Vulkanised 2026

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Making Friends and Influencing Bounding Volume Hierarchies.

John Talley, Samsung

The Problem

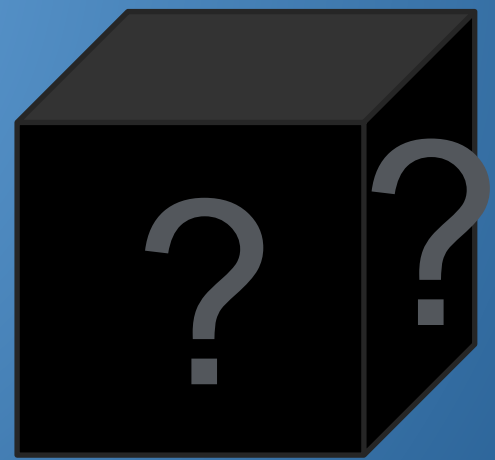
From a Developers' Perspective

The Vulkan API gave developers A LOT of control.

- We worked hard, but we were happy!

Then we finally got Ray Tracing capabilities, but…

- It feels like we lost control!
- vkBuildAccelerationStructuresKHR is a black box.
- We put geometry in, and a BVH comes out.



The Thesis

A New Hope

- The "friendship" between your geometry vertex/index buffers and the BVH builder isn't passive!
- How you organize data significantly impacts BVH footprint and traversal speed.

Session Goals

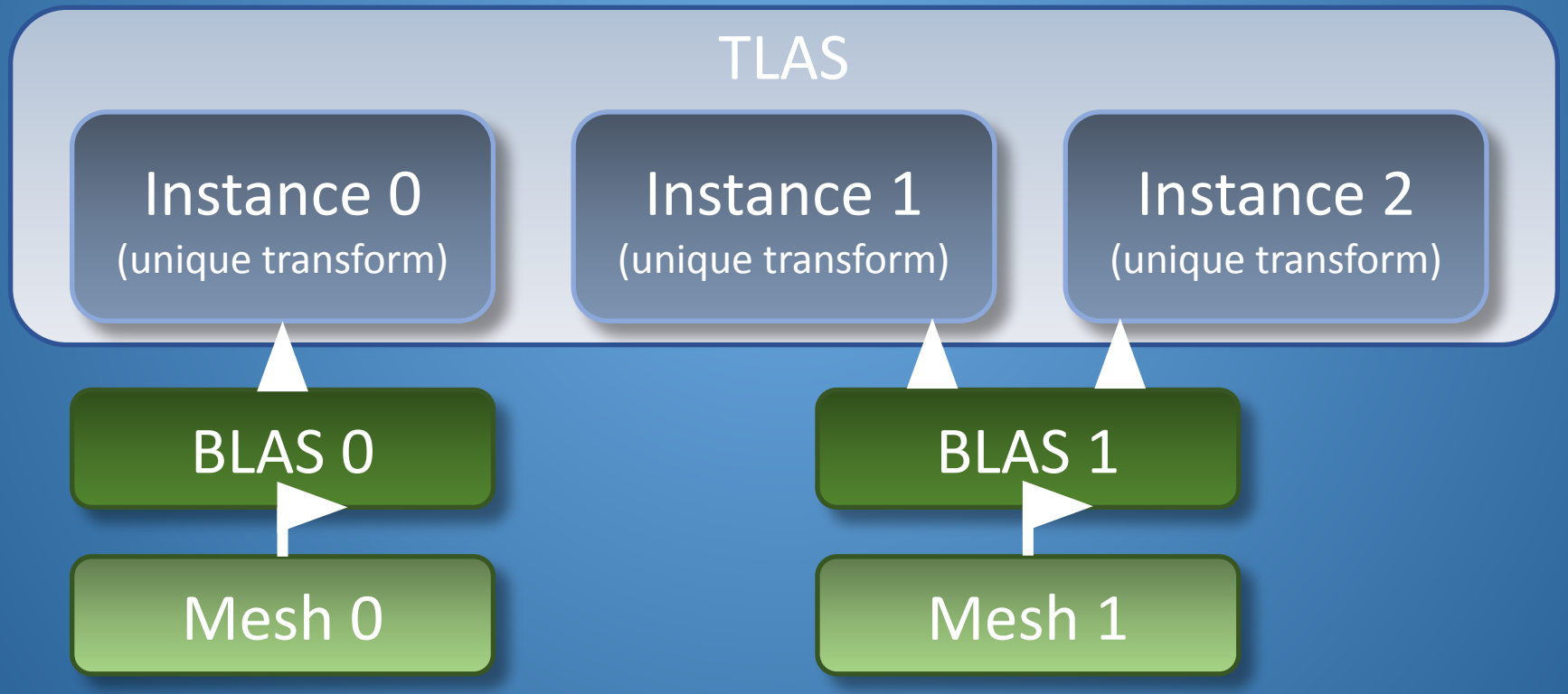
Return of the Geometry

- Quantify the impact of various options on BVH quality and build speed.
  - Vertex/Index Buffer Layouts
  - Acceleration Structure Geometry Merging & Subdivision
  - Build Flags
- Provide vendor-agnostic optimization strategies.
- Encourage developers to experiment

