BEHAVIOUR
INTERACTIVE

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HAVIOUR

Methodical GPU Profiling

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Introduction

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Behaviour Interactive

Socials at the end

Who are we?

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ROTTERDAM

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UK - NORTH

Agenda

- Motivation
- Strategy
- Investigate
- Planning
- Takeaways

Motivation

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Motivation

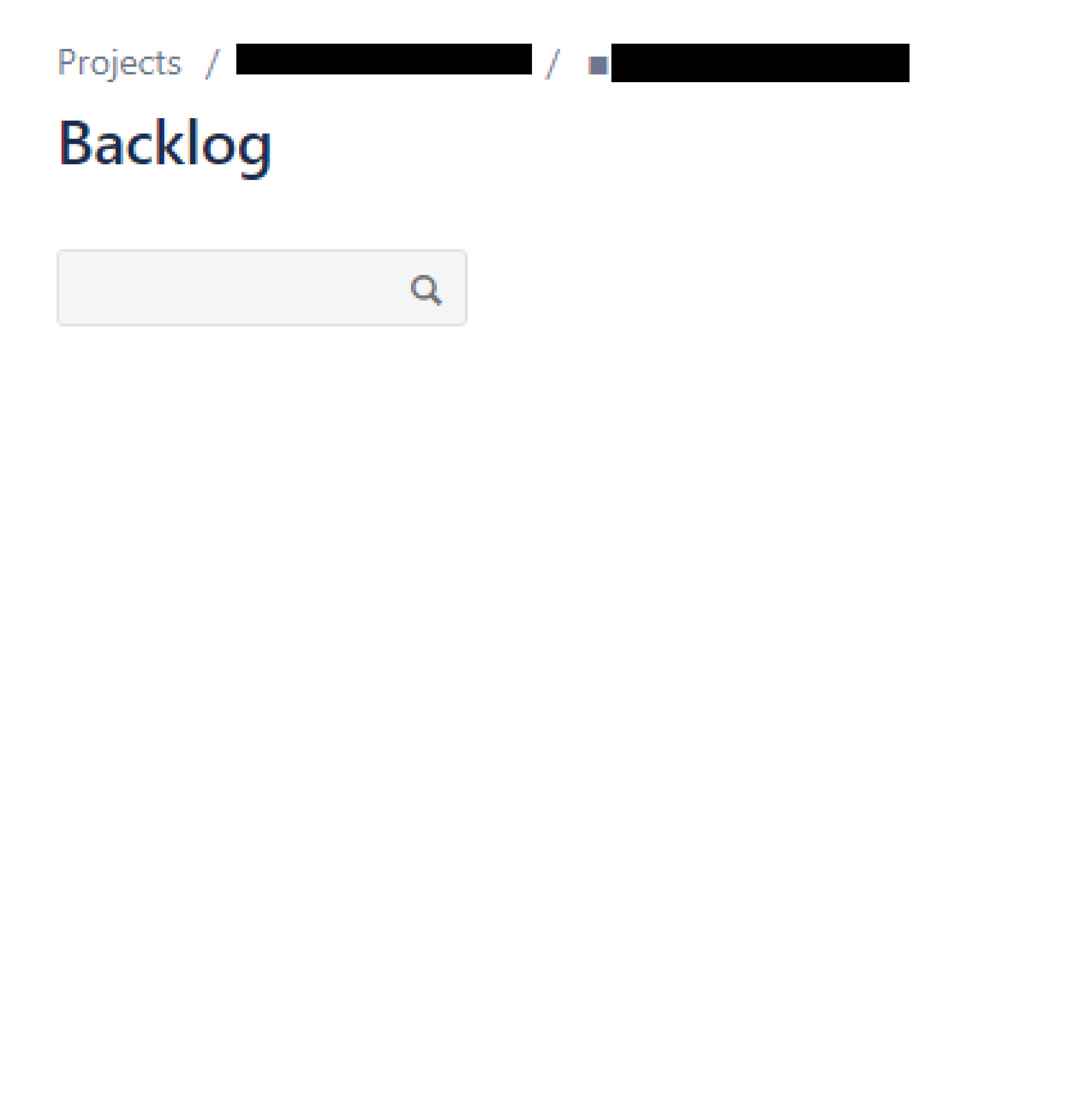
Scope

- WFH
- 3+ years w/ 6-10 prog
- Graphics support on consoles
- Optimizations ☺

Motivation

Workload

- Inherently undefined
- Bottlenecks are always changing
- Needed a strategy



Projects / [redacted] / [redacted]

Backlog

Origin

Optimization Origins

Ideas Familiarity with code base, articles, talks, discussions	1
Reports Observed performance issues by other developers & playtesters	2
Profiling Hard work!	3

Origin

Optimization Origins

Ideas Familiarity with code base, articles, talks, discussions Unreliable	1
Reports Observed performance issues by other developers or playtesters Might not Happen	2
Profiling Hard work! Scientific	3

Strategy

Strategy

while(frameTime > 16.6)

- Optimizing is scientific
- Clear Goal
- Defined & Provable Results
- Iterative workflow:
  - Analyze
  - Optimize
  - Confirm
  - Repeat

Strategy

Monthly Profiling Suite

- Goals
  - Find optimization ideas
  - Re-evaluate status
- Adjust to current phase
  - Do you *need* more data?
  - Don’t waste time

Strategy

Narrow it Down

- Our Profiling Suite
- Divide into steps
- Work our way downwards
    - Scope 1: Game
    - Scope 2: Level
    - Scope 3: POI
    - Scope 4: Investigate

