AR-VR : Computing Gets Interactive

Harsha Nagaraju

Sr. Segment Manager

Micron Technology

Agenda

- Micron – Company update
- AR-VR
  - What is it? Where is fits?
  - How is the market looking
  - Evolution and Landscape
- General Architecture
  - Memory Recommendations
- Road to advanced AR VR Devices

Micron by the Numbers

37 Years strong in

20 Countries with **13** Manufacturing and R&D sites,

30,000+ Team Members and

Net Sales in 2015 of

$16,100,000,000

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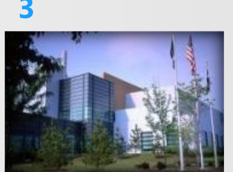
Global Manufacturing Scale

1

Boise, Idaho USA

2

Lehi, Utah USA

3

Manassas, VA USA

4

Agrate, Italy

5

Muar, Malaysia

6

Singapore

7

Taiwan (Inotera)

8

Taiwan

9

Xian, China

10

Hiroshima, Japan

11

Akita, Japan

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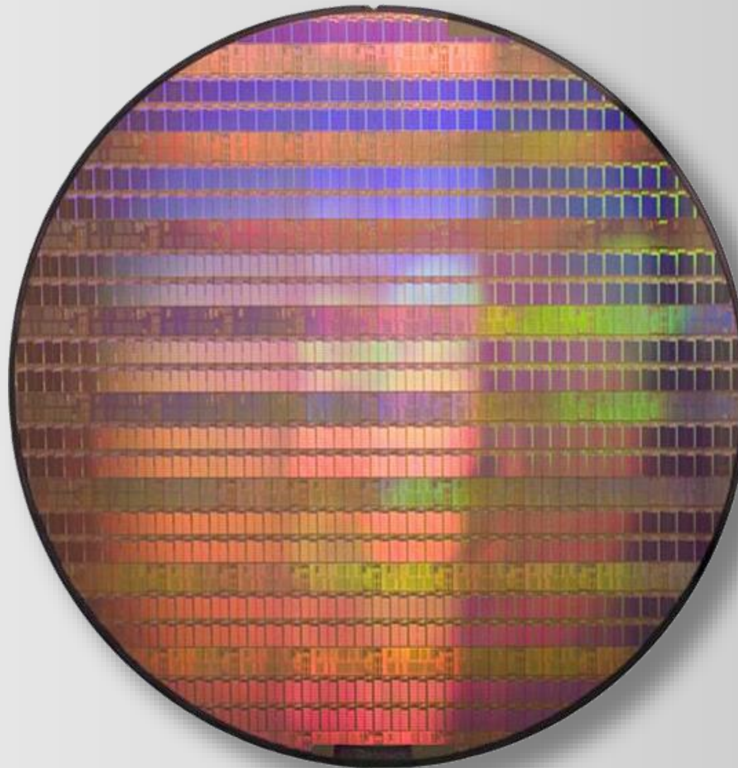
And an expansive product offering

Bare Die
Multiple
Technologies

NAND Flash
TLC, MLC, SLC
Serial NAND
Enterprise NAND
NAND MCP
3D NAND

DRAM Families
SDRAM
DDR
DDR2
DDR3
DDR4
RLDRAM®
Mobile LPDRAM

Solid State Drives
Client SSD
Enterprise SATA
Enterprise SAS
Enterprise PCIe



Managed NAND
MCP
eMMC™
Embedded USB

DRAM Modules
FBDIMM
RDIMM
VLP RDIMM
VLP UDIMM
UDIMM
SODIMM
SORDIMM
Mini-DIMM
VLP Mini-DIMM
LRDIMM
NVDIMM

NOR Flash
Parallel NOR
Serial NOR
NOR MCP

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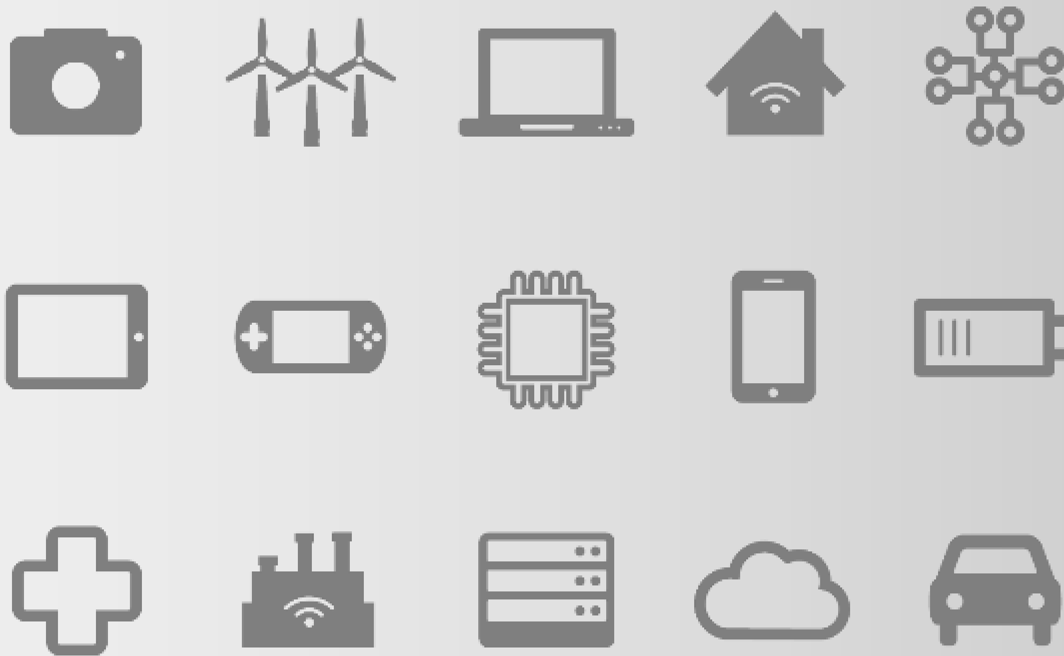
Serving a broad set of customer applications



You may not know it, but MICRON MEMORY is in the things you use every day.

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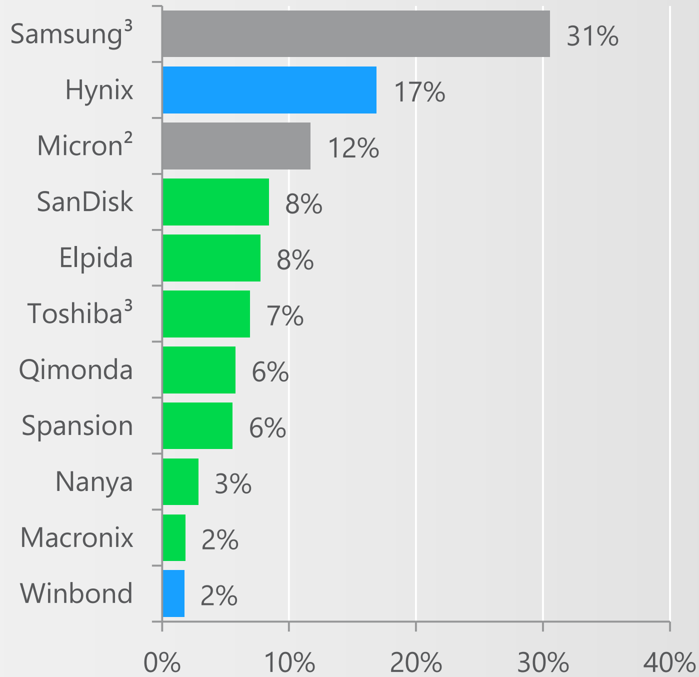
Memory Industry: FY 2008 vs Today

FY2008 Memory Revenue (% of Group Total)[1]

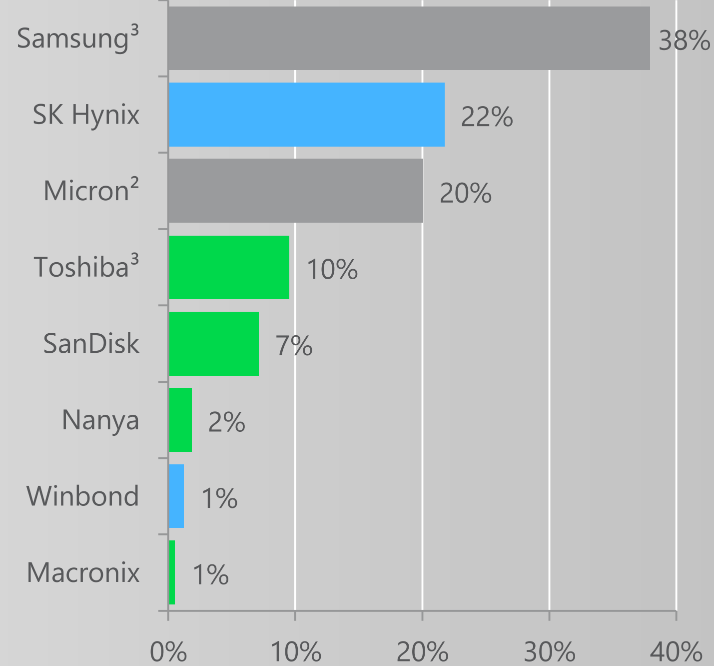


DRAM + NAND + NOR Developers

DRAM + NAND Developers

Single Memory Developers

LTM Memory Revenue (% of Group Total)[1]



