AN EVOLUTION OF MOBILE GRAPHICS

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DISCLAIMER

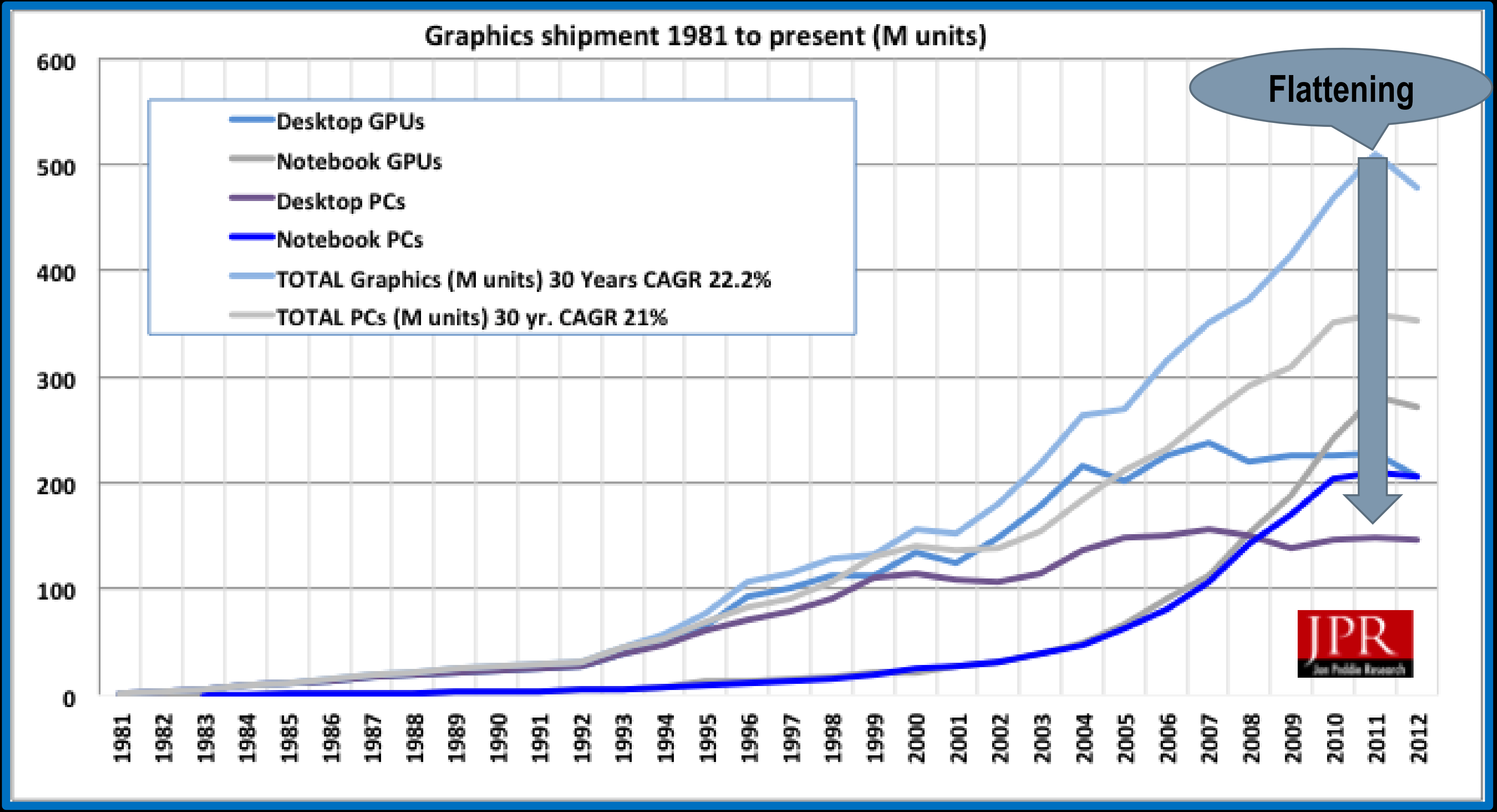
- The views herein are my own
- They do not represent Samsung's vision nor product plans

- The Mobile Market
- Review of GPU Tech
- GPU Efficiency
- User Experience
- Tech Challenges
- Summary

The Rise of the Mobile GPU & Connectivity

A NEW WORLD COMING?

DISCRETE GPU MARKET



MOBILE GPU MARKET

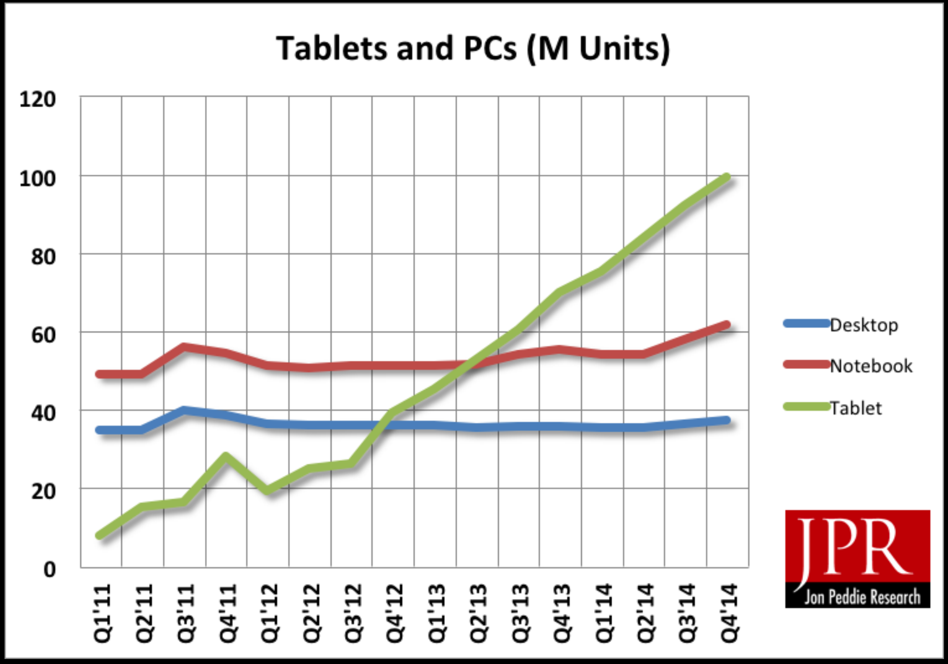
- In 2012, an estimated 800+ million mobile GPUs shipped
    - ~123M tablets
    - ~712M smart phones
- Will easily exceed 1B in the coming years

