GDC

Microsoft XBOX Windows

DirectX Raytracing

Matt Sandy
Program Manager
DirectX

Microsoft Windows

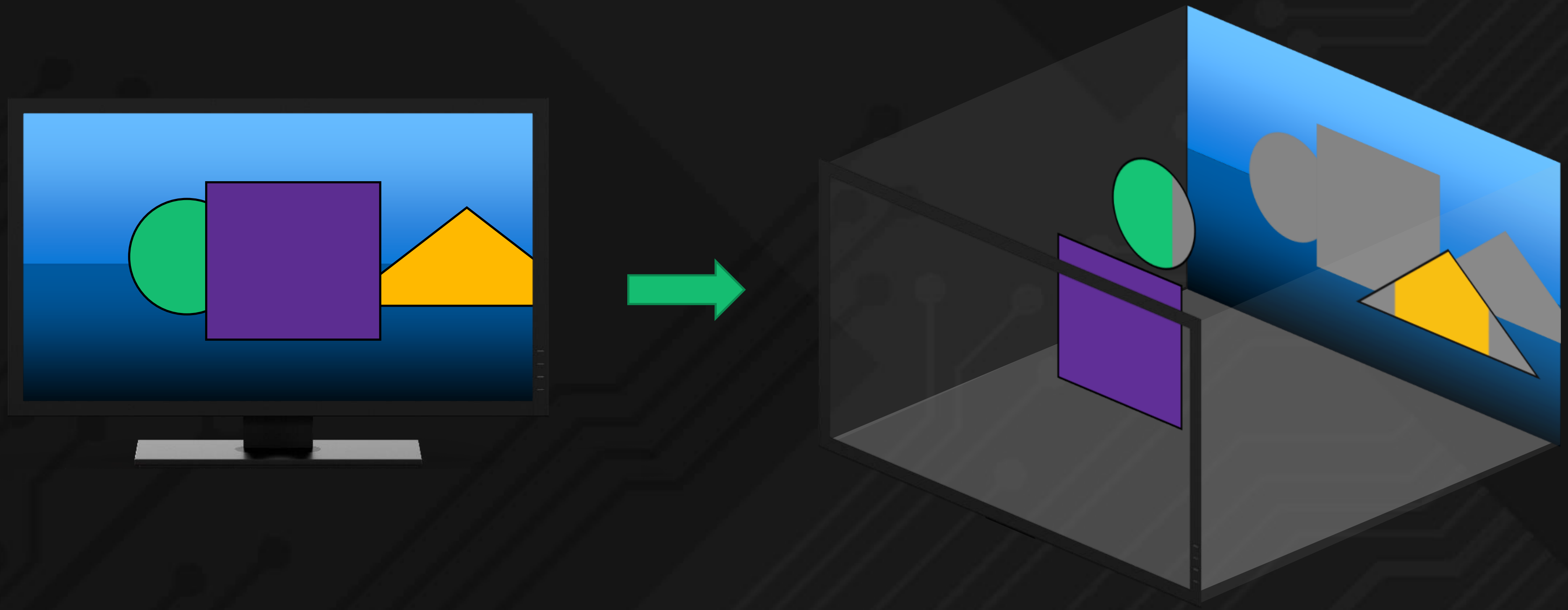
Agenda

- Why Raytracing?
- DXR Deep Dive
- Tools & Helpers
- Applied Raytracing (EA/SEED)
- Get Started

Microsoft Windows

3D Graphics is a Lie

- Solving the Visibility Problem



Microsoft Windows

Emergence of Exceptions

- Dynamic Shadows
- Environment Mapping
- Reflections
- Global Illumination

A Brief History of Pixels

- 1999 – Hardware T&L
- 2000 – Simple Programmable Shaders
- 2002 – Complex Programmable Shaders
- 2008 – Compute Shaders
- 2014 – Asynchronous Compute
- 2018…

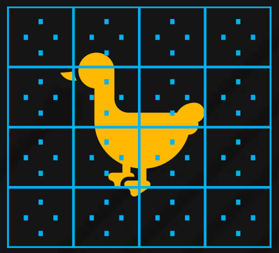
Microsoft Windows

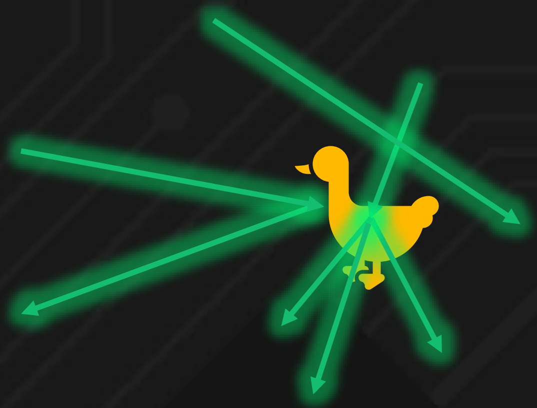
A Brief History of Pixels

- 1999 – Hardware T&L
- 2000 – Simple Programmable Shaders
- 2002 – Complex Programmable Shaders
- 2008 – Compute Shaders
- 2014 – Asynchronous Compute
- 2018 – **DirectX Raytracing**

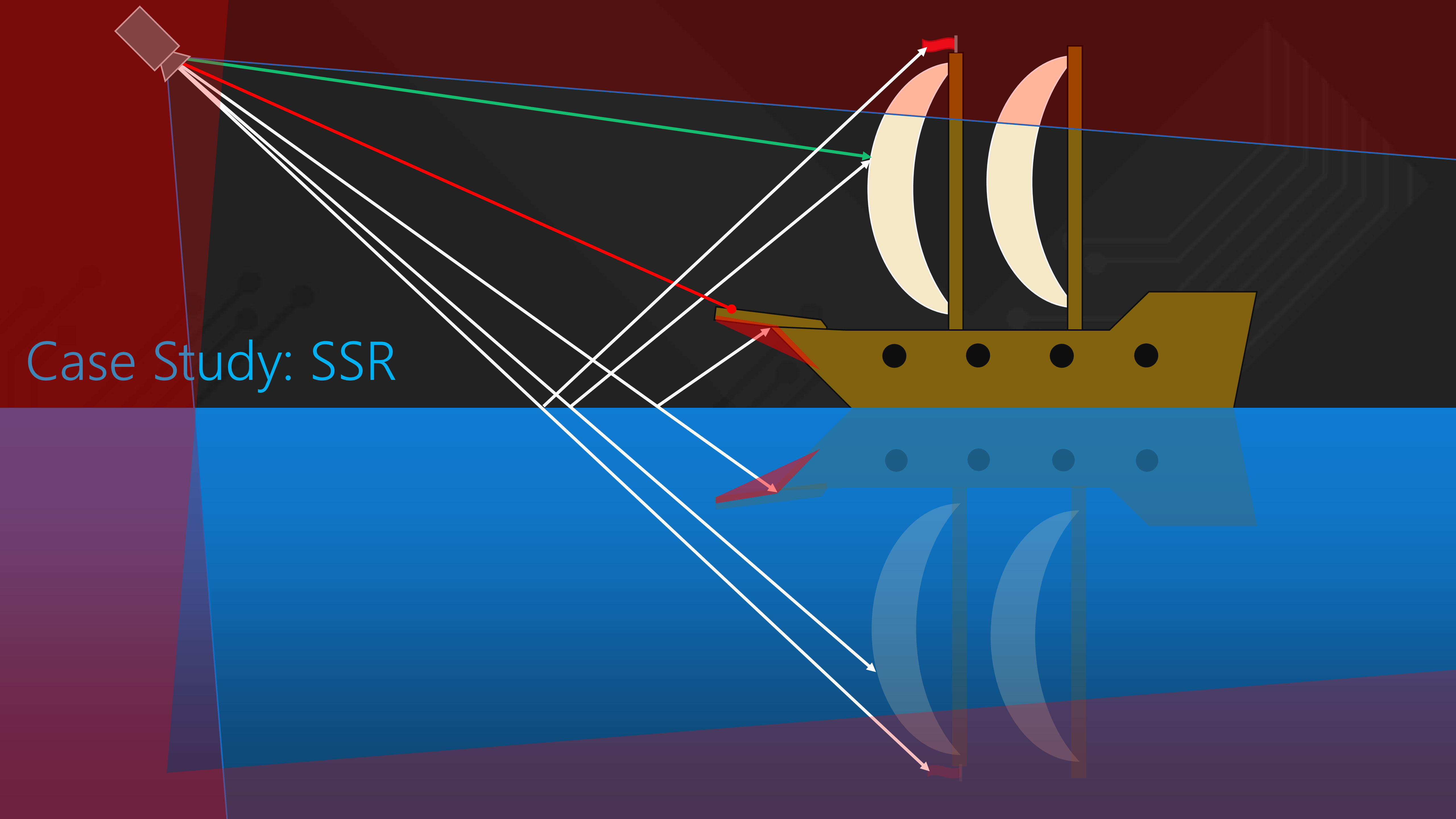
Raytracing 101

1. Construct a 3D representation of a scene.
2. Trace rays into the scene from a point of interest (e.g. camera).
3. Accumulate data about ray intersections.
4. Optional: go to step 2.
5. Process the accumulated data to form an image.

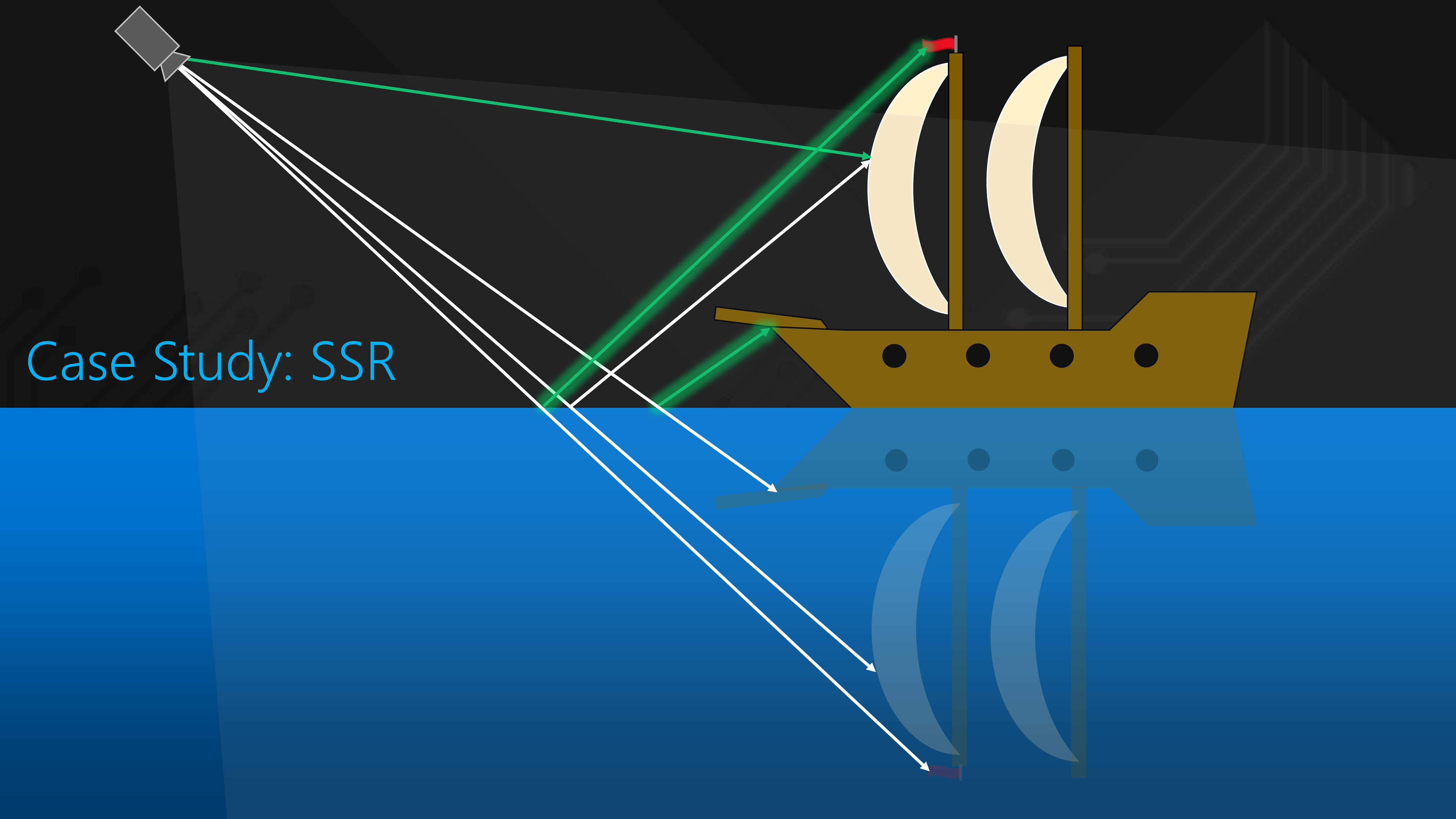




Case Study: SSR

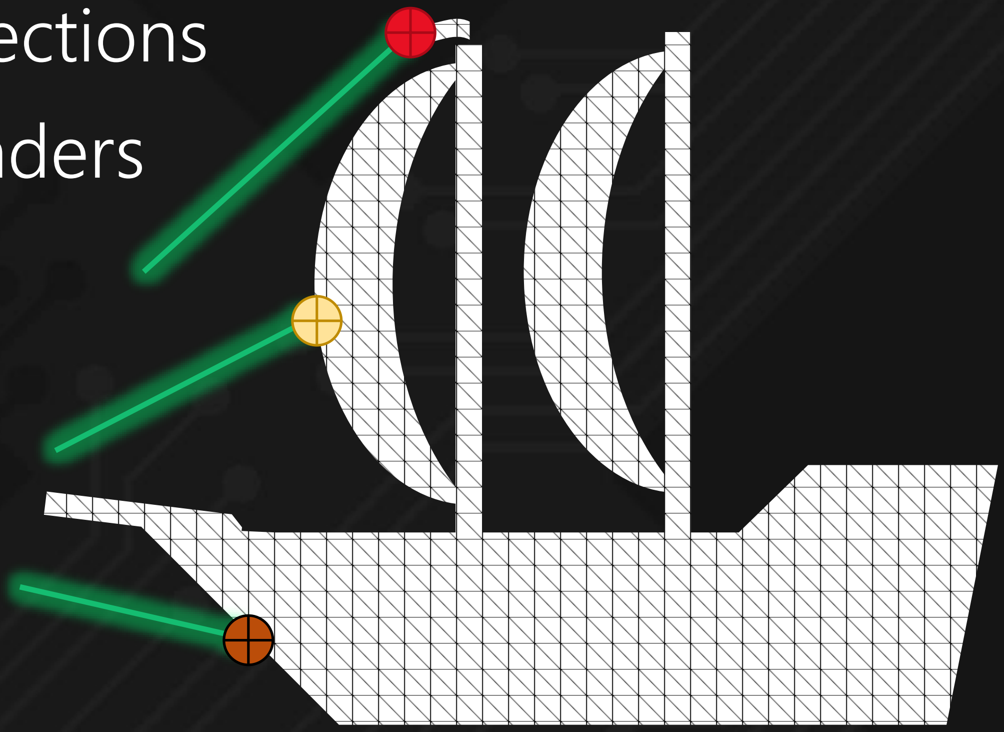


Case Study: SSR



Raytracing Requirements

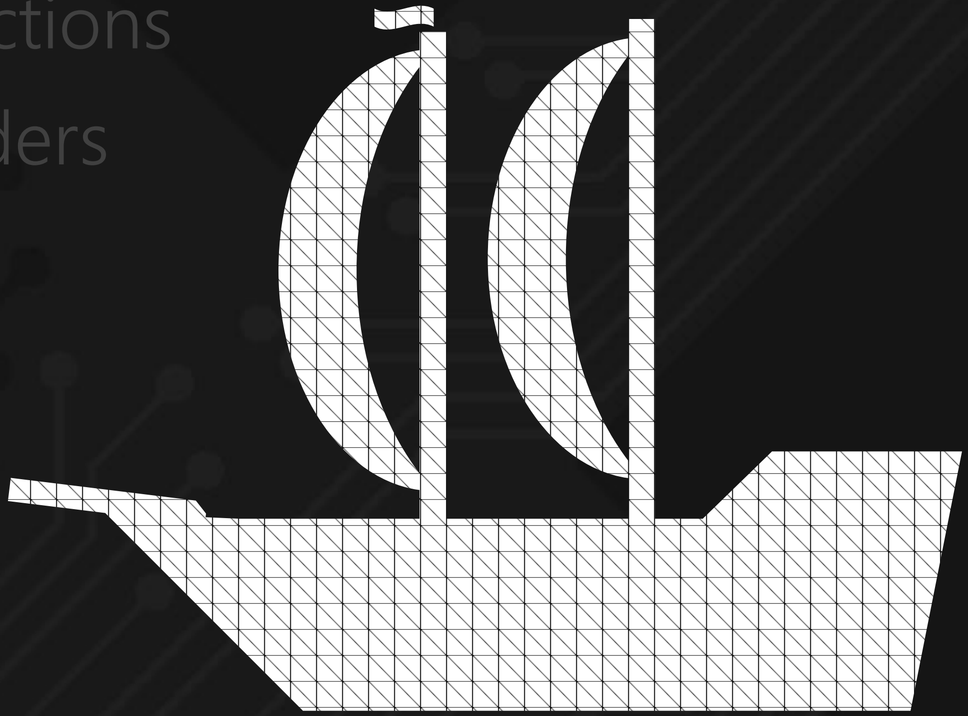
- Scene geometry representation
- Trace rays into scene and get intersections
- Determine and execute material shaders