BVH Fundamentals

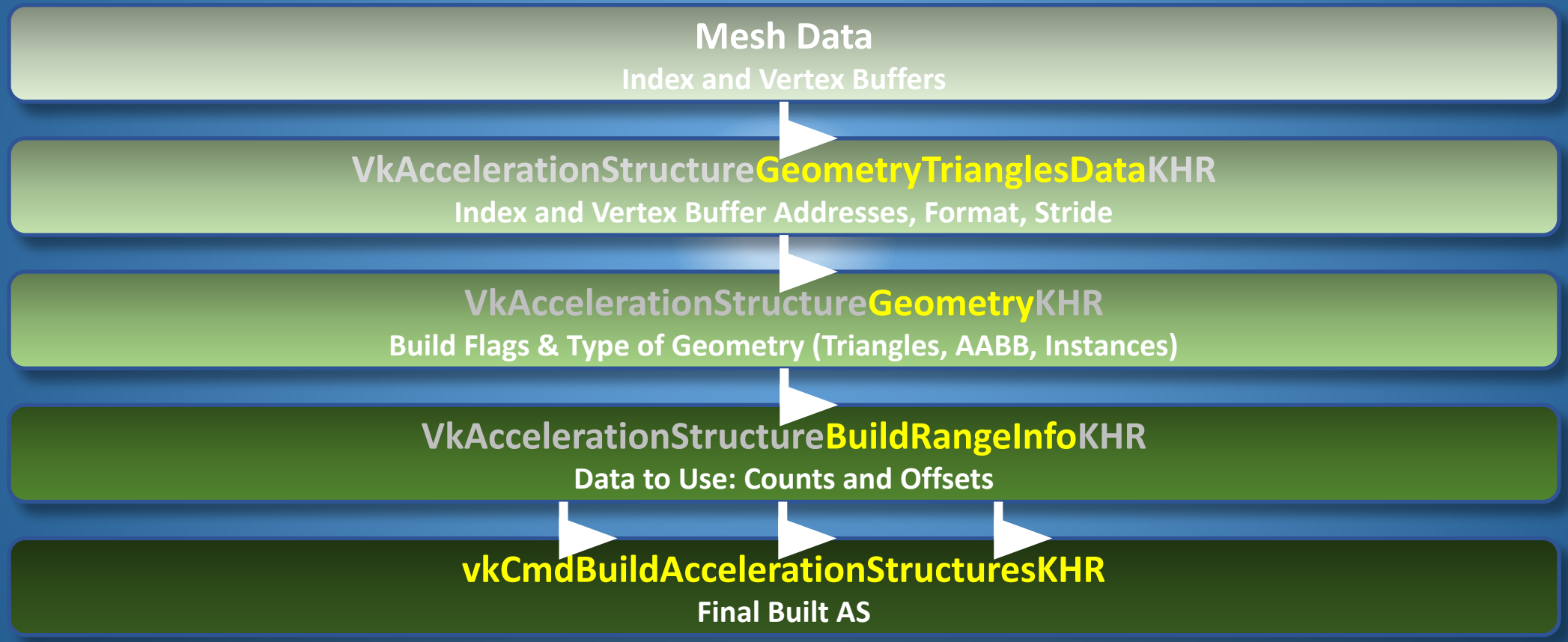
Vulkan Acceleration Structures

Top-Level (TLAS) & Bottom-Level (BLAS)



BVH Fundamentals

Building Acceleration Structures



BVH Fundamentals

Key Metrics

- **The "Black Box" Builder:** While the driver builds the BVH, it is constrained by the primitive data we provide.
- To provide good data, we need to understand what makes a “good” BVH.
  - **SAH (Surface Area Heuristic):** The gold standard for measuring BVH quality.
  - **Memory Footprint:** Size matters for cache hit rates during traversal.

