GEARS OF WAR 4

Project Triton

Pre-computed Environmental Wave Acoustics

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Microsoft Research

John Tennant

THE COALITION

Acoustics improves immersion

- We understand our surroundings audio-visually
- Can hear behind head, around corners: persistent awareness
- Need good acoustics in games

- VR/AR –

Positional Audio =

Directional Audio + Environmental Acoustics

Game acoustics today

- Compared to lighting, CPU/RAM are limited…

…but sound's behavior is more complex: wave effects crucial

- Mix of approximate methods w/ pitfalls and manual tagging
- Designer: Tedious work, limited time for creative expression
- Why not follow the path of game lighting?
  Reliable physics + design

The problem

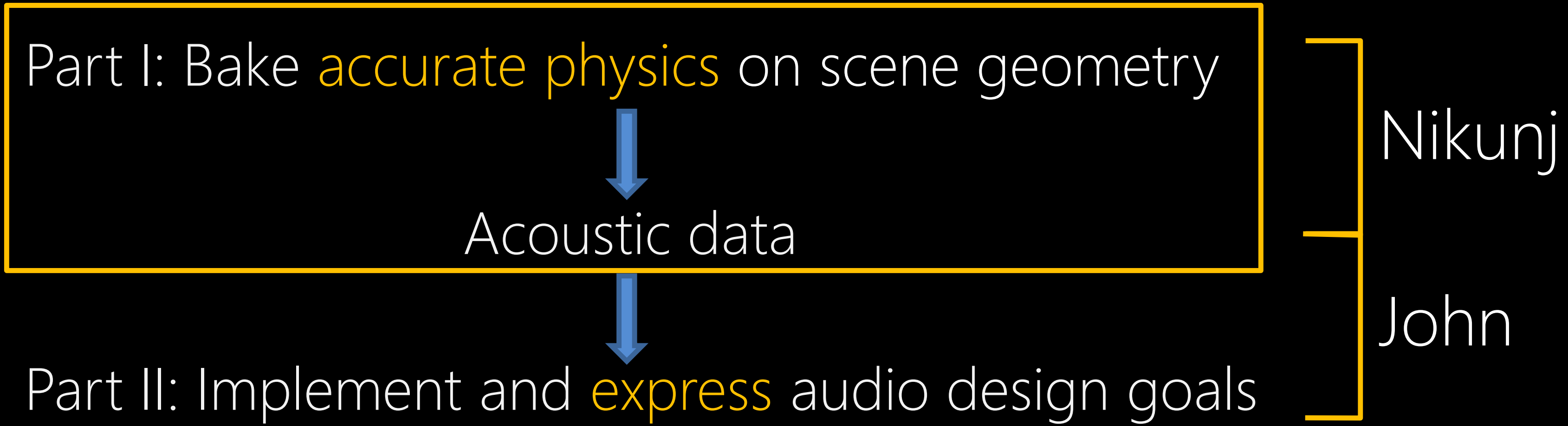
Part I: Accurate acoustic simulation =
robust results for dynamic sources & listener. But expensive!

@GDC 2011: Real-time wave acoustics: full core, GBs of RAM, custom audio engine.
Raghuvanshi, et. al., SIGGRAPH 2010, "Precomputed wave simulation for real-time sound propagation of dynamic sources in complex scenes"

Part II: How to design acoustic data & implement expressive audio?

Triton is the first shipped system to meet both challenges

Triton's solution



Part I: Bake accurate physics on scene geometry

Acoustic data

Part II: Implement and express audio design goals

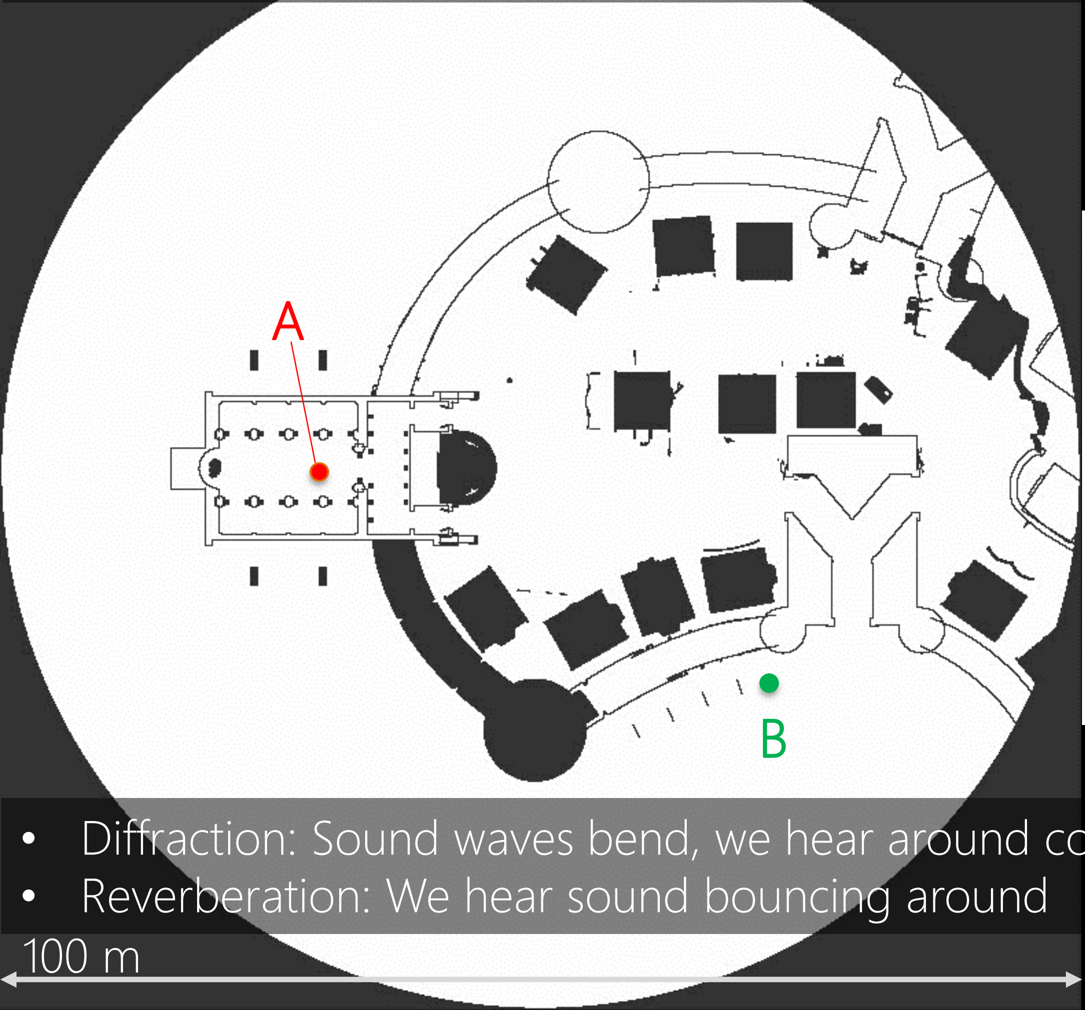
Nikunj

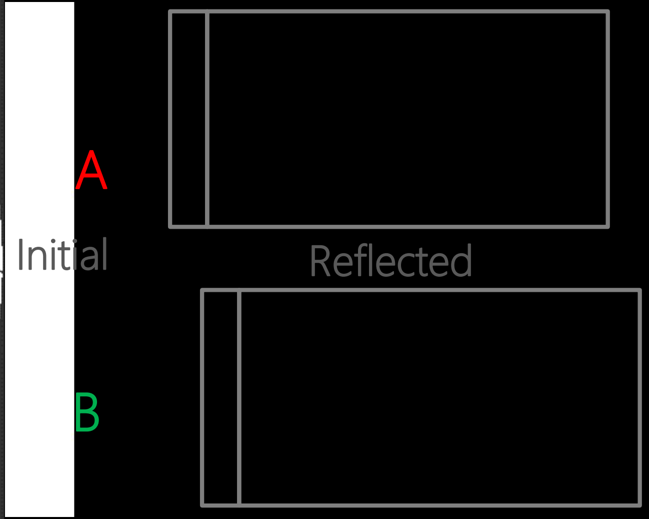
John

Goal: Combine fast wave acoustics with expressive audio design to bring game spaces to life

Wave acoustics

200× slomo, horizontal slice of 3D simulation





Impulse Response

- Diffraction: Sound waves bend, we hear around corners.
- Reverberation: We hear sound bouncing around

Important acoustic effects

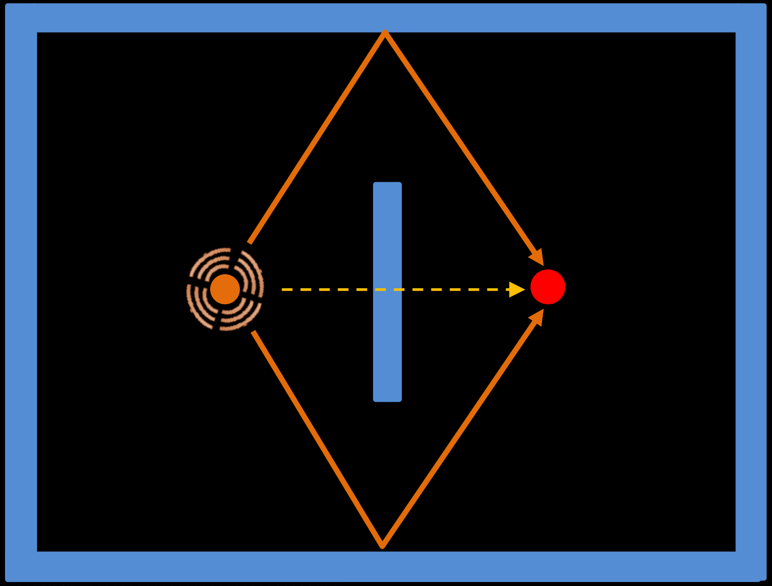
1. Obstruction
2. Occlusion
3. Wetness ratio
4. Reverb decay rate

…

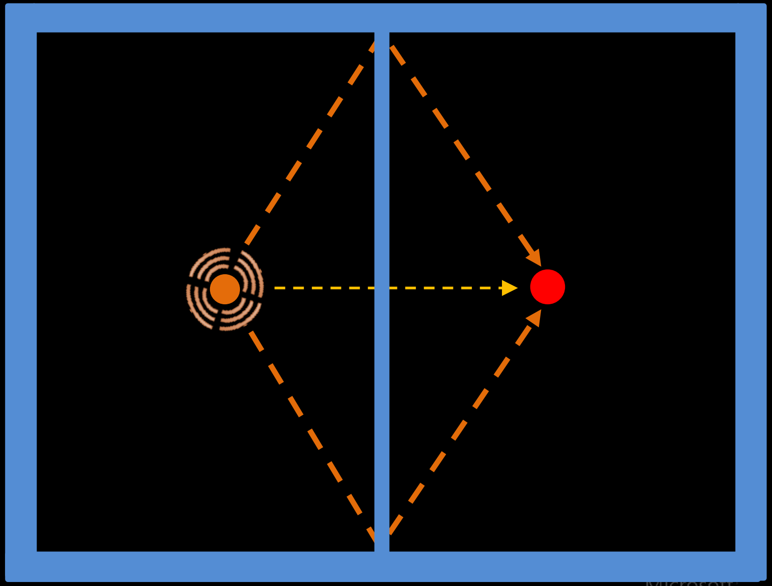
Effects 1 & 2: Obstruction & occlusion

Obstruction ~ initial (direct) sound energy
Occlusion ~ initial (direct) + reflected (indirect)

Strong obstruction, little occlusion



Strong obstruction, strong occlusion

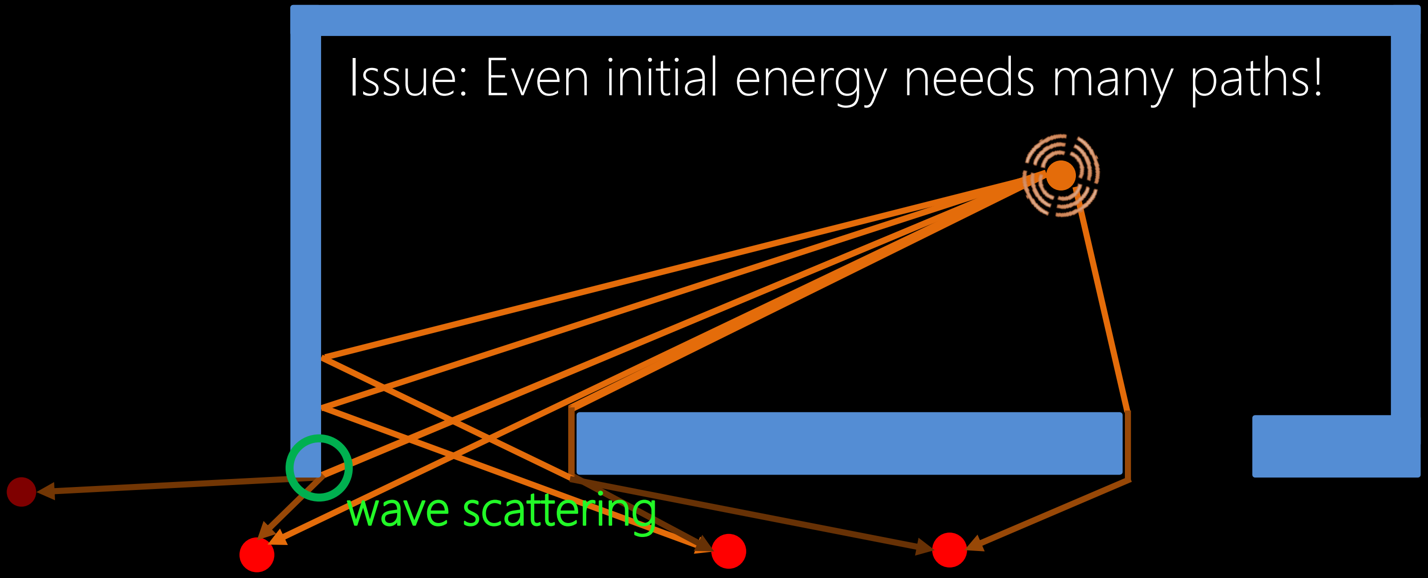


THE COALITION

Microsoft Research

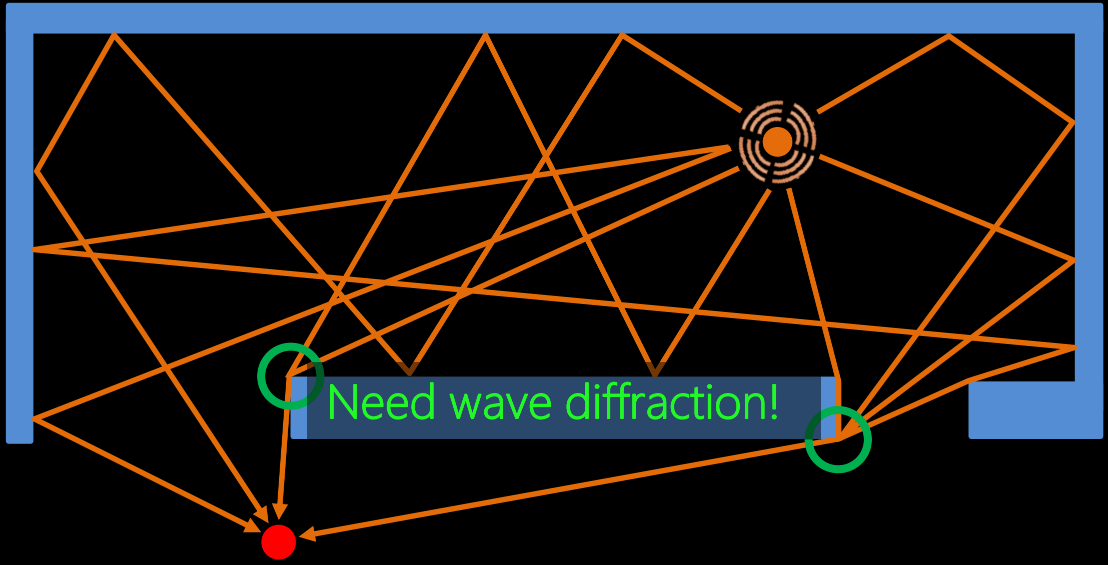
Effect 1: obstruction (initial energy)

Existing approximate method: Shortest path length



Upshot: Risk of making sound too weak

Effect 2: Occlusion?



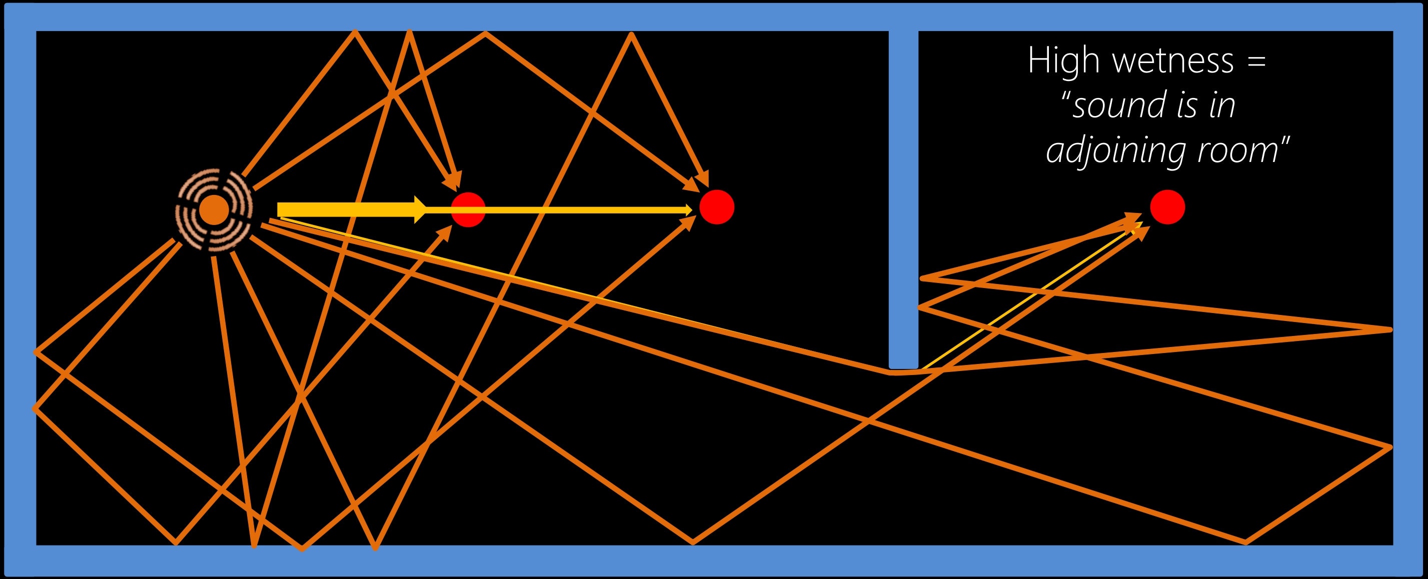
Ignore diffraction → sound too weak

Missing paths → glitches

Fast approximate method does NOT exist!

Effect 3: Wetness ratio (sense of distance)

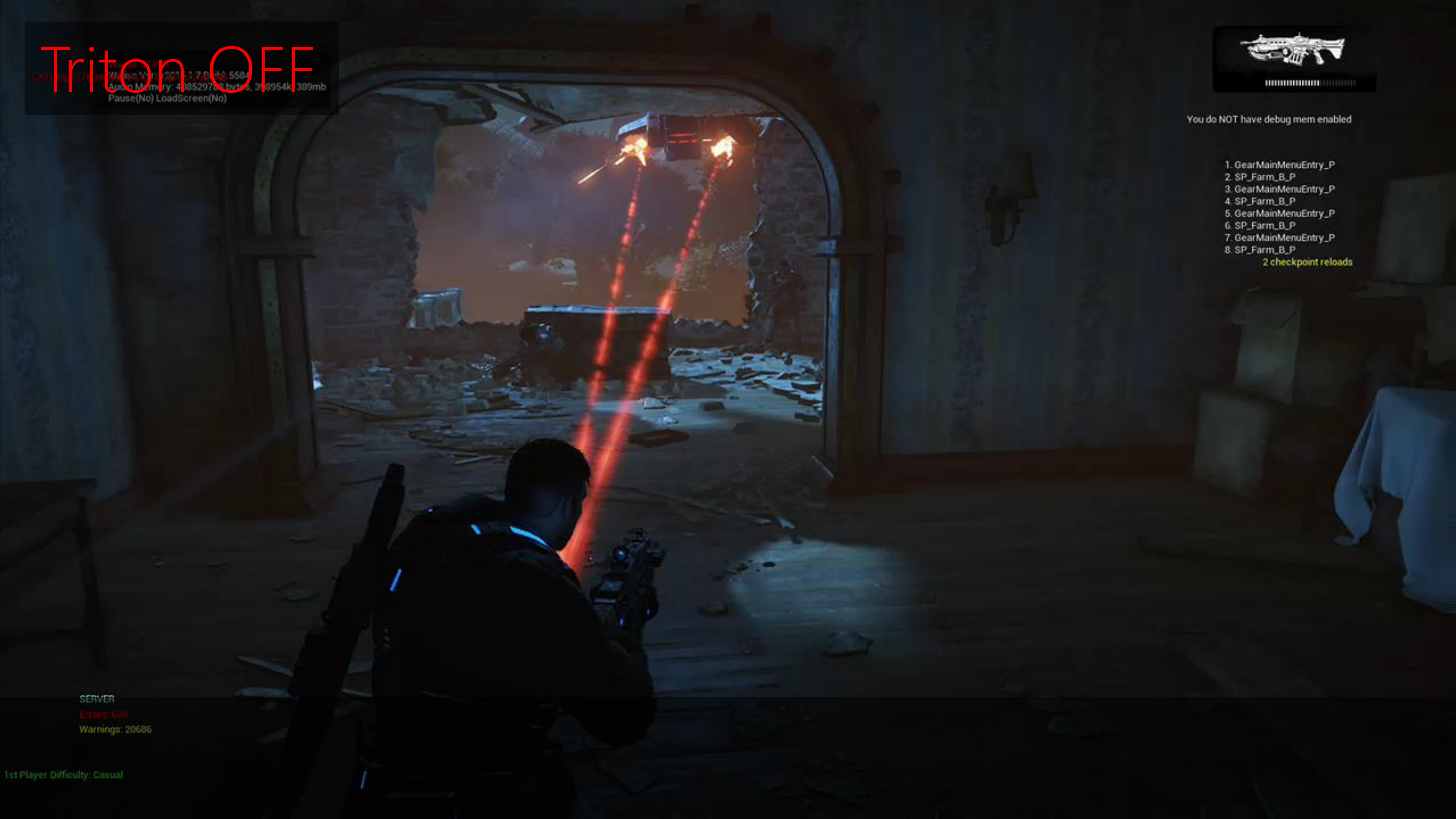
Wetness ~ ratio of reflected and initial energy



Common method: Designer specifies reverb distance roll-off curves

Room size and effect of geometry are ignored!