Strategy

Scope 1: Game

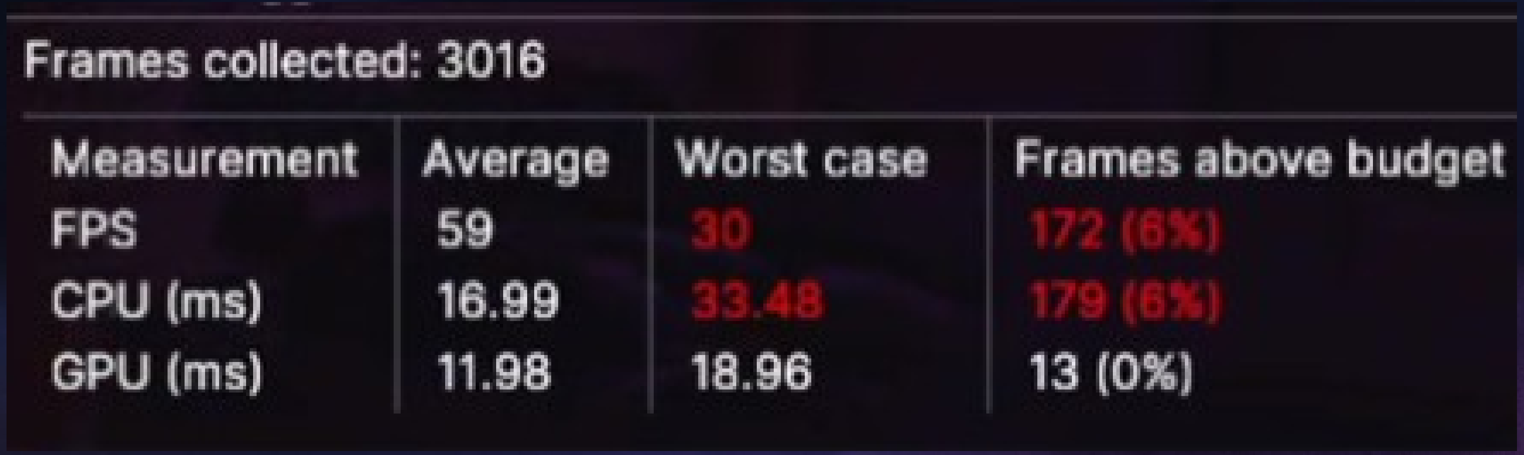
- 60 FPS
- Test all levels

KING OF MEAT
KING OF MEAT

Strategy

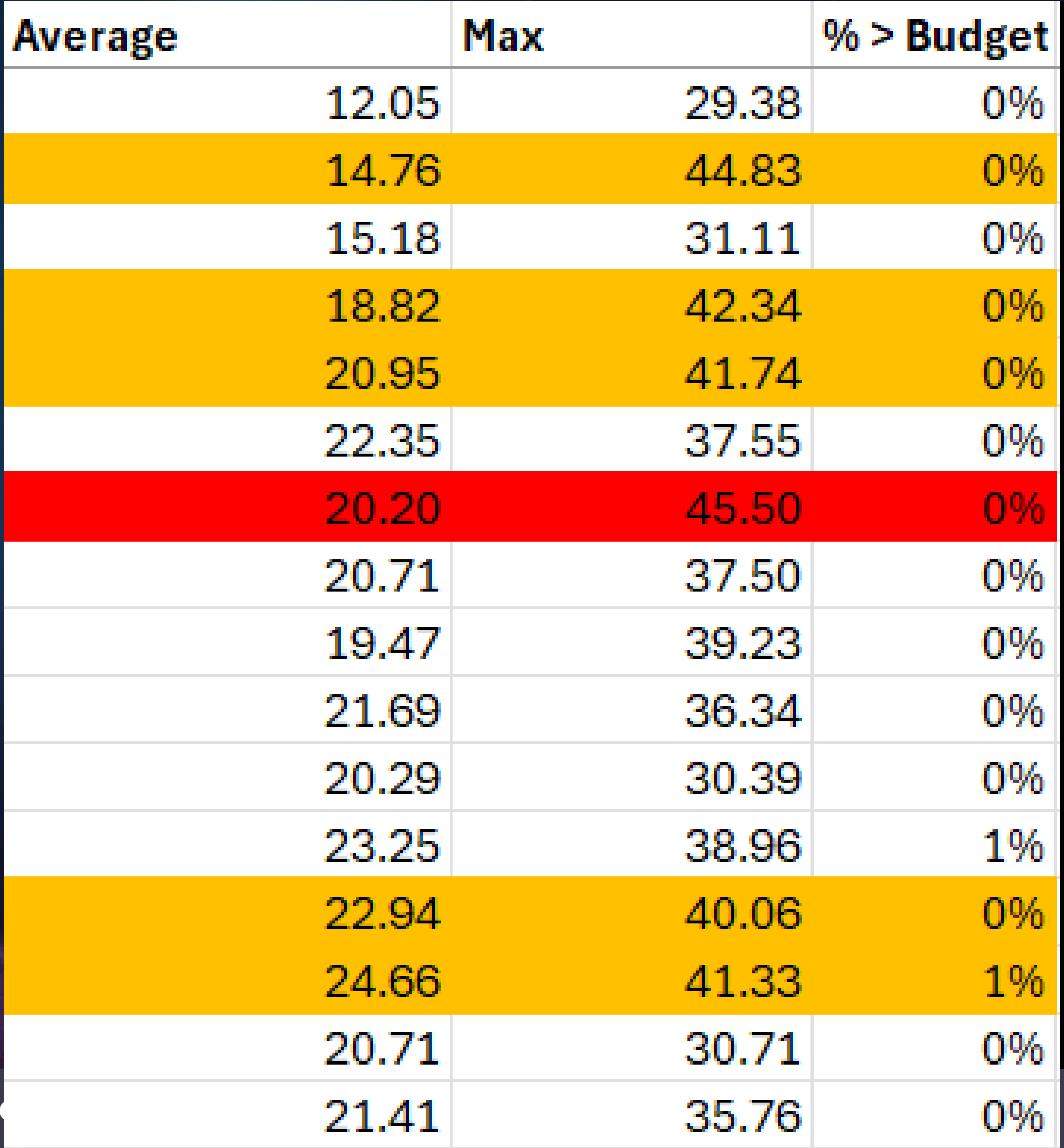
Scope 1: Game

- Fine, only official levels
- Still tons
- Quick tool for QA



Frames collected: 3016

Measurement	Average	Worst case	Frames above budget
FPS	59	30	172 (6%)
CPU (ms)	16.99	33.48	179 (6%)
GPU (ms)	11.98	18.96	13 (0%)

