KILLZONE®
SHADOW FALL

Michal Valient
Lead Tech
Guerrilla Games

Intro

- 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
- Our aim for announcement event was to run on PS4 hardware
  - 1080p, solid 30FPS, no cheats
- This talk is about the experiences we gained during the demo period

CPU

Demo CPU Load

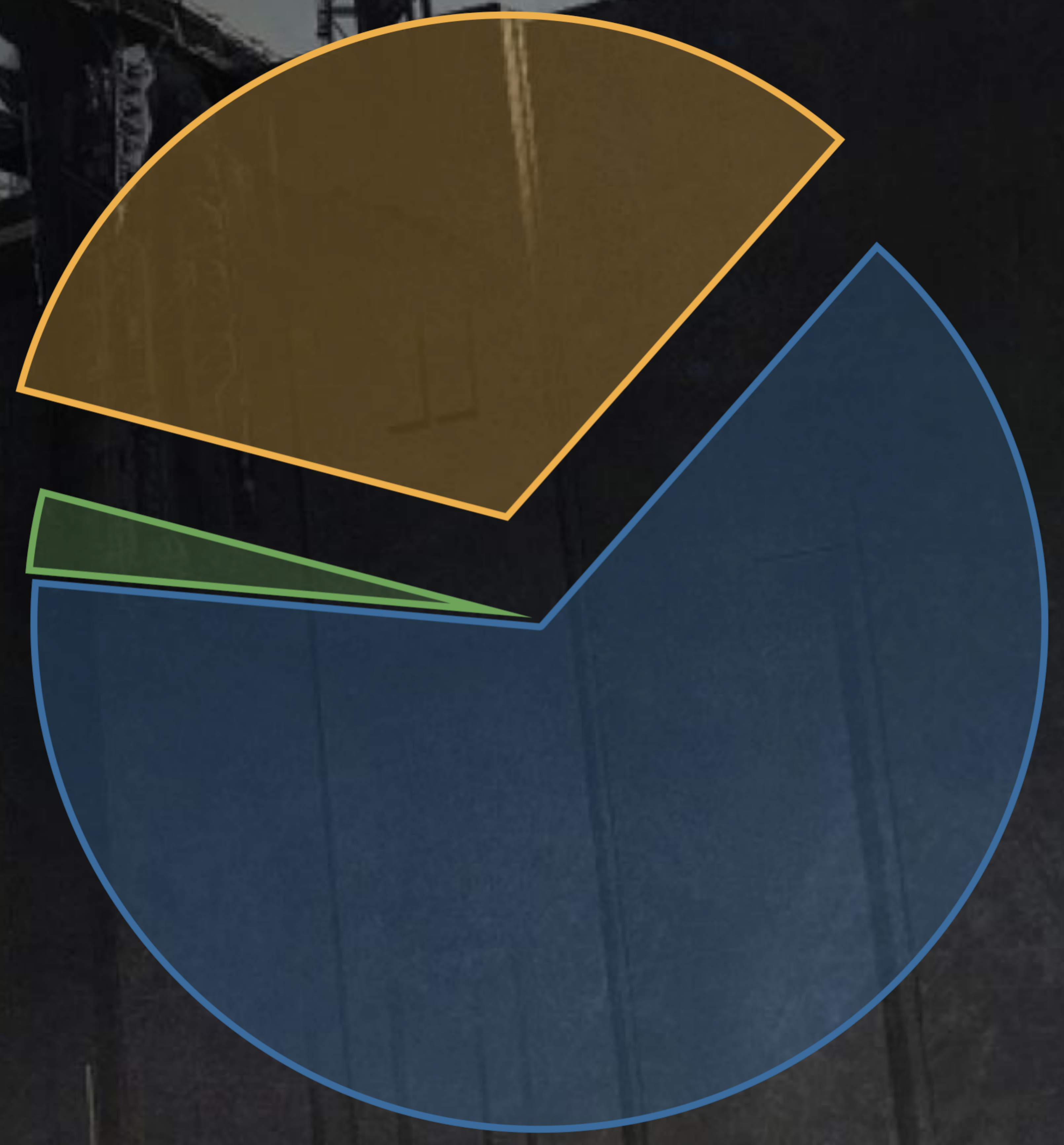
- 60 AI characters
- 940 Entities, 300 Active
- 8200 Physics objects (1500 keyframed, 6700 static)
- 500 Particle systems
- 120 Sound voices
- 110 Ray casts
- 1000 Jobs per frame

Memory Map

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

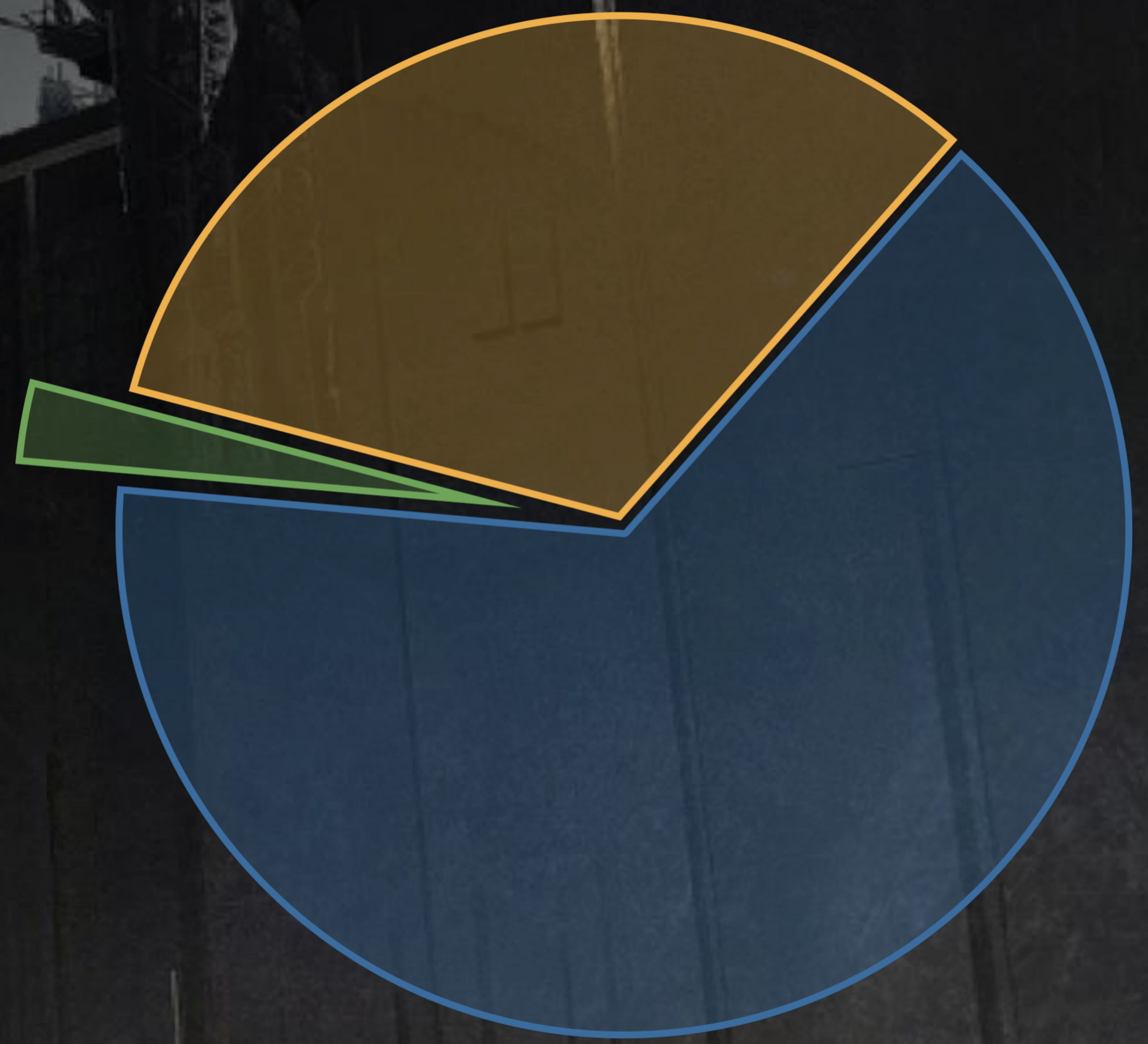
System Memory

Sound	553 MB
Havok Scratch	350 MB
Game Heap	318 MB
Various Assets, Entities, etc.	143 MB
Animation	75 MB
Executable + Stack	74 MB
LUA Script	6 MB
Particle Buffer	6 MB
AI Data	6 MB
Physics Meshes	5 MB
Total	**1,536 MB**



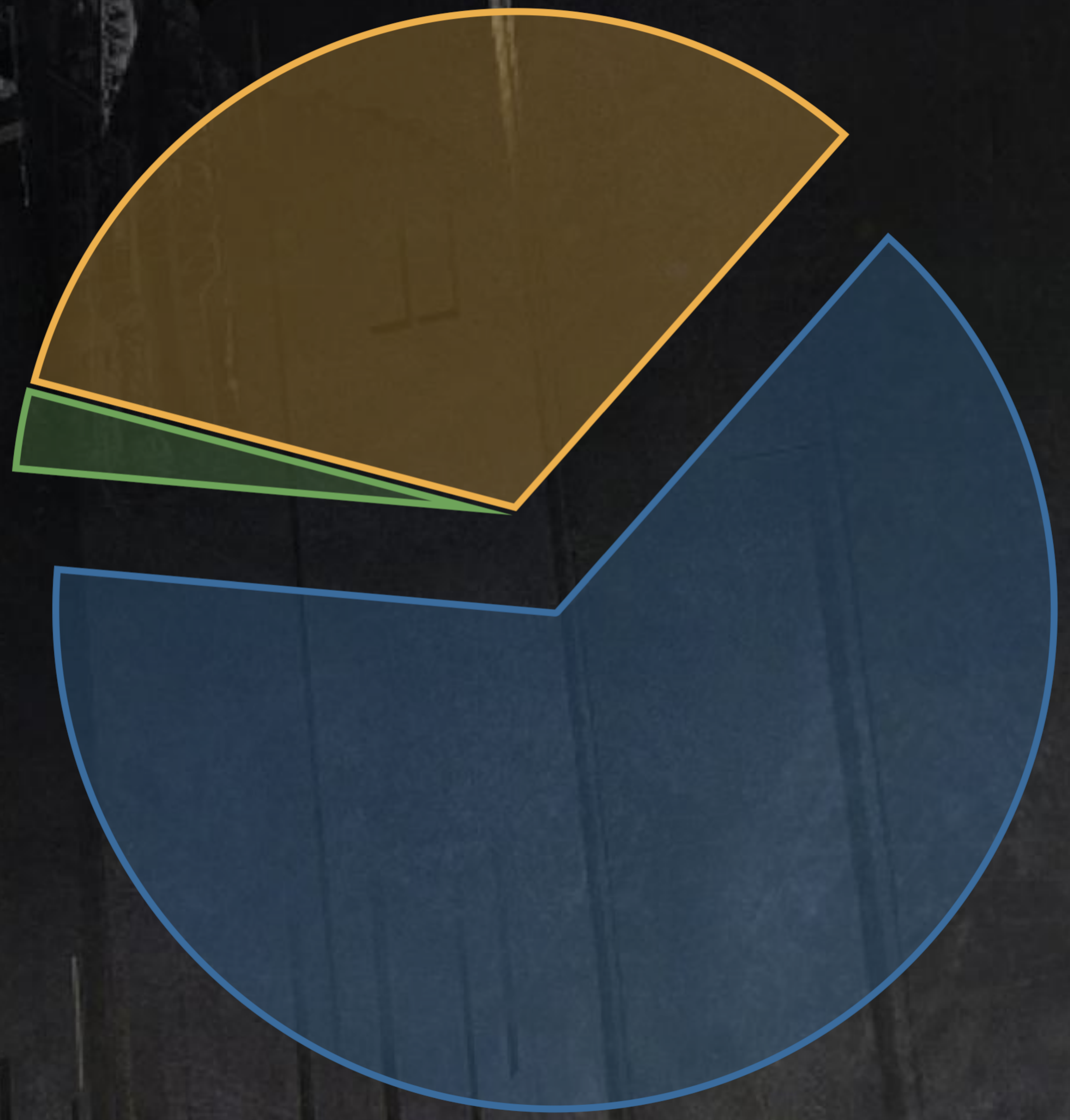
Shared Memory

Display list (2x)	64 MB
GPU Scratch	32 MB
Streaming Pool	18 MB
CPU Scratch	12 MB
Queries / Labels	2 MB
Total	**128 MB**



Video Memory

Non-Steaming Textures	1,321 MB
Render Targets	800 MB
Streaming Pool (1.6 GB of streaming data)	572 MB
Meshes	315 MB
CUE Heap (49x)	32 MB
ES-GS Buffer	16 MB
GS-VS Buffer	16 MB
Total	**3,072 MB**



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


Edit Tools View Renderer Performance Pie Menu Sound HUD Help
Graphics
Overlay
Profile HUD
FIOS Profile
CPU Profile Ctrl+Alt+Shift+C
GPU Profile Ctrl+Alt+Shift+G
Global Profile
Particle Stats Shift+P
AI
Game
Physics