Triton OFF



```
[illegible] Ver: [illegible] Build: 5584
Audio Memory: 408529788 bytes, 398954k, 389mb
Pause(No) LoadScreen(No)
```

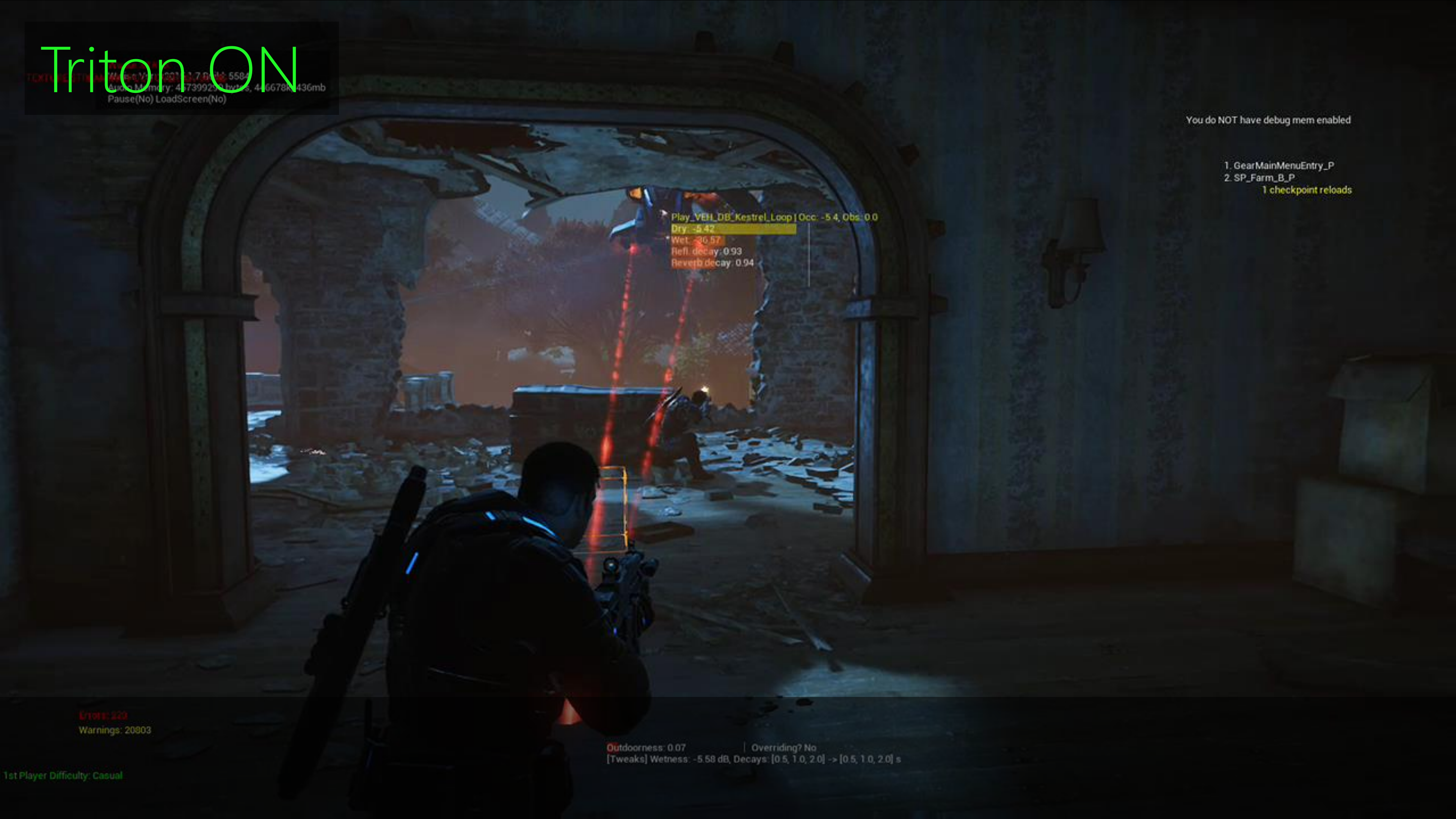
```
You do NOT have debug mem enabled

1. GearMainMenuEntry_P
2. SP_Farm_B_P
3. GearMainMenuEntry_P
4. SP_Farm_B_P
5. GearMainMenuEntry_P
6. SP_Farm_B_P
7. GearMainMenuEntry_P
8. SP_Farm_B_P
2 checkpoint reloads
```

```
SERVER
Errors: [illegible]
Warnings: 20686

1st Player Difficulty: Casual
```

Triton ON



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Audio Memory: 457399290 bytes, 446678k, 436mb
Pause(No) LoadScreen(No)
```

```
You do NOT have debug mem enabled

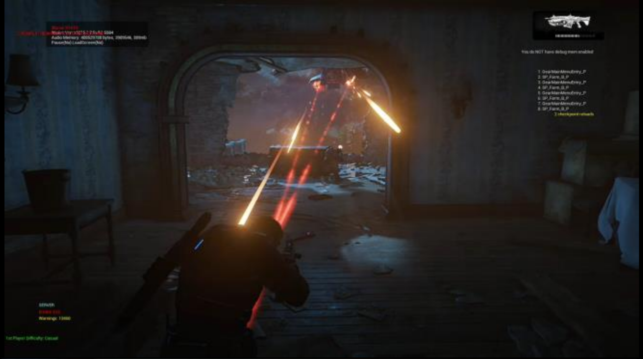
1. GearMainMenuEntry_P
2. SP_Farm_B_P
        1 checkpoint reloads
```

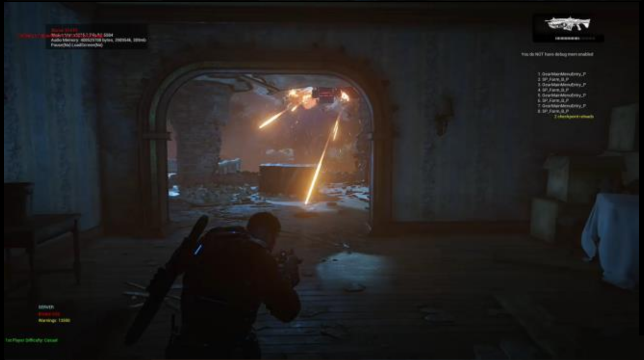
```
Play_VEH_DB_Kestrel_Loop | Occ: -5.4, Obs: 0.0
Dry: -5.42
Wet: -36.57
Refl. decay: 0.93
Reverb decay: 0.94
```

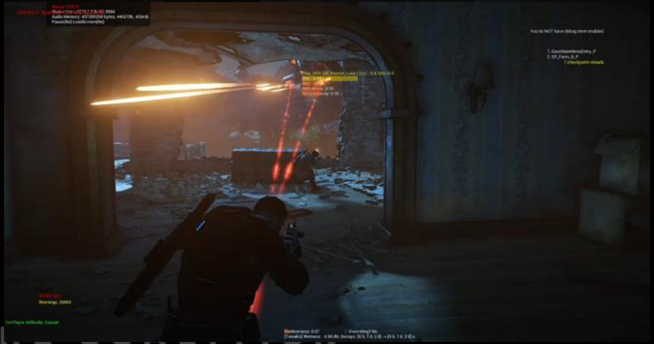
```
Errors: 223
Warnings: 20803

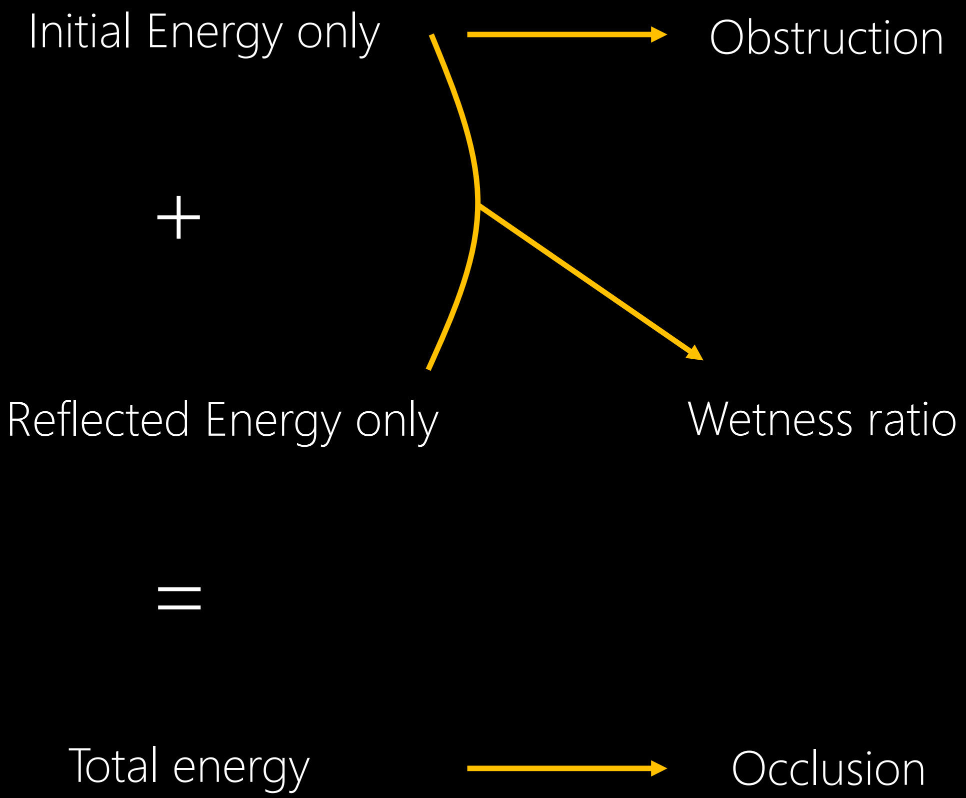
1st Player Difficulty: Casual
```

```
Outdoorness: 0.07                | Overriding? No
[Tweaks] Wetness: -5.58 dB, Decays: [0.5, 1.0, 2.0] -> [0.5, 1.0, 2.0] s
```









Initial Energy only → Obstruction

+

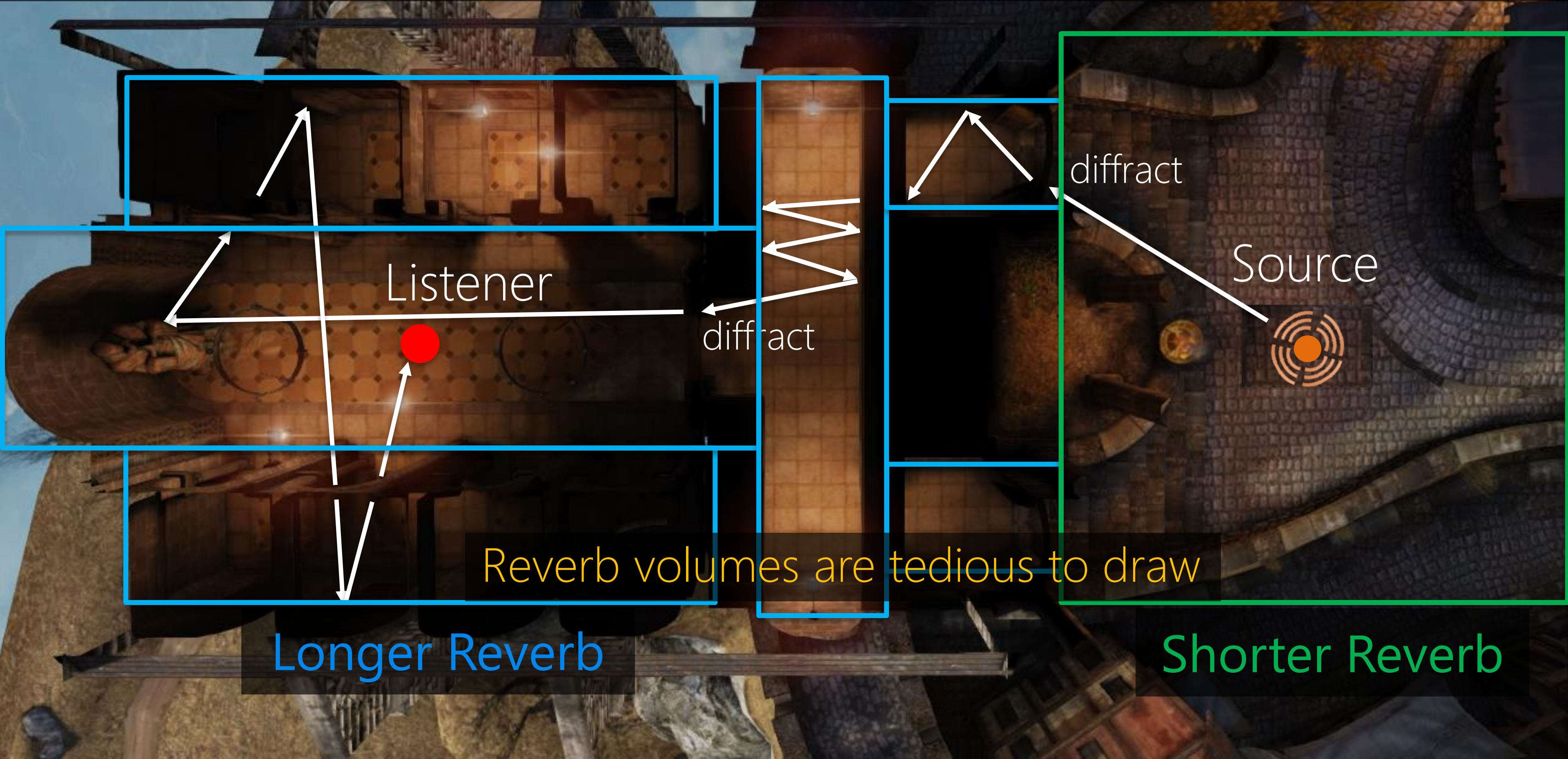
Reflected Energy only

Initial Energy only + Reflected Energy only → Wetness ratio

=

Total energy → Occlusion

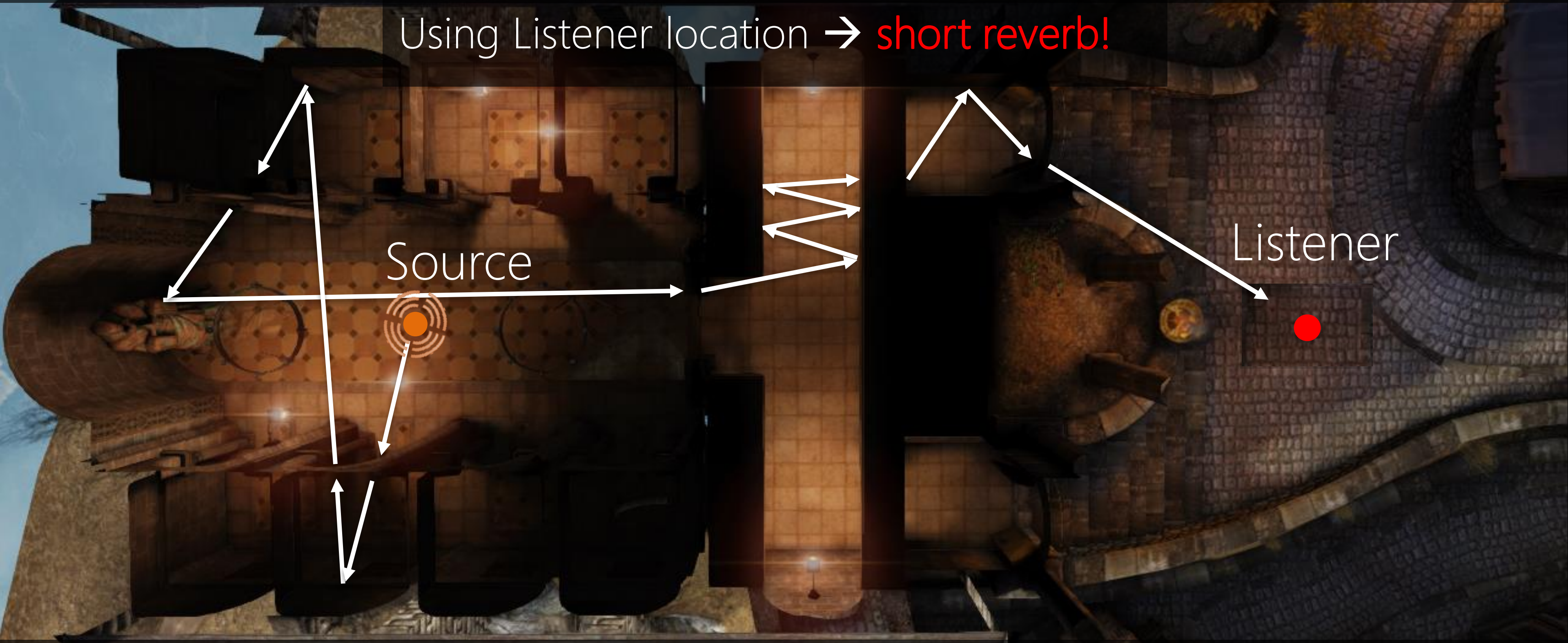
Effect 4: Decay rate



Reverb volumes are tedious to draw

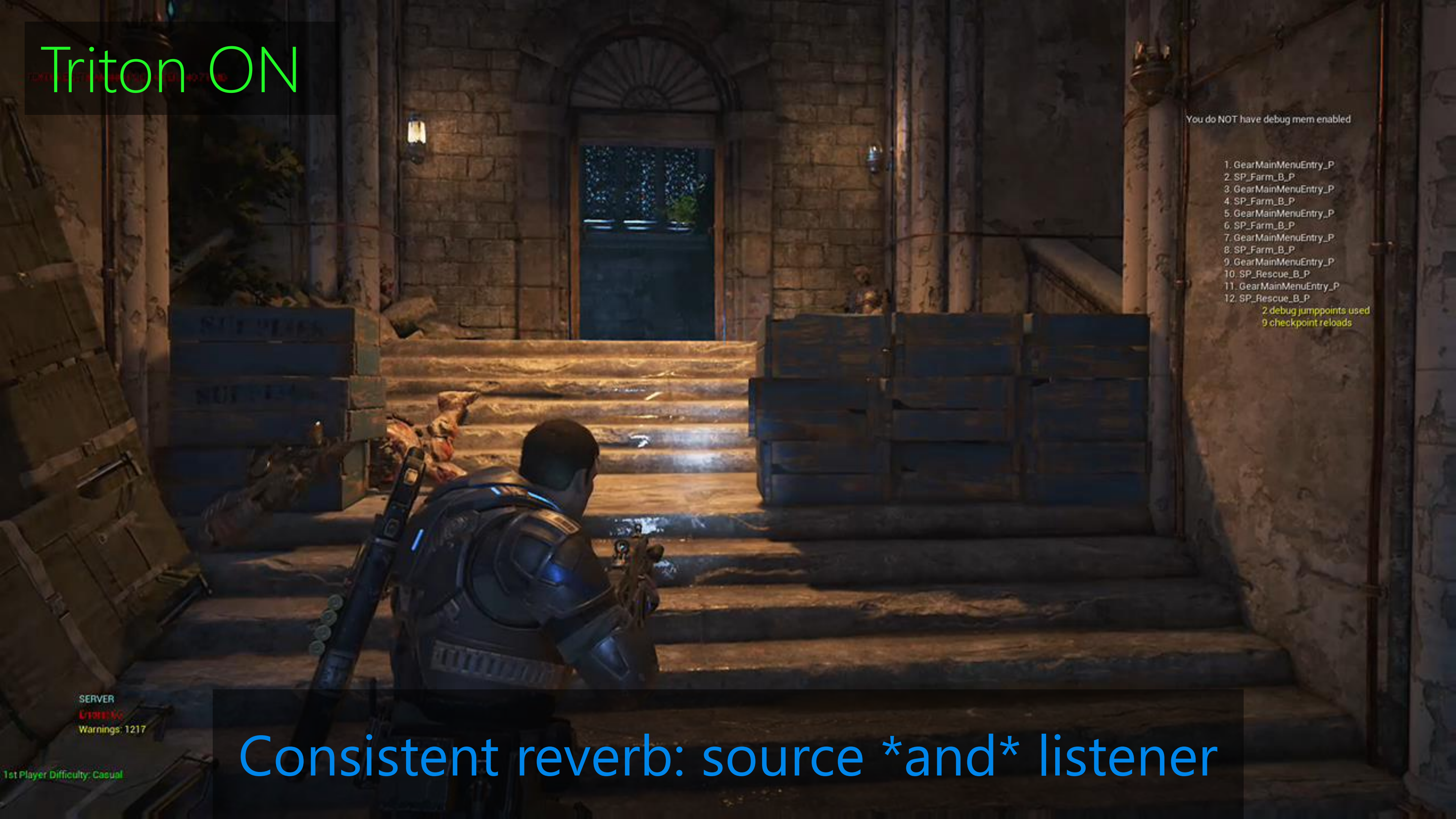
Effect 4: Decay rate

Using Listener location → short reverb!



Decay rate also depends on both source and listener locations!

Triton ON



```
You do NOT have debug mem enabled

1. GearMainMenuEntry_P
2. SP_Farm_B_P
3. GearMainMenuEntry_P
4. SP_Farm_B_P
5. GearMainMenuEntry_P
6. SP_Farm_B_P
7. GearMainMenuEntry_P
8. SP_Farm_B_P
9. GearMainMenuEntry_P
10. SP_Rescue_B_P
11. GearMainMenuEntry_P
12. SP_Rescue_B_P
2 debug jumppoints used
9 checkpoint reloads

SERVER
Warnings: 1217

1st Player Difficulty: Casual
```

Consistent reverb: source *and* listener

Triton ON

```
252
You do NOT have debug mem enabled

1. GearMainMenuEntry_P
2. SP_Farm_B_P
3. GearMainMenuEntry_P
4. SP_Farm_B_P
5. GearMainMenuEntry_P
6. SP_Farm_B_P
7. GearMainMenuEntry_P
8. SP_Farm_B_P
9. GearMainMenuEntry_P
10. SP_Rescue_B_P
11. GearMainMenuEntry_P
12. SP_Rescue_B_P
2 debug jumppoints used
16 checkpoint reloads

SERVER
[illegible]
Warnings: 2285

1st Player Difficulty: Casual
```

Acoustics conveys *location*

Important acoustic effects

1. Obstruction
2. Occlusion
3. Wetness ratio
4. Reverb decay rate

- Depend on *both* (moving) source and listener location
- Depend on scene geometry
- Triton can model them

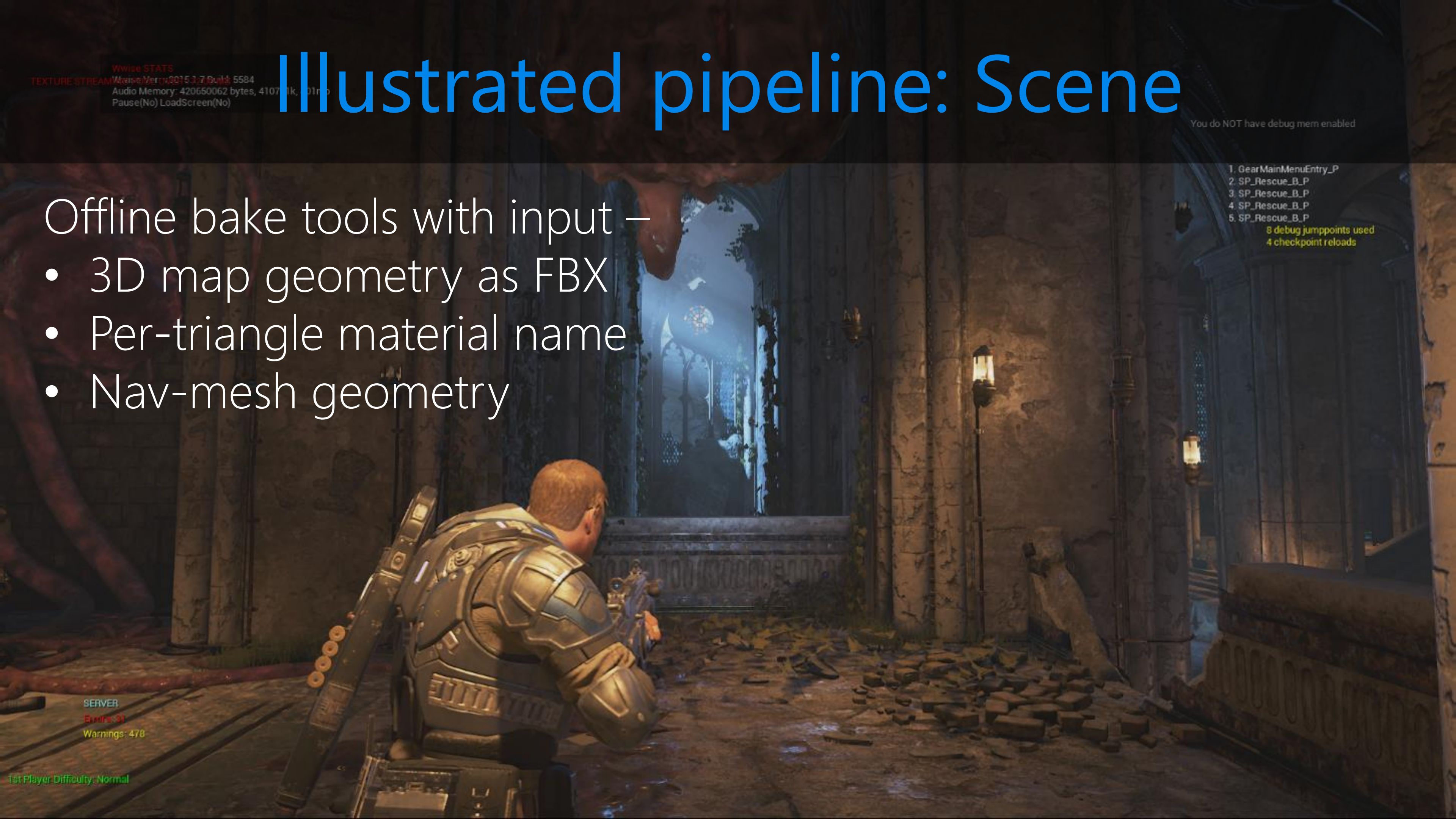
Triton = baked wave simulation

- Wave simulation: Accurate & reliable results on complex scenes
- Runtime = lookup + interpolation. Light on CPU.
- Need *dynamic* source & listener: large RAM!
- Baking is restricted to static geometry
  - Feasible first step
  - Dynamic scenes (doors/destruction): could layer heuristics on top, like lighting

Illustrated pipeline: Scene

Offline bake tools with input –

- 3D map geometry as FBX
- Per-triangle material name
- Nav-mesh geometry



