KILZONE® SHADOVV FALL

Michal Valient Lead Tech Guerrilla Games

- Guerrilla is based in Amsterdam and we're part of Sony since 2005
- We're working on two titles
 - Unannounced new IP
 - Killzone: Shadow Fall
- The new Killzone is PS4 launch title
- 1080p, solid 30FPS, no cheats
- This talk is about the experiences we gained during the demo period

Intro

Our aim for announcement event was to run on PS4 hardware





60 Al characters 940 Entities, 300 Active 8200 Physics objects (1500 keyframed, 6700 static) 500 Particle systems 120 Sound voices 110 Ray casts 1000 Jobs per frame

Demo CPU Load



Memory Map

Three memory areas System - CPU Shared - CPU + GPU Yideo - GPU

1,536 MB System

128 MB Shared

3,072 MB Video



System Memory

Sound	
Havok Scratch	
Game Heap	
Various Assets, Entities, etc.	
Animation	
Executable + Stack	
LUA Script	
Particle Buffer	
Al Data	
Physics Meshes	
Total	-

553	MB
350	MB
318	MB
143	MB
75	MB
74	MB
6	MB
6	MB
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5	MB
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Shared Memory

Display list (2x)

GPU Scratch

Streaming Pool

CPU Scratch

Queries / Labels

Total

64	MB
32	MB
18	MB
12	MB
2	MB
128	MB



Non-Steaming Textures	1
Render Targets	
Streaming Pool (1.6 GB of streaming data)	
Meshes	
CUE Heap (49x)	
ES-GS Buffer	
GS-VS Buffer	
Total	3

Video Memory

1,3	21	MB
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5	72	MB
3	15	MB
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Baseline Performance

- No low-level CPU optimizations Just SIMD based math library (using SCE intrinsics) Focused optimizations on going 'wide'
 - Almost all code is multi-threaded / jobified



PS4 Concurrency model

- Same model as PS3
 - One main 'orchestrator' thread
 - All other code runs in jobs across all cores Easier to program, so much more code in jobs
- Jobification of code, ballpark improvements:
 - (PS3 > PS4 % of code running in jobs)
 - ▶ 80% ▶ 90% Rendering code
 - ▶ 10% ▶ 80% Game Logic
 - 20% ► 80% AI Code



Optimizing

Demo was optimized quite well 1080p30 with very few dropped frames on CPU and GPU

Profiling tools are still in development this early on

...so we developed our own CPU and GPU Profiler





Ctrl+Alt+Shift+C Ctrl+Alt+Shift+G

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<u>A</u>l <u>G</u>ame

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Legend

Pan Area Zoom Area Zoom Bar Zoom All Record Record Missed Frames Scrub Frame Live View



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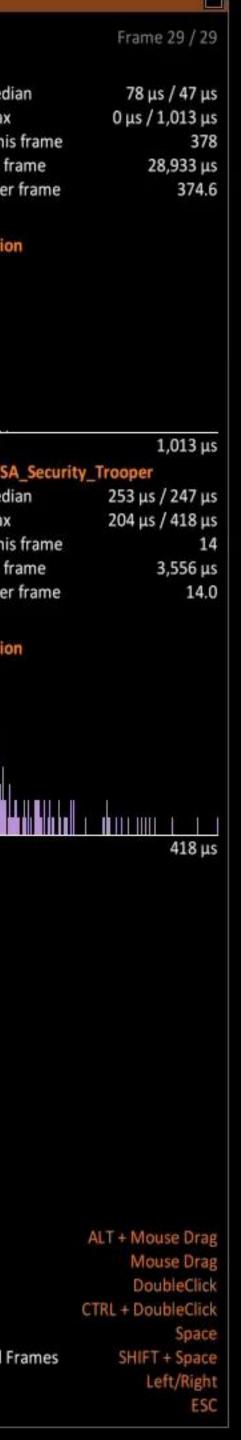
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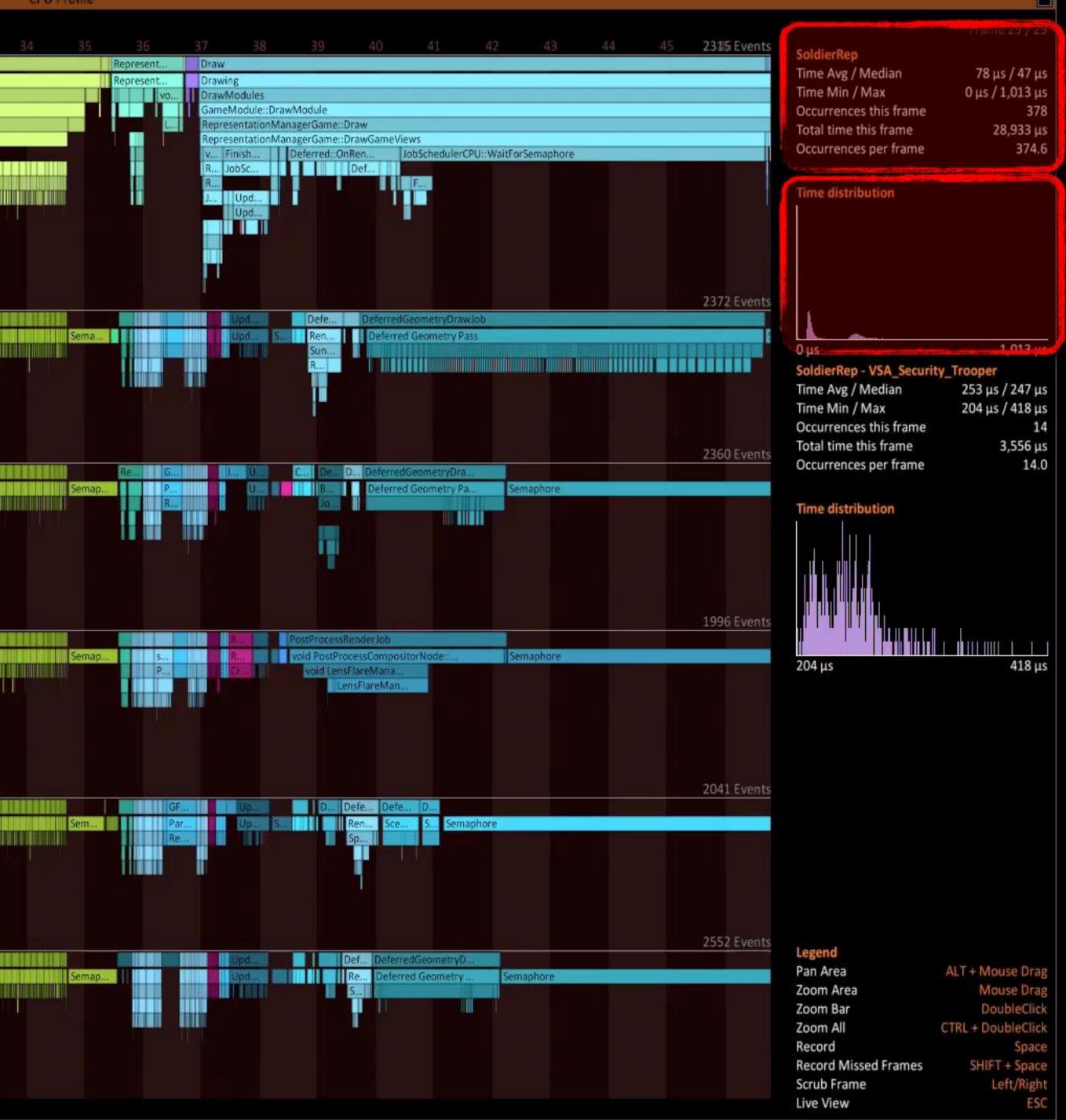
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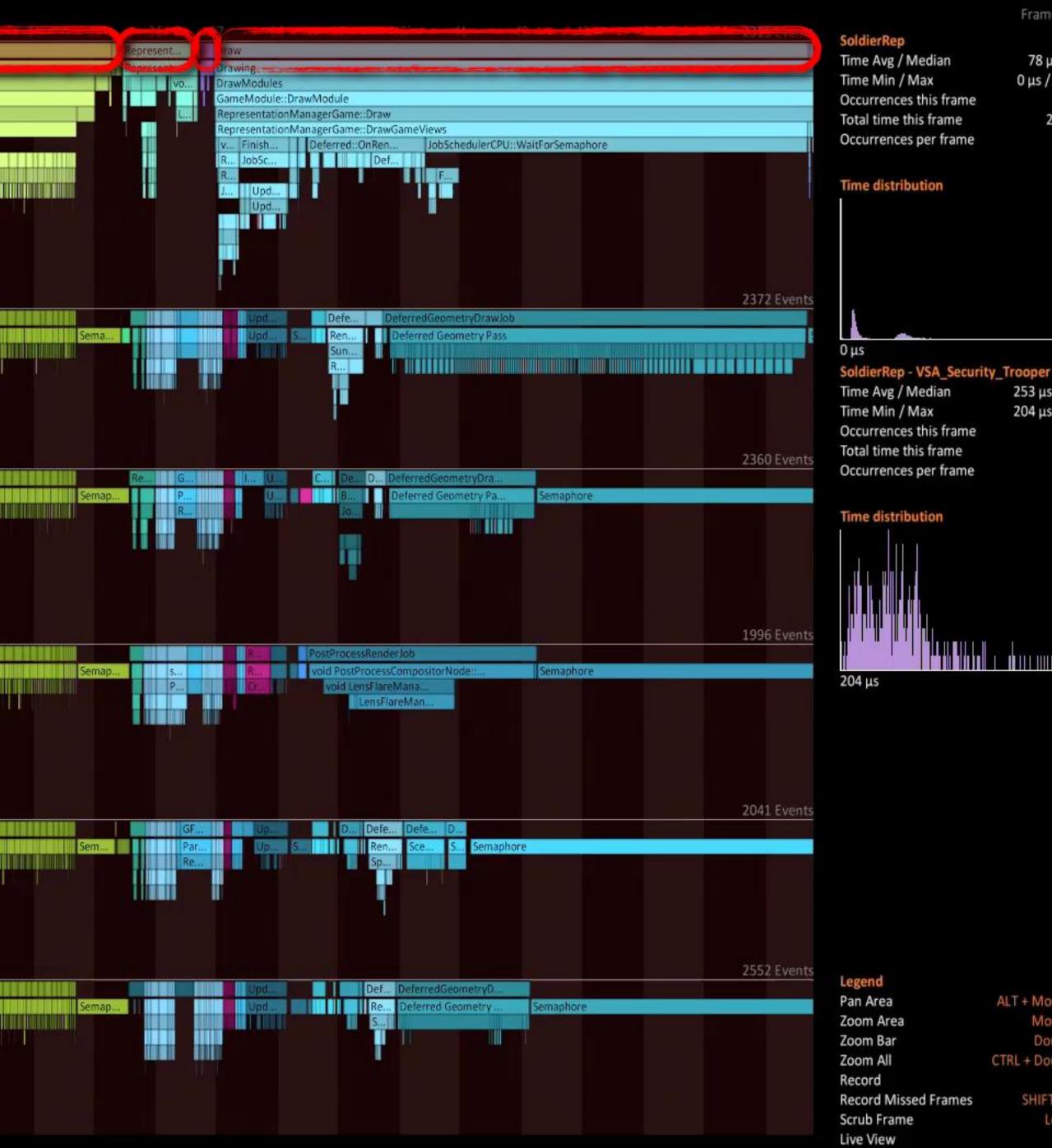


