Henry Moreton NVIDIA Corporation October 13, 2011

Why tessellation?

Lack of geometric detail…

- Pixels are meticulously shaded,
  but geometric detail is modest



Image from Far Cry® 2, courtesy of Ubisoft


Geometry in Film

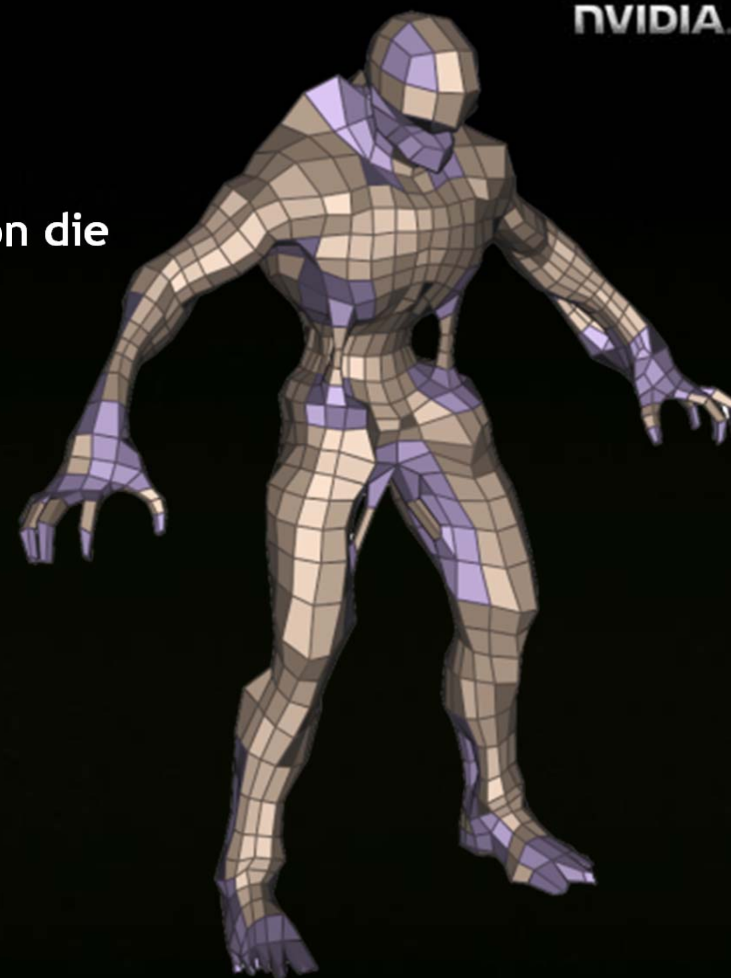
- Pixels are meticulously shaded and geometric detail is substantial
- Tessellation + displacement mapping is the defacto standard
- Enables richer content and animation

GF100 enables much greater geometric detail

- Before GF100 - minimal progress in geometry performance
  - GeForce FX 5800 to GeForce GT200
    - >150x shading performance
    - <3x geometry performance
- APIs unable to support a significant increase in geometry
  - Chicken & egg - really…
- GF100 — New geometry processing architecture delivers 8x performance to support DX11

Tessellation - What and Why

- Memory footprint & BW savings
  - Store coarse geometry, expand on-demand, keep data on die
  - Enables more complex animations
- Scalability
  - Dynamic LOD allows for performance/quality tradeoffs
  - Scale into the future - resolution, compute power
- Computational efficiency
  - Dynamic LOD
  - GPU animate and expand compact representation
- Real geometry
  - Dynamic shadows
  - 3D Vision™



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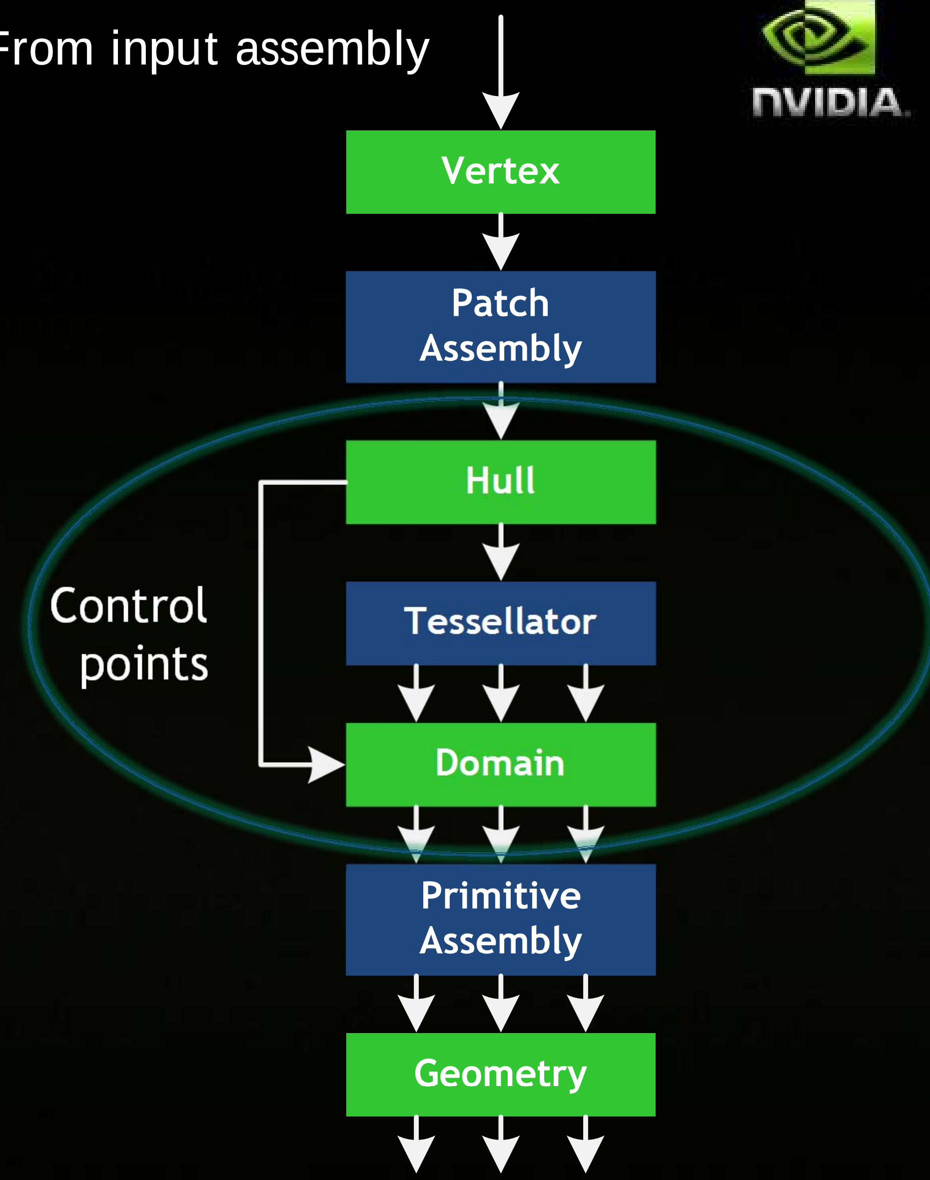
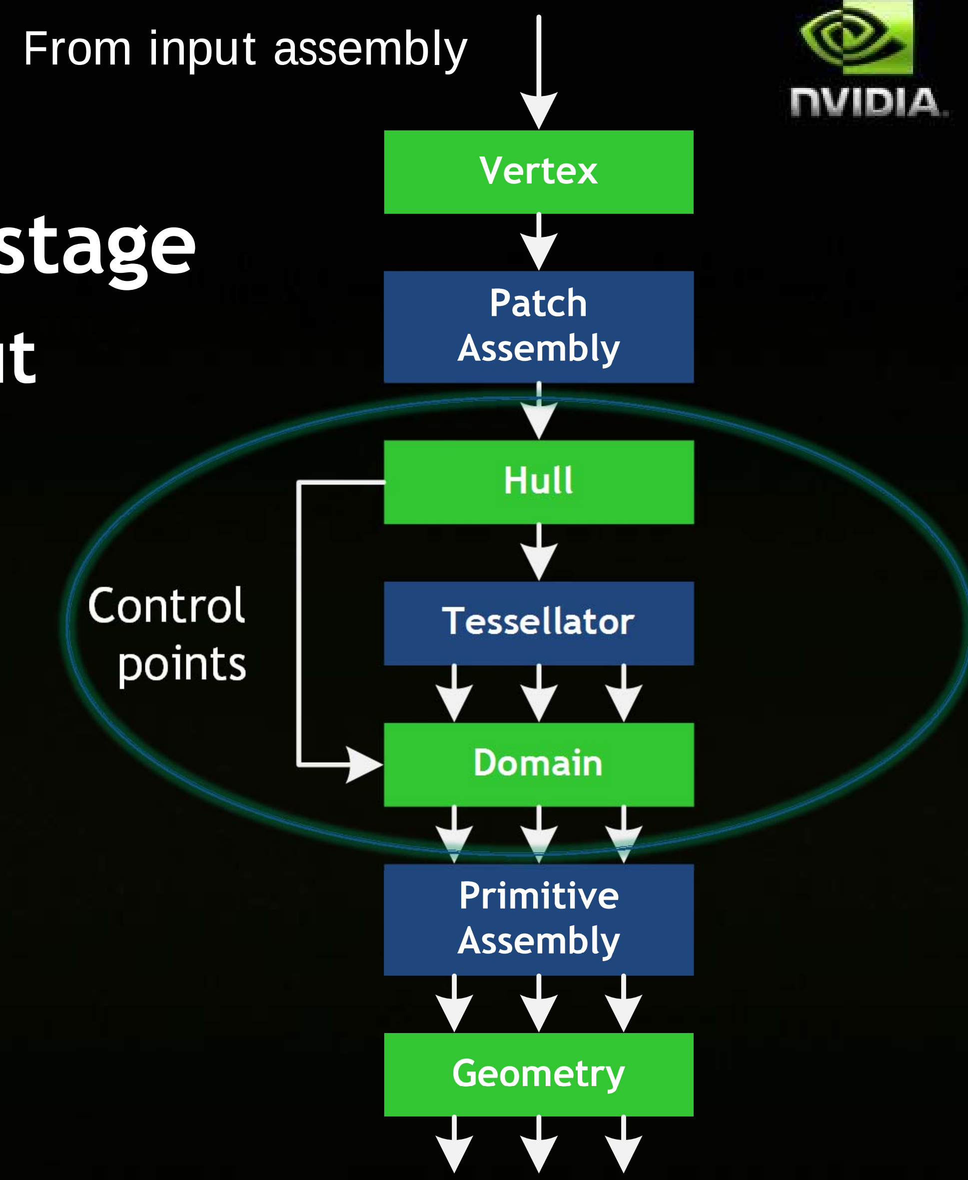
Tessellation in DirectX 11