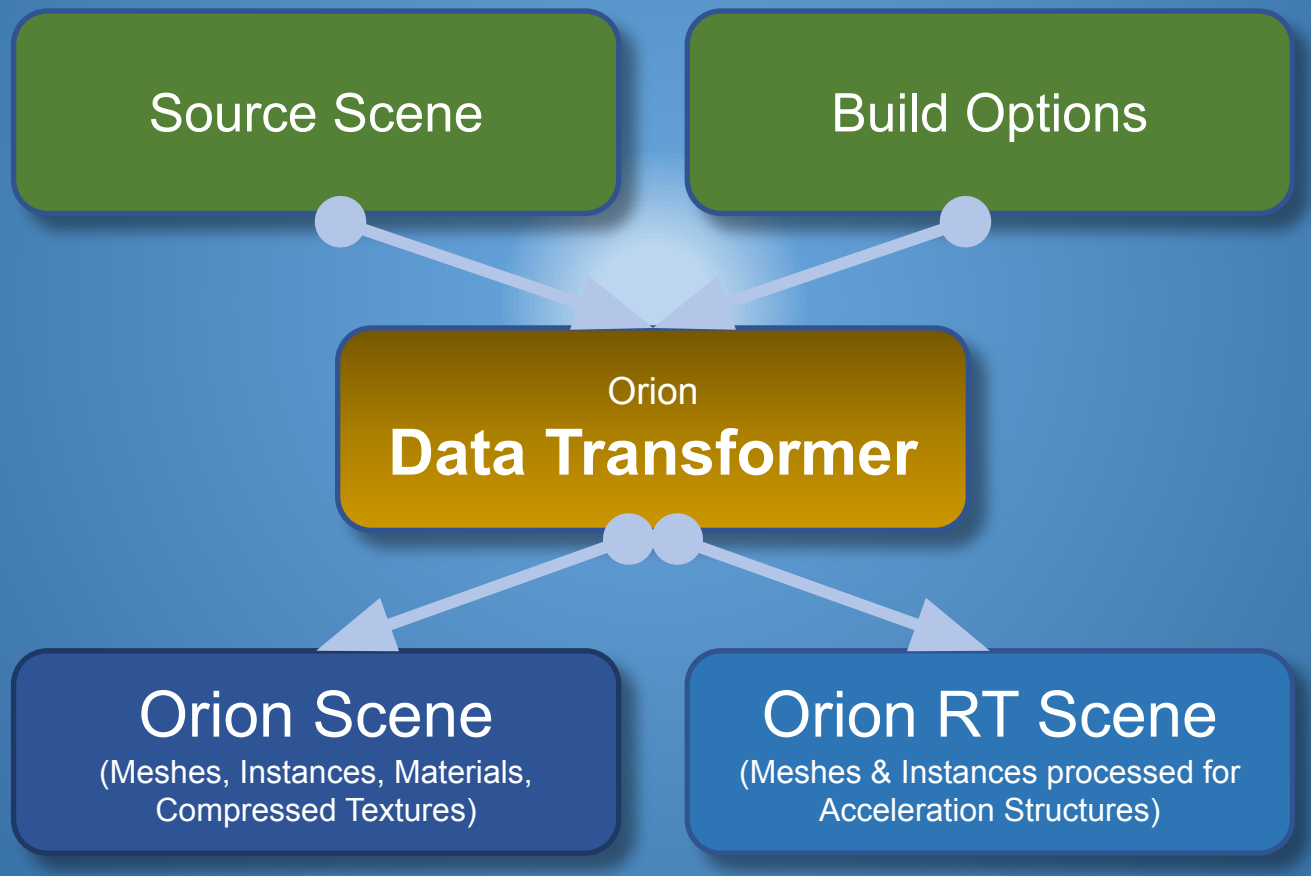
Methodology & Environment

Orion

- The Orion SDK
  - Rendering Framework and Toolset
  - Data Driven Render-Graph
    - Visual Graph Editor
    - Provides Rapid Experimentation
  - Vulkan 1.3 bindless design
  - Independent data transformation pipeline
  - Supports Android, Windows, Linux
  - Open source in Q2/Q3

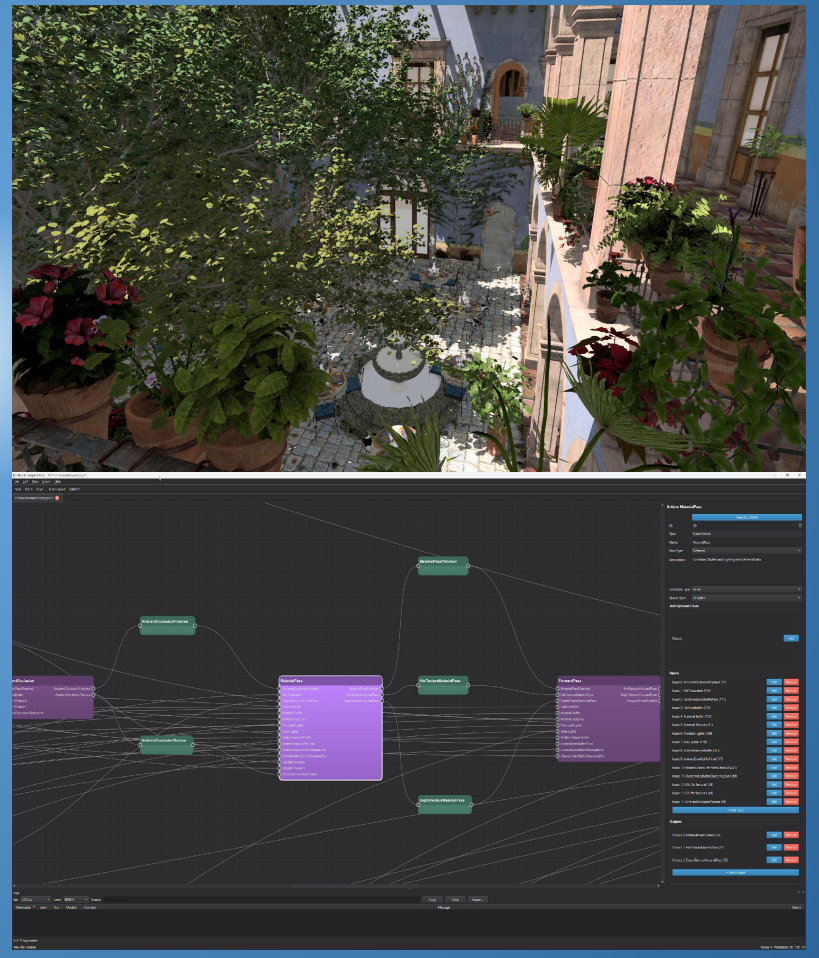
Methodology & Environment

Orion



Methodology & Environment

Orion



SAMSUNG

SARC/ACL

Methodology & Environment

Test Devices

- Tests were run on three separate vendor devices
  - Samsung Exynos 2500
  - Qualcomm Snapdragon Adreno 830
  - NVIDIA RTX 2000 Ada Generation (similar to RTX 4060)
- Premise:
  - Results are normalized to device baselines
  - Evaluate changes for each device independently
    - **Not compare the devices to one another.

Methodology & Environment

Test Scenes

Bistro

- Triangles: 4,209,006
- Instances: 2909
- Meshes: 551
- Lights: 116
- Credit: Amazon Lumberyard (2017)

San Miguel

- Triangles: 10,502,029
- Instances: 160,297
- Meshes: 809
- Lights: 81
- Credit: Guillermo M. Leal Llaguno from PBRT V3 archive

Parameter Sensitivity

Primitive Ordering

Does spatial sorting (e.g., Morton code sorting) of your index buffer prior to building lead to better node splitting?

- Morton Codes
- SAH optimization (mesh optimizer)