```
Wwise STATS
TEXTURE STREAMI[illegible] Wwise Ver [illegible] 2015.1.7 Build 5584
Audio Memory: 420650062 bytes, 4107[illegible]k, [illegible]mb
Pause(No) LoadScreen(No)
```

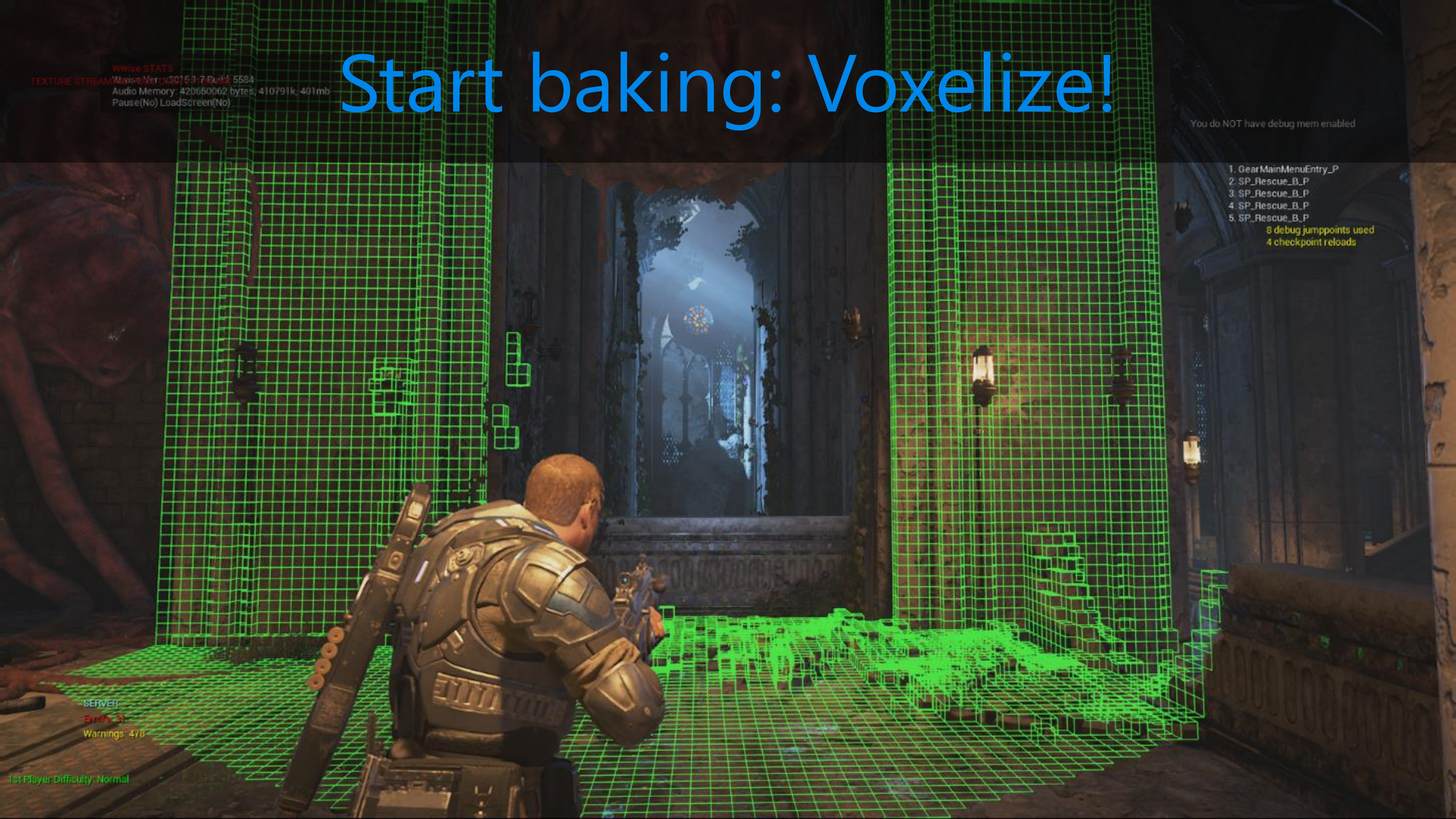
You do NOT have debug mem enabled

```
1. GearMainMenuEntry_P
2. SP_Rescue_B_P
3. SP_Rescue_B_P
4. SP_Rescue_B_P
5. SP_Rescue_B_P
   8 debug jumppoints used
   4 checkpoint reloads
```

```
SERVER
Errors: 31
Warnings: 478
```

1st Player Difficulty: Normal

Start baking: Voxelize!



```
Wwise STATS
TEXTURE STREAM
Wwise Ver: v2015.1.7 Build 5584
Audio Memory: 420660062 bytes, 410791k, 401mb
Pause(No) LoadScreen(No)
```

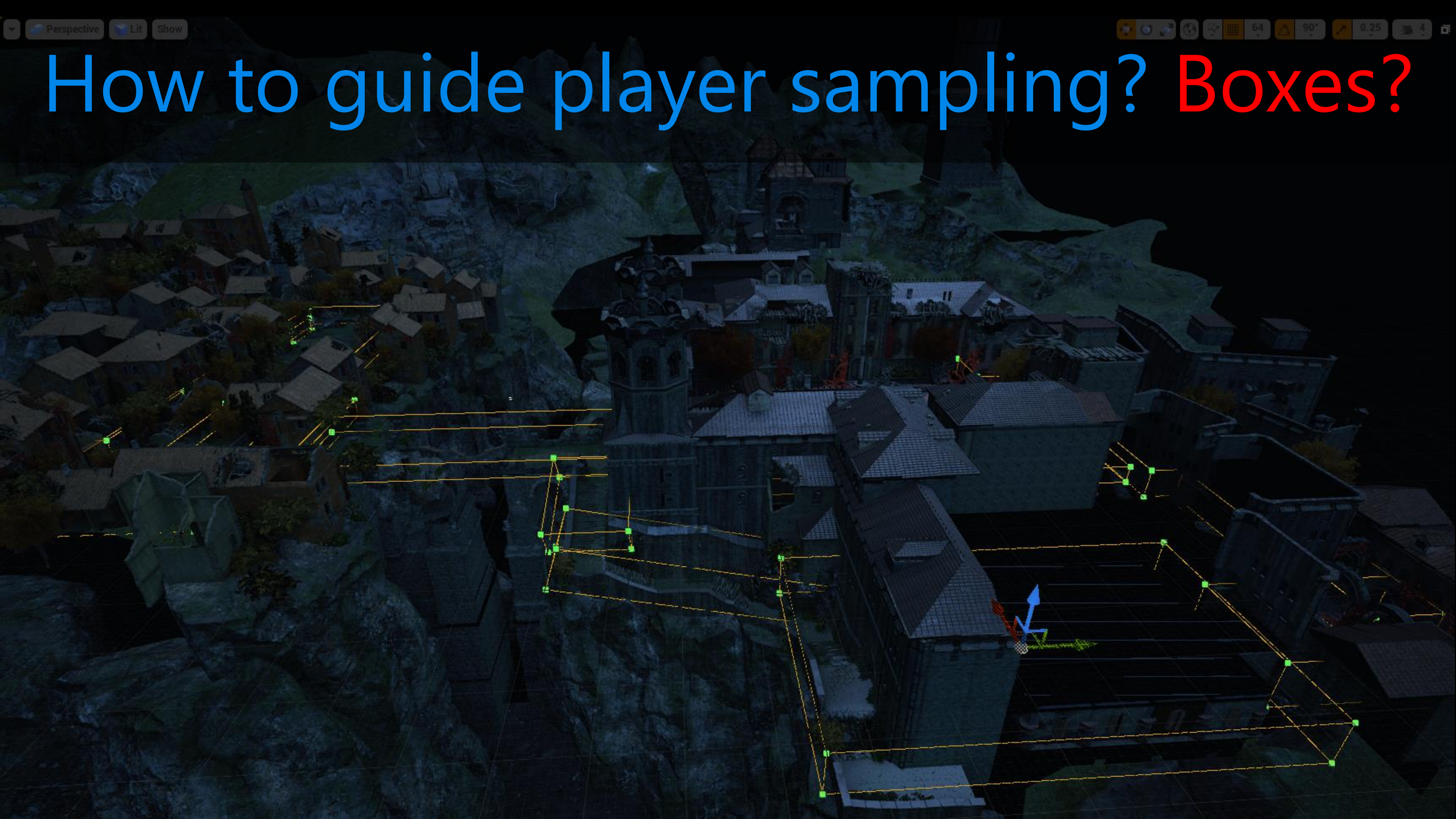
```
You do NOT have debug mem enabled
```

```
1. GearMainMenuEntry_P
2. SP_Rescue_B_P
3. SP_Rescue_B_P
4. SP_Rescue_B_P
5. SP_Rescue_B_P
   8 debug jumppoints used
   4 checkpoint reloads
```

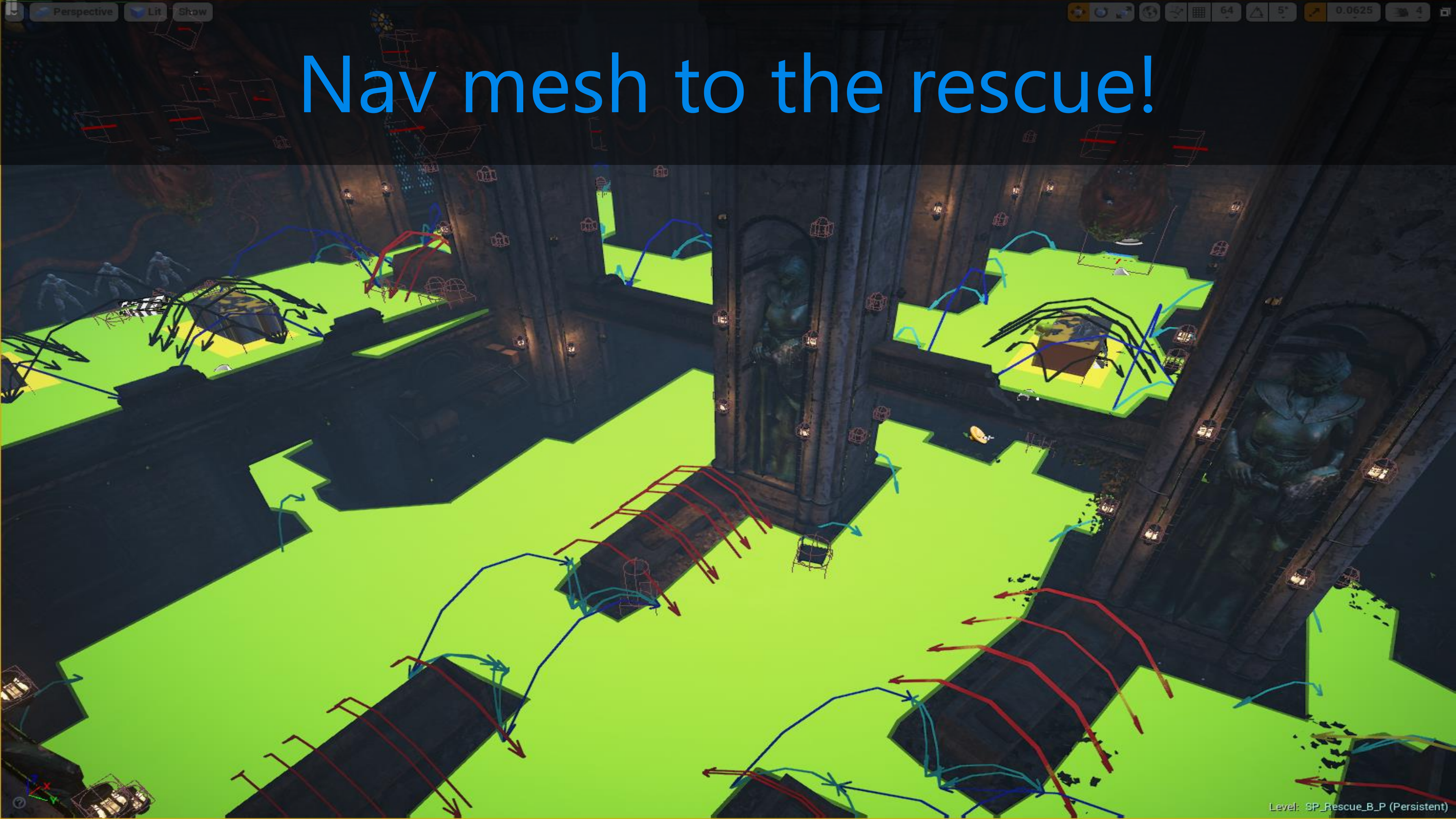
```
SERVER
Errors: 31
Warnings: 478
```