- Hull shader
  - Runs pre-expansion
  - Explicitly parallel
    - Output control points and LODs



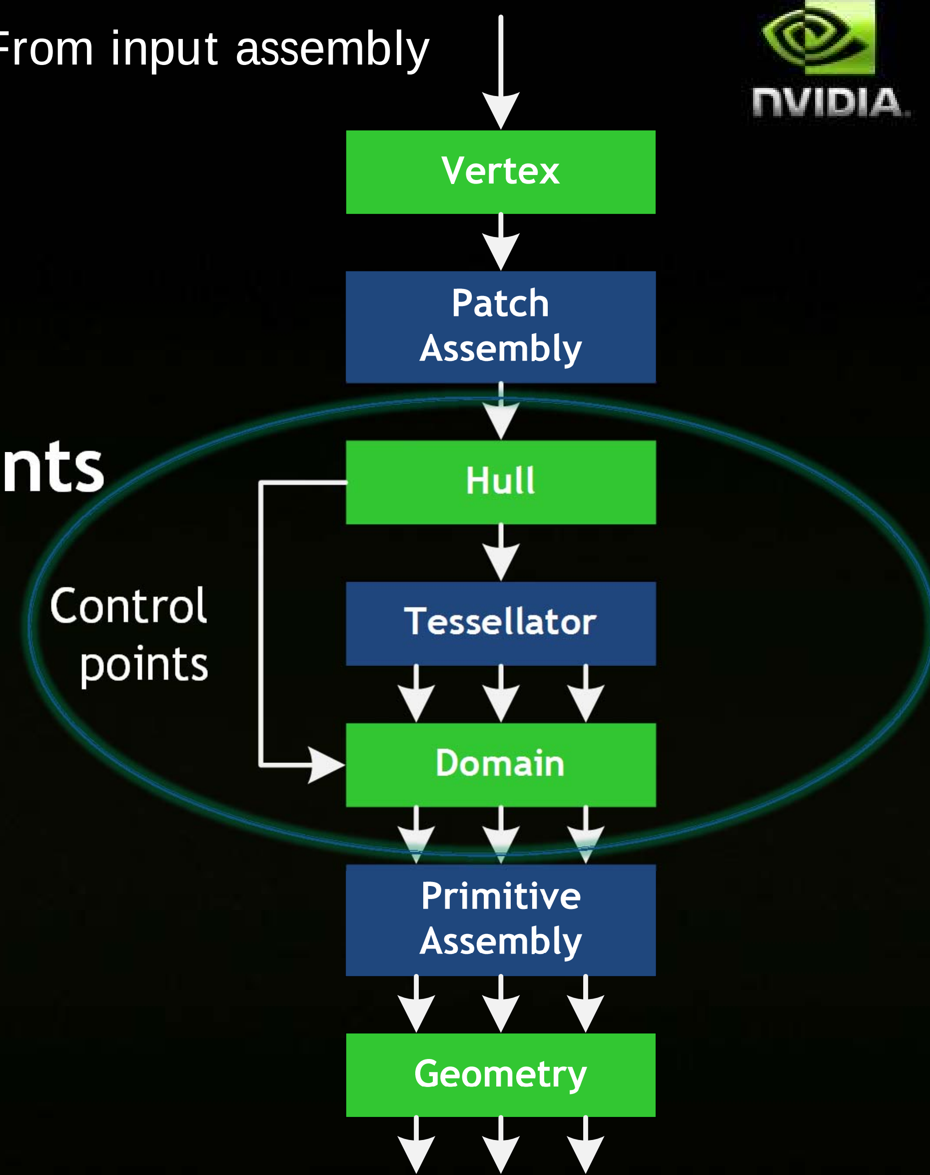
Tessellation in DirectX 11

- Fixed function tessellation stage
  - Configured by HS LOD output
  - Produces
    - U,V values
    - Primitive topology
  - Supports triangles and lines

