



# Trends and challenges in virtual reality services for 360° video delivery and consumption

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# Forms of reality- VR/AR/MR...RR?

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VR

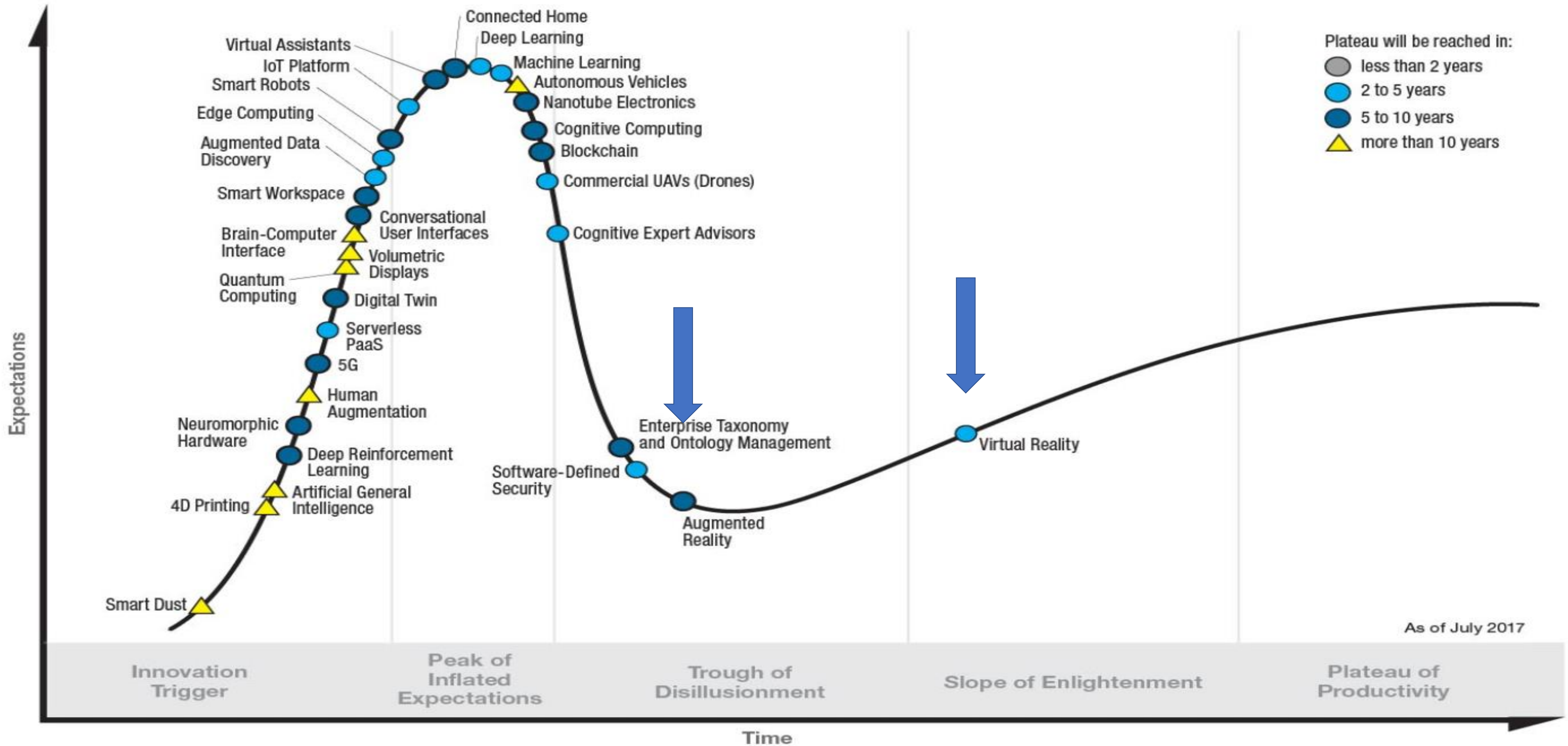


AR

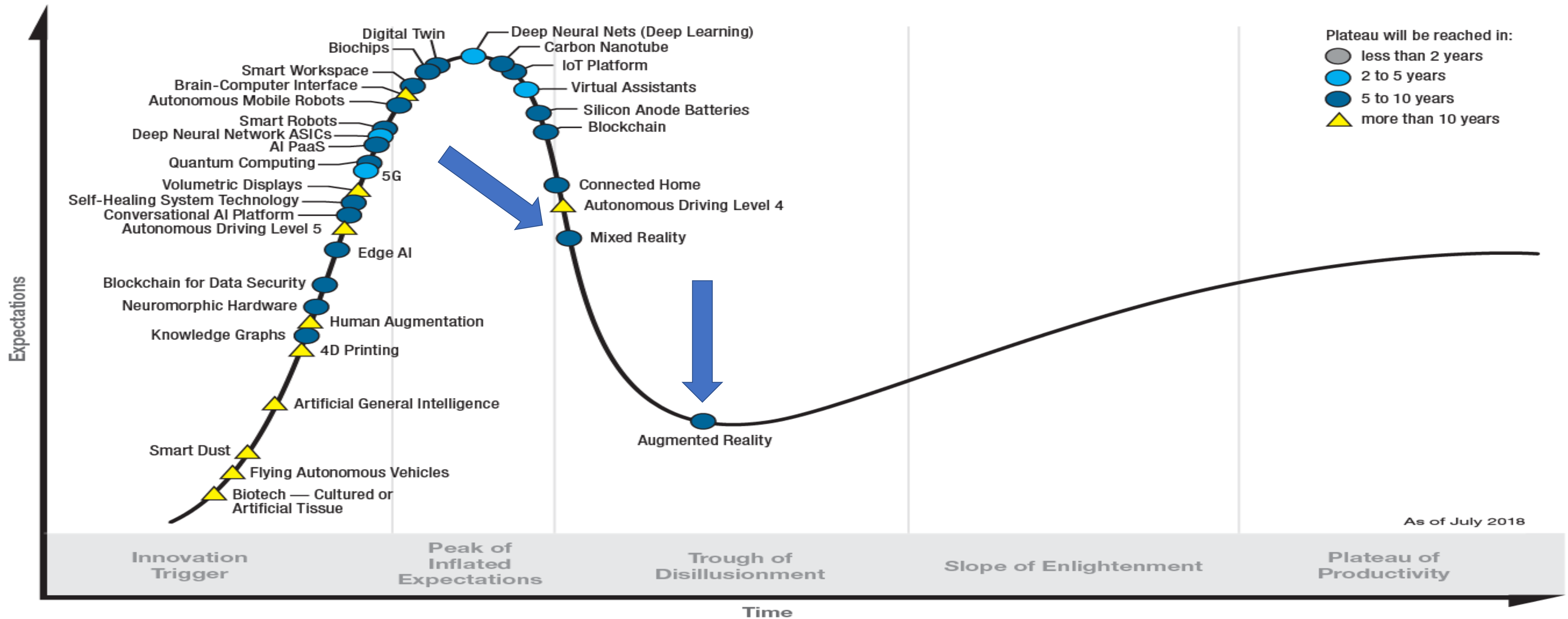


MR

# Gartner **Hype Cycle** for Emerging Technologies, 2017



# Hype Cycle for Emerging Technologies, 2018

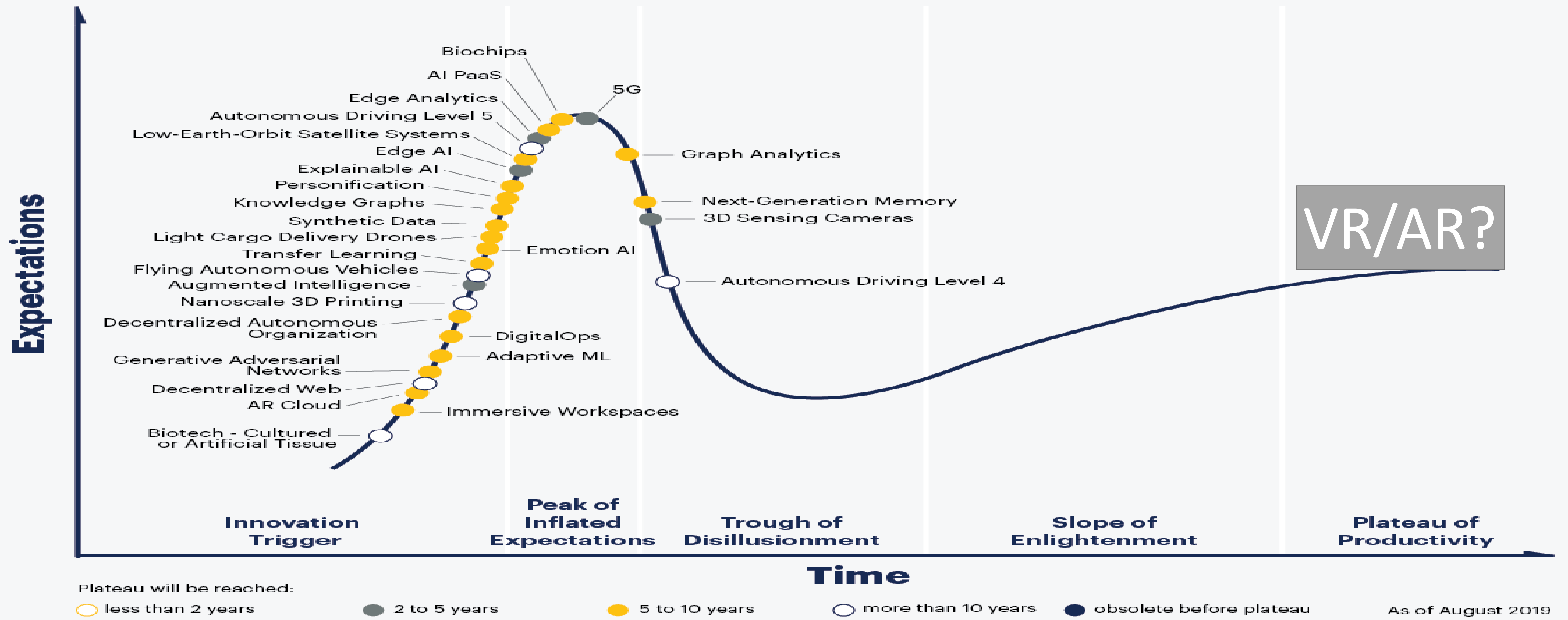


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# Gartner Hype Cycle for Emerging Technologies, 2019