Top Five Market Share: 75%

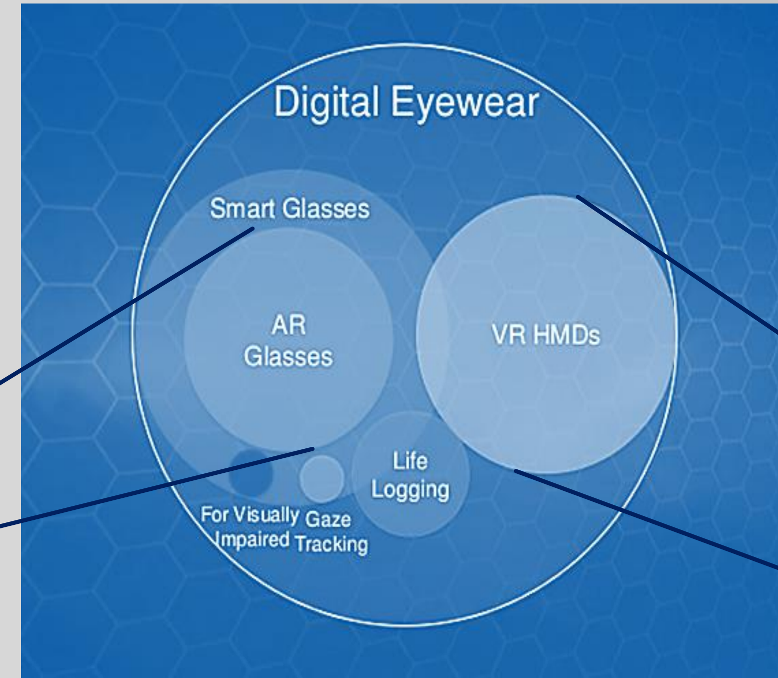
Top Five Market Share: 96%

Source: Micron
Micron data is from FY 2008; Competitor data is from CQ4-07 – CQ3-08.
1 Group total defined as only those companies listed on this page, although others may also exist. Micron data is fiscal, competitor data is calendar. Percentages vary due to rounding.
2. Micron Includes NAND sold to Intel from IM Flash.
3. Samsung and Toshiba include total memory revenue as reported.

Source: Micron
Micron data is FQ1-15 – FQ4-15; Competitor data from CQ4-14 – CQ3-15.
1. Group total defined as only those companies listed on this page, although others may also exist.
2. Micron Includes NAND sold to Intel from IM Flash
3. Samsung and Toshiba include total memory revenue as reported.

AR VR – What is it?

THE NEXT WAVE OF TECH



AR Applications:
Commercial & Industrial
Medical
Education & Training
eCommerce, Advertising
Gaming & Entertainment

VR Applications:
Gaming & Entertainment
Concerts & Theme parks

Image Source: Wikipedia

AR and VR headsets both provide stereo 3D high definition video and audio, but….

- AR is open and partly immersive – you can see through and around it.
  - AR puts virtual things into users' real worlds, augmenting them

- VR is closed and fully immersive
  - VR puts users inside virtual worlds, immersing them

- Images are created using applications that mix virtual content and real life contents together

- Creation of an actual world, not just some contents of it

- Primary addressable markets: eCommerce, Voice calls, Web Browsing, Education/Training, Medical, Advertising

- Primary addressable markets: 3D films, Games, Theme parks, Live Sports and Concerts

Image Source: Wikipedia

*Other names and brands may be claimed as the property of others

AR VR – Where does it fit

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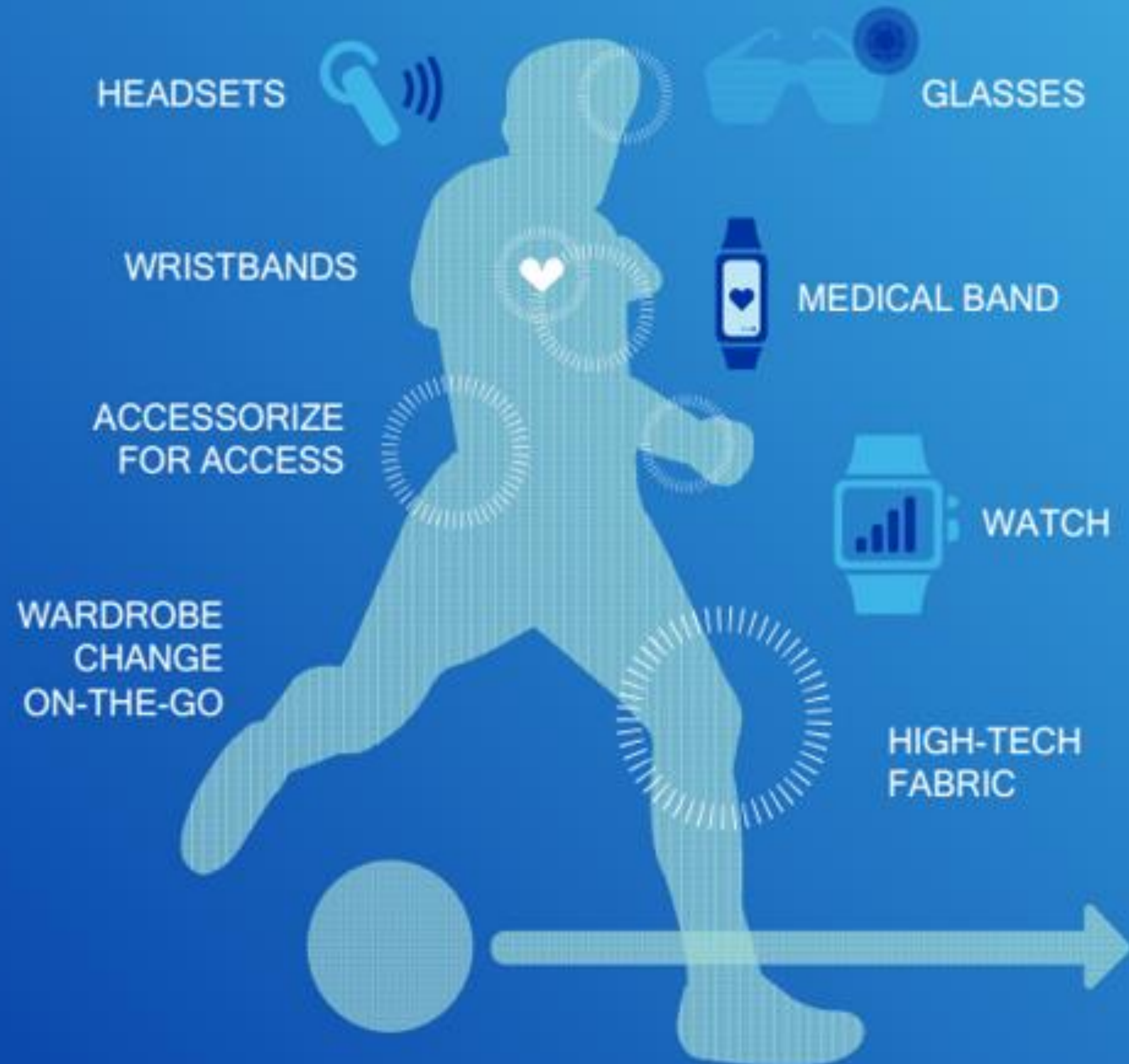
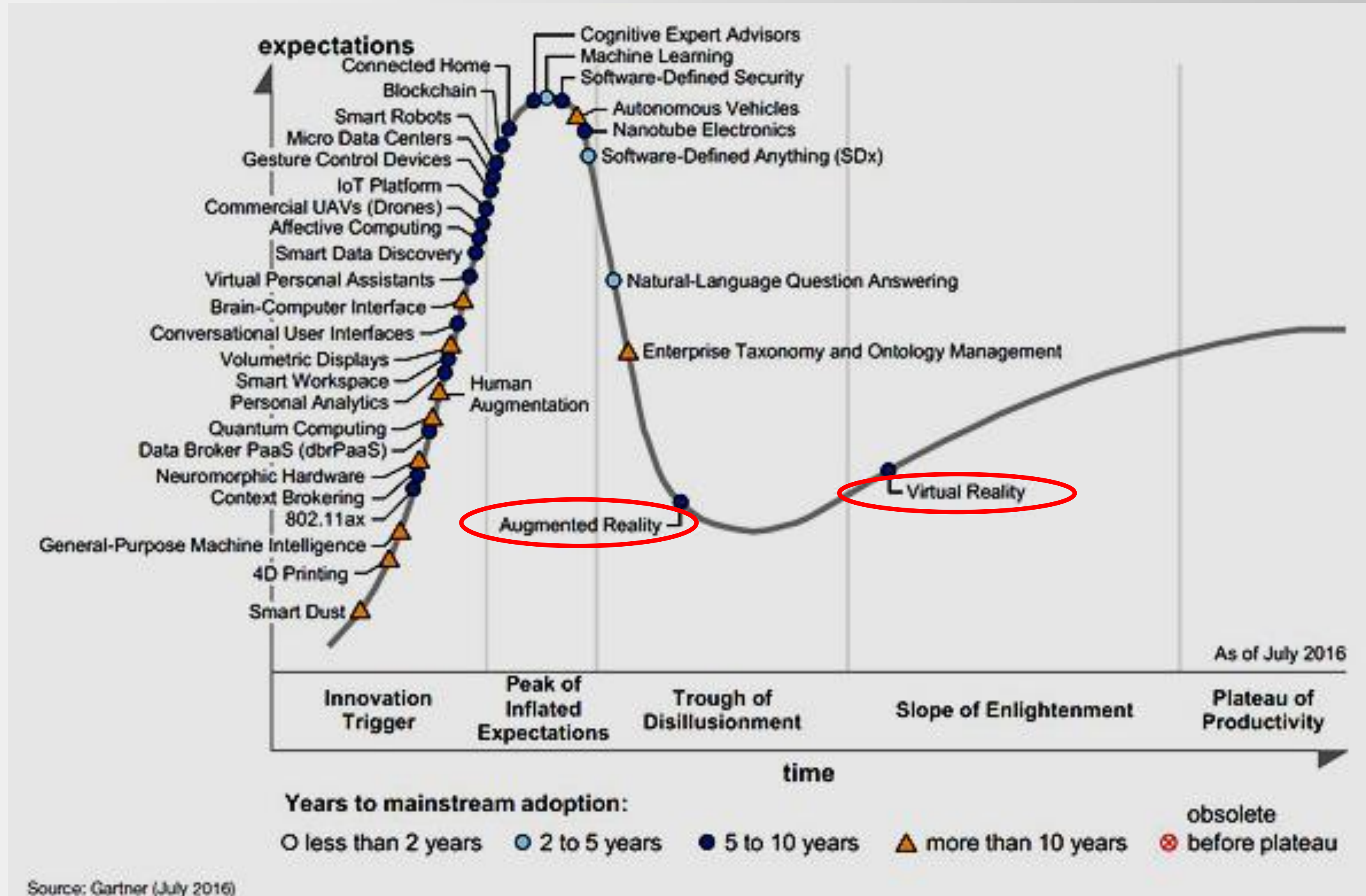
Wearable Vision