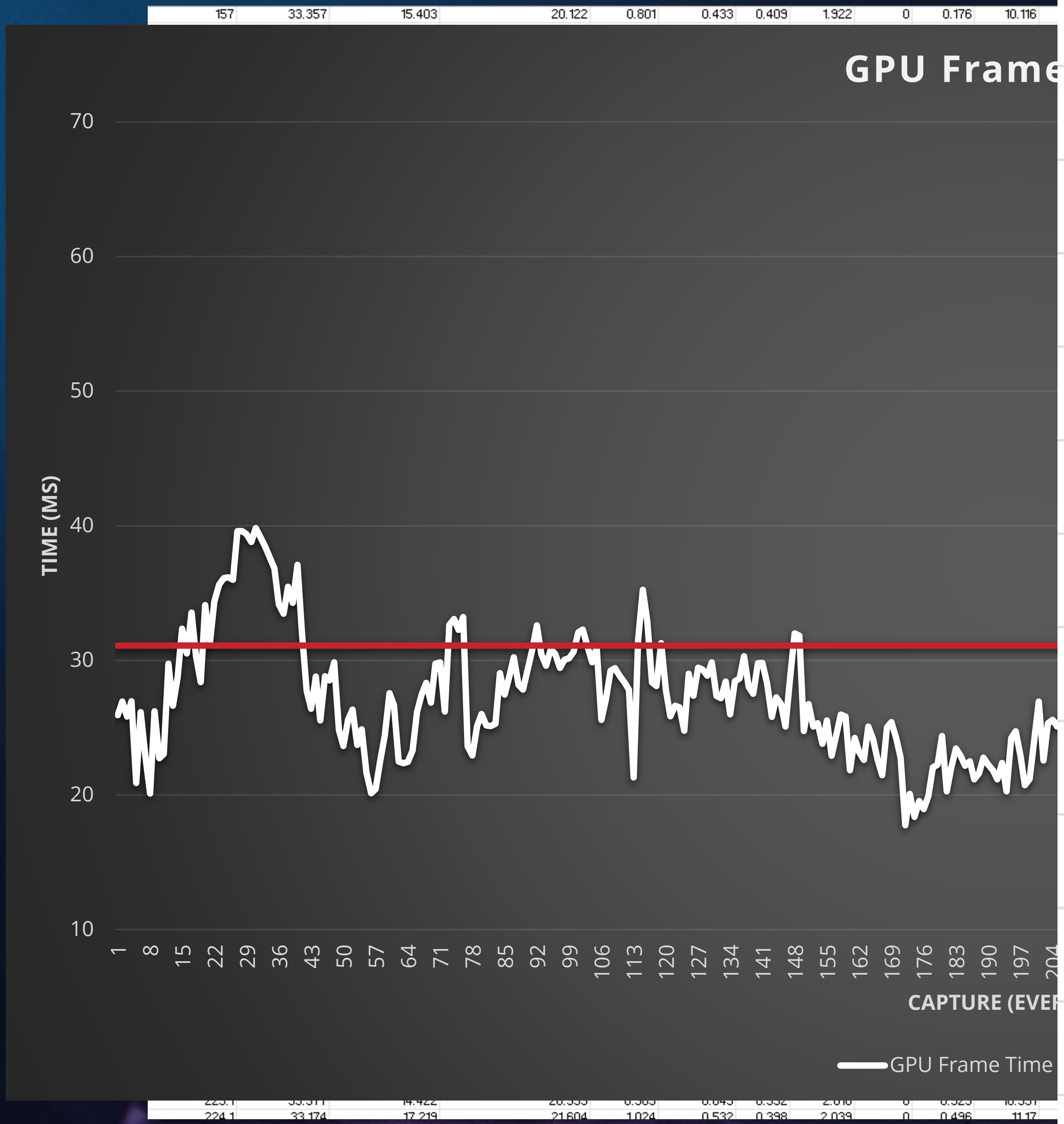


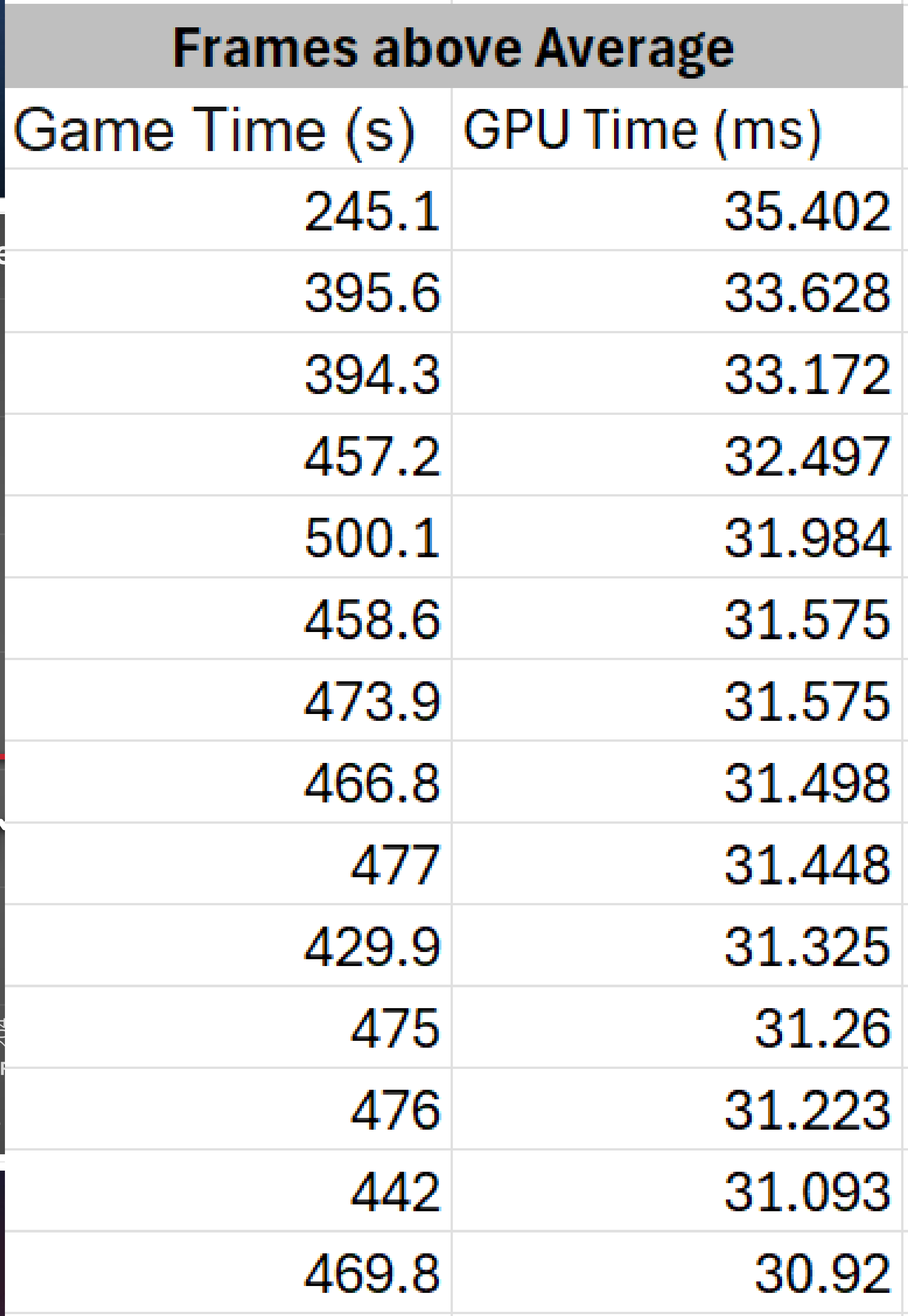
Average	Max	% > Budget
12.05	29.38	0%
14.76	44.83	0%
15.18	31.11	0%
18.82	42.34	0%
20.95	41.74	0%
22.35	37.55	0%
20.20	45.50	0%
20.71	37.50	0%
19.47	39.23	0%
21.69	36.34	0%
20.29	30.39	0%
23.25	38.96	1%
22.94	40.06	0%
24.66	41.33	1%
20.71	30.71	0%
21.41	35.76	0%