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# AR/VR Leaders\*

\* Includes funded/exited startups and selected corporates

<b>Advertising/marketing</b> 	<b>Art/design</b> 	<b>Business</b> 	<b>Distribution</b> 
<b>eCommerce</b> 	<b>Education</b> 	<b>Enterprise</b> 	<b>Entertainment</b> 
<b>Games</b> 		<b>Health/Fitness</b> 	<b>Kids</b> 
<b>Location based</b> 	<b>Medical</b> 	<b>Music</b> 	<b>Lifestyle</b> 
<b>Navigation</b> 			

AR/VR market transition begins as startups raise record \$3.6 billion

<b>News</b> 	<b>Peripherals</b> 	<b>Photo/video</b> 
<b>Productivity</b> 	<b>Smartglasses</b> 	<b>Solutions/services</b> 
<b>Social</b> 	<b>Sports</b> 	<b>Tech</b> 
<b>Travel/transport</b> 	<b>Utilities</b> 	<b>VR headset</b> 



Content acquisition and creation

# Virtual reality content

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- Computer generated content (3D)
- Real world content (images/video)
  - Omnidirectional video (360° video)
  - Omnidirectional video 3D (stereoscopic)
- A combination of both!

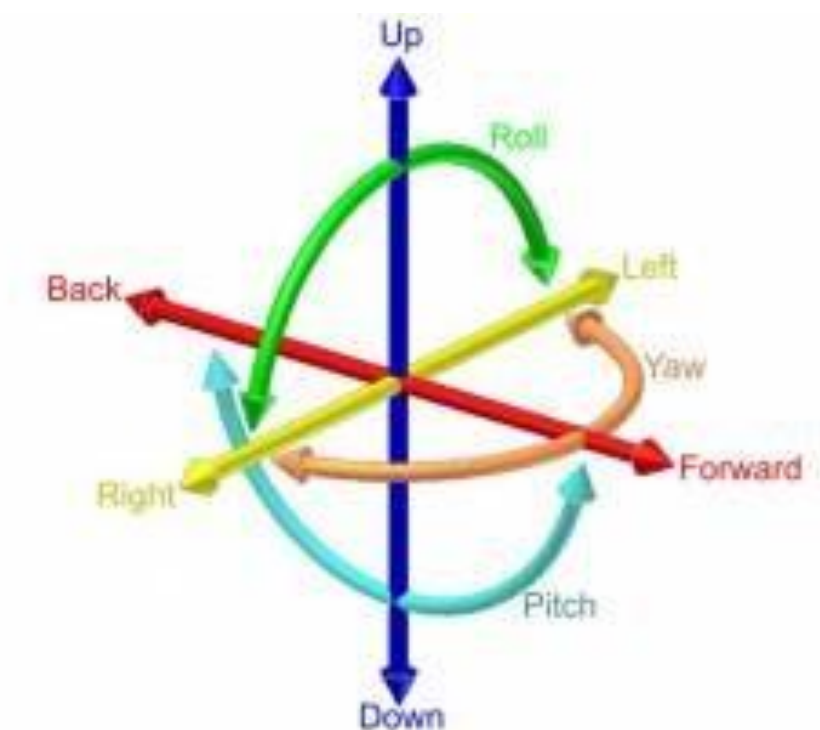




# 360° video

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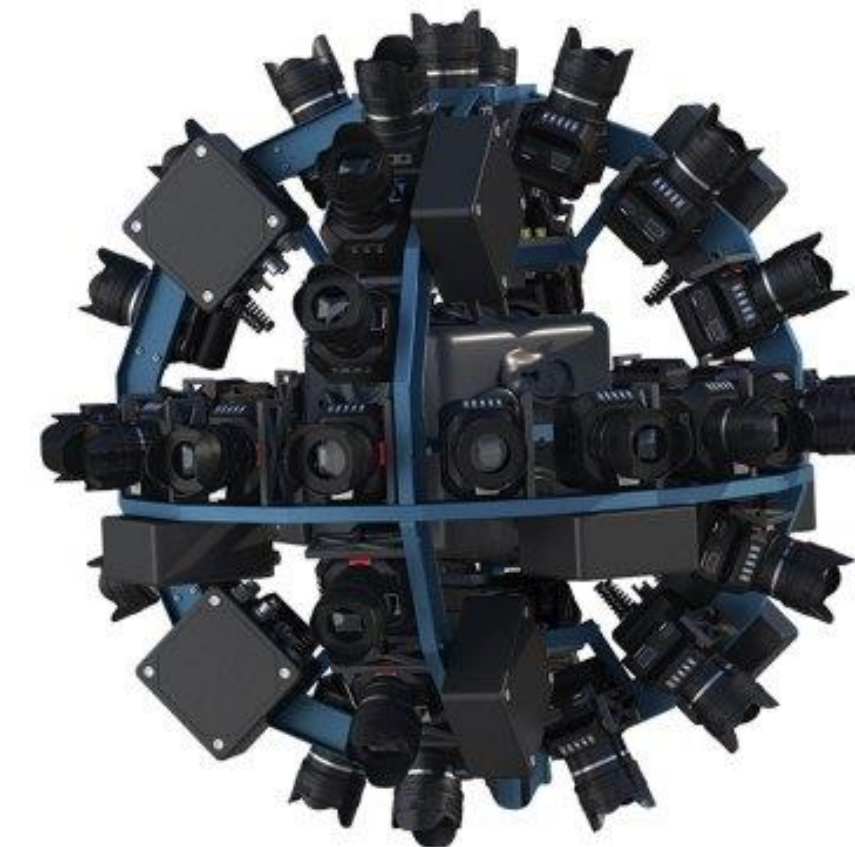
- Omnidirectional video (spherical, immersive, 360° video) is a recording, which captures all directions of view around the viewer/camera
- Captured with special, multi lens cameras
  - 2, 4, 6,...50
- 6 Degrees-Of-Freedom video (6DoF ), allows for movement through the scene
  - a.k.a Volumetric video



# Professional cameras for 360° videos

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- Integrated cameras or rig assemblies
- Up to 50 cameras
  - Up to 14K in 3D 360°
- Price range: 4.000\$ do 200.000\$ per rig



# Consumer cameras for 360° videos

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- Simpler cameras with 2 lenses
  - 2D 360° or 3D 180° content
  - 5.7K@30 fps, 360° video
  - 4K@60fps, 360° video
  - 30Mbit/s - 120Mbit/s
  - H.264 or H.265
- Price range: 400\$ do 800\$













# Head mounted displays (HMD)

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# Head mounted displays (HMD) -2

		Resolution per eye	Refresh rate	Field of view					
	Sony PlayStation VR	960 × 1080	120	100					
	PIMAX 8K	3840 × 2160	120	200					
	StarVR	2560 × 1440	90	210					
	PIMAX 4K	1920 × 2160	60	110					
	HTC VIVE Pro	1440 × 1600	90	110					
	HTC VIVE Focus	1440 × 1600	75			Oculus Go	1280 × 1440	60	101
	Oculus Quest	1440 × 1600	72			Oculus Rift S	1280 × 1440	80	110
						Samsung Gear VR	1280 × 1440	60	101