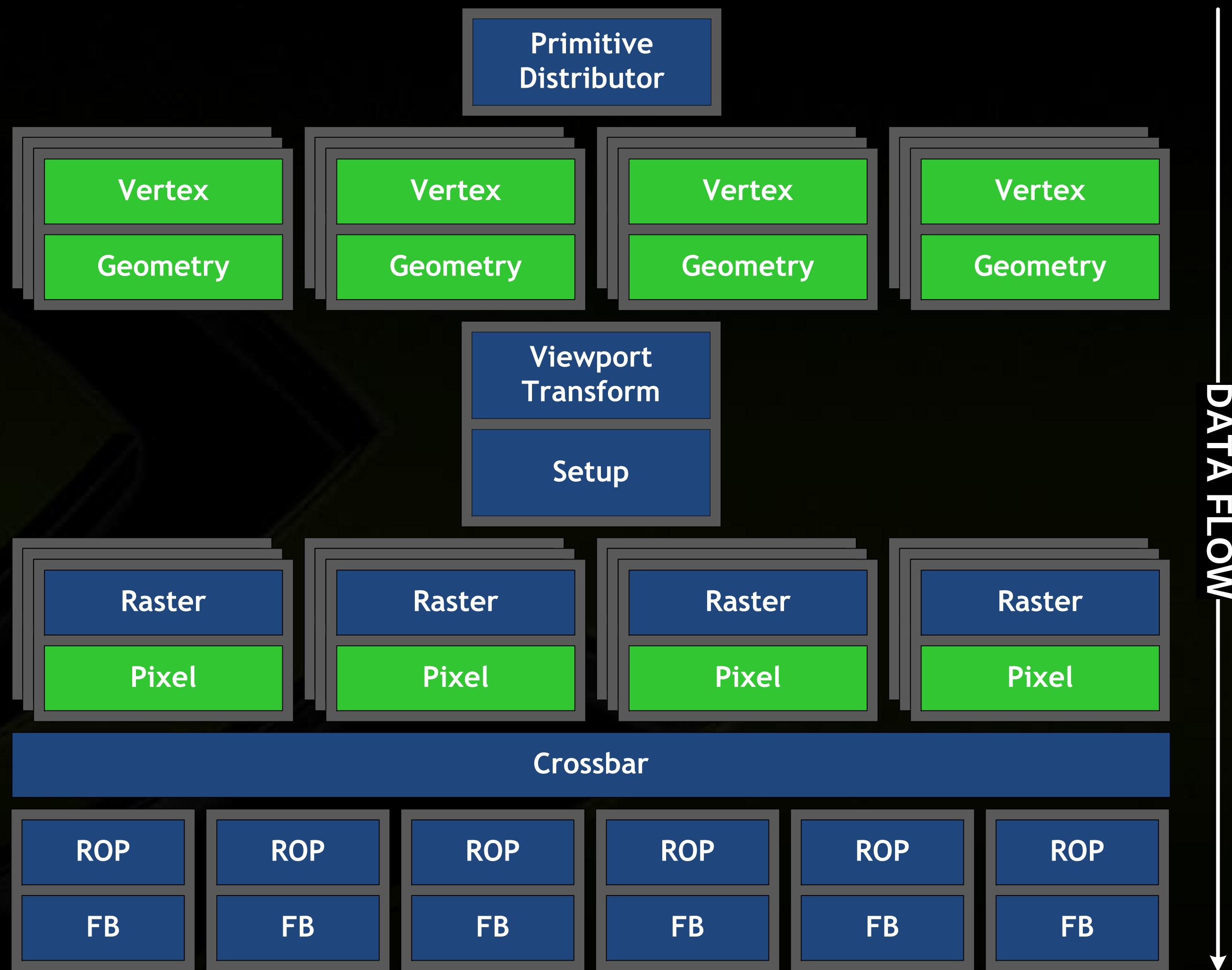


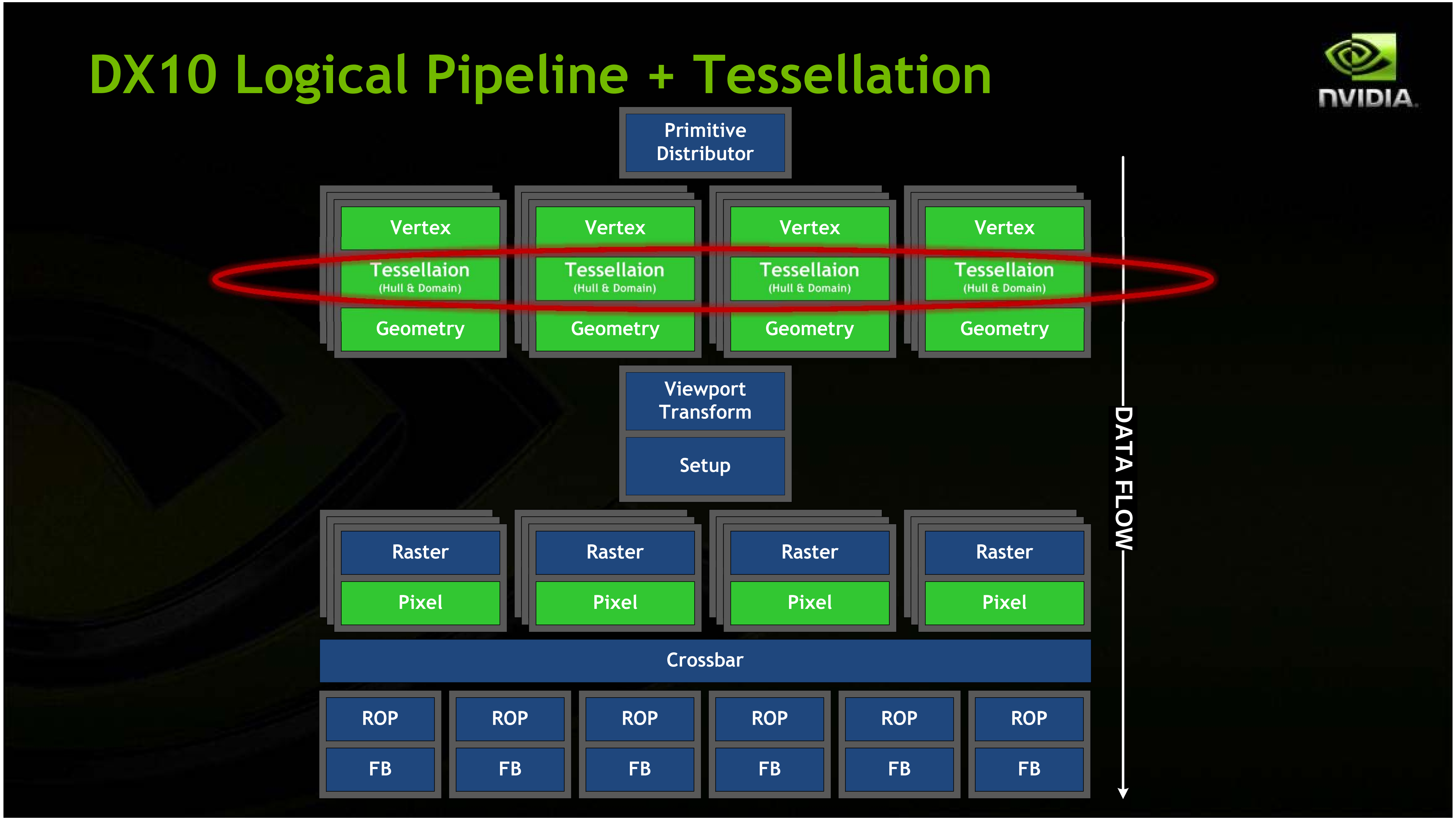
Tessellation in DirectX 11

- Domain shader
  - Runs post-expansion
  - Input: LOD, (u,v), control points
  - Maps (u,v) to (x,y,z,w)
    - Attributes
  - Implicitly parallel



