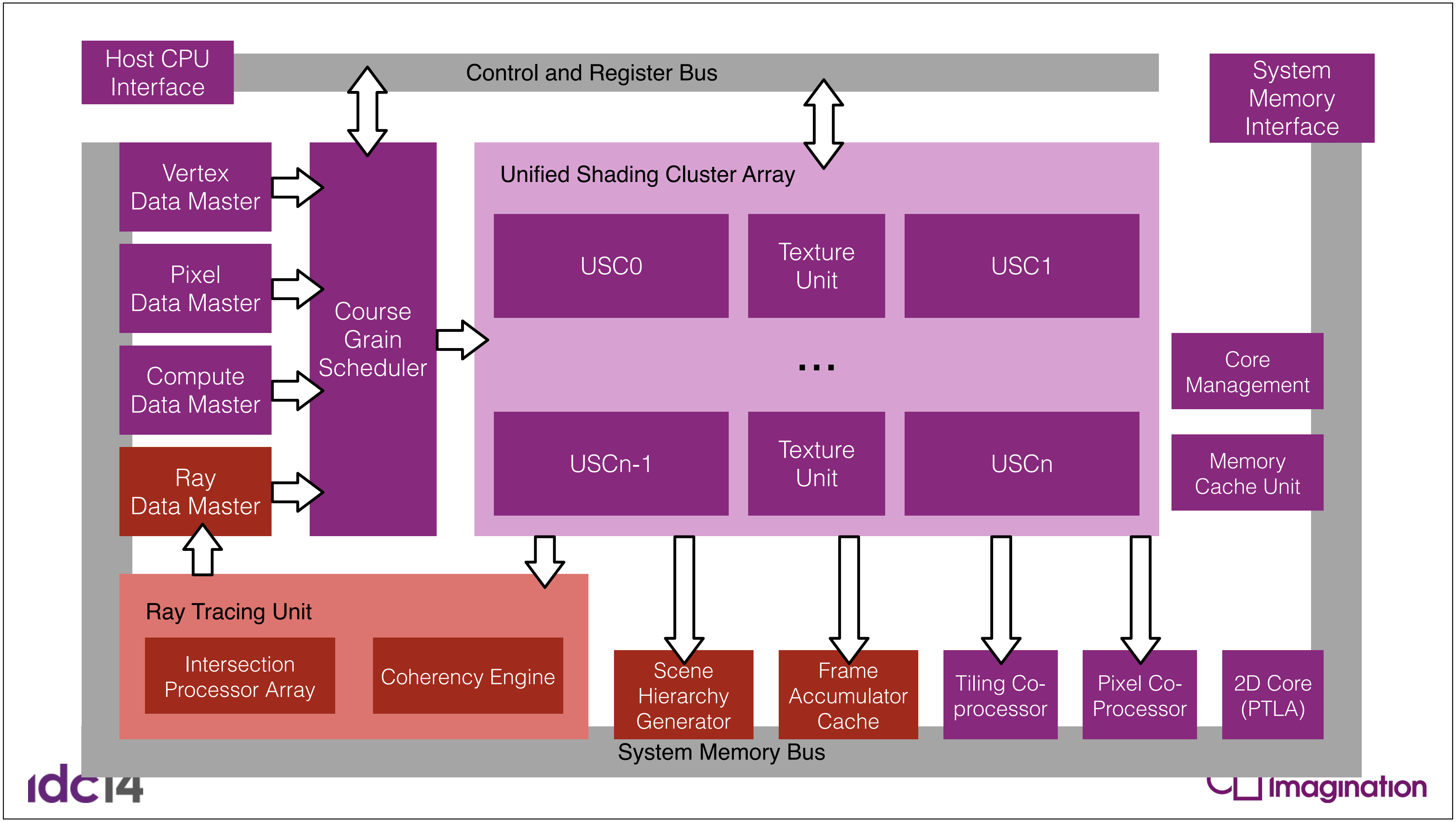
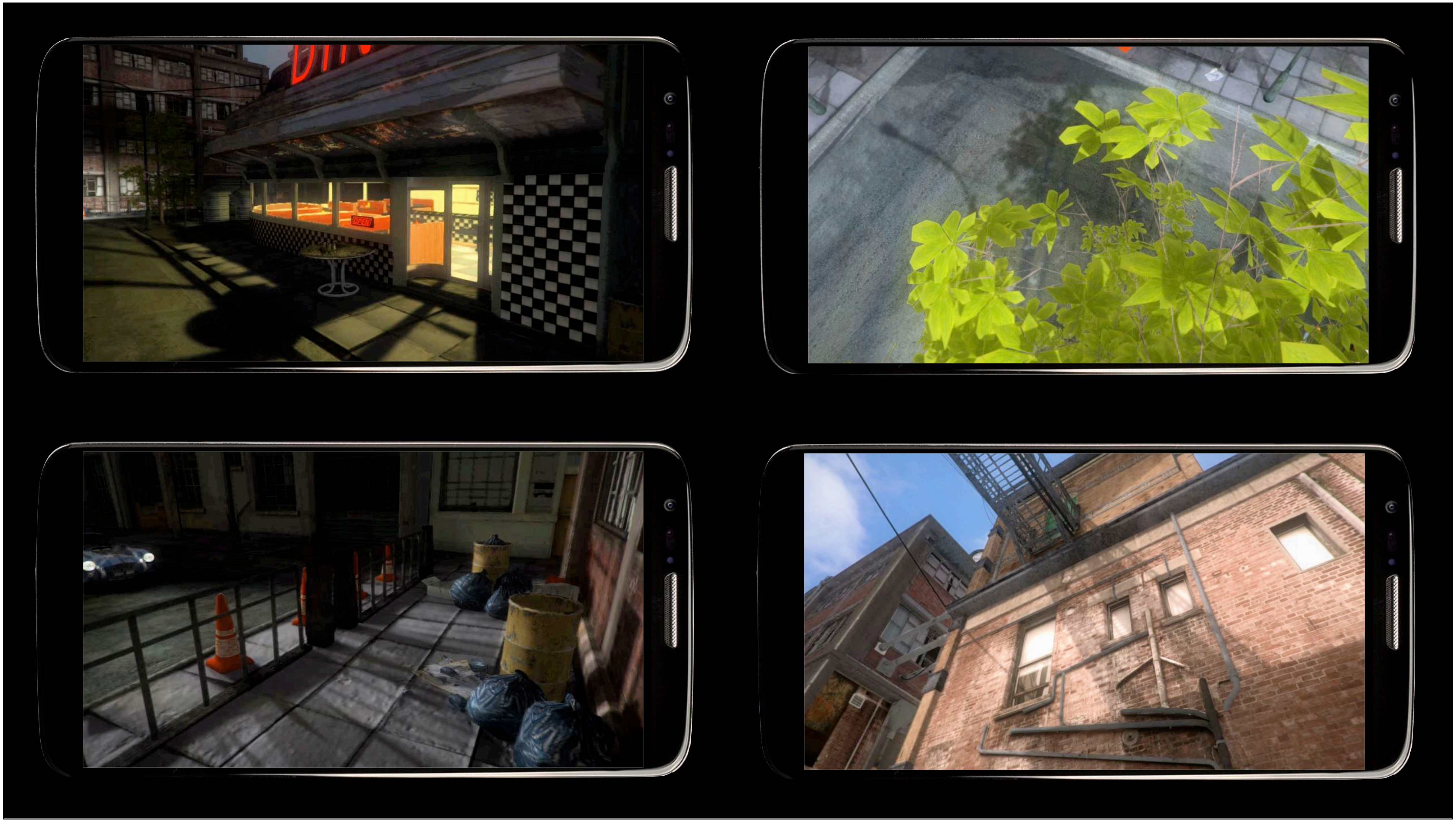
Introduction to PowerVR Ray Tracing

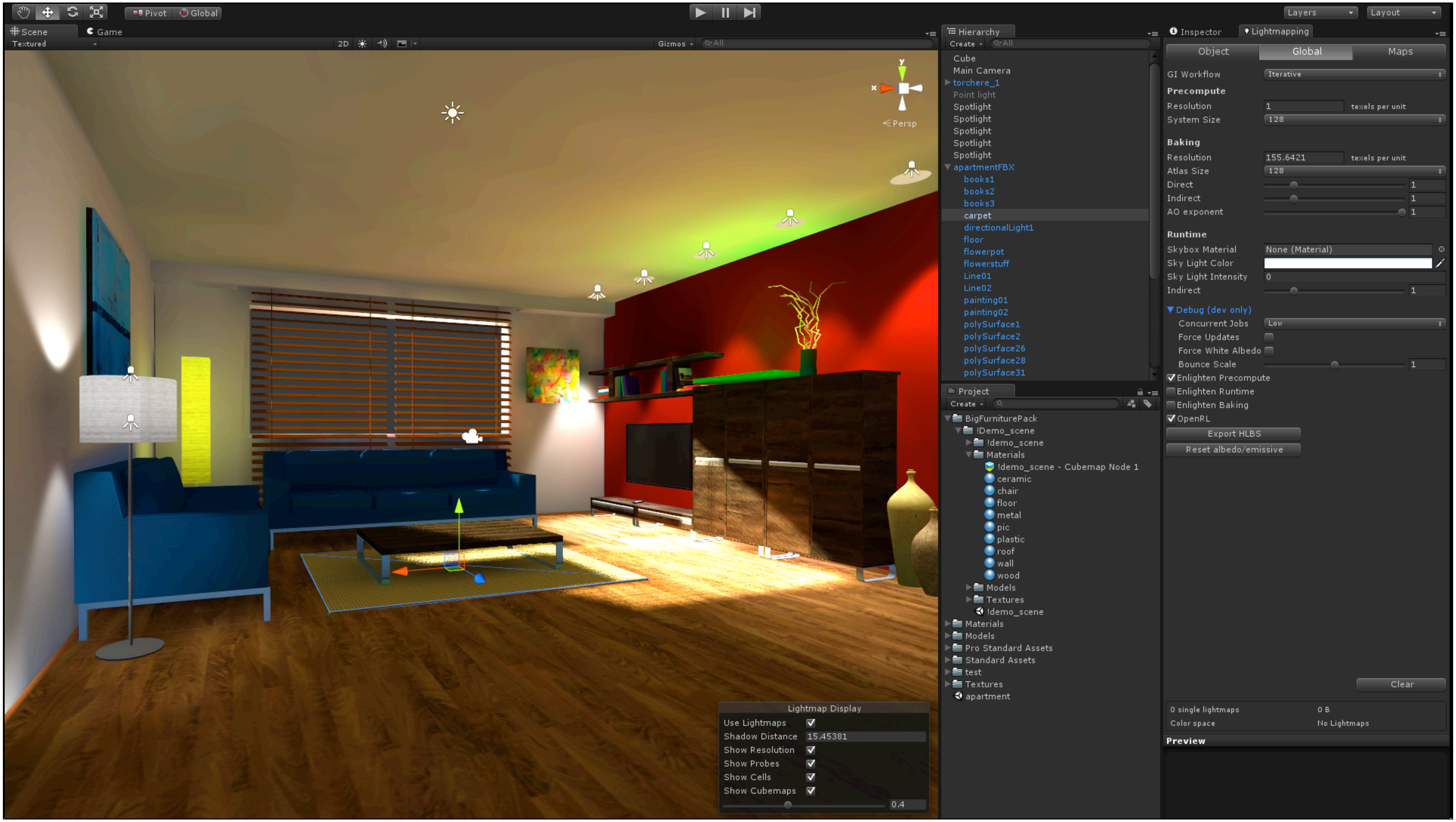
Tuesday 18th March, 2014 @ GDC

James A. McCombe

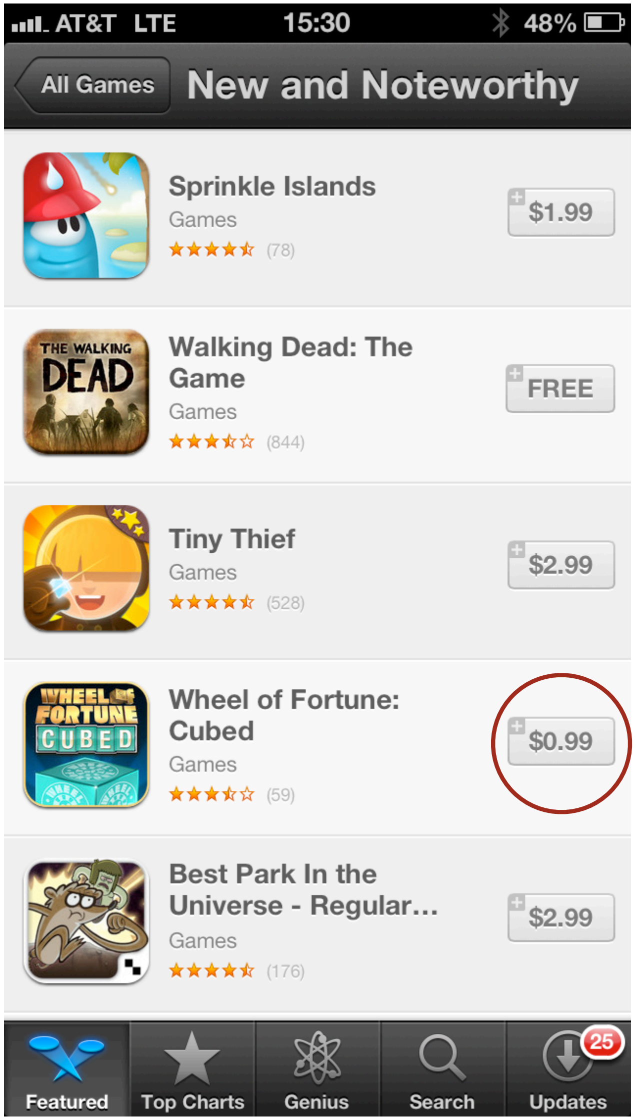
What are we launching today?


Host CPU Interface
Control and Register Bus
System Memory Interface
Vertex Data Master
Pixel Data Master
Compute Data Master
Ray Data Master
Course Grain Scheduler
Unified Shading Cluster Array
USC0
Texture Unit
USC1
...
USCn-1
Texture Unit
USCn
Core Management
Memory Cache Unit
Ray Tracing Unit
Intersection Processor Array
Coherency Engine
Scene Hierarchy Generator
Frame Accumulator Cache
Tiling Co-processor
Pixel Co-Processor
2D Core (PTLA)
System Memory Bus
idc14
Imagination




Pivot
Global
Layers
Layout
Scene
Game
Textured
2D
Gizmos
All
Persp
Hierarchy
Create
Cube
Main Camera
torchere_1
Point light
Spotlight
Spotlight
Spotlight
Spotlight
Spotlight
apartmentFBX
books1
books2
books3
carpet
directionalLight1
floor
flowerpot
flowerstuff
Line01
Line02
painting01
painting02
polySurface1
polySurface2
polySurface26
polySurface28
polySurface31
Project
Create
BigFurniturePack
!Demo_scene
!demo_scene
Materials
!demo_scene - Cubemap Node 1
ceramic
chair
floor
metal
pic
plastic
roof
wall
wood
Models
Textures
!demo_scene
Materials
Models
Pro Standard Assets
Standard Assets
test
Textures
apartment
Inspector
Lightmapping
Object
Global
Maps
GI Workflow
Iterative
Precompute
Resolution
1
texels per unit
System Size
128
Baking
Resolution
155.6421
texels per unit
Atlas Size
128
Direct
1
Indirect
1
AO exponent
1
Runtime
Skybox Material
None (Material)
Sky Light Color
Sky Light Intensity
0
Indirect
1
Debug (dev only)
Concurrent Jobs
Low
Force Updates
Force White Albedo
Bounce Scale
1
Enlighten Precompute
Enlighten Runtime
Enlighten Baking
OpenRL
Export HLBS
Reset albedo/emissive
Clear
0 single lightmaps
0 B
Color space
No Lightmaps
Preview
Lightmap Display
Use Lightmaps
Shadow Distance
15.45381
Show Resolution
Show Probes
Show Cells
Show Cubemaps
0.4

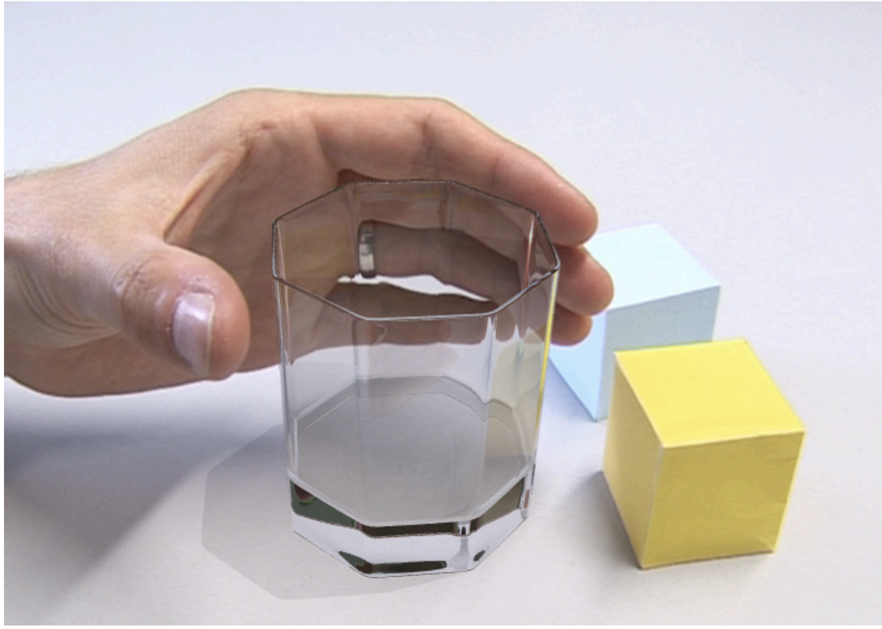
What are the applications for this?