Commercial 360° videostreaming services

# Pyeongchang Olympic games 2018

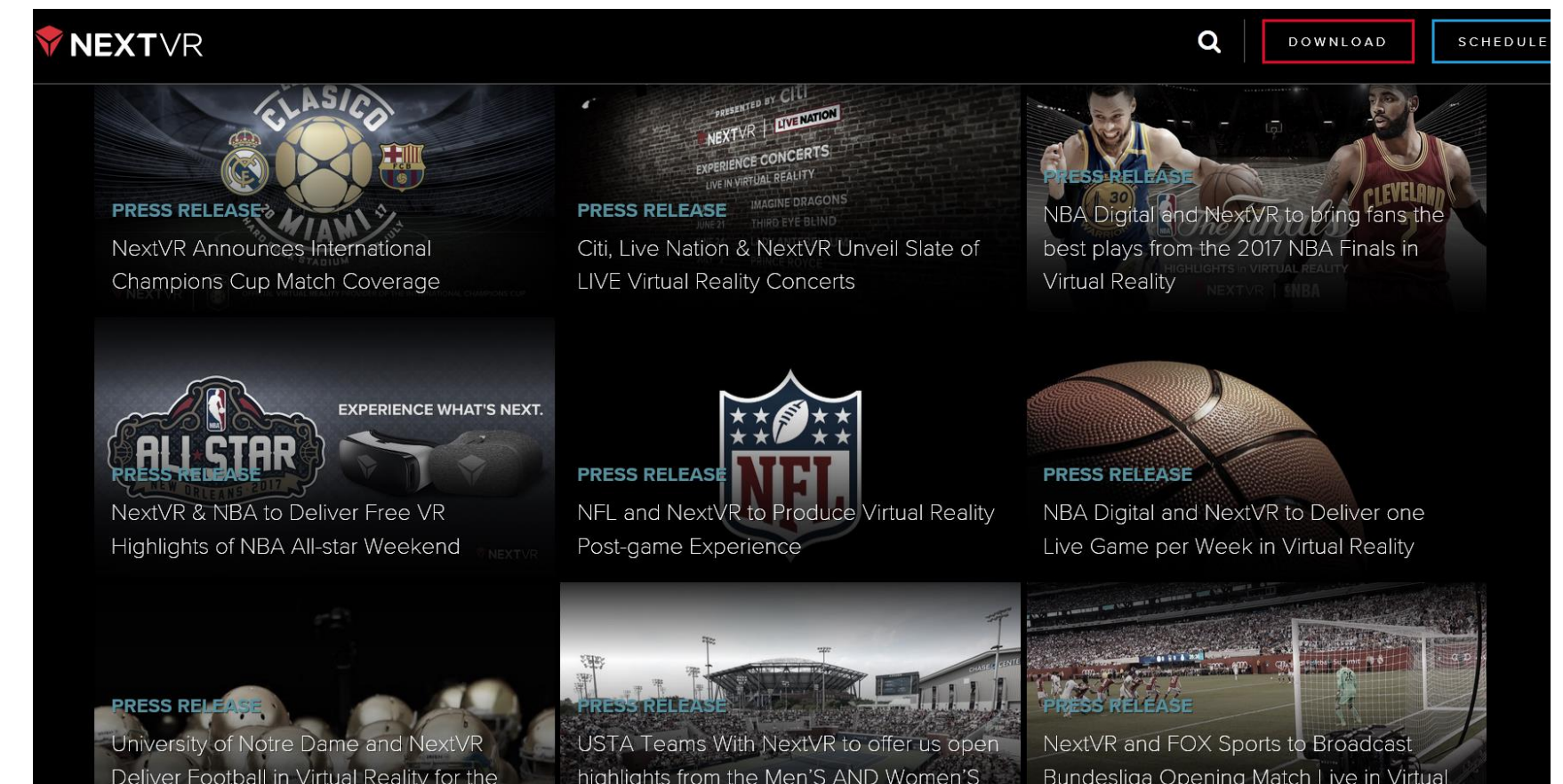
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- VR live broadcast
- Broadcast to 80 countries
- VR simulation devices with adrenalin rides and games



# NextVR

- Content:
  - NBA, NFL, WWE, Wimbledon, Fox sports, boxing,
  - Moscow ballet, Comedy central, documentaries
- VR platforms:
  - Gear VR, Google Daydream, Microsoft Mixed Reality, PlayStation VR, Oculus Go, HTC Vive, HTC Vive Pro, and Oculus Rift.
- 180° + 3D view with 60fps,
- 6K cameras, 4K content (in-house camera development!)
- Bitrate: 8Mbit/s





# NextVR future

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- Acquired by Apple in April 2020



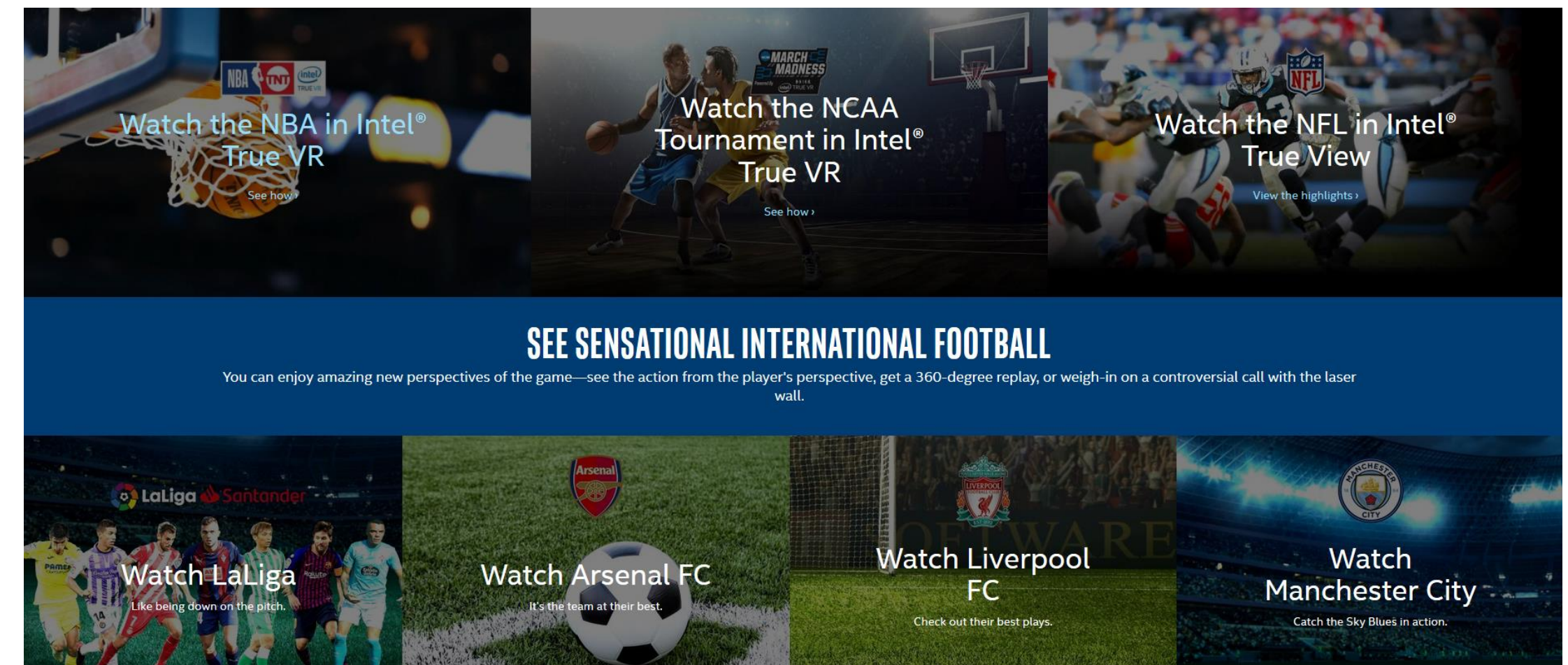
## **NextVR is Heading in a New Direction**

Thank you to our partners and fans around the world for the role you played in building this awesome platform for sports, music and entertainment experiences in Virtual Reality.

