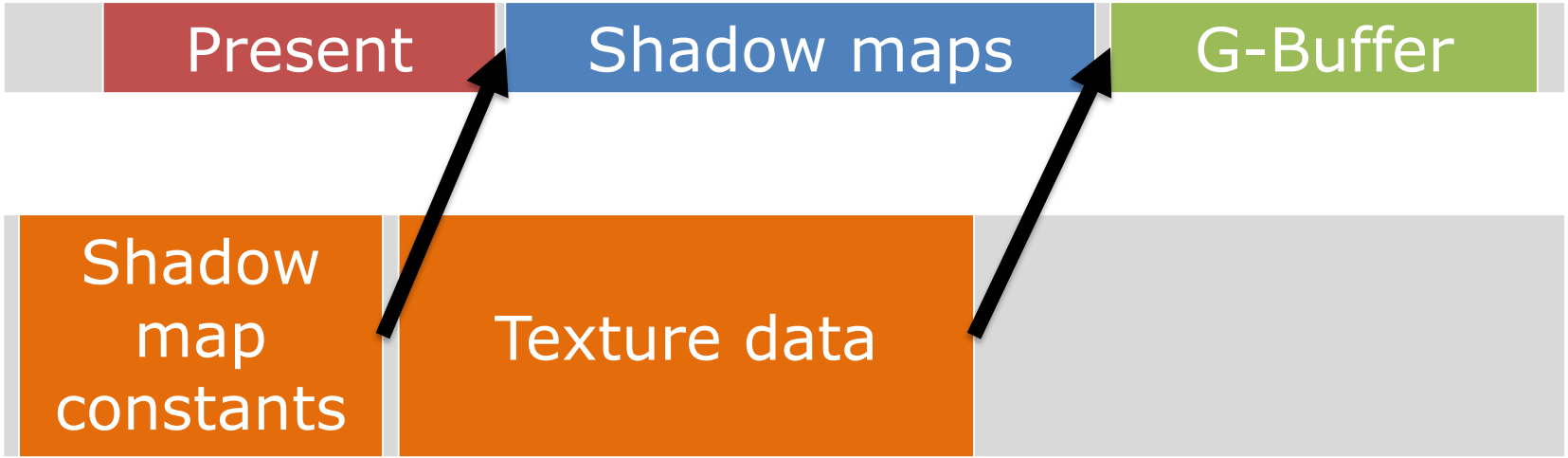
- Schedule independent work on independent queues
- Fill up the whole GPU



Lessons learned / Copy queue

- Copy queue is low-latency, low-speed, but it's **separate hardware**
  - Copy queue is **optimized for transfer over PCIe®**, not for GPU local copies
  - For PCIe®, it is the **fastest way** to transfer data
  - Avoid waiting on copy queue from graphics/compute
  - Ideal use of copy queue is streaming data over a few frames
- Some games still don't use it …
  - **Multi-millisecond-savings** are common
  - If you go from CPU to GPU or back, the copy queue is the queue of choice!

Copy queue

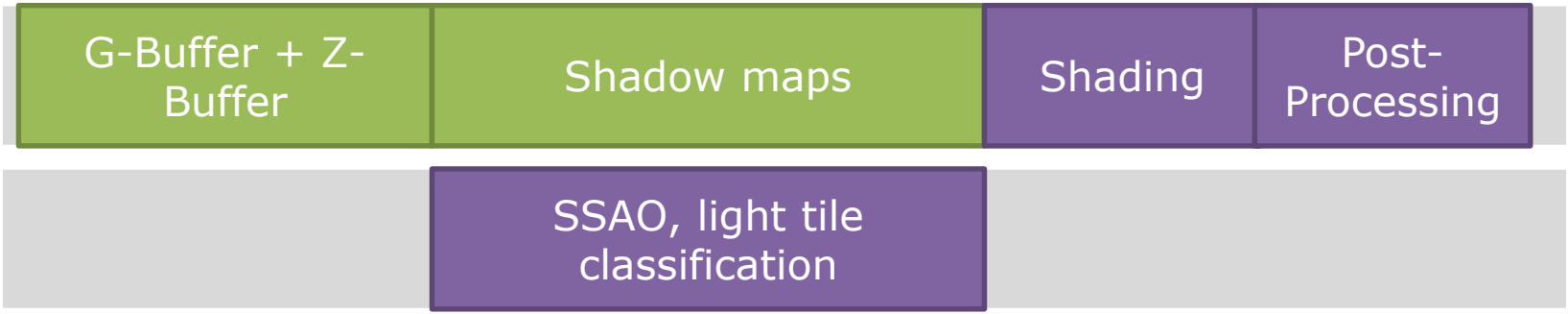

Present
Shadow maps
G-Buffer
Shadow map constants
Texture data

Lessons learned / Copy queue

- Use to it upload all your buffers (constants, index buffers, etc.)
- Use it to defragment memory

