Mobile: The Future of VR

ARM

Sam Martin, ARM
Juan Wee, Samsung
Alon Or-bach, Samsung

Game Developers Conference
1st March 2017

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http://www.telephonearchive.com/phones/sc/sc-mckinley-fig8.html

Not Samsung

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Flickr/Julien Prive

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http://rlogin.dk/sites/messenger-dead-due-to-Skype-but-good-replacements-exist/page2.html

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https://firefoxos.mozfr.org/post/2015/09/Nicolas-Hoizey-pionnier-creation-jeu-Firefox-OS

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https://en.wikipedia.org/wiki/File:Game-Boy-FL.png

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https://www.cnet.com/products/samsung-gear-vr/


4,800
MISSILE WARNING

VR HMD

6m+

2016
GearVR, PSVR, Rift, Vive

VR HMD

?

2017
GearVR, PSVR, Rift, Vive
Daydream, Windows 10 VR

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Data: SuperData

Mobile VR Session

< 10 min

Mobile VR Sessions per Month

50 times

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Data: SuperData

VR Content Consumption

44 %

Games

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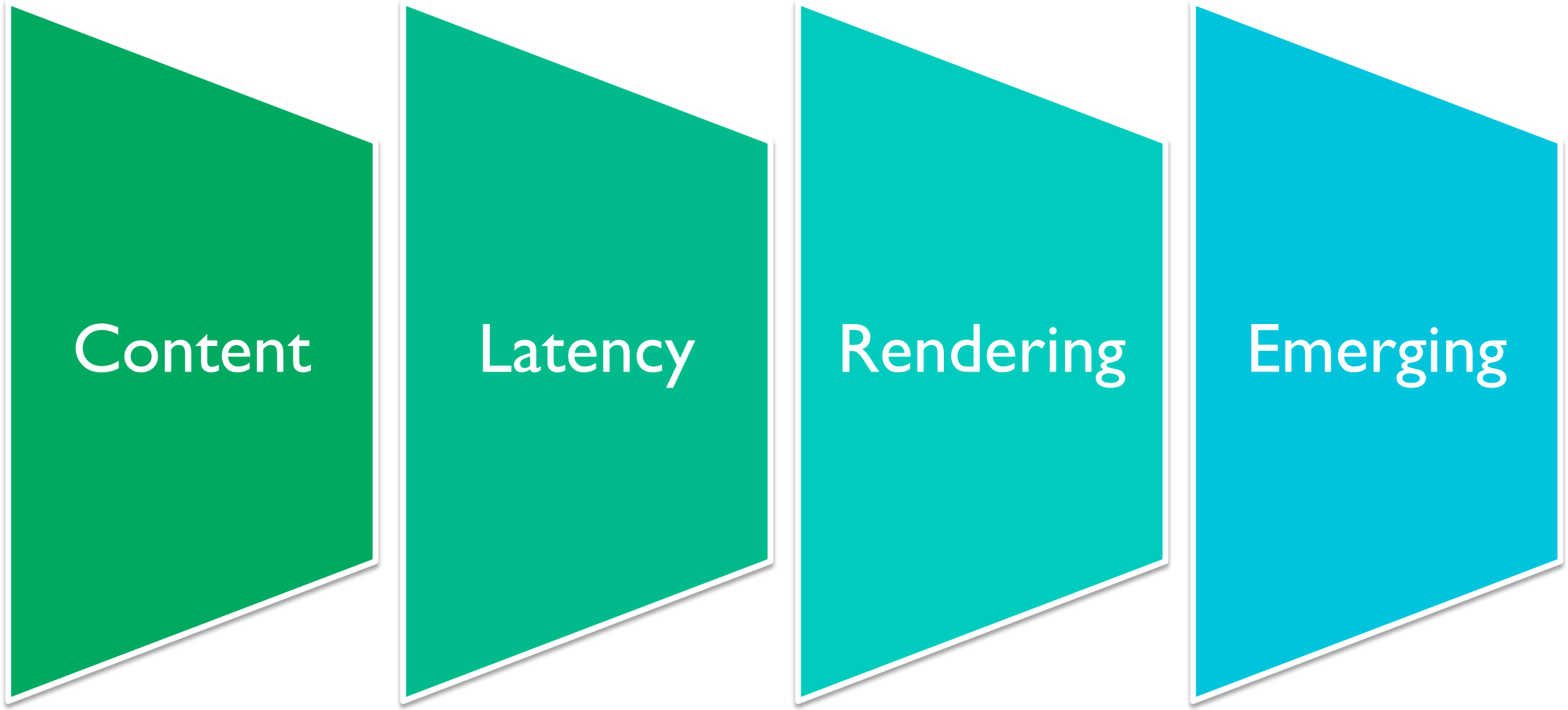
Data: SuperData

Frontiers



Content frontier

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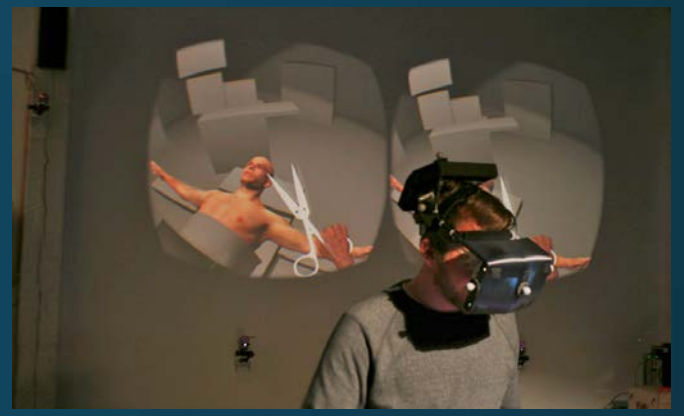
Juan Wee, Samsung Electronics