Microsoft Windows

Raytracing Requirements

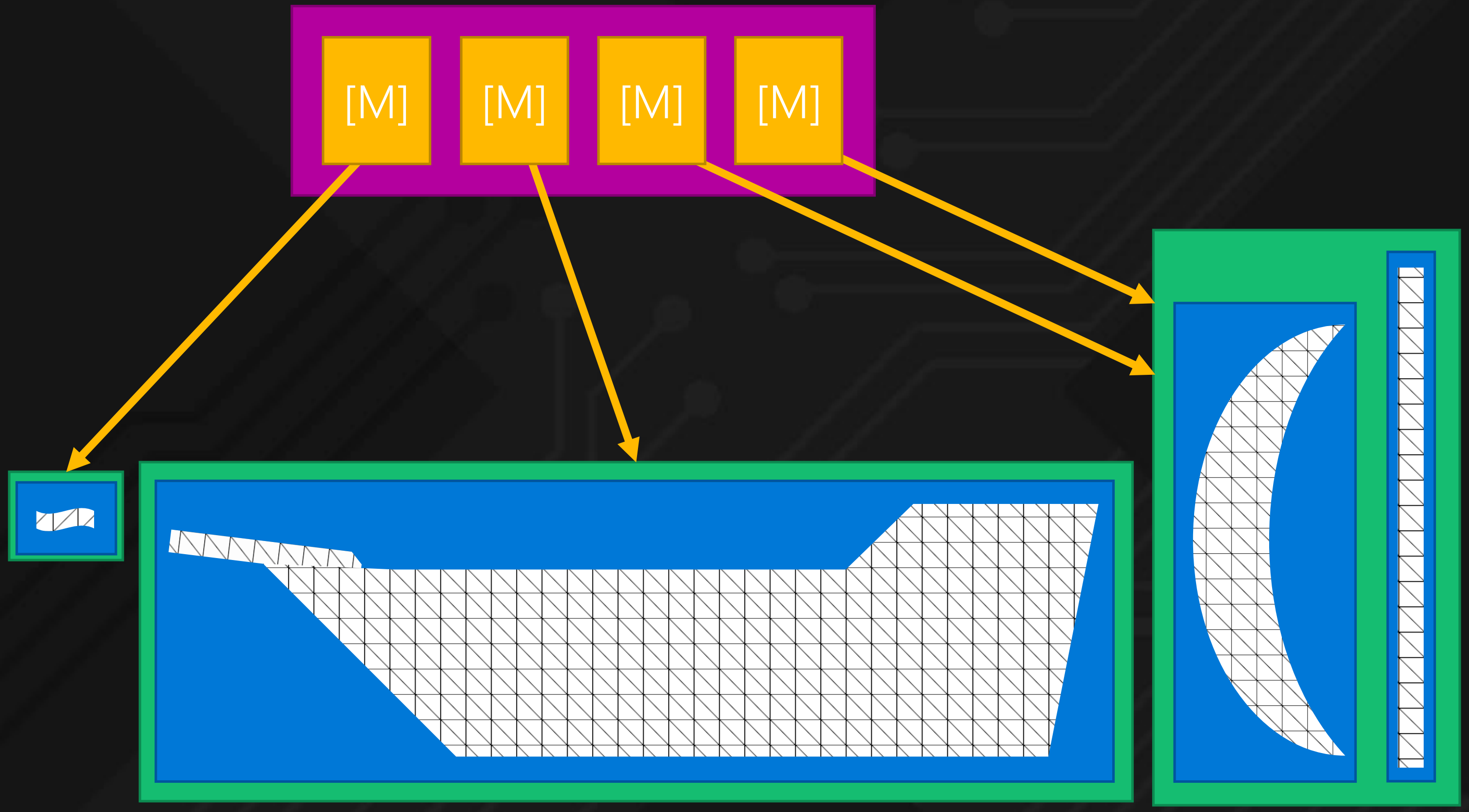
- Scene geometry representation
- Trace rays into scene and get intersections
- Determine and execute material shaders



Microsoft Windows

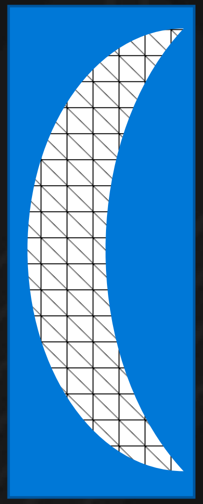
Acceleration Structures

- Opaque buffers that represent a scene
- Constructed on the GPU
- Two-level hierarchy



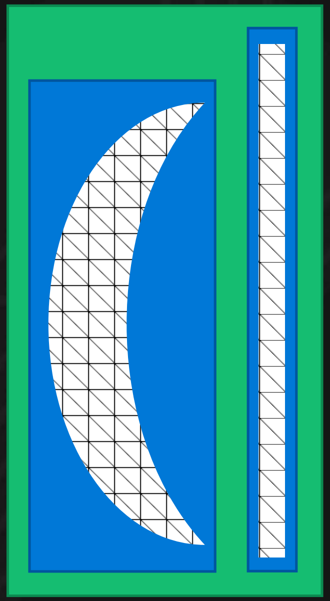
Geometries

- Triangles
  - Vertex Buffer (float16x3 or float32x3)
  - Index Buffer (uint16 or uint32)
  - Transformation matrix
- Programmable Geometry
  - Defined using shader code
  - Specify enclosing AABBs



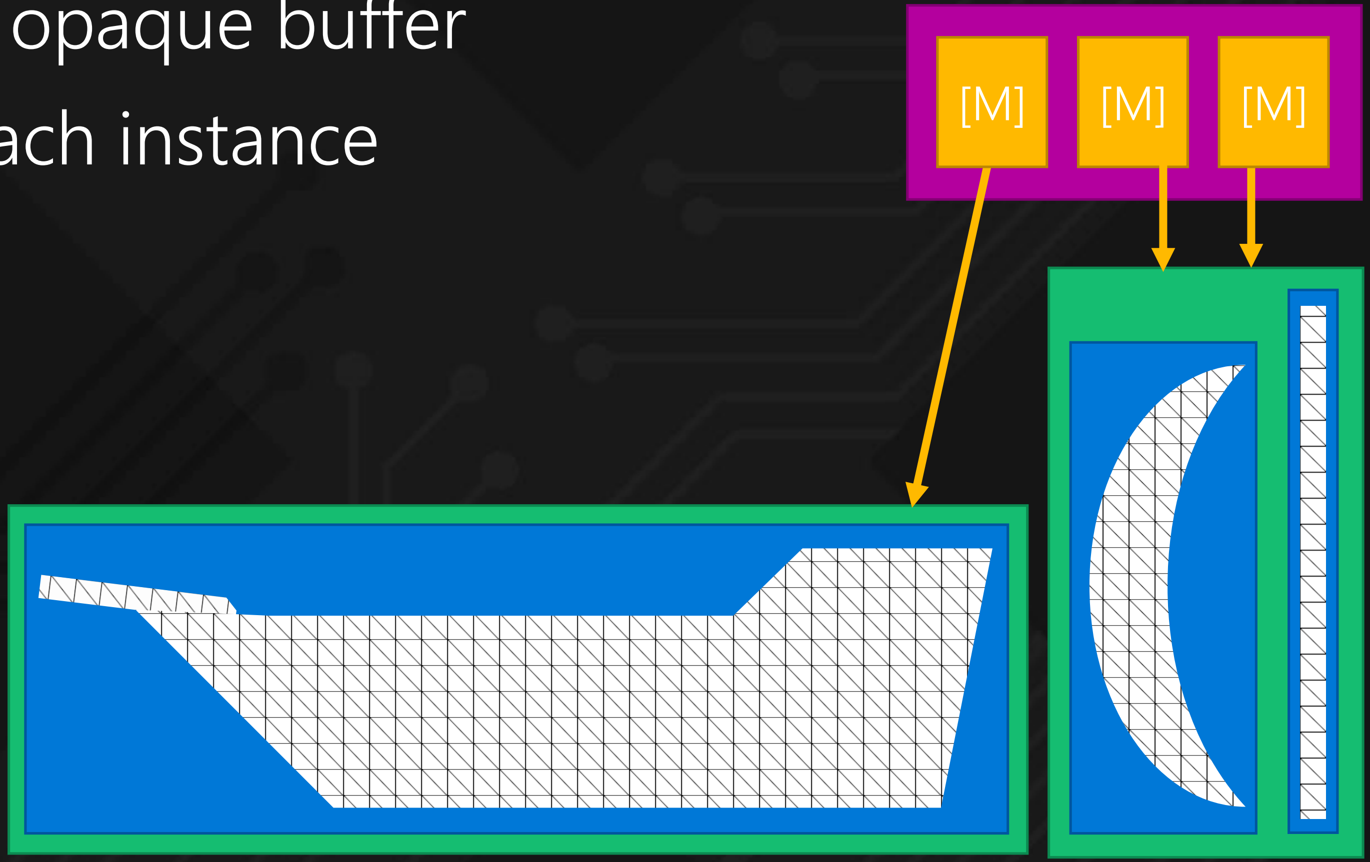
Bottom-Level Acceleration Structure

- Defined by a set of geometries
- Built on the GPU, written to opaque buffer



Top-Level Acceleration Structures

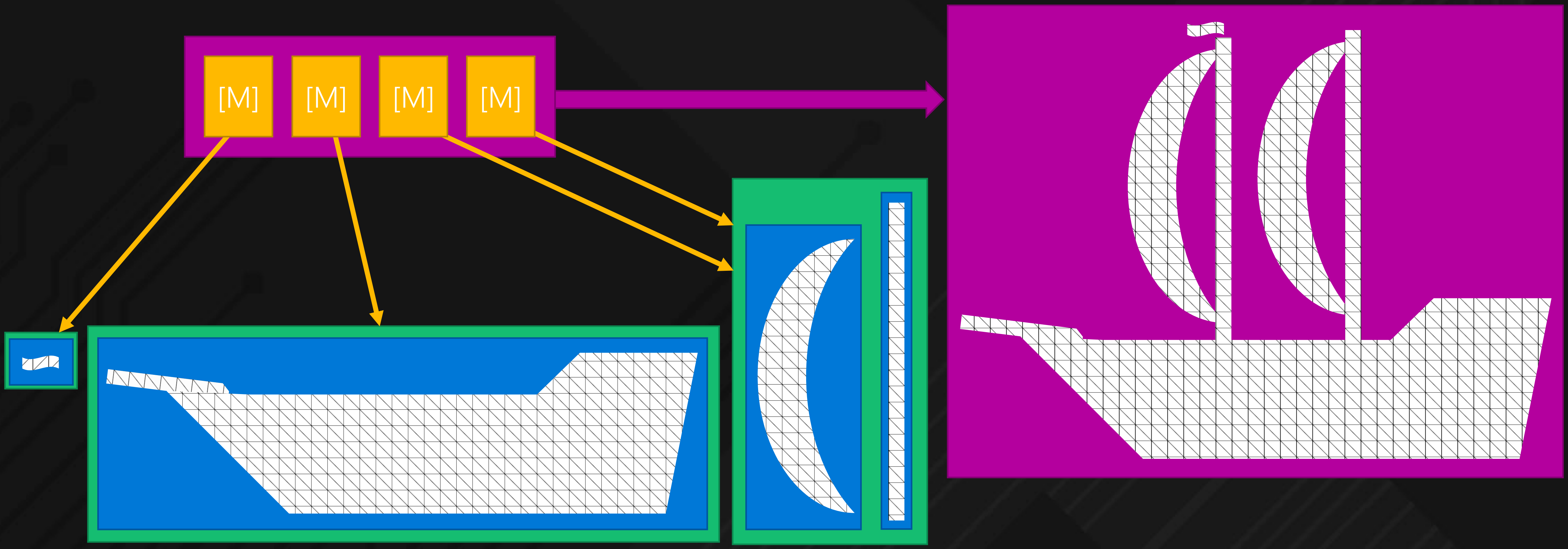
- Defined by a set of instances of bottom-level structures
- Built on the GPU, written to opaque buffer
- Transformation matrix for each instance



Acceleration Structure Details

- Prebuild info
  - Query driver for allocation requirements
  - Returns conservative result and scratch sizes required
- Postbuild info available
  - Query compacted size for reallocation
- Updates supported
  - Incrementally update top/bottom level structs
  - Can do async full rebuild when drifting too far

