



UNREAL ENGINE GAME OPTIMIZATION ON A BUDGET

TOM LOOMAN @t_looman

tomlooman.com





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WHO AM I?

- Tom Looman (Twitter: [@t_looman](#))
- Guerilla Games / Epic Games
- Indie Developer & Unreal Engine Consultant
- 10+ Years of Unreal Engine
- Creating Unreal Courses and Tutorials ([tomlooman.com](#))



PREPARATIONS

- `r.vsync 0`
- `t.maxfps 0`
- `SmoothFrameRate=False` (Project Settings)
- Lighting Built & MapCheck Errors fixed.
- Packaged Game build
 - 'Standalone' is convenient (Memory and timings may be (very) off)



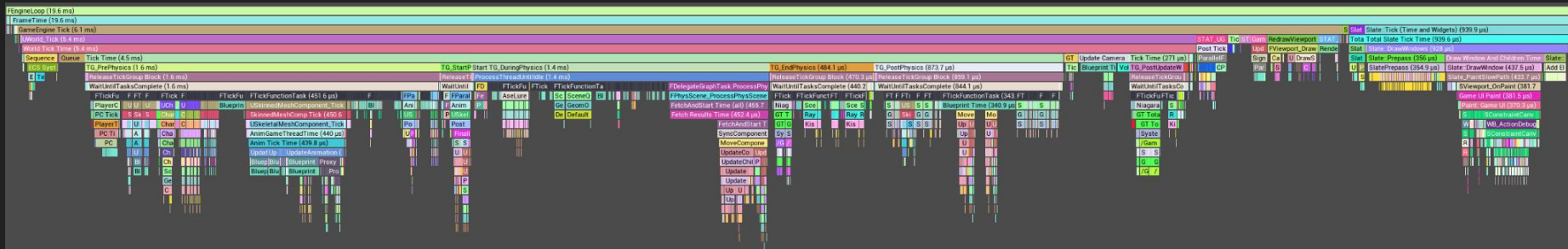
FIND THE BOTTLENECK

- Game Thread / Render Thread / GPU
 - Unreal Insights
 - ProfileGPU (+ r.RHISetGPUCaptureOptions 1)
 - 'stat unitgraph', 'stat detailed'
 - 'r.screenpercentage 20'
 - 'pause' (Freeze Game Thread)
- Memory & Loading
 - Unreal Insights (-trace=memory,loadtime,file)
 - memreport -full
 - loadtimes.dumpreport



UNREAL INSIGHTS

- Detailed Insights into the frame timings:
 - CPU/GPU
 - Memory
 - File Loading
 - Threading
- Drill down on a single frame or session





INSIGHTS: PROFILING CATEGORIES

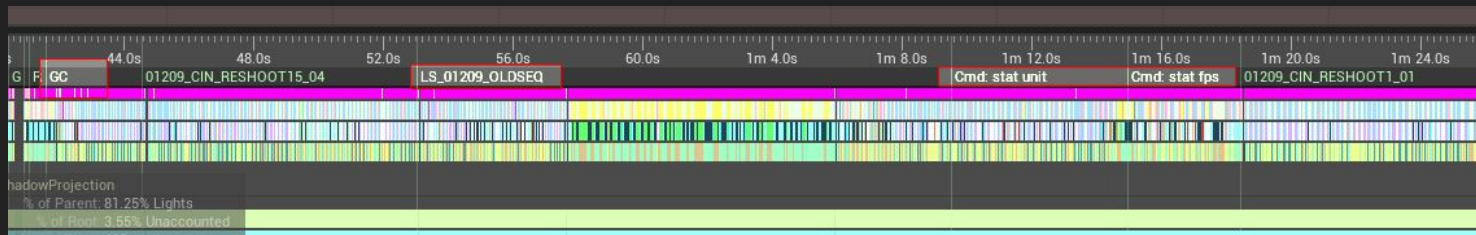
- `-trace=log,cpu,gpu,frame,bookmark,loadtime,file,memory,net`
- `-statnamedevents`
- docs.unrealengine.com/5.0/en-US/unreal-insights-reference-in-unreal-engine-5
 - Lists available Trace Channels

▲ Play in Standalone Game	
Command Line Options	<input type="checkbox"/> Disable Sound (-nosound)
Additional Launch Parameters	<code>-trace=cpu,frame,log -statnamedevents</code>
Additional Launch Parameters for Mobile	<input type="text"/>