# Intel TrueVR

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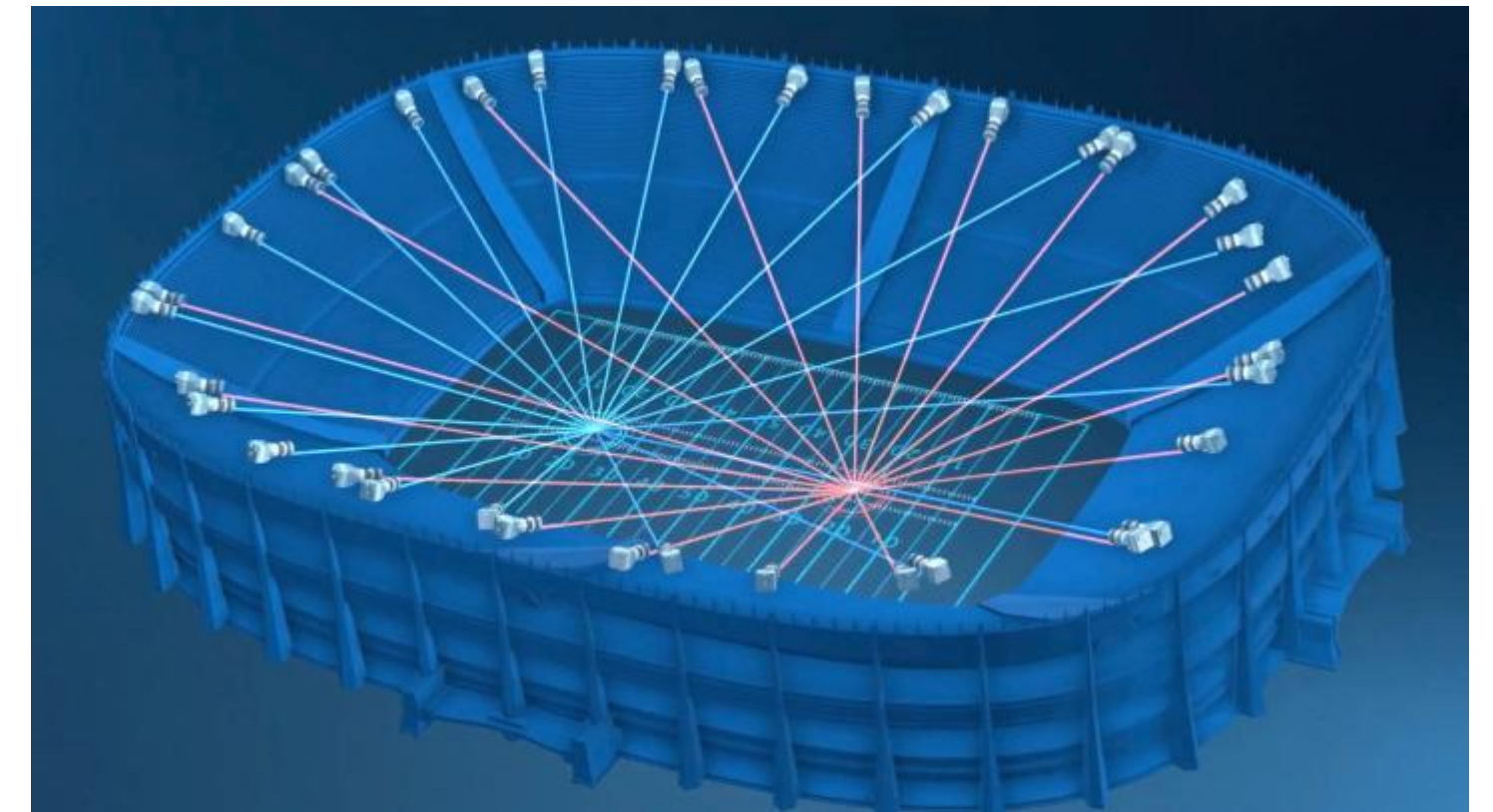
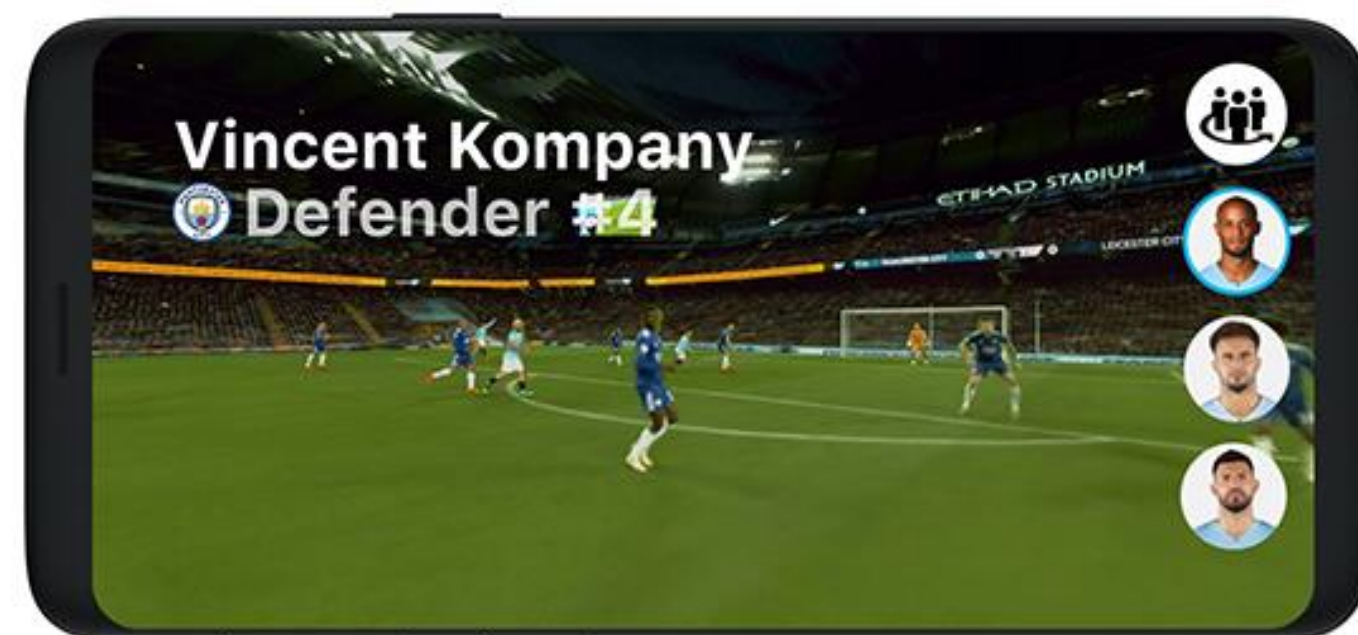
- Content:
  - NBA, La liga, Premier league, NCAA, NFL, MLB
  - OI 2018
- VR platforms:
  - Oculus GO, PC, mobile phones



# Intel TrueVR

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- 38 5K cameras
- 6DoF - players' perspective!
- Unknown bitrate



# Facebook 360FB

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- Recording and live broadcasting for Facebook users
- VR platforms: mobile phones, Samsung gear, Oculus,...
- Recommended cameras for recording ( 2K - 8K formats)
- 360° video recording
  - Live up to 4K@30fps (15 -20Mbit/s)
  - Offline upload up to 5120 x 2560@30fps (4K: 25 – 60Mbit/s)
- Media studio tool for video editing



# 360° educational video

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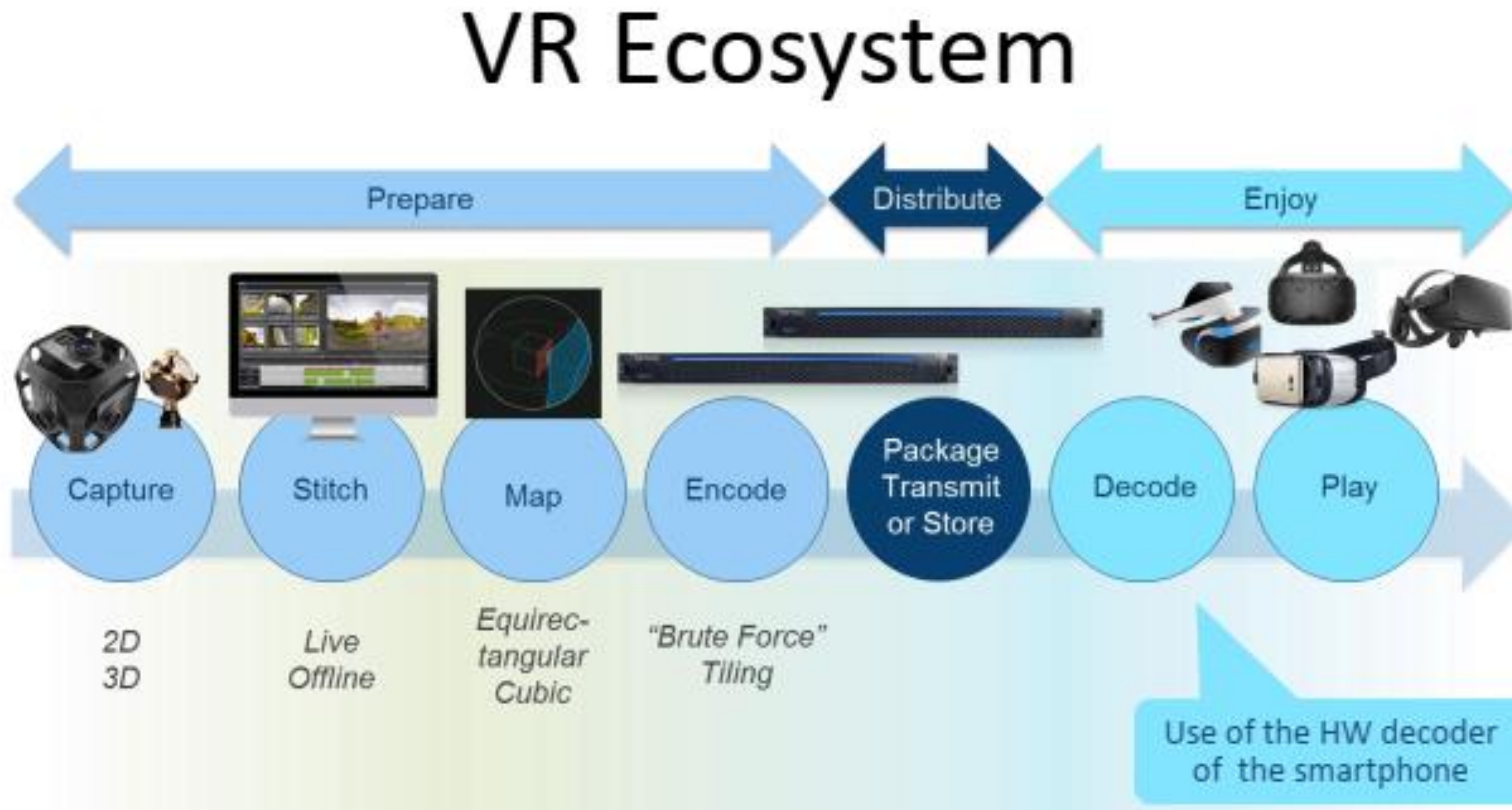
- Interactive VR presentation of selected occupations
- Smart phone, Oculus Go, Web browser
- 4K video, 15Mbit/s using H.264





360° video streaming

# Typical 360° video ecosystem



# Video bitrate factors

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- Codec
- Resolution
- FPS (25/50/100)
- Bit depth
- GOP
- Recorded scenes (dynamic/static)
  
- Comparisons are difficult!!!