```
1st Player Difficulty: Normal
```

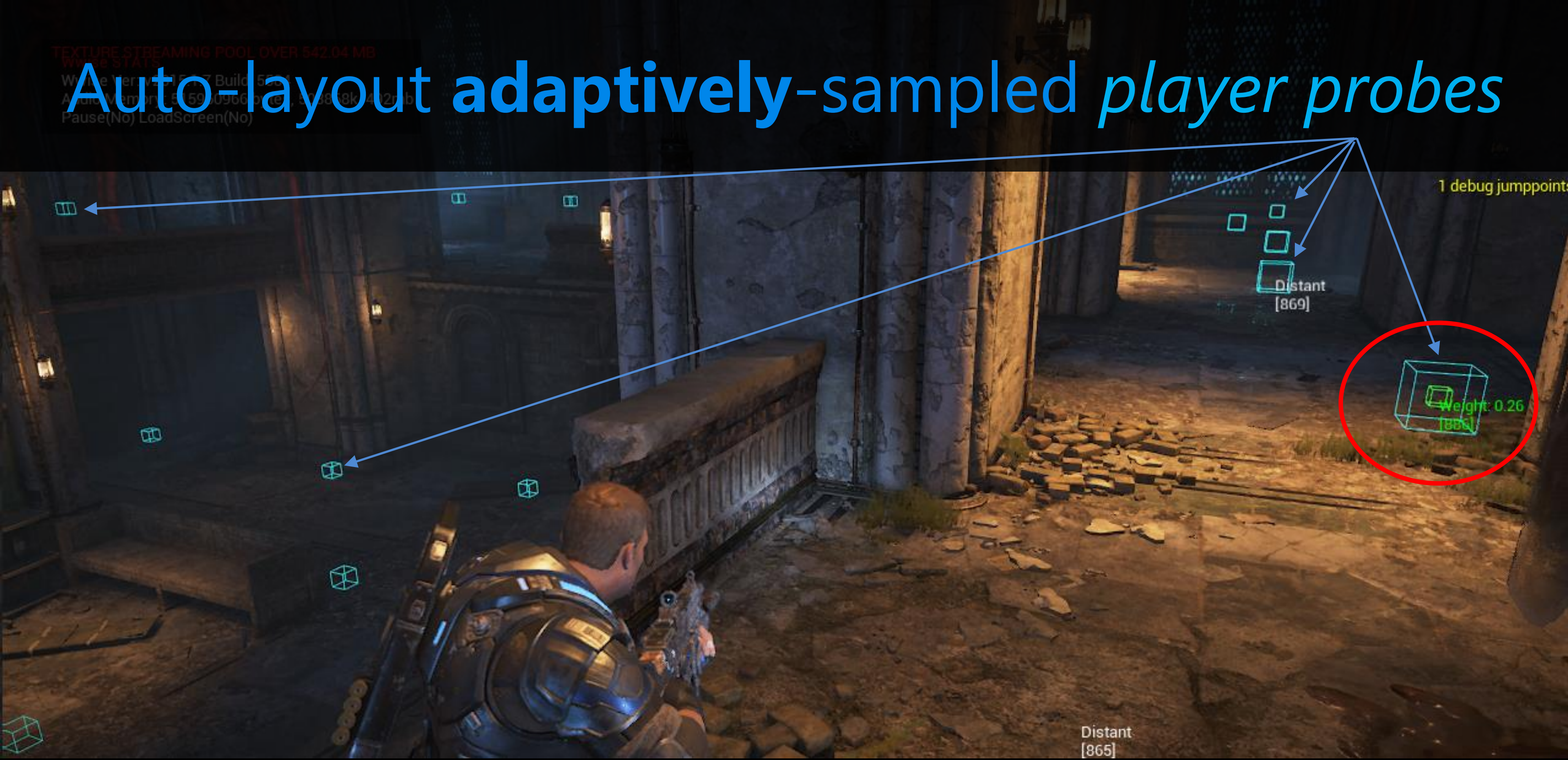
How to guide player sampling? Boxes?



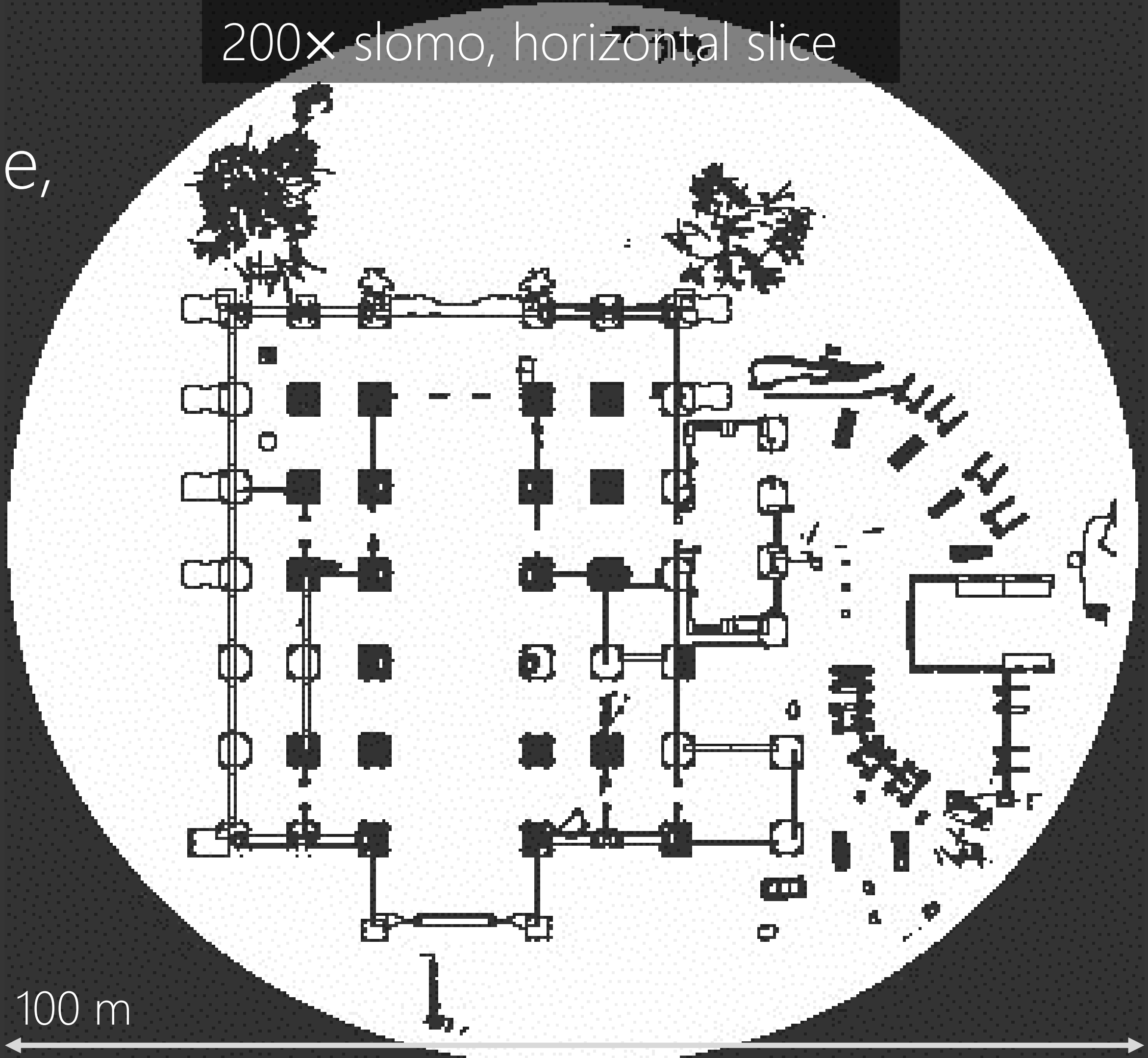
Nav mesh to the rescue!



Auto-layout **adaptively**-sampled *player probes*

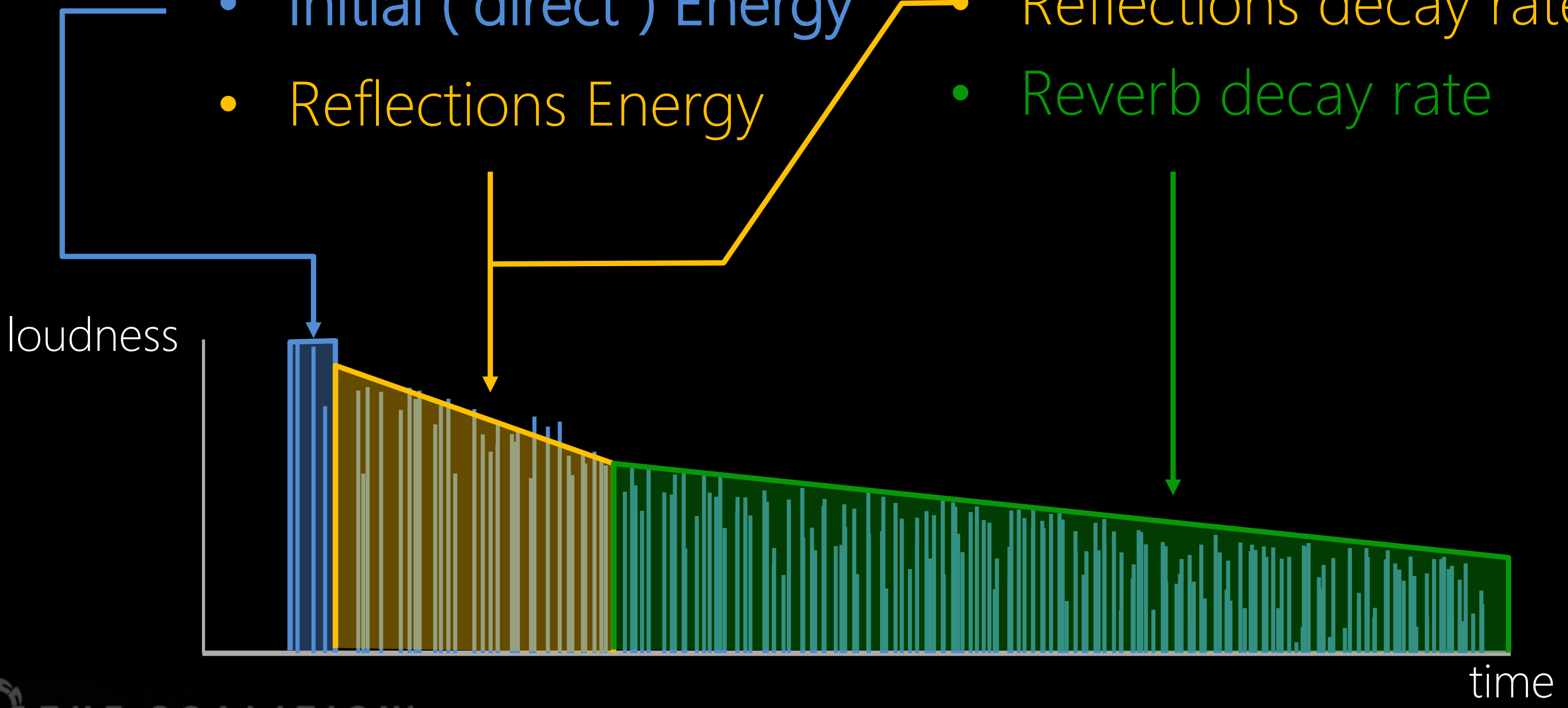


Triton map bake = For each player probe, 3D wave simulation

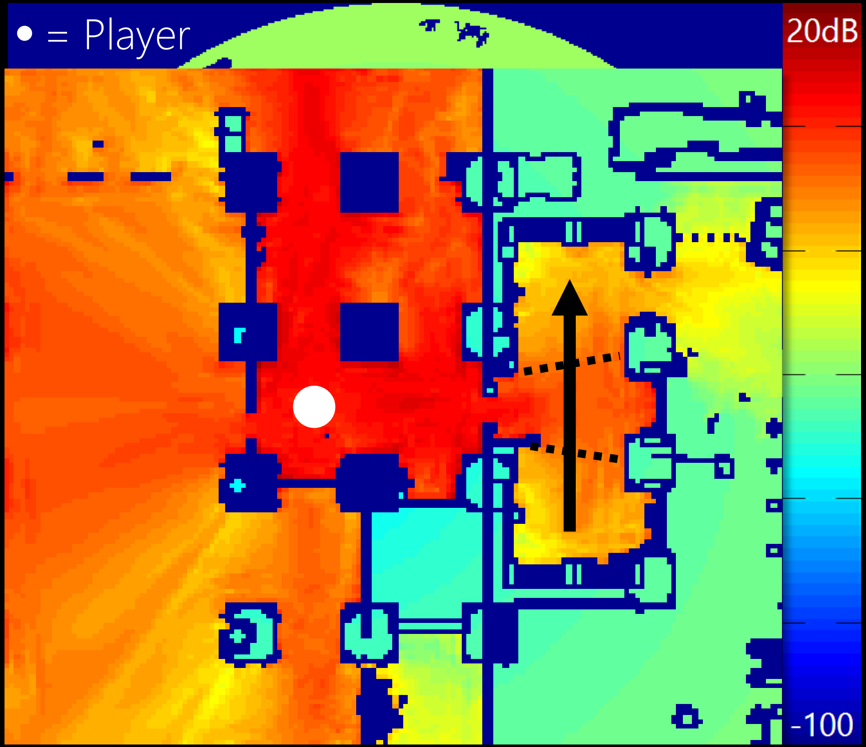


Main Idea: Response → 4 perceptual parameters [for each source & listener location pair]

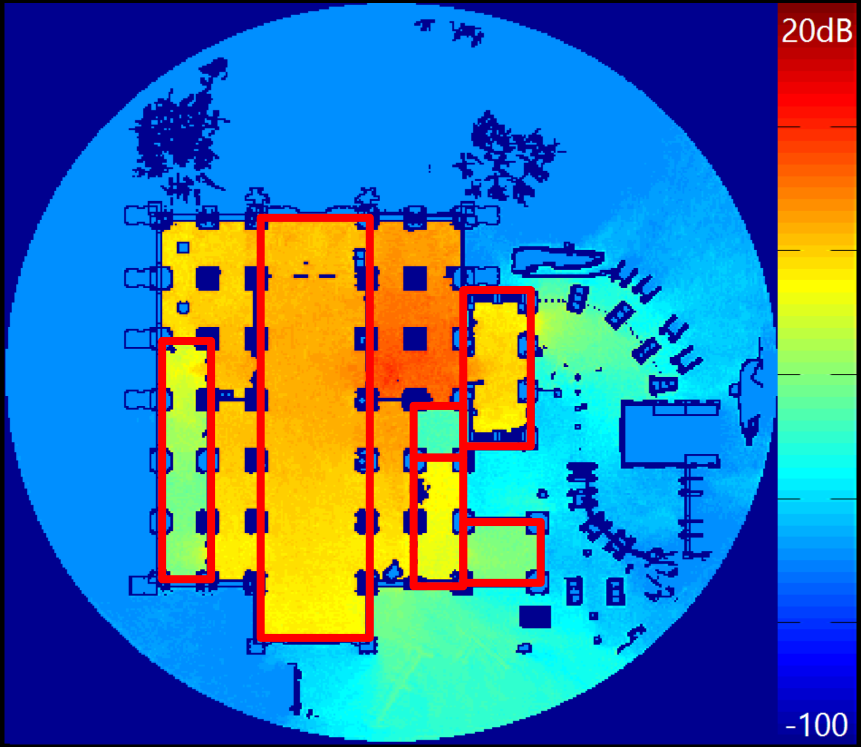
- Initial ("direct") Energy
- Reflections Energy
- Reflections decay rate
- Reverb decay rate



Per-player-probe data: loudness

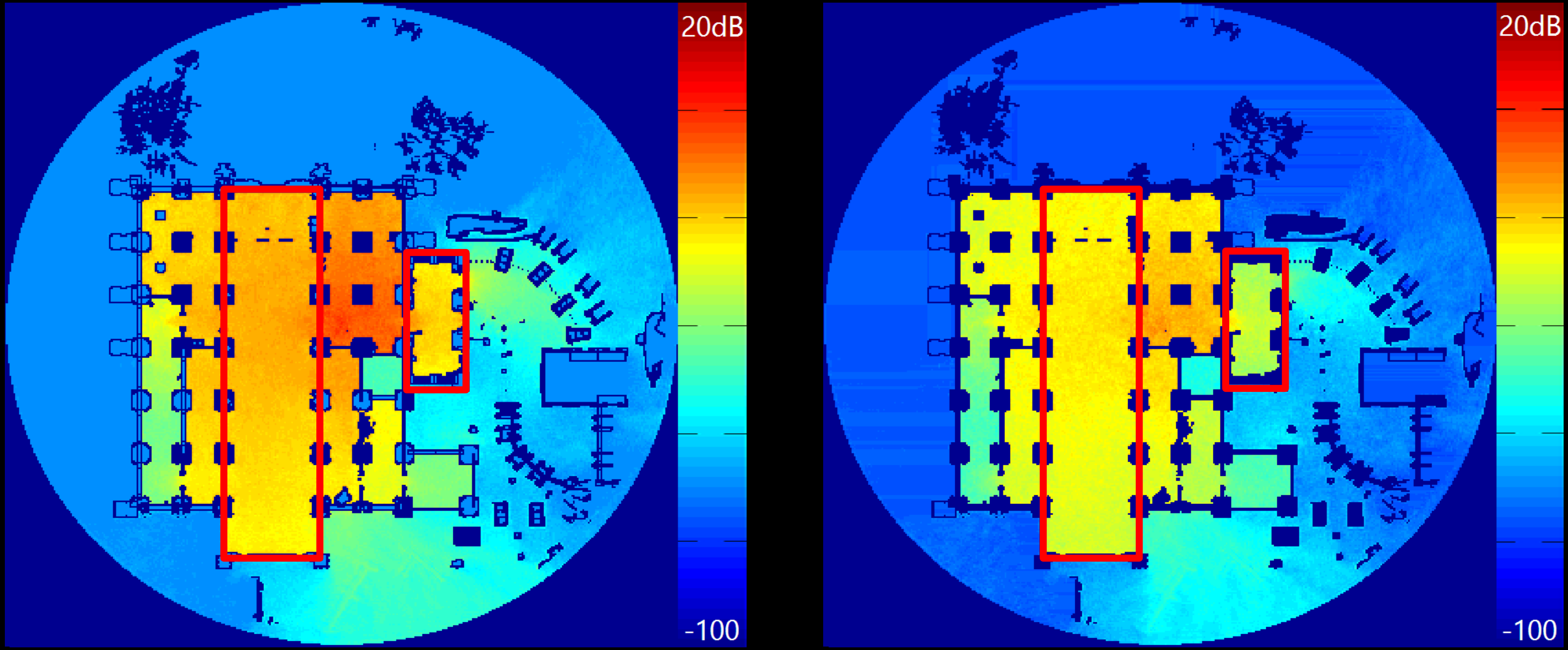


Initial energy (0-10ms)



Reflected energy (10-210ms)

Per-player-probe data : early sound decay



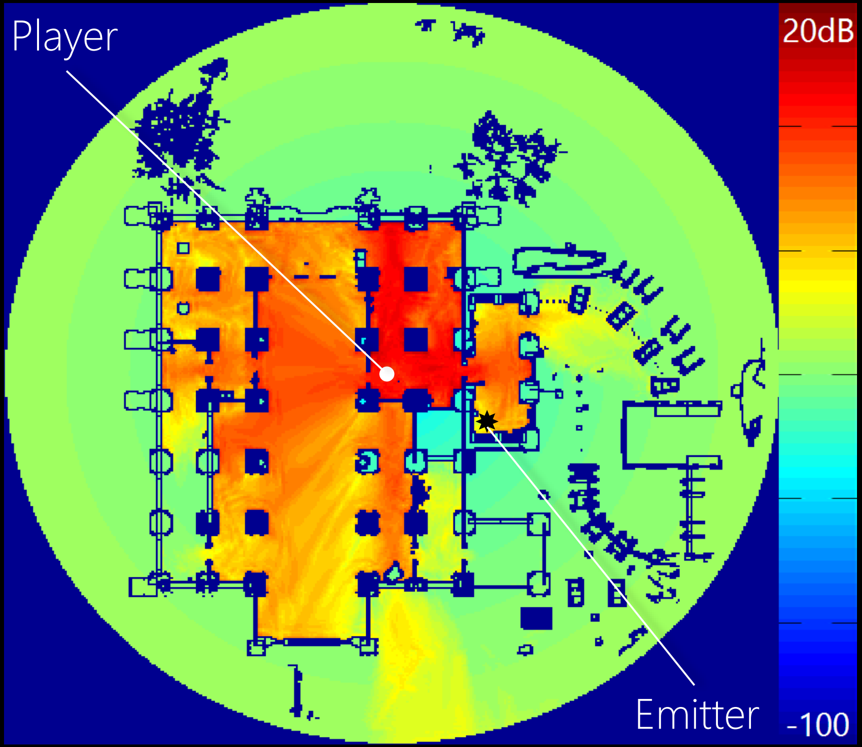
after 250ms →

50 TB → 100 MB

Baking for moving sources & listener is costly

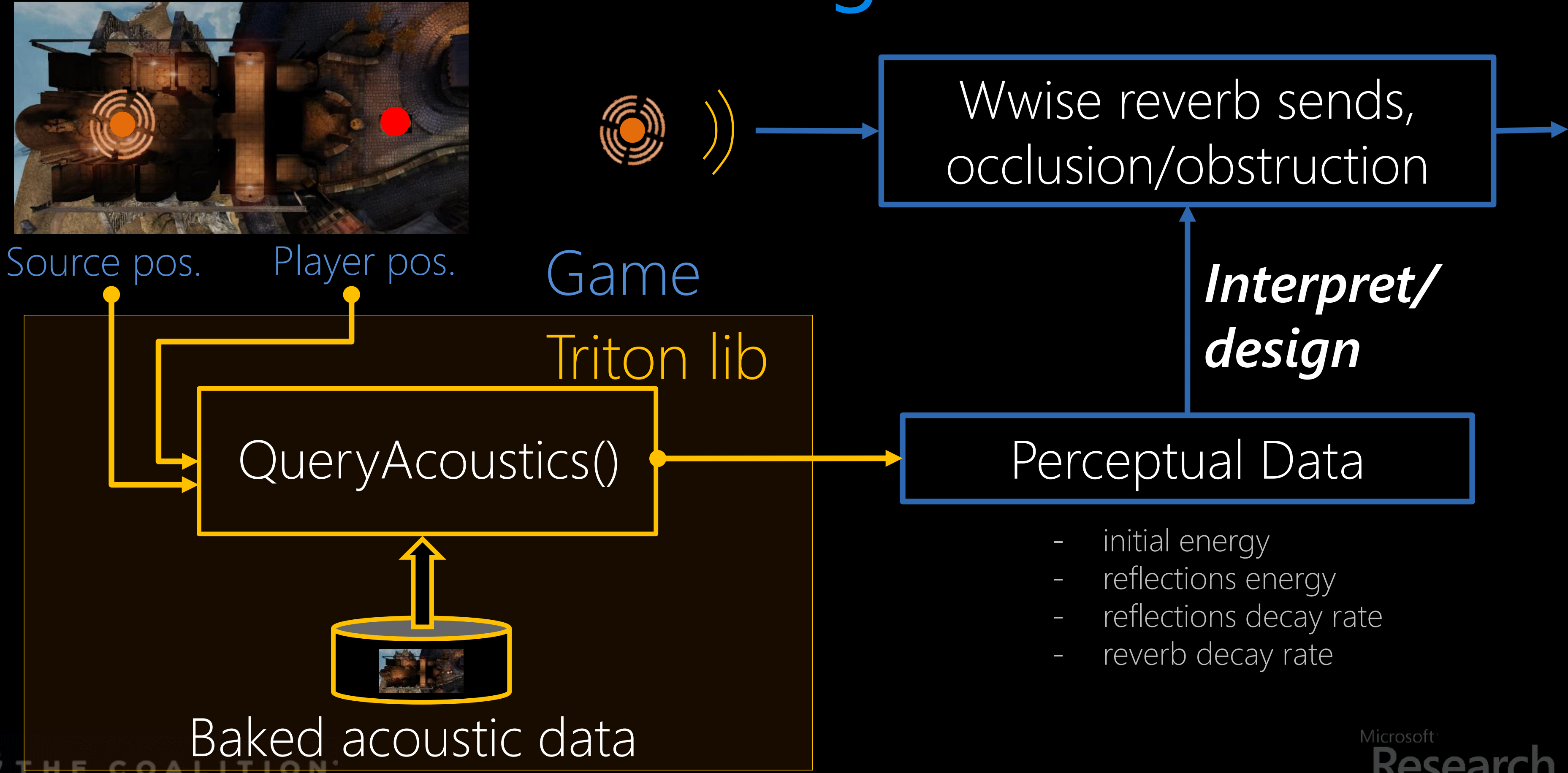
- 100 machines → ~4 hours
  - ~10-20 minutes per player probe
  - ~1000-1500 player probes per Gears campaign map
- Trivially parallel: double machines, half time
- Bake tool runs on PC/Xbox (latter as "bake game")

Runtime: Interpolated lookup



- For each parameter: Decompress slice (Zlib) & do interpolation
- Fixed caches, 20MB overhead
- Worker thread on shared core
- Updated at visual frame rates [30/60FPS in single/multi-player]
- Averages ~100μs per query, spikes of ~200μs on cache miss
- 32 sources served per-frame ~10-20% of shared Xbox core

Game integration



Source pos.

Player pos.

Game

Triton lib

QueryAcoustics()

Baked acoustic data

Perceptual Data

- initial energy
- reflections energy
- reflections decay rate
- reverb decay rate

Interpret/ design

Wwise reverb sends, occlusion/obstruction

THE COALITION

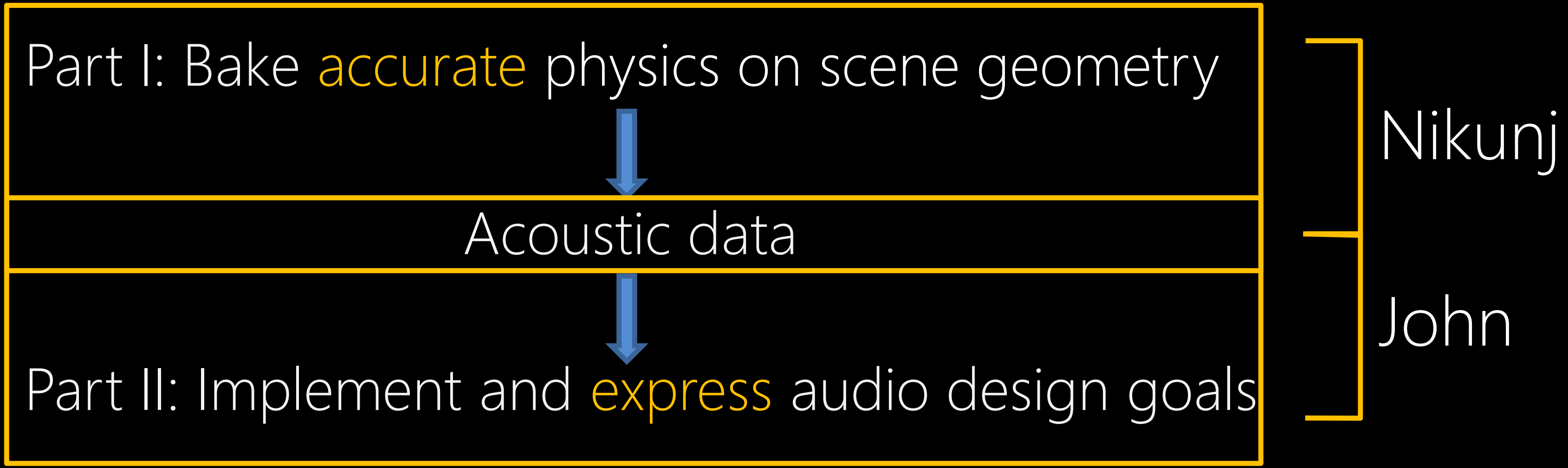
Microsoft Research

Wave baking + perceptual compression = practical acoustics

Technical ↑	Efficient	CPU: ~100μs for acoustic lookup **RAM: ~100MB for Campaign, ~20MB for Multiplayer**
	Robust	Smooth results on complex level geometry
Design ↓	Automation	No geometry to clean, no volumes to draw
	Expressivity	Interpret Triton data via Unreal blueprint and Wwise

Paper reference: *Raghuvanshi & Snyder, SIGGRAPH 2014,*
“Parametric wave field coding for precomputed sound propagation”

Triton's design



Part I: Bake accurate physics on scene geometry

Acoustic data

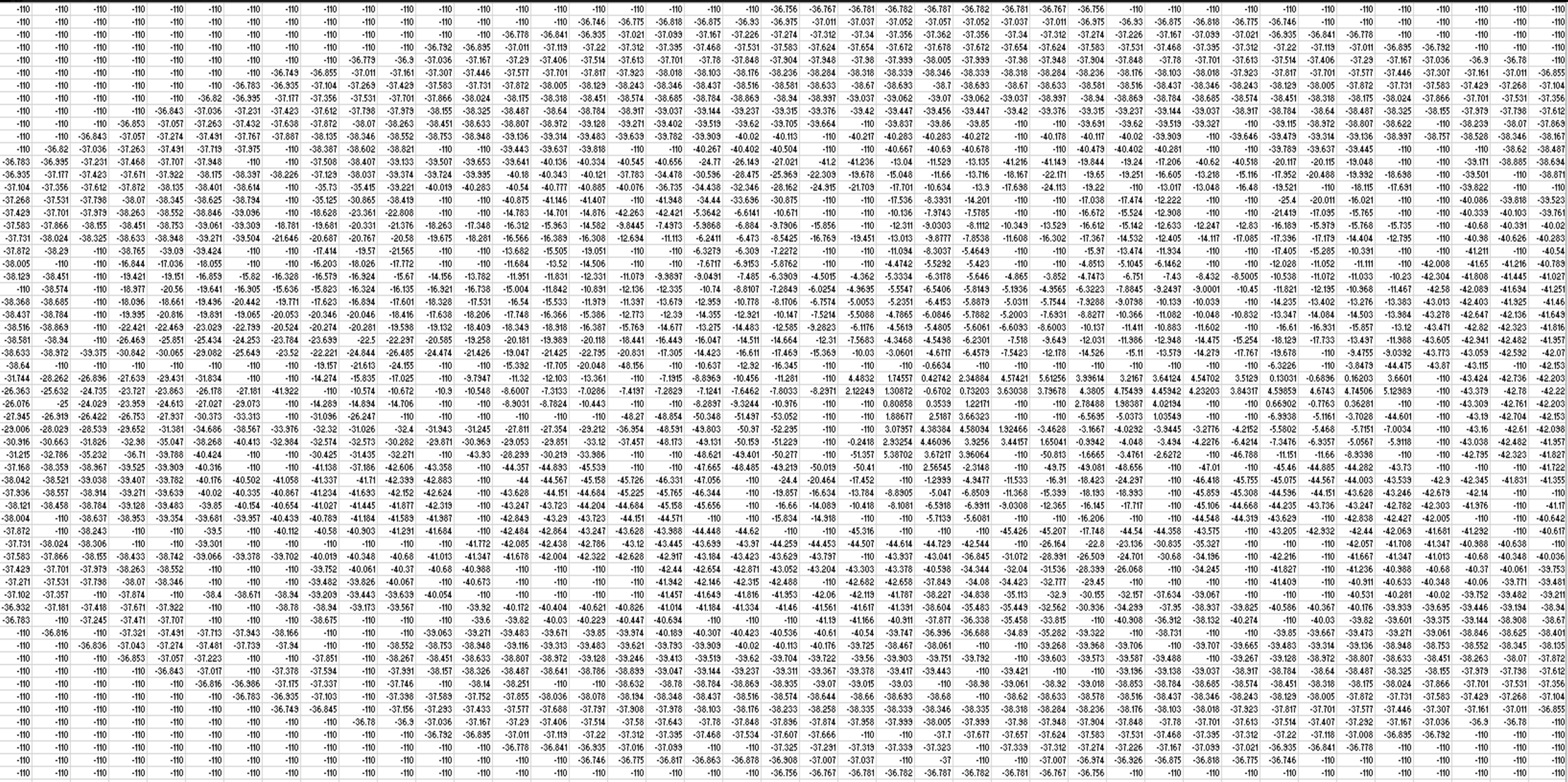
Part II: Implement and express audio design goals

Nikunj

John

Combine fast wave acoustics with expressive audio design to bring game spaces to life

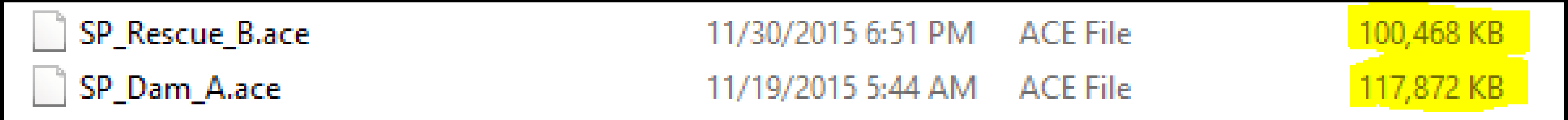
How does a Sound Designer work with this?



-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.756	-36.767	-36.781	-36.782	-36.787	-36.782	-36.781	-36.767	-36.756	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.746	-36.775	-36.818	-36.875	-36.93	-36.975	-37.011	-37.037	-37.052	-37.057	-37.052	-37.037	-37.011	-36.975	-36.93	-36.875	-36.818	-36.775	-36.746	-110	-110	-110	-110	-110	-110	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.778	-36.841	-36.935	-37.021	-37.099	-37.167	-37.226	-37.274	-37.312	-37.34	-37.356	-37.362	-37.356	-37.34	-37.312	-37.274	-37.226	-37.167	-37.099	-37.021	-36.935	-36.841	-36.778	-110	-110	-110	-110	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.792	-36.895	-37.011	-37.119	-37.22	-37.312	-37.395	-37.468	-37.531	-37.583	-37.624	-37.654	-37.672	-37.678	-37.672	-37.654	-37.624	-37.583	-37.531	-37.468	-37.395	-37.312	-37.22	-37.119	-37.011	-36.895	-36.792	-110	-110	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.779	-36.9	-37.036	-37.167	-37.29	-37.406	-37.514	-37.613	-37.701	-37.78	-37.848	-37.904	-37.948	-37.98	-37.999	-38.005	-37.999	-37.98	-37.948	-37.904	-37.848	-37.78	-37.701	-37.613	-37.514	-37.406	-37.29	-37.167	-37.036	-36.9	-36.78	-110
-110	-110	-110	-110	-110	-110	-110	-36.749	-36.855	-37.011	-37.161	-37.307	-37.446	-37.577	-37.701	-37.817	-37.923	-38.018	-38.103	-38.176	-38.236	-38.284	-38.318	-38.339	-38.346	-38.339	-38.318	-38.284	-38.236	-38.176	-38.103	-38.018	-37.923	-37.817	-37.701	-37.577	-37.446	-37.307	-37.161	-37.011	-36.855
-110	-110	-110	-110	-110	-110	-36.783	-36.935	-37.104	-37.269	-37.429	-37.583	-37.731	-37.872	-38.005	-38.129	-38.243	-38.346	-38.437	-38.516	-38.581	-38.633	-38.67	-38.693	-38.7	-38.693	-38.67	-38.633	-38.581	-38.516	-38.437	-38.346	-38.243	-38.129	-38.005	-37.872	-37.731	-37.583	-37.429	-37.268	-37.104
-110	-110	-110	-110	-110	-36.82	-36.995	-37.177	-37.356	-37.531	-37.701	-37.866	-38.024	-38.175	-38.318	-38.451	-38.574	-38.685	-38.784	-38.869	-38.94	-38.997	-39.037	-39.062	-39.07	-39.062	-39.037	-38.997	-38.94	-38.869	-38.784	-38.685	-38.574	-38.451	-38.318	-38.175	-38.024	-37.866	-37.701	-37.531	-37.356
-110	-110	-110	-110	-36.843	-37.036	-37.231	-37.423	-37.612	-37.798	-37.979	-38.155	-38.325	-38.487	-38.64	-38.784	-38.917	-39.037	-39.144	-39.237	-39.315	-39.376	-39.42	-39.447	-39.456	-39.447	-39.42	-39.376	-39.315	-39.237	-39.144	-39.037	-38.917	-38.784	-38.64	-38.487	-38.325	-38.155	-37.979	-37.798	-37.612
-110	-110	-110	-36.853	-37.057	-37.263	-37.432	-37.638	-37.872	-38.07	-38.263	-38.451	-38.633	-38.807	-38.972	-39.128	-39.271	-39.402	-39.519	-39.62	-39.705	-39.664	-110	-39.837	-39.86	-39.85	-110	-110	-39.691	-39.62	-39.519	-39.327	-110	-39.115	-38.972	-38.807	-38.622	-110	-38.239	-38.07	-37.869
-110	-110	-36.843	-37.057	-37.274	-37.491	-37.767	-37.887	-38.135	-38.346	-38.552	-38.753	-38.948	-39.136	-39.314	-39.483	-39.639	-39.782	-39.909	-40.02	-40.113	-110	-40.217	-40.283	-40.283	-40.272	-110	-40.178	-40.117	-40.02	-39.909	-110	-39.646	-39.479	-39.314	-39.136	-38.997	-38.757	-38.528	-38.346	-38.167
-110	-36.82	-37.036	-37.263	-37.491	-37.719	-37.975	-110	-38.387	-38.602	-38.821	-110	-110	-39.443	-39.637	-39.818	-110	-110	-40.267	-40.402	-40.504	-110	-110	-40.667	-40.69	-40.678	-110	-110	-40.479	-40.402	-40.281	-110	-110	-39.789	-39.637	-39.445	-110	-110	-110	-38.62	-38.487
-36.783	-36.995	-37.231	-37.468	-37.707	-37.948	-110	-110	-37.508	-38.407	-39.133	-39.507	-39.653	-39.641	-40.136	-40.334	-40.545	-40.656	-24.77	-26.149	-27.021	-41.2	-41.236	-13.04	-11.529	-13.135	-41.216	-41.149	-19.844	-19.24	-17.206	-40.62	-40.518	-20.117	-20.115	-19.048	-110	-110	-39.171	-38.885	-38.694
-36.935	-37.177	-37.423	-37.671	-37.922	-38.175	-38.397	-38.226	-37.129	-38.037	-39.374	-39.724	-39.995	-40.18	-40.343	-40.121	-37.783	-34.478	-30.596	-28.475	-25.969	-22.309	-19.678	-15.048	-11.66	-13.716	-18.167	-22.171	-19.65	-19.251	-16.605	-13.218	-15.116	-17.952	-20.488	-19.992	-18.698	-110	-39.501	-110	-38.871
-37.104	-37.356	-37.612	-37.872	-38.135	-38.401	-38.614	-110	-35.73	-35.415	-39.221	-40.019	-40.283	-40.54	-40.777	-40.885	-40.076	-36.735	-34.438	-32.346	-28.162	-24.915	-21.709	-17.701	-10.634	-13.9	-17.698	-24.113	-19.22	-110	-13.017	-13.048	-16.48	-19.521	-110	-18.115	-17.691	-110	-39.822	-110	-110
-37.268	-37.531	-37.798	-38.07	-38.345	-38.625	-38.794	-110	-35.125	-30.865	-38.419	-110	-110	-40.875	-41.146	-41.407	-110	-41.948	-34.44	-33.696	-30.875	-110	-110	-17.536	-8.3931	-14.201	-110	-110	-17.038	-17.474	-12.222	-110	-110	-25.4	-20.011	-16.021	-110	-110	-40.086	-39.818	-39.523
-37.429	-37.701	-37.979	-38.263	-38.552	-38.846	-39.096	-110	-18.628	-23.361	-22.808	-110	-110	-14.783	-14.701	-14.876	-42.263	-42.421	-5.3642	-6.6141	-10.671	-110	-110	-10.136	-7.9743	-7.5785	-110	-110	-16.672	-15.524	-12.908	-110	-110	-21.419	-17.095	-15.765	-110	-110	-40.339	-40.103	-39.761
