GPU TECHNOLOGY CONFERENCE

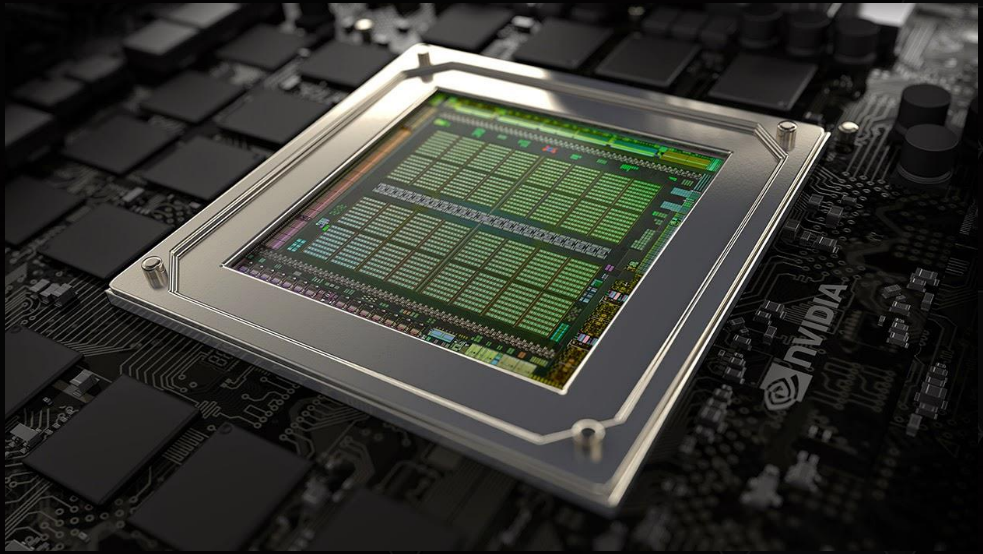
NEW GPU FEATURES
OF NVIDIA'S MAXWELL ARCHITECTURE

ALEXEY PANTELEEV

DEVELOPER TECHNOLOGY ENGINEER, NVIDIA

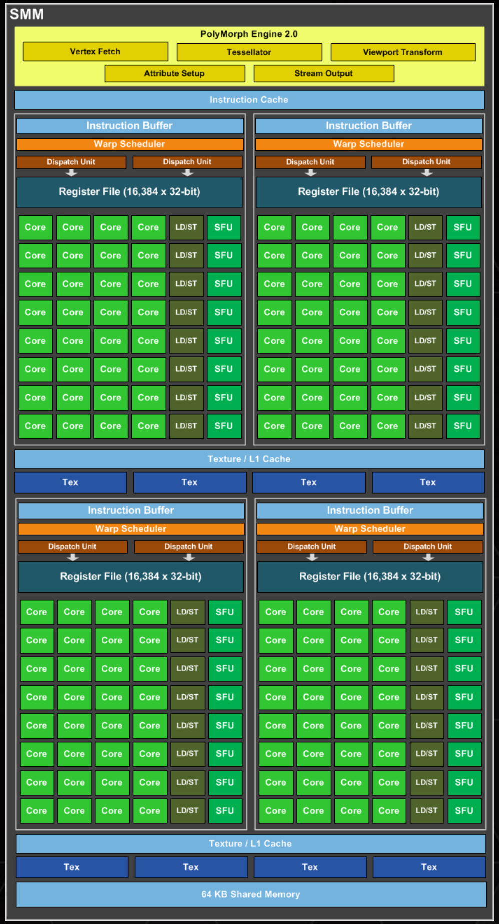
OUTLINE

- Architectural goals of Maxwell
- DirectX12 hardware features
  - Conservative Rasterization
  - Raster Order Views
  - Tiled Resources
- Multi-Projection Acceleration
- New Antialiasing Features
- Misc other new features
- Questions and Answers



MAXWELL ARCHITECTURAL GOALS

- New architecture for improved effiency
- Massively improved perf / watt
  - Still on a 28nm process
- Focus on new graphics features
  - Real-time GI for rich dynamic scenes
  - Higher quality, programmable AA
  - Working set management
  - SVG rendering acceleration
  - Create the best platform for DirectX 12



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	680	780	980
TFLOPS	3	4	5
MEMORY	2GB	3GB	4GB
PERFORMANCE	1	1.5	2
POWER	195W	250W	165W
GFLOPS / WATT	15	15	30

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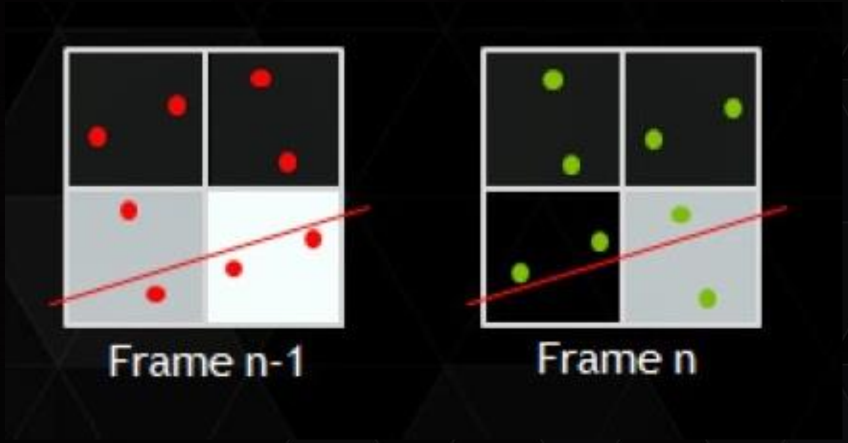

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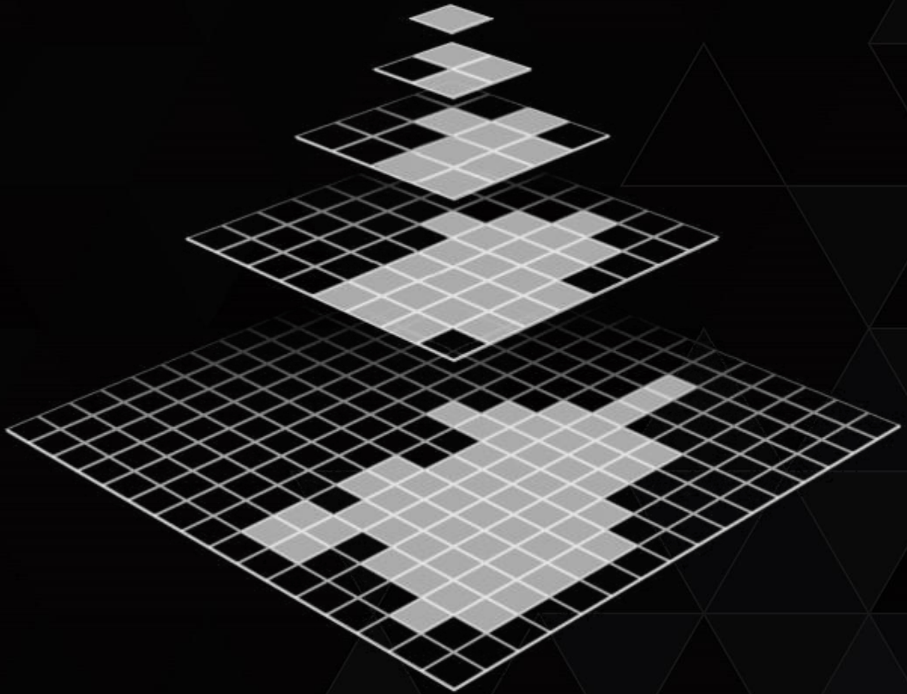

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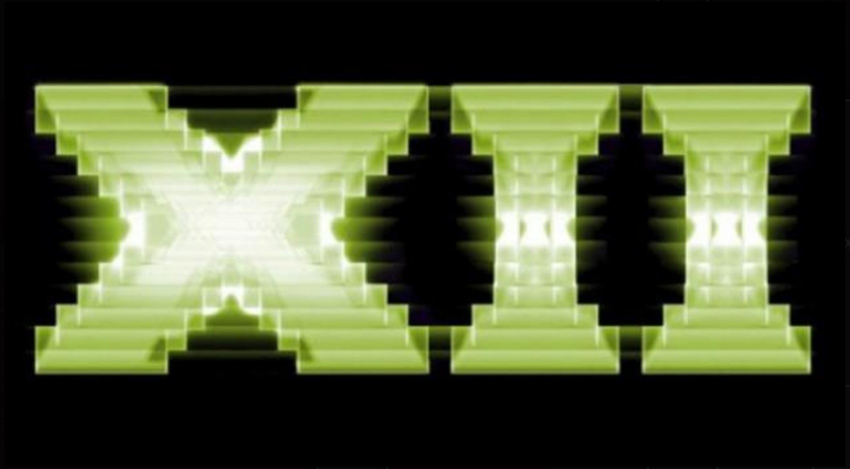

DIRECTX 12 FEATURES

- New API is parallelizable for rendering on multicore CPUs
- Reduced API overhead for single-core work
- More nimble resource binding model using indexing
- More efficient data management/transfer model
- More explicit work scheduling model
- New hardware features