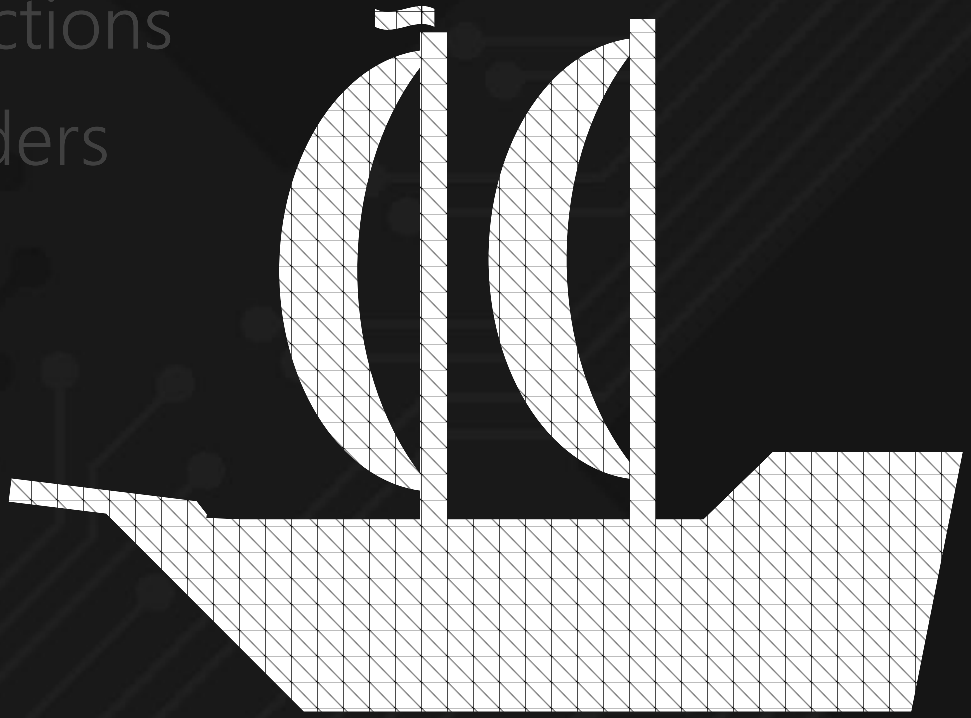
Acceleration Structure Recap



Microsoft Windows

Raytracing Requirements

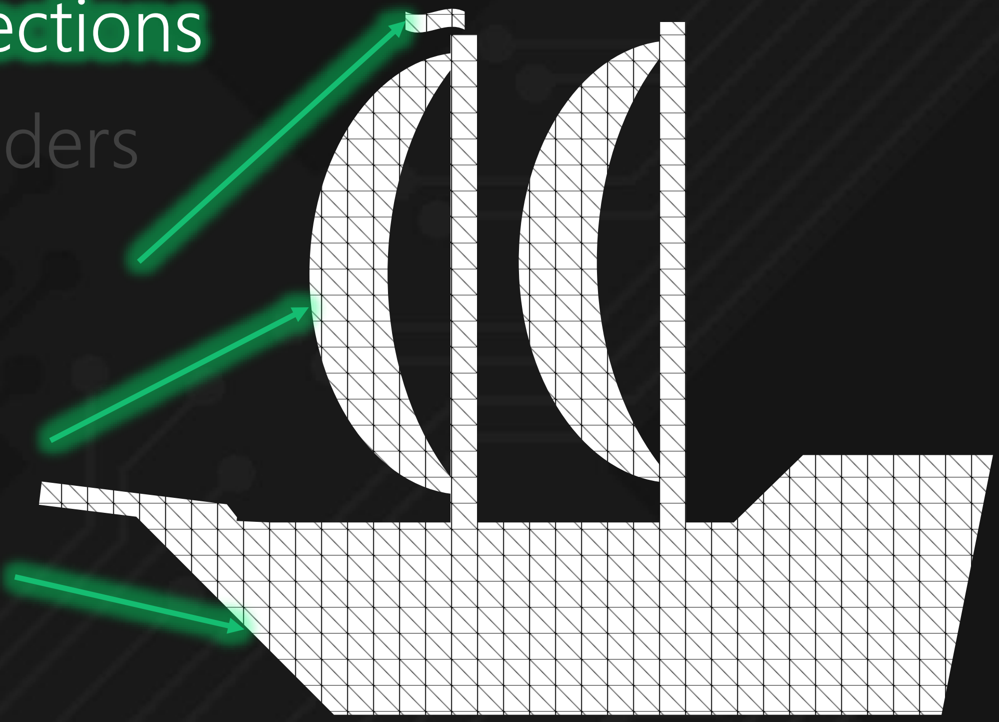
- Scene geometry representation
- Trace rays into scene and get intersections
- Determine and execute material shaders



Microsoft Windows

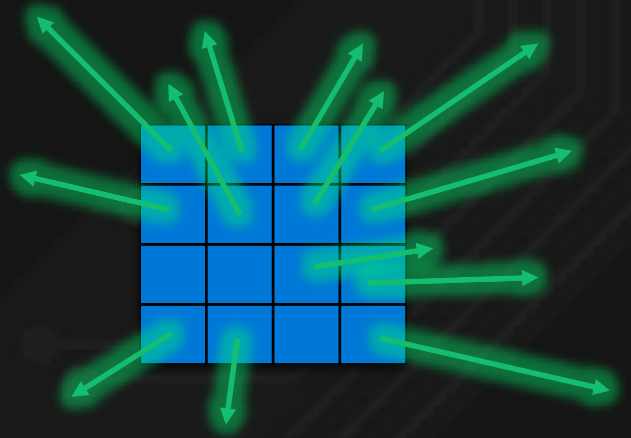
Raytracing Requirements

- Scene geometry representation
- Trace rays into scene and get intersections
- Determine and execute material shaders



Ray Generation Shader

- Invoked via CommandList::DispatchRays()
  - Specify 2D grid of threads
- Emit any number of rays per thread
  - Use TraceRay intrinsic
- Write traversal results to UAVs



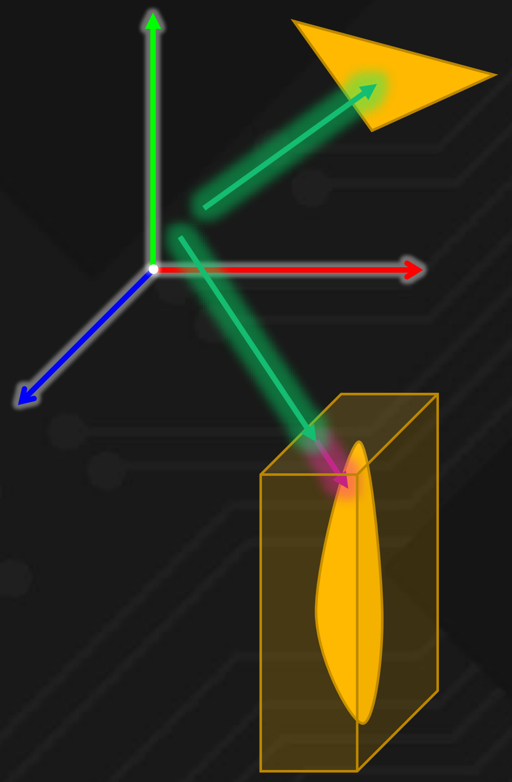
Microsoft Windows

TraceRay Intrinsic

- Origin
- Direction
- `TMin/TMax`
- App-defined “payload”

Determining Intersections

- Triangle Geometry
  - Determination: Automatic
  - Attributes: Barycentrics
- Programmable Geometry
  - Determination: Intersection Shaders
  - Attributes: Application-defined



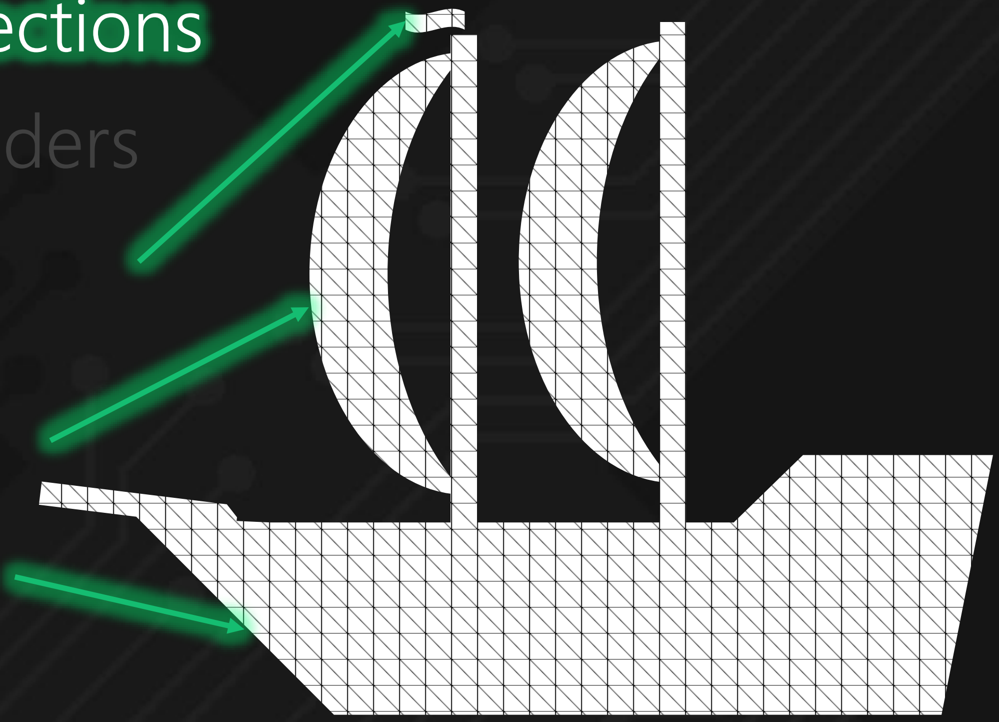
DXC / DXIL

- Everything new requires the DXIL compiler
  - ✓ dxc.exe / dxcompiler.dll
  - ✗ fxc.exe / d3dcompiler_47.dll
- Get it here: http://aka.ms/HLSL
  - For DXR, use the pre-built binary in the experimental SDK

Microsoft Windows

Raytracing Requirements

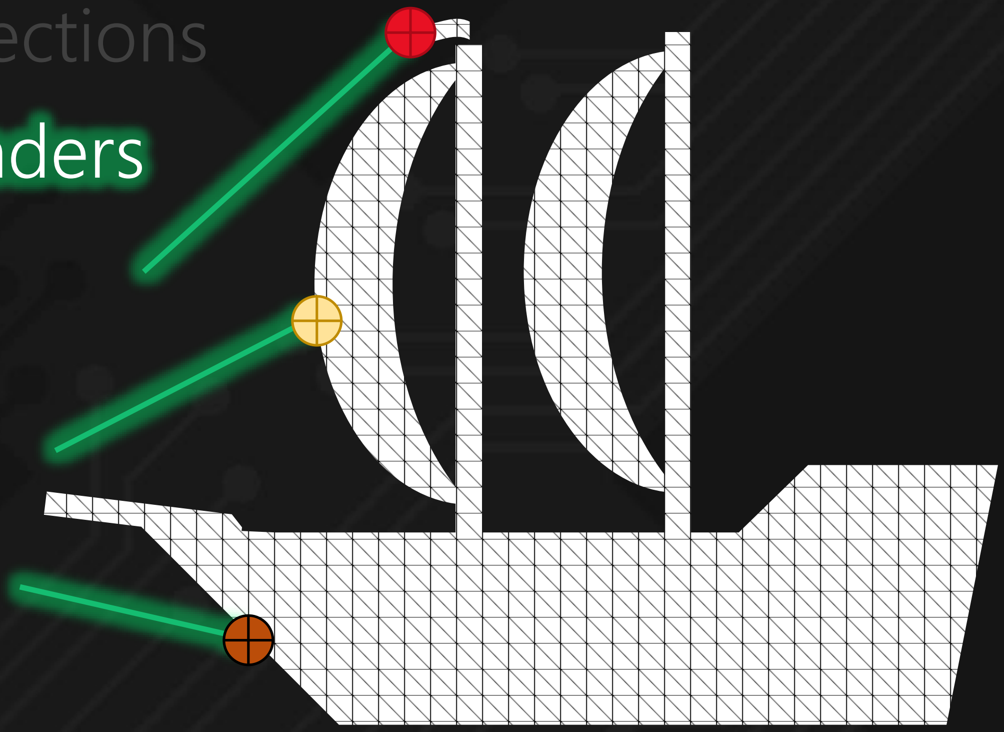
- Scene geometry representation
- Trace rays into scene and get intersections
- Determine and execute material shaders



Microsoft Windows

Raytracing Requirements

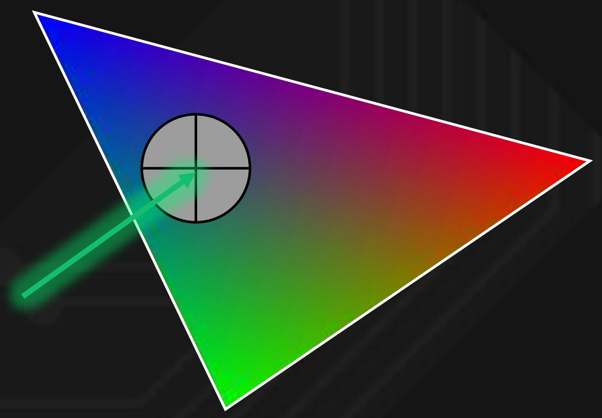
- Scene geometry representation
- Trace rays into scene and get intersections
- Determine and execute material shaders



Microsoft Windows

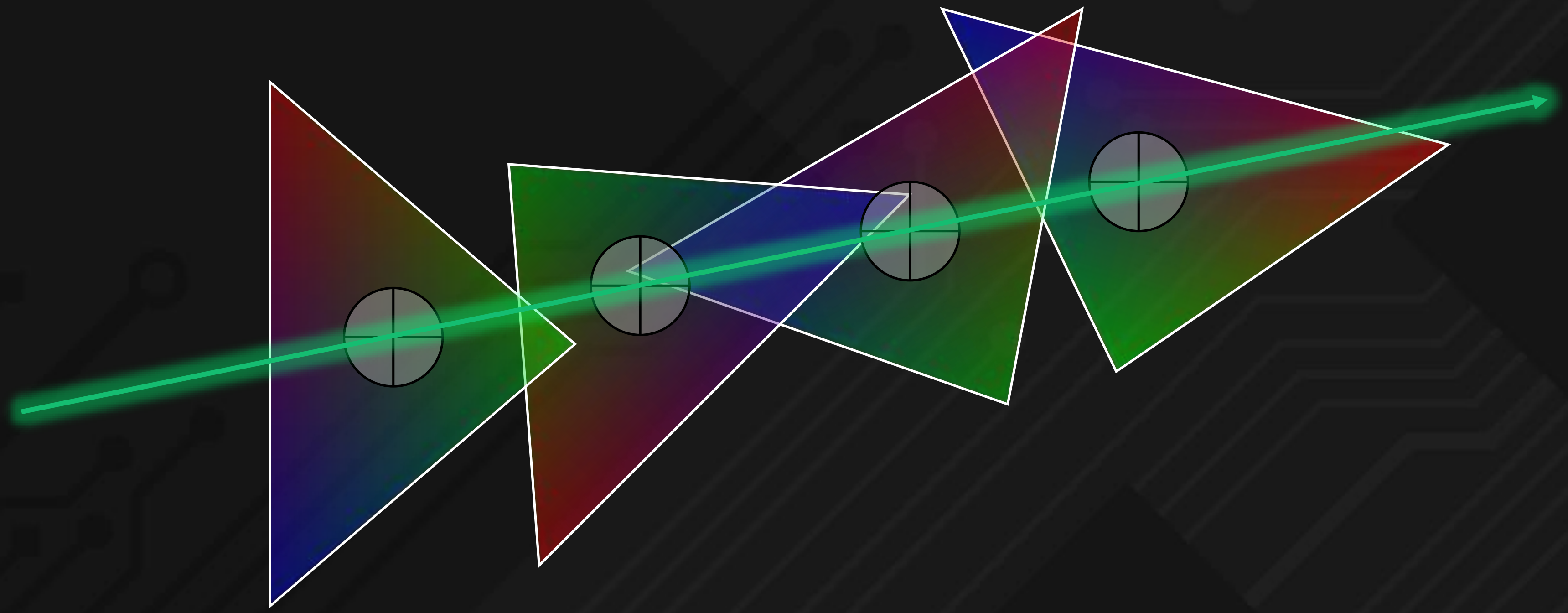
Hit Shaders

- Invoked at geometry intersection points
- Access to intersection attributes (tri: barycentrics)
- Read/write access to app-defined ray payload
- Call TraceRay() for recursive traversal