Frame 29 / 29
Worker 0
2315 Events
Game
AI Manager
Draw
Debug UI
Application::UpdateDebug
void UIWindowManager::Update(float)
CPUProfileWindow
void ProfileDisplayFrame::Build(rStringPool, rcProfileTracePacketParser, rcapProfileTrace, rc...
virtual void EntityManager::Update(rcEntityUpdateInfo)
void EntityUpdater::Update(rcEntityUpdateInfo)
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
UpdateUsingJobs - 167 Jobs
JobSchedulerCPU::WaitForSemaphore
Drawing
DrawModules
GameModule::DrawModule
RepresentationManagerGame::Draw
RepresentationManagerGame::DrawGameViews
JobSchedulerCPU::WaitForSemap...
UIWindowManager
CPUProfileWindow
ProfileBars
virtual bool ProfileBarsW...
Worker 1
2372 Events
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Worker 2
2360 Events
Semaphore
Worker 3
1996 Events
PostProcessRender...
void PostProcessC...
Semaphore
Worker 4
2041 Events
Semaphore
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
Semaphore
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Frame 29 / 29
Worker 0
2315 Events
Game
AI Manager
Draw
Debug UI
Application::UpdateDebug
void UIWindowManager::Update(float)
CPUProfileWindow
void ProfileDisplayFrame::Build(rStringPool, rcProfileTracePacketParser, rcapProfileTrace, rc...
AI Individual...
JobSchedule...
virtual void EntityManager::Update(rcEntityUpdateInfo)
void EntityUpdater::Update(rcEntityUpdateInfo)
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
UpdateUsingJobs - 167 Jobs
JobSchedulerCPU::WaitForSemaphore
Drawing
DrawModules
GameModule::DrawModule
RepresentationManagerGame::Draw
RepresentationManagerGame::DrawGameViews
JobSchedulerCPU::WaitForSemap...
UIWindowManager
CPUProfileWindow
ProfileBars
virtual bool ProfileBarsW...
Worker 1
2372 Events
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Worker 2
2360 Events
Semaphore
Worker 3
1996 Events
PostProcessRender...
void PostProcessC...
void Lens...
LensFl...
Semaphore
Worker 4
2041 Events
Semaphore
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
Semaphore
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC


Worker 0
2315 Events
Frame 29 / 29
AI Manager
Phys...
Game
Represent...
Draw
AI Individuals
virtual void EntityManager::Update(rcEntityUpdateInfo)
Drawing
JobSchedulerCPU::Wait...
void EntityUpdater::Update(rcEntityUpdateInfo)
DrawModules
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
GameModule::DrawModule
UpdateUsingJobs - 167 Jobs
RepresentationManagerGame::Draw
JobSchedulerCPU::WaitForSemaphore
RepresentationManagerGame::DrawGameViews
Deferred::OnRen...
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
Entity Update Job - 2809 µs p...
DeferredGeometryDrawJob
Deferred Geometry Pass
SoldierRep - VSA_Security_Trooper
Time 305 µs
Time 487,710 Cycles
Selection
Child Packets 6
Time in / outside children 290 µs / 15 µs
Worker 2
2360 Events
DeferredGeometryDra...
Deferred Geometry Pa...
Semaphore
Worker 3
1996 Events
PostProcessRenderJob
void PostProcessCompositorNode::...
Semaphore
void LensFlareMana...
LensFlareMan...
Worker 4
2041 Events
Entity Update Job - 2836 µ...
Semaphore
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
DeferredGeometryD...
Deferred Geometry ...
Semaphore
SoldierRep
Time Avg / Median 78 µs / 47 µs
Time Min / Max 0 µs / 1,013 µs
Occurrences this frame 378
Total time this frame 28,933 µs
Occurrences per frame 374.6
Time distribution
0 µs
1,013 µs
SoldierRep - VSA_Security_Trooper
Time Avg / Median 253 µs / 247 µs
Time Min / Max 204 µs / 418 µs
Occurrences this frame 14
Total time this frame 3,556 µs
Occurrences per frame 14.0
Time distribution
204 µs
418 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Worker 0
2315 Events
AI Manager
Phys...
Game
Represent...
Draw
AI Individuals
virtual void EntityManager::Update(rcEntityUpdateInfo)
Drawing
JobSchedulerCPU::Wait...
void EntityUpdater::Update(rcEntityUpdateInfo)
DrawModules
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
GameModule::DrawModule
UpdateUsingJobs - 167 Jobs
RepresentationManagerGame::Draw
JobSchedulerCPU::WaitForSemaphore
RepresentationManagerGame::DrawGameViews
Deferred::OnRen...
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
Entity Update Job - 2809 µs p...
DeferredGeometryDrawJob
Deferred Geometry Pass
Worker 2
2360 Events
DeferredGeometryDra...
Deferred Geometry Pa...
Semaphore
Worker 3
1996 Events
PostProcessRenderJob
void PostProcessCompositorNode::...
Semaphore
void LensFlareMana...
LensFlareMan...
Worker 4
2041 Events
Entity Update Job - 2836 µ...
Semaphore
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
DeferredGeometryD...
Deferred Geometry ...
Semaphore
SoldierRep - VSA_Security_Trooper
Time 305 µs
Time 487,710 Cycles
Selection
Child Packets 6
Time in / outside children 290 µs / 15 µs
SoldierRep
Time Avg / Median 78 µs / 47 µs
Time Min / Max 0 µs / 1,013 µs
Occurrences this frame 378
Total time this frame 28,933 µs
Occurrences per frame 374.6
Time distribution
0 µs
1,013 µs
SoldierRep - VSA_Security_Trooper
Time Avg / Median 253 µs / 247 µs
Time Min / Max 204 µs / 418 µs
Occurrences this frame 14
Total time this frame 3,556 µs
Occurrences per frame 14.0
Time distribution
204 µs
418 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC


Frame 29 / 29
AI Manager
Phys...
Game
Represent...
Draw
virtual void EntityManager::Update(rcEntityUpdateInfo)
JobSchedulerCPU::Wait...
void EntityUpdater::Update(rcEntityUpdateInfo)
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
UpdateUsingJobs - 167 Jobs
JobSchedulerCPU::WaitForSemaphore
DrawModules
GameModule::DrawModule
RepresentationManagerGame::Draw
RepresentationManagerGame::DrawGameViews
Deferred::OnRen...
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
Entity Update Job - 2809 µs p...
DeferredGeometryDrawJob
Deferred Geometry Pass
SoldierRep - VSA_Security_Trooper
Time 305 µs
Time 487,710 Cycles
Selection
Child Packets 6
Time in / outside children 290 µs / 15 µs
Worker 2
2360 Events
Semaphore
Worker 3
1996 Events
PostProcessRenderJob
void PostProcessCompositorNode::...
void LensFlareMana...
LensFlareMan...
Worker 4
2041 Events
Entity Update Job - 2836 µ...
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
SoldierRep
Time Avg / Median 78 µs / 47 µs
Time Min / Max 0 µs / 1,013 µs
Occurrences this frame 378
Total time this frame 28,933 µs
Occurrences per frame 374.6
Time distribution
0 µs
1,013 µs
SoldierRep - VSA_Security_Trooper
Time Avg / Median 253 µs / 247 µs
Time Min / Max 204 µs / 418 µs
Occurrences this frame 14
Total time this frame 3,556 µs
Occurrences per frame 14.0
Time distribution
204 µs
418 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Frame 29 / 29
Worker 0
2315 Events
AI Manager
AI Individuals
JobSchedulerCPU::Wait...
Phys...
Game
virtual void EntityManager::Update(rcEntityUpdateInfo)
void EntityUpdater::Update(rcEntityUpdateInfo)
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
UpdateUsingJobs - 167 Jobs
JobSchedulerCPU::WaitForSemaphore
Represent...
Draw
Drawing
DrawModules
GameModule::DrawModule
RepresentationManagerGame::Draw
RepresentationManagerGame::DrawGameViews
Deferred::OnRen...
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
Entity Update Job - 2809 µs p...
DeferredGeometryDrawJob
Deferred Geometry Pass
SoldierRep - VSA_Security_Trooper
Time 305 µs
Time 487,710 Cycles
Selection
Child Packets 6
Time in / outside children 290 µs / 15 µs
Worker 2
2360 Events
Semaphore
Worker 3
1996 Events
PostProcessRenderJob
void PostProcessCompositorNode::...
void LensFlareMana...
LensFlareMan...
Semaphore
Worker 4
2041 Events
Entity Update Job - 2836 µ...
Semaphore
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
Semaphore
SoldierRep
Time Avg / Median 78 µs / 47 µs
Time Min / Max 0 µs / 1,013 µs
Occurrences this frame 378
Total time this frame 28,933 µs
Occurrences per frame 374.6
Time distribution
0 µs
1,013 µs
SoldierRep - VSA_Security_Trooper
Time Avg / Median 253 µs / 247 µs
Time Min / Max 204 µs / 418 µs
Occurrences this frame 14
Total time this frame 3,556 µs
Occurrences per frame 14.0
Time distribution
204 µs
418 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Frame 29 / 29
Worker 0
2315 Events
AI Manager
AI Individuals
JobSchedulerCPU::Wait...
Game
virtual void EntityManager::Update(rcEntityUpdateInfo)
void EntityUpdater::Update(rcEntityUpdateInfo)
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
UpdateUsingJobs - 167 Jobs
JobSchedulerCPU::WaitForSemaphore
Draw
Drawing
DrawModules
GameModule::DrawModule
RepresentationManagerGame::Draw
RepresentationManagerGame::DrawGameViews
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
Entity Update Job - 2809 µs p...
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Time 204 µs
Time 325,288 Cycles
Worker 2
2360 Events
DeferredGeometryDra...
Deferred Geometry Pa...
Semaphore
Worker 3
1996 Events
PostProcessRenderJob
void PostProcessCompositorNode::...
void LensFlareMana...
LensFlareMan...
Semaphore
Worker 4
2041 Events
Entity Update Job - 2836 µ...
Semaphore
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
DeferredGeometryD...
Deferred Geometry ...
Semaphore
Semaphore
Time Avg / Median 18,696 µs / 228 µs
Time Min / Max 10 µs / 321,979 µs
Occurrences this frame 58
Total time this frame 1,487,176 µs
Occurrences per frame 53.0
Time distribution
10 µs
321,979 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Frame 29 / 29
Worker 0
2315 Events
AI Manager
AI Individuals
JobSchedulerCPU::Wait...
Game
virtual void EntityManager::Update(rcEntityUpdateInfo)
void EntityUpdater::Update(rcEntityUpdateInfo)
void EntityUpdater::DoUpdate(rcEntityUpdateInfo)
UpdateUsingJobs - 167 Jobs
JobSchedulerCPU::WaitForSemaphore
Represent...
Draw
Drawing
DrawModules
GameModule::DrawModule
RepresentationManagerGame::Draw
RepresentationManagerGame::DrawGameViews
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
Entity Update Job - 2809 µs p...
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Time 204 µs
Time 325,288 Cycles
Worker 2
2360 Events
Deferred Geometry Pa...
Semaphore
Worker 3
1996 Events
PostProcessRenderJob
void PostProcessCompositorNode::...
void LensFlareMana...
LensFlareMan...
Semaphore
Worker 4
2041 Events
Entity Update Job - 2836 µ...
Soldier - ISA_L...
Semaphore
Worker 5
2552 Events
Entity Update Job - 8151 µs previously
Deferred Geometry ...
Semaphore
Semaphore
Time Avg / Median 18,696 µs / 228 µs
Time Min / Max 10 µs / 321,979 µs
Occurrences this frame 58
Total time this frame 1,487,176 µs
Occurrences per frame 53.0
Time distribution
10 µs
321,979 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Frame 29 / 29
Worker 0
2315 Events
Draw
Drawing
DrawModules
GameModule::DrawModule
RepresentationManagerGame::Draw
RepresentationManagerGame::DrawGameViews
FinishUpdateDrawab...
Deferred::OnRenderScene
JobSchedulerCPU::WaitForSemaphore
Debug UI
Worker 1
2372 Events
UpdateDrawable...
DeferredLightRe...
DeferredGeometryDrawJob
RenderLights -
SunLight -
Deferred Geometry Pass
Semaphore
DeferredGeometryDrawJob
Time 6,962 µs
Time 11,098,191 Cycles
Selection
Child Packets 2
Time in / outside children 6,895 µs / 66 µs
Worker 2
2360 Events
ImageBl...
DeferredGeometryDrawJob
BuildSort...
Deferred Geometry Pass
Worker 3
1996 Events
PostProcessRenderJob
void PostProcessCompositorNode::OnEvaluate(rRenderSystem, rRenderingContext, rcDrawInfoList)
void LensFlareManager::Render(rRenderingContext, rcDraw...
LensFlareManager::DrawInstances
Semaphore
Worker 4
2041 Events
DeferredLightRe...
DeferredShading...
RenderLights ...
SceneRenderer...
SpotLight -
Semaphore
Worker 5
2552 Events
UpdateDrawable...
DeferredLigh...
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
DeferredGeometryDrawJob
Time Avg / Median 4,165 µs / 2,438 µs
Time Min / Max 2,141 µs / 8,625 µs
Occurrences this frame 3
Total time this frame 11,627 µs
Occurrences per frame 3.0
Time distribution
2,141 µs
8,625 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Frame 29 / 29
Worker 0
2315 Events
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Worker 2
2360 Events
Worker 3
1996 Events
Worker 4
2041 Events
DeferredShadingPassJob
SceneRendererDeferre...
Worker 5
2552 Events
StaticModelEntity
Time Avg / Median 55 µs / 33 µs
Time Min / Max 9 µs / 369 µs
Occurrences this frame 154
Total time this frame 7,327 µs
Occurrences per frame 148.1
Time distribution
9 µs
369 µs
Owner Object
Name StaticModelEntity
Location entities/sequencer/staticmodelentity
Type EntityRep
Mesh
models/skybox/vehicles/skybox_isa_dropship/model:Skybox_ISA_Dropship[1]
ISA_Dropship_L5[6]
polySurface2049
Primitive
Triangles 54
Vertices 67
Sort Mode Off - 2
Cast Shadows False
Allow Static Decals True
Allow Dynamic Decals True
Stream 0 8
Pos 6
Stream 1 16
Normal 4
TangentBFlip 4 Unused in Direct
UV0 8
Shader
Name AO_on_LM@IBL
Location models/skybox/vehicles/skybox_isa_dropship/model
Unlit Cycles 0 / 0
Deferred Cycles 0 / 0
StaticModelEntity
Time 30 µs
Time 47,865 Cycles
Selection
Child Packets 1
Time in / outside children 16 µs / 14 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Worker 0
40
41
42
43
44
45
46
2315 Events
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Worker 2
2360 Events
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Worker 3
1996 Events
Semaphore
Worker 4
2041 Events
DeferredShadingPassJob
Semaphore
Worker 5
2552 Events
DeferredGeometryDrawJob
Deferred Geometry Pass
Semaphore
Owner Object
Name StaticModelEntity
Location entities/sequencer/staticmodelentity
Type EntityRep
Mesh
|--+ models/skybox/vehicles/skybox_isa_dropship/model:Skybox_ISA_Dropship[1]
|--+ ISA_Dropship_L5[6]
|--+ polySurface2049
Primitive
Triangles 54
Vertices 67
Sort Mode Off - 2
Cast Shadows False
Allow Static Decals True
Allow Dynamic Decals True
Stream 0 8
Pos 6
Stream 1 16
Normal 4
TangentBFlip 4 Unused in Direct
UV0 8
Shader
Name AO_on_LM@IBL
Location models/skybox/vehicles/skybox_isa_dropship/model
Unlit Cycles 0 / 0
Deferred Cycles 0 / 0
StaticModelEntity
Time 30 µs
Time 47,865 Cycles
Selection
Child Packets 1
Time in / outside children 16 µs / 14 µs
Frame 29 / 29
StaticModelEntity
Time Avg / Median 55 µs / 33 µs
Time Min / Max 9 µs / 369 µs
Occurrences this frame 154
Total time this frame 7,327 µs
Occurrences per frame 148.1
Time distribution
9 µs
369 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

