Mobile VR: Challenges and Opportunities

Matt Pharr
Google / Daydream (my opinions only, etc.)

Mobile VR: definitions & foundations

A recent history of interactive graphics...

1990-1995: CPU SW rendering

1995-2000: Fixed-function GPU rendering

2000–2008: GPU programmability!

NV30, R300, G80, Larrabee, Fermi...

Rapidly approaching peak GPU

guru3d.com

The end(?)

Is that a LRB heat-sink?

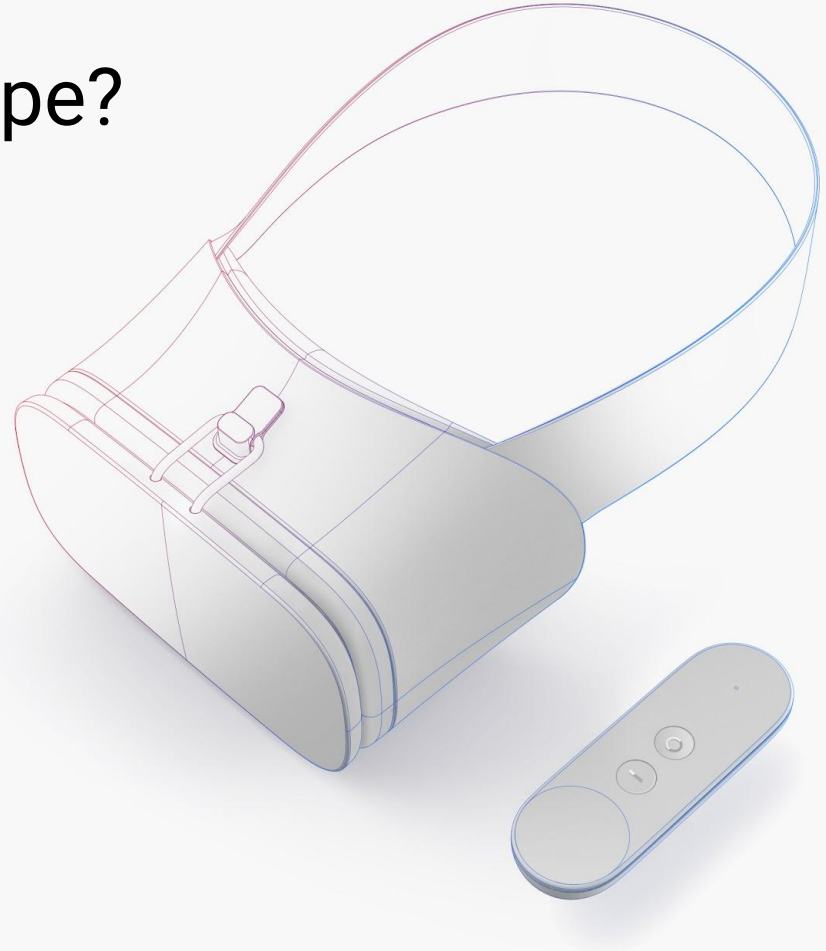
– Kayvon Fatahalian

A stall in the graphics pipeline

2000–2008: GPU programmability!

2008 – 2016: power efficiency!

A New Hope?



Theses

For VR to be commercially viable, HMDs must eventually sell ~100M/year

This will only happen with mobile form-factors

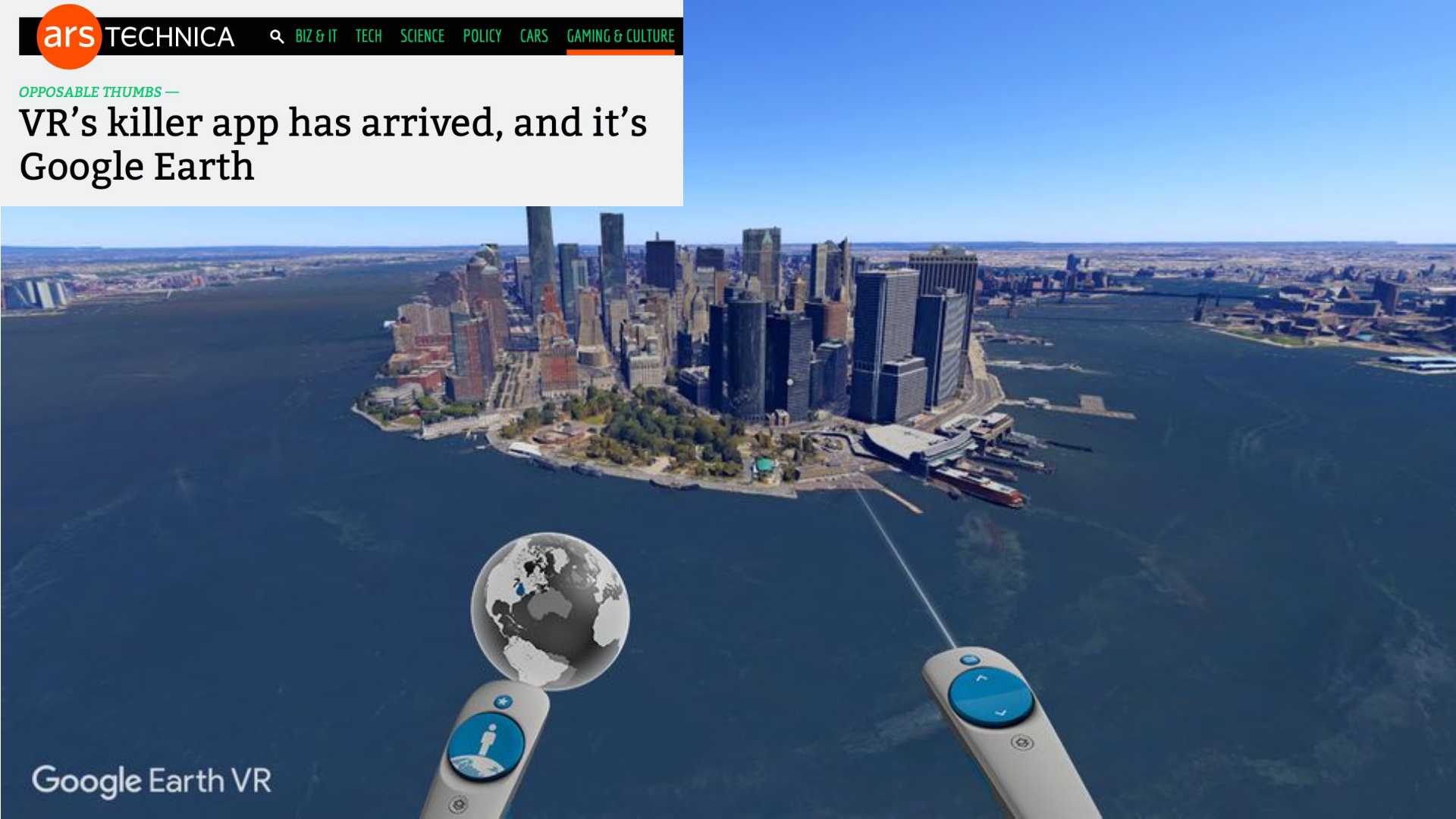
VR on mobile is hard today; the slowing of Moore’s law will make it harder