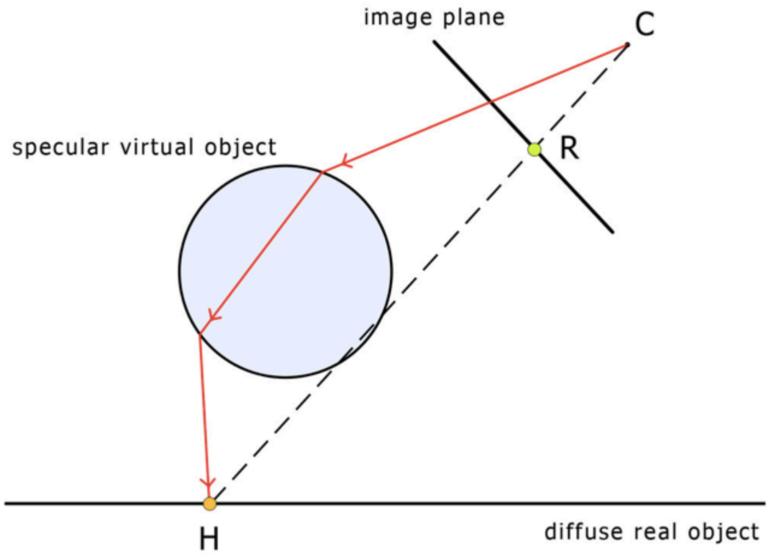


idc14

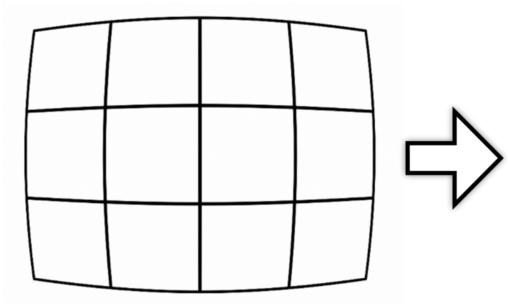
Imagination

Augmented Reality

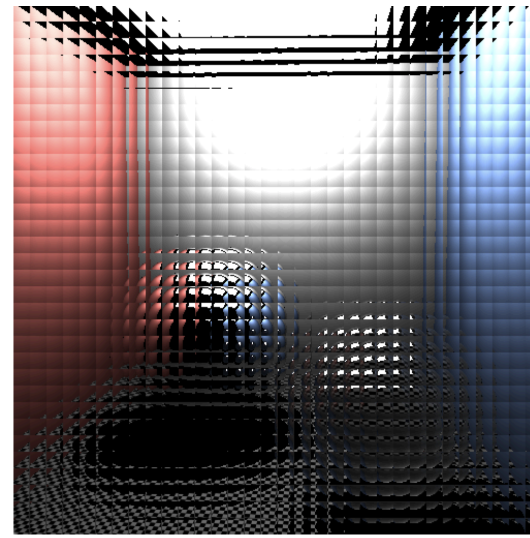




Virtual Reality a.k.a Multi-persective rendering



Lens distortion and aberration correction



Lenticular Displays

Ultra-low latency rendering

Hybrid rendering in games

- Shadows
- Reflections
- Transparency
- Better scaling with multiple dynamic lights
- Real-time light map updates for the rasteriser
- Easy to bolt on

Fully ray traced graphics

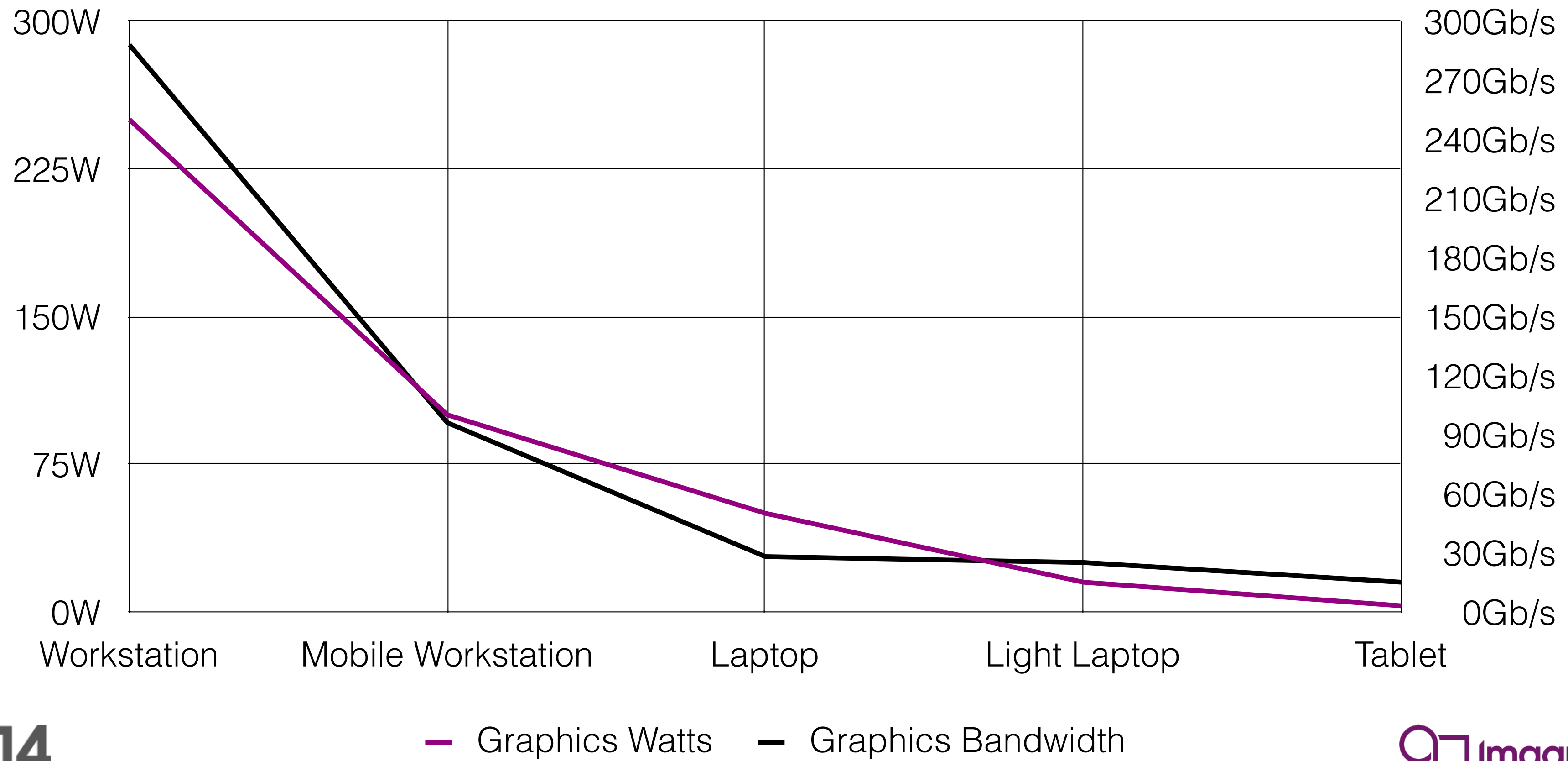
- Brute force path tracing
- Produces photo realism easily
- Pretty much requires all the 3D content to be ray traced
- Possible in todays technology in console / desktop using Wizard
- Probably not practical for fully real-time use in mobile for a couple more generations. Fine for sub-realtime use.

Non-graphics

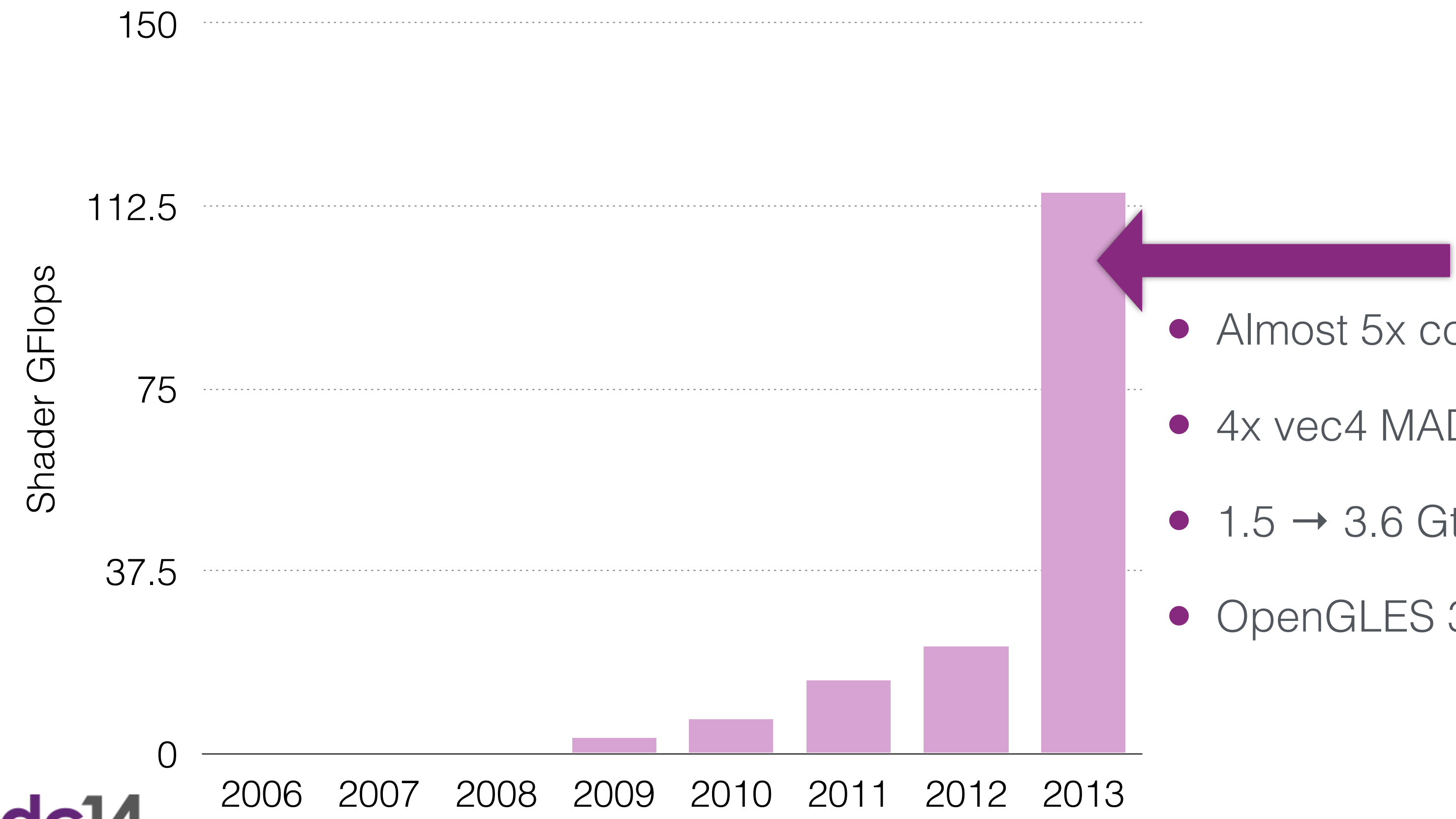
- Better in-game AI
- Collision Detection
- 3D spatial search

Overview of PowerVR

Power and Bandwidth



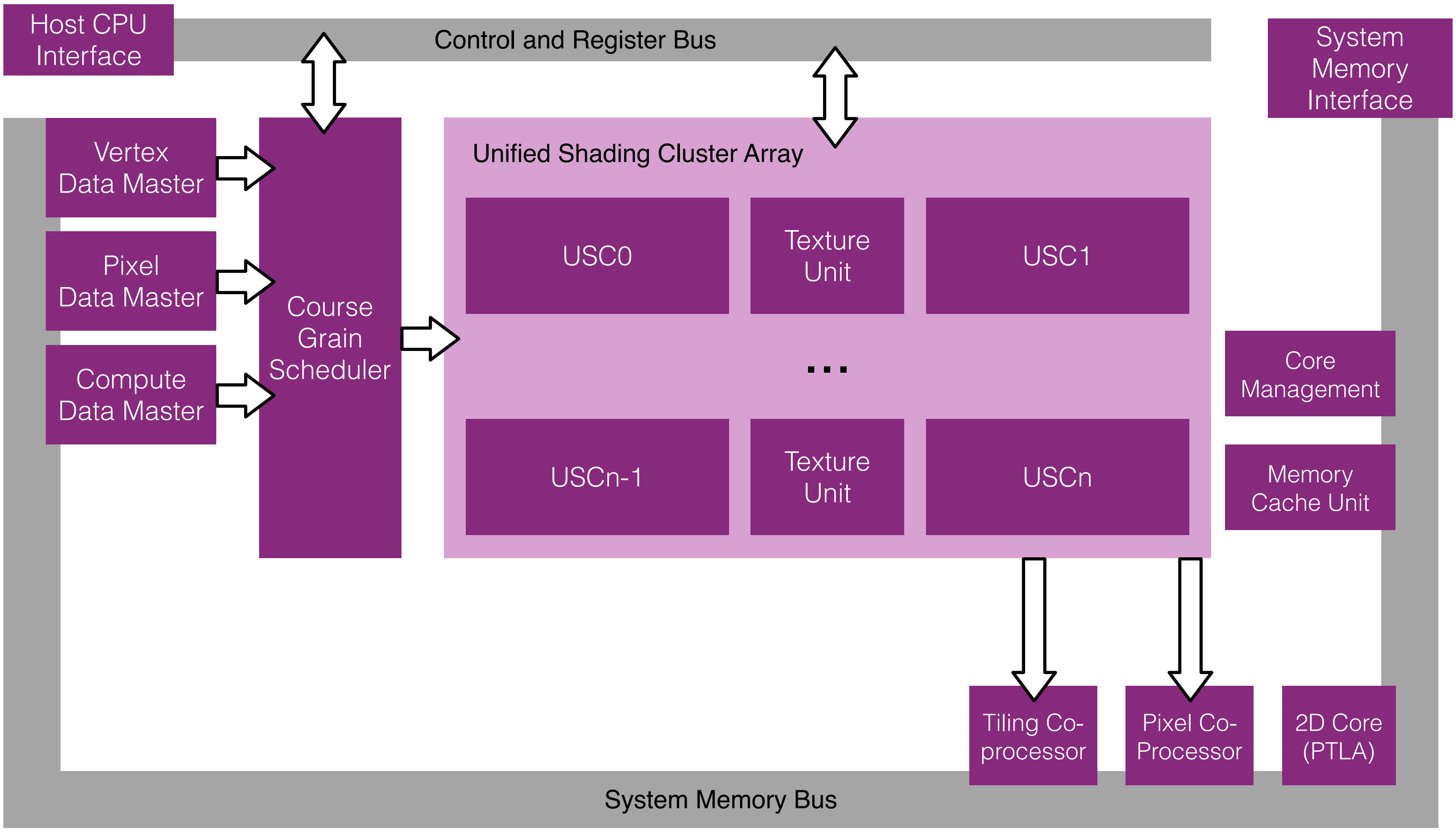
Capability of our mobile graphics



- Almost 5x compute capability
- 4x vec4 MAD → 16x Scalar 2xMAD
- 1.5 → 3.6 Gtexels/s
- OpenGLES 3.0 Support