Frame 29 / 29
Worker 0
18
19
20
2315 Events
Physics
AI Individuals
JobSchedulerCPU::WaitForSemaphore
Worker 1
2372 Events
Worker 2
2360 Events
Worker 3
1996 Events
Worker 4
2041 Events
Worker 5
2552 Events
AIndividual::ExecuteTasks - VSA_Civi...
AIndividual::UpdateLowLevelBehaviour - VSA_Civilia...
AIHTNPrimitiveTaskWalkSeg...
AISkillManager::Update
AIndividual::UpdateHighLevelBeh...
Semaphore
sAllocatorMutex::Lock()
Time 42 µs
Time 68,233 Cycles
sAllocatorMutex::Lock()
Time Avg / Median 6 µs / 2 µs
Time Min / Max
Occurrences this frame 320
Total time this frame 2,261 µs
Occurrences per frame
Time distribution
0 µs
954 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC


Frame 29 / 29
sAllocatorMutex::Lock()
Time Avg / Median 6 µs / 2 µs
Time Min / Max 0 µs / 954 µs
Occurrences this frame 320
Total time this frame 2,261 µs
Occurrences per frame 259.0
Time distribution
0 µs
954 µs
Worker 0
2315 Events
Worker 1
2372 Events
Worker 2
2360 Events
Worker 3
1996 Events
Worker 4
2041 Events
Worker 5
2552 Events
AI Individuals
JobSchedulerCPU::WaitForSemaphore
sAllocatorMutex::Lock()
Time 42 µs
Time 68,233 Cycles
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC

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

GPU

- 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

- Volumetrics supported on every light

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

Render targets

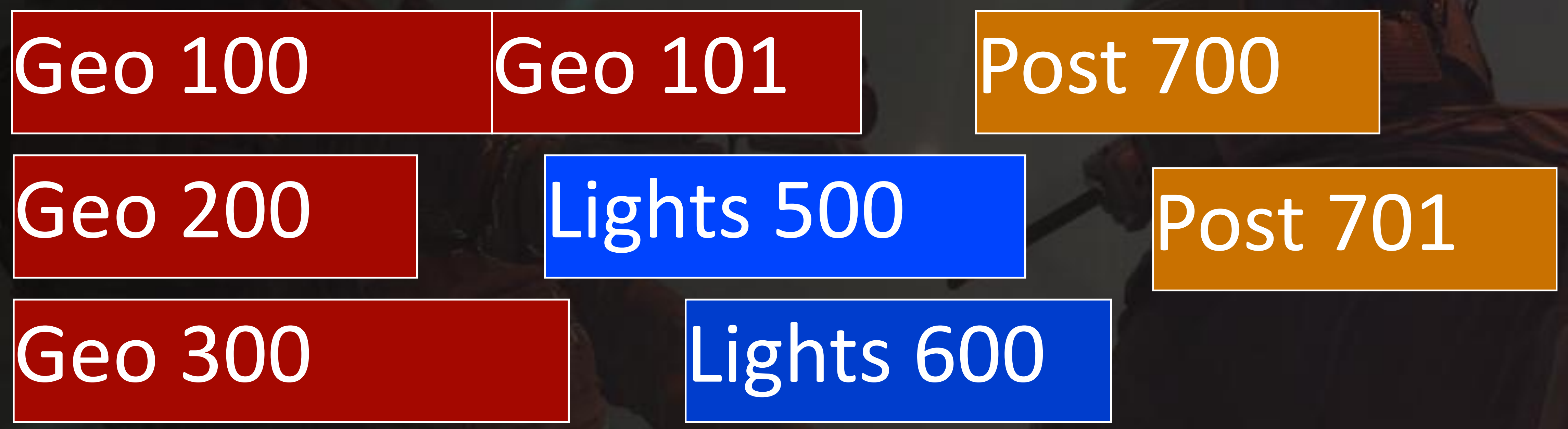
- G-buffer with 5 MRTs + 32bit depth
  - 1080p, RGBA16f, no MSAA at the moment
- 2x 8bit backbuffers
- 4x 2048x2048x32bit shadow maps
  - We don’t use HiZ to avoid decompression before reads.
- A lot of low resolution buffers for post process effects
- Most of the buffers are overlapping in memory
- We still need to optimize the layout and formats

Display list

- Out of order generation using jobs
  - Geometry passes are split into multiple jobs too
- We kick up to 60 command buffers per frame
  - CBs are sorted based on a how they need to be consumed
  - All double buffered
- We issue WaitForFlip at the very last moment in the frame
  - Right before the next flip when the GPU renders into the back buffer
  - Allows to avoid blocking waits on CPU during long frames

Display list

- CPU
  - Core 0
  - Core 1
  - Core 2

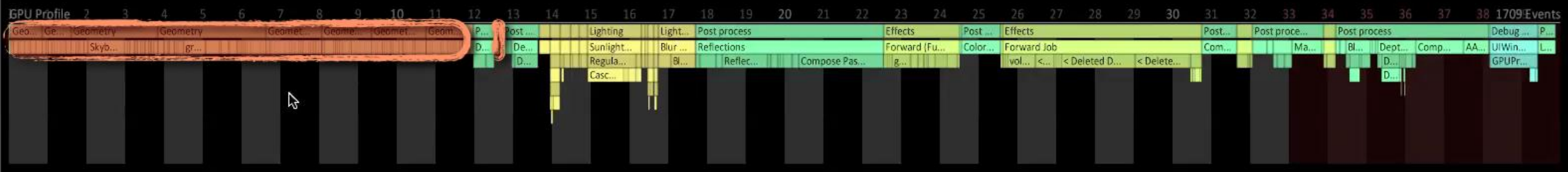


- GPU


Edit
Tools
View
Renderer
Performance
Pie Menu
Sound
HUD
Help
Graphics
Overlay
Profile HUD
FIOS Profile
CPU Profile Ctrl+Alt+Shift+C
GPU Profile Ctrl+Alt+Shift+G
Global Profile
Particle Stats Shift+P
AI
Game
Physics

GPU Profile

Frame 16 / 16



Name	Time	Pixels	Tris	Prims	Count	Type
▸ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▸ Effects	10.27%	254.31%	24,370	159	159	
▸ Lighting	0.60%	59.57%	179,439	47	47	

Legend

Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T

GPU Profile

Frame 16 / 16

Name	Time	Pixels	Tris	Prims	Count	Type
▸ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▸ Effects	10.27%	254.31%	24,370	159	159	
▸ Lighting	0.60%	59.57%	179,439	47	47	

Legend

Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T

GPU Profile

Frame 16 / 16

Name	Time	Pixels	Tris	Prims	Count	Type
▸ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▸ Effects	10.27%	254.31%	24,370	159	159	
▸ Lighting	0.60%	59.57%	179,439	47	47	

Legend

Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T

GPU Profile

Frame 16 / 16

Name	Time	Pixels	Tris	Prims	Count	Type
▸ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▸ Effects	10.27%	254.31%	24,370	159	159	
▸ Lighting	0.60%	59.57%	179,439	47	47	

Legend

Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T

GPU Profile

Frame 16 / 16

Name	Time	Pixels	Tris	Prims	Count	Type
▸ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▸ Effects	10.27%	254.31%	24,370	159	159	
▸ Lighting	0.60%	59.57%	179,439	47	47	

Legend

Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T

GPU Profile

Frame 16 / 16

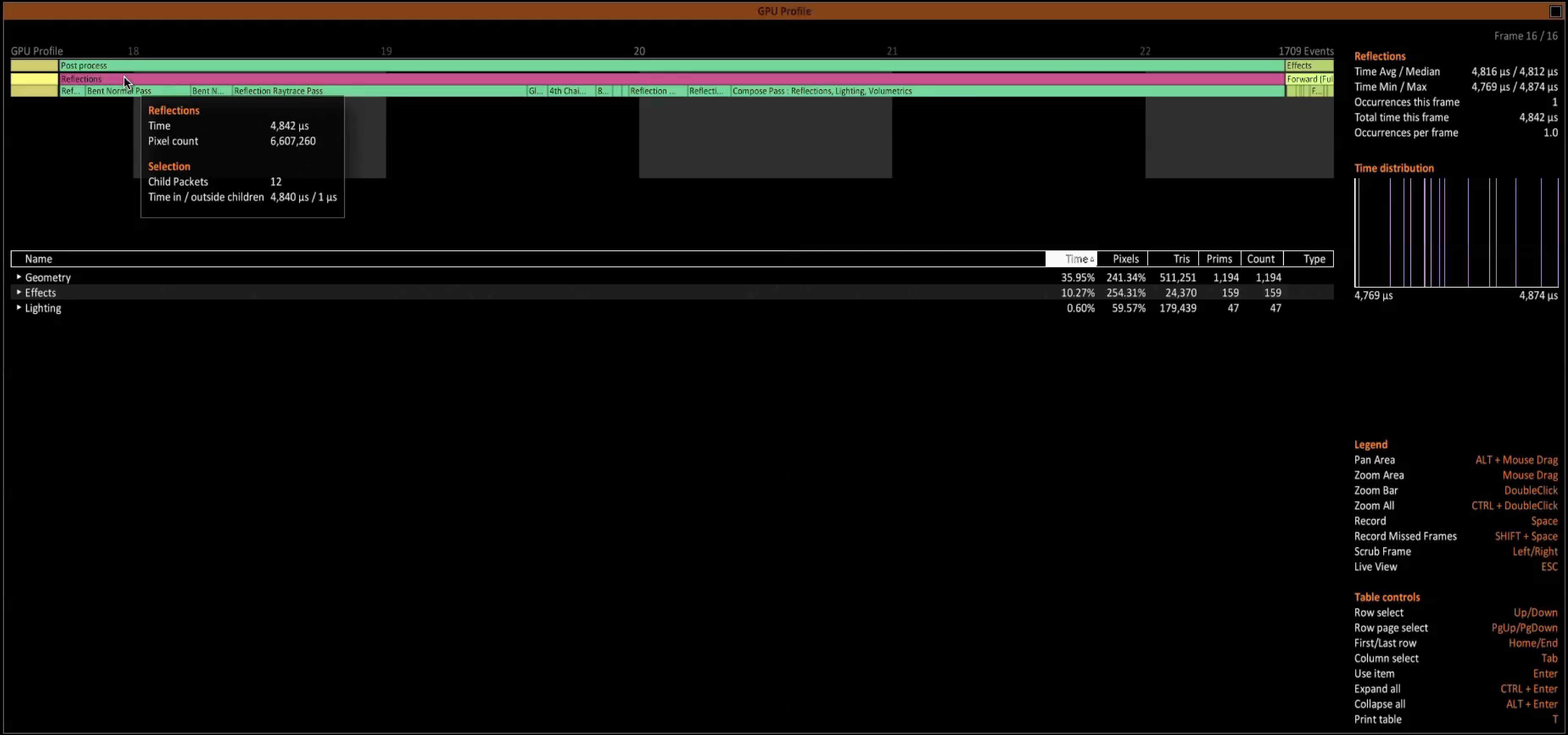
Name	Time	Pixels	Tris	Prims	Count	Type
▸ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▸ Effects	10.27%	254.31%	24,370	159	159	
▸ Lighting	0.60%	59.57%	179,439	47	47	