- There are some great problems to solve in the path to getting there

A new computing platform, or
A new gaming peripheral?

OPPOSABLE THUMBS —

VR's killer app has arrived, and it's Google Earth



The New York Times Magazine

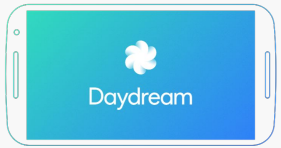
The Displaced: Introduction

Nearly 60 million people are currently displaced from their homes by war and persecution — more than at any time since World War II. Half are children. This multimedia journey in text, photographs and virtual reality tells the stories of three of them.

By JAKE SILVERSTEIN NOV. 5, 2015

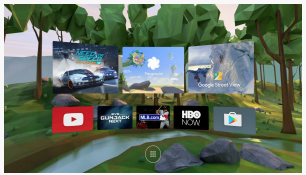

Starry Night, 1888

Daydream



Daydream-Ready Smartphones

+



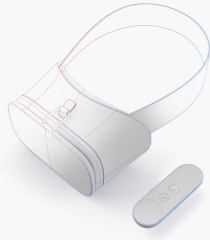
VR Platform Built on Android

+

hulu

Engaging VR Experiences

+



VR Viewer & Controller


NEED FOR SPEED
NO LIMITS VR
Playground
Google Street View
EVE
GUNJACK
NEXT
MLB.com
HBO
NOW

Economies of scale

How we got this far

Oculus Rift DK2 teardown: is that a Samsung phone?

1

Chris Burns - Jul 31, 2014

Facebook Twitter Google Reddit

https://www.slashgear.com/oculus-rift-dk2-teardown-is-that-a-samsung-phone-31339384/

Economies of scale

2016 Smartphone sales: 1.4B (high-end: ~450M)

2016 TV sales: 226M

PS3/XBox 360 (lifetime): 86M

PS4: 54M


SONY
PS4

≈


Start

Uneconomies of scale

Estimated Vive, Rift sales to date: 500k

PSVR: <750k

2016 Enthusiast ($250+) GPU sales: ~4M

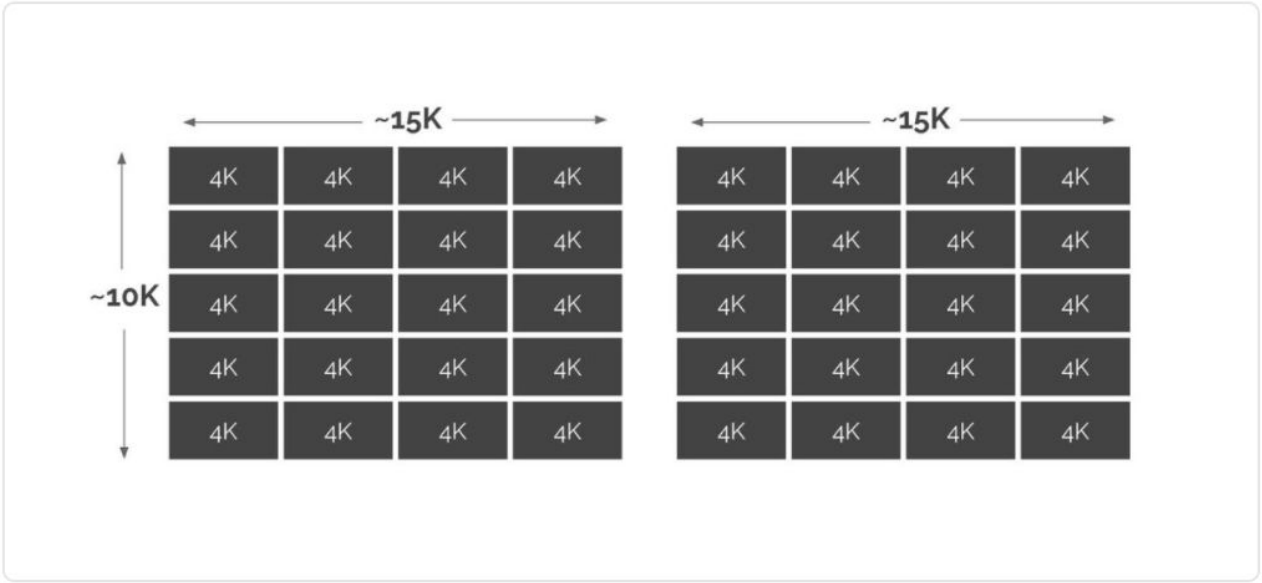
2016 Performance ($100-250) GPU sales: ~20M