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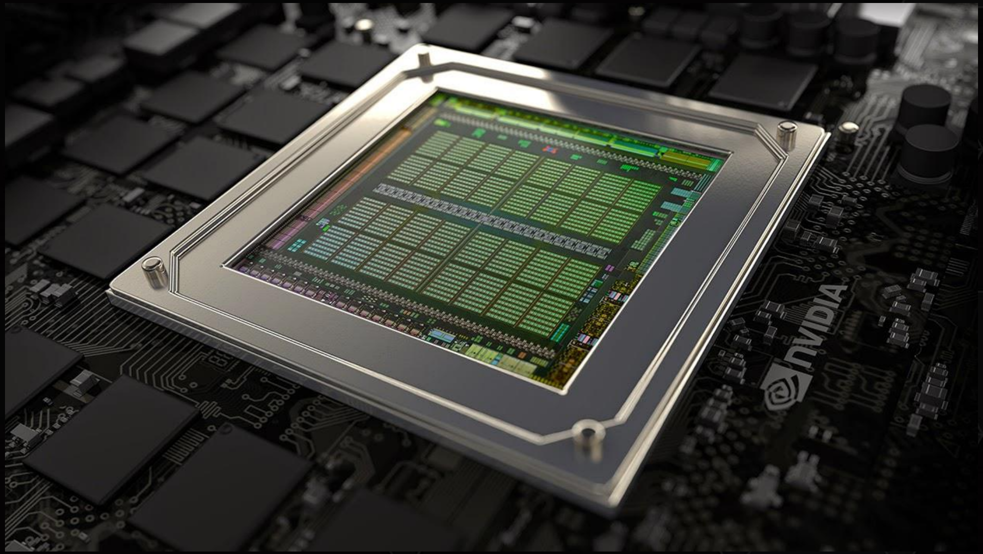
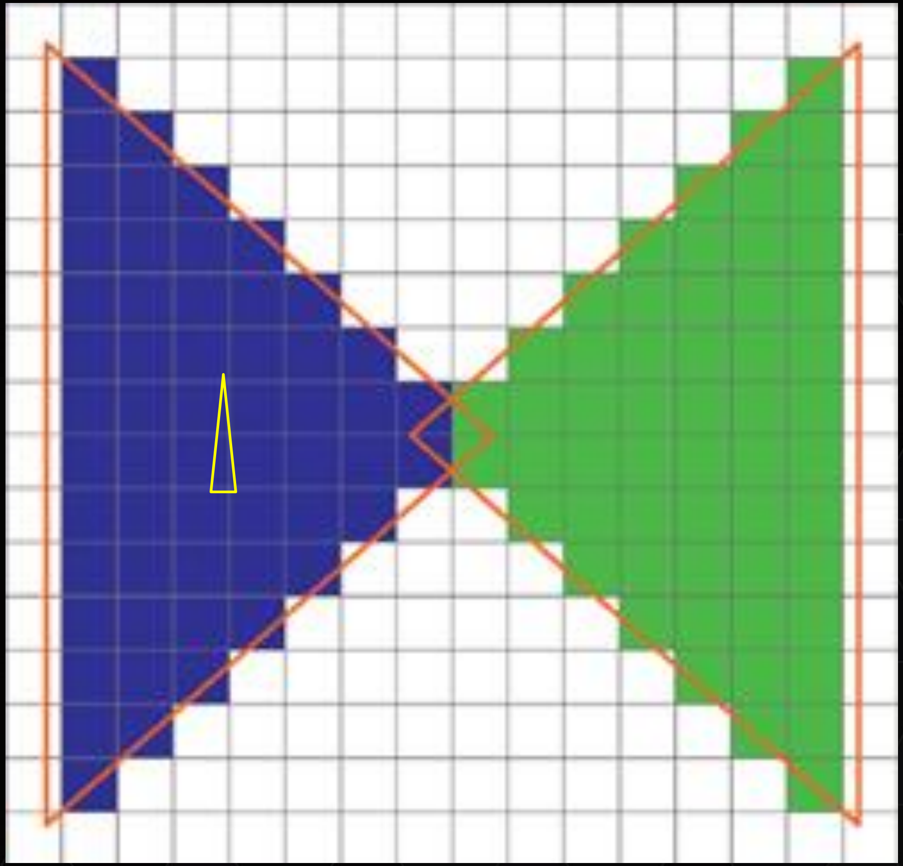


REGULAR RASTERIZATION

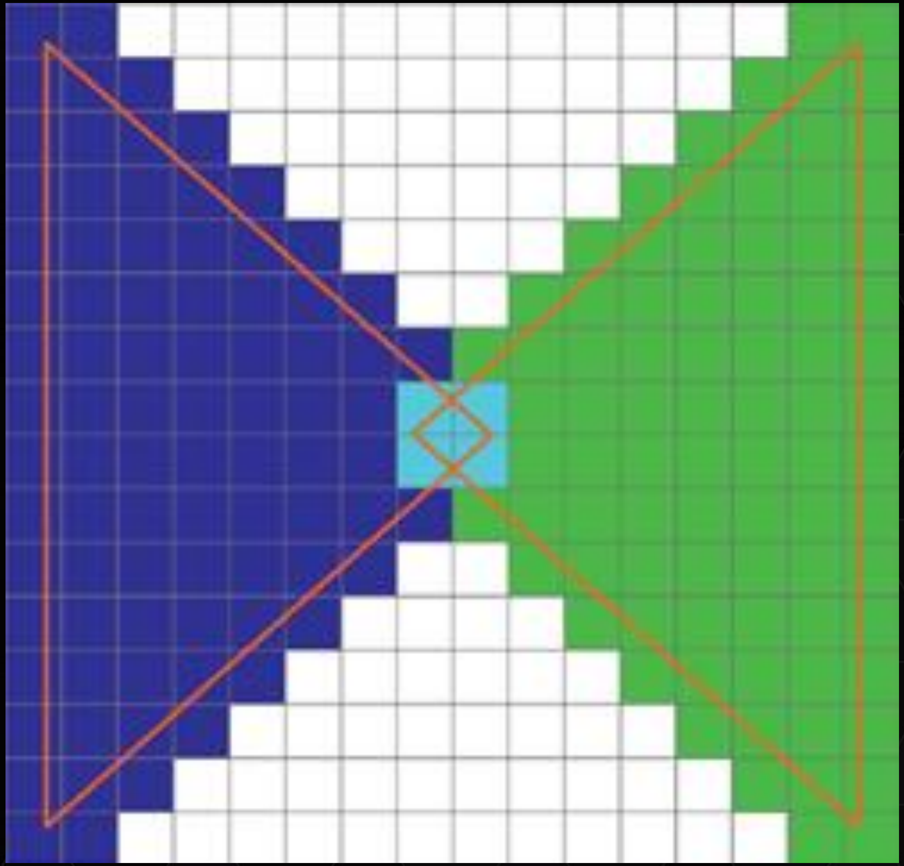
- Test each pixel center
- Include fragments with center covered
- Small triangles can be dropped

- Can’t easily create data structures
  - E.g. triangle lists for ray tracing



CONSERVATIVE RASTERIZATION

- Draws all pixels a triangle touches
  - Different Tiers – see DX spec
- Possible before through GS trick but relatively slow
  - See J. Hasselgren et al. “Conservative Rasterization“, GPU Gems 2
- Now we can use rasterization do implement some nice techniques!

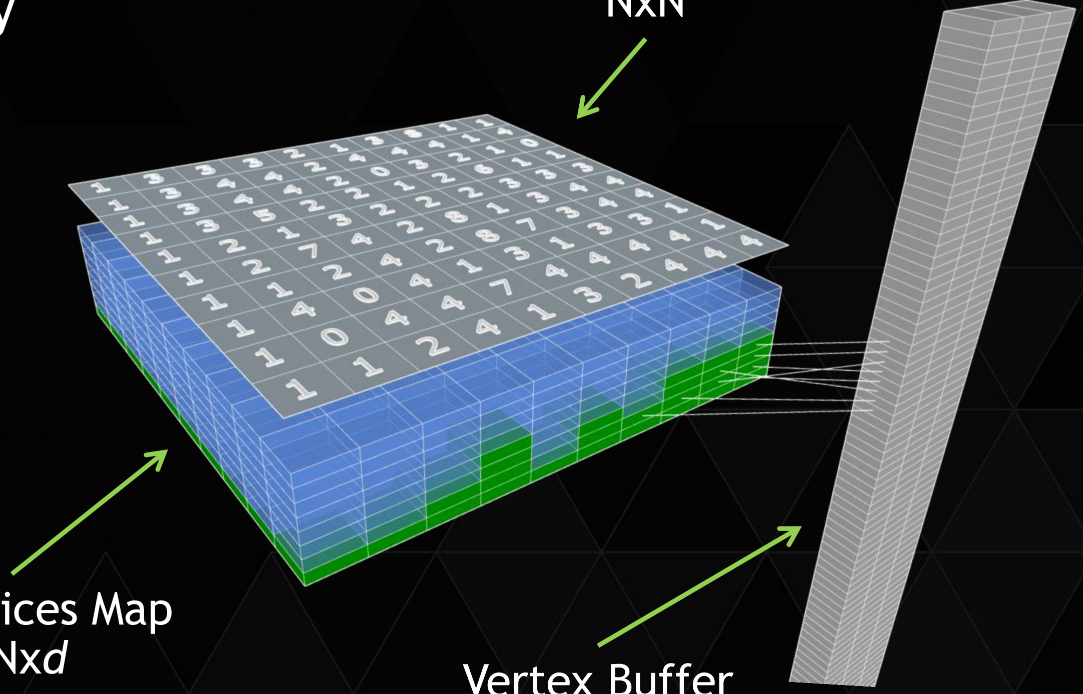


HYBRID RAYTRACED SHADOWS

C. Wyman et al. “Frustum-Traced Raster Shadows: Revisiting Irregular Z-Buffers“, I3D 2015

J. Story “Hybrid Ray-Traced Shadows“, D3D Day GDC 2015

- Rasterize light view conservatively
- Store triangle info in buffers:
  - Vertex Buffer
  - *NxNxd* Prim Indices Map
  - *NxN* Prim Count Map
- Raytrace triangles in a later pass