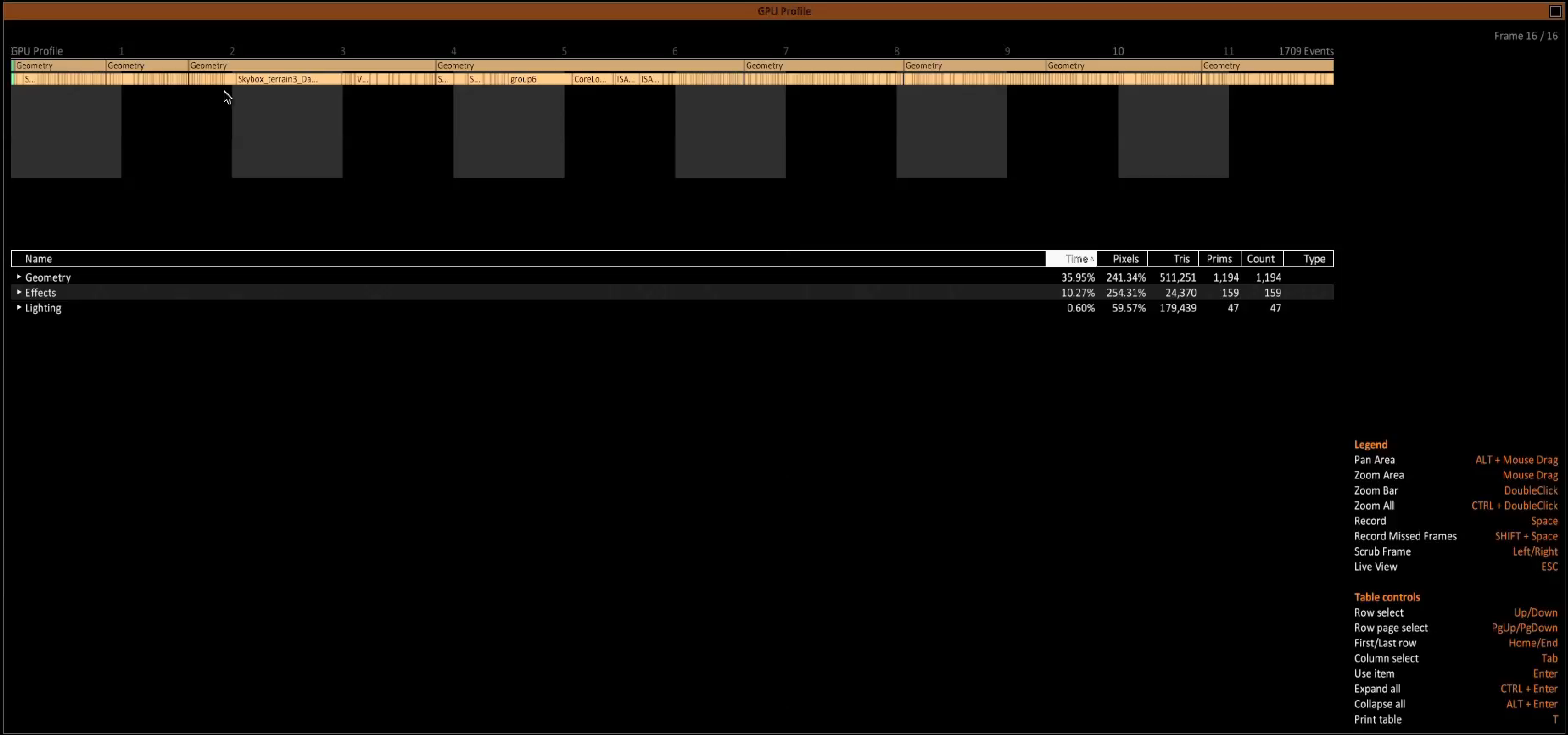
Legend

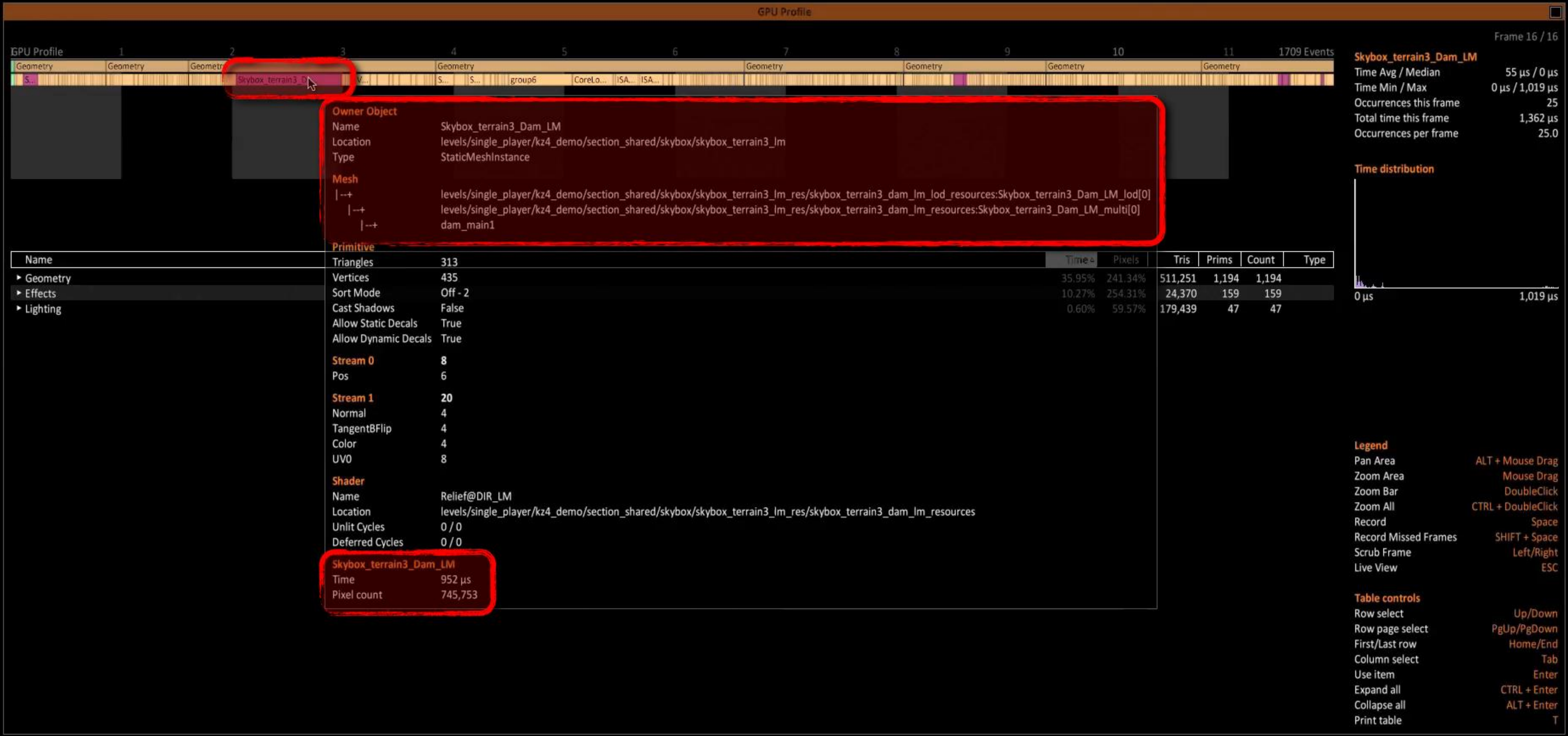
Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

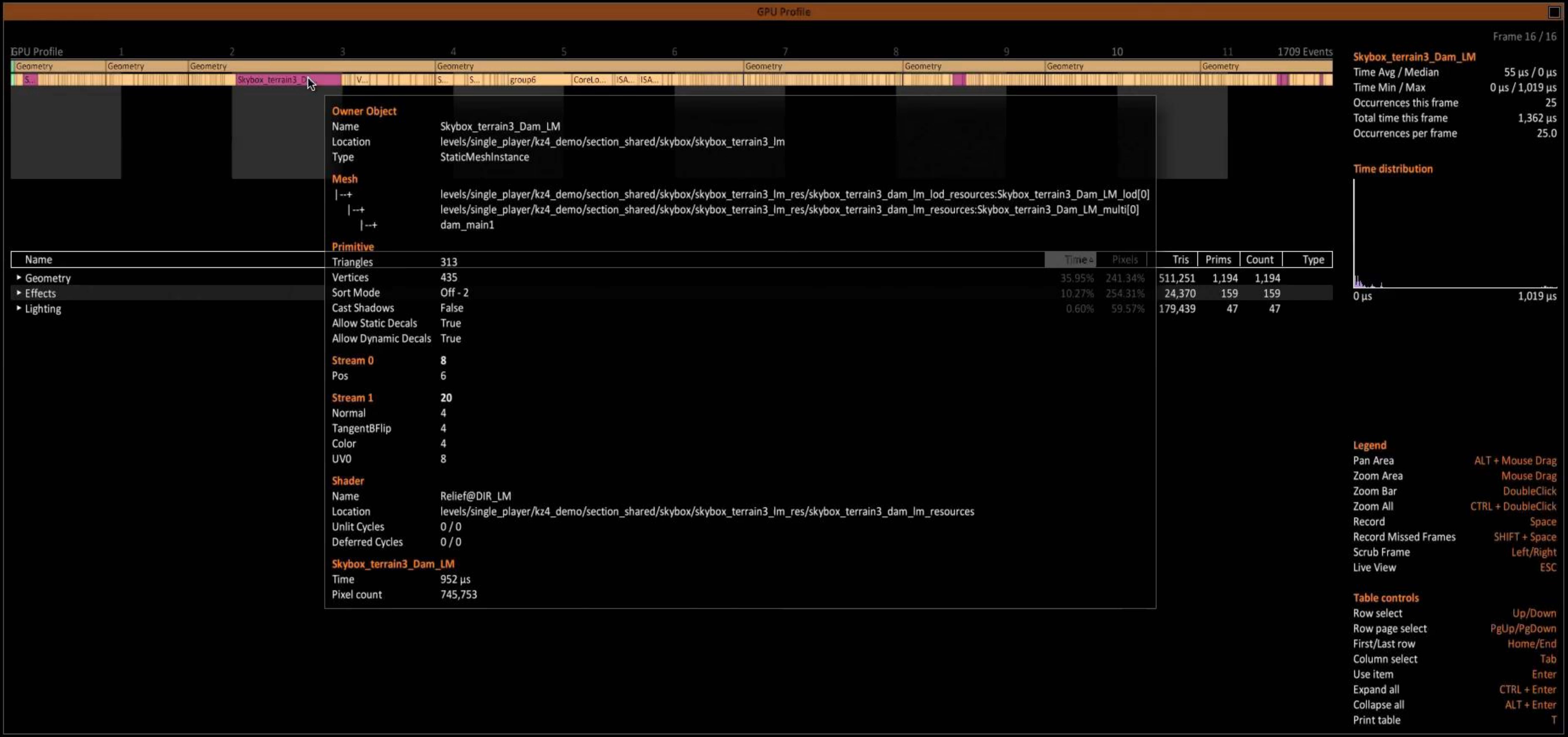
Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T


GPU Profile
Frame 16 / 16
GPU Profile
18
19
20
21
22
1709 Events
Post process
Effects
Reflections
Forward (Ful
Ref...
Bent Normal Pass
Bent N...
Reflection Raytrace Pass
Gl...
4th Chai...
B...
Reflection ...
Reflecti...
Compose Pass : Reflections, Lighting, Volumetrics
F...
Reflections
Time 4,842 µs
Pixel count 6,607,260
Selection
Child Packets 12
Time in / outside children 4,840 µs / 1 µs
Name
Time
Pixels
Tris
Prims
Count
Type
Geometry 35.95% 241.34% 511,251 1,194 1,194
Effects 10.27% 254.31% 24,370 159 159
Lighting 0.60% 59.57% 179,439 47 47
Reflections
Time Avg / Median 4,816 µs / 4,812 µs
Time Min / Max 4,769 µs / 4,874 µs
Occurrences this frame 1
Total time this frame 4,842 µs
Occurrences per frame 1.0
Time distribution
4,769 µs
4,874 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC
Table controls
Row select Up/Down
Row page select PgUp/PgDown
First/Last row Home/End
Column select Tab
Use item Enter
Expand all CTRL + Enter
Collapse all ALT + Enter
Print table T


GPU Profile
Frame 16 / 16
GPU Profile
1
2
3
4
5
6
7
8
9
10
11
1709 Events
Geometry
Skybox_terrain3_Da...
group6
CoreLo...
Name
Time
Pixels
Tris
Prims
Count
Type
Geometry 35.95% 241.34% 511,251 1,194 1,194
Effects 10.27% 254.31% 24,370 159 159
Lighting 0.60% 59.57% 179,439 47 47
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC
Table controls
Row select Up/Down
Row page select PgUp/PgDown
First/Last row Home/End
Column select Tab
Use item Enter
Expand all CTRL + Enter
Collapse all ALT + Enter
Print table T