DX10 Logical Pipeline




DX10 Logical Pipeline + Tessellation
Primitive Distributor
Vertex
Tessellaion (Hull & Domain)
Geometry
Vertex
Tessellaion (Hull & Domain)
Geometry
Vertex
Tessellaion (Hull & Domain)
Geometry
Vertex
Tessellaion (Hull & Domain)
Geometry
Viewport Transform
Setup
Raster
Pixel
Raster
Pixel
Raster
Pixel
Raster
Pixel
Crossbar
ROP
FB
ROP
FB
ROP
FB
ROP
FB
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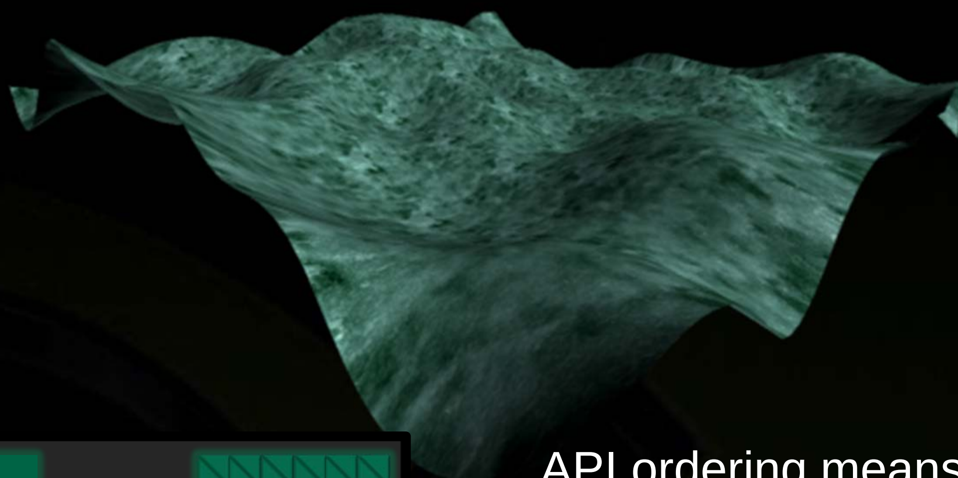
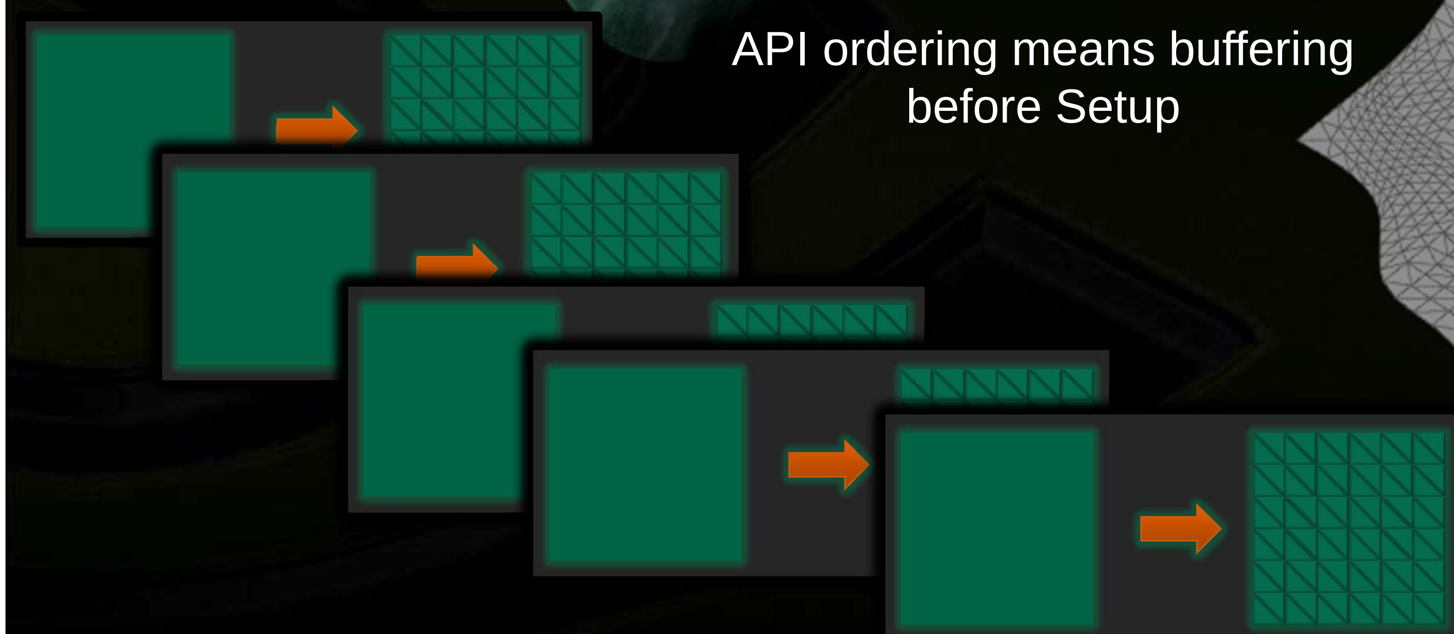
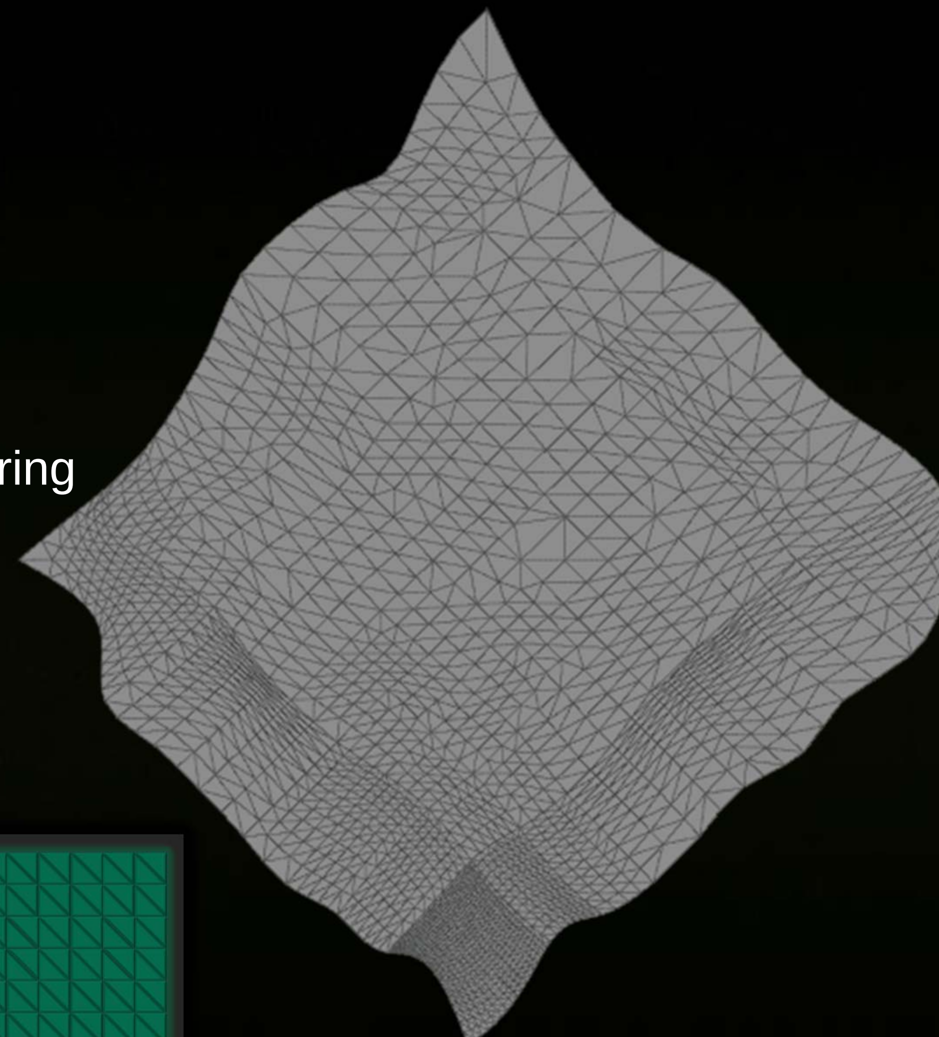
DATA FLOW
NVIDIA