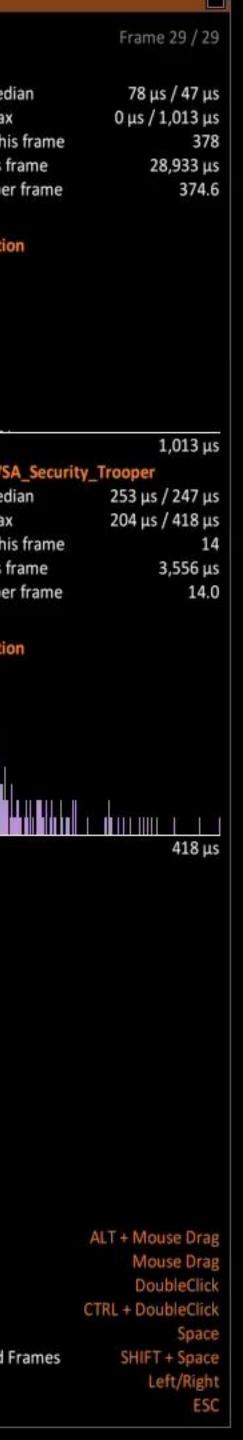


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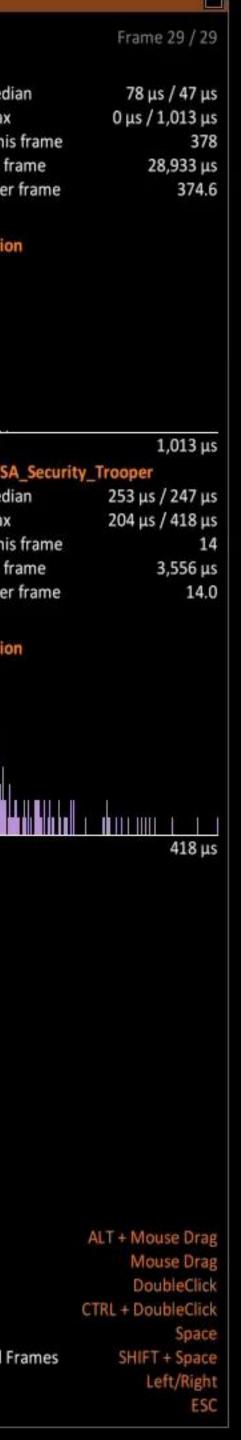
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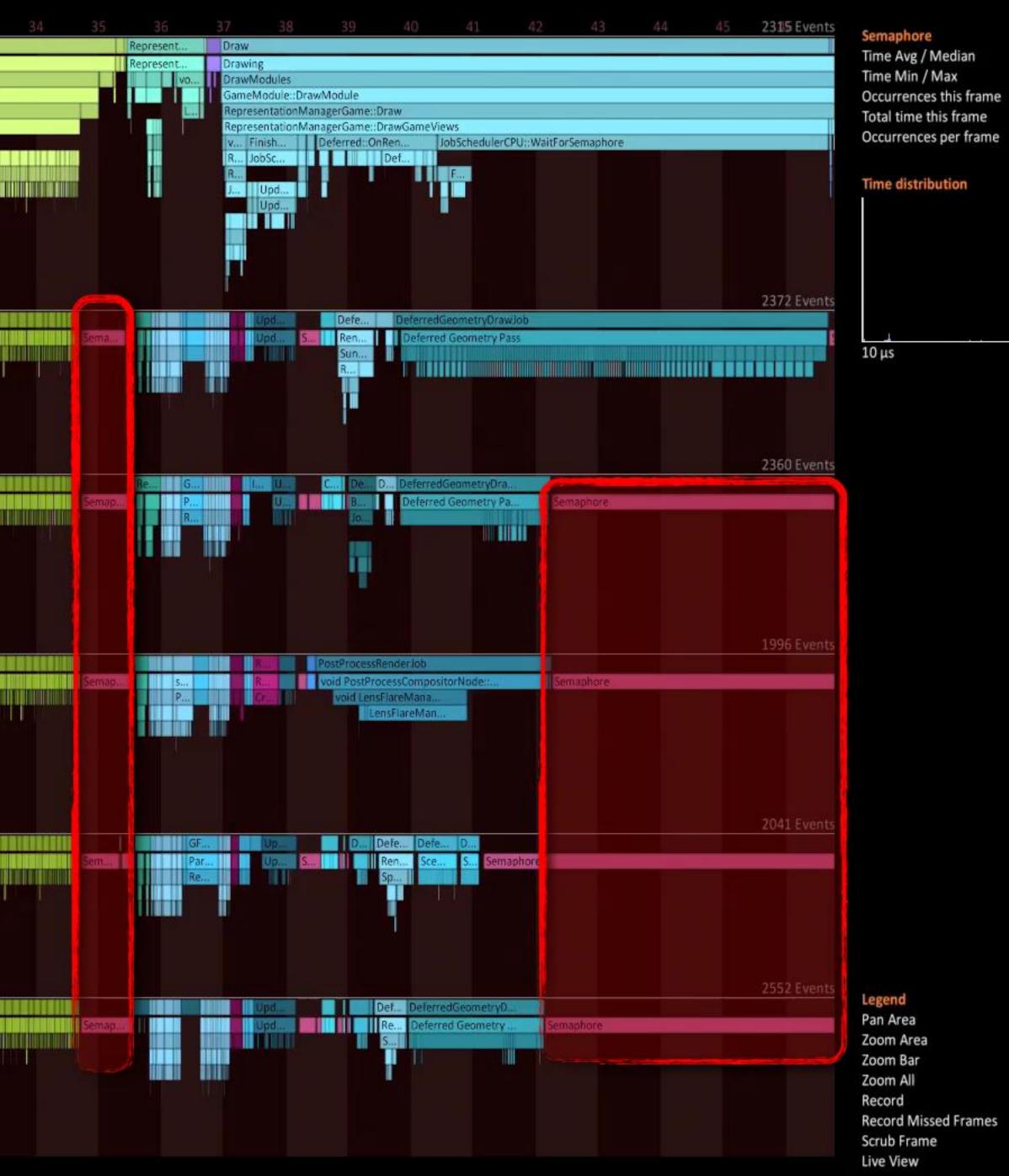
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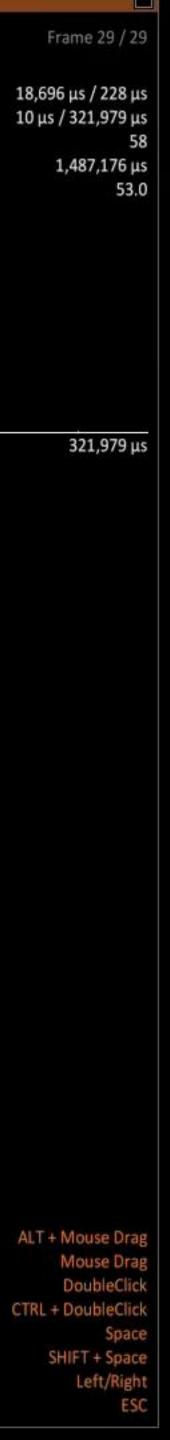




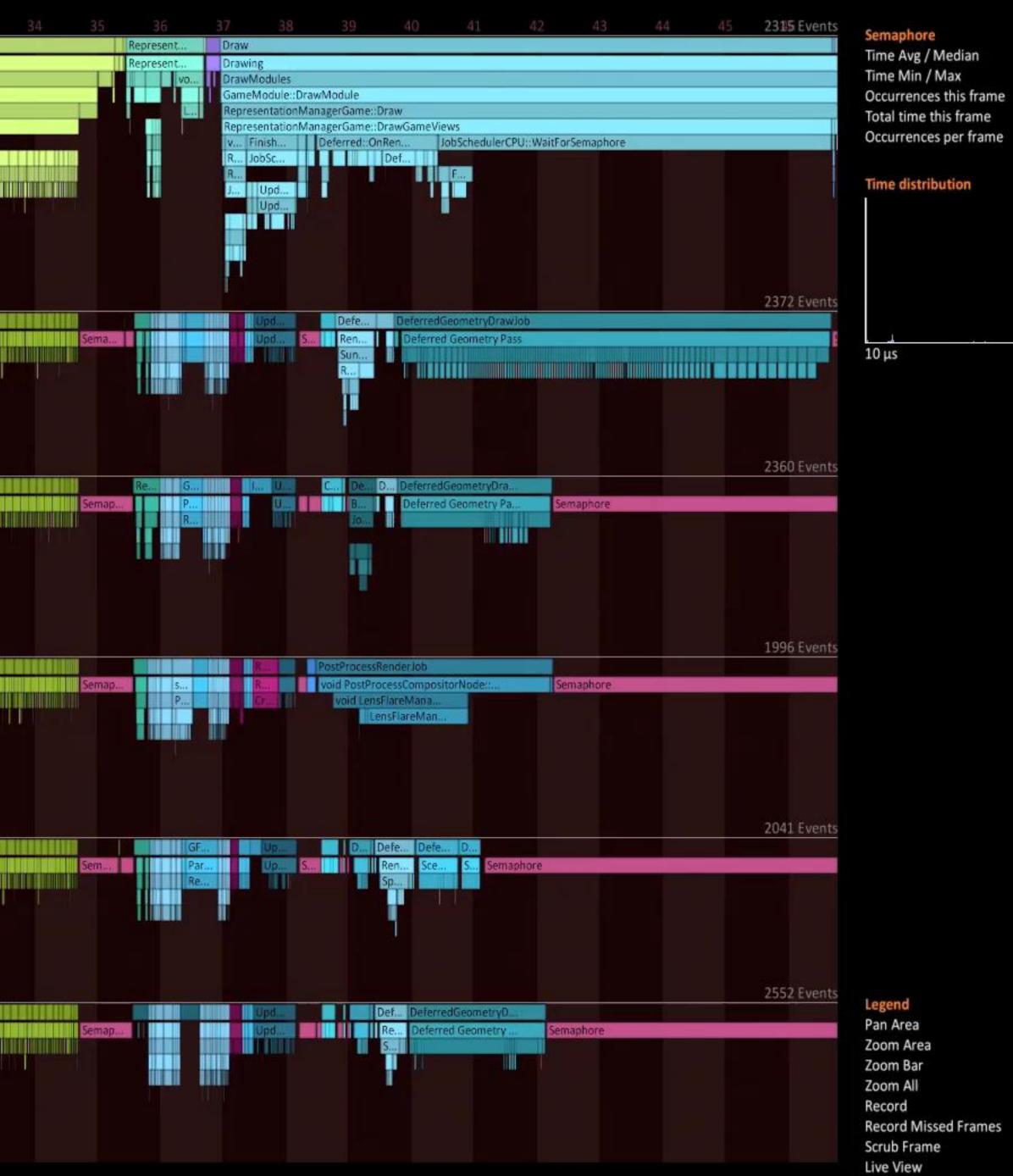
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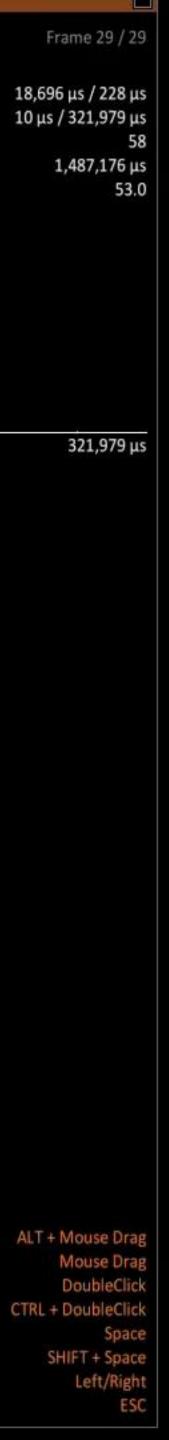
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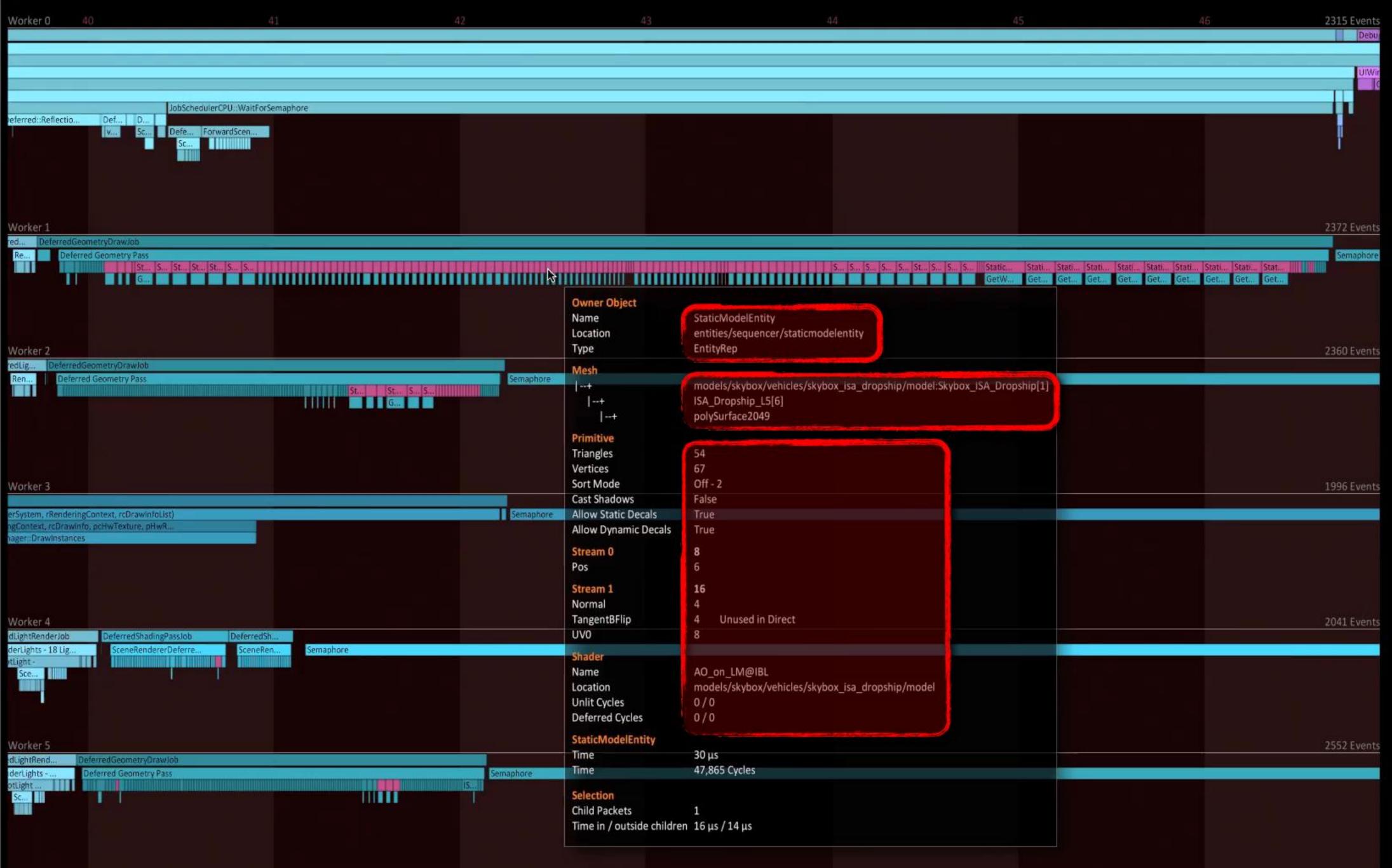
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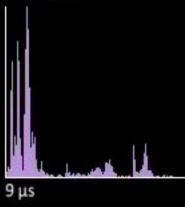