-37.583	-37.866	-38.155	-38.451	-38.753	-39.061	-39.309	-18.781	-19.681	-20.331	-21.376	-18.263	-17.348	-16.312	-15.963	-14.582	-9.8445	-7.4973	-5.9868	-6.884	-9.7906	-15.856	-110	-12.311	-9.0303	-8.1112	-10.349	-13.529	-16.612	-15.142	-12.633	-12.247	-12.83	-16.189	-15.979	-15.768	-15.735	-110	-40.68	-40.391	-40.02
-37.731	-38.024	-38.325	-38.633	-38.948	-39.271	-39.504	-21.646	-20.687	-20.767	-20.58	-19.675	-18.281	-16.566	-16.389	-16.308	-12.694	-11.113	-6.2411	-6.473	-8.5425	-16.769	-19.451	-13.013	-9.8777	-7.8538	-11.608	-16.302	-17.367	-14.532	-12.405	-14.117	-17.085	-17.396	-17.179	-14.404	-12.795	-110	-40.98	-40.626	-40.283
-37.872	-38.29	-110	-38.765	-39.09	-39.424	-110	-110	-17.414	-19.57	-21.565	-110	-110	-13.682	-15.505	-19.051	-110	-110	-6.3279	-6.309	-7.2272	-110	-110	-11.094	-8.3037	-5.4649	-110	-110	-15.97	-13.474	-11.934	-110	-110	-17.405	-15.285	-10.391	-110	-110	-41.211	-110	-40.54
-38.005	-110	-110	-16.844	-17.036	-18.055	-110	-110	-16.203	-18.026	-17.772	-110	-110	-11.684	-13.52	-14.506	-110	-110	-7.6717	-6.9153	-5.8762	-110	-110	-4.4742	-5.5292	-5.423	-110	-110	-4.8513	-5.1045	-6.1462	-110	-110	-12.028	-11.052	-11.111	-110	-42.008	-41.65	-41.216	-40.789
-38.129	-38.451	-110	-19.421	-19.151	-16.859	-15.82	-16.328	-16.579	-16.924	-15.67	-14.156	-13.782	-11.951	-11.831	-12.331	-11.079	-9.9897	-9.0491	-7.485	-6.3909	-4.5015	-4.362	-5.3334	-6.3178	-5.646	-4.865	-3.852	-4.7473	-6.751	-7.43	-8.432	-8.5005	-10.538	-11.072	-11.033	-10.23	-42.304	-41.808	-41.445	-41.027
-110	-38.574	-110	-18.977	-20.56	-19.641	-16.905	-15.636	-15.823	-16.324	-16.135	-16.921	-16.738	-15.004	-11.842	-10.891	-12.136	-12.335	-10.74	-8.8107	-7.2849	-6.0254	-4.9695	-5.5547	-6.5406	-5.8149	-5.1936	-4.9565	-6.3223	-7.8845	-9.2497	-9.0001	-10.45	-11.821	-12.195	-10.968	-11.467	-42.58	-42.089	-41.694	-41.251
-38.368	-38.685	-110	-18.096	-18.661	-19.496	-20.442	-19.771	-17.623	-16.894	-17.601	-18.328	-17.531	-16.54	-15.533	-11.979	-11.397	-13.679	-12.959	-10.778	-8.1706	-6.7574	-5.0053	-5.2351	-6.4153	-5.8879	-5.0311	-5.7544	-7.9288	-9.0798	-10.139	-10.039	-110	-14.235	-13.402	-13.276	-13.383	-43.013	-42.403	-41.925	-41.46
-38.437	-38.784	-110	-19.995	-20.816	-19.891	-19.065	-20.053	-20.346	-20.046	-18.416	-17.638	-18.206	-17.748	-16.366	-15.386	-12.773	-12.39	-14.355	-12.921	-10.147	-7.5214	-5.5088	-4.7865	-6.0846	-5.7882	-5.2003	-7.6931	-8.8277	-10.366	-11.082	-10.048	-10.832	-13.347	-14.084	-14.503	-13.984	-43.278	-42.647	-42.136	-41.649
-38.516	-38.869	-110	-22.421	-22.469	-23.029	-22.799	-20.524	-20.274	-20.281	-19.598	-19.132	-18.409	-18.349	-18.918	-16.387	-15.769	-14.677	-13.275	-14.483	-12.585	-9.2823	-6.1176	-4.5619	-5.4805	-5.6061	-6.6093	-8.6003	-10.137	-11.411	-10.883	-11.602	-110	-16.61	-16.931	-15.857	-13.12	-43.471	-42.82	-42.323	-41.816
-38.581	-38.94	-110	-26.469	-25.851	-25.434	-24.253	-23.784	-23.699	-22.5	-22.297	-20.585	-19.258	-20.181	-19.989	-20.118	-18.441	-16.449	-16.047	-14.511	-14.664	-12.31	-7.5683	-4.3468	-4.5498	-6.2301	-7.518	-9.649	-12.031	-11.986	-12.948	-14.475	-15.254	-18.129	-17.733	-13.497	-11.988	-43.605	-42.941	-42.482	-41.957
-38.633	-38.972	-39.375	-30.842	-30.065	-29.082	-25.649	-23.52	-22.221	-24.844	-26.485	-24.474	-21.426	-19.047	-21.425	-22.795	-20.831	-17.305	-14.423	-16.611	-17.469	-15.369	-10.03	-3.0601	-4.6717	-6.4579	-7.5423	-12.178	-14.526	-15.11	-13.579	-14.279	-17.767	-19.678	-110	-9.4755	-9.0392	-43.773	-43.059	-42.592	-42.07
-38.64	-110	-110	-110	-110	-110	-110	-110	-19.157	-21.613	-24.155	-110	-110	-15.392	-17.705	-20.048	-48.156	-110	-10.637	-12.92	-16.345	-110	-110	-110	-0.6634	-110	-110	-110	-110	-110	-110	-110	-110	-6.3226	-110	-3.8479	-44.475	-43.87	-43.115	-110	-42.153
-31.744	-28.262	-26.896	-27.639	-29.431	-31.834	-110	-110	-14.274	-15.835	-17.025	-110	-9.7947	-11.32	-12.103	-13.361	-110	-7.1915	-8.8969	-10.456	-11.281	-110	4.4832	1.74557	0.42742	2.34884	4.57421	5.61256	3.99614	3.2167	3.64124	4.54702	3.5129	0.13031	-0.6896	0.16203	3.6601	-110	-43.424	-42.736	-42.203
-26.363	-25.632	-24.735	-23.727	-23.863	-26.178	-27.181	-41.922	-110	-10.574	-10.672	-10.9	-10.548	-8.6007	-7.3133	-7.0286	-7.4197	-7.2829	-7.1241	-7.6462	-7.8033	-8.2971	2.12249	1.30872	-0.6702	0.73203	3.63038	3.79678	4.3805	4.75499	4.45942	4.23203	3.84317	4.59859	4.6743	4.74506	5.12989	-110	-43.379	-42.78	-42.22
-26.076	-25	-24.029	-23.959	-24.613	-27.027	-29.073	-110	-14.289	-14.894	-14.706	-110	-110	-8.9031	-8.7824	-10.443	-110	-110	-8.2897	-9.3244	-10.976	-110	-110	0.80858	0.3539	1.22171	-110	-110	2.78488	1.98387	4.02194	-110	-110	0.66902	-0.7763	0.36281	-110	-110	-43.309	-42.761	-42.203
-27.945	-26.919	-26.422	-26.753	-27.937	-30.373	-33.313	-110	-31.096	-26.247	-110	-110	-110	-110	-110	-110	-48.27	-48.854	-50.348	-51.497	-53.052	-110	-110	1.88677	2.5187	3.66323	-110	-110	-6.5695	-5.0373	1.03549	-110	-110	-6.9938	-5.1161	-3.7028	-44.601	-110	-43.19	-42.704	-42.153
-29.006	-28.029	-28.539	-29.652	-31.381	-34.686	-38.567	-33.976	-32.32	-31.026	-32.4	-31.943	-31.245	-27.811	-27.354	-29.212	-36.954	-48.591	-49.803	-50.97	-52.295	-110	-110	3.07957	4.38384	4.58094	1.92466	-3.4628	-3.1667	-4.0292	-3.9445	-3.2776	-4.2152	-5.5802	-5.468	-5.7151	-7.0034	-110	-43.16	-42.61	-42.098
-30.916	-30.663	-31.826	-32.98	-35.047	-38.268	-40.413	-32.984	-32.574	-32.573	-30.282	-29.871	-30.969	-29.053	-29.851	-33.12	-37.457	-48.173	-49.131	-50.159	-51.229	-110	-0.2418	2.93254	4.46096	3.9256	3.44157	1.65041	-0.9942	-4.048	-3.494	-4.2276	-6.4214	-7.3476	-6.9357	-5.0567	-5.9118	-110	-43.038	-42.482	-41.957
-31.215	-32.786	-35.232	-36.71	-39.788	-40.424	-110	-110	-30.425	-31.435	-32.271	-110	-43.93	-28.299	-30.219	-33.986	-110	-110	-48.621	-49.401	-50.277	-110	-51.357	5.38702	3.67217	3.96064	-110	-50.813	-1.6665	-3.4761	-2.6272	-110	-46.788	-11.151	-11.66	-8.9398	-110	-110	-42.795	-42.323	-41.827
-37.168	-38.359	-38.967	-39.525	-39.909	-40.316	-110	-110	-41.138	-37.186	-42.606	-43.358	-110	-44.357	-44.893	-45.539	-110	-110	-47.665	-48.485	-49.219	-50.019	-50.41	-110	2.56545	-2.3148	-110	-49.75	-49.081	-48.656	-110	-47.01	-110	-45.46	-44.885	-44.282	-43.73	-110	-110	-110	-41.722
-38.042	-38.521	-39.038	-39.407	-39.782	-40.176	-40.502	-41.058	-41.337	-41.71	-42.399	-42.883	-110	-44	-44.567	-45.158	-45.726	-46.331	-47.056	-110	-24.4	-20.464	-17.452	-110	-1.2999	-4.9477	-11.533	-16.91	-18.423	-24.297	-110	-46.418	-45.755	-45.075	-44.567	-44.003	-43.539	-42.9	-42.345	-41.831	-41.355
-37.936	-38.557	-38.914	-39.271	-39.639	-40.02	-40.335	-40.867	-41.234	-41.693	-42.152	-42.624	-110	-43.628	-44.151	-44.684	-45.225	-45.765	-46.344	-110	-19.857	-16.634	-13.784	-8.8905	-5.047	-6.8509	-11.368	-15.399	-18.193	-18.993	-110	-45.859	-45.308	-44.596	-44.151	-43.628	-43.246	-42.679	-42.14	-110	-110
-38.121	-38.458	-38.784	-39.128	-39.483	-39.85	-40.154	-40.654	-41.027	-41.445	-41.877	-42.319	-110	-43.247	-43.723	-44.204	-44.684	-45.158	-45.656	-110	-16.66	-14.089	-10.418	-8.1081	-6.5918	-6.9911	-9.0308	-12.365	-16.145	-17.717	-110	-45.106	-44.668	-44.235	-43.736	-43.247	-42.782	-42.303	-41.976	-110	-41.17
-38.004	-110	-38.637	-38.953	-39.354	-39.681	-39.957	-40.439	-40.789	-41.184	-41.589	-41.987	-110	-42.849	-43.29	-43.723	-44.151	-44.571	-110	-110	-15.834	-14.918	-110	-110	-5.7139	-5.6081	-110	-110	-16.206	-110	-110	-44.548	-44.319	-43.629	-110	-42.838	-42.427	-42.005	-110	-110	-40.642