Games

Experiences



Training

Education

TV and Film

Advertising

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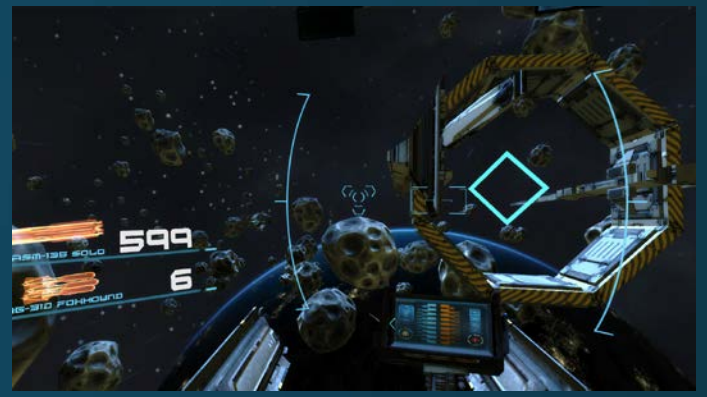
Immersive but stationary



Use impressive scale and perspective

Captive audience

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VR Video Content Consumption

10m+

Hours

2016 GearVR

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Bridges physical distances of places and experiences

Bridges personal distances

Brings people together to share experiences

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All of this comes at a cost…

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Latency frontier

Sam Martin, ARM

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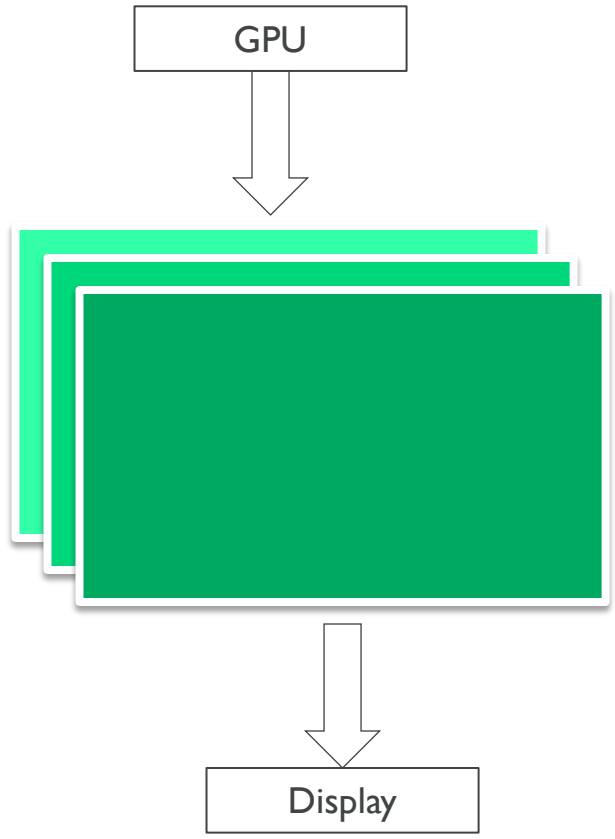
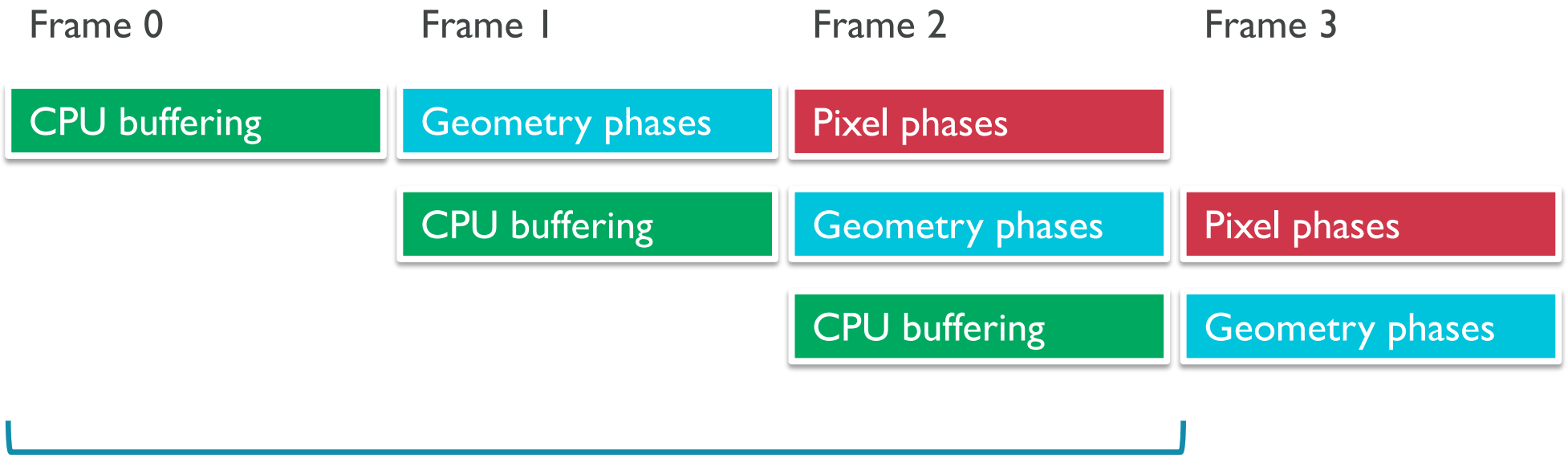
<20ms Latency

- "Motion to photons"
  - 20ms is accepted imperceptible latency
- But… GPUs are throughput processors
- Usually ok to increase latency if it improves throughput
  - Android can/may triple buffer
  - Graphics pipeline spread over multiple frames



Worst-case frame pipelining



Up to 50 ms @ 60 Hz!