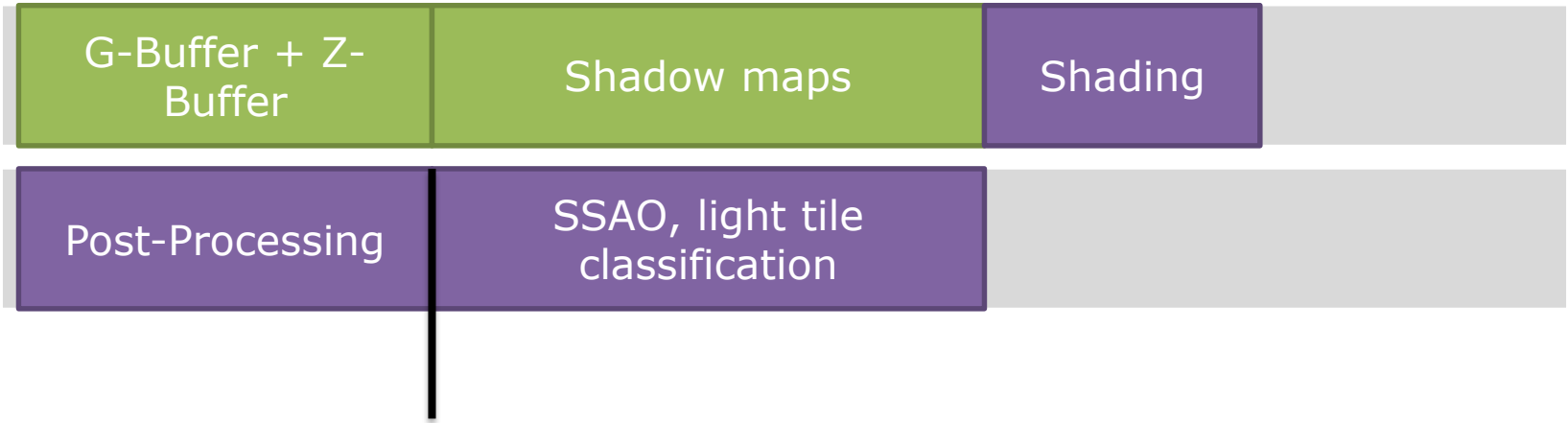
Lessons learned / Async compute

- Most games right now



Lessons learned / Async compute

- Best performance & production proven!



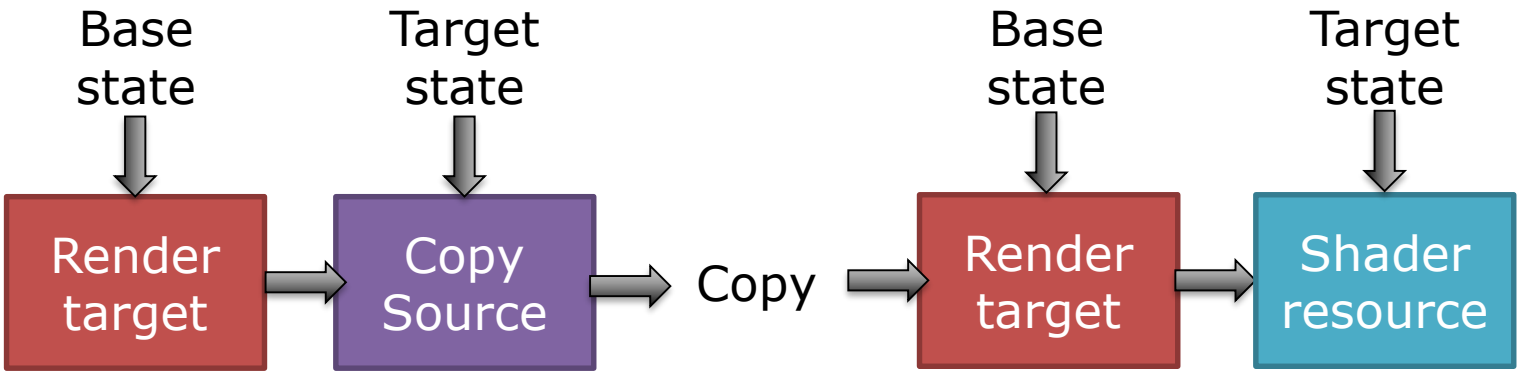
Lessons learned / Barriers

- Barriers are **hard**
- Most issues come from **retrofitting** engines
- New engine designs handle them **much more robustly**