-37.872	-110	-38.243	-110	-110	-39.5	-110	-40.112	-40.58	-40.903	-41.291	-41.684	-110	-42.484	-42.864	-43.247	-43.628	-43.988	-44.448	-44.62	-110	-110	-45.316	-110	-110	-110	-45.426	-45.207	-17.748	-44.54	-44.358	-43.575	-110	-43.205	-42.932	-42.44	-42.069	-41.681	-41.292	-110	-40.617
-37.731	-38.024	-38.306	-110	-110	-39.301	-110	-110	-110	-110	-110	-110	-41.772	-42.085	-42.438	-42.786	-43.12	-43.445	-43.699	-43.97	-44.259	-44.453	-44.507	-44.614	-44.729	-42.544	-110	-26.164	-22.8	-23.136	-30.835	-35.327	-110	-110	-110	-42.057	-41.708	-41.347	-40.988	-40.638	-110
-37.583	-37.866	-38.155	-38.433	-38.742	-39.066	-39.378	-39.702	-40.019	-40.348	-40.68	-41.013	-41.347	-41.678	-42.004	-42.322	-42.628	-42.917	-43.184	-43.423	-43.629	-43.797	-110	-43.937	-43.041	-36.845	-31.072	-28.991	-26.509	-24.701	-30.68	-34.196	-110	-42.216	-110	-41.667	-41.347	-41.013	-40.68	-40.348	-40.036
-37.429	-37.701	-37.979	-38.263	-38.552	-110	-110	-110	-39.752	-40.061	-40.37	-40.68	-40.988	-110	-110	-110	-110	-42.44	-42.654	-42.871	-43.052	-43.204	-43.303	-43.378	-40.598	-34.344	-32.04	-31.536	-28.399	-26.068	-110	-34.245	-110	-41.827	-110	-41.236	-40.988	-40.68	-40.37	-40.061	-39.753
-37.271	-37.531	-37.798	-38.07	-38.346	-110	-110	-110	-39.482	-39.826	-40.067	-110	-40.673	-110	-110	-110	-110	-41.942	-42.146	-42.315	-42.488	-110	-42.682	-42.658	-37.849	-34.08	-34.423	-32.777	-29.45	-110	-110	-110	-110	-41.409	-110	-40.911	-40.633	-40.348	-40.06	-39.771	-39.481
-37.102	-37.357	-110	-37.874	-110	-38.4	-38.671	-38.94	-39.209	-39.443	-39.639	-40.054	-110	-110	-110	-110	-110	-41.457	-41.649	-41.816	-41.953	-42.06	-42.119	-41.787	-38.227	-34.838	-35.113	-32.9	-30.155	-32.157	-37.634	-39.067	-110	-110	-110	-40.531	-40.281	-40.02	-39.752	-39.482	-39.211
-36.932	-37.181	-37.418	-37.671	-37.922	-110	-110	-38.78	-38.94	-39.173	-39.567	-110	-39.92	-40.172	-40.404	-40.621	-40.826	-41.014	-41.184	-41.334	-41.46	-41.561	-41.617	-41.391	-38.604	-35.483	-35.449	-32.562	-30.936	-34.299	-37.95	-38.937	-39.825	-40.586	-40.367	-40.176	-39.939	-39.695	-39.446	-39.194	-38.94
-36.783	-110	-37.245	-37.471	-37.707	-110	-110	-110	-38.675	-110	-110	-110	-39.6	-39.82	-40.03	-40.229	-40.447	-40.694	-110	-110	-110	-41.19	-41.166	-40.911	-37.877	-36.338	-35.458	-33.815	-110	-40.908	-36.912	-38.132	-40.274	-110	-40.03	-39.82	-39.601	-39.375	-39.144	-38.908	-38.67
-110	-36.816	-110	-37.321	-37.491	-37.713	-37.943	-38.166	-110	-110	-110	-39.063	-39.271	-39.483	-39.671	-39.85	-39.974	-40.189	-40.307	-40.423	-40.536	-40.61	-40.54	-39.747	-36.996	-36.688	-34.89	-35.282	-39.322	-110	-38.731	-110	-110	-39.85	-39.667	-39.473	-39.271	-39.061	-38.846	-38.625	-38.401
-110	-110	-36.836	-37.043	-37.274	-37.481	-37.739	-37.94	-110	-110	-38.552	-38.753	-38.948	-39.116	-39.313	-39.483	-39.621	-39.793	-39.909	-40.02	-40.113	-40.176	-39.725	-38.467	-38.061	-110	-110	-39.268	-39.968	-39.706	-110	-39.707	-39.665	-39.483	-39.314	-39.136	-38.948	-38.753	-38.552	-38.345	-38.135
-110	-110	-110	-36.853	-37.057	-37.223	-110	-110	-37.851	-110	-38.267	-38.451	-38.633	-38.807	-38.972	-39.128	-39.246	-39.413	-39.519	-39.62	-39.704	-39.722	-39.56	-39.903	-39.751	-39.792	-110	-39.603	-39.573	-39.587	-39.488	-110	-39.267	-39.128	-38.972	-38.807	-38.633	-38.451	-38.263	-38.07	-37.872
-110	-110	-110	-110	-36.843	-37.017	-110	-37.378	-37.594	-110	-37.991	-38.157	-38.326	-38.487	-38.641	-38.786	-38.899	-39.047	-39.144	-39.237	-39.311	-39.367	-39.378	-39.417	-39.443	-110	-39.421	-110	-110	-39.196	-39.138	-39.037	-38.917	-38.784	-38.64	-38.487	-38.325	-38.155	-37.979	-37.798	-37.612
-110	-110	-110	-110	-110	-36.816	-36.986	-37.175	-37.337	-110	-37.746	-110	-38.14	-38.251	-110	-110	-38.632	-38.78	-38.784	-38.869	-38.935	-39.07	-39.015	-39.03	-110	-38.98	-39.061	-38.92	-39.018	-38.853	-38.784	-38.685	-38.574	-38.451	-38.318	-38.175	-38.024	-37.866	-37.701	-37.531	-37.356
-110	-110	-110	-110	-110	-110	-36.783	-36.935	-37.103	-110	-37.398	-37.589	-37.752	-37.855	-38.036	-38.078	-38.194	-38.348	-38.437	-38.516	-38.574	-38.644	-38.66	-38.693	-38.68	-110	-38.62	-38.633	-38.578	-38.516	-38.437	-38.346	-38.243	-38.129	-38.005	-37.872	-37.731	-37.583	-37.429	-37.268	-37.104
-110	-110	-110	-110	-110	-110	-110	-36.749	-36.845	-110	-37.156	-37.293	-37.433	-37.577	-37.688	-37.797	-37.908	-37.978	-38.103	-38.176	-38.233	-38.258	-38.335	-38.339	-38.346	-38.335	-38.318	-38.284	-38.236	-38.176	-38.103	-38.018	-37.923	-37.817	-37.701	-37.577	-37.446	-37.307	-37.161	-37.011	-36.855
-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.78	-36.9	-37.036	-37.167	-37.29	-37.406	-37.514	-37.58	-37.643	-37.78	-37.848	-37.896	-37.874	-37.958	-37.999	-38.005	-37.999	-37.98	-37.948	-37.904	-37.848	-37.78	-37.701	-37.613	-37.514	-37.407	-37.292	-37.167	-37.036	-36.9	-36.78	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.792	-36.895	-37.011	-37.119	-37.22	-37.312	-37.395	-37.468	-37.534	-37.607	-37.666	-110	-110	-37.7	-37.677	-37.657	-37.624	-37.583	-37.531	-37.468	-37.395	-37.312	-37.22	-37.118	-37.008	-36.895	-36.792	-110	-110	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.778	-36.841	-36.935	-37.016	-37.099	-110	-110	-37.325	-37.291	-37.319	-37.339	-37.323	-110	-37.339	-37.312	-37.274	-37.226	-37.167	-37.099	-37.021	-36.935	-36.841	-36.778	-110	-110	-110	-110	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.746	-36.775	-36.817	-36.863	-36.878	-36.908	-37.007	-37.037	-110	-37	-110	-110	-37.007	-36.974	-36.926	-36.875	-36.818	-36.775	-36.746	-110	-110	-110	-110	-110	-110	-110
-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-36.756	-36.767	-36.781	-36.782	-36.787	-36.782	-36.781	-36.767	-36.756	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110

What Triton Is

- Listener and Source Positions → Occlusion/Obstruction, Reverb Wetness, and Reverb Decay Rate values.
- This data is inert and must be *interpreted*.
- The RAM requirements are next-gen.



SP_Rescue_B.ace	11/30/2015 6:51 PM	ACE File	100,468 KB
SP_Dam_A.ace	11/19/2015 5:44 AM	ACE File	117,872 KB

What Triton Isn't

Triton is a Data-Set //not a 'Reverb Plug-in'

Triton Implementation Challenge

The ideal Triton implementation with no CPU/RAM limitations

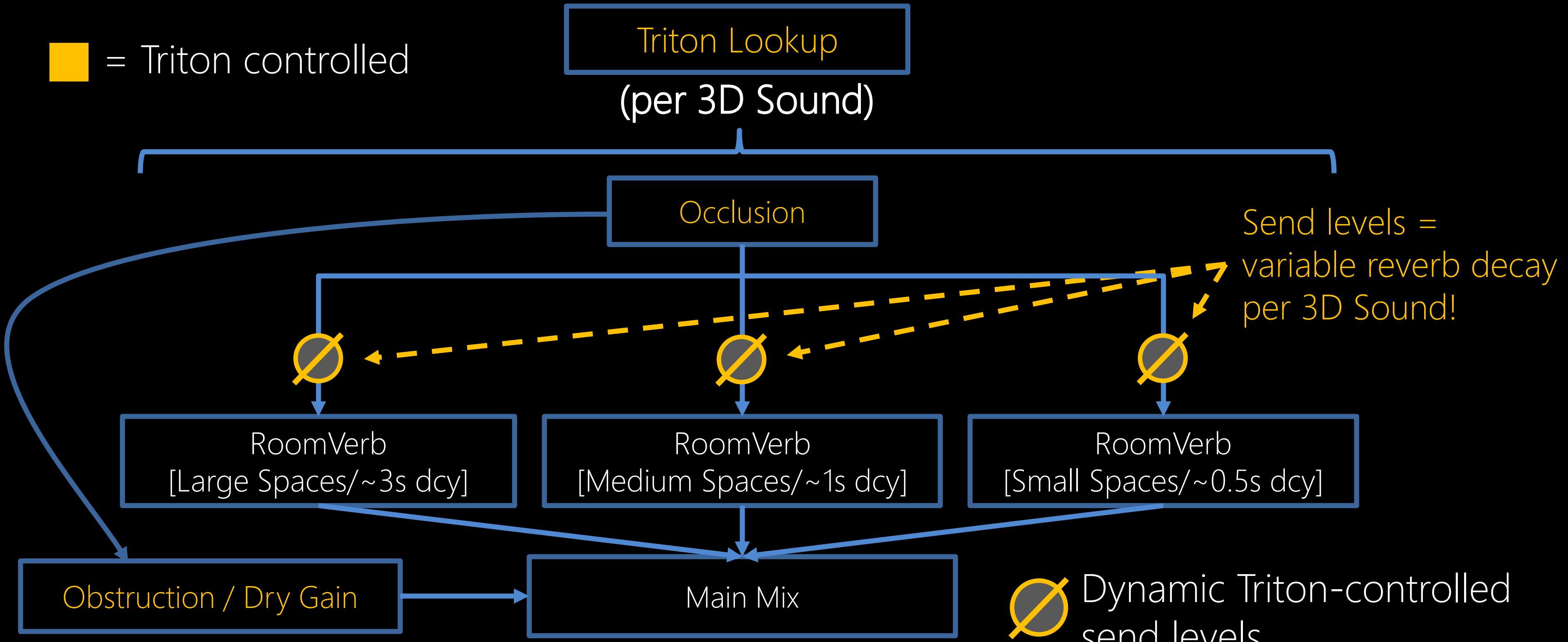
- Per-Sound Impulse Responses Updated Every Frame
  no middleware support, over RAM budget [10-100GB] ☹

- Per-Sound Convolution Reverb
  ~100 instances; way over CPU budget ☹

Not practical for video game audio…

V1.0

Implementation Progression


🟨 = Triton controlled
Triton Lookup
(per 3D Sound)
Occlusion
Send levels = variable reverb decay per 3D Sound!
RoomVerb [Large Spaces/~3s dcy]
RoomVerb [Medium Spaces/~1s dcy]
RoomVerb [Small Spaces/~0.5s dcy]
Obstruction / Dry Gain
Main Mix
Dynamic Triton-controlled send levels

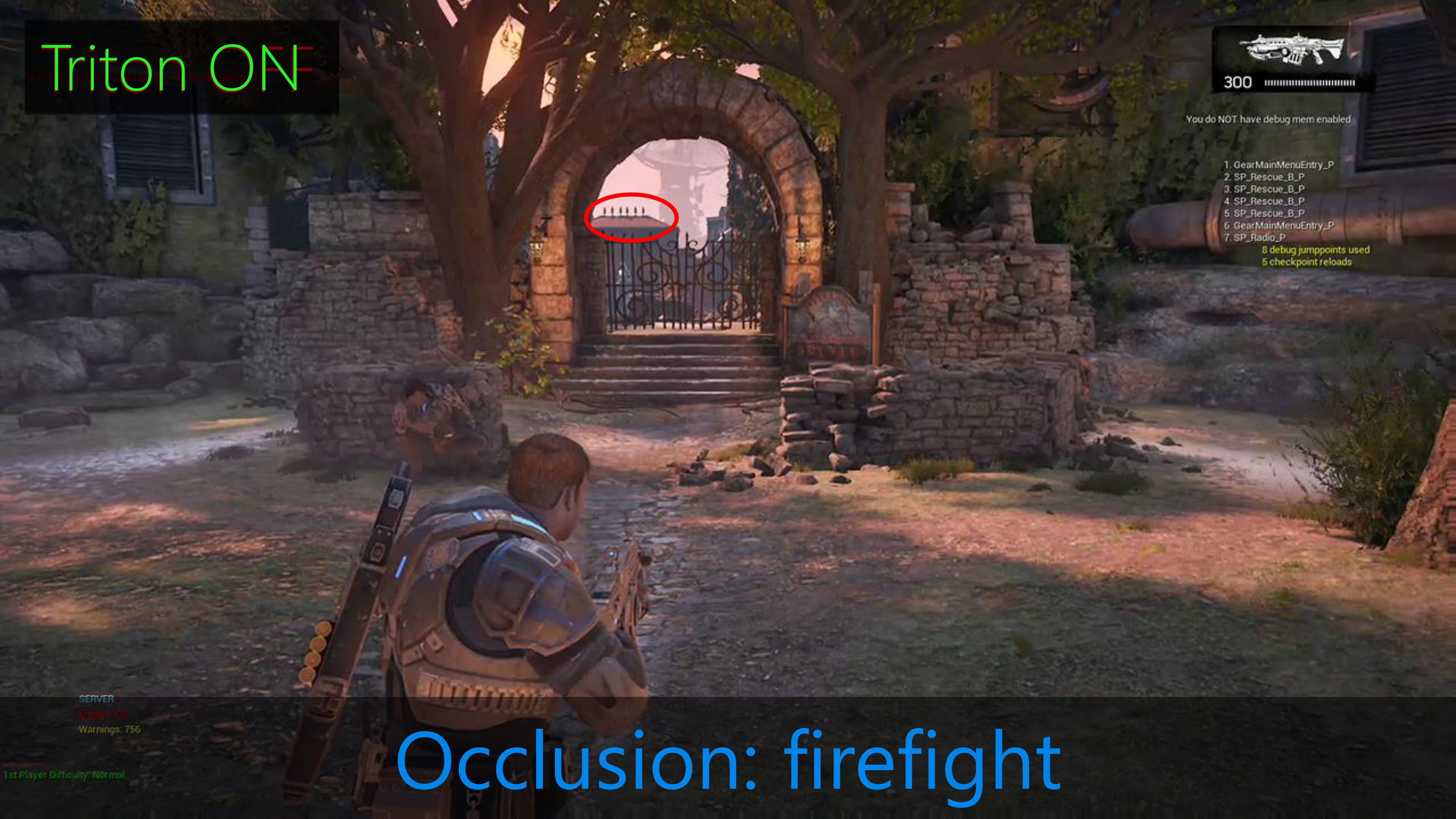
V1.0

Implementation Progression

V1.0 – Summary:

- Triton Reverb Data controls levels sent 3 instances of Wwise RoomVerb.
- Occlusion/Obstruction uses Wwise built in architecture.
  - Strengths: Occlusion/Obstruction is excellent. (Video Example) Dynamic Space Transitions, Responsive, Revelatory moments, Successful Proof-of-Concept.
  - Weaknesses: No solution for outdoor reverb, RoomVerb sounds crowded when stacked, unpredictable behaviour ~25% of the time. Not yet shippable.

Triton ON