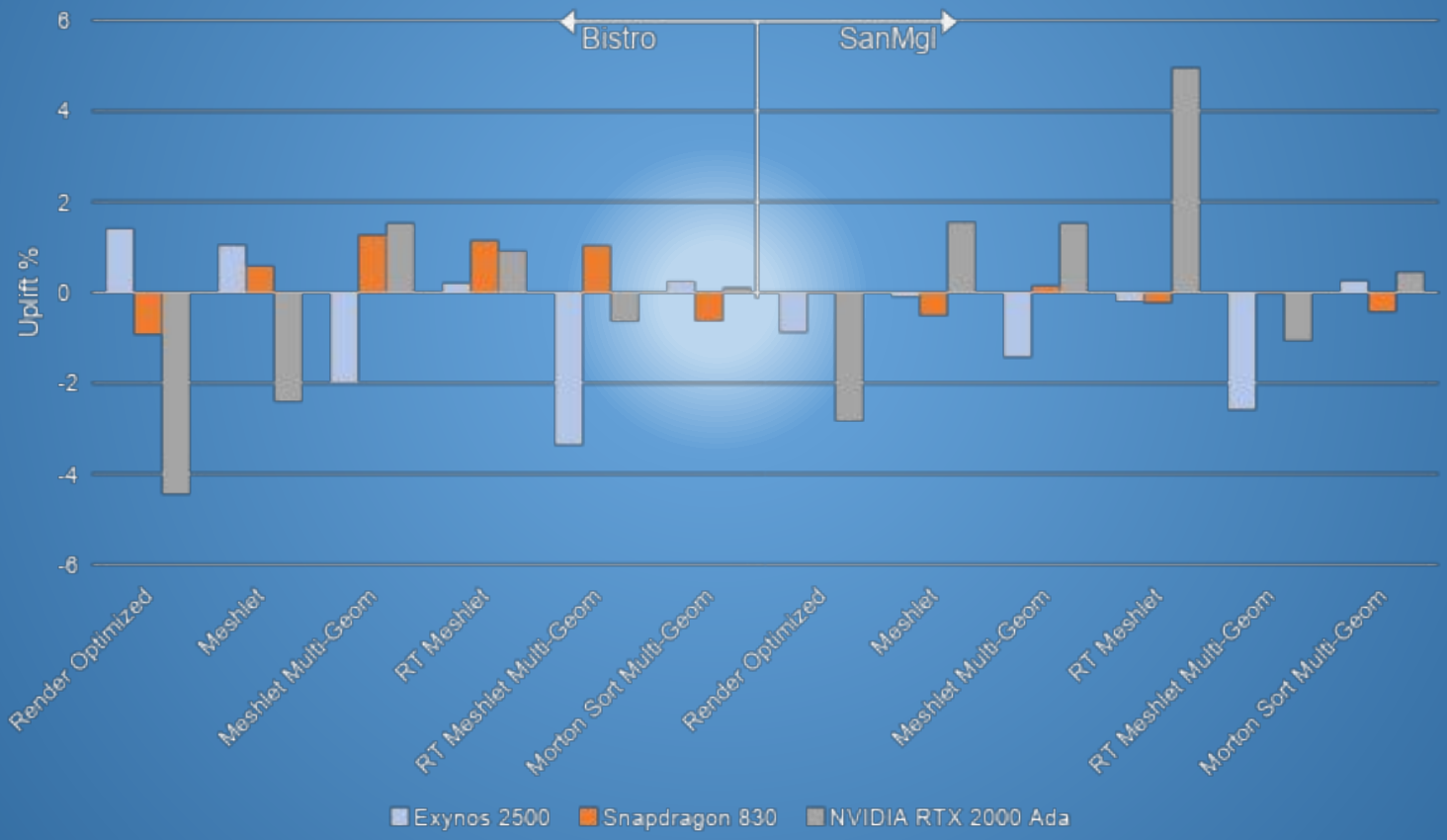
Parameter Sensitivity

Geometry Ordering

- **Geometry Layouts:** Subdividing or Merging Meshes into pre-grouped Geometries
- **Geometry Size:** Impact of individual geometry size on the build and trace performance.