Strategy

Scope 2: Level

- Selected some levels
- Look deeper
- Playthrough Profiler
  - Collect detailed frame data
  - GPU frame-time
  - Detailed breakdown into passes
  - Exported as .tsv files, imported in excel
- Lot of data
  - Process w/ Graphs/Algorithms
  - Worst frames -> POI



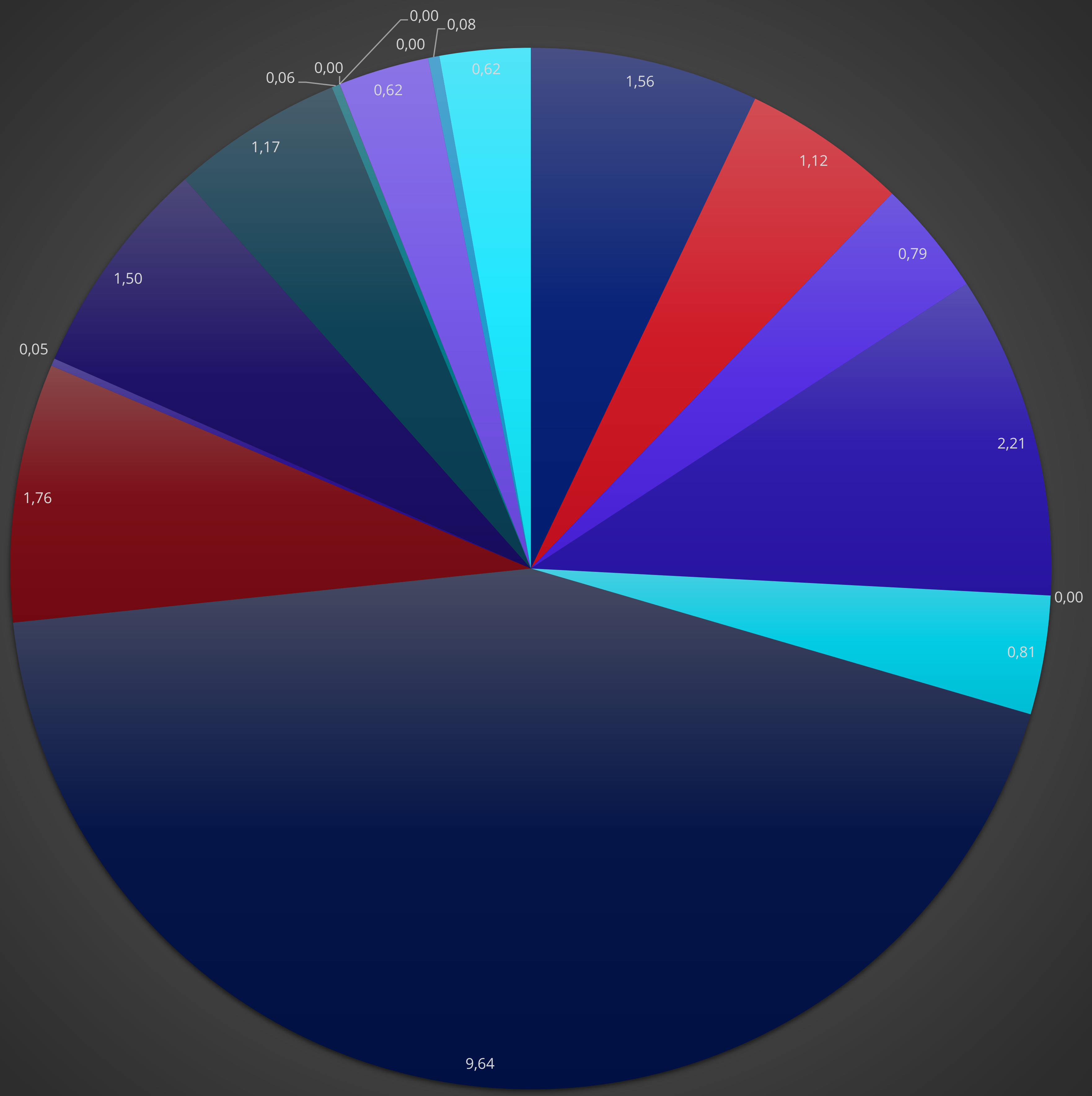


Frames above Average	
Game Time (s)	GPU Time (ms)
245.1	35.402
395.6	33.628
394.3	33.172
457.2	32.497
500.1	31.984
458.6	31.575
473.9	31.575
466.8	31.498
477	31.448
429.9	31.325
475	31.26
476	31.223
442	31.093
469.8	30.92

Strategy

Scope 3: Point of Interest

- List of POIs
- Enough to start diving deeper?
- Narrow down
  - Match with gameplay video using game time
  - Find new performance issues
  - Skip
    - Similar spikes
    - Non-prog work
    - Known issues



Frame Breakdown

Strategy

Scope 4: Investigate

- Look at POI
- Poor performance on a render pass?
- How to optimize?

Investigate

Investigate

How?

- How do you optimize something?
- Depends on what you're optimizing
  - Rasterized Meshes
  - Full-screen Shader
  - Compute Shader