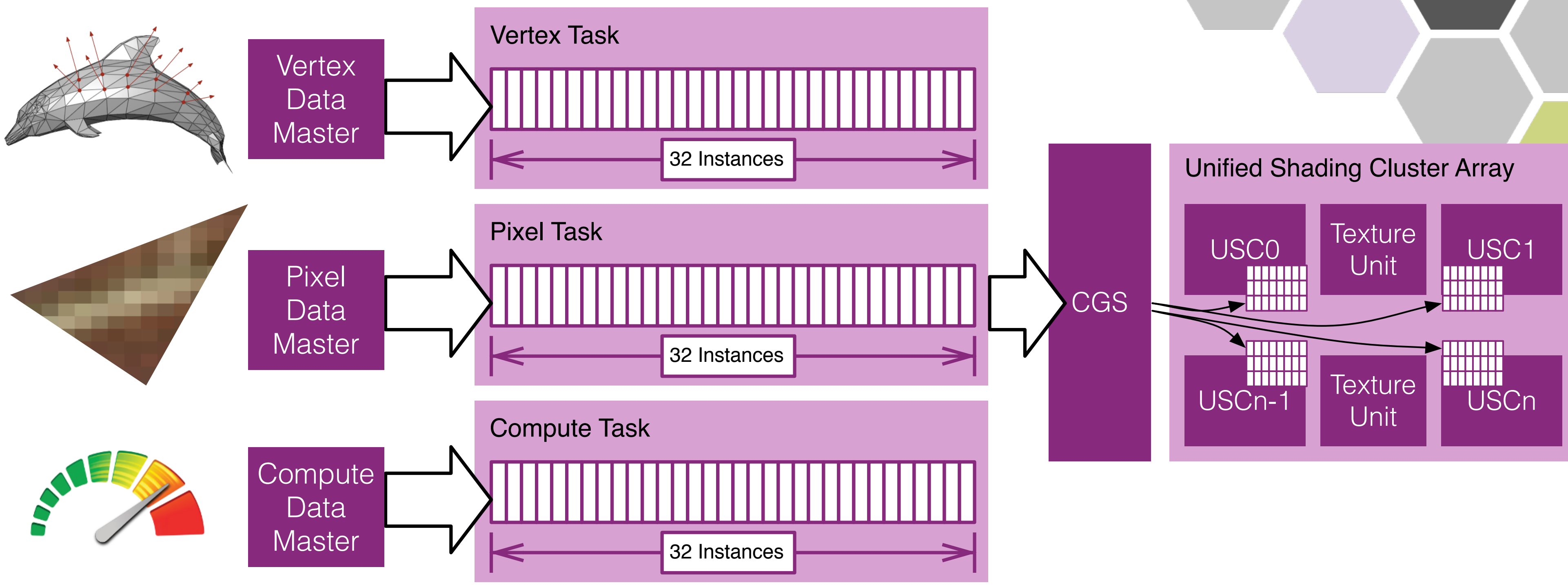
idc14

Imagination

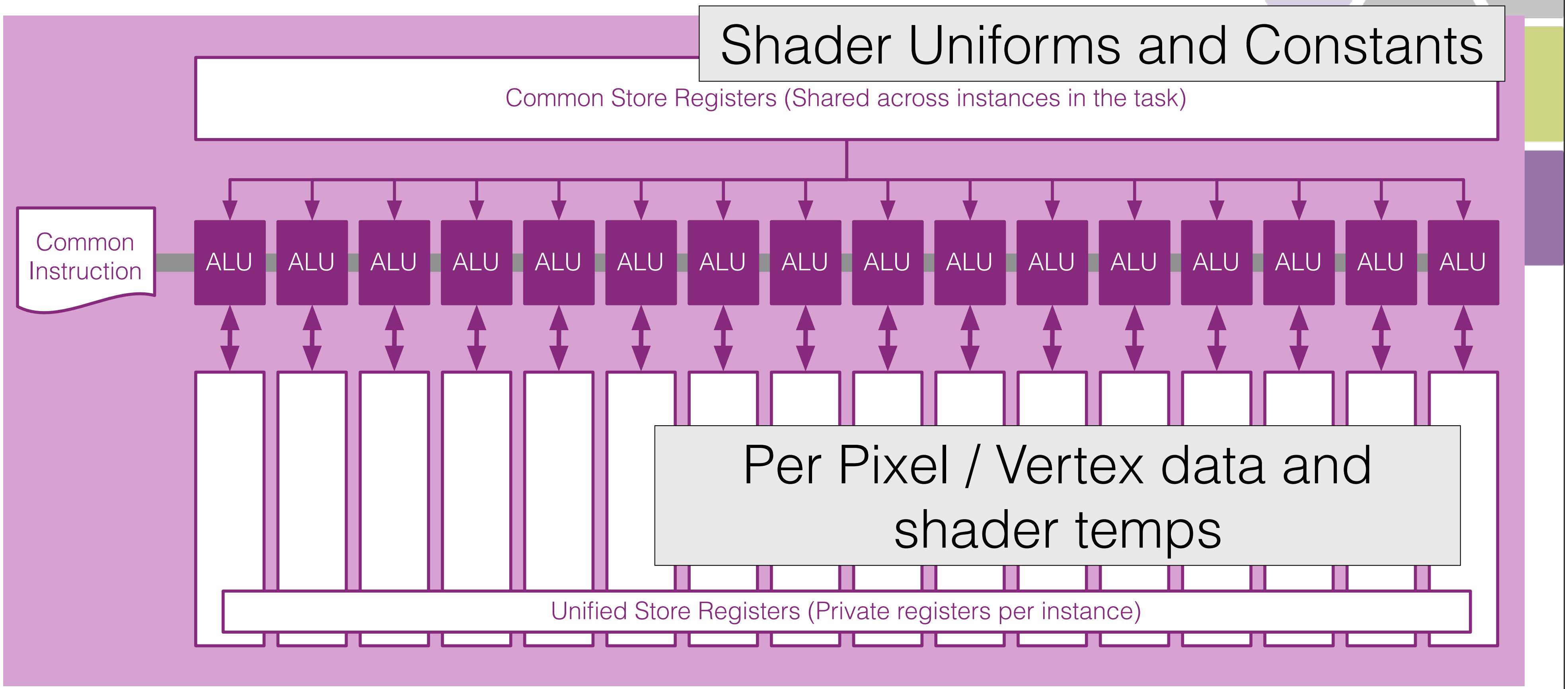


idc14

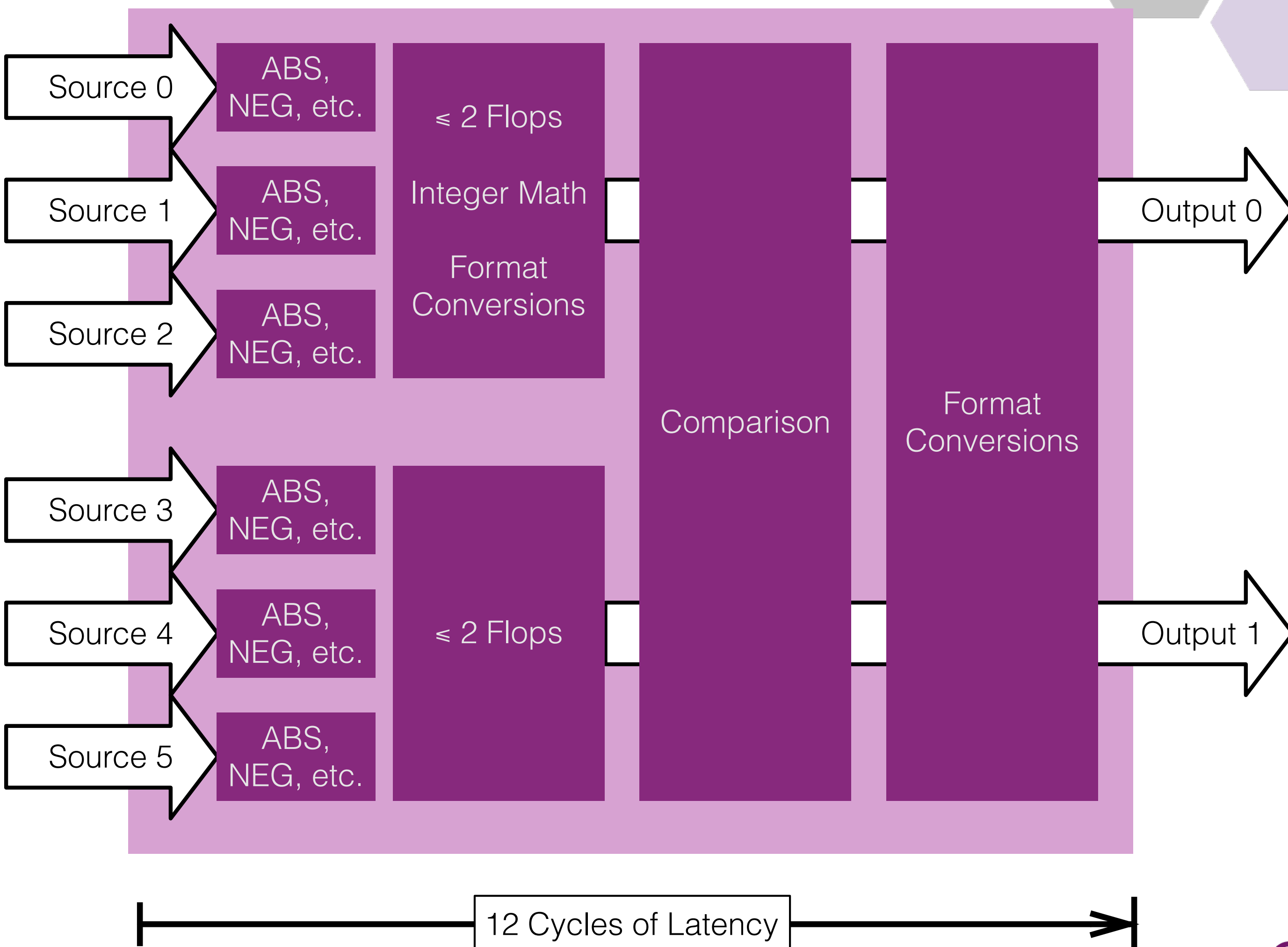
Imagination



- An instance is a vertex, pixel or OpenCL thread
- All instances in the task share Program, Uniforms, Parameters, etc.


Shader Uniforms and Constants
Common Store Registers (Shared across instances in the task)
Common Instruction
ALU ALU ALU ALU ALU ALU ALU ALU ALU ALU ALU ALU ALU ALU ALU ALU
Per Pixel / Vertex data and shader temps
Unified Store Registers (Private registers per instance)

(not exact)


Source 0
Source 1
Source 2
Source 3
Source 4
Source 5
ABS, NEG, etc.
ABS, NEG, etc.
ABS, NEG, etc.
ABS, NEG, etc.
ABS, NEG, etc.
ABS, NEG, etc.
≤ 2 Flops
Integer Math
Format Conversions
≤ 2 Flops
Comparison
Format Conversions
Output 0
Output 1
12 Cycles of Latency

(not exact)

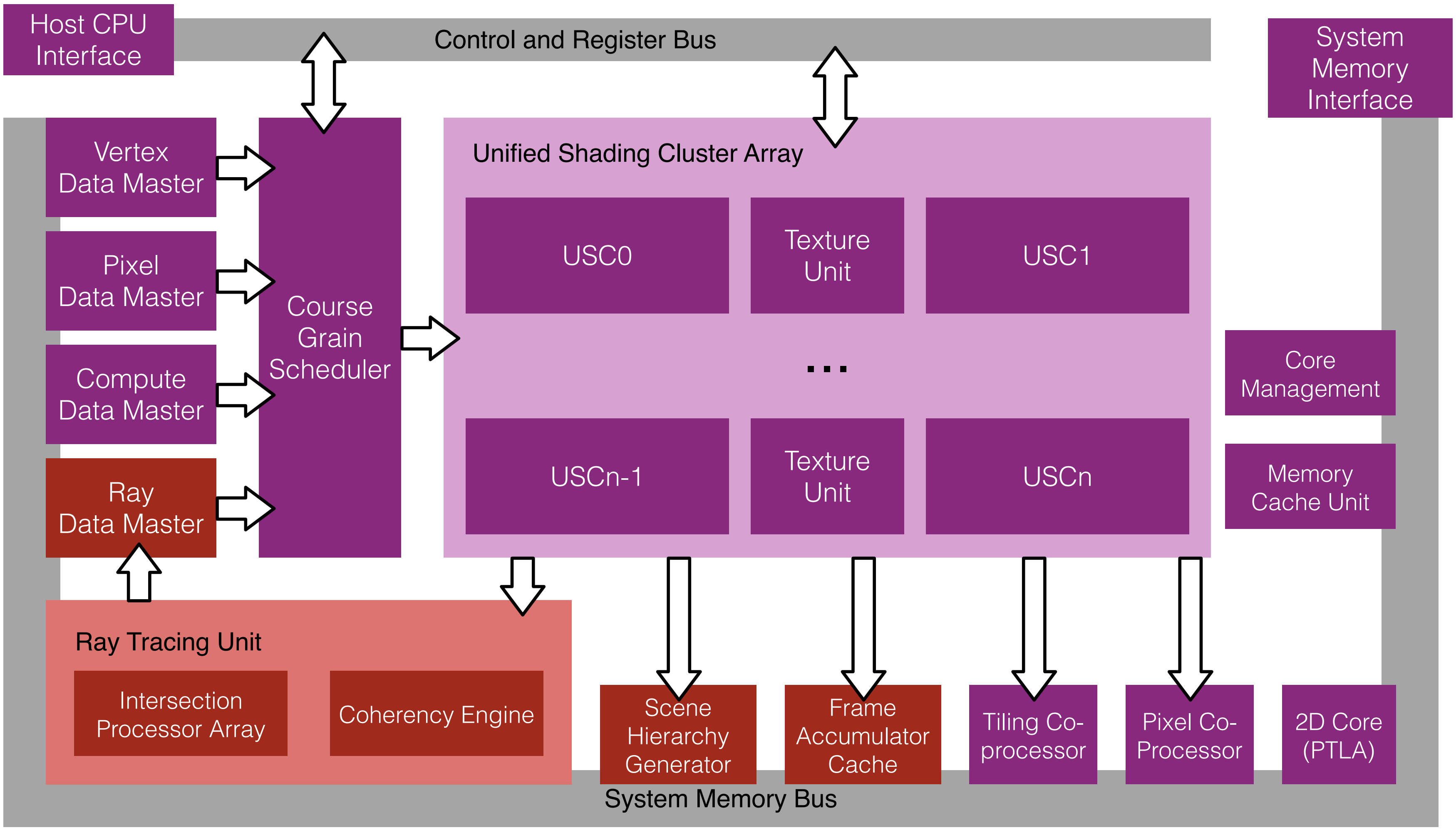

```
varying vec2 texCoord;

void main() {
   if (texCoord.x > 0.5) {
      ...
      ...
   } else {
      ...
      ...
   }
```