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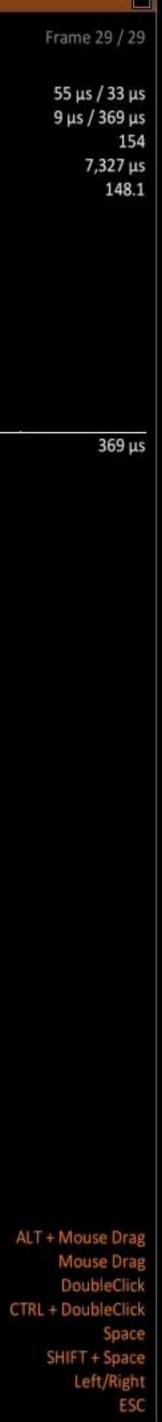
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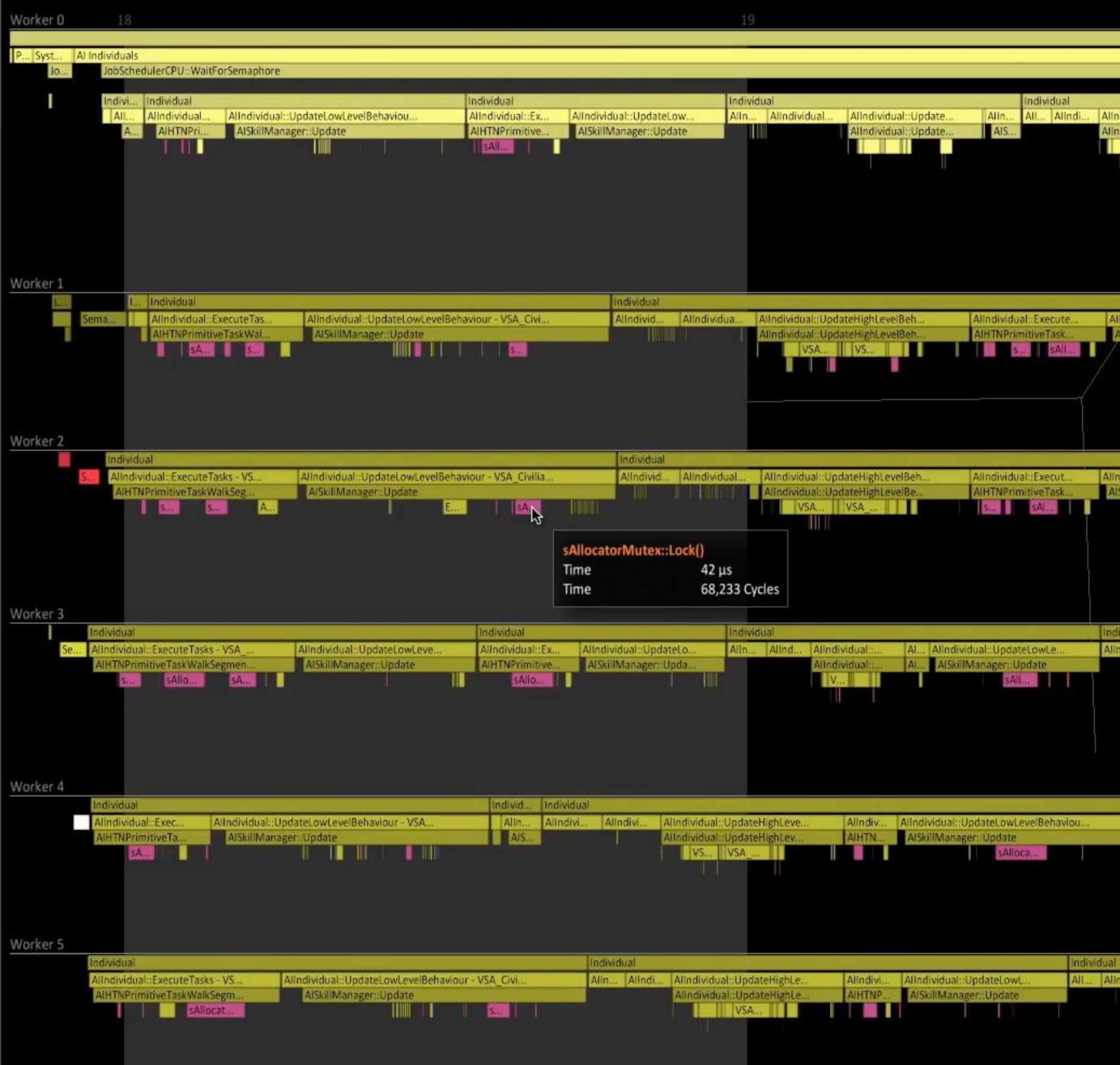


Legend

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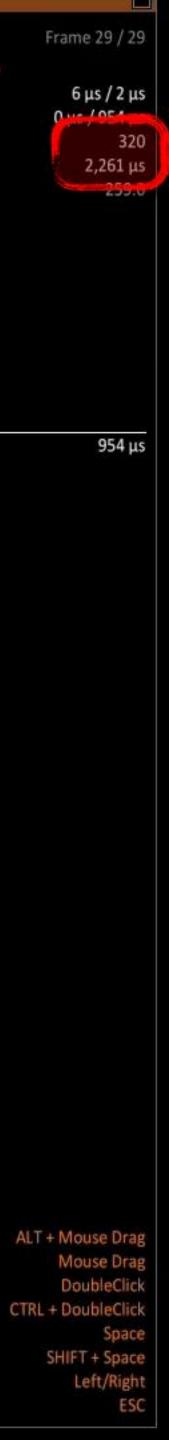