- **Trend:**
    - **Discrete GPU relatively flat**
    - **Mobile is growing rapidly**

“Phablets”

Smart Phones

Tablets



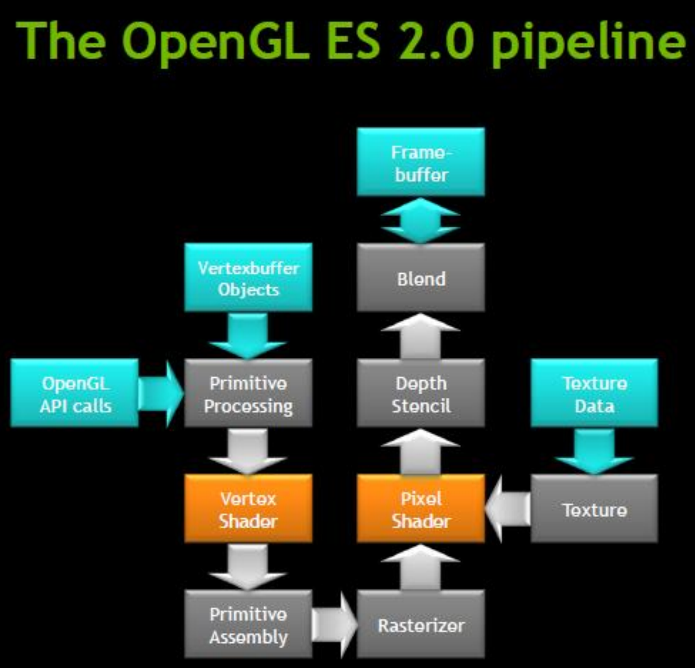
WW INTERNET TRAFFIC

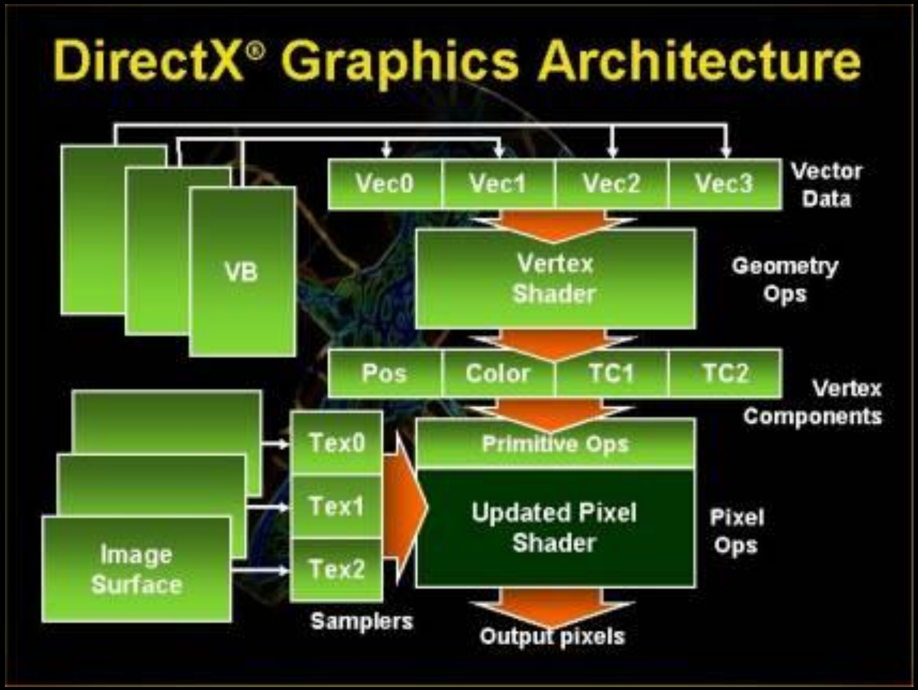
- Source: Cisco VNI
- Internet traffic growth rate is staggering
  - **2012** total traffic is **13.7 GB per person per month**
  - **2012** smart phone traffic at **0.342 GB per person per month**
  - **2017** smart phone traffic expected at **2.7 GB per person per month**

Year	IP Traffic (TB/sec)	growth rate	Mobile INET Traffic (TB/sec)
2005	0.9		0.00
2006	1.5	65%	0.00
2007	2.5	61%	0.01
2008	3.8	54%	0.01
2009	5.6	45%	0.04
2010	7.8	40%	0.10
2011	10.6	36%	0.23
2012	12.4	17%	0.34

WHERE ARE WE HEADED?...