INSIGHTS: BOOKMARKS

- Bookmarks for context and transitions
 - GC
 - Sequencer Start
 - Level streaming (Start/Complete)
 - Console Commands
- **TRACE_BOOKMARK**(Format, Args)





INSIGHTS: Add “stat” profiling

- Add profiling detail to your game code
- Track as “stat *YourCategory*” in viewport or via Insights

```
TArray<AWSShipModule*> AWSShip::GetModulesByClass(TSubclassOf<AWSShipModule> ModuleClass) const
{
    SCOPE_CYCLE_COUNTER(STAT_GetMultiModulesByClass);

    if (ModuleClass)
    {
        TArray<AWSShipModule*> Modules = ShipRootComponent->ModulesByClass.Find(ModuleClass);
    }
}
```

ReleaseTickGroup Block (697.4 µs)

WaitUntilTasksComplete (696.6 µs)

FTickFunctionTask (196.7 µs)

Blueprint Time (194.8 µs)

GetModulesByClass (Multi) (1.7 µs)

tomlooman.com/unreal-engine-profiling-stat-commands/



INSIGHTS: TIPS

- Run commands to compare during session (Shows as Bookmark)
 - `r.ScreenPercentage 20`
 - “Pause”
- Use only necessary categories for lower overhead
- Add custom Bookmarks for gameplay context



MEMREPORT -full

- `memreport -full`
 - Runs a number of individual commands for memory profiling
- `obj list class=`
 - Example: `obj list class=AnimSequence`
- Only in Packaged Builds
 - Example: `AnimSequence` twice as large in editor builds.



obj list class=AnimSequence

AnimSequence	/Game/DeliverUsMars/Art/Characters/Animation_V5/DutM/A_Astro_Space_Breach_GiveUpPose_Add.A_Astro_Space_Breach_GiveUpPose_Add	7.89	8.08			
AnimSequence	/Game/DeliverUsMars/Art/Characters/Animation_V5/DutM/A_Look_C.A_Look_C	7.76	7.96			
AnimSequence	/Game/DeliverUsMars/Art/Characters/Kathy/HelmetMesh/Helmet_ANIM_Open.Helmet_ANIM_Open	5.57	5.76			
AnimSequence	/Game/DeliverUsTheMoon/Characters/Holograms/ASE_SinglePoses/A_ASE_Holo_Idle.A_ASE_Holo_Idle	4.56	4.75			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterB.A_ASE_ThrusterB	4.12	4.31			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterBL.A_ASE_ThrusterBL	4.12	4.31			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterBR.A_ASE_ThrusterBR	4.12	4.31			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterF.A_ASE_ThrusterF	4.12	4.31			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterFL.A_ASE_ThrusterFL	4.12	4.31			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterFR.A_ASE_ThrusterFR	4.12	4.31			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterL.A_ASE_ThrusterL	4.10	4.30			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterR.A_ASE_ThrusterR	4.10	4.29			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterF_local.A_ASE_ThrusterF_local	3.99	4.18			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterTurnR_local.A_ASE_ThrusterTurnR_local	3.97	4.16			
AnimSequence	/Game/DeliverUsTheMoon/Characters/ASE_NEW/A_ASE_ThrusterCenter.A_ASE_ThrusterCenter	3.93	4.12			
AnimSequence	/Game/DeliverUsTheMoon/Art/Props/Switches/Test/A_New_Button_Push_Out.A_New_Button_Push_Out	2.80	2.99			
AnimSequence	/Game/DeliverUsTheMoon/Art/Props/Switches/A_Interact_Button_PushShort.A_Interact_Button_PushShort	2.28	2.47			
AnimSequence	/Game/DeliverUsTheMoon/Art/Props/Switches/Test/A_New_Button_PushShort.A_New_Button_PushShort	2.28	2.47			
AnimSequence	/Game/DeliverUsMars/Art/Characters/Kathy/HelmetMesh/Helmet_Pose_Opened.Helmet_Pose_Opened	2.25	2.44			
AnimSequence	/Game/DeliverUsMars/Art/Characters/Kathy/HelmetMesh/Helmet_Pose_Closed.Helmet_Pose_Closed	2.19	2.38			
AnimSequence	/Game/DeliverUsMars/Art/Props/ClimbingAxe/A_ClimbingAxe_Pose_Closed.A_ClimbingAxe_Pose_Closed	2.06	2.25			
AnimSequence	/Game/DeliverUsTheMoon/Art/Props/Switches/A_Button_Pose_A.A_Button_Pose_A	1.90	2.09			
AnimSequence	/Game/DeliverUsTheMoon/Art/Props/Switches/A_Button_Pose_B.A_Button_Pose_B	1.90	2.09			
AnimSequence	/Game/DeliverUsTheMoon/Art/Props/Switches/Test/A_New_Button_Pose_A.A_New_Button_Pose_A	1.90	2.09			
AnimSequence	/Game/DeliverUsTheMoon/Art/Props/Switches/Test/A_New_Button_Pose_B.A_New_Button_Pose_B	1.90	2.09			
	Class Count NumKB MaxKB ResExcKB ResExcDedSysKB ResI					
AnimSequence	997	191824.09	192015.00	0.00	0.00	