https://uploadvr.com/superdata-headset-sales-analysis/,
http://www.gamespot.com/articles/playstation-vr-sales-estimates-downgraded-hugely-b/1100-6445859/
http://www.anandtech.com/show/10864/discrete-desktop-gpu-market-trends-q3-2016/2

Challenges: Display

Clay Bavor @claybavor · 30 Jun 2016

To get 20/20 visual acuity over a ~200 degree field of view in a VR headset, you'll need ~40 4K TVs worth of pixels.



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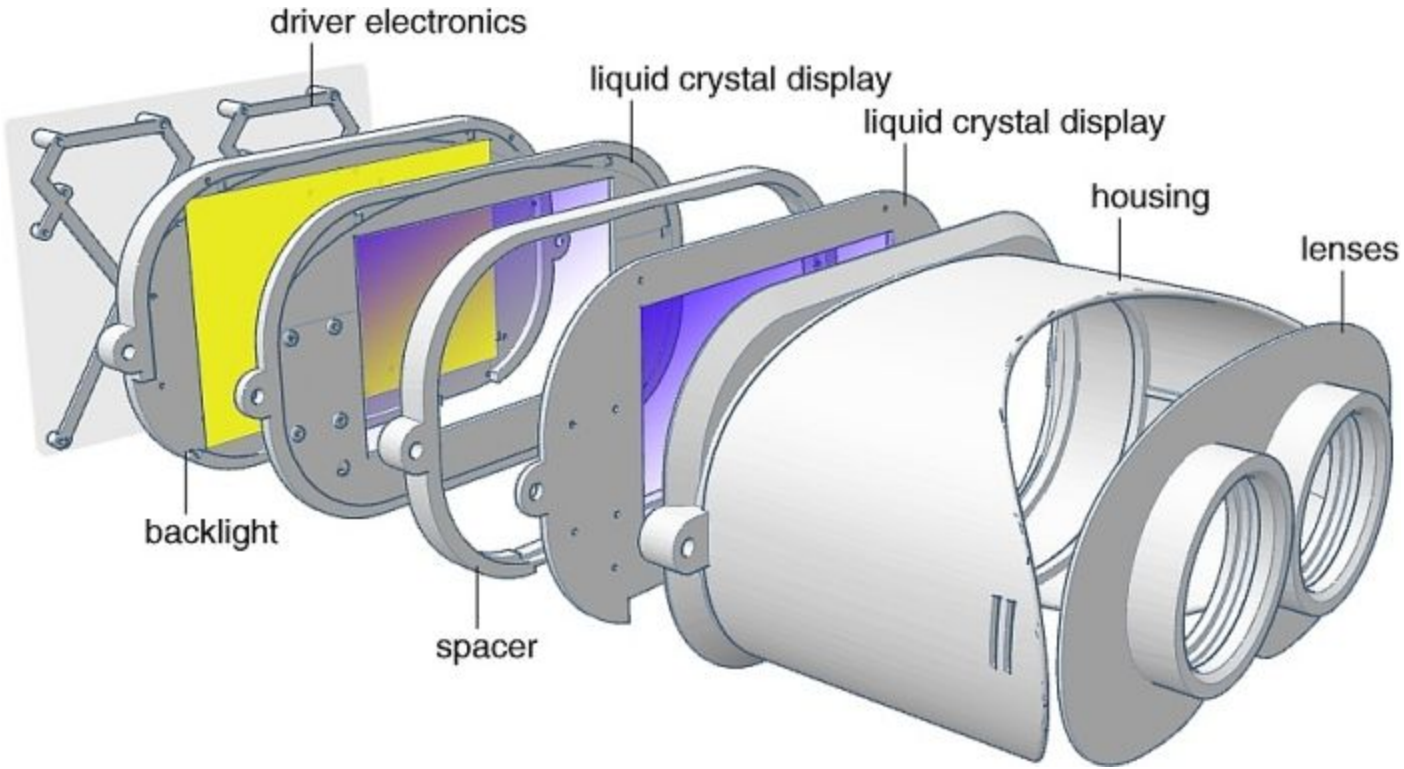