Investigate

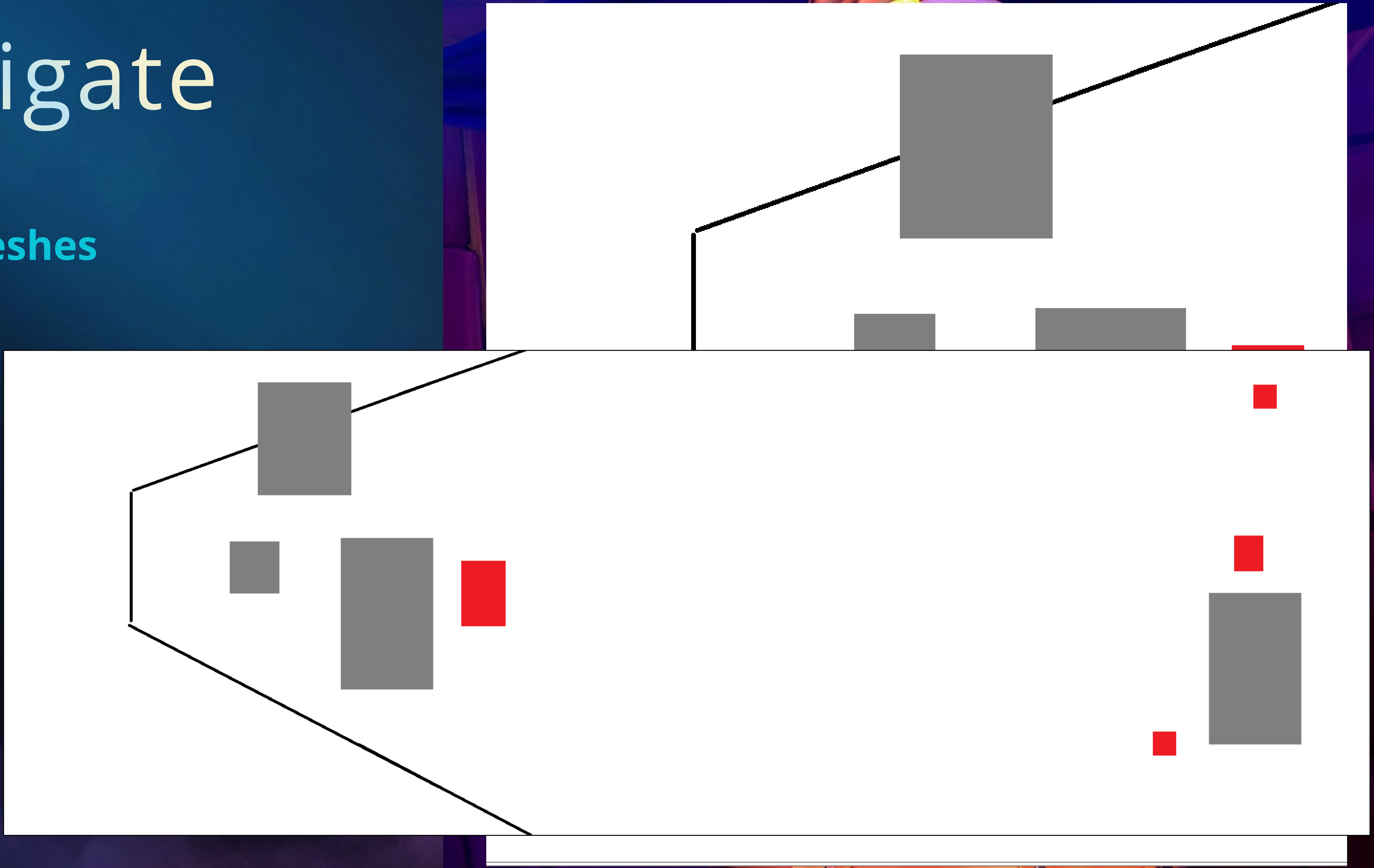
Rasterized Meshes

- GPU deals with large quantities
- Draw call spawns vert shaders, spawns …
- Take a top-down approach
- What can you reduce?

Investigate

Rasterized Meshes

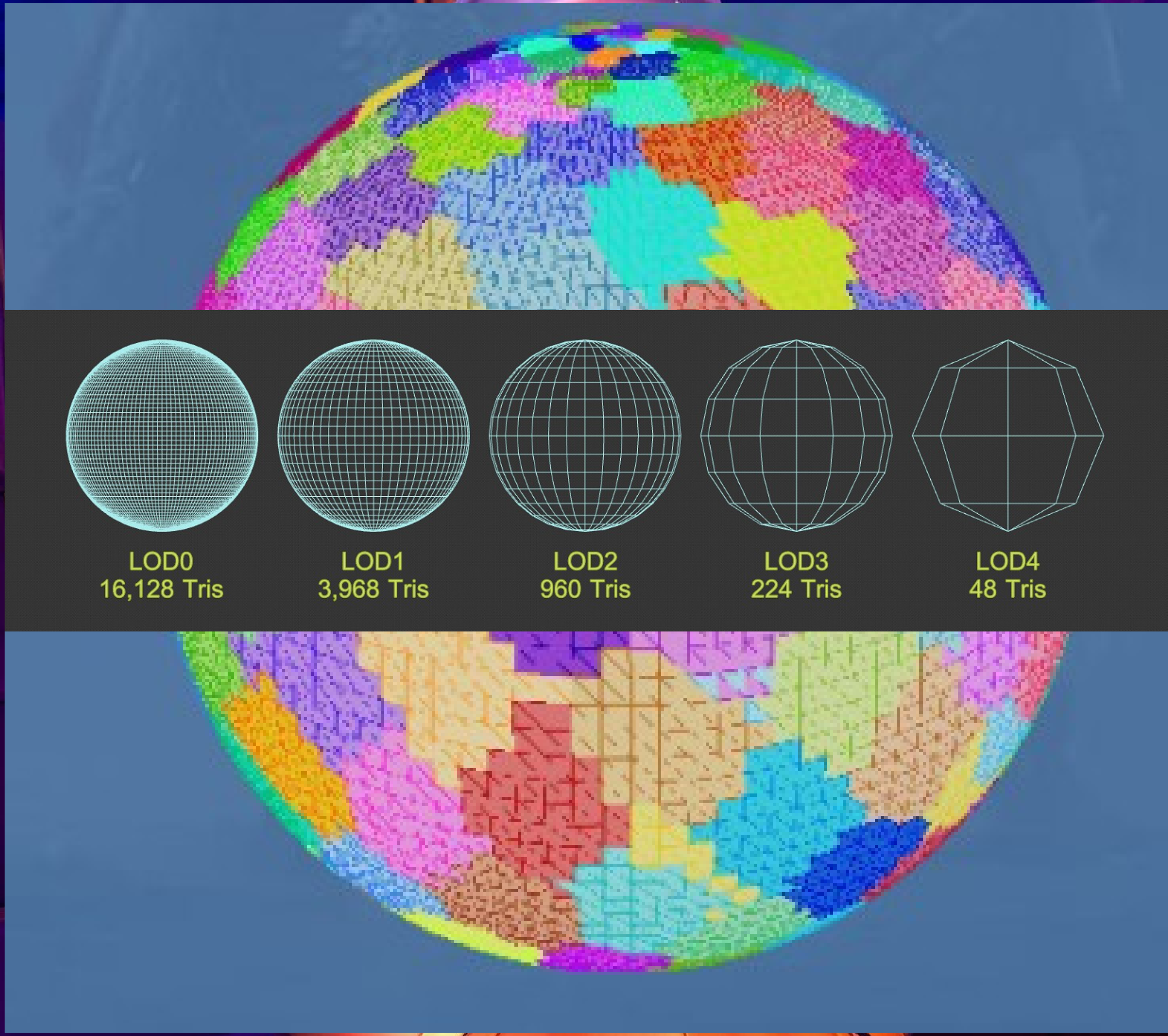
- Draw calls
  - Frustum Culling
  - Occlusion Culling
  - Distance Culling