DX10 + Tessellation - data expansion

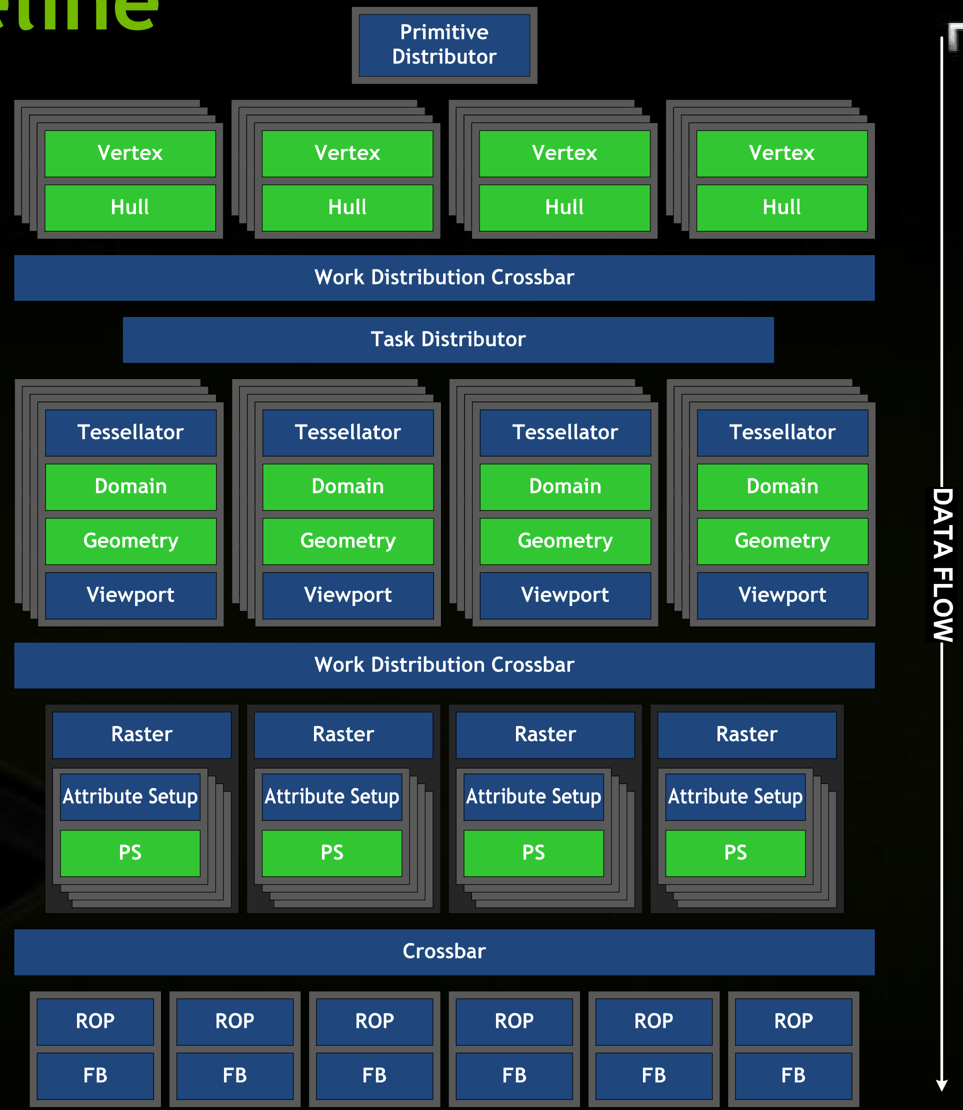


API ordering means buffering before Setup



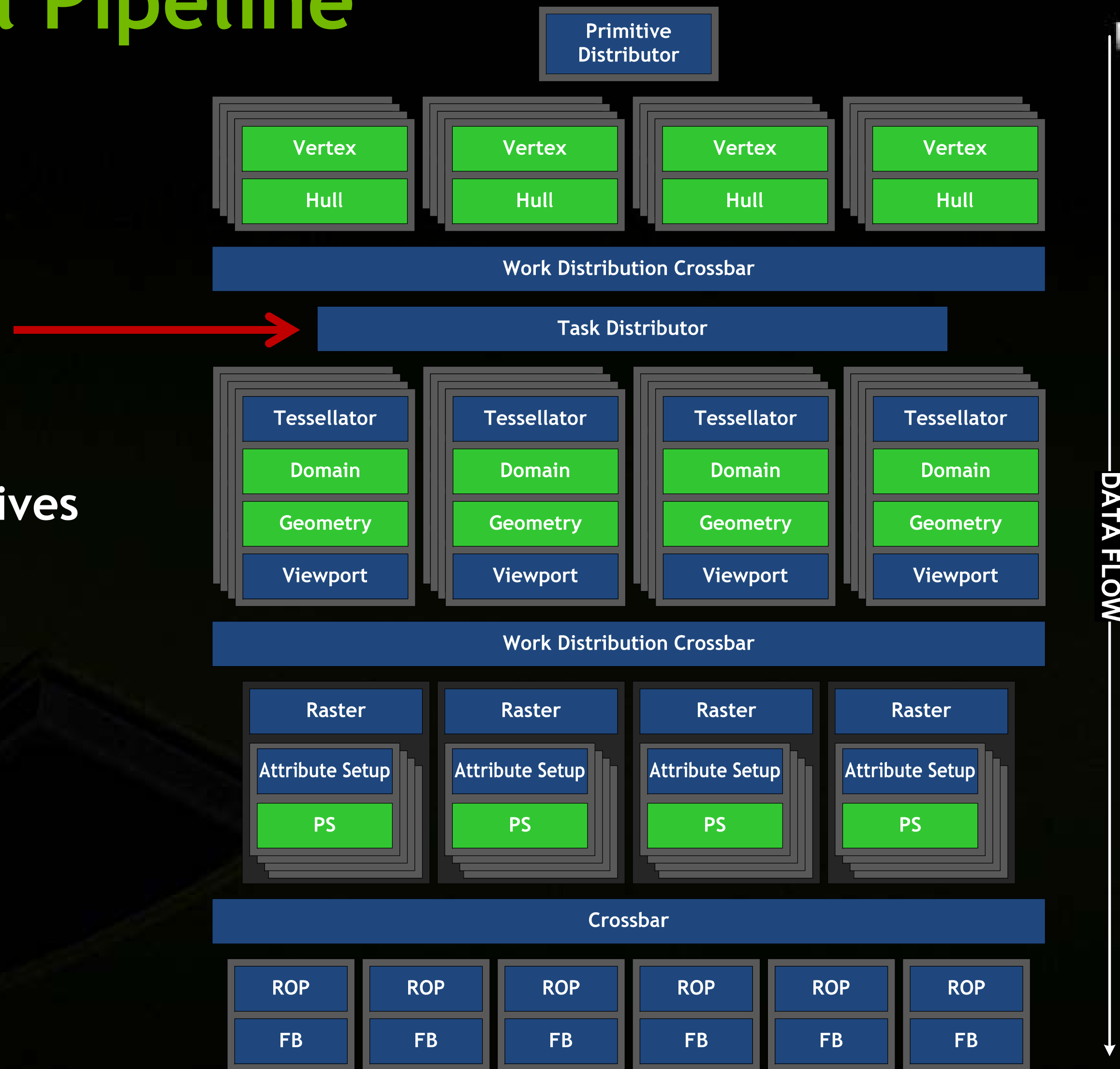


Fermi GF100 Logical Pipeline



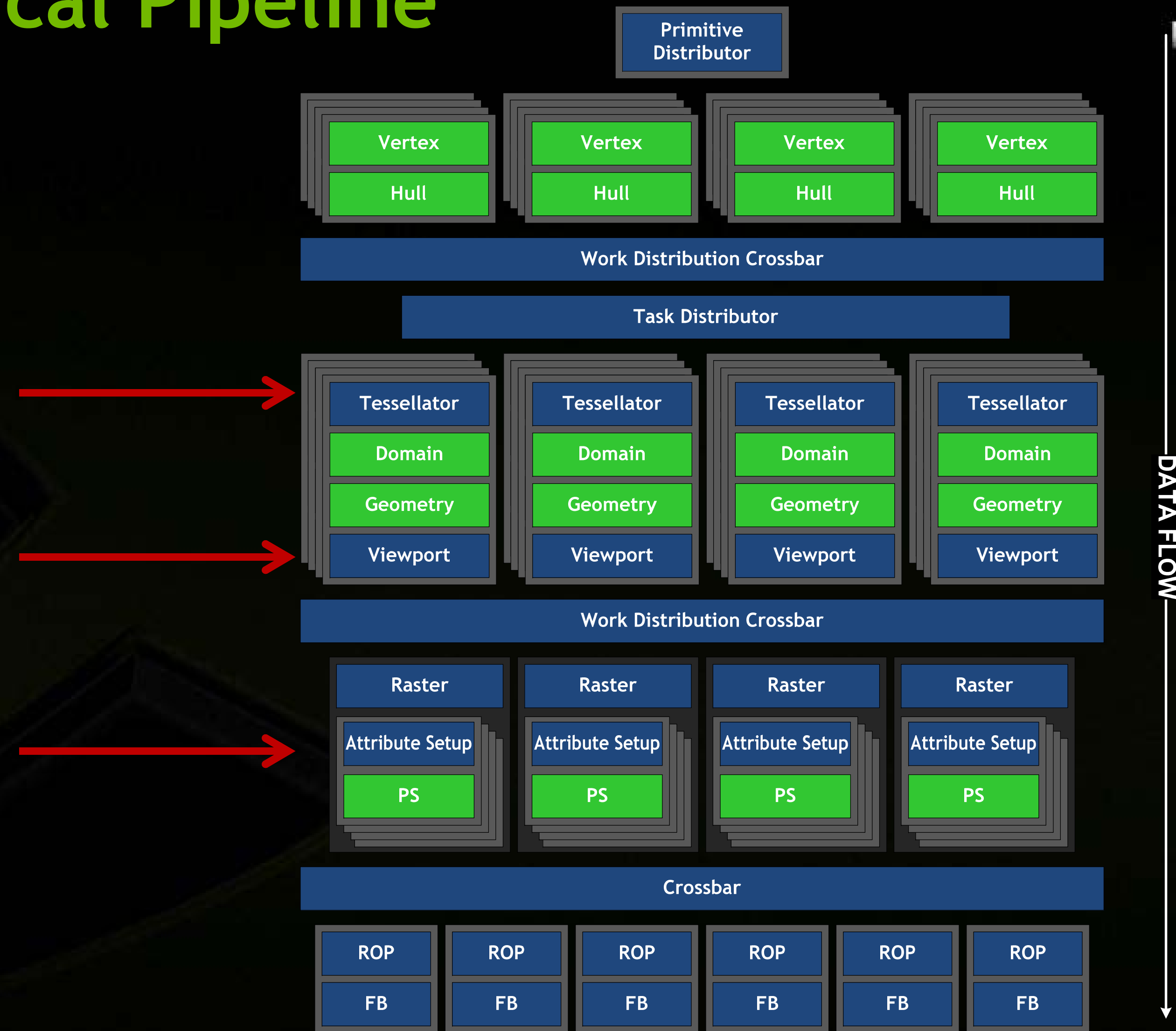
Fermi GF100 Logical Pipeline

- Task Distributor
  - Task ≈ Hull Shader output
    - Control points + LOD
    - Pre-expansion
  - Distribute tasks
    - Expand patch into primitives
    - Optional GS