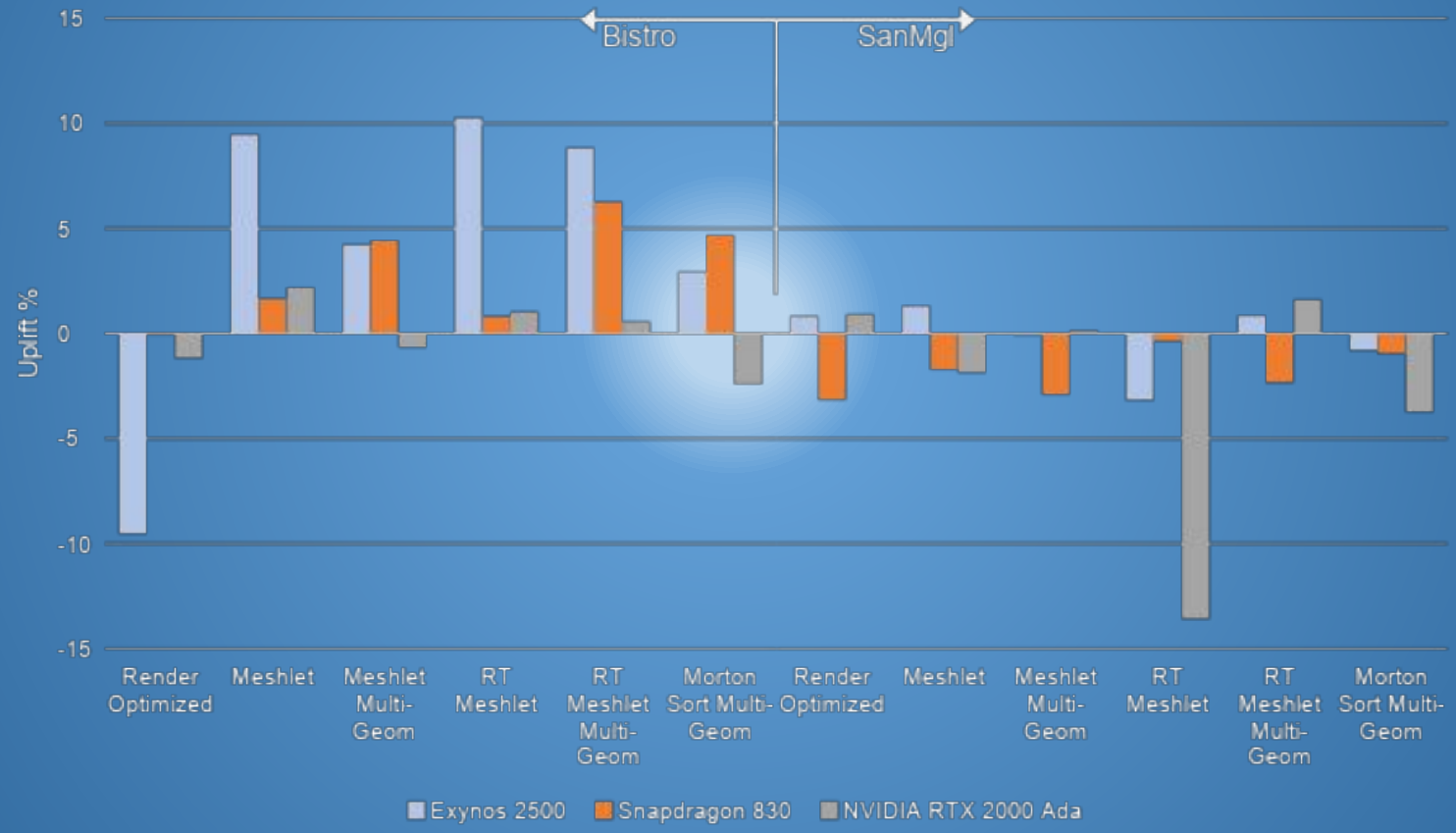
Results

Primitive & Geometry effects on Build Time



Results

Primitive & Geometry effects on Trace Time



Parameter Sensitivity

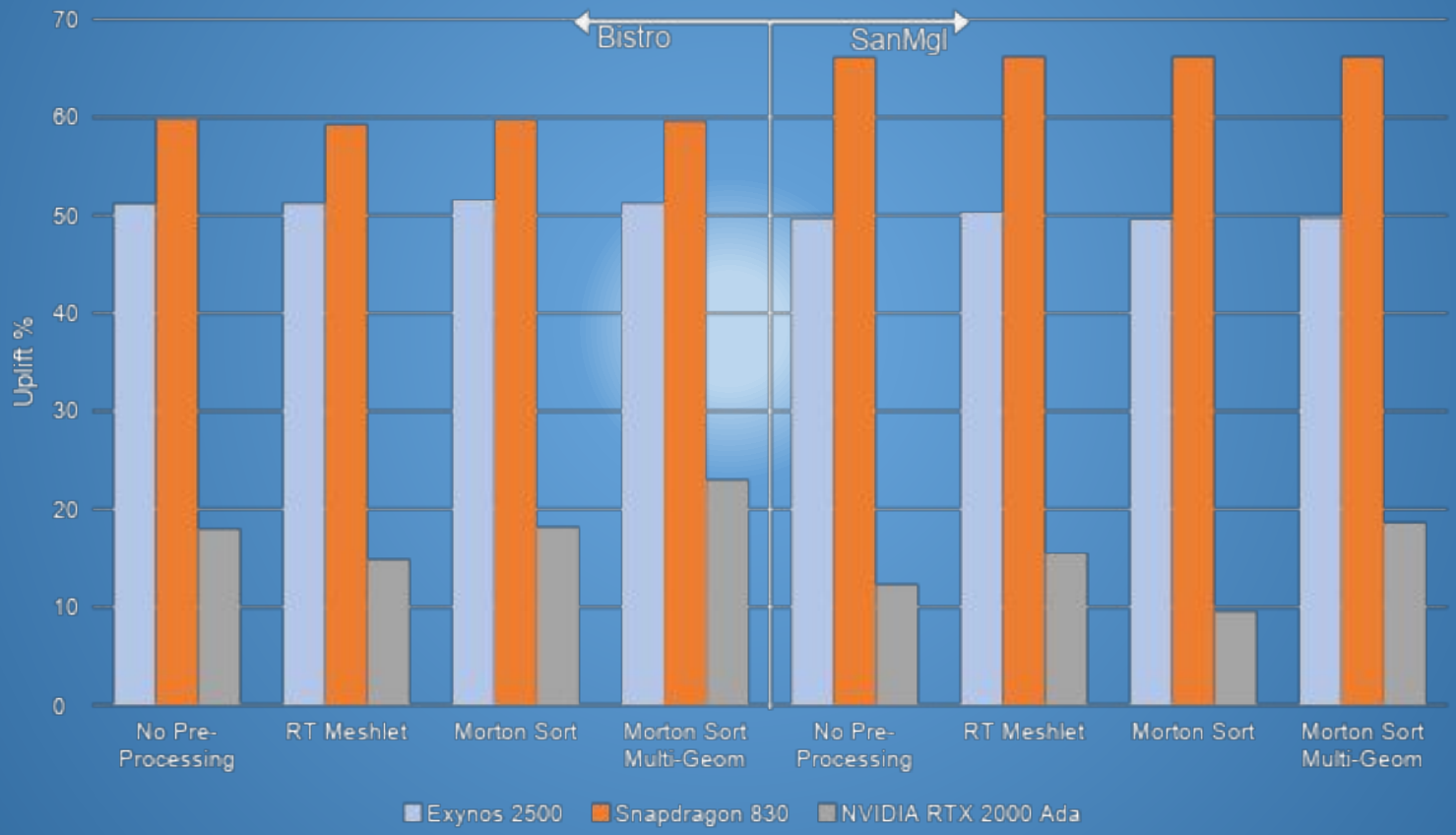
Fast Build

Fast Build vs Fast Trace

- What are the trade offs of building with the fast build option vs the fast trace option?
- How does Fast Build interact with primitive and geometry ordering strategies?