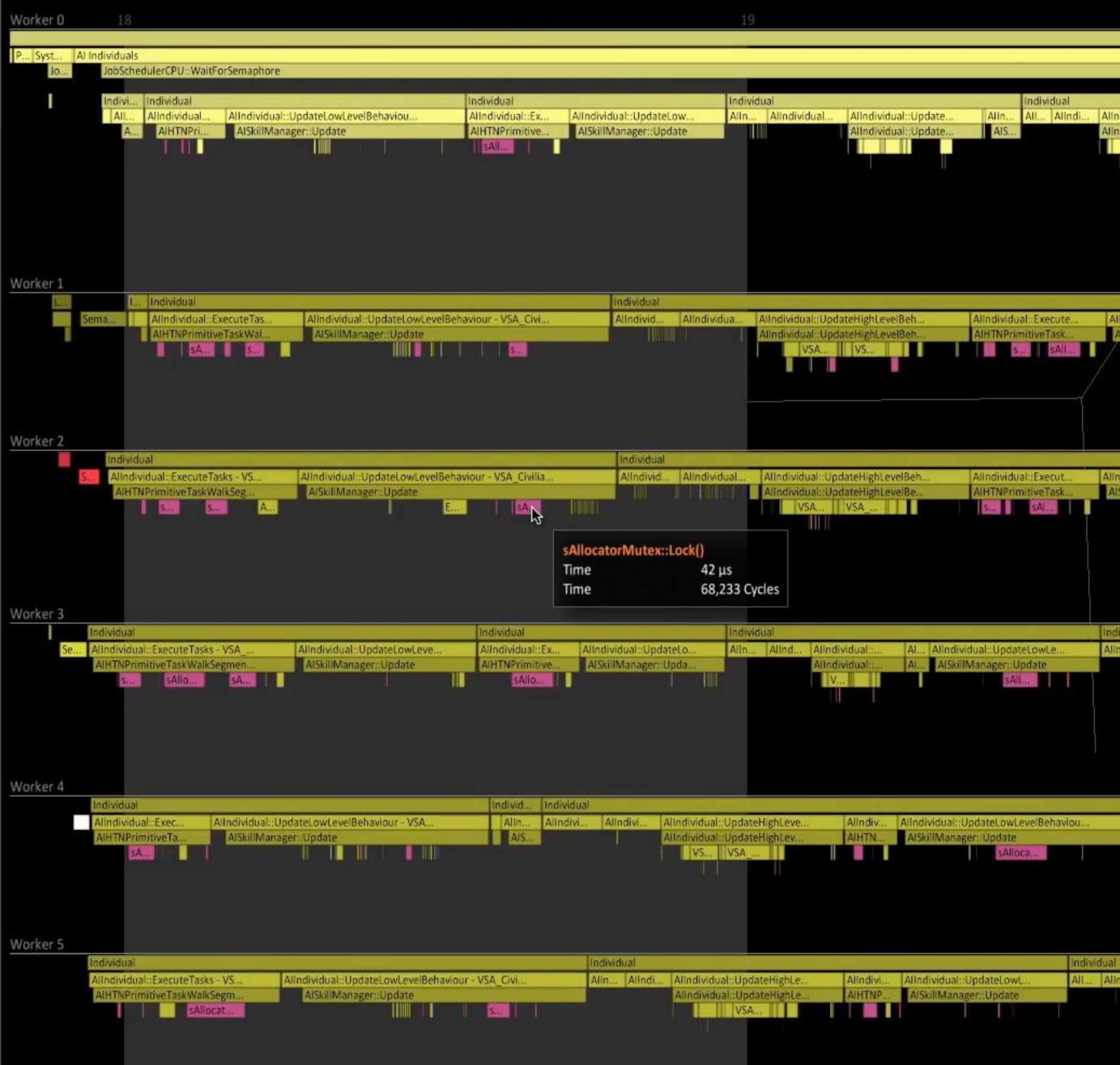


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Live View

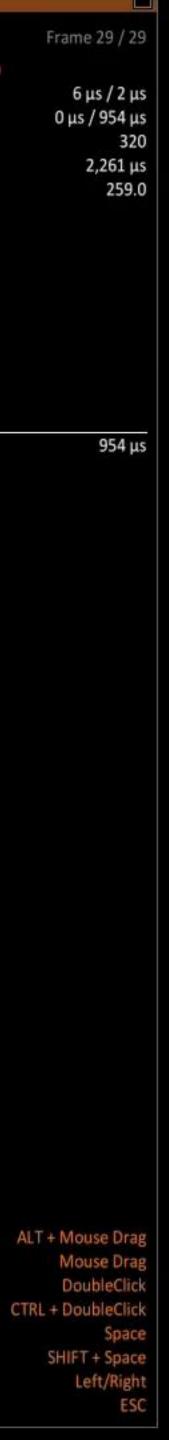




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Total time this frame Occurrences per frame

Live View



Optimizations

- The biggest performance challenge was thread contention Shared memory allocator, ton of mutexes. We gained approximately 50% of the CPU back by fixing high level

 - code.
- Do this first before you try to switch to some low level multithreading friendly malloc.
- We had a few fights with the PS4 thread scheduler A lot of our SPU code used spinlocks Spinlocking is not nice for on any multicore system Just play nice, system mutexes are very fast





We still use deferred shading
The entire pipeline is HDR and linear space



We switched to physically correct lighting model Energy preserving Properly calculated geometry attenuation factors All materials support translucency and Fresnel effect



All our lights are area lights

CC:55

A TANK

THE DIT



Volumetrics supported on every light



Real-time reflections and localized reflection cubemaps
 Proper roughness response matching the real-time lights





Render targets

- G-buffer with 5 MRTs + 32bit depth 1080p, RGBA16f, no MSAA at the moment
- 2x 8bit backbuffers
- Ax 2048x2048x32bit shadow maps
- A lot of low resolution buffers for post process effects
- Most of the buffers are overlapping in memory
- We still need to optimize the layout and formats

We don't use HiZ to avoid decompression before reads.



- Out of order generation using jobs
 - Geometry passes are split into multiple jobs too
- We kick up to 60 command buffers per frame
 - All double buffered
- We issue WaitForFlip at the very last moment in the frame

 - Allows to avoid blocking waits on CPU during long frames

Display list

CBs are sorted based on a how they need to be consumed

Right before the next flip when the GPU renders into the back buffer



· CPU • Core 0 Geo 100 Post 700 Geo 101 • Core 1 Geo 200 Lights 500 Post 701 • Core 2 Geo 300 Lights 600

• GPU



Display list

Lights 500 Lights 600 Geo 300

WaitForFlip #N-1 Flip #N Blit





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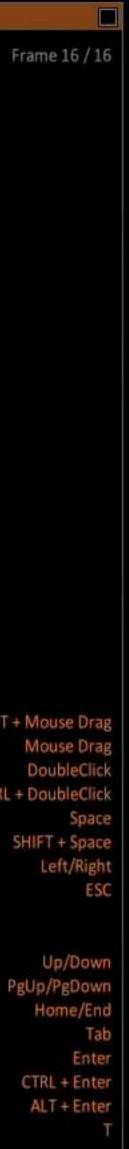
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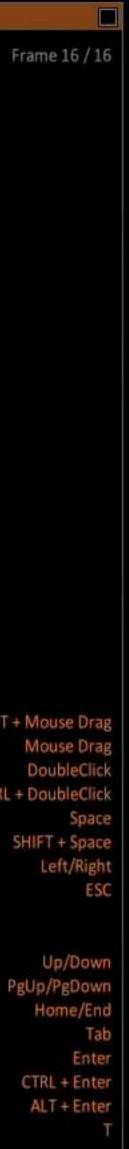
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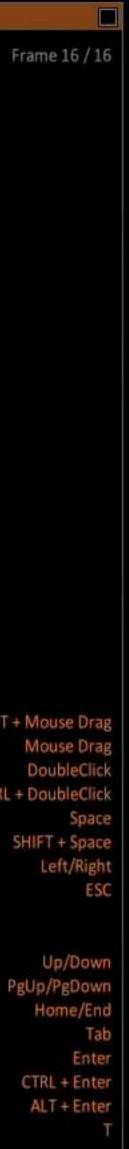
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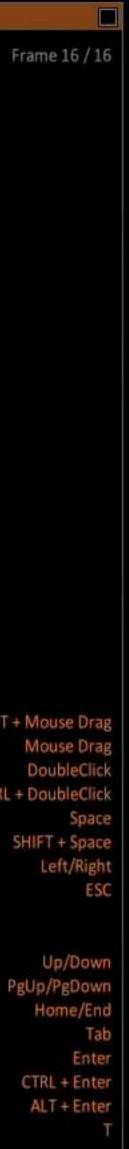
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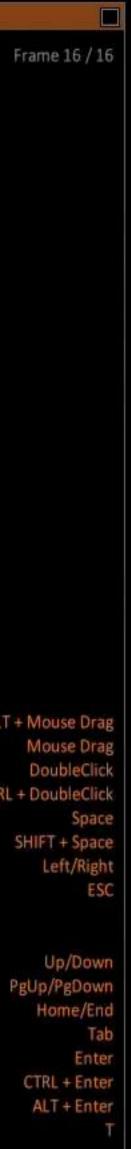
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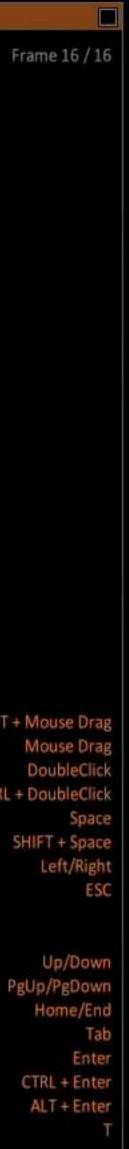
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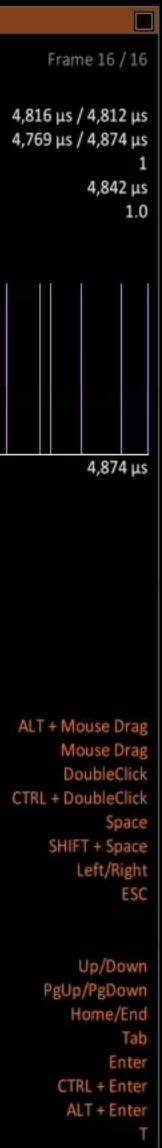
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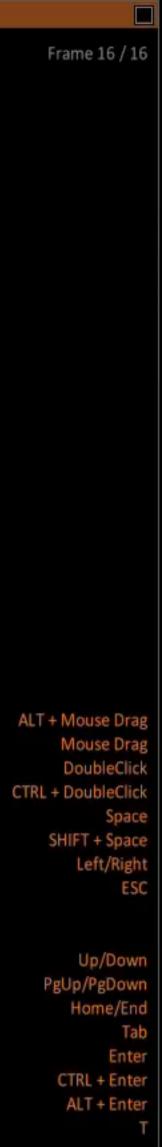
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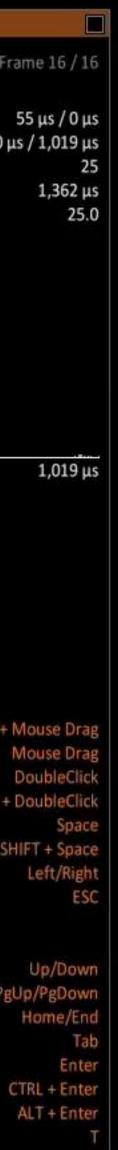
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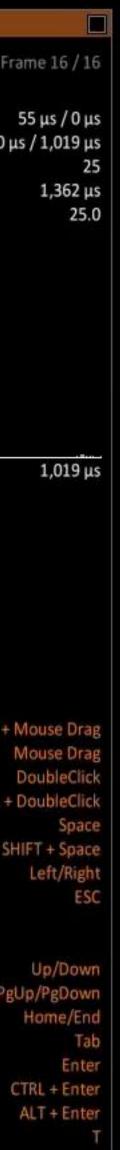
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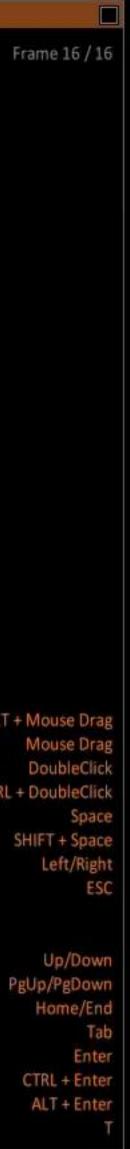


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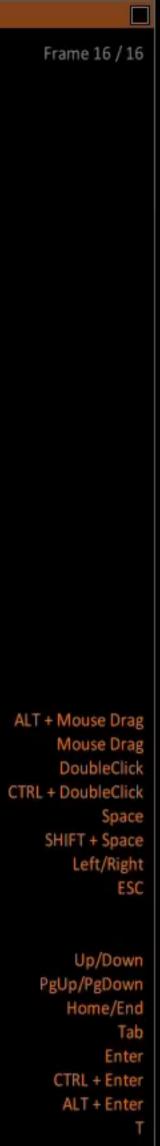


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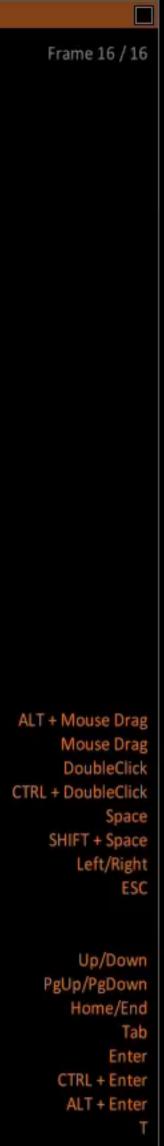