  - Reduced buffering



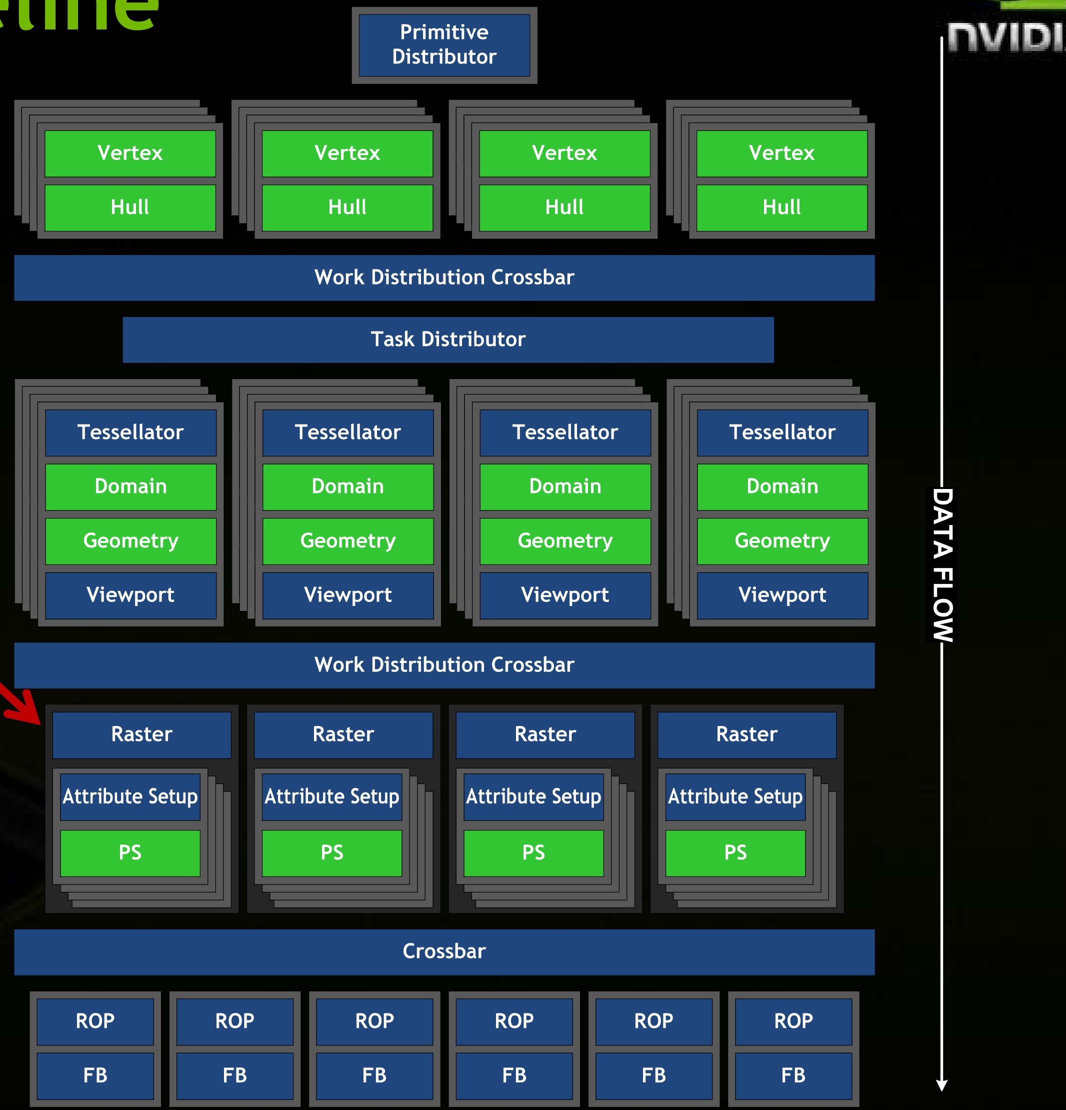
Fermi GF100 Logical Pipeline

- Polymorph Engine
  - Tessellator
  - Viewport Transform
  - Attribute Setup



Fermi GF100 Logical Pipeline

- Parallel Rasterization
  - Edge Setup, Raster & Z Cull
  - Multiple primitives per clock
  - Screen mapped load balancing



GF100 Block Diagram

- 512 CUDA cores
- 16 geometry units
- 4 raster units
- 64 texture units
- 48 ROP units
- 384-bit GDDR5