GPU Profile
GPU Profile
1709 Events
Frame 16 / 16
Geometry
Skybox_terrain3_D
group6
Owner Object
Name Skybox_terrain3_Dam_LM
Location levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm
Type StaticMeshInstance
Mesh
|--+ levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm_res/skybox_terrain3_dam_lm_lod_resources:Skybox_terrain3_Dam_LM_lod[0]
|--+ levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm_res/skybox_terrain3_dam_lm_resources:Skybox_terrain3_Dam_LM_multi[0]
|--+ dam_main1
Primitive
Triangles 313
Vertices 435
Sort Mode Off - 2
Cast Shadows False
Allow Static Decals True
Allow Dynamic Decals True
Stream 0 8
Pos 6
Stream 1 20
Normal 4
TangentBFlip 4
Color 4
UV0 8
Shader
Name Relief@DIR_LM
Location levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm_res/skybox_terrain3_dam_lm_resources
Unlit Cycles 0 / 0
Deferred Cycles 0 / 0
Skybox_terrain3_Dam_LM
Time 952 µs
Pixel count 745,753
Name
Geometry
Effects
Lighting
Time
Pixels
Tris
Prims
Count
Type
35.95% 241.34% 511,251 1,194 1,194
10.27% 254.31% 24,370 159 159
0.60% 59.57% 179,439 47 47
Skybox_terrain3_Dam_LM
Time Avg / Median 55 µs / 0 µs
Time Min / Max 0 µs / 1,019 µs
Occurrences this frame 25
Total time this frame 1,362 µs
Occurrences per frame 25.0
Time distribution
0 µs
1,019 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC
Table controls
Row select Up/Down
Row page select PgUp/PgDown
First/Last row Home/End
Column select Tab
Use item Enter
Expand all CTRL + Enter
Collapse all ALT + Enter
Print table T



GPU Profile
GPU Profile 1 2 3 4 5 6 7 8 9 10 11 1709 Events
Frame 16 / 16
Geometry
Skybox_terrain3_D...
group6
CoreLo...
ISA... ISA...
Owner Object
Name Skybox_terrain3_Dam_LM
Location levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm
Type StaticMeshInstance
Mesh
|--+ levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm_res/skybox_terrain3_dam_lm_lod_resources:Skybox_terrain3_Dam_LM_lod[0]
|--+ levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm_res/skybox_terrain3_dam_lm_resources:Skybox_terrain3_Dam_LM_multi[0]
|--+ dam_main1
Primitive
Triangles 313
Vertices 435
Sort Mode Off - 2
Cast Shadows False
Allow Static Decals True
Allow Dynamic Decals True
Stream 0 8
Pos 6
Stream 1 20
Normal 4
TangentBFlip 4
Color 4
UV0 8
Shader
Name Relief@DIR_LM
Location levels/single_player/kz4_demo/section_shared/skybox/skybox_terrain3_lm_res/skybox_terrain3_dam_lm_resources
Unlit Cycles 0 / 0
Deferred Cycles 0 / 0
Skybox_terrain3_Dam_LM
Time 952 µs
Pixel count 745,753
Name
Geometry
Effects
Lighting
Time Pixels Tris Prims Count Type
35.95% 241.34% 511,251 1,194 1,194
10.27% 254.31% 24,370 159 159
0.60% 59.57% 179,439 47 47
Skybox_terrain3_Dam_LM
Time Avg / Median 55 µs / 0 µs
Time Min / Max 0 µs / 1,019 µs
Occurrences this frame 25
Total time this frame 1,362 µs
Occurrences per frame 25.0
Time distribution
0 µs 1,019 µs
Legend
Pan Area ALT + Mouse Drag
Zoom Area Mouse Drag
Zoom Bar DoubleClick
Zoom All CTRL + DoubleClick
Record Space
Record Missed Frames SHIFT + Space
Scrub Frame Left/Right
Live View ESC
Table controls
Row select Up/Down
Row page select PgUp/PgDown
First/Last row Home/End
Column select Tab
Use item Enter
Expand all CTRL + Enter
Collapse all ALT + Enter
Print table T

GPU Profile

Frame 16 / 16

Name	Time	Pixels	Tris	Prims	Count	Type
▼ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▼ levels	26.56%	225.82%	331,183	685	685	
▼ single_player	26.56%	225.82%	331,183	685	685	
▼ kz4_demo	26.56%	225.82%	331,183	685	685	
▼ section_shared	15.17%	171.72%	161,317	323	323	
▽ skybox	14.41%	171.72%	159,091	238	238	
► skybox_terrain3_lm	11.34%	112.10%	156,999	216	216	
► skybox_sheets	2.75%	55.74%	664	11	11	
► skybox_dome3	0.32%	3.88%	444	10	10	
► skybox_terrain5_lm	0.00%	0.00%	984	1	1	
► lighting	0.77%	0.00%	2,226	85	85	
► section_01	11.38%	54.10%	169,854	361	361	
► section_dropship_chase	0.00%	0.00%	12	1	1	
► entities	9.13%	15.39%	175,301	504	504	
	0.27%	0.13%	4,767	5	5	
► Effects	10.27%	254.31%	24,370	159	159	
► Lighting	0.60%	59.57%	179,439	47	47	

Legend

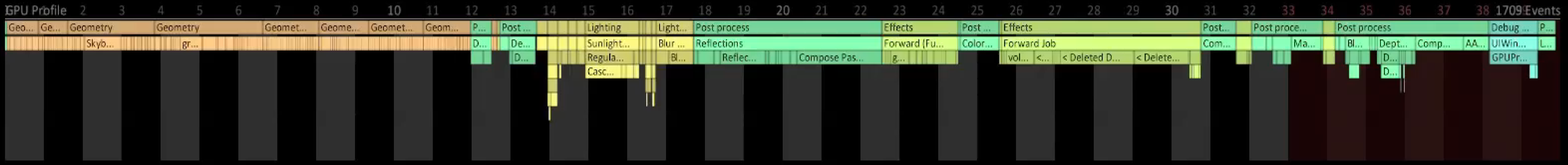
Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T

GPU Profile

Frame 16 / 16



Name	Time	Pixels	Tris	Prims	Count	Type
▼ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▼ levels	26.56%	225.82%	331,183	685	685	
▼ single_player	26.56%	225.82%	331,183	685	685	
▼ kz4_demo	26.56%	225.82%	331,183	685	685	
▼ section_shared	15.17%	171.72%	161,317	323	323	
▽ skybox	14.41%	171.72%	159,091	238	238	
▸ skybox_terrain3_lm	11.34%	112.10%	156,999	216	216	
▸ skybox_sheets	2.75%	55.74%	664	11	11	
▸ skybox_dome3	0.32%	3.88%	444	10	10	
▸ skybox_terrain5_lm	0.00%	0.00%	984	1	1	
▸ lighting	0.77%	0.00%	2,226	85	85	
▸ section_01	11.38%	54.10%	169,854	361	361	
▸ section_dropship_chase	0.00%	0.00%	12	1	1	
▸ entities	9.13%	15.39%	175,301	504	504	
	0.27%	0.13%	4,767	5	5	
▸ Effects	10.27%	254.31%	24,370	159	159	
▸ Lighting	0.60%	59.57%	179,439	47	47	

Legend

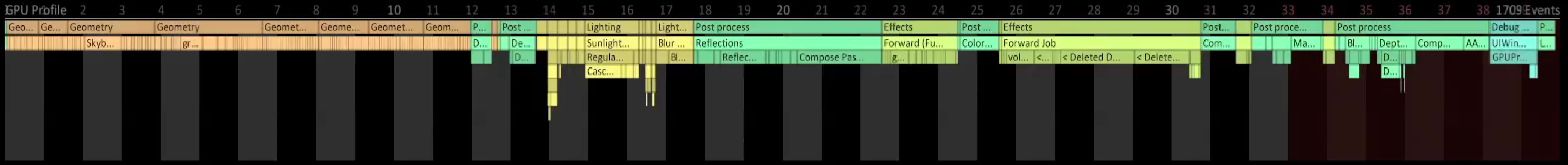
Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T

GPU Profile

Frame 16 / 16



Name	Time	Pixels	Tris	Prims	Count	Type
▼ Geometry	35.95%	241.34%	511,251	1,194	1,194	
▼ levels	26.56%	225.82%	331,183	685	685	
▼ single_player	26.56%	225.82%	331,183	685	685	
▼ kz4_demo	26.56%	225.82%	331,183	685	685	
▼ section_shared	15.17%	171.72%	161,317	323	323	
▼ skybox	14.41%	171.72%	159,091	238	238	
▷ skybox_terrain3_lm	11.34%	112.10%	156,999	216	216	
▶ skybox_sheets	2.75%	55.74%	664	11	11	
▶ skybox_dome3	0.32%	3.88%	444	10	10	
▶ skybox_terrain5_lm	0.00%	0.00%	984	1	1	
▶ lighting	0.77%	0.00%	2,226	85	85	
▶ section_01	11.38%	54.10%	169,854	361	361	
▶ section_dropship_chase	0.00%	0.00%	12	1	1	
▶ entities	9.13%	15.39%	175,301	504	504	
	0.27%	0.13%	4,767	5	5	
▶ Effects	10.27%	254.31%	24,370	159	159	
▶ Lighting	0.60%	59.57%	179,439	47	47	

Legend

Pan Area	ALT + Mouse Drag
Zoom Area	Mouse Drag
Zoom Bar	DoubleClick
Zoom All	CTRL + DoubleClick
Record	Space
Record Missed Frames	SHIFT + Space
Scrub Frame	Left/Right
Live View	ESC

Table controls

Row select	Up/Down
Row page select	PgUp/PgDown
First/Last row	Home/End
Column select	Tab
Use item	Enter
Expand all	CTRL + Enter
Collapse all	ALT + Enter
Print table	T


www.fraps.com
VEKTA CITY - 2381
VSA HEADQUARTERS

Characters

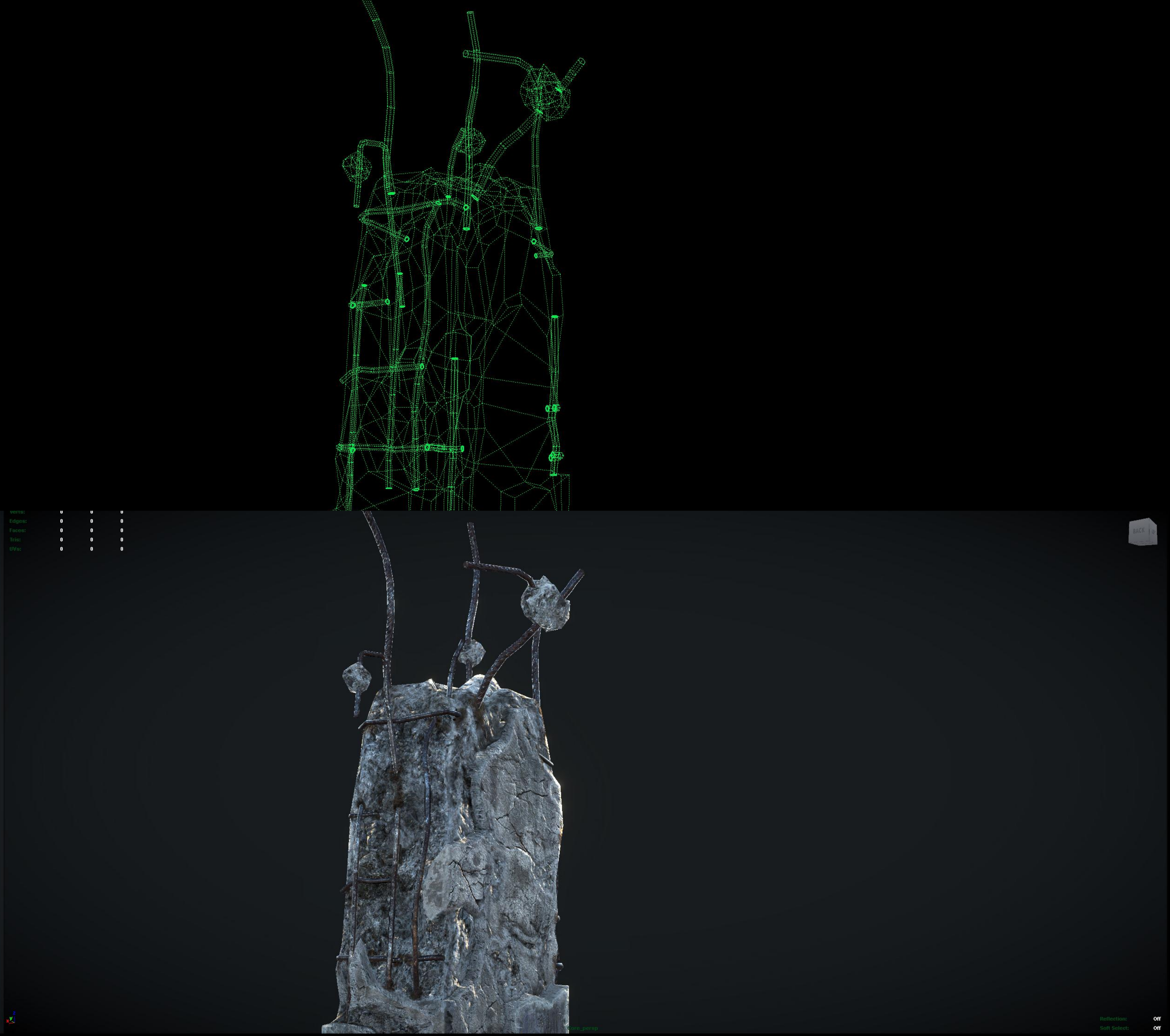
- Around 40k polygons for the highest LOD
  - Enough to capture all detail for closeups
  - We provided detail guide for LOD setups
- Up to 8 bone influences per vertex
  - Most vertices use 4-5, drops with LOD#
- 6 x 2k x 2k textures for character body
  - Plus detail maps and head textures
  - 10ppi,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