- Enormous quantity of GPUs
- Large amount of interconnectivity
- Better I/O





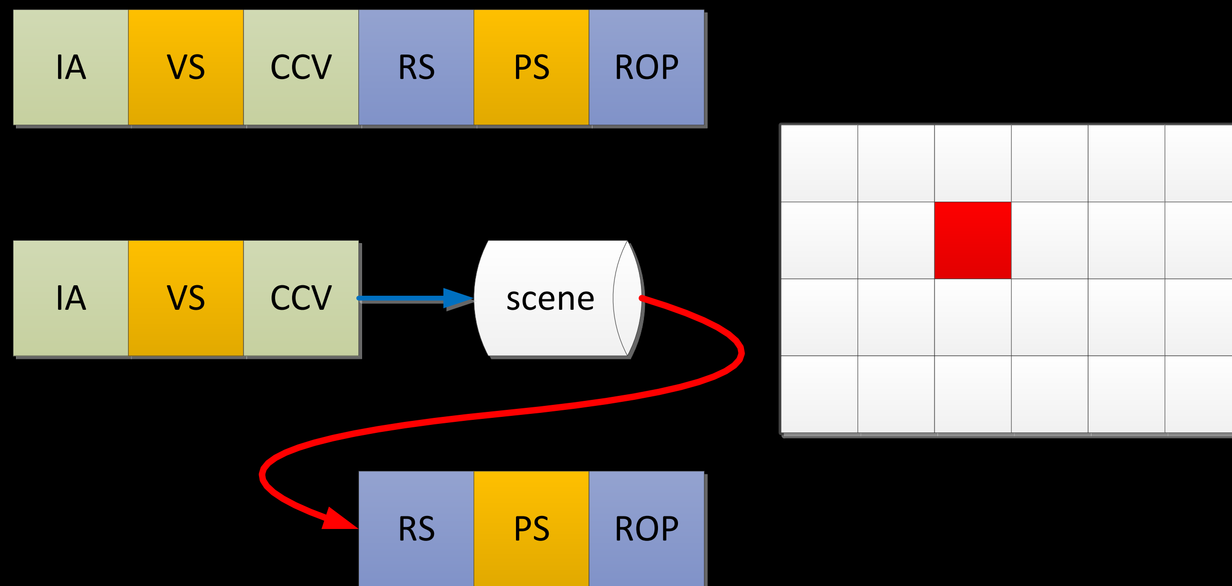
GPU Pipelines

A BRIEF REVIEW OF GPU TECH

MOBILE GPU PIPELINE ARCHITECTURES

Tile-based immediate mode rendering (TBIMR)

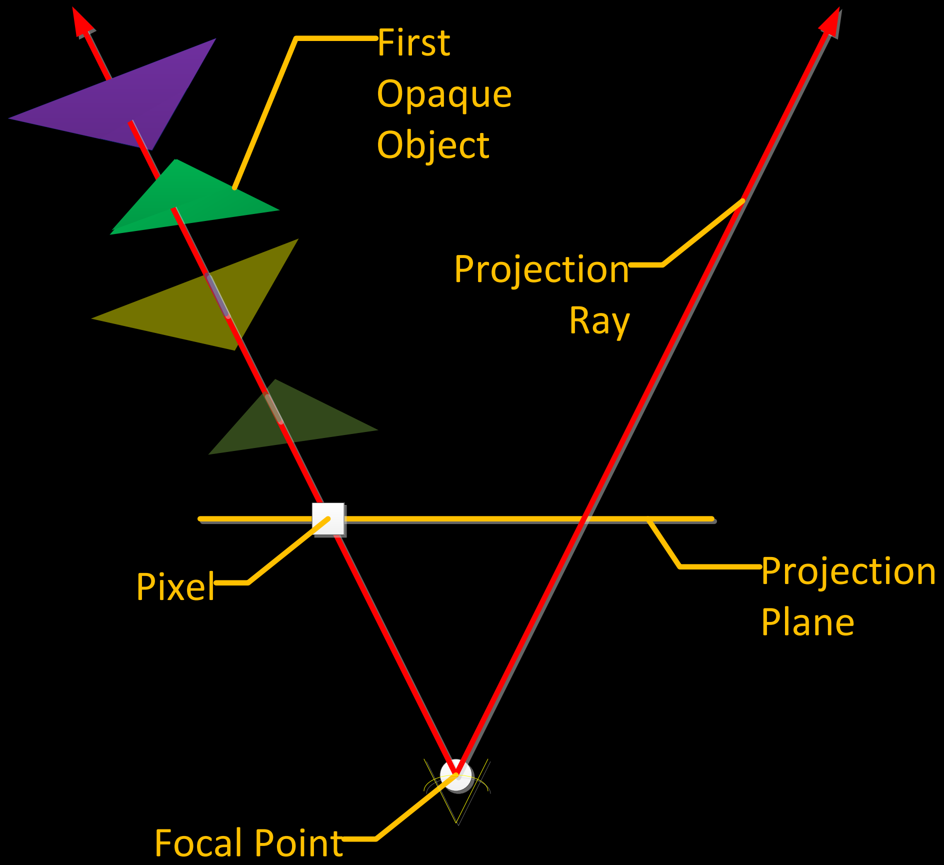
Tile-based deferred rendering (TBDR)



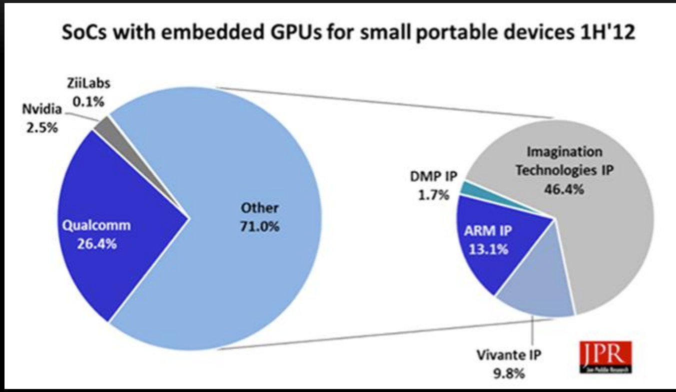
IA = input assembler
VS = vertex shader
CCV = cull, clip, viewport transform
RS = rasterization, setup
PS = pixel shader
ROP = raster operations (blend)

TBDR W/ HSR

- HSR = *hidden surface removal*
  - Sort all objects across each projection ray
    - Use tiling to reduce data set size
  - Only nearest opaque and closer transparent objects need to be drawn
  - Remaining fragments can be killed => not drawn



MOBILE GPU LANDSCAPE



Company	Product	Pipeline	Notes
ARM	Mali	TBIMR	Unified shader, 2-4 math pipes per core
Imagination	PowerVR	TBDR/HSR	Latest is Rogue (S6). Unified shader. DX11 support
Qualcomm	Adreno	FlexRender	Unified shader. "FlexRender" = automatic switching between direct render (IMR) and tile-based deferred rendering (TBDR).
NVIDIA	Tegra	TBDR & TBIMR	Evolution: • Tegra 1/2/3/4: non-unified TBDR architecture • Logan: Kepler-based GPU, TBIMR • Parker: Maxwell-based GPU, TBIMR
Vivante	ScalarMorphic	IMR	Unified Shader.
Intel	Gen | Atom	IMR | PowerVR	Market leader in integrated graphics. Atom-based devices using Imagination PowerVR
AMD	Radeon	IMR	Hondo/Temash pipes.