Conclusion:
We need to shortcut this pipeline for latency-sensitive changes

Composition in “traditional” Android apps

App →

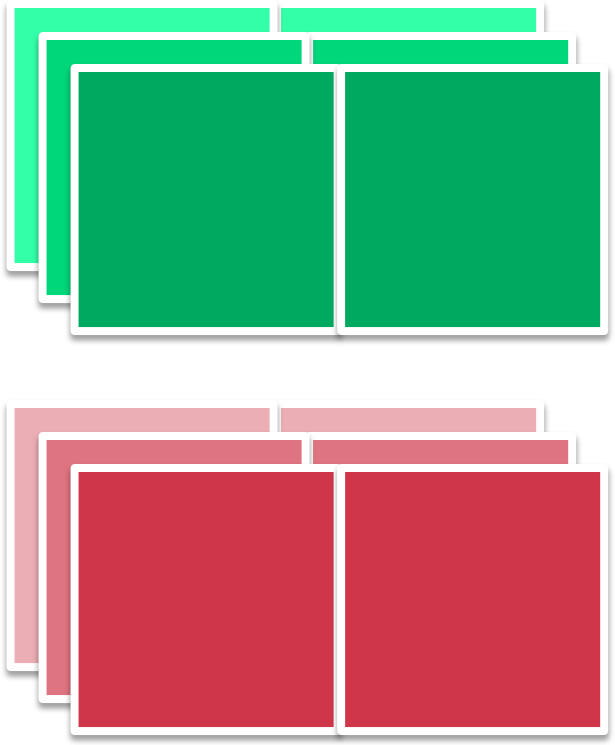
UI,
Notifications,
Video,
Buttons,
etc

Android
compositing
process

GPU

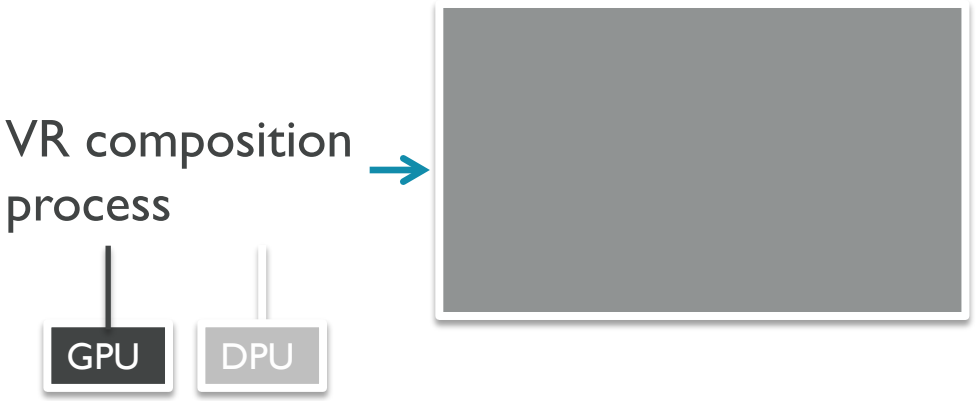
DPU

VR application



…

- Head-tracked layers
- Head-locked layers
- System layers
  - UI / notifications / input
- Not just flat textures!
  - Quad (video)
  - Cylindrical
  - Cubemaps