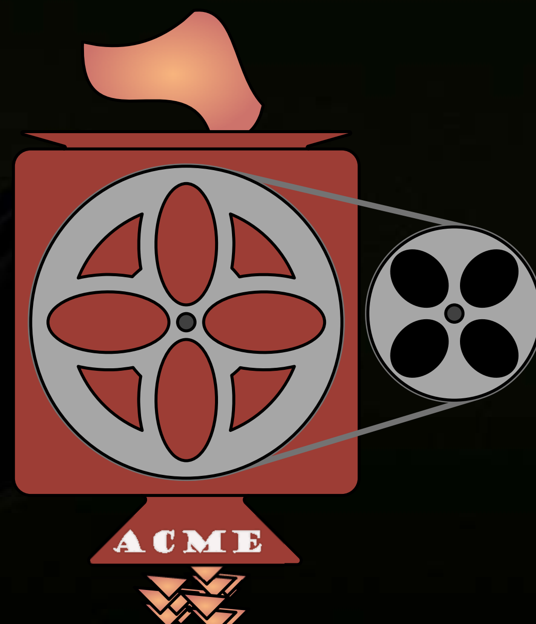
GF100 Scalable Parallel Implementation

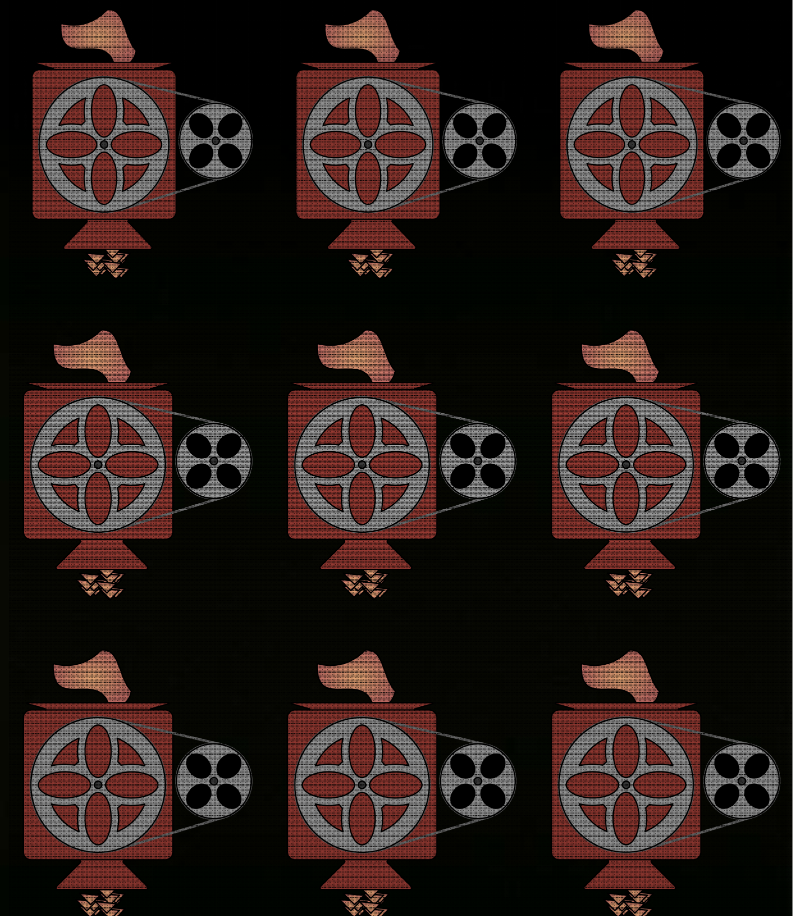
Distributed, parallel geometry

The Challenge:
Sequential Rendering Semantics

Maintaining API Order

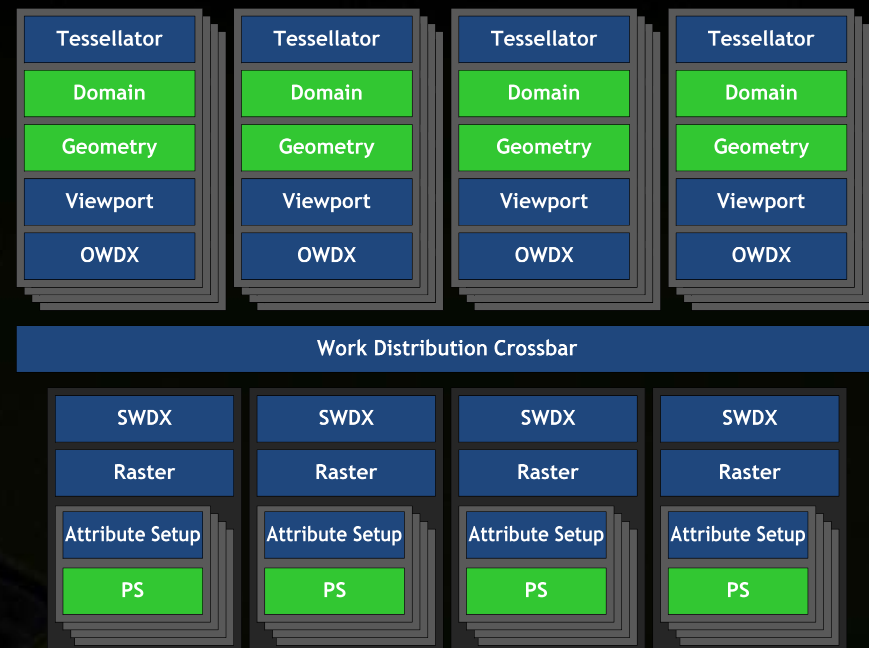
- Greater parallelism is straightforward
- API order is the challenge
- WDX - Work Distribution Crossbar
  - Between Viewport and Raster
  - Distributes work
  - Maintains order





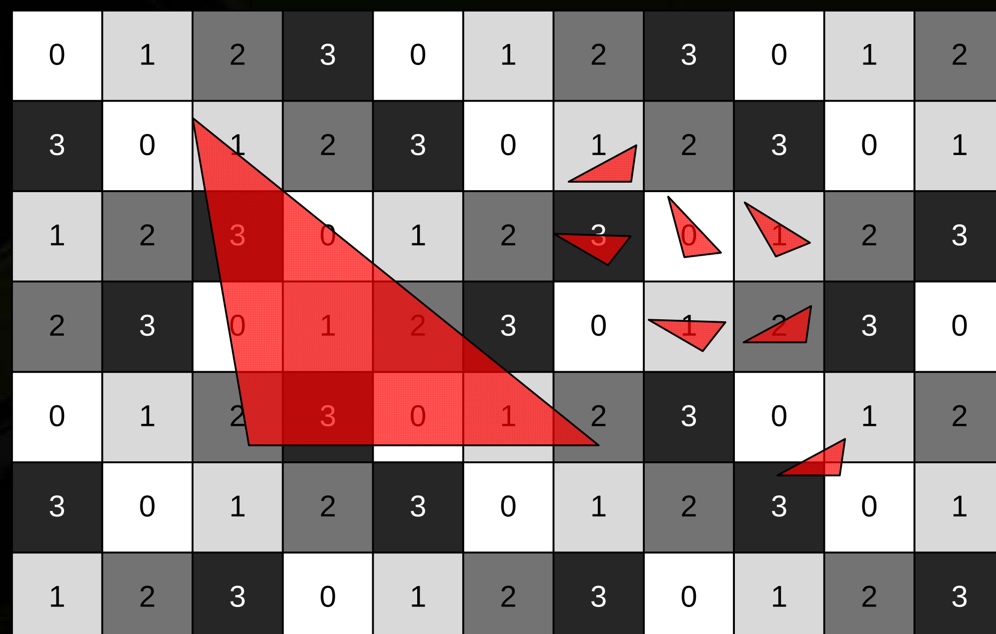
Work Distribution Crossbar

- OWDX
  - Bounding box
  - Broadcast to Raster
- SWDX
  - Reconstructs API order
- Each Raster owns its pixels
  - No further sorting