997 Objects (Total: 187.328M / Max: 187.515M / Res: 0.000M | ResDedSys: 0.000M / ResShrSys: 0.000M / ResDedVid: 0.000M / ResShrVid: 0.000M / ResUnknown: 0.000M)



'DUMPTICKS' [Console Command]

- 'dumpticks' / 'dumpticks grouped'
 - Outputs all Actor and Component Ticks
- 'listtimers'
 - Run on low frequency
 - avoid heavy load (stuttering)
- 'stat uobjects'
- Disable/Reduce further with *Significance Manager*
 - *More on that later...*

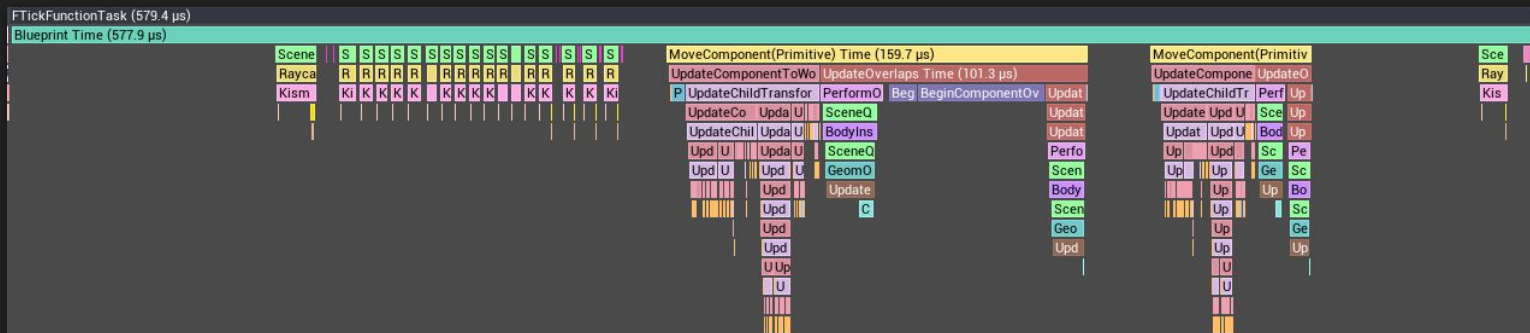


COLLISION & PHYSICS

- Unreal configured to work out of the box.
 - “Collision Enabled” => Physics + Query
 - Most things require just ‘QueryOnly’
- Disable on components players can’t reach or interact with.
- Profiling
 - `stat physics, stat collision`
 - `obj list class=BodySetup`
 - `show CollisionPawn, show CollisionVisibility`
- *Tip: Landscape may use lower collision MIPs*