VR composition

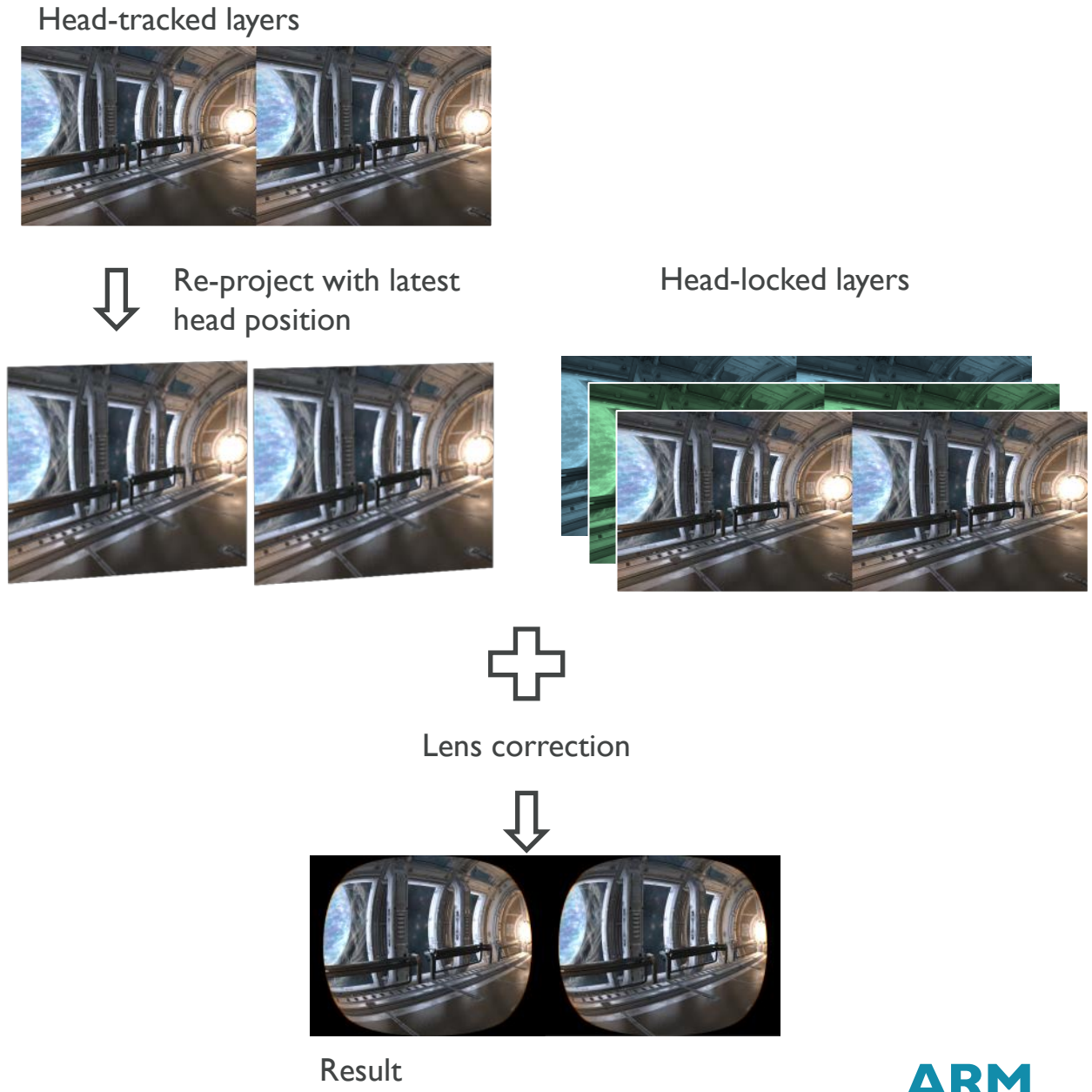
- Logically, a just-in-time process that :

  Re-projects head-tracked layers

  Composites all layers

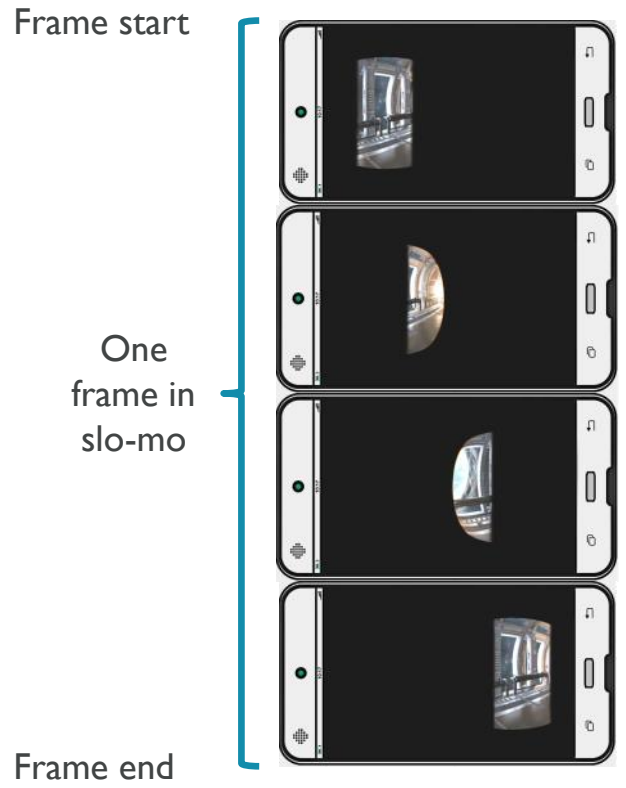
  Lens-corrects the result

- 15-30% of the GPU + a lot of bandwidth

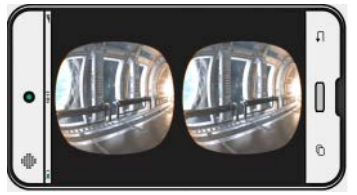


Lots of fiddly details

- Two more problems:
  - Display transfer time too long: 16.6ms @ 60 Hz
  - VR devices need low persistence panels to reduce blurring
- OLED panels are ideal – they progressively illuminate pixels
  - Low persistence and each pixel has a unique illumination time
- All GearVR and Daydream devices have OLED panels
- TLDR: Can use these properties to achieve latency goals



But looks like this to the end user…



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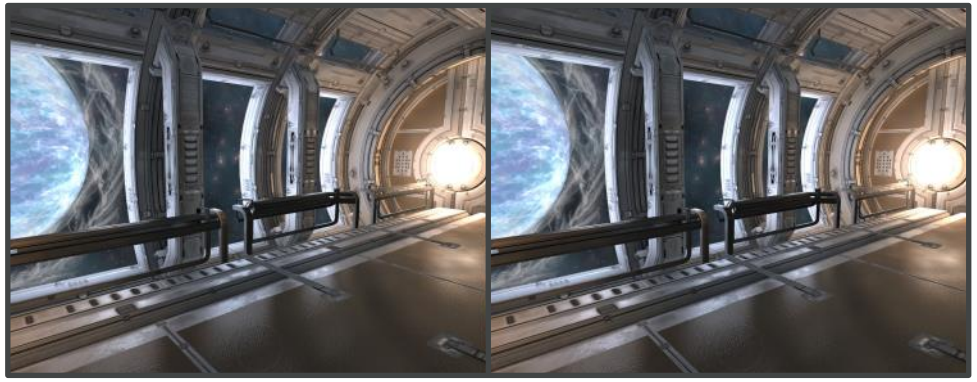
Result: 2 GPU interleaved processes