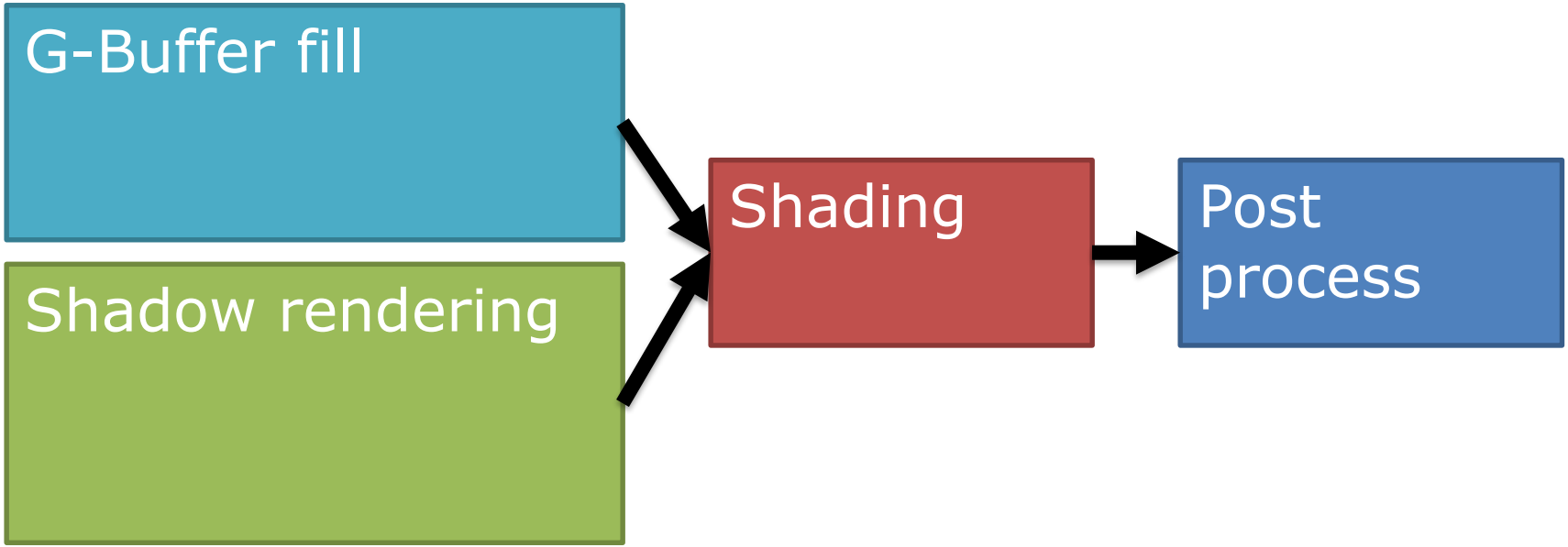
Lessons Learned / Barriers

- Missing barriers
  - Validation layer helps
  - No longer a big issue
- Missing batching
- The „base state“ problem