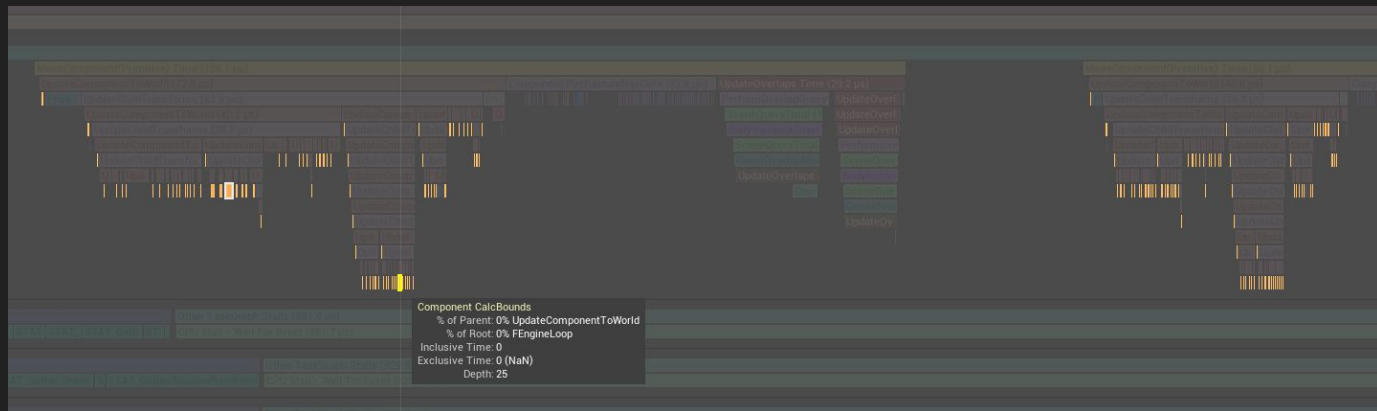
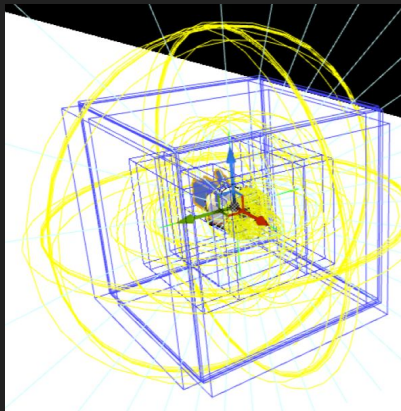
- Move/Rotate only once per frame
- Disable Collision & GenerateOverlaps=False
- AutoManageAttachment
 - Audio & Niagara
- Profiling
 - stat component





MOVING COMPONENTS - BOUNDS

- UseAttachParentBound=True
 - Skips "CalcBounds"
- 'show Bounds' / 'showflag.bounds 1'





SIGNIFICANCE MANAGER

- Scale down fidelity based on game specific logic
 - Distance To
 - Max number of objects in full fidelity ('buckets')
- Calculates 'significance value' to scale-down game objects.
 - Examples: NPCs, puzzle Actors, Vehicles, other Players
- Reduce/Cull:
 - Tick rate
 - Traces / Queries
 - Animation updates (SKs)
 - Audio/Particle playback or update rate

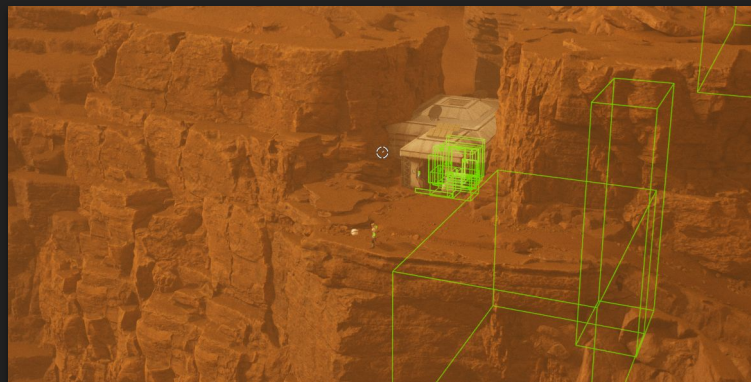
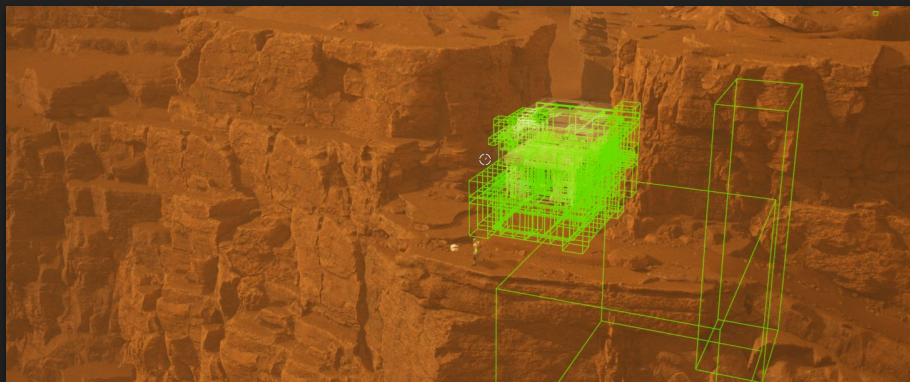


SIGNIFICANCE MANAGER

- Profiling
 - ShowDebug SignificanceManager
 - `sigman.filtertag <name>`
 - `stat significancemanager`
- Examples
 - **[GitHub.com/tomlooman/ActionRoguelike](https://github.com/tomlooman/ActionRoguelike)**
 - `USSignificanceComponent.h`
 - Blogpost to follow: tomlooman.com