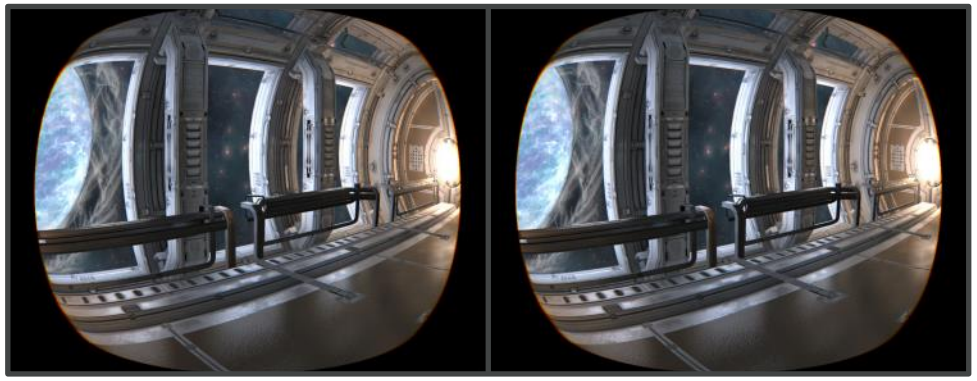
2x 1024x1024

Application draws eye buffers @ 30-60 Hz



- Rotation-only pipeline latency = ~8.3ms
- Decoupled from application
  - App can drop frames (sort of)
- OLED panels aren't cheap → limits availability
- Latency for other inputs is still perceivable

Re-project with latest head rotation 2 'slices' @ 60 Hz



2560x1440

Where does this go next?

- More stable system operation
  - Too much judder in real world systems today
    → Use logcat-based tools to see what happens today
  - Need more sweeping defences against this

- Latency of other inputs
  - E.g. animations, → Spacewarp?
  - Controller inputs, camera inputs, ... → active area of interest
  - Audio! (including 3d audio)

Where does this go next?

- 90Hz, 120Hz, … higher framerates?
  - Yes, but not about latency – diminishing returns beyond 20ms
  - Higher refresh rate → less 'flicker', less blur, brighter displays
  - Higher refresh rate → better panel response times
  - Higher refresh rate → LCD panels → lower cost → more devices
- Attention to detail

Rendering frontier

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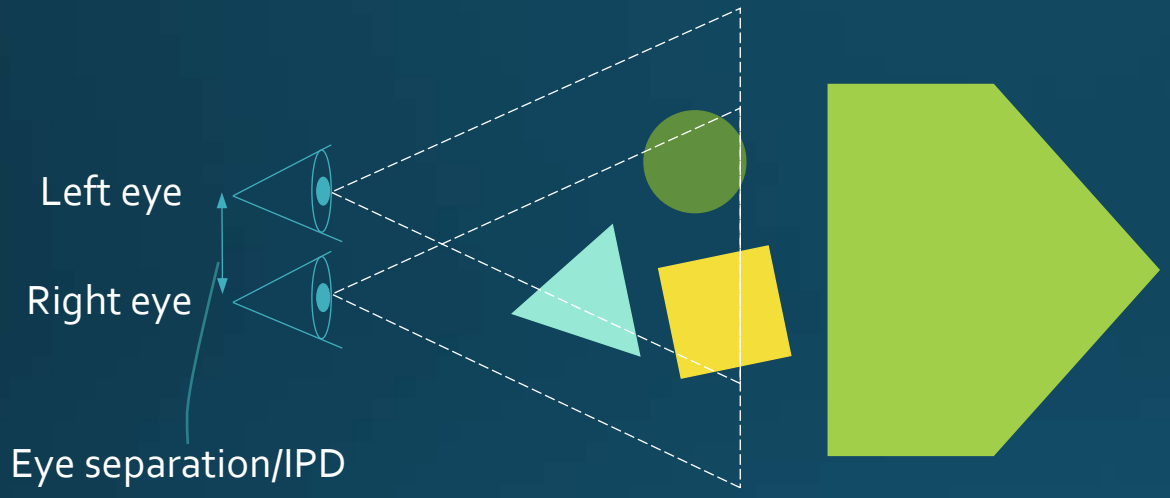
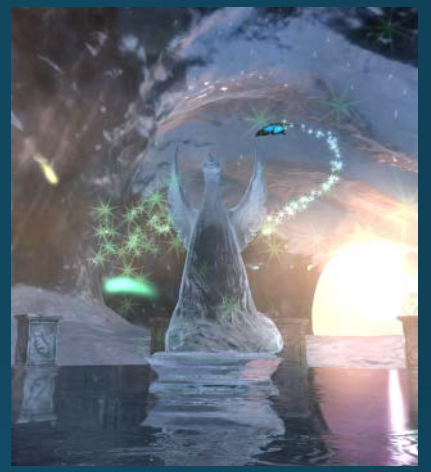
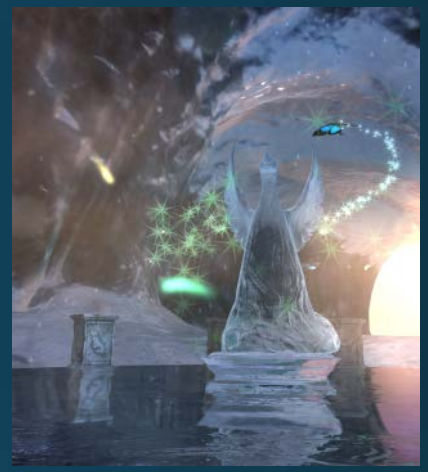
Alon Or-bach, Samsung Electronics

Stereo output 2x work in ½ the time!?