# Codecs and bitrates

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- H.264
- VP8 in VP9 (YouTube)
- H.265 (HEVC)
- AV1 - 100x slower encoding than H.265
  
- Upcoming
  - H.266 (VVC)
  - 30% less bitrate than H.265

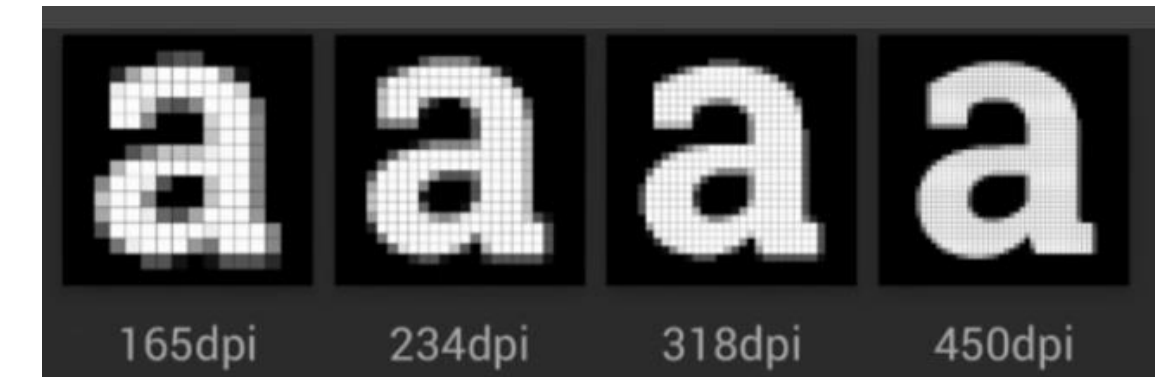




# Optimal resolution?

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- Human eye can perceive 60 pixels per degree
  - Retina displays
- 360° video requirements:
  - 360° horizontal x 180° vertical → 21.600 x 10.800 pixels
  - Optimal resolution is 24K (24576 x 12288 pixels )
- HMD retina displays:
  - 150° horizontal in 120° vertical → 9.600 x 7.200 pixels per eye



# Required bitrates - estimations

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- High quality 360° video using H.265
  - 4K, 30 fps, 8 bit → 15 - 40 Mbit/s
  - 8K, 30 fps, 8 bit → 60 - 90 Mbit/s
  - 12K, 30 fps, 10 bit → 100- 300 Mbit/s
  - 24K, 30fps, 12 bit → up to 1Gbit/s
- **A better 360° video streaming approach is needed**
- Latencies :
  - 20ms are acceptable, they may induce cyber sickness!
  - Network and devices are both contributing to latencies

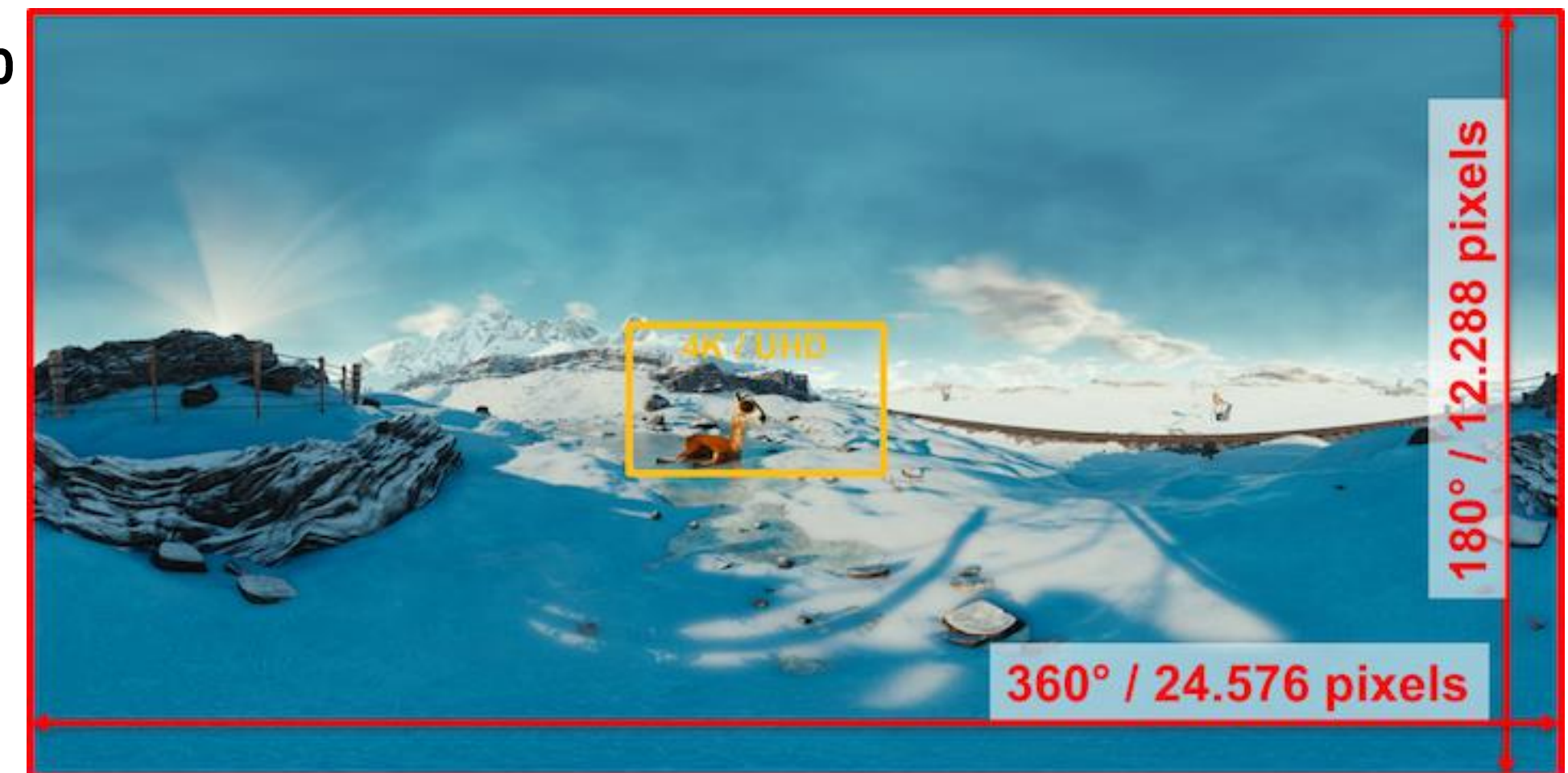
# Video consumption specifics on HMDs

- Typical Field of View (FOV):
  - Oculus: 110°
  - HTC Vive: 110°
  - Samsung Gear: 95°
  - Playstation VR: 100°

#	360° Video Resolution	Width of FOV Angle	FOV Video Resolution	Wasted data
1	4K : 4096x2048	120°	1280x720	90 %
2	4K : 4096x2048	90°	960x540	93.75 %
3	4K : 4096x2048	60°	640x360	97.22 %
4	16K: 16384x8192	120°	5120x2880	90 %
5	16K: 16384x8192	90°	3840x2160	93.75 %
6	16K: 16384x8192	60°	2560x1440	97.22 %
7	24K: 24576x12288	120°	7680x4320	90 %
8	24K: 24576x12288	90°	5760x3240	93.75 %
9	24K: 24576x12288	60°	3840x2160	97.22 %