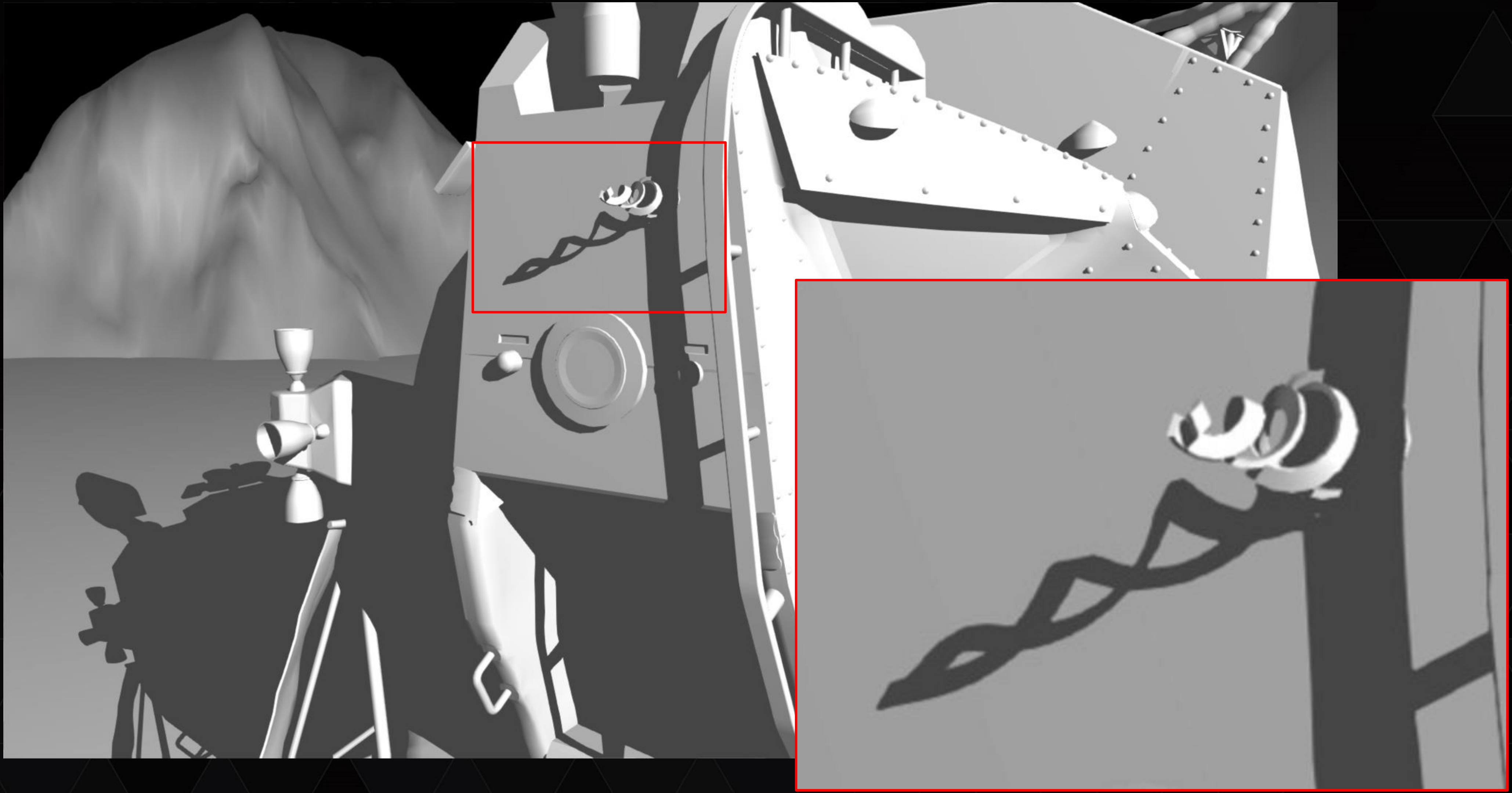


Prim Count Map
NxN

Prim Indices Map
NxNx*d*

Vertex Buffer

RAYTRACED SHADOWS DEMO



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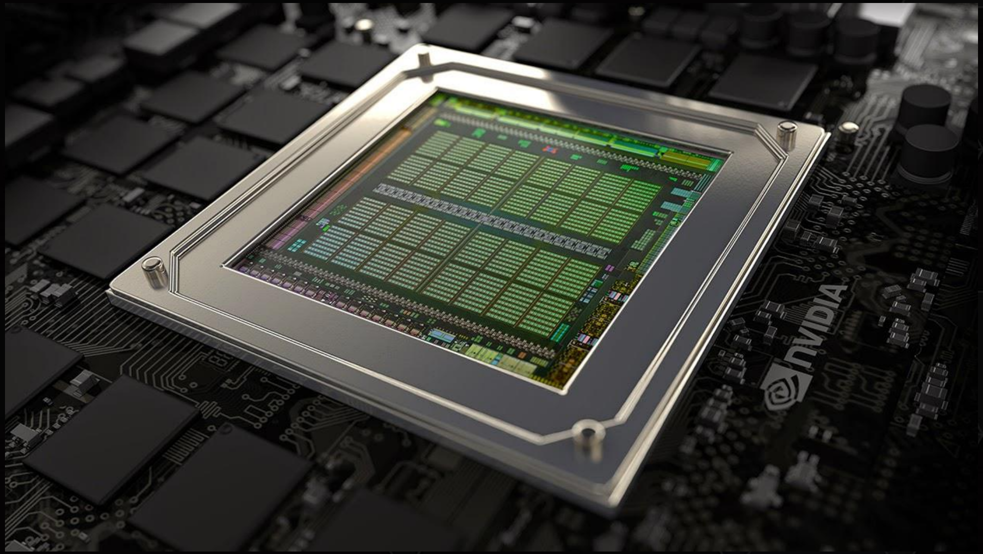
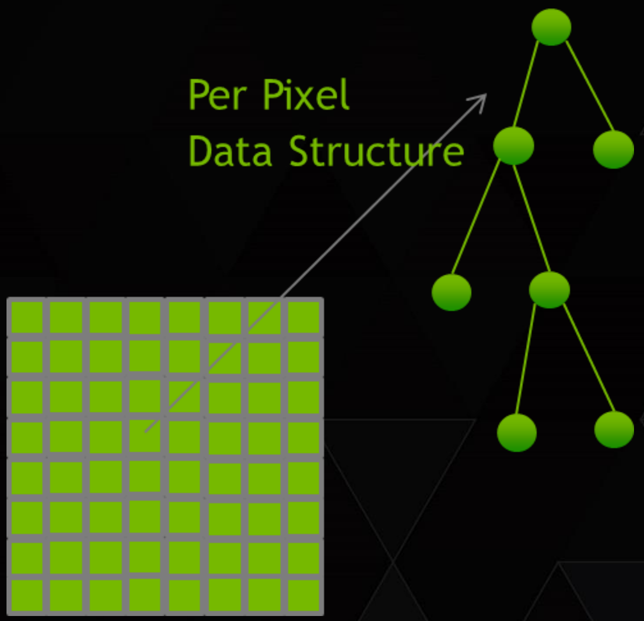


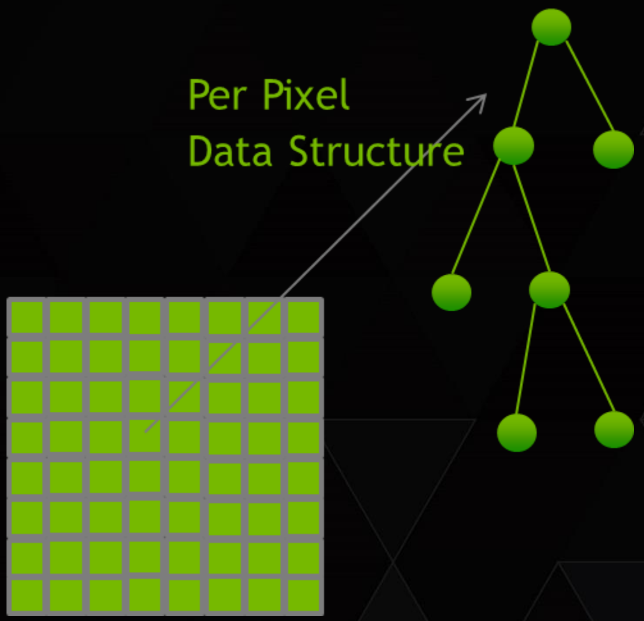
UAV RACE CONDITION ISSUE

- Pixel shader writes to UAVs are unordered
  - Can‘t guarantee determinism
- Can‘t do…
  - Programmable Blending
  - Smart OIT implementations
  - Arbitray g-buffer data packing
  - Other per-pixel data structures



RASTER ORDER VIEWS (ROV)

- ROVs guarantee ordering and atomicity
- Ordering doesn‘t come for free
  - Depth complexity affects performance
- Always compare with other options
  - Advanced blending operations
  - Atomics, lock-free algorithms



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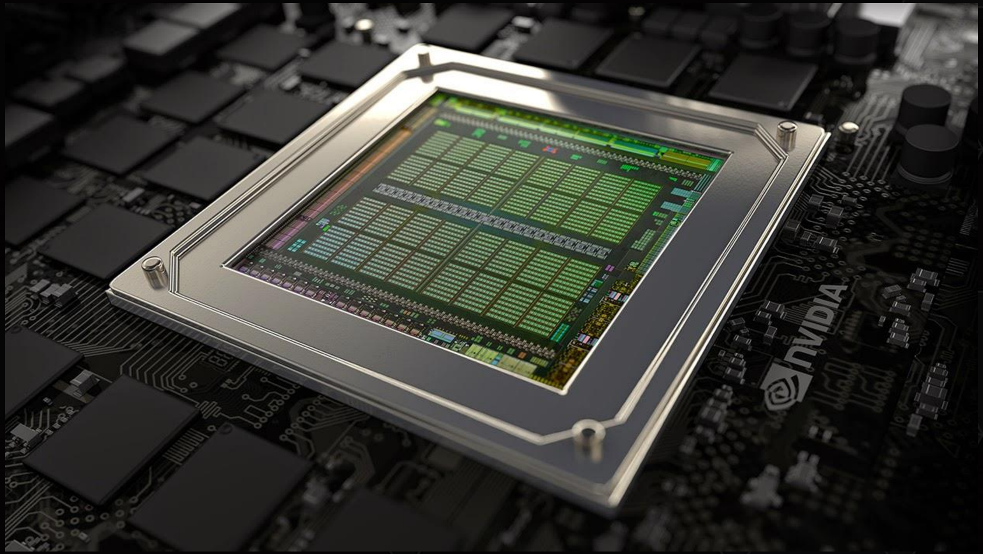
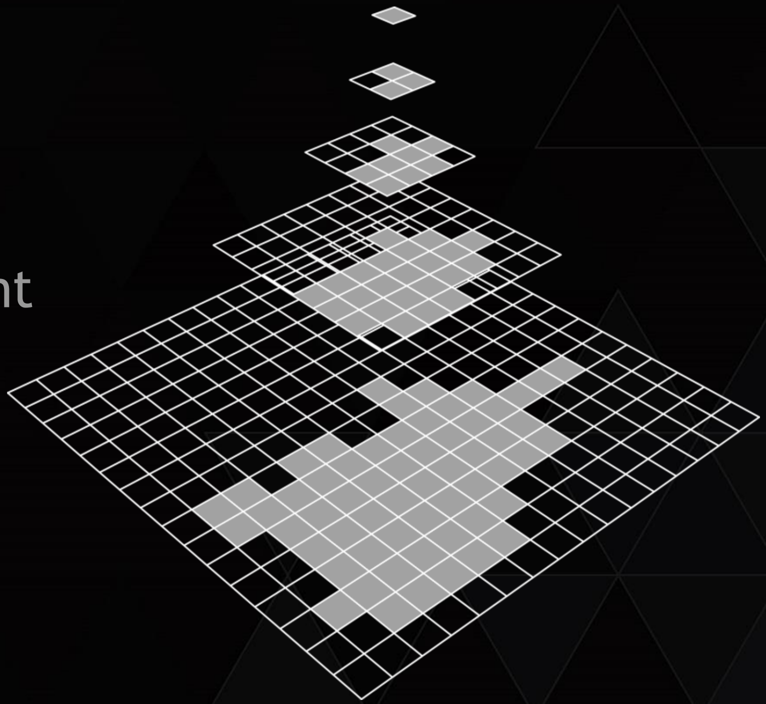


DX12 TILED RESOURCES

- Full support for tiled 3D Textures/Arrays
  - On top of what DX11.2 provides

- Enable fine grained working set management
- Texture defined as a set of 64 KB tiles
- Memory for tiles is allocated separately



