



March 21-25, 2022
San Francisco, CA

BUILDING 'ZETA HALO'

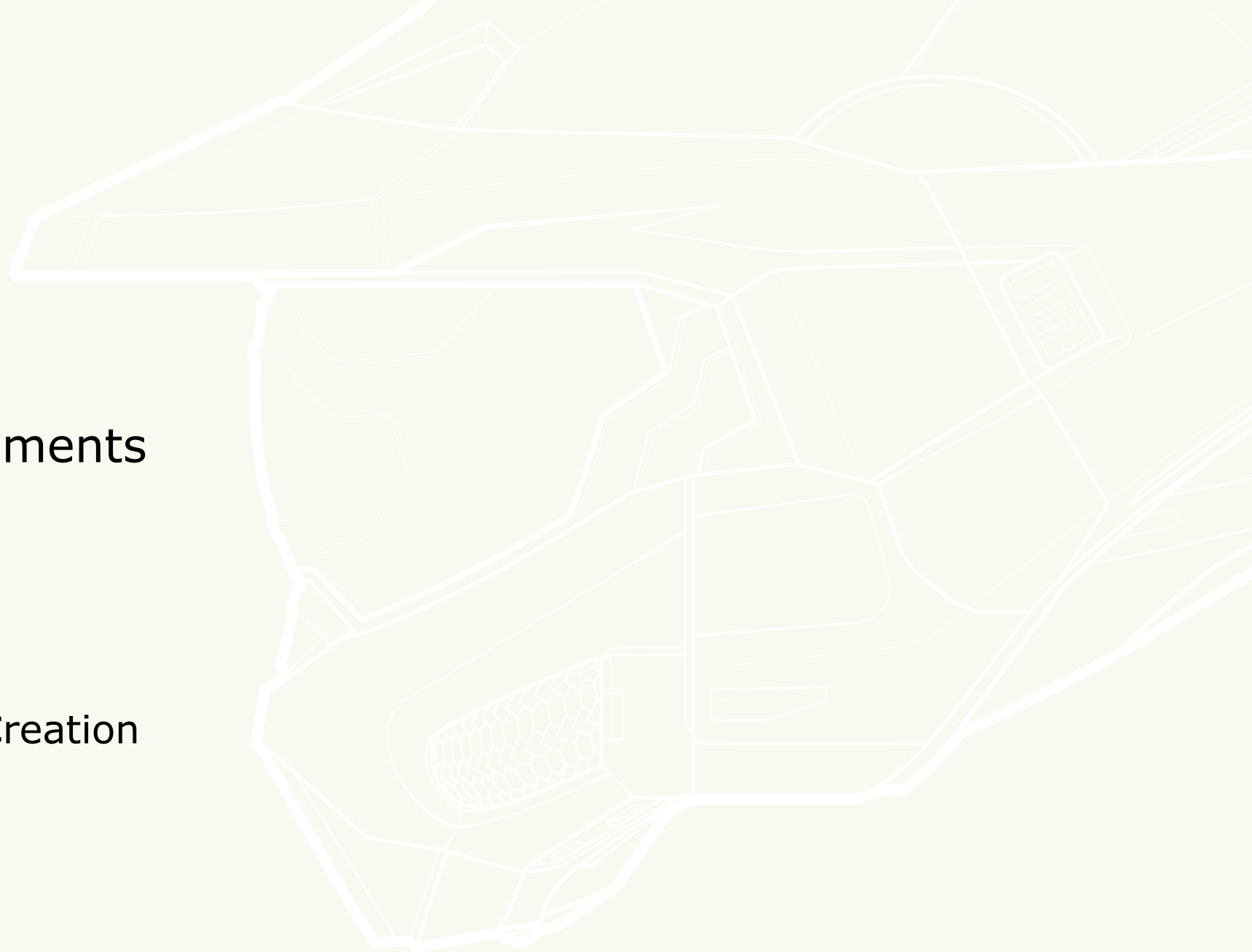
SCALING CONTENT CREATION FOR
THE LARGEST 'HALO' EVER

KURT DIEGERT (he/him) | Lead Environment Technical Artist, 343 Industries

MIKAEL NELLFORS (he/him) | Technical Art Director, 343 Industries

Agenda

- History
- Goals
- Workflows Improvements
 - Mask Painter
 - Terrain System
 - HLODs
 - Procedural Content Creation
- Content Scalability



History

- Halo FPS
 - Linear, Unique, Hand-crafted
 - Very specialized workflows
 - Destructible/time-consuming
 - No terrain system or procedural techniques
- Single Platform
- Not scalable

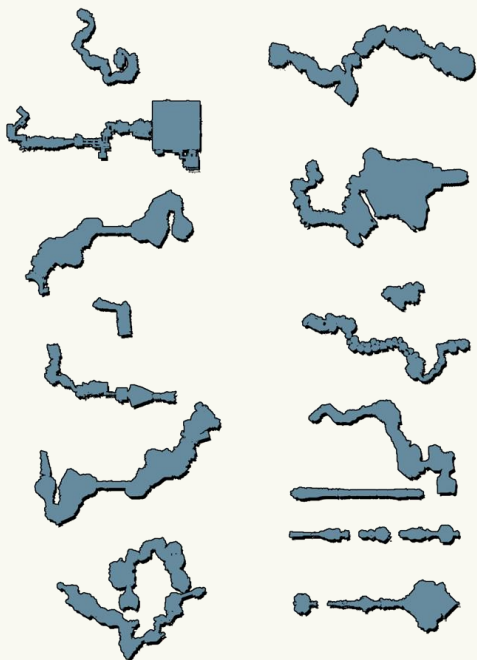


Goals for Halo Infinite

- Support large open playable space
- Improve iteration speed and stability
- Modular workflows
 - Need enough variety to fill world
- Procedural workflows
 - More content than before
- Non-destructive workflows
 - Fast iteration time
- Multi-Platform
 - Scalability of content complexity



"Campaign Levels"



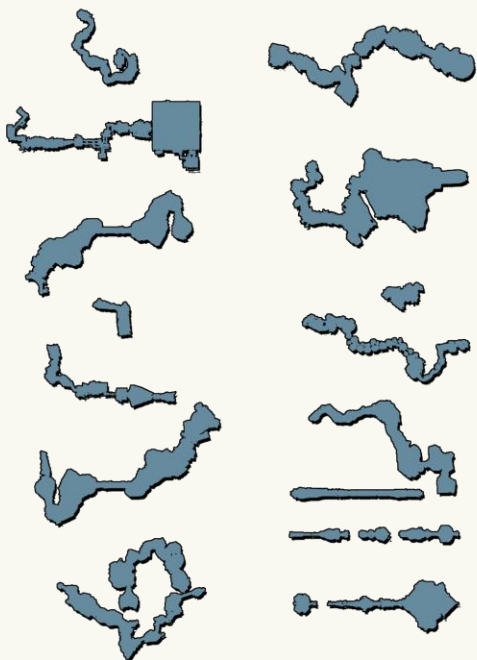
VS

"Campaign Island"



Approx
7.5km
(4.5mi)

"Campaign Levels"



VS

"Campaign Island"



Approx
7.5km
(4.5mi)

Mask Painter



Mask Painter

- Goals
 - Efficiently build more content
 - Mitigate repetition from modular workflows



Mask Painter



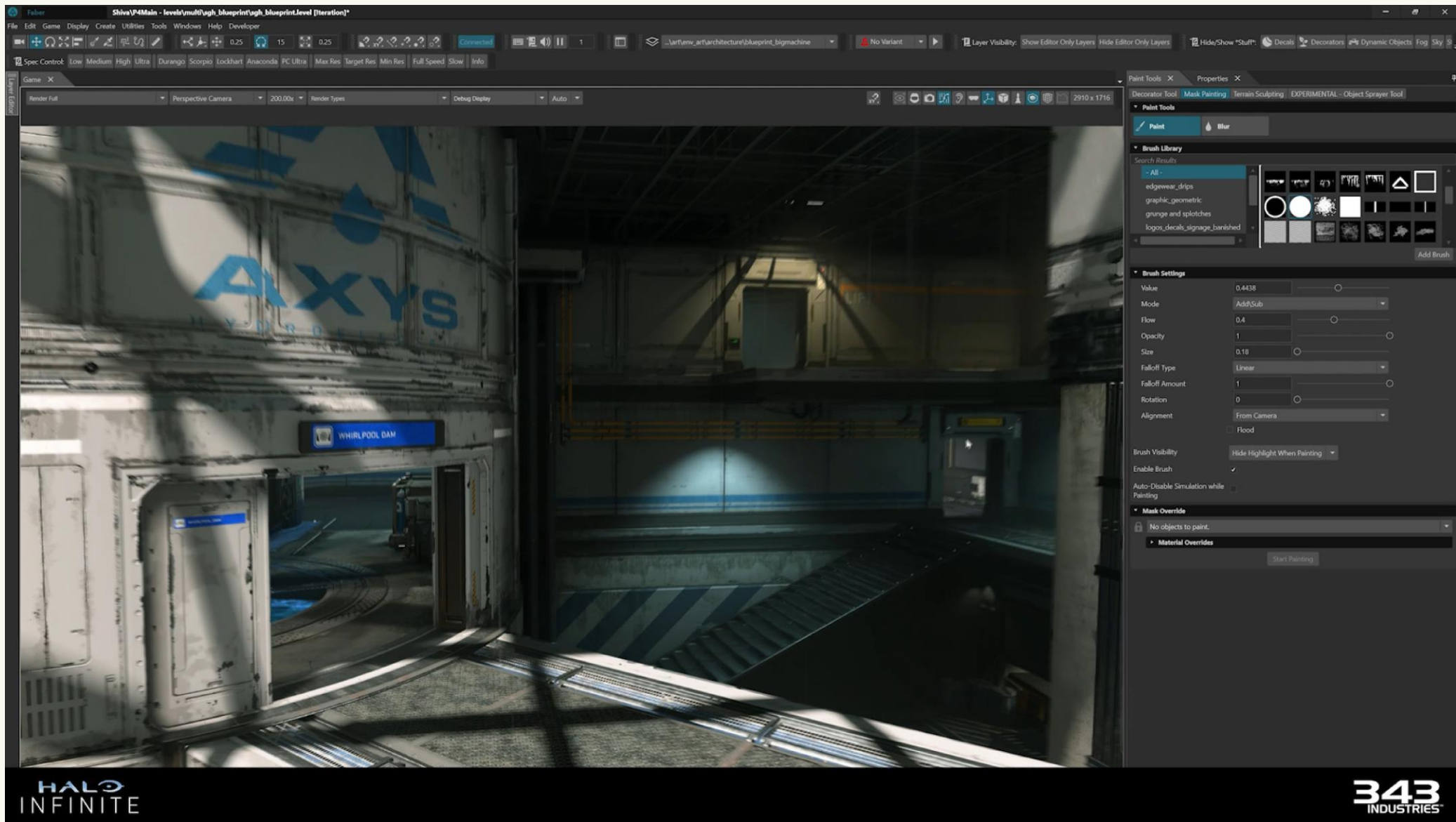
- Goals
 - Efficiently create variety
 - WYSIWYG
 - Non-destructive
 - Minimal Popping
 - Affordable



Mask Painter



- Design
 - Texture masks
 - Artist-controlled mask resolution
 - Artist-controlled variants
 - GPU-based, In-editor implementation
 - Paint across multiple meshes