Overall capability

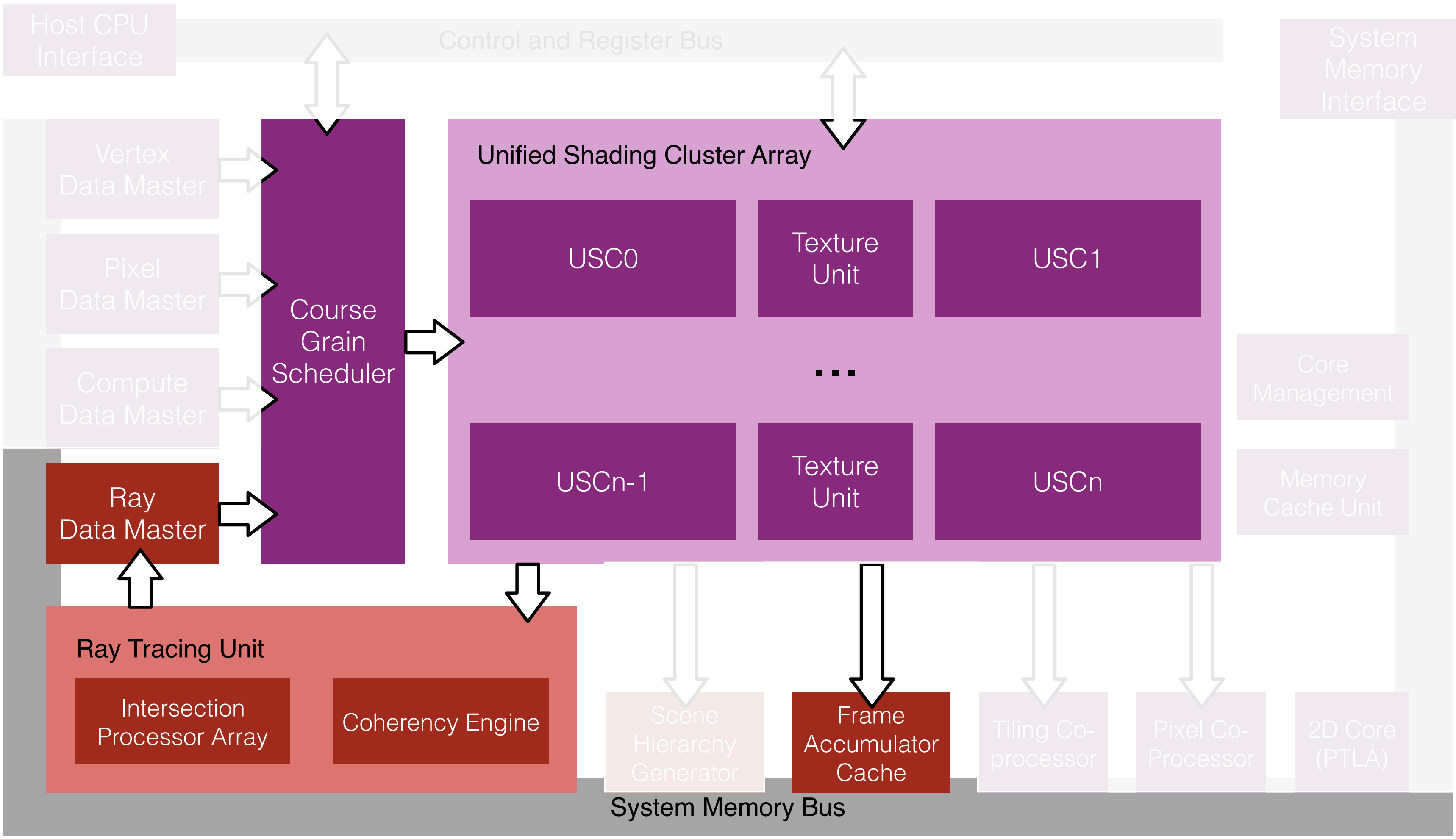
- Series6 gives you over 100Gflops for shading on latest mobile devices
- OpenGL ES 3.0 support
- Massive capability gain allowing math heavy shaders
- Mobile graphics is where the actual innovation is happening
- Try it!

A Technical introduction to Wizard



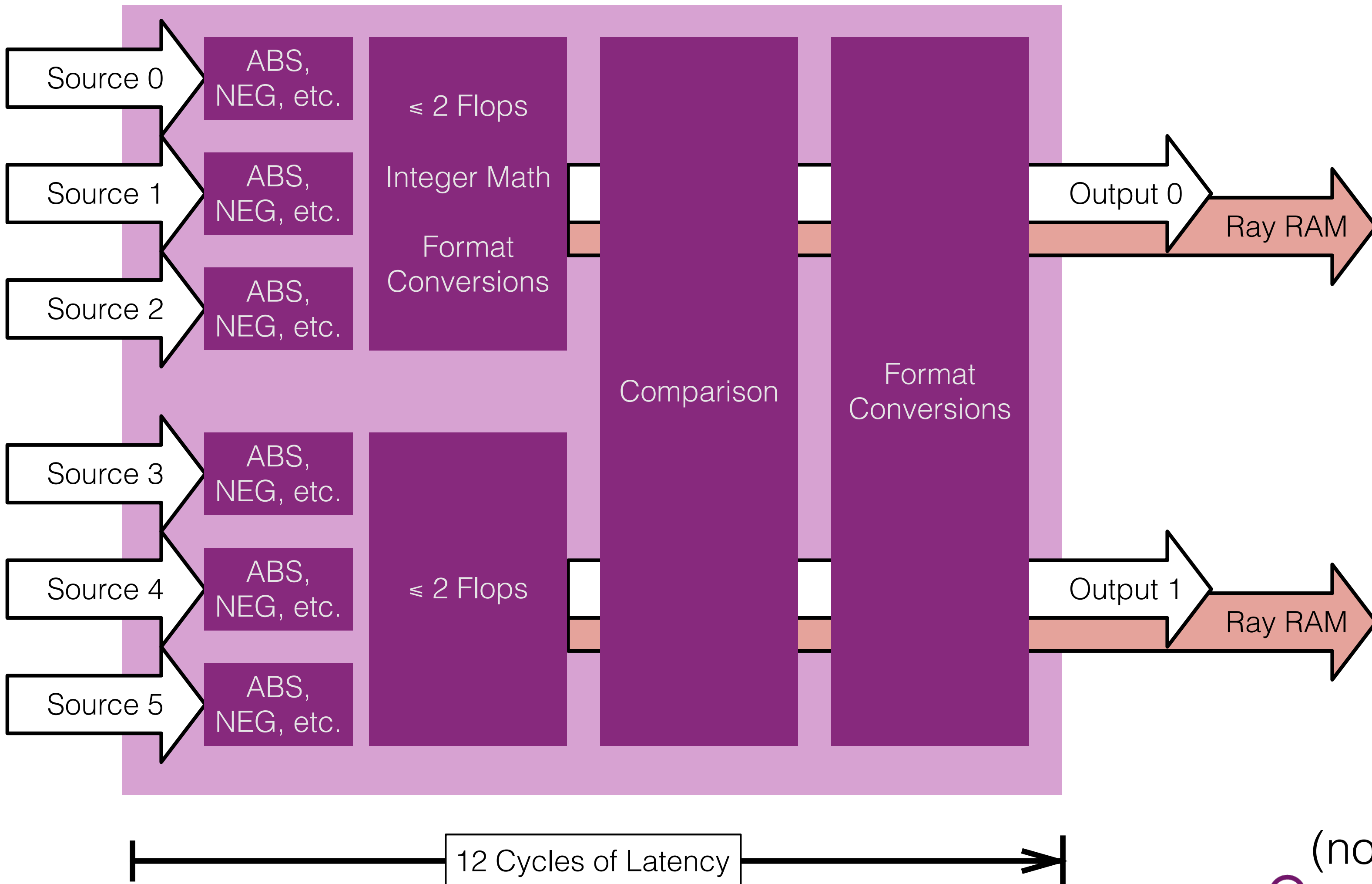
idc14

Imagination



idc14

Imagination



(not exact)

idc14

Imagination

New shader type

- Ray Shaders are invoked when a ray intersects a triangle
- Shaders types can emit any number of rays
- OpenRL has a frame shader to emit primary rays
- Existing fragment / pixel shaders can emit rays also!

- GLSL Programming model is the same
- Built-in functions, parameters, etc.

Primitive Objects

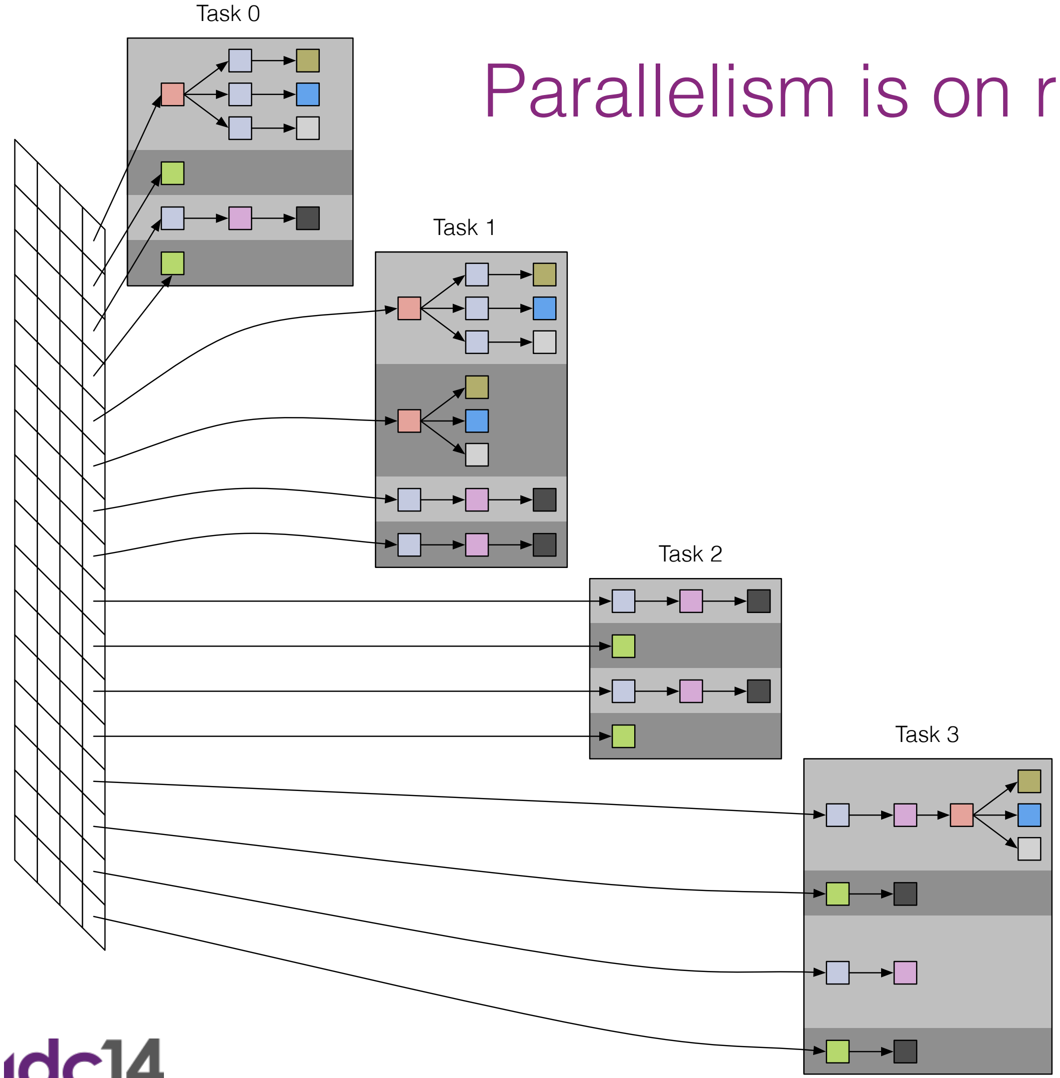
- Encapsulate the rendering state for one mesh
- Includes VBOs, uniforms, shader programs, texture bindings, etc.
- Ray tracing unit sorts rays into tasks with common primitive objects

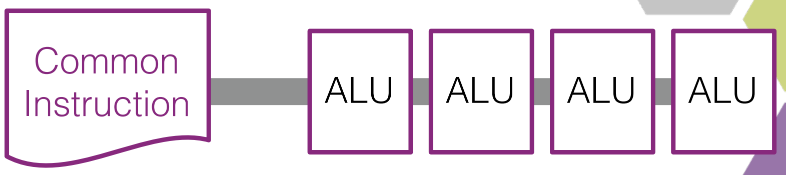
- Persistent between frames
- Mutable objects by the client

Constraints / Limitations

- Shaders cannot wait for results of individual ray trace operations
- Shaders must provide a worst case estimate on number of child rays
- Per-ray user data payload must be carefully managed

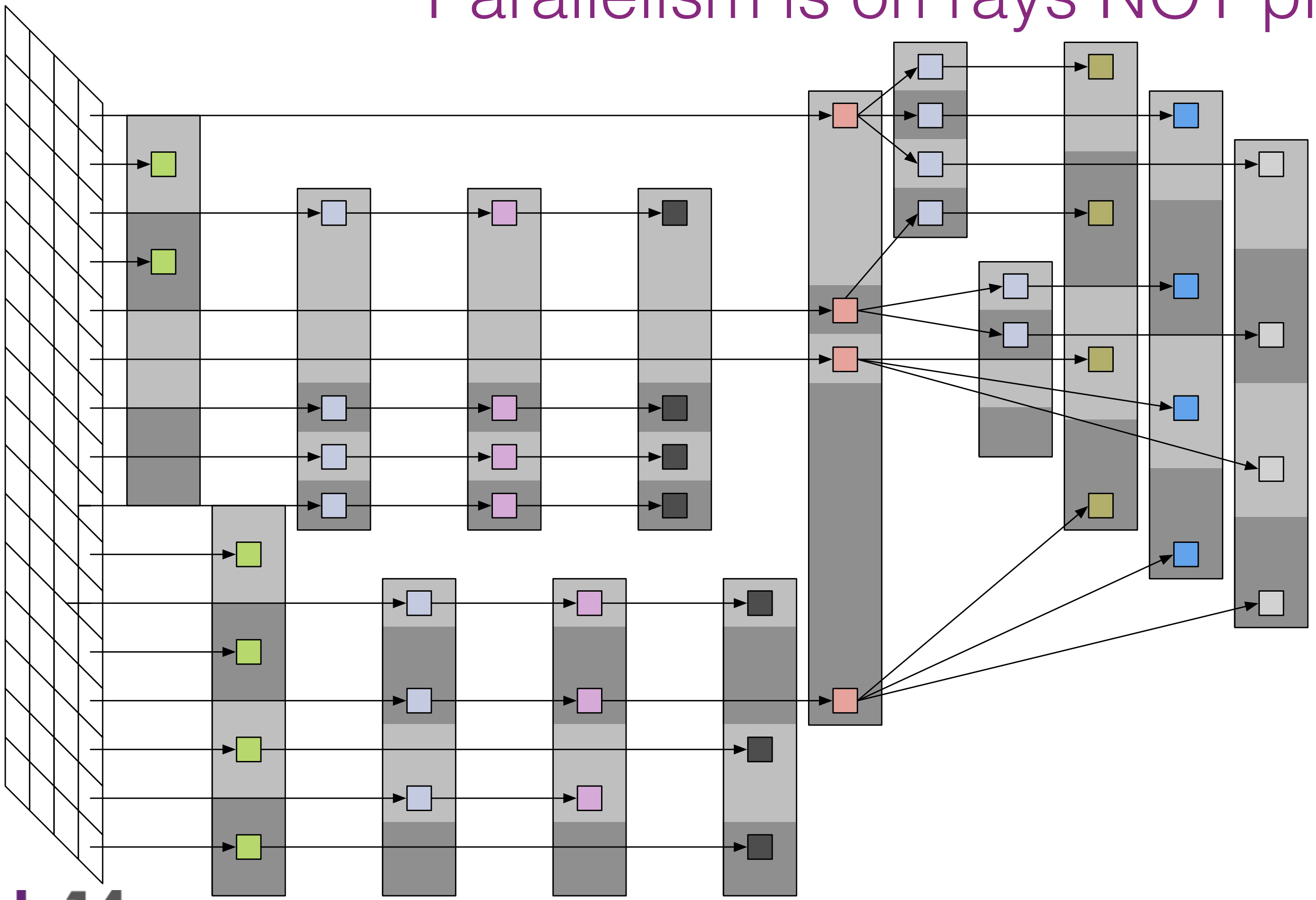
Parallelism is on rays NOT pixels





(In this example, ALU width is 4 to make the diagram smaller)