Efficiency

A PATH TO A BETTER MOBILE GPU? [PART 1]

WHAT IS IMPORTANT?

- More with less
- Better user experience

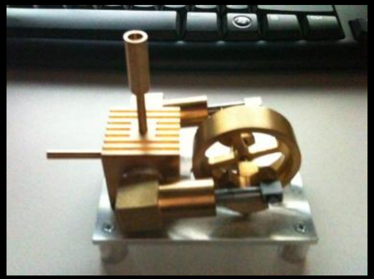
POWER EFFICIENCY

- Performance = power efficiency
- Two types of efficiency:
  - "perf@watts":

    The ability to deliver maximum performance

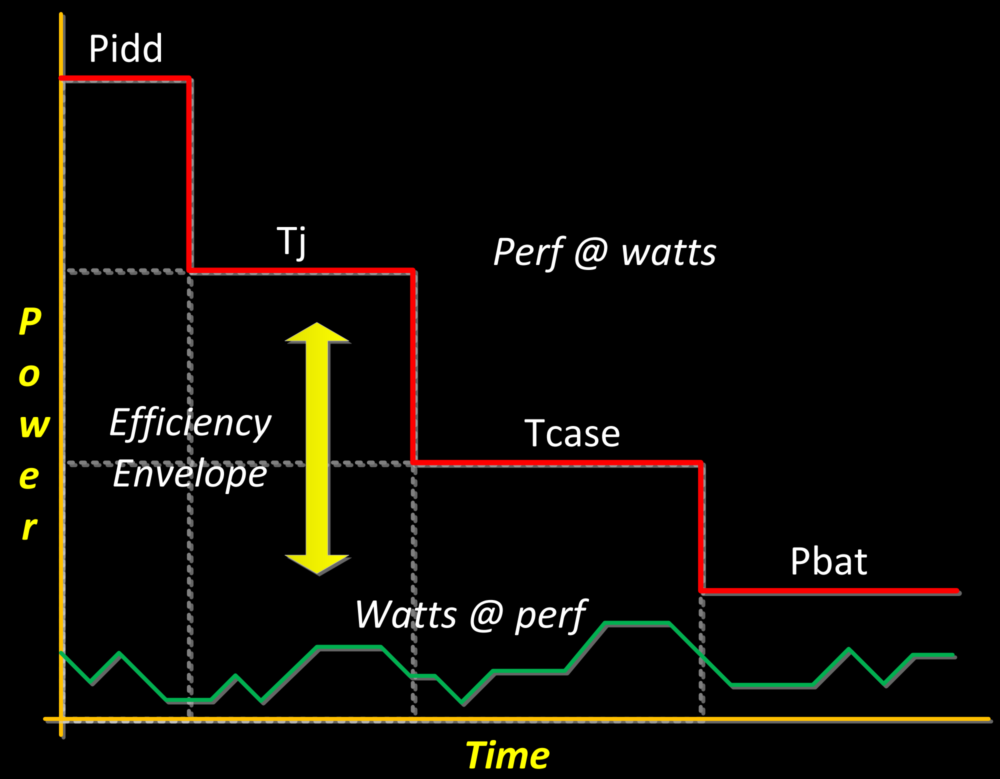
  - "watts@perf":

    The ability to deliver maximum battery life at a minimum required performance



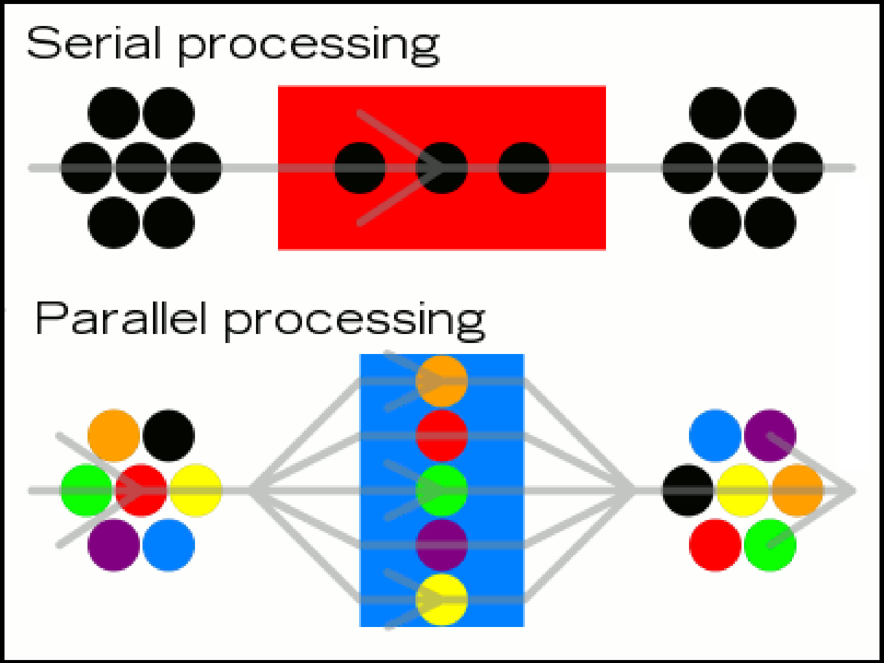
WHAT IS EFFICIENCY?