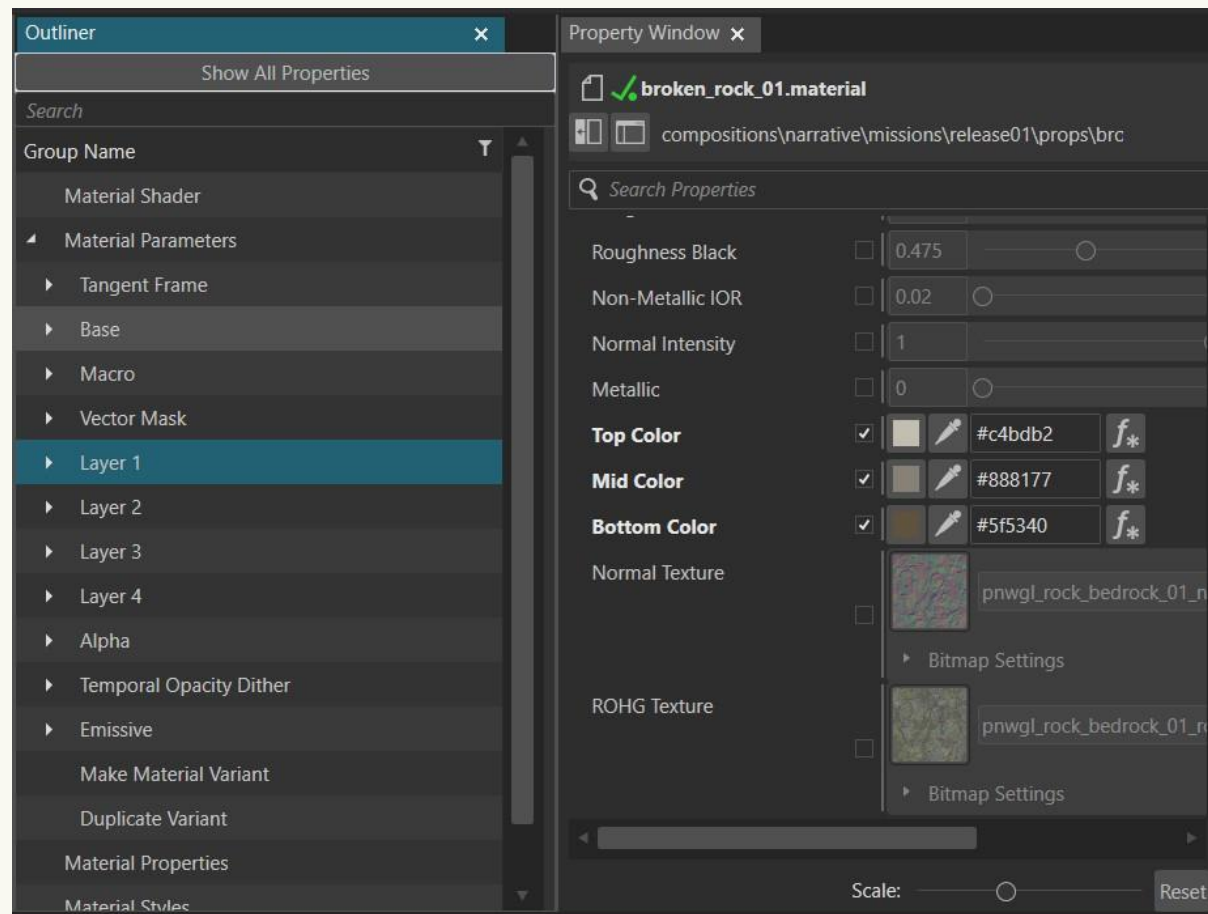


<https://vimeo.com/663103122>

Mask Painter



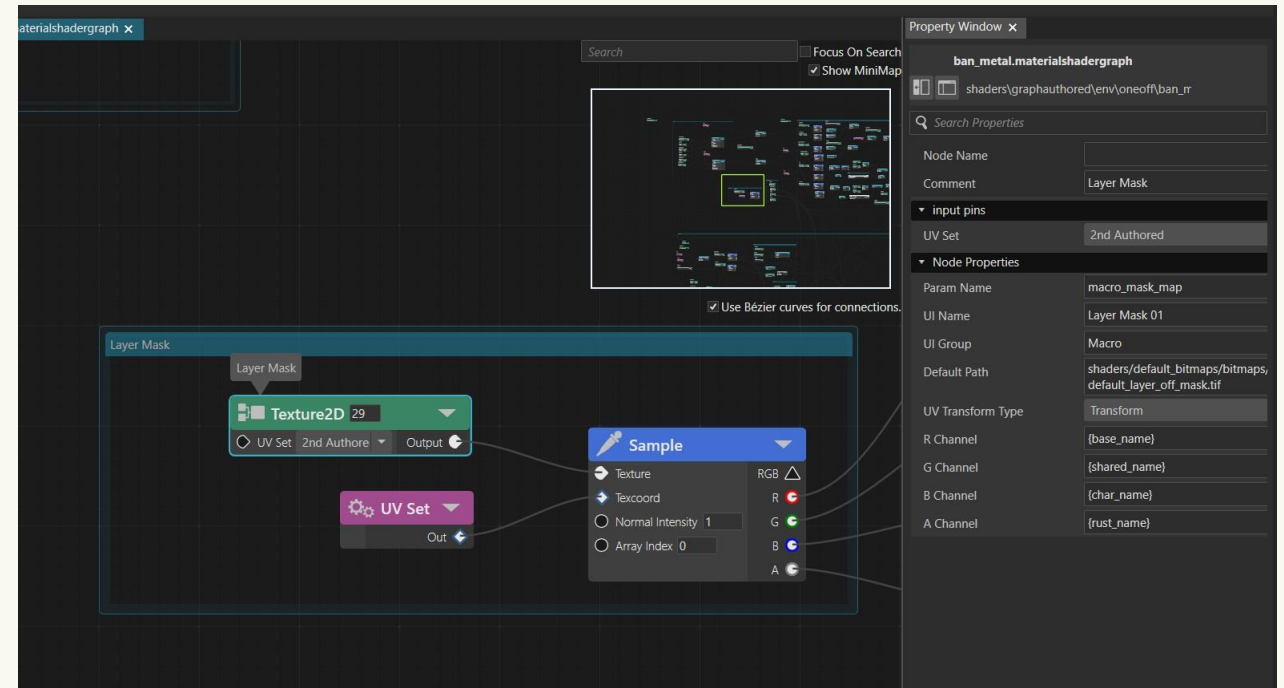
- Shader Interface
 - Developed alongside multi-layered ubershader



Mask Painter



- Shader Interface
 - Developed alongside multi-layered ubershader
 - Supports any shader
 - Annotate any texture as paintable



Mask Painter



- Shader Interface
 - Developed alongside multi-layered ubershader
 - Supports any shader
 - Annotate any texture as paintable
 - Used for special cases like river/waterfall intersections



Mask Painter



- Implementation
 - Paint Operation
 - Undo Stack
 - Mask Painter UVs

Terrain



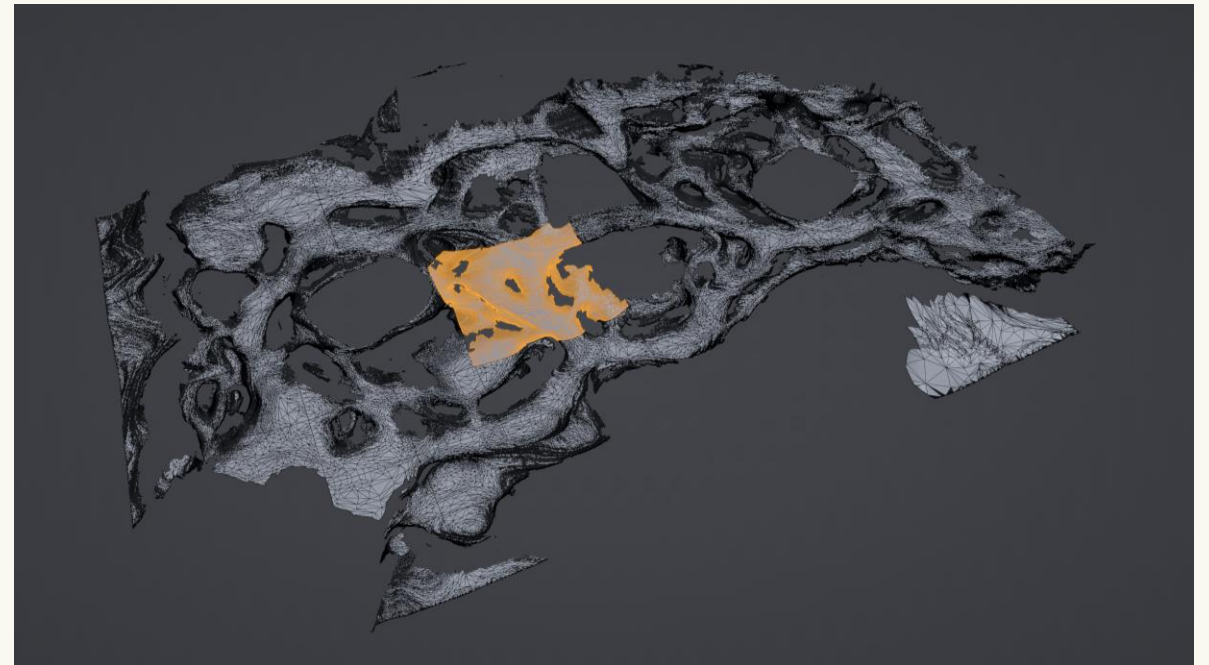
Terrain - History



- Unique terrain meshes
 - Maya, World Machine
- Limited number of material layers
- Mask painted/generated in DCCs
- Optimized by hand



Terrain – History



Terrain - Goals

- WYSIWYG Data Driven Workflow
- Support small to large landscapes
- Multi-user
- Material Painting
- Procedural Ground cover generation
- Non-destructive
- Platform Scalable

HALO
INFINITE



Type:
Arena Map

Playable area:
120x120m (400x400ft)

"Live Fire"



"Campaign Island"



Approx
7.5km
(4.5mi)