Investigate

Rasterized Meshes

- Draw calls
- Vertices
  - Optimize Assets
  - Create LODs (and implement)
  - Mesh Clusters
  - Triangle Culling



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Investigate

Rasterized Meshes

- Draw calls
- Vertices
- Pixels
  - Upscaling
  - VRS

Investigate

Rasterized Meshes

- Draw calls
- Vertices
- Pixels
- Lights
  - Spawns even more work!
  - Lights, decals
  - We use clustered rendering
    - With a simple z-range filter
    - (short sight-lines)

Investigate

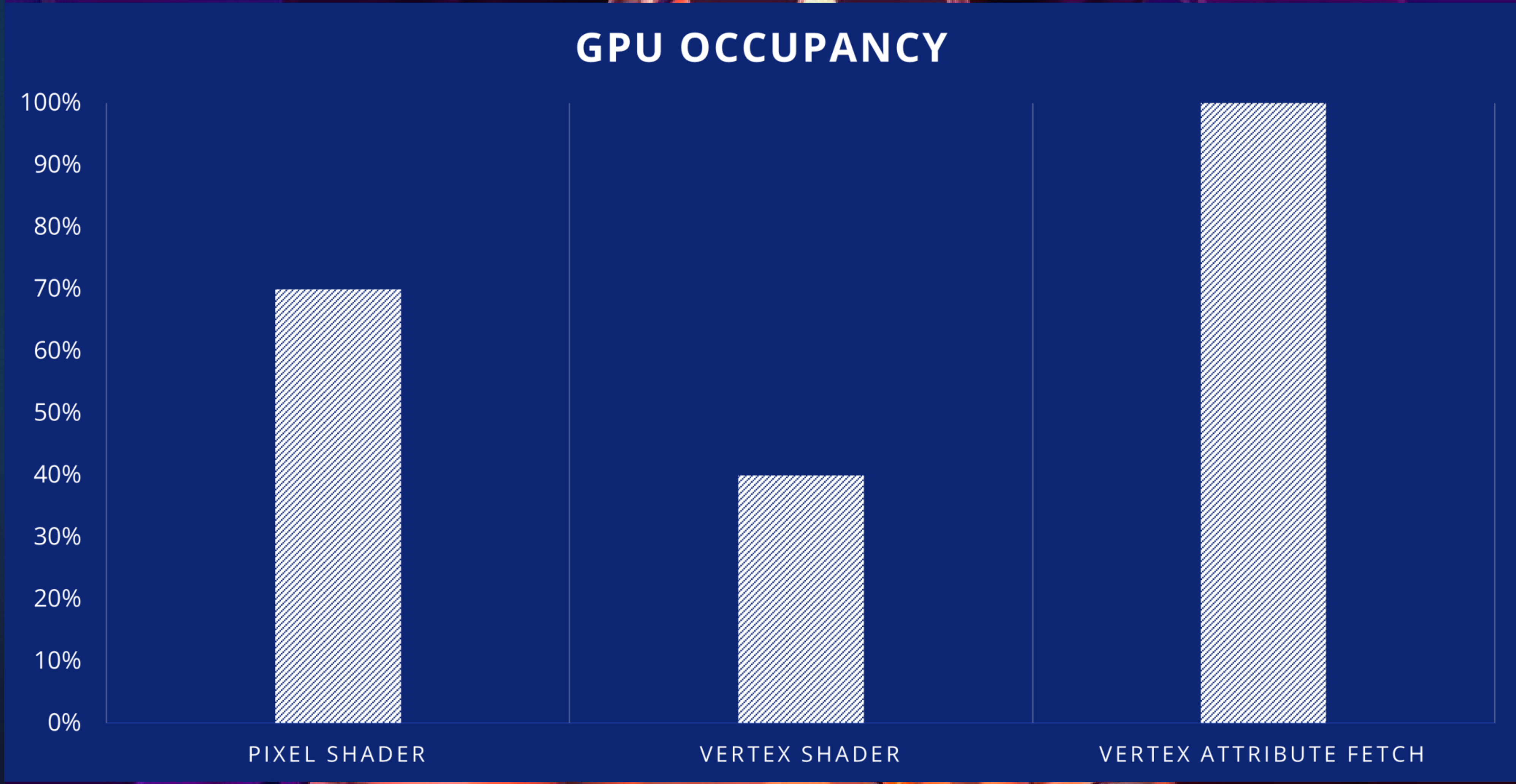
Rasterized Meshes

- Draw calls
- Vertices
- Pixels
- Lights
- Don’t do everything blindly

Investigate

Learn From Our Mistakes