- Perf @ Watts
  - *Maximum performance at some power limit*
  - Limits:
    - electrical (Pidd)
    - die temp (Tj)
    - skin temp (Tcase)
    - battery life (Pbat)
- Watts @ Perf
  - *Minimum power at constant performance*
  - Example: deliver 60 frames/sec at lowest power



PARALLELISM

- Parallel vs. Sequential
  - Parallel → independence
  - Sequential → dependence
- Three fundamental forms of parallelism
  - Spatial: executing operations between threads at the same time
  - Temporal: executing operations between threads at the same place
  - ILP: executing operations from within the same thread in parallel
- Fundamental differences between ILP-only machines and massive TLP-ILP machines
  - CPUs vs. GPUs



THROUGHPUT VS. LATENCY

- Throughput = rate at which operations complete
- Latency = time it takes to complete an operation or set of operations
- CPUs versus GPUs
  - In CPUs, the primary objective is low latency
  - In GPUs, the primary objective is high throughput
- CPUs versus GPUs
  - In an application suitable for CPUs, we assume a low degree of TLP
  - In an application suitable for GPUs, we assume a high degree of TLP

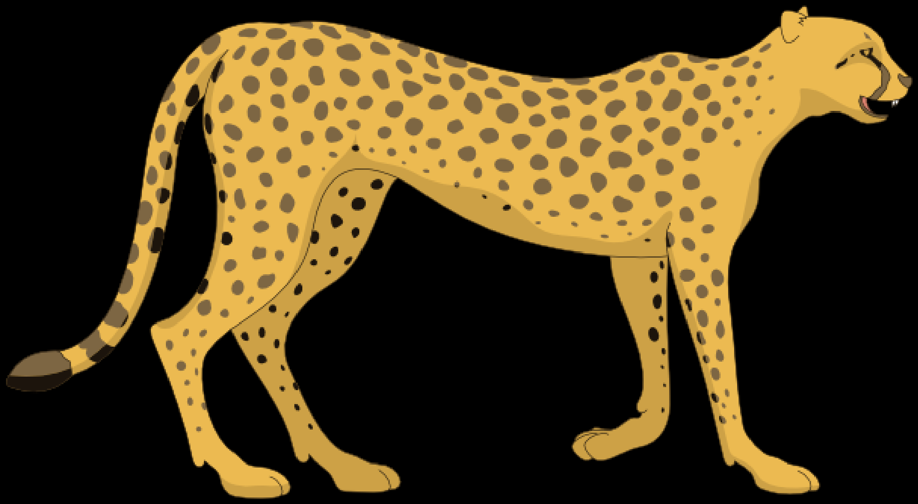
GPU PERFORMANCE

- Supply and demand:

$$\vec{S} \geq \lambda \vec{D}$$

("limiter equation")

- Lambda (λ) is throughput
- Supply examples:
  - FP BW (flops/clock)
  - Texture BW (quads/clock)
  - Memory BW (bytes/clock)
- Demand density examples:
  - FP ops per shader
  - Sample ops per shader



ENERGY REDUCTION TECHNIQUES

- Work Reduction
- Memory Avoidance
- Memory BW Reduction
- Memory Access Management

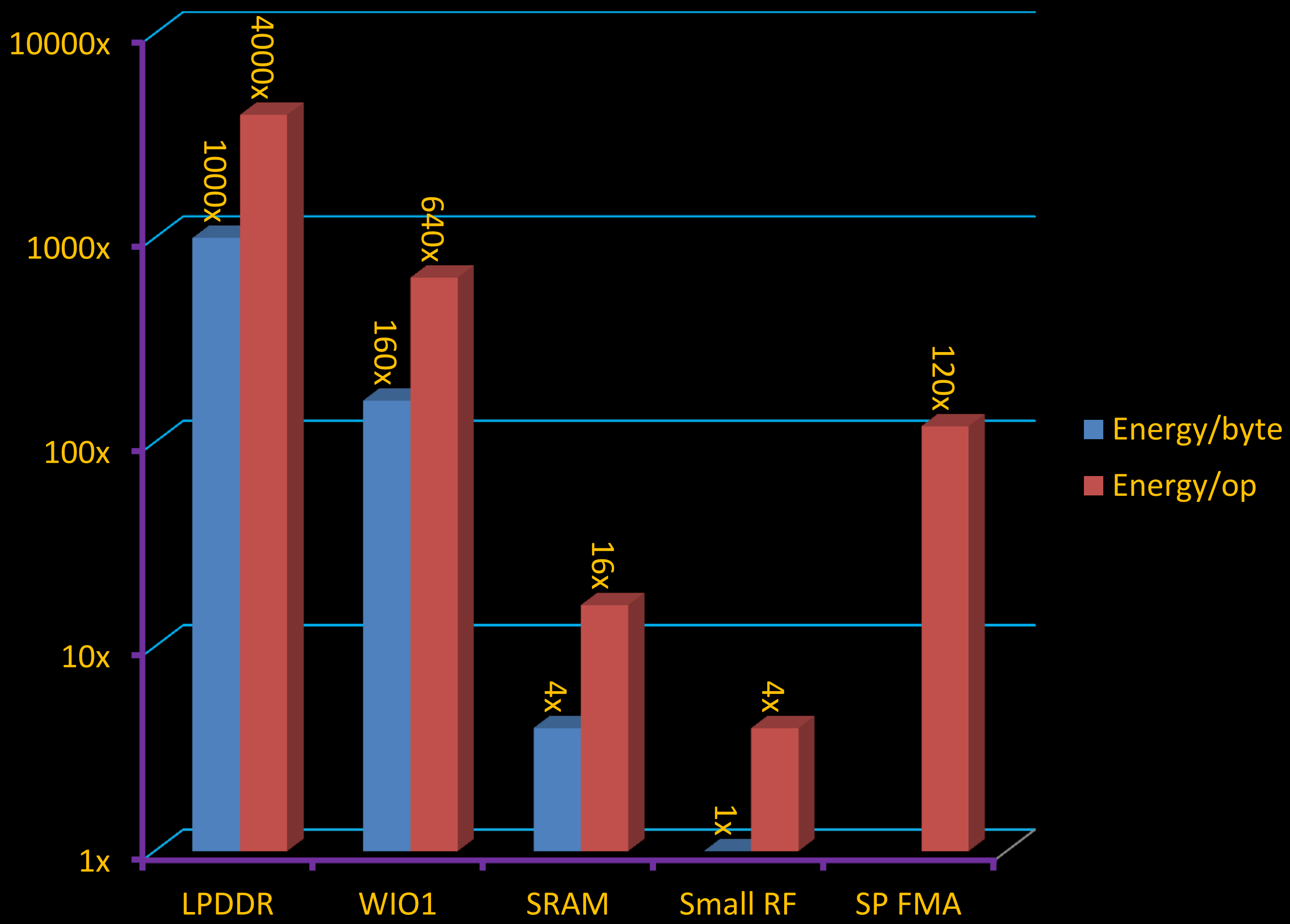
WORK REDUCTION

- Pixel shaders in ES games ~95% of the shader load
  - A pixel shader killed is raw power savings
  - HSR can kill 30-50% of the shader threads

- Geometry in DX11 a problem
  - Unigine Heaven ~10M Tri/frame

- Inter-frame work reduction?