NVIDIA / Stanford

LG Display to Spend About $9 Billion on Factory for OLEDs

by **Jungah Lee**

November 26, 2015, 2:50 PM PST *Updated on* November 26, 2015, 11:15 PM PST

TECHNOLOGY NEWS | Wed Feb 11, 2015 | 1:46am EST

Samsung Display to invest $3.6 billion in new OLED production line

Challenges: Compute

Mobile GPU Performance

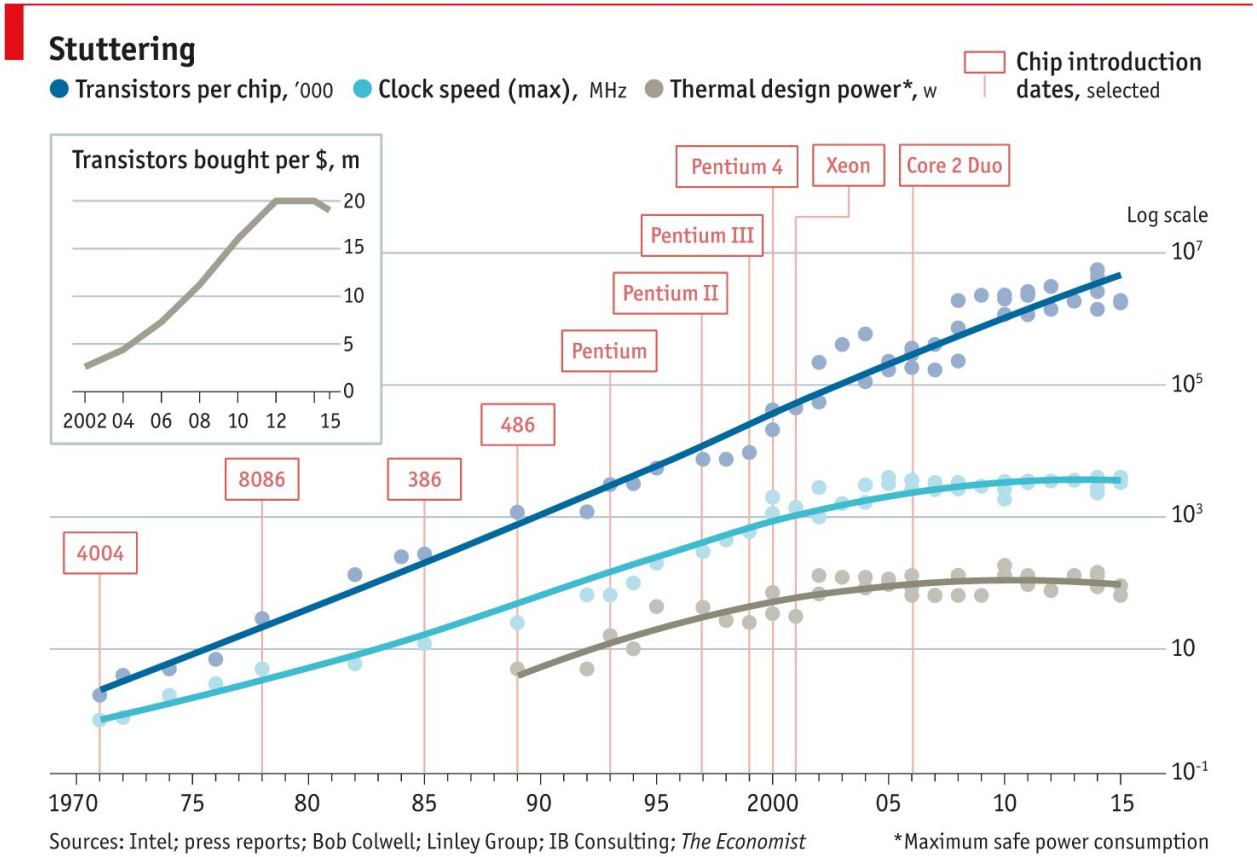
	Adreno 320	Adreno 420	Adreno 530
Year	2013	2014	2016
Fab	28nm	28nm	14nm
GFLOPS	~20	~150	~500
Memory BW	~4 GB/s	~8 GB/s	~30 GB/s

Sources: https://en.wikipedia.org/wiki/Adreno, Tom's Hardware.