TILED RESOURCES APPLICATIONS

- Fine-grained working set management
  - Texture streaming, Clip-maps
- Variable resolution resources
  - Adaptive shadow maps
  - Sparse multi-resolution rendering
- Sparse representation
  - Voxel grids
  - Simulation – physics, path finding

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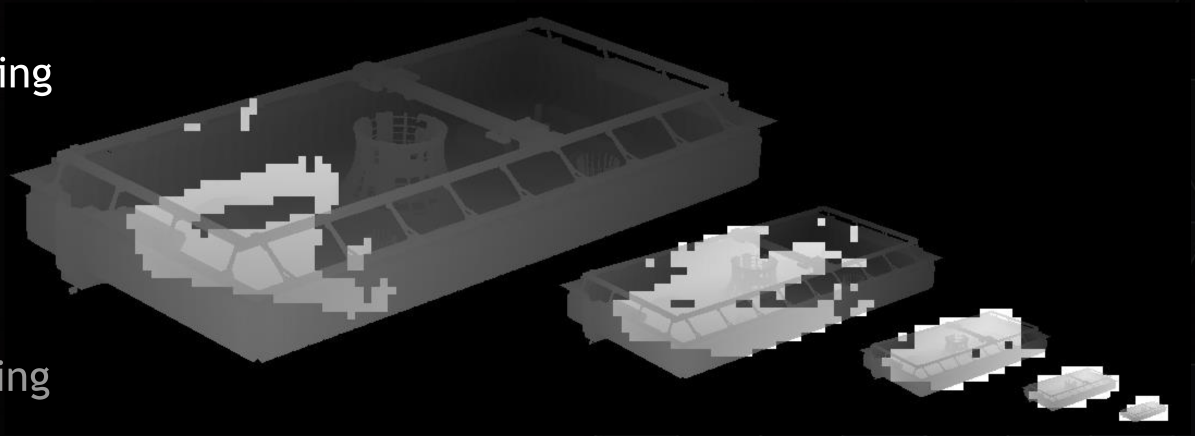

SPARSE SHADOW MAPS DEMO

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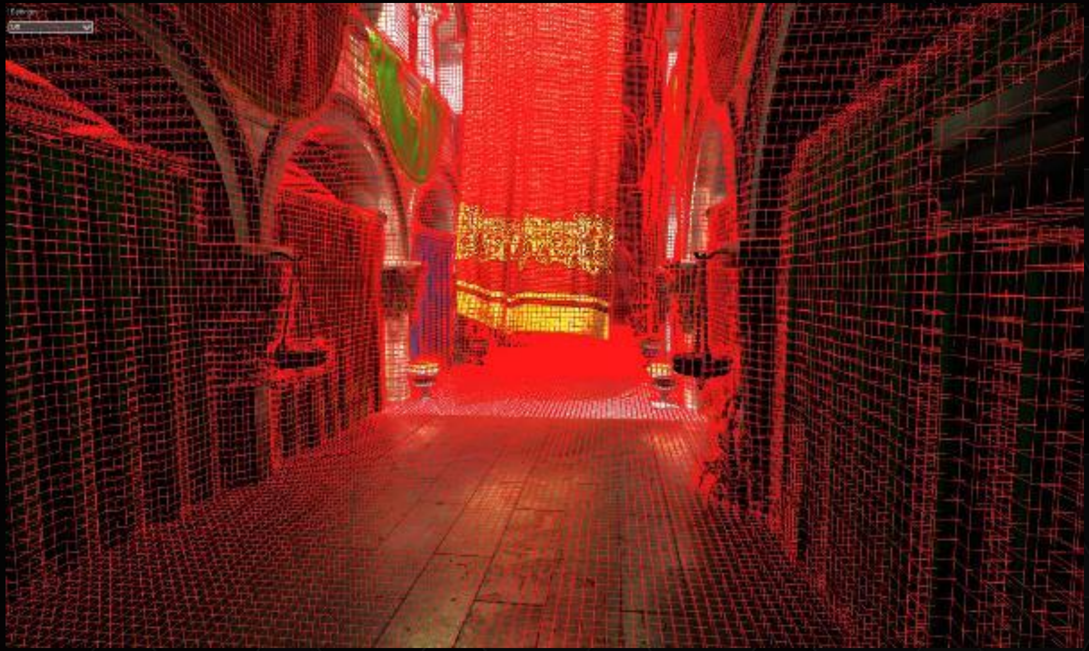
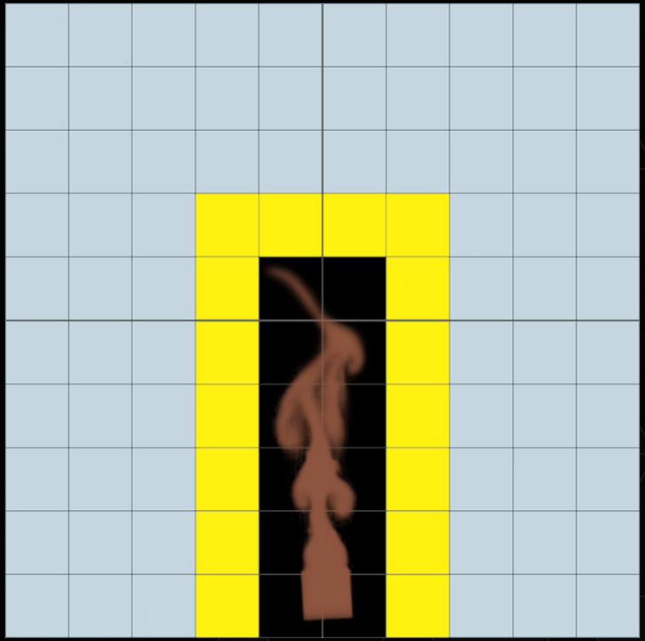


SPARSE FLUID SIMULATION

- Uses tiled resources to only simulate/store grid cells that contain fluid

- Save computation time and memory

- See Alex Dunn, ”Sparse Fluid Simulation in DirectX” at GTC’15 Thursday 2:30 PM



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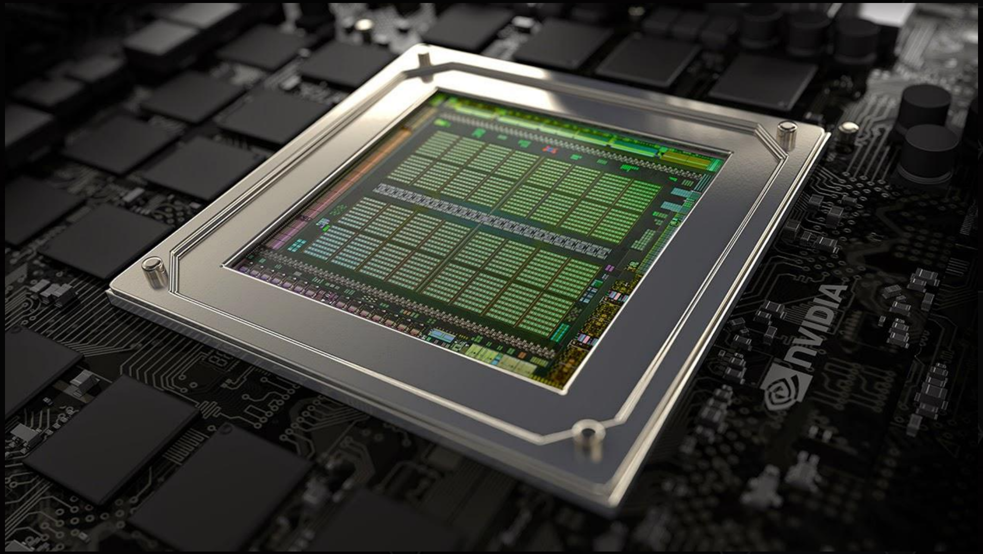
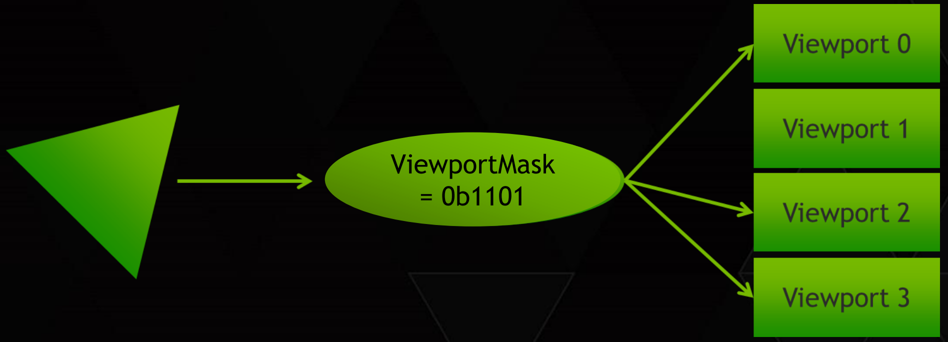


GEOMETRY SHADER CHALLENGES

- Significant overhead even for pass-through cases
- Significant overhead for viewport selection
- Significant amplification overhead for multiple viewports

MULTI-PROJECTION ACCELERATION

- Fast Geometry Shader pass-through
- Fast Viewport/RT multi-casting
- Maxwell accelerates:
  - Voxelization
  - Cube-map rendering
  - Cascaded shadow maps
  - Multi-resolution rendering



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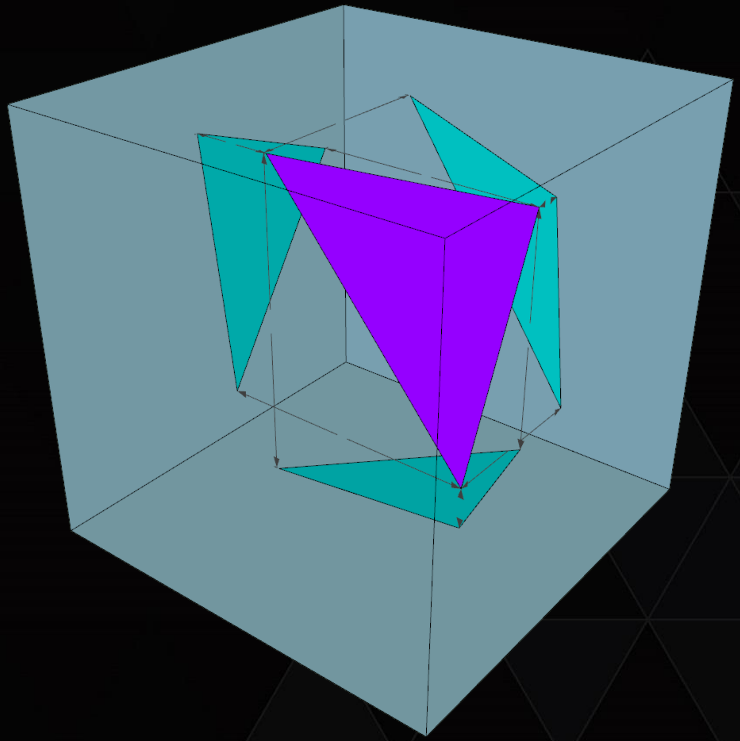