LOD#	Polycount	Distance
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+

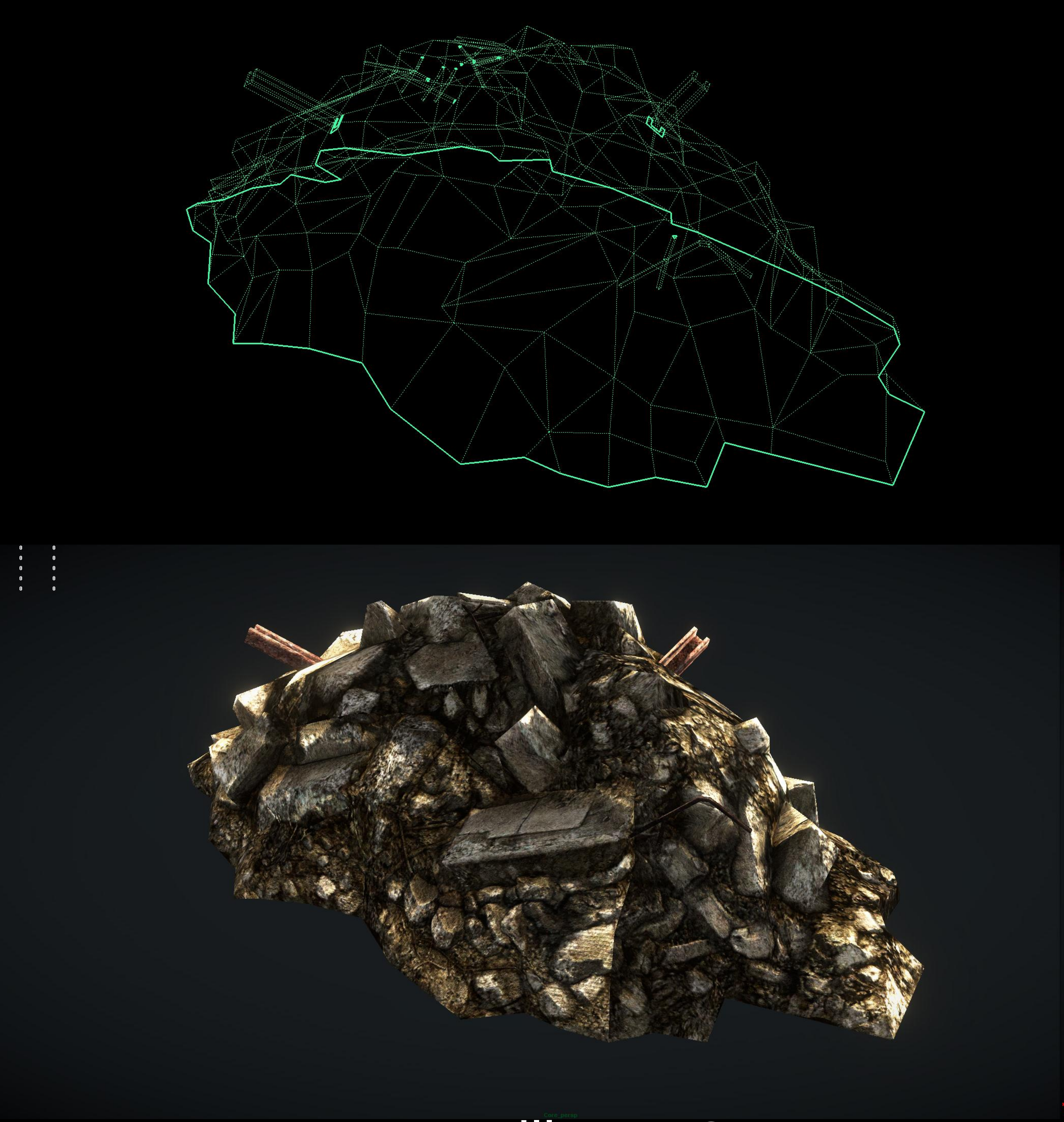

Killzone: Shadow Fall
Killzone 3

Killzone 3 Killzone: Shadow Fall

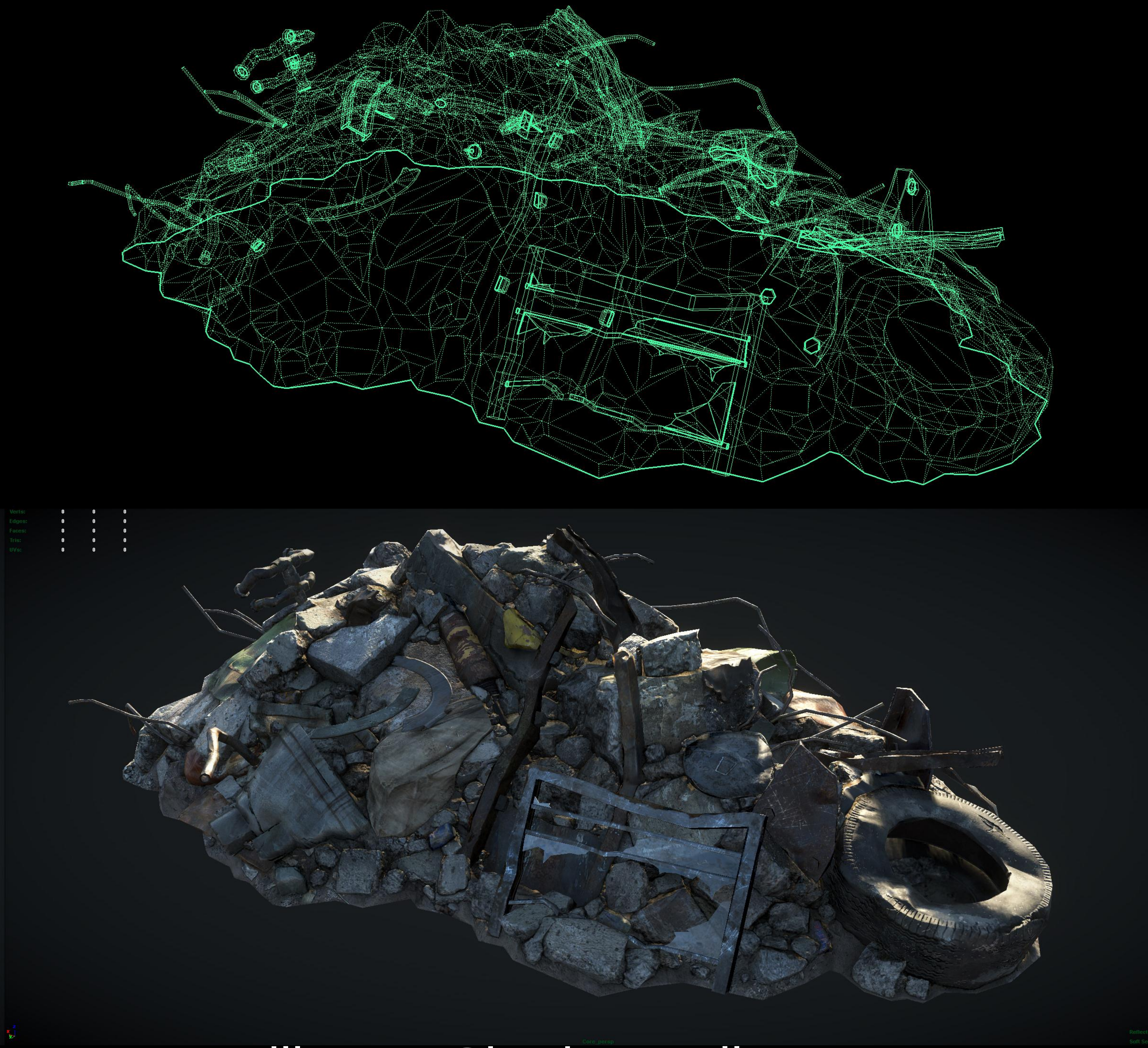
Killzone 3



Killzone: Shadow Fall



Killzone 3



Killzone: Shadow Fall

Geometry pass optimizations

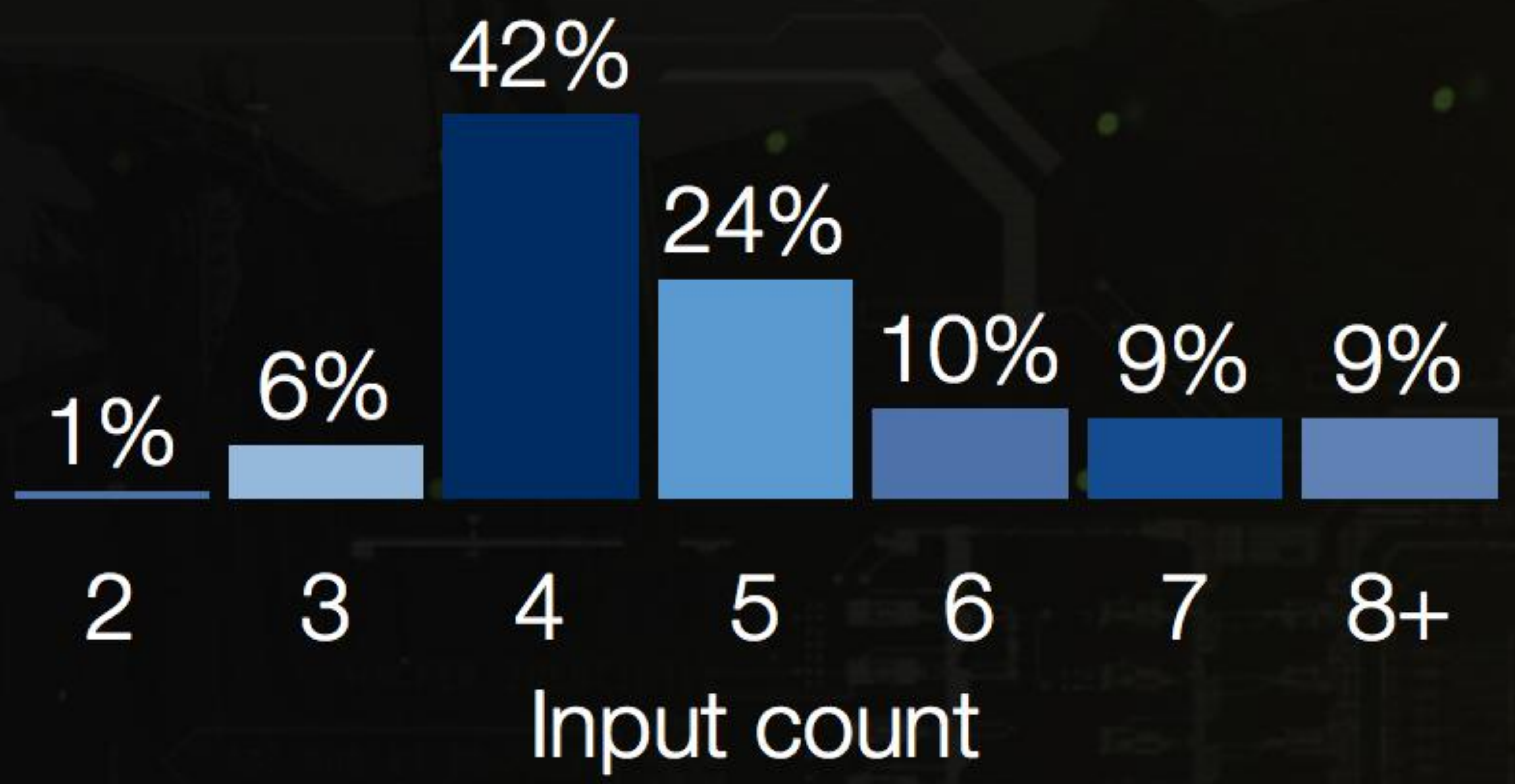
Optimization	Saving
Sorting by (vertex) shader still helps	☺ ms
More aggressive threshold for minimum bone influence (1%)	☺ ms
Normal/Tangent/Binormal compression with x10y10z10w2	☺ ms
Only store Normal + Tangent + sign bit for Binormal	☺ ms
We removed the tangent space for distant static LODs Required adjustments to the directional lightmap sampling	☺ ms