Parallelism is on rays NOT pixels



idc14

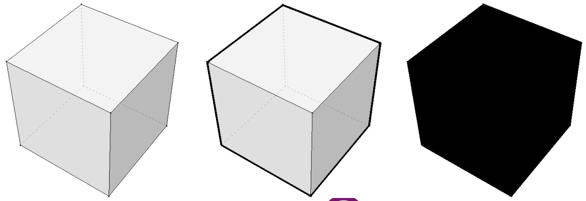
Imagination

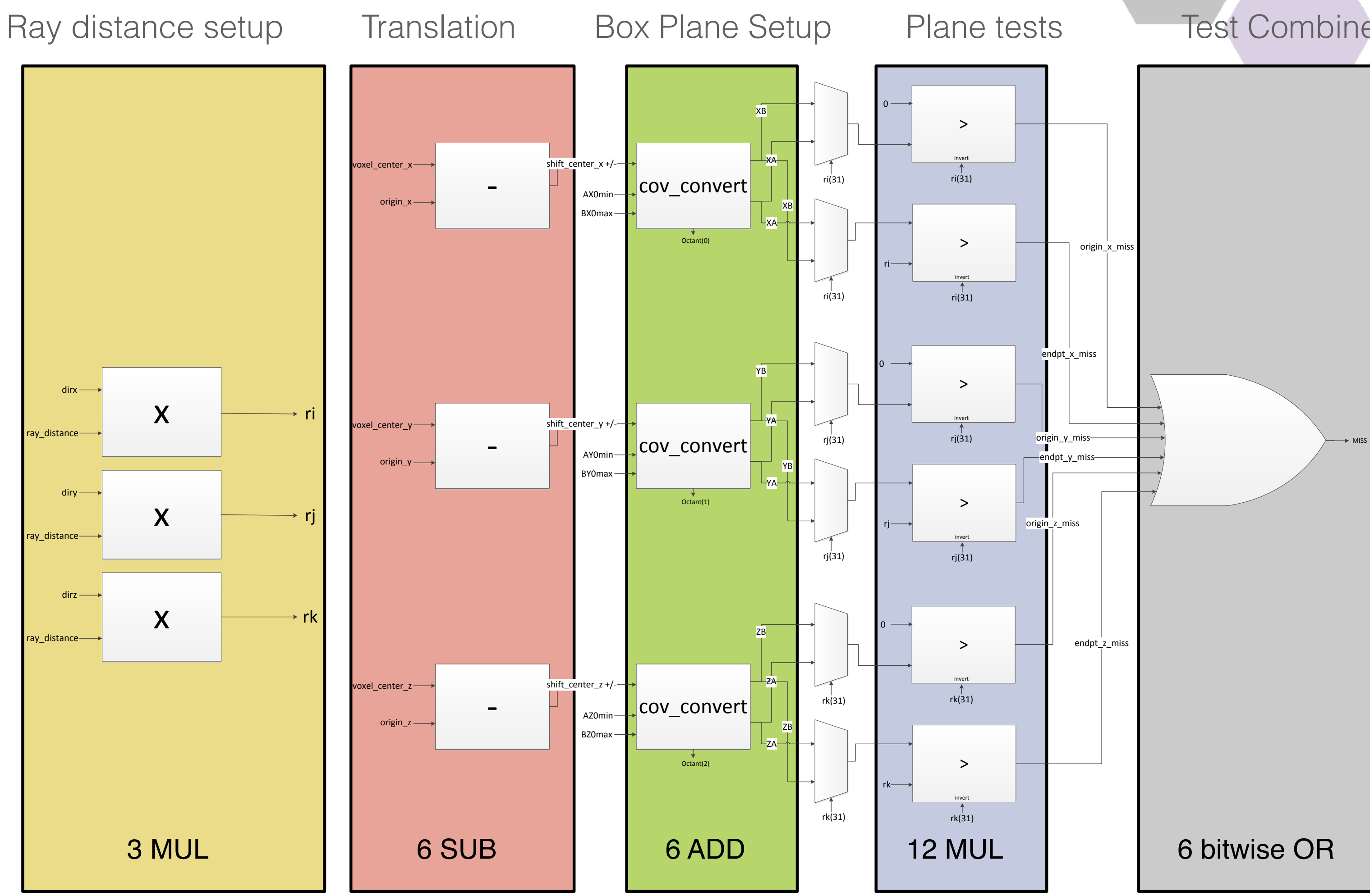
Relief: Quick ray emission demo

Intersection Processor Array
or
"Who needs Fixed Function?"

Ray:AABB Test

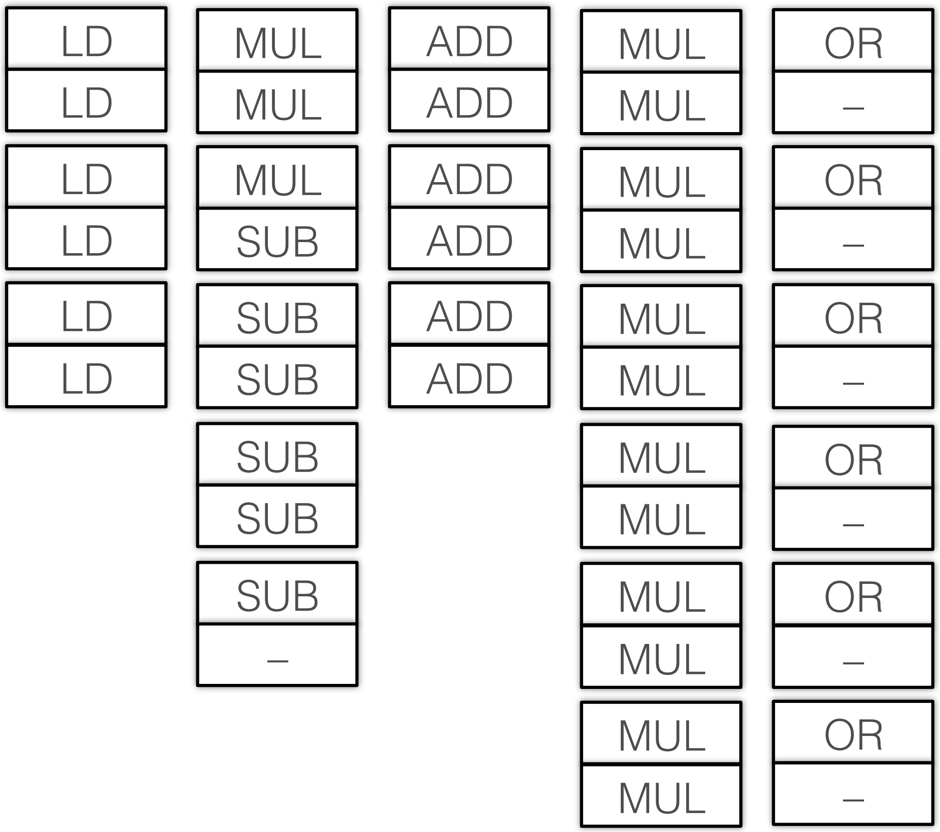
- “Fast Ray-Axis Aligned Bounding Box Overlap Tests with Plucker Coordinates.” – Jeffrey Mahovsky and Brian Wyvill
- 6 lines form the silhouette of the AABB
- 6 planes from the ray origin and each edge vector
- Dot product of plane normal and ray direction vector
- 6 signs must match and be negative.




Ray distance setup
Translation
Box Plane Setup
Plane tests
Test Combine
dirx
ray_distance
diry
ray_distance
dirz
ray_distance
X
X
X
ri
rj
rk
voxel_center_x
origin_x
voxel_center_y
origin_y
voxel_center_z
origin_z
-
-
-
shift_center_x +/-
AX0min
BX0max
shift_center_y +/-
AY0min
BY0max
shift_center_z +/-
AZ0min
BZ0max
cov_convert
cov_convert
cov_convert
Octant(0)
Octant(1)
Octant(2)
XB
XA
YB
YA
ZB
ZA
ri(31)
rj(31)
rk(31)
>
invert
origin_x_miss
endpt_x_miss
origin_y_miss
endpt_y_miss
origin_z_miss
endpt_z_miss
MISS
3 MUL
6 SUB
6 ADD
12 MUL
6 bitwise OR

Hit
or
Miss

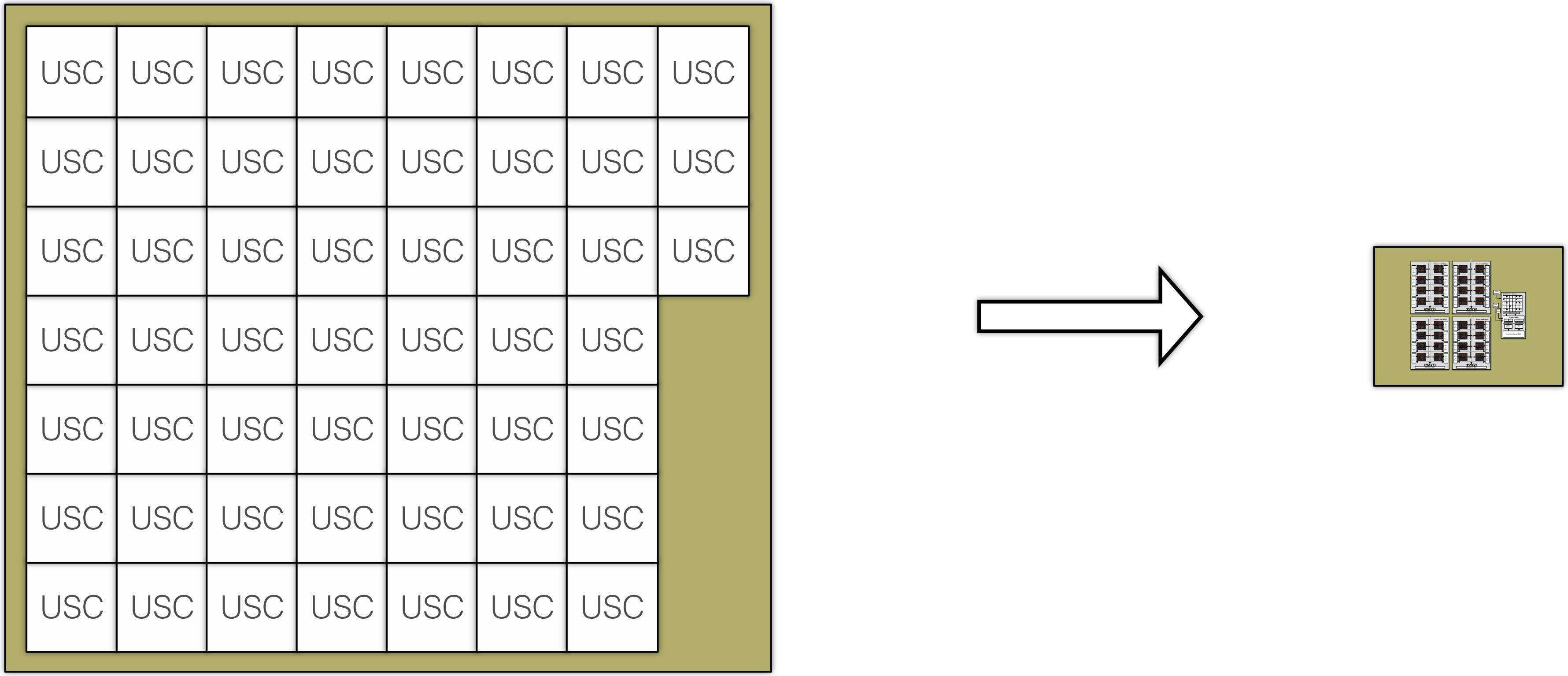
USC instruction group packing



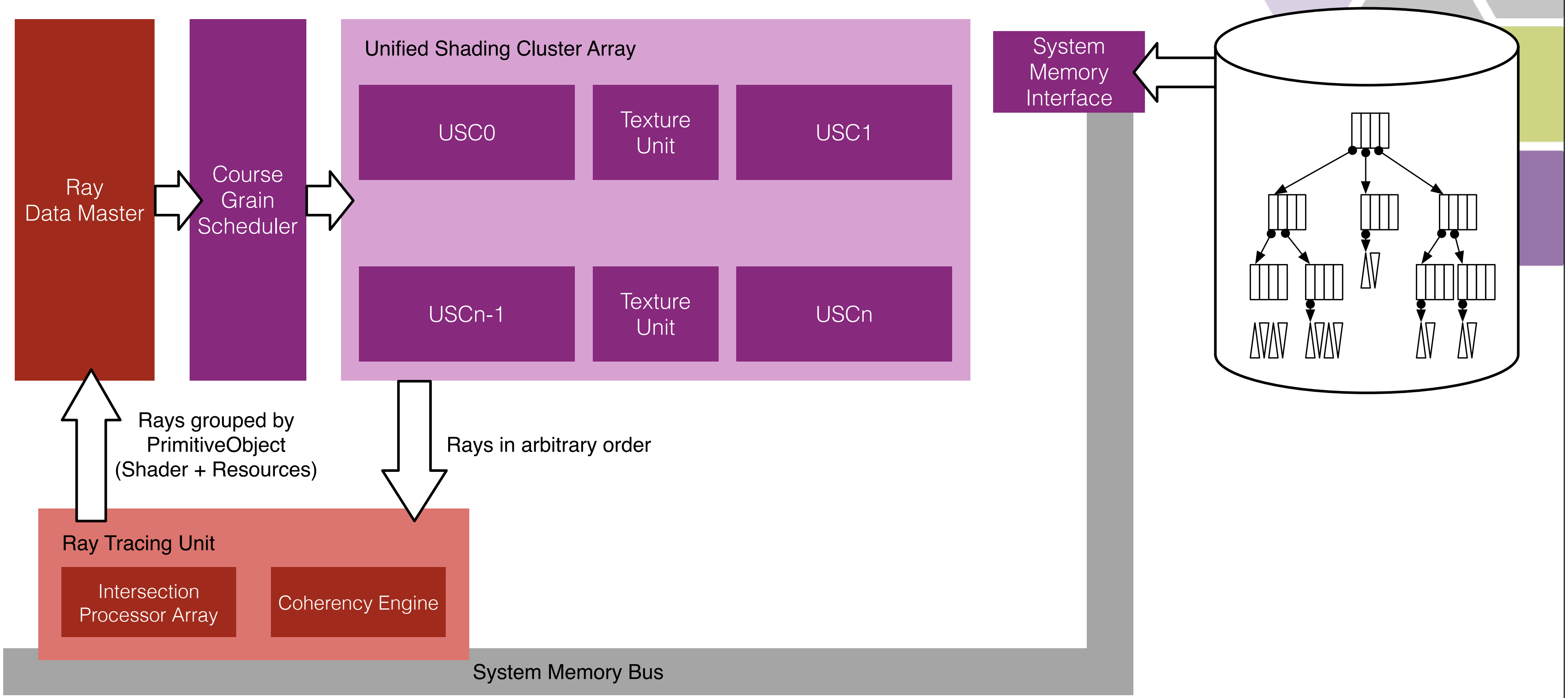
26 Instructions

(32 if using compressed data formats)

44x less area for this function



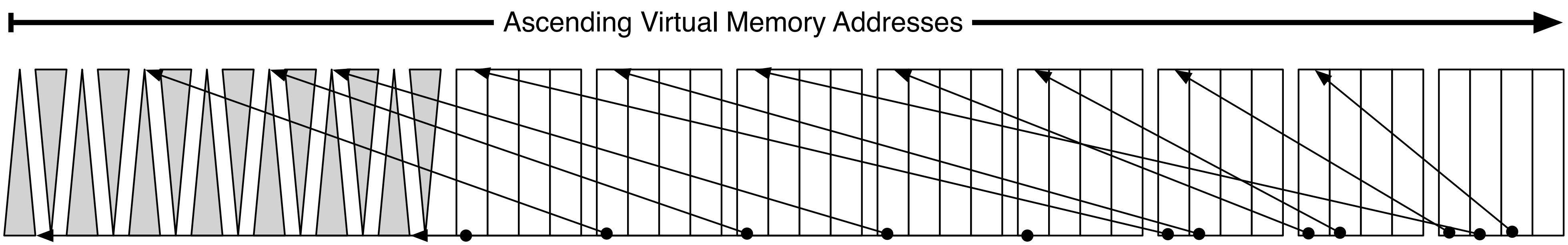
The Ray Tracing Unit and Coherence Engine


Unified Shading Cluster Array
USC0
Texture Unit
USC1
USCn-1
Texture Unit
USCn
Ray Data Master
Course Grain Scheduler
System Memory Interface
Rays grouped by PrimitiveObject (Shader + Resources)
Rays in arbitrary order
Ray Tracing Unit
Intersection Processor Array
Coherency Engine
System Memory Bus