```
You do NOT have debug mem enabled

1. GearMainMenuEntry_P
2. SP_Rescue_B_P
3. SP_Rescue_B_P
4. SP_Rescue_B_P
5. SP_Rescue_B_P
6. GearMainMenuEntry_P
7. SP_Radio_P
      8 debug jumppoints used
      5 checkpoint reloads
```

```
SERVER
[illegible]
Warnings: 756

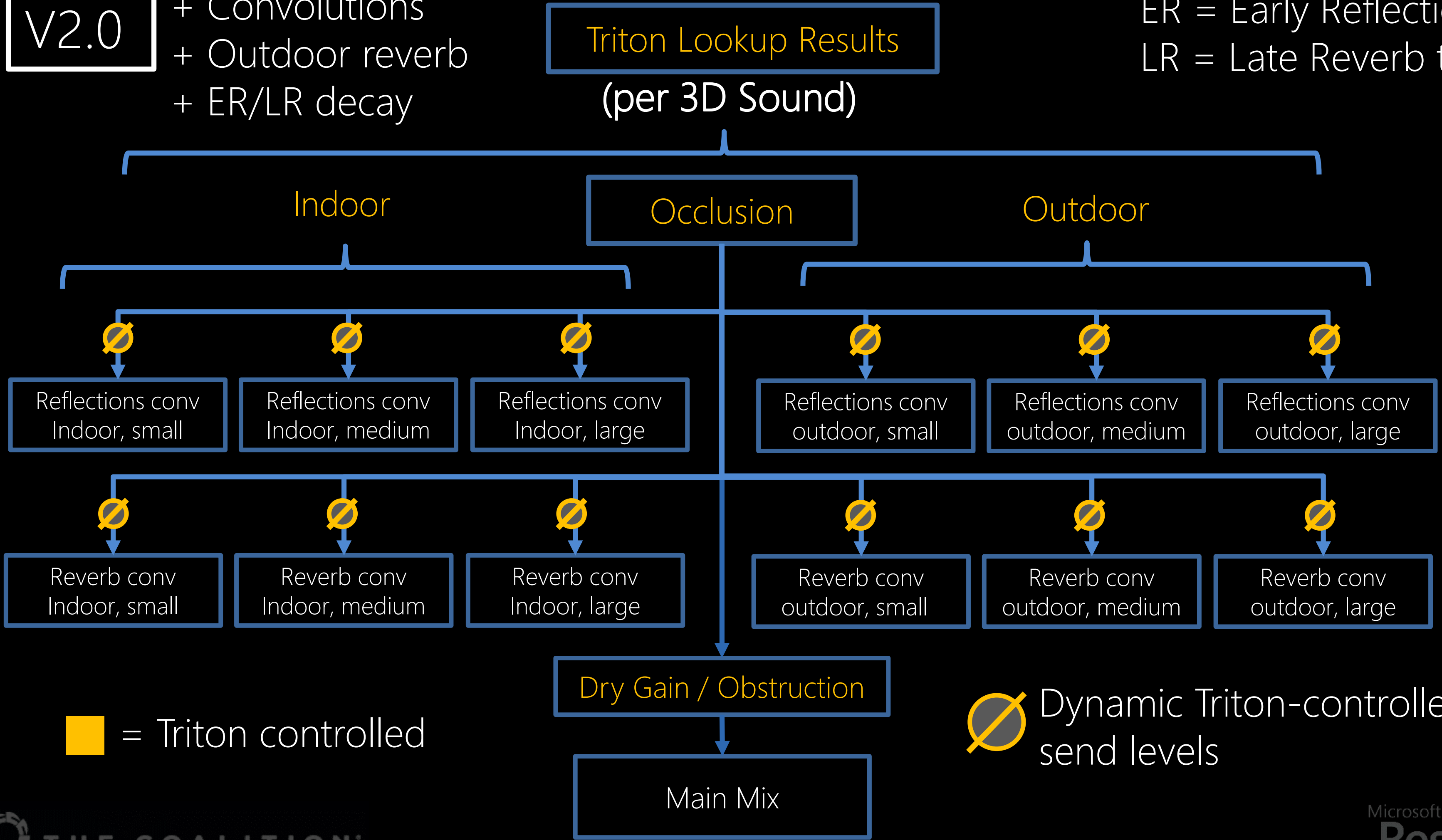
1st Player Difficulty: Normal
```

Occlusion: firefight

V2.0

+ Convolutions
+ Outdoor reverb
+ ER/LR decay

ER = Early Reflections
LR = Late Reverb tail



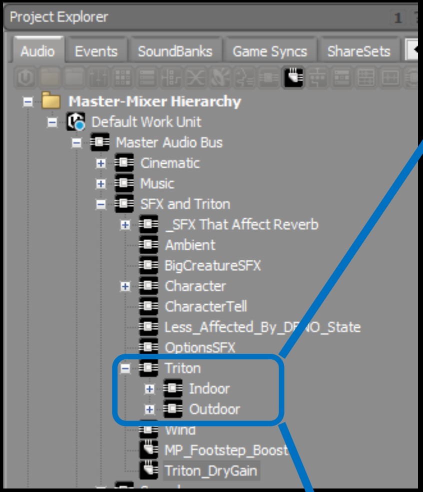
Triton Lookup Results
(per 3D Sound)
Indoor
Occlusion
Outdoor
Reflections conv Indoor, small
Reflections conv Indoor, medium
Reflections conv Indoor, large
Reflections conv outdoor, small
Reflections conv outdoor, medium
Reflections conv outdoor, large
Reverb conv Indoor, small
Reverb conv Indoor, medium
Reverb conv Indoor, large
Reverb conv outdoor, small
Reverb conv outdoor, medium
Reverb conv outdoor, large
Dry Gain / Obstruction
Main Mix

🟨 = Triton controlled

⌀ Dynamic Triton-controlled send levels

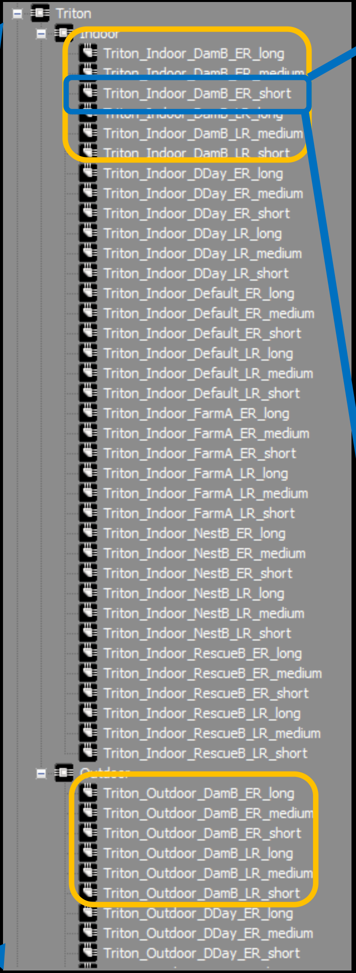
THE COALITION

Microsoft Research

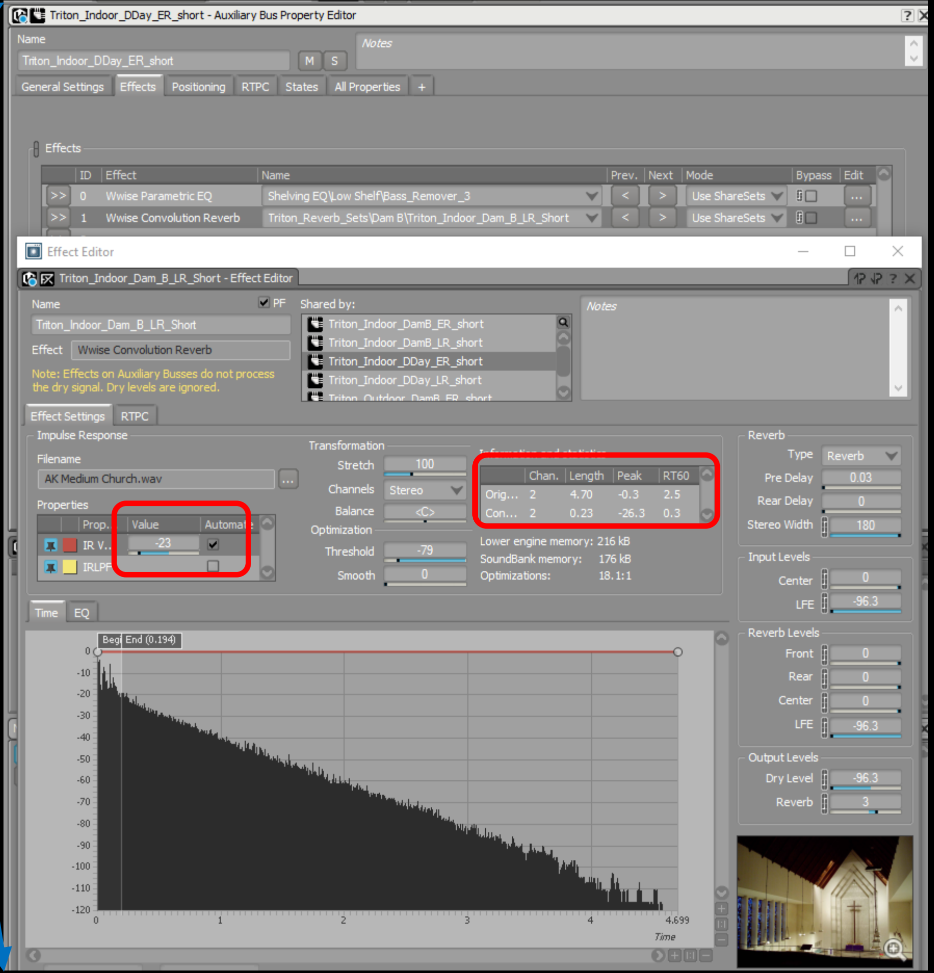


Project Explorer

- Master-Mixer Hierarchy
  - Default Work Unit
    - Master Audio Bus
      - Cinematic
      - Music
      - SFX and Triton
        - _SFX That Affect Reverb
        - Ambient
        - BigCreatureSFX
        - Character
        - CharacterTell
        - Less_Affected_By_DRNO_State
        - OptionsSFX
        - Triton
          - Indoor
          - Outdoor
        - Wind
        - MP_Footstep_Boost
        - Triton_DryGain



- Triton
  - Indoor
    - Triton_Indoor_DamB_ER_long
    - Triton_Indoor_DamB_ER_medium
    - Triton_Indoor_DamB_ER_short
    - Triton_Indoor_DamB_LR_long
    - Triton_Indoor_DamB_LR_medium
    - Triton_Indoor_DamB_LR_short
    - Triton_Indoor_DDay_ER_long
    - Triton_Indoor_DDay_ER_medium
    - Triton_Indoor_DDay_ER_short
    - Triton_Indoor_DDay_LR_long
    - Triton_Indoor_DDay_LR_medium
    - Triton_Indoor_DDay_LR_short
    - Triton_Indoor_Default_ER_long
    - Triton_Indoor_Default_ER_medium
    - Triton_Indoor_Default_ER_short
    - Triton_Indoor_Default_LR_long
    - Triton_Indoor_Default_LR_medium
    - Triton_Indoor_Default_LR_short
    - Triton_Indoor_FarmA_ER_long
    - Triton_Indoor_FarmA_ER_medium
    - Triton_Indoor_FarmA_ER_short
    - Triton_Indoor_FarmA_LR_long
    - Triton_Indoor_FarmA_LR_medium
    - Triton_Indoor_FarmA_LR_short
    - Triton_Indoor_NestB_ER_long
    - Triton_Indoor_NestB_ER_medium
    - Triton_Indoor_NestB_ER_short
    - Triton_Indoor_NestB_LR_long
    - Triton_Indoor_NestB_LR_medium
    - Triton_Indoor_NestB_LR_short
    - Triton_Indoor_RescueB_ER_long
    - Triton_Indoor_RescueB_ER_medium
    - Triton_Indoor_RescueB_ER_short
    - Triton_Indoor_RescueB_LR_long
    - Triton_Indoor_RescueB_LR_medium
    - Triton_Indoor_RescueB_LR_short
  - Outdoor
    - Triton_Outdoor_DamB_ER_long
    - Triton_Outdoor_DamB_ER_medium
    - Triton_Outdoor_DamB_ER_short
    - Triton_Outdoor_DamB_LR_long
    - Triton_Outdoor_DamB_LR_medium
    - Triton_Outdoor_DamB_LR_short
    - Triton_Outdoor_DDay_ER_long
    - Triton_Outdoor_DDay_ER_medium
    - Triton_Outdoor_DDay_ER_short



Triton_Indoor_DDay_ER_short - Auxiliary Bus Property Editor

Name: Triton_Indoor_DDay_ER_short

Effects

	ID	Effect	Name	Prev.	Next	Mode	Bypass	Edit
>>	0	Wwise Parametric EQ	Shelving EQ\Low Shelf\Bass_Remover_3	<	>	Use ShareSets	□	...
>>	1	Wwise Convolution Reverb	Triton_Reverb_Sets\Dam B\Triton_Indoor_Dam_B_LR_Short	<	>	Use ShareSets	□	...

Effect Editor

Triton_Indoor_Dam_B_LR_Short - Effect Editor

Name: Triton_Indoor_Dam_B_LR_Short ☑ PF

Effect: Wwise Convolution Reverb

Note: Effects on Auxiliary Busses do not process the dry signal. Dry levels are ignored.

Shared by:

- Triton_Indoor_DamB_ER_short
- Triton_Indoor_DamB_LR_short
- Triton_Indoor_DDay_ER_short
- Triton_Indoor_DDay_LR_short
- Triton_Outdoor_DamB_ER_short

Impulse Response

Filename: AK Medium Church.wav

Properties

Prop.	Value	Automate
IR V...	-23	☑
IRLPF		□

Transformation

Stretch: 100
Channels: Stereo
Balance: <C>

Optimization

Threshold: -79
Smooth: 0

	Chan.	Length	Peak	RT60
Orig...	2	4.70	-0.3	2.5
Con...	2	0.23	-26.3	0.3

Lower engine memory: 216 kB
SoundBank memory: 176 kB
Optimizations: 18.1:1

Reverb

Type: Reverb
Pre Delay: 0.03
Rear Delay: 0
Stereo Width: 180

Input Levels

Center: 0
LFE: -96.3

Reverb Levels

Front: 0
Rear: 0
Center: 0
LFE: -96.3

Output Levels

Dry Level: -96.3
Reverb: 3

Map = Dam B

V2.0

Implementation Progression

V2.0 – Summary:

- Triton Data controls levels to 12 Wwise Convolution Reverbs.
  - Strengths: Indoor/Outdoor threshold blending is excellent (video example), dynamic reverb decay response
  - Weaknesses: Setup and calibration, bugs were difficult to stomp

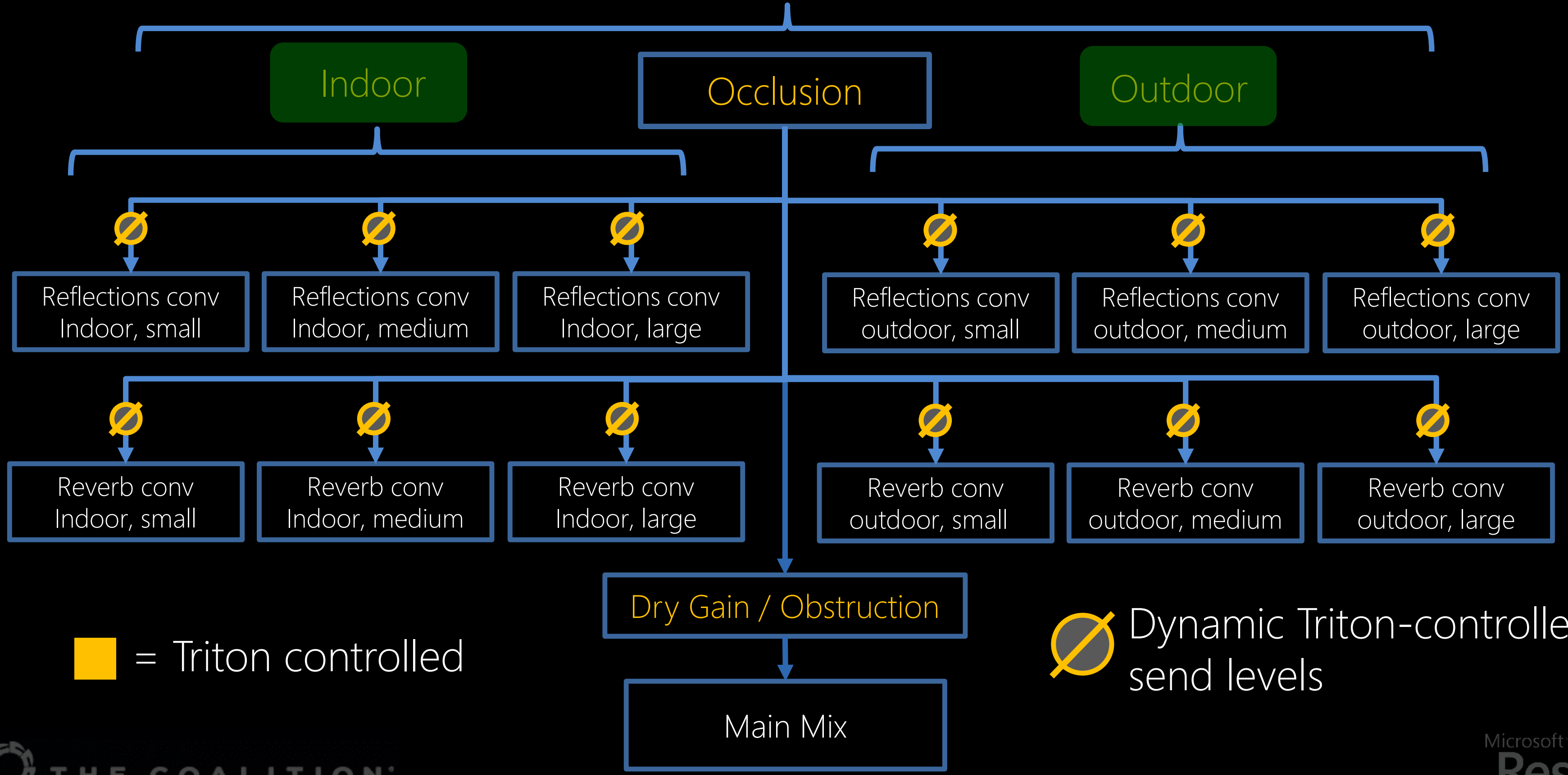
V2.0

+ Convolutions
+ Outdoor reverb
+ ER/LR decay

Triton Lookup Results

(per 3D Sound)

ER = Early Reflections
LR = Late Reverb tail



Indoor

Occlusion

Outdoor

Reflections conv Indoor, small

Reflections conv Indoor, medium

Reflections conv Indoor, large

Reflections conv outdoor, small

Reflections conv outdoor, medium

Reflections conv outdoor, large

Reverb conv Indoor, small

Reverb conv Indoor, medium

Reverb conv Indoor, large

Reverb conv outdoor, small

Reverb conv outdoor, medium

Reverb conv outdoor, large

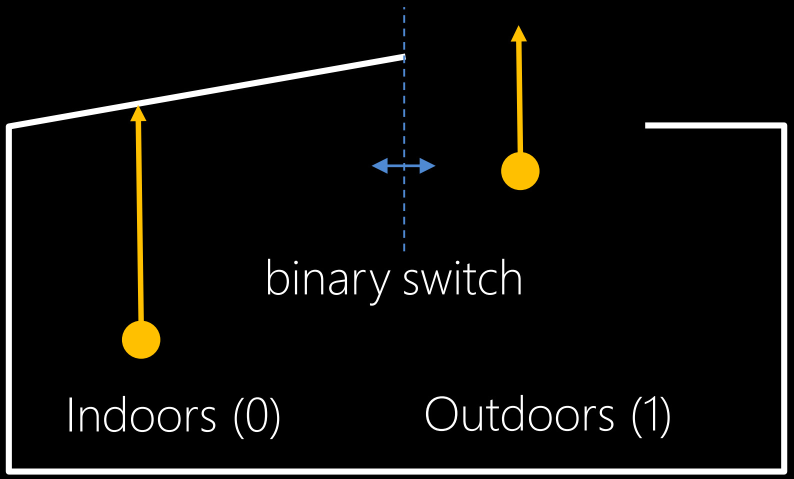
Dry Gain / Obstruction

Main Mix

🟨 = Triton controlled

Ø Dynamic Triton-controlled send levels

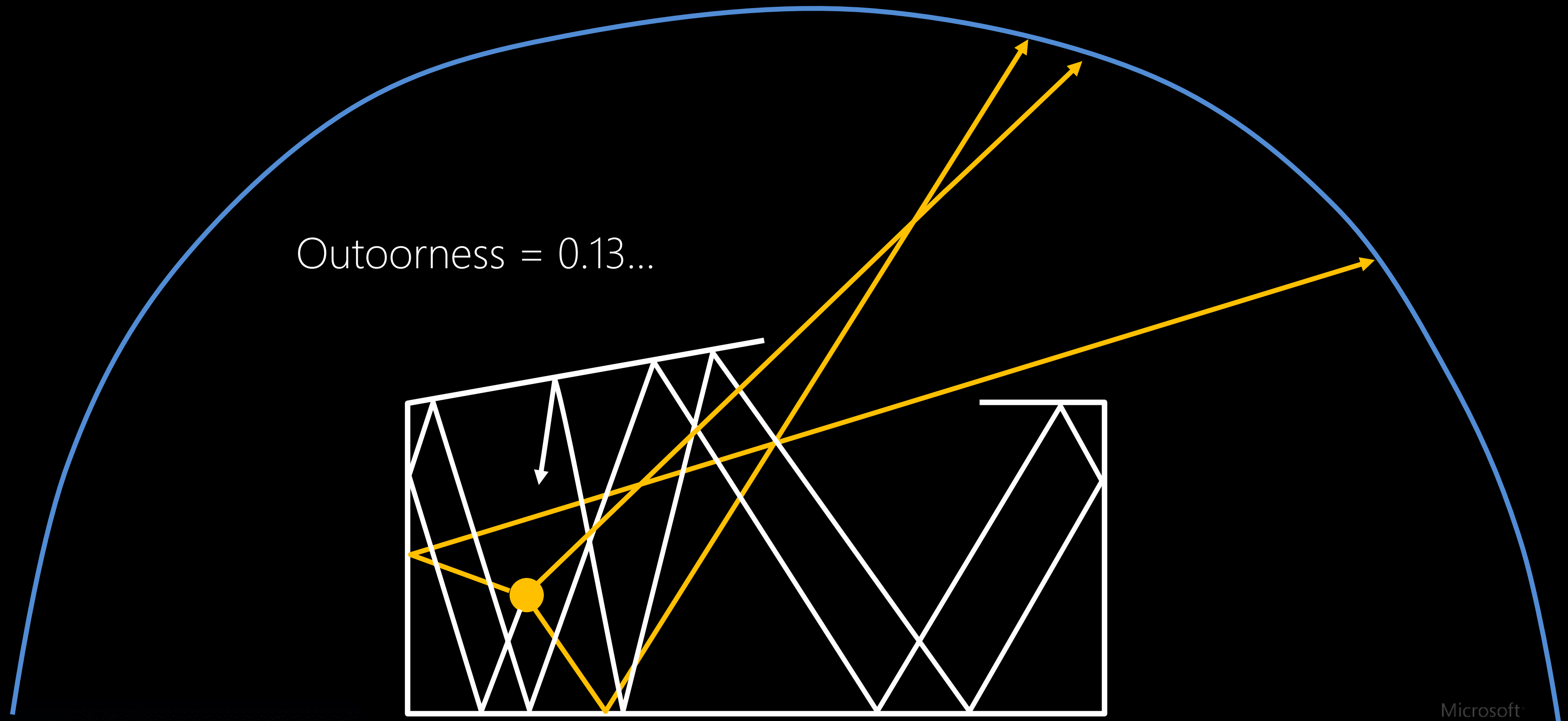
Mixing Indoor/Outdoor Reverbs Through Thresholds



Problem: **This concept is not binary.**

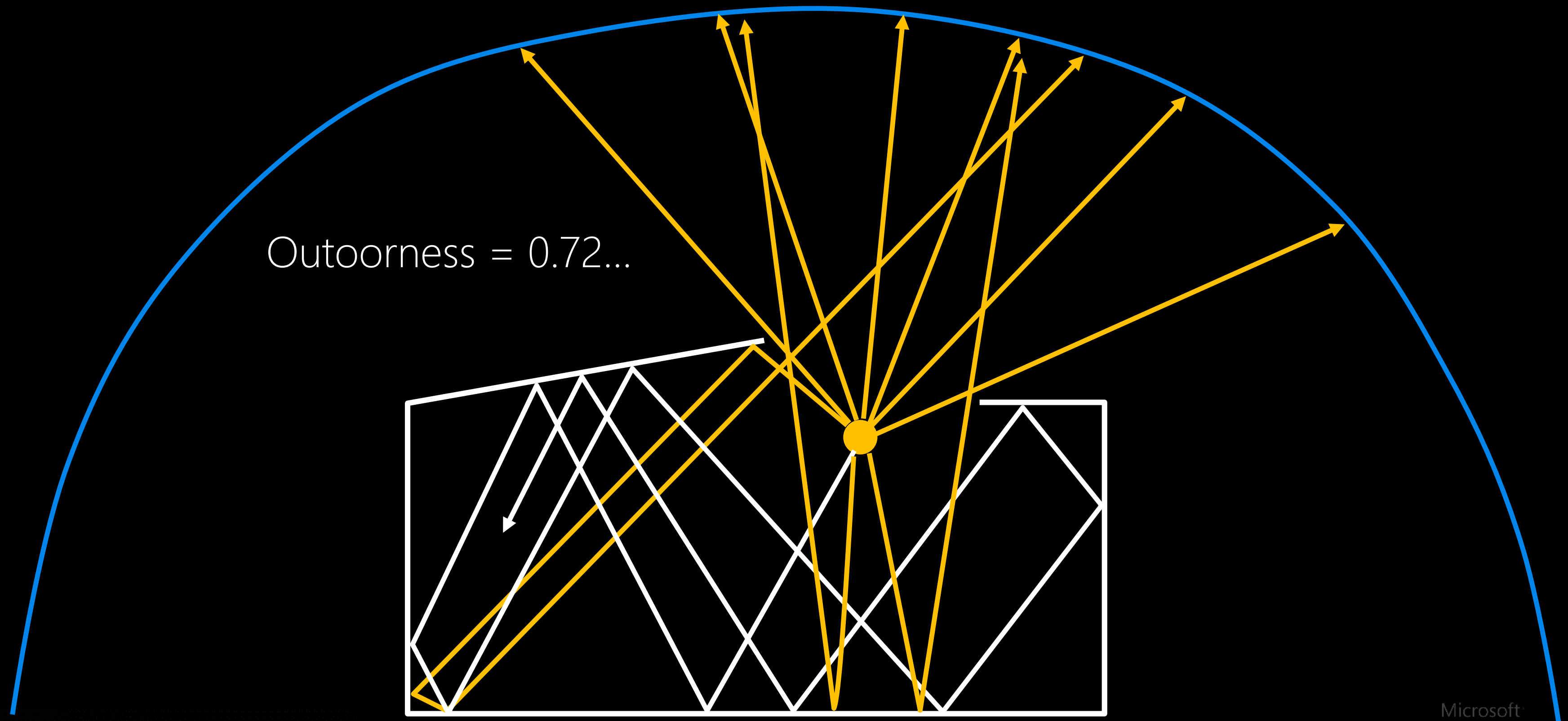
Solution: Triton pre-computes a smooth “Outdoorness”

Solution: $\text{Outdoorness} = \dfrac{\text{Energy reaching sky}}{\text{Total Energy shot}}$



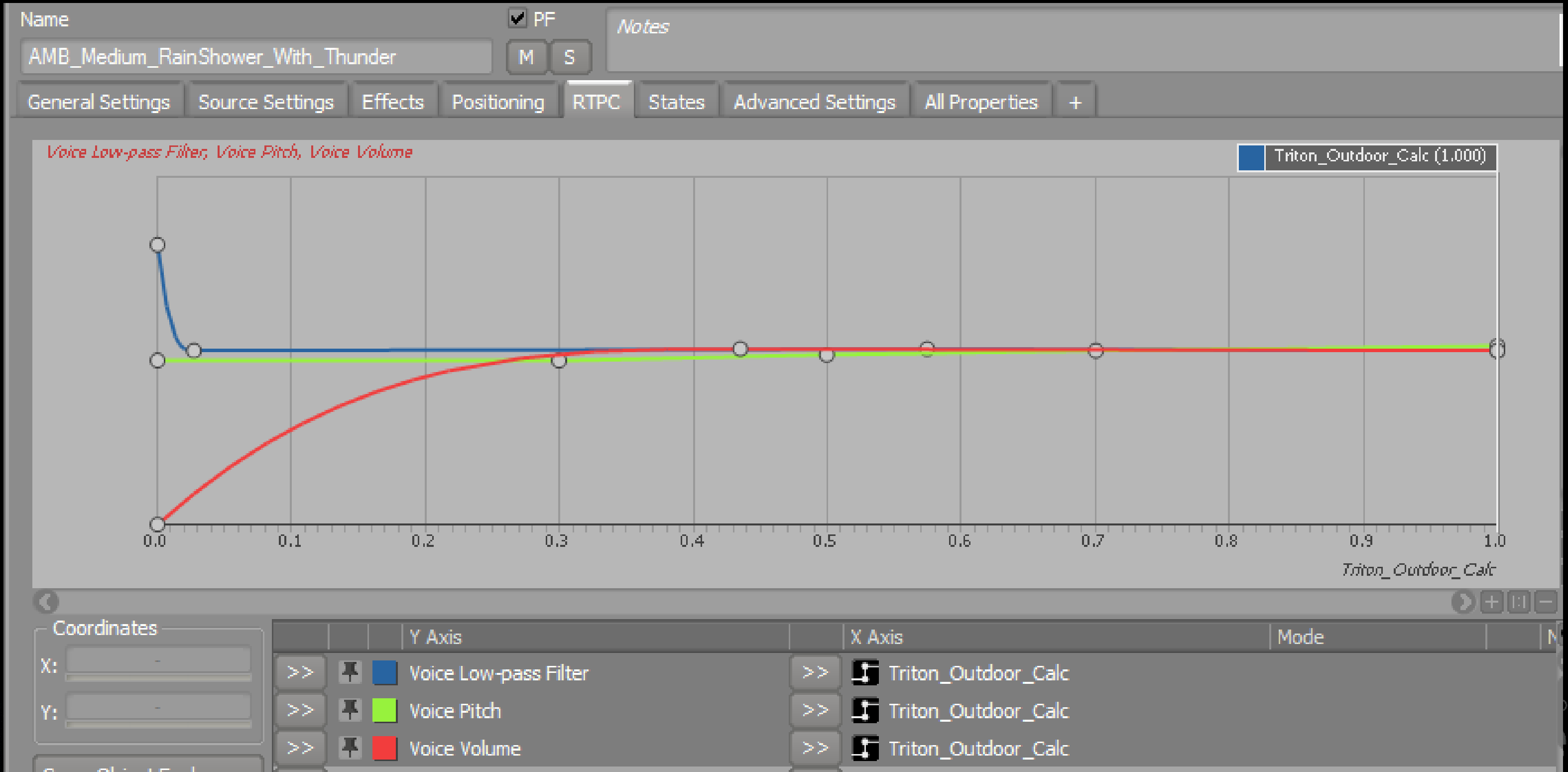
Outoorness = 0.13…

Outdoorness changes **smoothly** as player approaches transition



Unforeseen Uses: Threshold Blending for Rain and Wind

- Triton uses this for determining sends for inside/outside reverb blending
- Exposed as RTPC: Driving sound of Wind, Rain, etc.

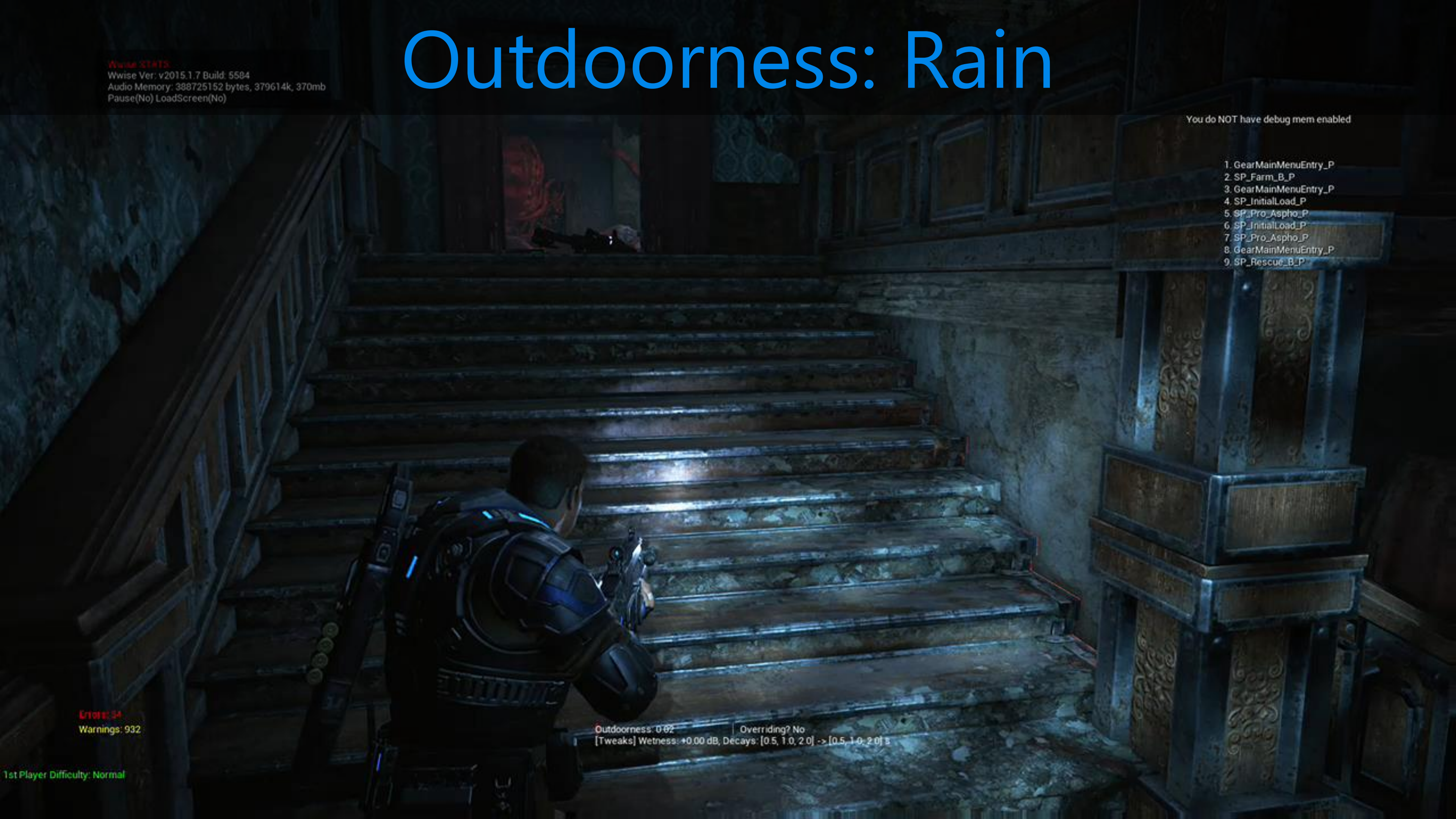


Name: AMB_Medium_RainShower_With_Thunder

☑ PF

		Y Axis		X Axis	Mode
>>		🟦 Voice Low-pass Filter	>>	Triton_Outdoor_Calc	
>>		🟩 Voice Pitch	>>	Triton_Outdoor_Calc	
>>		🟥 Voice Volume	>>	Triton_Outdoor_Calc	

Outdoorness: Rain