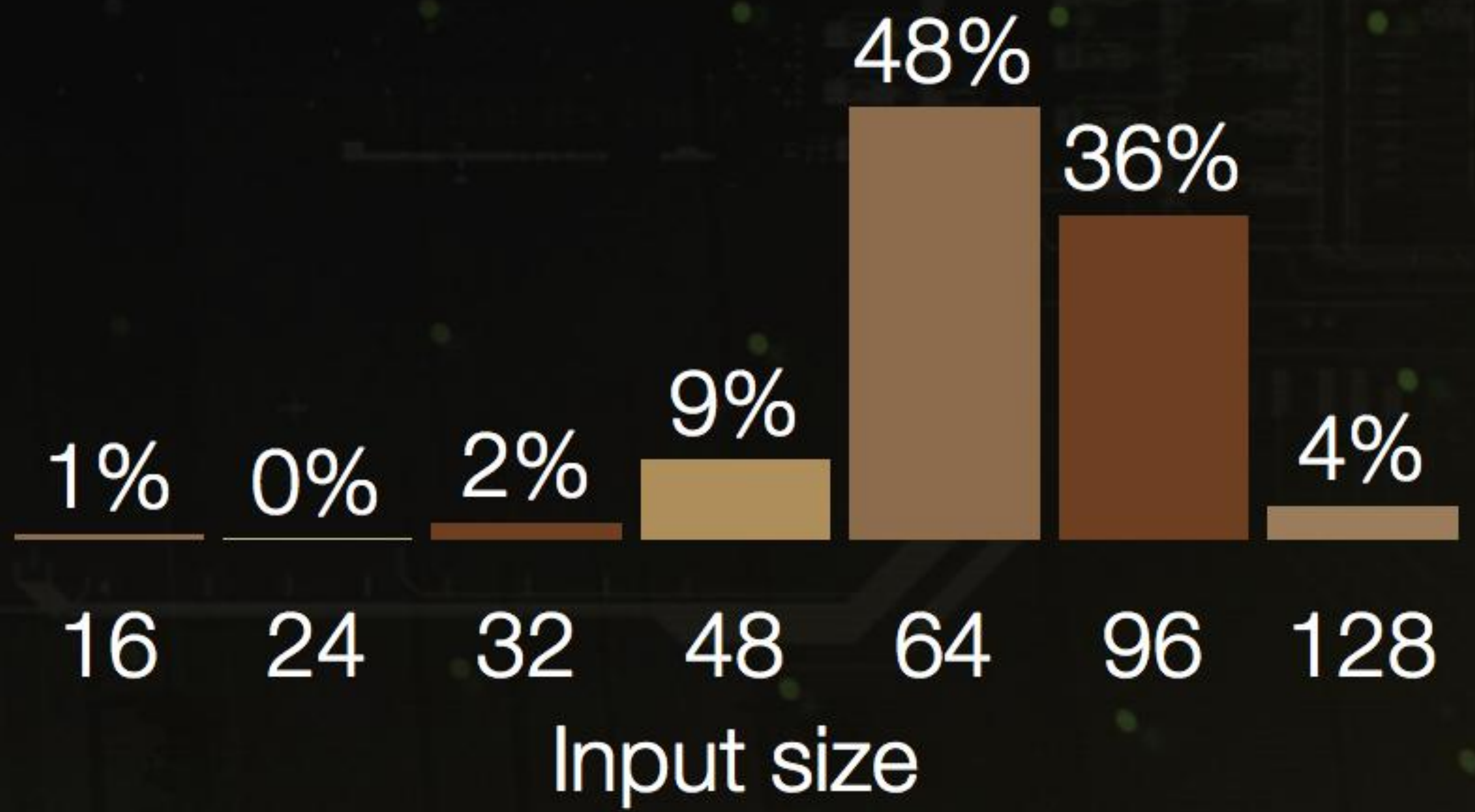
Geometry pass optimizations

Optimization	**Saving**
Sorting by (vertex) shader still helps	☺ ms
More aggressive threshold for minimum bone influence (1%)	☺ ms
Normal/Tangent/Binormal compression with x10y10z10w2	☺ ms
Only store Normal + Tangent + sign bit for Binormal	☺ ms
We removed the tangent space for distant static LODs Required adjustments to the directional lightmap sampling	☺ ms

Vertex shader statistics

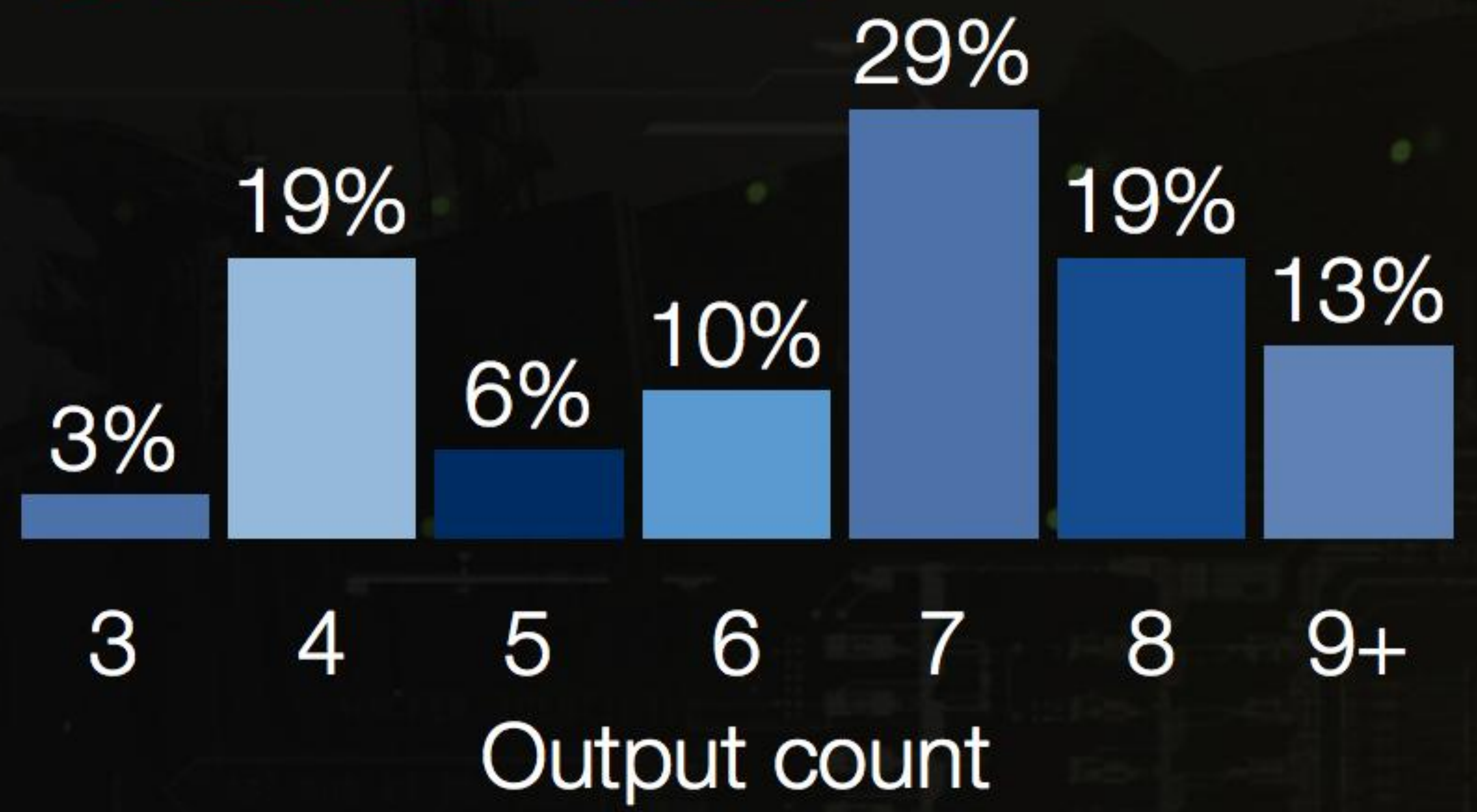
- Demo uses 874 shaders
- 3-4 inputs - low LOD shaders
- 4+ inputs - high LOD shaders
- Skinning adds 2 or 4 attributes
- Error metric based vertex compression
  - Float, Int16, HalfFloat, x10y10z10w2