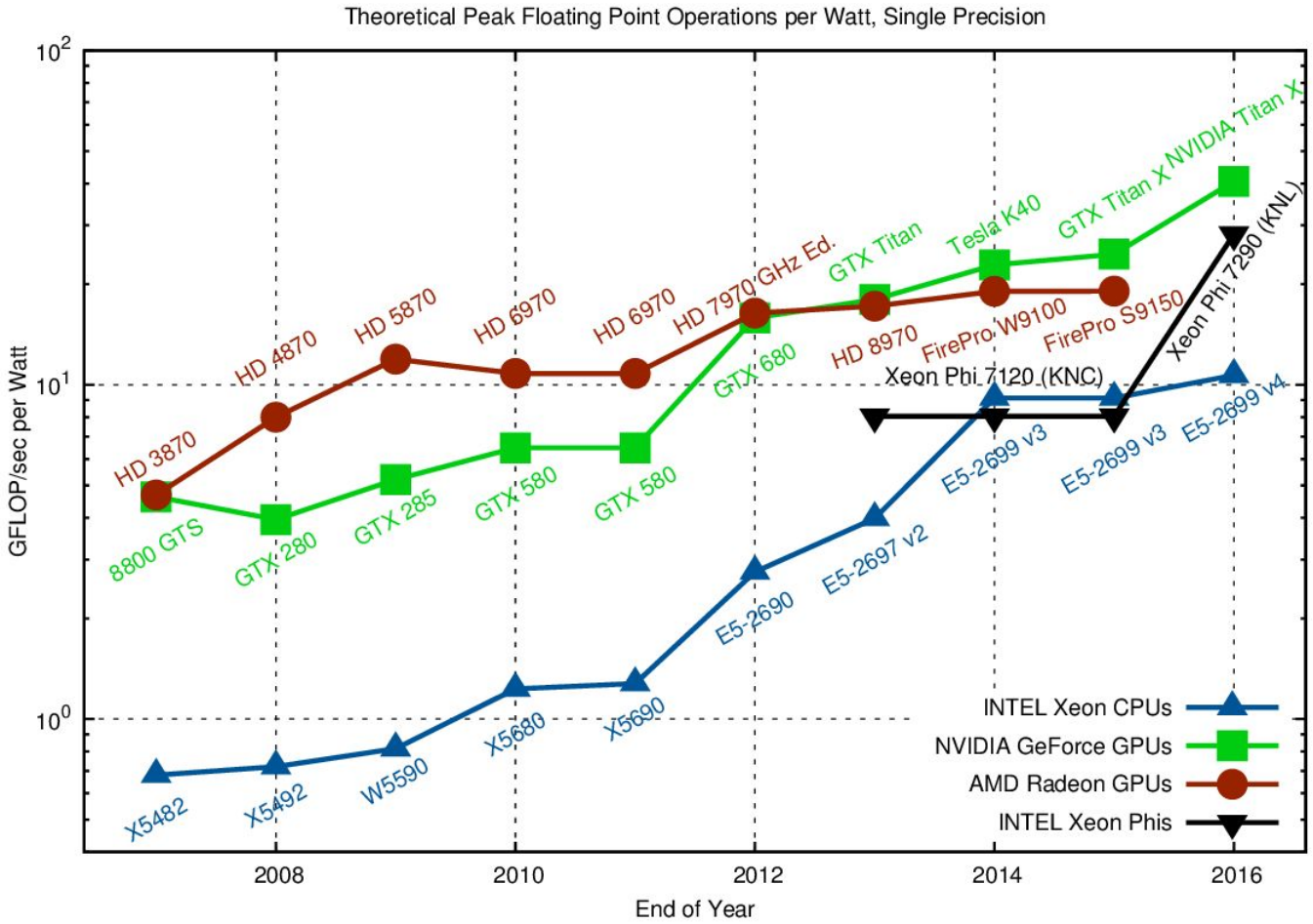
Mobile vs. desktop

	NVIDIA 1080	Adreno 530
Year	2016	2016
Fab	16nm	14nm
GFLOPS	~8000	~500
Memory BW	~320 GB/s	~30 GB/s
Power	180 W	~small n W
FLOPS/pixel	34k	2.2k

The Slowing of Moore’s Law
(and slowing power efficiency improvements)



http://www.economist.com/technology-quarterly/2016-03-12/after-moores-law



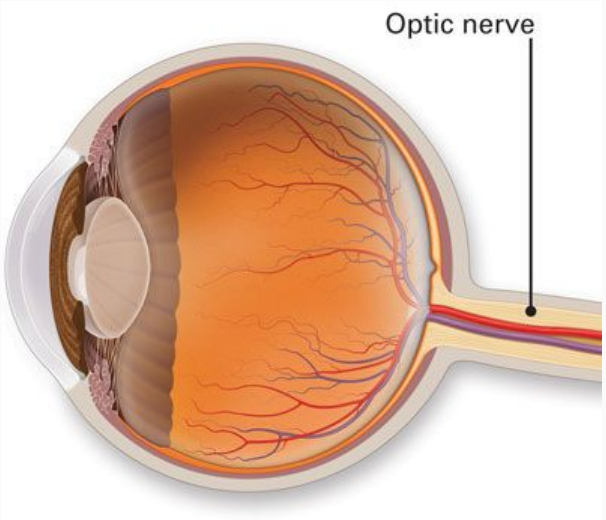
Karl Rupp: https://www.karlrupp.net/2013/06/cpu-gpu-and-mic-hardware-characteristics-over-time/