OCCCLUSION CULLING

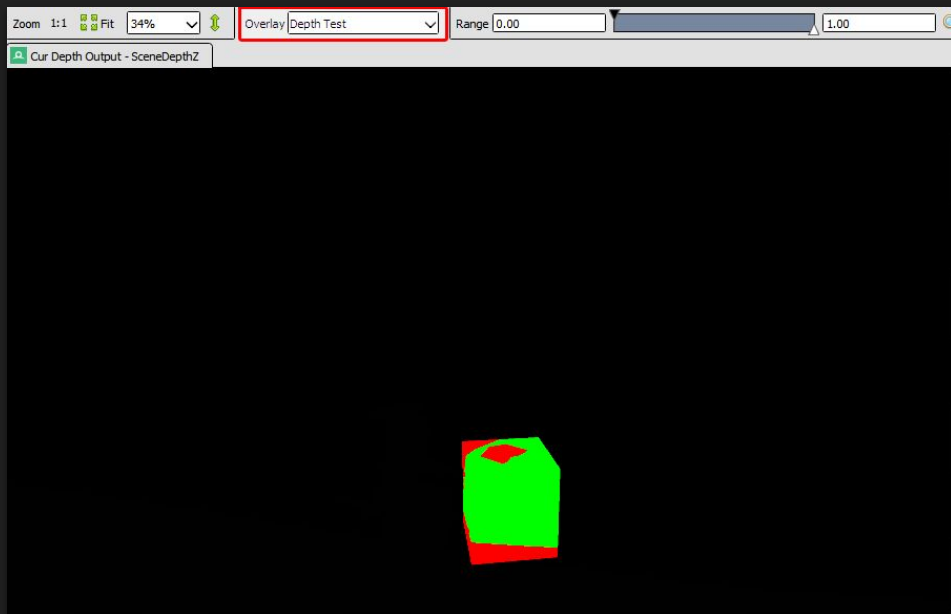
- Frustum Culling and Occlusion Queries
- GPU query results polled in next frame
- **HLOD** Can greatly reduce occlusion cost (See below)
- Profiling
 - `r.visualizeoccludedprimitives 1`
 - `stat initviews`





RENDERDOC: OCCLUSION RESULTS

- DepthTest Overlay in RenderDoc
- Easily find 'wasteful' queries on tiny/far objects





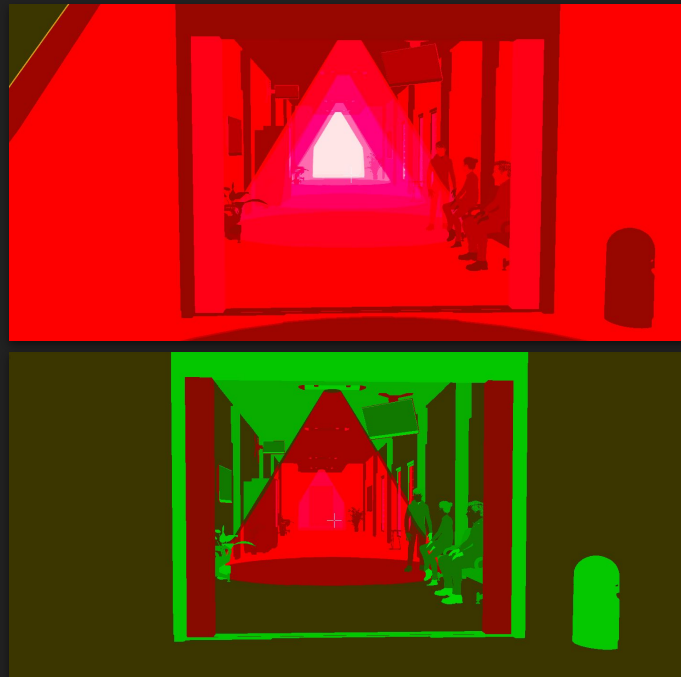
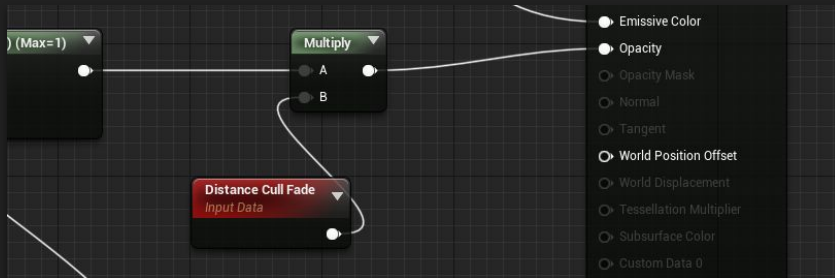
DISTANCE CULLING