Any-Hit Shaders

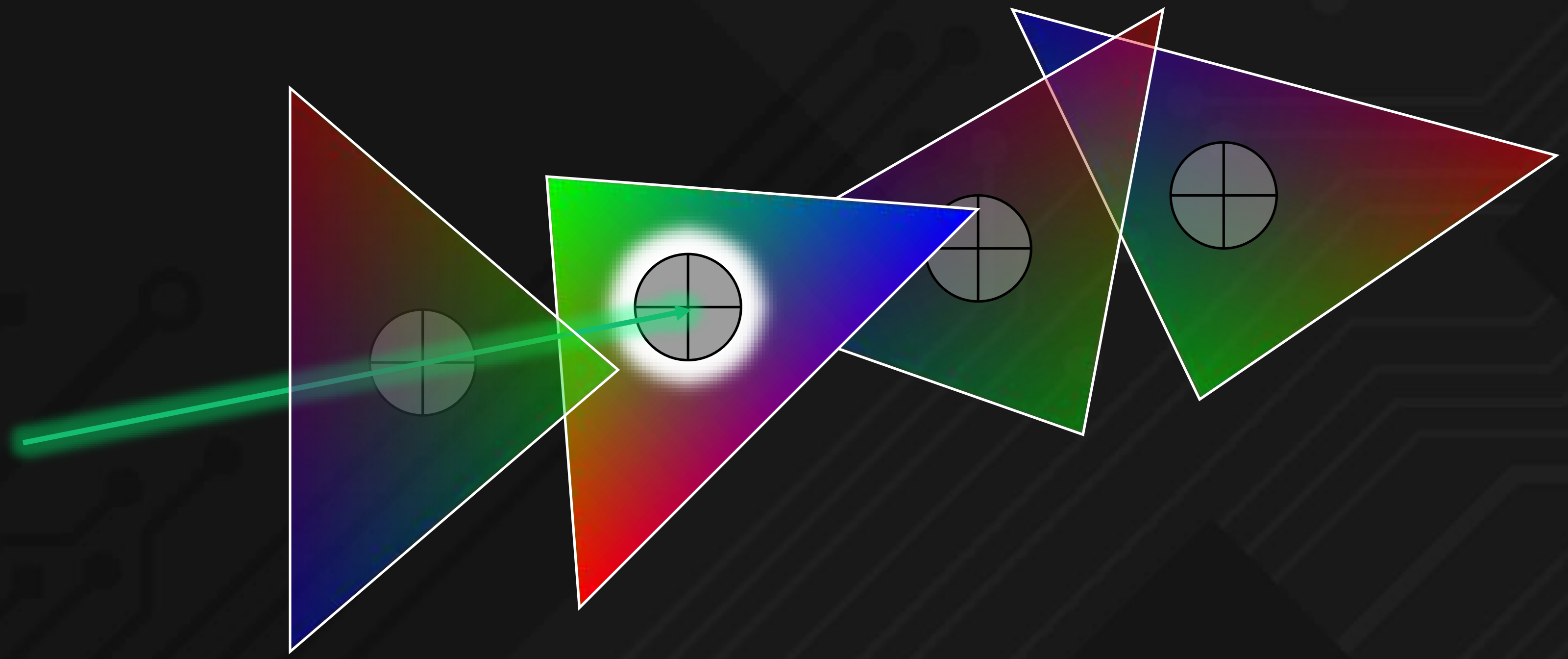
- Invoked for all intersections along ray path
- Read attributes, modify ray payload for subsequent hit shaders
- May call IgnoreHit() / AcceptHitAndEndSearch()



Microsoft Windows

Closest-Hit Shaders

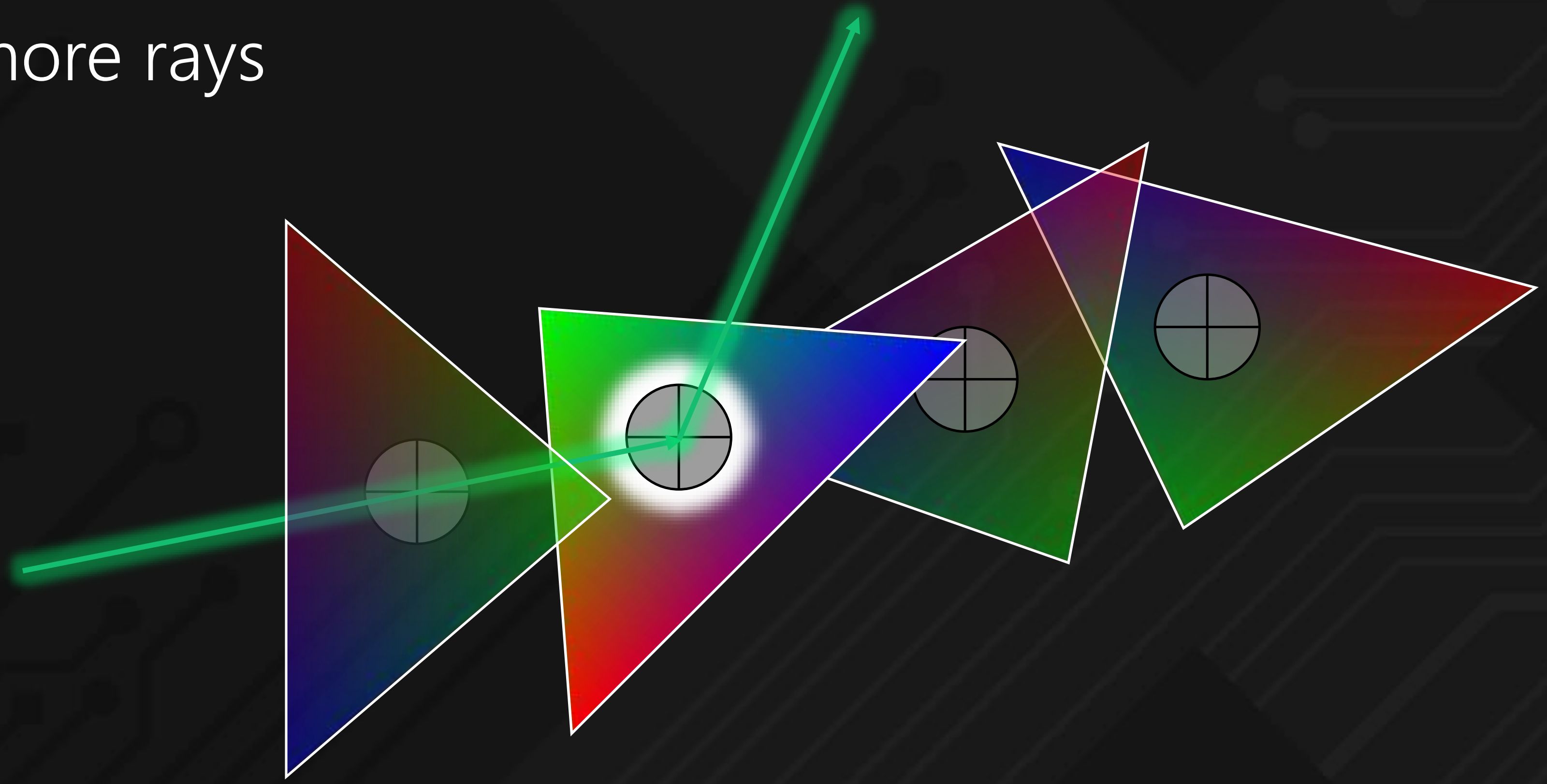
- Invoked for closest <u>accepted</u> intersection along ray path
- Read attributes, modify ray payload for TraceRay() caller



Microsoft Windows

Closest-Hit Shaders

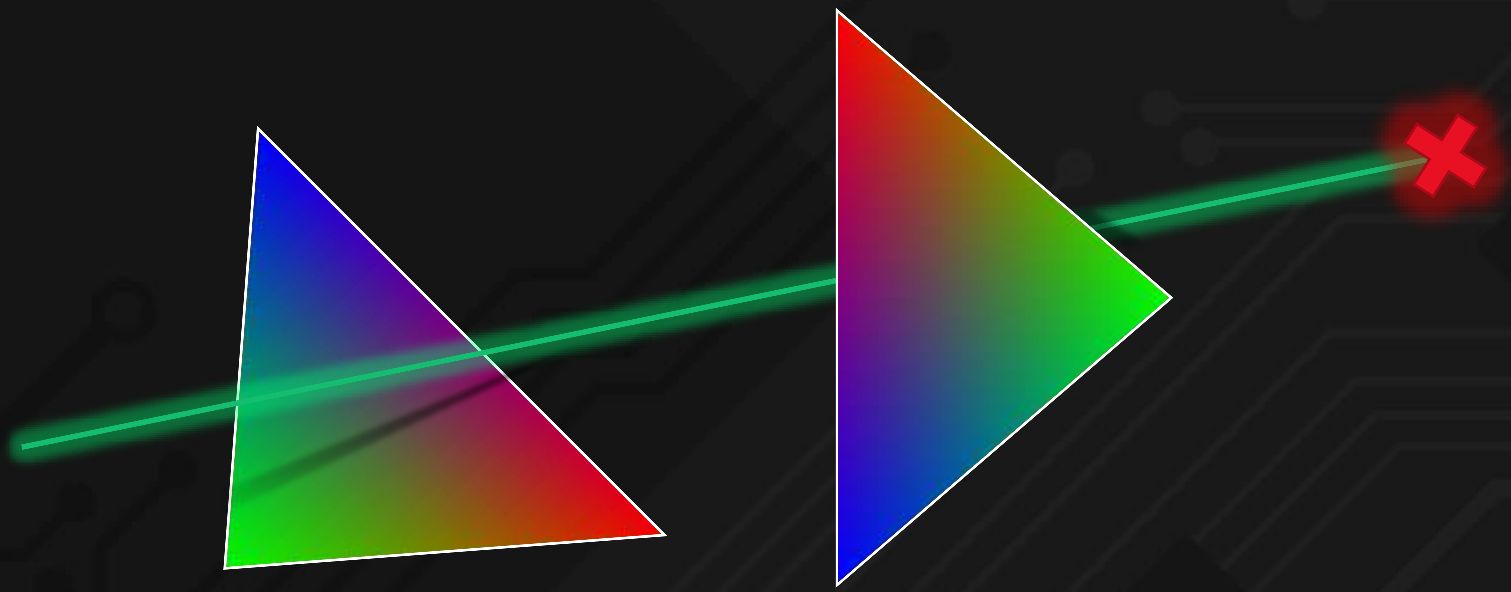
- Invoked for closest <u>accepted</u> intersections along ray path
- Read attributes, modify ray payload for TraceRay() caller
- Trace more rays



Microsoft Windows

Miss Shader

- Invoked for rays with no accepted hits through `TMax`
- May trace more rays (e.g. into lower-LOD acceleration structure)
- Return transparent-black, sample skybox, etc.



Which Shaders to Run?

- Rays can intersect any geometry, need any shader, any resource

✔ Bindless resources (arbitrarily indexable table)

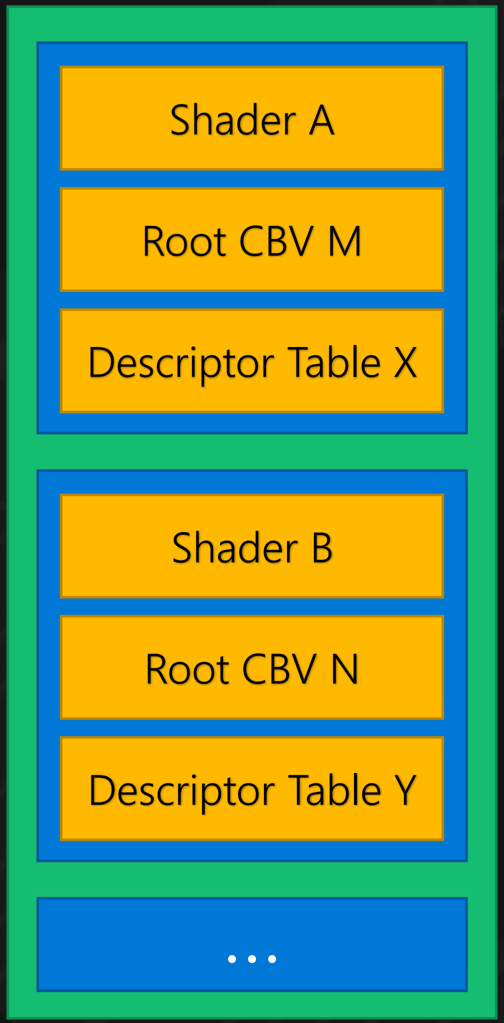
? Bindless shaders

Which Shaders to Run?

- Rays can intersect any geometry, need any shader, any resource
- ✓ Bindless resources (arbitrarily indexable table)
- ✓ Bindless shaders: **shader tables**

Shader Tables

- GPU buffer of "**shader records**"
  - Shader ID
  - Root arguments
- Flexible indexing in DXR
  - Instance properties
  - DispatchRays arguments
  - TraceRay arguments
- Shader IDs acquired from "**state objects**"



State Objects (PSOs v2)

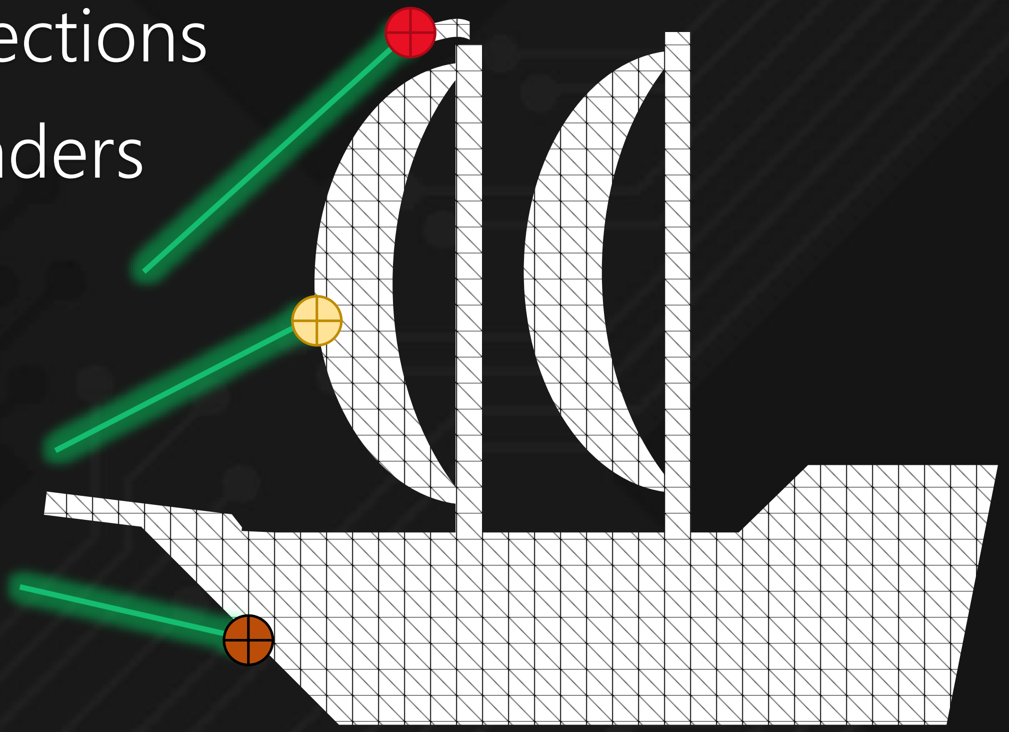
- Set of shaders and root signatures
- Associate root signatures with DXIL library exports
- Create pipeline-specific sub-objects and associations
- Flexibility to support future pipelines
- **State Object Properties** interface for post-compile information

Raytracing State Objects

- Configure maximum ray recursion depth
- Configure ray payload and attribute size
- Create "**hit groups**" from individual shaders
  - 0/1 intersection shader
  - 0/1 any-hit shader
  - 0/1 closest-hit shader
- Use state object properties interface to get:
  - Ray generation shader IDs
  - Miss shader IDs
  - Hit group IDs

Raytracing Requirements

- ✓ Scene geometry representation
- ✓ Trace rays into scene and get intersections
- ✓ Determine and execute material shaders