Bridging the gap

Optic Nerve Bandwidth: 8.75Mb/s

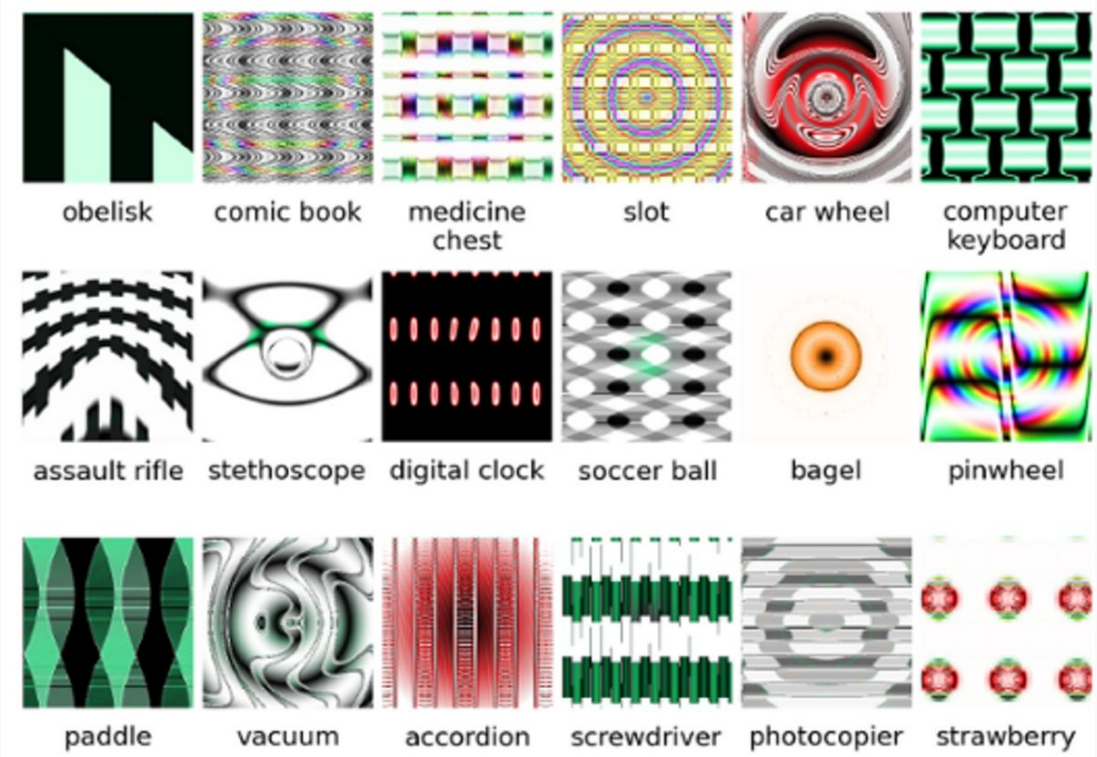
Koch et al., How Much the Eye Tells the Brain, *Current Biology* 16, 1428–34, 2006.

Today's mobile GPU → 57k FLOPS per bit(!)



American Academy of Opthamology

Turning the tables; can we fool the human visual system?



Nguyen et al., Deep Neural Networks are Easily Fooled: High Confidence Predictions for Unrecognizable Images, CVPR 2015

Programmable parts change more slowly?

HW arch: the design constraints settle down

SW: target is more fixed, easier to specialize / go deep

- Going to the metal has been a big win for consoles
- Need documented internal texture formats, memory system, and cache architecture, ...
- x86 consistency has enabled ecosystem, building expertise

Software occlusion culling

Rasterize coarse zbuffer on SPU/CPU

- 256x114 float
  - Good fit in SPU LS, but could be 16-bit
- Low-poly occluder meshes
  - Manually conservative
  - 100 m view distance
  - Max 10000 vertices/frame
- Parallel SPU vertex & raster jobs
- Cost: a few milliseconds

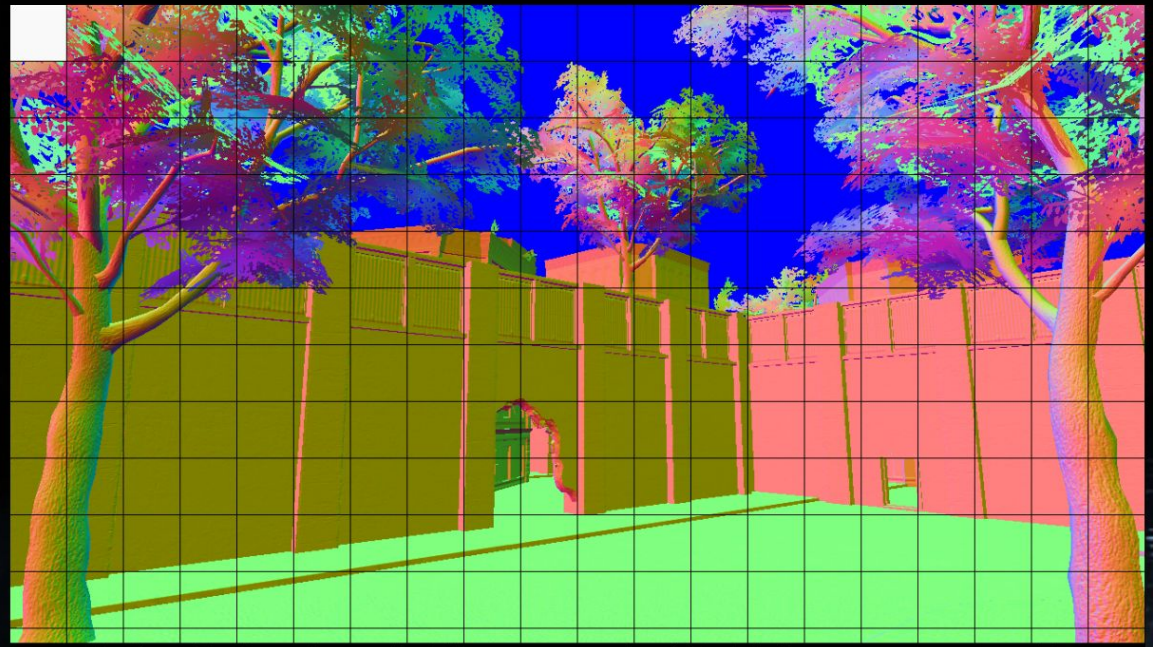
Then cull all objects against zbuffer

- Before passed to all other systems = big savings
- Screen-space bounding-box test

Pictures & numbers from Battlefield: Bad Company PS3

Johan Andersson
BPS Course,
SIGGRAPH 2009

SPU Tile Based Shading work units



Vulkan to the rescue?