Terrain – Design



- Inspired by Far Cry and Horizon Zero Dawn

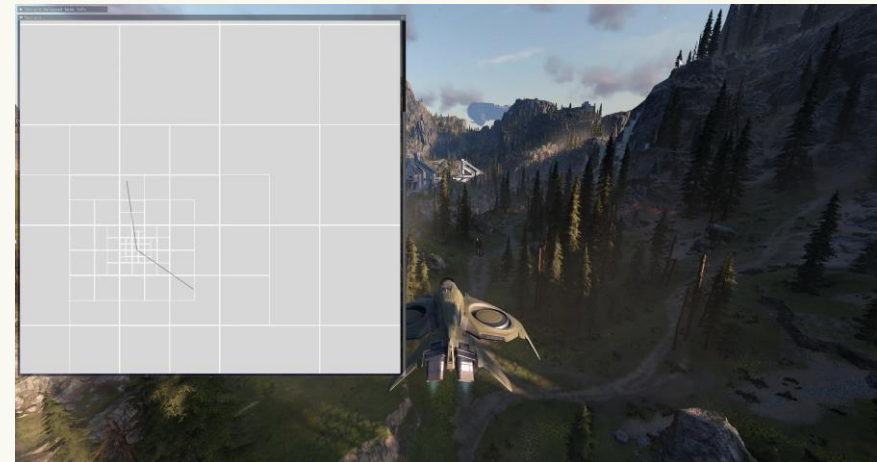
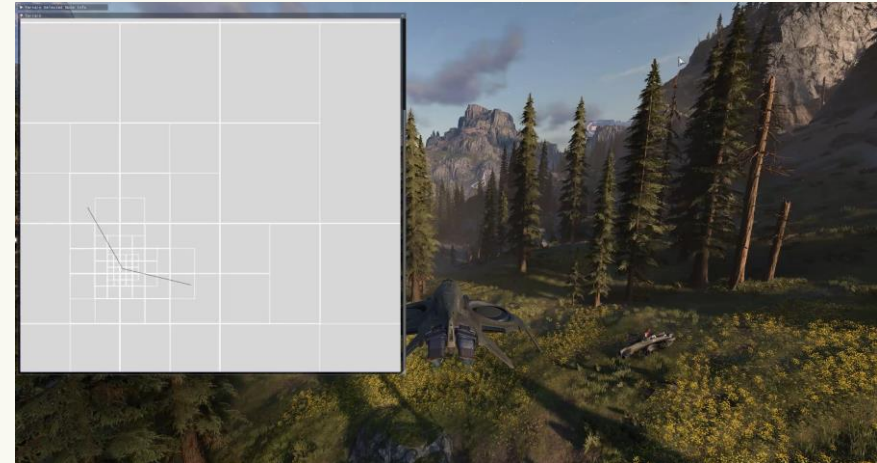
- Adaptive Virtual Texture Rendering in Far Cry 4
<https://gdcvault.com/play/1021760/Adaptive-Virtual-Texture-Rendering-in>
- Terrain Rendering in Far Cry 5
<https://gdcvault.com/play/1025261/Terrain-Rendering-in-Far-Cry>
- GPU-Based Run-Time Procedural Placement in 'Horizon: Zero Dawn'
<https://gdcvault.com/play/1024120/GPU-Based-Run-Time-Procedural>



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- Heightmap
- Tile Based
- Quad Tree
 - Scalability control over resolution and tiles/frame
 - Virtual Texturing



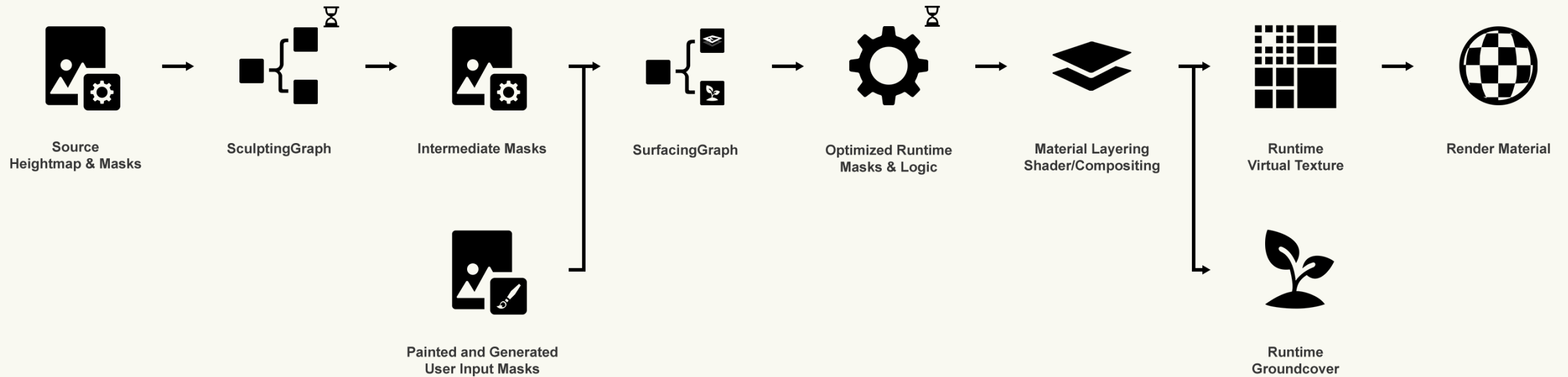
Terrain – Design



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- Heightmap
- Tile Based
- Quad Tree
 - Scalability control over resolution and tiles/frame
 - Virtual Texturing
- Micro Displacement



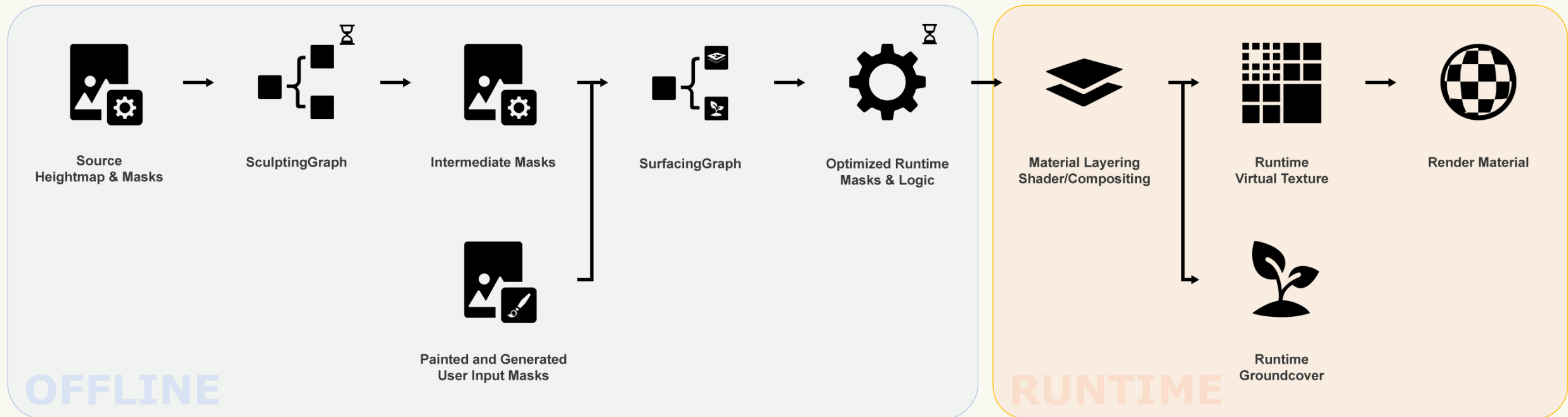
Terrain – Design



Terrain – Design



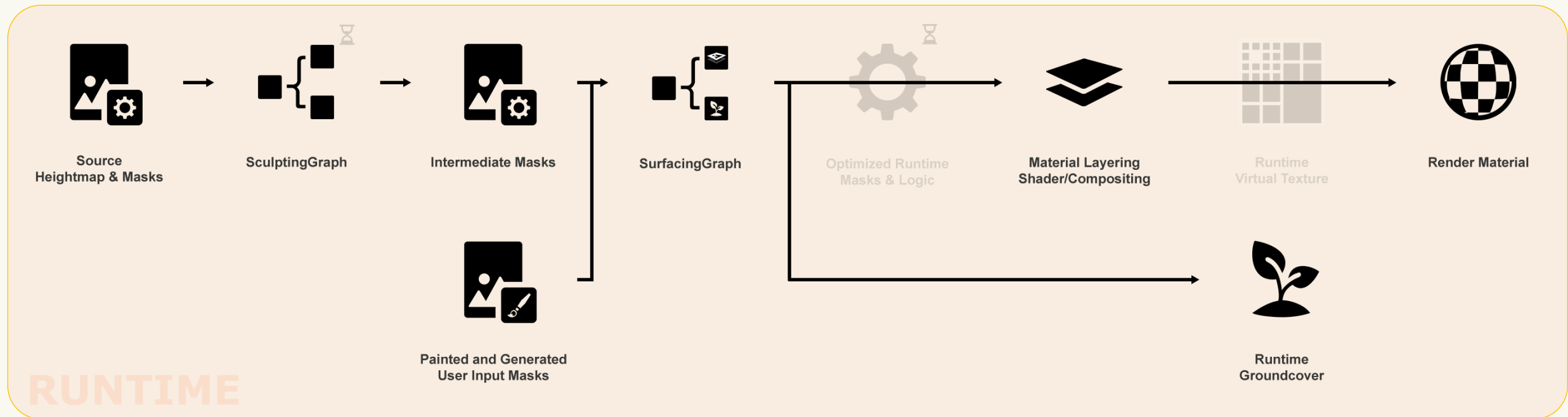
- 2 Modes
 - **Runtime – Compiled HLSL**
 - Edit – Live GPU interpreted



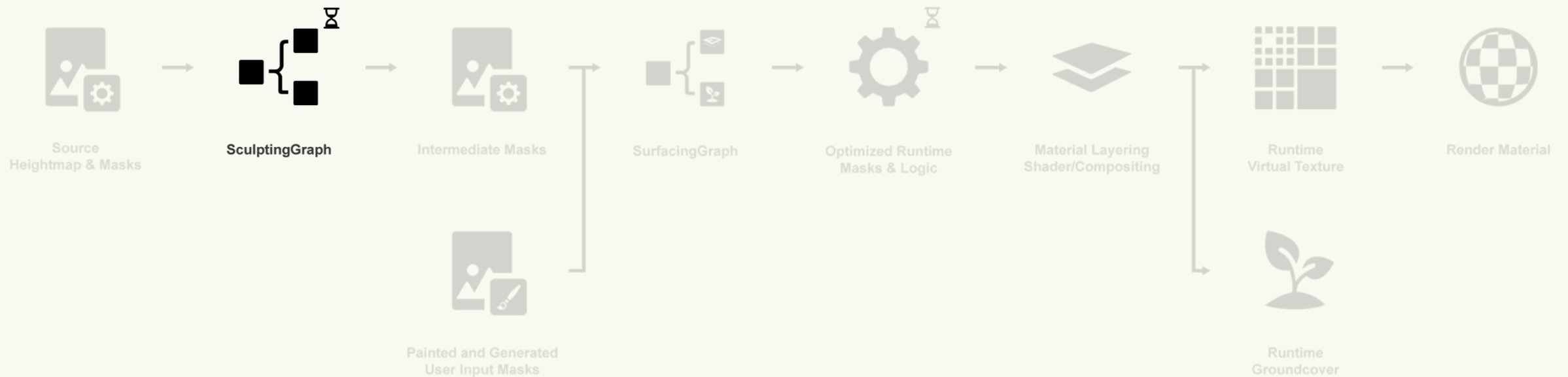
Terrain – Design



- 2 Modes
 - Runtime – Compiled HLSL
 - **Edit – Live GPU interpreted**
- Pro
 - Instant Edit / Fast Runtime
- Con
 - 2 Code paths
 - Cost of compiling after edit