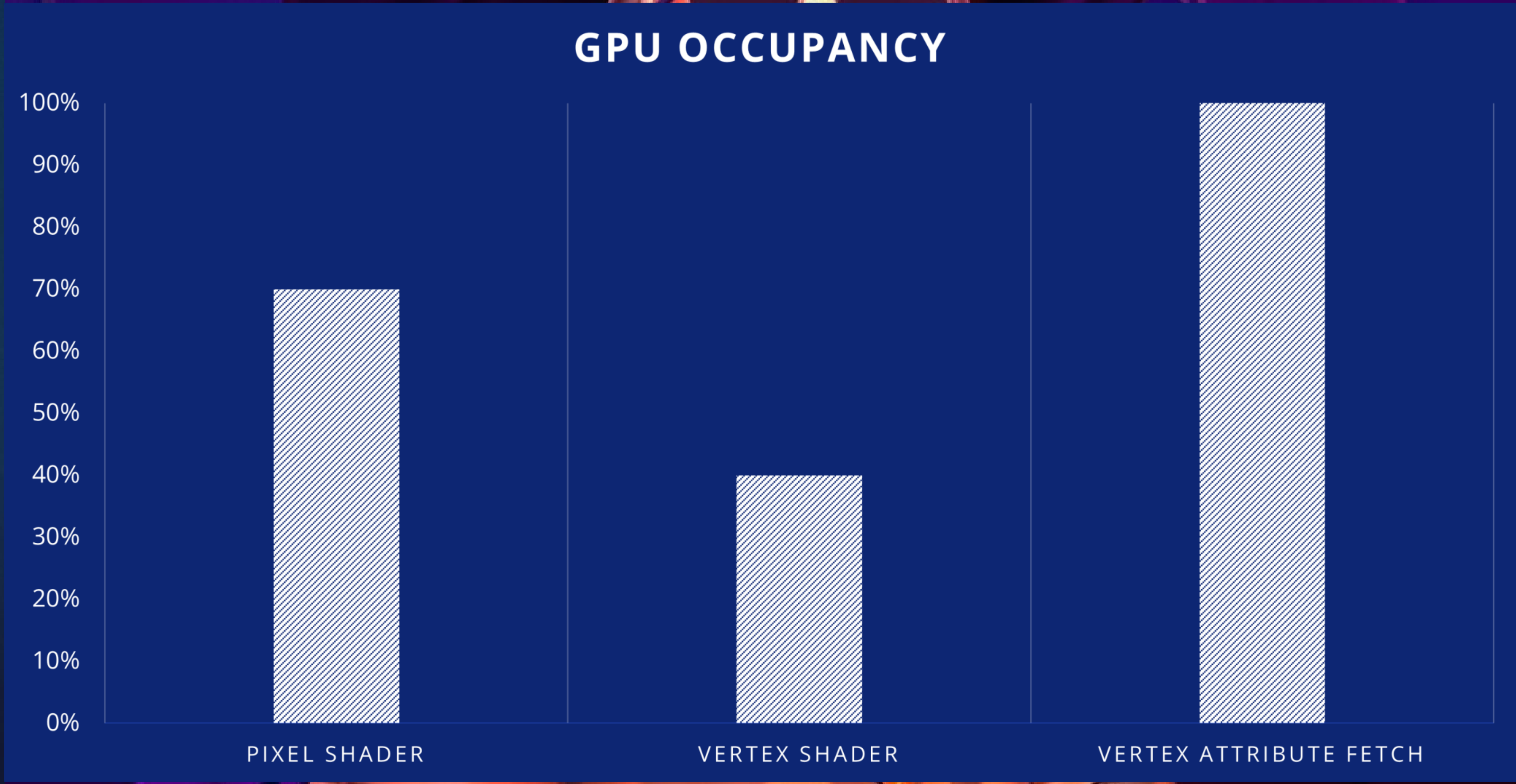
- Main pass slow
  - Bottleneck should be pixel shaders
  - Pixel shaders low occupancy
  - Vertex shaders also low
  - Bottleneck in VAF



Investigate

Learn From Our Mistakes

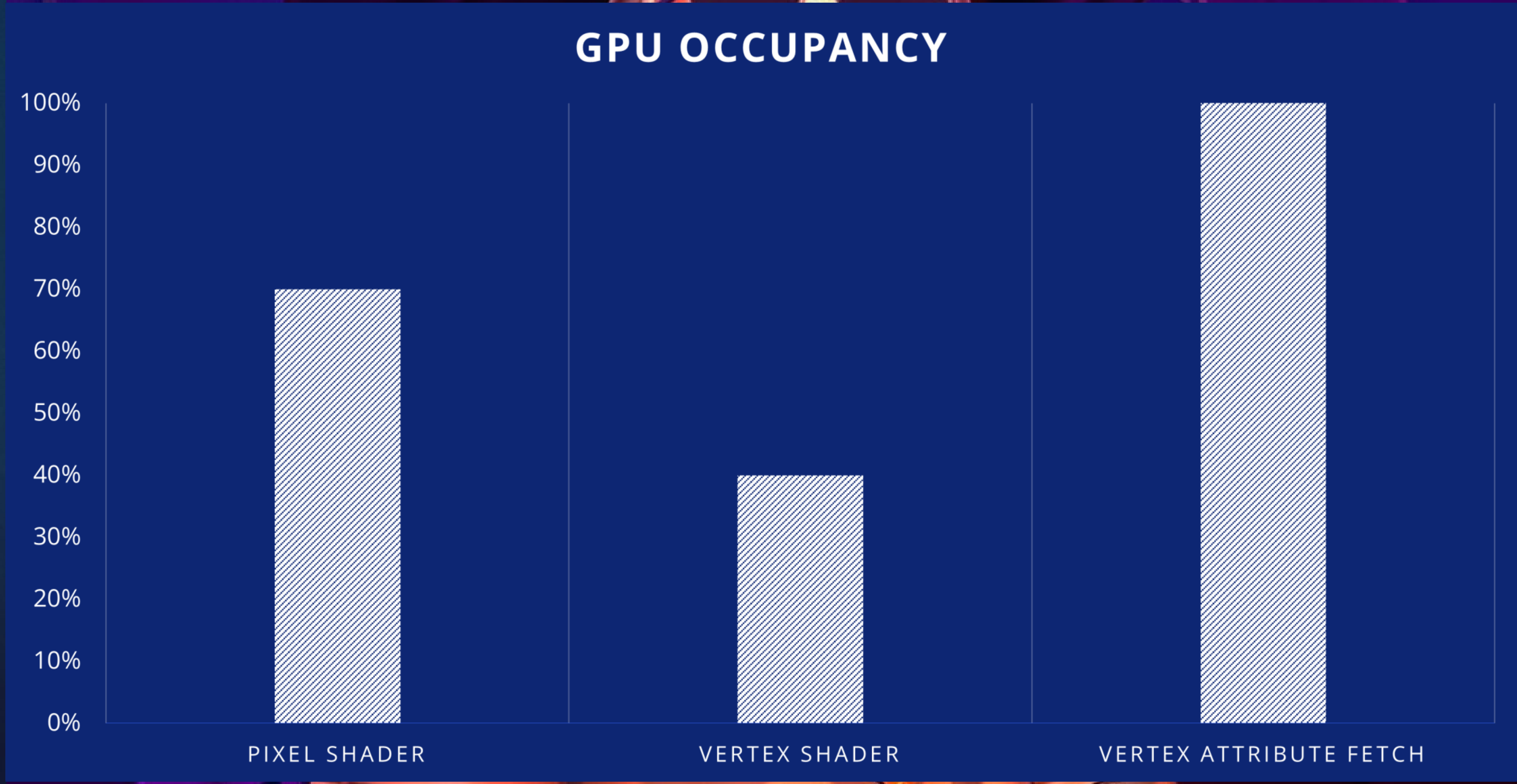
- Main pass slow
- Tried everything we thought we could
  - Don’t read attributes you don’t need
  - Separate vertex attribute streams
  - Compress vertex attributes



Investigate

Learn From Our Mistakes

- Main pass slow
- Tried everything we thought we could
- Nothing worked
    - Goal: Unlock pixel shader
    - Overzealous shader optimizations
    - Vertex workload vs pixel workload
    - Rebalance, change the input