- Multiple wearables per person
- Connected with each other

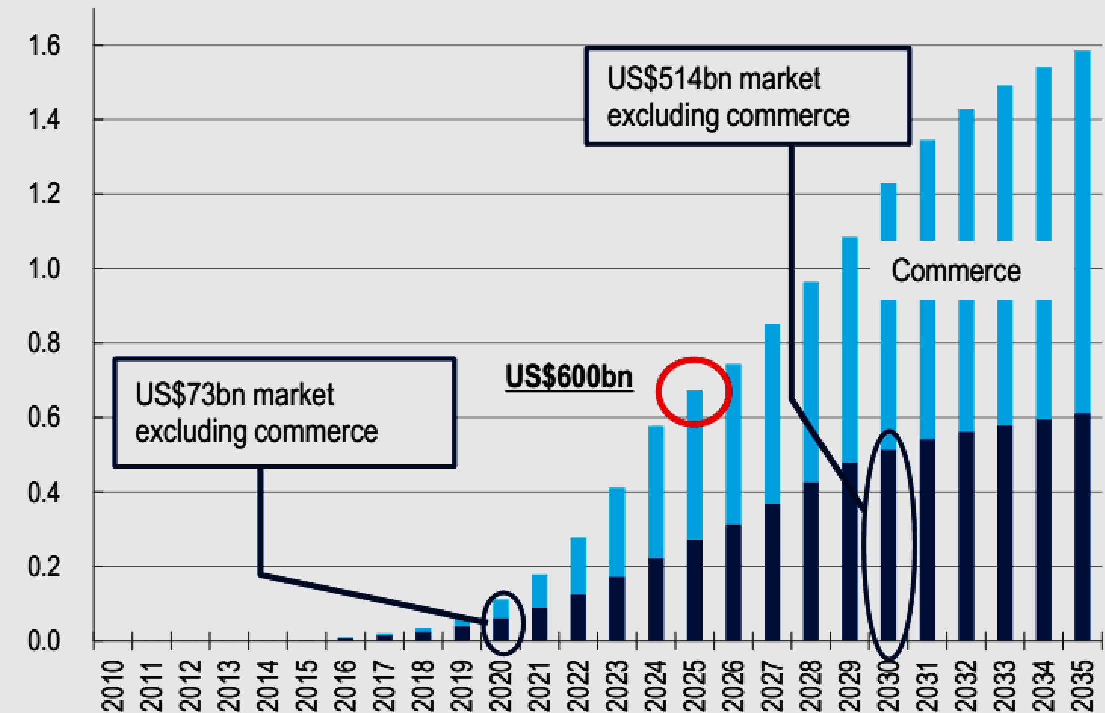


AR VR – What's the fuss?

Past the Hype Cycle peak?

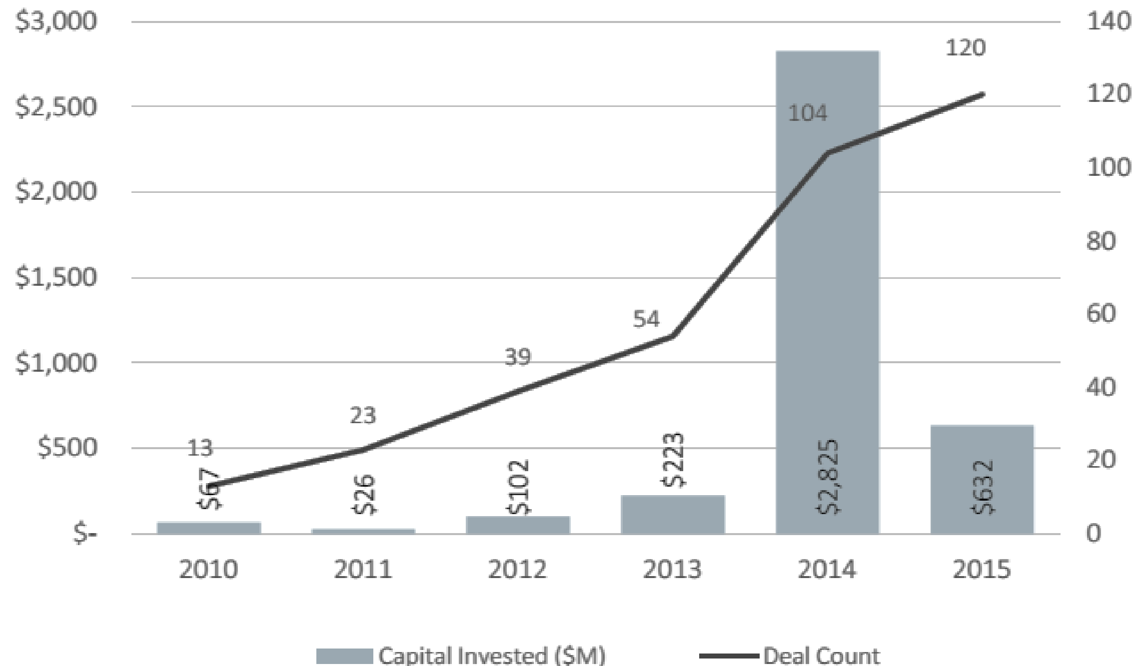


- Hardware: 18-20$B opportunity in 2020
- AR to outsell VR devices in the long term



Investments in AR VR

- $5B capital invested since 2010 with more than 60% in the 2014-2016
- $1.1B already invested in Q1 2016
- Diverse range of investor types – VCs have led the way, strategic capital and private equity have followed



MOST ACTIVE VR INVESTORS

		Number of investments
1	Rothenberg Ventures	12
2	River*	11
3	Intel Capital	10
4	Google Ventures	6
5	Partech Ventures	5
6	Qualcomm Ventures	5
7	Dolby Family Ventures	4
8	Formation 8	4
9	JAFCO	4
10	Andreessen Horowitz	3

*River is a program of Rothenberg Ventures

MOST CAPITALIZED VR COMPANIES

		Total amount raised
1	Oculus VR	$2.1B*
2	Magic Leap	$593.7M
3	LENSAR**	$191.1M
4	Jaunt	$101.3M
5	Blippar	$70.1M
6	Vuforia	$65M
7	Matterport	$57.7M
8	Avegant	$37M
9	NextVR	$36M
10	Playful	$33M

Notable: Metaio acquired by Apple for $32M in May 2015
*Includes FB acquisition
**Agreed to $59M acquisition on 11/16/2015

Source: Pitchbook 2015

AR VR – Evolution and Landscape

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Tethered/Untethered...Immersive/Non-Immersive

- Places the user in a virtual world, immersing them
- Limited mobility
- 3D Films, Gaming, Theme parks, Live sports, Concerts and Training

- Puts virtual things into users' real worlds, augmenting them
  - Use can see through and around glass
- Mobile experiences possible
- eCommerce, Voice Calls, Web Browsing, Medical, Advertising, Automobile