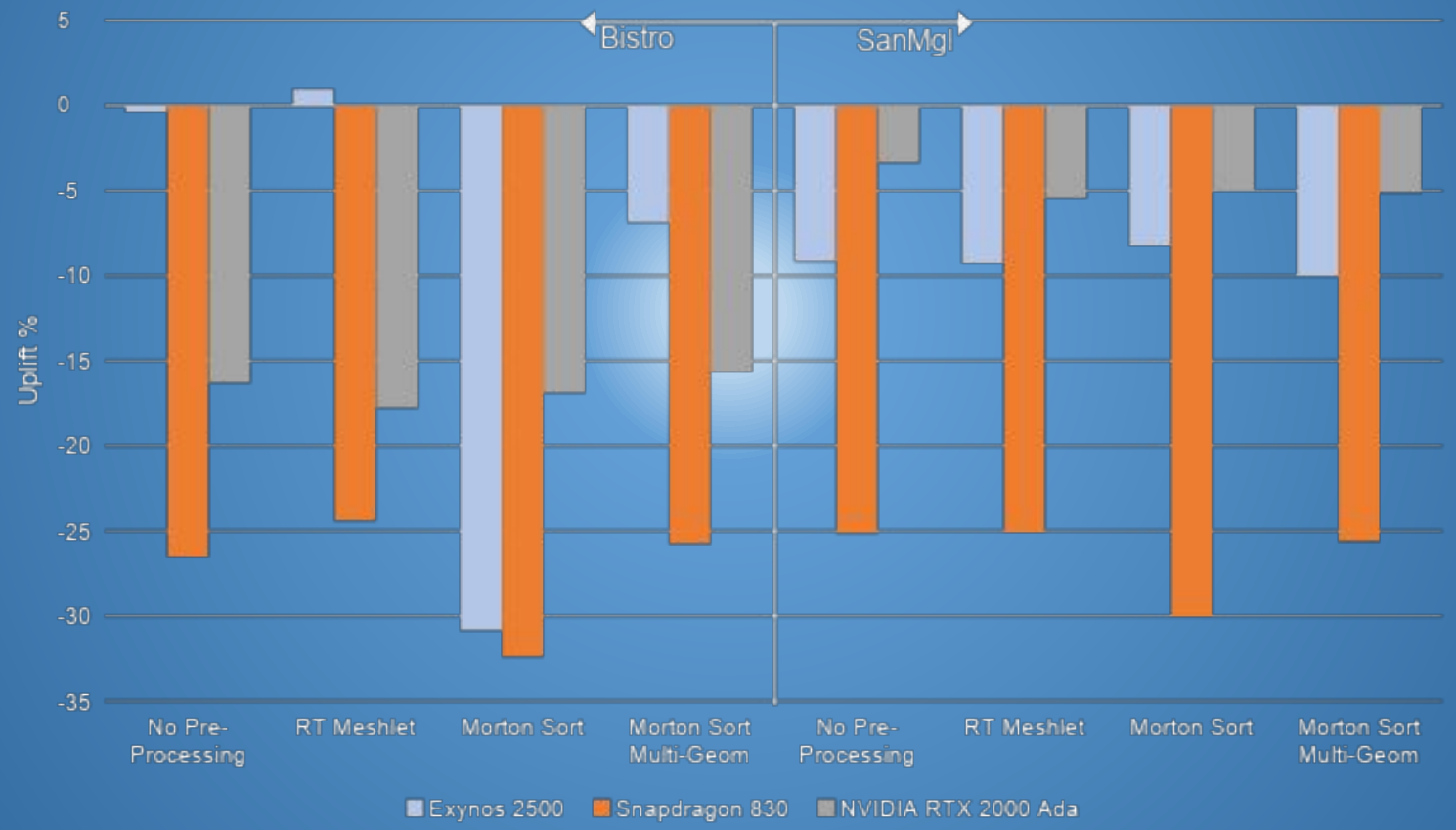
Results

Fast Build effects on Build Time



Results

Fast Build effects on Trace Time



Parameter Sensitivity

Data Size Optimization

- **Compaction:** Impact of BVH Compaction via vkCmdCopyAccelerationStructureKHR with VK_COPY_ACCELERATION_STRUCTURE_MODE_COMPACT_KHR
- **Alpha Test:** Does VK_GEOMETRY_OPAQUE_BIT_KHR influence the builder's ability to optimize or trace times?
  - Leave non-opaques out of BVH when possible?