Investigate

Shader Optimizations

- Can we optimize shaders now?
- After you've done everything else
  - (usually)
  - Optimize (pixel) shaders
- FS pass / Compute
  - No larger pipeline
  - 1 consideration

Investigate

Shader Optimizations

- Not entirely in the scope of this talk
- Quick Thoughts:
  - Waste less!
  - Reduce
  - Reuse
  - ~~Recycle~~

Reduce
do calculations once

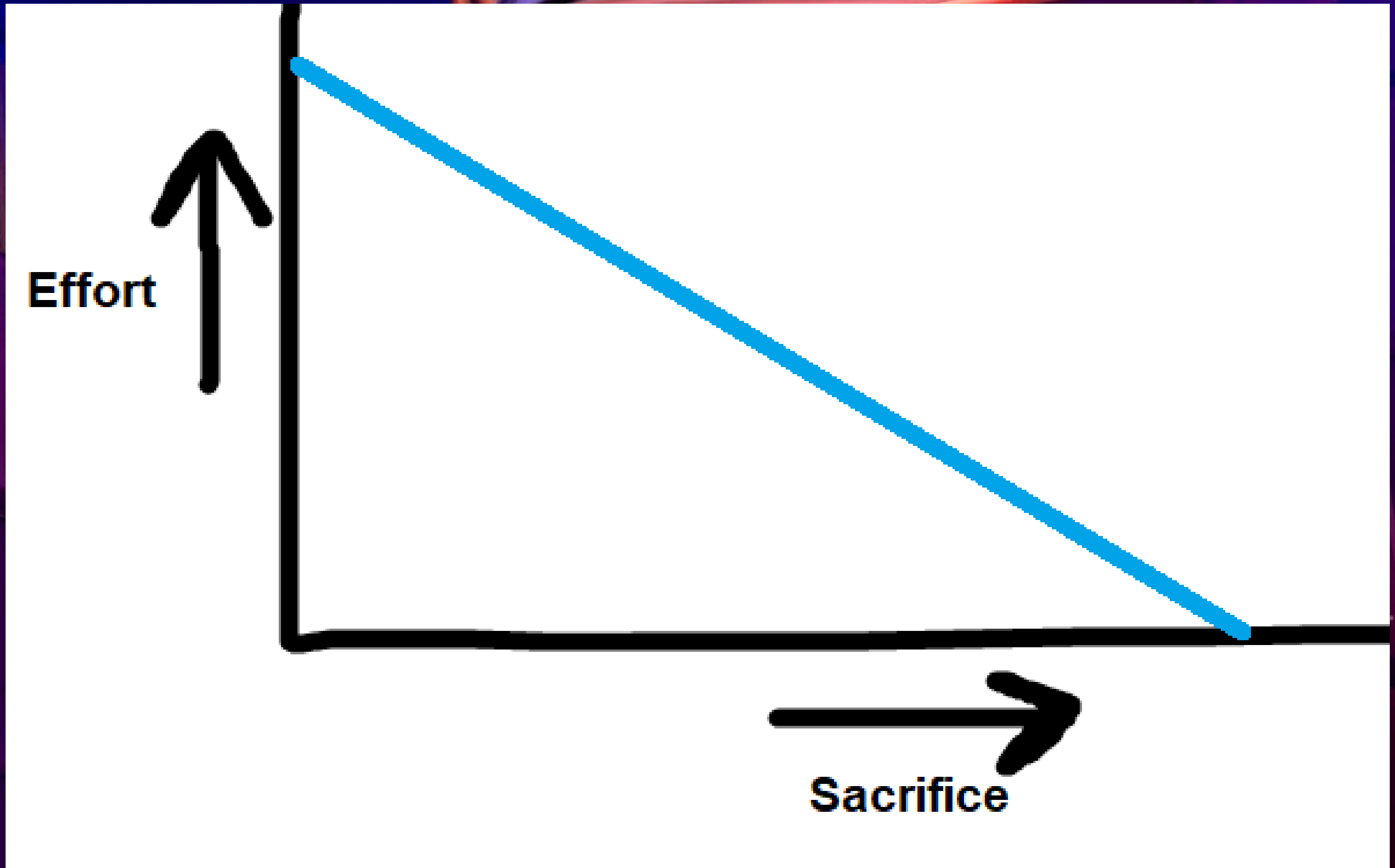
Reuse
use data you already computed

~~**Recycle**~~
~~Create new products from waste~~

Investigate

Know Your Project

- Consider this
  - You know your project the best
  - Optimizations are rarely without a sacrifice
- What are you willing to give up?
- Less Sacrifice = More Effort



Investigate

Post-Optimization

- Sacrifices were made
- Don’t keep them blindly!
- Prove impact & stability:
    - Profile before/after
    - Screenshot before/after

Planning

Planning

Agile

- Very agile
- We had a lot of autonomy
- Status update
- Re-evaluate monthly
- Sprint-like planning

Planning

Prioritize

- How do you determine priority?
- Discuss:
  - Impact
  - Complexity
  - Risk
  - Sacrifice
- Every idea should be considered

Planning

Longer Term

- How to stay on track?
  - Leave leeway
  - Determine goal
  - Set periodic targets

Planning

Longer Term

- Example
  - 45ms -> 30ms in 4 months
  - 5ms/month
  - Profile, analyze, etc. as discussed
    - Tasks with little visual impact
    - Fallbacks with worse tradeoffs
    - Only use fallbacks to hit targets

Takeaways

Takeaways

Optimization is Scientific

- Our decisions are backed by hard facts along the way
- This helps us make the best decisions we can
- Monthly results provided a record

Takeaways

Don’t Let It Get Stale

- This workflow evolved over time
- You can’t force yourself into a single workflow and never reconsider
- We constantly adjusted for our needs, the project’s state, etc.

Takeaways

It Worked

- This approach works for us
  - Measurable results
  - Backlog full of potential work
  - Most valuable work is prioritized
- Consistent and significant performance improvements

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Sources

For Reading?

- Occlusion Culling:
  https://blog.selfshadow.com/publications/practical-visibility/
- Practical Clustered Culling
  https://www.humus.name/Articles/PracticalClusteredShading.pdf
- Siggraph 2015: Advances in Real-Time Rendering in Games
  https://advances.realtimerendering.com/s2015/aaltonenhaar_siggraph2015_combined_final_footer_220dpi.pdf
- Octahedral Mapping
  https://knarkowicz.wordpress.com/2014/04/16/octahedron-normal-vector-encoding/
- Harnessing Wave Intrinsics For Good (And Evil)
  https://youtu.be/U6t33RLa0XM?si=_KIA-EnzYVgS3ZxV

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