AR-VR Evolution

VR

immersive

virtual world

tele-existence
(being at the place and interact)

ambient

immersive AR
(solid objects/human CG in the real fileld)

video call
FPS game

automotive HUD

real world

isolated

AR

text box in the air

transparent objects
in the real field

solid objects in teh
real world

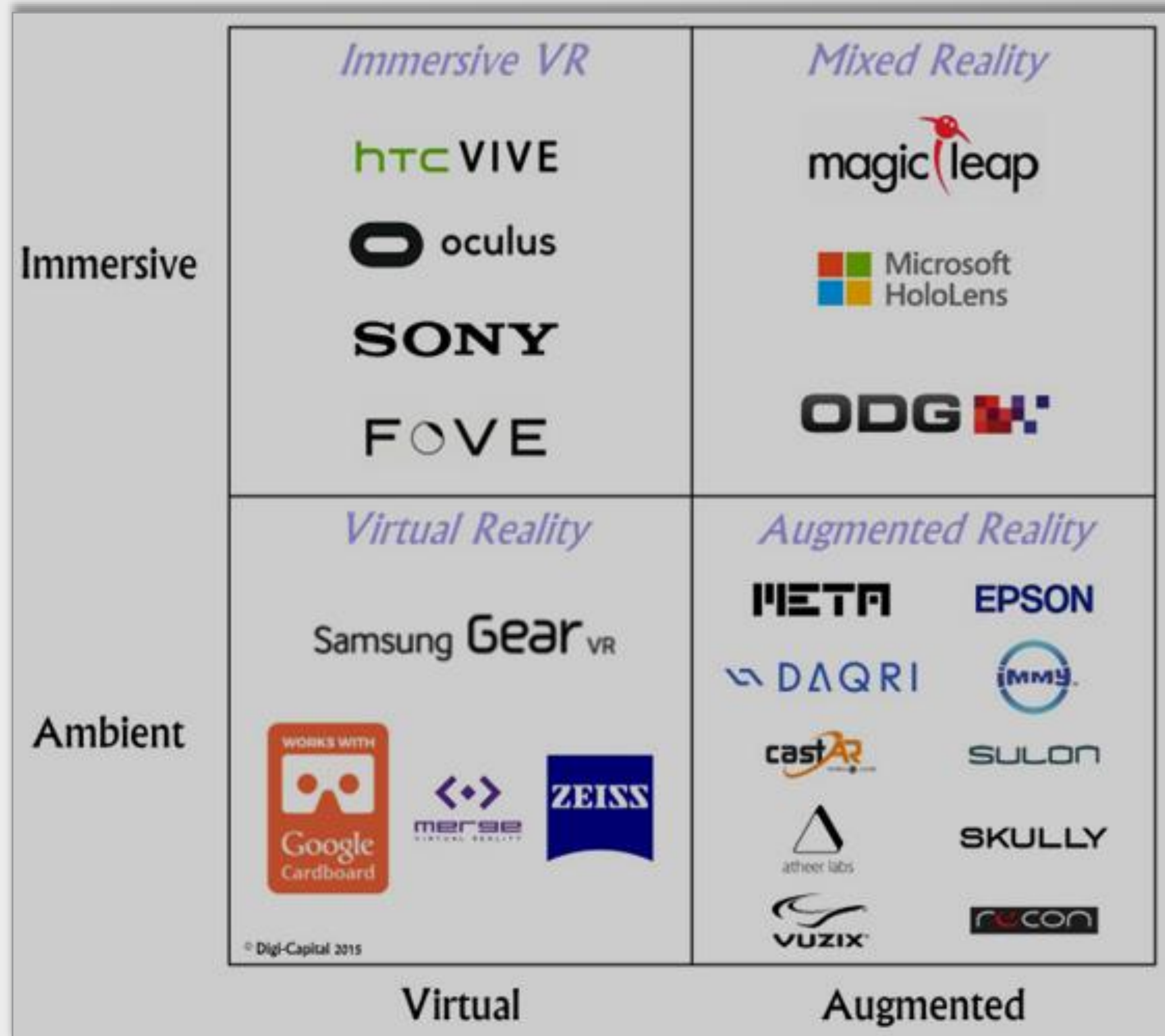
Source: Citi Research

Virtual Reality Evolution

Augmented Reality Evolution

*Other names and brands may be claimed as the property of others

Competitive Landscape



Virtual: real world is blocked out (i.e. user can only see the virtual world and virtual objects)

Augmented: real world is not blocked out (i.e. user can see the real world and virtual objects)

Immersive: trick the user's brain into reacting as though it was a real experience

Ambient: one or more of the characteristics(position tracking, FOV etc.) doesn't provide the same level of experience as Immersive

*Other names and brands may be claimed as the property of others

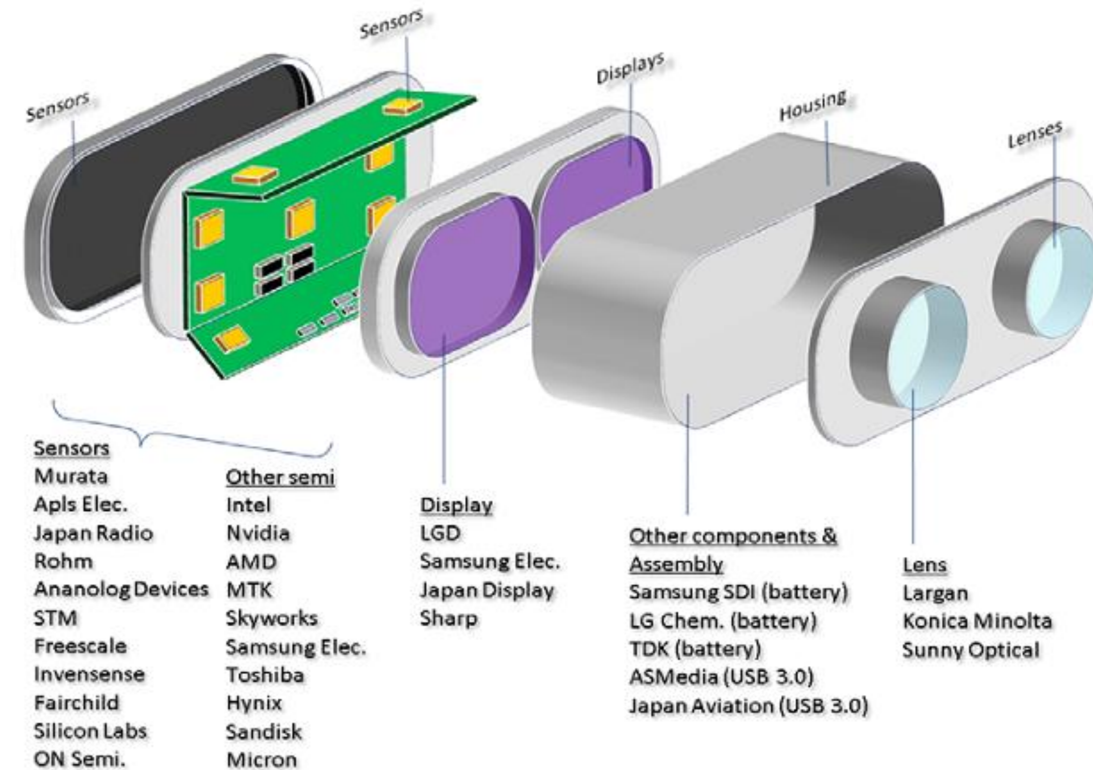
AR VR – Architecture & Recommendations

VR platform components

- VR
  - Software
    - Content
      - Film
      - Video games
      - Live streams
    - Enterprise
      - Virtual design
  - Hardware
    - Tracking devices & cameras
    - HMDs
      - Screen displays
    - Control inputs
    - Computing platforms
      - CPUs
      - Graphics cards & GPUs

Typical HMD Design

- VR experiences are complex with many moving pieces involved
- They must all come together near perfectly for a realistic experience



Source: Citi Research.

Keys Specifications

- **Key to good VR Experience**
  - Refresh rates (min: 60fps)
  - Field of View (min: 100 deg)
  - Display quality (OLED or LCDs)
- **Memory utilization**
  - Not all designs will have significant memory in them
  - Due to its mobile nature, requirement for continuous image processing, AR and untethered VR devices likely to be memory rich

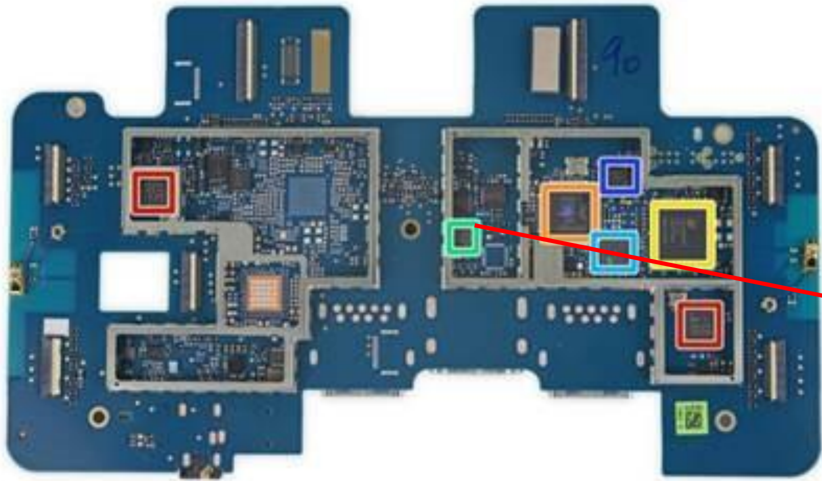
Table 1. Major VR specifications and release dates