Left eye



Right eye

- Additional app overhead to prepare 2x draws
- 2x driver overhead to handle draws
- 2x vertex-tiling process

…but in ½ the time to get the same frame rate

CPU overhead

Geometry overhead

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Multiview

1. Draw into a texture array
2. Shaders see a new constant: `g_ViewID`
3. Use it to vary shading between eyes!

- Pros:
  - Simple!
  - Widely supported
  - Efficient on existing hardware
  - Generalises beyond 2 views

- Support in Unreal (4.14+) and Unity (5.6 beta)

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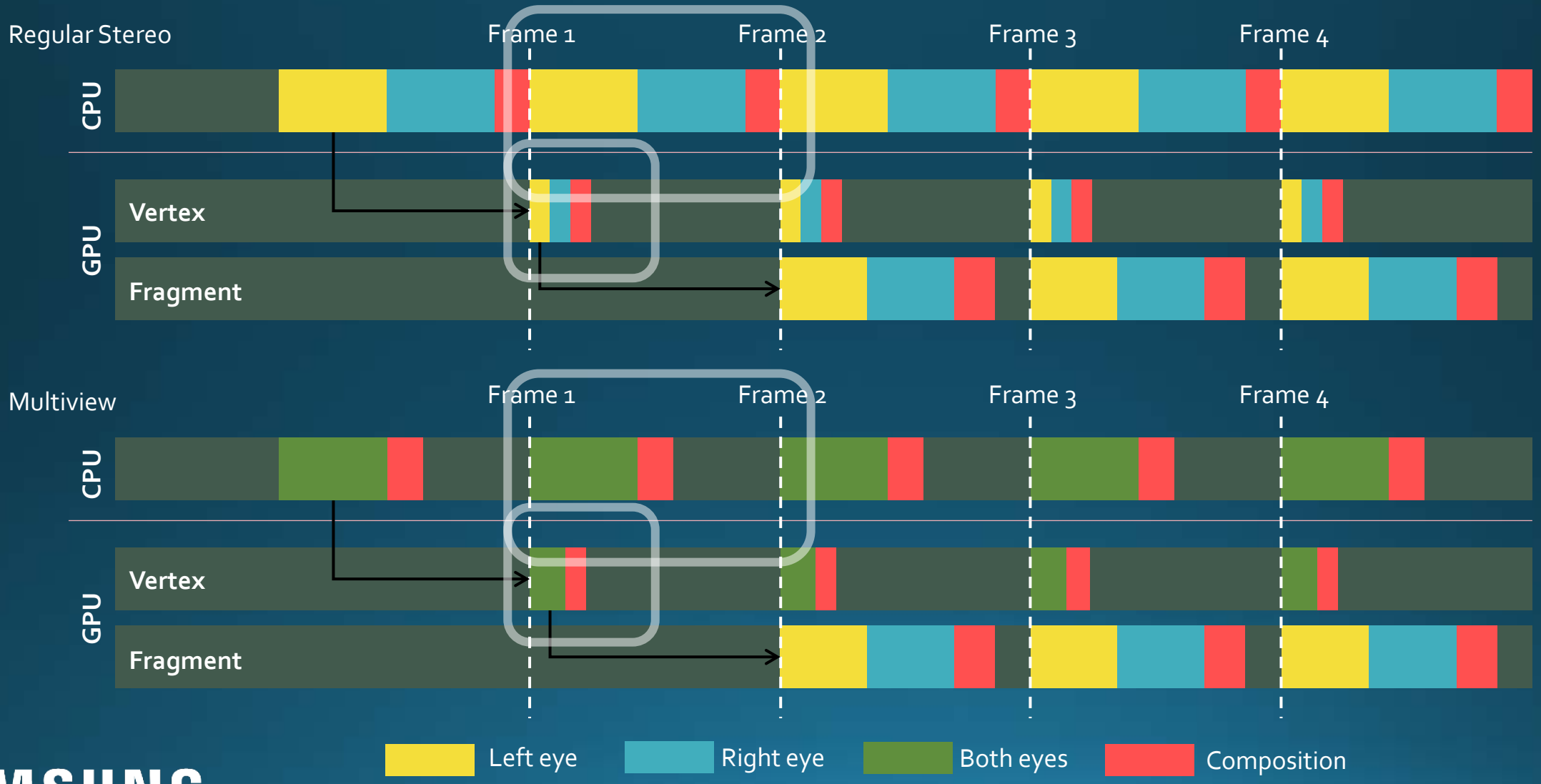
Multiview illustration on Mali



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What is Vulkan?