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VEKTA CITY - 2381 VSA HEADQUARTERS

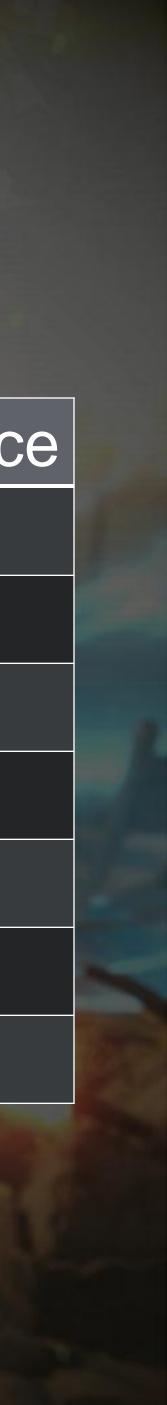


charge and

- Around 40k polygons for the highest LOD
 - Enough to capture all detail for closeups
 - We provided detail guide for LOD setups
- Up to 8 bone influences per vertex
 - Most vertices use 4-5, drops with LOD#
- 6 x 2k x 2k textures for character body
 - Plus detail maps and head textures
 - 10ppi, everything authored as 4k
- KZ3 used 10k polygons, 3 LODs and 1k textures

Characters

and the second se		
LOD#	Polycount	Distanc
1	40,000	0-2
2	20,000	2-5
3	10,000	5-10
4	3,200	10-15
5	800	15-20
6	350	20-30
7	150	30+

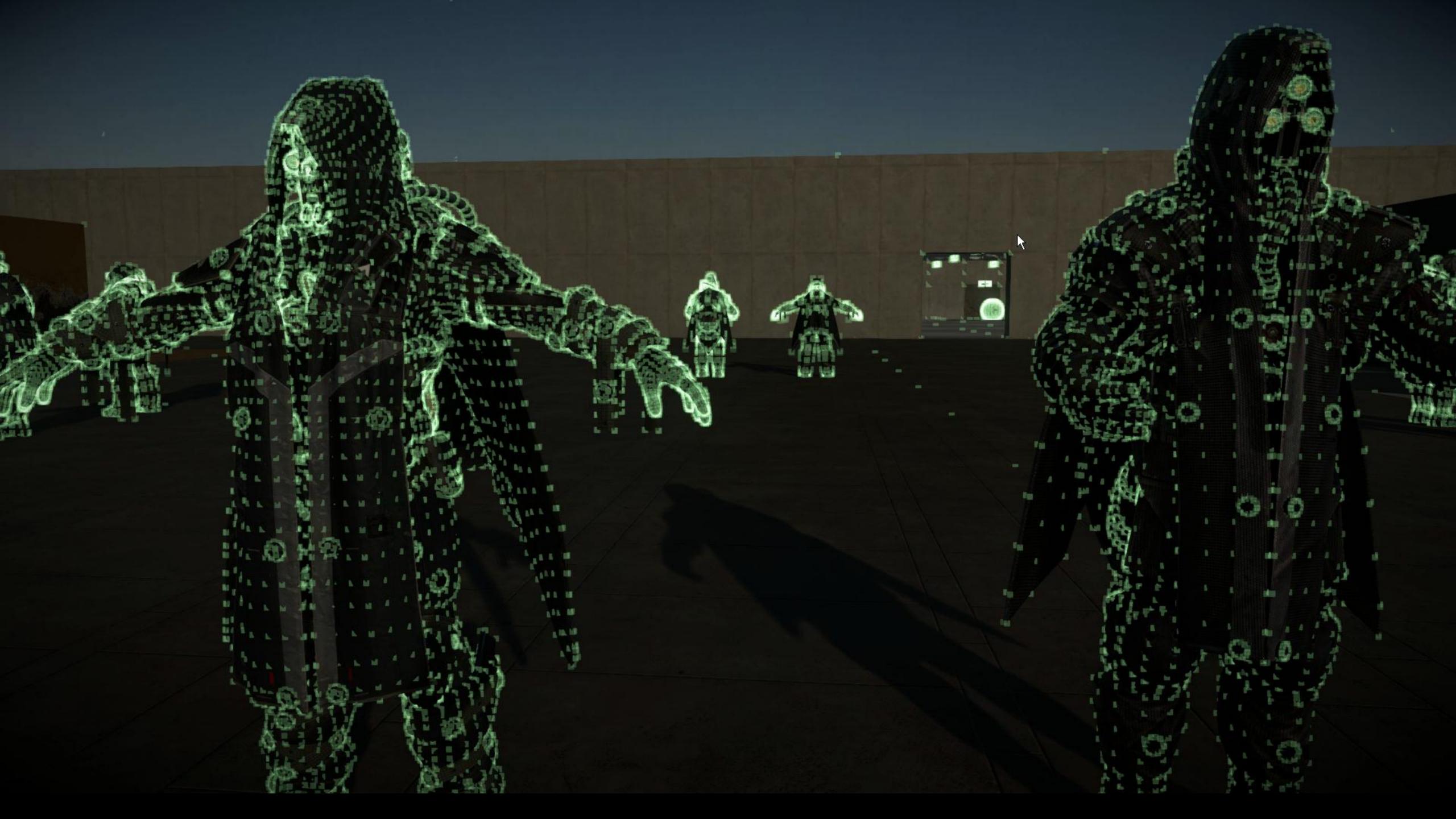


Killzone: Shadow Fall

MI

Killzone 3

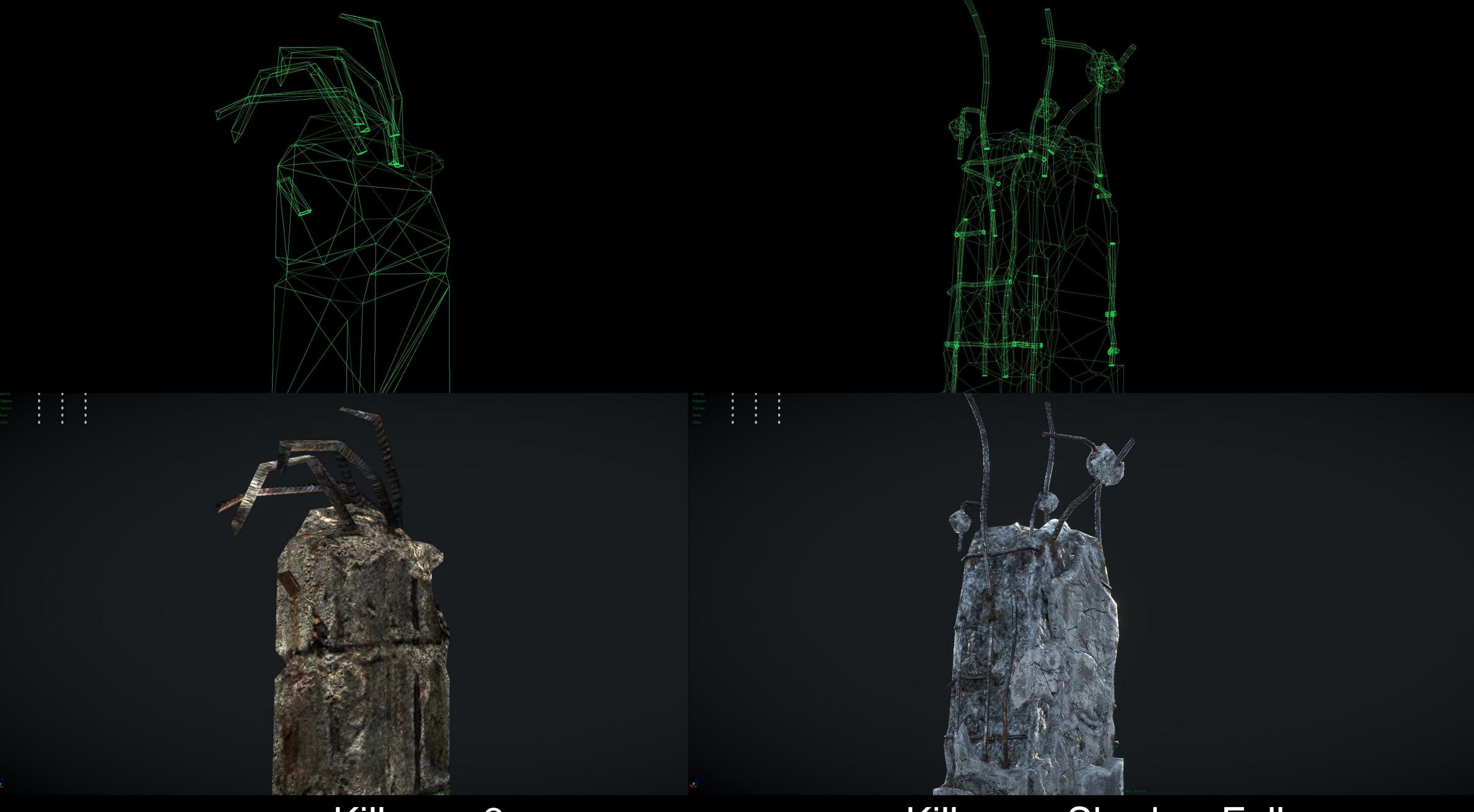






Killzone 3

Killzone: Shadow Fall



Killzone 3

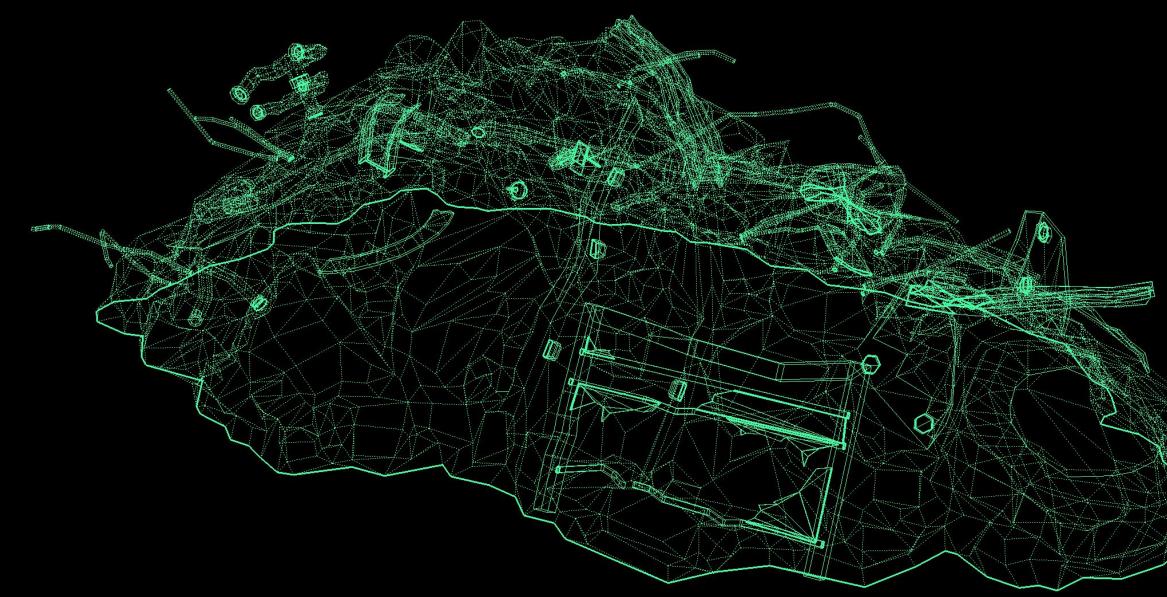
Killzone: Shadow Fall







Killzone 3



Killzone: Shadow Fall





Geometry pass optimizations

Optimization

Sorting by (vertex) shader still helps

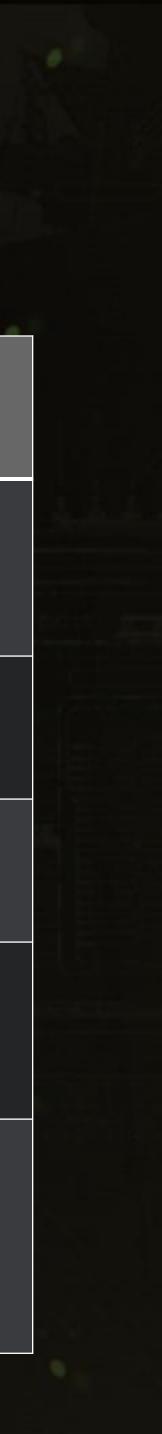
More aggressive threshold for mini

Normal/Tangent/Binormal compress

Only store Normal + Tangent + sigr

We removed the tangent space for Required adjustments to the direction

	Saving
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sion with x10y10z10w2	I ms
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Geometry pass optimizations