	Platform	Display Technology	Resolution	Refresh Rate	Head Tracking	Field of View	Price	Release date
Virtual Reality HMD								
Zeiss VR One	Smartphone	4.7~5.2 inch	Full HD (1080p), 4K Display	-	Internal tracking by smartphone sensors	100°	$120	December, 2014
Fove VR	PC	5.7 inch	WQHD (2560 x 1440)	60 fps (90 fps projected)	Interactive eye-tracking	100°	$349	2016
Valve/HTC Vive	PC	OLED	2160x1200 (1080x1200 per eye)	90 Hz	Lighthouse (2 base stations emitting pulsed lasers)	110°	$201 to $600	April, 2016 for consumer version
Oculus Rift	PC	OLED	2160x1200 (1080x1200 per eye)	90 Hz	6DOF (3-axis rotational tracking + 3-axis positional tracking)	110°	$599 (Pre Order Price)	March 28, 2016
Sony PlayStation VR	Console	5.7 inch OLED	1920×1080 px (960×1080 per eye)	120 Hz	6-axis head tracking sensor	100°	$800	June, 2016
Modular Systems								
Samsung Gear VR	Smartphone	-	-	-	Custom IMU for rotational tracking	96°	$99	November, 2015
Apple Mattel View-Master VR	Smartphone	-	-	-	-	-	$30	February, 2016
	Platform	**Resolution**	**Processor**	**Memory**	**Storage**	**Field of View**	**Price**	**Release date**
Augmented Reality HMD								
Epson Moverio BT-200	Android Smartphone	960x540	TI OMAP 4460 1.2Ghz Dual Core	1 GB RAM	8 GB	23° for each eye	$699	2014
VUZIX M100 Prosumer	Smartphone	400 x 240 WQVGA	1.2 GHz OMAP4460	1 GB RAM	4 GB flash	15°, equivalent to a 4" mobile device screen viewed at a distance of 14"	$999	2013
Meta 1	-	-	960x540 per eye	-	-	23-degree for each eye	$750	September, 2014
Recon Jet	Android Smartphone	400x240 WQVGA	1 Ghz dual-core ARM Cortex-A9	1 GB SDRAM	8 GB flash	30" HD display at 7'	$499	-
Fujitsu IoT Solution Ubiquitousware HMD	Android Smartphone	854 x 480 (FWVGA)	APQ8026 Quad Core 1.2GHz	2 GB RAM	8 GB ROM	-	-	May, 2015
Hybrid HMD								
Microsoft HoloLens	PC	Full HD (1080p) or HD (720p)	Intel Atom processor	-	-	15" screen at 2'	$3,000	1Q16
Head-Up Display								
Google Glass	Smartphone	Prism projector, 640×360 pixels (equivalent of a 25 in/64 cm screen from 8 ft/2.4 m away)	OMAP 4430 SoC, dual-core 1GHz	2 GB RAM	16 GB flash	25" HD screen from 8' away	$1500 + Tax	February, 2013 for developers
GlassUp	Smartphone	320x240	OMAP 4430 SoC, dual-core 1GHz	-	-	-	$349	-

Source: News reports, Korea Investment & Securities

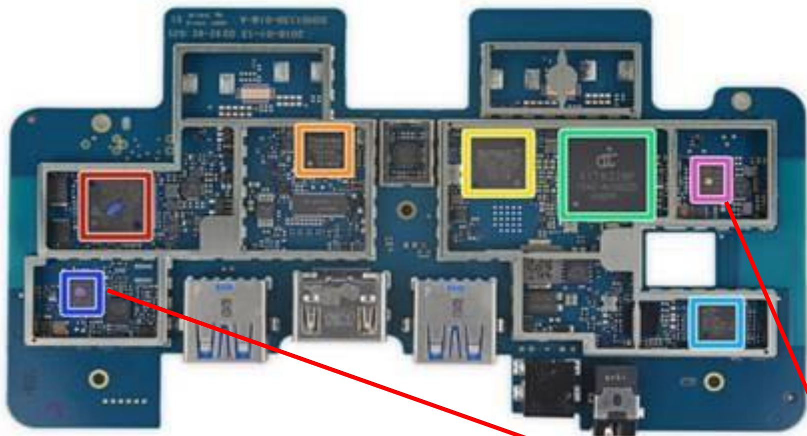
Teardown of HTC Vive* (Tethered VR)

- Tethered devices likely to outsource computing to standalone computing devices like PC/Gaming Consoles
- Flash Memory(Serial NOR) in densities ranging from *4Mb -256Mb most popular*
- Likely to migrate to Serial NAND as sophisticated features push for higher densities



Step 11 Edit

- Bringing up the rear, we have:
  - Nordic Semiconductor nRF24LU1P 2.4 GHz SoC (x2)
  - NXP Semiconductors 11U35F ARM Cortex-M0 Microcontroller
  - Lattice Semiconductor ICE40HX8K-CB132 Ultra-low Power FPGA
  - Invensense MPU-6500 6-axis Gyroscope and Accelerometer Combo
  - Micron N25Q032A13ESE40E 32 Mb Serial Flash Memory
  - National Semiconductor 61AE81U L00075B



Step 9 Edit

- We have liftoff—of the motherboard, that is. Let's see what sort of silicon is lurking beneath those huge ~~heat~~ EMI shields. On the front side of the board:
  - STMicroelectronics 32F072R8 ARM Cortex-M0 Microcontroller
  - Toshiba TC358870XBG 4K HDMI to MIPI Dual-DSI Converter (Also found in Oculus Rift CV1)
  - SMSC USB5537B 7-Port USB Hub Controller
  - Alpha Imaging Technology AIT8328 SoC With Image Signal Processor
  - Cmedia CM108B USB Audio Codec
  - Micron M25P40 4 Mb Serial Flash Memory
  - Micron N25Q032A13ESE40E 32 Mb Serial Flash Memory

Source: iFixit

Image Source: Wikipedia

*Other names and brands may be claimed as the property of others

HoloLens Hardware Specifications

OS	Windows 10.0.11802.1033 32-bit
CPU	Intel Atom x5-Z8100 1.04 GHz Intel Airmont (14nm) 4 Logical Processors 64-bit capable
GPU/HPU	HoloLens Graphics
GPU Vendor ID	8086h (Intel)
Dedicated Video Memory	114 MB
Shared System Memory	980 MB
RAM	2GB
Storage	64GB (54.09 GB available)
App Memory Usage Limit	900 MB
Battery	16,500 mWh
Camera Photos	2.4 MP (2048x1152)
Camera Video	1.1 MP (1408x792)
Video Speed	30 FPS

Source: Windows Central

Microsoft Hololens* (Untethered)

- Untethered devices likely pack powerful processors and high density memory for local compute capabilities
- Cutting Edge Mobile Memory – *16-64Gb LPDDR4/LPDDR5 most popular*
- Higher Storage Density requirements – *32-128GB eMMC. UFS likely as well*

Image Source: Wikipedia

*Other names and brands may be claimed as the property of others

Recommended Memory Technologies (Summary)

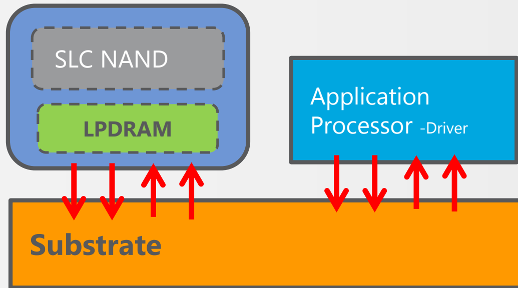
Application	Package	Memory	Storage	
Tethered VR	Discrete	-	SPI NOR *(4Mb – 256Mb)*	TODAY
		LPDRAM	SPI NAND *(1Gb – 8Gb)*	FUTURE
	MCP (Multi-Chip Package)	LPDRAM + Flash		
Untethered AR VR	Discrete	LPDDR 4 *(8Gb – 32Gb)* LPDDR 5*	eMMC (NAND + uC) *(8GB – 128GB)*	TODAY
			UFS (NAND + uC) *(64GB-256GB)*	
			SD Cards*** *(32GB – 512GB)*	FUTURE
			BGA SSDs*** *(128GB – 512GB)*	
	MCP (Multi-Chip Package)	eMCP (e.MMC + LPDDR) uMCP (UFS + LPDDR)		

* Likely follow mobile adoption
** All densities are package only. Different pkgs. Possible.

*** Potential data storage for future designs

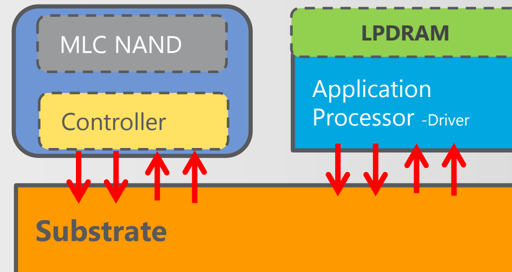
Package Options

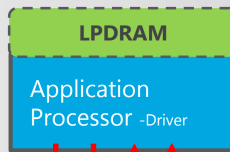
NAND MCP



Ultra low cost smart Phones
AIMM, DSC, CH

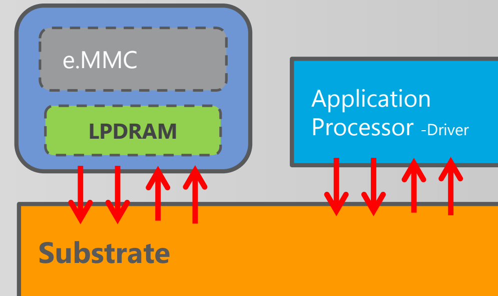
e.MMC





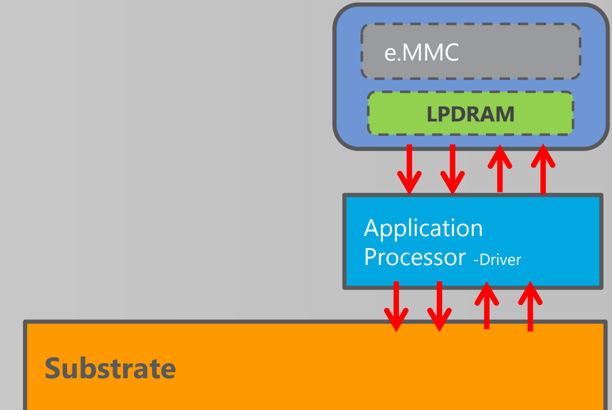
Premium smart phones &
Tablets, Auto, Wearables., AR/VR