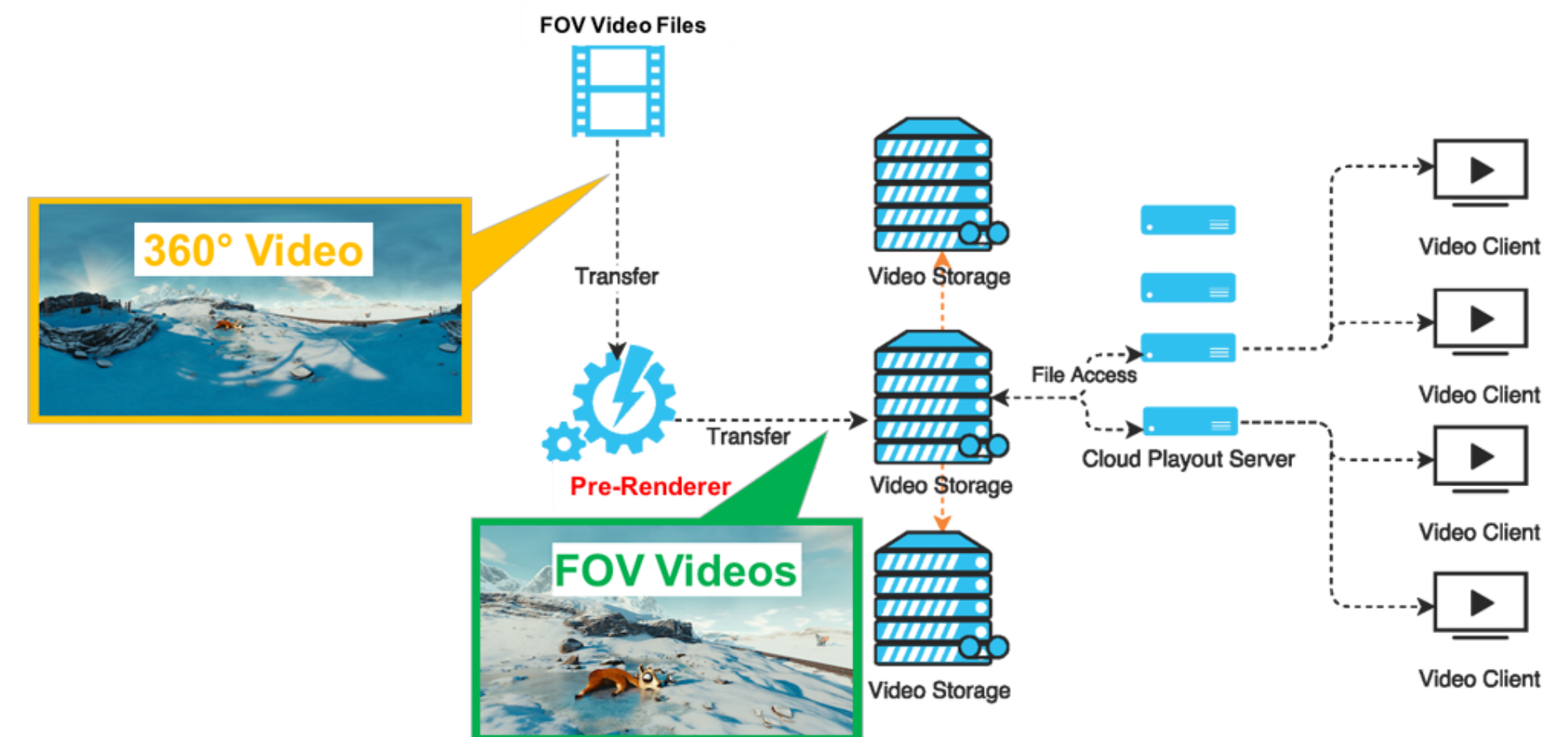
# Video consumption on HMDs -2

- Users can see only a small part of the 360° video
  - cca. 8% - 10%



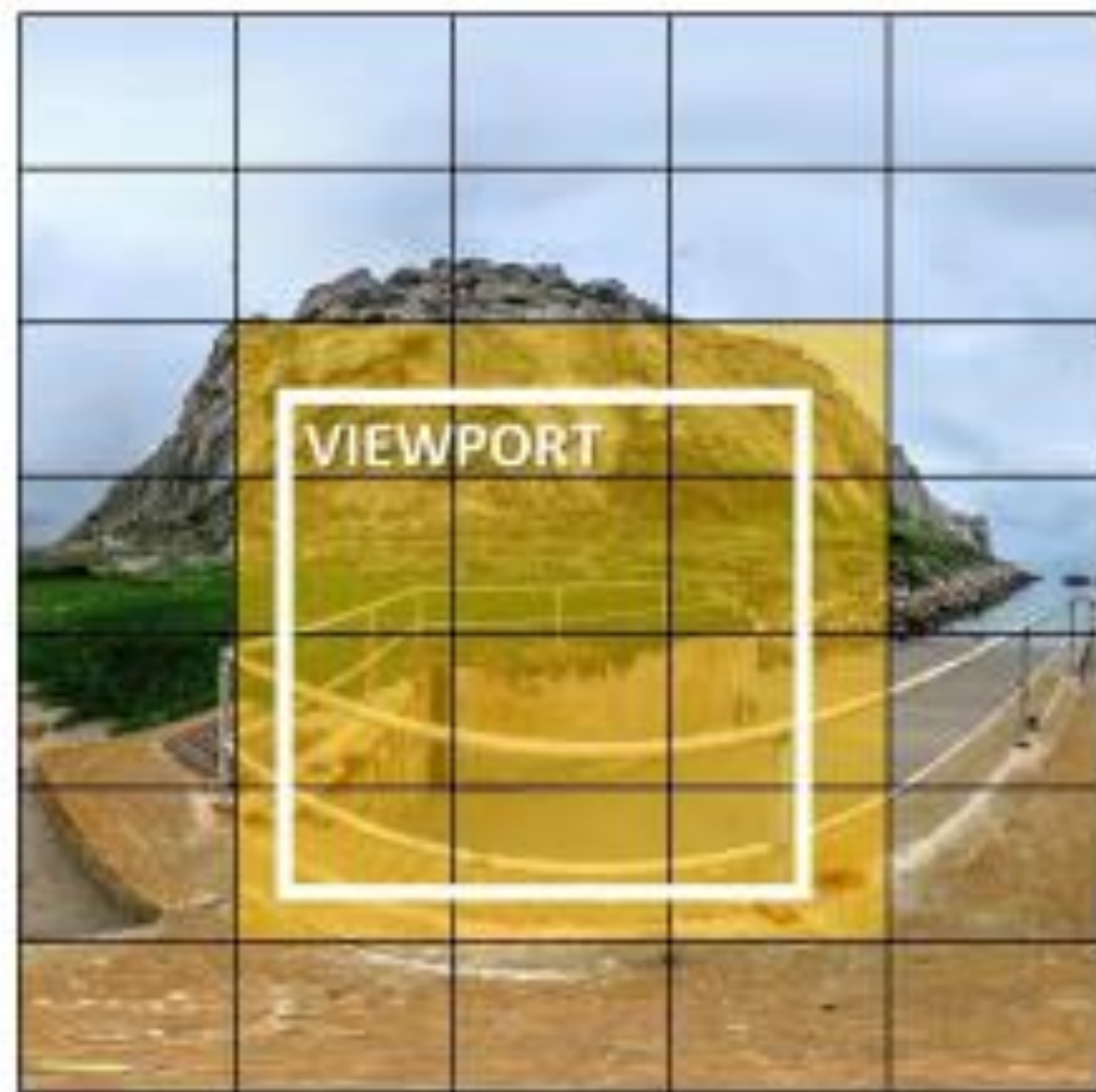
# FOV transmission of 360° video


- Different video qualities for each viewport/tile
- Also reduces the required processing power of the client (HMD)