Sculpting Graph



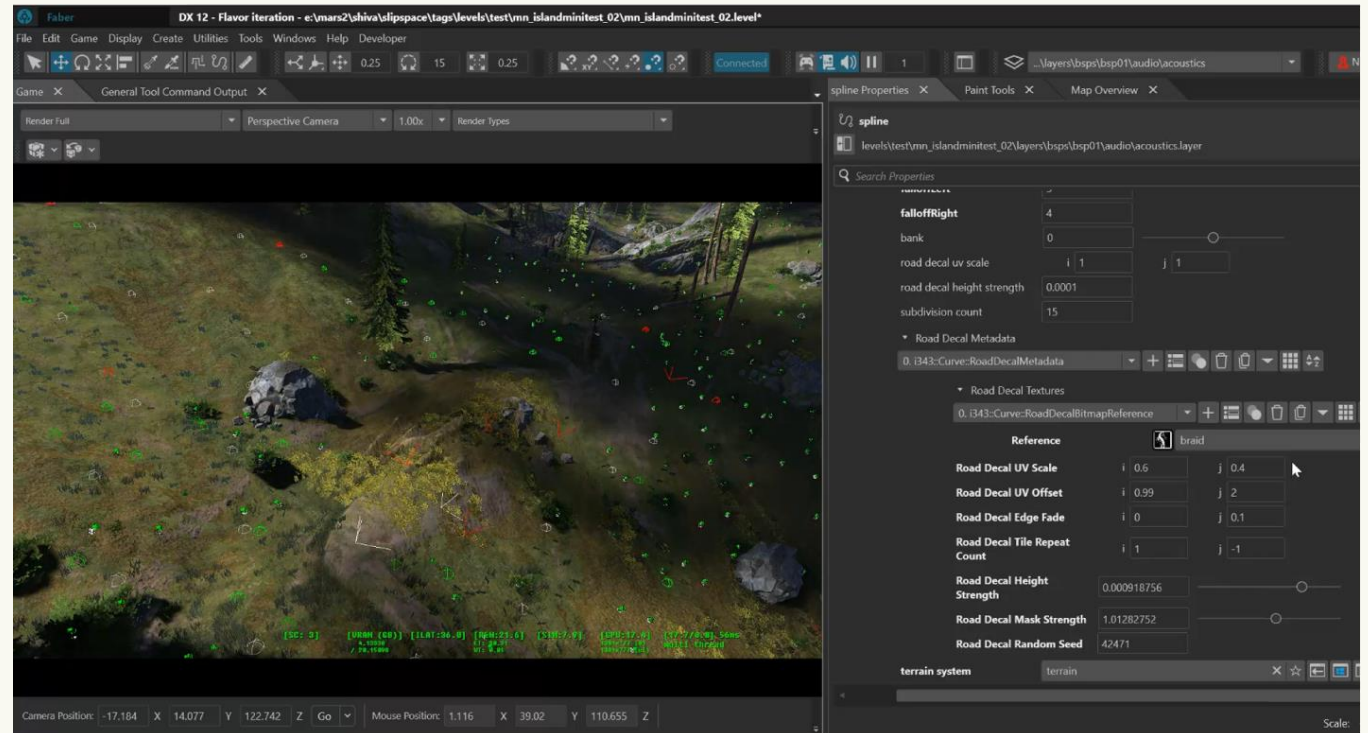
A simple black outline icon of a mountain range with two peaks, the first being taller than the second.

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Sculpting Graph



- Spline Roads
 - Non-destructive
 - World artists place Bezier spline control points
 - Geometry shader
 - Road decals

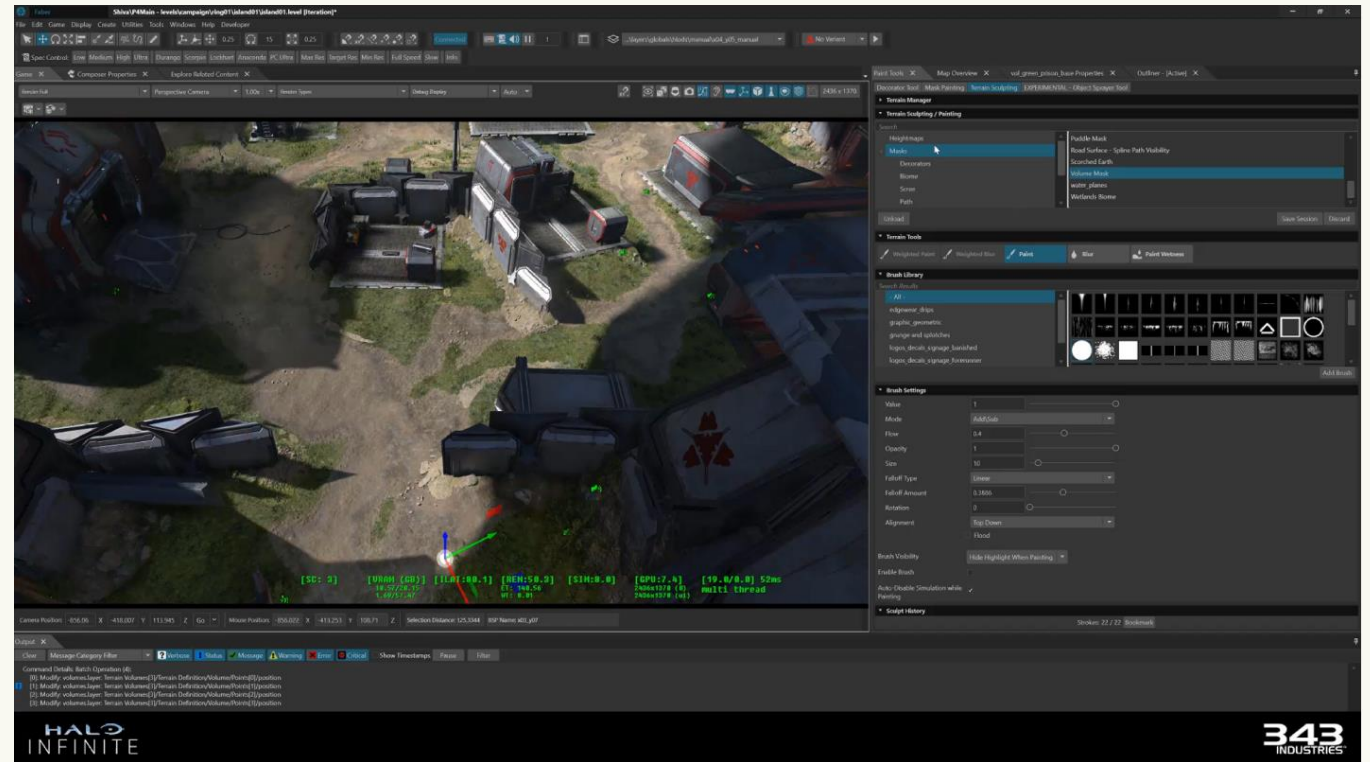


<https://vimeo.com/663070978>

Sculpting Graph



- Terrain Volumes
 - Just like Photoshop Layers for terrain
 - Multi-user workflows

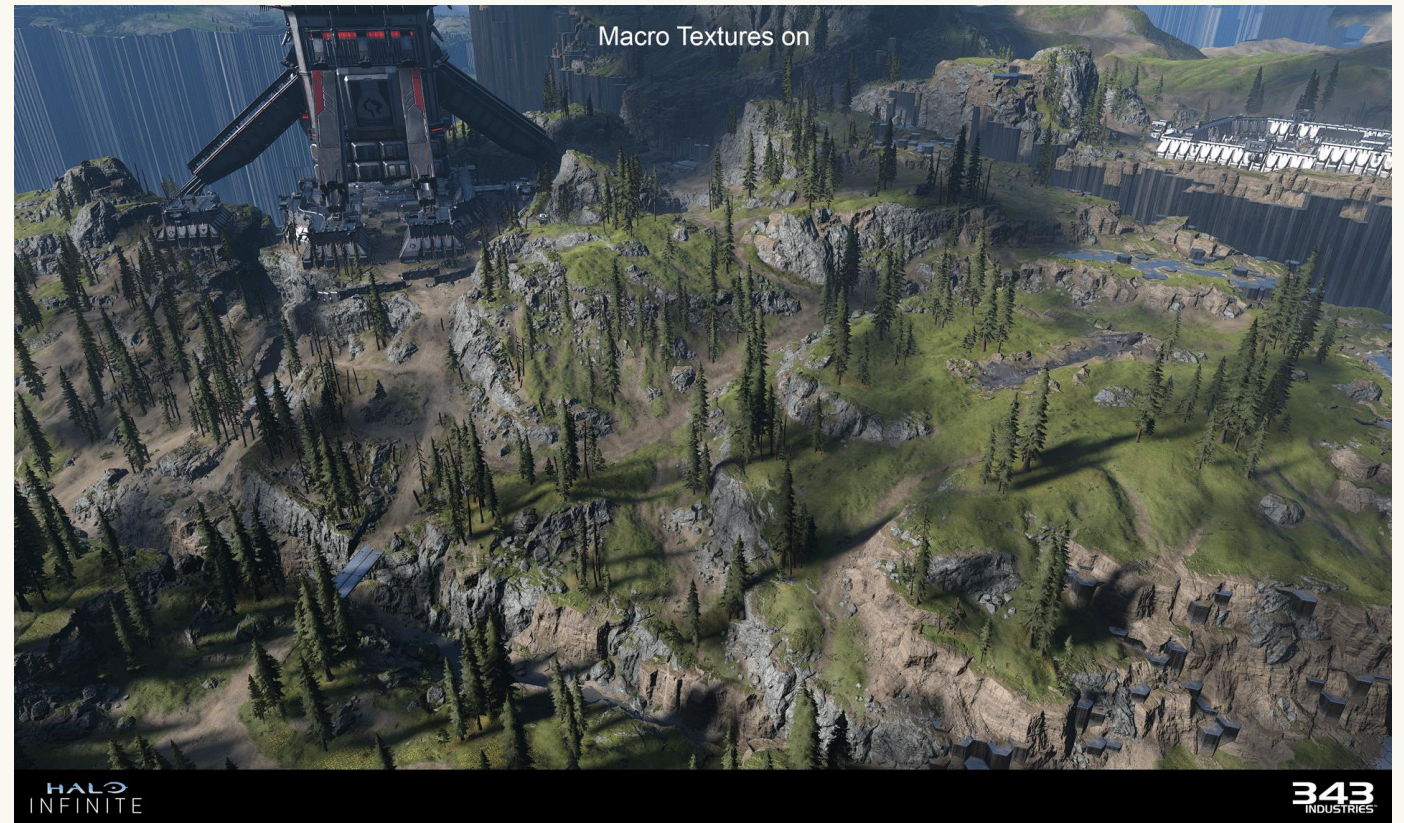


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Sculpting Graph



- Erosion and Macro Textures
 - Applied in additive layer in sculpt graph
 - Houdini reads/writes game data files via Python API