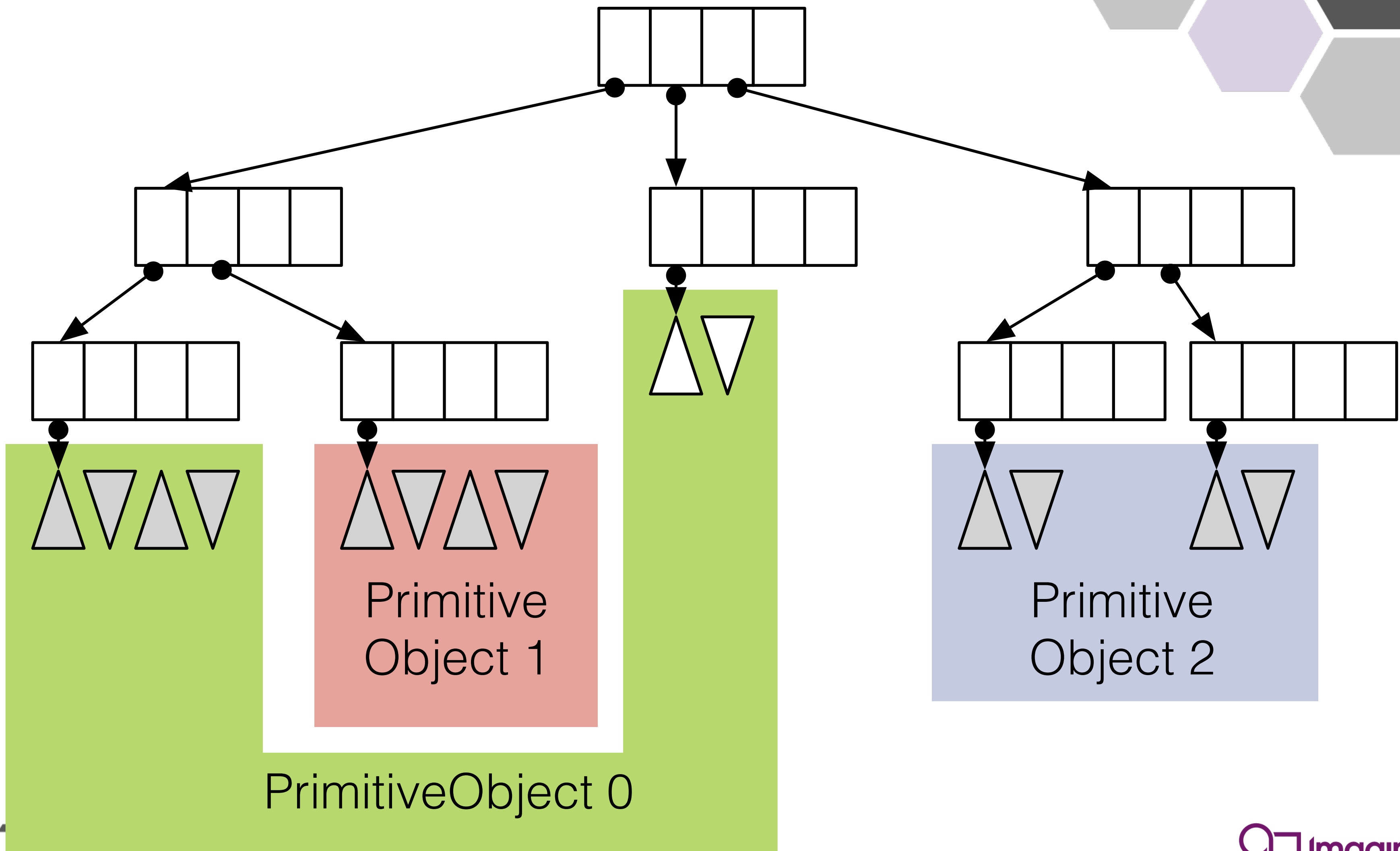
AABB Blocks

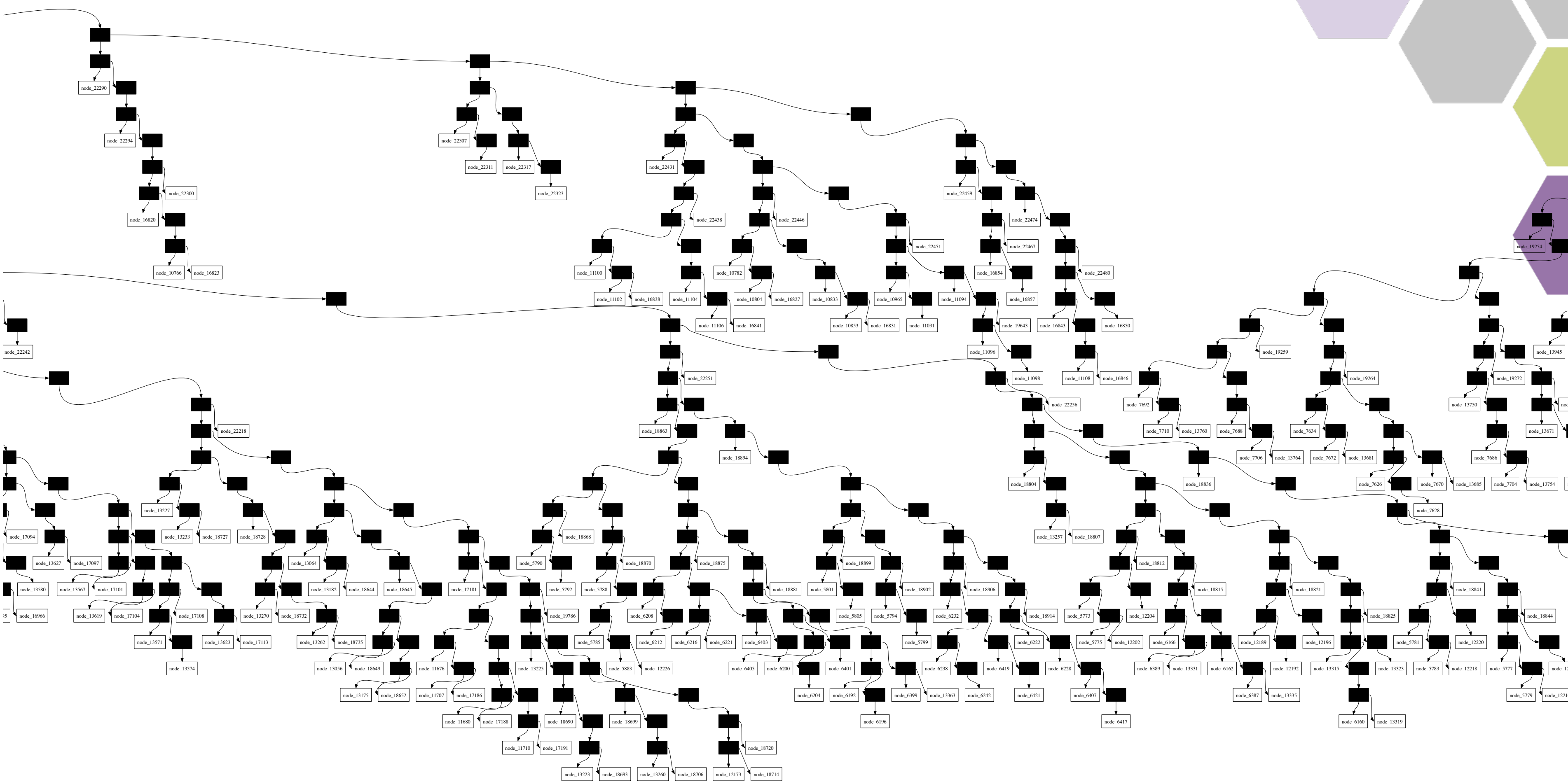
Vertex Blocks

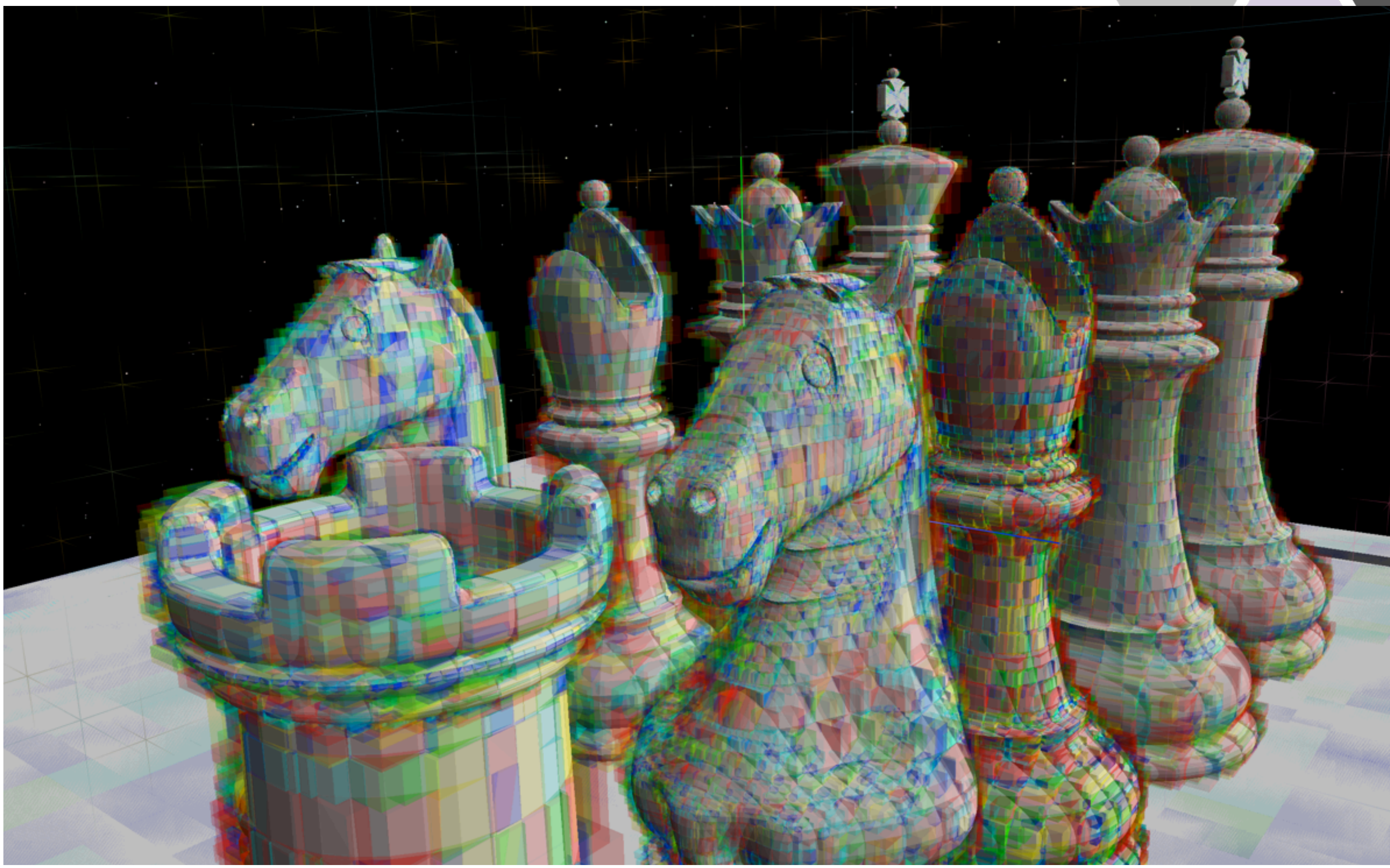
Varyings

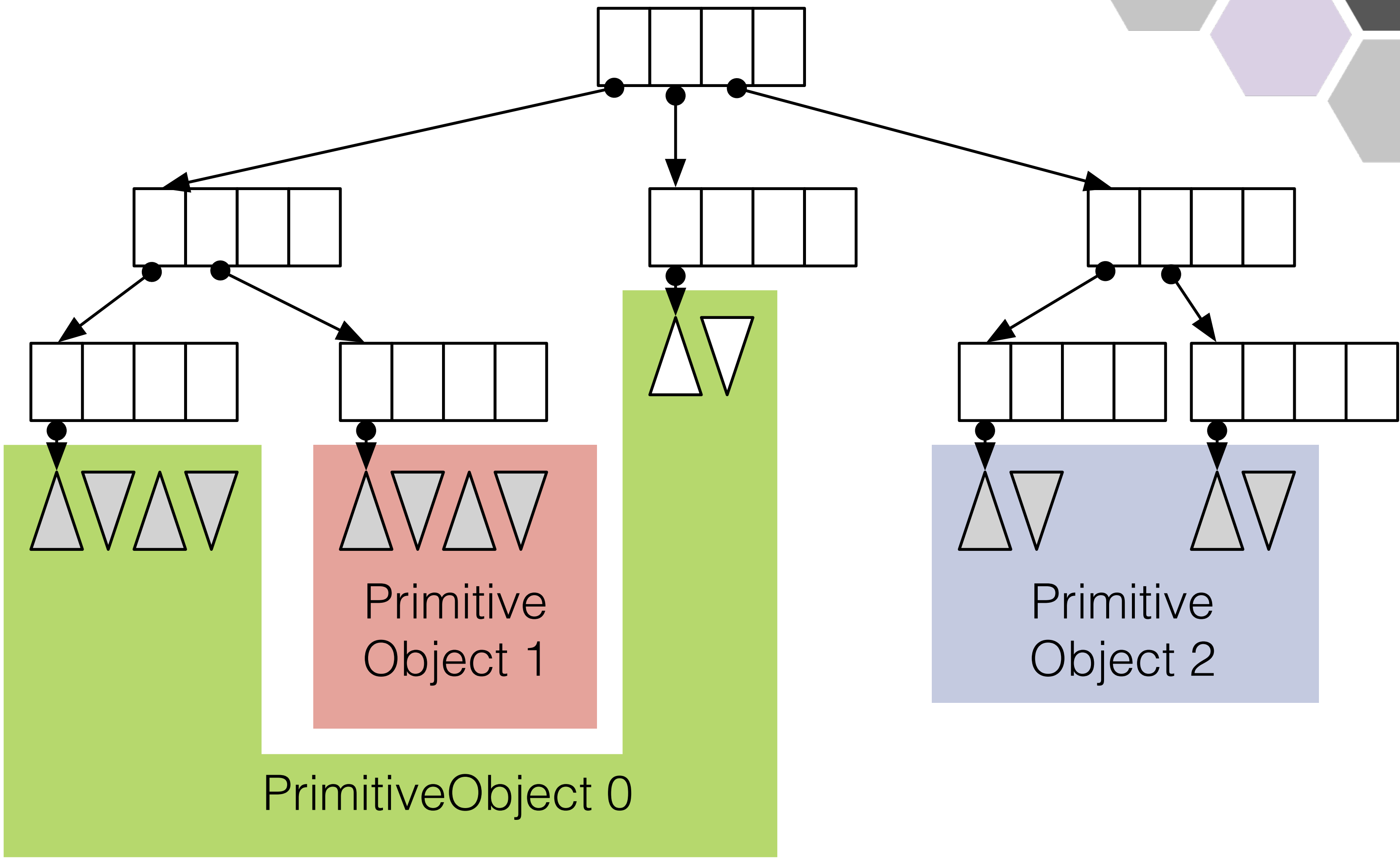


(around 100Mbytes for 1M triangles including varyings)