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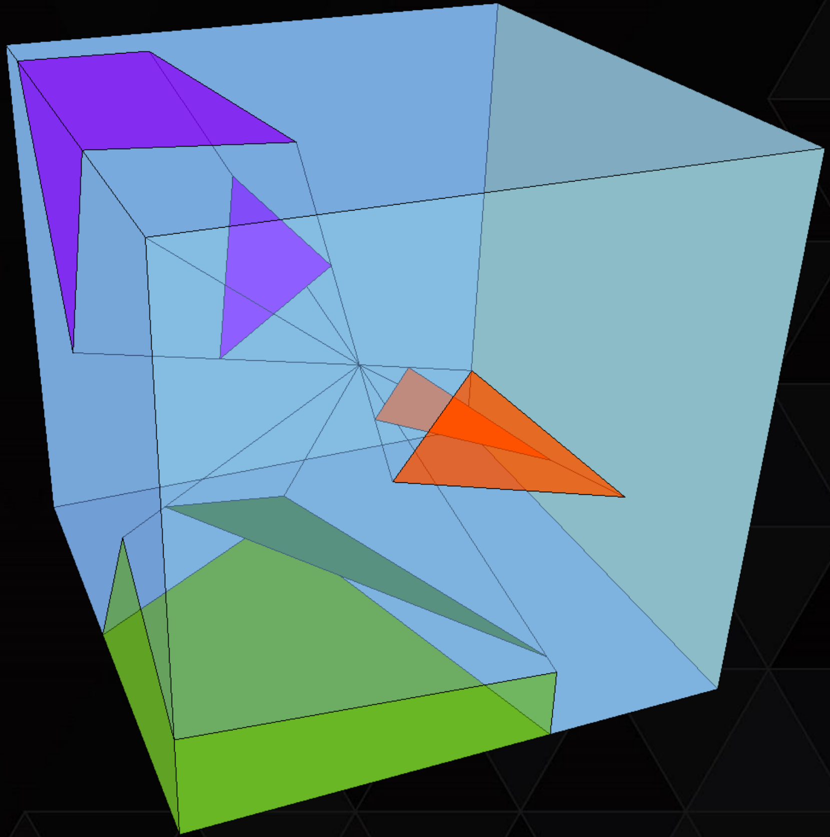

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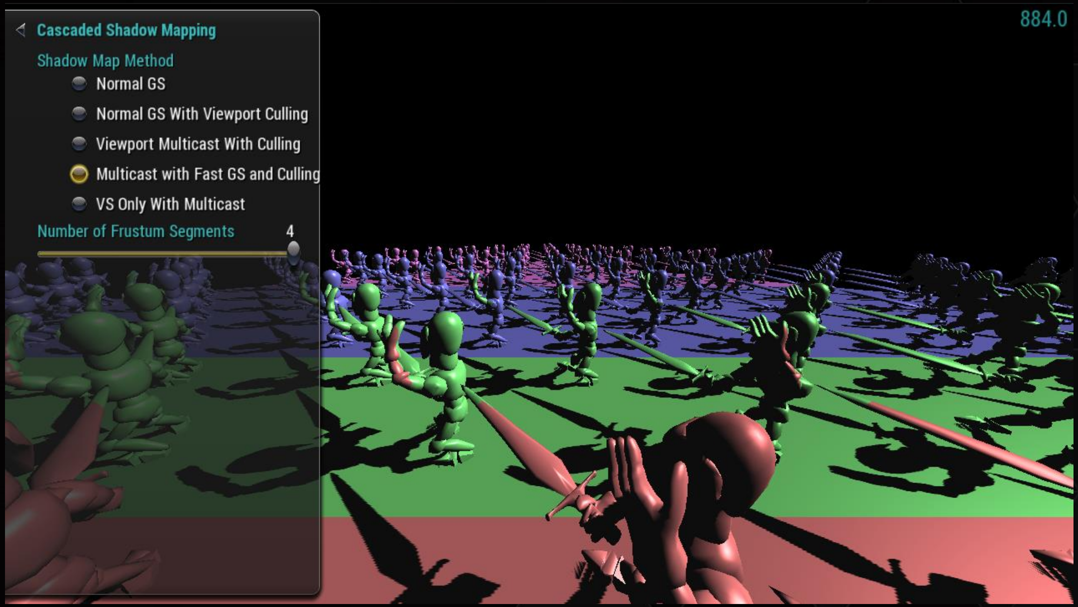

Cascaded Shadow Mapping

Shadow Map Method

○ Normal GS

○ Normal GS With Viewport Culling

○ Viewport Multicast With Culling

● Multicast with Fast GS and Culling

○ VS Only With Multicast

Number of Frustum Segments 4

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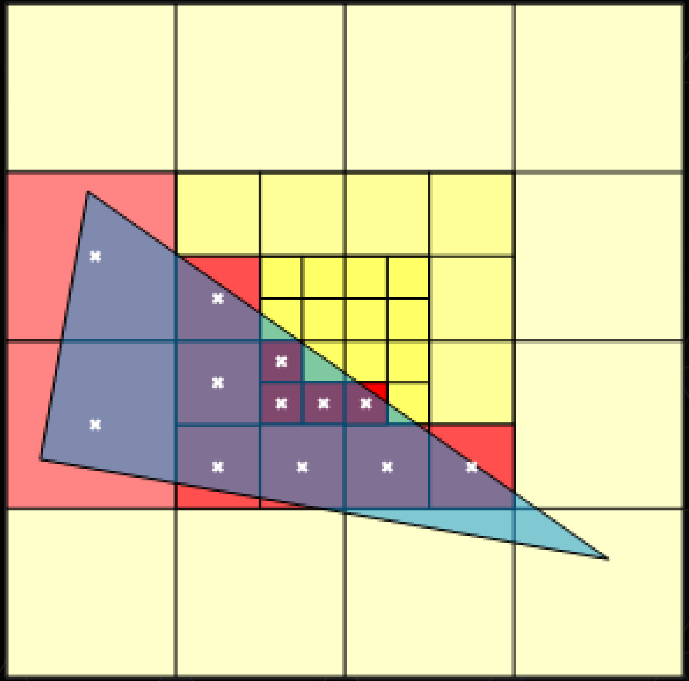
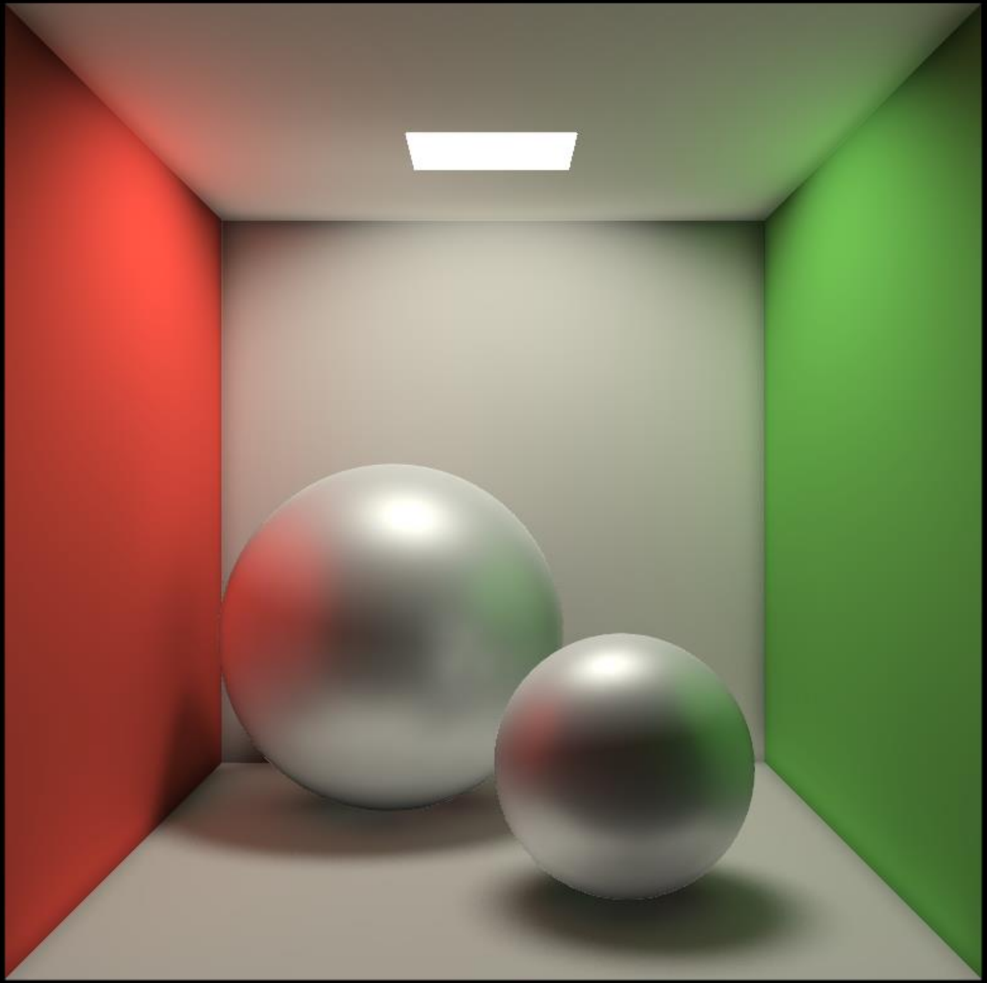


VXGI DEMO



MULTI-PROJECTION API SUPPORT

- OpenGL+Android:
  - NV_geometry_shader_passthrough extension for GS pass-through
  - NV_viewport_array2 extension for viewport multicast
  - The extension specs have good shader examples
- DX11/DX12:
  - No explicit API publicly available yet – stay tuned