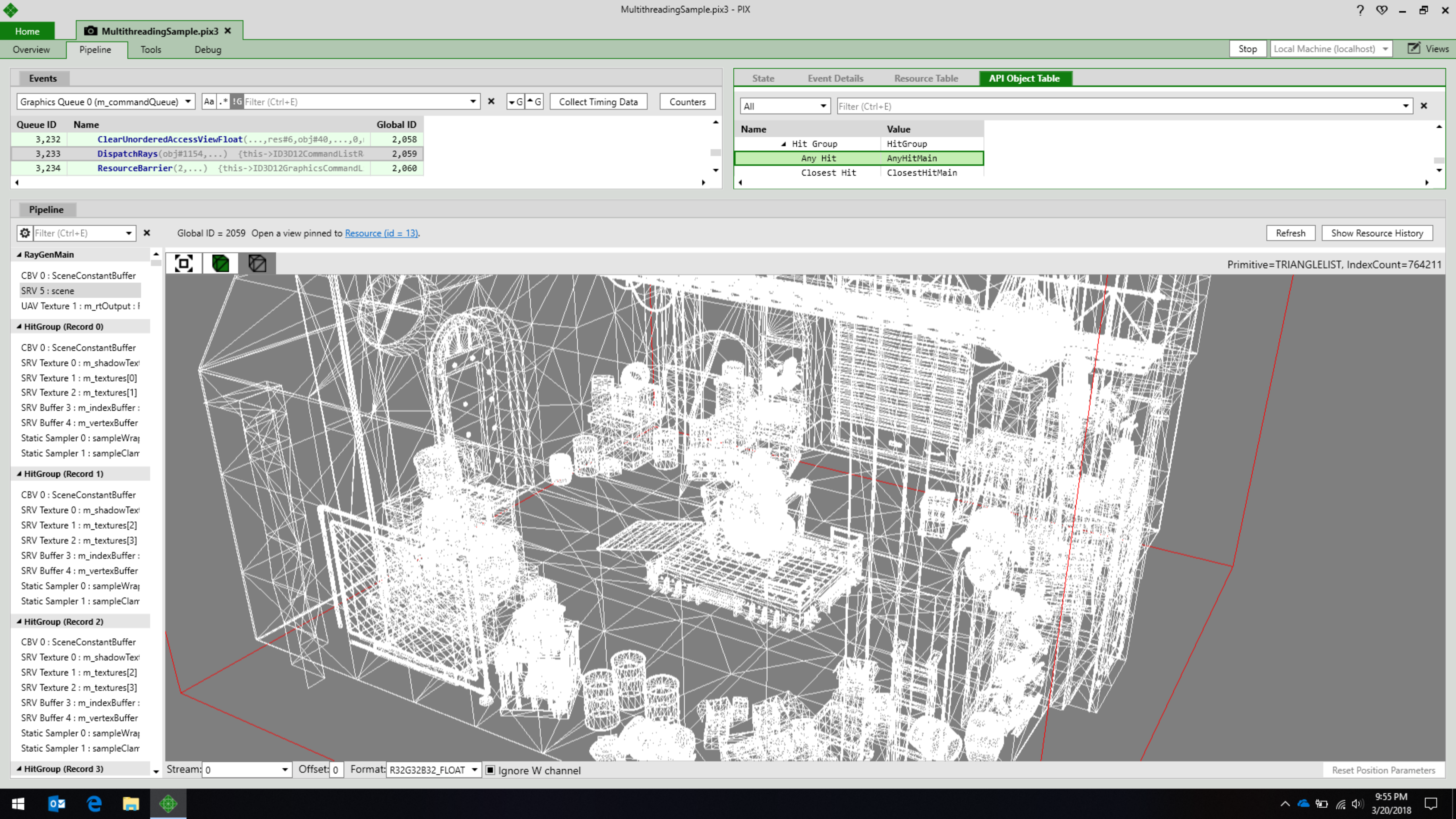


Putting it All Together

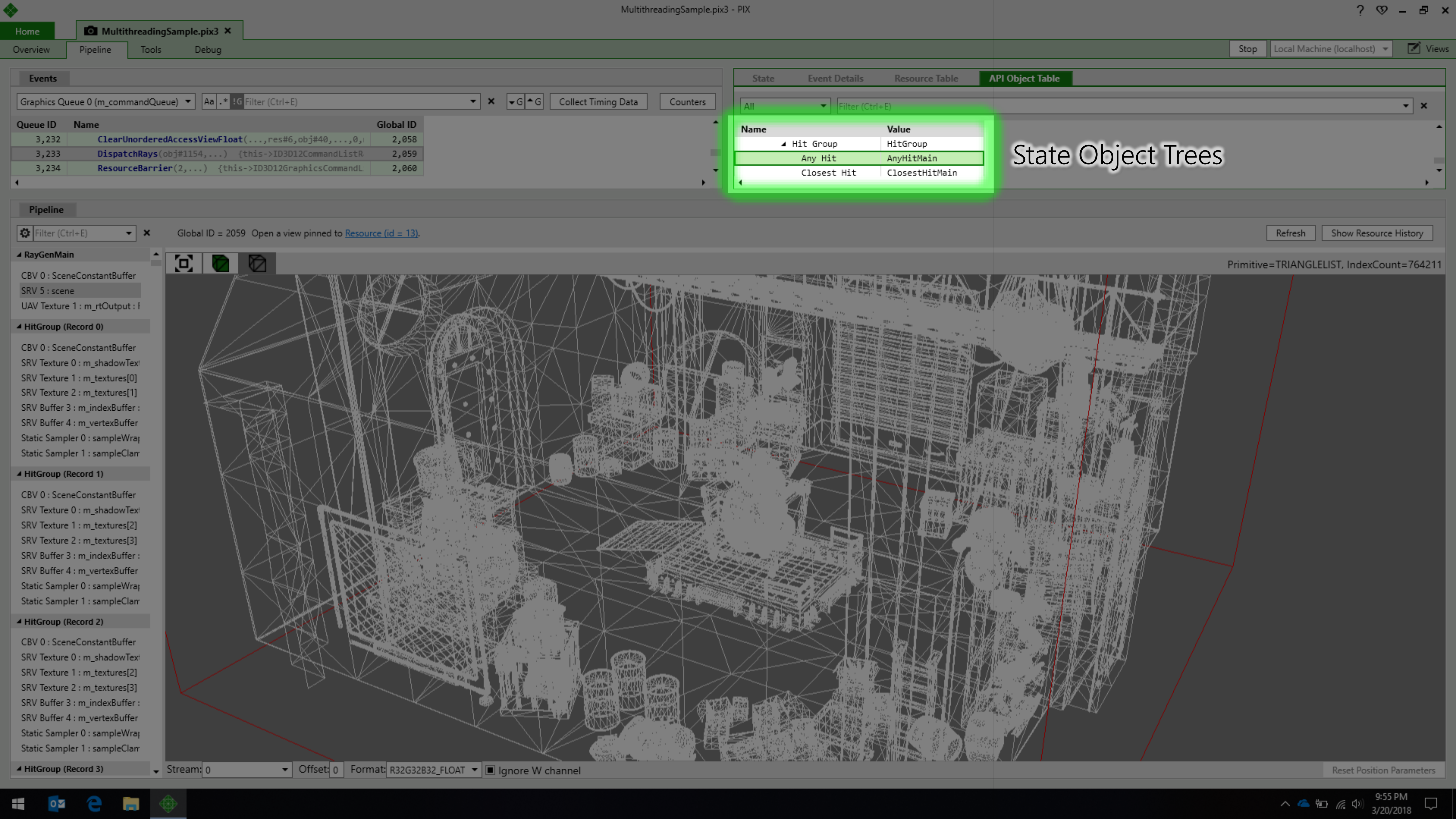
- Create state objects with set of potential material shaders
- Create top/bottom level acceleration structures
- Create shader tables with hit groups / root parameters
- Call DispatchRays
  - Invoke ray-generation shader, call TraceRay()
  - Execute hit shaders, write results into a UAV
- Incorporate UAV results into final scene render

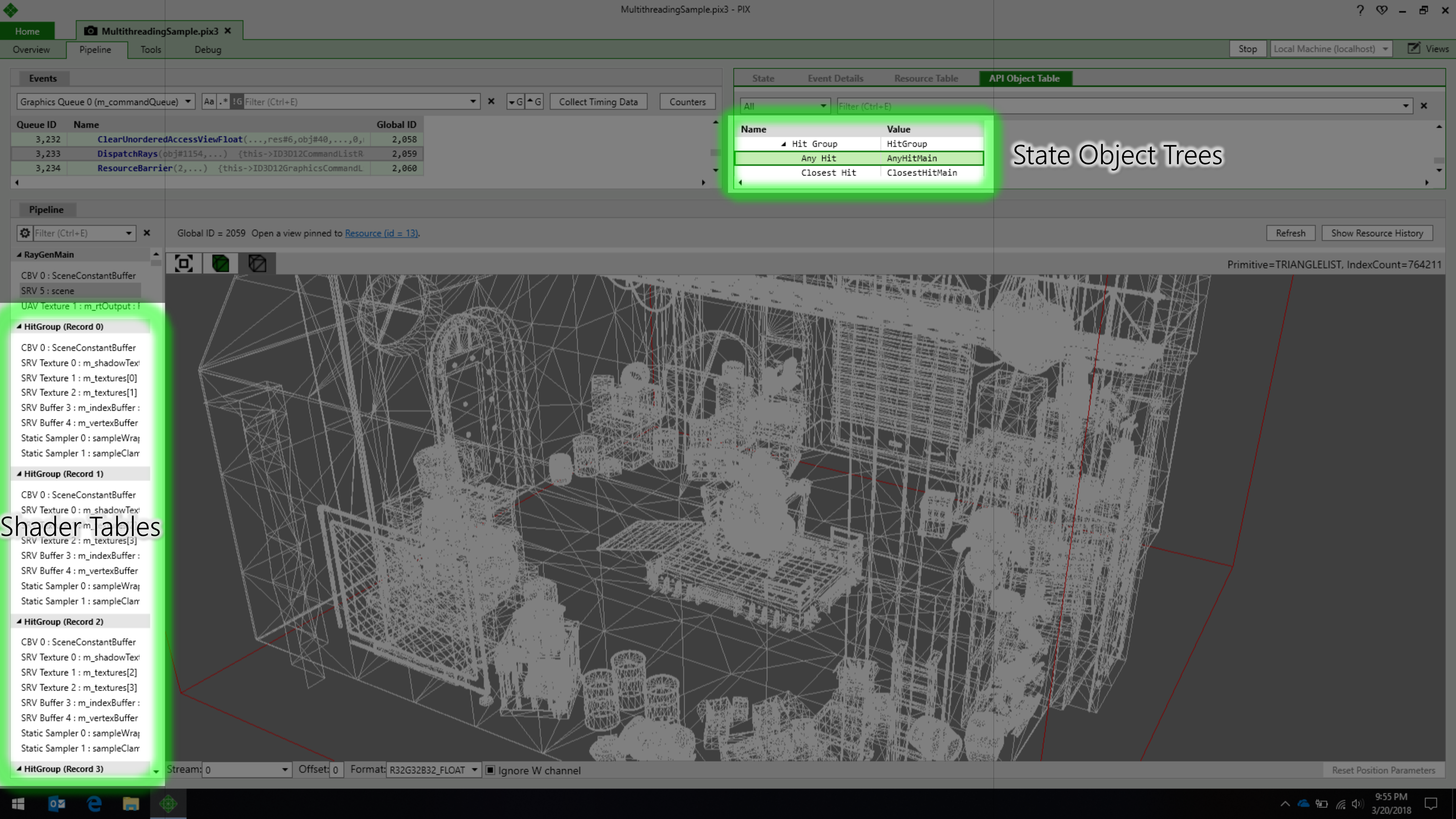
Tools

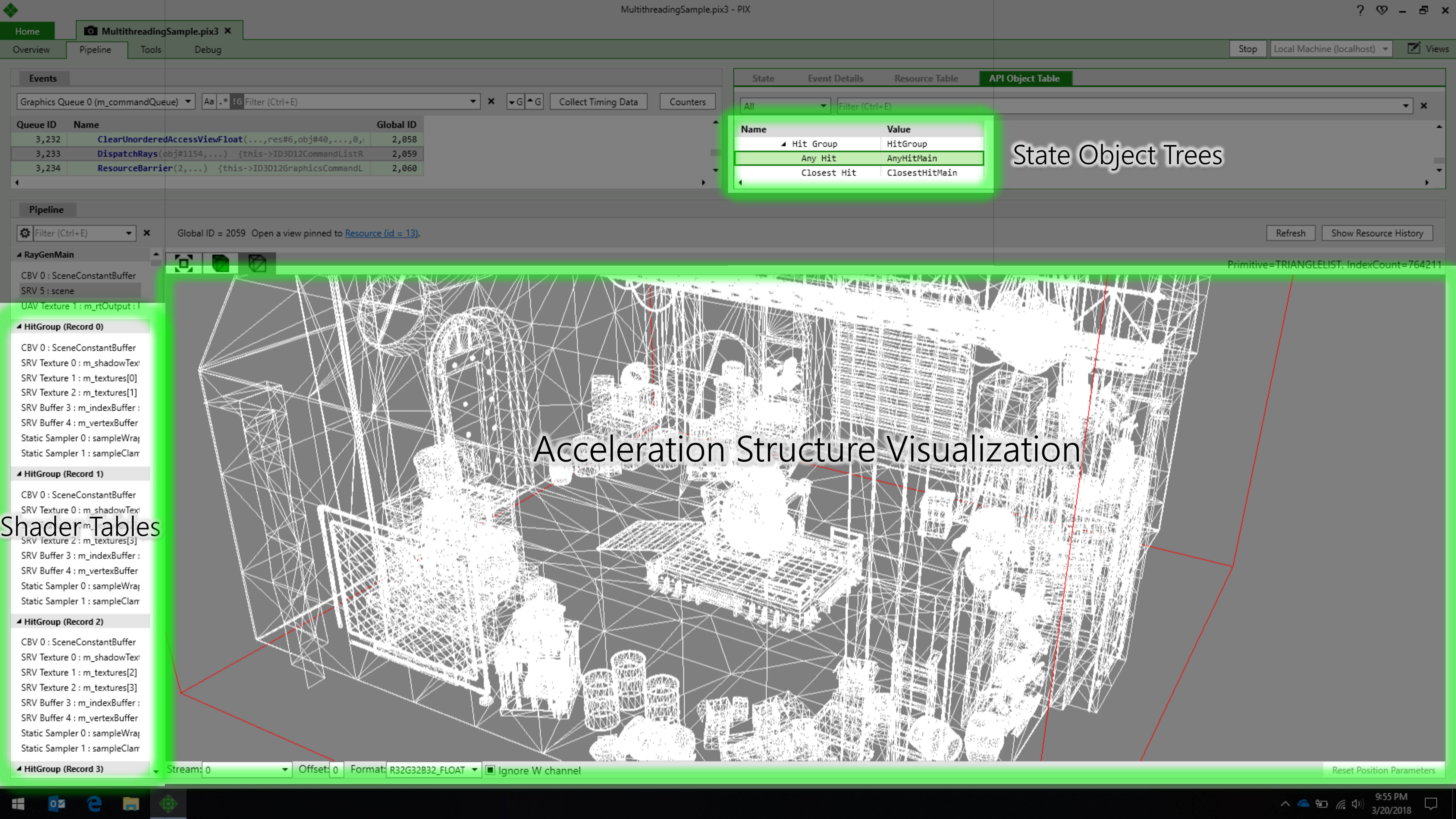
- PIX support available now
  - See also: Direct3D Graphics Debugging and Optimization
  - Thursday 12:45 PM, Room 2009, West Hall (this room)
- Fallback layer
  - Open-source reference implementation
  - Compute shader based (requires DXIL support)
- VS/PS → Hit Group conversion
  - Reuse existing shader content
- Raytracing helper header
  - Very useful for building state objects



MultithreadingSample.pix3 - PIX
Home
MultithreadingSample.pix3
Overview
Pipeline
Tools
Debug
Stop
Local Machine (localhost)
Views
Events
Graphics Queue 0 (m_commandQueue)
Filter (Ctrl+E)
Collect Timing Data
Counters
Queue ID
Name
Global ID
3,232 ClearUnorderedAccessViewFloat(...,res#6,obj#40,...,0, 2,058
3,233 DispatchRays(obj#1154,...) {this->ID3D12CommandListR 2,059
3,234 ResourceBarrier(2,...) {this->ID3D12GraphicsCommandL 2,060
State
Event Details
Resource Table
API Object Table
All
Filter (Ctrl+E)
Name
Value
Hit Group HitGroup
Any Hit AnyHitMain
Closest Hit ClosestHitMain
Pipeline
Filter (Ctrl+E)
Global ID = 2059 Open a view pinned to Resource (id = 13).
Refresh
Show Resource History
RayGenMain
CBV 0 : SceneConstantBuffer
SRV 5 : scene
UAV Texture 1 : m_rtOutput : I
HitGroup (Record 0)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowText
SRV Texture 1 : m_textures[0]
SRV Texture 2 : m_textures[1]
SRV Buffer 3 : m_indexBuffer :
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWra
Static Sampler 1 : sampleClam
HitGroup (Record 1)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowText
SRV Texture 1 : m_textures[2]
SRV Texture 2 : m_textures[3]
SRV Buffer 3 : m_indexBuffer :
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWra
Static Sampler 1 : sampleClam
HitGroup (Record 2)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowText
SRV Texture 1 : m_textures[2]
SRV Texture 2 : m_textures[3]
SRV Buffer 3 : m_indexBuffer :
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWra
Static Sampler 1 : sampleClam
HitGroup (Record 3)
Primitive=TRIANGLELIST, IndexCount=764211
Stream: 0
Offset: 0
Format: R32G32B32_FLOAT
Ignore W channel
Reset Position Parameters
9:55 PM
3/20/2018