Primitive Object 1
Primitive Object 2
PrimitiveObject 0



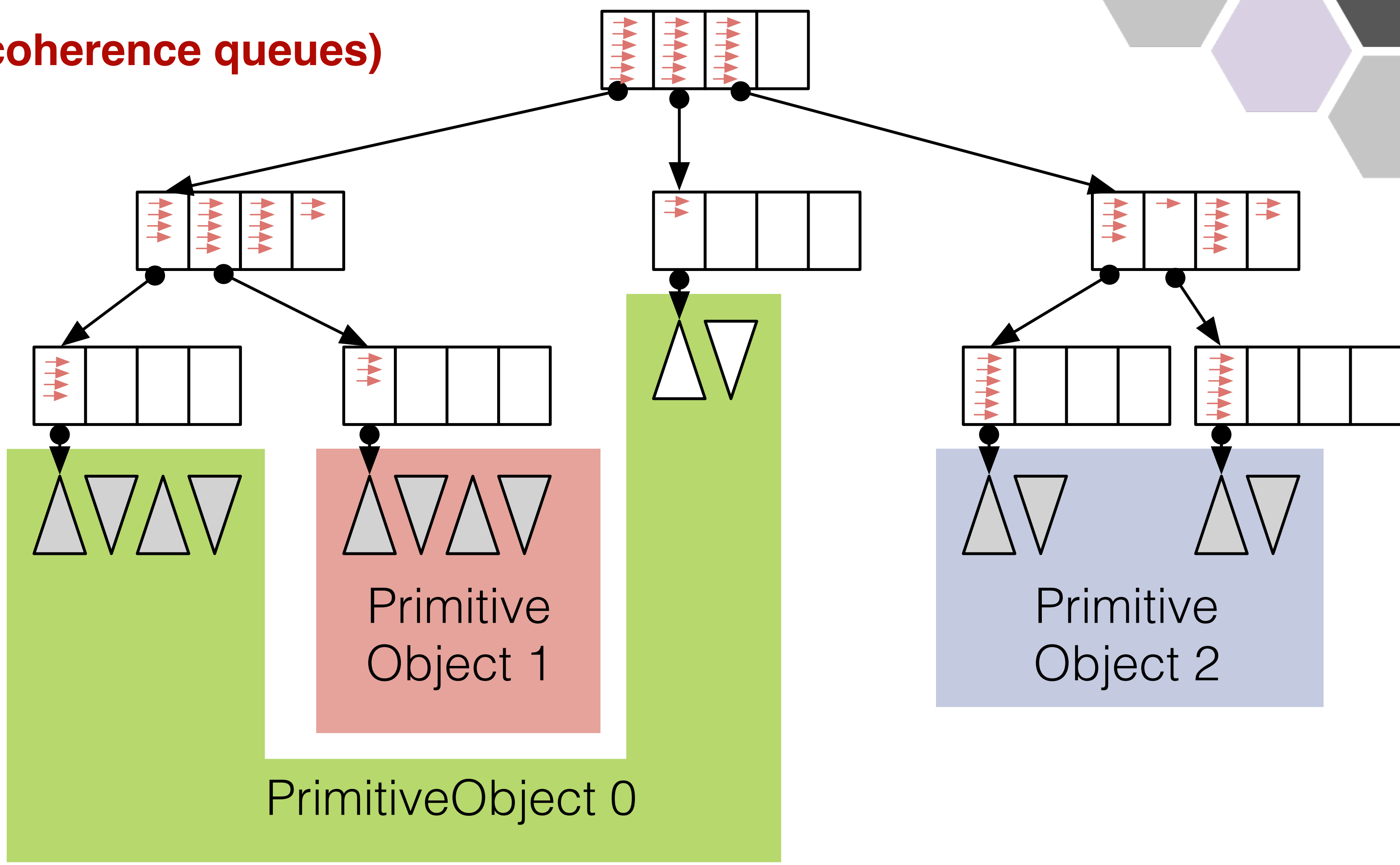




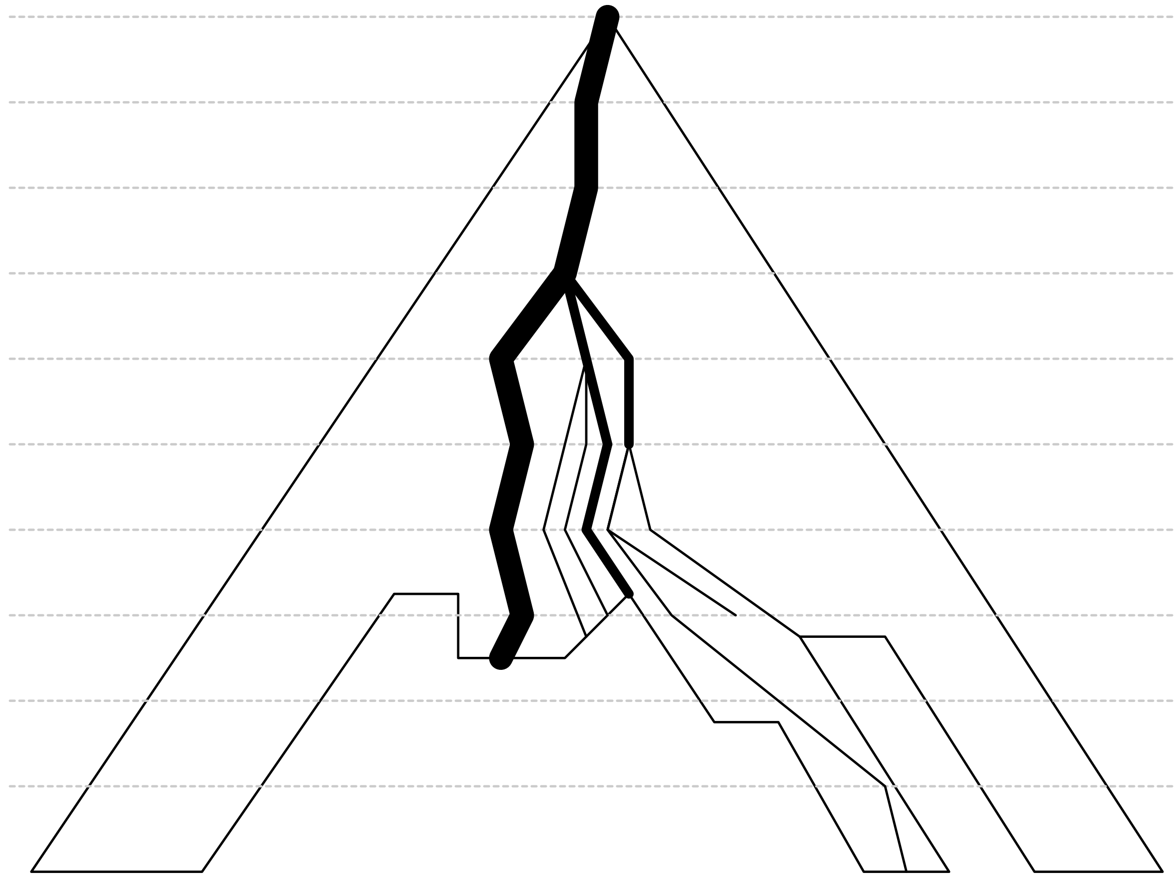
idc14

Imagination

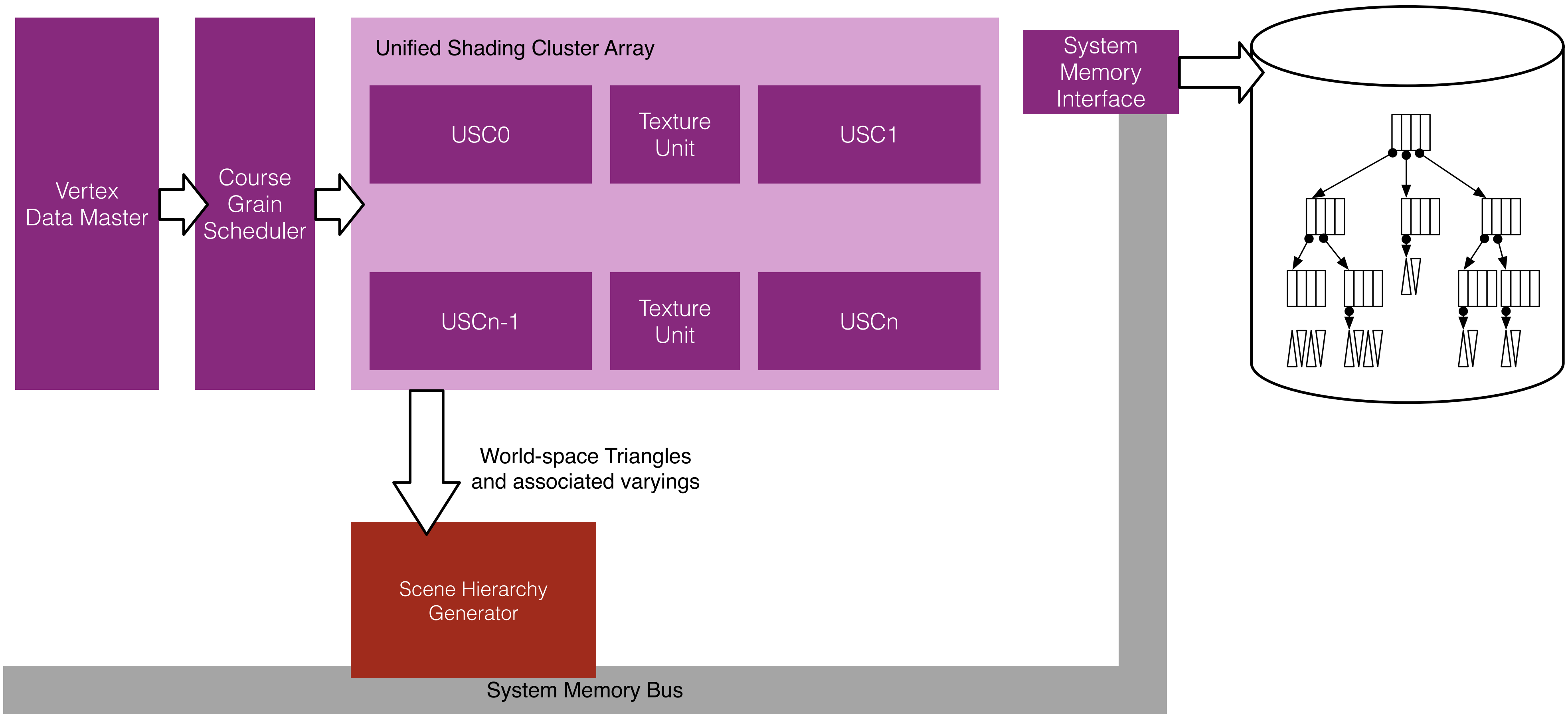
(coherence queues)



Automatically finds coherence paths



The Scene Hierarchy Generator


Vertex
Data Master
Course
Grain
Scheduler
Unified Shading Cluster Array
USC0
Texture
Unit
USC1
USCn-1
Texture
Unit
USCn
System
Memory
Interface
World-space Triangles
and associated varyings
Scene Hierarchy
Generator
System Memory Bus

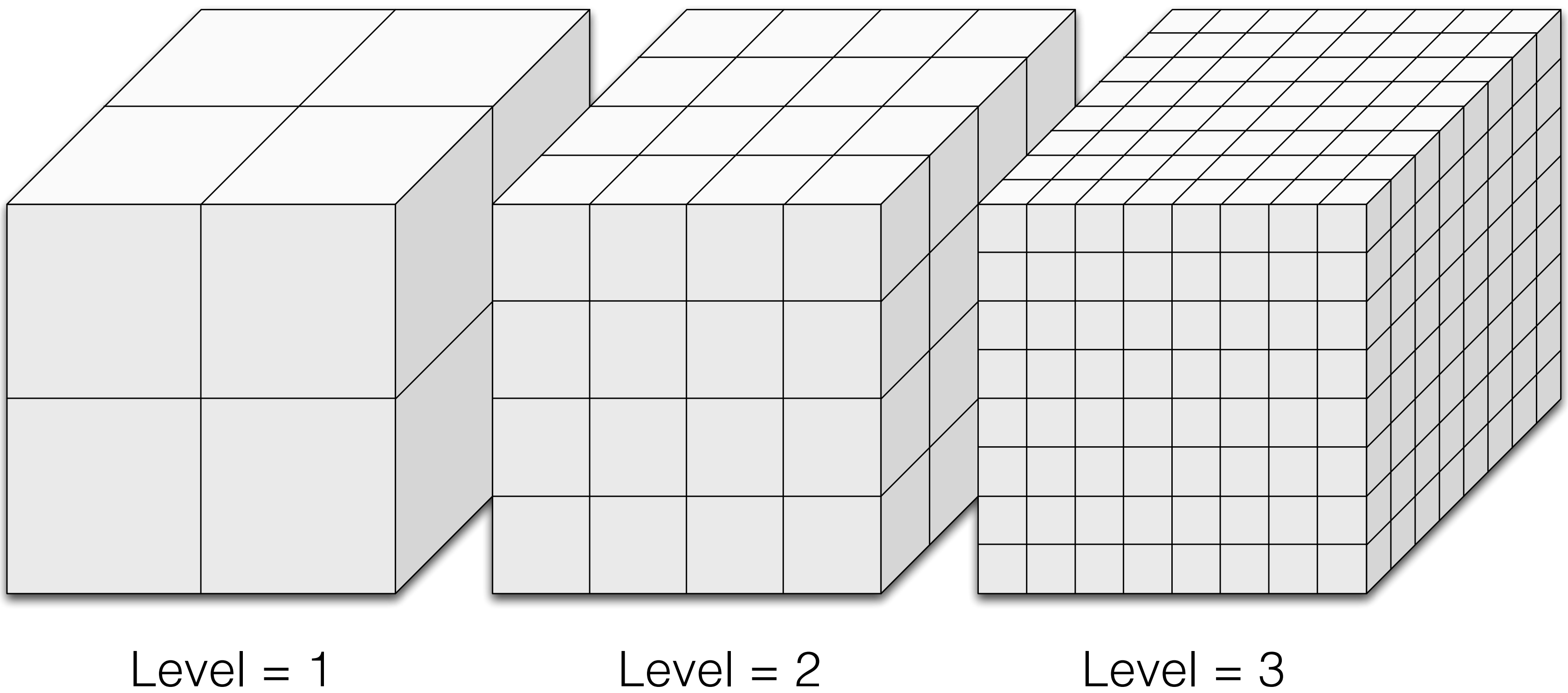
Limitations

- Scene is represented by triangles – same as today
- BVH is in a defined format optimised for construction and traversal
- Triangle order must generally follow a spatially coherent flow
- An approximate scene scale estimation is needed
- Geometry shaders are not inline with the ray tracing pipeline

Strengths

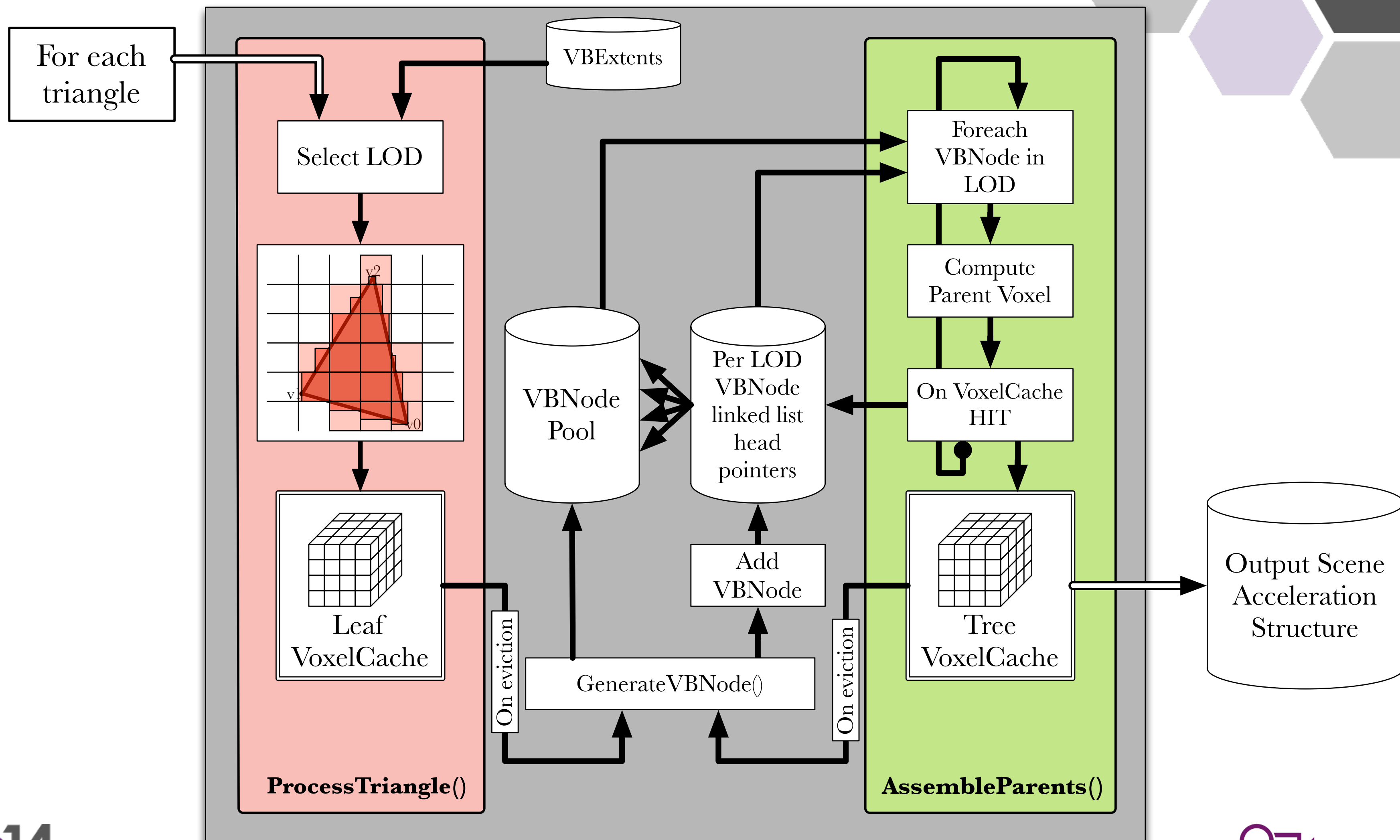
- Shading cluster workload is no higher than a vertex shader
- Only needs to process geometry that actually moved in world space
- Unique algorithm constrains working set to internal registers only
- Single pass operation: in-line with vertex shader execution
- Handles the “long skinny triangles” problem well
- Streaming writes to external memory
- Losslessly compressed output formats due to build algorithm
- Compact logic