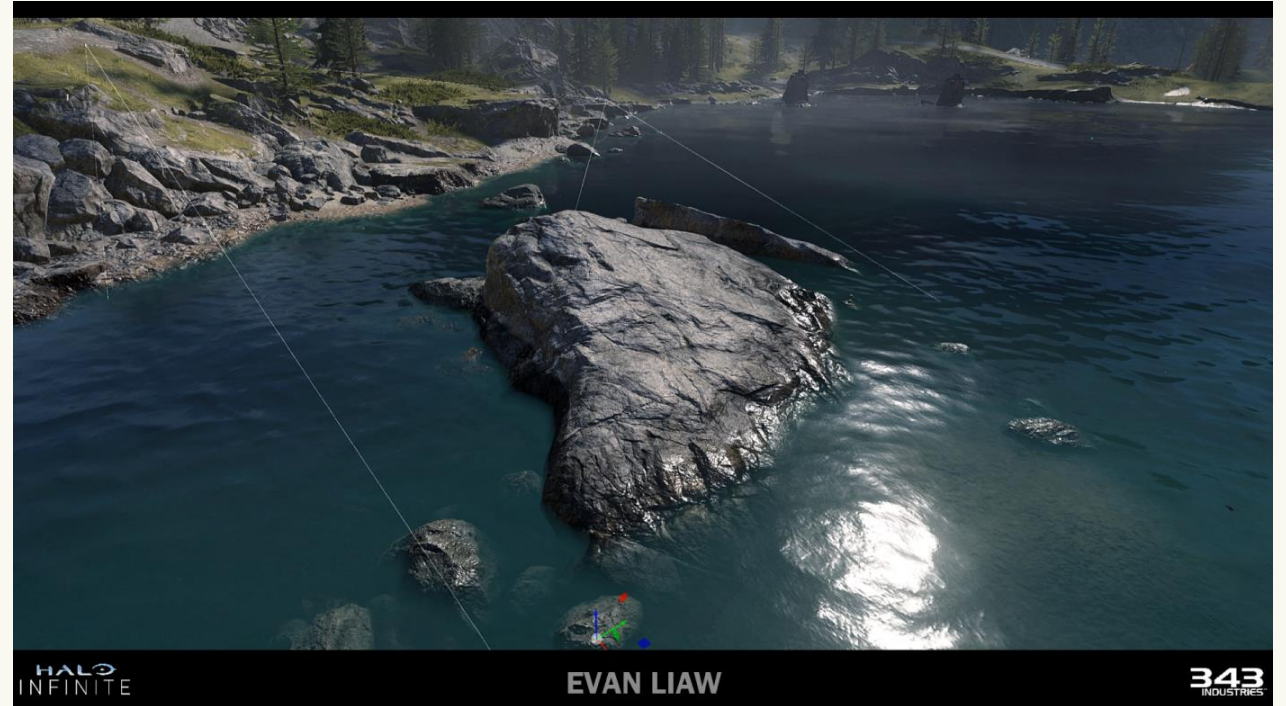
<https://www.artstation.com/artwork/LeaB6R>

Sculpting Graph



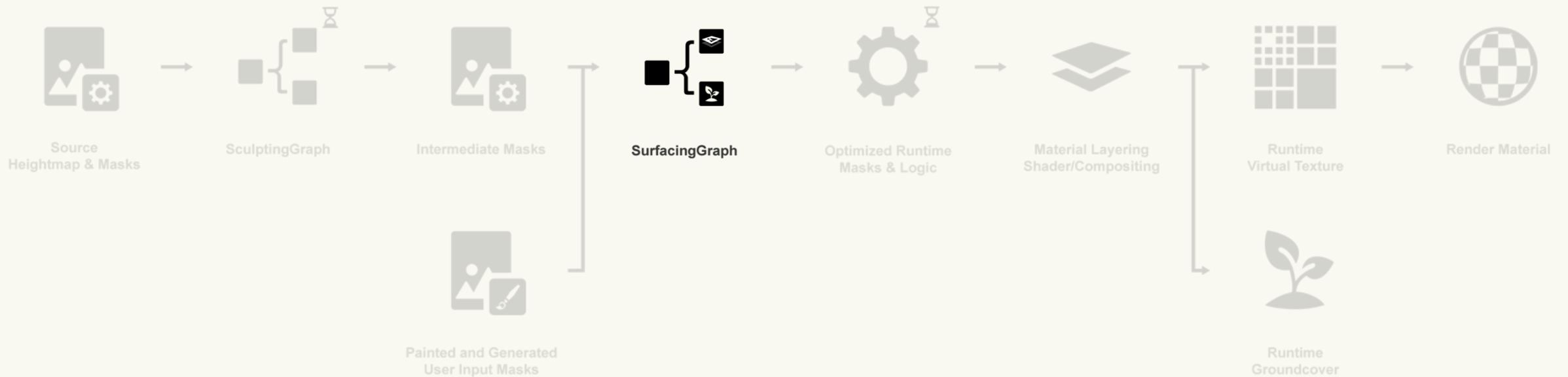
- Wetness

- Water table height sculpted / generated
- Stored in VT relative to terrain height
- Used by terrain and placed meshes



<https://www.artstation.com/artwork/xY31YY>

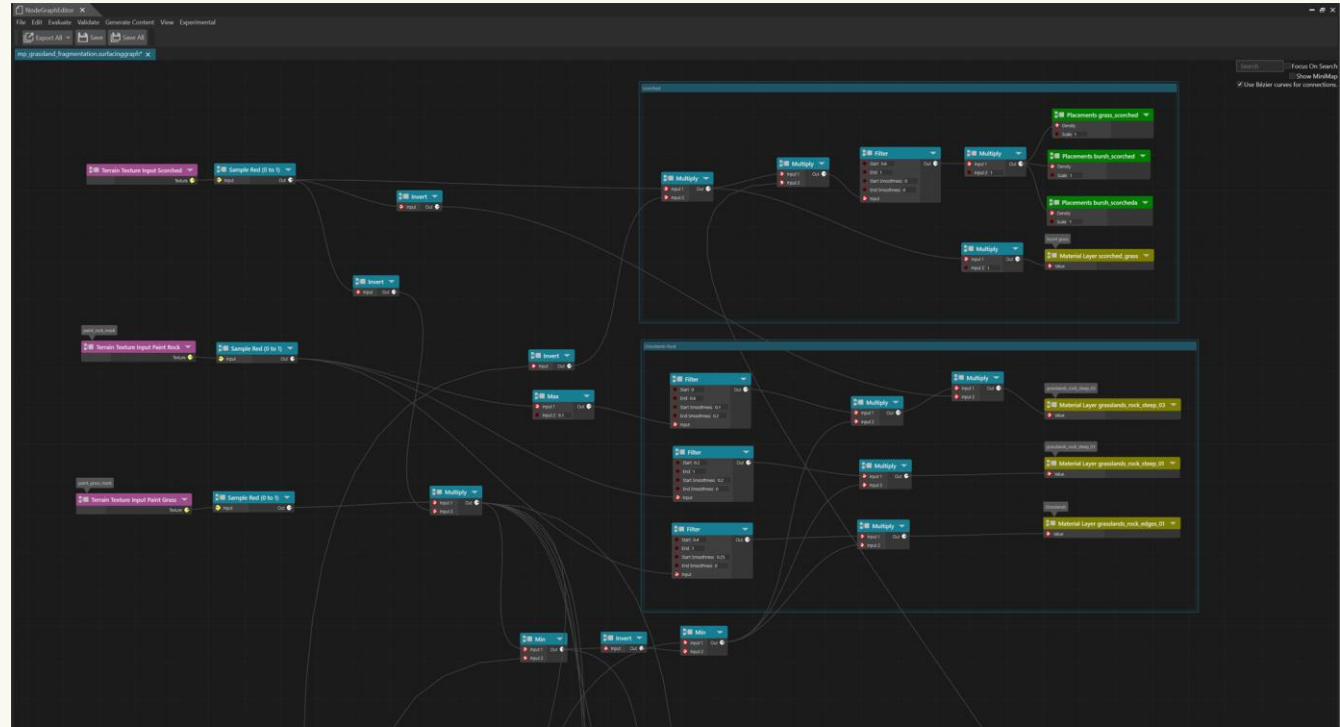
Terrain – Design



Surfacing Graph



- Controls the look of the terrain
- Mask Based Inputs
 - From the sculpting graph or user created masks
- Nodebased rule system
- Material and groundcover outputs
 - FX and Audio somewhat supported



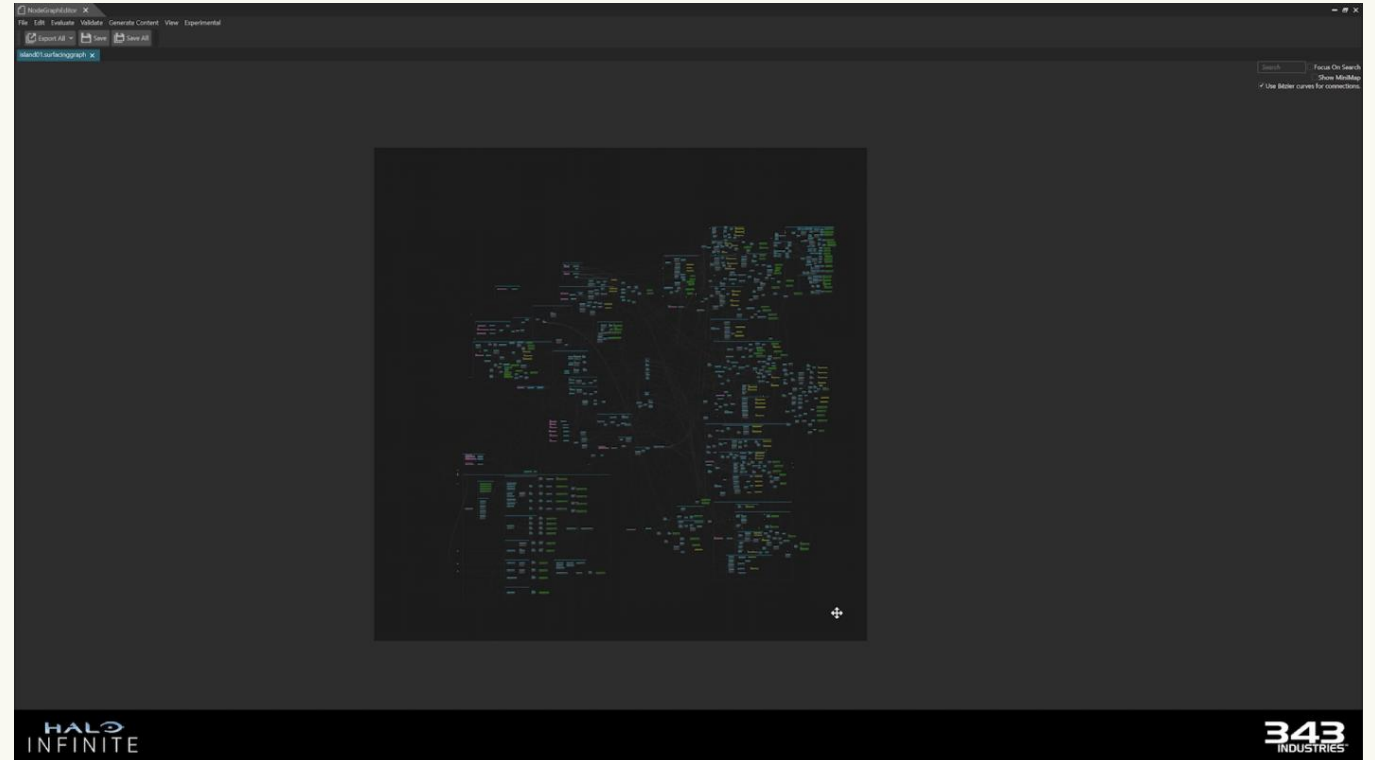


GDC

Surfacing Graph



- Campaign Island
 - 22 input masks
 - 53 ground cover placement
 - 65 material outputs
 - 24 audio placements
 - 19 FX Placements