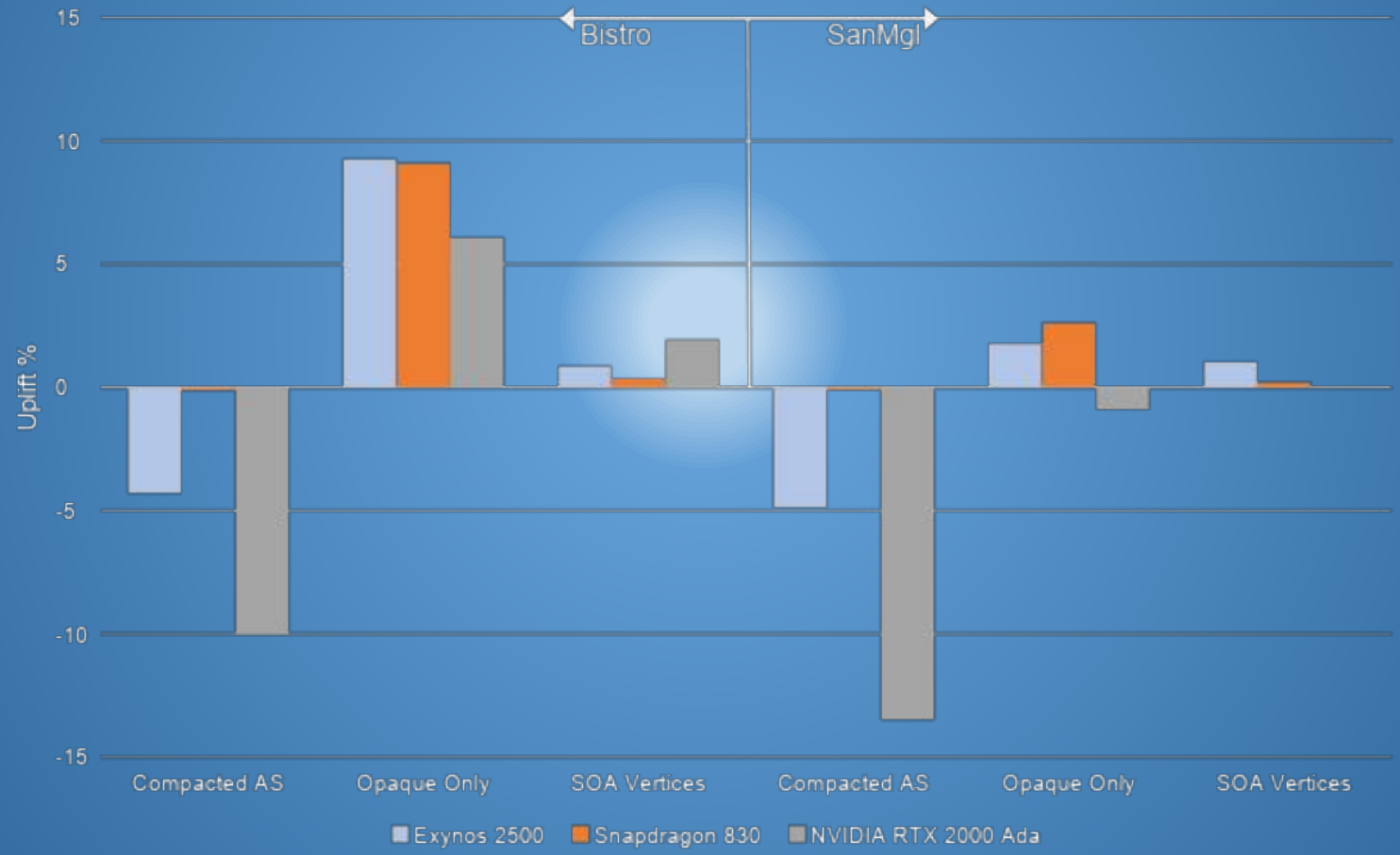
Parameter Sensitivity

Data Size Optimization

- **Vertex Layouts:** AOS (Array of Structures) vs. SOA (Structure of Arrays).
- **Vertex Size:** Impact of data size on the builder's memory access patterns.