eMCP



Mid-to-Low cost smart phones,
Wearables, IoT, M2M, IMM,
Telemetrics, AR/VR

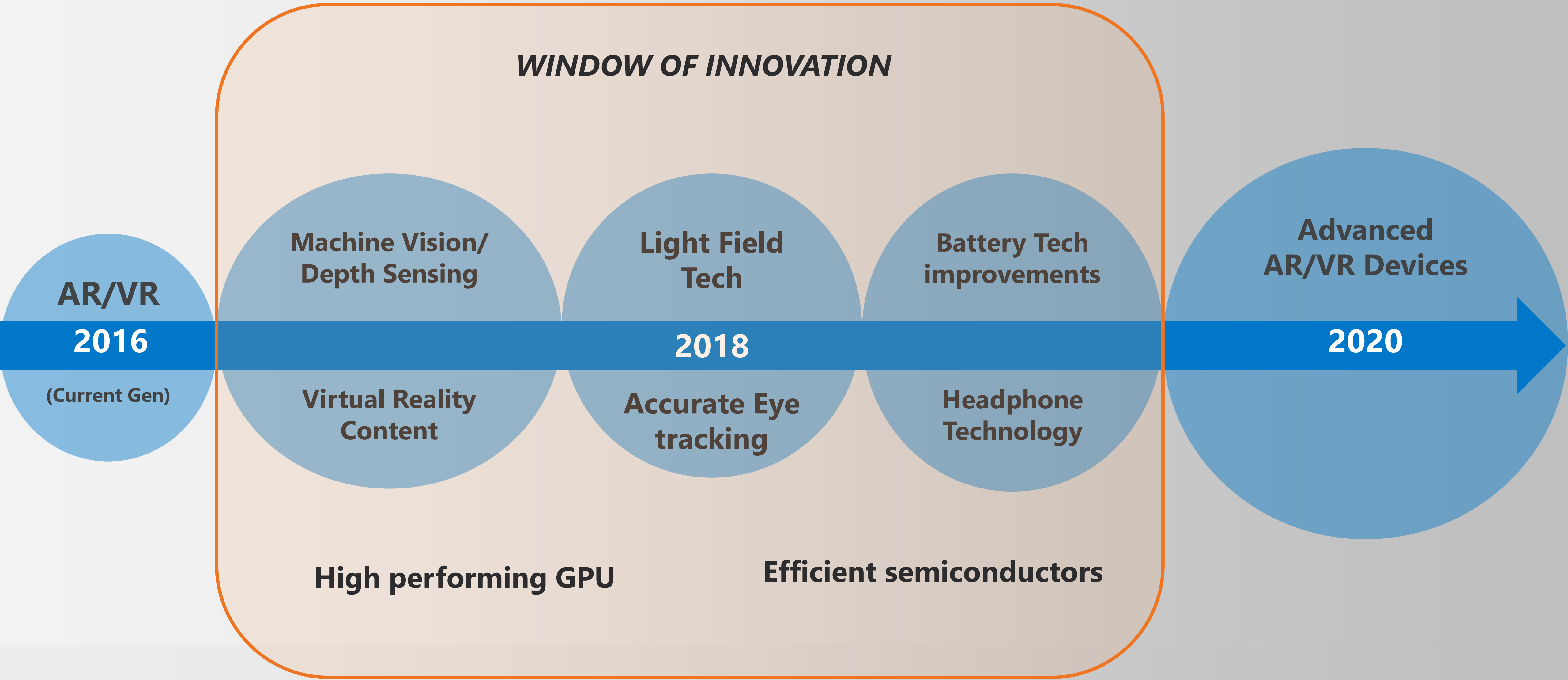
ePOP



High end smart watches,
High-to-Mid cost wearables,
Industrial, IoT

Likely Packages for AR/VR Devices

AR VR – Road to Advanced Devices


WINDOW OF INNOVATION
AR/VR
2016
(Current Gen)
Machine Vision/
Depth Sensing
Virtual Reality
Content
Light Field
Tech
2018
Accurate Eye
tracking
Battery Tech
improvements
Headphone
Technology
Advanced
AR/VR Devices
2020
High performing GPU
Efficient semiconductors

Micron®

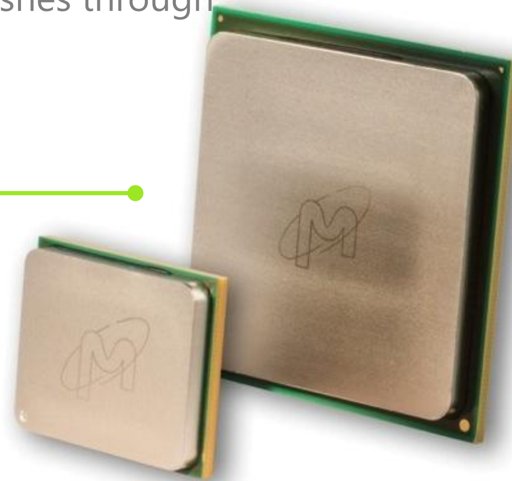
Leading with new innovations: HMC

Breaking through "memory wall"

- Evolutionary DRAM roadmaps hit limitations of bandwidth and power efficiency
- Micron introduces a new class of memory: Hybrid Memory Cube
- Unique combination of DRAMs on Logic smashes through the memory wall

Unparalleled performance

- Provides 15X the bandwidth of a DDR3 module
- Uses 70% less energy per bit than existing memory technologies
- Reduces the memory footprint by nearly 90% compared to today's RDIMMs



Key applications

- Data packet processing, data packet buffering, and storage applications
- Enterprise and computing applications

How did we do it?

- Micron-designed logic controller
- High speed link to CPU
- Massively parallel "Through Silicon Via" connection to DRAM

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Leading with new innovations: 3D NAND

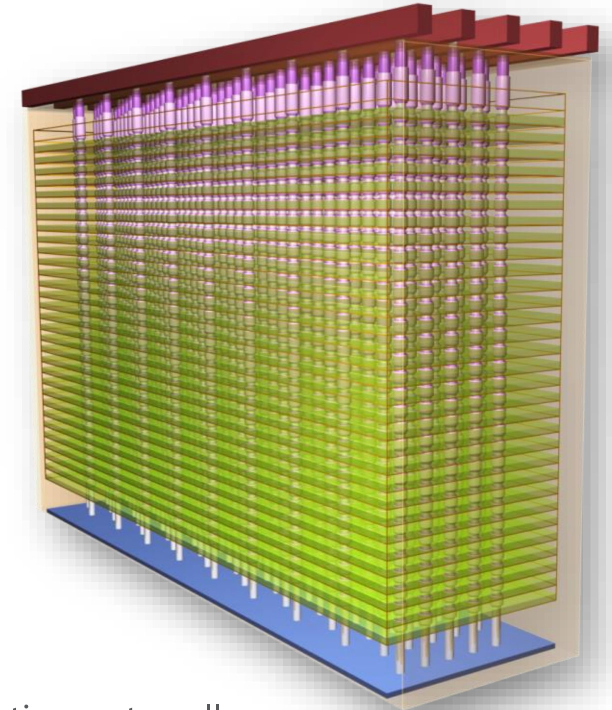
HOW 3D NAND ENABLES INNOVATION

Our 3D NAND solutions bring significant performance, power, and capacity advantages to storage applications

Pack in More Capacity
Get 3 times the capacity of existing NAND products—enough to enable 3.5TB gum stick-sized SSDs or more than 10TB in standard 2.5-inch SSDs.

Boost Performance
Achieve significantly higher read/write bandwidth and I/O speeds, as well as improved random read performance, thanks to our 3D NAND's fast 4K read mode.

Save Power
Reduce power consumption significantly in standby mode thanks to 3D NAND's new sleep mode features that cut power to inactive NAND die (even when other die in the same package are active).



How did we do it?
We're the first to employ floating gate cell technology in 3D NAND—a proven cell technology that enables better performance, quality, and reliability. We stack 32 storage tiers to achieve the highest-capacity NAND die available today: 256Gb multilevel cell (MLC) and 384Gb triple-level cell (TLC) 3D NAND.