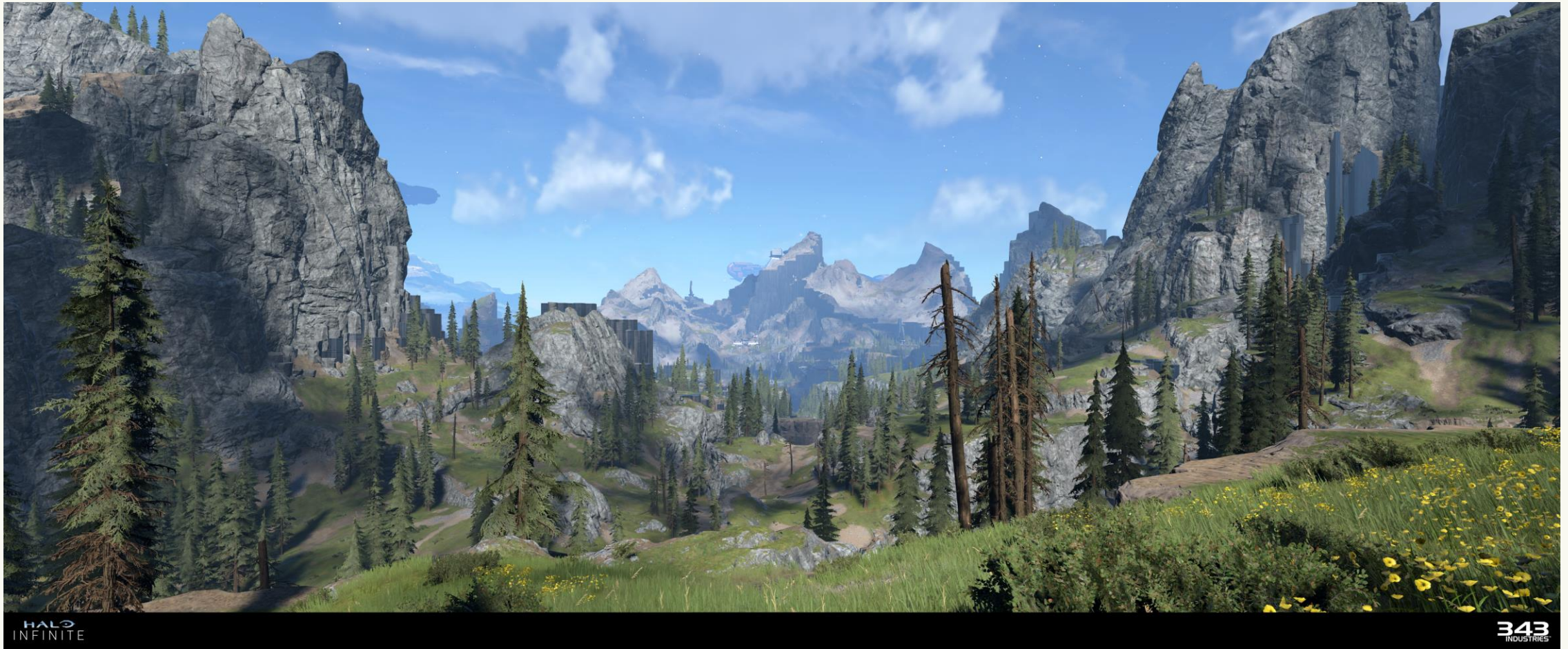
Examples



Examples



Examples



Examples



Examples

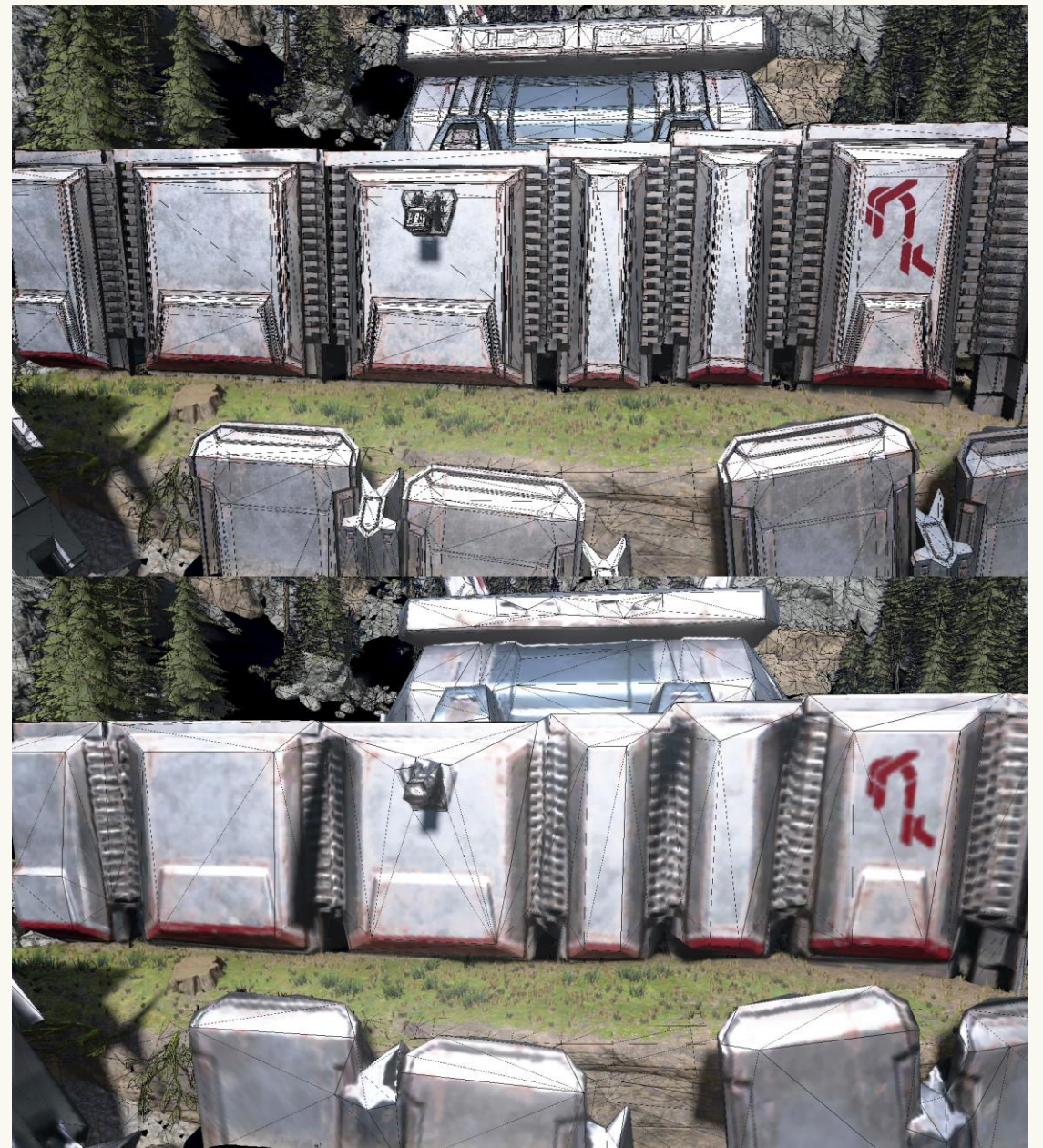


Examples



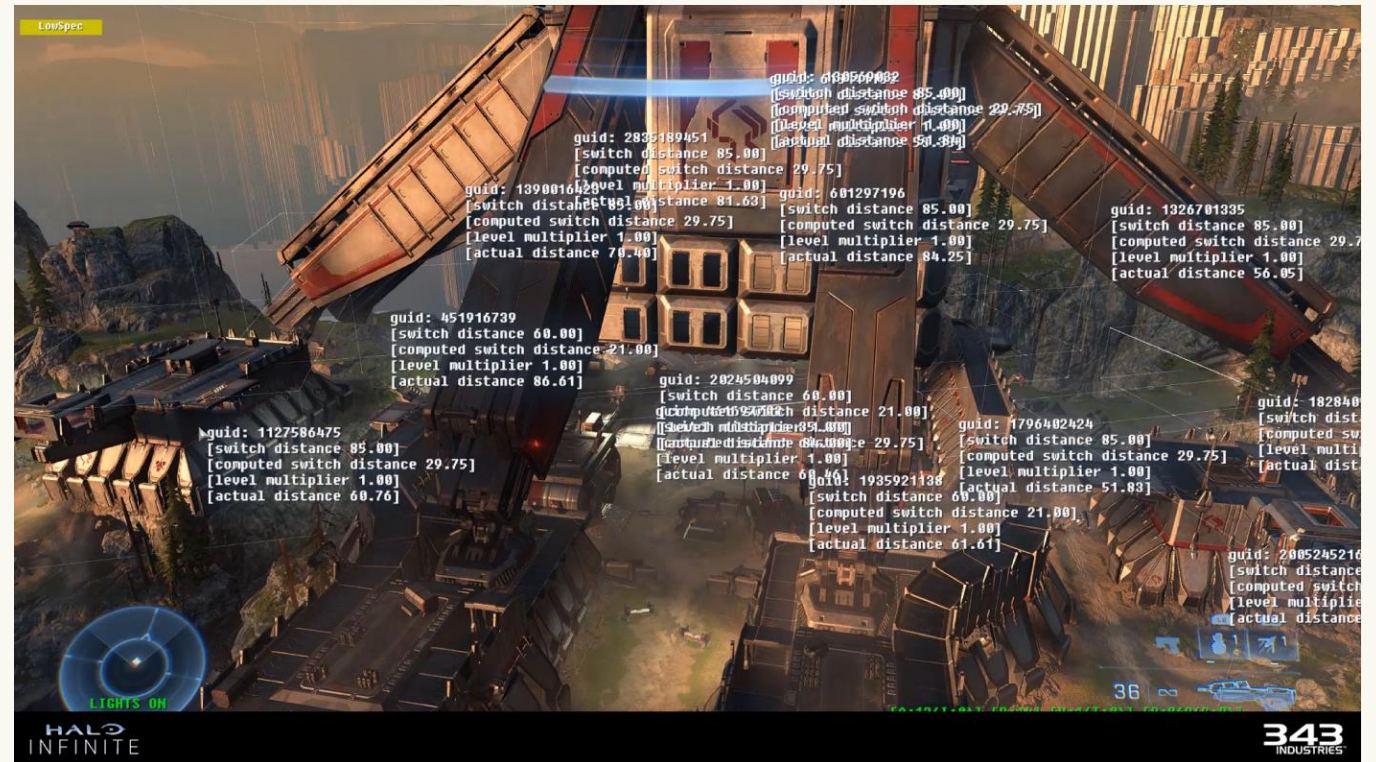
HLODs

- We built HLODs manually for past games
- Heavy geometry, heavy shaders
- Remeshing



HLODs

- Low spec needs GPU savings
- Low spec also needs memory savings
- Balancing is tricky
- We built a lot of control to iterate
 - Reduction / remeshing settings per-HLOD
 - Mesh inclusion
 - Manual volumes
 - Auto-grid HLODs
 - Distance Multipliers



