

UNREAL ENGINE GAME OPTIMIZATION ON A BUDGET

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- Built-in Profiling Tools & Commands
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- "Did you know?"



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	Disable Sound (-nosound)
Additional Launch Parameters	-trace=cpu,frame,log -statnamedevents
Additional Launch Parameters for Mobile	



INSIGHTS: BOOKMARKS

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

	44.0s	48.0s	52.0s	56.0s	60.0s	1m 4.0s	1m 8.0s	1m 12.0s	1m 16.0s	1m 20.0s	1m 24.0s
G F GC		CIN_RESHOOT15_04		LS_01209_OLDSEQ		à		Cmd: stat unit	Cmd: stat fps	01209_CIN_RESH	IOOT1_01
% of Pa	arent: 81.25% Light:	3									
		ounted									



INSIGHTS: Add "stat" profiling

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

ReleaseTickGroup Block (697.4 µs)	
WaitUntilTasksComplete (696.6 µs)	
FTickFunctionTask (196.7 µs)	
Blueprint Time (194.8 µs)	
	GetModulesByClass (Multi) (1.7 µs)
TArray <awsshipmodule*> AWSShip::GetModulesByClass(TSubclassOf<awsshipmodule> <u>Mo</u>duleClass) const</awsshipmodule></awsshipmodule*>	
<pre>SCOPE_CYCLE_COUNTER(STAT_GetMultiModulesByClass);</pre>	
🗊 🖬 (ModuleClass)	
TAppay AWCChipNedulaus, Medulaes - ChipDestComponent, MedulaeDuClass Find (MedulaClass);	

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

Authipedice straines pertivel rownal style cyclinal accel stylutina (rown anihoeau "o stylubleau"o s	1.05	0.00
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/Climbing_Axe/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	ResExcDedSy	ysKB Resl
AnimSequence 997 191824.09 192015.00 0.00		0.00
97 Objects (Total: 187.328M / Max: 187.515M / Res: 0.000M ResDedSys: 0.000M / ResShrSys: 0.000M / ResDedVid: 0.000M / ResShrVid: 0.000M / Res	Unknown: 0.0	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
 - \circ 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
 - \circ stat physics, stat collision
 - obj list class=BodySetup
 - show CollisionPawn, show CollisionVisibility
- Tip: Landscape may use lower collision MIPs



MOVING SCENE COMPONENTS

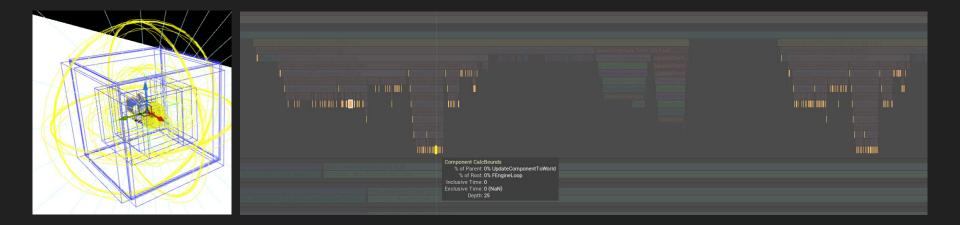
- Move/Rotate only once per frame
- Disable Collision & GenerateOverlaps=False
- AutoManageAttachment
 - Audio & Niagara
- Profiling
 - \circ stat component

FTickFunctionTask (579.4 µs)						
Blueprint Time (577.9 µs)						
	Scene	S S S S S S S S S S S S S S S S S	MoveComponent(Primitive) Time (1	59.7 µs)	MoveComponent(Primitiv	Sce
81	Rayca	R R R R R R R R R R R R R	UpdateComponentToWo UpdateOve	erlaps Time (101.3 µs)	UpdateCompone UpdateO	Ray
	Kism	KI K K K K K K K K K K K K K K K	P UpdateChildTransfor PerformO	Beg BeginComponentOv Updat	UpdateChildTr Perf Up	Ray Kis
			UpdateCo Upda U SceneQ	Updat	Update Upd U Sce Up	
			UpdateChil Upda U BodyIns	Updat	Updat Upd U Bod Up	
			Upd U Upda U SceneQ	Perfo	Up Upd Sc Pe	
			Upd U Upd U GeomO	Scen	Up Up Ge Sc	
			Upd Update	Body	Up Up Bo	
			Upd C	Scen	Up Sc	
			Upd	Geo	Up Ge	
			Upd	Upd	Up	
			UUp			
			U.		U	