- PrimitiveComponent: Max/Min Draw Distance
 - Light Cones, Fog Volumes, Blueprint Components
- Distance Cull Volume
 - Maps object “Size” with “CullDistance”
 - Reduce Occlusion Query cost
- Profiling
 - `showflag.distanceculledprimitives 1`
 - `stat initviews`



MIN/MAX DRAW DISTANCE

- Example: Light Cones
- Vis: Shader Complexity
 - Pixel Overdraw
- DistanceCullFade
 - Blends 0-1, 1-0





FREEZERENDERING

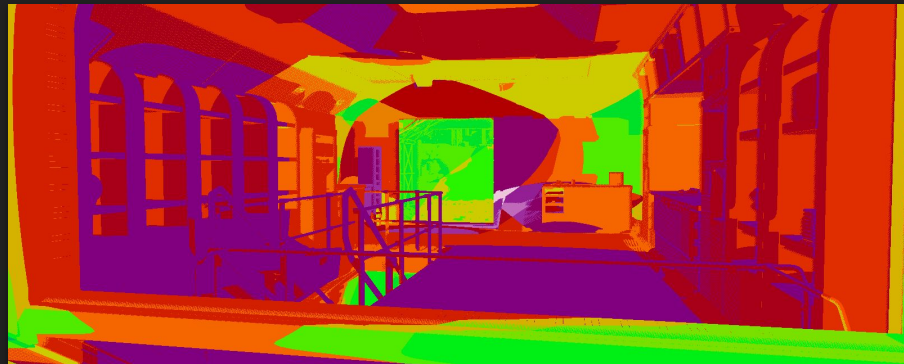
- 'FreezeRendering' + ; (semi-colon) to fly with DebugCamera
- Verify occlusion is working as expected





LIGHT CULLING (Stationary & Movable)

- Automatic ScreenSize culling not strict enough
 - `MinScreenRadiusForLights` (0.03)
- Cull earlier case-by-case
 - `MaxDrawDistance`
 - `MaxDistanceFadeRange`
- Profiling
 - `Show > LightComplexity` (Alt+7)
 - `Show > StationaryLightOverlap`
 - `ToggleLight <partialname>`





LEVEL STREAMING

- Streaming Volumes vs. Manual Load/Unload
 - Camera Location based (caution: third person view and cinematic shots)
 - Cannot combine both on a specific sublevel, can mix within the game
- Profiling
 - `stat levels`
 - `Loadtimes.dumpreport (+ loadtimes.reset)`
 - Unreal Insight
 - Look for level load & “GC” bookmarks
 - `loadtime,file` categories