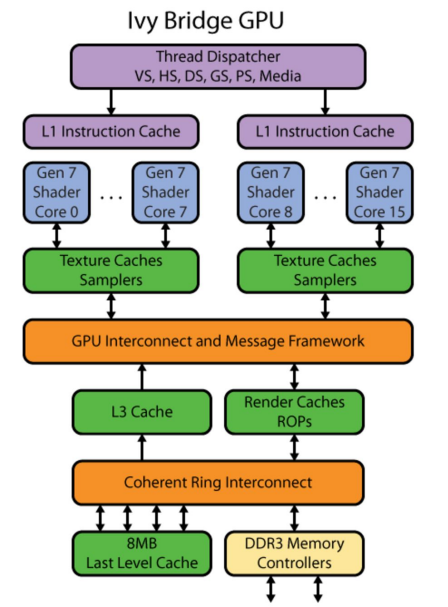
Drivers and abstractions: big win for average programmers, limiter for great ones–the Vulkan motivation

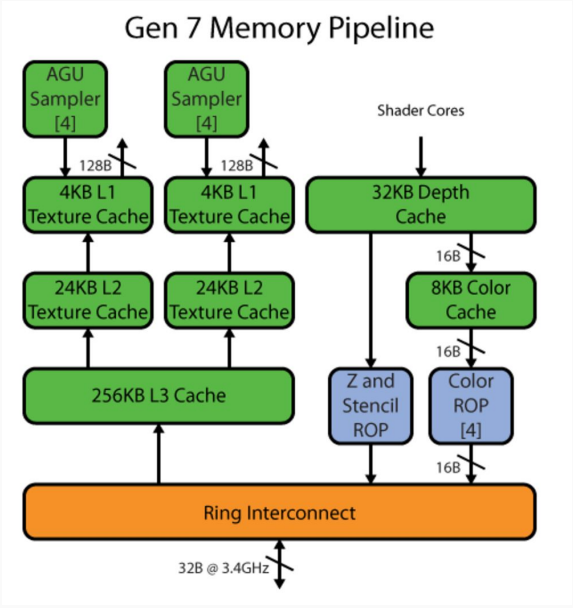
Is SPIR-V the right abstraction?

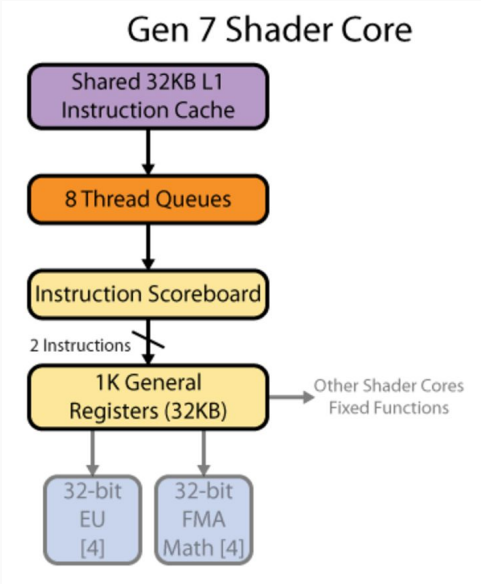
Whither Agner Fog for mobile?

http://www.agner.org/optimize/microarchitecture.pdf

Whither Real World Tech for mobile?