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Leading with new innovations: 3D XPoint™ Memory

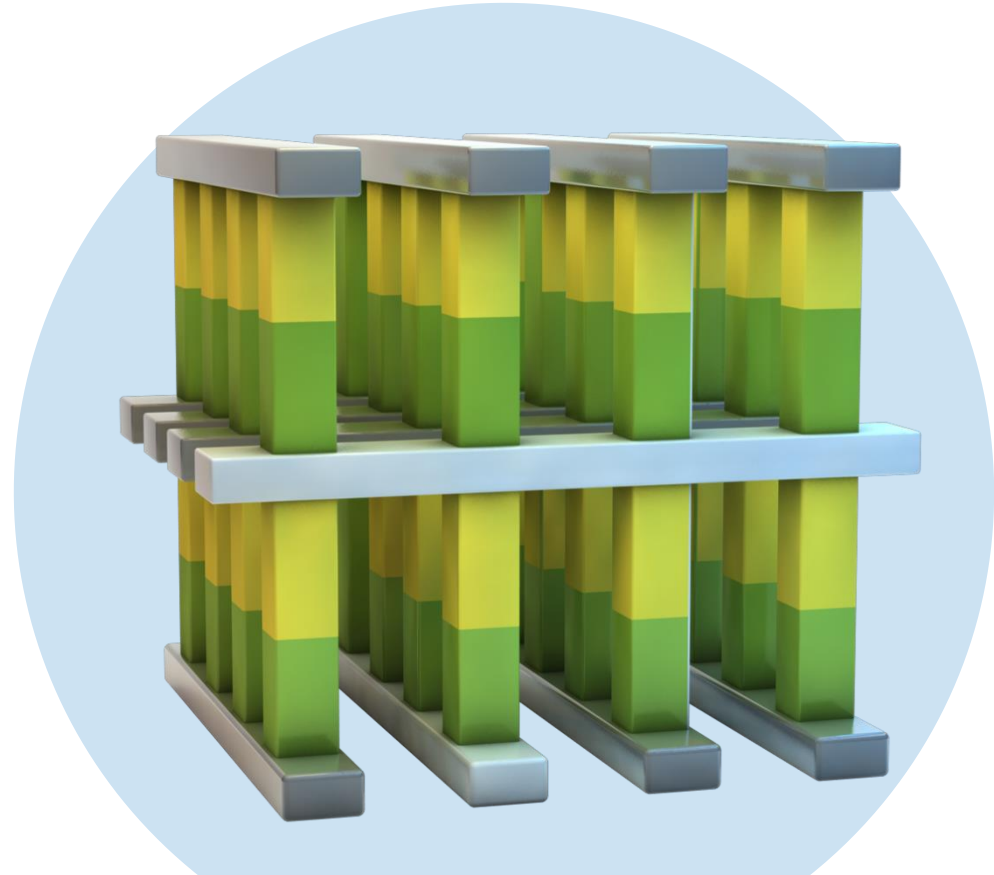
FIRST NEW MEMORY CATEGORY IN DECADES

- Combining the very best capabilities of existing technologies, 3D XPoint has the potential to dramatically transform computing architectures

1000X FASTER THAN NAND

1000X ENDURANCE OF NAND

10X DENSER THAN CONVENTIONAL MEMORY



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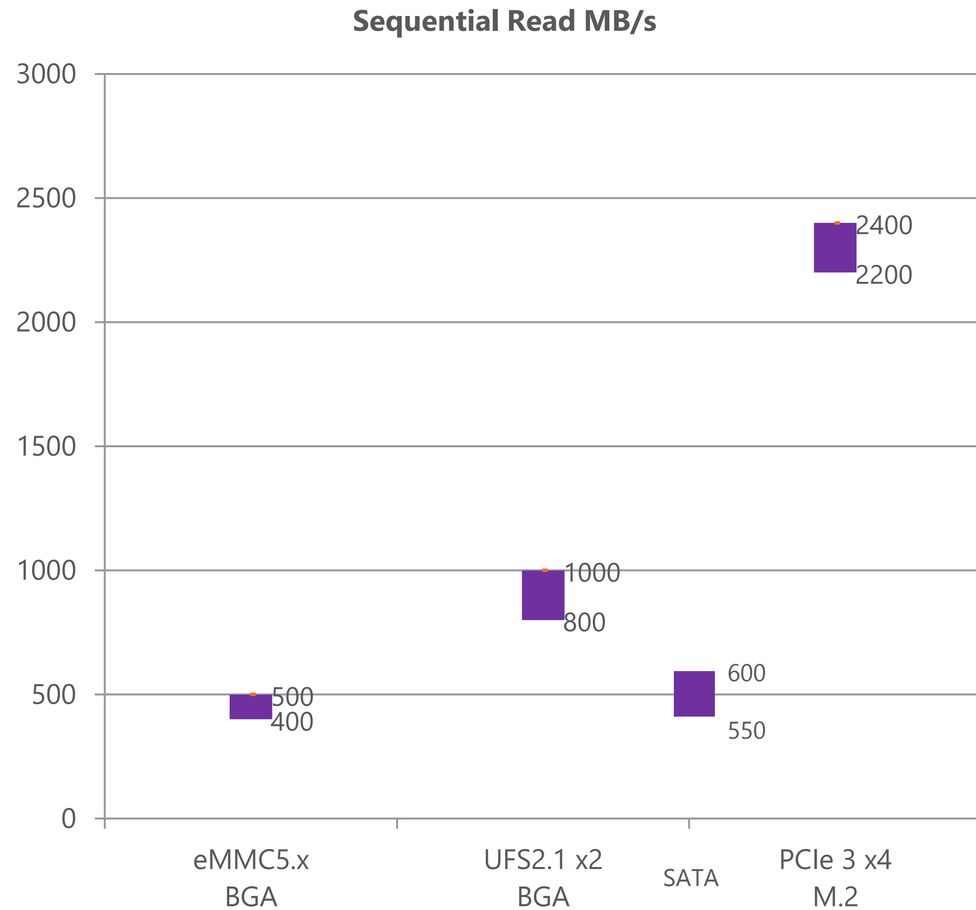
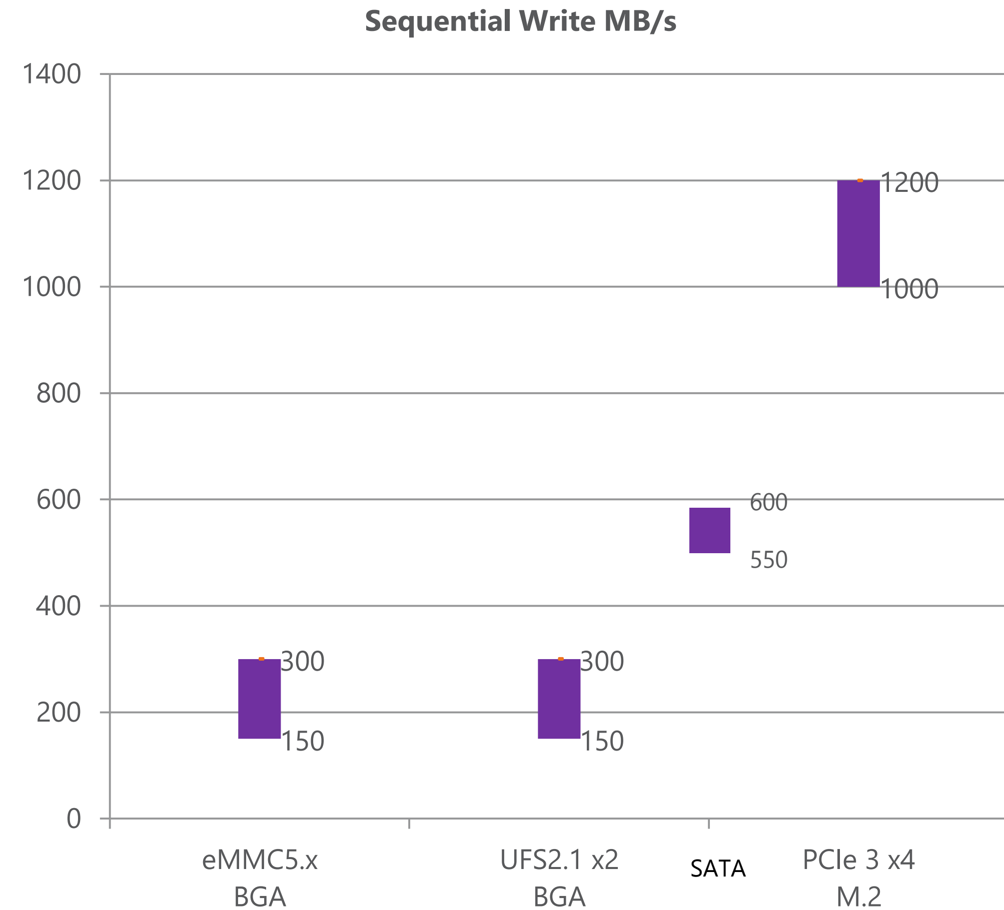
eMMC, UFS, and PCIe Comparison (32-256GB)