- Cross-platform open standard next-gen graphics & compute API
- A more explicit alternative to OpenGL / OpenGL ES
- Features
  - Cross-platform & designed for modern GPU architectures
  - Low-overhead drivers
  - Explicit control / predictable performance
  - Multi-threading friendly

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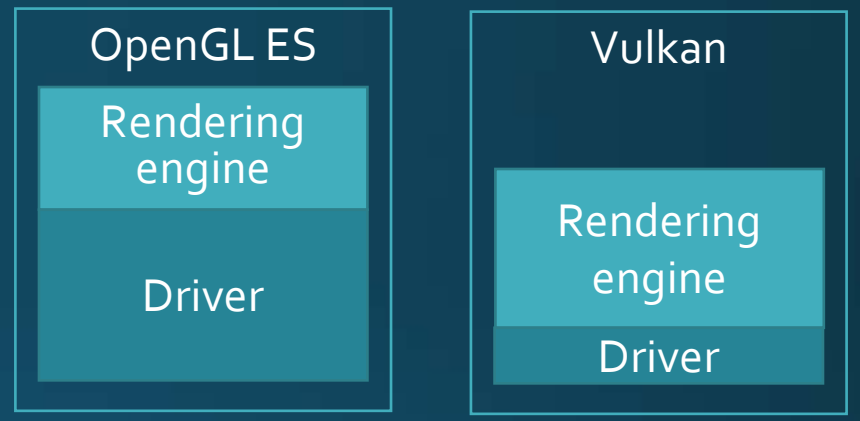
Why Vulkan benefits VR on mobile

- Reduced CPU overhead
  - Draw calls no longer the bottleneck!
- Decreased power consumption
  - Lower overhead and multithreading
- Or more impressive graphics



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Vulkan: Improved framerate stability

- Engine/Application has far more control over when work happens
- Heavy lifting done away from critical path
  - Building resources (command buffers, pipelines)
  - Shader compilation
- Pipeline caches enable re-use of resources

=> Avoid draw-time stuttering!

Vulkan features enabling VR

Technique	Component	Feature / extension
Multiview rendering	• Game	• Multiview or instancing
Lens correction & image warp	• VR compositor	• Queue priorities or cross-process sharing and synchronization
Rendering to front buffer	• VR compositor	• Shared presentable images

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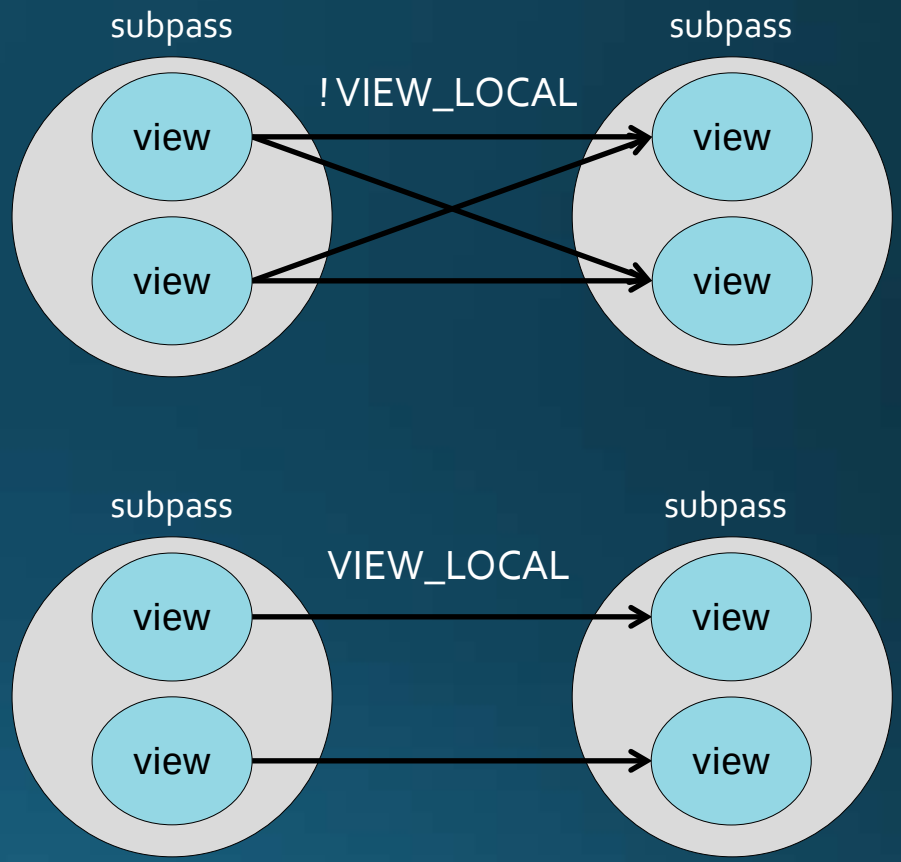
Vulkan: Multiview

- **VK_KHX_multiview** experimental extension just released!
  - Keen to get developer feedback
  - Warning! It **will** be removed when functionality finalized
- Accompanied by SPIR-V extension **SPV_KHR_multiview**
- Based on GL_OVR_multiview, redefined to use render passes
- Commands executed across multiple views
- Shaders can differ per-view using **ViewIndex**

Vulkan: Multiview

- Aim to achieve best performance across differing implementations
- Enables recording command buffers that differ between views
- Introduces mechanism to associate render pass with multiple views
- Supports tiling-friendly VIEW_LOCAL dependencies



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Emerging frontiers

Sam Martin, ARM

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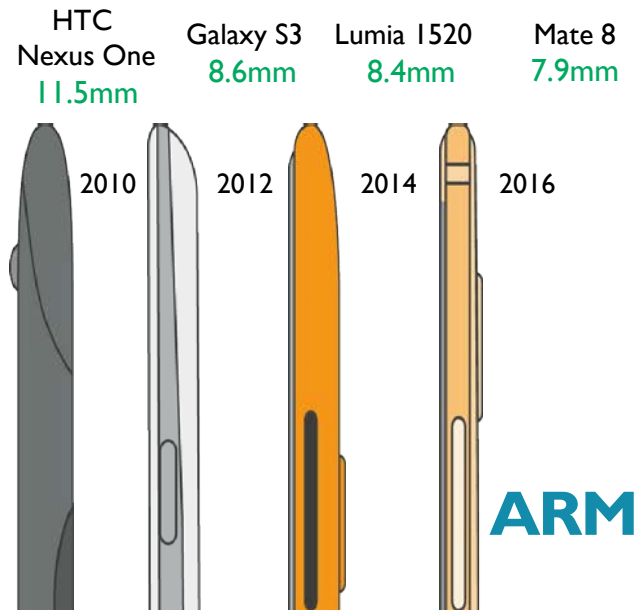
Performance limits as thermal limits