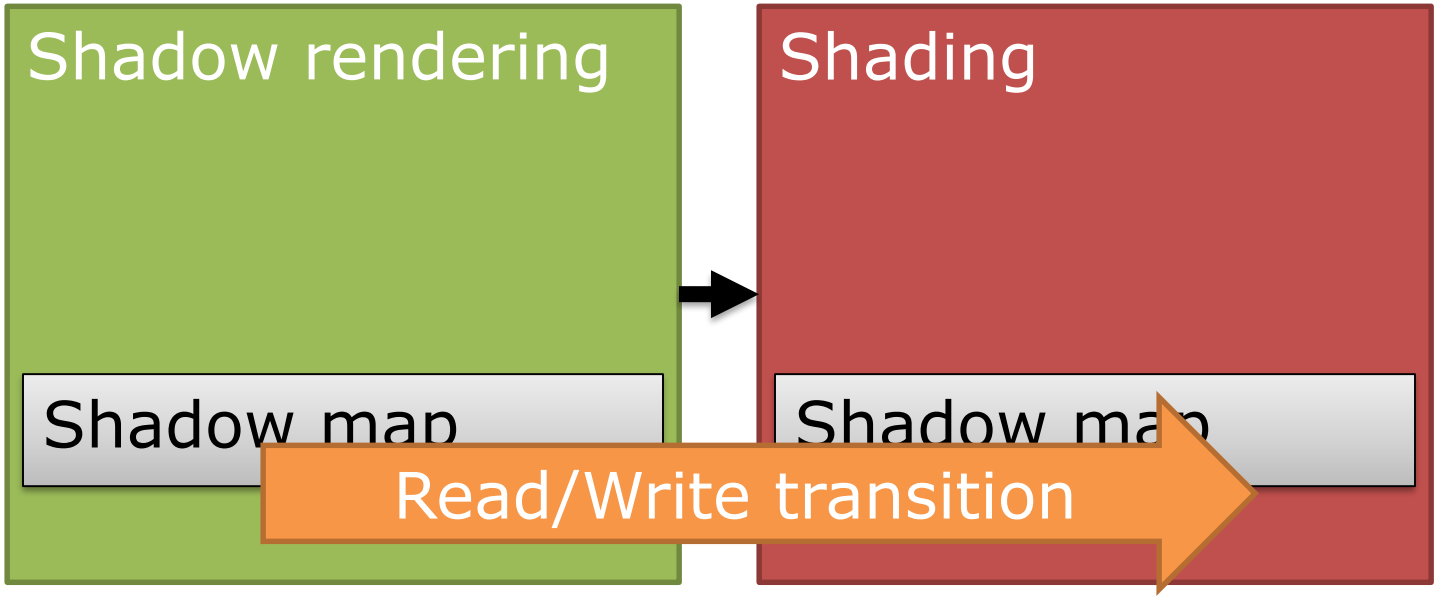
The “base state” problem



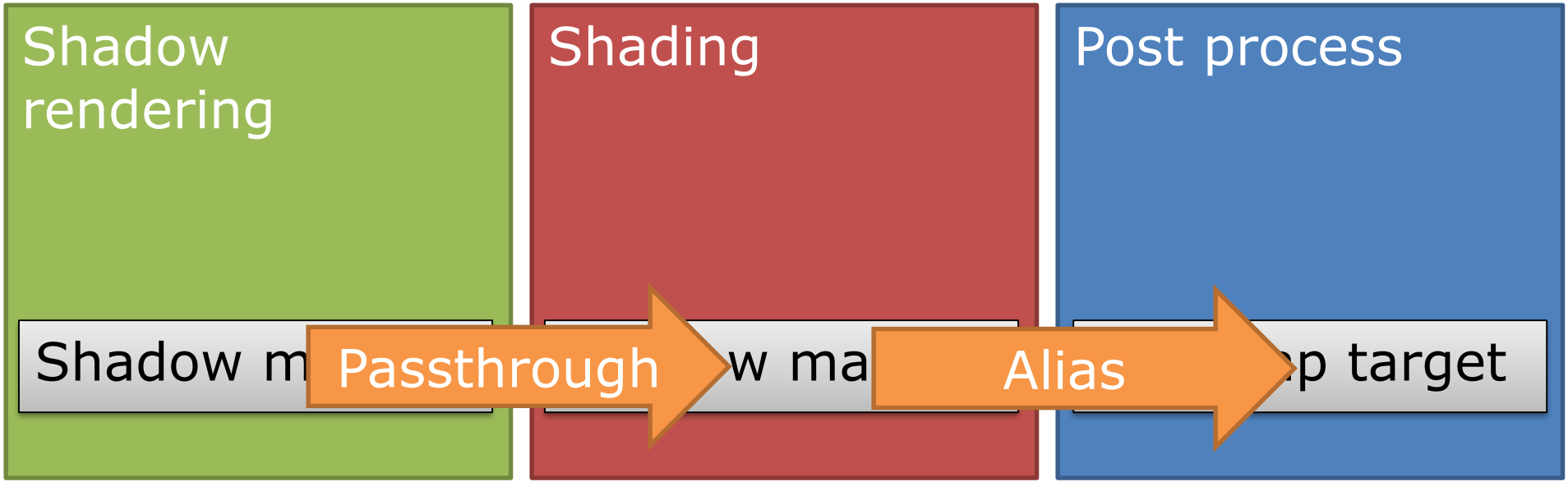
Engine evolution / Task graphs



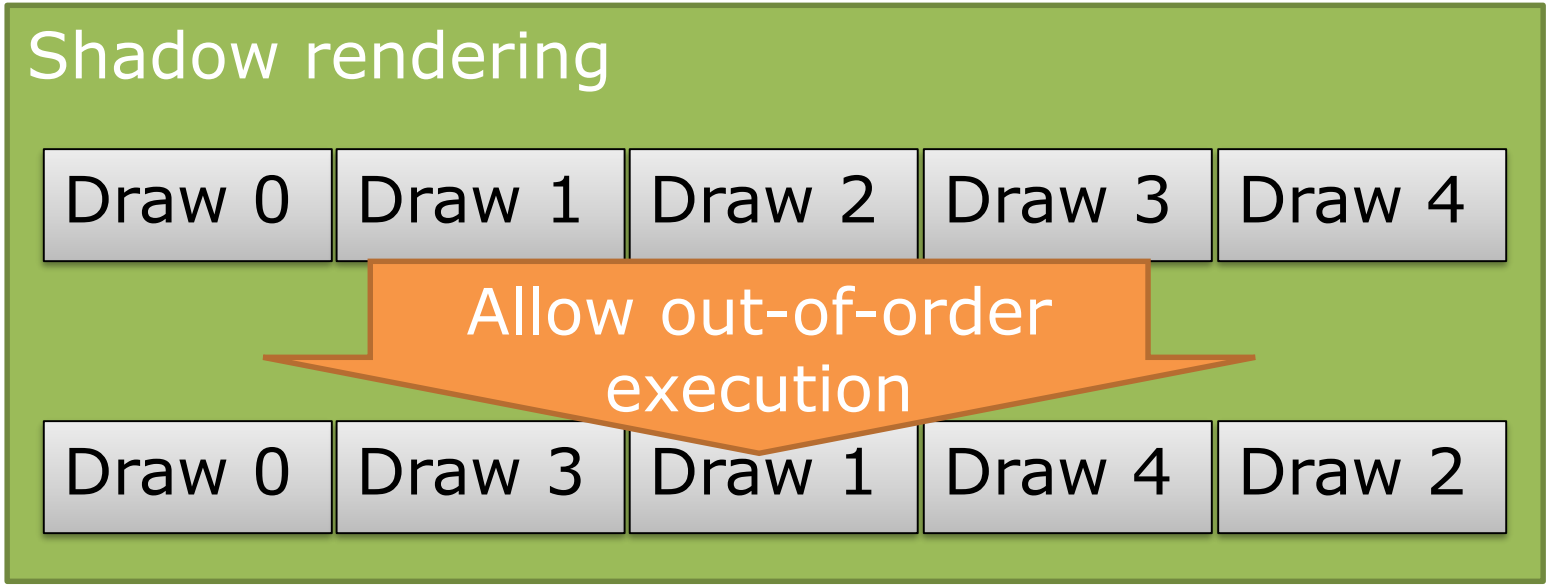
Engine evolution / Task graphs



Engine evolution / Task graphs



Engine evolution / Task graphs



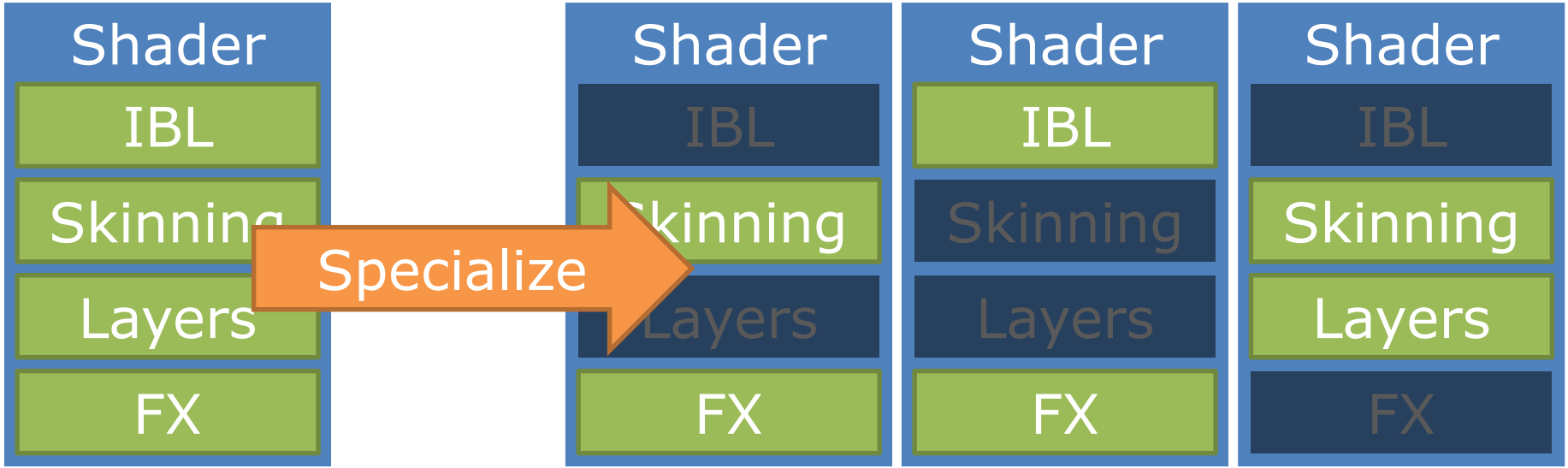
Engine evolution / Barriers

- Manual handling *doesn't cut it any more*
- Need higher level abstractions – render graphs
  - This is happening – check out the FrameGraph presentation from Frostbite!
  - Native support in Vulkan since day 1