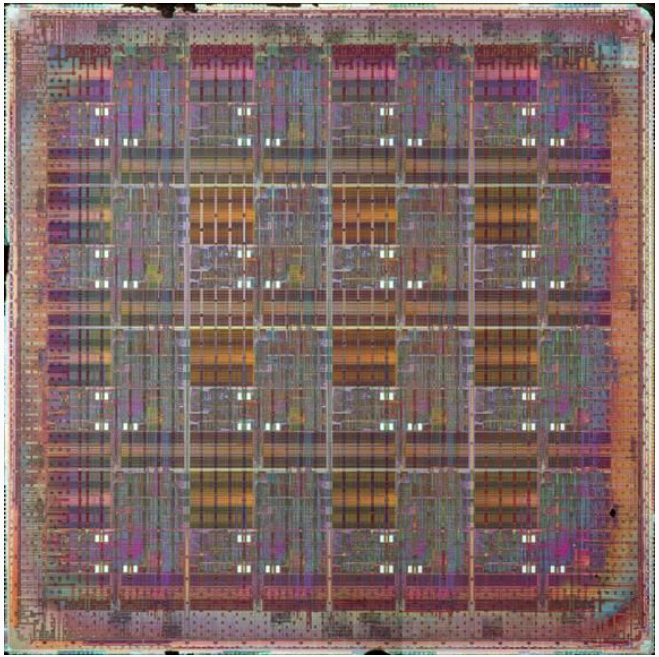




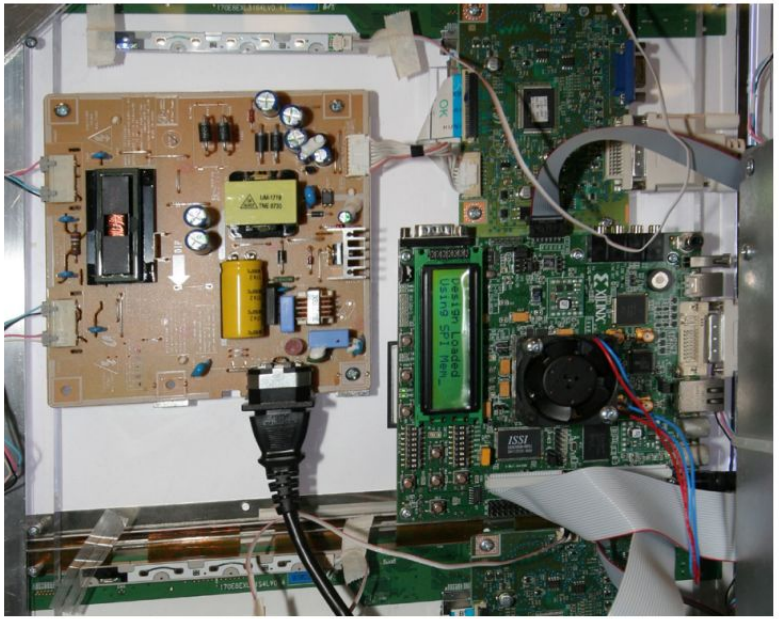


http://www.realworldtech.com/ivy-bridge-gpu/

Will the time for exotic architectures come?



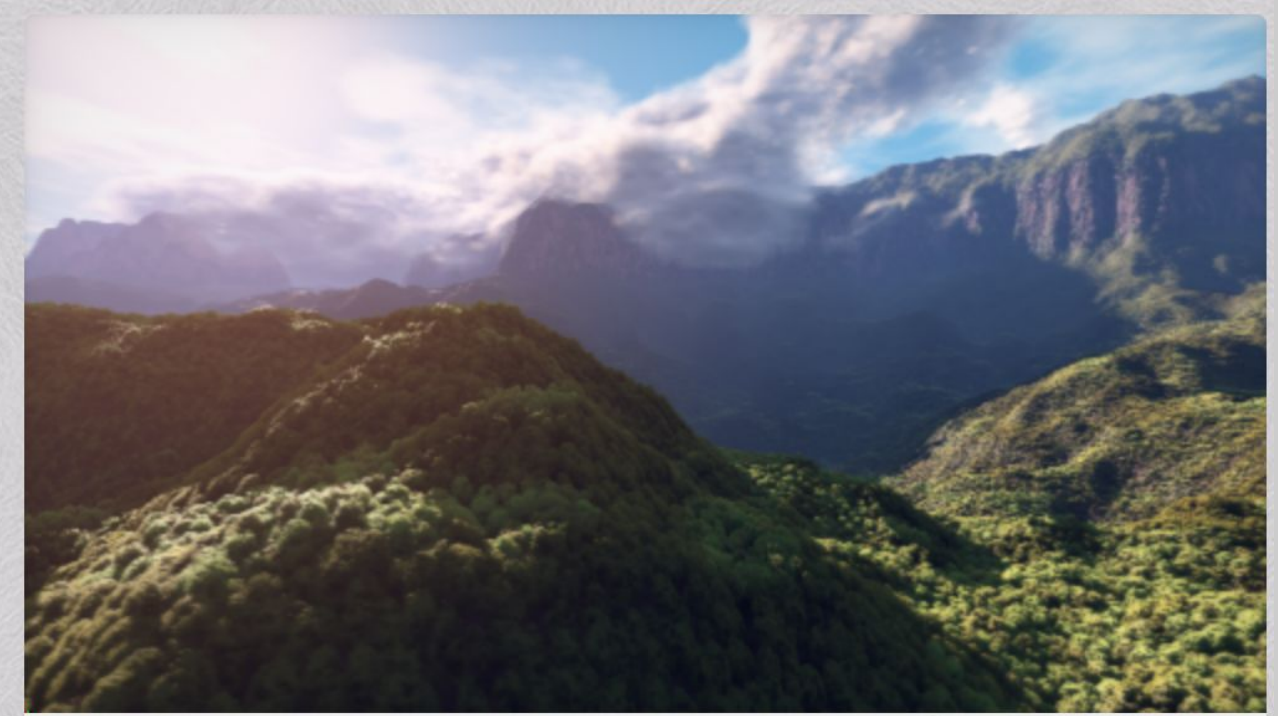
MIT RAW



Whitted et al., *Embedded Function Composition*

Shadertoy

Search...



Rainforest

19674 154 53

Tags: **procedural**, **3d**, **raymarching**, **reprojection**

Created by **iq** in 2016-Dec-21

Greater importance of fixed-function HW

Dark Silicon and the End of Multi-Core Scaling, Esmaeilzadeh et al. ISCA 2011

The study shows that regardless of chip organization and topology, multicore scaling is power limited to a degree not widely appreciated by the computing community. Even at 22 nm (just one year from now), 21% of a fixed-size chip must be powered off, and at 8 nm, this number grows to more than 50%

More negatively: programmability is expensive (power & transistor-wise); why do so much of it?

HW/SW feedback loop

SW algorithms and workloads adapt to HW architecture (as it exists)

Future HW architecture adapts to SW algorithms (as they exist)

Better: future HW architecture adapts to SW (extrapolated, forward looking)

How do researchers work on fixed-function?

FPGAs?

Hard to work on one piece without having a complete system (CPU, GPU, etc.) to be embedding it in.

Designing hardware isn't easy...

?

https://chisel.eecs.berkeley.edu/

Summary

VR @ Google

Faculty Research Awards

Internships, full-time jobs after graduation

Summary

Widespread VR adoption is critical for the economics to work out

- Mobile VR devices present the best chance of widespread VR adoption

Multiple challenges targeting mobile-class / battery-powered devices

- Some intrinsic: power == compute capability
- Some extrinsic: ecosystem, programmer expertise

End of Moore’s law makes deep specialization (HW and SW) make more sense

Thanks!