RELATIVE ACCESS ENERGY COSTS



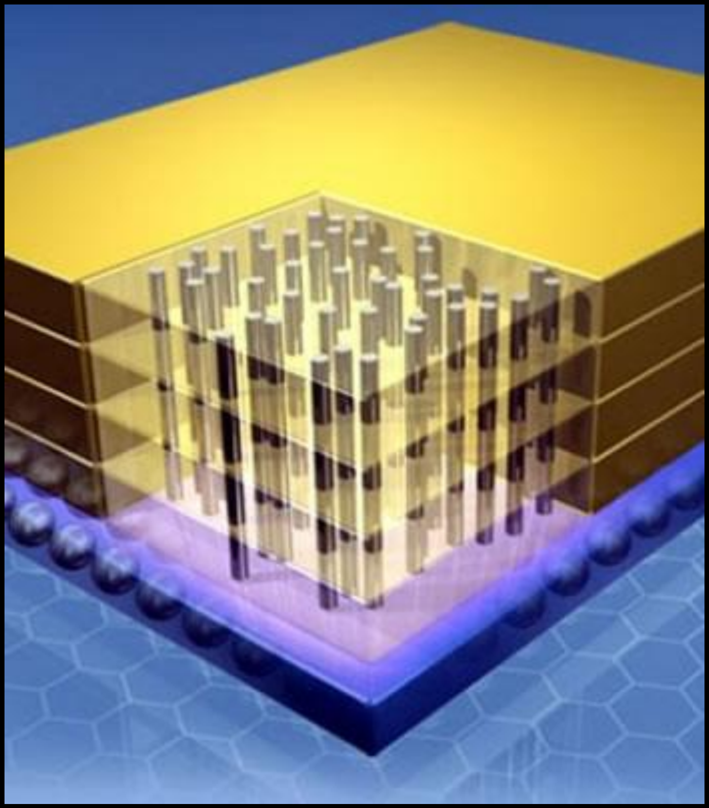
MEMORY AVOIDANCE

- Memory power a problem
  - LPDDR ~150 pJ/byte
    (150 mW @ 1 GB/sec)
  - WIO1 ~24 pJ/byte
    (24 mW @ 1 GB/sec)
  - On-chip SRAM ~0.6 pJ/byte
    (0.6 mW @ 1 GB/sec)

- Reduction in working set for non-essential traffic (i.e., not texture, attribute, command, or render target)
  - Rematerialize? (computation vs. BW)
  - Scheduling to reduce lifetimes?

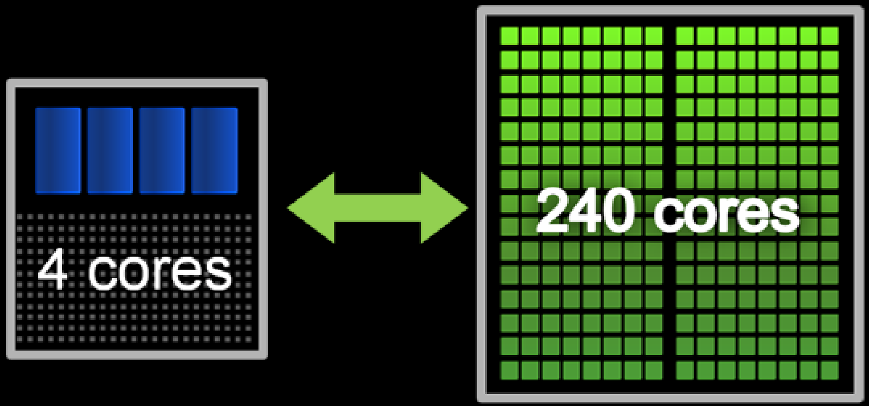
MEMORY BW REDUCTION

- Texture compression (RD)
  - Better compression?
  - Tessellation use of textures?
- Tile compression (WT)
  - TB-based signature checking
  - Lossless compression
- Attribute compression (RD)
  - Reduce stream BW



MEMORY ACCESS MANAGEMENT

- SOC memory architecture
  - Blood rivals (antagonists)
  - Effect of CPU/GPU traffic on Memory Controller (MC)
    - Intelligent page open/close management
    - Balance latency vs. BW



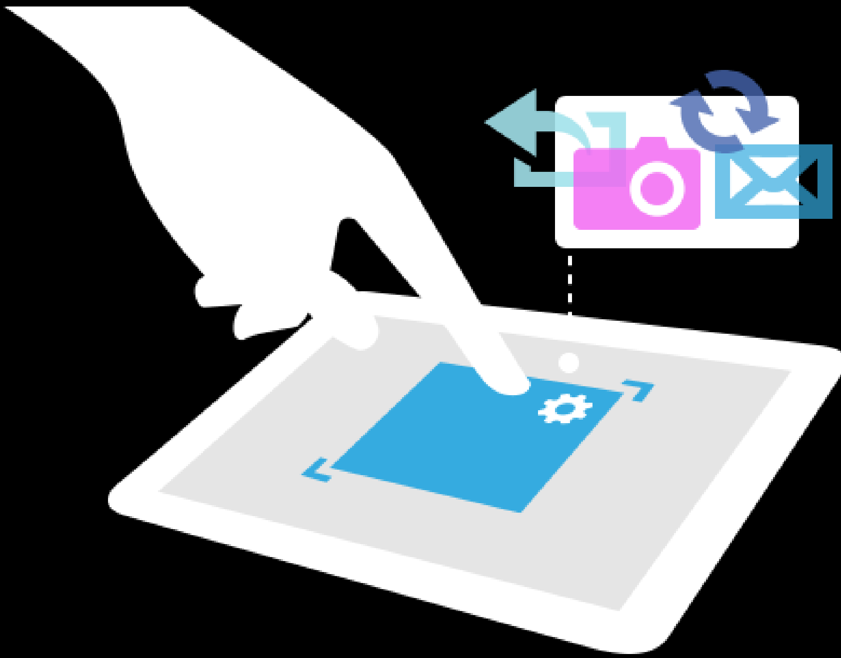
- Mismanaging DRAM results in both performance loss AND extra energy – double whammy