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



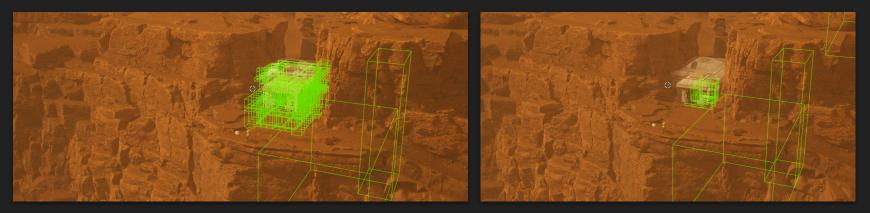
SIGNIFICANCE MANAGER

- Profiling
 - ShowDebug SignificanceManager
 - sigman.filtertag <name>
 - stat significancemanager
- Examples
 - GitHub.com/tomlooman/ActionRoguelike
 - USSignificanceComponent.h
 - Blogpost to follow: tomlooman.com



OCCLUSION CULLING

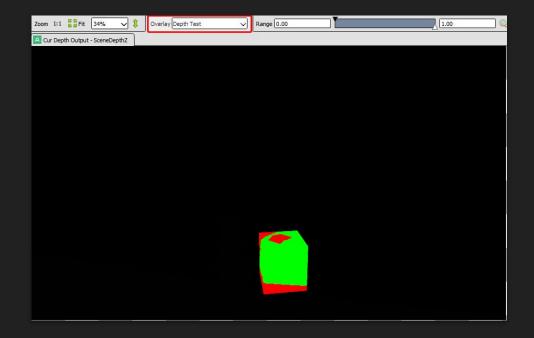
- Frustum Culling and Occlusion Queries
- GPU query results polled in next frame
- **HLOD** Can greatly reduce occlusion cost (See below)
- Profiling
 - r.visualizeoccludedprimitives 1
 - stat initviews





RENDERDOC: OCCLUSION RESULTS

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





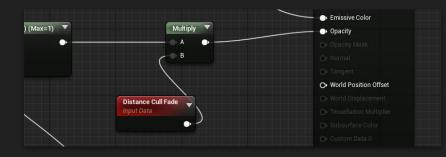
DISTANCE CULLING

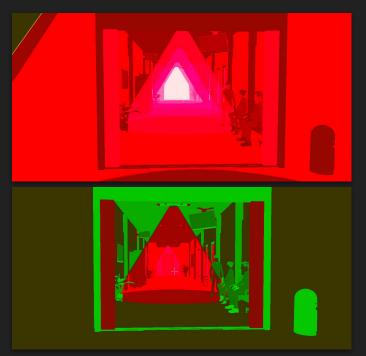
- PrimitiveComponent: Max/Min Draw Distance
 - Light Cones, Fog Volumes, Blueprint Components
- Distance Cull Volume
 - Maps object "Size" with "CullDistance"
 - Reduce Occlusion Query cost
- Profiling
 - \circ showflag.distanceculledprimitives 1
 - stat initviews



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

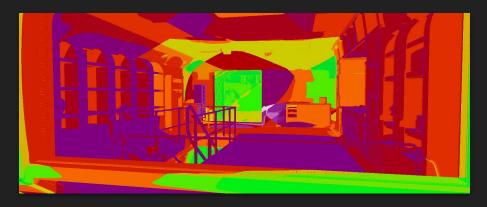






LIGHT CULLING (Stationary & Movable)

- 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



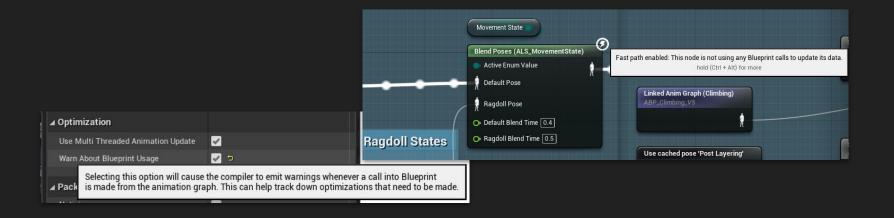
LEVEL STREAMING

- 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
 - \circ $\,$ 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
 - \circ stat anim





ANIMATION: QUICK WINS

- Update Rate Optimization (URO) for distant SkelMeshes
- VisibilityBasedAnimTickOption (DefaultEngine.ini)
 - OnlyTickPoseWhenRendered
 - AlwaysTickPoseAndRefreshBones
 - ...
- More Bools!
 - 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="00DLE_"
; 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
; bForceRD00ff uses the Oodle non-RDO encoders for BC1-7, high speed and good quality but no size reduction
bForceRD00ff=False
; bDebugColor shows the BC1-7 format used
;bDebugColor=False
; Lambda controls the quality vs size tradeoff for RDO
;6lobalLambdaMultiplier=1.000000
;DefaultRD0Lambda=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

1 Merge Actors			in the state of the	- - X
😪 🍛 🏘				
Mesh components used to compute t Cube19 - Cube - StaticMeshCom Cube8 - Cube - StaticMeshCom Cube15 - Cube - StaticMeshCom Cube14 - Cube - StaticMeshCom Choraf - SM, Template: Map. Floo Cube16 - Cube - StaticMeshCom Cube19 - Cube - StaticMeshCom	ponent0 onent0 ponent0 ponent0 r - StaticMeshCom ponent0	ponent0		
▲ Proxy Settings				
▲ Proxy Settings				
	300			
Calculate Correct LODModel				
Overide Spatial Sampling Dista	3.0	3		
D Material Settings				
				Merge Actors