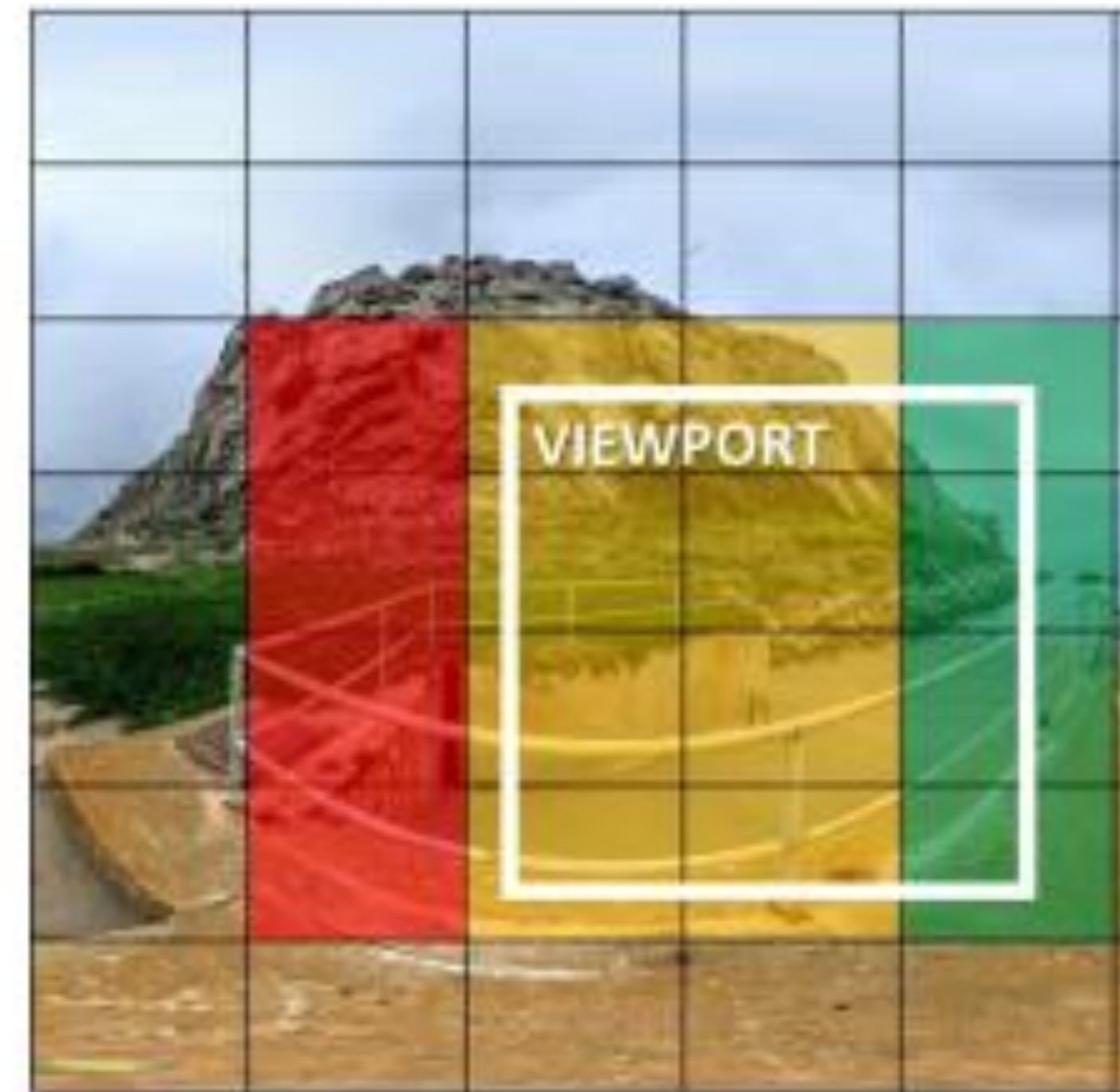


# FOV transmission of 360° video -2

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 Tiles in viewport



 Cancelled tiles  Newly requested tiles



# FOV transmission of 360° video -3

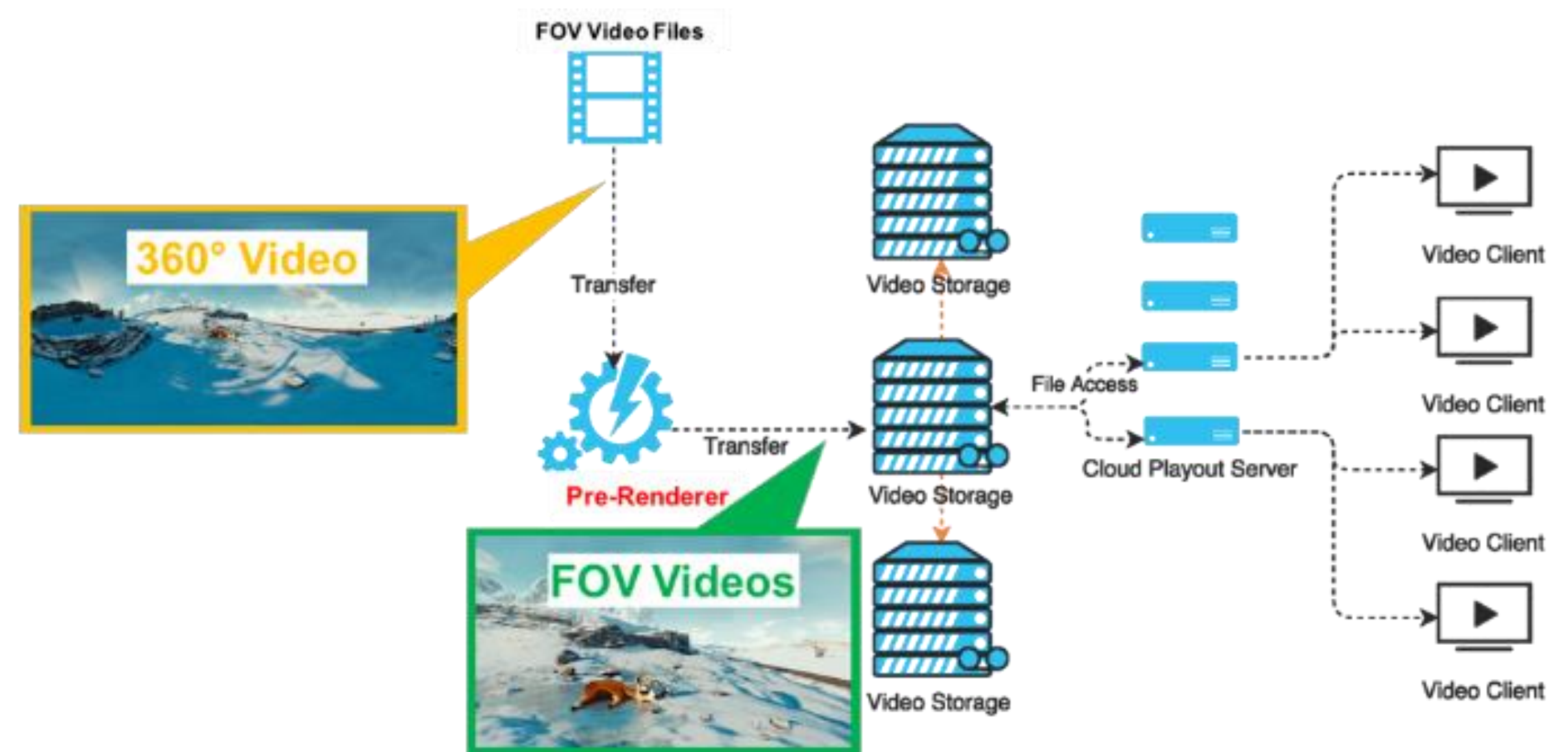
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- Cube map projection is suitable



# Media format for 360° video

- OMAF
  - Omnidirectional Media Format
  - Storage
  - Delivery
- Transmission of views/tiles
  - Client assembles tiles
  - Transmission over MPEG-DASH



# OMAF

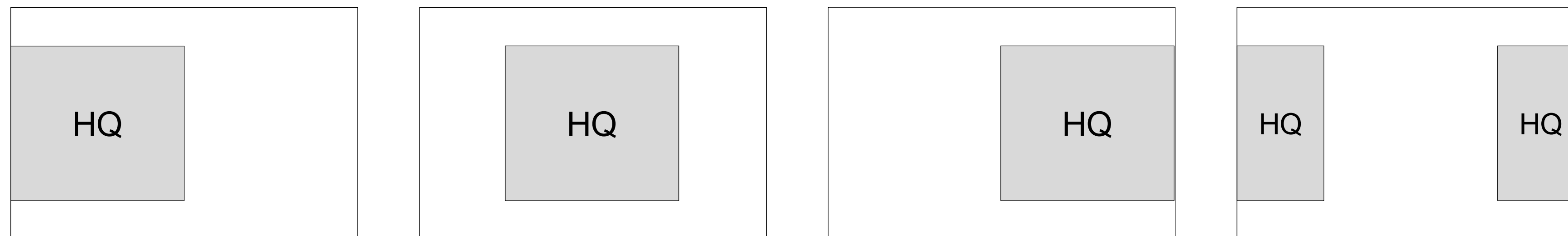
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- 360° video, images, audio in subtitles, only 3DOF!
- Defines
  - Coordinate system
  - Projections and packaging of video regions (region wise packaging)
  - Storage of omnidirectional video and metadata
  - Profiles for video, audio, images and text
- Describes approaches to viewport-dependent 360° video processing

# Region-wise quality ranked encoding of omnidirectional content

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- Multiple versions/qualities of video on server
- Each version includes full 360° video
- Each version has other region in high quality (HQ)

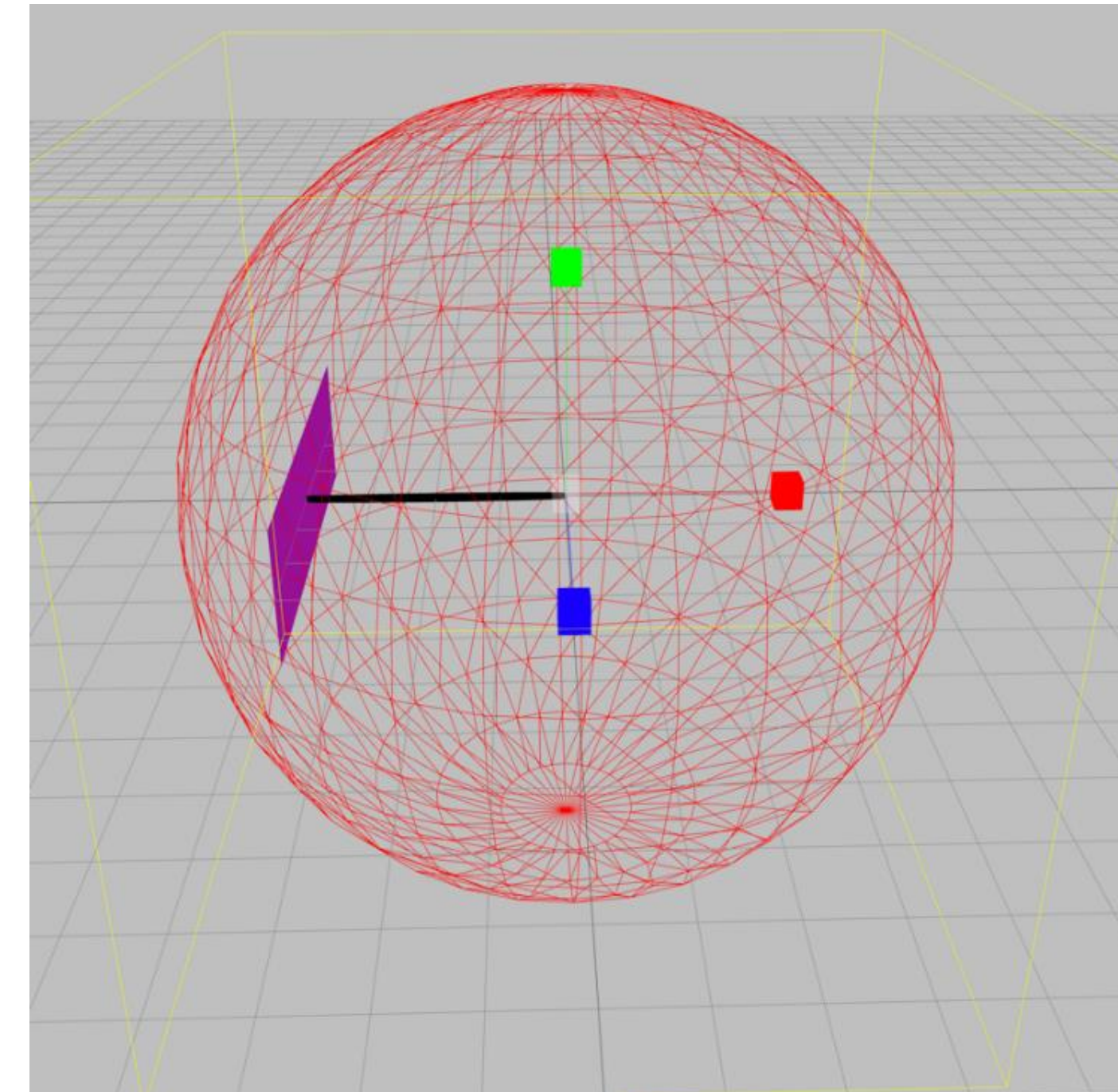


- Field of view is labelled with metadata (quality ranking metadata)
- Selection of a version on the server and streaming to the client

# What else is transmitted

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- Subtitles in a certain location on the sphere
- Initial field of view
- Recommended field of view
- Images
- ...