A better user experience…

A PATH TO A BETTER MOBILE GPU? [PART 2]

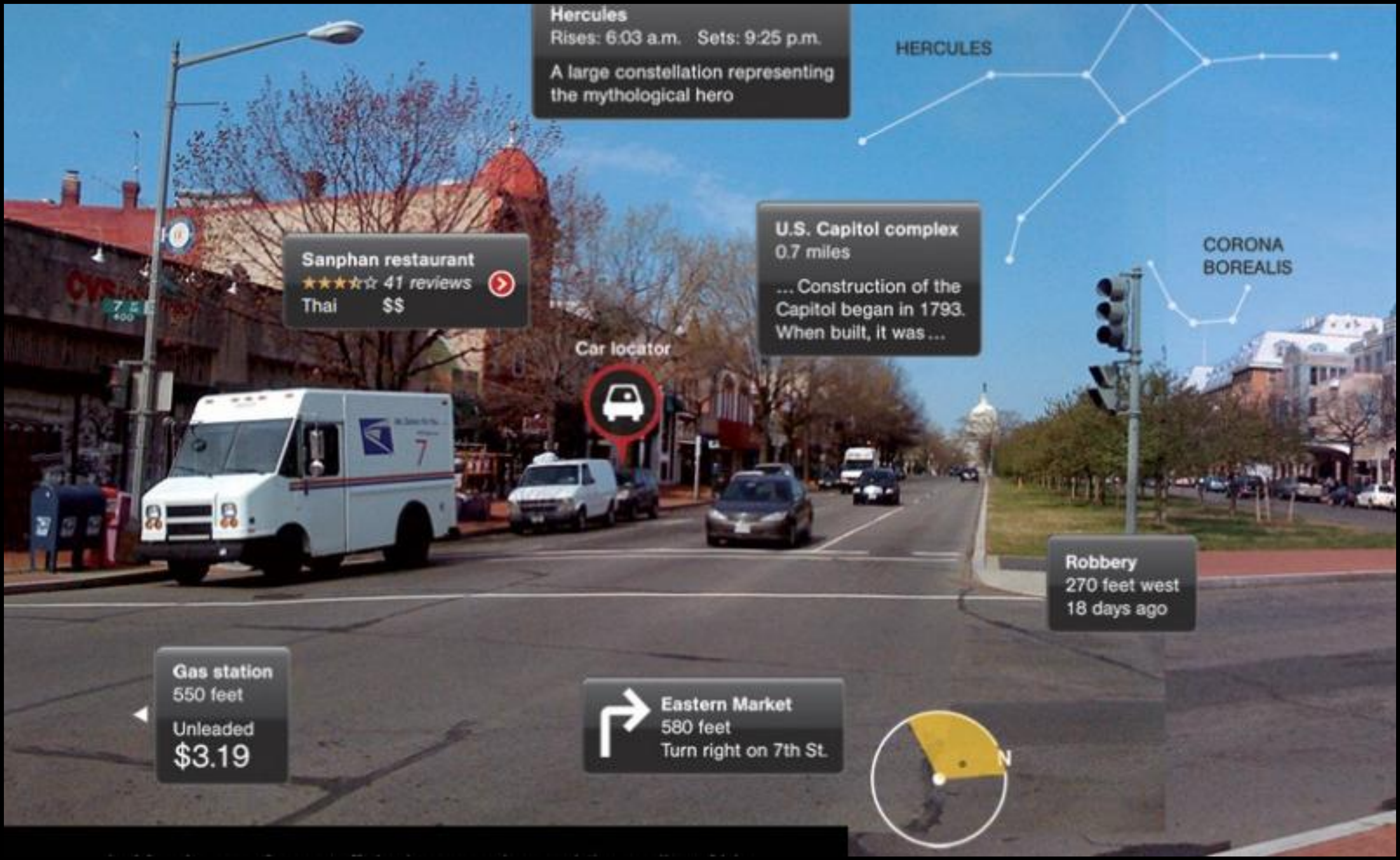
USER EXPERIENCE (UX)

- User Experience = perception of device:
  - Functionality
  - Integration into every day life
  - Ease of use (intuitive)



ISO 9241-210[1] defines user experience as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". - Wikipedia

APPLICATION: NAVIGATION



APPLICATION: FACE RECOGNITION

APPLICATION: TELEPRESENCE

http://www.youtube.com/watch?feature=player_detailpage&v=Nzi0sm81tP4

"General-Purpose Telepresence with Head-Worn Optical See-Through Displays and Projector-Based Lighting." by Maimone A., Yang, X., Dierk, N., State, A., Dou, M., and Fuchs, H. , IEEE Virtual Reality 2013

APPLICATION: VIRTUAL COMPUTER

THE UX OPPORTUNITY

- Killer apps will be integration of:
  - AR/MR technology
  - Big Data operations