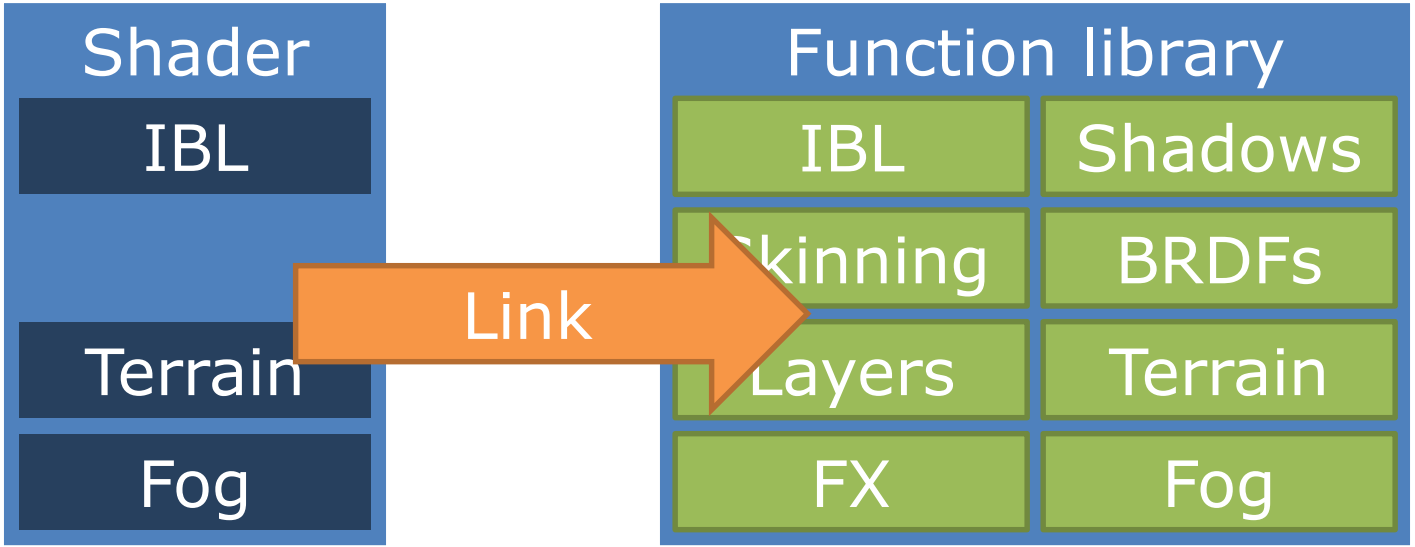
Engine evolution / Shaders

- Shader permutations are getting fewer
  - Doom has only a couple hundred total
  - More games are changing creation pipelines to prune variations earlier
- More high-level work (around compilers) is happening

Engine evolution / Shaders



Engine evolution / Shaders



Engine design

- Engines moving towards more **high-level** rendering
- APIs improve to make them easier to use
- Gamers benefit!

Open topics / Scalability

- Scalability is not solved at all yet
  - Games support old and new APIs for all settings
  - Mobile → desktop increasingly important
- New APIs *only* seems to be the path forward

A new approach to APIs

- **Strong collaboration** between ISVs, IHVs and standard bodies
- **APIs evolved** along with game engines
- Loads of changes since release to make your life easier!

Conclusion

- APIs continue to change
  - What do **you** need?
  - What would make **your** life simpler?
- Community collaboration is critical
  - Especially for shader language changes
  - It’s easy to contribute – give it a shot!

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