# FOV bitrates – commercial service (Tiledmedia ClearVR)

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Motion-to-photon latency	<i>~Instantaneous (limited by refresh rate of HMD)</i>
Motion-to-high-resolution latency	<i>20-40ms using typical CDN (Akamai, Cloudfront, etc.)</i>
# of required decoders	<i>1 single decoder (Hardware or software)</i>
Bandwidth reduction	<i>Factor of ~5</i>

	Typical Bandwidth Use
4K panorama	<i>~ 4 – 6 Mbps</i>
8K panorama	<i>~ 12 – 16 Mbps</i>
12K panorama	<i>~ 16 – 20 Mbps</i>

# Network implications

- Cloud based VR services and content
- Video transmission (cloud : video -> network -> VR HMD)
- High demands for the network infrastructure (edge nodes processing)
- Lower interactivity (video)
- High interactivity (games)

Table 1-1 Cloud VR service scenario overview

Cloud VR B2C Application Scenario	Cloud VR B2B Application Scenario
Cloud VR IMAX	Cloud VR education
Cloud VR live broadcast	Cloud VR eSports arena
Cloud VR 360° video	Cloud VR marketing
Cloud VR gaming	Cloud VR healthcare
Cloud VR music	Cloud VR tourism
Cloud VR fitness	Cloud VR real estate
Cloud VR karaoke	Cloud VR engineering
Cloud social VR	
Cloud VR shopping	



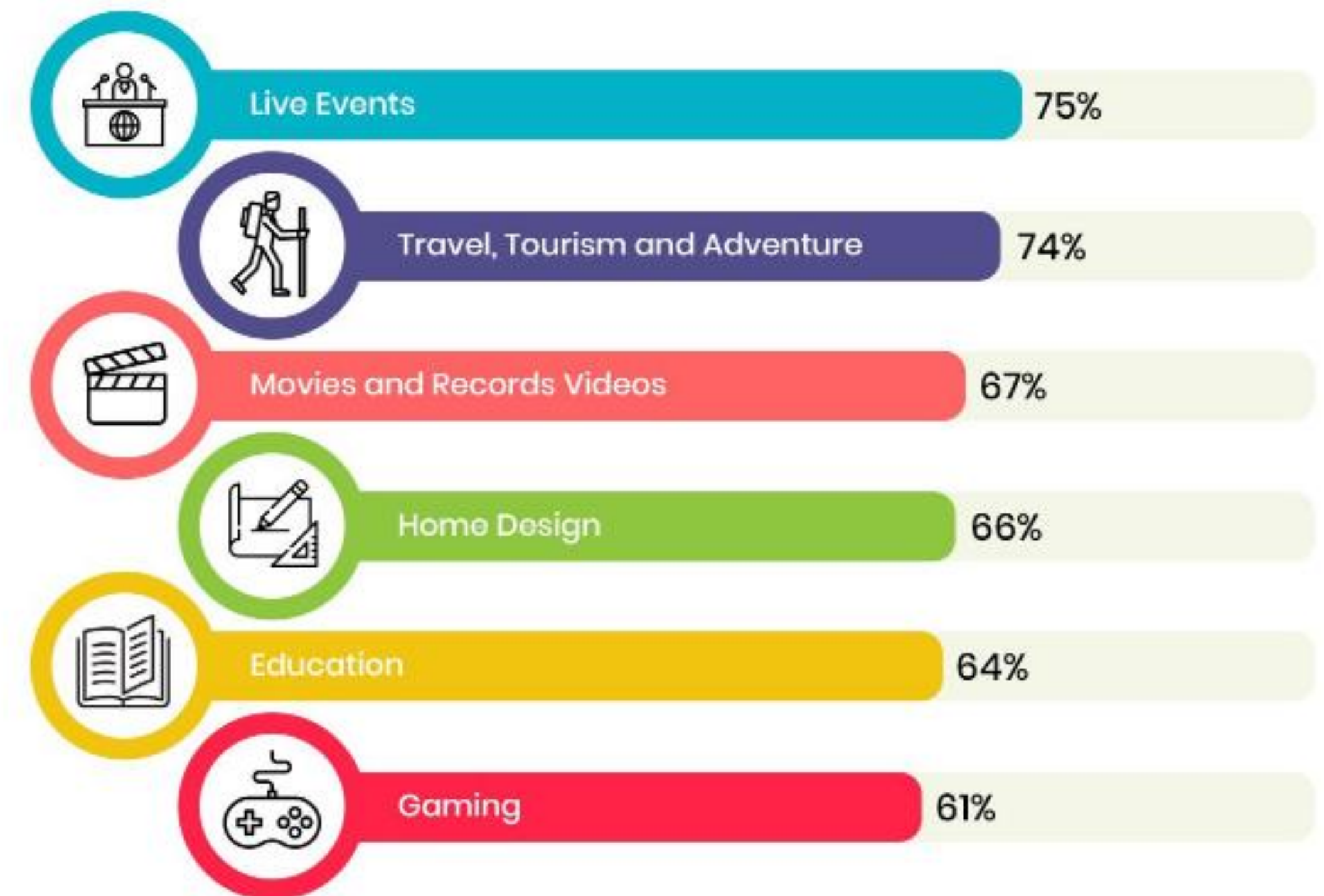
# Trends and challenges



# Trends

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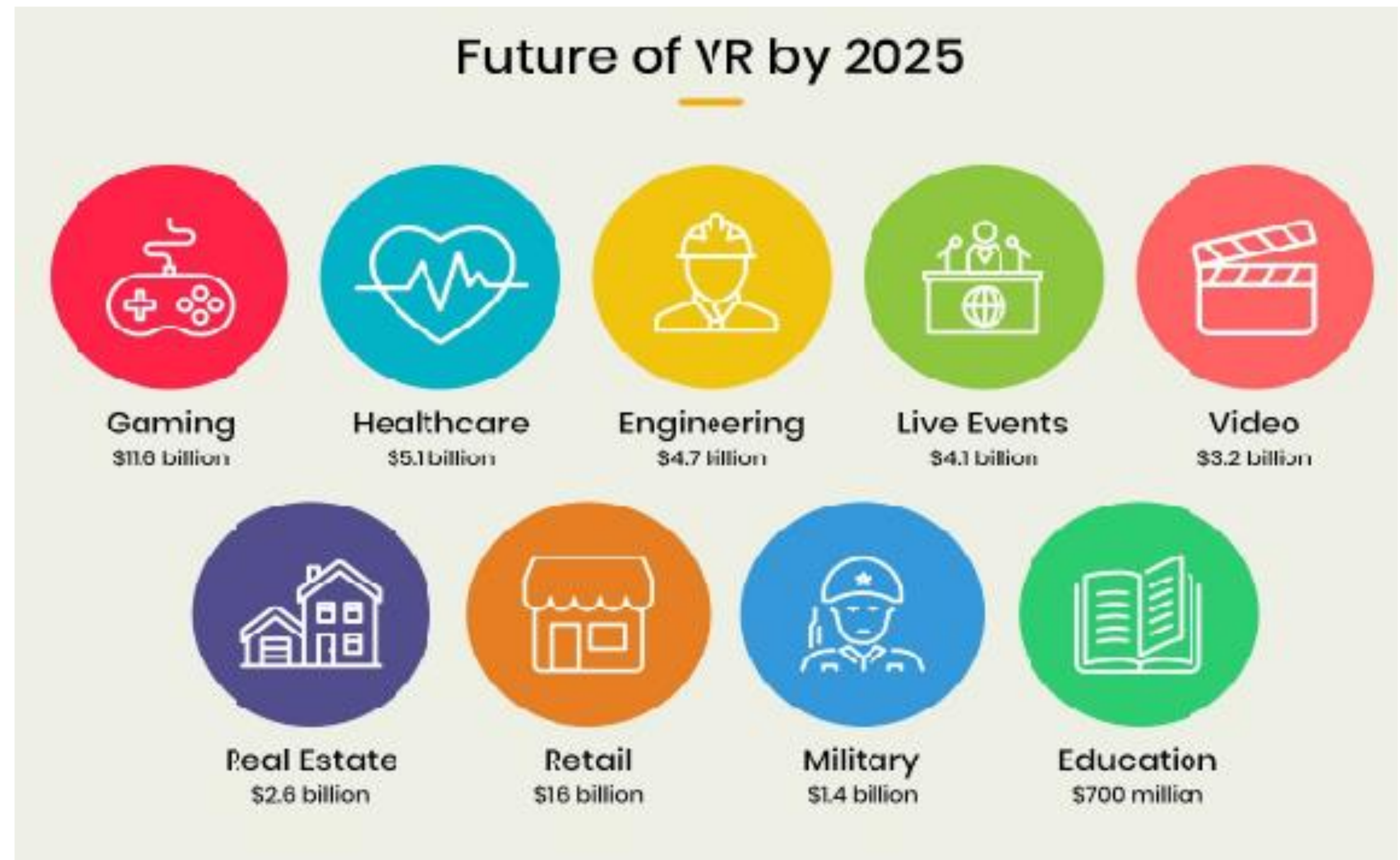
- More!
  - Resolution -> 4k+, 8k+
  - Temporal resolution-> 60/90/120 Hz
  - New display technology
- Freedom of movement - wireless
- Eye-tracking
- Blending of VR in AR/MR worlds (space awareness)
- New interactions and haptics
- Multiplayer



# Challenges

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- Social effects / asocial
- Eye strain
- User experience challenges
- Cybersickness
- Network
- ...
- Do we really need all this?



*„VR is like the first iPhone – a small number of people are extremely excited about it, but its true power still hasn't been created"*

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Thank you for your attention!

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