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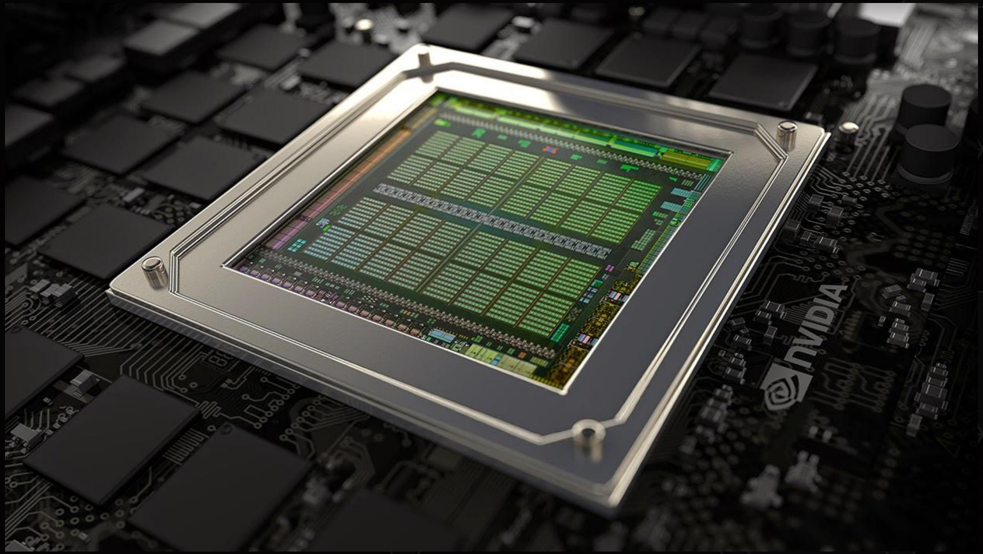
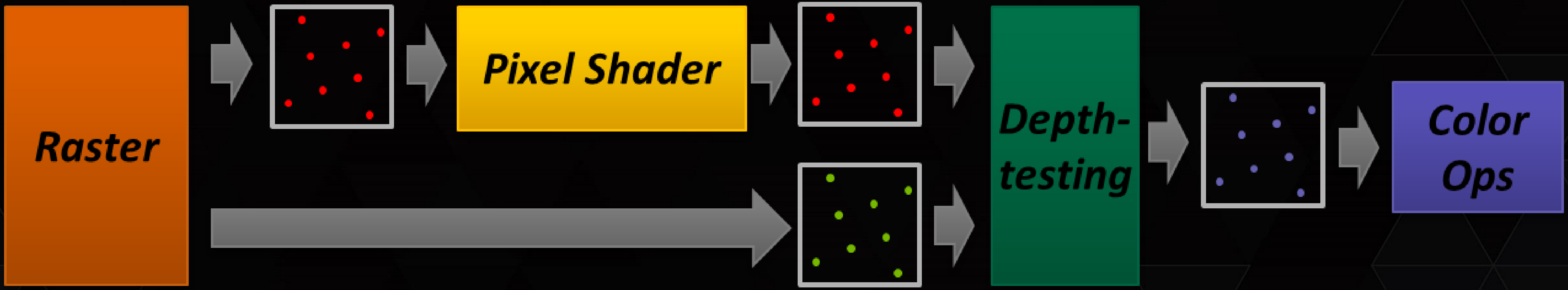
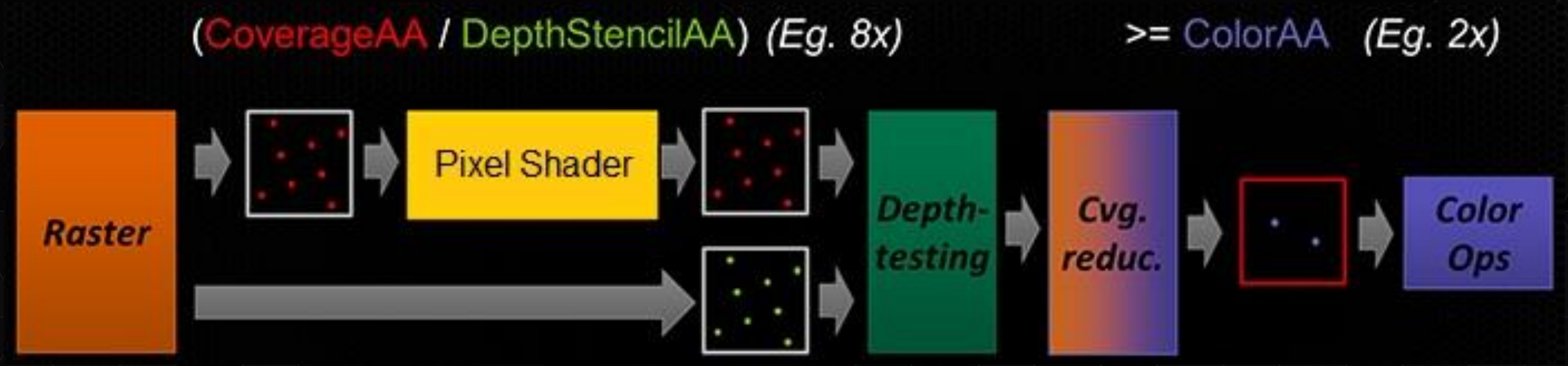


QUICK MULTISAMPLING RECAP



TARGET-INDEPENDENT RASTER

- Decouples visibility & raster rate from color sample rate
- Allows lower color buffer storage cost for custom AA techniques
- Introduces coverage reduction stage



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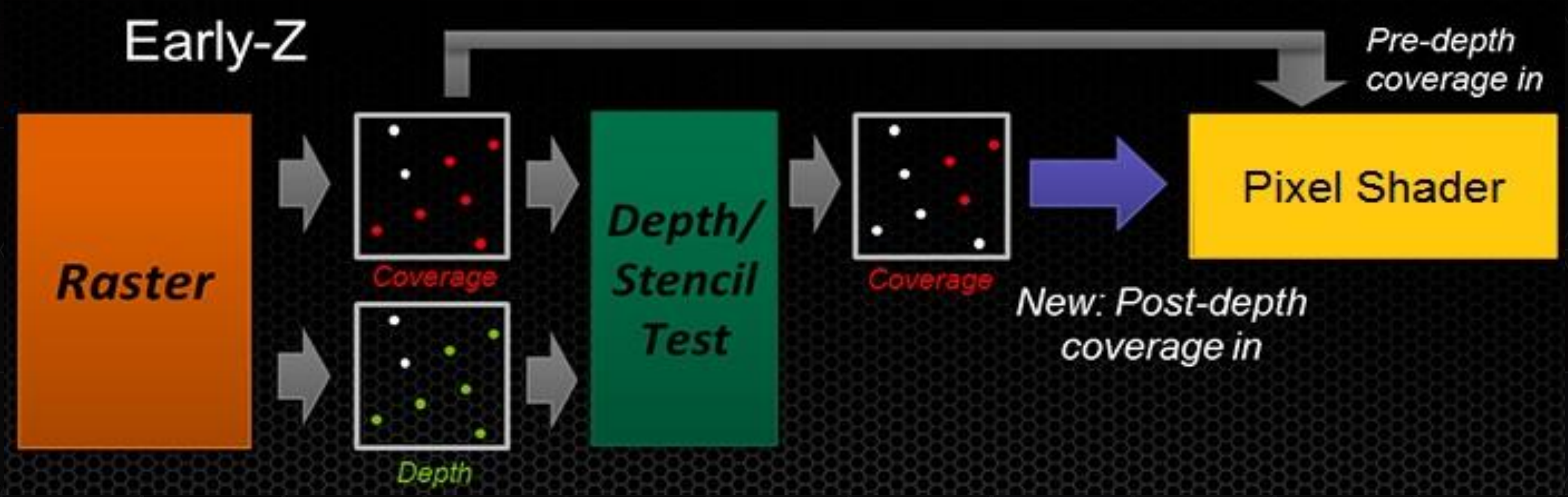
POST-DEPTH COVERAGE

- Pre-Maxwell : Coverage Mask delivered is pre-depth-test coverage
  - No way to get at the post-depth-test coverage

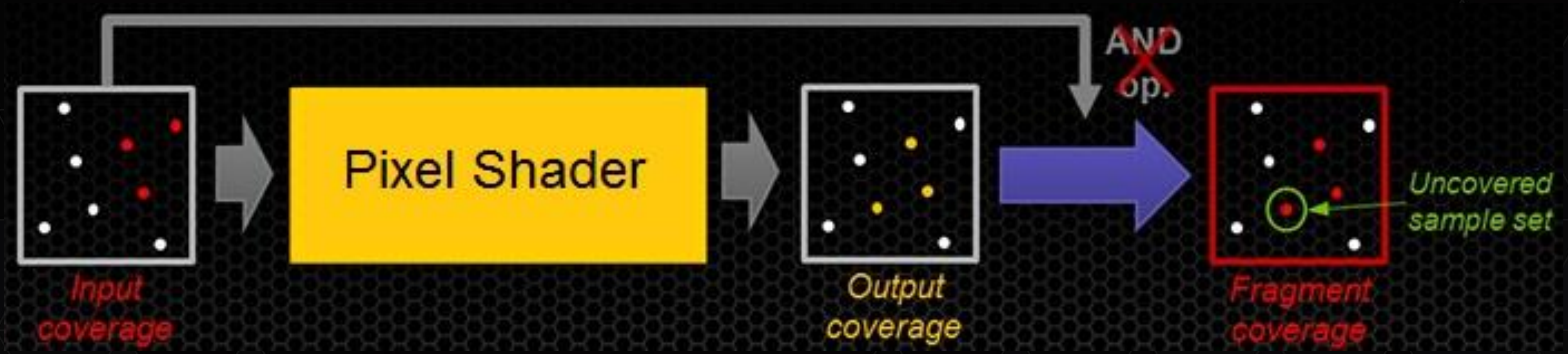
- Maxwell can deliver post-depth-coverage to the pixel shader



SAMPLE COVERAGE OVERRIDE

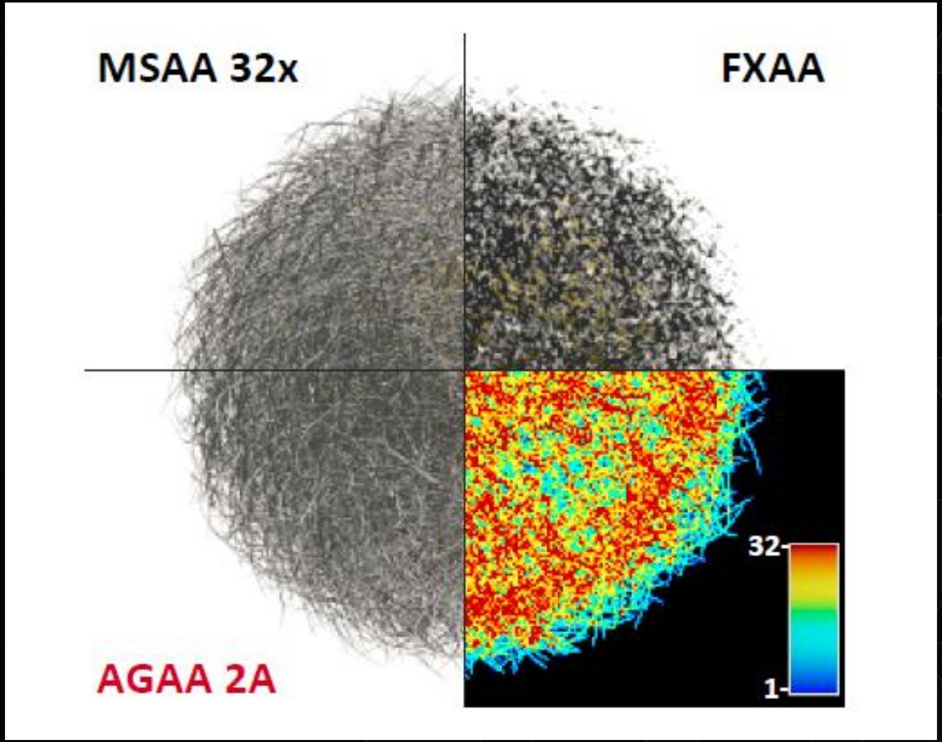
- Pre-Maxwell : Shader can only reduce coverage sample set