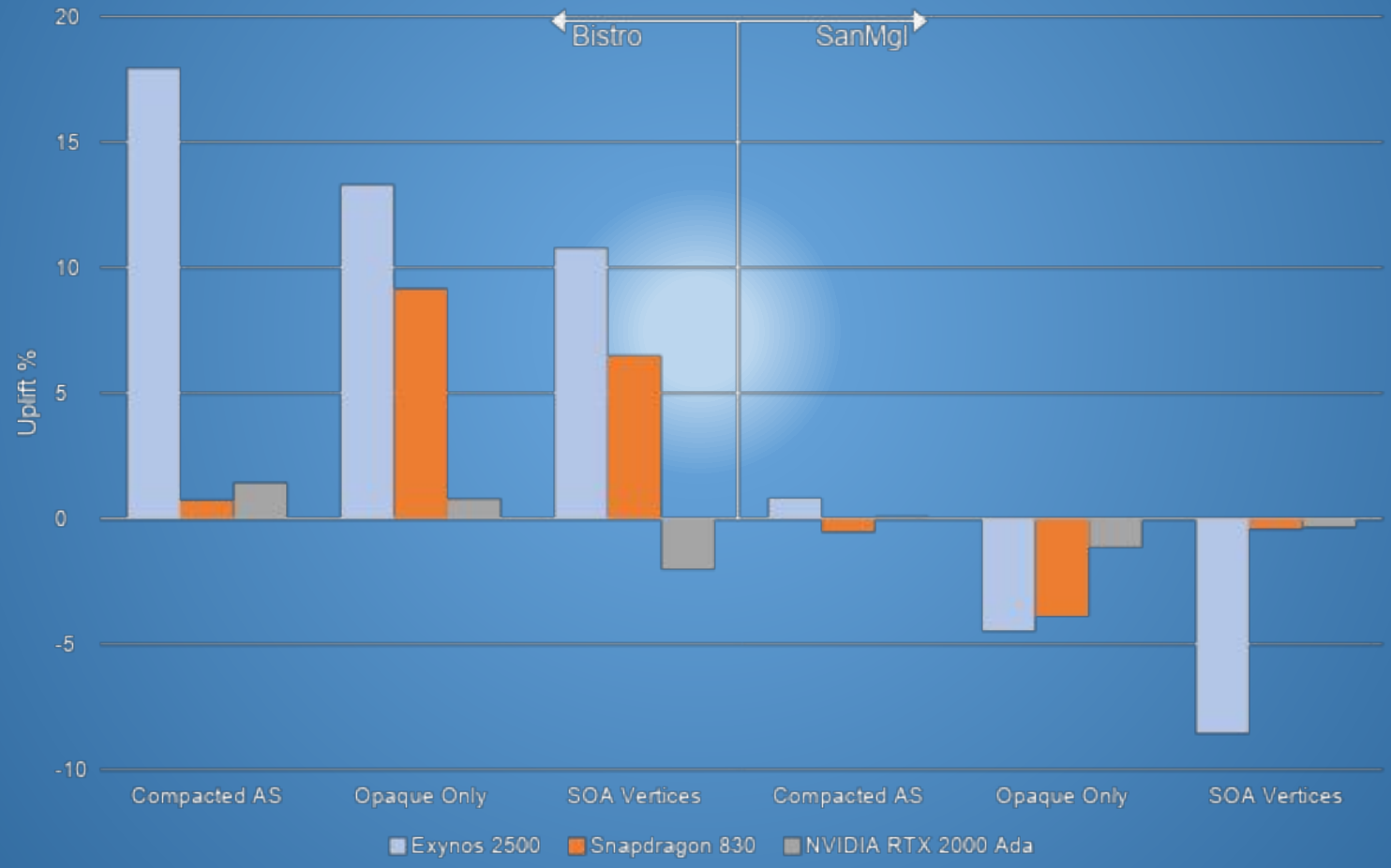
Results

Data Size effects on Build Time



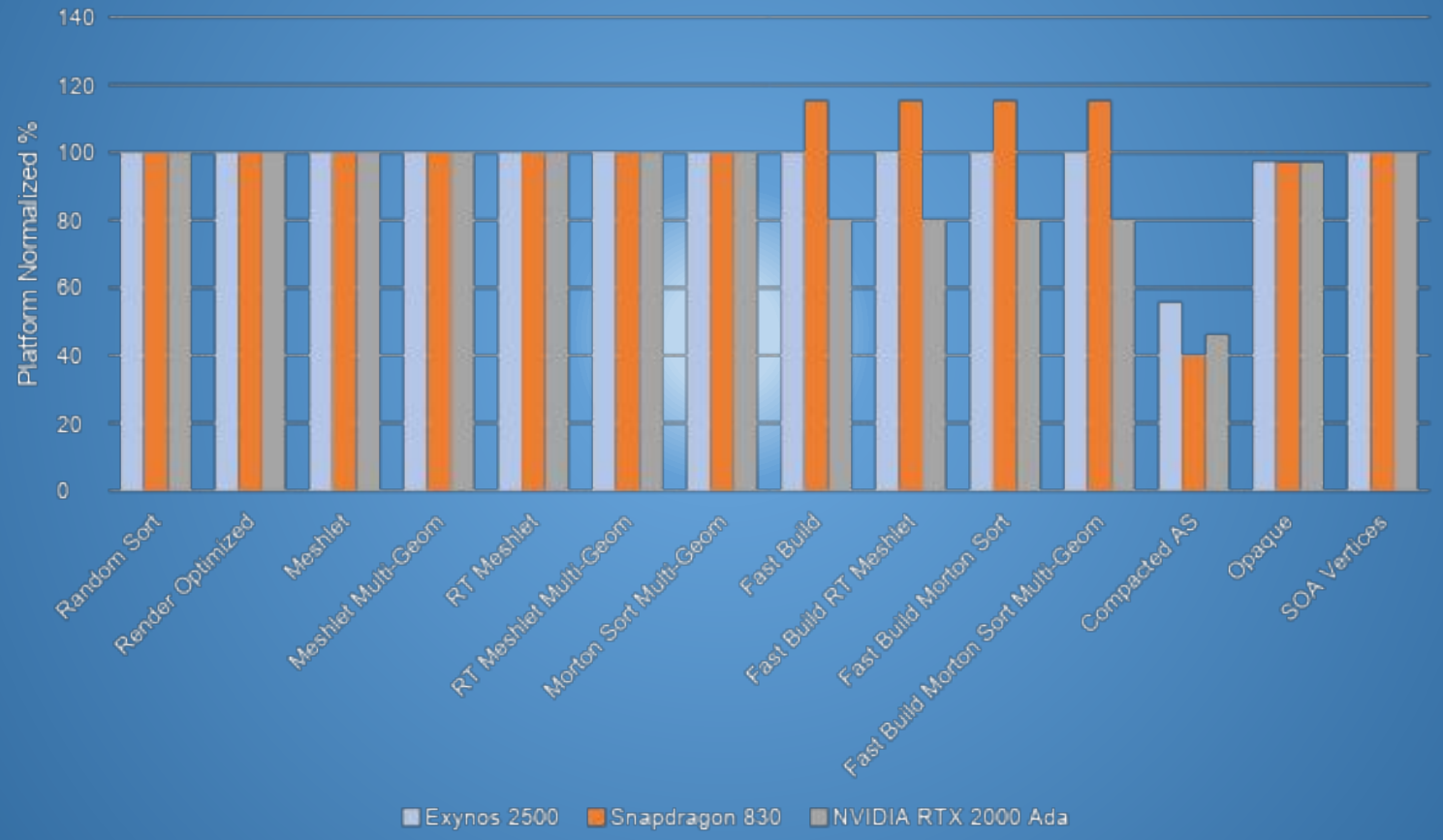
Results

Data Size effects on Trace Time



Results

Influences on Build Size



Recommendations

No Universal "Golden Rules"

- **Find Your Rules:** To truly master ray tracing in Vulkan, we must stop treating the Acceleration Structure as an "uncontrollable" object.
  - **Test Your Data:** Don't assume all data is the same. Implement various compression, ordering, and update options.
  - **Measure the Build vs. Trace:** Don't just optimize for the fastest build time. If a 3ms longer build saves 2ms on every subsequent frame's trace, that is a massive win for your frame budget.
  - **Cross-Vendor Validation:** Test on at least two different Devices. What is "free" on one architecture may be a bottleneck on another.

Conclusion

Happy Buffer Happy BVH

Summary: Good BVHs start at the buffer level.

- A BVH is only as good as the indices that define it. By treating our geometry buffers as spatial databases rather than simple lists, we can 'free' up some of our frame budget without changing a single line of ray-tracing shader code.

Final Thought: Influence your BVH early so it treats your rays friendly later.

Coming Soon

Exynos Tools & Technology

Sokatoa, our new graphics profiling solution for Android, will be available to download for free.

https://github.com/sarc-acl/sokatoa

We Are Hiring

Come join our team

https://semiconductor.samsung.com/about-us/careers/us/sarc-acl/

Thank You!

Samsung SARC Advanced Rendering Team

Tim Little, John Talley, Mike Kelley

BACKUP


RenderGraph Editor - ForwardRenderGraphDebug.json *
File Edit View Graph Help
New Open Save Auto Layout Validate
ForwardRenderGraphDebug.json *
Graph Metadata
Version
Major: 0
Minor: 4
RenderGraphType: Base
Name: Forward Render - GPU Cull and Cluster Lights Debug
Comment: Debug renders in LDR buffer
Logs
Tab: All Tabs
Level: ERROR
Search:
Copy
Clear
Export...
Timestamp
Level
Tab
Module
Function
Message
Details
0 of 41 log entries
Nodes: 0 Validation: Not checked Tabs: 1/1


Exported from Unreal store to glTF

BACKUP