Optimization

Sorting by (vertex) shader still helps

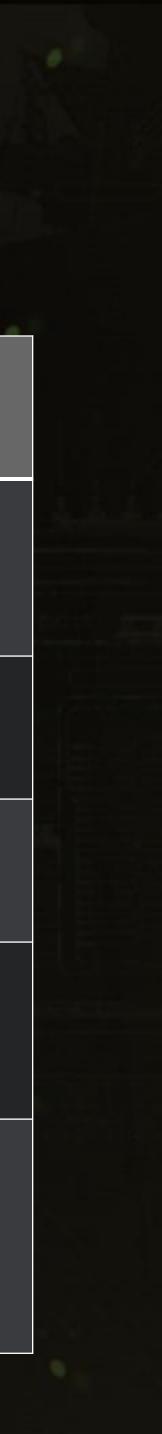
More aggressive threshold for mini

Normal/Tangent/Binormal compress

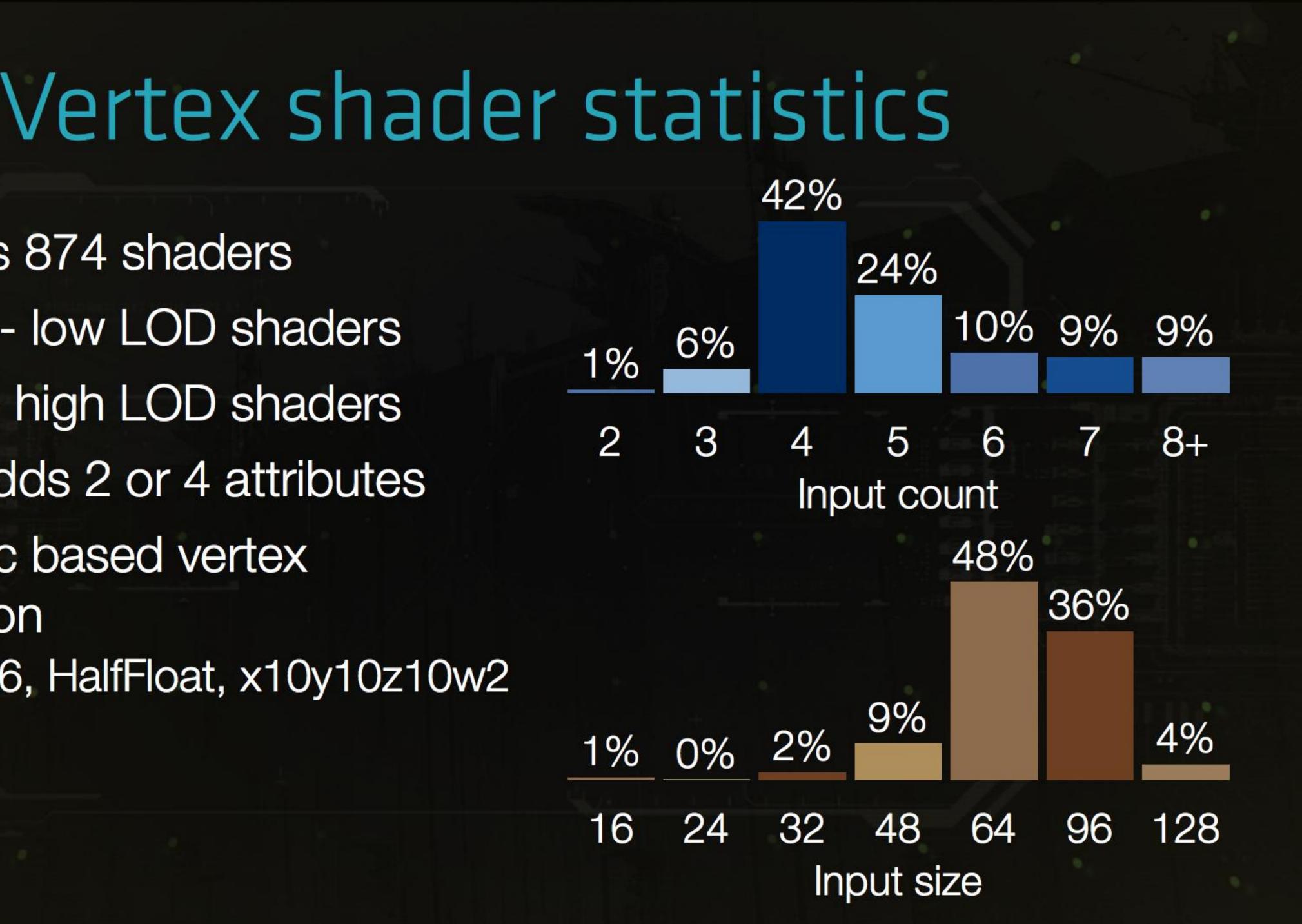
Only store Normal + Tangent + sigr

We removed the tangent space for Required adjustments to the direction

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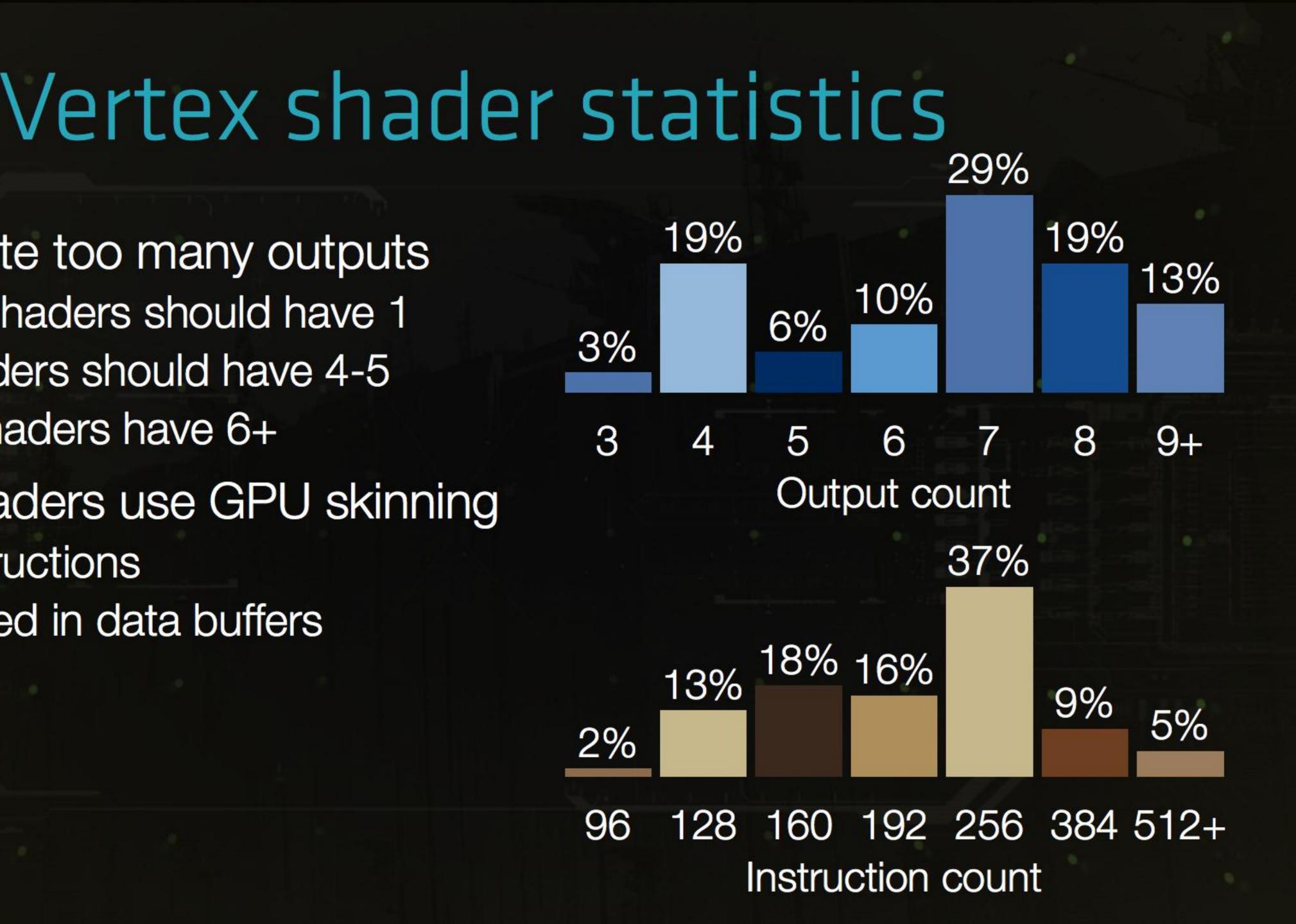


- Demo uses 874 shaders
- 3-4 inputs low LOD shaders
- 4+ inputs high LOD shaders
- Skinning adds 2 or 4 attributes
- Error metric based vertex compression
 - Float, Int16, HalfFloat, x10y10z10w2