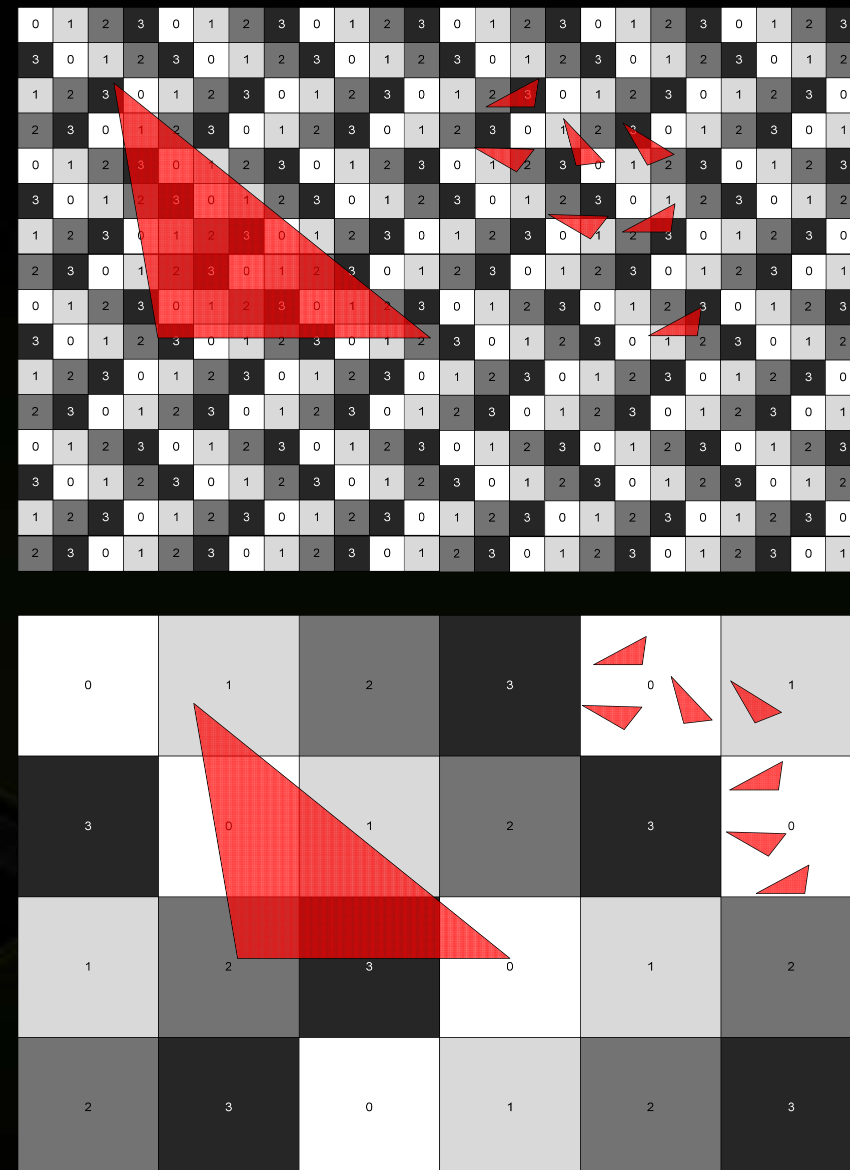
Screen-mapped Rasterization

- Each block is a tile of pixels
- Blocks are bound to rasterizers
- Small primitives can still straddle tiles



Load balance tension

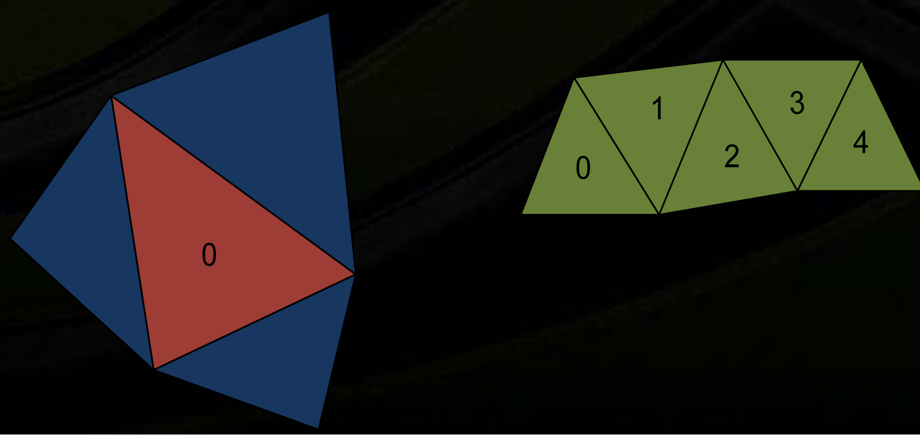
- Small tiles
  - + Better pixel distribution
  - - More redundant Setup
- Large tiles
  - - Risk camping
  - + Not Setup limited

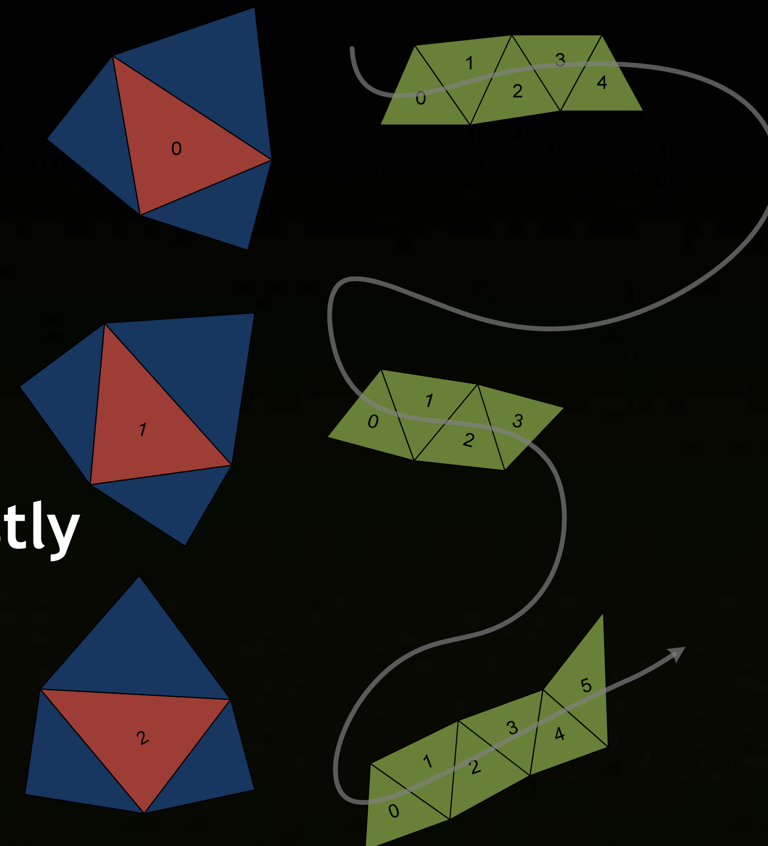


Questions?

Geometry Shaders - a postmortem

- Introduced as part of DX10
- Intended as a tessellation post-processor
  - Vestige of stencil shadow volumes
- Implements legacy features – sprites
- API sequential rendering semantics are costly
- Outputs are spilled to memory or buffered





Future

- More transistors
- No more watts
- More dark silicon
  - Special purpose units
    - Video encode/decode
    - Camera
    - Copy
  - Suspended cores
- Vision
  - The killer consumer application?
  - OpenCV - low level
  - Is there an API at a higher semantic level?
    - Analogous to touch….

Thanks