Built on sparse log2 oct-tree scaffolding



idc14

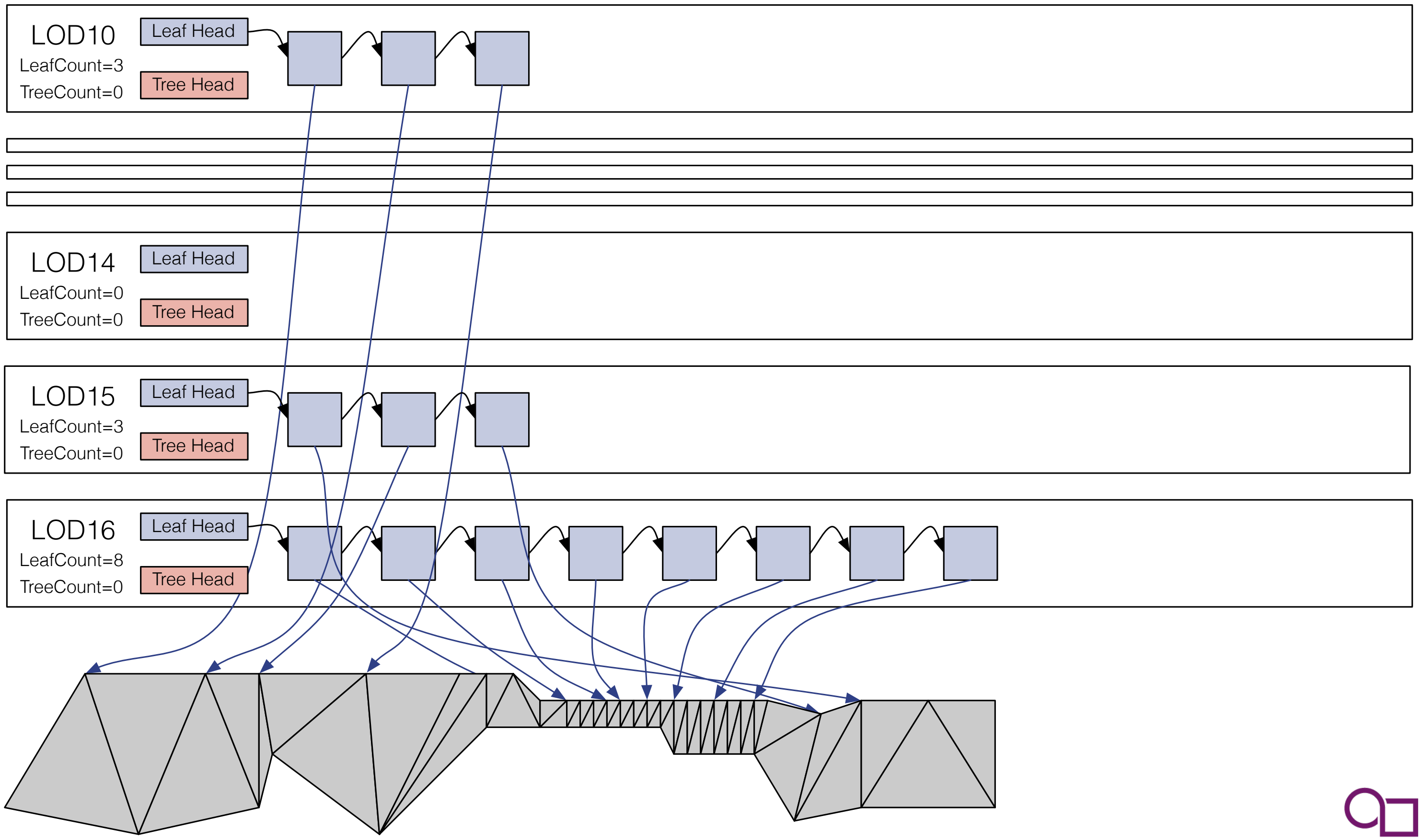
Imagination



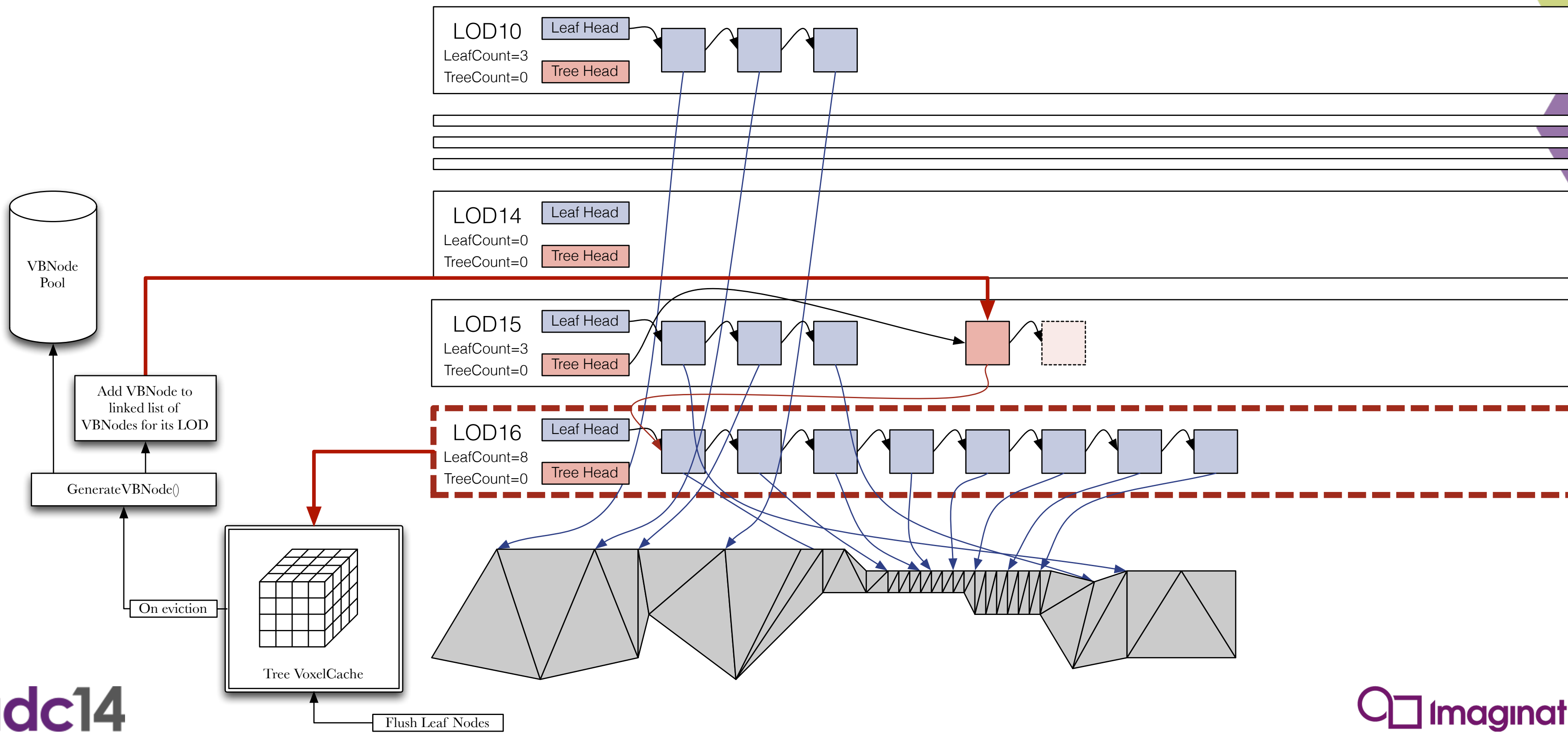
idc14

Imagination

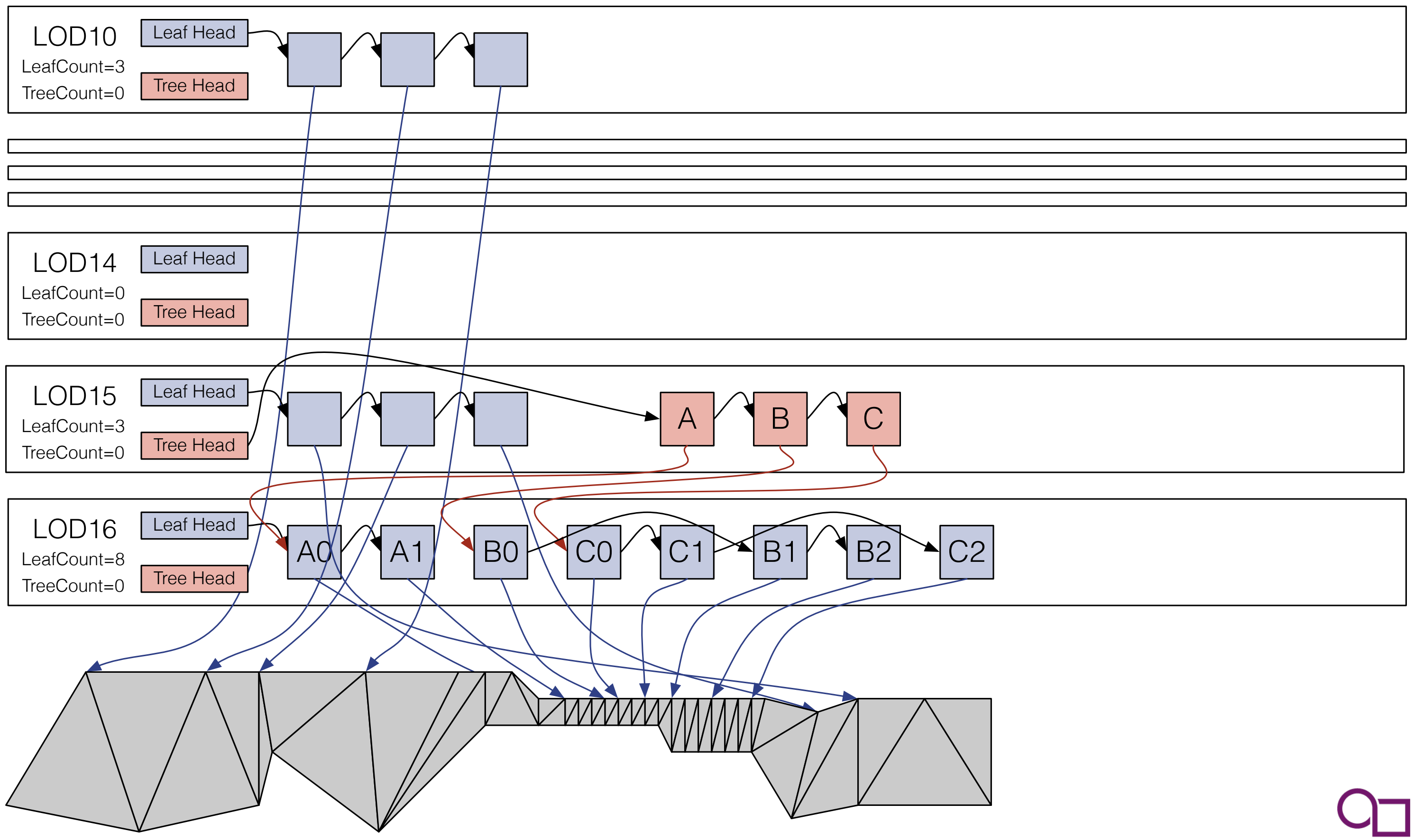
After some triangles...



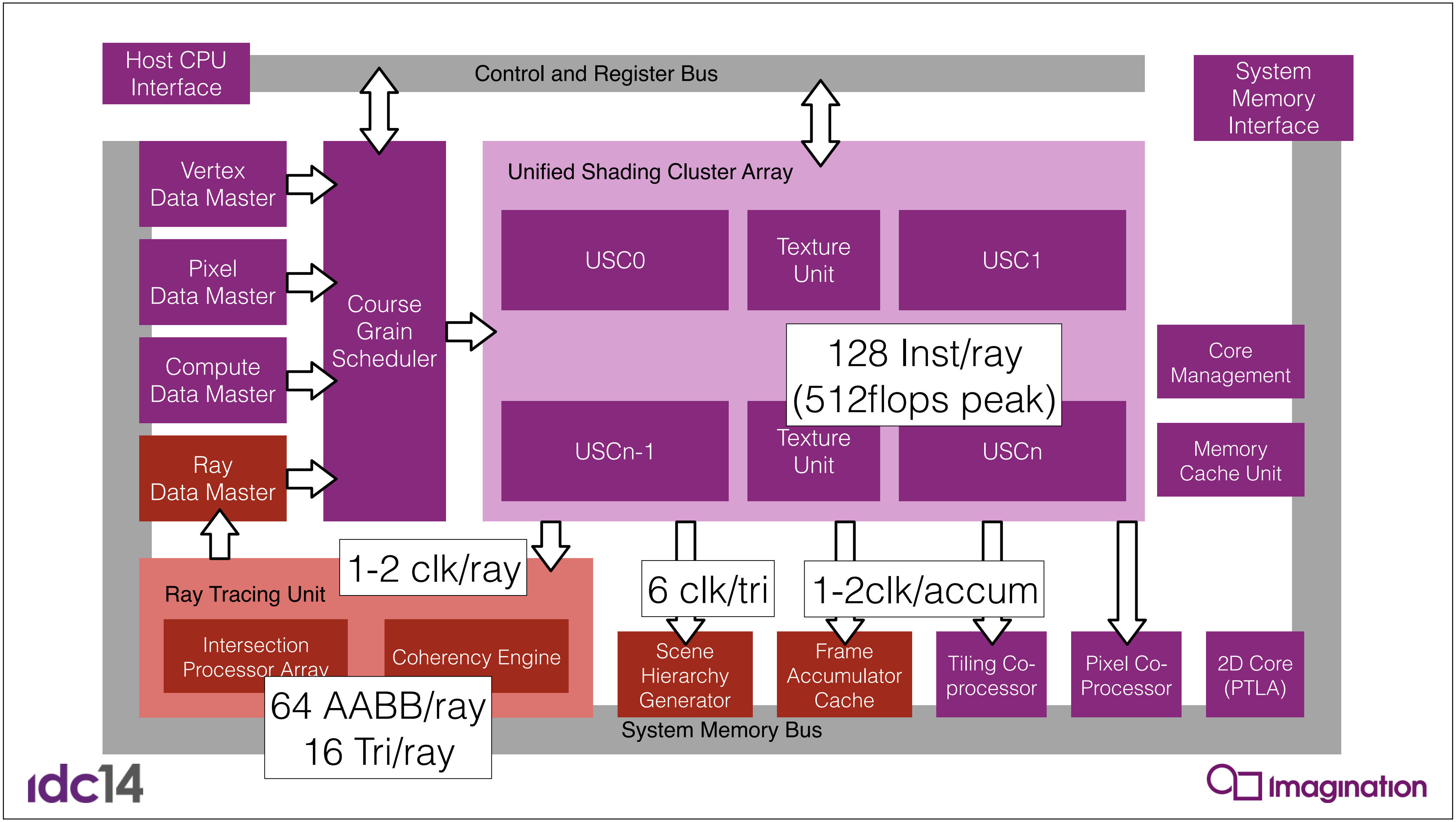
Assembling parents...



After parents for one level have been assembled...



Performance Expectations


Host CPU Interface
Control and Register Bus
System Memory Interface
Vertex Data Master
Pixel Data Master
Compute Data Master
Ray Data Master
Course Grain Scheduler
Unified Shading Cluster Array
USC0
Texture Unit
USC1
128 Inst/ray (512flops peak)
USCn-1
Texture Unit
USCn
Core Management
Memory Cache Unit
Ray Tracing Unit
1-2 clk/ray
Intersection Processor Array
Coherency Engine
64 AABB/ray 16 Tri/ray
6 clk/tri
1-2clk/accum
Scene Hierarchy Generator
Frame Accumulator Cache
Tiling Co-processor
Pixel Co-Processor
2D Core (PTLA)
System Memory Bus
idc14
Imagination

Get early access to the programming concepts at:
http://tinyurl.com/9ddlsv2

Talk immediately after this on Hybrid rendering

See the demos at Imagination Booth #402 South Hall

QA

Thank you