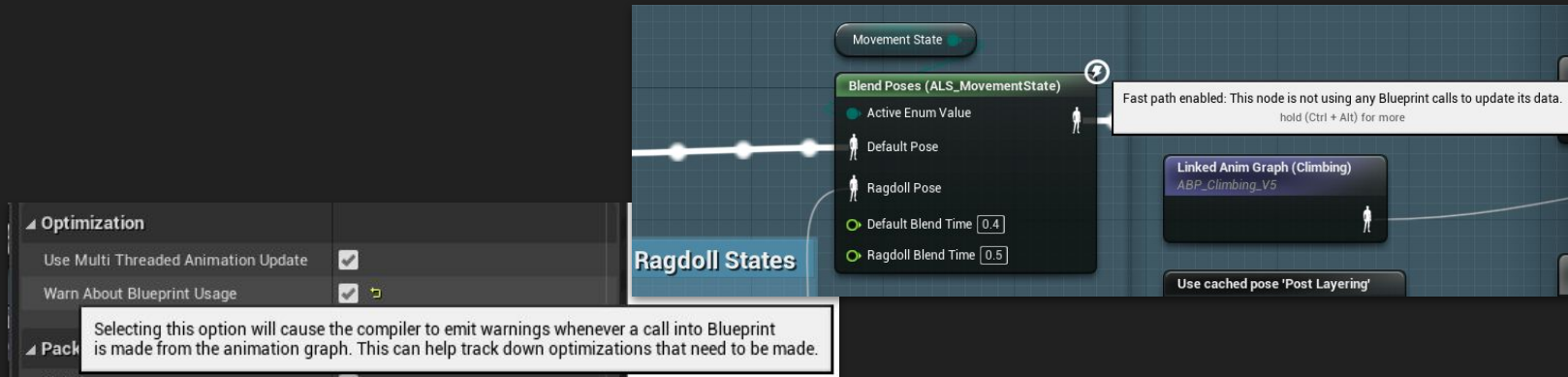
LEVEL STREAMING

- Performance Impacts
 - Initial level load time
 - Occlusion cost
 - Memory
- Options: Load, LoadNotVisible, LoadVisible
 - Keep in memory while hiding to aid the renderer
- Consider streaming early in Level Design!
 - Splitting into multiple ULevels
 - Line of sight, natural corridors and points of no return



ANIMATION: FAST PATH

- Allow 'Fast Path' by moving Computations out of AnimGraph (into EventGraph)
 - Use WarnAboutBlueprintUsage to get warnings in AnimGraph
- Profiling
 - stat anim





ANIMATION: QUICK WINS

- Update Rate Optimization (URO) for distant SkelMeshes
- VisibilityBasedAnimTickOption (DefaultEngine.ini)
 - OnlyTickPoseWhenRendered
 - AlwaysTickPoseAndRefreshBones
 - ...
- More Booleans!
 - bRenderAsStatic
 - bPauseAnims
 - bNoSkeletonUpdate

```
[/Script/Engine.SkeletalMeshComponent]  
VisibilityBasedAnimTickOption=OnlyTickPoseWhenRendered
```



ANIMATION: Animation Compression Library (ACL)

- ACL Plugin (by Nicholas Frechette)
- **Compression** speed-up (from minutes to seconds!, 56x faster)
- **Decompression** Speed (8.4x faster)
- **Memory** Size (cut in half across the game)
- Used in *Fortnite* and other AAA titles
- Eventually built-in 5.0?



Oodle Data & Oodle Texture

- RDO (Rate Distortion Optimization) Compression
 - Significant gains in compression compared to default
 - Takes longer to compress (off by default in-editor)
- RDO Works with Oodle Data by 'preparing' the texture data

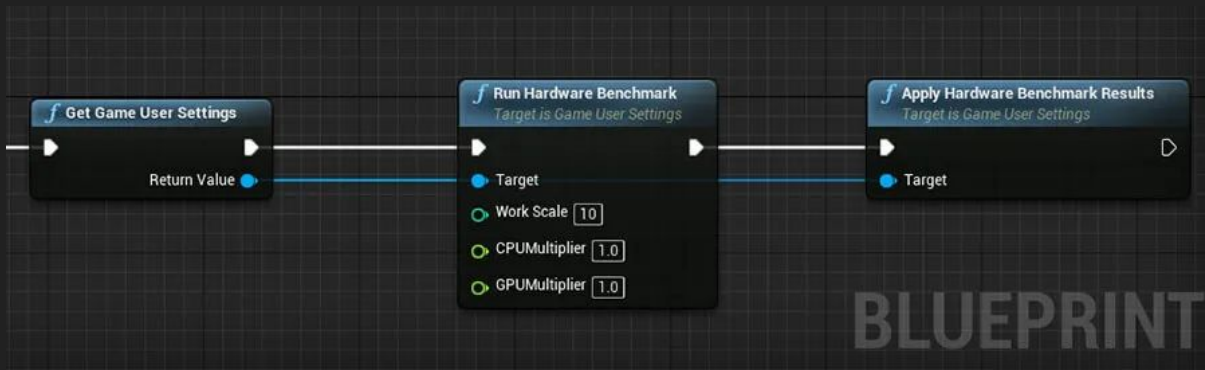
```
[AlternateTextureCompression]
TextureCompressionFormat="TextureFormatOodle"
TextureFormatPrefix="OODLE_"
; disabling in editor still uses non RDO encoding and Oodle, but only in cooked builds since RDO encoding locally is slow (use fast DCC)
bEnableInEditor=False

[TextureFormatOodle]
; should BC2 and 3 (DXT3 and 5) be changed to BC7
bForceAllBC23ToBC7=False
; bForceRDOOff uses the Oodle non-RDO encoders for BC1-7, high speed and good quality but no size reduction
bForceRDOOff=False
; bDebugColor shows the BC1-7 format used
;bDebugColor=False
; Lambda controls the quality vs size tradeoff for RDO
;GlobalLambdaMultiplier=1.000000
;DefaultRDOLambda=30
```