State Object Trees
MultithreadingSample.pix3 - PIX
Home
MultithreadingSample.pix3
Overview
Pipeline
Tools
Debug
Stop
Local Machine (localhost)
Views
Events
Graphics Queue 0 (m_commandQueue)
Filter (Ctrl+E)
Collect Timing Data
Counters
Queue ID
Name
Global ID
3,232 ClearUnorderedAccessViewFloat(...,res#6,obj#40,...,0, 2,058
3,233 DispatchRays(obj#1154,...) {this->ID3D12CommandListR 2,059
3,234 ResourceBarrier(2,...) {this->ID3D12GraphicsCommandL 2,060
State
Event Details
Resource Table
API Object Table
All
Name
Value
Hit Group HitGroup
Any Hit AnyHitMain
Closest Hit ClosestHitMain
Pipeline
Global ID = 2059 Open a view pinned to Resource (id = 13).
Refresh
Show Resource History
Primitive=TRIANGLELIST, IndexCount=764211
RayGenMain
CBV 0 : SceneConstantBuffer
SRV 5 : scene
UAV Texture 1 : m_rtOutput
HitGroup (Record 0)
HitGroup (Record 1)
HitGroup (Record 2)
HitGroup (Record 3)
Stream: 0
Offset: 0
Format: R32G32B32_FLOAT
Ignore W channel
Reset Position Parameters
9:55 PM
3/20/2018


MultithreadingSample.pix3 - PIX
Home
MultithreadingSample.pix3
Overview
Pipeline
Tools
Debug
Stop
Local Machine (localhost)
Views
Events
Graphics Queue 0 (m_commandQueue)
Filter (Ctrl+E)
Collect Timing Data
Counters
Queue ID
Name
Global ID
3,232
ClearUnorderedAccessViewFloat(...,res#6,obj#40,...,0,
2,058
3,233
DispatchRays(obj#1154,...) {this->ID3D12CommandListR
2,059
3,234
ResourceBarrier(2,...) {this->ID3D12GraphicsCommandL
2,060
State
Event Details
Resource Table
API Object Table
All
Name
Value
Hit Group
HitGroup
Any Hit
AnyHitMain
Closest Hit
ClosestHitMain
State Object Trees
Pipeline
Global ID = 2059 Open a view pinned to Resource (id = 13).
Refresh
Show Resource History
Primitive=TRIANGLELIST, IndexCount=764211
RayGenMain
CBV 0 : SceneConstantBuffer
SRV 5 : scene
UAV Texture 1 : m_rtOutput
HitGroup (Record 0)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowText
SRV Texture 1 : m_textures[0]
SRV Texture 2 : m_textures[1]
SRV Buffer 3 : m_indexBuffer
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWrap
Static Sampler 1 : sampleClam
HitGroup (Record 1)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowText
Shader Tables
SRV Texture 2 : m_textures[3]
SRV Buffer 3 : m_indexBuffer
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWrap
Static Sampler 1 : sampleClam
HitGroup (Record 2)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowText
SRV Texture 1 : m_textures[2]
SRV Texture 2 : m_textures[3]
SRV Buffer 3 : m_indexBuffer
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWrap
Static Sampler 1 : sampleClam
HitGroup (Record 3)
Stream: 0
Offset: 0
Format: R32G32B32_FLOAT
Ignore W channel
Reset Position Parameters
9:55 PM
3/20/2018


MultithreadingSample.pix3 - PIX
Home
MultithreadingSample.pix3
Overview
Pipeline
Tools
Debug
Stop
Local Machine (localhost)
Views
Events
Graphics Queue 0 (m_commandQueue)
Filter (Ctrl+E)
Collect Timing Data
Counters
Queue ID
Name
Global ID
3,232 ClearUnorderedAccessViewFloat(...,res#6,obj#40,...,0, 2,058
3,233 DispatchRays(obj#1154,...) {this->ID3D12CommandListR 2,059
3,234 ResourceBarrier(2,...) {this->ID3D12GraphicsCommandL 2,060
State
Event Details
Resource Table
API Object Table
All
Name
Value
Hit Group
HitGroup
Any Hit
AnyHitMain
Closest Hit
ClosestHitMain
State Object Trees
Pipeline
Global ID = 2059 Open a view pinned to Resource (id = 13).
Refresh
Show Resource History
RayGenMain
CBV 0 : SceneConstantBuffer
SRV 5 : scene
UAV Texture 1 : m_rtOutput
HitGroup (Record 0)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowTex
SRV Texture 1 : m_textures[0]
SRV Texture 2 : m_textures[1]
SRV Buffer 3 : m_indexBuffer
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWra
Static Sampler 1 : sampleClam
HitGroup (Record 1)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowTex
Shader Tables
SRV Texture 2 : m_textures[3]
SRV Buffer 3 : m_indexBuffer
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWra
Static Sampler 1 : sampleClam
HitGroup (Record 2)
CBV 0 : SceneConstantBuffer
SRV Texture 0 : m_shadowTex
SRV Texture 1 : m_textures[2]
SRV Texture 2 : m_textures[3]
SRV Buffer 3 : m_indexBuffer
SRV Buffer 4 : m_vertexBuffer
Static Sampler 0 : sampleWra
Static Sampler 1 : sampleClam
HitGroup (Record 3)
Primitive=TRIANGLELIST, IndexCount=764211
Acceleration Structure Visualization
Stream: 0
Offset: 0
Format: R32G32B32_FLOAT
Ignore W channel
Reset Position Parameters
9:55 PM
3/20/2018

DirectX: Evolving Microsoft's Graphics Platform

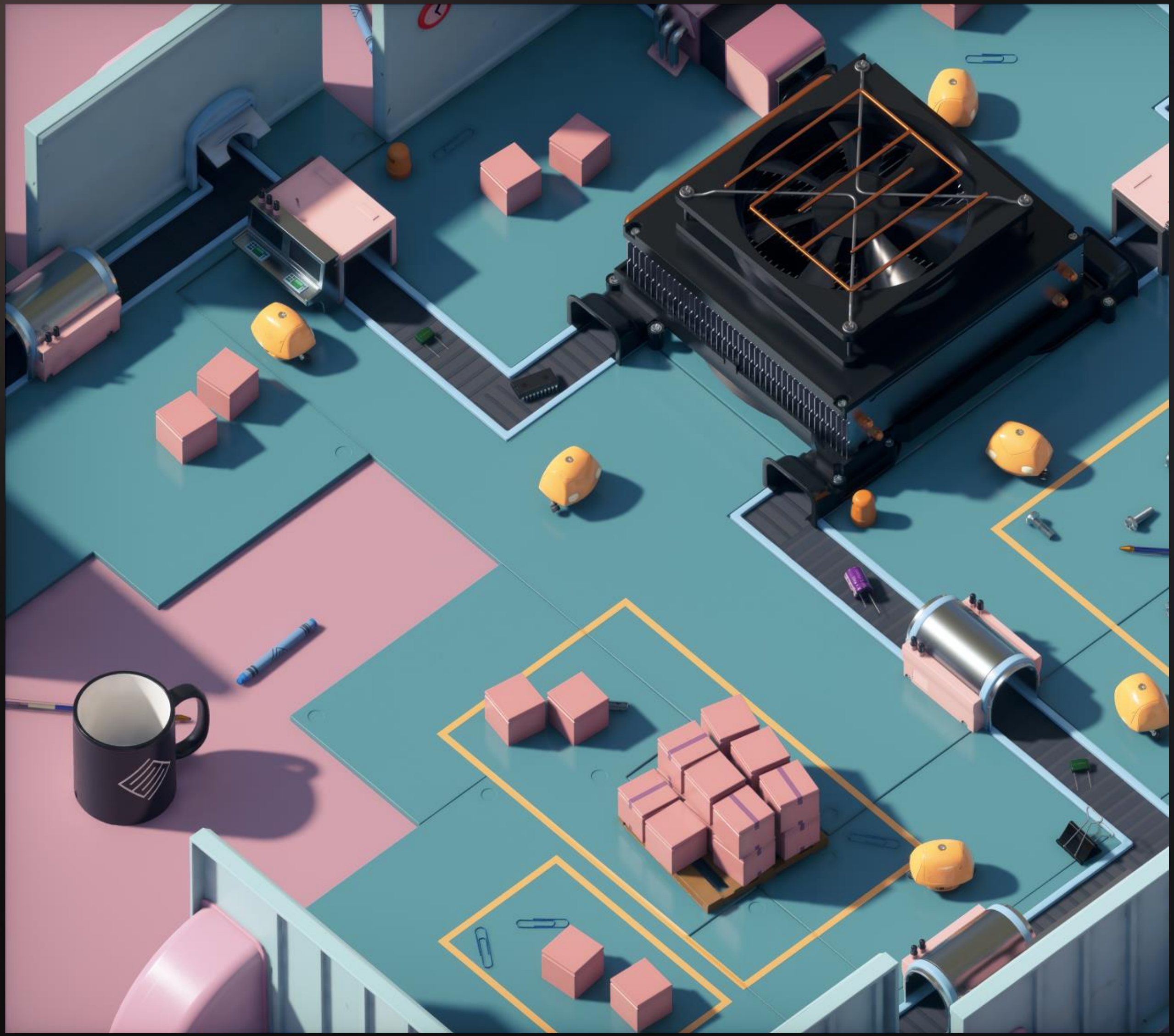
Johan Andersson & Colin Barré-Brisebois
Electronic Arts

SEED

“PICA PICA”

Exploratory mini-game & world

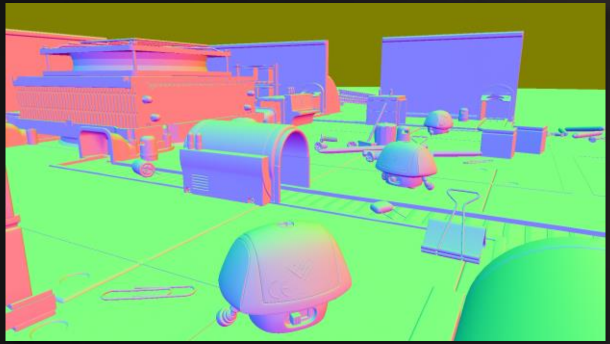
- For our self-learning AI agents to play, not for humans ☺
- Uses SEED’s ***Halcyon*** R&D engine
- Goals
  - Explore hybrid raytracing with DXR
  - Clean and consistent visuals
  - Procedurally-generated worlds
  - No precomputation



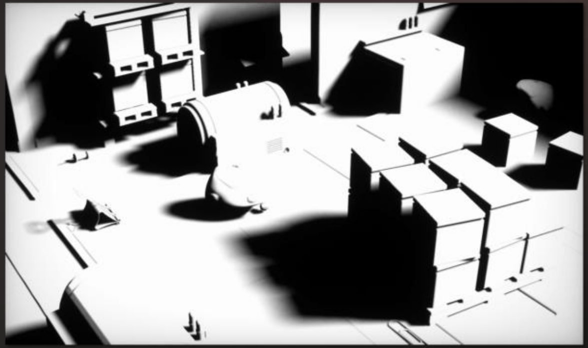
Why raytracing?

- Flexible new tool in the toolbox
- Solve sparse & incoherent problems
- Unified API + performance (DXR + RTX)
- Simple high quality - easy ground truth

Hybrid Rendering Pipeline

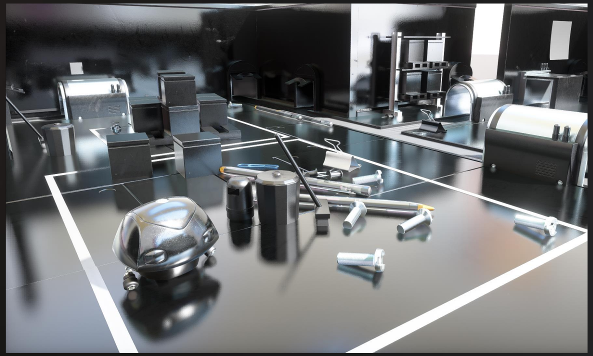


Deferred shading (raster)



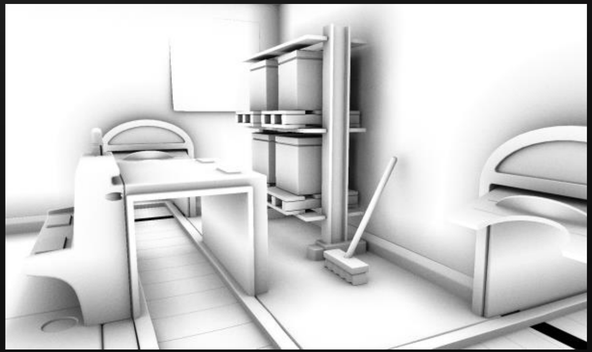
Direct shadows (raytrace or raster)

Direct lighting (compute)



Reflections (raytrace)

Global Illumination (raytrace)



Ambient occlusion (raytrace or compute)

Transparency & Translucency (raytrace)

Post processing (compute)

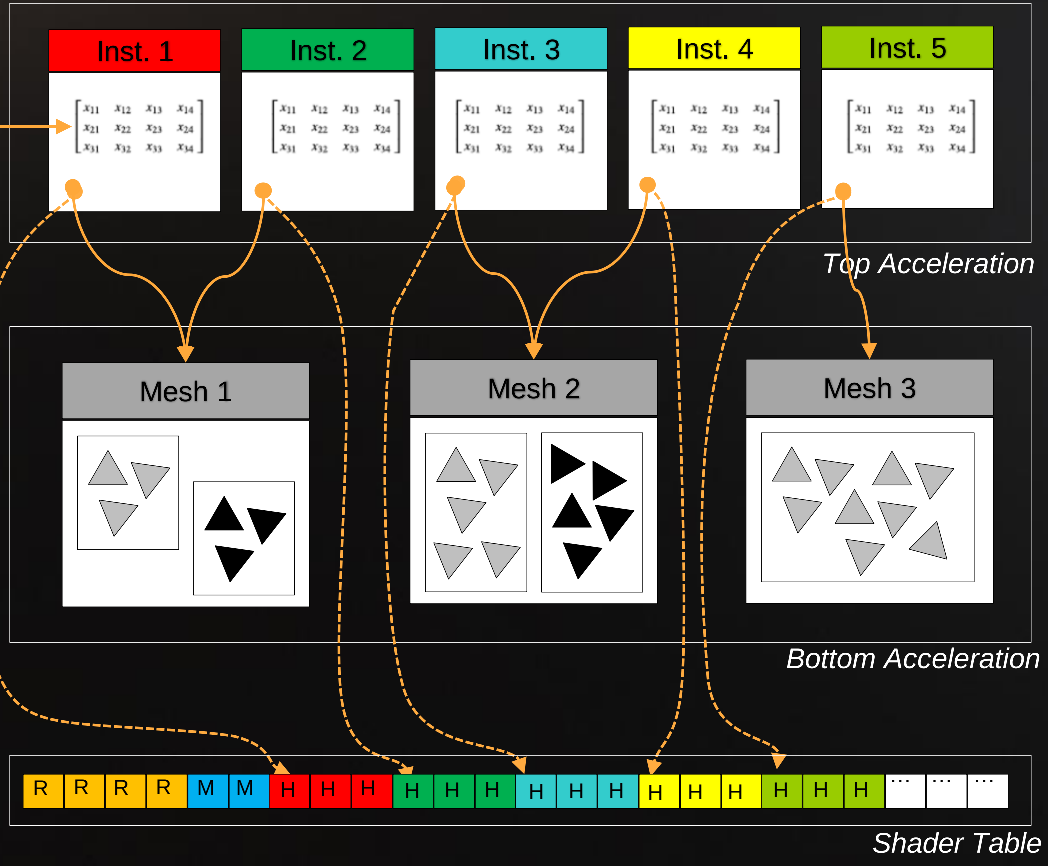
Live demo

XII?