- Maxwell can fully override raster-coverage mask

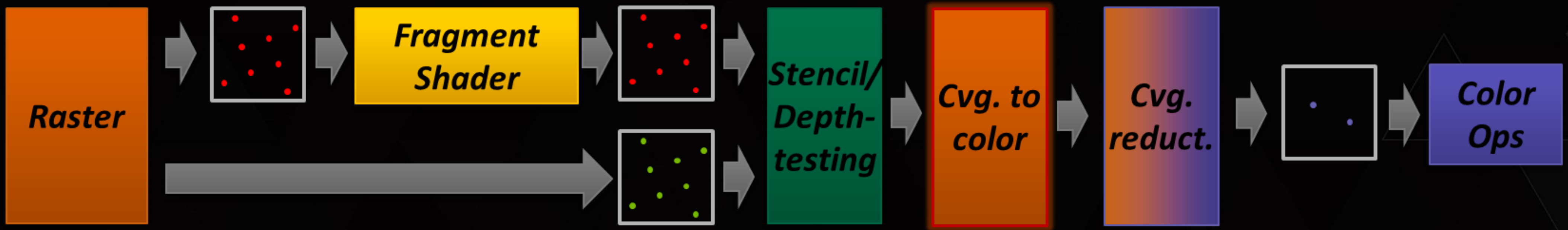


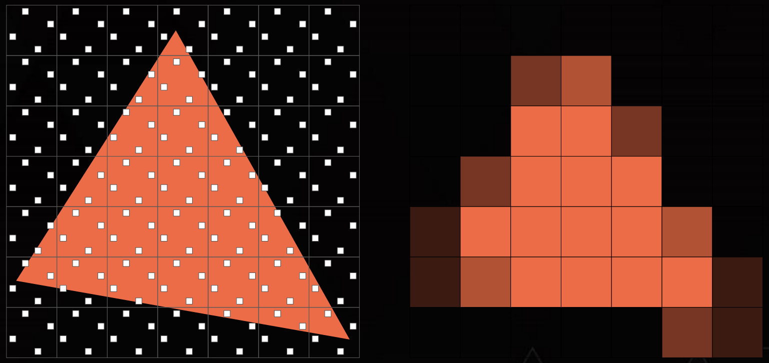
AGGREGATE G-BUFFER AA

- C. Crassin et al., ”Aggregate G-Buffer Anti-Aliasing”, ID3D 2015
- Uses post depth coverage to only process visible sub-samples
- Uses coverage override to route to right sub-sample cluster
- Other work using Maxwell AA features:
  - E. Enderton et. al, ”Accumulative Anti-Aliasing”, to appear



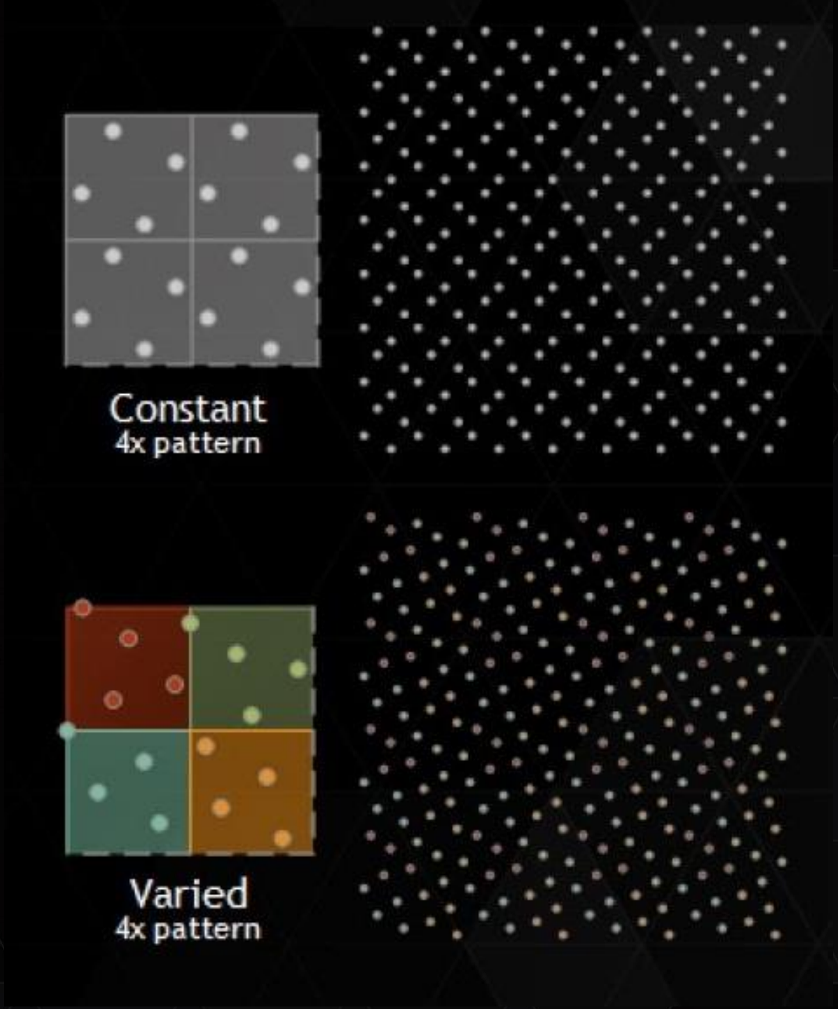
COVERAGE TO COLOR CONVERSION





PROGRAMMABLE SAMPLE LOCATIONS

- Sample locations fully programmable
- Interleaved sample positions
  - 16x sample locations can be tiled to a set of pixels
- Foundation for Multi Frame sampled AA



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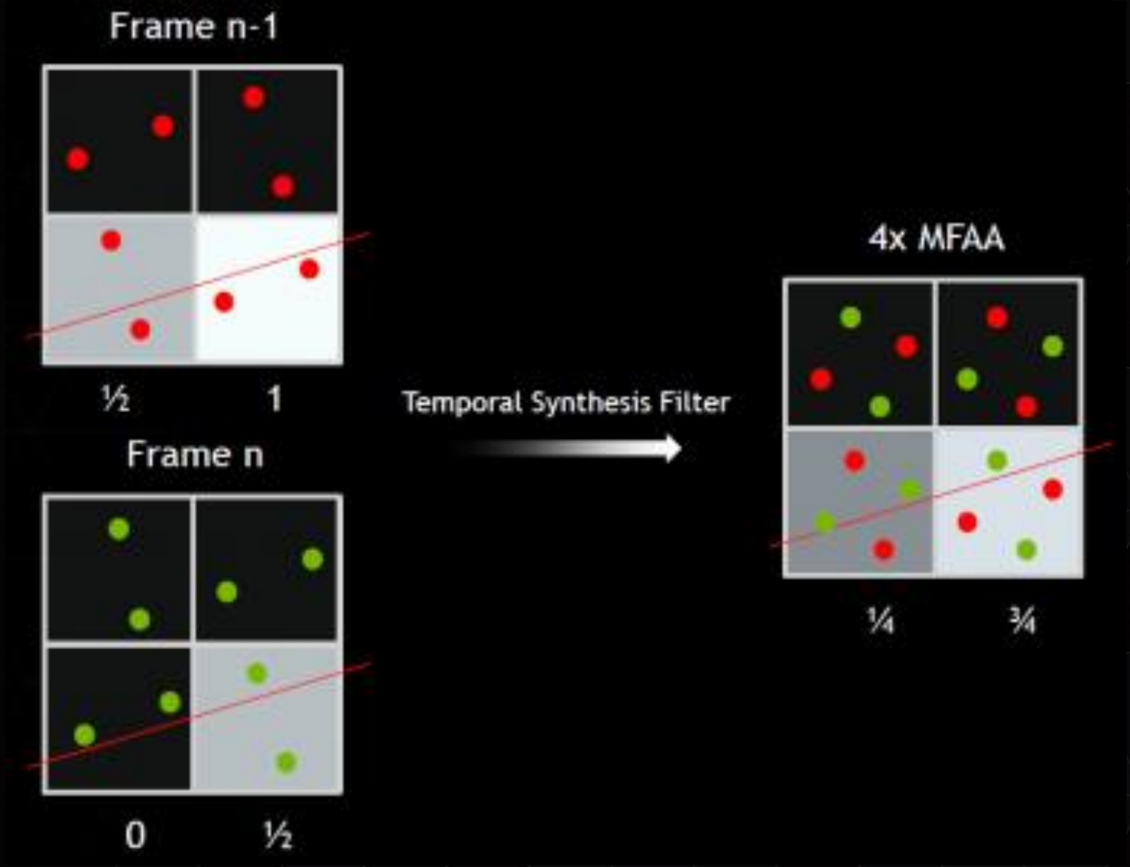

AA FEATURES API SUPPORT

- OpenGL+ Android:
  - Target-independent multisampling control:
    - NV_framebuffer_mixed_samples
    - EXT_raster_multisample
  - Coverage to color conversion: NV_fragment_coverage_to_color
  - Post-depth coverage : EXT_post_depth_coverage
  - Multisample coverage override : NV_sample_mask_override_coverage
  - Programmable sample locations : NV_sample_locations