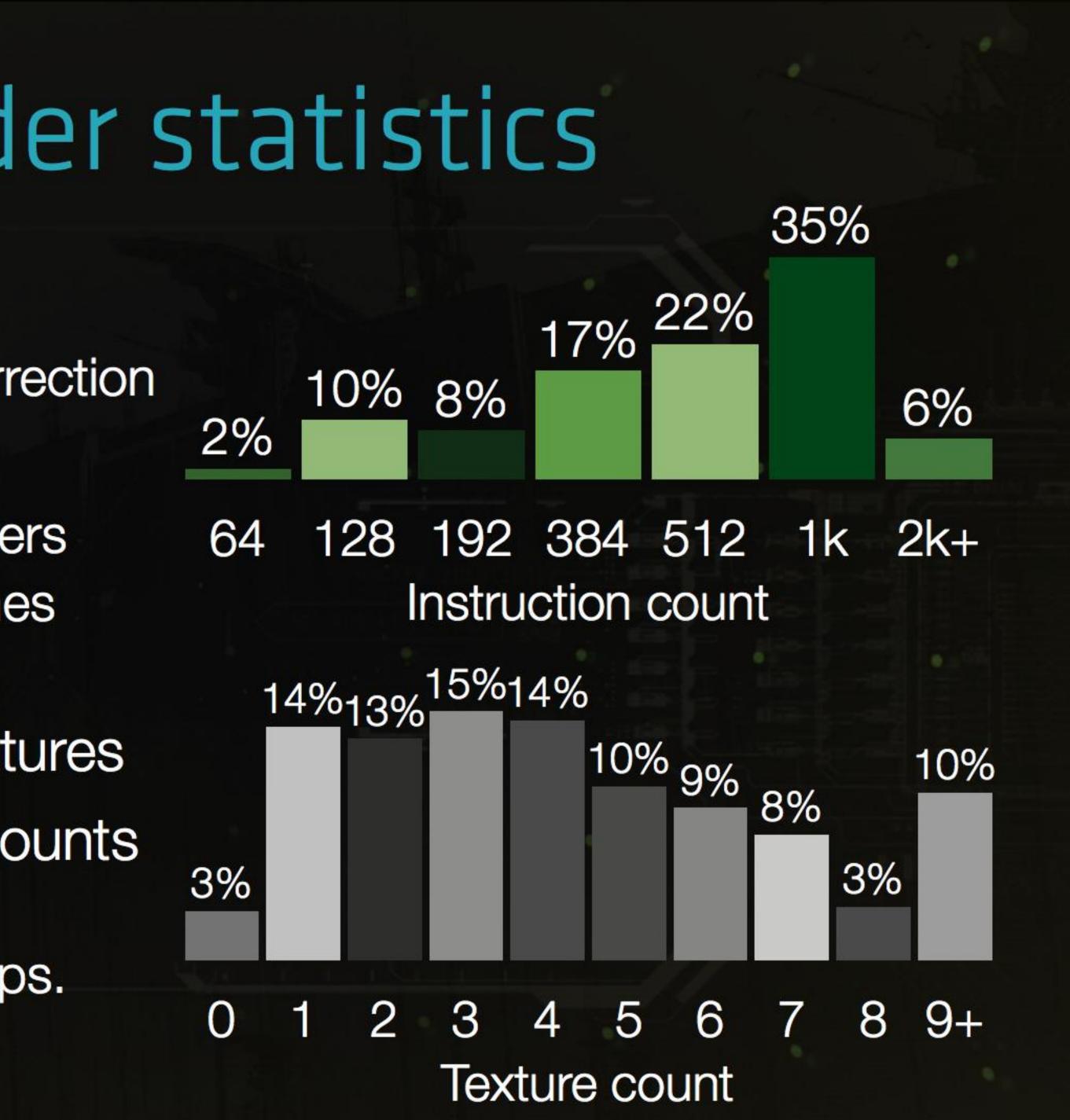
We generate too many outputs

- Shadow shaders should have 1
- Most shaders should have 4-5
- 71% of shaders have 6+
- 26% of shaders use GPU skinning
 - 256+ instructions
 - Pose stored in data buffers



Pixel shader statistics

- Forward shaders are large
 - All include lighting code, color correction
- Shader compiler still improving
 - Recently added instruction modifiers
 - Hand tuned shaders can be 3 times smaller
- Layered shaders use a lot of textures
- System textures increase total counts
 - BRDF lookups, cubemaps, light textures, volumetric lighting lookups.





Systems: Total 105, Visible 13, Updated 60 (12.4%) Particles: Alive 9174, VB Size: 1874816, Particles Size: 1214656, Particle Buffer: 1323Kb of 4096Kb used Virtual emitter: 0 (average: 0) Particles spawned: 0 (average: 0)

1-

Total GPU usage: Total CPU time: 9.39ms (over multiple threads) Update Jobs: 85 (average: 85) Manager Job: 0.38ms (average: 0.35ms) Post Update Commands: 29



Particles

- Probably the most extensive and customizable system we have Can render in full resolution or half resolution or in deferred mode

 - Can read from- and write to the g-buffer
 - Can spawn another particles, meshes, lights and sounds on impact
 - All particles use artist created shaders just like any other object
- Engine supports deferred lighting and shadowing of all particles
- Each particle can sample from forcefields (our artist placed forces)
- All this means artists don't need millions of particles to achieve the desired effect.



 All particles are generated on the CPU - 10ms Manager job determines what is visible and needs to update One particle logic update job and one vertex job per subsystem Extensive code optimizations for PS4 • Update 'static' particles early after the camera is available • Use simple double buffered linear allocator to avoid contention Only generate vertices for visible particles Plans to move to compute in the future

Particles



inic = 250.5 oral particle count: 992 ielected particle count: 0 listance: 60.2

FORCEFIELDS DISABLED

ISA -



- T.

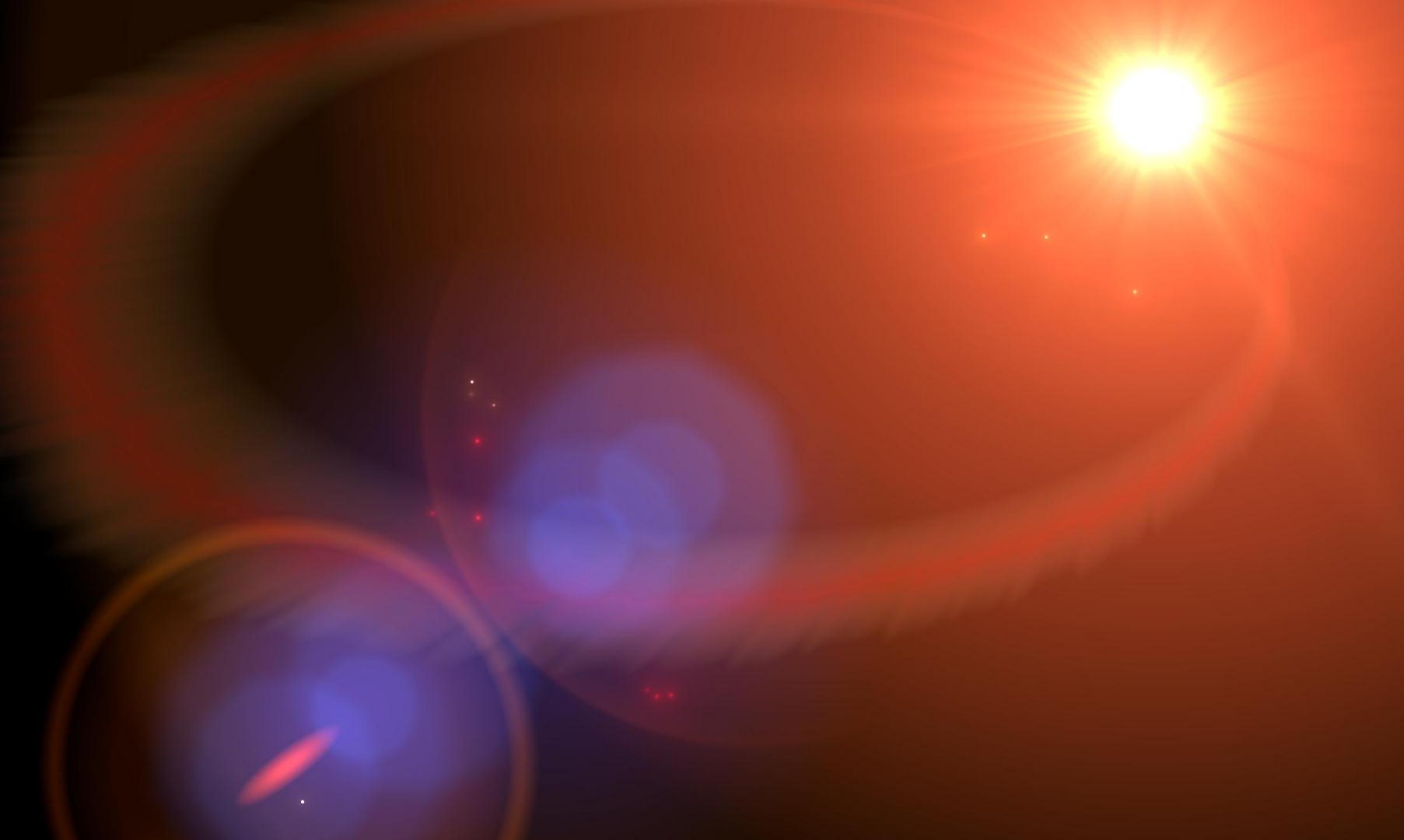
Post processing

- Real-time reflections
- Depth based and color cube color correction
- Exposure control
- Ambient occlusion
- Bloom and screen space godray effects
- Bokeh depth of field and motion blur
- Extensive artist driven lens flares
- FXAA









Optimization tips

- Post processing is usually bandwidth bound Performance scales linearly with texture format size We switched from RGBA16F to smaller minifloat or integer formats Heavy cache trashing, FP16 gave us 2x speed improvement
- Bloom downsample chain is 2x faster with R11G11B10 SSAO randomly sampled depth in FP32 FXAA used RGBA16F as color input + luminance
- 2x speedup by switch to R11G11B10 for RGB and FP16 for luminance



Optimization tips

- We found out that it's benefici texture in packs of 4
 - We're now partially unrolling our dynamic loops.
 - Almost doubled performance of our reflection raytrace
- MRT blending performance seems to scale linearly with the number of targets.
 - Blending in shader can be faster better scheduling of reads.
 - Saved 50% on our full screen dust shader.

We found out that it's beneficial to perform reads from the same

r dynamic loops. our reflection raytrace ems to scale linearly with the

er - better scheduling of reads. lust shader.



Optimization tips

- Branching can be faster than a texture fetch hit
- We merged a lot of individual passes
 - Saves read / write performance
 - DoF Near & Far CoC is calculated once and output to MRT We have a "mega" post process composite pass Merges results of all effects with the full resolution scene image. Avoids alpha blending and re-reads from memory.





Depth of field

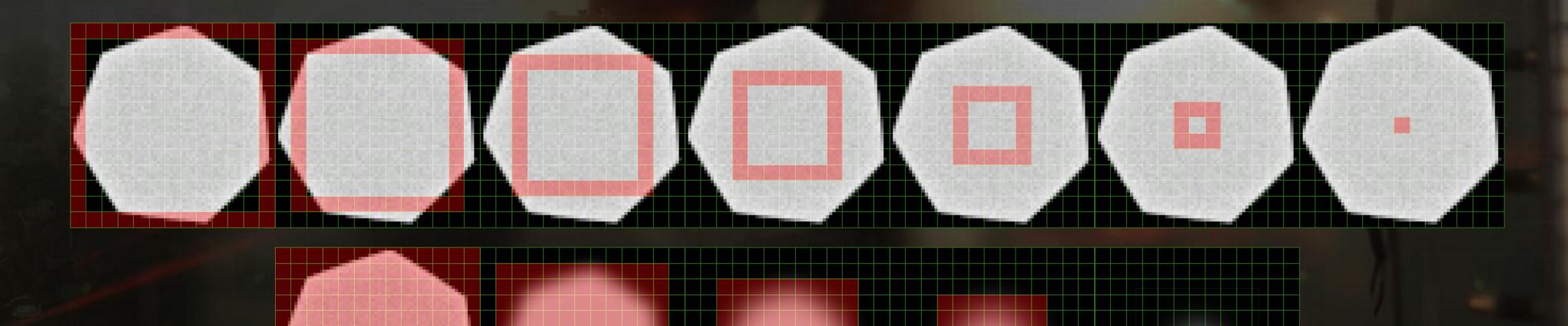
- Quarter resolution
 - Full resolution compute and point-sprite based version is not ported to PS4 yet.