SYNTHBENCHMARK

- Run CPU/GPU benchmark and apply Scalability Settings
- Returns “score” with 100 baseline for Avg. CPU/GPU

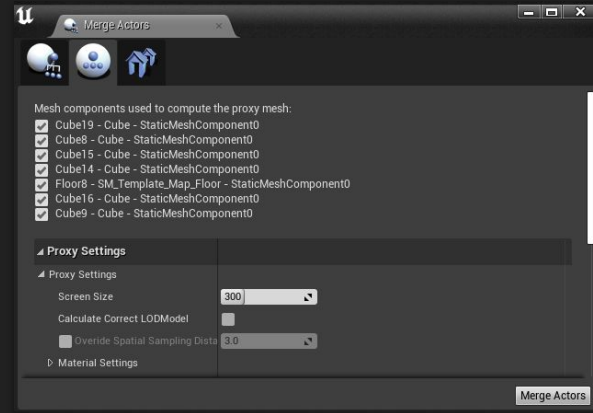


tomlooman.com/unreal-engine-optimal-graphics-settings/



SHADOW PROXIES

- Single low-poly silhouette mesh
 - `RenderMainPass=False`
- Bespoke mesh or using built-in Mesh Tools
 - 'Merge Actors' (Right-Click assets in level)
 - UE5 Geometry Script
- Profiling
 - 'ShadowDepths' in Insights &
 - `ProfileGPU + r.RHISetGPUCaptureOptions 1`





SizeMap (Disk & Memory)

- Find unexpected references, and bloated content
- Use on Blueprints and (sub)Levels early and often





STATISTICS WINDOW

- Stats on current level
 - Primitive Stats
 - Texture Stats
- Tip: Shift-click for *secondary* sort.
 - Sort 'Count' + 'Tris' or 'Size' (Find large assets used only once)

Primitive Stats ▾ Refresh Export											
Object	Actor(s)	Type	Count 12,379	HWInstan 32,052	Inst Sectio 38,010	Tris 35,816,589	Sum Tris 110,421,0	Size 1,522,691.875 KB	VC 18,44	Inst VC 13,083.4	Avg LM 69,346
Landscape_0	Landscape_0	Landscape	1	55	220	28,611,000	28,611,000	296,970.594 KB	0 KB	0 KB	350
Limestone_Rubble_LOD0ubxbejwda	672 Actors	StaticMesh	672	672	672	18,256	12,268,032	1,393.141 KB	0 KB	0 KB	1,209
SM_FieldGrass_Dry_01	InstancedFoliageActor...	StaticMesh	1	13,312	13,312	765	10,183,680	130.593 KB	5.57 KB	0 KB	44
Quarry_Cliff_LOD0_ubhwbepda	127 Actors	StaticMesh	127	127	127	26,016	3,304,032	3,718.258 KB	0 KB	0 KB	849
SM_Quarry_Cliff_00_ubhubhyda	120 Actors	StaticMesh	120	120	120	26,774	3,212,880	2,702.691 KB	0 KB	0 KB	583
uchpbq3fa_LOD0	122 Actors	StaticMesh	122	122	122	19,631	2,394,982	3,800.345 KB	0 KB	1,930.832	468
Quarry_Cliff_LOD0_ubhvccfda	116 Actors	StaticMesh	116	116	116	20,001	2,320,116	2,135.489 KB	0 KB	513.492	714
SM_Canyon_Sandstone_Cliff_umdjfh	47 Actors	StaticMesh	47	47	47	48,410	2,275,270	4,636.271 KB	0 KB	0 KB	237
SM_FieldGrass_Dry_Storm	7 Actors	StaticMesh	7	2,765	2,765	765	2,115,225	125.327 KB	5.586 KB	0 KB	48
Canyon_Sandstone_Ledge_LOD0_ul	50 Actors	StaticMesh	50	50	50	41,569	2,078,450	4,003.815 KB	0 KB	0 KB	38
SM_Quarry_Cliff_07_ub5tefsda	87 Actors	StaticMesh	87	87	87	22,913	1,993,431	3,061.643 KB	0 KB	0 KB	572



Useful Console Commands

- ToggleForceDefaultMaterial
- stat Dumphitches
- stat none (clear all categories on screen)
- r.ForceLODShadow

Thanks!

Follow me **@t_looman**

tomlooman.com for more!

Questions?

(or feel free to @ on Twitter)