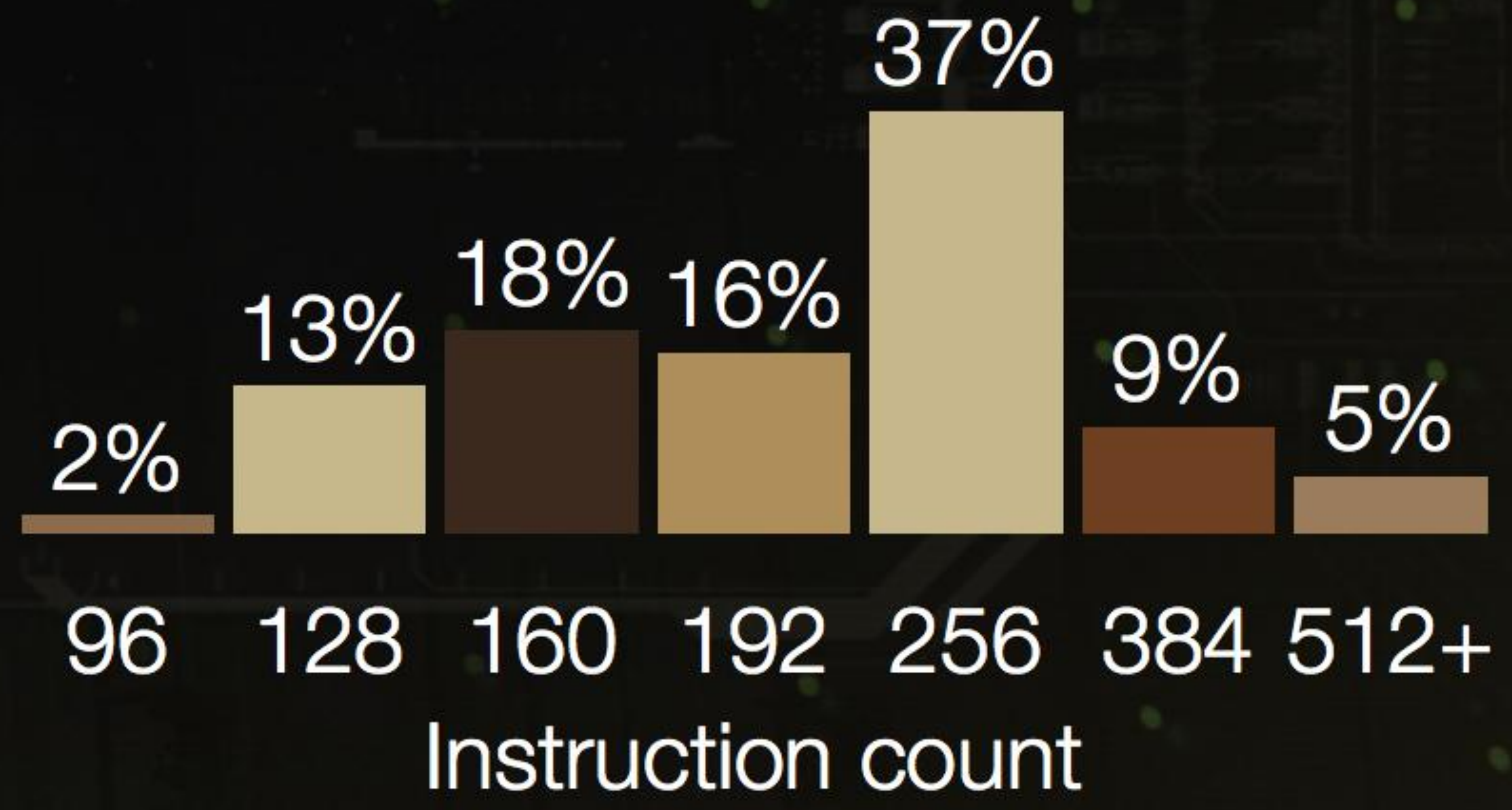




Vertex shader statistics

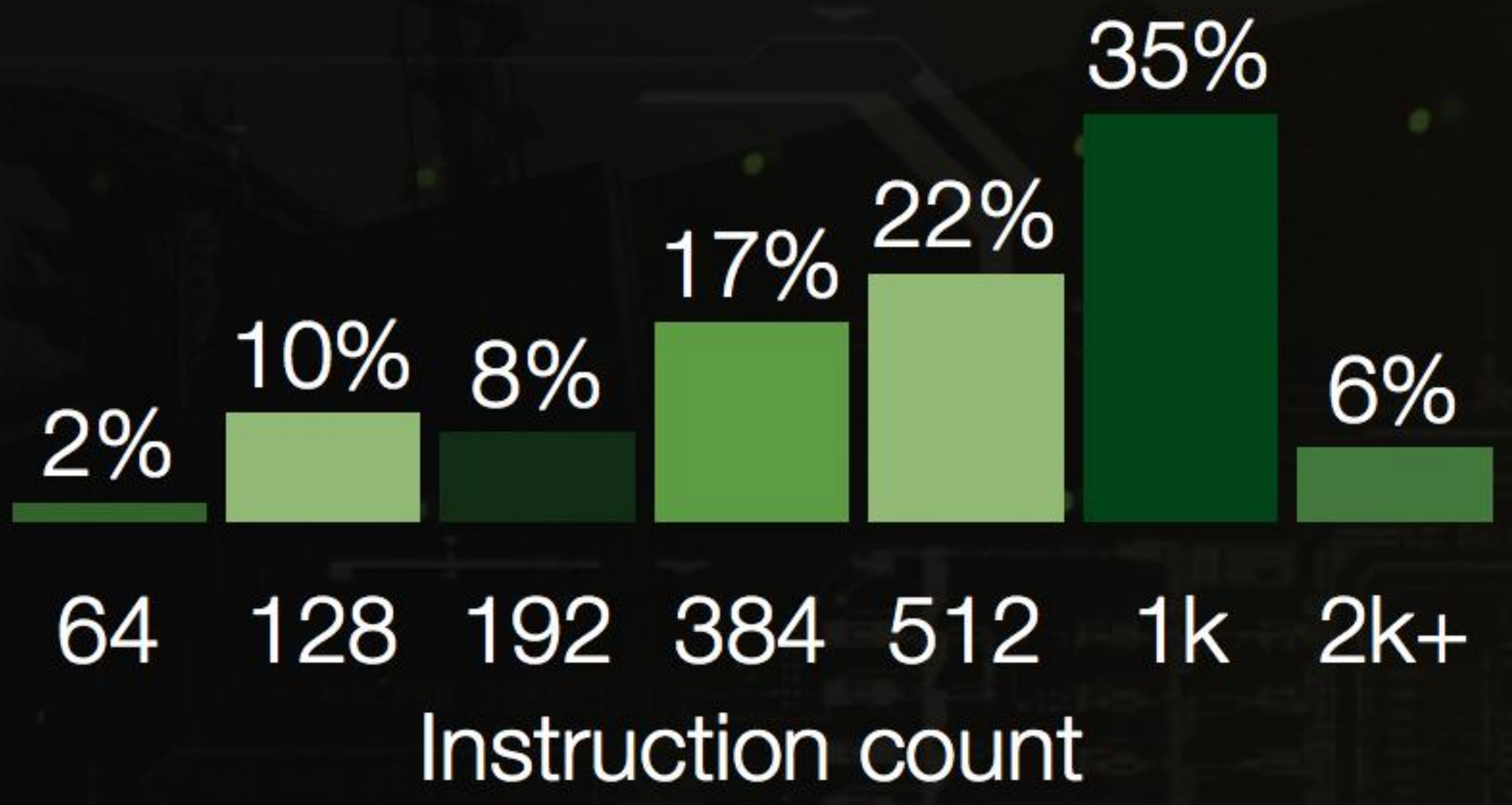
- We generate too many outputs
  - Shadow shaders should have 1
  - Most shaders should have 4-5
  - 71% of shaders have 6+
- 26% of shaders use GPU skinning
  - 256+ instructions
  - Pose stored in data buffers

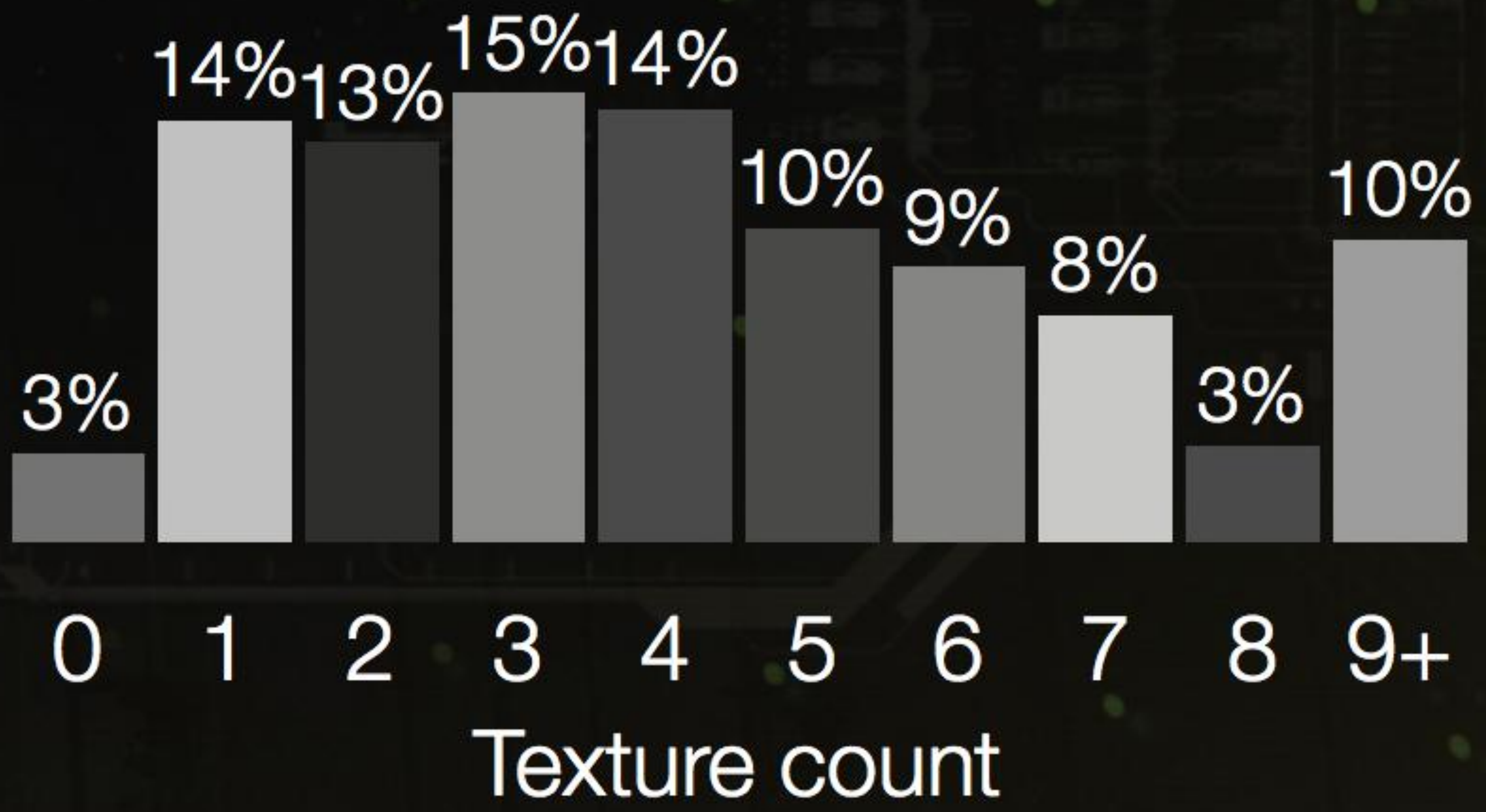




Pixel shader statistics

- 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)
Live view
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.

Particles

- 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


FORCEFIELDS DISABLED

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
- Bloom downsample chain is 2x faster with R11G11B10
- SSAO randomly sampled depth in FP32
  - Heavy cache trashing, FP16 gave us 2x speed improvement
- 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 beneficial to perform reads from the same 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.

Optimization tips

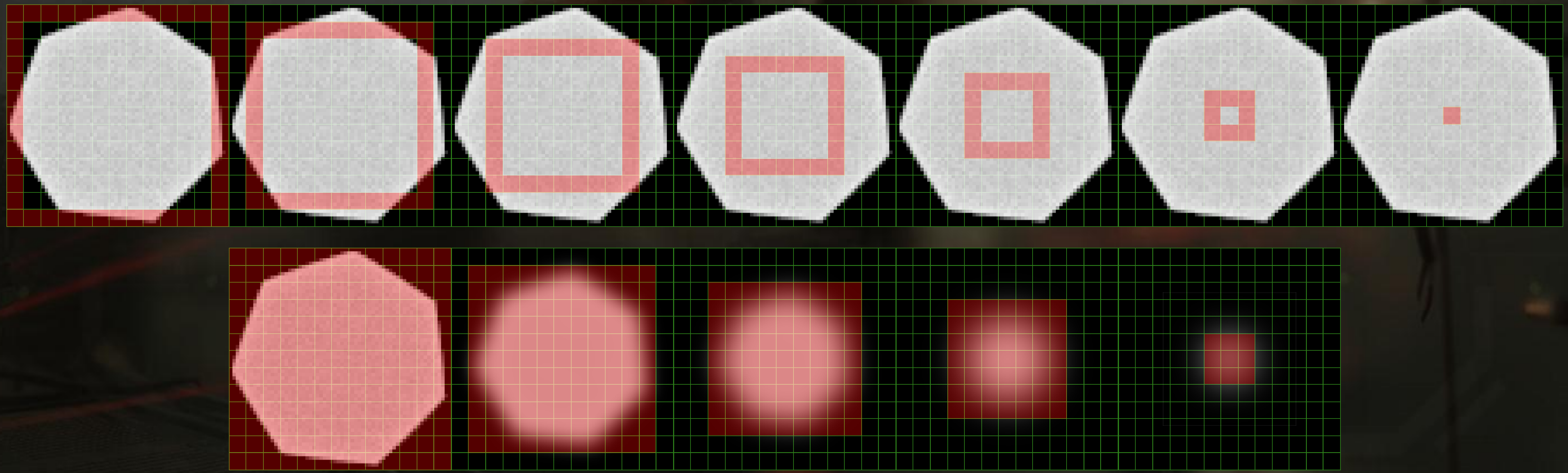
- Branching can be faster than a texture fetch hit
- We merged a lot of individual passes
  - Saves read / write performance
  - DoF Near & Far CoC is calculated once and output to MRT
  - We have a “mega” post process composite pass
    - Merges results of all effects with the full resolution scene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

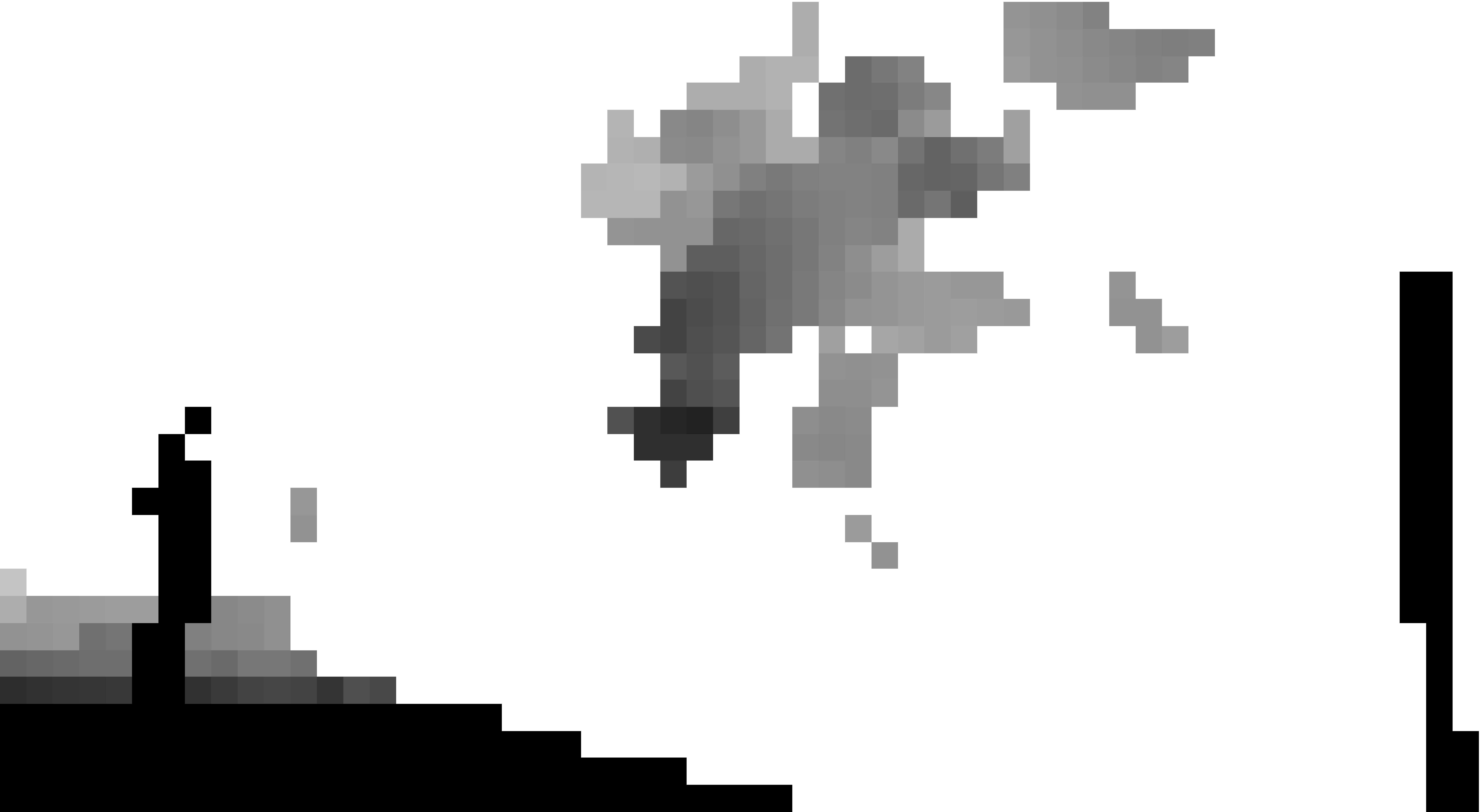
Depth of field

- 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 all neighbors affecting the current pixel to 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



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


Raytrace ON
Cubemaps ON


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


Currently in Localized Cubemap Zone:
CubemapZone_level_extension (levels/single_player/kz4_demo/section_shared/zones/cubemap_zones) : Priority(8) : Resolution(128) : Fade distance(0.5m)


YOUME

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

Volumetrics

- 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
  - We wanted something fancier and faster, but were pleasantly surprised with the PS4 performance

Volumetrics

- 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


VSA


VSA

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