- Subject to:
  - Real-time constraints
  - Parallelization on a massive scale

Making a better UX

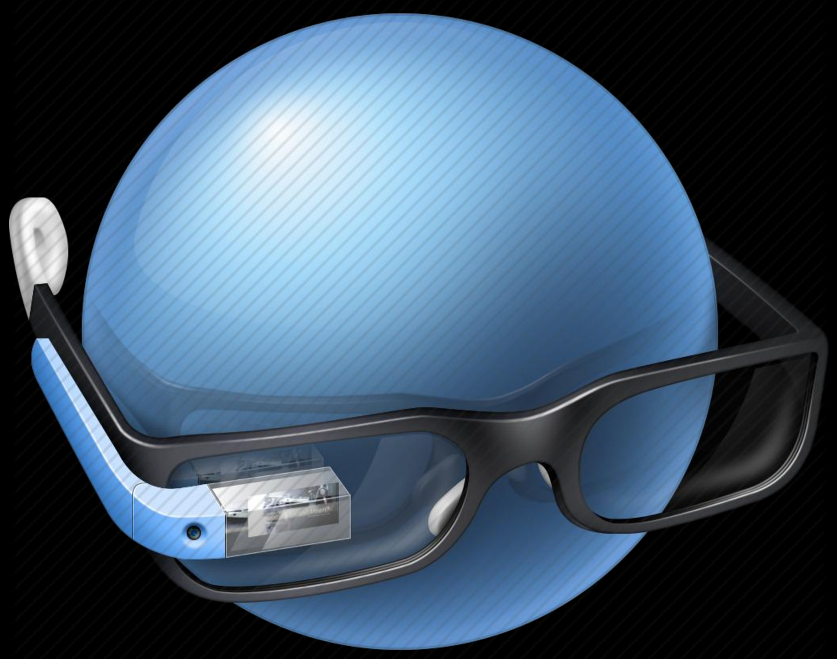
FUTURE MOBILE TECH CHALLENGES?

KEY CHALLENGES

- I/O:
  - AR Headsets
  - Environment Imaging
- Computational:
  - API Improvements
  - Cloud-device integration

AR HEADSETS

- Google Glass is pretty cool, but…
- Better imaging
  - Stereo/Light field
  - HD → UHD
  - Speed
- More sensors
- Wireless power?
- Fashion/ubiquity



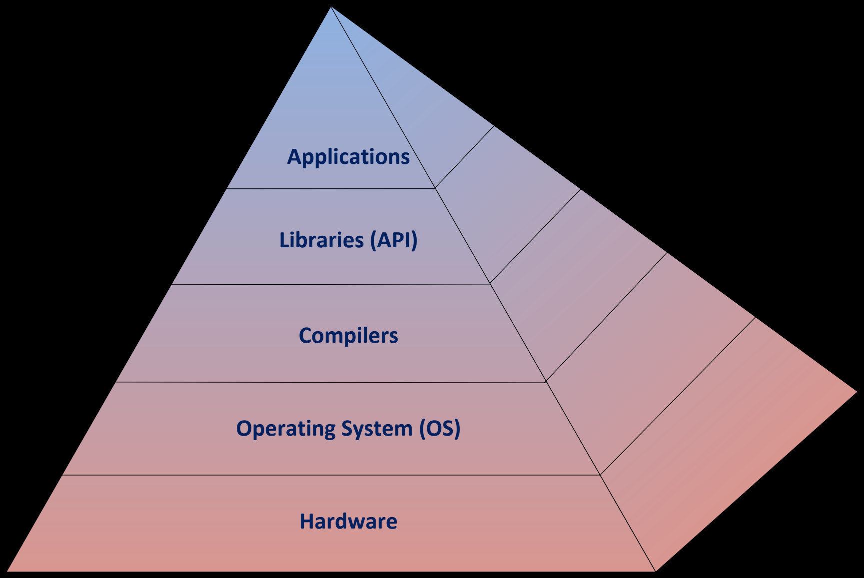
ENVIRONMENT IMAGING

- For telepresence, headset camera is insufficient
- Need “environment cameras”

- Lots of privacy concerns
- Localizing environment to a client?

API IMPROVEMENTS

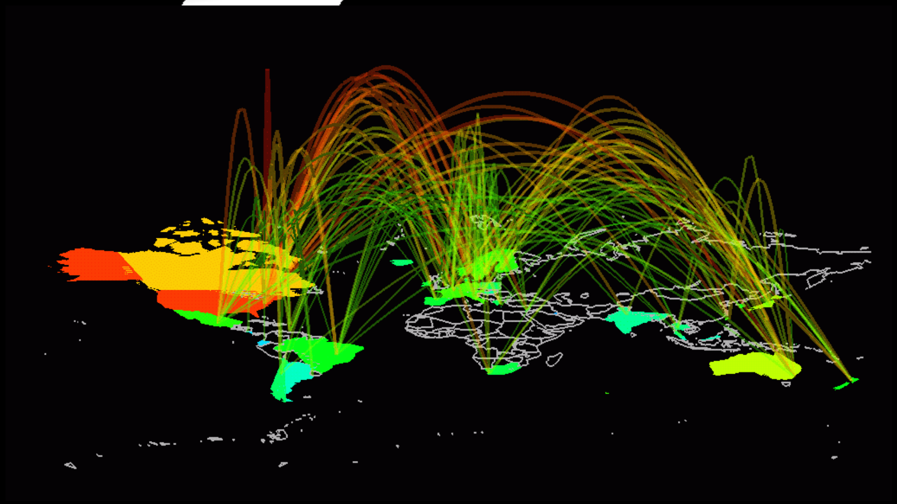
- Today's APIs are power inefficient
- Needed:
  - Hints
  - State-less rendering
    - API commands supply state with action
  - Frame-less rendering
    - Compositing deferred and on-demand
  - Hierarchical geometry
    - Deferred detail



CLOUD-DEVICE INTEGRATION

- SW Challenge:
  - Making cloud queries easier
  - Utilizing the parallelism of the cloud

- Ultimate challenge:
  - The “network GPU”
  - Analogously extend the GPU model to network scale
  - 10^9 GPUs → 10^{21} FLOPs?



SUMMARY

- Mobile computing, in particular graphics, is growing rapidly and becoming ubiquitous
- Tomorrow's machines:
    - Ever improving efficiency
    - Integrated visual UX
    - Tied to the cloud
- Challenges remain to make this a reality
- Exciting prospects…


The End