- DirectX FL 11.1
  - Target-independent multipsampling

- DirectX 11 NvAPI:
  - NvAPI_D3D11_CreateRasterizerState

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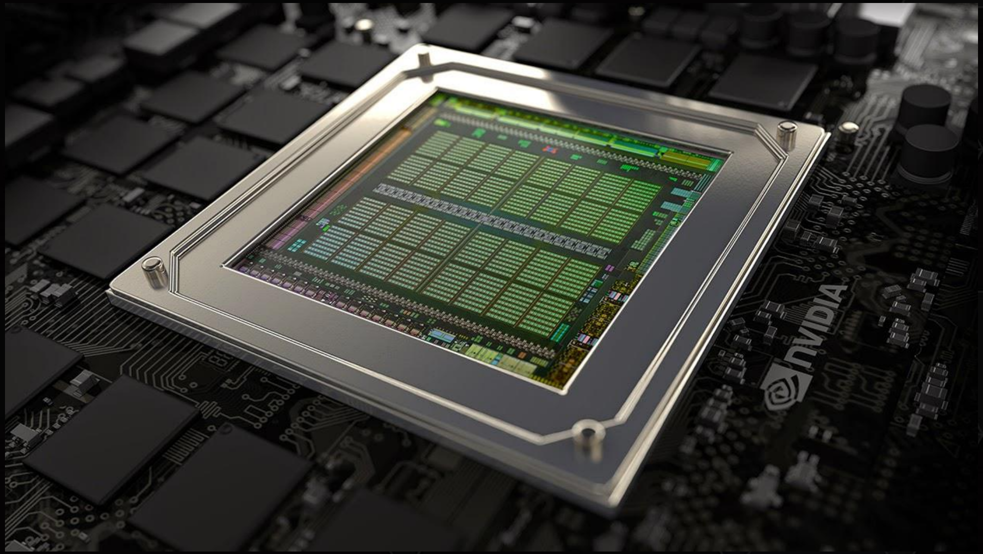

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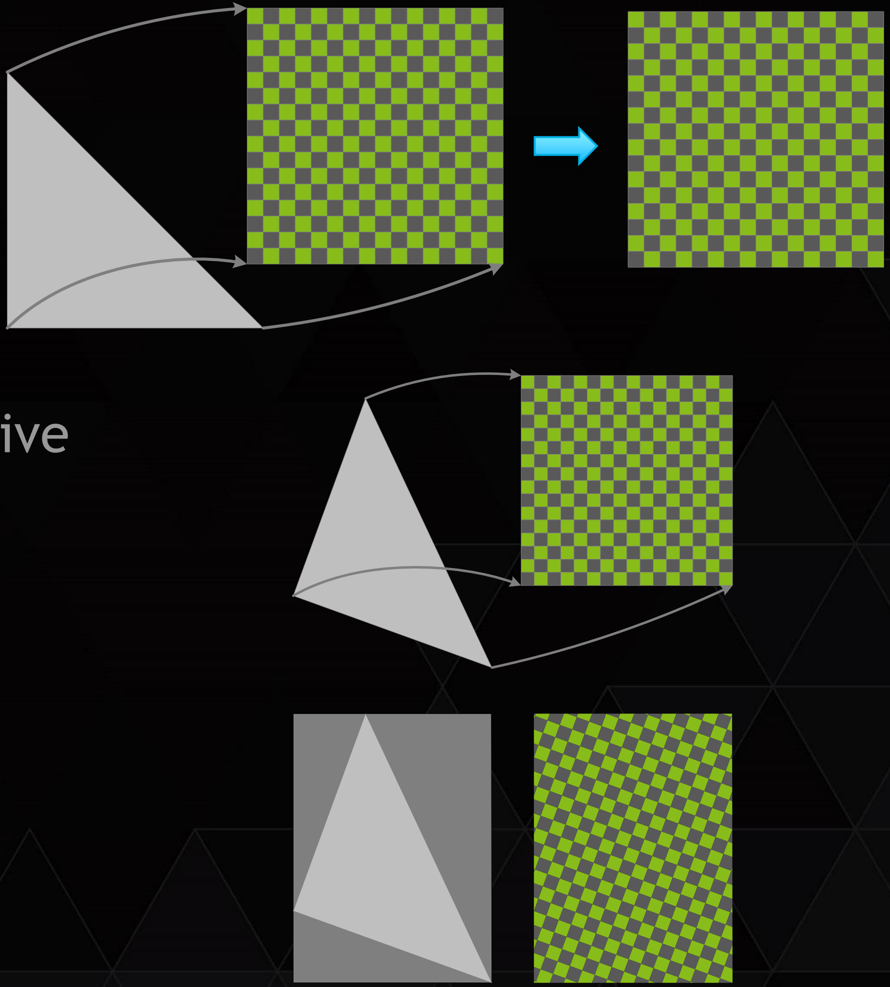
BBOX RASTERIZATION

- Screen Space Bonding Box rasterization
  - Reduce # of vertices sent to GPU
  - Speeds up particle systems, point sprite etc.

- Attributes are extrapolated outside the primitive

- Supported by these APIs:
  - OpenGL: NV_fill_rectangle
  - NvAPI: NvAPI_D3D11_CreateRasterizerState

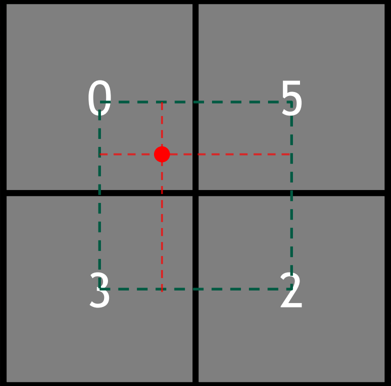


MIN/MAX TEXTURE FILTERING

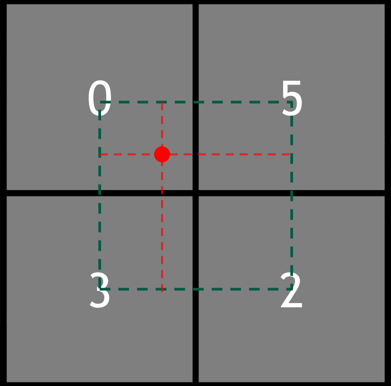
- Hardware support for min/max filtering

- Usecases:
  - Min-Max shadow maps
  - LOD maps for tiled textures
  - Other min-max reduction chains

- API support:
  - OpenGL: EXT_texture_filter_minmax
  - DirectX11.2



MAX returns "5"



MIN returns "0"

EXTENDED BLEND MODES

- ZERO SRC
- DST
- SRC_OVER
- DST_OVER
- SRC_IN
- DST_IN
- SRC_OUT
- DST_OUT
- SRC_ATOP
- DST_ATOP
- XOR PLUS
- PLUS_CLAMPED
- PLUS_CLAMPED_ALPHA
- MULTIPLY
- SCREEN
- OVERLAY
- DARKEN
- LIGHTEN
- COLORDODGE
- COLORBURN
- HARDLIGHT
- SOFTLIGHT
- SOFTLIGHT_SVG
- DIFFERENCE
- MINUS
- MINUS_CLAMPED
- EXCLUSION
- CONTRAST
- INVERT INVERT_RGB
- INVERT_KHR
- LINEARDODGE
- LINEARBURN
- VIVIDLIGHT
- LINEARLIGHT
- PINLIGHT
- HARDMIX
- RED
- GREEN
- BLUE
- HSL_HUE
- HSL_SATURATION
- HSL_COLOR
- HSL_LUMINOSITY

OpenGL: NV_blend_equation_advanced

FP16 ATOMIC OPERATIONS

- Vector 2x16-bit floating point atomic ADD, MIN, MAX
  - API supports 4x16-bit FP ops through 2 instructions

- Usecases:
  - Reduce the number of atomic ops during e.g. light accumulation
  - Save memory if you only need 16bit values

- API support:
  - OpenGL + Android: NV_shader_atomic_fp16_vector
  - NvAPI HLSL backdoor (described later):

```
NvInterlocked{Add,Min,Max}Fp16x2(UAV, address, float2 value)
NvInterlocked{Add,Min,Max}Fp16x4(UAV, address, float4 value)
```

NVAPI DX11 HLSL BACKDOOR

- Provides access to various new features from DX11 HLSL

- Host part:

```
NvAPI_Initialize();
NvAPI_D3D11_SetNvShaderExtnSlot(7); // enable the backdoor on UAV 7 for example
pD3DDevice->Create{Pixel,Compute…}Shader(…);
NvAPI_D3D11_SetNvShaderExtnSlot(~0u); // disable the backdoor
// Call NvAPI_D3D11_IsNvShaderExtnOpCodeSupported(…) to test feature support
```

- Shader part:

```
#define NV_SHADER_EXTN_SLOT u7 // must match the slot used above
#include “NvHlslExtns.h”
```

Then call the functions defined in that header.

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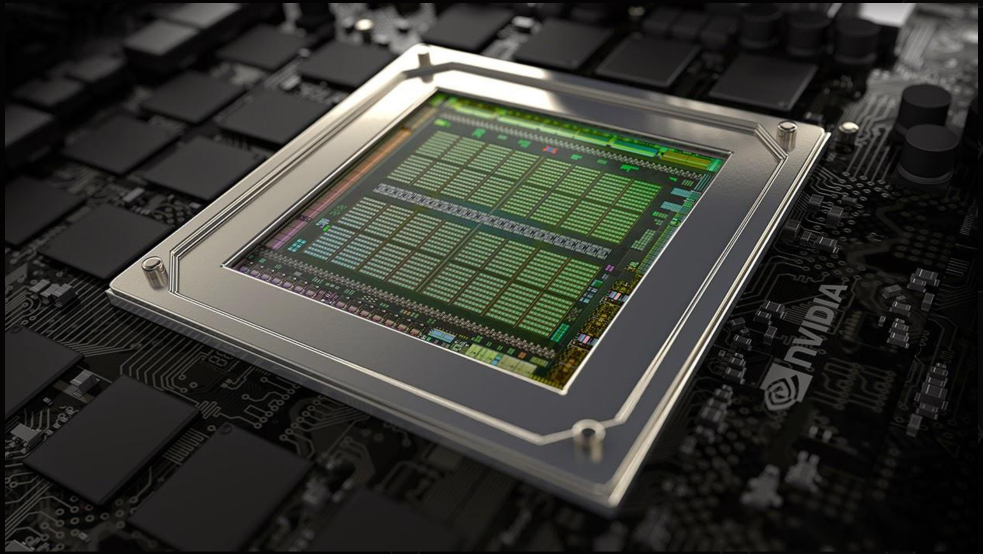
OTHER HLSL FUNCTIONS

- FP32 atomic ADD (Kepler+):
  - NvInterlockedAddFp32(UAV, address, float value)
- Warp shuffle (Kepler+):
  - NvShfl, NvShflUp, NvShflDown, NvShflXor(value, srcLane, width)
- Other warp-synchronous functions (Fermi+):
  - NvAny, NvAll, NvBallot(predicate)
  - NvGetLaneId()
- Warp-synchronous functions work in pixel shaders too

OUTLINE

- Architectural goals of Maxwell
- DirectX12 hardware features
  - Conservative Rasterization
  - Raster Order Views
  - Tiled Resources
- Multi-Projection Acceleration
- New Antialiasing Features
- Misc other new features
- Questions and Answers



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THANK YOU!

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