SizeMap (Disk & Memory)

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

Size map for HS_DescentCliff	(LIC DescentCliff	(Marid 1 C CD)		Gize to t	Display: Memory Size			
HS_DescentCliff (World, 1.6 GB)									
SM_rock_boulder_b1 (Static Wesh, 15 MLboulder_b (MaterialinstanceConstant, M.master_rock-vorid (Material: 54.1 M TextuseD 22.4 MB TextuseD TextuseD TextuseD TextuseD	HS_DescentCliff_O_HLOD ML_stone_Llonat T_stories_LNonme T_stories_LNonme T_stories_LNonme D_3_WB Canyon_Sandstone_Rook_ul Norma_sk_c_upp T_stories_D D_2_wB	Rock_Sandstone_07_(V Qu Rock_Sandstone_07_1 Q	LQuarry_Outcrop_(iarry_Outcrop_02_Not uarry_Outcrop_02_(8 Juarry_Outcrop_02 Textup020 995_4_0AD	Limestone_Rocks_LO Rock_Sandstone_14_NC Rock_Sandstone_14 (Rock_Sandstone_14 Rock_Sandstone_14 Rock_Sandstone_14	Canyon_Sandstone_R Rock_Sandstone_10_fk Rock_Sandstone_10_f rock_Sandstone_10_f 22.4 MB	Canyon_Sandstone_ Rock_Sandstone_12 (Rock_Sandstone_12 (Rock_Sandstone_12 (Textures) 2.2.4 MB			
22.4 ME 22.4 MB Track-120 22.4 ME 22.4 ME	MI_Landscape_Herschel M_Landscape (Material, 50	SM_Limestone_Rocks_16. Rock_Sandstone_16 (Mate Rock_Sands Tosture20 22.31MB	Canyon_Sandstone Rock_Sandstone_02; AgeLrock_st Texture2D Active2D		Nordic_Beach_Boulde	SM_Hovs_Beach_ Hovs_Beach_Rock_t T_Normal_4R_ukxk Texture2D 22.4 MB			
SM_stone_I (StaticMesh, 98.7 MB) MLstone_L_Inst (MaterialInstanceConst T_stone_LNorms T_common_reachines Textine20 2.2.4 MB 2.2.4 MB	SM_LargePlainsBoulder00 MI_LargePlainsBoulder002	Canyon_Sandstone_Rocky Rock_Sandstone_05_NoBle Rock_Sandstone_05_(Mat	Canyon_Sandstone_R Canyon_Sandstone_R Normal_41.L Testure2D 22.4MB	NofmaL4K_ubu Texture2D 22_4MB	2 Rock_Sandstone_09 Rock_Sandstone_0	Quarry_Cliff_06_C ujqrean_4C_No Texture2D #2:3.W6			
T_stens_a.Nerret =ortin_actio 22,4 MB Cracked_Boulder_LOD0_ujomfhrfa (S	T, LargePlair T, LargePlair Texture20 223 MB 223 MB 223 MB	HS_DescentCliff_BuiltDate MapBuildDataRegistry 45 MB	Canyon_Sandstone_R Canyon_Sandstone_R Normal_4C1 Positine2D 22.3 MB	Canyon_Sant Car ub4bdhwda_LO	sm_sno	ELF NS.Sa uch			
Stacked, Boulder, uponthinta, Sd, NoBlen Stacked, Boulder Vorfmit, Kt, CO Texting of the state of the state of the state State of the state of the s	Rock_Sandstone_LODOrk Rock_Sandstone_04 (Ma Rock_Sandstone_04INc Continue20 22 4 MR	Rock_Sandstone_03 (Mat Rock_Sandsto Texture20 22.4 MB	SM_Canyon_Sands Canyon_Sandstone_R Canyon_Sandstone_	sjzbj_LOD1 (St	allLtime: SM_Qua SM_Qua SM_Qua SM_Qua	VE Quat SMU GA			



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)	Туре	Count 12,379	HWInstan 32,052	Inst Section 38,010	Tris 35,816,589	Sum Tris 110,421,0	Size 1,522,691.875 I		Inst VC 13,083.4	
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 K	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 0
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 0
uchpbg3fa_LOD0	122 Actors	StaticMesh	122	122	122	19,631	2,394,982	3,800.345 KB	0 KB	1,930.832	468 0
Quarry_Cliff_LOD0_ubhvccfda	116 Actors	StaticMesh	116	116	116	20,001	2,320,116	2,135.489 KB	0 KB	513.4921	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 0
	7 Actors	StaticMesh	7		2,765	765	2,115,225	125.327 KB	5.586		48 0
Canyon_Sandstone_Ledge_LOD0_ul	50 Actors	StaticMesh	50		50	41,569	2,078,450	4,003.815 KB	0 KB		38 0
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 0



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)