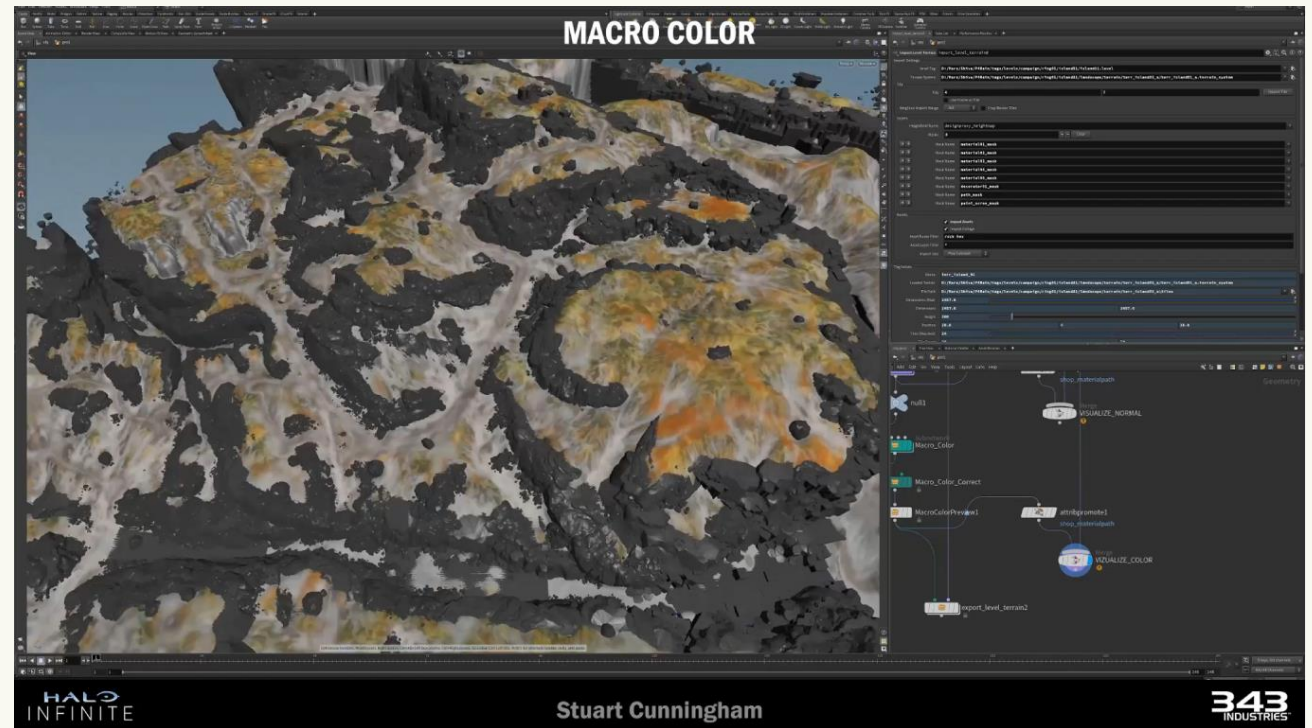
HLODs

- Trial and error
- Manual per-mesh HLOD inclusion is unnecessary
- Manual HLOD texture res is unnecessary
- Rocks in HLODs?
 - No, too much memory
- Each base is a single parent HLOD and several child HLODs
- Planned budget: 100mb
- Actual budget: 300mb



Procedural Content Creation

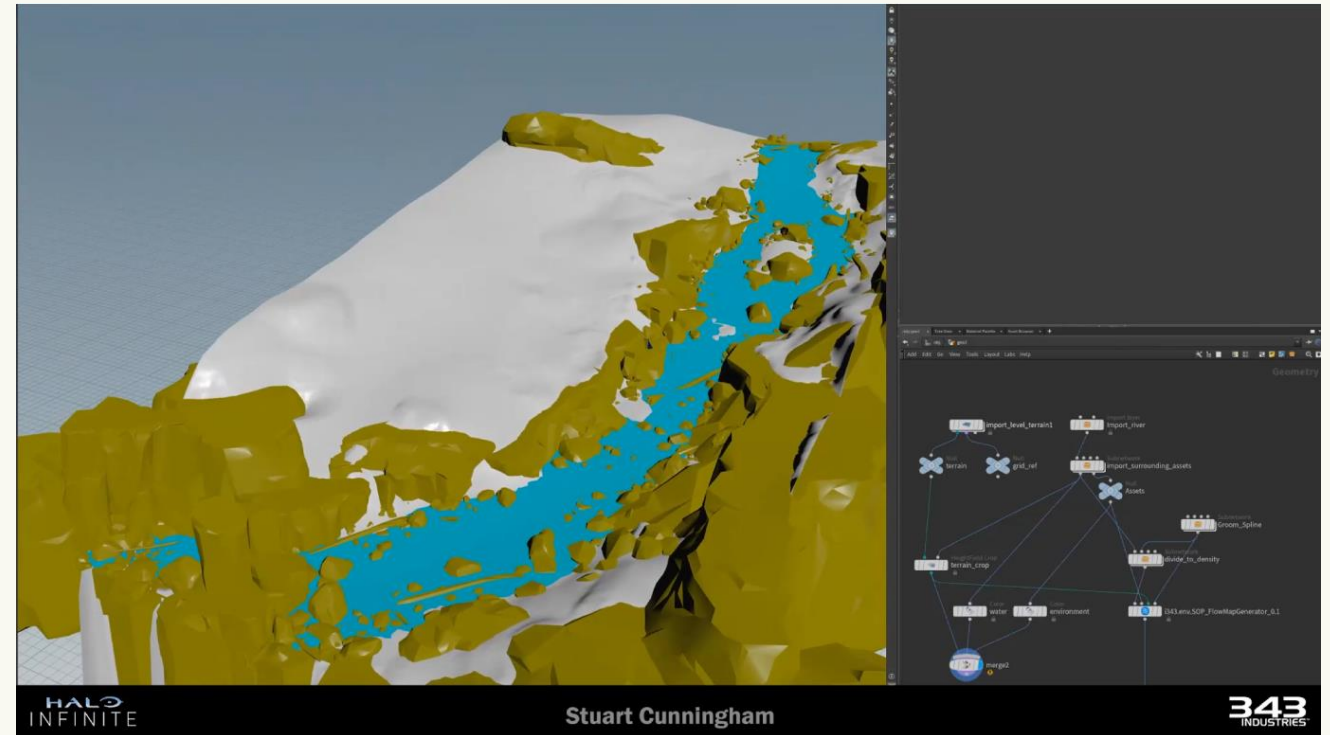
- Houdini reads/writes game data files directly
- Many of our native systems provide hooks for Houdini to allow faster iteration
 - Erosion
 - Terrain Macro



<https://www.artstation.com/artwork/LeaB6R>

Procedural Content Creation

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 - Flowmaps



<https://www.artstation.com/artwork/o2xAXO>

Procedural Content Creation

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 - Erosion
 - Terrain Macro
 - Flowmaps
 - Hex Placements
 - Chunker



Content Scalability



History



- Only one platform
- Progressive Resolution
- Throttling system
- Few scalable systems
- Some parameters exposed, some hardcoded

Goals

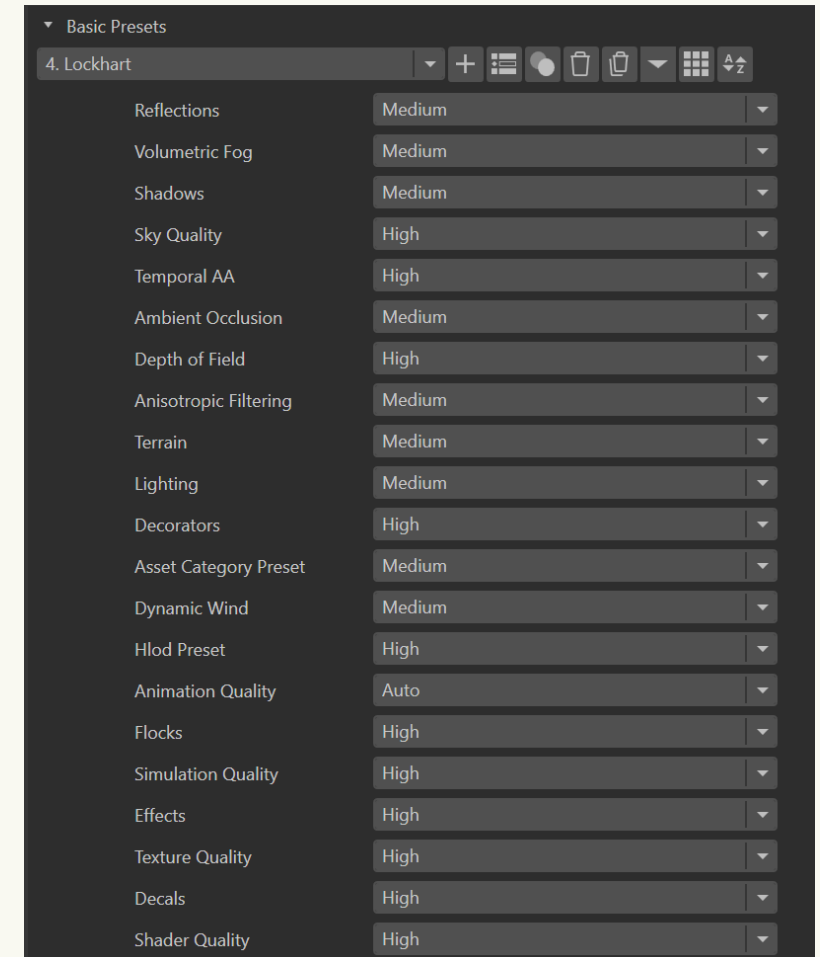


- Flexible/Support multiple hardware specs
- Data-driven system
- Manual tuning
- Content makes decisions about where to sacrifice visual quality for CPU, GPU and memory

Scalability Presets



- Ambient Occlusion
- Animation Quality
- Anisotropic Filtering
- Anti Aliasing
- Damage
- Decals
- Depth of Field
- Effects
- Emblems
- Geometry
- Ground Cover
- HLODs
- Lighting
- Reflections
- Shader Quality
- Shadows
- Simulation
- Sky Quality
- Terrain
- Texture Quality
- Virtual Texturing
- Volumetric Fog
- Wildlife
- Wind



Scalability Presets



- Ambient Occlusion
- Animation Quality
- Anisotropic Filtering
- Anti Aliasing
- Damage
- Decals
- Depth of Field
- Effects
- Emblems
- **Geometry**
 - Skip LODs
 - Scale LOD Distances
 - Scale Render Distance and more...
- Lighting
- Reflections
- Shader Quality
- Shadows
- Simulation
- Sky Quality
- Terrain
- Texture Quality
- Virtual Texturing
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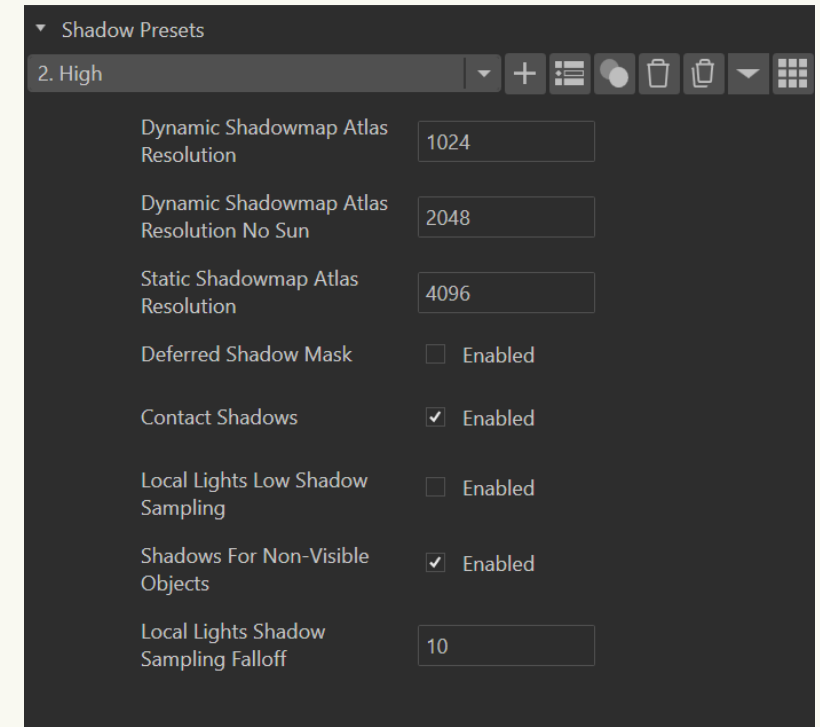
▸ Low Setting				
▸ Medium Setting				
▾ High Setting				
LOD Distance Multiplier	low	0.5	high	0.6
Number of LODs to skip				0
Hide After Distance Multiplier	low	0.5	high	0.6
Static IO Shadow Casting Maximum Distance				256
Dynamic Object Shadow Casting Maximum Distance				50
Dynamic Object Cast Shadow Outside of Camera Frustum Distance				0
LOD - 2 Player Splitscreen				0.7
LOD - 3 Player Splitscreen				0.3
LOD - 4 Player Splitscreen				0.1
HAD - 2 Player Splitscreen				0.7
HAD - 3 Player Splitscreen				0.3
HAD - 4 Player Splitscreen				0.1
▸ Ultra Setting				