- Performance on premium mobile is limited by capacity to dissipate heat

- Phones are not getting bigger
- Process shrinkage is getting more expensive

Must find ways to do more in less

- Some inefficiencies that will give us a short term boost
- Need to look for domain-specific optimisations
  - Foveated rendering? HW composition? VR video?



Alternative facts

- Increase your thermal limit

- Phone-in-a-headset form factor
  - Low cost, compelling experience, largest potential market

- Standalone ("all in one") VR devices
  - Better cooling options, custom display

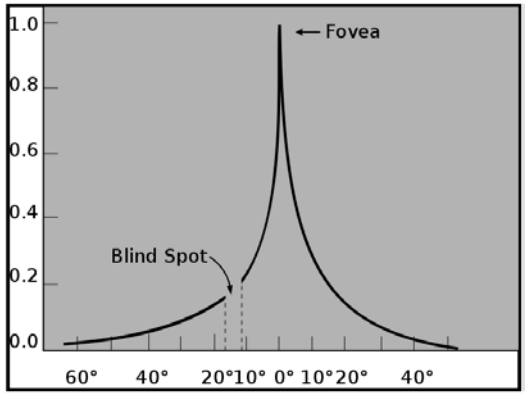
- Separate headset and device form factors
  - Thermal limits dependent upon non-headmounted device – phone to a rucksack
  - Lightest possible headset

Foveated rendering (two flavours)

- Lens-matched
- Gaze-tracked

- May / may not have the same solution
- Both need the app to ‘opt in’
- 4k panels
  - Need a 2x improvement to realise

- Many other uses for eye tracking
  - IPD measurement, biometric sign in, social



Other active fields

- Tracking – near future
  - Positional head tracking
  - Tracked controllers
  - Tracking people
  - Tracking environments
- Video
  - Position-independent (“lightfield”) video
  - 360 video
  - Voxel/”other” video

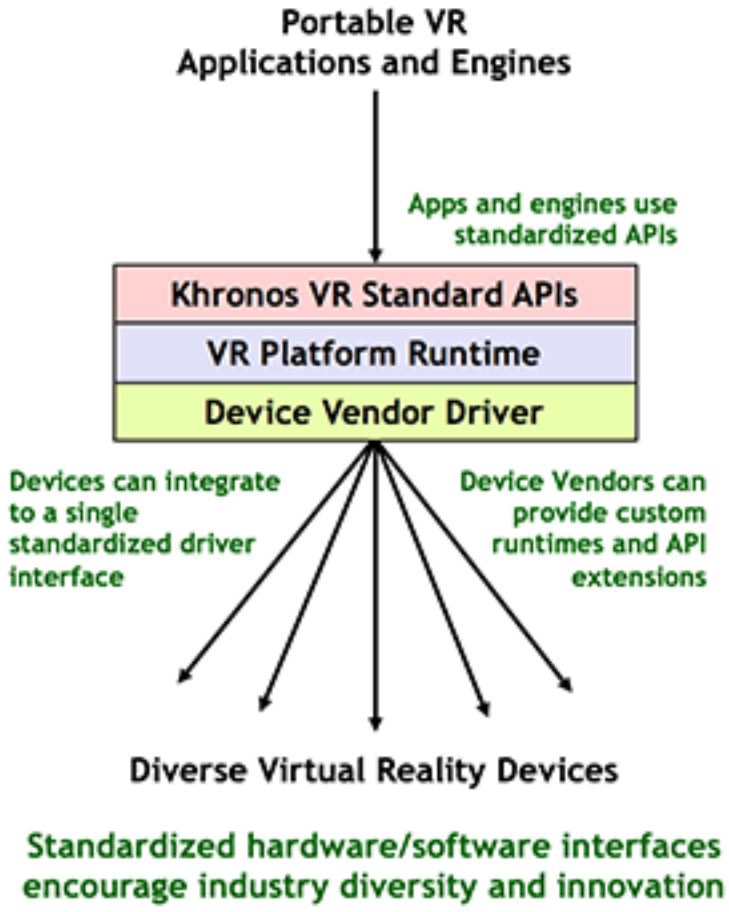
OpenXR™

AMD ARM EPIC GAMES Google Imagination intel

LG LUNARG MEDIATEK NOKIA NVIDIA oculus

QUALCOMM RAZER SAMSUNG sensics tobii

unity VALVE VeriSilicon 兆芯 zSpace



Standardized hardware/software interfaces encourage industry diversity and innovation

Thanks! Questions?

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- Juan Wee, Samsung — juan.wee@samsung.com
- Alon Or-bach, Samsung — alon.orbach@samsung.com — @alonorbach

- Also highly recommended at GDC 2017:
  - "Get the Most from Vulkan in Unity with Practical Examples from Infinite Dreams"
    - 10-11am tomorrow (Thursday, room 3022)
  - "Achieving Console Quality Games on Mobile with Digital Legends Case Study"
    - 5-6pm today (Wednesday, room 3007)

ARM