- 13x13 (169 samples) gather kernel • Uses texture to define the bokeh shape Runs twice - once for far DoF, once for near DoF Was one of our most expensive effects before the optimizations



Depth of field

We wanted to utilize branching to reduce the sample count for smaller CoC values The idea - split the loop and gather in 'rings'





Depth of field

- But this is a gather filter
 - We need to know the CoC of al find the starting 'ring'.
- Solution create the max tree of CoC values
 - 4 mips are enough for our 13x13 pixel filter, takes 0.05ms
 - Also forces filtering to be coherent on tile granularity
 - Construction cost is almost inmeasurable
- Average DoF cost went down to 1/8th of the original cost
- Peak cost in demo 1/4th of the original cost

We need to know the CoC of all neighbors affecting the current pixel to

of CoC values 3 pixel filter, takes 0.05ms ent on tile granularity easurable to 1/8th of the original cos ne original cost









Reflections

- A mixture of screen space raytrace and a set of localized cubemaps.
- A lot of Guerrilla secret sauce[™] in this one...
 - Temporal reprojection for secondary bounces
 - Hierarchical buffers to accelerate the raytrace
 - Color buffer convolution matching our roughness





Raytrace OFF Cubemaps ON

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Raytrace ON Cubemaps ON

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Raytrace OFF Cubemaps ON





Raytrace ON Cubemaps ON



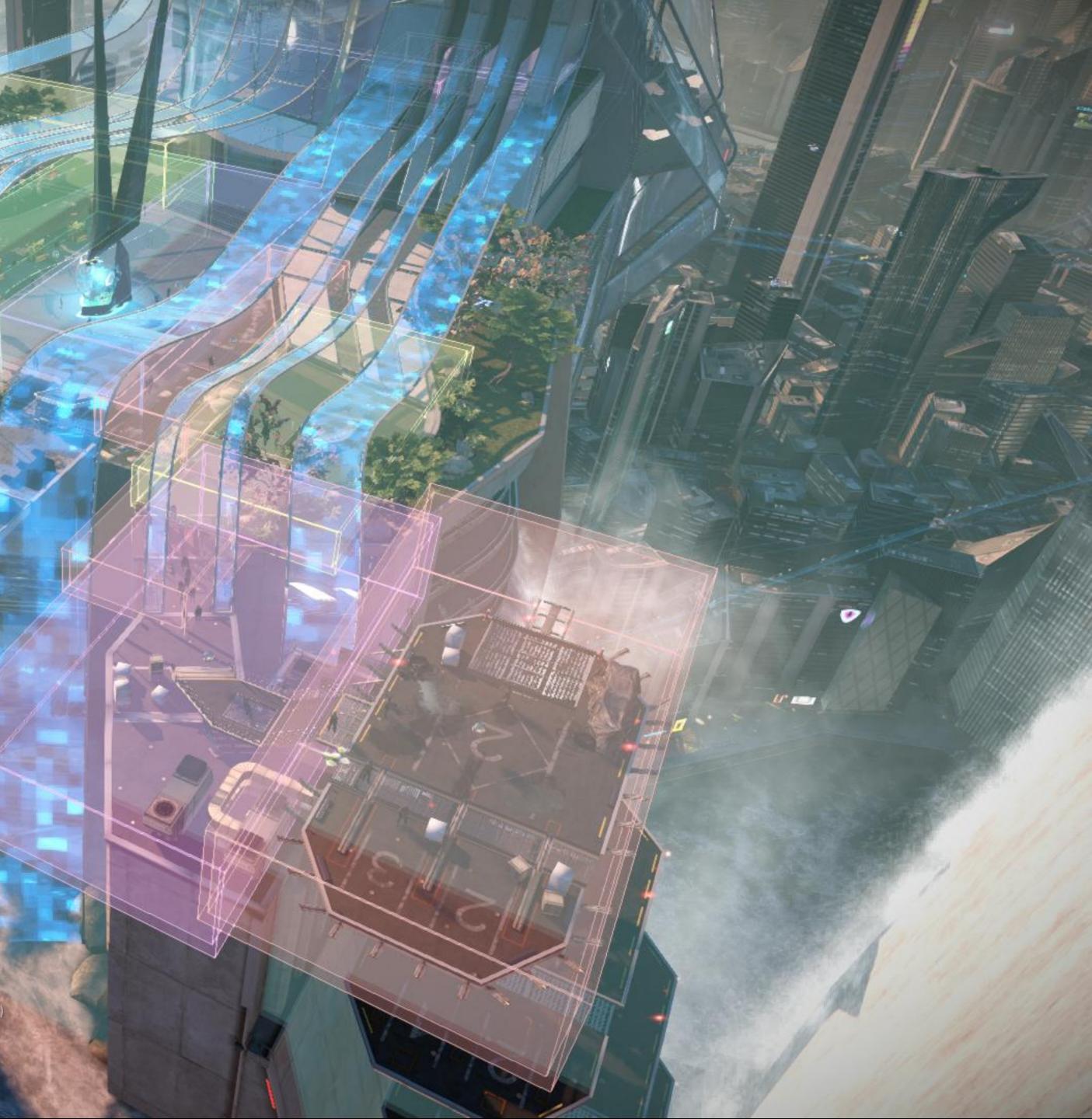
Localized cubemaps reflections

- Fallback in case the screen-space reflection cannot give result
 Reflected point is behind geometry or outside the screen
- Single global cubemap produces wrong reflections
 Classical example is seeing skybox reflection while you are standing indoor against a wall.
- The idea is to have many small, local, cubemaps
 - To capture the reflections inside a single room
 - Or on the a landing platform in Killzone demo

all, local, cubemaps e a single room Killzone demo



urrently in Cocilized Cubernap Zone. CubernapZone_level_extension (levels/single_player/kz4_demo/section_shared/zones/cubernap_zones) : Priority(8) : Resolution(128) : Fade distance(0.5m)





Localized cubemaps reflections

- We currently pick only 8 localized cubemaps per frame
- Reflection shader finds cubemaps affecting current pixel
 - Simple loop through all cubemaps
 Check if point is inside the cubemap AABB
- Fallback to global cubemap if there's no hit
- Relies on dynamic branching to avoid cubemap sampling
 - When point check fails
 - When total accumulated reflection amount reaches one





Raytrace OFF Cubemaps ON





Raytrace ON Cubemaps ON





Very important part of the Killzone look Each of our light types support volumetrics Implemented as straightforward raymarching Rendered in quarter resolution during lighting pass with the PS4 performance

Volumetrics

We wanted something fancier and faster, but were pleasantly surprised

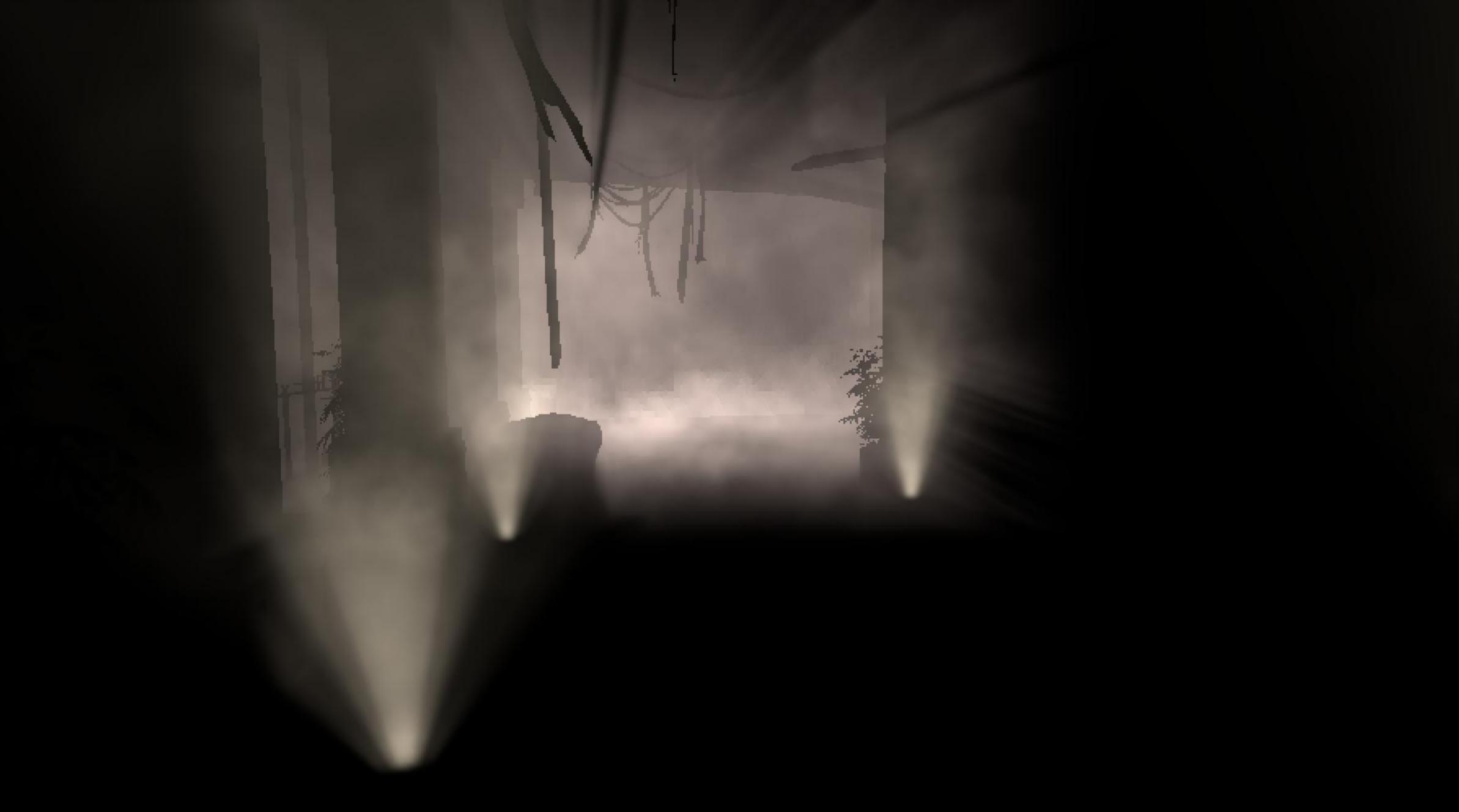


- We use a couple of tricks to improve the quality Per pixel depth dithering of raymarch
- Bilateral filter and upsample
- 16 layers deep screen space participating media buffer Contains vesired intensity of volumetric effect at given camera distance We use particles to fill this buffer
- 16 layers deep screen space volume light buffer Amount of rendered volumetric lighting at given camera distance Allows blending of volumetrics and transparencies

Volumetrics





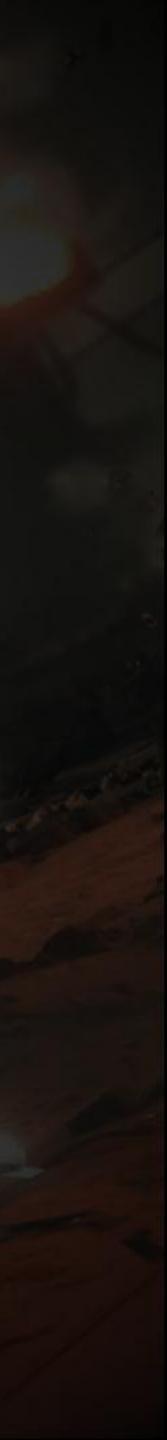






What we've learned

- PS4 is really easy to program for!
- Wide multithreading is a must, consider using jobs
 - Be nice to the OS thread scheduler and avoid spinlocks
- GPU is really fast!
 - Watch your vertex shader outputs
 - Don't be afraid of using conditionals
- GDDR5 bandwidth is awesome!
 - If you map your memory properly
 - Use the smallest pixelformat for the job
- Use compute (and tell us about your experiences)



We've only scratched the surface