Scalability Presets



- Ambient Occlusion
- Animation Quality
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- Decals
- Depth of Field
- Effects
- Emblems
- Geometry
- Ground Cover
- HLODs

- Lighting
- Reflections
- Shader Quality
- **Shadows**
 - Dynamic Shadowmap Atlas Resolution
 - Static Shadowmap Atlas Resolution
 - Deferred Shadow Mask
 - Contact Shadows
 - Local Lights Low Shadow Sampling
 - Local Lights Shadow Sampling Falloff
 - and more...
- Volumetric Fog
- Wildlife
- Wind

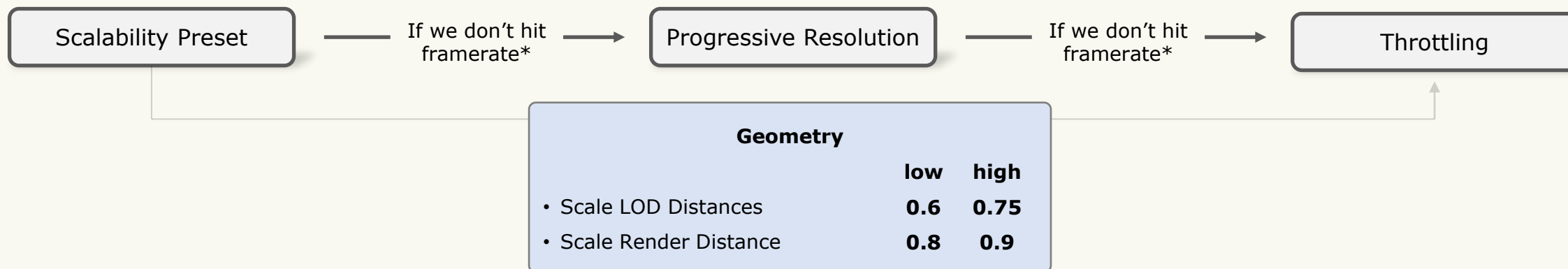


Staying at framerate



*this only applies to PC if using minimum framerate setting

Staying at framerate



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Staying at framerate



- Regular performance reviews
- PowerBI

Platform GPU																												
max camera point per map over recent builds																												
Release																												
Team																												
Mode																												
Build Date																												
	Platform	PC-Ultra-Nvidia			PC-High-Nvidia			PC-Mid-Nvidia			PC-Low-Nvidia			XboxSeriesX			XboxLockhart			Xbox1X			Xbox1					
	Map (in ms)	GPU	ENV	SHAD	GPU	ENV	SHAD	GPU	ENV	SHAD	GPU	ENV	SHAD	GPU	ENV	SHAD	GPU	ENV	SHAD	GPU	ENV	SHAD	GPU	ENV	SHAD			
	aa_gun_island	13.24	4.92	1.98	14.81	4.25	1.63	23.27	7.68	2.34	23.81	12....	3.27	15.50	5.65	2.59	14.79	6.96	1.69	29.07	10....	3.10	31.79	13...	4.81			
	boss_hq_exterior	11.27	2.85	1.41	13.58	2.52	1.00	22.25	4.71	1.83	19.06	6.71	2.51	13.47	3.90	1.66	12.58	4.29	1.22	25.03	7.37	2.17	25.89	9.48	3.17			
	digsite	15.22	3.80	3.05	17.10	4.59	2.06	25.11	8.78	4.64	23.68	10....	2.75	16.14	4.51	5.09	13.97	5.69	2.72	27.14	9.01	5.28	31.09	12...	8.90			
	island01_q1_b	9.95	2.07	1.36	11.60	2.62	1.45	17.95	4.39	2.03	16.71	6.20	2.42	12.13	3.66	1.81	11.23	4.47	1.20	22.53	6.67	2.34	22.80	9.98	4.53			
	island01_q1_d	15.22	3.59	1.64	17.23	4.46	1.65	24.80	7.28	2.25	23.40	10....	3.23	15.72	6.04	1.98	15.18	7.64	1.28	29.07	11....	2.53	30.62	15...	2.94			
	island01_q1_g	13.09	3.13	2.03	14.84	3.67	1.89	21.88	6.09	2.07	20.51	9.32	3.03	13.48	4.74	2.64	12.59	5.76	1.52	26.36	9.09	3.95	26.81	11...	6.01			
	island01_q2_d	9.24	3.30	1.11	8.48	2.71	0.94	17.01	4.64	1.91	16.09	7.67	2.10	12.53	4.83	1.25	12.03	5.82	0.96	22.34	7.73	2.05	22.94	9.63	1.54			
	island01_q2_g	9.88	3.29	1.45	8.88	2.81	1.09	17.44	4.70	2.09	15.89	7.14	2.48	12.62	4.68	1.42	11.38	5.34	1.10	23.14	8.28	2.21	23.24	10...	1.84			
	island01_q2_h	10.35	3.43	1.34	11.38	2.81	1.05	19.49	5.11	2.01	17.71	6.88	2.84	12.60	4.69	1.55	11.72	5.03	1.23	23.45	8.25	2.22	24.97	9.93	3.29			
	island01_q3_c	10.84	3.71	2.14	10.05	2.86	1.58	19.48	5.37	2.14	18.23	7.90	3.59	13.19	4.80	2.71	12.42	5.55	1.71	24.30	8.42	4.69	26.20	11...	7.44			
	island01_q3_g	11.02	4.72	1.20	9.75	3.56	0.97	19.50	6.43	1.95	19.59	10....	2.48	14.32	6.37	1.41	13.92	7.57	1.10	25.88	10....	2.47	26.30	13...	4.18			
	island01_q3_h	11.17	4.68	1.71	10.35	3.54	1.22	19.58	6.53	2.26	19.77	10....	3.03	14.17	6.37	1.55	13.82	7.46	1.27	25.08	10....	2.27	25.27	13...	2.21			
	island01_q4_a	9.71	3.14	1.34	10.53	2.91	1.37	17.01	4.38	2.17	15.77	6.64	2.91	12.47	4.40	1.44	11.70	5.11	1.21	22.65	7.55	2.08	23.50	9.96	2.01			
	island01_q4_d	13.30	4.57	1.88	16.04	4.79	1.82	23.39	7.31	2.25	23.29	11....	3.05	15.27	5.78	2.39	14.23	6.58	1.63	27.60	10....	2.73	30.21	12...	4.54			
	island01_q4_e	11.02	3.33	1.60	13.82	3.65	1.53	20.56	5.77	2.06	19.25	8.69	2.61	13.63	4.70	1.97	12.64	5.40	1.41	25.03	8.88	2.42	26.97	12...	3.39			
	island01_q4_g	11.99	3.86	1.77	14.18	4.23	1.62	22.44	6.71	2.29	21.58	9.54	3.15	13.87	4.84	2.08	13.05	5.75	1.44	26.15	9.35	2.33	28.09	12...	3.47			
	island01_q4_h	12.21	3.47	1.68	15.10	3.81	1.53	22.12	5.76	2.14	21.62	9.29	2.57	14.53	4.92	1.66	13.85	5.94	1.22	27.12	8.94	2.33	29.00	12...	2.57			
	outpost_baboon	16.64	3.41	1.94	18.26	4.05	1.94	24.02	6.70	2.50	22.43	10....	3.16	15.11	5.10	2.52	13.93	6.08	1.61	27.97	9.70	2.88	29.46	13...	3.50			
	outpost_bonobo	13.50	3.73	1.96	17.75	4.21	1.83	24.05	6.54	2.19	23.76	9.99	2.92	15.52	5.35	2.87	14.75	6.05	1.78	27.70	9.37	2.96	32.42	13...	5.88			
	outpost_gibbon	17.45	5.37	1.53	18.89	4.51	1.54	26.02	8.93	2.16	25.43	13....	2.93	15.44	5.53	1.79	14.92	7.21	1.27	27.40	9.83	2.22	29.94	14...	2.94			
	outpost_howler	13.94	4.39	3.34	15.36	3.47	2.23	24.59	7.02	2.12	23.14	10....	4.47	15.74	4.92	5.19	14.48	6.49	2.33	28.63	9.85	4.69	30.75	13...	7.46			
	outpost_mandrill	14.52	5.28	1.78	16.52	4.12	1.24	25.19	8.42	2.17	25.55	13....	2.99	15.55	5.56	1.80	15.06	6.85	1.35	28.58	10....	2.41	29.69	13...	2.68			
	outpost_marmoset	16.34	3.89	2.58	18.00	4.67	2.46	24.93	7.32	2.42	24.15	11....	3.57	15.85	5.56	3.72	14.93	7.18	1.99	27.79	10....	3.95	30.08	13...	6.04			

LOW / XBOX ONE



MEDIUM / XBOX ONE X / SERIES S*

*SERIES S IS A MIX BETWEEN MEDIUM AND HIGH



HIGH / SERIES S*&X

*SERIES S IS A MIX BETWEEN MEDIUM AND HIGH



ULTRA



LOW / XBOX ONE



MEDIUM / XBOX ONE X / SERIES S*

*SERIES S IS A MIX BETWEEN MEDIUM AND HIGH



HIGH / SERIES S*&X
*SERIES S IS A MIX BETWEEN MEDIUM AND HIGH



ULTRA



LOW / XBOX ONE



MEDIUM / XBOX ONE X / SERIES S*

*SERIES S IS A MIX BETWEEN MEDIUM AND HIGH



HIGH / SERIES S* & X
*SERIES S IS A MIX BETWEEN MEDIUM AND HIGH



ULTRA



Thanks!



343 Industries at GDC 2022

- One Frame in 'Halo Infinite'

Programming

Daniele Giannetti | Principal Architect, 343 Industries

- Inclusive Leadership @ Xbox Game Studios

Game Career Development

Bonnie Ross | Corporate Vice President, 343 Industries

- Deconstructing the Combat Dance: Designing Multiplayer Bots for 'Halo Infinite'

Design

Sara Stern | Multiplayer Designer, 343 Industries

- Engineering Player Like Behaviors for Multiplayer Bots in 'Halo Infinite'

Programming

Brie Chin-Deyerle | Senior Lead Gameplay Engineer, 343 Industries

A Spartan in Halo armor stands in an office setting. The Spartan is positioned on the right side of the frame, facing left. The office background includes a bulletin board with various papers, a desk with a laptop, and shelves with boxes and supplies. The lighting is dim, creating a professional yet mysterious atmosphere.

We're Hiring!

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