- **Spawn a Mesh?**
  - DXR: build its bottom acceleration structure
  - Multiple geometries for multiple materials
    - Triangles, AABBs, custom
  - Mesh instances specified in top acceleration

- **Move a Mesh?**
  - Update the instance's position/orientation in the top acceleration

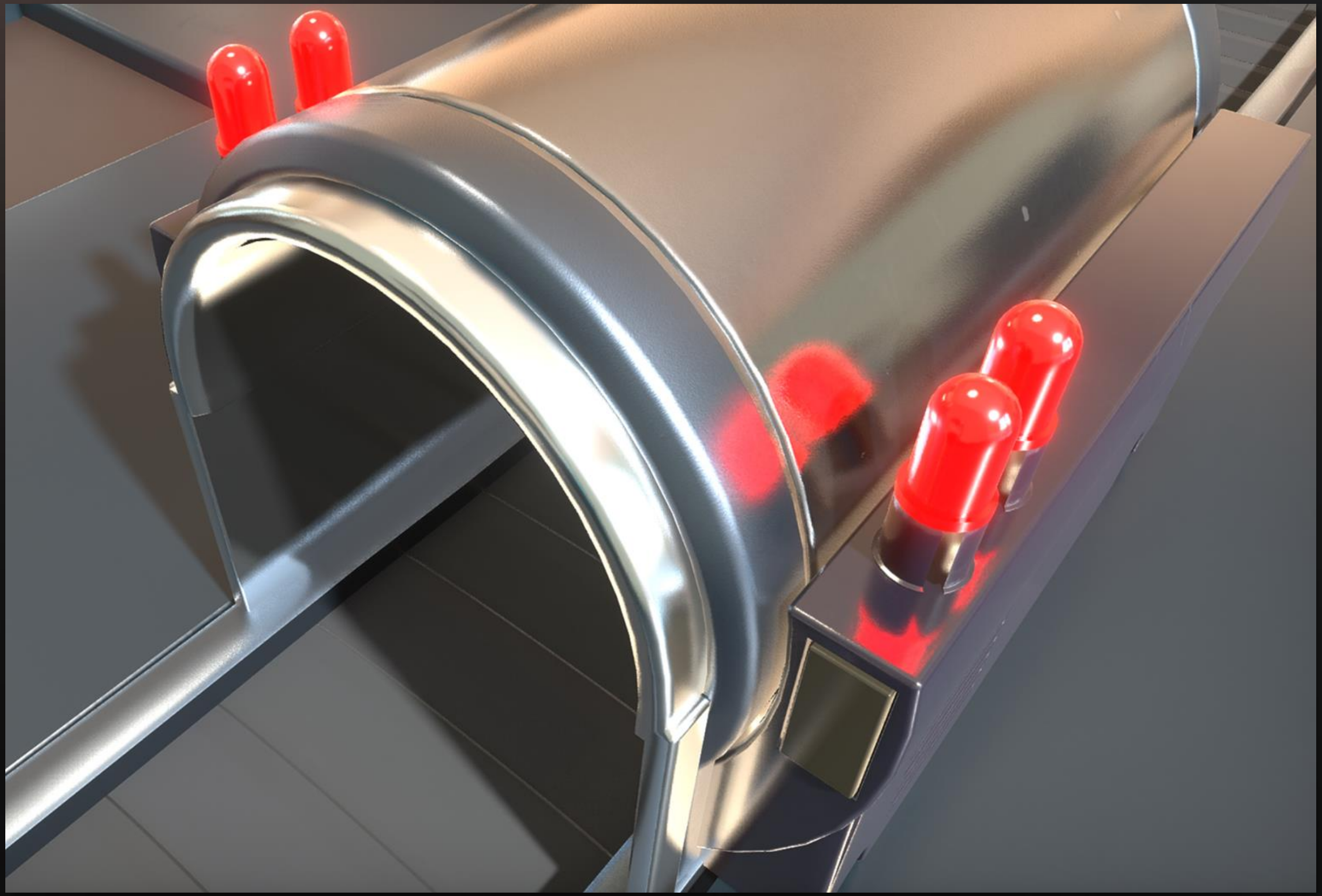
- **Spawn [some] Rays?**
  - Multiple Hit and Miss shaders possible



Raytraced Reflections

- Rasterize primary visibility
- Launch rays from the G-Buffer
- Raytrace at half resolution
- Reconstruct at full resolution
    - Spatiotemporal filtering

- Works on both flat and curved surfaces



Raytraced Reflections

Reflection Rays

Let's launch some reflection rays:

1. Select one of the (2x2) pixels to trace
2. Reconstruct position and vectors
3. Initialize Halton & random number seq.
4. Initialize the payload
5. Prepare a new ray
6. Trace
7. Gather results from ray payload
    - Reflection Color, Direction, HitT, 1/pdf

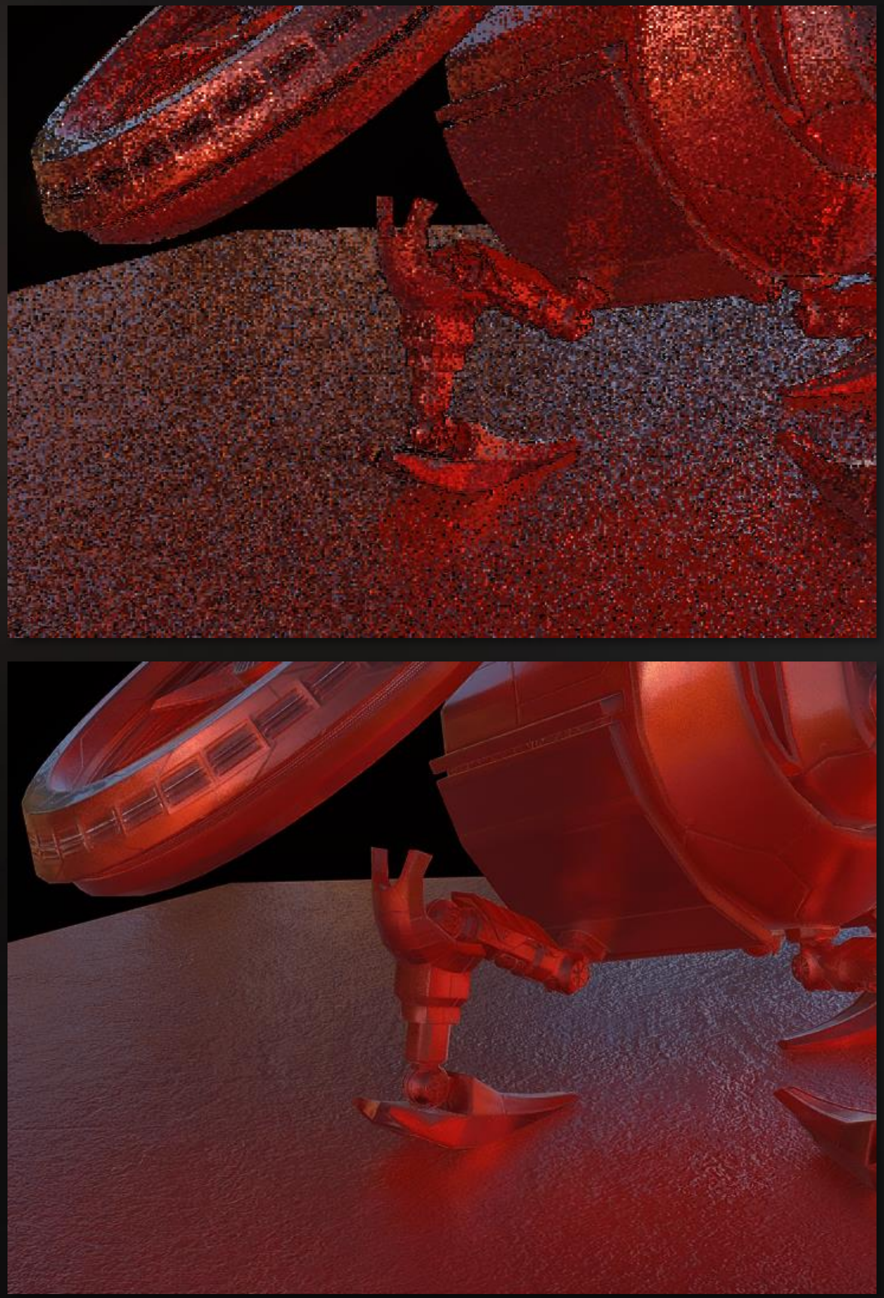
```
RaytracingAccelerationStructure g_rtScene  : register(t0, space0);
ConstantBuffer<RaytracingConstants> g_rt   : register(b0, space0);
RWTexture2D<float4> g_tex0                 : register(u0, space0);
RWTexture2D<float4> g_tex1                 : register(u1, space0);

[shader("raygeneration")]
void reflectionRaygen()
{
    uint2 px = DispatchRaysIndex();
    uint2 launchDim = DispatchRaysDimensions();

    // Select one of the four full-res pixels to trace from
    const uint2 noiseCoord = (px / 2 + (g_rt.frameIndex / 2) * uint2(3, 7)) & 31;
    const uint subpixelIdx = g_blueNoise[noiseCoord.x + noiseCoord.y * 32] + g_rt.frameIndex;
    const uint2 gbufferPx = px * 2 + uint2(subpixelIdx & 1, (subpixelIdx >> 1) & 1);

    // Reconstruct position and the various vectors
    const Gbuffer gbuffer = loadGbuffer(gbufferPx, g_gbuffer);
    const float depth = g_depth[gbufferPx];
    float2 uvPos = (gbufferPx + 0.5f) / g_rt.viewDimensions.xy;
    float4 csPos = float4(uvToCs(uvPos), depth, 1.0f);
    float4 wsPos = mul(g_rt.clipToWorld, csPos);
    const float3 P = wsPos.xyz / wsPos.w;
    const float3 E = g_rt.eyeWorldPosition;
    const float3 V = normalize(E - position);
    const float3 N = gbuffer.normal;

    // Initialize the Halton sequence for each ray and random number generator to rotate the sequence
    Halton halton = haltonInit(px, g_rt.frameIndex, ...);
    uint seed = randomInit(px);

    // Initialize a new payload
    Payload payload = payloadInit(seed, halton);

    // Initialize a new ray
    RayDesc ray;
    ray.Origin = position + V * max(1, length(frame.position)) * 1e-4f;    // epsilon
    ray.Direction = sampleDirectionFromBrdf(gbuffer, V, N, halton, seed); // stochastic BRDF
    ray.TMin = 0;
    ray.TMax = 1000; // perf: ray stops at 1000 meters

    // Launch the ray
    TraceRay(g_rtScene, RAY_FLAG_CULL_FRONT_FACING_TRIANGLES, RaytracingInstanceMaskAll,
             HitType_Primary, SbtRecordStride, MissType_Primary,
             ray, hitData);

    g_tex0[px] = float4(hitData.lighting.rgb, depth);
    g_tex1[px] = float4(ray.Direction * hitData.hitT, 1.0f / brdfSample.pdf);
}
```

Reflections Raytracing HLSL Pseudo-Code

Reflection Filtering

Inspired by *Stochastic Screen-Space Reflections* [Stachowiak 2015]

- For every full-res pixel, sample 16 pixels in half-res ray results
  - Blue Noise offsets, decorrelated every 2x2 pixels
- Build color bounding box of ray-hit results
  - Clamp temporal history to bounding box
- Followed by a variance-driven bilateral filter
  - Helps with rough reflections



Unfiltered (Top) and Filtered (Bottom) Results

Screen-Space Reflections

G-Buffer Raytraced

Path Tracing Reference

Screen-Space Reflections

G-Buffer Raytraced

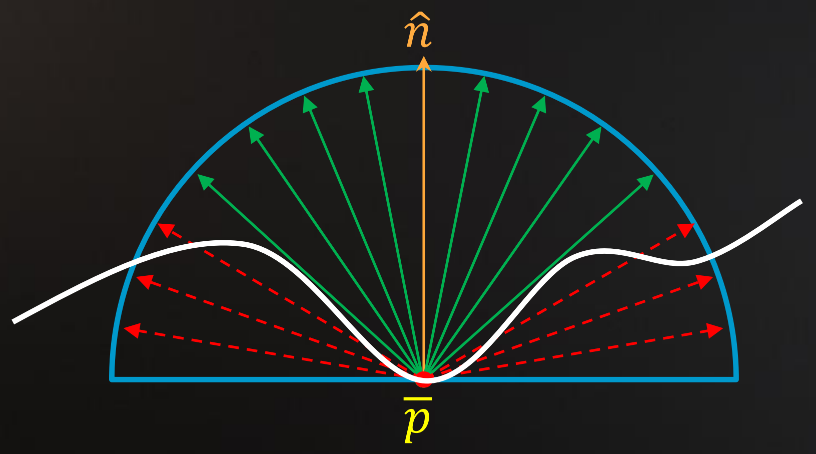
Path Tracing Reference

Ambient Occlusion

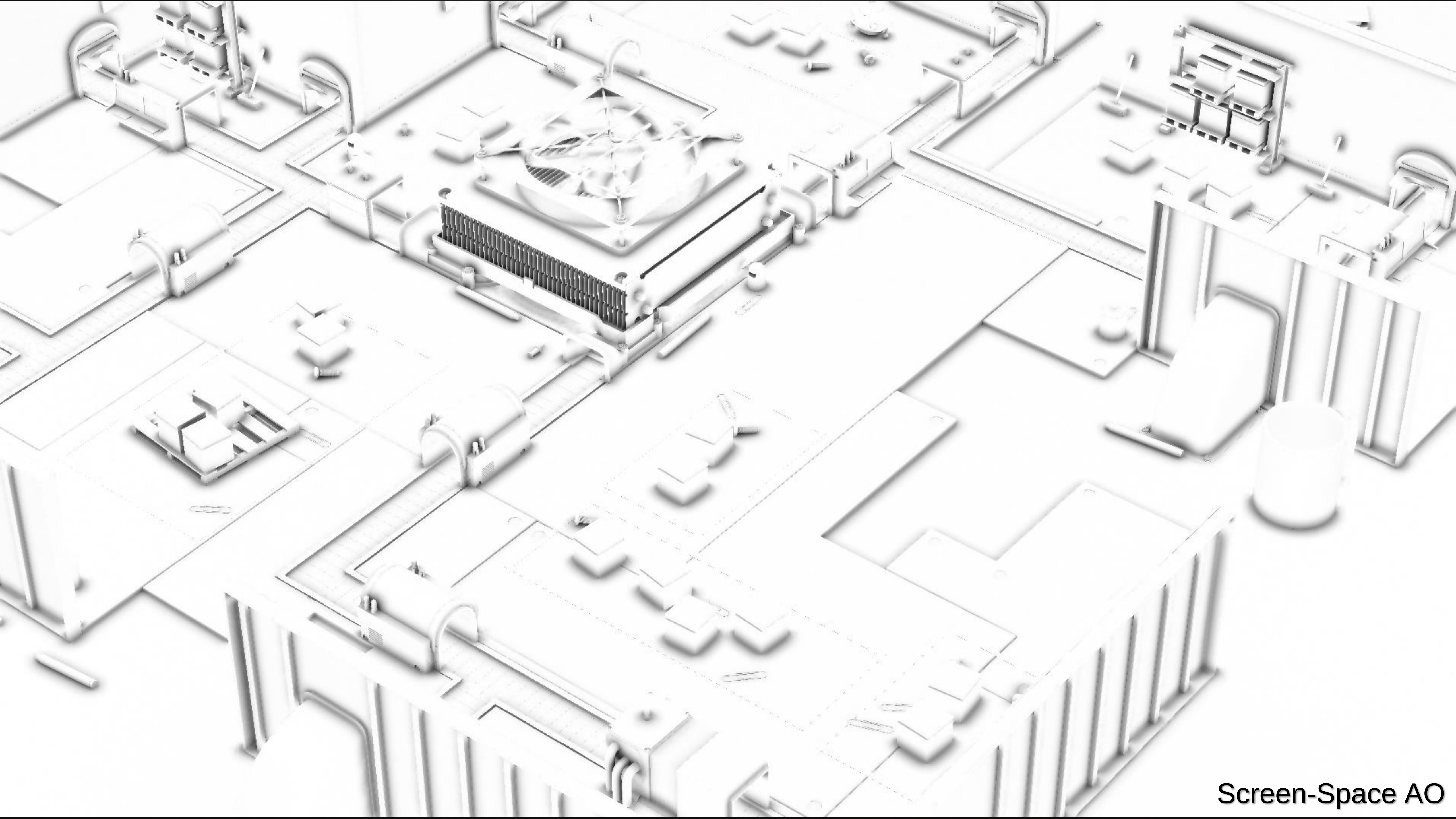
Ambient Occlusion (AO) [Langer 1994] [Miller 1994] maps and scales directly with real-time ray tracing:

- Integral of the visibility function over the hemisphere Ω for the point $\overline{p}$ on a **surface** with normal $\hat{n}$ with respect to the projected solid angle

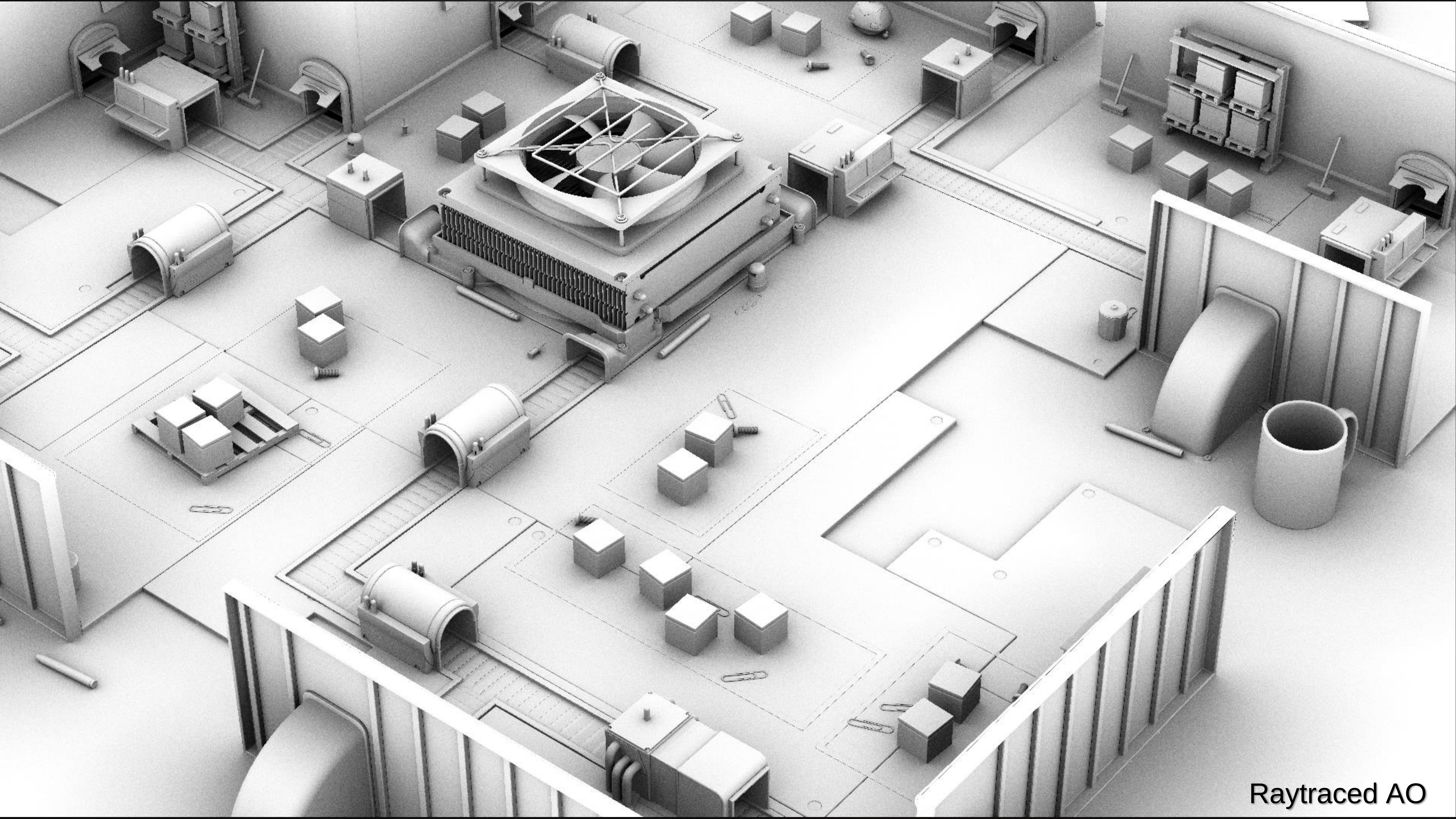
- Games often approximate this in screen-space
- With RT, more grounded & improves visual fidelity!
  - Random directions $\widehat{w}$
  - Can be temporally accumulated or denoised



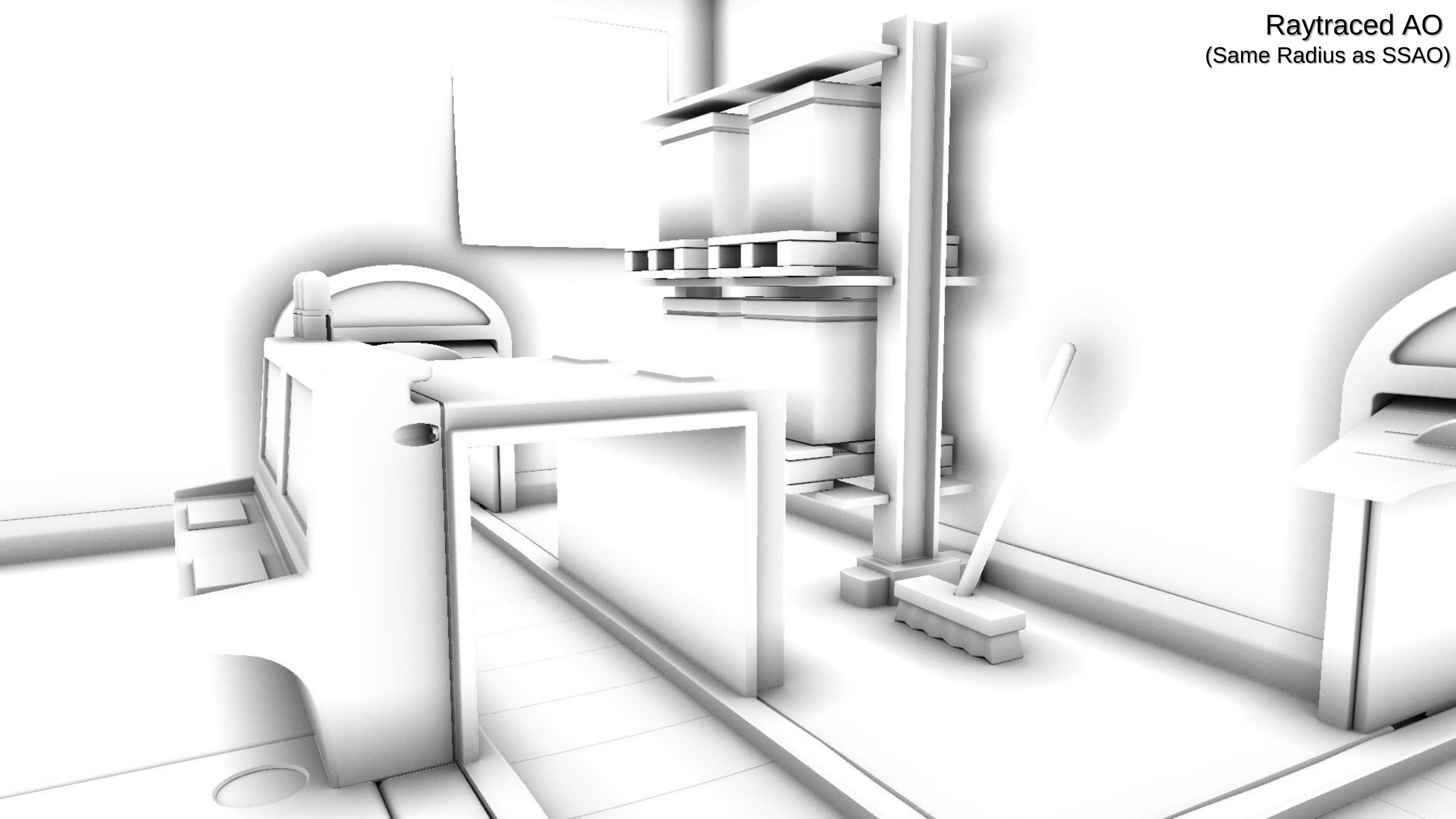
$$A_{\overline{p}} = \frac{1}{\pi}\int_{\Omega} V_{\overline{p},\widehat{w}}(\hat{n}\cdot\widehat{w})\,d\omega$$



Screen-Space AO


Raytraced AO


Screen-Space AO

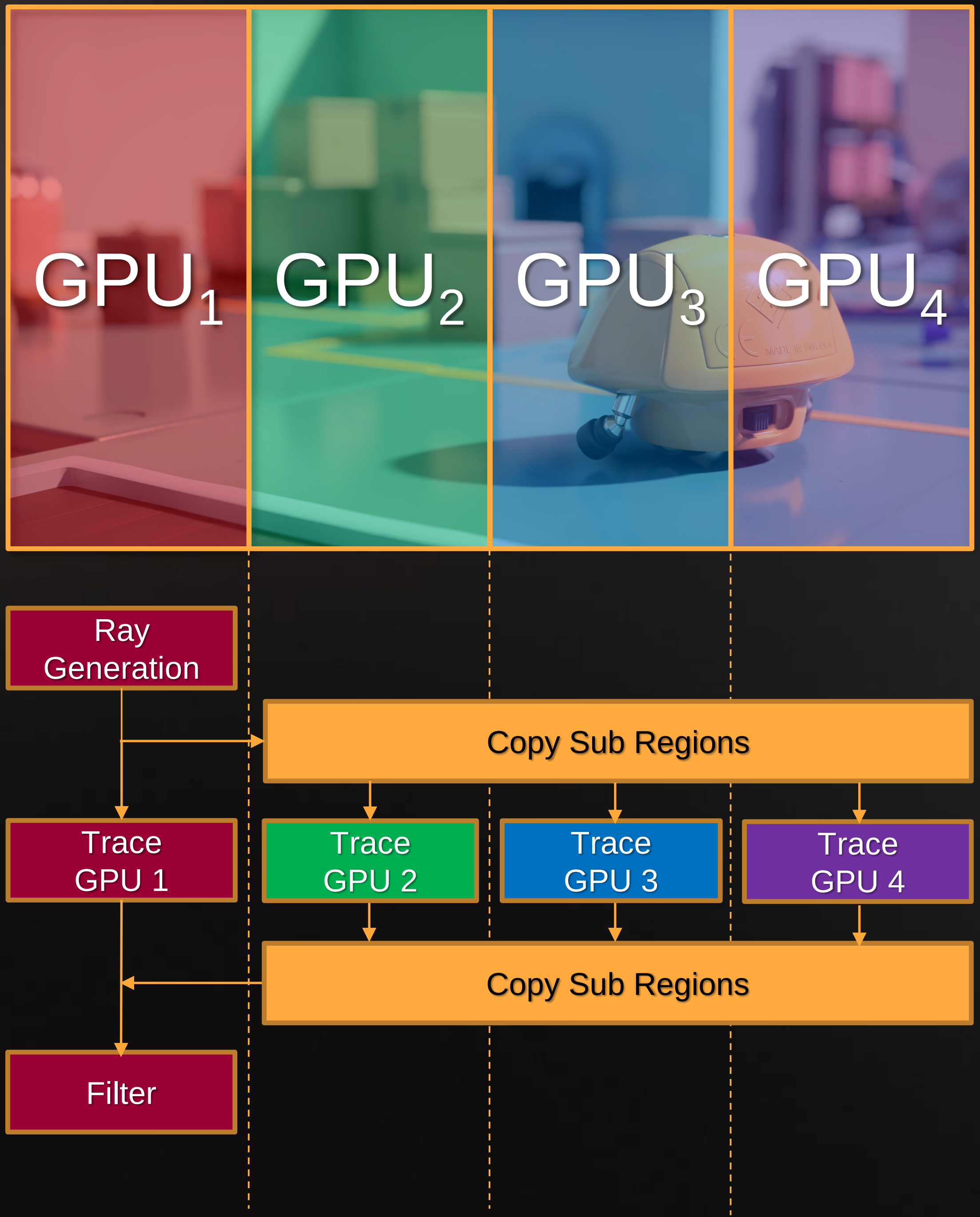

Raytraced AO
(Same Radius as SSAO)

Raytraced AO
(Far-field)

mGPU

Explicit Heterogenous Multi-GPU

- Parallel Fork-Join Style
- Resources copied through system memory using copy queue
- Minimize PCI-E transfers
- Approach
  - Run ray generation on primary GPU
  - Copy results in sub-regions to other GPUs
  - Run tracing phases on separate GPUs
  - Copy tracing results back to primary GPU
  - Run filtering on primary GPU



Summary

- Just the beginning – important new tool going forward
- Unified API – easy to experiment and integrate
- Flexible but complex tradeoffs - noise vs ghosting vs perf
- Can enable very high quality cinematic visuals
- Lots more to explore – perf, raster vs trace, sparse render, denoising, new techniques

SEED @ GDC 2018

- **Shiny Pixels & Beyond: Rendering Research at SEED (presented by Nvidia)**
  - Johan Andersson and Colin Barré-Brisebois
  - Room 3022, West Hall, Wednesday, March 21st, 5:00pm - 6:00pm

- **Deep Learning - Beyond the Hype**
  - Magnus Nordin
  - Room 2016, West Hall, Thursday, March 22nd, 11:30am - 12:30pm

- **Creativity of Rules and Patterns: Designing Procedural Systems**
  - Anastasia Opara
  - GDC Show Floor, Thursday, March 22nd, 12:30PM-1:00PM and Friday, March 23rd @ 11:00AM-11:30AM

Thanks

- **SEED**
  - Jasper Bekkers
  - Joakim Bergdahl
  - Ken Brown
  - Dean Calver
  - Dirk de la Hunt
  - Jenna Frisk
  - Paul Greveson
  - Henrik Halen
  - Effeli Holst
  - Andrew Lauritzen
  - Magnus Nordin
  - Niklas Nummelin
  - Anastasia Opara
  - Kristoffer Sjöö
  - Tomasz Stachowiak
  - Ida Winterhaven
  - Graham Wihlidal
- **Microsoft**
  - Chas Boyd
  - Ivan Nevraev
  - Amar Patel
  - Matt Sandy
- **NVIDIA**
  - Tomas Akenine-Möller
  - Nir Benty
  - Jiho Choi
  - Peter Harrison
  - Alex Hyder
  - Jon Jansen
  - Aaron Lefohn
  - Ignacio Llamas
  - Henry Moreton
  - Martin Stich

SEED // SEARCH FOR EXTRAORDINARY EXPERIENCES DIVISION

STOCKHOLM – LOS ANGELES – MONTRÉAL – REMOTE

WWW.EA.COM/SEED

WE'RE HIRING!

How to get started

- Windows Insider Preview (RS4)
- Experimental SDK + spec: http://aka.ms/DXRSDK
- PIX-raytracing: http://aka.ms/DXRPIX
- DXR overview: http://aka.ms/DXR
- Give us feedback (really!): http://forums.directxtech.com

Ray Tracing Gems – Call for Papers

- A new book series with focus on real-time and interactive ray tracing for game development using the DXR API.
- We invite articles on the following topics:
  Basic ray tracing algorithms, effects (shadows, reflections, etc.), non-graphics applications, reconstruction, denoising, & filtering, efficiency and best practices, baking & preprocessing, ray tracing API & design, rasterization and ray tracing, global Illumination, BRDFs, VR, deep learning, etc.
- Important dates:
  - 15th of October 2018: submission deadline for full papers
  - GDC 2019: publication of Ray Tracing Gems (paper version + e-book)
- Eric Haines and Tomas Akenine-Möller will lead the editorial team
  http://developer.nvidia.com/raytracinggems/

Microsoft Windows NVIDIA

Questions?

Microsoft