```
Wwise STATS
Wwise Ver: v2015.1.7 Build: 5584
Audio Memory: 388725152 bytes, 379614k, 370mb
Pause(No) LoadScreen(No)
```

```
You do NOT have debug mem enabled
```

```
1. GearMainMenuEntry_P
2. SP_Farm_B_P
3. GearMainMenuEntry_P
4. SP_InitialLoad_P
5. SP_Pro_Aspho_P
6. SP_InitialLoad_P
7. SP_Pro_Aspho_P
8. GearMainMenuEntry_P
9. SP_Rescue_B_P
```

```
Outdoorness: 0.02          Overriding? No
[Tweaks] Wetness: +0.00 dB, Decays: [0.5, 1.0, 2.0] -> [0.5, 1.0, 2.0] s
```

```
Errors: 54
Warnings: 932

1st Player Difficulty: Normal
```

V2.0 Generated some uncomfortable questions:

Triton Reverb worked well *sometimes*—why?

Time investment for shippable quality?

Storytime…

One day, we were given a deadline by Rod Fergusson (Gears Co-Creator/Studio Head) and Chuck Osiega (Creative Director):

“Get Triton Reverb sounding shippable on one map in 2 weeks or we switch to a proven conventional reverb solution.”

Change of Strategy

1. Reduce number of sounds going into Triton Reverb.
2. Reduce the number of reverb outputs.

Simplification revealed **root causes** of the problems.

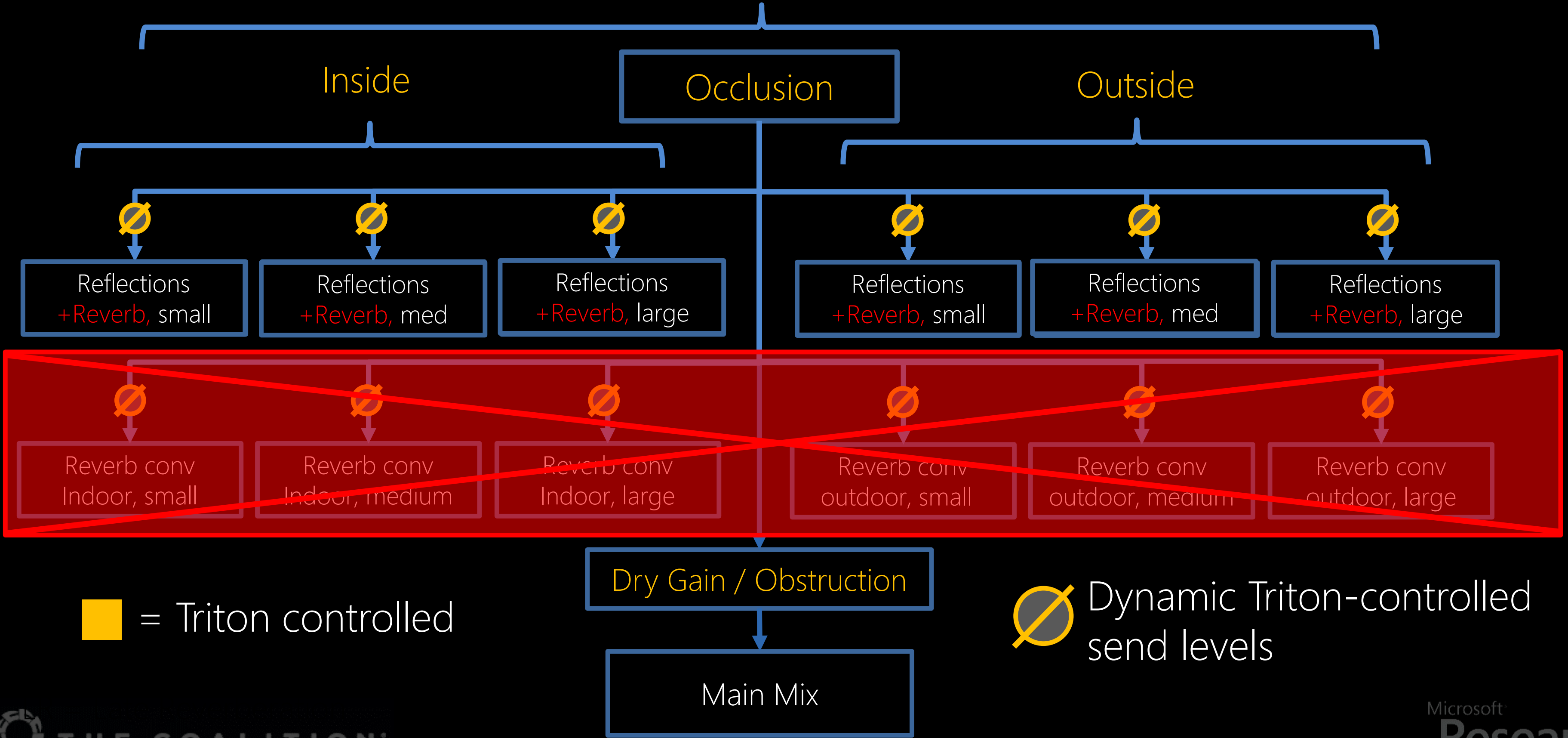
Triton-calculated Occlusion/Obstruction remained enabled for almost all 3D sounds.

V2.5

+ Convolutions
+ Outdoor reverb
+ ER/LR decay

Triton Lookup Results
(per 3D Sound)

ER = Early Reflections
LR = Late Reverb tail



Inside

Occlusion

Outside

Reflections +Reverb, small

Reflections +Reverb, med

Reflections +Reverb, large

Reflections +Reverb, small

Reflections +Reverb, med

Reflections +Reverb, large

~~Reverb conv Indoor, small~~

~~Reverb conv Indoor, medium~~

~~Reverb conv Indoor, large~~

~~Reverb conv outdoor, small~~

~~Reverb conv outdoor, medium~~

~~Reverb conv outdoor, large~~

Dry Gain / Obstruction

Main Mix

🟨 = Triton controlled

Ø Dynamic Triton-controlled send levels

THE COALITION

Microsoft Research

Root Causes of our Triton Challenges

1. Physical dynamic range vs. Aesthetic dynamic range
2. Dry Gain added to point source sounds
3. Physics-based vs. Aesthetics-based reverb wetness/decay times: Emotionally Interpreted Spaces

A Shift in Thinking:
How “Real” is “Too Real” for Game Acoustics?

A Shift in Thinking: How “Real” is “Too Real” for Game Acoustics?

Triton datasets are formed with reality based calculations. BUT:
Not all physical aural phenomena are creatively desirable all the time!

Lesson 1: Dynamic Range

Triton’s ‘real world’ dynamic range needs interpretation into a smaller gameplay range.

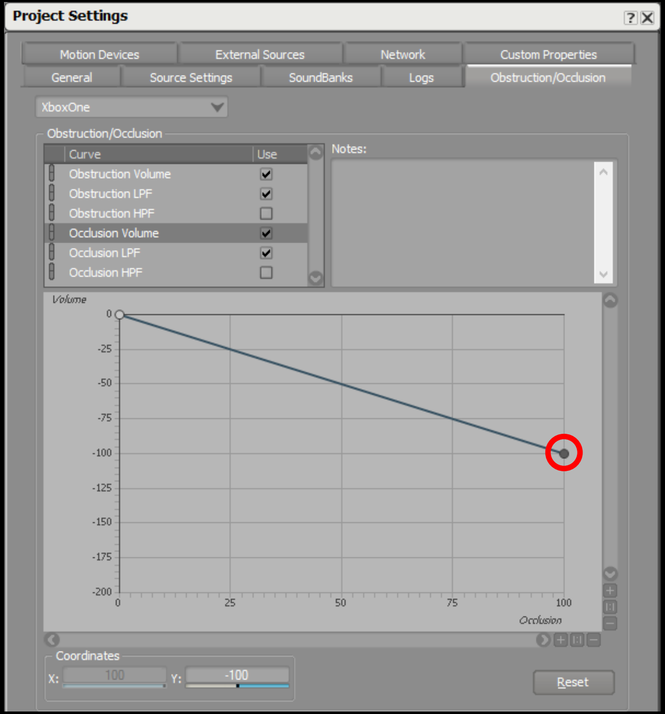
Sound designers in film and games have ALWAYS made this interpretation to create a mix.
Realizing that we needed to apply this same interpretive process to
Triton-Reverb inputs was crucial to shipping.

Physical dB Range vs. Game dB range

Decibel/SPL Range Chart		
	Real World Sounds	**Gears 4 Sounds in "real world dB range"**
0dB	Threshold of human hearing	
10dB	Breathing	
20dB	Whispering	
30dB	Room tone/Light ambient tones	Quiet Level Ambience
40dB		Typical World Sound (Fire, Trees in Light Wind… etc.)
50dB	Conversation	→ Squad Speech ←
60dB	Busy street	
70dB	Vacuum, noisey restaurant	
80dB	Kitchen Blender	Loud World Sound (Large Machinery… etc.)
90dB	Lawn Mower	
100dB	Helicopter 30m above	Kestrel
110dB	Loud Rock Concert	
120dB	Thunderclap (close range)	
130dB	Gunshot	Lancer
140dB		
150dB		
160dB		
170dB		
180dB		
190dB		Grenade (close range)
200dB	Eardrum Rupture	

~35dB of usable Dynamic Range

Final adjustment of occlusion/obstruction curves to account for game-relative dynamic range



XboxOne

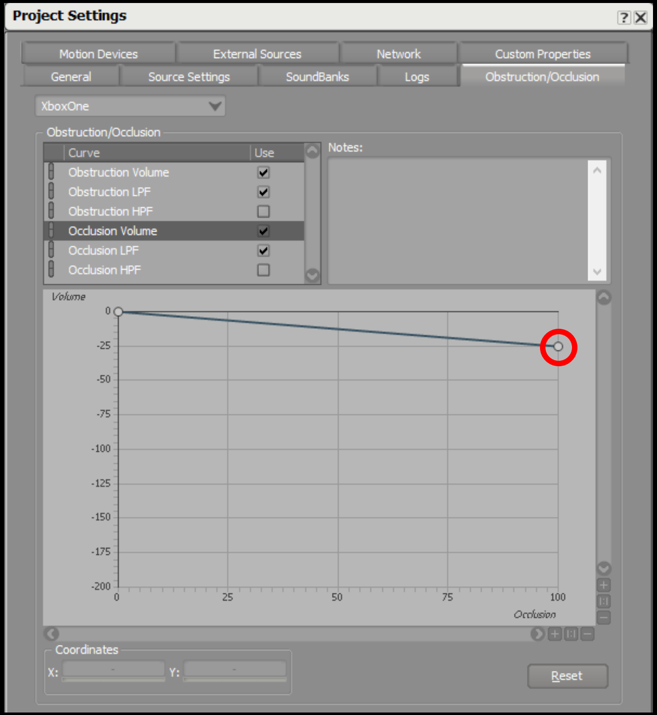
Obstruction/Occlusion

Curve	Use
Obstruction Volume	☑
Obstruction LPF	☑
Obstruction HPF	□
Occlusion Volume	☑
Occlusion LPF	☑
Occlusion HPF	□

Coordinates

X: 100 Y: -100

Physics based dynamic range: 100dB



XboxOne

Obstruction/Occlusion

Curve	Use
Obstruction Volume	☑
Obstruction LPF	☑
Obstruction HPF	□
Occlusion Volume	☑
Occlusion LPF	☑
Occlusion HPF	□

Coordinates

X: - Y: -

Game based dynamic range: 25dB

THE COALITION

Microsoft Research

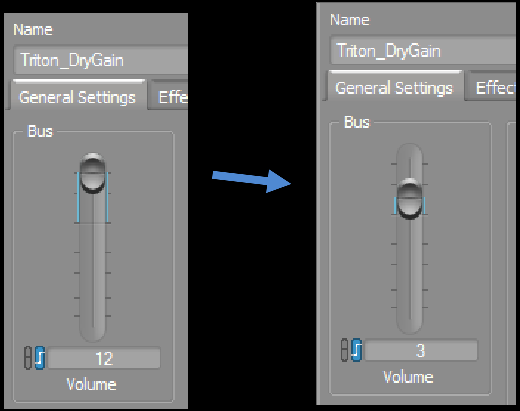
A Shift in Thinking: How “Real” is “Too Real” for Game Acoustics?

Lesson 2: Dry Gain

Small enclosed spaces can amplify dry sound in reality.

When simulated in gameplay, this can sound unexpected.

Solution: The ceiling of this value was originally +12db - we clamped this gain to +3dB



Name

Triton_DryGain

General Settings | Effe

Bus

12

Volume

Name

Triton_DryGain

General Settings | Effec

Bus

3

Volume

A Shift in Thinking: How "Real" is "Too Real" for Game Acoustics?

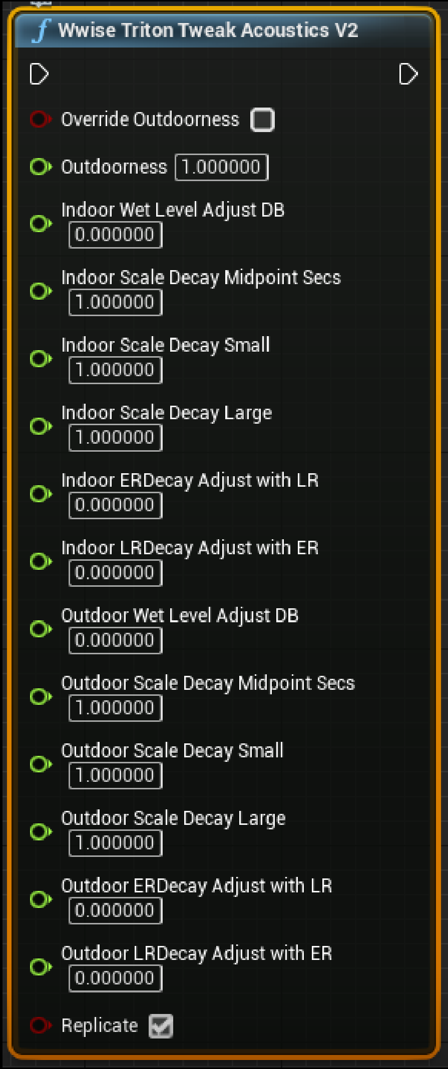
Lesson 3:

Triton simulations can violate expectations:

- small spaces can generate **very** long decay times.
- large spaces can generate short decay times.

In games, we have emotional requirements for reverb to inform storytelling.

Solution: Scriptable designer-based interpretations of the Triton data. AKA The "Triton Tweak Acoustics node".


Wwise Triton Tweak Acoustics V2

Override Outdoorness □

Outdoorness 1.000000

Indoor Wet Level Adjust DB 0.000000

Indoor Scale Decay Midpoint Secs 1.000000

Indoor Scale Decay Small 1.000000

Indoor Scale Decay Large 1.000000

Indoor ERDecay Adjust with LR 0.000000

Indoor LRDecay Adjust with ER 0.000000

Outdoor Wet Level Adjust DB 0.000000

Outdoor Scale Decay Midpoint Secs 1.000000

Outdoor Scale Decay Small 1.000000

Outdoor Scale Decay Large 1.000000

Outdoor ERDecay Adjust with LR 0.000000

Outdoor LRDecay Adjust with ER 0.000000

Replicate ☑

THE COALITION

Triton OFF

```
[illegible] 5584
Audio Memory: 435558502 bytes, 425350k, 415mb
Pause(No) LoadScreen(No)
```

```
You do NOT have debug mem enabled

1. GearMainMenuEntry_P
2. SP_Rescue_B_P
3. SP_Rescue_B_P
4. SP_Rescue_B_P
   6 debug jumppoints used
   4 checkpoint reloads
```

```
Warnings: 3446
1st Player Difficulty: Normal
```

Designer crafted spaces: reverb/rain transition

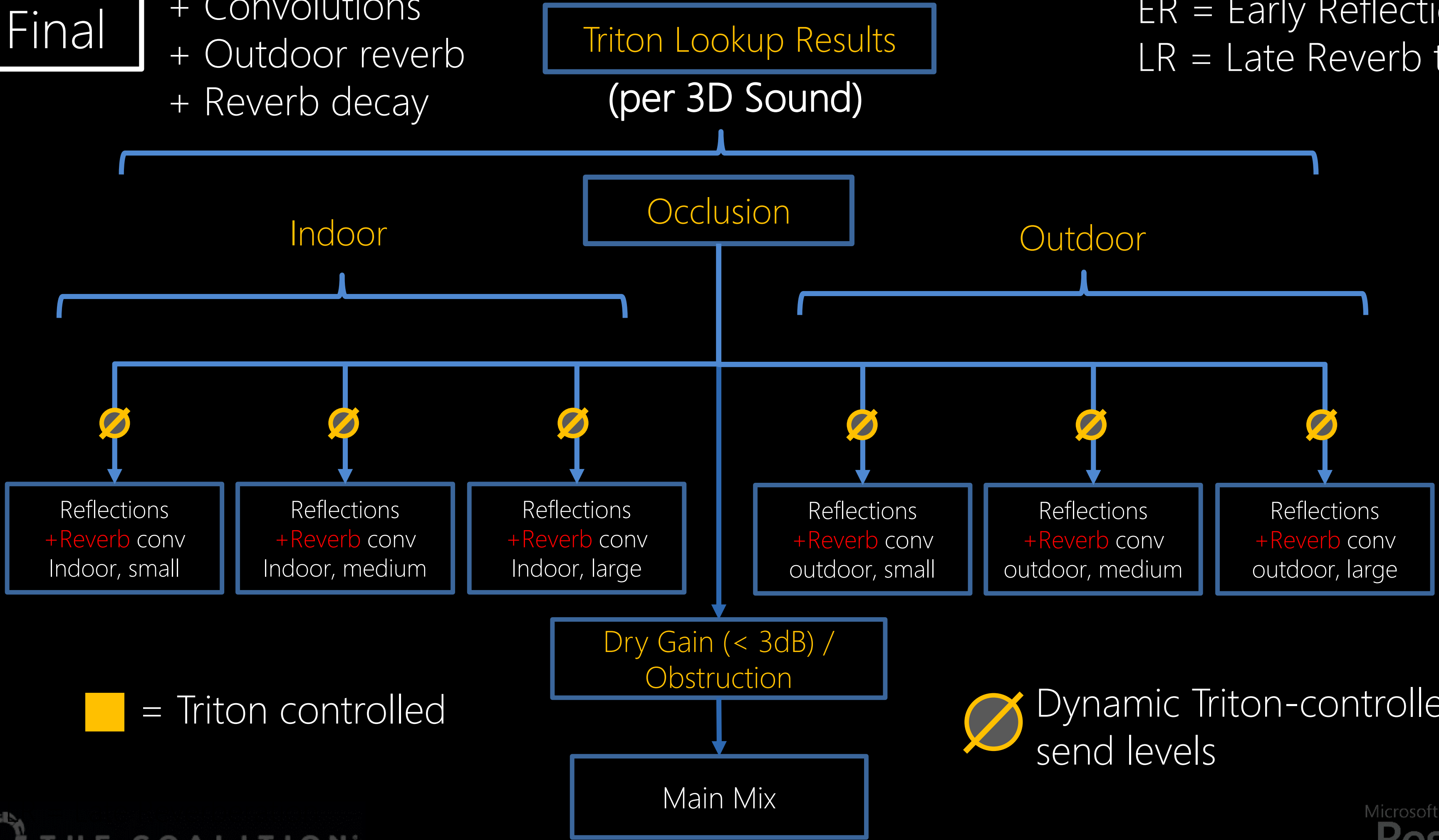
Triton ON

Designer crafted spaces: reverb/rain transition

Final

+ Convolutions
+ Outdoor reverb
+ Reverb decay

ER = Early Reflections
LR = Late Reverb tail



Triton Lookup Results

(per 3D Sound)

Occlusion

Indoor

Outdoor

Reflections +Reverb conv Indoor, small

Reflections +Reverb conv Indoor, medium

Reflections +Reverb conv Indoor, large

Reflections +Reverb conv outdoor, small

Reflections +Reverb conv outdoor, medium

Reflections +Reverb conv outdoor, large

Dry Gain (< 3dB) / Obstruction

Main Mix

🟨 = Triton controlled

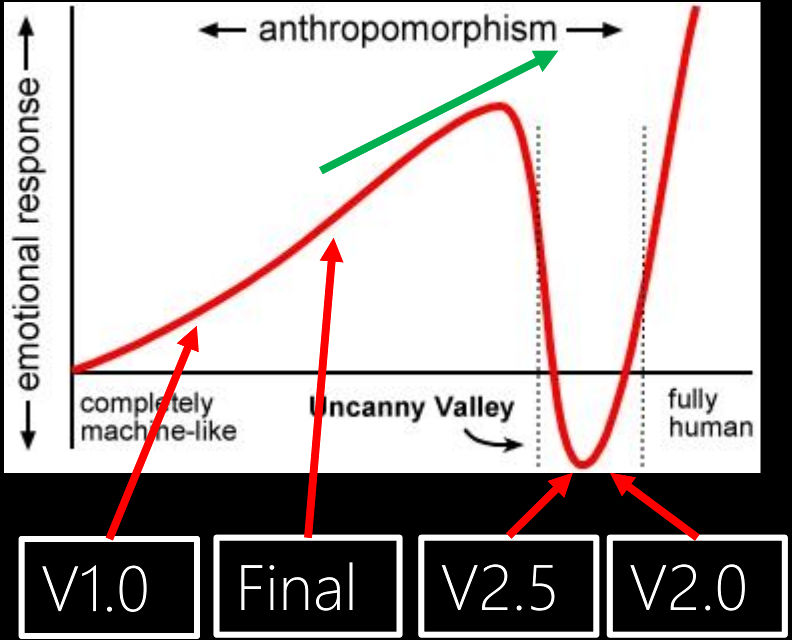
⌀ Dynamic Triton-controlled send levels

Gears 4 Triton Implementation: Final

Lessons Learned; Summary

- Tuning and Testing of this unprecedented system was our biggest risk.
  - Reduce number of Wwise parameters Triton is driving. Simplify! Limit Triton Reverb to a sensible dB range.
- Focus on the *emotionally* motivated "Cinematic Experience" instead of the reality-inspired "Realistic Experience".

Our Trip to The Uncanny Valley…



V1.0

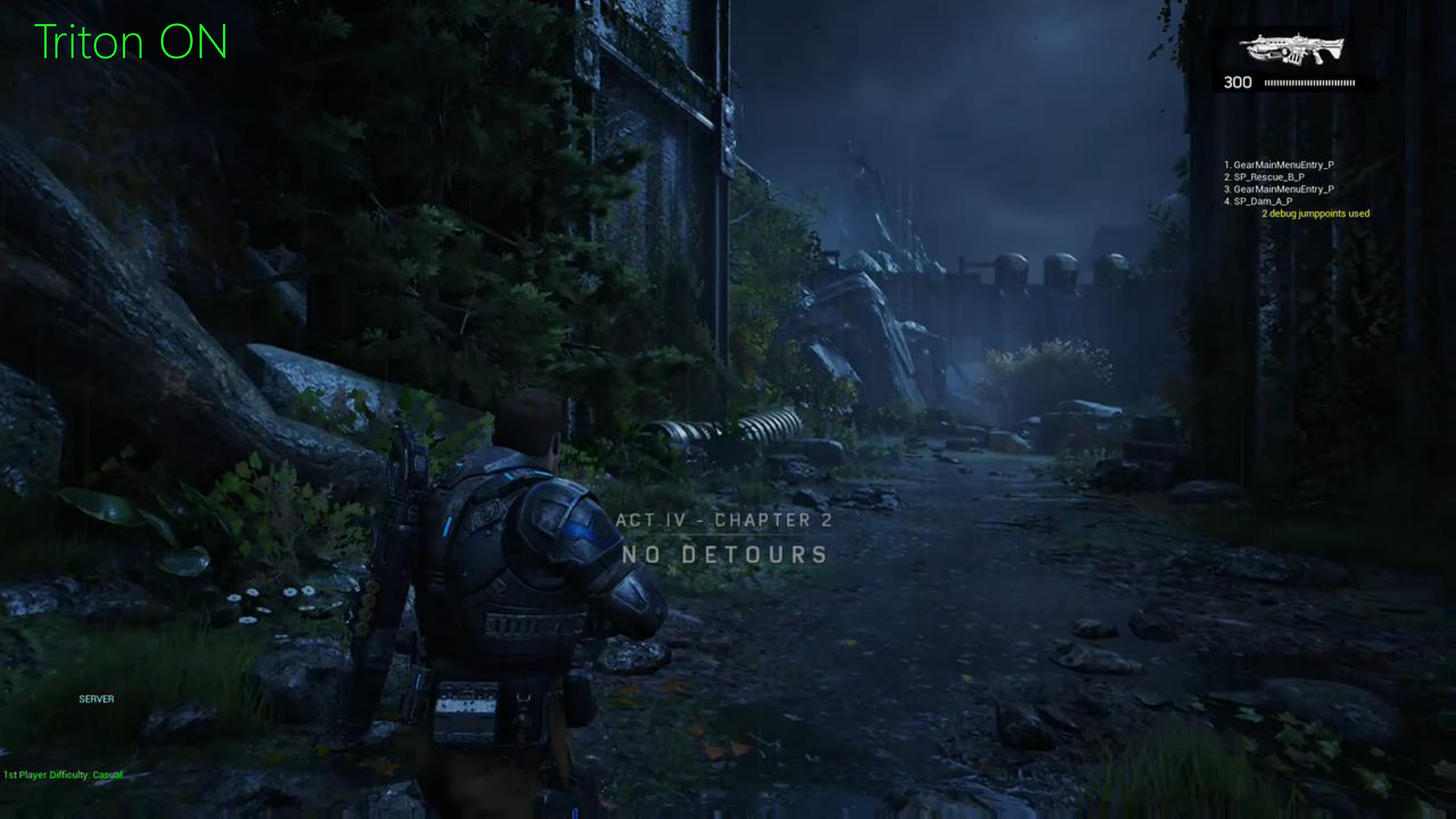
Final

V2.5

V2.0

We've only scraped the surface of what's possible with Triton.

Triton ON



```
1. GearMainMenuEntry_P
2. SP_Rescue_B_P
3. GearMainMenuEntry_P
4. SP_Dam_A_P
        2 debug jumppoints used
```

1st Player Difficulty: Casual

Conclusion

- Baked wave acoustics for dynamic sources & listener is now practical
- Designed occlusion, obstruction, reverb wetness, and decay times in production game levels
- Key idea: Do accurate physics → perceptual data → game
- Future
  - Next: directional initial sound and early reflections, outdoor echoes, streaming 100→25MB RAM, faster bakes
  - Portability
  - Longer term: dynamic geometry e.g. doors/destruction

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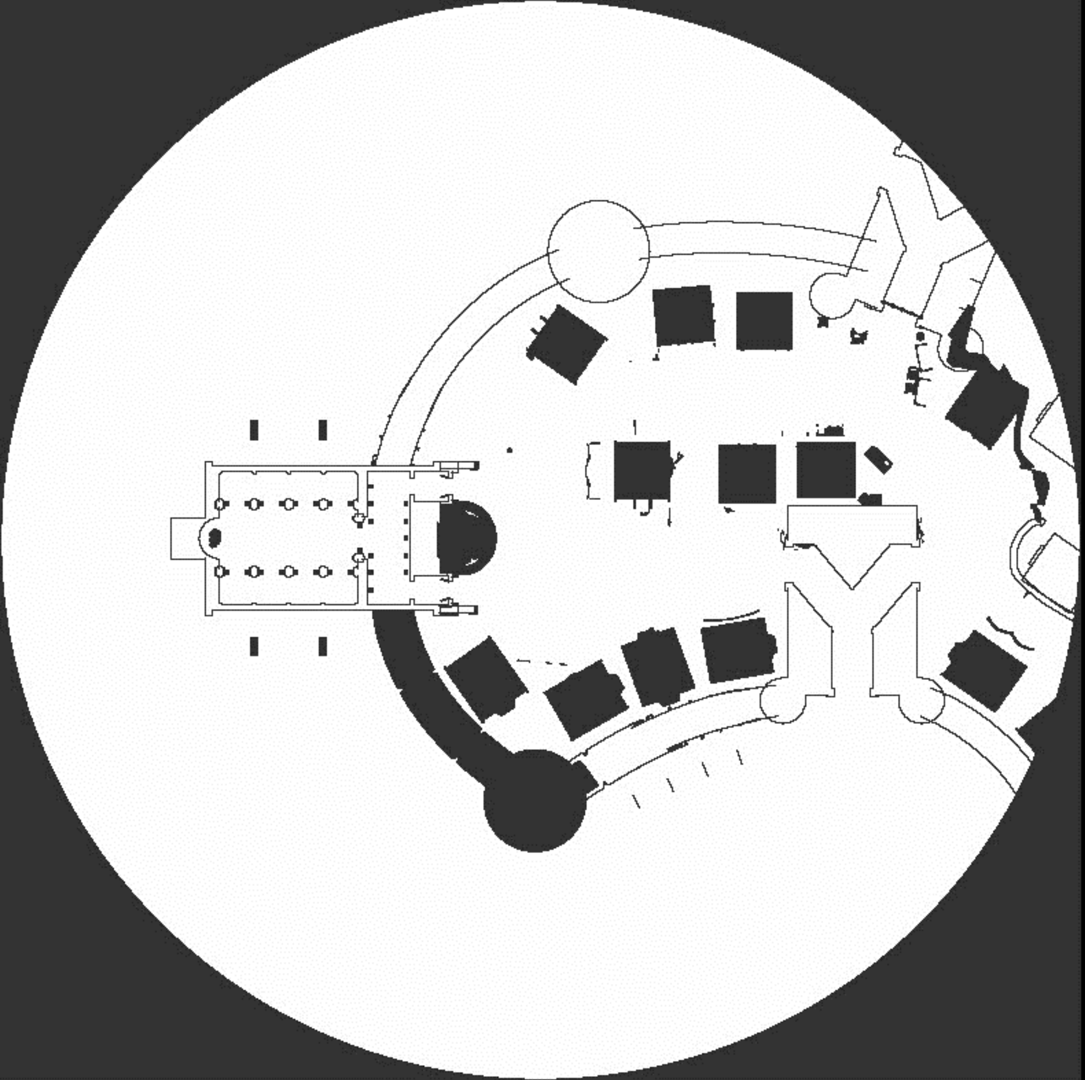
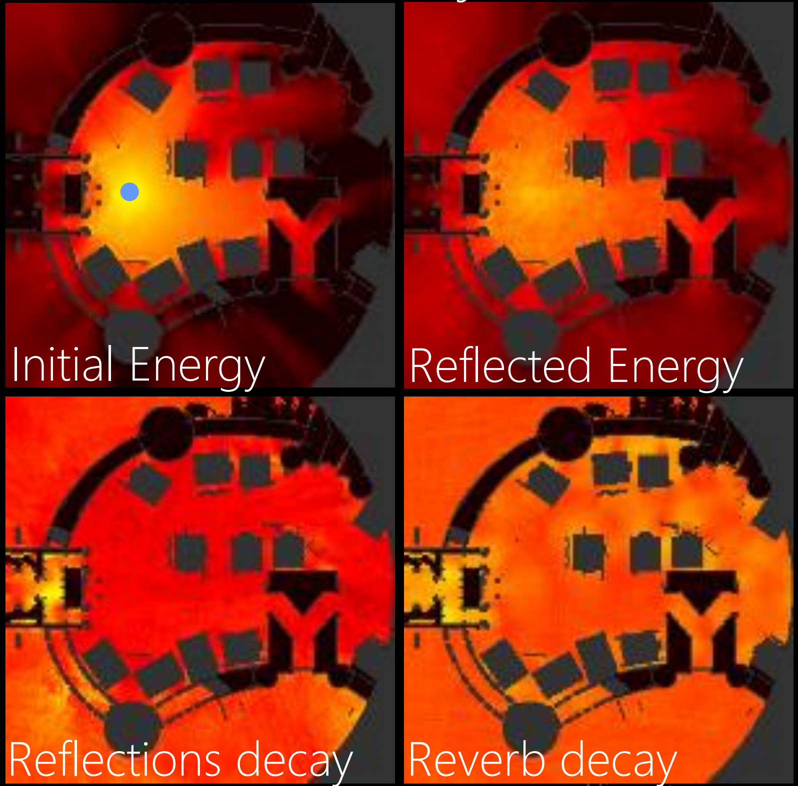
…for helping invent adaptive sampler

Kristofor Mellroth (Head of Audio),
…for bridging Research and Games



Questions?

Slide deck with videos and papers available @www.nikunjr.com



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