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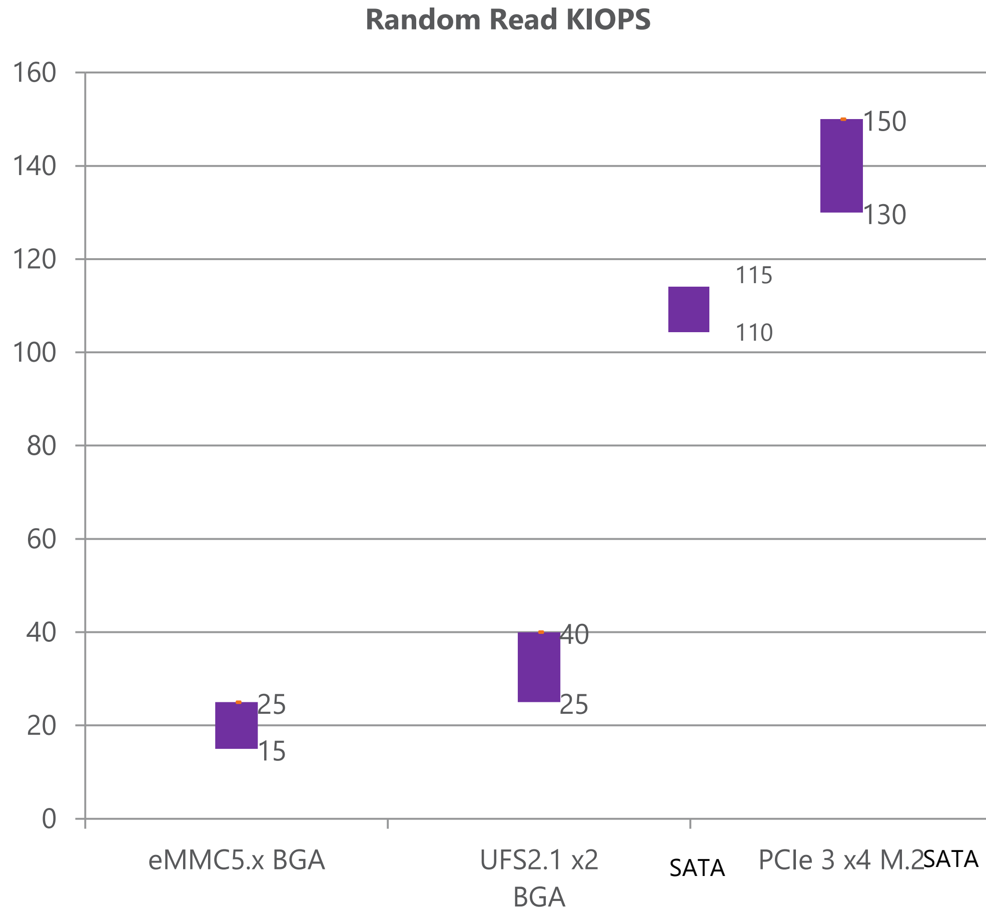
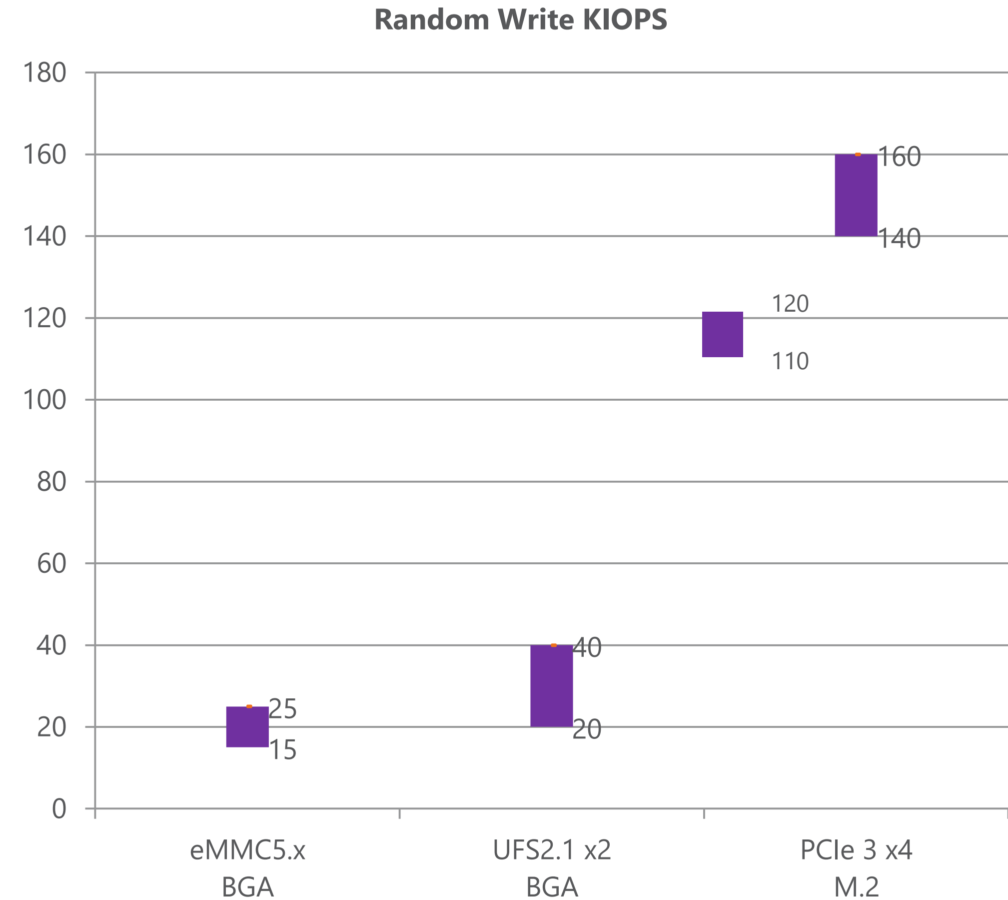
eMMC, UFS, and PCIe Comparison





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What can hardware look like?

OVERVIEW

R-7 is a totally new device incorporating ODG's next generation optics, electronics and industrial design.

Targeted to Enterprise customers, the R-7 delivers a powerful and robust solution in a new lighter and tighter profile.

DETAILS

HARDWARE:

Qualcomm SnapdragonTM 805 2.7GHz quad-core Processor

3GB Pop LP-DDR3 RAM

64GB Storage

1300mAH Lithium-Ion Battery Capacity

3 Replaceable Magnetic Nose Bridges

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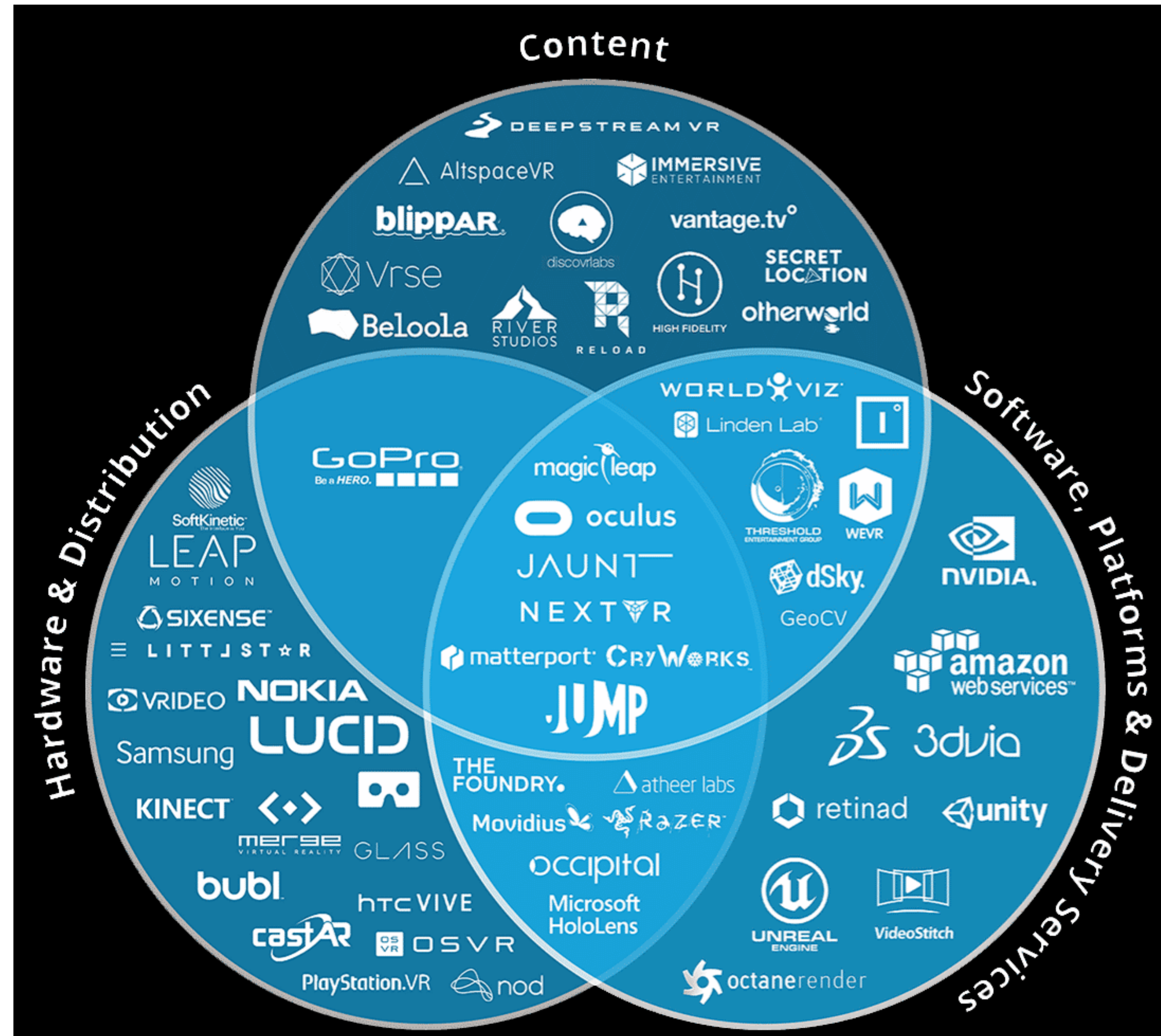
Ecosystem



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